RAI Volume 2, Chapter 2.1.1.1, Second Set, Number 1: Provide a geological map covering the footprints and geological cross sections (in the east–west and north south directions) of the surface and subsurface portions of the Geological Repository Operations Area (GROA) at a scale sufficient to delineate geologic features such as faults and stratigraphic contacts, and their relationship to major GROA features such as drifts, shafts, ramps and SSCs [structure, system, or component] important to safety and waste isolation (SAR [Safety Analysis Report, part of the License Application] Section 1.1.5.1.2; SAR Section 1.1.5.1.4).

The geological map provided at a scale of approximately 1:15,000 as Figure 1.1-64 in SAR Section 1.1.5.1.4, covers only the central and western portion(s) of the surface GROA footprint and DOE does not provide a detailed geological map of the subsurface GROA footprint. The geological cross sections shown in Figures 1.1-65 to 1.1-67 cover only a portion of the surface GROA footprint. SAR Section 1.1 does not provide any detailed geological cross sections intersecting the width and length of the subsurface GROA footprint. This information is needed to support the preclosure safety analysis and the GROA design and establish compliance with 10 CFR 63.21(c) (1) (ii) and 10 CFR 63.112(c).

1. Response

1.1 OVERVIEW

Information requested by this RAI is provided in two parts. The first part, transmitted to the NRC on February 4, 2009 provided a map of the overall site layout, a map of the surface facilities layout and geologic cross section locations, a map of the underground layout configuration overlain with the lithostratigraphic units with cross section locations, a map of fault trace locations at the emplacement elevation, and geologic cross sections through the subsurface facility.

The second part, submitted within this response, is related to the surface GROA and consists of the following:

- Geologic map of the surface GROA, Figure 1.

- Geologic cross sections beneath the surface facilities, including aging pads. Figure 1 shows the locations of the cross sections. Figure 2 shows the explanation of symbols of the cross sections. Figures 3 through 8 show the cross sections. The cross sections have a plan scale of approximately 1:3,000 (which provides greater detail than the 1:4,800 scale proposed in the February 4 response).

- Updated interpretation of fault locations and characteristics.

- Geologic logs for eight additional boreholes in the geotechnical boring program update that were not provided in the response to RAI 2.2.1.1.1-004.

- Revised geologic logs for three repository facilities boreholes whose geologic logs were included in the LA SAR and have since been revised based upon re-evaluation of the cuttings.

The geologic cross sections of the surface GROA display the geologic conditions influencing the design of the surface facilities. Three of the sections, traversing aging pads 17P and 17R and the Initial Handling Facility (IHF), are oriented east–west. Of the remaining sections, one is oriented southwest–northeast, and two are oriented northwest–southeast to provide slices through the foundations of several important to safety (ITS) structures. No north–south cross sections are provided because the faults in this area trend north–south and would be parallel to such cross sections.

The response describes fault locations, fault characteristics, and impacts on the seismic hazards for the surface facilities and aging pads. The updated borehole information and geologic cross sections provide the NRC staff with the most recent analysis of the site geology underlying the surface facilities.

1.2 GEOLOGIC MAPPING FOR SURFACE FACILITIES

Geologic and geotechnical investigations within the surface GROA are based primarily on the geologic map by Day et al. (1998), Repository Facilities (RF) series boreholes located in Midway Valley, and borehole UE-25 NRG#1 (North Ramp Geology) located in Midway Valley and the UE-25 NRG#2-series boreholes located west of Exile Hill. A three-dimensional volumetric geologic framework, "Geologic Framework of the Surface GROA" (GFSG; DTN MO0902GFSRGROA.000), was developed for the surface GROA using the three-dimensional geologic modeling and visualization software EarthVision (EarthVision, version 7.5.3) to integrate surface exposures and borehole information. To minimize extrapolation beyond the area containing boreholes, the GFSG is based on the RF-series and NRG#1 boreholes in Midway Valley and the NRG#2-series boreholes west of Exile Hill. Lithologic logs for these NRG boreholes are documented in reports made available to the NRC and are located in ADAMS at accession numbers ML040080439 and ML003747862.

1.2.1 Geologic Map of the Surface GROA

Five lithostratigraphic units are exposed at the surface on the geologic map of the surface GROA (Figure 1; Day et al. 1998). Quaternary to Tertiary undivided alluvium-colluvium (QTu) is exposed across most of the map area. The nonengineered pad fill and muck pile (Fill) is east of Exile Hill. The Miocene Rainier Mesa Tuff (Tmr) is exposed in a small area on the west side of Exile Hill. Two units from the Miocene Tiva Canyon Tuff (Tpc), the crystal-rich (r) nonlithophysal (n) zone (Tpcrn) and the crystal-poor (p) upper lithophysal (ul) zone (Tpcpul), are exposed on Exile Hill.

Faults included on the surface GROA map are based on various types of information; however, almost all faults are concealed under the alluvium-colluvium and have no surface expression. The only fault with established Quaternary activity is the Bow Ridge fault, documented in the Trench-14-series trenches on the west side of Exile Hill (Keefer et al. 2004, Table 1 and p. 59-

65). North of Exile Hill, the Bow Ridge fault does not have a surface trace and could not be identified in other trenches. A fault penetrated in borehole UE-25 RF#76 just north of the surface GROA is consistent with the position of a previously inferred west-dipping fault (Day et al. 1998), and this data point led to the refinement of the northward projection of the Bow Ridge fault as shown in SAR Figure 1.1-59. However, there are no data in the area of UE-25 RF#76 with which to determine Quaternary activity on this projected segment of the fault.

Two other faults within the surface GROA have been investigated for Quaternary activity: the Midway Valley and Exile Hill faults. The Midway Valley fault, which was identified in the 1980s based only on geophysical magnetic and gravity data, has no surface expression and no evidence of Quaternary activity (Keefer et al. 2004, Table 5). Three boreholes (UE-25 RF#32, UE-25 RF#57, and UE-25 RF#82) penetrated faults and these penetrations are consistent with the approximate location of the Midway Valley fault. The Exile Hill fault, which is located on the east side of Exile Hill, has only a small amount of separation in the Miocene bedrock exposures. Tertiary to Quaternary sediments are deposited across small steps in the top of the bedrock; however, there are no fault separations in these sedimentary deposits and no evidence of Quaternary fault activity (Swan et al. 2001, p. 37-39).

Several of the faults within the surface GROA map (Figure 1) are based on or modified from inferred faults depicted on the geologic map of Day et al. (1998) and within the Geologic Framework Model 2000 (GFM2000; BSC 2004). The "Exile Hill fault splay" was identified in the drilling in 2000 (BSC 2002), and the location and geometry of the fault were refined on the basis of drilling in 2007 with penetration of the fault in boreholes UE-25 RF#40 and UE-25 RF#97. Most of the concealed faults are inferred between boreholes to reconcile changes in thickness of lithostratigraphic units (Buesch and Lung 2008), and in the GFSG they are based on construction of a reference structure contour map on top of the crystal-rich, nonlithophysal zone of the Tiva Canyon Tuff (Tpcrn). Several other RF-series boreholes penetrate faults that are consistent with the inferred position of faults, and therefore, these penetrations were used to geometrically constrain the faults. The following three guidelines were used in constructing all the concealed faults in the surface GROA:

1. Faults are constructed with the assumption that the separation on a fault can vary along the strike, but not along the dip of the fault.

2. Faults have constant dip directions along faults rather than resorting to unique types such as scissor faults.

3. Fault traces on the geologic map are the upward projection along the dip of the fault to the ground surface, not the trace of the fault along the alluvium-bedrock contact.

The lithostratigraphic units in the surface GROA are primarily based on the geologic logs; however, three units within the surface GROA represent a grouping of two or more lithostratigraphic units observed in geologic logs (Table 1). The surface GROA unit "Tpcrn" consists of the crystal-rich nonlithophysal and lithophysal zones of the Tiva Canyon Tuff (Tpcrn and Tpcrl, respectively) because the Tpcrl occurs in only three boreholes. The surface GROA unit "Tp_btun" consists of the pre-Tiva Canyon Tuff bedded tuff (Tpbt4), Yucca Mountain Tuff

(Tpy), pre-Yucca Mountain Tuff bedded tuff (Tpbt3), Pah Canyon Tuff (Tpp), and the pre-Pah Canyon Tuff bedded tuff (Tpbt2) because these rocks form a continuous sequence in only one borehole (UE-25 RF#75), and occur only as slivers along faults in other boreholes. The surface GROA unit "Tptp_un" consists of the crystal-rich lithophysal and crystal-poor upper lithophysal zones of the Topopah Spring Tuff (Tptrl and Tptpul, respectively) because these rocks occur in only one borehole (UE-25 RF#85), and it also includes "crystal-poor, undivided" rocks that occur at the base of the cross sections.

1.2.2 Salient Geologic Relations in Cross Sections

Six geologic cross sections are oriented such that they provide the general geologic relations beneath several planned important to safety (ITS) structures (Figure 2, explanation of symbols for the cross sections; Figures 3 to 8, cross sections). Cross section SA-SA′ is oriented southwest–northeast. Cross sections SB-SB′ and SC-SC′ are oriented northwest–southeast, and intersect section SA-SA′. Three east–west oriented cross sections, SE-SE′, SD-SD′, and SF-SF′, traverse aging pads 17P and 17R and the IHF 51A, respectively. Some of the cross sections transect the units and faults within the surface GROA at an oblique angle; therefore, some features display an apparent dip that is less than the true dip. In the following descriptions, the location of a feature is indicated in feet measured from the left end of the cross section.

Cross section SA-SA′ (Figure 3)—Oriented southwest–northeast and intersects sections SB-SB′ and SC-SC′

The alluvium-colluvium thickens from southwest to northeast across the valley; in the easternmost part of the cross section, the alluvium-colluvium thins to the east. Near the southwest edge of the section the alluvium-colluvium is approximately 51 ft thick. The thickest part of the alluvium-colluvium is between locations 2200 and 3100 where it varies from approximately 174 to 192 ft. For example, this thickness at the northeastern edge it is approximately 141 ft thick. The contact of the alluvium-colluvium and bedrock is broadly curviplanar, but in detail, has minor undulations. These undulations do not correlate to locations of any of the faults in the Miocene rocks, nor do they coincide with changes in GFSG units. The uppermost bedrock surface resulted from erosion of the faulted and tilted Miocene rocks; however, the low relief of the erosional surface itself does not appear to be influenced by juxtaposition of structural blocks of Miocene age, nor by differing erosional characteristics of lithostratigraphic units. These relations indicate the base of the alluvium-colluvium is not faulted. Named faults in the section include the east-dipping Exile Hill fault splay (about location 725) and the west-dipping Midway Valley fault (between locations 2350 and 2800). Other unnamed faults have normal separation and are either west-dipping or east-dipping. Typically, the Miocene section is shallowly dipping to the east. Geologic relations of note on the cross section are:

1. Between locations 100 and 600, there are near horizontal or slightly west-dipping units, and similar relations occur in a few other structural blocks in some sections. These shallowly west-dipping units likely represent either differential foundering of structural blocks, or stratigraphic surfaces that are oriented based on thinning and

thickening relations of units relative to the reference structure contours on the top of the crystal-rich, nonlithophysal zone of the Tiva Canyon Tuff (Tpcrn).

2. Along several faults there is an apparent “drag” or “reverse drag” of lithostratigraphic units, but the drag is not based on geologic information. Rather, the apparent drag along faults appears to be an artifact of the modeling software, which modeled gridded surfaces.

3. Between locations 100 and 600, middle nonlithophysal and lower lithophysal zones of Tiva Canyon Tuff (Tpcpmn and Tpcpll) thin to 0 ft thick, and the lower part of the upper lithophysal zone of Tiva Canyon Tuff (Tpcpul) and upper part of the lower nonlithophysal zone of Tiva Canyon Tuff (Tpcpln) also thin relative to the surrounding parts of the sections. The reason for this thinning of these units is based on the influence of a faulted section in borehole UE-25 RF#34. The omission of these thinned units slightly changes the amounts of apparent dips of the lithostratigraphic units along the edges of the structural blocks. These locally thinned units have negligible geologic effects because this thinning is localized, and a minimum number of units are involved, especially because they are in the middle part of the Tiva Canyon Tuff.

4. Along the Midway Valley fault, between locations 2400 and 2800, the ignimbrite of the rhyolite of Comb Peak (Tpki) and the crystal-poor, upper lithophysal zone of the Tiva Canyon Tuff (Tpcpul) appear to have different thicknesses on either side of the fault. These differences likely result from the following two modeling practices: (a) EarthVision software representation of lithostratigraphic units across a fault. The “offset” along a fault results from shifting the surface (or isochore values) vertically; they are not shifted along a fault. There is a distance (or “gap”) in cross section between a surface on one side of a fault and the surface on the other side of a fault. It is this gap in the isochore that is not represented in the depiction of units across a fault. For faults with steep dips, there is minimal effect of the omitted part of the isochore; however, for faults with moderate to shallow dips, the effect is much greater. (b) Application of additional control to gridded surfaces adjacent to structural block boundaries.

Cross section SB-SB′ (Figure 4)—Oriented northwest–southeast, and intersects section SA-SA′

The alluvium-colluvium only varies in thickness from approximately 67 to 73 ft. The two unnamed faults in section SB-SB′ are the same as those between locations 0 and 400 in section SA-SA′; they are just transected at different angles. The upper lithophysal to lower nonlithophysal zones (Tpcpul, Tpcpmn, Tpcpll, and Tpcpln) thin between locations 200 and 750 in section SB-SB′. As in section SA-SA′, the omission of these thinned units slightly changes the amounts of apparent dips of the lithostratigraphic units along the edges of the structural blocks.

Cross section SC-SC′ (Figure 5)—Oriented northwest–southeast, and intersects section SA-SA′

The alluvium-colluvium varies in thickness with approximately 163 ft on the northwest end of the section, approximately 165 ft on the southeast end, and the thickest part is near borehole UE-25 RF#85 where 174.0 ft is measured. Two faults depicted on the eastern side of section SC-SC′ (locations 300 to 750 and 500 to 575), the Midway Valley fault and an unnamed fault to the east, respectively, also are shown on section SA-SA′ at locations 2350 to 2800 and 2975 to 3050. Because of the geometric relations of these faults, separations of units within the surface GROA below the lower nonlithophysal zone of the Tiva Canyon Tuff (Tpcpln) are accommodated along a combination of these two faults, and separations of the surface units within the GROA Tpcpln and above are accommodated along the Midway Valley fault. As with section SA-SA′, the apparent drag and reverse drag along the faults might result from artifacts of modeling gridded surfaces in the software.

Cross section SD-SD′ (Figure 6)—Oriented west–east through Aging Pad 17R

The alluvium-colluvium varies in thickness with approximately 99 ft on the west end of the section, approximately 128 ft on the east end, and the thickest part is near borehole UE-25 RF#95 where 182.1 ft is measured. Two named faults are on section SD-SD′: the Bow Ridge fault is the west-dipping normal fault between locations 475 and 500, and the Exile Hill fault splay is the east-dipping normal fault between 500 and 525. The small horst between the Bow Ridge fault and the Exile Hill fault splay is the northern end of the structural block that contains Exile Hill. Across most of the section, the Miocene section is shallowly dipping to the east. Because of how faults are used or inferred in GFSG, the two faults on the eastern side of the section are explained as follows:

1. The fault at location 1600 is depicted as a reverse fault with the east-side block as the upthrown side of the fault. This reverse sense of separation is not typical of faults in the Yucca Mountain area, and two modeling practices contribute to the reverse separation on this fault in section SD-SD′.

    a. The emphasis during development of the structural framework for the surface GROA was to attempt to maintain as closely as possible a historical lineage from the geologic map of Day et al. (1998), through the GFM2000 (BSC 2004), to selected faults described in BSC (2002).

    b. Where there are no direct geologic constraints, it was decided to use constant dip directions along faults rather than resorting to unique fault types such as scissor faults.

    Four specific factors contribute to the reverse separation on this fault.

    a. The fault at location 1600 on section SD-SD′ is from the geologic map of Day et al. (1998) as depicted in the GFM2000 (BSC 2004).

b. The southern trace of this fault was modified in BSC (2002) and the fault intersects section SA-SA′ between locations 1025 and 1100.

c. To accommodate the cluster of borehole data along the fault near section SA-SA′, where there are more controls, the dip of the fault was changed to an eastward dip.

d. The eastward dip was applied to the entire trace length of the fault, including the northern part, thereby resulting in the "reverse" sense of separation in the section SD-SD′.

To accommodate the dip and sense of separation along this fault in the geologic framework, an alternative depiction would be to divide the fault into two faults instead of portraying it as a single fault.

2. The normal fault between locations 2225 and 2375 has a down-to-the-east normal separation. A similar normal fault was depicted in this area on the geologic map of Day et al. (1998); however, the fault was not included in the GFM2000 (BSC 2004). The fault was included during the development of the GFSG and is the same as the fault between locations 1950 and 2050 on section SA-SA′.

Cross section SE-SE′ (Figure 7)—Oriented west–east through Aging Pad 17P

The alluvium-colluvium varies in thickness with approximately 122 ft on the west end of the section, approximately 139 ft on the east end, and the thickest part is near borehole UE-25 RF#69 where 142.8 ft is measured. The one named fault on section SE-SE′ is the Bow Ridge fault, the west-dipping normal fault near location 400. The two unnamed faults on the eastern side of the cross section (between 1800 and 1875, and 1925 and 2000), are the same two faults transected in section SD-SD′ near 1600 and 2225, respectively. Across most of the section, the Miocene section is shallowly dipping to the east. In the central block of the cross section, there is an angular unconformity with the pre-Rainier Mesa Tuff bedded tuff (Tmbt1) deposited on the ignimbrite of the rhyolite of Comb Peak (Tpki, between 1125 and 1800) and on the post- Tiva Canyon Tuff bedded tuff (Tpbt5, between 700 and 1125). This stratigraphic relation is consistent with a period of erosion and slight tilting of the structural block prior to deposition of the Tmbt1.

Cross section SF-SF' (Figure 8) – Oriented west–east through building IHF

The alluvium-colluvium varies in thickness from west to east approximately 39 ft to 96 ft. The two faults in section SF-SF′, one east-dipping normal fault and one west-dipping normal fault, form a small graben between locations 25 and 125. The Miocene section is nearly horizontal or shallowly dipping to the east. Adjacent to the west-dipping fault, the abrupt variations in thicknesses of the Tpki and Tmbt1 are probably due to unconstrained contouring of apparent thicknesses in boreholes (isochores) near boundaries between fault blocks.

1.2.3 Results and Conclusions

Within the surface GROA, a "Geologic Framework of the Surface GROA" (GFSG) was constructed using the geologic map and the RF-series and NRG#1 boreholes in Midway Valley and the NRG#2-series boreholes west of Exile Hill to produce a set of internally consistent cross sections. There are four main results and conclusions that can be inferred from the cross sections:

1. The units used to depict geology within the surface GROA are based on Miocene lithostratigraphic units from the Rainier Mesa Tuff (Tmr) to the crystal-poor upper lithophysal zone of the Topopah Spring Tuff (Tptpul). The lowest GFSG unit is Tptp_un, and this unit consists of the crystal-rich lithophysal zone of the Topopah Spring Tuff (Tptrl), the Tptpul, and undivided crystal-poor rocks that are deeper than the Tptpul.

2. Throughout most of the geologic framework, the Miocene lithostratigraphic units are shallowly east-dipping; however, locally, units within the surface GROA are nearly horizontal to shallowly west-dipping. These shallowly west-dipping units probably represent either differential foundering of structural blocks, or a result of modeling of thinning and thickening relations of units relative to the reference structure contours on top of the crystal-rich, nonlithophysal zone of the Tiva Canyon Tuff (Tpcrn).

3. Structurally, Midway Valley consists of generally eastward-dipping and westward-dipping normal faults that result in a series of grabens and half-grabens. The four named faults in the surface GROA are the Bow Ridge, Exile Hill, and Midway Valley faults, and the Exile Hill fault splay. Most of the concealed faults are inferred and based on construction of a reference structure contour map on top of the crystal-rich, nonlithophysal zone of the Tiva Canyon Tuff (Tpcrn). Several RF-series boreholes penetrated faults that are consistent with the inferred position of faults, and therefore, these penetrations were used to geometrically constrain the faults.

4. Across the surface GROA, the contact between the base of the alluvium-colluvium and bedrock is broadly curviplanar, but in detail, has minor undulations. These undulations do not correlate with locations of any of the faults in the Miocene rocks, nor do they coincide with changes in GFSG units. The uppermost bedrock surface resulted from erosion of the faulted and tilted Miocene rocks; however, the low relief of the erosional surface itself does not appear to be influenced by juxtaposition of structural blocks of Miocene age, nor by differing erosional characteristics of lithostratigraphic units. These relations indicate the base of the alluvium-colluvium is not faulted.

1.3 GEOLOGIC LOGS

Eight additional geologic logs of boreholes are provided. Six of these logs are detailed geologic logs. These detailed geologic logs are identified in Table 2.

The remaining two boreholes, UE-25 RF#62 and UE-25 RF#63, were drilled at a location to the northwest of Exile Hill that was being considered for the site of an aging pad. Geologic logs were completed for these boreholes by Sample Management Facility staff. Because this location was abandoned as the potential site of an aging pad, detailed geologic logs that provide Unified Soil Classification System (USCS) categorization of soil units and engineering indexes of rock units were not needed and therefore were not completed. The Sample Management Facility borehole logs are provided as identified in Table 3.

In addition to these eight logs, three geologic logs (for boreholes UE-25 RF#15, UE-25 RF#20, and UE-25 RF#21) are being transmitted because, although they were originally included in the SAR, they have since been revised based on re-evaluation of the cuttings. Acquisition and reduction of additional data indicated that a re-appraisal of these holes was required. These revised borehole logs are provided as identified in Table 4.

The details of the revisions to the three revised borehole logs are provided in Tables 5, 6, and 7.

1.4 IMPACT TO SEISMIC HAZARD ANALYSIS

Development of the geologic framework for the surface GROA based on geologic mapping and geologic logs from boreholes confirms the descriptions and conclusions in the SAR, including those of Buesch and Lung (2008). Fault locations, other than for the Bow Ridge fault north of Exile Hill, are generally consistent with their locations as inferred at the time of the Probabilistic Seismic Hazard Analysis (CRWMS M&O 1998). Some additional minor faults are interpreted. Of these faults in the vicinity of the surface GROA, the Exile Hill and Midway Valley faults were investigated for, but have no documented evidence of, Quaternary fault activity. Only the Bow Ridge fault located near Exile Hill has demonstrated displacement of Quaternary sediments. Also, except for the Bow Ridge fault, there is no indication that the base of the alluvium is faulted. The impact to seismic hazard analysis of the adjustment in the position of the Bow Ridge fault north of Exile Hill was addressed in the response to RAI 2.2.1.1.1-010. Based on the results presented here for fault locations and characteristics, there are no additional potential seismic hazard impacts to evaluate for the surface GROA.

2. COMMITMENTS TO NRC

DOE commits to update the LA as described in Section 3, below. The changes to the LA will be included in a future LA update.

3. DESCRIPTION OF PROPOSED LA CHANGE

LA SAR Figures 1.1-97 (Borehole UE-25 RF#15), 1.1-102 (Borehole UE-25 RF#20), and 1.1-103 (Borehole UE-25 RF#21) will be changed to reflect the revision of geologic logs as discussed in Section 1.3 of this RAI.

4. REFERENCES

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Table 1. Lithostratigraphic and Surface Geologic Repository Operations Area Units and Symbols

Lithostratigraphic Unit	Unit Symbol	Included Units[1]
Non-engineered material (pad fill and muck)	Fill	
Quaternary and Tertiary alluvium-colluvium, undivided	QTu	
Rainier Mesa Tuff	Tmr	
Pre-Rainier Mesa Tuff bedded tuff	Tmbt1	
Ignimbrite of the rhyolite of Comb Peak	Tpki	
Post-Tiva Canyon Tuff bedded tuff	Tpbt5	
Tiva Canyon Tuff (Tpc)		
Tpc, crystal-rich, vitric zone	Tpcrv	
Tpc, crystal-rich nonlithophysal zone	Tpcrn	Tpcrl
Tpc, crystal-poor upper nonlithophysal zone	Tpcpun	
Tpc, crystal-poor upper lithophysal zone	Tpcpul	
Tpc, crystal-poor middle nonlithophysal zone	Tpcpmn	
Tpc, crystal-poor lower lithophysal zone	Tpcpll	
Tpc, crystal-poor lower nonlithophysal zone	Tpcpln	
Tpc, crystal-poor vitric zone	Tpcpv	
Paintbrush bedded tuffs, undivided	Tp_btun	Tpbt4, Tpy, Tpbt3, Tpp, Tpbt2
Topopah Spring Tuff (Tpt)		
Tpt, crystal-rich vitric zone	Tptrv	
Tpt, crystal-rich nonlithophysal zone	Tptrn	
Tpt, crystal-poor member, undivided	Tptp_un	Tptrl, Tptpul

NOTE: [1]crystal-rich lithophysal zone of the Tiva Canyon Tuff (Tpcrl), pre-Tiva Canyon Tuff bedded tuff (Tpbt4), Yucca Mountain Tuff (Tpy), pre-Yucca Mountain Tuff bedded tuff (Tpbt3), Pah Canyon Tuff (Tpp), pre-Pah Canyon Tuff bedded tuff (Tpbt2), crystal-rich lithophysal zone of the Topopah Spring Tuff (Tptrl), crystal-poor upper lithophysal zone of the Topopah Spring Tuff (Tptpul)

Table 2. Detailed Geologic Logs

Borehole Identifier	RAI Figure Number	Source
UE-25 RF#32	Figure 9	DTN: GS081083114233.009
UE-25 RF#88	Figure 10	DTN: GS081083114233.009
UE-25 RF#90	Figure 11	DTN: GS081083114233.009
UE-25 RF#110	Figure 12	DTN: GS081083114233.009
UE-25 RF#111	Figure 13	DTN: GS080983114233.008
UE-25 RF#113	Figure 14	DTN: GS081083114233.009

Table 3. Sample Management Facility Borehole Logs

Borehole Identifier	RAI Figure Number	Source
UE-25 RF#62	Figure 15	DTN: MO0811SMFGRF62.000
UE-25 RF#63	Figure 16	DTN: MO0708SMFGLGIB.000

Table 4. Revised Borehole Logs

Borehole Identifier	RAI Figure Number	LA SAR Figure Number	Source
UE-25 RF#15	Figure 17	1.1-97	DTN: GS081083114233.010
UE-25 RF#20	Figure 18	1.1-102	DTN: GS081083114233.010
UE-25 RF#21	Figure 19	1.1-103	DTN: GS081083114233.010

Table 5. Details of Revisions to Borehole Log UE-25 RF#15

Borehole	ORIGINAL INTERVAL / DATA		REVISED INTERVAL / DATA	
	DTN: GS030783114233.001		DTN: GS081083114233.010	
UE-25 RF#15	Header data	Depth to Bedrock: 5.0 ft.	Header data	Depth to Bedrock: 6.5 ft.
	0.0 to 5.0 ft	PAD FILL (Fill)	0.0 to 6.5 ft	PAD FILL (Fill)
	0.0 to 5.0 ft	POORLY GRADED GRAVEL (GP) Predominately fine to coarse, hard, subangular gravel with a trace of nonplastic fines on gravel surfaces; derived from moderately to densely welded Tuff	0.0 to 6.5 ft	POORLY GRADED GRAVEL (GP) Predominately fine to coarse, hard, subangular gravel with a trace of nonplastic fines on gravel surfaces; derived from moderately to densely welded Tuff
	5.0 to 78.0 ft	TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn) Pyroclastic flow, densely welded, devitrified, light gray to pale red tuff with 15 to 20 percent phenocrysts of plagioclase, sanidine, and minor (less than 1 percent) biotite. Pumice clasts compose up to 10 percent of the tuff, pumice clasts increase to up to 25 to 30 percent at a depth of 67.4 feet. Generally the tuff is moderately hard (H4), moderately to slightly weathered (W4), and intensely to moderately fractured (FD6). Upper contact is unconformable (erosional), lower contact is conformable.	6.5 to 78.0 ft	TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn) Pyroclastic flow, densely welded, devitrified, light gray to pale red tuff with 15 to 20 percent phenocrysts of plagioclase, sanidine, and minor (less than 1 percent) biotite. Pumice clasts compose up to 10 percent of the tuff, pumice clasts increase to up to 25 to 30 percent at a depth of 67.4 feet. Generally the tuff is moderately hard (H4), moderately to slightly weathered (W4), and intensely to moderately fractured (FD6). Upper contact is unconformable (erosional), lower contact is conformable.

Table 6. Details of Revisions to Borehole Log UE-25 RF#20

Borehole	ORIGINAL INTERVAL / DATA		REVISED INTERVAL / DATA	
	DTN: GS030783114233.001		DTN: GS081083114233.010	
	Header	Depth to Bedrock: 98.0 ft	Header	Depth to Bedrock: 94.0 ft
UE-25 RF#20	0.0 to 28.0 ft	PAD FILL (Fill) Predominately fine to coarse, hard, subangular gravel with a trace of nonplastic fines on gravel surfaces; derived from moderately to densely welded Tuff.	0.0 to 8.0 ft	PAD FILL (Fill) Predominately fine to coarse, hard, subangular gravel with a trace of nonplastic fines on gravel surfaces; derived from moderately to densely welded Tuff.
	28.0 to 98.0 ft	QUATERNARY ALLUVIUM (Qal) Tuffaceous alluvium consisting of a mixture of pale red and light gray densely welded ignimbrite with minor fragments of white non-welded tuff. Up to 15 percent of the densely welded material have white to light gray caliche coatings.	8.0 to 94.0 ft	QUATERNARY ALLUVIUM (Qal) Tuffaceous alluvium consisting of a mixture of pale red and light gray densely welded ignimbrite with minor fragments of white non-welded tuff. Up to 15 percent of the densely welded material have white to light gray caliche coatings.
	98.0 to 102.0 ft.	POST TIVA CANYON BEDDED TUFFS (Tpbt5): Bedded tuff, nonwelded, argillic with 1 to 2 percent quartz and sanidine phenocrysts. Pumice clasts compose up to 20 percent pumice clasts and 5 percent volcanic lithic clasts. Tuff is predominately very pale orange and white.	94.0 to 101.0 ft	COMB PEAK IGNIMBRITE - TUFF X (Tpki): Pyroclastic flow, nonwelded, crystallized, with up to 30 percent pumice clasts. Tuff contains 1 to 2 percent sanidine, plagioclase, quartz, and less than 1 percent biotite and hornblende phenocrysts. Up to 15 percent moderate red to medium dark gray, volcanic lithic clasts. Tuff is predominately grayish-orange pink with possible minor silicification.
			101.0 to 102.0 ft	POST TIVA CANYON BEDDED TUFFS (Tpbt5): Bedded tuff, nonwelded, argillic with 1 to 2 percent quartz and sanidine phenocrysts. Pumice clasts compose up to 20 percent pumice clasts and 5 percent volcanic lithic clasts. Tuff is predominately very pale orange and white.
	102.0 to 127.0 ft.	TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPYSAL ZONE (Tpcrn) Pyroclastic flow, moderately to densely welded, crystallized, with 8 to 10 percent sanidine and plagioclase phenocrysts, and less than 1 percent biotite phenocrysts. From 102 to 110 ft. the tuff has up to 7 percent dark gray pumice clasts. From 110 to 123 ft. the tuff is crystal poor with only 1 percent Clasts content. From 123 to 127 ft. the tuff has a mix of light brownish-gray and very light gray pumice clasts, composing up 10 percent of rock	102.0 to 135.0 ft.	TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn) Pyroclastic flow, moderately to densely welded, crystallized, with 8 to 10 percent sanidine and plagioclase phenocrysts, and less than 1 percent biotite phenocrysts. From 102 to 110 ft. the tuff has up to 7 percent dark gray pumice clasts. From 110 to 123 ft. the tuff is crystal poor with only 1 percent Clasts content. From 123 to 127 ft. the tuff has a mix of light brownish-gray and very light gray pumice clasts, composing up 10 percent of rock

Table 6. Details of Revisions to Borehole Log UE-25 RF#20 (Continued)

Borehole	ORIGINAL INTERVAL / DATA		REVISED INTERVAL / DATA	
	DTN: GS030783114233.001		DTN: GS081083114233.010	
	127.0 to 160.0 ft	TIVA CANYON TUFF CRYSTAL POOR UPPER LITHOPHYSAL ZONE (Tpcpul) Pyroclastic flow, densely welded, crystallized, vapor-phase altered, light gray, with 2 to 3 percent sanidine and plagioclase, and less than 1 percent biotite phenocrysts. Tuff has up to 15 percent, very light gray, pumice clasts. Lithophysae are distinguished by vapor-phase altered chips, indicating the edges of voids in the tuff.	135.0 to 160.0 ft.	TIVA CANYON TUFF CRYSTAL POOR UPPER LITHOPHYSAL ZONE (Tpcpul) Pyroclastic flow, densely welded, crystallized, vapor-phase altered, light gray, with 2 to 3 percent sanidine and plagioclase, and less than 1 percent biotite phenocrysts. Tuff has up to 15 percent, very light gray, pumice clasts. Lithophysae are distinguished by vapor-phase altered chips, indicating the edges of voids in the tuff.

Table 7. Details of Revisions to Borehole Log UE-25 RF#21

Borehole	ORIGINAL INTERVAL / DATA		REVISED INTERVAL / DATA	
	DTN: GS030783114233.001		DTN: GS081083114233.010	
UE-25 RF#21	Header data	Depth to Bedrock: 115.0 ft	Header data	Depth to Bedrock: 74.0 ft
	0.0 to 5.0 ft	PAD FILL (Fill)	0.0 to 74.0 ft	QUATERNARY ALLUVIUM (Qal) Tuffaceous alluvium consisting of a mixture of pale red and light gray densely welded ignimbrite with minor fragments of white non-welded tuff. Up to 15 percent of the densely welded material has white to light gray caliche coatings.
	5.0 to 115.0 ft	QUATERNARY ALLUVIUM (Qal) Tuffaceous alluvium consisting of a mixture of pale red and light gray densely welded ignimbrite with minor fragments of white non-welded tuff. Up to 15 percent of the densely welded material has white to light gray caliche coatings		
			74.0 to 91.0 ft	COMB PEAK IGNIMBRITE - TUFF X (Tpki): Pyroclastic flow, nonwelded, crystallized, with up to 30 percent pumice clasts. Tuff contains 1 to 2 percent sanidine, plagioclase, quartz, and less than 1 percent biotite and hornblende phenocrysts. Up to 15 percent moderate red to medium dark gray, volcanic lithic clasts. Tuff is predominately grayish-orange pink with possible minor silicification.
			91.0 to 97.0 ft	POST TIVA CANYON BEDDED TUFFS (Tpbt5): Bedded tuff, nonwelded, argillic with 1 to 2 percent quartz and sanidine phenocrysts. Pumice clasts compose up to 20 percent pumice clasts and 5 percent volcanic lithic clasts. Tuff is predominately very pale orange and white.
	115.0 to 165.0	TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn) Pyroclastic flow, moderately to densely welded, crystallized, with 8 to 10 percent sanidine and plagioclase phenocrysts, and less than 1 percent biotite phenocrysts. From 102 to 110 ft. the tuff has up to 7 percent dark gray pumice clasts. From 110 to 123 ft. the tuff is crystal poor with only 1 percent clast content. From 123 to 127 ft . the tuff has a mix of light brownish-gray and very light gray pumice clasts, composing up 10 percent of rock.	97.0 to 175.0 ft	TIVA CANYON TUFF CRYSTAL RICH NON-LITHOPHYSAL ZONE (Tpcrn) Pyroclastic flow, moderately to densely welded, crystallized, with 8 to 10 percent sanidine and plagioclase phenocrysts, and less than 1 percent biotite phenocrysts. From 102 to 110 ft. the tuff has up to 7 percent dark gray pumice clasts. From 110 to 123 ft. the tuff is crystal poor with only 1 percent clast content. From 123 to 127 ft. the tuff has a mix of light brownish-gray and very light gray pumice clasts, composing up 10 percent of rock.

Table 7. Details of Revisions to Borehole Log UE-25 RF#21 (Continued)

Borehole	ORIGINAL INTERVAL / DATA		REVISED INTERVAL / DATA	
	DTN: GS030783114233.001		DTN: GS081083114233.010	
	165.0 to 192.2 ft	TIVA CANYON TUFF CRYSTAL POOR UPPER LITHOPHYSAL ZONE (Tpcpul) Pyroclastic flow, densely welded, crystallized, vapor-phase altered, light gray, with 2 to 3 percent sanidine and plagioclase, and less than 1 percent biotite phenocrysts. Tuff has up to 15 percent, very light gray, pumice clasts. Lithophysae are distinguished by vapor-phase altered chips, indicating the edges of voids in the tuff.	175.0 to 192.2 ft	TIVA CANYON TUFF CRYSTAL POOR UPPER LITHOPHYSAL ZONE (Tpcpul) Pyroclastic flow, densely welded, crystallized, vapor-phase altered, light gray, with 2 to 3 percent sanidine and plagioclase, and less than 1 percent biotite phenocrysts. Tuff has up to 15 percent, very light gray, pumice clasts. Lithophysae are distinguished by vapor-phase altered chips, indicating the edges of voids in the tuff.

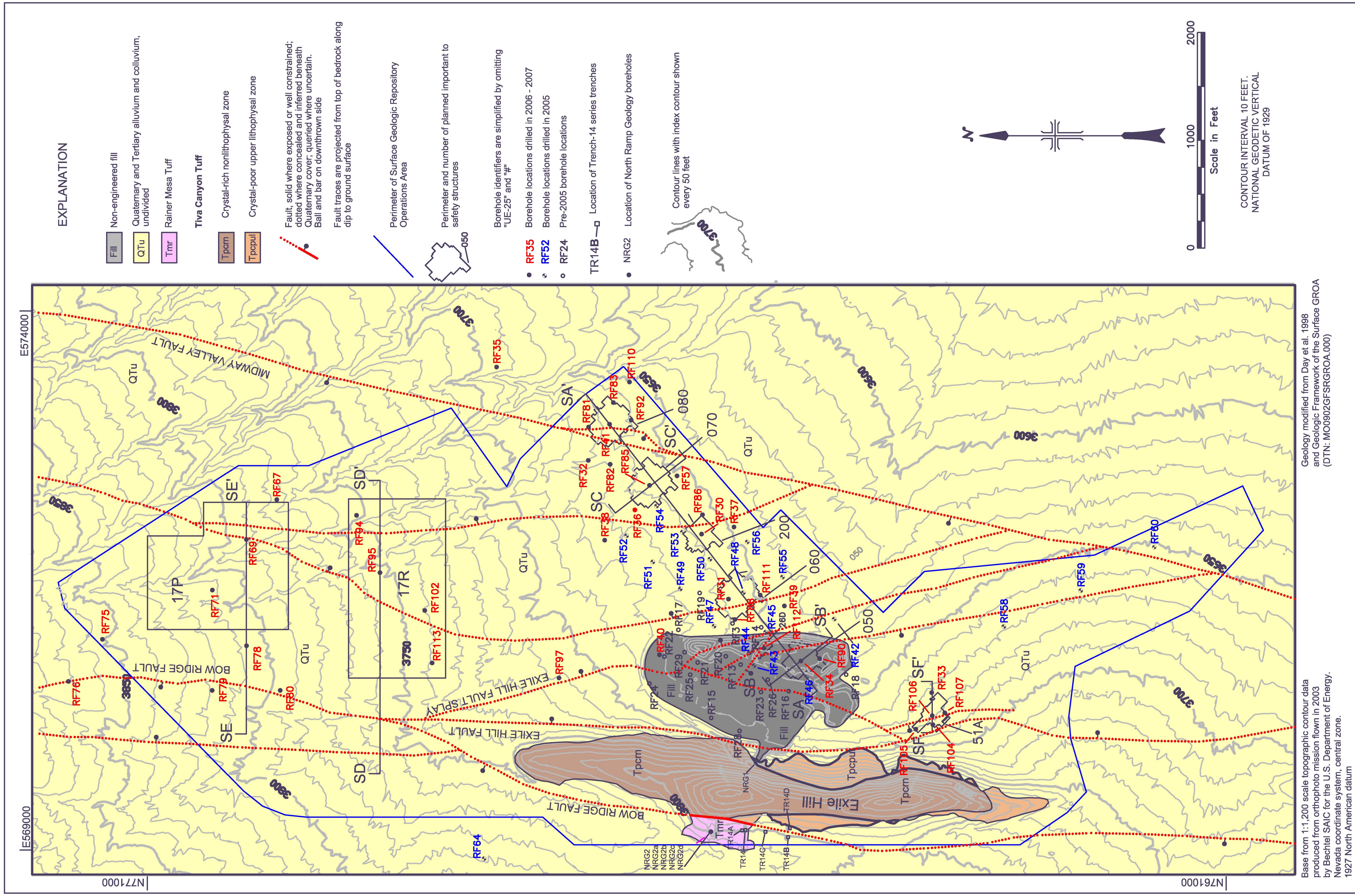

Figure 1. Geologic Map of the Surface Geologic Repository Operations Area with the Locations of Six Geologic Cross Sections, Boreholes, and Planned Important to Safety (ITS) Structures

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