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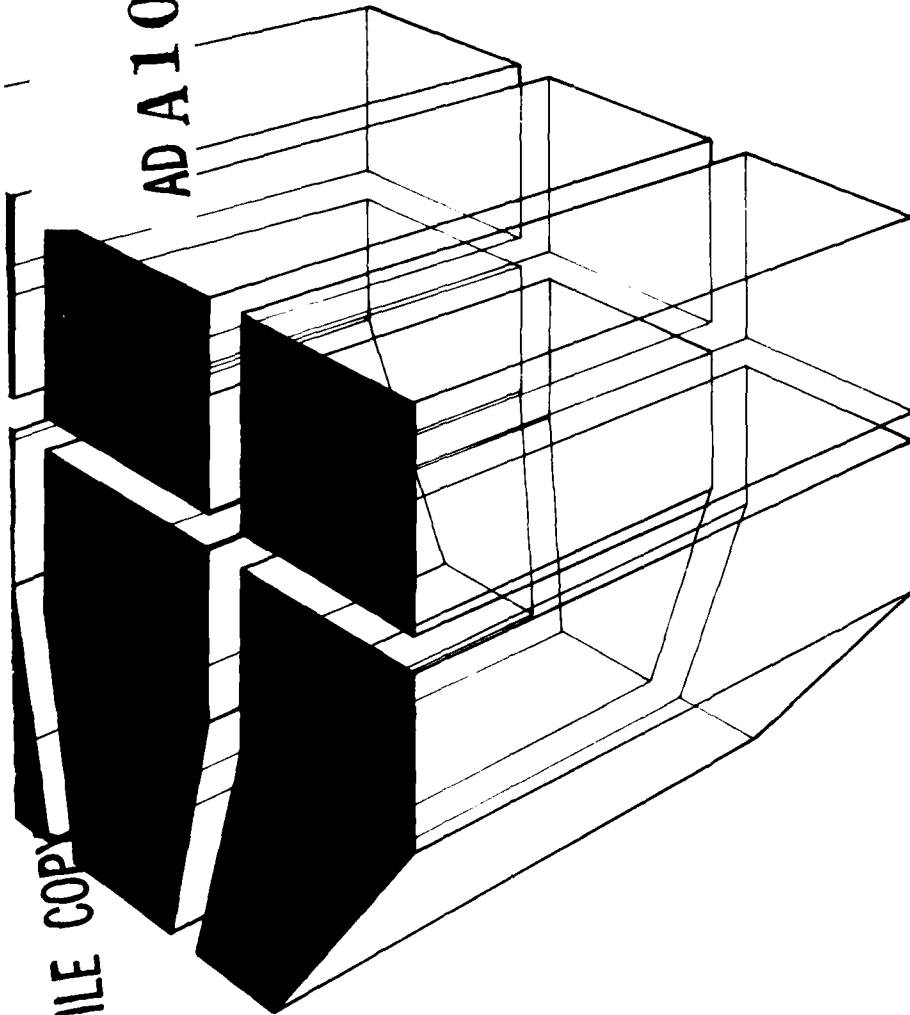
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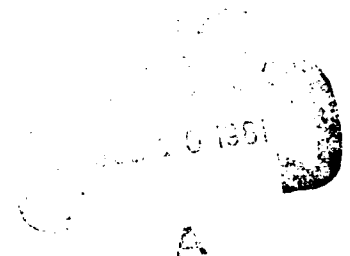
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SEISMIC INDEXING SYSTEM FOR ARMY INSTALLATIONS  
VOLUME II  
SEISMIC HAZARD PRIORITY-RANKING PROCEDURE  
FOR ARMY BUILDINGS: BASIC CONCEPT

AD A101195



by  
J. D. Prendergast  
W.E. Fisher



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↓  
The basic concept of a seismic hazard priority-ranking procedure for Army buildings described in this volume is an integral part of the facility seismic hazard indexing procedure. The basic concept provides the framework for a preliminary, subjective seismic safety evaluation of existing Army buildings based on an analysis of the information contained in the inventory of Army military real property and the anticipated seismic exposure hazard. Further development of the basic concept is required to refine the basic indices, to establish weighting factors, and to automate the concept. ↙

Volume I describes a procedure for screening the real property inventory of Army installations in order to eliminate minor facilities from the larger inventory and to provide a more manageable inventory for subsequent priority ranking.

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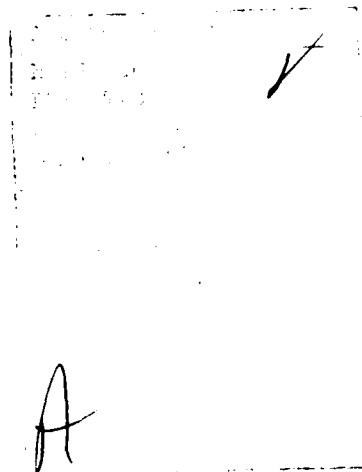
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## FOREWORD

This project was conducted for the Directorate of Military Programs, Office of the Chief of Engineers (OCE), under RDT&E Program 6.27.12A; Project 4A762719AT41, "Design and Construction of Fixed Military Facilities"; Task B, "Advanced Technology for Military Construction"; Work Unit 017, "Mission Affordable Seismic Strengthening." The applicable QCR is 3.07.005. The OCE Technical Monitor was Mr. G. M. Matsumura, DAEN-MPE-B.

The work was performed by the Engineering and Materials Division (EM) of the U.S. Army Construction Engineering Research Laboratory (CERL).

Dr. R. Quattrone is Chief of EM. COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.



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SEISMIC INDEXING SYSTEM FOR ARMY INSTALLATIONS  
VOLUME II: SEISMIC HAZARD PRIORITY-RANKING  
PROCEDURE FOR ARMY BUILDINGS: BASIC CONCEPT

1 INTRODUCTION

Background

The Army currently operates and maintains 164 installations and major activities in the United States.<sup>1</sup> More than 127,000 buildings are located at these installations and major activities, and their original acquisition cost, excluding any adjustments for appreciation and depreciation, exceeds \$11.5 billion.<sup>2</sup> Table 1 indicates the distribution of these installations and major activities by the seismic zones specified in the 1980 Draft Edition of TM 5-809-10, Seismic Design for Buildings (Figures 1 through 4).<sup>3</sup> Tables 2 and 3 indicate the distributions of the buildings and acquisition costs by seismic zones. Current DOD criteria require that studies be undertaken in areas of high earthquake activity (1) to evaluate the earthquake resistance of existing military facilities such as hospitals, fire stations, emergency operation centers, garages for emergency vehicles, and other operationally critical facilities, and (2) to develop a phased and orderly plan for completing the necessary seismic strengthening of these facilities.<sup>4</sup>

The huge inventory of existing buildings and the astronomical cost of retrofitting whole classes of hazardous buildings makes the hazard abatement problem a complicated, costly issue. The Army must develop a realistic and cost-effective capability to address this problem, i.e., Mission Affordable Seismic Strengthening (MASS). The generalized process for seismic strengthening of Army facilities and the technological needs to achieve MASS are summarized in Figure 5. MASS will provide a facility seismic indexing/priority ranking system to economically identify and evaluate the seismic capacity and strengthening strategies for essential and high potential loss facilities at Army installations. MASS includes processes to identify existing facilities that are potentially hazardous, to index the order for conducting seismic safety evaluations of potentially hazardous facilities, to evaluate the seismic capacity and upgrade requirements, to identify affordable strengthening designs and to prioritize the required strengthening in accordance with budgetary constraints and command goals.

<sup>1</sup> United States Army Installations and Major Activities, DA PAM 210-1, (Department of the Army, February 1980).

<sup>2</sup> Inventory of Army Military Real Property (Department of the Army, 30 September 1979).

<sup>3</sup> Seismic Design for Buildings, TM 5-809-10, Draft Edition (Department of the Army, 1980).

<sup>4</sup> Construction Criteria Manual, DOD 4270.1-M (Department of Defense, June 1978.)

Table 1

Distribution of Installations and Major Activities in the  
United States by 1980 TM 5-809-10 Seismic Zones

(From Inventory of Army Military Real Property [Department of the Army,  
30 September 1979], and United States Army Installations and Major  
Activities [Department of the Army, February 1980].)

Installation/Activity	Seismic Zone					Total	Percentage
	0	1	2	3	4		
Barrack, Camp, Fort, Presidio, Reservation, or Station	4	29	23	3	10	69	42.1
Depot or Terminal	2	11	5	7	2	27	16.5
Arsenal or Plant	2	14	17	1	1	35	21.3
Medical Center	1	2	3	2	1	9	5.5
Special Mission	0	11	10	2	1	24	14.6
Total	9	67	58	15	15	164	100.0
Percentage	5.5	40.9	35.4	9.1	9.1	100.0	

Table 2

Total Acquisition Cost (\$M) for Installations and Major Activities in the  
United States by 1980 TM 5-809-10 Seismic Zones

(From Inventory of Army Military Real Property [Department of the Army,  
30 September 1979] and United States Army Installations and Major  
Activities, [February 1980].)

Installation/Activity	Seismic Zone					Total	Percentage
	0	1	2	3	4		
Barrack, Camp, Fort, Presidio, Reservation, or Station	709.7	2830.2	2869.1	537.3	559.3	7505.6	64.4
Depot or Terminal	5.9	406.8	223.1	269.3	38.8	943.9	8.1
Arsenal or Plant	3.8	1034.7	1000.2	16.8	79.8	2135.3	18.3
Medical Center	7.4	213.0	88.98	5.3	15.4	329.9	2.8
Special Mission	0	299.4	383.9	16.7	47.0	747.0	6.4
Total	726.8	4784.1	4565.1	845.4	740.3	11661.7	100.0
Percentage	6.2	41.0	39.1	7.3	6.4	100.0	

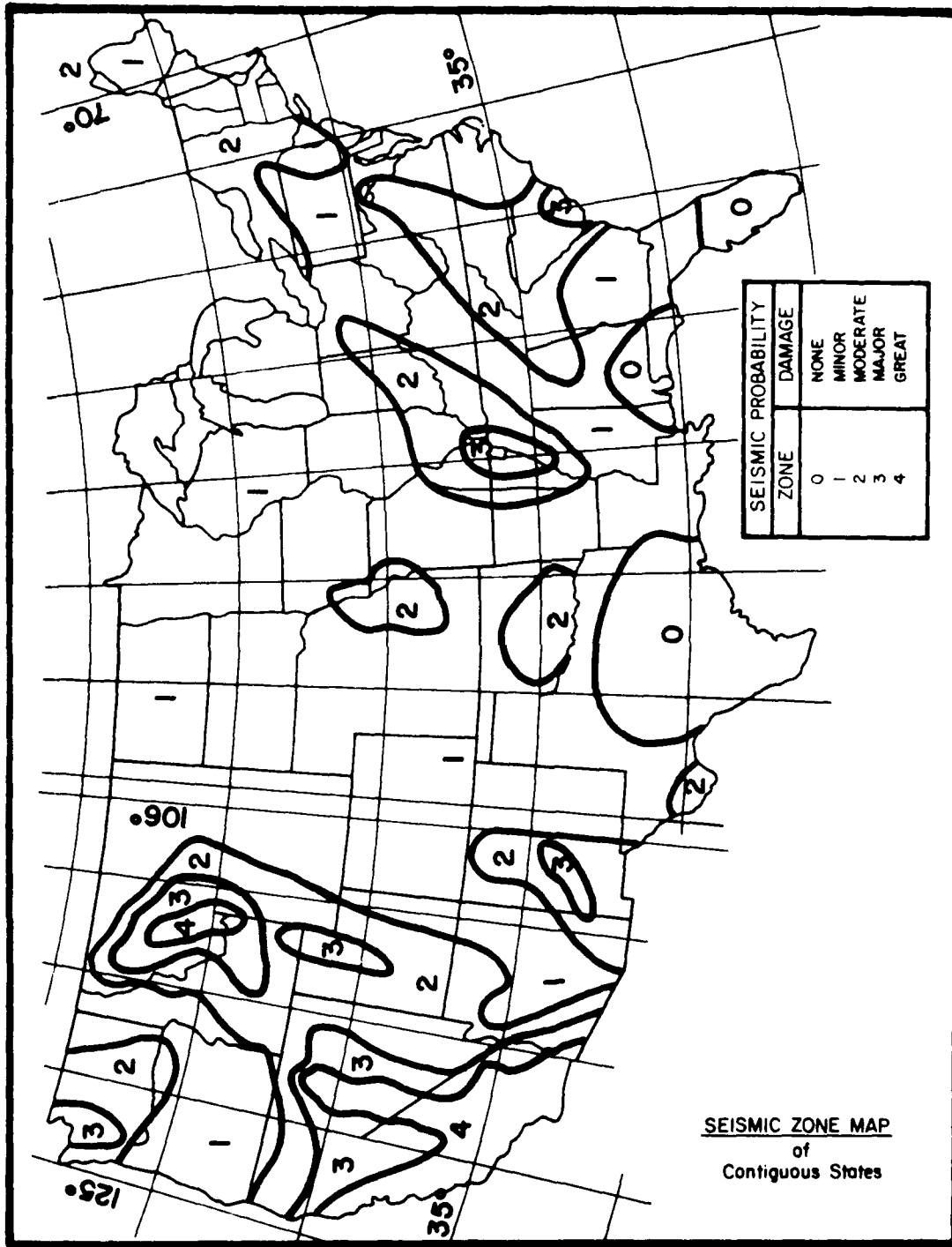


Figure 1. Seismic zone map for contiguous states. (From Seismic Design for Buildings, TM 5-809-10, Draft Edition [Department of the Army, 1980].)

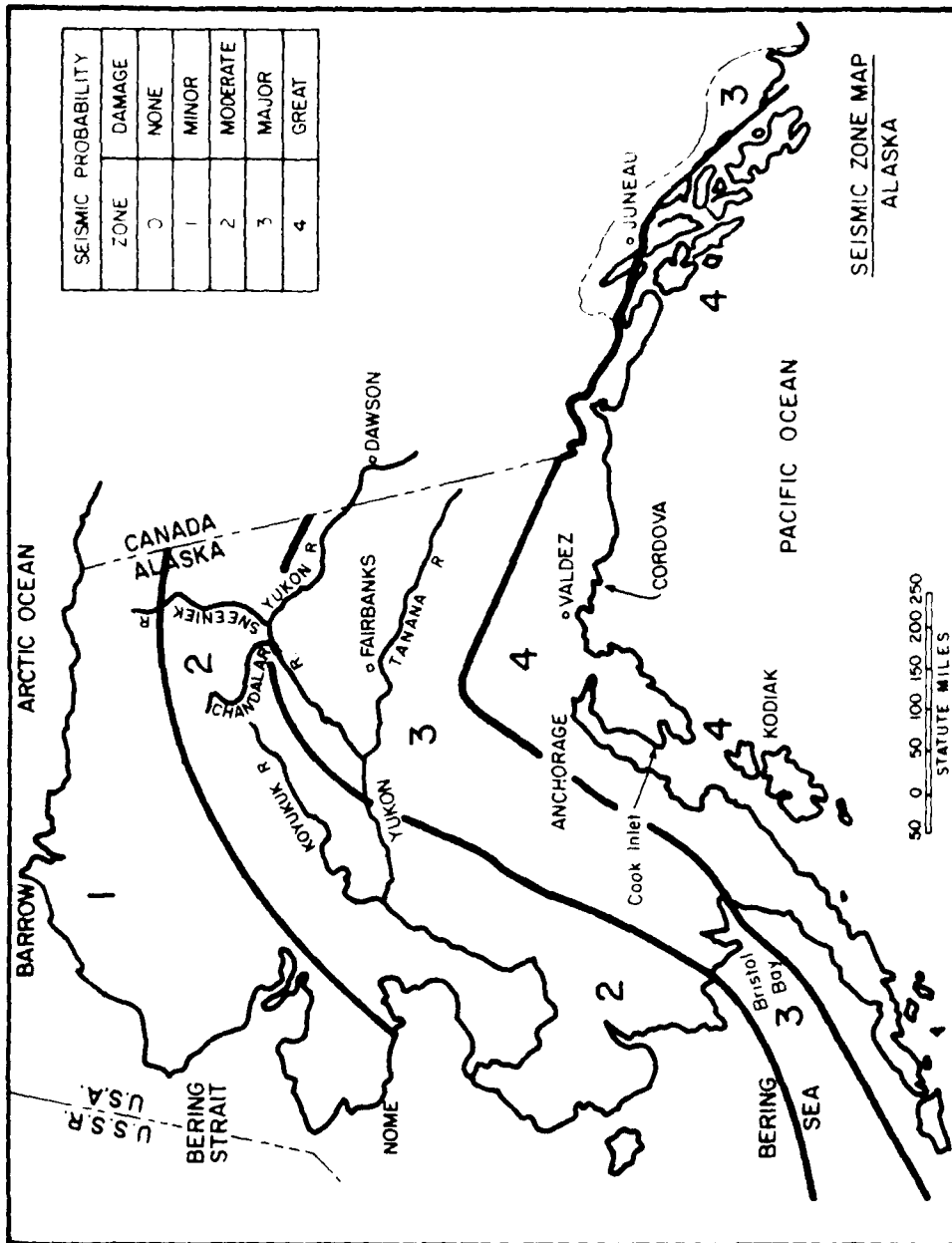


Figure 2. Seismic zone map for Alaska. (From Seismic Design for Buildings, TM 5-809-10, Draft Edition [Department of the Army, 1980].)

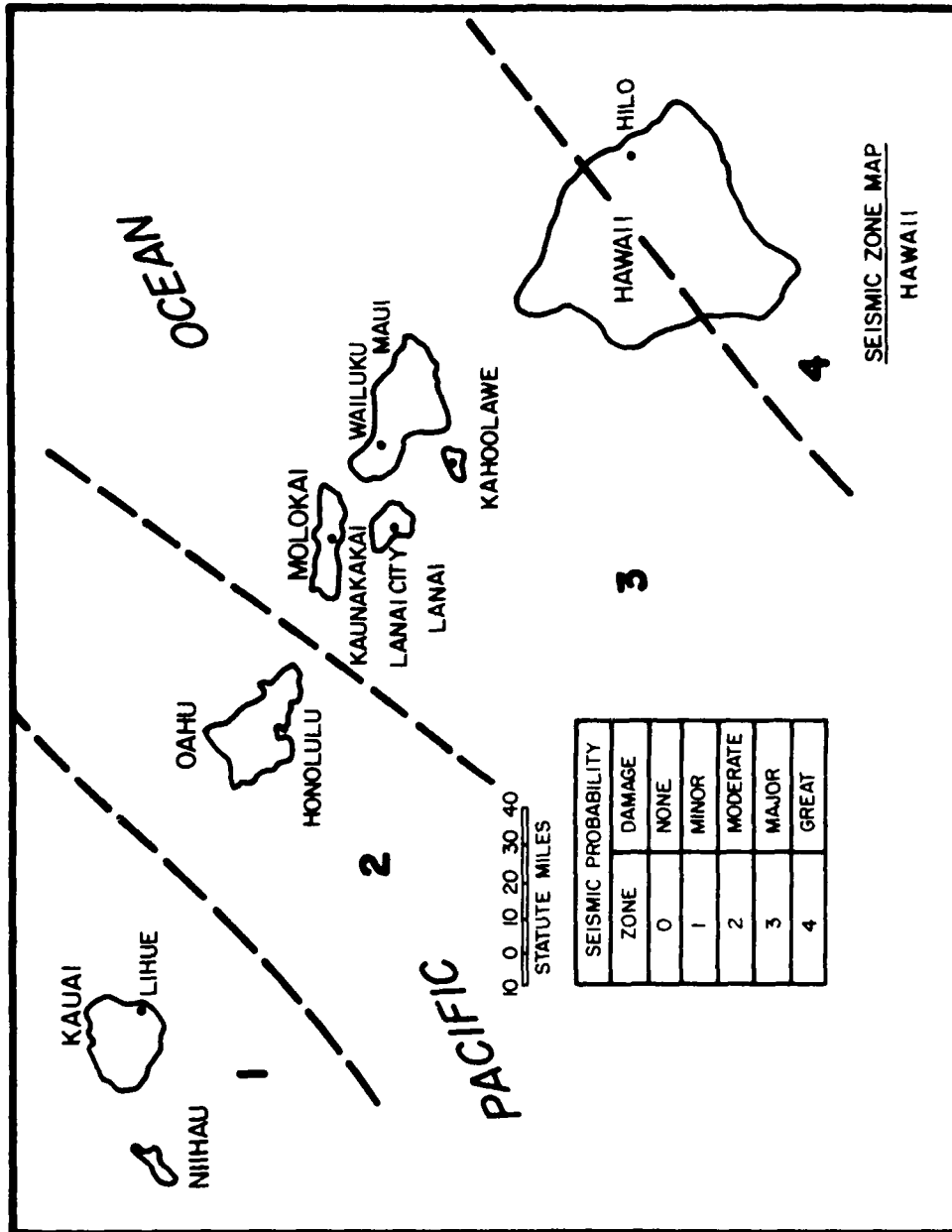


Figure 3. Seismic zone map for Hawaii. (From Seismic Design for Buildings, TM 5-809-10, Draft Edition [Department of the Army, 1980].)

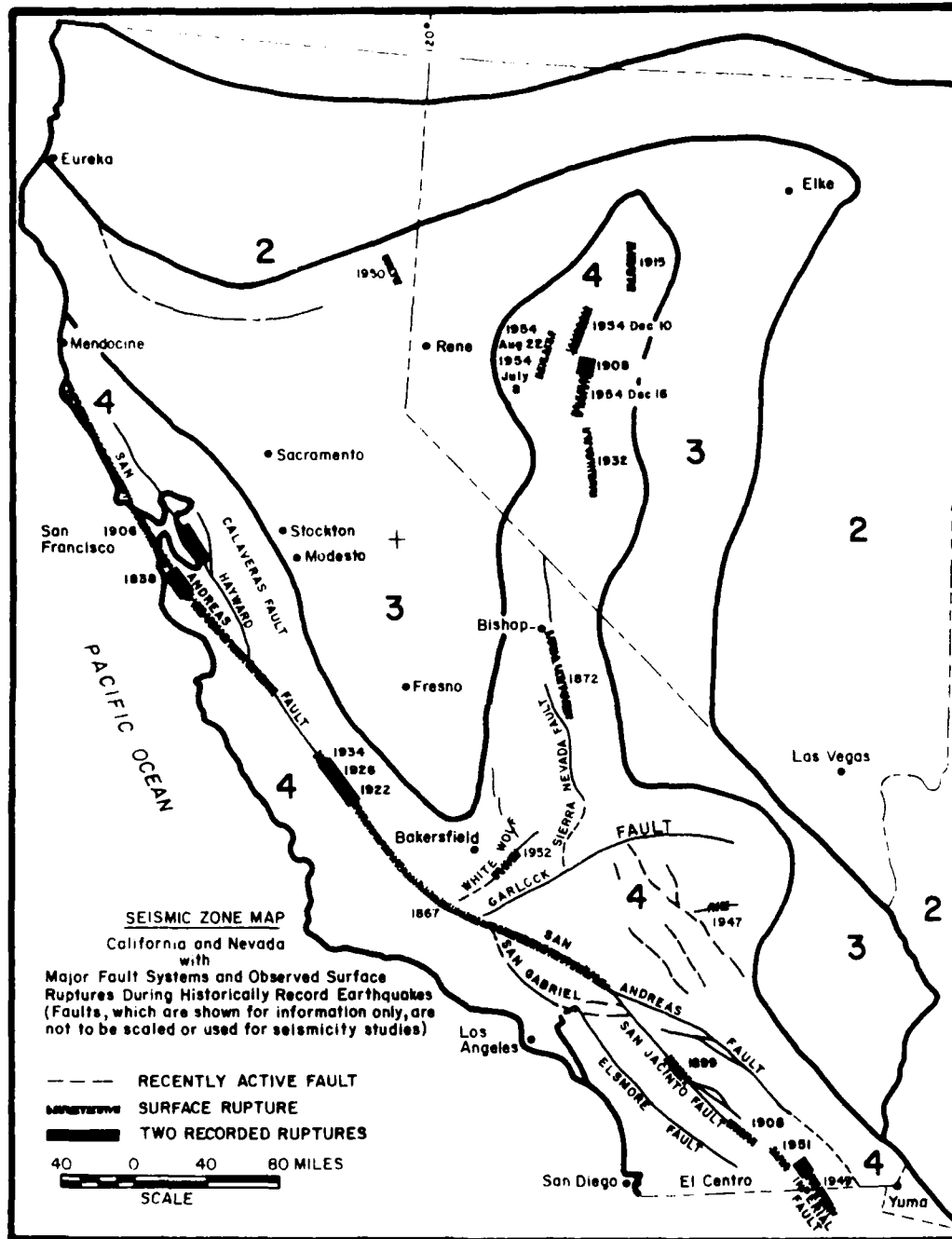


Figure 4. Seismic zone map for California and Nevada.  
 (From *Seismic Design for Buildings*, TM 5-809-10,  
 Draft Edition [Department of the Army, 1980].)

Table 3

Total Number of Buildings Within Installations and Major Activities in the United States by 1980 TM 5-809-10 Seismic Zones

(From Inventory of Army Military Real Property [Department of the Army, 30 September 1979], and United States Army Installations and Major Activities [Department of the Army, February 1980].)

Installation/Activity	Seismic Zone					Total	Percentage
	0	1	2	3	4		
Barrack, Camp, Fort, Presidio, Reservation, or Station	8499	32,612	30,126	4,464	6,488	83,189	65.5
Depot or Terminal	214	8,834	4,204	3,211	106	16,569	13.0
Arsenal or Plant	23	9,441	8,873	131	2,891	21,359	16.8
Medical Center	1	358	100	1	1	461	0.4
Special Mission	0	1,457	3,263	209	518	5,447	4.3
Total	8,737	52,702	46,566	9,016	10,004	127,025	100.0
Percentage	6.9	41.5	36.6	7.1	7.9	100.0	

### GENERALIZED PROCESS VS. TECHNOLOGICAL NEEDS

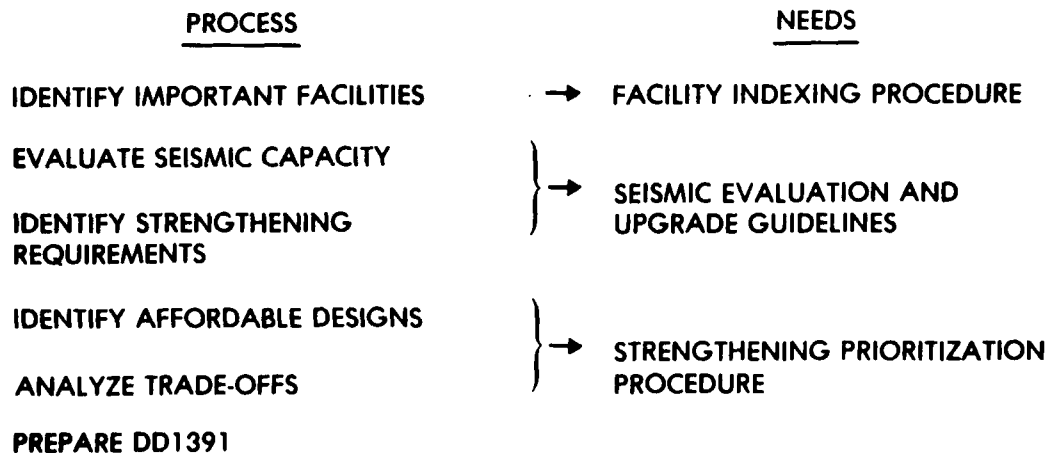


Figure 5. Overview of Mission Affordable Seismic Strengthening (MASS).



The seismic hazard priority-ranking procedure for Army buildings described in this report is an integral part of the on-going work to develop a facility seismic hazard indexing procedure.

### Objective

The overall objective of this work is to develop a facility seismic indexing/priority-ranking system to economically identify and evaluate the seismic capacity and strengthening strategies for essential and high potential loss facilities at Army installations. The basic concept for a seismic hazard priority-ranking procedure for buildings is described in this volume. The objective of this work is to develop the framework for a preliminary subjective seismic safety evaluation of existing Army buildings based on analysis of the information contained in the inventory of Army military real property and the anticipated seismic exposure.

### Scope

The seismic hazard priority-ranking procedure described in this report is applicable to building structures contained in the Army's real property inventory and is intended to provide meaningful rankings of buildings with a minimum of information. The procedure is still in an evolutionary state and has not been validated.

### Mode of Technology Transfer

The information in this report will be used to prepare other material for inclusion in a new volume of TM 5-809-10, Seismic Design for Buildings.

## 2 INVENTORY OF ARMY MILITARY REAL PROPERTY

### General

The key to a viable seismic hazard priority-ranking system for existing buildings is a comprehensive data base containing all the information and data required to make a rational seismic safety evaluation of the building. In view of this requirement, it is essential to review the existing inventory for Army facilities and identify the information cataloged in it.

The Army maintains a central inventory of military real property, which is a basic source of information on the status, cost, capacity, condition, use, maintenance, and management of real property both overall and by individual installations.<sup>5</sup> The central inventory is used as the basis for the annual publication Inventory of Army Military Real Property, for the Building Information Schedule, and for supplying information to other government offices and agencies. Installation reports are generally updated and revised at the end of each quarter in which reportable changes have occurred to reflect the real property as of that date. These reports, in the form of magnetic tape or punched cards, are submitted to HQDA (DAEN-REP-S).<sup>\*</sup> These reports contain detailed information for each facility or item of real property that:

1. Describes its physical features
2. Reports its accountability
3. Furnishes location information on it
4. Describes its designed or permanently converted use.

### Real Property Inventory (RPI)

Real property includes land and rights therein, ground improvements, utility systems, and buildings and structures, excluding plant equipment. Real property is classified according to the category codes and nomenclature system contained in AR 415-28.<sup>6</sup> Table 4 is a sample of this classification. A complete inventory of real property is maintained for each existing or newly acquired or activated installation located wholly within a state or country. When an installation is located in more than one state, each portion is treated as a separate installation and is given a separate installation number and submitted as a separate report.

<sup>5</sup> Inventory of Army Military Real Property, AR 405-45 (Department of the Army, 18 March 1977).

<sup>6</sup> Department of the Army Facility Classes and Construction Category, AR 415-28 (Department of the Army, August 1973).

\* Systems Operation and Management Branch Programs Division, Directorate of Real Estate, Office of the Chief of Engineers.

Table 4

Sample of Facility Classes and Construction Categories

(From Department of the Army Facility Classes and Construction Categories, AR 415-28 [Department of the Army, August 1973].)

Facility classes, category groups, basic categories, and Army five-digit codes	Category short title	Unit of measure			General ledger account No.
		Con-struction Area	Form 2541	Other	
100 OPERATIONAL AND TRAINING FACILITIES					1702
110 Airfield Pavements					
111 Airfield Pavements -- Runways, landing strips, helicopter landings pads, LTA landing mats.	RUNWAYS				
111 10 Fixed Wing Runway	FW Runway	SY			
111 20 Rotary Wing Runway	RW Runway	SY			
111 30 Helipads and Helicopter Parking Pads	Hlp & Hel Pk P	SY			
111 40 Hoverpoint	Hoverpoint	SY			
112 Airfield Pavements -- Taxiways.	TAXIWAYS				1702
112 10 Standard Taxiways	Std Taxiway	SY			
112 20 High Speed Exit Taxiway	High Spd Ex Twy	SY			
113 Airfield Pavements -- Aprons.	APRONS				1702
Maintenance, parking, access, operational and other aprons.					
113 10 Fixed Wing Aircraft Parking Apron	FW Ac Pk Apron	SY			
113 20 Rotary Wing Aircraft Parking Apron	RW Ac Pk Apron	SY			
113 30 Aircraft Maintenance Parking Apron	Ac Mt Pk Apron	SY			
113 31 Field Maintenance Apron	Fld Mnt Apron	SY			
113 32 Organization Maintenance Apron	Org Mnt Apron	SY			
113 40 Hangar Access Apron	Hgr Access Apr	SY			
113 50 Aircraft Holding Apron	Ac Holding Apr	SY			
113 60 Aircraft Dispersed Hardstands	Ac Disprsd Hstd	SY			
113 70 Aircraft Washing Apron	Ac Washing Apr	SY			
113 80 Aircraft Loading Apron	Ac Loading Apr	SY			
113 81 Personnel Loading Apron	Pers Ldg Apr	SY			
113 82 Special Purpose Apron	SP Purp Apr	SY			
116 Airfield Pavements -- Other.	OTHER AFLD PVMT				1702
All other misc airfield pavements such as aircraft, washracks, compass swing bases, seaplane ramps.					
116 10 Aircraft Compass Swinging Base	Comp Swing Base	SY			
116 90 Other	(Use Local Description)	SY			
120 Liquid Fueling and Dispensing Facilities					
121 Aircraft Dispensing	FUEL DISP/ACFT				1715
High and low speed normal fuel dispensing facilities.					
121 10 Aircraft Direct Fueling Facility	Ac Dir Fuel Fac	GM	(SF)		GM

Table 4 (Cont'd)

Facility classes, category groups, basic categories, and Army five-digit codes	Category short title	Unit of measure			General ledger account No.	
		Con- struc- tion	Form 2541 Area	Other		
121 70 Aircraft Truck Fueling Facility.....	Ac Trk Fuel Fac.....	GM	(SF)	GM	1715	
121 90 Other.....	(Use Local Description).....	GM	SF	GM		
122 Marine Dispensing.....	FUEL/DISP/MARIN.....	.....	.....	.....		
High and low speed normal fuel dis- pensing facilities.						
122 10 Marine Fueling Facility.....	Marine Fuel Fac.....	GM	(SF)	GM	1715	
122 20 Small Craft Fuel Station.....	Sm Crft Fuel Sta.....	GM	SF	GM		
122 90 Other.....	(Use Local Description).....	GM	SF	GM		
123 Land Vehicle Dispensing.....	FUEL/DISP/LAND.....	.....	.....	.....		
High and low speed normal fuel dis- pensing facilities.						
123 10 Gasoline Station With Building.....	Gas Sta w/Bldg.....	OL	SF	OL	1715	
123 11 Gasoline Station Without Building.....	Gas Sta wo/Bldg.....	OL	.....	OL		
123 20 Diesel Fuel Station With Building.....	Dsl Sta w/Bldg.....	OL	SF	OL		
123 21 Diesel Fuel Station Without Building.....	Dsl Sta wo/Bldg.....	OL	.....	OL		
123 90 Other.....	(Use Local Description).....	OL	(SF)	OL		
124 Operating Fuel Storage.....	OPER FUEL STOR.....	.....	.....	.....		
Immediate backup storage for dispensing facilities (exclude bulk, see 400 series at airfield and other land and marine sta- tions.						
124 10 Aircraft Fuel Storage Aviation Gasoline.....	Ac Fuel Str Gas.....	GA	.....	GA	1721	
124 11 Aircraft Fuel Storage Jet Fuel.....	Ac Fuel Str Jet.....	GA	.....	GA		
124 20 Tank Car Fuel Storage.....	Tk Car Fuel Str.....	GA	.....	GA		
124 30 Drum Fuel Storage.....	Drum Fuel Str.....	GA	.....	GA		
124 40 Marine Fuel Storage.....	Mar Fuel Str.....	GA	.....	GA		
124 50 Vehicle Fuel Storage.....	Veh Fuel Str.....	GA	.....	GA		
124 60 Propellant Storage.....	Propellant Str.....	GA	.....	GA		
124 70 Fuel Oil Storage Tanks.....	Fuel Str Tank.....	GA	.....	GA		
124 80 Diesel Oil Storage.....	Diesel Str.....	GA	.....	GA		
124 90 Other.....	(Use Local Description).....	GA	.....	GA		
125 POL Pipeline.....	FUEL POL LINES.....	.....	.....	.....		
Pipeline, pumping stations, accessory equipment and appurtenances. (Exclude terminal and bulk storage tanks.)						
125 10 Pipeline Aboveground.....	Pipeline Ag.....	MI	.....	MI		1715
125 20 Pipeline Underground.....	Pipeline Ug.....	MI	.....	MI		
125 30 Pump Station Aboveground.....	Pump Sta Ag.....	(MI)	(SF)	(MI)		
125 40 Pump Station Underground.....	Pump Sta Ug.....	(MI)	(SF)	(MI)		
125 90 Other.....	(Use Local Description).....	MI	(SF)	(MI)		
Liquid Fuel and Dispensing -- Other.	FUEL DISP/QTR.....	.....	.....	.....		
126 Propellant Fueling Facility.....	Propel Fuel Fac.....	OL	.....	OL		
126 30 Tank Truck Loading Facility.....	Tnk Load Fac.....	OL	.....	OL		
126 35 Tank Truck Unloading Facility.....	Tnk Unld Fac.....	OL	.....	OL		
126 40 Tank Car Loading Facility.....	Car Load Fac.....	OL	.....	OL		

Table 4 (Cont'd)

Facility classes, category groups, basic categories, and Army five-digit codes	Category short title	Unit of measure			General ledger account No.
		Con- struction	Form 2541 Area	Other	
126 45 Tank Car Unloading Facility.....	Car Unld Fac.....	OL	OL	OL	
126 50 Barge Loading Facility.....	Barge Load Fac.....	OL	OL	OL	
126 55 Barge Unloading Facility.....	Barge Unld Fac.....	OL	OL	OL	
126 60 Tanker Loading Facility.....	Tanker Load Fac.....	OL	OL	OL	
126 65 Tanker Unloading Facility.....	Tanker Unld Fac.....	OL	OL	OL	
126 90 Other.....	(Use Local Description).....	OL	(SF)	OL	
130 Communications, Navigational Aids and Airfield Lighting					
131 Communications Buildings.....	COMMS BUILDINGS.....	.....	.....	.....	1715
Buildings for radio, radar, relay, telephone including globecom, base, net and similar operations. Exclude navigation and aviation aids.					
131 10 Cable House.....	Cable House.....	SF	SF	SF	
131 20 Communications Center.....	Comm Center.....	SF	SF	SF	
131 25 Military Affiliate Radio System Station.....	MARS Sta.....	SS	SF	SF	
131 30 Communications Central Link Building.....	Comm Cen Bldg.....	SF	SF	SF	
131 50 Helix House.....	Helix House.....	SF	SF	SF	
131 60 Transmitter Building (Radio).....	Xmtr Bldg Rdo.....	SF	SF	SF	
131 65 Transmitter Building (TV).....	Xmtr Bldg TV.....	SF	SF	SF	
131 70 Receiver Building.....	Rcvr Building.....	SF	SF	SF	
131 80 Telephone Exchange Building.....	Tel Exch Bldg.....	SF	SF	SF	
131 81 Terminal Equipment Building.....	Term Eqp Bldg.....	SF	SF	SF	
131 82 Commercial Facilities.....	Commercial Fac.....	SF	SF	SF	
131 90 Other.....	(Use Local Description).....	SF	SF	SF	
132 Communications -- Other Than Buildings.....	COMMS/OTHER.....	.....	.....	.....	1715
Antenna system towers, communication control link facilities. Exclude navigation and aviation aids.					
132 10 Antenna Tower Supported.....	Ant Tower Supp.....	EA			
132 20 Antenna Vertical Radiator.....	Ant Vert Rad.....	EA			
132 30 Antenna Pole and Wire.....	Ant Pole & Wire.....	EA			
132 40 Switch Station Outdoor Antenna.....	Switch Sta Ant.....	EA			
132 50 Public Address System Outdoor.....	Pub Address Sys.....	EA			
132 90 Other.....	(Use Local Description).....	EA			
133 Navigation and Traffic Aids Buildings.....	NAVTR BLDGS -- AIR.....	.....	.....	.....	1715
Buildings to house air traffic control.					
133 10 Flight Control Tower (High Density Traffic).....	Flt Con Tow HD.....	SF	SF	SF	
133 15 Flight Control Tower (Low Density Traffic).....	Flt Con Tow LD.....	SF	SF	SF	
133 20 Navigational Aids Building.....	Nav Aids Bldg.....	SF	SF	SF	
133 40 Radar Building.....	Radar Building.....	SF	SF	SF	
133 55 High Power Acquisition Radar Building.....	HIPAR Bldg.....	SF	SF	SF	
133 56 Alternate Battery Acquisition Radar Building.....	ABAR Bldg.....	SF	SF	SF	
133 60 Weather Station (Meteorological Building).....	Weather Sta.....	SF	SF	SF	
Other.....	(Use Local Description).....	SF			

Table 4 (Cont'd)

Facility classes, category groups, basic categories, and Army five-digit codes	Category short title	Unit of measure			General ledger account No.
		Con-struction Area	Form 2541	Other	
134 Navigation and Traffic Aids Other..... Than Buildings. Radar approach control, visual aids, antenna systems, vaults, foundations, towers, beacons, and other structures which are non-ship related.	NAVTR AID/OTHER.....	.....	.....	.....	1715
134 10 Low Frequency Nondirectional Radio Beacon.....	LF Radio Beacon.....	EA			
134 15 Radio Beacon Marker (75 MC).....	Rdo Bea Mkr 75MC.....	EA			
134 20 Radio Beacon TVOR (Class "B" VOR).....	TVOR.....	EA			
134 30 Ground Control Approach System.....	GCA.....	EA			
134 40 Instrument Landing System.....	ILS.....	EA			
134 50 Rotating Light Beacon.....	Rot Lt Beacon.....	EA			
134 60 Flashing Light Beacon.....	Fl Lt Beacon.....	EA			
134 70 Lighted Wind Direction Indicator.....	Lt Wind Dir Ind.....	EA			
134 80 Air Navigation Obstruction Lighting.....	Airnav Obst Ltg.....	EA			
134 90 Other.....	(Use Local Description).....	EA			
135 Communication Lines..... Marine cables, underground and overhead cables, open wire lines.	COMMS Lines.....	.....	.....	.....	1721
135 10 Communication Lines.....	Comm Lines.....	MI	.....	MI	
135 20 Marine Cables.....	Marine Cables.....	MI	.....	MI	
135 90 Other.....	(Use Local Description).....	MI	.....	MI	
136 Airfield Pavement Lighting..... Lighting both sides and approaches for all airfield pavements. Exclude airfield perimeter lighting, street lighting, and other general illumination. (See S12)	AFLD PVMT LTING.....	.....	.....	.....	1715
136 10 Runway and Threshold Lighting -- Medium Intensity.	Runway Ltg-MI.....	LF	.....	LF	

The RPI includes specific information regarding the installation such as its number, name, command code, using agency code, type, etc. In addition, the RPI contains a detailed inventory record for buildings and facilities, which includes the following information:

1. Category Code. The five-digit numerical code specified by AR 415-28 for identifying and classifying each item of real property.
2. Ownership Code. A numerical code from Table 5 representing the type of ownership or tenure for buildings and facilities.
3. Type of Construction Code. Permanent, semipermanent, and temporary construction are designated by the letters "P," "S," or "T," respectively.
4. Building/Facility Number. This is the five-character number assigned to a building, facility, or land for inventory purposes.
5. Building Code. Single- and multipurpose buildings and their uses are designated by a letter. The letter "B" indicates a single building used for only one purpose, as indicated by its assigned category code. The letter "P" indicates the principal category use of a multipurpose building. The letter "M" indicates secondary category uses.
6. Total Area. The amount of area for each item according to the applicable unit of measure specified in AR 415-28.
7. Outgrant Area. The amount of area outgranted by lease, easement, license, or permit to others.

Table 5

Type of Ownership Code

<u>Code</u>	<u>Type of Ownership or Tenure</u>
1. Owned.	Includes buildings and facilities constructed, purchased, or having a title owned by the U.S. Government, no matter how they were acquired.
2. Leased (Inleased).	Includes buildings and facilities held under lease agreements, including condemnation leaseholds.
3. Other.	Includes buildings and facilities acquired for use by license, permit (other than from the Air Force or Navy), temporary public land order, temporary executive land order, or furnished rent-free by a foreign government under treaty or other agreement.
4. Permit--Military.	Includes buildings and facilities other than land held under permit (not transfers) from the Air Force or Navy.

8. Planned Disposition Code. An appropriate code from Table 6 which indicates the planned disposition of vacant space.

9. Vacant Area. The amount of vacant area for each item.

10. Total Capacity (Other Measure). The quantity or number of units according to the applicable unit of measure specified in the "Other" column of Table 4. Table 7 lists the symbols for those units of measure.

11. Total Cost to U.S. Government. The cost expended by the U.S. Government to purchase or construct real property items.

12. Cost to U.S. Government of Improvements on Leased or Rent-Free Land. The cost of owned units of real property constructed on leased or rent-free land.

13. Annual Rental Received. The amount of annual rental received for each item of outleased or outgranted real property.

14. Annual Rental Paid. The amount of annual rental paid for each item of real property under lease, license, or permit.

15. Appraisal or Estimated Value. The appraisal or estimated value of each item in leased, donated, or furnished by a foreign government.

16. Year Built or Acquired. The year of completion for buildings and facilities constructed by the Army or the year of initial acquisition or reacquisition for land and/or buildings and facilities not constructed by the Army.

17. Condition Code. The letters "U" and "N" designate whether the building or facility is usable or nonusable, respectively.

18. Number of Floors. The number of usable floors in a building, including full basement and attics.

19. Wall Material. A code (see Table 8) that represents the exterior surface material of the walls of a reported building.

#### Building Information Schedule (BIS)

BIS data is reported only for installations listed in Appendix A of AR 210-20 and for other Army installations that have mobilization potential expansion capability.<sup>7</sup> Table 9 lists installations currently in Appendix A of AR 210-20.

BIS data is not available if a building or facility is not in the RPI record. The BIS information includes the first four items in the RPI

<sup>7</sup> Master Planning for Army Installations, AR 210-20 (Department of the Army, 26 January 1976).



Table 6

## Planned Disposition Code

<u>Code</u>	<u>Planned Disposition</u>
A	Mobilization requirement
B	To be disposed of
C	Planned future use
D	To be rehabilitated
E	Disposal under consideration
F	None

Table 7

## Symbols for Units of Measure

(From Department of the Army Facility Classes and Construction Categories, AR 415-28 [Department of the Army, August 1973].)

<u>Symbol</u>	<u>Unit of Measure</u>
AC	Acres
BD	Hospital Beds, Normal Capacity
BL	Barrels, Capacity
BX	Boxes
CF	Cubic Feet
CY	Cubic Yards
EA	Each
FA	Family Unit
FB	Feet of Berthing
GA	Gallons, Capacity
GM	Gallons Per Minute, Capacity
KG	Thousand Gallons Per Day, Capacity
KV	Kilovolt-Amperes, Capacity (KVA)
KW	Kilowatt, Capacity
LF	Lineal Feet
MB	Million British Thermal Units Per Hour, Capacity
MI	Miles, Statute
MN	Persons, Designed Capacity
OL	Outlets, Number of
OU	Operating Units
SE	Seats
SF	Square Feet
SY	Square Yards
TN	Tons, Capacity
VE	Vehicles

Table 8

Wall Material Code

<u>Code</u>	<u>Material</u>	<u>Abbreviation Used in Printout of Building Information Schedule</u>
A	Wood	Wood
B	Brick (brick veneer)	Brick
C	Concrete	Concr
D	Concrete block or slag block	Block
E	Stone	Stone
F	Structural tile	Tile
G	Steel	Steel
H	Other	Other
J	Adobe	Adobe
K	Combination brick and wood asbestos shingle	Comb
L	Aluminum	Alum
M	Cement asbestos	C Asb
N	Cast iron	CI
P	Glass, plastic, transparent or translucent material	GL
Q	Roll, composition	R Comp

record -- the category code, ownership code, type of construction code, and buildings/facility number -- as well as information on the following items:

1. Utilities Available. The utilities available in the building or facility are indicated by an eight-digit/letter designation (see Table 10). The letter "X" designates that a utility or service is not available.

2. Current Use Code. The appropriate five-digit category code shown in Table 4 that best describes the facility's current use.

3. Recommended Use Code. The appropriate category code from AR 415-28 that best identifies the recommended long-range use if the estimated life of the facility is 20 years or more from the current date. If the estimated life is less than 20 years, the word "NONE" is used followed by a "D" or an "R," indicating demolition or replacement, respectively. The symbol "HIST" is used if the facility is to be maintained for historical purposes only.

4. Estimated Life. The estimated economic life of a building, and, when applicable, of a facility. A building's economic life is estimated using three factors: the foundation material, the principal type of building material, and the secondary type of building material, if it consists of more than one-third of the structure. The length of life is judged on the shortest life of the materials for the first three factors considered and then adjusted by special conditions. Figure 6 shows various materials and the ranges for estimating their economic lives.

Table 9

Army Installations for Which Permanent Construction  
Will Be Planned and Programmed

(From Master Planning for Army Installations, AR 210-20  
[Department of the Army, 26 June 1976].)

List of installations for which  
complete master plans will be  
prepared.

US Army Training and Doctrine Command

Fort Belvoir, VA  
Fort Benning, GA  
Fort Bliss, TX (includes William  
Beaumont General Hospital)  
Carlisle Barracks, PA  
Fort Dix, NJ  
Fort Eustis, VA  
Fort Gordon, GA  
Fort Hamilton, NY  
Fort Benjamin Harrison, IN  
Fort Jackson, SC  
Fort Knox, KY  
Fort Leavenworth, KS  
Fort Lee, VA  
Fort McClellan, AL  
Fort Monroe, VA  
Monterey, Presidio of, CA  
Fort Rucker, AL  
Fort Sill, OK  
Fort Story, VA  
Fort Leonard Wood, MO

US Army Forces Command

Fort Bragg, NC  
Fort Campbell, KY  
Fort Carson, CO  
Fort Clayton, CZ  
Fort Devens, MA  
Fort Gulick, CZ  
Fort Hamilton, NY  
Fort Hood, TX  
Fort Sam Houston, TX (includes Brooke  
AMC activity)  
Fort Lewis, WA (includes Madigan  
General Hospital)  
Fort McPherson, GA  
Sharpe Army Depot, CA

Fort George G. Meade, MD  
Fort Ord, CA  
Fort Polk, LA  
Fort Richardson, AK  
Fort Riley, KS  
Schofield Barracks, HI  
Fort Shafter, HI  
San Francisco, Presidio of, CA  
(includes Letterman General Hospital  
and Western Medical Research Laboratory)  
Fort Sheridan, IL  
Fort Stewart, GA (includes Hunter AAF)  
Fort Wainwright, AK

US Army Materiel Development and  
Readiness Command

Aberdeen Proving Ground, MD (includes  
Edgewater Arsenal)  
Anniston Army Depot, AL  
Army Materials and Mechanics Research  
Center, MA  
Deseret Test Center (Dugway Proving  
Ground), UT  
Detroit Arsenal, MI  
Frankford Arsenal, PA  
Harry Diamond Laboratories, MD  
Letterkenny Army Depot, PA  
Lexington-Blue Grass Army Depot, KY  
Fort Monmouth, NJ  
Natick Development Center, MA  
New Cumberland Army Depot, PA  
Picatinny Arsenal, NJ  
Pine Bluff Arsenal, AR  
Pueblo Army Depot, CO  
Red River Army Depot, TX  
Redstone Arsenal, AL  
Rock Island Arsenal, IL  
Sacramento Army Depot, CA  
Savanna Army Depot, IL  
Seneca Army Depot, NY

Table 9 (Cont'd)

Sierra Army Depot, NA  
Tobyhanna Army Depot, PA  
Tooele Army Depot, UT  
Watervliet Arsenal, NY  
White Sands Missile Range, NM  
Yuma Proving Grounds, AZ

US Army Security Agency

Arlington Hall Station, VA  
Vint Hill Farm Stations, VA

US Army Communications Command

Fort Huachuca, AZ

US Army Military District of Washington

Fort McNair, DC  
Fort Myer, VA  
Cameron Station, VA

Military Traffic Management Command

Oakland Army Base, CA

Department of the Army Staff Agencies

West Point Military Reservation, NY

US Army Health Service Command

Fort Detrick, MD  
Fitzsimmons General Hospital, CO  
Walter Reed Medical Center, DC

List of US Army installations for which  
basic information documents will be  
prepared.

US Army Training and Doctrine Command

Fort Chaffee, AR  
Fort A. P. Hill, VA  
Fort Hancock, NY  
Fort Hays, OH  
Fort Hunter Liggett, CA  
Fort Pickett, VA  
Rocky Mountain Arsenal, CO  
St. Louis Army Ammunition Plant, MO  
Fort Totten, NY  
Scranton Army Ammunition Plant, PA  
Sunflower Army Ammunition Plant, KS  
Twin Cities Army Ammunition Plant, KS  
US Army St. Louis Area Support  
Center, MO  
Volunteer Army Ammunition Plant, TN  
Wingate Army Depot, MN

US Army Forces Command

Fort Amador, CZ  
Fort Baker, CA  
Fort Buchanan, PR  
Camp Bullis, TX  
Fort DeRussy, HI  
Fort Douglas, UT  
Fort Drum, NY  
Fort Gillem, GA  
Fort Greely, AK  
Helemano Military Reservation, HI  
Fort Indiantown Gap, PA  
Fort Kobbe, CZ  
Fort Lawton, WA  
Fort MacArthur, CA  
Fort McCoy, WI  
Oakdale Support Center, PA  
Quarry Heights, CZ  
Fort Tilden, NY  
Fort Totten, NY  
Tripler Army Medical Center, HI  
Fort Wadsworth, NY  
Yakima Firing Center, WA

US Army Materiel Development and  
Readiness Command

Badger Army Ammunition Plant, WI  
Burlington Army Ammunition Plant, NJ  
Gateway Army Ammunition Plant, MO  
Holston Army Ammunition Plant, TN  
Indiana Army Ammunition Plant, IN  
Iowa Army Ammunition Plant, IA  
Jefferson Proving Ground, IN  
Joliet Army Ammunition Plant, IL  
Kansas Army Ammunition Plant, KS  
Lake City Army Ammunition Plant, MO  
Lima Army Modification Center, OH  
Lone Star Army Ammunition Plant, TX  
Longhorn Army Ammunition Plant, TX  
Louisiana Army Ammunition Plant, LA  
Michigan Army Missile Plant, MI  
Milan Army Ammunition Plant, TN  
Navajo Army Depot, AZ  
Newport Army Ammunition Plant, IN  
Radford Army Ammunition Plant, VA  
Ravenna Army Ammunition Plant, OH  
Riverbank Army Ammunition Plant, CA

US Army Communications Command

Fort Ritchie, MD

Military Traffic Management Command

Bayonne Military Ocean Terminal, NJ  
Sunny Point Military Ocean Terminal, NC

Table 10

## Utilities Available Code

Digit Position	Letter Designation	Meaning of Designation
1	W	Water is available
	X	Water is not available
2	S	Sewer (sanitary) is available
	X	Sewer (sanitary) is not available
3	E	Electricity is available
	X	Electricity is not available
4	T	Telephone is available
	X	Telephone is not available
5	D	Heated by space heaters
	H	Heated by individual heating plant
	M	Heated by plant that serves more than one building
	X	Not heated by any means Note: if either character in position 5 or 6 is ", " then both should be "X."
6	C	Major heating fuel is coal
	O	Major heating fuel is oil
	I	Interruptible gas is supplemented with fuel oil for heating
	G	Major heating fuel is a firm supply of natural gas
	L	Major heating fuel is liquified petroleum gas
	Z	Major heating source is electricity
	X	No fuel or source of power required Note: if either character in position 5 or 6 is "X," then both should be "X."
7	Y	Cooled by evaporative cooling
	V	Mechanical ventilation only is available
	U	Cooled by individual direct expansion air-conditioning units
	R	Cooled by chilled water from a recip- rocating central unit
	P	Cooled by chilled water from a cent- rifugal central unit
	A	Cooled by chilled water from an ab- sorption central unit
	X	No means employed to cool the building or facility
8	B	Cooled air is circulated by-- Low-velocity air from a single or multiple zone
	F	Fan coil unit
	J	High-velocity air utilizing double duct
	K	High-velocity air using induction
	Z	No distribution of cool air required

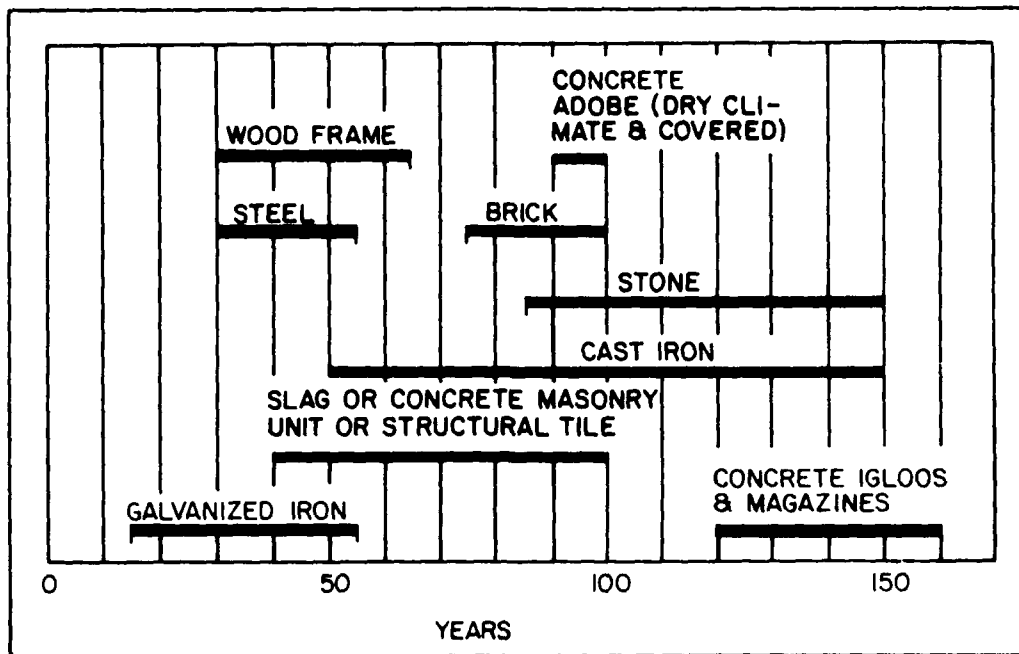


Figure 6. Estimated range of economic life for construction materials. (From Department of the Army Facility Classes and Construction Categories, AR 415-28 [Department of the Army, August 1973].)

5. Foundation Material. A two-code designation (see Table 11) which represents the foundation material. The first code indicates the foundation form, and the second indicates the pile or foundation material.

6. Structural Material. A two-code designation (see Table 12) which represents the structural material. The first code indicates the principal structural material, and the second indicates the secondary material. In smaller buildings, the surface material identified in Table 8 may be the only structural support. However, in larger buildings, the principal and secondary support may differ from the surface material.

7. Roof Material. A four-code designation (see Table 13) which represents the roof material. The first code indicates the type and material of roof support, the second indicates the roof deck material, the third indicates the roof surface material, and the fourth indicates the fire resistance rating of the entire structure.

8. MCA Number. The temporary or official DA line item number (MCA number) of the project that replaces a specific facility.

9. Current Use Description. A brief, descriptive phrase of the principal current use of facilities whose Current Use Code ends in 90.

Table 11

Foundation Material Code  
1st Character -- Foundation Form

<u>Code</u>	<u>Description</u>	<u>Abbreviation Used in Printout of Building Information Schedule</u>
1	Pile -- all piles will be assumed to be capped with a continuous footing	PL
2	Pier	PR
3	Continuous footing of various shapes and forms	CON
X	No foundation	NF

2nd Character -- Pile or Foundation Material

M	Adobe	ADB
B	Clay or concrete brick	BK
C	Concrete	CN
L	Concrete, reinforced	CR
D	Slag, or concrete block	BLK
G	Steel	ST
E	Stone	STN
F	Tile, structural	TST
A	Wood	WD
X	No foundation material	NF

Note: If the first character is an "X," the second character must also be an "X."

Table 12

Structural Material Code

<u>Code</u>	<u>Description</u>	<u>Abbreviation Used in Printout of Building Information Schedule</u>
M	Adobe	ADB
N	Aluminum	AL
S	Cement asbestos	CA
I	Cast iron	CI
B	Clay or concrete brick	BK
C	Concrete	CN
L	Concrete, reinforced	CR
P	Glass, plastic, transparent, or translucent material	GL
D	Slag or concrete block	BLK
G	Steel	ST
E	Stone	STN
F	Tile, structural	TST
A	Wood	WD

Table 13

Roof Material Code

1st Character -- Type and Material of Roof Support

<u>Code</u>	<u>Description</u>	<u>Abbreviation Used in Printout of Building Information Schedule</u>
1	Flat truss -- concrete, reinforced	CRF
2	Flat truss -- steel	STF
3	Flat truss -- wood	WDF
4	Gable or arch truss -- concrete, reinforced	CRG
5	Gable or arch truss -- steel	STA
6	Gable or arch truss -- wood	WDG
7	Joist or beam -- concrete, reinforced	CRJ
8	Joist or beam -- concrete, prestressed	CPJ
9	Joist or beam -- steel	STJ
Y	Joist or beam -- wood	WDJ
Z	Slab -- concrete, reinforced	CRS
R	Rafters	RAF
X	Arch -- no support required	

2nd Character -- Material of Roof Deck

<u>Code</u>	<u>Description</u>	<u>Abbreviation Used in Printout of Building Information Schedule</u>
1	Cement asbestos	1
2	Asbestos protected metal	2
3	Asphalt protected metal	3
4	Gypsum or lightweight concrete	4
5	Masonry arch	5
6	Metal	6
7	Reinforced concrete	7
8	Wood (less than 2 in. thick)	8
9	Wood (2 or more in. thick)	9
0	Wood fiber cement	0
C	Concrete arch	C
S	Steel arch	S
G	Glass, plastic, transparent, or translucent material	G
M	No roof decking	M



Table 13 (Cont'd)

3rd Character -- Material of Roof Surface

<u>Code</u>	<u>Description</u>	<u>Abbreviation Used in Printout of Building Information Schedule</u>
N	Aluminum, copper, or lead	AL
P	Built-up roll roofing without gravel	RBU
B	Built-up roll roofing with gravel	RBG
X	Cement asbestos	CAS
M	No surface	NS
Q	Roll--building paper	PRB
R	Roll--composition	CPS
S	Shingles--composition	SC
T	Shingles--slate	SL
U	Shingles--wood	SWD
V	Steel, galvanized	STG
L	Tar or silicone	TS
W	Tile	TL
G	Glass, glass fiber, plastic, transparent, or translucent materials	GL

4th Character--Building Fire Resistive Rating and Degree of Sprinkler Protection

<u>Code</u>	<u>Description</u>	<u>Abbreviation Used in Printout of Building Information Schedule</u>
1 5 W D	Combustible	1 5 W D
2 6 F R	Unprotected noncombustible	2 6 F R
3 7 T Y	Protected/noncombustible (1 hr fire resistance)	3 7 T Y
4 8 S P	Fire resistive (2 hr or more fire resistance)	4 8 S P

### 3 BASIC CONSIDERATIONS

#### General

Two independent parameters must be characterized in order to assess the potential seismic hazard posed by a building because of a strong-motion earthquake. The first is the likelihood of occurrence of a strong-motion earthquake, and the second is the likelihood of damage and loss of life, assuming that the destructive earthquake occurs. Neither of these parameters alone is sufficient to assess potential seismic hazard. Therefore, it is essential to identify the key factors influencing these parameters and to develop a method of characterizing them.

#### Earthquake Hazards

The potential damage to a building from a moderate to great earthquake is influenced by such factors as the magnitude of the earthquake, duration of ground shaking, depth of the earthquake's focus, orientation of the building with respect to an active fault, distance from the epicenter, and the characteristics of the rock and earth through which the earthquake motions propagate to reach the building. The significance of some of these factors is not yet fully known or understood. Moreover, the relative importance of these factors may vary considerably from one location to another, and sometimes within a relatively short distance.

During a moderate to great earthquake, these factors and possibly others may combine to produce four potential hazards at a particular site:

1. Ground Shaking. The energy released during an earthquake causes the earth to vibrate within the vicinity of the earthquake's epicenter. As the earth vibrates, all ground surface elements, whether natural or manmade, will respond to that vibration in varying degrees. The violent and random nature of the ground motions induce inertia forces in manmade structures and cause the structures to vibrate in a complex manner.

2. Surface Faulting. Most great earthquakes will be accompanied by several feet of fault displacement, which may extend for many miles along the fault trace. Surface faulting produces scraps, grabens, fractures, and mole tracks or "pressure ridges." Ground displacements along the fault may be horizontal, vertical, or both.

3. Ground Failures. Moderate earthquakes generally induce ground failures in the form of landslides, settlement, and liquefaction. In great earthquakes, there are usually large movements of rock and earth over wide areas. Tectonic subsidence, uplift, tilting, and warping may also occur.

4. Tsunami and Seiches. A tsunami, or seismic seawave, is produced by abrupt movement of land masses on the ocean floor. Tsunamis are very high-velocity waves with long periods of oscillation. Their low wave height gives little evidence of their existence in the open sea. However, as the waves approach land, their velocity decreases and their height increases.

Inundation heights of 20 to 30 ft (6 to 9 m) have been observed during a tsunami. Seiches, or periodic oscillations (sloshing), of bodies of water such as ponds, lakes, bays, and landlocked seas also usually occur in moderate-to-great earthquakes. Seiches may raise and lower a water surface from a few inches to several feet and may occur many miles from the epicenter.

Of the four potential earthquake hazards, ground shaking is the predominant factor in terms of structural damage to buildings.

### Indexing Earthquake Hazard

Except for ground shaking, little work has been done to develop a nationwide indexing system for earthquake hazards. In some areas, maps have been prepared to identify potential landslide areas or other areas of soil instability and these have been useful in land-use planning. However, it may be some time before it will be possible to develop a meaningful indexing system for earthquake hazards other than ground shaking.

A number of indexing systems have been developed for ground shaking. Using past earthquake history, it is possible to construct a map of the United States for the historically recorded Modified Mercalli Intensities (Figure 7). Using historical data of this type, it is possible to create a pseudo-seismic risk map like the ones shown in Figures 1, 2, 3, 4, and 8. The problem associated with these maps is that they are based on estimates of the maximum ground shaking experienced during the recorded historical period, with only minor consideration of how frequently such motions have occurred. Recently, the Applied Technology Council made a first attempt at incorporating seismic risk procedures into zoning maps for the United States. These seismic hazard maps were developed (1) to incorporate the attenuation of ground motions from the anticipated earthquake sources, and (2) to have the probability of exceeding the design ground shaking roughly the same in all parts of the country. However, the maps did not include detailed representation of the fault system or provisions for incorporating uncertainty. To represent the intensity of ground shaking, two parameters were adopted: effective peak acceleration (EPA) and effective peak velocity-related acceleration (EPV). Figures 9 and 10 show the EPA and EPV maps, respectively.

In Figure 9, the maximum value assigned to EPA at any point on the map is 0.4 g; however, this maximum is not intended to represent an absolute upper bound. There are locations inside the 0.4-g contour where higher values of EPA would be appropriate; however, contouring such small areas would have required special site-dependent studies.

The EPV map shown in Figure 10 was constructed by modifying the EPA map, but a different attenuation relationship was used in the eastern half of the country. In the western half, the distance required for the EPV from a large earthquake to be reduced to one-half its original value is about 80 miles. However, attenuation data of Modified Mercalli Intensity in the eastern United States has indicated that reduction of EPV to one-half its original value required 100 miles; thereafter, the distance required for the one-half reduction almost doubles. These modifications produced the map shown in Figure 10.

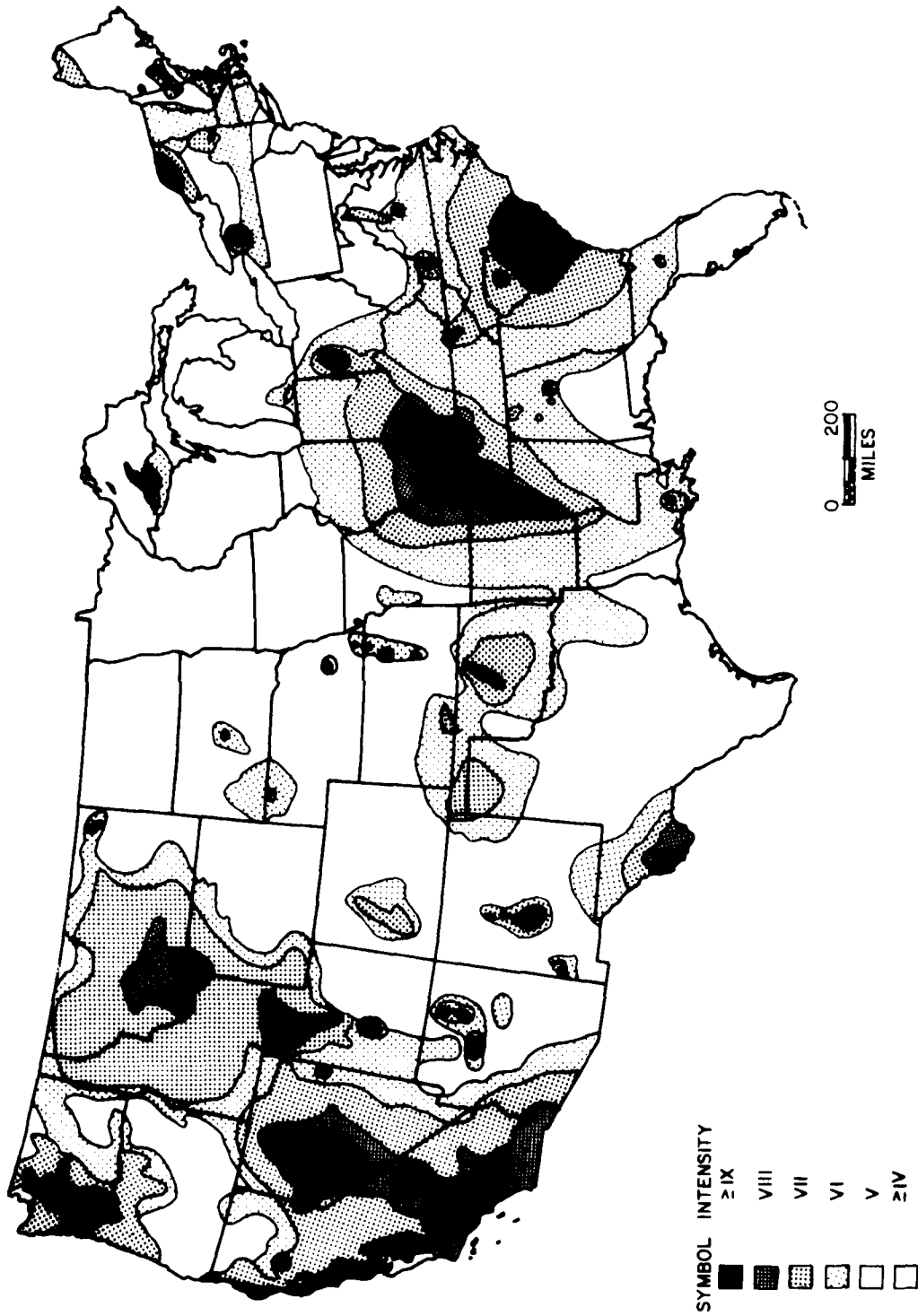


Figure 7. Maximum Modified Mercalli Intensities through 1965. (From Natural Hazards Evaluation of Existing Buildings, NBS BSS 61 [National Bureau of Standards, January 1975].)

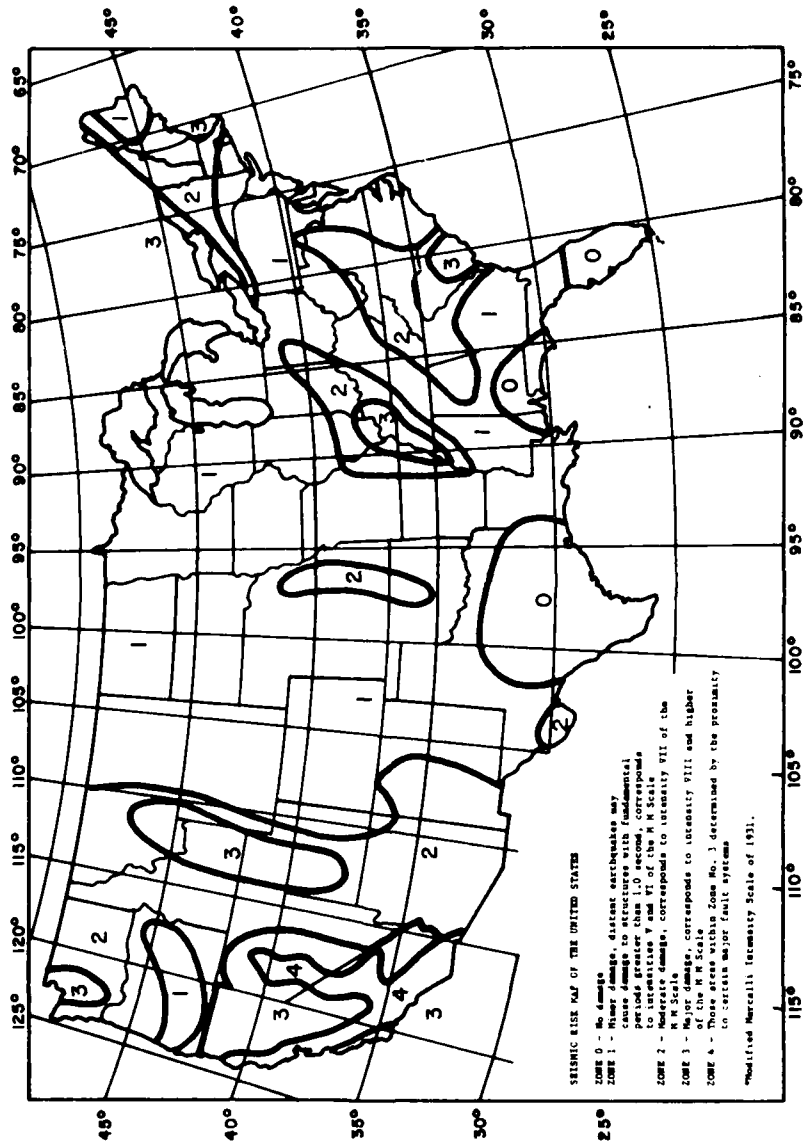
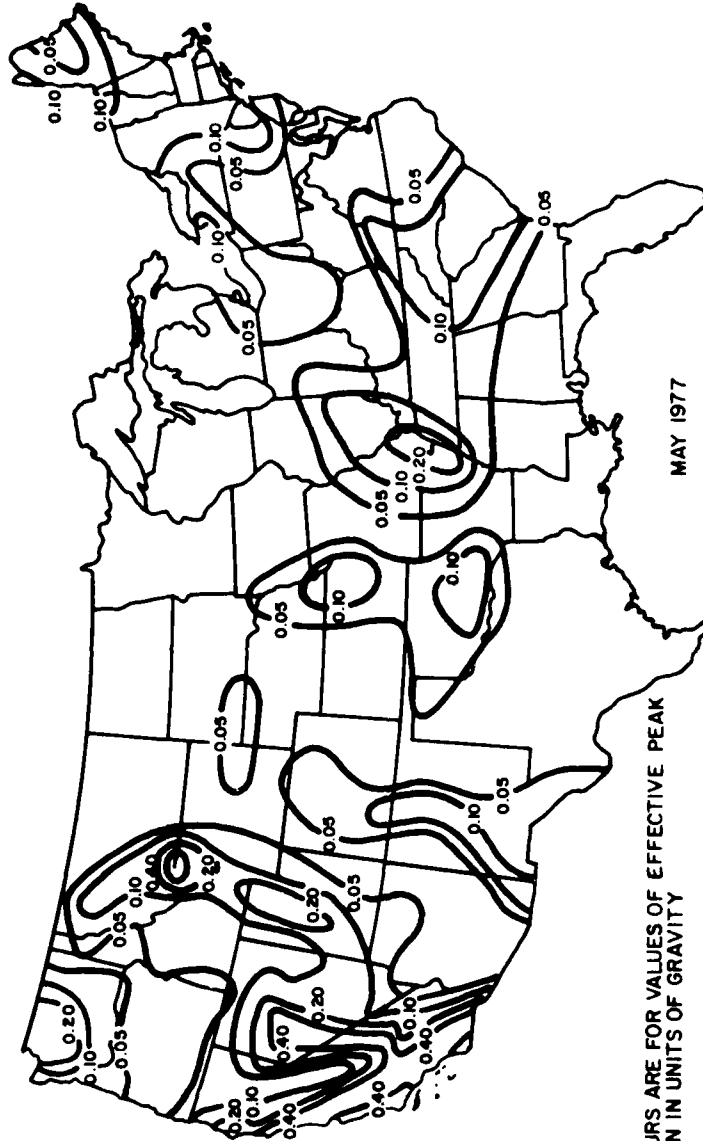


Figure 8. Seismic risk map of the contiguous United States. (Reproduced from the 1979 edition of the Uniform Building Code with permission of the publisher, the International Conference of Building Officials.)



NOTE: CONTOURS ARE FOR VALUES OF EFFECTIVE PEAK ACCELERATION IN UNITS OF GRAVITY

Figure 9. Contour map of effective peak acceleration (EPA) for the 48 contiguous states. (Contours represent EPA levels with non-exceedance probability of between 80 and 95 percent during 50-year period.) (Reprinted with permission from N. C. Donovan, B. A. Bolt, and R. V. Whitman, "Development of Expectancy Maps and Risk Analysis," ASCE, *Journal of Structural Division*, Vol 104, No. St 8 (1978), pp 1179-1192.)

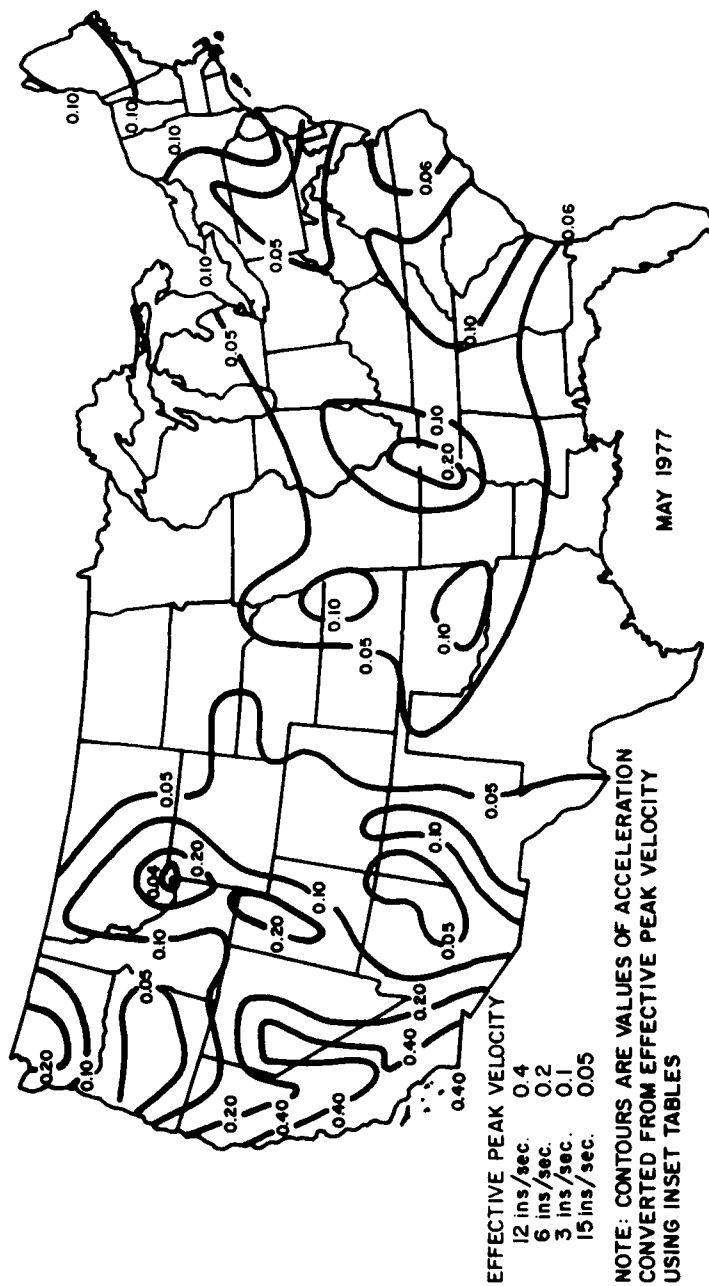


Figure 10. Contour map of effective peak velocity-related acceleration (EPV) for 48 contiguous states. (Contours represent values based on velocity but have been expressed equivalent to acceleration for use in developing lateral design forces.) (Reprinted with permission from N. C. Donovan, B. A. Bolt, and R. V. Whitman, "Development of Expectancy Maps and Risk Analysis," ASCE Journal of the Structural Division, Vol 104, No. St 8 (1978), pp 1179-1192.

While these maps are a marked improvement over the seismic zone maps shown in Figures 7 and 8, they have not been officially adopted by the Army. Therefore, for the purpose of this investigation, the seismic zone maps in TM 5-809-10 (1980 Draft Edition) will be adopted for indexing the ground shaking hazard. Tables 14 and 15 give the appropriate seismic zone for each of the 164 Army installations and major activities.

### Building Response and Damage

Earthquake ground motions are transmitted to a building through its foundation when the foundation is set in motion and the rest of the building is forced to move and respond. The complex vibratory motion which follows is a function of the dynamic properties of the ground motion (e.g., frequency content, duration, acceleration level, etc.) and the dynamic characteristics of the building (e.g., natural frequencies of vibration, mode shapes or characteristic patterns of vibration at each of the natural frequencies, and damping). The building's physical properties, such as weight (mass), stiffness, damping, etc., determine the building's dynamic characteristics. The way these properties affect a building's dynamic characteristics and ultimately its response is discussed below:

1. Mass. A building's mass influences its period of vibration. If the predominant periods of the building are close to the predominant periods of the input motions, the building's response may be amplified. The distribution of the mass within the building also has important effects on its response. Uneven or assymmetrical distribution of the mass will cause the building to respond with motions that include torsion as well as translations.

2. Stiffness. Stiffness will also influence the period of the building. A building's overall stiffness is dependent upon the material stiffness of its components: its configuration (i.e., number of stories, general form in plan and elevation, and geometry of various systems and components); and the type of connections between the components. This stiffness will determine the building's mode of response during an earthquake. Flexible buildings will undergo large deformations and relative movements, while stiff buildings generally experience small deformations. In addition, a building may exhibit torsional motions because various parts of a building are stiffer than others.

3. Damping. A building's damping property is related to the degree to which it will dissipate energy. Damping is the measure of the building's resistance to continued vibration and is determined by all its materials and finishes. Buildings with many partitions, ceilings, and ductile finishes tend to have higher damping coefficients than buildings with fewer components. Damping is a major factor in determining building response, because the higher the damping coefficient, the smaller the acceleration for which the building must be designed.

A building's mass, stiffness, and damping characteristics are a function of several other factors such as those discussed below.



Table 14

Seismic Zone Tabulation for Army Installations and  
Major Activities in the Continental United States

<u>Installation or Major Activity</u>	<u>Seismic Zone</u>
Aberdeen Proving Ground	1
Anniston Army Depot	2
Arlington Hall Station	1
Army Materials and Mechanics Research Center	3
Army Topographic Station	1
Baker, Fort	4
Ballistics Missile Defense Advanced Tech. Center	1
Belvoir, Fort	1
Benning, Fort	1
Bliss, Fort	2
Blue Grass Depot Activity	1
Bragg, Fort	1
Brooke Army Medical Center	0
Bullis Camp	0
Cameron Station	1
Campbell, Fort	2
Carlisle Barracks	1
Carson, Fort	1
Catalog Data Activity	1
Chaffee, Fort	1
Coosa River	2
Corpus Christi Army Depot	0
Crane Army Ammunition Activity	2
DARCOM Ammunition Center	1
Defense Construction Supply Center	1
Defense General Supply Center	1
Defense Personnel Support Center	2
Detrick, Fort	1
Detroit Arsenal	1
Devens, Fort	2
Diamond, Harry Laboratories	1
Dix, Fort	1
Drum, Fort	2
Dugway Proving Ground	2
Dwight David Eisenhower Army Medical Center	2
Electronic R&D Command	1
Eustis, Fort	1
Fitzsimmons Army Medical Center	1
Frankford Arsenal	2
Gateway Army Ammunition	2

Table 14 (Cont'd)

<u>Installation or Major Activity</u>	<u>Seismic Zone</u>
Gillem, Fort	2
Gordon, Fort	2
Gulf Outport	1
Hamilton, Fort	2
Harrison, Fort Benjamin	2
Hawthorne Army Ammunition Plant	4
Hayes Army Ammunition Plant	1
Hill, Fort AP	1
Holston Army Ammunition Plant	2
Hood, Fort	0
Houston, Fort Sam	0
Huachuca, Fort	2
Hunter Army Airfield	2
Indiana Army Ammunition Plant	2
Indiantown Gap, Fort	1
Iowa Army Ammunition Plant	1
Irwin, Fort	4
Jackson, Fort	2
Jefferson Proving Ground	2
Joliet Army Ammunition Plant	1
Kansas Army Ammunition Plant	1
Knox, Fort	2
Lake City Army Ammunition Plant	2
Leavenworth, Fort	2
Lee, Fort	1
Letterkenny Army Depot	1
Letterman Army Medical Center	4
Lewis, Fort	3
Lexington-Blue Grass Depot Activity	1
Liggett, Fort Hunter	4
Lima, US Army Modification Center	2
Lone Star Army Ammunition Plant	1
Longhorn Army Ammunition Plant	1
Louisiana Army Ammunition Plant	1
MacArthur, Fort	4
Madigan Army Medical Center	3
McAlester Army Ammunition Plant	2
McClellan, Fort	2
McCoy, Fort	1
MacKall, Camp	1
McNair, Fort Lesley J.	1
McPherson, Fort	1
Meade, Fort George G.	1

Table 14 (Cont'd)

<u>Installation or Major Activity</u>	<u>Seismic Zone</u>
Memphis Defense Depot	3
Michigan Army Missile Plant	1
Milan Army Ammunition Plant	2
Mississippi Army Ammunition Plant	0
Monmouth, Fort	2
Monroe, Fort	1
Monterey, Presidio of	4
Myer, Fort	1
Natick Research and Development Center	2
Navajo Depot Activity	1
New Cumberland Army Depot	1
Oakdale Support Center	1
Oakland Army Base	4
Ogden Defense Depot	3
Ord, Fort	4
Parks, Camp	4
Phosphate Development Works	1
Picatinny Arsenal	2
Pickett, Fort	1
Pine Bluff Arsenal	2
Polk, Fort	1
Pueblo Army Depot Activity	1
Radford Army Ammunition Plant	2
Ravenna Army Ammunition Plant	1
Red River Army Depot	1
Redstone Arsenal	2
Riley, Fort	2
Ritchie, Fort	1
Riverbank Army Ammunition Plant	3
Roberts, Camp	4
Rock Island Arsenal	1
Rocky Mountain Arsenal	
Rucker, Fort	0
Sacramento Army Depot	3
Saginaw Army Aircraft Plant	0
St. Louis Army Ammunition Plant	2
St. Louis Area Support Center	2
San Francisco, Presidio of	4
Savannah Army Depot Activity	1
Scranton Army Ammunition Plant	2
Seneca Army Depot	2
Sharpe Army Depot	3
Sheridan, Fort	1
Sierra Army Depot	3

Table 14 (Cont'd)

<u>Installation or Major Activity</u>	<u>Seismic Zone</u>
Sill, Fort	2
South Atlantic Outport	3
Southern California Outport	4
St. Louis Area Support Center Illinois	2
Stanley, Camp Storage Activity	0
Stewart, Fort	1
Story, Fort	1
Stratford Army Engine Plant	2
Sunny Point Military Ocean Terminal	1
Tarcom Support Activity Selfridge	1
Tarheel Army Missile Plant	2
Tobyhanna Army Depot	2
Tooele Army Depot	3
Twin Cities Army Ammunition Plant	1
Umatilla Depot Activity	2
United States Military Academy	2
Vancouver Barracks	1
Vint Hill Farms Station	1
Volunteer Army Ammunition Plant	2
Wadsworth, Fort	1
Walter Reed Army Medical Center	1
Watervliet Arsenal	2
West Point Military Reservation	2
White Sands Missile Range	2
William Beaumont Army Medical Center	2
Wingate Depot Activity, Fort	1
Wood, Fort Leonard	1
Yakima Firing Center	2
Yuma Proving Ground	4

Table 15

Seismic Zone Tabulation for Army Installations and Major Activities in Alaska and Hawaii

Major Activities in Alaska and Hawaii

<u>Installation or Major Activity</u>	<u>Seismic Zone</u>
<u>Alaska</u>	
Greely, Fort	3
Richardson, Fort	4
U.S. Army Medical Dept. Activity	3
Wainwright, Fort	3
<u>Hawaii</u>	
Pohakuloa Training Area	3
Schofield Barracks	2
Tripler Army Medical Center	2
Wheeler Army Airfield	2

1. Construction Materials. Different materials display varying inelastic behavior. Ductile materials, such as steel, have an extended inelastic range in which they can undergo permanent deformations without rupture. On the other hand, brittle materials, such as brick, masonry, and plain concrete, display almost no inelastic behavior under loading, and experience sudden failures at or near the elastic limit. A material's ability to absorb energy while undergoing inelastic deformation without failure is termed ductility. Ductility can be thought of as providing a quality of toughness which, to a large extent, determines a building's survivability under earthquake conditions. Without proper reinforcement, brick, masonry, and concrete have low ductility values and are very susceptible to failure during an earthquake.

2. Structural System. Another important factor affecting building performance during an earthquake is the lateral-force resisting elements of a building's structural system. The structural system must transmit the lateral forces by horizontal diaphragm action of the roof and floor systems to the vertical resisting elements (ductile moment resisting space frame, shear walls, or braced frames) and down to the foundation. The rigidity of the diaphragms is very important. Rigid diaphragms tend to reduce the effects of unsymmetrical forms and structural features, because more torsional resistance can be developed. Flexible diaphragms may permit portions of the building to vibrate out of phase with the rest of the building, creating major torsional and displacement problems. Foremost among the requirements is the necessity for the building to be tied together as a unit, with all connections having adequate capacity for load transfer by shear, tension, compression, or moment, as applicable.

For the purpose of seismic analysis and design, building structural systems can be grouped into four general categories: bearing wall system, building frame system, moment-resisting frame system, and dual system.

a. A bearing wall system refers to a structural support system in which major load-carrying columns are omitted and the walls and/or partitions are strong enough to carry the loads. The walls and partitions supply lateral stiffness and stability to resist earthquake loading and other lateral loadings. During past earthquakes, failures in the bearing wall system have frequently been caused by a lack of redundancy in the vertical and horizontal load support.

b. A building frame system carries the gravity loads primarily by a frame supported on columns rather than bearing walls. Lateral resistance is provided by nonbearing structural walls or braced frames. Generally, past performance of this structural system has been better than the bearing wall system.

c. A moment-resisting frame system, like the building frame system, has a complete frame. However, in this system, the lateral resistance is provided by moment-resisting connections between columns with interacting beams or girders.

d. A dual system consists of a space frame made up of columns and beams which provide support for the gravity loads. Lateral resistance is supplied by structural nonbearing walls or bracing. The frame has a redundant lateral force system capable of resisting at least 25 percent of the specified earthquake lateral forces. Past performance has indicated that this system is one of the most effective structural systems for resisting lateral forces.

3. Building configuration. Irregularities in the plan and vertical configurations can radically change a building's dynamic behavior.

a. Plan configuration. Plan configuration irregularities affect the diaphragm forces and the distribution of the inertial forces to the vertical components of the lateral force-resisting system. Pure symmetry in plan does not necessarily guarantee well-balanced response of a building. Buildings with H- or cruciform-shaped plans are symmetrical, yet the response of the wings of these buildings is generally different from the response of the building as a whole, and produces high stress concentrations at the re-entrant corners. Likewise, a stiff core located off center in the plan causes the center of rigidity not to coincide with the center of mass, and this increases torsional effects. Some common irregularities in plan include the following:

- (1) Mass and resistance eccentricity
- (2) Discontinuity in the diaphragm stiffness
- (3) Geometric irregularities, such as +, H, U, E, T, and L shapes
- (4) Core-type layouts.

b. Vertical configuration. Uniformity in a building's vertical configuration is also very important. Vertical configuration irregularities affect the response of various levels of a building and may impose loads at these levels which can be significantly different from those obtained by normal assumptions. Irregularities in the vertical configuration are created by the following features:

- (1) Unsymmetrical vertical geometry with respect to the vertical axis of the building
- (2) Setbacks at one or more levels
- (3) Significant changes in the mass-to-stiffness ratio in adjoining levels

c. Structural features. Other structural features which may adversely affect the structure's response include:

- (1) Discontinuities in the vertical and lateral load-resistance systems
- (2) Nonredundant systems
- (3) Lack of ties and continuity
- (4) Lack of collector elements.

4. Foundation. The basic principle of earthquake engineering is that the buildings should act as an integral unit, and that there should be adequate load paths for carrying the lateral forces down to the foundation. Ultimately, the foundation must transfer the lateral forces to the subsoil, resist overturning effects from the lateral forces, resist the vertical gravity loadings, and provide sufficient reserve strength to deal with some of the differential ground movements. Continuous rafts and box foundations generally have adequate strength and stiffness to resist differential settlement.<sup>8</sup>

5. Nonstructural components. Recent earthquakes have demonstrated that the cost of damage to nonstructural components can be excessive. Moreover, earthquake damage studies have shown that the placement of nonstructural elements on or in a building may significantly affect the structure's seismic response. Some of the factors that cause damage are discussed below.

a. Architectural elements. Damage to architectural elements can result in both significant dollar losses and hazards to occupants. For example, stairways have been blocked by the collapse of surrounding partitions or wall claddings. There have been widespread collapses of suspended ceilings with light "T" bar metal runners and splined or lay-in acoustical tiles. In addition, building elements without intended structural function, such as unfill walls, partitions, curtain walls, suspended ceilings, and surface finishes, may interact with the structural system. The interaction of the architectural element with the structural system, exterior treatment and elements, and interior treatment and elements are all important items that could potentially cause damage and loss of life.

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<sup>8</sup> D. J. Dowick, Earthquake Resistant Design (John Wiley, 1977), p 90.

b. Elevators and stairways. Damage to building exits is a common problem, particularly when stairways are blocked by surrounding partitions and elevators are rendered inoperable due to lack of electrical power and/or damage to the equipment. Elevator counterweights are frequently thrown out of their guide system because of inadequate strength in the guides or the nature of their attachments to the structural frame.

c. Mechanical, electrical, and plumbing. Insufficient attention has been given to the lateral force design for equipment or to its anchorage and bracing. Equipment has often been placed on vibration isolators that are inadequate to resist strong earthquake motions. Suspended electrical light fixtures have proved vulnerable to earthquake motions, except for those systems incorporating specially developed restraining systems. Equipment that has been adequately bolted to concrete floors and foundations and which has adequate supports has performed satisfactorily.

### Indexing Hazardous Buildings

Based on lessons learned from past earthquakes and in the interest of simplicity, it appears that two fundamental parameters can define the potential hazardousness of an existing building: a structural system index and an importance index. The structural system index reflects the type of lateral force-resisting system in the building, including the type of materials from which it is constructed, such as reinforced masonry, load-bearing wall systems; reinforced concrete, ductile, moment-resisting frames; or light steel x-braced frame. The basic structural system index can be modified by weighting factors to account for additional elements (e.g., number of stories, irregularities in the plan and vertical configuration, foundation system, etc.) as such information becomes available. The importance index reflects both the building's occupancy potential and its post-earthquake operational requirements. The importance index can be modified by weighting factors to account for such factors as cost and size of the building.

Based on the information available in the RPI, there does not seem to be a good basis for correlating a structural system index. The type of wall material is hardly sufficient information on which to judge the required type of lateral force-resisting structural system. For example, concrete walls could be cast-in place concrete shear walls or precast concrete wall panels. The behavior of these two systems is radically different. Moreover, in reviewing the detailed RPI for Fort Ord, CA, it was noted that in several instances, a building's type of wall material was not specified. With some additional research and field data, it may be possible to formulate a more rational scheme for characterizing the structural system index.

It appears that the RPI and BIS systems contain enough information for the importance index. The likely occupancy of many of the buildings is given or can be calculated on the basis of the total area of the building and the number of square feet per occupant. The latter must be established on the basis of engineering judgment and modified on the basis of field experience. In addition, the building area and the acquisition cost can be used as weighting factors.



#### 4 SEISMIC HAZARD PRIORITY-RANKING CONCEPT FOR BUILDINGS

##### Basic Philosophy

Since the Army has a huge inventory of buildings, it must have an effective strategy to identify the ones that present potentially unacceptable seismic hazards in order to perform seismic safety evaluations of potentially hazardous buildings on a priority basis. The degree of sophistication of a concept for identifying potentially hazardous buildings is at least initially dependent on information and data in the RPI or BIS or in data that can be developed with a minimal expenditure of time and funds. It is not practical for the Army to resurvey its existing inventory of buildings to collect additional data for a detailed analytical evaluation that would probably require a dynamic analysis of each building. The seismic hazard priority-ranking procedure must be structured to provide meaningful information without such detailed data; however, it should use detailed safety data to provide more refined estimates of the potential seismic hazard if it is available or becomes available during the preliminary seismic safety evaluations or in conjunction with modernization projects.

Basically, the objectives in formulating the seismic hazard priority-ranking procedure are:

1. To produce meaningful results which are as simple as possible, considering the existing databases.
2. To minimize the amount of data required for meaningful results, i.e., the database should contain only the most fundamental building characteristics.
3. To provide an orderly means of associating the building characteristics with hazard potential.
4. To provide a database structure that can accommodate additional detailed data if and when it becomes available in order to refine or update the seismic vulnerability index value.

##### Basic Concept

The basic concept for the seismic hazard priority-ranking procedure is based on calculating a seismic vulnerability index that reflects a building's relative potential seismic hazard. The index is calculated from factors associated with the seismic exposure, the building's structural characteristics, and aspects of the building which reflect the importance of the building. The basic algorithm for calculating the seismic vulnerability index is:

$$SVI = f(EI*SSI*II) \quad [Eq 1]$$

where

SVI = seismic vulnerability index

EI = exposure index

SSI = structural system index

II = importancy index

f = proportioning function

The seismic vulnerability index has a range of value between 0 and 100. The closer the value is to 100, the greater the likelihood is of significant damage to the building or loss of life. Likewise, the exposure index, the structural system index, and the importancy index all have values ranging between 0 and 100. Within a given population of buildings, the building with the greatest potential hazard (i.e., the largest numerical value for the product of the exposure index, structural system index, and importancy index) is assigned a seismic vulnerability index value of 100 and the seismic vulnerability index value for other buildings in the population is proportioned accordingly.

The exposure index represents the level of anticipated strong motion shaking at the building's location, and it can be modified by subjective weighting factors for the effects of site-structure resonance conditions, potential liquefaction, landslides, surface faulting, differential settlement, tsunamis, etc. For Army installations in the United States, the exposure index value can be based on the coefficient in Table 16 that corresponds to the appropriate seismic zone tabulated in Tables 14 and 15. Initially, most of the associated weighting factors will have a value of zero, since the effects of many of these secondary hazards have not been indexed in a meaningful way.

The structural system index represents the level of anticipated performance of the building's structural system, and it can be modified by subjective weighting factors for the effects of irregularities in plan and vertical

Table 16  
Basic Exposure Index

Seismic Zone	0	1	2	3	4
Coefficient	0	3/16	3/8	3/4	1

configuration, foundation type, number of stories, redundancy of structural members, etc. The index is a function of both the type of structural system and the materials comprising it. Initially, the structural system index can be assigned a value based on the data for wall material in the RPI or the structural material in the BIS. However, a more rational method for characterizing the structural performance is needed if the results are to be meaningful. Likewise, many of the weighting factors associated with the structural system index will have a value of zero, since many of these structural features have yet to be indexed in a meaningful way.

The importance index represents the relative importance of the building either in terms of or post-disaster recovery requirements or potential occupancy. Typical examples of buildings with post-disaster recovery requirements are:

- (1) Hospitals
- (2) Fire stations, rescue stations, and garages for emergency vehicles
- (3) Power stations and other utilities required as emergency facilities
- (4) Mission-essential and primary communication or data-handling facilities
- (5) Facilities involved in operational missile control, launch, tracking, or other critical defense capabilities
- (6) Facilities involved in handling, processing, or storing sensitive munitions, nuclear weaponry or processes, gas and petroleum fuels, and chemical or biological contaminants.

High potential-occupancy buildings are those where primary occupancy is for assembly of a large number of people, or where services are provided to a large area having many other buildings. Buildings in this category may suffer damage in a large earthquake but are recognized as warranting a higher level of safety than the ordinary building. Typical examples are:

- (1) Buildings whose primary occupancy is that of an auditorium, recreation facility, dining hall, or commissary which is subject to occupancy by more than 300 persons
- (2) Confinement facilities
- (3) Central utility (power, heat, water, sewage) that are not required as emergency facilities and that serve large areas
- (4) Buildings having high value equipment whose justification is provided by the using agency.

All other buildings not covered by the categories listed above are considered ordinary buildings requiring no special consideration.

The importance index can be modified by weighting factors for the effects of occupancy or the building's basic acquisition cost area, historical value, etc.

One of the major purposes of the seismic hazard priority-ranking procedure is to provide a tool to help Army personnel decide which buildings require seismic safety evaluations, and in what order to proceed through the inventory. The ranking process for achieving this goal is structured on the concept that a building's relative position in a priority list can be based on an accumulation of "points." The points are determined from the relative magnitude of various factors and weights assigned to them. The weights measure the relative importance of each factor, i.e., the higher the weight, the more points are accumulated for a building's position in the overall ranking. The following example illustrates the procedure.

Suppose the importance index for three buildings designated A, B, and C is to be calculated on the basis of the relative importance of the building and three weighting factors: occupancy, cost, and area. Building A is a fire station with specific post-disaster recovery requirements. Buildings B and C are used for training and administrative purposes, respectively, but neither has any post-disaster recovery requirements. For purposes of this example, assign Building A a basic index of 2.0 and Buildings B and C a basic index of 1.0. Similarly, assign a weight of 4 to "occupancy," 3 to "area," and 2 to "cost." The steps in the ranking process are as follows:

- a. Step 1: Store the building identifiers and relevant data in a table.

<u>Building</u>	<u>Occupancy</u>	<u>Area</u>	<u>Cost</u>
A	15	9,900	296
B	92	11,400	252
C	30	22,000	317

- b. Step 2: Sort on the occupancy factor. Use an ascending order so that the largest occupancy is last in the sort and has the largest rank number.

<u>Building</u>	<u>Occupancy</u>	<u>Area</u>	<u>Cost</u>
A	15	9,900	296
C	30	22,000	317
B	92	11,400	252

- c. Step 3. Assign a rank order to the occupancy factor.

<u>Building</u>	<u>Occupancy</u>	<u>Area</u>	<u>Cost</u>
A	1	9,900	296
C	2	22,000	317
B	3	11,400	252

d. Step 4. Sort on the area factor.

<u>Building</u>	<u>Occupancy</u>	<u>Area</u>	<u>Cost</u>
A	1	9,900	296
B	3	11,400	252
C	2	22,000	317

e. Step 5: Assign a rank order to the area factor.

<u>Building</u>	<u>Occupancy</u>	<u>Area</u>	<u>Cost</u>
A	1	1	296
B	3	2	252
C	2	3	317

f. Steps 6 and 7: Sort and assign rank order for the cost factor.

<u>Building</u>	<u>Occupancy</u>	<u>Area</u>	<u>Cost</u>
A	1	1	2
B	3	2	1
C	2	3	3

g. Step 8: Calculate the numbers of raw points for each parameter, and subtotal the raw points for each building.

<u>Building</u>	<u>Occupancy</u>	<u>Raw Points</u>		<u>Subtotal</u>
		<u>Area</u>	<u>Cost</u>	
A	1x4=4	1x3=3	2x2=4	4+3+4=11
B	3x4=12	2x3=6	1x2=2	12+6+2=20
C	2x4=8	3x3=9	2x3=6	8+9+6=21

h. Step 9: Multiply the subtotal of the raw points for each building by the basic index to obtain the total raw points for each building.

<u>Building</u>	<u>Subtotal</u>	<u>Basic Index</u>	<u>Total</u>
A	11	2.0	22
B	20	1.0	20
C	21	1.0	21

i. Step 10: Assign the importance index for each building based on Building A receiving a value of 100, and proportion the values for Buildings C and B accordingly.

<u>Building</u>	<u>Importance Index</u>
A	22/22 (100) = 100
C	21/22 (100) = 95
B	20/22 (100) = 91

Based on the factors and weights specified in this example, Building A would warrant first priority, followed by Buildings C and B, respectively.

### Trial Application

A trial application of the ranking concept was performed using a subset of the existing buildings at Fort Ord, CA. The subset was obtained by screening the inventory of real property for Fort Ord and excluding all items except buildings having an area greater than 3000 sq ft (270 m<sup>2</sup>), and an acquisition cost greater than \$200 K. Of the 3620 buildings at Fort Ord, 127 met the specified criteria. The Appendix lists these buildings by category code.

Since all the buildings were located at one installation, the exposure index was the same for all buildings. Moreover, due to the lack of definitive information regarding the buildings' structural systems, the structural system index was assumed to be the same for all buildings. Computation of the importance index involved modifying the basic index by weighting factors for occupancy potential, building area, and acquisition cost. To establish a potential occupancy level for some of the buildings, it was necessary to establish values for the number of square feet per occupant. These values were established on the basis of engineering judgment; Table 17 lists the specific values used for this application by facility class. Subsequently, buildings were ranked in accordance with the process outlined in the previous section.

Each of the 127 buildings was sorted on the basis of potential occupancy, area, and acquisition cost; then, each building was assigned a rank from 1 to 127 for each factor. Where identical buildings such as enlisted personnel barracks were encountered, the rank assigned to each building was the average of the number of total ranked points for the entire group of identical buildings. For example, if three buildings were tied for fifth place, each was assigned a rank of 6, and the fifth and seventh positions were eliminated. Weighting factors of 4 for "potential occupancy," 3 for "area," and 2 for "acquisition cost" were assigned. Buildings with potential post-disaster recovery requirement, or having high occupancy were assigned basic indices of 1.5 and 1.25, respectively. The calculations were performed manually, following the procedure outlined in the example calculation.

Table 18 lists the ten buildings with the highest ranking based on the importance index. This listing is presented to illustrate the potential results of a seismic hazard priority-ranking procedure, and should not be construed as a final ranking of the potentially hazardous buildings at Fort Ord, CA. The basic concept is still under development in many areas, particularly with regard to finding a more rational scheme to characterize the structural performance of buildings based on the limited data contained in the RPI and BIS.

Table 17

## Square Feet Per Occupant

(Metric Conversion Factor: 1 sq ft = .09 m<sup>2</sup>)

<u>Facility</u>	<u>Sq Ft/Occupant</u>
Telephone Exchange	1000
Regimental Brigade Headquarters	300
Aircraft Instrument Trainer	100
Battalion Administration and Classroom	100
Maintenance Aircraft Hangar, Organizational	2000
Field Maintenance Aircraft Hangar	2000
Motor Repair Shop	1000
Maintenance Shop, General Purpose	2000
Aircraft Accountable Parts suppl's	2000
General-Purpose Storage	2000
General Storage Family Housing	6000
Hospital	500
Dental Clinic	1000
Administration Building, General Purpose	300
Enlisted Personnel Mess	60
Administration and Supply	2000
Confinement Facility	500
Fixed Laundry	1500
Bowling Center	500
Commissary	200
Gymnasium	100
Library, Main	1000
Open Mess, NCO	100
Open Mess, Officers	100
Exchange, Main	200
Post Office, Main	2000
Enlisted Men's Service Club	100
Indoor Swimming Pool	200
Sewage Treatment Plant	1000

Table 18

List of Facilities Ranked by Priority

<u>Facility</u>	<u>Building/Facility Number</u>
1 Hospital	4385
2 Commissary	4240
3 Enlisted Men's Service Club	2075
4 Open Mess NCO	4260
5 Confinement Facility	4953
6 Exchange Main Retail Store	4235
7 Enlisted Personnel Mess	3641
8 Post Chapel	4280
9 Enlisted Men's Service Club	4600
10 Enlisted Personnel Barracks	4552



## 5 CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of the study, some general conclusions and recommendations can be made.

The basic concept for the seismic hazard priority-ranking procedure appears to satisfy the objectives of requiring a minimum amount of information and relating a building's characteristics to the seismic hazard in an orderly manner. Although the basic concept has the potential to provide meaningful results, this is not yet a certainty. Realistically, this can be evaluated only after further development of the concept and comparing more comprehensive trial evaluations with actual experience at installations.

The current RPI and BIS databases do not adequately describe the buildings' structural systems or the structural materials that comprise them; this information is necessary to meet the needs and requirements of the seismic hazard priority-ranking concept. The RPI and BIS databases should be modified to incorporate a more suitable description of the buildings' structural systems and the materials comprising them.

In addition, further development of the seismic hazard priority-ranking concept is necessary to refine the basic index values, to establish weighting factor values, and to automate the concept.

## REFERENCES

- Construction Criteria Manual, DOD 4270.1-M (Department of Defense, June 1978).
- Department of the Army Facility Classes and Construction Categories, AR 415-28 (Department of the Army, August 1973).
- Donovan, N. C., B. A. Bolt, and R. V. Whitman, "Development of Expectancy Maps and Risk Analysis," ASCE, Journal of the Structural Division, Vol 104, No. St 8 (1978), pp 1179-1192.
- Dorwick, D. J., Earthquake Resistant Design (John Wiley, 1977), p 90.
- Inventory of Army Military Real Property (Department of the Army, 30 September 1979).
- Master Planning for Army Installations, AR 210-20 (Department of the Army, 26 June 1976).
- Natural Hazards Evaluation of Existing Buildings, NBS B5561 (National Bureau of Standards, January 1975).
- Seismic Design for Buildings, TM 5-809-10, Draft Edition (Department of the Army, 1980).
- Uniform Building Code (International Conference of Building Officials, 1979).
- United States Army Installations and Major Activities, DA Pam 210-1 (Department of the Army, February 1980).

APPENDIX: SUBSET OF EXISTING BUILDINGS AT FORT ORD, CA

SCREENED INVENTORY OF MILITARY REAL PROPERTY AT (ORD FORT 1)

AS OF DATE 063080  
 CATEGORY CODE FORMAT #8  
 SCREENING PARAMETERS

MINIMUM AREA, SF FT ----- (3000)\*  
 EARLIEST ACQUISITION/BUILT YR -- (1980)\*  
 MINIMUM ACQUISITION COST, \$K --- (200)\*

CATEGORY CODE	CATEGORY DESCRIPTION	TYPE CONST	BUILDING / FACILITY NO	ACQUISITION COST (\$K)	TOTAL AREA	UNIT MEASURE	YEAR BUILT	NUMBER FLOORS	WALL MATERIAL	TOTAL CAPACITY	UNIT MEASU
13180	TEL EXCH BLDG	P	04230	289	13088	SF	53	3	C	0	0
14186	RGY/PDE HQ BLDG	P	04463	202	9797	SF	70	3	D	0	0
17110	AC TRAINER BLDG	P	00521	655	7222	SF	78		G	0	0
17150	BN CLASSROOMS	P	04900	4130	5627	SF	54			0	0
17151	BN ADM - CLRM	P	03628	248	5880	SF	77	1	H	0	0
17151	BN ADM - CLRM	P	03629	352	5820	SF	78		H	0	0
17151	BN ADM - CLRM	P	03630	352	5820	SF	78		H	0	0
21110	MNT AC HG CRG	P	00510	465	21497	SF	59	2	C	0	0
21110	MNT AC HG CRG	P	00524	814	38007	SF	61	2	C	0	0
21110	MNT AC HG CRG	P	00527	2084	39446	SF	77	2		0	0
21114	FL MNT AC PG	P	00507	2045	64920	SF	78	2	C	0	0
21114	FL MNT AC HQ	P	00533	756	35000	SF	63	2	C	0	0
21410	MOTOR REP SHOP	P	00509	289	5300	SF	77	2		0	0
21410	MOTOR REP SHOP	P	01483	720	15592	SF	77	2		0	0
21410	MOTOR REP SHOP	P	01489	673	14578	SF	77	2		0	0
21410	MOTOR REP SHOP	P	01495	583	12634	SF	77	2	C	0	0
21410	MOTOR REP SHOP	P	04495	411	8682	SF	77	2	D	0	0
21410	MOTOR REP SHOP	P	04499	684	14535	SF	77	2		0	0
21410	MOTOR REP SHOP	P	04506	684	14520	SF	77	2		0	0
21410	MOTOR REP SHOP	P	04512	684	14517	SF	77	2		0	0
21410	MOTOR REP SHOP	P	04538	468	12006	SF	77	2		0	0
21410	MOTOR REP SHOP	P	04544	531	12820	SF	77	2		0	0

SCREENED INVENTORY OF MILITARY REAL PROPERTY AT (ORD) FORT

AS OF DATE 063080

CATEGORY CODE FORMAT #8

SCREENING PARAMETERS

MINIMUM AREA, SQ FT ----- (3000)\*  
 EARLIEST ACQUISITION/BUILT, YR -- (1980)\*  
 MINIMUM ACQUISITION COST, \$K --- (200)\*

CATEGORY CODE	DESCRIPTION	TYPE CONST	BUILDING / FACILITY NO	ACQUISITION COST (\$K)	TOTAL AREA	UNIT MEASURE	YEAR BUILT	NUMBER FLOORS	MALL MATERIAL	TOTAL CAPACITY	UNIT MEASU
21410	MOTOR REP SHOP	P	04548	337	6128	SF	77	2	D	0	0
21885	MVT SH GEN PURP	P	04900	320	23296	SF	56	1	C	0	0
44211	AC ACC PTS SUPL	P	00535	341	27456	SF	63			0	
44220	GEN PURP W/SE	P	02063	246	31223	SF	52	1	C	0	0
44271	GEN STOR FH	T	02450	201	24180	SF	41	1	A	0	0
51010	HOSPITAL	P	04385	15257	366589	SF	71	8	C	440	80
54010	DENTAL CLINIC	P	04399	1235	15924	SF	77	2	D	28	0U
54010	DENTAL CLINIC	P	04787	460	12743	SF	64	1	D	28	0U
61050	ADM GEN PURP	P	02798	215	37945	SF	41	2	A	0	0
71124	FH CAPE CO - WO	P	06300	337	3379	SF	59	1		2	FA
71124	FH CAPE CO - WO	P	06301	337	8379	SF	59	1		2	FA
72110	EM BKS W/MESS	P	04430	446	42017	SF	54	4	D	143	MN
72110	EM BKS W/MESS	P	04432	344	40653	SF	54	4	D	143	MN
72110	EM BKS W/MESS	P	04434	344	40653	SF	54	4	D	143	MN
72110	EM BKS W/MESS	P	04436	344	40653	SF	54	4	D	143	MN
72110	EM BKS W/MESS	P	04440	700	42017	SF	54	4	D	143	MN
72110	EM BKS W/MESS	P	04442	347	40653	SF	54	4	D	143	MN
72110	EM BKS W/MESS	P	04444	344	40653	SF	54	4	D	143	MN
72110	EM BKS W/MESS	P	04446	347	40653	SF	54	4	D	143	MN
72111	EM BK W/O PS	P	04471	784	40587	SF	70	3		194	MN
72111	EM BK W/O PS	P	04472	784	40587	SF	70	3	D	194	MN
72150	OTHER	P	03620	1064	22439	SF	77	3	H	110	MN

SCREENED INVENTORY OF MILITARY REIL PROPERTY AT (ORD FORT

1)

AS OF DATE 063080

CATEGORY CODE FORMAT #8

SCREENING PARAMETERS

MINIMUM AREA, SQ FT ----- (3000)\*  
 EARLIEST ACQUISITION/BUILT, YR -- (1980)\*  
 MINIMUM ACQUISITION COST, \$K --- (200)\*

CATEGORY CODE	DESCRIPTION	CATEGORY	TYPE CONST	BUILDING / FACILITY NO	ACQUISITION COST (\$K)	TOTAL AREA	UNIT MEASURE	YEAR BUILT	NUMBER FLOORS	WALL MATERIAL	TOTAL CAPACITY	UNIT MEASU
72150	OTHER		P	03621	1064	22439	SF	77	3	H	110	MN
72150	OTHER		P	03623	1064	22439	SF	77	3	H	110	MN
72150	OTHER		P	03625	701	22439	SF	78	3	H	110	MN
72150	OTHER		P	03627	701	22489	SF	78	3	H	110	MN
72150	OTHER		P	03631	701	22439	SF	78	3	H	110	MN
72150	OTHER		P	03632	701	22489	SF	78	3		110	MN
72150	OTHER		P	03635	701	22439	SF	78	3	H	110	MN
72150	OTHER		P	03636	701	22439	SF	78	3		110	MN
72150	OTHER		P	03638	701	22439	SF	78	3	H	110	MN
72150	OTHER		P	04386	615	19011	SF	74	3	C	134	MN
72150	OTHER		P	04387	615	19011	SF	74	3	C	115	MN
72150	OTHER		P	04451	785	40587	SF	70	3	D	194	MN
72150	OTHER		P	04452	785	40587	SF	70	3	D	194	MN
72150	OTHER		P	04454	785	40587	SF	70	3		194	MN
72150	OTHER		P	04456	785	40587	SF	70	3	D	194	MN
72150	OTHER		P	04457	785	40587	SF	70	3	D	194	MN
72150	OTHER		P	04466	785	40587	SF	70	3	D	194	MN
72150	OTHER		P	04467	785	40587	SF	70	3	D	194	MN
72150	OTHER		P	04469	785	40587	SF	70	3		194	MN
72150	OTHER		P	04552	1274	42017	SF	54	4	D	132	MN
72150	OTHER		P	04554	1000	40653	SF	54	4	D	132	MN
72150	OTHER		P	04556	1132	40653	SF	54	4	D	132	MN

SCREENED INVENTORY OF MILITARY REAL PROPERTY AT (ORD FORT

AS OF DATE 063080

CATEGORY CODE FORMAT #0

SCREENING PARAMETERS

MINIMUM AREA, SQ FT ----- (3000)  
 EARLIEST ACQUISITION/YR -- (1980)  
 MINIMUM ACQUISITION COST, \$K --- (200)

CATEGORY CODE	CATEGORY DESCRIPTION	TYPE CONST	BUILDING / FACILITY NO	ACQUISITION COST (\$K)	TOTAL AREA	UNIT MEASURE	YEAR BUILT	NUMBER FLOORS	WALL MATERIAL	TOTAL CAPACITY	UNIT MEASU
72150	OTHER	P	04558	1000	4853	SF	54	4	D	132	MN
72150	OTHER	P	04562	1102	42017	SF	54	4	D	132	MN
72150	OTHER	P	04564	1052	40653	SF	54	4	D	132	MN
72150	OTHER	P	04566	969	40653	SF	54	4	D	132	MN
72150	OTHER	P	04568	1101	40653	SF	54	4	D	132	MN
72150	OTHER	P	04580	1243	42017	SF	54	4	D	132	MN
72150	OTHER	P	04582	933	40653	SF	54	4	D	132	MN
72150	OTHER	P	04584	1204	40653	SF	54	4	D	132	MN
72150	OTHER	P	04586	974	40653	SF	54	4	D	132	MN
72150	OTHER	P	04590	1117	42017	SF	54	4	D	132	MN
72150	OTHER	P	04592	1132	40653	SF	54	4	D	132	MN
72150	OTHER	P	04594	1000	40653	SF	54	4	D	132	MN
72150	OTHER	P	04596	1118	40653	SF	54	4	D	132	MN
72150	OTHER	P	04782	1334	42017	SF	54	4	D	132	MN
72150	OTHER	P	04784	969	40653	SF	54	4	D	132	MN
72150	OTHER	P	04786	1102	40653	SF	54	4	D	132	MN
72150	OTHER	P	04791	332	10195	SF	74	3	D	63	MN
72150	OTHER	P	04792	1243	42017	SF	54	4	D	132	MN
72150	OTHER	P	04793	319	9804	SF	74	3	D	63	MN
72150	OTHER	P	04794	1057	40653	SF	54	4	D	132	MN
72150	OTHER	P	04796	1059	40653	SF	54	4	D	132	MN
72150	OTHER	P	04797	323	9933	SF	74	3	C	55	MN

SCREENED INVENTORY OF MILITARY REAL PROPERTY AT (ORD FORT

AS OF DATE 063000

CATEGORY CODE FORMAT #2

SCREENING PARAMETERS

MINIMUM AREA, SQ FT ----- (3000)\*  
 EARLIEST ACQUISITION/BUILT, YR --- (1940)\*  
 MINIMUM ACQUISITION COST, \$K ----- (200)\*

CATEGORY CODE	CATEGORY DESCRIPTION	TYPE COST	BUILDING / FACILITY NO	ACQUISITION COST (\$K)	TOTAL AREA	UNIT MEASURE	YEAR BUILT	NUMBER FLOORS	HALL MATERIAL	TOTAL CAPACITY	UNIT MEASU
72150	OTHER	P	04758	1077	40653	SF	54	4	D	132	MN
72150	OTHER	P	04799	319	9804	SF	74	3	D	63	MN
72210	ENL PERS MESS	P	03641	1540	13887	SF	78	1	H	845	MN
72210	ENL PERS MESS	P	04453	252	11399	SF	70	1	D	800	MN
72210	ENL PERS MESS	P	04455	252	11399	SF	70	1	D	800	MN
72210	ENL PERS MESS	P	04468	252	11399	SF	70	1	D	800	MN
72210	ENL PERS MESS	P	04470	252	11399	SF	70	1	D	800	MN
72330	ADM - SUP BLDG	P	03640	862	29022	SF	77		C	0	
72330	ADM - SUP BLDG	P	03643	1056	29022	SF	78		C	0	
72330	ADM - SUP BLDG	P	04450	215	12194	SF	70	1	C	0	
72330	ADM - SUP BLDG	P	04458	215	12193	SF	70		C	0	
72330	ADM - SUP BLDG	P	04464	239	12393	SF	70		C	0	
72330	ADM - SUP BLDG	P	04473	215	12194	SF	70		C	0	
72410	800 MIL MALE	P	04360	313	14269	SF	53	3	C	14	MN
72410	800 MIL MALE	P	04361	304	13843	SF	53	3	C	14	MN
72410	800 MIL MALE	P	04362	304	13843	SF	53	3	C	14	MN
72410	800 MIL MALE	P	04363	295	22053	SF	56	4	C	30	MN
72410	800 MIL MALE	P	04364	261	18936	SF	66	2	C	40	MN
72410	800 MIL MALE	P	04366	261	18936	SF	66	2	C	40	MN
73015	CONFINEMENT FAC	P	04953	1125	55487	SF	53	2	C	0	
73030	FIXED LAUNDRY	T	02068	383	49140	SF	41	1	A	0	
74012	BOWLING CENTER	P	03955		20180	SF	66	1	D	0	



SCREENED INVENTORY OF MILITARY REAL PROPERTY AT (ORD FORT

AS OF DATE 063080

CATEGORY CODE FORMAT #2

SCREENING PARAMETERS

MINIMUM AREA, SQ FT ----- (3000)\*  
 EARLIEST ACQUISITION/BUILT, YR --- (1980)\*  
 MINIMUM ACQUISITION COST, \$K --- (200)\*

CATEGORY CODE	CATEGORY DESCRIPTION	TYPE CONST	BUILDING / FACILITY NO	ACQUISITION COST (\$K)	TOTAL AREA	UNIT MEASURE	YEAR BUILT	NUMBER FLOORS	HALL MATERIAL	TOTAL CAPACITY	UNIT MEASU
74016	POST CHAPEL	P	04280	675	24670	SF	58	1	D	600	SE
74018	UNIT CHAPEL	P	04483	317	7562	SF	70	1	D	300	SE
74019	UNIT CHAPEL	P	04601	515	7820	SF	77	1	H	300	SF
74018	UNIT CHAPEL	P	04788	226	7898	SF	58	1	D	300	SE
74021	COMMISSARY	P	04240	1082	80550	SF	73	1	D	0	
74034	GYMNASIUM	P	04480	500	20457	SF	70	1	D	0	
74041	LIBRARY MAIN	P	04275		14480	SF	70	1	K	0	
74047	OPEJ MESS NCO	P	04260	806	35612	SF	65	1	D	0	
74048	OPEN MESS OFF	P	04368		24192	SF	71	1	D	0	
74050	EXCH BRANCH	P	03642	345	7151	SF	78	1	H	0	
74052	EXCH SVC STA	P	04220		6147	SF	64	1	D	0	
74053	EXCH MAIN RETL	P	04235		72709	SF	70	1	G	0	
74059	PO MAIN	P	04225	226	5216	SF	77	1	D	0	
74068	EM SERVICE CLUB	P	02075	600	51882	SF	43	3	A	0	
74068	EM SERVICE CLUB	P	04600	678	31770	SF	62	1	D	0	
74072	INDR SWIM POOL	P	02237	235	24937	SF	44	1	D	0	
74076	THEAT W/STAGE	P	04230		15908	SF	70	1	R	1000	SE
74077	THEAT W/O STAGE	P	04789	323	14481	SF	58	2	D	1002	SF
83110	SEWAGE TRMT PL	P	02076	2157	3942	SF	65	1	C	164500	KG

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Washington, DC 20305  
Chief, Electronic Vulnerability Div.

Prendergast, James D.

Seismic indexing system for Army installations / by J. D. Prendergast, W. E. Fisher. -- Champaign, IL : Construction Engineering Research Laboratory ; Springfield, VA : available from NTIS, 1981.  
2v. (Technical report ; M-290)

Contents: v. 1. Real property inventory screening procedure. -- v. 2. Seismic hazard priority-ranking procedure for Army buildings: basic concept.

1. Earthquakes and building. I. Fisher, Walter E. II, Title. III. Series: U. S. Army Construction Engineering Research Laboratory. Technical report ; M-290.