REPORT

SURFACE FAULT RUPTURE HAZARD EVALUATION

PROPOSED UINTAH WATER RESERVOIR
ABOUT 6384 BYBEE DRIVE
OGDEN, UTAH

Prepared for

Christensen Geotechnical
8143 South 2475 East
South Weber, Utah 84405

April 29, 2020

Prepared by

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April 29, 2020

Mark Christensen, P.E.
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8143 South 2475 East
South Weber, Utah 84405

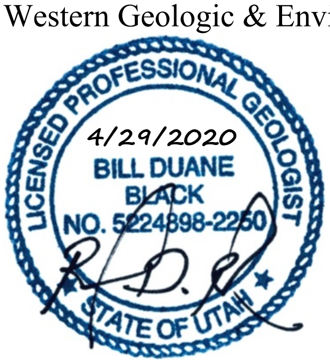
Letter of Transmittal: REPORT
Surface Fault Rupture Hazard Evaluation
Proposed Uintah Water Reservoir
About 6384 Bybee Drive
Ogden, Utah 84403

Dear Mr. Christensen:

Western Geologic & Environmental has completed a Surface Fault Rupture Hazard Evaluation for the proposed Uintah Water Reservoir at about 6384 Bybee Drive in Ogden, 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



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WG&E Project No. 5379

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1.0 INTRODUCTION

This report presents the results of a surface fault rupture hazard evaluation conducted by Western Geologic & Environmental LLC (Western Geologic) for the proposed Uintah Water Reservoir at about 6384 Bybee Drive in Ogden, Utah (Figure 1 – Project Location). The water tank location has not been formalized, but the tank will reportedly be near or replace an existing Uintah City water tank on Weber County Assessor parcel number 07-099-0014 (1.04 acres). The existing water tank is about 1.0 miles northwest of the mouth of Weber Canyon at the south end of a north-south trending ridge west of Broad Hollow at the western base of the Wasatch Range front. The Project is located in the SW1/4 Section 24, Township 5 North, Range 1 West (Salt Lake Base Line and Meridian) at an elevation of 4,853 to 4.973 feet above mean sea level.

2.0 PURPOSE AND SCOPE

Weber County hazard maps and Coogan and King (2016; Interim Geologic Map of the Ogden 30' x 60' Quadrangle, UGS OFR-653DM) show a main west-dipping trace of the Weber section of the Wasatch fault zone about 500 feet east of the Project and an east-dipping antithetic trace ending about 450 feet to the southeast. Given the above, the proposed reservoir site is in the Surface Fault Rupture Special Study Area on Weber County hazard maps where trenching studies are required to evaluate the risk from surface faulting. The purpose of this investigation was therefore to evaluate the hazard from surface faulting to the proposed reservoir. Other geologic hazards possibly present were not evaluated and beyond the scope of our study. Our investigation was conducted concurrently with a geotechnical engineering study being performed by Christensen Geotechnical.

2.1 Methodology

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

- Examination and logging of two trenches north and south of the existing water tank at the site to identify and locate possible active faults crossing the area, assess zones of fault-related deformation (if present), and recommend appropriate fault setback distances and safe "buildable" areas should faults be discovered;

- Review of available geologic maps, reports and air photos, including a prior fault study report prepared for the site by Terracon in June 2000 (Terracon, 2000); and

- Evaluation of available data and preparation of this report, which presents the results of our study.

Our evaluation was conducted following guidelines in Lund and others (2016) and current generally accepted professional engineering geologic principles and practice in Utah, and generally meets specifications in Chapter 27 of the Weber County Land Use Code. Our investigation incorporates and relies on prior trenching data for the site provided in Terracon (2000). A copy of this report is provided in the Appendix. No formal review of the trenches conducted for our study was requested or performed, but the exposures were digitally photographed at five-foot intervals to document subsurface conditions. The photos are not included herein, but are available upon request.

2.2 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.

3.0 GEOLOGY

3.1 Surficial Geology

The property is located on the south flank of a south-trending ridge west of Broad Hollow at the western base of the Wasatch Range (Figure 1). Spring Creek flows southwestward about 200 feet east of the Project and occupies a roughly 300-foot wide swale downcut in lacustrine sediments. Coogan and King (2016) map surficial geology of the Project as fine-grained lacustrine sediments associated with the transgressive stage of Lake Bonneville (unit Qlfb; Figure 2). No faults are mapped by Coogan and King (2016) crossing the Project.

Coogan and King (2016) describe surficial geologic units in the site area on Figure 2 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.

Qaf, Qafy, Qaf3, Qaf3?, Qaf4, Qaf4?, Qaf5 *– Alluvial-fan deposits (Holocene and Pleistocene).* Mostly sand, silt, and gravel that is poorly bedded and poorly sorted and that is not close to late Pleistocene Lake Bonneville and is geographically in the Huff Creek and upper 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. 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.

Where possible, subdivided into relative ages, indicated by letter and number suffixes (like Qa and Qat suffixes) and relative ages only apply to the local drainage, with unit Qafy being the lowest (youngest) fans and unit 3 may or may not post-date Lake Bonneville.

Relative ages of these fans are partly based on heights above present drainages at drainage-eroded edge of fan. The relative age is queried where the age is uncertain, generally due to the height not fitting into the typical order of surfaces. The various deposits listed, Qafy and Qaf3 through Qaf5, are 20 to 140 feet (6-40 m) above and west of Saleratus Creek, and also above Yellow Creek and the Bear River. Qafy fans are active, impinge on present-day floodplains, divert active streams, and overlie low terraces.

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.

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).

Qat2, Qat3 *– Stream-terrace alluvium (Holocene and Pleistocene).* Sand, silt, clay, and gravel in terraces inset into late Pleistocene Weber River delta above Weber River flood plain; moderately to well-sorted, pebble and cobble gravel and gravelly sand with subangular to rounded clasts; unconsolidated to weakly consolidated; upper surfaces slope gently downstream; locally includes thin and small mass-movement and alluvial-fan deposits; subdivided into relative ages, indicated by number suffixes, with 2 being the lowest/youngest terraces and 3 divided by a scarp on the map into an upper and lower terrace; terraces 20 to 50 feet (6-16 m) above the Weber River; exposed thickness less than 20 to 50 feet (6-16 m) (after Yonkee and Lowe, 2004). These terraces do not fit into table 1 or 2 because they post-date the regression of Lake Bonneville from the Provo shoreline and appear to be graded to lake levels below the Gilbert shoreline.

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.

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).

Qct *– Colluvium and talus, undivided (Holocene and Pleistocene).* Unsorted clay- to boulder-sized angular debris (scree) at the base of and on steep, typically partly vegetated slopes; shown mostly on steep slopes of resistant bedrock units; 6 to 30 feet (2-9 m) thick.

Qlf, Qlf?, Qlfb, Qlfb? *– Fine-grained lacustrine deposits (Holocene and upper Pleistocene).* Mostly silt, clay, and fine-grained sand deposited near- and off-shore in Lake Bonneville; typically mapped as Qlf below the Provo shoreline (P) because older transgressive (Qlfb) deposits are indistinguishable from younger regressive deposits; mapped as Qlfb above the Provo shoreline because these deposits can only be related to the Bonneville shoreline (B) and transgression; grades upslope with more sand into Qls or Qlsp; typically eroded from shallow Norwood Formation in Ogden and Morgan Valleys and at least 12 feet (4 m) thick near Mountain Green. Qlf and Qlfb queried where grain size is uncertain.

In the Kaysville quadrangle, Qlf deposits that are below the Gilbert (G) shoreline are at least partly the same age as this shoreline (Holocene-latest Pleistocene) and post-date late Pleistocene Lake Bonneville. Qlf deposits below the Holocene (H) highstand shoreline are Holocene. Both ages of deposits are generally less than 15 feet (5 m) thick.

Deeper water fine-grained deposits overlie older shoreline and delta gravels (Qlf/Qdlb) at the mouths of several drainages along the Weber River. These gravels were deposited above the Provo shoreline during transgression of Lake Bonneville to the Bonneville shoreline (see unit Qdlb).

Qadp, Qadp? *– Provo-shoreline and regressive 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; mapped below/near the Provo shoreline and related to the Provo and slightly lower regressional shorelines; deposits prominent east of Brigham City, at mouth of North Ogden Canyon, and on bench north of the Weber River; deposited as delta foreset beds with original dips of 30 to 35 degrees that allow separation from mixed lacustrine deposits (Qdlp); deltaic deposits at least 40 feet (12 m) thick and contain subrounded to well-rounded pebble and cobble gravel in a matrix of sand and silt with interbeds of sand and silt; capped by gently dipping alluvial-fan and stream topset beds that are less than 16 feet (5 m) thick, are poorly to moderately sorted, silty to sandy, subangular to well-rounded pebble and cobble gravel, and contain subangular to angular clasts in a matrix of sand and silt with interbeds of sand and silt (see units lpd and alp of Personius, 1990).

East of Brigham City at the mouth of Box Elder Canyon these deposits have been extensively excavated for sand and gravel. King estimates these deposits are about 200 feet (60 m) thick (from topographic contours) south of the mouth of Box Elder Creek, while Smith and Jol (1992) implied they are 400 feet (120 m) thick to the west of the Ogden map area.

The Provo shoreline fan-delta sediments were eroded from Bonneville-shoreline lacustrine and alluvial deposits, contain 20 to 70 percent rounded recycled Lake Bonneville clasts (Personius, 1990), and were redeposited during and soon after the Bonneville flood, which occurred during the drop of Lake Bonneville to the Provo shoreline. The Qadp unit probably includes Provo-stillstand deltaic deposits, sub-Provo-stillstand (regressional) alluvial-fan and lacustrine-deltaic deposits that contain abundant reworked materials from the Provo-shoreline delta, and locally overlying alluvial-fan deposits. Personius (1990) noted that deposits at the mouth of Box Elder Canyon are a fan-delta. A fan-delta is built when an alluvial fan enters a lake or ocean, and includes both the fan and the delta.

Qlg, Qlg?, Qlgp, Qlgb, Qlgb? *– Lake Bonneville gravel and sand (upper Pleistocene).* Mostly interbedded pebble and cobble gravel and sand deposited along beaches and slightly offshore; varies from clast supported to only rare gravel clasts in a matrix of sand and silt; grades downslope and, locally, laterally into finer grained deposits (Qls, Qlsp, Qlsb); mapped as Qlg downslope from topographic slope break of Provo and regressive beaches (Qlgp) because gravel and sand may be related to Lake Bonneville transgression on this gentler slope; also mapped as Qlg where Provo shoreline not distinct or relationships to shorelines uncertain; Qlg and Qlgb queried where grain size or unit identification uncertain; up to about 100 feet (30 m) thick in gravel pits but less than 20 feet (6 m) thick on most valley slopes. Constructional landforms (beach ridges, bars, and spits) and transgressive (t) shorelines limited in Ogden map area.

Qlgp is mapped in beaches near and below the erosional bench at the Provo shoreline (P); gravel typically subrounded to rounded, but locally along bedrock mountain fronts marked by a carbonate-cemented, poorly sorted, angular pebble to boulder gravel in a sandy matrix.

Qlgb is mapped in beaches mostly just downslope from Bonneville shoreline (B), typically an eroded bench, and above Provo shoreline; deposited during transgression to and occupation of the Bonneville shoreline; clasts typically subrounded to rounded but contains subangular to angular clasts on steep bedrock mountain fronts; mountain front Bonneville shoreline benches covered by locally mappable (> 6 feet [2 m] thick) colluvium and talus (Qmt, Qc, Qct).

Xfcb, Xfcb? *– Biotite-rich schist (Paleoproterozoic).* Medium-gray to dark-brown, strongly foliated, biotite-rich schist with widespread garnet and sillimanite; displays alternating biotite-rich and quartz-feldspar-rich bands that are rotated into complex fold patterns; cut by garnet-bearing pegmatite dikes; also contains some thin layers of amphibolite, quartz-rich gneiss, and granitic gneiss; gradational contacts with migmatitic gneiss.

Citations, tables, and/or figures referenced above are not provided herein, but are in Coogan and King (2016).

3.2 Seismotectonic Setting

The property is located west of the western base of the Wasatch Range, a major north-south trending mountain range marking the eastern boundary of the Basin and Range physiographic province (Stokes, 1977, 1986). The Basin and Range province 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 the prominent, west-facing escarpment along the 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 WFZ is one of the longest and most active normal-slip faults in the world, and extends for 213 miles along the western base of the Wasatch Range from southeastern Idaho to north-central Utah (Machette and others, 1992). The fault zone generally trends north-south and, at the surface, can form a zone of deformation up to several hundred feet wide containing many subparallel west-dipping main faults and east-dipping antithetic faults. Previous studies divided the fault zone into 10 sections, each of which rupture independently and are capable of generating large-magnitude surface-faulting earthquakes (Machette and others, 1992). The central five sections of the fault (Brigham City, Weber, Salt Lake, Provo, and Nephi) have each produced two or more surface-faulting earthquakes in the past 6,000 years (Black and others, 2003). The site is located along the Weber section of the WFZ, which extends for about 35 miles from the southern edge of the Plain View salient near North Ogden to the northern edge of the Salt Lake salient near North Salt Lake (Machette and others, 1992). The main trace of the Weber section is mapped about 500 feet east of the Project (Figure 2, heavy black line). Overall trend of the main fault trace in the area is about N14°E. Figure 2 also shows two east-dipping antithetic fault traces ending about 450 feet to 750 feet to the south of the Project that trend N1°W to N5°E.

Several paleoseismic studies have been conducted on the Weber section to evaluate its Holocene earthquake history. Nelson and others (2006) report finding evidence for four large-magnitude earthquakes at the Garner Canyon and East Ogden sites, including what they infer was a partial section rupture (with 1.6 feet of displacement) around 500 years ago. This partial section rupture was not evident at the Kaysville site of McCalpin and others (1994), although chronologic intervals for the remaining three earthquakes were similar. DuRoss and others (2009) indicate that paleoseismic data from the 2007 Rice Creek site support a preferred scenario of six surface-faulting earthquakes in Holocene time, with four events since about 5,400 years ago, a fifth event from 5,500 to 7,530 years ago, and a sixth event about 7,810 to 9,930 years ago. The preferred recurrence interval (mean time between events) based on this chronology is 1,500 years (DuRoss and others, 2009). Timing for events at the Rice Creek site was reportedly similar to those at the Garner Canyon, East Ogden, and Kaysville sites, except for one previously undiscovered event.

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_S 7.5 event in 1959 near Hebgen Lake, Montana. However, none of these earthquakes occurred along the WFZ or other known late Quaternary faults (Arabasz and others, 1992; Smith and Arabasz, 1991). The closest of these events was the 1934 Hansel Valley (M_S 6.6) event north of the Great Salt Lake.

3.3 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).

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, 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). The proposed tank site is below the Bonneville shoreline, which are mapped on Figure 2 in higher slopes to the east (blue lines denoted with "B"). The Project is slightly above the elevation of the Provo shoreline, although this shoreline is not mapped on Figure 2.

Following the Bonneville flood, the lake stabilized and formed a lower shoreline referred to as the Provo shoreline 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. Oviatt and others (1992) deem this low stage the end of the Bonneville lake cycle. Drainages that fed Lake Bonneville (such as the Weber River) began downcutting through stranded deltaic complexes and near-shore deposits as the lake receded from the Provo shoreline. 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).

4.0 SITE CHARACTERIZATION

4.1 Air Photo Observations

Color orthophotography from 2012 available from the Utah AGRC (Figure 3A), and geoprocessed LIDAR DEM imagery available from the Utah AGRC (Figure 3B) were reviewed to obtain information about the geomorphology of the Project area. The proposed tank site is on the south flank of a south-trending ridge west of the western base of the Wasatch Range. The tank site is on the ridge top, which slopes away from the site to the west, south and east and overlooks Spring Creek further east. No suspect lineaments or surficial evidence for active faults was observed at the Project on the air photos.

4.2 2000 Subsurface Investigation

Terracon (2000) conducted a prior subsurface investigation at the site in May 2000 that included one generally east-trending, 104-foot long trench (Trench ABC), and a shorter northeast-trending trench (Trench DE) south of the existing water tank. Location of Terracon's (2000) trenches are shown on Figures 3A-B. The original logs of Terracon's (2000) trenches are provided on Figure 4 at a scale of 1 inch equals 5 feet (1:60). A copy of Terracon (2000) is included in the Appendix. The trenches reportedly primarily exposed fine-grained silty sand with interbedded, 4- to 8-inch thick layers of silt to clay. The native sediments exposed in trench ABC were reportedly displaced a net 12 inches down to the east across two east-dipping faults at station 0+23 feet, and 10 inches down to the east across a fault at station 0+57 feet. These faults were observed to trend N5°E and N10°W, respectively. The native sediments exposed in trench DE were reportedly displaced 9 inches down to the east across one fault at station 0+05 that trended N40°W. Terracon (2000) believed the faults exposed in the trenches at the site were tectonic features associated with antithetic deformation of the Weber section of the Wasatch fault zone, but noted that the Slope-Failure Inventory Map of the Ogden Quadrangle (Lowe, 1988) showed the Project area as underlain by a possible lateral spread landslide. They indicated that no evidence of liquefaction, lateral spreading, or deep-seated landslide activity was observed in the trenches.

4.3 2020 Subsurface Investigation

On April 6, 2020 two trenches were excavated at the site to assess subsurface conditions and the potential hazard from surface faulting. Trench 1 was located south of Terracon (2000) trench ABC and extended from slightly east of the western property an overall S77°E for a total distance of 53 feet. No exploration was conducted further eastward to avoid disturbing the access road to the tank and outlet drainpipes. Trench 2 was located northeast of the tank and extended from slightly west of the fence surrounding the existing tank an overall N40°W for a total distance of 41 feet. Figures 3A-B show location of the trenches at a scale of 1 inch equals 50 feet (1:600). Field locations were measured using a handheld GPS unit and by trend and distance methods from known points. Although no detailed surveying was conducted, we consider the locations to be accurate to within one foot given there was good location control. Figures 5 and 6 are detailed logs of the trenches at a scale of 1 inch equals 5 feet (1:60). Trench logging followed methodology in McCalpin (1996).

Trench 1 exposed a sequence of silty fine sand with silt interbeds resembling the deposits observed by Terracon (2000) in trench ABC. These deposits were displaced in trench 1 (Figure 5) a total of 12 inches down to the east across four faults at stations 0+18.9 (F1a), 0+19.4 (F1b), 0+22.7 (F2) and 0+24.9 feet (F3). Faults F1a-b trended N5°E and showed a reverse sense of displacement. Fault F2 trended N10°W and also showed reverse displacement. Fault F3 trended N20°W and showed normal displacement. The faults appear to correspond to the faults observed in Terracon (2000) trench ABC at station 0+23 feet (Figure 4) and show the same cumulative displacement (12 inches). Trench 2 (Figure 6) exposed mainly silt with interbedded and interfingering poorly graded fine sand lenses. No faults were observed in trench 2, but the sediments displayed evidence for liquefaction or subaqueous soft-sediment deformation consistent with lateral spread landsliding. The chaotic sense of displacement observed in trench 1 is also a characteristic feature of lateral spread landslides (e.g. Hylland and Lowe, 1998). Such a failure may have occurred during or shortly after Lake Bonneville catastrophically dewatered and retreated from the Bonneville shoreline, prior to downcutting by Spring Creek and multiple large magnitude earthquakes on the main trace of the Weber section of the WFZ further east.

Figures 3A-B show the inferred locations of the faults crossing the site based on trenching data in Terracon (2000) and from our subsurface investigation. We note that the faults do not correspond to any surficial features, are at a significant distance from the nearest main fault trace, and are contra-aspected with regard to the slopes bounding the ridge further north. Based on our experience, a contra-aspect is unusual for an antithetic fault that is not in close proximity to a degraded free face from a main fault.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The proposed reservoir site is about 500 feet west of a main west-dipping trace of the active Weber section of the WFZ and about 450 feet north-northwest of the north end of an east-dipping antithetic trace. Surficial geology of the Project is mapped as fine-grained lacustrine deposits from late Pleistocene Lake Bonneville. Terracon (2000) conducted a prior fault study at the site that exposed several small faults in two trenches south of the existing water tank. These faults reportedly displayed up to a discrete offset of up to 10 inches and a cumulative 22 inches of down-to-the-east displacement over a distance of 35 to 40 feet.

To confirm Terracon's fault data and check for additional evidence of active faulting, we observed and logged two trenches slightly south of Terracon's (2000) trench ABC (trench 1) and north of the existing water tank (trench 2). Trench 1 exposed a series of faults with a similar location and cumulative displacement as the westernmost fault observed in Terracon (2000) trench ABC. However, three of the four faults observed in trench 1 showed a reverse sense of displacement. Trench 2 exposed no evidence for faulting, but exposed evidence for soft-sediment deformation. Such deformation would be consistent for a lateral spread landslide that occurred during or shortly after Lake Bonneville retreated from the Bonneville highstand. The risk from surface faulting to the water tank would be low if the deformation was related to lateral spread landsliding because conditions are no longer conducive for such a failure. However, a tectonic origin for the faults observed in Terracon's (2000) and our trenches cannot be ruled out.
Based on the data and findings in this report, we recommend the following:

- ***Structural Design and Location Considerations*** – We conservatively recommend that the proposed water tank be structurally reinforced and designed to withstand a discrete displacement of up to 10 inches in the event of a future large magnitude earthquake, which is the maximum displacement observed at the site. The reservoir should also include appropriate flow monitoring systems and control valves, or other technology as deemed needed by the civil and/or structural engineer, to prevent catastrophic failure. In the event that the water reservoir can't be engineered to this level of displacement, we recommend it be located at least 20 feet east-northeast of the easternmost fault trace on Figures 3A-B (in the area of trench 2). This distance would be a minimum setback value per Lund and others (2016).

- ***Report Availability*** – The report should be made available to architects, building contractors, and in the event of a future property sale, real estate agents and potential buyers. This 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 the authors and should not be copied, used, or modified without their express permission.

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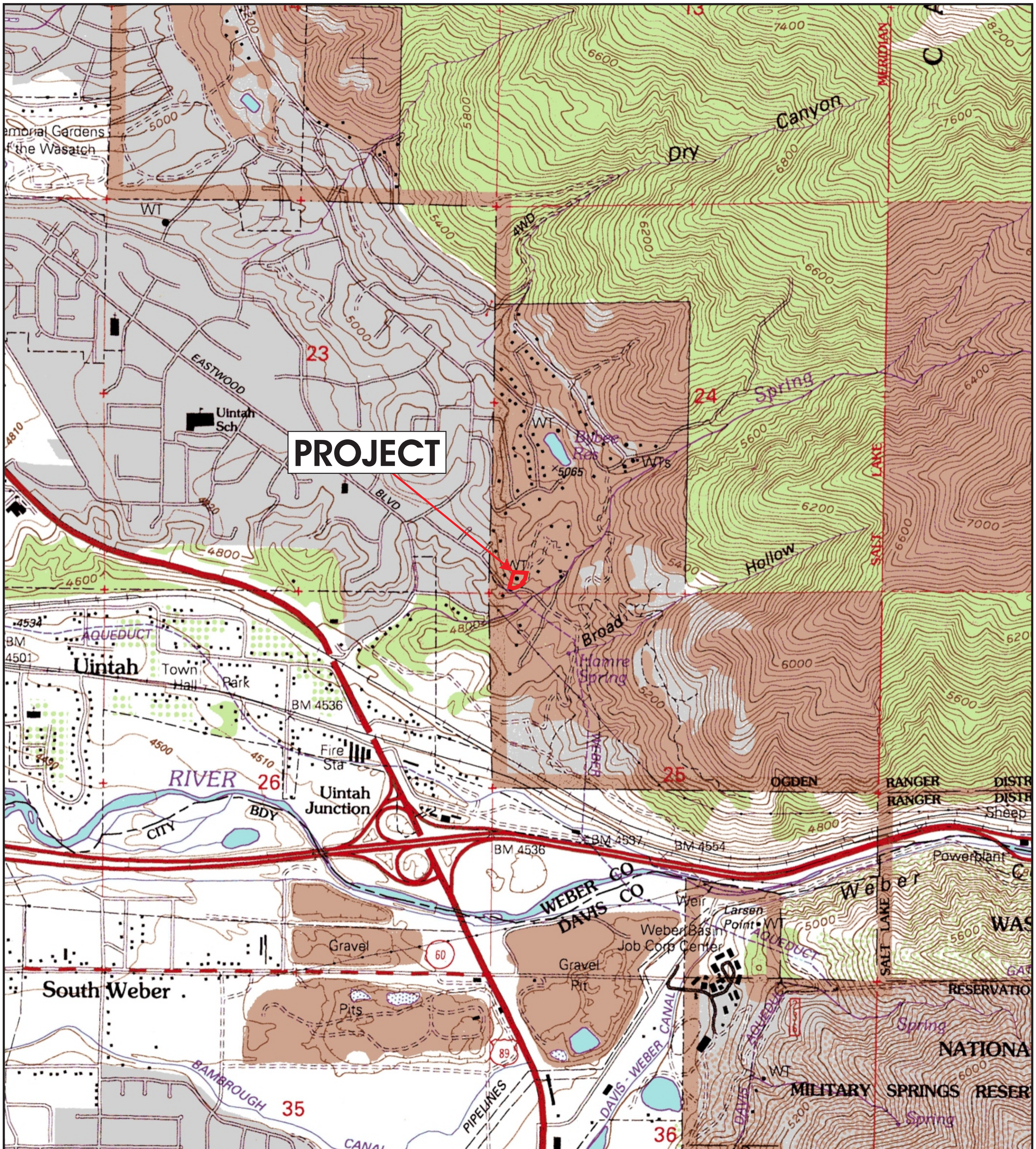
FIGURES



Source: U.S. Geological Survey 7.5 Minute Series Topographic Maps, Utah - Ogden, 1998;
Project location SW1/4, Section 24, T5N, R1W (SLBM).

WESTERN GEOLOGIC

N
W E
S

0 1000 2000 feet

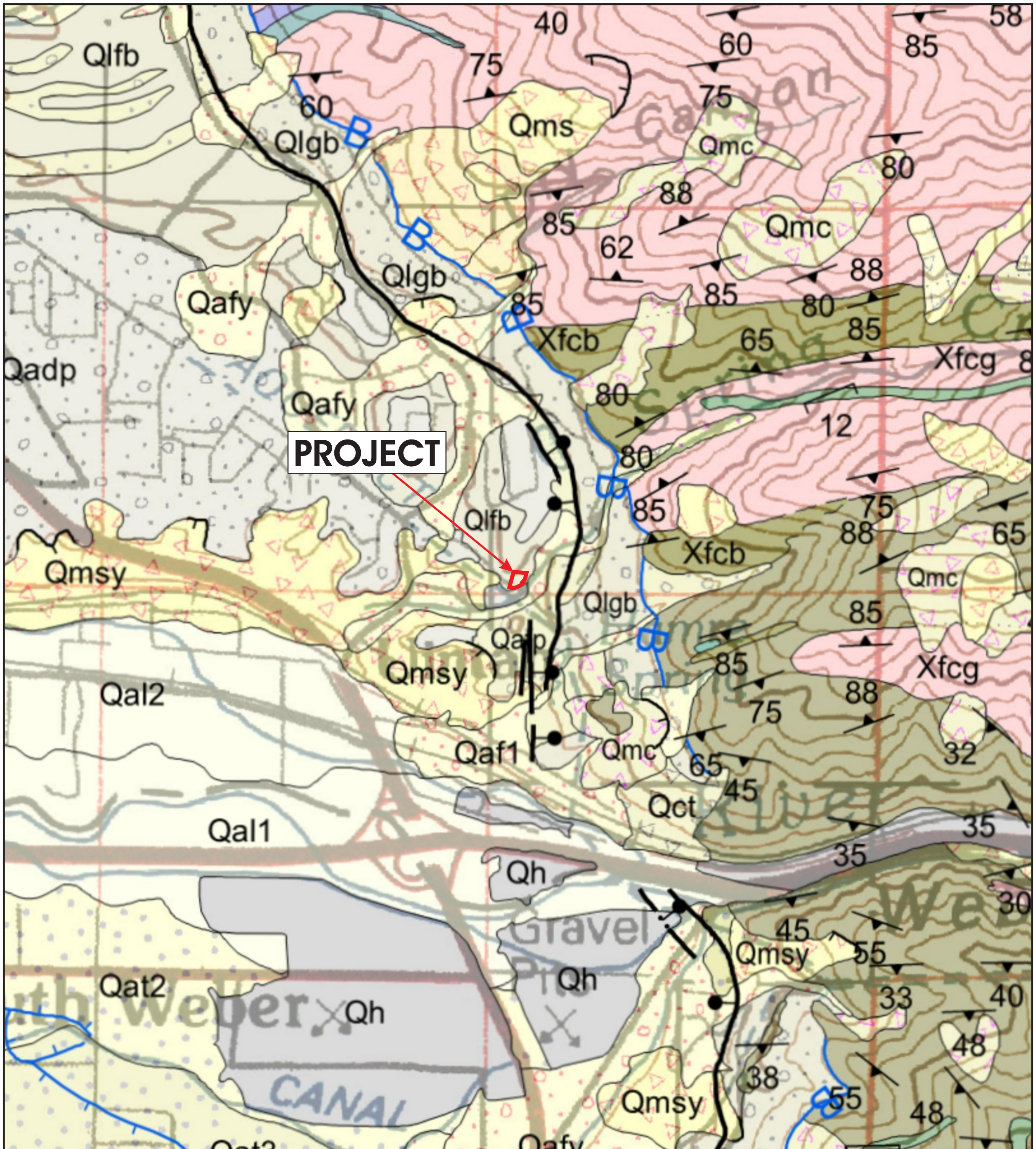
Scale 1:24,000
(1 inch = 2000 feet)

LOCATION MAP

SURFACE FAULT RUPTURE
HAZARDS EVALUATION

Proposed Water Reservoir
About 6384 Bybee Drive
Ogden, Utah 84403

FIGURE 1



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

N W E S

0 1000 2000 feet

Scale 1:24,000
(1 inch = 2000 feet)

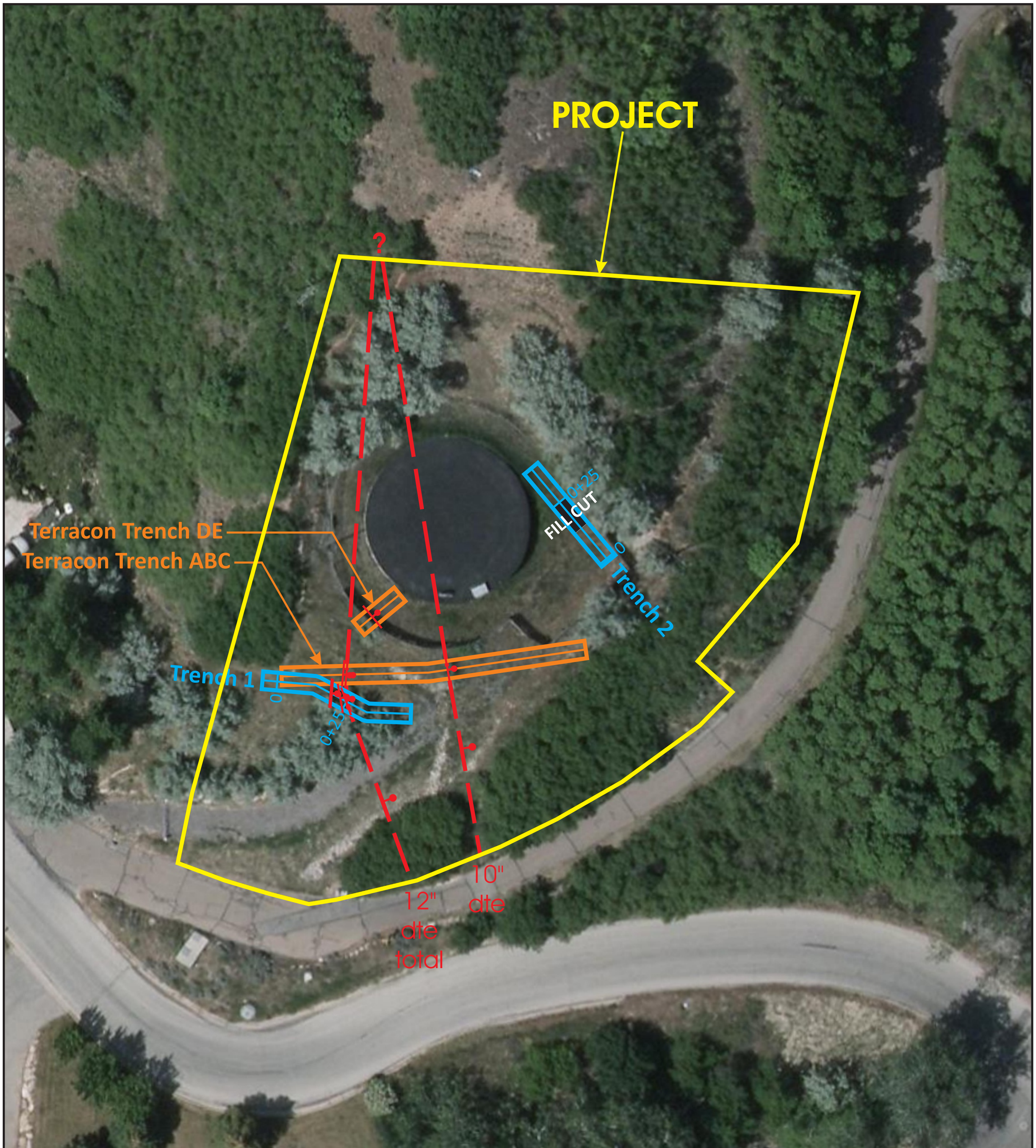
WESTERN GEOLOGIC

GEOLOGIC MAP

SURFACE FAULT RUPTURE HAZARDS EVALUATION

Proposed Water Reservoir
About 6384 Bybee Drive
Ogden, Utah 84403

FIGURE 2



Source: Utah AGRC high-resolution orthophoto, 2012, 12.5cm resolution.

WESTERN GEOLOGIC

N W E S

0 25 50 feet

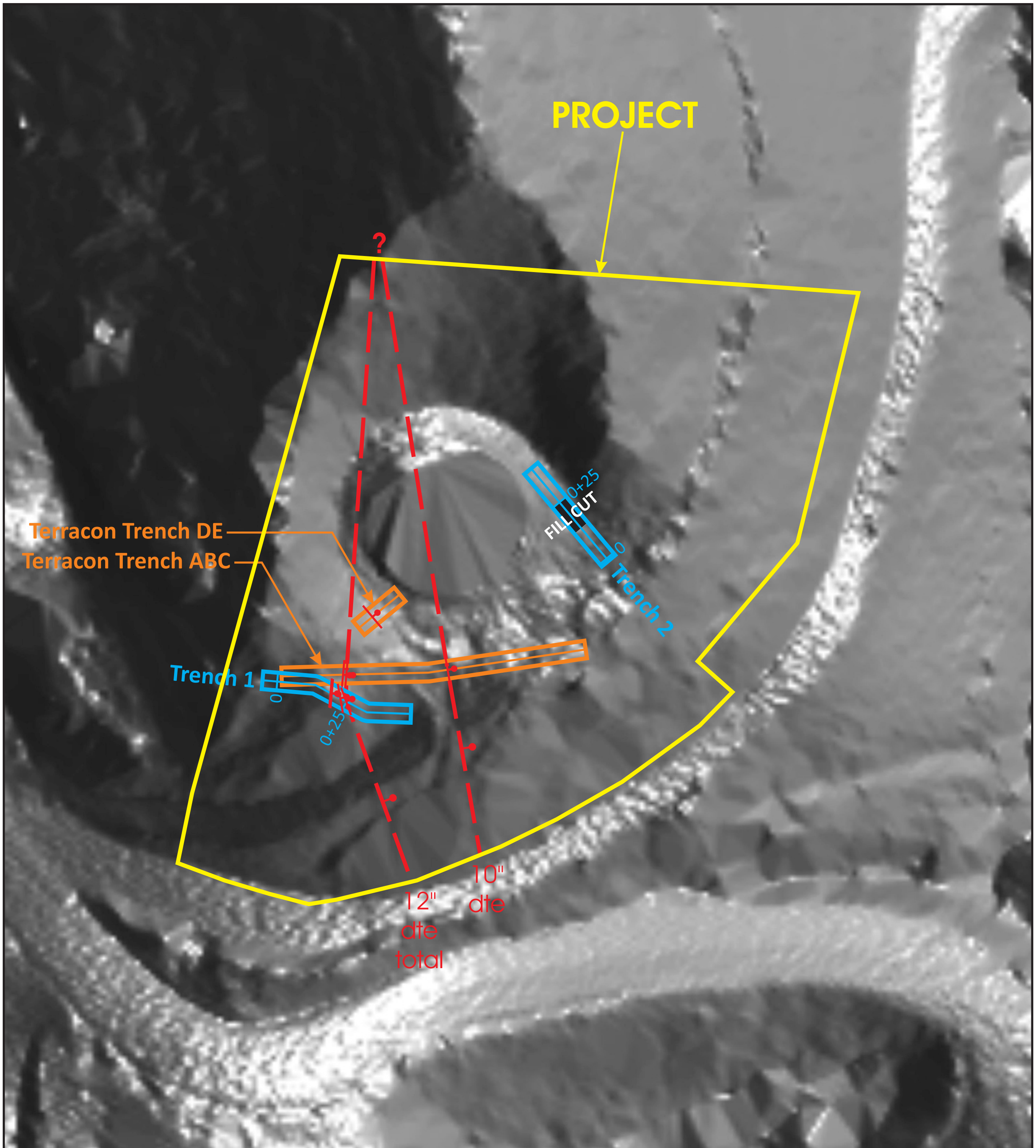
Scale 1:600
(1 inch = 50 feet)

2012 AIR PHOTO

SURFACE FAULT RUPTURE HAZARDS EVALUATION

Proposed Water Reservoir
About 6384 Bybee Drive
Ogden, Utah 84403

FIGURE 3A



Source: Utah AGRC Bare Earth LIDAR DEM, 2013, 50cm resolution.

WESTERN GeoLogic

N W E S

0 25 50 feet

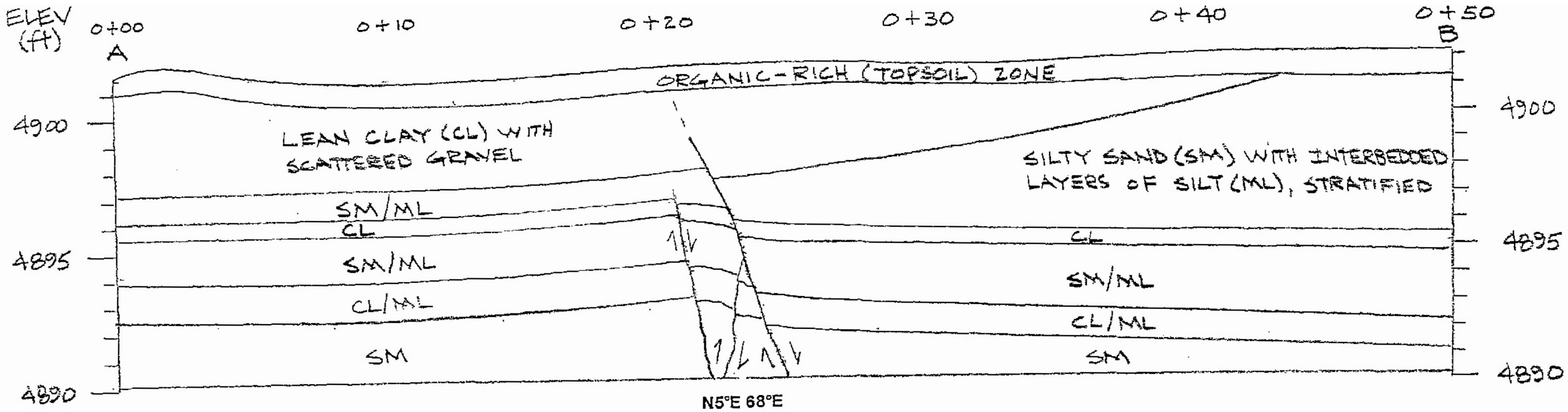
Scale 1:600
(1 inch = 50 feet)

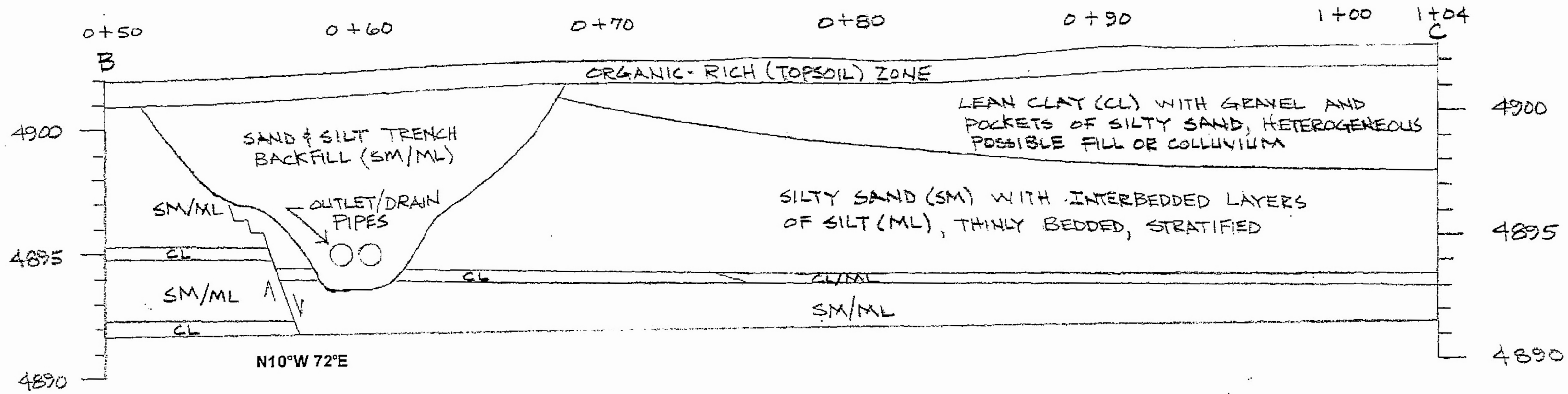
LIDAR ANALYSIS

SURFACE FAULT RUPTURE HAZARDS EVALUATION

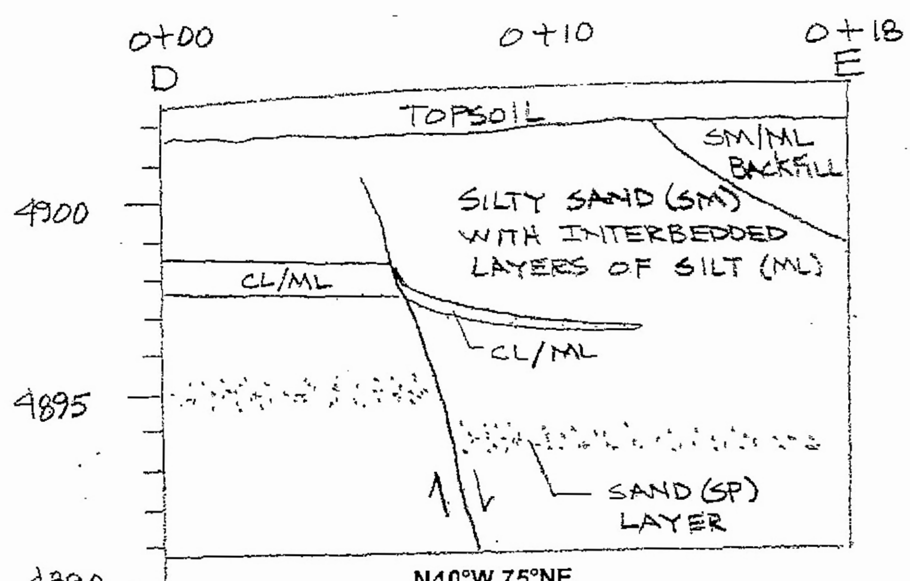
Proposed Water Reservoir
About 6384 Bybee Drive
Ogden, Utah 84403

FIGURE 3B





Source: Terracon (2000). Trenches logged by David K. Fadling, P.E., P.G., on May 24, 2000.



EXPLANATION

SOIL DESCRIPTIONS

SM - Silty Sand
SP – Poorly Graded Sand
ML – Silt
CL – Lean Clay

SYMBOLS

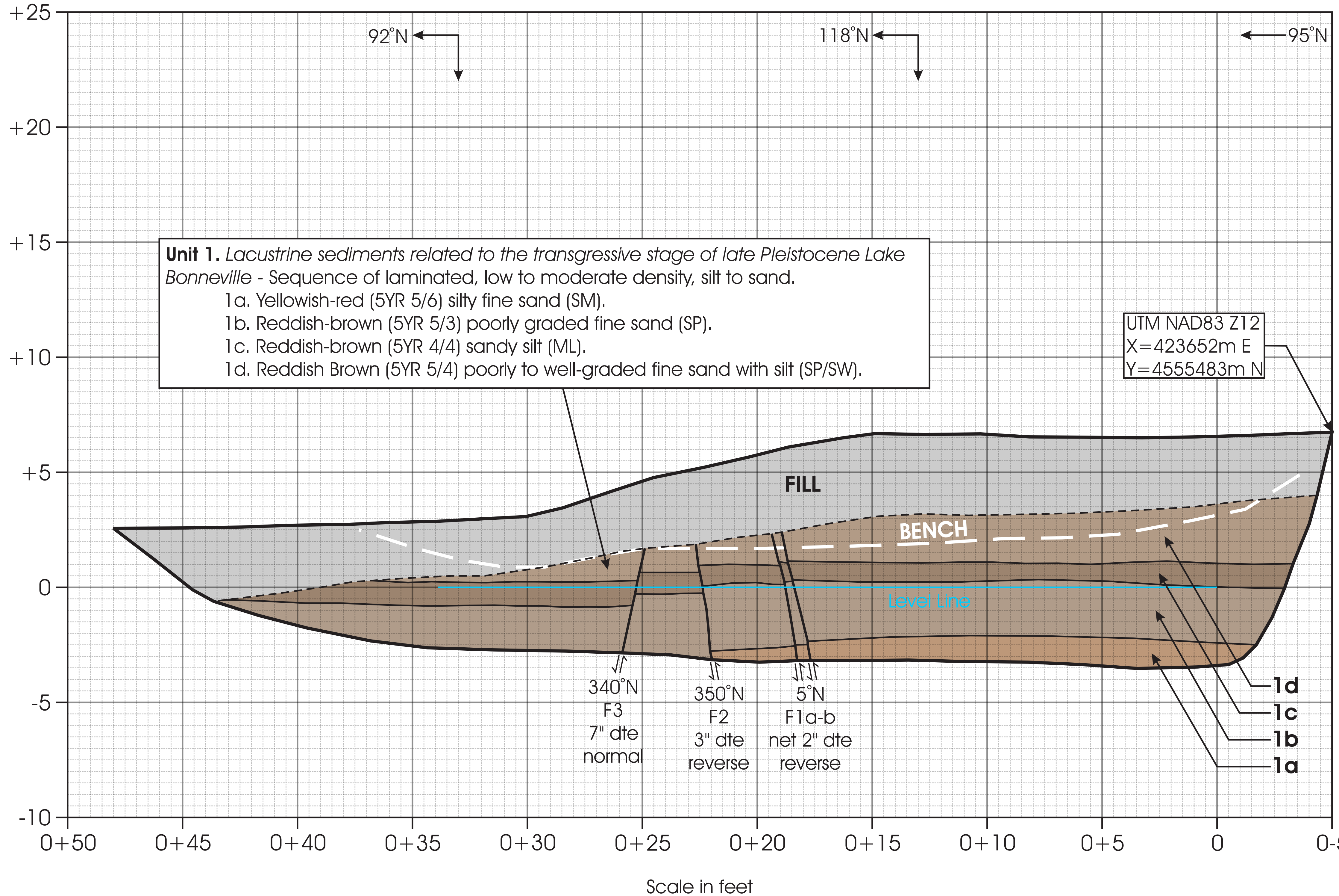
——	**Layer Contact (dashed where indistinct)**
⇅	**Fault (arrows indicate relative movement)**
N10°W 72°E	**Strike and dip of fault plane**

Horizontal and Vertical Scale
1 in = 5 ft

TERRACON TRENCH LOGS

SURFACE FAULT RUPTURE HAZARDS EVALUATION
Proposed Water Reservoir
About 6384 Bybee Drive
Ogden, Utah 84403

FIGURE 4



SCALE: 1 inch = 5 feet
(no vertical exaggeration)
South Wall Logged, West to East
Trench logged by Bill D Black, P.G.
on April 6, 2020

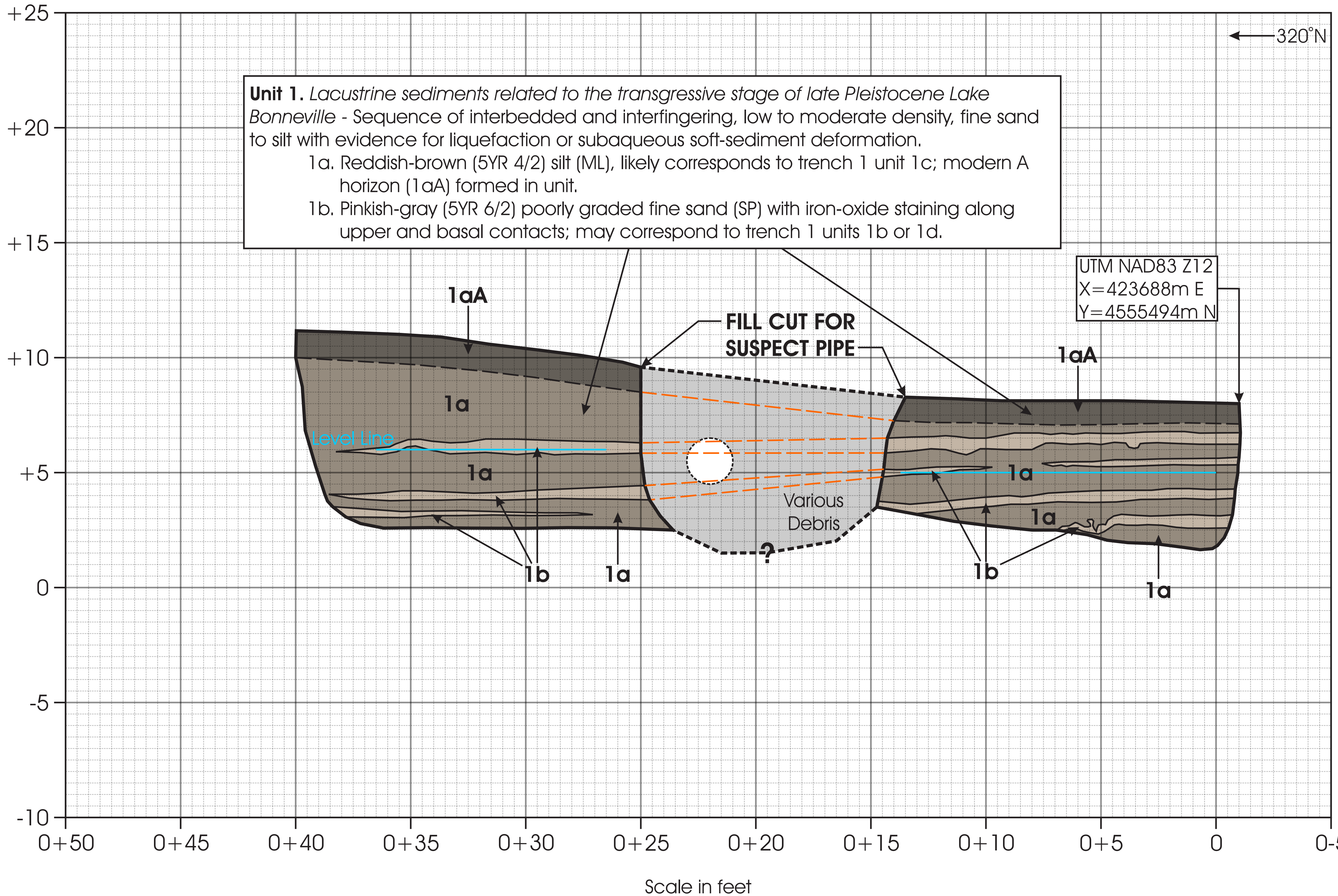
TRENCH 1 LOG

SURFACE FAULT RUPTURE HAZARDS EVALUATION

Proposed Water Reservoir
About 6384 Bybee Drive
Ogden, Utah 84403

FIGURE 5

WESTERN GEOLOGIC



SCALE: 1 inch = 5 feet
(no vertical exaggeration)
South Wall Logged, West to East
Trench logged by Bill D Black, P.G.
on April 6, 2020

WESTERN GEOLOGIC

TRENCH 2 LOG

SURFACE FAULT RUPTURE HAZARDS EVALUATION

Proposed Water Reservoir
About 6384 Bybee Drive
Ogden, Utah 84403

FIGURE 6

APPENDIX

REPORT OF SURFACE FAULT RUPTURE HAZARD EVALUATION

PROPOSED 1.25 MG WATER STORAGE RESERVOIR
2850 EAST BYBEE DRIVE
WEBER COUNTY, UTAH

Terracon Project No. 61005034
June 8, 2000

Prepared for:

TOWN OF UINTAH
Uintah, Utah

Prepared by:

TERRACON
Consulting Geotechnical Engineers
Salt Lake City, Utah

June 8, 2000

Town of Uintah
c/o Jones & Associates Consulting Engineers
4768 South Harrison Boulevard
Ogden, Utah 84403

Attn: Mr. Greg Seegmiller, P.E.

Re: Report of Surface Fault Rupture Hazard Evaluation
Proposed 1.25 MG Water Storage Reservoir
2850 East Bybee Drive - Weber County, Utah
Terracon Project No. 61005034

Dear Mr. Seegmiller:

Terracon has completed a surface fault rupture hazard evaluation for the above-referenced site in accordance with our proposal to you dated May 12 and approved on May 16, 2000. Trench excavations revealed faulted soil strata beneath the proposed reservoir site. Vertical displacements ranging from 9 to 12 inches were measured at three locations. The faults trend approximately north-south, with relative displacement downward on the east side. Because relative displacement is opposite to large-scale movement associated with the Wasatch fault (downward on the west side), we believe the observed faults are secondary features of the main fault. However, the fault mechanism is considered active, and displacement magnitudes similar to those observed could occur during the life of the reservoir. The accompanying report presents our findings, analyses and recommendations for the subject project.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report, we are available at your convenience.

Sincerely,
TERRACON

Prepared by:

David K. Fadling, P.E., P.G.
Engineering Geologist

Reviewed by:

William G. Turner, P.E.
Senior Geotechnical Engineer

DKF/dkf:wgt;n:\geo\1999\5034rpt.doc
Copies To: Addressee (4)

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REPORT OF SURFACE FAULT RUPTURE HAZARD EVALUATION
PROPOSED 1.25 MG WATER STORAGE RESERVOIR
2850 EAST BYBEE DRIVE
WEBER COUNTY, UTAH

Terracon Project No. 61005034
June 8, 2000

INTRODUCTION

This report presents the results of a surface fault rupture hazard evaluation for the proposed 1.25 MG water storage reservoir to be located at 2850 East Bybee Drive in Weber County, Utah. The approximate location of the site is shown on the Project Vicinity Map, Figure 1 in the Appendix. The work was performed in response to the Utah Geological Survey's recommendation for further characterization of potential geologic hazards at the site.

PURPOSE AND SCOPE

We understand the existing 0.25 million-gallon reservoir will be replaced with a new reservoir having a capacity of 1.25 million gallons. The new reservoir will have a diameter of about 98 feet, a height of about 25 feet, and will be partially embedded in the hillside. Limited property area will require removal of the existing reservoir to accommodate the new reservoir. The purpose of the evaluation was to perform a detailed investigation of the subsurface stratigraphy and structure to determine if active faults or evidence of other geologic hazards are present beneath the site. The evaluation included field explorations, office studies, and a review of existing geologic information. This report describes the work accomplished and provides our conclusions and recommendations regarding geologic hazards at the site.

GEOLOGIC AND SEISMOTECTONIC SETTING

Regional Geology

The project site is located in southern Weber County near the base of the Wasatch Mountains. The Wasatch Front is located on the eastern margin of the Basin and Range Province and is bounded to the east by the Middle Rocky Mountain Province, with the Wasatch fault being the approximate boundary between the two provinces. The Basin and Range Province is characterized by north-south-trending mountain ranges and valleys bounded by high-angle normal faults produced by east-west regional extension of the earth's crust. The Middle Rocky Mountain Province is made up of the Wasatch and Uintah Mountains, with intervening back valleys.

During the late Pleistocene (about 32,000 to 10,000 years ago), Lake Bonneville occupied about 20,000 square miles of northwestern Utah and was about 1,000 feet deep at its highest level (Currey, et. al., 1983). About 16,000 to 14,500 years ago, the project site was submerged below the lake level, which varied from a maximum elevation of about 5,090 feet to 4,740 feet at the Bonneville and Provo shorelines, respectively. During this time, primarily sand and silt were deposited in the project area in what was then the northern portion of the Weber River Delta.

Tectonic Setting

The Wasatch Front Region is located within a 62-mile-wide zone characterized by pronounced seismic activity known as the Intermountain Seismic Belt (Hecker, 1993). This zone of diffuse, but locally intense, zone of seismic activity extends from northern Montana to northern Arizona. It is estimated that 50 to 120 surface rupture earthquakes have occurred in the Wasatch Front Region in the last 15,000 years. Over half of these events occurred on the five central segments of the Wasatch fault zone between Brigham City and Nephi (Hecker, 1993). The project site is located adjacent to the Weber segment of the Wasatch fault. In general, the Wasatch fault is a high-angle normal fault with relative displacement down to the west, that is believed capable of producing a 7.5 (Richter magnitude) earthquake. Hecker (1993) estimates a maximum average regional recurrence interval for magnitude 6.5+ earthquakes of 125 to 300 years in the Wasatch Front Region.

SITE DESCRIPTION

The project site is located on a narrow ridgeline that plunges downward gently to the south-southwest. The property is approximately 170 feet wide and 220 feet long, with the long dimension parallel to the ridge. Excavation of the existing reservoir has resulted in a relatively flat area surrounding the reservoir and cut slopes on the north and west sides. The cuts are sloped at about 1.5H:1V and range in height from about 45 feet and 10 feet on the north and west sides, respectively. Beyond the east and west boundaries of the property, the ground surface slopes downward at about 2H:1V to the southeast, south and southwest. Ground surface elevations range from about 4,955 to 4,870 on the north and southwest sides of the property, respectively. Ground surface vegetation consists primarily of sagebrush, oak shrubs, and Russian Olive trees.

OFFICE INVESTIGATION

Nelson and Personius (1993) mapped the surficial deposits in the project area as deltaic deposits, consisting of fine sand and silt deposited during the transgressive phase of the Bonneville lake cycle (32,000 to 14,500 years ago). Younger landslide deposits and stream alluvium are mapped to the west and east of the site, respectively. The main trace of the Weber segment of the Wasatch fault is located about 600 feet east of the project area. North and south of the project area, an east-dipping normal fault is mapped approximately 250 to 300 feet west of the main fault, which dips to the west. The relative movement is such that the block between the opposing faults has dropped down. This structure is expressed as a narrow, northerly-trending valley or "graben." As mapped, this opposing (or antithetic) fault appears to terminate beneath the stream alluvium about 500 feet south to the project site. If projected north, the trace of the fault(s) appears to extent through the project area. Topographic observations suggest a graben-like feature is present east of the project area. Figure 2 in the Appendix is a reproduction of the map prepared by Nelson and Personius that has been enlarged by about 200 percent and shows the location of the project area with respect to surficial geologic units exposed in the area.

Lowe and Yonkee (in preparation) mapped the project area similar to Nelson and Personius; however, the landslide boundaries are mapped about 100 feet further west and do not extend south of the project area. The Slope-Failure Inventory Map of the Ogden Quadrangle (Lowe, 1988) shows the project area as underlain by a possible lateral spread deposit.

FIELD INVESTIGATION

On May 24, 2000, a trench designated ABC was excavated from west to east across the property to depths ranging from about 10 to 12 feet below the ground surface to explore subsurface materials and conditions at the site. A second, shorter trench designated DE was excavated perpendicular to the existing reservoir on the southwest side. The trench was logged by Terracon at a scale of 1 inch = 5 feet to record the details of the materials, layering, and structure in the trench. The elevation of the ground surface was estimated using topographic information provided by Jones & Associates. The locations of the trenches, with respect to the property boundaries and the existing and proposed reservoirs, are shown on Figure 4 in the Appendix. Logs of the trenches are provided on Figure 5. Photographs of selected features in the trenches are also included in the Appendix.

The trench explorations exposed primarily fine-grained silty sand (SM) with interbedded layers of silt (ML) and clay (ML) 4- to 8-inches-thick. Based primarily on elevation of the project site at about 4,900 feet, these soils are interpreted as sediments deposited during the high stand of the Bonneville lake cycle approximately 16,000 to 14,500 years ago (late Pleistocene) when the lake level was between the Bonneville and Provo shorelines at about elevations 5,090 and 4,740 feet, respectively.

Fill or colluvial soils were encountered at the ground surface, extending to depths of about 1.5 to 5.0 feet between Stations 0+75 and 1+04 on the west side of the main trench. Below depths of about 5 feet, layer stratigraphy was relatively well preserved across the entire trench. In general, the stratigraphy can be described as relatively flat lying, interbedded layers of silty sand, silt, and clay.

A distinct clay (CL) or silt (ML) layer is traceable along the entire trench between elevations 4,893 to 4,896. The clay/silt layer is about 4 to 8 inches thick, dark brown to brown, and easily distinguished from light gray sandy soils above and below. On the west side of the trench (Station 0+00 to 0+50) the clay layer contains horizontal roots, presumably from nearby trees at the ground surface. East of about Station 0+75, the layer becomes increasingly silty, lighter brown in color, and without roots.

Vertical offset of the clay/silt marker bed was observed at two locations in the main trench (ABC), Station 0+23 and 0+57 (see Trench Logs, Figure 5 and Photos 2 – 7 in the Appendix). At Station 0+23, the bed is displaced on several faults within a horizontal distance of about 5 feet. Total vertical displacement of the bed was measured at about 12 inches over the 5-foot interval. Offset on the primary fault feature was measured at 9 inches, with the remaining 3 inches made up of two minor faults within the faulted zone. At Station 0+57, the marker bed is offset a vertical distance of about 10 inches on a single fault. Both fault planes trend in a northerly direction and dip steeply to the east, with relative movement down on the east side. Fault offset of about 9 inches was also observed in trench DE at about Station 0+05. The orientation of this fault plane was measured at N40°W 72°NE, with relative movement down to the northeast. It is not clear whether this fault is continuous with one of the faults in trench ABC (perhaps with Station 0+57) or a separate fault of limited lateral dimension. Orientations of the fault traces are shown on Figure 4 in the Appendix. Trench logs (Figure 5) and photographs of the trenches are included in the Appendix.

CONCLUSIONS

The results of the trench explorations indicate fault-related features are present beneath the proposed reservoir site. Total vertical displacements of about 12 inches and 10 inches were measured in trench ABC at Station 0+23 and 0+57, respectively. Cumulatively, these two features total 22 inches of vertical displacement over a horizontal distance of about 35 to 40 feet.

Because relative movement is down on the east side and counter to relative large scale movement on the Wasatch fault (down on the west side), we believe the faults beneath the reservoir site represent antithetic features (opposite orientation to the main fault). These faults could be extensions of the antithetic fault mapped south of the site, or sympathetic features related to an unmapped antithetic fault east of the reservoir site. The slope east of the reservoir site could be interpreted as the eroded escarpment of such a fault, with the fault trace located near the bottom of the slope.

Faults that produce offset of Lake Bonneville sediments are considered to be active. The maximum age of the faults at this site is estimated at 14,500 to 16,000 years ago based on the age the sediments underlying the site. The minimum age of faulting is not known, but can reasonably be inferred to be less than 10,000 years ago (Holocene). Hecker (1993) estimates single-event fault displacements along the Weber segment of the Wasatch at 1 to 3 meters (3 to 10 feet), with the most recent event occurring about 1,000 years ago. The magnitude of fault displacement on antithetic faults is not as well defined, but is most likely much less than for the main fault. It is not known whether the 10 to 12 inches of vertical offset observed on the faults at this site represent the maximum possible offset. Without other supporting evidence, it must be assumed that fault displacements of similar magnitude could occur again at this site during the life of the proposed reservoir.

Evidence of liquefaction, lateral spreading, or deep-seated landslide activity was not observed in the trenches excavated at this site. However, the fault trench did not extend beyond the property boundaries to the west where landslide deposits are mapped.

RECOMMENDATIONS

If the reservoir can be designed to withstand vertical offsets of 10 to 12 inches at discrete locations, and up to 22 inches cumulative offset over a distance of 35 to 40 feet, then the risk of surface fault rupture causing catastrophic damage to the reservoir could be significantly reduced. We recommend that the design structural engineer, or other experts, be consulted to evaluate whether the reservoir can be designed to tolerate such vertical offsets. If the reservoir cannot be designed to tolerate these magnitudes of offset, then we recommend an alternative site be selected for the reservoir.

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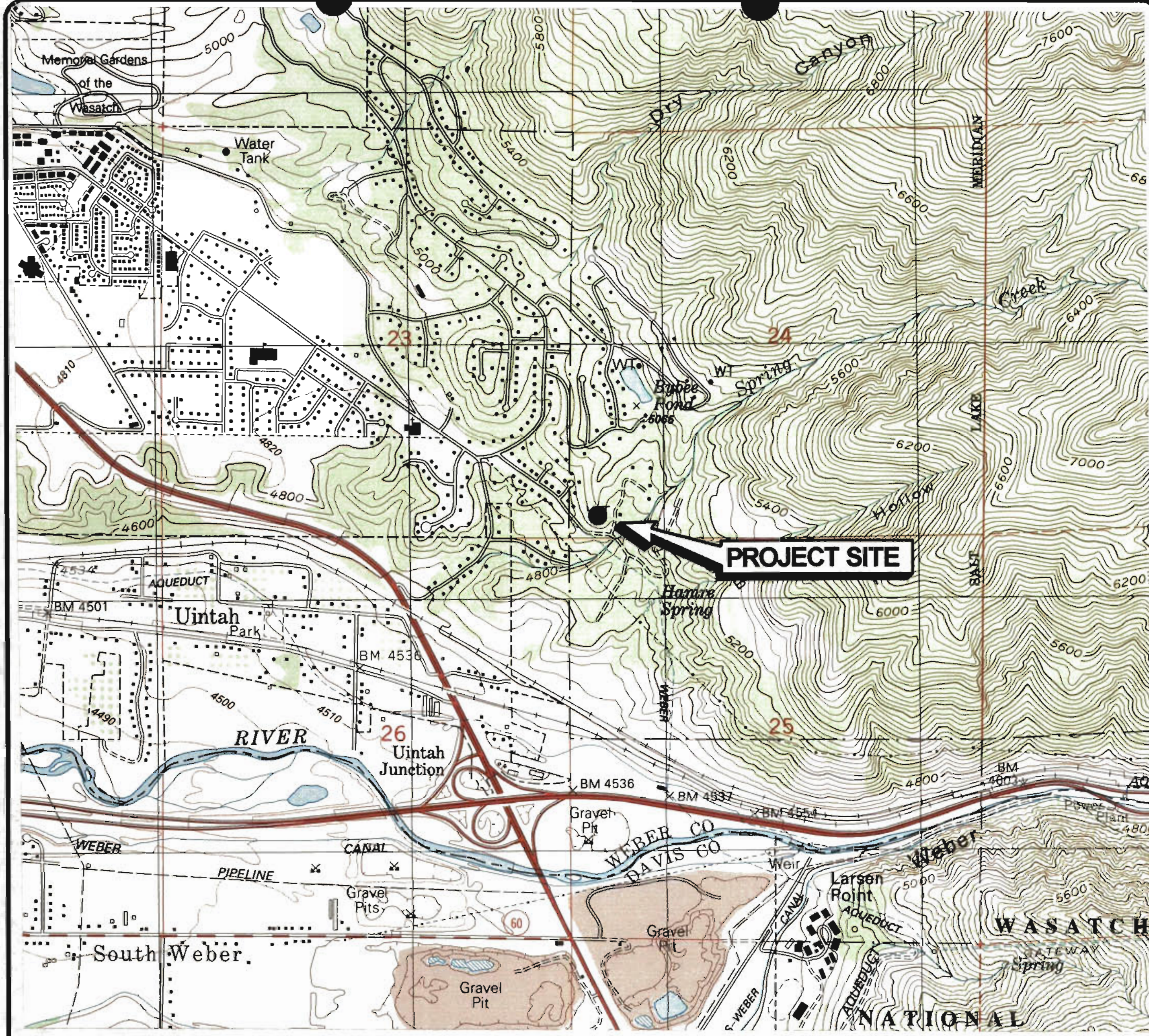
APPENDIX

PROJECT VICINITY MAP – FIGURE 1
GENERAL GEOLOGY MAP– FIGURE 2
DESCRIPTION OF GEOLOGIC MAP UNITS – FIGURE 3
SITE MAP – FIGURE 4
TRENCH LOGS – FIGURE 5
PHOTOGRAPHS
UNIFIED SOIL CLASSIFICATION SYSTEM



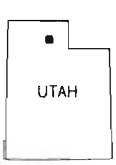
Reference: USGS 7.5-Minute Quadrangle for Ogden, Utah, 1992

SCALE 1:24,000

1 1/2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER



QUADRANGLE LOCATION

CONTOUR INTERVAL 40 FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

N

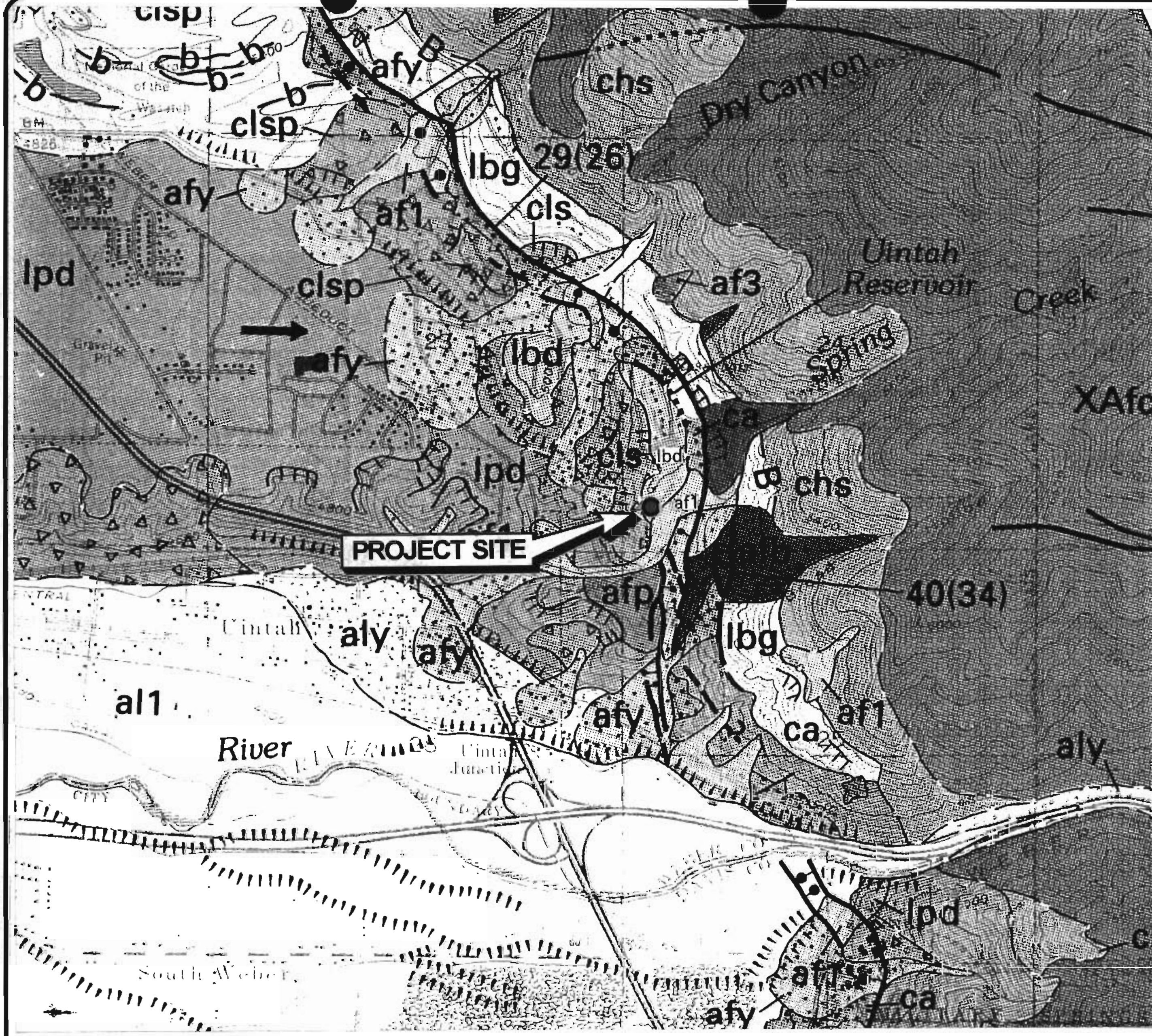
FIGURE 1 - PROJECT VICINITY MAP

1.25 MG Water Storage Reservoir

Town of Uintah, Utah

Job No. 61005034	Date: June 2000	Drawn By: dkf

Terracon



Reference: Nelson, A.,R. and Personius, S.F., 1993, Surficial geologic map of the Weber segment, Wasatch fault zone, Weber and Davis Counties, Utah: U.S. Geological Survey Miscellaneous Investigation Series Map I-2199, scale 1:50,000.

SCALE 1:24,000

1 — 1/2 — 0 — 1 MILE

1000 — 0 — 1000 — 2000 — 3000 — 4000 — 5000 — 6000 — 7000 FEET

1 — .5 — 0 — 1 KILOMETER

CONTOUR INTERVAL 40 FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

N

FIGURE 2 – GENERAL GEOLOGIC MAP

1.25 MG Water Storage Reservoir
Town of Uintah, Utah

Job No. 61005034	Date: June 2000	Drawn By: dkf

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FIGURE 3 - DESCRIPTION OF GEOLOGIC MAP UNITS

LACUSTRINE DEPOSITS

Deposits of the Provo (regressive) phase of the Bonneville lake cycle
(uppermost Pleistocene)

lpd **Deltaic deposits related to regressive phase**—Clast-supported pebble and cobble gravel interbedded with thin sand beds, and matrix-supported gravelly sands; moderate to well sorted; clasts subround to round, with weak carbonate cementation common. Deposited as foreset beds with original dips of 30°–35°. Commonly capped with <5 m of topset alluvium (unit **alp**), which is a less well sorted, silty to sandy, pebble and cobble gravel. Mapped at the mouths of North Ogden, Ogden, Weber, and Ward Canyons, and the canyon of Mill Creek

Deposits of the Bonneville (transgressive) phase of the Bonneville lake cycle
(uppermost Pleistocene)

lbd **Deltaic deposits related to transgressive phase**—Interbedded sand, silty sand, and gravelly sand; moderately to well sorted within beds; clasts subround to round. Mapped only north of the mouth of Weber Canyon; other deposits that existed in map area have been largely eroded by streams

lbg **Lacustrine sands and gravels related to transgressive phase**—Clast-supported pebble and cobble gravel with lesser amounts of matrix-supported gravelly sand; commonly interbedded with clean sand beds; well sorted within beds; clasts subround to round; may be carbonate cemented, especially along shorelines. Thin to thick bedded; bedding ranges from horizontal to original dips of as much as 15°. Forms constructional landforms such as beaches, bars, spits, and small deltas. Mapped between the Provo and Bonneville shorelines (1,475–1,591 m (4,840–5,220 ft)); commonly covered by hillslope colluvium (unit **chs**). Typically forms bench at the highest (Bonneville) shoreline, and several less well developed shorelines between the highest Bonneville and Provo shorelines in map area. Very sandy where mapped southeast of Bountiful

ALLUVIAL DEPOSITS

Stream alluvium deposits

al1 **Stream alluvium 1 (upper Holocene)**—Clast-supported pebble and cobble gravel, gravelly sand, and silty sand; moderately sorted; clasts subangular to round; thin to medium bedded. Deposited by perennial streams on modern flood plains and on low terraces <10 m above modern stream level. May include minor debris-flow deposits and colluvial deposits overlying alluvium along steep stream embankments. Widely distributed along North Ogden Canyon, Farmington Canyon, the canyon of Mill Creek, and North Canyon (south of Bountiful), and as a series of several low terraces at the mouth of Weber Canyon. Deposits in many canyons grade downvalley into large Holocene alluvial fans (units **af1** and **afy**)

aly **Younger stream alluvium, undivided (Holocene to uppermost Pleistocene)**—Undivided flood-plain and terrace gravel, sand, and silty sand that postdate regression of Lake Bonneville from the Provo level; moderately sorted; clasts subangular to round; thin to medium bedded. Deposited by streams on the modern flood plain and in terraces <10 m above modern stream level. May include minor debris-flow deposits and colluvial deposits overlying alluvium along steep stream embankments. Mapped in many drainages where upper Holocene alluvium (unit **al1**) was not distinguished from older postregressive phase alluvium of Holocene age (unit **al2**). Widely distributed in drainages west of the mountain front between Kaysville and the Weber River, near Ogden, and at the mouth of the Ogden River

Reference: Nelson & Personius, 1993, U.S. Geological Survey Map I-2199

Terracon

Form 101—1-87

FIGURE 3 - DESCRIPTION OF GEOLOGIC MAP UNITS (Cont.)

Alluvial-fan deposits

af1 **Fan alluvium 1 (upper Holocene)**—Clast-supported pebble and cobble gravel, locally bouldery, and matrix-supported gravelly and silty sand; poorly sorted; clasts angular to subround, with very rare well-rounded clasts derived from gravels of the Bonneville lake cycle; medium to thick bedded to massive. Deposited by intermittent streams, debris flows, and debris floods graded to modern stream level. Forms small, discrete fans on some of the older alluvial fans (units afy and af2), and large fans that bury lacustrine and older fan deposits at the mouths of many canyons throughout map area. Mapped units may contain small deposits of units cd1, al1, afy, and af2. No lacustrine shorelines occur on surfaces formed by this unit. Surfaces commonly bouldery; braided channel morphology is occasionally preserved on surfaces. Usually grades downslope into units afy or lbpm. Typical soil profiles range from A-Cn to A-Bw-Cox-Cn; a few profiles have stage I carbonate morphology (Machette, 1985)

afy **Younger fan alluvium, undivided (Holocene to uppermost Pleistocene)**—Undivided fan alluvium that postdates the regression of Lake Bonneville from the Provo level. Mapped in areas where both units af1 and af2 occur, but are too small to map separately; also mapped where the age of Holocene fan deposits has not been determined

afp **Fan alluvium related to regressive phase of the Bonneville lake cycle (uppermost Pleistocene)**—Clast-supported pebble and cobble gravel, locally bouldery, and gravelly sand; poor to moderately sorted; clasts angular to well rounded; medium to thick bedded to massive. Deposited by streams associated with the Provo (regressional) phase of the Bonneville lake cycle. Reworked in part from deltaic or fan-delta deposits. Forms fans graded to the Provo shoreline, and other regressional shorelines above the modern flood plain. Regressional shorelines locally preserved on the surfaces of fans graded to levels below the Provo shoreline. Preserved mostly as remnants at mouths of larger canyons; Holocene stream and fan alluvium overlaps or fills channels cut in deposits of unit afp. Includes small areas of colluvium on fan remnants. Typical soil profiles range from A-Bw-Cox-Cn to A-Bt-Cox-Cn

afb **Fan alluvium related to transgressive phase of the Bonneville lake cycle (uppermost Pleistocene)**—Clast-supported pebble and cobble gravel, locally bouldery, and gravelly sand; poorly sorted; clasts angular to subangular; medium to thick bedded to massive. Forms fans graded to levels of the transgressive phase of Lake Bonneville. Commonly covered by thin deposits of younger alluvium and colluvium. Mapped at the mouths of several small canyons just north and south of the Weber River and at the southern boundary of the Weber segment. Typical soil profiles range from A-Bt(weak)-Cox-Cn to A-Bt/Bk-Cox-Cn; some have stage II+ carbonate (Machette, 1985)

COLLUVIAL DEPOSITS

chs **Hillslope colluvium (Holocene to upper Pleistocene)**—Pebble, cobble, and boulder gravel, gravelly sand, silty sand, and sandy silt; usually unsorted, unstratified; clasts usually angular to subangular, but may contain rounded gravel from lacustrine units of the Bonneville lake cycle. Includes small debris-flow, talus, and landslide deposits too small to map. Deposited by surface wash, creep, and other mass-wasting processes on moderate to steep mountain slopes and along stream valleys in steep-sided canyons. Units >1 km from the Wasatch fault zone are compiled from previous maps and 1:60,000-scale aerial photographs

Reference: Nelson & Personius, 1993, U.S. Geological Survey Map I-2199

FIGURE 3 - DESCRIPTION OF GEOLOGIC MAP UNITS (Cont.)

COLLUVIAL DEPOSITS

clsp **Lateral-spread deposits (Holocene to upper Pleistocene)**—Pebble gravel, sand, silt, and minor clay of the Bonneville lake cycle and younger lacustrine, marsh, and alluvial deposits; redeposited by lateral spreading as a result of liquefaction. Bedding commonly contorted, or often tilted within large landslide blocks. Upper parts of failures have headscarps, elongate grabens and ridges parallel to the headscarps, and undrained depressions between the ridges. Lower (distal) parts of failures are characterized by hummocky topography. Much of the redeposited material consists of units lbpm and ly. Major areas of these deposits are mapped on north and south edges of Ogden (Miller, 1980) and west of Farmington (Van Horn, 1975). Two large deposits in the southwestern corner of map area west of Bountiful were recognized on aerial photographs by Van Horn (1982). The northern lateral spread appears to truncate the southern lateral spread; the contact between the two is drawn on differences in vegetation and the degree of preservation of hummocky topography. Both deposits west of Bountiful partly cover the Gilbert shoreline, indicating both lateral spreads formed <10,500 years ago

cls **Landslide deposits (Holocene to middle Pleistocene)**—Unsorted, unstratified deposits that range in size from small slump-earthflows of clay and silt to massive slides of boulder-rich, open-work gravels and bedrock blocks; texture reflects that of deposits in source area. Usually deposited on relatively steep slopes. Includes many small areas of alluvium and colluvium; many small areas are unmapped or are included in units chs and clsp. Units >1 km from the Wasatch fault zone are compiled from previous maps and 1:60,000-scale aerial photographs; many old (pre-Bonneville lake cycle) landslides are not mapped

ca **Colluvium and alluvium, undivided (Holocene to middle Pleistocene)**—Gravel, sand, silt, and clay; texture reflects that of deposits directly upslope. Generally poorly sorted; commonly massive. Unit consists of stream and fan alluvium, hillslope colluvium, and small landslide and talus deposits; also mapped near the base of large fault or landslide scarps. Mapped mainly from aerial photography, except immediately adjacent to some fault scarps (includes unit cfs of Machette, 1989)

BEDROCK

XAfc **Farmington Canyon Complex (Early Proterozoic and Archean)**—Consists of high-grade metamorphic rocks; makes up most of the bedrock in the Wasatch Range south of Taylor Canyon

Reference: Nelson & Personius, 1993, U.S. Geological Survey Map I-2199

FIGURE 3 - DESCRIPTION OF GEOLOGIC MAP UNITS (Cont.)

MAP SYMBOLS

Contact—Dashed where approximately located; dotted and dashed between geomorphic features of different relative ages within same map unit

7(6) **Normal fault**—Bar and solid ball on downdropped side along Wasatch fault zone; bar and hollow ball along other faults in bedrock (where sense of displacement is known). Dashed where approximately located; dotted where concealed; queried where tectonic origin is uncertain. Height of fault scarp and amount of vertical offset of geomorphic surface (in parentheses) shown in meters

Thrust fault—Sawteeth indicate overriding plate or block (mapped in bedrock only). Dashed where approximately located; dotted where concealed

30 **Strike and dip of beds**

Major shorelines related to levels of Bonneville lake cycle—May coincide with geologic contacts

B **Highest shoreline of Bonneville (transgressive) phase**

b **Other shorelines of Bonneville phase**

P **Highest shoreline of Provo (regressive) phase**

p **Other shorelines of Provo phase**

G **Highest shoreline of Gilbert phase**

X **Undesignated shorelines of Bonneville lake cycle**

Topographic crest of major lacustrine bar or spit

Topographic escarpment—Escarpments along stream channels, terraces, and deltas; formed primarily by fluvial processes. Hachures face upslope. May coincide with geologic contacts

Landslide escarpment—Major headscarps and (or) fissures in landslides (unit cls), lateral-spread deposits (unit clsp), alluvial deposits (units af1 and afy), and lacustrine deposits (unit lbpm). Hachures face downslope. May coincide with geologic contacts

Paleostream channel—Preserved margin of abandoned stream channel or debris-flow levee. Arrows near outer margin of feature

Tilted geomorphic surface—Arrow points in general direction of downward tilt

lps/clsp **Thin surficial deposit (upper unit symbol) covering older unit (lower unit symbol)**—For example, lps/clsp indicates thin lacustrine sands (lps) overlying lateral-spread deposits (clsp)

Reference: Nelson & Personius, 1993, U.S. Geological Survey Map I-2199

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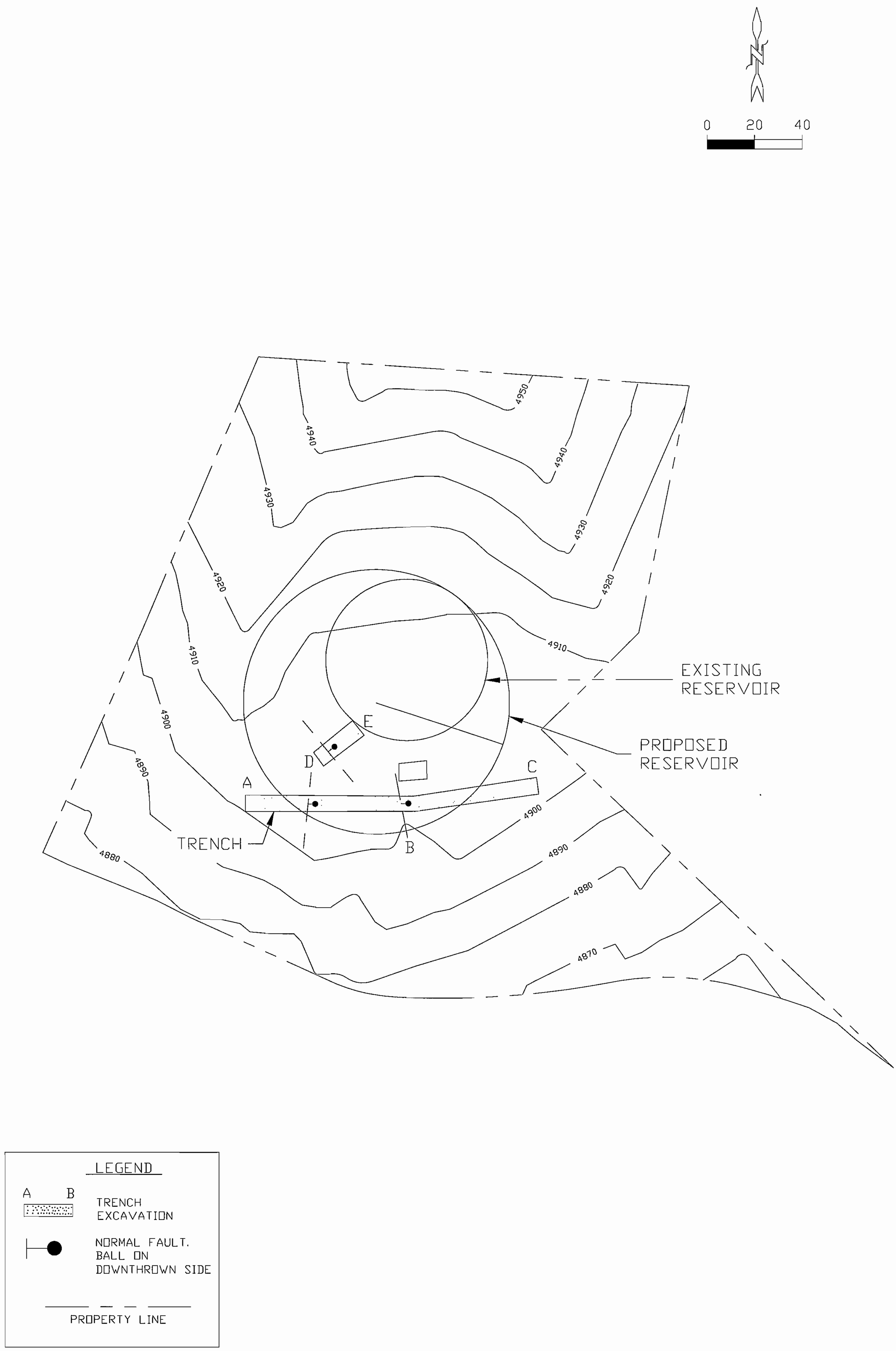

FIGURE 4 SITE MAP

UINTAH WATER STORAGE RESERVOIR

JOB NO. 61005034	DATE: JUNE 2000	DRAWN: TLC	SHEET: 1

Terracon

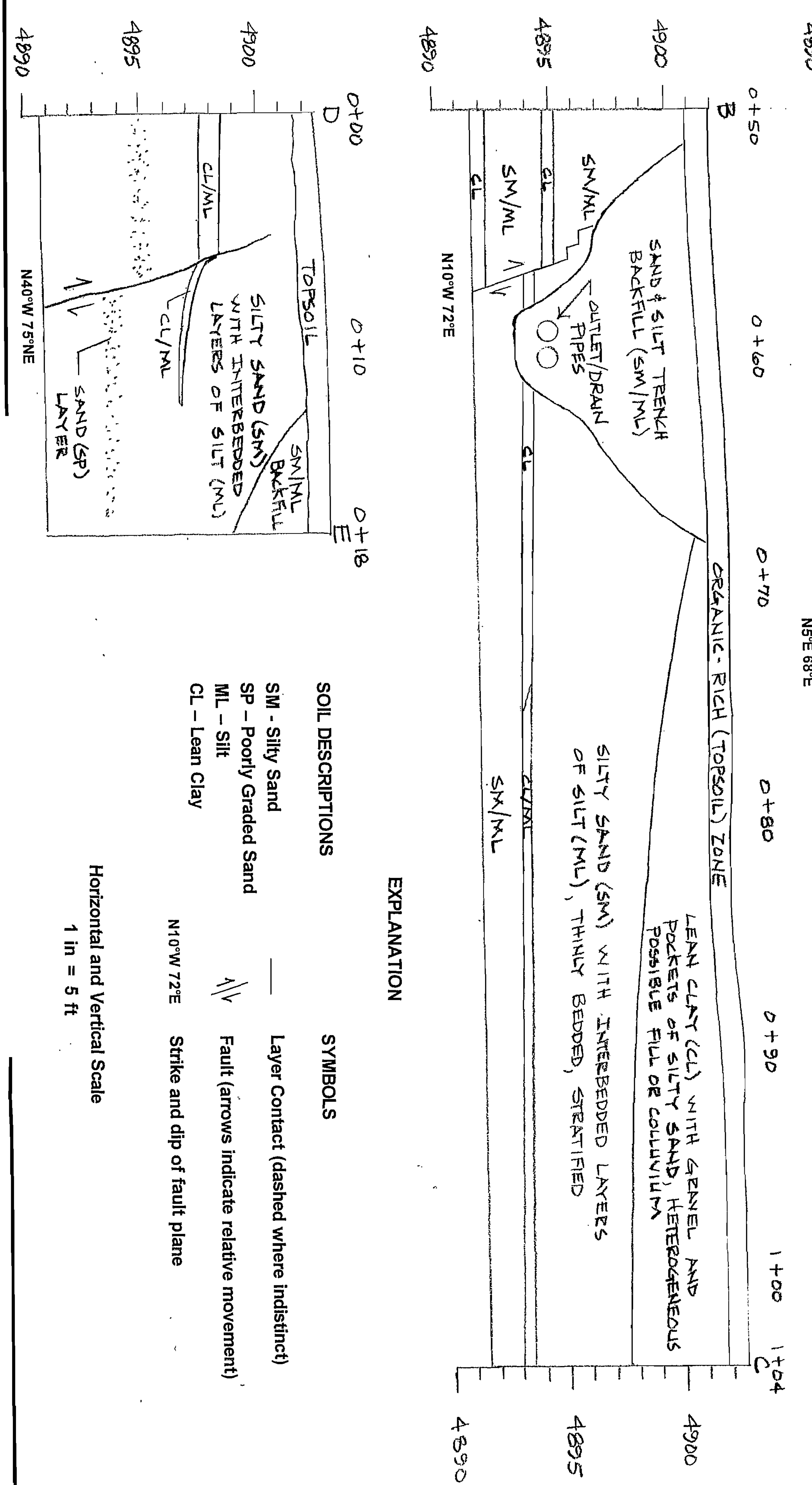

FIGURE 5 – TRENCH LOGS
UINTAH WATER STORAGE RESERVOIR
WEBER COUNTY, UTAH

Job # 61005034	Date June 2000	Drawn dkf	Scale 1 in = 5 ft

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Form 149—10-85

Photo 1. View facing south along Wasatch Front. Project area with existing reservoir in foreground.

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Photo 2. View of trench from west to east. Note flexure/offset of dark brown clay layer in lower center at trench Sta 0+23. Total vertical offset of about 12 inches over a horizontal distance of 5 feet.

Photo 3. Close up view of offset bedding at Sta 0+23. Dark brown clay layer offset about 9 inches vertically. Trowel on downthrown side (east).

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Photo 4. Bedding offset at trench Sta 0+23. Trowel on downthrown (east) side.

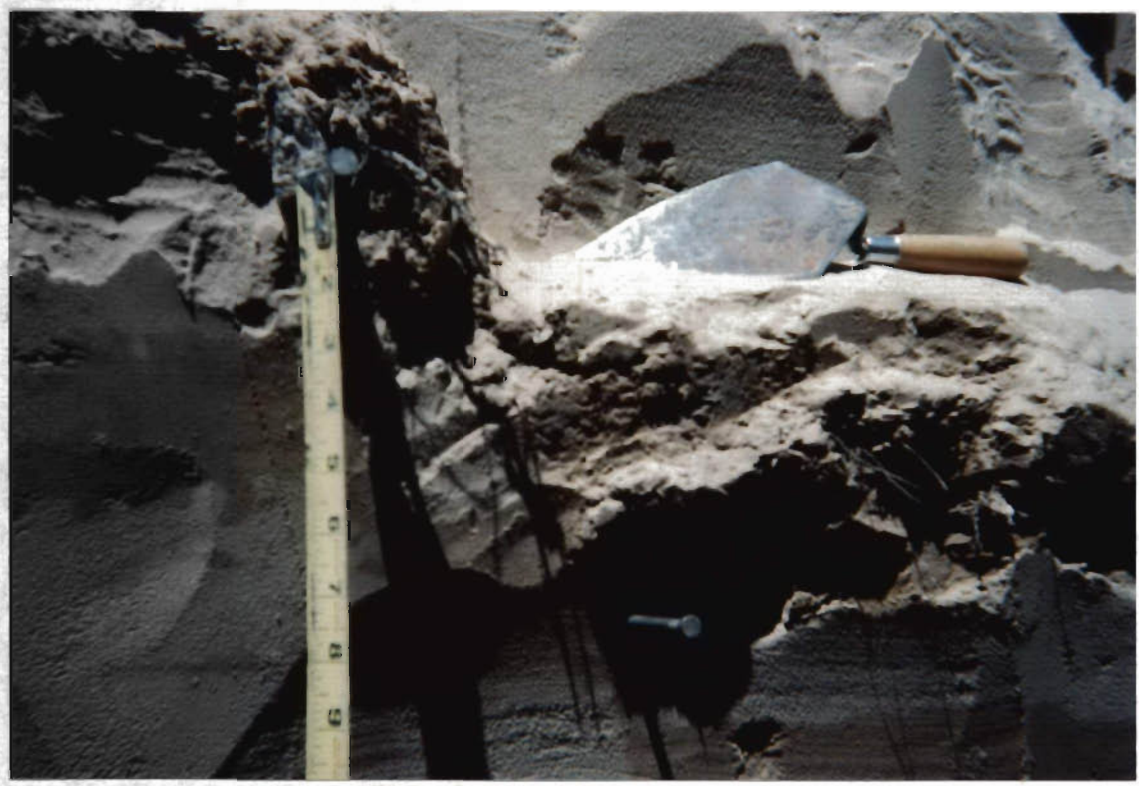

Photo 5. Close up of bed offset at Sta 0+23. Tape measure and trowel for scale.

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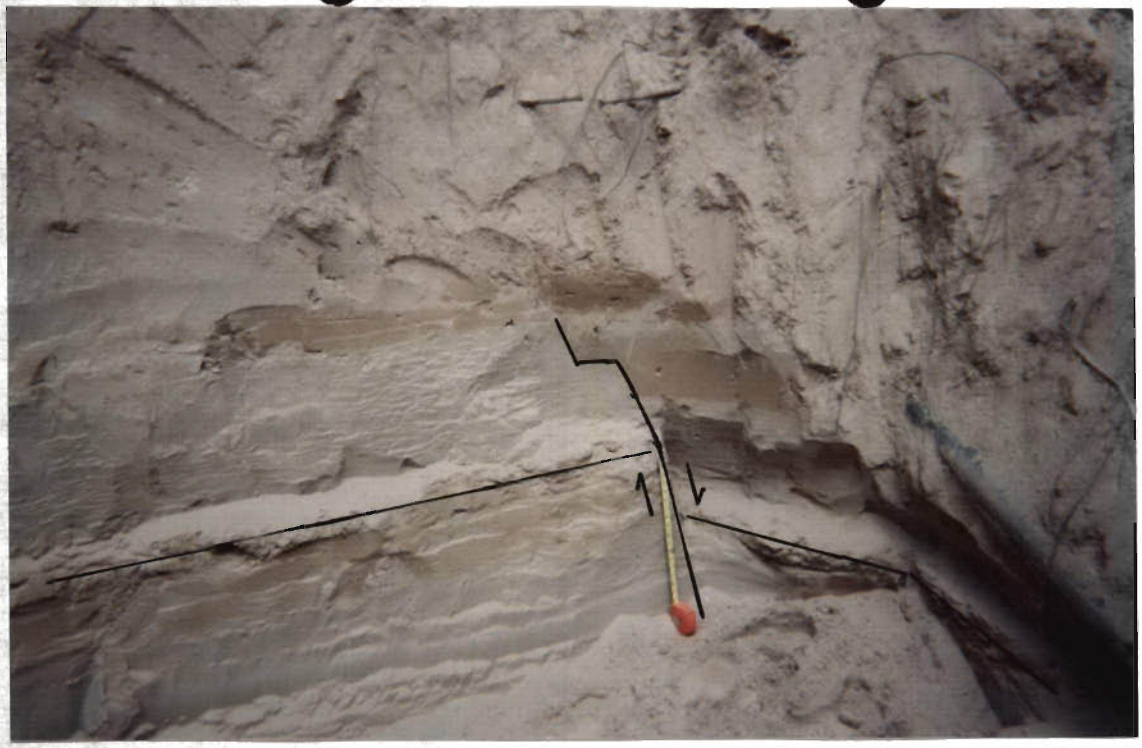


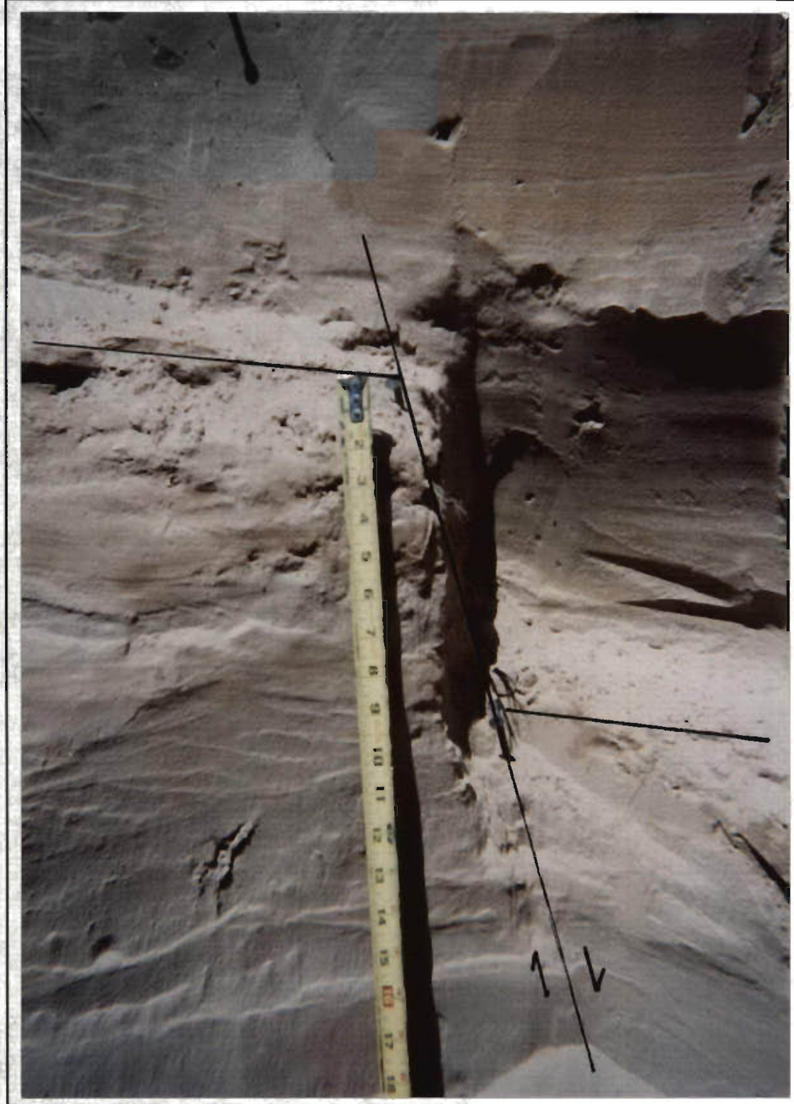
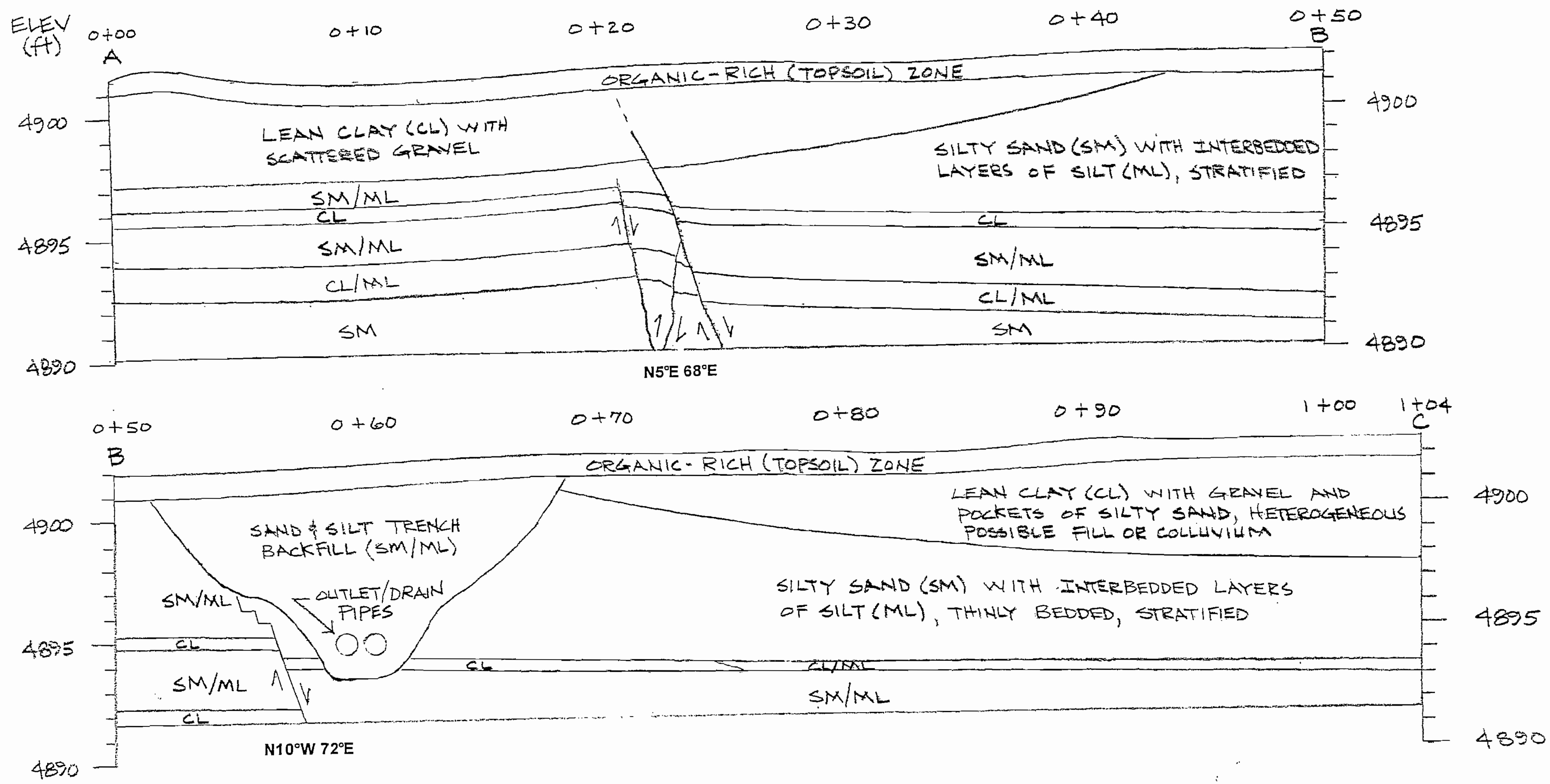
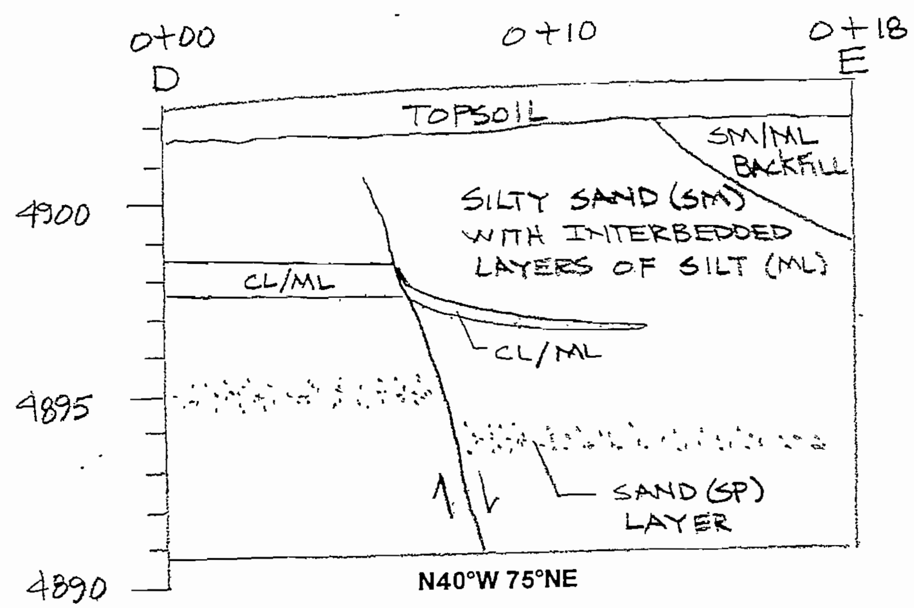


Photo 6. (Above) Stepped offset of bedding at Sta 0+57. Reservoir outlet and drain pipes at right of photo. Total vertical offset of lower clay layer is approximately 10 inches.

Photo 7. Close up view of lower clay layer with nails marking top of bed. Right side (east) is displaced downward approximately 10 inches.





EXPLANATION

SOIL DESCRIPTIONS

SM - Silty Sand
SP – Poorly Graded Sand
ML – Silt
CL – Lean Clay

SYMBOLS

——	Layer Contact (dashed where indistinct)
⇅	Fault (arrows indicate relative movement)
N10°W 72°E	Strike and dip of fault plane

Horizontal and Vertical Scale
1 in = 5 ft

FIGURE 5 – TRENCH LOGS
UINTAH WATER STORAGE RESERVOIR
WEBER COUNTY, UTAH

Job #	Date	Drawn	Scale
61005034	June 2000	dkf	1 in = 5 ft

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Form 149—10-85

UNIFIED SOIL CLASSIFICATION SYSTEM

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A]				Soil Classification	
				Group Symbol	Group Name[B]
Coarse-Grained Soils More than 50% retained on No. 200 sieve	Gravels More than 50% of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5% fines[C]	$Cu \geq 4$ and $1 \leq Cc \leq 3$[E]	GW	Well-graded gravel[F]
			$Cu < 4$ and/or $1 > Cc > 3$[E]	GP	Poorly graded gravel[F]
		Gravels with Fines More than 12% fines[C]	Fines classify as ML or MH	GM	Silty gravel[F, G, H]
			Fines classify as CL or CH	GC	Clayey gravel[F, G, H]
	Sands 50% or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5% fines[E]	$Cu \geq 6$ and $1 \leq Cc \leq 3$[E]	SW	Well-graded sand[I]
			$Cu < 6$ and/or $1 > Cc > 3$[E]	SP	Poorly graded sand[I]
		Sands with Fines More than 12% fines[D]	Fines classify as ML or MH	SM	Silty sand[G, H, I]
			Fines classify as CL or CH	SC	Clayey sand[G, H, I]
Fine-Grained Soils 50% or more passes the No. 200 sieve	Silts and Clays Liquid limit less than 50	inorganic	PI > 7 and plots on or above "A" line[J]	CL	Lean clay[K, L, M]
			PI < 4 or plots below "A" line[J]	ML	Silt[K, L, M]
		organic	Liquid limit — oven dried / Liquid limit — not dried < 0.75	OL	Organic clay[K, L, M, N]
					Organic silt[K, L, M, O]
	Silts and Clays Liquid limit 50 or more	inorganic	PI plots on or above "A" line	CH	Fat clay[K, L, M]
			PI plots below "A" line	MH	Elastic silt[K, L, M]
		organic	Liquid limit — oven dried / Liquid limit — not dried < 0.75	OH	Organic clay[K, L, M, P]
					Organic silt[K, L, M, Q]
Highly organic soils	Primarily organic matter, dark in color, and organic odor			PT	Peat

[A]Based on the material passing the 3-in. (75-mm) sieve.

[B]If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C]Gravels with 5 to 12% fines require dual symbols:
GW-GM well-graded gravel with silt
GW-GC well-graded gravel with clay
GP-GM poorly graded gravel with silt
GP-GC poorly graded gravel with clay

[D]Sands with 5 to 12% fines require dual symbols:
SW-SM well-graded sand with silt
SW-SC well-graded sand with clay
SP-SM poorly graded sand with silt
SP-SC poorly graded sand with clay

[E]$Cu = D_{60}/D_{10}$ $\quad Cc = \dfrac{(D_{30})^2}{D_{10} \times D_{60}}$

[F]If soil contains ≥ 15% sand, add "with sand" to group name.

[G]If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H]If fines are organic, add "with organic fines" to group name.

[I]If soil contains ≥ 15% gravel, add "with gravel" to group name.

[J]If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

[K]If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel", whichever is predominant.

[L]If soil contains ≥ 30% plus. No. 200 predominantly sand, add "sandy" to group name.

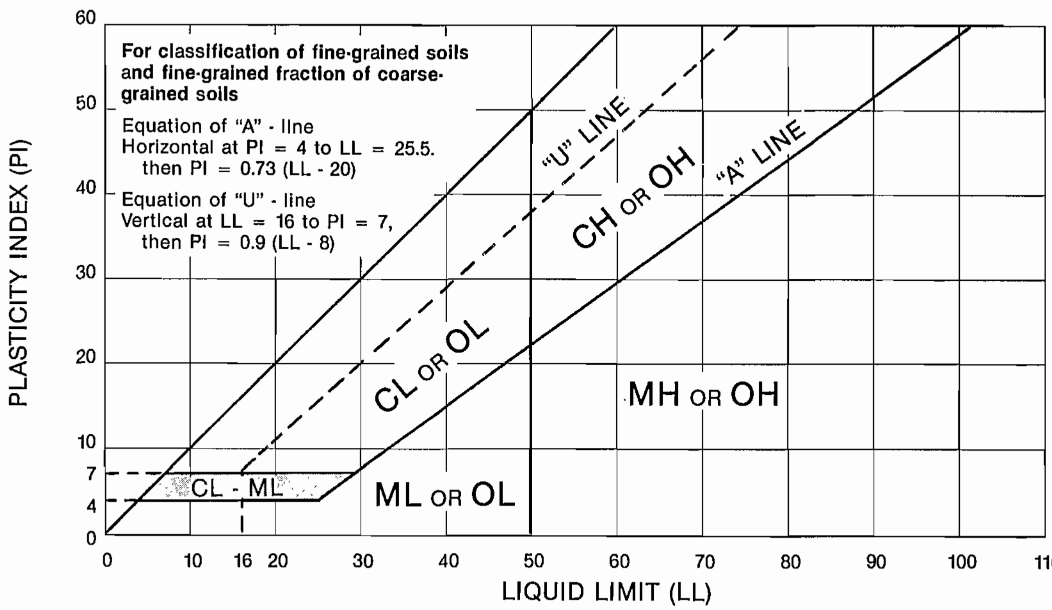
[M]If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N]PI ≥ 4 and plots on or above "A" line.

[O]PI < 4 or plots below "A" line.

[P]PI plots on or above "A" line.

[Q]PI plots below "A" line.



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GEOTECHNICAL STUDY
UINTAH WATER TANK
UINTAH, UTAH

PREPARED FOR:

UINTAH CITY
c/o JONES & ASSOCIATES
4768 S. HARRISON BLVD.
OGDEN, UTAH 84403

ETE JOB NO.: 99E-419

AUGUST 30, 1999

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1.0 INTRODUCTION

125 W. 8.

We understand Uintah City plans to remove an existing small water storage tank and replace it with a larger 2 million gallon water tank. The tank site is located at approximately 6200 East Bybee Drive in Uintah, Utah.

This study was made to assist in evaluating the subsurface conditions and engineering characteristics of the foundation soils and developing our opinions and recommendations concerning appropriate foundation support and cut slope stability. This report presents the results of our geotechnical investigation including field exploration, engineering analysis and our opinions and recommendations. Data from the study is summarized on Figures 1 through 8.

2.0 CONCLUSIONS

1. The subsurface materials at this site generally consist of medium dense silty sand (SM) which extends beyond the maximum depth explored of 21.5 feet below existing tank base. Groundwater was not encountered at the time of drilling.

2. The native sands at this site should provide adequate to support for ring footings and roof columns with an allowable bearing capacity of 2500 psf. A one third increase can be applied for transient loads such as wind and earthquake forces.

3. To maintain stability of the site slopes we recommend the water tank footings have a minimum horizontal setback distance of 20 feet from the face of the hillside slope. The cut slope north of the tank should be no steeper than 2.25:1 (Horizontal:Vertical) to maintain a 1.5 factor of safety against slope movement.

3.0 PROPOSED CONSTRUCTION

We understand that the existing tank on the site will be razed and replaced with a 2 million gallon capacity concrete water tank For design purposes we estimated the ring wall loadings will be between 3 and 5 klf. If our assessment of the tank in not correct, then we should be notified and allowed to reevaluate our recommendations.

4.0 SITE CONDITIONS

The property is located on the north side of Bybee Drive. The site currently supports an existing concrete water tank which is to be removed to make room for the new tank. The existing tank is located on a pad which has an average downward slope to the south of about 5 to 10 percent. The grade to the south steepens to about 31 and 33 percent down to Bybee drive. The ground surface to the east drops at about 30 percent into a drainage. To the west and north of the tank pad the grade rises at about 28 to 35 percent with portions that have been cut steeper immediately around the tank pad. A small valve house is located south of the existing tank. The site is covered with native brush and grasses. There is residential development to the south and west of the site and heavily vegetated vacant ground to the north and east. The surrounding residences appears to be preforming adequately from a foundation viewpoint based on a visual observation. The existing tank has some cracking in the walls and it appears the roof is slightly crowned. At this point we can't tell if the roof crown is the result of differential settlement if the ring walls with respect to the center roof support column or if the roof was simply placed that way. Although the site is located in an areas designated as a possibly experiencing lateral spread movement we found no evidence of localized slope movement or toe spreading on the subject property.

5.0 FIELD INVESTIGATION

The field investigation consisted of drilling a test hole to a depth of 21.5 feet at the approximate location shown on Figure 2. Before drilling the area drilled was excavated down to the estimated floor elevation of the existing tank. The soils encountered at the site were continuously logged by an engineering technician from our office. Disturbed samples were obtained and returned to our office. A graphical representation of the soils encountered in the boring is shown on Figure 3 , Drill Hole Log, with a key to the symbols used on the log presented in Figure 4.

Samples obtained from the test hole were sealed and returned to our laboratory where each one was inspected to confirm field classification in accordance with the Unified Soil Classification System. Because of the granular nature of the soils classification could be made without additional laboratory testing and soil parameters were based on field standard penetration data. The samples gathered will be retained in our laboratory for 30 days following the date of this report at which time they will be disposed of unless a written request for additional holding time is received prior to the disposal date.

6.0 SUBSURFACE CONDITIONS

The subsurface materials at this site generally consist of medium dense, fine to medium grained silty sand (SM) which extends beyond the maximum depth explored of 21.5 feet. Groundwater was not encountered at the time of drilling. A graphical representation of the soils encountered is shown on Figure 3, Drill Hole Log.

7.0 SITE GRADING

Debris from the existing tank, topsoil (although none was encountered), man-made fill (if encountered) and soils loosened by construction activities should be removed (stripped) from the tank area. Following stripping and any required excavation the subgrade should be proof rolled to a firm, non-yielding surface. Soft spots identified during the proof rolling should be removed up to 18 inches deep and replaced with structural fill. Where soft soils extend deeper than 18 inches the area should be stabilized with a geo-fabric such as Mirafi 600X and an angular, coarse gravel and cobble (6 inch minus) stabilization fill.

All fill placed below the tank should be structural fill. All other fills should be considered as backfill. Structural fill should consist of imported material. Imported material should consist of well-graded sandy gravels with a maximum particle size of 3 inches and 5 to 15 percent fines (materials passing the No. 200 sieve). The liquid limit of fines should not exceed 35 and the plasticity index should be below 15. All fill soils should be free from topsoils, organics, debris and other deleterious materials. Structural fill should be placed in maximum 8-inch thick loose lifts at a moisture content within 2 percent of optimum and compacted to at least 95 percent of maximum density (ASTM D 1557) under structure and 90 percent under any pavements or concrete flatwork.

Groundwater was not encountered in our test holes; however, in this area there could be unknown isolated springs or zones of perched water. If wet areas are encountered we should be immediately notified and allowed to evaluate the situation. It should be anticipated that if springs or perched water areas are found they will need to be collected in drains and the water removed from the site.

The native sands may be used as backfill in utility trenches, grading for access drives and against outside tank walls. Backfill should be placed in lift heights suitable to the compaction equipment used and compacted to at least 90 percent density (ASTM D 1557). Trenches over 4 feet deep should be shored prior to allowing personnel to enter and all OSHA safety requirements should be followed.

8.0 SEISMIC CONSIDERATIONS

Based on the Weber County Potential-Fault rupture sensitive area overlay mapping conducted by Mike Lowe 1988, this site is located on the west border of the Wasatch Fault rupture influence zone. There are no faults mapped directly under the tank with the nearest surface rupture trace located about 400 feet southeast of the project site. The fault rupture zone is an offset from existing faults showing the area with a higher likelihood of having fault ruptures from future earthquake events. The tank is located in an area designated as "Zone 3" by the Uniform Building Code. The tank should meet the appropriate seismic requirements for this area using a soil profile type of S_E. A maximum credible acceleration of 0.6g may occur at this site. The maximum acceleration with a 90% probability of not being exceeded within 50 years is 0.25g.

Liquefaction is a phenomenon where soils lose their intergranular strength due to the increase of pore pressures during a dynamic event such as an earthquake. The sands at this site are not saturated and therefore are not susceptible to liquefaction within the depth investigated; however, the area has been tagged as having potential for lateral spread which could be the result of deep liquefaction.

9.0 FOUNDATIONS

Based on field observations, the existing sands at this site should provide suitable support the expected tank loads. The recommendations presented below should be followed during design and construction of this project:

1. Spread footings founded on undisturbed native sands should be designed for a maximum allowable soil bearing pressure of 2500 psf. A one-third increase is allowed for short term transient loads such as wind and seismic events. Footings should be uniformly loaded.

2. The ring wall footings should be set at least 20 horizontal feet from the face of the slope.

3. Exterior footings subject to frost should be placed at least 30 inches below final grade. Footings not subject to frost should be placed with at least 18 inches of cover.

4. The tank ring wall should be well reinforced. We recommend the steel be designed as a simply supported beam spanning a space of 12 feet.

5. The bottom of footing excavations should be compacted with 4 passes of a hand thumper or other approved compactor to densify soils loosened during excavation and to identify soft spots. If soft areas are encountered the soft soil should be removed and replaced with structural fill. If the soft soils extend more than 18 inches deep the area should be overexcavated by 18 inches and stabilized as discussed in Section 7.0 of this report.

During first filling a uniform settlement of between 1 to 2 inches should be expected. If the structure is designed and constructed in accordance with the recommendations presented above the risk of total differential movement exceeding 0.5 inch for a 25-foot span will be low. Greater settlement should be expected during a strong, long duration earthquake.

10.0 SURFACE DRAINAGE

Wetting of the foundation soils will generally cause some degree of volume change within the soil and should be prevented both during and after construction. We recommend that the final ground surface be graded to drain away from the structure in all directions. We recommend a minimum fall of 8 inches in the first 10 feet. A water collection system below and around the tank to intercept and discharge leaks from the tank is also recommended.

11.0 LANDSLIDE POTENTIAL

An inspection of the site was conducted by the undersigned engineer (E.I.T.). Although the site is in an area designated as having potential lateral spread movement on the Weber County slope failure inventory map prepared by Mike Lowe 1988, no visually evident signs of currently unstable slopes were found and no slumping of the existing slopes were evident. Springs have been mapped below the hillside but none were evident on the property during our investigation. Based on grain size and the subangular nature of the sands it is our opinion that the silty sands at the site have a moderate angle of internal friction.

To evaluate the stability of the existing site, at the location of the planned water tank, a slope stability analysis was conducted with the XSTABLE computer program which uses the modified Bishop's method of slices in the analysis. Assuming an angle of internal friction of 33 degrees and no cohesive strength for the silty sand soils we found a static factor of safety against slope failure of 1.20 and 1.15 for the lower slope to the south and the upper slope to the north respectively. When subjected to an earthquake loading of 0.15g the factor of safety reduces to 0.88 and 0.85 respectively. These factors of safety are below acceptable engineering standards.

We recommend that the edge of the footing should be placed no closer than 20 horizontal feet from the face of the slope which drops below the tank pad. The static factor of safety of a slope failure extending deep enough to effect the tank is 1.59 and 1.1 when subjected to an earthquake loading of 0.15g. The slopes extending upward from the tank should be cut to a slope of 2.25:1 (H:V). This increases the static factor of safety against slope failure above the structures to 1.55 and 1.09 when subjected to an earthquake loading of 0.15g. These factors of safety are within acceptable engineering standards.

Setback

12.0 TANK WALLS AND RETAINING WALLS

We understand that the tank may be set into the slope and partially buried. If this is the case the walls not only need to be designed to withstand internal hydrostatic loads when full but must also withstand the soil loads when empty. You may also have to retain the slope rising above the tank if a 2.25:1 slope cannot be achieved. The soil load is dependent on the amount of movement the walls can have and on the slope of the backfill behind the wall. Assuming the backfill slope is no steeper than 30 degrees from the horizontal the lateral earth pressure can be determined using an equivalent fluid weight of 60 pcf for walls that can move sufficiently to achieve active pressure (0.1 percent of the wall height) and 84 pcf for walls that cannot move. If foundation drains are placed behind the walls hydrostatic loading from saturated soils need not be considered

The lateral loads on the tank will be resisted by friction between the tank and the native soils and by passive pressure from soils on the down slope side of the tank. A coefficient of friction of 0.33 may be used for the native soils at this site. A passive pressure may be approximated using an equivalent fluid unit weight of 250 pcf. An appropriate factor of safety (at least 2) should be used on resisting forces.

13.0 GENERAL CONDITIONS

The exploratory data presented in this report were collected to provide geotechnical design recommendations for this project. Variations from the conditions portrayed in the test hole may occur and could be sufficient to require modifications in the design. Thus it is important that we observe subsurface materials exposed after stripping and in the excavations to take advantage of the opportunity to identify unusual soil conditions which could influence the performance of the facilities being planned. An experienced geotechnical engineer or technician from our office should observe site preparation activities and conduct testing as required to confirm the use of proper procedures.

Further, we recommend that plans and specifications be reviewed by our office to determine if the recommendations presented in this report were understood and properly implemented.

The geotechnical study as presented in this report was conducted within the limits prescribed by our client, with the usual thoroughness and competence of the engineering profession in the area. No other warranty or representation, either expressed or implied, is intended in our proposals, contracts or reports.

We appreciate the opportunity of providing our services on this project. If we can answer questions or be of further service, please call.

Respectfully;
EARTHTEC TESTING AND ENGINEERING, P.C.

REGISTERED PROFESSIONAL ENGINEER
168431
ROBERT E
BARTON
8-27-99
STATE OF UTAH

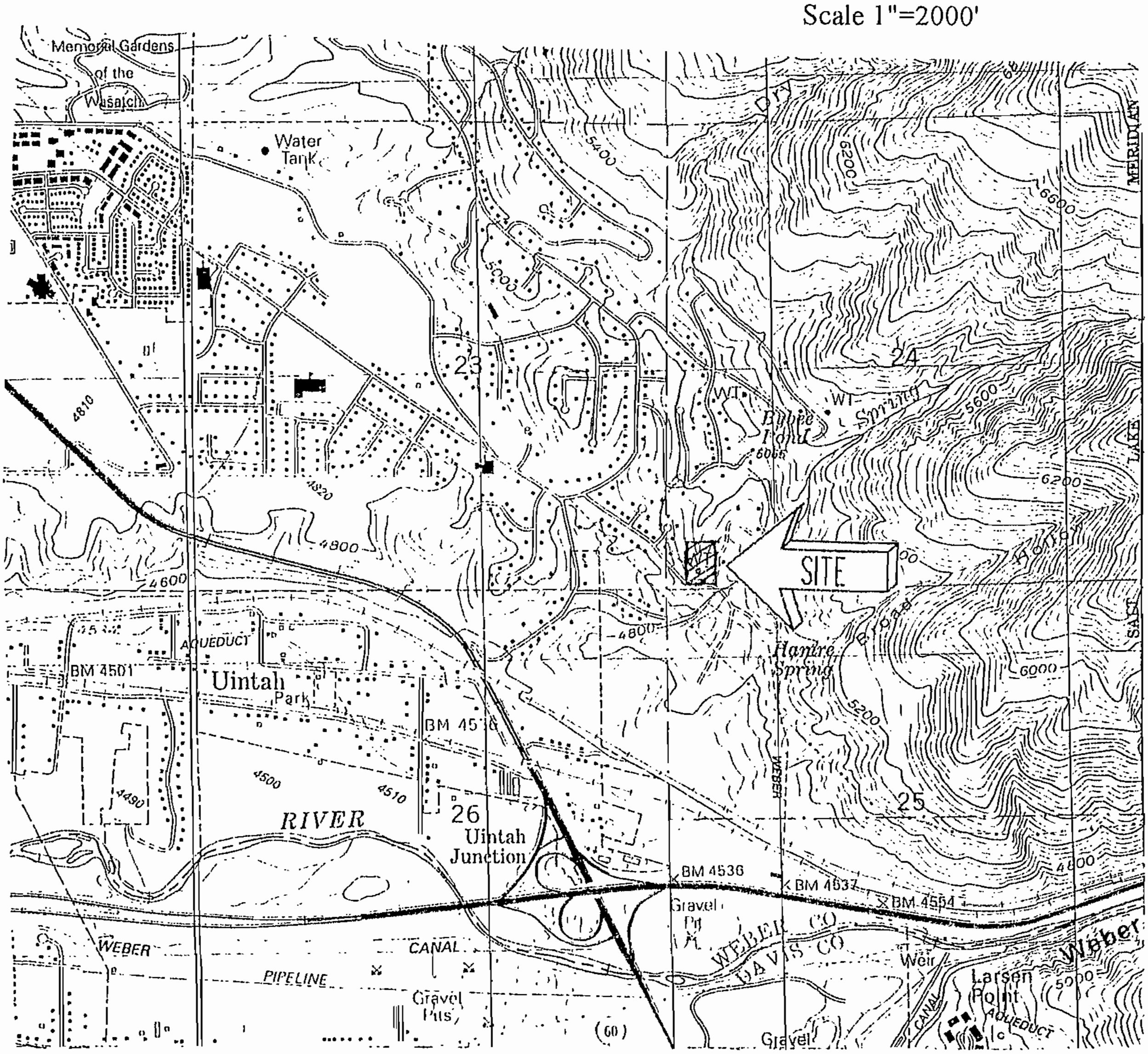
Robert E. Barton, P.E.
Principal Engineer

3 copies sent

EARTHTEC ENGINEERING

North

Scale 1"=2000'

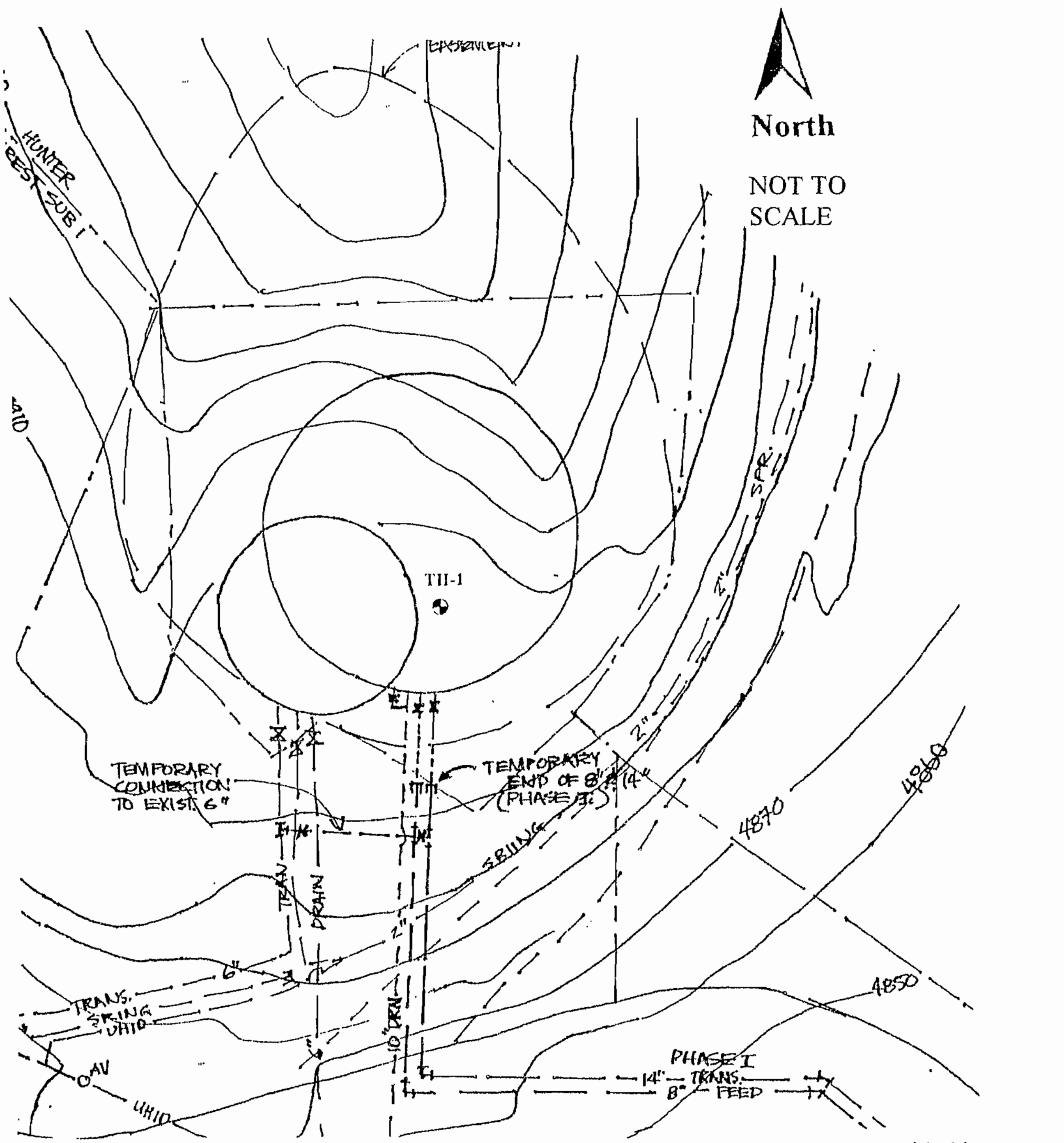


BASE MAP TAKEN FROM
USGS 7.5' "OGDEN"
QUADRANGLE

VICINITY MAP

ETE JOB NO. 99E-419 **FIGURE 1**

EARTHTEC ENGINEERING



Base map provided by
Jones & Associates

SITE PLAN SHOWING LOCATION OF TEST HOLES

ETE JOB NO. 99E-419 **FIGURE 2**

DRILL HOLE LOG

BORING NO.: TH-1

PROJECT: Uintah Water Tank
CLIENT: Uintah City
LOCATION: East of Existing Tank
DRILLER: All Seasons Drilling
DRILL RIG: ATV mounted drill rig
DEPTH TO WATER > INITIAL ∇ : none ft. **AT COMPLETION** ▼ :

PROJECT NO.: 99E-419
DATE: 8/20/99
ELEVATION: NM
LOGGED BY: Jay Yahne

Depth (Ft.)	Graphic Log	USCS	Description	Samples	Blows/ Foot	TEST RESULTS: PL ├──┤ LL; Water Con. - ●; Blows - ▨ (10 20 30 40 50)	Dry Dens. pcf	Water Cont. %	Gravel %	Sand %	Fines %	Torvane Cohesion (psf)	Other Tests
0		SM	Silty Sand, with occasional clay seams, medium dense, moist, brown	▌	19								
4				▌	10								
8				▌	12								
				▌	13								
12													
16			N Avg = 14.5 (15)	▌	14								
20				▌	19								

Notes:

Tests Key:
A = Atterberg Limits
C = Consolidation
G = Gradation
DS = Direct Shear
SO = Solubility
UC = Unconf. Compress. Strength

KEY TO SYMBOLS

Symbol Description

Strata symbols

Silty sand

Misc. Symbols

Water table during drilling

Water table at boring completion

Soil Samplers

Standard penetration test

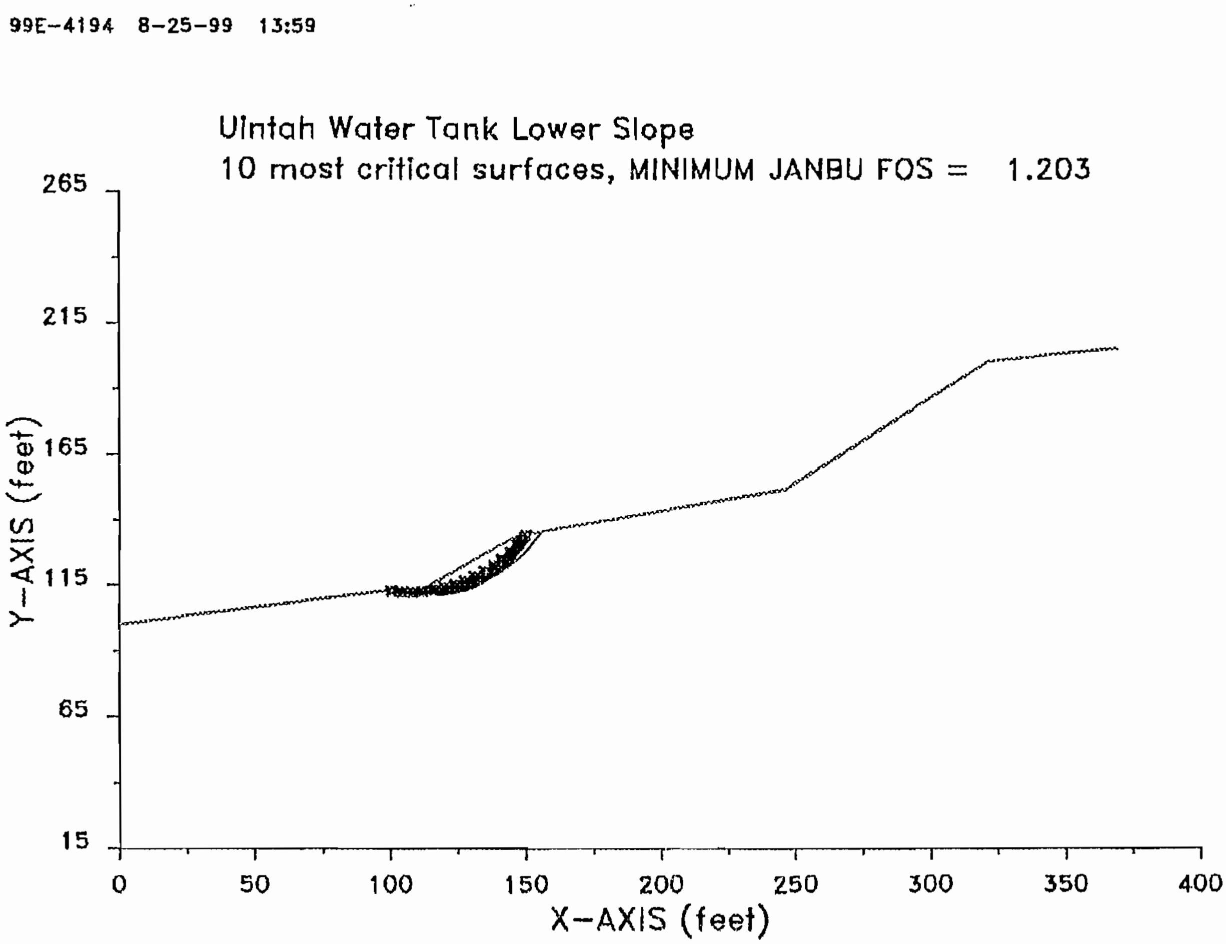
Notes:

1. Exploratory boring was drilled on 8/20/99 using a 3-inch diameter solid stem continual flight auger on an ATV mounted drill rig.
2. Free water was not encountered at the time of drilling.
3. Boring location was appoximated from existing features.
4. This log is subject to the limitations, conclusions, and recommendations in this report.

FIGURE NO.: 4

EARTHTEC ENGINEERING

Soil Layer	*Moist Unit Wt. (pcf)*	*Sat. Unit Wt. (pcf)*	*Cohesion (psf)*	*Friction Angle (degrees)*
1	*120*	*125*	*0*	*32*



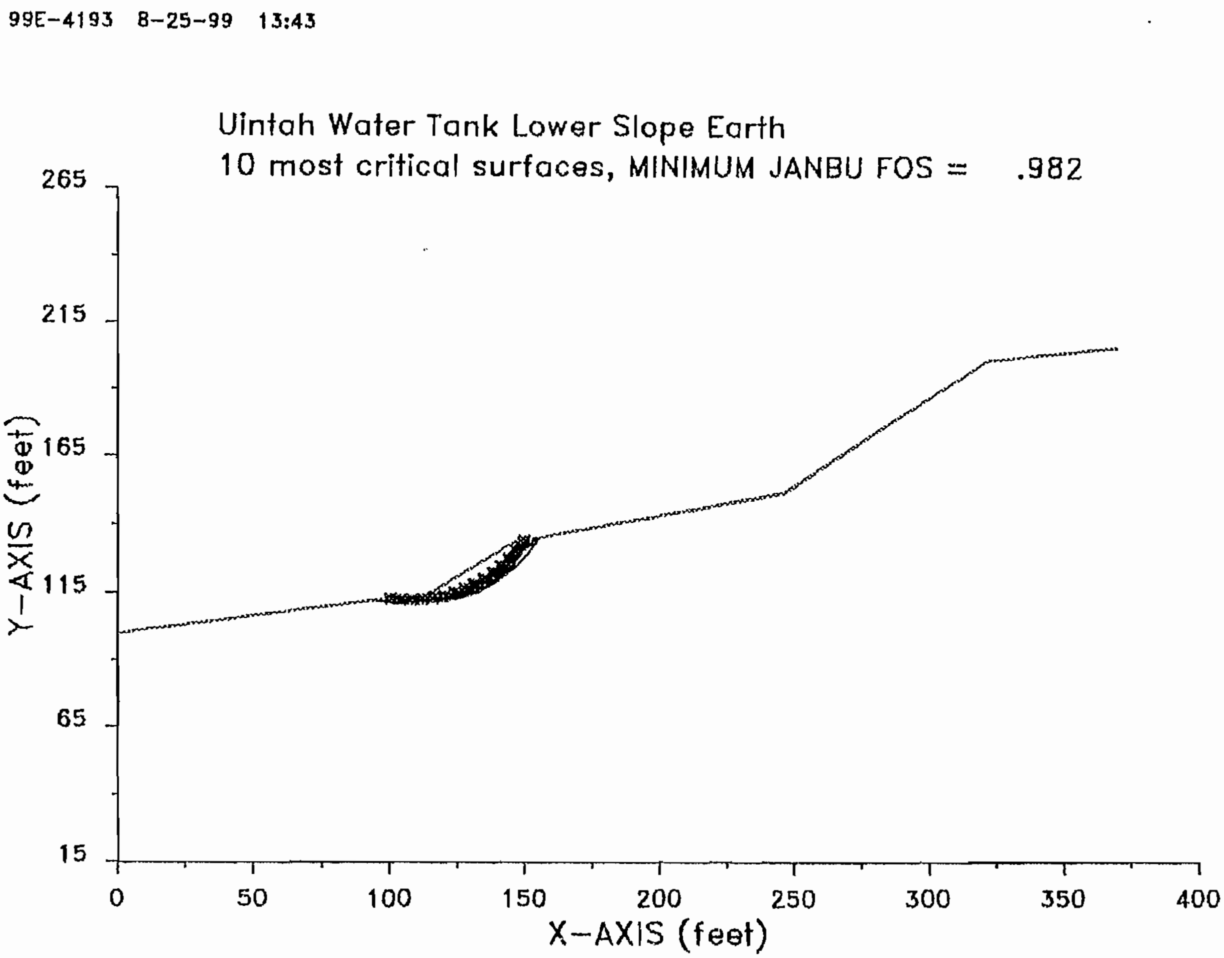
STATIC STABILITY ANALYSIS, CURRENT LOWER SLOPE CONFIGURATION

ETE JOB NO. 99E-419

FIGURE 5

Soil Layer	*Moist Unit Wt. (pcf)*	*Sat. Unit Wt. (pcf)*	*Cohesion (psf)*	*Friction Angle (degrees)*
1	*120*	*125*	*0*	*32*

Horizontal Acceleration of 0.15 G

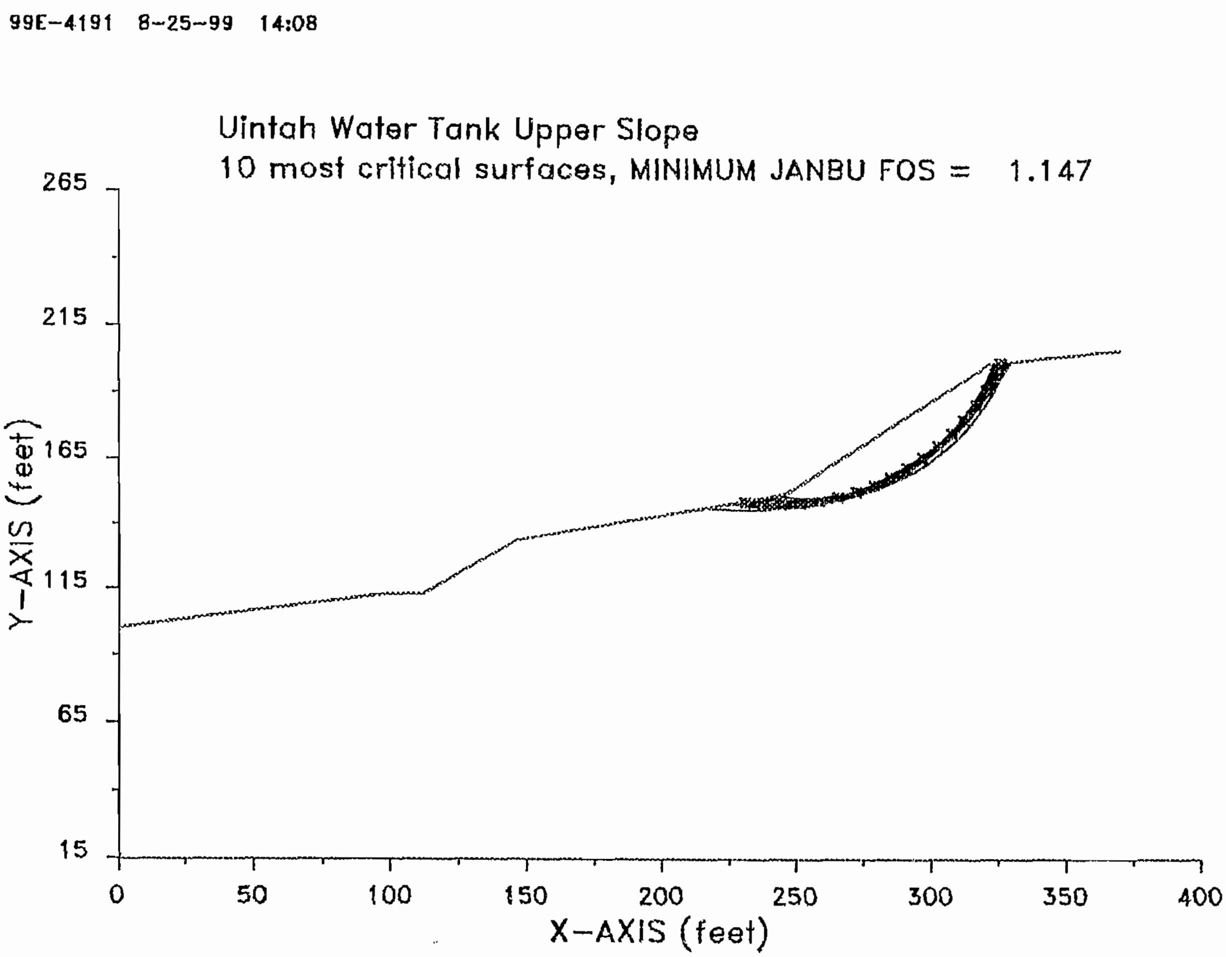


**PSEUDO STATIC STABILITY ANALYSIS,
CURRENT LOWER SLOPE CONFIGURATION**

ETE JOB NO. 99E-419 **FIGURE 6**

EARTHTEC ENGINEERING

Soil Layer	*Moist Unit Wt. (pcf)*	*Sat. Unit Wt. (pcf)*	*Cohesion (psf)*	*Friction Angle (degrees)*
1	*120*	*125*	*0*	*32*



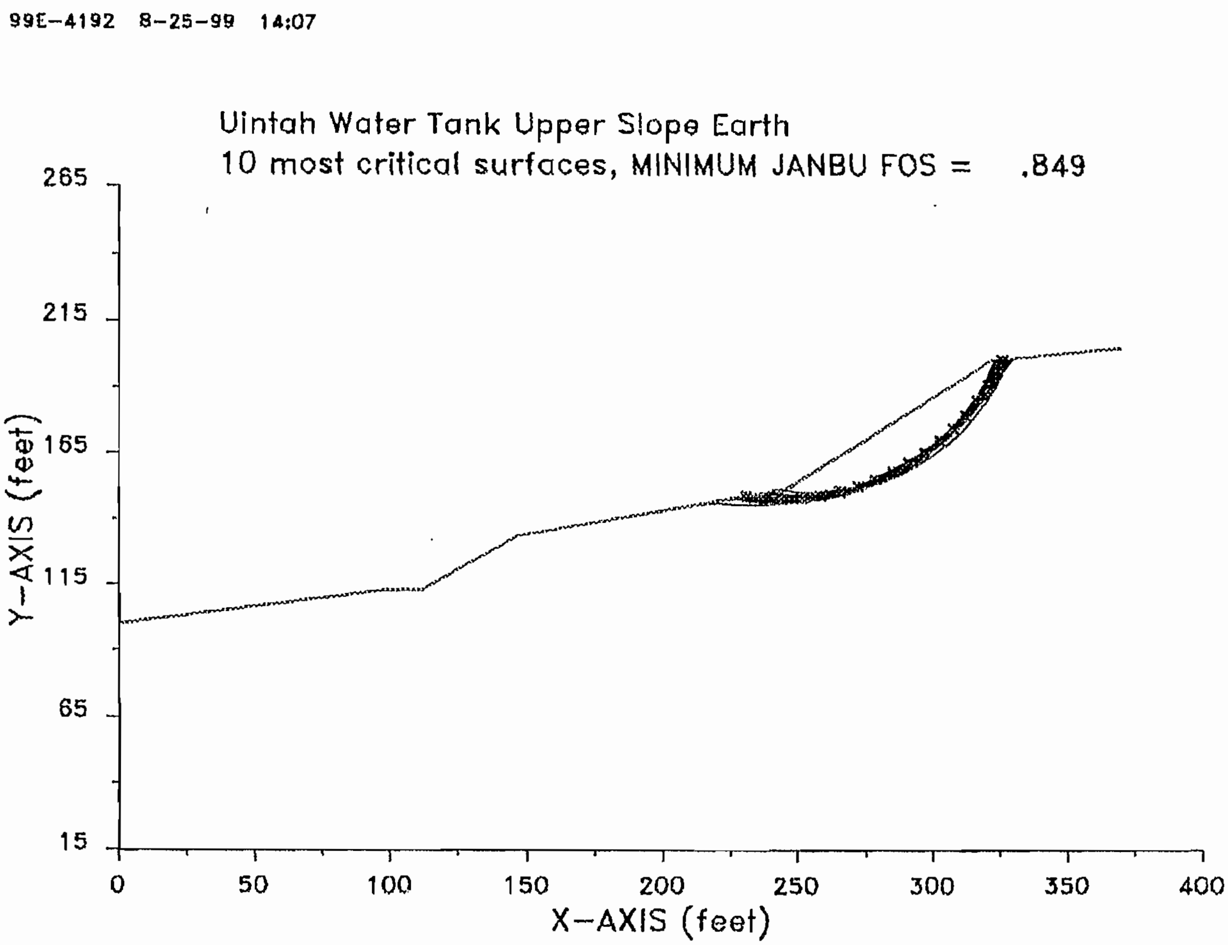
STATIC STABILITY ANALYSIS, CURRENT UPPER SLOPE CONFIGURATION

ETE JOB NO. 99E-419 FIGURE 7

EARTHTEC ENGINEERING

Soil Layer	*Moist Unit Wt. (pcf)*	*Sat. Unit Wt. (pcf)*	*Cohesion (psf)*	*Friction Angle (degrees)*
1	*120*	*125*	*0*	*32*

Horizontal Acceleration of 0.15 G



PSEUDO STATIC STABILITY ANALYSIS, CURRENT UPPER SLOPE CONFIGURATION

ETE JOB NO. 99E-419 **FIGURE 8**