Earth Consultants International

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## EDUCATION

Ph.D. pending in Environmental Health, Science, and Policy, University of California at Irvine, 1998-Present [Research *Tectonic geomorphology and seismic hazards of Orange County*]

Post-graduate study in Geomorphology, University of California at Riverside, 1993-1996 [Research *Tectonic geomorphology of the southeastern Los Angeles basin*]

Post-graduate study in Engineering Geology, California State at Los Angeles, 1982-1990 [Research *Tectonic geomorphology and neotectonics of the Whittier fault in southern California* ]

B.S. in Geology, University of Minnesota, Institute of Technology, 1978 [Emphasis *Quaternary geology and geomorphology* ]

## PROFESSIONAL REGISTRATIONS

Professional Geologist: California, PG 4140, (1986)
Engineering Geologist: California, EG 1292, (1986)

## PROFESSIONAL HISTORY

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| 1997-Present: | President, Earth Consultants International, Santa Ana, California |
| 1992-2000: | Board of Directors, Leighton & Associates and GTG Inc., Irvine, California |
| 1988-1996: | Principal Geologist, Leighton & Associates, Inc., Irvine, California |
| 1986-1993: | Director of Geology, Leighton & Associates, Inc., Los Angeles County Office, Diamond Bar, California |
| 1984-1986: | Staff/Senior/Project Geologist, Leighton & Associates, Inc., Orange County Office, Irvine, California |
| 1980-1984: | Staff Geologist, Pacific Soils Engineering, Irvine, California |
| 1979-1980: | Field Technician, Irvine Soils Engineering, Irvine, California |
| 1977-1979: | Senior Laboratory Technician, Soil Testing Laboratory, University of Minnesota, St. Paul, Minnesota |

## PROFESSIONAL SUMMARY

Eldon Gath has over 30 years of experience in the identification, investigation, and remediation of geologic hazards, involving land use planning, environmental assessments, field exploration and analysis, and presentation of findings. Mr. Gath has particular experience with the evaluation of active faults for construction site planning, the development of seismic safety programs and policies, and the determination of remediation and design alternatives for geologically sound site development. His experience with fault evaluation studies in California includes investigations on the San Andreas, Garlock, San Jacinto, Pelican Hill, Peralta Hills, Whittier, Sierra Madre, Springville, Elsinore, Cucamonga, Newport-Inglewood, Malibu Coastal, Palos Verdes, and Santa Monica faults. He has published slip rate studies for the Whittier fault, displacement and recurrence intervals for the Whittier Extension fault, and magnitude, displacement, and slip history of the Springville fault.

Mr. Gath's international experience includes several field projects in Turkey, Mexico, and Panama, plus participation on projects in Japan, Pakistan, Indonesia, Afghanistan, and Honduras. In particular, his projects in Panama on the Pedro Miguel, Miraflores, Gatún, Limón, Azota, and other faults have led to a complete redefinition of the seismotectonic understanding of Panama. He has played a prominent team role in the quantitative determination of the seismic hazard for the Panama Canal Expansion Project, and is the lead geologist for the Program Management Team of the Canal Expansion Program's Locks Design-Build contract.

Eldon Gath's experience in the translation of geologic and seismic hazards into municipal policy and mitigation spans public agencies, private developers, and research. He was the Principal-in-Charge for the Safety Elements of Los Angeles and Riverside Counties, and the cities of Santa Monica, Burbank, Garden Grove, Rolling Hills, Rolling Hills Estates, Calimesa, Yucca Valley, Chino Hills, and Culver City. He was the Principal-level geologic consultant to the City of Brea for their future city expansion planning. All of these projects involved intense interaction with public and technical review groups, planning commissions, and city councils or county supervisory boards.

His experience with geologic investigations and hazard assessments of oil field redevelopment includes the Whittier, West Coyote, Olinda, Signal Hill, Mineral Springs, Potrero, and Puente Hills oil fields. Mr. Gath was invited by the Division of Oil and Gas to be their participant in a DOG, RWQCB, and DHS-sponsored, 1993 workshop on *"Geoenvironmental Issues in the Redevelopment of Abandoned Oil Fields."*

He has represented both private and public parties in the preparation or technical review of dozens of Environmental Impact Reports for projects covering new freeways, harbor expansions, landfills, large housing developments, water infrastructure, and large commercial, industrial, or recreational facilities. For nearly ten years he was an invited engineering geology member of the Los Angeles County Department of Public Works' *Land Development Technical Advisory Committee,* a policy advisory forum and liaison group between the public and private sectors in planning, permitting, and grading activities within the County.

Mr. Gath has served as a consultant and expert in several large litigation cases. He has served as an expert for defendants in earthquake damage, landslides, and environmental impacts, including La Conchita Ranch, Laguna Summit, Kerr McGee, Thrifty Oil, City of Yorba Linda, and Chevron. Several of these projects involved claims in excess of $100M. In addition, he has worked on dozens of other consulting assignments that were conducted under attorney-client privilege confidentiality.

He is also heavily involved in professional practice organizations, including the Association of Engineering Geologists (National President-1997/98, as well as a Southern California Section Chair-1990/92), the Earthquake Engineering Research Institute (Technology Transfer and Professional Ethics committees), and was the geosciences representative for the Ethical Issues in Earthquake Engineering EERI workshop. Mr. Gath represented the Geoscience and Planning disciplines on the National Academy of Sciences, National Research Council's Engineering and Infrastructure committee to *Develop a Long-Term Research Agenda for Earthquake Engineering*, and is currently serving on the Technical Advisory Committee on Geology and Geophysics for the California Board for Professional Engineers and Land Surveyors. He has given over one hundred presentations before professional, academic, and public groups, and has published on a wide range of geological and professional practice topics for which he has received several awards for outstanding presentations and papers.

## PROJECT EXPERIENCE

**Project Manager for the Seismic Hazard Assessment of four large manufacturing facilities in Japan and Taiwan [2010].** ECI was retained by a large US company to assess the seismic hazard and vulnerability of their manufacturing facilities in Asia. The project consisted of a desktop research and compilation of published materials, supplemented with unpublished materials by Japanese and Taiwanese colleagues. Separate repots were prepared for each of the facilities in Shizuoka and Saki City Japan, and Tainan and Taichung Taiwan, detailing the faults, slip rates, recurrence, and probabilities, within 100 km of the plant sites. The Shizuoka facility was then selected to complete a PSHA analysis and Spectral Matching at three different probabilities for three different earthquakes.

**Principal Investigator to identify the seismic hazards of the Santa Ana Mountains in Orange County, California [2004-2010].** The project involved the structural and geomorphic characterization of a seismotectonic model to understand the deformation associated with movement and uplift of the Santa Ana Mountains. The project was funder under a research grant from the USGS National Earthquake Hazards Reduction Program to UC Irvine, and was done in collaboration with Dr. Lisa Grant. The results of the study indicate that the present Santa Ana Mountains are acting as an indenter, pushing through and crushing the weaker sedimentary basin sediments of Orange County. The differential movement has resulted in a northwest-trending left-lateral shear zone along the western side of the mountains, multiple north-south tear faults offsetting Santiago Canyon, and the uplift has created Loma Ridge, Peralta Hills, and the Anaheim Hills. An on-going collision of the Santa Ana Mountains with the Puente Hills is resulting in accelerated uplift of the Chino and Puente Hills, including secondary faulting and folding that likely generated the July 2008 earthquake.

**Project Manager for the preparation of a new Hazard Mitigation Plan [Public Safety Element] for the County of Riverside, California [1999-2001].** The project involved an extensive collection, digitization, and analysis of geologic and cultural data for the entire County of Riverside, an area of over 7,000 square miles (35,000 km$^2$). The data were all compiled into a MapInfo and ArcInfo GIS database for use in hazard abatement planning by the Department of County Planning. All supporting metadata plus discussions as to the data sources, reliability, adequacy, and recommended programs for either current usage or future enhancement were compiled into a large Technical Report entitled *Natural Hazard Mapping, Analysis, and Mitigation*. The main focus of the project was to develop a map-based hazard management and mitigation plan for the County of Riverside to implement over the next twenty years. The final preparation of the Element has involved close coordination and meetings with the County Planning staff, including testimony before the County Planning Commission, and presentations to a select technical review board.

**Principal Geologist and Project Manager for a fault hazard investigation of the northern San Jacinto fault within the Lytle Creek drainage in Rialto to locate the active traces of the fault, and quantify probable displacement magnitudes for bridge structure design [1995].** The purpose of the study was to quantify the fault rupture hazard of the northern segment of the San Jacinto fault where several new freeway bridge structures are proposed for the I-210 extension in San Bernardino County (Foothill Freeway). The project was two-phased, an air photo and geomorphic analysis to locate evidence for probable active traces of the San Jacinto fault in the area of Lytle Creek, followed by a subsurface trenching investigation across the major bridge locations to screen the area for secondary faults. The project required that the trench excavations be backfilled in conformance with Caltrans design specifications, and the final trenching and compaction report was reviewed by Caltrans.

**Principal Geologist and Project Manager for a geological and geotechnical review and design-level analysis of Phase 2B of ALARKO's Alkent Istanbul 2000, an upscale residential development project in Istanbul, Turkey [2001].** The Alkent Istanbul 2000 project is a master planned residential development and community east of Istanbul, Turkey. Developed by the ALARKO Group, it consists of large single-family homes, plus recreational, commercial, and educational facilities to support a contained and secure community environment. Over 800 homes have already been constructed. ECI was initially retained to provide ALARKO with a second opinion on landslide stability issues for their upcoming Phase 2B development of nearly 100 additional home (villa) sites. Shallow slope failures and landslides extensively impacted the site. The slides were initiated from a perched water condition that had developed within a weathered regolith that was capping a hard shale unit. Following the initial consultation, ECI was requested to complete a design-level geotechnical analysis to develop the construction stabilization requirements and detailed implementation drawings. Because of difficulties in relying on good fill compaction, the stabilization measures relied on pile support for all

villas, slopes, and retaining walls. Construction design details were also developed for site dewatering subdrains.

**Principal Geologist and Project Manager for a fault hazard investigation of San Bernardino Valley College to locate the active traces of the San Jacinto fault for campus redevelopment planning [1995-2007].** The San Bernardino Valley College campus in San Bernardino was constructed gradually from the early 1930's to the early 1970's upon an elevated pressure ridge (the Bunker Hill Dike) formed along the San Jacinto fault. As part of an overall campus redevelopment planning, this study was undertaken to quantify the fault rupture hazard through the SBVC. In addition to the threat posed by surface rupture, other secondary seismic impacts were addressed, including liquefaction, shaking amplification, and ground deformation due to folding. The project involved the excavation of eight trenches within the campus area to expose the traces of the San Jacinto fault, completion of ten boreholes to depths of 50-100 feet coupled with nearly 100 cone penetrometer tests, and shear wave velocity profiling of the borings. The trenches revealed that the surface trace of the fault passes through four of the school's buildings. Eight other buildings were determined to be at risk due to secondary ground fracturing or their location across an active surface fold caused by shallow blind thrust faulting.

**Principal Investigator to identify and quantify active seismic sources in the Eastern Los Angeles Basin using tectonic geomorphic mapping [2003-2006].** The study was funded by the U.S. Geological Survey under the National Earthquake Hazard Reduction Program to compile geomorphic indicators of active tectonics in the area of the eastern Puente Hills, Chino Hills, and northern Santa Ana Mountains. By identifying and mapping fluvial terraces in the Puente Hills and Santa Ana Mountains, uplift rates were calculated for both topographic features. OSL age dating, combined with soil stratigraphy and radiocarbon, provided age control. The study results were compiled into a Technical Report submitted to the U.S. Geological Survey and included into the Southern California Earthquake Center's Community Fault Model.

**Principal in Charge for the preparation of a FEMA-funded education and outreach pamphlet on Unreinforced Masonry Building Hazard Mitigation for Local Building Officials [2007-2008].** Under contract to the Applied Technology Council (ATC), and with funding from FEMA, Earth Consultants International prepared an illustrated pamphlet detailing the hazards of Unreinforced Masonry Buildings (URM), steps to take for a community vulnerability assessment, and a range of mitigation alternatives to improve community economic stability and public safety. Entitled *"Unreinforced Masonry Buildings: Don't Play the Odds - Protect Your Community from Earthquake Catastrophes - A Guide for Officials and Others Concerned About Earthquake Safety"*, the 12-page booklet is well illustrated with numerous photos, drawings, and tables. Now in final editorial review by ATC and FEMA, the booklet is due to be released nationally in early 2009.

**Project Manager for the preparation of a new Hazard Mitigation Plan [Seismic and Safety Element] for the County of Los Angeles [1988-1992].** The project necessitated the collection, collation, and analysis of geologic and cultural data for the entire County of Los Angeles, an area of over 4,000 square miles. The data was transcribed onto eight separate 1:100,000-scale overlay sheets for use in hazard abatement analysis by the Department of Regional Planning. All supporting technical data and discussions as to the data sources, reliability, adequacy, and recommended programs for either current usage or future enhancement were compiled into a 430 page Technical Report *"Hazard Reduction in Los Angeles County"*. In addition to the extensive data collection effort, the main focus of the project was to develop the Goals, Policies, and Programs for Los Angeles County to implement as part of their Five Year Seismic Hazards Reduction Program. The final preparation of the Element involved close coordination and meetings with the County Planning staff, including testimony before the County Planning Commission, several local public hearings, presentations to civic groups, and County Board of Supervisors' presentations prior to final adoption. The project was awarded the 1991 Distinguished Service Award by the National Association of Counties.

**Principal Geologist and technical reviewer of the Hazard Mitigation Plans [Safety Elements] for the cities of Rolling Hills and Rolling Hills Estates [1992].** The Rolling Hills and Rolling Hills Estates Safety Elements focused on landslide management and prevention programs. As part of this management plan, development standards, geological investigations, and water-related issues were identified as requiring the most attention within the city. Following the mapping compilation of all known landslides within the two cities, the landslide susceptibility map was combined with relevant mitigation alternatives and presented to city council. The Safety Elements that were prepared were both adopted into the respective city's General Plan.

**Principal Geologist and technical reviewer of the Hazard Mitigation Technical Report to the Safety Elements for the cities of Burbank, and Culver City [1992].** The Burbank and Culver City Safety Elements were oriented towards mitigating the impacts of earthquakes and ground failure, through pre-development site investigations and post-earthquake emergency response planning. Both cities are traversed by active faults, the Verdugo and Newport-Inglewood faults respectively. Both cities have large areas potentially susceptible to earthquake-induced liquefaction and slope failures. Burbank and Culver both must deal with the potential for flooding and inundation. Numerous mitigation strategies were suggested for each city to use in developing their hazard reduction plans. The Planning Departments of each city used the technical information collected to prepare their own Safety Elements.

**Principal Geologist and Project Manager for the revision and updating of the Santa Monica Hazard Mitigation Plan (Safety Element) [1994-1995].** The project involved a very close working relationship with several city departments, including engineering, planning, emergency services, and fire, to incorporate the current efforts of the City into the action programs of the new Safety Element. The study also resulted in the relocation and reclassification of the Santa Monica fault as an active seismic hazard. However, because of our association with the Southern California Earthquake Center, the City Council and planning staff were fully apprised of this new earthquake threat, two weeks before the SCEC press release on the Santa Monica fault was issued. During the Safety Element review period, the M6.7 Northridge earthquake occurred, causing extensive structural damage in the city. At city request, we served as information sources for displaced citizens at a public information meeting immediately after the earthquake, and provided guidance and recommendations to city emergency response officials.

**Principal Geologist and Consultant to the City of Brea for their Vision Building project in planning a 7,000-acre expansion to the City [1993-1994].** The Sphere of Influence expansion area includes the active Whittier fault, several hundred landslides and oil wells, thousands of cubic yards of non-engineered earth fill, and large zones of active crude oil seepage (*brea*). The purpose of the project was to involve the citizens of Brea, the property owners, potential land developers, oil field representatives, and a selected team of consultants (Core Team) in an intimate design process to master plan the future of Brea, involving field trips, weekend design charettes, and weekly meetings.

**Project Investigator to develop the geologic evaluation criteria for 56 alternative alignment segments of a proposed 32-mile freeway project [Foothill Transportation Corridor] in Orange County, California [1984].** The project necessitated a review of existing geologic data, a field reconnaissance of all 170 miles of the alternative alignments, GIS computation of all collected data, and preparation of a geologic evaluation matrix for incorporation into the complete EIR document. Project was presented to the Orange County Board of Supervisors, the preferred alignment was selected, and detailed site investigations and initial construction is proceeding.

**Instructor at the Red Cross Emergency Manager Training Academy [2001 & 2005].** Participated as the leader of several training modules in the Red Cross and Emergency Management Agency's annual Disaster Management Training Academy. In 2001, we prepared materials and conducted a daylong workshop on *Natural Hazard Mitigation and Management Before the Disaster—an Assessment of the Available Options*. In 2005, we again participated as trainers, conducting workshops on 1) *What Do We Have To Fear? A quantitative analysis of three earthquake scenarios on Orange County,* 2) *Natural Hazard Identification, Impact Analysis, and Risk Assessment for Disaster Mitigation Planning,* and 3) *The Effect of Geology on the Southern California Landscape.* All of the training workshops were attended by emergency management responders, including police, fire department, city officials, and non-governmental organizations. The project included preparation of workshop manuals, handouts and lecture materials, making presentations and facilitating workshop discussions, and serving as a technical resource to workshop participants.

**Convener and Organizer of an Education and Outreach Workshop for the California State Legislature on Earthquake Hazards of California [1995].** In support of a Public and Government Awareness program, the Education and Outreach Program of the Southern California Earthquake Center retained us to organize, advertise, and conduct a state of the knowledge earthquake hazards seminar specifically directed at the members, and staff, of the California State Legislature. *Bringing earthquake risk to the California State Legislature: an earthquake hazards seminar that involves the decision and policy makers of the State of California* was the result of that effort. The seminar brought together the leading researchers and practitioners on active faults across the entire state of California for a full day of technical presentations, culminated by a far

reaching panel discussion session that dealt with future-oriented issues like earthquake prediction, earthquake probabilities, damage and loss estimates, legislative priorities, and certainty and uncertainty. The project solicited speakers and panel members, advertised the program to the legislative staff, met with legislative staff to increase awareness, prepared several presentations on various active faults, prepared and sent out several meeting announcement mailers, organized the various talks and discussion sessions, prepared and printed an expanded abstract program, moderated the program, sent out follow up news briefs and press releases, and prepared a summary report for the Southern California Earthquake Center.

**Field Geologist for the 10,000-acre Ahmanson Ranch in Ventura County, California for the purpose of site characterization prior to ultimate land use decision making [1983].** The project resulted in a series of maps presenting geologic hazards and conditions for planning evaluation. Follow up subsurface studies were instrumental in documenting that a portion of the site would be suitable for a Class II landfill, and that extensive slope stability problems would economically prohibit a desired low density development of the southern half of the ranch.

**Principal Investigator for a detailed geologic study of the Whittier fault in Los Angeles and Orange Counties to determine slip rates and recurrence intervals for large earthquakes [1992].** The study was funded by the U.S. Geological Survey under the National Earthquake Hazard Reduction Program. Thirty miles of the fault between the Santa Ana River and the San Gabriel River were mapped using air photos to identify tectonic geomorphic features indicative of the most recently active traces of the fault. A detailed three-dimensional paleoseismic trenching study was completed which allowed calculation of the fault's slip rate and slip history. The study results were compiled into a Technical Report submitted to the U.S. Geological Survey. Based on the results of this research, the California Division of Mines and Geology created an Alquist-Priolo zone map for the La Habra quadrangle.

**Principal Investigator to determine the activity and fault kinematics of the northern extension zone of the Whittier fault, in the epicentral region of the 1987 Whittier Narrows earthquake [1994].** This research project involved three dimensional trench excavations and detailed paleoseismic logging to define both lateral and vertical slip on the northwest trending Alhambra Wash fault. The fault lies within the step-over zone where the Whittier fault transitions into the Elysian Park-Monterey Park anticlinorium set of faults. The study began with a detailed aerial photographic reconnaissance to map the potential fault features, and to select optimal trenching sites. The fault was excavated in three dimensions to directly measure the lateral and vertical slip components. Preliminary results indicate recurrent displacements of fault-crossing late Pleistocene stream channels as older units are displaced increasingly larger amounts. The fault is dominantly right lateral with a down to the east component. The study was funded by the Southern California Earthquake Center as part of its mission to quantify and model the seismic risk within the Los Angeles basin.

**Principal Geologist and Project Manager for development of the seismic design parameters for San Bernardino Valley College [2001].** San Bernardino Valley College lies directly on the active San Jacinto fault. As part of the campus-wide redevelopment planning study, ECI was contracted to update the prior seismic design values to account for new code changes that were effective since 1997. In particular, the DSA was concerned about near-fault effects due to a large San Jacinto fault earthquake. ECI evaluated several fault rupture scenarios for both the San Jacinto and San Andreas faults and produced a design-level report that included probabilistic and deterministic analysis of peak ground accelerations, response spectra, time histories, site and sediment amplification factors, displacement pulse velocities, and permanent deformation analysis. The resultant report was approved by DSA and CGS.

**Principal Geologist and Project Manager for a third-party review and subsurface investigation of a potential landslide hazard under the new business building at Crafton Hills College in Yucaipa, California [2001].** ECI was retained by the Crafton Hills College administration to review geologic reports and data they had received indicating the presence of a landslide under the site of their newly proposed business building. After reviewing all of the materials, and visiting the site, a testing protocol investigation was developed and recommended to the administration. This testing program consisted of two trench excavations that were positioned in key locations to confirm or refute the existence of the proposed landslide. Based on the exposures in the trenches, and a review by the prior consultants and city geologists, everyone agreed that no landslide existed at the site. ECI's documentation report removing the landslide from the map was approved by DSA.

**Principal Geologist for a geologic hazard investigation of Crafton Hills College in Yucaipa, CA, for campus redevelopment planning [2004-2005].** San Bernardino Community College District retained Earth Consultants International to review the geologic constraints and hazards to their proposed campus-wide redevelopment planning project. ECI geologists reviewed and compiled all available geotechnical reports and published geologic materials relevant to the campus area, geologically mapped the entire campus property, and produced a geologic constraints map for use in the initial planning period. The analysis determined that landslides were not a significant planning constraint, but that mud and debris flows were a hazard that needed to be considered in land use planning. Additionally, two splays of the active Crafton Hills fault zone trended into the campus, and could adversely affect several potential building site areas. A supplemental trenching study was authorized to quantify the fault constraint. This investigation is underway.

**Principal Geologist for stormwater erosion damage assessment, repair, and mitigation planning at Rio Hondo College, Los Angeles County, California [1999].** The storms of late 1998 and early 1999 caused extensive flooding, erosion and damage at Rio Hondo College on the western tip of the Puente Hills. ECI was retained by the college maintenance department to assist in damage assessment, and to develop repair options for three of the most critical locations on the northern perimeter road. French drains, deflection walls, freeboard extensions, detention basins, and drainage rerouting solutions were all discussed with college officials, and the most cost effective solutions were selected for implementation. A campus-wide stormwater management plan was requested and a proposal was developed, but it was never implemented.

**Principal Geologist for a detailed fault hazard assessment of the 700-acre West Coyote Hills oil field into a master planned residential community for Chevron Land and Development [1994-1997].** The site is a young anticlinal uplift in the eastern Los Angeles Basin, immediately south of the Whittier fault. Due to the extensional tectonics of the uplifting fold, numerous secondary faults were created. The occurrence of a minor ground rupture along one of these small faults in 1968 prompted the State to include that fault in an Alquist-Priolo Special Studies Zone. For future development planning, other secondary faults within the development area were investigated as to their structural style, recency of activity, and risk to the development. A tectonic model of the area was developed to better characterize the pattern of faulting, and to enhance future risk predictive capabilities.

**Program Manager for the site characterization and construction of 200+ permanent Global Positioning Satellite (GPS) receiver monuments for JPL [1998-2004].** As the construction contractor to the Southern California Integrated GPS Network (SCIGN), 200 permanent GPS receiver stations were sited, geologically characterized for stability, and constructed using the Wyatt-type braced monument. The entire program spanned ten southern California counties, received three scope increases, took three years, and involved a budget of over $4 million. Intensive scheduling and coordination was required between SCIGN's site selection review group, the geological site review team of Earth Consultants Int., the construction contractor Gradient Engineering, and the drilling contractor APEX. Depending upon the site conditions, either a hollow stem auger or an air percussion rotary drill rig was used.

**Project Geologist for fault hazard investigations within the Santa Fe Energy Olinda oil field in Brea [1994-1999].** The purpose of the studies were to comply with the provisions of the Alquist-Priolo Act by locating the Whittier fault and providing minimum setback limits to future development. The studies were phased as the development planning progressed, and ultimately involved logging over 50 trenches and road cut exposures within the 220-acre site. The fault locations were used by the site planner to adjust the final design grades in such a way as to minimize the impact of the fault and fault setback zones.

**Principal Geologist for fault hazard investigations at the proposed Rancho San Andreas development project, Highlands Area, San Bernardino, California [2002].** ECI was retained by the Highland Hills Development Company to take over the fault hazards and constraints investigation for a 700 acre development project in the San Bernardino Mountain southern foothills. The site is bisected by the northern and southern strands of the San Andreas fault. Prior geological investigations of the faults were considered inadequate for development planning by the regulatory reviewer. ECI exhumed selected portions of the prior trenches to QA/QC the previous work, and ultimately completed excavation and geological logging of 23 new trenches and over 2600 linear feet of new trench when the prior fault locations could not be confirmed. Appropriate fault setbacks were proposed, a new development plan was created by the site planner, and our report was approved by the regulator.

**Project Manager/Director for the development of Fullerton Road through the Puente Hills of Los Angeles County [1990-1991].** Detailed subsurface investigations were undertaken, several proposed alignments were reviewed, and remedial grading quantities calculated for each alignment. Massive landslides and generally weak bedrock materials were common along the entire project, and two active segments of the Whittier fault crossed the alignment corridor. The project involved the excavation of over 12-million cubic yards of material to achieve final road grades. Close planning and interface was a requirement of the County of Los Angeles Department of Public Works. Meetings were held with the District Supervisor, Pete Schabarum, to keep him apprised of the project's progress.

**Principal Geologist for an earthquake risk assessment of the AKSA Fabrication Facility in Yalova, Turkey [2000].** The AKSA petrochemical plastic fabrication facility sits on the Yalova Delta in the Marmara Sea. It suffered considerable damage in the August, 1999 earthquake, including delta front slippage, amplified ground shaking, secondary fault rupture, lateral spreading, and liquefaction. Earth Consultants International was retained to provide a seismic hazard assessment to AKSA for the potential impacts of future earthquakes in the Marmara Sea region. Using a combination of trenching, borings, and cone penetrometer (CPT) probes, we were able to geologically characterize the deltaic area into relative hazard zones for ground failure. The project was completed in partnership with geotechnical engineers from Istanbul Technical University.

**Principal Geologist for a 450-acre hillside development project within the Puente Hills for Shea Homes [1988-1993].** The project took over five years in the conceptual planning and design stages before final construction began in 1988. Extensive meetings and interaction with the County of Los Angeles was required due to the construction of two miles of Fullerton Road and one mile of Pathfinder Road, both under the review of the Department of Public Works. Numerous large landslides were investigated and analyzed for design buttresses, a 170-foot deep fill was placed into an offsite canyon and monitored for secondary consolidation, and debris flow basins were sized and constructed within three drainages entering the site. The site was a former Shell oil field, necessitating the consideration of contaminated soils and the reabandonment of 12 oil wells. An interstate aviation fuel pipeline was relocated due to the grading, and the relocation plan was reviewed for geotechnical impacts. During canyon cleanout operations for Fullerton Road, both the north and south traces of the Whittier fault were exposed, and charcoal samples from the faulted alluvial sediments were sent for radiocarbon dating to provide valuable technical data on the slip history of the fault.

**Principal Geologist for the planning and redevelopment of the Signal Hill oil field into a master planned residential community, within the Newport-Inglewood fault zone.** The project commenced with a thorough data review of the site, followed by subsurface trenching to locate the active strands of the Newport-Inglewood fault system as required by the Alquist-Priolo Act. The Cherry Hill fault and Northeast Flank faults were located and provisional structural setbacks were developed. Extensive geotechnical issues were encountered, including hydrocarbon contaminated soils, thick oil field fills, existing production infrastructure, and adjacent development. Detailed design investigations, and construction mapping, observation, and testing services were provided throughout the phasing of the development.

**Project Geologist and Manager for a fault hazard reassessment of the Sierra Madre fault through the proposed La Viná development of Southwest Diversified in the San Gabriel Mountains north of Altadena.** The project involved the excavation of 15 trenches across the mapped trace of the Sierra Madre fault. Dr's. Thomas Rockwell, Kerry Sieh, and Charlie Ruben of the Southern California Earthquake Center were retained to review the trench exposures and conclusions of the investigation. Based upon sedimentary unit relationships and relative rates of soil development exposed in the trench excavations, the fault was determined to be inactive for at least the last 12-15,000 years and, therefore, does not pose physical development constraints. The study findings were successfully presented before the Los Angeles County Planning Commission and the Board of Supervisors.

**Project Geologist for a detailed fault investigation of the western end of the Las Posas Hills in Camarillo into a master planned residential community for the Spanish Hills Development Company.** The development site has been elevated above the Ventura Basin by the active Springville fault, which has also created numerous smaller secondary faults trending through the proposed development. Utilizing two 30-foot deep trench excavations, the study successfully located the Springville fault, and characterized the frequency and magnitude of activity. Based upon over 30 additional trenches, all but three of the secondary faults were determined to be inactive by use of fault zone mechanics. Development setback zones were provided for the active faults, and, by working closely with the site planners and engineers, a safe and viable land

development plan was obtained.

**Principal Geologist for a geological constraints investigation for Nuevo (Torch) Energy's Stearns Lease [Unocal] oil field in Brea, California for the purpose of site characterization prior to land use planning.** This 700-acre oil field was being reviewed for residential land development opportunities. As one piece of the planning process, the project resulted in a series of maps presenting geologic hazards and conditions for planning evaluation. Follow up subsurface studies were instrumental in documenting that the active traces of the Whittier fault were confined to the extreme northeastern corner of the property, and that the mapped faults through the central portions of the field were inactive under Alquist-Priolo Act residential design criteria. The site has been extensively modified by oil production activities. Uncompacted fills were mapped, unstable or oversteepened slopes were identified, naturally occurring oil seeps were mapped, and mitigation measures were identified for the conditions.

**Principal Geologist for a geological constraints investigation for Murdock Development's Yorba Linda properties for the purpose of site characterization prior to land use planning.** This 1000-acre series of properties were being reviewed for residential land development opportunities. The Planning Center recognized the early importance of a geological constraints map for this property due to the ruggedness of the landscape, and due to the presence of an Alquist-Priolo Earthquake Fault Zone (Whittier fault) through the property. Using only historical aerial photographs, published and unpublished geological maps, geotechnical consulting reports for adjacent properties, and onsite geological field mapping, the project produced a map that presented the geologic hazards and conditions for planning consideration. The properties evaluated contain approximately thirty landslides, high unstable and oversteepened slopes, oil production activities, uncompacted fills, the active Whittier fault, and active utility easements (high-voltage transmission lines, trunk natural gas lines, Diemer main water line, and oil transportation lines). Follow up analytical studies resulted in a ballpark remedial quantity (yardage) estimate to apply towards planning alternatives analysis.

**Project Manager for a 4-parcel, 2,300-acre residential development in the south Corona area for Devere Anderson Enterprises.** The project lies within the active Elsinore fault zone, and has severe development planning constraints due to faulting and massive landsliding. Extensive trenching studies were completed to locate the active traces of the fault, resulting in structural setbacks from six fault segments, and a determination that six other faults could be considered as inactive and pose no significant design constraints. The project is in the conceptual design stage, with design being based upon a geologic constraints and opportunities map prepared following the geotechnical investigation.

**Project Geologist for a seismic risk evaluation of the New Madrid fault at a Department of Energy-regulated uranium ore processing facility in Metropolis, Illinois.** The investigation's probabilistic risk assessment, created smoothed site response spectra for differing risk levels, and assessed the probable structural performance of the facilities under the modeled seismic loading. Subsequent phases of the project involved the detailed structural retrofit of the facilities.

**Project Geologist of the geotechnical investigation for design of new wharf and pile structures for Berths 88-96 at Pier A, Port of Long Beach.** The project used 12 land and 7 offshore borings to correlate subsurface sediment strata for dredge borrow quantities, subsidence prediction, and liquefaction analysis. Probabilistic seismic design parameters were developed for dike and pile design based on the new slip rates for the Palos Verdes Hills fault.

**Project Geologist and Manager for a feasibility investigation to review mitigation options for active crude oil seeps (tar) and methane generation within the Santa Fe Energy Olinda oil field in Brea.** The purpose of the study was to provide the land developer with preliminary remediation and/or planning alternatives for development within a site heavily impacted by naturally occurring surface oil seeps. The project focused on mapping the limits of the naturally occurring tar deposits, and identifying the structural geologic conditions within which the oil seeps are occurring. The volume of methane being produced was investigated with three gas collection boreholes. Several preliminary mitigation measures were outlined.

**Project Manager for a 350-acre hillside residential development in the Puente Hills for The Lusk Company.** The project had been in the tentative tract design stage for six years, with numerous plan revisions developed to finally achieve a viable development concept. A detailed subsurface investigation involving

nearly 50 borings and 100 trenches was completed, followed by comprehensive geotechnical analysis of the 20 onsite landslides and proposed cut slope stability, and summarized into a cost benefit analysis of the various development alternatives. The design modifications have necessitated regular working meetings between the consultant team, and several meetings with the County of Los Angeles Planning Commission. Major design efforts and innovative geotechnical remedial solutions were required to preserve historical oak trees at several localities on the site.

**Project Geologist for a 700-acre residential development project by Hon Development in the Laguna Niguel area of southern Orange County.** This large hillside parcel was investigated for both active faults and large landslide constraints. Three very large perimeter landslides were studied to determine their impact upon the proposed upslope development, and the impact of the future development on the landslide stability. Of particular concern was the reactivation of one of the landslides due to the presence of nearly 100 existing homes constructed on the landslide without prior recognition or stabilization of the slide. To isolate the proposed development from the slide and to increase the in situ stability of the residual slide mass, a 190-foot deep by 1,000-foot long shear key was constructed, an elaborate subdrainage system was designed, and several land use plans were reviewed. The project was mass graded into smaller tracts, involving over two years of earthwork and the moving and compacting of nearly 20 million cubic yards of earth fill.

**Project Geologist for a geotechnical investigation and planning study to rehabilitate and develop a shale slag quarry in the Chino Hills.** The site was a former burnt (expanded) shale facility where the bedrock shales were quarried, baked, and processed as lightweight aggregate materials. After approximately 15 years of operation, the facility was closed and the site abandoned. As part of the redevelopment study, the site was explored using borehole and trench excavations, field geologic mapping of bedrock outcrops and mine waste and debris, and depths to ground water mapped as part of a feasibility study for onsite sewage disposal. Based upon the investigation, a land use plan was developed, and recommendations for the remediation of the developable portions of the site were presented.

**Principal Geologic Consultant for a technical review of the Toland Canyon Landfill near Santa Paula, in Ventura County.** The purpose of the study was to complete a third-party technical review of the geologic issues at the Toland Canyon Landfill in Ventura County. The review focused on the issue of active faulting, seismic design, and groundwater monitoring and slope stability. The initial review stimulated the RWQCB to require the landfill operator to undertake extensive new investigations designed to address the age of faulting across the landfill footprint. The new trenching results were reviewed and discussed in the field with all interested parties, which led to additional focused investigations to address newly uncovered faulting issues. The review was instrumental in stimulating these new studies by generating enhanced regulatory appreciation of the issues, and also led to the development of different, more appropriate, design measures to mitigate the site's geologic conditions for safe landfill operation.

**Field Geologist for the feasibility and design investigations of a proposed Class 2 landfill in the Verdugo Mountains of Los Angeles County.** The project involved detailed field mapping of bedrock units, structural features, joint patterns, and ground water seeps. The study included packer permeability testing of boreholes, fault trenching and activity characterization, water sampling and laboratory testing, rock evaluation for cover material, seismicity assessment from the Verdugo and La Tuna Canyon faults, and design and quantification of clay liner material needs. The site was feasible from a geologic perspective, however, access limitations, site hydrology, and neighborhood opposition combined to terminate the siting study.

**Project Manager for the preparation of the geology, environmental, and geotechnical engineering sections of an EIR/EIS for the Ports of Long Beach and Los Angeles 2020 Plan.** The proposed 2020 Plan would result in the expansion of the two port facilities by approximately 1,500 additional acres of new dredged landfill area. The project was particularly sensitive due to the potential presence of toxic materials within the harbor bottom sediments that were to provide the majority of the landfill materials. The EIR/EIS evaluated the conditions, the impacts, and the alternatives both avoidable and unavoidable. Four different expansion alternative concepts were evaluated, including the no project alternative. The findings of the EIR/EIS were instrumental in focusing the awareness of harbor officials onto the issue of seismic risk from an active fault [Palos Verdes Hills fault] causing surface rupture or deformation of the new landfill area, and onto the new issue of a "blind" fault underlying the entire harbor area [Torrance-Wilmington fault].

**Principal Geologist for the geologic, soils, and hydrologic portions of an EIR/EIS on the**

**Firestone Boy Scout Reservation in Los Angeles County, California.** Proposed land uses evaluated included two golf courses, a resort hotel complex, a perimeter cluster of medium rise condominiums, and a sprawling equestrian complex. Several large landslides were determined to be present on the margins of the project, alternative land uses and mitigation alternatives were discussed. The primary consideration for analysis was the preservation of the Tonner Canyon drainage and habitat. This ecological preserve was an important wildlife area. Specific mitigation measures developed that would accommodate the ecology, while simultaneously resulting in adequate levels of slope stability.

**Project Manager for the geotechnical portion of the EIR for the proposed Ascot Sports Complex in eastern Los Angeles.** The facility included several mixed-sport fields, an indoor complex, and an extensive amount of earthwork to achieve design grades. Abandoned oil wells and slope stability were the two dominant geotechnical impacts to the project. Although the geological conditions of the site were favorable for the proposed project, political and financial interests combined to relocate the project to an alternative site.

**Project Manager for the geotechnical portion of the EIR for the proposed Powder Canyon Golf Course facility and private residential community in the La Habra Heights portion of the Puente Hills, Los Angeles County.** The project involved moving over 10 million cubic yards of earth to achieve design grades. The dominant geotechnical impacts to the project were landslide mitigation and risk to offsite properties, deep fill subsidence, and the activity of faults throughout the project. Design alternatives were developed to avoid two very large (>1M $m^3$) landslides, but still achieve the desired golf course, clubhouse, meeting facilities, and residential housing.

**Project Geologist and Manager for a planning study of 200 acres in preparing the Malibu Civic Center Specific Plan.** The project area contained severe constraints from the Malibu Coastal fault, shallow ground water, earthquake induced liquefaction, and wastewater disposal. To evaluate the impact of the fault, 80 cone penetrometer (CPT) and 5 continuous core borings were emplaced, and stratigraphic units correlated between the borings. The project involved presentation and discussion of findings at three public workshops and several General Plan Task Force meetings. The project also comprised technical consultants for Planning, Civil, Biology, Traffic, and Economics all working towards a comprehensive, mixed-use development plan for a "downtown" Malibu; a plan that incorporated site constraints and public input into a viable town center. The study was able to document that the mapped fault was an older structure, and posed no impacts to the proposed land plan. These findings were presented to the California Division of Mines and Geology for their use in defining Alquist-Priolo Special Study Zones for the Malibu Coast fault.

**Project Manager for the geotechnical investigation and land planning constraints of the 800-acre La Conchita Ranch in the coastal area of northern Ventura County.** The La Conchita Ranch was impacted by severe landsliding problems involving an elevated 500-foot high coastal bluff, with occupied residences at the toe of the slide. The ranch was further affected by large-scale landsliding in the higher reaches of the property, the active Red Mountain fault, extensive erosion and mud flow problems, and severe drainage incision resulting in near-vertical 300-foot high channel walls. The scope of the study was phased to investigate those geologic issues posing the highest risk (both public safety and economic) to the planning process. Remedial recommendations were developed for arroyo side-slope stability, access road alignments, debris flow protection, fault setbacks, landslide dewatering, and landuse planning.

**Principal Geologist and Project Manager for a fault investigation of the Malibu Coast Fault across Winter Mesa, Malibu.** The Malibu Coast fault on Winter Mesa was investigated to confirm the active nature of the fault and to develop residential development setbacks away from the fault. Three deep trenches were excavated across previously mapped traces of the fault zone. Unlike prior studies, we were able to definitively show that the faults previously interpreted to be active, were actually inactive under State development laws. The principal fault was investigated in greater detail and it was determined that the last event (dated using the optically stimulated luminescence technique) was a 14,000 year old liquefaction event, not surface fault rupture. After extensive review, the City of Malibu geologists agreed with this determination. A petition was made to the California Geological Survey to remove the Alquist-Priolo Earthquake Fault Zone from this fault zone.

**Principal Geologist and Project Manager for the geologic assessment of land planning constraints for the 1100 acre Whittier oil field in the westernmost Puente Hills of Los Angeles County.** The Whittier oil field includes several land development planning constraints, including the

active Whittier fault, a 160-acre landslide, 350 oil wells and associated sumps, infrastructure, and non-engineered cuts and fills. The project involved a general background and air photo review, geologic mapping, and numerous team planning meetings to best incorporate the site's existing geotechnical constraints into the future use options. During the course of the planning efforts Chevron was actively engaged in well abandonment and limited environmental assessment. Data and geologic exposures created by these activities were included in the land planning analysis.

**Expert Geologic Consultant on a landslide litigation case in the Savage Canyon portion of the Whittier oil field in eastern Los Angeles County.** During the course of construction excavation for expansion of the City of Whittier's Savage Canyon landfill, adverse geologic conditions resulted in the failure of the canyon slope. The landslide grew to include one oil well and enlargement endangered several other wells, plus pipelines and access roads. In an emergency mode to attempt to predict the maximum growth dimensions of the landslide, six borings were excavated around the perimeter, the region was geologically mapped, cross sections were prepared and analyzed, and a map was prepared to guide oil field personnel in their response options. The resultant litigation was ultimately settled in the oil company's favor.

**Project Manager and Principal Geologist for the Geologic Constraints Investigation, Planning, and Environmental Impact Report for a new 35,000-acre resort community in Kern County.** As part of the master planning team, Earth Consultants International undertook and completed a phased assessment of the geological and geotechnical constraints to the planning of this large resort and residential project. In Phase 1, ECI used existing materials, aerial photographs, and on-site field mapping to delineate the major geological issues: active faulting, liquefaction susceptibility, slope and landslide instability, and flooding. In Phase 2, ECI used a series of trenches to locate and delimit the active fault avoidance zones in bedrock, and cone penetrometer (CPT) and continuously cored borings to locate and constrain the fault through deep saturated sediments. ECI also participated in the planning process and in the preparation of the environmental documentation for the project EIR.

**Project Manager and Principal Geologist of the Active Fault Constraints Investigation phase of the Planning and Environmental Impact Report for the 17,000-acre "Centennial" project, a new master planned residential community proposed in northern Los Angeles County, 1999-2002 & 2006.** As a consultant to the project's principal geotechnical consultant, Earth Consultants International was tasked with identifying, characterizing, and constraining the active fault hazards within this master planned community immediately adjacent to the San Andreas fault, and near to the Garlock fault. In Phase 1, all previously mapped and newly interpreted faults were compiled into a GIS database. All of these faults were evaluated for mapping accuracy, sense and magnitude of offsets, and their impact on overlying sediments so as to constrain their age. In Phase 2, those faults that could not be demonstrated to be inactive or to not exist, and which were in potential development areas, were trenched and quantitatively evaluated as to age of activity, width of the fault zone, and their impact to the development planning. Fault hazard management zones were recommended, and structural setbacks were established. During subsequent, more detailed geotechnical studies, ECI has been called to provide on-call field review and interpretation of fault features as they are revealed in the field investigation exposures.

**Third Party Geologic Reviewer for an investigation of the Hayward fault in support of the expansion of the UC Berkeley Coliseum Stadium, 2006.** Under contract to the University of California Berkeley's legal division, ECI was retained to conduct a third party field review of the trenches excavated by Geomatrix during their Hayward fault investigation in support of the UC Berkeley's expansion of their Coliseum stadium. The Hayward fault crosses through the existing stadium. This study was looking for any secondary faults that may transect the proposed athletic office expansion.

**Expert Geologic Consultant for a $120M litigation case involving property devaluation based on geotechnical mitigation costs in oil field redevelopment, 2002-2003.** The project involved litigation between the original property owner and a long term leasing oil company in the northern Los Angeles area. The property owner required a cash settlement from the oil company for environmental cleanup, rather than allowing the oil company to undertake the work themselves. The property owner's environmental consultant developed a remediation plan that was presented to the oil company for payment. The oil company considered the costs to be excessive, and using ECI to evaluate the geological and geotechnical constraints at the site, determined that the conditions at the site were so severe that the property was virtually undevelopable. In trial, it was presented that the excessive environmental remediation costs were intended as an offset to the geotechnical

remediation costs in order to lower the development costs. The case settled during the trial for approximately 20% of the original claim.

**Expert Geologic Consultant for a $1.5M litigation case involving property damage from slope instability initiated by improperly maintained municipal storm drainage in Yorba Linda, 1997-2005.** This case involved a dispute as to the responsible party for a landslide that failed in the rear yard of three homes in Yorba Linda. Earth Consultants International was retained by the property owners to assist in understanding the cause of failure and in determining stabilization and repair alternatives. The work done was used by the litigation experts to prove a case of design inadequacy and maintenance negligence against the City, following a judge-trial, leading to a cash settlement for the plaintiffs.

**Expert Geologic Consultant for La Conchita Ranch in the litigation case over the catastrophic landslide failure in 1995.** During the El Nino storms of 1995, a portion of the 400-foot high bluff above the town of La Conchita failed catastrophically, crushing and destroying over a dozen homes. ECI was retained by the La Conchita Ranch above the failure to serve as an expert witness and geologic consultant in their defense of a lawsuit filed by the homeowners. The plaintiffs had asserted that the Ranch's avocado orchard contributed to the failure. Using the isotopic geochemistry of the ground water, a temporal correlation chart of precipitation and previous landslide failures, geologic structure maps, and soil stratigraphy to refute the arguments, the defense prevailed in court.

**Peer Review Panel Member providing technical review and binding arbitration mediation between the Ocean Trails Golf Course's and the City of Rancho Palos Verdes' geotechnical consultants, 2004-2007.** A technical Peer Review Panel was established to provide binding mediation and direction between the geotechnical consultants to the Ocean Trails Golf Course and the geotechnical reviewers for the City of Rancho Palos Verdes. Several years of dispute existed over the three-dimensional subsurface geometry of several bentonitic clay layers, and the resultant stability analysis. Despite over 40 geologically logged borings, the two sides were unable to reach consensus on the stratigraphic correlations. After extensive review, the Peer Review Panel recommended the drilling of four additional borings targeted towards specific points of contention. All four borings were also refit with inclinometers and grouted-in-place multi-level piezometers. The borings were successful in resolving the geological model to all parties, and new stability analysis based on that model is underway.

**Project Manager for a coseismic deformation analysis of the Coyote Pass Blind Thrust Fault for design of the Northeast Interceptor Sewer tunnel [NEIS], 1999.** Earth Consultants International was retained by the City of Los Angeles to assist in the design of the NEIS tunnel through the area of the Coyote Pass Escarpment, an area of active surface folding associated with a blind thrust fault. Using core data obtained by the City geologists for the geotechnical investigation, supplemented with two additional borings, we were able to geographically constrain the passive and active hinges of the fold where the NEIS tunnel would experience deformation strains and tilts in the next earthquake. Using paleoseismic and geomorphic data collected on another study (LA MTA Red Line tunnels), we were able to quantify these coseismically generated strains, extrapolated to the next earthquake. Based on this analysis, the City's tunnel design engineers were able to design strengthening measures appropriate to resisting the earthquake-generated deformations.

**Project Manager for the faulting and folding hazard assessment of four new Police Facilities in the City of Los Angeles, 2003-2004.** The City of Los Angeles retained Earth Consultants International to undertake a detailed fault hazard assessment of the proposed new Emergency Operations Center, Metro Jail, a relocated Rampart police station, and an enlarged Hollenbeck station. All four facilities were within the possible zone of deformation above the Coyote Pass Escarpment, created by an active blind thrust fault. Using a trench excavation at Rampart, existing geotechnical borings at the Metro Jail, existing geotechnical and six new borings at the EOC, and 20 new borings at Hollenbeck, we were able to conclude that the Rampart, EOC, and Metro Jail sites were north of the active deformation zone, but that the Hollenbeck facility was impacted not only by fold growth and tilting, but also by a transfer fault through the facility that segmented the fold hinge. Using the borehole data we were able to develop a model of fold growth and surface deformation and tilting over the past several thousand years, predict the location and magnitude of future coseismic deformation, and extrapolate the probable surface location, but not displacements, for the tear fault.

**Project Manager for a paleoseismic fault investigation of the Gatún and Limón faults to develop a seismic hazard model for the Autoridad del Canal de Panamá (ACP, formerly**

**Panama Canal Authority), Panamá [2005].** The Autoridad del Canal de Panamá is undergoing an extensive planning program to expand the capacity of the existing Canal. As part of this program, considerable concern was raised by ACP's geologists about the validity of the existing seismic hazard models being used for seismic risk assessments and design. Earth Consultants International was retained by the ACP to undertake a paleoseismic investigation of two high-risk faults: Gatún and Limón. After detailed imagery mapping and geomorphic field reconnaissance, it was concluded that the fault's impacts on the landscape clearly indicated that they were active faults. Then, using 2-D and 3-D trenching techniques, ECI geologists were able to determine an average geologic slip rate of 8 mm/yr for the Gatún and 5 mm/yr for the Limón faults, while recurrence intervals were radiocarbon dated at 150 years for the Gatún and 500 years for the Limón. After presentation to the ACP management and the ACP's Geotechnical Advisory Board, including a field trip to view the youthful tectonic geomorphology of the Limón fault, the geologically determined recurrence intervals and slip rates were incorporated into the ACP's new seismic hazard model.

**Project Manager for a regional tectonic geomorphic reconnaissance of the Western Gatún, Pedro Miguel, Miraflores, Azota, Caballo, and several other faults within the Panama Canal watershed area, for the Autoridad del Canal de Panamá (ACP), Panamá [2006].** Building on the findings of ECI's prior studies of the Gatún and Limón faults, ECI was again retained to review a large area centered on Gatún Lake for indications of other active faults that would impact the seismic hazard model. Using stereo aerial photographs, a 10-m digital elevation model, helicopter reconnaissance, and extensive field verification and geomorphic mapping, ECI identified that the Azota, Pedro Miguel, and Miraflores faults were active and should be incorporated into the seismic hazard model. The results were presented to the ACP's management.

**Principal Consultant for several Seismic Hazard Model Development Workshops for the Autoridad del Canal de Panamá (ACP), Panamá [2006 & 2007].** Following the results of ECI's previous studies on active faults of central Panama, ECI geologists Rockwell and Gath were retained by ACP to participate as source experts for a workshop to finalize the input parameters for the evolving seismic hazard model of Panama. The workshops, led by ACP, also included seismologists from the University of Panama, geologists and seismologists from URS Consultants, and William Lettis Associates, plus the members of the Seismic Advisory Board, Structural Advisory Board, Geotechnical Advisory Board, and Paleoseismic Review Board. Through the several meetings, we made multiple presentations, led several field trips to the fault investigation sites for the various Board members, and actively participated in the development of the seismic hazard parameters, weighting factors and logic tree formulation.

**Project Manager for a paleoseismic investigation of the Pedro Miguel fault to quantify input to the seismic hazard model for the Autoridad del Canal de Panamá (ACP), Panamá [2007].** The recent findings by ECI that the Pedro Miguel fault had a tectonic geomorphic signature indicative of an active fault led the ACP to contract with ECI for an emergency investigation designed to generate quantitative data on the fault's past seismic history. The prior geomorphic study had identified a prospective trenching site in the Cocoli area immediately west of the Miraflores Lock that was viewed as a good chance to prove the fault was active, and to develop a slip rate for the fault. ECI excavated 14 trenches across and parallel to the fault to measure laterally displaced (offset) channel deposits to calculate a slip rate for the fault, and to find sufficient datable alluvial sediments to determine a recurrence interval for the fault. Based on the study, ECI confirmed that the Pedro Miguel fault is indeed highly active, with an average 5 mm/yr geological slip rate and a recurrence interval of 500-1000 years for M7-level surface-rupturing earthquakes. The results were presented to the ACP's management and their new Seismic Advisory Board, including a field trip to visit a trench excavation showing recurrent fault offsets of alluvial and colluvial units.

**Project Manager for a detailed paleoseismic investigation of the Pedro Miguel fault to determine event chronology and the timing of the last earthquake, for the Autoridad del Canal de Panamá (ACP), Panamá [2007].** Findings by ECI's last investigation were that the Pedro Miguel fault was active, and that it was a leading candidate for generating the 1621 AD earthquake, that was highly destructive within Panama City. At the request of the Chief Administrative Officer of the ACP, ECI was retained to conduct a supplemental study of the Pedro Miguel fault, specifically designed to develop a detailed understanding of the magnitude and timing of the Pedro Miguel fault's earthquake history. We completed three 3-D and paleoseismic recurrence interval studies of the fault within the Cocoli area. The study confirmed the presence of a large earthquake within the timeframe of the 1621 event, and determined an average recurrence interval of 500 years for such events. As a consequence of all prior findings by ECI, but particularly because of this study, the

seismic design loads for the structural building code of Panamá will need to be significantly revised.

**Project Manager for an investigation of the Miraflores fault to quantify input to the seismic hazard model for the Autoridad del Canal de Panamá (ACP), Panamá [2007].** A 2006 finding by ECI that alluvial gravels were sheared and in fault contact with the Miraflores fault in a new exposure along the Centennario Bridge Road triggered an investigation of the fault to determine its level of activity. Using trenches excavated across the fault, ECI was able to determine that the fault was had experienced repeated late Holocene earthquakes, estimated a slip rate of 5 ± 3 mm/yr based on the age of the displaced gravels, and recommended that it should be included into the seismic hazard model.

**Project Manager for an investigation of the surface rupture risks posed by the Pedro Miguel and Miraflores faults to the existing Pedro Miguel and Miraflores Locks, for the Autoridad del Canal de Panamá (ACP), Panamá [2008].** Findings by ECI that the Pedro Miguel and Miraflores faults were both active triggered ACP to retain ECI for additional studies of both faults to make a determination as to whether they pose a surface rupture risk to the existing Pedro Miguel and Miraflores Locks, and their associated infrastructure. Using historical maps, eighty years of historical geological data and boring logs, detailed geological field mapping, backhoe trenches, and geophysical transects of the Miraflores Lake (by Technos Inc.), ECI geologists drilled several borings within Miraflores Lake to correlate lake stratigraphy within the fault zones identified by Technos. Trenching and geologic mapping along both sides of the Lake allowed ECI to determine that both faults lie outside the lock footprints, but that their approach causeways are potentially at risk of fault-rupture damage.

**Project Manager for a detailed kinematic investigation of the Pedro Miguel and Miraflores faults within the footprint of the proposed Borinquen Dam portion of the Canal Expansion Project, for the Autoridad del Canal de Panamá (ACP), Panamá [2008 & 2010].** As part of the new Panama Canal Expansion Project, the 5 km long Borinquen Dam is proposed to separate the new third lock from the existing Pedro Miguel and Miraflores Locks. Findings by ECI that the Pedro Miguel and Miraflores faults were both active triggered ACP to retain ECI for additional studies of both faults to prepare detailed maps and fault kinematic measurements for design of the Borinquen Dam to resist future fault rupture failure. Using extensive subsurface trenching excavations and previous geophysical transects by Technos Inc., ECI was able to present a 3-D spatial and kinematic model of faulting within the dam footprint for use by the dam's designers.

**Project Manager to locate abandoned underground mine workings beneath a proposed surface haul road and ore crusher facility for General Moly's Mt. Hope mine in Eureka, Nevada [2009].** In conjunction with Technos Geophysical Services, ECI was retained as program manager to attempt to locate undocumented and abandoned underground mine workings under the Mt. Hope Molybdenum mine's proposed mile-long primary haul road. Combining detailed geologic field mapping and borehole correlation with Micro-gravity, Resistivity, and Ground Penetrating Radar (GPR), the team identified numerous anomalies that were likely to be air-filled mine workings. Following good initial results, the project was expanded to include an additional area proposed for a large crusher mill.

**Geologic Expert for a landslide-related litigation case involving twelve large apartment buildings in Laguna Niguel California [2008-11].** In conjunction with Diaz Yourman Associates for geotechnical engineering, ECI was retained by GMA Insurance Adjusters to provide engineering geologic expertise on a $65M litigation case alleging that nearly the entire apartment complex was underlain by a large and active landslide due to observed damages in some of the structures. ECI and DYA evaluated the existing geotechnical and geologic data, made several field visits, generated cross sections and maps from the data, participated in several meetings, and completed a final report that refuted the landslide interpretation in favor of long duration slow consolidation of thick fills, complicated by progressive shrink-swell of expansive soils. The case is still underway.

## PROFESSIONAL AFFILIATIONS

Association of Engineering Geologists (AEG)
- President—1996-1997
- Vice President—1995-1996
- Treasurer—1993-1995
- Southern California Section Chair—1990-92

Earthquake Engineering Research Institute (EERI)
- Technology Transfer Committee—1991-93
- Liquefaction Subcommittee Co-chair—1992-93
- Ethics Committee —1997-98
- NEHRP Coalition Legislative Committee—1992-99

South Coast Geological Society (SCGS)
- President—1987
- Vice President—1986
- Secretary—1985
- Treasurer—1983-84
- Publications—1981-82

Geological Society of America (GSA)
International Association of Engineering Geologists (IAEG)
American Association for the Advancement of Science (AAAS)
American Geophysical Union (AGU)
Seismological Society of America (SSA)
American Association of Petroleum Geologists (AAPG)
Inland Geological Society (IGS)
San Diego Association of Geologists (SDAG)
Los Angeles Basin Geological Society (LABGS)
Coast Geological Society (CGS)

## COMMITTEE MEMBERSHIPS

Technical Advisory Committee on Geology and Geophysics to the California Board for Professional Engineers and Land Surveyors (2010 - Present)
National Research Council of the National Academy of Sciences, Committee to Develop a Long-Term Research Agenda for the Network for Earthquake Engineering Simulation-NEES (2002)
Board of Directors of Association of Engineering Geologists (1990, 91, 93, 94, 95, 96, 97, 98)
President of the Association of Engineering Geologists (1996-1997)
Vice President of the Association of Engineering Geologists (1995-1996)
Treasurer of the Association of Engineering Geologists (1993-1995)
Land Development Technical Advisory Committee of the Los Angeles County Department of Public Works (1991-1999)
Technology Transfer Committee of the Earthquake Engineering Research Institute (1992-1995)
Professional Ethics Committee of the Earthquake Engineering Research Institute (1996-1999)
Liaison for Association of Engineering Geologists to Earthquake Engineering Research Institute (1992-1999)
Association of Engineering Geologists representative to The NEHRP Coalition (1992-1999)
Geology Working Group of the Southern California Earthquake Center (1992-Present)
Assistant Chairman of Association of Engineering Geologists Annual Meeting (1992)
Management Reorganization Committee of Association of Engineering Geologists (1991)
Field Trip Chairman of South Coast Geological Society (1984, 1985, 1987)
Treasurer of the Association of Engineering Geologist's Annual Meeting (2007)

## RESEARCH GRANTS AWARDED

*Evaluation of the late Quaternary rate of slip, Whittier fault, southern California;* from the U.S. Geological Survey's National Earthquake Hazards Reduction Program, with Thomas Rockwell of San Diego State University as Co-Principal Investigator, Contract No. 14-08-0001-G1696 (1990).
*Continuing research into the Holocene slip rate of the Whittier fault;* from the Geology Working Group of the Southern California Earthquake Center (1992).
*A paleoseismic investigation at the northern terminus of the Whittier fault zone, in the Whittier Narrows area, Rosemead, California;* from the Geology Working Group of the Southern California Earthquake Center (1993).

***Tectonic geomorphic mapping of the eastern Los Angeles basin;*** from the Geology Working Group of the Southern California Earthquake Center (1994).

***Stratigraphic evidence for late Quaternary temporal clustering of large earthquakes on the Puente Hills segment of the Elysian Park thrust, eastern Los Angeles basin, California;*** from the National Science Foundation's National Earthquake Hazards Reduction Program, with Stephen Wells of UC Riverside as Principal Investigator (1994).

***Tectonic geomorphology of the eastern Los Angeles basin: a quantitative analysis of the location, kinematics, and rates of active transpressional structures;*** from the U.S. Geological Survey's National Earthquake Hazards Reduction Program, Contract No. 1434-95-G-2525 (1994).

***Bringing earthquake risk to the California State Legislature: an earthquake hazards seminar that involves the decision and policy makers of the State of California:*** from the Education and Outreach Program Group of the Southern California Earthquake Center (1995).

***Neotectonic uplift of the San Joaquin Hills;*** from the Geology Working Group of the Southern California Earthquake Center (1996 & 1997).

***Fault investigation planning and trench logging—a training workshop and field seminar for consulting engineering geologists;*** from the Knowledge Transfer and Education Working Group of the Southern California Earthquake Center (1999).

***Active deformation and earthquake potential of the southern Los Angeles Basin, Orange County, California;*** from the U.S. Geological Survey's National Earthquake Hazards Reduction Program, with Lisa Grant, University of California, Irvine as Principal Investigator, Contract No. 01HQGR0117 (2001) and Contract No. 03HQGR0062 (2003).

## HONORS AND AWARDS

**Aki Award** for Outstanding Student Paper Presentation in the Geosciences, Southern California Academy of Sciences, Annual Meeting, California State University at Fullerton, May 5, 1995. *[Active tectonic structures in the eastern Los Angeles basin].*

**President** of the Association of Engineering Geologists: Elected and served as President of the Association of Engineering Geologists, Sudbury, MA from Sept. 1996 to Oct. 1997, following previous years as Treasurer and Vice President, Sept. 1994 to 1996, and was a Member of the Board of Directors from 1990 to 1998.

**Shlemon Mentor** of the Geological Society of America: Nominated and served as a "Shlemon Mentor" for professional mentoring of geoscience students at the Cordilleran Section Annual Meeting, Century City, 2001.

**American Geological Institute's** Profiles of Geoscientists: Selected as one of the 37 geoscientists to be profiled in their *Careers in the Geosciences* web, audio, and video series, 2003. www.earthscienceworld.org/careers/profiles/bios/egbio.html and www.careercornerstone.org/geosciences/profiles/gath.htm

**AAPG Division of Environmental Affairs Award** for the Outstanding Paper Presentation at the American Association of Petroleum Geologists' Annual Convention and Exhibition, Long Beach, California, April 2, 2007. *[Quaternary geomorphic development and seismic hazards of Orange County, southern Los Angeles Basin, California].*

**Floyd T. Johnston Outstanding Service Award** from the Association of Engineering Geologists, for at least nine years of service to the profession and AEG, 2008.

**E.B. Burwell, Jr. Award** from The Geological Society of America, for "recognition of outstanding contributions to the interdisciplinary field of engineering geology and for the publication of *Geology of Los Angeles*", 2010.

## CONTINUING EDUCATION SHORT COURSES (non-transcripted)

*Determination of seismic ground motion for earthquake engineering;* American Society of Civil Engineers Short Course, Park City, Utah (1988)

*Critical facilities and site selection;* Geological Society of America Short Course, Dallas, Texas (1990)

*Wetlands and wetland mitigation issues for the engineering geologist;* Association of Engineering

Geologists Short Course, San Antonio, Texas (1991)

***Introduction to TECHBASE;*** MineSoft Inc., three day software training program, Denver, Colorado (1996)

***Paleoseismology in Seismic Hazard Assessment;*** Association of Engineering Geologists Short Course, Salt Lake City, Utah, (1999)

# PUBLICATIONS

## Papers Written

**Gath, E.M.**, 1983, Style of faulting interpreted from a trenching investigation, Glen Ivy South fault, Riverside County, California; in Steller, D.L., Bryant, M., and **Gath, E.M.** (eds.), Geology of the Northern Elsinore Trough; South Coast Geological Society, Santa Ana, California, p. 105-114.

**Gath, E.M.**, 1983, Bishop ash exposed in a road cut near Murrieta, California; in Steller, D.L., Bryant, M., and **Gath, E.M.** (eds.), Geology of the Northern Elsinore Trough; South Coast Geological Society, Santa Ana, California, p. 136-139.

**Gath, E.M.**, 1984, An overview of glacial chronology for the Mammoth Lakes regions, eastern Sierra Nevada, California; in Payne, C.M., Ruff, R.W., and **Gath, E.M.** (eds.), Geology of the Long Valley, Mono Craters; Mammoth Lakes Area; South Coast Geological Society, Santa Ana, California, p. 54-60.

**Gath, E.M.**, 1985, Brief overview of the tectonic origin of the Southern California Continental Borderland; in **Gath, E.M.** and Bottoms, M.M. (eds.), Field Trip to Santa Catalina Island; South Coast Geological Society, Santa Ana, California, p. 9-15.

Guptill, P.D., **Gath, E.M.**, and Ruff, R.W., (eds.), 1985, Geology of the Imperial Valley, California; South Coast Geological Society, Santa Ana, California, 225 p.

**Gath, E.M.**, 1987, Quaternary lakes in the Owens River system; in **Gath, E.M.** and Others (eds.), Geology and Mineral Wealth of the Owens Valley Region, California; South Coast Geological Society, Santa Ana, California, p. 44-57.

Leighton, F.B., Cann, L.R., **Gath, E.M.**, and Bergmann, M.C., 1987, Fault activity and recurrence interval of the western segment of the Whittier fault, California; Final Technical Report to the U.S. Geological Survey, Contract No. 14-08-001-21368, dated August 14, 1987, by Leighton and Associates, Inc.

Rockwell, T.K., **Gath, E.M.**, and Cook, K.D., 1988, Soil chronology and tectonic geomorphology of the Whittier fault zone, Yorba Linda, California: a preliminary estimate of the late Quaternary lateral slip rate; in **Gath, E.M.**, and Cann, L.C. (eds.), Neotectonics of the Whittier Fault; Association of Engineering Geologists, Southern California Section, Field Trip Guidebook.

Sanchez, P.E. and **Gath, E.M.**, 1990, Hazard reduction in Los Angeles County: Technical Appendix to the Safety Element of the Los Angeles County General Plan; Los Angeles County Department of Regional Planning, 2 volumes, 430 p., 8 plates.

Sanchez, P.E., Clark, B.R., Ziony, J.I., McKnight, J.S., and **Gath, E.M.**, 1991, Seismic zonation in the Los Angeles region; in Proceedings of the Fourth International Conference on Seismic Zonation; Earthquake Engineering Research Institute, p. 797-844.

Whitney, R.A. and **Gath, E.M.**, 1991, Structure, tectonics, and surface rupture hazard at the Las Posas anticline, Ventura County, California; in Blake, T.F. and Larson, R.A. (eds.), Engineering Geology along the Simi-Santa Rosa Fault System and Adjacent Areas, Simi Valley to Camarillo, Ventura County, California; Field Trip Guidebook of the 1991 Annual Field Trip, Southern California Section, Association of Engineering Geologists, p. 164-182.

**Gath, E.M.**, 1992, Geologic hazards and hazard mitigation in the Los Angeles region; in Pipkin, B.W. and Proctor, R.J. (eds.), Engineering Geology Practice in Southern California; Association of Engineering Geologists, Southern California Section, Special Publication No. 4, p. 1-32.

Barrie, D., Tatnall, T.S., and **Gath, E.M.**, 1992, Neotectonic uplift and ages of Pleistocene marine terraces, San Joaquin Hills, Orange County, California; in Ehlig, P.L. and Steiner, E.A. (eds), Engineering geology field trips: Orange County, Santa Monica Mountains, and Malibu; Association of Engineering Geologists, Southern California Section, 35th Annual Meeting, Guidebook and Volume, p. A55-A61.

Bausch, D., **Gath, E.M.**, Gonzalez, T., Dolan, J., and Sieh, K., 1992, Application of new developments in seismic hazard assessment, revised Safety Element of the General Plan, City of Santa Monica, California; in Stout, M.L. (ed), Proceedings of the 35th Annual Meeting, Association of Engineering Geologists, p.707-713.

**Gath, E.M.**, Gonzalez, T., and Rockwell, T.K., 1992, Evaluation of the late Quaternary rate of slip, Whittier fault, southern California; USGS Final Technical Report, NEHRP Contract No. 14-08-0001-

G1696, 24 p., numerous plates.

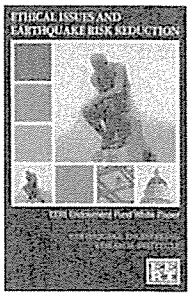
Bray, J.D., Ashmawy, A., Mukhopadhyay, G., and **Gath, E.M.**, 1993, Use of geosynthetics to mitigate earthquake fault rupture propagation through compacted fill; in Geosynthetics '93 Conference Proceedings, Industrial Fabrics Association International, St. Paul, MN, v.1, p. 379-392.

**Gath, E.M.**, Gonzalez, T., Drumm, P.L., and Buchiarelli, P., 1994, A paleoseismic investigation at the northern terminus of the Whittier fault zone, in the Whittier Narrows area, Rosemead, California; Technical Report to the Southern California Earthquake Center, 37 p., numerous plates.

Yogachandra, C., Bausch, D., **Gath, E.M.**, and Hayden, R., 1994, Techniques of liquefaction mitigation; Earthquake Engineering Research Institute, "Earthquake Basics" series, 7 p., 20 35 mm slides.

Dolan, J.F., Sieh, K., Rockwell, T.K., Yeats, R.S., Shaw, J., Suppe, J., Huftile, G.J., and **Gath, E.M.**, 1995, Prospects for larger or more frequent earthquakes in the Los Angeles metropolitan region; Science, v. 267, p. 199-205.

**Gath, E.M.**, 1997, Tectonic geomorphology of the eastern Los Angeles Basin; USGS Final Technical Report, NEHRP Contract No. 1434-95-G-2526, 13 p., 1 plate, 6 figures, 6 tables.



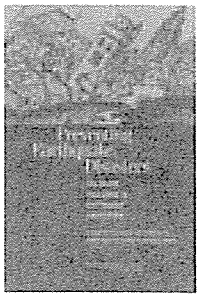

Healy, T., with EERI Seismic Ethics Committee—Lizunda, B., Comartin, C.D., **Gath, E.**, Nigg, J.M., Tobin, L.T., and Greene, M., 1998, Ethical issues and earthquake risk reduction: Earthquake Engineering Research Institute, EERI Endowment Fund White Paper, 70 p.

Grant, L.B., Mueller, K.J., **Gath, E.M.**, Cheng, H., Edwards, R.L., Munro, R., and Kennedy, G.L., 1999, Late Quaternary uplift and earthquake potential of the San Joaquin Hills, southern Los Angeles basin, California; Geology, v.27, p. 1031-1034.

**Gath, E.M.**, 1999, Incorporating multi-hazard awareness into land planning for future disaster reduction: lessons learned in Southern California, USA: in Karaca, M. and Ural, D.N. (eds) Proceedings of the ITU-IAHS International Conference on the Kocaeli Earthquake of 17 August, 1999—a scientific assessment and recommendations for re-building, Istanbul Technical University, Istanbul, Turkey, p. 221-228.

Grant, L.B., Mueller, K.J., **Gath, E.M.**, and Munro, R., 2000, Late Quaternary uplift and earthquake potential of the San Joaquin Hills, southern Los Angeles basin, California: Comment and Reply; Geology, v.28, p. 383-384.

**Gath, E.M.**, Runnerstrom, E.E., and Grant, L.B., 2003, Active deformation and earthquake potential of the southern Los Angeles Basin, Orange County, California: USGS Final Technical Report NEHRP Grant 01HQGR0117, 27 p.



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**Gath, E.**, 2004, The Gap Ahead: The Pending Conflict Between "Engineering Geology" and "Environmental Geology" and What It Means for AEG; in Tepel, R.E. (ed), Symposium Proceedings (CD), Visioning the Future of Engineering Geology, Association of Engineering Geologists Special Publication No. 19, 12 p.

Yeats, R.S. and **Gath, E.M.**, 2004, The role of geology in seismic hazard mitigation; in Bozorgnia, Y. and Bertero, V.V. (eds), *Earthquake Engineering: From Engineering Seismology to Performance-Based Engineering,* CRC Press, p. 3.1-3.23.

Yeats, R.S. and **Gath, E.M.**, 2005, Paleoseismology of surface ruptures: research tool or standard of practice?; Association of Engineering Geologists, AEG NEWS, March, 2005, p. 21-23.

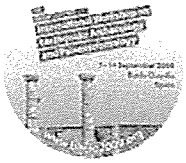
Grant, L.B., **Gath, E.M.**, Owen, L.A., Runnerstrom, 2006, Active deformation and earthquake potential of the southern Los Angeles Basin, Orange County, California, in Bonsangue, J. and Lemmer, R. (eds), *Geology of the Orange County Region, Southern California;* South Coast Geological Society, Annual Field Trip Guidebook No. 33, p. 101-134.

Bilodeau, W.L., Bilodeau, S.W., **Gath, E.M.**, Oborne, M., and Proctor, R.J., 2007, Geology of Los Angeles, California, United States of America; Environmental

and Engineering Geoscience, v. XIII, n. 2, p. 99-160. *[Received the E.B. Burwell Award from the Geological Society of America.]*

Andreas Plesch, John H. Shaw, Christine Benson, William A. Bryant, Sara Carena, Michele Cooke, James Dolan, Gary Fuis, **Eldon Gath**, Lisa Grant, Egill Hauksson, Thomas Jordan, Marc Kamerling, Mark Legg, Scott Lindvall, Harold Magistrale, Craig Nicholson, Nathan Niemi, Michael Oskin, Sue Perry, George Planansky, Thomas Rockwell, Peter Shearer, Christopher Sorlien, M. Peter Süss, John Suppe, Jerry Treiman, and Robert Yeats, 2007, Community Fault Model (CFM) for Southern California; Bulletin of the Seismological Society of America, v. 97, p. 1793–1802.

**Gath, E.M.** and Rockwell, T.K., 2009, Coseismic offset of the Camino de Cruces confirms the Pedro Miguel fault as the cause of the AD 1621 Panama Viejo earthquake: in Pérez-Lopez, R., Grützner, C., Lario, J., Reicherter, K, & Silva, P.G. (eds), *Archeeoseismology and Palaeoseismology in the Alpine-Himalayan Collisional Zone*: 1st INQUA-IGCP-567 International Workshop on Earthquake Archaeology and Palaeoseismology, Baelo Claudia (Cádiz), Spain, Abstracts Volume, p. 32-34.

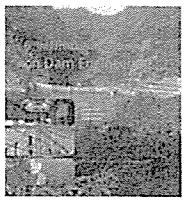


Rockwell, T.K., Bennett, R. A., **Gath, E.,** Franchechi, P., 2010, Unhinging an Indenter: A New Tectonic Model for the Internal Deformation of Panama; Tectonics, v. 29, n. 4, TC4027, doi:10.1029/2009TC002571.

**Gath, E.,** 2010, The San Gabriel Fault: A Summary of its Structural History and Neotectonics; in Saint, P, Herzberg, M., and Zaprianoff, B. (eds), *Geology and Hydrology in the San Gabriel Mountains;* South Coast Geological Society Field Trip Guidebook, n. 36, p. 157-168.

Rockwell, T., **Gath, E.,** Gonzalez, T., Madden, C., Verdugo, D., Lippencott, C., Dawson, T., Owen, L.A., Fuchs, M., Cadena, A., Williams, P., Weldon, E., Franceschi, P., (2010), Neotectonics and paleoseismology of the Limón and Pedro Miguel faults in Panamá: Earthquake Hazard to the Panama Canal; Bulletin of the Seismological Society of America, Vol. 100, No. 6, pp. 3097-3129, doi: 10.1785/0120090342.

**Gath, E.,** González, T., and Rockwell, T., 2011, Quantification of Coseismic Fault Rupture Through the Panamá Canal Expansion Project's Borinquén Dam; in Pina, C., Portela, E., Gomes, J.P., (eds), Proceedings of the 6th International Conference on Dam Engineers; Laboratório Nacional de Engenharia Civil, Lisbon, Portugal, 15-17 February 2011, p. 485-498, ISBN: 978-981-08-7896-2.



## Abstracts Presented

**Gath, E.M.**, Hansen, J.H., Clark, B.R., and Rockwell, T.K., 1987, The Whittier fault in southern California; preliminary results of investigations (abs); American Geophysical Union, EOS, v. 69, n. 16, p. 260.

**Gath, E.M.**, Cann, L.C., and Bergmann, M.C., 1988, Evidence of paleo-surface rupture on the Whittier fault, 4 km east of Whittier, California (abs); Abstracts with Programs, Cordilleran Section, Geological Society of America, v. 20, n. 3, p. 162.

**Gath, E.M.**, and Clark, B.R., 1988, The Safety Element of the General Plan: a database for urban hazard reduction (abs); Geological Society of America, Annual Meeting, Abstracts with Programs, v. 20, n. 7, p. A389.

**Gath, E.M.** and Sanchez, P.E., 1990, The Safety Element of Los Angeles County (abs); Engineering Geology for the 90's, Association of Engineering Geologists, 33rd Annual Meeting, p. 104.

**Gath, E.M.** and Sanchez, P.E., 1990, The Safety Element of Los Angeles County and urban hazard reduction (abs); Abstracts with Programs, Geological Society of America, 1990 Annual Meeting, p. A376.

**Gath, E.M.** and Whitney, R.A., 1992, Faulting and tectonic model of the Las Posas anticline, western Transverse Ranges, and implications for seismic risk in the Ventura basin region, California (abs); American Association of Petroleum Geologists, v. 76, n.3, p. 419.

**Gath, E.M.**, Gonzalez, T., Drumm, P.L., and Buchiarelli, P., 1994, Paleoseismic investigation at the northern terminus of the Whittier fault zone in the Whittier Narrows area, Rosemead, California (abs); Engineering Geology: Past, Present, and Future; Association of Engineering Geologists, 37th Annual Meeting, Program and Abstracts, p. 47.

**Gath, E.M.**, 1995, Active tectonic structures in the eastern Los Angeles basin (abs); Annual Meeting Program & Abstracts, Southern California Academy of Sciences, p. 23.

**Gath, E.M.**, 1995, Seismic hazards of the eastern Los Angeles basin (abs); AEG NEWS, Association of Engineering Geologists, v.39, p. 49.

**Gath, E.M.** and Gonzalez, T., 1995, Earthquake risk assessment at San Bernardino Valley College: hazard mitigation astride the San Jacinto fault in southern California (abs); Engineering Geology in the Metropolitan Environment; Association of Engineering Geologists, 39th Annual Meeting, Program and Abstracts, p. 44.

**Gath, E.M.,** Gonzalez, T., and Sieh, K., 1998, Earthquake risk assessment at San Bernardino Valley College: hazard mitigation astride the San Jacinto fault in southern California (abs); Seismic Safety of Big Cities, Earthquake Prognostics World Forum, International Commission on Earthquake Prognostics and the Turkish Earthquake Foundation, Istanbul, Turkey, p. TMS–3.

**Gath, E.M.,** 1999, Geologic conclusions rarely are: the art and science of geologic reasoning; Association of Engineering Geologists, 42nd Annual Meeting, Program with Abstracts, p. 66.

**Gath, E.M.,** 2000, Tectonic geomorphic development of the southwestern Los Angeles and Orange County Basins: a hypothesis (abs); American Association of Petroleum Geologists, v. 84, n.6, p. 870.

**Gath, E.M.,** 2000, Laguna Beach and the evolution of its ocean views: a 1.4 Ma perspective (abs); Program with Abstracts, Association of Engineering Geologists 2000 Annual Meeting, AEG NEWS, v. 43, n. 4, p. 86.

**Gath, E.M.,** 2001, Incorporating multi-hazard awareness into land planning for future disaster reduction: lessons learned from the California experience (abs); Program with Abstracts, Association of Engineering Geologists 2001 Annual Meeting, AEG NEWS, v. 44, n. 4, p. 62.

Bausch, D. and **Gath, E.M.,** 2001, The Big One: a quantitative comparison of differing earthquake scenarios on southern California (abs); Program with Abstracts, Association of Engineering Geologists 2001 Annual Meeting, AEG NEWS, v. 44, n. 4, p. 55.

**Gath, E.M.** and Grant, L.B, 2002, Is the Elsinore fault responsible for the uplift of the Santa Ana Mountains, Orange County, California (abs); 2002 Abstracts with Programs, 98th Annual Meeting, Cordilleran Section, Geological Society of America, v. 34, n. 5, p. A-87.

**Gath, E.M.,** Grant, L., and Runnerstrom, E., 2003, Using strike-slip offsets for temporal control on the development of a Quaternary drainage network in southern California (abs); Program with Abstracts, Association of Engineering Geologists 2003 Annual Meeting, AEG NEWS, v. 46, p. 56.

**Gath, E.M.** and Grant, L.B., 2004, Learning from Northridge: A progress report on the active faults of Orange County, California (abs); Seismological Society of America, Annual Meeting, Palm Springs, CA. Seismological Research Letters, v. 74, n. 2, p.260.

**Gath, E.M.,** Gonzalez, T., and Sieh, K., 2006, Coseismic ground deformation at San Bernardino Valley College, California (abs); Seismological Research Letters, v. 77, n. 2, p. 277-278.

**Gath, E.M.** and Grant, L., 2007, Quaternary geomorphic development and seismic hazards of Orange County, Southern Los Angeles Basin, California (abs); Abstracts Volume, AAPG Annual Convention and Exhibition, p. 52. *[Received the 2007 Annual Meeting's Outstanding Paper Award by the AAPG-DEG.]*

**Gath, E.M.,** Gonzalez, T., Madden, C., Dawson, T., Rockwell, T., and Franceschi, P., 2007, Seismic hazard studies for the Panama Canal Expansion Project using tectonic geomorphology (abs); AEG NEWS Program with Abstracts, 2007 Annual Meeting, Los Angeles, CA, v. 50, p. 84-85.

**Gath, E.M.,** Rockwell, T., Gonzalez, T., Madden, C., and Verdugo, D., 2008, Quantitative determination of the Pedro Miguel fault's slip displacement and slip kinematics for design of the Panama Canal Expansion Project's Borinquen Dam (abs): AEG NEWS Program with Abstracts, 2008 Annual Meeting, New Orleans, LA, v. 51, p 64.

**Gath, E.M.,** 2009, The Santa Ana Mountains: indenter-driven seismotectonics of the O.C. (abs); AEG NEWS, 2009 Annual Meeting, Program with Abstracts, South Lake Tahoe, CA, v. 52, p. 73.

**Gath, E.M.** and Grant-Ludwig, L., 2010, Collisional tectonics of the Santa Ana Mountains and Puente Hills, Orange County, California (abs); Southern California Earthquake Center, 2010 Annual Meeting Proceedings and Abstracts, v. 20, p. 215.

**Gath, E.M.,** 2010, An aerial and ground reconnaissance of the M7.2 Sierra El Mayor earthquake of April 4, 2010, Baja California, Mexico (abs); AEG NEWS, 2009 Annual Meeting, Program with Abstracts, Charleston, SC, v. 53, p. 72.

**Gath, E.,** González, T., and Rockwell, T., 2011, Quantification of Coseismic Fault Rupture Through the

Panamá Canal Expansion Project's Borinquén Dam; in Pina, C., Portela, E., Gomes, J.P., (eds), Extended Abstracts of the Proceedings of the 6th International Conference on Dam Engineers; Laboratório Nacional de Engenharia Civil, Lisbon, Portugal, 15-17 February 2011, p. 80-81, ISBN: 978-981-08-7896-2.

## Abstracts Co-Authored

Clark, B.R., Zeiser, F.L., and **Gath, E.M.**, 1986, Evidence for determining activity level of the Pelican Hill fault, coastal Orange County, California (abs); Program with Abstracts, Association of Engineering Geologists, p. 46.

Rockwell, T.K., **Gath, E.M.**, and Cook, K.D., 1988, Sense and rate of slip on the Whittier fault zone near Yorba Linda, California (abs); Abstracts with Programs, Cordilleran Section, Geological Society of America, v. 20, n. 3, p. 224.

Hansen, J.H., **Gath, E.M.**, and Cook, K.D., 1988, Geotechnical investigation of the Whittier fault for seismic hazard and structural setback determination, Yorba Linda, California (abs); Abstracts with Programs, Cordilleran Section, Geological Society of America, v. 20, n. 3, p. 166.

**Gath, E.M.**, Gonzalez, T.K., and Rockwell, T.K., 1992, Slip rate of the Whittier fault based on 3-D trenching at Brea, Southern California (abs); Abstracts with Programs, Geological Society of America 88th Annual Cordilleran Section, v. 24, n. 5., p. 26.

Gonzalez, T., **Gath, E.M.**, and Rockwell, T.K., 1992, Exploratory excavations for fault investigations: logging techniques; in Stout, M.L. (ed), Proceedings of the 35th Annual Meeting, Association of Engineering Geologists, p. 205.

Rockwell, T.K., **Gath, E.M.**, and Gonzalez, T., 1992, Sense and rate of slip on the Whittier fault zone, eastern Los Angeles basin, California; in Stout, M.L. (ed), Proceedings of the 35th Annual Meeting, Association of Engineering Geologists, p. 679.

Legg, M.R., Rockwell, T.K., and **Gath, E.M.**, 1993, Active faulting along California's southern coast; American Association of Petroleum Geologists Bulletin, v. 77, n. 4, p. 707.

Whitney, R.A. and **Gath, E.M.**, 1994, Evolution of the Las Posas anticline, western Transverse Ranges, California (abs); American Association of Petroleum Geologists Bulletin, v. 78, n. 4, p. 677.

Wohlgemuth, P.M., **Gath, E.M.**, Everett, R.G., Miller, R.L., and Wells, S.G., 1995, Quaternary history of pluvial Lake Dumont, Mojave Desert, California (abs); Annual Meeting Program & Abstracts, Southern California Academy of Sciences, p. 81.

Mueller, K.J., Grant, L.B., and **Gath, E.M.**, 1998, Late Quaternary growth of the San Joaquin Hills - A new source of blind thrust earthquakes in the Los Angeles basin: Seismological Research Letters, v. 69, p. 161-162.

Cato, K., **Gath, E.**, Gonzalez, T., Bornyasz, M., Walls, C., and Galetzka, J., 2000, The process of installing southern California's seismic GPS network (abs); Program with Abstracts, Association of Engineering Geologists 2000 Annual Meeting, AEG NEWS, v. 43, n. 4, p. 79.

Gath, E.M., Grant, L.B., and Owen, L.A., 2006, Temporal controls on uplift and slip rates for the Puente Hills and Santa Ana Mountains, southern Los Angeles basin, Orange County, California (abs); EOS Transactions of the American Geophysical Society, Fall Meeting Supplemental, v. 87, n. 52, T-13B-0514.

Bilodeau, W.L., Bilodeau, S.W., **Gath, E.M.**, Oborne, M., and Proctor, R.J, 2007, Geology of Los Angeles, California: Lessons learned, laws passed, and policies enacted (abs); AEG NEWS Program with Abstracts, 2007 Annual Meeting, Los Angeles, CA, v. 50, p. 71.

Gonzalez, T, Rockwell, T., **Gath, E.**, Dawson, T., and Cadena, A., 2007, Tectonic geomorphology and paleoseismology of the Limón fault, Panama (abs); AEG NEWS Program with Abstracts, 2007 Annual Meeting, Los Angeles, CA, v. 50, p. 86.

Madden, C., Gonzalez, T, Rockwell, T., Dawson, T., and **Gath, E.**, 2007, Tectonic geomorphology and paleoseismology of the Pedro Miguel fault, Panama (abs); AEG NEWS Program with Abstracts, 2007 Annual Meeting, Los Angeles, CA, v. 50, p. 102.

Rockwell, T., **Gath, E.**, Gonzalez, T, Dawson, T., and Cadena, A., 2007, Tectonic geomorphology and paleoseismology of the Gatún fault, Panama (abs); AEG NEWS Program with Abstracts, 2007 Annual Meeting, Los Angeles, CA, v. 50, p. 114.

Bennett, R., Rockwell, T., Gath, E., Abrego, A., and Spinler, J., 2011, New continuous GPS

measurements from central Panamá with implications for episodic deformation of the Central American Arc; GSA Penrose Conference, xxxx Columbia, poster.

## PROFESSIONAL PRESENTATIONS (no published abstract)

***Glacial and volcanic geology of the Mammoth Lakes area:*** given to the South Coast Geological Society, Santa Ana, CA, 1984.

***Geology, tectonics, and mineral resources of the Searles, Panamint, and Owens Valleys:*** given to the South Coast Geological Society, Santa Ana, CA, 1987.

***The role of the engineering geologist in land development planning and construction:*** given to the California Council of Civil Engineers and Land Surveyors, Los Angeles, CA, 1988.

***Paleoseismic investigations of the Whittier fault in Brea:*** given to the South Coast Geological Society, Santa Ana, CA, 1990.

***The Los Angeles County Safety Element, and the role of the engineering geologist in public safety:*** given to the Association of Engineering Geologists, 1990, Montebello, CA.

***Neotectonics in Southern California, where are we?:*** given to the American Institute of Professional Geologists, Long Beach, CA, 1990.

***Earthquakes, faults, and seismic safety:*** given to the Association of Environmental Professionals, Costa Mesa, CA, 1991.

***Paleoseismic investigations of the Whittier fault in Brea:*** given to the Inland Geological Society, San Bernardino, CA, 1991.

***Geologic features of the Los Angeles—Long Beach Harbor area:*** field trip leader for the International Coastal Engineering Conference, Long Beach, CA, 1991.

***Seismic and geologic hazard reduction in Los Angeles County:*** given to the Ventura County Section of the Society of American Military Engineers, Port Hueneme, CA, 1992.

***Implications of the Landers earthquake for the engineering geologist:*** invited presentation and panelist at the Association of Engineering Geologists 35th Annual Meeting, Long Beach, CA, 1992.

***The Whittier fault as a strain partitioning fault system:*** given to the American Association of Petroleum Geologists, West Coast Meeting, Long Beach, CA, 1993.

***Geotechnical and environmental issues in the redevelopment of abandoned oil fields:*** invited presentation and panelist at a Division of Oil and Gas hosted workshop on geoenvironmental issues in oil field abandonment, Solvang, CA, 1993.

***Engineering geologic observations of the January, 1994 Northridge earthquake:*** invited presentation at the Annual Meeting of the Association of Engineering Geologists in Williamsburg, VA, 1994.

***Earthquakes and active faults of Orange County, lessons from the 1994 Northridge earthquake:*** invited presentation to the Fullerton College science symposium, Fullerton, CA, 1994.

***Engineering geologic findings of the January, 1994 Northridge earthquake, and probabilities for future earthquakes in southern California:*** invited presentation at the Rocky Mountain Section Meeting of the Association of Engineering Geologists in Denver, CO, 1994.

***Tectonic geomorphology of northern Orange County:*** invited presentation to the California State University at Fullerton geology symposium, Fullerton, CA, 1995.

***Active tectonic structures of the eastern Los Angeles basin:*** invited presentation to the South Coast Geological Society, Tustin, CA, 1995.

***Seismic hazard assessment of the San Bernardino Valley College campus:*** presentation to the San Bernardino Community College District's Board of Trustees, San Bernardino, CA, 1996.

***Earthquake risk assessment at San Bernardino Valley College: Hazard mitigation astride the San Jacinto fault in southern California:*** invited presentations to:

- Association of Engineering Geologists' San Francisco Section, San Francisco, California, Jan. 1997
- U.S. Geological Survey's Active Tectonics Symposium, Menlo Park, California, Jan. 1997
- Association of Engineering Geologists' Colorado School of Mines Student Section, Golden, Colorado, Feb. 1997
- Association of Engineering Geologists' Rocky Mountain Section, Denver, Colorado, Feb. 1997
- Association of Engineering Geologists' Great Basin Section, Reno, Nevada, Mar. 1997

- Association of Engineering Geologists' Mackie School of Mines Student Section, University of Nevada, Reno, Nevada, Mar. 1997
- Geology Department Symposium, Oregon State University, Corvallis, Oregon, Mar. 1997
- Association of Engineering Geologists' Southwestern Section, Las Vegas, Nevada, Apr. 1997
- Geological Engineering Department Symposium, University of Nevada, Las Vegas, Nevada, Apr. 1997
- Association of Engineering Geologists' Oregon Section, Portland, Oregon, Apr. 1997
- Geology Department Symposium, California State University, Northridge, California, Apr. 1997
- South Coast Geological Society, Tustin, California, May 1997
- Association of Engineering Geologists' University of Missouri Rolla Student Section, Rolla, Missouri, May 1997
- Civil Engineering Department Symposium, University of Missouri, Rolla, Missouri, May 1997
- Association of Engineering Geologists' St. Louis Section, St. Louis, Missouri, May 1997
- Association of Engineering Geologists' Texas Section, College Station, Texas, May 1997
- Association of Engineering Geologists' South African Section, Johannesburg, South Africa, Jun. 1997
- Association of Engineering Geologists' Sacramento Section, Sacramento, California, Aug. 1997
- International Symposium on Earthquake Hazards of Big Cities, Istanbul, Turkey, September, 1998
- Civil Engineering Graduate Symposium, University of California Irvine, October, 1998

***The future for engineering and environmental geology in southern Africa:*** presentation to the AEG Workshop on Urban Planning in Southern Africa, Johannesburg, South Africa, 1997.

***Regulating urban growth using multi-hazard planning: the importance and role of the engineering geologist:*** presentation to the AEG Workshop on Urban Planning in Southern Africa, Johannesburg, South Africa, 1997.

***The geological evaluation criteria for the design-build of a new 20-mile freeway project in Orange County, California:*** presentation to the AEG Workshop on Urban Planning in Southern Africa, Cape Town, South Africa, 1997.

***Santa Monica's Mandatory Seismic Retrofit Ordinance:*** presentation at the Fourth Annual Congress on Natural Hazard Loss Reduction, Insurance Institute for Property Loss Reduction and Federal Emergency Management Agency, Irvine, California, 1997.

***Tectonic geomorphology of northern Orange County:*** invited presentation to the Earth Sciences Department Symposium, University of Missouri, Rolla, Missouri, 1997.

***A trek into South Africa: Engineering geology down under:*** invited presentation to the Southern California Section of the Association of Engineering Geologists, Los Angeles, California, 1998.

***GPS site construction: a progress report from SCIGN's front line:*** invited presentation to the Southern California Integrated GPS Network (SCIGN) Annual Meeting, University of Southern California, Los Angeles, California, 1999.

***"The Big One": a comparative analysis of three earthquake scenarios in southern California:*** invited presentations to:

- The Real Meaning of Seismic Risk symposium sponsored by LA County Emergency Preparedness Commission, 1999
- The Business and Industry Council on Planning and Preparedness, 1999
- The Southern California Earthquake Center, Los Angeles, California, 1999.

***Incorporating multi-hazard awareness into land planning for future disaster reduction: lessons learned in Southern California, USA:*** invited presentation at the ITU-IAHS International Conference on the Kocaeli Earthquake of 17 August, 1999—a scientific assessment and recommendations for re-building, Istanbul, Turkey, 1999.

***"The Big One": a quantitative comparison of earthquake scenarios on Orange County, California:*** invited presentation to the Orange County Emergency Management Organization (OCEMO), Laguna Woods, California, 2000.

***A quantitative comparison of San Andreas, Newport-Inglewood, Elysian Park, and San Joaguin Hills earthquake scenarios on Orange County, California:*** invited presentation to the Water Emergency Response Organization of Orange County (WEROC), Fountain Valley, California,

2000.

***Natural Hazard Mitigation and Management Before the Disaster—an Assessment of the Available Options:*** invited presentation to the Red Cross and Orange County's Emergency Manager Training Symposium, Santa Ana, California, 2001.

***Geologic Hazards of Orange County:*** invited presentation to the Continuing Learning Education Center, California State University, Fullerton, California, 2001.

***Earthquake Hazards and Future Disaster Reduction in Kahramanmaras: Expensive Lessons Learned from California, USA:*** invited presentation to a special Administration and Faculty seminar, Kahramanmaras, Turkey, 2001.

***The New Riverside County Safety Element – Hazard Mapping, Hazard Management, and Disaster Reduction:*** invited presentations to:

- Inland Geological Society (IGS), Riverside, California, 2002.
- Civil Engineers and Land Surveyors of California, Inland Empire Section (CELSOC), Rancho Cucamonga, California, 2002.

***Laguna Beach and the Evolution of Its Ocean Views — a 1.4 Million Year Perspective:*** invited presentation to the American Society of Civil Engineers, Irvine, California, 2002.

***Hazard Mapping for Risk Management in Southern California:*** invited presentation to the International Association of Engineering Geologists Congress, Durban, South Africa, 2002.

***Tectonic Geomorphology, Blind Thrust Uplift, and Elevated Property Values — a Southern California Perspective on Earthquake Risk:*** invited presentation to the International Association of Engineering Geologists Congress, Durban, South Africa, 2002.

***Is the Elsinore Fault Responsible for the Uplift of the Santa Ana Mountains?:*** invited presentations to:

- LA Basin Geological Society (LABGS), Long Beach, California, 2002.
- South Coast Geological Society (SCGS), Santa Ana, California, 2003.
- Inland Geological Society (IGS), Riverside, California, 2003.

***What Do We Have To Fear? A quantitative analysis of three earthquake scenarios on Orange County, including the 2003 Keilis-Borok prediction event:*** invited presentation to the Association of Contingency Planners, Orange County Section, Anaheim, California, 2004.

***Natural Hazard Identification, Impact Analysis, and Risk Assessment for Disaster Mitigation Planning:*** invited presentation and training session at the 21st Orange County Disaster Preparedness Academy sponsored by the American Red Cross, Anaheim, California, 2005.

***The Effect of Geology on the Southern California Landscape:*** invited presentation for a training session at the 21st Orange County Disaster Preparedness Academy sponsored by the American Red Cross, Anaheim, California, 2005.

***LA's Future Earthquake:*** consultant and talking screen role for the National Geographic Channel's *Explorer* television show (60 minutes) on the consequences to Los Angeles of a large earthquake on the San Andreas and Puente Hills faults, aired Sept. 6, 2006.

***Paleoseismic Investigations of the Gatún and Limón faults, Panama:*** invited presentation to the Geotechnical Advisory Board for the Autoridad del Canal de Panamá, August, 2005.

***Geomorphic Evaluation of the Miraflores, Pedro Miguel, Azota, Caballo, and other faults of Central Panama:*** invited presentation to the Autoridad del Canal de Panamá management team, and the Seismic Advisory Board, August, 2006.

***Seismic Hazard Evaluation: Results of Studies on the Faults of Central Panama:*** invited presentation to the Seismic and Geotechnical Advisory Boards to the Autoridad del Canal de Panamá, January, 2007.

***Seismic Hazard Evaluation of the Panama Canal: Results of Geologic Studies on the Faults of Central Panama:*** invited presentation to the Chief Administrative Officer and Board of Directors of the Autoridad del Canal de Panamá, January, 2007.

***Geologic and paleoseismic investigations of the Gatún, Limón, Pedro Miguel, and Miraflores faults for design of the Panama Canal Expansion Program:*** invited presentation to the Structural Advisory Board Members of the Autoridad del Canal de Panamá, September, 2007.

***Geologic, geomorphic, and paleoseismic investigations within Central Panamá for seismic design of the Panama Canal Expansion Program:*** invited presentations to:

- Paleoseismic Advisory Board Members of the Autoridad del Canal de Panamá, December, 2007
- Panama Canal Society Quarterly Meeting, Laguna Woods, California, 2008

***Tectonic Geomorphic and Paleoseismic Investigations for the Panama Canal Expansion Project:*** invited presentations to:

- Coast Geological Society, Ventura, California, 2008 (with Tom Rockwell)
- South Coast Geological Society, Costa Mesa, California, 2008 (with Tom Rockwell)
- Association of Engineering Geologists, Southern California Section, Los Angeles, California, 2008 (with Tom Rockwell)
- El Colegio de Geólogos de Costa Rica symposium *"La gestión del riesgo en la planificatión y el desarrollo"*, San Jose, Costa Rica, 2009
- University of Oregon, Geoscience Departmental Seminar, 2010
- California State University, Geology Department Seminar, Fullerton, California, 2010

***The Santa Ana Mountains: Indenter Tectonics and the Earthquake Hazards of "The OC":*** invited presentations to:

- South Coast Geological Society, Santa Ana, California, 2009
- San Diego State University, San Diego, California, 2009
- Association of Engineering Geologists, Southern California Section, North Hollywood, California, 2009
- University of Oregon, Geoscience Departmental Seminar, 2010
- Inland Geological Society, Riverside, California, 2010
- Oregon State University, Geoscience Departmental Seminar, Corvalis, Oregon, 2010

***An aerial and ground reconnaissance of the April 4, 2010 M7.2 "Sierra El Mayor" earthquake in Baja California, Mexico:*** invited presentations to:

- Autoridad del Canal de Panamá geological and geotechnical engineering management team, April 28, 2010.
- Portland State University Departmental Seminar, Portland, Oregon, 2010
- Oregon State University, Geoscience Departmental Seminar, Corvalis, Oregon, 2010

***Three-dimensional geologic investigation of the Pedro Miguel fault within the proposed Borinquen Dam footprint, Panama Canal Expansion project:*** invited presentations to:

- Association of Engineering Geologists, Oregon Section, Portland, Oregon, 2010

## FIELD TRIP LEADERSHIP

**Association of Engineering Geologists**

- 1988 – Geology of the Whittier Fault Zone [Leader]
- 1991 – Engineering Geology along the Simi-Santa Rosa Fault System and Adjacent Areas, Simi Valley to Camarillo, Ventura County [Presenter]
- 1992 – Engineering Geology of Orange County [Presenter]
- 1995 – Engineering Geology of the Malibu Coast [Presenter]

**Earthquake Engineering Research Institute**

- 1997 – Japanese Earthquake Engineering Field Conference [Leader]

**Friends of the Pleistocene**

- 2008 – Cross-Correlation of Quaternary Dating Techniques, Slip Rates, and Tectonic Models in the Western Salton Trough [Assistant Leader]

**Geological Society of America**

- 1995 – Engineering Geology of the Los Angeles Basin Oil Fields [Co-Leader]

**International Congress of Coastal Engineering**

- 1993 – Engineering Geology of the Los Angeles Harbor and Palos Verdes Peninsula [Leader]

**South Coast Geological Society**

- 1982 – Geology and Mineral Wealth of the California Transverse Ranges [Assistant Leader]
- 1984 – Geology of the Northern Elsinore Fault Zone [Assistant Leader, Presenter]
- 1983 – Geology of the Long Valley, Mono Craters, Mammoth Lakes Area [Leader, Presenter]

- 1985 – Geology of Santa Catalina Island [Leader, Presenter]
- 1986 – Geology of the Imperial Valley [Assistant Leader]
- 1987 – Geology and Mineral Wealth of the Owens Valley [Leader, Presenter]
- 1989 – Geology of the San Andreas Fault Zone [Assistant Leader]
- 1999 – The Long Valley Caldera, Mammoth Lakes, and Owens Valley Region [Assistant Leader, Presenter]
- 2002 – Neotectonics, geomorphology, and water resources of Ventura and Santa Barbara Counties [Assistant Leader, Presenter]
- 2006 – Geology of the Orange County Region [Presenter]
- 2009 – Geology and Hydrology in the Eastern San Gabriel Mountains [Presenter]

**Southern California Earthquake Center**

- 1996 – Geology of the Newport Inglewood and Whittier Fault Zones [Leader]
- 1998 – Geology of the San Joaquin Hills [Co-Leader]

Earth Consultants International

Project No. 3104
April 15, 2011

13a-A

**To:** **Lozeau | Drury LLP**
410 12th Street, Suite 250
Oakland, California 94607

**Attention:** **Michael R. Lozeau**

**Subject:** **Geologic Review of Potential Faulting and Tsunami Inundation Hazards for the Homewood Resort Project**

**Introduction:**
This letter was prepared at your request to review and comment upon the faulting and tsunami sections of the Homewood Resort EIR and supporting geotechnical reports by Holdridge and Kull. I was not able to review the earlier geohazards report prepared by Kleinfelder, and referenced in the Holdridge and Kull (2010a) report. The two Holdridge and Kull geotechnical reports that I did review (2010 a&b) do contain a general geological discussion, and are signed by two licensed geologists, but they do not contain even a geologic map for the proposed projects, let alone cross-sections, a quantitative geologic analysis of the sites, or even current geologic references. The majority of my information therefore came from independent sources, readily available papers in published journals, and easily located through internet search engines. I am disappointed with the rigor apparently applied to researching and discussing the faulting, seismic, and tsunami hazards sections of either the geotech reports or the EIR. In my opinion, this falls well below the level of practice I expect, especially for a significant project.

Lake Tahoe and the Tahoe Basin have been created by episodic, differential displacements across a suite of generally north-south trending faults (Figure 1). Although the faults were always suspected of being geologically young, it is really only in the past decade that research has begun to both confirm, and generate quantitative results on just how active they are. In essence, the paradigm of seismic hazards and vulnerability of the Tahoe Basin is in flux, and that hazard is definitely increasing. It is therefore unfortunate that the Homewood Resort's EIR relies on generally older references to the seismic hazards, sources which have mostly been superseded by more recent, and more technically advanced, studies. That the two geotechnical engineering reports do not provide this information either probably made the EIR preparer's task more difficult.

The geotech reports and the EIR are completely silent on the potential hazard generated by an earthquake-induced or a landslide-induced lake tsunami or seiche. This is an issue, that while unlikely, has definitely occurred multiple times in the geologic past, obviously has the potential to occur in the future, and has received significant media attention, both locally and nationally. Since this is a resort project, the majority of the users would likely

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be from out of the area. The 2004 Indonesian tsunami clearly demonstrated that coastal tourists are a highly vulnerable population because they are unaware of the hazard, have no recognition of the warnings, and have no idea how to respond if they did. For the EIR to fail to even mention the word tsunami, let alone discuss its potential to be an impact to the project, is stunning.

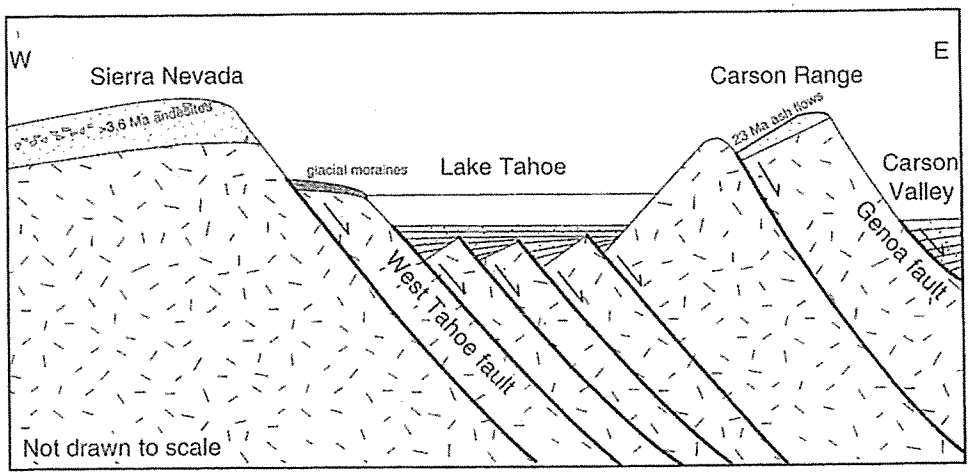


**Figure 1:** Structural geometry interpreted from recent seismic reflection and bathymetric data showing the basin to be a half-graben (Schweickert et al., 2004). Note the presence of a major boundary fault to the west of the West Tahoe fault, and west of the Lake Tahoe lake shore. Absent fault-specific geologic investigations, no one could preclude that any or all of these faults are active Holocene structures.

**Faulting:**

On Page 14-8, the EIR makes a point that the Unnamed Fault #1 (Figures 2 & 3) is shown as a Quaternary-age fault on the more recent Geologic Map of the Lake Tahoe Basin (Saucedo, 2005), but they make more of a point that the fault is not shown on the older geologic map of the Chico Quad (Saucedo and Wagner, 1992). The obvious interpretation is that Unnamed Fault 1 was discovered during the significant focus on Lake Tahoe seismic studies in the past decade. Indeed, the newer map is authored by the same geologist. Who better to revise their own work? This does not make it a new fault, it has been there all along, but it had not been mapped during the prior work. This is a frequent (though unfortunate) event in geology, because while the science builds on the past work, it progresses from new exposures, new understanding of processes, and new expertise being applied. In this case, I would note that it was from studies focused on the seismic hazards of Lake Tahoe that identified this fault, that mapped this fault, and that consider it to be at least a Quaternary-age fault, which makes it "potentially active" under California A-P regulations.

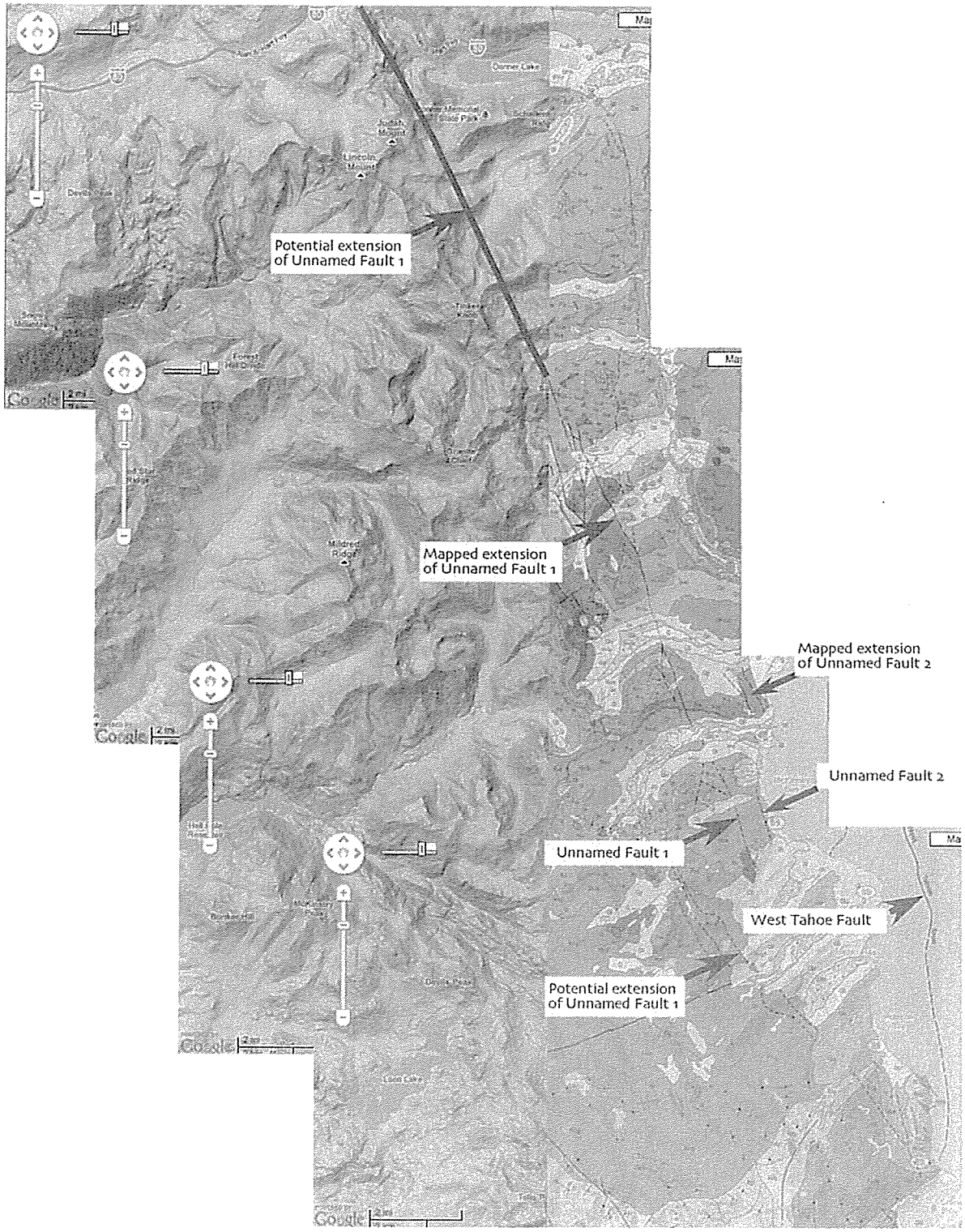


**Figure 2:** Annotated geologic map of the western side of Lake Tahoe, labeled to show the primary fault systems, and a potential northward extension of the Unnamed Fault 1. Modified from Saucedo, 2005, and available at http://www.quake.ca.gov/gmaps/RGM/tahoe/tahoe.html

The EIR also states that the fault is short and discontinuous, making the hazard low for it to be big enough to be hazardous. This is neither accurate nor true. The Unnamed Fault 1 has been mapped at least another 5.5 miles north of the project site (to the limits of the Tahoe Basin mapping), and the geomorphology of the fault can be interpreted for at least 4.5 more miles past the map limits (Figure 2). Furthermore, the southern termination of the Unnamed Fault 1 can (and should) be interpreted as stepping to the west onto another unnamed fault system that continues an additional 5 miles southeast before joining with the West Tahoe Fault in Emerald Bay (Figure 2).

In my opinion, Unnamed Fault 1 is <u>the</u> west bounding fault system for the Tahoe Basin graben (Figure 1 and 4). It has a total length of at least 15 miles, it controls the location of Quail Lake (Figure 3), it ties directly into the known active fault through the lake (West Tahoe fault), it is identified as potentially active, and it has major hazard implications for the project that have never been quantitatively addressed.

**Figure 14-1. Project Area Geology and Fault Map**

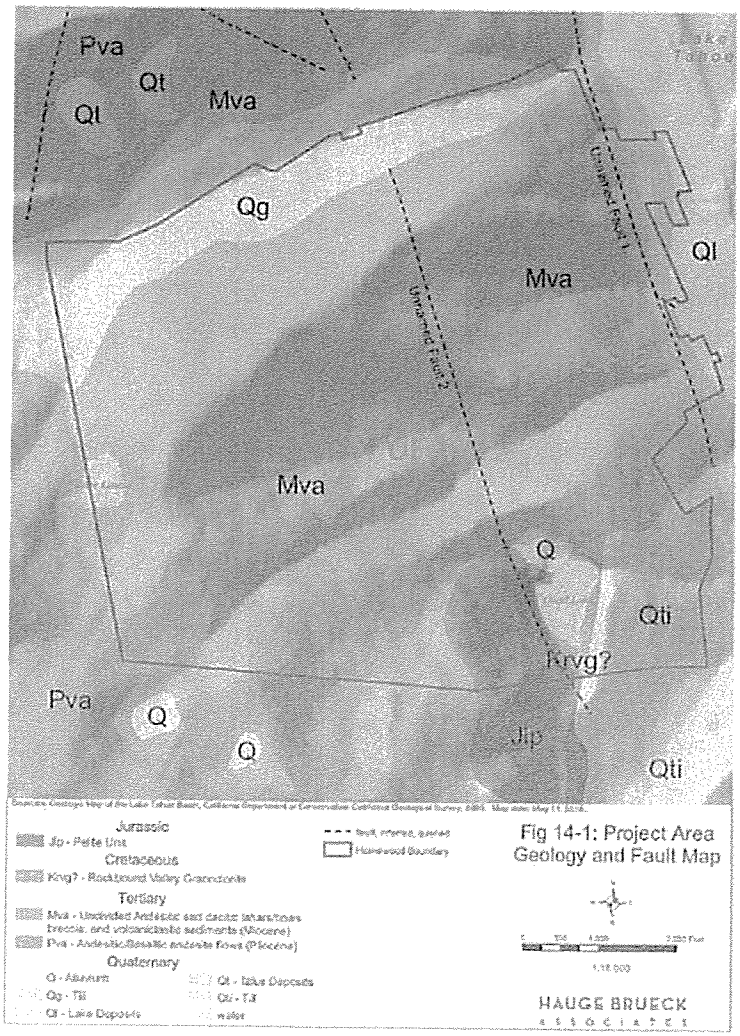


**Figure 3:** Modified geologic map of the site as taken from the EIR report. The map shows the two faults across the site, but it has the fault name labels reversed from the text of the report. Based on the text of the EIR report, Unnamed Fault 1 lies on the west, and Unnamed Fault 2 is to the east. This is the convention used in this letter and relabeled in green on the figure. UF-1 forms the western boundary of Quail Lake, leaving open the question of whether Holocene movement on the fault is responsible for the creation of the lake. UF-2 lies parallel to the shoreline of the lake along a break in slope that leaves open the question as to whether that geomorphic feature is a fault scarp.

Unnamed Fault 2 (Figures 2 and 3) is in a similar category. The fault is considered to be Quaternary in age, making it potentially active according to the A-P Act and as stated in the EIR. it appears to form the margin for the lake level of Lake Tahoe (Figure 2), indicating that it may be an active structural feature controlling the shoreline location (Figure 3). The EIR even states that the fault is located along a break in slope. This geomorphic feature is presumably formed of the surficial (and therefore young) deposits that underlie this eastern part of the project (Figure 3). Is this "break in slope" a fault scarp, which, when combined with the young deposits, would certainly make this a Holocene-age feature? No matter what it is, it is inconceivable that the presence of a potentially active fault, lying parallel and proximal to a known active fault, and coincident with a scarp-like geomorphic feature, would not trigger a competent and professional geologic investigation.

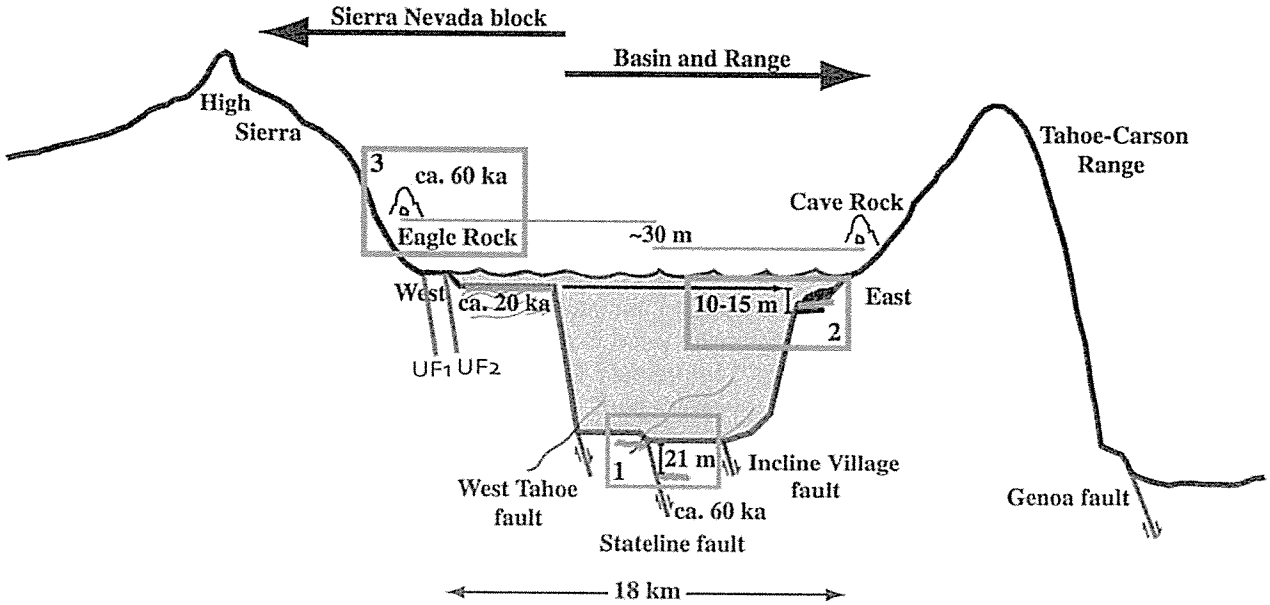


**Figure 4:** Schematic cross section across the Tahoe basin showing relations of the 10 m offset of ~20 ka submerged shorelines and 21-25 m offset of the 60 ka McKinney Bay landslide (Kent et al., 2005). The original figure has been modified to show the approximate locations of the Unnamed Faults 1 and 2 that trend across the site on the western side of Lake Tahoe.

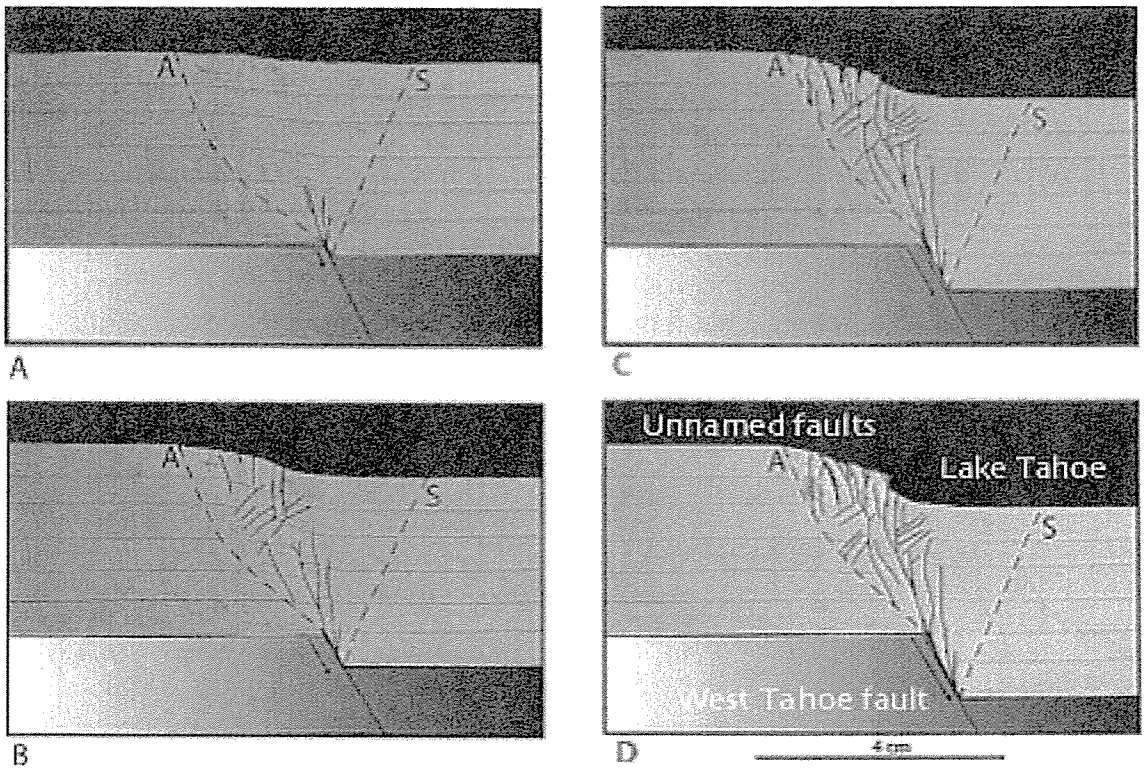


**Figure 5:** Experimental results of oblique (strike slip and extensional) faulting through a layered clay model. The results clearly demonstrate the messy nature of immature faulting, wherein dozens of secondary fault structures are created, any of which may be reactivated in a major event on the main fault. As slip accumulates and the fault system "matures", a dominate fault emerges and the slip on the secondary faults diminishes. In the figure above, consider the real world case where the main fault is the West Tahoe fault, and the secondary faults to the left are the zone of faults that comprise the Unnamed Faults 1 and 2, as hypothetically labeled in D. Figure modified only by insertion of analogy labels from Miller and Mitra, 2011.

That these two faults have not been incorporated into an A-P Zone may be due to several factors: 1) the CGS is not currently working on A-P zones in the Tahoe area since these faults were discovered, or 2) no one has yet trenched the faults to quantify their recency of activity. The three principal fault strands now recognized from the high-resolution bathymetry in the Tahoe basin include the West Tahoe-Dollar Point, Stateline-North Tahoe, and Incline Village faults, but only the Incline Village fault has been trenched to reveal its paleoseismic history (Figure 6). The last event on the Incline Village fault has been dated to about 500 years ago. Whether this segment of the Tahoe Basin fault zone ruptured separately, or was linked in a cascading rupture spanning multiple fault segments, is unknown.

The only way to definitively confirm or refute a fault rupture hazard on these two potentially active faults is to conduct exploratory geologic trenching similar to that done for the Incline Village fault (Figure 6). The boreholes and test pits conducted for

geotechnical engineering and hydrogeological analysis are totally inadequate for active fault determination. The standard of practice for fault investigations requires that the fault actually be exposed in direct contact with sediments which are of a suitable age to show the timing of the last fault rupture. Selection of the trenching sites for such studies require a consideration of the fault's kinematics (anticipated sense of movement), the geologic conditions along the fault, the age of the sediments, and the hydrogeology. Since the state's A-P Act has defined an active fault as one which has displaced sediments of Holocene age (about the last 11,000 years), it is therefore necessary to expose the fault trace as overlain by sediments at least that old in order to conclude that the fault is not active. If the sediments are younger than 11,000 years, and are impacted (offset) by the fault, then the fault is considered active and structural setbacks from occupied buildings are required, and additional design impacts (especially infrastructure) should also be evaluated. If the faults are determined to be active, then additional trenching will be necessary to accurately track the fault locations across the site and to define an appropriate width for the setback zones; which may vary with fault zone complexity changes across the site.

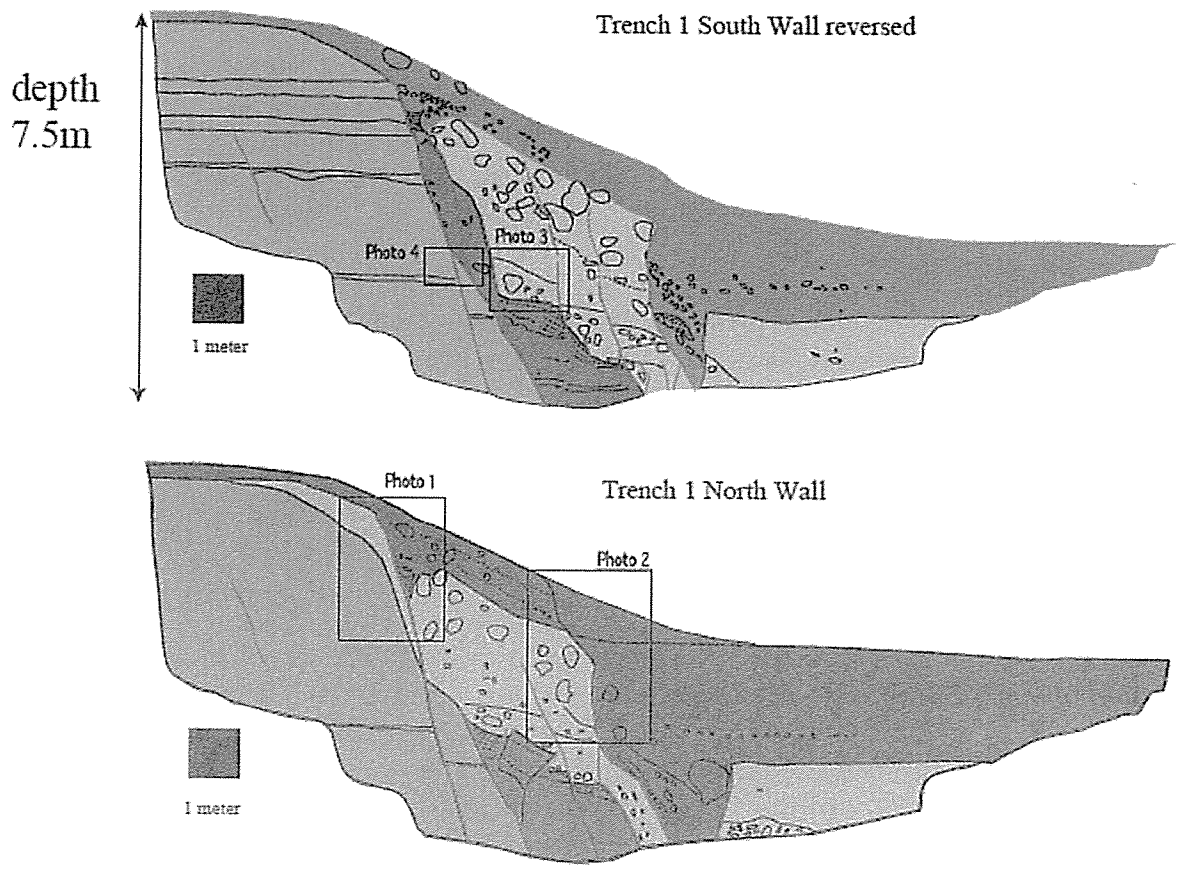


**Figure 6:** Geologic logs of the paleoseismic trenches excavated across the Incline Village fault, showing the scarp derived colluvial deposits on the hanging wall block. Blue: most recent event deposits, Yellow: penultimate event deposits, Green: triultimate deposits. Figure from Seitz and Kent, 2005.

However, instead of trenching to determine if the faults are active or not, the criteria as to whether there is a fault hazard across the site appears to have been decided solely upon whether the California Geological Survey had previously A-P zoned the faults or not. Perhaps the CGS made an incorrect assessment based on limited exposures, or (more likely) has not even reviewed them yet? There is no evidence that any independent geological analysis occurred either in the preparation of the geotechnical report, or in the analysis for the EIR, as to whether these faults posed a hazard. The faults are identified as "potentially active" because they apparently affect Quaternary-age units, and this alone should have triggered a geologist to question (and to investigate) whether they had evidence of Holocene-age displacement or not. Whether required by the A-P Act or not, a prudent professional geologist would certainly recommend that their client investigate a potentially active fault hazard in sufficient detail as to determine whether it poses a surface rupture hazard to the project. If such an action is not included in the geotechnical site reports, it calls into question the ability of the EIR to evaluate the project's feasibility, because the impact of an active fault (or two) bisecting the project certainly must be included as a factor into a project's design and feasibility analysis.

The most recent assessment of the basin-wide seismic strain results in a cumulative extension rate of 0.52-0.99 mm/yr (Dingler et al., 2009). While this may sound trivial, it means that in 1000 years, approximately 1 meter of strain is accumulated. One meter of strain released in an earthquake would generate an earthquake magnitude of about 6.5-6.7. That means that across all of the faults in the Tahoe Basin (Figures 1 and 4), there should be the expectation of a large magnitude earthquake, on average, every millennia. It is possible that the earthquake recurrence is longer than 1000 years, but if so, the earthquakes would be larger (2000 years = 2 meters = M~7). It appears that a large earthquake ruptured the Incline Village fault segment about 500 years ago (Figure 6), and that the West Tahoe fault ruptured about 4,000 years ago (Brothers et al., 2009), but what is the timing of the last earthquake on the other faults? And, in particular, what is the relationship to the potentially active Unnamed Faults that trend through the Homewood project site to the known active fault West Tahoe fault? Unless a competent geologic and paleoseismologic investigation is completed for these "unnamed faults" across this project, we will likely never know until the next earthquake.

**Tsunami:**

The tsunami hazard for the properties surrounding Lake Tahoe has received considerable media attention in the last few years, based on a series of studies of the geological record of past tsunami events within the Tahoe Basin (Gardner et al., 2000; Ichinose et al., 2000; Moore et al., 2006; and Schweickert et al., 2004).

Ichinose et al. (2000) modeled the lake basin deformation from Mw 7.0-7.2 earthquakes on the Tahoe basin faults and estimated that tsunami wave amplitudes could be between 3 and 10 m, depending on the shoreline geometry around the lake. At the Homewood project site, they model a 3.5 to 6.0 meter wave height runup (Figure 7). While still

somewhat controversial, Gardner et al (2000) proposed that a large earthquake on the Tahoe basin faults triggered the McKinney Bay mega-slide [Schweickert et al. (2004) estimated a Holocene age for the event], and modeled that the landslide could have produced a tsunami wave more than 100 m in height.

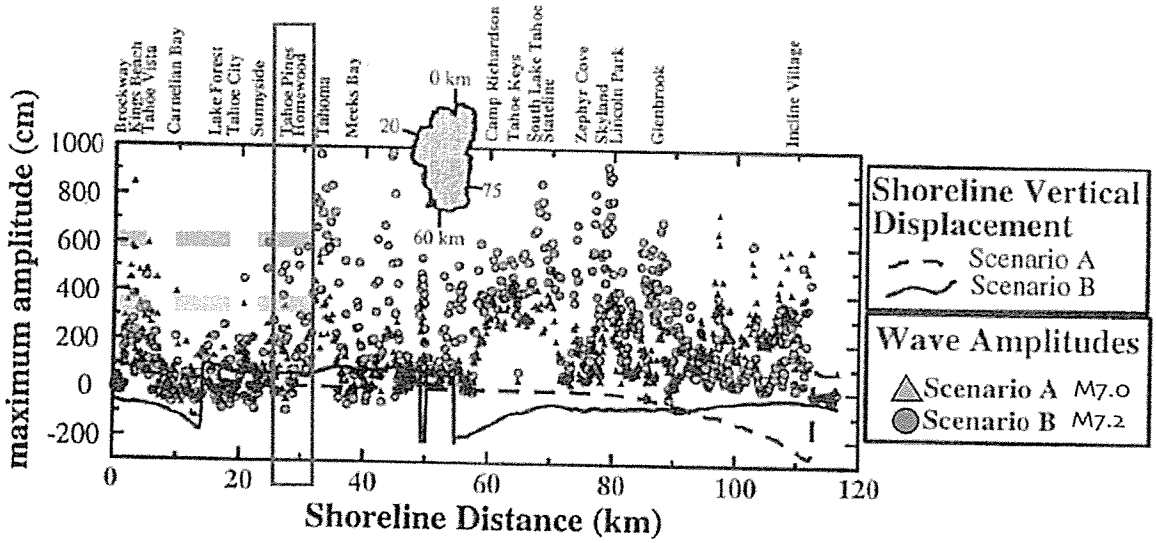


**Figure 7:** Modeled tsunami runup heights around Lake Tahoe, based on two plausible earthquake magnitudes for Tahoe Basin faults. The Homewood project site location is shown in the red box. Based on magnitude 7.0 and 7.2 earthquakes, the predicted runup heights of a tsunami wave are 3.5 and 6.0 meters, respectively, at the project site. Figure modified from Ichinose, et al., 2000.

While it is acknowledged that the McKinney Bay mega-landslide and tsunami event (Gardner et al., 2000) is highly implausible, and the earthquake-induced lake-bottom tsunami of Ichinose (et al., 2000) is also unlikely, their omission from discussion in the EIR is unacceptable. The 3.5-6.0 meter tsunami event is the expected result of a rupture of the basin's faults across the lake bottom, and the possibility of this event must be disclosed and potential mitigation measures discussed. In California, the definition of an active fault is one which has had surface rupture within the Holocene (about the last 11,000 years) time period. The faults of the Tahoe Basin certainly qualify under this definition, the seismic hazard for the Tahoe Basin could expect a large earthquake on a millennial scale, and a plausible scenario is for the lake-bottom faults to rupture together in a chain reaction (a "cascade" event), leading to generation of the tsunami.

**Summary:**

Although this was only a brief review, I hope that some of the material herein is useful to you in your analysis of the project's geologic and seismic hazard setting. I was quite frankly stunned to find that the two faults were considered as "potentially active", that the geotechnical reports were signed by two licensed professional geologists, and that neither

they, nor the EIR team, ever considered it necessary to prove that the two faults across the site posed no hazard. Indeed, when I consider that these two faults have geomorphic expression, that they splay from the proven to be active West Tahoe fault only 5 miles to the south, and that they seem to be part of a significant, sub-parrallel fault zone that forms the western margin of the Tahoe Basin, I would strongly urge that they be considered as "active" faults unless proven otherwise. If active, they pose a significant design constraint that is never considered in the EIR's feasibility or hazard analysis. As for the tsunami hazard, it is simply inconceivable that neither the geotechnical nor the EIR reports even mention it as a possibility. I thought that the entire world became sensitive to tsunami hazards after the 2004 Indonesian earthquake, and indeed the Tahoe Basin spawned several tsunami hazard studies in the last decade, all of which demonstrated that it is a geologic event that has occurred before around the lake. But, there is no mention of it at all in the hazards analysis of the EIR. Perhaps the 2011 Japanese earthquake and tsunami will trigger someone to require that the EIR at least examine the tsunami hazard potential for this project.

I appreciate the opportunity to do this review for you. If you have any questions or desire just to talk about something in this letter, please do not hesitate to call me at [714-412-2653] or email at [gath@earthconsultants.com] me.

**Respectfully submitted,**

**EARTH CONSULTANTS INTERNATIONAL, INC.**

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