# GEOMORPHIC EVALUATION OF

# PROPOSED SHAFT AND RAMP LOCATIONS

# YUCCA MOUNTAIN HIGH LEVEL WASTE SITE

Draft Report No. LLNL/NRC-NNWSI-CRP-87/88-YM1

Submitted to: Dr. D.H. Chung,
Lawrence Livermore National Laboratory

Submitted by: Charles (Rus) Purcell

January 1988

# GEOMORPHIC EVALUATION OF PROPOSED SHAFT AND RAMP LOCATIONS YUCCA MOUNTAIN HIGH LEVEL WASTE SITE

## ( LLNL/NRC-NNWSI-CRP-87/88-YM1 )

## INTRODUCTION

Two days, August 6 and 7, 1987, were spent in the field in the Yucca Mountain area examining the geomorphic characteristics in the vicinity of the proposed shaft, ramp, and ramp portal locations, including the 1) Exploratory Shaft ( ES ), 2) Steel Lined Shaft ( SLS ), 3) Men and Materials Shaft ( MMS ), 4) Waste Emplacement Ventilation Exhaust Shaft ( WEVES ), 5) Muck Handling Ramp ( MHR ) and portal, and 6) Waste Handling Ramp ( WHR ) and portal. These features are located on Figure 1. The locations were supplied by the NRC and are the best estimates available at the time of authorization. I was accompanied in the field by Mr. Robert Gillson ( LLNL ) on August 6, 1987. This study was authorized in a May 19, 1987 letter from M. Blackford ( NRC ) to D. Chung ( LLNL ) and has subsequently been redefined by an authorization letter dated November 18, 1987. These authorization letters are included as Appendices A and B respectively.

The data presented in this report will be pertinent to the evaluation of the proposed erosion and surface studies anticipated in the upcoming Site Characterization Report ( SCP ) from DOE. In particular, it will help in determining the adequacy of the proposed shaft, ramp, and ramp portal locations and evaluating the completeness of the erosion studies recommended in the SCP.

This report presents a brief Background section which discusses pertinent literature and previous NRC documents regarding the erosion potential in the area of the proposed shaft and ramp locations . The Background section is followed by a discussion of the Field Activities conducted for this study and includes the general field area covered and the observations made at specific field stops. The Field Activities section is followed by a Discussion and Recommendations section that presents basic data analyses of the field observations combined with pertinent technical data from the literature, and concludes with recommendations on the adequacy of the proposed locations and the geomorphic parameters important to the site characterization process. The recommendations are related to the specific locations being evaluated in this report. These

1ST DRAFT

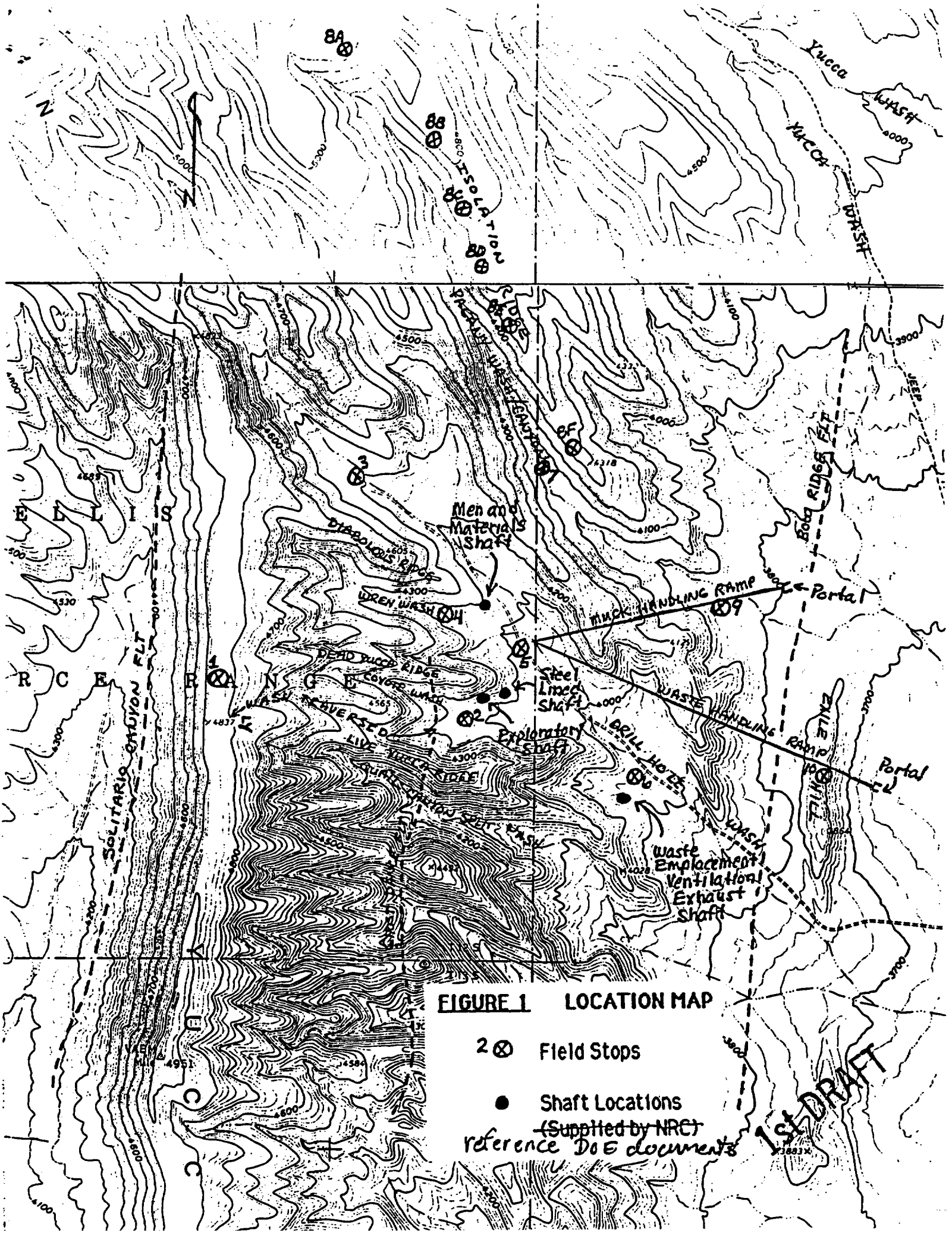



FIGURE 1 LOCATION MAP

2⊗ Field Stops

● Shaft Locations

~~(Supplied by NRC)~~

reference DOE documents

1st DRAFT

recommendations do not supercede those presented on pages 10 through 13 of my 1986 report titled "Potential Erosion at the Yucca Mountain Nuclear Waste Site".

## BACKGROUND

Previous investigations have regionally addressed the subject of erosion in the area of the Nevada Test Site, but none really present data directly applicable to the proposed shaft, ramp and ramp portal locations. These previous investigations were detailed in my report submitted to the NRC in September, 1986. The 1986 report emphasized the lack of specific data regarding erosion in the vicinity of the proposed Yucca Mountain High Level Waste Site. Additional comments on erosion were made in an earlier Technical Note on Erosion based on the NRC review comments on the Environmental Assessment, July 1986.

Recently, on May 5, 1987, the NNWSI Project was visited by Ted Johnson of the NRC to observe site features and to assess the flooding and erosion potential at the proposed surface locations of the various shafts and ramps. This site visit resulted in a Trip Report by Ted Johnson to R. John Starmer, Section Leader, Technical Branch, Division of Low-Level Waste Management and Decommissioning ( Appendix C ). This report concluded that " many of the shafts and ramps are likely to be susceptible to flooding and erosion during the site characterization, operational, and post-closure phases". This report also suggests that DOE should conduct "flooding, erosion and geomorphic analyses " to fully understand design problems and to re-examine the process used to locate the proposed shafts and ramps.

My most recent involvement at the site was to observe the geomorphic characteristics at the specific locations for the proposed shafts, ramps, and ramp portals, and to evaluate these observations in light of the potential for erosion, debris dam formation, and/or other geomorphic changes and the possible resultant entrance of surface waters (Appendices A and B ).

1ST DRAFT

## FIELD ACTIVITIES

This section locates the specific field stops conducted for the geomorphic evaluation, and presents the general observations at each stop. Pertinent comments regarding the specific shaft, ramp and ramp portal locations are presented. Detailed discussions of the long-term geomorphic implications, recommendations for characterization studies, and recommended site location reevaluations are presented under Discussion and Recommendations.

### Thursday, August 6, 1987

**Stop #1:** TOP OF YUCCA MOUNTAIN AT LIVE AND DEAD YUCCA RIDGES

Because of my unfamiliarity with the location and names of the drainages and ridges in the proposed shaft areas, I started at the top of Yucca Mountain for an aerial overview to topographically locate myself. A drainage was traversed on foot from Yucca Crest to Drill Hole Wash to visually examine the surficial characteristics of the wash and slopes ( Figure 1 ). The drainage walked was immediately north of Quail Canyon Split Wash and immediately south of Coyote Wash ( ? ), and actually forms the southernmost tributary to Coyote Wash.

The upper 10% of the wash had relatively gentle, grass covered slopes with shallow soils. The wash itself was very narrow, no more than a meter wide, and primarily bottomed in bedrock. Continuing down the wash, the area of farthest headward retreat ( steepest topography ) was encountered ( Figure 1, approximately at elevation 4,700 feet along the wash traversed ). This area had about 12 to 23 meters of steep, vertical elevation change below which the natural stream profile was typically smooth and uninterrupted to its confluence with Drill Hole Wash. The surface slopes in the area below the upper 10% of the drainage are steep with thin soil and grass cover and abundant boulders on the surface. The thin soil cover results in high surface runoff from direct precipitation on the slopes of all the drainages on the east side of Yucca Mountain. Minor rills are cut into the bedrock on the steep slopes but most wearing away appears attributable to mass wasting. Total relief ( the difference from the top of the surrounding divides to the bottom of the active wash ) on the tributaries to Drill Hole Wash coming from the east side of Yucca Mountain rangers from about 40 to 55 meters. Little debris other than

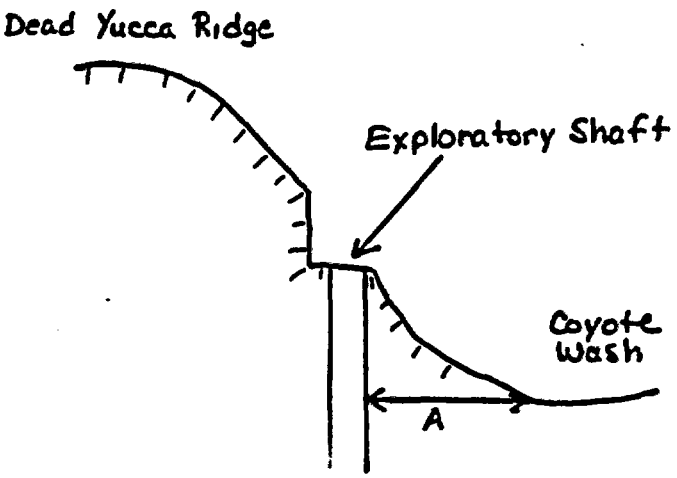
loose boulders and cobbles is contained in the canyon. A few small areas of debris deposits are found near the mouth of the wash but most are deposited beyond the mouth where the wash converges with Coyote Wash before joining Drill Hole Wash. This area is addressed as Stop #2.

**Stop #2:** MOUTH OF THE TRAVERSED CANYON AND EXPLORATORY SHAFT AND STEEL LINED SHAFT LOCATIONS

This area has been greatly altered by man making it difficult to estimate its natural state. The area is about 300 meters west of the location of the proposed ES and 395 meters west of the SLS ( Figure 1 ). Small debris flow deposits are found at the mouth of the traversed wash and Coyote Wash. These deposits are about 2 to 3 meters thick ( above the active wash ) with a predominantly coarse, bouldery nature. There were no noticeable debris deposits in the area directly adjacent to the proposed shafts. All the debris deposits are dumped upstream of the shaft locations.

Based on the supplied maps ( Figure 1 ), the exploratory shaft is estimated to be approximately 9 to 12 meters above the active wash. This vertical distance is interpreted to be adequate to avoid any hazards from flooding and debris flow deposits coming from the tributaries to the west or from Drill Hole Wash. However, an important aspect that becomes evident is the horizontal distance from the active channel in Coyote Wash to the actual subsurface shaft, i.e. distance A on the following diagram.





The potential for erosion along line A at this location is highly probable in the future as the area continues to erode. Careful remedial actions should be used in these areas. Appropriate construction should be more than adequate to prevent or at least minimize the potential lateral erosion.

Stop #3: END OF PAVED ROAD IN DRILL HOLE WASH

This area was examined to observe the amount of debris that may be transported in Drill Hole Wash. Drill Hole Wash is very wide in its entire reach around the shaft locations. With the shafts located about 9 to 12 meters above the wash and somewhat up a side tributary valley, the likelihood of any hazards from Drill Hole Wash debris flows is minimal. This specific area of Drill Hole Wash is extremely disturbed by man making it difficult to estimate it natural state.

Stop #4: WREN WASH

This wash is the closest to the MMS. It has essentially the same characteristics as the wash traversed for Stop #1. The shaft location is slightly different then the exploratory shaft because ~~it's~~ more on the nose or eastern end of Diabolous Ridge where it may possibly be affected by lateral erosion from Drill Hole Wash as well as from Wren Wash. The concern regarding lateral erosion presented for the exploratory shaft also is true for this shaft ( see diagram under Stop #2 ). The area at the mouth of Wren Wash is highly disturbed by man but is also interpreted to be similar to Stop #2. Debris is expected to be rapidly dumped at the mouth of the wash and not impose any real hazard to the shaft which is located about 9 to 12 meters above the active channel.

Stop #5: DRILL HOLE WASH NEAR THE JUNCTION OF THE MUCK HANDLING AND WASTE HANDLING RAMPS

At this location, Drill Hole Wash is a wide ( about 240 meters ), active wash with a very gravelly, bouldery bedload. The wash contains both active gravel bars and terrace deposits. Tributaries enter from the west near this location. Drill Hole Wash is the major drainage from the

northeast side of Yucca Mountain. No evidence of extensive downcutting near the shaft locations or along the lower reaches of Drill Hole Wash were evident. However, analyses must be made to anticipate the potential future downcutting in relation to the depth of the underground ramps. This should include a detailed chronology of the terraces along the wash and longitudinal profiling from the headwaters to its confluence with Fortymile Wash. Another major concern for this area is the access roads. Careful planning and design will be necessary to maintain proper roads during the import of waste and workers to the site to avoid washouts similar to those now present on the road to Drill Hole Wash.

Stop #6: WASTE EMPLACEMENT VENTILATION EXHAUST SHAFT

In contrast to the other shaft locations, the WEVES is essentially in the mid-channel area of a small, unnamed watershed immediately south of the canyon where the ES is located. This location is possibly subject to flooding from Drill Hole Wash and the unnamed drainage. There are no debris deposits in the shaft area and such deposits are not deemed a major concern because of the very small watershed and associated amount of debris available. The wash is interpreted to be similar in character to Coyote Wash but smaller in drainage area. However, because of its location, the WEVES needs careful characterization.

Friday, August 7, 1987

Stop #7: END OF DIRT ROAD IN PAGANY WASH ( SEVIER WASH? )/PAGANY CANYON

Pagany Wash is in a different type of topographic environment than the washes traversed on the east side of Drill Hole Wash. Pagany Wash is east of the major ridge that forms the east side of Drill Hole Wash. There are no major tributaries to Drill Hole Wash from the east in the vicinity of the shafts. In contrast to the rounded divides with grass covered slopes and narrow washes draining the east side of Yucca Mountain, Pagany Wash drains a large watershed and is characterized by steep side slopes, a wide wash, and relatively flat, divides.

Pagany Wash ~~is the wash that~~ crosses the MHR near the portal location and is thusly important to the integrity of the ramp and the portal. Pagany Wash is a tributary to Yucca Wash, the larger drainage northeast of Isolation Ridge and the MHR portal. Compared to the washes previously examined on the east side of Yucca Mountain, Pagany Wash is in a steeper sided canyon with total relief of 60 to 75 meters at the mouth of the canyon, much greater than the tributaries to Drill Hole Wash. The canyon sides are steeper and expose more natural bedrock on the surface, especially in the upper slopes. The wash is wider at the bottom, about 15 to 24 meters, and contains more than one level of valley fill ( debris flow ) materials.

Pagany Wash was traversed on foot about 1/2-mile up the canyon beyond the end of the dirt road. Various levels ( ages ) of valley fill material ranging from contemporaneous gravel bars and stone stripes to the highest ( oldest ) material , about 6 to 7.5 meters above the modern channel, were observed. The lowest ( youngest ) deposits are about 1 to 2 meters above the active channel and display evidence of being topped during the most recent flood events. The valley fill materials are primarily restricted to the area inside meanders of the active channel and thusly their location fluctuates from side to side in the canyon ( Figure 2 ). Bedload in the active channel contains boulders up to 4 feet ( long axis ) by 2 feet ( short axis ) but is predominantly cobbles, gravel and sand. The wash bottom is not typically in bedrock and the slope of the wash is more gentle than the tributaries to Drill Hole Wash, and probably similar to the slope of Drill Hole wash itself.

**Stop #8:** ISOLATION RIDGE AT THE EASTERN HEADWATERS OF PAGANY WASH ( CANYON )

Pagany Canyon is very deep ( 105 to 120 meters ) at its headwaters and is steep sided with boulders and grasses covering most of the slope. The channel bottoms primarily in thin ( ? ) fluvial material with some outcroppings of bedrock in and adjacent to the active channel. Minor amounts of valley fill material are present in the upper reaches of the wash and, where present, are probably best described as colluvial mantle and not debris flow deposits. The area is predominantly one of present day erosion. Eroded materials are transported down valley and primarily deposited as alluvial fan material at the mouth of Pagany Canyon

( Figure 2 ). These characteristics are applicable to the entire upper reaches that were observed from 6 Stops ( labeled 8A through 8F, on Figure 1 ) going downslope ( southeast ) along Isolation Ridge from the headwaters to the nose of the ridge.

**Stop # 9:** ALLUVIAL FAN AT THE MOUTH OF PAGANY WASH NEAR THE AREA OVERLYING THE MUCK HANDLING RAMP

This is an area of fairly recent ( young ) alluvial fan building. The area has been modified by man as evidenced by the aerial photographs of twenty eight years ago and the rills and man-made irregularities on the ground. Presently the main channel ( if there really is a contemporaneous channel ) is only cut about 1 to 2 meters into the fan. However, this area is a potential prime area for future erosion and deposition making the relationship of the channel to the underlying ramp ( depth to the ramp is unknown ) very important.

The muck handling ramp portal is located far enough to the west of Yucca Wash that the major hazards come from the potential alluvial fan deposits and/or erosion from Pagany Wash and not from the larger Yucca Wash watershed.

**Stop #10:** TOP OF EXILE HILL OVERLOOKING THE WASTE HANDLING RAMP

The WHR portal is located on the alluvial/colluvial slope on the eastern flank of Exile Hill. The ramp extends northwesterly under Exile Hill and under the eastern divide of Drill Hole Wash to about the center of Drill Hole Wash. Deposition and/or erosion from major washes are unlikely in this area. The runoff generated from precipitation on Exile Hill will be very minor and can be accommodated in design structures. Erosion in Drill Hole Wash needs to be evaluated as discussed under Stop #5.

1st DRAFT

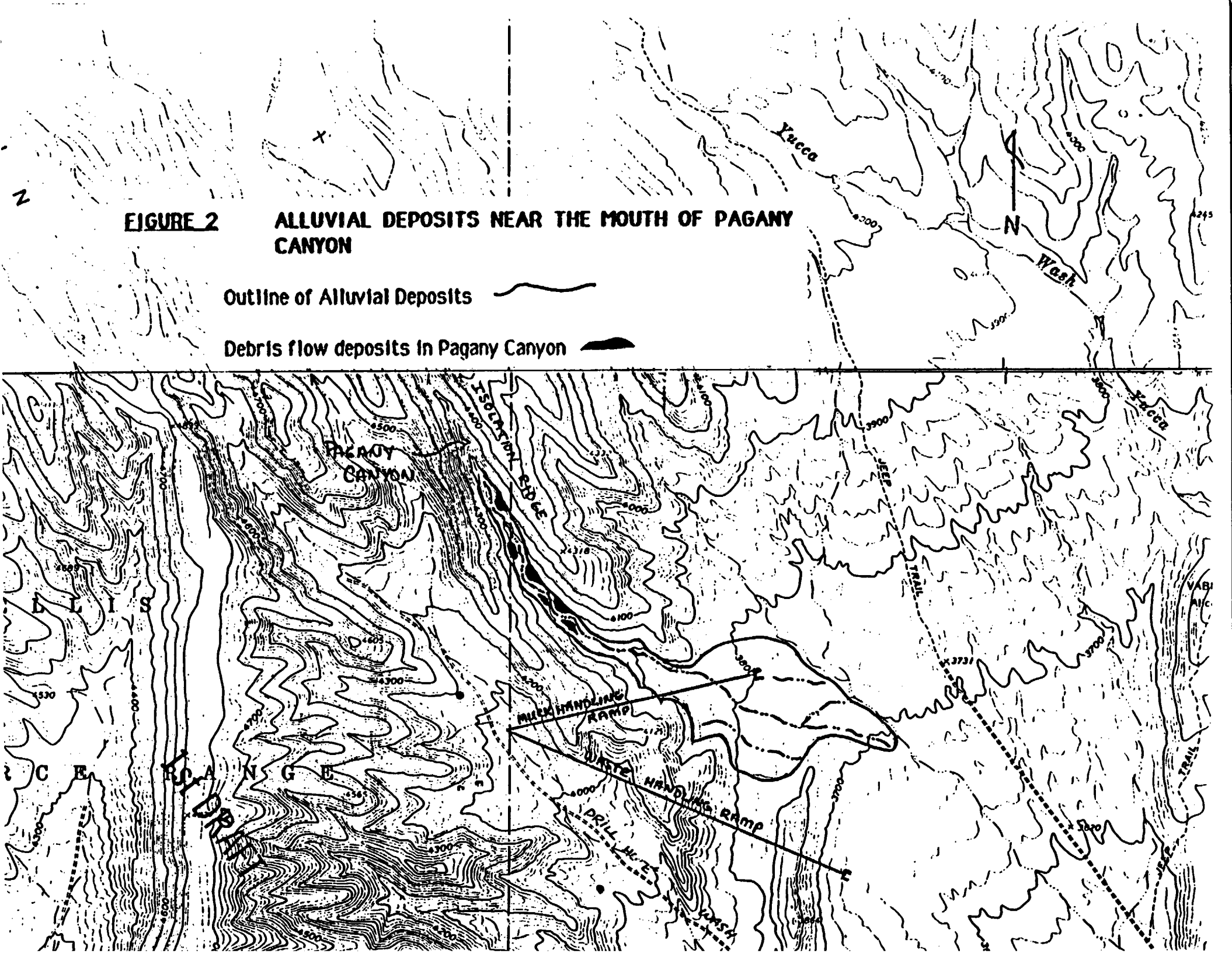


FIGURE 2 ALLUVIAL DEPOSITS NEAR THE MOUTH OF PAGANY CANYON
Outline of Alluvial Deposits
Debris flow deposits in Pagany Canyon
N
Yucca
Wash
PAGANY CANYON
ISOLATED RIDGE
JEEP TRAIL
MILL HANDLING RAMP
WASTE HANDLING RAMP
DRILL MUD PIT
WASH
D E L I S
C E R C A N G E
Yucca
TRAIL

## DISCUSSION AND RECOMMENDATIONS

This section will present a discussion of how the geomorphic observations presented in the Field Activities section relate to the geomorphic characterization of the proposed locations for the 1) ES and SLS, 2) MMS, 3) WEVES, 4) MHR and portal, and 5) WHR and portal. The geomorphic observations will address the four subject areas as requested in the authorization letters ( Appendices A and B ). These subject areas are the 1) potential effect of 10,000 years of geomorphic change on drainage configuration, 2) quantification of geomorphic changes with respect to stream and flood plain erosion, 3) definition of potential lateral, vertical ( downcutting ) and/or upstream movement and erosion of streams and gullies, and 4) discussion of more suitable shaft and ramp locations. Where the geomorphic evidence are insufficient to address the above four categories, the following will be discussed: 1) is there a potential problem related to flooding and/or erosion, 2) why is there a problem, 3) what data are necessary to adequately characterize the problem and 4) what can DOE do to solve the problem?

### Exploratory Shaft, Steel Lined Shaft and the Men and Materials Shaft

The ES, and SLS are located on the southern slope of Dead Yucca Ridge near Drill Hole Wash, and the MMS shaft is located on the southeastern slope of Diabolous Ridge near Drill Hole Wash ( Figure 1 ). All three locations are about 9 to 12 meters above the active wash. Field observations suggest these locations are adequate as far as the hazards of flooding and debris deposits are concerned. However, care should be taken during construction and operation to protect against lateral erosion.

Data presented by Squires and Young ( 1983 ) show the maximum level of flood waters for the 500-year flood on Drill Hole Wash to be about 2 to 3 meters above the active channel, and to be about 3.5 to 4 meters above the active channel for the regional maximum flood. These data suggest flooding is not a major concern at the present locations that are 9 to 12 meters above the active channel of a tributary to Drill Hole Wash.

The hazard of surface runoff and channelization above the location of the shafts has been addressed by Ted Johnson. This hazard can be

remedied with the construction and regular maintenance of appropriate diversion structures

Field evidence regarding debris deposits suggest this potential hazard is also not a major concern at the proposed shaft locations. These materials tend to be deposited at the mouth of the tributaries west of the shafts and in thicknesses of less then 3 meters.

The main hazard to the shafts is interpreted to come from the potential for lateral erosion and the possibility of exposure of the shafts below the ground surface. Although this hazard is present, it can be minimized by proper construction design and protection of the side slopes of the ridges near the shaft locations, and is further minimized if the shafts are in bedrock.

The effects of 10,000 years of geomorphic change in the area of the shafts have primarily been presented and include both vertical and lateral erosion, and the wearing away of unprotected slopes. Quantification of these processes can not be estimated from the available data. Purcell (1986) presented theoretical values of downcutting of up to 820 meters in the next 10,000 years, which were described as being highly unlikely, yet without additional site specific data cannot be totally ignored.

A geomorphic change to be considered in the safety of the shafts is the potential for stream piracy ( capture ) upstream of the shaft locations. Specifically, the potential for Drill Hole Wash to capture the upper drainage reaches of Yucca Wash. Considering this potential change, the flooding potential would probably not exceed that of Fortymile Wash whose maximum regional flooding level is estimated to be about 6 to 9 meters above the active channel ( Squires and Young, 1983 ) and safely below the levels of the proposed shafts. The additional drainage area from stream capture needs to be factored into the site specific analyses of potential vertical erosion ( Downcutting ).

In addition to the potential erosion and deposition from the natural geomorphic processes during the next 10,000 years, the likelihood of these processes being modified by tectonic events also needs to be considered. The impact of uplift and /or lateral movement on any of the local faults ( i.e. Solitario Canyon, Ghost Dance, and Bow Ridge ) and the potential for basin subsidence due to underground testing will most probably accelerate the geomorphic processes.

The necessity for DOE to characterize the lateral erosion potential in Coyote and Wren washes is important to help design remedial activities

at the shaft locations. Slope protection i.e. rip-rap and concrete, should be adequate to remedy the potential hazards in the shaft areas.

## Waste Emplacement Ventilation Exhaust Shaft

The WEVES is located in the drainage channel of an unnamed tributary to Drill Hole Wash immediately south of the tributary containing the ES ( Figure 1 ). Field and map observations show this location to be no more than 6 meters above the active channel of Drill Hole Wash. This location is marginally adequate as far as the hazards of flooding and debris deposits. Furthermore, the location is essentially in the channel bottom and should probably be reconsidered for this reason alone.

Data presented by Squires and Young ( 1983 ) show the maximum level of flood waters for the 500-year flood on Drill Hole Wash to be about 2 to 3 meters above the present day channel, and for the regional maximum flood to be about 3.5 to 4 meters above the active channel. Based on the accuracy of the available data, the potential for flooding from Drill Hole Wash is questionable at this site. The margin of safety is definitely smaller than for the other shaft locations.

Additional flooding and possible debris deposit hazards come from the unnamed drainage in which the WEVES is located. Because of the proposed inchannel location, careful engineering design and appropriate diversion structures will be necessary to avoid flooding of the shaft. Furthermore it may actually be easier to move the WEVES farther upslope to avoid the need for many of the costly protective structures associated with the inchannel location.

The effects of 10,000 years of geomorphic change in the area of the WEVES primarily include both vertical and lateral erosion and the wearing down of slopes. Quantification of these processes can not be estimated from the available data. Purcell (1986) presented theoretical values of downcutting ranging up to 820 meters in the next 10,000 years, which were described as being highly unlikely, yet without additional site specific data cannot be totally ignored.

A geomorphic change to be considered in the safety of the WEVES location is the potential for stream piracy upstream of the shaft location. Specifically the potential for Drill Hole Wash to capture the upper drainage reaches of Yucca Wash. In the case of the WEVES location, considering this potential change, and anticipating the maximum regional

flooding to be about equal to that of Fortymile Wash, which is 6 to 10 meters above the active channel ( Squires and Young, 1983 ), this location could potentially be under water. These data suggest reconsidering the location of this shaft.

In addition to the potential erosion and deposition from the natural geomorphic processes during the next 10,000 years, the likelihood of these processes being modified by tectonic events also needs to be considered. The impact of uplift and/or lateral movement on any of the local faults and the potential for basin subsidence from underground testing will most probably accelerate the geomorphic processes.

Careful characterization of the potential flooding at the WEVES location is necessary to adequately evaluate the proposed shaft location. Estimates of the maximum flooding potential and the flooding potential associated with the theorized stream capture of Yucca Wash by Drill Hole Wash, based on drainage basin size and increased discharge should be presented. If the results of these analyses confirm the likely potential of flooding at the shaft location, DOE should consider relocating the WEVES farther upslope, out of the channel of the unnamed drainage.

## Muck Handling Ramp and Portal

The MHR portal is located southeast of the end of Isolation Ridge on an alluvial fan coming from Pagany Canyon, and west of the major influence of Yucca Wash ( Figure 1 ). The ramp extends westerly across the alluvial fan, under the ridge separating Pagany Wash from Drill Hole Wash to a point near the center of Drill Hole Wash. Field observations suggest the site is probably adequate as far as flooding from Yucca Wash, however, the potential hazards of flooding, deposition, and erosion across the alluvial fan coming from Pagany Canyon suggest the site needs to be carefully characterized.

Data presented by Squires and Young ( 1983 ) show the maximum level of flood waters for the 500-year flood on Yucca Wash to be about 1.5 to 2 meters above the present active channel, and the regional maximum flood to be about 3.5 to 4 meters above the active channel. These data suggest flooding from Yucca Wash is probably not an important concern at the ramp portal location which is about 12 meters above the active channel of Yucca Wash. However, because of the relatively flat nature of the alluvial plain

1st DRAFT

between the southernmost active channel of Yucca Wash and the portal location, sheet flooding from Yucca Wash , especially from the northeast, will have to be considered during design of the facility.

Data presented by Cooke, Brunsden, Doornkamp, and Jones ( 1985 ) regarding zones of flooding on a typical alluvial fan in the western United States shows the MHR portal to presently be in an area of moderate to slight flooding danger ( Figure 3 ). The characteristics of the alluvial fan coming from the mouth of Pagany Wash suggest the fan is relatively young ( < 10,000 years old ) and probably still periodically building. Alluvial fans build in pulses of alluviation which typically migrate across the fan surface. This migration of the main, active channel, suggests the potential exists for the MHR portal area to also be exposed to extreme flooding danger during the evolution of the alluvial fan in the next 10,000 years of geomorphic development.

Schumm, Mosley, and Weaver (1987) present theoretical data defining probabilities of erosion and deposition at various segments of an alluvial fan system. These segments include 1) entire fan surface, 2) fan apex, 3) upper midfan, 4) lower midfan, and 5) toe. The probability matrices can be used to identify hazardous areas on evolving alluvial fans ( Figure 4 and Tables 1 through 3 ). The underlying factor shown by these data is that erosion and deposition are ongoing and changing their location throughout the fan building process. These theoretical results further confirm the potential for erosion and deposition across the entire fan surface. Therefore the potential for erosion into the underlying shaft ( I have no data to suggest the depth to the shaft at various locations along its length ) and deposition and surface flooding at the MHR portal are factors that need to be carefully evaluated.

The effects of 10,000 years of geomorphic change in the area of the MHR and portal are primarily covered by the concern for the development of the alluvial fan eminating from Pagany Canyon. The hazards as shown include potential surface flooding, deposition and erosion at unpredictable locations along the eastern half of the MHR and the portal location. Quantification of these processes can not be estimated from the available data. Purcell (1986) presented theoretical values of downcutting ranging up to 820 meters in the next 10,000 years, which were described as being highly unlikely, yet without additional site specific data cannot be ignored.

An additional possible geomorphic change to be considered in the safety of the MHR portal location is the potential for stream piracy

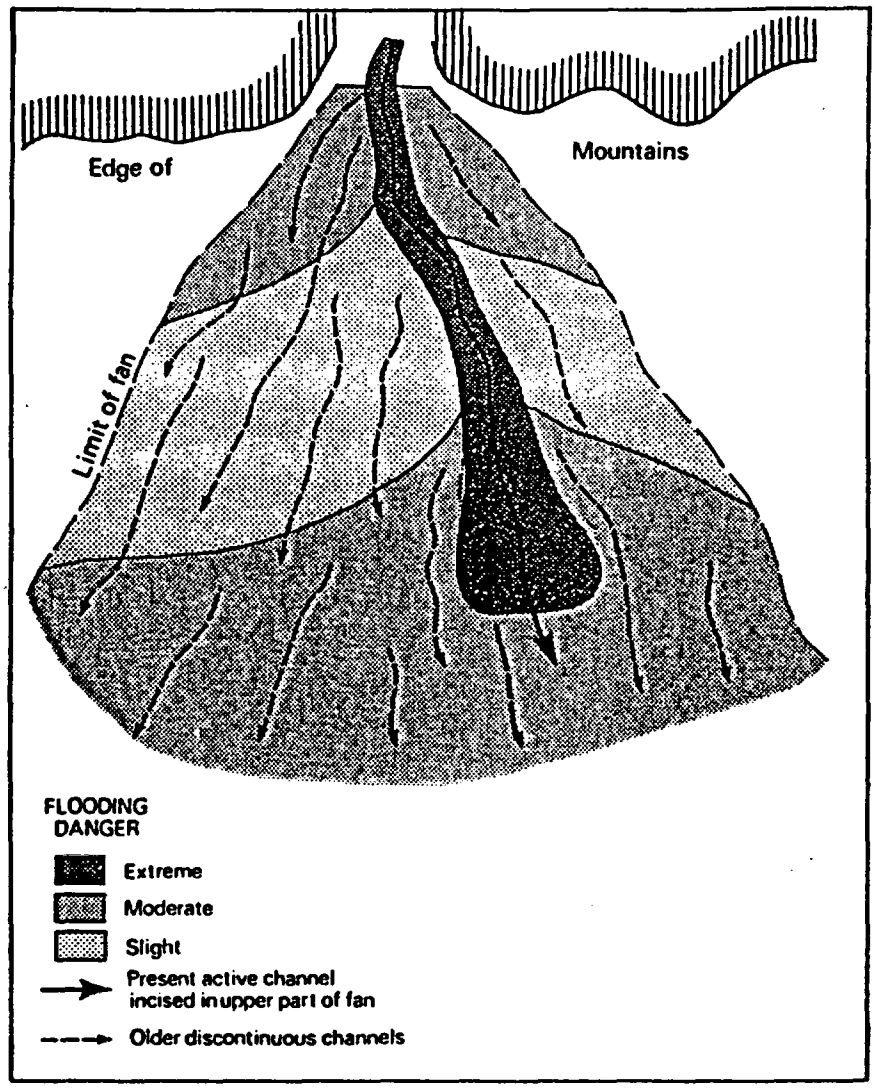



**FIGURE 3** THE PATTERN OF FLOOD HAZARD ON A TYPICAL ALLUVIAL FAN IN THE WESTERN UNITED STATES
(From Cooke and others, 1985)

1st DRAFT

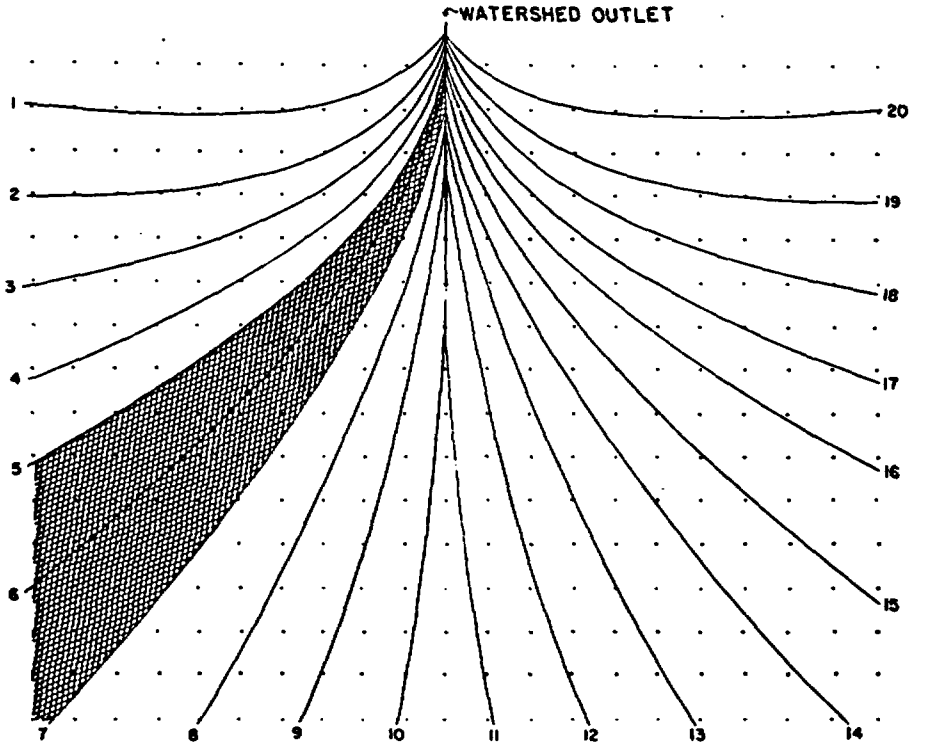



FIGURE 4 FLOW LINES DIVIDE THE FAN SURFACE INTO 20 OVERLAPPING, EQUAL-AREA SEGMENTS. THE SEGMENTS FLANKING FLOWLINE 6 ARE SHADED AS AN EXAMPLE. EACH FLOW LINE REPRESENTS THE SEMIARCUATE COURSE TYPICALLY TAKEN BY A CONCENTRATED FLOW OF WATER AND SEDIMENT DISCHARGE.
(From Schumm and others, 1987, and Weaver, 1984)

1st DRAFT

# TABLE 1

**Probability Matrices for the entire fluvial fan surface, Runs 9A–11P[a]**

| Former State* | Following State | | | | |
|---|---|---|---|---|---|
| | Erosion | No Change | Moderate Deposition | Heavy Deposition | Total |
| Erosion | 0.01 | 0.24 | 0.41 | 0.35 | 1.0 ($n$ = 187) |
| No change | 0.01 | 0.67 | 0.21 | 0.11 | 1.0 ($n$ = 7745) |
| Moderate deposition | 0.02 | 0.57 | 0.28 | 0.13 | 1.0 ($n$ = 2932) |
| Heavy deposition | 0.02 | 0.57 | 0.27 | 0.14 | 1.0 ($n$ = 1554) |
| Total | 0.02 | 0.63 | 0.24 | 0.12 | 1.0 ($n$ = 12418) |

* Note: To define the probabilities of erosion and deposition on the fan surface, frequency matrices were constructed from data collected at each measurement pin (shown on Figure 4). Changes were classified as (1) erosion (greater than or equal to 6mm/run); (2) no significant change (+3 to -3 mm/run); (3) moderate deposition (6 - 9mm/run); and (4) heavy deposition (greater or equal to 12mm/run).
(From Schumm and others, 1987)

1ST DRAFT

# TABLE 2

**Probability Matrices for the Apex (A) and the Upper Midfan (B)**

| Former State | Following State: Erosion | No Change | Moderate Deposition | Heavy Deposition | Total |
|---|---|---|---|---|---|
| | | | A. Apex | | |
| Erosion | 0.01 | 0.21 | 0.45 | 0.33 | 1.0 ($n$ = 87) |
| No change | 0.03 | 0.68 | 0.21 | 0.08 | 1.0 ($n$ = 1374) |
| Moderate deposition | 0.06 | 0.63 | 0.24 | 0.07 | 1.0 ($n$ = 483) |
| Heavy deposition | 0.04 | 0.61 | 0.21 | 0.13 | 1.0 ($n$ = 206) |
| Total | 0.04 | 0.64 | 0.23 | 0.09 | 1.0 ($n$ = 2150) |
| | | | B. Upper Midfan | | |
| Erosion | 0.00 | 0.26 | 0.43 | 0.31 | 1.0 ($n$ = 54) |
| No change | 0.02 | 0.64 | 0.25 | 0.09 | 1.0 ($n$ = 1638) |
| Moderate deposition | 0.03 | 0.56 | 0.32 | 0.10 | 1.0 ($n$ = 734) |
| Heavy deposition | 0.03 | 0.59 | 0.24 | 0.14 | 1.0 ($n$ = 283) |
| Total | 0.02 | 0.60 | 0.27 | 0.10 | 1.0 ($n$ = 2709) |

(From Schumm and others, 1987)

# TABLE 3

**Probability Matrices for the Lower Midfan (A) and Toe (B) Regions of the Experimental Alluvial Fan**

| Former State | Following State: Erosion | No Change | Moderate Deposition | Heavy Deposition | Total |
|---|---|---|---|---|---|
| | | | A. Lower Midfan | | |
| Erosion | 0.00 | 0.27 | 0.27 | 0.47 | 1.0 ($n$ = 30) |
| No change | 0.01 | 0.69 | 0.19 | 0.11 | 1.0 ($n$ = 2212) |
| Moderate deposition | 0.01 | 0.56 | 0.28 | 0.14 | 1.0 ($n$ = 775) |
| Heavy deposition | 0.01 | 0.55 | 0.27 | 0.17 | 1.0 ($n$ = 466) |
| Total | 0.01 | 0.64 | 0.22 | 0.13 | 1.0 ($n$ = 3483) |
| | | | B. Toe | | |
| Erosion | 0.00 | 0.31 | 0.38 | 0.31 | 1.0 ($n$ = 16) |
| No change | 0.00 | 0.66 | 0.20 | 0.14 | 1.0 ($n$ = 2521) |
| Moderate deposition | 0.00 | 0.55 | 0.28 | 0.16 | 1.0 ($n$ = 940) |
| Heavy deposition | 0.01 | 0.57 | 0.29 | 0.13 | 1.0 ($n$ = 599) |
| Total | 0.00 | 0.62 | 0.23 | 0.14 | 1.0 ($n$ = 4076) |

(From Schumm and others, 1987)

* Note: Refer to Table 1 for explanation of terms.

upstream of the portal location. Specifically the potential for Yucca Wash to capture Beatty Wash. In the case of the MHR portal location, considering this potential change, and anticipating the maximum regional flooding to be to be about equal to that of Fortymile Wash which is 6 to 9 meters above the active channel ( Squires and Young, 1983 ), this location could potentially be subject to sheet flooding and would require appropriate diversion structures.

In addition to the potential erosion and deposition from the natural geomorphic processes during the next 10,000 years, the likelihood of these processes being modified by tectonic events also needs to be considered. The impact of uplift and/or lateral movement on any of the local faults ( Solitario Canyon, Ghost Dance, and Bow Ridge ) and the potential for basin subsidence due to underground testing will most probably accelerate the geomorphic processes and especially the evolution of the alluvial fan at the mouth of Pagany Canyon.

A complete geomorphic evaluation of the area of the MHR and portal will be necessary to adequately characterize the proposed location. This evaluation should include at least the development of a chronology of the debris deposits located in the lower reaches of Pagany Canyon, an estimate of the amount of debris that could add to the development of the alluvial fan at the mount of Pagany Canyon and an evaluation of the age of the alluvial fan surfaces and /or deposits. These data should quantify the geomorphic processes active at the MHR and portal locations and address the potential for acceleration of the rates of these processes by tectonic events. Based on the data developed, DOE should present appropriate design considerations to adequately accommodate the potential flooding, erosion and deposition hazards ( i.e. diversion structures, channelization of the waters eminating from Pagany Canyon ), or present plans to relocate the facility.

## Waste Handling Ramp and Portal

The WHR portal is located on the eastern slope of Exile Hill. Field observations suggest the location is adequate for the hazards of flooding, deposition and erosion. The ramp extends northwestward under Exile Hill and the eastern divide of Drill Hole Wash to about the center of Drill Hole Wash. Concerns along this ramp are basically tectonic because of the Bow

Ridge Fault and only involve erosion as it pertains to the main channel of Drill Hole Wash.

Data presented by Squires and Young ( 1983 ) show the maximum level of flood waters for the 500-year flood on Yucca Wash to be about 1.5 to 2 meters above the active channel, and for the regional maximum flood to be about 3.5 to 4 meters above the active channel. These data suggest flooding is not a major concern at the present location which is at least 6 meters above the active wash and in a wide flat area that would cause flood waters to spread out in sheet flood fashion in the area east of the portal location. Sheet flooding can be controlled with appropriate diversion structures.

The hazard of surface runoff and channelization above the portal location on Exile Hill is minimal. The waters and debris from direct precipitation on Exile Hill can be remedied by appropriately designed and maintained diversion structures.

The effects of 10,000 years of geomorphic change in the area of the WHR and portal include the wearing down of Exile Hill and the other topographic features crossed by the ramp. Quantification of these processes can not be estimated from the available data. Purcell (1986) presented theoretical values of downcutting ranging up to 820 meters in the next 10,000 years, which were described as being highly unlikely, yet without additional site specific data cannot be ignored. Furthermore, the potential for increased flooding from stream piracy upstream of the WHR portal by Yucca Wash capturing Beatty Wash needs to be evaluated. Considering this potential change, and anticipating the maximum regional flooding to be about equal to that of Fortymile Wash which is 6 to 9 meters above the active channel ( Squires and Young, 1983 ), this location could potentially be subjected to sheet flooding. As already explained, the hazard from sheet flooding can be controlled with appropriate diversion structures.

In addition to the potential erosion and deposition from the natural geomorphic processes during the next 10,000 years, the likelihood of the processes being modified by tectonic events also needs to be considered. The impact of uplift and/or lateral movement on any of the local faults, especially the Bow Ridge Fault, and the potential for basin subsidence due to underground testing will most probably accelerate the geomorphic processes.

Estimates of the maximum flooding potential and the flooding

associated with the theorized stream capture of Beatty Wash by Drill Hole Wash, based on drainage basin size and increased discharge, should be characterized. In all probability the data will not present any major hazards to the present location of the WHR and portal. Final design structures should be presented to show the necessary remedial measures for the proposed location.

Needs summary ??

1st DRAFT

## REFERENCES CITED


1) Cooke, R.U., Brunsden, D., Doornkamp, J.C., and Jones, D.K., 1985, Urban Geomorphology in Drylands: Oxford Univ. Press, New York, N.Y., 324p.

2) Purcell, C.R., 1986, Potential Erosion at the Yucca Mountain Nuclear Waste Site: Consultant report submitted to Lawrence Livermore National Laboratory in September, 1986, 35p.

3) Schumm, S.A., Mosley, M.P., and Weaver, W.E., 1987, Experimental Fluvial Geomorphology: John Wiley and Sons, New York, N.Y., 413p.

4) Squires, R.R., and Young, R.L., 1984, Flood Potential of Fortymile Wash and its Principal Southwestern Tributaries, Nevada Test Site, Southern Nevada: U. S. Geological Survey Water-Resources Investigations Report 83-4001, 33p.

5) Weaver, W.E., 1984, Experimental Study of Alluvial Fans: unpubl. Ph.D. Dissertation, Colorado State Univ., Fort Collins, CO., 423p.

DOE, 1987, Proposed changes to the Nevada Nuclear Waste storage investigations project exploratory shaft facility: background paper for the U.S. Nuclear Regulatory Commission and State of Nevada Agency for Nuclear Projects Nuclear Waste Project Office.

MacDougall, H.R., 1985, Two-Stage Repository Development at Yucca Mountain: An engineering feasibility study: Sandia National Laboratories, Sand84-1351.


1st DRAFT

APPENDIX C

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JUL 22 1987

MEMORANDUM FOR: R. John Starmer, Section Leader
Technical Branch
Division of Low-Level Waste Management
and Decommissioning

FROM: T. L. Johnson
Technical Branch
Division of Low-Level Waste Management
and Decommissioning

SUBJECT: REPORT OF SITE VISIT TO NNWSI PROJECT

On May 5, 1987, I was accompanied by Paul Prestholt on a site visit to the NNWSI Project. The purpose of the visit was to observe site features and to assess the flooding and erosion potential at the proposed surface locations of the various shafts and ramps associated with the project.

The proposed locations for repository access were delineated in Figure 3-10 of "Two-Stage Repository Development at Yucca Mountain: An Engineering Feasibility Study," (SAND 84-1351); this report was used to approximately locate the surface entrances to the shafts and ramps.

In general, I have concluded that many of the shafts and ramps are likely to be susceptible to flooding and erosion during the site characterization, operational, and post-closure phases. In my opinion, DOE should perform detailed flooding, erosion, and geomorphic analyses to fully characterize the design problems that may be present. DOE may also wish to re-examine the siting process used to locate these shafts and ramps, particularly in light of the flooding and erosion problems identified.

Assessments of each of the proposed shaft and ramp locations are enclosed. If you have any questions, I may be contacted at X74490.

T. L. Johnson
Technical Branch
Division of Low-Level Waste Management
and Decommissioning, NMSS

1st DRAFT

Enclosure: As stated

NNWSI SITE VISIT

FLOODING AND EROSION COMMENTS

SHAFT AND RAMP LOCATIONS

A. Exploratory Shaft

1. Location. This shaft will be located approximately 400 feet east of the location shown in SAND 84-1351 on a very steep hillside, apparently to avoid potential flooding problems on Coyote Wash. Using a cut-and-fill operation, a pad will be constructed immediately adjacent to Coyote Wash.

2. Flooding and Erosion Potential. The proposed shaft will be located at an elevation such that surface runoff in Coyote Wash will apparently not enter the shaft under normal flooding conditions. However, surface runoff on the face of the steep hillslope above the shaft could possibly enter the shaft. Very high flow velocities can be anticipated if the runoff becomes channelized.

   Particularly for the long term, flood velocities in Coyote Wash could present problems. Over a 10,000-year period, a significant amount of lateral and vertical erosion is a possibility, due to the hydraulically steep channel slopes present. Therefore, it may be necessary to provide a significant amount of erosion protection to stabilize the channel and prevent erosion toward the sealed shaft. If the shaft seal is exposed by erosion, deterioration due to weathering could be expected, resulting in the entrance of surface runoff into the shaft; the runoff could be produced both by the localized channels and Coyote Wash.

3. Feasibility of Hydraulic Design Measures. Depending upon the results of performance assessments, it may be necessary to construct a permanent diversion berm to prevent surface water inflow. While the contributing drainage area appears relatively small, flow velocities in channels and gullies are likely to be very high due to the steep slope, necessitating the possible use of very large riprap to prevent erosion of the berm. Additionally, sedimentation behind the berm could pose an unacceptable long-term maintenance problem.

   Flow velocities in Coyote Wash adjacent to the shaft area will also likely require the use of very large riprap to prevent lateral and vertical erosion in the main stream channel. The riprap will likely be needed for some distance upstream and downstream of the shaft location.

If the shaft will be imbedded in rock along Coyote Wash, the situation is much improved. However, the competency of the rock in the area will need to be assessed to verify its resistance to erosion and long-term weathering. A detailed geomorphic analysis should be performed to determine if the potential for significant lateral and/or vertical erosion exists. This analysis should then be followed by a detailed hydraulic analysis to determine if the shaft may be susceptible to flooding and erosion under the changed conditions identified in the geomorphic study.

B. Waste Handling Ramp Portal

1. Location. The waste handling ramp opening will be located immediately adjacent to the east side of Exile Hill. At this location, the eastern slopes of Exile Hill are relatively steep (approximately 25%) and are subject to gullying. The surface opening will be placed at an approximate elevation of 3660 ft. msl, which will place it in an area having a surface slope of approximately 8-10%.

2. Flooding and Erosion Potential. The proposed ramp opening will be located such that surface runoff from Yucca Wash is not likely to enter the ramp, even under extreme flood conditions. However, surface runoff from the eastern slopes of Exile Hill may be a potential problem, particularly if the runoff becomes channelized in the immediate vicinity of the surface entrance.

   Very high flow velocities can be expected on the 25% slopes of Exile Hill and the 8-10% slopes in the immediate ramp vicinity, thus requiring the possible use of heavily-armored diversion structures to prevent erosion and entrance of surface water. These flow velocities and potential for erosion could pose problems during the site characterization, operation, and post-closure phases.

3. Feasibility of Hydraulic Design Measures. Depending upon the results of performance assessments and flooding analyses, it may be necessary to provide diversion structures to divert flows on the steep hillslope above the shaft. While the contributing drainage area appears relatively small, flow velocities in channels and gullies are likely to be very high, necessitating the use of very large riprap to prevent erosion. Additionally, sedimentation behind the berm could pose a long-term maintenance problem.

   Flow velocities on the 8-10% slopes adjacent to the ramp opening will also likely necessitate the use of very large riprap to prevent erosion. The riprap armoring will likely be needed for some distance upstream and downstream of the shaft location.

C. Muck Handling Ramp Portal

1. Location. This portal will be located approximately 2500' northwest of the high point of Exile Hill at an approximate elevation of 3800 ft. msl. The ramp entrance is located in an area of numerous gullies and appears to be located in or very near to the floodplains of Pagany Wash and several other small intermittent drainages.

2. Flooding and Erosion Potential. The proposed ramp entrance will be sited such that surface runoff from Pagany Wash and several other unnamed washes could potentially cause flooding of the ramp entrance. The slope of the ground surface in this area appears to be approximately 5%. Very high flow velocities can be expected on such a slope, particularly in well-defined channels.

   Due to the relatively large drainage areas involved (particularly Pagany Wash), erosion can be expected in the area. Therefore, it may be necessary to provide a significant amount of erosion protection in order to stabilize the existing channels and to prevent erosion of any engineered structures.

3. Feasibility of Hydraulic Design Measures. Depending upon the results of a performance assessment, it may be necessary to construct extensive diversion structures to divert surface water flows away from the ramp entrance. The contributing drainage areas appear relatively large, and flow velocities in nearby channels and gullies are likely to be high, necessitating the use of very large riprap to prevent erosion. Additionally, sedimentation could pose a long-term maintenance problem.

   For this particular ramp, the situation is further complicated by the existence of several separate drainage areas which could impact the site; in addition to Pagany Wash, the site could possibly be inundated and eroded by separate flows from the northwest and southwest. A very detailed flooding and erosion analysis will be needed to determine flow patterns and velocities in this area. Additionally, a geomorphic investigation should be undertaken to assess the potential for long-term changes which could occur in this area.

D. Men and Materials Shaft

1. Location. This shaft will be located adjacent to Drill Hole Wash, about 2000' feet north of the proposed exploratory shaft. The shaft entrance will apparently be located on a steep hillslope at an elevation of approximately 4200 ft. msl. The hillslope above the entrance is relatively steep (25%), and the tributary drainage areas of potential upstream gullies are relatively small (several acres).

2. Flooding and Erosion Potential. The shaft will be located at an elevation such that surface runoff in Drill Hole Wash will apparently not enter the shaft even under severe flood conditions. However, surface runoff on the face of the steep hillslope could possibly enter the shaft, particularly if the runoff becomes channelized. Very high flow velocities could be anticipated in the localized channels, thus necessitating the use of diversion measures to prevent erosion near the shaft.

   Particularly for the long-term, flood velocities in Drill Hole Wash could present problems. Drill Hole Wash has a relatively large drainage area, and over a 10,000-year period, a significant amount of erosion, both lateral and vertical, is a possibility, due to the hydraulically steep channel slopes present in this wash. It may be necessary to provide a significant amount of erosion protection to stabilize the channel and prevent erosion toward the sealed shaft.

3. Feasibility of Hydraulic Design Measures. Depending upon the results of a performance assessment, it may be necessary to construct a diversion berm to divert flows on the steep hillslope above the shaft. While the contributing drainage area appears relatively small, flow velocities in channels and gullies are likely to be very high, necessitating the possible use of very large rock sizes to prevent erosion of the berm. Additionally, sedimentation behind the berm could pose a long-term maintenance problem.

   Flow velocities in Drill Hole Wash adjacent to the shaft may require the use of very large riprap to prevent lateral and vertical erosion in the main stream channel. A detailed geomorphic analysis should be performed to determine if the potential for significant lateral and/or vertical erosion exists. This analysis should then be followed by a detailed analysis to determine if the shaft will be susceptible to flooding and erosion.

E. Waste Emplacement Ventilation Exhaust Shaft

1. Location. The shaft will be located approximately 3000' southeast of the proposed exploratory shaft. The ramp entrance is located in an area of several channels and gullies, and appears to be located in or very near to the floodplain of an unnamed drainage area which flows to the east.

2. Flooding and Erosion Potential. The shaft entrance will be sited such that surface runoff from an unnamed wash could potentially cause flooding. The slope of the ground surface in this area appears to be approximately 4%. Very high flow velocities can be expected on such a slope, particularly in localized channels and gullies.

Because some erosion could occur in this area, it may be necessary to provide erosion protection to stabilize (laterally and vertically) the existing channels and to prevent erosion of any engineered structures.

3. Feasibility of Hydraulic Design Measures. Depending upon the results of a performance assessment, it may be necessary to construct diversion structures to divert surface water flows away from the shaft entrance. Flow velocities in nearby channels and gullies may be high, thus requiring the use of large rock. Sedimentation and long-term maintenance could also pose a problem.

   A very detailed flooding and erosion analysis will be needed to determine the flow patterns and velocities in this area. Additionally, geomorphic investigations should be conducted to assess the potential long-term changes which could occur.

APPENDIX A

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

MAY 19 1987

Dr. Dae Chung
Staff Scientist
Lawrence Livermore National Laboratory
University of California
Livermore, CA 94550

Dear Dr. Chung:

In accordance with Task 2 of Contract A-0297, I request that you initiate the following task:

Conduct a geomorphic examination of the Yucca Mountain HLW site at and near the locations of the proposed shaft and ramp openings (maps attached). Shaft and ramp locations should be examined for the potential for erosion, debris dam formation, and/or other geomorphic changes and the possible resultant entrance of surface waters. The completed report should (1) address the potential effect of 10,000 years of geomorphic change on drainage configurations at the Yucca Mountain site, specifically in the area of the proposed shafts and drifts and in Drill Hole Wash, (2) quantitatively assess the geomorphic changes that could occur with respect to stream and flood plain erosion in those areas, (3) define the potential lateral, vertical (downcutting), and/or upstream movement and erosion of streams and gullies in those areas and (4), assess the possibilities of locating more suitable shaft and ramp locations in those areas.

The results of this study should be transmitted to the NRC in a topical letter report. It is anticipated that this task shall require four staff-weeks of effort to be accomplished by June 30, 1987. A draft of the topical letter report should be submitted by the geomorphologist directly to the NRC staff no later than June 19, 1987 for their review and comment.

The action taken by this letter is considered to be within the scope of the current contract (A-0297). No changes to cost or delivery of contracted services and products are authorized. Please notify me immediately if you believe that this letter would result in changes to cost or delivery of contracted products.

Sincerely,

Michael E Blackford

Michael E. Blackford, Project Manager
Geology/Geophysics Section
Geotechnical Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards

1st DRAFT

Attachments
As stated

APPENDIX B

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

NOV 18 1987

Dr. Dae Chung
Staff Scientist
Lawrence Livermore National Laboratory
University of Californa
Livermore, CA 94550

Dear Dr. Chung:

On November 3, 1987, Ted Johnson and Rus Purcell discussed two recent draft field investigation reports which were prepared by Mr. Purcell and submitted to partially fulfill the requirements of a work assignment which was given to him on May 28, 1987. Based on these discussions, I now feel that the original scope of work for that assignment was overly ambitious and that it is unlikely Mr. Purcell, through no fault of his own, will be able to complete the tasks, as assigned.

Mr. Purcell indicated to Mr. Johnson that an extensive amount of data and analyses will be needed to complete the original task that very little of this data is currently available. Mr. Purcell stated that he could identify the data needed in a relatively short period of time.

I now conclude that the original assignment and scope of work should be changed. Therefore, in accordance with Task 2 of Contract A-0297, I request that Mr. Purcell complete the following task: Conduct a geomorphic examination of the Yucca Mountain HLW site at and near the locations of the proposed shaft and ramp openings. Shaft and ramp locations should be examined for the potential for erosion, debris dam formation, and/or other geomorphic changes and the possible resultant entrance of surface waters. The completed report should (1) address the potential effect of 10,000 years of geomorphic change on drainage configurations at the Yucca Mountain site, specifically in the area of the proposed shafts and drifts and in Drill Hole Wash, (2) quantitatively assess the geomorphic changes that could occur with respect to stream and flood plain erosion in those areas, (3) define the potential lateral, vertical (downcutting), and/or upstream movement and erosion of streams and gullies in those areas and (4), assess the possibilities of locating more suitable shaft and ramp locations in those areas.

If there is insufficient information available to address the subject areas above, the study should focus on the data, information, and analyses which will be needed to reach definitive conclusions in those subject areas. As a minimum, the study should be sufficiently complete to provide answers to the following questions:

(1) Is there a potential problem related to flooding and/or erosion at the various shaft and ramp locations?
(2) Why is there a potential problem at those locations?
(3) What information, data, and analyses need to be provided by DOE to adequately characterize the problem?

1st DRAFT

(4) What can DOE do to solve the problem?

The results of this study should be transmitted to the NRC in a topical letter report. A draft of the topical letter report should be submitted by the geomorphologist directly to the NRC staff no later than December 15, 1987 for their review and comment.

The action taken by this letter is considered to be within the scope of the current contract (A-0297). No changes to cost or delivery of contracted services and products are authorized. Please notify me immediately if you believe that this letter would result in changes to cost or delivery of contracted products.

Sincerely,

Charlotte Abrams for

Michael E. Blackford, Project Manager
Geology/Geophysics Section
Technical Review Branch
Division of High-Level Waste Management
Office of Nuclear Material Safety
and Safeguards

1st DRAFT