1997 Uniform Building Code Ground Shaking Criteria

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Abstract

The recently published 1997 Uniform Building Code incorporates two significant changes to the ground shaking criteria which apply to all structures. The first change is a revision to soil types and soil amplification factors. The second change is the incorporation of near source factors in UBC seismic Zone 4. Together these changes result in the largest increases in code ground shaking criteria which has occurred in the past 30 years. Records obtained from the strong motion Instrumentation Program (SMIP) along with USGS records were the primary sources of data used to justify these code changes.

Soil Types and Soil Amplification Factors

The ground shaking basis for code design is reflected in the 5% damped elastic response spectra shown in Figure 1 (UBC Figure 16-3). The response spectra is defined in terms of two site seismic coefficients C_a and C_v. The site seismic coefficients are determined as a function seismic zone, soil type, and in Zone 4 near source factors. The soil profiles are subdivided into six types based on the average soil properties in top 100 feet of the soil profile. The types are identified as S_A through S_F are defined in accordance with Table 16-J (attached). The types are based on consensus deliberations from the USGS/NCEER/SEAOC workshop held at USC in 1992. These are identical to soil profile types that are found in 1994 NEHRP Provisions.

The site seismic coefficients C_a and C_V are determined from Tables 16-Q and Table 16-R (attached) based upon the soil profile type, seismic zone and in UBC Zone 4 the near source factors N_a and N_v. It should be noted that the value of the soil factors depart significantly from previous codes in that both short period and long period structures are effected by soil effects and that the amplifications increase significantly at lower ground acceleration levels. In previous codes soil effects were only considered for long period structures. . The amplification factors are consistent with the consensus from the previously referenced USC workshop and are identical to those found in the 1994 NEHRP provisions. These effects are consistent with observations in the Mexico City and the Loma Prienta earthquakes

Near Source Factors

The near source factors were developed by Ground Motion-Ad-Hoc-Committee of the SEAOC Seismology Committee to account for the effects of ground motions near the source of seismic events. The factors are a refinement of what was developed for seismically isolated structures included initially in the 1991 UBC. Near source ground motion records and observed damage from Northridge and Kobe have provided convincing evidence of significantly more intense ground shaking near the fault rupture than had been previously accounted for.

In order to establish, the near source factors, the first step is to identify and locate known active faults in UBC Zone 4 and classify them into one of three source type based on maximum moment magnitude and slip rate in accordance with Table 16-U (attached). Faults are classified based on their maximum magnitude M and slip rate R. Type A sources are faults that have a moment magnitude potential of $M \geq 7.0$ and a slip rate SR equal to or greater than 5 mm/year. These types of faults are considered to be active and capable of producing large magnitutde events. Most segments of the San Andreas fault would be classified as a Type A fault. Type C sources are faults that have a moment magnitude potential of M less than 6.5 and a slip rate of SR less than or equal to 2 mm/year. Type C faults are considered to be sufficiently inactive and not capable of producing large magnitude events such that potential near-source ground shaking effects can be ignored. Most faults outside of California are Type C. Type B sources are all faults that are not either Type A or Type C and include most of the active faults in California. The 1997 UBC requires that the locations and characteristics of these faults be established based on approved geotechnical data from reputable sources such as the California Division of mines and Geology and the USGS.

Once faults are located relative to a site and the source type is established, the near source factors N_a and N_v are determined in accordance with Table 16-S and 16-T (attached). These factors were established by the Ad Hoc Ground Motion Committee and are based on the average increase, measured in the near field from Northridge and other earthquakes. The near source factors apply to both strike-slip and reverse-slip (thrust) fault mechanism although reverse-slip faults produce about 20% greater shaking on the average. The short period (acceleration domain) near source factor (N_a) is based on response at 0.3 seconds and long-period (velocity-domain) near source factor (N_v) based on 1.0 second response. Values of N_v are bumped upward by about 20% to account for the increase in average response in the fault-normal direction above that predicted by the attenuation function for the random component of horizontal ground shaking (ref. Somerville, 1996 7th US/Japan Workshop, Lessons learned from Kobe and Northridge). The commentary to the SEAOC bluebook notes ground shaking at "forward directivity" sites is likely to be 1.25 times the C_v and C_a coefficients based on average fault normal response. The values of N_a and N_v are used in Tables 16-S and 16-T to determine the values of C_a and C_v in UBC Zone 4 ($Z = 0.40$).

Distance from Faults and Fault Maps

The rules for measuring distance from a fault were also established by the Ad Hoc ground motion committee and are found in the code. The rules are illustrated in figure 2 for a variety of fault types and depths. It is interesting to note that for non-vertical faults a zero distance fault zone has been established as illustrated. The distance from a fault is measure from this zero distance fault zone.

Active fault near field maps are currently being developed for California Zone 4 for California Mines and Geology. The form of the maps will be like a Thomas Guide and will be at a scale of 1:150,000. The background will include street maps and freeways. An individual will be able to find their house on the maps. The USGS is providing fault information developed for Project 97 for maps outside of California and the maps will be developed by donated private sources. The maps will be published for sale by ICBO in fall of this year. Examples of the legend sheet is shown in Figure 3 and examples of expected near field maps are shown in Figures 4 and 5.

Conclusion

In conclusion, the inclusion of soil and near field effects in the 1997 UBC represent one of the most state-of-the-art, meaningful, and impactive changes in the code by the geoscience community in the history of seismic codes. The effects will continue to be improved in the new International Building Code which replaces the UBC begining in the year 2000.

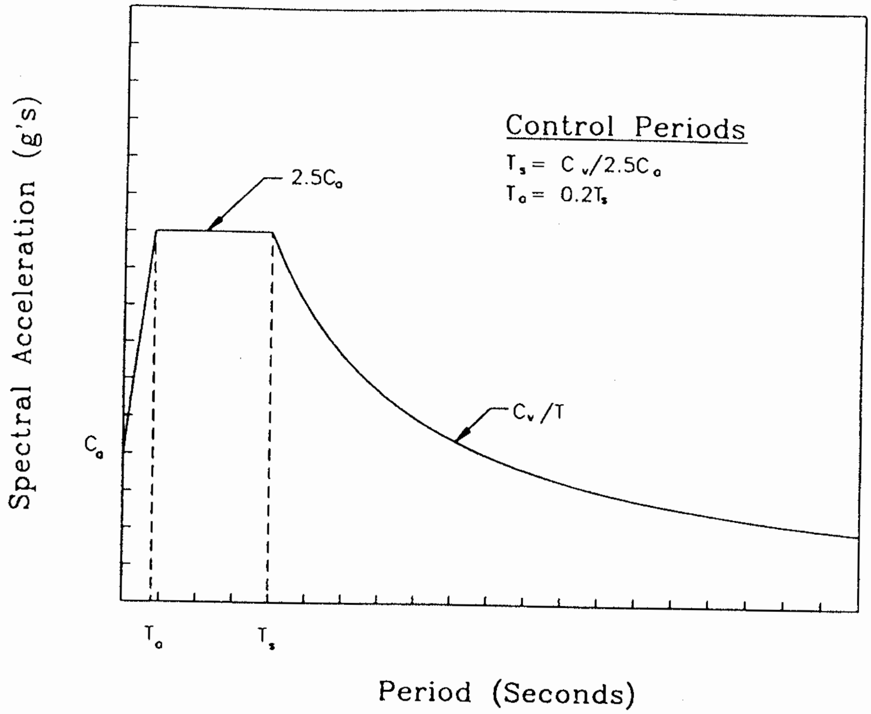


Figure 1: Design Response Spectra

Table 16-J. *Soil Profile Types*

Soil Profile Type	Soil Profile Name/Generic Description	Average Soil Properties for Top 100 Feet (30 480 mm) of Soil Profile		
		Shear Wave Velocity, $\bar{v}_s$ feet/second (m/s)	Standard Penetration Test, $\bar{N}$ (or $\bar{N}_{CH}$ for cohesionless soil layers) (blows/foot)	Undrained Shear Strength, $\bar{S}_u$ psf (kPa)
S_A	Hard rock	> 5,000 (1500)		
S_B	Rock	2,500 to 5,000 (760 to 1500)		
S_C	Very dense soil and soft rock	1,200 to 2,500 (360 to 760)	> 50	> 2,000 (100)
S_D	Stiff soil profile	600 to 1,200 (180 to 360)	15 to 50	1,000 to 2,000 (50 to 100)
S_E[1]	Soft soil profile	< 600 (180)	< 15	< 1,000 (50)
S_F	Soil requiring site-specific evaluation. See Section 1644.3.1			

1. Soil profile Type S_E also includes any soil profile with more than 10 ft (3048 mm) of soft clay defined as a soil with a plasticity index, $PI > 20$, $w_{mc} > 40$ percent and $\bar{S}_u < 500$ psf (25 *kPa*). The Plasticity Index, *PI*, the moisture content, w_{mc}, shall be determined in accordance with approved national standards.

Table 16-Q. Seismic Coefficient C_a

Soil Profile Type	Seismic Zone Factor, Z				
	Z=0.075	Z = 0.15	Z = 0.2	Z = 0.3	Z = 0.4
S_A	0.06	0.12	0.16	0.24	$0.32N_a$
S_B	0.08	0.15	0.20	0.30	$0.40N_a$
S_C	0.09	0.18	0.24	0.33	$0.40N_a$
S_D	0.12	0.22	0.28	0.36	$0.44N_a$
S_E	0.19	0.30	0.34	0.36	$0.36N_a$
S_F	See Footnote 1				

1 Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients for Soil Profile Type S_F.

Table 16-R. Seismic Coefficient C_v

Soil Profile Type	Seismic Zone Factor, Z				
	Z=0.075	Z = 0.15	Z = 0.2	Z = 0.3	Z = 0.4
S_A	0.06	0.12	0.16	0.24	$0.32N_v$
S_B	0.08	0.15	0.20	0.30	$0.40N_v$
S_C	0.13	0.25	0.32	0.45	$0.56N_v$
S_D	0.18	0.32	0.40	0.54	$0.64N_v$
S_E	0.26	0.50	0.64	0.84	$0.96N_v$
S_F	See Footnote 1				

1 Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients for Soil Profile Type S_F.

Table 16-U. Seismic Source Type[1]

Seismic Source Type	Seismic Source Description	Seismic Source Definition	
		Maximum Moment Magnitude, M	Slip Rate, SR (mm/year)
A	Faults that are capable of producing large magnitude events and which have a high rate of seismic activity	$M \geq 7.0$ and	$SR \geq 5$
B	All faults other than Types A and C		
C	Faults which are not capable of producing large magnitude earthquakes and which have a relatively low rate of seismic activity	$M < 6.5$ and	$SR \leq 2$

1 Subduction sources shall be evaluated on a site specific basis.

Table 16-S. Near Source Factor N_a[1]

Seismic Source Type	Closest Distance to Known Seismic Source[2,3]		
	≤ 2 km	5 km	10 km
A	1.5	1.2	1.0
B	1.3	1.0	1.0
C	1.0	1.0	1.0

1 The near-source factor may be based on the linear interpolation of values for distances other than those shown in the table.

2 The location and type of seismic sources to be used for design shall be established based on approved geotechnical data (e.g. most recent mapping of active faults by the United States Geological Survey or the California Division of Mines and Geology).

3 The closest distance to seismic source shall be taken as the minimum distance between the site and the area described by the vertical projection of the source on the surface (i.e., surface projection of fault plane). The surface projection need not include portions of the source at depths of 10 km, or greater. The largest value of the near-source factor considering all sources shall be used for design.

Table 16-T. Near Source Factor N_v[1]

Seismic Source Type	Closest Distance to Known Seismic Source[2,3]			
	≤ 2 km	5 km	10 km	15 km
A	2.0	1.6	1.2	1.0
B	1.6	1.2	1.0	1.0
C	1.0	1.0	1.0	1.0

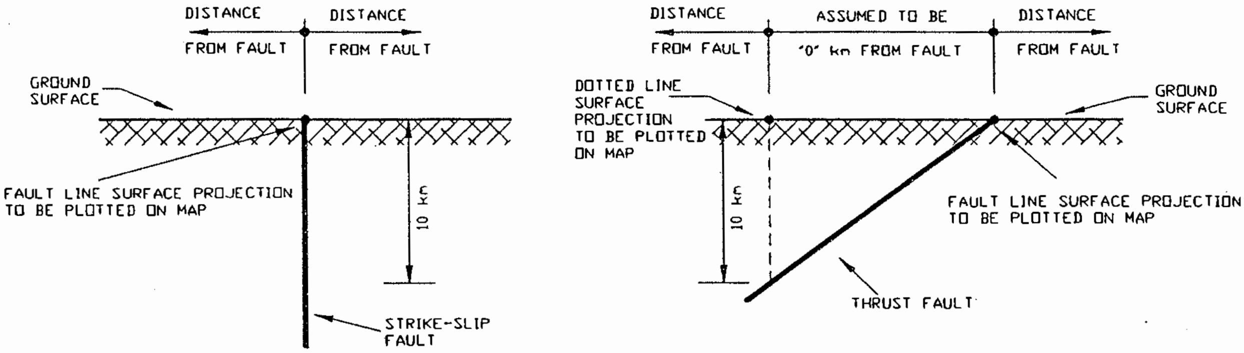
1 The near-source factor may be based on the linear interpolation of values for distances other than those shown in the table.

2 The location and type of seismic sources to be used for design shall be established based on approved geotechnical data (e.g. most recent mapping of active faults by the United States Geological Survey or the California Division of Mines and Geology).

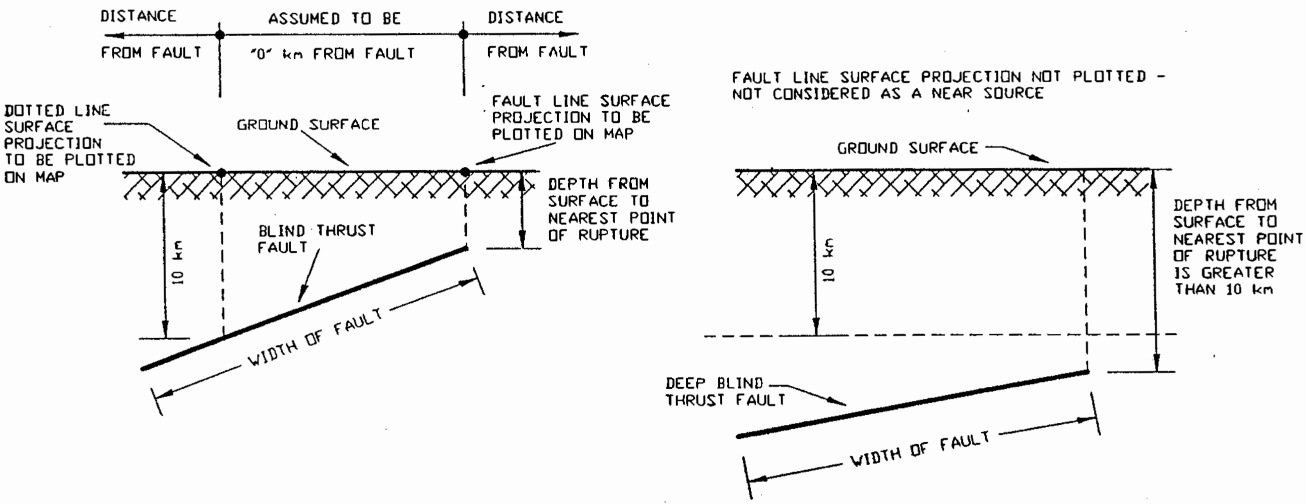
3 The closest distance to seismic source shall be taken as the minimum distance between the site and the area described by the vertical projection of the source on the surface (i.e., surface projection of fault plane). The surface projection need not include portions of the source at depths of 10 km, or greater. The largest value of the near-source factor considering all sources shall be used for design.

Figure 2.

1997 UBC NEAR SOURCE FACTOR RULES FOR DETERMINING PLOTTED FAULT LOCATION AND DISTANCE FROM FAULT



ACTIVE A & B SEISMIC SOURCES
WHOSE FAULT PLANE EXTENDS TO SURFACE



ACTIVE A & B SEISMIC SOURCES WHOSE
FAULT PLANE DOES NOT EXTEND TO SURFACE

EXPANDED LEGEND

The maps are intended for use with the 1997 Uniform Building Code (UBC), Tables 16-S and 16-T, to determine near fault seismic factors N_a and N_v.

The shaded areas are near field zones of active faults where the the near source factors are maximum (within 2 km of "zero" fault width zones).

Active faults are classified as A or B in accordance with Table 16-u of 1997 UBC.

The dotted lines indicate distances of 5, 10, and 15 km from the "zero" fault width zones.

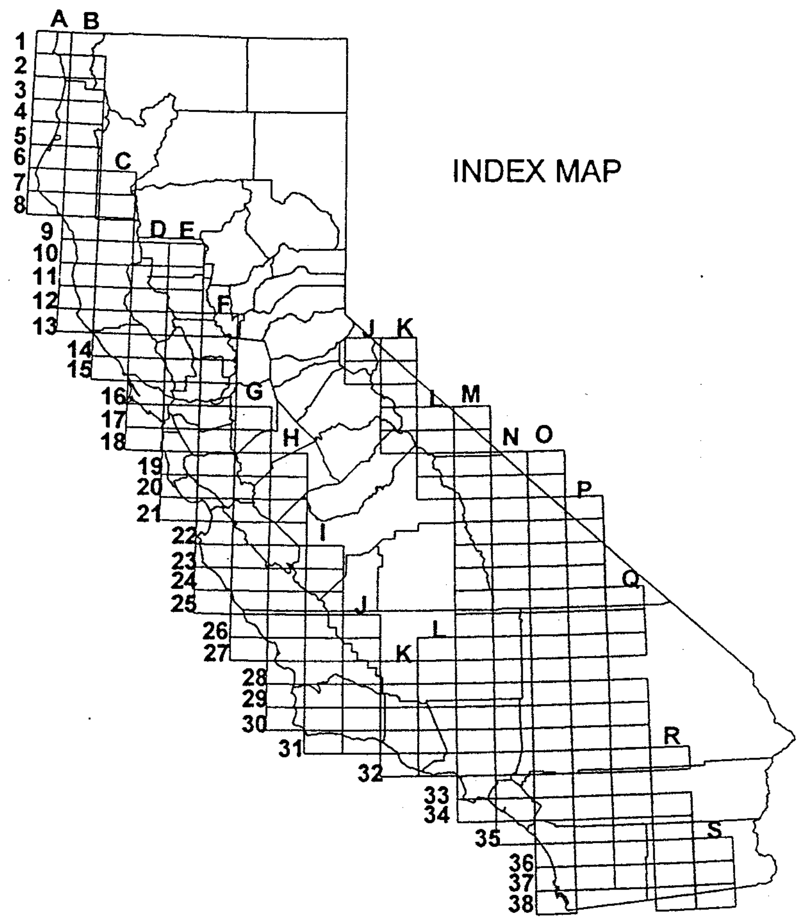


Figure 3: Example Legend Page for Near Field Fault Maps

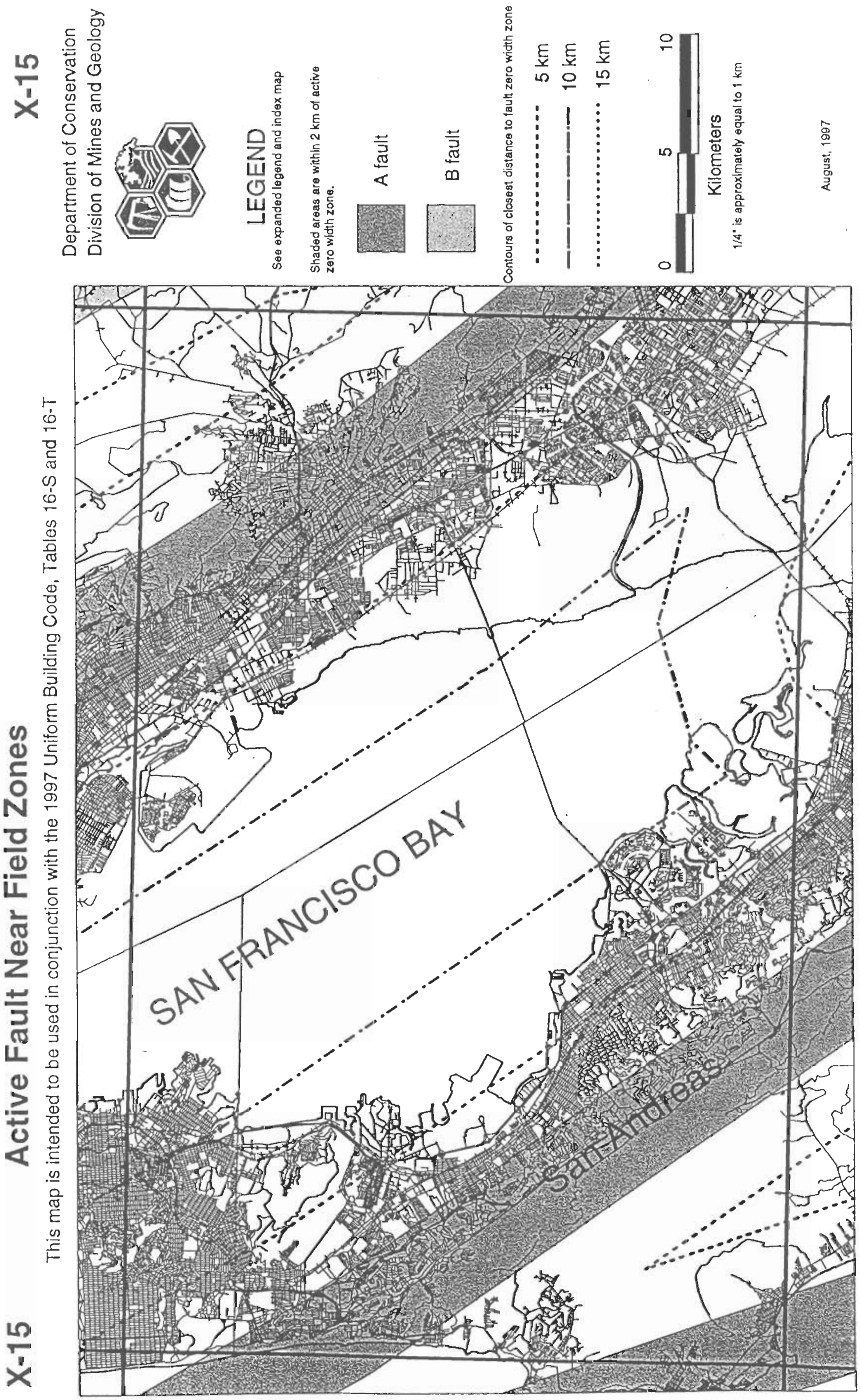


Figure 4: Example of Active Fault Near Field Map for San Francisco Bay Area

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Near fault zones, La Jolla, City of San Diego. (Scale 1: approx. 98,000)

Figure 5: Example of Active Fault Near Field Map for La Jolla, City of San Diego