APPENDIX C

CULTURAL RESOURCES GEOLOGY AND PALEONTOLOGY

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This cultural, geology and paleontological information for the Wildfire Hazard Reduction and Resource Management Plan Environmental Impact Report was prepared by LSA Associates Inc.

This report briefly summarizes the paleontological resources setting of the Study Area. The subsection presents the general geological background of the Study Area and vicinity, including the types of fossils known to occur.

The Study Area is in the western coastal margin of the Coast Range Geomorphic Province of northern California, a geologically young and seismically-active region, and is dominated by northwest-southeast-trending low hills and intervening valleys. The Study Area consists of numerous park units generally located on the bayshore and in the East Bay Hills. The Hayward fault, which runs through the generalized center of the Study Area, is a highly active fault zone with a high probability of producing a magnitude 7 and above earthquake within the next 30 years.[1]

In general, the Study Area consists of Tertiary strata resting with angular unconformity on two complexly deformed Mesozoic rock complexes. One of these Mesozoic Rock complexes is made up of Coast Range ophiolite, serpentinite, basalt, gabbro, keratophyre, and overlying Great Valley sequence with some volcanic rocks in the Berkeley area. The other Mesozoic complex is the Franciscan complex, which is composed of strongly metamorphosed greywacke, limestone, argillite, serpentinite, basalt, and other rocks. The following summary of the Study Area geologic units is presented in stratigraphic sequence from youngest to oldest.

Younger Alluvium: Holocene (10,000 Years Ago [ya] to Present). Holocene alluvium lies along creeks running through most of the Study Area and at San Francisco Bay margins. These alluvial deposits consist of moderately-to-poorly-bedded sand, gravel, silt, and clay deposits. Holocene deposits are generally too young to contain fossils, and this alluvium has low paleontological sensitivity.

Older Alluvium: Pleistocene (10,000 ya to 2,000,000 Years Ago [mya]). Pleistocene alluvial deposits are found predominantly in the lower parts of the Study Area as thin strips of outcrop. This alluvium consists of sand, silt, clay and gravel deposits that are usually capped by well-developed soils.[2] Locally, these sediments contain invertebrate and extinct vertebrate fossils, many of which represent the Rancholabrean (Late Pleistocene) land mammal age.[3,4,5] Significant Rancholabrean

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[1] Working Group on California Earthquake Probabilities, 2003. Earthquake Probabilities around San Francisco, California. Berkeley Seismological Laboratory, University of California, Berkeley. Website: http://pubs.usgs.gov/fs/2003/fs039-03/.

[2] Graymer, R.W., D.L. Jones, and E.E. Brabb, 2002. *Geologic Map and Map Database of Northeastern San Francisco Bay Region, California.* United States Department of the Interior, U.S. Geological Survey.

[3] Helley, E.J., K.R. LaJoie, W.E. Spangle, and M.L. Blair, 1979. *Flatland Deposits of the San Francisco Bay Region – their geology and engineering properties, and their importance to comprehensive planning.* Geological Survey Professional Paper 943. U.S. Geological Survey and Department of Housing and Urban Development, Washington, D.C.

[4] Helley, E.J., and Graymer, R.W., 1997. Quaternary geology of Alameda County, and parts of Contra Costa, Santa Clara, San Mateo, Stanislaus, and San Joaquin Counties, California: A digital database. U.S. Geological Survey Open-File Report 97-97. Website: http://geopubs.wr.usgs.gov/open-file/of97-97/.

vertebrate fossils include bison, mammoth, ground sloths, saber-toothed cats, dire wolves, cave bears, rodents birds, lizards and amphibians.[6,7,8,9]

Landslide Deposit: Pleistocene and/or Holocene (2,000,000 ya to Present). Landslide deposits occur throughout the Study Area and are usually not mapped. The exception to this occurs around Lake Chabot, where unusually large landslide deposits are mapped. These deposits consist of poorly sorted clay, silt, sand, and gravel. Landslide deposits have yielded significant paleontological resources.

Unnamed Sedimentary and Volcanic Rocks: Miocene and Pliocene (24 mya -1.8 mya). This unit includes marine and nonmarine conglomerate, sandstone, and siltstone, as well as minor amounts of basalt and limestone. Sediments of these ages contain significant fossil resources, including early horses such as *Pliohippus*, *Nannippus,* and *Hipparion*.[10,11] It is mapped only locally in Tilden Regional Park, and is of high paleontological sensitivity.

Bald Peak Basalt: Miocene (8.4 mya). The Bald Peak Basalt is a massive basalt flow that has been dated to 8.4 mya.[12] This geologic unit does not contain fossils of paleontological significance.

Siesta Formation: Miocene (24-25 mya). This is a rare non-marine siltstone, claystone, and sandstone, with minor amounts of limestone. The formation has a high paleontological sensitivity, having yielded the San Francisco Bay Area's earliest land mammals, including ancient horses, hippos, and beavers.[13]

Moraga Formation: Miocene (24-25 mya). This geologic unit consists of basalt, andesite flows, and minor amounts of rhyolite tuff. This unit has no paleontological significance.

Orinda Formation: Miocene (24-25 mya). This unit consists of a wide range of bedded pebble to boulder conglomerates, conglomeratic sandstone, and coarse-to-medium-grained lithic sandstone. Ancient beaches and shorelines are recorded in this geologic unit, which is up to 1,500 meters thick. The Orinda Formation is usually easily distinguished from other conglomerates by its

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[5] Bell, C.J., E.L. Lundelius, Jr., A.D. Barnosky, R.W. Graham, E.H. Lindsay, D.R. Ruez, Jr., H.S. Semken, Jr., S.D. Webb, and R.J. Zakrzewski, 2004. The Blancan, Irvingtonian, and Rancholabrean Mammal Ages. In *Late Cretaceous and Cenozoic Mammals of North America*, edited by M.O. Woodburne, pp. 232-314. Columbia University Press, New York.

[6] Savage, Donald, 1951. *Late Cenozoic Vertebrates of the San Francisco Bay Region.* U.C. Publications Bulletin of the Dept. of Geological Sciences 28(10), pp. 215:314.

[7] Stirton, R.A., 1951. Prehistoric Land Animals of the San Francisco Bay Region. In *Geology Guidebook of the San Francisco Bay Counties: History, Landscape, Geology, Fossils, Minerals, Industry, and Routes to Travel*, prepared by Olaf P. Jenkins, pp. 177-186. Bulletin 154. State of California Division of Mines, San Francisco.

[8] Helley et al., op. cit.

[9] Bell et al., op. cit.

[10] Savage, Donald, op. cit.

[11] Stirton, R.A., op. cit.

[12] Curtis, G.H., 1989. Berkeley Hills. In *Geology of San Francisco and Vicinity*, C. Wahrhaftig, ed., 28th International Geological Congress Field Trip Guidebook T105: American Geophysical Union, Washington, D.C., pp. 47-52.

[13] United State Geological Survey, 2006. Land Mammals of the Siesta Formation. Website: http://sfgeo.wr.usgs.gov/geologic/stories/berkeley_beaver.html.

red and green color. Many vertebrate fossils have been found in the Orinda Formation, giving this geological unit a high paleontological sensitivity.

Claremont Chert: (Miocene 24-25 mya). This geologic unit consists of laminated and bedded marine brown chert, sandstone, and shale. Distinctive black, laminated chert occurs locally in the Berkeley Hills. Vertebrate fossils have been found in this formation.

Great Valley Sequence (Late Jurassic to Cretaceous: 161-65 mya). The Great Valley sequence consists of interbedded marine mudstone, sandstone, and conglomerate that normally lie on Coast Range ophiolite, except where disrupted by faults.[14] It commonly crops out as thick, bedded sections of strata that generally are less deformed and more coherent than sedimentary sections of the Franciscan, and also have greater lateral continuity. The aggregate stratigraphic thickness of Great Valley sequence is at least 12 kilometers. The following geologic units comprise the Great Valley sequence:

- Pinehurst Shale: (Late Cretaceous 99-65 mya). The Pinehurst Shale is a siliceous shale with interbedded sandstone and siltstone, and represents a marine depositional environment. This geologic unit has not yielded significant paleontological discoveries.
- Redwood Canyon Formation: (Late Cretaceous 99-65 mya). This geologic unit is a massive sandstone and siltstone unit that has distinct beddings of sandstone with some interbedded siltstone layers. No paleontological discoveries have been reported from the Redwood Canyon Formation.
- Shephard Creek Formation: (Late Cretaceous 99-65 mya). This is a dominantly shale and mudstone formation with some minor sandstone. It also contains distinct mica-rich siltstones and thin beds of greywacke. This unit has a low paleontological sensitivity.
- Oakland Conglomerate: (Late Cretaceous 99-65 mya). This geologic unit consists of mainly silicic volcanic clasts and distinct massive biotite-rich quartz sandstone. Conglomerate comprises as much as 50% of the unit in the Oakland hills, but it becomes a progressively smaller portion of the unit to the south. Although not common, there have been significant paleontological discoveries in this formation.
- Joaquin Miller Formation: (Late Cretaceous 99-65 mya). This unit consists of thinly bedded shale and minor sandstone that grades into thinly bedded, fine-grained sandstone near the top of the formation. The contact with the overlying Oakland Conglomerate is gradational. No paleontological discoveries have been reported in this unit.
- Franciscan Mélange: (Late Jurassic to Early Cretaceous 159-99 mya). This geologic unit consists of argillite, greywacke sandstone, green tuff and lenses of chert, shale, marble, basalt, greenschist, and conglomerate. The blocks within this unit range in size from pebbles to several hundred meters in length. Only the largest blocks have been mapped. Vertebrate fossils in the Franciscan mélange are rare, but the few that have been found are highly significant.
- Knoxville Formation: (Late Jurassic to Early Cretaceous 159-99 mya). This unit consists of mainly dark, greenish-gray silt or clay shale with thin sandstone interbeds. In its lower part, the

[14] Bailey, E.H., Irwin, W.P., and Jones, D.L., 1964. *Franciscan and related rocks, and their significance in the geology of western California.* California Division of Mines and Geology Bulletin 183.

Knoxville Formation consists of thick pebble-to-cobble conglomerate beds and angular, volcanoclastic breccia. This geologic unit has a high paleontological sensitivity due to abundant specimens of bivalve fossils.

Coast Range Ophiolite (Jurassic: 206-144 mya). The Coast Range ophiolite represents oceanic crust on which much of the sedimentary rock of the Great Valley sequence was deposited. Only in a few places is a nearly complete lithologic sequence of Coast Range ophiolite preserved, and at these locations the total stratigraphic thickness of the ophiolite is about 3 to 5 km (Hopson et al. 1981).[15] Paleontologic and paleomagnetic evidence suggests that the Coast Range ophiolite formed in an equatorial setting and was transported great distances northward before being accreted to North America and overlain by the Great Valley sequence.[16,17] However, paleontological evidence is extremely rare in the Coast Range ophiolite. The following rocks and rock units are found in Coast Range ophiolite:

- Keratophyre: (Late Jurassic 159-144 mya). This volcanic rock unit consists of highly altered silicic rocks. Distinct to this unit is the fact that Feldspars are almost all replaced by albite. In some places, this unit is closely associated with basalt. This unit represents an ancient volcanic arc from the Jurassic. No paleontological resources have been reported from this geologic unit.
- Serpentinite: (Jurassic 206-144 mya). Seprentinite is a secondary mineral that is green or grayish green and is commonly found in metamorphosed or volcanic rocks. This unit does not contain paleontological resources.
- Gabbro and Basalt: (Jurassic 206-144 mya). These rock units often occur together in the Study Area. Gabbro is the intrusive equivalent of basalt. The basalt occurs locally as pillow basalt. Neither Gabbro nor Basalt is sensitive for paleontological resources.

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[15] Hopson, C.A., Mattinson, J.M., and Pessagno, E.A., 1981. Coast Range ophiolite, western California. In *Geotectonic Development of California* (Rubey volume 1, Ernst, W.G., ed.). Prentice-Hall, Englewood Cliffs, N.J. pp. 418-510.

[16] Pessagno, E.A., Jr., Hull, D.M., and Hopson, C.A., 2000. Tectonostratigraphic significance of sedimentary strata occurring within and above the Coast Range ophiolite (California Coast Ranges) and the Josephine ophiolite (Klamath Mountains), northwestern California. In *Ophiolites and oceanic crust: New insights from ›eld studies and the Ocean Drilling Program*. Geological Society of America Special Paper 349, Y. Dilek, E. Moores, D. Elthon, and A. Nicolas, eds., pp. 383-394.

[17] McLaughlin, R.J., Blake, M. C., Jr., Griscom, Andrew, Blome, C.D., and Murchey, B.L, 1988. Tectonics of formation, translation, and dispersal of the Coast Range ophiolite of California. *Tectonics* 7(5), pp. 1033-1056.