Appendix A: Lifeline Report No. 1

A-1. Introduction

a. Overview. Corps of Engineers civil works projects play an important role in the recovery of communities following a major earthquake. The nation's inland waterway system, which is operated and maintained by the Corps, will be essential in the aftermath of a earthquake for the delivery of materials and equipment needed for the recovery of devastated communities. Hydropower-generating facilities at Corps projects provide electrical power that will be important to postearthquake recovery. Corps projects also include reservoirs and outlet works that supply water to communities. Water supplies will be needed for postearthquake recovery and to control fires resulting from gas mains ruptured by earthquake ground motions.

b. Objectives. Lifeline Report No. 1 is the first of a series of three reports on Corps of Engineers civil works lifelines. These reports:

(1) Identify Corps lifelines.

(2) Assess lifeline vulnerability to earthquakes.

(3) Identify mitigation measures to correct deficiencies and improve earthquake resistance.

(4) Establish priorities for mitigation and remedial work.

(5) Recommend funding levels and schedules for the implementation of mitigation and remedial work.

c. Importance of Corps lifelines. Corps lifelines are not only those facilities important to post-earthquake recovery of communities, but also include facilities required for emergency response to earthquake damage at projects, and facilities required for continued operation of critical project functions. Lifelines include those facilities essential in providing:

(1) Electrical power for the emergency operation of spillway gates and reservoir outlet works required to lower reservoir levels or to prevent overtopping.

(2) Electrical power for postearthquake recovery of communities.

(3) Communication for project operation and systems operation during an emergency.

(4) Transportation systems (project roads and bridges) required for personnel and equipment access to critical project features during an emergency.

(5) Transportation systems, such as the inland waterway, required for the transportation of supplies and equipment needed for postearthquake recovery of communities.

(6) Water needed for emergency response and postearthquake recovery of communities.

A-2. Corps Lifeline Reports

a. Purpose and schedule. Three lifeline reports will be prepared describing the vulnerability of typical Corps projects to earthquake ground motions. These reports form the basis for an engineer regulation which provides direction for an overall Corps of Engineers lifeline evaluation and mitigation program. The program's purpose is to reduce earthquake vulnerabilities and comply with the national goals and standards of Public Law (PL) 101-614. Lifeline Report No. 2 will be completed by the end of FY 94, and Lifeline Report No. 3 by the end of FY 96. Lifeline Report No. 1 describes the overall lifeline evaluation program and assesses in general terms the vulnerability of Corps power-generating facilities, emergency power systems, and communication systems to the damaging effects of earthquakes. Lifeline Report No. 1 also recommends action to correct deficiencies associated with mechanical, electrical, and communication systems. Lifeline Report No. 2 will assess the vulnerability of Corps transportation systems (i.e., the inland waterway system and project roads and bridges) to the damaging effects of earthquakes. Lifeline Report No. 3 will evaluate the vulnerabilities of Corps water supply systems critical to communities for emergency response and postearthquake recovery. Report No. 3 will also report in detail and summarize the earthquake evaluations performed to date on Corps dams and appurtenant structures under ER 1110-2-1806.

b. Legislation. PL 101-614, enacted on 16 November 1990, reauthorized the National Earthquake Hazards Reduction Act of 1977. The purpose of the law is to develop a national program to reduce risks to life and property from future earthquakes. One of the stated objectives is “the development of technologically and economically feasible design and construction methods and procedures to make new and existing structures, in areas of seismic risk, earthquake resistant, giving priority to the development of such methods and procedures for power generating plants, dams, hospitals, schools, public utilities and other lifelines, public safety structures, high occupancy buildings, and other structures which are especially needed in time of disaster.” According to PL 101-614, the term “lifeline” means: “public works and utilities, including transportation facilities and infrastructure, oil and gas pipelines, electrical power and communication facilities, and water supply and sewage treatment facilities.”

c. Corps projects with lifeline systems in moderate and high risk seismic areas. Moderate, as well as severe or high intensity earthquakes, can cause significant damage to communities and lifeline systems. Moderate earthquakes can be especially devastating when structures are founded on soft clays which amplify earthquake motions or founded on saturated, fine-grained materials which liquefy. The scope of the lifeline evaluation effort, therefore, includes Corps projects located in regions of moderate and high intensity earthquake risk. Regions of seismic risk for this report are described by the Uniform Building Code (UBC) seismic zone map (Figure A-1). For the purpose of this report, zones 2A and 2B represent regions of moderate risk, and zones 3 and 4 represent regions of high seismic risk. Figures A-2 through A-7 show the Corps projects located in regions of moderate and high seismic risk. The regions identified by these figures are:

(1) Northeastern region, including New England and New York (Figure A-2).

(2) Southeastern region, including the central Appalachian seismic region activity and the area near Charleston, South Carolina (Figure A-3).

(3) Central region, which consists of the area between the regions just described and the Rocky Mountains (Figure A-4).

(4) Southwestern region, including New Mexico and Arizona (Figure A-5).

(5) Northwestern region, including Washington, Oregon, Montana, and Idaho (Figure A-6).

(6) California (Figure A-7).

(7) Hydroelectric power plant facilities at risk. The disposition of Corps hydroelectric power plant facilities with respect to the various UBC seismic zones is provided in Table A-1. This table also provides information on the power-producing capacity, the plant location, the river system, and the responsible Corps district and division. The Corps has 8 hydroelectric power plants located in zones of high seismic risk (zones 3 or 4) and 27 plants in zones of moderate seismic risk (zones 2A and 2B).

(8) Guidance and evaluation of major structural features of projects with lifeline systems. Corps of Engineers dams, for the most part, were designed by the traditional seismic coefficient method which does not realistically account for the inertial forces and stresses generated in a dam due to earthquake ground motions. However, in the past 10 years, all Corps dams in seismic zones 2, 3, and 4 were reevaluated for a maximum credible earthquake using the latest state-of-the-art dynamic analysis procedures. The reevaluation effort included all earth-fill, rock-fill, and concrete dams; appurtenant structures; navigation structures; and levees. The Corps has developed a new, state-of-the-art seismic evaluation procedures for intake towers (ETL 1110-2-339). Based on ETL 1110-2-339 procedures, towers designed by the old seismic coefficient method and located in seismic zones 2, 3, and 4 will be reevaluated. The status of all seismic reevaluations will be included in Lifeline Report No. 3. Dams were reevaluated in accordance with ETL 1110-2-301, ER 1110-2-1806, and ETL 1110-2-303.

Figure A-1. Seismic zone map of the United States

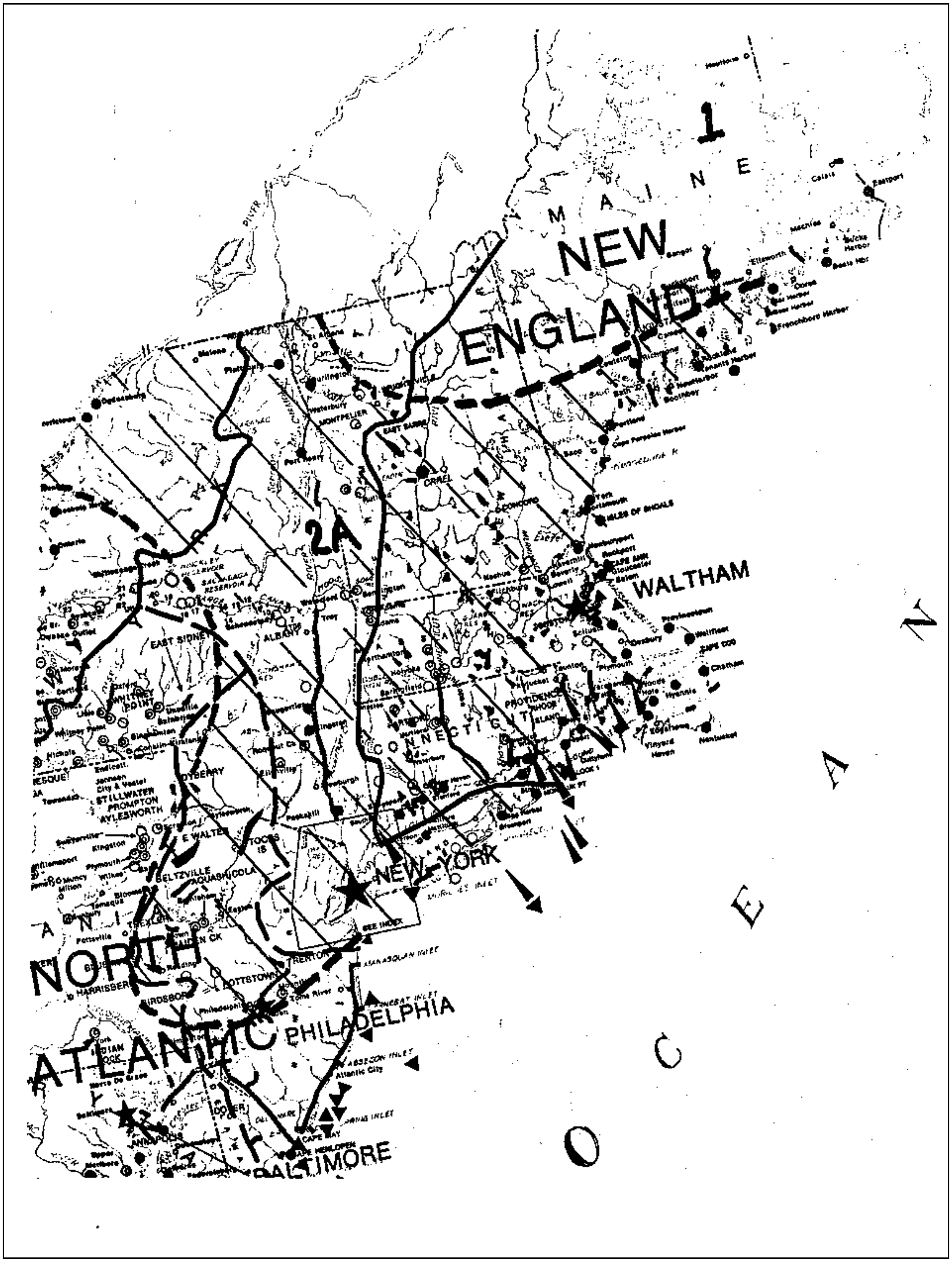

Figure A-2. Corps projects, northeastern region

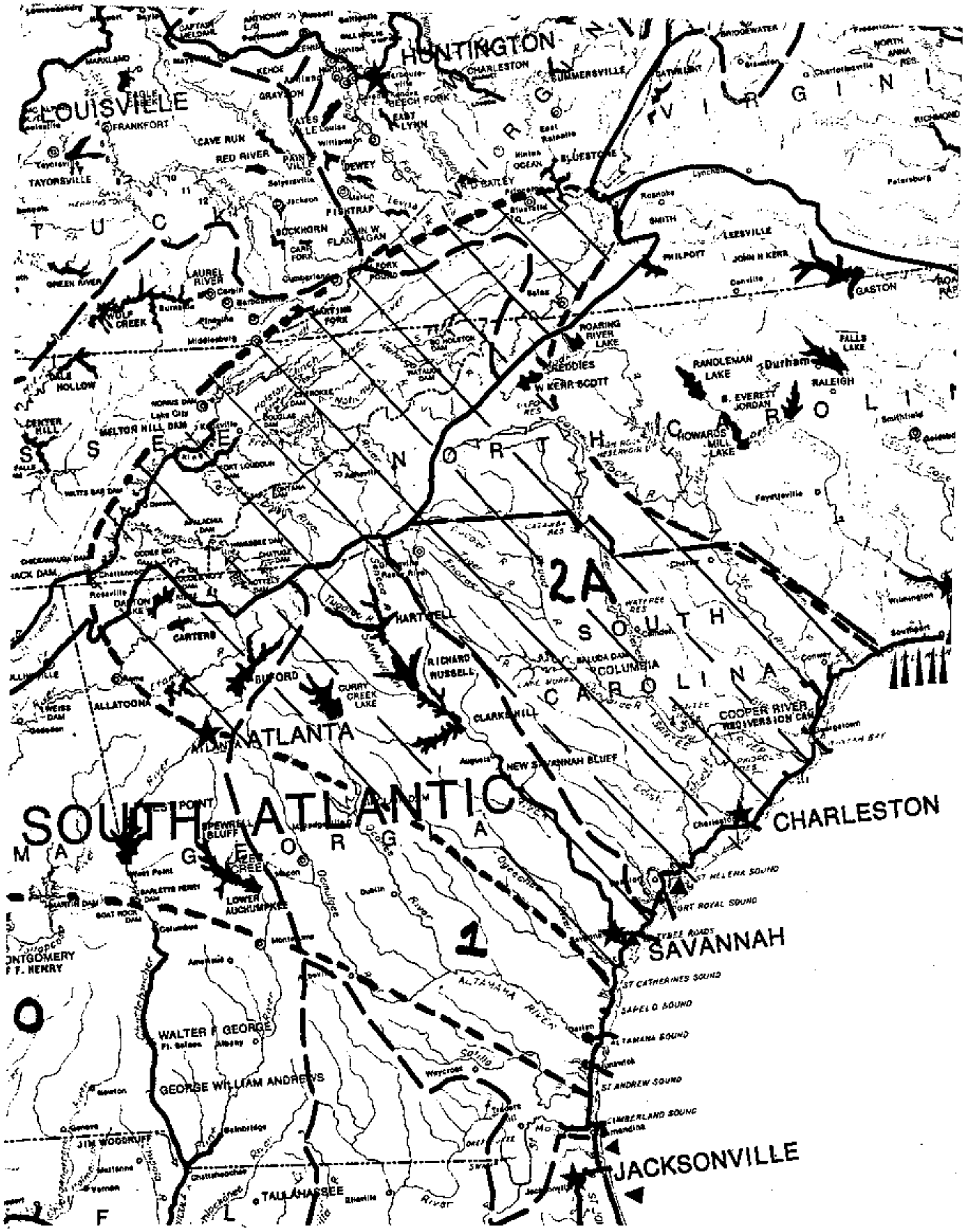

Figure A-3. Corps projects, southeastern region

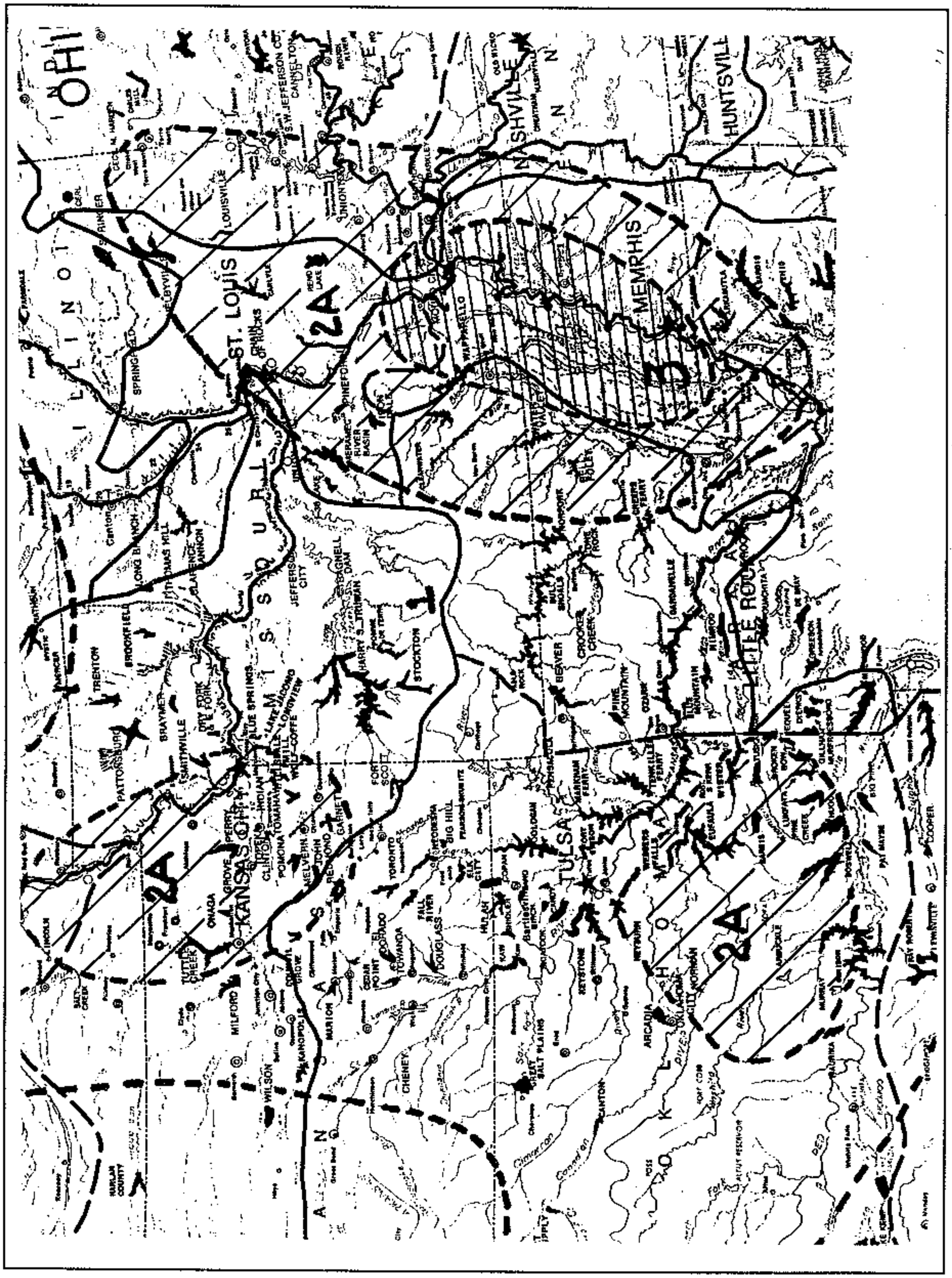

Figure A-4. Corps projects, central region

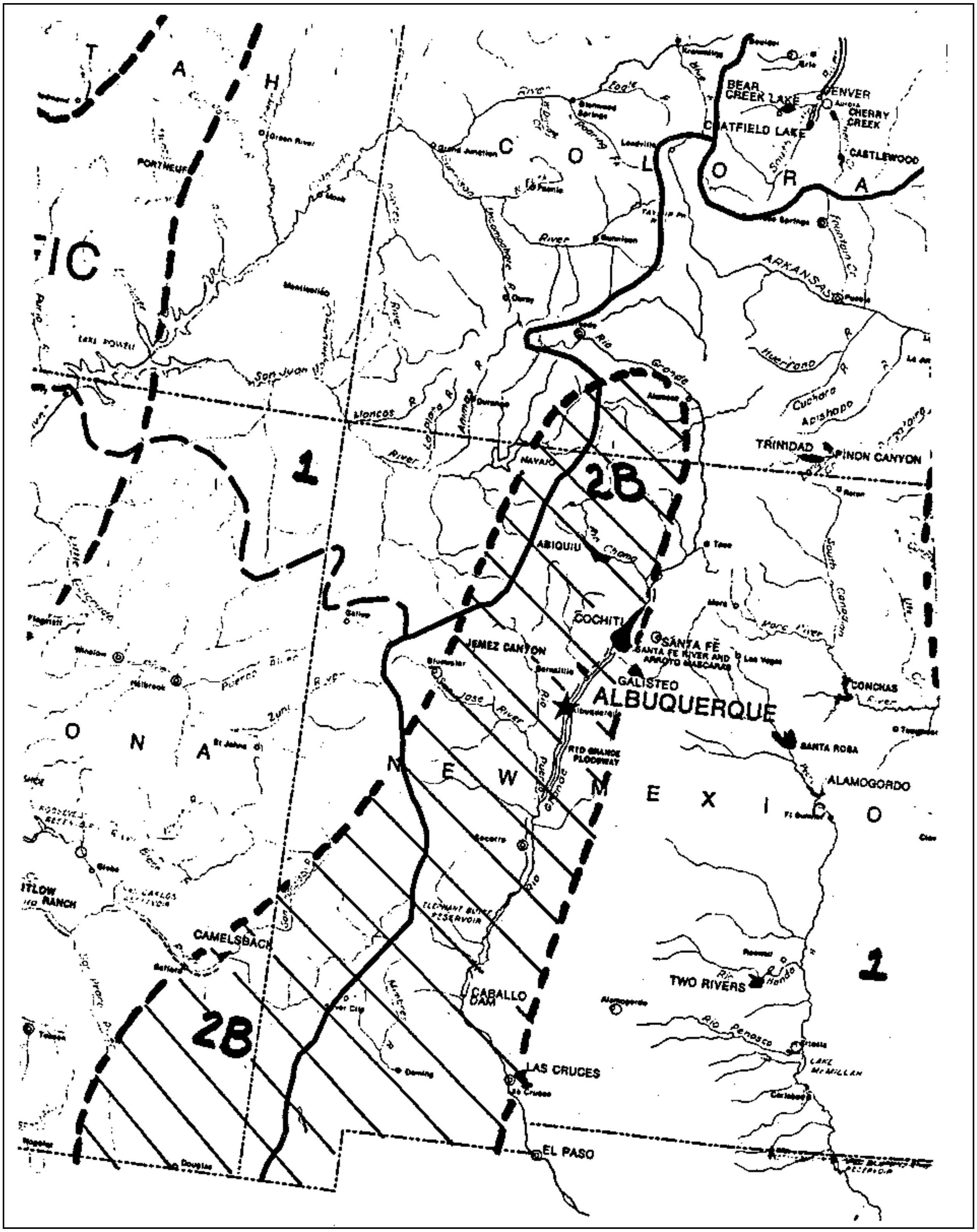

Figure A-5. Corps projects, southwestern region

Figure A-6. Corps projects, northwestern region (reflects zone changes to Oregon and Washington)

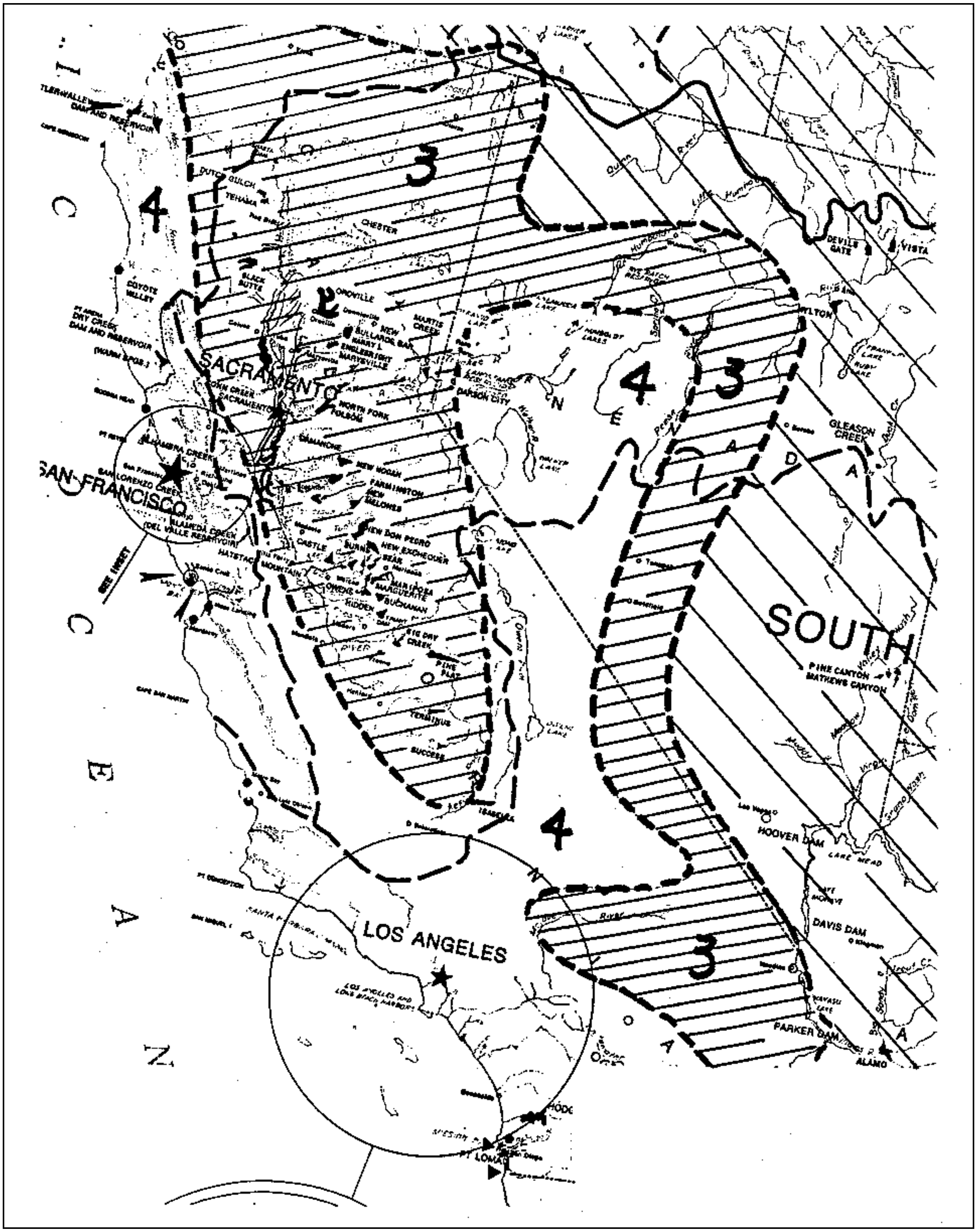

Figure A-7. Corps projects, California

Table A-1
Corps of Engineers Power Plant Facilities

Project	Zone	Corps Division	Corps District	Location	River	Capacity KW
Albeni Falls	2B	North Pacific	Seattle	Idaho	Pend Oreille	42,600
Allatoona	2A	South Atlantic	Mobile	Georgia	Etowah	110,000
Barkley	2A	Ohio River	Nashville	Kentucky and Tennessee	Cumberland	130,000
Beaver	1	Southwestern	Little Rock	Arkansas	White	112,000
Big Bend	0	Missouri River	Omaha	South Dakota	Missouri	468,000
Big Cliff	3	North Pacific	Portland	Oregon	N. Santiam	18,000
Blakely Mt.	1	Lower Mississippi Valley	Vicksburg	Arkansas	Ouachita	75,000
Bonneville	3	North Pacific	Portland	Oregon and Washington	Columbia	1,076,620
Broken Bow	1	Southwestern	Tulsa	Oklahoma	Mt. Fork	100,000
Buford	2A	South Atlantic	Mobile	Georgia	Chattahoochee	86,000
Bull Shoals	1	Southwestern	Little Rock	Arkansas and Missouri	White	340,000
Carters	2A	South Atlantic	Mobile	Georgia	Coosawattee	500,000
Center Hill	1	Ohio River	Nashville	Tennessee	Ganey Fork	135,000
Cheatham	2A	Ohio River	Nashville	Tennessee	Cumberland	36,000
Chief Joseph	2B	North Pacific	Seattle	Washington	Columbia	2,089,000
Clarence Canon	1	Lower Mississippi Valley	St. Louis	Missouri	Salt	58,000
Cordell Hull	1	Ohio River	Nashville	Tennessee	Cumberland	100,000
Cougar	3	North Pacific	Portland	Oregon	McKenzie	25,000
Dale Hollow	1	Ohio River	Nashville	Tennessee	Obey	54,000
Dardanelle	1	Southwestern	Little Rock	Arkansas	Arkansas	124,000
DeGray	1	Lower Mississippi Valley	Vicksburg	Alabama	Caddo	68,000
Denison	1	Southwestern	Tulsa	Oklahoma and Texas	Red	70,000
Detroit	3	North Pacific	Portland	Oregon	N. Santiam	118,000
Dexter	2B	North Pacific	Portland	Oregon	Middle Fork Willamette	15,000
Dworshak	2B	North Pacific	Walla Walla	Idaho	Clearwater	400,000
Eufaula	2A	Southwestern	Tulsa	Oklahoma	Canadian	90,000
Ft. Gibson	1	Southwestern	Tulsa	Oklahoma	Grand	45,000
Ft. Peck #1	0	Missouri River	Omaha	Montana	Missouri	185,300
Ft. Peck #2	0	Missouri River	Omaha	Montana	Missouri	--
Ft. Randall	1	Missouri River	Omaha	South Dakota	Missouri	320,000
Foster	3	North Pacific	Portland	Oregon	S. Santiam	--
Garrison	0	Missouri River	Omaha	North Dakota	Missouri	400,000
Gavins Pt.	1	Missouri River	Omaha	Nebraska and South Dakota	Missouri	100,000
Green Peter	3	North Pacific	Portland	Oregon	S. Santiam	100,000
Greers Ferry	2B	Southwestern	Little Rock	Alabama	Little Red	96,000
Harry S. Truman	1	Missouri River	Kansas City	Missouri	Osage	160,000
Hartwell	2A	South Atlantic	Savannah	Georgia and South Carolina	Savannah	344,000
Hills Creek	2B	North Pacific	Portland	Oregon	Willamette	30,000
Ice Harbor	2B	North Pacific	Walla Walla	Washington	Snake	602,000
J. Strom Thurmon	2A	South Atlantic	Savannah	Georgia and South Carolina	--	--
J. Percy Priest	1	Ohio River	Nashville	Tennessee	Stones	28,000
Jim Woodruff	0	South Atlantic	Mobile	Florida	Apalachicola	30,000
John Day	2B	North Pacific	Portland	Oregon and Washington	Columbia	2,160,000

(Continued)

**Table A-1
(Concluded)**

Project	Zone	Corps Division	Corps District	Location	River	Capacity KW
John H. Kerr	1	South Atlantic	Wilmington	North Carolina and Virginia	Roanoke	240,000
Jones Bluff	1	South Atlantic	Mobile	Alabama	--	68,000
Keystone	1	Southwestern	Tulsa	Oklahoma	Arkansas	70,000
Laurel	1	Ohio River	Nashville	Kentucky	Laurel	61,000
Libby	2B	North Pacific	Seattle	Montana	Kootenai	525,000
Little Goose	2B	North Pacific	Walla Walla	Washington	Snake	810,000
Look Out Point -Dexter	3	North Pacific	Portland	Oregon	Willamette	135,000
Lost Creek	3	North Pacific	Portland	Oregon	Rogue	49,000
Lower Granite	2B	North Pacific	Walla Walla	Washington	Snake	810,000
L. Monumental	2B	North Pacific	Walla Walla	Washington	Snake	810,000
McNary	2B	North Pacific	Walla Walla	Oregon and Washington	Columbia	980,000
Millers Ferry	0	South Atlantic	Mobile	Alabama	Alabama	75,000
Narrows	1	Lower Mississippi Valley	Vicksburg	Arizona	Little Mo.	25,500
Norfolk	1	Southwestern	Little Rock	Arkansas and Missouri	White	80,550
Oahe	0	Missouri River	Omaha	North Dakota and South Dakota	Missouri	640,000
Old Hickory	1	Ohio River	Nashville	Tennessee	Cumberland	36,000
Ozark	1	Southwestern	Little Rock	Arkansas	Arkansas	100,000
Philpott	2A	South Atlantic	Wilmington	Virginia	Roanoke	14,000
R. B. Russell	2A	South Atlantic	Savannah	Georgia and South Carolina	Savannah	600,000
Rob't S. Kerr	2A	Southwestern	Tulsa	Oklahoma	Arkansas	110,000
St. Marys	2A	North Central	Detroit	Michigan	St. Marys	18,400
Sam Rayburn	0	Southwestern	Ft. Worth	Texas	Angelina	52,000
St. Stephen	2A	South Atlantic	Charleston	South Carolina	Santee/Cooper	84,000
Stockton	1	Missouri River	Kansas City	Missouri	Sacramento	45,200
Table Rock	1	Southwestern	Little Rock	Arkansas and Missouri	White	200,000
Tenkiller - Ferry	1	Southwestern	Tulsa	Oklahoma	Illinois	9,100
The Dalles	2B	North Pacific	Portland	Oregon and Washington	Columbia	1,806,000
Walt George	0	South Atlantic	Mobile	Georgia and Alabama	Chattahoochee	130,000
Webbers Falls	2A	Southwestern	Tulsa	Oklahoma	Arkansas	60,000
West Point	0	South Atlantic	Mobile	Georgia	Chattahoochee	73,375
Whittney	0	Southwestern	Ft. Worth	Texas	Brazos	30,000
Wolf Creek	1	Ohio River	Nashville	Kentucky	Cumberland	270,000

A-3. Electrical Power and Communications Lifelines

a. General. The original purpose of this report was to assess the vulnerability of hydroelectric power plants to earthquake damage that would impair the plants' ability to deliver electricity to communities recovering from the devastating effects of a major earthquake. The vulnerability of this lifeline function was assessed by a walk-through of three Corps hydroelectric power plants by a team composed of a recognized lifeline expert, Corps design engineers, and project operations personnel. During the walk-through process, it became evident that the most important electrical power lifeline function was one of providing electrical power onsite in response to emergency conditions. For instance, hydroelectric power plants can be isolated from the power grid when earthquake ground motions trip pressure-sensitive relays in transformers. These pressure-sensitive relays, provided to protect the transformer from damage due to overheating, often trip due to sloshing of the cooling oil during an earthquake. If this happens, the wicket gates close to prevent generator runaway. All station power must then be provided by sources in the powerhouse. This can include station service units, main units running at speed no load supplying power to plant through reactors and transformers, emergency generators, and batteries. If the emergency power sources are damaged, it is possible the spillway gates or other reservoir control gates cannot be raised. This can jeopardize dam safety if project inflows are sufficient to cause the project to be overtopped before the gates can be put back into service. It can also jeopardize dam safety if embankment dam sections have been damaged by the earthquake and the control gates cannot be operated to effect rapid drawdown of the impoundment. Communications are also dependent on electrical power, and if the communications equipment or its power source is damaged during the earthquake, the project's ability to communicate emergency conditions to upriver plants and others required to take emergency actions would be jeopardized. Therefore, the protection of onsite electrical power and communication is often of much greater importance than that of providing electrical power for postearthquake recovery of communities. Onsite electrical power and communication during and following a major earthquake are critical to Corps flood control projects, navigation lock projects, and water supply projects as well as hydroelectric power plant projects. Therefore, many of the vulnerabilities cited in Appendix B to this report are applicable to all Corps projects.

b. Hydroelectric power plants. Corps hydroelectric power plant projects consist of dam, spillway, and nonoverflow structures; a powerhouse with turbines, generators, transformers, and other electrical equipment; and sometimes a substation with transformers and switching equipment. Navigation locks are often a part of Corps hydroelectric power projects. The dam may be earth-fill, rock-fill, or concrete. The main structural features of power plant structures have been designed for the inertial effects induced by earthquake ground motions and therefore are not the subject of this lifeline report. Turbines and generators are rugged, and damage to these features has not occurred during past earthquakes. This report focuses on the electrical, mechanical, and communications equipment that have in the past been shown to be vulnerable to earthquake ground motion damage. When properly anchored, this equipment performs well. However, unanchored equipment can slide or overturn and experience substantial damage. Switching equipment and ceramics are vulnerable to earthquake damage.

c. Emergency power. Emergency power is an essential feature of all Corps projects. On hydroelectric power plant projects, batteries provide power for control systems and communication equipment. Batteries also provide power to start diesel-powered emergency generators. Emergency generator power is critical to most Corps projects during system outages. These emergency generators provide backup power to operate spillway gates, sump pumps, and outlet works control gates. Unanchored batteries and unanchored or inadequately anchored emergency generators are vulnerable to the damaging effects of earthquakes.

d. Communications equipment. Communications equipment plays an important role in the operation of Corps projects and in the response to emergency conditions occurring on Corps projects. Communication equipment at Corps projects is extremely vulnerable to seismic damage because of its fragile nature and because it is typically unanchored.

A-4. Identifying Earthquake-Vulnerable Electrical and Mechanical Equipment on Corps Projects.

a. General. Evaluating Corps projects for earthquake vulnerability can be accomplished by analytical methods, by onsite walk-through inspections, or a combination of both. Analytical methods are most useful for major structures such as powerhouses, dams, and intake towers where response spectrum analysis or time-history analyses can be used to determine the earthquake forces that are likely to occur during a major earthquake. The vulnerability of mechanical and electrical equipment, however, is best assessed by walk-through inspections which concentrate on features that are known from past earthquakes to be susceptible to earthquake damage. These walk-through inspections should be accomplished by a team of mechanical, electrical, and structural engineers accompanied by someone familiar with the seismic performance of the various types of equipment on the project, and someone who under stands project systems operation and systems critical to project emergency response.

b. Corps walk-through inspections. Walk-through inspections were performed on two hydro-electric power plant projects as part of the Corps of Engineers Hazard Reduction Program. Professor Anshel J. Schiff, a recognized expert in the seismic performance of electrical power systems, performed the walk-through inspections accompanied by various design engineers and project engineers from the Corps. Professor Schiff is chairman of the Electrical Power and Communications Committee and the Earthquake Investigations Committee of the American Society of Civil Engineers Technical Council on Lifeline Earthquake Engineering, and of the Earthquake Records Committee of the Earthquake Engineering Research Institute. The type of expertise provided by Dr. Schiff ensured that the Corps' effort to assess the seismic vulnerability of its power-generating lifeline systems was in accordance with, and consistent with, standards used by other government agencies and private utilities. As a result of his walk-through inspections, Professor Schiff prepared two reports. The first report provided his findings and recommendations with respect to the specific projects visited. It is evident from his report that the Corps has critical mechanical, electrical, and communications equipment that is vulnerable to earthquake damage. Professor Schiff's second report was structured so it could be used as a guide for evaluating the seismic vulnerabilities of Corps lifeline systems. This second report is attached as Appendix B.

c. Findings. On the projects inspected, much of the mechanical, electrical, and communications equipment was found to be unanchored or inade quately anchored to resist the damaging effects of earthquake ground motions. The equipment described is often critical to continued operation of Corps projects and to emergency response. Particularly vulnerable were batteries required for emergency power, transformers, and communications equipment. The projects inspected are considered typical of all Corps-owned hydropower facilities.

d. Goals and recommendations.

(1) Existing projects. Special walk-through inspections should be conducted on all Corps projects in zones of high or moderate seismic risk. These walk-through inspections should concentrate on vulnerable areas cited in Appendix B. The Corps should take action to provide training for engineers performing these special walk-through inspections, and regulations should be developed which require that the walk-through inspections be conducted in conjunction with periodic inspections of all Corps projects located in seismic zones 2A, 2B, 3, and 4.

(2) New projects. Specifications requiring that all mechanical and electrical equipment be anchored to resist the damaging effects of earthquake ground motion should be included in the contract documents for new projects. Military guide specification CEGS-13080 can be used for this purpose. CEGS-13080 is in the process of being updated to meet current seismic code requirements. As part of the National Earthquake Hazards Reduction Program (NEHRP), national standards are being developed for the seismic protection of lifelines. Any new standards developed under NEHRP should be incorporated into Corps designs when appropriate.