ATTACHMENT I

Typical SEDIMOT II Inputs
For Life-of-Mine Sedimentation Ponds

Typical SEDIMOT II Input

Sediment Ponds (Life-of-Mine)

Card Code	Parameter	Input
1	Watershed Identification	--
2	Storm Type	2 (SCS Type II Storm)
	No. of Depth Time Values	2
3	Rainfall Depth (inch)	2.10 (10-yr, 24-hr storm)
	Storm Duration (hr)	24.0
	Storm Time Increment	0.1
	Max. 30 Min. Intensity	1.0
4	Number of Junctions	1
	Hydrology and Sedimentology	2 (Hydrology and Sedimentology)
5	Number of Branches per Junction	1
6	Specific Gravity	2.5
	Coeff. for Distributing Sediment Load	1.5
	Submerged Bulk Specific Gravity	1.5
7	No. of Particle Size Distributions	1
	No. of Data Values per Distribution	15
8	Particle Size (1)	- -
	Particle Size (2)	- -
	Particle Size (3)	- -
	Particle Size (4)	- -
	Particle Size (5)	- -
	Particle Size (6)	- -
	Particle Size (7)	- -
	Particle Size (8)	- -
	Particle Size (9)	- -
	Particle Size (10)	- -
	Particle Size (11)	- -
	Particle Size (12)	- -
	Particle Size (13)	- -
	Particle Size (14)	- -
	Particle Size (15)	- -

Typical SEDIMOT II Input

Sediment Ponds (Life-of-Mine)

Card Code	Parameter	Input
9	Percent Finer (1)	- -
	Percent Finer (2)	- -
	Percent Finer (3)	- -
	Percent Finer (4)	- -
	Percent Finer (5)	- -
	Percent Finer (6)	- -
	Percent Finer (7)	- -
	Percent Finer (8)	- -
	Percent Finer (9)	- -
	Percent Finer (10)	- -
	Percent Finer (11)	- -
	Percent Finer (12)	- -
	Percent Finer (13)	- -
	Percent Finer (14)	- -
	Percent Finer (15)	- -
10	Number of Structures per Branch	1
11	Travel Time Between Structures (hr)	0.0
	Muskingums k Between Structures (hr)	0.0
	Muskingums X Between Structures (hr)	0.0
12	Number of Subwatersheds per Structure	1
	Type of Sediment Control Structure	1 (Null Structure)
	Print Control Variable for Total Drainage	2 (Hydrograph)
	Print Control Variable for Between Structures	2 (Hydrograph)
	Print Option for Subwatershed	1 (Input Tables)
13	Subwatershed Area (Acres)	- - -
	Curve Number	- - -
	Time of Concentration	- - -
	Travel Time (to Structure)	0.0
	Muskingum's k (to Structure)	0.0

Typical SEDIMOT II Input

Sediment Ponds (Life-of-Mine)

Card Code	Parameter	Input
13	Muskingum's X (to Structure)	0.0
	Hydrology Print Option	1.0 (Input Tables)
	Hydraulic Surface Conditions	- -
	Number of Flow Segments	0.0

ATTACHMENT J

Review Reports - MSHA Sedimentation

Structure N14-F

REVIEW REPORT

Sedimentation Structure

N14-F

Kayenta Mine

Navajo County, Arizona

for

PEABODY COAL COMPANY

Dames & Moore
10139-011-22

TABLE OF CONTENTS

INTRODUCTION

Sedimentation Structure N14-F is a zoned earthen embankment, designed and constructed by Peabody Coal Company. This report reviews the hydrology and hydraulics of the structure. Geotechnical aspects were not assessed.

INSPECTION

Structure N14-F was not inspected by Dames & Moore.

SITE DESCRIPTION

LAND USE

Structure N14-F has a 376-acre tributary drainage area and is located near Moenkopi Wash at the Kayenta Mine. The watershed is classified as 100% reclaimed.

EMBANKMENT

Structure N14-F is a zoned earthen embankment classified as an MSHA structure. Physical characteristics of the embankment were not measured.

ANALYSES

STABILITY

The stability of Structure N14-F was not analyzed.

HYDROLOGY

The hydrologic analysis was completed using the U.S. Army Corps of Engineers generalized computer program HEC-1, Flood Hydrograph Package. Structure N14-F is not in series with any other structure. However, it is an MSHA structure and therefore the spillway was analyzed using the 100-year, 6-hour storm. The storage capacity of Structure N14-F was analyzed using the 10-year, 24-hour storm.

The following parameters were used in the hydrologic analysis:

1.	Water Course length, L	0.871	mi
2.	Elevation Difference, H	230	ft
3.	Time of Concentration, T_c	0.272	h
4.	Lag time, $0.6T_c$	0.164	h
5.	SCS Curve Number	81	
6.	Rainfall Depth, 10-year, 24-hour storm .	2.1	in.
	100-year, 6-hour storm. .	2.4	in.
7.	Drainage Area	376	acres

HYDRAULICS

The HEC-1 program was used to evaluate inflow to the sedimentation structure, outflow from the structure and the resulting water surface elevations. The initial conditions and results of the analysis are summarized in the following table.

N14-F HYDRAULICS

	Units	10-year 24-hour Storm	100-year 6-hour Storm
Initial Reservoir Volume Condition		Empty	6655.00
Inflow			
Peak Flow	cfs	310	617
Volume	acre-ft	20.37	26.01
Storage			
Peak Stage	ft	6650.14	6659.73
Spillway Elevation . .	ft	6659.70	--
Peak Storage	acre-ft	20.37	--
Storage Capacity . . .	acre-ft	61.11	--
Outflow			
Peak Flow	cfs	0	30
Embankment Crest Elevation	ft	--	6661.20
Peak Stage	ft	--	6659.73
Freeboard	ft	--	1.47
Spillway Channel			
Flow Depth	ft	--	0.03
Manning's "n"		--	0.040

Spillway Channel

The existing spillway for N14-F has a trapezoidal channel with the following dimensions:

Channel depth	1.5	ft
Channel width	350	ft
Channel length	110	ft
Side slopes (horizontal to vertical). .	50:1	
Average exit slope	0	percent

STORAGE CAPACITY

The impoundment volume-elevation curve is based on site specific surveys conducted for Peabody Coal Company's August 1984 inspection, and 1985 resurveys, where available. Additionally, the most current topographic maps available were used.

The calculations for the sediment load entering Structure N14-F were made utilizing the Universal Soil Loss Equation with the following parameters:

1. Rainfall Factor, R 40
2. Soil Erodibility Factor, K 0.042
3. Slope Factor, LS 1.69
4. Cover Factor, C 0.15
5. Erosion Control Factor, P 1.0

The hydrologic analysis gives the storage volume required to contain the 10-year, 24-hour storm, and the remaining storage volume available for storing sediment. The existing storage capacity of N14-F and the results of the sediment inflow analysis are summarized in the following table.

N14-F STORAGE

Total Storage Capacity	61.11 acre-ft
10-year, 24-hour Storm Inflow	20.37 acre-ft
Available Sediment Storage Capacity . .	40.74 acre-ft
Sediment Inflow Rate	1.23 acre-ft/yr
Sediment Storage Life	33 yrs

* * *

The following appendix is attached and completes this report.

Appendix A - Hydrology and Hydraulic Calculations

APPENDIX A

HYDROLOGY AND HYDRAULIC CALCULATIONS

REVISIONS
BY ___ DATE ___ TO EO ___
BY ___ DATE ___ TO EO ___

Time of Concentration

Elevation Difference = 6965 - 6658 = 307 ft. ✓

Water Course Length = 12.0(400) = 4800 ft. = 0.909 mi. ✓

$$T_c = \left(\frac{11.9\ (0.909)^3}{307}\right)^{0.385} = 0.256\ hr.$$ ✓

Lag Time = $0.6T_c$ = 0.154 hr. ✓

SCS Curve Number

Drainage Area (ac)	Cover Type	Hydrologic Condition	Soil Type	Weighted Curve Number
376.0	RECL	fair	EH #35	#81 (1.00)

100% EH #35

Drainage Basin Area

376.0 ACRE 0.598 SQ MILE ✓

BY ___ DATE ___
CHECKED BY RHM 11/5/85
COPY TO EO ___

FILE Hardy Coal Co 10139-011-22
SUBJECT Sediment Inflow
N14-F SHEET ___ OF ___

REVISIONS BY ___ DATE ___ TO EO ___ BY ___ DATE ___ TO EO ___

Universal Soil Loss Equation

Rainfall Factor

R = 40

Soil Erodibility Factor

Soil Type = 100% EH #35 = 0.42

K = 0.42

Slope Factor

Length (ft.)	Δ Elev (ft.)	Slope (%)	LS
500	25	5%	1.20 (.50)
650	120	18%	9.39 (.20)
350	25	7%	1.59 (.30)

LS = 2.96

Cover Factor

Area (ac)	Cover Type	% Cover	Canopy (%)	Weighted C
100%	Reclaimed	—	—	0.15 (1.00)

Erosion Control Factor

P = 1.0

Sediment Inflow

$A = 40(0.42)(2.96)(.15)(1.0) = 7.46$ ton/acre/year

$A = 7.46\left(\frac{1}{2047}\right)(376.0)(0.9) = 1.23$ acre-feet/year

BY ___ CHECKED BY BHM DATE 11/5/85 COPY TO EO ___

Dames & Moore

ATTACHMENT K

1985 Peabody Inspection of

MSHA-Sized Dams

Sediment Impoundment Name: J-7 DAM
Page: 4ID.1211-AZ-9-0003

INSPECTION CHECK LIST

ITEM	YES	NO	REMARKS
1. CREST			
a. Any visual settlements?		X	
b. Misalignment?		X	
c. Cracking?		X	
2. UPSTREAM SLOPE			
a. Adequate grass cover?	X		
b. Any erosion?		X	
c. Are trees growing on slope?		X	
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Adequate riprap protection?			NA
g. Any stone deterioration?			NA
h. Visual depressions or bulges?		X	
i. Visual settlements?		X	
j. Animal burrows?		X	
3. DOWNSTREAM SLOPE			
a. Adequate grass cover?	X		
b. Any erosion?		X	
c. Are trees growing on slope?		X	
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Visual depressions or bulges?		X	
g. Visual settlements?		X	
h. Is the toe drain dry?	X		
i. Are the relief wells flowing?			NA
j. Are boils present at the toe?		X	
k. Is seepage present?		X	
l. Animal burrows?		X	
4. ABUTMENT CONTACT. RIGHT			
a. Any erosion?		X	
b. Visual differential movement?		X	
c. Any cracks noted?		X	
d. Is seepage present?	X		≃ 5 gpm, Clear
e. Type of Material?			Sandstone Outcrop
5. ABUTMENT CONTACT. LEFT			
a. Any erosion?		X	
b. Visual differential movement?		X	
c. Any cracks noted?		X	
d. Is seepage present?	X		≃ 10 gpm, Clear
e. Type of Material?			Sandstone Outcrop

ITEM	YES	NO	REMARKS
6. SPILLWAY/NORMAL			
a. Location:			
Left abutment?			3-160" CMP'S
Right abutment?			
Crest of Embankments?			
b. Approach Channel:	X		
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?		X	
c. Spillway Channel:			NA
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
d. Outflow Channel:	X		
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?		X	
e. Weir:			NA
Condition?			
7. SPILLWAY/EMERGENCY			
a. Location:			None
Left abutment?			
Right abutment?			
Crest of Embankments?			
b. Approach Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
c. Spillway Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
d. Outflow Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
e. Weir:			
Condition?			

Sediment Impoundment Name: J-7 DAM
Page: 6I.C. 1211-AZ-9-0003

ITEM	YES	NO	REMARKS
8. IMPOUNDMENT			
a. Sinkholes?		X	(Elev.) feet
b. Water present?	X		(Elev.) 6360.1 feet
c. Siltation?	X		Minor; A small percentage of Capacity
d. Watershed matches ~~soil~~ drainage map?	X		

9. GENERAL COMMENTS

HAUL ROAD ACROSS dam.

Sediment Impoundment Name: V16-A
Page: 4 1211-AZ-9-0009

INSPECTION CHECK LIST

ITEM	STATUS		REMARKS
1. CREST			
a. Any visual settlements?		X	
b. Misalignment?		X	
c. Cracking?		X	
2. UPSTREAM SLOPE			
a. Adequate grass cover? NA			Riprapped
b. Any erosion?		X	
c. Are trees growing on slope?		X	
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Adequate riprap protection?	X		
g. Any stone deterioration?		X	
h. Visual depressions or bulges?		X	
i. Visual settlements?		X	
j. Animal burrows?		X	
3. DOWNSTREAM SLOPE			
a. Adequate grass cover? NA			Riprapped
b. Any erosion?		X	
c. Are trees growing on slope?		X	
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Visual depressions or bulges?		X	
g. Visual settlements?		X	
h. Is the toe drain dry?	X		
i. Are the relief wells flowing?			NA
j. Are boils present at the toe?		X	
k. Is seepage present?		X	
l. Animal burrows?		X	
4. ABUTMENT CONTACT. RIGHT			
a. Any erosion?		X	
b. Visual differential movement?		X	
c. Any cracks noted?		X	
d. Is seepage present?		X	
e. Type of Material?			Sandy Silt w/s Sandstone
5. ABUTMENT CONTACT. LEFT			
a. Any erosion?		X	
b. Visual differential movement?		X	
c. Any cracks noted?		X	
d. Is seepage present?		X	
e. Type of Material?			Sandy Silt

Sediment Impoundment Name: J16-A
Page: 5 1211-AZ-9-0009

ITEM	YES	NO	REMARKS
6. SPILLWAY NORMAL			
a. Location:		X	2-24" Decant pipes
Left abutment?		X	
Right abutment?			
Crest of Embankments?	X		
b. Approach Channel: NA			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
c. Spillway Channel: NA			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
d. Outflow Channel:	X		
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?	X		
e. Weir: NA			
Condition?			
7. SPILLWAY/EMERGENCY			
a. Location:			Overtopping Crest
Left abutment?		X	
Right abutment?		X	
Crest of Embankments?	X		
b. Approach Channel: NA			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
c. Spillway Channel:			
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?	X		
d. Outflow Channel:			
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?	X		
e. Weir: NA			
Condition?			

Sediment Impoundment Name: J16-A
Page: 6 1211-AZ-9-0009

ITEM	YES	NO	REMARKS
8. IMPOUNDMENT			
a. Sinkholes?		X	(Elev.) feet
b. Water present?	X		(Elev.) 6606.5 feet
c. Siltation?	X		Small percentage of total capacity.
d. Watershed matches ~~soil~~ [illegible] map?	X		

9. GENERAL COMMENTS

General Service road across dam.

Sediment Impoundment Name: J16-L

 1211-AZ-9-0010

INSPECTION CHECK LIST

ITEM	YES	NO	REMARKS
1. CREST			
a. Any visual settlements?		X	
b. Misalignment?		X	
c. Cracking?		X	
2. UPSTREAM SLOPE			
a. Adequate grass cover?			Rip Rapped
b. Any erosion?		X	
c. Are trees growing on slope?		X	
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Adequate riprap protection?	X		
g. Any stone deterioration?		X	
h. Visual depressions or bulges?		X	
i. Visual settlements?		X	
j. Animal burrows?		X	
3. DOWNSTREAM SLOPE			
a. Adequate grass cover?	X		
b. Any erosion?		X	
c. Are trees growing on slope?		X	
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Visual depressions or bulges?		X	
g. Visual settlements?		X	
h. Is the toe drain dry?	X		
i. Are the relief wells flowing?			NA
j. Are boils present at the toe?		X	
k. Is seepage present?		X	
l. Animal burrows?		X	
4. ABUTMENT CONTACT. RIGHT			
a. Any erosion?		X	
b. Visual differential movement?		X	
c. Any cracks noted?		X	
d. Is seepage present?		X	
e. Type of Material?			Sandy Silt W/some Sandstone
5. ABUTMENT CONTACT. LEFT			
a. Any erosion?		X	
b. Visual differential movement?		X	
c. Any cracks noted?		X	
d. Is seepage present?		X	
e. Type of Material?			Sandy Silt

ITEM	YES	NO	REMARKS
6. SPILLWAY NORMAL			
a. Location:			18" Driscopipe (Decant)
Left abutment?		X	
Right abutment?		X	Near RT Abutment
Crest of Embankments?	X		
b. Approach Channel: NA			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
c. Spillway Channel: NA			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
d. Outflow Channel:			STILLING BASIN
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?	X		
e. Weir: NA			
Condition?			
7. SPILLWAY/EMERGENCY			
a. Location:			
Left abutment?		X	
Right abutment?	X		Trapezoidal Rock-cut (28' wide)
Crest of Embankments?		X	
b. Approach Channel:			
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?	X		
c. Spillway Channel:			
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?	X		
d. Outflow Channel:			
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?	X		
e. Weir: NA			
Condition?			

Sediment Impoundment Name: J16-L DAM
Page: 6I.D.#1211-AZ-9-0010

ITEM	YES	NO	REMARKS
8. IMPOUNDMENT			
a. Sinkholes?		X	(Elev.) feet
b. Water present?	X		(Elev.) 6550.3 feet
c. Siltation?	X		Small percentage of Storage Capacity
d. Watershed matches ~~soil~~ drainage map?	X		

9. GENERAL COMMENTS

Sediment Impoundment Name: KM-FW POND
Page: 4 ID, #1211-A8-9-0001

INSPECTION CHECK LIST

ITEM	YES	NO	REMARKS
1. CREST			
a. Any visual settlements?		X	
b. Misalignment?		X	
c. Cracking?		X	
2. UPSTREAM SLOPE			
a. Adequate grass cover?	X		
b. Any erosion?		X	
c. Are trees growing on slope?		X	
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Adequate riprap protection?			N.A.
g. Any stone deterioration?			N.A.
h. Visual depressions or bulges?		X	
i. Visual settlements?		X	
j. Animal burrows?		X	
3. DOWNSTREAM SLOPE			
a. Adequate grass cover?	X		
b. Any erosion?		X	
c. Are trees growing on slope?		X	
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Visual depressions or bulges?		X	
g. Visual settlements?		X	
h. Is the toe drain dry?	X		
i. Are the relief wells flowing?			N.A.
j. Are boils present at the toe?		X	
k. Is seepage present?		X	
l. Animal burrows?		X	
4. ABUTMENT CONTACT. RIGHT			
a. Any erosion?		X	
b. Visual differential movement?		X	
c. Any cracks noted?		X	
d. Is seepage present?		X	
e. Type of Material?			Sandy Silt
5. ABUTMENT CONTACT. LEFT			
a. Any erosion?		X	
b. Visual differential movement?			
c. Any cracks noted?			
d. Is seepage present?			
e. Type of Material?			Sandy Silt

Sediment Impoundment Name: KM - FW POND
Page: 5 I.D.# 1211-AZ-9-0001

ITEM	YES	NO	REMARKS
6. SPILLWAY/NORMAL			
a. Location:			
Left abutment?			
Right abutment?			
Crest of Embankments?	X		12" CMP
b. Approach Channel: NA			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
c. Spillway Channel: NA			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
d. Outflow Channel:			
Are side slopes eroding?	X		
Are side slopes sloughing?	X		
Bottom of channel eroding?	X		
Obstructed?		X	
Erosion protection?		X	
e. Weir: NA			
Condition?			
7. SPILLWAY/EMERGENCY			
a. Location:			None
Left abutment?			
Right abutment?			
Crest of Embankments?			
b. Approach Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
c. Spillway Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
d. Outflow Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
e. Weir:			
Condition?			

ITEM	YES	NO	REMARKS
8. IMPOUNDMENT			
a. Sinkholes?		X	(Elev.) feet
b. Water present?	X		(Elev.) 6615.6 feet
c. Siltation?		X	
d. Watershed matches ~~soil~~ drainage map?	X		

9. GENERAL COMMENTS

Inflow controlled by pump.

Sediment Impoundment Name: N 14-D DAM
Page: 4 ID#1211-AZ-9-0004

INSPECTION CHECK LIST

ITEM	YES	NO	REMARKS
1. CREST			
a. Any visual settlements?		X	
b. Misalignment?		X	
c. Cracking?		X	
2. UPSTREAM SLOPE			
a. Adequate grass cover? N.A.			Rip Rapped
b. Any erosion?		X	
c. Are trees growing on slope?		X	
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Adequate riprap protection?	X		
g. Any stone deterioration?		X	
h. Visual depressions or bulges?		X	
i. Visual settlements?		X	
j. Animal burrows?		X	
3. DOWNSTREAM SLOPE			
a. Adequate grass cover? N.A.			Rip Rapped
b. Any erosion?		X	
c. Are trees growing on slope?		X	
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Visual depressions or bulges?		X	
g. Visual settlements?		X	
h. Is the toe drain dry?	X		
i. Are the relief wells flowing?			N.A.
j. Are boils present at the toe?		X	
k. Is seepage present?		X	
l. Animal burrows?		X	
4. ABUTMENT CONTACT. RIGHT			
a. Any erosion?		X	
b. Visual differential movement?		X	
c. Any cracks noted?		X	
d. Is seepage present?		X	
e. Type of Material?			Sandy Silt
5. ABUTMENT CONTACT. LEFT			
a. Any erosion?		X	
b. Visual differential movement?		X	
c. Any cracks noted?		X	
d. Is seepage present?		X	
e. Type of Material?			Sandy Silt

Sediment Impoundment Name: N14-D DAM
Page: SID #1211-AZ-9-0004

ITEM	YES	NO	REMARKS
6. SPILLWAY NORMAL			
a. Location:			Overtopping Crest
Left abutment?		X	
Right abutment?		X	
Crest of Embankments?	X		
b. Approach Channel: NA			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
c. Spillway Channel:			
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?		X	HAUL ROAD
d. Outflow Channel:			
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?	X		
e. Weir: NA			
Condition?			
7. SPILLWAY/EMERGENCY			
a. Location:			None
Left abutment?			
Right abutment?			
Crest of Embankments?			
b. Approach Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
c. Spillway Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
d. Outflow Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
e. Weir:			
Condition?			

Sediment Impoundment Name: *N14-D DAM*
Page: *ID#1211-AZ-9-0004*

ITEM	YES	NO	REMARKS
8. IMPOUNDMENT			
a. Sinkholes?		X	(Elev.) feet
b. Water present?	X		(Elev.) *6629.7* feet
c. Siltation?	X		*Small percentage of Capacity.*
d. Watershed matches ~~soil~~ *drainage* map?	X		

9. GENERAL COMMENTS

Dirt Road across dam

Sediment Impoundment Name: N/4-E DAM
Page: ID #1211-AZ-9-0005

INSPECTION CHECK LIST

ITEM	YES	NO	REMARKS
1. CREST			
a. Any visual settlements?		X	
b. Misalignment?		X	
c. Cracking?		X	
2. UPSTREAM SLOPE			
a. Adequate grass cover? N.A.			Rip Rapped
b. Any erosion?		X	
c. Are trees growing on slope?		X	
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Adequate riprap protection?		X	
g. Any stone deterioration?		X	
h. Visual depressions or bulges?		X	
i. Visual settlements?		X	
j. Animal burrows?		X	
3. DOWNSTREAM SLOPE			
a. Adequate grass cover? N.A.			Rip Rapped
b. Any erosion?		X	
c. Are trees growing on slope?		X	
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Visual depressions or bulges?		X	
g. Visual settlements?		X	
h. Is the toe drain dry?	X		
i. Are the relief wells flowing?			N.A.
j. Are boils present at the toe?		X	
k. Is seepage present?		X	
l. Animal burrows?		X	
4. ABUTMENT CONTACT. RIGHT			
a. Any erosion?		X	
b. Visual differential movement?		X	
c. Any cracks noted?		X	
d. Is seepage present?		X	
e. Type of Material?			Sandy Silt w/some Sandstone
5. ABUTMENT CONTACT. LEFT			
a. Any erosion?		X	
b. Visual differential movement?		X	
c. Any cracks noted?		X	
d. Is seepage present?		X	
e. Type of Material?			Sandy Silt w/some Sandstone.

Sediment Impoundment Name: *N14-E DAM*
Page: *SID #1211-AZ-9-0005*

ITEM	YES	NO	REMARKS
6. SPILLWAY NORMAL			
a. Location:			*Over Topping Crest*
Left abutment?		X	
Right abutment?		X	
Crest of Embankments?	X		
b. Approach Channel: *N/A*			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
c. Spillway Channel:			
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?	X		[illegible]
d. Outflow Channel:			
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?	X		
e. Weir: *N.A.*			
Condition?			
7. SPILLWAY/EMERGENCY			
a. Location:			*None*
Left abutment?			
Right abutment?			
Crest of Embankments?			
b. Approach Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
c. Spillway Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
d. Outflow Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
e. Weir:			
Condition?			

ITEM	YES	NO	REMARKS
8. IMPOUNDMENT			
a. Sinkholes?		X	(Elev.) feet
b. Water present?	X		(Elev.) 6667.5 feet
c. Siltation?	X		Minor, only a small percentage of Capacity
d. Watershed matches ~~soil~~ drainage map?	X		

9. GENERAL COMMENTS

Overland conveyor beltline across dam.

Sediment Impoundment Name: N14-F DAM
Page: 4 I.D.#1211-AZ-9-0006

INSPECTION CHECK LIST

ITEM	YES	NO	REMARKS
1. CREST			
a. Any visual settlements?		X	
b. Misalignment?		X	
c. Cracking?		X	
2. UPSTREAM SLOPE			
a. Adequate grass cover? N.A.			Rip Rapped
b. Any erosion?		X	
c. Are trees growing on slope?		X	
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Adequate riprap protection?	X		
g. Any stone deterioration?		X	
h. Visual depressions or bulges?		X	
i. Visual settlements?		X	
j. Animal burrows?		X	
3. DOWNSTREAM SLOPE			
a. Adequate grass cover? NA			Rip Rapped
b. Any erosion?		X	
c. Are trees growing on slope?		X	
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Visual depressions or bulges?		X	
g. Visual settlements?		X	
h. Is the toe drain dry?		X	
i. Are the relief wells flowing?			N.A.
j. Are boils present at the toe?		X	
k. Is seepage present?		X	
l. Animal burrows?		X	
4. ABUTMENT CONTACT. RIGHT			
a. Any erosion?		X	
b. Visual differential movement?		X	
c. Any cracks noted?		X	
d. Is seepage present?		X	
e. Type of Material?			Sand Stone OutCrop
5. ABUTMENT CONTACT. LEFT			
a. Any erosion?		X	
b. Visual differential movement?		X	
c. Any cracks noted?		X	
d. Is seepage present?		X	
e. Type of Material?			Sand Stone OutCrop + Sandy Silt

Sediment Impoundment Name: N14-F DAM
Page: SID#1211-AZ-9-0006

ITEM	YES	NO	REMARKS
6. SPILLWAY NORMAL			
a. Location:			Overtopping Crest
Left abutment?		X	
Right abutment?		X	
Crest of Embankments?	X		
b. Approach Channel: NA.			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
c. Spillway Channel:			
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?	X		[illegible]
d. Outflow Channel:			
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?	X		
e. Weir: NA.			
Condition?			
7. SPILLWAY/EMERGENCY			
a. Location:			None
Left abutment?			
Right abutment?			
Crest of Embankments?			
b. Approach Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
c. Spillway Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
d. Outflow Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
e. Weir:			
Condition?			

ITEM	YES	NO	REMARKS
8. IMPOUNDMENT			
a. Sinkholes?		X	(Elev.) feet
b. Water present?	X		(Elev.) 6640.8 feet
c. Siltation?	X		Small Percentage of Storage Capacity
d. Watershed matches ~~soil~~ drainage map?	X		

9. GENERAL COMMENTS

Haul Road across dam.

Item 3H. Small pool of water @ downstream toe;

Width ≈ 3.0 ft, Length ≈ 7.0 ft; depth ≈ 1.0 ft

Unknown Source.

Sediment Impoundment Name: N14-G DAM
Page: ID,#1211-AZ-9-0007

INSPECTION CHECK LIST

ITEM	YES	NO	REMARKS
1. CREST			
a. Any visual settlements?		X	
b. Misalignment?		X	
c. Cracking?		X	
2. UPSTREAM SLOPE			
a. Adequate grass cover? N.A.			Rip Rapped
b. Any erosion?		X	
c. Are trees growing on slope?		X	
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Adequate riprap protection?	X		
g. Any stone deterioration?		X	
h. Visual depressions or bulges?		X	
i. Visual settlements?		X	
j. Animal burrows?		X	
3. DOWNSTREAM SLOPE			
a. Adequate grass cover? N.A.			Rip Rapped
b. Any erosion?		X	
c. Are trees growing on slope?		X	
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Visual depressions or bulges?		X	
g. Visual settlements?		X	
h. Is the toe drain dry?	X		
i. Are the relief wells flowing?			N.A.
j. Are boils present at the toe?		X	
k. Is seepage present?		X	
l. Animal burrows?		X	
4. ABUTMENT CONTACT. RIGHT			
a. Any erosion?		X	
b. Visual differential movement?		X	
c. Any cracks noted?		X	
d. Is seepage present?		X	
e. Type of Material?			Sandy Silt
5. ABUTMENT CONTACT. LEFT			
a. Any erosion?		X	
b. Visual differential movement?		X	
c. Any cracks noted?		X	
d. Is seepage present?		X	
e. Type of Material?			SandStone OutCrop

Sediment Impoundment Name: N14-G DAM
Page: 5 ID#1211-AZ-9-0007

ITEM	YES	NO	REMARKS
6. SPILLWAY NORMAL			
a. Location:			Overtopping Crest
Left abutment?		X	
Right abutment?		X	
Crest of Embankments?	X		
b. Approach Channel: N.A.			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
c. Spillway Channel:			
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?	X		HAUL ROAD.
d. Outflow Channel:			
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?	X		
e. Weir: N.A.			
Condition?			
7. SPILLWAY/EMERGENCY			
a. Location:			None
Left abutment?			
Right abutment?			
Crest of Embankments?			
b. Approach Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
c. Spillway Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
d. Outflow Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
e. Weir:			
Condition?			

ITEM	YES	NO	REMARKS
8. IMPOUNDMENT			
a. Sinkholes?		X	(Elev.) feet
b. Water present?	X		(Elev.) 6642.9 feet
c. Siltation?	X		Small percentage of Storage Capacity
d. Watershed matches ~~soil~~ [illegible] map?	X		

9. GENERAL COMMENTS

Haul Road crosses dam.

Sediment Impoundment Name: N14-H DAM
Page: 4 ID#1211-AZ-9-0008

INSPECTION CHECK LIST

ITEM	YES	NO	REMARKS
1. CREST			
a. Any visual settlements?		X	
b. Misalignment?		X	
c. Cracking?		X	
2. UPSTREAM SLOPE			
a. Adequate grass cover? N.A.			Rip Rapped
b. Any erosion?		X	
c. Are trees growing on slope?		X	
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Adequate riprap protection?	X		
g. Any stone deterioration?		X	
h. Visual depressions or bulges?		X	
i. Visual settlements?		X	
j. Animal burrows?		X	
3. DOWNSTREAM SLOPE			
a. Adequate grass cover? N.A.			Rip Rapped
b. Any erosion?		X	
c. Are trees growing on slope?		X	
d. Longitudinal cracks?		X	
e. Transverse cracks?		X	
f. Visual depressions or bulges?		X	
g. Visual settlements?		X	
h. Is the toe drain dry?	X		
i. Are the relief wells flowing?			NA
j. Are boils present at the toe?		X	
k. Is seepage present?		X	
l. Animal burrows?		X	
4. ABUTMENT CONTACT. RIGHT			
a. Any erosion?		X	
b. Visual differential movement?		X	
c. Any cracks noted?		X	
d. Is seepage present?		X	
e. Type of Material?			Silty Sand, Carbonacious Shale
5. ABUTMENT CONTACT. LEFT			
a. Any erosion?		X	
b. Visual differential movement?		X	
c. Any cracks noted?		X	
d. Is seepage present?		X	
e. Type of Material?			Shale

ITEM	YES	NO	REMARKS
6. SPILLWAY NORMAL			400' X 1' deep trapezoidal channel
a. Location:			Overtopping Crest
Left abutment?		X	
Right abutment?		X	
Crest of Embankments?	X		
b. Approach Channel: NA			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
c. Spillway Channel:			
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?	X		
d. Outflow Channel:			
Are side slopes eroding?		X	
Are side slopes sloughing?		X	
Bottom of channel eroding?		X	
Obstructed?		X	
Erosion protection?	X		
e. Weir: N.A.			
Condition?			

ITEM	YES	NO	REMARKS
7. SPILLWAY/EMERGENCY			
a. Location:			None
Left abutment?			
Right abutment?			
Crest of Embankments?			
b. Approach Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
c. Spillway Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
d. Outflow Channel:			
Are side slopes eroding?			
Are side slopes sloughing?			
Bottom of channel eroding?			
Obstructed?			
Erosion protection?			
e. Weir:			
Condition?			

Sediment Impoundment Name: N14-H DAM
Page: 6ID#1211-AZ-9-0008

ITEM	YES	NO	REMARKS
8. IMPOUNDMENT			
a. Sinkholes?		X	(Elev.) feet
b. Water present?	X		(Elev.) 6673.8 feet
c. Siltation?		X	No Inflow, yet.
d. Watershed matches ~~soil~~ drainage map?	X		

9. GENERAL COMMENTS

ATTACHMENT L

Dam Break Analysis for Sedimentation
Ponds J28-B, J28-C, J28-D and J28-G

REPORT

Dam-Break Analysis

for

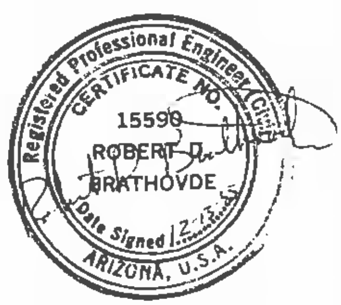
Sedimentation Structures J28-B, J28-C, J28-D, and J28-G

Kayenta Mine

Navajo County, Arizona

for

PEABODY COAL COMPANY



Dames & Moore
10139-011-22

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1.0 INTRODUCTION

This report presents the results of a dam break analysis performed for Sedimentation Structures J28-B, J28-C, J28-D and J28-G at Peabody Coal Company's Kayenta Coal Mine in Navajo County, Arizona. The purpose of the analysis was to determine whether the downstream Mine Safety and Health Administration (MSHA) dams, J16-A and Reed Valley, could safely pass the floodwater resulting from postulated accidental breaches in the embankments of the respective upstream sedimentation structures.

Sedimentation Structures J28-B, J28-C, and J28-D are located upstream of MSHA Dam J16-A, and J28-G is located upstream of the Reed Valley MSHA Dam. The locations of these structures are shown on Figure 1, Vicinity Map. The MSHA structures were designed and are maintained under the regulations set forth in the Office of Surface Mining (OSM) Indian Lands Regulations, 30 CFR, Part 77. The sedimentation structures have been inspected by Dames & Moore according to regulations 30 CFR, Parts 780 and 816.

2.0 POSTULATIONS FOR DAM-BREAK ANALYSES

2.1 BREACH CHARACTERISTICS

Accidental breaches in the sedimentation structures may result from overtopping, piping, earthquakes, or foundation failure. Available techniques for dam-break analyses require information regarding the geometric and temporal characteristics of the breach. At the present time, there are no definite standards or regulations defining these characteristics of postulated breaches. For the present study, certain postulations and assumptions have been made to obtain conservative estimates of the impacts of dam-breaks on the respective MSHA structures. These are described in the following paragraphs.

The fully formed breach in an earthen dam tends to have an average width, b, in the following range (Fread, 1983):

$$H < b < 3H$$

where H = height of the dam. A value of b = 2H is supported by case histories of past breaches (Fread, 1983; Johnson and Illes, 1976). In view of this, two trapezoidal breaches with the following average widths have been analyzed for each sedimentation structure:

(i) $b = H$
(ii) $b = 2H$

The side slopes of breaches in earthen embankments have been found to be in the following range (Fread, 1983; MacDonald and Monopolis, 1984),

$$0 < z < 2$$

where z is the horizontal component of slope. A reasonable value of z for a full-depth breach is 0.5 (MacDonald and Monopolis, 1984). Accordingly, a value of $z = 0.5$ has been used for breaches in all the sedimentation structures in this study.

The time of breach development, t, in earthen dams is reported to be in the following range (Research Institute of Colorado, 1984):

$$10 \text{ minutes} < t < 3 \text{ hours}.$$

Since the time of breach development is a function of the size of the breach, different failure times have been used for different sedimentation structures in this study (MacDonald and Monopolis, 1984). The times are shown in Table 2-1.

Table 2-1

PARAMETERS USED IN DAM-BREAK ANALYSES
(Side slopes of breach 0.5H:1V)

Parameters	J28-B Crest El. 6860.50 ft	J28-C Crest El. 6815.64 ft	J28-D Crest El. 6791.10 ft	J28-G Crest El. 6805.00 ft
Scenario 1				
100-year, 24-hour Inflow Hydrograph, Negligible Spillway Discharge				
Bottom elevation of breach	6838.5 ft	6802.5 ft	6774.50 ft	6782.5 ft
Water surface elevation at which breach occurs	6860.0 ft	6815.0 ft	6790.60 ft	6804.0 ft
Bottom width of breach	10 ft	6.5 ft	8 ft	10 ft
Failure time	30 min	15 min	20 min	30 min
Initial channel condition	Dry bed	Dry bed	Dry bed	Dry bed
Scenario 2				
10-year, 24-hour Inflow Hydrograph, Negligible Spillway Discharge				
Bottom elevation of breach	6838.5 ft	6802.5 ft	6774.50 ft	6782.5 ft
Water surface elevation at which breach occurs	6960.5 ft	6815.64 ft	6791.10 ft	6805.0 ft
Bottom width of breach*	33 ft	19.71 ft	24.90 ft	33.75 ft
Failure time**	15 min	10 min	12 min	15 min
Initial water depth in channels	1 ft	1 ft	1 ft	1 ft

*Based on average breach width (b) = 2 x height of dam.
**From Figure 2, MacDonald and Monopolis, 1984.

2.2 INITIAL RESERVOIR AND CHANNEL CONDITIONS

A preliminary review of the storage and spillway capacities of Sedimentation Structures J28-B, J28-C, J28-D, and J28-G indicated that an overtopping failure of these structures up to a 100-year, 24-hour event is not possible. For the probable maximum precipitation event, overtopping failure may be postulated if the spillway is assumed to be blocked. In view of this, the following two scenarios for initial reservoir conditions have been analyzed:

1) Non-overtopping failure with 100-year, 24-hour inflow hydrograph, negligible spillway discharge, and failure commencing when the water surface elevation is less than 1.0 foot below the crest of the embankment with b = H.

   In this case, the downstream channel is assumed to be dry at the time of occurrence of the postulated breaches. This appears to be a reasonable assumption for non-overtopping, clear day breaches in structures located on ephemeral streams.

2) Overtopping failure with negligible spillway discharge and failure commencing when water surface in the reservoir is at the crest of the embankment with b = 2H. This is an extremely conservative assumption. For convenience of modeling, a 10-year, 24-hour storm is assumed to occur over the watershed of each sedimentation structure at the time of occurrences of the postulated breach.

It is unlikely that the dam-break flood wave will arrive at a particular location along the downstream channel at the same time when the runoff hydrograph from the contributing drainage area reaches that location. However, it is reasonable to expect some pre-existing flow in the downstream channel for postulated overtopping failures of dams. The annual flooding conditions of the ephemeral channels in the area indicate that the average annual floodwater depths in these channels may be approximately 1 foot. In view of this and for the sake of computational simplicity, it is assumed that all downstream channel reaches will have a flow depth of 1 foot at the time of arrival of the dam-break flood wave.

2.3 PARAMETERS USED IN DAM-BREAK ANALYSES

The numerical values of the breach parameters and hydrologic/hydraulic conditions used in the dam-break analyses are abstracted in Table 2-1.

3.0 DAM-BREAK ANALYSES

3.1 METHODS OF ANALYSES

The HEC-1 computer program of the U.S. Army Corps of Engineers (USACE, 1981) has been used to develop the dam-break flood hydrographs for different sedimentation structures and to combine and route these hydrographs through stream channels and through the respective MSHA structures, i.e., J16-A and Reed Valley Dams.

As a conservative estimate of the peak stage and peak outflow discharge for MSHA Dam J16-A resulting from postulated breaches in Sedimentation Structures J28-B, J28-C, and J28-D, it is assumed that all the breaches occur simultaneously. Also, it is assumed that the combined dam-break flood hydrograph reaches the J16-A Reservoir at a time when the reservoir water surface elevation is at the crest of its spillway (El. 6635.0 ft). A flow chart indicating the sequence of computations for this analysis is shown in Table 3-1.

Table 3-1

SEQUENCE OF COMPUTATIONS FOR
SEDIMENTATION STRUCTURES J28-B, J28-C, AND J28-D
(J16-A WATERSHED)

---

1) Develop 100-year, 24-hour (Scenario 1) or 10-year, 24-hour (Scenario 2) hydrograph for the watershed of Sedimentation Structure J28-B.

2) Route this hydrograph through Sedimentation Structure J28-B with the parameters shown in Table 2-1 assuming negligible spillway outflow (i.e. a blocked spillway).

3) Route the outflow hydrograph through the natural channel (Reach 1) between Sedimentation Structure J28-B and the outlet channel for Sedimentation Structure J28-C.

4) Develop the 100-year, 24-hour or 10-year, 24-hour hydrograph for the watershed of Sedimentation Structure J28-C.

5) Route this hydrograph through Sedimentation Structure J28-C with the parameters shown in Table 2-1 assuming negligible spillway outflow (i.e. a blocked spillway).

6) Combine the two hydrographs for Sedimentation Structures J28-B and J28-C.

7) Route the combined hydrograph through the natural channel (Reach 2) between Sedimentation Structure J28-C and the outlet channel from Sedimentation Structure J28-D.

8) Develop 100-year, 24-hour, or 10-year, 24-hour hydrograph for the watershed of Sedimentation Structure J28-D.

9) Route this hydrograph through Sedimentation Structure J28-D with the parameters shown in Table 2-1 assuming negligible spillway outflow (i.e. a blocked spillway).

10) Combine this with the routed hydrograph from Sedimentation Structures J28-E and J28-C.

11) Route the combined hydrograph through the natural channel from the outlet channel of Sedimentation Structure J28-D to the inlet at Station 5+00 of J16 Diversion Channel (Reach 3).

12) Route the resulting hydrograph from Station 5+00 to Station 21+60 of J16 Diversion Channel (Reach 4).

13) Route the resulting hydrograph from Station 21+60 to Station 38+50 of J16 Diversion Channel (Reach 5).

Table 3-1 (Continued)

14) Route the resulting hydrograph from Station 38+50 to Station 57+50 of J16 Diversion Channel (Reach 6).

15) Route the resulting hydrograph through J16-A Reservoir.

Similarly, the dam-break flood hydrograph for Sedimentation Structure J28-G has been routed through the natural outlet channel for J28-G through the proposed Reed Valley Diversion Channel, and through the Reed Valley Dam. For the sake of conservatism, it is assumed that the dam-break flood reaches Reed Valley Reservoir at a time when the water surface behind the dam is at the spillway crest elevation. The sequence of computations for this case is shown in Table 3-2.

Table 3-2

SEQUENCE OF COMPUTATIONS FOR SEDIMENTATION STRUCTURE J28-G
(REED VALLEY WATERSHED)

---

1) Develop 100-year, 24-hour (Scenario 1) or 10-year, 24-hour (Scenario 2) hydrograph for the watershed of Sedimentation Structure J28-G.

2) Route this hydrograph through Sedimentation Structure J28-G with the parameters shown in Table 2-1 assuming negligible spillway outflow (i.e. a blocked spillway).

3) Route the resulting hydrograph through the natural channel from Sedimentation Structure J28-G to Station 187+30 of the proposed Reed Valley Diversion Channel (Reach 1).

4) Route the resulting hydrograph from Station 187+30 to Station 162+50 of the proposed Reed Valley Diversion Channel (Reach 2).

5) Route the resulting hydrograph from Station 162+50 to Station 99+00 of the proposed Reed Valley Diversion Channel (Reach 3).

6) Route the resulting hydrograph through Reed Valley Reservoir.

For the sake of comparison, the peak flows due to dam-break, Q_{max}, for each sedimentation structure have been estimated using the following approximate methods:

1) $Q_{max} = \frac{8}{27} b h^{1.5} g^{0.5}$ (USACE, 1977)

Where b = average breach width
h = depth of water behind the dam
g = gravitational constant

2) $Q_{max} = C Y^{2.5}$ (State of California, 1977)

Where C = 1.2 for triangular breach with 0.5H:1V side slopes
Y = depth of water in feet at one half reservoir capacity

3) The NWS Simplified Dam-Break Flood Forecasting Model (Wetmore & Fread, 1983).

Generally, the first of these approximate methods tends to give higher values of peak flows because the derivation of the equation in this method assumes instantaneous development of a full-depth breach with a width equal to that of the downstream channel (USACE, 1977). The second method (State of California, 1977) is purely empirical and is used by the Office of Emergency Services for safety assessment of dams in California.

3.2 DESCRIPTION OF INPUT

The distributions of 100-year, 24-hour, and 10-year, 24-hour precipitation events for the Kayenta Mine site used in this study are shown in Table 3-3 (NOAA, 1973).

Table 3-3

DISTRIBUTIONS OF 100-YEAR AND 10-YEAR, 24-HOUR PRECIPITATION EVENTS

Duration	100-year Precipitation (inches)	10-year Precipitation (inches)
5 min	0.56	0.35
15 min	1.09	0.68
1 h	1.92	1.20
2 h	2.08	1.34
3 h	2.19	1.43
6 h	2.40	1.6
12 h	2.75	1.8
24 h	3.05	2.1

The hydrologic characteristics of the watersheds of Sedimentation Structures J28-B, J28-C, J28-D, and J28-G used in the analyses are shown in Table 3-4.

Table 3-4

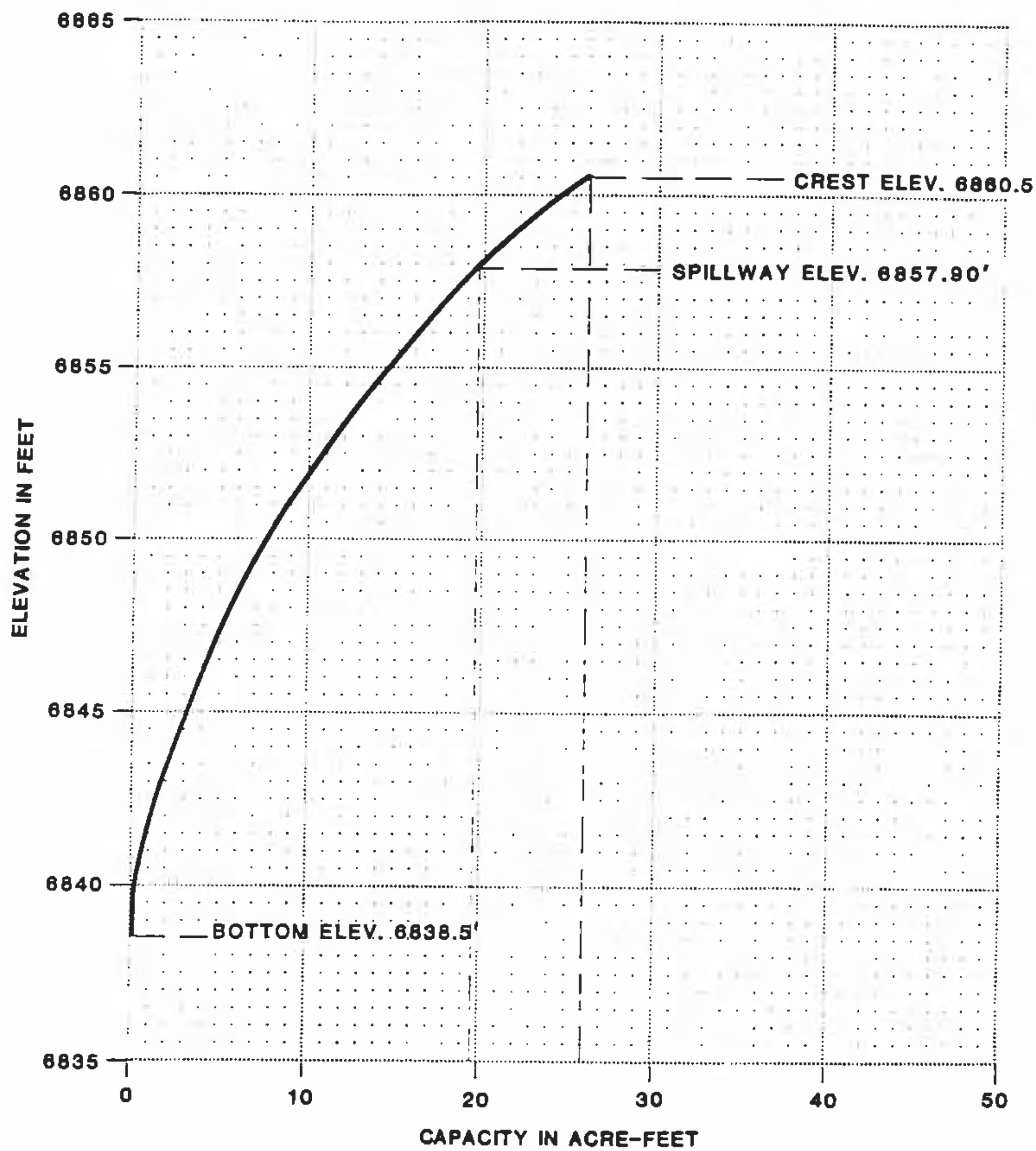
HYDROLOGIC CHARACTERISTICS OF WATERSHEDS

Parameters	Sedimentation Structure J28-B	J28-C	J28-D	J28-G
Drainage Area (sq. mi.)	0.022	0.049	0.048	0.093
SCS Curve Number	89	88	88	84
Lag Time (hour)	0.04	0.06	0.047	0.066
Storage Capacity at Failure* (Scenario 1) (acre-feet)	24.3	19.7	21.3	27.0
Storage Capacity at Failure* (Scenario 2) (acre-feet)	26.0	21.0	22.5	31.2
Surface Area at Failure* (Scenario 1) (acres)	2.6	2.8	2.4	3.6
Surface Area at Failure* (Scenario 2) (acres)	2.7	2.9	2.5	3.7

*Used for Simplified Dam-Break Flood Forecasting Model (Wetmore & Fread, 1983).

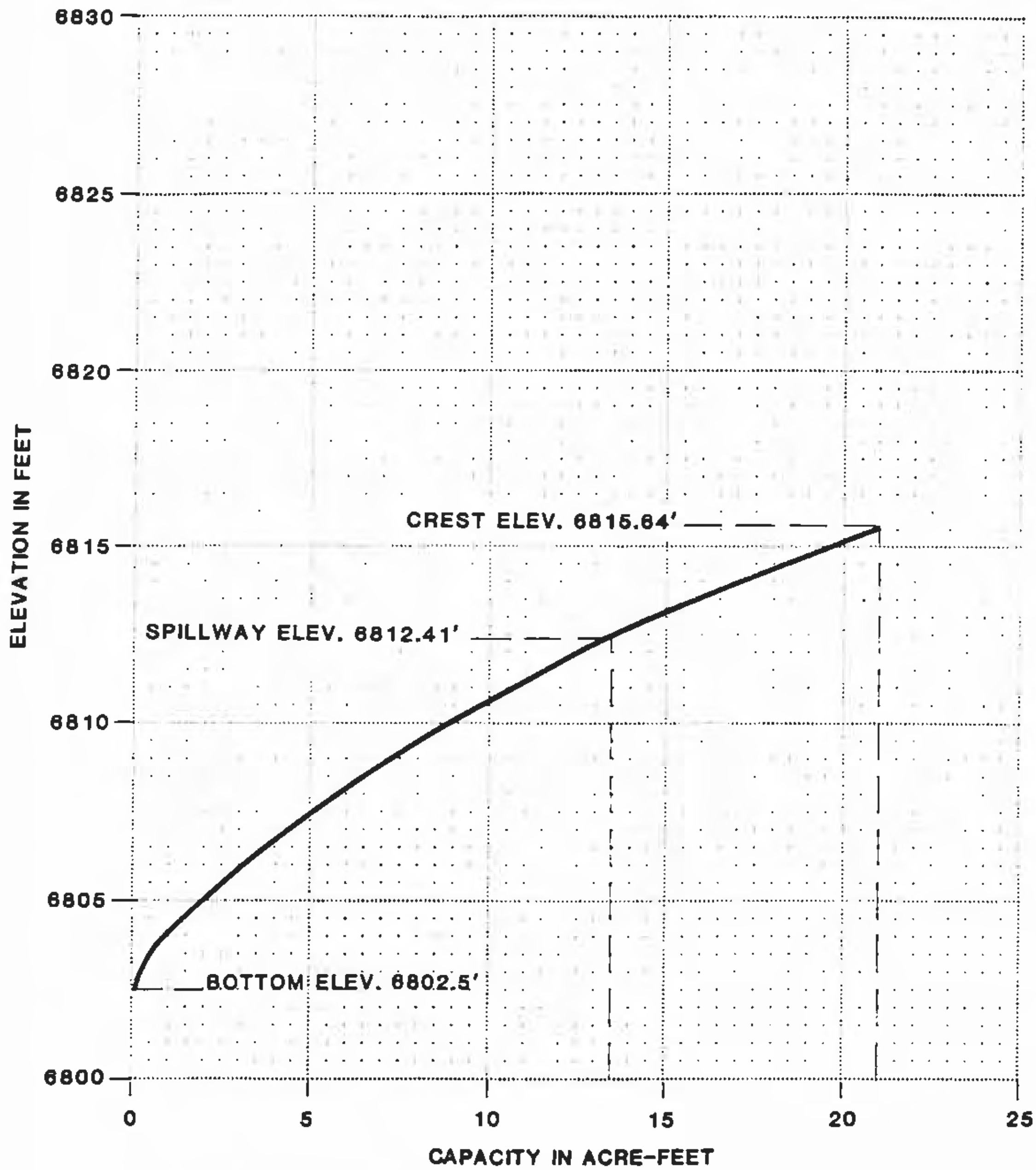
The elevation-storage curves for Sedimentation Structures J28-B, J28-C, J28-D, and J28-G are shown in Figures 2, 3, 4, and 5, respectively. The elevation-storage and spillway rating curves for the J16-A and Reed Valley Dams are shown in Figures 6, 7, 8, and 9, respectively.

To estimate the alteration of dam-break floods by channel storage, the total channel lengths for the J16-A and Reed Valley drainages are divided into smaller channel reaches. Each of these reaches is represented by an average channel cros section obtained from 1"=400' topographic maps of the area having 10-foot contour intervals. The coordinates of these cross sections are given in the computer outputs included in Appendices A, B, C, and D. The other hydraulic characteristics for each channel reach are shown in Table 3-5.



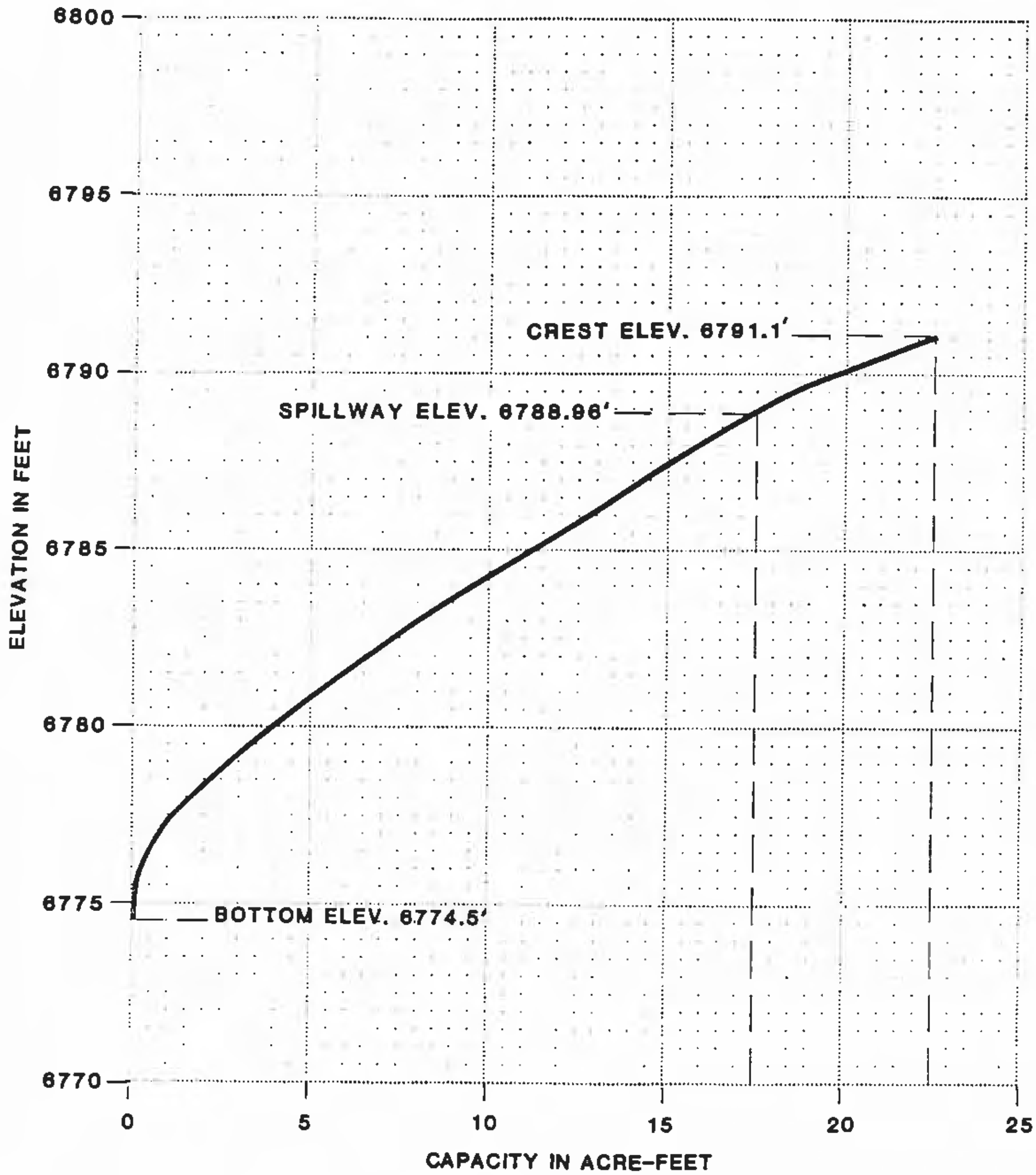
VOLUME-ELEVATION CURVE
J28-B

BY **Dames & Moore** Figure 2



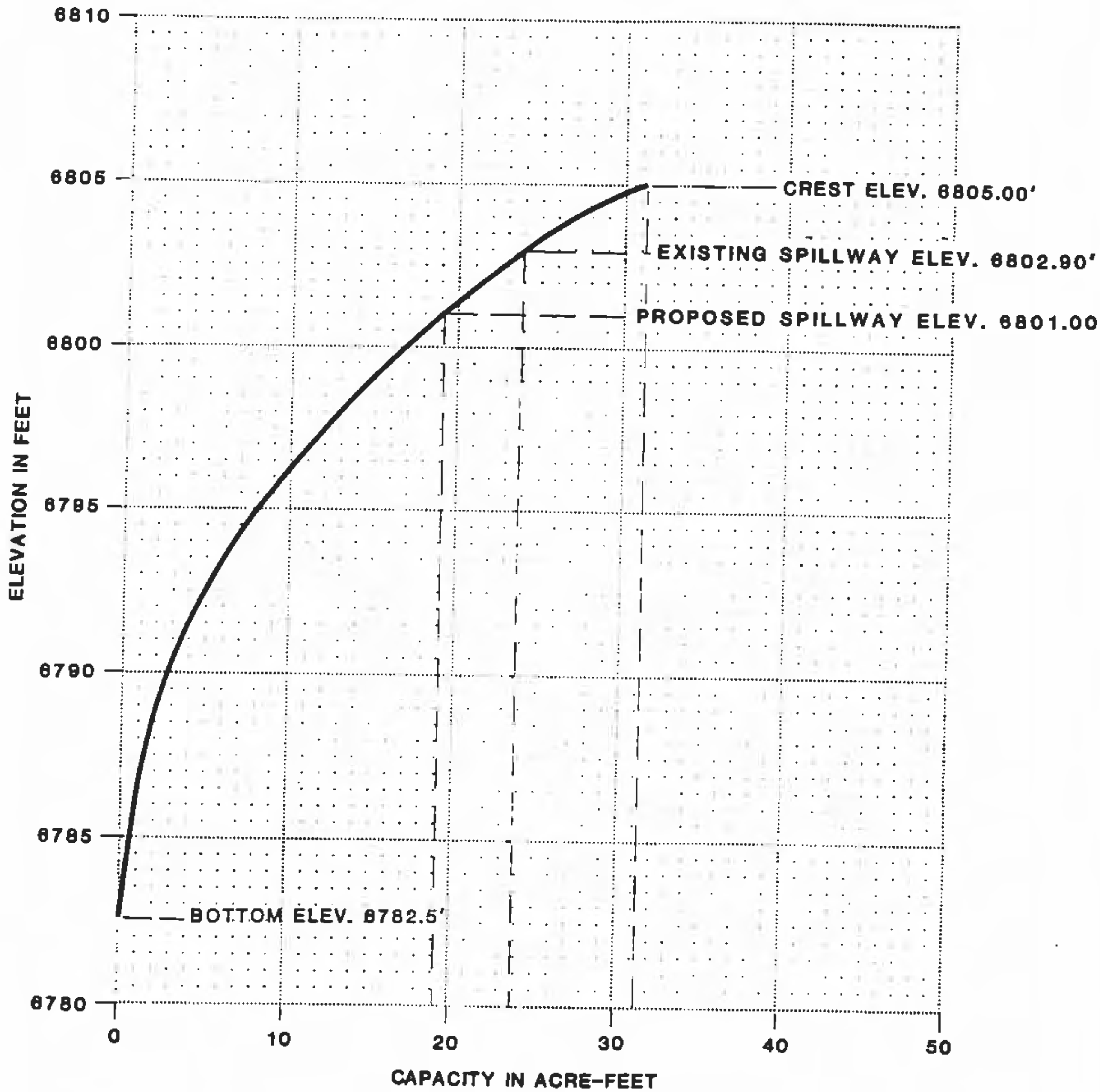
VOLUME-ELEVATION CURVE
J28-C

BY **Dames & Moore** Figure 3



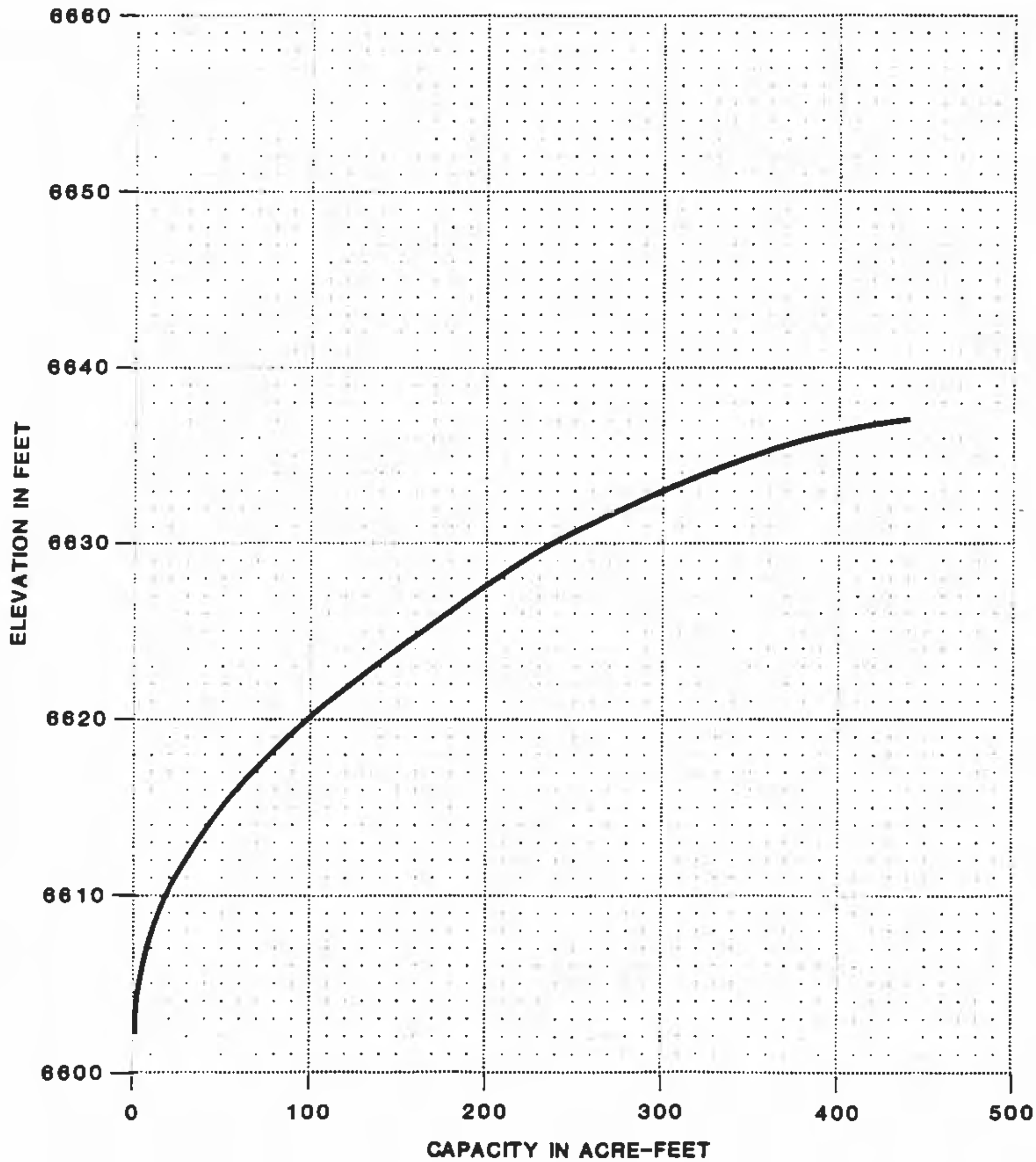
VOLUME-ELEVATION CURVE
J28-D

BY **Dames & Moore** Figure 4



VOLUME-ELEVATION CURVE
J28-G

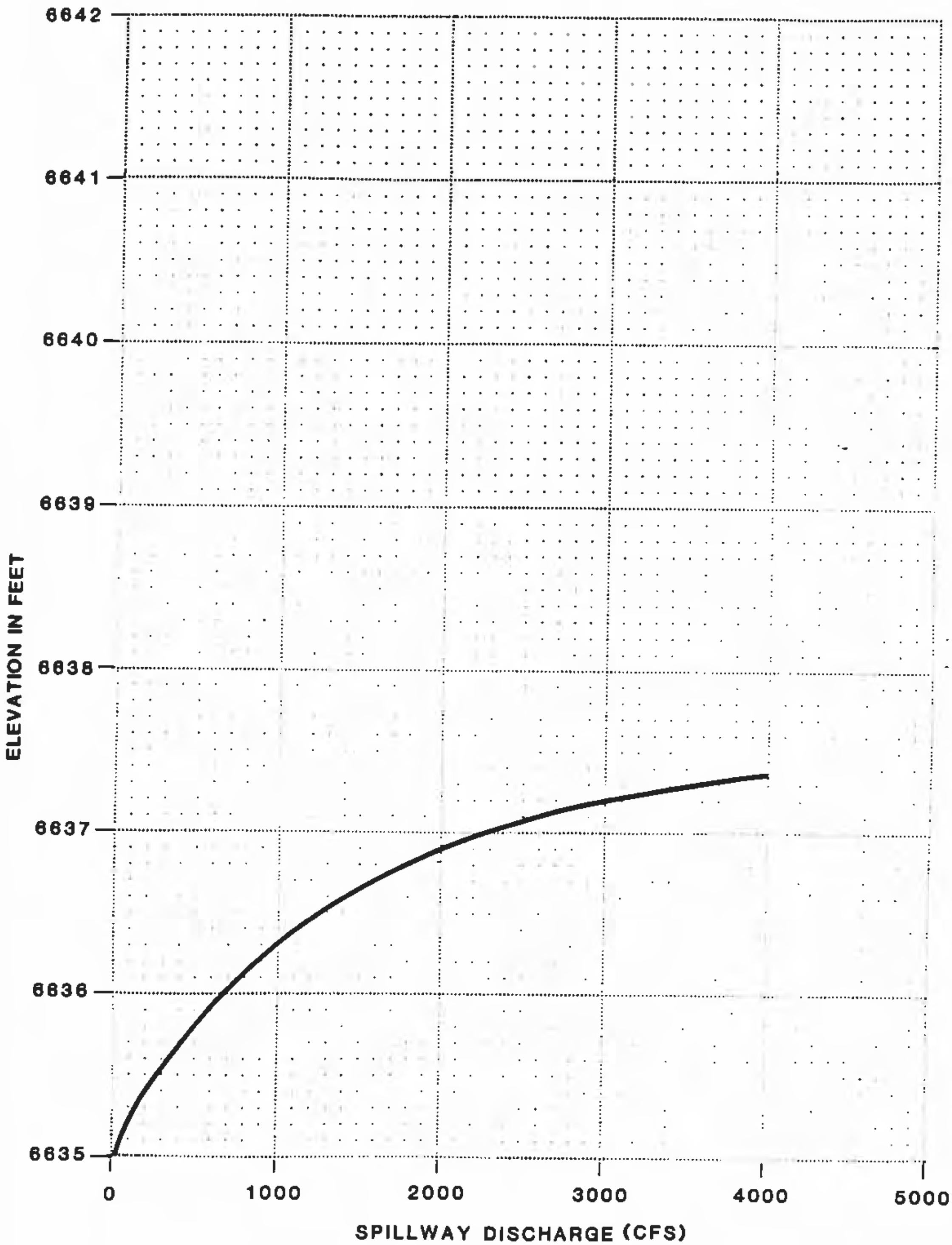
BY **Dames & Moore** Figure 5



VOLUME-ELEVATION CURVE J16-A RESERVOIR

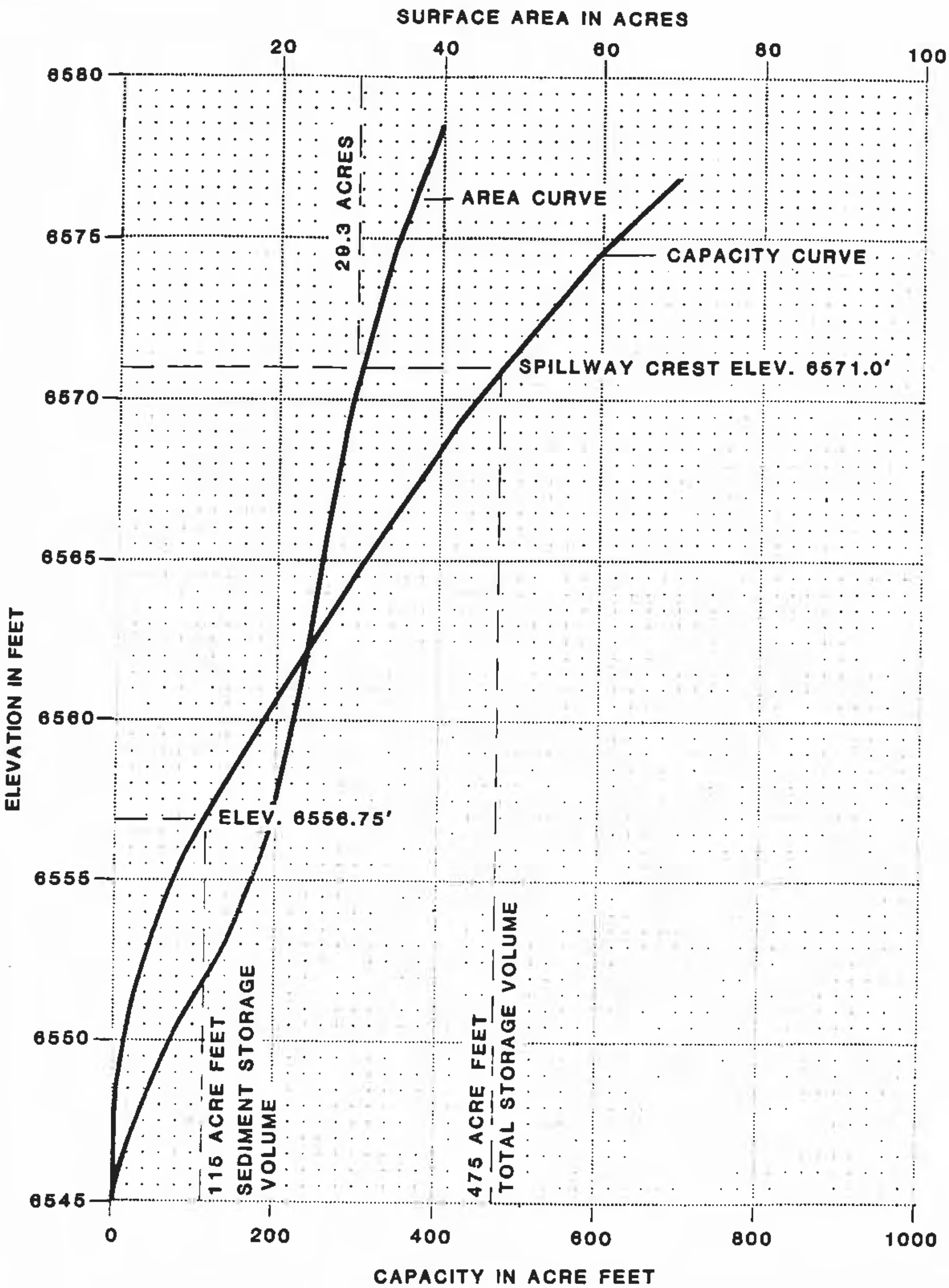
BY Dames & Moore

Figure 6



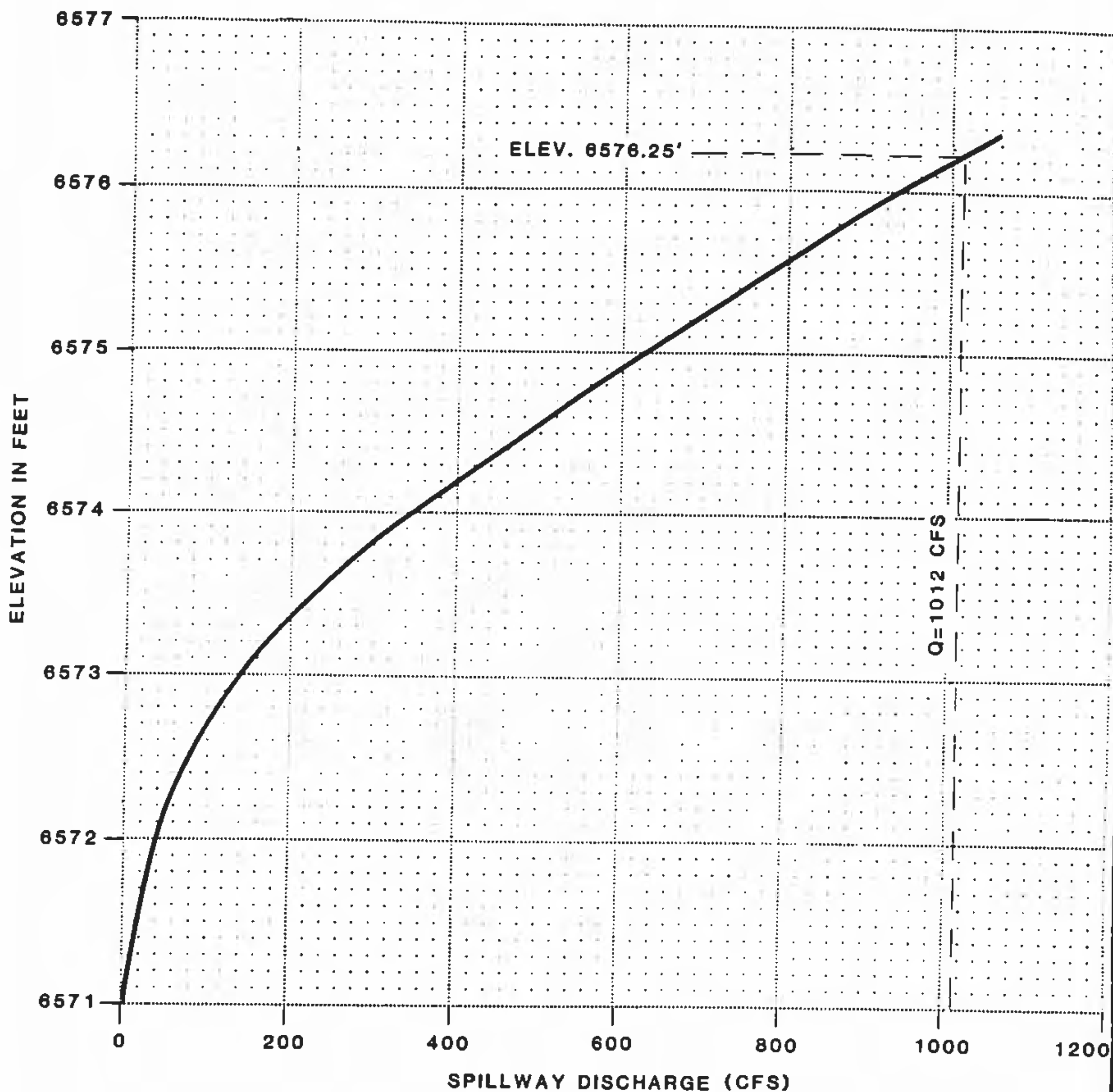
SPILLWAY RATING CURVE
J16-A

BY Dames & Moore Figure 7



VOLUME-ELEVATION
CURVE
REED VALLEY
RESERVOIR

BY Dames & Moore Figure 8



SPILLWAY RATING CURVE REED VALLEY DAM

Table 3-5

HYDRAULIC CHARACTERISTICS OF CHANNEL REACHES

Reach No.	Description	Mannings "n" Left Overbank	Mannings "n" Channel	Mannings "n" Right Overbank	Length (ft)	Slope (ft/ft)	Maximum Ground El. (ft)
A - Channel entering J16-A Reservoir							
1	Between Sedimentation Structures J28-B and J28-C	0.05	0.04	0.05	1350	0.051	6840.0
2	Between Sedimentation Structures J28-C and J28-D	0.05	0.04	0.05	1850	0.013	6810.0
3	Sedimentation Structure J28-D to Sta. 5+00 J16 Diversion Channel	0.05	0.04	0.05	1950	0.023	6780.0
4	Sta. 5+00 to 21+60 J16 Diversion Channel	0.05	0.04	0.05	1660	0.0196	6714.0
5	Sta. 21+60 to 38+50 J16 Diversion Channel	0.05	0.04	0.05	1690	0.01	6680.0
6	Sta. 38+50 to 57+50 J16 Diversion Channel	0.05	0.04	0.05	1900	0.021	6640.0
B - Channel entering Reed Valley Reservoir							
1	Between Sedimentation Structure J28-G and Sta. 187+30 on Reed Valley Diversion Channel	0.05	0.04	0.05	1830	0.042	6790.0
2	Sta. 187+30 to 162+50 on Reed Valley Diversion Channel	0.05	0.04	0.05	2480	0.017	6716.0
3	Sta. 162+50 to 99+00 on Reed Valley Diversion Channel	0.05	0.04	0.05	6350	0.0147	6670.0

3.3 DESCRIPTION OF ANALYSES

Using the aforementioned information, dam-break floods for Sedimentation Structures J28-B, J28-C, and J28-D have been computed and the resulting hydrographs have been combined and routed through the channel up to Dam J16-A and thereafter through J16-A reservoir using the HEC-1 computer program (USACE, 1981). Copies of the computer outputs for Scenarios 1 and 2 defined in Table 2-1 are included in Appendices A and B, respectively.

Similarly, the dam-break floods for Scenarios 1 and 2 for Sedimentation Structure J28-G have been computed and the resulting hydrograph has been routed through the channel to Reed Valley Dam and thereafter through the Reed Valley reservoir using the HEC-1 computer program (USACE, 1981). Copies of the computer outputs for this case for Scenarios 1 and 2 are included in Appendices C and D, respectively.

Results of the above-mentioned analyses, along with those obtained by the approximate methods described in Section 3-1, are presented in Section 4.0.

4.0 RESULTS AND CONCLUSIONS

4.1 RESULTS

Table 4-1 show the peak flows at different locations of the downstream channel, and the peak outflows and stages for the J16-A Reservoir given by the HEC-1 computer program simulating Scenarios 1 and 2 of simultaneous breaches in Sedimentation Structures J28-B, J28-C, and J28-D. The peak flows at different locations of the Reed Valley Diversion Channel and its tributary (the natural channel downstream of Sedimentation Structure J28-G) and the peak outflows and stages for the Reed Valley Reservoir due to the two postulated dam-break scenarios, are also shown in Table 4-1.

Table 4-1

ESTIMATED PEAK FLOWS AND RESERVOIR STAGES

Reach	Peak Outflows (cfs) Scenario 1	Scenario 2
A - J16-A Watershed		
J28-B	990	2,142
Reach 1	968	1,760
J28-C	989	1,969
Reach 2*	1,156	2,349
J28-D	1,083	1,960
Reach 3**	1,673	3,200
Reach 4	1,690	2,869
Reach 5	1,575	2,946
Reach 6	1,614	2,693
J16-A Dam	771	974

(Scenario 1) Peak Stage at J16-A Dam = 6636.06 ft
Freeboard = 3.94 ft
(Scenario 2) Peak Stage in J16-A Dam = 6636.19 ft
Freeboard = 3.81 ft

Reach	Scenario 1	Scenario 2
B - Reed Valley Watershed		
J28-G	1,343	2,839
Reach 1	1,260	1,952
Reach 2	1,196	1,671
Reach 3	736	856
Reed Valley Dam	502	529

(Scenario 1) Peak Stage at Reed Valley Dam = 6571.32 ft
Freeboard = 7.68 ft
(Scenario 2) Peak Stage at Reed Valley Dam = 6571.34 ft
Freeboard = 7.66 ft

*Combined flows from breaches in Sedimentation Structures J28-B and J28-C.
**Combined flows from breaches in Sedimentation Structures J28-B, J28-C, and J28-D.

A review of the estimated peak stages and freeboards for the J16-A and Reed Valley Dams shown in Table 4-1 indicates that these dams can safely pass the dam-break flood waves resulting from accidental breaches in the sedimentation structures located in their respective watersheds.

The approximate methods described in Section 3.1 were also used to estimate the peak outflows from postulated breaches in the sedimentation structures in each watershed. For the sake of comparison, the results of these computations for both scenarios are summarized in Table 4-2.

Table 4-2

ESTIMATED PEAK FLOWS AT BREACH LOCATIONS
(cfs)

Method of Analysis	Scenario 1				Scenario 2			
	J28-B	J28-C	J28-D	J28-G	J28-B	J28-C	J28-D	J28-G
HEC-1	990	989	1,083	1,343	2,142	1,969	1,960	2,839
USACE (1977)	3,478	947	1,742	3,477	7,634	2,103	3,775	8,075
State of California (1977)	1,046	217	380	1,228	1,135	253	429	1,430
Simplified Dam-Break Model	1,173	692	950	1,490	2,518	1,792	2,137	3,571

The results given by different methods vary widely and those given by the HEC-1 computer program lie between the maximum and minimum estimated values. As stated previously, the USACE (1977) method assumes instantaneous failure and the State of California (1977) method is purely empirical. The results of the HEC-1 and Simplified Dam-Break model are quite close. Both these methods take the gradual development of the breach into account and are based on generally accepted equations of flow through breach openings. Therefore, the results of the HEC-1 computer program used in this study are considered reasonable.

4.2 CONCLUSION

The MSHA Dams J16-A and Reed Valley have adequate storage and spillway capacities to safely discharge the dam-break flood waves resulting from accidental breaches in the sedimentation structures in their respective watersheds.

It should be noted that the mechanisms hypothesized to induce breaches in the sedimentation structures are extremely conservative and highly unlikely. These conservation assumptions include:

1) Continued blockage of the spillways causing water levels to fill to the embankment crests. This condition could only occur if the sedimentation structures are left unattended for extended periods of time.

2) That the MSHA Dams J16-A and Reed Valley are full to their respective spillway crests when the dam-break flood wave arrives.

3) That the sedimentation structures in the J16-A watershed, J28-B, J28-C and J28-D, will fail simultaneously. This event would have an extremely low probability of occurrence.

In view of these assumptions, the results of the analyses presented in this report are considered to be highly conservative.

5.0 REFERENCES

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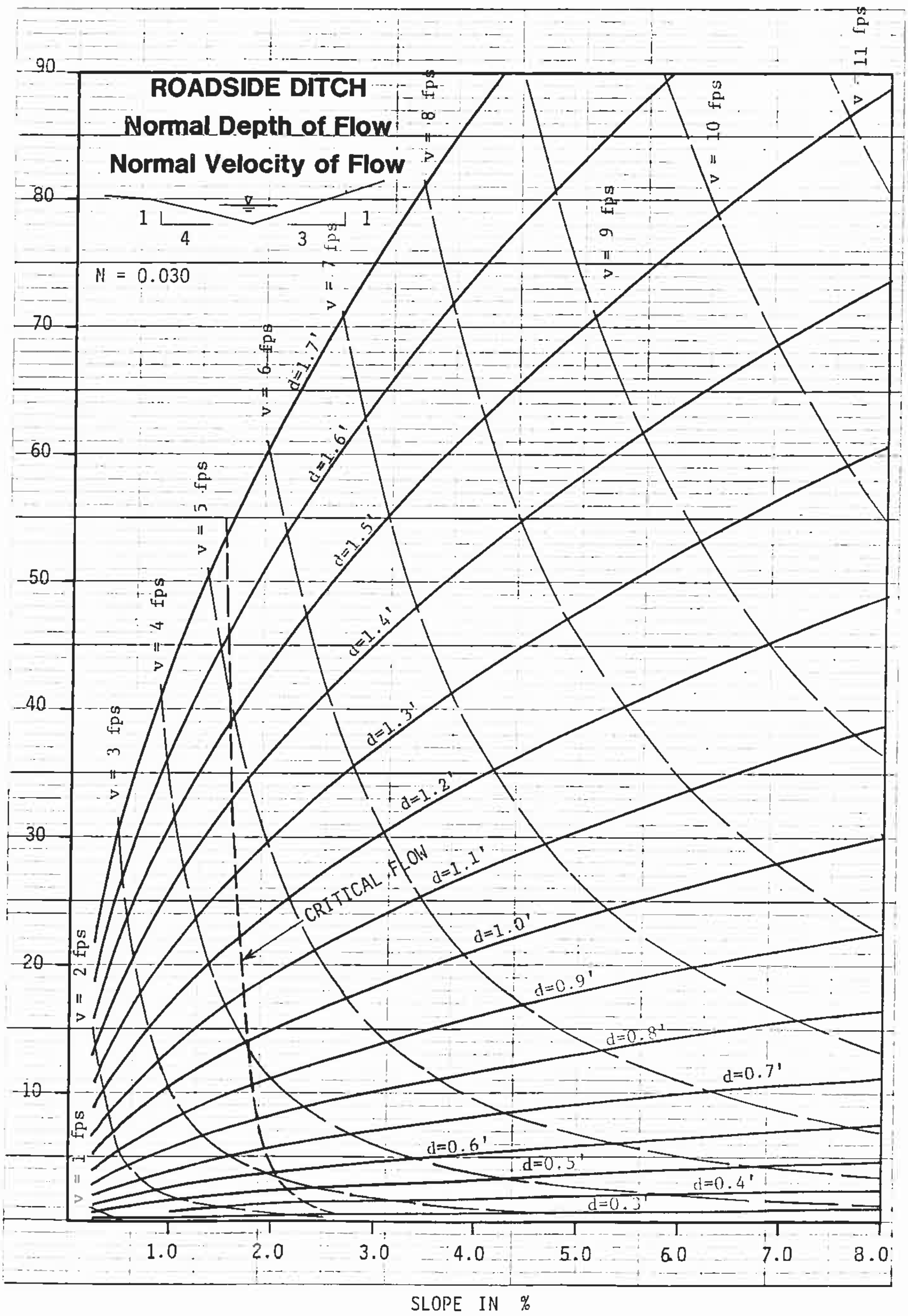
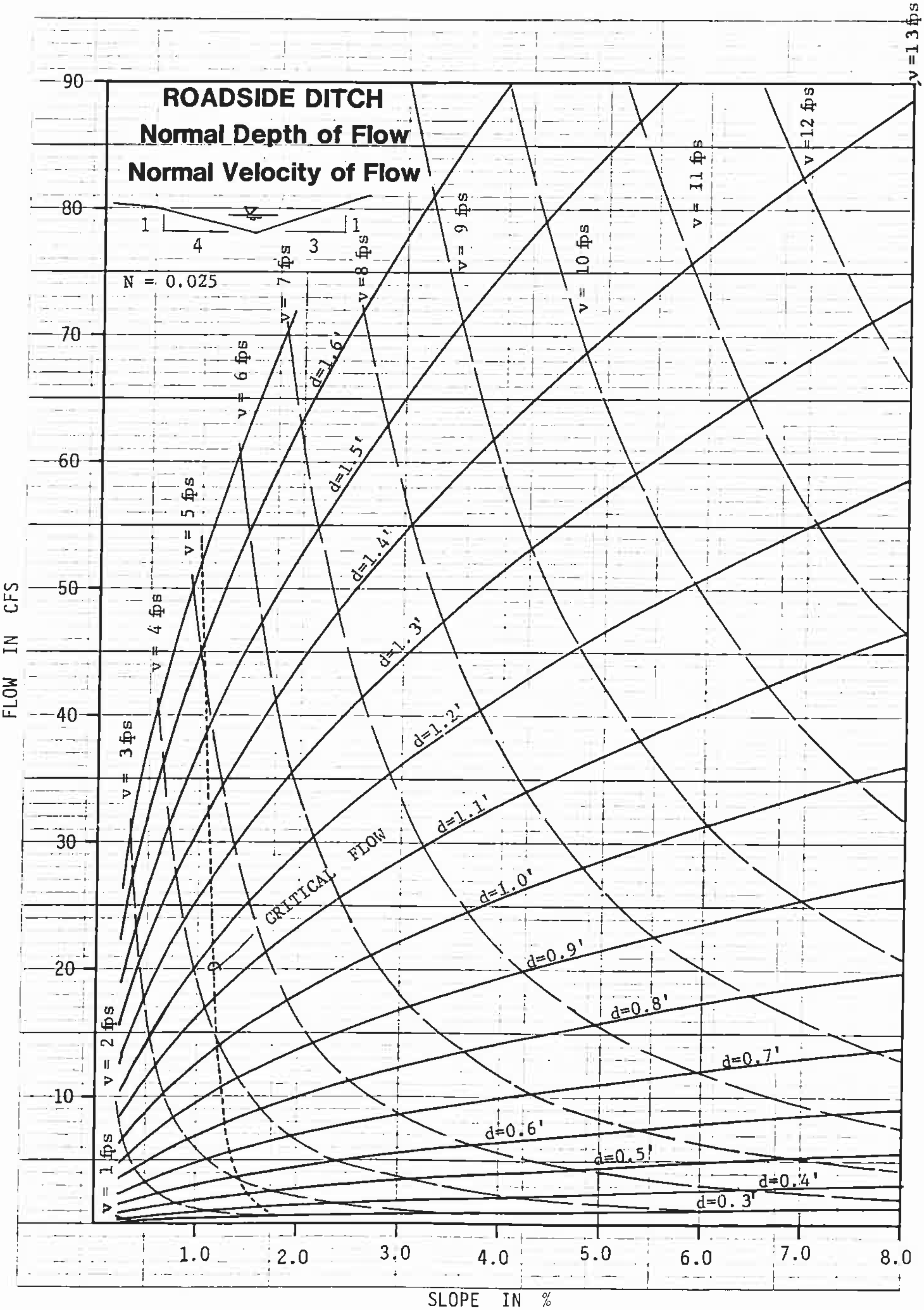
ATTACHMENT M

Roadside Ditches Capacity Charts


ROADSIDE DITCH
Normal Depth of Flow
Normal Velocity of Flow
1
4
3
1
N = 0.030
v = 1 fps
v = 2 fps
v = 3 fps
v = 4 fps
v = 5 fps
v = 6 fps
v = 7 fps
v = 8 fps
v = 9 fps
v = 10 fps
v = 11 fps
d=1.7'
d=1.6'
d=1.5'
d=1.4'
d=1.3'
d=1.2'
d=1.1'
d=1.0'
d=0.9'
d=0.8'
d=0.7'
d=0.6'
d=0.5'
d=0.4'
d=0.3'
CRITICAL FLOW
FLOW IN CFS
90
80
70
60
50
40
30
20
10
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
SLOPE IN %


ROADSIDE DITCH
Normal Depth of Flow
Normal Velocity of Flow
N = 0.025
1
4
3
1
v = 1 fps
v = 2 fps
v = 3 fps
v = 4 fps
v = 5 fps
v = 6 fps
v = 7 fps
v = 8 fps
v = 9 fps
v = 10 fps
v = 11 fps
v = 12 fps
v = 13 fps
d=1.6'
d=1.5'
d=1.4'
d=1.3'
d=1.2'
d=1.1'
d=1.0'
d=0.9'
d=0.8'
d=0.7'
d=0.6'
d=0.5'
d=0.4'
d=0.3'
CRITICAL FLOW
FLOW IN CFS
SLOPE IN %
10
20
30
40
50
60
70
80
90
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0

ATTACHMENT N

Geotechnical Inspection Report -
Haul Roads and Conveyor Beltline

GEOTECHNICAL INSPECTION REPORT

Haul Roads and Conveyor Beltlines

Kayenta and Black Mesa Coal Mines

Navajo County, Arizona

for

PEABODY COAL COMPANY

Dames & Moore
10139-011-22

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1.0 INTRODUCTION

This report presents the results of geotechnical inspections completed for the two main haul roads and the conveyor beltline at Peabody Coal Company's Kayenta and Black Mesa Coal Mines in Navajo County, Arizona. The inspections were conducted to determine compliance with the Office of Surface Mining (OSM) Regulations 30 CFR, Parts 780.37, 816.150, and 816.151.

For purposes of the inspections, the haul roads have been designated the Black Mesa Haul Road and the Kayenta Haul Road. The Black Mesa Haul Road provides the main coal haulage access to the coal resource areas and facilities along the western and southern parts of the coal leases. The Black Mesa Haul Road, together with branches and access to ramps of active open pits, is approximately 12.22 miles (64,500 feet) in length. The Kayenta Haul Road provides coal haulage access to the coal resource areas and facilities along the northern and eastern parts of the coal leases. The total length of the Kayenta Haul Road, including branches and access to ramps, is approximately 18.02 miles (95,000 feet).

The conveyor beltline consists of nine segments comprising a total of about 15.72 miles (83,000 feet) and transports coal from the Kayenta mine facilities near J-28 to the silos at the rail loading site. The beltline was constructed in three phases: the pre-law phase from the silos to the N7/8 area was constructed in the mid 1970s; Phase I from the N7/8 to N14 area was built in 1982; and Phase II from the N14 to J28 area was built in 1983.

The locations of the haul roads in relation to existing facilities are shown on Plate 1A, Site Plan, Haul Roads. The location of the conveyor beltline is shown on Plate 1B, Site Plan, Conveyor Beltline.

2.0 PURPOSE AND SCOPE

The purpose of the inspections was to observe the existing conditions of the cuts and fills along the haul road and conveyor beltline alignments and to evaluate the stability of the haul road and conveyor beltline against the performance standards set forth in 30 CFR, Parts 780.37, 816.50 and 816.51. More specifically, the performance standards require that all embankment slopes have, at a minimum, a static factor of safety of 1.3.

To achieve this purpose, the following scope of work was accomplished:

- A review of pertinent records in Peabody Coal Company's site files, including topography, design drawings, inspection reports and construction records.
- A detailed reconnaissance of each alignment by a Dames & Moore senior geotechnical engineer during which lengths, widths, heights and slopes of all embankments were measured and signs of distress were recorded.
- A limited drilling program of selected road embankment fills and subsequent laboratory testing to evaluate the general characteristics of the materials used to construct the fills.
- Engineering analyses to evaluate stability of slopes.
- Preparation of a remedial compliance plan for slopes that do not meet the minimum performance standards for slope stability.

3.0 SITE DESCRIPTION

3.1 GENERAL SURFACE CONDITIONS

The mine site is located on Black Mesa, a moderately dissected highland within the Colorado Plateau Physiographic Province. The surface generally slopes gently to the southwest; drainage is also to the southwest by Moenkopi Wash and its tributaries. Overall relief within the mine site area ranges from about elevation 8100 feet along the rim of the mesa to about elevation 6150 feet where Moenkopi Wash exits the leasehold. Local relief between upland areas and the bottoms of adjacent washes is generally less than 250 to 300 feet.

3.2 GENERAL SUBSURFACE CONDITIONS

Throughout most of the site, the bedrock units exposed in cuts and as outcrops belong to the Wepo Formation which is part of the Upper Cretaceous Mesa Verde Group. The Wepo Formation consists of a series of thickly interbedded siltstones, mudstones, sandstones and coal. The siltstones and mudstones weather to low- to medium-plastic clayey soils, forming gentle yet extensively eroded slopes. The sandstones vary in competence, forming cliffs in areas where the sandstone is firmly cemented and weathering to slopes where it is weakly cemented.

Overburden soils mantling the bedrock consist of colluvium and materials from residual weathering on slopes and on the uplands and recent alluvium filling the washes. The colluvial and residual weathered materials vary from clay to sandy gravel depending on the parent material. The alluvial soils are predominantly silty and clayey sands with interbeds of platey gravel.

4.0 FIELD INSPECTION OF HAUL ROAD AND CONVEYOR BELTLINE ALIGNMENTS

4.1 SUMMARY OF INSPECTION RESULTS

In general, the 30.24 miles of haul roads and 15.72 miles of conveyor beltline are in good shape with only three or four major items that require remedial actions. These items fall into the category of small slope failures or slumps, possible settlement of conveyor beltline trestle footings and one or two cases of severe erosion which may lead to potential instability of embankment slopes. The remainder of the observations are in the category of routine and/or periodic maintenance tasks such as drainage ditch erosion, raveling and/or minor sloughing of slopes, erosion of slopes around conveyor footings and poorly developed drainage ditches.

General and specific inspection items are detailed in the following section and on Plates 2A through 2D; recommended remedial actions are discussed in the remedial compliance plan section of this report.

4.2 INSPECTION PROCEDURES

Field inspection of the haul roads and conveyor beltline was accomplished between August 29 and September 11, 1985 by a senior geotechnical engineer from Dames & Moore. Inspection procedures consisted of the following steps:

- a review of pertinent records and maps,
- a visual inspection of the haul road and conveyor beltline alignments,

- measurements of relevant dimensions and slope angles,
- notation of observed evidence of embankment distress including sloughing, tension cracks, erosion, and other signs of instability, and
- observations of drainage systems.

In general, 1 inch equals 400 feet scale maps of the transportation alignments were used to orient the inspection, and all visual observations were noted on these maps. Measurements of embankment slopes, crest widths and heights were made with a hand level, cloth tape and a calibrated rod. Table 4-1 presents the definitions of terms used during the inspection.

Table 4-1

DEFINITIONS OF INSPECTION TERMS

A. EROSION

Rill - less than 12 inches wide or 12 inches deep

Gully - greater than 12 inches wide or 12 inches deep

Minor erosion - rills on less than 25 percent of the surface; no gullies

Moderate erosion - rills on more than 25 percent but less than 50 percent of the surface; gullies on less than 5 percent of the surface

Severe erosion - rills on more than 50 percent of the surface; gullies on more than 5 percent of the surface

B. ROAD CONDITIONS

Good - fresh graveled/recently graded; ruts less than 1/4 inch deep and covering less than 10 percent of the traveled surface; no rills or gullies

Lightly rutted - ruts 1/4 to 1/2 inch deep over less than 25 percent of the traveled surface

Moderately rutted - ruts 1/2 to 1 inch deep over more than 25 percent of the traveled surface

Severely rutted - ruts greater than 1 inch deep

C. DEGREE OF DISTRESS

N - none to insignificant

P - potential or developing distress

Y - existing distress (slumps, undercutting, major settlement, etc.)

M - integrity of structure not threatened, but maintenance recommended

O - beyond scope of study

4.3 DESCRIPTION AND INSPECTION RESULTS OF TYPICAL ROUTE SECTIONS

4.3.1 General Dimensions and Typical Sections

The traveled lanes of the haul roads vary from 36 to 63 feet in width. Where it is planned to walk a dragline between mine areas, road widths increase up to 130 feet, usually by adding a second, untraveled lane to the right-of-way. Roadside drainage is provided by ditches ranging in width from 8 to 20 feet and in depth from less than 6 inches to 4 feet. Major embankment fills are commonly provided with safety berms outside the drainage ditches.

Conveyor beltlines are built on berms ranging from about 14 feet in width where no service road occupies the berm to about 42 feet in width where a service road has been built on either side of the beltline.

Construction of the haul roads and the conveyor beltlines was completed using four distinct typical sections:

1) At-grade construction
2) Cut
3) Cut-and-fill, Type A - longitudinal
4) Cut-and-fill, Type B - transverse or sidehill

These four section types are described in the following sections. Other facilities related to the alignments, including major embankments, trestles, underpasses and drainage, are also described.

4.3.2 At-Grade Construction

At-grade construction comprises those segments of the haul roads and conveyor beltlines where cuts or fills that were constructed to achieve subbase grade are generally less than 3 feet in height. Foundation preparation consists of stripping prior to placement of 1 to 3 feet of compacted subbase for the roads or footings for the conveyor beltline supports.

A summary of our inspection of all the at-grade construction sections along the haul road and beltline alignments is presented on Plate 2A along with a typical cross section to indicate the features of this section. Stationing of the roads and beltlines where this form of construction applies is also presented. In general, it is our opinion that the conditions of the at-grade construction sections of the haul roads and beltline are good; however, maintenance of the drainage ditches is required at a few locations in order to better divert water from the roadbed. Severe erosion, which can be addressed through periodic maintenance, was noted at Station 126+40 and the perimeter slope of the West Bypass.

4.3.3 Cut Slopes

Construction of segments of the haul roads and beltline that involve excavation falls into two categories: rock slopes and soil slopes. Further, cuts are subdivided into excavation to level crests of hills to form platforms and excavation into the slope to reduce the gradient of the alignment. Segments of the alignments involving cut slopes as the predominant construction feature are identified on Plate 2B along with descriptions of salient features of the alignment segments involving cut slopes and a summary of our field inspection.

Slopes excavated in rock range from less than 10 feet in height to in excess of 65 feet. The average inclination of slopes cut in rock ranges from 4:1 (14°) to 1:5 (80°), with localized vertical excavation. The steepness of rock cuts appears to be a function not only of rock competence, but also of available space and inclination of adjacent slopes. As shown on the typical cross section presented on Plate 2B, a gently sloping base is commonly constructed at the toe of excavated slopes between the cut slope and the drainage ditch.

Cut slopes in soil generally have been excavated at an inclination of about 3:1. The cut slopes range up to 40 feet in height, although a few slopes continue to rise above the lower cut at a flatter inclination. As part of site reclamation activities, cut slopes in both rock and soil that are flatter than 2:1 have been revegetated.

No instability or distress was revealed in cut slopes in either rock or soil during the field inspection. Some raveling of slopes along the conveyor beltline between Stations 529+40 and 541+40 and minor to moderate erosion was noted, which can be addressed through periodic maintenance.

4.3.4 Cut-and-Fill

Cut-and-fill construction has been used to build about 55 percent of the total lengths of the haul roads and conveyor beltline. This method of construction involves excavation of high ground or steep slopes and use of the excavated material as fill to raise alignment grade in adjacent depressions. The cut-and-fill construction was divided into two categories for purposes of this inspection: (1) Type A - longitudinal and (2) Type B - transverse.

4.3.4.1 Type A - Longitudinal

The longitudinal cut-and-fill sections (Type A) are completed parallel to the axis of the alignment where it is necessary to smooth out the natural hummocks and swales in the terrain. Material from excavation is pushed into depressions to raise the grade as shown on Plate 2C. This construction method usually results in cut slopes on both sides of the alignment and embankment fills across topographic lows; natural drainage is commonly disrupted by the fills, and culverts are required to provide drainage.

Excavated slopes associated with the longitudinal cut-and-fill sections range from as steep as vertical for rock slopes to as flat as 3:1 for cuts in soils. Embankment fills range up to 45 feet in height. The fills have been constructed by spreading the excavated materials in compacted lifts. In general, the side slopes of the embankment fills in the cut-and-fill sections are no steeper than 3:1. However, some embankment fills exist that have exterior slopes as steep as 1.35:1. Embankment fills with such steep side slopes were generally constructed prior to 1977 or were otherwise approved by OSM.

The results of our field inspection of all the longitudinal (Type A) cut-and-fill sections along the haul road and beltline alignments are presented on Plate 2C. No areas of major instability of Type A cut-and-fill sections were observed during the field inspection; however, small slumps have occurred along the conveyor beltline at Stations 24+60 and 497+00 which should be repaired as recommended in later sections of this report. Minor to moderate erosion was evident on both cut-and-fill slopes, and drainage ditches were discontinuous in some places. However, these problems are not considered to be of major consequence and can be addressed during normal maintenance.

4.3.4.2 Type B - Transverse

The transverse (Type B) cut-and-fill section involves excavation into a sidehill with the excavated materials being pushed out over the slope forming an extension of the excavated bench. The typical cross section, shown on Plate 2B, consists of the level, or slightly superelevated, grade of the alignment flanked by a cut slope on the inboard side and a fill slope on the outboard side.

The interior slopes (excavations) of the transverse cut-and-fill sections are as steep as vertical for competent rock slopes while the exterior slopes of the fills are 3:1 or flatter. Roadside drainage is provided by a ditch constructed at the toe of the excavated slope. Type B cut-and-fill sections result in less disruption of natural drainage than Type A because the fill is built on a side slope rather than across a drainage course.

The results of our inspection of the transverse (Type B) cut-and-fill sections are summarized on Plate 2D. No significant distress or instability of Type B cut-and-fill was noted during the field inspection. Some minor erosion of both cut slopes and fill slopes was evident and the drainage ditches needed to be cleared in a few places; these problems can be corrected during normal periodic maintenance.

4.3.5 Embankments

Haul road crossings of major washes are accomplished by means of major earthfill embankments. Five such embankments exist along the haul road alignments: (1) Black Mesa Haul Road Crossing of Moenkopi Wash, (2) Kayenta Haul Road Crossing of Reed Valley, (3) Kayenta Haul Road Crossing of Moenkopi Wash, (4) Kayenta Haul Road Crossing of Coal Mine Wash, and (5) Kayenta Haul Road Crossing of Yellow Water Canyon. The typical cross-section of each embankment is presented on Plates 3A through 3E, respectively. From one to five CMP culverts are installed at the base of the embankments to provide positive drainage at each crossing. The diameter of the culverts ranges from 54 to 108 inches.

The earthen embankments have been constructed with random fill to heights ranging from 30 to 50 feet; crest widths vary from 107 to 190 feet.

The typical cross section includes safety berms at the edges of the crest, ditches for drainage, and double lane (or provision for double lane) roadway. Side slopes of the embankments range from as steep as 1.3:1 to as flat as 4:1.

No significant evidence of major instability of any of the embankments was noted during our field inspection. However, some shallow surface sloughing and relatively severe erosion existed on the steep slopes of the Kayenta Haul Road Crossings at Coal Mine Wash and Yellow Water Canyon where gullies up to 8 feet deep and 3 feet wide are cut into the fill and tension cracks are evident in the fill. The Black Mesa Haul Road Crossing at Moenkopi Wash showed some shallow surface sloughing, however, the 1.3:1 embankments were the steepest observed slopes. Therefore, these three embankments were selected for a more detailed subsurface investigation and stability analyses which are described in subsequent sections of this report. Results of the stability analyses indicate that the factor of safety against deep-seated failure under static loading conditions for slopes flatter than 1.3:1 exceeds 1.3, which is the minimum factor of safety required by OSM.

4.3.6 Trestles

Overhead crossings and crossings of washes along the conveyor beltline are accomplished with trestle-supported structures. Most commonly, trestles consist of bipod steel pipes or wide-flange beams resting on 2- to 4-foot concrete pedestals. Occasionally, the trestle support consists of a single 12- or 18-inch-diameter steel pipe or, where very high sections occur, four legs consisting of wide-flange beams with cross-bracing. Support spacing is about 60 feet center-to-center. Possible settlement or movement of trestle footings has occurred at Stations 96+20 and 738+20; these trestle supports should be monitored at intervals to verify and document the movements.

4.3.7 Underpasses

Underpasses are associated with roads crossing above the conveyor beltline. The underpasses typically consist of 10-foot-diameter CMP culverts, which provide sufficient room for the beltline, and an access catwalk for inspection and maintenance. Only one underpass is larger; it consists of a 12- by 20-foot elliptical culvert section. Soil cover above the CMP culverts ranges from 18 inches to 4 feet.

4.3.8 Ditches and Culverts

Surface drainage control for the haul roads and conveyor beltlines is provided by ditches and culverts. Hydrologic and hydraulic analyses have been performed by Peabody Coal Company to design the ditches and culverts. These analyses are maintained in Peabody Coal Company's files.

Standard design procedures were reportedly followed to select CMP culvert sections appropriate to specific site requirements. Culverts ranging in diameter from 18 to 108 inches have been installed along the transportation alignments.

The design cross section of a roadside ditch consists of a "v"-notch with a 3:1 limb extending down from the roadbed and a 2:1 to 4:1 limb rising to form the outboard side of the ditch. The design cross section allows for about 1 foot of freeboard during the design 10-year discharge.

Our inspection showed that drainage ditches for the haul roads are generally in good shape with only minor to moderate erosion occurring at some stations. Exact locations where these drainage/erosion problems exist are listed on Plates 2A through 2D. Two factors contribute to the erosion problem in the ditches: (1) on inclined grades there are no provisions for reducing the velocity of flowing water, and (2) outfalls to sedimentation ponds commonly consist of open, unlined channels with down cut or fill slopes. Both factors contribute to severe erosion and gully development. Measures to reduce ditch flow erosion, including straw bales, have been tried with mixed results after erosion has initiated. A further problem involves continuity of ditches at road intersections. At several intersections, ditches end blindly and discharge onto the road.

The drainage system for the conveyor beltline is poor or undeveloped in the pre-law section (silos to N7/8 area) of the beltline and somewhat discontinuous in the Phase I and II sections. Exact locations where these conditions were noted are listed on Plates 2A through 2E. Remedial actions are recommended in later sections of this report.

5.0 FIELD EXPLORATION AND LABORATORY TESTING

5.1 FIELD EXPLORATION

As mentioned previously, field explorations were conducted at three of the major haul road embankments in order to investigate the composition of the fill materials used in construction of the embankments. The three embankments were the Black Mesa Haul Road Crossing of Moenkopi Wash, the Kayenta Haul Road Crossing of Coal Mine Wash, and the Kayenta Haul Road Crossing of Yellow Canyon Wash. These three embankments are the highest of the five haul road crossings and have the steepest slopes. Based on the assumption that quality of construction and material properties were similar in all of the inspected haul road embankments, it was assumed that these three embankments represented the most critical stability conditions.

One boring was drilled at each of these haul road crossings. The drilling was performed with a Mobile B-61 drilling rig supplied and operated by the Jim Winnek Drilling Company. The three borings were completed using hollow stem augers to depths ranging from 41.5 to 58 feet. The locations of the borings are shown on Plate 1A. Representative samples of the various soils encountered in the borings were recovered at 5- to 10-foot vertical intervals by driving a ring sampler through the hollow stem of the auger. The number of blows required to advance the sampler 1 foot using a 140-pound hammer falling 30 inches per blow was recorded for each sample recovered. A more detailed description of the sampling method has previously been provided in Section 3.5 of the General Report. These blow counts provide an indication of the relative density of the materials that were sampled. The samples were returned to Dames & Moore's laboratory for further classification and testing.

The drilling program was completed under the direction of a Dames & Moore field engineer who maintained a continuous log of each boring. The Log of Borings is presented on Plates 4A to 4C and a Key to the Log of Borings is presented on Plate 5. The soils were classified according to the Unified Soil Classification System shown on Plate 6. Ground water was encountered in the borings at the depths shown on the Log of Borings.

5.2 LABORATORY TESTING

All samples recovered from the borings were inspected in the laboratory to confirm the field classification. In addition, laboratory testing was completed to determine moisture content, dry density and particle size distribution of selected soil samples.

5.2.1 Moisture Content and Dry Density Determinations

The moisture content and dry density of selected soil samples were determined as an aid in estimation of their engineering properties and in correlation with other samples. Moisture content was determined in accordance with ASTM D 2216 procedures. The results of the moisture content and dry density determinations are presented on the Log of Borings, Plates 4A through 4C.

5.2.2 Particle Size Distribution

The particle size distribution of a representative sample of the random fill was determined by passing a specimen of the soil through a nested set of standard sieves. The test was completed in accordance with ASTM D422 procedures. The test results are presented on Plate 7, Composite Gradation Curve of Embankment Fill.

6.0 STABILITY ANALYSES

Using data provided by the field inspection, field exploration, and laboratory testing, stability analyses were completed to determine the factor of safety of existing haul road embankments against deep-seated failure. The analyses were performed using the computer program STABL2. STABL2 uses the Modified Bishop Method of Slices in a limiting equilibrium analysis.

Stability analyses were performed on the inlet side of three haul road embankment sections. The sections chosen for analysis are representative of the steepest and highest embankment slopes encountered during the field inspection. Stability analyses were performed for the following embankment sections:

- Black Mesa Haul Road, Moenkopi Wash Crossing (see Plate 3A)
- Kayenta Haul Road, Coal Mine Wash Crossing (see Plate 3D)
- Kayenta Haul Road, Yellow Water Canyon Crossing (see Plate 3E)

Stability analyses were also performed to evaluate surface loading caused by 180-ton mine haul trucks. The Black Mesa Haul Road at Moenkopi Wash Crossing is the steepest roadway embankment section analyzed and was therefore assumed to be a "worst case" analysis for point loading. One and two haul trucks were analyzed passing over the roadway embankment section; the two haul truck analysis had both trucks passing over the embankment simultaneously with a distance of 8 feet between the trucks.

The engineering properties of the embankment materials and alluvial soils that were selected for the purpose of the stability analyses were based on the results of the field investigation and. laboratory testing conducted for this assignment. The results of investigations and laboratory testing for other embankment design and construction projects that have been completed at the Black Mesa and Kayenta Coal Mines were also given consideration in the selection of engineering properties for use in the stability analyses.

One boring was drilled at each of the three haul road locations listed above. The borings and results of laboratory tests on samples from these borings (Borings RB-1, RB-2, and RB-3) suggest that the embankment materials are similar and are typically composed of sandstone and shale rock fragments in a fine silty sandy matrix. In order to estimate typical shear strength properties for the embankment materials, we assumed that the material composition is closer to that of a residual shalestone than a residual sandstone. Based on this assumption, we used the same effective stress strength parameters for the haul road embankment materials as were used for the stability analyses of sediment control structures composed predominantly of residual shalestone material.

The engineering properties of bedrock materials that underlie the embankments were assumed based on our experience and on information and data provided in the literature. A summary of the unit weight and shear strength properties used in the analyses is presented in Table 6-1.

Table 6-1

SUMMARY OF UNIT WEIGHTS AND EFFECTIVE STRESS
SHEAR STRENGTH PARAMETERS USED IN STABILITY ANALYSES

Material Type	Total Unit Weight (pcf)	Friction Angle Angle (degrees)	Cohesion (psf)
Embankment Materials	118	33	200
Sandstone Bedrock	118	25	20,000
Shalestone Bedrock	118	25	20,000

The stability of the haul road embankment sections was analysed under dry conditions. Our discussions with Peabody Coal Company operational personnel indicate that, during the life of these embankment crossings, water has ponded against the slopes on two occasions for only a few hours until the water drained through the culverts. Therefore, it appears extremely unlikely that water would be impounded for a sufficient period to cause deep saturation of the embankment materials. On these rare occasions, any damage to the embankment slopes would be limited to minor sloughing of surficial, saturated material below the waterline and we do not believe that the stability of the slopes would be affected significantly.

The results of the stability analyses are summarized in Table 6-2 and on Plates 8A and 8B. In each case, the "critical" failure surface which we have identified is circular and of sufficient depth to be classified as "significant" (greater than 5-foot depth). The factors of safety calculated for each of the surfaces exceed OSM regulation 30 CFR Part 186.150 (b,9) requirements of 1.3 for static loading conditions. These results are supported by the fact that no major slope instabilities were observed at the haul road crossings.

In determining the influence of one and two 180-ton mine haul trucks, the calculated factors of safety were greater than the "critical" factor of safety. This indicates that the presence of haul trucks does not affect the stability of the roadway embankment section. The results of the stability analyses with one and two haul trucks included as line loads are shown on Table 6-2 and on Plate 8B.

Table 6-2

SUMMARY OF STABL2 STABILITY ANALYSIS RESULTS
FOR DRY SLOPE AND STATIC CONDITIONS

Haul Road	Crossing	Embankment Height (ft)	Embankment Slope	Computed Factor of Safety
Black Mesa	Moenkopi Wash	45	1.3:1	1.43
Black Mesa	Moenkopi Wash	45	1.3:1(one truck)	1.57
Black Mesa	Moenkopi Wash	45	1.3:1(two trucks)	1.83
Kayenta	Coal Mine Wash	58	2.3:1	1.63
Kayenta	Yellow Water Canyon	53	1.7:1	1.69

In the event that the additional haul road embankments are constructed, it would be reasonable to use the results of these stability analyses as a guide when embankment slopes are designed. However, more detailed analyses should be performed if the material to be used for embankment construction is not similar to the predominantly silty combination of residual shalestones and sandstones encountered in the existing embankments.

7.0 REMEDIAL COMPLIANCE PLAN

7.1 GENERAL

In general, there were no signs of major instabilities along the haul roads and conveyor beltline. The control of surface runoff and erosion were the only maintenance deficiencies encountered during the inspection. Erosion of steep and unprotected embankment slopes is to be expected of the highly erodible soils of Black Mesa, and continuous maintenance is needed to prevent erosion from impacting adversely on the haul road and conveyor beltline facilities. For example, ditch discharges have resulted in the development of severe erosion and deep gullying in some locations. Unless the open channels are lined with rock, half-culverts, Fabriform or other suitable erosion protection, the discharge from roadside ditches will continue to cause gully erosion.

It is recommended that straw bales be installed in roadside ditches to control the velocity of flow below the threshold velocity for erosion. For the ditch gradients observed, it is anticipated that spacing of the straw bales should range from about 400 feet for 2 percent grades to less than 100 feet for 6 percent grades. For steeper gradients, it may be more practical to line the ditches with rock and to dissipate flow energy with drop boxes. If remedial measures such as suggested above are not implemented, the erosion can be corrected through regular maintenance, although this may require periodic regrading and reconstruction of the eroded areas to the design lines and grades.

The remedial actions recommended consist of repairing a few small slumps that have occurred in embankment fills. An inventory of areas where existing or potential distress has been noted is listed on Table 7-1. Specific recommendations for the remedial actions are given in the subsequent sections.

Table 7-1

DISTRESS - LOCATION AND REMEDIAL TREATMENT

Route	Location (Station)	Distress	Remedial Treatment	Schedule of Proposed Remedial Work (year after approval)
Black Mesa Haul Road	213+50-225+10 Moenkopi Wash	Potential instability	Erosion and drainage control	1
Kayenta Haul Road	544+20-551+60 Coal Mine Wash	Surface sloughing; severe erosion	Erosion and drainage control	completed-
	Yellow Water Canyon	Potential instability	Erosion control; clear culverts	2
Conveyor Beltline	24+60	Slump at culvert outfall	Buttress with rock	completed-1985
	96+20	Possible settlement of tower footing	Monitor by survey; if movement detected, adjust beltline or underpin footing	No Movement detected-1985
	497+00	Slump in cut slope	Trim and buttress slope as detailed on Plate 13	completed-1985
	529+40-541+40	Raveling of slope; debris slides	Remove debris; gunite and/or anchored wire mesh on slope	completed-1986, ongoing - Routine Maintenance

Table 7-1 (Con't)

DISTRESS - LOCATION AND REMEDIAL TREATMENT

Route	Location (Station)	Distress	Remedial Treatment	Schedule of Proposed Remedial Work (year after approval)
	618+50-623+00	Debris slides	Remove debris; gunite and/or anchored wire mesh on slope	completed-1986 ongoing - Routine Maintenance
	738+20	Possible movement of tower footing	Monitor by survey; if movement detected, replace tower	No movement detected-1985

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7.2 BLACK MESA HAUL ROAD

The inclination of the haul road embankment fill slopes which cross Moenkopi Wash range from 1.3:1 to 1.5:1 (horizontal to vertical). No incipient slope failures were noted during our field inspection and results of the stability analysis conducted during this assignment indicate that embankment slopes of 1.3:1 (horizontal to vertical) have a factor of safety under static loading conditions in excess of 1.3. Since 1.3 is the minimum factor of safety required by OSM's performance standards for haul roads, the existing embankment slopes are stable; however, severe erosion, if not controlled, could lead to steeper slopes which would be unstable.

Severe erosion has occurred at Stations 126+40, 496+20, and the perimeter slope of the West Bypass at the Black Mesa Mine. At each of these locations, it is recommended that the parts of the slope affected by erosion be trimmed, reconstructed to grade, and protected with rockfill. The runoff or flow contributing to the erosion should be controlled with straw bales, silt fences or other suitable means and collected into drains consisting of gravel-filled trenches (French drains), Fabriform blankets, half-culverts or other suitable alternative.

7.3 KAYENTA HAUL ROAD

No incipient slope failures were observed along the 18.02 miles of this alignment, nor along its branches. The cuts and embankments, with few exceptions, have slopes of 3:1 (horizontal to vertical) or flatter. Areas of existing distress and/or potential instability are noted on Table 7-1.

Surficial instability was observed at only one location, the Coal Mine Wash Crossing, where tension cracks and sloughing occurred in the crest at the northeast end of the embankment. Explorations indicated that the embankment consists of a dense to very dense random fill comprised of silty sand to boulder-size fragments of sandstone derived from excavation into the flanks of the wash. The observed instability was related to erosion and sloughing of soils placed close to the angle of repose at the exterior of the slope. The embankment crossing of Yellow Water Canyon along the haul road to the N7 and N8 area has been constructed with side slopes ranging from 1.4 to 1.75:1 (horizontal to vertical); however, no evidence of existing instability was observed.

While there has been no deep-seated instability at either of the embankment crossings, the slopes are very susceptible to erosion. It is not anticipated that a deep-seated failure would occur under normal operating conditions, and buttressing or flattening the slopes is not a requirement. However, the program of regular observation, maintenance and drainage control should be continued to control gully erosion, as discussed in the following section.

The major areas of erosion occur where ditch flow is discharged over embankment or cut slopes through open, unlined channels to the sedimentation structures. Severe cases of gully erosion occur at the Coal Mine Wash and Yellow Water Canyon Crossings, where concentrated runoff has cut steep-sided gullies up to 8 feet deep and 3 feet wide into the fill. At those locations, the sides of the gullies are sloughing and tension cracks are developing parallel to the gullies.

It is recommended that the gullies be trimmed and backfilled with random fill and rock, as shown on Plate 9, to prevent further degradation of the slopes. Filter fabric should be installed between the random fill and rock. As an alternative, the gullies could be backfilled with random fill and a half-culvert, Fabriform or other suitable alternative laid on the surface as a flume to discharge ditch flow to the sedimentation structures.

Erosion of cut slopes and embankments due to general runoff varies from insignificant to moderate. Good surface erosion control appears to have been achieved where the slopes have been mulched. The best results have been achieved where the mulch has been crimped.

At Stations 585+20, 622+60 and 638+60, the road embankment blocks small drainage areas. No outlets have been provided for the drainages, although with improved ditching, storm discharge could be directed into internal impoundment N2-RA. However, this would effectively double the watershed area contributing to N2-RA. This alternative should be reviewed, as well as the alternative to provide culverts under the haul road at these locations.

7.4 CONVEYOR BELTLINE

Along the 15.7 miles of the conveyor beltline alignment only six occurrences of instability were noted. These are summarized in Table 7-1 and discussed below.

A slump is developing adjacent to the culvert outfall at Station 24+60 due to undercutting of the slope. The incipient slump is far enough away from the conveyor beltline that the slump would not affect conveyor operation. The main impact would be disruption of drainage and possible damage to the culvert. It is recommended that the toe of the slump block be buttressed with rockfill and that the channel around the culvert outlet be protected with riprap.

A second slump is developing at Station 497+00 where the conveyor beltline crosses over a road. A tension crack about 25 feet in diameter has developed in the cut slope on the right side of the road near the trestle footing. Horizontal and vertical movement along the tension crack is on the order of 4 inches. Further slippage of this block would potentially undermine the pier support of the conveyor trestle at this location. To stabilize this slope, it is recommended that the slope be trimmed and buttressed with rockfill as shown on Plate 10. Remedial actions have been taken by Peabody Coal Company during preparation of this report.

Extensive cuts into rock slopes have been excavated for the conveyor beltline, especially in the off-lease sections of the beltline where right-of-way limitations are 100 feet. Slope angles vary from 60 degrees to vertical, and excavated slope heights in the immediate vicinity of the beltline reach up to 60 feet. Where shale and mudstone layers are exposed, rapid weathering has resulted in accumulations of cones of debris at the toe of the cut slopes and some local raveling. Debris falls have obstructed the right service road between Stations 529+40 and 541+40. Cleaning of this service road is considered part of the routine maintenance program.

Elsewhere, between Stations 618+50 and 623+00, the debris slope is restrained from encroaching on the beltline by a retaining wall composed of wire mesh supported between wide-flange steel beams. Debris has accumulated to about one-third the height of the retention structure.

To prevent block and debris raveling from weathered cut slopes in rock, it is recommended that the cut slopes be stabilized by application of gunite, by wire mesh spread on the surface of the slope and held in place by rock anchors, wire mesh retaining walls, or by a combination of these methods. If the gunite alternative is chosen, provision must be made for weep holes to prevent buildup of water pressure behind the gunite layer.

The inspection identified locations where movement of trestle support footings was suspected, but could not be verified with the available information. At Station 96+20, settlement of the footing is suspected based on a barely detectable vertical misalignment of the beltline determined by visual inspection. At Station 738+20, apparent twisting of the cross-braced tower indicates a possible movement of an exfoliation block at the rim of the mesa. Before remedial measures can be developed, the amount and rate of movement, if any, at each of these sites should be determined. It is recommended that survey bench marks be established on the concrete footings and beltline frame at these locations. These markers should be surveyed at regular intervals.

East of the N8 Preparation Plant, the conveyor beltline extension to the J28 area has experienced only minor erosion. The steepest grade is about 6 percent, and erosion is limited to minor rills and channels on the service road. Footings for beltline support are individual 12-inch-diameter concrete pedestals extending through the gravel pad into natural ground to a depth of 6 feet.

West of the N8 Preparation Plant to the loadout silos in Long House Valley, erosion of both the service road and beltline foundation varies from minor to severe. Grades along the original beltline alignment reach up to 20 percent in places, and gravel fill or ballast is minimal. Overburden soils obtained adjacent to the beltline have been used extensively for grading the alignment. These soils are susceptible to erosion. Beltline support footings are concrete ties spanning the width of the beltline. Erosion along the beltline has undermined and exposed the base of the concrete ties at several locations. In 1986, Peabody Coal Company plans to replace the concrete ties with 12-inch-diameter by 6-foot-deep concrete pedestals.

Progressive erosion of fill embankments also threatens to undermine portions of the alignment. It is recommended that, to reduce erosion, the section of the beltline alignment between Stations 549+50 and 634+20 and from Stations 745+50 to 827+50 be trimmed and reballasted with 12 inches of gravel to cover the top of the ties with at least 6 inches of ballast. Severely eroded side slopes of embankment fills should also be regraded and protected with rockfill.

One of the main contributing factors of the severe erosion of the pre-law portion of the conveyor beltline is the poorly developed runoff control. Drainage ditches are minimal along the toes of excavated slopes, and runoff flows over the entire width of the right-of-way. The runoff concentrates along depressions in the alignment, aggravating the erosion. Therefore, it is recommended that, in addition to the reballasting of the beltline surface, drainage ditches be excavated and maintained along the edge of the service road. The discharge from the ditches should be carried down embankment slopes either in rock-lined channels, half culverts, Fabriform blankets or other suitable alternatives.

7.5 TRANSFER STATIONS

The conveyor beltline is composed of 10 segments varying in length from 5,000 to 14,000 feet. At the articulation between each segment is a transfer station containing the machinery and beltdrive for the next segment of beltline. The transfer stations are listed on Table 7-2.

Table 7-2

INVENTORY OF CONVEYOR BELTLINE TRESTLES

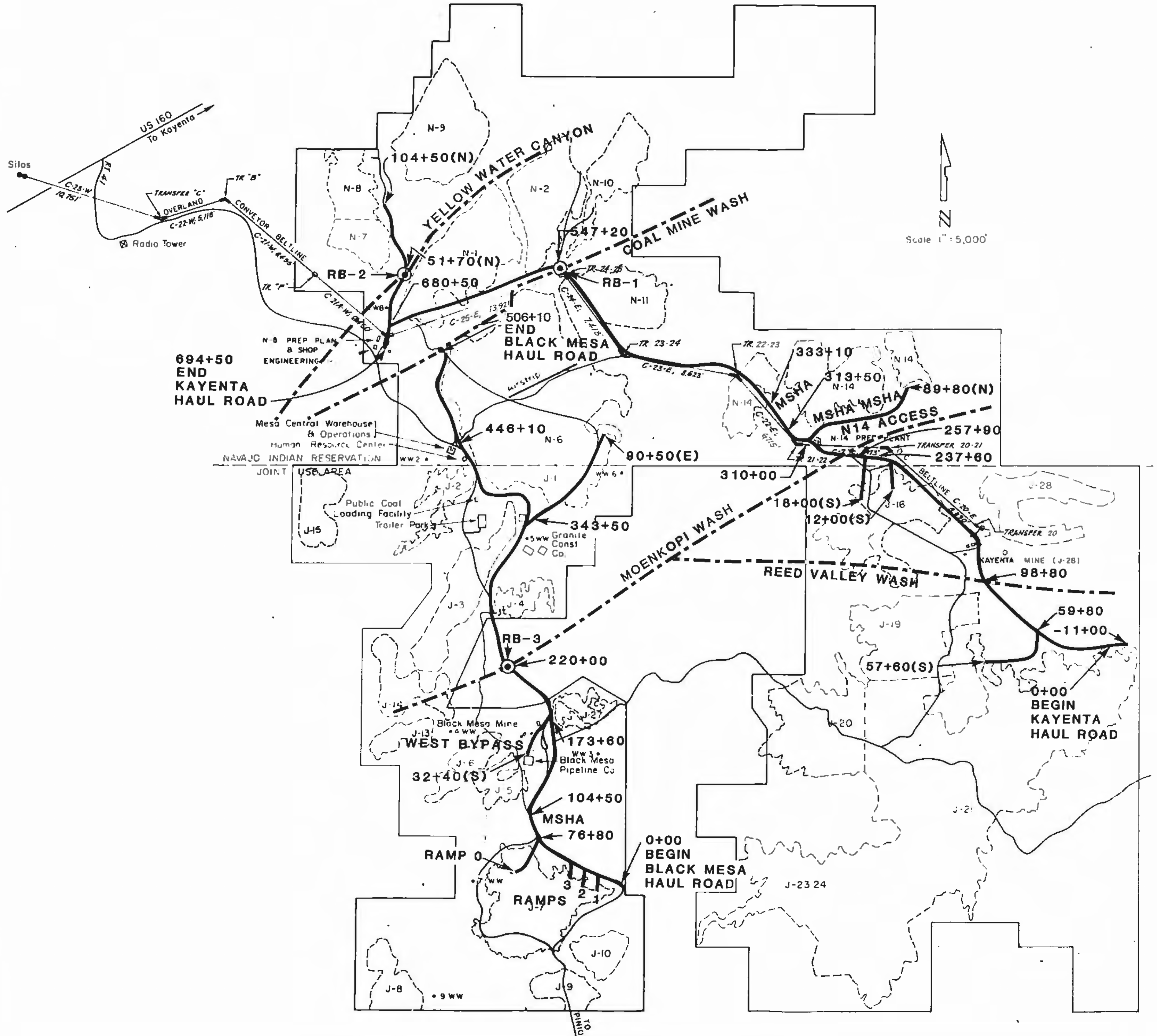
Interval (Station to Station)	No. of Towers	Condition of Footings	Distress
94+80- 99+90	5	Good	None; possible settlement of #2 tower
432+70-435+50	3	Good	None
495+20-500+40	6	Good	Slump 3' from #1
513+30-525+40	17	Good	None
544+10-547+10	1	Fair to Good	Partial undercutting of abutment
730+60-745+50	7	Fair to Good	Possible movement #2 footing
779+40-783+10	1	Good	Localized gully, slough east abutment
809+90-819+50	42	Good	None
827+50-838+10	7	Good	None

Note: For location of Stations, see Plate 1B.

The foundation for each transfer station has been developed by cut-and-fill, with a base fill of granular material. The foundation distress is the same at each transfer station. Uncontrolled runoff of washdown water from cleaning equipment and vehicles softens the base and subbase materials, resulting in potholes, and causes erosion and gully formation in the driveway and yard areas.

The most serious development of this type of distress is at the transfer station at Station 549+50. The facilities at this location consist of feeder conveyors as well as the main beltline, and have been constructed on three levels with two intervening cut slopes. Runoff of washdown water from the upper levels has undercut the concrete abutment of one of the feeder lines, and retaining walls have been built to stabilize the cut slopes.

It is recommended that at each transfer station the drainage be upgraded to collect washdown water and to discharge directly to a sedimentation structure. The drainage should include an asphaltic apron around the concrete slabs of the transfer structure. The apron should be sloped toward one or more catch basins, which should be connected to a buried drain pipe leading to the sedimentation structure. The outfall of the drain pipe should be within 5 feet of the ultimate high water level of the pond to prevent unnecessary erosion of the slope. Finally, the rutted surface of the yard area and driveway should be regraded and resurfaced with gravel.

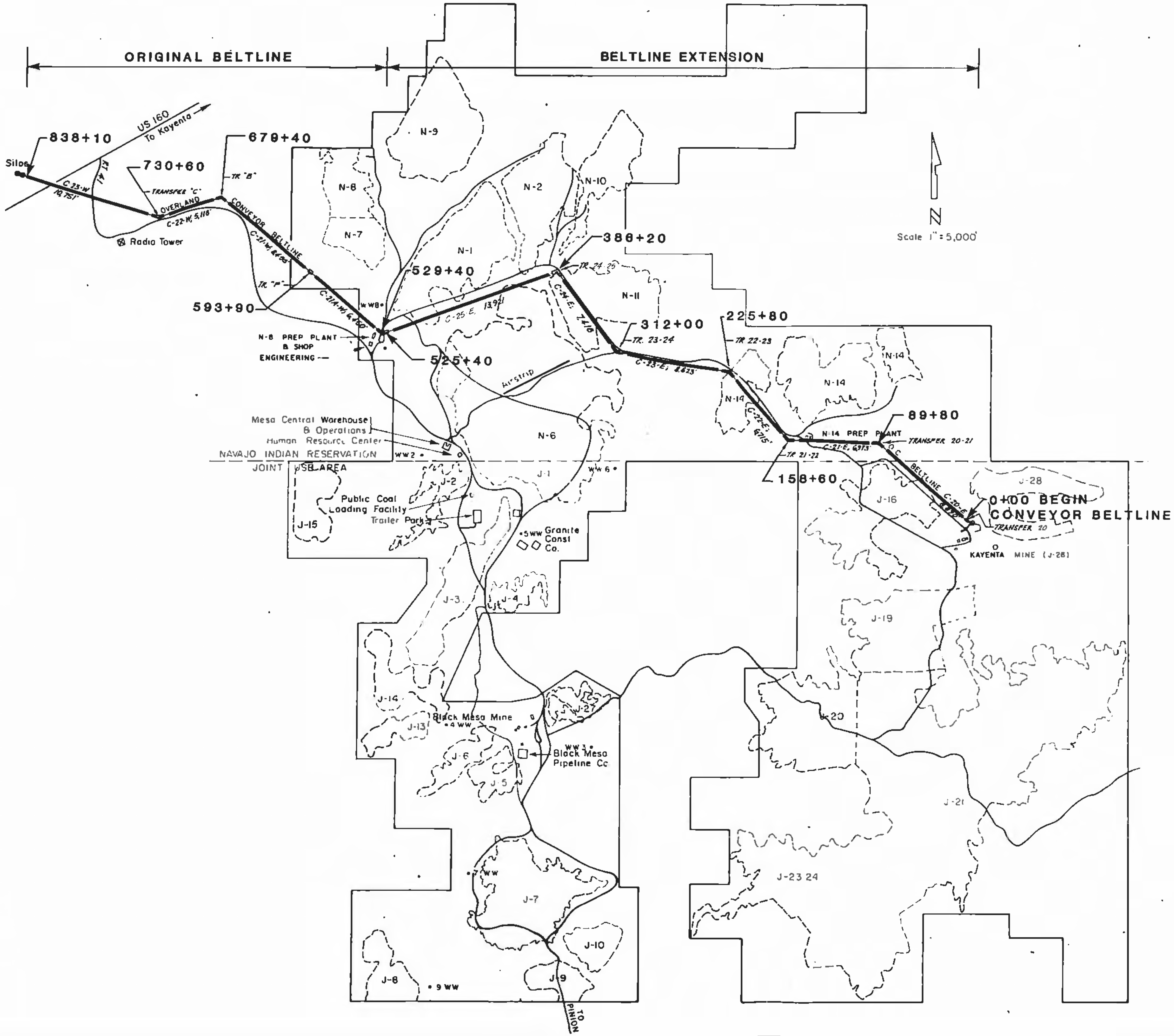


LEGEND

⊙ BORING LOCATION

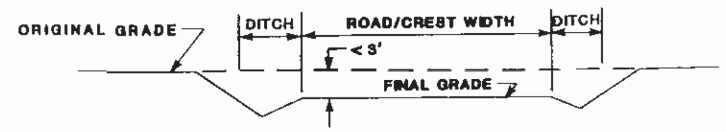
SITE PLAN
HAUL ROADS

BY **Dames & Moore** Plate 1A

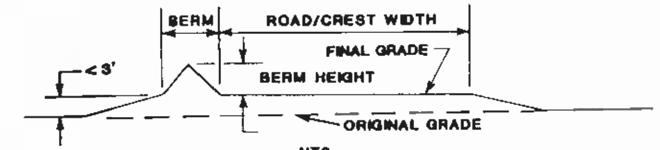


SITE PLAN
CONVEYOR BELTLINE

BY **Dames & Moore** Plate 1B



NTS
TYPICAL AT-GRADE CUT



NTS
TYPICAL AT-GRADE FILL

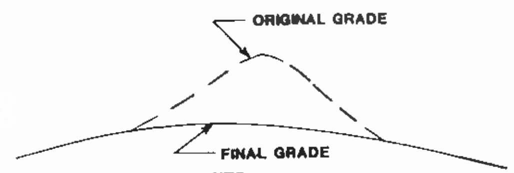
Route	Interval	Road/Crest Width (ft)	Ditch Width Left (ft)	Ditch Width Right (ft)	Berm Height Left (ft)	Berm Height Right (ft)	Conditions: Road/Crest	Conditions: Ditch/Drainage	Degree of Distress
Black Mesa Haul Road	0+00- 21+60	37	N.A.	N.A.	N.A.	N.A.	Lightly rutted	N.A.	N
	21+60- 46+40	45	12	6.5	N.A.	N.A.	Good to lightly rutted	Good to minor erosion	N
	104+50-153+30	63 - 71	12.5	7.5	N.A.	2 - 3	Good to lightly rutted	Minor to severe erosion	P
	153+30-173+60	57 - 63	14	12	N.A.	3	Lightly rutted	Minor to moderate erosion	N
	280+50-343+50	58 - 61	16 - 19	17	N.A.	N.A.	Good to lightly rutted	Good to minor erosion	N
Ramp 1	21+60- 12+00(s)	43	8	5	N.A.	N.A.	Good	Good to minor erosion	N
Ramp 2	37+40- 12+00(s)	63	19	19	N.A.	N.A.	Good	Good; but discharges on haul road	N,M-ditch outlet
Ramp 3	46+40- 12+00(s)	45	1	5	N.A.	N.A.	Good	Good to moderate erosion	N
Ramp 0	76+80- 20+50(s)	51	9	12	N.A.	N.A.	Good	Minor to moderate erosion	N
West Bypass	173+60- 10+20(s)	57	10	10	N.A.	4.5	Good to lightly rutted	Good to minor erosion	N
West Bypass	10+20(s)-19+90(s)	50	N.A.	N.A.	N.A.	N.A.	Lightly to moderately rutted	None: contributes to road distress	P-severe road erosion
Kayenta Haul Road	219+60-257+90	63	14	12	N.A.	N.A.	Good to lightly rutted	Good to moderate erosion	N
Ramp 19	237+60- 12+00(s)	66	12	17	N.A.	N.A.	Good to lightly rutted	Good to minor erosion	N
Ramp 20	257+90- 18+00(s)	71	10	9	0 - 2.5	0 - 3	Lightly rutted	Minor to moderate erosion	N
Ramp Access	310+00- 67+00(n)	86	20	9	N.A.	3.5- 5	Good to lightly rutted	Good	N
Access N7	58+40(n)-87+70(n)	57 - 70	0 - 12	11 - 15	N.A.	6	Good to lightly rutted	Minor to moderate erosion	N
Conveyor Beltline	186+70-210+60	35	N.A.	N.A.	N.A.	N.A.	Good	N.A.	N
	312+00-318+60	22	N.A.	N.A.	N.A.	N.A.	Good	N.A.	N
	435+50-448+10	35	N.A.	N.A.	N.A.	N.A.	Good	N.A.	N
	476+10-495+20	33	11	17	N.A.	N.A.	Good	N.A.	N
	634+20-669+00	28	N.A.	N.A.	N.A.	N.A.	Moderate erosion of support ties	Poor drainage control	M-tie bedding
	679+40-730+60	33 - 43	N.A.	N.A.	N.A.	N.A.	Good; support ties on rock	Poor drainage control	N
	750+60-779+40	28	20	N.A.	N.A.	N.A.	Good to minor erosion: erodable soils	Minor erosion	N,M-regrading
	801+60-809+90	28	N.A.	N.A.	N.A.	N.A.	Minor erosion of bedding	N.A.	M-regrading
	819+50-827+50	11	N.A.	N.A.	N.A.	N.A.	Good: gravel on erodable soils	N.A.	N

LEGEND
Degree of Distress
N = none
P = potential
Y = existing
M = maintenance required

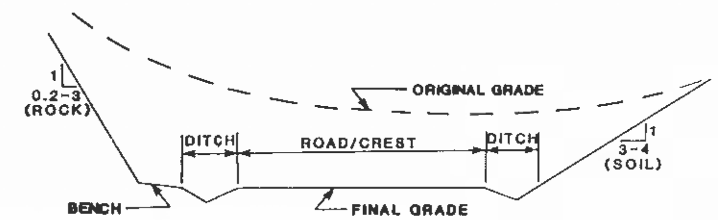
Notes: 1) For location of intervals, see Plates 1A and 1B
2) For description of erosion and road/crest conditions, see Table 4-1

INSPECTION SUMMARY AT-GRADE CONSTRUCTION SECTIONS

BY Dames & Moore Plate 2A



NTS
TYPICAL GRADING CUT



NTS
TYPICAL AT-GRADE CUT

Route	Interval	Road/Crest Width (ft)	Ditch Width		Berm Height		Slope						Conditions			Degree of Distress
							Left			Right						
			Left (ft)	Right (ft)	Left (ft)	Right (ft)	Height (ft)	Slope	Mat.	Height (ft)	Slope	Mat.	Road	Drainage	Slopes	
Kayenta Haul Road	38+80- 88+80	97	12	11	N.A.	N.A.	30	4:1	S/R	20	4:1	S/R	Good	Good	Good	N
	652+20-680+50	56	9	10	N.A.	N.A.	20	4:1	M	40	3:1	M	Good to lightly rutted	Good	Good to minor erosion	N
N8 Access	680+50- 45+80(n)	60	8	12	N.A.	N.A.	25	to vert	R	25	3-4:1	R	Lightly rutted	Good to minor erosion	Good to minor raveling	N
Conveyor Beltline	147+00-154+50	30	N.A.	N.A.	N.A.	N.A.	35	3:1	S/R	30	2-3:1	S/R	Good	N.A.	Minor to moderate erosion	N
	262+60-269+90	22	N.A.	N.A.	N.A.	N.A.	45	3:1	S/R	----	-Grade-	----	Good	N.A.	Minor erosion	N
	286+20-303+10	22	11 - 14	N.A.	N.A.	N.A.	20	3:1	S/R	----	-Grade-	----	Good	Minor erosion	Minor erosion	N
	366+10-380+10	27	8 - 10	N.A.	N.A.	N.A.	65	3:1	S/R	----	-Grade-	----	Good	Minor erosion	Minor erosion	N
	529+40-541+40	25 - 32	N.A.	N.A.	N.A.	N.A.	15	0.2-0.6:1	R	60	0.2-3:1	R	Fair; erosion, tilting	Poorly developed	Raveling and debris slide	P to Y

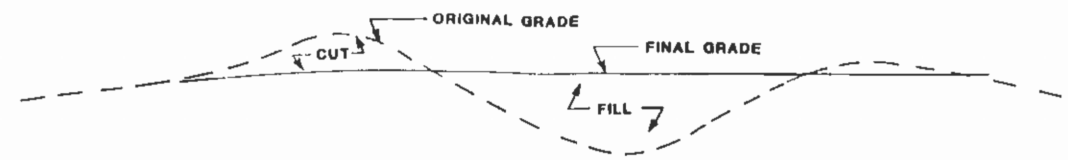
LEGEND
Mat. = material
S = soil
R = bedrock
S/R = soil overlying bedrock
M = mine waste (reclaimed area)

LEGEND
Degree of Distress
N = none
P = potential
Y = existing
M = maintenance required

Notes: 1) For location of intervals, see Plates 1A and 1B
2) For description of erosion and road/crest conditions, see Table 4-1

INSPECTION SUMMARY
CUT SLOPE
CONSTRUCTION SECTIONS

BY Dames & Moore Plate 2B



NT6
TYPICAL PROFILE
CUT AND FILL TYPE A

Route	Interval	Road/Crest Width (ft)	Fill Slopes: Left Height (ft)	Fill Slopes: Left Slope	Fill Slopes: Right Height (ft)	Fill Slopes: Right Slope	Cut Slopes: Left Height (ft)	Cut Slopes: Left Slope	Cut Slopes: Left Mat.	Cut Slopes: Right Height (ft)	Cut Slopes: Right Slope	Cut Slopes: Right Mat.	Ditch Width: Left (ft)	Ditch Width: Right (ft)	Berm Height: Left (ft)	Berm Height: Right (ft)	Conditions: Road/Crest	Conditions: Drainage	Conditions: Slope	Degree of Distress
Black Mesa Haul Road	225+10-263+40	54 - 60	N.A.		35	1.35:1	25	0.8:1	R	20	3:1	R	11	18	N.A.	5	Good; gravel	Good to minor erosion	Good to minor erosion	N
	343+50-409+10	54 - 60	8	1.4:1	12	3:1	12	2:1	M	10	3:1	M	11-17	11-17	6.5	2.5-5	Good	Moderate to severe erosion	Good to minor erosion	N
	446+10-464+10	53 - 56	15	1.5:1	N.A.			N.A.		50	3-4:1	M	10	12	3-5	N.A. 3.5	Good; gravel	Good to minor erosion	Minor to moderate erosion	N
Ramp to N6	343+50-62+00(e)	55 - 57	12	1.4:1	12	1.35:1		Grade			Grade		12-17	5-17	N.A.	5	Lightly rutted	Good to minor erosion	Good	N
Kayenta Haul Road	20+40- 38+40	92	35	4:1	35	4:1	40	4:1	R		N.A.		10	18	N.A.	N.A.	Good	Good to minor erosion	Minor erosion; no berms	N,O
	386+30-544+20	101 - 111	45	2-3:1	45	1.5-3:1	50	3:1	R	40	3:1	R	15	14	N.A.	N.A.	Good to lightly rutted	Good to moderate erosion	Minor erosion	N,M
	626+20-652+20	44	45	4:1	N.A.			Grade			Grade		6	8	N.A.	N.A.	Good to lightly rutted	Good to minor erosion	Good	N
Conveyor Beltline	0+00- 30+10	33	20	3-4:1	20	3-4:1		Grade			Grade		D	D	N.A.	N.A.	Good	Discontinuous; minor erosion	Cracks	P
	71+20- 88+90	33	45	3:1	N.A.			N.A.		45	3:1	R	N.A.	D	N.A.	N.A.	Good	Discontinuous; minor erosion	Minor erosion	N,M
	88+90- 96+90	33	60	3:1	50	2.5:1		N.A.		25	3-4:1	R	N.A.	D	N.A.	N.A.	Good; trestle settlement	Discontinuous; minor erosion	Minor erosion	N to P
	98+70-113+90	41	40	3:1	25	3:1		N.A.			N.A.		N.A.	N.A.	N.A.	N.A.	Good	N.A.	Minor erosion	N,M
	113+90-133+30	44	32	3:1	20	3:1	30	3:1	R	28	3:1	R	D	D	N.A.	N.A.	Good	Discontinuous; minor erosion	Minor erosion	N,M
	172+40-186+70	35	30	3:1	15	3:1	50	3:1	R	0	0	R	D	D	N.A.	N.A.	Good	Discontinuous; minor erosion	Minor to moderate erosion	N,M
	210+60-225+80	35	15	3:1	25	3:1	5	3:1	S	15	3:1	R	D	D	N.A.	N.A.	Good	Discontinuous; minor erosion	Minor erosion	N
	329+80-366+10	27	40	3:1	N.A.		15	2-3:1	R	0	0	R	D	D	N.A.	N.A.	Good	Discontinuous; minor erosion	Minor to moderate erosion	N
	448+10-476+10	34	35	3:1	20	3:1	15	3:1	R	30	3:1	R	D	D	N.A.	N.A.	Good	Discontinuous; minor erosion	Minor erosion	N,M
	500+40-513+30	32	15	3:1	15	3:1		N.A.		23	3:1	M	N.A.	D	N.A.	N.A.	Good	Discontinuous; minor erosion	Minor erosion	N,M
	549+50-593+90	38 - 40	28	1.4-1.5:1	30	1.5:1	25	to vert	R	15	0.6:1	R	N.A.	N.A.	N.A.	N.A.	Fair; erosion of ftgs.	Poor; undeveloped	Minor to moderate erosion; raveling	N to P
	593+90-634+20	28	45	1.4:1	30	1.4-1.5:1	60	to vert	R	50	to vert	R	N.A.	N.A.	N.A.	N.A.	Fair; erosion of ftgs.	Poor; undeveloped	Minor to moderate erosion; raveling	Y
	783+10-801+60	28	10	1.5:1	15	1.5:1	30	0.6:1	R	20	0.6:1	R	D	D	N.A.	N.A.	Good to fair	Poor; undeveloped	Minor erosion	N,M

LEGEND
Mat. = material
S = soil
R = bedrock
S/R = soil overlying bedrock
M = mine waste (reclaimed area)

D = discontinuous

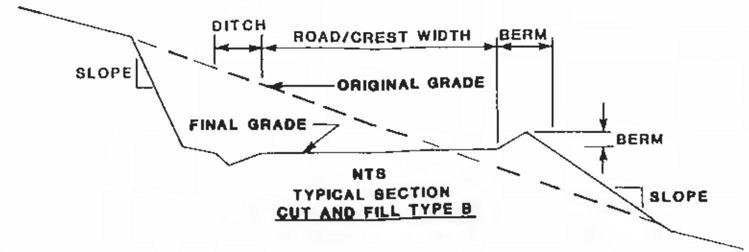
LEGEND
Degree of Distress
N = none
P = potential
Y = existing
M = maintenance required

Notes: 1) For location of intervals, see Plates 1A and 1B
2) For description of erosion and road/crest conditions, see Table 4-1

INSPECTION SUMMARY TYPE A CUT-AND-FILL CONSTRUCTION SECTIONS

BY Dames & Moore

Plate 2C



NTS
TYPICAL SECTION
CUT AND FILL TYPE B

Route	Interval	Road/Crest Width (ft)	Fill Slopes Left Height (ft)	Fill Slopes Left Slope	Fill Slopes Right Height (ft)	Fill Slopes Right Slope	Cut Slopes Left Height (ft)	Cut Slopes Left Slope	Cut Slopes Left Mat.	Cut Slopes Right Height (ft)	Cut Slopes Right Slope	Cut Slopes Right Mat.	Ditch Width Left (ft)	Ditch Width Right (ft)	Berm Height Left (ft)	Berm Height Right (ft)	Conditions Road/Crest	Conditions Drainage	Conditions Slope	Degree of Distress
Black Mesa Haul Road	46+40- 76+80	61	10	5:1	10	4:1	---	Grade	---	---	Grade	---	3-6	N.A.	N.A.	N.A.	Good to lightly rutted	Good to minor erosion	Good	N
	173+60-213+50	59	N.A.		18	1.5:1	---	Grade	---	---	Grade	---	19	12	N.A.	5	Good	Good to moderate erosion	Good	N
	263+40-280+50	61	N.A.		15	1.4:1	---	Grade	---	---	Grade	---	14	17	N.A.	5	Good	Good to minor erosion	Good	N
	409+10-446+10	41 - 47	35	1.4-3:1	N.A.		30	2:1	M	70	1.4:1	M	9	8-10	4-14	N.A.	Good	Good to severe erosion	Raveling, erosion	N to P
	464+10-506+10	48	45	1.4:1	N.A.		---	N.A.	---	50	4:1	M	N.A.	30	8	1.5	Good to lightly rutted	Minor to moderate erosion	Minor erosion	N to P
Access to N6	62+00(e)-90+50(e)	60	N.A.		40	1.35-4:1	25	5:1	M	---	N.A.	---	11	7.5	N.A.	7.5	Lightly rutted	Minor to moderate erosion	Minor erosion	N
West Bypass	19+90(s)-32+40(s)	50 - 100	N.A.		25	1.5-3:1	---	Grade	---	---	Grade	---	N.A.	N.A.	N.A.	N.A.	Good to lightly rutted	None	Severe erosion	P
Kayenta Haul Road	-11+00- 20+40	98 - 103	35	4:1	35	4:1	45	4:1	R	---	N.A.	---	10	23	N.A.	N.A.	Good	Good to minor erosion	Good	N
	111+40-140+30	107	40	4:1	45	4:1	---	N.A.	---	40	4:1	S/R	12	N.A.	3	N.A.	Good	Good	Minor erosion	N
	140+30-161+30	N.A.	N.A.		20	3:1	---	N.A.	---	30	3-4:1	R	N.A.	N.A.	N.A.	N.A.	Good	N.A.	Minor erosion	N
	161+30-219+60	141	35	4:1	35		---	Grade	---	---	Grade	---	12	10	3	N.A.	Lightly rutted	Good to minor erosion	Minor erosion	N
	271+90-298+20	124 - 134	15	3-4:1	10		40	4:1	R	25	4:1	R	11	14	3-5	N.A.	Good to lightly rutted	Good to moderate erosion	Minor erosion	N
	310+00-313+50	58	25	2:1	N.A.		---	Grade	---	---	Grade	---	14	11	N.A.	4	Good to lightly rutted	Good to minor erosion	Minor erosion	N
	333+10-386+30	126	30	3:1	50		50	3-4:1	R	---	N.A.	---	10	12	N.A.	N.A.	Good to lightly rutted	Good to minor erosion	Minor erosion	N
	551+60-569+20	75 - 85	15	4:1	N.A.		---	N.A.	---	70	4:1	M	10	N.A.	N.A.	N.A.	Good to lightly rutted	Good to minor erosion	Minor erosion	N
	569+20-613+60	44	20	4:1	N.A.		---	Grade	---	---	Grade	---	11	10	N.A.	N.A.	Good to lightly rutted	Good to minor erosion	Good	N
	613+60-626+20	36 - 44	42	4:1	N.A.		---	Grade	---	---	Grade	---	N.A.	9	N.A.	N.A.	Good to lightly rutted	Good to minor erosion	Good	N
	680+50-694+50	N.A.	40	1.3-1.5:1	N.A.		---	Grade	---	---	Grade	---	10-20	15	7	N.A.	Good to lightly rutted	Good to moderate erosion	Minor to moderate erosion	N to P
Access to N14	75+20(n)-89+80(n)	98	20	3:1	N.A.		---	N.A.	---	40	3:1	R	11	20	3	N.A.	Good to lightly rutted	Good to minor erosion	Minor to moderate erosion	N
Ramp to N8	87+70(n)-104+50(n)	78	N.A.		30	3:1	15	2:1	M	---	N.A.	---	12	13	N.A.	3-3.5	Lightly rutted	Good to minor erosion	Minor erosion	N
Conveyor Beltline	30+10- 71+20	33	14	4:1	N.A.		---	N.A.	---	235	3:1	R	N.A.	D	N.A.	N.A.	Good	Discontinuous	Minor erosion	N,M
	154+50-160+80	110	60	3:1	N.A.		---	N.A.	---	30	3:1	S	N.A.	D	N.A.	N.A.	Good	Discontinuous	Minor erosion	N
	160+80-172+40	35	15	1.5:1	N.A.		---	N.A.	---	---	Grade	---	N.A.	N.A.	N.A.	N.A.	Good	N.A.	Good	N,M
	225+80-262+60	42	30	3:1	25	3:1	20	3:1	S/R	50	3:1	S/R	D	D	N.A.	N.A.	Good	Discontinuous	Minor erosion	N,M
	318+60-329+80	27 - 48	30	3:1	N.A.		---	N.A.	---	---	Grade	---	N.A.	N.A.	N.A.	N.A.	Good	N.A.	Minor to moderate erosion	N

LEGEND
Mat. = material
S = soil
R = bedrock
S/R = soil overlying bedrock
M = mine waste (reclaimed area)

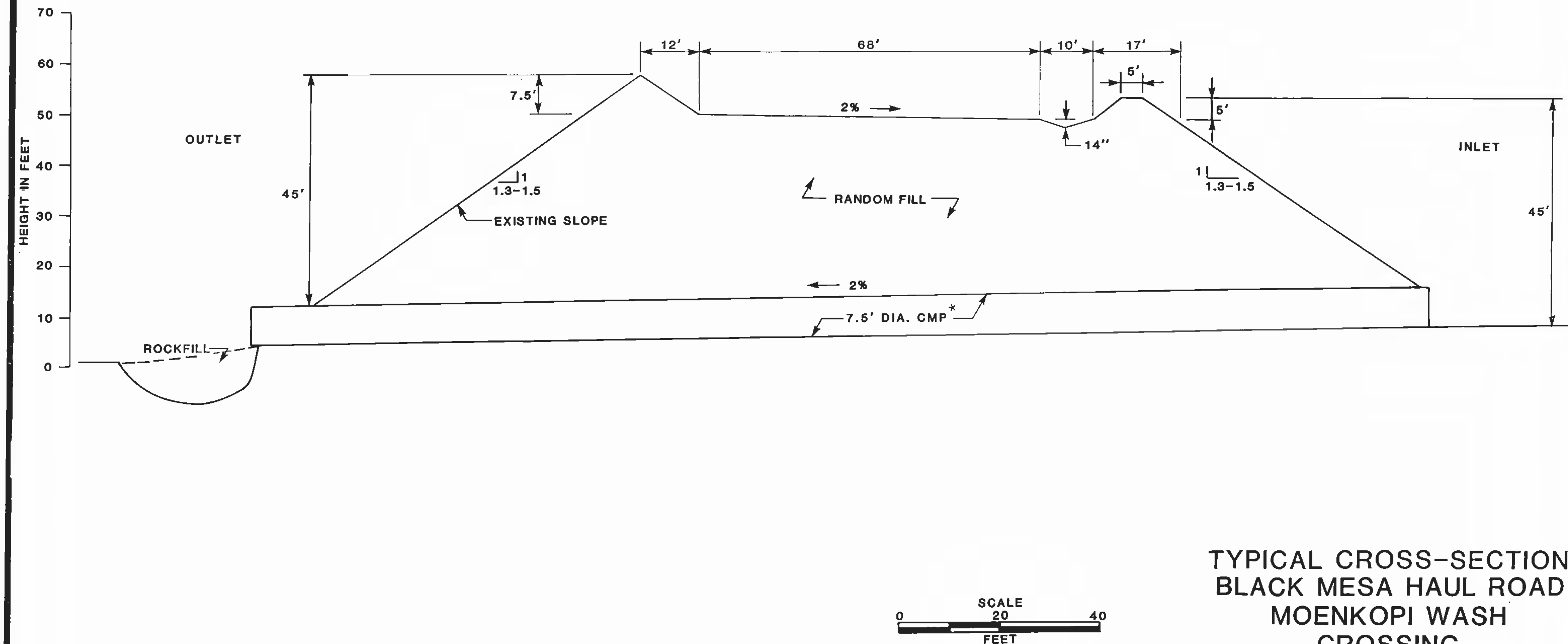
D = discontinuous

LEGEND
Degree of Distress
N = none
P = potential
Y = existing
M = maintenance required

Notes: 1) For location of intervals, see Plates 1A and 1B
2) For description of erosion and road/crest conditions, see Table 4-1

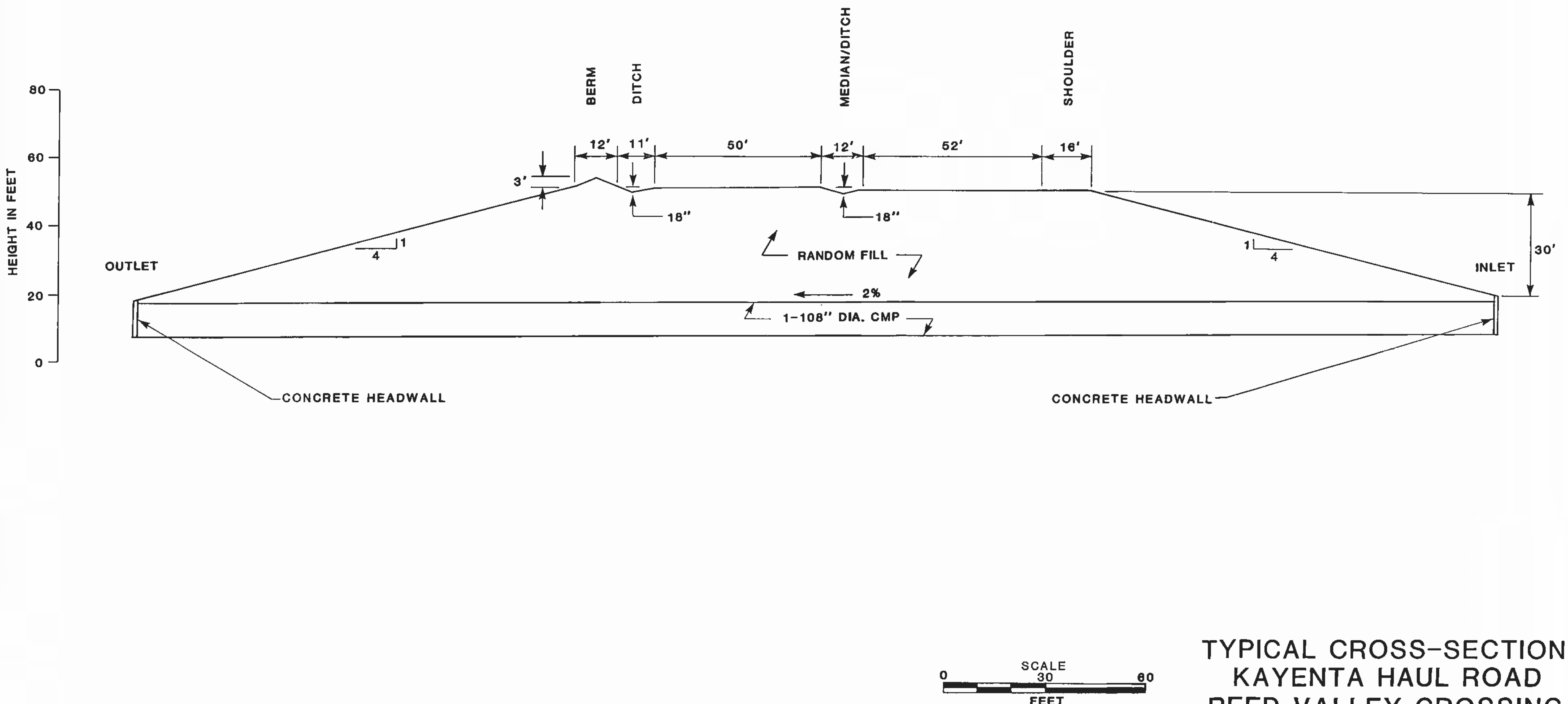
INSPECTION SUMMARY TYPE B CUT-AND-FILL CONSTRUCTION SECTIONS

BY Dames & Moore Plate 2D



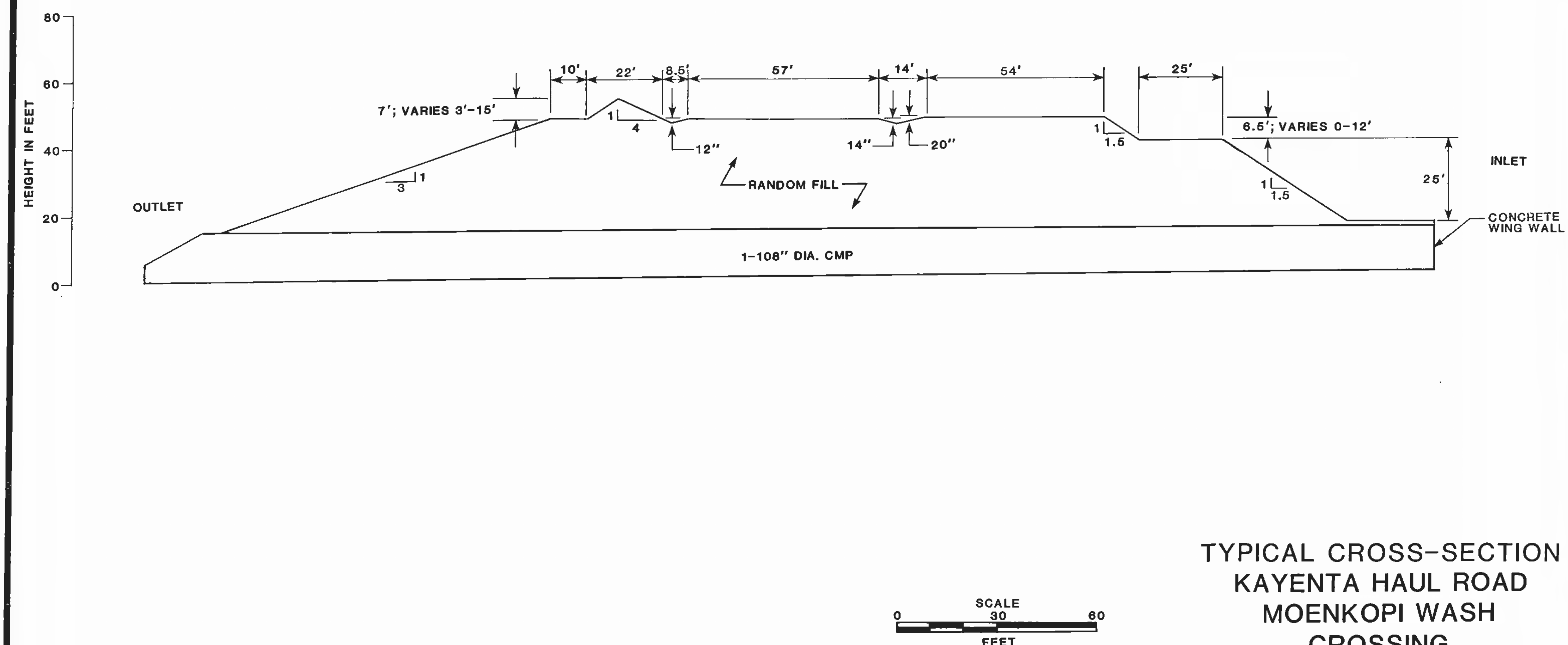
TYPICAL CROSS-SECTION BLACK MESA HAUL ROAD MOENKOPI WASH CROSSING

BY Dames & Moore Plate 3A



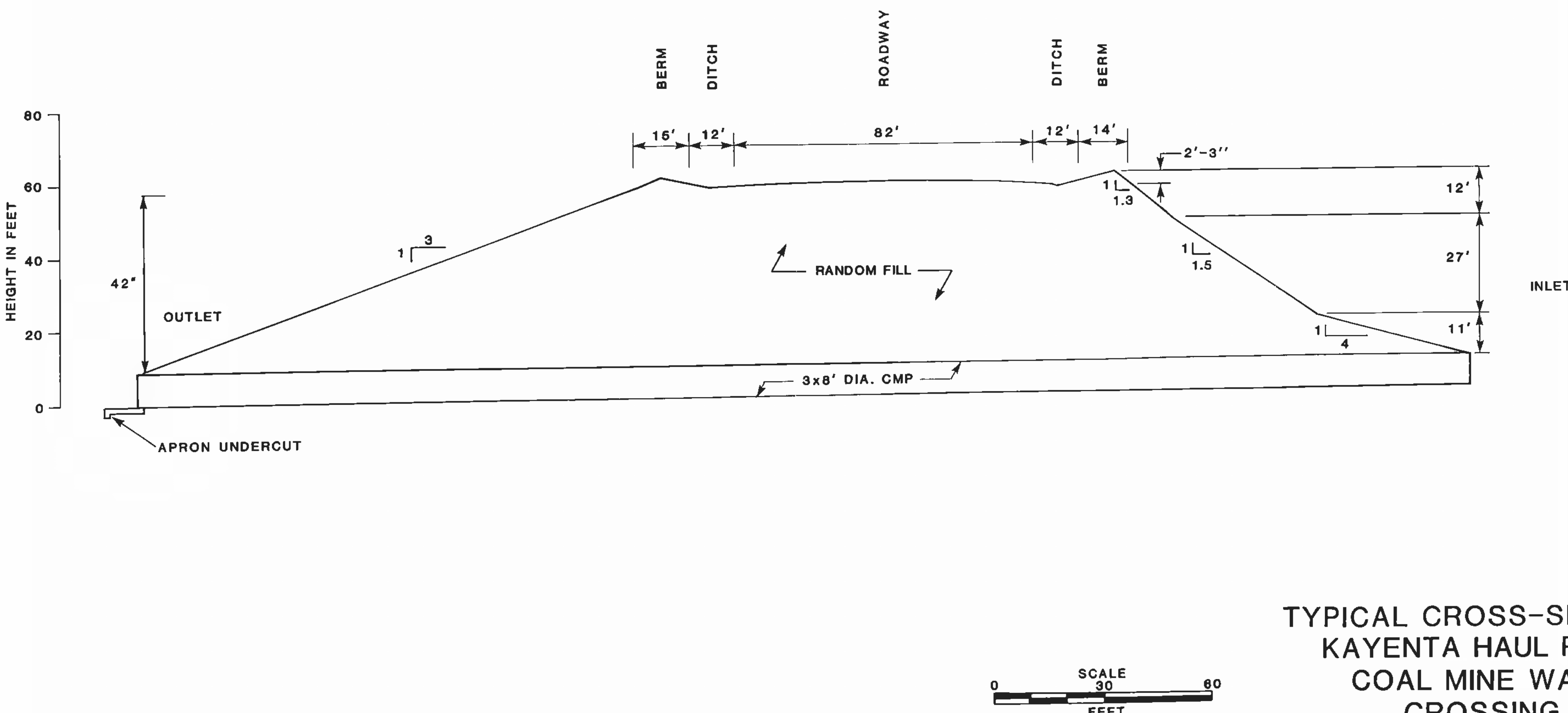
TYPICAL CROSS-SECTION KAYENTA HAUL ROAD REED VALLEY CROSSING

BY **Dames & Moore** Plate 3B



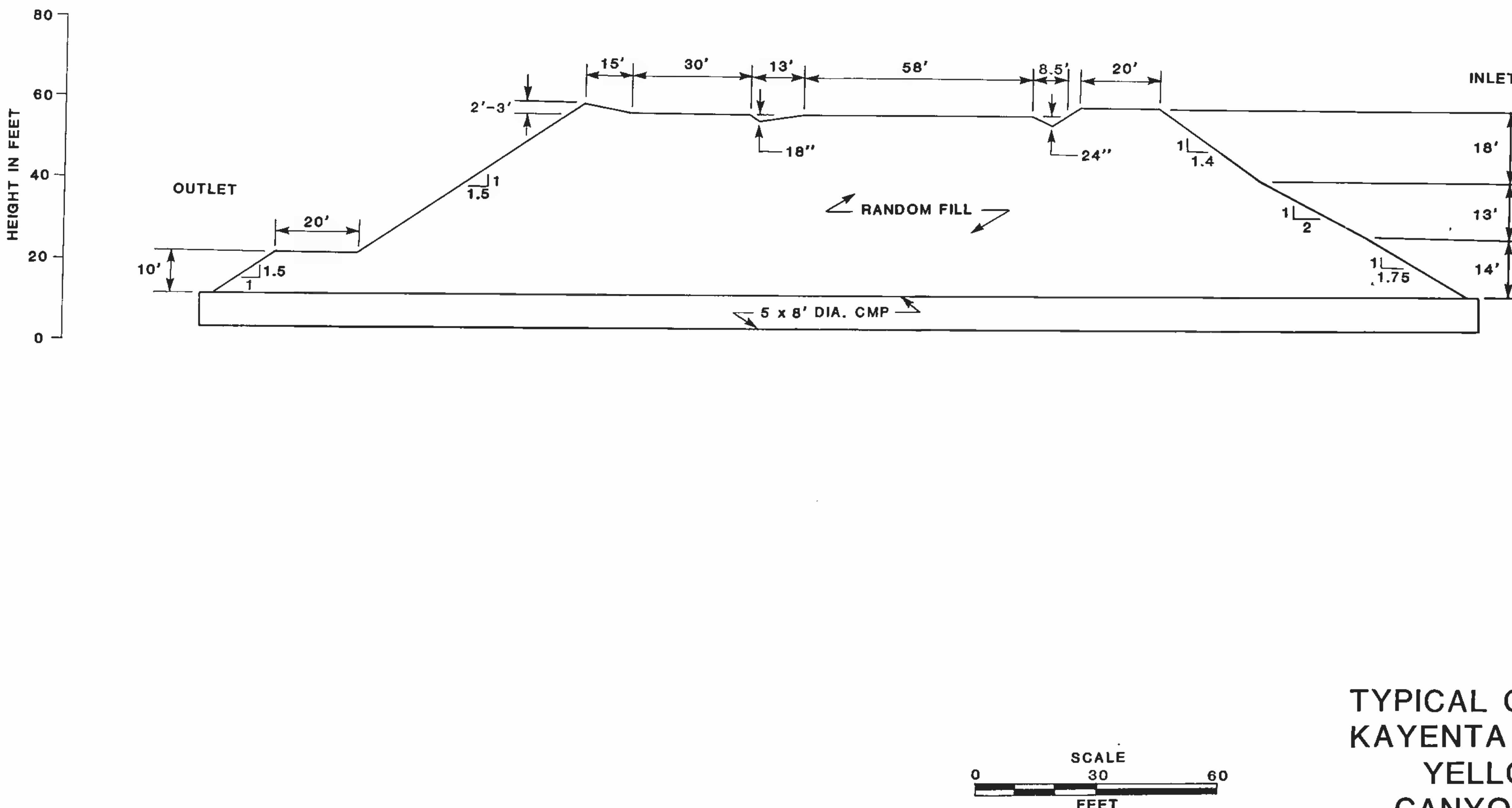
TYPICAL CROSS-SECTION KAYENTA HAUL ROAD MOENKOPI WASH CROSSING

BY Dames & Moore Plate 3C



TYPICAL CROSS-SECTION KAYENTA HAUL ROAD COAL MINE WASH CROSSING

BY **Dames & Moore** Plate 3D



TYPICAL CROSS-SECTION
KAYENTA HAUL ROAD (N8)
YELLOW WATER
CANYON CROSSING

BY **Dames & Moore** Plate 3E

BORING RB-1

SURFACE ELEVATION: 6604.6 FEET
PCC COORDINATES
S 2234
E 31530

LABORATORY TEST DATA

Approx. Depth (ft)	Tests Reported Elsewhere	Atterberg Limits: Liquid Limit (%)	Atterberg Limits: Plasticity Index (%)	Strength Test Data: Type of Test	Strength Test Data: Normal or Confining Pressure (PSF)	Strength Test Data: Shear Strength (PSF)	Strength Test Data: Deviator Stress (PSF)	Moisture Content (%)	Dry Density (PCF)	Blows/Ft.
3.5	MA*							9.8	113.3	92
5.5								12.2	100.7	100/5"
8.5	MA*									101
12.5	MA*									
17.5	MA*									
20.5	MA*							10.6	78.9	100/6"
27.5	MA*									
33.5								9.3	104.7	60
43.5								7.3	100.5	36
53										100/5"
57										100/5"

Depth scale: 0 to 80 feet.

SYMBOLS / DESCRIPTION

Symbol	Description
GM–GC	MULTIPLE SHADES OF BROWN FILL CONSISTING OF SHALE AND SANDSTONE FRAGMENTS IN A MATRIX OF SANDSTONE SILT (DENSE)
	VERY DENSE
	VERY DENSE
	VERY DENSE
	FILL (0 to approx. 32 feet)
SM	BROWN SILTY FINE SAND WITH FRAGMENTS OF SANDSTONE (MEDIUM DENSE)
SP	BROWN FINE SAND (MEDIUM DENSE)
GP	GRAVEL IN BROWN FINE TO COARSE SAND MATRIX (VERY DENSE)
SHALE	GRAY SHALE (VERY DENSE)

BORING TERMINATED AT 57.5 FEET ON 9/17/85.
GROUNDWATER ENCOUNTERED AT 48.0 FEET ON 9/17/85.

* MA RUN ON A COMPOSITE SAMPLE

LOG OF BORING

BORING RB-2

SURFACE ELEVATION: 6606.3 FEET
PCC COORDINATES
S 1658
E 19732

LABORATORY TEST DATA

Depth (ft)	Tests Reported Elsewhere	Atterberg Limits: Liquid Limit (%)	Atterberg Limits: Plasticity Index (%)	Strength Test Data: Type of Test	Strength Test Data: Normal or Confining Pressure (PSF)	Strength Test Data: Shear Strength (PSF)	Strength Test Data: Deviator Stress (PSF)	Moisture Content (%)	Dry Density (PCF)	Blows/Ft.	Symbols	Description
0											SM	MULTIPLE SHADES OF BROWN FILL CONSISTING OF SHALE AND SANDSTONE FRAGMENTS IN A MATRIX OF SAND AND SILT
30								6.7	108.8	69		MOTTLED BROWN, TAN RESIDUAL SANDSTONE (DENSE)
40								10.4	111.5	87		MULTI-COLORED RESIDUAL SHALE (DENSE)
47											ML	BROWN FINE SANDY SILT (MEDIUM DENSE)
50								7.0	88.9	48		
58.5										100/5"	SHALE	BROWN SHALE (VERY DENSE)

FILL (0 to approx. 48 feet)

BORING TERMINATED AT 58.5 FEET ON 9/17/85.
NO GROUNDWATER ENCOUNTERED.

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80

LOG OF BORING

BY **Dames & Moore** Plate 4B

BORING RB-3

SURFACE ELEVATION: 6314.5 FEET
PCC COORDINATES
S 32249
E 28146

LABORATORY TEST DATA

Depth (ft)	Tests Reported Elsewhere	Atterberg Limits: Liquid Limit (%)	Atterberg Limits: Plasticity Index (%)	Strength Test Data: Type of Test	Strength Test Data: Normal or Confining Pressure (PSF)	Strength Test Data: Shear Strength (PSF)	Strength Test Data: Deviator Stress (PSF)	Moisture Content (%)	Dry Density (PCF)	Blows/Ft.	Samples	Symbols	Description
0												SM	MULTIPLE SHADES OF BROWN FILL CONSISTING OF SHALE AND SANDSTONE FRAGMENTS IN A MATRIX OF SAND AND SILT
~24								6.5	111.5	44			MEDIUM DENSE
~34								10.2	117.6	39			MEDIUM DENSE
~41.5													BOULDER (?) OR BEDROCK (?)

FILL (0 to 41.5 ft)

BORING TERMINATED AT 41.5 FEET ON 9/21/85.
NO GROUNDWATER ENCOUNTERED.

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80

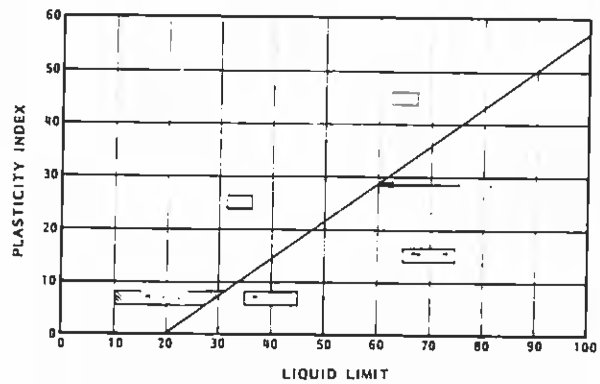
LOG OF BORING

BY Dames & Moore

Plate 4C

SYMBOL	TYPE OF TEST
M	MOISTURE
QD	QUICK MD TEST BASED ON ASSUMED SPECIFIC GRAVITY
MD	MOISTURE-DENSITY
CD	CHUNK DENSITY ON BULK SAMPLE
RD	RELATIVE DENSITY
COMP	COMPACTION CURVE
CI	CALIFORNIA IMPACT
CC	COMPACTED CORE
G	SPECIFIC GRAVITY
pH	HYDROGEN ION CONCENTRATION
MA	MECHANICAL ANALYSIS *
SA	SIEVE ANALYSIS (-200 ONLY)
HA	HYDROMETER ANALYSIS (-200 ONLY)
AL	ATTERBERG LIMITS (LL & PL)
SL	SHRINKAGE LIMIT
FS	FREE SWELL
SS	SHRINK-SWELL
EXP	EXPANSION
C (COL)	CONSOLIDATION (COLLAPSE)
VC	VIBRATING CONSOLIDATION
P	PERMEABILITY
FP	FIELD PERMEABILITY
UC	UNCONFINED COMPRESSION
	TRIAXIAL COMPRESSION TEST
TXUU	1. UNCONSOLIDATED-UNDRAINED
TXCU	2. CONSOLIDATED-UNDRAINED
TXCUM	3. CU/MULTIPHASE**
TXCUPP	4. CU/WITH PORE PRESSURE MEASUREMENTS
TXCD	5. CONSOLIDATED-DRAINED
	DIRECT SHEAR TEST
DS/UU	1. UNCONSOLIDATED-UNDRAINED
DS/CU	2. CONSOLIDATED-UNDRAINED
DS/CD	3. CONSOLIDATED-DRAINED
DS/CD/M:	4. CD/MULTIPHASE**
LV	TORVANE SHEAR (LAB VANE SHEAR)

* INCLUDES COMPLETE ANALYSIS, SIEVING AND HYDROMETER
** SERIES OF TESTS RUN ON SAMPLE



PLASTICITY CHART

INDICATES DEPTH OF AUGER CUTTINGS SAMPLE

INDICATES DEPTH OF UNDISTURBED SAMPLE

INDICATES DEPTH OF DISTURBED SAMPLE

INDICATES DEPTH OF SAMPLING ATTEMPT WITH NO RECOVERY

INDICATES DEPTH OF STANDARD PENETRATION TEST

INDICATES DEPTH OF STANDARD PENETRATION TEST WITH NO RECOVERY

70% 5% INDICATES DEPTH AND LENGTH OF CORE RUN

RQD (ROCK QUALITY DETERMINATION) PERCENT OF THE TOTAL CORE RUN HAVING AN UNFRACTURED LENGTH OF 4" OR MORE

PERCENT OF CORE RUN RECOVERED

INDICATES DEPTH OF FIELD VANE SHEAR TEST

NOTE
UNLESS OTHERWISE NOTED SAMPLING RESISTANCE IS MEASURED IN BLOWS PER FOOT REQUIRED TO DRIVE SAMPLER 12-INCHES AFTER SAMPLER HAS BEEN SEATED 6-INCHES. A 140-POUND HAMMER, FREE FALLING A DISTANCE OF 30 INCHES IS USED TO DRIVE THE SAMPLER.

KEY TO SAMPLES

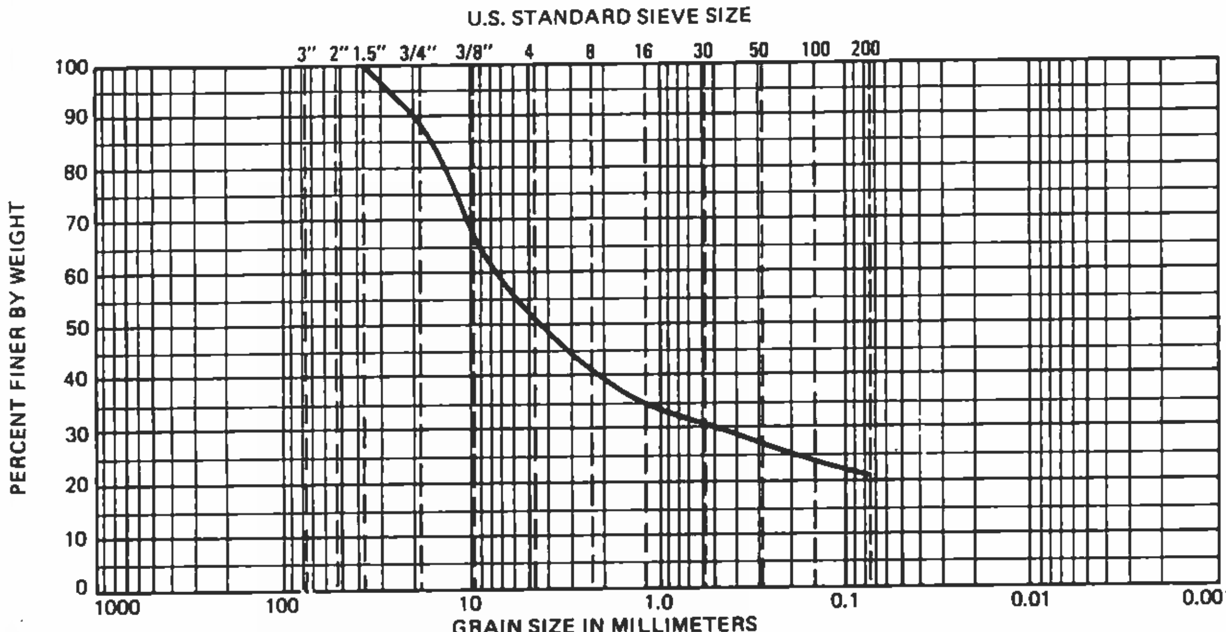
KEY TO LOG OF BORINGS

MAJOR DIVISIONS			GRAPHIC SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS <u>LARGER</u> THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION <u>RETAINED</u> ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION <u>PASSING</u> NO. 4 SIEVE	CLEAN SAND (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
				SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS <u>SMALLER</u> THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT <u>LESS</u> THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT <u>GREATER</u> THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

UNIFIED SOIL CLASSIFICATION SYSTEM

BY **Dames & Moore** Plate 6

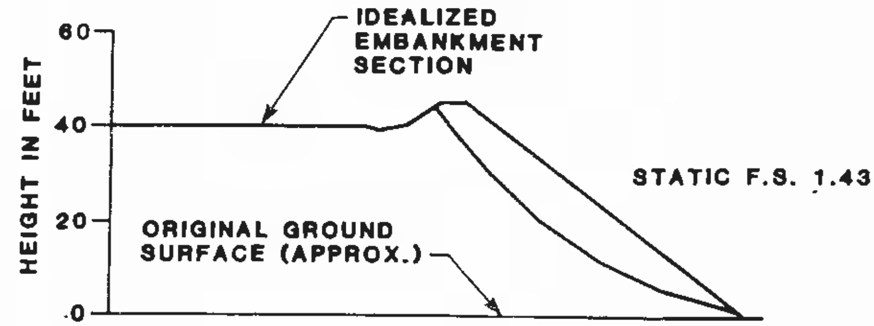


COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

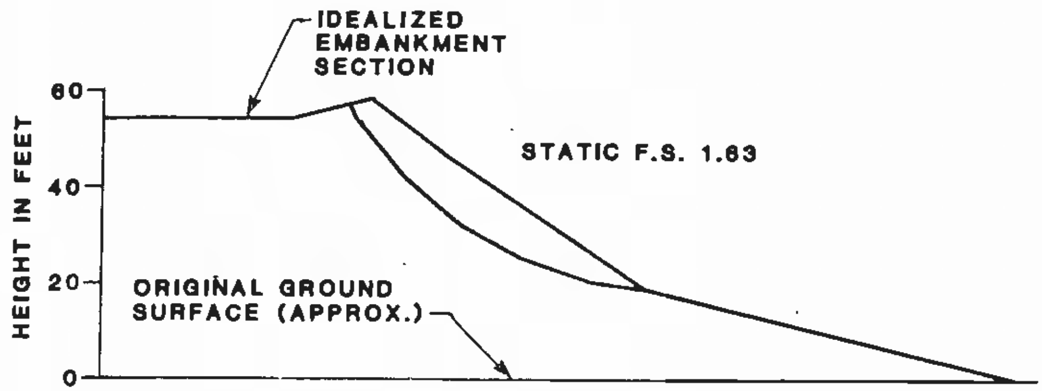
RB-1	DEPTH	CLASSIFICATION		NAT. W C	LL	PL	PI
SAMPLE 1-8	COMPOSITE	GM-GC	BROWN FILL CONSISTING OF SHALE & SANDSTONE FRAGMENTS IN A MATRIX OF SAND AND SILT	7.7	-	-	-

COMPOSITE GRADATION CURVE OF EMBANKMENT FILL

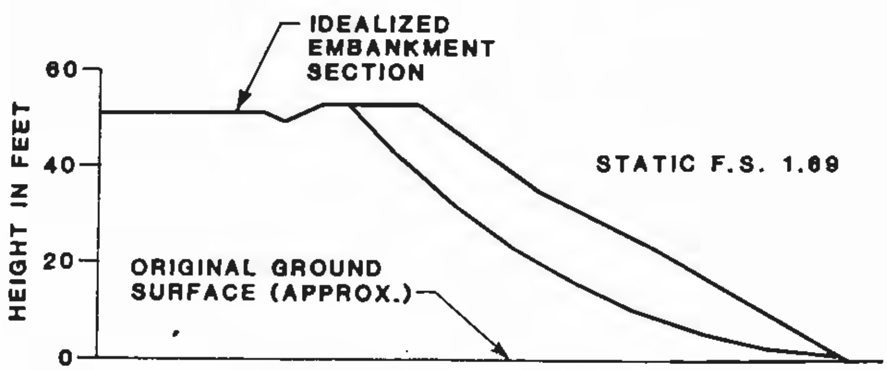
BY **Dames & Moore** Plate 7



BLACK MESA HAUL ROAD
MOENKOPI WASH CROSSING



KAYENTA HAUL ROAD
COAL MINE WASH CROSSING



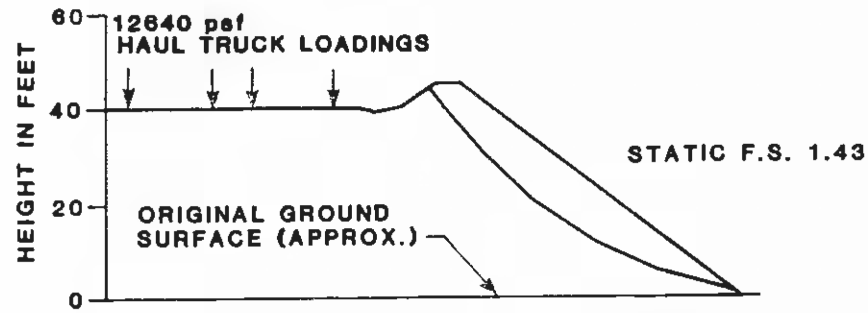
KAYENTA HAUL ROAD
YELLOW WATER CANYON CROSSING

SCALE: 1" = 40'

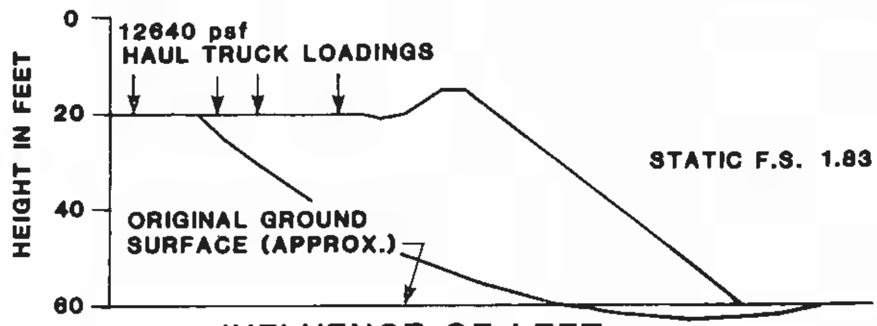
STABILITY ANALYSIS CRITICAL FAILURE SURFACES HAUL ROAD EMBANKMENTS

BY **Dames & Moore** Plate 8A

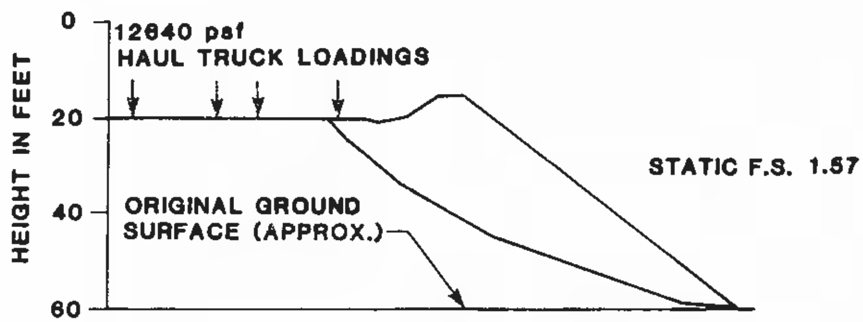
BLACK MESA HAUL ROAD
MOENKOPI WASH CROSSING



CRITICAL FAILURE SURFACE



INFLUENCE OF LEFT
MOST WHEEL LOADS

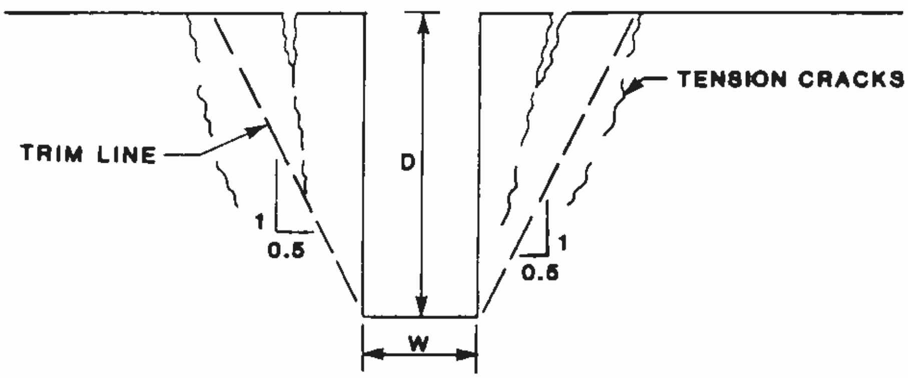


INFLUENCE OF RIGHT
MOST WHEEL LOADS

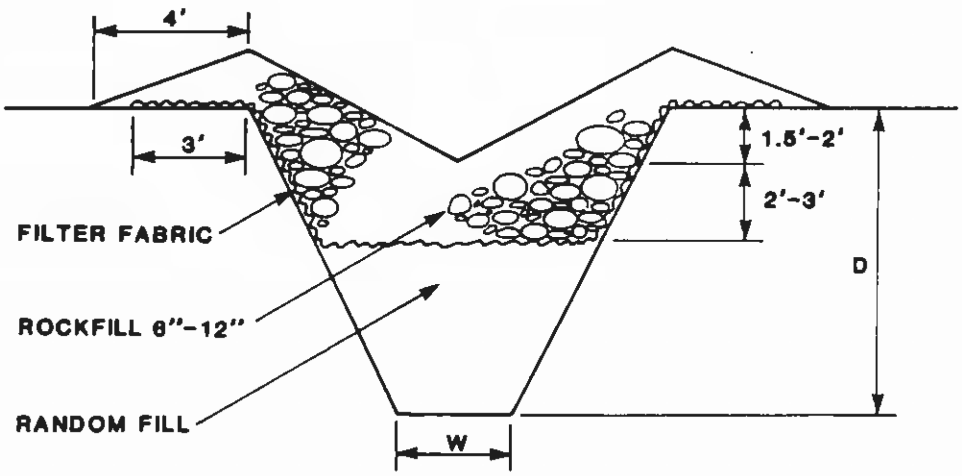
SCALE 1" = 40'

STABILITY ANALYSIS
CRITICAL
FAILURE SURFACES
HAUL ROAD EMBANKMENTS

BY **Dames & Moore** Plate 8B



DETAIL OF GULLY TRIMMING



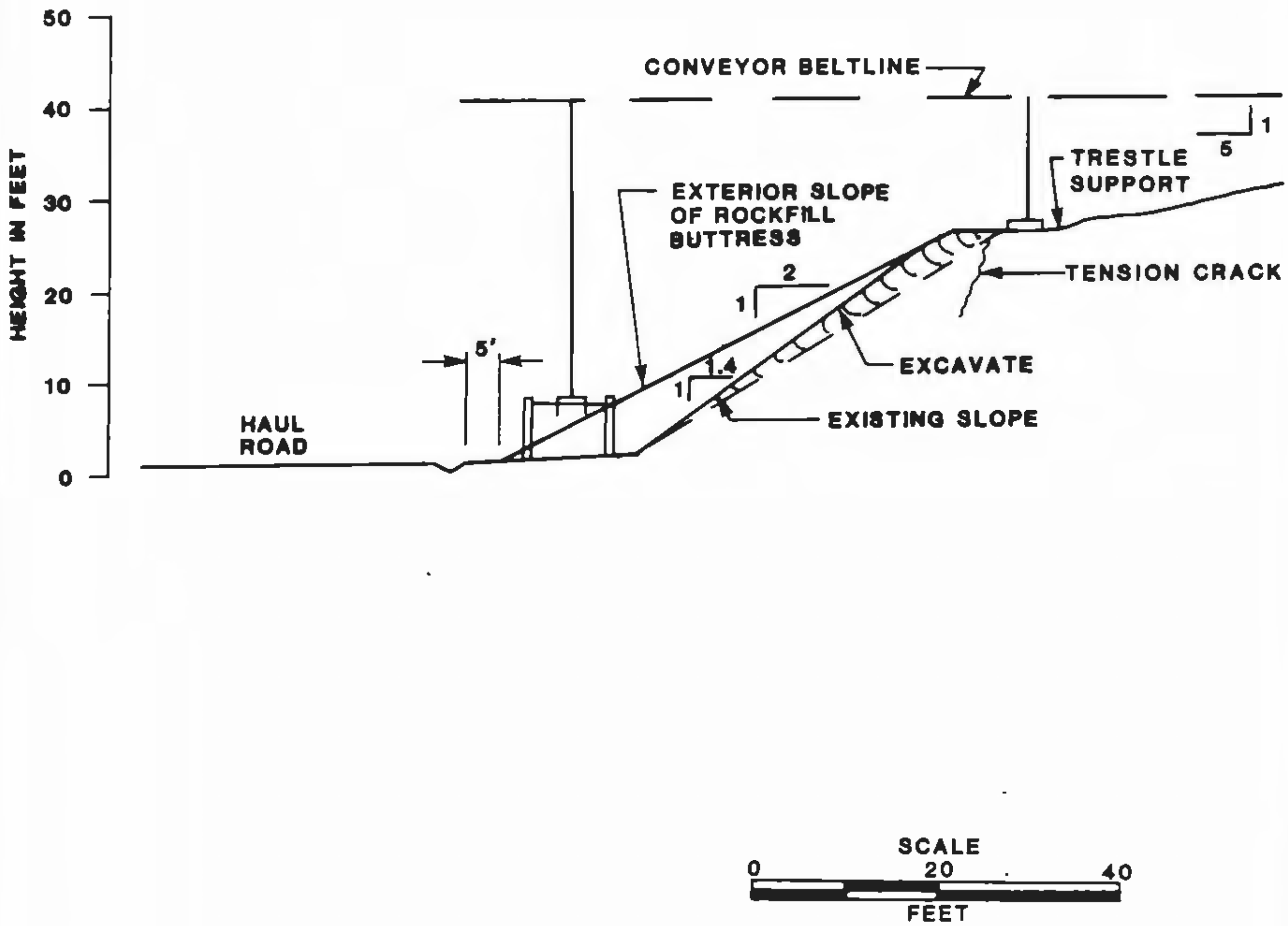
DETAIL OF REMEDIAL ROCK-LINING
FOR GULLIES

W = EXISTING BASE WIDTH OF GULLY

D = EXISTING DEPTH OF GULLY TRIM

REMEDIAL TREATMENT FOR GULLIES

BY **Dames & Moore** Plate 9



RECOMMENDED REMEDIAL SLOPE STABILIZATION

CONVEYOR BELTLINE STATION 497+00

BY **Dames & Moore** Plate 10

ATTACHMENT N-1

Condition #15 Response of 12-28-90

Revised 09/18/91

CONDITION #15 RESPONSE

Comment:

15. Within 180 days of permit issuance, PCC shall demonstrate to OSM in writing that all roads proposed as part of the postmining land use plan would facilitate access to residential areas and grazing lands. As part of this demonstration, PCC shall submit to OSM supporting documentation incorporating comments from BIA and the Navajo Tribe on the proposed road locations and design.

Response:

The location and design of roads for the Black Mesa Complex is discussed in Chapter 6, "Transportation Facilities", Volume 1 of the PAP. In Volume 11, Chapter 24, Bonding, approximately 13.5 miles of roads in the AZ-0001C permit area and 7.6 miles of roads in the AZ-0001 permit area are proposed as permanent primary roads. These roads will become part of the postmining land use plan to provide a permanent transportation network on Black Mesa to facilitate the access to residential and grazing areas scattered throughout the Black Mesa lease area. Drawing No. 85445, "Permanent Roads Map", was prepared to show the location of these proposed roads, the location of residential homesites, and the location of grazing boundaries within the Black Mesa lease area. Note some of these homesites and grazing boundaries are still being reviewed by local, Tribal, and BIA officials; therefore, they may be revised in the future. Included with Drawing No. 85445 are two indexes to the map. The first is the "Homesites Index" and the second is the Grazing Rights Index. These indexes contain the names of the people associated with the homesite and grazing identification numbers on the map.

After the review of Drawing No. 85445 and the two indexes, it becomes very apparent the proposed roads are the major all-weather access points across the major drainages on Black Mesa (i.e., Coal Mine Wash, Moenkopi Wash [both Black Mesa side and J-16 area], Red Peak Valley Wash, etc.). Total reclamation of these proposed roads will hinder access for residences and grazing right owners on the south and east portion of the permit area, as well as school buses, emergency vehicles, and the general public who need to traverse this area.

Finally, OSMRE has requested as part of this condition, Peabody contact BIA and Navajo Tribal officials and solicit comments on the proposed road locations and designs. In addition, OSMRE officials said BIA would be the lead agency to solicit and coordinate the submittal of comments to Peabody. Based on the above, Peabody representatives have had numerous telephone and written communications with the BIA representative during the 180 days, including an informational meeting in Window Rock, Arizona at BIA's office on August 22, 1990. This meeting included representatives from all interested BIA agencies, as well as Navajo Tribal, and Peabody Coal Company representatives. In this meeting, the requirements of this condition was discussed, the representatives were given a copy of Drawing 89800, "Bonding Map", which shows the locations of the proposed permanent roads, a copy of the road design specifications found in Chapter 6 of the AZ-0001C permit, and a map showing the homesite locations on Black Mesa.

Based on a telephone conversation with the BIA representative on December 26, 1990, he has surveyed the BIA and Tribal representatives and has received no objections to the proposed roads. In addition, he did not believe the BIA and Tribal representatives will have any comments by the end of the 180-day period.

In conclusion, based on the enclosed information, map, and design specifications for primary roads in Chapter 6 of the AZ-0001C permit, Peabody respectfully concludes the response to this condition.

PERMANENT ROADS MAP

(Drawing No. 85445)

Homesites Index

1. Bilta and Alice Begay, Phillip Begay, Wayne and Martha Lufkins, Leo Begay

2. John and Helen Kescoli, Maxine Kescoli, Jimmy and Teresa Little

3. Kee and Julia Russell, Jerry Russell, Bilta Begay

4. Alice Yazzie, Norman Yazzie, George and Mae Pulinosis, George Williams, Jack Williams, Tom and Julia Sherlock, Katherine Draper

5. Maxine Kescoli, Mary Gilmore

6. Cindy Lake, Ated Lake, Dzanh Lake

7. Esther Lake, Ated Lake

8. Tom Lake, Anita Lake

9. Bah Begay, Raymond Begay, Leonard and Molly Honnie, Oscar and Zonnie Whitehair

10. Kathie Charley

11. Steven and Katherine Manymules

12. Preston and Sadie Kelly

13. Priscilla Yazzie

14. Roy and Alice Tso

15. Billy and Sally Chief

16. Simon and Thelma Crank, Robert Crank, Thomas Crank, Mabel and Bennie Jim

17. Paul and Thelma Johnson, Spences Johnson

18. Keith and Pauletta Russell

19. Alice Crank, Teresa and Jim Little, Johnson Crank

20. Rose Yazzie, Rube Begishie, Sally Chief

21. Eli and Lilly Crank, Bessie Parrish, Harrison Crank

22. James Cody

23. Billy Austin, Billy Austin, Jr.

24. Leo and Rena Peaches

25. James Yazzie

26. Alice Yazzie

27. James Cody, Roger Cody, Myrata Cody

28. Earlene Albert

29. Calvin Etsitty

30. George and Lena Begay, Phillip Etsitty

31. Bessie Luna

32. Alta R. Albert

33. Annie Herrera

34. Betty Crank, Keevin and Irene Becenti, Stanley and Fannie Tallman, Albert Crank, Lilly Johnson, Cornelius Farley, Steven and Irene Etsitty, Ben Crank, Annie Herrera, Raymond James, Edward Yazzie, Robert Little, Bessie Luna, Don Benally, Evelyn Seaton

35. Irene Freeman

36. Betty Crank

37. Jack Chief

38. Nephi Chief, Lilly Chief, Paul Chief

39. Gary and Elsie Vandever

40. Rose Farley, Bessie Begay, Mable Thomas

41. Leslie Etsitty, Calvin Etsitty

42. Laura Edcitty

43. Fred Smith, Bobby and Annie Smith

44. Nelson Blackhat

45. Bessie Smith, Ambrose Smith

46. Merlin Begay, Daniel Benally

47. Cindy Lake

48. Dzanh Lake

49. Frank Lake

50. Daniel and Mabel Benally

51. Ated Lake, Chester Lake

52. Earl and Anita Kescoli

53. Mary Lake, Clarence Lake, Milton Lake, Duane Lake, Lorraine Vandever, Manymules daughter

54. Mary Boyd

55. Johnson Little, Amy Little

56. Sam and Ella Little, Ben and Ida Little

57. Mary Boyd

58. Cindy Lake

59. Henry Schmitt

60. Eddie Bigman

61. Eugene Leonard

62. Charlie and Sarah Keith

63. John Bahe

64. Anna Herrera

65. James Yazzie

66. Bessie Luna

67. Gary and Elsie Vandever

68. Bessie Begay

69. Bessie Begay

70. Woody Anderson

71. Ated Lake

72. Molita Lake

73. Lenora Begay

74. Leonard and Molly Honnie

75. Stanley Tsosie

PERMANENT ROADS MAP
(Drawing No. 85445)

Grazing Rights Index

Grazing Area #	Grazing Right Owners	Grazing Area #	Grazing Right Owners
3-B	Betty Crank	9	Silas Yazzie
3-C	Bessie Luna	9	Lucille Benally
3-C	Alta Rose Albert	9	Mary Lake
3-C	Annie Herrera	10	(Unavailable)
4-A	Lilly Chief	13	Rose Farley
4-C	Lilly Chief	13	Benny Etsitty
5	Rose Farley	13	John Bahe
5	Benny Etsitty	13	Carmelita Clark
5	John Bahe	13	Mabel Thomas
5	Carmelita Clark	13	Inez Cody
5	Mabel Thomas	13	Elsie Vandever
5	Inez Cody	13	Edward Begay, Sr.
5	Elsie Vandever	13	Calvin Etsitty
5	Edward Begay, Sr.	14	Eli Crank
5	Calvin Etsitty	15	Rose Yazzie
6	Rose Farley	15	Kee Crank
6	Benny Etsitty	15	Sally Chief
6	John Bahe	15	Thelma Johnson
6	Carmelita Clark	15	Helen Kescoli
6	Mabel Thomas	15	Ruby Begishe
6	Inez Cody	15	Johnson Crank
6	Elsie Vandever	16	Rose Farley
6	Edward Begay, Sr.	16	Benny Etsitty
6	Calvin Etsitty	16	John Bahe
7-B	Anita Lake Yazzie	16	Carmelita Clark
7-B	Joe Lake	16	Mabel Thomas
7-B	Lilly Chief	16	Inez Cody
7-B	Daniel Benally	16	Elsie Vandever
7-C	Anita Lake Yazzie	16	Edward Begay, Sr.
7-C	Joe Lake	16	Calvin Etsitty
7-C	Daniel Benally	17	Betty Crank
7-D	Anita Lake Yazzie	18	Bessie Luna
7-D	Joe Lake	18	Annie Herrera
7-E	Anita Lake Yazzie	18	Alta Rose Albert
7-E	Joe Lake	19	Ned Yazzie
7-E	Daniel Benally	20	John Billy Tsosie
8-A	Anita Lake Yazzie	20	Walter Begay, Sr.
8-A	Joe Lake	21	Alice Yazzie
8-A	George Pulinos	22	Rose Farley
8-A	Mary Lake	22	Benny Etsitty
8-B	George Pulinos	22	John Bahe
8-B	Mary Lake	22	Carmelita Clark
9	Roy Huskey	22	Mabel Thomas
9	Jacqueline Boyd	22	Inez Cody
9	Elouise Interpreter	22	Elsie Vandever
9	Eugene Leonard	22	Edward Begay, Sr.

PERMANENT ROADS MAP
(Drawing No. 85445)

Grazing Rights Index
(Continued)

Grazing Area #	Grazing Right Owners
22	Calvin Etsitty
23	Billy Austin
24	James Cody
25	Inez Cody
26	Alta Rose Albert
26	Bessie Luna
26	Annie Herrera
27	Rose Yazzie
27	Kee Crank
27	Sally Chief
27	Thelma Johnson
27	Helen Kescoli
27	Ruby Begishe
27	Johnson Crank
28	Rose Farley
28	Benny Etsitty
28	John Bahe
28	Carmelita Clark
28	Mabel Thomas
28	Inez Cody
28	Elsie Vandever
28	Edward Begay, Sr.
28	Calvin Etsitty
28	Betty Crank
29	Bessie Luna
29	Annie Herrera
29	Alta Rose Albert
29	Alice Yazzie
30	Marilyn Yazzie
30	Woodie Anderson
30	Alice Tso
30	Katherine Manymules
30	Ella M. Yazzie
30	Lena Tso
30	Sarah Kee
31	Simon Crank
32	Julia Jane Russell
33	Leonard Honnie, Jr.

ATTACHMENT O

Typical SEDIMENT II Inputs for

Drainage Control Structures

Typical SEDIMOT II Input (Culverts and Ditches)

Card Code	Parameters	Inputs
1	Watershed Identification	= ____________
2	Storm Type	= (SCS Type II)
	No. of Depth Time Values	= 2
3	Rainfall Depth (inch)	= 1.61 (10yr.-6hr. Storm)
	Storm Duration (hr)	= 6.00
	Storm Time Increment	= 0.1
	Max. 30 Min. Intensity	= 1.0
4	Number of Junctions	= 1
	Sedimentology and/or Hydrology	= 1 (Hydrology Only)
5	Number of Branches per Junction	= 1
10	Number of Structures per Branch	= 1
11	Travel Time Between Structures (hr)	= 0.0
	Muskingum's k Between Structures (hr)	= 0.0
	Muskingum's X Between Structures (hr)	= 0.0
12	Number of Subwatersheds per Structures	= 1
	Type of Sediment Control Structure	= 1 (Null Structure)
	Print Control Variable for Total Drainage	= 2 (Hydrograph)
	Print Control Variable for Drainage Between Structures	= 2 (Hydrograph)
	Print Option for Subwatershed Inputs	
13	Subwatershed Area (Acres)	= ____
	Curve Number	= ____
	Time of Concentration = $\frac{11.9(L)^3}{H}$ = 0.385	
	Travel Time (to Structure)	= 0.0
	Muskingum's k (to Structure)	= 0.0

Typical SEDIMOT II Input (Culverts and Ditches) (Cont.)

Card Code	Parameters	Inputs
	Muskingum's X (to Structure)	= 0.0
	Hydrology Print Option	= 1.0 (Input Tables)
	Hydraulic Surface Condition	= ______
	Number of Flow Segements	= 0.0

Note: If the disturbance in the watershed exceeds 50%, use 1.0 (disturbed) for "Hydraulic Surface Condition", otherwise use 2.0 (agricultural).

ATTACHMENT P

Dodson and Associates Hydraulic Programs

-TRAP

-PIPE

1 INTRODUCTION

1.1 PURPOSE OF THE PROGRAM

A trapezoidal channel has flat bottom and sloping sides, as illustrated on Exhibit 1, in Appendix A of this manual. Trapezoidal shapes are often used for man-made channels, because they are relatively easy to construct and maintain, and provide good flow capacity. This program quickly computes the Normal Depth, Critical Depth, and Rating Curve for flow in a trapezoidal channel. One section of this manual is devoted to each of these procedures.

Using this computer program, you can quickly and easily analyze the hydraulic characteristics of almost any trapezoidal channel, including those with a different side slope on each bank. It's important to realize that triangular and rectangular channels can be easily analyzed by this program, because they are both special kinds of trapezoidal channels. A triangular channel is a trapezoidal channel with a channel bottom width of zero. A rectangular channel is a trapezoidal channel with side slopes of zero (vertical sides).

1.2 INFORMATION TO HELP YOU GET STARTED

1.2.1 Files on the Program Disk

Your program disk contains at least two files:

TRAP.COM is the file containing the trapezoidal channel analysis program and all of the on-line help screens.

TRAP87.COM is a special version of the program designed for use only on computers with the 8087 or 80287 math co-processors. Except for its faster operation, TRAP87.COM is identical to TRAP.COM.

In addition to these files, your disk may also contain several demonstration programs of other software products available from Dodson & Associates, Inc. You may select any of these demonstration programs by simply typing the file name and pressing the return key.

1.2.2 Getting Started Quickly

To start the program, do the following:

1) Start up your computer using the hard disk or a floppy disk with the DOS system files on it.

2) Insert the program disk, and close the disk drive door.

3) Type TRAP or TRAP87 and press the return key to start the trapezoidal channel analysis program.

4) In a few seconds the program will be loaded and you will be able to proceed through this manual and practice the use of each procedure.

2 NORMAL DEPTH PROCEDURE

2.1 PURPOSE OF NORMAL DEPTH PROCEDURE

Normal Depth is the depth at which uniform flow will occur in an open channel. In other words, if you had a uniform channel of infinite length, carrying a constant flow rate, then flow in the channel would be at a constant depth at all points along the channel, and this depth would be the normal depth.

It is often useful to determine Normal Depth, because it may represent a good approximation of the actual depth of flow within a channel segment. It is common practice, for example, to use Normal Depth computations to prepare a preliminary design for channel improvements, and then to check or refine the design by computing the water surface profile in the channel using the Standard Step or Direct Step Methods, or computer programs based on these methods.

2.2 REQUIRED INPUT DATA FOR NORMAL DEPTH PROCEDURE

2.2.1 Flow Rate

The user must supply the flow rate which the channel is to convey, in cubic feet per second (cfs). Sometimes, the flow rate may vary through the length of a channel segment, because of local inflow to the channel. In such cases, you must decide whether to base your analysis on the maximum flow rate or the average flow rate in the channel segment. Local drainage regulations or practice may provide guidance in this regard. When in doubt, it is recommended that the analysis be performed with each flow rate and the results compared.

2.2.2 Channel Bottom Slope

The channel bottom slope is the average drop in elevation per foot of length along the channel. For example, if the channel bottom drops 1 foot in a lenth of 1000 feet, then the channel bottom slope is 0.001 feet per foot. Channel bottom slopes are sometimes expressed in percent. A slope of 0.001 feet per foot is the same as a 0.1% slope.

The slopes of the water surface and the energy grade line are assumed to be the same as the channel bottom slope for normal flow conditions. Therefore, it is important to provide the best possible estimate of the channel bottom slope.

2.2.3 Manning's Roughness Coefficient

This program uses Manning's Equation to analyze open-channel flow. The roughness of the channel is represented by Manning's Roughness Coefficient, commonly called the "n-value". Suggested values for Manning's n-value are listed in Appendix B of this manual, and in many hydraulics reference books. Roughness coefficients should be adjusted according to experience in your geographic area.

2.2.4 Channel Side Slopes

The slope of each channel bank is illustrated on Exhibit 1. The program expects the side slopes to be represented as the "Z-Ratio", which is the ratio of horizontal distance to vertical rise in the channel bank. For example, a channel bank which rises 1 foot for each three feet of horizontal distance would have a side slope of 3:1, and a Z-Ratio of 3. Z-Ratios of 3 or 4 are common for earthen channels. Concrete-lined channels may have steeper banks, with Z-Ratios of 1.5 or 2.

This program has the capability of analyzing channels with a different side slope for each channel bank. For example, flow in a street gutter can be analyzed using this program. The vertical curb would cause the side slope to be 0 on one side. On the other side, a 6-inch difference between the pavement crown elevation and the gutter elevation, divided by a 12-foot lane width, would yield a side slope of 24.

2.2.5 Channel Bottom Width

Exhibit 1, in Appendix A, illustrates the bottom width of the channel section.

2.3 DESCRIPTION OF RESULTS OF NORMAL DEPTH PROCEDURE

2.3.1 Normal Depth

This program computes Normal Depth using an iterative approach to arrive at a value which satisfies Manning's Equation:

$$Q = \frac{1.486}{n} AR^{(2/3)} S^{(1/2)}$$

in which:

- Q = Flow Rate in the channel (cfs)
- n = Manning's Roughness Coefficient
- A = Area of Flow (square feet)
- R = Hydraulic Radius (feet) = (Flow Area)/(Wetted Perimeter)
- S = Slope of Energy Grade Line (feet per foot)

The equation is re-arranged in terms of the depth of flow. An initial flow depth estimate of 1 foot is substituted into the equation, and a new approximation is computed for the flow depth. The new value is compared with the previous approximation, and if the difference is less than 0.001 feet, the depth is assumed to be the Normal Depth. If not, a new approximation for Normal Depth is computed as the geometric mean of the previous two approximations. This method gives very quick, precise, and reliable values for the Normal Depth of flow in a trapezoidal channel.

2.3.2 Flow Velocity

After the program computes the Normal Depth, the flow velocity in the channel is computed as simply the flow rate divided by the cross-sectional area of the flow. The velocity is assumed to be constant throughout the cross-section.

The flow velocity is an important consideration in many channel design situations. The allowable flow velocity may be limited by local drainage criteria.

2.3.3 Froude Number

The Froude Number is the ratio of the inertial forces to the gravitational forces in a flowing fluid. It is computed using this formula:

$$\text{Froude Number} = \frac{V}{(gA/T)^{(1/2)}}$$

in which:

V = Flow Velocity (fps)
g = Acceleration due to gravity = 32.2 feet/sec/sec
A = Cross-sectional Area of Flow (square feet)
T = Top Width of Flow (feet)

If the Froude Number is greater than one (1.00), then flow in the channel is "super-critical". A Froude Number less than one is more common, indicating "sub-critical" flow. Section 3 of this manual contains more information on critical flow and critical depth.

2.3.4 Velocity Head

Water flowing in an open channel contains two major types of energy: potential energy and kinetic energy. Potential energy is expressed as the elevation of the water surface. Kinetic energy is expressed as the "velocity head". The term "head" can also be stated as "energy level".

The velocity head is computed using the following formula:

$$\text{Velocity Head} = \frac{V^2}{2g}$$

in which

V = Flow Velocity in the channel (fps)
g = Acceleration due to gravity = 32.2 feet/sec/sec

2.3.5 Energy Head

The "Energy Head" of the flow is the total energy of the flow, including both potential energy and kinetic energy. In other words, the energy head is simply the sum of the water surface elevation and the velocity head.

2.3.6 Cross-Sectional Area of Flow

The cross-sectional area of flow is computed in order to provide a quick check on the other computed quantities, and also to aid in computing excavation requirements for a channel. The flow area is computed using the following formula:

$$\text{Flow Area} = (B+T)(D/2)$$

in which:

B = Channel Bottom Width (feet)
T = Top Width of Flow (feet)
D = Depth of Flow (feet)

2.3.7 Top Width of Flow

The top width of flow is illustrated on Exhibit 1, in Appendix A. It is computed in order to make it easier to quickly estimate the required right-of-way width for a channel. The top width of the channel will probably be greater than the top width of the flow, because most channels are required to have some freeboard.

2.4 EXAMPLE OF NORMAL DEPTH PROCEDURE

```
---------------------------------------------------------------------
              TRAPEZOIDAL CHANNEL ANALYSIS
                NORMAL DEPTH COMPUTATION
Flow Rate (cubic feet per second)                         200
Channel Bottom Slope (feet per foot)                      .0005
Manning's Roughness Coefficient (n-value)                 .040
Channel Side Slope - Left Side (horizontal/vertical)      3
Channel Side Slope - Right Side (horizontal/vertical)     3
Channel Bottom Width (feet)                               6

                    *** RESULTS ***

NORMAL DEPTH (FEET)                                            5.33
Flow Velocity (feet per second)                                1.71
Froude Number                                                  .171
Velocity Head (feet)                                           .05
Energy Head (feet)                                             5.37
Cross-Sectional Area of Flow (square feet)                     117.05
Top Width of Flow (feet)                                       37.95

Press Return to repeat this operation, or Esc to return to Main Menu
---------------------------------------------------------------------
```

3 CRITICAL DEPTH PROCEDURE

3.1 PURPOSE OF CRITICAL DEPTH PROCEDURE

Critical Depth occurs when the flow in a channel has minimum specific energy. Specific Energy refers to the sum of the depth of flow and the velocity head. It can be shown mathematically that the velocity head is equal to one-half the depth of flow at Critical Depth. Critical Depth depends only on the channel shape, roughness, and flow rate.

It is sometimes useful to compute Critical Depth in order to analyze the type of flow profile which will occur in a particular channel.

3.2 REQUIRED INPUT DATA FOR CRITICAL DEPTH PROCEDURE

In order to compute the Critical Depth of flow in a channel, the program requires that you supply the following items of input data:

1) The Flow Rate in the channel.

2) The Manning's Roughness Coefficient for the channel.

3) The Channel Side Slopes (which may differ for each side, and may be zero).

4) The Channel Bottom Width (which may be zero).

Each of these items is described in connection with the Normal Depth procedure in Section 2.2 of this manual.

3.3 DESCRIPTION OF RESULTS OF CRITICAL DEPTH PROCEDURE

3.3.1 Critical Depth

This program computes the critical depth by an iterative procedure, which arrives at a value which satisfies the following equation:

$$\frac{Q^2}{g} = \frac{A^3}{T}$$

in which

Q = Flow Rate in the channel, in cfs
g = Acceleration due to gravity (32.2 ft/sec/sec)
A = Cross-sectional area of flow (square feet)
T = top width of flow (feet)

The Newton-Raphson method of locating roots of a polynomial equation is used to solve the equation for the Critical Depth. This method gives a quick and efficient solution which is accurate to within 0.001 foot.

3.3.2 Critical Slope

Critical Slope is the channel slope at which Normal Depth equals Critical Depth. Critical Slope is computed by inserting the Critical Depth in Manning's Equation, which is re-arranged as follows:

$$S^{(1/2)} = \frac{Qn}{1.486AR^{(2/3)}}$$

in which:

- S = Slope of Energy Grade Line (feet per foot)
- Q = Flow Rate in the channel (cfs)
- n = Manning's Roughness Coefficient
- A = Area of Flow (square feet)
- R = Hydraulic Radius (feet) = (Flow Area)/(Wetted Perimeter)

3.3.3 Flow Velocity

The flow velocity is computed as the flow rate divided by the cross-sectional area of flow.

3.3.4 Froude Number

The Froude Number is the ratio of the inertial forces to the gravitational forces in a flowing fluid. It is computed using this formula:

$$\text{Froude Number} = \frac{V}{(gA/T)^{(1/2)}}$$

in which:

- V = Flow Velocity (fps)
- g = Acceleration due to gravity = 32.2 feet/sec/sec
- A = Cross-sectional Area of Flow (square feet)
- T = Top Width of Flow (feet)

At Critical Depth, the Froude Number equals 1. Therefore, the computed Froude Number provides a quick check on the accuracy of the computed critical depth. The Froude Number should always be very close to 1.000 for the Critical Depth procedure.

3.3.5 Other Results

The Velocity Head, Energy Head, Cross-section Area of Flow, and Top Width of Flow are computed for the Critical Depth as described for the Normal Depth procedure, in Section 2.3 of this manual.

3.4 EXAMPLE OF CRITICAL DEPTH PROCEDURE

TRAPEZOIDAL CHANNEL ANALYSIS
CRITICAL DEPTH COMPUTATION

Flow Rate (cubic feet per second)	200
Manning's Roughness Coefficient (n-value)	.040
Channel Side Slope - Left Side (horizontal/vertical)	3
Channel Side Slope - Right Side (horizontal/vertical)	3
Channel Bottom Width (feet)	6

*** RESULTS ***

CRITICAL DEPTH (FEET)	2.26
Critical Slope (feet per foot)	.0215
Flow Velocity (feet per second)	6.90
Froude Number	1.000
Velocity Head (feet)	.74
Energy Head (feet)	3.00
Cross-Sectional Area of Flow (square feet)	28.98
Top Width of Flow (feet)	19.59

Press Return to repeat this operation, or Esc to return to Main Menu

---

4 RATING CURVE PROCEDURE

4.1 PURPOSE OF RATING CURVE PROCEDURE

A Rating Curve is simply a table or curve which relates the flow rates to flow depths in a channel. As you insert flow depths, the Rating Curve procedure quickly computes the flow rate in the channel, and other information about flow at the specified depth. You may specify as many depths as you like.

Rating Curves are useful in estimating the capacity of a channel over a wide range of flood events or storm frequencies, or in quickly relating a known flood stage to a certain peak flow rate.

4.2 REQUIRED INPUT DATA FOR RATING CURVE PROCEDURE

4.2.1 Description of Channel

In order to compute a Rating Curve for the channel, the program requires that you supply the following items of input data:

1) The Channel Bottom Slope.

2) The Manning's Rougnness Coefficient for the channel.

3) The Channel Side Slopes (which may differ for each side, and may be zero).

4) The Channel Bottom Width (which may be zero).

Each of these items is described in connection with the Normal Depth procedure in Section 2.2 of this manual.

4.2.2 Flow Depths

Once you have defined the shape and roughness of the channel, the program begins to prompt you for flow depths. As you enter each flow depth and press the Return key, the program quickly computes the flow rate and other information about flow at the specified depth. Any reasonable flow depth may be entered. For best results, however, you may wish to enter a series of flow depths at selected intervals. For example, from 1 foot to 10 feet, at one foot intervals.

4.3 DESCRIPTION OF RESULTS OF RATING CURVE PROCEDURE

4.3.1 Flow Rate

For each Flow Depth which you specify, the program computes the flow rate using Manning's Equation:

$$Q = \frac{1.486}{n} AR^{(2/3)} S^{(1/2)}$$

in which:

Q = Flow Rate in the channel (cfs)
n = Manning's Roughness Coefficient
A = Area of Flow (square feet)
R = Hydraulic Radius (feet) = (Flow Area)/(Wetted Perimeter)
S = Slope of Energy Grade Line (feet per foot)

The Flow Area and Hydraulic Radius are computed from the given Flow Depth.

4.3.2 Other Results

The other results of the Rating Curve procedure, including the Flow Velocity, the Froude Number, the Velocity Head, the Energy Head, the Flow Area, and the Top Width, are all computed by the methods described in Section 2.3, which deals with the Normal Depth procedure.

4.4 EXAMPLE OF RATING CURVE PROCEDURE

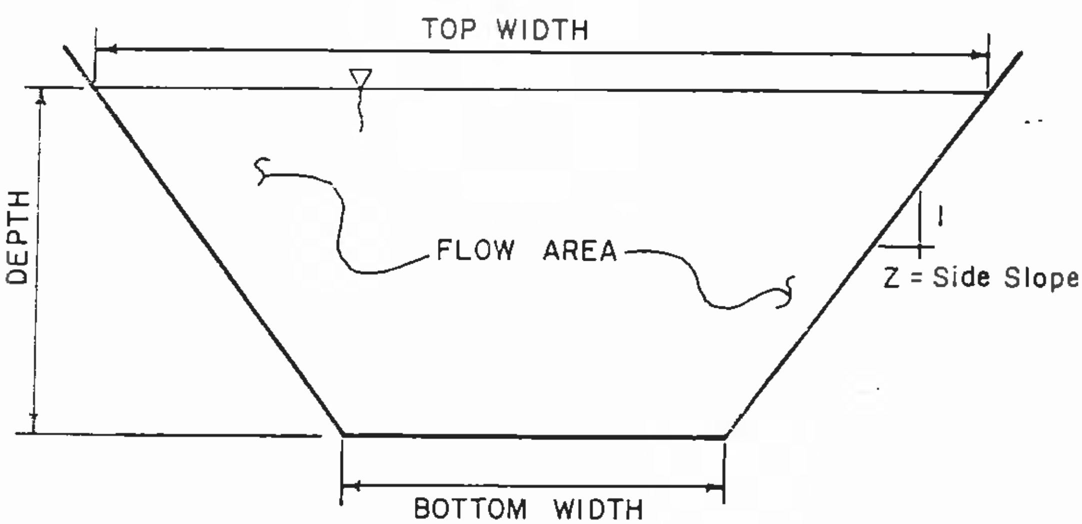
TRAPEZOIDAL CHANNEL ANALYSIS
RATING CURVE COMPUTATION

Channel Bottom Slope (feet per foot)	.0005
Manning's Rougnness Coefficient (n-value)	.040
Channel Side Slope - Left Side (horizontal/vertical)	3
Channel Side Slope - Right Side (horizontal/vertical)	3
Channel Bottom Width (feet)	0

*** RESULTS ***

Depth (ft)	Flow Rate (cfs)	Velocity (fps)	Froude Number	Velocity Head(ft)	Energy Head(ft)	Flow Area (sq ft)	Top Width (ft)
1.00	6.06	.67	.137	.01	1.01	3.00	12.00
2.00	23.59	.98	.150	.01	2.01	24.00	18.00
3.00	55.35	1.23	.158	.02	3.02	45.00	24.00
4.00	104.23	1.45	.165	.03	4.03	72.00	30.00
5.00	172.90	1.65	.170	.04	5.04	105.00	36.00
6.00	263.89	1.83	.174	.05	6.05	144.00	42.00
7.00	379.60	2.01	.178	.06	7.06	189.00	48.00
8.00	522.32	2.18	.182	.07	8.07	240.00	54.00
9.00	694.24	2.34	.185	.08	9.08	297.00	60.00
10.00	897.47	2.49	.188	.10	10.10	360.00	66.00
11.00	1134.07	2.64	.191	.11	11.11	429.00	72.00
12.00	1406.02	2.79	.193	.12	12.12	504.00	78.00
13.00	1715.25	2.93	.196	.13	13.13	585.00	84.00

Enter Depth of Flow, or Press the Esc Key to End



TRAPEZOIDAL CHANNEL

DODSON & ASSOCIATES, INC.

JOB NO.	DATE	EXHIBIT
		1

Applied Hydraulics in Engineering

Henry M. Morris and James M. Wiggert, 1972, the Ronald Press Company, New York. This book is a general text on hydraulics. Chapters 4, 5, and 6 are especially related to open-channel flow.

Civil Engineering Hydraulics

R. E. Featherstone and C. Nalluri, 1982, Granada Publishing Limited, London. This book is fairly theoretical, but with many examples. Chapter 8 applies to open-channel flow.

Design Charts for Open-Channel Flow

1980, U. S. Department of Transportation, Federal Highway Administration, Washington, D.C. This is an excellent reference, containing many charts for computing normal depth and critical depth of flow in open channels. The charts can be cross-checked with the results of this computer program.

Handbook of Hydraulics

Ernest F. Brater and Horace Williams King, 1976, McGraw-Hill, Inc. New York. This book is not a good place to start learning about hydraulics, but we keep coming back to it for information not easily available elsewhere.

Modern Sewer Design

1980, American Iron and Steel Institute, Washington, D.C. This book is an excellent reference on practical hydraulics.

Open Channel Hydraulics

Ven Te Chow, 1959, McGraw-Hill, Inc. New York. This is the classic text on hydraulics.

Water Resources Engineering

Ray K. Linsley and Joseph B. Franzini, 1979, McGraw-Hill, Inc., New York. This is an excellent general text. Chapter 10 relates to open channels.

1 INTRODUCTION

1.1 PURPOSE OF THE PROGRAM

A pipe culvert is a relatively short segment of a round pipe which connects two channels or bodies of water, as illustrated on Exhibit 1, in Appendix A of this manual. This program can analyze Pressure Flow in a culvert, or can determine the type of flow in a culvert by Control Design. One section of this manual is devoted to each of these procedures.

1.2 INFORMATION TO HELP YOU GET STARTED

1.2.1 Files on the Program Disk

Your program disk contains at least two files:

PIPE.COM is the file containing the pipe culvert analysis program and all of the on-line help screens.

PIPE87.COM is a special version of the program designed for use only on computers with the 8087 or 80287 math co-processors. Except for its faster operation, PIPE87.COM is identical to PIPE.COM.

In addition to these files, your disk may also contain several demonstration programs or other software products available from Dodson & Associates, Inc. You may select any of these demonstration programs by simply typing the file name and pressing the return key.

1.2.2 Getting Started Quickly

To start the program, do the following:

1) Start up your computer using the hard disk or a floppy disk with the DOS system files on it.

2) Insert the program disk, and close the disk drive door.

3) Type CIRC or CIRC87 and press the Return key to start the circular channel analysis program.

4) In a few seconds the program will be loaded and you will be able to proceed through this manual and practice the use of each procedure.

2 CONTROL DESIGN PROCEDURE

2.1 PURPOSE OF CONTROL DESIGN PROCEDURE

The analysis of flow in culverts is complicated. It is common to use the concepts of "Inlet Control" and "Outlet Control" to simplify the analysis. Inlet Control flow occurs when the flow capacity of the culvert entrance is less than the flow capacity of the culvert barrel. Outlet Control flow occurs in other cases.

For Inlet Control, the headwater required to produce a certain flow rate is computed by assuming that the culvert inlet acts as an orifice. Therefore, the Inlet Control headwater depends only on the geometry of the culvert opening. The headwater of a culvert is the difference between the upstream culvert flow-line elevation and the elevation of the water surface in the channel immediately upstream of the culvert. The headwater is illustrated on Exhibit 1.

For Outlet Control, the required headwater is computed by taking the depth of flow at the culvert outlet plus all head losses, minus the change in flow-line elevation of the culvert from the upstream to downstream end. The program considers the entrance losses, the friction loss in the culvert barrel, and the loss of velocity head at the outlet (which is reduced if there is flow velocity in the channel downstream of the culvert).

This procedure computes the headwater required for Inlet Control conditions and for Outlet Control conditions. The type of flow is determined by the greater headwater.

Exhibit 2, in Appendix A of this manual, contains a flow chart for the Control Design Procedure of this program. You may find it convenient to refer to this flow chart as you read this section of the manual and use the program.

2.2 REQUIRED INPUT DATA FOR CONTROL DESIGN PROCEDURE

2.2.1 Flow Rate

The required flow rate, in cfs, may be any reasonable positive value.

2.2.2 Culvert Diameter

The inside diameter of the culvert opening is important not only in determining the total flow area of the culvert, but also in determining whether the headwater and tailwater elevations are adequate to submerge the inlet or outlet of the culvert. Exhibit 1 of this manual illustrates the culvert diameter.

2.2.3 Tailwater Elevation

The Tailwater of a culvert is the difference between the downstream culvert flow-line elevation and the elevation of the water surface in the channel immediately downstream of the culvert. The tailwater is illustrated on Exhibit

1.

It is important to remember that the headwater and tailwater depths are each measured from the culvert flow-line elevation on different ends of the culvert. Therefore, just because the headwater and the tailwater are equal for a particular culvert, it is not necessarily true that the water surface elevations on the upstream and downstream side of the culvert are equal.

2.2.4 Mannings Roughness Coefficient

This program uses Manning's Equation to compute friction losses in the culvert barrel. The roughness of the culvert is represented by Manning's Roughness Coefficient, commonly called the "n-value". Suggested values for Manning's n-value are listed in Appendix B of this manual, and in many hydraulics reference books. Roughness coefficients should be adjusted according to experience in your geographic area, and according to your judgment of the culvert condition.

Some engineers have a tendency to be "conservative" in estimating n-values. However, values which are conservative in one respect may be non-conservative in another. It is not generally acceptable as a designer to simply add a certain percentage to all coefficients in order to produce a conservative design. For example, a culvert which has more flow capacity than the design computations indicate may have excessive flow velocities which cause downstream erosion.

2.2.5 Entrance Loss Coefficient

The Entrance Loss Coefficient is used to determine the amount of head loss which occurs at the entrance to the culvert. A higher value for the coefficient gives a higher head loss.

Appropriate values for the entrance loss coefficient range from 0.2 to about 0.8 for pipe culverts. For a sharp-edged culvert entrance with no rounding, 0.5 is recommended. For a well-rounded entrance, 0.2 is appropriate. An example of a fairly well-rounded entrance is the socket end of a concrete pipe section.

Appendix C of this manual contains a further discussion of the entrance loss coefficient, and presents a list of values for different types of culvert entrances.

2.2.6 Orifice Flow Coefficient

The Orifice Flow Coefficient is used in the program to determine the flow capacity of the culvert inlet as an orifice. A higher value for the coefficient gives a higher flow capacity. Appropriate values range from 0.55 to about 0.90. A value of 0.62 is appropriate for many common situations.

2.2.7 Culvert Length

The culvert length should be measured in feet, along the center-line of the culvert.

2.2.8 Culvert Slope

The flow-line of a culvert is the lowest point on the inside of the culvert opening. Most culverts are installed with some "positive slope". That is, the flow-line of the culvert is slightly lower on the downstream end than the upstream end, so that some flow velocity can be maintained in the culvert even under low flow conditions. A sufficient slope to maintain a minimum flow velocity of 3 feet per second is often required.

The culvert flow-line slope is the average drop in elevation per foot of length along the culvert. For example, if the culvert flow-line drops 1 foot in a lenth of 100 feet, then the culvert flow-line slope is 0.01 feet per foot. Culvert flow-line slopes are sometimes expressed in percent. A slope of 0.01 feet per foot is the same as a 1% slope.

This program assumes that the size, shape, roughness, and slope of the culvert is constant throughout the length of the culvert. The slope of the culvert is used by the program to compute the drop in flow-line between the upstream and downstream ends of the culvert. It is also used to compute the normal depth of flow in the culvert under inlet control conditions.

2.2.9 Downstream Flow Velocity

In analyzing flow through culverts, it is common to assume that the kinetic energy of the water flowing through the culvert is lost when the water exits the culvert and enters a "still pool" of water on the downstream side of the culvert. The exit loss would then equal the velocity head of the flow in the culvert.

Often, however, the culvert is located in a channel in which the flow continues downstream of the culvert without being detained downstream of the culvert. In such cases, the velocity head in the culvert may not be completely lost. For this reason, this program allows you to enter a value for the downstream channel velocity. The program then considers the downstream flow velocity in computing the exit loss of the culvert, as described in Section 2.3.3.4 of this manual.

2.3 DESCRIPTION OF RESULTS OF CONTROL DESIGN PROCEDURE

2.3.1 Inlet Control Headwater

As mentioned previously, this procedure computes the required headwater for both inlet control and outlet control conditions. The results of both computations are displayed. However, the higher computed headwater is listed first and highlighted, so that it is convenient to quickly tell whether the culvert will operate under inlet control or outlet control.

For inlet control conditions, the capacity of the culvert is limited by the capacity of the culvert opening, rather than by conditions farther downstream. For inlet control flow, the culvert inlet acts as an orifice. Therefore, the inlet control headwater can be determined by the orifice flow equation:

$$H = R/2 + [1/C^2][Q^2/(2gA^2)]$$

in which:

H = Headwater (feet), measured above the culvert flow-line
R = Rise of culvert (height of culvert opening) (feet)
C = Orifice Flow Coefficient
Q = Flow Rate (cfs)
g = Acceleration due to gravity (feet/second/second)

2.3.2 Outlet Control Headwater

For outlet control flow, the required headwater must be computed considering several conditions within the culvert and downstream. The headwater required for outlet control conditions is computed as follows:

$$HeadWater = D + H - LS$$

in which:

D = The flow depth at the culvert outlet (feet) (see Section 2.3.8.1)
H = The head loss in the culvert (feet) (see Section 2.3.3)
L = The length of the culvert (feet)
S = The slope of the culvert flow-line (feet/foot)

2.3.3 Head Loss Through Culvert

2.3.3.1 Head Loss Formula

The total Head Loss, or energy loss, through the culvert is measured in feet. The head loss is computed using the following formula:

HeadLoss = Friction Loss + Entrance Loss + Exit Loss

As described in Section 2.3.8.1 of this manual, the head at the culvert outlet may be greater than the tailwater under certain conditions. Under these conditions, the total head loss through the culvert will include an additional exit loss equal to the difference between the culvert outlet head and the tailwater.

The following sections of this manual describe the methods used by the program to compute each of these losses.

2.3.3.2 Method of Computing Friction Losses

The friction loss in the culvert is computed using Manning's formula, which is expressed as follows:

$$F = L\left[Qn/1.486AR^{(2/3)}\right]^2$$

in which:

F = Friction Loss (feet)
L = Culvert Length (feet)
Q = Flow Rate in the culvert (cfs)
n = Manning's Roughness Coefficient
A = Area of Flow (square feet)
R = Hydraulic Radius (feet) = (Flow Area)/(Wetted Perimeter)

2.3.3.3 Method of Computing Entrance Losses

The entrance loss is computed as described in Section 2.2.5 and Appendix C of this manual.

2.3.3.4 Methods of Computing Exit Losses

2.3.3.4.1 Pressure Flow Conditions

For pressure flow, the exit loss is computed by the following formula, which is taken from page 111 of "Modern Sewer Design" (see Appendix D, References):

$$L = (V-C)^2/(2g)$$

in which:

L = Exit Loss (feet)
V = Flow Velocity in culvert (fps)
C = Flow Velocity in channel downstream (fps)
g = Acceleration due to gravity (feet/second/second)

If the downstream channel flow velocity is greater than the flow velocity in the culvert, the exit loss is assumed to be zero.

2.3.3.4.2 Open-Channel Flow Conditions

For open-channel flow, the exit loss is computed by the following formula, which is taken from page 110 of "Modern Sewer Design" (see Appendix D, References):

$$L = 0.2\{[V^2/(2g)] - [C^2/(2g)]\}$$

in which:

L = Exit Loss (feet)
V = Flow Velocity in culvert (fps)
C = Flow Velocity in channel downstream (fps)
g = Acceleration due to gravity (feet/second/second)

0.2 = the expansion loss coefficient

If the downstream channel flow velocity is greater than the flow velocity in the culvert, then this formula provides a negative value for the exit loss. In such a case, the exit loss is assumed to be zero.

2.3.4 Flow Velocity in Culvert

The flow velocity in the culvert is computed as simply the flow rate divided by the cross-sectional area of the flow. The depth of flow in the culvert depends on the conditions of flow. If the tailwater exceeds the culvert height, or the critical depth of flow in the culvert exceeds the culvert height, then the culvert will flow full, and the cross-sectional area of flow is equal to the cross-sectional area of the culvert opening.

For other conditions, however, the flow depth may be equal to the tailwater elevation, the normal depth of flow in the culvert, or a value between the critical depth of flow and the height of the culvert. The Program Flow Chart contained in Exhibit 2 of this manual illustrates the determination of the flow depth in the culvert.

The allowable flow velocity of a culvert may be restricted to a certain value, such as 10 feet per second. In some cases, high flow velocities at the downstream end of a culvert may create the need for erosion protection.

2.3.5 Froude Number in Culvert

Froude Number is the ratio of the inertial forces to the gravitational forces in a flowing fluid. It is computed using this formula:

$$\text{Froude Number} = \frac{V}{(gA/T)^{(1/2)}}$$

in which:

V = Flow Velocity (fps)
g = Acceleration due to gravity = 32.2 feet/sec/sec
A = Cross-sectional Area of Flow (square feet)
T = Top Width of Flow (feet)

If the Froude Number is greater than one (1.00), then flow in the culvert is "super-critical". A Froude Number less than one indicates "sub-critical" flow. Critical flow is indicated by a Froude Number of 1.00.

2.3.6 Velocity Head in Culvert

The velocity head represents the level of kinetic energy within the culvert. The velocity head is used to estimate the culvert entrance and exit losses, and is computed using the following formula:

$$\text{Velocity Head} = V^2 / 2g$$

in which
- V = Flow Velocity in the culvert (fps)
- g = Acceleration due to gravity = 32.2 feet/second/second

2.3.7 Special Information for Inlet Control

2.3.7.1 Normal Depth of Flow In Culvert

For Inlet Control conditions, the depth of flow within the culvert is assumed to be Normal Depth. This assumption is only valid if the culvert pipe is sufficiently long to allow the flow depth to stabilize at Normal Depth. Some of the references listed in Appendix D indicate that the culvert length should be at least 6 times the culvert height before normal depth is attained.

This program uses a procedure based on Manning's equation to solve for normal depth:

$$Q = \frac{1.486}{n} A R^{(2/3)} S^{(1/2)}$$

in which:
- Q = Flow Rate in the channel (cfs)
- n = Manning's Roughness Coefficient
- A = Area of Flow (square feet)
- R = Hydraulic Radius (feet) = (Flow Area)/(Wetted Perimeter)
- S = Slope of Energy Grade Line (feet per foot)

The first step in the procedure is to compute the maximum flow capacity of the culvert. This capacity occurs at a flow depth of 0.938 times the culvert diameter. If this capacity is less than the required flow rate (as entered by you), then the program assumes full flow conditions.

Assuming that the channel has sufficient capacity to convey the required flow rate, this program computes normal depth using an iterative approach. Manning's Equation is re-arranged in terms of the depth of flow. An initial flow depth estimate of one-half of the channel diameter is substituted into the equation, and a new approximation is computed for the flow depth.

The new value is compared with the previous approximation, and if the difference is less than 0.001 feet, the depth is assumed to be the Normal Depth. If not, a new approximation for Normal Depth is computed as the geometric mean of the previous two approximations.

This method gives very quick, precise, and reliable values for the Normal Depth of flow in a circular channel, except in cases in which the normal depth is above about 88% of the channel diameter. In such cases, the program may complete the maximum 30 iterations without reaching the required accuracy.

2.3.8 Special Information for Outlet Control

2.3.8.1 Head at Culvert Outlet

The head at the culvert outlet is one of the most important determinants of the type of flow in a culvert. The program flow chart contained on Exhibit 2 illustrates the assumptions made by the program in determining the culvert outlet head.

If the tailwater is equal to or greater than the culvert height, then the culvert flows full, and the outlet head is equal to the tailwater. If the tailwater is less than the culvert height, however, the program computes the critical depth of flow in the culvert (as described in the following section). The program then assumes that the outlet head is halfway between the critical depth and the height of the culvert, unless the tailwater is higher than this value, in which case the outlet head is equal to the tailwater. It is evident, then, that the outlet head is equal to the tailwater except in low tailwater conditions.

2.3.8.2 Critical Depth of Flow in Culvert

This program computes the critical depth by an iterative procedure, which arrives at a value which solves the following equation:

$$(Q/g)^{2} = (A/T)^{3}$$

in which

- Q = Flow Rate in the channel, in cfs
- g = Acceleration due to gravity (32.2 ft/sec/sec)
- A = Cross-sectional area of flow (square feet)
- T = top width of flow (feet)

The program first estimates the critical depth in a square channel having an area equal to the circular channel. This depth is as follows:

$$F = Q^{2}/(g\ r^{2}) + r(1+\quad /2)$$

in which:

- F = Estimate of Critical Depth (feet)
- Q = Flow Rate (cfs)
- g = Acceleration due to gravity (32.2 feet/sec/sec)
- = 3.1415926+
- r = Radius of Channel (feet)

This estimate is then inserted into the first equation. If the two sides of the equation do not agree to within 0.001 feet, a new estimate of the critical depth is computed by the following equation:

$$d = F[(Q^{2}/g)/(a^{3}/T)]^{\{(2/9)[|(d-r)/r|+1]\}}$$

in which:

- d = new estimate of critical depth (feet)
- c = old estimate of critical depth (feet)
- Q = flow rate (cfs)
- g = acceleration due to gravity (32.2 feet/sec/sec)
- a = cross-sectional area of flow (square feet)
- T = top width of flow (feet)
- r = radius of channel (feet)

The critical depth procedure automatically terminates after 30 iterations, even if the desired accuracy cannot be attained. This usually results from a situation in which the critical depth exceeds about 88% of the channel diameter.

2.4 EXAMPLES OF CONTROL DESIGN PROCEDURE

2.4.1 Example of Inlet Control

```
--------------------------------------------------------------------------
                    PIPE CULVERT ANALYSIS
     DETERMINATION OF CONTROL AND HEADWATER ELEVATION
Flow Rate (cubic feet per second)                                200
Culvert Diameter (feet)                                          4
Tailwater Elevation above Culvert Flow-Line (feet)               3
Manning's Roughness Coefficient (n-value)                        .013
Entrance Loss Coefficient of Culvert Opening                     .5
Orifice Flow Coefficient of Culvert Opening                      .62
Culvert Length (feet)                                            100
Culvert Slope (feet per foot)                                    .020
Channel Flow Velocity Downstream (feet per second)               3
                         *** RESULTS ***

INLET CONTROL HEADWATER ABOVE CULVERT FLOW-LINE (FEET)              12.23
Outlet Control Headwater above Culvert Flow-Line (feet)              8.46
Head Loss Through Culvert (feet)                                    12.23
Flow Velocity (feet per second)                                     18.43
Froude Number                                                       1.755
Velocity Head (feet)                                                 5.28
SPECIAL INFORMATION FOR INLET CONTROL CONDITIONS:
Normal Depth of Flow in Culvert (feet)                               3.22

Press Return to repeat this operation, or Esc to return to Main Menu
--------------------------------------------------------------------------
```

2.4.2 Example of Outlet Control with High Tailwater

```
                    PIPE CULVERT ANALYSIS
        DETERMINATION OF CONTROL AND HEADWATER ELEVATION
Flow Rate (cubic feet per second)                              200
Culvert Diameter (feet)                                        4
Tailwater Elevation above Culvert Flow-Line (feet)             3
Manning's Roughness Coefficient (n-value)                      .013
Entrance Loss Coefficient of Culvert Opening                   .5
Orifice Flow Coefficient of Culvert Opening                    .62
Culvert Length (feet)                                          150
Culvert Slope (feet per foot)                                  .020
Channel Flow Velocity Downstream (feet per second)             3
                        *** RESULTS ***

OUTLET CONTROL HEADWATER ABOVE CULVERT FLOW-LINE (FEET)          12.46
Inlet Control Headwater above Culvert Flow-Line (feet)           12.03
Head Loss Through Culvert (feet)                                 [illegible]
Flow Velocity (feet per second)                                  15.92
Froude Number                                                    1.402
Velocity Head (feet)                                             [illegible]
SPECIAL INFORMATION FOR OUTLET CONTROL CONDITIONS:
Head at Culvert Outlet (feet)                                    [illegible]

Press Return to repeat this operation, or Esc to return to Main Menu
```

2.4.3 Example of Outlet Control with Low Tailwater

```
                    PIPE CULVERT ANALYSIS
        DETERMINATION OF CONTROL AND HEADWATER ELEVATION
Flow Rate (cubic feet per second)                              200
Culvert Diameter (feet)                                        4
Tailwater Elevation above Culvert Flow-Line (feet)             8
Manning's Roughness Coefficient (n-value)                      .013
Entrance Loss Coefficient of Culvert Opening                   .5
Orifice Flow Coefficient of Culvert Opening                    .70
Culvert Length (feet)                                          150
Culvert Slope (feet per foot)                                  .010
Channel Flow Velocity Downstream (feet per second)             2
                        *** RESULTS ***

OUTLET CONTROL HEADWATER ABOVE CULVERT FLOW-LINE (FEET)          10.38
Inlet Control Headwater above Culvert Flow-Line (feet)           10.03
Head Loss Through Culvert (feet)                                  8.88
Flow Velocity (feet per second)                                  15.92
Froude Number                                                    1.402
Velocity Head (feet)                                              3.93
SPECIAL INFORMATION FOR OUTLET CONTROL CONDITIONS:
Head at Culvert Outlet (feet)                                     4.00
Critical Depth of Flow in Culvert (feet)                          4.00

Press Return to repeat this operation, or Esc to return to Main Menu
```

3 PRESSURE FLOW PROCEDURE

3.1 PURPOSE OF PRESSURE FLOW PROCEDURE

Pressure flow occurs in a culvert when the culvert inlet and outlet (the upstream and downstream openings) are both submerged.

In pressure flow, the head loss through the culvert is caused by three main factors: the losses at the culvert entrance, the losses due to friction in the culvert barrel, and the loss of kinetic energy when the flow leaves the culvert.

In this procedure, the computer program allows you to quickly compute a pressure flow "rating curve" for a pipe culvert. A rating curve is simply a table or curve which relates the flow rates to energy losses. You must first describe the pipe culvert. Then, as you insert flow rates, the program quickly computes the head losses through the culvert, and other information about flow. You may specify as many flow rates as you like.

3.2 REQUIRED INPUT DATA FOR PRESSURE FLOW PROCEDURE

3.2.1 Culvert Diameter

The inside diameter of the culvert opening is important not only in determining the total flow area of the culvert, but also in determining whether the headwater and tailwater elevations are adequate to submerge the inlet or outlet of the culvert.

3.2.2 Mannings Roughness Coefficient

This program uses Manning's Equation to compute friction losses in the culvert barrel. The roughness of the channel is represented by Manning's Rougnness Coefficient, commonly called the "n-value". Suggested values for Manning's n-value are listed in Appendix B of this manual, and in many hydraulics reference books.

Please refer to Section 2.2.4 of this manual for comments about the appropriate choice of n-value and other coefficients.

3.2.3 Entrance Loss Coefficient

The Entrance Loss Coefficient is used to determine the amount of head loss which occurs at the entrance to the culvert. A higher value for the coefficient gives a higher head loss.

Appropriate values for the entrance loss coefficient range from 0.2 to about 0.8 for pipe culverts. For a sharp-edged culvert entrance with no rounding, 0.5 is recommended. For a well-rounded entrance, 0.2 is appropriate. An example of a fairly well-rounded entrance is the socket end of a concrete pipe section.

Appendix C of this manual contains a further discussion of the entrance loss coefficient, and presents a list of values for different types of culvert entrances.

3.2.4 Culvert Length

The culvert length should be measured in feet, along the center-line of the culvert.

3.2.5 Channel Flow Velocity Downstream

In analyzing flow through culverts, it is common to assume that the kinetic energy of the water flowing through the culvert is lost when the water exits the culvert and enters a "still pool" of water on the downstream side of the culvert. This "exit loss" would then equal the "velocity head" of the flow in the culvert.

Often, however, the culvert is located in a channel in which the flow continues downstream of the culvert without ever being detained in a "still pool". In such cases, the velocity head in the culvert may not be completely lost. For this reason, this program allows you to enter a value for the downstream channel velocity. The program then considers the downstream flow velocity in computing the exit loss of the culvert, by the method described in Section 2.3.3.4.1 of this manual.

3.2.6 Flow Rates

After you have inserted all of the input data values which describe the size and condition of the culvert, the program allows you to begin entering flow rates. As you enter each flow rate and press the return key, the program quickly computes the head loss and other details about the flow through the culvert.

You may enter as many flow rates as you like. They may be of any reasonable value (zero or positive). If you enter an excessively large flow rate, the program may not be able to compute and propertly display the corresponding head loss.

When you are ready to stop entering flow rates, you may press the Esc key.

3.3 DESCRIPTION OF RESULTS OF PRESSURE FLOW PROCEDURE

3.3.1 Head Loss

The Head Loss is measured in feet, and represents the total energy loss of flow through the culvert. The head loss is computed for each flow rate using the following formula:

$$\text{HeadLoss} = \text{Friction Loss} + \text{Entrance Loss} + \text{Exit Loss}$$

The friction loss in the culvert is computed using Manning's formula, as described in Section 2.3.3.2 of this manual.

The entrance loss is computed as described in Section 2.3.3.3 and Appendix C of this manual.

The Exit Loss for pressure flow conditions is computed by the formula given in Section 2.3.3.4.1 of this manual.

3.3.2 Velocity

The flow velocity in the culvert is computed as simply the flow rate divided by the cross-sectional area of the flow. Since the culvert flows full under pressure flow conditions, the flow area equals the cross-sectional area of the culvert opening.

3.3.3 Froude Number

Froude Number is the ratio of the inertial forces to the gravitational forces in a flowing fluid. It is computed as described in Section 2.3.5 of this manual.

3.3.4 Velocity Head

The velocity head represents the level of kinetic energy. The velocity head is used to estimate the culvert entrance and exit losses, and is computed using the formula stated in Section 2.3.6 of this manual.

3.4 EXAMPLE OF PRESSURE FLOW PROCEDURE

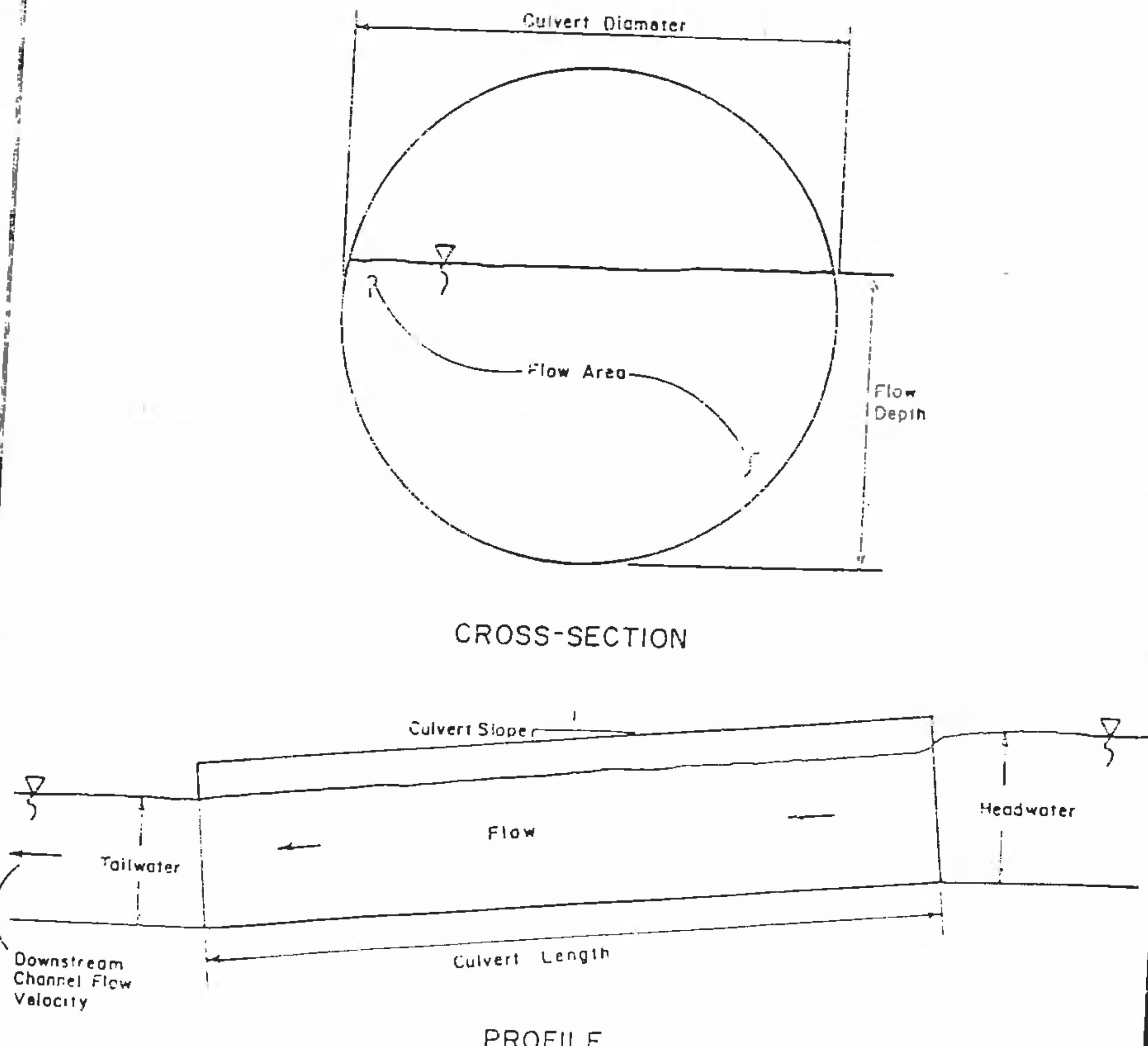
PIPE CULVERT ANALYSIS
PRESSURE FLOW ANALYSIS

Culvert Diameter (feet)	3.5
Manning's Roughness Coefficient (n-value)	.013
Entrance Loss Coefficient of Culvert Opening	.5
Culvert Length (feet)	150
Channel Flow Velocity Downstream (feet per second)	3

*** RESULTS ***

Flow Rate (cfs)	Head Loss (ft)	Velocity (fps)	Froude Number	Velocity Head (ft)
0.00	0.00	0.00	0.000	0.00
10.00	0.02	1.04	0.098	0.02
20.00	0.09	2.08	0.196	0.07
30.00	0.21	3.12	0.294	0.15
40.00	0.39	4.16	0.392	0.27
50.00	0.66	5.20	0.490	0.42
60.00	1.00	6.24	0.587	0.60
70.00	1.42	7.28	0.685	0.82
80.00	1.92	8.32	0.783	1.07
90.00	2.51	9.35	0.881	1.36
100.00	3.17	10.39	0.979	1.68
110.00	3.91	11.43	1.077	2.03
120.00	4.74	12.47	1.175	2.42

Enter Flow Rate, or Press the Esc Key to End



PIPE CULVERT

DODSON & ASSOCIATES, INC.

JOB NO.	DATE	EXHIBIT
	APRIL 85	1

PURPOSE OF THE ENTRANCE LOSS COEFFICIENT

The entrance loss coefficient is used to estimate the amount of energy lost as flow enters the culvert from upstream. Entrance losses are computed as a fraction of the "velocity head" or kinetic energy of flow in the culvert. The velocity head in the culvert is computed as:

$$\text{Velocity Head} = V^2/(2g)$$

in which:

V = flow velocity in the culvert (fps)
g = acceleration due to gravity (32.2 feet/second/second)

The velocity head is multiplied by the entrance loss coefficient to estimate the amount of energy loss at the culvert entrance. As shown in the following table, entrance losses can vary from about 0.1 to about 0.8 of the velocity head for pipe culverts.

The source of the information in the following table is "Street and Highway Drainage", Institute of Transportation and Traffic Engineering, University of California at Berkeley, 1969.

VALUES OF ENTRANCE LOSS COEFFICIENT

TYPE OF STRUCTURE AND DESIGN OF ENTRANCE	COEFFICIENT
Concrete Pipe Projecting from Fill (no headwall):	
Socket end of pipe	0.20
Square cut end of pipe	0.50
Concrete Pipe with Headwall or headwall and wingwalls:	
Socket end of pipe	0.10
Square cut end of pipe	0.50
Rounded entrance, with rounding radius = 1/12 of diameter	0.10
Corrugated Metal Pipe:	
Projecting from fill (no headwall)	0.80
With Headwall or headwall and wingwalls, square edge	0.50

Applied Hydraulics in Engineering

Henry M. Morris and James M. Wiggert, 1972, the Ronald Press Company, New York. This book is a general text on hydraulics. Chapters 4, 5, and 6 are especially related to open-channel flow.

Civil Engineering Hydraulics

R. E. Featherstone and C. Nalluri, 1982, Granada Publishing Limited, London. This book is fairly theoretical, but with many examples. Chapter 8 applies to open-channel flow.

Design Charts for Open-Channel Flow

1980, U. S. Department of Transportation, Federal Highway Administration, Washington, D.C. This is an excellent reference, containing many charts for computing normal depth and critical depth of flow in open channels. The charts can be cross-checked with the results of this computer program.

Handbook of Hydraulics

Ernest F. Brater and Horace Williams King, 1976, McGraw-Hill, Inc. New York. This book is not a good place to start learning about hydraulics, but we keep coming back to it for information not easily available elsewhere.

Modern Sewer Design

1980, American Iron and Steel Institute, Washington, D.C. This book is an excellent reference on practical hydraulics.

Open Channel Hydraulics

Ven Te Chow, 1959, McGraw-Hill, Inc. New York. This is the classic text on hydraulics.

Water Resources Engineering

Ray K. Linsley and Joseph B. Franzini, 1979, McGraw-Hill, Inc., New York. This is an excellent general text. Chapter 13 relates to open channels.

ATTACHMENT Q

Existing and Proposed Culvert Inventory

Revised 03/26/2010

EXISTING AND PROPOSED PIPE CULVERTS

BLACK MESA/KAYENTA MINES

OBS	CULVERT ID	TOTAL WATERSHED (ac)	CURVE NUMBER	FLOW RATE (cfs)	HEADWATER[2] 10YR -6HR. (ft)	DW/D RATIO	CULVERT DIAMETER (in)	PIPE LENGTH (ft)	PIPE SLOPE (%)	DOWNSTREAM[1] VELOCITY (fps)
1	E0001	25.0	77	1.68	2.00	0.50	48	96	4.2	1.43
2	E0002	25.0	77	1.68	1.01	0.51	24	96	4.2	3.42
3	E0007	6.0	85	5.31	1.12	0.56	24	51	2.6	3.93
4	E0008	3.7	91	4.69	1.09	0.55	24	75	3.8	4.98
5	E0009	288.6	77	49.07	4.28	1.43	36	55	0.0	6.94
6	E0011	32.0	83	24.60	3.03	0.51	(design) 72	230	5.0	9.68
7	E0012	16.2	83	12.45	4.00	0.50	96	176	6.0	5.90
8	E0013	3.3	83	2.54	1.51	0.50	36	110	8.0	4.47
9	E0014	129.8	83	64.83	2.74	0.34	96	250	5.8	8.67
10	E0015	80.6	83	43.32	4.03	0.50	96	200	4.9	8.44
11	E0016	67.0	83	17.78	3.52	0.44	96	100	1.0	5.60
12	E0017	67.0	83	17.78	3.52	0.44	96	100	1.0	5.60
13	E0018	7.4	84	6.11	1.31	0.52	30	91	12.3	7.35
14	E0019	1.2	83	0.92	4.00	0.50	96	98	3.2	2.84
15	E0020	2.8	85	2.48	1.03	0.52	24	67	4.9	4.11
16	E0021	3.0	84	2.48	1.26	0.50	30	112	4.0	3.49
17	E0022	9.9	81	6.54	1.32	0.53	30	120	4.14	5.17
18	E0023	8.3	81	5.48	1.30	0.52	30	120	4.1	6.14
19	E0024	18.9	82	7.32	1.31	0.52	30	120	1.9	5.12
20	E0025	12.9	81	8.52	1.31	0.44	36	130	2.1	5.46
21	E0026	27.2	82	19.41	1.80	0.60	36	110	2.3	6.77
22	E0027	6.5	82	2.56	1.03	0.52	24	210	3.6	3.93
23	E0028	4.1	81	2.71	1.03	0.52	24	50	4.5	3.34
24	E0029	26.9	83	20.68	1.85	0.62	36	135	2.6	6.84
25	E0030	84.3	80	32.57	3.08	1.03	36	150	2.0	3.24
26	E0031	12.0	73	1.76	2.50	0.50	60	125	2.0	2.64
27	E0032	12.0	73	1.76	2.50	0.50	60	125	2.0	2.64
28	E0033	15.9	85	10.19	1.58	0.63	30	380	3.5	6.53
29	E0034	46.7	84	39.55	3.50	1.17	36	460	4.7	5.81
30	E0035	watershed	combined	with	E0034					
31	E0036	45.4	76	19.05	1.79	0.60	36	370	3.0	2.48
32	E0037	66.0	73	10.55	1.48	0.49	36	420	3.7	2.12
33	E0038	14.6	83	5.61	2.01	0.50	54	322	3.2	4.13
34	E0039	136.3	83	73.26	3.11	0.69	54	420	4.0	3.48
35	E0040	6.0	83	4.61	1.09	0.55	24	220	6.7	5.64
36	E0041	36.8	83	28.29	2.15	0.72	36	480	6.7	2.74
37	E0042	11.8	81	5.24	1.52	0.51	36	220	4.5	4.61
38	E0043	5.3	82	3.78	1.06	0.53	24	260	5.3	3.45

EXISTING AND PROPOSED PIPE CULVERTS

BLACK MESA/KAYENTA MINES

OBS	CULVERT ID	TOTAL WATERSHED (ac)	CURVE NUMBER	FLOW RATE (cfs)	HEADWATER[2] 10YR -6HR. (ft)	DW/D RATIO	CULVERT DIAMETER (in)	PIPE LENGTH (ft)	PIPE SLOPE (%)	DOWNSTREAM[1] VELOCITY (fps)
39	E0044	9.5	83	7.30	1.54	0.51	36	220	3.6	4.68
40	E0045	70.2	83	53.97	3.53	0.88	48	640	1.5	9.07
41	E0046	23.7	83	11.40	1.61	0.54	36	120	10.2	4.82
42	E0047	5.7	82	1.26	0.77	0.39	24	80	4.3	4.22
43	E0048	5.7	85	1.26	0.70	0.39	24	80	4.3	4.22
44	E0049	2.0	86	1.89	1.01	0.51	24	58	0.5	4.11
45	E0050	15.2	90	18.30	2.08	0.69	36	314	1.5	5.30
46	E0051	5.7	89	6.48	1.17	0.59	24	260	1.9	5.34
47	E0052	23.2	73	6.81	1.54	0.51	36	180	3.4	6.08
48	E0053	16.9	73	4.96	1.10	0.55	24	140	1.6	3.70
49	E0054	10.1	80	3.08	1.04	0.52	24	50	4.4	8.00
50	E0055	10.1	80	3.08	1.04	0.52	24	100	2.5	8.00
51	E0057	37.4	73	10.97	1.49	0.75	36	150	5.0	4.11
52	E0058	68.4	73	20.06	1.83	0.61	36	100	5.4	6.35
53	E0059	89.6	73	13.43	2.05	0.51	48	130	3.1	6.58
54	E0060	7.1	73	2.08	1.02	0.51	24	70	6.4	3.35
55	E0061	60.8	75	13.33	2.05	0.51	48	150	4.9	5.08
56	E0062	5.3	73	1.55	1.01	0.51	24	164	6.0	3.78
57	E0063	17.3	73	2.54	0.77	0.39	24	71	2.3	4.72
58	E0064	17.3	73	2.54	0.77	0.39	24	71	2.3	4.72
59	E0065	38.3	73	11.23	4.00	0.50	96	240	2.5	3.74
60	E0066	89.2	75	17.96	2.30	0.51	54	330	2.5	9.17
61	E0067	32.1	91	40.82	2.85	0.95	36	112	3.0	6.16
62	E0069	14.3	91	18.21	1.77	0.59	36	106	4.0	7.09
63	E0070	14.6	89	16.88	2.76	1.38	24	93	3.0	3.45
64	E0071	7.7	91	9.74	1.39	0.70	24	80	8.9	7.40
65	E0072	16.7	89	18.77	2.11	0.70	36	120	4.7	5.16
66	E0074	6.8	91	8.69	1.31	0.66	24	94	1.0	4.78
67	E0076	22402.4	80	754.60	17.16	2.15	96	366	0.9	6.53
68	E0077	22402.4	80	754.60	17.16	2.15	96	366	0.9	6.53
69	E0078	22402.4	80	754.60	17.16	2.15	96	366	0.9	6.53
70	E0079	21363.0	80	1385.00	14.01	1.00	168	312	0.8	4.92
71	E0080	21636.0	80	1385.00	14.01	1.00	168	312	0.8	4.92
72	E0081	27165.0	80	315.90	7.87	0.98	96	324	0.6	11.48
73	E0082	27165.0	80	315.90	7.87	0.98	96	324	0.6	11.48
74	E0083	27165.0	80	315.90	7.87	0.98	96	324	0.6	11.48
75	E0084	27165.0	80	315.90	7.87	0.98	96	324	0.6	11.48
76	E0085	27165.0	80	315.90	7.87	0.98	96	324	0.6	11.48

Revised 01/28/2005

EXISTING AND PROPOSED PIPE CULVERTS

BLACK MESA/KAYENTA MINES

OBS	CULVER ID	TOTAL WATERSHED (ac)	CURVE NUMBER	FLOW[1] RATE (cfs)	HEADWATER[2] 10YR-6HR (ft)	DW/D RATIO	CULVERT DIAMETER (in)	PIPE LENGTH (ft)	PIPE SLOPE (%)	DOWNSTREAM[1] VELOCITY (fps)
77	E0086	42323.7	81	752.00	30.00	4.62	78	262	2.0	6.30
78	E0087	42323.7	81	1039.00	30.00	4.00	90	262	2.0	6.03
79	E0088	6.4	91	8.14	1.55	0.52	36	250	3.8	5.34
80	E0089	20.9	76	5.23	1.52	0.51	36	460	1.0	2.95
81	E0090	79.9	75	14.85	2.06	0.52	48	300	2.5	3.85
82	E0091	1649.0	79	431.00	6.35	0.71	108	540	2.1	9.00
83	E0092	7.1	78	3.63	1.05	0.53	24	240	6.0	2.43
84	E0093	12.2	90	14.69	1.67	0.56	36	334	6.0	3.72
85	E0094	11.8	91	12.00	1.59	0.80	24	200	1.5	4.14
86	E0095	17.2	91	21.87	1.89	0.63	36	220	6.0	4.68
87	E0096	283.9	91	243.36	8.71	1.74	60	380	3.5	8.03
88	E0097	16.4	91	20.86	1.85	0.62	36	160	4.0	4.84
89	E0098	29.6	91	29.91	2.22	0.74	36	240	6.0	4.77
90	E0099	75.0	90	71.08	3.95	1.13	42	325	5.0	7.19
91	E0100	340.2	84	152.01	4.92	0.98	60	290	3.0	7.02
92	E0101	29.8	84	24.60	1.99	0.66	36	170	3.0	5.70
93	E0102	111.2	85	62.81	3.47	0.99	42	290	3.0	5.69
94	E0103	4.2	91	5.34	1.22	1.04	14	127	4.6	3.84
95	E0106	35.0	85	21.30	1.87	0.62	36	100	3.3	6.05
96	E0107	81.8	83	43.97	-3.06	1.05	36	126	4.3	7.12
97	E0108	1.4	83	1.08	1.00	0.50	24	71	1.1	1.28
98	E0109	7.6	81	5.02	1.52	0.51	36	520	5.0	5.13
99	E0110	8.2	81	3.64	1.76	0.50	42	220	2.7	3.01
100	E0111	6.0	73	0.88	1.00	0.50	24	160	2.0	2.68
101	E0116	2.0	91	2.54	1.03	0.69	18	75	2.9	3.13
102	E0117	8.8	73	2.58	1.03	0.52	24	150	8.0	3.74
103	E0119	214.1	82	88.29	10.82	3.61	36	96	2.5	4.01
104	E0120	29.8	83	16.02	2.05	1.03	24	58	2.0	.08
105	E0122	43.3	87	31.20	2.98	0.99	36	320	4.7	4.52
106	E0125	89.6	81	6.34	2.58	1.29	24	60	3.0	3.64
107	E0127	29.7	79	10.14	1.42	0.71	24	160	2.0	1.10
108	E0128	33.1	82	23.62	1.95	0.97	24	160	2.0	1.19
109	E0143	41.0	83	16.09	2.64	1.32	24	160	2.0	3.79
110	E0144	59.6	82	18.38	2.38	1.19	24	140	2.0	4.00
111	E0146	46.7	84	38.56	2.70	0.90	36	160	2.0	9.20
112	P0147	5.3	83	4.06	1.03	0.52	24	140	2.0	2.71
113	P0148	350.6	83	127.68	6.17	1.54	48	160	3.0	5.54

Revised 01/25/2002

EXISTING AND PROPOSED PIPE CULVERTS

BLACK MESA/KAYENTA MINES

OBS	CULVER ID	TOTAL WATERSHED (ac)	CURVE NUMBER	FLOW[1] RATE (cfs)	HEADWATER[2] 10YR-6HR (ft)	DW/D RATIO	CULVERT DIAMETER (in)	PIPE LENGTH (ft)	PIPE SLOPE (%)	DOWNSTREAM[1] VELOCITY (fps)
114	E0150	26.5	91	33.70	2.42	0.80	48	120	1.0	6.96
115	P0152	42323.7	81	1946.00	30.00	3.00	120	260	0.5	6.30
116	P0153	42323.7	81	1946.00	30.00	3.00	120	260	0.5	6.30
117	E0159	24.4	81	5.49	1.12	0.69	24	120	3.6	3.49
118	E0160	46.9	84	24.70	1.99	0.56	24	40	6.8	5.58
119	E0172	4.8	91	4.81	1.09	0.55	24	80	3.4	1.10
120	E0173	6.5	91	8.23	2.07	1.38	18	100	2.0	3.05
121	E0180	2.8	93	3.95	1.01	0.51	24	120	0.5	1.48
122	E0181	3.6	93	4.74	1.23	0.62	24	110	0.5	1.55
123	E0182	9.0	93	9.21	1.35	0.68	24	180	3.0	3.58
124	E0183	4.9	93	5.78	1.14	0.57	24	180	3.0	3.17
125	E0201	177.4	78	43.56	2.69	0.54	60	380	1.1	7.82
126	E0203	26.7	81	10.74	1.50	0.50	36	120	2.0	2.31
127	E0204	31.7	81	20.68	2.25	0.75	36	60	3.0	5.80
128	E0205	188.3	81	58.71	5.43	1.81	36	40	3.0	7.79
129	E0207	4.9	80	2.96	0.74	0.25	36	100	2.0	3.40
130	E0208	24.9	88	22.02	2.35	0.78	36	120	3.0	7.51
131	E0209	24.7	87	18.41	2.98	1.49	24	80	4.0	4.41
132	E0215	20.3	82	14.34	2.37	1.19	24	110	1.4	3.98
133	E0216	2.5	91	2.87	0.84	0.42	24	140	4.1	3.64
134	E0217	4.4	84	2.09	0.70	0.35	24	70	1.1	2.42
135	E0222	41.6	64	0.92	0.44	0.22	24	30	6.9	2.38
136	E0228	192.6	81	59.64	5.55	1.85	36	135	3.0	7.61
137	E0229	3.5	89	3.91	1.00	0.50	24	40	2.0	2.20
138	E0237	42.8	76	17.64	2.84	1.42	24	40	2.0	2.20
139	E0238	16.0	78	8.07	1.58	0.79	24	30	4.0	9.86
140	E0239	20.9	81	13.61	2.28	1.14	24	30	2.0	3.23
141	E0240	30.3	80	18.20	2.07	0.69	36	40	2.0	5.30
142	E0241	588.6	81	137.78	8.81	2.20	48	60	2.5	8.04

EXISTING AND PROPOSED PIPE CULVERTS

BLACK MESA/KAYENTA MINES

OBS	CULVER ID	TOTAL WATERSHED (ac)	CURVE NUMBER	FLOW[1] RATE (cfs)	HEADWATER[2] 10YR-6HR (ft)	DW/D RATIO	CULVERT DIAMETER (in)	PIPE LENGTH (ft)	PIPE SLOPE (%)	DOWNSTREAM[1] VELOCITY (fps)
143	E0244	2.0	89	2.21	0.72	0.36	24	100	2.0	6.04
144	E0246	8.1	89	9.11	DROP INLET	N/A	36	300	2.0	3.32
145	E0247	9.8	90	11.67	2.03	1.02	24	100	2.0	8.97
146	E0248	2.7	91	3.44	0.93	0.47	24	50	2.0	6.25
147	E0259	538.8	78	99.92	4.07	0.68	72	140	2.0	4.61
148	E0266	2340.5	78	795.60	5.67	0.63	108	280	3.0	6.93
149	E0270	404.2	81	29.82	2.89	0.96	36	160	2.0	5.54
150	E0271	404.2	81	29.82	2.89	0.96	36	160	2.0	5.54
151	E0272	404.2	81	29.82	2.89	0.96	36	160	2.0	5.54
152	E0273	16.2	81	10.54	1.89	0.95	24	42	2.0	4.93
153	E0274	564.4	81	20.15	4.72	2.51	24	160	2.0	6.58
154	P0275	564.4	81	80.60	4.72	1.26	48	160	2.0	6.58
155	E0280	344.5	80	121.98	5.30	1.06	60	80	1.0	8.08
156	E0292	0.6	91	0.77	0.41	0.20	24	60	3.0	3.20
157	E0293	1.4	91	1.77	0.63	0.31	24	80	5.0	4.90
158	E0294	25.1	77	7.96	1.26	0.42	36	80	2.0	5.26
159	E0300	112.0	89	104.27	4.73	0.95	60	20	3.0	10.01
160	E0301	5.0	81	3.21	0.89	0.45	24	20	2.0	2.14
161	E0302	5.0	81	2.58	0.79	0.40	24	20	2.0	2.07
162	E0304	19.6	81	8.99	1.70	0.85	24	100	2.0	2.28
163	E0305	0.3	81	0.19	0.25	0.25	12	55	2.0	0.46
164	E0306	1.5	91	1.68	0.89	0.89	12	60	1.0	5.93
165	E0309	27.1	91	7.86	1.54	0.77	24	40	10.3	9.77
166	E0310	6.4	92	8.46	1.63	0.82	24	50	7.6	8.92
167	E0311	4.9	91	6.12	1.09	0.36	36	100	2.0	4.87
168	E0312	4.8	91	6.01	1.08	0.36	36	100	1.8	4.66

Revised 01/25/2002

EXISTING AND PRO‿ ‿ED PIPE CULVERTS
BLACK MESA/KAYENTA MINES

OBS	CULVER ID	TOTAL WATERSHED (ac)	CURVE NUMBER	FLOW RATE (cfs)	HEADWATER[2] 10YR-6HR (ft)	HW/D RATIO	CULVERT DIAMETER (in)	PIPE LENGTH (ft)	PIPE SLOPE (%)	DOWNSTREAM[1] VELOCITY (fps)
169	E0314	12.5	91	14.02	2.33	1.17	24	60	3.0	7.21
170	E0315	6.1	91	6.91	1.16	0.39	36	40	2.0	5.05
171	E0319	160.9	86	47.0	5.0	1.7	36	160	2.5	6.1
172	E0322	160.9	86	47.0	5.0	1.7	36	160	2.5	6.1
173	E0328	5.5	86	5.3	5.0	2.5	24	160	2.5	1.88
174	E0329	14.2	86	13.5	5.0	2.5	24	160	2.5	2.92
175	E0330	28.8	86	21.8	5.0	2.5	24	160	2.5	2.82
176	E0331	218.0	86	68.6	6.0	2.0	36	160	2.5	3.79
177	E0332	0.51	91	0.65	.9	1.8	6	36	1.0	1.44
178	E0333	0.74	91	0.94	.8	.8	12	105	2.0	1.59
179	E0334	0.14	91	0.18	0.5	0.5	12	14	1.0	0.99
180	E0340	9.40	86	8.96	1.41	0.56	18 (design)	60	5.0	7.68
181	E0400	3.11	91	2.52	1.57	1.35	14	50	1.1	3.46
182	E0401	792	86	402.6	14.39	2.4	72	270	2.0	7.65
183	P0402	22410.6	80	754.60	17.16	1.90	108	430	0.9	6.53
184	P0403	22410.6	80	754.60	13.2	1.32	120	430	0.9	5.94
185	P0404	22410.6	80	754.60	17.16	1.90	108	430	0.9	6.53
186	P0405	34.9	81	12.5	2.0	0.8	30	250	2.0	2.60
187	P0406	286.5	84	112.3	4.5	0.75	72	440	2.0	5.63
188	P0407	14407.7	82	347.9	8.4	1.05	96	430	1.0	5.66
189	P0408	14407.7	82	347.9	8.4	1.05	96	430	1.0	5.66
190	P0409	14407.7	82	347.9	8.4	1.05	96	430	1.0	5.66
191	P0410	14407.7	82	347.9	8.4	1.05	96	430	1.0	5.66
192	P0411	15.8	91	17.2	3.0	1.5	24	215	1.5	3.8
193	P0412	326.7	86	120.65	12.0	3.4	42	270	3.5	9.6

Note: [1] When the Downstream Velocity is greater than 6.0 ft/sec, adequate downstream erosion-resistant channel lining will be installed where competent bedrock does not exist.

[2] Design Headwater Depth (DHW) = Headwater depth plus one foot for freeboard

Culvert ID#: EXXXX = Existing Culvert

PXXXX = Proposed Culvert

APR 2010
APPROVED

Revised 03/26/2010

PEABODY WESTERN

Peabody Western Coal Company

May 19, 2000

00-05-22-18

Mr. Jerry Gavette
Office of Surface Mining
Reclamation and Enforcement
1999 Broadway, Suite 3320
Denver, CO 80202-5733

Re: **Kayenta Mine / Permit AZ-0001D / Culvert Removal Minor Field Permit Revision**

Dear Mr. Gavette:

Pursuant to our telephone conversation on May 18,2000, PWCC received approval from Edzel Pugh, OSM Inspector, to remove three culverts (i.e. Culvert #E0303, #E0245 and #E0249) in the permit document and from their field location.

Enclosed are eleven copies of the minor field permit revision submittal, and the notarized verification statement. Please insert the minor field permit revision submittal in the AZ-0001D Permit, Volume 7, Chapter 6, at the end of Attachment Q. If you have any questions, please feel free to contact Gary Wendt or me.

Sincerely,

Jim Schlenvogt

James G. Schlenvogt, P.E.
Engineering and Reclamation Manager
Kayenta Mine

Enc.

C: B. Dunfee (PHCI)
R. Lehn (PWCC-BM)
E. Pugh (OSM – AFO)
G. Wendt (PWCC-KM)

VERIFICATION

I verify under oath that the information contained in this application for a permit, revision, renewal, bond release, or transfer, sales or assignments of permit rights is true and correct to the best of my information and belief.

Signature of Responsible Official Gary W. Wendt

Title Manager, Environmental Date March 26, 2010

SUBSCRIBED AND SWORN TO BEFORE ME BY Gary W. Wendt

This 26th Day of March, 2010

NOTARY PUBLIC James G. Schlenvogt

MY COMMISSION EXPIRES April 9, 2012

OFFICIAL SEAL
JAMES G. SCHLENVOGT
Notary Public - State of Arizona
COCONINO COUNTY
My commission expires April 09, 2012

APR 2010
APPROVED

VERIFICATION

I verify under oath that the information contained in this application for a permit; revision; renewal; or transfer, sales or assignments of permit rights is true and correct to the best of my information and belief.

Signature of Responsible Official Gary W. Wendt

Title Supervisor, Environmental Program Date May 19, 2000

SUBSCRIBED AND SWORN TO BEFORE ME BY Gary W. Wendt

This 19th Day of May 2000

NOTARY PUBLIC Jean M. Schlenvogt

MY COMMISSION EXPIRES ____________________

OFFICIAL SEAL
JEAN M. SCHLENVOGT
NOTARY PUBLIC - STATE OF ARIZONA
COCONINO COUNTY
My commission expires March 31, 2004.

Field Approval of a Permit Revision

U.S. Office of Surface Mining

Permit ID: A Z-0001D

Approval Date: 05/18/2000

Permittee: Peabody Western Coal Company-Kayenta Mine

Description of Permit Revision: Approval to remove Culverts: #E0303, #E0245, #E0249 around the J-28 Facilities Area.

Based on a field review of the proposed revision described above, I have made the findings listed on the back of this form and hereby approve this permit revision:

(✓) without conditions–this revision approval form is incorporated into the approved permit application for the permit identified above.

( ) with the following condition: The permittee shall submit to OSM within days after this permit revision approval, the required number of copies of the revised or added pages, maps, etc. needed to update the approved permit application with this approved revision, along with clear instructions for updating the permit application.

Edzel R Pugh

Inspector

179

Inspector ID No.

Receipt by Permittee:

James Schlenvogt

Printed Name of Permittee's Representative

Mgr, Engineering & Reclation

Title of Permittee's Representative

James Schlenvogt

Signature of Permittee's Representative

May 18, 2000

Date of Service

Findings for Field Approval of a Permit Revision

1. Reclamation as required by the Surface Mining Control and Reclamation Act of 1977 (SMCRA) and the Indian Lands Program (30 CFR Chapter VII, Subchapter E) can be accomplished under the reclamation plan contained in the permit application, as revised by this permit revision.

2. The revision described herein is not significant and complies with all requirements of the Surface Mining Control and Reclamation Act and

   the Indian Lands Program at 30 CFR Chapter VII, Subchapter E.

3. No other requirements under 30 CFR 773.15(c) are applicable.

4. The proposed revision does not indicate that the applicant has added a new partner, officer, principal, principal shareholder, director, or person with a similar ownership or control function required to be listed in the application pursuant to 30 CFR 778.13(c).

5. This revision approval is for a minor revision to the permit where the environmental impacts of the permit approval have been adequately analyzed in:

   the 05/17/90 Environmental Assessment of the approval of the Kayenta Mine permit application, (EIS).

   The actions proposed in the permit revision do not change the environmental impacts. The discussion of environmental impacts in the document identified above remain current and adequate for OSM to take action on this proposed permit revision because no additional environmental impacts would occur beyond those identified in the document identified above.

OSM Office Addresses and Contacts

Office of Surface Mining
505 Marquette Ave. NW
Suite 1200
Albuquerque, NM 87102

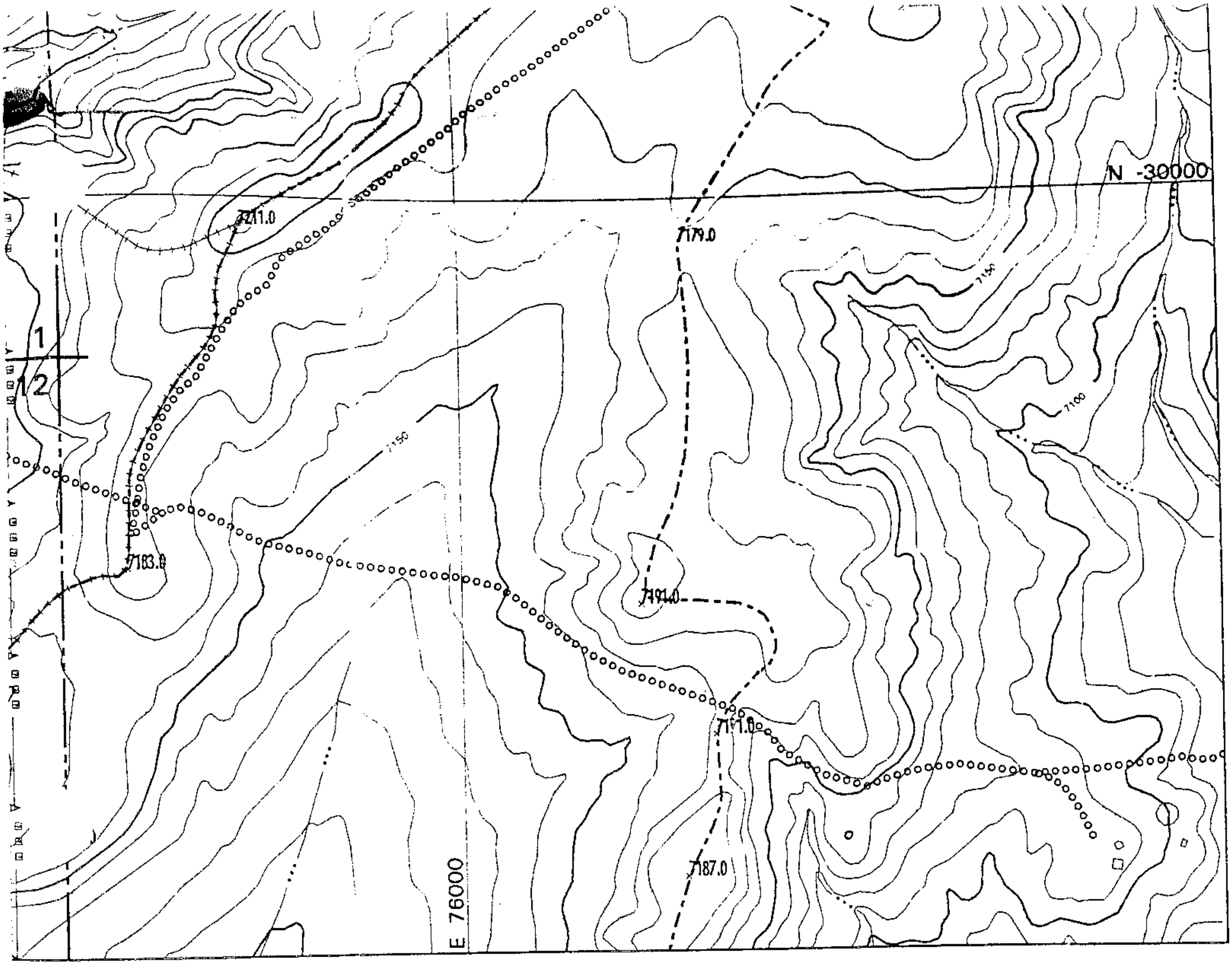
Edzel R Pugh
Field Coordinator

505 - 248 - 5088
Telephone

Office of Surface Mining
1999 Broadway
Suite 3320
Denver, CO 80209

Jerry Gavette
Permit Coordinator

303-844-1496
Telephone



J21-A1

REVISIONS		
CHK'D	DATE	DESCRIPTION
JGS	3/1/95	5YR Permit Ren
JGS	10-18-95	E Q SITES
JGS	6-26-96	CULVERT REV.
JGS	12-2-96	5 YR. MINE PLAN REV.
JGS	10-15-97	OSM RESPONSE

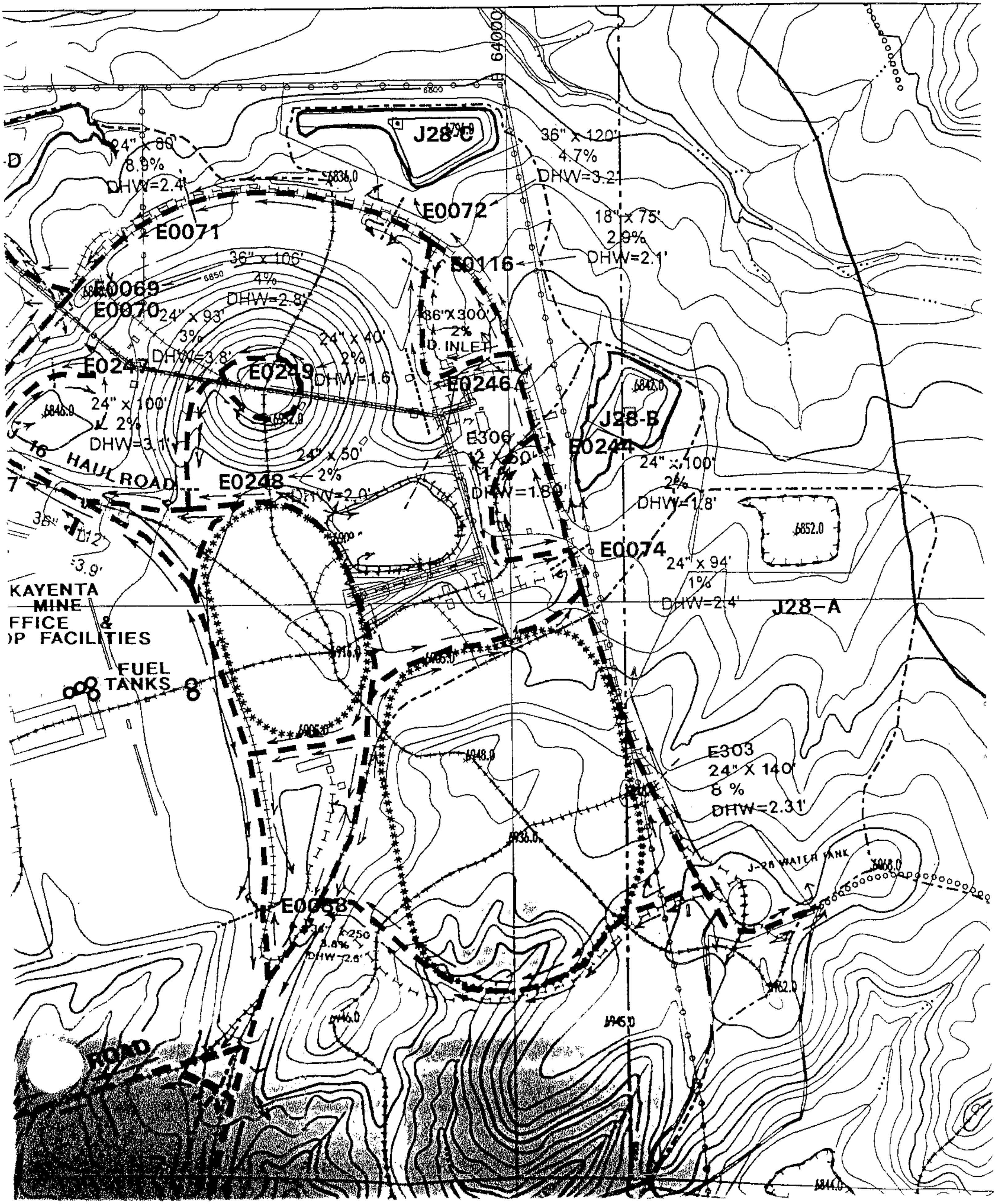
Drawing No. 85400

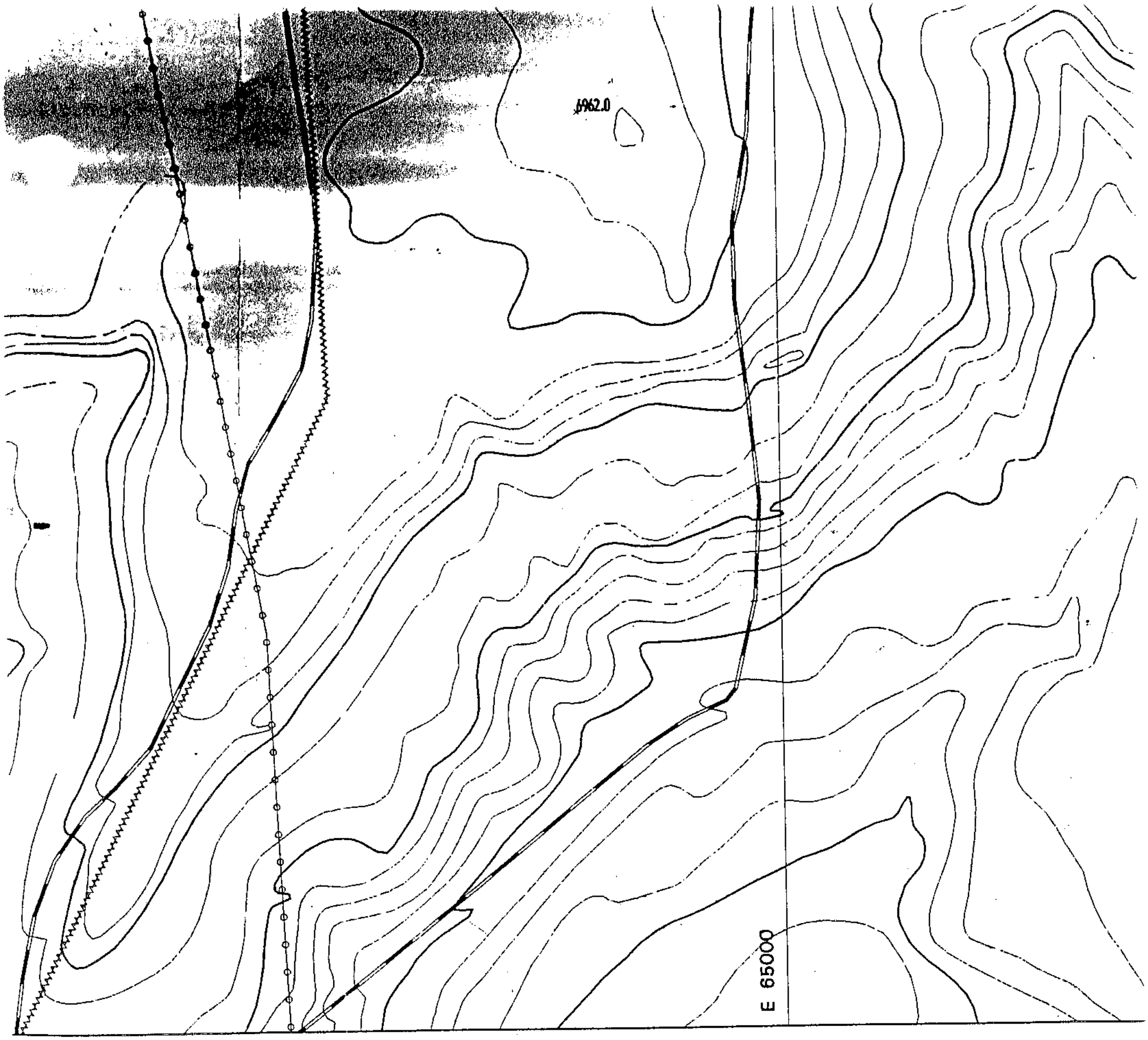
Drainage Area and Facilities Map
Sheet No. N-9

Black Mesa Complex

P.W.C.C. 1300 S. Yale Flagstaff, AZ 86001

DESIGNED BY:	P.W.C.C.	SCALE:	1 in. = 400 ft.
DRAWN BY:	P.W.C.C.	DRAWING DATE:	02/23/95
CHECKED BY:	J. Schlenvogt	PHOTO DATE:	11/19/84
CONTOUR INTERVAL: 10			


J28-C
36" x 120'
4.7%
DHW=3.2'
24" x 80'
8.9%
DHW=2.4'
E0071
E0072
18" x 75'
2.9%
DHW=2.1'
E0116
36" x 106'
4%
DHW=2.8'
E0069
E0070
24" x 93'
3%
DHW=3.8'
36"X300'
2%
D. INLET
24" x 40'
2%
DHW=1.6'
E0247
E0249
E0246
24" x 100'
2%
DHW=3.1'
J28-B
E0244
E306
24" x 50'
2%
DHW=2.0'
E0248
HAUL ROAD
24" x 100'
2%
DHW=1.8'
E0074
24" x 94'
1%
DHW=2.4'
J28-A
KAYENTA
MINE
FFICE &
P FACILITIES
FUEL
TANKS
E303
24" X 140'
8 %
DHW=2.31'
J-28 WATER TANK
E0068
DHW=2.6'
ROAD



(Sheet 6A)

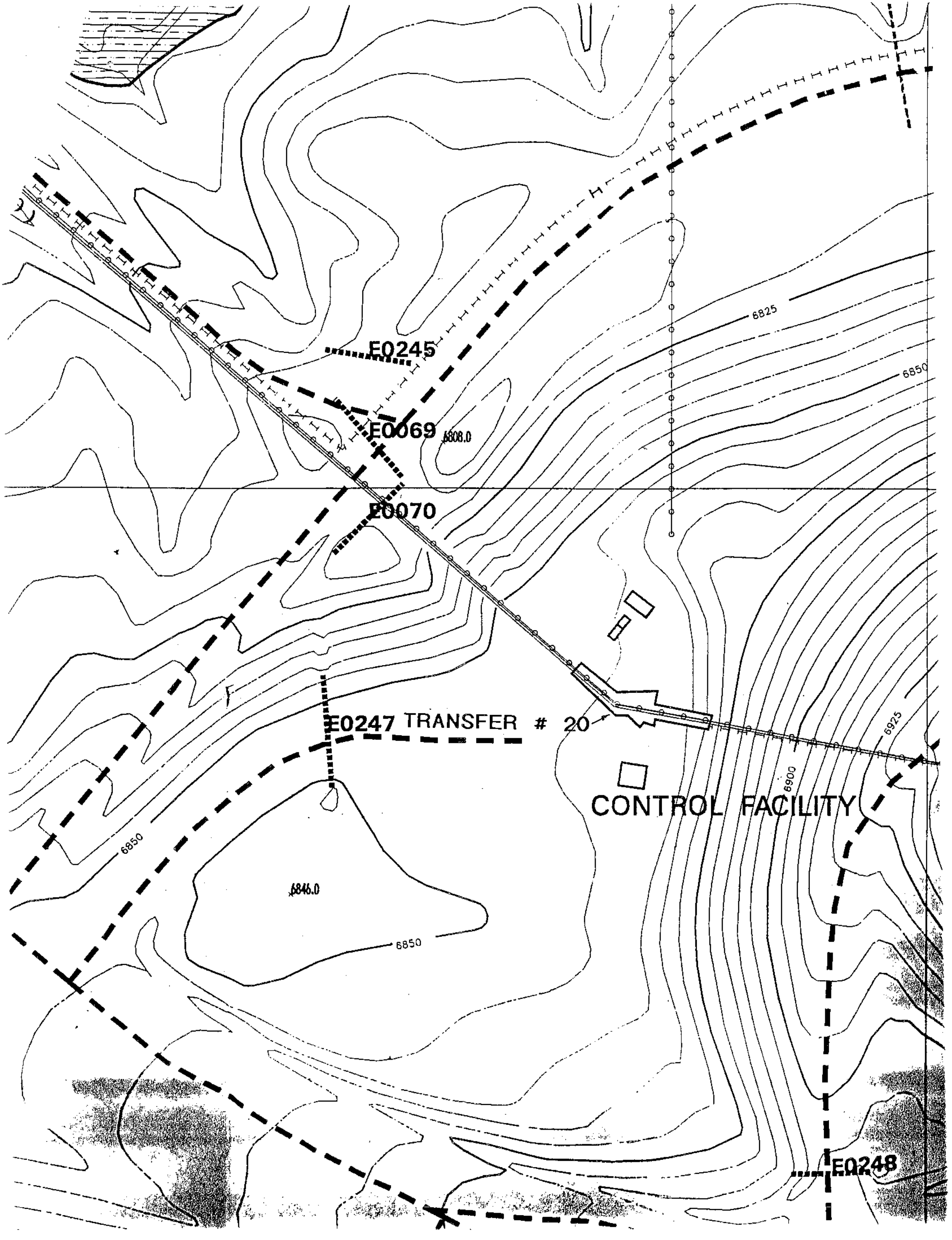
REVISIONS		
CHK'D	DATE	DESCRIPTION
J.G.S.	3 / 1 / 95	5 Yr. Permit rev.
JGS	6-26-96	CULVERT REV.

Kayenta Mine Facilities Map
Drawing No. 85480

Black Mesa Complex

Peabody Western 1300 S. Yale Flagstaff, AZ 86001

DESIGNED BY:	J. Schlenvogt	SCALE:	1 in. = 100 ft.
DRAWN BY:	S. Walker	DRAWING DATE:	2/15/95
CHECKED BY:	J. Schlenvogt	PHOTO DATE:	7/1/92
CONTOUR INTERVAL: 20			



6825
6850
E0245
E0069
6808.0
E0070
E0247
TRANSFER # 20
6925
6900
CONTROL FACILITY
6850
6846.0
6850
E0248

Culvert #E0034 Redesign with Culvert #E0035 Included 07/15/2005

J. SCHLENVOGT

General Information

Storm Information:

Storm Type:	NRCS Type II
Design Storm:	10 yr - 6 hr
Rainfall Depth:	1.610 inches

Structure Summary:

	Immediate Contributing Area (ac)	Total Contributing Area (ac)	Peak Discharge (cfs)	Total Runoff Volume (ac-ft)
#2	46.700	46.700	39.55	1.88

Structure Detail:

Structure #2 (Culvert)

Culvert Inputs:

Length (ft)	Slope (%)	Manning's n	Max. Headwater (ft)	Tailwater (ft)	Entrance Loss Coef. (Ke)
460.00	4.70	0.0240	4.00	0.68	0.90

Culvert Results:

Design Discharge = 39.55 cfs

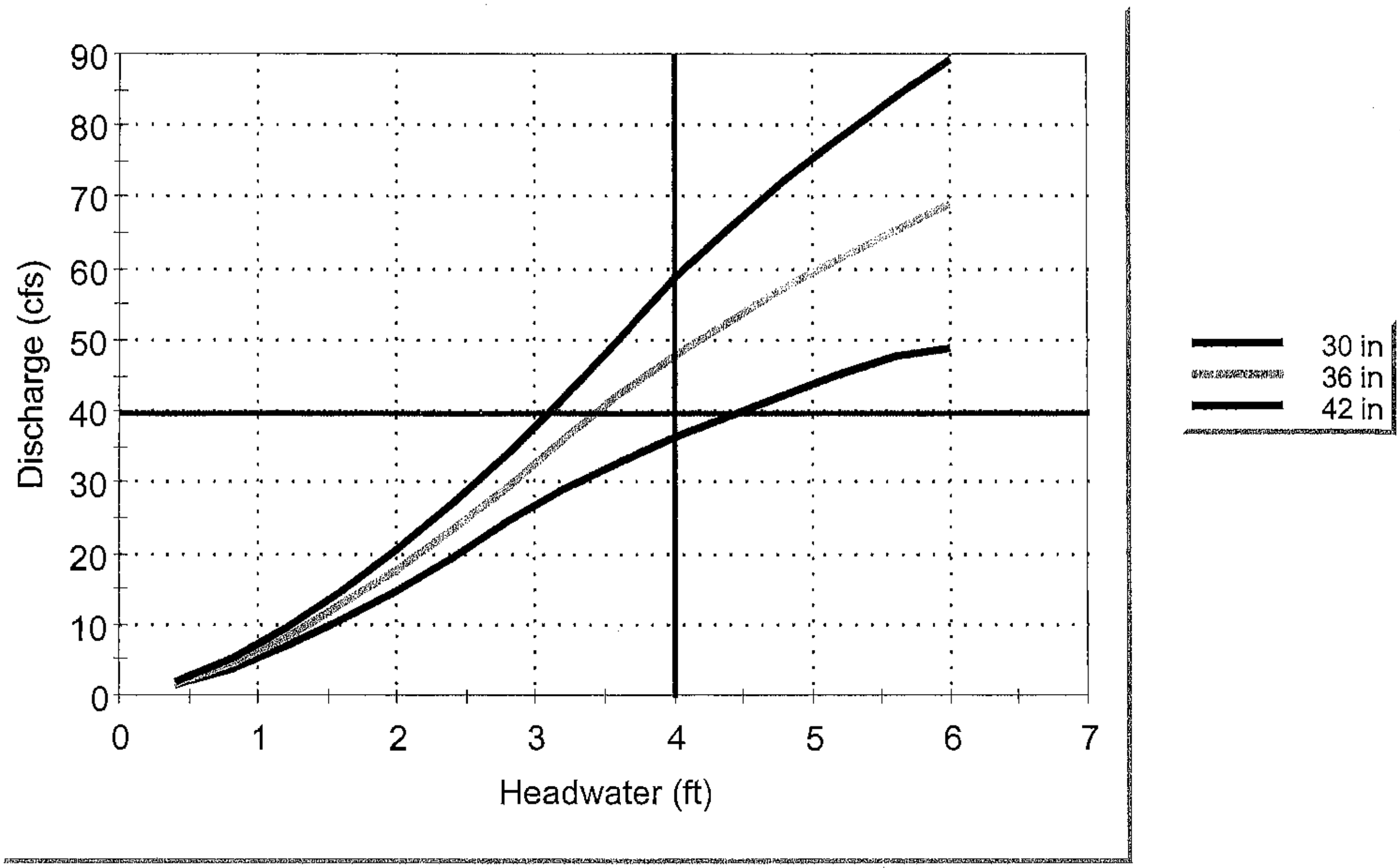
Minimum pipe diameter: 1 - 36 inch pipe(s) required

APPROVED

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#2	1	46.700	0.110	0.000	0.000	84.000	F	39.55	1.876
	Σ	**46.700**						**39.55**	**1.876**

Culvert Performance Curves - Structure # 2



J19/J21 DRAGLINE REPAIR ENTRANCE ROAD CULVERT DESIGN

Gary Altsisi, P.E.

Peabody Western Coal Co.
P.O. Box 650
Kayenta, AZ 86033

Phone: 928-677-3201

General Information

Storm Information:

Storm Type:	NRCS Type II
Design Storm:	10 yr - 6 hr
Rainfall Depth:	1.600 inches

Structure Networking:

Type	Stru #	(flows into)	Stru #	Musk. K (hrs)	Musk. X	Description
Null	#1	==>	End	0.000	0.000	

#1
Null

Structure Summary:

	Immediate Contributing Area (ac)	Total Contributing Area (ac)	Peak Discharge (cfs)	Total Runoff Volume (ac-ft)
#1	326.700	326.700	120.65	14.31

Structure Detail:

Structure #1 (Null)

Subwatershed Hydrology Detail:

Stru #	SWS #	SWS Area (ac)	Time of Conc (hrs)	Musk K (hrs)	Musk X	Curve Number	UHS	Peak Discharge (cfs)	Runoff Volume (ac-ft)
#1	1	326.700	0.891	0.000	0.000	86.000	F	120.65	14.309
	Σ	**326.700**						**120.65**	**14.309**

Subwatershed Time of Concentration Details:

Stru #	SWS #	Land Flow Condition	Slope (%)	Vert. Dist. (ft)	Horiz. Dist. (ft)	Velocity (fps)	Time (hrs)
#1	1	5. Nearly bare and untilled, and alluvial valley fans	3.01	167.00	5,550.01	1.730	0.891
#1	**1**	**Time of Concentration:**					**0.891**

Culvert Inputs:

Length (ft)	Slope (%)	Manning's n	Max. Headwater (ft)	Tailwater (ft)	Entrance Loss Coef. (Ke)
250.00	3.50	0.0240	12.00	0.50	0.90

Culvert Results:

Minimum pipe diameter: 1 - 42 inch pipe(s) required

Detailed Performance Curves

Design Discharge = 120.65 cfs

Maximum Headwater = 12.00 ft

(BOLD indicates design pipe size)

Headwater (ft)	Discharge (cfs) (36 in)	**Discharge (cfs) (42 in)**	Discharge (cfs) (45 in)
1.20	8.26	**9.64**	10.32
2.40	23.36	**27.25**	29.20
3.60	42.58	**50.06**	53.63
4.80	57.14	**72.27**	79.59
6.00	68.05	**89.27**	99.80
7.20	73.09	**103.53**	116.56
8.40	76.30	**110.47**	129.34
9.60	79.35	**115.05**	135.56
10.80	82.34	**119.46**	140.83
12.00	85.18	**123.71**	145.91
13.20	87.95	**127.83**	150.81
14.40	90.63	**131.82**	155.55
15.60	93.23	**135.67**	160.16
16.80	95.77	**139.42**	164.64
18.00	98.23	**143.09**	169.00