UNITED STATES DEPARTMENT OF INTERIOR
GEOLOGICAL SURVEY

REPORT ON RECOMMENDED LIST OF STRUCTURES FOR SEISMIC INSTRUMENTATION IN SAN BERNARDINO COUNTY, CALIFORNIA

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1 U.S. Geological Survey, Menlo Park, CA 94025
2 Applied Technology Council, Palo Alto, CA 94303
3 California Institute of Technology, Pasadena, CA 91125
4 University of California, Los Angeles, Los Angeles, CA 90024
5 University of California, Irvine, Irvine, CA 92717
6 Community Development, County of San Bernardino, San Bernardino, CA 92415
7 Tridis Engineers, San Marino, CA 91108

COMMITTEE MEMBERS

G. Brady	- USGS
M. Celebi (Chair)	- USGS
C. Rojahn	- ATC
R. Haskell	- Tridis Engineers
W. Iwan	- California Institute of Technology
G. Hart	- University of California, Los Angeles
G. Pardoen	- University of California, Irvine
L. Schoelkopf	- County of San Bernardino
K. Topping	- County of San Bernardino
E. Safak	- USGS
R. Maley	- USGS

INTRODUCTION

The main objective of any instrumentation program for structural systems is to improve the understanding of the behavior, and potential for damage, of structures under seismic loading. The acquisition of structural response data during earthquakes is essential to confirm and/or further develop methodologies used for analysis and design of earthquake resistant structural systems. This objective can best be realized by selectively instrumenting structural systems to acquire strong ground motion data, and recording of the responses of structural systems (buildings, components, lifeline structures, *etc.*) to the strong ground motion. As a long term result, one may expect design and construction practices to be modified to minimize future earthquake damage (1).

Various codes in effect in the United States, whether nationwide or local, recommend different quantities and schemes of instrumentation. For example the Uniform Building Code (UBC) (2) recommends for Seismic Zones 3 and 4, a minimum of three accelerographs be placed in every building over six stories in height with an aggregate floor area of 60,000 square feet or more, and every building over 10 stories in height regardless of floor area. The City of Los Angeles adopted the above recommendation in 1966 but in 1983 revised this requirement to only one accelerograph. Experience from past earthquakes shows that the instrumentation guidelines given by the UBC code, for example, although providing sufficient data for the limited analyses projected at the time, do not now provide sufficient data to perform the model verifications and structural analysis demanded by the profession.

On the other hand, valuable lessons have been derived from the study of the data obtained from a well-instrumented structure--Imperial County Services Building--during the moderate size Imperial Valley earthquake (M 6.5) of October 15, 1979 (3).

To reiterate, it is expected that a well-instrumented structure for which a complete set of recordings has been obtained would provide useful information to:

- check the appropriateness of the dynamic model (both lumped mass and finite element) in the elastic range,
- determine the importance of non-linear behavior on the overall and local response of the structure,
- follow the spreading non-linear behavior throughout the structure as the response increases and the effect of the non-linear behavior on frequency and damping,
- correlate the damage with inelastic behavior,
- determine ground motion parameters that correlate well with building response damage, and
- make recommendations eventually to improve seismic codes.

To enhance the effort in instrumentation of structures, the USGS recently established an advisory committees program. The committees formed so far within California are fully aware of the California Division of Mines and Geology (CDMG) Strong Motion Instrumentation Program (SMIP) and the USGS's intent is to complement the CDMG program. The advisory committees are in essence regional committees comprised of professionals from universities,

state, federal and local government agencies, and private companies. The advisory committees are formed in regions of seismic activity and are requested to develop recommended lists of structures for possible instrumentation. The first of these committees was formed in the San Francisco Bay Region (1).

San Bernardino County is one of the regions where the potential during the next several decades for large damping is high. According to Lindh (4), there is a 45% probability of occurrence of an earthquake of M = 6-3/4 within the next 30-year period on the San Jacinto Fault (Riverside segment) in San Bernardino. The probability for a M = 7-1/2 - 8 earthquake on the San Andreas Fault (Indio segment) is given by Lindh as 24% within the same 30 years. Furthermore, the San Bernardino region has been previously recommended with top priority by Iwan and others (5) for integrated instrumentation of structures and free-field arrays.

Objectives of the Committee

The USGS-San Bernardino Advisory Committee on Instrumentation of Structures was formed with the following objectives:

- o develop a list of structures in the San Bernardino County within the objectives of the USGS program
- o develop priorities for the list of structures,
- o coordinate the effort on instrumentation of structures with other programs and organizations,
- o communicate to the public and private sectors the importance of programs for instrumentation of buildings,
- o extend the program to other regions as required,
- o enhance the maintenance of instruments in a coordinated way, and
- o provide guidance and develop methodologies related to instrumentation of structures.

Scope

This report documents the development of a list of structures for recommending to the USGS for instrumentation. Every effort has been made to incorporate the input of local government officials, who have provided the majority of the data.

The lists presented in this report consist of those structures which are deemed to be non-typical. The reason for this is that the main objective of this committee was to develop lists and priorities in order to complement the CDMG-SMIP program of the State of California and not to duplicate efforts. However, during the course of this work, some typical structures were naturally in the preliminary list. These have been tabulated in the appendices for consideration of the CDMG-SMIP program. It is not presumed that they will be automatically adopted by that program.

It must also be mentioned herein that a unique structure was under construction during the time the committee started working. This six story steel structure with a basement is the Foothills Communities Law and Justice Center in the City of Rancho Cucamonga and it is a base-isolated structure constructed on 98 natural rubber bearings. This structure is given the highest priority by the Committee. However, if the CDMG-SMIP program decides that the

structure should be instrumented through their program, then it will not be taken up by USGS programs. At the time of writing of this report, the information available was such that CDMG-SMIP is placing 1 CRA with 13 channels of FBA's and additional free-field (3 channels) sensors. In this context, because of the significance of this structure, any update to the designated instruments will be provided by the USGS in cooperation with CDMG-SMIP program.

SELECTION PROCESS FOR STRUCTURES

A list of 104 structures was prepared by L. Schoelkopf for the committee to make preliminary observations and selection. Seventy-three structures were eliminated in this initial cut, and two added. It was clear from the photographs of the structures and the location maps prepared for the initial meeting, that the ranking for the strutures would have to consider both the structural interest on the one hand, and on the other, the seismic hazard at the structure's site. For ranking purposes, a site term and a structural term were to be considered for each structure. These terms were to be additive and not multiplicative, so that a low level of structural interest or of seismic hazard would not totally eliminate a structure which had already survived the first cut. Guidelines for the selection of the participating criteria for each of these terms are given in the following. Each term allows reasonable flexibility in the evaluation of the ranking for each structure.

Site Term

It had been the original intention to have the site term the same for all structures in the designated area of San Bernardino because all structural sites were to be on the alluvial plain between the two main faults in the area, the San Andreas and San Jacinto. As the investigation proceeded, it was clear that there were some structures close to these two faults and that the uniform site term concept would need to be adjusted. The basic site term is now derived from the probability of an earthquake occurring on either of these two faults, or the Cucamonga fault, and the expected level of shaking from such an event. For sites within two miles of a fault, the contribution to the site term is doubled because of desire to obtain data from near sources. Outside of this strip, the basic site term from a specific fault is applied for an arbitrarily selected distance of 15 miles, unless another four-mile wide zone surrounding a fault is reached, beyond which the basic term is not applied any more.

Table 1 provides the criteria for the basic site term for the three seismographic faults in the area considered: San Andreas, San Jacinto, and Cucamonga. The probability of occurrence of an event of the listed magnitude is taken from Lindh (1983). The shaking level is estimated for the particular event directly from the expected magnitude. The basic site term, in the last column, is the product of the normalized probability and the shaking level.

Sites within the boundaries of the city of San Bernardino and not within two miles of the San Andreas or San Jacinto faults receive basic site term contributions from each fault, totalling 8, listed in Table 2. Sites within two miles of either fault receive double the basic site term for that fault, and just the basic term for the other, totalling 12. Sites outside the area between the faults receive the basic site term of 4. The one office building in Rancho Cucamonga, near the Cucamonga fault, receives a site term of 1. Provision is made for any minor adjustment to a site term.

The maximum value for the site term column in Table 2 is 12. For coordination with other advisory committees in other areas, this is reduced to 3 using the factor 0.25.

Structure Term

Three structural characteristics were considered for contribution to the structure term, namely, the presence of anti-symmetry or irregularity, construction material, and any special interest. The committee recognized the specifications for instrumentation of structures within the CDMG strong motion instrumentation program and could therefore restrict its own considerations to the three above.

1. Material of construction. Allow 1.0 for reinforced concrete, 0.5 for steel, and 0.25 for timber.

2. Complexity of structure. Anti-symmetry/symmetry; or irregular/regular. Allow 1.0 for anti-symmetry and 0.5 for symmetry.

3. Special interest in the structure by the members of the advisory committee, even after taking into account the site term, and the two preceding characteristics in the structure term. Allow a maximum of 2.0.

The three aspects of the structure term are listed in Table 2. Each column has a maximum of 1.0; the calculation for the structure term, keeping its maximum value at 3 (to correspond in importance with the site term) is given by:

$$\text{STRUCTURAL TERM} = 0.75\ (\text{Material} + \text{Complexity} + 2\ (\text{Interest})).$$

Final Priority List

Table 2 has ranked the structures in order of decreasing priority for instrumentation in accordance with the sum of the two terms, site and structure. Thus ranking in Table 2 is obtained by:

$$\text{RANK} = \text{SITE TERM} + \text{STRUCTURE TERM}$$

$$= 1/4\ (S_{site}) + 3/4\ (\text{Material} + \text{Complexity} + 2\ [\text{Interest}])$$

Structures that are not on the Final List

For the sake of brevity and immediate reference, only Table 2 which contains the final list of structures recommended for instrumentation is provided in the main text.

However, since a lot of effort was already spent in compilation of relevant data, the remaining structures are also provided in Appendix A. These structures can be used for future reference. In addition, in Table A-3, a suggested list of structures emerged for possible recommendation to the CDMG-SMIP and other programs. To repeat, this list is only a suggestion by this committee and does not presume any further deliberation.

REFERENCES

1. Celebi, *et al.*, 1984, Report on recommended list of structures for seismic instrumentation in the San Francisco Bay Region: *U.S. Geological Survey Open-File Report 84-488.*

2. _____, *Uniform Building Code, International Conference of Building Officials,* Whittier, CA, 1970, 1976, 1982 editions.

3. Rojahn, C., and Mork, P.N., 1982, An analysis of strong motion data from a severely damaged structure--The Imperial County Services building, El Centro, California in The Imperial Valley, California, earthquake of October 15, 1979: *U.S. Geological Survey Professional Paper 1254.*

4. Lindh, A.G., 1983, Preliminary assessment of long-term probabilities for large earthquakes along selected fault segments of the San Andreas fault system in California: *U.S. Geological Survey Open-File Report 83-63.*

5. Iwan, W.D. (editor), 1981, U.S. Strong-Motion earthquake instrumentation: *Proceedings of U.S. National Workshop on Strong motion earthquake instrumentation,* Santa Barbara, CA.

TABLE 1. Basic Site Term

Fault	Probability in the next 30 years	Magnitude	Approx. Normalized Probability	Shaking Level	Basic Site Term
San Andreas[1]	24%	7-1/2 - 8	1	4	4
San Jacinto[1]	45%	6-3/4	2	2	4
Cucamonga[2]	~12%		0.5	2	1

1 Lindh, 1983.
2 The 30-year probability was estimated from available information and maps and possibly represents a higher than a realistic value.

TABLE 2
San Bernardino County
List of Structures Rated With Top Priority

No.*	Description of Structure	Site & Structural Weights Site	Matl	Cplx	Intr	Total
--	Foothill Communities Law and Justice Center					**
86a	Flammable Liquid Pipeline	12	0.50	0.75	1.00	5.44
24	ESBCWD Water Tank	12	0.50	0.50	1.00	5.25
15	St. Bernardine Plaza	8	1.00	1.00	1.00	5.00
31	CSUSB Physical Education Center	12	1.00	0.75	0.75	5.44
33	State Water Project	12	0.75	0.50	1.00	5.44
4	Wells Fargo Bank	8	1.00	0.50	0.75	4.25
5	Meadowbrook Tower	8	1.00	0.50	0.75	4.25
6	Ramada Hotel	8	1.00	1.00	0.50	4.25
10	County Government Center	8	0.50	1.00	0.75	4.25
72	University of Redlands Armacost Library	8	1.00	0.50	0.75	4.25
95	Parking Structure & Commerical Building	4	1.00	1.00	1.00	4.00
2	City Hall	8	1.00	0.50	0.50	3.87
18	Medical Office Building	8	1.00	0.50	0.50	3.87
23a	Pacific Federal Savings	8	1.00	0.50	0.50	3.87
76	West San Bernardino County Water District	7	1.00	0.50	0.50	3.62
99a	Lake Gregory Dam	4	1.00	1.00	0.75	3.62
19	St. Bernardine's Hospital	8	0.50	0.50	0.50	3.50
82	Office Building (near base isolated Structure in Rancho Cucamonga)	1	1.00	1.00	1.00	3.25
99	Crestline Sanitation District	4	1.00	0.50	0.25	2.50
94	Papoose Lake Dam	4	0.50	0.50	0.25	2.12
97	Calvary Chapel Convention Center	4	0.25	0.50	0.25	1.94

* These numbers refer to initial listing and for easy reference to the photos prepared by L. Schoelkopf.

** Because this structure is unique, non-typical, and especially interesting in design and behavior, it is placed on top of the list with the understanding that it will be instrumented by USGS if not by the CDMG-SMIP Program.

TABLE 3
San Bernardino County
List of Structures Ranked and Categorized
(Note: Some structures appear in two categories)

CATEGORY A

Structures Recommended for Extensive Instrumentation

1.* Foothill Communities Law and Justice Center (Base Isolated Structure in Rancho Cucamonga)
2. Wells Fargo Bank Building
3. Ramada Hotel
4. County Government Center
5. University of Redlands Armacost Library
6. San Bernardino City Hall
7. Medical Office Building
8. Pacific Federal Savings
9. St. Bernardine's Hospital
10. New Reinforced Concrete Office Building (near Base Isolated Building in Rancho Cucamonga)

CATEGORY B

Structures Recommended for Simple Instrumentation

1. St. Bernardine's Plaza
2. CSUSB Physical Education Center
3. Meadowbrook Tower
4. Parking Structure and Commercial Building
5. West San Bernardino County Water District
6. Lake Gergory Dam
7. Crestline Sanitation District
8. Papoose Lake Dam
9. Calvary Chapel Convention Center

CATEGORY C

Structures Recommended for Special Instrumentation
That May Require Further Development

1.* Foothill Communities Law and Justice Center (Base Isolated Structure in Rancho Cucamonga)
2. Flammable Liquid Pipeline
3. ESBCWD Water Tank
4. State Water Project
5. West San Bernardino County Water District

* Because this structure is unique, non-typical, and especially interesting in design and behavior, it is placed on top of the list with the understanding that it will be instrumented by USGS if not by the CDMG-SMIP Program.

APPENDIX A

ORIGINAL LIST OF STRUCTURES AFTER RANKING
AND
OTHER LISTS THAT EMERGED

TABLE A-1
Description of Structures Considered in Ranking in Table 1

(2)	City Hall -	reinforced concrete framed, no shear wall, composite steel floors, 6 stories.
(4)	Wells Fargo Bank	17 feet high first floor columns, symmetric, concrete with steel elements
(5)	Meadowbrook Tower	Symmetric, precast slab, concrete block masonry shear wall
(6)	Ramada Hotel -	(under construction, L shaped, 11 stories, poured in place concrete.
(10)	County Government Center -	braced steel frame.
(15)	St. Bernardine Plaza	12 story, regular, conc. shear wall
(18)	Medical Office Building	concrete, 5 story frame
(19)	St. Bernardine's Hospital	6 story, steel frame
(23a)	Pacific Federal Savings	concrete frame
(24)	ESBCWD water tank -	on the fault.
(31)	CSUSB - Physical Ed Bldg.	Gym with long span tilt-up walls with cantilevering roof
(33)	State Water Project	steel upper structure on concrete power plant
(52)	O.K. Kruse Grain Elevator	equipment response possibility, r. concrete shell
(56)	LLU Medical Center	concrete round towers with shear walls
(59)	Redlands Federal Savings	tall first story (steel)
(71)	Crafton Hills College Library	soft first story (concrete) 3 stories
(72)	Un. of Redlands. Armacost Library	box system with shear walls and soft first floor
(76)	West San Bernardino County Water District	possibility for system investigation with reservoir, distribution network, $\varepsilon\tau\psi$~
(82)	Office Building -	next to base isolated building, concrete frame.
(85)	Industrial Building	tilt-up, large span, diaphragm?

TABLE A-1 (continued)
Description of Structures Considered in Ranking in Table 1

(86a)	Flammable liquid pipeline -	(crossing San Andreas - subject to differential ground motion)
(95)	Parking Structure & commercial building	concrete, (precast & cast in place parking structure with timber structure erected on top and alongside.
(97)	Calvary Chapel Convention Center	timber
(99)	Crestline Sanitation District	on dam, 1 story masonry and 1 story timber
(99a)	Lake Gregory Dam	earth fill with concrete overflow spillway

TABLE A-2
Structures Already Instrumented

32	CSUSB - Library	CDMG
50	Hilton Hotel	CDMG
58	VA Hospital (Loma Linda)	USGS
101	Cedar Springs Dam (Moderately Instrumented)	CDWR

TABLE A-3
Structures for Possible Recommendation to Other Programs

(53)	Guthrie Interchange	refer to CalTrans
(64)	Oak Glen Conservation Camp	refer to CDMG
(66)	Forest Home Conference Center	refer to CDMG
69	Bridge #54-0934-L	refer to CalTrans
75	Colton High School Gym	refer to CDMG
86	I-10/I-15 Interchange	refer to CalTrans
100	Bridge 54-589, SR#138	refer to CalTrans
104	I-15 Devore Freeway	refer to CalTrans

TABLE A-4

Structures Requiring More Information or Structures of Secondary Importance
(Not Considered for Recommendation)

		Tentative Description
(28)	Arrowhead Springs Lodge E	2 story, concrete block
(35)	Doane Products Co. title,	metal tower
(41)	Big Bear Lake Dam -	temporary instrumentation is recommended
(42)	" " " "	temporary instrumentation is recommended
(45)	SCE Stearn Geo. Plant	non typical - 2 miles from San Jacinto
(45a)	Norton AFB Tower	
(47)	SB Co. Museum	dome is metal
(51)	Office Buildings	steel frame
(54)	Home Club Warehouse	tilt-up
(73)	Mill Street Viaduct	on San Jacinto
(84)	Bleachers	Chaffey College, concrete
(89)	SPPL Tank Farm	oil storage tanks
(94)	Papoose Lake Dam	more info

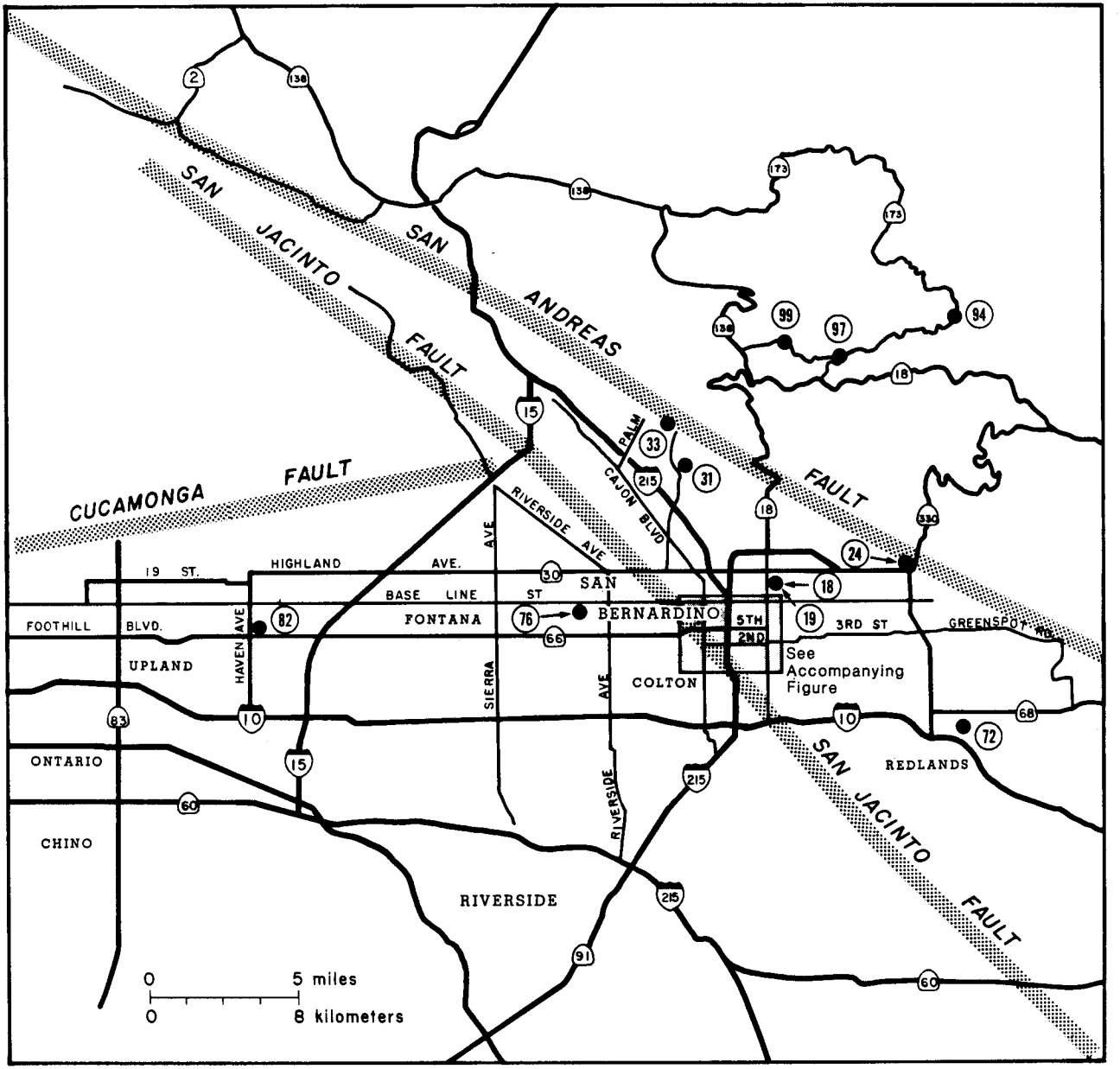

Figure 1. Locations of structures on final priority list for seismic instrumentation, San Bernardino County, California. The structures are identified by their numbers from Table. 2.

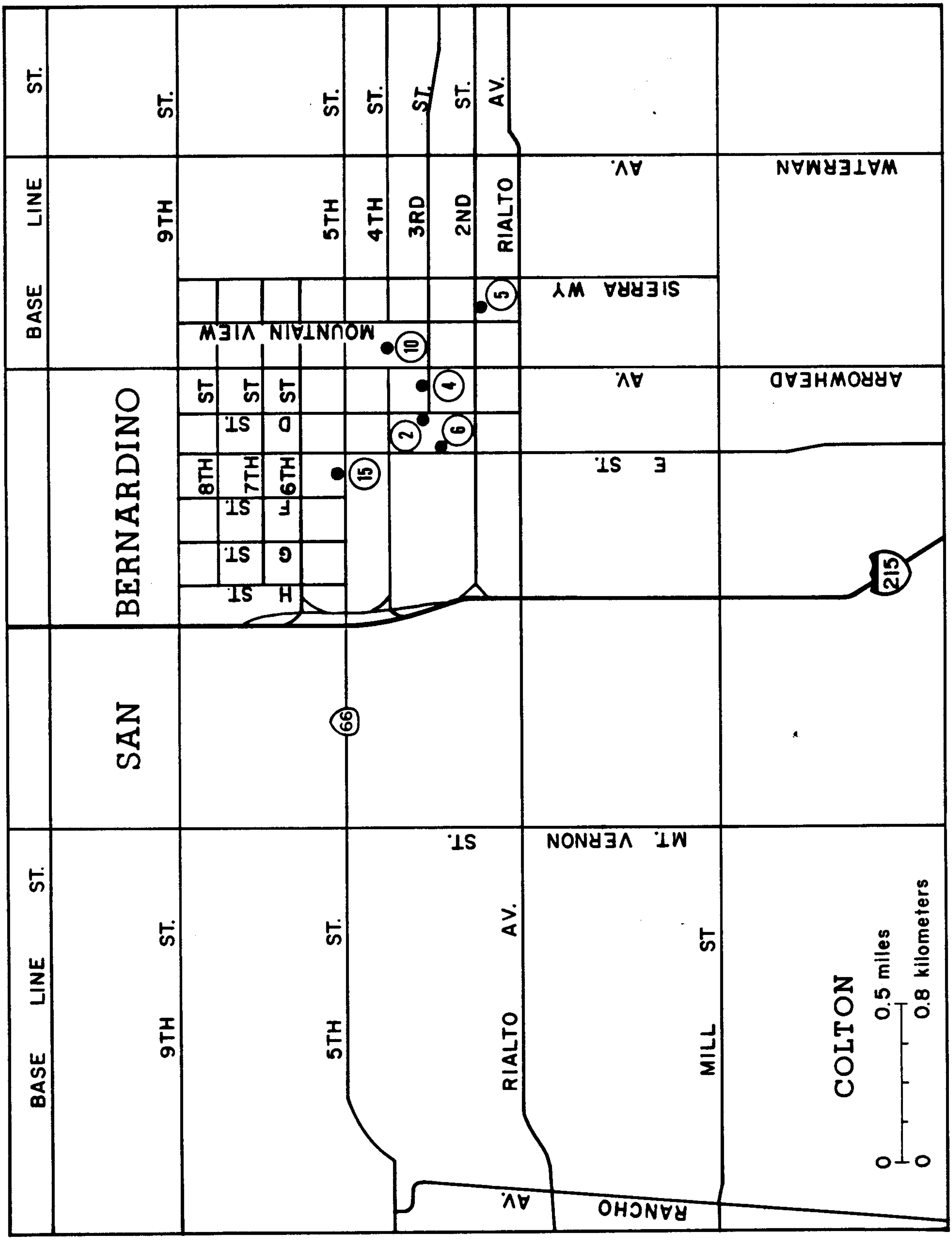

Figure 2. Locations of structures on final priority list for seismic instrumentation, City of San Bernardino. The structures are identified by their numbers from Table 2.