DEPARTMENT OF CONSERVATION

CALIFORNIA GEOLOGICAL SURVEY

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Mr. Nelson Cayabyab
Chief Facilities Official
Beverly Hills Unified School District
255 S. Laskey Drive
Beverly Hills, CA 90212

May 21, 2012

Subject: Fault Rupture Hazard Review
Beverly Hills High School
241 S. Moreno Drive, Beverly Hills, CA
CGS Application No. 03-CGS0960

Dear Mr. Cayabyab:

In accordance with your request and transmittal of documents on April 24, 2012, the California Geological Survey (CGS) reviewed the campus-wide fault rupture study report prepared for Beverly Hills High School. It is our understanding future improvements are planned for the campus but no definite site plan is currently available. It should be noted the submitted report addresses only the fault-rupture potential at the high school site and does not address other geologic/seismic hazards that need to be considered for acceptance of school construction projects. As such, this review is only for the assessment of fault rupture issues at the site. The following report was provided for our review:

> **Fault Hazard Assessment of the West Beverly Hills Lineament, Beverly Hills High School, 241 South Moreno Drive, Beverly Hills, CA:** Leighton Consulting, Inc., 10532 Acacia Street, #B-6, Rancho Cucamonga, CA, 91730, dated April 22, 2012, Project No. 603314-002, 23 pages, appendices and figures attached.

The above referenced report documents an investigation to evaluate the presence or absence of active or potentially active faulting associated with the West Beverly Hills Lineament (WBHL) at the school site. The consultants reviewed published geologic maps, literature, and aerial photos, as well as the recently completed fault investigation report for the proposed MTA Westside Subway Extension (Parsons Brinkerhoff, 2011). Parsons Brinkerhoff suggested the presence of several northwest-southeast trending faults extending through the school site based on three transects of closely spaced CPTs and borings.

Overview

The subject fault study was performed to assess the potential presence of active faulting associated with the WBHL. The consultants state this report does not purport to address hazards

from other potential fault systems (i.e. the Santa Monica Fault Zone). The WBHL is described as a north-northwest trending series of "continuous east-facing escarpments", which separate elevated older alluvium to the west and a gently sloping, younger alluvial plain to the east. They also report it is unclear whether the WBHL is related to faulting or other surficial geologic processes; however, various tectonic models have been postulated to explain it. North of its intersection with the east-west trending Santa Monica Fault Zone (SMFZ), the WBHL appears to represent a fault that transfers slip from the SMFZ to the east-west trending Hollywood Fault (Dolan and Sieh, 1992; Dolan et al., 1997). Dolan et al., (1997) suggest, alternatively, the WBHL may represent an east-dipping normal fault, a right-lateral strike-slip fault that is the northernmost extension of the Newport-Inglewood Fault zone to the south, or a "complex, oblique reverse-right-lateral, north-northwest-trending fault system, encompassing both the Newport-Inglewood right-lateral strike-slip fault system and a northern extension of the Compton blind thrust system."

Fault Investigation and Discussion

As part of the fault investigation, the consultants excavated and geologically logged four fault trenches, advanced 12 CPTs, and drilled 21 borings in the school property to evaluate fault rupture hazard. Detailed observations were made of the soil types, textures and colors, as well as any fractures or other discontinuities. The consultants also provide interpretations of depositional environment and estimated ages of the sedimentary deposits and paleosols exposed in the trenches. Representatives from CGS visited the fault trenches on five occasions between January 27 and February 14, 2012 to observe successive trench exposures. Subsequent to submittal of the report, CGS representatives returned to the school site on April 30, May 1, and May 10, 2012 to review rock core samples taken from the borings drilled at the site.

In addition to the subsurface data provided by the consultants, CGS reviewed pertinent logs of borings and CPTs from the MTA fault study (Parsons Brinkerhoff, 2011). The samples from two of these continuous core borings (T4-B-1 and T4-B10) from the western edge of the northern transect were also made available for our inspection.

A-A' (central transect)

In the central portion of the campus, the consultants drilled 15 continuous core borings and excavated two fault trenches (FT-1 and FT-2), which were approximately 135 feet and 360 feet long, respectively along a southwest-northeast trending profile. According to the plates provided in the report, there is a gap of about 215 feet between FT-1 and FT-2 due to existing utilities in Heath Avenue. There is also a gap of approximately 15 feet within FT-2 because of a buried utility line. These trenches also did not extend far enough to the east to cover that portion of the campus. Section A-A' depicts the graphic logs of both trenches, as well as the subsurface data and interpreted correlations from the core borings. The consultants state both trench locations "would have intercepted interpreted faults" from the MTA study; however, this assumes the trend of the suggested faults is well understood.

Based on soil development in the older alluvium at the western trench (FT-1), the sediments underlying this elevated surface were estimated to range from 70,000 to 100,000 years old. No

faulting or offsets within the older alluvium were observed in this trench. This conclusion appears reasonable based on our observations in the field and the data provided in the report.

The eastern trench (FT-2) exposed older alluvium in its western portion and younger alluvium in the lower, eastern portion. Several "clay filled fractures or cracks" were observed and documented in the western half of this trench (between stations 1+45 to 1+70). The consultants state these "fractures showed apparent vertical offset of up to ½ inch, east side up…and several of the fractures extended to the trench surface (in areas where the near surface soils had been removed)." They also noted the displacements along the fractures did not increase with depth and, "locally, some appeared to die out." Based on this evidence, the consultants "rule out a fault origin for these fractures." Additionally, the consultants note station 2+00 represents the base of the east-facing topographic escarpment, which defines the WBHL. Based on their trench observations they indicate the older alluvial deposits are not folded or faulted at this location, but instead they are laterally truncated, which indicates an erosional origin for this slope. The erosional contact between the older alluvium and the younger alluvium of Benedict Canyon forms a 'buttress unconformity', which the consultants state can be followed below the trench exposure and observed in their core borings along this portion of their subsurface profile. In the older alluvium, a moderately well developed paleosol with strong angular blocky structure was exposed just west of this erosional contact. Between stations 2+10 to 2+28 the ped faces within the argillic horizon are tilted to the east up to 22 degrees from vertical. The measured tilt increases from west to east in proximity to the erosional contact with the younger alluvium. We observed another paleosol above this that also appeared tilted, but to a lesser degree.

The consultants propose a model where the east-side up fractures and tilted ped surfaces are related to "outward dilation" and "downslope creep" of the older alluvial soils along the paleo-margin of the Benedict Canyon drainage channel. They provide a soil microfabric analysis (Appendix D of the consultants' report), which concludes the fractures are filled with translocated clay that is "demonstrably not sheared and is on the order of tens to thousands of years old." With regard to the proposed model, CGS has several concerns. *The conclusion that a fault origin can be ruled out for the observed fractures based on lack of increased displacement with depth or fractures dying out near the surface is not justified.* Bonilla & Lienkaemper (1991) document circumstances where active faults observed in trench exposures die out upward and/or downward. Also, CGS notes our field measurements of these fractures indicated up to 4-5 cm (about 2 inches) of apparent vertical offset and some thickness variations within corresponding layers on either side of some fractures, which may be indicative of a lateral slip component. At station 1+65 (north wall), CGS representatives observed a fracture that consisted of several sub-parallel shears, which could be traced to the bottom of the trench. The consultants logged this feature upward to the base of the disturbed zone at the top of the trench wall. This zone had approximately 1 inch of vertical separation and rotated clasts within the shear zone. These observations, including indications of lateral offset, are inconsistent with a slope extension model but may be suggestive of faulting. Also, it appears the microfabric study only analyzed samples from one clay-filled fracture (collected at 1+46.5 on the north wall and 1+50 on the south wall) where no offset was reported. Therefore, the basis for conclusions and application to other clay-filled fractures that have offset appears unwarranted. CGS also observed other fractures in FT-2 with measurable offset, which were not clay-lined.

In the vicinity of station 2+20, where paleosols indicate tilting or folding, an elevation difference of three to five feet between marker beds in borings CB-8 and CB-9 is compatible with an interpretation of fault offset at depth. The proximity to a zone of possible faults immediately to the west invites such consideration. The consultant's interpretation of continuity of the lower sedimentary units, while valid, is not a unique explanation of the data. The presence of a fault in this area is not adequately addressed by the other transects. The consultants should provide additional detailed logging of the trench between stations 1+20 to 2+40 (if available) or provide additional subsurface data to demonstrate an unbroken horizontal stratigraphic sequence below the fractures and tilted ped surfaces.

CGS is also concerned with the gaps between the fault trenches at the site. The consultants state their trenches "sufficiently overlapped to provide continuous exposure from the crest of BHHS to its eastern boundary." CGS notes that, considering the uncertainty of potential fault trends, the trench locations and transect lines are too far apart to provide continuous exposure in order to adequately address the potential for surface faulting at the site. *Some discrepancies in some sedimentary unit elevations were evident in the core samples we reviewed from borings within the gap between FT-1 and FT-2.* Specifically, between CB-3 and CB-4 an elevation drop of approximately six to seven feet is noted between paleosols (i.e. B_t horizons), the base of a unique varved sequence, and the San Pedro Formation contact.

<u>B-B' (northern transect)</u>

The consultants drilled six continuous core borings and advanced 12 CPTs to generate a subsurface profile (B-B') along Durant Drive at the far northern end of the campus. The consultants' profile essentially follows the same alignment as "Transect 4" from the MTA fault study (Parsons Brinkerhoff, 2011), but did not extend as far east and therefore does not cover the eastern side of the campus. Along this transect, the MTA consultants postulated the existence of eight faults as depicted on Leighton's boring and trench location base map.

The district's consultants defined several paleosols, other marker beds, and the contact with the underlying San Pedro Formation in their core borings, which they trace along the entire transect. The consultants also include the data from boring T-4 B-10, which was drilled immediately west of the school property by the MTA consultants. The consultants indicate "the traceable paleosols and marker beds document unbroken stratigraphy across the entire transect" and "[n]o discernable offset is noted in the paleosols, nor in the San Pedro Formation." The interpretation of continuous stratigraphy is a valid explanation of the data, but the spacing of the borings and the presence of faulting exposed in FT-3 (see below) allow for other valid interpretations such as fault offset. Based on our review of the core samples and the data provided in the boring logs and cross section B-B', it appears there is some vertical separation of the markers beds between borings. *Various marker beds and the San Pedro Formation contact appear to be offset five to ten feet vertically between borings T-4 B-10 and CB-13, as well as between CB-17 and CB-18. Interpreted variations in thickness of sedimentary units might imply a lateral slip component as well. Although these anomalies may represent faulting, if the consultants could demonstrate continuous unbroken and undeformed sediments in the near surface Pleistocene soils above*

them, the unbroken Pleistocene layers would demonstrate than any faults are inactive, similar to those exposed in FT-3.

Trenches FT-3 and FT-4 (southern transect)

These two fault trenches were excavated in the southern portion of the campus. FT-3 was located immediately south of the lacrosse field in the "zone of interpreted faulting [by the MTA consultants]". Two "zones of minor faulting" were observed by the consultants in this trench. The two faults branch vertically and are part of a zone of faults about one foot wide. Attitudes on the subvertical faults ranged from N14°W to N27°W and the consultants report there is approximately 4 inches of apparent vertical displacement across this zone. The log shows these faults abruptly truncated by a channel deposit, the irregular base of which is explained as having eroded preferentially into the upper portion of the fault zone. The consultants note in addition to the prospect of erosion, "it is possible to interpret the fault as displacing the lowermost 1-inch of the channel bottom", but go on to state "the remaining two feet of channel deposits are unaffected by the fault." Based on the approximate date of the soil encountered in FT-1, located on the same geomorphic surface as FT-3, the consultants conclude the capping channel deposit is older than 70,000 to 100,000 years and thus these faults are not active. This conclusion appears reasonable based on the data provided in the report. However, CGS notes the trench log for FT-3 (as well as our field observations) shows Unit 1c to the west of the fault zone and Unit 4 to the right. To achieve this juxtapositioning of alluvial units appears to require significantly more than 4 inches of vertical offset, suggesting this is not a minor fault as reported by the consultants. This trench indicates offsets along NNW-trending faults have occurred at this site in the past and there may be other similar faults in the vicinity that are not yet fully discovered. Such faults may explain some of the apparent stratigraphic offsets noted elsewhere in the boring transects.

Trench FT-4 was located approximately 70 feet to the east of FT-3. The consultants report several clay-filled fractures were observed between stations 0+58 and 0+68. According to the report, these fractures "showed apparent vertical offset of about ¼ inch, east side up" but said they did not extend up to the buried soil and "showed no recognizable offset lower in the trench." CGS notes our field measurements indicate up to 1.25 inch of apparent vertical offset on a fracture at 0+62. The fractures and sense of offset are nearly identical to those observed in FT-2 between stations 1+60 and 1+80. The consultants conclude these fractures are surficial features related to slope movement during strong seismic shaking, not faulting. The area to the east of FT-4 is not explored and is not necessarily covered by the central transect due to distance (almost 400 feet) and uncertainty of fault orientation.

CGS notes none of the alluvial units from FT-3 can be correlated across to FT-4 because the bottom of the FT-3 trench exposure is located at approximately the same elevation as the top of the FT-4 exposure. Also, unlike profile A-A', there are no borings drilled along the FT-3/FT-4 alignment to supplement the surficial trench exposures. *Small faults in FT-4 (similar to those exposed in FT-2), and gaps in the data, including lack of any data to the east of these trenches, leaves open the question of both presence and activity of related faults on site.*

Conclusions

Based on our review of the data provided in the report and our observations at the site, the consultants do not provide sufficient evidence to preclude active faulting at the site. The consultants excavated four fault trenches across the site; however, the gaps between these trenches and the uncertain strike of potential faults result in uncertainties with regard to age constraint on those faults observed in the trenches and the possibility of faulting between trench exposures. Some significant marker bed and geologic contact elevation changes were noted in borings that spanned the trench gap between FT-1 and FT-2. Additionally, the soils exposed in FT-3 and FT-4 could not be correlated due to notable elevation differences. The borings and CPTs performed by the consultants are helpful in determining larger vertical offsets, but are insufficient to preclude smaller-scale vertical offsets, or larger horizontal offsets due to strike-slip faulting. **The consultants should evaluate and discuss the potential for faulting between borings T4 B-10/CB-13, CB-3/CB-4, CB-8/CB-9 and CB-17/CB-18. Additionally, they should adequately address the gaps between trenches and the area east of FT-4, Finally, they should provide additional data to address the potential for strike-slip faulting at the site.**

On page 22 of the report, the consultants state their fault study "did not focus on possible east-west trending faults through the school campus (such as may be associated with the SMFZ)." *Based on the boring logs provided in the report, the contact between the older alluvium and the San Pedro Formation bedrock drops approximately 100 feet in elevation from the central portion of the campus (at A-A') to the northern portion (at B-B').* CGS notes this sharp drop in elevation of the bedrock surface *towards* the Santa Monica Mountains appears anomalous. **Therefore, the consultants should address this anomaly and evaluate the potential for all possible faults, not just those associated with the WBHL, at the school site. Further studies should include the southeastern portion of the campus, which is not yet explored.**

In conclusion, ***the fault rupture hazard issues at this site are not adequately assessed in the referenced report***. Additional information should be provided as requested. The consultants are reminded that one copy of all supplemental documents should be submitted directly to CGS, and should include the CGS application number. If you have any questions about this review letter, please telephone the California Geological Survey at (213) 239-0893.

Respectfully submitted,

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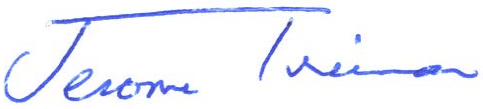

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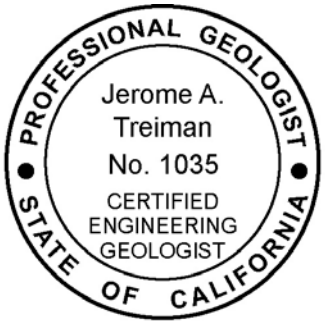

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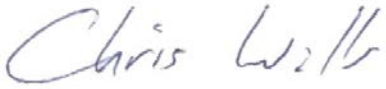

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Selected References

Bonilla, M.G. and Lienkaemper, J.J., 1991, Factors affecting the recognition of faults in exploratory trenches: U.S. Geological Survey Bulletin 1947, 54 p.

Parsons Brinkerhoff, 2011, Century City Area Fault Investigation Report, Westside Subway Extension Project, Contract No. PS-4350-2000, dated October 14, 2011