R E P O R T

GEOLOGIC HAZARDS EVALUATION
COBABE RANCH DESIGN TANK
ABOUT 2720 NORTH 5100 EAST
EDEN, WEBER COUNTY, UTAH

Prepared for

Eden Valley Opportunity LLC
3718 North Wolf Creek Drive
Eden, Utah 84310

June 23, 2025

Prepared by

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June 23, 2025

Eden Valley Opportunity LLC
Rick Everson
3718 North Wolf Creek Drive
Eden, Utah 84310

Letter of Transmittal: Geologic Hazards Evaluation
Cobabe Ranch Design Tank
About 2720 North 5100 East
Eden, Weber County, Utah

Dear Mr. Everson:

Western Geologic & Environmental has completed a Geologic Hazards Evaluation for the Cobabe Ranch Design Tank at about 2720 North 5100 East in Eden, Utah and submits the attached report for your review.

If you have any questions regarding this report, please contact us at (801) 359-7222.

Sincerely,
Western Geologic & Environmental LLC

Bill. D. Black, P.G.
Subcontract Geologist

Reviewed By:

Kevin J. Thomas, P.G.
Principal Geologist

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WG&E Project No. 6669

TABLE OF CONTENTS

FIGURES

1.0 INTRODUCTION

This report presents results of a geology and geologic hazards evaluation conducted by Western Geologic & Environmental LLC (Western Geologic) for the Cobabe Ranch Design Tank at about 2720 North 5100 East in Eden, Utah (Figure 1 – Project Location). The Project is in the NW1/4 Section 26, Township 7 North, Range 1 East (Salt Lake Base Line and Meridian; Figure 1). Elevation of the tank location ranges between about 5,305 to 5,314 feet above sea level. The Project is currently proposed for development of one 500,000-gallon, 75-foot diameter, concrete water reservoir (tank) in the northeast corner of the proposed Cobabe Ranch Development in Weber County Assessor parcel number 22-020-0040.

2.0 PREVIOUS STUDIES

Western Geologic previously completed a geologic hazards evaluation for the proposed Cobabe Ranch Development in February 2022 in conjunction with a geotechnical engineering investigation conducted by Christensen Geotechnical. Our investigation included excavation and logging of 35 walk-in test pits to evaluate subsurface conditions. No test pits were in the area of the tank location, but one test pit (TP-15) was about 600 feet to the southwest. Test pit TP-15 from our 2022 investigation exposed about 5 feet of upper Pleistocene alluvial fan deposits comprised of clayey gravel to clayey sand (GC-SC) with subangular to subround cobbles overlying weathered tuffaceous conglomerate of the Tertiary Norwood Formation. Based on site-specific surficial geologic mapping included on Plate 3 in Western Geologic (2022), the tank location would be in an area underlain by Pleistocene alluvial fan deposits and Tertiary Norwood Formation bedrock.

Western Geologic (2022) identified high-risk hazards to the proposed Cobabe Ranch Development from earthquake ground shaking and landslides, and moderate- (equivocal) risk hazards from shallow groundwater and problem soil. With regard to these hazards, we recommended: (1) habitable structures be constructed to current adopted seismic building codes; (2) the Project geotechnical engineer assess soil foundation conditions, provide recommendations regarding subsurface drainage, and evaluate slope stability based on the characterizations in the report; (3) no unplanned slope cuts be made without geotechnical analyses and proper surface and subsurface drainage be maintained; (4) test pit backfill be replaced with structural fill where beneath structures; and (5) hazards identified as posing a high risk at the site be disclosed to future buyers.

3.0 PURPOSE AND SCOPE

The purpose and scope of this investigation was to identify and interpret surficial geologic conditions at the site to identify potential risk from geologic hazards to the Project. This investigation is intended to: (1) provide geologic information and assessment of geologic conditions at the site; (2) identify potential geologic hazards that may be present and qualitatively assess their risk to the intended site use; and (3) provide recommendations for additional site- and hazard-specific studies or mitigation measures, as may be needed based on our findings. The latter may include analyses and/or design criteria that are beyond our professional scope. Christensen Geotechnical conducted a geotechnical engineering study concurrently with our evaluation.

3.1 Methodology

The following services were performed in accordance with the above-stated purpose and scope:

- A site reconnaissance conducted by an experienced certified engineering geologist to assess the site setting and look for adverse geologic conditions;
- Review of readily-available geologic maps, reports, and air photos;
- Logging of two deep test pits to assess subsurface conditions;
- Preparation of one geologic cross section based on geoprocessed LIDAR data, observed and inferred surficial conditions, and site-specific subsurface data; and
- Evaluation of available data and preparation of this report, which presents the results of our study.

Our investigation was conducted in accordance with Bowman and Lund (2020) and current generally accepted professional engineering geologic principles and practice in Utah within the above stated scope. The report herein meets specifications provided in Chapter 108-22 (Natural Hazard Areas) of the Weber County Code.

3.2 Limitations and Exceptions

This investigation was performed at the request of the Client using the methods and procedures consistent with good commercial and customary practice designed to conform to acceptable industry standards. The analysis and recommendations submitted in this report are based upon the data obtained from site-specific observations and compilation of known geologic information. This information and the conclusions of this report should not be interpolated to adjacent properties without additional site-specific information. In the event that any changes are later made in the location of the proposed site, the conclusions and recommendations contained in this report shall not be considered valid unless the changes are reviewed and conclusions of this report modified or approved in writing by the engineering geologist.

This report has been prepared by the staff of Western Geologic for the Client under the professional supervision of the principal and/or senior staff whose seal(s) and signatures appear hereon. Neither Western Geologic, nor any staff member assigned to this investigation has any interest or contemplated interest, financial or otherwise, in the subject or surrounding properties, or in any entity which owns, leases, or occupies the subject or surrounding properties or which may be responsible for environmental issues identified during the course of this investigation, and has no personal bias with respect to the parties involved.

The information contained in this report has received appropriate technical review and approval. The conclusions represent professional judgment and are founded upon the findings of the investigations identified in the report and the interpretation of such data based on our experience and expertise according to the existing standard of care. No other warranty or limitation exists, either expressed or implied.

The investigation was prepared in accordance with the approved scope of work outlined in our proposal for the use and benefit of the Client; its successors, and assignees. It is based, in part, upon documents, writings, and information owned, possessed, or secured by the Client. Neither this report, nor any information contained herein shall be used or relied upon for any purpose by any other person or entity without the express written permission of the Client. This report is not for the use or benefit of, nor may it be relied upon by any other person or entity, for any purpose without the advance written consent of Western Geologic.

In expressing the opinions stated in this report, Western Geologic has exercised the degree of skill and care ordinarily exercised by a reasonable prudent environmental professional in the same community and in the same time frame given the same or similar facts and circumstances. Documentation and data provided by the Client, designated representatives of the Client or other interested third parties, or from the public domain, and referred to in the preparation of this assessment, have been used and referenced with the understanding that Western Geologic assumes no responsibility or liability for their accuracy. The independent conclusions represent our professional judgment based on information and data available to us during the course of this assignment. Factual information regarding operations, conditions, and test data provided by the Client or their representative has been assumed to be correct and complete. The conclusions presented are based on the data provided, observations, and conditions that existed at the time of the field exploration.

4.0 HYDROLOGY

The U.S. Geological Survey (USGS) topographic map of the Huntsville Quadrangle shows the site is in eastern Ogden Valley about 1.1 miles southeast of Wolf Creek Resort (Figure 1). No active or intermittent drainages cross the Project, but Heinz Canyon Creek and one unnamed intermittent drainage cross the western half of the overall Cobabe Ranch Development. No springs are mapped on Figure 1 at the Project, but several springs are in the nearby area (including Patio Springs).

Ogden Valley is dominated in the valley bottom by unconsolidated lacustrine and alluvial basin-fill deposits. Slopes in the site area are mainly in weathered Tertiary-age tuffaceous bedrock overlain by a veneer of unconsolidated Quaternary alluvial and colluvial deposits. Avery (1994) indicates groundwater in Ogden Valley occurs under perched, confined, and unconfined conditions in the valley fill to depths of 750 feet or more. A well-stratified lacustrine silt layer forms a leaky confining bed in the upper part of the valley-fill aquifer. The aquifer below the confining beds is the principal aquifer, which is in primarily fluvial and alluvial-fan deposits. The principal aquifer is recharged from precipitation, seepage from surface water, and subsurface inflow from bedrock into valley fill along the valley margins (Avery, 1994). The confined aquifer is typically overlain by a shallow, unconfined aquifer recharged from surface flow and upward leakage. Groundwater flow is generally from the valley margins into the valley fill, and then toward the head of Ogden Canyon (Avery, 1994).

No site-specific groundwater information was available for the Project, but the Utah Department of Water Rights Well Driller's database shows eight water wells in the vicinity of the overall Cobabe Ranch Development (Figure 1). The drillers' logs for these wells report depths to static groundwater of from 15 to 40 feet, with a mean depth of 32.6 feet and a median depth of 35 feet. No groundwater was encountered in the test pits conducted for our investigation to their explored depths (up to 29 feet below existing grade). Based on all the above, we infer groundwater is about 30 to 40 feet deep beneath the tank location.

Groundwater depths at the Project may vary seasonally from snowmelt runoff and infiltration, annually from climatic fluctuations, and locally with topography and subsurface conditions. Seasonal saturation of near-surface unconsolidated deposits during spring snowmelt would be typical for the area. Groundwater may also be perched above less-permeable bedrock layers in the subsurface following spring snowmelt. After spring snowmelt, groundwater depths typically increase at a rate dependent on the hydraulic conductivity of the underlying unconsolidated sediments and bedrock. A detailed analysis of hydrogeologic conditions at the site was beyond the scope of our investigation.

5.0 GEOLOGY

5.1 Surficial Geology

The site is located in eastern Ogden Valley, a sediment-filled intermontane valley within the Wasatch Range, a major north-south trending mountain range marking the eastern boundary of the Basin and Range physiographic province (Stokes; 1977, 1986). Surficial geology of the site is mapped by Coogan and King (2016; Figure 2A) and McDonald (2020; Figure 2B). Coogan and King (2016) is a regional geologic map, whereas McDonald (2020) is a surficial geologic map for the Huntsville quadrangle. Coogan and King (2016; Figure 2A) map the tank location as underlain by landslide deposits, whereas McDonald (2020; Figure 2B) maps the tank location as underlain by pre-Lake Bonneville alluvial fan deposits. We favor the latter interpretation based on subsurface evidence from the test pits conducted for our evaluation.

Coogan and King (2016) describe surficial geologic units in the site area on Figure 2A (from youngest to oldest) as follows:

***Qh, Qh?** – Human disturbances (Historical).* Mapped disturbances obscure original deposits or rocks by cover or removal; only larger disturbances that pre-date the 1984 aerial photographs used to map the Ogden 30 x 60- minute quadrangle are shown; includes engineered fill, particularly along Interstate Highways 80 and 84, the Union Pacific Railroad, and larger dams, as well as aggregate operations, gravel pits, sewage-treatment facilities, cement plant quarries and operations, brick plant and clay pit, Defense Depot Ogden (Browning U.S. Army Reserve Center), gas and oil field operations (for example drill pads) including gas plants, and low dams along several creeks, including a breached dam on Yellow Creek.

Qal, Qal1, Qal2, Qal2? *– Stream alluvium and flood-plain deposits (Holocene and uppermost Pleistocene).* Sand, silt, clay, and gravel in channels, flood plains, and terraces typically less than 16 feet (5 m) above river and stream level; moderately sorted; unconsolidated; along the same drainage Qal2 is lower than Qat2 and has likely been subject to flooding, at least prior to dam building; present in broad plains along the Bear, Ogden, and Weber Rivers and larger tributaries like Deep, Cottonwood, East Canyon, Lost, and Saleratus Creeks, along Box Elder, Heiners, and Yellow Creeks, and in narrower plains of larger tributary streams; locally includes muddy, organic overbank and oxbow lake deposits; composition depends on source area, so in back valleys typically contains many quartzite cobbles recycled from the Wasatch Formation; mostly Holocene, but deposited after regression of Lake Bonneville from the late Pleistocene Provo shoreline; width in Morgan Valley is combined flood plain of Weber River and East Canyon and Deep Creeks; 6 to 20 feet (2-6 m) thick and possibly as much as 50 feet (15 m) along Weber River and thinner in the Kaysville quadrangle; greater thicknesses (>50 feet [15 m]) are reported in Morgan Valley (Utah Division of Water Rights, well drilling database), but likely include Lake Bonneville and older Pleistocene deposits.

Suffixes 1 and 2 indicate ages where they can be separated, with 1 including active channels and 2 including low terraces 10 to 20 feet (3-6 m) above the Weber and Ogden Rivers, and the South Fork Ogden River that may have been in the flood plain prior to damming of these waterways. Qal2 queried in low terraces above Bear River, Saleratus Creek, and Dry Creek where deposits may not be in the flood plain.

Qaf, Qaf?, Qafy, Qafy?, Qaf1, Qaf2 *– Alluvial-fan deposits (Holocene and Pleistocene).* Mostly sand, silt, and gravel that is poorly bedded and poorly sorted and is near late Pleistocene Lake Bonneville and is geographically in the Ogden and Weber River, and lower Bear River drainages; variably consolidated; includes debris flows, particularly in drainages and at drainage mouths (fan heads); generally less than 60 feet (18 m) thick; in subsurface, about 100 feet (30 m) thick in section 22, T. 9 N., R. 1 W. northwest of Mantua, and about 150 feet (45 m) thick beneath Qac in sections 9 and 16, T. 9 N., R. 1 W. (Utah Division of Water Rights website). Qaf with no suffix used where age uncertain or for composite fans where portions of fans with multiple ages cannot be shown separately at map scale; toes of some fans have been removed by human disturbances, so their age cannot be determined, for example in Upper Weber Canyon. Qaf queried where relative age uncertain, generally due to height not fitting into ranges in table 1 and/or typical order of surfaces contradicts height-derived age (see following paragraphs).

Where possible, subdivided into relative ages, indicated by letter and number suffixes (like Qa and Qat suffixes). These alluvial fans near Lake Bonneville (Qaf1, Qaf2, Qafy, Qafp, Qafpb, Qafb, Qafm, Qafo, Qafoe) are listed and described separately below. Relative ages of these fans are partly based on heights above present drainages in Morgan Valley area, in this case at drainage-eroded edge of fan. This height-based subdivision apparently works in and is applied in Ogden, Henefer, and Lost Creek Valleys and above the North, Middle and South Forks of Ogden River (see tables 1 and 2) (note revisions from Coogan and King, 2006; King and others, 2008; Coogan, 2010a-b). Despite the proximity to Lake Bonneville, alluvial fans along and near Box Elder Creek in the northwest corner of the map area (Mantua quadrangle) do not fit into table 1 and overall appear to be higher than comparable fans in Morgan Valley. Their relative ages are queried where the age is uncertain, generally due to the height not fitting into the ranges in table 1 and/or the typical order of surfaces contradicts height-derived age.

***Qac** – Alluvium and colluvium (Holocene and Pleistocene).* Unsorted to variably sorted gravel, sand, silt, and clay in variable proportions; includes stream and fan alluvium, colluvium, and, locally, mass-movement deposits too small to show at map scale; typically mapped along smaller drainages that lack flat bottoms; more extensive east of Henefer where Wasatch Formation (Tw) strata easily weather to debris that “chokes” drainages; 6 to 20 feet (2-6 m) thick. Some deposits are “perched” on benches 80 feet (25 m) and more above present-day drainages like Left Fork Heiners Creek (Heiners Creek quadrangle) and Harris Canyon (Henefer quadrangle). In the Devils Slide quadrangle, some deposits are “perched” on benches about 60 to 130 feet (18-40 m) above Quarry Cottonwood Canyon indicating the alluvium is at least partly Lake Bonneville age and older (see Qab and Qao in tables 1 and 2).

***Qay, Qa2, Qa2?, Qa3, Qa3?, Qa4, Qa4?, Qa4-5, Qa5, Qa6** – Alluvium (Holocene and Pleistocene).* Sand, silt, clay, and gravel in stream and alluvial-fan deposits that are not close to late Pleistocene Lake Bonneville and are geographically in the Huff Creek and upper Bear River drainages; variably sorted; variably consolidated; composition depends on source area; deposits lack fan shape of Qaf and are distinguished from terraces (Qat) based on upper surface sloping toward adjacent streams from sides of drainage, or are shown where fans and terraces are too small to show separately at map scale; Qay is at to slightly above present drainages and not incised by active drainages, so is the youngest unit; generally 6 to 20 feet (2-6 m) thick.

Age-number and letter suffixes on alluvium (undivided, channel, flood plain, terrace, and fan) that is not close to late Pleistocene Lake Bonneville are relative and only apply to the local drainage, with suffix 2 being the second youngest; the relative age is queried where age uncertain, generally due to the height not fitting into the typical order of surfaces. The various numbered deposits listed, Qa2 through Qa6, are 20 to 180 feet (6-55 m) above the Bear River, Saleratus Creek, and Yellow Creek. Qa5 and Qa3? are only used in stacked units (Qa5/Tfb and Qa3?/Tfb).

***Qafp, Qafp?, Qafb, Qafb?, Qafpb, Qafpb?** – Lake Bonneville-age alluvial-fan deposits (upper Pleistocene).* Like undivided alluvial fans, but height above present drainages appears to be related to shorelines of Lake Bonneville and is within certain limits (see table 1); these fans are inactive, unconsolidated to weakly consolidated, and locally dissected; fans labeled Qafp and Qafb are related to the Provo (and slightly lower) and Bonneville shorelines of late Pleistocene Lake Bonneville, respectively, while unit Qafpb is used where fans may be related to the Provo or Bonneville shoreline (for example Qafpb is ~40 feet [12 m] above Lost Creek Valley), or where fans of different ages cannot be shown separately at map scale; Qafp fans typically contain well-rounded, recycled Lake Bonneville gravel and sand and are moderately well sorted; generally 10 to less than 60 feet (3-18 m) thick. Lake Bonneville-age fans are queried where relative age is uncertain (see Qaf for details); fans labeled Qafpb? are above the Bonneville shoreline and might be Qafo or like Qafm; see the note under Qao about two possible ages of older alluvium (Qao, Qato, and Qafo).

Most of the Lake Bonneville-age fans in the James Peak quadrangle are far from the Bonneville shoreline and their age is inferred from their stratigraphic relationship(s) to coeval Pinedale glacial outwash (see age equality in Table 3).

The channels (Qafp/Qdlb) on the Weber River delta and Lake Bonneville fines (Qafp on Qlfb) probably record scour and fill during the rapid drawdown of the lake as it fell from the Bonneville shoreline to the Provo shoreline.

***Qmc** – Landslide and colluvial deposits, undivided (Holocene and Pleistocene).* Poorly sorted to unsorted clay- to boulder-sized material; mapped where landslide deposits are difficult to distinguish from colluvium (slope wash and soil creep) and where mapping separate, small, intermingled areas of landslide and colluvial deposits is not possible at map scale; locally includes talus and debris flow and flood deposits; typically mapped where landslides are thin (“shallow”); also mapped where the blocky or rumpled morphology that is characteristic of landslides has been diminished (“smoothed”) by slope wash and soil creep; composition depends on local sources; 6 to 40 feet (2-12 m) thick. These deposits are as unstable as other landslide units (Qms, Qmsy, Qmso).

***Qms, Qms?, Qmsy, Qmsy?, Qmso, Qmso?** – Landslide deposits (Holocene and upper and middle? Pleistocene).* Poorly sorted clay- to boulder sized material; includes slides, slumps, and locally flows and floods; generally characterized by hummocky topography, main and internal scarps, and chaotic bedding in displaced blocks; composition depends on local sources; morphology becomes more subdued with time and amount of water in material during emplacement; Qms may be in contact with Qms when landslides are different/distinct; thickness highly variable, up to about 20 to 30 feet (6-9 m) for small slides, and 80 to 100 feet (25-30 m) thick for larger landslides. Qmsy and Qmso queried where relative age uncertain; Qms queried where classification uncertain. Numerous landslides are too small to show at map scale and more detailed maps shown in the index to geologic mapping should be examined.

Qms without a suffix is mapped where the age is uncertain (though likely Holocene and/or late Pleistocene), where portions of slide complexes have different ages but cannot be shown separately at map scale, or where boundaries between slides of different ages are not distinct. Estimated time of emplacement is indicated by relative-age letter suffixes with: Qmsy mapped where landslides deflect streams or failures are in Lake Bonneville deposits, and scarps are variably vegetated; Qmso typically mapped where deposits are "perched" above present drainages, rumpled morphology typical of mass movements has been diminished, and/or younger surficial deposits cover or cut Qmso. Lower perched Qmso deposits are at Qao heights above drainages (95 ka and older) and the higher perched deposits may correlate with high level alluvium (QTa) (likely older than 780 ka) (see table 1). Suffixes y and o indicate probable Holocene and Pleistocene ages, respectively, with all Qmso likely emplaced before Lake Bonneville transgression. These older deposits are as unstable as other slides, and are easily reactivated with the addition of water, be it irrigation or septic tank drain fields.

Qmdf, Qmdf? *– Debris- and mud-flow deposits (Holocene and upper and middle? Pleistocene)*. Very poorly sorted, clay- to boulder-sized material in unstratified deposits characterized by rubbly surface and debris-flow levees with channels, lobes, and mounding; variably vegetated; in drainages typically form mounds, an indication of more viscous Qmdf, rather than being flat like unit Qac; Qmdf queried where may not be mostly debris- and mud-flow deposits; many debris flows cannot be shown separately from alluvial fans at map scale; 0 to 40 feet (0-12 m) thick. Age(s) uncertain; deposits in drainages likely post-date the Provo shoreline of Lake Bonneville, while deposits above drainages, like north of the Right Hand Fork Peterson Creek, are likely as old as Bull Lake glaciation, but could pre-date Bull Lake glaciation and be middle Pleistocene.

Qls, Qls?, Qlsp, Qlsb, Qlsb? *– Lake Bonneville sand (upper Pleistocene).* Mostly sand with some silt and gravel deposited nearshore below and near the Provo shoreline (Qlsp) and between the Provo and Bonneville shorelines (Qlsb); Qls mapped downslope from slope break below Provo shoreline beach deposits where thin Lake Bonneville regressional sand may overlie transgressional sand; grades downslope into unit Qlf with decreasing sand content and laterally with more gravel into units Qdlp, Qdlb, and upslope with more gravel into unit Qlgb; Qls and Qlsb queried where grain size or unit identification uncertain; may be as much as 75 feet (25 m) thick, and thickest near Ogden; typically less than 20 feet (6 m) thick in Morgan Valley; may include small deltas and deltas that lack typical delta shape.

Qla, Qla? *– Lake Bonneville lacustrine deposits and post- and pre-Lake Bonneville alluvial deposits, undivided (Holocene and upper? Pleistocene).* Mostly poorly sorted and poorly bedded sand, silt, and clay, with some gravel; mapped where Lake Bonneville deposits are reworked by later stream action or covered by thin stream and fan deposits, and where lake deposits are thin and overlie older alluvial deposits; unit queried where may be dominantly alluvium; deposits typically eroded from shallow Norwood Formation; mostly mapped near Bonneville shoreline; also mapped in Peterson quadrangle along upper Deep Creek above Bonneville shoreline where lake deposits seem to indicate landslide dam of creek; thickness uncertain.

Qdlb, Qdlb? *– Transgressive and Bonneville-shoreline deltaic and lacustrine deposits (upper Pleistocene)*. Mostly sand, silty sand, and gravelly sand deposited near shore in Lake Bonneville; extensive at mouth of Weber Canyon; related to transgression to and occupation of the Bonneville shoreline with lacustrine deposits covering deltaic deposits; in Morgan Valley and near mouth of Coldwater Canyon (North Ogden quadrangle) contain more cobbles and overall more gravel; 0 to at least 40 feet (12 m) thick in Ogden and Morgan Valleys; about 400 feet (120 m) thick in bluff at the mouth of Weber Canyon. These deposits are prone to slope failures.

Qadb, Qadb? *– Transgressive and Bonneville-shoreline alluvial and deltaic deposits (upper Pleistocene).* Cobbly gravel, sand, silt, and clay deposited above (subaerial) and in Lake Bonneville (subaqueous); typically mapped where shorelines are obscure, so that line cannot be drawn between alluvial fan and delta; include rounded to subangular clasts in a matrix of sand and silt with interbeds of sand and silt; mapped above the Provo shoreline and deposited as lake transgressed to and was at the Bonneville shoreline; typically better sorted delta and lake deposits over poorly sorted alluvial-fan deposits; Qadb prominent along Deep Creek (Morgan quadrangle) and Strawberry Creek (Snow Basin quadrangle); 0 to at least 40 feet (0-12+ m) thick.

Note that the Bonneville-shoreline fan-delta unit (Qadb), at 80 to 100 feet (24-30 m) above present drainages, is typically higher than the related alluvial units (Qab, Qafb) (see table 1). A fan-delta is built when an alluvial fan enters a lake or ocean, and includes both the fan and the delta.

Qafp, Qafp?, Qafb, Qafb?, Qafpb, Qafpb? *– Lake Bonneville-age alluvial-fan deposits (upper Pleistocene)*. Like undivided alluvial fans, but height above present drainages appears to be related to shorelines of Lake Bonneville and is within certain limits (see table 1); these fans are inactive, unconsolidated to weakly consolidated, and locally dissected; fans labeled Qafp and Qafb are related to the Provo (and slightly lower) and Bonneville shorelines of late Pleistocene Lake Bonneville, respectively, while unit Qafpb is used where fans may be related to the Provo or Bonneville shoreline (for example Qafpb is ~40 feet [12 m] above Lost Creek Valley), or where fans of different ages cannot be shown separately at map scale; Qafp fans typically contain well-rounded, recycled Lake Bonneville gravel and sand and are moderately well sorted; generally 10 to less than 60 feet (3-18 m) thick. Lake Bonneville-age fans are queried where relative age is uncertain (see Qaf for details); fans labeled Qafpb? are above the Bonneville shoreline and might be Qafo or like Qafm; see the note under Qao about two possible ages of older alluvium (Qao, Qato, and Qafo).

Most of the Lake Bonneville-age fans in the James Peak quadrangle are far from the Bonneville shoreline and their age is inferred from their stratigraphic relationship(s) to coeval Pinedale glacial outwash (see age equality in Table 3).

The channels (Qafp/Qdlb) on the Weber River delta and Lake Bonneville fines (Qafp on Qlfb) probably record scour and fill during the rapid drawdown of the lake as it fell from the Bonneville shoreline to the Provo shoreline.

Qao, Qao? *– Older alluvium (mostly upper Pleistocene).* Sand, silt, clay, and gravel above and likely older than the Bonneville shoreline; mapped on surfaces above Lake Bonneville-age alluvium (Qap, Qab, Qapb); deposits lack fan shape (Qaf) and are distinguished from terraces (Qat) based on upper surface sloping toward adjacent streams from sides of drainage; also shown where areas of fans and terraces are too small to show separately at map scale; composition depends on source area; at least locally up to 110 feet (34 m) thick. Queried where classification or relative age is uncertain (see Qa for details); for example near head of Saleratus Creek.

Qafo, Qafo? *– Older alluvial-fan deposits (mostly upper Pleistocene).* Incised and at least locally dissected fans of mostly sand, silt, and gravel that is poorly bedded and poorly sorted; includes debris flows, particularly in drainages and at drainage mouths (fan heads); older fans are typically above the Bonneville shoreline, with an eroded bench at the shoreline; upstream and above the Bonneville shoreline, unit Qafo is topographically higher than fans graded to the Bonneville shoreline (Qafb), and is typically dissected; generally less than 60 feet (18 m) thick. In Mantua Valley, exposed thickness up to about 100 feet (30 m), but water wells (sections 26 and 27, T. 9 N., R. 1 W.) were still in gravelly to bouldery valley fill at depths of 505 and 467 feet (154 and 142 m), respectively, and red coloration that may indicate Wasatch Formation bedrock was not noted (see Bjorklund and McGreevy, 1973, p. 16).

Qafo queried where relative age is uncertain (see Qaf for details), for example in Mantua quadrangle where it is as high as Qafoe in Morgan Valley (see table 1). Qafo queried in East Canyon graben because the deposits are not dissected and some deposits mantle Qafoe (see also unit Qafm above), resulting in a reversal of relative height and only local incision. These irregular deposits are likely the result of salt movement in the East Canyon graben. Our Qafo is roughly shown to south by Bryant (1990) as Qgp (pediment gravel); farther south he showed Qoa (dissected alluvium) adjacent to the East Canyon fault, which may be the QTaf or Qafoe we mapped.

Amino-acid age estimates presented in Sullivan and Nelson (1992) imply Qafo north of Morgan considerably predates Lake Bonneville and is middle Pleistocene in age (>400 ka). However, the Bonneville shoreline is obscure on this fan, and soil-carbonate age estimates (>70-100 ka) and other amino-acid age estimates (~98-155 ka) in Sullivan and others (1988) imply these older fans are related to Bull Lake glaciation (95,000 to 130,000 years old; see Chadwick and others, 1997; Phillips and others, 1997). As noted under Qao, Qafo deposits may contain two ages (levels) of alluvial surfaces that are not easily recognized in Morgan Valley but are recognized upstream in the Henefer and Lost Creek Valleys (Devils Slide quadrangle) and along the North and South Forks of Ogden River.

Tn, Tn? *– Norwood Formation (lower Oligocene and upper Eocene).* Typically light-gray to light-brown altered tuff (claystone), altered tuffaceous siltstone and sandstone, and conglomerate; unaltered tuff, present in type section south of Morgan, is rare; locally colored light shades of red and green; variable calcareous cement and zeolitization; involved in numerous landslides of various sizes; estimate 2000-foot

(600 m) thick in exposures on west side of Ogden Valley (based on bedding dip, outcrop width, and topography). Norwood Formation queried where poor exposures may actually be surficial deposits. For detailed Norwood Formation information see description under heading "Sub-Willard Thrust - Ogden Canyon Area" since most of this unit is in and near Morgan Valley and covers the Willard thrust, Ogden Canyon, and Durst Mountain areas.

***Zpu, Zpu?** – Formation of Perry Canyon, Upper member (Neoproterozoic).* Olive drab to gray, thin-bedded slate to argillite to phyllite to micaceous meta-siltstone to meta-graywacke to meta-sandstone in variable proportions such that unit looks like both the "greywacke-sandstone" and "mudstone" members of previous workers; unit identification based on underlying diamictite in Mantua quadrangle; rare meta-gritstone and meta-diamictite (actually conglomerate?); locally schistose; meta-sandstone contains poorly sorted lithic, quartz, and feldspar grains in silty to micaceous matrix; meta-sandstone is quartzose in outcrops on west margin of Mantua quadrangle (Crittenden and Sorensen, 1985a) and medial zone of sandstone is feldspathic east of Ogden Valley, where mapped and described as argillite member of Maple Canyon Formation by Crittenden (1972) and Sorensen and Crittenden (1979); thickness uncertain, but appears to be about 600 feet (180 m) thick on west flank of Grizzly Peak in the Mantua quadrangle and about 1000 feet (300 m) thick between Ogden Canyon and North Ogden divide. In Ogden Valley typically non-resistant and tan weathering such that gray to green to dark-gray fresh color is seldom seen except in cut slopes and excavations. This unit is prone to slope failures.

***Zmcg, Zmcg?** – Maple Canyon Formation, Lower (green arkose) member (Neoproterozoic).* Grayish-green, fine-grained arkosic (feldspathic) meta-sandstone and sandy argillite (meta-graywacke), with local quartzite lenses up to 200 feet (60 m) thick; weathers darker gray to brown to greenish-gray and greenish-brown; 500 to 1000 feet (150-305 m) thick and lower thickness would eliminate the need for faulting in southwest part of Huntsville quadrangle. This unit is prone to slope failures.

McDonald (2020) describes surficial geologic units in the site area on Figure 2B (from youngest to oldest) as follows:

***Qmsh** – Landslide deposits, historical (Holocene).* Poorly sorted clay- to boulder-sized material in slides, slumps, flows, and landslide complexes; generally characterized by hummocky topography, head, lateral, and/or internal scarps, and chaotic bedding in displaced blocks; composition depends on local sources; morphology becomes more subdued with increasing age and/or rate of movement; includes landslides having historical movement that has been observed, documented, or is apparent on aerial imagery; thickness highly variable.

***Qaly** – Stream alluvium and floodplain deposits (Holocene to upper Pleistocene).* Poorly to moderately sorted, pebble to cobble gravel with a matrix of sand, silt, and clay in channels and floodplains and low terraces typically less than 10 feet (3 m) above modern channel level; angular to subangular grains; composition depends on source area; moderately sorted within beds; locally includes muddy overbank and organic-rich marsh deposits; present along the major valley-bottom streams including the North, Middle, and South Forks of the Ogden River, and Wolf Creek; 0 to 20 feet (0–6 m) thick.

***Qat1** – Stream terrace deposits (middle Holocene? to upper Pleistocene?).* Poorly to well sorted pebble to cobble gravel in a matrix of sand, silt and clay in terraces above modern streams and/or floodplains; subangular to subrounded grains; poorly to moderately bedded; typically about 5 to 10 feet (1–3 m) above modern channels; 0 to 10 feet (0–3 m) thick.

***Qafy** – Younger alluvial-fan deposits (Holocene to upper Pleistocene).* Poorly to moderately sorted pebble to cobble gravel with silt, sand and minor clay matrix; angular to subangular grains; poorly to moderately bedded; composition depends on source area; includes debris flows, debris floods, and channel deposits on large alluvial fans notably at the mouth of Geertzen Canyon where a large, nearly 1.5-mile-wide (2.5 km) by over 1-mile-long (1.5 km) fan exists; elsewhere, smaller alluvial fans grade into active stream channels or lacustrine surfaces; the Geertzen Canyon fan contains abundant cobbles and boulders derived from Paleozoic quartzites and Paleogene conglomeratic surface deposits above and flanking the northeast margin of Ogden Valley; 0 to 30 feet (0–6 m) thick.

***Qmsy** – Landslide deposits, younger (Holocene to upper Pleistocene?)* – Poorly sorted clay- to boulder-sized material in slides, slumps, flows, and landslide complexes; generally characterized by hummocky topography, head, lateral, and/or internal scarps, and chaotic bedding in displaced blocks; composition depends on local sources; morphology becomes more subdued with increasing age and/or rate of movement; morphology suggests likely post-Lake Bonneville movement with relatively sharp and pronounced landslide deformation features and may include parts that are historic and active; thickness highly variable.

***Qla** – Lacustrine and alluvial deposits, undivided (Holocene to upper Pleistocene)*. Poorly to moderately sorted silt, sand, clay, and gravel; subangular to rounded clasts; moderately to well-bedded; includes Lake Bonneville-age transgressional deposits below and near the highstand shoreline and post-Bonneville stream alluvium overlain by, interbedded with, and/or reworked by streams; includes alluvial deposits aggraded to the Provo shoreline that are likely time equivalent to the overflowing and regressive phases of Lake Bonneville; 1 to 10 feet (0.3–3 m) thick.

***Qac** – Alluvium and colluvium (Holocene to middle Pleistocene?)*. Unsorted to variably sorted silt, sand, gravel, clay, cobble and boulder in variable proportions and roundness; includes stream and fan alluvium, colluvium, sheetwash deposits, and locally mass-movement deposits that are too small to map separately at map scale; typically mapped along drainages bounded by hillslopes where colluvium grades into alluvium without distinct break in slope and in smaller drainages lacking flat bottoms or too small to subdivide at map scale; 0 to 20 feet (0–6 m) thick.

***Qms** – Landslide deposits, undifferentiated (Holocene to middle Pleistocene?).* Poorly sorted clay- to boulder-sized material in slides, slumps, flows, and landslide complexes; generally characterized by hummocky topography, head, lateral, and/or internal scarps, and chaotic bedding in displaced blocks; composition depends on local sources; morphology becomes more subdued with increasing age and/or rate of movement; mapped where relative age cannot be distinguished or where landslide complexes have portions with different ages and/or rates of activity; thickness highly variable.

***Qmc** – Mass-movement and colluvial deposits, undivided (Holocene to middle Pleistocene?).* Poorly sorted to unsorted, mostly clay, silt, sand, gravel, cobble, and boulder; angular to rounded clasts; nonbedded; mapped on slopes where individual landslides, slumps, slope wash, and soil creep are difficult to distinguish from one another; often characterized by hummocky slopes composed of numerous slumps of various sizes and ages includes soil creep, sappy areas, talus, slope wash, and debris-flow deposits but lack clear landslide scarps and lateral margins to allow separate mapping; typically forms on slopes overlying clay-bearing, landslide prone bedrock units—notably Neogene volcaniclastics and argillic Proterozoic formations; 0 to 40 feet (0–12 m) thick.

***Qafb** – Younger alluvial-fan deposits (upper Pleistocene).* Poorly sorted pebble to cobble gravel with silt, sand and minor clay matrix; angular to subangular grains; poorly to moderately bedded; composition depends on source area; includes debris flows, debris floods, and channel deposits that grade into Lake Bonneville transgressive or highstand shoreline deposits or at a height above modern fan surfaces consistent with correlative deposits; 0 to 30 feet (0–6 m) thick.

***Qls** – Lake Bonneville sand and gravel deposits (upper Pleistocene).* Moderately to poorly sorted, moderately to well-bedded sand and gravel with silt and clay; subangular to rounded clasts; deposited in transgressive Lake Bonneville nearshore environments; includes thin clay and silt interbeds deposited off shore; may grade laterally into Qlf or Qdl; typically less than 20 feet (6 m) thick.

***Qlf** – Lake Bonneville fine-grained deposits (upper Pleistocene)*. Moderately to well-sorted and moderately bedded to thinly laminated clay, silt, and sand deposited during the transgression and highstand of Lake Bonneville; rounded to well-rounded clasts; deposited in shallow to moderately deep water; typically overlies pre-Bonneville alluvium and may overlie middle Pleistocene Little Valley lake cycle (Scott and others, 1983; Oviatt and others, 1999) fine-grained deposits in the central part of the valley; 5 feet (2 m) thick or greater.

***Qao** – Older alluvium (upper to middle Pleistocene?).* Poorly to moderately sorted sand, silt, clay, and gravel on surfaces; subangular to subrounded grains; poorly to moderately bedded; deposits are typically isolated remnants in the valley or along valley margin drainages; located above and presumed older than Lake Bonneville-age alluvium and likely same age as Qafo but lacking alluvial-fan morphology; 10 to 50 feet (3–15 m) thick.

***Qafo** – Older alluvial-fan deposits (upper to middle Pleistocene?).* Poorly to moderately sorted pebble to cobble gravel with a matrix of silt, sand and clay; subangular to subrounded clasts; poorly bedded; fans are typically eroded and incised locally with isolated fan remnants, deposits may be somewhat lithified, and characterized by a reddish, clay-rich matrix; deposits are likely early to middle Pleistocene-age and may include deposits previously mapped as Huntsville Fanglomerate (Eardley, 1955; Lofgren; 1955; Coody, 1957) and may include deposits where fan age is uncertain, or for composite fans, where parts of fans with different ages cannot be shown separately at map scale; 10 to 50 feet (3–15 m) thick.

***Qmso** – Landslide deposits, older (upper to middle Pleistocene?)* – Poorly sorted clay- to boulder-sized material in slides, slumps, flows, and landslide complexes; generally characterized by hummocky topography, head, lateral, and/or internal scarps, and chaotic bedding in displaced blocks; composition depends on local sources; morphology becomes more subdued with increasing age and/or rate of movement; mapped where deposits generally have a more subdued morphology and are likely early Holocene and Pleistocene in age; include very large complexes underlain by argillite-rich bedrock where entire hillsides appear to be part of a landslide complex but where defining their boundaries are often difficult; thickness highly variable.

***BR** – Rock (Tertiary to Precambrian)*. Mapping of bedrock structure and stratigraphy is beyond the scope of this project. Sorenson and Crittenden (1979) provide the most recent published 1:24,000-scale geologic map of the Huntsville quadrangle. Coogan and King (2016) performed a cursory revision of the bedrock of Sorenson and Crittenden (1979) in compiling the Ogden 30′ x 60′ quadrangle. For more information, refer to these maps and other maps and studies cited in the Previous Work section of this report.

Citations, tables, and figures above are not provided herein, but are in Coogan and King (2016) or McDonald (2020). Descriptions of other geologic units not provided above are also available in Coogan and King (2016) or McDonald (2020)

5.2 Seismotectonic Setting

The property is located in Ogden Valley, a roughly 40-square mile back valley described by Gilbert (1928) as a structural trough similar to Cache and Morgan Valleys to the north and south, respectively. The back valleys of the northern Wasatch Range are in a transition zone between the Basin and Range and Middle Rocky Mountains physiographic provinces (Stokes, 1977, 1986). The Basin and Range is characterized by a series of generally north-trending elongate mountain ranges, separated by predominately alluvial and lacustrine sediment-filled valleys and typically bounded on one or both sides by major normal faults (Stewart, 1978). The boundary between the Basin and Range and Middle Rocky Mountains provinces is marked by the Wasatch fault zone (WFZ) at the base of the Wasatch Range. Late Cenozoic normal faulting, a characteristic of the Basin and Range, began between about 17 and 10 million years ago in the Nevada (Stewart, 1980) and Utah (Anderson, 1989) portions of the province. The faulting is a result of a roughly east-west directed, regional extensional stress regime that has continued to the present (Zoback and Zoback, 1989; Zoback, 1989). The back valleys are morphologically similar to valleys in the Basin and Range, but exhibit less structural relief (Sullivan and others 1986).

Ogden Valley occupies a structural trough created by up to 2,000 feet of vertical displacement on normal faults bounding the east and west sides of the valley. The Utah Geological Survey Quaternary Fault Database (Black and others, 2003; 2020 update) maps the Ogden Valley Southwestern Margin fault about 1.7 miles southwest of the Project and the Ogden Valley Northeastern Margin fault about 1.4 miles to the northeast. Sullivan and others (1986) indicate the most recent movement on these faults is pre-Holocene. The nearest active (Holocene-age) fault to the site is the Weber section of the WFZ about 6.5 miles to the west.

The site is also in the central portion of the Intermountain Seismic Belt (ISB), a generally north-south trending zone of historical seismicity along the eastern margin of the Basin and Range province extending from northern Arizona to northwestern Montana (Sbar and others, 1972; Smith and Sbar, 1974). At least 16 earthquakes of magnitude 6.0 or greater have occurred within the ISB since 1850; the largest of these earthquakes was a M 7.5 event in 1959 near Hebgen Lake, Montana. None of these earthquakes occurred along the WFZ or other known late Quaternary faults (Arabasz and others, 1992; Smith and Arabasz, 1991). The closest event was the 1934 Hansel Valley (M 6.6) event north of the Great Salt Lake. The March 18, 2020 M 5.7 Magna earthquake[1] reportedly showed a style, location, and slip depth consistent with an earthquake on the WFZ system. Despite being less than magnitude 6.0, this earthquake damaged multiple buildings and was felt from southern Idaho to south-central Utah[2]. The University of Utah Seismograph Stations indicates the Magna earthquake[3] was weakly felt in Ogden Valley, with a peak acceleration of about 0.005 g and an instrument intensity of II-III (on a Roman numeral scale of I-X).

5.3 Lake Bonneville History

Lakes occupied nearly 100 basins in the western United States during late-Quaternary time, the largest of which was Lake Bonneville in northwestern Utah. The Bonneville basin consists of several topographically closed basins created by regional extension in the Basin and Range (Gwynn, 1980; Miller, 1990), and has been an area of internal drainage for much of the past 15 million years. Lake Bonneville consisted of numerous topographically closed basins, including the Salt Lake and Cache Valleys (Oviatt and others, 1992). Portions of Ogden Valley were inundated by Lake Bonneville at its highstand. The highest Bonneville shoreline is mapped southeast of the Project on Figure 2B at an elevation of between 5,180 and 5,200 feet.

[1] https://earthquake.usgs.gov/earthquakes/eventpage/uu60363602/executive
[2] https://www.ksl.com/article/46731630/
[3] https://earthquakes.utah.gov/magna-quake/#

Timing of events related to the transgression and regression of Lake Bonneville is indicated by calendar age estimates of significant radiocarbon dates in the Bonneville Basin (Oviatt, 2015). Approximately 30,000 years ago, Lake Bonneville began a slow transgression (rise) to its highest level of 5,160 to 5,200 feet above mean sea level. The lake rise eventually slowed as water levels approached an external basin threshold in northern Cache Valley at Red Rock Pass near Zenda, Idaho. Lake Bonneville reached the Red Rock Pass threshold and occupied its highest shoreline, termed the Bonneville beach (blue line and B north of the Project on Figure 2), around 18,000 years ago. During the transgression and highstand, major drainages that emanate from within the Wasatch Range (such as the Weber River) formed large deltaic complexes in the lake at their canyon mouths. Headward erosion of the Snake River-Bonneville basin drainage divide then caused a catastrophic incision of the threshold and the lake level lowered by roughly 360 feet in fewer than two months (Jarrett and Malde, 1987; O'Conner, 1993).

Following the Bonneville flood, the lake stabilized and formed a lower shoreline termed the Provo beach between about 16,500 and 15,000 years ago. Climatic factors then caused the lake to regress rapidly from the Provo shoreline, and by about 13,000 years ago the lake had eventually dropped below historic levels of Great Salt Lake. Drainages that fed Lake Bonneville began downcutting through stranded deltaic complexes and near-shore deposits as the lake receded from the Provo shoreline. Oviatt and others (1992) deem this low stage the end of the Lake Bonneville cycle. Great Salt Lake then experienced a brief transgression around 11,600 years ago to the Gilbert level at about 4,250 feet before receding to and remaining within about 20 feet of its historic average level (Lund, 1990).

6.0 SITE CHARACTERIZATION

Site conditions and geology were interpreted through an integrated compilation of regional and site-specific data, including review of pertinent literature and geologic mapping (Coogan and King, 2016; and McDonald, 2020); excavation, logging and field interpretation of two onsite test pits; field reconnaissance of the site in conjunction with the subsurface exploration; photogeologic analysis of historical aerial photography; and GIS analyses of geoprocessed Light Detection and Ranging (LIDAR) digital elevation mapping (DEM) data from 2016 and 2020.

6.1 Empirical Observations

On May 1, 2025, Bill D. Black, P.G., of Western Geologic conducted a reconnaissance of the Project in conjunction with the subsurface investigation discussed below. Weather at the time of the reconnaissance was clear and sunny with temperatures in the 50s (°F). The Project is in the northeast corner of the proposed Cobabe Ranch Development on south-facing slopes overlooking Pineview Reservoir. Native vegetation at the site consists mainly of grasses and brush. Surficial sediments appeared coarse and bouldery. Slopes at the tank location are mainly gentle to moderate. No evidence for seeps, springs, characteristic debris flow morphology, bedrock outcrops, rockfalls, recent or ongoing slope instability, or other geologic hazards was observed. No conditions were observed that appeared to differ from those observed in the inclusive Cobabe Ranch Development in 2022.

6.2 Remote Sensing and Site-Specific Geology

Stereographic black and white aerial photography from 1958 available from the Utah Geological Survey (U.S. Department of Agriculture frames AAJ_26V-69 and AAJ 26V-70 dated 6-17-58, scale 1:20,000), high-resolution color orthophotography from 2012 available from the Utah Geospatial Resource Center (UGRC), and color aerial photography from 2022 available from Google Earth™ were reviewed to obtain information about the geomorphology of the Project and nearby area (Figures 3A-C). No bedrock outcrops, seeps, springs, rockfall boulders, landslide scarps, evidence of recent or ongoing slope instability, or indication of other geologic hazards are evident at the Project on the air photos. Figure 3D is a slope analysis based on geoprocessed 2016 and 2020 Light Detection and Ranging (LIDAR) digital elevation mapping (DEM) data available from the UGRC. Figure 3D shows areas where slope gradients are <15 percent (unshaded, gentle), 15 to 30 percent (shaded in yellow, moderate), and >30 percent (shaded in red, steep) on a daylight shader base. Based on Figure 3D, slopes are gentle to moderate. Figure 3E is a site-specific geologic map for the Project at a scale of 1 inch equals 100 feet (1:1,200) based on the mapping on Western Geologic (2022) Plate 3. Units and labels correspond to those provided by McDonald (2020) in Section 5.1 above.

6.3 Subsurface Investigation

Two test pits were excavated at the Project on May 1, 2025, to assess subsurface conditions. The test pits were logged by Bill D. Black, P.G., of Western Geologic concurrently with the Project geotechnical investigation conducted by Christensen Geotechnical. Locations of the test pits were measured using a hand-held GPS unit and by trend and distance methods and are shown on Figures 3A-E at a scale of 1 inch equals 100 feet (1:1,200). The test pits were logged at a scale of 1-inch equals five feet (1:60) following methodology in McCalpin (1996), and digitally photographed at 5-foot intervals to document the exposures. The photos are not provided herein but are available on request. Logs of the test pits are provided on Figures 4 and 5. Stratigraphic interpretations and descriptions are provided on the logs. Both test pits at the site exposed pre-Lake Bonneville alluvium overlying weathered claystone and siltstone bedrock of the Tertiary Norwood Formation. No groundwater was encountered in the test pits to their explored depths.

6.4 Geologic Cross Section

Figure 6 shows one geologic cross section (A-A') across the tank location at a scale of 1 inch equals 25 feet with no vertical exaggeration. Location of the cross section is displayed on Figures 3A-E. Units and contacts are based on subsurface data from the onsite test pits (Figures 4 and 5) and the site-specific geologic mapping on Figure 3E. Digital files (with XYZ, distance and slope values) are available on request. The topographic profile is based on geoprocessed LIDAR data from 2016 and 2020. The LIDAR data provide a snapshot of topographic conditions at the time of acquisition; past, present and future surficial topography may vary. Units and contacts should be considered approximate and inferred, and variations should be expected at depth and laterally. Some portions of the cross section have limited or no subsurface data, particularly at depth. Groundwater is conservatively assumed to be at a depth of 30 feet based on the discussion in Section 4.0. The cross section also includes a secondary perched groundwater zone in the upper 5 feet of weathered bedrock to model possible localized perching above less-permeable bedrock layers following spring snowmelt.

7.0 GEOLOGIC HAZARDS

Assessment of potential geologic hazards and the resulting risks imposed is critical in determining the suitability of the site for development. Table 1 below shows a summary of the geologic hazards reviewed at the tank location, as well as a relative (qualitative) assessment of risk for each hazard.

Table 1. *Geologic hazards summary.*

Hazard	H	M	L	Recommendations
Earthquake Ground Shaking	X			Construction in accordance with current adopted building code. See Table 2 for seismic values.
Surface Fault Rupture			X	None
Liquefaction			X	None
Tectonic Deformation			X	None
Seismic Seiche and Storm Surge			X	None
Stream Flooding			X	None
Shallow Groundwater			X	None
Landslides and Slope Failures		X		Slope stability assessment for tank location.
Debris Flows and Floods			X	None
Rock Fall			X	None
Problem Soil and Rock			X	None

A "high" hazard rating (H) indicates a hazard is present (whether currently or in the geologic past) that is likely to pose significant risk and/or may require further study or mitigation techniques. A "moderate" hazard rating (M) indicates a hazard that poses an equivocal (uncertain or unconfirmed) risk. Moderate-risk hazards may also require further studies or mitigation. A "low" hazard rating (L) indicates the hazard is not present, poses an insignificant risk, and/or is not likely to impact the proposed development. Low-risk hazards typically require no additional studies or mitigation. For large sites, these hazard ratings represent a conservative assessment for the entire site and risk may vary. Recommendations with regard to high- and moderate-risk hazards are summarized in Table 1 based on the hazard-specific discussions provided below.

7.1 Earthquake Ground Shaking

Ground shaking refers to the ground surface acceleration caused by seismic waves generated during an earthquake. Strong ground motion is likely to present a significant risk during moderate to large earthquakes located within a 60 mile radius of the Project area (Boore and others, 1993). Seismic sources include mapped active faults, as well as a random or "floating" earthquake source on faults not evident at the surface. The Utah Geological Survey Quaternary Fault Database (Black and others, 2003; December 2024 update) shows numerous class A faults within 60 miles of the Project that may pose potential seismic sources.

The extent of property damage and loss of life due to ground shaking depends on factors such as: (1) proximity of the earthquake and strength of seismic waves at the surface (horizontal motions are the most damaging); (2) amplitude, duration, and frequency of ground motions; (3) nature of foundation materials; and (4) building design. Based on ASCE 7-22 provisions, a site class of C (Very Dense Soil and Soft Rock), and a risk category of IV, calculated seismic values centered on 41.318268 °N, -111.808082 °W are summarized below:

Table 2. *Seismic hazard summary.*

Type	Value
S_S	*0.95 g*
S_1	*0.3 g*
S_{MS} (F_a x S_S)	*1.01 g*
S_{M1} (F_v x S_1)	*0.43 g*
S_{DS} (2/3 x S_{MS})	*0.67 g*
S_{D1} (2/3 x S_{M1})	*0.29 g*
Seismic Design Category, SDC	*D*
Site-Modified Peak Ground Acceleration, PGA_M	*= 0.42 g*

The site class should be confirmed by the Project geotechnical engineer based on site-specific data. The site-modified PGA for the site in Table 2 is about 84 times that reportedly experienced in Ogden Valley (0.005 g) from the March 18, 2020 M 5.7 Magna earthquake. Given the above, we rate the hazard from earthquake ground shaking as high. Earthquake ground shaking is a regional hazard common to all Wasatch Front areas. The hazard is mitigated by design and construction in accordance with the current adopted building code.

7.2 Surface Fault Rupture

Movement along faults at depth generates earthquakes. During earthquakes larger than Richter magnitude 6.5, ruptures along normal faults in the intermountain region generally propagate to the surface (Smith and Arabasz, 1991) as one side of the fault is uplifted and the other side down dropped. The resulting fault scarp has a near-vertical slope. The surface rupture may be expressed as a large singular rupture or several smaller ruptures in a broad zone. Ground displacement from surface fault rupture can cause significant damage or even collapse to structures located on an active fault.

No evidence for active (Holocene-age) faulting is mapped or was observed at the Project, and the site is not in an area where Lund and others (2020) recommend additional investigation be conducted to evaluate the risk of active surface faulting. The nearest active fault to the site is the Weber section of the WFZ about 6.5 miles to the west. Given all the above, we rate the risk from surface faulting as low.

7.3 Liquefaction and Lateral-Spread Ground Failure

Liquefaction occurs when saturated, loose, cohesionless, soils lose their support capabilities during a seismic event because of the development of excessive pore pressure. Earthquake-induced liquefaction can present a significant risk to structures from bearing-capacity failures to structural footings and foundations, and can damage structures and roadway embankments by triggering lateral spread landslides. Earthquakes of Richter magnitude 5 are generally regarded as the lower threshold for liquefaction. Liquefaction potential at the site is a combination of expected seismic (earthquake ground shaking) accelerations, groundwater conditions, and presence of susceptible soils.

Although the Project is in an area of potentially strong ground shaking, groundwater appears to be 30 to 40 feet deep based on nearby water well data, and no soils susceptible to liquefaction were observed in any of the test pits conducted at the site. Anderson and others (1994) show the Project in an area of very low liquefaction potential (zone 1). Based on all the above, we rate the risk from liquefaction as low.

7.4 Tectonic Deformation

Tectonic deformation refers to subsidence from warping, lowering, and tilting of a valley floor that accompanies surface-faulting earthquakes on normal faults. Large-scale tectonic subsidence may accompany earthquakes along large normal faults (Lund, 1990). Tectonic subsidence is believed to mainly impact those areas immediately adjacent to the downthrown side of active normal faults.

The Project is not in close proximity to and on the downthrown side of any mapped active (Holocene-age) faults. Based on this, we rate the risk from tectonic subsidence as low.

7.5 Seismic Seiche and Storm Surge

Earthquake-induced seiche presents a risk to structures within the wave-oscillation zone along the edges of large bodies of water, such as the Great Salt Lake. Given the elevation of the subject property and distance from any large water bodies, we rate the risk from seismic seiches as low.

7.6 Stream Flooding

Stream flooding may be caused by direct precipitation, melting snow, or a combination of both. In much of Utah, floods are most common in April through June during spring snowmelt. High flows may be sustained from a few days to several weeks, and the potential for flooding depends on a variety of factors such as surface hydrology, site grading and drainage, and runoff.

No active or intermittent drainages were observed at the tank location. Federal Emergency Management Agency flood insurance rate mapping (Map Number 49057C0233F, effective 6/2/2015) shows the property in "Zone X" (Areas of Minimal Flood Hazard). Based on the above, we rate the risk from stream flooding as low. Surface drainage should be addressed in the civil engineering design for the tank in accordance with applicable Weber County planning requirements.

7.7 Shallow Groundwater

As discussed in the Section 4.0 above, nearby well data and the onsite test pit exposure suggest groundwater is about 30 to 40 feet deep beneath the tank location. However, groundwater depths may vary seasonally from snowmelt runoff and infiltration, annually from climatic fluctuations, and locally with topography and subsurface conditions. Seasonal saturation of near-surface unconsolidated deposits during spring snowmelt is typical for the area. After spring snowmelt, groundwater depth increases at a rate depending on the hydraulic conductivity of the underlying and downslope surficial deposits and bedrock.

Given all the above, we rate the risk from shallow groundwater as low. Discussion of and recommendations regarding groundwater and subsurface drainage should be provided in the Project geotechnical engineering evaluation. Groundwater is a significant trigger for slope instability. Care should therefore be taken that proper surface and subsurface drainage is maintained.

7.8 Landslides and Slope Failures

Slope stability hazards such as landslides, slumps, and other mass movements can develop along moderate to steep slopes where a slope has been disturbed, the head of a slope loaded, or where increased groundwater pore pressures result in driving forces within the slope exceeding restraining forces. Slopes exhibiting prior failures, and also deposits from large landslides, are particularly vulnerable to instability and reactivation.

Based on Figure 3E and the onsite test pit exposures, the site appears to be underlain by pre-Lake Bonneville alluvium and weathered Tertiary Norwood Formation bedrock comprised of claystone and siltstone. No evidence for landslides or recent or ongoing slope instability was observed on air photos or during our reconnaissance in the area of the proposed tank, but landslides are mapped in other areas of the Cobabe Ranch Development and nearby. Slopes at the site are mainly gentle to moderate. All the above suggests risk to the tank location from landslides and slope failures is low, but not negligible. Given this, we rate the risk from landsliding at the Project as moderate (equivocal).

Because the tank is a critical structure, we conservatively recommend the Project geotechnical engineer evaluate stability of slopes across the tank location based on site-specific soil conditions and the data provided in this report. Recommendations should be provided to reduce the landslide hazard risk if factors of safety are determined to be unsuitable. Although groundwater at the site appears to be 30 to 40 feet deep based on nearby well data, near-surface seasonal groundwater conditions may vary. Figure 6 therefore includes a 5-foot saturated zone at the contact between the alluvium and bedrock to account for possible perching. Water, steep man-made cuts, and non-engineered fill materials are often major contributors to slope instability. Care should therefore be taken to maintain proper site drainage, that site grading does not destabilize slopes at the site without prior geotechnical analysis and grading plans, and that water from man-made sources is minimized in potentially unstable slope areas.

7.9 Debris Flows

Debris flow hazards are typically associated with unconsolidated alluvial fan deposits at the mouths of large range-front drainages, such as those along the Wasatch Front. Debris flows have historically caused significant damage in areas along the Wasatch Front. The tank is situated on a relic alluvial fan that was formed prior to when Lake Bonneville occupied Ogden Valley in upper Pleistocene time. This alluvial fan is no longer a zone of active alluvial deposition. The site is not in a mapped active alluvial fan and no evidence for characteristic debris flow morphology was observed on air photos or during our reconnaissance. Based on this, we rate the risk from debris flows and floods as low.

7.10 Rock Fall

No large bedrock outcrops were observed upslope or onsite that appeared to pose a significant rock fall source area. Based on the above, we rate the hazard from rock falls as low.

7.11 Problem Soil and Rock

Certain soils and bedrock can swell or collapse when cyclically hydrated. Such volumetric changes can cause significant foundation problems The tank location is in an area mapped by the U.S. Department of Agriculture as underlain by “Yeates Hollow very stony loam, 10 to 30 percent slopes”. This unit is described as a well-drained, very low to moderately high permeability, alluvial-fan, bench, and mountain-side soil formed in colluvium and/or slope alluvium over residuum weathered from conglomerate. The typical soil profile is reported to be:

- *A1 - 0 to 10 inches:* very stony loam
- *B21t - 10 to 19 inches:* very gravelly loam
- *B22t - 19 to 29 inches:* very gravelly clay loam
- *B23t - 29 to 55 inches:* very gravelly clay loam
- *R - 55 to 59 inches:* unweathered bedrock

Based on the above, we rate the risk from problem soil as low. Soil conditions and site-specific recommendations for site grading, subgrade preparation, and footing and foundation design should be provided in the Project geotechnical engineering evaluation.

8.0 CONCLUSIONS AND RECOMMENDATIONS

Earthquake ground shaking is the only hazard identified as posing a high relative risk to the Project. Landslides and slope failures also pose a moderate (equivocal) risk. The following recommendations are provided with regard to the geologic characterizations in this report:

- ***Seismic Design*** **–** All structures developed at the property should be constructed to current adopted seismic building codes to reduce the risk of damage, injury, or loss of life from earthquake ground shaking. The Project geotechnical engineer should confirm the ground-shaking hazard and provide appropriate seismic design parameters as needed. Earthquake ground shaking is a common hazard for all Wasatch Front areas.

- ***Geotechnical Considerations*** **–** The design-level geotechnical engineering study currently being conducted by Christensen Geotechnical should address soil foundation conditions and slope stability. The stability evaluation should be based on geologic characterizations in this report and site-specific geotechnical data, and provide recommendations for reducing the risk of landsliding if the factors of safety are deemed to be unsuitable (below minimum values). Discussion of and recommendations regarding subsurface drainage should also be provided in the Project geotechnical engineering evaluation. Surface water and water from man-made sources should be minimized to the extent possible in all slope areas identified as potentially unstable in the Project geotechnical evaluation.

- ***Site Modifications and Drainage*** **–** No unplanned cuts should be made in the slopes at the site without prior geotechnical analyses, and proper surface and subsurface drainage should be maintained. We recommend that final site drainage and grading plans be reviewed by a licensed geologist and geotechnical engineer.

- ***Excavation Backfill Considerations*** **–** The test pits may be in areas where a structure could subsequently be placed. However, backfill may not have been replaced in the excavation in compacted layers. The fill could settle with time and upon saturation. Should a structure be located over an excavated area, no footings or structure should be founded in the disturbed soils unless they are removed and replaced with structural fill.

- ***Hazard Disclosures and Report Availability*** **–** All hazards identified as posing a high risk should be disclosed to relevant parties with a development or ownership interest so that they may understand and be willing to accept potential developmental challenges and/or risks posed by these hazards. This report should be made available to architects, building contractors, and in the event of a future property sale, real estate agents and potential buyers. The report should be referenced for information on technical data only as interpreted from observations and not as a warranty of conditions throughout the site. The report should be submitted in its entirety, or referenced appropriately, as part of any document submittal to a government agency responsible for planning decisions or geologic review. Incomplete submittals void the professional seals and signatures we provide herein. Although this report and the data herein are the property of the client, the report format is the intellectual property of Western Geologic and should not be copied, used, or modified without express permission of the authors.

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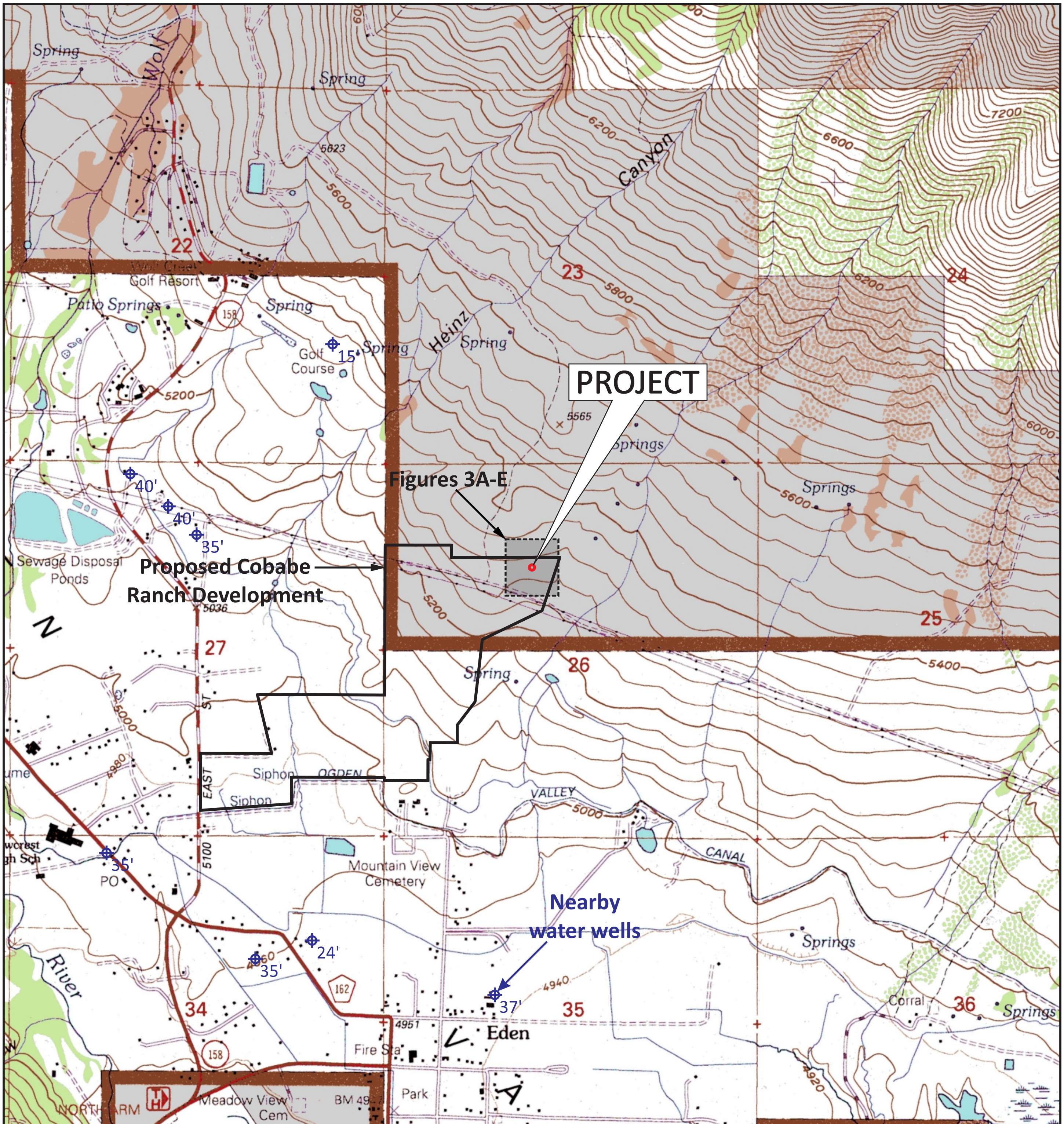
FIGURES



Source: U.S. Geological Survey 7.5 Minute Series Topographic Map, Huntsville, Utah, 1998; Project location: NW1/4 Section 26, Township 7 North, Range 1 East (SLBM).

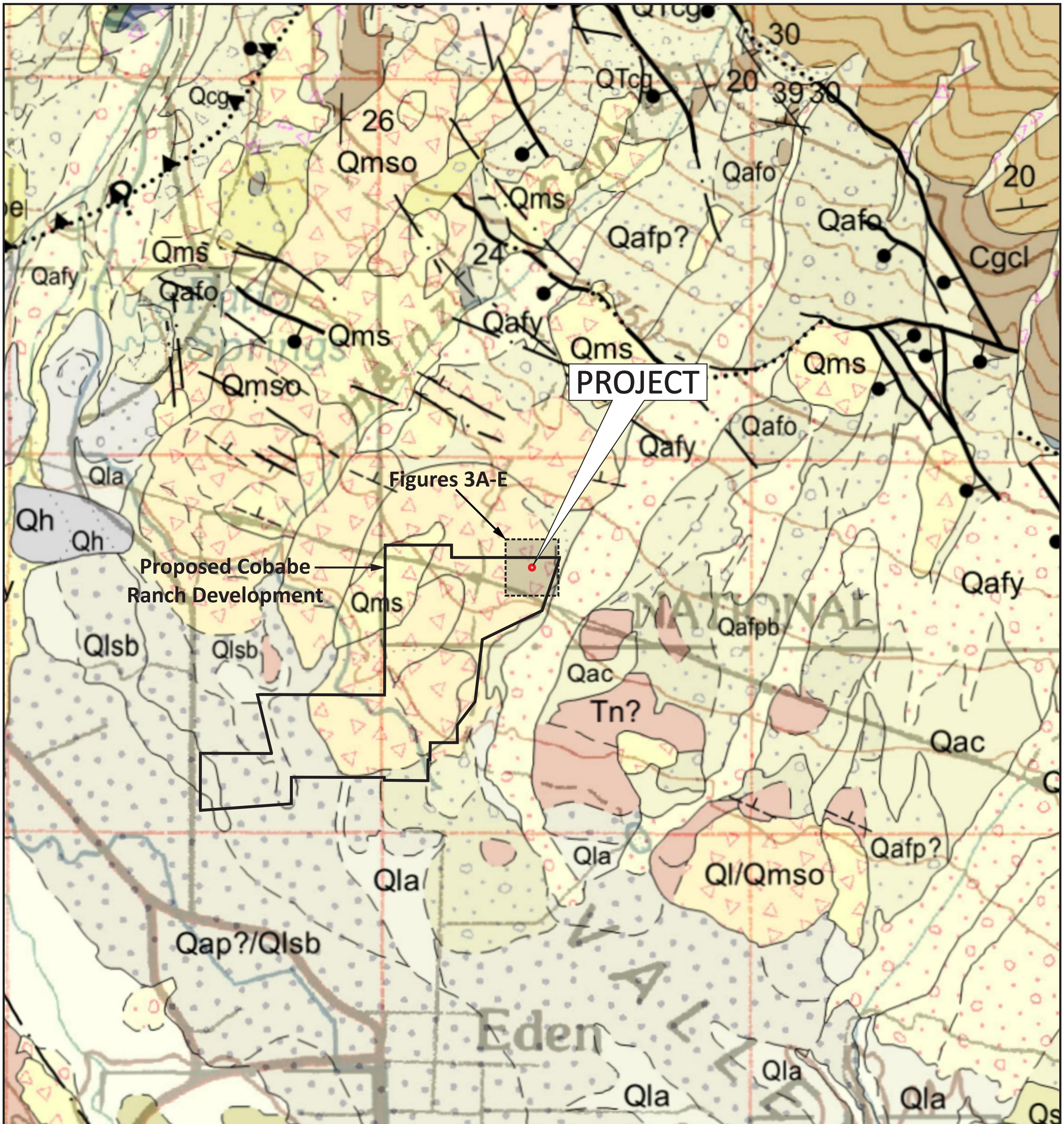
N W E S

0 1000 2000 4000
Scale 1:24,000
(1 inch equals 2,000 feet)

LOCATION MAP

GEOLOGIC HAZARDS EVALUATION
Cobabe Ranch Design Tank
About 2720 North 5100 East
Eden, Weber County, Utah

FIGURE 1



Source: Coogan and King (2016), original map scale 1:100,000. See text for explanation of nearby surficial geologic units.

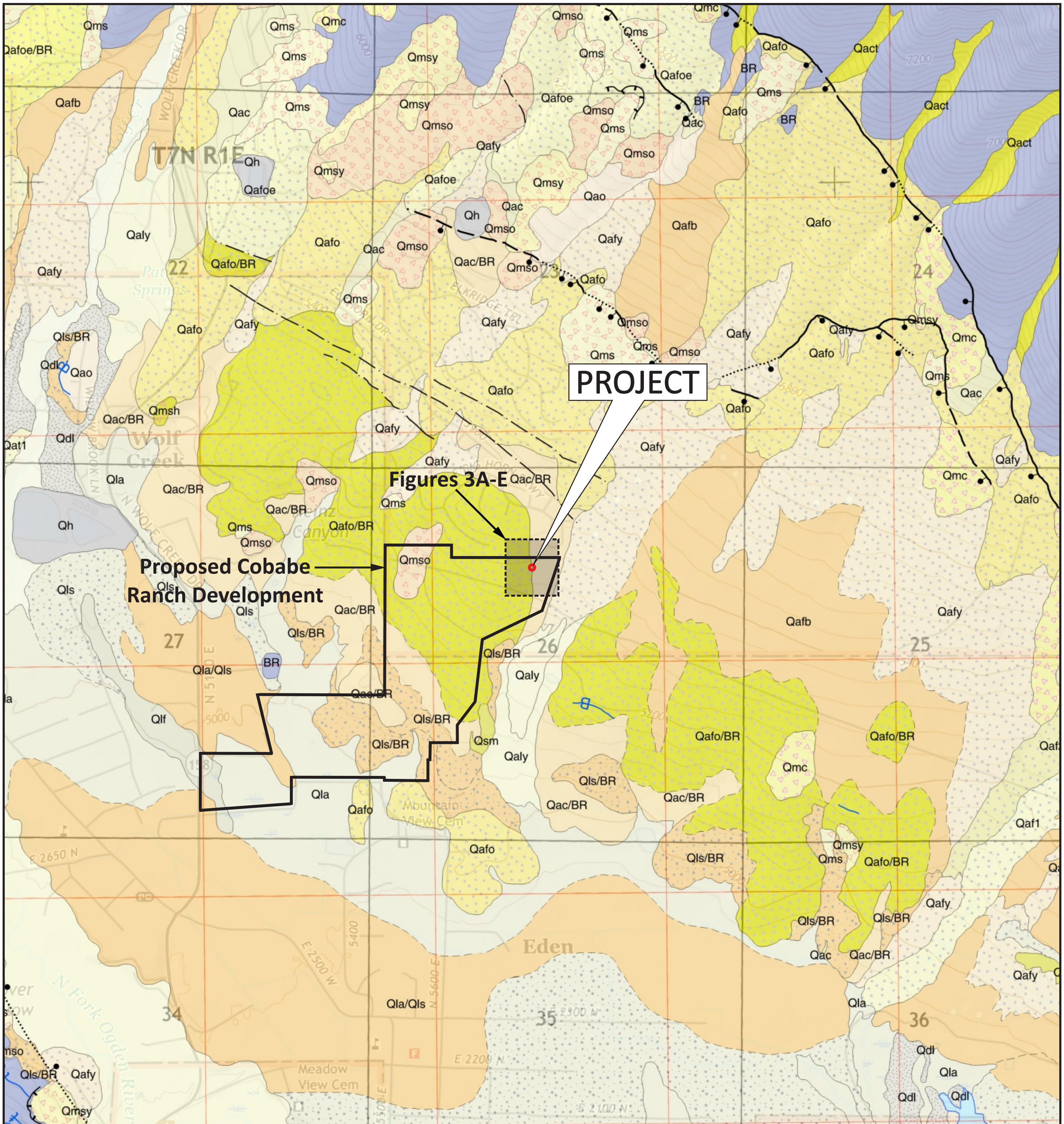
0 1000 2000 4000
Scale 1:24,000
(1 inch equals 2,000 feet)

REGIONAL GEOLOGIC MAP

GEOLOGIC HAZARDS EVALUATION

Cobabe Ranch Design Tank
About 2720 North 5100 East
Eden, Weber County, Utah

FIGURE 2A



Source: McDonald (2020), original map scale 1:24,000. See text for explanation of nearby surficial geologic units.

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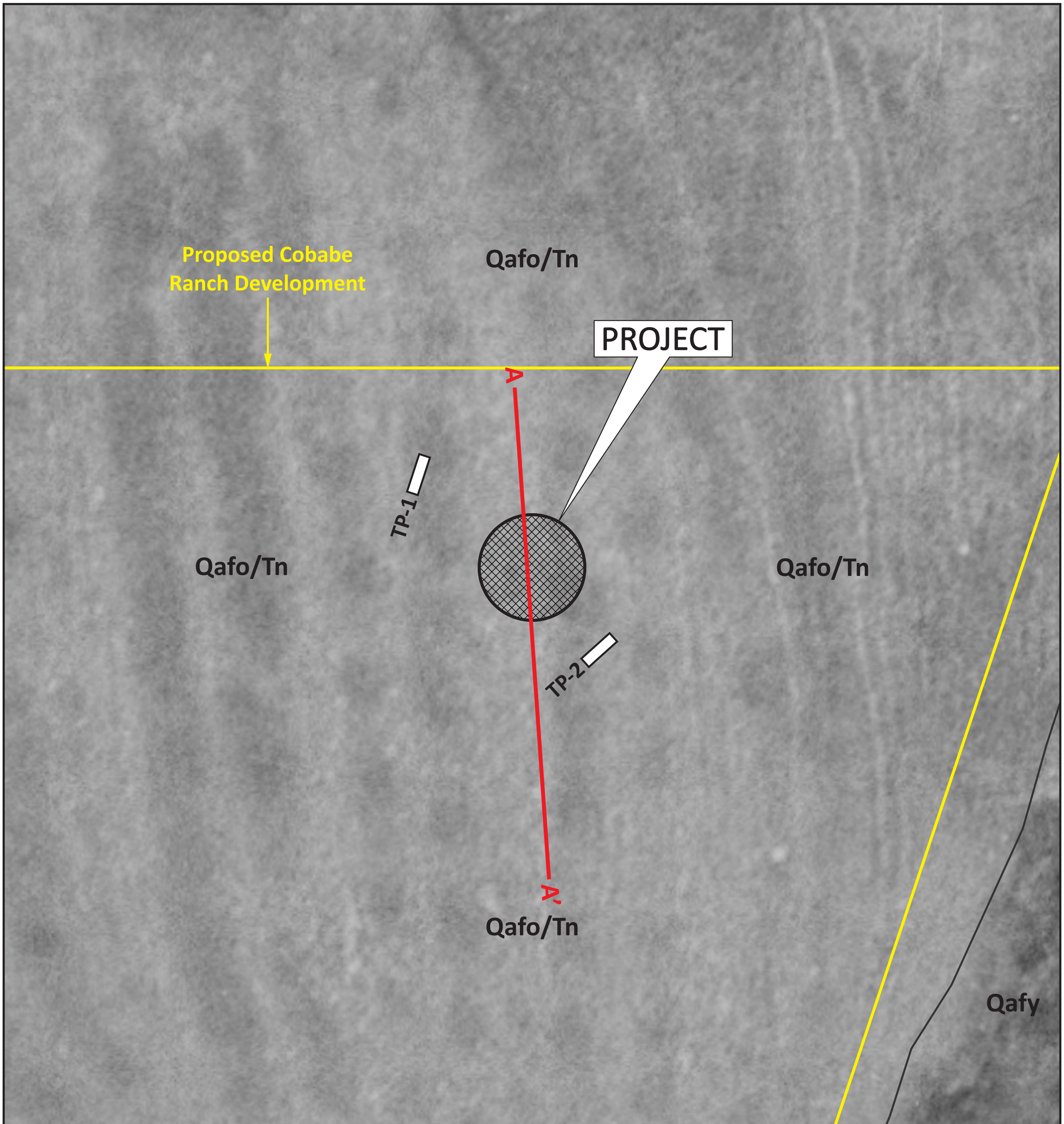
0 1000 2000 4000
Scale 1:24,000
(1 inch equals 2,000 feet)

SURFICIAL GEOLOGIC MAP

GEOLOGIC HAZARDS EVALUATION

Cobabe Ranch Design Tank
About 2720 North 5100 East
Eden, Weber County, Utah

FIGURE 2B



Source: U.S. Department of Agriculture, June 1958, frames AAJ 26V-69 and AAJ 26V-70.

N
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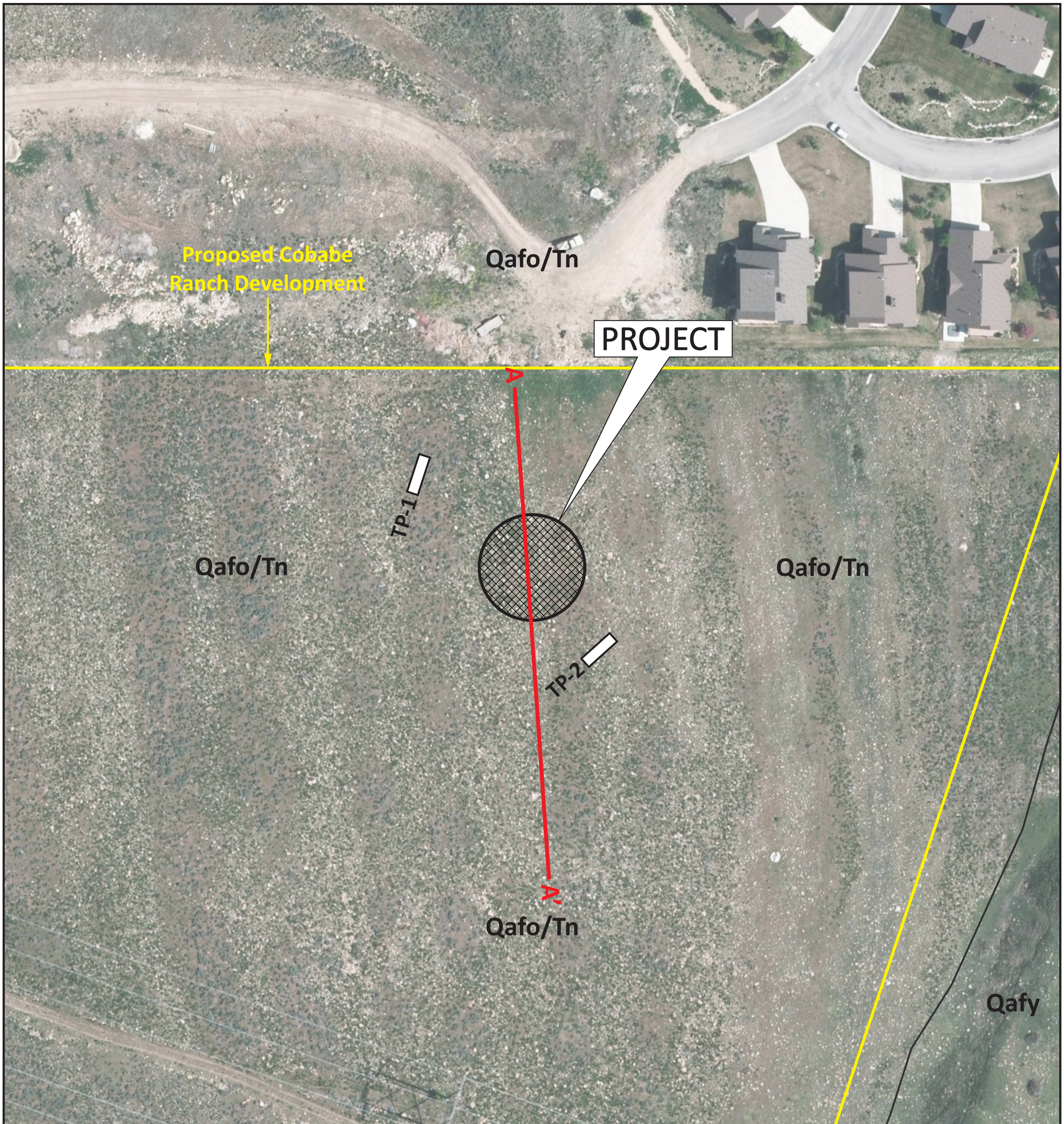
S
0 50 100 200
Scale 1:1,200
(1 inch equals 100 feet)

1958 AIR PHOTO

GEOLOGIC HAZARDS EVALUATION
Cobabe Ranch Design Tank
About 2720 North 5100 East
Eden, Weber County, Utah

FIGURE 3A



Source: Utah Geospatial Resource Center high resolution orthophoto, 12.5cm resolution.

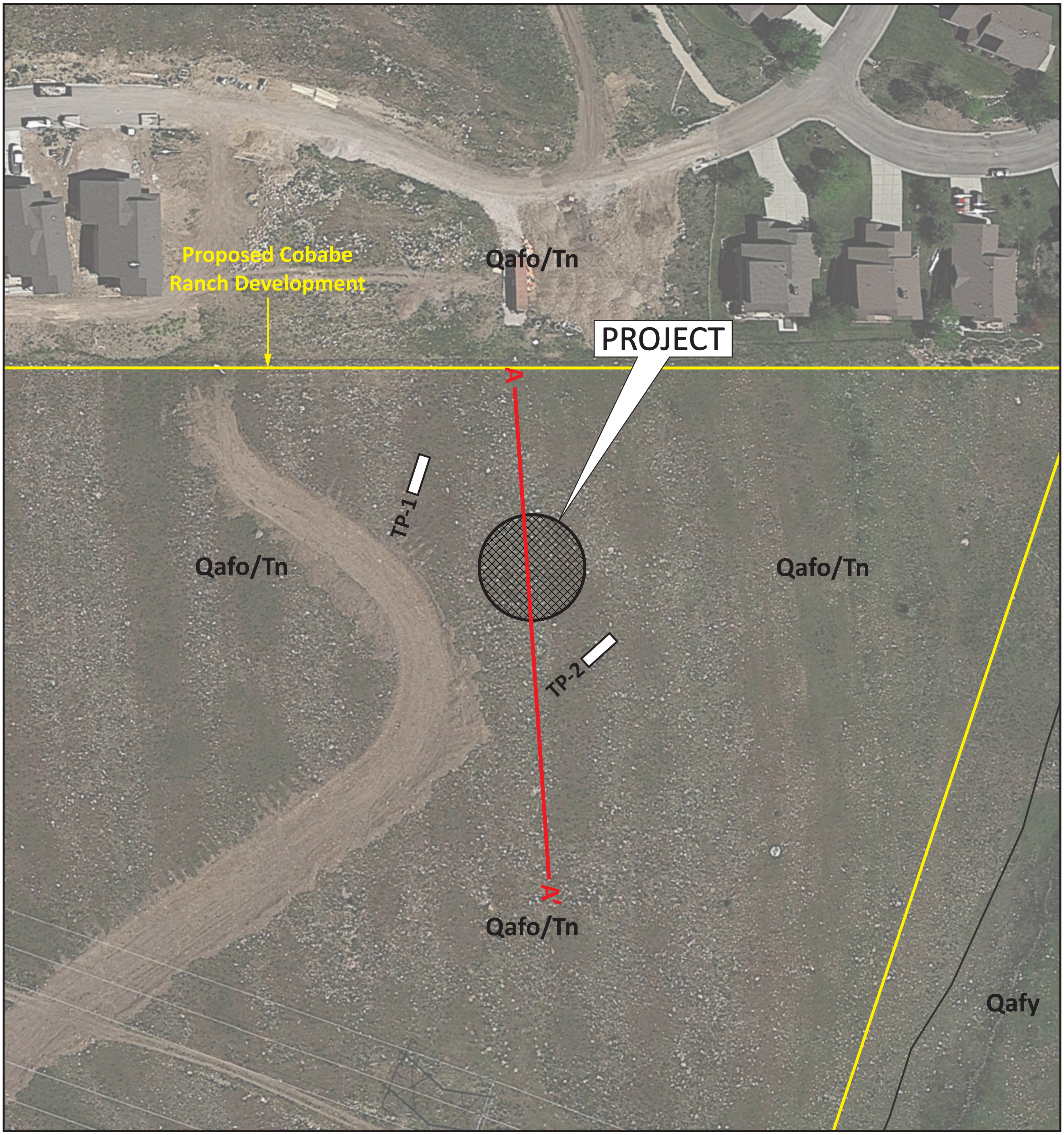
0 50 100 200
Scale 1:1,200
(1 inch equals 100 feet)

2012 AIR PHOTO

GEOLOGIC HAZARDS EVALUATION

Cobabe Ranch Design Tank
About 2720 North 5100 East
Eden, Weber County, Utah

FIGURE 3B



Source: Google Earth, May 2022.

WESTERN GEOLOGIC

N
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0 50 100 200

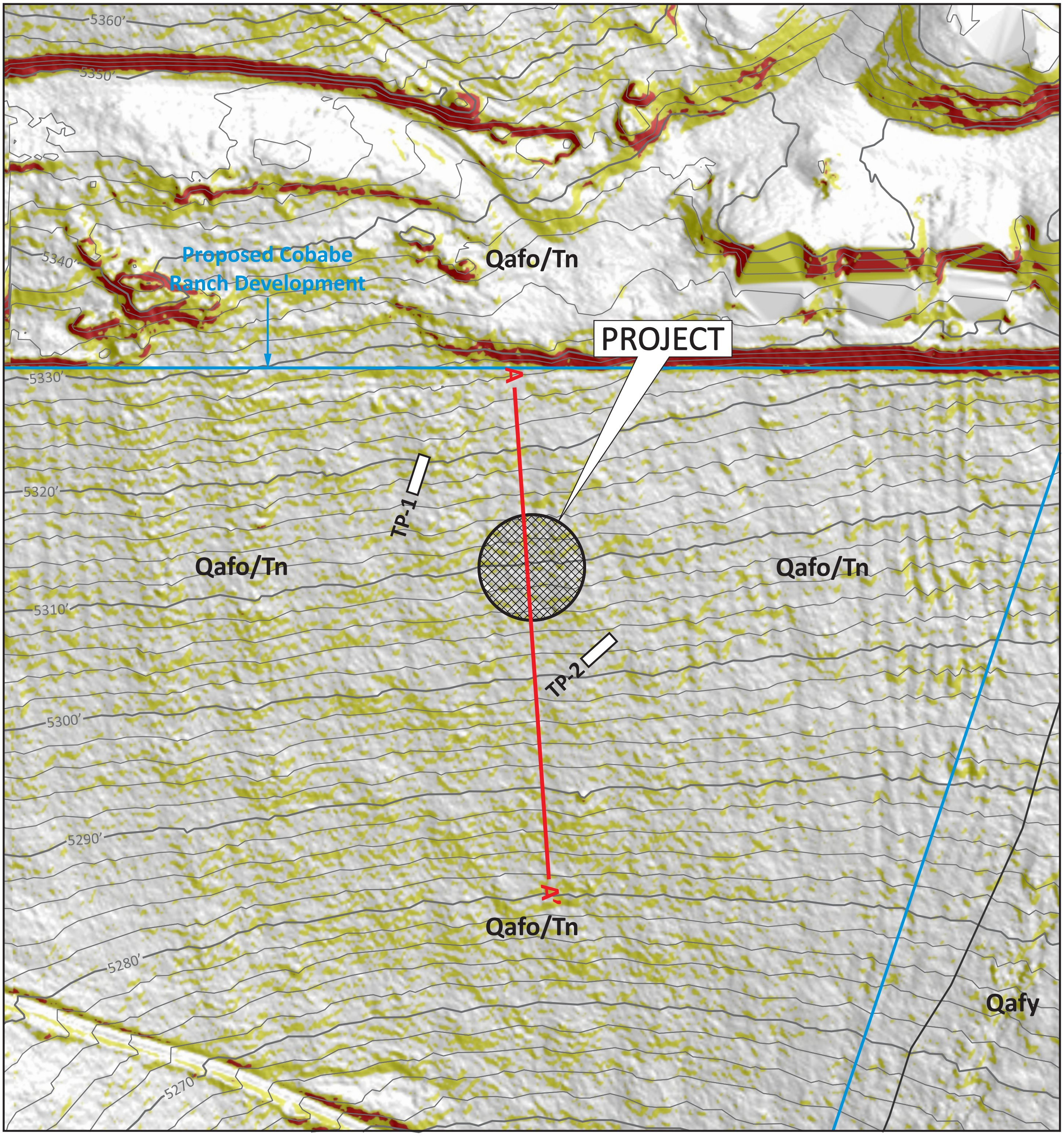
Scale 1:1,200
(1 inch equals 100 feet)

2022 AIR PHOTO

GEOLOGIC HAZARDS EVALUATION

Cobabe Ranch Design Tank
About 2720 North 5100 East
Eden, Weber County, Utah

FIGURE 3C



Source: Utah Geospatial Resource Center, 2016-2020 LIDAR Bare Earth DEM, 50 centimeter resolution; slope gradients <15% unshaded, 15-30% in yellow, and >30% in red.

N
W E
S

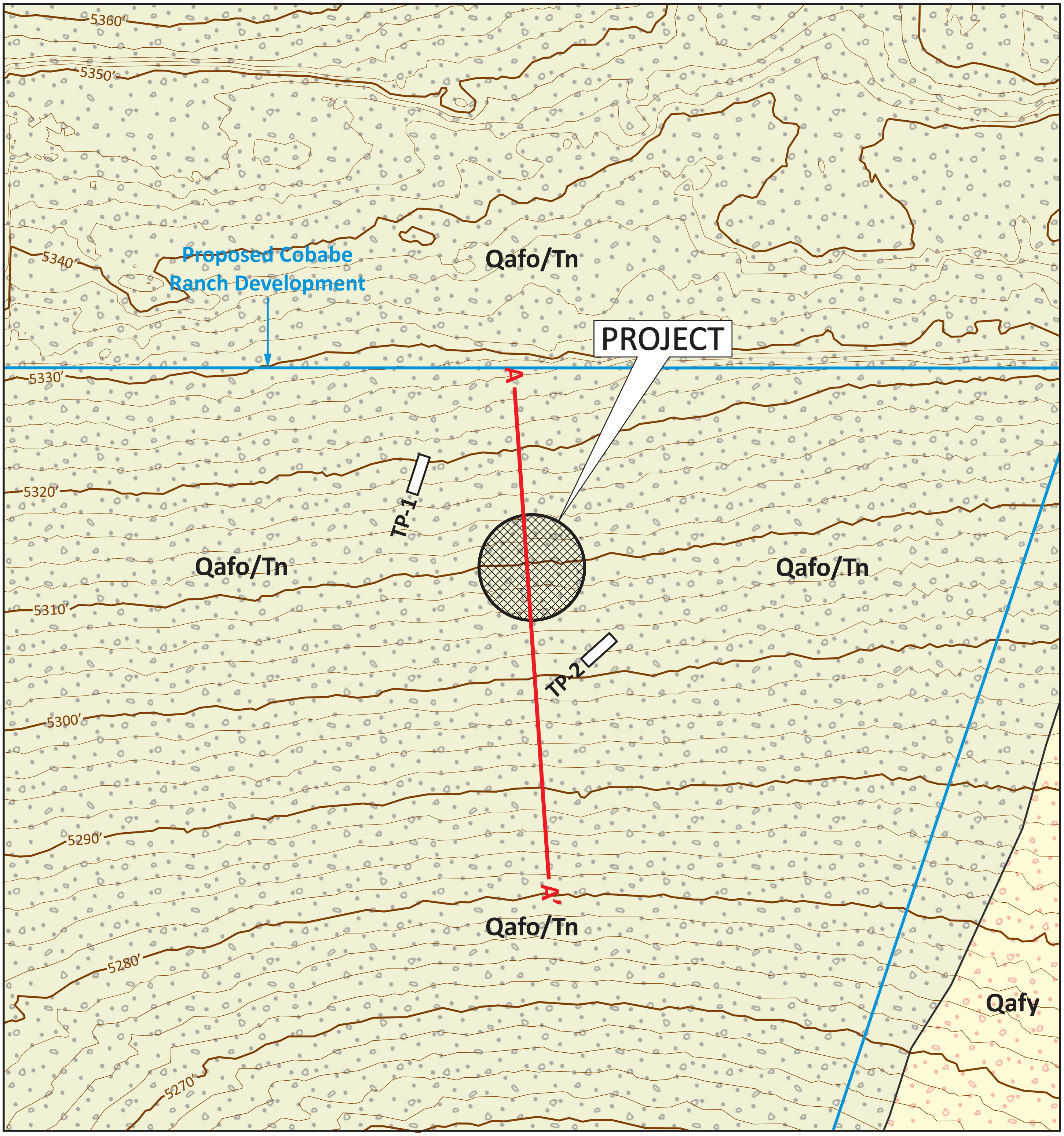
0 50 100 200
Scale 1:1,200
(1 inch equals 100 feet)

WESTERN GEOLOGIC

SLOPE ANALYSIS

GEOLOGIC HAZARDS EVALUATION
Cobabe Ranch Design Tank
About 2720 North 5100 East
Eden, Weber County, Utah

FIGURE 3D



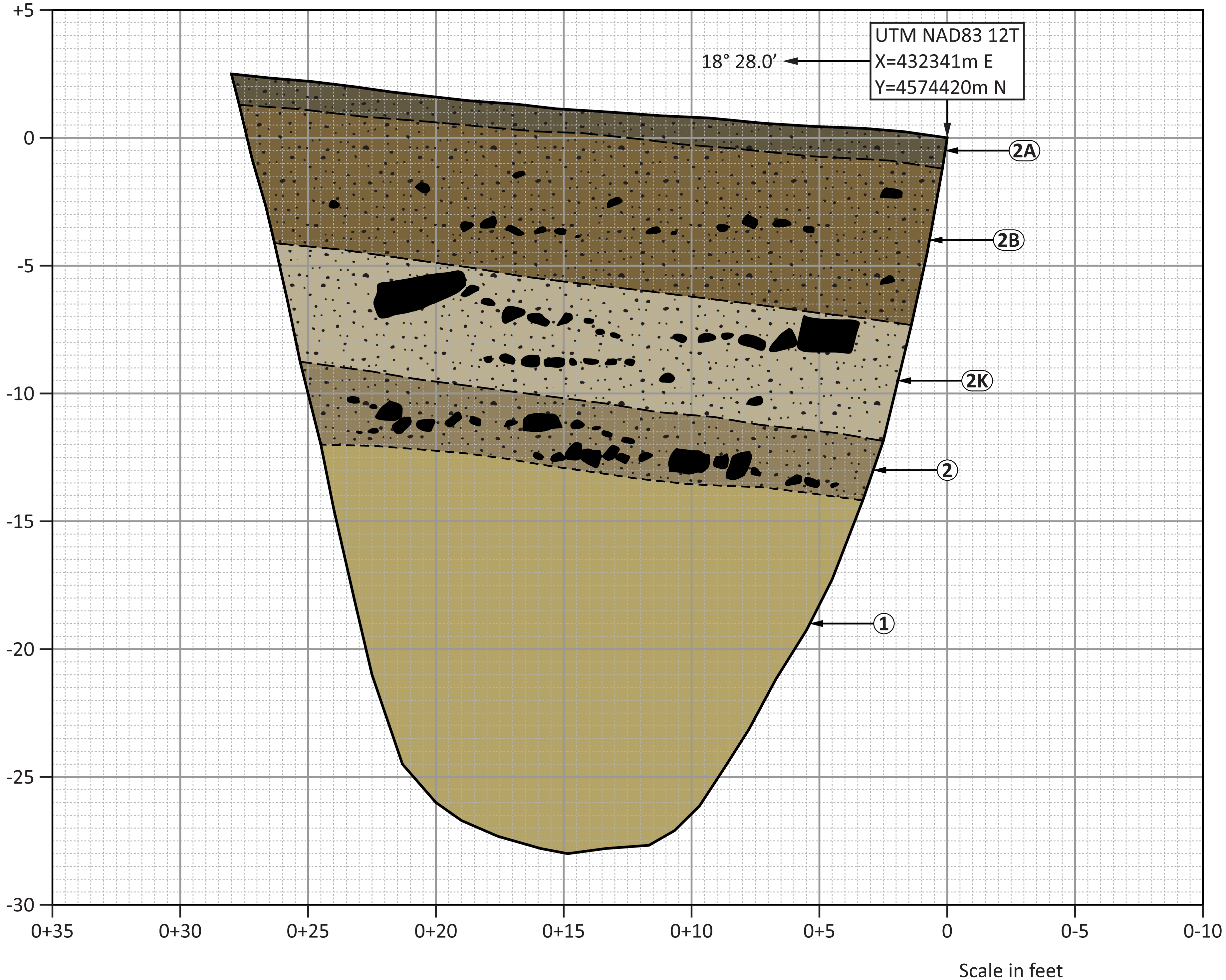
Source: Modified from Coogan and King (2016) and McDonald (2020). Contours at 2 foot intervals.

0 50 100 200
Scale 1:1,200
(1 inch equals 100 feet)

SITE-SPECIFIC GEOLOGY

GEOLOGIC HAZARDS EVALUATION
Cobabe Ranch Design Tank
About 2720 North 5100 East
Eden, Weber County, Utah

FIGURE 3E



UNIT DESCRIPTIONS

Unit 1. *Tertiary Norwood Formation* - olive-brown to light orange-brown, strong, poorly bedded, claystone grading downward to siltstone in lower part of test pit.

Unit 2. *Middle to upper Pleistocene alluvial fan deposits* - brown and light brown, dense, massive to poorly bedded, clayey gravel (GC) with sand and subangular to subround cobbles and boulders with strong stage II carbonate; soil A, B and K horizons formed in unit (2A, 2B and 2K).

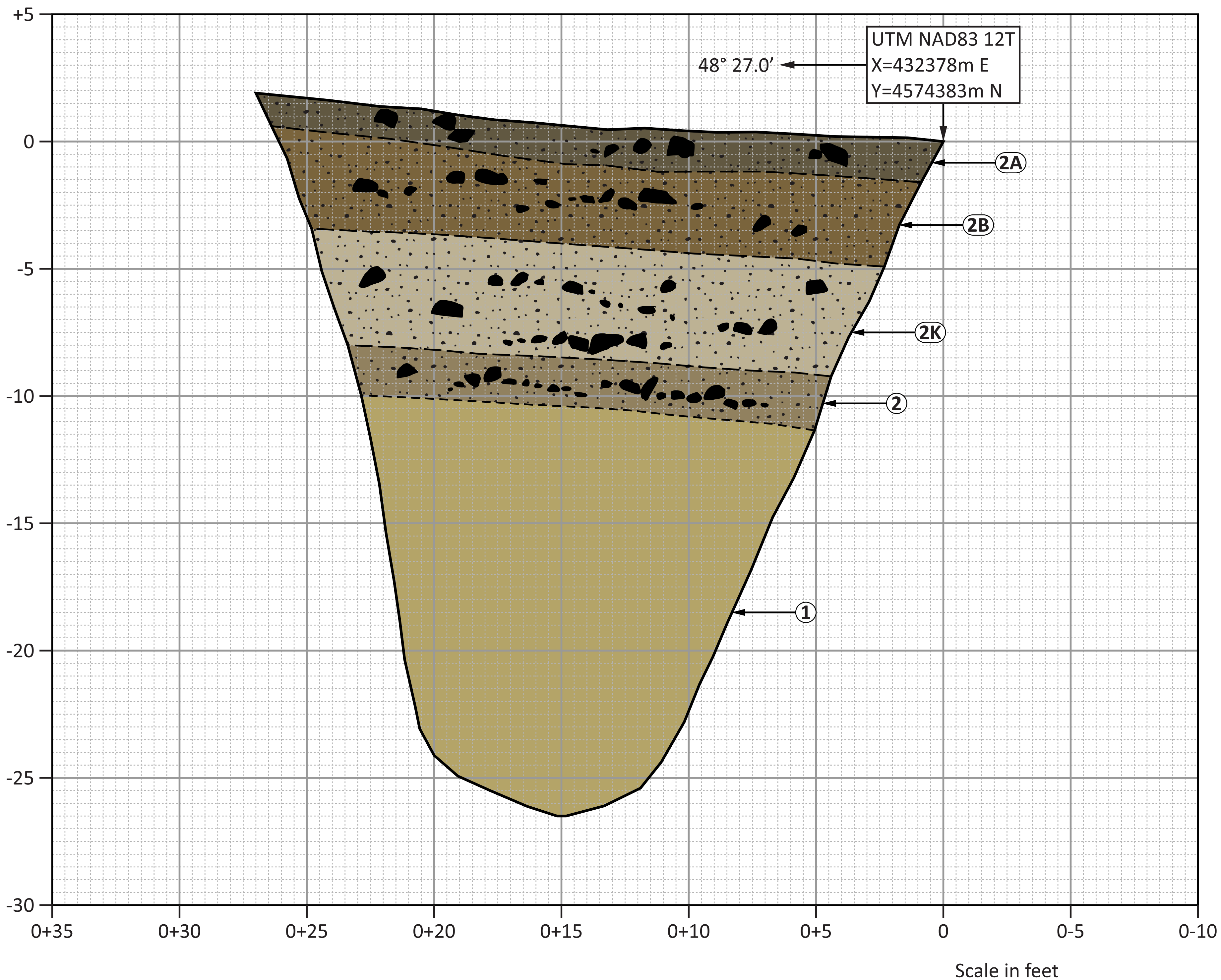
Scale 1 inch equals 5 feet with no vertical exaggeration.
Logged by Bill D. Black, P.G. on May 1, 2025.

WESTERN GeoLogic

TEST PIT 1 LOG

GEOLOGIC HAZARDS EVALUATION
Cobabe Ranch Design Tank
About 2720 North 5100 East
Eden, Weber County, Utah

FIGURE 4



UNIT DESCRIPTIONS

Unit 1. *Tertiary Norwood Formation* - olive-brown to light orange-brown, strong, poorly bedded, claystone grading downward to siltstone in lower part of test pit.

Unit 2. *Middle to upper Pleistocene alluvial fan deposits* - brown and light brown, dense, massive to poorly bedded, clayey gravel (GC) with sand and subangular to subround cobbles and boulders with strong stage II carbonate; soil A, B and K horizons formed in unit (2A, 2B and 2K).

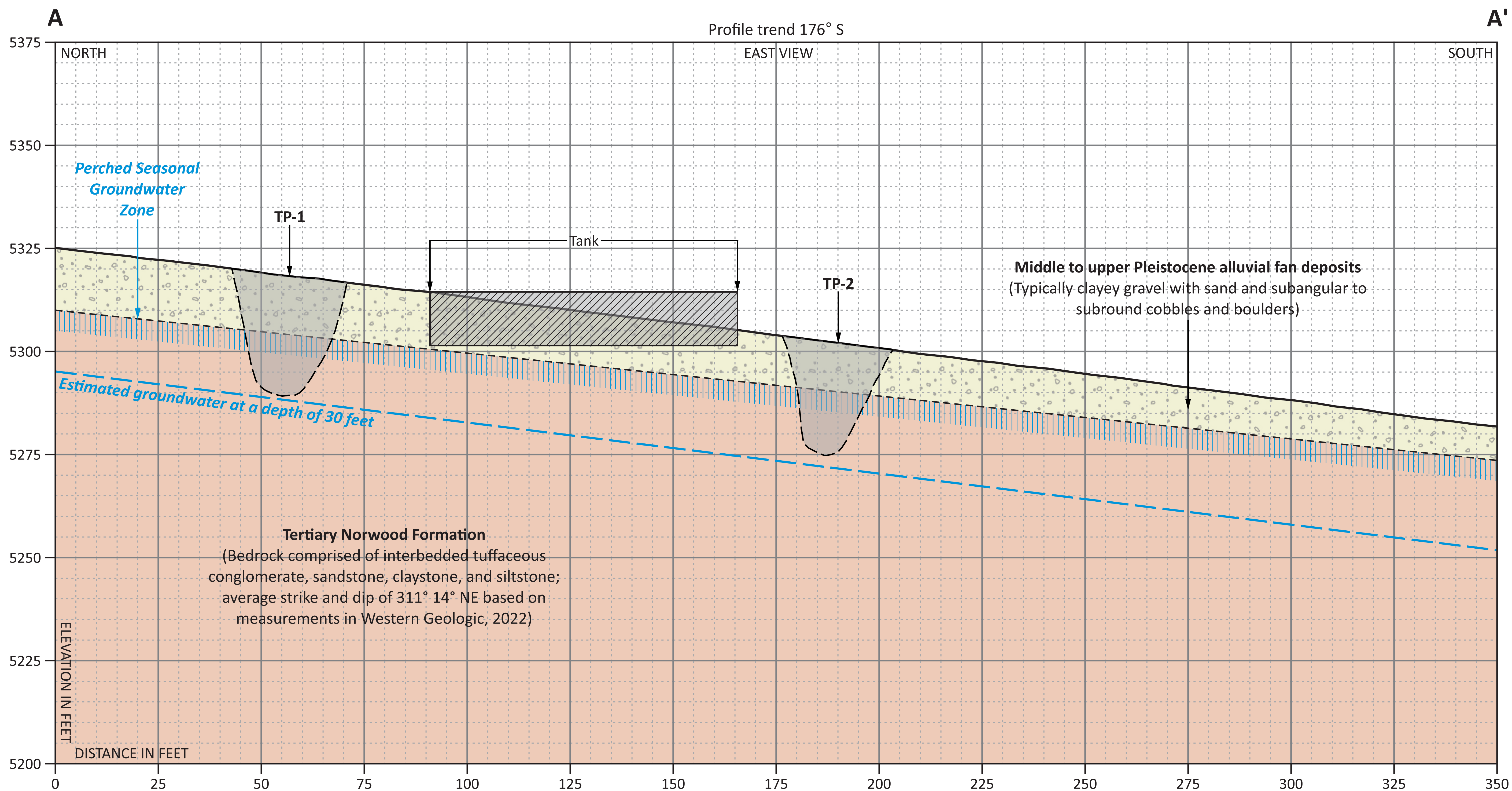
WESTERN GeoLOGIC

Scale 1 inch equals 5 feet with no vertical exaggeration.
Logged by Bill D. Black, P.G. on May 1, 2025.

TEST PIT 2 LOG

GEOLOGIC HAZARDS EVALUATION
Cobabe Ranch Design Tank
About 2720 North 5100 East
Eden, Weber County, Utah

FIGURE 5



WESTERN GEOLOGIC

Scale 1 inch equals 25 feet (1:300) with no vertical exaggeration. All units and contacts are approximate and inferred based on limited subsurface data; variations should be expected laterally, at depth and within units. Topographic profile based on geoprocessed LIDAR data from 2016 and 2020.

GEOLOGIC CROSS SECTION A-A’

GEOLOGIC HAZARDS EVALUATION

Cobabe Ranch Design Tank
About 2720 North 5100 East
Eden, Weber County, Utah

FIGURE 6