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Contract NRC–02–97–009
Account No. 20.01402.861

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Subject: Intermediate Milestone 20.01402.861.210, Hydrogeologic Properties of the Alluvial Basin Beneath Fortymile Wash and Northern Amargosa Valley, Southern Nevada

Dear Mr. Coleman:

This letter transmits Intermediate Milestone 20.01402.861.210, Review of Valley Fill-Hydrology—Letter Report. This report provides a summary of available information regarding the hydrology of the valley-fill alluvium aquifer system in the northern Amargosa desert region, south of Yucca Mountain, Nevada. As you know, valley-fill alluvium provides a potentially important natural barrier to radionulide migration from the proposed Yucca Mountain nuclear waste repository.

The descriptions of alluvial aquifer properties presented in this report should be considered predecisional because much of the information on alluvial sediments collected from the Nye County drilling program is still preliminary and a great deal of data from hydraulic and tracer tests remains to be collected and analyzed by the U.S. Department of Energy (DOE). This work continues to be coordinated with the Structural Deformation and Seismicity Key Technical Issue. Specifically, independent interpretations of alluvial basin geometry and alluvial sediment properties were provided by Structural Deformation and Seismicity Key Technical Issue staff, and found to be generally consistent with DOE interpretations. The improved understanding of valley fill alluvium properties and basin geometry facilitates evaluation of DOE work and resolution of the saturated zone flow subissue of the Unsaturated and Saturated Flow under Isothermal Conditions Key Technical Issue.

The preliminary nature of available data notwithstanding, a conceptual model of flow through alluvium is beginning to emerge. The location of the shallow saturated zone transition from tuff to alluvium is better constrained by more recent data from Nye County wells and new depictions of alluvial basin geometry in cross sections recently developed by DOE.

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If you have any questions about this deliverable, please contact me (210.522.5540) or Mr. James Winterle (210.522.5249).

Sincerely yours,

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# HYDROGEOLOGIC PROPERTIES OF THE ALLUVIAL BASIN BENEATH FORTYMILE WASH AND NORTHERN AMARGOSA VALLEY, SOUTHERN NEVADA

*Prepared for*

**U.S. Nuclear Regulatory Commission**
**Contract NRC–02–97–009**

*Prepared by*

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**August 2002**

# ABSTRACT

This letter report provides a summary of available information about the hydrology of the valley-fill alluvium aquifer system in the northern Amargosa Desert region, south of Yucca Mountain, Nevada. The descriptions of alluvial aquifer properties presented in this report should be considered predecisional because much of the information on alluvial sediments collected from the Nye County drilling program is still preliminary, and data from hydraulic and tracer tests remain to be collected and analyzed by the U.S. Department of Energy (DOE). The preliminary nature of available data notwithstanding, a conceptual model of flow through alluvium is beginning to emerge. Flow paths from beneath Yucca Mountain transition from a volcanic tuff flow system to a valley-fill alluvium flow system. The location of the shallow saturated zone transition from tuff to alluvium is better constrained by more recent data from Nye County wells and new depictions of alluvial basin geometry in cross sections recently developed by DOE. The nature of this tuff-alluvium transition is likely much more complicated than is depicted in these low-resolution cross sections and in idealized hydrogeologic framework models. Continued investigations of the hydrogeologic properties at the tuff-alluvium interface would reduce this uncertainty. Within the valley-fill alluvium flow system, hydrologic properties are spatially heterogenous. Evaluation of well data and outcrop studies suggests the most permeable flow paths in alluvium should be in the paleo-stream-channel deposits beneath the Fortymile Wash area. Further east, beneath the Lathrop Wells area, the clay content of alluvial sediments increases and thick clay layers are prevalent, resulting in significantly lower permeability and probably limiting the eastward migration of flow originating from Yucca Mountain.

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# ACKNOWLEDGMENTS

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The authors wish to thank C. Manepally for her thorough technical review and useful insights; B. Long, A. Woods, and C. Cudd for editorial reviews; and P. Mackin for programmatic review. The administrative and format support provided by A. Ramos is greatly appreciated.

**DATA ANALYSES AND CODE:** This report provides a summary of existing data and analyses pertaining to the hydrologic properties of valley-fill alluvial sediments beneath Fortymile Wash and Northern Amargosa Valley, near Yucca Mountain, in Central Nevada. No original data are presented, and no computer codes were used in the analyses of data presented in this report.

# 1 INTRODUCTION

This letter report provides the U.S. Nuclear Regulatory Commission (NRC) with a summary of available information regarding the hydrology of the valley-fill alluvium aquifer system in the northern Amargosa Desert region, south of Yucca Mountain, Nevada.

The U.S. Department of Energy (DOE) recommended Yucca Mountain as a suitable site for the nation's repository for permanent disposal of high-level waste. Risk insights gained from total system performance assessments of a potential repository indicate the ability of saturated alluvium to delay radionuclide transport is a potentially important natural feature of the multiple-barrier system, which is a required design component for any potential nuclear waste repository at Yucca Mountain [10 CFR 63.113(a)]. For example, DOE conducted a total system performance assessment analysis to compare a degraded saturated zone (i.e., parameters chosen to reduce saturated zone transport time) to an enhanced saturated zone (i.e., parameters chosen to increase saturated zone transport time) (CRWMS M&O, 2000a, Figure 5.3-13). This DOE analysis showed that combined saturated zone parameter uncertainty, including flow and radionuclide transport parameters, can affect dose estimates by as much as a factor of 100 during a 100,000-year simulation.

Another DOE sensitivity study (Bechtel SAIC Company, LLC, 2001, Figures 3.2.10-4) compared a basecase total system performance assessment, with 5 km [3.1 mi] of flow in saturated alluvium, to a case with only about 1 km [0.62 mi] of saturated alluvium. The differences in estimated doses for these two cases were generally less than 10 percent for a 100,000-year simulation period. As expected, however, the dose estimates were greater for the case with a shorter alluvial flow path. The apparently small sensitivity to flow in alluvium in this analysis is a result of reasonably conservative transport parameters selected for the basecase; it is not an indication that flow in alluvium is unimportant.

The NRC sensitivity and uncertainty analyses indicate retardation coefficients for neptunium and americium in alluvium rank among the more important uncertain parameters affecting repository performance for various scenarios of radionuclide release (Mohanty and McCartin, 1999, Table 4-5).

Retardation coefficients for saturated alluvium are determined by physical and geochemical characteristics of the alluvial sediments and the water flowing through those sediments. Bounding uncertainty of estimated retardation coefficients for alluvium is complicated because alluvial deposits are spatially heterogenous. It is, therefore, important to develop an understanding of the spatial distribution of hydrologic properties within alluvial sediments to determine which types of alluvial sediments accommodate significant portions of groundwater flow. Hydrologic properties of interest in this regard are bulk permeability (or hydraulic conductivity), effective flow porosity, particle-size distributions, mineralogy, and the spatial dimensions of various alluvial sediment types (facies). Available information pertaining to these hydrologic and physical properties of alluvium are the subject of Chapter 2 of this report.

Because retardation of contaminants in alluvium is important to potential repository performance, one can infer that the distance groundwater travels through alluvial flow paths is

also an important natural-system feature. The zone of transition of groundwater flow from volcanic tuff to alluvial flow paths downstream from Yucca Mountain has, in previous performance assessments, been poorly delineated, making it necessary to consider a large range of uncertainty. More recently, however, new wells in alluvium have substantially narrowed this important uncertainty. To properly describe the remaining uncertainty in the tuff-alluvium transition zone, it is necessary to delineate the approximate geometry of saturated alluvial sediments that overlie the volcanic tuff aquifer system. Available information pertaining to the geometry of the alluvial basin is reviewed and summarized in Chapter 3 of this report.

Much of the information reviewed in this report is presently considered preliminary and is, therefore, subject to change or reinterpretation by DOE researchers. Also, there are several ongoing and planned projects focused on improved characterization of the hydrologic and transport properties of alluvium. Data from ongoing and planned single- and multiple-well hydraulic and tracer tests at the alluvial testing complex remain to be interpreted and made available for review. Several Nye County Early Warning Drilling Program wells have only recently been completed, and interpretations of stratigraphic logs, water table elevations, and tuff-alluvium interface elevations are only available anecdotally through presentations of preliminary information at technical conferences. Other wells are either presently under construction or planned for future construction. Because much of the information on alluvium is either preliminary or remains to be collected, the descriptions of alluvial aquifer properties presented in this report should be considered preliminary and predecisional. This report is intended to be a starting point for gathering available hydrologic information about the alluvial basin beneath Fortymile Wash and Northern Amargosa Valley that can be used to evaluate which features and processes are potentially significant to performance of the proposed repository at Yucca Mountain.

# 2 HYDROLOGIC PROPERTIES OF SATURATED ALLUVIUM

This chapter provides a summary of information on the hydrologic properties of alluvium obtained from the Nye County Early Warning Drilling Program, the Alluvial Testing Complex, and alluvium outcrop studies along Fortymile Wash.

## 2.1 Information from Nye County Wells and Alluvial Testing Complex

Figure 2-1 shows the locations of existing and planned Nye County Early Warning Drilling Program wells. The location of Well NC–EWDP–19D is also the site of the alluvial testing complex. Wells completed in saturated alluvium along potential flow paths from Yucca Mountain include NC–EWDP–2DB, 4PB, 5S, 19D, 22S, 10S, and NC–Washburn–1x. As shown in Figure 2-1, several additional wells along potential flow paths are planned.

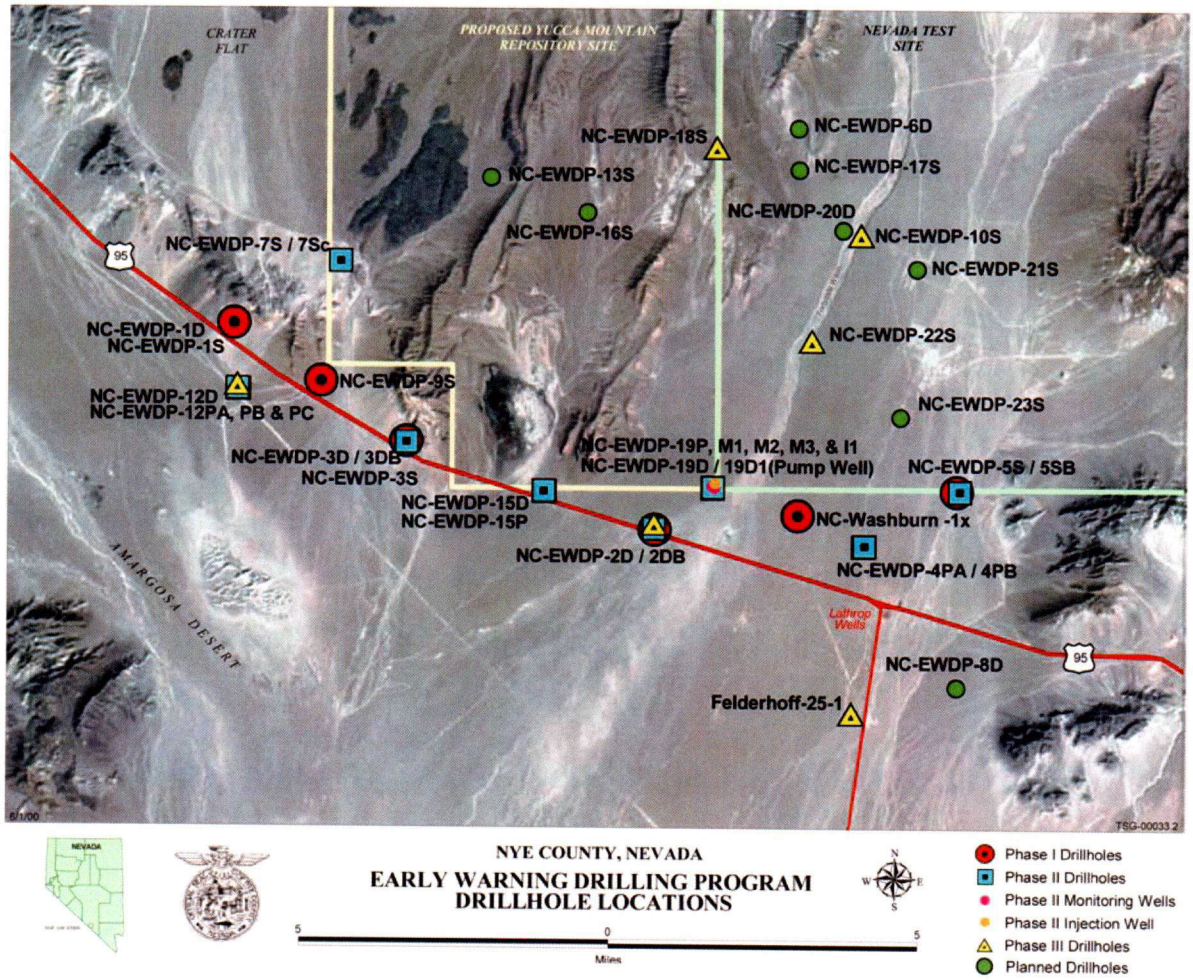


**Figure 2-1. Locations of Existing and Planned Nye County Early Warning Detection Program Wells**



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Table 2-1 provides a summary of available information from the Nye County wells that penetrate saturated alluvium. As indicated in the footnotes of Table 2-1, much of the information on sediment descriptions and hydrologic testing has only been available through presentations at meetings and conferences and must be considered preliminary until more complete documentation and source data are available for review.

Some general conceptualizations of the distribution of hydrologic properties of alluvium have been presented by Nye County staff and consultants at meetings and conferences. One conceptualization is that a subsurface clay layer is present under the Lathrop Wells area at a depth of about 110–140 m [350–450 ft].[1] The thickness of this clay varies, ranging from more than 140 m [450 ft] at NC–EWDP–5S to only 2 m [7 ft] at NC–Washburn–1x. The driller's log from the recently completed NC–EWDP–4PB, which is just south of a line between the NC-Washburn–1x and NC–EWDP–5S, also shows a thick sequence of clay-rich sediments and is consistent with this conceptual model. A thick sandy clay layer is also present in the saturated alluvium penetrated by NC–EWDP–2DB at a depth of about 220 m [720 ft], which is approximately 125 m [400 ft] below the water table (Nye County, 1999); this clay layer may or may not be contiguous with the clay layer beneath the Lathrop Wells area.

The low-permeability clay layers seem to lens out north of a line connecting NC–EWDP–2DB and NC–Washburn–1x, and give way to thick sequences of high-permeability sands and gravels beneath the entrenched channel of Fortymile Wash in the area of the NC–EWDP–19D and northward to the area of NC–EWDP–10S. This apparent zone of higher permeability sediments beneath Fortymile Wash likely reflects the history of channel deposits in Fortymile Wash. These channel deposits may provide a preferential pathway for groundwater flow in alluvium and may explain, at least in part, why groundwater flow converges from the east and west toward this area [e.g., see water table map of Hill and Winterle (2002)].

Nye County staff and consultants recently presented[2] preliminary interpretations of alluvial sediments at the NC–EWDP–10S, 22S, and 23S well sites, which penetrate saturated alluvium within or near the area of Fortymile Wash channel deposits. The Nye County investigators reported an average hydraulic conductivity of 5 m/day [17 ft/day] and an average porosity of 0.28 for saturated zone core samples.

Further insight into the spatial distribution of hydrologic properties of channel deposits can be gained from studies of alluvium outcrops in entrenched reaches of Fortymile Wash, as discussed in the following section.

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[1]Buqo, T., Nye County consultant. *Presentation to U.S. Nuclear Waste Technical Review Board July 28–30, 1999.* Beatty, Nevada. Transcripts are available from U.S. Nuclear Waste Technical Review Board. 1999.

[2]Hammermeister, D., et al. *Nye County Poster Presentation, Devil's Hole Workshop May 29-31, 2002.* Pahrump, Nevada. 2002.

| Table 2-1. Summary of Information for Nye County Wells | | |
|---|---|---|
| **Well ID** | **Description of Saturated Alluvium Penetrated by Well** | **Summary of Hydrologic Testing** |
| **NC–EWDP–1S** | ~34 m [110 ft] of saturated alluvium above interpreted volcanic tuff contact<br><br>Clayey gravels and sands; gravelly sands with some cobbles<br><br>Source: Nye County (1999) | Hammermeister, et al. (2002) reported a composite transmissivity of 7,300 $m^2$/day [80,000 $ft^2$/day] for a 34-m [110-ft] screened interval in volcanic tuff directly below the valley fill. Cox, et al. (2000) report a composite permeability of 300 darcies for this interval. Although the tested interval was in volcanic tuff, this very high permeability estimate could be partly influenced by three-dimensional flow from the alluvium directly overlying the tested interval. |
| **NC–EWDP–2DB** | ~270 m [890 ft] of saturated alluvium above an interpreted Tertiary ash-flow tuff layer. Older Tertiary sedimentary sequence underlies the ash-flow tuff<br><br>Silty gravels and sands, amount of clay increases with depth below 185 m [610 ft], including a 40-m [130-ft] sandy clay layer; interpreted ashflow tuff layer (Tram); thick sequence 550 m [1,800 ft] of interbedded Tertiary sediments with widely varying textures; Paleozoic Dolomite below 910 m [3,000 ft]<br><br>Source: Nye County (1999); Nye County Internet site† | No hydraulic test data are available. The juxtaposition of coarse sands and gravels with a thick sandy clay layer indicates a layered flow system. {e.g., Freeze and Cherry (1979) suggest a hydraulic conductivity range of on the order of 1–100 m/day [3–300 ft/day] for clean sands and gravels, and a much lower range of $10^{-3}$–$10^{-5}$ m/day [0.3–3 ft/day] for silts and clays.} |
| **NC–EWDP–4PB** | ~160 m [525 ft] of saturated alluvium. Alluvium extends beyond bottom of well.<br><br>Sandy and gravelly clays; alternating layers of sandy gravels, silty clays, and silty sands.<br><br>Source: Nye County Internet site† | No hydraulic test data available.<br><br>Flow through alluvium in this area is likely well stratified between layers of low and high clay content. The logged clay layers at this location are consistent with the concept of increasing clay layer thicknesses eastward between NC-Washburn–1x and NC–EWDP–5S, proposed by Buqo, T., Nye consultant. |

| Table 2-1. Summary of Information for Nye County Wells (continued) | | |
|---|---|---|
| **Well ID** | **Description of Saturated Alluvium Penetrated by Well** | **Summary of Hydrologic Testing** |
| **NC–EWDP–5S** | ~250 m [820 ft] of saturated alluvium. Alluvium extends below well bottom.<br><br>Sandy clays with angular gravel, possible thin bedded tuff layer, gravelly sandy clays of varying degrees of plasticity, alternating layers of sands and gravels with lower and higher clay content.<br><br>Source: Nye County (1999) | No hydraulic test data are available.<br><br>Layers with high clay content are more than 137 m [450 ft] thick at this well location, which suggests low hydraulic conductivity in the upper portions of the alluvial sediments in this area except within thin lenses of sand and gravel. |
| **NC–EWDP–7SC** | ~164 m [540 ft] of saturated alluvium above interpreted volcanic tuff contact.<br><br>Sandy spring deposits; silty sands and fine gravels; thin ashfall tuff layer; sand; alternating silty and sandy clays, clayey sandy gravels, and clay.<br><br>Source: Nye County Internet site.[†] | Spinner logs and a 48-hour aquifer pumping test were conducted following well completion (Questa Engineering Corp., 2002). Approximately 50 percent of water production came from an interval logged as ash-flow tuff; 40 percent came from an interval screened in silty sandy clay; 10 percent came from an interval screened in silty sand. A composite transmissivity of 180 $m^2$/day [1,900 $ft^2$/day] was estimated based on drawdown in adjacent Well NC–EWDP–7S. These results suggest a bulk hydraulic conductivity of approximately 1 m/day [3 ft/day] for the alluvium in this area. |
| **NC–EWDP–9S** | ~56 m [185 ft] of saturated alluvium above interpreted volcanic tuff contact.<br><br>Clayey gravels and sands; sandy gravel with some cobbles; possible volcanic tuff deposits overlying older clay and sandy gravel layers.<br><br>Source: Nye County (1999) | Hammermeister, et al. (2002) reported composite transmissivity to be between 1,900 and 3,600 $m^2$/day [20,000 and 40,000 $ft^2$/day]. Spinner logs indicate that 60 percent of well production came from a screened interval in volcanic tuffs; the remaining 40 percent came from three screened intervals in the saturated alluvium (Cox, et al., 2000). These results suggest a hydraulic conductivity of alluvium on the order of 10–20 m/day [30–60 ft/day]. |

| Table 2-1. Summary of Information for Nye County Wells (continued) | | |
|---|---|---|
| **Well ID** | **Description of Saturated Alluvium Penetrated by Well** | **Summary of Hydrologic Testing** |
| **NC–EWDP–10S** | ~65 m [210 ft] of saturated alluvium. Alluvium with welded tuff fragments extends below well bottom.<br><br>Well-graded sand with silt and gravel; silty sand with gravel; silty sand; volcanic conglomerate.<br><br>Source: Preliminary presentation by Hammermeister, et al. (2002) | No hydraulic test data are available. Silty sand content in the upper saturated portions of alluvium suggest relatively moderate hydraulic conductivity in this area {e.g., Freeze and Cherry (1979) suggest a range of 0.1–1 m/day [0.3–3 ft/day] for silty sand}.<br><br>This well is, to date, the farthest north NC–EWDP well within the area of potential flow paths from Yucca Mountain. The thickness of saturated alluvium below the water table indicates the water table transition from volcanic tuff to alluvium occurs north of this location. |
| **NC–EWDP–12PA** | 45 m [150 ft] of saturated alluvium above interpreted volcanic tuff contact.<br><br>Mostly silty, sandy clays; some gravelly clayey sands.<br><br>Source: Nye County Internet site† | No hydraulic test data available.<br><br>Far removed from potential flow paths from Yucca Mountain. High clay content suggests relatively low hydraulic conductivity. |
| **NC–EWDP–15P** | ~19 m [63 ft] of saturated alluvium above interpreted volcanic tuff contact.<br><br>Sandy gravel; sandy and gravelly clay; clayey sand and gravel. Volcanic tuff contact less than 20 m [65 ft] below water table.<br><br>Source: Nye County Internet site.† | No hydraulic test data available.<br><br>Note: The shallow distance to the tuff-alluvium contact below the water table provides a good data point for delineation of the westernmost zone of the water table transition from tuff to alluvium. |

| Table 2-1. Summary of Information for Nye County Wells (continued) | | |
|---|---|---|
| **Well ID** | **Description of Saturated Alluvium Penetrated by Well** | **Summary of Hydrologic Testing** |
| **NC–EWDP–19P/19D** | ~185 m [610 ft] of saturated alluvium above interpreted volcanic tuff contact.<br><br>Coarse sands and gravels with cobbles; occasional thin layers of clayey sands and gravels.<br><br>These alluvial sediments overlay a thick sequence of ash flow tuff that overlies older interbedded sandstone, siltstone, and claystone layers. | Nye County contractors (Questa Engineering Corp., 2001) estimated a composite transmissivity for Well NC–EWDP–19P of 370 $m^2$/day [4,000 $ft^2$/day] and conducted a spinner-log survey that indicated approximately 83 percent of flow comes from the saturated alluvial sediments and the remaining flow comes from the upper portion of the volcanic tuffs. These results suggest a bulk hydraulic conductivity of approximately 2 m/day [6 ft/day] for alluvium in this area.<br><br>DOE (Reimus and Umari, 2002) reported a hydraulic conductivity estimate of only 0.2 m/day [0.7 ft/day] for the same test. The difference from the Nye County estimate stems from a different analytical approach. |
| **NC–EWDP–22S** | ~220 m [720 ft] of saturated alluvium. Alluvium with welded tuff fragments extends below well bottom.<br><br>Well-graded sand with silt and gravel; silty sand with gravel; silty sand; volcanic conglomerate.<br><br>Alluvium extends beyond bottom of well.<br><br>Source: Preliminary presentation by Hammermeister, et al. (2002). | No hydraulic test data available.<br><br>Silty sand content in the upper saturated portions of alluvium suggest relatively moderate hydraulic conductivity in this area {e.g., Freeze and Cherry (1979) suggest a range of 0.1–1 m/day [0.3–3 ft/day] for silty sand}. |
| **NC–EWDP–23P**<br><br>**(Located near planned NC–EWDP–23S)** | Preliminary stratigraphic log extends to just below the water table. These sediments are interpreted as well-graded sand with silt and gravel.<br><br>Source: Preliminary presentation by Hammermeister, et al. (2002). | No hydraulic test data available.<br><br>Same as Well NC–EWDP–22S. |

| Table 2-1. Summary of Information for Nye County Wells (continued) | | |
|---|---|---|
| **Well ID** | **Description of Saturated Alluvium Penetrated by Well** | **Summary of Hydrologic Testing** |
| **NC–Washburn–1x** | ~93 m [3.5 ft] of saturated alluvium above interpreted volcanic tuff contact.<br><br>Coarse sands and pebbly gravels; thin 2-m [7-ft] clay layer; more coarse sands and fine gravels.<br><br>Source: Nye County (1999) | No hydraulic testing data are available. Hammermeister, et al. (2002) reported that, during preliminary testing, groundwater production was insufficient for adequate determinations of transmissivity.<br><br>Nye County (1999) interprets a 2-m [7-ft] clay layer logged in this well as the same strata that is 120 m [400 ft] thick beneath Lathrop Wells. |

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Buqo, T., Nye County consultant. *Presentation to U.S. Nuclear Waste Technical Review Board July 28–30, 1999.* Beatty, Nevada. Transcripts are available from U.S. Nuclear Waste Technical Review Board. 1999.
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Reimus, P. and M.J. Umari. "Test Plan for Alluvial Testing Complex—Single-Well, Multi-Well, and Laboratory Studies." Letter Report SITP–02–SZ–003. North Las Vegas, Nevada: DOE, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Office. 2002.
Notes:
†Driller's log and a stratigraphic summary obtained from http://nyecounty.com, website accessed on July 15, 2002.

## 2.2 Alluvium Outcrop Studies

The Center for Nuclear Waste Regulatory Analyses conducted a study of the hydrologic properties of alluvial sediments found in outcrops in the entrenched channel of Fortymile Wash. Preliminary results of this study were presented by Ressler, et al. (2000); the complete study results were published in a Master's thesis by Ressler (2001). The pertinent observations and results of the alluvium outcrop study are summarized in this section.

Ressler (2001) identified eight different types (facies) of alluvial sediments in Fortymile Wash outcrops. Table 2-2 provides illustrations and descriptions of these facies. The facies are distinguished mainly by inferred depositional processes that result in sediment deposits of differing physical characteristics (e.g., size and shape of the deposits, and grain-size

| Table 2-2. Alluvial Facies Delineated in Fortymile Wash Outcrop Studies (Ressler, 2001) | |
|---|---|
| **Facies Description** | **Example Photograph** |
| **F1**. Most common and volumetrically significant facies.<br><br>Clast-supported, imbrication; sand to cobble; horizontally stratified alternating layers of gravel and coarse; sand forming gravel-sand couplets; gravel couplets 10–50 cm [4–20 in] thick; open framework gravels variably contained within couplets.<br><br>Interpreted as longitudinal bar deposits. | <br>F1 deposits with small F2 lenses flagged in red |
| **F2**. Clast-supported, well-sorted pebble to boulder conglomerate with a matrix of medium-to-coarse sand; lenticular for lengths of 10–50 m [30–160 ft]; 0.1–1 m [0.3–3 ft] thick; coarser units tend to be thicker.<br><br>Occurs as lenses within F1 deposits.<br><br>Interpreted as channel deposits between longitudinal bars. | |



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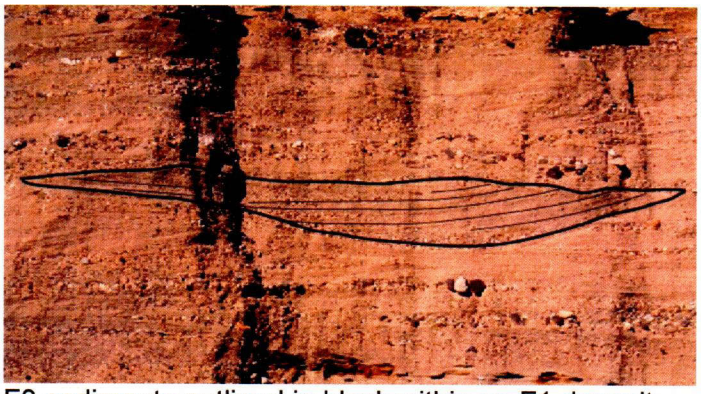
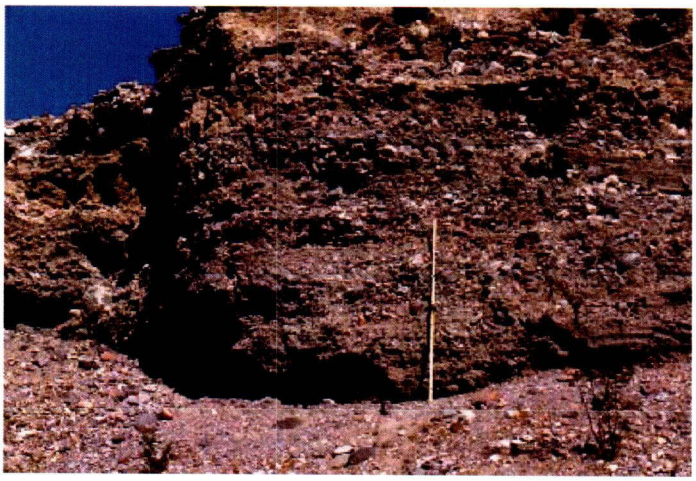
| Table 2-2. Alluvial Facies Delineated in Fortymile Wash Outcrop Studies (Ressler, 2001) (continued) | |
|---|---|
| **Facies Description** | **Example Photograph** |
| **F3.** Clast-supported; gravel to cobble; lenticular unit of cross-stratified gravel within horizontally stratified gravel; 5–15 m [16–50 ft] in length; 2 m [7 ft] in thickness.<br><br>Interpreted as pool scours at convergence of two braid channels. |  <br>F3 sediments outlined in black within an F1 deposit |
| **F4**. Clast-supported; poorly sorted, poorly organized; imbrication; sand to boulders, coarse gravel to cobbles predominating; crude stratification to massive; crude gravel couplets; variably contains small lenses of sand; cross-stratified gravel and sand commonly present at top of facies. Gravel couplets are 40–50 cm [16–20 in] thick; lenses of sand <30 cm [12 in] thick; facies are 2–3 m [7–10 ft] thick.<br><br>Interpreted as deposits of turbulent flood flows. |  |



C03

| Table 2-2. Alluvial Facies Delineated in Fortymile Wash Outcrop Studies (Ressler, 2001) (continued) | |
|---|---|
| **Facies Description** | **Example Photograph** |
| **F5**. Clast-supported to matrix-supported; dominantly monolithologic angular gravel to boulders with a matrix of medium-to-coarse sand. Laterally extensive for 10–15 m [30–50 ft]; variable in thickness, but <1 m [3 ft].<br><br>Interpreted to be debris flow or rockfall; expected to be more prevalent near mountain slopes. | |
| **F6**. Gravel to boulders; calcrete horizons; 5–30 cm [12–20 in] in thickness; laterally continuous for hundreds of meters, though facies may be discontinuous over that length.<br><br>Interpreted to be pedogenic carbonate associated with paleosols. | |



C04

| Table 2-2. Alluvial Facies Delineated in Fortymile Wash Outcrop Studies (Ressler, 2001) (continued) | |
|---|---|
| **Facies Description** | **Example Photograph** |
| **F7**. Matrix-supported, in some instances nearing clast-supported; mild-to-heavy bioturbation common; medium-to-coarse sand, with varying concentrations of gravel to cobbles, distinctive reddish-tan coloration, and strong caliche development, internal structure is complex; thickness ranges from 0.5 to 2 m [1.6–7 ft]; laterally extensive for ten to hundreds of meters.<br><br>Interpreted as paleosols. | <br>F7 paleosol between F4 deposits in central part of image |
| **F8**. Horizontal stratification to massive; dominantly well sorted, medium-coarse sand; some scattered fine gravel clasts mild bioturbation in some units.<br><br>Commonly found in association with bimodal gravel units (facies F2 or facies F1); <30 cm [12 in] thick; laterally continuous <2 m [7 ft].<br><br>Interpreted as finer sediments deposited during waning flow. | |

Reference:
Ressler, T.R. "Preliminary Characterization of the Valley-Fill Aquifer in Fortymile Wash, Southwestern Nevada." Master's thesis. Graduate School of the University of Texas at Austin. Austin, Texas. 2001.



C05

| Table 2-3. Summary of Hydrologic Properties of Alluvium in Fortymile Wash | | | |
|---|---|---|---|
| **Facies** | **Parameter** | **Sample Type** | **Measurement Statistics** |
| **F1** | Porosity | Undisturbed | n = 7; range 0.25–0.35; average = 0.27 |
| | | Disturbed | n = 11; range 0.26–0.40; average = 0.29 |
| | Hydraulic Conductivity | Undisturbed | n = 7; range $3.0 \times 10^{-4}$–$3.9 \times 10^{-3}$ cm/s [0.9–11 ft/day]<br>Geometric mean = $8.7 \times 10^{-4}$ cm/s [2.5 ft/day] |
| | | Disturbed | n = 14; range $4.8 \times 10^{-5}$–$2.3 \times 10^{-3}$ cm/s [0.14–6.5 ft/day]<br>Geometric mean = $5.1 \times 10^{-4}$ cm/s [1.4 ft/day] |
| **F2** | Porosity | Undisturbed | n = 1; value = 0.29 |
| | | Disturbed | n = 1; value = 0.40 |
| | Hydraulic Conductivity | Undisturbed | n = 1; value = $9.0 \times 10^{-5}$ cm/s [0.25 ft/day] |
| | | Disturbed | n = 5; range $1.67 \times 10^{-4}$–$2.24 \times 10^{-3}$ cm/s [0.5–6.4 ft/day]<br>Geometric mean = $5.9 \times 10^{-4}$ cm/s [1.7 ft/day] |
| **F4** | Porosity | Undisturbed | not measured |
| | | Disturbed | n = 1; porosity = 0.27 |
| | Hydraulic Conductivity | Undisturbed | not measured |
| | | Disturbed | n = 4; range $2.6 \times 10^{-4}$–$7.8 \times 10^{-4}$ cm/s [0.74–2.2 ft/day]<br>Geometric mean = $4.33 \times 10^{-4}$ cm/s [1.2 ft/day] |
| **F7** | Porosity | Undisturbed | n = 2; range 0.32–0.35; average = 0.34 |
| | | Disturbed | n = 2; range 0.26–0.42; average = 0.34 |
| | Hydraulic Conductivity | Undisturbed | n = 4; range $2.0 \times 10^{-4}$–$2.5 \times 10^{-3}$ cm/s [0.57–7.1 ft/day]<br>Geometric mean = $5.7 \times 10^{-4}$ cm/s [1.6 ft/day] |
| | | Disturbed | n = 7; range $5.4 \times 10^{-6}$–$7.1 \times 10^{-5}$ cm/s [0.015–0.20 ft/day]<br>Geometric mean = $2.2 \times 10^{-5}$ cm/s [0.06 ft/day] |

| Table 2-3. Summary of Hydrologic Properties of Alluvium in Fortymile Wash (continued) | | | |
|---|---|---|---|
| **Facies** | **Parameter** | **Sample Type** | **Measurement Statistics** |
| **F8** | Porosity | Undisturbed | n = 3; range 0.30–0.36; average = 0.32 |
| | | Disturbed | n = 3; range 0.40–0.41; average = 0.40 |
| | Hydraulic Conductivity | Undisturbed | n = 3; range $4.0 \times 10^{-4}$–$2.6 \times 10^{-3}$ cm/s [1.1–7.4 ft/day]<br>Geometric mean = $8.6 \times 10^{-4}$ cm/s [2.4 ft/day] |
| | | Disturbed | n = 4; range $2.0 \times 10^{-5}$–$5.6 \times 10^{-5}$ cm/s [0.06–0.16 ft/day]<br>Geometric mean = $3.4 \times 10^{-5}$ cm/s [0.1 ft/day] |

Notes:
1. Disturbed sample hydraulic conductivity measurements reported in Table 4-5 of Ressler, et al. (2000) and Table 5-7 of Ressler (2001); undisturbed hydraulic conductivity measurements reported in Table 5-8 of Ressler (2001); all porosity measurements reported in Table 5-6 of Ressler (2001).
2. To obtain hydraulic conductivity in meters per day, multiply centimeters per second by 864.

References:
Ressler, T.R., J.A. Stamatakos, K.D. Ridgeway, and J. Winterle. "Preliminary Hydrostratigrphy of the Valley-Fill Aquifer in Fortymile Wash and the Amargosa Dester." Letter Report. San Antonio, Texas: CNWRA. 2000.
Ressler, T.R. "Preliminary Characterization of the Valley-Fill Aquifer in Fortymile Wash, Southwestern Nevada." Master's thesis. Graduate School of the University of Texas at Austin. Austin, Texas. 2001.

distribution within the deposit). Several of the alluvium facies have similar hydrologic properties despite differences in their physical properties. Laboratory determined hydrologic properties (Ressler, et al., 2000; Ressler, 2001) for facies F1, F2, F4, F7, and F8 are summarized in Table 2-3. Hydraulic conductivity was estimated for both disturbed and undisturbed sediment samples using a constant-head permeameter. Porosity estimates were developed from undisturbed sediment samples and grain-size analyses of disturbed sediment samples. Note that it was not possible to obtain undisturbed samples for coarse unconsolidated sediments and sediments containing large cobbles and boulders. The hydraulic conductivity measurements were generally greater for the undisturbed samples. The geometric mean hydraulic conductivities are greatest and of similar magnitude for facies F1, F2, and F4. Hydraulic conductivities are lower by approximately one order of magnitude for facies F7 and F8. Total porosity estimates do not differ greatly among the facies examined by Ressler (2001).

Figure 2-2 shows generalized stratigraphic columns for the five alluvium outcrop locations in Fortymile Wash that were interpreted by Ressler, et al. (2000). This figure shows that the combination of facies F1, F2, and F4, which have similar hydraulic conductivity estimates, constitute more than 70 percent of the alluvium profiles observed in outcrop. Facies F3 is also relatively common as lenses within F1 and F4 deposits. Although no hydraulic conductivity measurements were reported for facies F3, its high gravel content suggests a relatively high permeability. Of the lower-permeability facies, F7 is most commonly observed. Facies F6 is

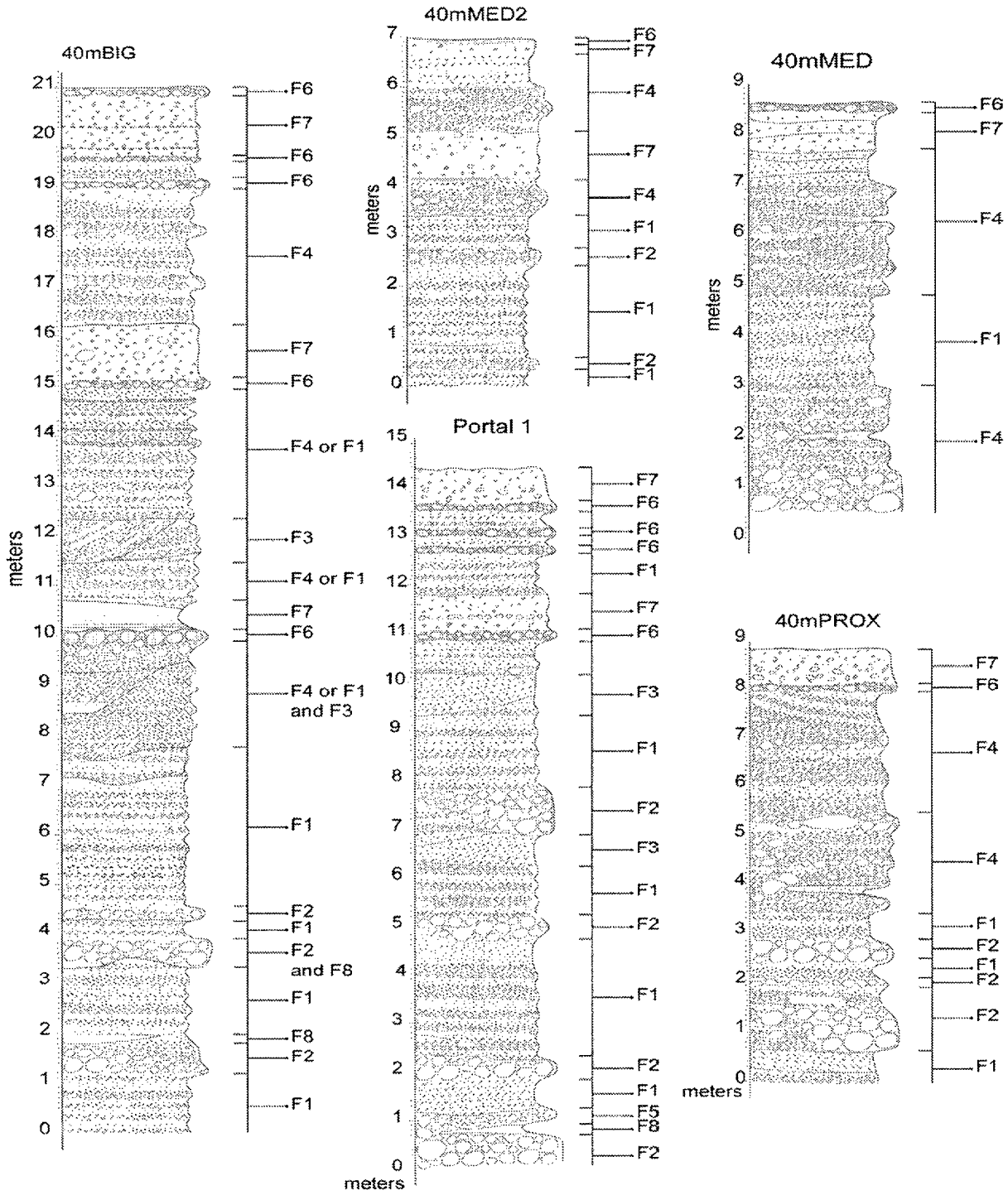



**Figure 2-2. Stratigraphic Interpretations of Alluvium Outcrops from Ressler (2001)**

also fairly common as thin layers and is likely of relatively low permeability, owing to its calcrete composition. Facies F5 and F8 are relatively rare in outcrop. Figure 2-3 illustrates the generalized distribution of alluvial sediment facies in outcrop Portal1. The Portal1 outcrop is of particular interest because it is oriented oblique to Fortymile Wash, thus providing an indication of the sediment profile in the general direction of saturated zone groundwater flow beneath Fortymile Wash. A generalized conceptual model for the layering of the more and less permeable facies makes it possible to obtain crude estimates of horizontal and vertical permeability. Layers F1, F2, and F4 appear to have relatively similar hydraulic conductivity; for purposes of rough estimates, let us assume facies F3 can also be lumped into this group of facies that have a geometric mean hydraulic conductivity on the order of 0.5 m/day [1.6 ft/day]. Facies F6, F7, and, to a lesser extent, the combination of facies F5 and F8, form three continuous lower permeability layers across the Portal1 outcrop. For a rough estimate, let us also assume that these layers can be lumped into a group represented by the lower hydraulic conductivities of F7 and F8, which are on the order of 0.05 m/day [0.16 ft/day]. The higher-permeability sediments compose about 80 percent of the Portal1 outcrop and the lower-permeability sediments compose the remaining 20 percent.

For a unit-length outcrop profile, the horizontal hydraulic conductivity, $K_x$, can be estimated from $K_x = \sum K_i d_i$, where $K_i$ represents hydraulic conductivity of a layer type, and $d_i$ is the fraction of the vertical profile occupied by each layer type. For the simplified example of outcrop Portal1, this yields an estimated bulk hydraulic conductivity of $K_z = 0.41$. Vertical hydraulic conductivity for a unit-length outcrop can be estimated from $K_z = 1/\sum d_i/K_i$, which yields $K_z = 0.18$ m/day [0.6 ft/day]. Thus a vertical anisotropy ratio ($K_x$:$K_z$) of approximately 2:1 could be expected for alluvial sediments with facies distributions similar to that of the Portal1 outcrop.

These rough estimates of hydraulic conductivity are subject to considerable uncertainty, however, considering the lack of hydraulic conductivity measurements for several of the sedimentary facies. Additionally, the low-permeability clay layers observed in several of the Nye County wells are not observed in Fortymile Wash outcrops. Where such clay layers are prevalent, vertical anisotropy ratios could be orders of magnitude greater.

Another factor to consider for hydraulic conductivity estimates is the scale of the measurement. For the laboratory measurements of hydraulic conductivity by Ressler (2001), the sample volume analyzed was typically a few liters at most. At much larger scales, hydraulic conductivity can be significantly increased by high-permeability pathways that cannot be evaluated at the laboratory scale. It is generally expected that estimates of hydraulic conductivity in heterogenous formations will increase with scale. Indeed, the preliminary hydraulic conductivity estimates reported from pumping tests in the Nye County wells (see Table 2-1) are several times as great as the conductivity estimates obtained in laboratory measurements.

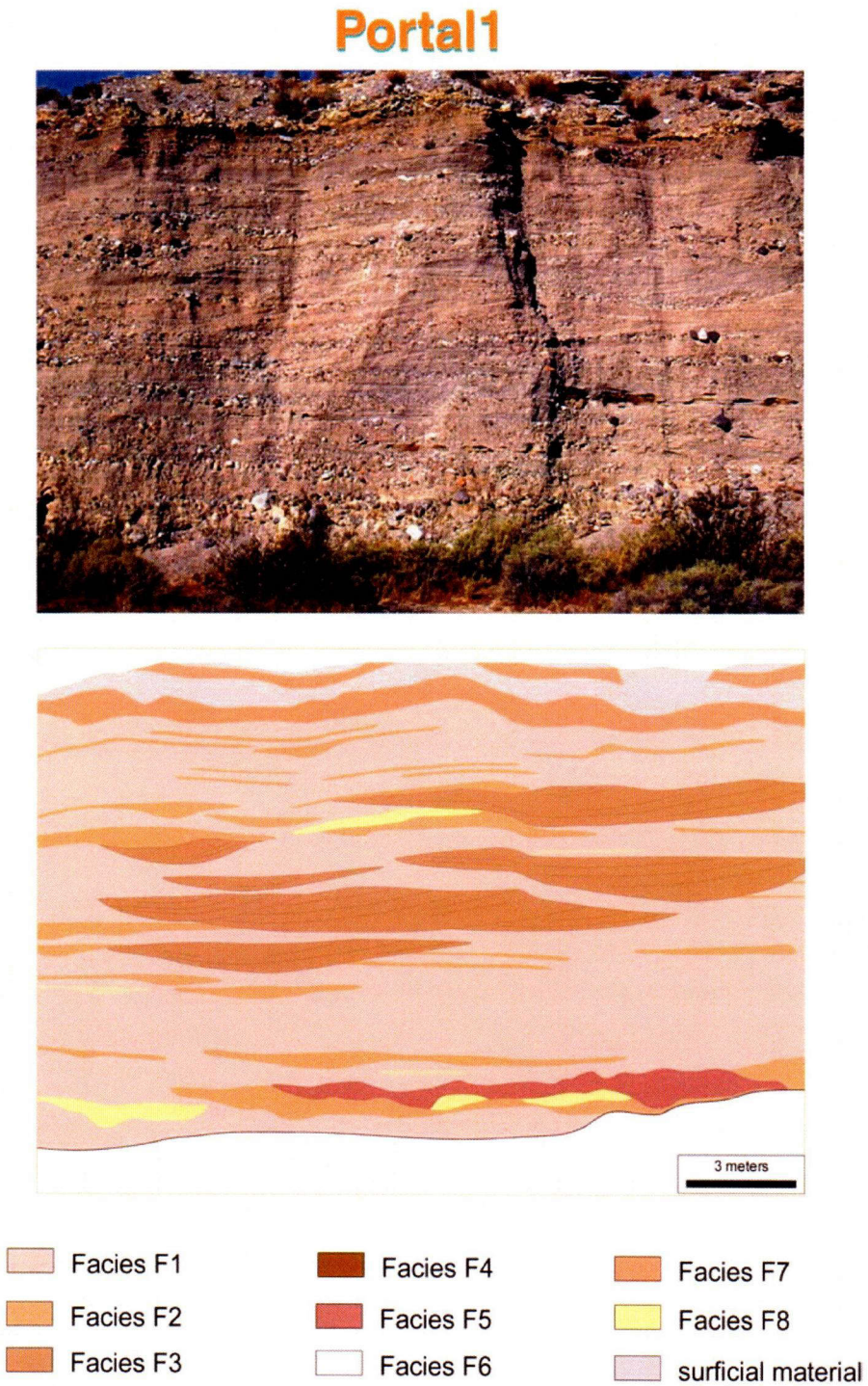



**Figure 2-3. Generalized Sediment Facies Distribution in Outcrop Portal1, As Described by Ressler (2001)**



C06

# 3 ALLUVIAL BASIN GEOMETRY

Areas of potential flow paths from Yucca Mountain in the alluvial basin include the southern portion of Fortymile Wash and the northern portions of Amargosa Valley. From a site performance perspective, the alluvial basin is important because the alluvial sediments that comprise the basin result in a reduction in radionuclide transport times to the receptor group because of their low hydraulic conductivity and high porosity and their high radionuclide sorption capacity. Because traveltimes in the alluvium are important to site performance, the location of the tuff-alluvium contact is also important because it controls the length of the pathway that occurs in alluvium. For these reasons, an understanding of the geometry of the alluvial basin and its sedimentary framework is important. The DOE characterization of the tuff-alluvium interface is reflected in the hydrogeologic framework model (CRWMS M&O, 2000b) that provides the hydrostratigraphic basis for the DOE site-scale flow model (CRWMS M&O, 2000c).

Since the initial development of the DOE hydrogeologic framework model, the Nye County Early Warning Detection Program has completed several additional wells in the alluvial sediments south of Yucca Mountain, including southern Fortymile Wash, and the northern portions of Amargosa Valley. DOE researchers have used driller's logs and cuttings from those Nye County Early Warning Detection Program wells and previously existing wells to produce three new hydrostratigraphic cross sections of the area beneath Fortymile Wash and northern Amargosa Valley (Spengler and Chornack, 2002). These three cross sections are referred to as Nye–1, Nye–2, and Nye–3.

Present DOE plans do not include an update of the hydrogeologic framework model using these new cross sections. Rather, it appears the cross sections will be used to validate the existing hydrogeologic framework model. In this report section, the three new cross sections are reviewed to ensure consistency with available data and to determine if they indeed provide validation of the existing hydrogeologic framework model. The focus of this review, however, is limited to the delineation of the tuff-alluvium interface on each of the cross sections. In particular, the review addresses the section of alluvium constrained between Lathrop Wells Cinder Cone, to the west, and Gravity fault, to the east. It is within this region that radionuclides migrating from Yucca Mountain would be expected to converge.

The following sections provide preliminary reviews and discussions of the three cross sections developed by DOE. The reviews and discussions focus primarily on the alluvial basin geometry and hydrologic characteristics of the basin important for performance assessment. This document provides minimal discussion on the volcanic and paleozoic units present in the cross sections. Indepth reviews and discussions for these units will be presented in a future report.

## 3.1 The DOE Interpretation of Alluvial Basin Geometry

DOE recently completed three stratigraphic cross sections for the Yucca Mountain area (Spengler and Chornack, 2002) that can be used to evaluate the saturated zone flow paths in alluvium considered in their performance assessment models. The three cross sections, referred to as Nye–1, Nye–2, and Nye–3, represent the southern portion of Fortymile Wash and

the northern portion of Amargosa Valley. Nye–1 and Nye–3 are predominately east-west cross sections, while Nye–2 is a predominately north-south section coincident with the modern fluvial channel in Fortymile Wash. In all three cases, the transects used to build the cross sections were designed to coincide with current or future NC–EWDP wells. This design allows the observed geologies in these wells to act as either constraints for the developed sections or validation points for the developed cross sections.

The DOE cross sections also incorporated information from wells, field mapping of rock and sediment distribution, and geophysical data. These approaches were used to infer the locations of most of the faults contained in the sections concealed below the alluvium. The geophysical data, aeromagnetic and gravity data in particular, and analyses used to identify and characterize concealed faults are not detailed in the report. References to other reports that contain some of this information have been provided. At the time of this report writing, however, only a preliminary review of these reports has been performed. Because the technical review of these cross sections is ongoing, the discussion in this report is focused mainly on the geometry of the alluvial basin south of Yucca Mountain. No discussion of the deep geologic units interpreted in these cross sections is provided.

Nye–1 Cross Section

The Nye–1 cross section is the southernmost of the two east-west cross sections. The section extends more than 26 km [16 mi] and essentially parallels U.S. Highway 95. Along its length, the section crosses the southern portion of Fortymile Wash and the northern portion of the Amargosa Valley. From a site-performance perspective, the cross section is of interest because it traverses the region of saturated zone flow paths from Yucca Mountain.

Several NC–EWDP wells currently lie along the transect: 5S, NC–Washburn–1x, 2DB, 15D, 3D, 9S, and 1D. Of these wells, 1D, 9S, 3D, 15D, and 2DB were used to provide geologic controls for the development of the cross-section. The quality of the cross section thus reflects the quality of the geologic characterization in the wells. Wells NC–EWPD–5S and NC–Washburn–1x appear to have been used only to locate the transect. In addition to the well data, structural geologic information and information on geologic units that extend below the NC–EWDP wells, that appear on the cross section were obtained from models derived from gravity and aeromagnetic data.

The structural framework along the Nye–1 cross section includes several faults that influence alluvial basin geometry. Most of the faults along the transect have no surface expression in the area, and thus were inferred from geophysical interpretations. Major faults along the transect include Gravity fault, Bare Mountain fault and associated splays, Windy Ridge fault, and Highway-95 fault. With the exception of the east-west trending Highway-95 fault, faults along the transect are oriented north-south. The interpreted Highway-95 fault is of particular interest because it transects along the predicted groundwater flow pathway beneath southern Fortymile Wash. While gravity data indicate a local topographic basement high in the area of the Highway-95 fault, there appears to be no consensus on the cause of the basement high. Other

interpretations of the anomaly include the presence of an ancient basin bounding ridge.[1] Thus, it is possible that the inferred Highway-95 fault is not a fault at all. Additional investigation into the geologic structure of this feature is warranted.

In the interpretation of the Nye–1 cross section, the southern portion of the alluvial basin is bounded to the east by the Striped Hills and the associated Gravity fault, and to the west by an unnamed fault that lies between Wells NC–EWDP–3D and 15D. The distance between these faults, and, thus, the width of the alluvial basin along the transect, is approximately 15 km [9.3 mi]. As a result, information from Wells NC–EWDP–2DB, 5S, and 15D, and NC–Washburn–1x can be used to constrain the alluvial geometry in this area. Of these wells, only NC–Washburn–1x did not penetrate the entire alluvial thickness. The Nye–1 cross section indicates that the alluvial basin is V-shaped with a maximum depth along the cross section of approximately 500 m [1,600 ft]. This maximum depth is between Wells NC–EWDP–2DB and NC–Washburn–1x and coincides with the location of a buried unnamed normal fault. The vertical displacement along this unnamed fault is approximately 150 m [500 ft]. From a hydrologic perspective, the displacement along the fault is interesting because it provides a surface along which hydrologic exchanges can occur between the alluvial aquifer, and deeper units within the volcanic aquifer system. The cross section further indicates that several different tuff units contact the base of the alluvial deposits across the basin. These units include the Rainier Mesa Tuff, the Topopah Spring Tuff, the Pre-Topopah Bedded Tuff, Pre-Tram sediment rocks, and the Pre-Tram Bedded Tuff. Finally, along the eastern flank of the cross section, the alluvial deposits are in contact with Paleozoic aquifer and aquitard units. As previously mentioned, the DOE interpretation of these underlying tuff units is presently being reviewed.

Measured water table elevations in Wells NC–EWDP–2DB, 5S, and 15D, and NC–Washburn–1x projected onto the Nye–1 cross section show that, to the east, the water table would transition into the Paleozoic units, and, to the west, the water table would transition into the Topopah Spring Tuff. Transition to the west is at best approximate because of the low resolution of the cross section provided.

Nye–2 Cross Section

The Nye–2 cross section is the only north-south cross section of the three provided by DOE. The section extends more than 21 km [13 mi] and is coincident with the Fortymile Wash fluvial channel, extending south to the northern portion of Amargosa Valley. From a site-performance perspective, the cross section is of interest because it approximately parallels the flow paths where groundwater flow from Yucca Mountain is predicted to occur. An additional important aspect of the cross section is that it traverses the northern reaches of the tuff-alluvium contact where groundwater transitions from the tuff into the valley-fill.

Wells indicated along the transect include WT#13, J–13, JF#3, and NC–EWDP–2DB,19D, and 22S. The location of the proposed Well NC–EWDP–20D also lies along the transect, which could provide useful future validation. It should be noted, however, that Well NC–EWDP–20D

[1]Sims, D. Personal communication (July 5) to D. Farrell, CNWRA. San Antonio, Texas: CNWRA. 2002.

is not included among the list of wells used to support the cross section (Spengler and Chornack, 2002, Table 1). Three wells that lie along the transect but are not included in the cross section are J–12 and NC–EWDP–10S and 22S. These wells should be either included or used to validate the cross section.

The structural framework along Nye–2 cross section includes several faults. None of the faults along the transect bear surface expressions; they were inferred from geophysical interpretations. Apart from the Highway-95 fault discussed previously, none of the faults are named on the Nye–2 cross section. The geologic structure of the northern portion of the cross section appears to be well constrained by Wells WT#13, J–13, and JF#3. The inclusion of Well J–12 would help to further constrain the depth and thickness of geologic units between Wells J–13 and JF#3.

A fault of interest, from a site-performance perspective, is an inferred south-dipping normal fault between Wells NC–EWDP–20D (proposed) and 22S on the cross section, approximately 5-km [3.1 mi] south of Well JF#3. The estimated maximum vertical displacement along this fault is approximately 250 m [820 ft]. This fault may mark the northern boundary of the alluvial basin. Based on ground magnetic data, Farrell, et al. (2000) identified a similar basin-deepening structure in that vicinity. The structure identified by Farrell, et al. (2000) is located approximately 4 km [2.5 mi] south of well JF#3 and was described as an erosional surface. The current DOE characterization appears more plausible. The lower base of the alluvial basin, expressed as an erosional unconformity, appears to steepen toward the south and achieves a maximum depth of approximately 400 m [1,300 ft] in the vicinity of the Highway-95 fault splay.

Measured water table elevations in Wells NC–EWDP–2DB and 19D, and the older wells, J–13 and JF#3, projected onto the DOE cross section indicate that the transition of the water table from tuff to alluvium occurs along the unnamed fault contact described in the preceding paragraph. This finding is consistent with that documented in Farrell, et al. (2000).

Nye–3 Cross Section

The Nye–3 cross section extends 27 km [17 mi] and is the more northern of the two east-west cross sections provided. Along its length, the section crosses Fortymile Wash. From a site-performance perspective, the cross section is of interest because it traverses the northern area of the alluvial basin where radionuclide transport from Yucca Mountain is predicted to occur.

Several existing and proposed wells lie along the Nye–3 transect; these are JF#3 and Wells NC–EWDP–1D, 6D, 7Sc, 13S, 16S, and 18S. Of these wells, only JF#3 to the east and NC–EWDP wells 7Sc and 1D to the west have been drilled. Geologic information from these wells is used to constrain the geologic structure represented in the cross section. The other proposed NC–EWDP wells are currently used to locate the cross section. It is anticipated that geologic information obtained in the future from these wells will be used to validate the cross section.

The width of the alluvial basin along Nye–3 cross section is approximately 8 km [5 mi]. Of the wells represented along the cross section only, JF#3 is located in the alluvial basin. The other existing and proposed wells are all located west of the alluvial basin and, therefore, provide minimal information to constrain its structure. Several faults are represented on the cross section beneath the alluvial deposits. The largest of these interpreted faults is Gravity fault to the east of the alluvial basin, which is also represented in the Nye–1 cross section. Compared to Nye–1, however, no fault splays are associated with Gravity fault along this cross section. Also shown are two eastward dipping faults located west of Gravity fault, one of which was previously identified along the Nye–1 cross section. The maximum depth of the alluvial basin along the cross section is approximately 140 m [460 ft]. This coincides with an east-dipping fault beneath the center of the basin. The northward narrowing and shallowing of the alluvial basin, suggested by a comparison of the Nye–1 and Nye–3 cross sections, are supported by residual gravity data for the Yucca Mountain region.

Hydrologically, the alluvium deposits of the basin along the cross section are described as belonging to the older alluvial aquifer. Based on hydrologic information from well JF#3, however, the water table along the cross section is located in the volcanic units. Other than well JF#3, there are no other wells located in the alluvial basin portion of the Nye–3 cross section, but current water table interpretations (e.g., Hill and Winterle, 2002) suggest the water table transition from tuff to alluvium occurs south of the Nye–3 cross section.

## 3.2 Previous DOE Interpretation of Alluvial Basin Geometry

In their presentation of the Nye-1, Nye-2, and Nye-3 cross sections, Spengler and Chornack (2002) make references to and extract several cross sections from "2002 Hydrogeologic Framework Model." The hydrogeologic framework model used in DOE performance assessments to date—the one reviewed by NRC—was published in 2000 (CRWMS M&O, 2000b). No reference is provided for the source of the 2002 Hydrogeologic Framework Model, the extracted cross sections are simply presented with no explanation for their purpose. It is thus not clear if the more recent hydrogeologic framework model mentioned by Spengler and Chornack (2002, Figure 4-12) is an updated version resulting from their interpretations of stratigraphy, or if the extracted cross sections are presented simply as a comparison of the DOE hydrogeologic framework to their interpretation. Because of this confusion, the discussion in this report is limited to comparison of the Nye cross sections to the original DOE hydrogeologic framework model (CRWMS M&O, 2000b) that was used in the performance assessment to support a site recommendation (CRWMS M&O, 2000a).

The DOE hydrogeologic framework model (CRWMS M&O, 2000b) provides the fundamental geometric framework for constructing the site-scale groundwater flow model used to support total system performance assessments. At the time the hydrogeologic framework model was developed, much of the well and geophysical data used to develop the Nye cross sections was not available. Thus, the Nye cross sections can provide useful validation of the DOE abstraction of saturated zone hydrostratigraphy in performance assessments, including the location of the groundwater transition from tuff to alluvium.

For the DOE hydrogeologic framework model, the groundwater transition from tuff to alluvium beneath the Fortymile Wash area appears to be coincident with the interpreted Highway-95 fault, passing just north of Well NC–EWDP–2DB and south of the Well NC–Washburn–1x (CRWMS M&O, 2000a, Figure 6-21). With the new compliance boundary located 18 km [11.2 mi] south of the currently proposed repository location, the DOE hydrogeologic framework model suggests essentially none of the likely flow paths from Yucca Mountain pass through saturated valley-fill alluvium. The more recent observation of saturated alluvium in Well NC–EWDP–10S, however, combined with a projection of the water table elevation in the Nye–2 cross section, suggests the tuff-alluvium transition of the water table occurs much farther north within the central portion of the alluvial basin.

In the DOE performance assessment model, uncertainty in the location of this tuff-alluvium transition area is incorporated in the particle-tracking transport simulations by assuming this transition occurs somewhere within a trapezoidal region constrained by well log data and outcrop locations (CRWMS M&O, 2000b, Figure 2). The east-west extent of this area averages approximately 5 km [3.1 mi] in width and is bounded by surface outcrops of volcanic units on the west. The northern extent of this region is varied for performance assessments from a full 10 km [6.21 mi] of flow in valley fill to a case with no flow in valley fill. The western boundary of this region is also varied within about 2 km [1.2 mi] from its most westerly position, which is approximately a line between Wells NC–EWDP–15D and 17S. Moving this western boundary farther to the east results in longer transport distances in tuffs for those flow paths that fall to the west of the boundary. For each particle-tracking transport simulation, the locations of these boundaries are selected stochastically within their geometric constraints.

Evaluation of the Nye cross sections and more recent water table elevation data from Nye County wells suggest that the area of the uncertainty zone for the tuff-alluvium transition can be significantly reduced for future performance assessment calculations.

## 3.3 Other Interpretations and Complicating Factors

Murray, et al. (2002) recently developed regional cross sections based on interpretations of Oligocene and Lower Miocene sedimentary deposits observed in outcrops in the Funeral Mountains and the Nevada Test Site and in the subsurface in Wells NC–EWDP–1D, 2DB, and 2D. The focus of their work was to demonstrate spatial continuity of older sedimentary deposits that predate Tertiary volcanic rocks in the Yucca Mountain region. The cross section developed by Murray, et al. (2002) divides the Oligocene and Lower Miocene sedimentary deposits into three lithostratigraphic units continuous across Northern Amargosa Valley. Unit 1, the lowermost of the three, is a white-to-brown stromatolite and gastropodrich limestone that overlies Paleozoic Carbonate Strata in the Northern Amargosa region. Unit 2 consists of conglomerates and sandstones. Unit 3 consists of tuffaceous and volcaniclastic sandstone and tuff. Overlying these older sedimentary units in the Amargosa region is a layer interpreted as Tertiary volcanic strata, which, in turn, is overlain by Quaternary alluvial deposits.

The cross section developed by Murray, et al. (2002, Figures 4-1 and 4-2) generally encompasses the area represented by the DOE Nye–1 cross section (Spengler and Chornack, 2002) but covers a much larger area, extending from the Funeral Mountains to the

Spotted Range. Although a detailed review of the DOE cross sections is not complete, a quick comparison of the Nye–1 and Murray, et al. (2002) cross sections reveals similar interpretations of stratigraphy in the vicinity of Well NC–EWDP–2DB. That is, both show a layer of Tertiary volcanic tuff that separates younger Quaternary alluvium from the thick sequence of older sedimentary strata that overlie Paleozoic carbonate rocks.

The presence of a Tertiary volcanic layer separating older and younger sedimentary deposits is a potential complicating factor for the conceptual model of a smooth transition of flow paths from the tuff to the alluvial aquifer system. The Nye–2 cross section (Spengler and Chornack, 2002) interprets this tuff layer as the distal edges of several Tertiary volcanic layers, including the Tram Tuff, the Topopah Spring Tuff, and several poorly defined bedded tuff layers. Presently, however, there is no clear consensus about which volcanic tuff layers are observed in Well NC–EWDP–2DB.

Understanding the hydrologic properties of these distal tuff layers is also important because it may affect the conceptual model for how flow paths from Yucca Mountain transition from tuff to alluvial aquifer systems. The currently prevailing conceptual model is that potential contaminant releases would remain near the water table and simply flow out of the tuff system and into the alluvial system in the same area that the water table makes this transition. If, however, the layered bedded tuffs form confining units in the distal southern reaches of Tertiary volcanic deposits, transport pathways could conceivably be contained within these tuff units far south of the water table transition from tuff to alluvium.

Well NC–EWDP–19D, part of the Alluvial Testing Complex, provides some insight into the hydraulic properties of the distal tuff layers of interest. As indicated in Table 2-1, preliminary results of hydraulic testing in Well NC–EWDP–19D indicate the tuff units tested are relatively permeable, which would favor a smooth transition of flow paths from tuff to alluvium near the water table. The proposed Well, NC–EWDP–20D, which is about 8 km [5 mi] further north along Fortymile Wash, would provide useful validation for the concept of a smooth tuff-alluvium flow path transition in the area where this transition is presently thought to occur. Ideally, Well NC–EWDP–20D would be deep enough to completely penetrate the Tertiary volcanic tuffs, and thorough pumping tests and spinner surveys would be conducted.

# 4 CONCLUSIONS

Flow paths beneath Yucca Mountain transition from a volcanic tuff flow system to a valley-fill alluvium flow system. The location of the shallow saturated zone transition from tuff to alluvium is better constrained by more recent data from Nye County wells and new depictions of alluvial basin geometry in cross sections recently developed by DOE. The nature of this tuff-alluvium transition is likely much more complicated than is depicted in these low-resolution cross sections and in idealized hydrogeologic framework models. Continued investigations of the hydrogeologic properties at the tuff-alluvium interface would reduce this uncertainty. Within the valley-fill alluvium flow system, hydrologic properties are spatially heterogenous. Evaluation of well data and outcrop studies suggests the most permeable flow paths in alluvium should be in the paleo-stream-channel deposits beneath the Fortymile Wash area. Further east, beneath the Lathrop Wells area, the clay content of alluvial sediments increases and thick clay layers are prevalent, resulting in significantly lower permeability and probably limiting the eastward migration of flow originating from Yucca Mountain.

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