CALIFORNIA GEOLOGICAL SURVEY
FAULT EVALUATION REPORT 265

THE ROSE CANYON FAULT ZONE in the Point Loma and La Jolla 7.5 Minute Quadrangles San Diego County, California

By
Michael DeFrisco
Engineering Geologist
February 18, 2021
(revised September 23, 2021)

INTRODUCTION

The purpose of this Fault Evaluation Report (FER) is to re-evaluate portions of the Rose Canyon Fault Zone (RCFZ) in San Diego for zoning under the Alquist-Priolo Earthquake Fault Zoning Act (A-P Act). The California Geological Survey (CGS) previously evaluated the RCFZ and Alquist-Priolo Earthquake Fault Zones (APEFZs) were established around strands of the RCFZ that met the criteria of "sufficiently active" (surface displacement during Holocene time) and "well-defined" (Bryant and Hart, 2007). APEFZs were released in 1991 for the La Jolla 7.5-minute Quadrangle (CDMG, 1991) and in 2003 for the Point Loma 7.5-minute Quadrangle (CGS, 2003).

Since 2002, new studies provide additional information on the location and activity of the RCFZ. These recent studies include site-specific evaluations triggered by the A-P Act; geologic investigations required by the City of San Diego Seismic Safety Study; projects aimed at assessing surface rupture hazard for infrastructure such as the San Diego Trolley; and research projects aimed at characterizing the recurrence and timing of earthquakes on the RCFZ. This report is a synthesis of data developed along portions of the RCFZ since 2002 as well as new mapping completed for this evaluation. While many recent studies have been conducted within existing APEFZs for the RCFZ, this study focuses on areas that have not been previously zoned and extensions to existing zones. Based on this evaluation, this report recommends the establishment of additional Alquist-Priolo Earthquake Fault Zones (APEFZs) within the La Jolla and Point Loma 7.5-minute Quadrangles.

TECTONIC SETTING OF THE ROSE CANYON FAULT ZONE

The RCFZ is a dextral strike-slip fault that is part of the greater San Andreas Fault System which forms the plate boundary between the Pacific and North American tectonic plates and consists of several onshore and offshore northwest-trending right-lateral strike-slip faults (Figure 1). The Newport-Inglewood Fault Zone/RCFZ (NIFZ/RCFZ) is the easternmost fault system within the inner Continental Borderlands (ICB) offshore region of southern California and poses a significant seismic hazard to coastal southern California (Sahakian *et al*., 2017). Geodetic measurements indicate that up to approximately 49 mm of right-lateral displacement occurs across the plate boundary annually (e.g. Bennett *et al*., 1996). Approximately 84% (41 mm/yr) of displacement occurs on the San Andreas, San Jacinto and Elsinore Faults onshore, and the remaining 6 to 8 mm/yr occurs along the NIFZ/RCFZ and offshore faults to the west. Deflected stream channels and paleoseismic studies in La Jolla and San Diego indicate a minimum slip rate of ~1.1 to 2 mm/yr for the onshore RCFZ (Lindvall and Rockwell, 1995; Rockwell and Murbach, 1996; and Rockwell, 2010a).

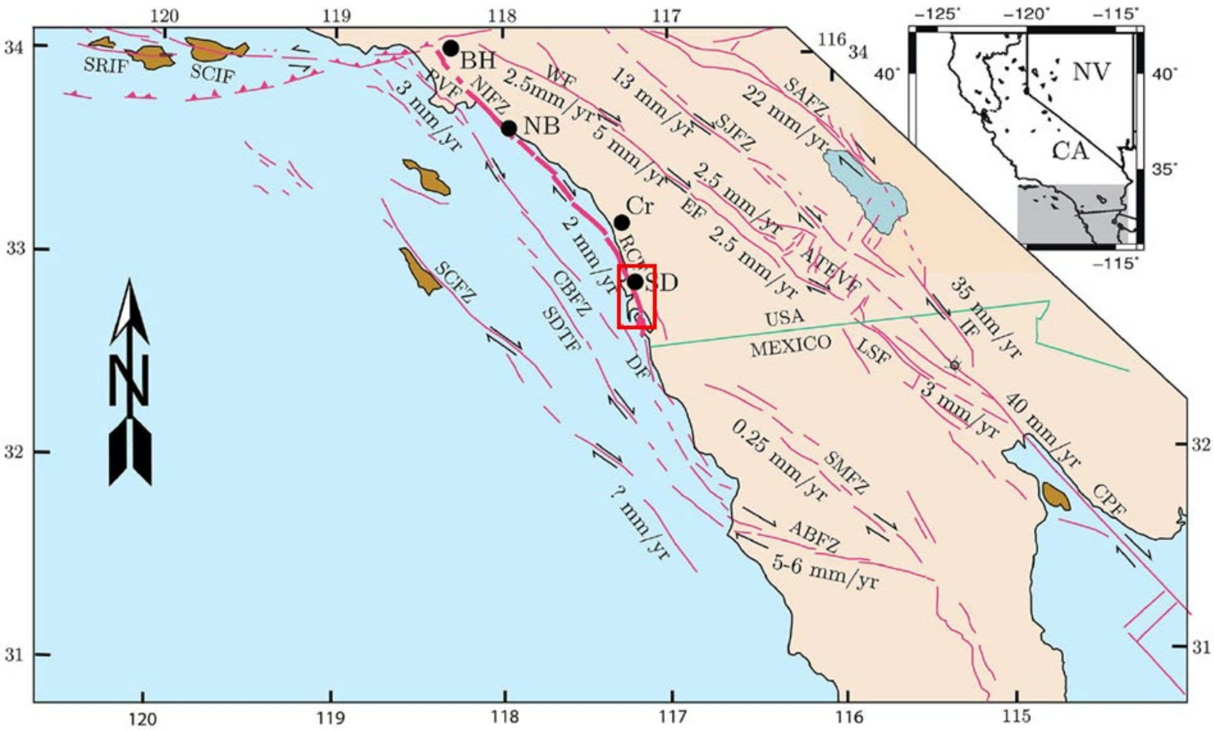


Figure 1. Active faults of southern California with their corresponding slip rates (modified from Singleton et al., 2019). Shaded box in inset shows location in California. Red rectangle shows location of the La Jolla and Point Loma Quadrangles evaluated for this study and illustrated on Plate 1. The trace of the Newport-Inglewood-Rose Canyon Fault system is bolded. Circles are locations of urban centers: BH=Beverly Hills, NB=Newport Beach, Cr=Carlsbad, and SD-San Diego. SAFZ=San Andreas Fault zone, IF=Imperial Fault, SJFZ=San Jacinto Fault zone, EF=Elsinore Fault zone, CPF=Cerro Prieto Fault, LSF=Laguna Salada Fault zone, SMFZ=San Miguel Fault zone, ABFZ=Agua Blanca Fault zone, DF=Descanso Fault, RCF=Rose Canyon Fault zone, NIFZ=Newport-Inglewood Fault zone, PVF=Palos Verdes Fault zone, CBFZ=Coronado Bank Fault zone, SDTF=San Diego Trough Fault, SCFZ=San Clemente Fault zone, WF=Whittier Fault zone, SCIF=Santa Cruz Island Fault, and SRIF=Santa Rosa Island Fault.

The Newport–Inglewood/Rose Canyon Fault System

The NIFZ/RCFZ stretches 170 km from near Beverly Hills in the Los Angeles Basin to San Diego Bay. Recent offshore seismic studies by Sahakian *et al.* (2017) improved the characterization of fault geometry and identified four main fault strands between Newport Bay and La Jolla. These offshore fault strands are separated by three stepovers, each of which are 2 km or less in width. Their modeling results suggest that rupture along the entire 170-km length of the NIFZ/RCFZ is possible and would produce a M 7.3 earthquake for rupture of the offshore segments or a M 7.4 if it included the northern onshore segment, which extends to Culver City. They suggested an even larger magnitude earthquake would result if the southern onshore RCFZ, which extends through the San Diego metropolitan area, ruptured as well.

Results of paleoseismic trenching at the Presidio Hills Golf Course in Old Town San Diego by Singleton *et al*. (2019) provided evidence for four large surface rupturing earthquakes on the Old Town section of the RCFZ and two smaller events within the last ~3300 years. The youngest paleoearthquake cuts the early historical living surface and is likely the 1862 San Diego Earthquake which had an estimated magnitude of M 6 (Legg and Agnew, 1979). Their results suggested a recurrence interval of ~700 years for the inferred larger events during the late-Holocene. Considering additional earthquakes during the mid-Holocene suggested by geotechnical studies at the San Diego International Airport (Kleinfelder, 2013a) and the close agreement with the early-Holocene recurrence interval of ~800 years for events observed at Rose Creek (Rockwell, 2010a), Singleton *et al*. (2019) suggest the Holocene recurrence interval for relatively larger magnitude earthquakes (M 6.7-7) that rupture the entire onshore portion of the RCFZ is ~700-800 years, which is several hundred years shorter than previous estimates. Based on low reported slip rates of the NIFZ/RCFZ, the relatively short recurrence interval, and the apparent lack of deformation along some offshore fault segments, they preferred an interpretation which favors a cascading sequence of earthquakes along the NIFZ/RCFZ, instead of very large earthquakes that rupture the entire 170-km length of the NIFZ/RCFZ from Beverly Hills to San Diego Bay.

Grant and Rockwell (2002) suggested that the NIFZ/RCFZ may be kinematically linked to the Descanso strand of the offshore Coronado Bank Fault and the coastal Agua Blanca Fault Zone in Baja California forming a >300-km-length fault zone of active faults along the coast. Rockwell *et al*. (1993) concluded the most recent rupture on the Agua Blanca Fault to be ~A.D. 1640 years, which is virtually indistinguishable from the most recent rupture of the Rose Canyon Fault documented as ~A.D. 1650 years by Rockwell and Murbach (1996) at sites in La Jolla and downtown San Diego. Based on fault investigations in northern Baja California and coastal southern California, Grant and Rockwell (2002) provided evidence for geologically contemporaneous or sequential earthquakes along this predominantly strike-slip fault zone and suggest this coastal fault zone has ruptured in a temporal cluster or northward propagating sequence of large earthquakes within the last few centuries.

The Rose Canyon Fault in the San Diego area

In the San Diego area, the RCFZ comes onshore east of La Jolla Cove as three relatively continuous oblique and reverse faults which form a zone up to 1.5 km wide (Treiman, 1993) (Plate 1). The Mount Soledad and Rose Canyon Faults traverse the north and northeast portion of Mount Soledad, respectively, and the County Club Fault traverses Mount Soledad approximately 0.7 km southeast of the summit. Mount Soledad is interpreted as an uplifted area resulting from a transpressive bend in the RCFZ (Rockwell, 2010a).

The RCFZ continues south through the Rose Creek drainage and extends along the east side of Mission Bay, where a down-dropped block appears to be present west of uplifted bedrock along the fault zone. The fault zone is not well expressed at the surface through the Mission Bay section and appears limited to a narrow band roughly parallel to and east of the Interstate 5 highway corridor as it continues south through Old Town San Diego.

South of Old Town the RCFZ splays and widens into multiple right-normal oblique faults due to a right-releasing step from the Silver Strand to the Spanish Bight Faults which may have resulted in subsidence and the formation of San Diego Bay. The locations of the Spanish Bight, Coronado, and Silver Strand Faults in San Diego were mapped by Kennedy and Clarke (1999a,b) using single- and multi-channel seismic reflection profiling. They interpreted the Holocene fault geometry of the San Diego Bay to be characterized by extensional faults that formed within a predominantly strike-slip environment and concluded the style of faulting to be consistent with an extensional opening of the San Diego Bay along N- to NE-trending normal faults that are subsidiary to a NNW-trending right-lateral wrench system. Age determinations developed from isotopic, amino acid, and paleontologic analyses conducted on core materials collected in the vicinity of Coronado Bridge concluded faulting is younger than 5 ka based on radiocarbon dated materials. Kennedy and Clarke (1999a,b) also reported the Coronado Fault cuts material at or very near the bay floor and considered it to be one of the most youthful faults in that part of the San Diego Bay. The distributed complex faulting within San Diego Bay is attributed to the RCFZ terminating and acting as the eastern margin of a large scale 10 km extensional step west to the Descanso Fault offshore before merging with the Agua Blanca Fault Zone in Baja California (Moore and Kennedy, 1975; Rockwell, 2010; Maloney *et al*., 2013; Singleton *et al*., 2019).

Kennedy *et al.* (1975) prepared a report on the character and recency of faulting onshore in the San Diego metropolitan area, and details of early sub-bottom acoustic profiling offshore were reported by Moore and Kennedy (1975). They suggested as much as 4-6 km of right-lateral displacement has occurred along the RCFZ, based on the observation that the San Diego Formation is found several kilometers farther north on the west side of the fault.

Local Fault Zoning

The City of San Diego first established Fault Zones in 1974, and they require that fault investigations be conducted for all new development within the Downtown Special Fault Zone (Plate 1). Due to the complex, widely distributed, and poorly understood character of faulting downtown, the fault zones established by the City are much more extensive and less specific than CGS fault zones that follow stricter criteria. The San Diego Seismic Safety Study (SDSSS) was completed and originally issued in 1974 to comply with California regulations which required cities to include a Seismic Safety Element in their General Plan. The SDSSS Geologic Hazard and Fault Maps were updated in 1983 and 2008, and they delineate and characterize geologic hazards that may be encountered at a site, including liquefaction and slope instability. They also identify three geologic hazard categories with potential for ground rupture from faulting: State of California APEFZs, areas 100-feet on both sides of mapped faults, and the Downtown Special Fault Zone. Proposed new development within these areas typically requires a geotechnical investigation to assess the potential risk of surface rupture from active faults.

Previous CGS Fault Zoning

Previous zoning of the RCFZ was based on fault evaluations conducted by Treiman (1991 and 2002). Treiman (1991) recommended zoning a portion of the downtown graben structure, the northern extension of the Silver Strand Fault, and an ~8-km-long stretch of the RCFZ extending from La Jolla Cove to near De Anza Cove.

Based on new data consisting of offshore geophysical data and geologic investigations, Treiman (2002) recommended additional APEFZs on Coronado Island and within downtown San Diego. They included: 1) Four zones on Coronado Island which extend into San Diego Bay and encompass traces of the Spanish Bight Fault, Coronado Fault, Silver Strand Fault, and an unnamed fault, 2) A 0.7-km-long section of the San Diego Fault in downtown San Diego, and 3) Traces of the Silver Strand Fault, also known as the Downtown Graben Area, located in downtown San Diego, west of Interstate 5. Treiman (2002) did not reevaluate previous mapping of the RCFZ in the area between De Anza Cove and the Downtown Area due to a general lack of new data in Old Town and this section of the RCFZ, leaving an ~10-km-long unzoned gap in the RCFZ between the APEFZ on the La Jolla Quadrangle and the APEFZs on the Point Loma Quadrangle. Existing APEFZs are illustrated on Plate 1.

Current Fault Evaluation

An overview of this fault evaluation is facilitated with three plates:

- Plate 1 depicts Quaternary fault mapping, existing Alquist - Priolo Earthquake Fault Zones, the City of San Diego Downtown Special Fault Zone, and site-specific investigation localities. Site-specific investigations reviewed for this study where faults were identified are summarized in Table 1. Site-specific investigations reviewed for this study where no faults were identified are listed in Table 3. In general, CGS reviewed all of the reports that we received or obtained through independent research prior to release of the Preliminary APEFZ maps and FER 265 on February 18, 2021. Additional research of select sites was planned at the City of San Diego, but onset of the Covid-19 pandemic in March of 2020 prohibited any additional research at the City of San Diego Development Service Department prior to release of FER 265.
- Plate 2 depicts mapping of fault-related geomorphic features from aerial photographs by CGS and others, Quaternary fault mapping, and existing Alquist - Priolo Earthquake Fault Zones. Numbered geomorphic features shown on Plate 2 are summarized in Table 2.
- Plate 3 shows Holocene-active faults recommended for zoning and updated Alquist - Priolo Earthquake Fault Zones.

Since the fault evaluation by Treiman (2002), many additional fault investigations have been conducted for development projects along the RCFZ within the APEFZs and as required by the San Diego Seismic Safety Study (SDSSS, 2008). This fault evaluation relies extensively on the geologic reports that are required as part of developments within the City of San Diego, particularly within the Downtown Special Fault Zone (Plate 1). This is supplemented by additional site-specific studies compiled as part of this evaluation acquired from the San Diego Association of Governments (SANDAG) or provided by geologists working in the area. This report does not address recent studies within the downtown graben area.

Geomorphic interpretation of the RCFZ is evaluated in this FER by incorporating detailed aerial photograph mapping by SANDAG (2014), Rockwell (2010a), and supplemented by mapping conducted as part of this evaluation. The results of this mapping are depicted on Plate 2 with numbered features corresponding to descriptions and evaluation comments in Table 2. Details of the geomorphic mapping are addressed in the Geomorphic Interpretation and Discussion sections below for each of the three fault sections.

FAULT SECTIONS

We have divided the fault zone into three sections based on continuity and uniform trends, described here from north to south (Plate 1). The Rose Canyon section extends from La Jolla Cove to Mission Bay. This section includes the Country Club, Mt. Soledad, and Rose Canyon Faults. The Old Town section takes a step to the west and extends from Mission Bay to near the San Diego International Airport (SDIA) and is located east of and largely parallel to Interstate 5. It includes the previously mapped Mission Bay Fault, the Old Town Fault, and the southern extension of the Rose Canyon Fault. The San Diego Bay section extends from north of the SDIA to San Diego Bay, where the fault zone is 6 to 8 km wide, and includes, from west to east, the Spanish Bight and East Bay Faults, the Coronado Fault, PCH Fault (named after Pacific Highway), San Diego Fault and downtown graben faults.

ROSE CANYON SECTION

Description

Treiman (1993) summarized the character and previous mapping of the Rose Canyon, Mt. Soledad, and Country Club Faults, which form the three main strands of the system onshore in the Rose Canyon section. The locations of the faults were largely based on Kennedy *et al*. (1975). Based on well records, Kennedy *et al*. (1975) estimated an average of 800 m of post-Eocene dip-slip separation has occurred across the contact between Upper Cretaceous and Eocene rocks, with Mt. Soledad being uplifted along the west side of the Mount Soledad strand. Treiman (1993), Lindvall and Rockwell (1995), and Rockwell (2010a) describe right-lateral, reverse-oblique, and right-oblique movement on these faults at a left-stepping transpressive bend in the fault zone that is responsible for local uplift of Mt. Soledad.

Evidence of Holocene activity along strands of the RCFZ is noted at several locations along the Rose Canyon section. Judy (1987) reported faulted Holocene sediments offshore in La Jolla submarine canyon based on radiocarbon-dated submerged lagoonal sediments which are deformed, truncated, and presumed to be faulted against undated submerged terrace deposits. Treiman (1991) and Kahle (1988) reported geomorphic features strongly suggestive of latest Quaternary faulting. Displaced Holocene soils are documented in a trench north of Balboa Avenue (Rockwell *et al*., 1991; Lindvall and Rockwell,1995; and Rockwell, 2010a). Paleoseismic trenching in La Jolla by Rockwell and Murbach (1996) exposed the fault rupturing up through a Native American midden deposit, further demonstrating Holocene activity of this section.

South of Balboa Avenue, the Rose Canyon Fault was mapped as the eastern boundary of the RCFZ and included a set of steeply east-dipping, left-stepping faults with normal separations north of

Clairemont Drive. The Mission Bay Fault was mapped as the southerly projected trace of the Country Club Fault extending along the eastern margin of Mission Bay to Old Town and inferred to be a concealed fault forming the western boundary of the RCFZ (Treiman, 1993) (Plate 1).

North of Clairemont Drive, the active fault appears to coincide with the alignment of the railroad tracks along the east side of the Interstate 5 corridor. This interpretation is supported in historic aerial photos by the right-lateral offset of drainage channels along the railroad tracks between Balboa Avenue and De Anza Cove (Lindvall *et al.*, 1989; Treiman, 1991; Rockwell, 2010a; and SANDAG, 2014).

Site-specific Investigations

<u>Locality 1 – Mid-Coast Corridor Project - Rose Creek Light Rail Transit (LRT) Overhead</u>

Kleinfelder, Inc. (2015) and SANDAG (2014) conducted geologic/geotechnical investigations for the San Diego Association of Governments (SANDAG) Mid-Coast Corridor Transit Project to evaluate the presence and character of previously mapped active faults that cross near or through proposed trolley stations and bridge sites. The project generally proposed extending the existing Metropolitan Transit Trolley system north along Interstate 5 from Old Town San Diego to the University of California, San Diego (UCSD) and the proposed University Towne Centre Transit Center terminus in University City north of Highway 52. Their evaluations included a comprehensive desktop study of previous mapping and consultant reports, detailed review and analysis of vintage aerial photographs to assess the presence of geomorphic features and landforms indicative of faulting, and field investigations utilizing continuous-core borings, angled sonic borings, trenching and cut-slope logging, CPTs and geophysical surveys.

Kleinfelder (2015) identified Holocene-active faulting at proposed trolley line bridge crossings at the Rose Creek Light Rail Transit (LRT) Overhead (RCO) located approximately 1 km south of the I-5/Hwy 52 interchange and at the Balboa Avenue Underpass (BAU) (Locality 1a, Plate 1). The results of Kleinfelder's investigation for the BAU indicated it is within a complex zone of faulting up to 185 feet wide, which they interpreted "to be related to a tensional fault step-over within the main Rose Canyon Fault through this area". Borehole and geophysical data indicated a notable thickness differential of recent alluvium across the most significant fault near the eastern edge of the fault zone. Faulting identified at the BAU site is within the existing APEFZ on the La Jolla Quadrangle.

Kleinfelder's fault investigation of the RCO (Plate 1, Locality 1b; Figure 2) "confirmed the presence of a system of faults closely aligned with that previously identified across the area". In a cut-slope located south of the RCO southern abutment, they found three small faults which vertically displaced Holocene alluvium on the order of 6 inches or less. Their analysis of two geophysical survey lines north of the cut-slope suggested the presence of a significant fault and was supported by stratigraphic discontinuities of geologic units and differences in structure across the zone, as illustrated in Figure 2c.

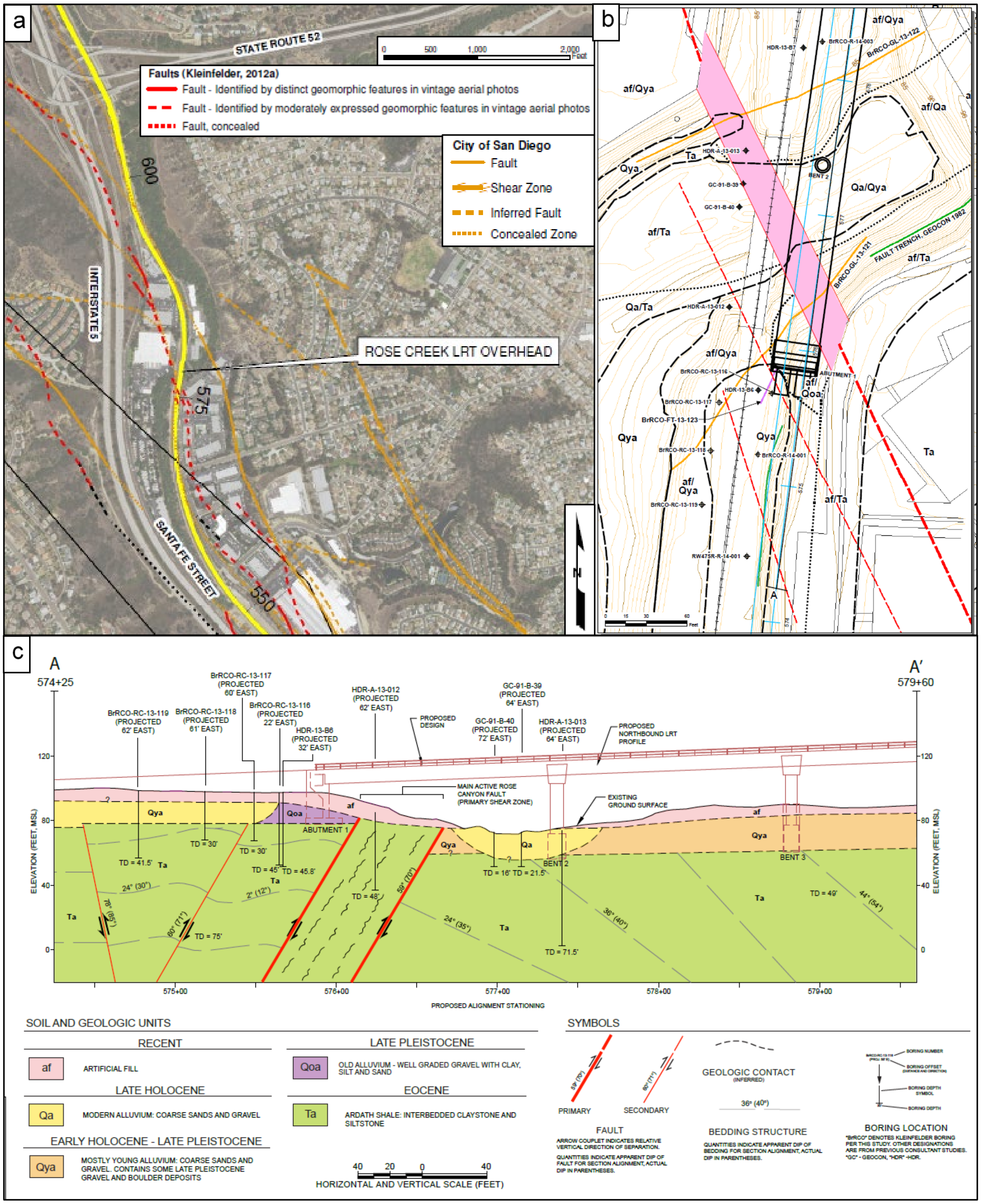


Figure 2. Location map and geologic profile at Locality 1b. a) Index map showing location of Rose Creek LRT Overhead site (modified from Kleinfelder, 2015, Figure 3-6). b) Map depicting location subsurface explorations and Geologic Cross Section A-A' (from (from Kleinfelder, 2015, Figure G-3). c) Geologic Cross Section A-A' constructed along trolley line alignment (from Kleinfelder, 2015, Figure G-11).

Analysis of CPT data along Santa Fe Street north of the RCO identified structural discontinuities related to faulting that was interpreted to offset young alluvium. Kleinfelder concluded this was likely the modern Rose Canyon Fault and that connection with the fault identified in the geophysical surveys at the RCO was consistent with geomorphic features indicative of faulting previously identified by SANDAG (2014).

Locality 2 – 2576 Clairemont Drive

Bagahi Engineering, Inc. (BEI, 2008) performed a site-specific fault investigation of the subject property at 2576 Clairemont Drive based on the site's location within a fault zone on the SDSSS map sheets. BEI observed and logged 5 trenches excavated to depths of about 5 feet. The trenches exposed clayey sandstone and sandy claystone/siltstone of the Eocene Scripps Formation. Trenches T-1, T-2, and T-4 exposed a fault zone trending N5W to N20W and dipping 66NE to vertical.

In Trench T-1, the fault comprised a sheared and brecciated zone 17 to 30 inches wide with clay-lined fault boundaries. The fault zone exhibited a crushed and brecciated zone about 10 feet wide in Trench 2, which was located about 30 feet south of Trench T-1. Further to the south in Trench T-4, the fault zone consisted of a brecciated zone about 4 to 6 feet wide. BEI suggested there was evidence for strike-slip movement along the fault zone in the trenches, but that no slickensides were evident to confirm the relative direction of slip.

Minor faults were also observed in Trenches T-1 and T-5. In Trench T-1, the minor fault was about 2 inches wide, lined with dark brown clay, and vertically offset a stratigraphic contact about 3 feet. The fault was oriented N65E and dipped 85 degrees northwest. The minor fault in Trench T-5 had a similar orientation of N55E and dipped 86 degrees northwest. Apparent vertical stratigraphic separation in the trench was observed to be on the order of 18 inches.

No Holocene or Quaternary surficial deposits that allowed age determination of faulting were present on the site. However, the consultants considered the fault zone an active fault trace of the Rose Canyon Fault, and recommended building setbacks for proposed buildings on the property.

Locality 3 – Bay View Plaza

South of Locality 2 across Clairemont Drive, Robert Prater Associates (Prater, 1998) performed a geologic investigation of the Bay View Plaza site located on the southeast corner of Clairemont Drive and Morena Boulevard. The subsurface exploration included three exploratory trenches 25 to 625 feet in length and 3 to 14 feet deep. The trenches encountered two larger zones of faulting and several minor breaks. Minor faults were observed to trend between N20W and N20E, and dip 66 to 76 degrees to the east. Apparent vertical separations ranged from 2 to 6 inches, and some of the minor faults had clay gouge seams less than ¼-inch thick.

A larger zone of faulting was encountered west of the main driveway entrance on Clairemont Drive. The fault zone consisted of two distinct shears 8 inches and 16 inches wide about 5 feet apart and trending N10W and N11W. The faults dipped 64 and 76 degrees to the east and the westernmost of the two shears had a clay gouge seam about 1/8-inch thick. East-side-down separation was indicated by slight drag folding of Scripps Formation mudstone along the westernmost shear. Unbroken younger terrace deposits with no fractures, partings, or other discontinuities were observed overlying both shears, and a small gravel-filled channel with unbroken sand lens overlies the erosional contact with the western shear. A detrital charcoal sample obtained within the unfaulted younger terrace deposits (Qt_1) just above the eastern shear yielded a radiocarbon date of 28,000 years.

East of the main driveway entrance to the site off Clairemont Drive, another zone of faulting was encountered which consisted of two significant shears 5 to 12 inches wide about 6 feet apart and a smaller fault about 2 feet to the east forming a graben structure (Figure 3). The westernmost of the two shear zones included clay gouge up to 6 inches thick. Older terrace deposits (Qt2) were faulted against Scripps Formation, and drag folding indicated a significant component of normal separation along with east-side-down apparent vertical separation. No soil or Holocene deposits were encountered across the fault zone. Prater concluded the relative age of faulting was unknown from direct evidence, but it was their opinion the faulting was pre-Holocene based on lack of geomorphic evidence of recent activity and similarity with faulting west of the main entrance.

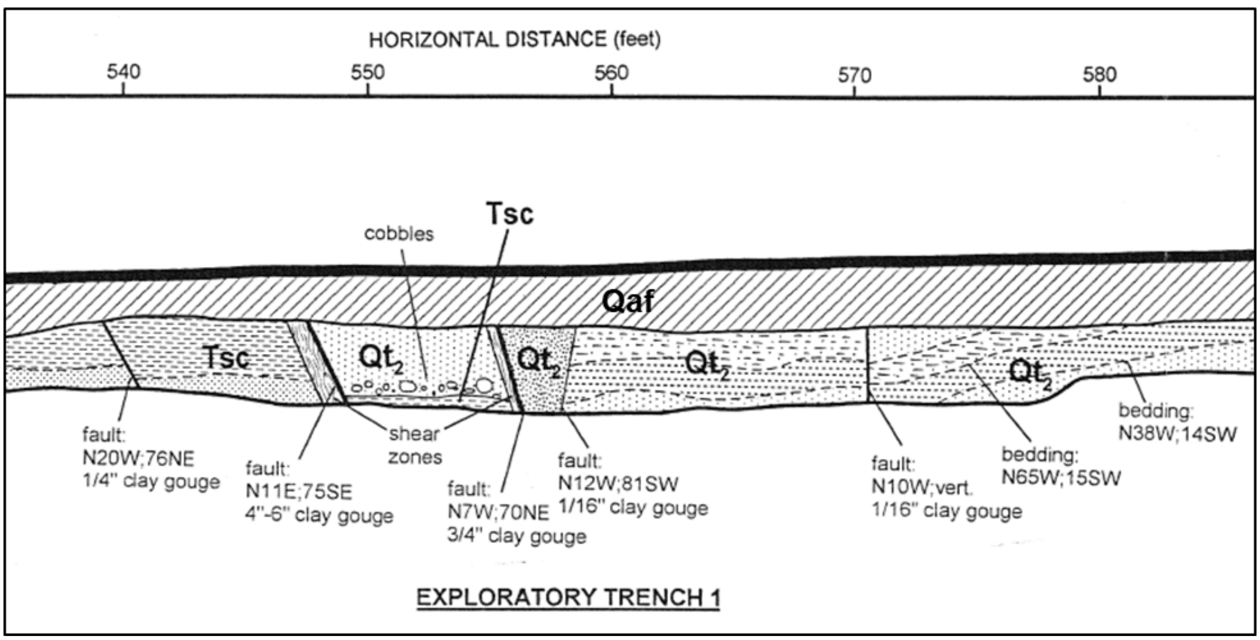


Figure 3. Portion of fault Trench 1 by Robert Prater Associates at Bay View Plaza (Locality 3). Qaf is existing fill; Qt2 is older terrace deposits; Tsc is Scripps Formation. (modified from Prater, 1998).

Geomorphic Interpretation

Early interpretation of geomorphic features in the Rose Canyon section from historical aerial photographs was performed by Kennedy *et al*. (1975), Treiman (1984), and Kahle (1988). Results of those studies identified the three main fault strands and resulted in establishment of the existing APEFZ from La Jolla to De Anza Cove (Treiman, 1991). Previous geomorphic interpretation of fault-related features on Mount Soledad and along Rose Creek were also summarized in Open File Report 93-02 (Treiman, 1993). Kleinfelder (SANDAG, 2014) performed additional interpretation of geomorphic features along Rose Creek from 1928 and 1953 aerial photos and identified Holocene-age fault-related landforms such as deflected streams and scarps. They reported the channel wall of Rose Creek appeared deflected near the Metropolitan Transit Tolley RCO site. Kleinfelder's interpretation of fault-related geomorphic features along Rose Creek largely coincide with previous mapping of the Rose Canyon Fault.

East of Morena Boulevard, between Gardena Avenue and Clairemont Drive, Kleinfelder interpreted a diffuse zone of right-stepping lineaments in the historical aerial imagery (Plate 2, Features 1 through 9), but they did not identify any clear or obvious scarps. This area is also structurally lower in elevation (Plate 2, Feature 10) than adjacent areas to the north and south and they interpreted it as a probable right-step in the fault zone where active faulting is broadly distributed along multiple, discontinuous fault strands (SANDAG, 2014 and Scott Rugg-Kleinfelder, personal communication 2019). Our review of these features confirm that geomorphic features 1 through 9 are weakly-expressed, discontinuous tonal lineaments with no obvious scarps or laterally offset features across this relatively flat surface.

Discussion and Recommendations for Zoning

The recent studies by Kleinfelder (2015) and SANDAG (2014) for the Mid-Coast Corridor Transit Project trolley line confirm Holocene activity of the Rose Canyon Fault strand at the RCO. The fault identified by Kleinfelder in Rose Canyon at the RCO site is closely aligned with faults previously mapped by Kennedy (1975), Kennedy *et al*. (1975), and Treiman (1993) and the faults associated with this strand that extend across the northeast flank of Mt. Soledad are recommended for zoning. Faults identified by Kleinfelder at the BAU site are near previously mapped active fault strands within the existing APEFZ (CDMG, 1991) and no modification to the existing APEFZ is recommended there. Fault zones identified during investigations at Localities 2 and 3 west of the intersection of Clairemont Drive and Denver Street revealed age-undetermined faulting along the southern projection of the active Rose Canyon Fault. The thick clay gouge zone and juxtaposition of Scripps Formation (Tsc) against older terrace deposits suggests that this is a fault with a significant, but unknown, amount of total separation across it. Therefore, based on the along-strike projection with faults within the existing APEFZ to the north, it is recommended that the existing APEFZ be extended to include these sites. Faults recommended for zoning in this section are illustrated on Plate 3.

In the area east of Mission Bay, we are in general agreement with the interpretation of a right-step across the topographical low area between Gardena Avenue and Clairmont Drive. However, the lineaments identified north of Asher St. (Plate 2, features 1 through 9) are weakly expressed, and we do not observe other geomorphic features that can be attributed to active faulting. We also did not obtain any new evidence or geomorphic interpretation which supports Holocene activity of the eastern boundary fault, mapped by Kennedy *et al*. (1975). Based on these lines of evidence, the aforementioned lineaments are not recommended for zoning at this time. However, site-specific subsurface investigations and geophysical studies across these mapped lineaments could provide valuable data on the existence and activity of these potentially active features.

OLD TOWN SECTION

Description

The Old Town section of the RCFZ extends from Mission Bay Park south past Old Town to the San Diego International Airport (SDIA), and was previously mapped by Kennedy *et al.* (1975) and Treiman (1993) as consisting of two principle strands: the southern extension of the Rose Canyon and Mission Bay Faults. Plate 1 illustrates previously mapped Quaternary fault traces (USGS/CGS, 2019) in the Old Town section and provides an index to Localities 4 through 9 discussed in the text and Table 1.

Previous analysis of historic aerial photographs indicated the RCFZ was not well expressed at the surface north of Old Town and the San Diego River, except for a few discontinuous, subtle features. Treiman (1993) concluded that Holocene displacement in this section may not be readily detectable and may be distributed across several fault strands. However, recent analysis and investigations by Kleinfelder (2015) and SANDAG (2014) for the Mid-Coast Corridor Transit Project extension of the Metropolitan Transit System Trolley along the Interstate 5 corridor provided additional identification and assessment of potential fault-generated surface features north of the San Diego River.

South of the San Diego River the fault zone remains consolidated in a narrow zone through Old Town before widening near Middletown and the SDIA. Kennedy *et al.* (1975) mapped the Mission Bay and Old Town Faults as the southern extension of the RCFZ in this section. They documented exposures of the Old Town Fault in cut-slopes near Heritage Park and along Washington Street northeast of the intersection with Andrews Street. Treiman (1993) described additional exposures of the Old Town Fault observed by other authors (Farrand and Elliot, 1979; Gastil *et al.,* 1979) between Washington Street and Old Town, including a cut-slope near the end of Congress Street where steeply tilted San Diego and Lindavista Formations are thrust over lower Bay Point Formation. These studies reported the reverse fault was overlain uncomformably by upper Bay Point Formation which was offset by another reverse fault, and also suggested that a major strike-slip fault zone appeared to be "*located west of Heritage Park, just east of Congress Street, and west of the exposures on Washington Street*" (Gastil *et al*., 1979). Recent investigations by Leighton (2008), Rockwell *et al.* (2012), and Singleton *et al.* (2019) document Holocene activity of the Old Town Fault.

Geotechnical Investigation by Geotechnics Incorporated (2000; Locality 71) does not appear to support the presence of the Mission Bay Fault inferred by Kennedy (1975) paralleling the Old Town Fault through this section. However, SANDAG (2014) suggested the fault bifurcates into two structurally variant strands near the intersection of Old Town Avenue and San Diego Avenue. Their analysis of 1928 aerial photos inferred a fault trending generally north-south toward SDIA and a set of three subparallel discontinuous faults trending approximately N55°W along the west-facing escarpment east of I-5, through Middletown. Fault investigations by Kleinfelder (2012a, 2012b, 2013a, 2013b) at the SDIA identified a previously unmapped Holocene-active fault which they named the East Bay Fault (Plate 1).

Site-specific Investigations

Locality 4 – Morena Pump Station

AECOM (2017) performed a fault hazard investigation for the proposed Morena Pump Station for Pure Water San Diego. Their investigation included 37 CPTs and 3 geotechnical borings along Sherman and Custer Streets, and indicated the site is underlain by 3 to 5 feet of fill overlying a thick sequence of young alluvium. AECOM interpreted the alluvium at the site to range from late Pleistocene to mid-Holocene age, based on correlation with dated lithologic and stratigraphic units south of the San Diego River channel at the Hilton Garden Inn site in the Old Town area (CTE, 2012).

Evaluation of cross sections developed from CPT profiles identified a drop in elevation of subsurface layering near the western end of Sherman Street that was interpreted to be the result of faulting. The fault appeared to offset a layer (Unit 2) that was correlated with Holocene sediments that date to approximately 7 to 7.5 ka at the Hilton Garden Inn site and indicated west-side-down separation. Overlying younger sediments (Unit 1) were also interpreted to be faulted. Apparent vertical separation of subsurface units appeared to increase slightly with depth, indicating the fault has moved repeatedly resulting in greater displacement of the older, deeper units. Based on their interpretation, AECOM determined the fault to be Holocene-active and recommended a 20-foot setback from the fault.

Locality 5 – Presidio Hills Golf Course

Singleton *et al*. (2019) presented results of two paleoseismic trenches excavated across the main trace of the fault at the Presidio Hills Golf Course in Old Town San Diego. The location of the fault was first interpreted from geomorphic features identified on 1927 aerial photographs which indicate right-lateral movement. Trench T-1 encountered a secondary strand of the fault in weakly to massively bedded silt stratigraphy but the trench could not be extended by mechanical equipment toward the presumed main fault strand to the southwest due to the presence of a Spanish colonial-era wall foundation. The authors suggest the main trace of the fault was not encountered in trench T-1 and that it's possible a trace of the fault exists east of T-1 as well. Trench T-2 (Figure 4) exposed three distinct stratigraphic sections interpreted as: 1) post-1850 alluvial fan and fluvial deposits loaded with historical debris; 2) Holocene alluvial fan and fluvial deposits; and 3) Pleistocene alluvial deposits with a well-developed clay-enriched soil.

The results of their paleoseismic study provided evidence for four large surface-rupturing earthquakes and two smaller events within the last ~3300 years, the youngest of which cuts the early historical living surface and is likely related to the 1862 San Diego Earthquake which had an estimated magnitude of M 6.

Locality 6 – 2510 Juan Street

Leighton Consulting, Inc., (2007) conducted an earthquake fault hazard study for a portion of the Mormon Battalion Historic Site located north of the intersection of Juan Street and Harney Street in Old Town. Based on observation and logging of 5 exploratory trenches with the assistance of

Dr. Tom Rockwell from San Diego State University (SDSU), they concluded that several active fault traces transect the site, and that the fault observed in trench T-2 had characteristics indicative of a relatively youthful, late Holocene age activity. Trench T-3 (Figure 5) was extended to a depth of 22 feet and encountered a fault that truncated a buried dateable pedogenic A-horizon. Two bulk soil samples were obtained from the faulted soil unit in trench T-3 for radiocarbon dating, and the age of the unit was determined to range between approximately 7,000 to 9,000 years BP, indicating early Holocene-age faulting at the site.

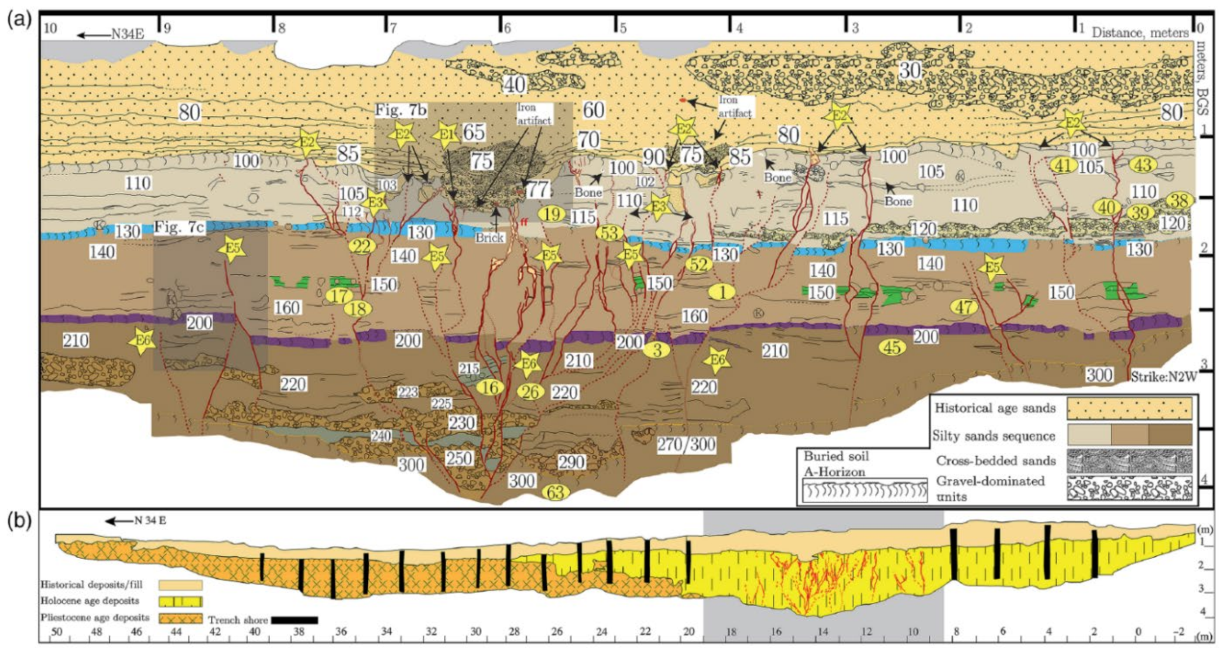


Figure 4. (a) Trench log T2 at the Presidio Hills Golf Course (Locality 5) in Old Town San Diego (from Singleton et al., 2019). Locations of interpreted event horizons are marked as stars. Locations where detrital charcoal was sampled for radiocarbon dating are marked as ovals. Stratigraphic units are marked with white boxes. K, krotovina; ff, fissure-fill. (b) Log of full south face of T2. Shaded area is the location of (a).

Based on their interpretation of San Diego County 1928 aerial photographs, Leighton mapped the main strand of the Old Town Fault approximately transecting the southwest corner of the subject site, and considered the faults observed at the Mormon Battalion Historic Site to be secondary faults paralleling the main trace. They concluded that the Holocene-age faulting at the site provided evidence for classifying the Old Town Fault as active and reported that prior to investigation of this site, no previous fault studies had confirmed Holocene movement of the Old Town Fault.

Locality 7 – Hacienda Hotel

Engineering Geology Consultants (EGC), Inc., (2000) performed a soils/geological investigation for a 28-unit addition to the existing Hacienda Hotel located south of the Mormon Battalion Historic Site. The investigation included observation, logging, and geologic interpretation of two utility trenches excavated adjacent to the site along Juan Street and Harney Street. The trench along Harney Street was excavated to a depth of about 7 feet along a pre-existing utility line and exposed Bay Point Formation (late Pleistocene old paralic deposits) and a moderately well-formed topsoil with A and B soil horizons. They reported no indication of faulting was exposed within the trench.

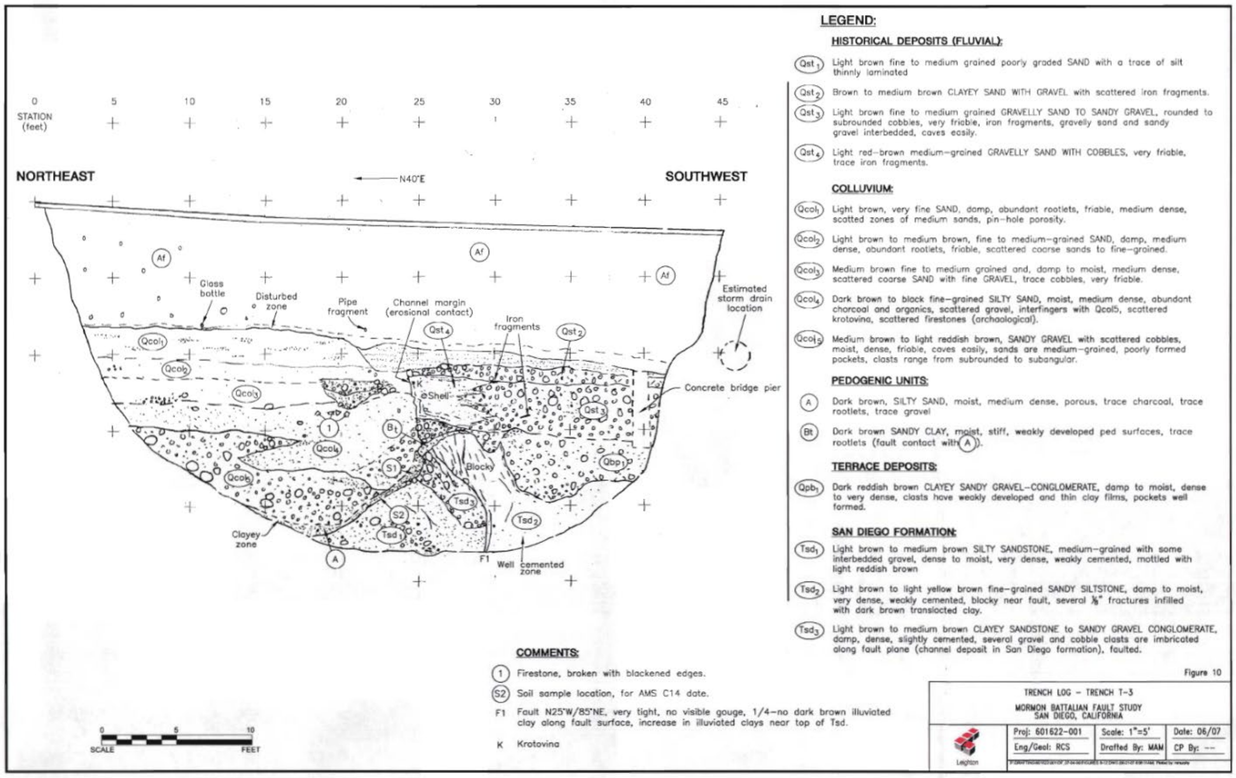


Figure 5. Trench log T-3 by Leighton Consulting, Inc. (2007) at 2510 Juan Street (Locality 6). The fault was found to truncate a buried pedogenic A-horizon. Radiocarbon dates (S1 and S2) indicated the offset A-horizon was of early Holocene age.

The trench along Juan Street was excavated to a depth of about 9 feet and exposed two northwest trending fault zones. One of the faults was located about 5 feet southeast of the middle of the intersection of Juan Street and Harney Street, and clearly and cleanly truncated gravel cobble beds of the Bay Point Formation. The fault had a strike approximately N20W to N30W and was at least 2 feet wide with a near vertical, slightly west dip. Steeply dipping sandstone and cobble conglomerate of the San Diego Formation and/or Linda Vista Formation (early to middle Pleistocene old paralic deposits) was exposed southeast of the fault.

Another fault was exposed near the southeast end of the trench and had a N15W strike and about a 50° east dip. EGC reported no topsoil was present over the fault exposures and there was no evidence to classify the faults as active, but that the faults could be classified as potentially active and were considered part of the Old Town Fault, a southern extension of the Rose Canyon Fault.

<u>Locality 8 – Lot adjacent to 2323 San Juan Road</u>

Hart (2002) conducted a geologic investigation of a residential site located adjacent to 2323 San Juan Road (subsequently identified as 2303 San Juan Road). The investigation included logging two exploratory trenches which varied in depth from 6 to 14 feet. The trenches revealed the property is traversed by several previously unmapped faults which Hart suggested are likely branches or splays of the Old Town Fault. The primary fault (Fault Zone A) exposed in the trenches juxtaposed fine sand with massive conglomerate of the San Diego Formation across an approximately one- to two-feet-wide zone characterized by dark brown translocated clays deposited along anastomosing shears. Hart reported that all but one of the shears was capped by a well-developed buried late Pleistocene argillic (Bt) horizon or colluvial wedge approximately one foot thick. Inspection of the contact between the buried Bt horizon and an overlying colluvial wedge above the primary fault in trench T-1 suggested this contact was possibly displaced approximately one inch. However, trench T-2 was excavated to verify this possible late Pleistocene to early Holocene faulting, and the trench indicated the colluvium/Bt horizon was not offset.

Another zone of faulting (Fault Zone B) located east of the primary fault zone exhibited total vertical separation of at least 4 feet. The faults in this zone were truncated by an overlying well-developed conglomeratic Bt horizon or argillic colluvial wedge, indicating a late Pleistocene or older age of faulting at this location.

The next zone of faulting to the east (Fault Zone C) consisted of minor faults with no more than one foot of vertical separation. Some of the faults were reportedly overlain by unfaulted Plio-Pleistocene sediments higher in the trench, and horizontal movement was demonstrated by variable thickness of a claystone conglomerate bed.

The easternmost zone of faulting (Fault Zone D) exposed in Trench T-1 exhibited approximately 2.5 feet of vertical separation (west side up). The fault trends N10W and dips 68° west, indicating an apparent reverse sense of movement. Hart reported an unknown amount of horizontal slip was suggested at this location by a 2- to 4-feet-thick displaced conglomerate bed.

Hart concluded that Fault Zones A and B were overlain by a late Pleistocene Bt horizon and did not display Holocene movement. He concluded that Fault Zones C and D have not had Holocene activity because they were overlain by unfaulted Plio-Pleistocene sediments or had no more than one foot of vertical slip.

Geomorphic Interpretation

Kleinfelder interpreted fault-related geomorphic features visible on historic 1928 aerial photos for the Mid-Coast Corridor Transit Project (SANDAG, 2014). North of Old Town and the San Diego River, they interpreted the fault to step to the right, forming a small graben (Plate 2, Feature 28), and continue north as an east-facing scarp along the west side of Morena Boulevard. Other geomorphic features they interpreted as an expression of the fault north of Old Town include lineaments, deflected drainages, a closed depression, deflected channel walls along Tecolote Creek, offset landslide margins, and a pressure ridge where an investigation by Liem (1977) identified a thrust fault found to be active in the late Quaternary. They also observed a fault in a railroad cut during construction activities along West Morena Boulevard south of the intersection with Asher St. The locations of these features are identified on Plate 2 and Table 2, Features 11 to 16 and 18 to 28.

Based on our review of the 1928 aerial photos, we interpret a potential compressional feature or scarp with west-side-down separation along which Morena Boulevard may have been built (Plate 2, Feature 17). This feature is supported by an apparent left-step in the fault toward the Interstate 5 corridor where the fault was observed by Kleinfelder along West Morena Boulevard south of the intersection with Asher St (Plate 2, Feature 12).

The feature 24 fault was observed to vertically offset a 29 ka radiocarbon dated sandstone unit with the faulting extending into unconformable overlying younger units (Treiman, 1993; Liam, 1977). However, prior modification of the ground surface at the site prevented determination of a minimum age of faulting.

South of the San Diego River, Rockwell (2010a) identified scarps and deflected drainages (Plate 2, Features 30 and 31) in the Old Town area suggestive of active strike-slip faulting. Site-specific fault investigations at the Presidio Hills Golf Course and 2510 Juan Street (Localities 5 and 6, respectively) confirmed Holocene-active faulting at these locations.

Review of historic topographic maps (U.S. Coast Survey Office, 1851, and USGS, 1904) for this study revealed the presence of a probable fault-related break in slope, pressure ridge, and ridgeline saddle south of Old Town near the intersection of Congress Street and Hortensia Street (Plate 2, Features 35, 36, and 37). These features are illustrated in Figure 6 and are near a fault exposure observed in a cut-slope at the end of Congress Street described by Treiman (1993), Farrand and Elliot (1979), and Gastil *et al.* (1979). The features also coincide with an interpreted bifurcation of the fault south of Old Town by Kleinfelder (SANDAG, 2014) into strands trending approximately N65W along San Diego Avenue (Plate 2, Features 38, 41, and 42) and N5W toward the Marine Corps Recruit Depot (Plate 2, Features 33, 34, 39 and 40).

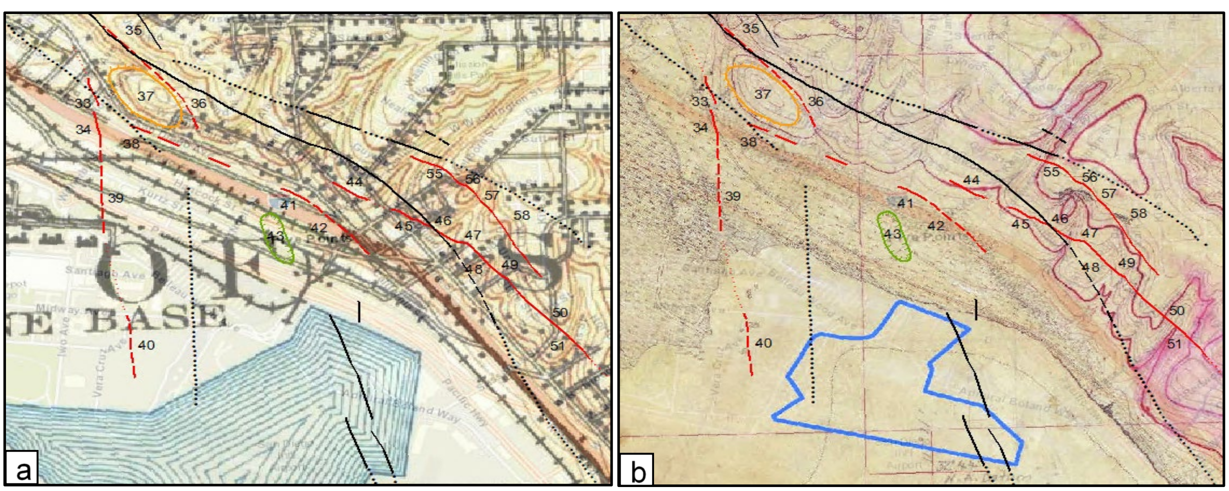


Figure 6. Historic topographic maps depicting a probable fault-related break in slope, saddle, and pressure ridge (numbered 35, 36, and 37, respectively) near Old Town. a) Base map USGS, 1904, San Diego Quadrangle map, 1:62,500-scale. b) Base map from Kleinfelder (2013b) and U.S. Coast Survey, 1851, Map of San Diego Bay, 1:10,000-scale map. Red lines depict fault-related geomorphic features identified by Kleinfelder (SANDAG, 2014) from 1928 aerial photographs. Black lines are faults from USGS and CGS Quaternary fault and fold database (2019). Blue polygon depicts boundary of SDIA North Side study by Kleinfelder (2013b; Locality 15). See Plate 2 and Table 2 for description of geomorphic features.

Discussion and Recommendations for Zoning

Recent fault studies and a detailed analysis of aerial photography by Kleinfelder for the Mid-Coast Corridor Transit Project (SANDAG, 2014) indicate a relatively continuous zone of northwest trending, active faulting that extends from Asher Street south through the Old Town area. Evidence of Holocene activity is postulated at the proposed Morena Pump Station site (Locality 4) located north of the San Diego River. The northern projection of this fault aligns with the secondary splay fault interpreted to branch west of the main scarp by Kleinfelder (SANDAG, 2014). Geomorphic features such as scarps, sags, pressure ridges, and offset channels are well expressed in the area between Asher Street and the San Diego River and provide additional evidence of active faulting in this area.

Recent studies have clearly demonstrated Holocene activity of the Old Town Fault in Old Town San Diego. Leighton (2008) first demonstrated Holocene activity of parallel strands of the Old Town Fault at the Mormon Battalion Historic Site north of the intersection of Juan and Harney Streets. Rockwell (2012) and Singleton *et al*. (2019) provided clear evidence for Holocene activity of the Old Town Fault at the Presidio Hills Golf Course and determined a late-Holocene recurrence interval of ~700 years for the RCFZ, which is the longest and most robust paleoseismic record of earthquake recurrence anywhere along the RCFZ. These studies suggest that faults exposed in a utility trench along Juan Street and observed by Engineering Geology Consultants (2000) should also be considered active and zoned along with the Old Town Fault. Historic topographic maps indicate the former presence of a fault-related pressure ridge and saddle and provide strong evidence for continuity of the Old Town Fault with the East Bay Fault discussed in the following section. Faults recommended for zoning in the Old Town section are shown on Plate 3.

SAN DIEGO BAY SECTION

Description

The San Diego Bay section extends from north of the San Diego International Airport (SDIA) to San Diego Bay (Plate 1). South of Old Town, the RCFZ widens to a distributed fault zone characterized by multiple subparallel faults exhibiting right-normal, oblique displacements. This is consistent with the right-releasing step-over from the offshore Descanso fault located 10 km to the west of the Silver Strand Fault (Weidman et al., 2019). The San Diego Bay section of the RCFZ includes the Spanish Bight, Coronado, and San Diego Faults, and combined with the Silver Strand Fault (previously evaluated in Treiman, 2002), these faults created an extensional basin forming San Diego Bay. Recent studies (Kleinfelder, 2007a, 2012a,b and 2013a,b; Ninyo and Moore, 2018; WLA, 2008a,b; URS, 2011a) in this section provide evidence for Holocene faulting onshore at the SDIA and in the downtown area, and offshore in San Diego Bay.

Active faults previously mapped within the downtown area include the San Diego Fault and downtown graben faults. A detailed history of previous work was provided in CDMG Open File Report 93-02 and FER-245 (Treiman, 1993 and 2002). The primary source of data for our evaluation of the San Diego Bay section of the RCFZ consisted of geotechnical consulting reports obtained through research at the City of San Diego Development Services Department (Geology and Records Sections). Many of the faults in the downtown area were discovered during the construction phase of development, with faults observed in foundation and basement excavations and documented in “as-graded” reports. We also obtained fault investigation reports for the San Diego Central Courthouse through coordination with the Judicial Council of California.

Many additional reports were also obtained from a compilation of geotechnical fault investigations completed as a Master’s Thesis at San Diego State University (Weidman, 2017). Weidman’s research provided the first comprehensive study of paleoseismic and geotechnical data for the downtown area. The study included development of an Environmental Systems Research Institute (ESRI) Geographic Information System (GIS) ArcMap geodatabase utilizing geology/geotechnical data from 29 consulting firms, with the biggest contributions from Construction Testing & Engineering, Inc., Geocon, Kleinfelder, Leighton and Associates, and URS/AECOM. Weidman georeferenced 268 site maps and associated data including “potentially active” and “active” fault strands, fault trench logs, boring logs, Cone Penetration Tests (CPTs), geologic cross sections, test pit logs, auger logs, and seismic profiles. Weidman (2017) mapped 93 fault segments within the downtown area, 49 of which were classified as Holocene-active. However, the geodatabase did not include many “as-graded” reports documenting faults discovered during site development and construction.

In this section, we briefly describe the characteristics of the Spanish Bight, Coronado and San Diego Faults, and discuss recent studies that indicate Holocene activity on these faults. We also discuss the recently discovered and previously unmapped East Bay and PCH Faults and suggest continuity of these faults with the Old Town Fault and Coronado Fault, respectively. Fault studies of the San Diego Bay section are summarized below with locations depicted on Plate 1 and discussed in Table 1. Recent fault studies in Coronado and the downtown graben area are outside the scope of this evaluation. Due to the extensive development in this area and relatively flat lying topography along the margins of San Diego Bay, we did not conduct a geomorphic analysis for this section.

SPANISH BIGHT AND EAST BAY FAULTS

South of Old Town San Diego, the RCFZ splays and widens into two main fault strands. One strand trends southeast toward Middletown and downtown San Diego, and the other strand trends south toward the SDIA (Plate 1). These fault strands splay offshore forming San Diego Bay, where they continue as the Spanish Bight, Coronado and Silver Strand Faults, and accommodate transtension created by a releasing stepover between the onshore RCFZ and offshore Descanso Fault (Weidman et al., 2019; Moore and Kennedy, 1975; Legg, 1985; Rockwell, 2010a; Maloney, 2013).

The Spanish Bight Fault (SBF) is named after the former shallow recess or embayment (bight) that formerly separated North Island from Coronado prior to its infilling in 1944. The fault was an apparent controlling structure for the Spanish Bight, and has been mapped as a continuous single structure from Harbor Island to North Island based on marine seismic profiles conducted by Kennedy and Clarke (1999a,b) in San Diego Bay. They also observed that the fault dips 75° east, displaces shallow Holocene-age sediments within a few feet of the seafloor, and may have seafloor expression. The fault exhibits normal separation and strike-slip movement and was found to have a flower structure in shallow sediments during fault investigations on the northern shore of North Island (Treiman, 2002; Woodward-Clyde, 1994; URS, 1998). These observations led to establishment of an APEFZ for the SBF by Treiman (2002).

Recent site investigations at the SDIA are summarized below and confirm the northward extension of the SBF (Plate 1). The investigations also identify a previously unmapped Holocene-active fault zone named the East Bay Fault by Kleinfelder (2012a,b, 2013a,b, 2019; SANDAG, 2014), which appears to be a splay of the SBF. Recent geomorphic interpretations of vintage aerial photographs and topographic maps (SANDAG, 2014; and this study) are also summarized below and provide strong evidence for structural continuity of the East Bay Fault with the Old Town Fault. We also discuss the previously mapped fault strand (Kennedy *et al*., 1975; Treiman, 1993) that splays and trends southeast from Old Town toward Middletown and downtown San Diego.

Site-specific Investigations

<u>Locality 10 – 1845 Titus Street</u>

Construction Testing and Engineering, Inc., (CTE, 2006) performed a fault investigation for a proposed residential development at this location. Their investigation included excavation and logging of two exploratory trenches to a maximum depth of 10 feet below existing grade. Both trenches exposed a fault zone characterized by an approximately one-foot thick gouge zone. The upper several feet of the gouge zone consisted of chips and blocks of San Diego Formation sandstone/siltstone within a clay matrix. The sandstone/siltstone fragments decreased with depth, and the lower portion of the gouge zone tapered and consisted of brown sandy clay. The fault was oriented N35-45W, dipped 50-80° southwest, and indicated 2 feet of down-to-the-west vertical separation. CTE noted the fault gouge did not show signs of antiquity, such as cementation or carbonate accumulation, and that deposits interpreted as Quaternary colluvium on the down-thrown side of the fault in trench T-2 suggested deposition after faulting. They concluded that evidence indicated possible Holocene fault activity and recommended a structural setback from the fault. This location also coincides with fault-related geomorphic features identified by Kleinfelder for the Mid-Coast Corridor Transit Project (SANDAG, 2014) discussed below.

<u>Locality 11 – Puterbaugh Street</u>

Applied Earth Technology (2006) and their subconsultant Michael W. Hart completed a geologic investigation of a residential site located on the west side of Puterbaugh Street approximately 100 feet south of Andrews Street. The site is situated between previously mapped traces of the RCFZ. A fault trench approximately 90 feet long and 6 to 10 feet deep was excavated across the area of proposed residential structures, and a fault zone was encountered that juxtaposed late Pliocene to early Pleistocene San Diego Formation against Pleistocene Linda Vista Formation (very old paralic deposits). The fault zone was observed to trend N31W and dip 58° west, with total vertical separation reportedly exceeding 15 feet down to the west.

Several unlogged test pits were also excavated to further assess the fault location, and to determine if dateable soils were present to evaluate the age of faulting. However, no topsoil or younger sediments which could provide evidence of Holocene activity were found overlying the fault. Hart also reviewed San Diego County 1928 aerial photographs and indicated the fault was not expressed in the topography as a lineament, bench or subdued scarp. However, Kleinfelder (SANDAG, 2014) interpreted a fault near this site expressed by a slope bench and ridgeline saddle, based on their review of the 1928 photos.

San Diego International Airport – Kleinfelder West, Inc.

Kleinfelder West, Inc. (2012a,b and 2013a,b) performed four fault studies at SDIA to evaluate the presence of through-going fault traces and estimate the recency of fault activity. Dr. Tom Rockwell developed soil profile descriptions, provided interpretation of the ages and structure of the geologic units to aid in the determination of the location and ages of faulting, and provided independent review and comment on results of the fault studies.

Locality 12 – SDIA Southside Airfield – East Ovals site

The Southside Airfield – East Ovals site (Ovals site) occupies a portion of the southeast side of the airport and consists of aircraft taxiways and large unpaved ovals (Kleinfelder, 2012a). Kleinfelder's evaluation of the Ovals site included 97 CPTs and 4 continuous core borings. Eleven samples of organic sediment and shells were obtained from bay deposits for radiocarbon dating. Their analysis of the CPT profiles revealed a Holocene-active fault located on the west side of the Ovals site which they named the East Bay Fault (Plate 1 and Figure 7).

The East Bay Fault was shown to be comprised of at least four branches, expressed by displaced stratigraphic units across an area up to 130 feet wide, and interpreted to be part of a larger fault which extends through the North Side area (see Locality 15) of SDIA along a northwest orientation. Analysis of CPT profiles indicated that stratigraphic units have vertical separation down on the east side of the fault, and significant lateral displacement along the East Bay Fault was demonstrated by thickness differences in stratigraphic units across the fault zone. The youngest unit reportedly displaced by faulting at the Ovals site was a bay deposit with a minimum age of 2,920 years BP. However, Kleinfelder reported the main branch of the East Bay Fault at the Ovals site extends up through most, if not all of the Holocene bay deposits, and that a radiocarbon age of 430 years BP was obtained from a sample near the top of the bay deposits approximately 1000 feet west of the fault, indicating the most recent faulting is likely as young as 400 years ago. They pointed out this is consistent with the timing of the most recent rupture in La Jolla and downtown San Diego dated around 1650 A.D. (Grant and Rockwell, 2002).

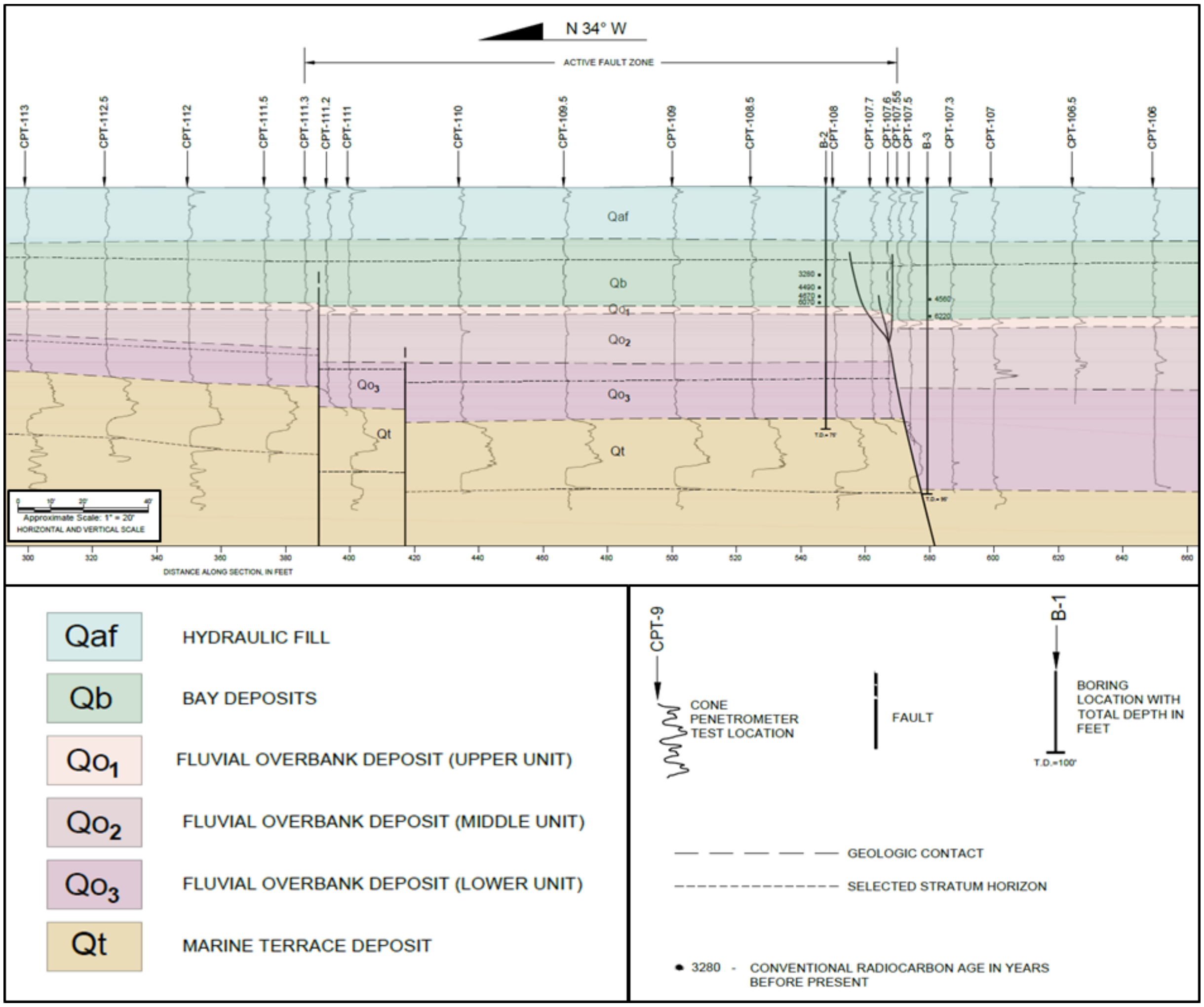


Figure 7. Portion of CPT Profile A from the SDIA Southside Airfields – East Ovals site (Locality 12). The East Bay Fault is shown offsetting mid- to late-Holocene bay deposits. Modified from Kleinfelder (2012a).

Based on interpretation of seismic reflection data collected in San Diego Bay, Kennedy and Clarke (1999a) described a branch of the Spanish Bight Fault which splayed northeasterly from the main strand near the shoreline at North Island and extended 1 km into the bay before dying out. The fault splay was interpreted to exhibit down-to-the-east displacement and appears to correlate with the East Bay Fault.

<u>Locality 13 – SDIA Rental Car Center (RCC)</u>

The Rental Car Center (previously named the ConRAC site) occupies an area within the northern portion of SDIA. Kleinfelder (2012b) performed a fault study consisting of 164 CPTs and 49 borings to bracket potential fault traces across the site. The results demonstrated the presence of one Holocene-active fault zone which ranges from about 20 to 60 feet in width. The fault zone was considered a projection of the East Bay Fault identified at the Ovals site to the south and exhibited displacement across an upward branching flower structure which displays up to 5 feet of down to the west vertical separation of Holocene bay deposits. They reported that radiocarbon dating of displaced organic bay deposit sediments yielded ages of 3,850 BP and 3,950 BP. Based on a notable mismatch of Pleistocene Bay Point Formation, stratigraphic unit thicknesses, and CPT signatures across the fault, Kleinfelder interpreted the majority of displacement on the East Bay Fault as lateral and on the order of tens to hundreds of feet.

Locality 14 – SDIA Teledyne Ryan facility

The former Teledyne Ryan manufacturing facility (TDY site) is located along the southeast side of the SDIA. Kleinfelder (2013a) performed a fault hazard study of the site which included 108 CPTs, 3 continuous-core borings, and 8 direct push borings. Their study revealed the northern extension of the Spanish Bight Fault and the trace of the East Bay Fault across the site. They reported that both faults penetrated and displaced Holocene bay deposits which yielded conventional radiocarbon ages between 430 to 6,110 years before present. At the southeastern area of the TDY site, they interpreted the East Bay Fault as a single flower structure approximately 38 feet in width, which displayed approximately 4 feet of east-side down separation of the bottom of the Holocene-age bay deposits. To the north, along the boundary with the Ovals site, the East Bay Fault comprised two areas of faulting, which exhibited a total of 6 feet of separation at the bottom of the Holocene-age bay deposits.

At the southwestern portion of the TDY site, Kleinfelder reported that fault zones were encountered along two CPT profiles. They interpreted these faults as the northern extension of the Spanish Bight Fault, because they are closely aligned with the northward projection of the fault where it crosses the marina area of Harbor Island south of the TDY site. Along both profiles, analysis revealed that fault strands extended up into the late Pleistocene Nestor Terrace deposits, which are about 120,000 years in age, but appeared to terminate at or near the contact with overlying Holocene bay deposits that were dated to about 6 ka. Therefore, Holocene activity could not be precluded. To investigate further, closely spaced borings were conducted along one of the CPT profiles to evaluate continuity of the paleosol which developed at the top of the Nestor Terrace unit after it was exposed to the subaerial environment following sea-level regression. The boring logs indicated a discontinuity in the soil profile that is likely the result of faulting, and Kleinfelder classified the faults as Holocene-active.

Kleinfelder noted the Spanish Bight Fault on the TDY site appeared to be much less significant than the East Bay Fault, and that it appeared to be diminishing and potentially dying out north of the TDY site.

Locality 15 – SDIA North Side

The North Side Fault study (Kleinfelder, 2013b) focused on identifying and classifying the activity of faults that may cross SDIA north of the runway approximately between the air traffic control tower to the west and the Pacific Highway to the east. The study utilized advancement of 298 CPT soundings and 34 borings. Shell and wood samples within the bay deposits were retrieved from the borings, and yielded ages ranging from 780 to 6,040 years Before Present (BP). The results of this study demonstrated the presence of the East Bay Fault Zone, one additional Holocene-active fault zone about 200 feet east of the north end of the East Bay Fault, and a small stratigraphic discontinuity at the southwest corner of the site.

Across the North Side site, Kleinfelder's analysis indicated the East Bay Fault Zone is comprised of an anastomosing band of discontinuous faults trending approximately N20W, and that stratigraphic units have vertical separation down on the west side of the fault. Near the southern portion of the site, the fault zone is about 200 to 240 feet wide and appeared to comprise at least 10 to 14 Holocene-active fault splays that either terminated at the bottom of the bay deposits or penetrated into them (Figure 8), juxtaposing Holocene bay deposits against the late Pleistocene Nestor Terrace unit. The width of the East Bay Fault Zone narrows to approximately 50 feet as it crosses the RCC, and further narrows to a width of approximately 10 feet at the northern boundary of the North Side site.

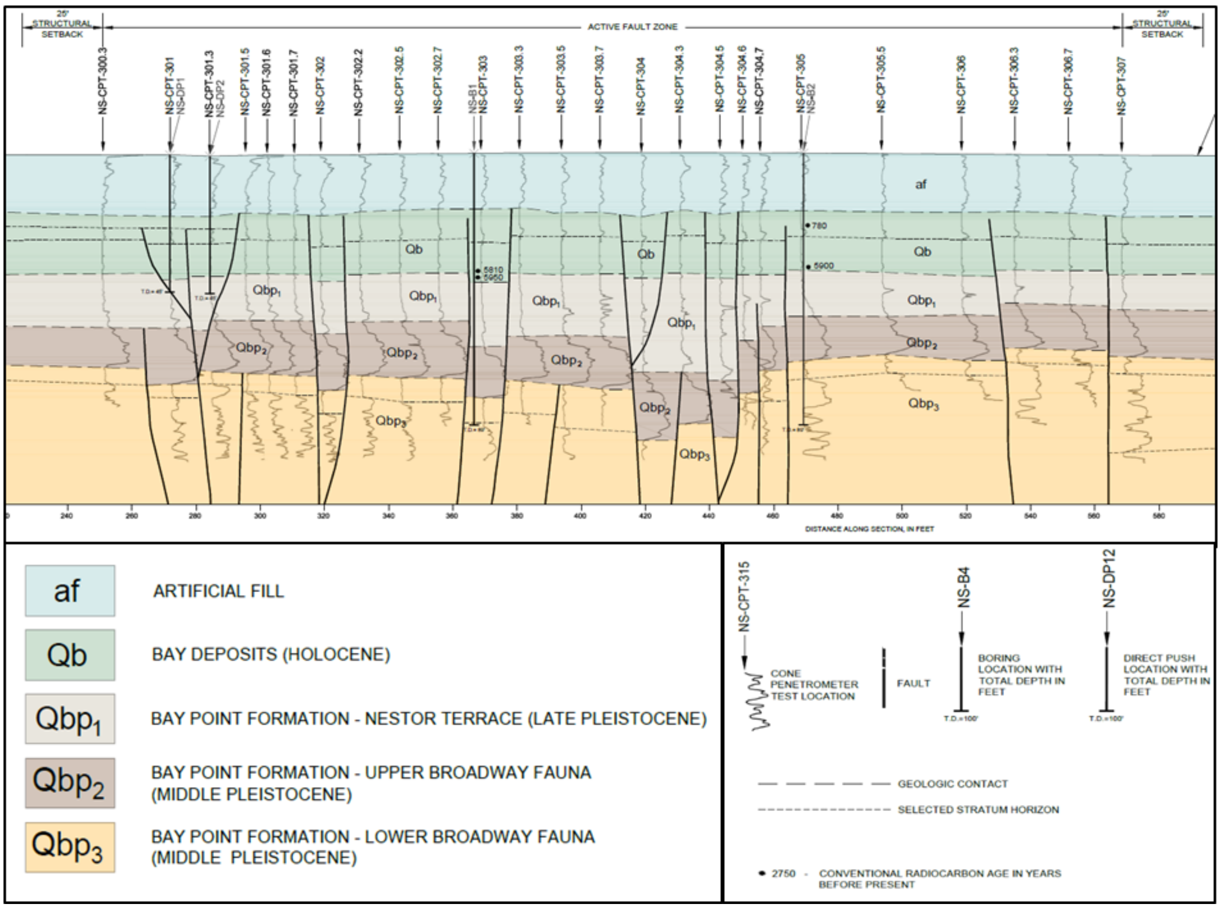


Figure 8. Portion of CPT Profile 300 from the SDIA North Side site (Locality 15). The East Bay Fault Zone is shown offsetting mid- to late-Holocene bay deposits. Holocene-active faults were also interpreted to extend to the pre-fill bay bottom surface producing scarps and suggesting fault displacement within the past several hundred years. Modified from Kleinfelder (2013b).

Kleinfelder also interpreted a graben structure within the East Bay Fault Zone between the North Side site southern boundary and the RCC site, which may represent a small transtensional basin due to a right step-over within a right-lateral fault system. They interpreted a maximum vertical separation of approximately 25 feet across the lower layers within the graben structure and a vertical separation of only several feet at the base of the bay deposits. They suggest that slip across the East Bay Fault Zone is primarily strike-slip, considering that overall vertical separation of stratigraphic layers across the fault zone is minimal. Radiocarbon dating of shells in displaced bay deposit sediments yielded ages ranging from 780 to 6,040 years BP for material retrieved from the bottom of this unit. In addition, the pre-fill bay bottom surface is uneven directly above Holocene-active fault traces, and they interpret this uneven surface as fault scarps onto which artificial fill was placed, suggesting a recent event of fault displacement likely within the past several hundred years.

Kleinfelder identified another Holocene-active fault zone along the northern boundary of the North Side site about 200 feet east of the East Bay Fault Zone. CPT data indicated the fault zone is about 50 feet wide and consists of two active faults which penetrate up to the base of undifferentiated alluvium/bay deposits forming a fault generated fold within the underlying Bay Point Formation. Holocene alluvium/bay deposits thin to a few feet over the top of the fold, indicating the fold was present at the surface during Holocene sea level transgression and deposition of the bay deposits. The fault zone was not identified in CPT profiles to the south, so Kleinfelder interpreted the fault to be a potential right step of the East Bay Fault Zone which may extend offsite to the northwest.

Locality 73 – Kennebec Railcar Storage Structure

Kleinfelder (2019) performed a fault hazard investigation along the northwestern projection of the East Bay Fault for the proposed Kennebec Railcar Storage Structure. The site is located southwest of the intersection of Washington Street and the railroad right-of-way (Plate 1). Their investigation consisted of two soil borings and 21 CPTs, from which they developed geologic cross sections and identified distinct fault-related disruption across all of the geologic units on the southeast side of the site.

Kleinfelder reported that the fault is directly on-strike with and exhibited an identical N25W trend with the East Bay Fault. They concluded the fault crossing the site is part of the Holocene-active East Bay Fault which they identified at the SDIA to the south. Other characteristics of the East Bay Fault at the Kennebec site reported by Kleinfelder include:

- Significant vertical offset and thickness differences across stratigraphic layers all the way up through the shallowest late Pleistocene old alluvial deposits.
- Stratigraphy on site did not allow for direct determination of Holocene activity, but alignment with the East Bay Fault and recent fault-related surface geomorphic expression provide evidence for Holocene activity.
- Steep southwest dip with down to the southwest vertical separation.
- The fault does not appear to be within a broad stepover zone, but is constrained to a narrow, mostly planar surface and does not display a branching upward structure or notable folding.
- The lateral component of displacement is larger than the vertical component, based on stratigraphic relationships and a notable thickness change of an old paralic deposit across the fault.
- The width of the zone across the site is approximately 10 feet.
- The CPT profile indicates an apparent fault scarp and large-scale uniform relative downdropping of the ground surface southwest of the fault, which is supported by a topographic depression interpreted from aerial photos and historic topographic maps.

Kleinfelder concluded the fault is Holocene-active and recommended a structural setback zone of 15 feet from the fault to protect the proposed building from surface fault rupture hazard.

Geomorphic Interpretation

Kleinfelder West, Inc., (SANDAG, 2014) provided detailed interpretation of fault-related geomorphic features from San Diego County 1928 stereo-paired aerial photographs near Old Town and Middletown east of Interstate 5. Their interpretations included scarps, lineaments, deflected drainages, aligned slope benches, ridgeline saddles, beheaded drainages, offset canyon slopes, and a trough. These features are illustrated on Plate 2 and summarized in Table 2. The interpretations generally support right-lateral Holocene movement along the fault zone.

As discussed in the Old Town section, Kleinfelder interpreted a bifurcation of the RCFZ and Old Town fault south of Old Town near the intersection of Old Town Avenue and San Diego Avenue, where a topographically higher area interpreted as a pressure ridge is apparent on historic topographic maps (Figure 6 and Plate 2, Feature 37). One strand was interpreted to trend approximately N55-65W and extends for up to 1.5 miles southeast toward downtown San Diego. Kleinfelder interpreted a set of three faults stepping up the west-facing escarpment east of I-5 as part of this strand (Plate 2, Features 38 and 41 through 54). Two of the faults extend southeast of the Washington Street drainage and generally coincide with mapping of the RCFZ by Kennedy *et al*. (1975) and Treiman (1993). Fault studies at Localities 10 and 11 (CTE, 2006 and Applied Earth Technology, 2006, respectively) generally corroborate these faults as interpreted by Kleinfelder (SANDAG, 2014).

The other strand of the fault zone was interpreted to project south toward the Marine Corps Recruit Depot, SDIA, and Spanish Bight Fault. This feature is less pronounced than the faults stepping up the escarpment through Middletown, but is suggested by a scarp, trough, and two probable lineaments (Plate 2, features 33, 34, 39 and 40, respectively) that trend toward the Spanish Bight Fault. Recent investigation by Kleinfelder at the SDIA described above (Locality 14, west side) confirms the northward projection of the Spanish Bight Fault onto the southern portion of the SDIA and aligns well with the geomorphic interpretation of a south trending fault strand south of Old Town.

Discussion and Recommendations for Zoning

Geomorphic and topographic analysis for this study suggests continuity of the Old Town Fault with the Holocene-active East Bay Fault identified by Kleinfelder (2012a, 2012b, 2013a, 2013b) at the San Diego International Airport (SDIA). An apparent fault-related pressure ridge and saddle south of Old Town identified on historic topographic maps align well between the Old Town Fault and East Bay Fault. South of SDIA the East Bay Fault projects toward a splay of the Spanish Bight Fault in San Diego Bay identified by Kennedy and Clarke (1999a,b) and suggests continuity of these fault strands. These faults are sufficiently active and well-defined and are recommended for zoning.

Kleinfelder (SANDAG, 2014) mapped three fault traces near Washington Street in Middletown based on interpretation of geomorphic features from vintage aerial photographs. Their interpretations are reasonable and supported by faults exposed in the road cut along Washington Street (Kennedy *et al*., 1975), as well as at Localities 10 and 11 (CTE, 2006 and Applied Earth Technology, 2006). The geomorphic expression of these faults suggests they are sufficiently active and well-defined and the faults are recommended for zoning (Plate 3).

In addition, the mapped fault splay south of Old Town (SANDAG, 2014) which crosses the Marine Corps Recruit Depot and aligns with the northern extension of the Holocene-active Spanish Bight Fault is also recommend for zoning.

CORONADO FAULT

The Coronado Fault was mapped in San Diego Bay and south of Coronado by Kennedy and Welday (1980) based on seismic profiles and was further defined by Kennedy and Clarke (1999a). The fault displaces sediments at or very near the bay floor and was found to be southeast dipping to nearly vertical and shallowing to approximately 75°E at depth (Kennedy and Clarke, 1999a), which led to establishment of an APEFZ for the Coronado Fault by Treiman (2002). A recent fault investigation by Kleinfelder West, Inc. for a proposed traffic tunnel project in Coronado was *"…the first to positively locate the Coronado fault on land and to show that approximately 29 cm of vertical displacement has occurred in the Holocene*" (Gingery *et al*., 2010). The study also provided evidence for strike-slip displacement on the fault.

The Coronado Fault has long been speculated onshore in the downtown area, and a recent study for a proposed redevelopment of Seaport Village (Ninyo and Moore, 2018) confirmed the location and Holocene activity of the fault onshore. This study corroborated a previous study at the Old San Diego Police Headquarters (William Lettis and Associates, Inc., 2008a,b), which identified a Holocene-active fault presumed to be the northern extension of the Coronado Fault.

Faulting along the northern trend of the Coronado Fault was revealed during redevelopment of four parcels east of Pacific Highway and north of Broadway. The fault was informally named the PCH Fault by Kleinfelder (2007a) and is interpreted here as structurally continuous with the Coronado Fault.

In the following sections, we discuss recent fault studies within the western area of downtown San Diego associated with the Coronado and PCH Faults. The localities discussed below are illustrated on Plate 1. Localities not discussed in the following sections are summarized in Table 1.

Site-specific Investigations

Locality 23 – Northeast Corner Ash Street and Pacific Highway (Breeza Site)

Kleinfelder (2004a) performed a fault hazard study for the parcel located on the northeast corner of Ash Street and Pacific Highway. The subsurface investigation included 3 borings, 22 CPTs in Ash Street with an average spacing of 15 feet, and a fault trench. A cross section was developed by Kleinfelder from the CPT data obtained along Ash Street and observations suggestive of faulting included:

- A sand marker bed was displaced approximately 4 feet down to the east.
- The thickness of the sand unit increased across the offset over a short distance of approximately 7 feet.
- The observations were consistent with characteristics of the PCH Fault to the south.

Following assessment of the CPT data, a fault trench approximately 35 feet in length was excavated in Ash Street to a depth of 15 feet directly above the suspected location of the fault. The trench exposed sand and clay units of late Pleistocene Bay Point Formation, but no offset stratigraphy or evidence of faulting was observed in the trench. Based on their observations, Kleinfelder concluded the suspected fault died out upward within late Pleistocene sediments of the Bay Point Formation and they considered activity of the fault to be potentially active or pre-Holocene.

We were unable to obtain a basement/foundation observation report for this project. However, Kleinfelder (2007b) prepared a Final Basement Excavation Geologic Inspection report for the Bayside Condominium Tower project (Santa Fe Depot Parcel 4) located to the south across Ash Street (see Locality 24 below) on the southeast corner of Ash Street and Pacific Highway. They observed a fault on the north wall of the excavation below Ash Street which had a flower structure that was nearly identical in size and pattern to the fault reportedly observed on the south wall of the excavation for Locality 23 (Breeza Site) along the north side of Ash Street. This observation indicated the fault was continuous across the two parcels on the north and south sides of Ash Street, east of Pacific Highway.

Localities 24 through 28 – Santa Fe Depot Development and the PCH Fault

The Santa Fe Depot development comprised several city block parcels located west of Santa Fe Depot train station where high-rise towers with multi-level basement structures and condominium residences were built beginning in 2002. The development is bound by Ash Street to the north, E Street to the south, Pacific Highway to the west, and the trolley/railroad lines to the east, with two additional parcels located west of Kettner Boulevard and south of Ash Street (Plate 1, Localities 24 through 28, 32, and 33). URS Grenier Woodward Clyde (URS) performed a fault hazard investigation (URS, 2000) which included excavation and logging of five fault trenches and numerous CPT soundings and borings and concluded that there were no indications of faulting in the late Pleistocene sediments underlying the site. However, the fault trenches were likely not deep enough to expose significant fault related features.

In July, 2002, during routine observation of ongoing basement excavation on Santa Fe Depot Parcel 2 (Locality 26), which is bound by B Street, Pacific Highway, C Street, and the railroad tracks, Kleinfelder discovered a fault located on the north side of the basement excavation and in the temporary slope above the shoring. Kleinfelder and their subconsultant, Michael W. Hart, subsequently conducted a geologic subsurface evaluation of the northern portion of the project site above the fault (Kleinfelder, 2002a, 2002b, and 2002c). Their evaluation included excavation and logging of four benches (subsequently named Trench T-1) to a depth of approximately 19 feet below ground surface in the temporary slope above the basement foundation shoring. Key results of their limited fault study include:

- Faulting was first observed at a depth of 30 feet as a discrete rupture surface offsetting a friable sand having numerous B-lamellae against a red-brown weakly cemented clayey sandstone to the east.
- The fault flowered up into a complex zone of faults and fractures that died-out up at a depth of approximately 9 feet below the ground surface.
- Faulting within the Bay Point Formation was characterized by interbedded clays apparently down dropped approximately 4 feet to the east across the fault.

Based on their observations and personal communication with Dr. Thomas Rockwell, Kleinfelder concluded that faults observed at the site died-out upwards and were truncated by early Holocene to late Pleistocene-age materials that displayed relatively continuous unfaulted B-lamellae. They classified the faults as potentially active (pre-Holocene), based on unfaulted B-lamellae being generally accepted indicators of late Pleistocene or older age.

Kleinfelder and Hart (Kleinfelder, 2002c and 2003a) conducted additional subsurface evaluations between August and November of 2002, which consisted of detailed logging of fault exposures located above the projected fault trace. Their evaluation included excavation of three benched trench excavations (trenches T-2, T-3a, and T-3b) up to 18 feet below ground surface on Santa Fe Depot Parcel 3 (Locality 25), excavation of five bench/trench excavations (T-4a, T-4b, T-4c, T-4d, and T-4e) up to 37 feet in depth in the southern temporary slope and haul road south of the Parcel 2 building basement footprint, and an additional trench excavation (T-5) up to 15 feet deep on Santa Fe Depot Parcel 4 (Locality 24). Results of these additional evaluations are summarized below:

- Several unfaulted units overlying the fault had distinctly developed A, E, and B-horizons along with zones of Stage I and Stage II carbonate development.
- Faulted units of the Bay Point Formation are down-dropped east of the fault.
- A gravel-cobble channel deposit located at a depth of 17-19 feet is unfaulted and overlying sand and gravel units were continuous and unfaulted.
- Within the unfaulted units were two late Pleistocene age B-horizons (paleosols), the stratigraphically lowest of which was observed at a depth of 12 to 14 feet and continuous across the excavation.

Kleinfelder conducted another fault study in 2006 on Santa Fe Depot Parcel 1 (Locality 27), located on the northeast corner of Broadway and Pacific Highway. Their investigation included excavation and logging of three trenches up to 17 feet below the ground surface, and Dr. Thomas Rockwell and Michael Hart assisted with the evaluation. The results of this study revealed the southern continuation of the fault observed on Parcels 2 and 3 to the north. Kleinfelder (2007a) unofficially named this fault the PCH Fault after Pacific Highway, located west of the Santa Fe Depot properties. Results of the fault study on Parcel 1 are summarized below:

- The fault is a relatively narrow, branching upward flower structure less than 5 feet wide near the surface. The flower structure narrows downward to a zone less than one foot wide at a depth of less than 20 feet.
- Movement across the fault is typically down to the east.
- Seven carbonized wood samples were obtained from trenches T-2 and T-3 for carbon isotope analysis. Faulting can be demonstrated after about 13.7 ka but older than 9.6 ka in trench T-2 (Figure 9). In trench T-3, displacement of stratigraphic units can be demonstrated as having occurred before about 10.1 ka.
- When analyzed in the context of post-glacial sea level rise and its attendant variations and regressions, Kleinfelder inferred the last movement on the fault likely occurred between 12 and 11.2 ka.

Based on the definition of an active fault that has *"…had surface displacement within Holocene time (about the last 11,000 years)*" and their interpretation that the last displacement event on the fault occurred between 12,000 to 11,200 years before present, Kleinfelder classified the fault as potentially active (pre-Holocene). They suggested that activity on the RCFZ had bypassed the PCH Fault just prior to the beginning of the Holocene, and apparently transferred activity to another fault strand outside of the Santa Fe Depot parcels.

Development of the Santa Fe Depot parcels continued with the basement excavation for the Bayside Condominium Tower on Parcel 4 (Locality 24), which took place between November 2006 and March 2007. Kleinfelder was onsite during excavation of the basement and performed geologic observations of exposed earth materials in the excavation sidewalls. In their Final

Basement Excavation Geologic Inspection report (Kleinfelder, 2007b), Kleinfelder documented observation of two main fault structures exposed in the foundation excavation.

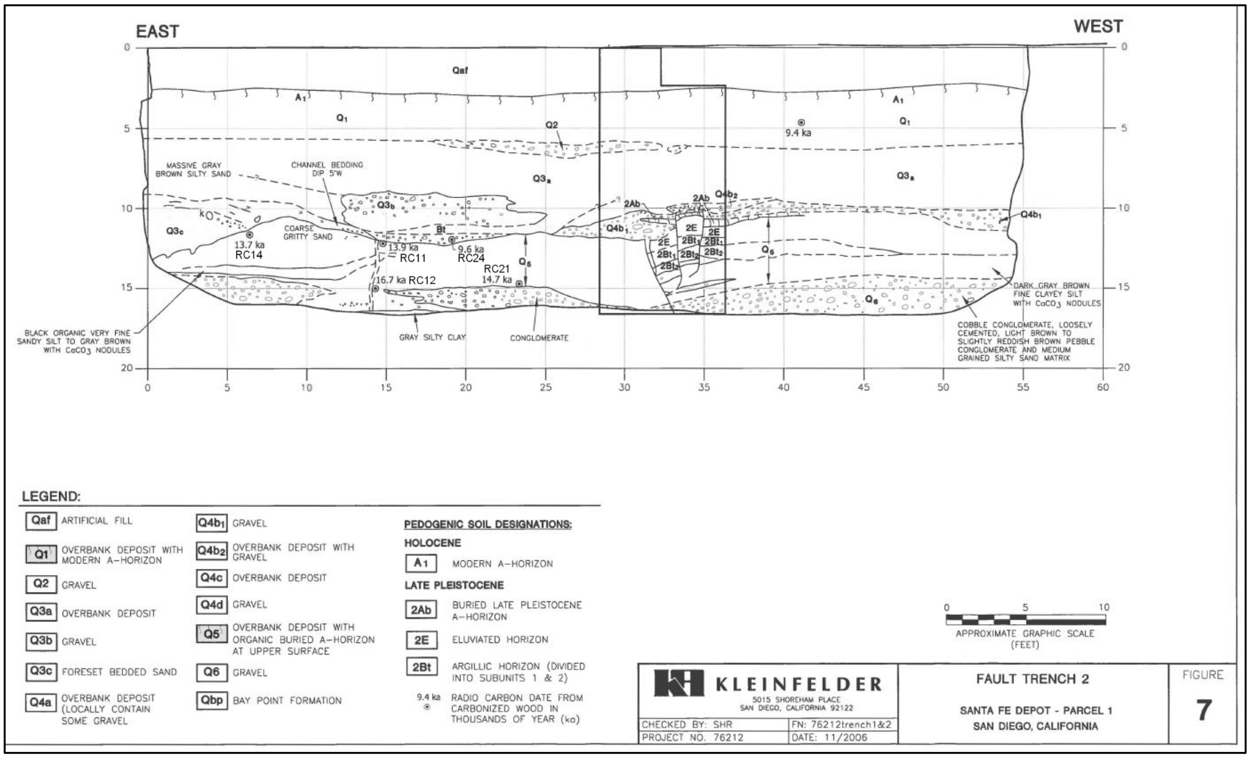


Figure 9. Log of Fault Trench 2 by Kleinfelder (2007a) at Santa Fe Depot Parcel 1 (Locality 27). Radiocarbon dating demonstrates faulting on the PCH Fault between 9.6 and 13.7 ka.

The westernmost fault exposed in the foundation excavation on Parcel 4 was approximately 2 feet in width at the central portion of the site and widened to 9 feet at the south wall cut, where the fault was in close proximity to the PCH fault previously identified on Santa Fe Depot Parcel 3 (Locality 25) to the south. The northeast trend of the fault differed from the slightly northwest strike of the PCH Fault on Parcels 1, 2, and 3, but this was interpreted to be a result of bending of the fault structure as it neared a step-over zone to the easternmost fault on Parcel 4. Characteristics of the easternmost fault on Parcel 4 (Locality 24) are summarized below:

- The fault trended approximately N15W and was on strike with a fault previously identified below Ash Street during Kleinfelder's fault study for the Breeza site (Locality 23).
- The fault exhibited eastward dip and down-to-the-east separation of stratigraphic units.
- The fault was comprised of an upward branching flower structure that was up to 19 feet wide at a depth of approximately 27 feet below ground surface and narrowed to 7 feet wide at the bottom of the foundation excavation.
- The flower structure exposed on the north wall of the Parcel 4 excavation (Locality 24) was nearly identical in size and pattern to the structure observed on the south wall excavation of the Breeza site to the north (Locality 23).
- The fault was interpreted to terminate within the interior of the foundation excavation on Parcel 4.

Based on the patterns of structural characteristics between the faults observed on Parcel 4, Kleinfelder suggested they were both segments of an overall larger fault structure separated by a down-dropped structural block across a step-over zone. They concluded the faults were potentially active (pre-Holocene) based on the following observations:

- Faults terminated near the base of a late Pleistocene pedogenic soil unit characterized by a relatively thick (over 5 feet thick in most areas) well developed argillic horizon which graded downward into a zone with local B-lamination development.
- Faults diminished upward within the base of the pedogenic zone and became unrecognizable within about 15 feet of the ground surface.
- No faults were observed within upper Holocene A- or B-Horizon soil units.
- Notable change and upward diminishing sharpness of the faults indicated they have been significantly altered by late Pleistocene soil development processes.

Between January and July of 2015, Kleinfelder performed similar geologic mapping services of foundation excavation sidewalls for the Pacific and Broadway Development on Santa Fe Depot Parcel 9 (Kleinfelder, 2017; Locality 28), located on the southeast corner of Pacific Highway and Broadway. Two faults were identified during mapping of the excavation wall cuts. One fault (identified as fault F1) traversed the entire length of the site along a trend of approximately N22W and branched upward to a depth of 24 feet. The fault flowered up, terminated at an erosional contact at a depth of approximately 17 feet below ground surface on the north and south walls of the excavation, and exhibited approximately 12 to 18 inches of vertical displacement. Kleinfelder concluded this fault was "…*likely a western en echelon step of the PCH Fault and may represent the southern fault section of the overall PCH Fault structure*".

Another fault (identified as fault F2) crossed the northeast corner of the site and was observed on the north and east walls of the excavation. The fault flowered upwards and exhibited approximately 4 feet of vertical displacement. It was truncated by an erosional surface at a depth of 17 feet below ground surface and was interpreted to be the southern continuation of the PCH Fault. Both faults were judged to be pre-Holocene structures and classified as potentially active, based on their termination within Bay Point Formation at a depth of 17 feet below ground surface. Kleinfelder (2017) also interpreted three other faults at the site from CPT data, presumably during prior investigation of the site, but they were not encountered in the basement excavation because they terminated at a depth below the bottom of the excavation.

Locality 29 – Old San Diego Police Headquarters Modification Project

William Lettis and Associates, Inc., (WLA) performed a fault rupture hazard investigation for proposed remodeling of existing structures at the Old San Diego Police Headquarters located at 879 W. Harbor Drive in downtown San Diego (William Lettis and Associates, Inc., 2008a,b). The investigation consisted of advancing 31 closely spaced CPTs and two sonic core borings, due to a thick cover of hydraulic fill and shallow groundwater at the site. Based on interpretation of geologic cross sections developed from the CPT soundings and borings, WLA found evidence for a zone of faulting trending N4E which traversed the western portion of the existing historic courthouse building and they recommended a 50-foot setback from the eastern limit of faulting. They demonstrated increased stratigraphic unit thickness west of the fault, stratigraphic mismatches, and vertical separations, and considered the faulting Holocene-active based on the following observations:

- Faults appear to offset uppermost Pleistocene Bay Point Formation in all geologic cross sections and appear to offset the base of Holocene alluvium by two feet in Geologic Section A-A' (Figure 10).
- No unfaulted strata of pre-Holocene age can be used to preclude Holocene slip.
- The Holocene-active Coronado Fault projects onshore near the western margin of the site, and the zone of faulting identified in this study may be associated with the Coronado Fault.

WLA also suggested this zone of faulting could be related to the PCH Fault discovered by Kleinfelder at the Santa Fe Depot sites located approximately 0.6 km to the north.

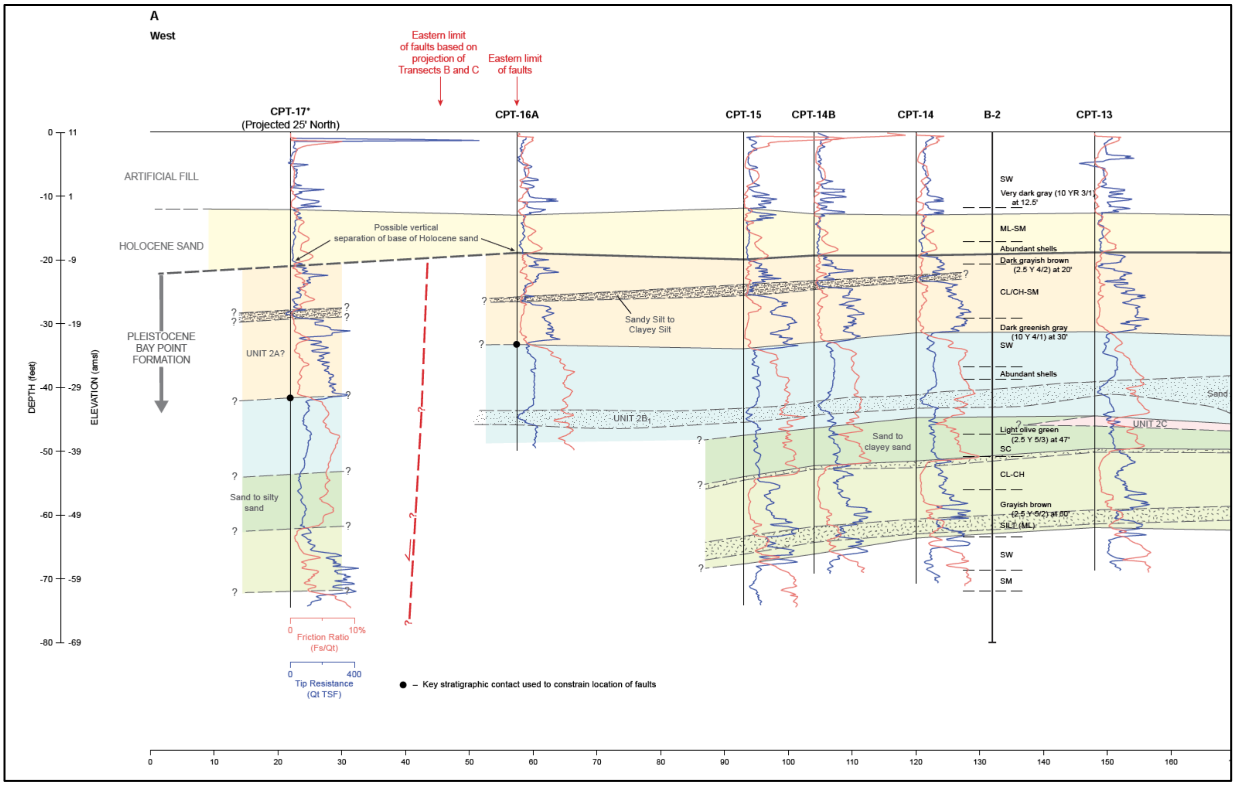


Figure 10. Portion of Geologic Cross Section A-A' by William Lettis & Associates, Inc. (WLA, 2008a) at the Old Police Headquarters (Locality 29). The fault appears to offset the base of the Holocene alluvium by 2 feet. WLA suggested the zone of faulting may be associated with the offshore Coronado Fault to the south and/or the PCH Fault to the north.

Locality 30 – Seaport Village/ Coronado Fault

A fault hazard evaluation was performed by Ninyo & Moore (2018) for the proposed World Class Waterfront Development project in the Seaport Village area of San Diego, which also includes public and private improvements to adjacent areas Ruocco Park, Tuna Harbor marina, and Embarcadero Park. Their field exploration program consisted of two phases. The first phase consisted of an onshore exploration program which included 23 small-diameter exploratory borings and 116 CPT soundings. The second phase consisted of an offshore geophysical survey of 33 seismic lines performed within San Diego Bay along the southern and western sides of the project area. Trenching was reportedly not feasible at the site due to the presence of shallow groundwater at a depth of approximately 10 feet, and fill thickness on the order of 10 feet.

The borings and CPTs revealed the site is underlain by fill, marine bay deposits considered to be less than 6500 years old, and Quaternary-age old paralic deposits, formerly designated as Bay Point Formation. Ninyo and Moore developed six interpretive geologic cross sections based on the boring and CPT data, and evidence for faulting was demonstrated along three of the cross sections. Characteristics of faulting onshore are summarized below:

- Multiple offsets and abrupt stratigraphic discontinuities.
- Near vertical, west side down separation.
- Width of the fault zone was interpreted as being approximately 25 feet wide at the north end of the site, and transitions to approximately 30 feet wide at the central and south portions of the site.
- Slightly tilted or “warped” beds east of the fault.
- Vertical separation of sub-units within the late Pleistocene old paralic deposits on the order of 15-20 feet.
- Faulting of multiple sub-units within the Holocene bay deposits.
- Observed progressive-with-depth offsets indicate movement along the fault zone in multiple events.
- Approximately 1.5 feet of offset within the lower bay deposit units.
- Fault orientation approximately N9E.

Ninyo and Moore and Environment and Marine Solutions also interpreted two roughly parallel fault structures from bay floor stratigraphic offsets within several of the CHIRP seismic lines performed as part of the offshore geophysical survey (Figure 11). The offsets were interpreted as being associated with folding/faulting within San Diego Bay. One fold/fault structure trends N40E and is located within the northwestern portion of the offshore study area southwest of the docks for Tuna Harbor. However, based on interpretation of CHIRP seismic lines performed in between the boat docks, the fold/fault is interpreted as having a northeast termination point that does not extend into Tuna Harbor or on to the adjacent shoreline.

The second fault structure interpreted from CHIRP seismic lines within the offshore study area is situated to the south of Seaport Village, and generally follows the anticipated trend and location of the Coronado Fault. Characteristics of the offshore fault south of Seaport Village are summarized below:

- Correlates well with faulting identified by the onshore subsurface exploration program.
- Interpreted as having an orientation of approximately N9E.
- Continuous with the fault zone interpreted from onshore geologic cross sections.
- Interpreted as being a near vertical structure with no observed splays.
- Characterized by westward dipping reflectors bounded by a near-vertical fault with ~4 to 4.5 m of throw.
- Offsets are observed within the shallow bay floor sediments and interpreted as occurring within Holocene bay deposits.
- Observed offset likely records 2 to 4 events.

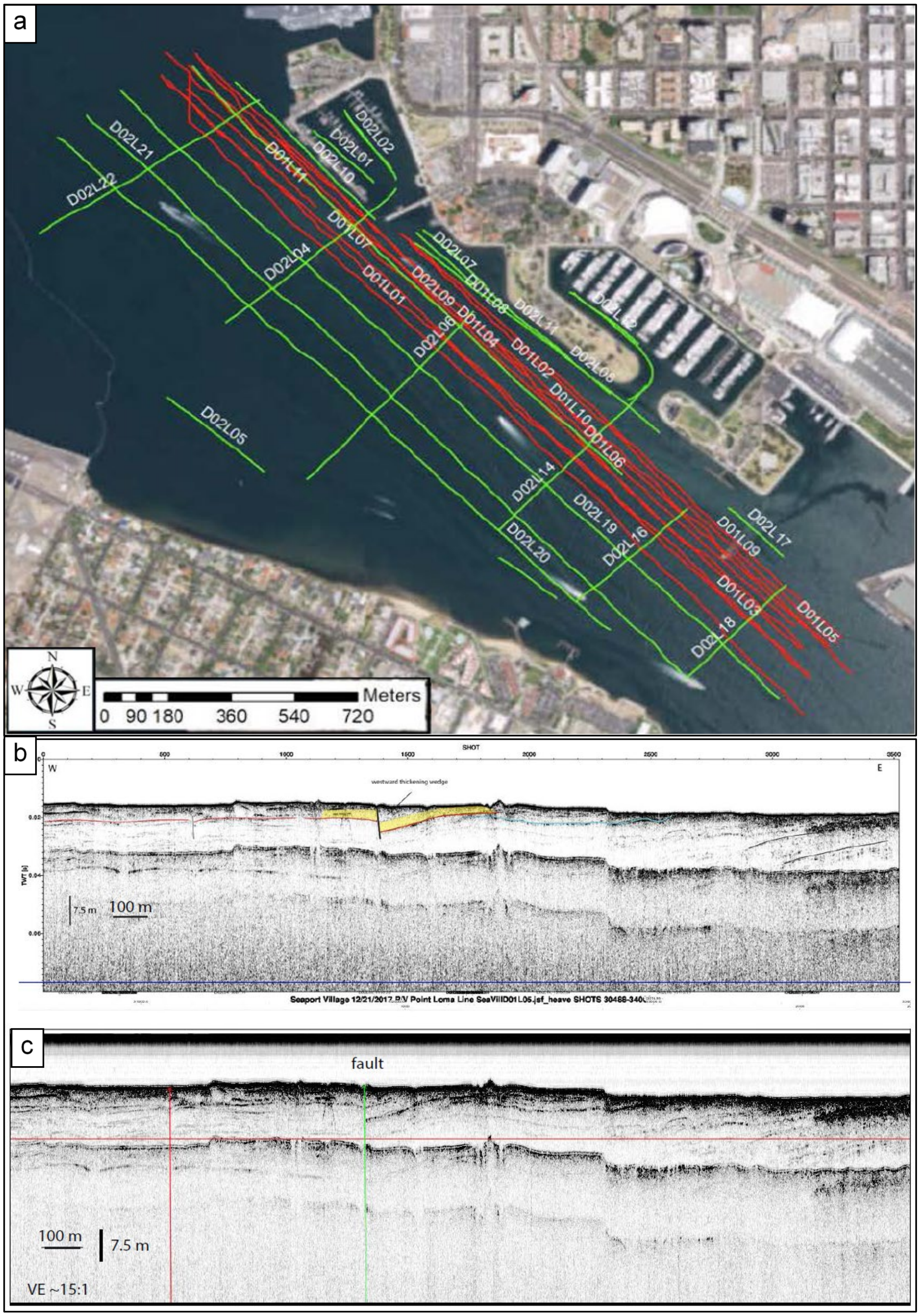


Figure 11. Seaport Village (Locality 30) CHIRP Seismic Survey by Environment and Marine Solutions. a) Shiptrack map for the geophysical survey. Red lines aquired on day 1; green lines aquired on day 2; line numbers labelled. b) CHIRP line D01L05 (low gain) showing western dipping stratigraphy (yellow) bound by the Coronado Fault (black line). c) CHIRP line D01L05 (high gain): green line is the main fault; red vertical line is a small secondary fault. Modified from Ninyo & Moore, 2018, Appendix B, Figures 3a and 5.

These observations are consistent with Kennedy and Clarke (1999a,b), who concluded the Coronado Fault cuts material at or very near the bay floor and considered it to be one of the most youthful faults in this part of the RCFZ. Based on results of the onshore and offshore field exploration programs, Ninyo and Moore concluded the fault zone at Seaport Village constitutes an onshore continuation of the active Coronado Fault, and recommended a building setback of 25 feet from the fault.

Discussion and Recommendations for Zoning

Fault studies by WLA (2008 a,b) and Ninyo & Moore (2018) provide direct evidence that the Holocene-active Coronado Fault comes onshore at Seaport Village (Locality 30) and projects beneath the western portion of the Old Police Headquarters building (Locality 29). South of Seaport Village offshore, high resolution seismic profiling provides clear evidence of the trend, location and age of faulting (Figure 11). North of Seaport Village, WLA suggested the faults discovered during investigation of the Old Police Headquarters site "…*may be part of the Holocene active Coronado Fault Zone and or could be related to the potentially active 'Pacific Coast Highway Fault' documented by a Kleinfelder (2007) study of the Santa Fe Depot site located approximately 0.5 mi to the north directly east of Pacific Highway*". The Coronado Fault trends northward toward the PCH Fault, which suggests this is one continuous structure. Although the Coronado/PCH Fault have been investigated and located along much of its Downtown reach, finding and interpreting clear evidence of Holocene-age activity at each individual site has been challenging at some sites due to the general lack of datable Holocene-age sediments. However, at multiple sites, favorable paleoseismic sedimentary conditions were encountered which allow a confident assessment of Holocene-age faulting.

The PCH Fault appears to be a pre-Holocene structure throughout much of its approximately 1400-foot length between Broadway to A Street. However, the timing of movement along the fault has been dated directly through modern radiocarbon dating techniques at one site. Kleinfelder (2007a) constrained the last event on the fault at between 13.7 ka and 9.6 ka based on dates determined from carbonized wood samples obtained from an alluvial channel incised into Santa Fe Depot Parcel 1 (Locality 27). Additionally, they suggested the last displacement event may have been sometime between 12 to 11.2 ka based on a speculative model that relates local aggradation and incision events of the alluvial units at the site with global sea level curves published by Liu et al. (2004).

We evaluated the most recent fault activity by updating the radiocarbon analysis with more recent calibration curves (Reimer *et al*., 2020) and standard Oxcal chronological modeling (Bronk-Ramsey, 1994) (Figure 12). The age of the most recent faulting was constrained the best in trench T2 (Figure 9) and is bracketed between samples RC24 and RC14. This results in a possible age of faulting ranging from 10.3 to 13.4 ka. In trench T3 a similar age can be interpreted. Regardless of which chronologic model is used, the timing of the most recent earthquake at Locality 27 is latest Pleistocene to early Holocene in age and classifies the fault as Holocene-active based on the current definition for an active fault as one which has moved within the last 11,700 years.

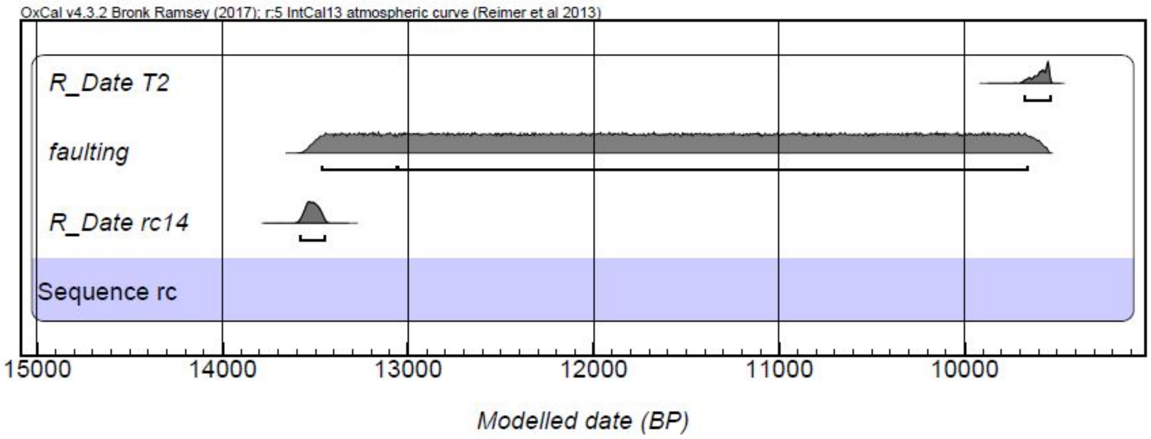


Figure 12. Oxcal chronological model (CGS, this study) of Radiocarbon data collected from Locality 27, Santa Fe Depot Parcel 1, indicating a range of faulting from 10.3 to 13.4 ka for the PCH Fault.

Our evaluation of fault investigations along the onshore extension of the Coronado/PCH Fault shows that the fault is demonstrably Holocene-active where it comes onshore. The PCH Fault, mapped in several fault investigations at Localities 23 – 28, continues the trend of the Coronado Fault and, based on the close spatial association, the PCH Fault likely represents the northward extension of the Coronado Fault. Although fault investigations suggest the PCH Fault may be dying out to the north, radiocarbon age constraints at Locality 27 clearly show at least one mapped trace having last moved in the early Holocene, demonstrating its activity. Furthermore, the PCH Fault has not been fully investigated throughout the downtown area, and additional Holocene-active faults strands may underlie these areas yet to be investigated. Based on the available mapping showing the likely association between the Coronado and PCH Faults, as well as age constraints showing Holocene activity along both faults, the Coronado and PCH Faults are recommended for zoning as shown on Plate 3.

SAN DIEGO FAULT

The San Diego Fault was named during monitoring of a sewer-line excavation along Broadway, between Front and 1st Streets (Treiman, 2002; Artim and Streiff, 1981; Elder, 1982; Elder-Mills, 1982; Streiff and others, 1982). Based on the exposure in the sewer trench, the fault was characterized by a distributed zone of normal faults about 46 m wide, and a maximum vertical separation of 3-4 m in middle to late Pleistocene terrace deposits. Additional studies confirmed the location of the San Diego Fault south of Broadway. One of the studies demonstrated Holocene activity and it was strongly indicated in two others. The studies were summarized in FER 245 (Treiman, 2002) and led to establishment of an APEFZ for the San Diego Fault.

Currently, the San Diego Fault has a mapped length of approximately 0.7 km, trends North to N8W, and dips 60-80°E with east-side-down displacement. Recent studies for the San Diego Central Courthouse indicate that the fault projects to the northwest of the current APEFZ, and there is additional evidence to suggest the fault extends as far north as Beech Street (Plate 1).

Site-specific Investigations

<u>Locality 34 – San Diego Central Courthouse/San Diego Fault</u>

URS (2011a) conducted a fault hazard investigation to assess the potential for fault rupture at a proposed tunnel which would connect the new San Diego Central Courthouse (located on the northwest corner of C Street and Union Street) to the existing County of San Diego detention facilities located on the southeast corner of B Street and Front Street. The proposed tunnel was about 350 feet long, ranged from 10 to 12 feet in diameter, and was expected to cross the Holocene-active San Diego Fault. URS reviewed previous subsurface investigation of the area by Law Crandall (2000), and performed additional subsurface explorations consisting of 3 trenches, 8 borings, and 27 CPTs.

The explorations encountered fill, Holocene alluvium, and Quaternary-age Bay Point Formation (old paralic deposits). URS developed geologic cross sections based on the subsurface data, which revealed stratigraphic anomalies suggesting a fault with down-to-the-east separation (Figure 13).

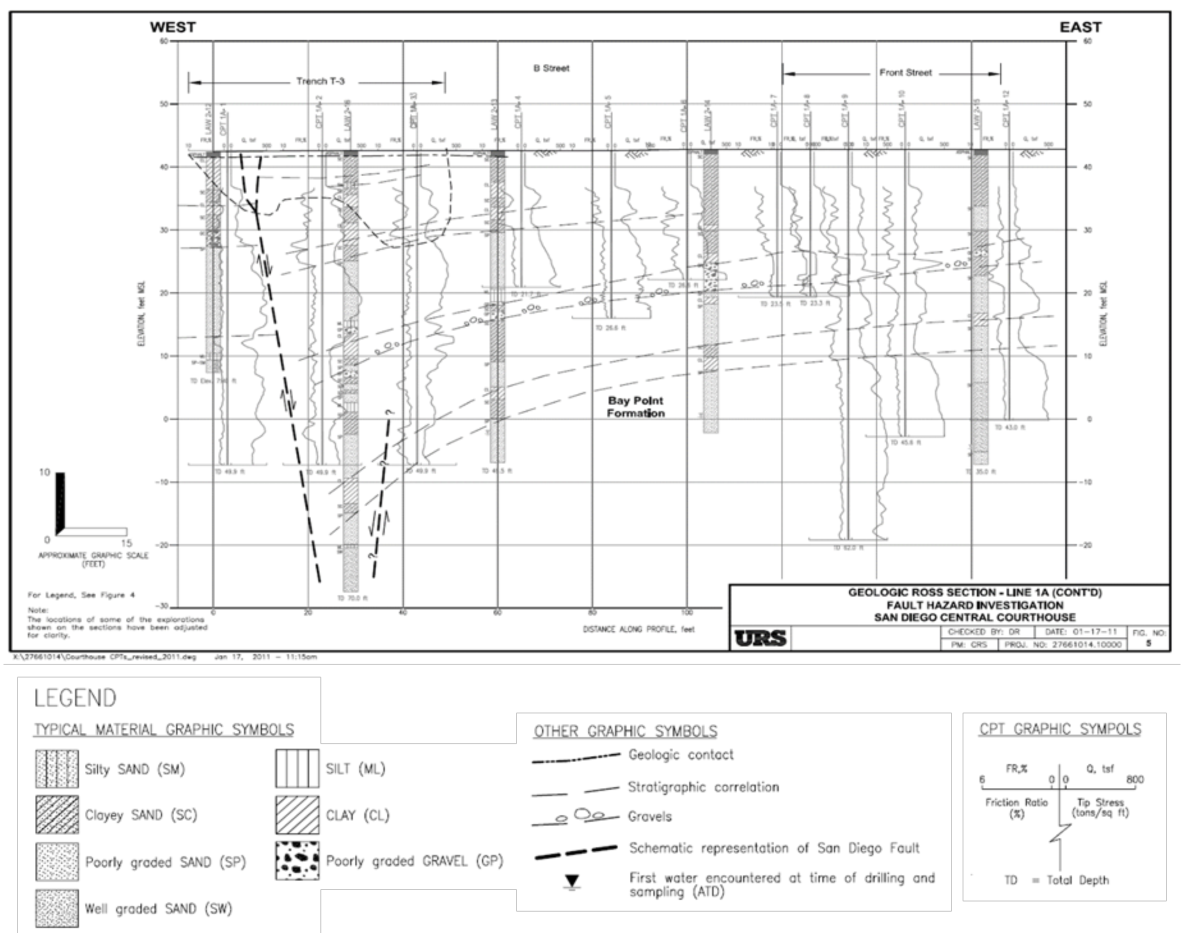


Figure 13. Portion of Geologic Cross Section Line 1A by URS (2011a) for the San Diego Central Courthouse (Locality 34), which suggests stratigraphic anomalies due to faulting with down to the east vertical separation. The location of trench T-3 is depicted in the upper left portion of the cross section.

Additionally, trench T-3 (Figure 14) encountered the San Diego Fault, which consisted of an approximately 5-foot wide zone with several pronounced steeply dipping fault planes or shears juxtaposing dissimilar geologic units of Bay Point Formation. They suggested the entire width of the fault zone may not have been captured by the trench due to the presence of backfill materials from an existing tunnel excavation.

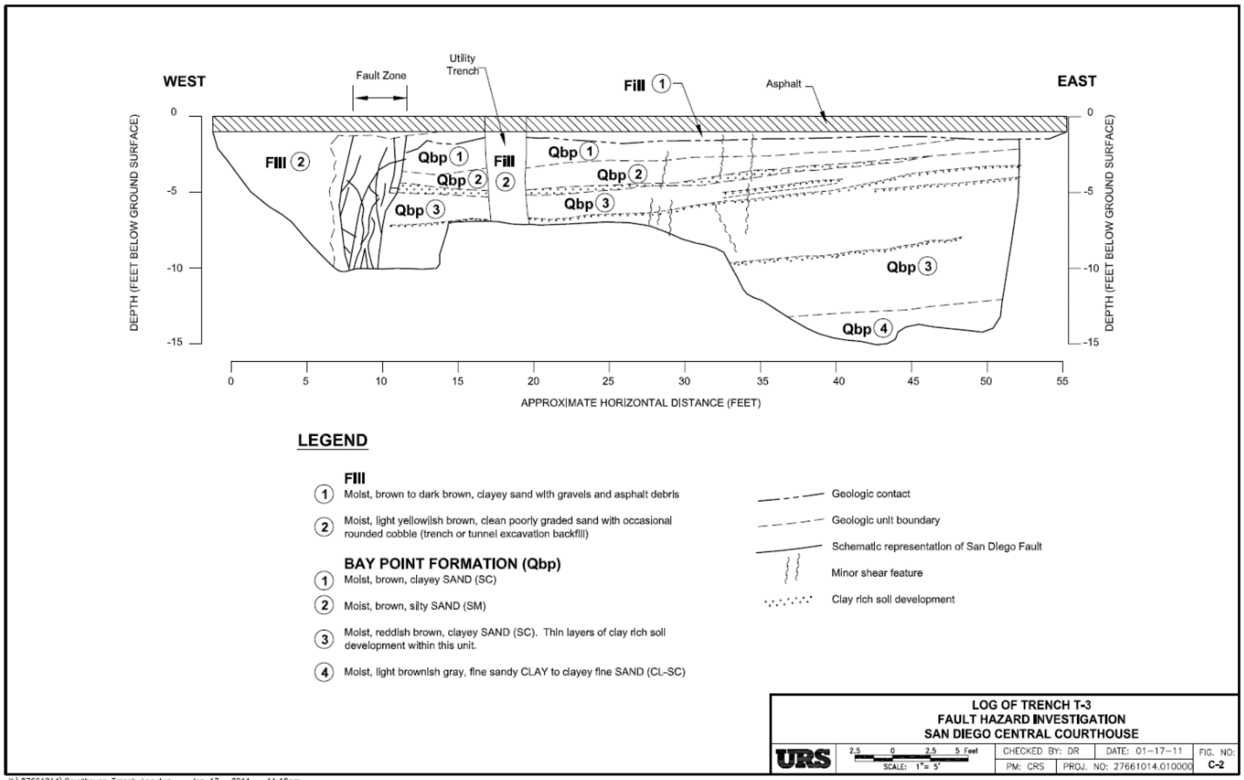


Figure 14. Log of Trench T-3 by URS (2011a) for the San Diego Central Courthouse (Locality 34). See Figure 13 for the location of trench T-3. The fault zone exposed in the trench was interpreted to be the northern projection of the Holocene-active San Diego Fault.

URS provided the following additional observations about the fault identified in the subsurface explorations:

- The fault appeared to strike N25W, and dip 70 to 80 degrees to the east.
- Minor folding or tilting within strata offset by the fault was suggested by the deeper CPT data.
- East of the fault, the dip angle of strata appeared to increase with depth, suggesting drag folding had accompanied past movement on the fault. URS suggested that increased dip angle with depth could have also represented presence of a possible deeper branch fault that didn't extend upwards into upper Bay Point Formation sediments, and therefore would not appear to be active.
- Offset gravel layers suggested a vertical component of offset across the fault; however, weak topographic expression and thickness differences in thin clay layers offset by minor shears in Trench T-2 suggested horizontal movement has also occurred on the fault.

URS concluded that near-surface faulting observed in trench T-3 appeared to have occurred along a projection of the mapped location of the Holocene-active San Diego Fault, just south of the site, and recommended the fault be considered active.

At the Central Courthouse site on the northeast corner of State and C Streets, no faults were found during investigation of the site which included fault trenches about 15 feet deep, but several minor faults were exposed within the walls and bottom of the basement excavation during grading (URS, 2017). URS reported that all of the faults were weathered and oxidized, subtle, narrow features with as much as 8 inches of apparent bedding displacement, and no significant clay gouge or other indicators of repeated displacement were observed. One fault (F3) indicated as much as two feet of apparent vertical separation. The faults were observed to terminate abruptly in the lower Bay Point Formation and did not intersect the overlying younger alluvial deposits. All of the faults were reportedly overlain by at least 20-25 feet of unfaulted Bay Point Formation and were classified as potentially active (pre-Holocene).

<u>Locality 35 – Little Italy Project</u>

SCST (2000) conducted a fault investigation for the proposed Little Italy project located on the parcel bound by Ash-Beech-Columbia-State Streets. The investigation consisted of excavating and logging 6 exploratory trenches. A fault observed to offset Bay Point Formation was encountered in trenches T-1 through T-4. A moderate to well-developed middle to late Pleistocene Bt soil horizon, which was not displaced by the fault, was identified in Trenches 3 and 4. They observed that fault splays in Trench 4 did not extend into the Bt horizon and appeared to terminate just below it. The fault displaced a claystone marker bed 14 to 16 inches with east-side-down separation and was characterized as a poorly developed flower structure below the Bt horizon which rooted down to a single fault splay at depth.

Review of logs for Trenches 1 and 2 suggests that the fault extended up through native materials and terminated at the contact with overlying artificial fill, suggesting an age-undetermined classification of the fault. The fault observed in Trench 1 included sand-filled fissures and shears shown adjacent to a Bt_K argillic soil horizon. The log for Trench 2 illustrates fault shears displacing a claystone bed with east side down separation. The fault shears are shown extending upward through terrace deposits with weak soil development (Bt) to the overlying contact with artificial fill.

SCST considered the fault a minor, isolated strand of an older fault not associated with the San Diego Fault, based on the minimal 14 to 16 inches of offset observed, and termination of the fault below the Bt horizon in Trenches 3 and 4. They concluded the major strand of the San Diego Fault, if it exists, was likely located east of the site.

CTE (2012c) performed a fault hazard investigation for the parcel directly south across Ash Street (Locality 41 - project address 445 West Ash Street) and bound by A, Columbia, Ash and State Streets. They suggested the fault observed by SCST at Locality 35 may be correlated with a western splay of the San Diego Fault identified by Law (2000) at Locality 34. See Table 1, for additional information on Locality 41.

Discussion and Recommendations for Zoning

The investigation by URS (2011) for the San Diego Central Courthouse provides strong evidence that the Holocene-active San Diego Fault projects along a northwest trend approximately 275 meters beyond its current mapped trace just north of Broadway. SCST (2000) documented a fault approximately two blocks northwest of the URS study along the northwest projection of the San Diego Fault. The fault exhibited a northwest trend, steep eastward dip, and down to the east vertical separation similar to the San Diego Fault less than 300 meters to the south. SCST concluded that activity on the fault was pre-Holocene based on an unfaulted argillic soil horizon observed in two trenches at the site. However, it appears that other trenches at the site indicate age-undetermined faulting. Based on the character and style of faulting documented by SCST and close proximity to the San Diego Fault, we interpret this fault to be the northward projection of the San Diego Fault and recommend extending the current APEFZ to include it. North of Locality 35, the San Diego Fault projects toward a concealed trace of the Rose Canyon Fault mapped by Kennedy and Tan (2008). However, site investigations in the Little Italy area of downtown San Diego (Plate 1) either: 1) did not identify the fault, 2) determined the faults are pre-Holocene in age, or 3) were not available for our review. At this time, we are unable to make recommendations for zoning in this area.

RECOMMENDATIONS FOR ZONING

Recommendations for encompassing faults in Alquist-Priolo Earthquake Fault Zones are based on the criteria of “sufficiently active” and “well-defined” (Bryant and Hart, 2007). The principle traces of the Rose Canyon Fault Zone as shown on Plate 3 are recommended for zoning as they are well-defined and believed to be active.

Michael J. DeFrisco
Engineering Geologist
PG 8624, CEG 2574

Timothy Dawson
Senior Engineering Geologist
PG 8502, CEG 2618

Aerial Photographs Reviewed

San Diego County, 1928 Scale 1:13,000 ± 2000 b/w 8x10

Frames: 59A6, 59A7, 59B5, 59B6, 59B7, 59C5, 59C6, 59C7, 59D5, 59D6, 59D7, 59E5, 59E6, 59E7, 66E7, 66E8, and 66E9

Acknowledgements

I would like to thank the following people for their assistance with obtaining fault investigation reports and completing this study: James Quinn, Dr. Thomas Rockwell, Luke Weidman, Diane Murbach, Carolyn Glockhoff, Robert Stroh, Scott Rugg, Jill Sommerville, Sharon Humphreys, Gordon Seitz, and Timothy Dawson.

REFERENCES

AECOM, 2017, Fault Investigation, Morena Pump Station, WW Force Main, and Brine Conveyance Predesign (NC01), San Diego, California, Project No. 60530732, dated August 31, 2017 (2nd Revision).

Applied Earth Technology, 2006, Soil Investigation and Geologic Investigation, Proposed Condominium Building Site, 1667-73 Puterbaugh Street, San Diego, California, Project No. 05-1268H6, dated February 17, 2006.

Artim, E.R., and Streiff, D., 1981, Trenching the Rose Canyon Fault Zone, San Diego, California: Woodward-Clyde Consultants, Final Technical Report, Sponsored by U.S. Geological Survey Contract No. 14-08-0001-19118, 34 p.

Bagahi Engineering, Inc., 2008, Geologic Fault Investigation, Proposed Retail Center, 2576 Clairemont Drive, Mission Bay, San Diego, CA, Project No. 181D-200-01, dated June 17, 2008.

Bennett, R.A., Rodi, W., and Reilinger, R.E., 1996, Global Positioning System constraints on fault slip rates in southern California and northern Baja, Mexico, Journal of Geophysical Research, vol. 101, No. B10, pp. 21,943-21,960.

Bryant, W.A., and Hart, E.W., 2007, Fault-Rupture Hazard Zones in California, Alquist-Priolo Earthquake Fault Zoning Act with Index to Earthquake Fault Zones Maps: California Geological Survey, Special Publication 42, 42 p. (digital version only, electronic document available at Special Publication 42).

Bronk-Ramsey, C., 1994, Analysis of Chronological Information and Radiocarbon Calibration: The Program OxCal. *Archaeological Computing Newsletter, 41*, 11-16.

California Division of Mines and Geology (CDMG), 1991, Special Studies Zones, La Jolla Quadrangle, Official Map, Effective November 1, 1991, 1:24,000.

California Geological Survey (CGS), 2003, Special Studies Zone, Point Loma Quadrangle, Official Map, Effective May 1, 2003, 1:24,000.

California Geological Survey (CGS), Revised 2018, Earthquake Fault Zones, A Guide For Government Agencies, Property Owners / Developers, and Geoscience Practitioners for Assessing Fault Rupture Hazards in California: Special Publication 42, 88 p., 2 plates.

Christian Wheeler Engineering, 2000, Report of Fault Study, Proposed Office Building Addition, 2415 San Diego Avenue, San Diego, California, CWE Project No. 199.673.3, dated April 18, 2000.

Construction Testing and Engineering (CTE), Inc., 1997, Geotechnical Investigation and Fault Study, Little Italy Family Housing Project, India Street and Cedar Street, San Diego, California, CTE Job No. 10-2275, dated June 16, 1997.

Construction Testing and Engineering (CTE), Inc., 1998, Geotechnical and Fault Investigation, Proposed Marriot Residence Inn, Elm Street and Pacific Highway, San Diego, California, CTE Job No. 10-2730, dated March 23, 1998.

Construction Testing and Engineering (CTE), Inc., 1999a, Geotechnical and Fault Investigation, Proposed Residential Development, SWC Cedar and State Streets, San Diego, California, CTE Job No. 10-3187, dated March 18, 1999.

Construction Testing and Engineering (CTE), Inc., 1999b, Geotechnical and Fault Investigation, Proposed Residential Development, NEC Cedar Street and Kettner Boulevard, San Diego, California, CTE Job No. 10-3274, dated June 28, 1999.

Construction Testing and Engineering (CTE), Inc., 2000a, Geotechnical Investigation, Proposed "The Park at Little Italy" Development, Kettner Boulevard Between Date and Cedar Streets, San Diego, California, CTE Job No. 10-4347, dated December 6, 2000.

Construction Testing and Engineering (CTE), Inc., 2000b, Geotechnical and Fault Investigation, Proposed Porto Siena Project, Little Italy Neighborhood, San Diego, California, CTE Job No. 10-3569, revised date February 21, 2000.

Construction Testing and Engineering (CTE), Inc., 2000c, Geotechnical and Fault Investigations, Proposed Chesapeake Luxury Apartments Project, San Diego, California, CTE Job No. 10-4354, dated December 15, 2000.

Construction Testing and Engineering (CTE), Inc., 2001a, Quaternary Fault Investigation, Proposed Harbor View Condominium Project, San Diego, California, CTE Job No. 10-4696, dated October 5, 2001.

Construction Testing and Engineering (CTE), Inc., 2001b, Fault Hazard Investigation, Proposed Park at Little Italy Project, San Diego, California, CTE Job No. 10-4347, dated November 7, 2001.

Construction Testing and Engineering (CTE), Inc., 2002a, Preliminary Geotechnical and Fault Investigation, Proposed Development 1918-1924 Columbia Street, San Diego, California, CTE Project No. 10-5443, dated May 10, 2002.

Construction Testing and Engineering (CTE), Inc., 2002b, Geotechnical and Fault Investigation, Proposed Billboard Lofts Project, NWC Ash and Union Streets, San Diego, California, CTE Job No. 10-5107, August 1, 2002.

Construction Testing and Engineering (CTE), Inc., 2006, Updated Preliminary Geotechnical and Fault Investigation, Proposed Residential Development, 1845 Titus Street, San Diego, California, CTE Project No. 10-8446G, dated July 6, 2006.

Construction Testing and Engineering (CTE), Inc., 2009, Fault Hazard Investigation, Proposed Columbia Towers, 1231 India Street, San Diego, California, CTE Project No. 10-9921G, dated April 22, 2009.

Construction Testing and Engineering (CTE), Inc., 2012a, Preliminary Geotechnical Investigation, Proposed Canada Dry Development, 1895 Hancock Street, San Diego, California, CTE Project No. 10-11166G, dated August 27, 2012.

Construction Testing and Engineering (CTE), Inc., 2012b, Fault Hazard Investigation, Proposed Hilton Garden Inn, 4200 Taylor Street, San Diego, California, CTE Project No. 10-11003G, dated May 7, 2012 (revised May 22, 2012).

Construction Testing and Engineering (CTE), Inc., 2012c, Fault Hazard Investigation, Midrise Development, 445 West Ash Street (APN: 533-402 thru 533-402-06), San Diego, California, CTE Job No. 10-11018G, dated March 30, 2012.

Construction Testing and Engineering (CTE), Inc., 2013a, Fault Hazard Investigation, Proposed Commercial Development, 2266 Kettner Boulevard, San Diego, California, CTE Job No. 10-11309G, dated August 20, 2013.

Construction Testing and Engineering (CTE), Inc., 2013b, Fault Hazard Investigation, Proposed Fat City Development, 2137 Pacific Coast Highway, San Diego, California, CTE Job No. 10-11039G, dated June 25, 2012, Revised February 4, 2013.

Construction Testing and Engineering (CTE), Inc., 2014a, Interim As-Graded Report, Harbor View Hotel Grading/ROW, San Diego, California, CTE Job No. 10-11039G, dated May 19, 2014.

Construction Testing and Engineering (CTE), Inc., 2014b, Fault Hazard Investigation, Proposed Development, 520 West Ash Street (APN: 533-334-05 and 06), San Diego, California, Job No. 10-12232G, dated October 31, 2014.

Construction Testing and Engineering (CTE), Inc., 2015, Preliminary Geotechnical and Fault Hazard Investigation, Proposed Restaurant Tenant Improvements, 2210 Kettner Boulevard, San Diego, California, CTE Job No. 10-12346GG, dated May 18, 2015.

Construction Testing and Engineering (CTE), Inc., 2016a, Preliminary Geotechnical and Fault Hazard Investigation, Proposed Born & Raised Tenant Improvements, 1909 India Street, San Diego, California, CTE Job No. 10-12851G, dated February 4, 2016.

Construction Testing and Engineering (CTE), 2016b, Update to Interim As-Graded Report, Proposed Lane Field South Hotel, North of West Broadway between Pacific Highway & Harbor Drive, San Diego, California, Project No. 463586, Tilted: Lane Field South (Garage Frame), CTE Project No. 10-12427T, dated August 23, 2016.

Construction Testing and Engineering (CTE), 2017a, Interim As-Graded Report, Proposed High Rise Development, 520 West Ash Street (APN: 533-334-05 and 06), San Diego, California, CTE Project No. 10-12232G, dated January 31, 2017

Construction Testing and Engineering (CTE), 2017b, Interim As-Graded Report, Proposed 401 West Ash Street – Carte Hotel Development, 401 West Ash Street, San Diego, California, CTE Project No. 10-12750G, dated August 7, 2017.

Construction Testing and Engineering (CTE), 2018, Interim As-Graded Report, Final As-Graded Geotechnical Report, Proposed Development, 520 West Ash Street (APN: 533-334-05 and 06), San Diego, California, CTE Project No. 10-12232G, dated January 17, 2018.

Converse Consultants, 2000a, Report of Geologic Hazards Evaluation and Geotechnical Investigation, The Park at Little Italy, San Diego, California, Converse Project No. 99-32191-02, July 21, 2000.

Converse Consultants, 2000b, Report of Geologic Hazards Evaluation and Geotechnical Investigation, Property Bounded by State, Cedar, Union and Beech Streets, Little Italy in San Diego, California, Converse Project No. 00-32-341-01, dated August 25, 2000.

Davis Earth Materials, Inc., 2007, As-Built Geology Report for: Sapphire Tower / Santa Fe 6, Kettner Blvd & A Street, San Diego, California, Project No. 05-01.02, Dated March 22, 2007.

Earthquake Engineering Research Institute (EERI), 2020, San Diego Earthquake Planning Scenario: Magnitude 6.9 on the Rose Canyon Fault Zone, Earthquake Engineering Research Institute, Oakland, CA, available at: https://sandiego.eeri.org/.

Elder, D.L., 1982, A critical examination and evaluation of the structure and stratigraphy in the downtown San Diego area, California: unpublished M.S. thesis, San Diego State University, 149 p.

Elder-Mills, D., 1982, Recognition and age of the San Diego fault, San Diego, California [abst.]: Geological Society of America Abstracts with Programs, v. 14, no. 4, p. 161.

Engineering Geology Consultants, 2000, Soil/Geological Investigation, Proposed 28 Unit Addition to Hacienda Hotel, Existing County Parking Lot and Adjacent Slope Areas, SW Corner of Intersection of Juan and Harney Streets, San Diego, California, Project No. 00-22, dated October 22, 2000.

Farrand, G.T., and Elliot, W.J., 1979, Road log to selected geologic hazards, San Diego metropolitan area, *in* Abbot, P.L., and Elliot, W.J., eds., Earthquakes and other Perils, San Diego Region: San Diego Association of Geologists, prepared for Geological Society of America field trip, November 1979, p. 217-227.

Gastil, R.G., Kies, R., and Melius, D.J., 1979, Active and potentially active faults: San Diego County and northernmost Baja California, *in* Abbot, P.L., and Elliot, W.J., eds., Earthquakes and other Perils, San Diego Region: San Diego Association of Geologists, prepared for Geological Society of America field trip, November 1979, p. 47-60.

Geocon, Inc., 1997, Fault Investigation, B Street and Union Street Parcel, San Diego, California, Geocon Project No. 06022-51-01, dated December 29, 1997.

Geocon, Inc., 1998, Fault Investigation, Parcel 533-313-09, San Diego, California, Geocon Project No. 06101-21-01, dated May 27, 1998.

Geocon, Inc., 2003a, (Draft) Preliminary Geotechnical Investigation, Pacific Highway Property APN 533-111-07-00, 2235 Pacific Highway, San Diego, California, Geocon Project No. 07075-52-01, dated June 6, 2003.

Geocon, Inc., 2003b, Geotechnical Investigation and Geologic Fault Investigation, Juniper Self-Storage Project, Juniper Street Between Kettner Boulevard and India Street, San Diego, California, Geocon Project No. 07121-22-02, dated November 11, 2003.

Geocon, Inc., 2003c, Geotechnical Investigation and Geologic Fault Investigation, Cedar/Kettner Parking/Residential Structure, San Diego, California, Geocon Project No. 06851-22-02, revised date October 14, 2003.

Geocon, Inc., 2005, Juniper Self-Storage Project, Juniper Street Between Kettner Boulevard and India Street, San Diego, California Addendum No. 2, Geocon Project No. 07121-22-02, dated May 4, 2005.

Geocon, Inc., 2012a, Revised Geotechnical and Geologic Fault Investigation, Lane Field, Pacific Highway and West Broadway, San Diego, California, Geocon Project No. 07769-22-01, revised date September 14, 2012.

Geocon, Inc., 2012b, Response to Review Comments, Lane Field, Broadway Between Pacific Highway and Harbor Drive, San Diego, California, Geocon Project No. 07769-52-02, dated November 15, 2012.

Geocon, Inc., 2016a, Site-Specific Fault Rupture Hazard Investigation, Pacific Gateway Complex, San Diego, California, Geocon Project No. 07695-52-02, Revised date May 13, 2016.

Geocon, Inc., 2016b, Response to City Comments, Pacific Gateway Complex, San Diego, California, Geocon Project No. 07695-52-02, Revised date May 17, 2016.

Gingery, J. R., Rugg, S.H., Hilton, B.R., and Rockwell, T.K., 2010, Fault Hazard Characterization for a transportation Tunnel Project in Coronado, California; Fifth International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics and Symposium in Honor of Professor I.M. Idriss: San Diego, California, Paper No. 7.0c, 13 pp.

Geotechnics Incorporated, 2000, Geotechnical Investigation, Caltrans Office Building Replacement, San Diego, California, Geotechnics Project No. 0166-004-00, Dated August 17, 2000.

Geotechnics Incorporated, 2001, Report of Subsurface Investigation, Columbia Street Lofts, San Diego, California, Project No. 0660-001-00, dated August 17, 2001.

Grant, L.B. and Rockwell, T.K., 2002, A Northward Propagating Earthquake Sequence in Coastal Southern California: Seismological Research Letters, v. 73, no.4, p. 461-469.

Grant, L.B., and Shearer, P.M., 2004, Activity of the Offshore Newport-Inglewood Rose Canyon Fault Zone, Coastal Southern California, from Relocated Microseismicity, Bulletin of the Seismological Society of America, Vol. 94, No. 2, pp.747-752.

Hart, M., 2002, Geologic Investigation, San Juan Road Residential Site, San Diego, California, File No. 518-2002, dated September 1, 2002.

Judy, T.C., 1987, Reconnaissance geology of the Holocene lagoonal deposits in the La Jolla submarine canyon and their relationship to the Rose Canyon fault: [unpublished] *in* San Diego State University, Department of Geological Sciences, Undergraduate Research Reports, v. 49, 15 p.

Kahle, J.E., 1988, A Geomorphic Analysis of the Rose Canyon, La Nacion, and Related Faults in the San Diego Area, California: California Division of Mines and Geology, Fault Evaluation Report FER-196, unpublished, 14p., 1 plate (1:100,000), dated June 30, 1988.

Kennedy, M.P., 1975, Geology of the Western San Diego Metropolitan Area, California; Del Mar, La Jolla, and Point Loma Quadrangles, *in* Geology of the San Diego Metropolitan Area, California: California Division of Mines and Geology Bulletin 200, p. 9-39.

Kennedy, M.P., Tan, S.S., Chapman, R.H., and Chase, G.W., 1975, Character and Recency of Faulting, San Diego metropolitan area, California: California Division of Mines and Geology Special Report 123, 33 p.

Kennedy, M.P., and Clarke, S.H., 1999a, Analysis of late Quaternary faulting in San Diego Bay and hazard to the Coronado Bridge: California Department of Conservation, Division of Mines and Geology Open-File Report 97-10A

Kennedy, M.P., and Clarke, S.H., 1999b, Age of faulting in San Diego Bay in the vicinity of the Coronado Bridge – an addendum to – Analysis of late Quaternary faulting in San Diego Bay and hazard to the Coronado Bridge: California Department of Conservation, Division of Mines and Geology Open-File Report 97-10B

Kennedy, M.P. and Tan, S.T., 2008, Geologic Map of the San Diego 30’ x 60’ Quadrangle, California: California Geological Survey, Regional Geologic Map Series, 1:100,000 Scale, Map No. 3.

Kleinfelder, 2001, Fault Hazard Investigation, Northeast Corner of Pacific Highway and F Street, San Diego California, dated May 24, 2001.

Kleinfelder, 2002a, Limited Fault Study, Santa Fe Depot, Parcel 2, San Diego, California, Project No. 13669, Dated August 1, 2002.

Kleinfelder, 2002b, Supplemental Fault Study, Santa Fe Depot, Parcel 2, San Diego, California, Project No. 13669, dated August 21, 2002.

Kleinfelder, 2002c, Addendum Supplemental Fault Study, Santa Fe Depot, Parcels 2 and 3, San Diego, California, Project No. 13669, Dated October 16, 2002.

Kleinfelder, 2003a, Supplemental Fault Study, Santa Fe Depot, Parcel 3, San Diego, California, Project No. 13669, Dated February 25, 2003.

Kleinfelder, 2003b, Supplemental Fault Hazard Evaluation, SDG&E Station B Site, Kettner Boulevard Between E Street and Broadway, San Diego, California, Kleinfelder Project No. 22648, June 23, 2003.

Kleinfelder, 2004a, Report of Earthquake Fault Study, 820 Ash Street, 1405 and 1431 Pacific Highway, Assessor Parcel Numbers 533-326-02, and -04, San Diego, California, Project No. 34496, Dated February 9, 2004.

Kleinfelder, 2004b, Geotechnical Investigation and Fault Hazard Evaluation, Proposed Residences, Santa Fe Depot Parcel 4, San Diego California, Project No. 17017, Dated August 18, 2004.

Kleinfelder, 2004c, Geotechnical Investigation, 820 Ash Street, 1405 and 1431 Pacific Highway, Assessor Parcel Numbers 533-326-02, and -04, San Diego, California, Project No. 47425, Dated October 20, 2004.

Kleinfelder, 2005, Interim Basement Excavation Geologic Inspection, Electra at 700 West E Street, San Diego, California, Kleinfelder Project No. 22648, Dated June 10, 2005.

Kleinfelder, 2006, Report of Earthquake Fault Hazard Study, City Block Bounded By Ash Street, Kettner Boulevard, A Street and Rail Transit Corridor, Project No. 61165, Dated January 26, 2006.

Kleinfelder, 2007a, Report of Earthquake Fault Hazard Study, Santa Fe Depot Parcel 1, Northeast Corner of Broadway and Pacific Highway, San Diego, California, Project No. 76212, Revised Date January 2, 2007

Kleinfelder, 2007b, Final Basement Excavation Geologic Inspection, Bayside Condominium Tower, Southeast Corner Ash Street and Pacific Highway, San Diego, California, Project No. 76751, Dated April 13, 2007.

Kleinfelder, 2012a, Fault Hazard Study, Proposed Southside Airfield – East Ovals, San Diego International Airport, San Diego, California, dated May 14, 2012, Project No. 125769.

Kleinfelder, 2012b, Fault Hazard Study, Proposed Conrac Site, San Diego International Airport, San Diego, California, dated June 12, 2012, Project No. 126619.

Kleinfelder, 2013a, TDY Fault Study, San Diego International Airport, San Diego, California, dated March 29, 2013, Project No. 125800.

Kleinfelder, 2013b, North Side Fault Study, San Diego International Airport, San Diego, California, dated April 2, 2013, Project No. 128500.

Kleinfelder, 2015, Mid-Coast Corridor Transit Project, Earthquake Fault Rupture Field Investigation, prepared for the San Diego Association of Governments (SANDAG), dated October 15, 2015.

Kleinfelder, 2016, Interim As-Graded Report, Soil Special Inspection Verification, Project Wide Geologic Mapping and Tower Crane Foundation Excavation, Kettner Boulevard and West Ash Street, Santa Fe Depot, Parcel 5, San Diego, California, Project No. 20170383.001A, Dated August 23, 2016.

Kleinfelder, 2017, Final As-Graded Report, Soil Special Inspection Verification, Foundation Excavation, Pacific and Broadway Development – Pacific Gate, Santa Fe Depot, Parcel 9, San Diego, California, Project No. 20154419.001A, Dated April 6, 2017.

Kleinfelder, 2019, Fault Hazard Investigation, Kennebec Railcar Storage Structure, Vacant Lot Southwest of Intersection of Washington Street and Railroad R.O.W., San Diego, California, dated June 3, 2019.

Law Crandall, 2000, Report of Fault Surface rupture Investigation, San Diego County Property between Broadway and “A” Street and Union Street and Front Street, San Diego, California, dated September 22, 2000, Law/Crandall Project No. 70300-9-0119.02.

La Monte, C.W., Company, Inc., 2008, Addendum to Report of Limited Geotechnical Investigation and Response to City of San Diego Geotechnical and Geological Review, Sterling Residence Renovation, 2261 San Juan Road, San Diego, California, APN: 443-520-12-00, Job No. 075375, dated February 18, 2008.

Legg, M.R., 1985, Geologic Structure and tectonics of the Inner Continental Borderland offshore northern Baja California, Mexico (Ph.D. thesis): Santa Barbara, University of California, 410 p.

Leighton and Associates, Inc., 1999a, Geotechnical Investigation and Fault Study, Proposed Commercial Development, State and B Streets, San Diego, California, Leighton Project No. 4990123-001, dated July 15, 1999.

Leighton and Associates, Inc., 1999b, Geotechnical Investigation and Fault Study, Proposed Residential Structure, A & B Streets at Kettner Blvd. and India Street, San Diego, California, Leighton Project No. 4990212-001, dated October 27, 1999.

Leighton and Associates, Inc., 2002, Observation of Onsite Faulting, Doma, Proposed Townhouse and Loft Complex, West of Kettner Boulevard, Between Fir and Date Streets, San Diego, California, Project No. 040314-002, dated January 10, 2002 (presented as an appendix in URS, 2005 report).

Leighton and Associates, Inc., 2009, Geotechnical and Fault Investigation, 1907 Columbia Street, San Diego, California, Leighton Project No. 042412-001, dated September 10, 2009.

Leighton and Associates, Inc., 2015, Geotechnical and Fault Investigation, 1st and Beech Street, San Diego, California, Leighton Project No. 11088.001, dated August 25, 2015.

Liem, T.J., 1977, Late Pleistocene maximum age of faulting, southeast Mission Bay area, San Diego, California, *in* Farrand, G.T., ed., Geology of southwestern San Diego County, California and northwestern Baja California: San Diego Association of Geologists, p. 61-64.

Lindvall, S.C., Rockwell, T.K., and Lindvall, C.E., 1989, The Seismic Hazard of San Diego Revised: New Evidence for Magnitude 6+ Holocene Earthquakes on the Rose Canyon Fault Zone *in* Proceedings, Workshop on “The Seismic Risk in the San Diego Region: Special Focus on the Rose Canyon Fault System”, June 29-30, 1989: The Southern California Earthquake Preparedness Project, p. 71-79.

Lindvall, S.C. and Rockwell, T.K., 1995, Holocene activity of the Rose Canyon Fault Zone in San Diego, California, Journal of Geophysical Research, v. 100, no. B12, pp. 24,141-24,132.

Liu, J.P., Milliman, J.D., Gao, S., and Cheng, P., 2004, Holocene development of the Yellow River’s subaqueous delta, North Yellow Sea. Marine Geology, 209 (1-4): 45-67.

MACTEC, 2005, Report of Geotechnical Hazards Evaluation Update, Archstone Harborview Apartments, Between Pacific Highway and ATSF Railroad Tracks, and Between F and G Streets, San Diego, California, Project 5014-05-0010, dated May 16, 2005.

Maloney, J.M., 2013, Fault segments and step-overs: Implications for geohazards and biohabitats (Ph.D. thesis): San Diego, Scripps Institute of Oceanography, University of California, 210 p.

Moore, G.W. and Kennedy, M.P., 1975, Quaternary faults at San Diego Bay, California, U.S. Geological Survey, Journal of Research, v. 3, no. 5, p. 589-595.

Ninyo & Moore, 2007, Geotechnical and Fault Evaluation, The Q Project, Fir and Kettner Boulevard, San Diego, California, N&M Project No. 106139001, dated December 13, 2007.

Ninyo & Moore, 2011, Update Geotechnical and Fault Evaluation, Ariel Suites Project, SWC West Beech Street and Kettner Boulevard, San Diego, California, N&M Project No. 106427003, dated June 8, 2011.

Ninyo and Moore, 2018, Fault Hazard Evaluation, World Class Waterfront Development, San Diego, California, Project No. 108290001, dated February 26, 2018.

Prater, R.R., 1998, Geologic Investigation, Bay View Plaza, Clairemont Drive and Moreno Boulevard, San Diego, California, dated November 12, 1998.

Reimer, P., Austin, W., Bard, E., Bayliss, A., Blackwell, P., Bronk Ramsey, C., Butzin, M., Cheng, H., Edwards, R., Friedrich, M., Grootes, P., Guilderson, T., Hajdas, I., Heaton, T., Hogg, A., Hughen, K., Kromer, B., Manning, S., Muscheler, R., Palmer, J., Pearson, C., van der Plicht, J., Reimer, R., Richards, D., Scott, E., Southon, J., Turney, C., Wacker, L., Adolphi, F., Büntgen, U., Capano, M., Fahrni, S., Fogtmann-Schulz, A., Friedrich, R., Köhler, P., Kudsk, S., Miyake, F., Olsen, J., Reinig, F., Sakamoto, M., Sookdeo, A., & Talamo, S., 2020, The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). Radiocarbon, Vol 62, Nr 4, 2020, p 725-757.

Rockwell, T.K., Lindvall, S., Haraden, C.C., Hirabayashi, K.C., Baker, E., 1991, Minimum Holocene Slip Rate for the Rose Canyon Fault in San Diego, California, in *Environmental Perils: San Diego Region*, edited by Patrick L. Abbot and William J. Elliott, 37-46. San Diego, CA: San Diego Association of Geologists for the Geological Society of America Annual Meeting.

Rockwell, T.K., Schug, D.L., and Hatch, M.E., 1993, Late Quaternary Slip Rates Along the Agua Blanca Fault, Baja California, Mexico, in P.L. Abbott (editor), *Geological Investigations of Baja California*, South Coast Geological Society, Annual Field Trip Guidebook No. 21, P. 53-92.

Rockwell, T.K. and Murbach, M.L., 1999, Holocene Earthquake History of the Rose Canyon Fault Zone: U.S. Geological Survey Final Technical Report for Grant No. 1434-95-2613.

Rockwell, T.K., 2010a, The Rose Canyon Fault Zone in San Diego: Fifth International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics and Symposium in Honor of Professor I.M. Idriss: San Diego, California, Paper No. 7.06c, 9 pp.

Rockwell, T.K., 2010b, Seismic Source Characteristics of Onshore Rose Canyon Fault. *San Onofre Nuclear Generating Station Seismic Hazard Assessment Program 2010 Seismic Hazard Analysis Report; Appendix A, Attachment A-2.*

Rockwell, T.K., Murbach, M., Murbach, D., Rockwell, K., Haaker, E., Sarmiento, A., and Smith, B.F., 2012, Paleoseismic Assessment of the Late Holocene Rupture History of the Rose Canyon Fault in San Diego, by Geopentech, Tom Freeman (editor), prepared for Southern California Edison, San Onofre Nuclear Generating Station, Seismic Source Characterization Research Project, December, 2012 (unpublished).

Sahakian, V., J. Bormann, N. Driscoll, A. Harding, G. Kent, and S. Wesnousky, 2017, Seismic Constraints on the architecture of the Newport-Inglewood/Rose Canyon Fault: Implications for the length and magnitude of future earthquake ruptures, Journal of Geophysical Research 122, no. 3, 2085-2105.

San Diego Association of Governments (SANDAG), 2014, *Mid-Coast Corridor Transit Project, Geotechnical, Geologic, and Seismic Impacts Technical Report*, dated August 2014.

San Diego Seismic Safety Study (SDSSS), 2008, City of San Diego Seismic Safety Study, Geologic Hazards and Faults, City of San Diego Development Services Department, explanation revised and updated 2018.

Southern California Soil & Testing (SCST), Inc., 2000, Fault Investigation, Proposed Little Italy Project, San Diego, California, SCS&T 0011150, dated October 10, 2000.

Southern California Soil & Testing (SCST), Inc., 2001, Foundation Investigation, Proposed Little Italy Residential Project, San Diego, California, SCS&T 0011150, dated March 29, 2001.

Southern California Soil & Testing (SCST), Inc., 2003, Geologic and Fault Observations, Allegro Towers, Kettner Boulevard Between Ash and Beech Streets, San Diego, California, Plan File Numbers: A111482-02, Foundation and Frame and A113472-02, Building, SCS&T No. 0312091, dated July 30, 2003.

Southern California Soil & Testing (SCST), Inc., 2004a, Fault Evaluation, APN 533-344-10-00, 1454 Union Street, San Diego, California, SCST No. 0411006, dated September 16, 2004.

Southern California Soil & Testing (SCST), Inc., 2004b, Response to Review of Fault Evaluation, 1454 Union Street, San Diego, California, APN 533-344-10-00, SCST No. 0411006 report no. 4, dated November 18, 2004.

Southern California Soil & Testing (SCST), Inc., 2012, Significant Geologic Hazards Letter, Ariel Suites, West of Kettner Boulevard between Ash and Beech Streets, San Diego California, SCS&T No. 1112185, dated June 26, 2012.

Singleton, D.M., Rockwell, T.K., Murbach, D., Murbach, M., Maloney, J.M., Freeman, T., Levy, Y., 2019, Late-Holocene Rupture History of the Rose Canyon Fault in Old Town, San Diego: Implications for cascading earthquakes on the Newport-Inglewood-Rose Canyon Fault System, Bulletin of the Seismological Society of America, Vol. 109, No. 3, pp. 855-874, June 2019.

Streiff, D., Elder-Mills, D., and Artim, E.R., 1982, The Rose Canyon fault zone, downtown San Diego and Coronado, *in* Abbott, P.L., ed., Geologic Studies in San Diego: San Diego Association of Geologists Field Trips, April 1982, p. 12-27.

Treiman, J.A., 1984, The Rose Canyon Fault Zone, A Review and Analysis: unpublished report for Federal Emergency Management Agency (FEMA), cooperative agreement EMF-83-K-0148; California Department of Conservation, Division of Mines and Geology, August 1984, 106p.

Treiman, J.A., 1991, The Rose Canyon Fault Zone, San Diego County, California: California Department of Conservation, Division of Mines and Geology, Fault Evaluation Report FER-216, July 10, 1990, revised January 25, 1991, 14 p., and Supplement No.1 dated August 30, 1991, 2p.

Treiman, J.A., 1993, The Rose Canyon Fault Zone, southern California: California Department of Conservation, Division of Mines and Geology, Open-File Report 93-02, 45 p.

Treiman, J.A., 2002, Silver Strand Fault, Coronado Fault, Spanish Bight Fault, San Diego Fault and Downtown Graben, Southern Rose Canyon Fault Zone, San Diego, California: California Department of Conservation, Division of Mines and Geology, Fault Evaluation Report FER-245, June 17, 2002, and Supplement No.1 dated April 22, 2003, 12p.

United States Coast Survey Office, 1851, Map of San Diego Bay, California from Point Loma to New Town, Scale 1:10,000: Image from National Oceanic and Atmospheric Administration's (NOAA) Office of Coast Survey Historical Map & Chart Collection (available at http://historicalcharts.noaa.gov).

URS, 1998, Additional Fault Investigation, CVN berthing wharf – Phase II (P-700A), Naval Air Station, North Island, Coronado, California: unpublished consultants report, Project Number 589751124H00-OEQ01, August 7, 1998, revised December 16, 1998.

URS Greiner Woodward Clyde, 2000, Fault Hazard Investigation, Santa Fe Depot Property, San Diego, California, dated March 1, 2000.

URS, 2005, Fault Study and Preliminary Geotechnical Investigation, Metro Volkswagen Site, City Block Bounded by Grape, Kettner and West Fir Streets, Downtown San Diego, California, Project No. 27664037.40000, dated September 22, 2005.

URS, 2007, Fault Investigation for the Monarch School, San Diego, California, Project No. 27663045.00060, dated April 6, 2007.

URS, 2011a, *DRAFT* – Fault Hazard Investigation, Pedestrian Tunnel, San Diego Central Courthouse, San Diego, California, dated January 17, 2011, URS Project No. 27661014.10000.

URS, 2011b, Geotechnical Data Report, San Diego Central Court, Inmate Transfer Tunnel, Superior Court of California, County of San Diego, dated December 22, 2011, URS Project No. 27661014.30000.

URS, 2012, Response to Third Party Review Comments, Inmate Transfer Tunnel, San Diego Central Court House, Superior Court of California, County of San Diego, dated March 9, 2012, URS Project No. 27661014.10000.

URS, 2013, Geotechnical Investigation and fault Hazard Assessment, San Diego Central Court, Superior Court of California, County of San Diego, dated April 29, 2013, URS Project No. 27661014.10000.

URS, 2014, (Draft) Preliminary Geotechnical and Fault Hazard Investigation, Kettner Lofts, Kettner & Hawthorn, San Diego, California 92101, URS Project No. 27661314.10000, dated June 16, 2014.

URS, 2016, Interim As -Built Geologic Report, Geologic Observation of Basement Excavation, Kettner Lofts, 2155 Kettner Boulevard, San Diego, California 92101, City of San Diego Building Permit No. 421037, URS Project No. 60505165.10000, dated August 4, 2016.

URS, 2017, As-Built Geologic and Geotechnical Report, San Diego Central Courthouse, Superior Court of California, County of San Diego, California, URS Project No. 60397654.27661422.90000, City of San Diego Project No. 352854, Permit No. 1235225, dated April 25, 2017.

U.S. Geological Survey (USGS), 1904, San Diego Quadrangle Map, showing topography, Scale: 1:62,500.

U.S. Geological Survey (USGS), 1903, La Jolla Quadrangle Map, showing topography, Scale: 1:62,500.

U.S. Geological Survey (USGS) and California Geological Survey (CGS), Quaternary fault and fold database for the United States, accessed December 2019, at: USGS Quaternary Fault Database.

Vallage, A., Klinger, Y., Lacassin, R., Delorme, A., and Pierrot-Desellingny, M., 2016, Geological Structures control on earthquake ruptures: The M_W 7.7, 2013, Balochistan earthquake, Pakistan: Geophysical Research Letters, v.43, p. 10,155-10,163.

Weidman, L. C., 2017, Assessing the Rose Canyon fault zone architecture, downtown San Diego, California: Geotechnical data synthesis [M.S. Thesis], San Diego State University, 70 p.

Weidman, L., Maloney, J.M., and Rockwell, T. K., 2019, Geotechnical data synthesis for GIS-based analysis of fault zone geometry and hazard in an urban environment: Geosphere, v. 15, no. 6, p. 1999-2017, https://doi.org/10.1130/GES02098.1.

Weidman, L., Maloney, J., Rockwell, T., 2019, Geotechnical data synthesis for GIS-based fault zone analysis: Geodatabase, downtown San Diego, CA, Mendeley Data, https://doi.org/10.17632/k2prx886jz.

William Lettis & Associates (WLA), Inc., 2008a, Fault Rupture Hazard Investigation, Old Police Headquarters Modification Project, San Diego, California, Dated May 20, 2008.

William Lettis & Associates (WLA), Inc., 2008b, Addendum to William Lettis & Associates, Inc., Fault Rupture Hazard Investigation Report dated May 20, 2008, Old Police Headquarters Modification Project, 879 W. Harbor Drive, San Diego, California, City of San Diego Project No: 120660, Dated June 23, 2008.

Woodward-Clyde, 1994, Seismic Hazards Assessment, proposed Nimitz Class aircraft carrier homeporting project, Naval Air Station, North Island, Coronado, California: unpublished consultants report, PN 9351143H-EQ01, May 11, 1994.

Woodward-Clyde, 1995, Fault Hazard Investigation, San Diego Convention Center Expansion, San Diego, California, dated February 1995.

Woodward-Clyde, 1998a, Fault Hazard Investigation, 101 California High-Rise Condominium Project, San Diego, California, Woodward-Clyde Project No. 9851049A-FHS1, dated July 13, 1998.

Woodward-Clyde, 1998b, Geotechnical Investigation, 101 California High-Rise Condominium Project, San Diego, California, Woodward-Clyde Project No. 9851049A-SIO1, dated August 24, 1998.

SUPPLEMENT NO. 1

September 23, 2021

INTRODUCTION

This Supplement to Fault Evaluation Report (FER) 265 (DeFrisco, 2021) addresses comments and data received since the release of FER 265 and Preliminary Earthquake Fault Zone Maps for the Point Loma and La Jolla Quadrangles on February 18, 2021. Public comments and additional reports were provided to the State Mining and Geology Board (SMGB) or California Geological Survey during the designated 90-day public comment period that ended on May 19, 2021. Several additional reports also became available after preparation of the FER.

The reader is referred to Figure 1 in FER 265 for the location of the study area and other necessary background material.

PUBLIC COMMENTS and RESPONSE

Comments on FER 265 received by the SMGB are listed in Table 1. Those comments that present technical data and analysis (noted with an "*" in Table 1) are addressed in this supplemental report. Other comments of a non-technical nature are not discussed herein.

Table 1. Chronological Summary of Comments Received from the SMGB for the Point Loma and La Jolla Quadrangles Preliminary Earthquake Fault Zones Maps.

Comment No.	Date	Commenter	Document
1	3/2/2021	Don Wood Pacific Energy Policy Center	Email correspondence titled "Comment on new earthquake fault maps"
*2	3/10/2021	Shawn Weedon Geocon, Inc.	Email correspondence titled "State of California Earthquake Fault Zones"
*3	5/12/2021	James Quinn City of San Diego Development Services	Letter titled "Preliminary Review Maps of the La Jolla and Point Loma Quadrangles, City of San Diego"
*4	5/13/2021	Brendan Reed San Diego County Regional Airport Authority	Letter titled "Preliminary Review Maps of Proposed Earthquake Fault Zones of February 18, 2021 for Affected Cities and Counties"

Comment No.	Date	Commenter	Document
*5	5/18/2021	Kathryn Rhodes La Playa Heritage	Letter titled "Technical Review Comments on Fault Evaluation Report FER-265 for the Draft Alquist-Priolo (A-P) Maps for the Rose Canyon Fault Zone (RCFZ) in the Point Loma and La Jolla Quadrangles"

Comment 2

A comment was submitted to the SMGB by Shawn Weedon of Geocon, Inc., on March 10, 2021 (Table 1, Comment No. 2), with reference to the base map used for the Preliminary Alquist-Priolo Earthquake Fault Zones (APEFZ) Map for the Point Loma Quadrangle. Mr. Weedon noted that much of the downtown area has changed and some of roadways are different than how they are illustrated on the USGS topographic base map for the Preliminary APEFZ Map, specifically near Petco Park and west of 14th Street. He requested that the Point Loma Quad map be updated to include the updated San Diego backgrounds.

CGS Response, comment 2

The GIS data CGS distributes are the official Earthquake Fault Zones of record. This data may be imported into any GIS platform and a variety of base maps may be used with the data. CGS also distributes the Official Zone Maps via the online application "EQZapp" which can be viewed here: EQZapp link. This web tool also gives the user several options for displaying different base maps and imagery.

Comment 3

A comment letter was emailed to the SMGB by James Quinn of the City of San Diego Development Services Department, Engineering Division, on May 12, 2021. The letter provided technical review and comments on FER 265, Plates 1 and 2, and the recommended zoning of faults southeast of Washington Street and east of Interstate 5. Comments about content on FER 265 pages 1, 3, 5, 6, and 39 have been addressed in the revised FER 265 report dated August 18, 2021. All other comments are addressed in the following section:

Comment 3.1

Page 5 – First paragraph, last sentence states "Treiman (2002) did not reevaluate the area between De Anza Cove and the Downtown Area, leaving an ~10-km-gap that straddles the La Jolla and Point Loma 7.5-minute Quadrangles un-zoned." Consider providing additional context for this statement. For example, although the Rose Canyon Fault Zone was mapped between the area of De Anza Cove and the Downtown area by Kennedy (1975), reevaluation for potential zoning of this area was not undertaken due to the general paucity of detailed information on fault activity and location. From an earthquake fault zoning perspective, this resulted in an approximately 10-km-long gap between the AP zoned segments of the Rose Canyon Fault Zone on the La Jolla Quadrangle and the AP zoned splays of the Rose Canyon Fault Zone on the Point Loma Quadrangle.

<u>CGS response, comment 3.1</u>

Additional context has been added to the main text of FER 265 (revised date September 23, 2021).

<u>Comment 3.2, page 27</u>

Discuss the possibility that the roughly coast parallel “side hill benches” south of Washington Street represent uplifted coastal terraces.

<u>CGS response, comment 3.2</u>

Sidehill benches on slopes along the coastal areas of San Diego County may be suggestive of uplifted coastal terraces. However, additional geomorphic features suggestive of active faulting near Middletown include deflected drainages, ridgeline saddles, beheaded drainages, and offset canyon slopes. In addition, uplifted coastal terraces are generally characterized by a veneer of marine terrace deposits such as beach sand and gravel lag on the wave-cut abrasion platform, which are commonly buried by Quaternary alluvium or colluvium (Haaker *et al*., 2016). We are not aware of these deposits on the sidehill benches near Middletown.

We also note that Kern and Rockwell (1992) conclude there is a strong correlation between terrace width and relative erodibility of the bedrock in which the terrace is cut. Wide terraces tend to form where they cut into easily erodible formations, such as the San Diego Formation present at Middletown, and coastal terraces typically narrow to only a few tens of meters or less where they are cut into more resistant Cretaceous or Eocene Formations. Therefore, one would expect the sidehill benches near Middletown to be wider if they were formed as a result of coastal processes. Based on these observations and characteristics, we concur with Kleinfelder that the aligned geomorphic features are best interpreted as faulting.

<u>Comment 3.3</u>

Plate 1 shows the local downtown special fault zone; however, it does not show the buffer zones associated with mapped faults, which are also regulatory zones.

<u>CGS response, comment 3.3</u>

CGS notes that page 6 of the FER indicates that the San Diego Seismic Safety Study (SDSSS) identifies three geologic hazard categories with potential for ground rupture from faulting, one of them being areas 100-feet on both sides of mapped faults. We were unable to obtain GIS files for these zones; therefore, they are not illustrated on plates prepared for the FER, but we note that these regulatory zones within the City of San Diego are generally associated with mapped faults of the USGS/CGS Quaternary Fault and Fold Database for the United States.

Comment 3.4, Plate 1

Faults were discovered at Sites 54, 62, and 67 during construction.

CGS response, comment 3.4

CGS was not previously aware that faults were identified on these parcels. However, we obtained additional fault investigation reports from the City of San Diego since the closing of the FER comment period on May 19, 2021. The additional reports and their findings are discussed in the following section of this report titled Additional Fault Studies.

Comment 3.5, Plates

Consider adding coordinate control on right margin of Plate 1 and Plate 2, and bottom margin of Plate 2.

CGS response, comment 3.5

Coordinate ticks were added to the right and bottom margins of Plates 1 and 2.

Comment 3.6

The recommended EFZ southeast of Washington Street is apparently based on the projection of information and interpretation of geomorphic features as faults. While the interpretation of these geomorphic features as faults may be reasonable, it is not clear that the features represent *well defined* faults. In addition, direct evidence of Holocene surface displacement was not clearly established for the faults in this area.

CGS response, comment 3.6

The fault investigation by Applied Earth Technology (2006) at Puterbaugh Street (Plate 1, Locality 11) and the fault zone mapped by Kennedy *et al*. (1975) along Washington Street provide direct evidence for a fault zone along the alignment of geomorphic features mapped by Kleinfelder (SANDAG, 2014) through Middletown. The geomorphic features align well with active faulting between Old Town and the downtown graben, and the tectonic framework for the pull-apart basin that forms San Diego Bay suggests the presence of boundary fault between Old Town and downtown San Diego. Although Holocene-active faulting has not been demonstrated along the fault zone mapped by Kennedy *et al*. (1975) southeast of Washington Street, Holocene-active faulting is well documented at Old Town and downtown San Diego, indicating that a fault zone through Middletown may be sufficiently active as well. In addition, CTE (2006) identified a fault with a one-foot thick gouge zone at 1845 Titus Street (Plate 1, Locality 10). They interpreted the fault as possibly Holocene-active due to deposition of colluvium on the down-thrown side of the fault and a lack of cementation or carbonate accumulation within the gouge zone. Based on this data, we consider that the fault zone southeast of Washington Street meets the criteria for zoning described in CGS Special Publication SP 42.

Comment 4

A comment letter was emailed to the SMGB by Brendan Reed of the San Diego County Regional Airport Authority on May 13, 2021. The comment letter states that the Airport Authority was aware that the Spanish Bight and East Bay Faults traversed portions of the San Diego International Airport, and that they took no issue with the recommended new APEFZs for these faults. However, they recommended that the final APEFZ maps incorporate a more recent USGS base map.

CGS response, comment 4

The GIS data CGS distributes are the official Earthquake Fault Zones of record. This data may be imported into any GIS platform and a variety of base maps may be used with the data. CGS also distributes the Official Zone Maps via the online application "EQZapp" which can be viewed here: EQZapp link. This web tool also gives the user several options for displaying different base maps and imagery.

Comment 5

A comment letter was emailed to the SMGB by Katheryn Rhodes of La Playa Heritage on May 18, 2021.

CGS response, comment 5

CGS has reviewed the letter and did not find any technical comments that provide additional data to refine the mapping of the Rose Canyon Fault Zone or modify the preliminary Earthquake Fault Zones. Many of the comments deal with other earthquake hazards and local development issues that are beyond the scope of this report.

ADDITIONAL FAULT STUDIES

Site localities are presented on Plate 1 of this supplemental report.

In addition to the public comments received by the SMGB, additional geologic/geotechnical reports were provided directly to CGS during and immediately after the public comment period. All of the additional fault studies received were located within the San Diego Bay section and are illustrated on Plate 1. CGS evaluated this new data and incorporated it into this Supplemental FER and the Earthquake Fault Zone Map for the Point Loma Quadrangle. Brief summaries of the additional fault studies, as listed in Table 2, are presented in the following section.

Table 2. Summary of Documents Received outside of those submitted to the SMGB for the Point Loma and La Jolla Quadrangles Preliminary Earthquake Fault Zones Maps.

Date Received	Received from	Document
3/30/2021	Kleinfelder	Kleinfelder, 2017, Fault Hazard Study, CIP 400002B ADP-Programmatic Documents-ADC, San Diego International Airport, San Diego, California, Kleinfelder Project No. 20174291.001A, dated April 28, 2017.
5/20/2021	City of San Diego Development Services	Leighton and Associates, Inc., 2018, Geotechnical Investigation and Fault Hazard Study, Union and Ash Street, San Diego, California, Leighton Project No. 11467.002, dated May 31, 2018.
5/20/2021	City of San Diego Development Services	Leighton and Associates, Inc., 2019a, Geotechnical Response to City of San Diego Cycle 4 LDR-Geology Review Comments, 1566 Kettner Boulevard Civic SD, San Diego, California, Leighton Project No. 12215.001, dated October 17, 2019 (revised October 29, 2019). Includes as an attachment: "G" Force, 2015, As-Graded Geotechnical Report, San Diego County Parking Structure, Cedar Street and Kettner Boulevard, San Diego CA 92101, "G" Force Project No. GF13596, dated July 28, 2015.
5/20/2021	City of San Diego Development Services	Leighton and Associates, Inc., 2019b, Fault Hazard Study, Two America Plaza, 1111 Kettner Boulevard, San Diego, CA 92101, Leighton Project No. 12394.001, dated October 14, 2019.

Locality 54 – 1566 Kettner Boulevard

CGS previously identified this site as a “Locality with no faults” in FER 265 (Plate 1 and Table 3) based on a fault investigation conducted by Geocon (2003). However, an additional report provided by the City of San Diego (Leighton, 2019a) includes an As-Graded Geotechnical Report by G-Force (2015) as an attachment, which indicates that a fault was identified at the site during excavation of subterranean levels of the proposed parking structure. G-Force reportedly mapped a minor fault near the bottom of the northeast portion of the excavation within Old Paralic Deposits. Clay up to 3/8-inch-thick was observed along the fault, which was observed to trend N30-40E and dip 65-70NW and vertically offset laminar to thinly bedded mafic sediment layers up to ¾ inch. The fault was observed to be laterally discontinuous in the bottom of the excavation and did not extend above an elevation of 8 feet above mean sea level, and a thin residual soil horizon above the fault showed no evidence of displacement. G-Force concluded there was no evidence of active faulting. In Revised FER 265 dated August 18, 2021, Plate 1 and Table 1 have been updated to include the fault identified by G-Force at Locality 54.

Locality 62 and new Locality 74 – Kettner Boulevard and B Street

CGS previously identified Locality 62 as a "Locality with no faults" in FER 265 (Plate 1 and Table 3) based on a fault investigation conducted by Leighton (1999b). However, Leighton (2019b) conducted a Fault Hazard Study for a project located at 1111 Kettner Boulevard on the southeast corner of Kettner Boulevard and B Street (see new Locality 74 on FER 265, Plate 1). The fault investigation was limited to 20 Cone Penetration Tests (CPTs) located in India Street, B Street, and Kettner Boulevard, due to constraints prohibiting the excavation and logging of fault trench explorations at the site. Based on Geologic Cross Section A-A' constructed from CPT data along B Street, Leighton interpreted a minor fault with less than about 2 feet of apparent vertical displacement within the late Pleistocene-age Old Paralic Deposits. They concluded the fault was not Holocene-active based on the presence of a gravel deposit with a very consistent elevation across the project site located on the southeast corner of Kettner Boulevard and B Street (Locality 74), which they interpreted as evidence that the gravels have not been displaced by faulting.

Leighton (2019b) also reported that the fault aligned with a minor fault that was observed by Leighton personnel in 2001 near the bottom of the southeast corner of the basement excavation during construction of the Treo at Kettner project on the northeast corner of B Street and Kettner Boulevard (Plate 1, Locality 62).

Locality 67 – Pacific Gateway Complex – Southwest of Broadway and Pacific Highway

We understand that a fault was recently observed at the site during ongoing construction activities based on personal communication with Dr. Tom Rockwell (San Diego State University; April 2021) and James Quinn (City of San Diego, Development Services Department; May 2021). However, additional information was not provided to CGS for review.

New Locality 75 – Northeast Corner of Ash Street and Union Street

CGS received two additional fault investigation reports by Leighton and Associates, Inc., (Leighton, 2018 and 2021) from the City of San Diego for a new development on the northeast corner of Union Street and Ash Street in the downtown area. The initial fault investigation by Leighton (2018) included one fault trench approximately 84 feet long in the northern area of the site and 11 CPTs advanced in Ash Street south of the site. Leighton reported that the stratigraphy was observed to be continuous across the site and they concluded that faults did not transect the site. Based on the CPTs advanced in Ash Street, an approximate 6-foot elevation difference across a contact within Old Paralic Deposits (Qop1 and Qop2) was identified, but it was interpreted as a buried paleo shoreline, not a fault. They concluded that the CPTs, borings, and trench indicated the presence of continuous, unfaulted stratigraphy within the old paralic deposits at the site.

However, Leighton (2021) observed several northeast trending minor faults transecting the basement excavation during recent site construction activities. Vertical displacements were reportedly on the order of a few inches to 6 feet, but none of the faults were observed to deform or truncate a generally continuous and overlying late Pleistocene-age gravel lag deposit. Leighton concluded the faults were not considered Holocene-active or a surface rupture hazard.

New Locality 76 – San Diego International Airport

Kleinfelder West, Inc., performed an additional fault hazard evaluation (Kleinfelder, 2017) of the CIP 400002B ADP-Programmatic Documents-ADC project at the San Diego International Airport (SDIA). The site is located within the southern portion of the SDIA, north of the previous study for the TDY site (Kleinfelder, 2013a; FER 265 Plate 1, Locality 14), where an active segment of the Spanish Bight Fault was identified. The fault study consisted of 41 CPT soundings which were used to develop four stratigraphic cross sections across the anticipated northern projection of the Spanish Bight Fault. The results of their analysis indicated both Holocene-active and pre-Holocene faulting across the site within a zone co-aligned with the Spanish Bight Fault. The faulting was interpreted to be more robust on the southern portion of the site and to progressively diminish toward the northern portion of the site, where the fault zone was narrowest and displayed the least amount of apparent displacement. Kleinfelder concluded the Spanish Bight Fault appeared to be diminishing and dying out to the north, where it may not penetrate the Holocene-aged bay deposits that were dated to about 6 ka, and that it appeared to be much less significant than the East Bay Fault.

RECOMMENDATIONS

Modification of the Spanish Bight Fault is recommended as shown on Plate 3 based on the fault investigation conducted by Kleinfelder (2017) at the San Diego International Airport.

Michael J. DeFrisco
Engineering Geologist
PG 8624, CEG 2574

Timothy Dawson
Senior Engineering Geologist
PG 8502, CEG 2618

ADDITIONAL REFERENCES

Applied Earth Technology, 2006, Soil Investigation and Geologic Investigation, Proposed Condominium Building Site, 1667-73 Puterbaugh Street, San Diego, California, Project No. 05-1268H6, dated February 17, 2006.

California Geological Survey, Revised 2018, Earthquake Fault Zones, A Guide for Government Agencies, Property Owners / Developers, and Geoscience Practitioners for Assessing Fault Rupture Hazards in California: Special Publication 42, 88 p., 2 plates.

Construction Testing and Engineering (CTE), Inc., 2006, Updated Preliminary Geotechnical and Fault Investigation, Proposed Residential Development, 1845 Titus Street, San Diego, California, CTE Project No. 10-8446G, dated July 6, 2006

DeFrisco, Michael, 2021, The Rose Canyon Fault in the Point Loma and La Jolla 7.5 Minute Quadrangles, San Diego County, California: California Geological Survey, Fault Evaluation Report FER-265, dated February 18, 2021, revised August 18, 2021.

Haaker, E.C., Rockwell, T.K., Kennedy, G.L., Grant Ludwig, L., Freeman, S.T., Zumbro, J.A., Mueller, K.J., and Edwards, R.L., 2016, Style and rate of long-term uplift of the southern California coast between San Diego and Newport Beach with potential implications for assessing blind thrust models: *in* Anderson, R. and Ferriz, H. eds., Applied Geology in California: 679-719.

Kennedy, M.P., Tan, S.S., Chapman, R.H., and Chase, G.W., 1975, Character and Recency of Faulting, San Diego metropolitan area, California: California Division of Mines and Geology Special Report 123, 33 p.

Kleinfelder, 2013a, TDY Fault Study, San Diego International Airport, San Diego, California; Project No. 125800, dated April 2, 2013.

Kleinfelder, 2017, Fault Hazard Study, CIP400002B ADP-Programmatic Documents-ADC, San Diego International Airport, San Diego, California, Project No. 20174291.001A, dated April 28, 2017.

Leighton and Associates, Inc., 1999b, Geotechnical Investigation and Fault Study, Proposed Residential Structure, A & B Streets at Kettner Blvd. and India Street, San Diego, California, Leighton Project No. 4990212-001, dated October 27, 1999.

Leighton and Associates, Inc., 2018, Geotechnical Investigation and Fault Hazard Study, Union and Ash Street, San Diego, California, Leighton Project No. 11467.002, dated May 31, 2018.

Leighton and Associates, Inc., 2019a, Geotechnical Response to City of San Diego Cycle 4 LDR-Geology Review Comments, 1566 Kettner Boulevard CivicSD, San Diego, California, Leighton Project No. 12215.001, dated October 17, 2019 (revised October 29, 2019). Includes as an attachment: "G" Force, 2015, As-Graded Geotechnical Report, San Diego County Parking Structure, Cedar Street and Kettner Boulevard, San Diego CA 92101, "G" Force Project No. GF13596, dated July 28, 2015.

Leighton and Associates, Inc., 2019b, Fault Hazard Study, Two America Plaza, 1111 Kettner Boulevard, San Diego, CA 92101, Leighton Project No. 12394.001, dated October 14, 2019.

Leighton and Associates, Inc., 2021, Interim As-Graded Letter, Union and Ash Street, San Diego, California, City of San Diego PTS No. 648134, Grading Plan No. 41418-D, Leighton Project No. 11467.003, dated March 23, 2021.

San Diego Association of Governments (SANDAG), 2014, *Mid-Coast Corridor Transit Project, Geotechnical, Geologic, and Seismic Impacts Technical Report*, dated August 2014.

Table 1. Summary of pertinent fault investigation reports.

Locality No.	Reference	Reported Conclusions	Evaluation Comments
1	SANDAG, 2015	Geophysical surveys, fault trenches, CPTs and a cut-slope identified the presence of a significant fault and some minor faults which displaced Holocene alluvium.	Holocene-active and pre-Holocene
2	Bagahi, 2008	Fault trenches identified a fault with a clay-lined brecciated and sheared zone up to about 10 feet wide. Minor faults were also observed. No Holocene or surficial Quaternary soils present on site. However, main fault zone considered active due to close proximity to active RCFZ, and building setbacks recommended.	age-undetermined faults in bedrock
3	Prater, 1998	Trenching identified two main zones of faulting. The western fault zone was overlain by younger terrace deposits which were not faulted, and had a radiocarbon date of 28,600 ± 200 years old. The eastern fault zone included shear zones with clay gouge up to 6 inches thick, and displaced older terrace deposits against Scripps Formation. No topsoil or Holocene deposits were encountered.	pre-Holocene and age-undetermined faults The western fault appears to be pre-Holocene. However, the eastern fault zone appears to be age-undetermined.
4	AECOM, 2017	CPT transects indicate that Holocene age sediments are offset by a fault.	Holocene-active
5	Singleton et.al., 2019	Paleoseismic trenches at the Presidio Hills Golf Course on the main trace of the RCF contained evidence for historical ground rupturing earthquakes as recently as 1862 and the mid-1700s. Results of the study also suggest the RCF has a ~700-800 year recurrence interval.	Holocene-active
6	Leighton, 2007	Fault trenches at the Mormon Battalion Historic Site indicated several active fault traces transect the site. The fault observed in trench T-2 reportedly had characteristics indicative of a relatively youthful, late Holocene age. Radiocarbon dating of a faulted unit in T-3 had an approximate age of 7,000 to 9,000 years BP. Faults observed on site were considered secondary faults parallel to the main trace to the south.	Holocene-active
7	Engineering Geology Consultants (EGC), 2000	A trench in Juan Street revealed two faults. Near the intersection with Harney Street, the fault was a highly sheared zone 2 feet wide. Another fault was observed east of the intersection. No soils were present over the faults, and the faults were judged to be potentially active based on a lack of evidence to classify them as active.	age-undetermined Review of the trench logs indicates the faults are age-undetermined.
8	Hart, 2002	Two trenches revealed four zones of faulting. Many of the faults were reportedly overlain by an unfaulted late Pleistocene argillic (Bt) horizon or colluvial wedge. Hart concluded the faults have not been active during the Holocene based on the presence of the overlying Bt Horizon and minor amounts of slip exhibited by the faults, and he classified the faults as potentially active. No structural setbacks were recommended.	pre-Holocene and age-undetermined faults Review of the trench logs indicates some of the faults are age-undetermined.
9	La Monte, 2008	Two trenches reportedly indicated a fault zone offset argillic soil horizons with estimated dates ranging from 375,000 to 525,000 years BP. The faults were considered potentially active and no structural setbacks were recommended.	pre-Holocene and age-undetermined faults CGS obtained the referenced Addendum report for this project, but was unable to obtain the Geologic Fault Study prepared by Stephen E. Jacobs, 2007 for the site. Faults appear to extend through an argillic Bt horizon to the base of colluvium/topsoil/A Horizon in trench log T-1.
10	CTE, 2006	Two trenches identified a fault in San Diego Formation with a gouge zone approximately one-foot thick. No Late Quaternary or Holocene deposits were present to constrain the age of faulting. CTE recommended a structural setback based on the young appearance of fault gouge and documented Late Quaternary/Holocene active fault segments north and south of the site.	age-undetermined
11	Applied Earth Technology, 2006	Trenches identified a primary fault zone and some minor faults subparallel to the main fault. Prior modification of the ground surface removed all topsoil overlying the fault. Structural setbacks were not recommended because there was no evidence to indicate the fault has been active during the Holocene.	age-undetermined Fault juxtaposes San Diego Formation against Linda Vista Formation (very old paralic deposits).
12	Kleinfelder, 2012a SDIA Ovals	CPTs and continuous core borings identified the "East Bay" fault at the Southside Airfield - East Ovals site. Radiocarbon dating of organic sediment and shell within displaced units yielded ages as young as 2,920 years BP. An active fault zone was defined and structural building setbacks were recommended.	Holocene-active and pre-Holocene

Locality No.	Reference	Reported Conclusions	Evaluation Comments
13	Kleinfelder, 2012b SDIA CONRAC	CPTs and continuous core borings identified the "East Bay" fault at the Southside Airfield - CONRAC site. Radiocarbon dating of displaced organic sediment yielded ages of 3,850 and 3,950 years BP. An active fault zone was defined and structural building setbacks were recommended.	Holocene-active and pre-Holocene
14	Kleinfelder, 2013a SDIA TDY	CPTs and borings at the TDY site indicate the Spanish Bight fault and "East Bay" fault penetrate and displace Holocene age bay deposits with conventional radiocarbon ages between 430 and 6,110 years BP. An active fault zone was defined and structural building setbacks were recommended.	Holocene-active and pre-Holocene
15	Kleinfelder, 2013b SDIA North Side	CPTs and borings at the North Side site identified the "East Bay" fault which displaces Holocene age bay deposits. An active fault zone was defined and structural building setbacks were recommended.	Holocene-active and pre-Holocene
16	CTE, 2013a 2266 Kettner Blvd	A combined total of 13 CPTs, 13 borings, and 9 fault trenches were conducted for a site-specific fault evaluation of this site. The explorations encountered fill and Quaternary old paralic deposits (formerly known as Bay Point Formation). CTE observed a fault in Trenches T-1 and T-3 during their investigation of the site. The faults were oriented N5E and N10E, and dipped 85 degrees northwest to vertical. Dr. Tom Rockwell described the argillic (Bt) horizon that covers most of the site, which "is expressed as a reddened, clay-enriched layer with strong angular blocky structure and continuous clay film development on ped faces, within pores, and as grain bridges within the soil matrix". Observations which led CTE and Dr. Tom Rockwell to conclude the faulting is older than 100,000 years include: 1.) the fault was not observed in two trenches located approximately 11 feet and 16 feet north of trench T-1, and observations suggested there was little or no lateral displacement and that the fault had very limited lateral extent. 2.) There appeared to be a colluvial wedge shed from the fault. The fault could be traced up to the colluvial wedge but not into it. The strong argillic (Bt1) horizon capped the colluvial wedge, indicating it is Late Pleistocene in age. They interpreted the observed fault displacement to be the result of a single faulting event. 3.) No trace of the fault cut into the Bt1 argillic horizon, which did not thicken across the fault, suggesting that most or all displacement on the fault took place before soil development. 4.) An older argillic (BT2) horizon was observed below the overlying Bt1 horizon and was developed within the colluvial wedge. This older BT2 horizon appeared to thicken across the fault, indicating faulting may have occurred during formation of the lower Bt2 horizon, sometime approximately 120,000 to 100,000 years ago.	pre-Holocene The faults reportedly exhibited down-to-the-west vertical separation of approximately 1.5 feet. The fault zone was approximately 6 inches wide, and observations suggested there was little or no lateral displacement. CTE concluded the faults could be representative of the same fault or could possibly indicate en-echelon, left-stepping fault segments. CTE concluded that faulting is potentially active and consisted of short, discontinuous northeast-trending fault segments.

Locality No.	Reference	Reported Conclusions	Evaluation Comments
17	CTE, 2013b (Fat City) and CTE 2014a Harbor View Hotel, 2137 Pacific Hwy	CTE conducted a fault investigation in two phases which included a combined total 41 CPTs, 12 borings, and two fault trenches to a max depth of 18 feet, some of which were performed by Ninyo and Moore during previous investigation of the site. The explorations encountered fill and Quaternary old paralic deposits (formerly known as Bay Point Formation). CTE identified several steps/irregularities on the order of two to four feet along mapped soil horizons within the old paralic deposits, which they suggested could be associated with potentially active faulting. However, they suggested the irregularities could also be a result of erosional and depositional processes, and concluded the site was not underlain by active or potentially active faults. Subsequent geologic mapping by CTE of exposed excavation walls during grading operations (CTE, 2014a) identified a northeast trending fault zone with several splays dipping steeply to the northwest. The vertical separation of lithologic units was approximately 1 to 2 feet. However, the most northern fault splay had an apparent vertical separation of 6 feet down-to-the-west of an estuarine claystone and siltstone unit. A pedogenic argillic soil horizon, interpreted as Bt to Btk, was observed unbroken across the upward projection of the fault zone, with no indications of structural warping or folding above it. Several northwest trending paleo-gravel channels were mapped along down-dropped paleo-scarps and extended as tongue-shaped wedges between bounding fault splays. The Bt soil was developed across the upper portions of these gravels, suggesting they were syn-depositional with the observed faulting. Several paleo-liquefaction features were also mapped below the Bt soil, indicating that faulting predated soil development. Several short discontinuous clay-lined fractures were also observed on the floor of the excavation. Mapping of the fractures was limited due to grading activities and limited exposure. However, CTE suggested they seemed to be related to the fault zone mapped along the east wall of the excavation, and that map relationships indicated the fault zone stepped left with distributed shear toward the east wall.	pre-Holocene
17 (cont'd)	CTE, 2013b (Fat City) and CTE 2014a Harbor View Hotel, 2137 Pacific Hwy	(Description continued from previous row) CTE considered the Bt soil to be the westward extension of the Bt1 soil encountered during site investigation of Locality 16 (CTE, 2013a), which was interpreted to have developed on old paralic deposits during the 125,000 year sea level high stand. CTE reported that faulting at the adjacent site to the northeast (Locality 16) had the same orientation and sense of displacement, approximately 1 to 2 feet down-to-the-west, along with an apparent left-stepping pattern, suggesting the faults are part of the same zone of faulting. They interpreted the Bt1 soil to be at least 50,000 years old and not greater than 100,000 years old, and concluded the faults were potentially active.	
18	URS, 2005 Metro Volkswagen	Trench T-3 encountered a NE trending zone of shears and fractures "defining a fairly broad zone of deformation" with some evidence of tilting and minor folding indicated by a draping or warped appearance of bedding. However, no soils or deposits younger than Bay Point Formation were exposed that would indicate Holocene activity. Trench T-5 encountered a projection of the fault in T-3. A silty sand unit (Unit 2a) with porous structure interpreted to represent development of an A-horizon topsoil and judged to be of Holocene age formed an irregular erosional unconformity along the top of the faulted Bay Point Formation. The erosion surface at the base of Unit 2a was not offset by the fault. Below the erosion surface, a zone of pedogenic carbonate accumulation was present, and was interpreted to likely be "older than the Holocene (i.e. greater than 10,000 years old)", based on the degree of development and a thickness of 1.5 feet. URS reported the carbonate horizon appeared to be continuous across the fault and offset no more than about 0.5 feet.	pre-Holocene Open voids were reported along the fault zone on the log for Trench T-3. Section 4 - Preliminary Discussions, Conclusions and Recommendations were missing from the electronic copy of the URS, 2005 report that CGS received.

Locality No.	Reference	Reported Conclusions	Evaluation Comments
19	Geotechnics Incorporated, 2001 Columbia Street Lofts	A fault which offset Bay Point Formation was observed in an exploration trench, but judged potentially active based on lack of offset in a well-developed Late Pleistocene argillic "B" soil horizon.	pre-Holocene
20	Leighton, 2002 (URS, 2005) Doma Project	A fault was identified at depth during observation of the basement excavation. On the north wall of the excavation, the fault reportedly offset very dense moderately cemented San Diego Formation sandstone 12 to 18 inches. Overlying Bay Point Formation exhibited only very minor fracturing near the base of the unit, and a gravel layer 2 to 3 inches thick was observed to drape across the fault with no apparent offset. No faulting was reportedly observed within the upper 8 feet of the excavation where a well-developed soil profile and strong argillic horizons were observed. On the south wall of the excavation, minor fracturing was observed in interbedded sands near the base of the Bay Point Formation. The fractures reportedly appeared to be short and discontinuous with minor offsets of 1 to 2 inches and could not be traced upward into overlying sediments. Unfaulted well-developed soil and argillic horizons were observed near the top of the excavation of the south wall also. Based on the assumption that unfaulted materials in the upper portion of the excavation have an approximate age of 80,000 to 200,000 years, they classified the fault as potentially active.	pre-Holocene The Leighton (2002) report for this site is included as an appendix in the URS, 2005 report for Locality 18.
21	Converse, 2000a, CTE, 2000a, and CTE, 2001b The Park at Little Italy	Converse (2000) excavated a trench to a maximum depth of 10 feet, but found no indication of ground displacement. CTE (2000a) concluded the site was not underlain by active or potentially active fault traces, based on site reconnaissance, evidence from previous trenching and borings by Converse, and literature and topographic map review. However, a fault was discovered and investigated by CTE (2001b) during excavation of the basement. The excavation exposed Quaternary Bay Point Formation which they estimated to be approximately 125,000 years before present, based on correlation with soils from the Ballpark project nearby. Clear evidence of faulting was reportedly not observed in the uppermost portions of the Bay Point Formation, and a zone of coarse sand with fine gravel appeared to extend horizontally across the projection of the fault. The fault was judged potentially active.	pre-Holocene
22	URS, 2007 Monarch School	CPTs, borings, and a trench identified a northeast-trending fault near the southwest corner of the site. The fault was judged potentially active based on the presence of an overlying unfaulted unit of the Bay Point Formation that contained manganese nodules and carbonate flakes, which they interpreted as representing a soil profile on the order of 80,000 to 120,000 years old.	pre-Holocene
23	Kleinfelder, 2004a and 2004c Breeza Development; 820 Ash and 1405 and 1431 Pacific Hwy	Closely spaced CPTs in Ash Street identified a suspected northwest-trending fault. An exploratory trench was excavated in Ash Street above the suspected fault to a depth of 15 feet, but no faulting was observed in the trench. However, a fault was observed during foundation excavations for this parcel and for the Bayside Development to the south (Locality 24; SE corner Ash and Pacific), which was reportedly excavated concurrently with this project. The fault was observed to be nearly identical in the south wall excavation of this parcel and the north wall excavation of Locality 24. Kleinfelder concluded that the fault died out upward in Late Pleistocene-age sediments of the Bay Point Formation on both parcels, and therefore, it was classified as potentially active.	pre-Holocene based on report text, but no logs were obtained for our review. The fault was described in the Final Basement Excavation report (Kleinfelder, 2004c) for the Bayside development located south of Ash Street (see Locality 24).

Locality No.	Reference	Reported Conclusions	Evaluation Comments
24	Kleinfelder, 2004b and 2007b Bayside development; Santa Fe Depot Parcel 4	No faulting observed in a 15-foot deep trench in Ash Street. However, two main fault structures were identified during basement excavation observations. The faults terminated near the base an approximately 5-foot thick late Pleistocene pedogenic soil unit characterized by a well-developed argillic horizon with occasional zones of B-lamination development.	pre-Holocene based on report text, but no logs were obtained for our review. URS Greiner Woodward Clyde (2000) performed an initial fault hazard investigation on several of the Santa Fe Depot property parcels which included four fault trenches. However, the fault trenches were not deep enough to expose significant fault related features, and they concluded there were no indications of faulting. The Final Basement Excavation report by Kleinfelder (2004c) included a Fault Map but did not include a log of the fault exposed in the excavation walls for this parcel or Locality 23 on the north side of Ash Street, where the same fault was reportedly observed to be nearly identical.
25	Kleinfelder, 2002c and 2003a Santa Fe Depot Parcel 3; Bayside Condo Tower	Three benched trench excavations up to 18 feet deep (T-2 and T-3a,b) on this parcel exposed the PCH fault. Kleinfelder concluded the fault died-out upwards within late Pleistocene sediments and classified the fault as potentially active, based on unfaulted soil horizons and B-lamellae.	pre-Holocene/age-undetermined (based on limited control of age of faulted/unfaulted soils) Kleinfelder also report that they were unsuccessful in finding publications that corroborate the relationship between relative age and development of B-lamellae in soils.
26	Kleinfelder, 2002c and 2003a Santa Fe Depot Parcel 2	The PCH fault was first identified on this parcel during a routine basement excavation inspection. Additional observations and exploratory bench/trench excavations (T-1 and T-4a,b,c,d,e) to a depth of 37 feet exposed the fault along the north and south sides of the foundation excavation for this parcel. Kleinfelder concluded that faults died-out upwards and were truncated by early Holocene to Late Pleistocene sediments that displayed relatively continuous unfaulted B-Lamellae, which they suggest are substantially pre-Holocene in age. They classified the fault as potentially active.	pre-Holocene/age-undetermined (based on limited control of age of faulted/unfaulted soils)
27	Kleinfelder, 2007 Santa Fe Depot Parcel 1	Additional trenches on this parcel exposed the PCH fault. Radiocarbon dating reportedly constrained the last event on the fault at between 13.7 and 10.1 ka. Comparison of aggradation and incision events of alluvial units in the trenches with sea level curves potentially constrains the last displacement event as having occurred between 12 to 11.2 ka.	age-undetermined/Holocene-active
28	Kleinfelder, 2017 Santa Fe Depot Parcel 9	Two faults were identified during observation of the foundation excavation. A northwest trending fault in the northeast corner of the excavation appears to be the southern extension of the PCH fault. A second northwest trending fault traversed the entire length of the site, and was terminated by an erosional contact at a depth of approximately 17 feet bgs. The erosional contact was interpreted to represent the bottom of the Late Pleistocene Bay Point Formation, and the faults were judged pre-Holocene in age.	pre-Holocene Attempts to obtain the Geotechnical and Fault Hazard Investigation report for this parcel were unsuccessful.
29	WLA, 2008a and 2008b Old Police HQ	CPTs and sonic core borings demonstrated increased stratigraphic thicknesses, stratigraphic mismatches, and vertical separations which identified a fault. The fault appeared to offset the base of Holocene alluvium two feet.	Holocene-active
30	Ninyo and Moore, 2018 Seaport Village	CPTs and borings on shore, and geophysical survey seismic lines offshore identified the northern extension of the Coronado Fault across San Diego Bay and onshore within Seaport Village.	Holocene-active
31	SCS&T, 2003 Allegro Towers	No faults were encountered during investigation of the site. However, three faults were observed in shoring wall cuts and in a temporary excavation near the center of the site. Faults A and C were observed to exhibit apparent offset of the contact between Bay Point Formation and underlying San Diego Formation approximately 4 and 22 inches, respectively. Unbroken units above the faults included Late Pleistocene Bay Point Formation.	pre-Holocene Review of Plate No. 3, Fault "B", Detail B suggests an apparent vertical displacement of approximately 3 feet of Bay Point Formation units. The lowermost unit of Bay Point Formation (Qbp4) exposed contains fossiliferous beds identified as approximately 120,000 years by Dr. George Kennedy.

Locality No.	Reference	Reported Conclusions	Evaluation Comments
32	Kleinfelder, 2006 and 2016 Santa Fe Depot Parcel 5	No faulting observed in two trenches excavated to a maximum depth of 14 feet during the Fault Hazard Study of the site in 2006. However, a fault trending N15°W was identified during geologic observation of basement excavation wall cuts. The fault was observed in the north and south walls of the excavation, and across the bottom of the excavation. The fault terminated at or near the Late Pleistocene Nestor Terrace unit at a depth of approximately 18 feet.	pre-Holocene
33	Davis Earth Material, Inc., 2007 Sapphire Tower Santa Fe Depot Parcel 6	Inspection of basement excavation walls identified three faults with vertical separations of less than 2 feet. The most significant fault died out at a depth of 5 feet in Bay Point Formation as a single fracture, where it terminated at the base of a clayey argillic soil horizon that was not offset. Other faults died out upwards at depths of 17 to 37 feet, prior to reaching overlying thick paleosols estimated to be no younger than Late Pleistocene based on an argillic horizon. All faults were classified as potentially active.	pre-Holocene
34	URS, 2011a and 2017 San Diego Central Courthouse	Borings, trenches, and CPTs identified a fault interpreted to be a northern projection of the active San Diego Fault. At the Central Courthouse site on the northeast corner of State and C Streets, no faults were found during investigation of the site, which included trenches up to 15 feet deep. However, several minor faults were exposed within the walls and bottom of the basement excavation during grading. All of the faults were subtle, narrow features with typically a few inches of apparent bedding displacement, and were overlain by 20 to 25 feet of unfaulted Bay Point Formation. Unfaulted Holocene alluvium was present above the Bay Point Formation.	Holocene-active
35	SCS&T, 2000 and 2001	A fault was encountered in four of six trenches on site. The fault offset Quaternary-age Bay Point Formation sediments approximately 14 to 16 inches. SCST considered the fault a minor, isolated strand of an older fault not associated with the San Diego Fault, based on the minimal offset observed and termination of the fault below the Bt horizon in Trenches 3 and 4.	pre-Holocene/age undetermined
36	URS, 2014 (Draft) (Kettner Lofts) and URS, 2016 Kettner Lofts	URS (2014) excavated two fault trenches at the site to a maximum depth of 6 feet. The trenches exposed fill and Bay Point Formation sediments, and no geologic features indicative of faulting were observed. URS (2016) performed geologic observation and mapping during excavation of the proposed subterranean parking structure which extended approximately 18 to 29 feet below grade. The excavation exposed fill over Pleistocene Bay Point Formation that included argillic horizons, calcium carbonate rich soil horizons, and A, E, and Bt (argillic) soil horizons. A minor north-south trending fault was observed on the west side of the excavation. The fault displayed less than 0.5 feet of apparent vertical separation and had a moderate dip to the west. The fault was discontinuous and did not extend across the site. The fault terminated in Pleistocene age deposits.	pre-Holocene
37	Ninyo & Moore, 2007	Ninyo & Moore performed an investigation that included three borings and two fault trenches to a maximum depth of 11 feet. The explorations encountered fill and Quaternary Old Paralic Deposits, but did not indicate any major abrupt near-vertical offsets or terminations of traceable beds. Based on the results of their investigation and review of other projects near the site, they concluded the site was not underlain by active or potentially faults.	A potentially active fault is mapped on this parcel according to San Diego City fault data (sandiegogeologists.org/faults_map.html); however, we were unable to obtain any additional reports for this site.
38	North of Date St. between Columbia and India	<null>	A potentially active fault is mapped on this parcel according to San Diego City fault data (sandiegogeologists.org/faults_map.html); however, we were unable to obtain a report for this site.
39	North of Elm St. between Columbia and State	<null>	A potentially active fault is mapped on this parcel according to San Diego City fault data (sandiegogeologists.org/faults_map.html); however, we were unable to obtain a report for this site.

Locality No.	Reference	Reported Conclusions	Evaluation Comments
40	Ninyo & Moore, 2011 and SCST, 2012 Ariel Suites	Ninyo & Moore performed three investigations of the site that included 9 borings and 3 fault trenches. The explorations encountered fill, Holocene deposits, old paralic deposits, and San Diego Formation. No faults were identified during their investigations of the site. However, SCST (2012) observed faults on exposed excavation walls and pad surfaces during excavation for a subterranean garage structure. The excavation reportedly exposed old paralic deposits and San Diego Formation, and SCST reported that no native soils younger than the old paralic deposits were exposed during construction.	No graphic logs of the excavation walls or map of the fault locations were included in the letter report by SCST (2012).
41	CTE, 2012c 445 West Ash St. and CTE, 2017b 401 West Ash Street	CTE (2012c) investigated the west and south portions of this city block with two fault trenches, and did not encounter a fault. The northeastern portion of the parcel was investigated by Leighton (2005), and no faults were encountered in their trenches. The Leighton trench logs were included in CTE, 2012c appendix. CTE (2017b, Interim As-Graded Report) reports that "the original geologic interpretation of the site indicated that a possible northwest trending potentially active fault transected the northeast corner of the site". CTE performed geologic mapping during grading operations for the Carte Hotel Development at 401 West Ash Street (southwest corner of State St and Ash St), and discovered a paleo-geomorphic feature consisting of a cut and fill channel sequence. They also discovered a zone of minor faulting and fracturing trending N20E and inclined vertical to approximately 80NW, with apparent normal separations up to 7.5 cm. The faulting was reportedly only recognized within a laminated sand unit interpreted to be equivalent to the Marine Isotope Stage (MIS) 5e transgressive sands, and no signs of faulting were observed above this unit. Based on their observations, they concluded that faulting occurred between approximately 85,000 and 120,000 years bp and they classified the fault as potentially active.	pre-Holocene CTE (2012c) suggests potential correlation of the fault found at Locality 35 (SCST, 2000) with the San Diego Fault.
42	CTE, 2014b, 2017a, and 2018 520 West Ash St.	CTE (2014) investigated the site with one fault trench and did not encounter a fault. CTE (2017a, 2018) performed geologic mapping during grading operations and discovered two primary faults zones and several smaller subsidiary fault/fractures. However, the faults were only recognized to cut MIS 5e or older deposits at depth in the excavation, and were overlain by unfaulted old paralic deposits. They concluded that faulting occurred prior to approximately 85,000 years bp and they classified the faults as potentially active.	pre-Holocene
54	Leighton, 2019a, and G-Force, 2015	A minor fault was mapped by G-Force (2015) in the bottom portion of the east wall of the excavation. The fault was observed within Old Paralic Deposits, but was not traceable into younger deposits above and was not laterally continuous across the bottom of the excavation. The fault vertically offset sediment layers up to 3/4 inch, and a relatively thin residual soil horizon in old paralic deposits above the fault showed no evidence of displacement.	pre-Holocene
62	Leighton, 1999b, and Leighton, 2019b	Leighton (1999) conducted a fault investigation at the site consisting of two trenches and did not observe any evidence of faulting. However, Leighton (2019b) reported that a minor fault was observed within the southeastern corner of the site during construction activities for the Treo development. The fault was observed near the bottom of the basement excavation and considered pre-Holocene in age.	pre-Holocene

Locality No.	Reference	Reported Conclusions	Evaluation Comments
66	Geocon, 2012a,b CTE, 2016b	The site investigation by Geocon included small diameter borings, CPTs and seismic reflection surveys. Fault trenching was impractical due to shallow groundwater and loose, saturated soil. They did not find any signs of faulting at the site. During construction, CTE discovered a series of short, discontinuous minor faults with 0.2 feet or less of offset within the deep mat foundation excavation below the temporary shoring. The faults were observed within the bottom of the excavation, could not be traced across the site, and were reportedly covered with unbroken Quaternary old paralic deposits. They were interpreted to be potentially active and possible compression faults or features associated with liquefaction or lateral spreading from past seismic events.	pre-Holocene The depth of the excavation and faults was not provided. The faults mapped by CTE (2016) were plotted on a foundation plan that could not be accurately georeferenced in ArcMap for this study without obtaining additional data.
67	Geocon, 2016a,b	We understand that a fault was recently observed at the site during ongoing construction activities based on personal communication with Dr. Thomas Rockwell (San Diego State University; April 2021) and James Quinn (City of San Diego, Development Services Department; May 2021). However, additional information was not provided to CGS for review.	
73	Kleinfelder, 2019 Kennebec site	Kleinfelder (2019) identified a fault on strike with the East Bay Fault and concluded the fault is Holocene-active.	Holocene-active
74	Leighton, 2019b Two America Plaza	Leighton (2019b) conducted a fault investigation for the proposed Two America Plaza project located on the southeast corner of Kettner Boulevard and B Street. Due to constraints prohibiting the excavation of fault trenches, the investigation was limited to 21 CPTs advanced in B street, India Street and Kettner Boulevard. Based on a stratigraphic profile developed from CPT data in B Street, Leighton interpreted a minor fault with less than about 2 feet of apparent vertical displacement within late Pleistocene Old Paralic Deposits. The location of the fault in the CPT profile reportedly correlated with the fault observed in the basement excavation for the Treo project north of B Street (Locality 62). Leighton concluded the fault was pre-Holocene in age based on a gravel deposit with very consistent elevation across the site, which was interpreted as evidence the fault did not extend upward into younger deposits.	pre-Holocene
75	Leighton, 2018 and 2021	The initial fault investigation by Leighton (2018) included one fault trench approximately 84 feet long and 11 CPTs advanced in Ash Street south of the site. The stratigraphy in the trench was observed to be continuous across the site and they concluded that faults did not transect the site. Based on the CPTs in Ash Street, an approximate 6-foot elevation difference across a contact within Old Paralic Deposits was identified, but it was interpreted as a buried paleo shoreline, not a fault. However, Leighton (2021) observed several northeast trending minor faults transecting the basement excavation during recent site construction activities. Vertical displacements were reportedly on the order of a few inches to 6 feet, but none of the faults were observed to deform or truncate a generally continuous and overlying late Pleistocene-age gravel lag deposit. Leighton concluded the faults were pre-Holocene.	pre-Holocene
76	Kleinfelder, 2017 SDIA	Kleinfelder (2017) performed an additional fault hazard evaluation within the southern portion of the SDIA where an active segment of the Spanish Bight Fault was previously identified. The fault study consisted of 41 CPT soundings across the anticipated northern projection of the Spanish Bight Fault. The results of their analysis indicated both Holocene-active and pre-Holocene faulting across the site within a zone co-aligned with the Spanish Bight Fault. The faulting was interpreted to be more robust on the southern portion of the site and to progressively diminish to the north, where the fault zone was narrowest and displayed the least amount of apparent displacement. Kleinfelder concluded the Spanish Bight Fault appears to be dying out to the north, where it may not penetrate Holocene-aged bay deposits dated to about 6 ka, and that it appeared to be much less significant than the East Bay Fault	Holocene-active and pre-Holocene

Table 2. Geomorphic Features Interpreted from 1928 Aerial Photos (modified from SANDAG, 2014, except where otherwise noted)

Feature No.	Feature Type*	Evaluation comment
1	Lineament	Discontinuous, tonal feature
2	Deflected drainage	Right-deflected
3	Lineament	See Localities 1 and 2 in report and Table 2 for additional discussion of faulting in this area.
4	Deflected drainage	Right-deflection
5	Lineament	Discontinuous, tonal feature
6	Lineament	Coincides with linear trough identified by Treiman (1993), Plate 2.
7	Lineament	Discontinuous, tonal feature; deflected drainage also inferred at southern end of this lineament
8	Lineament	Discontinuous, tonal feature; coincides with tonal lineaments and linear trough identified by Treiman (1993), Plate 2.
9	Lineament	Discontinuous, tonal feature; deflected drainage also inferred at southern end of this lineament.
10	Depression	Area of low topographic relief interpreted as a right-step in the fault zone (Scott Rugg personal communication, 2019), and an area where faulting may be broadly distribute along multiple discontinuous fault strands.
11	Pressure ridge	Local topographic high between faults
12	Fault in railroad cut	Fault observed in railroad cut, and in close proximity to a northeast-trending fault which displayed roughly 2 feet (60 cm) of normal separation of deposits questionably inferred to be 40 ka (Treiman, 1993).
13	Lineament	Discontinuous, tonal feature; coincides with tonal lineaments, linear trough, and linear drainage identified by Treiman (1993), Plate 2.
14	Lineament	Discontinuous, tonal feature
15	Offset	Offset in old paralic deposits
16	Deflected drainage	Right-deflection of channel walls across Tecolote Creek
17	Scarp	Compressional feature or west-facing scarp (CGS, this study)
18	Deflected drainage	Right-deflected
19	Lineament	Discontinuous, tonal feature; secondary fault splay interpreted to branch west from the main fault splay.
20	Offset landslide	Dextral offset of landslide deposit margins by the main trace of the fault.
21	Lineament	Discontinuous, tonal feature
22	Lineament	Continuous scarp interpreted to be the main fault trace through this area.
23	Pressure ridge	Local topographic uplift from secondary fault splay which branches off west of the main fault trace; also represented on historic topographic map (USGS, 1903, La Jolla Quadrangle).
24	Lineament	Lineament in close proximity to low angle reverse fault exposed in a trench and logged by Liem (1977). A sandstone unit radiocarbon dated at 28 ka, along with an overlying conglomerate, were faulted.
25	Lineament and Closed depression	Topographic depression; currently remains a local low elevation area
26	Deflected drainage	Right-lateral channel offset across interpreted main trace of the fault.
27	Scarp	Continuous east-facing scarp along the west side of Morena Blvd.
28	Graben	Small graben formed by apparent right step in main fault trace.
29	Lineament	Discontinuous, tonal feature
30	Scarp	The fault is still expressed as a linear depression through the Old Town Presidio Hills Golf Course, and presence of the fault was confirmed with CPTs and paleoseismic trenching (Rockwell, 2012 and Singleton et al, 2019). See Locality 5 in FER and Table 2.
31	Deflected drainage and scarp	Apparent right-deflection of drainages (Rockwell, 2010a and Singleton et al., 2019)
32	Scarp	Potential scarp indicated on historic topographic maps
33	Scarp	Shallow scarp
34	Trough	Shallow linear trough or sag
35	Break in slope	Break in slope observed in 1928 aerial imagery and on historic topographic maps (see Figure 6; USGS, 1904, San Diego Quadrangle, and U.S. Coast Survey Office, 1851).
36	Saddle	Apparent saddle indicated on historic topographic maps (see Figure 6; USGS, 1904, San Diego Quadrangle, and U.S. Coast Survey Office, 1851).
37	Pressure ridge	Pressure ridge suggested on historic topographic maps (see Figure 6; USGS, 1904, San Diego Quadrangle, and U.S. Coast Survey Office, 1851).
38	Scarp	Shallow scarp; Kennedy et al., 1975, note Pleistocene rocks of the Lindavista Formation dip 20° to the west and lie adjacent to the Rose Canyon fault zone at this location.
39	Lineament	Discontinuous, tonal feature
40	Lineament	Discontinuous, tonal feature
41	Scarp	Shallow scarp
42	Deflected drainage	Apparent right-deflection of drainage
43	Closed depression	Kleinfelder (2019) identified a depressed ground surface southwest of the East Bay fault zone, which they interpreted to be a result of large-scale uniform relative downdropping of the ground surface, not a localized area of fault deformation.
44	Bench	Sidehill bench; trends toward Locality 10 where age-undetermined fault was observed in trench along south side of Titus Street.
45	Bench	Sidehill bench appears as a subtle break in slope.
46	Deflected drainage	Apparent right-deflection of drainage

Feature No.	Feature Type*	Evaluation comment
47	Saddle	Ridgeline saddle
48	Deflection	Apparent left-lateral deflection in canyon wall
49	Bench	Sidehill bench
50	Bench	Sidehill bench
51	Deflected drainage	Slight deflection of drainage
52	Deflected drainage	Apparent right-deflection of drainage
53	Offset	Apparent offset canyon slope
54	Lineament	Discontinuous, tonal feature
55	Bench	Trends adjacent to Locality 11 where pre-Holocene and age-undetermined faulting was identified on Puterbaugh Street (Applied Earth Technology, 2006).
56	Saddle	Ridgeline saddle
57	Bench	Sidehill bench
58	Bench	Sidehill bench

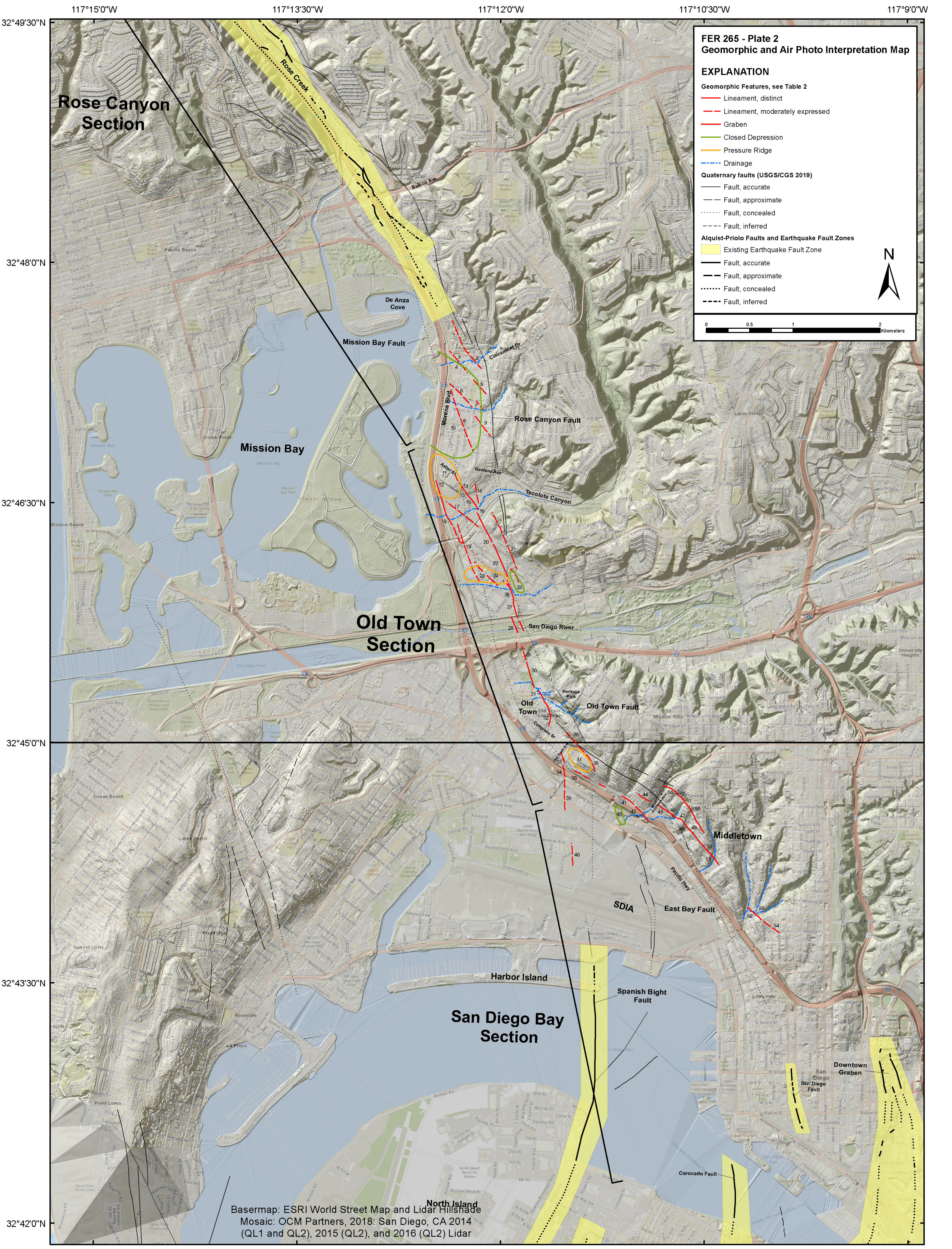
* Feature types classified as lineaments on Plate 2 include tonal lineaments, linear troughs, scarps, and alignments of other geomorphic features such as saddles, benches, deflected drainages, and fault exposures.

Table 3. Localities where no faults were identified.

Locality No.	Abbreviated Citation	Full Citation
43	Geocon, 2003a	Geocon, 2003, (Draft) Preliminary Geotechnical Investigation, Pacific Highway Property APN 533-111-07-00, 2235 Pacific Highway, San Diego, California, Geocon Project No. 07075-52-01, dated June 6, 2003.
44	CTE, 2015	Construction Testing and Engineering (CTE), Inc., 2015, Preliminary Geotechnical and Fault Hazard Investigation, Proposed Restaurant Tenant Improvements, 2210 Kettner Boulevard, San Diego, California, CTE Job No. 10-12346GG, Dated May 18, 2015.
45	Geocon, 2003b and 2005	Geocon, 2003, Geotechnical Investigation and Geologic Fault Investigation, Juniper Self-Storage Project, Juniper Street Between Kettner Boulevard and India Street, San Diego, California, Geocon Project No. 07121-22-02, dated November 11, 2003. Geocon, 2005, Juniper Self-Storage Project, Juniper Street Between Kettner Boulevard and India Street, San Diego, California Addendum No. 2, Geocon Project No. 07121-22-02, dated May 4, 2005.
46	CTE, 2001a	Construction Testing and Engineering (CTE), Inc., 2001, Quaternary Fault Investigation, Proposed Harbor View Condominium Project, San Diego, California, CTE Job No. 10-4696, dated October 5, 2001.
47	CTE, 2016a	Construction Testing and Engineering (CTE), Inc., 2016a, Preliminary Geotechnical and Fault Hazard Investigation, Proposed Born & Raised Tenant Improvements, 1909 India Street, San Diego, California, CTE Job No. 10-12851G, dated February 4, 2016.
48	CTE, 2002a	Construction Testing and Engineering (CTE), Inc., 2002a, Preliminary Geotechnical and Fault Investigation, Proposed Development 1918-1924 Columbia Street, San Diego, California, CTE Project No. 10-5443, dated May 10, 2002.
49	Leighton and Associates, 2009	Leighton and Associates, 2009, Geotechnical and Fault Investigation, 1907 Columbia Street, San Diego, California, Leighton Project No. 042412-001, dated September 10, 2009.
50	CTE, 1998	Construction Testing and Engineering (CTE), Inc., 1998, Geotechnical and Fault Investigation, Proposed Marriot Residence Inn, Elm Street and Pacific Highway, San Diego, California, CTE Job No. 10-2730, dated March 23, 1998.
51	CTE, 1999b	Construction Testing and Engineering (CTE), Inc., 1999b, Geotechnical and Fault Investigation, Proposed Residential Development, NEC Cedar Street and Kettner Boulevard, San Diego, California, CTE Job No. 10-3274, dated June 28, 1999.
52	Geocon, 1998	Geocon, 1998, Fault Investigation, Parcel 533-313-09, San Diego, California, Geocon Project No. 06101-21-01, dated May 27, 1998.
53	CTE, 2000b	Construction Testing and Engineering, Inc., 2000, Geotechnical and Fault Investigation, Proposed Porto Siena Project, Little Italy Neighborhood, San Diego, California, CTE Job No. 10-3569, revised date February 21, 2000.
55	CTE, 1997	Construction Testing and Engineering (CTE), Inc., 1997, Geotechnical Investigation and Fault Study, Little Italy Family Housing Project, India Street and Cedar Street, San Diego, California, CTE Job No. 10-2275, dated June 16, 1997
56	CTE, 1999a	Construction Testing and Engineering (CTE), Inc., 1999a, Geotechnical and Fault Investigation, Proposed Residential Development, SWC Cedar and State Streets, San Diego, California, CTE Job No. 10-3187, dated March 18, 1999.
57	Converse Consultants, 2000b	Converse Consultants, 2000b, Report of Geologic Hazards Evaluation and Geotechnical Investigation, Property Bounded by State, Cedar, Union and Beech Streets, Little Italy in San Diego, California, Converse Project No. 00-32-341-01, dated August 25, 2000.
58	CTE, 2000c	Construction Testing and Engineering (CTE), Inc., 2000c, Geotechnical and Fault Investigations, Proposed Chesapeake Luxury Apartments Project, San Diego, California, CTE Job No. 10-4354, dated December 15, 2000.

Locality No.	Abbreviated Citation	Full Citation
59	SCST, 2004a,b	Southern California Soil & Testing (SCS&T), Inc., 2004a, Fault Evaluation, APN 533-344-10-00, 1454 Union Street, San Diego, California, SCST No. 0411006 , dated September 16, 2004. Southern California Soil & Testing (SCS&T), Inc., 2004b, Response to Review of Fault Evaluation, 1454 Union Street, San Diego, California, APN 533-344-10-00, SCST No. 0411006 report no. 4, dated November 18, 2004.
60	CTE, 2002b	Construction Testing and Engineering (CTE), Inc., 2002b, Geotechnical and Fault Investigation, Proposed Billboard Lofts Project, NWC Ash and Union Streets, San Diego, California, CTE Job No. 10-5107, August 1, 2002.
61	Leighton, 2015	Leighton and Associates, Inc., 2015, Geotechnical and Fault Investigation, 1st and Beech Street, San Diego, California, Leighton Project No. 11088.001, dated August 25, 2015.
63	CTE, 2009	Construction Testing and Engineering (CTE), Inc., 2009, Fault Hazard Investigation, Proposed Columbia Towers, 1231 India Street, San Diego, California, CTE Project No. 10-9921G, dated April 22, 2009.
64	Leighton, 1999a	Leighton and Associates, Inc., 1999a, Geotechnical Investigation and Fault Study, Proposed Commercial Development, State and B Streets, San Diego, California, Leighton Project No. 4990123-001, dated July 15, 1999.
65	Geocon, 1997	Geocon, Inc., 1997, Fault Investigation, B Street and Union Street Parcel, San Diego, California, Geocon Project No. 06022-51-01, dated December 29, 1997.
68	Kleinfelder, 2003b and 2005	Kleinfelder, 2003b, Supplemental Fault Hazard Evaluation, SDG&E Station B Site, Kettner Boulevard Between E Street and Broadway, San Diego, California, Kleinfelder Project No. 22648, June 23, 2003. Kleinfelder, 2005, Interim Basement Excavation Geologic Inspection, Electra at 700 West E Street, San Diego, California, Kleinfelder Project No. 22648, Dated June 10, 2005.
69	CTE, 2012a	Construction Testing and Engineering (CTE), Inc., 2012a, Preliminary Geotechnical Investigation, Proposed Canada Dry Development, 1895 Hancock Street, San Diego, California, CTE Project No. 10-11166G, dated August 27, 2012.
70	CWE, 2000	Christian Wheeler Engineering (CWE), 2000, Report of Fault Study, Proposed Office Building Addition, 2415 San Diego Avenue, San Diego, California, CWE Project No. 199.673.3, dated April 18, 2000.
71	Geotechnics, Inc., 2000	Geotechnics Incorporated, 2000, Geotechnical Investigation, Caltrans Office Building Replacement, San Diego, California, Geotechnics Project No. 0166-004-00, Dated August 17, 2000.
72	CTE, 2012b	Construction Testing and Engineering (CTE), Inc., 2012b, Fault Hazard Investigation, Proposed Hilton Garden Inn, 4200 Taylor Street, San Diego, California, CTE Project No. 10-11003G, dated May 7, 2012 (revised May 22, 2012).

117°15'0"W
117°10'0"W
32°50'0"N
32°45'0"N
32°40'0"N
Downtown area
PCH Fault
San Diego Fault
Coronado Fault
La Jolla Cove
Mt Soledad
Rose Canyon Fault
Mt. Soledad Fault
Country Club Fault
Rose Creek
Rose Canyon Section
De Anza Cove
Mission Bay Fault
Rose Canyon Fault
Mission Bay
Old Town Section
San Diego River
Old Town
Old Town Fault
La Jolla
La Mesa
Middletown
SDIA
East Bay Fault
Harbor Island
Spanish Bight Fault
San Diego Bay Section
Downtown Graben
North Island
Coronado
Silver Strand Fault
Point Loma
National City
FER 265 - PLATE 1
FAULT TRACES AND SITE-SPECIFIC INVESTIGATION LOCALITIES
EXPLANATION
City of San Diego Downtown Special Fault Zone
Site-Specific Fault Investigation Localities
Localities with faults, see Table 1
Fault, Holocene-active
Fault, pre-Holocene
Localities with no faults, see Table 3
Quaternary faults (USGS/CGS 2019)
Fault, accurate
Fault, approximate
Fault, concealed
Fault, inferred
Existing Alquist-Priolo Faults and Earthquake Fault Zones
Earthquake Fault Zone
Fault, accurate
Fault, approximate
Fault, concealed
Fault, inferred
N
0 1 2 4 Kilometers
Basemap: ESRI World Street Map and Lidar Hillshade
Mosaic: OCM Partners, 2018: San Diego CA 2014 (QL1 and QL2), 2015 (QL2), and 2016 (QL2) Lidar



FER 265 - Plate 2
Geomorphic and Air Photo Interpretation Map
EXPLANATION
Geomorphic Features, see Table 2
Lineament, distinct
Lineament, moderately expressed
Graben
Closed Depression
Pressure Ridge
Drainage
Quaternary faults (USGS/CGS 2019)
Fault, accurate
Fault, approximate
Fault, concealed
Fault, inferred
Alquist-Priolo Faults and Earthquake Fault Zones
Existing Earthquake Fault Zone
Fault, accurate
Fault, approximate
Fault, concealed
Fault, inferred
N
0 0.5 1 2 Kilometers
117°15'0"W
117°13'30"W
117°12'0"W
117°10'30"W
117°9'0"W
32°49'30"N
32°48'0"N
32°46'30"N
32°45'0"N
32°43'30"N
32°42'0"N
Rose Canyon Section
Old Town Section
San Diego Bay Section
Rose Creek
Mission Bay Fault
Rose Canyon Fault
Tecolote Canyon
San Diego River
Old Town Fault
Middletown
East Bay Fault
Spanish Bight Fault
Downtown Graben
San Diego Fault
Coronado Fault
Mission Bay
De Anza Cove
Morena Blvd
Clairemont Dr
Balboa Ave
Gardena Ave
Heritage Park
Old Town
Congress St
Pacific Hwy
SDIA
Harbor Island
North Island
Basemap: ESRI World Street Map and Lidar Hillshade
Mosaic: OCM Partners, 2018: San Diego, CA 2014 (QL1 and QL2), 2015 (QL2), and 2016 (QL2) Lidar


FER 265 - PLATE 3
FAULTS RECOMMENDED FOR ZONING
EXPLANATION
N
Fault, Accurate
Fault, Approximate
Fault, Concealed
Fault, Inferred
Recommended Alquist-Priolo Earthquake Fault Zone
Existing Alquist-Priolo Earthquake Fault Zone
0 1 2 4 Kilometers
117°16'30"W
117°15'0"W
117°13'30"W
117°12'0"W
117°10'30"W
117°9'0"W
32°51'0"N
32°49'30"N
32°48'0"N
32°46'30"N
32°45'0"N
32°43'30"N
32°42'0"N
32°40'30"N
Basemap: ESRI World Street Map and Lidar Hillshade
Mosaic: OCM Partners, 2018: San Diego, CA 2014
(QL1 and QL2), 2015 (QL2), and 2016 (QL2) Lidar