Heatherglen Planned Development, TTM 17604, CUP 15-006

Initial Study – Notice of Preparation

Appendix D – Engineering Geology Investigation

**ENGINEERING GEOLOGY INVESTIGATION
PROPOSED HEATHERGLEN PROPERTY
APPROXIMATELY 58 ¾ ACRES, BETWEEN
GREENSPOT ROAD AND ABBEY WAY,
EAST HIGHLANDS AREA,
HIGHLAND, CALIFORNIA**

January 5, 2006

Project No. 3555

Prepared For

North American Residential Communities
326 West Arrow Highway
San Dimas, California 91773

GARY S. RASMUSSEN & ASSOCIATES, INC. / *ENGINEERING GEOLOGY*

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January 5, 2006

North American Residential Communities
326 West Arrow Highway
San Dimas, California 91773

Project No. 3555

Attention: Jenine Murrin

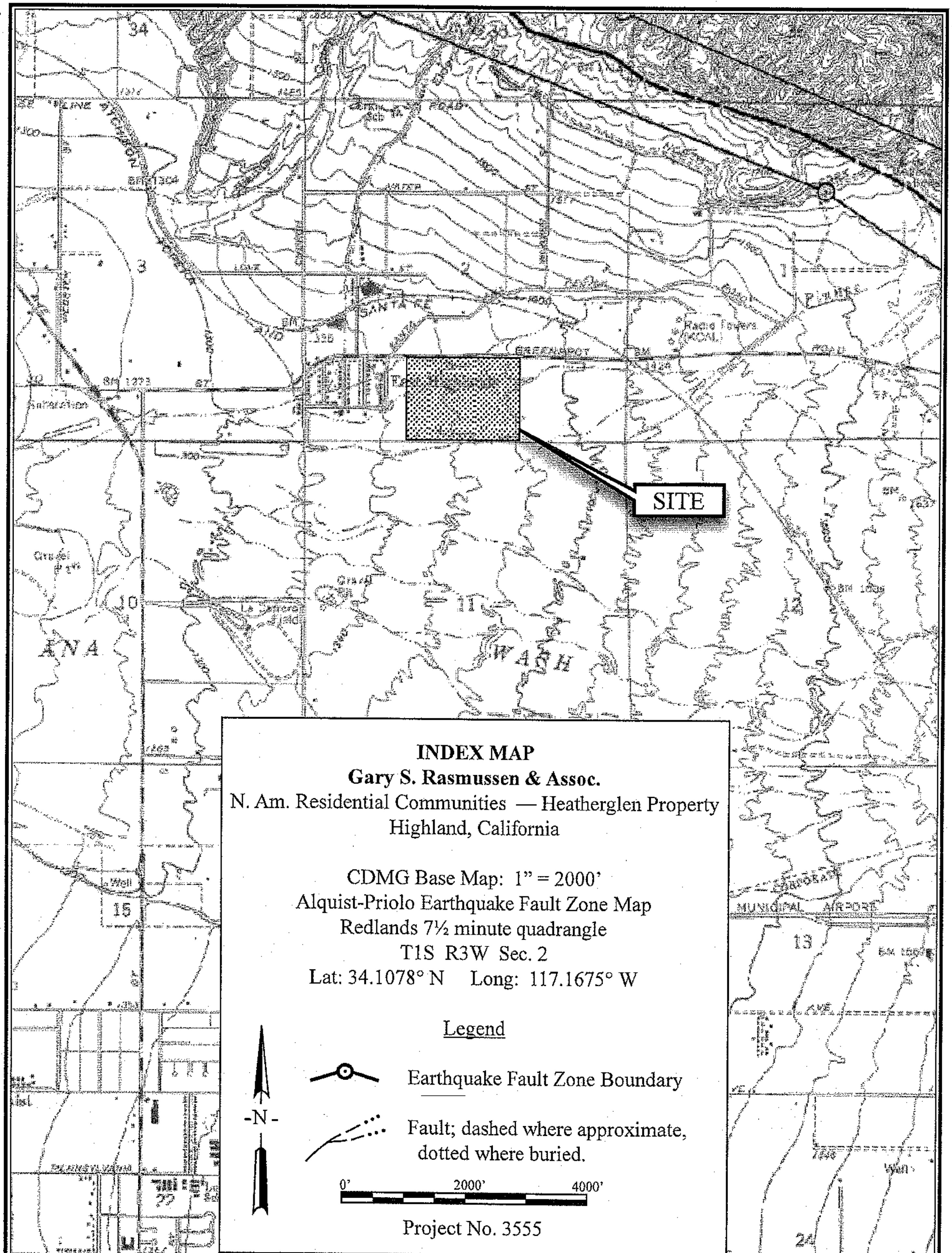
Subject: Engineering Geology Investigation, Proposed Heatherglen Property, Approximately 58¾ acres, between Greenspot Road and Abbey Way, East Highlands Area, Highland, California.

An engineering geology investigation of the proposed Heatherglen Property has been conducted in accordance with your request. The approximately 58¾ acre-site is located in the East Highlands area of Highland, California, between Greenspot Road and Abbey Way. The purpose of our investigation was to relate general geologic conditions of the site to future residential development. Approximately 330-scale San Bernardino County Assessor's maps dated September, 2001, were used in our investigation. The approximate location of the site is shown on the index map on page 2.

No grading plans were available at the time of our investigation. Existing site topography suggests that cut and fill slopes approximately 20 feet in maximum height may be required for development of the site.

SITE INVESTIGATION

A geologic field reconnaissance of the site and surrounding area was conducted on December 8, 2005. In addition, our investigation included review of stereoscopic aerial photographs flown in 1938, 1953, 1959, 1961, 1964, 1967, 1968, 1969, 1970, 1971, 1972, 1973, 1977, 1978, 1984, 1986, 1987, 1988, 1991, 1996, 2001 and 2005; review of pertinent geologic literature and maps, including reports in our files on nearby projects; and review of significant seismic information, including historic seismic activity. A list of aerial photographs reviewed and references cited in this report is included as Enclosure 1.



INDEX MAP
Gary S. Rasmussen & Assoc.
N. Am. Residential Communities — Heatherglen Property
Highland, California

CDMG Base Map: 1" = 2000'
Alquist-Priolo Earthquake Fault Zone Map
Redlands 7½ minute quadrangle
T1S R3W Sec. 2
Lat: 34.1078° N Long: 117.1675° W

Legend

Earthquake Fault Zone Boundary

Fault; dashed where approximate, dotted where buried.

Project No. 3555

SITE DESCRIPTION

The approximately 58 ¾ acre site is located east of East Street between Greenspot Road and Abbey Way in the East Highlands area of Highland, California. At the time of our investigation, the northwest portion of the site was occupied by groves of Eucalyptus trees. The southwest portion of the site was occupied by the remnants of a vineyard. At least 5 residences and at least 8 out-buildings were also observed in the southwest portion of the site. A former reservoir was located in the southern portion of Lot 23. Former irrigation cisterns were observed in the southeast corner of Lots 18 and 21. End dumped piles were observed in the central portion of Lot 21 on the aerial photographs reviewed. Evidence for moist soil conditions was also observed in the vicinity of these piles on the 2005 aerial photographs. Landscaping and trees grow adjacent to the residences in the southwestern portion of the site. Review of the aerial photographs suggests that a significant amount of end dumped fill formerly occupied the southern portion of Lot 21. This portion of the site was disced at the time of our reconnaissance. The central portion of Lots 18 and 21 were formerly occupied by orchards. Former sheds and out buildings occupied the southern portions of Lots 18, 21, 23 and 2 at various times based on review of the aerial photographs. Evidence for significant disturbances of the ground surface and filling was observed in the southwestern portion of the site and associated with a distributary drainage of Plunge Creek that traverses the north central portion of the site. The central and eastern portions of the site were occupied by brush, weeds, trees and boulders. East Valley Water District's Well No. 147 and associated equipment, supplies and infrastructure were located immediately south of Lot 23. Four relatively large west to southwest trending drainages traverse the site. Numerous smaller channels also traverse the site. The natural ground surface on the site slopes downward toward the west at an overall rate of approximately 2 percent. Total relief across the site is approximately 35 feet.

A partially concrete-lined, south trending flood control channel is coincident with the eastern boundary of the site. The remainder of the channel is unlined. Earthen fill berms border this channel. This flood control channel intercepts west-to southwest trending distributary drainages of Plunge Creek that traverse the site. Residences were observed north and west of the site. The drainage of Plunge Creek is located approximately 500 feet south of the site. Vacant land was observed east of the site.

SITE GEOLOGY

The San Bernardino Valley Block is bounded on the northeast by the San Andreas fault and the San Bernardino Mountains, and on the southwest by the San Jacinto fault. The San Bernardino Valley Block is subsiding in relation to the Perris Block, located southwest of the San Jacinto fault, and in relation to the San Bernardino Mountains, located northeast of the San Andreas fault.

The entire site is underlain by alluvium of Holocene age (Dutcher and Garrett,1963; Morton, 1974, 1978; Dibblee, 1970, 1974; Rogers, 1969; Bortugno and Spittler, 1986; Matti, *et al.*, 1992; Morton & Miller, 2003). Surficial materials on the site consist of gravelly sand with boulders. A geologic index map is included as Enclosure 2.

East Valley Water District's Production Water Well No. 147 is located immediately south of Lot 23. This well encountered sand, gravel, cobbles and boulders with trace amounts of silt and clay to a depth of approximately 360 feet during drilling (Rasmussen, February 1, 2001). Continued drilling encountered fine to course-grained sand with clay and minor gravel to a depth of 737 feet (Rasmussen, February 1, 2001).

The geologic subsurface materials underlying the site are considered to be characterized by dense, or stiff, soil, which corresponds to Classification S_D of Table 16A-J of the California Building Code (International Conference of Building Officials, 2001) to a depth of at least 100 feet below the ground surface, based on published geologic data and geologic field reconnaissance. This classification is equivalent to NEHRP Type D soil, as classified by the Building Seismic Safety Council (1994) and Boore *et al.* (1997). The corresponding Seismic Acceleration Coefficient, Ca, is 0.44 × Na from Table 16A-Q of the 2001 California Building Code. The Seismic Velocity Coefficient, Cv, is 0.64 × Nv from Table 16A-R of the 2001 California Building Code.

SEISMIC SETTING

The site lies within Seismic Zone 4 of the Seismic Hazard Zone Map for Hospitals and Public Schools in California on Figure 16A-2 of the 2001 California Building Code. The corresponding Seismic Zone Factor, Z, is 0.40 from Table 16A-I of the 2001 California Building Code.

The site does not lie within or immediately adjacent to an Earthquake Fault Zone (formerly Special Studies Zone) as defined by the Alquist-Priolo Earthquake Fault Zoning Act (Hart and Bryant, 1999). The closest Alquist-Priolo Earthquake Fault Zone is located approximately ¾ mile northeast of the site associated with the San Andreas fault.

Dutcher and Garrett (1963) mapped a northwest trending ground water barrier traversing the northwest portion of the site (Enclosure 2). Dutcher and Garrett (1963) identified this northwest-trending ground water barrier as Fault "K." Northwest trending tonal lineaments were observed traversing the site and southwest of the site on the aerial photographs reviewed. One of these lineaments is approximately coincident with fault "K", as shown by Dutcher and Garrett. These lineaments may represent fault strands associated with fault "K." Dana identified a northwest trending fault similar in trend and location to Fault "K" during a gravimetric study conducted 6 miles northwest of the site (San Bernardino Valley Municipal Water District, 1968). Dana identified this fault as the Shandin Hills fault. Morton (1974), Matti and Carson (1991) and Matti *et al.* (1992) showed the northwest-trending Oak Glen fault located approximately 4 miles southeast of the site. Rasmussen (March 12, 1999) and URS (1986) suggested that the Shandin Hills fault, Fault "K" and the Oak Glen fault are probably all portions of the same fault. These faults are probably an ancestral branch of, or related to, the San Andreas fault system. Fault "K" acts as a significant barrier to the southwestward flow of ground water (Rasmussen, March 12, 1999). Jennings (1994), Bortugno (1986), and Ziony and Jones (1989) did not show the Shandin Hills fault or Fault "K". Jennings (1975) and Ziony and Jones (1989) showed the Oak Glen fault as a potentially active fault.

Probably the most important fault to the site from a seismic shaking standpoint is the San Andreas fault. The active, northwest trending San Andreas fault is located approximately 1 mile northeast of the site. The location of the main, active trace of the San Andreas fault is evidenced by vegetation lineaments, fault scarps, springs, linear ridges, and offset drainages. Although the San Andreas fault is characterized overall by right-lateral, strike-slip movement, the San Bernardino Mountains have been uplifted along its trace.

Dutcher and Garrett (1963), Morton (1974) and Fife *et al.* (1976) showed a northwest trending ground water barrier located approximately 2 miles west of the site. Dutcher and Garrett (1963) identified this ground water barrier as Fault "L." Fault "L" also acts as a barrier to the southwestward flow of ground water. The northwest terminus of Fault "L" as shown by Dutcher and Garrett (1963) is approximately coincident with the northeast portion of Perris Hill. Perris Hill is composed of metamorphic rock consisting of Pelona Schist. Jennings (1994), Ziony and Jones (1989), and Bortugno (1986) did not show Fault "L". Dutcher and Garrett (1963), Izbicki *et al.,* (1998) and Danskin (1998) suggested that Fault "K" and Fault "L" form the northeast and southwest boundaries, respectively, of a fault-bounded graben.

The northeast trending Mentone branch of the Redlands fault is located approximately 2 ¼ miles southeast of the site. The northeast trending Redlands fault, located approximately 4 miles south of the site, forms a barrier to the subsurface movement of ground water. Its location is based, in part, on apparent termination of Pleistocene-age alluvium against older (Plio-Pleistocene-age) deposits. The Redlands fault apparently bifurcates 4 miles south of the site to form the Redlands and Mentone faults (Burnham and Dutcher, 1960; Eccles and Bradford, 1977). The northeast trending Mentone fault has been defined only from well logs and its effect on ground-water movement (Burnham and Dutcher, 1960). Bortugno (1986), Ziony and Jones (1989) and Jennings (1994) showed the Redlands fault as a potentially active fault.

Burnham and Dutcher (1960), Morton (1974), Ziony and Jones (1989) and Matti *et al.,* (1992a, 1992b), mapped the northwest trending Greenspot fault located approximately 2 ¾ miles east of the site. Motion along the Oak Glen fault may have transferred *en echelon* along the Greenspot fault to the San Andreas fault. The Greenspot fault is an effective ground-water barrier (Burnham and Dutcher, 1960). Wells drilled northeast of the fault reportedly had ground water rising to the surface when drilled. Springs and perched ground water were reported within a shallow drainage immediately northeast of the fault. The fault is associated with a degraded, southwest facing scarp in older alluvial material. Locally, the fault scarp is buried by younger alluvium. Bortugno (1986) and Jennings (1994) did not show the Greenspot fault. However, Ziony and Jones (1989) showed the Greenspot fault as a potentially active fault.

The northeast trending Crafton fault (also known as the Reservoir Canyon fault) is located approximately 4 miles southeast of the site. The Crafton fault forms the northwest boundary of the Crafton Hills. Ziony and Jones (1989) and Jennings (1994) showed the Crafton fault as a potentially active fault. Bortugno (1986) differentiated the Reservoir Canyon fault (southwest portion of the Crafton fault) from the remainder of the Crafton fault, but showed both portions of the fault as potentially active faults.

Izbicki *et al.*, (1998) and Danskin (1998) identified a northwest-trending fault located approximately 3 miles southwest of the site and suggested that this fault may be the northwest extension of the Banning fault. Burnham and Dutcher (1960) and Morton (1974) showed the northwest terminus of the Banning fault offsetting, or offset by, the Loma Linda fault approximately 6 ¼ miles southwest of the site. Morton (1974) inferred an unnamed, northwest-trending fault approximately coincident with the Banning(?) fault shown by Izbicki *et al.*, (1998) and Danskin (1998) based on microseismic activity. Izbicki *et al.*, (1998) and Danskin (1998) presented evidence that this fault offsets bedrock at depth but does not disrupt overlying alluvial units. The Banning(?) fault and the Loma Linda fault may form the northeast and southwest limits, respectively, of a fault-bounded graben (Izbicki *et al.*, 1998; Danskin, 1998).

The northwest-trending Loma Linda fault is located approximately 6 ¼ miles southwest of the site. The Loma Linda fault acts as a barrier to the southwest flow of ground water in the southwest portion of the San Bernardino Valley. Subsurface investigations conducted by our firm have shown the Loma Linda fault not to be an active fault as defined by the State of California. The Loma Linda fault may represent an older branch of the San Jacinto fault. The fault is also a source of geothermal water.

The northwest trending San Jacinto fault, located approximately 7 miles southwest of the site, is considered to be the most active fault in southern California (Allen *et al.*, 1965). Trenching in very young alluvium across the San Jacinto fault has confirmed very recent episodes of fault rupture. The San Jacinto fault is characterized by right-lateral, strike-slip movement.

The Glen Ivy North branch of the Elsinore fault zone is located approximately 30 miles southwest of the site. The Elsinore fault zone extends southeast into Mexico (Biehler *et al.,* 1964). The Elsinore fault separates the Santa Ana Mountains from the Temescal Basin on the Perris Block. Subsurface investigations by Rockwell *et al.,* (1986) have shown that the Elsinore fault is active and may have a recurrence interval of approximately 250 years for large earthquakes. Bergmann and Rockwell (1996) and Vaughan *et al.,* (1999) found additional evidence of active faulting associated with the Elsinore fault. Ziony *et al.,* (1974), Ziony and Jones (1989) and Jennings (1994) showed portions of the Elsinore fault zone to be active faulting. The State included portions of the Elsinore fault zone within Alquist-Priolo Earthquake Fault Zones.

A summary of significant faults and their distances from the site is presented in the following table:

FAULT	**DISTANCE (MILES)**	**DIRECTION**
Fault "K"	on site	---
San Andreas	1	northeast
Fault "L"	2	west
Mentone	2 ¼	southeast
Greenspot	2 ¾	east
Banning	3	southwest
Redlands	4	south
Crafton	4	southeast
Loma Linda	6 ¼	southwest
San Jacinto	7	southwest
Elsinore	30	southwest

Other active or potentially active faults are located within the general region, but because of their greater distance from the site and/or lower expected maximum probable earthquake, they are less important to the site.

SEISMIC HISTORY

The accuracy of locating earthquake epicenters is not always sufficient to determine which fault they are associated with. Estimates of magnitude and epicenter locations for earthquakes prior to implementation of recording instruments were based on descriptions of the earthquakes by individuals in different areas. Seismic instrumentation did not become available until about 1932, and these earlier instruments were imprecise. An earthquake epicenter map showing earthquake epicenters within 25 miles of the site is included as Enclosure 3 (EPI SoftWare, 2005). The earthquake locations shown on the earthquake epicenter map are based on instrument locations (Southern California Earthquake Center, 2005).

Magnitudes reported for earthquakes usually fall in a range of values depending on the recorded strength and frequency of the strong ground motion, type of seismometer recording the ground motion, location of the seismometer with respect to the earthquake, subsurface conditions at the seismometer location, and the scale used to classify the magnitude. Common scales used to classify earthquake magnitudes include the familiar Richter or "local" magnitude (M_L), moment magnitude (M_W) derived from the seismic moment (M_0), body-wave magnitude (M_b) and surface-wave magnitude (M_S). Estimates of earthquake size utilizing the moment magnitude scale and the seismic moment are preferred due to limitations associated with other measurement scales, including variations among distant recording locations, frequency response of geologic materials, and saturation (or response) of the recording seismometers (Wells and Coppersmith, 1994).

No significant earthquakes are known to have occurred during historic time along Faults "K" or "L", or along the Mentone, Greenspot, Redlands, Crafton, west portion of the Banning, or Loma Linda faults.

No large earthquakes have occurred along the San Andreas fault in the southern California area in recent time. This fault has a pattern of almost no movement for long periods of time (131 years, Pallett Creek, Sieh, 1984; 105 years, Wrightwood, Weldon *et al.,* 2004), followed by a sudden release of energy. The last major earthquake along it in this area was the great earthquake of January 9, 1857, which was centered at Fort Tejon, north of Gorman. The Fort Tejon earthquake had an estimated magnitude of approximately M8.0, comparable to the 1906 San Francisco earthquake (Wood, 1955). A large earthquake that occurred on December 8, 1812, affected a wide area of southern California and is now attributed to the San Andreas fault in the San Bernardino area (Jacoby, *et al.,* 1988; Fumal, *et al.,* 1993). The magnitude of the 1812 earthquake is estimated to have been approximately M7.5 (Petersen and Wesnousky, 1994). On December 4, 1948, a large earthquake occurred in the Desert Hot Springs area. This earthquake was originally assigned a magnitude of M_L6.5 and attributed to the Mission Creek fault (north branch of the San Andreas fault in this area) by Richter *et al.,* (1958). An evaluation of this earthquake by Nicholson (1996) placed the Desert Hot Springs earthquake on the Banning fault (south branch of the San Andreas fault) and revised the magnitude to M_L6.3 (M_W6.2). An earthquake of M_L6.0 (M_W6.1) occurred along the Banning fault on July 8, 1986, northwest of the 1948 earthquake (Jones *et al.,* 1986; Nicholson, 1996). Field reconnaissance by our firm found evidence for surface ground rupture associated with the 1986 earthquake. Other smaller earthquakes have occurred along the San Andreas fault northwest and southeast of these two locations.

The San Jacinto fault has been the most seismically active fault in southern California (Allen *et al.,* 1965). Between 1899 and 1995, eight earthquakes of M6.0 or greater have occurred somewhere along the San Jacinto fault between the San Gabriel Mountains and Mexico (Lamar *et al.,* 1973; Kahle *et al.*, 1988).

A summary of the dates of these earthquakes, their approximate locations, and their estimated magnitude is presented in the following table:

DATE	LOCATION	MAGNITUDE
December 25, 1899	Anza Valley	(estimated) 7.1
April 21, 1918	San Jacinto Valley	(estimated) 6.9
July 22, 1923	South of Loma Linda	(estimated) 6.3
March 25, 1937	Southeast of Anza	6.0
October 21, 1942	Fish Creek Mountains	6.6
March 19, 1954	East of Borrego	6.2
April 9, 1968	Borrego Mountain	6.5
November 24, 1987	Superstition Hills	6.6

Since 1899, earthquakes on the San Jacinto fault of magnitude 6.0 or greater have occurred every 5 to 19 years. The earthquakes in 1899, 1918 and 1923 occurred along the northern portion of the San Jacinto fault; the earthquake in 1937 occurred along the middle reach of the San Jacinto fault; and the earthquakes in 1942, 1954, 1968 and 1987 occurred along the southern portion of the San Jacinto fault (Lamar *et al.,* 1973; Kahle *et al.,* 1988).

Several earthquakes with estimated magnitudes between 6.0 and 6.5 have been located along the Elsinore fault zone between the Santa Ana River and the Gulf of California during historic time. In 1910, a moderately large earthquake (~M6) occurred in the Temescal Valley area, probably along the Glen Ivy North fault. In 1956 an earthquake of approximately Richter magnitude 4.7 occurred in the Temescal Valley area causing rock slides. A magnitude 7.0 earthquake occurred on the Laguna Salada strand of the Elsinore fault zone in northern Mexico in 1892 (Townley and Allen, 1939). However, no earthquakes of this magnitude or greater have been recorded along the northern end of the fault since 1910 (Lamar *et al.,* 1973).

SEISMIC ANALYSIS

Significant earthquakes affecting the site may occur on the San Andreas fault during the lifetime of the proposed residences. The San Andreas fault is considered to be the most important fault to the site from a seismic shaking standpoint due to its proximity to the site, style of faulting, recurrence interval, and Design Basis Earthquake ground motion. The Design Basis Earthquake (DBE) is that earthquake ground motion which has a 10 percent probability of exceedance in 50 years. The statistical return period for the DBE is approximately 475 years.

Recurrence intervals for large earthquakes cannot yet be precisely determined from a statistical standpoint, because recorded information on seismic activity does not encompass a sufficient span of time. However, based on the information available at this time, it is our opinion that a MPE of M_W7.3 along the San Andreas fault may occur. Large earthquakes could occur on other faults in the general area, but because of their greater distance and/or lower probability of occurrence, they are less important to the site from a seismic shaking standpoint.

Several authors presented data that showed a relationship between the distance from a causative fault and peak horizontal ground accelerations. Equations predicting the relationship between the earthquake magnitude, site parameters and peak ground acceleration were developed by Campbell (1997 [revised 2000, 2001]), Boore *et al.,* (1997), Bozorgnia *et al.,* (1999), Sadigh *et al.,* (1997), Abrahamson and Silva (1997) and Campbell and Bozorgnia (2003 [revised 2004]). Numerous additional attenuation relationships have been developed by various researchers over the years. Attenuation relationships developed after 1996 were considered appropriate for this site.

The California Geological Survey (2003) calculated the peak ground acceleration for a Design Basis Earthquake (DBE) in alluvium at the site as 0.76g. We have used the results of the attenuation relationship derived by Campbell (1997) for alluvium to derive ground motion parameters for the site. Based on Campbell's attenuation relationships for alluvium, a DBE ground motion based on the 2002 State fault model would result in a mean value of the peak ground acceleration on the site of 0.72g (Blake, 2000, revised 2002). This value is slightly lower than the State's calculated acceleration. These accelerations should not necessarily be used as design values for insertion in California Building Code formulas; rather, they should be considered as an aid in the evaluation of a structural design of the residences to be placed on the site.

Due to the proximity of the site to the San Andreas fault, near-field effects from strong ground motion associated with a large earthquake along this fault may occur at the site. These near-field effects, including "fling", focusing, and directivity of strong ground motion, may result in significantly higher accelerations at the site.

The San Bernardino segment of the San Andreas fault is the most significant fault for determining the Near-Source Acceleration and Velocity Factors applicable to the site. The San Bernardino segment of the San Andreas fault is considered to be a Type A fault (Cao *et al.,* 2003). The San Bernardino segment of the San Andreas fault is located approximately 1 mile (1½ kilometers) northeast of the site. The corresponding Near-Source Acceleration Factor, Na, is 1.5 from Table 16A-S of the 2001 California Building Code. The Near-Source Velocity Factor, Nv, for the site is 2.0 from Table 16A-T of the 2001 California Building Code.

The San Andreas fault is considered to be the most important fault to the site from a seismic shaking standpoint due to its proximity, style of faulting, recurrence interval and maximum probable earthquake ground motion. Fault lengths were determined from Jennings (1994) and California Geological Survey (2002). All criteria outlined in California Geological Survey Note 43 and Section 1631A of the 2001 California Building Code were considered when estimating the MPE for faults in the vicinity of the site. The Design Basis Earthquake is synonymous with the Maximum Probable Earthquake (California Geological Survey Note 48). The maximum magnitude earthquake (M_{max}) for individual faults presented by Working Group (1995, 1999, 2003), Cao *et al.,* (2003), and the Southern California Earthquake Center (1996) were also reviewed. The maximum magnitude earthquake (M_{max}) is the largest earthquake expected to occur on a fault under the current tectonic framework. The relationship of fault length versus earthquake magnitude as presented by Wells and Coppersmith (1994) constitute only one of those criteria. The structural geometry of the fault was considered very important in deciding the MPE for specific faults (Rasmussen, 1981).

SLOPE STABILITY

The State of California has not conducted seismic hazards mapping for the Redlands 7 ½ minute quadrangle and did not include the site within a Seismic Hazard Earthquake-Induced Landslide Zone as defined by the Seismic Hazards Mapping Act (California Division of Mines and Geology, 1997). The City of Highland (2005) did not show the site located within a landslide susceptibility area. San Bernardino County (1993) showed the closest area susceptible to landsliding located approximately 1,000 feet north of the site.

No evidence for landsliding was observed on or in the immediate vicinity of the site, in the field or on the aerial photographs reviewed. Due to the lack of significant topography, landsliding is not expected on the site.

GROUND WATER

The State of California has not conducted seismic hazards mapping for the Redlands, 7½ minute quadrangle and the site is not included within a Seismic Hazard Liquefaction Zone as defined by the Seismic Hazards Mapping Act (California Division of Mines and Geology, 1997). Matti and Carson (1991) included the entire site within a potential liquefaction area. Toppozada *et al.*, (1993) showed the extreme southeast portion of the site located adjacent to a potential liquefaction area. Highland (2005) and San Bernardino County (1993) showed the entire site located within an area of high liquefaction susceptibility.

No springs are known to exist on the site. No perched ground-water conditions are known to exist under the site. No evidence for spring activity or perched ground-water conditions was observed on or in the immediate vicinity of the site during the geologic field reconnaissance or on the aerial photographs reviewed.

Matti and Carson (1991) showed the minimum depth to ground water in the vicinity of the site during the period from 1973 through 1983 to have been between 30 and 50 feet in the western portion of the site and to have been between 10 and 30 feet in the eastern portion of the site. Following the years of abnormally high precipitation from 1978 to 1983, ground water levels in the basin rose significantly.

East Valley Water District Well No. 147 is located immediately south of Lot 23. The depth to ground water at the time of testing of Well No. 147 was approximately 130 feet below the ground surface (Rasmussen, February 1, 2001). East Valley Water District Well No. 143 is located approximately 550 feet west of the site and Well No. 146 is located approximately 1,500 feet west of the site. Well No. 143 has been abandoned. The depth to groundwater at Well No. 146 was approximately 200 feet (Rasmussen, February 1, 2001).

Fault "K" is mapped traversing the northwest portion of the site (Dutcher and Garrett, 1963). The trend of Fault "K" is subparallel to trend of the San Andreas fault. The location of Fault "K" was based primarily on differences in ground levels and wells located on opposite sides of the fault (Dutcher and Garret, 1963). Morton (1974) and Fife *et al.,* (1976) showed a ground water barrier traversing the northwest portion of the site approximately coincident with Fault "K."

Geomorphology suggests that Fault "K" may extend to the southeast and may represent an extension of the Oak Glen fault. The ground water barrier effect of Fault "K" is relatively strong during periods of historically low ground water conditions (Rasmussen, March 12, 1999). Portions of Fault "K" also act as significant barriers to the southwestern flow of ground water during periods of historically high ground water conditions (Dutcher and Garrett, 1963; Matti and Carson, 1991; Rasmussen, March 12, 1999). The ability of Fault "K" to influence ground water conditions at relatively shallow depths suggests that Fault "K" extends relatively close to the surface. In addition, Fault "K" appears to act as a barrier to the recharged ground water in the vicinity of the Santa Ana River (Rasmussen, March 12, 1999). Historic changes in ground water levels in the vicinity of the site suggest that natural and artificial recharge along the Santa Ana River is partially blocked by Fault "K" and migrates northwestward toward the vicinity of the site (Rasmussen, March 12, 1999). Fault "K" may act as a significant ground water barrier on the site. Shallower ground water may be present in the northeast portion of the site with respect to the ground water in the southwest portion of the site.

Youd and Perkins (1978) and Youd *et al.,* (1978) listed the parameters for increased liquefaction susceptibility as: 1) high ground water (less than 33 feet below the surface); 2) sandy sedimentary deposits; 3) recent age of material; and 4) close proximity to an active fault. The sediments encountered on the site fall into all four of these geologic parameters. Therefore, the sediments on the site are considered to have a high potential for liquefaction from a geologic standpoint.

SUBSIDENCE

Subsidence of the ground surface has occurred in the San Bernardino, San Jacinto, Antelope and Murrieta Valleys, and in the Chino Basin. The primary cause of non-tectonic subsidence in these areas has been the removal of large quantities of ground water from their respective ground-water basins (Miller and Singer, 1971; Lofgren, 1971, 1976; Fife *et al.,* 1976; Riverside County, 1988; Egan and Hall, 1994; Egan *et al.,* 1995).

Static ground-water levels in the vicinity of the site have declined by as much as 190 feet since the turn of the century (Mendenhall, 1905; California Department of Water Resources, 1990, 2005; East Valley Water District, 1996, 1997; Western Municipal Water District, 2005; Rasmussen, March 12, 1999). The greatest ground water declines have occurred in the East Highlands area between Fault "K" and the south branch of the San Andreas fault. The barrier effect of Fault "K" is more pronounced when ground water levels are lower (Rasmussen, March 12, 1999). Ground water levels have also declined significantly immediately southwest of Fault "K", reflecting a flattening of the static ground water table overall (Rasmussen, March 12, 1999).

Ground water levels in the vicinity of the site have risen by as much as 220 feet over the last 30 years This increase in the ground water levels is considered to be the result of natural and artificial recharge of water along the Santa Ana River.

Subsidence due to ground-water withdrawal may be a potential hazard to the site if static ground-water levels are allowed to decline significantly in the future. Cracking from subsidence in the future would be expected to occur along the boundaries of ground-water basins. Traces of Fault "K", if they traverse the site, could act as these basin boundaries.

FLOODING

The entire site lies within a 100-year flood plain associated with Plunge Creek (Highland, 2005; Federal Emergency Management Agency, 1996). San Bernardino County (1989) also showed the northern portion of the site located within a 100-year flood plain associated with Plunge Creek. The County showed a 100-year flood plain associated with the Santa Ana River coincident with the southern boundary of the site. At least four west-trending drainages traverse the site. Evidence for flooding of the site was observed during the geologic field reconnaissance and on the aerial photographs reviewed. Geologic field reconnaissance and review of the aerial photographs indicates that a concrete-lined diversion channel is coincident with the east boundary of the site. Sheet flow runoff on the site is expected during periods of intense or prolonged precipitation. An evaluation of the potential for flooding of the site falls under the purview of the project engineer.

The entire site is located within the limit of a Flooded Area associated with potential failure of Seven Oaks Dam (Highland, 2005). The County (1989) showed the entire site located within a dam inundation area.

No other large water storage reservoirs are located topographically higher than the site in the immediate vicinity of the site.

SEISMIC SETTLEMENT AND DIFFERENTIAL COMPACTION

Seismic settlement occurs when relatively loose natural materials undergo compaction due to seismic shaking. This results in settlement of the natural ground surface. Differential compaction of natural materials may occur across a site if significant geologic features (i.e. faults, bedrock contacts, landslide contacts, etc.) result in different thicknesses or different densities of materials across a site.

Seismic settlement or differential compaction may be potential problems on the site, if Fault "K" traverses the site. Seismic settlement or differential compaction on the remainder of the site are not expected, as no unusual geologic conditions or structures are known to exist under the remainder of the site.

MISCELLANEOUS

The San Bernardino County General Plan (1989, 1993) and Highland General Plan (2005) were reviewed and geologic hazards to the site have been addressed.

CONCLUSIONS

The site does not lie within or immediately adjacent to an Earthquake Fault Zone (formerly Special Studies Zone) as defined by the Alquist-Priolo Earthquake Fault Zoning Act.

The site lies within Seismic Zone 4 of the Seismic Hazard Zone Map for Hospitals and Public Schools in California on Figure 16A-2 of the 2001 California Building Code. The corresponding Seismic Zone Factor, Z, is 0.40 from Table 16A-I of the 2001 California Building Code.

Published geologic maps indicate that Fault "K" traverses the site. Evidence for northwest trending tonal lineaments traverse the site and vicinity on the aerial photographs reviewed. However, no indicators of fault movement were observed on the site during the geologic field reconnaissance or on the aerial photographs reviewed. Ground rupture on the site from surface faulting associated with Fault "K" is not expected during the lifetime of the proposed residences.

Severe shaking of the site can be expected within the lifetime of the proposed residences from an earthquake along the San Andreas fault.

The San Andreas fault is located approximately 1 mile northeast of the site. Therefore, near-field effects from strong ground motion associated with a large, nearby earthquake may occur at the site.

The mean value of the peak ground acceleration at the site may be higher due to the near field effect and directivity.

Published geologic maps indicate that the site is underlain by young alluvium. Near surface natural materials are considered to be relatively loose. Moderate to severe seismic shaking of the site is expected in the event of a large, nearby earthquake. Therefore, seismic settlement of natural materials on the site may be a concern. An evaluation of the suitability of natural materials on the site to support proposed structures and fills falls under the purview of the project geotechnical engineer.

The San Bernardino segment of the San Andreas fault is the most significant fault for determining the Near-Source Acceleration and Velocity Factors applicable to the site. The San Bernardino segment of the San Andreas fault is considered to be a Type A fault. The geologic subsurface materials underlying the site are considered to be characterized by dense, or stiff, soil, which corresponds to Classification S_D of Table 16A-J of the California Building Code to a depth of at least 100 feet below the ground surface. This classification is equivalent to NEHRP Type D soil, as classified by the Building Seismic Safety Council (1994) and Boore *et al.,* (1997). The corresponding

Near-Source Acceleration and Velocity Factors (Na and Nv), and Seismic Acceleration and Velocity Coefficients (Ca and Cv) are presented in the following table:

Na = 1.5	Ca = 0.44 x 1.5 = 0.66
Nv = 2.0	Cv = 0.64 x 2.0 = 1.28

The State of California has not conducted seismic hazards mapping for the Redlands 7 ½ minute quadrangle and did not include the site within a Seismic Hazard Earthquake-Induced Landslide Zone as defined by the Seismic Hazards Mapping Act. The City of Highland (2005) did not show the site within a landslide susceptibility area. San Bernardino County (1993) showed the closest area susceptible to landsliding located approximately 1,000 feet north of the site.

No evidence for landsliding was observed on or in the immediate vicinity of the site, in the field or on the aerial photographs reviewed. Due to the lack of significant topography, landsliding is not expected on the site.

The State of California has not conducted seismic hazards mapping for the Redlands 7 ½ minute quadrangle and the site is not included within a Seismic Hazard Liquefaction Zone as defined by the Seismic Hazards Mapping Act. Matti and Carson (1991) included the entire site within a potential liquefaction area. Toppozada *et al.,* (1993) showed the extreme southeast portion of the site located adjacent to a potential liquefaction area. Highland (2005) and San Bernardino County (1993) showed the entire site located within an area of high liquefaction susceptibility.

Fault "K" is mapped traversing the northwest portion of the site. Geomorphology suggests that Fault "K" may extend to the southeast and may represent an extension of the Oak Glen fault. The ground water barrier effects of Fault "K" are relatively strong during periods of both historically low and historically high ground water conditions. The ability of Fault "K" to influence ground water conditions to relatively shallow depths suggests that Fault "K" extends relatively close to the surface. In addition, historic changes in ground water levels in the vicinity of the site suggests that natural and artificial recharge along the Santa Ana River is partially blocked by Fault "K" and migrates northwestward toward the vicinity of the site. Fault "K" may act as a significant ground water barrier on the site. Ground water may be shallower in the northeast portion of the site with respect to the southwest portion. The sediments encountered on the site may fall into all four of the geologic parameters required for increased liquefaction susceptibility when shallow groundwater is present. Therefore, the sediments on the site are considered to have a high potential for liquefaction from a geologic standpoint.

Surficial materials on the site are considered to be moderately to highly susceptible to erosion by water.

Historic and recent depth to ground water data in the vicinity of the site suggest that static ground water levels in the vicinity of the site have declined more than 190 feet since the turn of the century, but may have recovered by as much as 220 feet during the past 30 years. Due to the significant decline in ground water levels in the vicinity of the site, subsidence may be a potential hazard to the site. Any future subsidence of the ground surface may affect proposed structures or facilities and subsidence of subsurface materials may affect proposed gravity sensitive pipelines such as sewers. Cracking from any subsidence in the future would be expected to occur along the boundaries of ground water basins. The northwest trending Fault "K", which may traverse the central portion of the site, could act as one of these basin boundaries.

The Federal Emergency Management Agency (1996) showed the entire site located within a 100-year flood plain associated with Plunge Creek. San Bernardino County (1989) also showed the northern portion of the site located within a 100-year flood plain associated with Plunge Creek. The County showed a 100-year flood plan associated with the Santa Ana River coincident with the southern boundary of the site. At least four west-trending drainages traverse the site. Evidence for flooding of the site was observed during the geologic field reconnaissance and on the aerial photographs reviewed. Geologic field reconnaissance and review of the aerial photographs indicates that a concrete lined diversion channel is coincident with the east boundary of the site. Sheet flow runoff on the site is expected during periods of intense or prolonged precipitation. An evaluation of the potential for flooding of the site falls under the purview of the project engineer.

The entire site is located within the limit of a Flooded Area associated with potential failure of Seven Oaks Dam (Highland, 2005). The County (1989) showed the entire site located within a dam inundation area. No other large water storage reservoirs are located topographically higher than the site in the immediate vicinity of the site.

An evaluation of the significance of all on-site fill to the proposed residences falls under the purview of the project geotechnical engineer.

The San Bernardino County General Plan (1989, 1993) and Highland General Plan (2005) were reviewed and geologic hazards to the site have been addressed.

RECOMMENDATIONS

A maximum probable earthquake of M_W 7.3 may occur along the San Bernardino segment of the San Andreas fault, located approximately 1 mile northeast of the site. Therefore, we recommend that the proposed human occupancy structures be designed accordingly.

Fault "K" may traverse the central portion of the site. Evidence for tonal lineaments was observed traversing the site on the aerial photographs reviewed. These lineaments may represent older faulting associated with Fault "K.". However, no evidence for active faulting was observed associated with Fault "K" on or in the vicinity of the site, on the aerial photographs reviewed or in the field. Ground surface rupture associated with Fault "K" is not expected during the lifetime of the proposed residences. Therefore, setbacks for human occupancy structures from Fault "K" are not recommended.

The maximum inclination of all cut slopes in alluvial materials on the site should be 2 horizontal to 1 vertical up to a maximum height of 15 feet. All cut slopes should be planted as soon as possible to minimize erosion, as material on-site may be susceptible to erosion from water.

Liquefaction may be a potential hazard to the site as the historic ground water table has been reported to be less than 30 feet below the ground surface in the eastern portion of the site. The additional parameters of soil density, grain size distribution and exact depth to ground water should be evaluated by the project geotechnical engineer to ascertain the final susceptibility of the site to liquefaction. We recommend that a depth to ground water of 10 feet from the ground surface be used for calculating the liquefaction potential of the site.

Positive drainage of the site should be provided, and water should not be allowed to pond behind or flow over any natural, cut or fill slopes. Where water is collected in a common area and discharged, protection of the native soils should be provided, as the native soils are moderately to highly susceptible to erosion by running water.

Subdrains may be recommended beneath any proposed fills placed within the on-site drainages. The need for subdrains should be evaluated by the engineering geologist during grading.

If shallow, perched ground water exists on the site, moisture sensitive structures should be protected.

The significance of all on-site fill with respect to the proposed development should be addressed by the project geotechnical engineer.

An evaluation of the potential for seismically induced flooding of the site in the event of a large earthquake should be addressed by the project engineer.

The final grading plan for the site should be reviewed and approved by an engineering geologist prior to any grading.

Grading of the site should be evaluated by the engineering geologist by in-grading inspections.

Any water wells that exist on the site that will not be used in the future should be abandoned in accordance with applicable state and local regulations.

Due to the potential hazard of tensional ground surface fracturing on the site as a result of differential response of geologic materials across the suspected traces of Fault "K" in the event of a large, nearby earthquake, subsidence, differential compaction, or seismic settlement, we recommend that foundations and slabs of the proposed residences be reinforced to resist tensional ground cracking.

Respectfully Submitted,
Gary S. Rasmussen & Associates, Inc.

Frank F. Jordan, Jr.
Engineering Geologist, EG 1913

FFJ/mc

Enclosure 1: References
Enclosure 2: Geologic Index Map
Enclosure 3: Earthquake Epicenter Map

Distribution: Jenine Murrin (6)

ENCLOSURE 1
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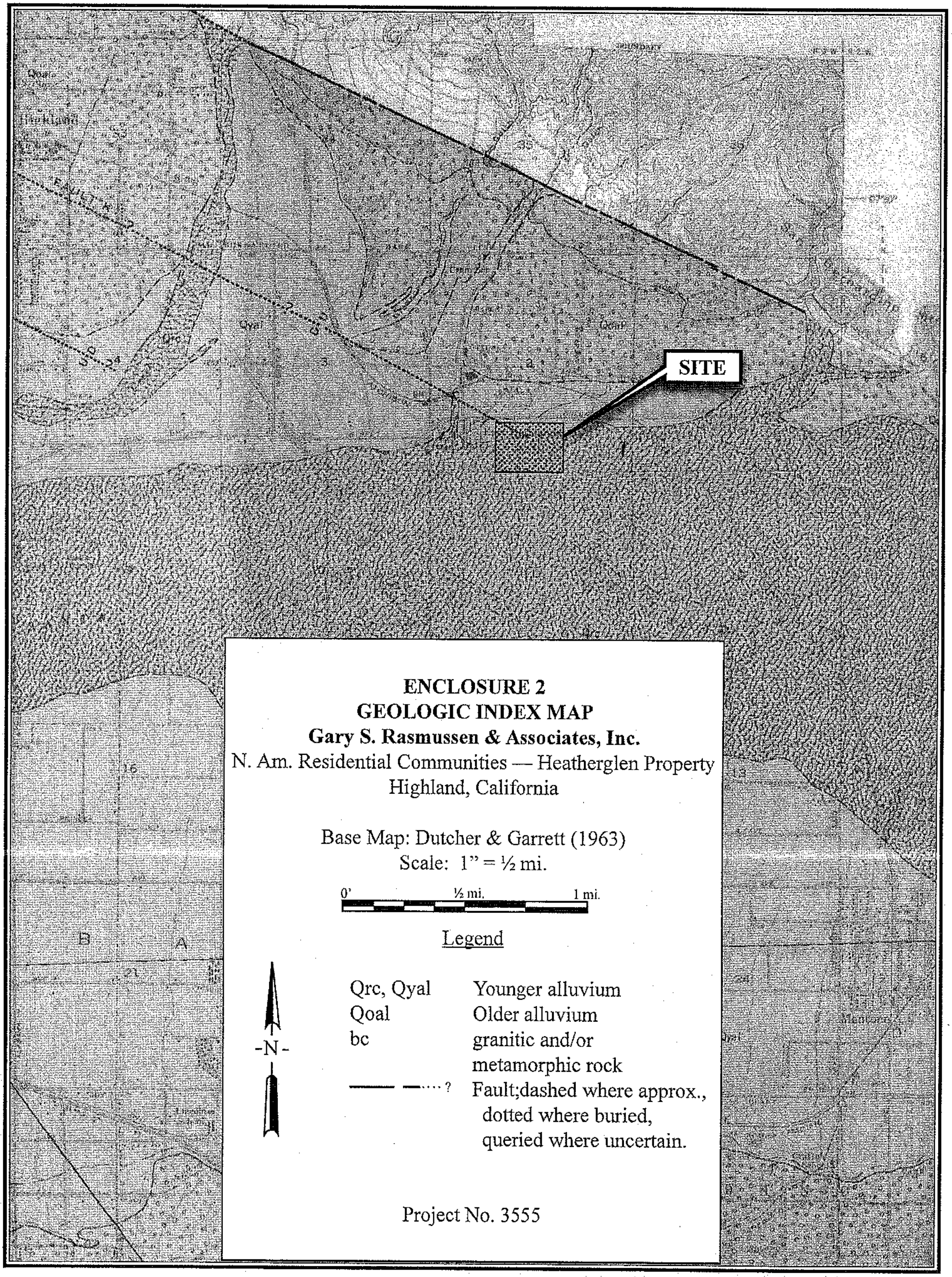


ENCLOSURE 2
GEOLOGIC INDEX MAP
Gary S. Rasmussen & Associates, Inc.
N. Am. Residential Communities — Heatherglen Property
Highland, California

Base Map: Dutcher & Garrett (1963)
Scale: 1" = ½ mi.

0' ½ mi. 1 mi.

Legend

-N-

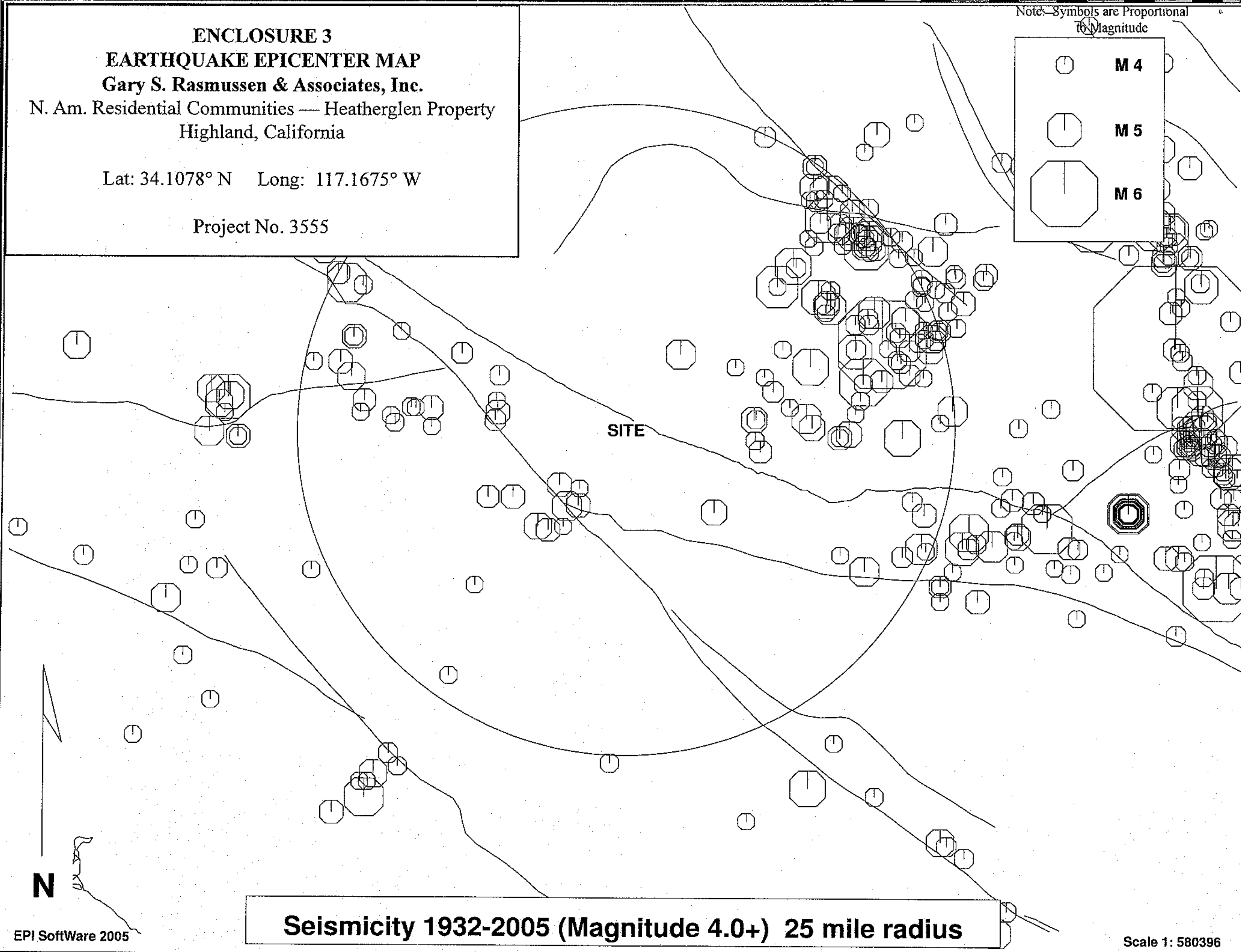
Qrc, Qyal	Younger alluvium
Qoal	Older alluvium
bc	granitic and/or metamorphic rock
——— —— · · · ?	Fault;dashed where approx., dotted where buried, queried where uncertain.

Project No. 3555

ENCLOSURE 3
EARTHQUAKE EPICENTER MAP
Gary S. Rasmussen & Associates, Inc.
N. Am. Residential Communities — Heatherglen Property
Highland, California

Lat: 34.1078° N   Long: 117.1675° W

Project No. 3555



Seismicity 1932-2005 (Magnitude 4.0+) 25 mile radius