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PROBABLE MAXIMUM FLOOD CONTROL

by

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ABSTRACT

This study proposes preliminary design concepts to protect the waste-handling facilities and all shaft and ramp entries to the underground from the probable maximum flood (PMF) in the current design configuration for the proposed Nevada Nuclear Waste Storage Investigation (NNWSI) repository site at Yucca Mountain, Nevada. PMF flows used for designing flood protection provisions were furnished by the United States Bureau of Reclamation (USBR) or developed from USBR data. Proposed flood protection provisions include site grading, drainage channels, and diversion dikes. Figures are provided to show these proposed flood protection provisions at each area investigated. These areas are the central surface facilities (including the waste-handling building and waste treatment building), tuff ramp portal, waste ramp portal, men-and-materials shaft, emplacement exhaust shaft, and exploratory shafts facility.

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EXECUTIVE SUMMARY

This study proposes preliminary design concepts to protect the waste-handling facilities and all shaft and ramp entries to the underground from the probable maximum flood (PMF) in the current design configuration for the potential nuclear waste repository at Yucca Mountain, Nevada.

The PMF flows determined by the United States Bureau of Reclamation (USBR) or developed from USBR data were used for the design of flood control and drainage provisions and for the design and selection of finished grades at the site areas investigated. The hydraulics calculations were performed, using an iterative process, to design and select the appropriate system of flood control provisions and finished grades at the site in order to provide the necessary protection from the PMF. To develop these preliminary design concepts, drainage channel sizes were first approximated to carry the peak debris-laden flows around the sites. Surface elevations of water in the cross sections of channels were then calculated to determine if the facilities and shaft or ramp entries were protected from the PMF. If not, designs were changed as necessary to accommodate the PMF flow. Figures in this report show the resulting design for site grading and flood control provisions at each area investigated. These figures detail the proposed elevations of the site's finished grades, drainage channels, and diversion or training dikes selected to protect the waste-handling facilities and the shaft and ramp entries to the underground.

The Bechtel technical staff, composed of qualified engineers and hydrologists, reviewed the USBR calculations for both clear water and debris influenced PMF flows and judged the flow calculations to be conservative. The low loss rates (due to evaporation, infiltration, and surface storage), short durations used in the unit hydrograph approach, and estimation that the debris influenced flows are two times the clear water PMF flows contribute to the conservatism. In future design phases, it is recommended that hydrologic characteristics be studied further to establish representative values for debris production in the drainage basins and to confirm the low loss rates used in the USBR study.

1.0 INTRODUCTION

In the design of the potential nuclear waste repository at Yucca Mountain, Nevada, the waste-handling facilities and all shaft and ramp entries to the underground need to be protected from the probable maximum flood (PMF). The objective of this study was to develop preliminary design concepts that will provide protection from the PMF. Areas investigated were the central surface facilities (including the waste-handling building and waste treatment building), tuff ramp portal, waste ramp portal, men-and-materials shaft, emplacement exhaust shaft, and exploratory shafts facility.

The PMF clear water flows for each area investigated result from the probable maximum precipitation (PMP) and were taken from United States Bureau of Reclamation (USBR) data (Bullard, 1986). Estimates of the amount of debris carried in flood flows, also made by the USBR, resulted in debris influenced PMF flows approximately twice as great as the clear water flows. These debris influenced flows were used for hydraulic analyses, selecting and sizing the appropriate diversion and drainage structures, determining water surface elevations during the PMF event, and selecting the site grading elevation at each area investigated.

This report provides a general overview of the site description, drainage basin characteristics, and topography, along with a review of the USBR's PMP and PMF information. The maps used for this study included the United States Geological Survey (USGS) metric maps of the Yucca Mountain area (with 2-m contour intervals) and USGS 7.5-minute-series maps of the Topopah Spring northwest and Busted Butte quadrangles (with 20-ft contour intervals).

The hydraulic design for selecting site grades and flood control and drainage provisions is considered preliminary. An iterative process was used to size drainage channels and select site grades.

2.0 ASSUMPTIONS

Some major assumptions used in the evaluation of the USBR PMP and PMF data and for the preliminary design of flood control provisions are summarized below. Where available, referenced material was used. Where references are not given below, engineering judgment was used.

- Design information presented in the Site Characterization Plan Conceptual Design Report (SCP-CDR) (SNL, 1987) was used as the current design and as a baseline for identifying any proposed changes to site grading and flood control provisions resulting from this study.

- The site layout recommended by Holmes and Narver (Holmes and Narver, 1987) for use in the DOE Title I design phase for the exploratory shafts was used for this study to evaluate the PMF at the exploratory shafts facility.

- The loss rate selected by the USBR (Bullard, 1986) is characteristic of all the drainage basins investigated. Precipitation losses are attributed to evaporation into the atmosphere, infiltration into the surface soils, and surface storage. Surface runoff occurs only when the rainfall or precipitation rate (intensity) exceeds the loss rate. This is also known as precipitation excess.

- Runoff is most often described analytically as the distribution of discharge over time for a point in the drainage area flow path. The particular form of description most used is a graphical representation called a hydrograph. The instantaneous discharge is plotted on the ordinate and the time scale is on the abscissa. In practice, what is called the unit hydrograph really a form of distribution graph of surface runoff volume that is equivalent to a one-inch depth on the drainage area and results from a uniform rate of precipitation excess over a specified time. The unit hydrograph approach used by the USBR (Bullard, 1986) is applicable for the small drainage areas investigated in this study. A complete description of the methodology used by the USBR is found in Bullard (1986).

- The USBR data (Bullard, 1986) can be extrapolated to determine peak rates of flow for drainage areas not investigated by the USBR.

- The large, debris influenced flow data developed by the USBR (Appendix B) are characteristic of actual flows and debris transport within the drainage areas. Flow volumes used for this preliminary design are conservative, and it is unrealistic to consider deposition of debris within the drainage channels in combination with these conservatively large flows.

- The iterative processes used for hydraulics design are adequate for this stage of repository design.

- The proposed flood control provisions have adequate scour protection and erosion control as provided for in this study. Erosion protection will be constructed of rock riprap or concrete paving.

- A freeboard allowance of 2.5 ft above the estimated maximum PMF water levels is adequate for all sites investigated. The recommended further analysis will influence the actual freeboard used in advanced stages of design.

- Flow from the upper reaches of Yucca Wash may influence the flood condition at the central surface facilities area. The training dike north and east of the finished tuff pile will divert this flow away from the central surface facilities area.

- The 0.3% slope in the waste operations area is acceptable for truck and rail surge storage (American Railway Engineering Association, 1986). The waste-receiving and inspection area can be overtopped by a maximum of 3 ft of flood flow.

- Ditching is proposed along the upstream side of the various facilities to handle localized PMF runoff in areas where no specific flood protection provisions are shown in the figures.

- The USGS 7.5-minute-series mapping with 20-ft contour intervals (USGS; 1961a, 1961b) is satisfactory for background to show the preliminary design of proposed flood control and drainage provisions. This mapping closely agrees with the more recently mapped USGS metric mapping, which has 2-m contour intervals (USGS, 1985).

3.0 SITE DESCRIPTION AND DRAINAGE BASIN CHARACTERISTICS

3.1 Site Location

The potential repository site at Yucca Mountain is located on and immediately adjacent to the southwestern portion of the Nevada Test Site (NTS) in Nye County, Nevada. The site is about 85 mi by air and 100 mi by road from Las Vegas and is located on federal lands under the separate control of the Department of Energy (DOE), the U.S. Air Force, and the U.S. Bureau of Land Management.

The central surface facilities are situated on gently sloping terrain at the eastern base of Yucca Mountain. The underground facilities are below the ridge line of the mountain. The repository surface and underground facilities are linked by a combination of shafts and ramps (Figure 1). A ramp is provided for transporting waste from the central surface facilities to the underground emplacement area. Another ramp is provided for conveying mined tuff to the surface. Four vertical shafts are located near the northeast boundary of the underground facilities for underground ventilation and access for personnel, materials, and equipment.

The elevations reported in Sections 3.1.1 and 3.1.2 for site grading around the various facilities are based on preliminary designs found in the SCP-CDR (SNL, 1987). These elevations were reported to provide a baseline for identifying any proposed changes to the site grading as a result of this study.

3.1.1 Central Surface Facilities

The central surface facilities are located on a level bench at the 3,665-ft elevation. The area is divided into three distinct functional areas -- the waste-receiving and inspection area, the waste operations area, and the general support facilities area. Each area is surrounded by security fencing and has sufficient room for security patrols at its perimeter.

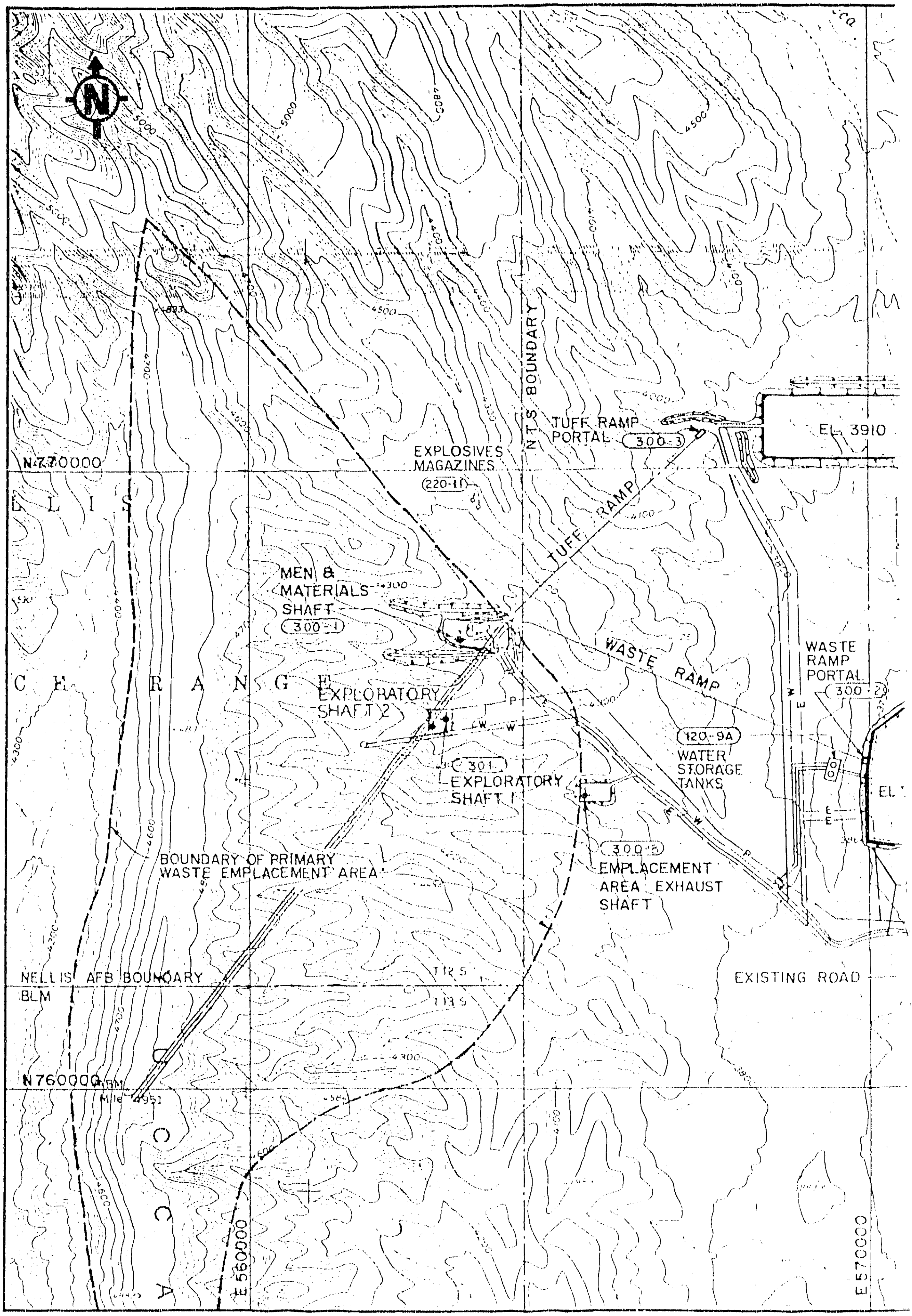

Figure 1. SCP Conceptu

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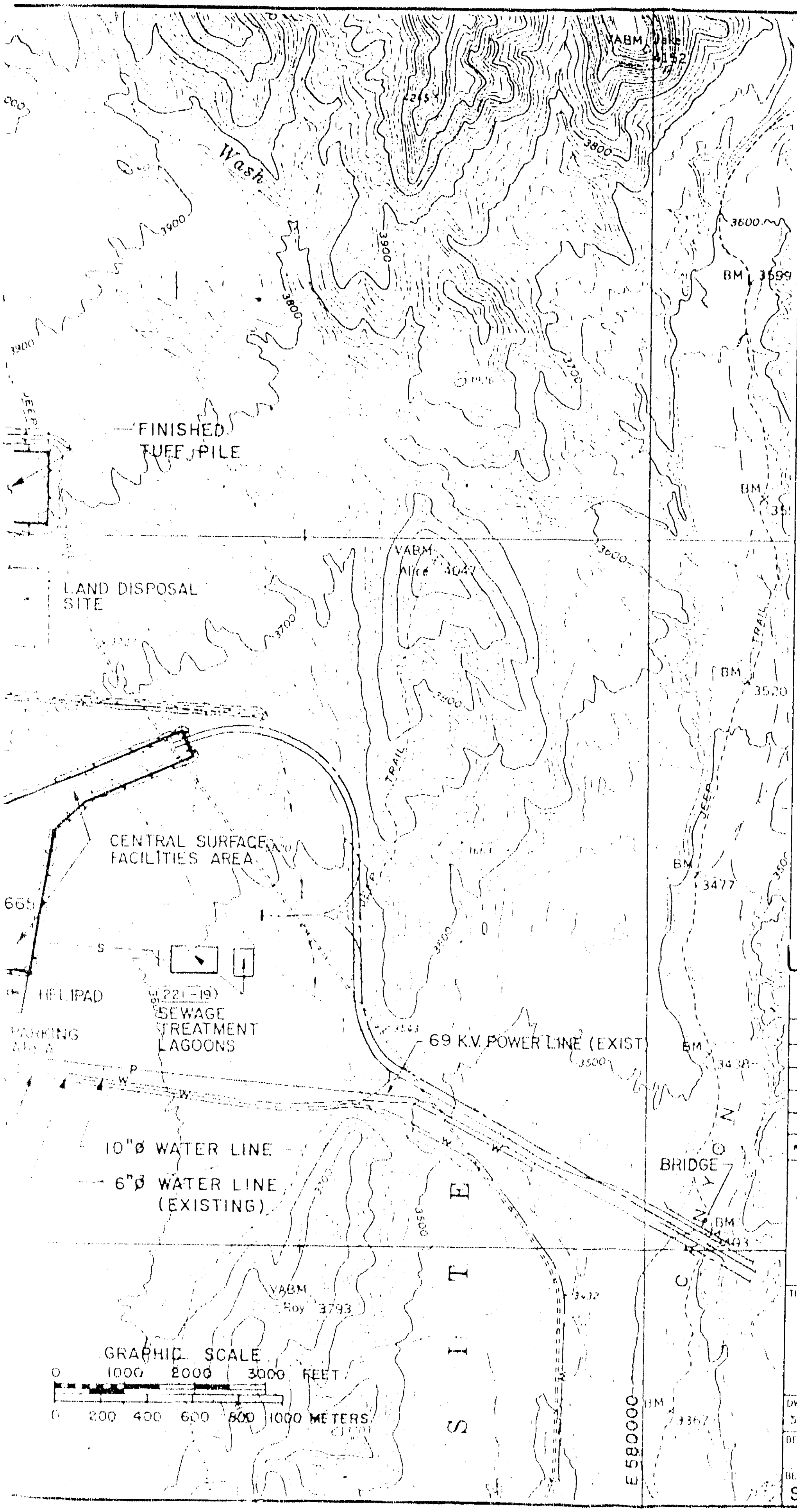

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TITLE
SCP CONCEPTUAL DESIGN
OVERALL SITE PLAN

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Design Overall Site Plan

The waste-receiving and inspection area, which begins at the northernmost gate, is oriented parallel to the incoming railroad and highway. There are railcar sidings and a truck parking area to accommodate receipt of incoming waste shipments and to provide temporary storage of empty casks awaiting transport offsite.

The surface portions of the waste operations area include all surface facilities in which radioactive materials are handled or stored. Most of the area is paved to accommodate trucks and to permit easy access between the waste-handling facilities. An unpaved railyard is provided, which includes switches between alternate tracks entering the waste-handling buildings and sidings for storage of railcars. There is parking space for trucks and railcars to provide surge storage for up to six weeks of waste throughput should a delay in repository operations occur. Health physics and security stations are located at the border of the waste-receiving and inspection area and at a central entrance that permits access to and from the general support facilities area.

The general support facilities area includes the facilities in the central surface facilities area that do not handle or treat radioactive materials. Entrance to this area is through the southernmost gate and is the primary access to the repository for personnel, visitors, and nonwaste deliveries.

3.1.2 Shaft and Ramp Areas

The exploratory shafts (ES-1 and ES-2), the men-and-materials shaft, the emplacement area exhaust shaft, and their related facilities are located 1-1.5 mi west of the central surface facilities area in the rugged terrain of Yucca Mountain. Access to these shafts is by means of a road located in Drill Hole Wash. All shaft sites are on level benches and are surrounded by security fencing. Surface facilities located at the shafts are founded on soil or rock.

The men-and-materials shaft is located near the junction of two washes that discharge into Drill Hole Wash. Facilities are situated on a split-level bench in consideration of the natural terrain. Essential facilities, such as the shaft collar, hoist house, change house, development ventilation supply building, and others, are on an upper bench at the 4,140-ft elevation. The remaining facilities are located on a lower bench at 4,120 ft.

South of the men-and-materials shaft are ES-1 and ES-2, located on a level embankment at an elevation of 4,130 ft. This embankment is large enough to support underground investigations during the site characterization phase. During emplacement operations, the exploratory shafts will be used as fresh air intakes for the emplacement area. The site layout from Holmes and Narver (1987), recommended for use in the DOE Title I design phase for the exploratory shafts, is used for this study.

The exhaust shaft collar and exhaust building for the emplacement area (including fans and a stack) are southeast of the exploratory shafts on a level bench at an elevation of 3,960 ft.

The tuff pile and tuff-handling equipment are located one mile north of the central surface facilities area near the tuff ramp portal. The area of the tuff ramp portal is reached by a road routed west of the central surface facilities area and the waste ramp portal. The tuff pile will be developed eastward over a 25-yr period to a maximum size of 3,000 by 1,000 by 120 ft high. Facilities at the portal are at an elevation of 3,900 ft.

3.2 Topography

The terrain at the site is characterized by prominent, north-trending, fault-block ridges and eastward tilted, volcanic rocks. Slopes are locally steep (15-30°) on the west side of Yucca Mountain and along some of the valleys that cut into the more gently sloping (5-10°) east side of the mountain. The valley floors are covered by alluvium. Alluvial and colluvial fans extend down from the lower slopes of the ridges.

Fortymile Wash, a major drainage channel running from north to south in the western portion of the NTS, is a primary feature of the terrain near the proposed repository site. Drainage washes on the east face of Yucca Mountain trend primarily from the northwest to the southeast and are tributary to Fortymile Wash.

Topographic information used for this study included USGS metric maps of the Yucca Mountain area (USGS, 1985) and USGS 7.5-minute-series maps of the Topopah Spring northwest and Busted Butte quadrangles (USGS; 1961a, 1961b). The metric maps are scaled so that 1 cm = 50 m, with 2-m contour intervals. The 7.5-minute-series maps are scaled so that 1 in. = 2,000 ft with 20-ft contour intervals.

The metric maps, published in 1985, are more recent by over two decades than the 7.5-minute-series maps published in 1961. A comparison of enlarged, cross-sectional information from the 7.5-minute-series maps with the USGS metric maps, where coverage overlaps, shows good correlation between the two sources.

3.3 Drainage Basin Characteristics

Drainage basins investigated in the USBR report, "PMF (Probable Maximum Flood) Study" (Bullard, 1986), for the shaft sites range in area from 0.06-0.27 mi^2, with natural channel (or stream) lengths ranging from 0.5-0.9 mi. The slopes of these natural channels range from 14-17%, which is indicative of the steep terrain at these locations.

The primary drainage basins investigated by the USBR study (Bullard, 1986) that influence the waste ramp, central surface facilities area, tuff ramp, and tuff pile are generally larger than those for the shaft sites. The former range from 0.86-4.31 mi^2 in area, with natural channel lengths of 2.9-4.4 mi. The slopes of the natural channels for these basins are steep, from 6-9%, but not as severe as those for the shaft sites. Smaller, localized drainage basins with characteristics similar to those for the shaft sites also contribute to flood flows at these facilities.

Small desert varieties of sage and creosote bush grow in the drainage basins, and the channel bottoms are sandy and gravel laden. The USBR report (Bullard, 1986) indicates that large quantities of sand, silt, and other natural debris could be carried in these steep, narrow channels.

4.0 PROBABLE MAXIMUM PRECIPITATION

The USBR (Bullard, 1986) estimated the PMP and determined the resulting PMF flows for each area investigated. These results were used for all hydraulic analyses in this study.

PMP values were estimated by the USBR for both a general storm and a local storm. These estimates were obtained from, and were in accordance with, procedures from the United States National Weather Service Hydrometeorological Report No. 49 [HMR 49 (National Weather Service, 1977)]. HMR 49 covers the area of concern and represents the current standard of practice for federal agencies such as the USBR and the U.S. Army Corps of Engineers involved in preparing PMF studies in the Colorado River and Great Basin drainages. HMR 49 is also specifically referenced in ANSI Standards (ANSI/ANS, 1981), as applicable for PMF designs for nuclear power plants and other nuclear facilities.

4.1 General Storm

For computing the general storm PMP, HMR 49 was used to determine that storms during September are the controlling events, resulting in a maximum 72-hr precipitation depth of 13.52 in. Storms during August and October were nearly as severe and resulted in 72-hr precipitation depths of 13.37 and 13.21 in., respectively.

4.2 Local Storm (Thunderstorm)

For a local storm lasting six hours, computation in accordance with HMR 49 resulted in a PMP average depth of 13.91 in., with 6.62 in. occurring in the maximum 15-minute increment of the storm. Because most of the drainage areas are small and because of the high intensity occurring within the maximum 15-minute increment, the local-storm PMP is the controlling flood-causing event for the site.

Some very severe storms have occurred in the region after the original publication of HMR 49 in 1977. The USBR (Bullard, 1986) evaluated historical data from these storms and considered whether HMR 49

PMP values may be too low. The USBR determined that the short-term intensities of these recent storms did not exceed those given by HMR 49; therefore, the local-storm PMP discussed above is the controlling design consideration and was used for developing the PMF.

5.0 PROBABLE MAXIMUM FLOOD

5.1 PMF Clear Water Flow

A dimensionless unit hydrograph approach, developed and used by the USBR (Bullard, 1986), was used to determine rates of flow for the areas investigated. Excess rainfall volumes were calculated by the USBR, using the PMP estimate discussed in Section 4.2, with an initial loss of one inch, and a uniform loss rate of 0.05 in./hr. These loss factors, selected by the USBR for the prospective repository site, were estimated on the basis of runoff observations made by the USGS during a storm on July 19, 1985 (Bullard, 1986). The unit hydrograph procedure was used to determine the peak rate and total volume of clear water runoff for the 15 drainage areas. The drainage areas range in size from 0.01-4.31 mi^2, and unit rates of runoff vary from 24,500-9,535 $ft^3/sec/mi^2$.

Because the small drainage areas analyzed have times of concentration on the order of one to five minutes, durations of one and two minutes were used in the unit hydrograph approach to determine the rate of runoff. The excess storm rainfall was divided into time increments as small as one minute. This approach yielded extremely high peak intensities (0.6-0.7 in./min). Also, the loss rate used is the lowest typically applied to natural ground in USBR flood studies (Bullard, 1986) and results in very conservative unit runoff rates.

Drainage areas other than those considered in the USBR report (Bullard, 1986) may impact the currently proposed facilities and were investigated. Specifically, the flow in Yucca Wash may not be contained in the natural alluvial channel, as is assumed in Bullard (1986), and may influence flood conditions at the central surface facilities area. The USBR results for clear water flow were used as a basis for estimating peak runoff rates from the additional drainage areas. This was done by plotting and extrapolating USBR data for peak rate of flow against drainage area. This plot is shown in Figure 2.

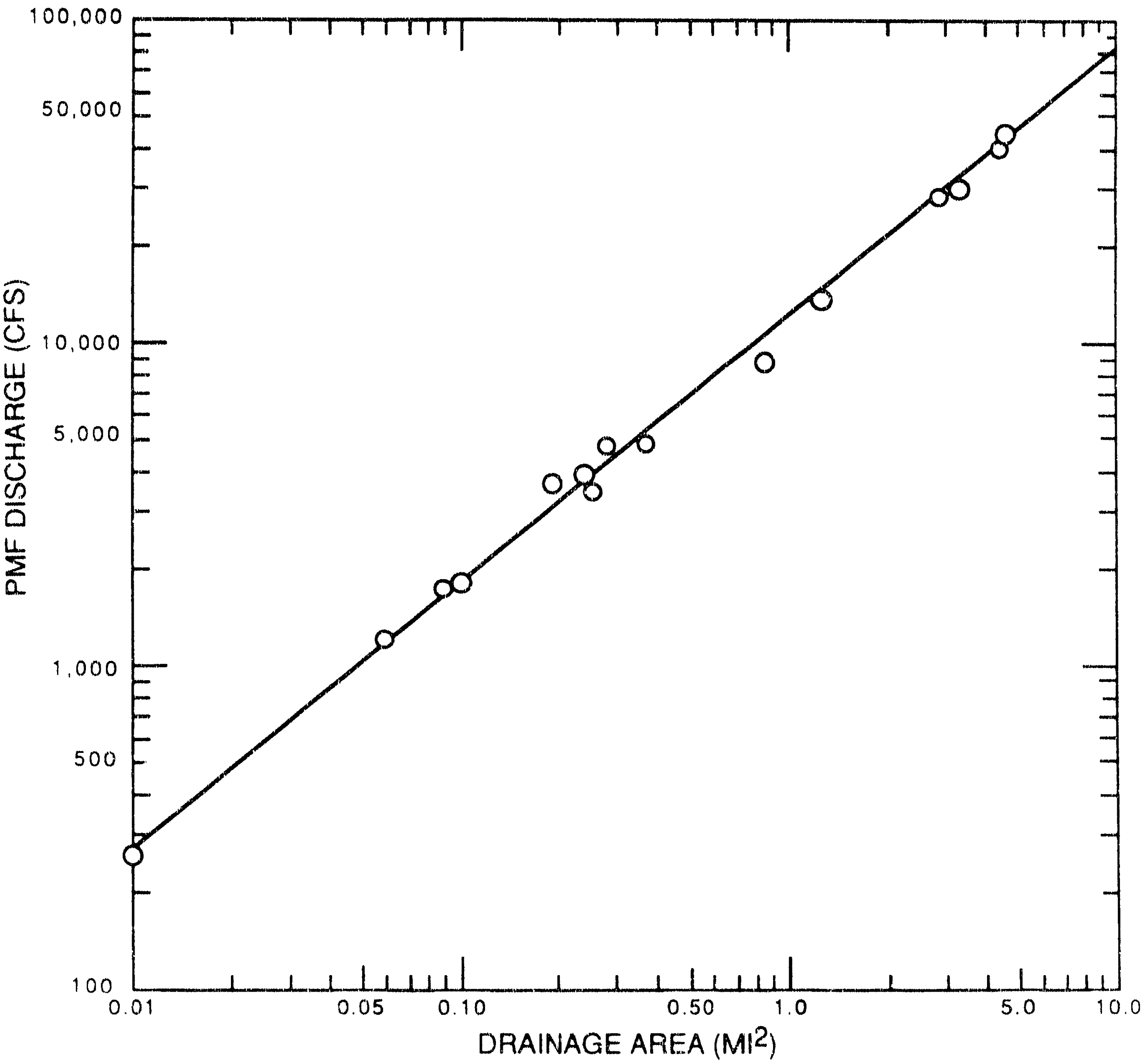


Figure 2. Probable Maximum Flood Discharge versus Drainage Area Relationship (Data Taken from Bullard, 1986)

The Bechtel technical staff that reviewed the USBR data agreed that the approach used to determine the PMF flows that are due to the PMP local storm is generally consistent with standard hydrological concepts. However, the use of a low loss rate and short durations in the unit hydrograph approach results in extremely high peak intensities that may not accurately represent the surface hydrology at the site. Further study is recommended to evaluate the loss rates, and a methodology more applicable to very small drainage areas should be used to develop peak flow rates.

5.2 Debris Influenced PMF Flow

Sediment concentrations in the form of coarse gravel, sands, silts, and other natural debris carried in flood runoff from areas similar to those at the site are generally large, and it is necessary to plan for the handling of this material. As stated in Section 3.3, Bullard (1986) indicates that large quantities of sand, silt, and other natural debris could be carried in the steep narrow drainage channels.

The USBR furnished data for debris influenced flows at each area investigated for this study (Appendix B). These data are basically double the previously calculated clear water, peak runoff rates (Bullard, 1986). No basis or calculation was provided by the letter in Appendix B to substantiate the values for debris influenced flow.

6.0 DESIGN FOR FLOOD PROTECTION

6.1 Hydraulic Design

For this study, the flood protection facilities were designed to handle the more severe of either clear water or debris influenced (bulked) PMF flows. Because the bulked flows were estimated to be double the clear water flows, as discussed in Section 5.2, it was concluded that they should be used in all cases for this conceptual design. Further design will need to consider the greater scour potential of clear water flows, but this study assumes that adequate scour protection, as well as general erosion control, will be provided.

Drainage areas, their concentration points (the point of interest where the storm runoff is being evaluated), and the relationship to the facilities investigated are identified and delineated in Figure 3. Table 1 summarizes the peak design runoff data for the drainage areas investigated.

Each area considered was analyzed to determine the nature and location of the hydraulic elements controlling the PMF flows and depths in that area. Calculated depths of flood flows and the location and grades of the proposed flood control features were based on available topographic maps and the basic facility layout data previously developed (see Section 3.0).

For hydraulics design, cross sections of the natural ground surface were plotted upstream from the specific facility under investigation. The locations of these cross sections, which can potentially control the peak PMF flows and, thus, the water surface level, were chosen based upon review of the available topographic maps. The topographic maps with 2-m contour intervals were used for plotting these cross sections.

Downstream from the central surface facilities, an area was identified as having potential for controlling the peak PMF flows and the corresponding water surface level. This area, west of the hill Roy (see

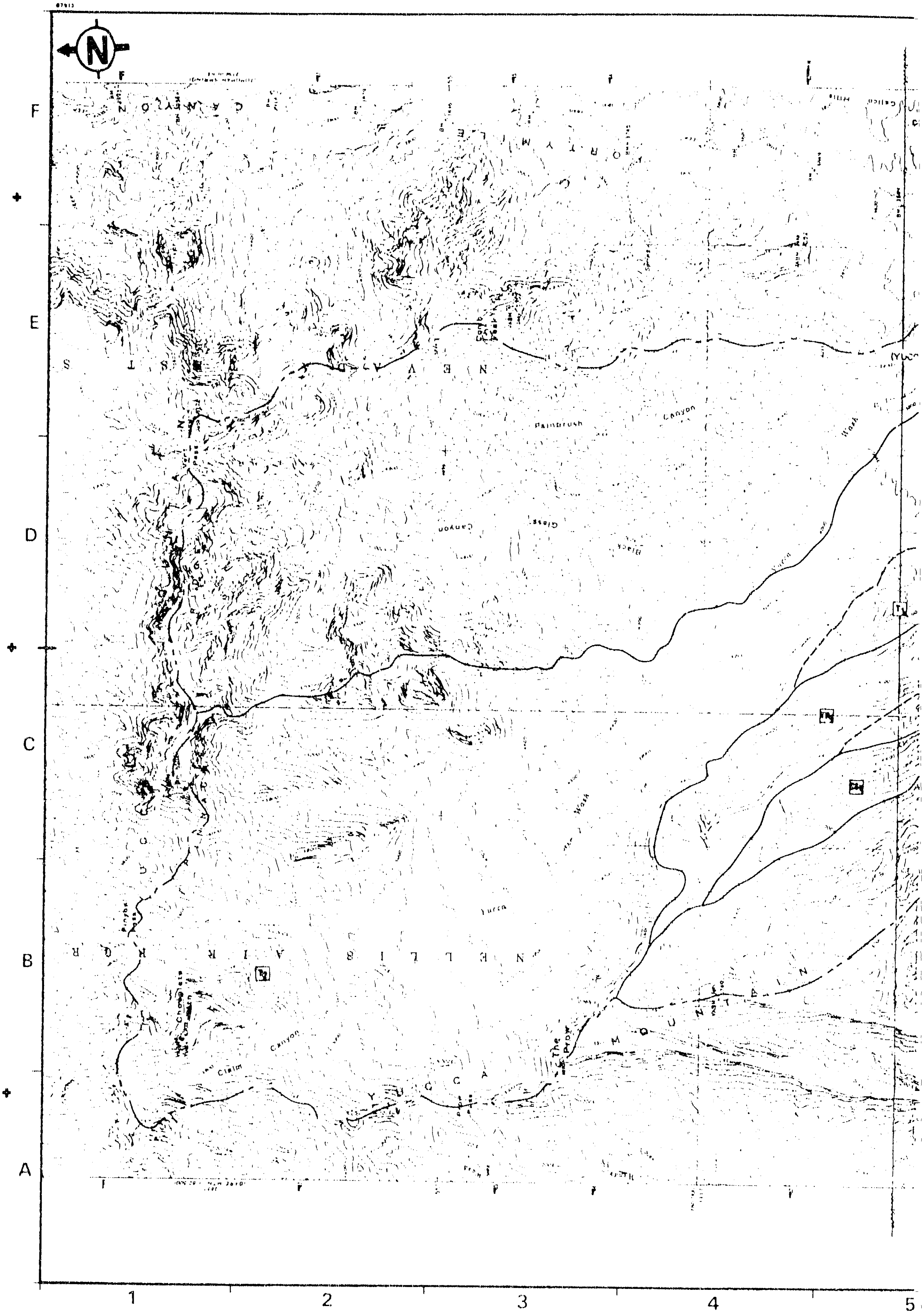
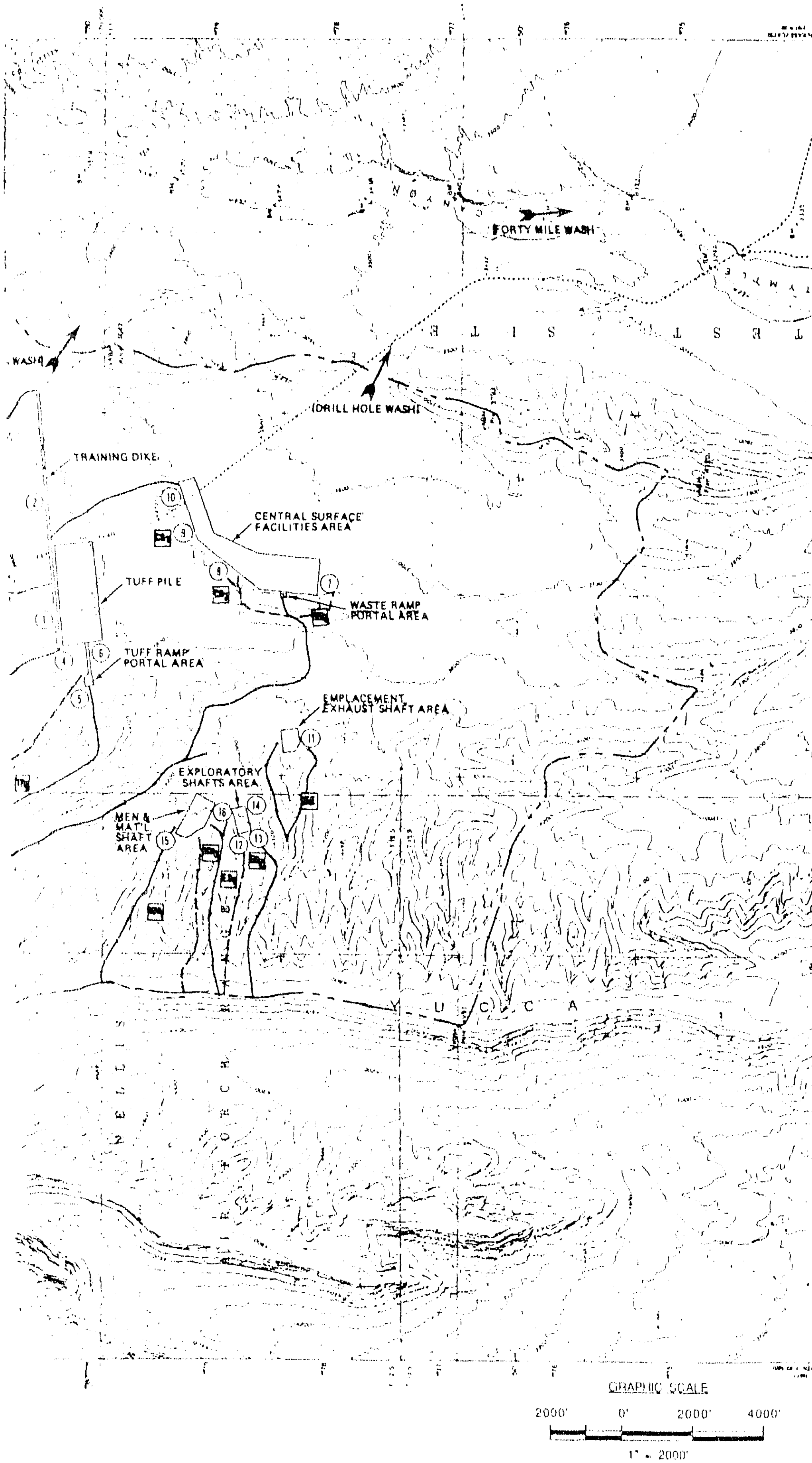


Figure 3. NNWSI Probable Maximum Flood



LEGEND:

- TOTAL DRAINAGE AREA
- FACILITY DRAINAGE
- SUBDRAINAGE AREA
- DRAINAGE AREA IDENTIFICATION
- (6) CONCENTRATION POINT
- AREA REQUIRING PMF PROTECTION
- MAJOR NATURAL FLOW OUTLET

REV	DATE	ISSUE DESCRIPTION		BY	CK'D	SUPV	PE
0	11/10/87	ISSUED FOR PMF STUDY SI TR87-7010	BNI / SNL				
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TITLE
NNWSI PROBABLE MAXIMUM FLOOD DRAINAGE AREAS AND CONCENTRATION POINTS

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TABLE 1

SUMMARY OF DRAINAGE AREAS AND PROBABLE MAXIMUM FLOOD PEAK DISCHARGES

Site	Drainage and Subdrainage Area		PMF Peak Discharge (cfs)		Concentration Point
	ID*	Area (mi^2)	Clear Water	Debris Influenced	ID*
Tuff Pile Training Dike	T_1	0.36	4,771	9,542	1
	T_2	9.45	77,912	155,824	2
	$T=T_1+T_2$	9.81	80,380	160,760	3
Tuff Ramp Portal Area	TR_1	1.35	15,375	30,750	4
	TR_2	0.23	3,844	7,688	5
	$TR=TR_1+TR_2$	1.58	17,530	35,060	6
Central Surface Facilities	CS_1+TR	3.29	32,317	64,635	9
Waste Ramp Portal (North)	CS_2	0.04	713	1,426	8
Waste Ramp Portal (South)	CS_3	0.03	552	1,104	7
	$CS=CS_1+CS_2+TR$	3.33	32,645	65,290	10
Emplacement Area Exhaust Shaft	EE	0.06	1,182	2,364	11
Exploratory Shaft Area	ES_1	0.09	1,611	3,322	12
	ES_2	0.10	1,743	3,486	13
	$ES=ES_1+ES_2$	0.19	3,354	6,708	14
Men-and-Materials Shaft Area	MM_1	0.27	4,634	9,268	15
	MM_2	0.10	1,754	3,458	16

*See Figure 3.

the lower right-hand portion of Figure 1), constricts flow from the alluvial plain (where the central surface facilities are located) to Fortymile Wash. The available metric topographic maps do not cover this area, so enlargements of the USGS 7.5-minute-series maps with 20-ft contour intervals were used for the hydraulic investigation in this area.

An iterative process was used for the hydraulic design of drainage channels, diversion dikes, and subsequent selection of site grades for each facility investigated. For this preliminary design, drainage channel sizes were first approximated to carry the peak debris-laden flows around the sites. Surface elevations of water in the channel cross sections were then calculated to determine if the facilities and shaft or ramp entries were protected from the PMF. If not, designs were changed as necessary for either the drainage channels or site grading, or both, to accommodate the PMF flow. Diversion (or training) dikes were used as required to direct the flow into the drainage channels.

The impact of deposition of debris within the drainage channels was not considered. Such conditions may increase water surface elevations and, thus, elevations of site grading. The debris influenced design flows for the USBR PMF are double the clear water PMF flows and are considered conservative. Estimates for debris influenced flow at sites with characteristics similar to those at Yucca Mountain have been 130-140% of the clear water flow rate. Consideration of debris deposition within the drainage channels, along with the USBR's debris influenced flows, may result in unrealistically conservative preliminary designs for site grading and flood control provisions. It is recommended that debris deposition within the drainage channels be considered after further, more detailed study of hydrologic characteristics and flood control provisions.

This study and preliminary design considered only the PMF flows and did not attempt coordination with potential drainage arrangements for runoff from storms of lesser magnitude. These lesser-magnitude storms will result in lesser flows and water surface levels. Drainage provisions such as swales, ditches, and culverts will be required to direct these lesser flows away from facilities.

To allow for general uncertainties and the conceptual nature of this design, an average freeboard allowance of about 2.5 ft was provided above the estimated maximum PMF water levels.

6.2 Selection of Site Grades, Flood Control, and Drainage Provisions

For selecting site grades and flood control provisions at the central surface facilities and waste ramp portal, the influence of backwater resulting from constricted flow out of Drill Hole Wash was checked. For this scenario, peak flows from all upstream drainage areas, including Yucca Wash, were assumed to simultaneously reach the Drill Hole Wash outlet located about one mile east of the central surface facilities area and north of the hill Roy (Figure 3). This analysis determined that the backwater effect from the constricted flow at this location will not reach the central surface facilities area and, therefore, will not control the PMF protection arrangements for the area.

Proposed site grading for the central surface facilities area is based on the prevention of PMF flows from Yucca Wash and drainage areas T1 and T2 (upper portion of Yucca Wash) from reaching the area by construction of a training dike north and east of the finished tuff pile. The proposed training dike will direct the flow to the Yucca Wash outlet, as shown in Figures 3 and 4. The remaining PMF flows, which peak at about 65,000 cfs, will pass over the waste-receiving and inspection area, with a maximum water surface at an elevation of 3,667 ft. The proposed finish grades and layout are shown in Figures 4 and 5. With a freeboard of 2.5 ft, the grade elevation near the waste ramp portal, waste-handling buildings (WHB), and waste treatment building (WTB) is recommended to be 3,669.5 ft. This is 4.5 ft higher than the current design as described in Section 3.1.1. The grade elevation at the waste-receiving and inspection area is recommended to be 3,664 ft so that the PMF flow will not be constricted. A maximum water depth of three feet

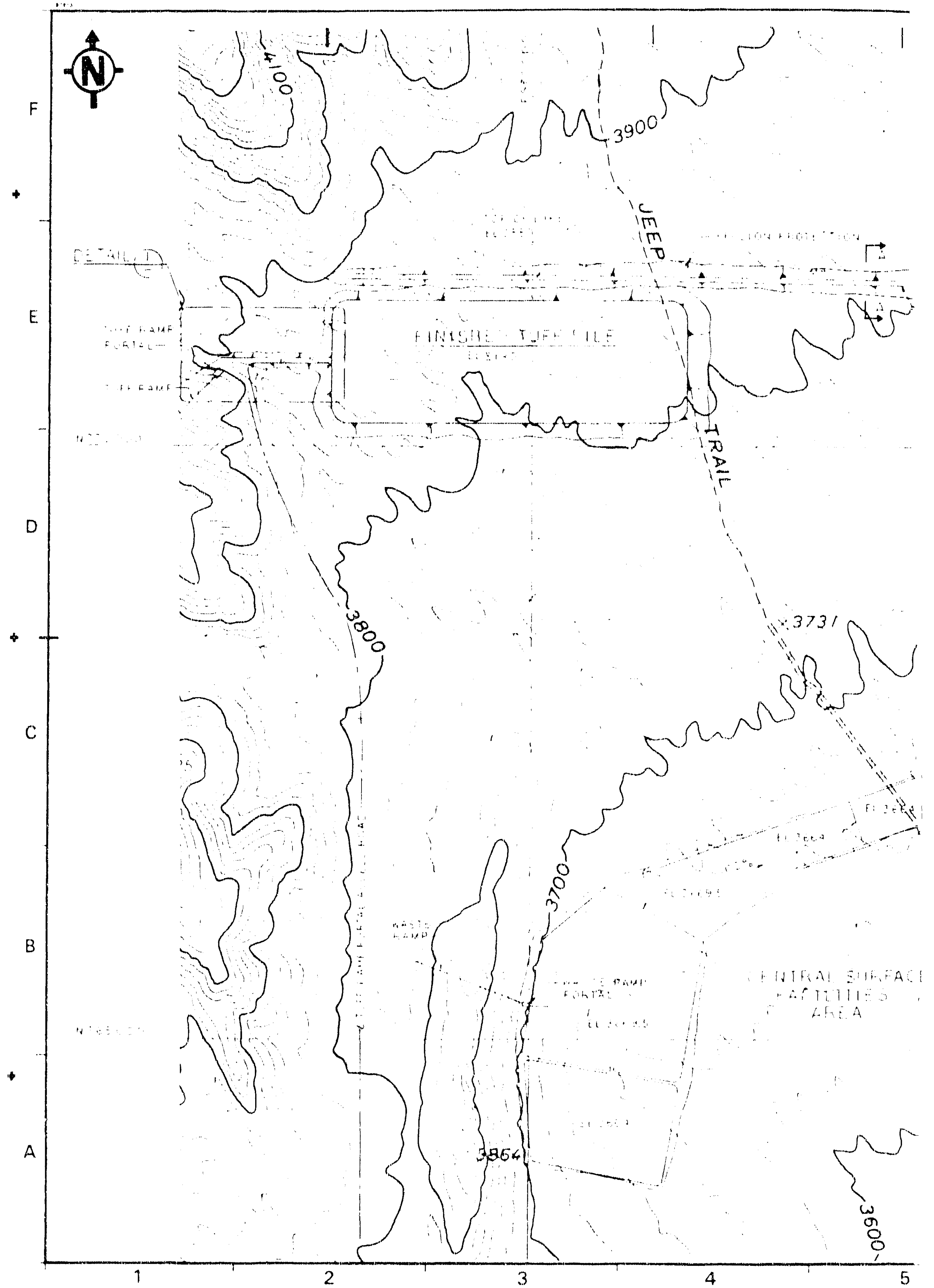
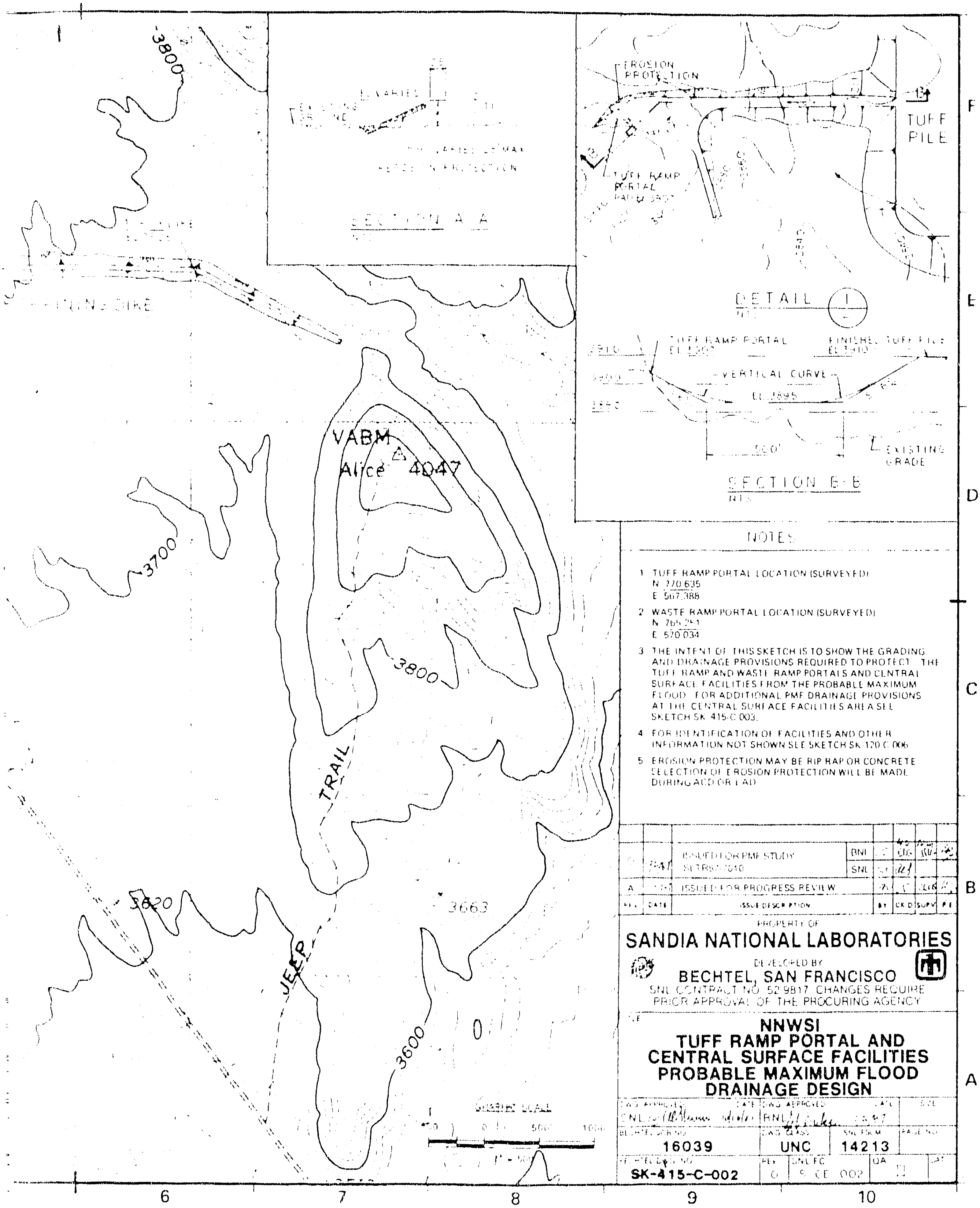


Figure 4. NNWSI Tuff Ramp Portal and Central



-3800
3700
3800
3620
3600
3663
VABM
Alice 4047
TRAIL
JEEP
EROSION PROTECTION
TUFF PILE
TUFF RAMP PORTAL
DETAIL 1
TUFF RAMP PORTAL
FINISHED TUFF PILE EL 3910
VERTICAL CURVE
EL 3895
EXISTING GRADE
SECTION B-B
SECTION A-A
NOTES
1 TUFF RAMP PORTAL LOCATION (SURVEYED) N 770,635 E 567,388
2 WASTE RAMP PORTAL LOCATION (SURVEYED) E 570,034
3 THE INTENT OF THIS SKETCH IS TO SHOW THE GRADING AND DRAINAGE PROVISIONS REQUIRED TO PROTECT THE TUFF RAMP AND WASTE RAMP PORTALS AND CENTRAL SURFACE FACILITIES FROM THE PROBABLE MAXIMUM FLOOD. FOR ADDITIONAL PMF DRAINAGE PROVISIONS AT THE CENTRAL SURFACE FACILITIES AREA SEE SKETCH SK-415-C-003.
4 FOR IDENTIFICATION OF FACILITIES AND OTHER INFORMATION NOT SHOWN SEE SKETCH SK-120-C-006
5 EROSION PROTECTION MAY BE RIP RAP OR CONCRETE SELECTION OF EROSION PROTECTION WILL BE MADE DURING ACD OR FAD
ISSUED FOR PMF STUDY
BNI
SNL
A
ISSUED FOR PROGRESS REVIEW
REV
DATE
ISSUE DESCRIPTION
BY
CK D
SUPV
PE
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SNL CONTRACT NO 52-9817 CHANGES REQUIRE PRIOR APPROVAL OF THE PROCURING AGENCY
NNWSI
TUFF RAMP PORTAL AND
CENTRAL SURFACE FACILITIES
PROBABLE MAXIMUM FLOOD
DRAINAGE DESIGN
DWG APPROVED
DATE
SNL
BNL
SIZE
BECHTEL JOB NO
16039
DWG CLASS
UNC
SNL FSCM
14213
PAGE NO
BECHTEL DWG NO
SK-415-C-002
REV
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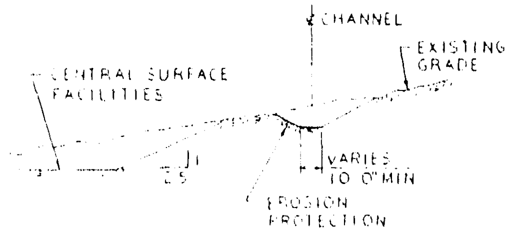
Figure 5. NNWST Central Surface Facilitie



NORTH & SOUTH DRAINAGE CHANNEL
TYPICAL SECTION
NTS

NOTES

1. WASTE RAMP PORTAL LOCATION (SURVEYED)
   N 765,251
   E 570,034
2. THE INTENT OF THIS SKETCH IS TO SHOW THE GRADING AND DRAINAGE PROVISIONS REQUIRED TO PROTECT THE WASTE RAMP PORTAL AND WASTE HANDLING FACILITIES FROM THE PROBABLE MAXIMUM FLOOD (PMF)

   FOR IDENTIFICATION OF FACILITIES AND OTHER INFORMATION NOT SHOWN SEE SKETCH SK 120-C 007

   EROSION PROTECTION MAY BE RIP RAP OR CONCRETE SELECTION OF EROSION PROTECTION WILL BE MADE DURING ACD OR FAD

LEGEND

WHB WASTE HANDLING BUILDING
WTB WASTE TREATMENT BUILDING

REV	DATE	ISSUE DESCRIPTION		BY	CK'D	SUPV	PE
1		REVISED AND REISSUED FOR PROGRESS REVIEW					
0		ISSUED FOR PMF STUDY SLTR87-7010	BNI				
			SNL				
A		ISSUED FOR PROGRESS REVIEW					

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SNL CONTRACT NO 52 9817 CHANGES REQUIRE PRIOR APPROVAL OF THE PROCURING AGENCY

TITLE
NNWSI
CENTRAL SURFACE FACILITIES AREA
PROBABLE MAXIMUM FLOOD
DRAINAGE DESIGN

DWG APPROVED	DATE	DWG APPROVED	DATE	SIZE
SNL		BNI		
BECHTEL JOB NO	DWG CLASS	SNL FSCM		PAGE NO
16039	UNC	14213		
BECHTEL DWG NO	REV	SNL FC	QA	CAT
SK-415-C-003	1	S-CE-003		

above the finish grade of the waste-receiving and inspection areas may occur during the PMF event. The resulting 0.3% slope proposed in the area reserved for truck parking and railcar sidings is within recommended slope percentages for freight-car storage yards according to the American Railway Engineering Association (1986). Waste stored in this area will be in transportation casks that have been extensively tested and are watertight.

As also shown in Figure 4, Detail 1, the portal area of the tuff ramp will be protected from a PMF by controlling the maximum elevation and length along the lower reach of the tuff pile haul road. This proposed arrangement will allow flood flows to overtop the sag portion of the road without endangering the portal area. It is recommended that the portal area be raised 7 ft from the current design to an elevation of 3,907 ft. Erosion protection is proposed along the north bank of the portal area.

As shown in Figure 6, the men-and-materials shaft area will be protected by two proposed flood conveyance systems located along the north and south sides of the area. A proposed training dike and channel intake located at the northwest corner of the area will conduct PMF flows into a proposed 50-ft-wide excavated channel on the north side of the area. Another proposed channel intake and a training dike at the southwest corner of the area will contain PMF flows within an existing natural channel along the south bank. The proposed finish grades for this area are those originally developed for the preliminary layout for the project facility, i.e., an elevation of 4,140 ft for the upper pad and shaft collar. Erosion protection is proposed along the slopes of the pad area.

The proposed finish grade at the emplacement exhaust shaft is at an elevation of 3,970 ft, which is 10 ft higher than the originally proposed grade for this area. In addition, it is proposed that the pad location be shifted north and the emplacement exhaust building reoriented to provide more area to carry flood flows to the south of the pad (Figure 7). This area will be protected by a proposed flood conveyance

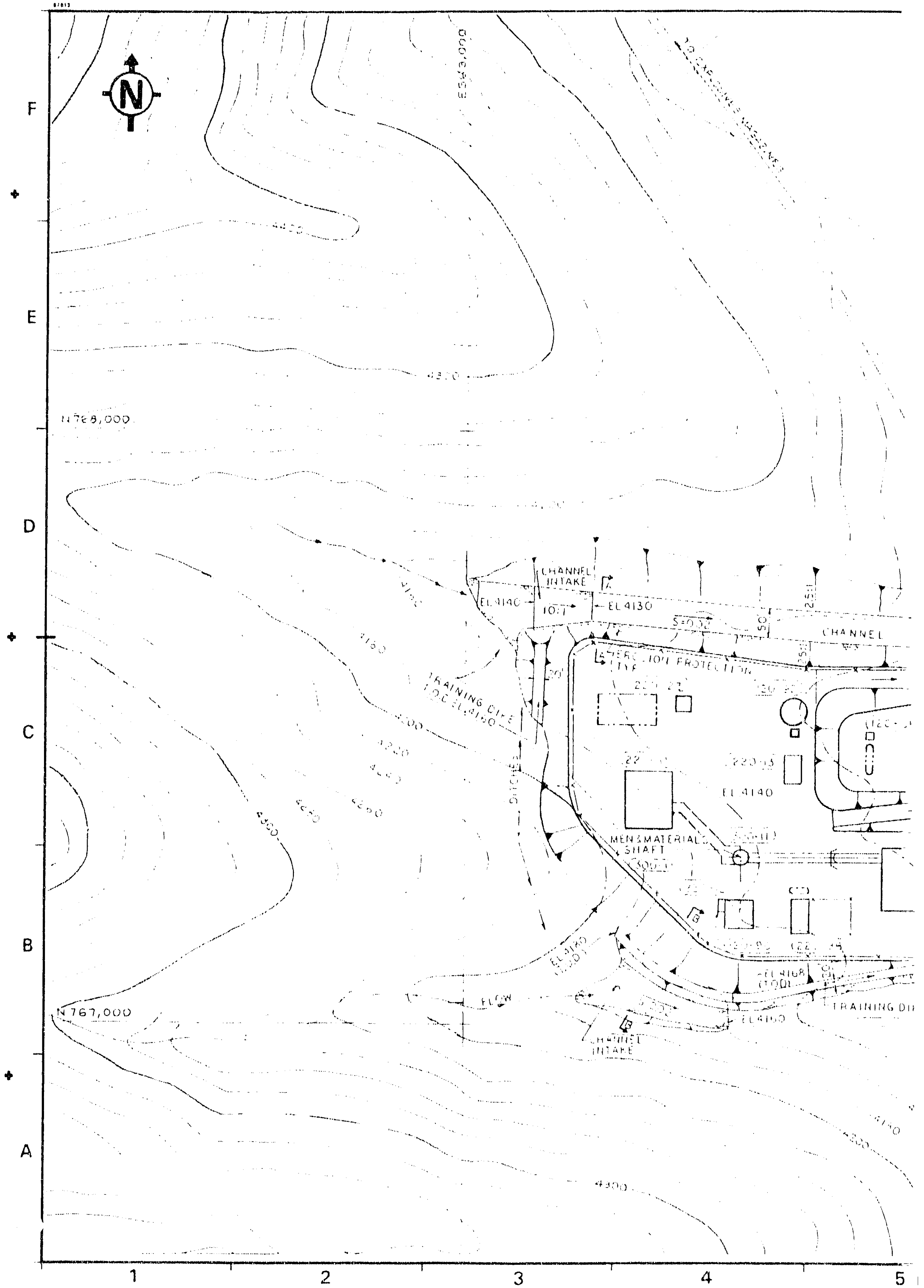
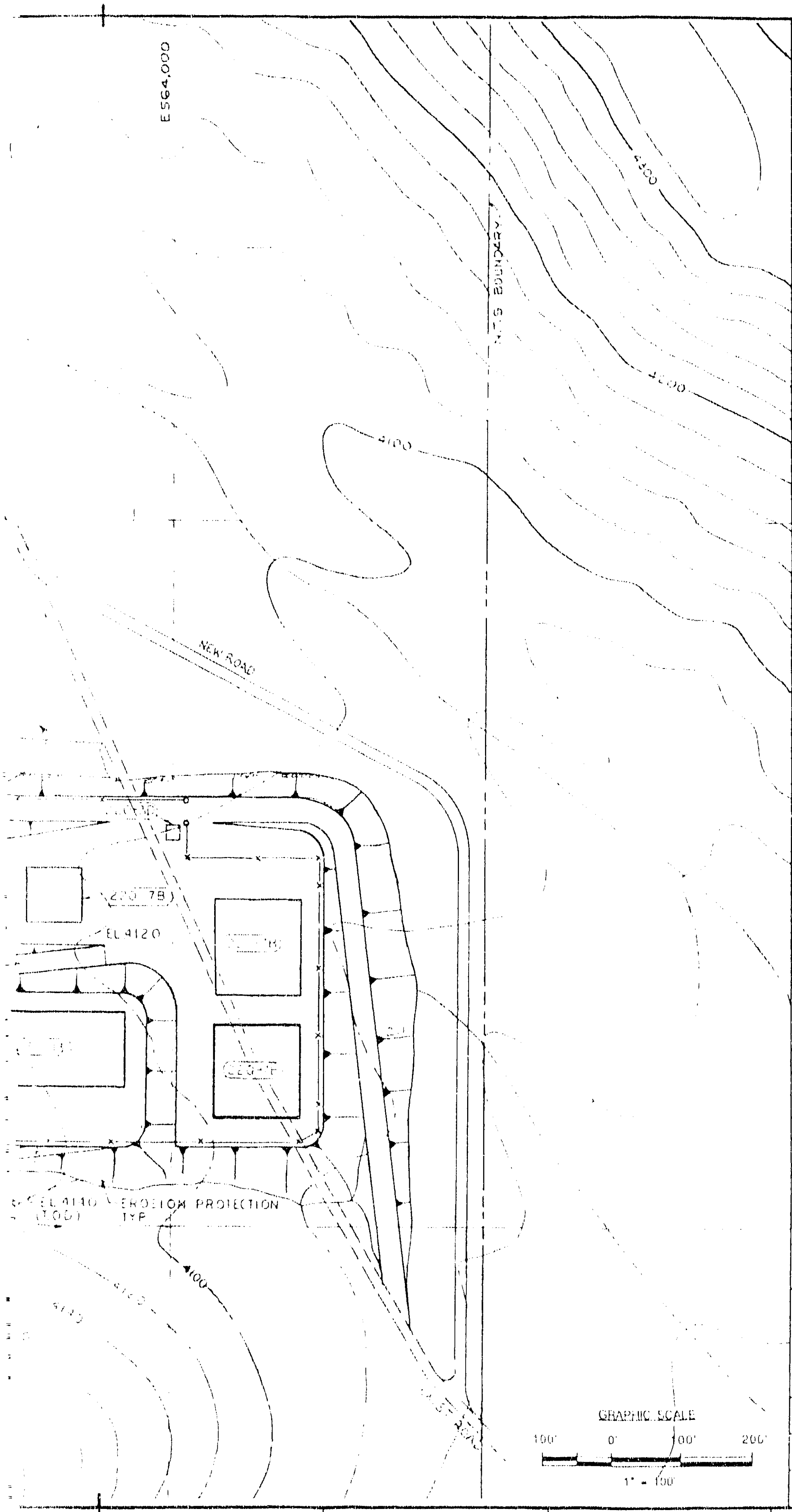
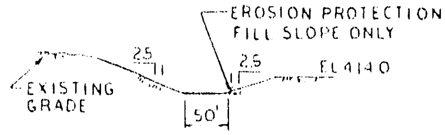
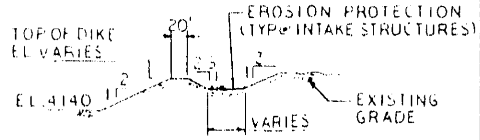


Figure 6. NNWSI Men-and-Materia





SECTION A-A
NTS



SECTION B-B
NTS

NOTES

1. SHAFT ℄ LOCATION (SURVEYED)
   N 767,284
   E 563,470
2. THE INTENT OF THIS SKETCH IS TO SHOW THE GRADING AND DRAINAGE PROVISIONS REQUIRED TO PROTECT THE MEN AND MATERIALS SHAFT COLLAR FROM THE PROBABLE MAXIMUM FLOOD (PMF).
3. FOR IDENTIFICATION OF FACILITIES AND OTHER INFORMATION NOT SHOWN SEE SKETCH SK-120 C 008.
4. EROSION PROTECTION MAY BE RIP RAP OR CONCRETE. SELECTION OF EROSION PROTECTION WILL BE MADE DURING ACD OR LAD.

REV	DATE	ISSUE DESCRIPTION	BY	CK'D	SUPV	P E
0	10/4/87	ISSUED FOR PMF STUDY SLTR87-7010	BNI / SNL	[illegible]	[illegible]	[illegible]
A	[illegible]	ISSUED FOR PROGRESS REVIEW	[illegible]	[illegible]	[illegible]	[illegible]

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SNL CONTRACT NO 52-9817. CHANGES REQUIRE PRIOR APPROVAL OF THE PROCURING AGENCY

TITLE
NNWSI MEN AND MATERIALS SHAFT AREA PROBABLE MAXIMUM FLOOD DRAINAGE DESIGN

DWG APPROVED	DATE	DWG APPROVED	DATE	SIZE
SNL	10/6/87	BNI	10/2/87	

BECHTEL JOB NO	DWG CLASS	SNL FSCM	PAGE NO
16039	UNC	14213	

BECHTEL DWG NO	REV	SNL FC	QA	CAT
SK-415-C-004	0	S-CE-004	II	

6 7 8 9 10

Shaft Area Maximum Flood Drainage Design

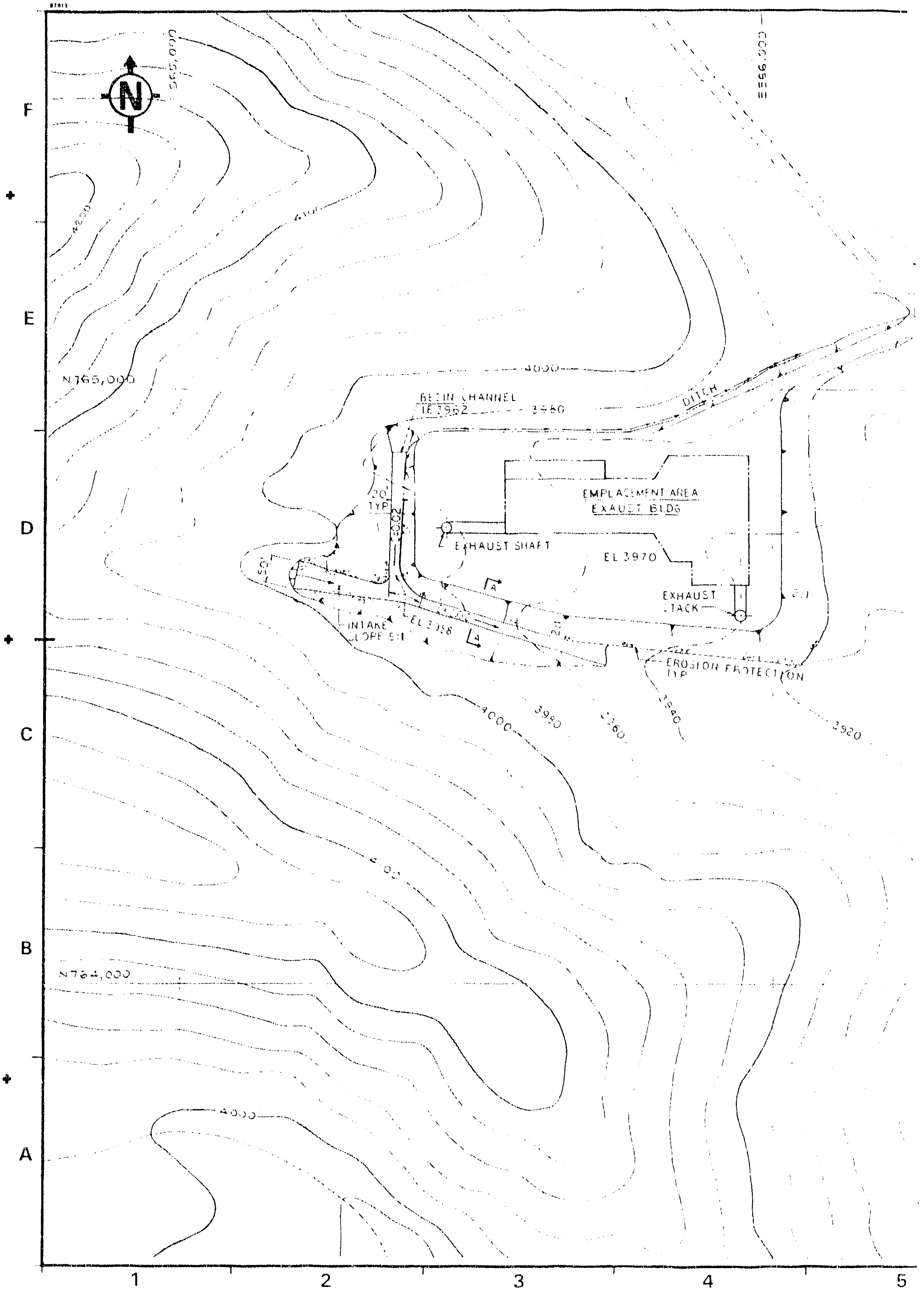
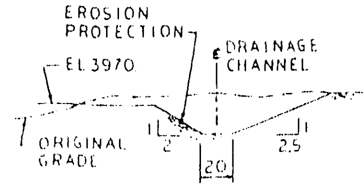


Figure 7. NNWSI Emplacement Exhaust Sh



SECTION A-A
NTS

NOTES

1. SHAFT ℄ LOCATION (SURVEYED)
N. 764,770
E. 565,452
2. THE INTENT OF THIS SKETCH IS TO SHOW THE GRADING AND DRAINAGE PROVISIONS REQUIRED TO PROTECT THE EMPLACEMENT EXHAUST SHAFT COLLAR FROM THE PROBABLE MAXIMUM FLOOD (PMF).
3. FOR IDENTIFICATION OF FACILITIES AND OTHER INFORMATION NOT SHOWN SEE SKETCH SK-120-C-009.
4. EROSION PROTECTION MAY BE RIP RAP OR CONCRETE. SELECTION OF EROSION PROTECTION WILL BE MADE DURING ACD OR LAD.

REV	DATE	ISSUE DESCRIPTION		BY	CK'D	SUPV	P.E.
0	10/1/87	ISSUED FOR PMF STUDY SL-TR87-7010	BNI				
			SNL				
A	9/3/87	ISSUED FOR PROGRESS REVIEW					

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BECHTEL, SAN FRANCISCO
SNL CONTRACT NO. 52-9817. CHANGES REQUIRE PRIOR APPROVAL OF THE PROCURING AGENCY

TITLE
NNWSI
EMPLACEMENT EXHAUST SHAFT
PROBABLE MAXIMUM FLOOD
DRAINAGE DESIGN

DWG APPROVED	DATE	DWG APPROVED	DATE	SIZE
SNL		BNI	10/2/87	

BECHTEL JOB NO	DWG CLASS	SNL FSCM	PAGE NO
16039	UNC	14213	

BECHTEL DWG NO	REV	SNL FC	QA	CAT
SK-415-C-005	0	S-CE-005	II	

system located along the west and south bank. An intake for the major PMF inflow from the west side will introduce the flood water into a channel, which will carry the flow downstream to a natural wash.

The exploratory shafts area as designed by Holmes and Narver (1987) can be protected from the PMF, as shown in Figure 8, by using a training dike to divert flow from the north to a diversion channel south of the shafts. The proposed diversion channel will direct the flow into the natural wash tributary to Drill Hole Wash. Some realignment of the access road and storage area access road is necessary to accommodate these proposed flood control provisions. The finished grade elevation of 4,130 ft, as originally designed, is considered satisfactory for protection of the exploratory shafts from the PMF.

Erosion protection shown in Figures 4 through 8 is assumed to be constructed using rock riprap or concrete paving. No design for the necessary erosion protection was made during this study. Erosion protection is shown for embankments, cut slopes, or roadways that have potential for erosion and subsequent impact on the integrity of the proposed PMF protection. It is recommended that there be local ditching along the upstream side of the various facilities to handle localized PMF runoff in areas where no specific flood protection facilities are shown in the figures.

The USGS metric topographic maps with 2-m contour intervals do not provide coverage to show all the drainage areas investigated and the flood control provisions recommended. Therefore, Figures 3 through 8 are shown on a background using the USGS 7.5-minute-series mapping with 20-ft contour intervals and enlargements of the contours. This background was chosen to ensure consistency in the presentation of the figures by precluding the use of both English and metric units and to show the necessary drainage areas and flood protection provisions. As discussed in Section 3.2, the two sources of maps closely agree with each other.

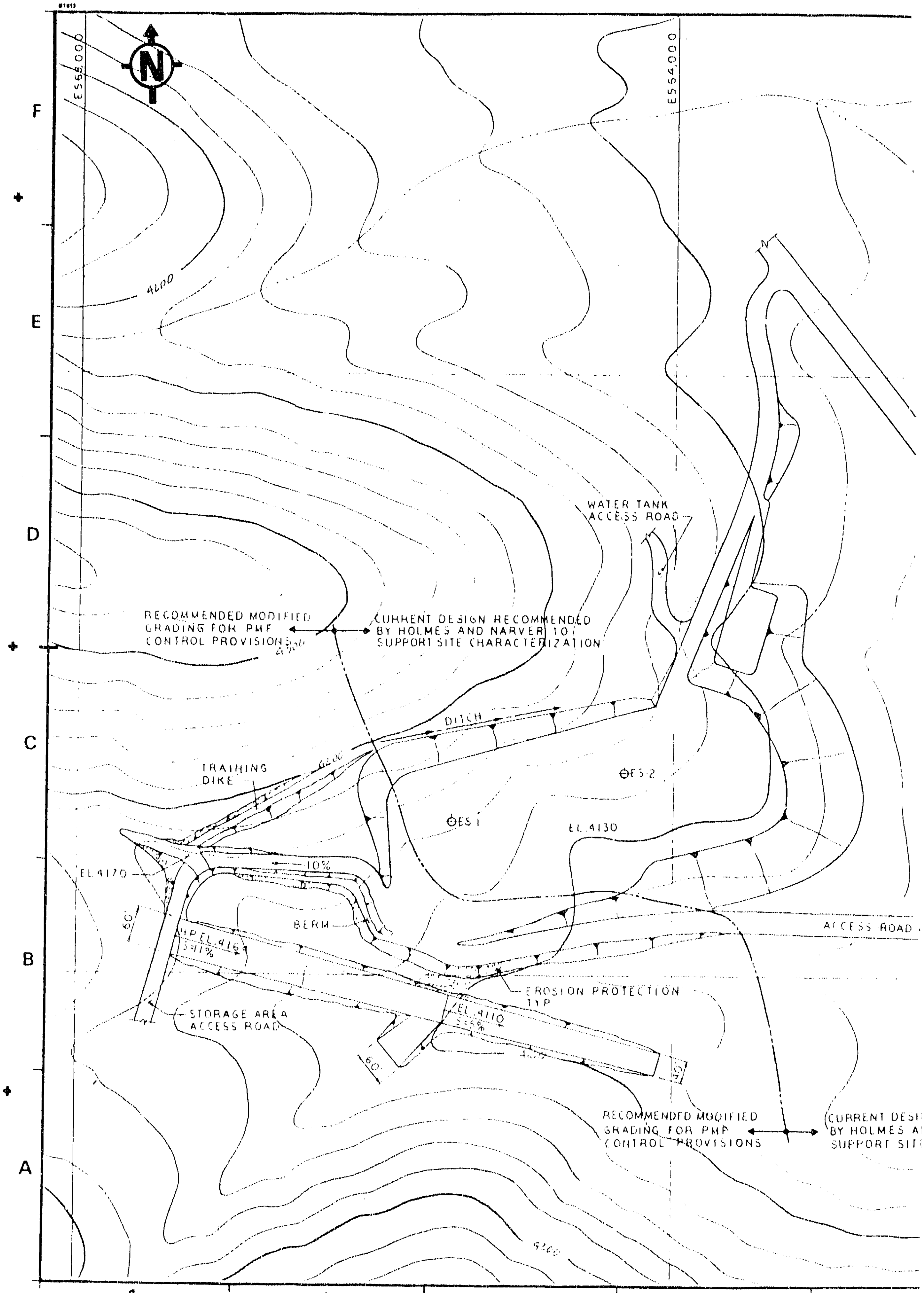
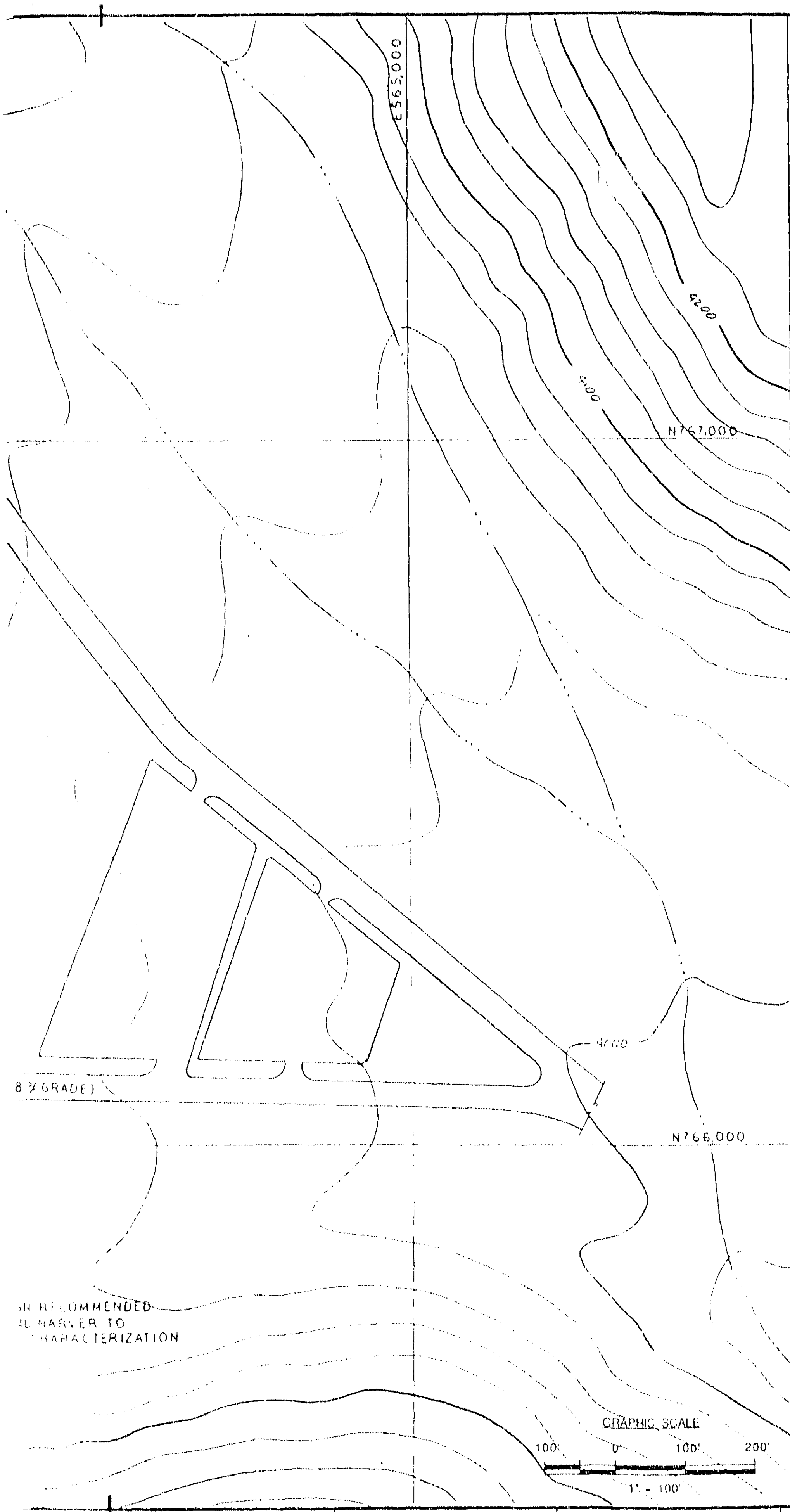


Figure 8. NNWSI Exploratory Shaft



NOTES

1. EXPLORATORY SHAFT LOCATIONS
   ES-1 N. 766,255 / E. 563,630
   ES-2 N. 768,337 / E. 563,818
2. THE INTENT OF THIS SKETCH IS TO SHOW THE GRADING AND DRAINAGE PROVISIONS REQUIRED TO PROTECT THE EXPLORATORY SHAFT COLLARS FROM THE PROBABLE MAXIMUM FLOOD (PMF).
3. FOR INFORMATION NOT SHOWN SEE HOLMES AND NARVER SKETCH SK-025-002 C18.
4. EROSION PROTECTION MAY BE RIP RAP OR CONCRETE. SELECTION OF EROSION PROTECTION WILL BE MADE DURING ACD OR LAD.

REV	DATE	ISSUE DESCRIPTION		BY	CK'D	SUPV	P.E.
1	12/8/88	REISSUED FOR PMF STUDY SLTR87-7010	BNI / SNL				
0	10/6/87	ISSUED FOR PMF STUDY SLTR87-7010	BNI / SNL				
A	7/3/87	ISSUED FOR PROGRESS REVIEW					

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BECHTEL, SAN FRANCISCO
SNL CONTRACT NO 52-9817. CHANGES REQUIRE PRIOR APPROVAL OF THE PROCURING AGENCY

TITLE
NNWSI EXPLORATORY SHAFTS FACILITY PROBABLE MAXIMUM FLOOD DRAINAGE DESIGN

DWG APPROVED	DATE	DWG APPROVED	DATE	SIZE
SNL	10/16/87	BNI	10/2/87	

BECHTEL JOB NO	DWG CLASS	SNL FSCM	PAGE NO
16039	UNC	14213	

BECHTEL DWG NO	REV	SNL FC	QA	CAT
SK-415-C-006	1	S-CE-006	II	

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F E D C B A

7.0 SUMMARY AND CONCLUSIONS

This study proposes preliminary design concepts for protecting the waste-handling facilities and all shaft and ramp entries to the underground from the PMF at the potential NNWSI Project repository site at Yucca Mountain, Nevada. To protect the waste-handling facilities and entries to the underground from the PMF, site grades have been selected and flood control and drainage provisions designed. Figures 4 through 8 show the proposed site grading, flood control, and drainage provisions at the central surface facilities, tuff ramp portal, waste ramp portal, men-and-materials shaft, emplacement exhaust shaft, and exploratory shafts facility. Mapping used for hydraulic analysis and design included USGS metric maps with 2-m contour intervals and 7.5-minute-series quadrangle maps with 20-ft contour intervals. These designs are considered preliminary.

At all areas, flood control and drainage systems are necessary to protect the essential facilities from the PMF flows used in this study. The proposed finished grade elevation at the emplacement exhaust shaft is 10 ft above the preliminary design shown in the SCP-CDR. In addition, the pad location has been shifted north and the emplacement exhaust building reoriented to provide more area to carry flood flows to the south of the pad. At the tuff ramp portal, the proposed new elevation for finished grading is 3,907 ft; in the SCP-CDR design, the tuff ramp portal was at an elevation of 3,900 ft. At the central surface facilities, the proposed finished grade has been raised to an elevation of 3,669.5 ft from 3,665 ft (the SCP-CDR design elevation at the waste ramp portal and around the waste-handling facilities). The finished grade elevation recommended by Holmes and Narver (1987) for the exploratory shaft facility is considered adequate to protect the shafts from the PMF. Some revision to the site grading will be necessary to accommodate access roads and proposed drainage provisions.

The PMF flows used for the hydraulic analysis and design were furnished by the USBR (Bullard, 1986; Appendix B) or developed from the USBR data. On the basis of the Bechtel technical staff's review of these documents, it was concluded that the flows recommended for use by the USBR are very conservative. The low loss rates, assumed short durations used in the unit hydrograph approach, and the very high debris influenced flow assumptions (double the clear water flow) made by the USBR contribute to the conservatism.

The impact of deposition of debris within the drainage channels was not considered directly in this study. For this preliminary design, considering debris deposition within the drainage channels along with the USBR's debris influenced flows might have resulted in unrealistically conservative selections for site grading and flood control provisions.

In future design phases, it is recommended that hydrologic characteristics be studied more precisely to establish representative values of debris production in the drainage basins and to confirm the low loss rates used in the USBR study. Such an investigation can be expected to result in reasonable design criteria.

Future studies should include the following:

- further evaluation of the loss rate,
- methodology more applicable to small drainage areas to develop peak flow rates,
- further evaluation of the potential for debris production and debris influenced flows, and
- the impact of deposition of debris within the drainage channels.

Development of further backwater calculations is also recommended for further study in conjunction with the items recommended above. In further designs, the scour potential of clear water flows should also be addressed and materials for erosion protection selected.

REFERENCES

American Railway Engineering Association, AREA Manual for Railway Engineering, 50 F Street N.W., Washington, DC, 1986 pp. 14-2-1 through 14-2-19. (NNA.900212.001).

ANSI/ANS-2.8, "Determining Design Basis Flooding at Power Reactor Sites," American Nuclear Society, La Grange Park, IL, 1981. (HQS.880517.1725)

Bullard, K. L., "PMF (Probable Maximum Flood) Study," U.S. Bureau of Reclamation, GR-87-8, January 1986. (HQS.880517.2628)

Holmes and Narver, Inc. "Nevada Nuclear Waste Storage Investigations/ Exploratory Shaft Facility Surface Site Layout," prepared for the U.S. Department of Energy, February 1987. (NNA.900212.0002)

National Weather Service, "Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages," Hydrometeorological Report No. 49, prepared for U.S. Department of Commerce, National Oceanic and Atmospheric Administration, and U.S. Department of the Army, Corps of Engineers, Silver Spring, MD, September 1977. (NNA.890714.0070)

SNL (Sandia National Laboratories), "Site Characterization Plan Conceptual Design Report," SAND84-2641, compiled by H. R. MacDougall, L. W. Scully, and J. R. Tillerson, Sandia National Laboratories, Albuquerque, NM, September 1987. (NN1.880902.0014-.0019)

USGS (U.S. Geological Survey), "Topopah Spring NW Quadrangle, Nevada, Nye County," 7.5-minute series (topographic) map, N3652.5-W11622.5/7.5, 1961a. (NNA.900403.00394)

USGS (U.S. Geological Survey), "Busted Butte Quadrangle, Nevada, Nye County," 7.5-minute series (topographic) map, N3645-W11622.5/7.5, 1961b. (HQS.880517.1536) Busted Butte Quadrangle was photo-revised in 1983.

USGS (U.S. Geological Survey), "Topographic Maps of Yucca Mountain Area, Nye County, Nevada," USGS-OFR-85-620, compiled by Sherman S. C. Wu, U.S. Geological Survey, Denver, CO, 1985. (HQS.880517.1929)

APPENDIX A

REFERENCE INFORMATION BASE AND SITE AND ENGINEERING PROPERTIES DATABASE

The following sections of the Reference Information Base (RIB) were indirectly used in this study.

1.17.1	Surface Hydrology
2.4.1	Overall Site Plan
2.4.2	Waste-Handling Facilities

Design information in the RIB pertains to the SCP-CDR. Information from the RIB was used selectively or indirectly from other reports as referenced.

There is no information generated by this study for inclusion in the Site and Engineering Properties Database.

APPENDIX B

"PR52-9817 - FLOOD INUNDATION DATA"
C. V. SUBRAMANIAN LETTER TO N. A. NORMAN, DATED DECEMBER 2, 1986

Sandia National Laboratories

Albuquerque, New Mexico 87185

December 2, 1986
6311-307

RECEIVED

DEC 1 0 1986

NEIL A. NORMAN

Neil A. Norman
Bechtel National, Inc.
P.O. Box 3965
San Francisco, CA 94119

Dear Neil:

Subject: PR52-9817 - Flood Inundation Data

Attached is a copy of preliminary flood inundation data from USBR. It includes data for both clear water and debris flows. This data indicates that the depths and widths of flood boundaries during extreme (PMF) events are such that major control measures may be needed for some of the cases. As soon as final data is available from USBR, it will be transmitted to you for your use in the special study task for PMF.

Sincerely,

C. V. Subramanian
NNWSI Repository Engineering
Division 6311

CVS:6311:1854q:sj

Attachment

Copy to:
6310 T. O. Hunter
6310 21/000/52-9817/CORII/QII
6310 NNWSICF
6311 L. W. Scully
6311 C. V. Subramanian
6311 J. T. Neal

Table 5

Characteristics of the Probable Maximum Flood at Cross Sections
PSEUDO Computer Program Used
Clear Water PMF Discharges

Site and Cross Section	Discharge (m^3/s)	Thalweg (m)	Maximum elevation (m)	Depth (m)	Depth (ft)	Width (m)	Width (ft)	Area (m^2)	Mean Velocity (m/s)
Exploratory Shaft - Main Location									
A11	46	1259	1260.55	1.55	5.1	42.6	140	23.7	
A12**	46	1261	1262.96	1.96	6.4	33.8	110	23.1	
A13	46	1263	1264.81	1.81	5.9	29.0	95	20.7	
Exploratory Shaft - Auxiliary Location									
A21	49	1258.8	1261.57	2.77	9.1	15.8	52	17.9	
A22	49	1260.9	1262.90	2.0	6.6	16.3	53	18.4	
A23**	49	1264	1265.98	1.98	6.5	15.9	52	15.7	
Exploratory Shaft - Combined Drainage									
A31	95	1252	1254.55	2.55	8.4	28.4	93	30.8	
A32**	95	1254.1	1256.18	2.08	6.8	30.1	99	29.7	
A33	95	1255.7	1257.65	1.95	6.4	35.2*	115	31.9	
Central Surface Facility - With Tuff Pile Drainage									
CSF1	1163	1109	1111.71	2.71	8.9	585.6	1921	533.6	
CSF2	1163	1111	1113.79	2.79	9.2	501.5	1645	484.9	
CSF3	1163	1114	1116.47	2.47	8.1	538.5*	1767	482.8	
CSF4	1163	1117.5	1119.52	2.02	6.6	422.1*	1385	401.2	
Central Surface Facility - Without Tuff Pile Drainage									
CSF1	809	1109	1111.48	2.48	8.1	523.6	1718	406.2	
CSF2	809	1111	1113.46	2.46	8.1	386.6	1268	339.9	
CSF3	809	1114	1116.25	2.25	7.4	479.4*	1573	371.3	
CSF4	809	1117.5	1119.31	1.81	5.9	396.0*	1299	312	
Central Surface Facility - East Arm									
CSFEA1	91	1104	1105.92	1.92	6.3	31.6	104	30.4	
CSFEA2	91	1106	1107.85	1.85	6.1	32.3	106	29.9	
CSFEA3	91	1108	1110.11	2.11	6.9	26.0	85	27.8	
CSFEA4	91	1110	1112.31	2.31	7.6	22.9	75	27.8	

*High ground bounded on both sides by floodwater was not included in tabulated width.

**Cross section nearest site.

Table 5 (continued)

Characteristics of the Probable Maximum Flood at Cross Sections
PSEUDO Computer Program Used
Clear Water PMF Discharges

Site and Cross Section	Discharge (m^3/s)	Thalweg (m)	Maximum elevation (m)	Depth (m)	Depth (ft)	Width (m)	Width (ft)	Area (m^2)	Mean Velocity (m/s)
Tuff Ramp									
C1	109	1184	1186.56	2.56	8.4	84.5	277	56.8	
C2**	109	1186	1188.85	2.85	9.4	49.7	163	44.0	
C3	109	1188	1189.69	1.69	5.5	24.7	81	31.0	
Waste Decline									
D1	7	1118	1118.18	0.18	0.6	58.0	190	6.8	
D2	7	1119.8	1120.30	0.50	1.6	33.0	108	12.7	
Emplacement Exhaust Shaft									
E1	33	1195	1196.11	1.11	3.6	26.8	88	14.1	
E2**	33	1197	1197.86	0.86	2.8	29.3	96	12.7	
E3	33	1199	1200.07	1.07	3.5	74.6	245	40.9	
Men and Materials Shaft									
F1	131	1252	1253.73	1.73	5.7	52.0	171	45	
F6**	131	1257	1258.74	1.74	5.7	45.0	148	44.8	
F8	131	1262	1263.74	1.74	5.7	56.7	186	49.4	
Finished Tuff Pile West Drainage									
FTPW1	135	1157	1159.02	2.02	6.6	54.7	179	51.2	
FTPW2	135	1161.4	1162.58	1.18	3.9	77.4	254	53.9	
FTPW3	135	1165	1166.23	1.23	4.0	75.3	247	52.7	
FTPW4	135	1167.8	1169.61	1.81	5.9	78.3*	257	61.0	
Finished Tuff Pile East Drainage									
FTPE1	251	1158	1159.83	1.83	6.0	92.1	302	93.1	
FTPE2	251	1162	1164.19	2.19	7.2	79	259	90.4	
FTPE3	251	1166	1167.80	1.80	5.9	58.5	192	72.9	
FTPE4	251	1172	1174.58	2.58	8.5	107.5	353	98.5	
Finished Tuff Pile Combined Drainage									
FTPC1	367	1152	1153.87	1.87	6.1	170.1*	558	145.2	
FTPC2	367	1154	1155.99	1.99	6.5	193.0*	633	156.7	

*High ground bounded on both sides by floodwater was not included in tabulated width.

**Cross section nearest site.

Table 6

Characteristics of the Probable Maximum Flood at Cross Sections
PSEUDO Computer Program Used
Debris Influenced PMF Discharges

Site and Cross Section	Discharge (m^3/s)	Thalweg (m)	Maximum elevation (m)	Depth (m)	Depth (ft)	Width (m)	Width (ft)	Area (m^2)	Mean Velocity (m/s)
Exploratory Shaft - Main Location									
A11	91	1259	1260.90	1.90	6.2	51.9	170	40.1	
A12**	91	1261	1263.36	2.36	7.7	62.6	205	46.6	
A13	91	1263	1265.30	2.30	7.5	40.4	133	37.7	
Exploratory Shaft - Auxiliary Location									
A21	99	1258.8	1262.52	3.72	12.2	40.0	131	42.2	
A22	99	1260.9	1263.56	2.66	8.7	18.1	59	29.9	
A23**	99	1264	1266.62	2.62	8.6	23.0	75	29.3	
Exploratory Shaft - Combined Drainage									
A31	190	1252	1255.28	3.28	10.8	34.2	112	53.6	
A32**	190	1254.1	1256.87	2.77	9.1	41.0	135	55.2	
A33	190	1255.7	1258.20	2.50	8.2	42.0	138	53.7	
Central Surface Facility - With Tuff Pile Drainage									
CSF1	2326	1109	1112.22	3.22	10.6	710.2	2330	869.0	
CSF2	2326	1111	1114.42	3.42	11.2	684.0	2244	867.1	
CSF3	2326	1114	1116.98	2.98	9.8	646.5*	2121	788.3	
CSF4	2326	1117.5	1120.18	2.68	8.8	609.3	1999	725.2	
Central Surface Facility - Without Tuff Pile Drainage									
CSF1	1619	1109	1111.94	2.94	9.6	648.8	2129	678.1	
CSF2	1619	1111	1114.09	3.09	10.1	598.8	1965	651.1	
CSF3	1619	1114	1116.69	2.69	8.8	585.5*	1921	608.8	
CSF4	1619	1117.5	1119.77	2.27	7.4	451.3*	1481	508.0	
Central Surface Facility - East Arm									
CSFEA1	181	1104	1106.47	2.47	8.1	38.9	128	50.1	
CSFEA2	181	1106	1108.42	2.42	7.9	39.9	131	50.8	
CSFEA3	181	1108	1110.80	2.80	9.2	32.6	107	48.2	
CSFEA4	181	1110	1113.01	3.01	9.9	27.1	89	45.3	

*High ground bounded on both sides by floodwater was not included in tabulated width.

**Cross section nearest site.

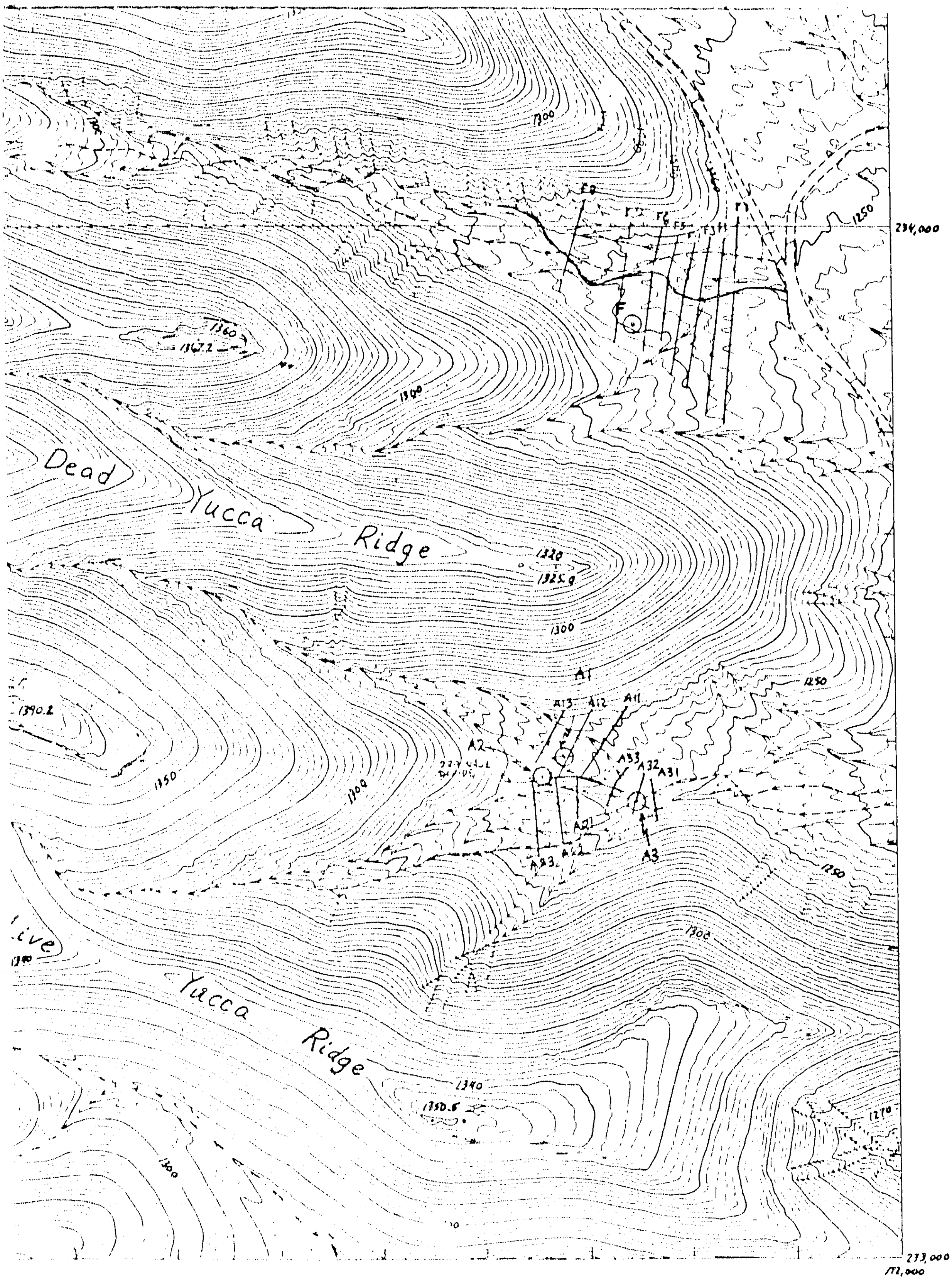
Table 6 (continued)

Characteristics of the Probable Maximum Flood at Cross Sections
PSEUDO Computer Program Used
Debris Influenced PMF Discharges

Site and Cross Section	Discharge (m^3/s)	Thalweg (m)	Maximum elevation (m)	Depth (m)	Depth (ft)	Width (m)	Width (ft)	Area (m^2)	Mean Velocity (m/s)
Tuff Ramp									
C1	218	1184	1186.94	2.94	9.6	98.5	323	91.8	
C2**	218	1186	1189.52	3.52	11.5	76.1	250	86.0	
C3	218	1188	1190.59	2.59	8.5	45.2	148	60.2	
Waste Decline									
D1	14	1118	1118.24	0.24	0.8	60.0	197	10.6	
D2	14	1119.8	1120.30	0.50	1.6	33.0	108	12.7	
Emplacement Exhaust Shaft									
E1	67	1195	1196.51	1.51	5.0	41.1	135	27.9	
E2**	67	1197	1198.30	1.30	4.3	70.3	231	32.9	
E3	67	1199	1199.93	0.93	3.1	67.3	221	31.4	
Men and Materials Shaft									
F1	262	1252	1254.25	2.25	7.4	63.1	207	75.3	
F6**	262	1257	1259.33	2.33	7.6	47.3	155	71.8	
F8	262	1262	1264.21	2.21	7.3	67.3	221	78.9	
Finished Tuff Pile West Drainage									
FTPW1	270	1157	1159.67	2.67	8.8	74.6	245	92.8	
FTPW2	270	1161.4	1163.01	1.61	5.3	88.2	289	89.8	
FTPW3	270	1165	1166.66	1.66	5.4	83.6	274	87.2	
FTPW4	270	1167.8	1170.09	2.29	7.5	108.6	356	106.7	
Finished Tuff Pile East Drainage									
FTPE1	501	1158	1160.36	2.36	7.7	100.0	328	145.9	
FTPE2	501	1162	1165.09	3.09	10.1	171.0	561	199.9	
FTPE3	501	1166	1168.71	2.71	8.9	85.7	281	136.5	
FTPE4	501	1172	1175.10	3.10	10.2	115.0	377	156.6	
Finished Tuff Pile Combined Drainage									
FTPC1	734	1152	1154.38	2.38	7.8	202.3	664	240.7	
FTPC2	734	1154	1156.50	2.50	8.2	242.0	794	270.1	

*High ground bounded on both sides by floodwater was not included in tabulated width.

**Cross section nearest site.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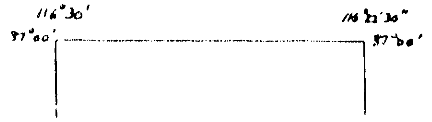
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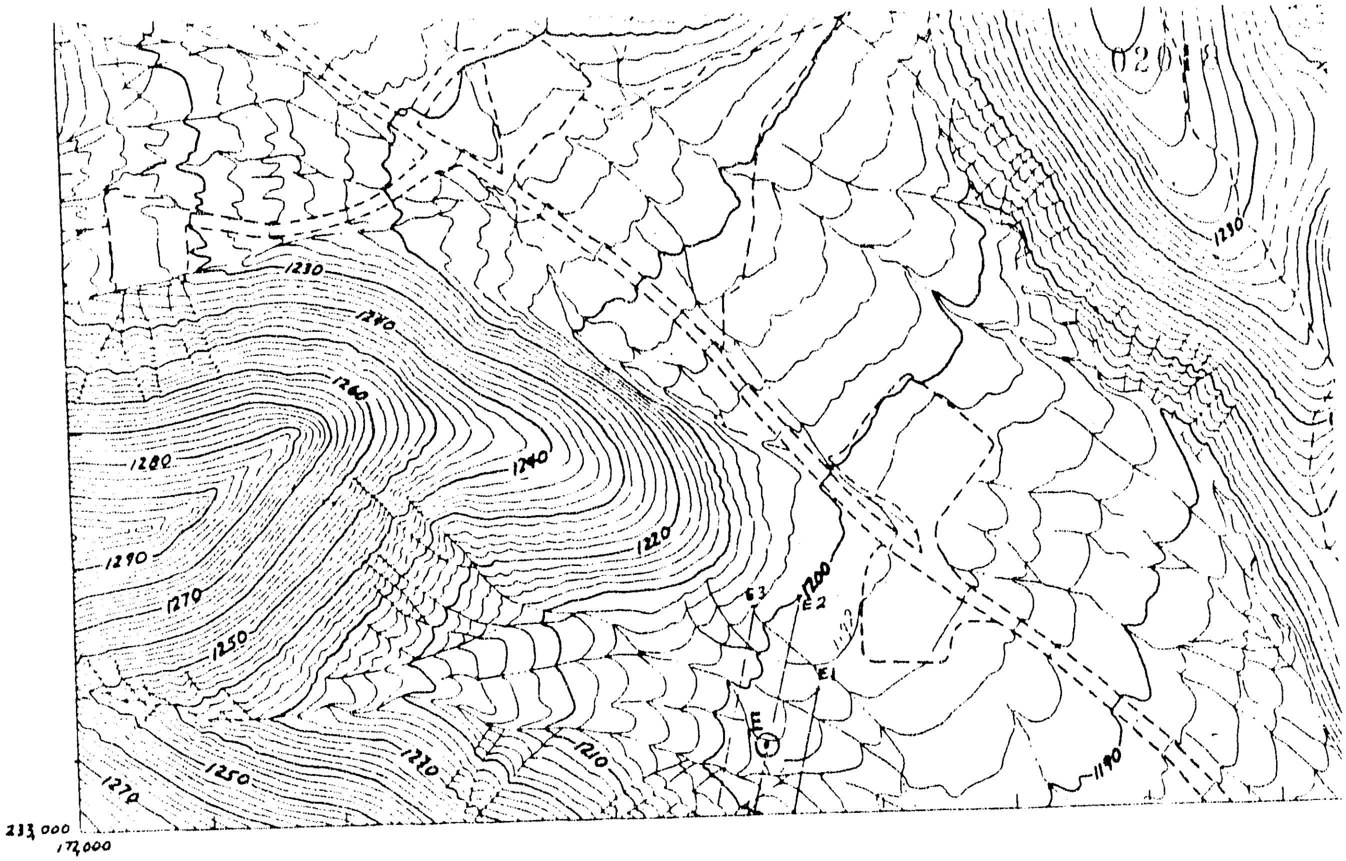

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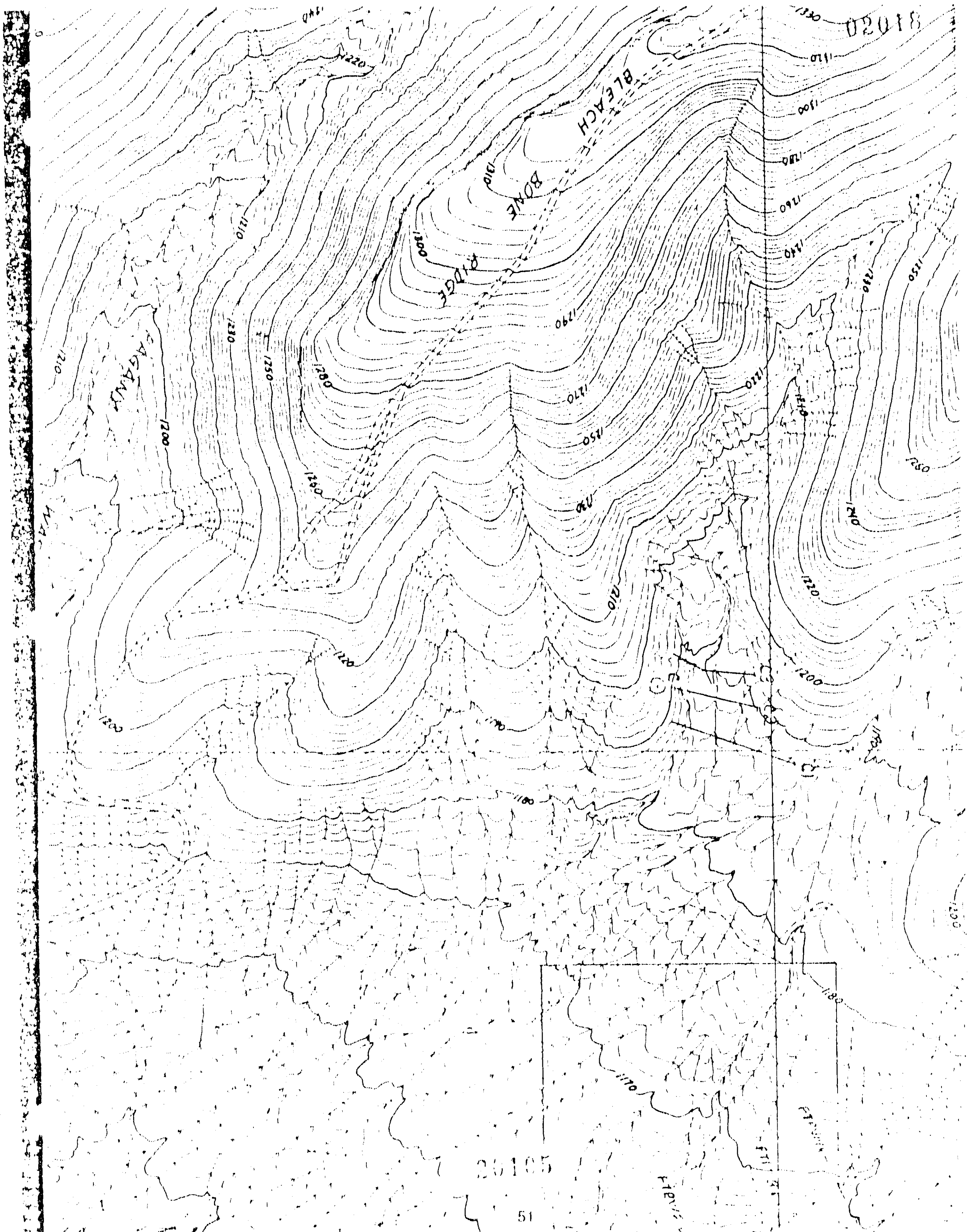
Topograph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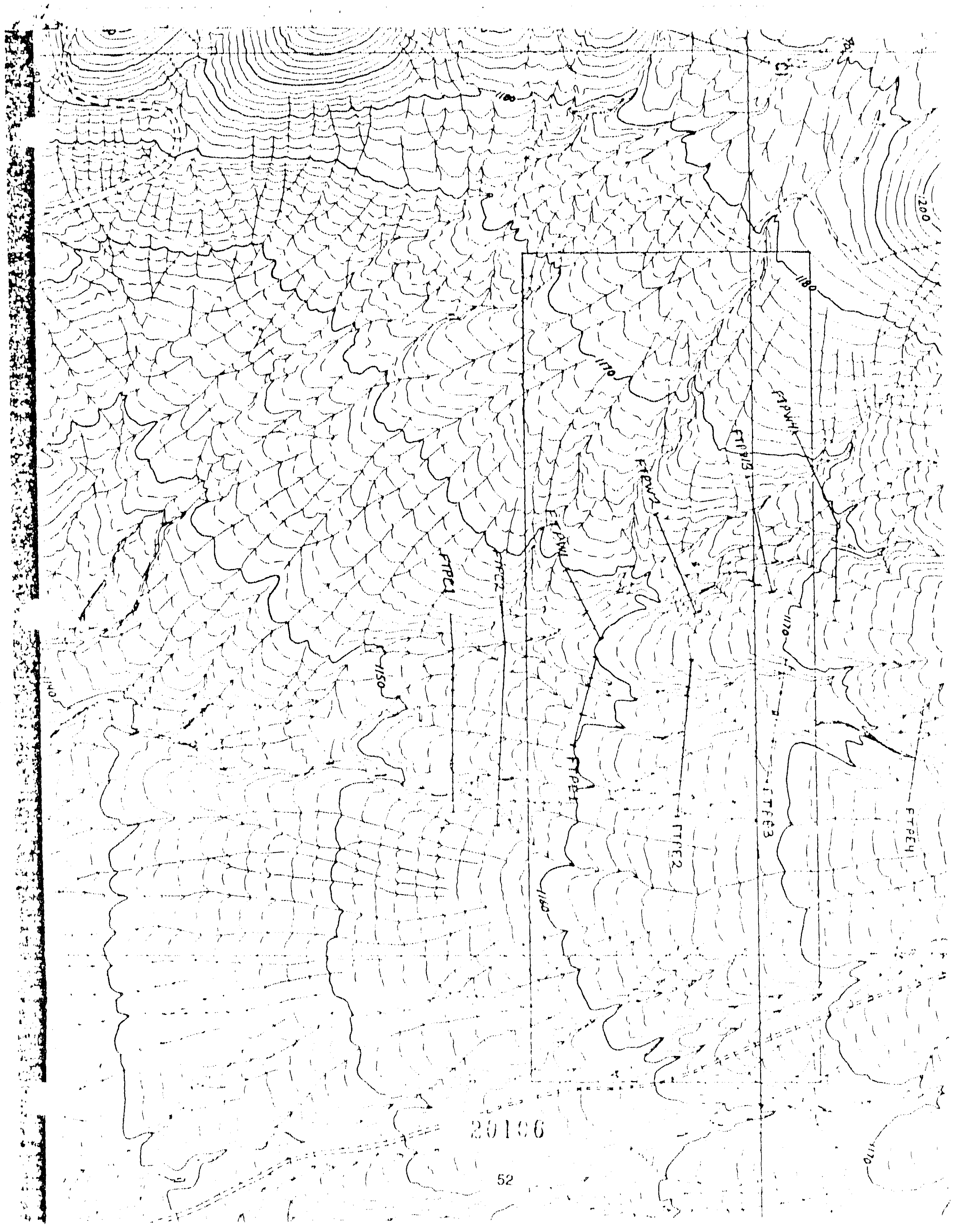
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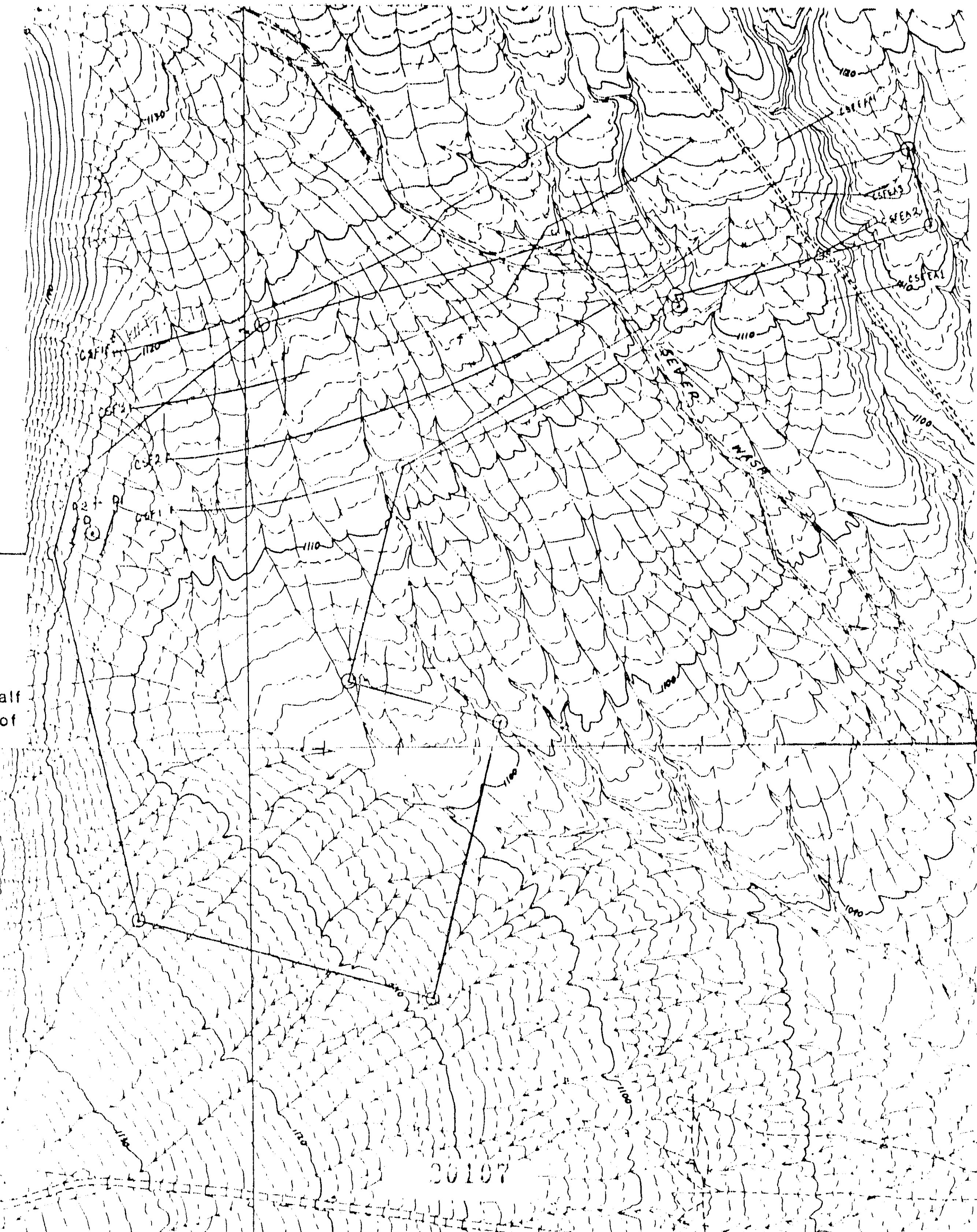

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