0459

November 13, 1995

MEMORANDUM TO: Joseph J. Holonich, Chief
HLUR/DWM/NMSS

FROM: John H. Austin, Chief
PAHB/DWM/NMSS

Michael J. Bell, Chief
ENGB/DWM/NMSS

SUBJECT: TRIP REPORT - NAS FIELD TRIP OF AUGUST 27-29, 1995, TO BEATTY, NEVADA, YUCCA MOUNTAIN, AND VICINITY

On August 27-29, 1995, NRC staff Neil Coleman, Harold Lefevre, and Chad Glenn, as well as CNWRA staff Ross Bagtzoglou and Mike Miklas, attended and participated in a National Academy of Sciences' (NAS) public meeting/field trip to Beatty, Nevada, Yucca Mountain, and environs. Messrs. Coleman, Lefevre, and Miklas were present for the full 3 days while Messrs. Glenn and Bagtzoglou were present only on August 27.

The purposes of the trip, the second meeting of the NAS's National Research Council Committee for Yucca Mountain Peer Review (Committee[1]), were: (1) to meet in a public forum at the Beatty, Nevada, Community Center on the afternoon of August 27, 1995; in order to discuss preclosure hydrologic matters with DOE and State of Nevada staffs; (2) to enable the public to comment on hydrologic matters relevant to the Committee's review of the TBR; and (3) to provide the Committee with the opportunity of personally observing the field conditions bearing on its review of the TBR. Attachment 1 of the appended trip report is a list of attendees for the 3-day trip as compiled by NAS staff prior to the field trip. Attachment 2 is the trip itinerary.

Handouts were pre-distributed to the Committee and, with few exceptions, were not available to other participants. See Attachment 3 for the handouts that were provided to NRC staff.

If there are any questions regarding this trip report, please contact either Neil Coleman at 415-6615 or Harold Lefevre at 415-6678.

Attachments: As stated

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[1] The charter of the Committee is to assess the scientific and technical validity of the Department of Energy's (DOE) Technical Basis Report (TBR) on Surface Characteristics, Preclosure Hydrology, and Erosion.

TRIP REPORT - NAS FIELD TRIP OF AUGUST 27-29, 1995
BEATTY, NEVADA, YUCCA MOUNTAIN AND VICINITY

1.0 INTRODUCTION

A three day (August 27-29, 1995) field trip to Yucca Mountain and vicinity was sponsored by the Department of Energy (DOE) for the National Research Council's Yucca Mountain Peer Review Committee (Committee) to facilitate the Committee's review of the scientific and technical validity of the DOE's Technical Basis Report (TBR) on Surface Characteristics, Preclosure Hydrology, and Erosion. See Attachment 1 for the list of attendees and Attachment 2 for the trip itinerary. During the course of the trip, presentations were made by representatives of the DOE and by the State of Nevada (State). The trip included a half-day public session on Sunday, August 27 at the Beatty, Nevada Community Center and field stops at the Yucca Mountain site and vicinity on August 27, 28 and 29, 1995. The public session focused on hydrologic matters including perched water, groundwater supply, and the probable maximum flood. Statements were made by several members of the public at the Beatty Community Center session. The remaining 1 1/2 days centered primarily on erosion (a post-closure matter) and techniques used by the DOE to date both alluvial and bedrock deposits. Handouts at the various field stops had been pre-distributed to the Committee and, with few exceptions, were not available to other participants. See Attachment 3 for the handouts that were made available to the NRC staff. Much of the material discussed during the field stops of August 28 and 29 had been previously presented to the NRC staff during a February 1 and 2, 1994, field trip. The 1994 site visit was conducted in response to questions and comments raised by the NRC Staff and CNWRA on the Erosion Topical Report. Because reports covering the February 1994 trip have been previously issued by the NRC and CNWRA staff, only post-February 1994 information will be addressed in this report.

2.0 REPORT ON FIELD STOPS AND PUBLIC MEETING

Sunday, August 27, 1995

Stop 1: U.S. Route 95 at Fortymile Wash

This stop was at a side channel of lower Fortymile Wash, very close to U.S. Route 95 and in view of the Lathrop Wells Cone. At this location, the alluvial fan deposited by past flows in the wash is about two miles wide. Patrick Glancy and David Beck of the USGS discussed the runoff event that occurred on March 11th, 1995, as well as other runoff events that occurred in the past (see Handout #1). For example, a runoff event occurred in February of 1969, the largest known event in the Amargosa River/Fortymile Wash system during the last 25 years. This event produced an estimated peak flow in the Amargosa River of about 16,000 cfs near

Beatty, NV. Some of this discharge actually reached Death Valley and formed a small lake. Flow in Fortymile Wash was first documented in March 1983. This was shortly before the initial streamflow gaging stations were installed under the Yucca Mountain program of site characterization. Three additional flows occurred during July and August of 1984. These various events were small compared to the 1969 flood.

The event in March of 1995 resulted from 2 to 6 inches of precipitation that occurred in the region during March 9th to 11th, with the larger amounts believed to have occurred at higher elevation areas (see Handout #1). This storm was not localized; it was a generalized storm that produced precipitation over a large region. Snowmelt in higher elevation areas also probably contributed to the surface flows. This runoff event is important because it is the first documented case during the site characterization period in which both the Amargosa River and Fortymile Wash flowed simultaneously along their entire reaches in Nevada. The initial flow surge in Fortymile Wash was witnessed, and reported to be a "5- to 6-foot wall of water and clattering rocks" followed by a rapidly rising water level (see Handout 1). The flow in Fortymile Wash lasted about 10 to 12 hours, causing U.S. Highway 95 to be closed from 8:00 a.m. to about 5:30 p.m. on March 11th. Heavy debris transport occurred in Fortymile Wash, with sediments collecting in some areas to a depth of 5 feet. The USGS flow gage near Highway 95 did not record the peak flow. The floodwaters branched before reaching the gage, causing much of the flow to bypass the measurement station. The gage did record a local peak flow of 1700 cfs. Some surface flow from the Amargosa River system actually reached Death Valley. This flooding event, along with the more severe event in 1969, demonstrated that, in the present climatic regime, the Fortymile Wash and Amargosa river can transport dissolved and suspended materials beyond the confines of the Nevada Test Site and the Yucca Mountain area in response to moderate and more severe precipitation events.

See Handouts #1 (fact sheet) and #2 (summary of peak streamflows) for additional hydrologic information.

Stop 2: Lathrop Wells Cone

Bruce Crowe of Los Alamos National Laboratory (LANL) described the multiple geochronological techniques that had been undertaken at the Lathrop Wells Volcanic Center (see Handout #3) and pointed out that the disparity of the results leave LANL both "frustrated" and "uncomfortable." Nevertheless, he indicated that LANL considers the results sufficient for site characterization purposes and that no further geochronological studies will be conducted.

Stop 3: Public Session at Beatty Community Center

After the morning field trip, a public meeting was held in Beatty starting around 2:00 p.m. At this meeting, members of the Committee viewed presentations on the topics of perched water, water supply, the large hydraulic gradient in the saturated zone, and estimates of the probable maximum flood (PMF) in Midway Valley. Also, David Beck of the USGS presented a very informative video of the 1969 and 1995 floods in Beatty, Nevada.

The information on perched water at Yucca Mountain was presented by Richard Luckey of the USGS, who summarized the various boreholes in which perched water has been found over the years. All of the perched water detected to date exists well below the repository horizon. DOE has demonstrated that perched water bodies can be detected, but cannot definitively predict where new perched water will be found. Handout #4 summarizes data on perched water.

John Czarnecki described various models that have been used to describe the zone of large hydraulic gradient that exists in the saturated zone north of the Yucca Mountain site. In brief, these conceptual models incorporate (1) faults, (2) volcanic dikes, (3) varying degrees of fracturing, and (4) major changes in stratigraphic thicknesses. In his previous two-dimensional modeling of the regional saturated zone, Czarnecki simulated the high gradient as a zone of relatively low transmissivity. Available data do not support the existence of a volcanic dike. The USGS is planning to drill a new well, WT-24, to directly investigate the cause of the high hydraulic gradient. The drilling pad has already been constructed for this well, and it was expected that the drilling rig would be in place during September, 1995.

Robert Barton of DOE described studies of the PMF in Midway Valley, near the portal of the ESF. He reported that a Probable Maximum Precipitation (PMP) of 10.3" (one hour) was used in the PMF calculations. The PMF levels that were calculated were doubled to compensate for entrained sediments and debris in floodwaters. As presented by Barton, the maximum height of a PMF event could reach part of the surface facilities to be built in Midway Valley, but would not reach the portal of the ESF. Some engineering measures would be needed to protect those portions of the surface facilities that could be affected by a PMF event. Based on comments from the NAS panel, they seemed reasonably satisfied that the PMF study was reasonably conservative, primarily because the estimated PMF levels were doubled to account for debris flows.

David Beck presented a video of the 1969 and 1995 floods in Beatty, Nevada. This video consisted of two films shot by a local resident during the floods. They show water levels at the height of the floods and resulting property damages. The 1969 flood washed out roads and flooded many houses. The discharge was so

great that several cars were picked up and transported by the floodwaters. The observed peak discharge in Beatty has been estimated at about 16,000 ft^3/sec. Although the 1995 flood had a much lower discharge than that in 1969, it still washed out roads and flooded several houses.

Representatives of the State of Nevada and local counties were invited to comment. John Bredehoeft, representing Inyo and Esmerelda Counties, expressed concerns about the deep carbonate aquifer, which is an important source of water supplies in the region. One borehole at the Yucca Mountain site penetrates the deep carbonate system. This well, UE-25p#1, is located a few km southeast of Yucca Mountain. This well shows that the hydraulic head in the carbonate aquifer at that location is about 60 ft higher than in the overlying tuff aquifer. Water quality in the carbonate aquifer should be protected so long as this upward gradient is preserved. Bredehoeft noted that DOE needs a better understanding of how areally extensive this upward gradient is. DOE should also avoid pumping in the carbonate aquifer, which would tend to reduce the upward gradient. DOE currently plans to obtain water supplies needed for site characterization work from wells J-13 and J-12, wells that are completed in the tuff aquifer.

Roger Morrison, a consultant to the State of Nevada, expressed a concern about the need to consider postclosure effects of climate change. Geoffrey Spaulding, also a consultant to the State, noted that DOE's Technical Basis Report should have cited a previous publication of the National Research Council, titled "Ground Water at Yucca Mountain: How High Can It Rise?" He also expressed concerns about anthropogenic effects on preclosure climate and hydrology.

Monday, August 28, 1995

Stop 1: Big Skull Mountain Vista

Following John Whitney's (USGS) discussion on the origin of the boulder stripes found throughout the Yucca Mountain site region a Committee member indicated that the cold climate origin as suggested by Dr. Whitney is not necessarily the only process under which the stripes could have been formed. (The Committee's observation is identical to that expressed by CNWRA consultant Dr. Andrew Watson during the February 1994 NRC/DOE field trip mentioned earlier in this report .)

Dr. Charles Harrington (LANL), in response to a query from the Committee, indicated that corroborative dating (^{10}Beryllium) had been considered at the Big Skull/Little Skull Mountain boulder deposits but was not implemented because of budget constraints.

Stop 2: Little Skull Mountain Boulder Deposit (LSM-1)

During the course of Dr. Harrington's discussion on cation ratio dating, many questions raised by the Committee were identical to those asked by NRC/CNWRA staff during the February 1994 extreme erosion topical report field trip. C. Harrington indicated that a Peer Review Group (Group) had been convened by LANL in 1989 for the purpose of critically reviewing rock varnish studies within the LANL Yucca Mountain Project. On June 9, 1989, it was acknowledged by Dr. W.A. Morris of LANL that rock varnish "is a new dating method involving relatively untested analytical procedures for which detailed technical criteria are not yet developed and for which there is disagreement within the technical community regarding the applicability or appropriateness of alternate means of deriving the scientific information." Dr. Harrington noted that although suggestions (dealing with, among other items, the varnish cation ratio calibration curve and substrate contamination) were made by the Group as a result of their review, there was no follow-up on the suggestions by LANL because of funding constraints. Dr. Harrington reported that he had received, two days ago, preliminary and predecisional results of ^{10}Beryllium dating of a number of samples taken from field locations identical to those from which rock varnish samples had been taken. These preliminary results appear to corroborate the rock varnish dates. Dr. Harrington further stated that these dates represent the first phase of the corroborative dating program and that additional sampling and testing will be conducted.

R. Dorn (Arizona State University , consultant to the State) strongly disagreed with the use of the rock varnish dating technique since it is not, in his view, suitable for licensing purposes. Dr. Dorn further indicated that the technique, as used by LANL, is the least desirable of the 12 methods available for varnish dating purposes.

Stop 3: Fortymile Wash Vista

S. Lundstrom (USGS) presented a background discussion of Fortymile Wash and its tributaries from inception to the present. Lundstrom has been mapping the alluvial deposits in the vicinity for the past few years. Lundstrom's presentation included a revised preliminary surficial deposits map that had been published within the past two weeks. This map is of greater aerial extent than that provided to the NRC as a part of the DOE's April 1995 response package to the NRC's comments on the extreme erosion topical report (Topical Report). He noted a major change in the date assigned to the main alluvial surface adjacent to Fortymile Wash from 270ka BP (based on the now generally discounted U-trend dating technique) to a more recent date range of 40-100 ka BP (based on TL/Carbon 14 techniques). This may mean that considerably more sediments in Fortymile Wash are of recent (late Pleistocene/Holocene) origin than previously thought. S. Lundstrom noted that

there is no age control for the lower terrace (current floodplain) of Fortymile Wash. J. Paces (USGS) noted that the U-trend dating technique has been challenged and that the geochronology that he would be discussing is not mentioned in the Technical Basis Report. A representative of the Committee indicated that the more he hears regarding the geochronology of Fortymile Wash area the more confused he becomes. The State of Nevada pointed out that the younger ages correlated favorably with alluvial terraces mapped by them on the west side of Yucca Mountain, primarily in Crater Flat. The USGS provided a basic discussion of various dating techniques and indicated that new techniques may yield younger dates on some alluvium than the previous methods. See Handout #5 for longitudinal profiles of two washes (Fortymile and Drillhole).

G. Spaulding (Dames and Moore, consultant to the State of Nevada) discussed his packrat midden studies in Fortymile Wash here and at other stops. He noted that the elevation of packrat middens in the washes can possibly be used to bound the maximum floods in the washes. He believes that the middens could not be well preserved if they have ever been inundated by floodwaters. He also noted that the presence of phreatophytic (plants which have roots in the water table) plant remains in some middens can be used to infer the elevation of the water table at the time the plant remains were incorporated in the middens by the packrats. One midden site in Fortymile Canyon provides unequivocal evidence that a perennial water source existed there around 50,000 years B.P. or earlier. This site is located about 13 km northeast of Yucca Mountain. The site is also north of the zone of high hydraulic gradient. The midden site led Spaulding to conclude that the water table was at least 75 m higher during the Early or early-Middle Wisconsin.

Spaulding also made some paleohydrologic inferences based on the abundance of archeological artifacts that occur along Fortymile Wash. He believes that these artifacts suggest that some perennial flow occurred in Fortymile Wash as recently as latest Pleistocene or very early Holocene. The sheer abundance of artifacts along Fortymile Wash suggests that food and water resources existed at that time that are no longer present in the now-dry wash. To date, no evidence has been found from packrat middens to support the hypothesis of perennial flow during latest Pleistocene to early Holocene, but only a small percentage of middens in the drainage basin have been studied.

Stop 4: Jake Ridge

The former USGS principal investigator of the Jake Ridge debris flow, J. Glancy, presented a discussion of this 1984 meteorologic event and its effect on Jake Ridge. The event was triggered by an estimated 2-inch rainfall in a few hours which was "stalled" over the site and which loosened about 7000 cubic meters of debris which moved down the slope a few hundred meters. Severe rainfall events like this one occur several times a year around southern Nevada. They occur

randomly and tend to be highly localized. John Whitney (USGS) estimated that approximately 15 per cent of the debris ended up on the primary (lower) terrace of Fortymile Wash. The DOE believes this is an unusual event (probably a 500 year event) and that it can occur only on slopes that have a significant storage of erosional debris. The 1984 event, although highly disruptive, was localized and occurred only on the Jake Ridge slope.

Stop 5: Trench 14D/Crest Exile Hill

The DOE (T. Sullivan) and USGS (S. Lundstrom and J. Whitney) reiterated the alluvial history of Fortymile Wash and its tributaries. R. Dorn, consultant to the State of Nevada, disagreed with the USGS assertions that local base level strongly controls slope erosion, but had no published work to provide to the Committee laying out this disagreement. A Committee member asked how much of the material from the Exile Hill area found its way into Fortymile Wash. S. Lundstrom responded that there is no way to estimate this volume without many more TL dates. For the most part, materials presented by the USGS were identified as "preliminary, predecisional."

Stop 6: Yucca Crest

C. Harrington (LANL) discussed very preliminary ^{10}Be dates of 400,000, 700,000 and 1.1M BP which he said suggested that the 700,000 year BP date obtained using VCR for Yucca Mountain boulder stripes was appropriate. C. Harrington also did some back calculations based on a date obtained in a bedrock deposit near the trace of the Ghost Dance fault. He contended that very little erosion of the bedrock could have occurred given the ^{10}Be date which he obtained. The State of Nevada disagreed with C. Harrington's conclusions regarding the age of the boulder deposits pointing to their recent studies in Crater Flat, the work of Peterson et al. (1994), and by R. Dorn (unpublished).

J. Whitney (USGS) presented unpublished information and data, acquired as a part of the tectonics program, on the erosion history of the Busted Butte sand ramps. Based on dates acquired on several horizons (including the Bishop ash) the USGS concludes that very little erosion of the cobbly sand has occurred over the past 800 ka with erosion being more pronounced at the head of the sand ramp deposits than at the base.

<u>Tuesday, August 29, 1995</u>

Stop 1: Steves Pass

The presentation by State of Nevada's J. Bell on its Crater Flat mapping included the varnish cation ratio (VCR) work of R. Dorn which refutes the DOE's contention

that boulder stripes are Mid-Pleistocene or older (greater than 500,000 BP). The belief, as expressed by J. Bell, that alluvial surfaces are considerably younger than the ages assigned in C. Harrington's work would mean that the VCR ages assigned by C. Harrington might be younger by as much as a factor of ten (which would mean that erosion rates calculated by DOE are underestimated by at least a factor of 10). R. Dorn's work on several deposits indicates boulder stripes are no older than 70,000 BP. The State's alluvial mapping in Crater Flat indicates that significant quantities of sediment have been deposited in Crater Flat during the late Pleistocene/Holocene. On the other hand , the DOE suggests that this is a period of erosional quiescence.

The DOE presented a discussion of S. Lundstrom's work in the Crater Flat area. S. Lundstrom disagreed with at least one of the ages assigned by J. Bell to a depositional surface in Crater Flat but did indicate that the work by the State of Nevada in Crater Flat is an improvement over the early work done by the USGS 's Swadley where most dates were based on the generally-discounted U-trend technique. S. Lundstrom noted that recent revisions of the ages of alluviated surfaces in Fortymile Wash have resulted in general agreement with the ages of surfaces of depositional terraces mapped by J. Bell in Crater Flat. Lundstrom indicated that the areas of agreement exceeded the areas of disagreement. DOE noted that even though the erosion rates calculated by the State of Nevada are younger than those suggested by the DOE by a factor of ten erosion rates are still very low and would not result in the uncovering of the repository horizon during the period of regulatory interest.

Stop 2: Crater Flats Cinder Cone

The State of Nevada pointed out that the rilling on Red and Black cones indicated that considerable erosion had occurred. This implies to the State that the age assigned to the cones by C. Harrington for the construction of his basic VCR age graph may be in error by hundreds of thousands of years. The State indicated this is so because C. Harrington assigned an age comparable to that of the lavas rather than that of the surface on which the varnish began to form. C. Harrington countered that his work indicated that there might be no more than a 150,000 year or so difference between the time the lava was deposited and the time that varnish formed on the lavas and that he factored that difference into his cation-ratio calibration curve. C. Harrington further indicated that preliminary, predecisional results from ^{10}Be dating of samples taken from the same locations as shown on the varnish cation ratio calibration curve are very similar (with a difference of only 30k).

Stop 3: Solitario Canyon Fault Trench Eight (SCFT-8)

J. Whitney indicated that the mapping by the State of Nevada in Crater Flat shows late Pleistocene deposits originating predominantly from Bare Mountain (a more readily erodible rock than that of Yucca Mountain) rather than from Yucca Mountain itself. Whitney also indicated that recent digital terrane work (unpublished) by the USGS has resulted in erosion rates very similar to those reported in the Topical Report. The USGS indicated that the dating of carbonates found in colluvium as exposed in the trench indicate the antiquity and stability of the colluvium. C. Harrington presented the rock varnish calibration curve, as depicted in the Topical Report, as well as a recently-revised curve (unpublished) based on dates that have appeared in both USGS and State of Nevada papers. The revised curve would result in an increase of the estimated amount of erosion from an average regional rate of 0.19 cm/k years to 0.22 cm/k years with a rate of 0.34 cm/k years for Yucca Mountain itself. Upon questioning by the Committee regarding when the "recent" age dating had been done (within the past seven years or so) and why this information had not been included in the TBR, C. Harrington indicated that he had just been informed of these dates and consequently could not have considered this information for possible inclusion in the TBR. When questioned by the Committee relative to work done by the DOE on unstable slope surfaces (those not covered by boulder stripes), which constitute approximately 95% of the slopes, Tim Sullivan indicated that the DOE has conducted no effort directed toward the study of the "unstable" surfaces. Sullivan further indicated that DOE has no study plan for extreme erosion and that information presented in the Topical Report and in the TBR had been acquired from other studies and that such information was considered adequate to satisfy questions related to site characterization from the erosion perspective.

Stop 4: Solitario Canyon Fault Trench Three (SCFT-3)

J. Whitney discussed the mapping in the eight Solitario Canyon trenches and indicated that the recent surficial mapping (unpublished) done by S. Lundstrom corroborates the USGS's dates acquired from the subsurface from materials exposed in the trenches. C. Harrington reported unpublished results of cosmogenic ^{14}Carbon on both Solitario Canyon and Windy Wash fault scarps indicating that there has been no detectable erosion of the scarps during the past >20k years.

<u>Technical Wrap Up and Committee Comments</u>

Tim Sullivan (DOE), Carl Johnson (State of Nevada), Ernest Smerdon (Committee Chair), and each Committee member presented their thoughts on the TBR as well as on the events of the past three days. The State's comments focused on the difficulty that the State perceives on the part of the Committee in weighing the supplemental information (both published and unpublished) which has been

presented to the Committee, both by the State and by the DOE and its contractors, over the several days of field trips and meetings. It is the view of the State that this new information, if presented, would result in a complete rewrite of the TBR. The Committee was urged by the State to request the DOE for confirmation of its newly-presented information. The Committee Chair indicated that the field trip was very informative and thanked the participants for all their work. Committee members expressed a number of points and indicated that the newly-presented data was needed for its evaluation of the TBR, that additional peer review of DOE's work was necessary, and that the Committee was unsure how it would handle the new information in preparing its report. The Committee Chair indicated that the data provided will be reviewed thoroughly by the Committee with no input from the DOE or other agencies and that, when released, the report will be provided to the public and to the DOE simultaneously.

ATTACHMENT 1

ATTENDEES LIST

LIST OF ATTENDEES

National Academy of Science's
National Research Council Committee for Yucca Mountain Peer Review:
Surface Characteristics, Preclosure Hydrology, and Erosion

Field Trip of August 27 - August 29, 1995

1. Susan Jones, DOE/YMSCO, Days 1-3
2. Steve Brocoum, DOE/YMSCO, Days 1-3
3. Bob Barton, DOE/YMSCO, Days 1-3
4. Jane Summerson, DOE/YMSCO, Days 1-3
5. Tim Sullivan, DOE/YMSCO, Days 1-3
6. Sheryl Morris, DOE/YMSCO, Days 1-3
7. Russ Patterson, DOE/YMSCO, Days 1-3
8. Tom Bjerstedt, DOE/YMSCO, Days 1-3
9. John Rosenthall, CRWMS M&O/PMO, Days 1-3
10. Ron Linden, CRWMS M&O/PMO, Days 1-3
11. Mike Cline, CRWMS M&O/PMO, Days 1-2
12. Martha Pendleton, CRWMS M&O/PMO, Days 1-3
13. August Matthusen, CRWMS M&O/PMO, Days 1-3
14. Keith Julien, YMSCO Suitability Process Facilitator, Day 2
15. Catherine Tice, YMSCO Suitability Process Facilitator, Day 2
16. Scott Lundstrom, USGS/YMPS, Days 1-3
17. David Beck, USGS/Nevada District, Days 1-2
18. Jim Paces, USGS/YMPS, Days 1-3
19. John Whitney, USGS/YMPS, Days 1-3
20. Chuck Harrington, CRWMS M&O/LANL, Days 1-3
21. Pat Glancy, USGS/Nevada District, Days 1-2
22. John Czarnecki, USGS/YMPS, Day 1
23. Bill Dudley, USGS/YMPS, Days 1-2
24. Bruce Crowe, CRWMS M&O/LANL Day 1
25. Rebecca Burks, NAS BRWM, Days 1-3
26. Kevin Crowley, NAS BRWM, Days 1-3
27. Scott Hansell, NAS BRWM Intern, Days 1-3
28. Leon Tune, NAS Office of New and Public Information, Days 1-3
29. Craig Hicks, NAS YMPR1 Committee, Days 1-3
30. Susan Brantley, NAS YMPR1 Committee, Days 1-3
31. Ernest Smerdon, NAS YMPR1 Committee, Days 1-3
32. Jean Bahr, NAS YMPR1 Committee, Days 1-3
33. Victor Baker, NAS YMPR1 Committee, Days 1-3
34. William Jury, NAS YMPR1 Committee, Days 1-3
35. Mark Kurz, NAS YMPR1 Committee, Days 1-3
36. Karen Prestegaard, NAS YMPR1 Committee, Days 1-3
37. Leonard Lane, NAS YMPR1 Committee, Days 1-3
38. Carl Johnson, State of Nevada

39. John Bell, State of Nevada Invitee
40. Ronald Dorn, State of Nevada Invitee
41. Martin Mifflin, State of Nevada Invitee
42. David Krinsley, State of Nevada Invitee
43. Maurice Morgenstern, State of Nevada Invitee
44. Roger Morrison, State of Nevada Invitee
45. W. Geoffrey Spaulding, State of Nevada Invitee
46. John Perry, Nye County
47. Catherine Cohen, Citizen Alert
48. Sandra Green, Eureka County
49. Leon Reiter, NWTRB, Days 1-2
50. Englebrecht Von Tiessenhausen, Clark County
51. Raymond Clark, EPA
52. Harold Lefevre, NRC, Days 1-3
53. Neil Coleman, NRC, Days 1-3
54. Ross Bagtzoglou, CNWRA, Day 1
55. Mike Miklas, Jr., CNWRA, Days 1-3
56. Chad Glenn, NRC, Day 1
57. Richard Luckey, USGS, Day 1

ATTACHMENT 2

TRIP ITINERARY

NATIONAL RESEARCH COUNCIL
COMMISSION ON GEOSCIENCES, ENVIRONMENT, AND RESOURCES
2101 Constitution Avenue Washington, D.C. 20418

BOARD ON
RADIOACTIVE WASTE MANAGEMENT
(202) 334-3066 Fax: 334-3077

Office Location:
Milton Harris Building
Room 456
2001 Wisconsin Avenue, N.W. 20007

Committee for Yucca Mountain Peer Review: Surface Characteristics, Preclosure Hydrology, and Erosion

Meeting #2 Field Trip
August 27-29, 1995

Note on Written Materials: The committee welcomes written materials from DOE or State scientists to illuminate/elucidate the issues that will be discussed during the open session and field trip. The committee requests 15 copies of all written materials, preferably with a standard 3-hole punch in the left margin.

Sunday, August 27

7:00 am — Field trip participants will depart for Beatty from the La Quinta Inn located at 3970 Paradise Road in Las Vegas (phone: 702-796-9000). NAS committee/staff will travel in a separate vehicle.

8:30 — Rendezvous at Lathrop Wells (Amargosa Valley), intersection of Routes 95 and 29, for introductions of committee and visitors and a brief review of the purpose and plan for the field trip.

Stop 1: U.S. Route 95 at Fortymile Wash. Erosional history of Fortymile Wash and historical flooding [DOE: Whitney, Lundstrom, and Beck; State: Mifflin]. One hour.

Stop 2: Lathrop Wells Cone. Comparison of dating techniques; techniques to infer erosion. [DOE: Crowe] One hour.

12:00 pm — Arrive at Beatty, Nevada.

2:00-6:00 — **Public Session at Beatty Community Center**

2:00-4:00 — **Committee Discussion on Hydrology.** DOE scientists should bring overheads and other materials and should be prepared for a question and answer exchange with the committee. The State may also wish to bring scientists to respond to questions. The committee does not want a formal presentation from the DOE or the State. The committee will ask questions on the following topics:

2:00-4:00 (Continued)

Perched water. Nature, extent, occurrence, and flux rates; dating and other geochemical work; experimental design to find perched water; how well perched water is understood and can be predicted. [DOE: Luckey and Czarnecki; State: Mifflin]

Groundwater supply. Given alternative conceptual models for steep hydrologic gradients north of Yucca Mountain, how do they affect predictions of groundwater drawdown. [DOE: Luckey and Czarnecki; State: Mifflin]

Probable Maximum Flooding. Details of calculations to determine probable maximum flood boundaries. [DOE: Barton]

4:00-6:00 **Committee Discussion and Public Comment**

Monday, August 28

6:00 am Depart Beatty to Nevada Test Site Gate 510 for badging.

6:30 Rendezvous at Gate 510 for badging.

7:00 Depart Nevada Test Site Gate 510 for Stop 1.

8:00-11:00 **Stop 1: Big Skull Mountain Vista.** Erosional history, debris flows, and varnish dating. [DOE: Whitney and Harrington; State: Dorn]

Stop 2: LSM-1 Boulder Deposit. Erosional history, debris flows, and varnish dating. [DOE: Whitney and Harrington; State: Dorn]

11:00-12:00 Lunch (Site Characterization Office)

12:00-3:00 **Stop 3: Fortymile Wash Vista.** Drainage evolution, incision rates, and Quaternary history. Geochronologic studies of surficial deposits at Yucca Mountain [DOE: Whitney, Lundstrom, and Paces; State: Spaulding]

Stop 4: Jake Ridge. Debris flows from a storm event. [DOE: Whitney]

3:00-4:00 **Stop 5: Trench 14D/Crest Exile Hill.** Surficial deposits and alluvium/colluvium relationships as evidence for erosion rates. Amounts of Quaternary faulting related to enhanced erosion. [DOE: Lundstrom, Whitney, and Paces; State: Bell]

4:00-5:30 **Stop 6: Yucca Crest.** Wrap-up and overview of tomorrow's work. [DOE: Whitney and Harrington]

5:30 Depart for Beatty via Test Site Gate 510.

Tuesday, August 29

6:00 am Committee will depart from Beatty.

6:45 Rendezvous at Steves Pass turnaround.

6:45 **Stop 1: Steves Pass.** Overview of Crater Flats, including geomorphology and soils. [DOE: Whitney; State: Bell, Spaulding]

Stop 2: Crater Flats Cinder Cone. Erosional history. Not interested in recurrence rates of volcanic processes. [DOE: Harrington; State: Bell, Spaulding]

Stop 3: Trench 8. Boulder deposits, relationship of colluvium with hillslope deposits, erosion rates, and antiquity of colluvial deposits as determined from K-horizon carbonates. Not interested in history of faulting. [DOE: Whitney, Harrington, and Paces; State: Bell]

Stop 4: SCFT-3. Boulder deposits, relationship of colluvium with hillslope deposits, erosion rates, and antiquity of colluvial deposits as determined from K-horizon carbonates. Not interested in history of faulting. [DOE: Whitney, Harrington, and Paces; State: Bell]

Technical wrapup (Whitney); next steps and schedule (Smerdon); comments by committee members and other participants.

12:00 pm Depart for Las Vegas

1:00 Committee will stop at Lathrop Wells (Amargosa Valley) for drinks and snacks.

ATTACHMENT 3

HANDOUTS

1. Fact sheet
2. Summary of peak streamflows
3. Summary of dating techniques
4. Borehole perched water
5. Longitudinal profiles in washes

HANDOUT #1

Overview of Runoff of March 11, 1995, in Fortymile Wash and Amargosa River, Southern Nevada

U.S. Department of the Interior—U.S. Geological Survey

Yucca Mountain, approximately 120 miles northwest of Las Vegas, Nev., is being studied by the U.S. Department of Energy as a potential repository for long-term storage of the Nation's high-level nuclear waste. This site-characterization study includes elements pertaining to surface-water runoff, including the potential for flooding. The U.S. Geological Survey (USGS), in cooperation with the U.S. Department of Energy, is monitoring streamflow in southern Nevada through a network of streamflow gaging stations and miscellaneous streamflow measurements in support of the site-characterization effort.

Yucca Mountain and much of the western part of the Nevada Test Site (NTS) are part of the Amargosa River drainage. The Amargosa River is a major drainage component (more than 5,000 mi^2) of the unique closed-basin, hydrologic regime known as the Great Basin. Fortymile Wash and Beatty Wash (fig. 2) are the major tributaries to the upper Amargosa River, which drains through several small, populated areas downstream. This river system terminates in Death Valley, a National Park with an expanding tourist population.

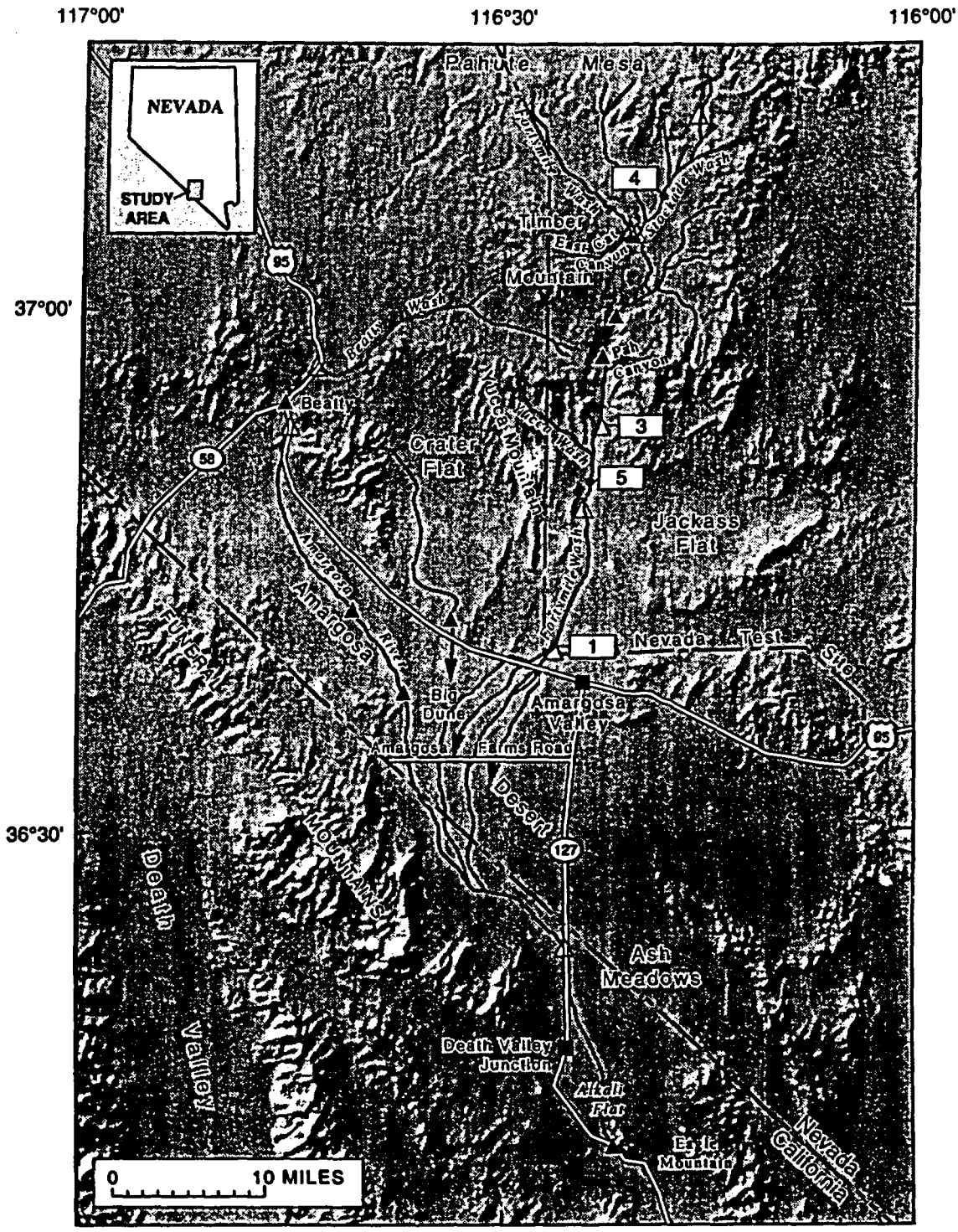
The rugged and sparsely vegetated Amargosa River drainage is within the rainshadow of the Sierra Nevada. As a result of dry, semi-arid, continental climate, flow of the Amargosa River is ephemeral except in a few relatively short reaches where discharging springs maintain small, perennial base flows. Prior to Yucca Mountain site-characterization studies, few data were available on the streamflow of the Amargosa River and its major tributaries. Flow characteristics of the basin are generally poorly understood.

Near U.S. Highway 95, the Fortymile Wash channel changes from being moderately confined to several distributary channels that are poorly confined. This poorly defined, distributary-drainage pattern persists downstream to its confluence with the Amargosa River. Streamflow losses to infiltration and evaporation within this reach are high (Savard and Beck, 1994). The Amargosa River is likewise moderately confined upstream from Big Dune (fig. 2). Downstream from Big Dune, the river splits into several channels that are poorly defined through the Amargosa Valley farm area. These areally abrupt changes in flow-pattern and channel-geometry characteristics of Fortymile Wash and the Amargosa River, wherein moderately to well-defined channels evolve downstream into poorly defined channels, cause uncertainty regarding flow continuity within and between the two drainages. Major questions throughout the Yucca Mountain site-characterization studies are whether, under the present climatic regime, Fortymile Wash is capable of flowing to the Amargosa River, and whether Amargosa River is similarly capable of flowing from its source to Death Valley.

The runoff of March 11, 1995, provided answers to these questions about flow continuity (fig. 1). Precipitation associated with a weather disturbance moving eastward from California caused the most extensive regional runoff in Fortymile Wash and Amargosa River (fig. 2) since February 1969. Preliminary data reported for selected USGS and NTS rain gages within the study area showed that cumulative precipitation ranged from about 2 to 6 inches during March 9-11, with the larger amounts falling at the higher-altitude sites. Eyewitness accounts of snowpack conditions on Timber Mountain and Pahute Mesa just before and after the storm indicate that, in addition to rainfall, high-altitude snowmelt probably contributed to the volume of runoff in Fortymile Wash and Beatty Wash. Runoff of the Amargosa River from Eagle Mountain to Death Valley has been documented several times during site-characterization studies.

The runoff of March 11 is important because it represents the first documented case during site-characterization studies in which Fortymile Wash and Amargosa River flowed

Figure 1. Evidence of debris-laden runoff of March 11, 1995, at Fortymile Wash near Amargosa Valley streamflow gaging station above U.S. Highway 95.



Base from U.S. Geological Survey digital elevation data, 1:250,000, 1987, and digital data, 1:100,000, 1981-89; Universal Transverse Mercator projection, Zone 11. Shaded-relief base from 1:250,000-scale Digital Elevation Model; sun illumination from northwest at 30 degrees above horizon

EXPLANATION

- △ Streamflow recording site
- ▲ Miscellaneous streamflow measurement site
- —— Stream channel with flow on March 11, 1995
- [1] Approximate location of photograph–Number corresponds to figure

Figure 2. Geographic setting and surface flow paths during the March 11, 1995, runoff in Fortymile Wash and Amargosa River.

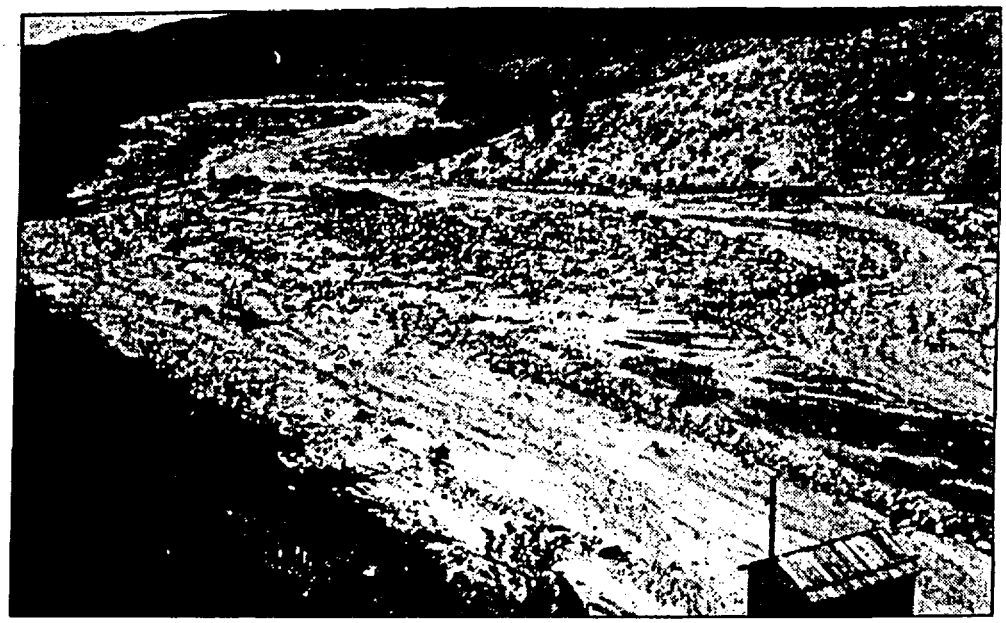


Figure 3. Bank erosion and sediment deposition in Fortymile Wash at Narrows as a result of runoff of March 11, 1995.

simultaneously throughout their entire Nevada reaches. These two fluvial systems were last reported to have flowed extensively within Nevada in February 1969 before site characterization started. The 1969 flood is overall the largest known in the Amargosa River system during the last 25 years. Flow in Fortymile Wash was first documented during site-characterization studies in March 1983, shortly before the initial streamflow gaging stations were installed. The Wash had flow again three times during July and August 1984 as the result of severe but localized convective storms. The extent of flows beyond the boundaries of NTS were not investigated for these early 1980's runoffs.

A field reconnaissance after the storm of March 1995 indicated moderate runoff throughout Fortymile Wash (figs. 1 and 2), several of its main tributaries (East Ca. Canyon Wash, Stockade Wash, Pah Canyon Wash, and Yucca Wash), and several minor tributaries that drain the eastern flank of Yucca Mountain (fig. 2). The Amargosa River also flowed, from above Beatty past the California-Nevada State line, with a large percentage of the flow contributed by Beatty Wash (fig. 2).

The duration of flow in Fortymile Wash was approximately 10 to 12 hours. U.S. Highway 95 was closed from about 8:00 a.m. to about 5:30 p.m. on March 11 because of the streamflow (Trooper William Graham, Nevada Highway Patrol, oral communication, 1995). All evidence indicated heavy debris transport. Bank erosion and sediment deposition were observed along most of Fortymile Wash (fig. 3) within the NTS with sediment deposits as thick as 5 feet in some areas. Other effects of the Fortymile Wash runoff include damage to the Stockade Wash culverts at Airport Road on Pahute Mesa (fig. 4), sediment deposition on H Road where it crosses Fortymile Wash east of Yucca Mountain (fig. 5) and on Amargosa Farm Road in Amargosa Valley. A near tragedy occurred at the H-Road crossing when an NTS worker was swept away by an initial flow surge while attempting to cross Fortymile Wash during the early morning of March 11. His account of the event described the surge as a "5- to 6-foot wall of water and clattering rocks" followed by a rapidly rising water level that moved at high velocities (Augustine Passalacqua, TRW Environmental Safety Systems, Inc., oral communication, 1995).

Amargosa River runoff duration was also approximately 10 to 12 hours. Minor bank erosion and sediment deposition were observed along the Amargosa River from Beatty to Amargosa Valley. Amargosa Farm Road acquired additional sediment deposits as a result of the Amargosa River flow.

Peak flow in Fortymile Wash was significantly attenuated when the flow split into several distributary channels near U.S. Highway 95. Peak flow was attenuated further when a part of the distributed flow was diverted to the west for about 6 miles along the north shoulder of U.S. Highway 95 before turning southward again. The Amargosa River peak flow attenuated between Beatty and Big Dune. Downstream from Big Dune, the flow turned southward and split into several shallow distributary channels through the Amargosa Valley farm area.

Peak flows for Fortymile Wash and Amargosa River were again attenuated at the confluence of the two streams near the southeast end of the Funeral Mountains. Flow within this broad, flat confluence area was slow and shallow (only inches deep) owing to the absence of well-defined channels and the low land-surface gradient. The merged flow of Fortymile Wash and Amargosa River converged into a shallowly incised, well-vegetated channel just upstream of California Highway 127 and flowed into the broad Alkali Flat near Death Valley Junction. The cumulative Fortymile Wash and Amargosa River runoff flowed through Alkali Flat where it combined with other runoff to the Amargosa River caused by localized precipitation near Eagle Mountain. The multi-source runoff then flowed to Death Valley (Larry Anderson, U.S. Bureau of Reclamation, oral communication, 1995).

The information provided by the USGS surface-water monitoring program documented flow from the headwater areas of Fortymile and Beatty Washes, and the combined flow downstream past Death Valley Junction that resulted from moderate runoff. This documentation confirms that Fortymile Wash and Amargosa River have the potential, in the present climatic regime, to transport dissolved and particulate material beyond the confines of NTS and the Yucca Mountain areas during moderate and more severe streamflow.

—David A. Beck and Patrick A. Glancy

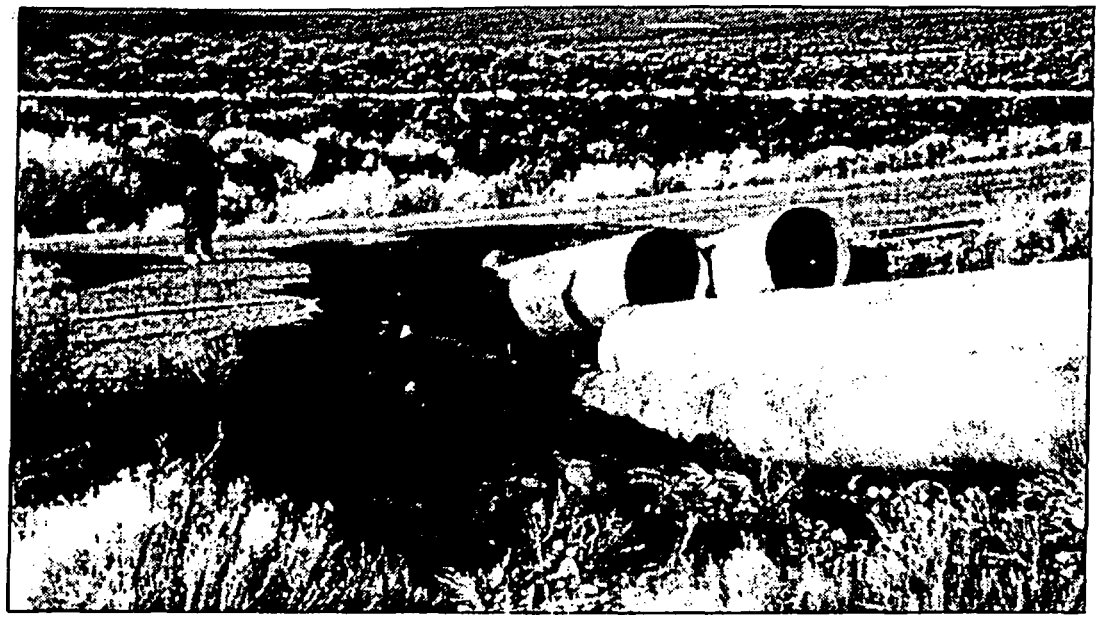


Figure 4. Culvert damage from runoff of March 11, 1995, along Stockade Wash at Airport Road, Nevada Test Site.

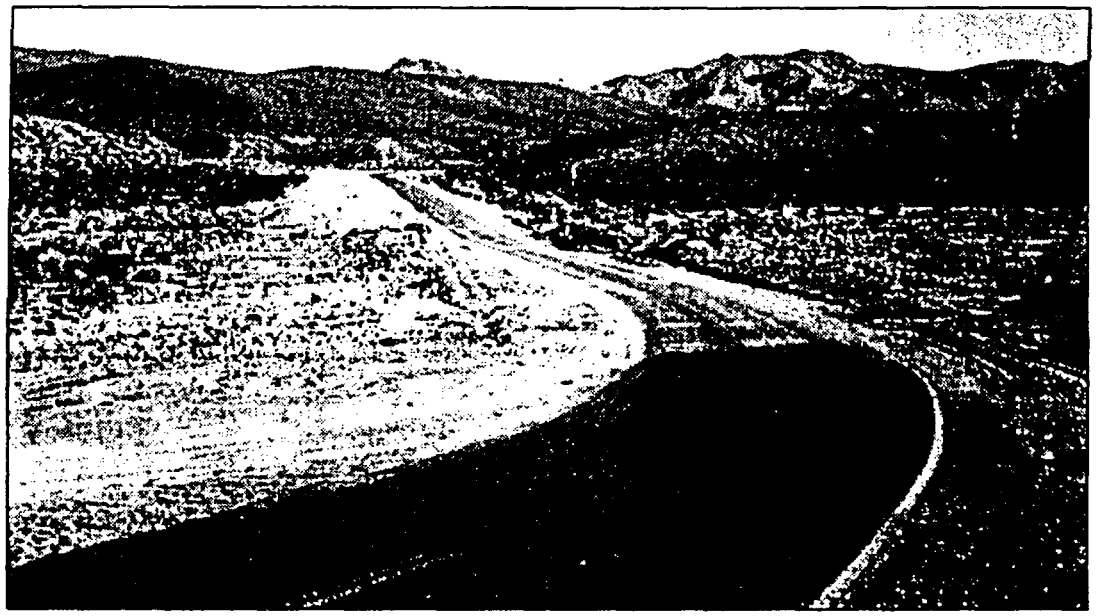


Figure 5. H-Road crossing Fortymile Wash, Nevada Test Site. Debris from runoff of March 11, 1995, was bulldozed to both shoulders of the road. Site is where NTS worker was swept downstream.

Selected References

Kane, T.G., Bauer, D.J., and Martinez, C.M., 1994, Streamflow and selected precipitation data for Yucca Mountain region, southern Nevada and eastern California, water years 1986-90: U.S. Geological Survey Open-File Report 94-312, 118 p.

Pabst, M.E., Beck, D.A, Glancy, P.A., and Johnson, J.A., 1993, Streamflow and selected precipitation data for Yucca Mountain and vicinity, Nye County, Nevada, water years 1983-85: U.S. Geological Survey Open-File Report 93-438, 66 p.

Savard, C.S., and Beck, D.A., 1994, Transmission losses in Fortymile Wash near Yucca Mountain, Nevada [abs.]: Eos, American Geophysical Union Transactions, v. 75, no. 44. p. 283.

U.S. Geological Survey, 1994-95, Water resources data, Nevada, water years 1993-94: U.S. Geological Survey Water-Data Reports NV-93-1 to NV-94-1 (published annually).

For more information about the Yucca Mountain surface-water studies, contact:

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(702) 897-4005
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HANDOUT #2

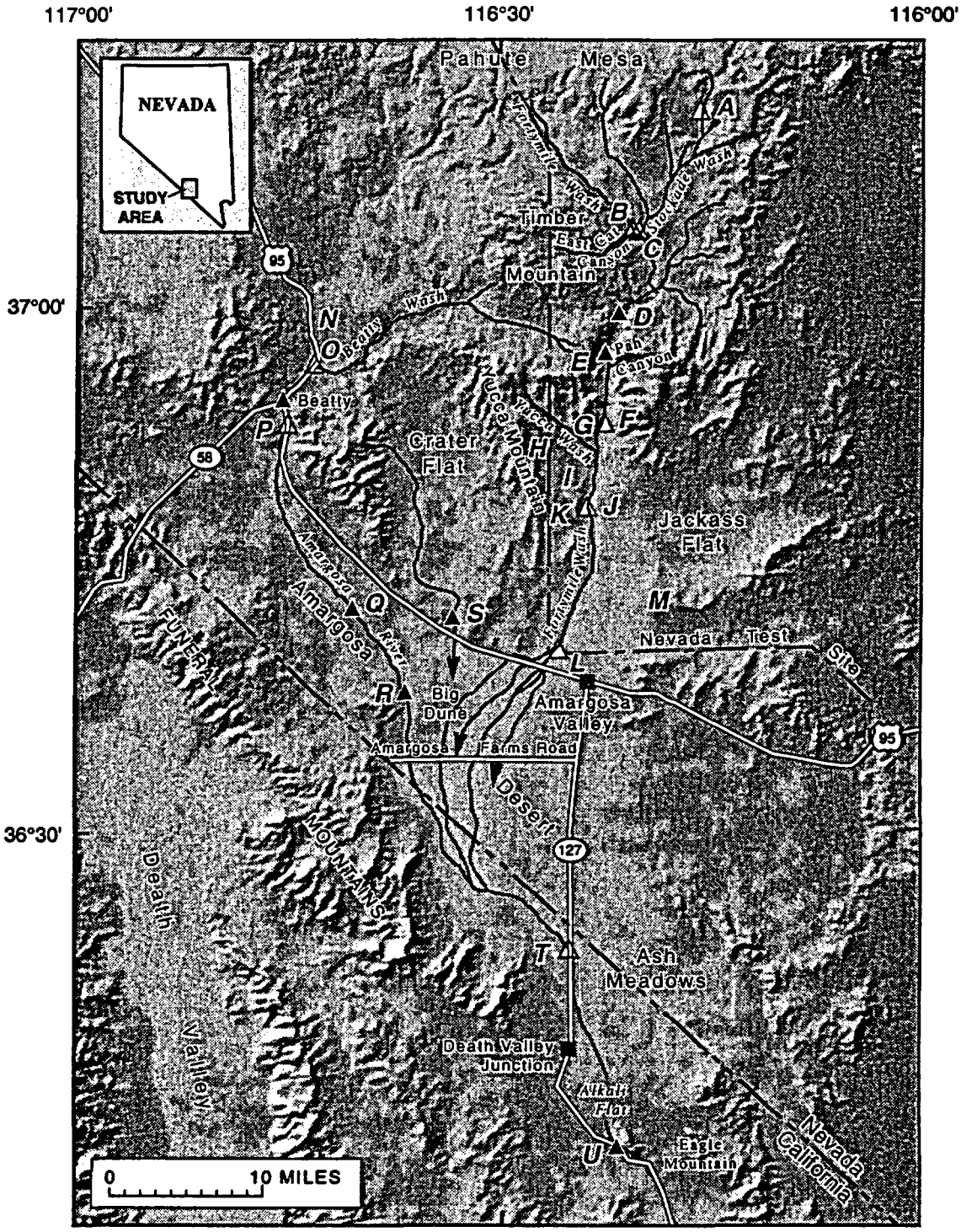
A SUMMARY OF SELECT PEAK STREAMFLOWS 1/ OF THE FORTYMILE WASH AND AMARGOSA RIVER DRAINAGES

Site Designation on Map	Measurement Site 2/	Peak Flow (ft^3/s)	Drainage Area (mi^2) 3/	Remarks
		January 25, 1969 (Regional Rain)		
L	F.M.W. Hywy. 95	1,000	316	
4/	Tecopa	1,500	3,090	Estimated peak
		February 24-26, 1969 (Regional Rain on Snow)		
O	Beatty Wash (mouth)	3,400	94.6	
N	A.R. - Thirsty Cany.	6,100	226	
P	A. R. - Beatty	16,000	470	
L	F.M.W. - Hywy. 95	3,330		
4/	A.R. - Tecopa	5,000		Estimated peak
		March 3, 1993 (Regional Rain)		
F	F.M.W. - Narrows	1,500	258	
J	F.M.W. - J13	570	304	
L	F.M.W. - Hywy. 95	400		
P	A.R. - Beatty	120		
		August 18-19, 1983 (Regional Rain with Convective Cells)		
	F.M.W. (all sites)	0	--	
4/	A.R. - Tecopa	10,600		Streamgage, highway, and culverts destroyed
		July 21-22, 1984 (Convective Storms)		
G	Yucca Wash - mouth	940	17.0	
H	N.Fk. Coyote Wash	130	0.1	
I	Drillhole Wash - mouth	790	16.3	
F	F.M.W. - Narrows	750		
J	F.M.W. - J13	1,800		
L	F.M.W. - Hywy. 95	1,400		
P	A.R. - Beatty	5		

		August 15, 1984 (Convective storm)	
F	F.M.W. - Narrows	50	
J	F.M.W. - J13	20	
L	F.M.W. - Hywy. 95	0	
		August 19, 1984 (Convective storm)	
F	F.M.W. - Narrows	840	
J	F.M.W. - J13	650	
L	F.M.W. - Hywy. 95	400	
M	Topopah Wash - Little Skull Mtn.	530	104
		July 19, 1985 (Convective storm)	
G	Yucca Wash - mouth	<.01	
I	Drillhole Wash - mouth	17	
K	Dune Wash - nr. mouth	94	6.8
F	F.M.W. - Narrows	40	
J	F.M.W. - J13	34	
L	F.M.W. - Hywy. 95	10	
P	A.R. - Beatty	5	
		March 11-13, 1995 (Regional Rain on Snow)	
A	Stockade Wash Trib.		3.9
B	F.M.W. - Above E. Cat Canyon	2,000	40.8
C	E. Cat Canyon		13.3
D	F.M.W. - Canyon, Upper Slope Conveyance	2,000	Undetermined
E	F.M.W. - Canyon, Lower Slope Conveyance	2,500	Undetermined
F	F.M.W. - Narrows		
J	F.M.W. - J13		
L	F.M.W. - Hywy. 95	1,700	
S	Crater Flat	30	Undetermined

O	Beatty Wash - at mouth	900		
P	A.R. - Beatty	1,000		
Q	A.R. - Ashton	700	Undetermined	
R	A.R. - Big Dune	200	Undetermined	
T	A.R. - Hywy. 127	30		Estimated Peak
U	A.R. - Eagle Mtn.	100	Undetermined	
4/	A.R. - Tecopa	150		

1/ All flow rates for March 11-13, 1995, are preliminary and subject to change during review.
2/ F.M.W. = Fortymile Wash; A.R. =Amargosa River
3/ Each area only listed once.
4/ Amargosa River at Tecopa not shown on accompanying map.



Base from U.S. Geological Survey digital elevation data, 1:250,000, 1987, and digital data, 1:100,000, 1981-89; Universal Transverse Mercator projection, Zone 11. Shaded-relief base from 1:250,000-scale Digital Elevation Model; sun illumination from northwest at 30 degrees above horizon

EXPLANATION

- Stream channels
- △ Streamflow recording site
- ▲ Miscellaneous streamflow measurement site
- *A* Measurement sites listed in in accompanying table

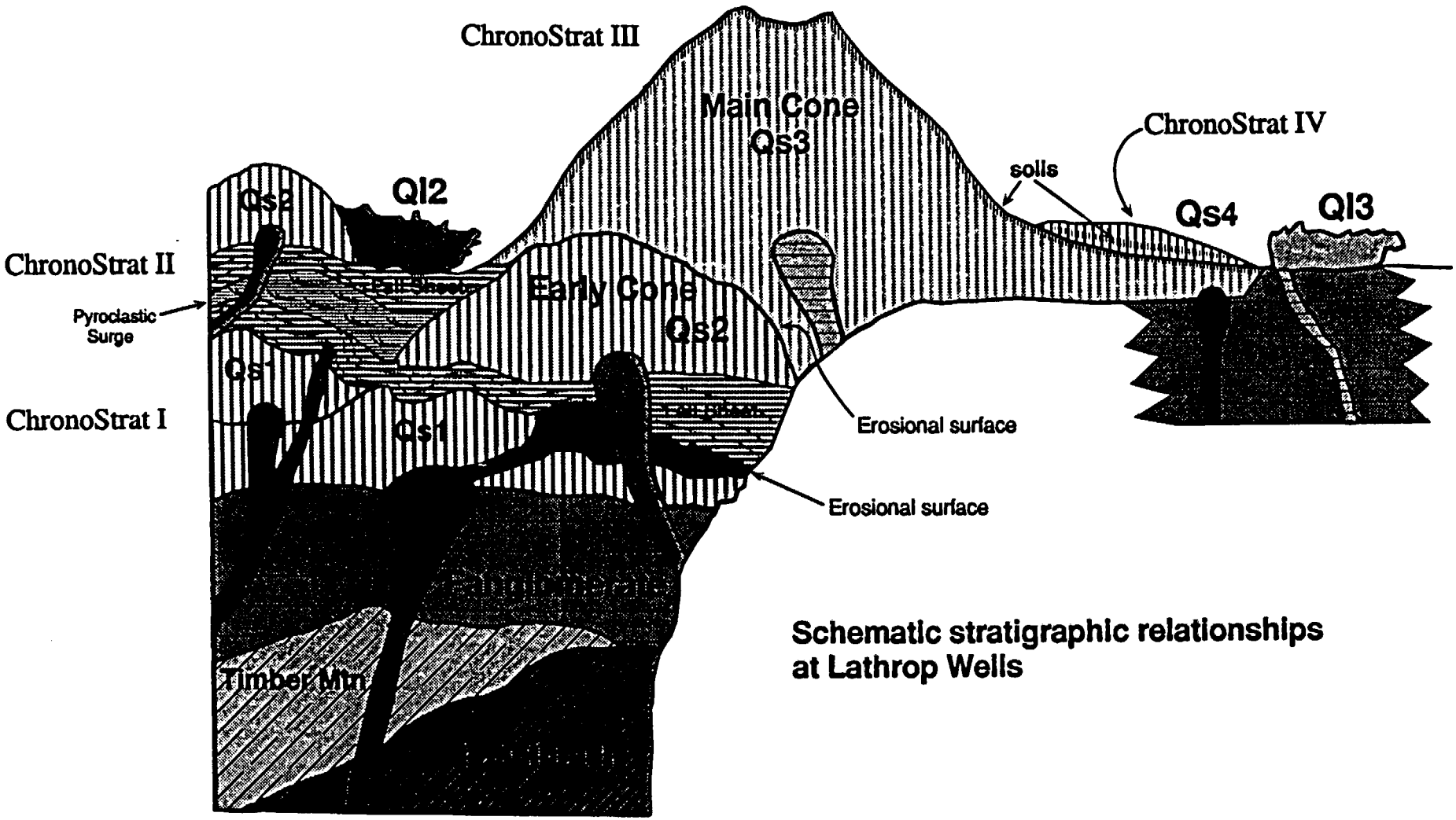
Figure. Geographic setting and surface flow paths during runoff in Fortymile Wash and Amargosa River.

HANDOUT #3

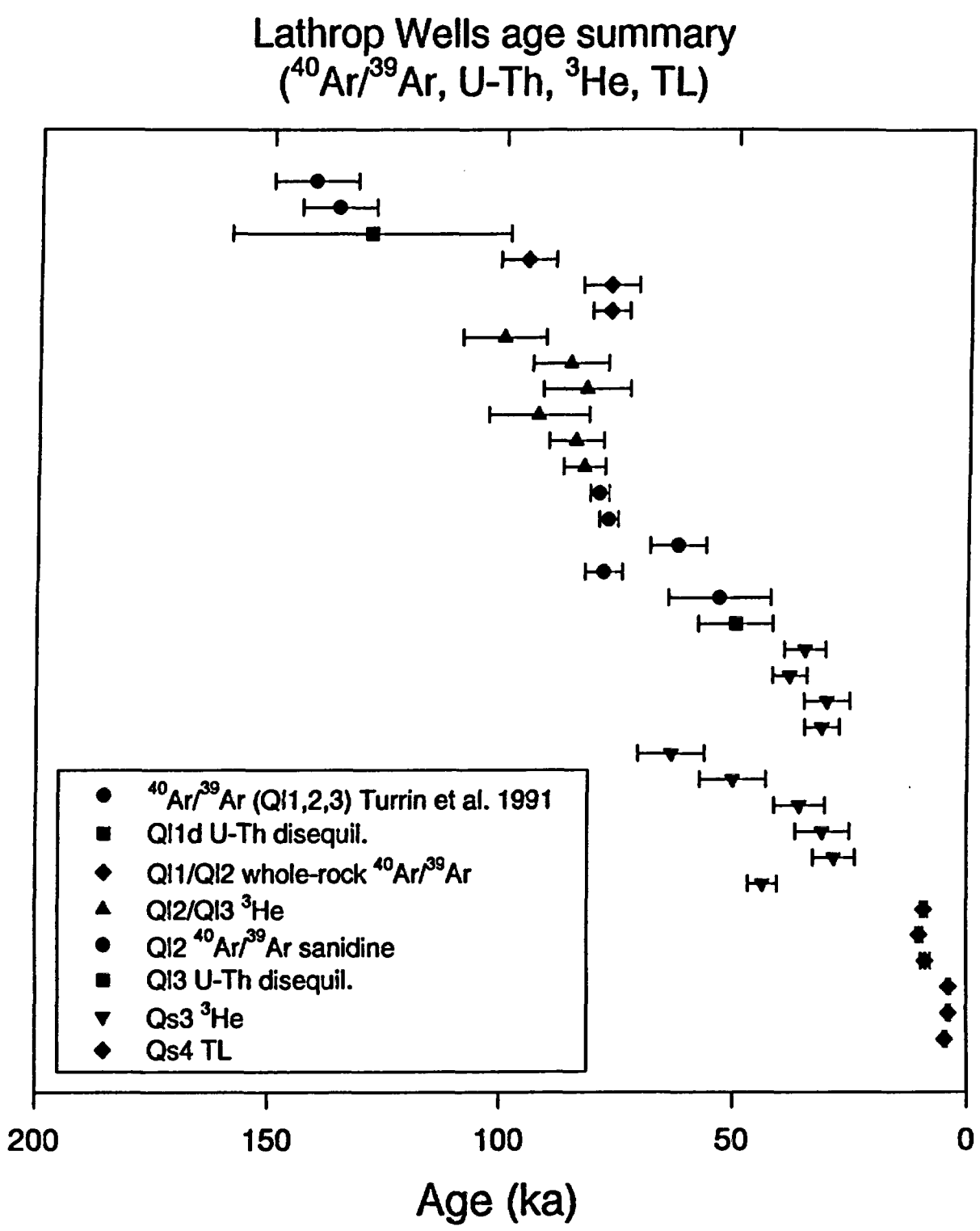
Summary of Geochronology Methods Used at the Lathrop Wells Volcanic Center

Method	Laboratory	Age	Comments
Whole Rock K-Ar	Multiple Laboratories	130-150 ka (Turrin et al. variance weighting) Range: 30 to > 500 ka	Poor reproducibility; results generally unacceptable
$^{40}Ar/^{39}Ar$ (total fusion)	USGS, Lehigh University	130-150 (Turrin et al. variance weighting) Range: negative ages to > 900 ka	Poor reproducibility; results generally unacceptable
$^{40}Ar/^{39}Ar$ (step heating; basalt)	New Mexico Bureau of Mines, USGS	107 ka (USGS) 70-100 ka (Heisler)	Fair reproducibility; possibly some differences between laboratories
$^{40}Ar/^{39}Ar$ (step heating; sanidine from tuff fragments)	New Mexico Bureau of Mines	60-80 ka (Heisler)	Consistent with TL and Helium ages, and youngest U-Th
Cosmogenic $^{3}He/^{4}He$	Los Alamos Natl. Lab	75-100 ka (lavas; Poths) 25-50 ka (cone; Poths)	Consistent data set; cone age may be different from lavas; cone ages difficult to reconcile with geomorphic models; lava ages slightly inconsistent with field data
U-Th Disequilibrium	Los Alamos Natl. Lab	129 ka (oldest lava; Murrell) 50 ka (youngest lava; Murrell)	some complications with isochrons; consistent with field data, He and TL (younger age)

Method	Laboratory	Age	Comments
Thermoluminescence	University of Ohio USGS	65 ka (fall sheet; USGS) 3-9 ka (youngest event, Forman)	Agreement field data, U-Th disequilibrium, step heating basalt (?); sanidine ages; helium (?); one lava site: reproducible but anomalous age
Cosmogenic ^{36}Cl	New Mexico Tech	75-85 ka (lavas and cone; Zreda)	Agreement with cosmogenic helium; marginal analytical assumptions
Soils Studies	University of New Mexico	Late Pleistocene to Holocene (McFadden)	Horizon development consistent with field data; scoria deposits somewhat difficult to interpret
Geomorphic Studies	U.C. Riverside (Desert Research Institute)	Late Pleistocene to Holocene (Wells)	Consistent with field data; cone degradation model: critical; fall-sheet versus cone; alluvial fan relations
Paleomagnetic Studies	USGS, University of New Mexico	Only constraints: duration (Champion, Geissman)	Champion: no *more* than century duration Geissman: paleomagnetic data provides no time constraints



Schematic stratigraphic relationships at Lathrop Wells


Lathrop Wells age summary
($^{40}Ar/^{39}Ar$, U-Th, ^{3}He, TL)
$^{40}Ar/^{39}Ar$ (Ql1,2,3) Turrin et al. 1991
Ql1d U-Th disequil.
Ql1/Ql2 whole-rock $^{40}Ar/^{39}Ar$
Ql2/Ql3 ^{3}He
Ql2 $^{40}Ar/^{39}Ar$ sanidine
Ql3 U-Th disequil.
Qs3 ^{3}He
Qs4 TL
200
150
100
50
0
Age (ka)

Preclosure Hydrology -- Perched Water

[NATURE, EXTENT, OCCURRENCE, AND FLUX RATES]

Borehole USW UZ-14

- Perched water on basal vitrophyre of Topopah Spring Tuff (below repository horizon)
- Depth to perched water 381 m (altitude 967 m)
- Saturated zone potentiometric surface at depth of 571 m (altitude 778 m)
- Hydraulically tested and sampled at 0.9 gal/min for 67 hours
  - *6,000 gal of water produced*
  - *Appeared to be areally extensive based on hydraulic response*
  - *Natural perched body contaminated with USW G-1 drilling fluid*

Preclosure Hydrology -- Perched Water

[NATURE, EXTENT, OCCURRENCE, AND FLUX RATES]

Borehole USW SD-7

- Perched water deep in Calico Hills Formation (below repository horizon)
- Depth to perched water 480 m (altitude 882 m)
- Estimated saturated zone potentiometric surface at depth of 572 m (altitude 731 m)
- Hydraulically tested and sampled at 3.3 gal/min for 30 hours; retested and sampled at 2.5 gal/min for 60 hours
  - *10,000 gal of water produced in first test, 12,000 in second test*
  - *Appeared to be areally limited based on hydraulic response*

Preclosure Hydrology -- Perched Water

[NATURE, EXTENT, OCCURRENCE, AND FLUX RATES]

Borehole USW NRG 7/7a

- Perched water in bedded tuff below Topopah Spring Tuff (below repository horizon)
- Depth to perched water 460 m (altitude 822 m)
- Estimated saturated zone potentiometric surface at depth of 551 m (altitude 731 m)
- Insufficient yield to perform hydraulic tests

Borehole USW SD-9

- Perched water in Calico Hills Formation; appeared to be coming from just above basal vitrophyre of Topopah Spring Formation (below repository horizon)
- Depth to perched water 453 m (altitude 850 m)
- Estimated saturated zone potentiometric surface at depth 572 m; altitude 731 m
- Insufficient yield (est. 0.1 gal/min) to perform hydraulic tests

Preclosure Hydrology -- Perched Water

[NATURE, EXTENT, OCCURRENCE, AND FLUX RATES]

Borehole USW UZ-16

- Initial reports of perched water in Prow Pass Tuff at 492 m (below repository horizon)
- First water was encountered below regional potentiometric surface
- *I believe* first water was produced from low-permeability fracture in the saturated zone
- Saturated zone potentiometric surface at depth of 489 m (altitude 731 m)

Borehole USW SD-12

- Damp core in Calico Hills Formation (below repository horizon)
- Completed in saturated zone without encountering any perched water

Borehole USW UZ-7a

- Reached total depth of 235 m in Ghost Dance Fault zone without encountering any perched water (not all that deep)

HANDOUT #4

Preclosure Hydrology -- Perched Water

[NATURE, EXTENT, OCCURRENCE, AND FLUX RATES]

Exploratory Studies Facility (ESF)

- Damp zone encountered short distance past Station 7+63 in the lower part of the Tiva Canyon Tuff (above repository level)
- Surface drilling typically finds moist rock at this level
- No free water has flowed into tunnel and no perched water has been found

Preclosure Hydrology -- Perched Water

[DATING AND OTHER GEOCHEMICAL WORK]

Data from late-test samples from two boreholes; bailed samples from other boreholes that are not reported here

Strontium

- USW UZ-14 samples resembled surficial calcite
  One interpretation (not unique) is that this is relatively local downward percolation
- USW SD-7 samples resembled regional saturated zone
  One interpretation (not unique) is that this is remnant of past stand of the water table

Uranium

- USW UZ-14 samples had extremely low U concentration and ^{234}U was enriched
  One interpretation (not unique) is that this is relatively local downward percolation
- USW SD-7 samples resembled regional saturated zone
  One interpretation (not unique) is that this is remnant of past stand of the water table

Preclosure Hydrology -- Perched Water

[DATING AND OTHER GEOCHEMICAL WORK]

Data from late-test samples from two boreholes; bailed samples from other boreholes that are not reported here

Carbon-14

- USW UZ-14 and USW SD-7 water had about 28% modern ^{14}C
- Apparent age (residence time since infiltration) of 10,800 years
- Not clear on how to correct apparent age
- Corrected age bounded by 5,000 years and 10,800 years
  Water may be a mixture if different ages
  Average age may be near midpoint between boundaries

Deuterium

- USW UZ-14 and USW SD-7 had similar results
- Not as depleted as would be expected from glacial-period recharge
- More depleted than modern precipitation
  Water may be a mixture of glacial and post-glacial recharge

Tritium

- No bomb-pulse samples found (including bailed samples)

Preclosure Hydrology -- Perched Water

[EXPERIMENTAL DESIGN TO FIND PERCHED WATER]

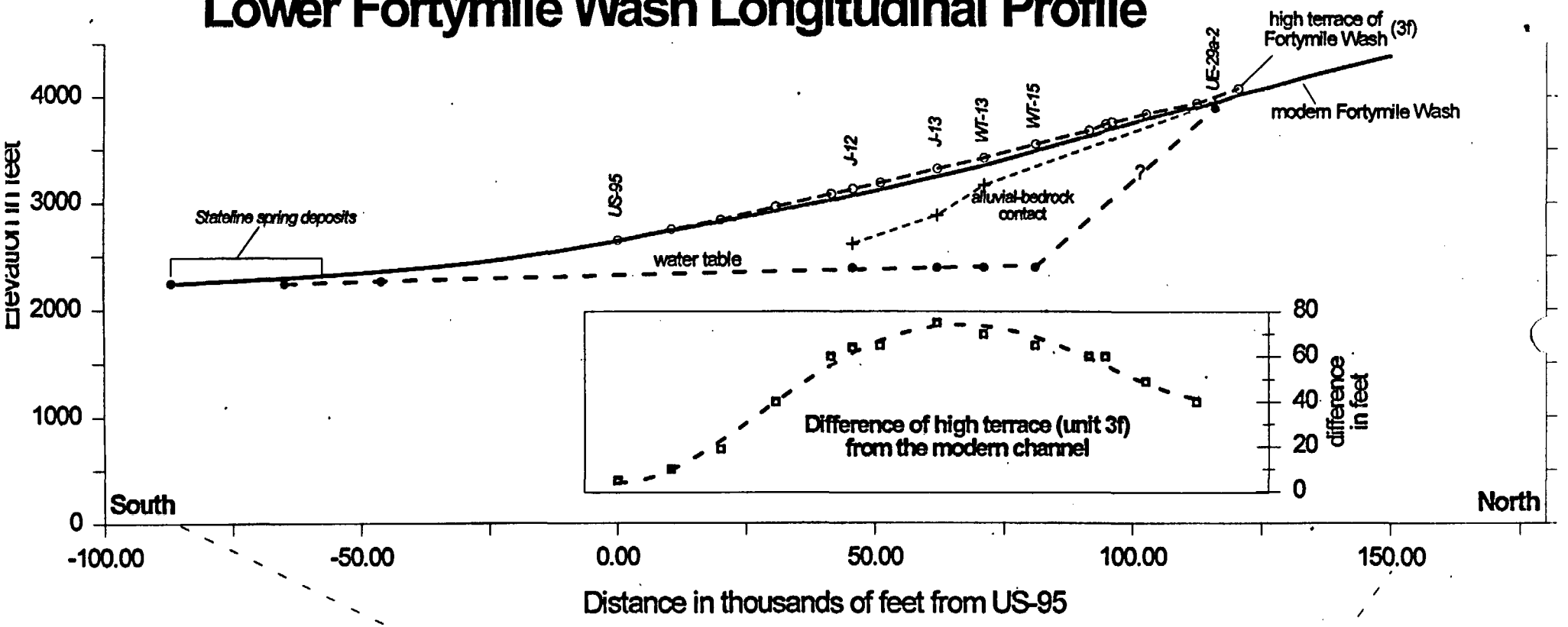
- Specific study aimed at perched water encountered in the ESF
- No specific study aimed at perched water encountered in Surface Based Testing
  In 1980's, drilling with fluids, including air-foam, made detecting perched water difficult (unless yield is very large)
  In 1990's, drilling with air made detecting perched water easier (unless yield is extremely small)
- Standard procedures followed whenever water is encountered in borehole
  Termed "perched water drill" but followed even in saturated zone
  Drilling stops
  Samples immediately collected
  Decision to test or continue drilling made by USGS
- UZ Modeling Studies use perched water as part of calibration and prediction process

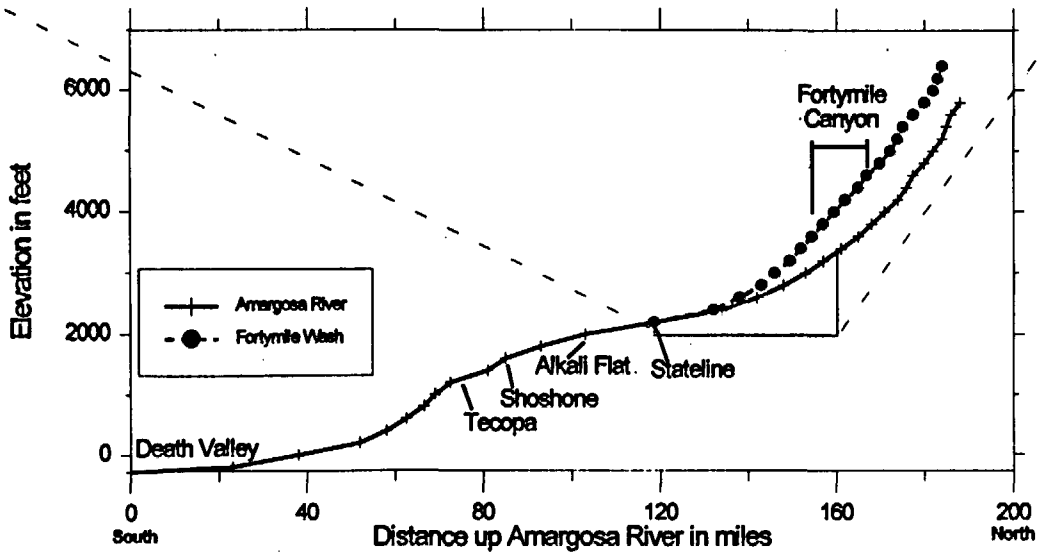
Preclosure Hydrology -- Perched Water

[HOW WELL IS PERCHED WATER UNDERSTOOD AND CAN BE PREDICTED]

- **Know stratigraphic position where perching is likely to occur**
  - *Basal vitrophyre of Topopah Spring Tuff is likely position*
  - *Calico Hills Formation is common position*
  - *Base of Tiva Canyon Tuff is possible position*
- **Know locations were perching is more likely or less likely**
  - *Know perched water is common beneath Drillhole Wash*
  - *Know perched water does occur elsewhere*
- **Do not have definitive prediction capability**

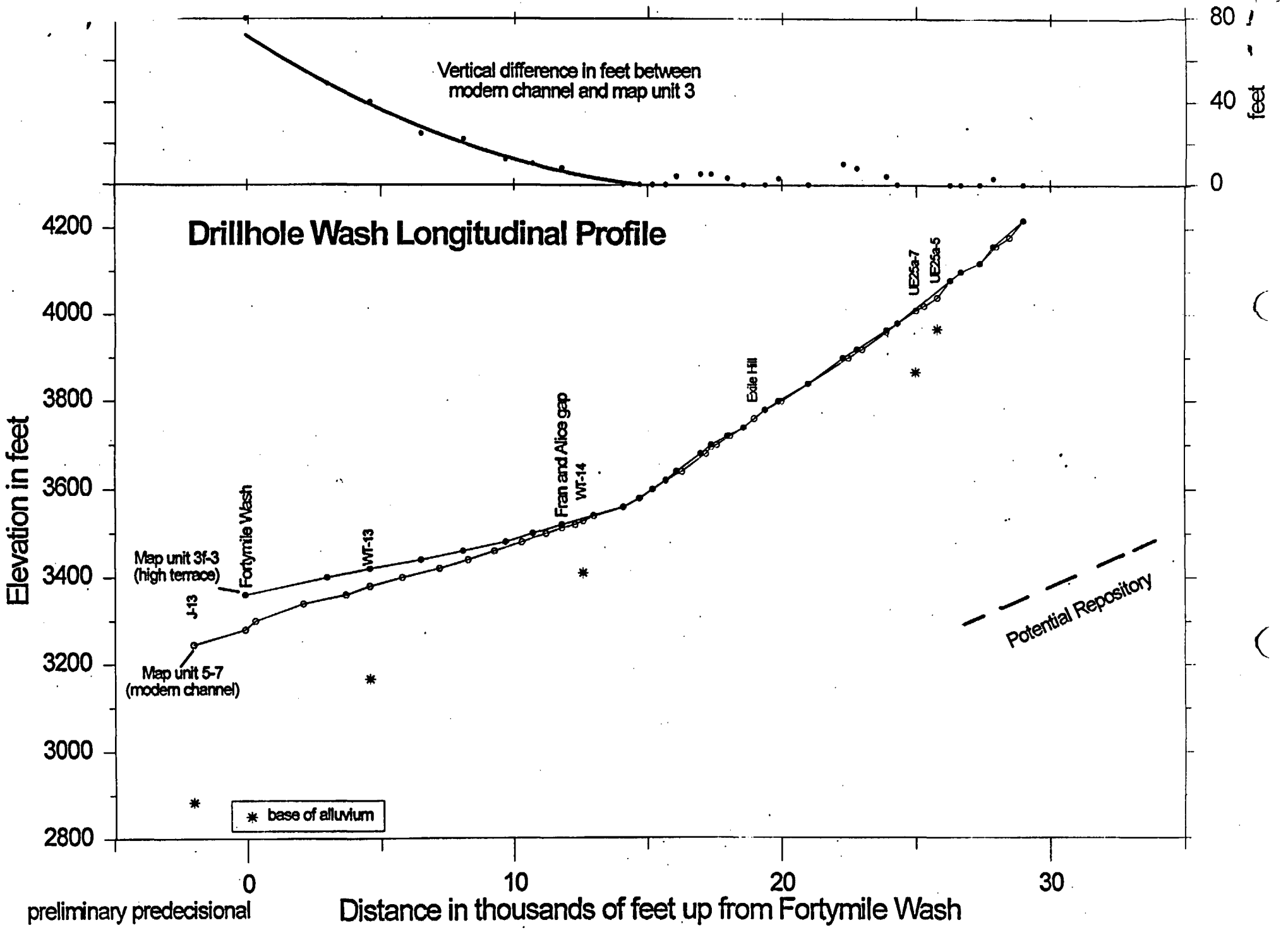
Lower Fortymile Wash Longitudinal Profile





preliminary predecisional

HANDOUT #5



preliminary predecisional