CNWRA Modeling of Site-Scale Saturated Zone Flow at Yucca Mountain

Presented by:

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Nuclear Waste Technical Review Board Meeting

March 10, 2004

Las Vegas, Nevada

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Notes

- The activities presented here were performed on behalf of the U.S. Nuclear Regulatory Commission (NRC) Office of Nuclear Material Safety and Safeguards, Division of Waste Management. This presentation is an independent product of the *CNWRA* and does not necessarily reflect the view or regulatory position of the NRC.

- Models scenarios and results presented here are exploratory in nature and intended only as a tool to better understand the saturated zone flow system near Yucca Mountain. As such, the modeling approach, scenarios, and results presented here should not be construed as being preferred by either *CNWRA* or NRC.

Outline

- *CNWRA* independent site-scale groundwater flow model: hydrogeologic framework and model description
- Effects of hydrogeologic interpretation on model calibration and modeled groundwater flow paths.
- Effects of local recharge at Yucca Mountain on modeled groundwater flow paths and travel times
- Effects of increased recharge and water table rise (potential climate change scenario) on modeled groundwater flow paths and travel times

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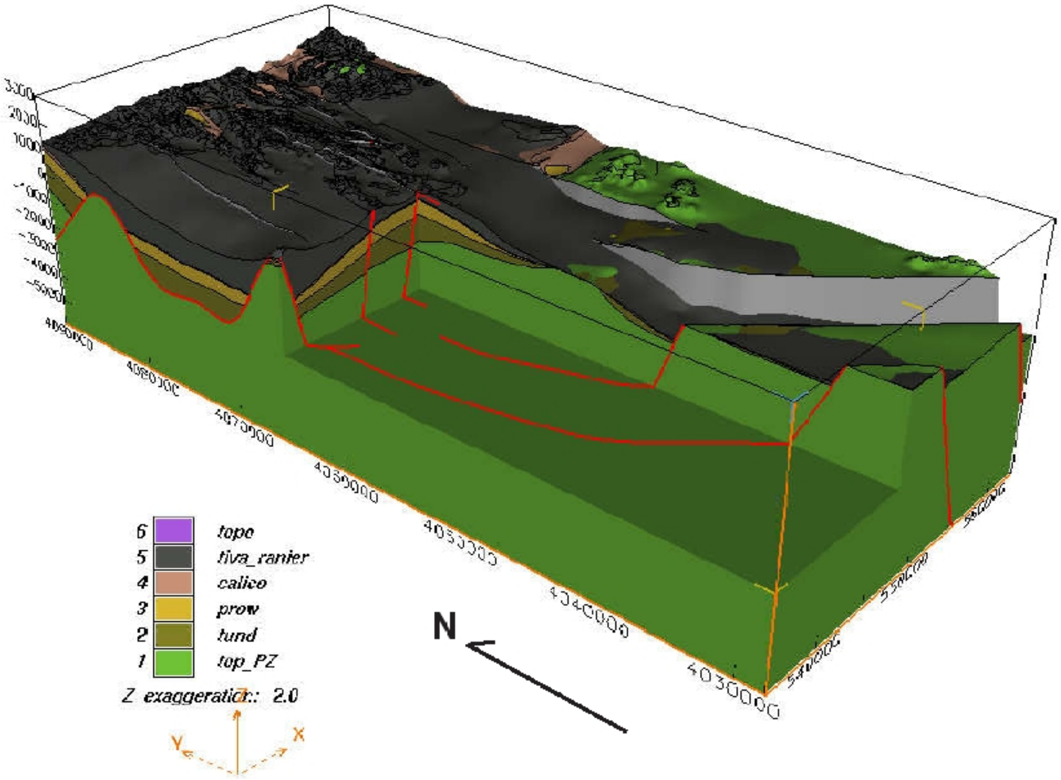
Hydrogeologic Framework

- Hydrogeologic Framework Model (HFM) based on Sims et al. (1999) 3-D Earth Vision model of Amargosa Region

- GFM 3.1 (CRWMS M&O, 1999) was starting point for HFM interior region; layers were grouped into hydrostratigraphic types and model region was extended based on independent interpretation of borehole and geophysics data



- Hydrologic properties for flow model were assigned based on correspondence to layers and structural features in HFM

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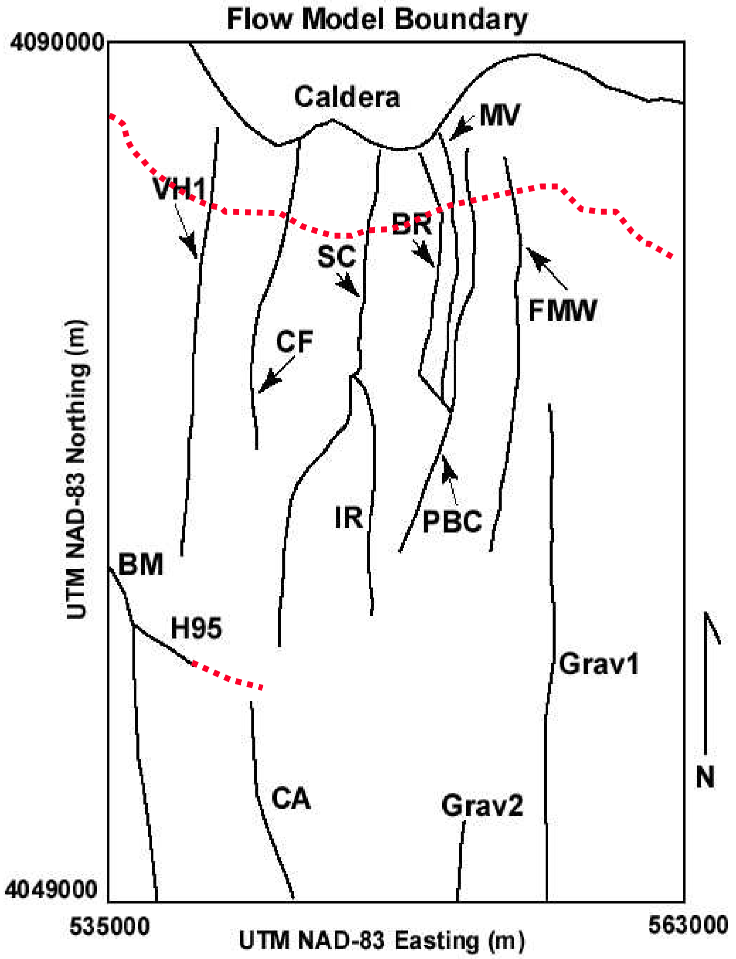
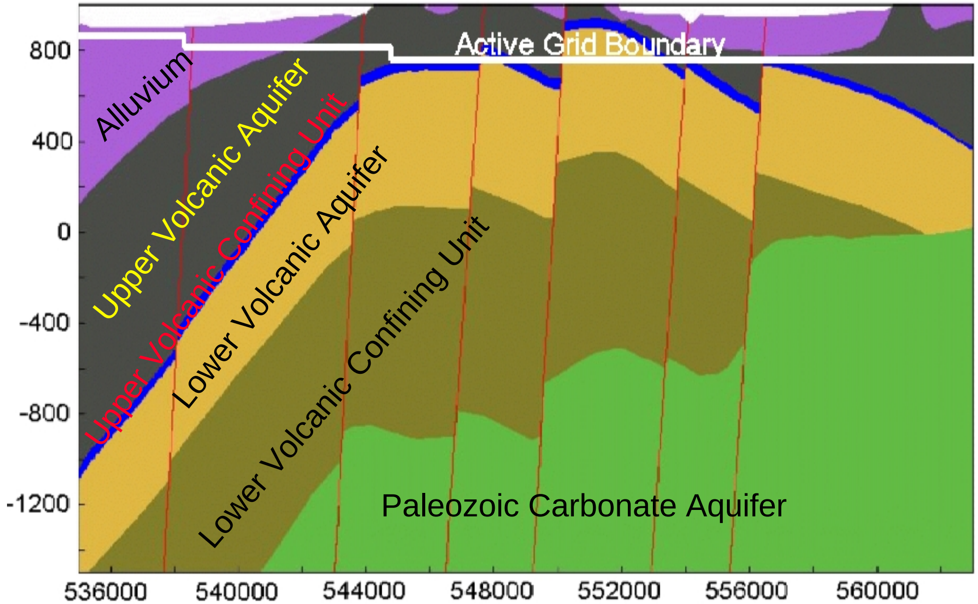
Structural Features Included in the Model Domain

- Changes from Sims et al. (1999) HFM were made during flow model grid construction and model calibration:
  - — Caldera Zone extended southward (upper red dashed line at right) to match large hydraulic gradient north of Yucca Mountain
  - — Bow Ridge (BR), Midway Valley (MV) and Paintbrush Canyon (PBC) faults were combined into a single, wide fault zone because 300-m grid size is too coarse to include them as separate features
  - — Area between PBC and Fortymile Wash (FMW) faults also made into a single, wide fault zone to improve calibration
  - — Highway-95 fault zone extended eastward (lower red dashed line at right) to match steep hydraulic gradient in this area

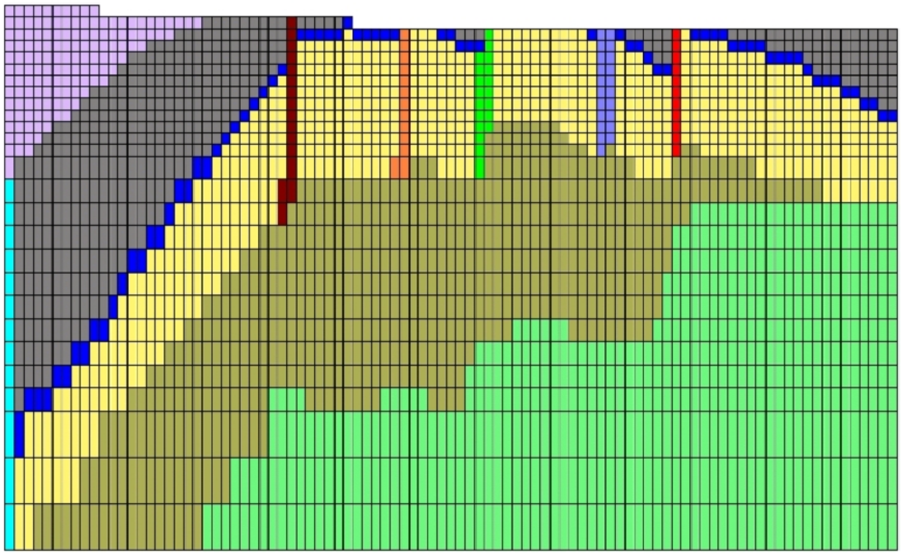


Flow Model Grid

- Comparison of hydrogeologic framework model to material types assigned to model grid



Sims et al. (1999) Framework Model
vertical scale = meters above sea level (masl)
horizontal scale = UTM NAD-83 Easting (m)
[note: 1 m = 3.281 ft]



Corresponding Section of
30-Layer Model Grid

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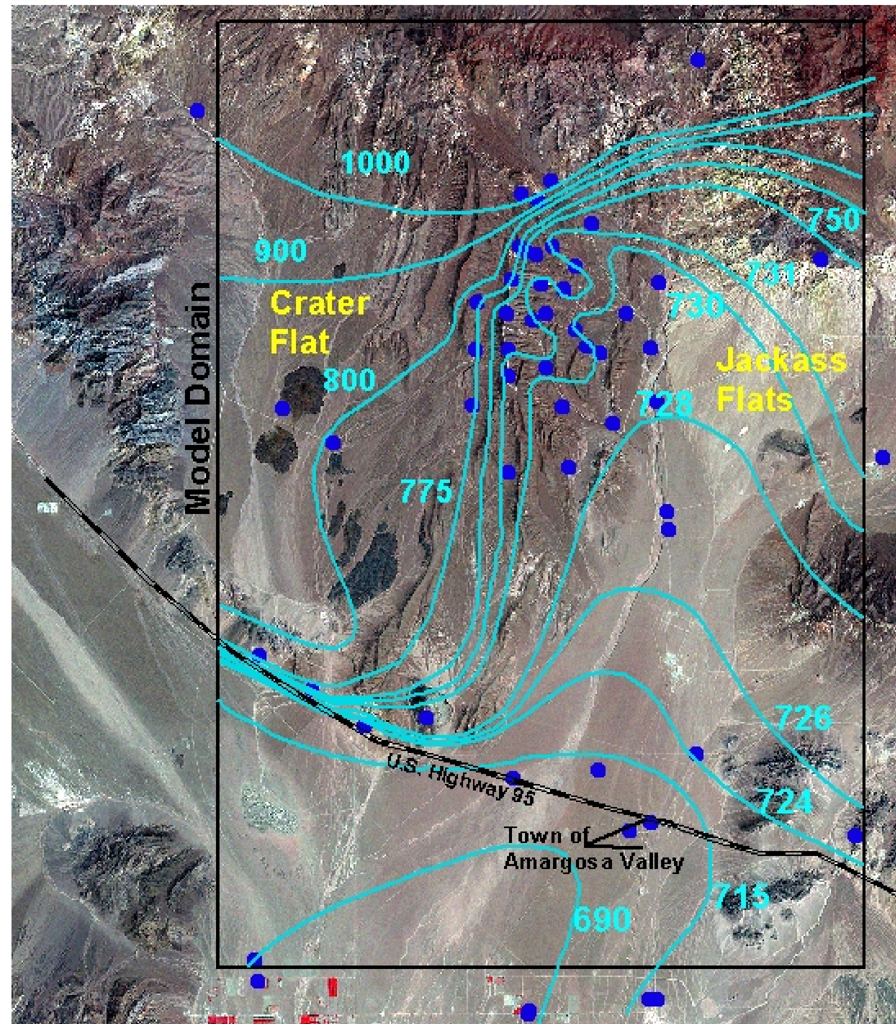
Boundary Conditions and Calibration Points

- Model Domain shown at right:
  - — 28.5 km × 41.4 km [17.7 × 25.7 mi]
  - — vertical extent is from -1500 masl to 1200 masl
- Interpretation of water table used to estimate constant head values for model sides; constant with depth
- No-flow bottom boundary
- Top 7 model grid layers make use of the MODFLOW confined/unconfined solution: allows top boundary to vary with water table elevation
- Recharge in northern high-elevation area; also considered in some scenarios for Yucca Mountain and Fortymile Wash areas
- 70 Wells used for calibration points



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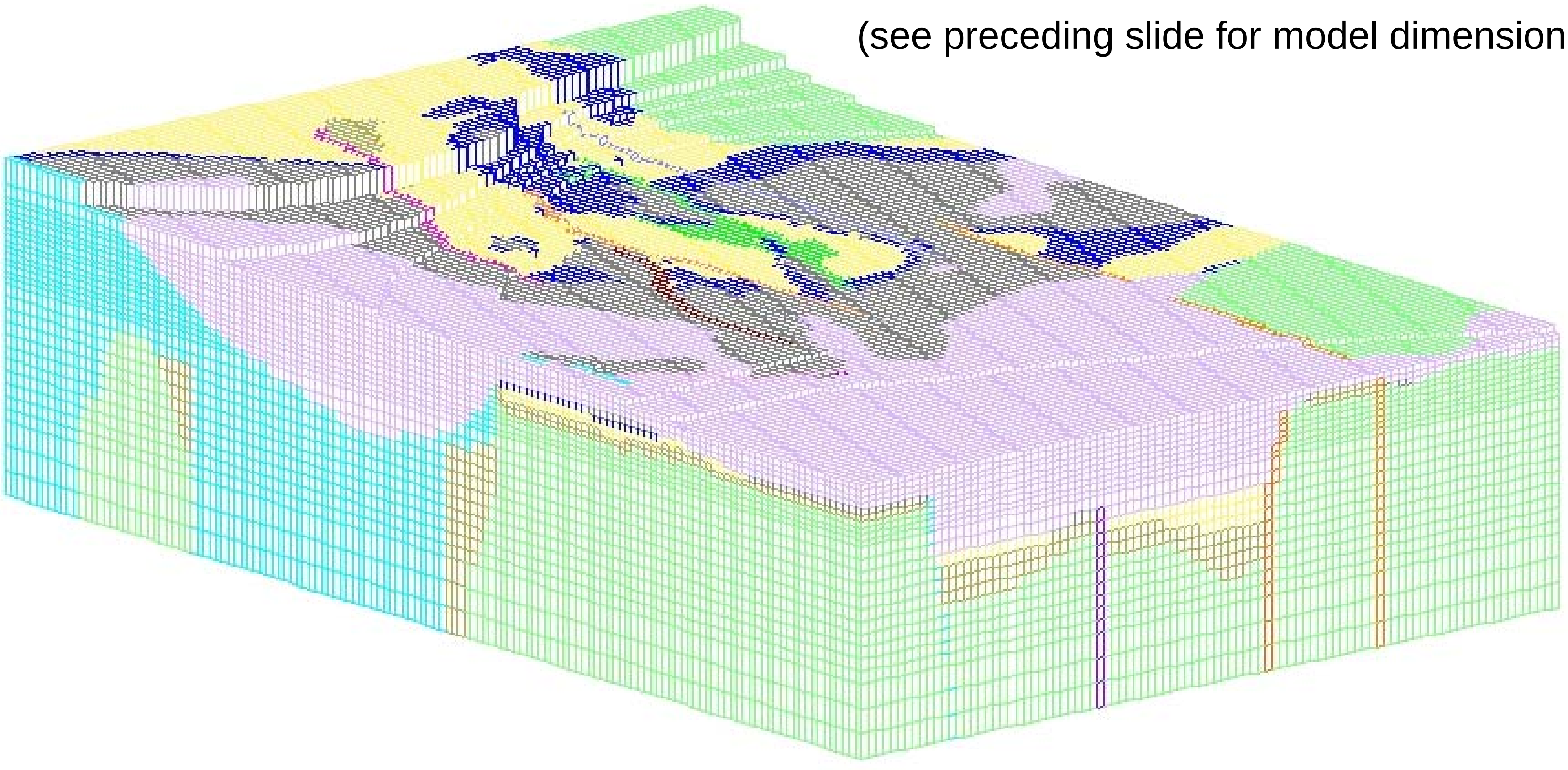
3-D Oblique View of Model

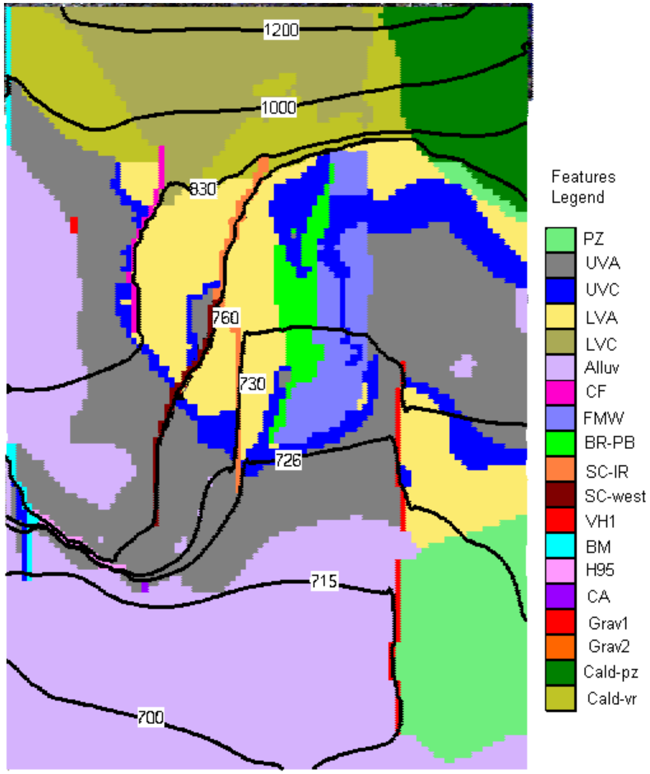
3-D Model View Looking Northeast

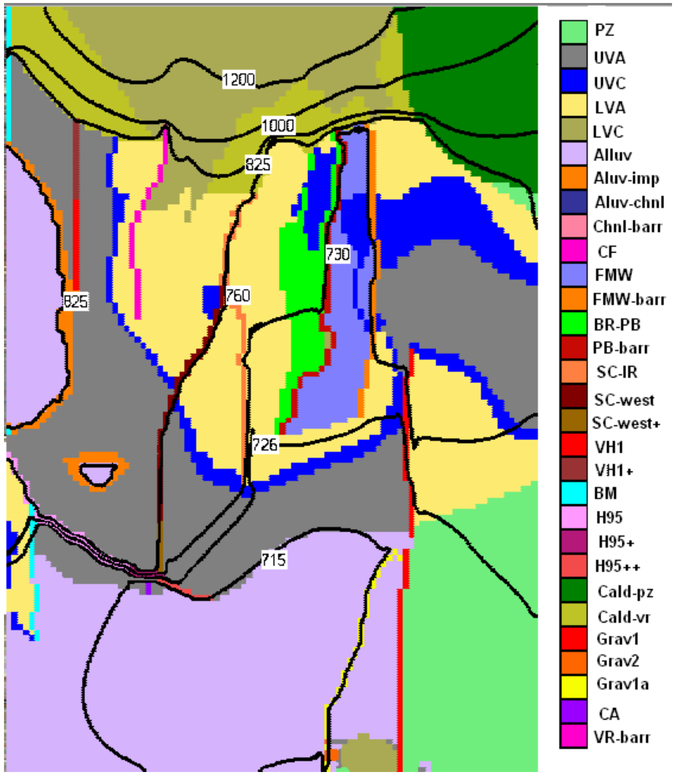
(see preceding slide for model dimensions)



Effects of Hydrogeologic Interpretation on Model Calibration and Modeled Flow Paths

Goal: reduce calibration error by modifying hydrogeologic features





Original Model: includes only features identified in Sims et al. (1999)

Alternative Model: several features added or modified to reduce calibration error (see Winterle et al. 2003)

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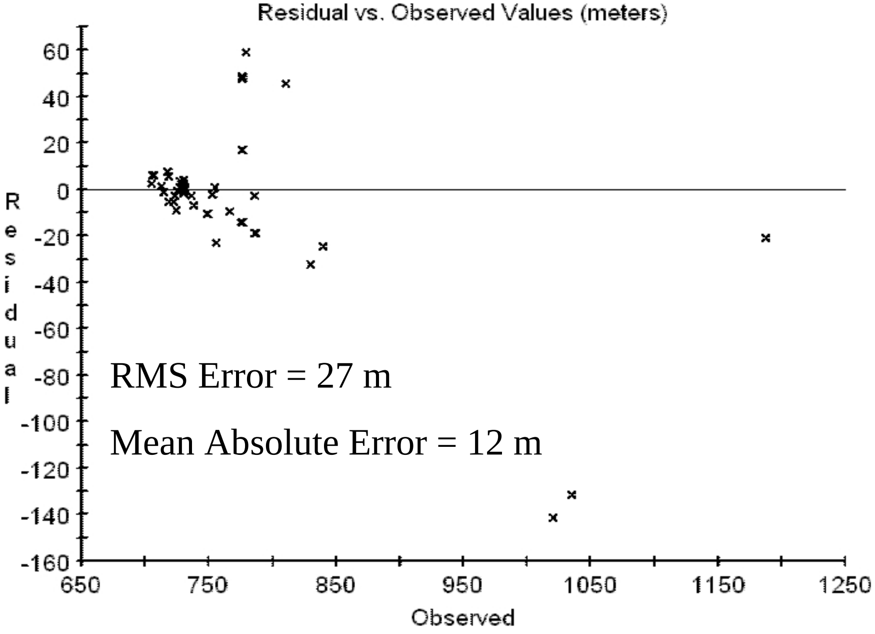
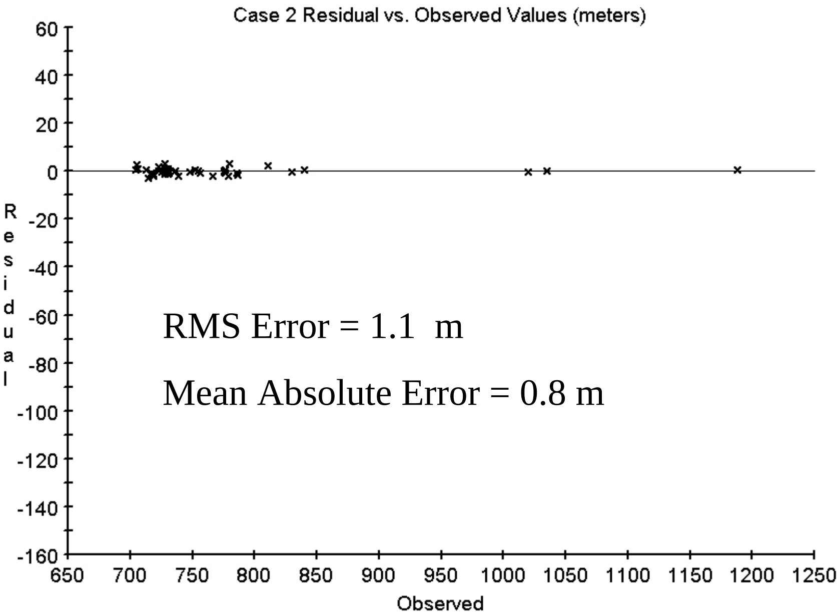
Effects of Hydrogeologic Interpretation on Model Calibration



Original Model Calibration



Alternative Model Calibration

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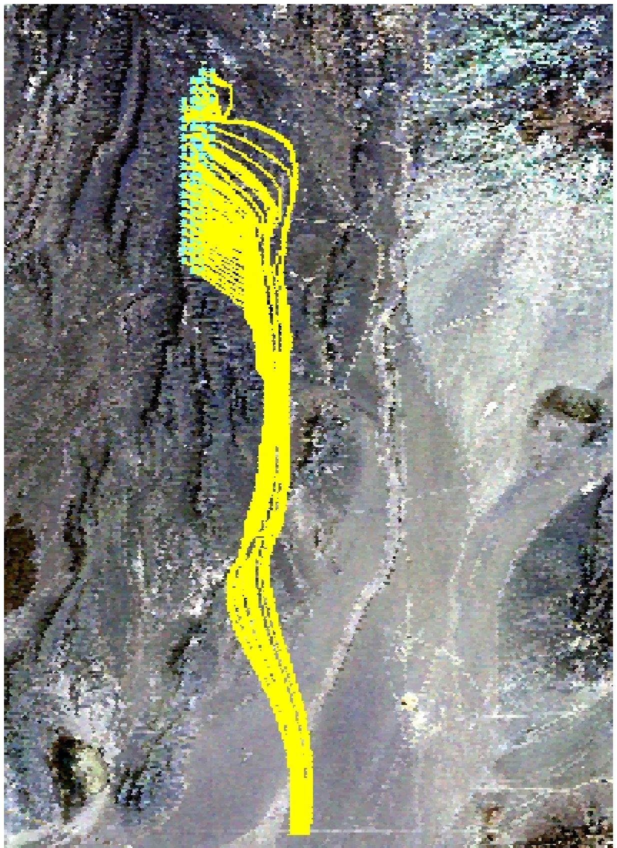
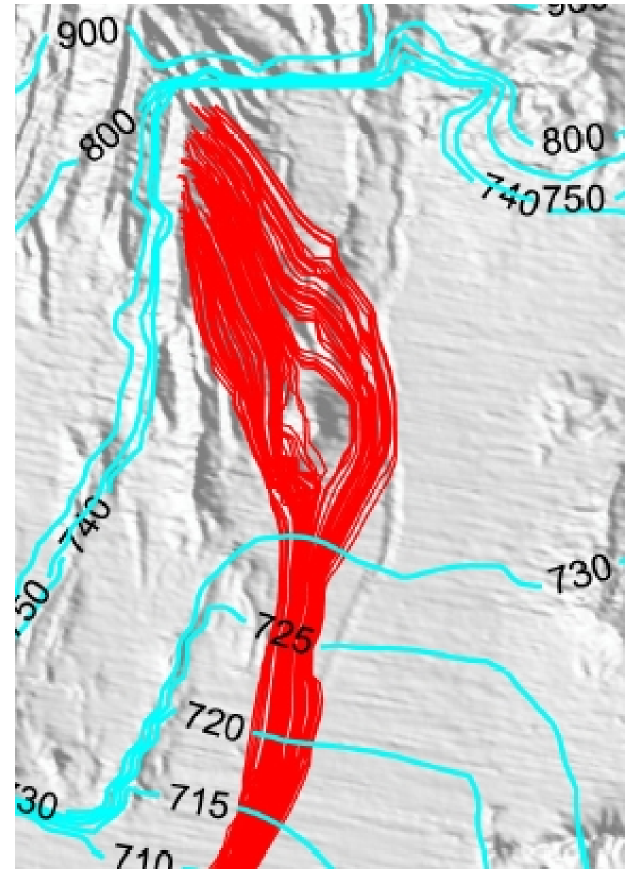
Effects of Hydrogeologic Interpretation on Modeled Flow Paths



Original Model

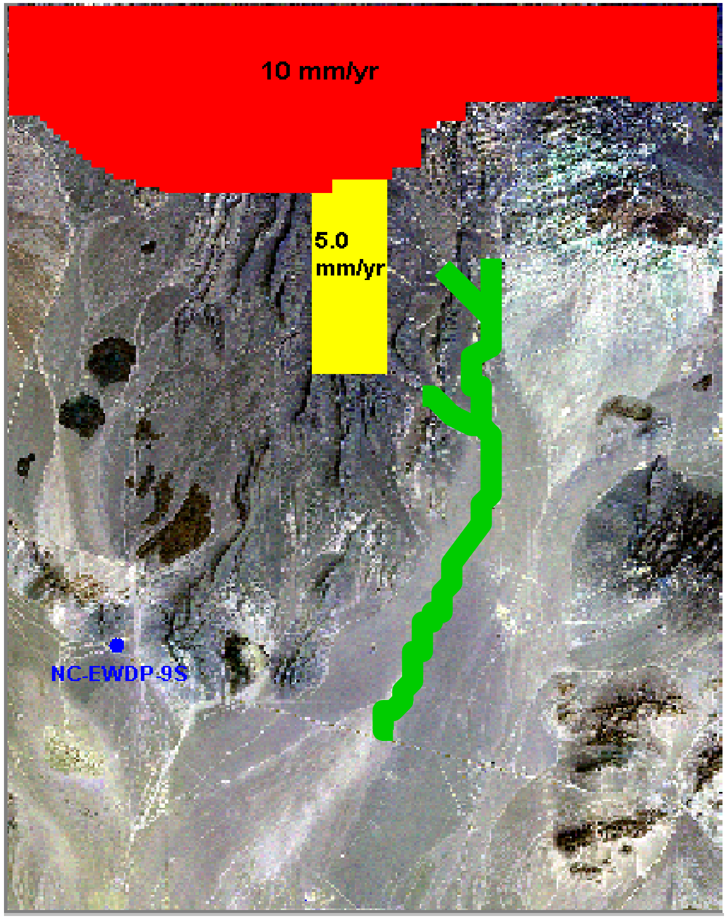
Alternative Model



DOE Model
(Source: Bechtel SAIC, 2003)

Effects of Recharge in Yucca Mountain Area

- Case 1:
  - — 10 mm/yr recharge in northern area only (shown right in red)
- Case 2:
  - — 10 mm/yr recharge in northern area
  - — 5 mm/yr recharge added in Yucca Mountain area (shown right in yellow)



Note: these modeling studies described in detail by Winterle (2003)

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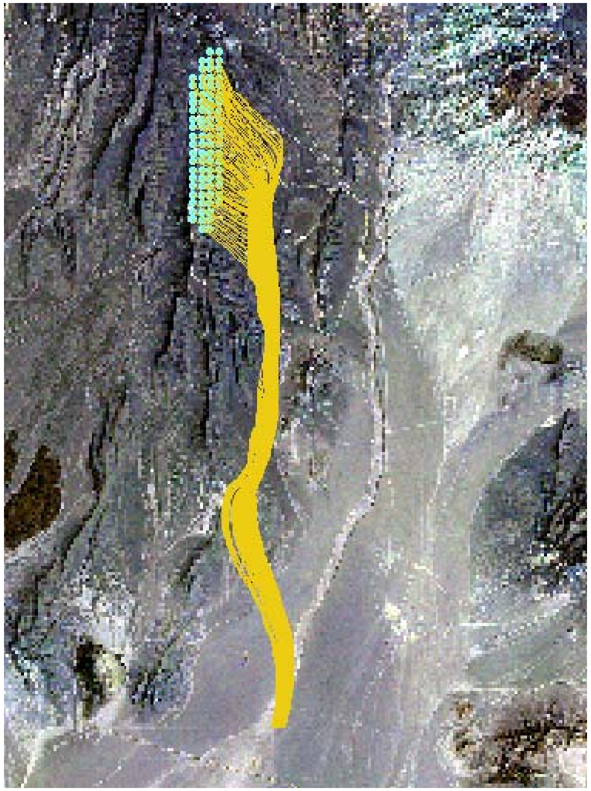
Effects of Recharge in Yucca Mountain Area

Case 1: Modeled flow paths with **no recharge** in the Yucca Mountain area

Case 2: Modeled flow paths with **5 mm/yr recharge** in the Yucca Mountain area



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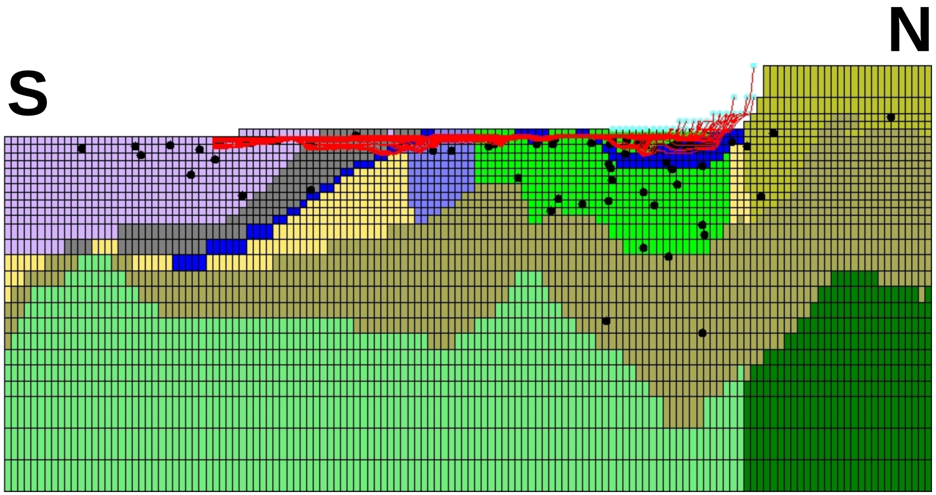
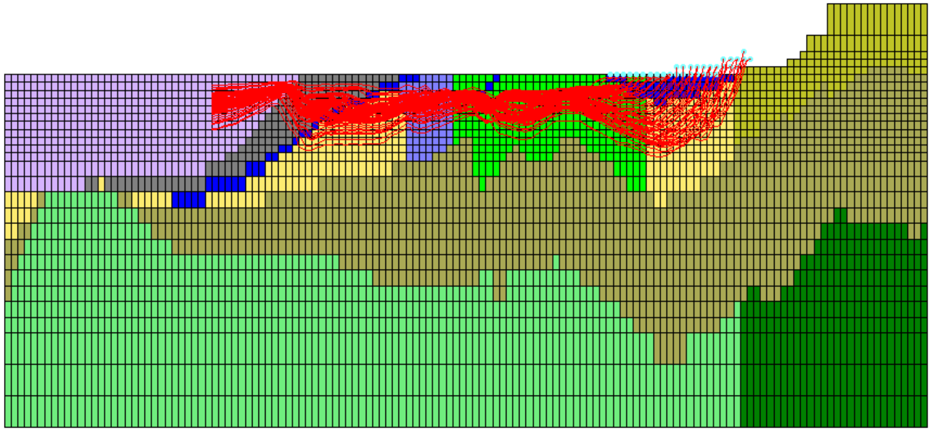
Effects of Recharge in Yucca Mountain Area



Case 1: North-south vertical cross section of modeled flow paths with **no recharge** in the Yucca Mountain area



Case 2: North-south vertical cross section of modeled flow paths with **5 mm/yr recharge** in the Yucca Mountain area

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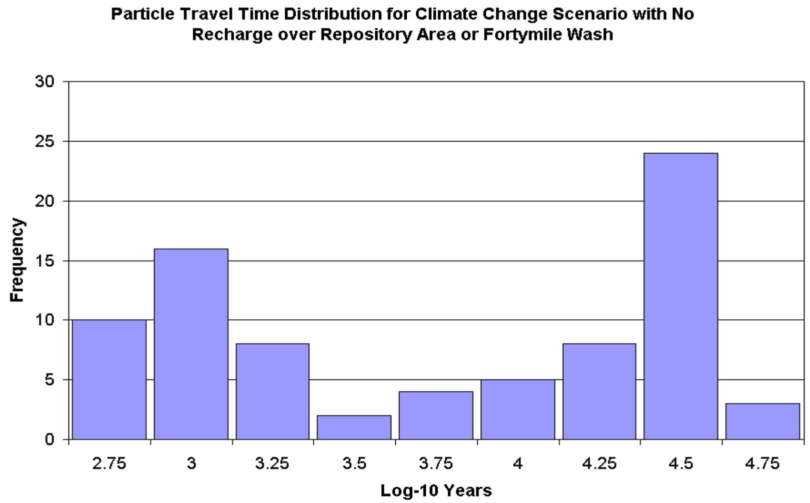
Effects of Recharge in Yucca Mountain Area



Case 1: Modeled groundwater travel times to compliance boundary with **no recharge** in the Yucca Mountain area

Case 2: Modeled groundwater travel times to compliance boundary with **5 mm/yr recharge** in the Yucca Mountain area

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Effects of Recharge in Yucca Mountain Area

- Groundwater travel time discussion points:
  - For these particle-tracking simulations, a porosity value of 0.001 was assigned for hydrologic units representing fractured welded tuff (e.g., PBC, UVA, and LVA units); a value of 0.1 was assigned for units representing porous non-welded tuff (e.g., UVC unit)
  - For a given flux, average linear groundwater flow velocity is inversely proportional to the assigned porosity
  - Simulations with no recharge at Yucca Mountain result in shallow flow paths that travel greater distance in the porous UVC unit
  - Simulations with 5 mm/yr recharge at Yucca Mountain result in deeper flow paths that bypass much of the UVC, flowing faster in the low-porosity fractured volcanic units
  - Setting all volcanic tuff units to the same porosity effectively eliminates the significant differences in modeled groundwater travel times for the two recharge scenarios
  - Historically, performance assessments have not assumed slow porous flow in saturated volcanic tuff units (i.e., they assume all fracture flow in saturated tuffs as a conservative assumption)

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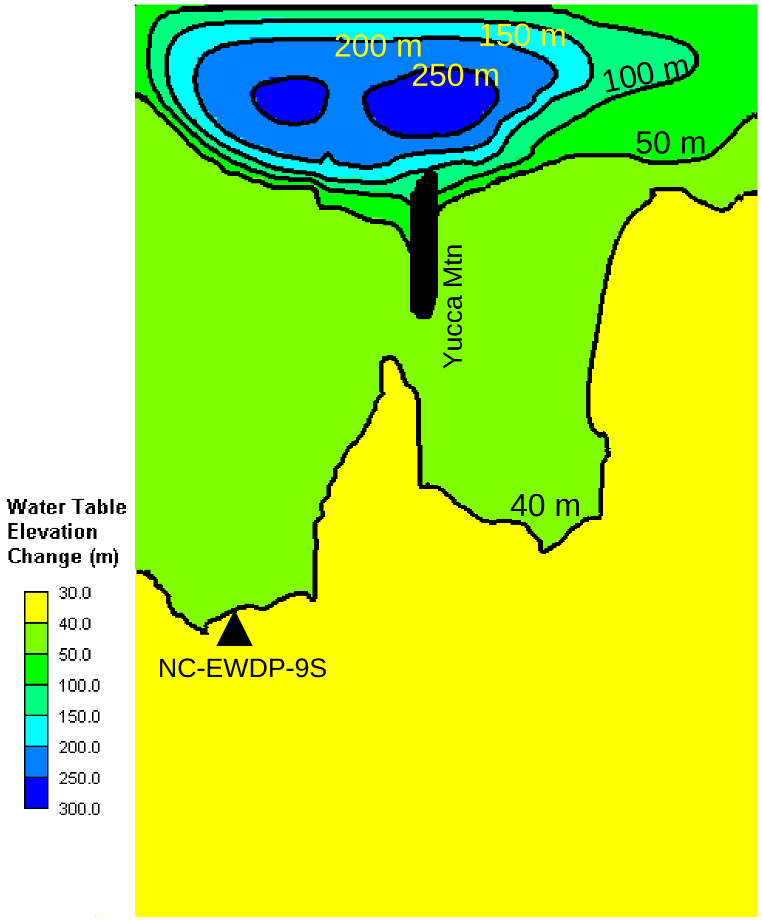
Effects of Potential Climate Change

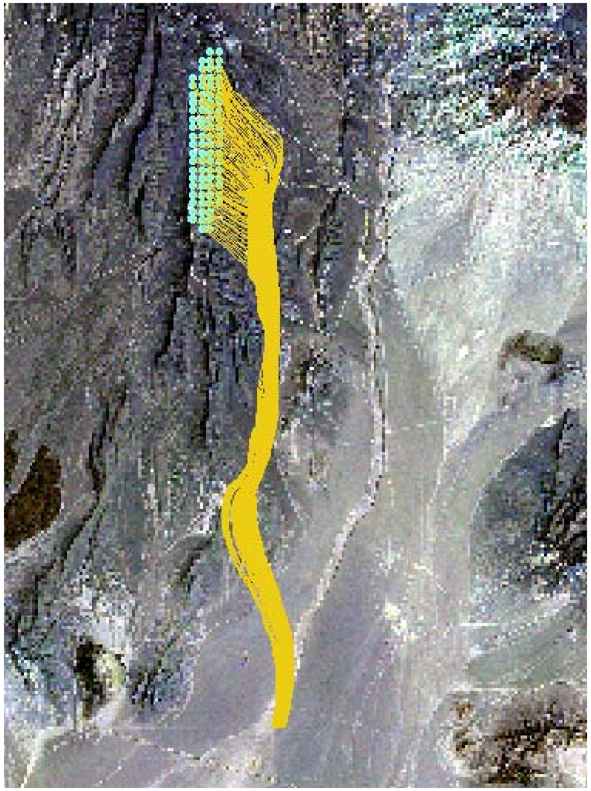
- Constant-head boundary values were increased by 5 percent
- Increase in boundary heads was constrained by criterion of just enough to initiate spring flow at location of NC-EWDP-9S
- Doubled recharge rates in northern and Yucca Mountain areas
- Added 200 mm/yr recharge in Fortymile Wash area (see green area on slide 12)
- Resulting change in water table elevation from original model is shown at right



Note: this modeling study described in detail by Winterle (2003)

Effects of Potential Climate Change

Modeled flow paths for original model with Case 2 recharge rates (previously shown)



Modeled flow paths for potential climate change scenario (described on preceding slide)

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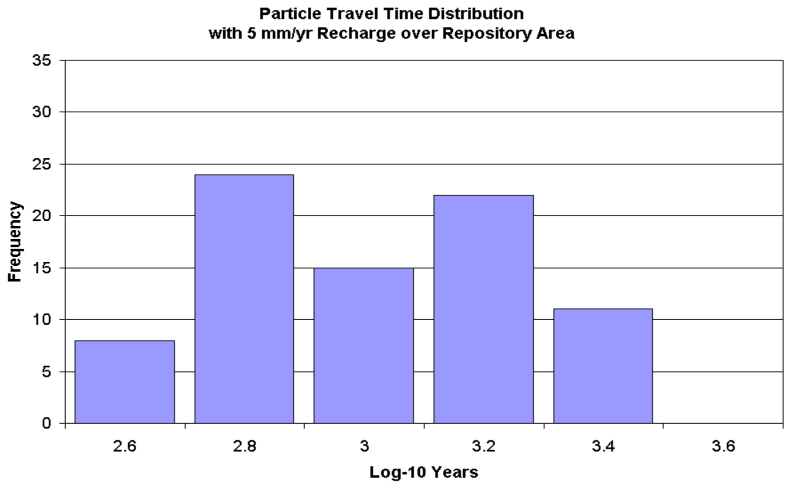
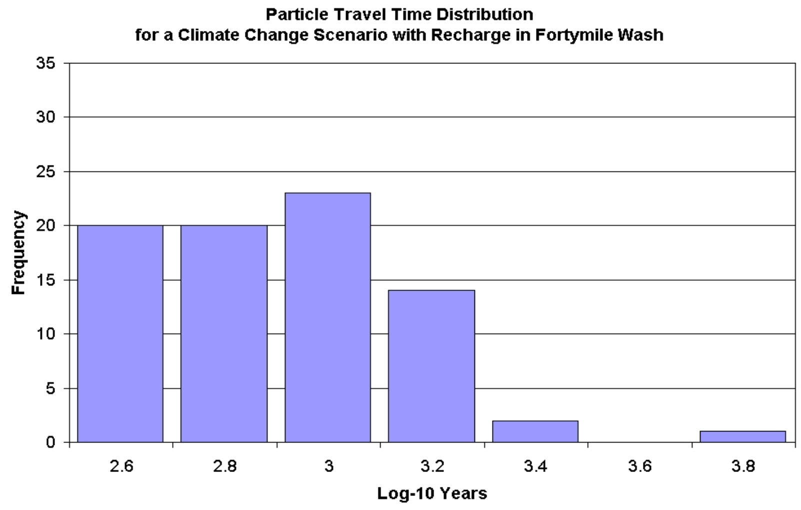
Effects of Potential Climate Change



Modeled groundwater travel times to compliance boundary for original model with Case 2 recharge rates



Modeled groundwater travel times to compliance boundary for potential climate change scenario

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Conclusions

- Model calibrations can be significantly improved by relatively minor adjustments to the interpreted geometry of hydrostratigraphic and structural features; however, the variability of modeled flow paths for the calibration scenarios considered was relatively modest

- Consideration of small amounts of recharge (5 mm/yr) in the potential repository area has a significant effect on the depth of modeled flow paths and volcanic units through which flow paths travel; further increases in recharge, however, do not appear to add to this effect

- The assumed effective porosity of the “upper volcanic confining unit” (mainly Calico Hills nonwelded tuff formation) can have a dramatic effect on modeled groundwater travel times to the compliance boundary; data collection efforts focused on evaluating effective porosity of this unit might improve understanding of the effectiveness of the saturated zone barrier

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Conclusions

- An assumed 5-percent increase in boundary head values to account for potential water table rise results in initiation of modeled spring flow near location of well NC-EWDP-9S, consistent with location of paleospring mineral deposits

- The 5-percent boundary head increase scenario resulted in modeled water table rise beneath the proposed repository footprint in the range of 50 to 150 meters, increasing from south to north; potential effects of water table rise should be considered if repository footprint is extend farther north

- The scenario of combined water table rise and increased recharge did not significantly change modeled groundwater flow paths or travel times to the compliance boundary

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