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Technical Memorandum

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Technical Memorandum No. 1

Subject: Criteria for Identifying Formational/Unit Boundaries in Drill Cuttings

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The purpose of this technical memorandum is to establish the criteria that will be used to distinguish the Tuscan Formation during drilling operations for the Lower Tuscan Aquifer Monitoring, Recharge, and Data Management Project. The nomenclature that will be followed is modified from Blair and Others (1991) with the primary objective of identifying the major water bearing units of the Tuscan Formation. However, where possible, the seven units of the Tuscan Formation defined by Helley and Hardwood (1985) will be distinguished based on the potential presence of distinct characteristics for each of the units. These seven units from youngest to oldest are as follows:

- Unit D
- Tuff of Hogback Road
- Unit C
- Ishi Tuff Member
- Unit B
- Unit A
- Nomlaki Tuff Member.

Hydrostratigraphically, the Tuscan Formation has been divided into two units: the Upper Tuscan Aquifer System consisting primarily of Unit C; and, the Lower Tuscan Aquifer Unit consisting of Units A and B.

Overlying the Tuscan Formation are numerous Quaternary Deposits. For this investigation, these units are defined to include all post-Tuscan sediments in the area and will be designated as Quaternary Deposits (Qd). This broader definition is employed because the numerous Quaternary formations others have proposed are based on geomorphic or buried-soil information rather than on criteria by which formal formations are distinguished. More importantly, the criteria used by others can not be easily distinguished in drill cuttings. In the Oroville area, Blair and Others (1991) used this same broader definition but designated all post-Nomlaki sediments as the Laguna Formation. Underlying the Nomlaki Formation in this area were sediments of the Tuscan Formation. Note, that Blair and Others (1991) designated the Tuscan Formation in this area as the Mehrten Formation following nomenclature used by Creely (1965). Busacca (1982) identified the Tuscan Formation in this area as an unnamed Dacitic Lahar underlying the Nomlaki Tuff.

Expected geologic units underlying the Tuscan Formation within the project area are the Miocene Lovejoy Basalt and Eocene Ione Formation. Some recent investigations have interpreted the presence of a unit referred to as the Upper Princeton Valley Formation. As defined by Redwine (1972), the Princeton Submarine Valley System is a morphological feature of the ancestral Sacramento River Basin and contains the geologic formations described above. For example, the Ione Formation is used by Redwine to separate the lower and upper Princeton Valley fills and the Lovejoy Basalt is interpreted to represent the rimrock of the upper Princeton Valley Fill. However, the Upper Princeton Valley Fill will be used to designate units that directly underlie the Tuscan Formation that do not correspond to the Ione Formation or Lovejoy Basalt as described below.

A key component for identification of formational boundaries will be the methods used for logging of lithologic samples collected during drilling. As required in the Contract for the

project based on the Request for Proposal (RFP) issued by Butte County (RFP number 06-10), lithologic samples collected during drilling will be described using the visual manual procedure for description of soils outlined in American Society for Testing and Materials (ASTM) Method D 2488-90. However, this method was developed for engineering purposes of naturally occurring soils and does not emphasize the petrographic analysis of samples that will be critical to identifying the formation boundaries. As such, each sample description will also include the approximate percentage of the following rock types:

- Dacite, andesite, and andesitic basalt.
- Pumice/tuff.
- Crystalline basement material including granitics and metamorphic rock.
- Rhyolite.
- Basalt.

It should also be noted that a large portion of the Tuscan Formation is lithified and falls outside the classification scheme of the ASTM method. For samples collected from these units, common rock nomenclature will be used such as siltstone and conglomerate.

A description of each of the units that may be encountered during drilling and the criteria that will be used to identify them during drilling is presented below.

Quaternary Deposits

As discussed above, for this investigation the Quaternary Deposits will include all post-Tuscan Formation sediments in the area including the recent deposits of the various stream channels in the area. If present, this formation will be the surficial unit at all proposed groundwater monitoring well drilling locations. This more broadly defined formation includes deposits varying from latest Pliocene through Quaternary in age.

In outcrop, the Quaternary Deposits consists of sandy gravel channel, sandy channel facies, and sandy clay to clay floodplain facies. The gravel deposits occur above sharp, scoured facies and are comprised of poorly to moderately sorted, sandy, clast-supported pebbles and cobbles. Well developed soils with red to red-brown argillic horizons are locally prevalent on the channel facies. The structures, fabric, and textures of the gravel facies are indicative of transportation by unidirectional water flow under upper-flow-regime conditions. The development of soils on the upper part of these channel fills denotes long periods during which the fill was subjected to pedogensis, most likely resulting from channel abandonment of the area due to river avulsion or downcutting. Towards the east side of the Study area, sand facies make up only a small percentage relative to gravel-channel deposits that reflect flow conditions in high-gradient river systems that are commonly to vigorous for sand deposition. The sand units that are present were probably deposited in the main channels during waning flood stage or during lower river discharge or in secondary channels as is demonstrated by the present Feather River system near Oroville. The clay facies are tan or reddish brown and represent sediment accumulation in floodplains adjacent to the main channels. Manganese oxide root casts and reddened buried soils are common in these deposits indicating periods during which the floodplain was vegetated and well drained.

Gravels clasts consist of a mixture of plutonic (including clasts from Tuscan Formation) and metamorphic lithologies. Based on petrographic analysis from outcrop and borehole samples near the Oroville area (Blair and others, 1991), both the sand facies and sandy component of gravel facies should reveal a wide variety of framework grain lithologies including monocyrstalline and polycrystalline quartz (5% to 25%), plagioclase and potassium feldspar (2% to 10%), metamorphic rock fragments (2% to 15%), granitic rock fragments (10% to 30%), porphyritic andesite-andesitic basalt-basalt-dacite rock fragments (10% to 50%), pumice fragments ((5% to 30%), sandstone and shale fragments (0% to 5%), and mica and heavy mineral grains (3% to 20%). This framework grain assemblage indicates that the Quaternary Deposits have a mixed provenance consisting of Sierra Nevada crystalline rocks and Mount Lassen-derived intermediate volcaniclastic rocks (Tuscan Formation), and pumice from Hogback Road, Ishi, and Nomlaki tuff members of the Tuscan Formation.

The base of the Quaternary Deposits can easily be distinguished in drill cuttings where pumiceous materials of the tuff members are encountered. Where the base of the Modesto Formation is not underlain by a tuff member, it will be identified by the presence of gravel clasts and/or sand grains consisting of a composition greater than 50 percent andesite, andesitic basalt, and/or dacite.

Tuscan Formation

The Tuscan Formation includes a sequence of variably cemented, interbedded clay, sand, and gravel. This formation consists predominantly of purple volcanic debris flow deposits and interbedded waterlain fluvial deposits rich in volcanic detritus, but in many areas containing crystalline basement-derived clasts and rare tuff beds. The reported occurrence of both channel-lain, clast supported, pebble- and cobble-gravel facies and interbedded volcanic-rich debris-flow facies in this formation suggests that debris flows related to volcanic events episodically choked the ancestral stream/river systems of the area. Blair and others (1991) described the gravel and sand fractions, as well as many intervals of the Tuscan Formation in the Oroville area encountered in the subsurface consisting of porphyritic-dacite rock fragments and disaggregated quartz and plagioclase phenocrysts. The sand fraction of this area comprised a mixture of porphyritic-dacite rock fragments (36% to 37%), granitic rock fragments ((32% to 49%), metamorphic rock fragments ((4% to 7%), Quartz (10% to 19%) and feldspar (0% to 3%). This composition indicates that in the Oroville area that the Tuscan Formation originated from the erosion of both Sierra Nevada crystalline rocks and a Mount Lassen-derived volcanic sequence.

As indicated above for Quaternary Deposits, the top of the Tuscan Formation will be identified either by the presence of greater than 50 percent pumiceous material or the presence of gravel clasts and/or sand grains consisting of a composition greater than 50 percent andesite, andesitic basalt, and/or dacite. Where possible, specific units of the Tuscan Formation as defined by Helly and Hardwood (1985) will be identified based on the characteristics discussed below. However, many of the criteria used to distinguish the units in outcrop may not be observable in drill cuttings.

> **Unit D:** Unit D predominantly consists of fragmental deposits characterized by large monolithic masses of gray hornblende andesite, augite-olivine basaltic andesite, black pumice, and smaller fragments of black obsidian and white and gray hornblende bearing pumice in a grayish-tan pumiceois mudstone matrix. If present, the tuff of

Hogback road separates Unit D from Unit C. If the tuff of Hogback road is absent, Unit D will be distinguished from Unit C in drill cuttings by the presence of black obsidian fragments and white and dove-gray dacite pumice fragments.

Tuff of Hogback Road: This unit is commonly thin bedded, locally cross bedded water-worked dacitic ash deposit that rests unconformably on Unit C. The unit consists of thin lapilli tuff, pumiceous sandstone, and conglomerate composed of rounded white hornblende- bearing dacitic pumice fragments and gray and black pumice fragments with varying amounts of andesitic detritus.

Unit C: Unit C is a lahar with some interbedded volcanic conglomerate and sandstone and is distinguished from Unit D as stated above. Where present the Ishi Tuff Member separates Unit C from the underlying Unit B. Where the Ishi Tuff Member is not present, Unit C cannot be distinguished from Unit B in drill cuttings.

Ishi Tuff Member: The Ishi Tuff Member is a white to light-gray, fine-grained, pumiceous air-fall tuff commonly reworked to include variable amounts of volcanic sandstone and silt. This unit will be identified in drill cuttings by the presence of abundant black and bronze biotite flakes.

Unit B: Unit B consists of interbedded lahars, volcanic conglomerate, volcanic sandstone, and siltstone similar to Unit C. As stated above, where present Unit B will be identified as the unit directly below the Ishi Tuff Member (unless unit is Unit A as defined below) and where the Ishi Tuff Member is not present, Unit B cannot be distinguished from Unit C in drill cuttings. Unit B will be distinguished from the underlying Unit A as described below.

Unit A: Unit A consists of interbedded lahars, volcanic conglomerate, volcanic sandstone, and siltstone all containing scattered fragments of metamorphic rocks. Metamorphic rock fragments include white vein quartz, green, gray, and black chert, greenstone, greenish-gray slate, and serpentinite. The presence of metamorphic rock fragments in drill cuttings will distinguish Unit A from the overlying Units B, C, and D.

Nomlaki Tuff Member: The Nomlaki Tuff Member is a white, light-gray, locally reddish-tan to salmon dacitic pumice tuff and lapilli tuff. In most areas, Helley and Harwood (1985) place this unit at the base of the Tuscan Formation. However, in some areas such as at the west end of the exposures of the Lovejoy Basalt in Bidwell Park, they observed the Nomlaki Tuff above Unit A of the Tuscan Formation. Blair and others (1991) used the Nomlaki Tuff to separate the Laguna Formation from the underlying Tuscan Formation in the Oroville area.

Lovejoy Basalt

The Lovejoy Basalt is a black, dense, hard, microcrystalline to extremely fine grained, equigranular to sparsely porphyritic basalt. This unit should be easily distinguished from the overlying Tuscan Formation during drilling from the presence of abundant basalt fragments and change to hard drilling conditions consistent with hard rock material.

Ione Formation

The Ione Formation consists of variably cemented, fine to coarse sandstone, siltstone, lignite, and claystone with variegated colors including red, yellow, white, blue, gray, orange, and black. Interbedded lenticular pebble-and-cobble "auriferous" or "greenstone" gravels are locally present and become more abundant eastwardly (Blair and others, 1991). In drill cuttings, the Ione Formation is easily identified from the overlying Tuscan Formation by its multicolored nature and volcanic-free composition.

Upper Princeton Valley Fill

As sated above, Redwine (1972) defined the Princeton Submarine Valley System as a morphological feature of the ancestral Sacramento River Basin that contains several of the geologic formations described for the area (Tuscan Formation is not part of this system). However, for this project, this designation will be given to material directly underlying the Tuscan Formation that does not correspond to the Lovejoy Basalt and Ione Formation and will be identified in drill cuttings by the complete absence of andesitic and dacitic material. In the Sacramento area, the Valley Springs Formation directly underlies the Mehrten Formation (stratigraphic correlative unit of Tuscan Formation) and consists of varying amounts of rhyolite ash, vitreous tuff, quartz sand containing abundant glass shards, pale beds of ashy clay, and fragments of pumice. This formation has not been recognized in the project area.