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Eagle Mountain Pumped Storage Project No. 13123

Final License Application

Technical Appendices for Exhibit E, Applicant Prepared Environmental Impact Statement. Volume 3 of 6

Palm Desert, California

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12.6 Stage 1 Design Level Site Investigation Plan

Eagle Mountain Pumped Storage Project: Stage 1 Design – Level Site Investigation Plan

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This memorandum describes a Phase 1 subsurface site investigation program for the Eagle Mountain Pumped Storage Project. This program will commence after the FERC license has been granted and in the initial stages of final engineering design when site access is arranged. Coupled with previous work on the site conducted for other purposes, the Phase 1 program will provide the information needed to finalize project features and to plan a second-stage program to support final design of the project.

Existing Data

Extensive geologic and geotechnical investigations have been carried out at the Eagle Mountain site. Initial investigations were conducted prior to, and during operation of the iron ore mining operations. More recently, comprehensive site investigations were completed as part of the landfill planning and preliminary design studies. These investigations included:

- Geologic mapping;
- Seismic refraction studies;
- Drilling of borings to depths in excess of 1,500 feet;
- Borehole video logs;
- Installation of monitoring wells and piezometers;
- Downhole pressure testing;
- Sampling and laboratory testing of rock samples collected from the major rock units present on site as well as sampling and extensive laboratory analyses of mine tailings materials; and
- Investigations into the age of several faults that pass through or close to the site including age dating of dikes which cross but are not offset by one or more faults.

Laboratory testing of both bedrock and alluvium involved an extensive program that included:

- Grain size distribution;
- Direct shear testing;
- L.A. abrasion;
- Specific gravity;
- Triaxial shear tests;
- Expansion index;
- Atterberg limits;
- Consolidation tests;
- Swell potential;
- Moisture content/dry density;
- Leachate compatibility and durability;

- Shrinkage limit;
- X-ray diffraction;
- Hydraulic conductivity;
- Pinhole dispersion;
- Petrographic analyses;
- Maximum dry density/moisture content; and
- Chemical analyses.

The site investigations and studies were completed between 1988 and the spring of 1993 by GeoSyntec Consultants of Huntington Beach, California, and GSi/Water of South Pasadena, California. Results of these investigations are presented in the Report on Waste Discharge, which was filed with the California Water Quality Control Board, as part of the landfill licensing process. Additional geologic information is presented in the Environmental Impact Statement for the Eagle Mountain Landfill, dated July, 1991.

Site Investigations

The data used for characterization of the site for the Final License Application are drawn from the previous reports and observations made during a reconnaissance visit to the mine during the 1992 to 1994 FERC licensing process. The previous investigations were not tailored specifically to gaining data that would support design of large dam, tunnel, and related structures for a hydroelectric development. However, data are available to understand the site characteristics in sufficient detail to document the feasibility of constructing the Eagle Mountain Pumped-Storage Project.

ECEC will undertake detailed site investigations to support final configuration and design of the Eagle Mountain Pumped Storage Project. These detailed investigations will be conducted in two stages, as follows:

- Stage 1 - Subsurface Investigations: Based on available information and the current project configuration, conduct a limited field program designed to confirm that basic project feature locations are appropriate and to provide basic design parameters for the final layout of the project features.

- Stage 2 - Subsurface Investigations: Using the results of the Stage 1 work, and based on any design refinements developed during pre-design engineering, conduct additional explorations that will support final design of the project features and bids for construction of the project.

The general scope of the Stage 1 program is discussed in the following paragraphs and shown on Figure 1. Laboratory testing would include a similar suite of tests to those performed for the landfill.

Water Storage Reservoirs

The project has two reservoirs, which will involve adapting existing mining pits for water storage. At the Upper Reservoir, the existing mine pit does not have adequate volume to contain the entire water storage needed. To create the required storage, two dams will be constructed in order to close off low areas around the mine pit rim. Both FERC and the California Division of Safety of Dams (DSOD) will review the design of these dams and confirm that the designs meet their strict safety criteria and standards. Both agencies require geologic and foundation conditions at the dam locations and construction materials for the dam to be thoroughly investigated and documented. The scope of these investigations must be appropriate for the dam size and type and the complexity of the foundation. The potentials for seepage from the reservoir that could affect the design and safety of the dams will also be investigated so that control measures can be designed and implemented.

- Upper Reservoir Dam 1: Three borings are planned for the pre-design program; one vertical at low point on the rim and one at each abutment, as follows –

  Abutments – Approximate surface El. 2500; boring depth 150 ft at 60 degrees (130 ft vertical, equals the proposed structural height). Rock coring methods will be used on the abutments; two set-ups, total of 300 lineal feet (lf); and permeability testing. These borings will be used to evaluate foundation conditions, depth of weathering, strength and hardness, faults and fractures, permeability, excavation requirements, and cut-slope slope stability.

  Low Point on Rim – Approximate surface El. 2380; boring depth 150 ft at 60 degrees (130 ft vertical, equals the proposed structural height). Rock coring methods will be used; one set-up, 150 lf; and permeability testing. This boring will be used to evaluate foundation conditions, type of surface deposits, depth to bedrock, depth of weathering, strength and hardness, faults and fractures, permeability, and excavation requirements.

- Upper Reservoir Dam 2: Plan three borings; one vertical at low point on the rim and one at each abutment, as follows –

  Abutments – Approximate surface El. 2500; boring depth 92 ft at 60 degrees (80 ft vertical, equals the proposed structural height). Use rock coring methods on both abutments; two set-ups, total of 184 lf; permeability testing. These borings will be used to evaluate foundation conditions, depth of weathering, strength and hardness, faults and fractures, permeability, excavation requirements, and cut-slope stability.

  Low Point on Rim – Approximate surface El. 2430; boring depth 92 ft at 60 degrees (80 ft vertical, equals the proposed structural height). Use rock coring methods; one set-up, 92 lf; permeability testing. This boring will be used to evaluate foundation conditions, type of surface deposits, depth to bedrock, depth of weathering, strength and hardness, faults and fractures, permeability and excavation requirements.

- Borrow Materials for Dam Construction: The dams will be built with roller-compacted concrete (RCC). To investigate the suitability of available materials near the lower reservoir, at least two borings are required for the pre-design field program. One boring would be made through the coarse-grained overburden spoil material and the other boring would be drilled through the processed fine-grained tailings material. Soil sampling methods will be used. Each of the borings will be vertical and extend to a depth of 50 ft. Lab test samples will be obtained. Based on topographic mapping and the borings a determination will be made of the available materials quantities. We understand that Kaiser will use the on-site materials for the landfill construction; therefore, the materials quantities and requirements for both projects will be determined and compared. If quantities are not adequate for the pumped storage project after landfill needs are met, alternate sources of borrow for dam construction will be identified and explored. Materials samples will be subjected to tests normally performed for concrete and RCC aggregates, as well as those normally performed for rockfill used in embankment dam construction. Because of the potential for high iron content, and the potential for iron to react with cement used for concrete, density tests and iron content tests will be critical for decision-making relative to use of mine spoil materials, as well as in-situ rock, for RCC construction.

- Upper Reservoir Conditions: Detailed geologic mapping of the upper reservoir will be performed to characterize conditions that will affect the stability of existing slopes during reservoir level fluctuations. Mapping will identify the degree and orientation of jointing and fracturing, faulting, weathering, and the dimensions of the benches excavated during mining. The apparent stability of the cut slopes and benches will be assessed. Potential measures to control seepage and leakage from the reservoir will be assessed in the field as observations of pit conditions are made.

- Lower Reservoir Conditions: Unlike the upper reservoir, the lower reservoir has two distinct characteristics. The west, north and south rims are primarily exposed bedrock, while the east rim exposes alluvial material (debris flow), which will be the primary location of seepage from the lower reservoir. A minimum of two borings, at approximate surface El. 1100 are planned to explore conditions of this material. Each boring will have a depth 300 ft and will be drilled vertically. Samples for laboratory testing will be obtained at pre-determined intervals and when changes in stratigraphy are apparent. In-situ permeability tests will be performed and piezometers will be installed. Total depth of drilling will be 600 lf. As in the case of the upper reservoir, geologic mapping will be performed to identify conditions of the exposed schistose meta-arkose rock types in the mine pit. Detailed geologic mapping will be performed to characterize conditions that will affect the stability of existing slopes during reservoir level fluctuations. Mapping will identify the degree and orientation of jointing and fracturing, faulting, weathering, and the dimensions of the benches excavated during mining. The apparent stability of the cut slopes and benches will be assessed. Potential measures to control seepage and leakage from the reservoir will be assessed in the field as observations of pit conditions are made.

Hydraulic Structures

In addition to the upper reservoir dams, there will be two large above-ground reinforced concrete hydraulic structures associated with the pumped storage project. These are the upper and lower reservoir inlet/outlet (I/O) structures. These structures will be built in excavations made at the east end of the upper reservoir and the northwest portion of the lower reservoir.

- Upper Reservoir I/O Structure: For the pre-design exploration, one boring is planned to be advanced from the top of the slope cut at approximate El. 2600 to about 10 ft below the proposed structure foundation at El. 2260. The estimated boring depth is 362 ft at an angle 70 degrees (340 ft vertical). Rock coring methods will be used and permeability tests will be performed in addition to logging and sampling the core for testing. The purpose of the boring and testing will be to evaluate slope integrity, rock type and quality, and foundation conditions. This information may be used to evaluate the upstream tunnel portal location and to provide preliminary criteria for design of the I/O structure.

- Lower Reservoir I/O: One boring is planned to be advanced from the top of the slope cut at approximate El. 1550 to about 10 ft below structure foundation El. 840. The boring depth will be 755 ft at 70 degrees (710 ft vertical). Rock coring methods will be used and permeability testing will be performed. Data from this boring will be used to evaluate slope integrity, rock type and quality, and foundation conditions. This information may be used to evaluate the upstream tunnel portal location and to provide preliminary criteria for design of the I/O structure.

Tunnels and Shaft

The Eagle Mountain project includes a number of large-diameter tunnels for water conveyance between the two I/O structures and for access to the proposed underground powerhouse. The water conveyance tunnel alignment is stationed from the I/O structure at the upper reservoir (Station 0+00) to the I/O structure at the lower reservoir (Station 130+00). The underground powerhouse is located at approximately Station 65+00. The access tunnel extends from near the lower reservoir I/O to the underground powerhouse.

- Water Conveyance Tunnels: One boring planned at Station 20+00 at approximate ground elevation El. 2600 drilled vertically to El. 2250, a boring depth of 350 ft. Another boring will be drilled at Station 90+00 at approximate ground El. 1800 and drilled vertically to El. 740, a boring depth of 1060 ft. A third boring would be drilled at Station 110+00 at approximate ground El. 1870 and drilled vertically to El. 800, a boring depth of 1070 ft. Rock coring methods will be used at these three set-ups, with total boring length of 2480 lf. In addition to logging and sampling for rock testing, permeability testing will be performed within 1.5 tunnel diameters (approximately 50 ft) above and below the tunnel spring-line elevation. The purpose of these borings will be to evaluate rock type, quality and permeability characteristics within the tunnel target elevations described above and to assess conditions for construction using a tunnel boring machine.

- Access Tunnel: The access tunnel will parallel the tailrace tunnel. At this time, we believe that explorations for the water conveyance tunnel between the lower reservoir I/O structure and the powerhouse, as well as exploration for the underground powerhouse, will be adequate to characterize the geologic conditions for preliminary design of the access tunnel.

- Shaft: The current project plan envisions a 1390 ft-deep shaft between the upper tunnel and the deeper lower tunnel section located just upstream of the powerhouse and the deeper tunnel that will form the project tailrace. The shaft is located at approximate Station 40+00. One boring is planned to be advanced from El. 2600 to El. 760, a depth of 1840 ft. The shaft boring will be used to evaluate rock type, quality and permeability and to provide design parameters for the shaft.

- Underground Powerhouse: One boring will be advanced from approximate ground El. 2000 at Station 65+00 to El. 680, a total depth of 1320 feet. Permeability testing will be performed above, at, and below the elevations defining the proposed powerhouse cavern. This boring will be used to evaluate rock type, quality and permeability and to provide design parameters for the powerhouse cavern and to help define rock treatment requirements.

Reservoir and Tunnel Seepage Potentials

Detailed mapping of rock types, faults, fractures and jointing in the two reservoirs, coupled with data obtained and interpretations made from the core drilling described above, will allow clearer definition of the seepage potentials from the Eagle Mountain project facilities. Data relative to primary and secondary permeabilities of the local bedrock will be collected during the Phase I program described above. As appropriate based on additional data obtained, the seepage model and the plan for seepage mitigation developed for the FLA will be updated and refined.

Hydrocompaction and Subsidence Potentials
As part of designs for the seepage monitoring system, several borings, in the depth range of 100 to 200 ft, will be made in the alluvial deposits downstream from the lower reservoir between the reservoir and the Colorado River Aqueduct (CRA). These borings will be equipped with piezometers and boring data and samples will be used to further assess potentials for hydrocompaction and subsidence in the vicinity of the CRA that could occur due to seepage from the Eagle Mountain Reservoirs. The seepage monitoring system is described in more detail in the seepage recovery wells, groundwater modeling report (Section 12.8).

Reservoir-Triggered Seismicity (RTS)
While the size and depth of the project reservoirs suggest that reservoir-triggered seismicity will not be an issue, further research may be needed. This issue cannot be addressed with subsurface investigations. In preparation for the FLA based on comments received on the DLA from several entities, GEI reviewed some of the literature on RTS. Findings are presented below.

Reservoir triggered seismicity (RTS) is the activation of fault movement, and hence the production of earthquakes, by the impoundment or operation of a reservoir. This phenomenon is most commonly referred to in the literature as reservoir induced seismicity (RIS). However, because those crustal masses experiencing RTS were likely only marginally stable to begin with, most experts consider the term "triggering" as more accurately describing increases in seismicity associated with reservoir impoundment.

From a worldwide perspective, only a small percentage of reservoirs impounded by large dams have triggered known seismic activity. It is generally accepted that reservoir filling will not cause damaging earthquakes in areas where they would not otherwise occur. Accordingly, the maximum credible earthquake for an area is not changed by the reservoir filling, although the frequency of earthquakes may be increased, at least on a temporary basis (FEMA, 2005).

General theory suggests that reservoir impoundment alters the stress regime within the crust of the earth by increasing shear stress due to the weight of the water, and reducing the shear strength by increasing pore-water pressure. While these changes appear insufficient to generate failure in unfractured rock, it is possible that faulted rock under significant tectonic strain may be induced to slip by the compounding effects of reservoir impoundment (USCOLD, 1997). As such, zones of active faulting appear to be the most susceptible to RTS.

Studies for the landfill investigated those faults that trend towards or through the proposed landfill footprint. These include several northwest trending fault segments among which are the Bald Eagle Canyon fault, the East Pit fault, and Fault A. The East Pit Fault crosses through the East Pit, which is the proposed site for the lower reservoir of the Eagle Mountain Pumped Storage Project. The Bald Canyon fault and Fault A extend through the broad area separating the proposed Upper (Central Pit) and Lower reservoirs. Reports by GeoSyntec (1996) and their consultants indicated that surface displacement has not occurred on these faults for at least 40,000 years and probably more than 100,000 years. Some of the faults were crossed by unbroken dikes estimated to be at least 100 million years old.

GeoSyntec (1996) indicates that other northwest trending fault segments exist in the proposed landfill area, but activity on these was indeterminable due to lack of dateable features. However, they argue that the en echelon structure of the northwest trending faults indicates a common age and tectonic stress regime during their formation. Therefore, they conclude that the other northwest trending fault segments have the same general age as the Bald Canyon fault, the East Pit fault and Fault A.

Detailed mapping of the Upper Reservoir (Central Pit) was not performed during the landfill studies. Previous mapping (PRA Group, 1991) indicates that northwest trending fault segments, similar to those in the area of the proposed landfill, extend across the Upper Reservoir. Based on the GeoSyntec (1996) investigations for the landfill site, it could be concluded that the northwest trending fault segments crossing the Upper Reservoir have also not experienced displacement within the past 40,000 years or more. All faults in the general Eagle Mountain mining area, whether northwest trending or oriented in other directions (e.g. the Substation and Victory Pass faults), are indicated as not displaying Quaternary (last 1.6 million years) movement on the State fault map (Jennings, 1994).

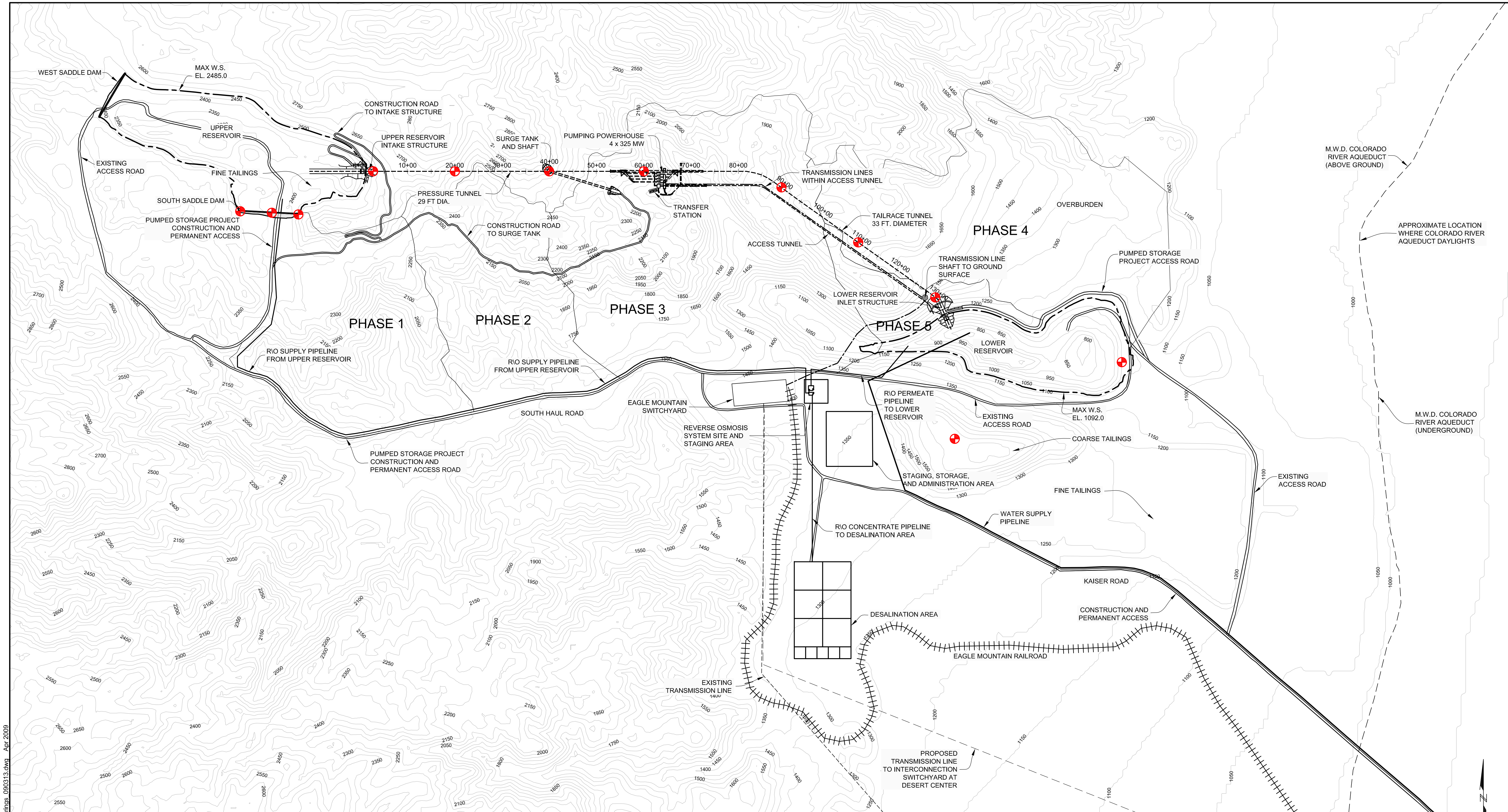
The California Division of Safety of Dams (DSOD) criterion for active faults (Fraser, 2001) is displacement within the last 35,000 years. Using this criterion, the on-site faults should be designated as inactive.

The mining pits selected to contain the Upper and Lower reservoirs were formed by the excavation of vast quantities of overburden and ore rock. The depth of excavation in the pit areas is estimated to range up to about 290 feet in the Upper Reservoir and up to about 480 feet in the Lower Reservoir. When the reservoirs are filled to maximum operation level, the deepest column of water will be about 255 feet in the Upper Reservoir and 377 feet in the Lower Reservoir. Considering that the weight of water is about 2 (overburden) to 2½ (ore rock) times less than that of the excavated material, the loads applied by the reservoirs at high-water will be substantially less than that originally imposed on the pit surfaces prior to mining. As such, the reservoir load may tend to restore some of the equilibrium lost through the site excavations rather than imposing potentially destabilizing stresses that could lead to earthquakes.

Because of the deepness of the pit excavations, only a 120-foot dam will be needed to contain the maximum water depth of about 377 feet at the Upper Reservoir. With 5 feet of freeboard, this indicates that the maximum water thickness added to the pre-excavation level of the land surface by the impoundment of the reservoir will be about 115 feet (34.5 meters). Water storage (active and inactive) for both reservoirs combined is estimated at about 24,200 acre-feet (3 x 107 cubic meters).

A statistical examination of 234 reservoirs (with and without RTS) was performed by Baecher and Keeney (1982) to better understand site characteristics that correlate with RTS and to develop a model for predicting RTS from these characteristics. In their analysis, five attributes of reservoirs appear to correlate with RTS: depth, volume, stress state, presence of active faulting, and rock type. These attributes were chosen based solely on the ready availability of data (either site specific or regional) with the recognition that other attributes such as water level fluctuation and pore pressure changes may also be important in RTS. The model criteria define the attributes of shallow and small as less than 92 meters in depth and less than 12 x 108 cubic meters in volume, respectively. Using this model, the proposed Upper and Lower Reservoirs would be designated as shallow (assumes only the maximum depth of water above the original ground surface) and small in volume. In their study, Baecher and Keeney (1982) indicate that shallow, small reservoirs were not pursued further in their analyses since they would have a probability of RTS that is “very near zero.” Macro-seismicity within 12 miles of the proposed reservoirs is rare with only one M4.0 to M4.99 event recorded about three miles south of the proposed reservoirs, possibly on the east-west trending Substation Fault. In consideration of the size of the proposed reservoirs coupled with the apparent lack of active faults in and near the areas of impoundment and the rarity of local seismicity, the potential of RST at the site appears remote and should not prove a hindrance to site development. Responding to the question of whether certain geologic settings are more prone to RTS than others, USCOLD (1997) states: “Studies that have examined the geologic setting of RTS have not been able to provide any clear guidance that would justify abandonment of any reservoir site because of concerns about the seismic safety of the dam.”

ICOLD (2008) recommends that an earthquake monitoring program be initiated at reservoir sites prior, during and after impoundment. This long-term monitoring is important as it provides the only conclusive evidence as to whether or not storage impoundment triggers earthquakes. Accordingly, a seismic monitoring program will be initiated at the site early on in the development process.



PROPOSED BORING IN PHASE I PROGRAM (POST-LICENSE)

0 500 1000 2000 3000
SCALE IN FEET

NOTES:

1. PLAN BASED ON MAP PREPARED BY C.M. ENGINEERING ASSOCIATES, SAN BERNARDINO, CA.

NO.	DATE	ISSUE/REVISION	DES	DRN	CHK	APP

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EAGLE MOUNTAIN PUMPED STORAGE PROJECT

PROPOSED BORINGS FOR PHASE I GEOTECHNICAL FIELD PROGRAM

FIGURE NO. 1

SHEET NO. 1 of 1

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