History of the Alquist-Priolo Earthquake Fault Zoning Act, California, USA

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ABSTRACT

The Alquist-Priolo Earthquake Fault Zoning (AP) Act was passed in California in 1972 following the destructive 1971 Mw 6.6 San Fernando earthquake. Surface-fault rupture hazard is addressed by prohibiting most structures for human occupancy from being placed over the trace of an active fault. Principal responsibilities under the AP Act are assigned to the following: 1) State Mining and Geology Board (SMGB), 2) State Geologist (California Geological Survey), and 3) lead agencies. The SMGB establishes specific regulations to guide lead agencies in implementing the law. The AP Act requires the State Geologist to issue maps delineating regulatory zones encompassing potentially hazardous faults that are sufficiently active (active in approximately the last 11 ka) and well defined. The first maps were issued in 1974—currently there are 547 maps affecting 36 counties and 104 cities. Lead agencies affected by the zones must regulate development "projects" in which structures for human occupancy are planned within the Earthquake Fault Zones (EFZs). Significant events in the history of the AP Act include A) the establishment of the Fault Evaluation and Zoning Program in 1976 (which also initiated the change from zoning faults with Quaternary displacement to those with Holocene displacement); B) the publication of the Reitherman-Leeds study in 1991, which evaluated the effectiveness of the AP Act; C) earthquakes associated with surface-fault rupture since the AP Act was passed, especially the 1992 Mw 7.3 Landers and 1999 Mw 7.1 Hector Mine events; D) release of digital versions of EFZ maps, Fault Evaluation Reports, and site investigation reports in 2000–2003; and E) the appeal to SMGB by the City of Camarillo, resulting in the establishment of the SMGB's Technical Advisory Committee.

INTRODUCTION

The Alquist-Priolo Earthquake Fault Zoning (AP) Act was passed into law in California following the destructive February 9, 1971, Mw 6.6 San Fernando earthquake. This earthquake was associated with a 16-km–long, complex zone of left-reverse oblique slip along traces of the San Fernando Fault Zone (Mission Wells, Sylmar, and Tujunga/Lakeview segments). Maximum left-lateral displacement of up to 2.5 m occurred along the Sylmar segment (Sharp, 1975). The lateral component of displacement was generally 1.3 times larger than the dip-slip component. Bonilla et al. (1971) reported that approximately 80 percent of buildings in the zone of surface-fault rupture associated with this earthquake had moderate to severe damage, compared to about 30 percent of the structures in immediately adjacent areas. Significantly, Bonilla et al. (1971) reported that 30 percent of the buildings within the fault zone were posted as unsafe (red-tagged), compared with only 5 percent of buildings outside of the fault zone.

Important seismic safety legislation in California typically has been enacted following destructive earthquakes. For example, the Field Act, which requires earthquake-resistant design and construction for public schools, was passed in April 1933 following the March 10, 1933, Mw 6.4 Long Beach earthquake. In addition to the AP Act, the Strong Motion Instrumentation Program and the Hospital Seismic Safety Act came into existence as a result of the San Fernando earthquake. Legislation in 1990 established the Seismic Hazards Mapping Act and hospital safety requirements (Senate Bill 1953) after the October 17, 1989, Mw 6.9 Loma Prieta earthquake. Rubin and Renda-Tanali (2006) provide a brief summary of California seismic safety legislation following significant earthquakes.

ALQUIST-PRIOLO ACT

The AP Act provided a mechanism to reduce losses from surface-fault rupture on a statewide basis (CDMG, 1976). Originally known as the Alquist-Priolo Geologic Hazard Zones Act when introduced as Senate Bill 520, the AP Act was signed into law on December 22, 1972, and went into effect on March 7, 1973. The AP Act is codified in the California Public Resources Code (CPR) as Sections 2621–2630 of Chapter 7.5, Division 2.

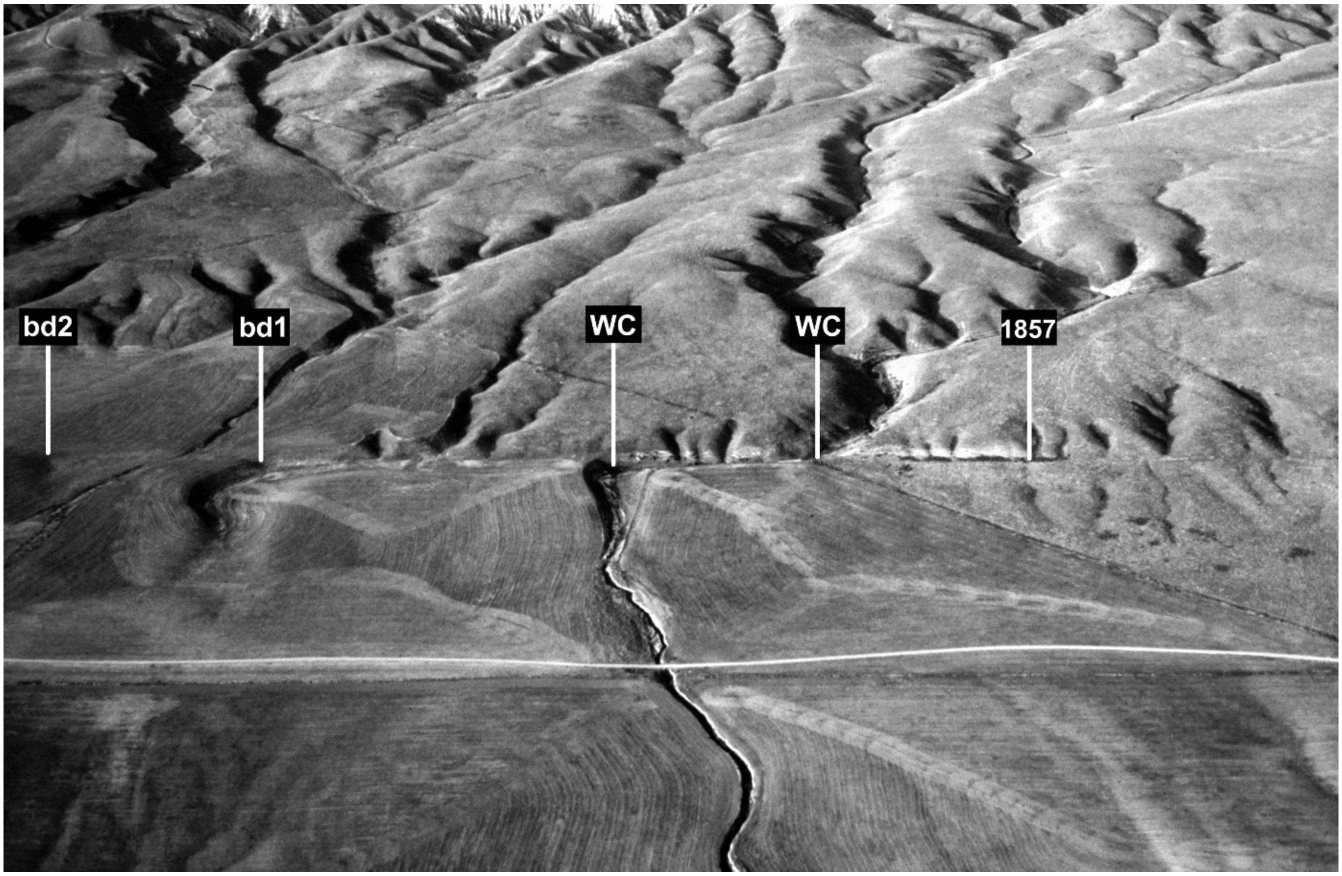

Figure 1. The San Andreas Fault strikes from left to right across the center of the image; view to the northeast. Wallace Creek has been cumulatively displaced about 130 m in the past 3,700 years (piercing points indicated by WC). If the 10–11-m dextral offset of stream channels observed after the 1857 Fort Tejon earthquake is typical of displacement along this section of the San Andreas Fault (an example is indicated by 1857), then about 14 surface-fault rupture events are recorded. The two beheaded drainages (bd1 and bd2) document older displacements of Wallace Creek. Cumulative dextral offset of bd2 and WC indicates that about 45 surface-fault rupture events have occurred in the past 13,200 years along this narrow fault zone (Sieh and Jahns, 1984; photo by R. E. Wallace).

The intent of the AP Act is to ensure public safety by prohibiting the siting of most structures for human occupancy across traces of active faults that constitute a potential hazard to structures from surface faulting or fault creep. The original wording in the AP Act (CPR §2621.5) stated that the Act was "… *to provide policies and criteria to assist cities, counties, and state agencies in the exercise of their responsibility to provide for the public safety in hazardous fault zones*." Note that original wording in the AP Act (statute) did not specifically prohibit the siting of structures across active faults. This prohibition was called for in the State Mining and Geology Board's (SMGB's) policies and criteria (regulation). Paragraph A in the SMGB's original "Specific Criteria" reads as follows: "*No structure for human occupancy, public or private, shall be permitted to be placed across the trace of an active fault*." A key part of the original AP Act gives authority to the SMGB to establish policies and criteria in order to implement the AP Act. CPR §2623 states: "*Within the special studies zones delineated pursuant to Section 2622, the site of every proposed new real estate development or structure for human occupancy shall be approved by the city or county having jurisdiction over such lands <u>in accordance with policies and criteria established by the State Mining and Geology Board and the findings of the State Geologist</u>*" [emphasis added]. As currently written in the AP Act, the only allowed type of mitigation for surface-fault rupture hazard is avoidance. CPR §2621.5 states that it "… *prohibit*[s] *the location of developments and structures for human occupancy across the trace of active faults*." Section 3603(a) of the California Code of Regulations (CCR) states that "*No structure for human occupancy … shall be permitted to be placed across the trace of an active fault*."

An important presumption of the AP Act is that future surface-fault rupture will most likely occur where previous recent displacement has taken place. Drainage channels offset by the San Andreas Fault in the Carrizo Plain help to illustrate this concept (Figure 1). Sieh (1978) observed that small drainage

Table 1. *Responsibilities under the Alquist-Priolo Earthquake Fault Zoning (AP) Act. Sections cited are from California Public Resources Code (CPR) and California Code of Regulations (CCR).*

State Mining and Geology Board	
1.	Formulates policies and criteria to guide cities and counties (CPR §2621.5 and 2623)
2.	Serves as Appeals Board (CPR §673)
State Geologist	
1.	Delineates Earthquake Fault Zones; compiles and issues maps to cities, counties, and state agencies (CPR §2622)
	a. Prepares Preliminary Review Maps
	b. Prepares Official Maps
2.	Reviews new data (CPR §2622)
	a. Revises existing maps
	b. Compiles new maps
3.	Approves requests for waivers initiated by cities and counties (CPR §2623)
Lead Agencies	
1.	Must adopt zoning laws, ordinances, rules, and regulations; primary responsibility for implementing AP Act (CPR §2621.5)
2.	Must post notices of new Earthquake Fault Zones Maps (CPR §2621.9 and 2622)
3.	Regulates specified "projects" within Earthquake Fault Zones (CPR §2623)
	a. Determines need for geologic reports prior to project approval
	b. Reviews and approves geologic reports prior to issuing development permits
	c. May initiate waiver procedures (CPR §2623)
Property Owners	
1.	Must prepare geologic report for specific projects and avoid surface-fault rupture hazard [CPR §2623.(a) and CCR §3603.(d)]
2.	Must disclose to prospective buyers if property is located within AP EFZs (CPR §2621.9)
Other	
1.	*Seismic Safety Commission*—advises State Geologist and State Mining and Geology Board (CPR §2360)
2.	*State Agencies*—prohibited from siting structures for human occupancy across active fault traces (CPR §2621.5)

channels just southwest of Wallace Creek were dextrally offset 10–11 m during the 1857 Mw 7.8 Fort Tejon earthquake. The active Wallace Creek drainage channel shows a cumulative dextral offset of about 130 m. Sieh and Jahns (1984) determined that this amount of displacement has taken 3,700 years to accumulate. To the northwest, beheaded drainage channels document older displacements of Wallace Creek. Approximately 475 m of cumulative dextral offset has occurred in the past 13,200 years (Sieh and Jahns, 1984). If one assumes that earthquakes with ground displacements of 10–11 m are typical for this section of the San Andreas Fault, then about 45 surface-fault rupture events have occurred along this very narrow fault zone over a period of 13,200 years.

Responsibilities for carrying out the Act are shared between the State Geologist (California Geological Survey), SMGB, affected lead agencies (cities, counties, and state agencies), and property owners (Table 1). These entities are discussed in the following paragraphs.

State Mining and Geology Board

Policies and criteria are developed by the SMGB to assist all concerned with implementing the AP Act. These policies and criteria were codified as Section 3600 et. seq., Division 2, Title 14 of the California Administrative Code (currently referred to as the California Code of Regulations) on January 31, 1979. The SMGB provides definitions of terms used in the AP Act, requires cities and counties to notify property owners within proposed new and revised Earthquake Fault Zones (EFZs), provides opportunity for the public to comment on preliminary review maps of EFZs, and serves as an appeals board (CPR §673).

State Geologist

The State Geologist evaluates potentially active faults (evidence of displacement in Quaternary time) and establishes regulatory zones (EFZs) encompassing those faults that are sufficiently active and well defined. Sufficiently active faults are those faults with evidence of surface displacement during Holocene time (approximately the last 11,000 years). Holocene surface displacement may be directly observed or inferred; it need not be present everywhere along a fault to qualify that fault for zoning. A fault is considered well defined if its trace is clearly detectable by a trained geologist as a physical feature at or just below the ground surface. The criterion of well defined is somewhat subjective and can be influenced by rock type, climate, vegetation, slip rate, and style of displacement. A critical consideration is that the fault, or some part of it, can be located in the field with sufficient precision and confidence so that the required site-specific investigation would meet with some success.

"Potentially active fault" is not defined in either the AP statute (AP Act) or the regulations (policies and criteria of the SMGB) and often has been inferred to denote a lack of Holocene displacement. The term "potentially" only appears in CPR §2622(a), which discusses zoning criteria for the State Geologist. An explanation for "potentially active fault" is found in Special Publication 42 (Bryant and Hart, 2007). This expression is generally referred to in the context of zoning criteria based on Quaternary displacement. It is important to note that the term potentially active fault does not exclude displacement in Holocene time (see figure 2 in Bryant and Hart [2007]). Therefore, it does not follow that a "potentially active fault" can be judged "inactive" unless there is evidence that supports the conclusion that the fault has not been active in Holocene time.

Preliminary Review Maps of Alquist-Priolo EFZs (AP EFZs) are issued by the State Geologist on standard U.S. Geological Survey 1:24,000-scale, 7.5-minute quadrangle maps. Following a 90-day review period, the SMGB will hold at least one public hearing to receive comments pertaining to the technical merit of the proposed AP EFZs. The State Geologist considers and incorporates review comments and issues Official Maps to affected lead agencies within 90 days of the close of the review period. Section 2622(c) requires the State Geologist to continually review new geologic and seismic data and to revise or issue additional new AP EFZ maps when warranted. To date the State Geologist has issued 551 Official Maps of EFZs. Of these, 161 maps have been revised and four have been withdrawn.

The State Geologist also has the authority to approve waiver requests submitted by lead agencies (CPR §2623). See the discussion under "Lead Agencies" (below) for further information on the waiver procedure.

Lead Agencies

Lead agencies (cities, counties, and state agencies) are responsible for ensuring that structures for human occupancy that are considered projects under the AP Act are not placed across the trace of an active fault. Affected lead agencies adopt the AP Act into their general plan. Counties specifically are required to post a notice identifying the location of AP EFZ maps in their jurisdiction and the effective date of the notice within 5 days of receiving an Official EFZ map. These notices are to be posted at the offices of the county recorder, county assessor, and county planning commission [CPR §2622(d)]. Lead agencies must require geologic investigations directed by a California-licensed Professional Geologist before building permits can be issued or subdivisions can be approved within an AP EFZ. A critical responsibility of the lead agency is to ensure that the fault-rupture hazard report is adequate by having the report reviewed by a third-party California-licensed Professional Geologist.

There may be occasions when a lead agency finds that the geologic report for a specific site may not be necessary because it determines that no undue fault rupture hazard exits. This condition typically occurs where several previous investigations in close proximity to the subject site have documented a lack of surface-fault rupture hazard. The lead agency has the option to submit a waiver request, along with accompanying documentation, to the State Geologist for approval [CPR §2623(a)]. If the State Geologist concurs that there is no undue hazard of surface-fault rupture at the site, the local lead agency may issue a building permit without the requirement of a site investigation. To date, there have been 85 waiver requests submitted to the State Geologist since the first maps were issued; 80 percent of these waiver requests have been approved.

Property Owners

Property owners and developers (applicants for building permits or subdivisions) are responsible for completing a geologic investigation and preparing a geologic report for projects within an AP EFZ. Ultimately it is the responsibility of the property owner, represented by a California-licensed Professional Geologist, to determine if the hazard of surface-fault rupture exits on the property and if so, to avoid the hazard [CPR §2623(a); CCR §3603(d)]. Property owners are also responsible for disclosing to potential buyers if their property is located in an AP EFZ (CPR §2621.9).

SIGNIFICANT HISTORICAL MILESTONES

Name Changes

The AP Act was originally named the Alquist-Priolo Geologic Hazard Zones Act and was intended to address a broader scope of seismically induced ground deformation hazards. It was decided by the original SMGB's Advisory Committee that the standard of practice in 1972 was not sufficiently developed to address ground deformation hazards other than surface-fault rupture. The AP Act was renamed the Alquist-Priolo Special Studies Zones Act in 1975 (as a result of Senate Bill 5, introduced by Senator Alquist in December 1974) and was changed to the Alquist-Priolo Earthquake Fault Zoning Act, which became effective January 1, 1994. The name change implemented in 1994 was the result of a recommendation by the Reitherman-Leeds study (Reitherman and Leeds, 1991; see discussion below).

Single-Family Dwelling Exemption

When first enacted, the AP Act did not exempt single-family wood-frame dwellings. The original text of the AP Act in CPR §2623 reads: "… *the site of every proposed new real estate development or structure for human occupancy shall be approved by the city or county having jurisdiction over such lands in accordance with policies and criteria established by the State Mining and Geology Board and the findings of the State Geologist*." This was changed on December 2, 1974, so that single-family wood-frame dwellings, if not part of a development of four or more dwellings, were exempt [CPR §2621.6(a)(2)]. This exemption was created in part as a result of real estate lobbying and the assumed benefit/cost ratio for single-family dwellings. In 1974, State Geologist Dr. James E. Slosson estimated that the benefit/cost ratio for surface-fault rupture investigations on multi-lot tracts or at the tentative tract stage, where all geologic hazards are considered, ranged from 5:1 to 10:1 (Slosson [1974], cited in Reitherman and Leeds [1991]). Slosson, however, reported that this benefit/cost ratio seems to decrease to about 0.05:1 where studies for fault-rupture hazard only are keyed to single lots after a tract has been approved.

Fault Evaluation and Zoning Program

The initial charge to the State Geologist was to zone all potentially and recently active traces of the San Andreas, Calaveras, Hayward, and San Jacinto Faults [CPR §2622(a)]. On July 1, 1974, 175 Official Maps of Special Studies Zones were issued, based entirely on compiling existing maps. An additional 81 maps were issued January 1, 1976. These map releases established regulatory zones encompassing faults with evidence of Quaternary displacement.

In early 1976, a 10-region Fault Evaluation and Zoning Program (Figure 2) was begun to systematically evaluate for possible zoning the "… *other faults* … [that are] *sufficiently active and well-defined as to constitute a potential hazard for structures from surface faulting or fault creep*" [CPR §2622(a)] (CDMG, 1976). The state was divided into 10 regions based on 1) the presence of known or suspected active faults and 2) developmental pressure. Initially this was planned as a 10-year project, but the schedule in some regions was extended as a result of heavy workloads. Faults evaluated included potentially active faults not yet zoned and previously zoned faults or fault segments that warranted zone revisions. Areas outside of the scheduled regions were also evaluated on an as-needed basis, typically to map fault rupture immediately after an earthquake. Although the 10-region project was completed at the end of 1991, work continues on the project at a maintenance level. The State Geologist has an ongoing responsibility to review *"new geologic and seismic data"* in order to revise AP EFZs and to *"delineate new zones when warranted by new information"* [CPR §2622(c)].

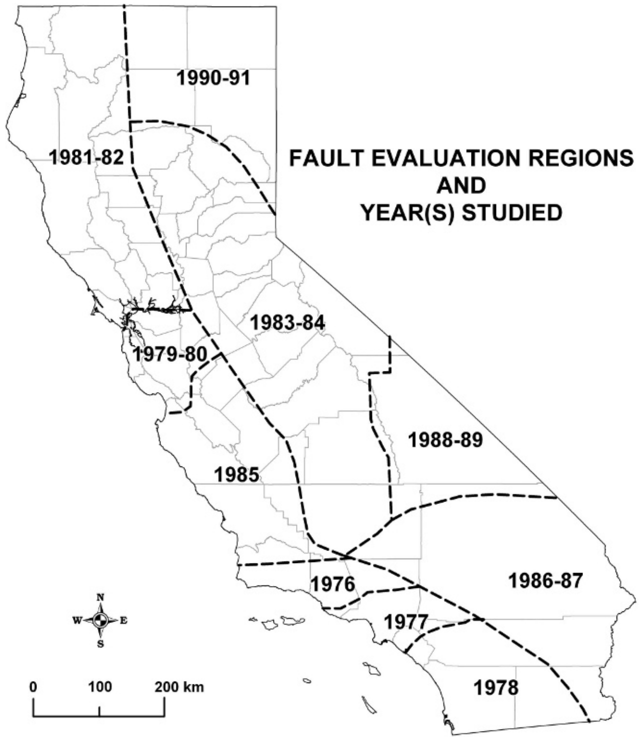

Figure 2. Map of 10-region work plan for Alquist-Priolo Fault Evaluation and Zoning Program, showing dates each region was studied.

For each fault evaluated, a Fault Evaluation Report (FER) was prepared that summarized data on the location, recency of displacement, sense and amount of displacement, and rationale for zoning decisions. Fault evaluation work consists of reviewing geologic and fault mapping by others, aerial photographic interpretation of fault-produced geomorphology, and limited field mapping. Although subsurface investigations are not budgeted, geologists at the California Geological Survey (CGS) use sub-surface data contained in site investigations submitted to the

State Geologist to augment the air photo interpretation and field mapping.

CGS geologists have produced about 250 FERs summarizing evidence for or against zoning decisions for potentially active faults throughout California. There have been 18 Official Map releases since the Fault Evaluation and Zoning Program began.

Reitherman-Leeds Study

In 1986 the California Seismic Safety Commission recommended an impartial evaluation of the AP Act. In 1991, CGS (then the Division of Mines and Geology) released the Reitherman-Leeds study (Reitherman and Leeds, 1991). This study evaluated 62 policy issues that ranged from increasing the authority and scope of the AP Act to abolishing the AP Act. Overall, Reitherman-Leeds concluded that the AP Act is effective, and they recommended implementing 27 policy issues. Most have been implemented, including the following:

1) establishing the Seismic Hazards Mapping Act,
2) more aggressive enforcement by the California Board for Geologists and Geophysicists,
3) revision of CGS Note 49 (guidelines for fault rupture hazard investigations),
4) changing the AP Act's name to the Earthquake Fault Zoning Act,
5) changing the disclosure statement (part of Natural Hazards Disclosure Act),
6) publishing a non-technical brochure explaining the AP Act, and
7) increasing the availability of FERs and consulting reports filed with the State Geologist.

One recommendation yet to be clarified is the issue of setback distance. There are varying degrees of application of setbacks among local lead agencies with respect to the interpretation of CCR §3603(a). The current language states the following:

> *No structure for human occupancy, identified as a project under Section 2621.6 of the Act, shall be permitted to be placed across the trace of an active fault. Furthermore, as the area within fifty (50) feet of such active faults shall be presumed to be underlain by active branches of that fault unless proven otherwise by an appropriate geologic investigation and report prepared as specified in Section 3603.d of this subchapter, no such structures shall be permitted in this area* [emphasis added].

Reitherman and Leeds found this language to be open to various interpretations: some lead agencies mandate a no-build zone 50 ft (15 m) from active faults, while others allow structures to be sited closer than 50 ft (15 m), if appropriate, based on site-specific investigations. As written, there is no specified minimum distance. However, the original wording of this section by the SMGB did state that 50 ft (15 m) represented a minimum standard:

> *… Furthermore, the area within fifty (50) feet of an active fault shall be assumed to be underlain by active branches of that fault unless and until proven otherwise by an appropriate geologic investigation and submission of a report by a geologist registered in the State of California. This 50 foot standard is intended to represent minimum criteria only for all structures. It is the opinion of the Board that certain essential or critical structures, such as high-rise buildings, hospitals, and schools should be subject to more restrictive criteria at the discretion of Cities and Counties* [emphasis added].

The wording as originally written remained in effect until 1984. Local lead agencies affected by the AP Act prior to 1984 adopted the AP Act into their general plan, and some jurisdictions may have included this 50-ft (15 m) minimum distance as a mandatory requirement. This may explain why some local jurisdictions currently mandate a specific 50-ft (15 m) setback from active faults within an AP EFZ.

In concept, a setback, or no-build zone, is delineated around active faults located during a site investigation to allow an appropriate level of conservatism or factor of safety. The width of a setback zone allows for the occurrence of near-fault deformation and the inherent uncertainties of projecting the location of the fault between known data points. The width of an appropriate no-build zone can vary, based on site-specific geologic conditions, style and complexity of faulting, and number and spacing of trenches. Thus, in some circumstances it may be appropriate to site a structure closer than 50 ft (15 m), and in other situations, 50 ft (15 m) may be entirely inadequate.

Earthquakes with Surface-Fault Rupture Since the Passage of the AP Act

Twenty-five earthquakes or earthquake sequences associated with surface-fault rupture have occurred since the first AP EFZ maps were issued in 1974 (Table 2). Thirteen events occurred along faults not previously zoned: nine (69 percent) occurred prior to the CGS regional evaluation, and four (31 percent) occurred after the region had been evaluated.

The most significant surface rupturing events to date were the 1992 Mw 7.3 Landers and the 1999 Mw 7.1 Hector Mine earthquakes (Figure 3). The Landers event was associated with the largest amount of surface-fault rupture in California since the 1906 San Francisco earthquake. Approximately 85 km of surface rupture, with maximum dextral offset of about 6 m and an average dextral offset of about 3 m, was recorded (Hart et al., 1993; Sieh et al., 1993). This earthquake was unique because several faults ruptured, including the Johnson Valley, Homestead Valley, Emerson, and Camp Rock Faults (Figure 3). The rupture was especially complex, with broad zones of distributed displacement between and connecting the principal faults. Most faults that ruptured had been zoned in 1988. However, many of the stepover areas had not been zoned. Faulting sometimes extended significantly beyond those AP EFZ boundaries encompassing the ends of faults (Figure 4). Hart et al. (1993) estimated that about 55 percent of fault rupture occurred within established AP EFZs. About 31 percent was outside of AP EFZs, and the remaining 14 percent of rupture outside of the zones occurred on previously unmapped faults not appearing to meet zoning criteria (Hart et al., 1993). Many of the faults that ruptured have been shown to have relatively low slip rates (about 0.5 mm/yr) with correspondingly long recurrence intervals (between 4 ka and 12 ka) (Hecker et al., 1993; Lindvall and Rockwell, 1994; Rubin and Sieh, 1997; and Rockwell et al., 2000).

The Hector Mine earthquake was similar in complexity where traces of the Lavic Lake Fault splayed off of the Bullion Fault. AP EFZs had been established in 1988 for traces of the Bullion Fault, but the Lavic Lake Fault had not been zoned. Post-earthquake studies indicated that the Lavic Lake Fault in the Bullion Mountains had not ruptured for tens of thousands of years prior to the 1999 event (Lindvall et al., 2000).

These observations indicate that caution should be used when evaluating faults characterized by low slip rates that have not had surface displacement for a long time. It is important to understand the age of the most recent event and the recurrence intervals of these faults. Another important consideration is the complexity and width of the surface faulting observed in both the Landers and Hector Mine earthquakes. Are the rupture patterns, complexity, and width indicative of and unique to the Eastern California Shear Zone, or are these complexities typical of large surface-faulting events?

In contrast to the Landers and Hector Mine earthquakes, the 2004 Mw 6.0 Parkfield earthquake was associated with surface faulting that was very similar to the location and pattern of displacement documented in the 1966 Mw 6.1 Parkfield event (Brown et al., 1967; Rymer et al., 2006). The 2004 surface faulting, with one minor exception, was located entirely within the previously established AP EFZs.

Digital Products

One of the recommendations of the Reitherman-Leeds study was to reproduce the FERs and site investigation reports filed with CGS in compliance with the AP Act. CGS (then the Division of Mines and Geology) issued microfiche copies of the FERs and tabulated data on site investigation reports (Division of Mines and Geology, 1990a, 1990b, 1990c, 1990d, 1990e; Wong et al., 1990; and Wong, 1995). Microfiche copies of the FERs, especially the map data, were generally not optimal, and those needing to reference or review specific consulting reports were required either to obtain copies from CGS or to visit the Bay Area regional office, where the site report collection was kept on file for public access.

In the late 1990s CGS began an effort to provide digital products from the AP Program in response to the Reitherman-Leeds study. Digital images of AP EFZ maps were released as portable document format (pdf) files in 2000, followed by vector GIS files of faults and EFZs in 2001. The 1990s vintage microfiche copies of FERs were replaced in 2002 by digital images of the reports, including high-resolution pdf files of the maps (Bryant and Wong, 2002a, 2002b, 2002c). The collection of site-specific fault investigation reports was released in 2003 (Wong, 2003a, 2003b). This fault investigation report collection includes specific reports in pdf format, an interactive site index map, and GIS files of site investigation locations. Site reports filed with the State Geologist through 2000 are available on compact disk. Hard copy reports are no longer filed in the Bay Area office. Reports received after 2000 are available for reference at the Sacramento office of CGS.

Camarillo Issue and State Mining and Geology Board

The City of Camarillo requested an interpretation of SMGB regulations in late 2006. At issue was how the AP Act was interpreted with respect to the presumption of activity of faults located within EFZs. Is the entire area within an AP EFZ presumed to be underlain by active faults until demonstrated otherwise? Another issue raised was the intent of the setback language in CCR §3603(a). Did this regulation mandate that structures cannot be placed closer than 50 ft (15 m) from each fault encountered in a site investigation, or was there some degree of flexibility? Must one setback from faults with small amounts of displacement that cannot be proven inactive, or is structural mitigation allowed for such faults?

This request for clarification resulted from an investigation of a site underlain by extensively faulted Plio-Pleistocene Saugus Formation. Principal active traces of the Simi–Santa Rosa Fault Zone were located on the site and setbacks were recommended. However, the site previously had been used for borrow and lacked any remaining younger stratigra-

Table 2. *Surface faulting associated with earthquakes in California, 1974–June 2009. List excludes fault creep and faulting triggered by shaking or movement on a different fault.[1] See Bonilla (1970), Jennings (1985), and Grantz and Bartow (1977) for earlier faulting events.*

	Fault (county where located)	Year of Rupture	Magnitude of Associated Earthquake	Surface Rupture,[2] Maximum Displacement (cm)	Total Length[2] (km)	Main Sense of Displacement[3]	Comments
1.	Brawley (Imperial)	1975	4.7	20	10.4	N	Also ruptured in 1940 and 1979, fault creep in part.
2.	Galway Lake (San Bernardino)	1975	5.3	1.5	6.8	RL	Fault previously unknown.
3.	Cleveland Hill (Butte)	1975	5.7	5	5.7	N	Fault not previously known to be Holocene-active.
4.	Stephens Pass (Siskiyou)	1978	4.3	30	2+	N	Fault previously unknown.
5.	Homestead Valley (San Bernardino)	1979	5.2	8	3.3	RL	Also minor rupture on Johnson Valley Fault.
6.	*Calaveras (San Benito, Santa Clara)	1979	5.9	1	39 (?)	RL	Minor, discontinuous rupture, mostly in creep-active section.
7.	*Imperial (Imperial)	1979	6.6	55	30	RL	Creep triggered on San Andreas and Superstition Hills Faults; also ruptured in 1940. Rico Fault not previously known.
	*Brawley (Imperial)			15	13	N	
	Rico (Imperial)			10	1	N	
8.	Greenville (Alameda)	1980	5.6	3	6.5	RL	Minor left-lateral slip also occurred on Las Positas Fault.
9.	Hilton Creek–Mammoth Lakes (Mono)	1980	6.0–6.5	30	20	N	Rupture on many minor faults; may relate to volcanic activity; Minor ruptures also in 1981.
10.	"Lompoc quarry" (Santa Barbara)	1981	2.5	25	0.6	R	Flexural slip on flank of syncline triggered by quarrying; do not plan to zone. Similar earthquake-associated ruptures occurred in 1985, 1988, and 1995.
11.	Little Lake (Kern)	1982	5.2	0+	10	RL/N	Fracture zones on monoclines.
12.	"Coalinga Nose" (Fresno)	1983	6.7	5	.005	R	Secondary fault (?) associated with 43 cm of anticlinal uplift; too minor to zone.
13.	Nunez (Fresno)	1983	5.2–5.9	60	3.3	R	Aftershocks associated with event (12) above.
14.	*Calaveras (Santa Clara)	1984	6.1	20 (?)	1.2	RL	Questionable faulting; triggered afterslip in 15-km–long creep zone to south.

Table 2. *Continued.*

	Fault (county where located)	Year of Rupture	Magnitude of Associated Earthquake	Surface Rupture,[2] Maximum Displacement (cm)	Total Length[2] (km)	Main Sense of Displacement[3]	Comments
15.	*Banning (Riverside)	1986	5.9	7	9	RL	Minor slip also triggered locally on Garnet Hill and Desert Hot Springs (?) Faults as well as more distant faults.
16.	*White Mountains (Mono, Inyo)	1986	6.4	11	13	RL/N	Event also associated with extensional cracks on faults in Volcanic Tableland in 40 km × 12 km area.
17.	Elmore Ranch (Imperial)	1987	6.2	12	12	LL	Event also associated with smaller left-lateral rupture on nearby faults.
18.	*Superstition Hills (Imperial)	1987	6.6	90	28	RL	Much of rupture occurred as afterslip; associated with event 17.
19.	*San Andreas (Santa Cruz)	1989	7.1	2.5	1?	RL	Surface rupture possibly triggered slip; slip also triggered on nearby Calaveras and San Andreas Faults outside of aftershock zone. Secondary faulting may have occurred with ridgetop spreading fissures.
20.	*Johnson Valley, *Homestead Valley, *Emerson, *Camp Rock (San Bernardino)	1992	7.3	460–600	85	RL	Most significant fault rupture since 1906; ruptures connected several separate faults; triggered slip also occurred on at least 10 other faults.
21.	"Eureka Valley" (Inyo)	1993	6.1	2	5+	RL/N	Two zones of left-stepping fractures along pre-existing fault scarps; incompletely mapped; remote area, not zoned.
22.	"Stevenson Ranch" (Los Angeles)	1994	6.7	19	0.6	R	Flexural slip faults on limb of fold near Newhall; related to blind thrust faulting. Minor slip also triggered on Mission Wells Fault, which ruptured in 1971.
23.	*Airport Lake (Kern and Inyo)	1995	5.4–5.8	1	2.5	RL/N	Discontinuous cracks along pre-existing scarp.

Table 2. *Continued.*

	Fault (county where located)	Year of Rupture	Magnitude of Associated Earthquake	Surface Rupture,[2] Maximum Displacement (cm)	Total Length[2] (km)	Main Sense of Displacement[3]	Comments
24.	Lavic Lake, *Bullion, *Mesquite Lake (San Bernardino)	1999	7.1	525	45	RL	Bullion and Mesquite Lake Faults previously zoned; Lavic Lake had not ruptured in Holocene.
25.	*San Andreas (Monterey, San Luis Obispo)	2004	6.0	15	32	RL	Parkfield section of San Andreas Fault zone; also ruptured in 1966. Much of rupture occurred as afterslip.

[1]Tectonic (aseismic) fault creep and triggered slip have occurred along various segments of the San Andreas, Hayward, Calaveras, Concord, Green Valley, Imperial, Superstition Hills, Maacama, and Garlock Faults as well as along more than 10 other faults. Human-induced fault creep has been reported on at least 12 other faults as a result of withdrawal of groundwater or oil-field fluids. See Jennings (1994) for map locations.
[2]Includes some afterslip. Rupture length measured from distal ends of rupture, which are often discontinuous.
[3]N = normal displacement; R = reverse displacement; RL = right-lateral displacement; LL = left-lateral displacement.
* = coseismic surface faulting occurred mostly or entirely within existing Earthquake Fault Zones during 11 events.

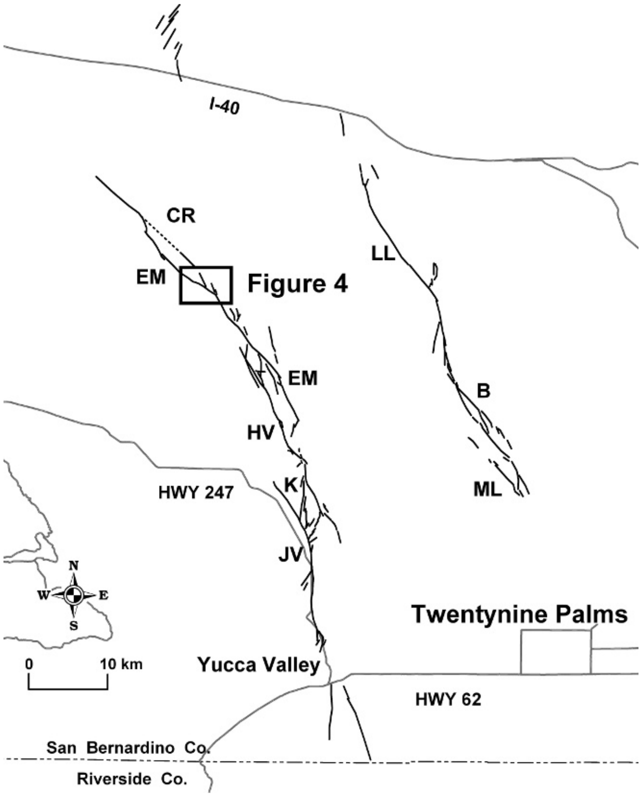

Figure 3. Map showing generalized surface-fault rupture patterns for the 1992 Mw 7.3 Landers earthquake and the 1999 Mw 7.1 Hector Mine earthquake. Principal faults that ruptured in the Landers event include the following: JV = Johnson Valley; HV = Homestead Valley; K = Kickapoo; EM = Emerson; and CR = Camp Rock. Principal faults that ruptured in the Hector Mine event include the following: LL = Lavic Lake; B = Bullion; and ML = Mesquite Lake. Box shows location of Figure 4.

phy overlying the faulted Saugus Formation. Without younger stratigraphy, it was impossible to constrain the age of most recent displacement for numerous other faults located on the site.

The SMGB's Geohazards Committee heard arguments from the city's review geologist, the developer's geologists, and the State Geologist. In mid-December 2006, the Geohazards Committee recommended that the SMGB should interpret the AP Act to mean that all faults within an Official EFZ should be considered active unless proven otherwise.

The Geohazards Committee also recommended formation of a Technical Advisory Committee (TAC) to review some of the issues raised by the Camarillo appeal and the 1991 Reitherman-Leeds study. A 16-member TAC, comprising experts and specialists in geoscience, engineering, and public administration, first met in July 2007. Some of the issues currently being reviewed by the TAC include the following: clarification of setbacks, presumption of activity within an AP EFZ, definition of an active fault, and whether mitigation methods, in addition to avoidance, can be used within an AP EFZ. The TAC will issue a report to the Geohazards Committee containing recommendations formed by a consensus of expressed expert views, based on science and engineering considerations. Recommendations by the TAC will be evaluated by the Geohazards Committee. Conclusions and recommendations made by the Geohazards Committee will be reviewed by the full SMGB, which will decide if the SMGB's regulations

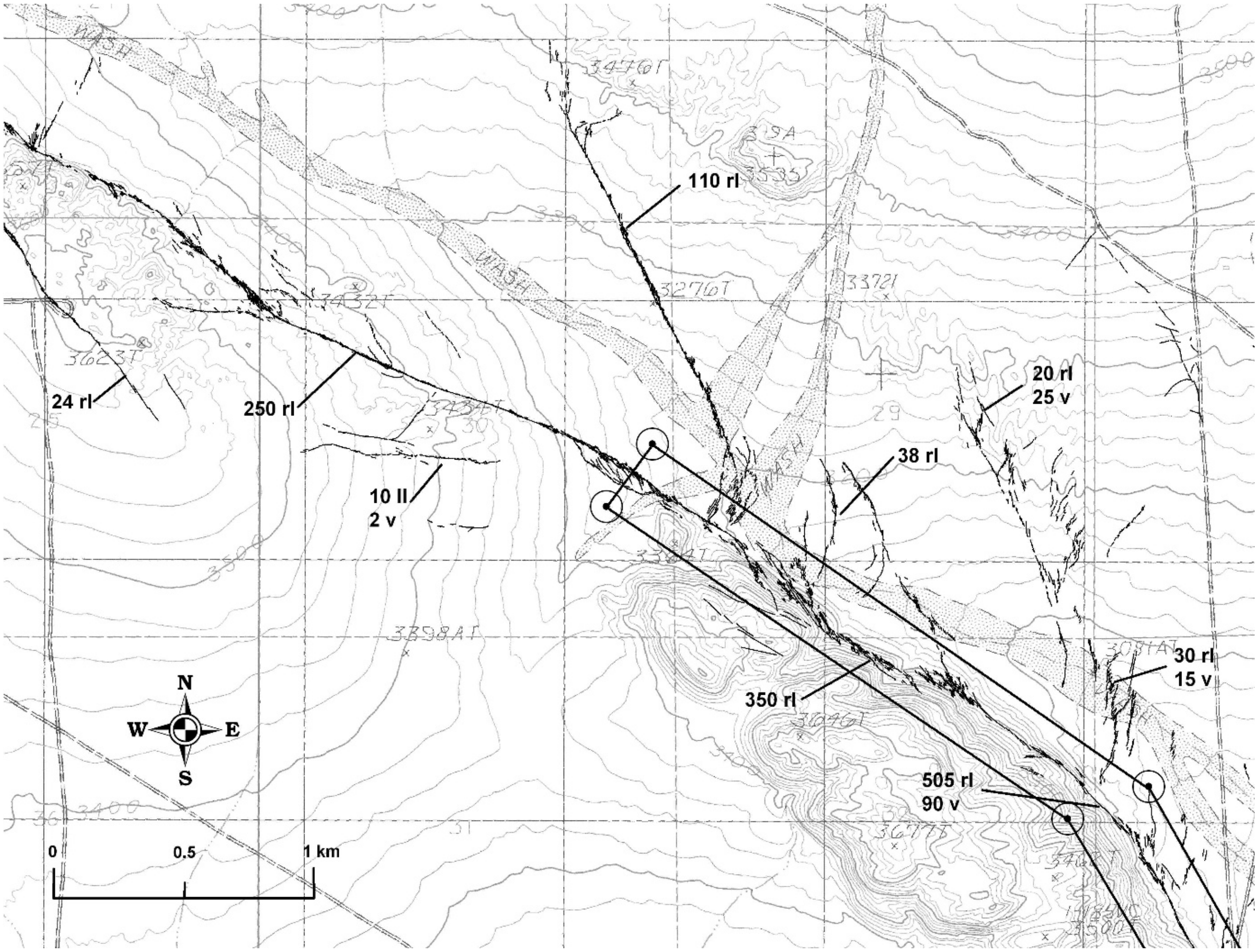

Figure 4. Detailed map of surface faulting along a portion of the Emerson Fault associated with the 1992 Landers earthquake. The numbers indicate observed slip components in centimeters (rl = right-lateral; ll = left lateral; and v = vertical). The Alquist-Priolo Earthquake Fault Zone (AP EFZ) that was in place in 1988 is depicted with circled turning points connected by straight-line segments. Pre-1992 Emerson Fault traces northwest of the AP EFZ boundary were not zoned because the complex right-step to the Camp Rock Fault (Figure 3) was generally concealed and poorly defined. Also, trench data northwest of this figure indicated that soils estimated to be 10–12 ka were not offset.

need revision or if the SGMB should recommend legislative changes to the AP Act.

SUMMARY

The AP Act addresses the geologic hazard of surface-fault rupture by prohibiting the placement of most structures for human occupancy across the traces of active faults. Responsibility for implementing the AP Act is shared by the State Geologist, SMGB, lead agencies (cities, counties, and state agencies), and property owners. Alquist-Priolo EFZs have been in effect for the past 34½ years. During that time there have been 25 earthquakes associated with surface-fault rupture, including the Mw 7.3 1992 Landers and Mw 7.1 Hector Mine earthquakes. Significantly, there has not yet been a large surface-faulting earthquake in an intensely urbanized area since the AP EFZs have been established. The AP Act generally has been considered effective in avoiding surface-fault rupture hazard (Reitherman and Leeds, 1991). However, complex sites offer unique and often difficult challenges to ensuring public safety and effective land use. Currently the SMGB's TAC is reviewing policies and criteria to clarify and possibly update regulations governing the implementation of the AP Act.

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