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A Hydrostratigraphic Framework Model and Alternatives for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 98: Frenchman Flat, Clark, Lincoln and Nye Counties, Nevada

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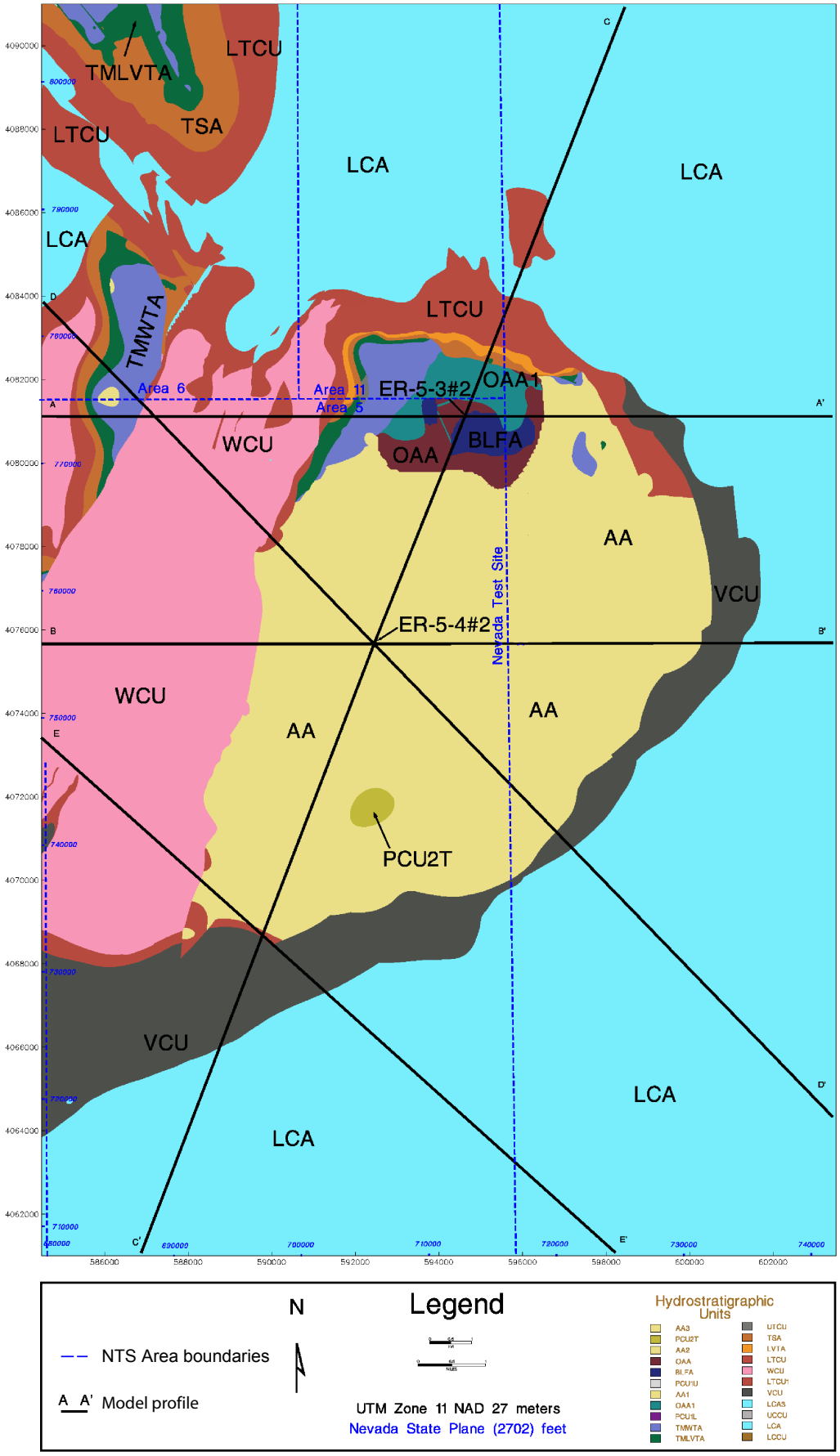

Figure 4-33
Map Showing HSUs at the Water Table within the Frenchman Flat Model Area

5.0 ALTERNATIVE SCENARIOS

As mentioned in previous sections of this report, the geologic complexity of the model area and non-unique interpretations incorporated into the base model made it necessary to address alternative interpretations for some of the more significant features in the model. This section describes the four alternative scenarios developed into separate models, as well as the process used to identify and construct the alternatives.

5.1 Process of Addressing Alternatives to the Base Model

Twenty-eight ideas for alternative interpretations to the base model were identified and evaluated during construction of the Phase II base framework model (Table 5-1). These alternatives included ideas from the original Phase I model (IT, 1998a) and alternative interpretations identified by the model builders during construction of the Phase II model. These alternative ideas were presented to the UGTA TWG pre-emptive review committee for their consideration and evaluation, and to solicit additional alternative ideas. Each alternative idea was evaluated and categorized. The main criterion for evaluating and categorizing alternatives was whether the proposed change or alternative interpretation had the potential to significantly affect groundwater flow and contaminant transport. The geological probability and how well constrained each alterative idea was also considered. Simplification of portions and specific aspects of the base model were also considered to explore ways to reduce future flow-and-transport modeling efforts without compromising the integrity of the base model.

The alternatives were grouped into four priority categories. Category A alternatives were ideas judged to be significant and viable enough to be included in the base model. Three alternatives were grouped as category A and incorporated directly into the base model. Two of these alternatives replaced base model interpretations that were subsequently developed as alternative models (see below).

Four alternative ideas were grouped as category B alternatives. These alternatives were judged to be significant enough to develop as separate models. Each alternative was inserted into a copy of the base model, resulting in four separate alternative models. Two of these were originally included in the draft base model, but were switched out for alternative ideas.

Category C alternatives were judged to be potentially significant, but might be further evaluated during flow modeling. If judged to be significant by the flow modelers, these alternative ideas

Table 5-1
Abridged List of Alternative Scenarios for the Frenchman Flat 3-D Hydrostratigraphic Model

Alternative	Priority Group [a]	Comment/Discussion
1.0 HYDROSTRATIGRAPHY-RELATED ALTERNATIVES		
1.1 Alternatives to Simplify Hydrostratigraphy		
1.1.1 Simplify HSUs above the water table.	**D**	Can HSUs in the unsaturated zone be lumped, simplified, or ignored? This would affect the outcrop area in the northern portion of the model. Reducing the detail in the unsaturated portions of the framework model will not significantly reduce the flow-and-transport modeling effort. Also, most of the HSUs that occur within unsaturated portions of the model also occur below the water table in other portions of the model area.
1.1.2 Decrease the depth of the model.	**D**	Is there any merit in raising the bottom of the model? Work on the regional model demonstrated that even after removing the lowest 2 km (1.2 mi) from the bottom of the model, there was no difference in the outcome compared to the original model. Conductivity below about 3,000 m (9,800ft) maybe negligible. However, the elevation of the bottom of the framework model is consistent with the regional model.
1.2 Alternatives to Add Hydrostratigraphic Detail		
1.2.1 Differentiate units of the lower tuff confining unit (LTCU).	**D**	Hydraulic conductivity of the several interbedded ash-flow tuff units within the LTCU may be worth considering. (e.g. the Bullfrog Tuff at ER-5-4#2) Very little data exists on the 3-D distribution and hydrologic character of the deeper ash-flow tuffs that may be present within the LTCU beneath Frenchman Flat. It is known that these ash-flow tuff units occur deep beneath the basin and within the lower portions of the LTCU. For example the top of the Bullfrog Tuff in Well ER-5-4#2 is 1,903.8 m (6,246 ft) below the ground surface and 540.7 m (1,774.0 ft) below the top of the LTCU. Information from other areas of the NTS, such as Yucca Flat and Rainier Mesa, indicate that the LTCU has a consistent TCU character throughout even where ash-flow tuff units are present within the HSU.

Table 5-1
Abridged List of Alternate Scenarios for the Frenchman Flat 3-D Hydrostratigraphic Model (continued)

Alternative	Priority Group [a]	Comment/Discussion
1.2.2 Subdivide the alluvium based on relative abundance of reactive minerals.	**A**	Is there enough information (e.g. in Warren et al., 2002), and are the differences significant and/or predictable enough to warrant subdividing these units? Perhaps this should be a separate sub-CAU-scale model. Information from Warren et al. (2002) and Pawloski (1996) indicate significant differences in the mineralogical and physical properties of the alluvium within Frenchman Flat that likely affect significantly groundwater flow and contaminate transport within the model area. Because much of the alluvium is saturated in Frenchman Flat, and 9 of the 10 underground nuclear tests conducted in Frenchman Flat were detonated within the alluvium, it is important to model as much detail as possible within the alluvium section.
1.2.3 Subdivide the volcaniclastic confining unit (VCU) in the southern portion of the model.	**C**	Though dominated by fine-grained clastic rocks and zeolitic tuff, the VCU also includes lenses of gravel and thin freshwater carbonate beds where it outcrops in the southern portion of Frenchman Flat. Beneath the basin, however, very little is known about this HSU. The deep occurrence of this HSU below thick LTCU within much of the basin likely reduces the hydrologic significance of any aquifer-like rocks intercalated within the HSU. The unit could be subdivided in a conceptual manner by varying hydrologic parameters during flow-and-transport modeling to approximate the occurrence of more aquifer-like rocks within the unit.
1.2.4 Maximize detail within 1,000 m (3,280 ft) of the water table.	**D**	Will small differences at, or just beneath the water table make significant differences in the flow-and-transport modeling results (e.g., raise or lower an HSU, or, add or remove HSUs)? The subdivision of the alluvium as discussed in 1.2.2 above will accomplish this in much of the model area.

Table 5-1
Abridged List of Alternate Scenarios for the Frenchman Flat 3-D Hydrostratigraphic Model (continued)

Alternative	Priority Group [a]	Comment/Discussion
1.2.5 Basalt-flow geometry. Note: Interpretation a) was designated the alternative and interpretation b) was utilized in the base model.	**B**	a) Model the basalt as a continuous unit from Well Cluster ER-5-3 to the basin-forming faults to the east (Alternative #1; see Section 5.2.1). Although surface magnetic data suggest that the basalt beneath northern Frenchman Flat is not a continuous flow, uncertainty associated with magnetic data allow for the possibility that the basalt is continuous.
	A	b) Model the basalt as if dissected by erosion, faulted, or composed of separate lobes. Surface magnetic data indicate that the basalt consists of several separate occurrences.
	D	c) How would a basalt dike affect groundwater flow? What properties should be assigned to this material? Can we define the hydrologic properties of such a thin tabular body? A basalt dike would likely have hydrologic properties similar to a basalt lava-flow aquifer. There is no evidence that basaltic dikes occur beneath Frenchman Flat, and thus the locations and geometries of any such features is completely unknown.
1.3 Alternatives Addressing Different Distributions for Pre-Tertiary HSUs		
1.3.1 Change the HSU designation for the Paleozoic carbonate rocks exposed around the margins of the basin (LCA or LCA3?).	**D**	These outcrops are currently modeled as LCA. Could they be LCA3? Published maps and reports indicate that carbonate rocks exposed around the margins of Frenchman Flat are part of a thick continuous carbonate sequence. Thrust faults are present southeast of the model area, suggesting that the carbonate rocks around the margins of the basin may be part of a thrust sheet. However, the thrust sheet would likely be very thick, based on surface exposures, and the base of the thrust sheet would occur at great depths below the basin. Thus it would likely have little hydrologic impact if the carbonate rocks around the margins of Frenchman Flat basin are designated LCA or LCA3.

Table 5-1
Abridged List of Alternate Scenarios for the Frenchman Flat 3-D Hydrostratigraphic Model (continued)

Alternative	Priority Group [a]	Comment/Discussion
1.3.2 Subdivide the LCA.	D	Would occurrences of the Dunderberg Shale or Eureka Quartzite alter flow in the LCA? The LCA, which is approximately 4,267 m (14,000 ft) thick, consists mainly of massive carbonate. However, siliciclastic units, such as the Dunderberg Shale and Eureka Quartzite, occur within the LCA. These units are generally less than 91 m (300 ft) thick each and thus account for less than 5 percent of the HSU. Few holes within the model area have encountered the LCA and none have encountered the Dunderberg Shale or Eureka Quartzite. Thus the 3-D distribution of these minor clastic units is unknown within most of the model area.
2.0 STRUCTURE-RELATED ALTERNATIVES		
2.1 Simplify the Structural Model	D	Omit all but the most profound structures and faults. The number of faults and structural detail in the model are sufficient, and any simplification of the structure will not significantly reduce future modeling efforts. In addition, the level of structural detail in the framework model already represents a considerable simplification of the structural geology of the area. Any further simplification may detrimentally affect the integrity of the model.
2.2 Remove Faults Along Edge of Model	D	Remove faults in the southeast corner of the model. Although removing faults might simplify flow-and-transport modeling, these faults define the structural fabric of the area which is likely important with regards to groundwater flow, particularly is direction.
2.3 Add More Structural Detail		
2.3.1 Add width to faults.	C	Modify faults from simple two-dimensional surfaces to 3-D features having some width. Flow-and-transport modeling might be used to explore whether this will help predict where and why faults might be a barrier or conduit to groundwater flow.

Table 5-1
Abridged List of Alternate Scenarios for the Frenchman Flat 3-D Hydrostratigraphic Model (continued)

Alternative	Priority Group [a]	Comment/Discussion
2.3.2 Add more Tertiary faults or fault zones.	**D**	Perhaps begin by adding more of the mapped faults (shown on Slate et al. [1999] or the individual USGS quadrangle maps). The number of faults in the model is sufficient and a good compromise between geologic reality and flow and transport modeling constraints.
2.3.3 Extend the CP thrust fault south of the Cane Spring fault.	**D**	The CP thrust is a poorly characterized, west-to-northwest-vergent thrust fault, that appears to be mostly outside the boundaries of the model area. Do we really need to add this complexity to the northwest corner of the model? Could the fault be elsewhere, too? The CP thrust is exposed at the surface just northwest of the model area where it places carbonate rocks over siliciclastic rocks. The fault likely extends at depth into the model area beneath CP Basin and is included in the model within this area. Resistivity data seem to show that the CP thrust fault may be rooted within the steeply-dipping Cane Spring fault which bounds CP basin on southeast. This is consistent with evidence from Yucca Flat that suggests the CP thrust dips steeply into the Topgallant/Carpetbag fault system. Drilling and resistivity data from northern Frenchman Flat and southern Yucca Flat indicate that the pre-Tertiary surface in these areas consists of carbonate rocks, and magnetotelluric (MT) data indicate that the carbonate rocks extend to great depths just southeast of the Cane Spring fault. Thus, if the CP thrust extends beyond the Cane Spring fault and into the northwestern portion of Frenchman Flat it is either very deep or places carbonate rocks over carbonate rocks, and thus will likely have minimal hydrologic effect if present beneath Frenchman Flat.
2.3.4 Explore fault-related groundwater pathways.	**B**	Increase or decrease fault displacements so aquifers are juxtaposed across faults. Deliberately juxtapose aquifer units across faults. Candidates for such adjustments would include the basin-forming faults in the east. (Alternative #3; see Section 5.2.3)

Table 5-1
Abridged List of Alternate Scenarios for the Frenchman Flat 3-D Hydrostratigraphic Model (continued)

Alternative	Priority Group [a]	Comment/Discussion
2.3.5 Explore variations of the CP thrust fault in CP Basin Note: Interpretation a) was used as the alternative, and interpretation b) was integrated into the base model.	 **B** **A**	The Cane Spring fault forms the southeast boundary of CP Basin. The fault seems to end abruptly at the Massachusetts Mountain/CP Hogback juncture. The fault termination geometry may influence deep inter-basin flow from Yucca Flat. a) The MT data suggest that the UCCU is limited in extent in this area, so the scenario of a continuous thrust sheet of UCCU beneath the CP Basin is modeled as an alternative. (Alternative #4; see Section 5.2.4) b) The pre-Tertiary structure (e.g. the CP thrust) beneath CP basin based mainly on the results of the MT survey, which limits the extent of the UCCU beneath the CP Basin. Also, the Cane Spring fault is modeled as terminating in an imbricate fan similar to the Rock Valley fault system.
2.3.6 Other fault variations	 **C**	Faults are depicted in the hydrostratigraphic framework model as single planes. Explore through flow-and-transport modeling, if warranted, whether there would be hydrologic consequences if the faults are zones consisting of multiple parallel individual fault planes.
2.4 Develop Different Structural Scenarios		
2.4.1 Vary fault dips.	 **C**	The basin-and-range normal faults are modeled using a 75-degree dip. Varying fault dips would present more consequences in the source areas, where fault proximity to working points is important. This might be better addressed in sub-CAU-scale hydrologic models.
2.4.2 Vary the depth to basement rocks.	 **D**	The uncertainty in depth to basement based on geophysical data (gravity) is roughly 300 m (1,000 ft) in places. This may not be geologically permissible in some areas. And where it is possible, what units would be thinned or thickened? Although some data, such as gravity, have relatively low resolution, other data sets particularly the most recent data such as deep drilling and 3-D seismic are higher resolution and constrain the depth to basin fairly well in the hydrologically significant areas such as the northern and central portions of Frenchman Flat.

Table 5-1
Abridged List of Alternate Scenarios for the Frenchman Flat 3-D Hydrostratigraphic Model (continued)

Alternative	Priority Group [a]	Comment/Discussion
2.4.3 Vary the geometry/ position of the Rock Valley fault.	**D**	This northeast-southwest striking strike-slip fault is intimately related to basin formation. Does it also control groundwater flow out of Frenchman Flat? The location and general geometry of this fault zone are relatively well constrained.
2.4.4 Vary displacement on basin-forming faults.	**D**	Distribute displacements along basin-forming faults along east side to better fit gravity data. The distribution of displacement along basin-forming faults matches relatively well with the gravity data, particularly considering the low resolution typically associated with gravity data. However, some fault displacements were varied as part of Alternative #3 (2.3.4) to juxtapose aquifers.
2.5 Other Structure-Related Alternatives		
2.5.1 "Smooth" versus "rough" HSU surface.	**D**	Computer idiosyncracies have produced "hills" and "indentations" on HSU surfaces where none were intended. Does it matter? A rough surface might better approximate the effect of faulting. The elevations of the "hills" and "indentations" are not great enough to be significant.
2.5.2 Consider defining basin slopes with faults.	**D**	The UGTA base model portrays many of the central basin gravity lows as syncline-type structures and not half-grabens (e.g. northeast of the Well Cluster ER-5-4). Are there more faults (possibly hydrologically significant) that are not discernable with geophysics? The overall shape of the central portion of the basin is a half-graben. The apparent synclinal shape is probably due to hanging wall drag along the large basin-forming faults. There are certainly more faults, however geophysical data (e.g. seismic and gravity) constrain additional faults as relatively small displacement. No large host blocks are observed within the central portion of the basin.
2.5.3 Explore variations of the accommodation zone between Frenchman and Yucca Flat.	**D**	This feature appears as a gravity high between two extensional basins. How does this area affect inter-basin groundwater flow? Although this area is complex, surface exposure is very good, and geophysical data are available for much of the area. The base model incorporates these data, including HSU contacts and faults exposed at the surface, and thus models the most important controls such as HSU distribution and fault orienations fairly well in this area.

Table 5-1
Abridged List of Alternate Scenarios for the Frenchman Flat 3-D Hydrostratigraphic Model (continued)

Alternative	Priority Group [a]	Comment/Discussion
2.5.4 Remove the detachment fault.	**B**	Model volcanic rocks in the northern portion of basin as moderately dipping surfaces to the south (Alternative #2; see Section 5.2.2).

a **Group A** are changes to the UGTA hydrostratigraphic framework base model recommended by the alternative scenario working group, and are already implemented.

Group B are considered viable alternative scenarios that will be modeled. See Section 5.2.

Group C are proposed alternatives that will be further evaluated during flow and transport modeling, if necessary, by manipulating parameter values, and are not addressed as alternatives to the hydrostratigraphic framework model.

Group D are proposed alternatives that were deemed to be low priority (due to perceived minimal consequences to groundwater flow and contaminant transport), not cost-effective, not practical (no data, too complex, etc.), or simply not necessary to model at this time.

Note: Earlier drafts of this table included a section on hydrologic alternatives. None of the listed hydrologic scenarios could be addressed in the hydrostratigraphic framework model, so they have been removed from this version of the table.

will be addressed during flow and transport modeling by manipulation of model parameters. Thus, separate alternative framework models were not developed for these ideas.

Category D alternatives were deemed not significant or viable enough to warrant development as alternative models. These alternative ideas will not be considered further.

The changes listed in Group A listed below were implemented and are part of the base model as reported in this document.

Group A - Changes Made in the Base Model

(Numbers in parentheses refer to Table 5-1, where more information about these changes can be found.)

1. Subdivide the alluvial section (1.2.2).
2. Portray the basalt lava-flow aquifer as smaller and discontinuous flows (1.2.5).
3. Model the pre-Tertiary structure (e.g., the CP thrust fault) based mainly on MT data, and terminate the Cane Spring fault in a imbricated fan as conceptualized for the Rock Valley fault system (2.3.5).

The short list of alternative scenarios which the working group deemed important enough to pursue (Group B) are listed below.

Group B - Viable Alternative Scenarios

Numbers in parentheses refer to Table 5-1, where more information about these changes can be found.
See also discussion of each alternative in Section 5.2

1. Portray the basalt HSU as a single, extensive, continuous lava flow (1.2.5).
2. Remove the detachment fault and portray volcanic rocks as moderately dipping surface (2.5.3).
3. Explore fault-related groundwater pathways. Vary displacement of the basin-forming faults to force juxtaposition of HSUs (2.3.4).
4. Explore variations in structural geometry for the CP Basin. Model UCCU as a continuous thrust sheet (2.3.5).

Proposed alternatives that would be better addressed, if deemed necessary, during the hydrologic modeling phase rather than as alternatives to the geologic framework model make up Group C. These alternatives might best be handled by various methods of generating flow model grids and assigning different hydraulic properties to faults or HSUs, rather than changing the framework model or building a separate model.

Group C - Proposed Alternatives to Address During the Hydrologic Modeling Phase

(Numbers in parentheses refer to Table 5-1, where more information about these changes can be found.)

1. Subdivide the volcaniclastic confining unit (VCU) (1.2.3).
2. Add width to fault planes (2.3.1).
3. Fault variations such as faults composed of parallel multiple planes (2.3.6).
4. Vary fault dips near source areas (2.4.1).

5.2 Alternative Models

This section describes the four alternative models developed for the Frenchman Flat hydrostratigraphic framework model.

5.2.1 Portray the Basalt as a Single, Continuous Lava Flow (Alternative #1)

The Frenchman Flat base model depicts the BLFA as three separate and discontinuous bodies embedded within the alluvial section (Figure 4-8). This geometry is based on drill hole and ground magnetic data (Section 4.3.4). However, there is some uncertainty associated with this interpretation. It is not known if these are three separate flows or erosional remnants of a single larger flow. Also, aeromagnetic and ground magnetic data do not extend far enough east to show definitively the eastern limit of the BLFA. Coincidently, the BLFA is located at or near the water table. The presence and geometry of such an aquifer near the water table may affect flow and transport of radionuclides away from underground nuclear tests in the vicinity.

Furthermore, the source of this BLFA is not known. Several of the basalt flows and dikes to the north in the Half Pint Range are associated with generally north-south trending faults (Hinrichs et al., 1965; Byers and Barnes, 1967). It is conceivable that one of the basin-forming faults in the Frenchman Flat model is the source for the Frenchman Flat basalt. If so, the BLFA could possibly provide a lateral conduit for contaminants from underground nuclear tests in northern Frenchman Flat eastward to the fault and ultimately to the LCA. This alternative will allow flow-and-transport modeling to explore the consequences of a contiguous basalt lave-flow

aquifer near the water table in the vicinity of the group of underground nuclear tests in northern Frenchman Flat. A comparison of the BLFA in the base model and in alternative scenario #1 is shown in Figure 5-1.

5.2.2 Remove the Detachment Fault (Alternative #2)

Drill hole and 3-D seismic data suggest that a detachment fault is present beneath the northern portion of Frenchman Flat (see Section 3.2.3 and Appendix D), and this interpretation was included in the base model. However, because of the uncertainty of this interpretation and the potential hydrologic consequences associated with such an interpretation, an alternative model was developed that did not include the detachment fault. In the alternative model, the detachment fault is removed, and volcanic rocks are modeled as dipping moderately southward from borehole UE-11b and nearby surface exposures to the deeper intercepts in drill holes located to the south (Figure 5-2).

5.2.3 Juxtaposition of HSUs Along Faults (Alternative #3)

Because basin-forming faults typically have large vertical displacements, the juxtaposition of shallow aquifers against deeper aquifers could occur and be significant with regard to flow-and-transport modeling in the Frenchman Flat area. In the base hydrostratigraphic framework model, no aquifers are juxtaposed due to faulting along the main basin-forming faults. However, the locations, orientations and amounts of displacements associates with these faults is poorly constrained. Therefore an alternative model was developed that juxtaposed shallow volcanic aquifer HSUs with the LCA along a major basin-forming fault (Figures 5-3a and 5-3b).

5.2.4 Variations of the CP Thrust Fault in CP Basin (Alternative #4)

Considerable uncertainty exists with regard to the pre-Tertiary structural geology beneath CP Basin. Consequently, the distribution of pre-Tertiary HSUs beneath the basin is poorly known, particularly the distribution of the UCCU. The UCCU is exposed in the footwall of the CP thrust fault just northwest of the model area, and MT recordings seem to indicate that the UCCU is present beneath the northeastern portion of CP Basin. The base model incorporates the MT data, and thus places the UCCU beneath CP Basin as part of the footwall of the CP thrust, and limits its extent to the northeastern portion of the basin. Overlying the footwall rocks is a continuous sheet of carbonate rocks that composes the hanging wall of the CP thrust.

Because of the uncertainties associated with the distribution of the UCCU beneath CP Basin, and the potential hydrologic influence of this major confining unit, particularly with regards to groundwater flux out of southern Yucca Flat and into the northwest portions of the model area, an alternative model was developed for CP Basin (Figure 5-4). The alternative model extends

the UCCU beneath all of CP basin, resulting in a continuous sheet of UCCU beneath the basin. As in the base model, a continuous sheet of carbonate rock comprising the hanging wall of the CP Thrust overlies the UCCU beneath the basin.

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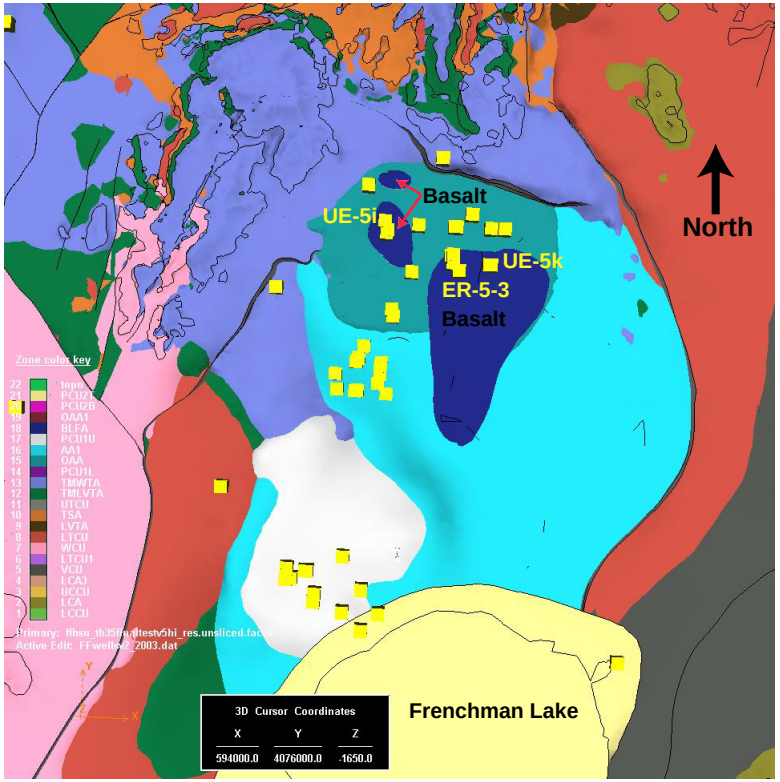
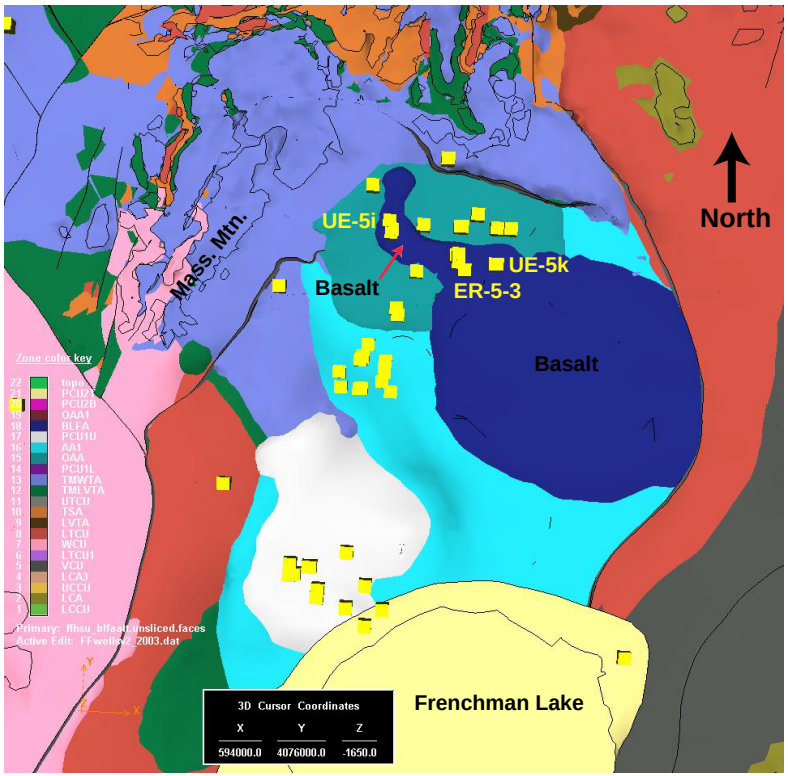


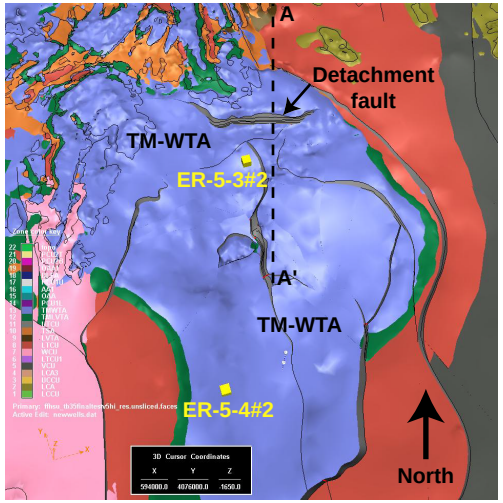
Extent of basalt in base model.



Extent of basalt in Alternative Scenario #1.

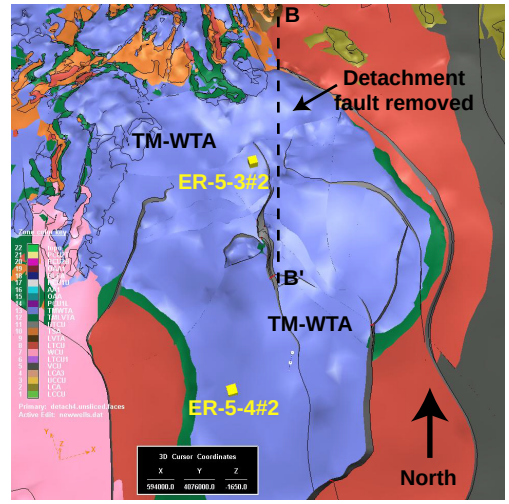
Figure 5-1
Comparison of the Basalt Lava-Flow Aquifer in the Base Model with Alternative Scenario #1.

Base Model with Detachment Fault

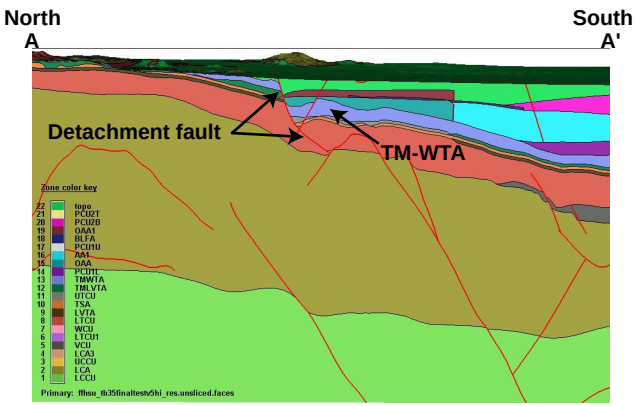


Map view of EarthVision model
with alluvial, playa, and basalt HSUs removed.

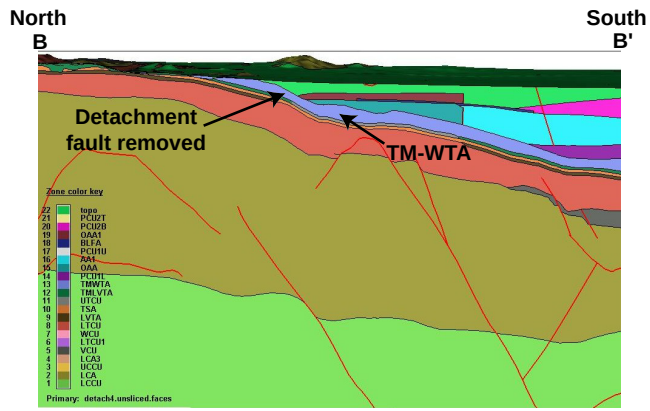
Alternative #2 without Detachment fault



Map view of EarthVision model
with alluvial, playa, and basalt HSUs removed.



North-south profile showing
detachment fault in base model.



North-south profile showing
detachment fault removed in the alternative model.

Figure 5-2
Comparison of the Base Model with the No Detachment Fault Alternative (Alternative #2).

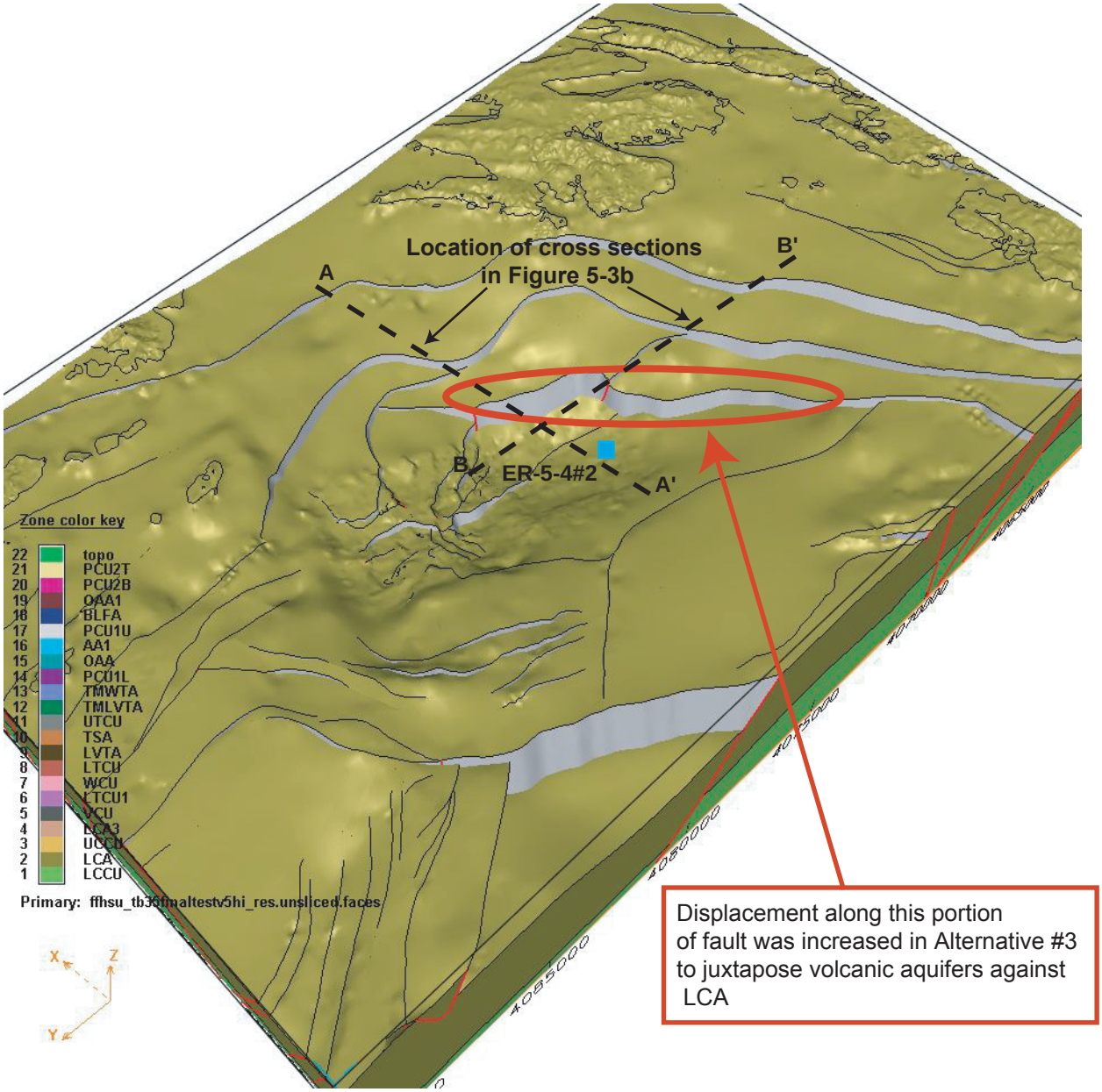


Figure 5-3a
Perspective View of the Base Model Showing
Top of LCA and Location of Alternative #3
(View is Southeast)

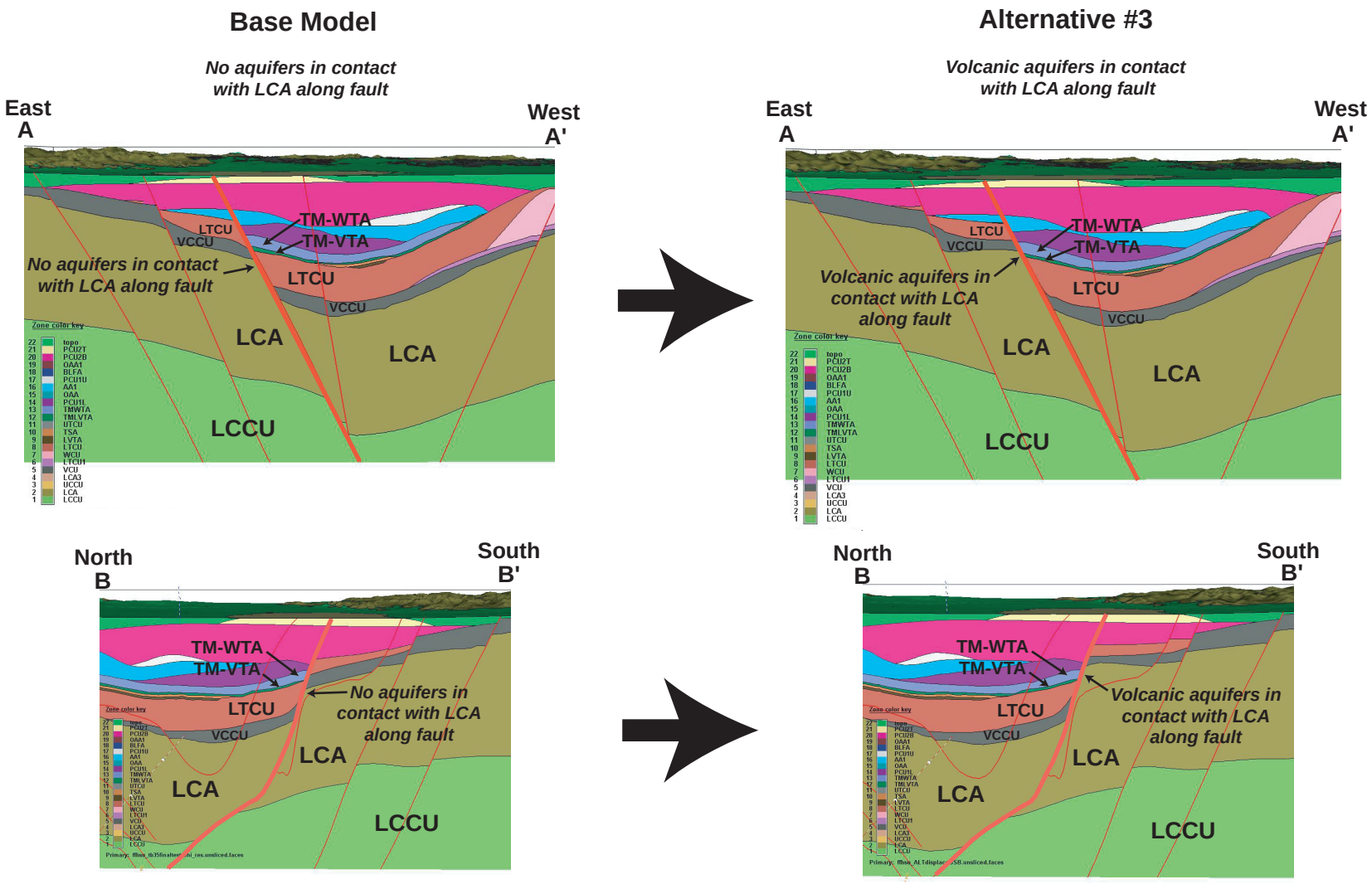
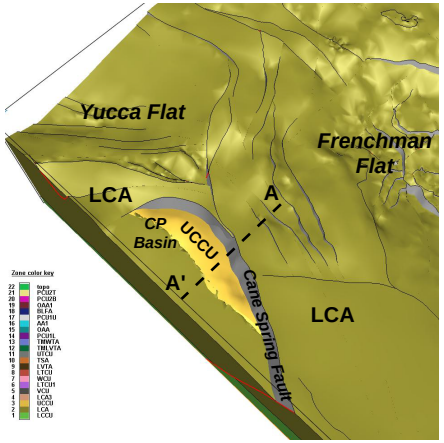


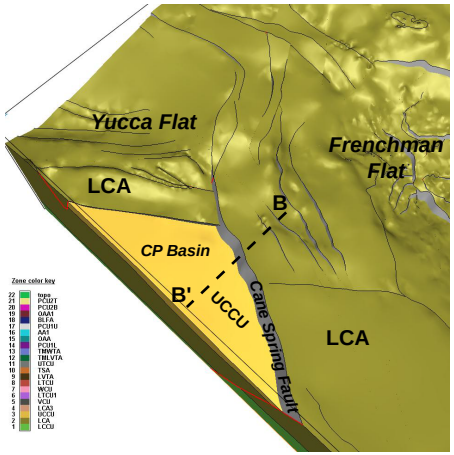
Figure 5-3b
Profiles Comparing Base Model with Alternative #3

Base model showing limited extent of UCCU beneath CP Basin

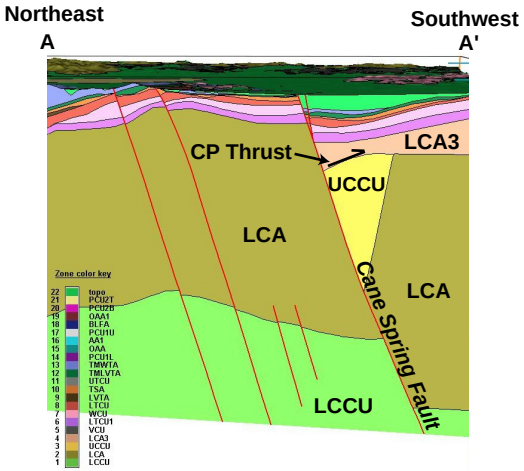


Perspective view of EarthVision model with LCA3 removed.

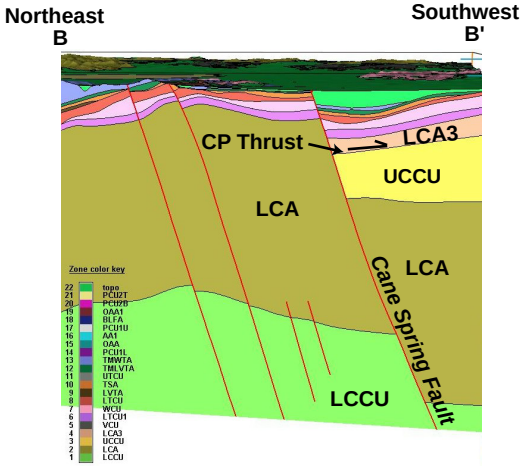
Alternative #4 showing continuous sheet of UCCU beneath CP Basin



Perspective view of EarthVision model with LCA3 removed.



Profile through CP Basin (Base model)



Profile through CP Basin (Alternative #4)

Figure 5-4
Comparison of the Base Model with the CP Basin Alternative (Alternative #4)

6.0 SUMMARY

Frenchman Flat, encompassing Areas 5 and 11 of the NTS (CAU 98), was the site of 10 underground nuclear tests. Because several of these tests were conducted near or below the water table, test-related contaminants are presumed available for transport via the groundwater flow system. Models are being developed by the UGTA Project of the NNSA/NSO Environmental Restoration Program to predict groundwater flow and contaminant transport from the source areas to groundwater discharge areas. The hydrologic modelers require a hydrostratigraphic framework that addresses the character and extent of geologic units in three dimensions. The development and description of this framework for the Frenchman Flat area is documented in this report.

The general hydrogeologic framework for the NTS and vicinity established by USGS geoscientists in the early 1970s, has provided the foundation for most subsequent hydrogeologic studies at the NTS, including the Frenchman Flat hydrostratigraphic model. The hydrostratigraphic framework for the Frenchman Flat area documented in this report is a product of several phases of work over several years supported by the UGTA Project, in which the hydrogeologic understanding of the model area has become increasingly detailed and refined as a result of the contributions of many people and organizations associated with the NTS.

The hydrogeology of the southeastern NTS, including Frenchman Flat, is complex. The thick sections of alluvium and volcanic rocks comprise a wide variety of lithologies that can range in hydraulic character from aquifer to aquitard. Basin and Range faulting have acted to further complicate the area, placing the various lithologic units in juxtaposition, and blocking or enhancing the flow of groundwater in a variety of ways.

In this study, earlier hydrogeologic framework models were integrated with drill-hole data (stratigraphic, lithologic, and alteration data), data from several geophysical, geological, and hydrological studies and a new conceptual structural model, to formulate a hydrostratigraphic classification system. Applying this updated understanding of Frenchman Flat area hydrogeology, the authors organized the volcanic units in the study area into 17 HSUs that include 9 aquifers, 8 confining units. In this model the alluvial section was subdivided into 5 HSUs including the alluvial aquifer, a basalt lava-flow aquifer, 2 playa confining units, and an older altered alluvium aquifer. The Tertiary volcanic rock section was subdivided into 7 HSU including 4 aquifers and 3 confining units. The older Tertiary-age sediments are lumped into a single confining unit HSU. The underlying pre-Tertiary rocks were divided into 4 HSUs,

including 2 aquifers and 2 confining units. The drill-hole database was then converted to a hydrostratigraphic database based on this hydrostratigraphic classification system, and, along with the new conceptual structural model, provided the basis to construct unit-extent and structure-contour maps for each HSU. Three-dimensional surfaces were derived from these maps using the EarthVision® modeling software. The 3-D volumes defined by these surfaces will serve as layers for the UGTA groundwater modeling process.

To construct this model, the raw data compiled by SNJV and BN geologists, and interpretative products prepared by BN geologists (fault framework, cross sections, etc.) were input into EarthVision®. SNJV personnel who are knowledgeable in the use of EarthVision® were responsible for building the digital 3-D model. The resultant model was reviewed and corrected as necessary by the authors in an iterative fashion, to resolve structural problems that tend to develop as a result of sparse data and the computerized model building process. The maps and profiles provided in this document are selected presentations from the digital model and are meant only to generally illustrate the character of the HSUs (model layers). This framework will be transmitted electronically in the form of an EarthVision® model that is directly usable by the hydrologic modelers.

The geologic complexity of the model area and sparse data for much of the region resulted in the incorporation of some non-unique interpretations into the base model. This made it necessary to address alternative interpretations for some of the major features in the model. Four of these alternatives were developed so they could be modeled in the same fashion as the base model, and are expected to aid the hydrologic modelers in exploring and refining the results of the flow and transport models.

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