GEOTECHNICAL FEASIBILITY STUDY

Bell Canyon Reservoir and Pipeline Alternatives
Ventura County, California

Prepared for:
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SC5089

VIA EMAIL: Brian.DAnna@ventura.org

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SUBJECT: **Geotechnical Feasibility Study**
RE: Bell Canyon Reservoir and Pipeline Alternatives
Ventura County, California

Dear Mr. D'Anna:

In accordance with your request, **Cotton, Shires, and Associates, Inc. (CSA)** is pleased to present this geotechnical feasibility study technical letter to the County of Ventura (County) for the proposed Bell Canyon Reservoir and Pipeline project to be located in the Bell Canyon area of unincorporated eastern Ventura County, California. The study consisted of a desktop feasibility evaluation of four alternative reservoir sites, each having associated access roads and source and distribution pipelines. The four alternative reservoir sites are located in predominantly natural terrain of the Simi Hills, within an area approximately 1.4 miles wide (east/west) and within ½ mile north of the developed area of Bell Canyon. The targeted pad elevation for the reservoir is 1,905 feet above mean sea level. The study was conducted in accordance with the scope of work outlined in the Phase I – Geotechnical Feasibility Investigation section of our proposal to the County dated December 6, 2019, and authorized on December 30, 2019.

SCOPE OF WORK

CSA's Phase I scope of work was structured to develop a general assessment of the likely subsurface conditions, geologic hazards, and possible geotechnical constraints at each of the four (4) possible reservoir sites. Our scope of work consisted of the following tasks:

- Research, review and data compilation from available regional geologic maps, seismic hazard maps, and publications;
- Stereographic review of multiple sets of aerial photographs, and review of Google Earth imagery, covering the project area;

- Review of as-built plans for the two existing reservoirs adjacent to the Alternative 1 Reservoir Site;
- Review of Preliminary Design Alternative exhibits for reservoir location and pipeline alignments, prepared by AECOM in December 2019;
- Qualitative engineering geological and geotechnical engineering review of potential geotechnical constraints and hazards for each reservoir alternative; and,
- Preparation of this technical letter, including preliminary feasibility conclusions for each reservoir alternative.

PHYSICAL AND GEOLOGIC SETTING

The four alternative reservoir sites ("project area") are generally located in the Simi Hills, within a 1.4 mile long (east-west) and ½ mile wide (north-south) area of natural terrain immediately north of the residential development area of Bell Canyon. Bell Canyon is generally an east-west oriented canyon that drains easterly via Bell Creek toward the West Hills area of the San Fernando Valley. Bell Creek is identified as a blueline stream on USGS topographic maps, and drains south from Burro Flats into and through the project area before turning east within the developed area of Bell Canyon. Elevations within the project area range from less than 1,500 feet in Bell Creek to nearly 2,000 feet along the highest ridges. The natural terrain in the project area predominantly consists of east-northeast trending ridgelines that are defined by the regional geologic structure and resistant bedrock formations. Gentle to moderately steep (15-45 degrees) north- to northwest-dipping geologic structure throughout the project area has resulted in north-facing natural slopes that tend to be dip-slopes at gradients mimicking the underlying dip of bedding, while south-facing slopes are "anti-dip" slopes which typically have steeper slope gradients, particularly in hard, resistant bedrock. Natural slope gradients at the alternative reservoir sites generally range between 2:1 and 4:1, with some locally steeper and flatter areas.

REGIONAL GEOLOGY

The project area for the four alternative reservoir sites is located within the Simi Hills, which are part of the Transverse Ranges geomorphic province. The Hollywood-Santa Monica and Malibu Coast fault zones form the southern boundary of the Transverse Ranges in this area. The Transverse Ranges geomorphic province consists of generally tightly folded Mesozoic and Cenozoic marine and non-marine sedimentary strata, extending from the Santa Ynez and San Gabriel Mountains on the north, the San Andreas Fault on the east, the Santa Monica Mountains (including the Santa Barbara Channel) on the south, to offshore west of Point Arguello (including the Santa Barbara Channel). The active tectonic stress environment acting upon this region since the late Tertiary consists of regional north-south oriented oblique transpression that has produced the characteristic east-west structural grain and the series of east-west trending ranges and valleys within the province.

Locally, this area of the Simi Hills is underlain by Cretaceous to Tertiary age bedrock formations identified as the Chatsworth and Santa Susana Formations (Dibblee, 1992; Yerkes and Showalter, 1993). These formations have been uplifted and deformed (folded) as a result of crustal compression and movement on regional fault systems, including the Hollywood-Santa Monica-Malibu Coast fault zones on the south and the Simi-Santa Rosa fault zone to the north. The project area is generally located on the south limb of the Simi Syncline, a major regional fold structure, thus resulting in gentle to moderately steep north to northwesterly-dipping bedding structure within the formations. These formations are described in more detail as follows:

Chatsworth Formation: The oldest bedrock in the project area is the Chatsworth Formation (Dibblee, 1992; Yerkes and Showalter, 1993; CDMG, 1984; Chico Formation of CDMG, 1973). Regional geologic maps indicate that this formation underlies the Alternative 1 and 2 reservoir sites and a portion of the Alternative 4 reservoir site. This formation is described as a light gray to light brown, predominantly arkosic and micaceous sandstone, with one-inch to 20-foot thick interbeds of siltstone and claystone, and lenses of conglomerate. It is considered to be moderately to very resistant to erosion, with some very hard, well-indurated resistant beds of sandstone and conglomerate common. Fine-grained sections within the formation tend to form gentler slopes compared to the resistant sandstone and conglomerate sections. Fine-grained interbeds dipping adverse to natural or graded slopes create susceptibility to bedding plane failure and landslides. Steep rocky slopes in this formation are generally considered not conducive to construction. Cut slopes excavated adjacent to steeper rocky slopes may require boulder removal or other mitigation for rockfall or rock mobilization. Rippability of this formation is considered moderately to extremely difficult with heavy earthmoving equipment, particularly within the hard resistant sandstone, and blasting may be required locally in near surface cuts and extensively in deeper cuts (CDMG, 1973; 1984).

Based upon as-built plans provided for the 2.0 MG reservoir (Bell Canyon Reservoir No. 2) which was constructed west of the Alternative 1 reservoir site, cuts up to 40 feet deep within the Chatsworth Formation were required to reach the design pad grade. At this time it is not known if blasting was required to achieve this grade, because as-built geotechnical information for the existing reservoir sites has not yet been provided. Where massive sandstone is present or where fine-grained beds within the formation are favorably oriented for stability (i.e., neutral or dipping into slope), the formation appears to possess sufficient shear strength to be grossly stable in construction cut slopes up to 40 feet high at ½:1 gradient, as was the case with construction of Bell Canyon Reservoir No. 2. Similar cuts of this nature, at significantly greater heights, were made in this formation along the north side of the CA-118 Freeway between Topanga Canyon Blvd and Rocky Peak Drive.

Santa Susana Formation: The Santa Susana Formation appears to conformably overlie the Chatsworth Formation in the project area, and consists of three sub-units or members that underlie all of the Alternative 3 reservoir site and a portion of the Alternative 4 reservoir site. The lowermost *Simi Conglomerate Member* (map unit Tsi of Dibblee, 1992) is described as being generally less than 25 feet thick in the area, and consists of gray to brown cobble conglomerate

with smooth cobbles of quartzite, metavolcanic and granitic rocks in a sandstone matrix that locally includes thin lenses of red clay. This member is described as yielding cobbly to bouldery soils, and has been found to be problematic during construction where resistant conglomerate is bordered by less-resistant rocks (CDMG, 1984). The *Las Virgenes Sandstone Member* (map unit Tsuv of Dibblee, 1992) overlies the Simi Conglomerate Member, and is described as a tan, semi-friable bedded sandstone that is locally pebbly. The uppermost member is unnamed (map unit Tsu of Dibblee, 1992) and consists of gray micaceous claystone and siltstone, with a few minor thin sandstone beds. The Las Virgenes Sandstone Member and the upper unnamed member of Dibblee (1992) comprise the Santa Susana Formation as defined by Weber (CDMG, 1984). These members are described as yielding clay-bearing soils and slopewash and may have landslide and debris flow susceptibility on very steep slopes. They are also described as being easily excavated on building sites, except for any resistant beds that may be encountered.

GEOLOGIC AND GEOTECHNICAL HAZARDS REVIEW

Potential geologic and geotechnical hazards that could impact the four alternative reservoir sites and associated access road and pipeline alignments include fault surface rupture, small to large landslides and other forms of slope instability including rockfall and debris flows, and secondary seismic hazards such as liquefaction, lateral spreading, and seismically-induced slope instability. For this desktop study, these hazards were screened qualitatively by reviewing published information. Based upon our review of regional, published information, the following screening-level conclusions are drawn:

- No known active faults trend on or near the project area, and the potential for fault surface rupture is therefore considered to be very low. The nearest active faults are the Simi-Santa Rosa fault approximately 5.5 miles to the north and the Malibu Coast fault approximately 12 miles to the south (USGS, 2020).

- No landslides are identified on regional geologic maps within the project area, inclusive of reservoir sites, access roads, and pipeline alignments; however, our aerial photograph review identified a possible ancient landslide west of and downslope from the Alternative 2 reservoir site; a possible ancient landslide which could affect the access road leading up to the Alternative 3 reservoir site; and a historically active landslide that will potentially impact the access road and pipeline alignment for the Alternative 4 reservoir site. These will be discussed further in the evaluation of preliminary design alternatives below.

- None of the alternative reservoir sites, access roads and pipeline alignments are located within a State-defined Zone of Required Investigation for liquefaction hazards (CGS, 1998). As such, the potential for hazards such as liquefaction and possible lateral spreading that is associated with liquefaction, is considered to be low at this time. A site-specific liquefaction evaluation will be performed during the design-level investigation and will likely focus on alluvial materials proximal to drainage areas within a pipeline and/or access road alignment.

- None of the alternative reservoir sites are located within a State-defined Zone of Required Investigation for earthquake-induced landsliding; however, such zones are mapped in close proximity to the reservoir locations for Alternatives 3 and 4. Proposed access roads on steeper slopes leading to the Alternative 2 and 4 reservoir sites are also located within such zones. These zones were defined by the California Geological Survey (formerly California Division of Mines and Geology) under the Seismic Hazards Mapping Act of 1990. The zones are based on earthquake ground-shaking estimates, geologic material-strength characteristics and slope gradient, and are considered to identify areas where the potential for earthquake-induced landslides is relatively high (CDMG, 1997). Site-specific, static and seismic slope stability analyses will be performed during the design-level investigation and will include appropriate ground acceleration parameters.

PRELIMINARY DESIGN ALTERNATIVES EVALUATION

The following evaluation is based upon review of Preliminary Design Alternatives prepared at a scale of 1 inch = 100 feet by AECOM in December 2019. Each reservoir site alternative appears to have a target pad elevation of 1,905 feet and proposes a 1.7 million gallon (MG) above-ground reservoir.

Preliminary Design Alternative 1

The Preliminary Design Alternative 1 reservoir site is located immediately east of the existing 1 MG and 2 MG reservoirs and will utilize the existing access road to those reservoirs for access and source/distribution pipeline alignments. The proposed reservoir location is approximately 1,500 feet north of existing residential developments on N. Hacienda Road and N. Marlboro Road. The preliminary reservoir pad location is on the south side of an east-northeast trending strike ridge, on a natural south-facing slope with gradients ranging from 3:1 to as steep as 2:1 (horizontal:vertical). The slope gradient south of the existing reservoirs appears to be locally as steep as 1-3/4:1. This area is underlain predominantly by resistant, locally very hard, well-cemented sandstone bedrock of the Chatsworth Formation; however this formation is also known to contain relatively thin fine-grained interbeds which can contribute to slope stability issues. Rippability of the site bedrock is a significant concern (described as moderately to extremely difficult with heavy earthmoving equipment) and may be highly dependent upon the depth of proposed cuts below existing grade. It is presently unknown if blasting was required for the construction of the existing reservoirs; however, the design cut depth was approximately 40 feet below natural grade. The presence of very hard, well-cemented sandstone bedrock in construction excavations may also result in the generation of a significant quantity of oversized materials that may not be reusable as fill material without special measures, and this may in turn adversely affect balanced grading design efforts.

Geologic structural data from regional maps indicate that bedding within the Chatsworth Formation strikes northeast and dips 15 to 20 degrees northwest near this location. Based on the bedding orientation, the design of north to west-facing cut slopes should be avoided in the reservoir pad design to avoid creating adverse bedding conditions, thereby limiting the potential for instability of design cut slopes and the need for remedial. The terrain in this area also contains numerous boulders and loose rocks at the ground surface. The grading plan for the adjacent Bell Canyon Reservoir No. 2 called for removal of several large boulders and leveling to the surrounding ground surface, on the natural slope within approximately 50 feet of the top of the design cut slope. A recommendation was also included on the plan to remove scattered loose rocks over 1-foot diameter within 20 feet of the top of cut. Inasmuch as similar surface conditions appear to exist east of Bell Canyon Reservoir No. 2, these remedial measures, which presumably were to mitigate rockfall hazard to the existing reservoir, should be anticipated for the Alternative 1 reservoir pad design.

As-built information indicates that the perimeter cut slope for Bell Canyon Reservoir No. 2 was made at a gradient of ½:1 in the Chatsworth Formation bedrock. This cut faces predominantly south to west, an orientation favorable for stability based upon the dip of bedding. The reservoir pad design for Alternative 1 should emphasize similarly oriented cut slopes.

Preliminary Design Alternative 2

The Preliminary Design Alternative 2 reservoir site is located generally at the west end of a prominent east-west trending ridgeline, approximately 4,200 feet west of the two existing Bell Canyon Reservoirs. The preliminary reservoir pad location appears to be on the immediate south side of the prominent ridge, near the intersection with a southwest trending ridge spur that descends towards Bell Creek. Natural slope gradients descending to the south, west and north from the design reservoir pad location average 2.5:1, with local gradients estimated to be as steep as 2:1 (horizontal:vertical). A 4,700 foot long, 20-foot wide access road, which will also contain the distribution water pipeline alignment, is shown extending from the proposed tie-in to existing distribution water pipe in the developed neighborhood of Bell Canyon, north to the reservoir site. The access road layout crosses hilly terrain containing several apparent smaller resistant bedrock ridges before climbing the prominent ridge and approaching the reservoir pad from the east. This alternative also has the source water pipeline aligned along 2,350 feet of existing dirt road, as well as along the upper 2,350 feet of the new access road.

The proposed reservoir pad for this alternative is underlain predominantly by resistant, locally very hard, well-cemented sandstone bedrock of the Chatsworth Formation; however, as noted above, this formation also contains relatively thin fine-grained interbeds (siltstone, clay shale) which can contribute to slope stability issues. A possible landslide was identified based on geomorphic expression and deflected drainage during our aerial photograph review. This feature is on the west-facing natural slope east of Bell Creek, well below the design pad elevation of the reservoir. This landslide, if present, is not anticipated to impact the proposed project. Rippability of the site bedrock is a significant concern (moderately to

extremely difficult with heavy earthmoving equipment) and may be highly dependent upon the depth of proposed cuts below existing grade. As mentioned for Alternative 1, there is also a potential for generation of significant oversize material that cannot be re-used as fill material elsewhere in the site grading without special measures.

Geologic structural data from regional maps (CDMG, 1973; Dibblee, 1992) indicate that bedding within the Chatsworth Formation strikes east to northeast, with dip ranges of 18 to 35 degrees north to northwest near this location. Based on this bedding orientation, the design of north to west-facing cut slopes should be avoided in the reservoir pad design to limit the potential for instability of design cut slopes, unless the slopes are cut generally flatter than the dip of bedding. The access road is aligned primarily across south-facing topography; therefore, bedding should be favorably supported in south-facing cut slopes that are anticipated for the access road design.

The easterly 2,350 feet of the source water pipeline alignment is along an existing dirt road that appears to have been created by minor cuts and fills and appears to be well-maintained based upon review of Google Earth imagery.

Preliminary Design Alternative 3

The Preliminary Design Alternative 3 reservoir site is located about 1/3 mile west of the Bell Creek drainage and 1/4 mile north of the cul-de-sac of Saddlebow Road on the east end of a prominent east-west oriented strike ridge. The reservoir site appears to be laid out slightly to the north side of the ridgeline. Natural slope gradients in the proposed reservoir area are 2:1 to 2.5:1 (horizontal:vertical) to the south of the ridgeline and 4:1 to 5:1 to the north of the ridgeline. The reservoir site would be accessed from the north by a 1,250-foot long, 20-foot wide access road (also containing source and distribution water lines) that climbs the north-facing natural slope of the ridgeline. Other components of this alternative include 7,200 linear feet of source water pipeline (including a new Bell Creek Crossing) and 3,500 linear feet of distribution line along existing dirt roads, 3,700 linear feet of in-street distribution line, and 2,100 linear feet of cross-country distribution line. An additional access road of 850 linear feet is shown extending from the cul-de-sac of Maverick Lane and trending north, tying into an existing dirt road north of the developed neighborhood.

A geologic contact between the Simi Conglomerate and Las Virgenes Sandstone members of the Santa Susana Formation is mapped below the ridgeline immediately south of the proposed reservoir site. Both of these geologic units may therefore be exposed in the reservoir pad excavation depending upon the final pad layout and depth of cut for the pad grade. These units of the Santa Susana Formation are described as being rippable with moderate to great difficulty, and blasting could be required if very hard resistant beds are present. A geologic contact between the Las Virgenes Sandstone and upper unnamed member of the Santa Susana Formation (map unit Tsu) is mapped immediately north of the ridgeline. The presence of the predominantly fine-grained Tsu unit on the north slope of the ridgeline is likely responsible for the subdued topography and lower slope gradients; however, a landslide has also been queried on a portion of this slope based upon geomorphic expression

and drainage patterns observed in our aerial photograph review. The landslide, if present, will potentially affect the access road alignment leading to the reservoir site, and remedial grading could be required.

Geologic structural data from regional maps (CDMG, 1973; Dibblee, 1992) indicate that bedding within the Santa Susana Formation strikes east to northeast, with dip ranges of 35 to 50 degrees north to northwest near this location. Based on this bedding orientation, the design of north- to west-facing cut slopes should be avoided in the reservoir pad and access road design to avoid undercutting bedding and thereby limiting the potential for instability of design cut slopes.

Preliminary Design Alternative 4

The Preliminary Design Alternative 4 reservoir site is located about 1/3 mile west of the Bell Creek drainage and about 600 feet northwest of the cul-de-sac of Saddlebow Road on the east end of a prominent east-west oriented strike ridge. Natural slope gradients are 2.5:1 to 3:1 (horizontal:vertical) on the north side of the ridge and 2.5:1 on the south side of the ridge, with local areas as steep as 2:1. The northerly property line for two residential lots on Saddlebow Road is located immediately south of the proposed reservoir site. A 2,000 linear foot, 20-foot wide access road is proposed from the terminus of Maverick Lane. The access road would run west on the north side of developed residential lots, then turning north and wrapping around the east side of the prominent ridge. The access road alignment then trends northwest adjacent to a tributary drainage that is north of the prominent ridge, before climbing south up the ridge to the reservoir site. Other components of this alternative include: 8,800 linear feet of source water pipeline (including a new Bell Creek Crossing) along an existing dirt road, 2,000 feet of cross-country source water pipeline, 3,700 linear feet of in-street distribution line and 2,000 linear feet of cross-country distribution line. An additional access road of 850 linear feet is shown extending from the cul-de-sac of Maverick Lane and trending north, tying into an existing dirt road north of the developed neighborhood.

A geologic contact between the Chatsworth Formation and the Simi Conglomerate member of the Santa Susana Formation is mapped on the south side of the prominent ridgeline. This contact is south of the proposed reservoir site and appears to be located at least 50 feet vertically below the ridgeline; therefore, we anticipate that the Simi Conglomerate would be exposed in the reservoir pad excavation. Rippability of the Simi Conglomerate is anticipated to be moderate to difficult and will be dependent upon the presence and thickness of resistant conglomerate beds in the proposed grading area. Geologic structural data from regional maps (CDMG, 1973; Dibblee, 1992) indicate that bedding within the Simi Conglomerate strikes east to slightly northeast, with dips of 45 degrees to the north-northwest. Based on this bedding orientation, the design of north- to northwest-facing cut slopes should be avoided in the reservoir pad and access road design to limit the potential for instability of design cut slopes and to avoid remedial grading measures. Depending upon the strength of the bedrock materials and local bedding structure, it may be possible to design north- to northwest-facing cut slopes at a gradient slightly flatter than 1:1 (i.e., 45 degrees).

Based upon aerial photograph review, a relatively recent landslide is present on the ridge spur below and northeast of the proposed reservoir site. This landslide appears be a slump and earthflow type of failure northeast along strike, between two resistant bedrock ridges. Landslide debris appears to have flowed into the tributary drainage, causing deflection of the drainage. The landslide deposit is crossed by the access road alignment, and the upper portion of the access road near the reservoir site is aligned close to the headscarp of the landslide. Significant remedial grading would be necessary for the access road where it is currently aligned across the landslide, and the upper portion of the access road would likely need to be realigned to avoid the landslide headscarp.

CONCLUSIONS

Based upon our evaluation of the four preliminary design alternatives:

- Preliminary Design Alternative 1 appears to have the least geotechnical constraints, although further information is needed regarding the previous grading for the adjacent Bell Canyon Reservoir No. 1 and 2 pads including the rippability of the Chatsworth Formation and whether blasting was required.

- Preliminary Design Alternative 2 also lacks significant geotechnical constraints other than rippability of the site bedrock, and appears to have favorable geologic structure conditions for construction cuts that are anticipated for the reservoir pad and access road alignment as currently proposed on the south side of a prominent ridgeline, although a portion of the access road leading to the reservoir site is within a mapped earthquake-induced landslide hazard zone.

- Preliminary Design Alternatives 3 and 4 have access road alignments that will be potentially impacted by landslides (existing and postulated) and could require significant remedial grading simply to establish a stable access road. These alternatives also appear to have reservoir site locations and access roads aligned on the north side of prominent ridgelines where north- to west-facing construction cuts may create adverse bedding conditions that could adversely affect slope stability. The Alternative 3 and 4 reservoir site locations and access roads are also near or within a mapped earthquake-induced landslide hazard zone.

LIMITATIONS

Our services consist of professional opinions and recommendations made in accordance with generally accepted engineering geology and geotechnical engineering principles and practices. No warranty, express or implied, or merchantability of fitness, is made or intended in connection with our work, by the proposal for consulting or other services, or by the furnishing of oral or written reports or findings.

This feasibility-level letter has been prepared for the exclusive use of the Ventura County Public Works Agency and their authorized agents for preliminary design and construction considerations for the proposed Bell Canyon Reservoir and Pipeline project. *The preliminary conclusions and recommendations contained in this letter should not be considered valid until site improvement plans have been developed and a design-level geotechnical investigation by Cotton, Shires & Associates, Inc. has been performed*.

This letter is issued with the understanding that it is the responsibility of the owner, or of his representative, to ensure that the preliminary information and recommendations contained herein are called to the attention of the project engineer and incorporated into the preliminary design plans, as appropriate.

CLOSURE

We appreciate the opportunity to provide you with this technical letter presenting our Phase 1 geotechnical feasibility study for the Bell Canyon Reservoir and Pipeline alternatives. Please do not hesitate to contact us should you have any questions regarding this letter. We look forward to discussing our findings with you and the design team.

Very truly yours,
COTTON, SHIRES AND ASSOCIATES, INC.

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MP:MJJ/st
Attachments: References

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