NORTH AMERICAN EQUITIES

BLAZON NO. 1 MINE
PLAN TO FINALIZE RECLAMATION

August 19, 1988

ACZ inc

Prepared For
NORTH AMERICAN EQUITIES
1401 Seventeenth Street, Suite 1510
Denver, Colorado 80202

BLAZON NO. 1 MINE
PLAN TO FINALIZE RECLAMATION

August 19, 1988

Prepared By
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Engineering & Environmental Division
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ACZ inc

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SUMMARY

The following reclamation plan has been prepared to address remaining reclamation liabilities at the Blazon No. 1 Mine located near Clear Creek, Utah. In addition, this plan contains a revised sediment pond design which will mitigate the Notice of Violation (NOV) No. 88-13-2-1 received June 30, 1988.

This plan has been developed in order for NAE to resolve all remaining reclamation liabilities in one coordinated effort. This plan specifically addresses issues discussed with NAE representative Bill Prince by the Utah Division of Oil, Gas and Mining (UDOGM) during a site visit on June 21, 1988, issues discussed with NAE's engineering consultant Dan Keuscher, ACZ INC. during a site visit on July 14, 1988 and a subsequent meeting between Dan Keuscher and UDOGM Division on August 1, 1988. In addition, this plan addresses questions and concerns of UDOGM in a conference call August 12, 1988

The following reclamation activities and facilities are discussed in this plan:

- Sediment Ponds
- Little Snyder Canyon Drainage Design
- Transformer Road
- Access Road and Cross Culverts
- Culvert "A" Area Channel Restoration
- Mud Creek Channel Repair
- Backfilling and Grading
- Water Well Disposition
- Riparian Vegetation
- Reclamation Monitoring Term
- Reclamation Sequence and Time Table

Where applicable, design criteria and methodology, and work methodology have been provided in this plan for the specific reclamation activities. The Final Reclamation Plan Summary Map (Map A-1) shows the location of remaining reclamation activities.

SEDIMENT PONDS

Based on discussions between NAE and UDOGM personnel, the redesign of the sediment pond system at the Blazon No. 1 Mine will result in a minor modification to the reclamation plan. Major aspects of the sediment pond redesign include:

- A one cell pond
- Combined 5H:1V embankment slopes
- Principal and emergency spillways

The design of the sediment pond involves three (3) major components:

- Hydrology
- Sediment Yield
- Hydraulic Design

HYDROLOGY

The required runoff volume for the sediment pond was based on the 10-year, 24-hour storm event. The peak flow resulting from the 100-year, 24-hour storm event was used as the design criteria for the principal and emergency spillways. The sediment pond drainage area is shown on Figure 1, Blazon Sediment Pond - Drainage, and the hydrology calculations for runoff and peak flow are shown on Figure 2, Blazon Sediment Pond - Hydrology.

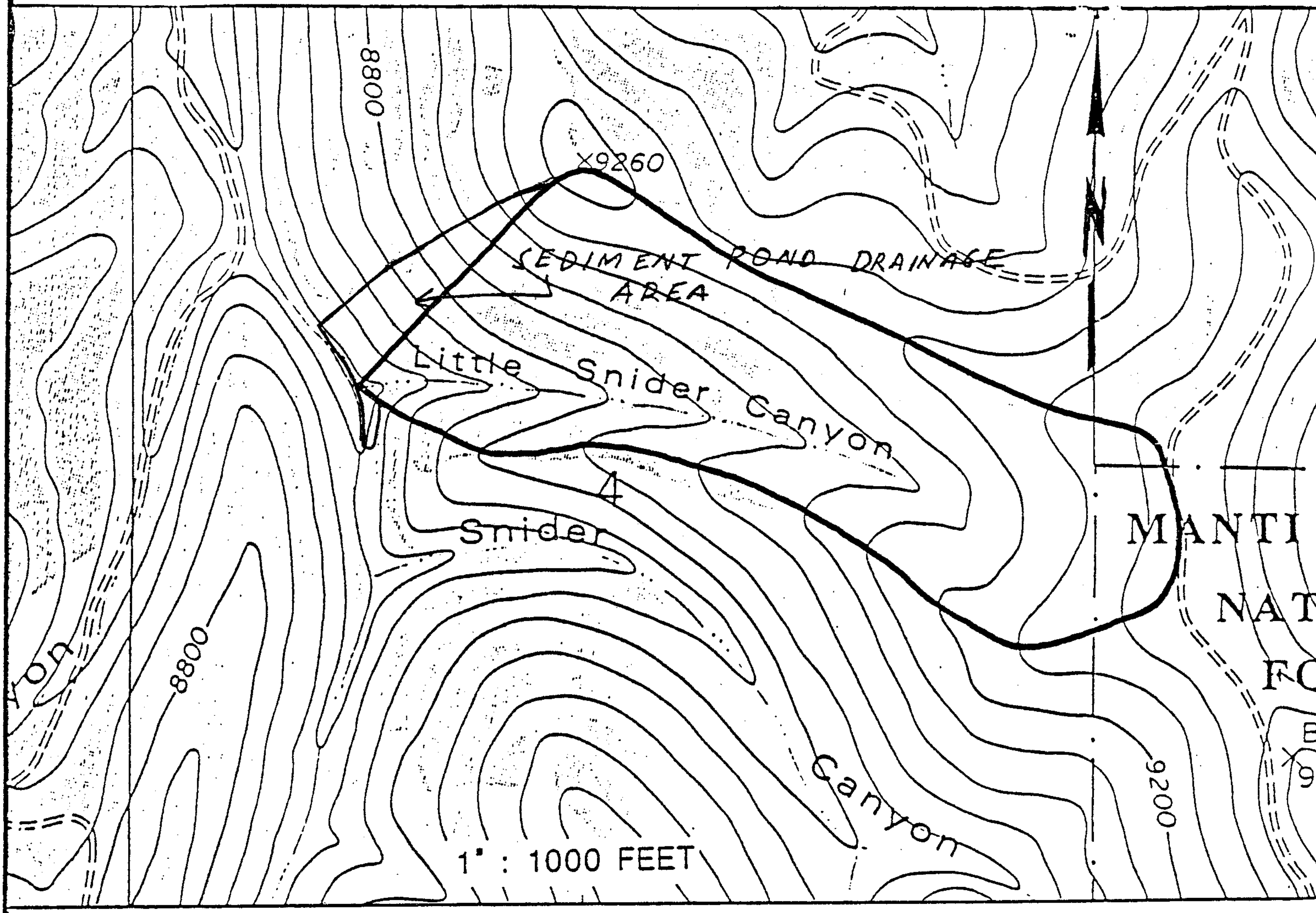
SEDIMENT YIELD

Sediment yield for areas which drain to the sediment pond was calculated using the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1965). The USLE is given by the following equation:

$$A = (R)(K)(LS)(CP)$$

Figure 1

BLAZON SEDIMENT POND - DRAINAGE



DRAINAGE AREA:

Undisturbed 8.5 Ac, CN = 64 Total 9.8 Ac, CN = 67

Disturbed 1.3 Ac, CN = 90

Tc, Use Kirpick $Tc = .0078\, L^{.77} (L/H)^{.385}$

L = 1,580' H = 760'

Tc = .028

10 Yr. Runoff = 0.26 Ac-Ft

Q_{10} = 3.3 cfs

Q_{25} = 5.8 cfs

Q_{100} = 7.5 cfs

1/Using the SEDIMOT II Hydrology Model

EarthFax

Figure 2
BLAZON SEDIMENT POND - HYDROLOGY - Part 1

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*     THEY CAN BE FOUND IN SUMMARY TABLES.                      *
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*      2. VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION      *
*         DURING PERIOD OF SIGNIFICANT CONCENTRATION            *
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*         DURING PEAK 24 HOUR PERIOD                            *
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*         DURING PEAK 24 HOUR PERIOD                            *
*                                                               *
*     ALL CONCENTRATIONS ARE IN ML/L.                           *
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                   WATERSHED IDENTIFICATION CODE
                   ------------------------------
 NAE SED POND - 10YR\24HR STORM VOLUME

            ********************************************
```

Figure 2
BLAZON SEDIMENT POND - HYDROLOGY - Part 2

********************INPUT VALUES********************

STORM DURATION	=	24.00	HOURS
PRECIPITATION DEPTH	=	2.42	INCHES

1

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	9.80	67.00	.028	.000	.000	.00	.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	3.34	.32

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	.2644	ACRE-FT
PEAK DISCHARGE	=	3.3410	CFS
AREA	=	9.8000	ACRES
TIME OF PEAK DISCHARGE	=	12.00	HRS

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NULL STRUCTURE
* * * * * * * * * * * * *

Figure 2
BLAZON SEDIMENT POND - HYDROLOGY - Part 3

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*         DURING PEAK 24 HOUR PERIOD                             *
*                                                                *
*     ALL CONCENTRATIONS ARE IN ML/L.                            *
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                  WATERSHED IDENTIFICATION CODE
                  -----------------------------
 NAE SED POND - 25YR\24HR STORM PEAK FLOW

            ********************************************
```

********************INPUT VALUES********************

STORM DURATION	=	24.00	HOURS
PRECIPITATION DEPTH	=	2.90	INCHES

1

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	9.80	67.00	.028	.000	.000	.00	.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	5.81	.54

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	.4378	ACRE-FT
PEAK DISCHARGE	=	5.8075	CFS
AREA	=	9.8000	ACRES
TIME OF PEAK DISCHARGE	=	12.00	HRS

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NULL STRUCTURE
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*                                                                *
*     ALL CONCENTRATIONS ARE IN ML/L.                            *
*                                                                *
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            ********************************************

                 WATERSHED IDENTIFICATION CODE
                 -----------------------------
 NEA SED POND - 100YR\24HR STORM PEAK FLOW

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Figure 2
BLAZON SEDIMENT POND - HYDROLOGY - Part 6

*********************INPUT VALUES********************

STORM DURATION	=	24.00	HOURS
PRECIPITATION DEPTH	=	3.20	INCHES

1

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	ROUTING COEFFICIENTS X	UNIT HYDRO
1	9.80	67.00	.028	.000	.000	.00	.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	7.50	.69

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	.5611	ACRE-FT
PEAK DISCHARGE	=	7.5021	CFS
AREA	=	9.8000	ACRES
TIME OF PEAK DISCHARGE	=	12.00	HRS

* * * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * * *

Where:

A = Sediment yield (tons/acre/year)
R = Rainfall factor
K = Soil erodibility factor
LS = Length slope factor
CP = Control practice factor

The sediment yield calculations for the sediment pond drainage area are as follows:

Sediment Yield Calculations

Watershed	Area (Sq ft)	Area (Ac)	Height (ft)	Length (ft)
Undisturbed	370,260	8.5	710	1,400
Unreclaimed	56,600	1.3	30	540
TOTAL	426,860	9.8		

Watershed Slopes

	Undisturbed	Unreclaimed
LC25	350	100
LC50	300	150
LC75	185	70

Average slope = S = .25Z(LC25 + LC50 + LC75)/A(Sq ft), Where Z = drainage height

Slope (%)	40.0	4
Slope (°)	21.8	2.3

USLE

Watershed	R[1]	K	LS[2]	CP[3]	Delivery Ratio[4]	Annual Yield (tons/acre)
Undisturbed	26	.28	47.1	.032	0.7	7.7
Unreclaimed	26	.28	.79	1.3	1	7.5

Footnote:

[1] Rainfall factor taken from approved reclamation plan

[2] Barfield (page 332) $LS = (L/72.6)^m (65.02\ x^2 + 4.54\ x + 0.065)$

Where: LS = Length slope factor

L = Slope length (ft)

m = 0.3 slope $< 3\%$

0.4 slopes 3% to 5%

0.5 slopes $> 5\%$

$x = \sin\theta$, θ = slope angle°

[3] Table I, C Factors

[4] Figure 3, Delivery Ratio

Sediment Calculations

Watershed	Annual Yield	Acres	Total Yield
Undisturbed	7.7	8.5	65.5
Unreclaimed	7.5	1.3	9.8
			75.3 T/yr

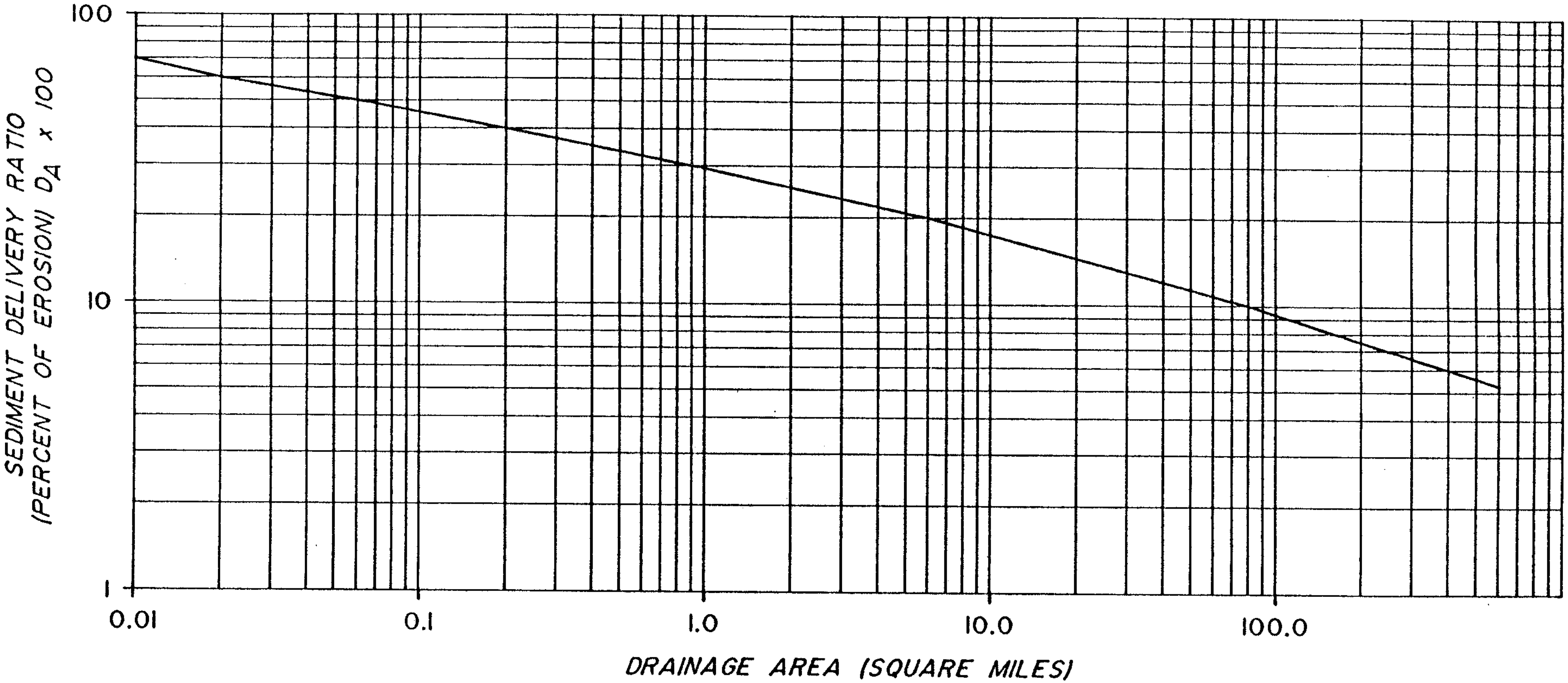
Conversion to Ac-Ft

$$75.3\ \text{T/Yr} \times 2{,}000\ \text{lb/T} \times \frac{\text{cu-ft}}{100\ \text{lb}} \times \frac{\text{ac-ft}}{43{,}560\ \text{ft}} = .03\ \text{ac-ft/yr}$$

Table 1

C FACTORS

Vegetative Canopy		Cover That Enters the Soil Surface						
Type and Height	Percent	Type	0	20	40	60	80	95+
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	.45	.24	.15	.091	.043	.011
Tall weeds or short brush	25	G	.36	.17	.09	.038	.013	.003
with average drop fall		W	.36	.20	.13	.083	.041	.011
height of 20 inches	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.076	.039	.011
	75	G	.17	.10	.06	.032	.011	.003
		W	.17	.12	.09	.068	.038	.011
Appreciable brush or bushes,	25	G	.40	.18	.09	.040	.013	.003
with average frop fall		W	.40	.22	.14	.087	.042	.011
height of 6½ feet	50	G	.24	.16	.08	.038	.012	.003
		W	.23	.19	.13	.082	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.078	.040	.011
Trees, but as appreciable low	25	G	.42	.19	.10	.041	.013	.003
brush. Average drop fall		W	.42	.23	.14	.089	.042	.011
height of 13 feet	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.31	.14	.087	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.084	.041	.011



DELIVERY RATIO
FIGURE 3

(BOYCE, 1975)

Sediment pond required capacity

Runoff Volume	=	0.26
Sediment Volume	=	0.03
TOTAL		0.29 ac-ft

HYDRAULIC DESIGN

The revised sediment pond design is shown on Map A-2, Blazon Sedimentation Pond Design.

The sedimentation pond spillway calculations are shown on Figure 4, Sediment Pond Spillway Design. Stage/storage relationship is shown on Map A-2, Blazon Sedimentation Pond Design.

The sedimentation pond as planned will be a permanent structure. During construction of the sedimentation pond a qualified field engineer will be on site.

SEDIMENT CONTROL TECHNIQUES DURING CONSTRUCTION

Care will be taken during the sediment pond construction activity to prevent any damage to the Mud Creek channel bottom.

During these activities, the following sediment control techniques will be incorporated to minimize impacts to the hydrologic regime:

- Sediment fence placed along Mud Creek at the approximate water level
- Straw bales placed at the north end of the sediment pond construction area
- Additional straw bales and sediment fence as needed

FIGURE 4

SEDIMENT POND SPILLWAY DESIGN

PRINCIPAL SPILLWAY

USE SHARPE CRESTED WEIR CONTROL

$Q = C b H^{1.5}$

WHERE $C = 3.27 + 0.4 H/W$

b = WEIR LENGTH (2.0' DIA RISER) = 6.28'

REQUIRED Q (10YR/24HR STORM) = 3.3 cfs

TRY H = 0.3', W = 4.5', C = 3.30

$Q = (3.3)(6.28)(0.3)^{1.5} = 3.4$ cfs OK

REQUIRED Q (100YR/24HR STORM) = 7.5 cfs

TRY H = 0.5', W = 4.5', C = 3.31

$Q = (3.31)(6.28)(0.5)^{1.5} = 7.3$ cfs

TRY H = 0.6', W = 4.5', C = 3.32

$Q = (3.32)(6.28)(0.6)^{1.5} = 9.7$ cfs

PRINCIPAL SPILLWAY PASSES PEAK FLOW FROM 100YR/24HR STORM AT H = 0.6 FEET

EMERGENCY SPILLWAY OVERFLOW

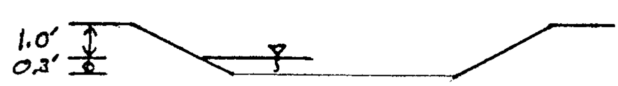
USE TRAPEZOIDAL SPILLWAY W/ 2H:1V SIDE SLOPES

$Q = 3.087\, b H^{1.5}$ (BROAD CRESTED WEIR CONTROL)

SET CREST OF EMERGENCY SPILLWAY AT Q100 HWL OF PRINCIPAL SPILLWAY

b = 5.1', H = 0.3'

$Q = (3.087)(5.1)(0.3)^{1.5} = 2.6$ cfs



LITTLE SNYDER CANYON DRAINAGE DESIGN

The drainage design for Little Snyder Canyon has been prepared by Earthfax Engineering, Inc., Salt Lake City, Utah. This plan has been submitted to UDOGM under separate cover and is currently under review. All design criteria and methodologies are contained under separate cover in the Little Snyder Canyon Drainage Plan.

TRANSFORMER ROAD

NAE plans to reclaim the transformer access road. The planned reclamation of the transformer road will result in a minor modification to the approved reclamation plan. Reclamation of the transformer road will involve the following activities:

- Removal of water tanks or collapsing tanks and backfilling.
- Removal of power pole adjacent to transformer pad.
- Removal of transformer pad.
- Repair of existing reclamation on water tank and access road.
- Pulling of material from the outslope of the road to the inside with a backhoe, regrading the area and reseeding.

ACCESS ROAD AND CROSS CULVERTS

The grade of the access road has been checked and the access road ditch redesigned to reflect a maximum and minimum grade. The reclamation plan has also been revised to show only two (2) cross culverts on the access road and the hydrology has been remodeled for the drainage area to show that the two (2) culverts will pass the design flow. The third culvert is apparently buried. An attempt will be made to uncover and restore the third culvert during reclamation activities. However, this culvert is not critical to site drainage and if reasonable efforts do not restore its function it will be abandoned in place.

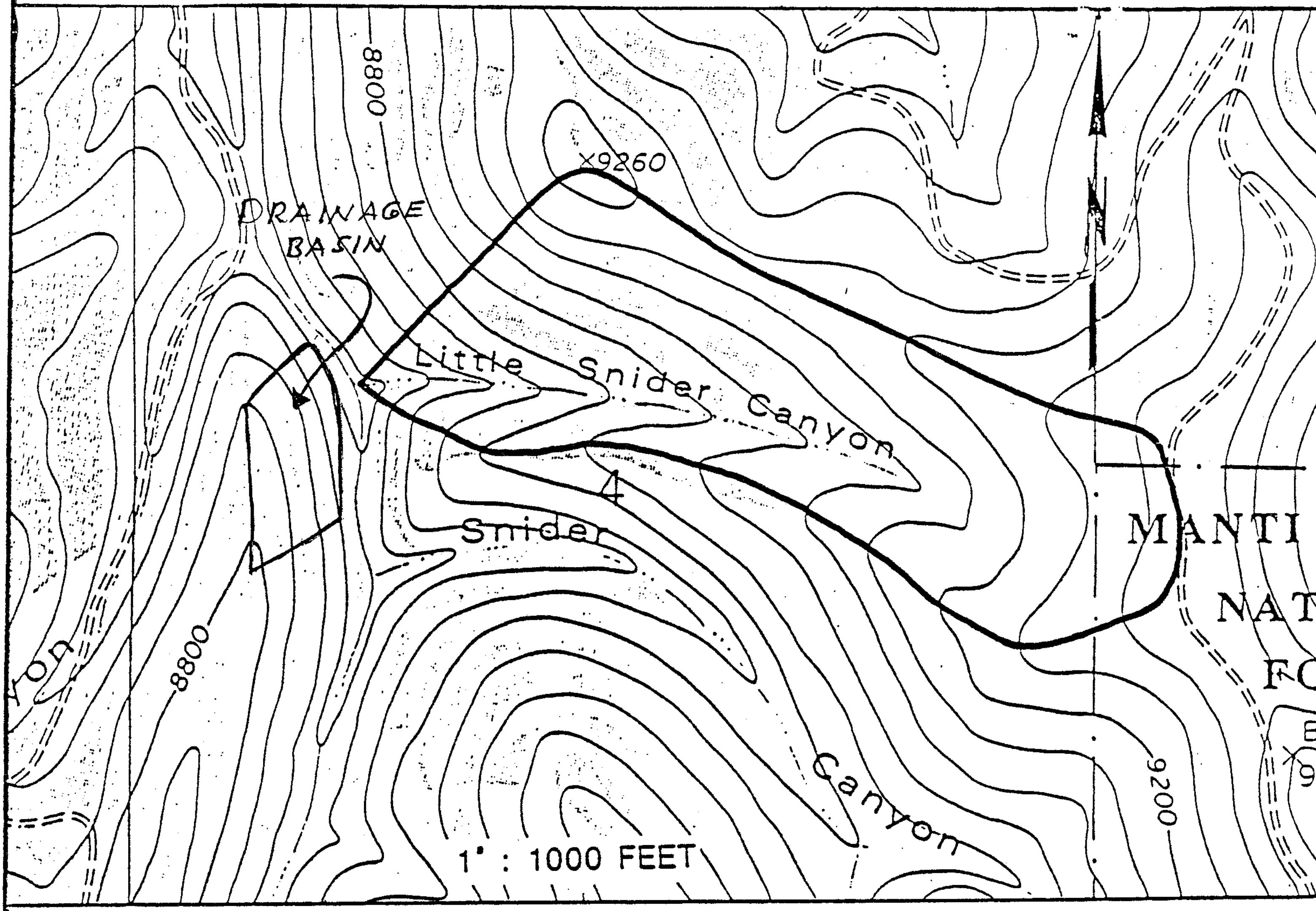
The culvert inlets will be cleaned and rock will be placed at the culvert entrances to serve as inlet structures. Straw bales will be placed and anchored above the culvert entrances and at the north end of the access road during construction to aid in sediment control. A small swale will be constructed at the access road entry gate which will divert runoff to the east side of the road.

Supporting hydrology and hydraulic calculations for the access road ditch and cross culverts are presented on the following figures:

- Figure 5, Blazon Access Road Drainage
- Figure 6, Access Road Ditch Design
- Figure 7, Access Road Ditch - Max. Slope
- Figure 8, Access Road Ditch - Min. Slope
- Figure 9, Access Road Hydrology
- Figure 10, Access Road Cross Culverts - Capacity

Figure 5

BLAZON ACCESS ROAD DRAINAGE



Area = 15.0 Ac
CN = 64

10 Yr/24 Hr Event = 2.42"
TC, Use Kirpick $Tc = .0078\ L^{.77}(L/H)^{.385}$
L = 1500 H = 420
Tc = 0.060

Q_{10} = 3.5 cfs, use 1.8 cfs/culvert

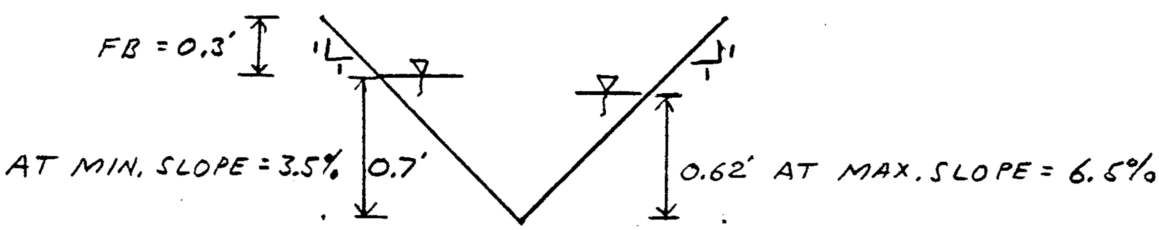
Q_{50} = 7.6 cfs

FIGURE 6

ACCESS ROAD DITCH DESIGN

DESIGN Q_{10} = 1.8 cfs

USE V DITCH



ACCESS ROAD CULVERTS

Q_{10} = 1.8 cfs

EXISTING 24" CULVERTS CAPABLE OF PASSING 11cfs (REFER TO FIGURE 10)

Figure 7

ACCESS ROAD DITCH - Max. Slope

CHANNEL # - AC-1 MAX SLOPE

DESIGN PEAK FLOW (cfs), Q = 1.80	CHANNEL SHAPE - TRIANGULAR
MANNING'S NUMBER, n = 0.0300	CHANNEL SLOPE = 6.50
CHANNEL SIDE SLOPE, Z = 1.0	VELOCITY = 4.6
HYDRAULIC RADIUS, R = 0.2206	DEPTH OF FLOW, d = 0.62
WETTED PERIMETER, P = 1.76	BOTTOM WIDTH, b = 0.00
X-SECTION AREA = 0.39	WIDTH OF STREAM, t = 1.25
FREEBOARD = 0.30	TOP WIDTH OF CHANNEL, T = 1.85

Figure 8

ACCESS ROAD DITCH - Min. Slope

CHANNEL # - AC-2 MIN SLOPE

DESIGN PEAK FLOW (cfs), Q = 1.80

MANNING'S NUMBER, n = 0.0300

CHANNEL SIDE SLOPE, Z = 1.0

HYDRAULIC RADIUS, R = 0.2478

WETTED PERIMETER, P = 1.98

X-SECTION AREA = 0.49

FREEBOARD = 0.30

CHANNEL SHAPE - TRIANGULAR

CHANNEL SLOPE = 3.50

VELOCITY = 3.7

DEPTH OF FLOW, d = 0.70

BOTTOM WIDTH, b = 0.00

WIDTH OF STREAM, t = 1.40

TOP WIDTH OF CHANNEL, T = 2.00

Figure 9
ACCESS ROAD HYDROLOGY - Part 1

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  *         DURING PEAK 24 HOUR PERIOD                            *
  *      4. ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION           *
  *         DURING PERIOD OF SIGNIFICANT CONCENTRATION            *
  *      5. ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION           *
  *         DURING PEAK 24 HOUR PERIOD                            *
  *                                                               *
  *     ALL CONCENTRATIONS ARE IN ML/L.                           *
  *                                                               *
  *****************************************************************


              *********************************************

                    WATERSHED IDENTIFICATION CODE
                    ------------------------------
   ACCESS ROAD DITCH AND CROSS CULVERTS - 10YR FLOW

              *********************************************
```

Figure 9
ACCESS ROAD HYDROLOGY - Part 2

*********************INPUT VALUES********************

STORM DURATION = 24.00 HOURS
PRECIPITATION DEPTH = 2.42 INCHES

1

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	ROUTING COEFFICIENTS X	UNIT HYDRO
1	15.00	64.00	.060	.000	.000	.00	.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	3.46	.24

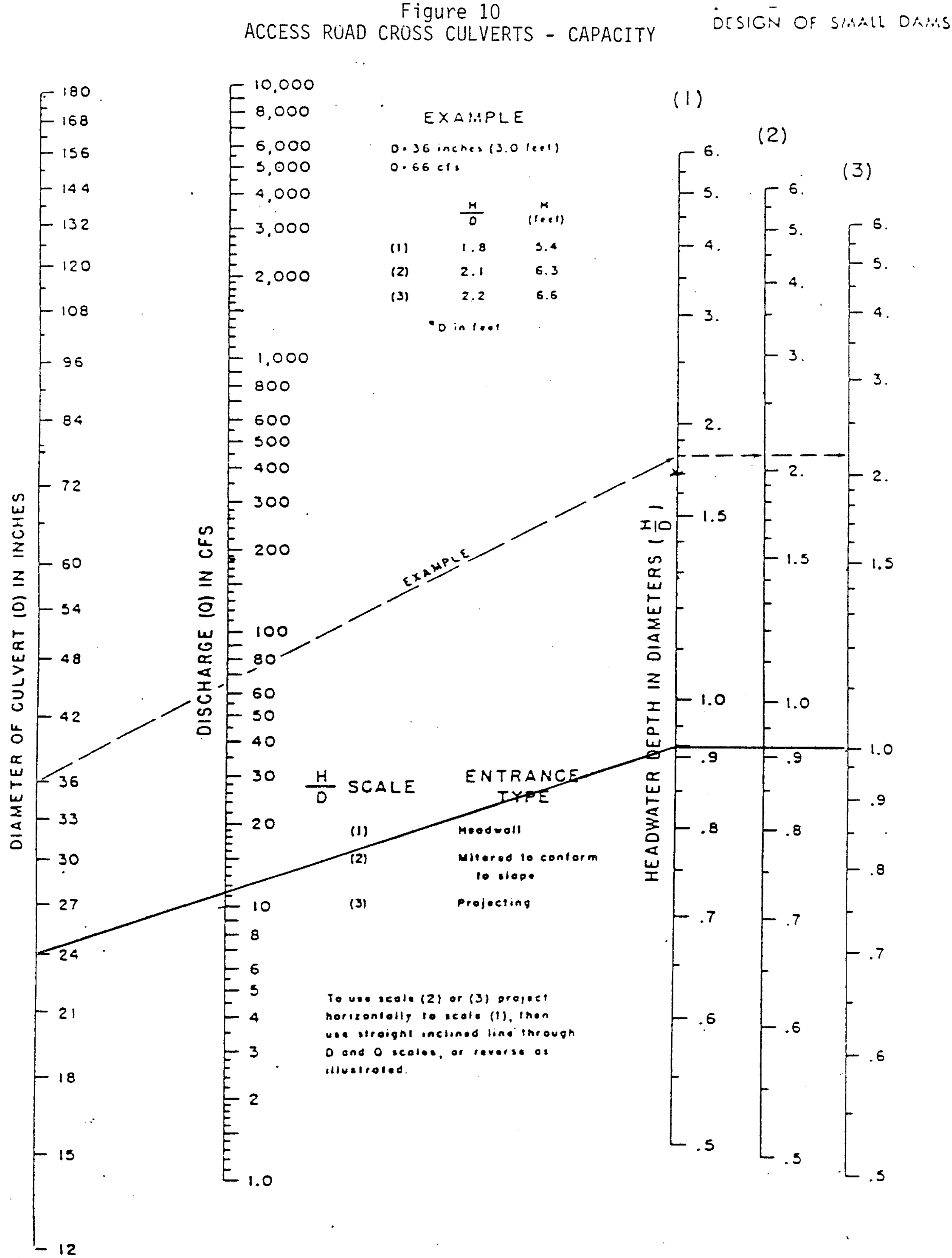
NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME = .3029 ACRE-FT
PEAK DISCHARGE = 3.4639 CFS
AREA = 15.0000 ACRES
TIME OF PEAK DISCHARGE = 12.00 HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

Figure 10
ACCESS ROAD CROSS CULVERTS - CAPACITY



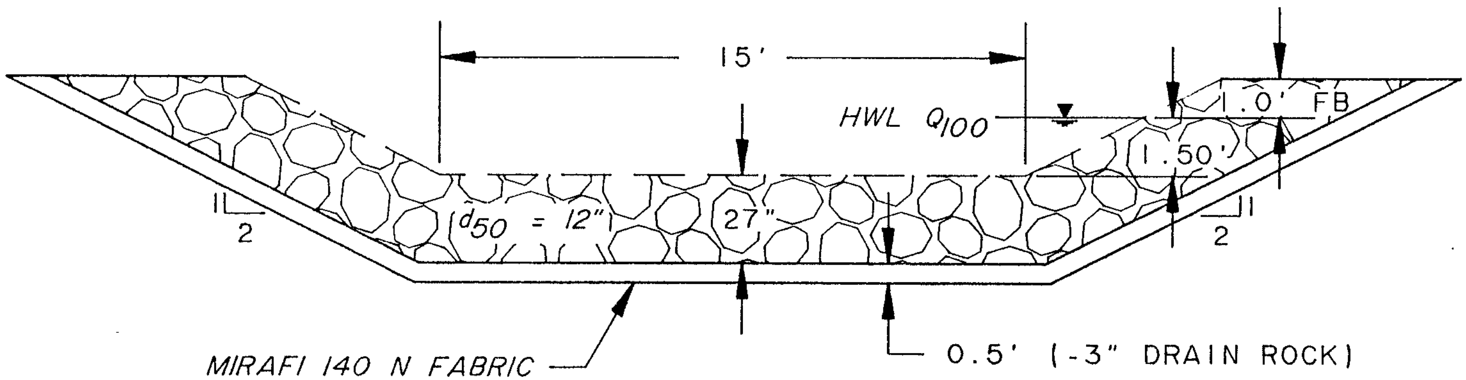
Headwater depth for corrugated-metal pipe culverts with entrance control. (U.S. Bureau of Public Roads.) 288-D-2904.

CULVERT "A" AREA CHANNEL RESTORATION

Culvert "A" as shown on the Final Reclamation Plan Summary Map (Map A-1) will be removed as part of final reclamation of the Blazon No. 1 Mine. As agreed upon with UDOGM, this section of Mud Creek channel will be designed for the 100-year, 24-hour precipitation event. In addition to the complete restoration of this channel section (approximately 40 feet in length), a cutback bank area adjacent and to the south of Culvert "A" will be repaired and stabilized with rock available on site.

Channel restoration design, design criteria, and hydrology calculations are presented on the following figures:

- Figure 11, Mud Creek Channel Restoration at Culvert "A" - Typical Section
- Figure 12, Channel Design - Culvert "A"
- Figure 13, Size Distribution of Riprap
- Figure 14, Culvert "A" Area Hydrology



SCALE: 1" = 5'

DESIGN EVENT: 100 YR/24 HR, 3.20 IN
DESIGN PEAK FLOW (Q) = 202 cfs
CHANNEL LENGTH: 40 FT
BEDDING: USE MIRAFI 140 N FABRIC COVERED
BY 6 INCHES OF -3" DRAIN ROCK

MUD CREEK CHANNEL RESTORATION AT CULVERT A
TYPICAL SECTION

FIGURE 11

Figure 12

CHANNEL DESIGN CULVERT "A"

CHANNEL # - CULVERT A

DESIGN PEAK FLOW (cfs), Q = 202.00	CHANNEL SHAPE - TRAPEZOIDAL
MANNING'S NUMBER, n = 0.0400	CHANNEL SLOPE = 3.50
CHANNEL SIDE SLOPE, Z = 2.0	VELOCITY = 7.8
HYDRAULIC RADIUS, R = 1.1937	DEPTH OF FLOW, d = 1.43
WETTED PERIMETER, P = 21.40	BOTTOM WIDTH, b = 15.00
X-SECTION AREA = 25.54	WIDTH OF STREAM, t = 20.72
FREEBOARD = 1.00	TOP WIDTH OF CHANNEL, T = 24.72
D50 RIP RAP DIAMETER (ins.) = 11.7	TOTAL DEPTH OF CHANNEL, D= 2.43
Dmax RIP RAP DIAMETER (ins.) = 17.5	
RIP RAP BED THICKNESS (ins.) = 26.2	

Use d50 = 12 in.

$d50 = 12(118QS^{2.1667}R/P)^{0.4}$

Figure 13

SIZE DISTRIBUTION OF RIPRAP

PERCENT	PASSING
80-100	$1.5 \times d_{50}$
30-70	d_{50}
0-40	$0.5 \times d_{50}$

Figure 14
CULVERT "A" AREA HYDROLOGY - Part 1

****

WATERSHED IDENTIFICATION CODE

MUD CREEK CHANNEL 100YR\24HR PEAK FLOW AT CULVERT A

****

*********************INPUT VALUES*********************

STORM DURATION	=	24.00	HOURS
PRECIPITATION DEPTH	=	3.20	INCHES

i

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	268.00	64.00	.480	.000	.000	.00	3.0
2	336.00	64.00	.631	.000	.000	.00	3.0
3	854.00	64.00	.881	.000	.300	.33	3.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	35.43	.56
2	38.03	.56
3	78.64	.56

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	67.9394	ACRE-FT
PEAK DISCHARGE	=	137.8210	CFS
AREA	=	1458.0000	ACRES
TIME OF PEAK DISCHARGE	=	12.90	HRS

Figure 14
CULVERT "A" AREA HYDROLOGY - Part 2

* *
JUNCTION 1, BRANCH 1, STRUCTURE 2
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	501.00	64.00	.744	.000	.032	.34	3.0
2	172.00	64.00	.391	.000	.130	.35	3.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	51.30	.56
2	25.99	.56

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	31.3602	ACRE-FT
PEAK DISCHARGE	=	75.7981	CFS
AREA	=	673.0000	ACRES
TIME OF PEAK DISCHARGE	=	12.70	HRS

SUMMARY TABLE OF COMBINED HYDROGRAPH AND SEDIGRAPH VALUES

PREVIOUS MUSKINGUM ROUTING X	=	.36	
PREVIOUS MUSKINGUM ROUTING K	=	.2690	HRS
PREVIOUS ROUTED PEAK DISCHARGE	=	135.52	CFS
TIME OF ROUTED PEAK DISCHARGE	=	16.50	HRS
TOTAL DRAINAGE AREA	=	2131.00	ACRES
TOTAL RUNOFF VOLUME	=	99.2997	AC-FT
PEAK RUNOFF DISCHARGE	=	202.26	CFS
TIME TO PEAK DISCHARGE	=	16.50	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

MUD CREEK CHANNEL REPAIR

SUMMARY

The following Mud Creek Channel repair plan was formulated based on hydraulic design, field survey of the entire stretch of channel, and suggestions by UDOGM personnel. Specific suggestions by UDOGM personnel which have been employed in the formulation of this plan include:

- Divide channel length into reaches and design armoring requirements for each reach rather than designing for a worst case section.

- Perform a field survey of each reach of the channel to determine existing median rock size and channel embankment slopes.

- Redesign sediment pond in such a manner as to slope the east bank of the lower reach of the channel adjacent to the sediment pond to a minimum 2H:1V slope.

The Mud Creek Channel has been divided into three (3) reaches. Locations of these reaches are shown on the Mud Creek Channel Location Map (Map A-3).

Two (2) major considerations in the design of the Mud Creek Channel repair are as follows:

- The Mud Creek Channel bottom is the natural stream bottom

- In various channel sections there exists considerable vegetative growth

Since the Mud Creek Channel bottom is the natural stream bottom, no additional armoring is contemplated. However, rocks will be placed in the channel bottom in specific locations as identified by UDOGM. The vegetative growth in the channel is graphically illustrated by pictures taken by UDOGM personnel. Vegetation is especially apparent in Reach 1, the lower half of Reach 2, and on the west bank of Reach 3.

A majority of the work to be performed on the channel will be to supplement the armoring which already exists.

HYDROLOGY

The peak flow utilized in the design criteria was estimated utilizing the SEDIMOT II computer model. SEDIMOT II is a second generation hydrologic and hydraulic calculation model designed for use on IBM compatible personal computers. The SEDIMOT II Model calculates runoff and peak flow via a numerical modeling technique based on the Soil Conservation Service (SCS) TR-55 Unit Hydrograph method. The SEDIMOT II model assumes an antecedent moisture condition of II. A detailed description of the SEDIMOT II model is presented in Addendum A, SEDIMOT II Computer Model. Inputs to the hydrology component of the SEDIMOT II computer model include:

- Precipitation Distribution
- Storm Duration
- Return Period/Precipitation
- Unit Hydrograph
- Routing Parameters
- Drainage Basin Area
- Time of Concentration
- Curve Number

Precipitation Distribution

A standard precipitation distribution is input to model the runoff hydrograph. SEDIMOT II allows the user to choose between the SCS Type I or Type II storms or to input a storm distribution based on measurements in the area. For the Blazon Mine the SCS Type II storm was used.

Storm Duration

A storm duration of 24 hours was input into the model.

Return Period/Precipitation

A precipitation amount is required for the appropriate return period. For the Blazon Mine the following precipitation amounts were used:

Return Period	Precipitation (inches)
10-Year, 24-Hour	2.42
25-Year, 24-Hour	2.90
50-Year, 24-Hour	3.00
100-Year, 24-Hour	3.20

(Rick Summers - UDOGM)

Unit Hydrograph

A unit hydrograph is chosen for each drainage area model. The runoff hydrographs available in the SEDIMOT II model are for forested, agricultural or urban (disturbed) areas. The forested hydrograph was chosen for the Mud Creek drainage basin.

Routing Parameters

Routing parameters (Muskingum K and Muskingum X) were calculated to express travel time and attenuation in the watersheds. The methodology outlined in the SEDIMOT II Users Manual was used to calculate these two (2) routing parameters. The specific equations and values used are detailed as follows:

Muskingum K and Muskingum X. The value for travel time was used to approximate Muskingum K. The SCS Upland Method was used to determine a water velocity. The travel distance was measured directly from a 1"=400' scale map. Muskingum's X was computed by the following equation:

$$X = \frac{0.5\ Vw}{1.7+Vw}$$

Where Vw = Weighted Average Velocity

Additional information on determination of routing parameter values is provided in Addendum B, Mud Creek Hydrology.

Drainage Basin Area

The area of each drainage was determined by measuring the drainage basins as shown on the Drainage Basins Map (Map A4). The areas were determined by direct measurement on a digitizing table from the 1"=1000' scale map.

Time of Concentration (Tc)

Time of concentration was calculated by using the SCS Upland Method as presented in Applied Hydrology and Sedimentology for Disturbed Areas page 100. The Upland Method is suggested in the SEDIMOT II Users Manual. Again, all hydraulic lengths, drainage heights, and slope percentages were taken directly off the Drainage Basins Map (Map A4) as they applied to each subwatershed. Time of concentration calculations are shown in Addendum B, Mud Creek Hydrology.

Curve Number

A curve number of 64 was input into the model, (approved Blazon Reclamation Plan).

HYDROLOGIC RESULTS

The hydrologic results for the three (3) reaches of the channel are presented on Table 2, Mud Creek Channel Hydrologic Results. Hydrologic calculations on Little Snyder Canyon were completed by EarthFax Engineering. Beginning at the outlet of Culvert "B", the design peak

Table 2

MUD CREEK CHANNEL HYDROLOGIC RESULTS

	Q_{50} (cfs)	Q_{100} (cfs)
Reach 1[1]	195	248
Reach 2[1]	195	248
Reach 3	166	202

[1] Mud Creek Basin Peak + Little Snyder Canyon Peak

flow from Little Snyder Canyon was added to the design peak flow estimated for Mud Creek Basin. The hydrologic results shown on Table 2, Mud Creek Channel Hydrologic Results, includes Little Snyder Canyon peak flows.

CHANNEL REPAIR DESIGN

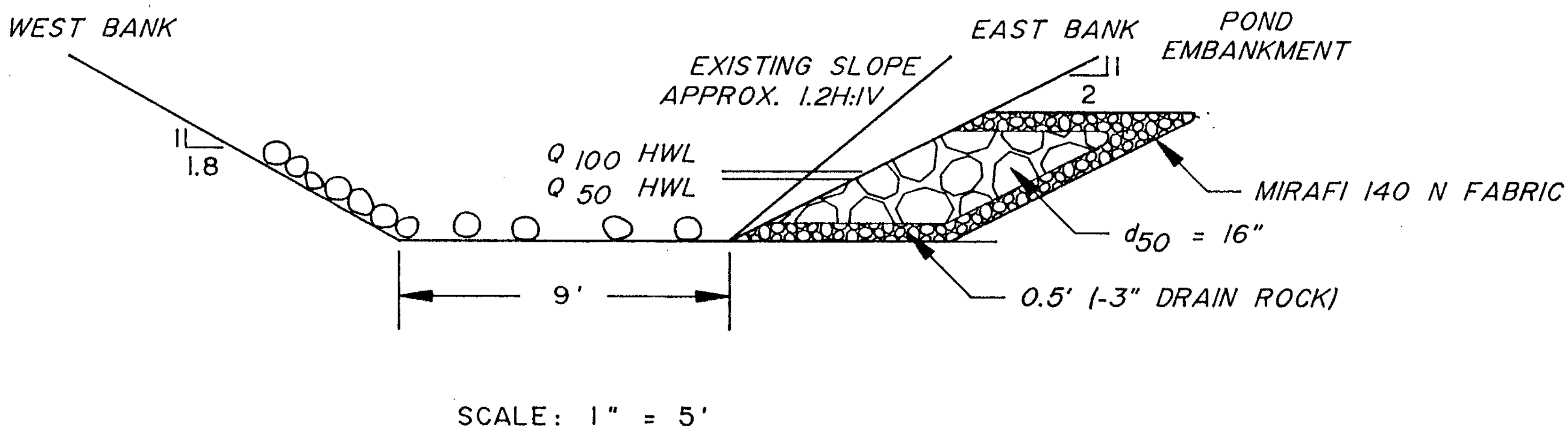
The Mud Creek Channel has been divided into three (3) reaches as shown on the Mud Creek Channel Location Map (Map A-3). A description of the three (3) reaches are as follows:

- Reach 1 - The reach of channel extending from the outflow of Culvert "C" to the northern extension of the existing sedimentation pond.
- Reach 2 - The reach extending from the outflow of Culvert "B" to the inflow of Culvert "C".
- Reach 3 - The reach extending from approximately 180 feet upstream of the inflow of Culvert "B" to the inflow of Culvert "B".

Reach 1

The entire east bank of Reach 1 extending approximately 160 feet will be reconstructed as shown on Figure 15, Mud Creek Reach 1 Typical Section. The size distribution for riprap placed on the east bank will be as shown on Figure 13, Size Distribution of Riprap. Design parameters for Reach 1 are listed below. The entire west bank of Reach 1 will require repair of the existing riprap. Addendum C, Field Notes, contains information regarding existing rock cover and approximate rock size. Rock will be added to the west bank to bring the riprap to the required D_{50} rock size. Rock in the channel bottom of Reach 1 will be supplemented as indicated in the field by UDOGM. D_{50} riprap calculations are shown on Figure 16, Mud Creek - Reach 1 Channel Design. The high water line (HWL) resulting from the 100yr/24hr precipitation event is calculated on Figure 17, Mud Creek - Reach 1 Q100 HWL.

- Design Event: 50yr/24hr Precipitation Event = 3.00 in
- Design Peak Flow: Q_{50} = 195 cfs (Mud Creek Basin and Little Snyder Canyon)
- Design Section Dimensions: Refer to Figure 15, Mud Creek Reach 1 Typical Section and Figure 16, Mud Creek Reach 1 Channel Design.



MUD CREEK - REACH I
TYPICAL SECTION

FIGURE 15

Figure 16

MUD CREEK REACH 1 - CHANNEL DESIGN

CHANNEL # - REACH 1 TYP

DESIGN PEAK FLOW (cfs), Q = 195.00	CHANNEL SHAPE - TRAPEZOIDAL
MANNING'S NUMBER, n = 0.0410	CHANNEL SLOPE = 4.50
CHANNEL SIDE SLOPE, Z = 2.0	VELOCITY = 9.1
HYDRAULIC RADIUS, R = 1.2758	DEPTH OF FLOW, d = 1.71
WETTED PERIMETER, P = 16.65	BOTTOM WIDTH, b = 9.00
X-SECTION AREA = 21.24	WIDTH OF STREAM, t = 15.84
FREEBOARD = 1.00	TOP WIDTH OF CHANNEL, T = 19.84
D50 RIP RAP DIAMETER (ins.) = 16.2	TOTAL DEPTH OF CHANNEL, D= 2.71

$D50 = 12(118Q(S)^{2.1667}R/P)^{0.4}$

Figure 17

MUD CREEK REACH 1 - Q100 HWL

CHANNEL # - REACH 1 TYP

DESIGN PEAK FLOW (cfs), Q = 248.00

MANNING'S NUMBER, n = 0.0410

CHANNEL SIDE SLOPE, Z = 2.0

HYDRAULIC RADIUS, R = 1.4195

WETTED PERIMETER, P = 17.72

X-SECTION AREA = 25.15

FREEBOARD = 1.00

TOTAL DEPTH OF CHANNEL, D = 2.95

CHANNEL SHAPE - TRAPEZOIDAL

CHANNEL SLOPE = 4.50

VELOCITY = 9.7

DEPTH OF FLOW, d = 1.95

BOTTOM WIDTH, b = 9.00

WIDTH OF STREAM, t = 16.80

TOP WIDTH OF CHANNEL, T = 20.80

Reach 2

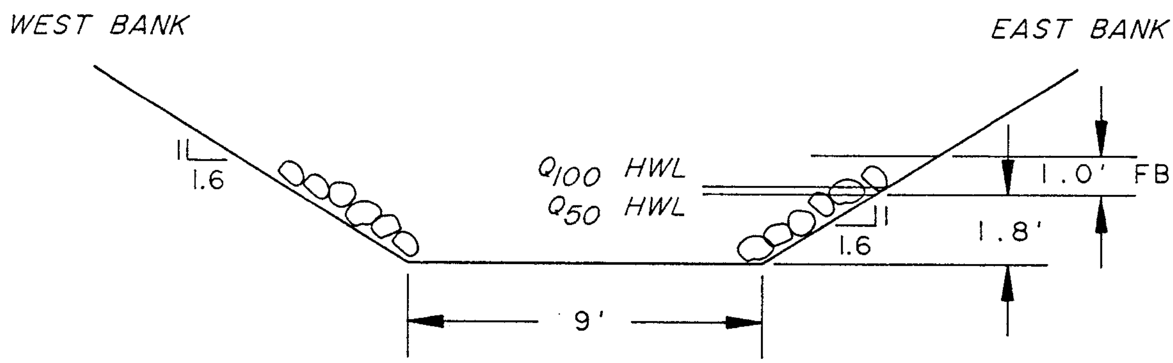
Repair work will be required on Reach 2 from Culvert "B" to station B+180. The repair work will involve supplementing existing riprap. Rock will be supplemented as necessary to meet the required riprap size of D_{50} = 20 inches. The field survey conducted on this reach indicated the median rock size to be about nine (9) inches. Therefore, mainly larger size rocks will be required for placement. Information gained from the field survey is presented in Addendum C, Field Notes.

Design parameters for Reach 2 are as follows:

- Design Event: 50yr/24hr Precipitation Event = 3.00 in
- Design Peak Flow: Q_{50} = 195 cfs (Mud Creek Basin and Little Synder Canyon)
- Design Section Dimensions: Refer to Figure 18, Mud Creek - Reach 2 Typical Section and Figure 19, Mud Creek - Reach 2 Channel Design.

The HWL resulting from the 100yr/24hr precipitation event is calculated on Figure 20, Mud Creek - Reach 2 Q_{100} HWL.

At Station B+20 additional riprap will be added at the outlet of the Little Snyder Drainage Culvert. Also, additional riprap will be placed in a steeper portion of Reach 2 between station B+160 and B+180. Beyond station B+180 rock will only be placed in the stream bottom as flagged by UDOGM personnel.



SCALE: 1" = 5'

MUD CREEK - REACH 2
TYPICAL SECTION

FIGURE 18

Figure 19

MUD CREEK REACH 2 - CHANNEL DESIGN

CHANNEL # - REACH 2 TYP

DESIGN PEAK FLOW (cfs), Q = 195.00	CHANNEL SHAPE - TRAPEZOIDAL
MANNING'S NUMBER, n = 0.0420	CHANNEL SLOPE = 4.50
CHANNEL SIDE SLOPE, Z = 1.6	VELOCITY = 9.2
HYDRAULIC RADIUS, R = 1.3418	DEPTH OF FLOW, d = 1.78
WETTED PERIMETER, P = 15.72	BOTTOM WIDTH, b = 9.00
X-SECTION AREA = 21.09	WIDTH OF STREAM, t = 14.70
FREEBOARD = 1.00	TOP WIDTH OF CHANNEL, T = 17.90
D50 RIP RAP DIAMETER (ins.) = 16.9	TOTAL DEPTH OF CHANNEL, D= 2.78

$D50 = 12(118Q(S)^{2.1667}R/P)^{0.4}$

Figure 20

MUD CREEK REACH 2 - Q100 HWL

CHANNEL # - REACH 2 TYP

DESIGN PEAK FLOW (cfs), Q = 248.00	CHANNEL SHAPE - TRAPEZOIDAL
MANNING'S NUMBER, n = 0.0420	CHANNEL SLOPE = 4.50
CHANNEL SIDE SLOPE, Z = 1.6	VELOCITY = 9.8
HYDRAULIC RADIUS, R = 1.4924	DEPTH OF FLOW, d = 2.03
WETTED PERIMETER, P = 16.66	BOTTOM WIDTH, b = 9.00
X-SECTION AREA = 24.86	WIDTH OF STREAM, t = 15.50
FREEBOARD = 1.00	TOP WIDTH OF CHANNEL, T = 18.70
TOTAL DEPTH OF CHANNEL, D = 3.03	

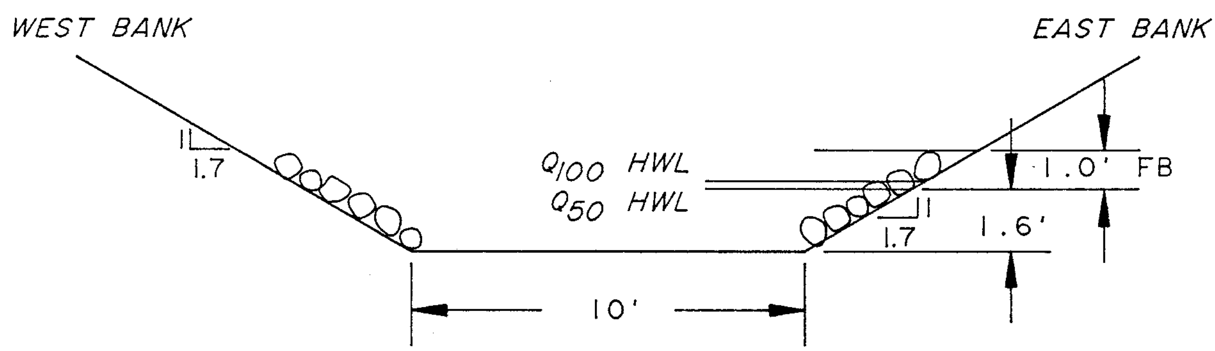
Reach 3

The field survey conducted for Reach 3 indicated a median rock size of approximately 16 inches. In several places along the bank, rock exceeded three (3) feet in diameter. In addition, there is considerable vegetation on the west bank of the channel. Repair work planned for Reach 3 will involve mainly supplementing existing rock specifically in places along the bank where no rock is present. This rock repair work will mainly be performed from station B-80 to B-140. From approximately station B-140 the natural stream flood plain begins and no repair work is planned. A typical section for Reach 3 is shown on Figure 21, Mud Creek Reach 3 Typical Section. Information gained from field work on Reach 3 is found in Addendum C, Field Notes.

Design parameters for Reach 3 are as follows:

- Design Event: 50yr/24hr Precipitation Event = 3.00 in
- Design Peak Flow: Q_{50} = 166 cfs (Mud Creek Basin and Little Synder Canyon)
- Design Section Dimensions: Refer to Figure 21, Mud Creek - Reach 3 Typical Section and Figure 22, Mud Creek - Reach 3 Channel Design.

The HWL for the 100yr/24hr precipitation event is calculated on Figure 23, Mud Creek - Reach 3 Q_{100} HWL.



SCALE: 1" = 5'

MUD CREEK - REACH 3
TYPICAL SECTION

FIGURE 21

Figure 22

MUD CREEK REACH 3 - CHANNEL DESIGN

CHANNEL # - REACH 3 TYP

DESIGN PEAK FLOW (cfs), Q = 166.00	CHANNEL SHAPE - TRAPEZOIDAL
MANNING'S NUMBER, n = 0.0410	CHANNEL SLOPE = 4.00
CHANNEL SIDE SLOPE, Z = 1.7	VELOCITY = 8.3
HYDRAULIC RADIUS, R = 1.2218	DEPTH OF FLOW, d = 1.56
WETTED PERIMETER, P = 16.15	BOTTOM WIDTH, b = 10.00
X-SECTION AREA = 19.74	WIDTH OF STREAM, t = 15.30
FREEBOARD = 1.00	TOP WIDTH OF CHANNEL, T = 18.70
D50 RIP RAP DIAMETER (ins.) = 13.7	TOTAL DEPTH OF CHANNEL, D= 2.56

$D50 = 12(118Q(S)^{2.1667}R/P)^{0.4}$

Figure 23

MUD CREEK REACH 3 - Q100 HWL

CHANNEL # - REACH 3 TYP

DESIGN PEAK FLOW (cfs), Q = 202.00	CHANNEL SHAPE - TRAPEZOIDAL
MANNING'S NUMBER, n = 0.0410	CHANNEL SLOPE = 4.00
CHANNEL SIDE SLOPE, Z = 1.7	VELOCITY = 8.8
HYDRAULIC RADIUS, R = 1.3370	DEPTH OF FLOW, d = 1.74
WETTED PERIMETER, P = 16.86	BOTTOM WIDTH, b = 10.00
X-SECTION AREA = 22.55	WIDTH OF STREAM, t = 15.92
FREEBOARD = 1.00	TOP WIDTH OF CHANNEL, T = 19.32
TOTAL DEPTH OF CHANNEL, D = 2.74	

FIELD ENGINEER SUPERVISION

Due to the variability of conditions within all three (3) reaches of the channel, a field engineer will be on site during repair work.

SEDIMENT CONTROL MEASURES UNDERTAKEN DURING CHANNEL REPAIR WORK

The following sediment control measures will be undertaken while repair work is occurring on the stream channel:

- Care will be taken to not disturb the existing natural channel bottom.
- Straw bales will be placed in the stream bottom at approximate 100 foot intervals.
- Sediment fences will be used where applicable.

BACKFILLING AND GRADING

All remaining backfilling and grading activities will be completed. Specifically, the backfilling and grading activities include the following:

- Movement of excess material from Little Snyder Canyon drainage construction to portal bench.
- Movement of excess material dumped at toe of portal slope back to portal bench.
- Regrading of area not affected by sediment pond redesign.
- Regrading of portal bench access road.

Upon completion of all backfilling and grading activities, available topsoil will be spread, ripped, and seeded.

WATER WELL DISPOSITION

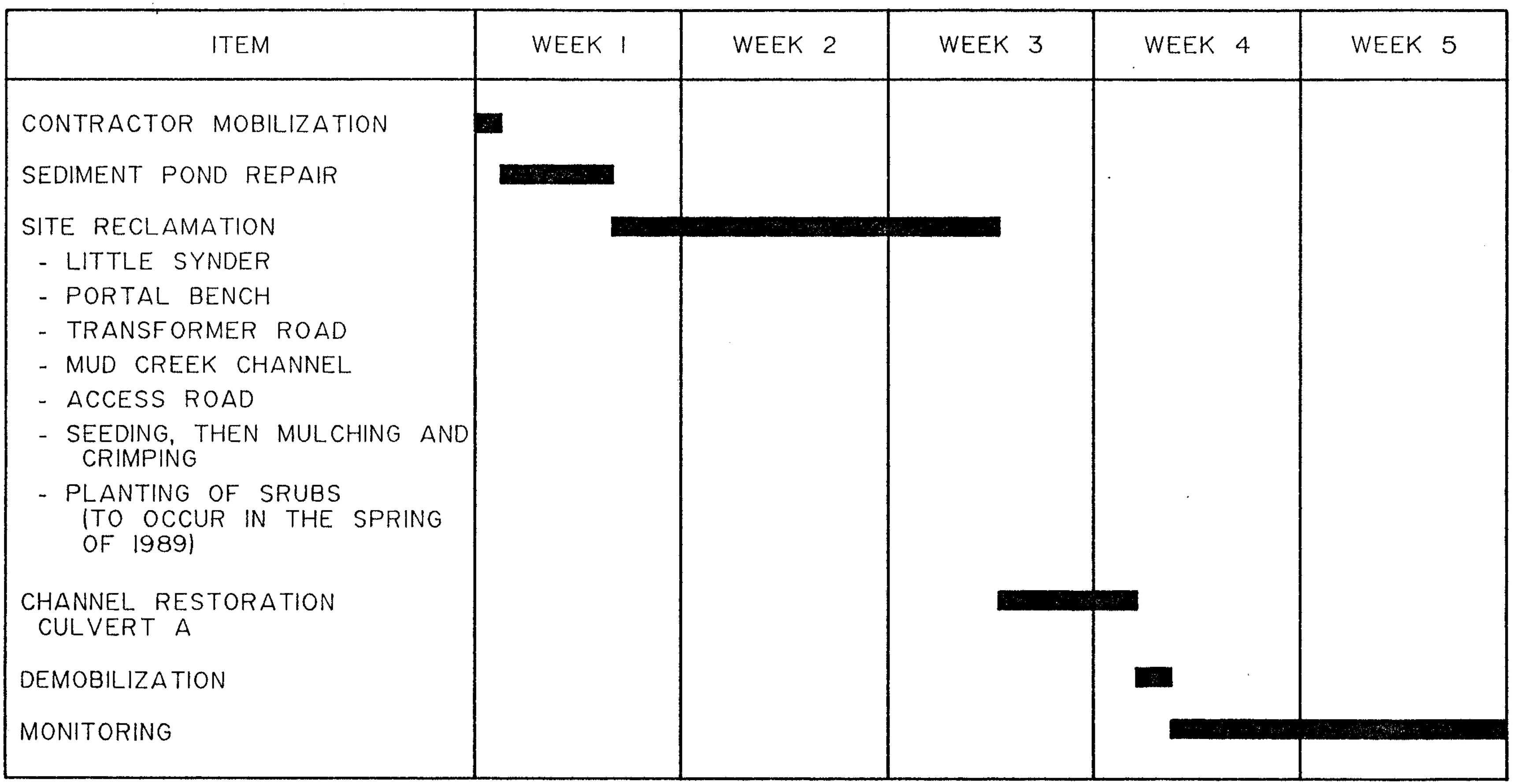
The disposition of the water well is explained under separate cover by NAE.

RIPARIAN VEGETATION

Riparian vegetation will be planted as proposed in the approved reclamation plan. NAE will monitor revegetation success according to the following schedule:

- First Year - NAE will perform a reconnaissance survey on the reseeded site and inspect for shrub survival.
- Second Year - NAE will monitor the reseeded area for cover and density and monitor shrub survival.
- Third Year - Same as second year.
- Fourth Year - Same as second year.
- Fifth Year - Same as second year.

Transects will be randomly located within the reference area and the reseeded area. Sample size will be dependent upon the number needed to obtain statistical adequacy using a least minimum sample size as presented in UDOGM guidelines. All seeding will take place prior to mulching. Shrubs will be planted in the spring of 1989. The reclamation sequence and time table is presented on Figure 24, Blazon No. 1 Mine Reclamation Sequence and Time Table. It is noted that the first reclamation activity to be performed will be reconstruction of the sedimentation ponds. The only other reclamation activity which will be conducted prior to reconstruction of the sedimentation ponds will be repair work of the access road ditch because this area does not drain to the sedimentation ponds.



(1) TIMETABLE DEPENDENT ON CONTRACTOR BID

MINE RECLAMATION SQUENCE AND TIMETABLE[1]

FIGURE 24

FIELD ENGINEER SUPERVISION

A qualified field engineer will be present during reclamation activities.

AS-BUILT CERTIFICATION

Once reclamation activities are completed, the various components of the reclamation work will be certified "as-built" by a qualified Professional Engineer, registered in the State of Utah. As-built drawings of all applicable components of the reclamation work will be submitted to UDOGM as required.

REFERENCES

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ADDENDUM A

SEDIMOT II COMPUTER MODEL

The following are excerpts from the SEDIMOT II Users Manual describing the history and purpose of the SEDIMOT II Hydrology Model.

November 21, 1983

USER'S GUIDE

TO

SEDIMOT II - PC VERSION

by

Jesse G. Mayes

Oklahoma Technical Press
815 Hillcrest
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PREFACE

The University of Kentucky, College of Agriculture, Department of Agricultural Engineering (UKAE) has developed a model for design of runoff and sediment control structures, referred to as SEDIMOT II, which is described in the Design Manual for the SEDIMOT II Hydrology and Sedimentology Model[1]. (This manual is referenced later in this paper as "the UKAE SEDIMOT II Manual".) Two computer programs (actually, two versions of the same program) written by UKAE and described in the UKAE SEDIMOT II Manual, have been converted to run on the IBM Personal Computer (PC or XT) by Jesse G. Mayes[2].

The first program, SEDPC, is an IBM PC (Microsoft) fortran version of the IBM 370 mainframe fortran batch program for sediment pond design. The only modifications that have been made are the programming changes necessary to convert from the IBM 370 fortran to the IBM PC fortran. All the algorithms remain the same and the capabilities of the PC version are identical to those of the mainframe version. The date of the latest UKAE update included is indicated on the program output.

The second program, SEDCREAT, is an IBM PC (Microsoft) fortran version of the HP 3000 mainframe fortran interactive program for sediment pond design. In addition to the programming changes necessary to convert from the HP 3000 fortran to the IBM PC fortran, all the design calculations have been deleted. Thus. SEDCREAT only allows the user the options of building a new batch data file (to be run using SEDPC) or of modifying an existing file. The interactive format remains identical to that of the HP version, making the use of SEDCREAT very convenient for those users already familiar with the HP version. In addition to the instructions included here, the user should have available the UKAE SEDIMOT II Manual for interpreting the input.

The PC version of SEDIMOT II is available from:

Oklahoma Technical Press
815 Hillcrest
Stillwater, OK 74074

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1 Design Manual for the SEDIMOT II Hydrology and Sedimentology Model, University of Kentucky, College of Agriculture, Department of Agricultural Engineering

2 Mr. Mayes is a principal in Tech Engineering, Inc.

CHAPTER 1

INTRODUCTION

The Surface Mine Control and Reclamation Act, PL-95-87, requires that surface mining activities be planned and conducted to minimize changes in the hydrologic balance. Proposed regulations (30 CFR 715, 717, 816, and 817, 1981) will allow the miner to use alternative surface mine strategies and sediment control methods to meet a settleable solid standard of 0.5 ml/l. To evaluate the effectiveness of these alternatives, hydrology and sedimentology simulation models may be used. Ideally these models should be both simple and accurate. In practice, however, trade-off between simplicity and theoretical accuracy is necessary. This report describes a simulation model, constructed using simple algorithms requiring easily measured or calculated input parameters, that can be used to evaluate the effectiveness of surface mine and sediment control strategies. The input parameters to this model can be estimated from map and site survey data.

It is possible to model the response of the entire runoff-erosion-transport process for a watershed using either a lumped parameter approach or distributed parameter approach. Lumped parameter models evaluate the response of the entire watershed as a single hydrologic unit. A single set of input parameters are used to characterize the total drainage basin. Variations in watershed characteristics are considered by adjusting these input parameters with area-weighted methods and/or regression equations. Lumped parameter models are relatively inexpensive and simple to use but tend to mask out important sub-processes and spatially varied response from different land uses within a watershed. Examples of lumped parameter models are HYSIM (Betson et al., 1980) and TENN-I (Overton and Crosby, 1979). In contrast to the lumped parameter approach distributed parameter models divide the watershed into subareas each having relatively uniform but distinctly individual characteristics. Each subarea is characterized by its own set of input parameters.

Common solution techniques in distributed parameter models are finite difference and finite element approximations to the governing flow and transport equations. Distributed parameter models are capable of predicting the spatial-varied response from different land uses but often require large amounts of input data and computer time. Examples of distributed parameter models are the CSU model (McWhorter et al., 1979), ANSWERS (Beasley et al., 1980) and FESHM (Wolfe et al., 1981). Because of the drastically different land use on a stripmine watershed a distributed parameter approach should be used to evaluate the effectiveness of mining strategies and sediment control methods.

Recently, a simple distributed parameter simulation model called SEDIMOT I (Wells et al., 1980; Barfield et al., 1980) has been developed by University of Kentucky personnel. Empirical routing techniques are used in SEDIMOT I to reduce the input requirements of the distributed models described in the previous paragraph. A composite runoff hydrograph is calcualted by using the SCS's TR-55 (1975) tabulated runoff values. Sediment yield, particle size distribution, and sediment graphs are predicted for each subwatershed using Williams' technique (1975a, 1975b) and combined at the watershed outlet. SEDIMOT I is also capable of evaluating the performance of a single detention pond. Because the SCS's TR-55 tables are used in SEDIMOT I it is virtually impossible to test it against observed runoff data. SEDIMOT I is an event (rather than continuous) simulation model.

Ward et al. (1980) also developed a simple distributed simulation model called WASHMO. Like SEDIMOT I, empirical routing techniques are used, but in WASHMO, unit hydrographs are used to predict runoff from each subwatershed. The runoff hydrographs are then translated to the watershed outlet (based on travel time) and combined to form a composite hydrograph. WASHMO has been tested on five watersheds (Ward et al., 1980). No sediment routines are included in WASHMO; hence, it is necessary to separately estimate sediment yield and sediment size in order to evaluate the performance of a detention pond. WASHMO is also an event simulation model.

Based on the results of these two studies it was decided that a second generation model should be developed that incorporates the general modeling approach used in WASHMO and SEDIMOT I. Furthermore it was decided that the second generation model should be expanded to include algorithms to evaluate the performance of additional types of sediment control structures, as well as combinations of these structures. This second generation model is referred to as SEDIMOT II (SEdimentology by DIstributed MOdel Treatment) in reference to the similar format and modeling philosophy adopted from the original SEDIMOT I model.

SEDIMOT II will be described in two parts. Part I contains a literature review and a description of the modeling techniques used in SEDIMOT II. It is divided into four major areas: (1) rainfall component, (2) runoff component, (3) sediment component, and (4) sediment control component. For each component a literature review is first presented and then followed by a description of the modeling technique used in SEDIMOT II. About the same level of sophistication was strived for in all four components. Part II is the user guide to SEDIMOT II which contains the required format of input parameters. A representative watershed is used to illustrate recommended procedures to obtain these inputs.

The definition of symbols used in this manual will change with topics. We believe that the material can best be presented by adopting the nomenclature that is most frequently used in their respective disciplines. Unfortunately, this required us to duplicate symbols between different subjects.

A HYDROLOGY AND SEDIMENTOLOGY

WATERSHED MODEL. PART II:

USERS' MANUAL

BY

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ACKNOWLEDGEMENTS

Perhaps it is unusual to thank one's co-authors in the acknowledgement section, but without their wholehearted, enthusiastic support this users' manual could not have been produced in a three week time frame in response to the heavy demand generated by recent regulatory developments. I am particularly indebted to Bruce Wilson who wrote the draft of the users' manual for the first batch version of SEDIMOT II. He, more than anyone else, is the father of SEDIMOT II. The model provides a quantum improvement beyond the concepts embroidered in the original SEDIMOT program. Specifically, Bruce is responsible for most of the conceptual basis of the SEDIMOT II Model. The mathematics, which he explains so clearly in Manual 1, were formulated through his efforts. The pond performance evaluation method (CSTRS) is reflective of his original insights into pond-sedimentation mechanisms. The adaptation of recent soil loss equations into the SLOSS routine; improvements in the DEPOSITS algorithm, grass filter (GRASSF) routine, and sediment routing routine; and extensions and modifications of various hydrologic and hydraulic methods have greatly enhanced the capabilities of SEDIMOT II. The efficiency of the model in predicting the combined performance of a series of alternative sediment controls is evidenced by low program computational cost. Mr. Wilson was primarily responsible for developing the actual batch version of the computer program and directing related programming activities.

Dr. Billy Barfield, with the assistance of Drs. Ian Moore and Larry Wells, developed the original version of SEDIMOT. SEDIMOT proved to be a valuable starting point in the formulation of SEDIMOT II. Also, Dr. Barfield directed the research resulting in the grass filter model by Dr. John Hayes, as well as obtaining funding and providing overall guidance in the development of SEDIMOT II.

The SEDIMOT II Model incorporates a great deal of research conducted at the Agricultural Engineering Department of the University of Kentucky. The DEPOSITS Model, developed by Drs. Andy Ward, Billy Barfield, and Tom Haan, was incorporated into SEDIMOT II. The porous rock check dam, developed by Mr. Michael Hirschi, was also incorporated. Extensions to predicting pond performance due to flocculation and basin hydraulics was accomplished by Dr. John Tapp and Mr. Mitch Griffin, respectively.

Mr. David Logsdon was primarily responsible for the computer modification from a batch program to an interactive user-friendly program. Ms. Betty Guiglia did the initial interactive programming. Mr. Logsdon completed the interactive conversion, added numerous input checks, converted the IBM 370 batch version to be compatible with the HP3000 batch version, tested all facets of both versions, accomplished most computer work related to the users' manual, and provided some draft tables and figures for the manual. Additionally, Mr. Logsdon provided advice about the level of information needed to understand the essentials of SEDIMOT II from a non-engineer's perspective.

Ms. Pamela Nebgen was primarily responsible for the layout and figures of the users' manual. Figures that illustrate the step-by-step progression of a methodology are fundamental to understanding. Ms. Nebgen provided this vehicle through her example illustrations, work sheets, and card code documentation. She worked through some of the example problems and was responsible for most of the batch file documentation and values listed on the batch data sheets. Also, Ms. Nebgen acted as a liaison between programmer, typist, writer, and prospective model user. This proved to be invaluable. It is indeed unusual to find a new graduate student who enthusiastically works forty hours per week on various projects, carries a full-time course load of twelve hours, and does both in an exceptional manner. We are fortunate to have her.

The manual was professionally typed in an exceptionally efficient manner by Ms. Nina Rotter. This was accomplished under very severe time constraints and required many weekends and long days. We are grateful for her dedication.

Two three-day short courses were taught to consulting engineers and the coal industry. Their recommendations have been incorporated into the manual and we feel that this has assisted in increasing the usefulness of this manual to the practitioner.

We would like to extend our thanks to Dr. Joe Ross, Chairman of the Agricultural Engineering Department of the University of Kentucky, for his support and enthusiastic encouragement. Through example, he has shown us that a team effort is essential to accomplishing teaching, research, and technology transfer. The team spirit needed to accomplish the production of this manual in a limited time frame is reflective of the camaraderie that he instills in our department.

We wish to acknowledge the support from the Kentucky Department of Energy and Institute for Mining and Minerals Research that was provided to develop the interactive version of SEDIMOT II.

INTRODUCTION

This is the users' manual for the SEDIMOT II model. It is written to help you understand the model to the extent necessary to apply it to your day-to-day hydrologic and sediment control design needs. The users' manual is written intentionally in an informal tutorial fashion. The manual is written to teach you how to apply the model in a step-by-step fashion. It contains a complete explanation of terms, numerous illustrations, example problems drawn from actual mine plans, and example input data.

From its very conception, the SEDIMOT II model was formulated with the ultimate user in mind. The techniques and methodologies used in the model are, where available, those which many users have had in their schooling and use in every day applications. The authors have drawn from experiences gained in teaching over 2,000 short course participants. These teaching experiences combined with consulting applications have made this a very pragmatic model balancing data requirements, cost, time constraints, model complexity, and user informational needs.

Some of the features of this users' manual are:

(1) an interactive question and answer format written in simple terms and providing a list of choices;

(2) a batch input data file option for those who have become more familiar with the model and its data input sequence;

(3) a check of each input data value to determine if it is within expected lower and upper limits;

(4) default values for input parameters that the user may not have ready access to and/or parameters that we have found not to be especially sensitive to final designs and predictions;

(5) a comprehensive list and explanation of input parameters;

(6) listing of suggested parameter values;

(7) listing of the expected range of parameters;

(8) an estimate of parameter sensitivity;

(9) step-by-step explanation of input sequence;

(10) illustration of the method used to determine the value of the input parameter;

(11) thoroughly explained error messages to help in quickly identifying input errors;

(12) complete example input data for illustrated examples;

(13) clearly stated major assumptions, limitations, and constraints;

(14) modular subroutines;

(15) increasing levels of complexity for analysis;

(16) analysis of output and results;

(17) etc.

CAPSULE MODEL OVERVIEW

This capsule model overview is presented simply to provide the reader with a single page statement, in nontechnical terms, of the overall model capabilities. An expanded overview follows and then a step-by-step discussion of the needed input sequences.

The model is capable of predicting a storm hydrograph and storm sediment graph for a user specified design storm. The hydrograph and sediment graph can be routed along a stream to a given point of interest.

Three sediment control structures are currently modeled:

(1) A sediment basin of the type commonly found in surface mining, farm ponds, urban storm water containment structures, etc.,

(2) a porous rock check dam, and

(3) a grass filter.

The sediment trap efficiency of each of these individual sediment control structures can be predicted. The user may specify sediment control structural designs. The sediment trap efficiency of one control or a series of a mix of these controls can also be predicted.

Through use of the model the performance of alternative sediment control options can be readily evaluated. The user can specify the design of alternative sediment control structures and locate a mix of these structures throughout a watershed. Combining a given sediment control scheme with a design storm, watershed characteristics, and the mine plan, the SEDIMOT II model can predict if regulatory mandated sediment performance standards will be met.

EXPANDED MODEL OVERVIEW

The purpose of this section is to present an overview of the SEDIMOT II model. Terms and techniques described in this section will be explained in greater detail in the step-by-step model description section of this users' manual. It is felt that a broad overview of the model would help the user understand the major model elements.

Major Model Elements

The major overall steps which the user should be aware of are:

(1) **Problem Formulation** - i.e. dissection into the necessary model components, i.e., junctions, branches, structures, and subwatersheds (all terms will be subsequently defined and illustrated);

(2) **Hydrologic Element** - i.e. development of a storm hydrograph for a given subwatershed;

(3) **Hydraulic Element** - i.e. routing and combining storm hydrographs;

(4) **Sedimentologic Element** - i.e. determining the quantity of sediment eroded and routing this sediment load to a sediment control structure; and

(5) **Sediment Control Structures** - i.e. design parameters for each sediment basin, check dam, and grass filter.

Problem Formulation

Prior to any data input it will be useful to separate the watershed into the necessary model components. Typically the watershed will be separated into a series of junctions, branches, structures, and subwatersheds as illustrated in Figure 1. As can be seen from Figure 1, a junction is where two or more streams (branches) meet. Also, a junction is always placed at the outlet of the total watershed, e.g. Junction 3 shown in Figure 1. Three junctions have been designated in Figure 1.

A branch is simply a stream which has a structure located on it. Four structure types are available: (1) sediment basin, (2) check dam, (3) grass filter, and (4) a null structure. The term "structure" is used because these locations often designate locations where the user will evaluate the effectiveness of sediment control structures.

A null structure is used at any location where information about a composite hydrograph, sedimentgraph, or particle size distribution is needed. Note that the null structure is simply a mechanism to allow the user to get information about a composite hydrograph, etc. at that location. More will be said about the use of the null structure in the step-by-step model description section of this users' manual.

Hydrologic Element

The storm hydrograph is developed in the hydrologic element for each designated subwatershed. The principal steps in developing a storm hydrograph are:

(1) specify a design storm, e.g. a 10-year, 24-hour event;

(2) specify a temporal storm pattern, e.g., an SCS Type I, Type II, or accumulated precipitation and associated time increment.

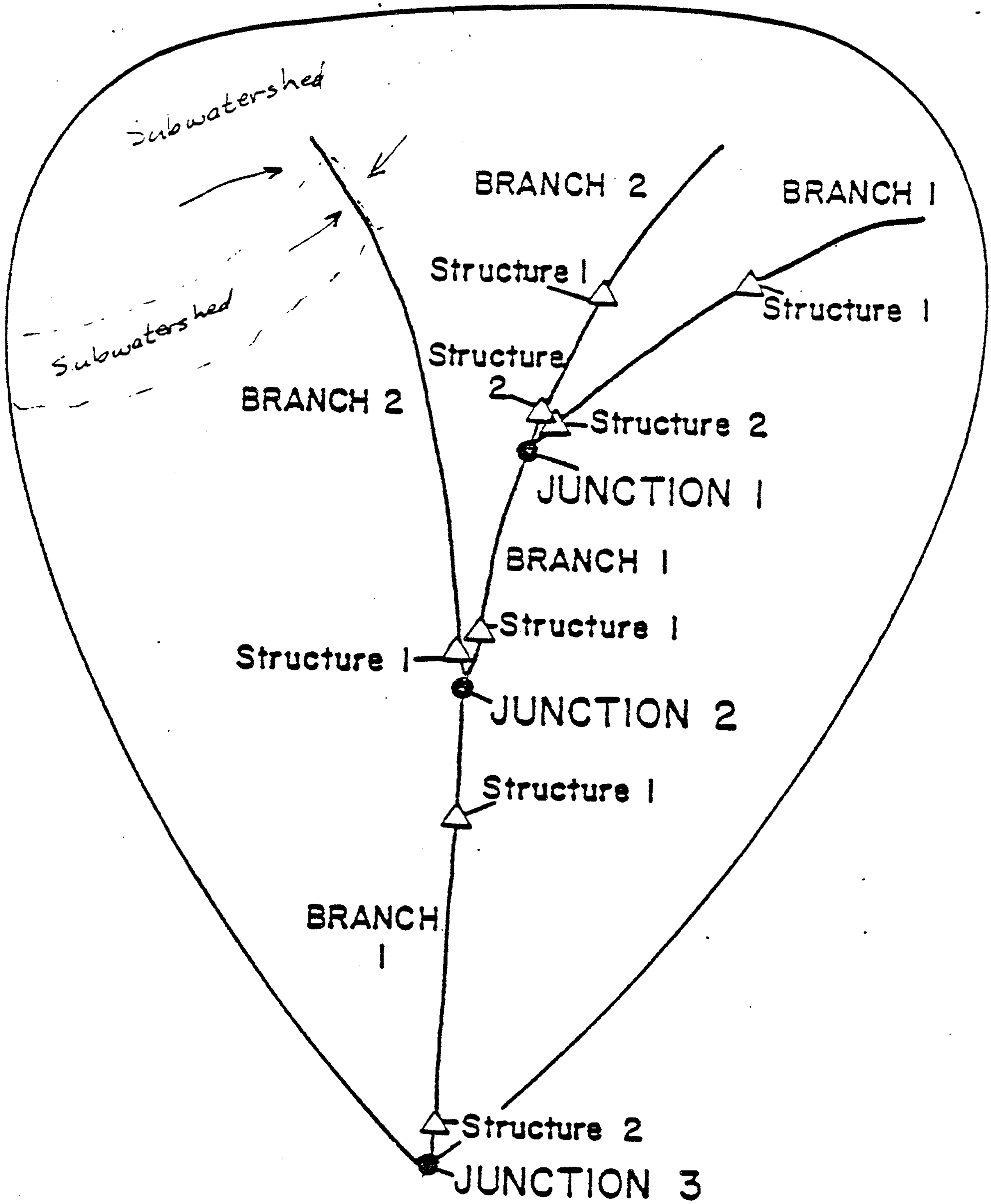

Figure 1. Schematic of SEDIMOT II Nomenclature

(3) determine rainfall extraction using the SCS's curve number model; and

(4) convolution of a selected dimensionless unit hydrograph (This simply means that the model user selects one of three unit hydrograph shapes depending upon watershed conditions, e.g., disturbed, agricultural, or forested).

Hydraulic Element

Storm hydrographs are routed to and between structures by Muskingum's routing procedure. This method was selected due to its ease of application and in order to eliminate the need to obtain stream cross sections.

Sedimentologic Element

SEDIMOT II has two different options available to calculate sediment yield: (1) MUSLE and (2) SLOSS. Sediment yield is calculated for each subwatershed, routed to the specified sediment control structure, and then combined to determine the total sediment entering the structure from all upstream subwatersheds and upstream structures.

In Subroutine MUSLE sediment yield is estimated using Williams' Modified Universal Soil Loss Equation (Manual 1, p. 1.6.33, Red Book, pp. 365-366. The parameters required are K (soil erodibility), slope length and gradient, and CP (control practice factor). Sediment yield from each subwatershed is routed to a structure by Williams' model (Manual 1, pp. 1.6.39 - 1.6.43, Red Book, pp. 366-369. Travel time and the particle size distribution are needed input data. The eroded particle size distribution is adjusted during routing to account for selected deposition.

The SLOSS Subroutine is a second option available to estimate the quantity of sediment eroded and transported to a specified location. The flow path of a subwatershed is separated into slope segments and detachment, transport, and deposition are calculated for each segment.

Sediment Control Structures

Four sediment control structures can be designed and their performances evaluated using SEDIMOT II. These structures are: (1) retention basin (pond, sediment basin, etc.), (2) grass filter, (3) porous check dam, and (4) a null structure.

The sediment trap efficiency of a pond (or ponds in series) can be evaluated by two alternative methodologies: (1) DEPOSITS Model or (2) CSTRS Model. The DEPOSITS Model considers the incoming storm hydrograph, sedimentgraph, and particle size distribution and basin geometry and hydraulic characteristics (stage-storage and stage-discharge relationships). The pond is conceptually divided into four layers and trap efficiency and effluent concentrations are determined through use of Stokes' Law.

The CSTRS Model employs a series of continuous stirred type reactors to evaluate the performance of a pond. The main difference between the CSTRS Model and the DEPOSITS Model is that the CSTRS Model accounts for the mixing between inflow concentrations once flow has entered the pond. The DEPOSITS Model uses a first-in, first-out plug flow concept and does not allow for this mixing.

Both models will predict the storm volume discharged, peak discharge, peak stage, peak and average effluent sediment concentrations, storm detention time, and basin trap efficiency.

The sediment trap efficiency of a rock check dam can be predicted by the check dam sediment control option. A gabion type rock dam would be typical of the structure to be evaluated. Calculation of the trap efficiency of a check dam is based upon water being backed up upstream of the check dam for a length of time sufficient to allow particles to settle out of the flow. This is accomplished by determining the backwater surface profile for a given storm flow and channel configuration and by predicting subsequent deposition for an estimated settling velocity of sediment particles.

The grass filter sediment control option predicts reduced velocity of sediment laden flow and subsequent deposition associated with a designed filter. The sediment trap efficiency of such a filter is related to the storm hydrograph and sedimentgraph, incoming sediment load, vegetal height and density, and filter width, length, and slope.

ADDENDUM B

MUD CREEK HYDROLOGY

Parameters

Total Basin Area	2131 Ac	- Given
50 Yr/24 Hr Event	3.00 In	- UDOGM
Curve Number	64	- Given
Tc		Calculated by Upland Curves Pg. 100 Red Book

****

WATERSHED IDENTIFICATION CODE

MUD CREEK CHANNEL - 50YR/24HR PEAK FLOW

****

**********************INPUT VALUES*********************

STORM DURATION	=	24.00	HOURS
PRECIPITATION DEPTH	=	3.00	INCHES

1

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	268.00	64.00	.480	.000	.000	.00	3.0
2	336.00	64.00	.631	.000	.000	.00	3.0
3	854.00	64.00	.881	.000	.300	.33	3.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	28.26	.47
2	30.40	.47
3	63.15	.47

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	56.9531	ACRE-FT
PEAK DISCHARGE	=	112.6100	CFS
AREA	=	1458.0000	ACRES
TIME OF PEAK DISCHARGE	=	12.90	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

1

* *
JUNCTION 1. BRANCH 1, STRUCTURE 2
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	501.00	64.00	.744	.000	.032	.34	3.0
2	172.00	64.00	.391	.000	.130	.35	3.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	41.10	.47
2	20.34	.47

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	26.2891	ACRE-FT
PEAK DISCHARGE	=	60.1413	CFS
AREA	=	673.0000	ACRES
TIME OF PEAK DISCHARGE	=	12.70	HRS

SUMMARY TABLE OF COMBINED HYDROGRAPH AND SEDIGRAPH VALUES

PREVIOUS MUSKINGUM ROUTING X	=	.36	
PREVIOUS MUSKINGUM ROUTING K	=	.2690	HRS
PREVIOUS ROUTED PEAK DISCHARGE	=	110.82	CFS
TIME OF ROUTED PEAK DISCHARGE	=	16.50	HRS
TOTAL DRAINAGE AREA	=	2131.00	ACRES
TOTAL RUNOFF VOLUME	=	83.2422	AC-FT
PEAK RUNOFF DISCHARGE	=	165.62	CFS
TIME TO PEAK DISCHARGE	=	16.50	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

*** RUN COMPLETED ****

****

WATERSHED IDENTIFICATION CODE

MUD CREEK CHANNEL - 100YR\24HR PEAK FLOW

****

*********************INPUT VALUES********************

STORM DURATION	=	24.00	HOURS
PRECIPITATION DEPTH	=	3.20	INCHES

1

* *
JUNCTION 1, BRANCH 1, STRUCTURE 1
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	268.00	64.00	.480	.000	.000	.00	3.0
2	336.00	64.00	.631	.000	.000	.00	3.0
3	854.00	64.00	.881	.000	.300	.33	3.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	35.43	.56
2	38.03	.56
3	78.64	.56

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	67.9394	ACRE-FT
PEAK DISCHARGE	=	137.8210	CFS
AREA	=	1458.0000	ACRES
TIME OF PEAK DISCHARGE	=	12.90	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

1

* *
JUNCTION 1, BRANCH 1, STRUCTURE 2
* *

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	501.00	64.00	.744	.000	.032	.34	3.0
2	172.00	64.00	.391	.000	.130	.35	3.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)
1	51.30	.56
2	25.99	.56

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	31.3602	ACRE-FT
PEAK DISCHARGE	=	75.7981	CFS
AREA	=	673.0000	ACRES
TIME OF PEAK DISCHARGE	=	12.70	HRS

SUMMARY TABLE OF COMBINED HYDROGRAPH AND SEDIGRAPH VALUES

PREVIOUS MUSKINGUM ROUTING X	=	.36	
PREVIOUS MUSKINGUM ROUTING K	=	.2690	HRS
PREVIOUS ROUTED PEAK DISCHARGE	=	135.52	CFS
TIME OF ROUTED PEAK DISCHARGE	=	16.50	HRS
TOTAL DRAINAGE AREA	=	2131.00	ACRES
TOTAL RUNOFF VOLUME	=	99.2997	AC-FT
PEAK RUNOFF DISCHARGE	=	202.26	CFS
TIME TO PEAK DISCHARGE	=	16.50	HRS

* * * * * * * * * * * *
NULL STRUCTURE
* * * * * * * * * * * *

*** RUN COMPLETED ****

MUD CREEK

STRUCTURE 1

SUBWATERSHED 1

WORK SHEET 2

for

Subwatershed Time of Concentration

and

Routing Hydrograph from Subwatershed Outlet to a Structure

Time of Concentration for Subwatershed SWS1

Junction J1, Branch B1, Structure S1

Seg-ment	Surf. Cond.	Horizontal Distance (ft.)	Vertical Distance (ft.)	Diagonal Distance (ft.)	Slope (%)	Velocity (ft./sec.)	Time of Conc. (hr.)
1 -a	1	990	452	1090	45.7	1.7	.178
1 -b	5.5	2580	640	2660	24.8	6.0	.123
1 -c	6	3815	640	3868	16.8	6.0	.179
-d							

7385

ΣT_c = .480

Travel Time from Subwatershed ____ to Structure ____

Seg-ment	Surf. Cond.	Horizontal Distance (ft.)	Vertical Distance (ft.)	Diagonal Distance (ft.)	Slope (%)	Velocity (ft./sec.)	Travel Time (hr.)
-1							
-2							
-3							

Σ ______ Σ ______ ΣT_t = ____

$\overline{V}_w$ = ______, X = ______, K = ______

$$X = \frac{.5\,\overline{V}_w}{1.7 + \overline{V}_w} \qquad K = \Sigma T_t$$

MUD CREEK
STRUCTURE 1
SUBWATERSHED 2

WORK SHEET 2

for

Subwatershed Time of Concentration

and

Routing Hydrograph from Subwatershed Outlet to a Structure

Time of Concentration for Subwatershed SWS2
Junction J1, Branch B1, Structure S1

Segment	Surf. Cond.	Horizontal Distance (ft.)	Vertical Distance (ft.)	Diagonal Distance (ft.)	Slope (%)	Velocity (ft./sec.)	Time of Conc. (hr.)
1-a	1	1770	586	1864	33	1.4	.370
1-b	5.5	1077	190	1094	17.6	4.7	.065
1-c	6	2467	135	—	5.5	3.5	.196
-d							

5314

$T_c = \frac{\text{DIAG. DIST}}{V \times 3600}$

$\Sigma T_c =$ .631

Travel Time from Subwatershed ____ to Structure ____

Segment	Surf. Cond.	Horizontal Distance (ft.)	Vertical Distance (ft.)	Diagonal Distance (ft.)	Slope (%)	Velocity (ft./sec.)	Travel Time (hr.)
-1							
-2							
-3							

Σ ____ Σ ____ $\Sigma T_t =$ ____

$\overline{V}_w =$ ____, $X =$ ____, $K =$ ____

$$X = \frac{.5\,\overline{V}_w}{1.7 + \overline{V}_w} \qquad K = \Sigma T_t$$

STRUCTURE 1
SUBWATERSHED 3

WORK SHEET 2

for
Subwatershed Time of Concentration
and
Routing Hydrograph from Subwatershed Outlet to a Structure

Time of Concentration for Subwatershed SWS3

Junction J1, Branch B1, Structure S1

Seg-ment	Surf. Cond.	Horizontal Distance (ft.)	Vertical Distance (ft.)	Diagonal Distance (ft.)	Slope (%)	Velocity (ft./sec.)	Time of Conc. (hr.)
1-a	1	3058	1003	3218	32.8	1.4	.638
1-b	5.5	3908	480	3937	12.3	4.5	.243
-c							
-d							

$\Sigma T_c =$ .881

Travel Time from Subwatershed SWS3 to Structure S1

Seg-ment	Surf. Cond.	Horizontal Distance (ft.)	Vertical Distance (ft.)	Diagonal Distance (ft.)	Slope (%)	Velocity (ft./sec.)	Travel Time (hr.)
1-1	6	3452	160	—	4.6	3.2	.300
-2							
-3							

Σ ______ Σ ______ $\Sigma T_t =$ .300

$\overline{V}_w =$ 3.2, $X =$ .33, $K =$ .300

$$X = \frac{.5\,\overline{V}_w}{1.7 + \overline{V}_w} \qquad K = \Sigma T_t$$

MILL CREEK

STRUCTURE 2

SUBWATERSHED 1

WORK SHEET 2
for
Subwatershed Time of Concentration
and
Routing Hydrograph from Subwatershed Outlet to a Structure

Time of Concentration for Subwatershed SWS1

Junction J1, Branch B1, Structure S2

Seg-ment	Surf. Cond.	Horizontal Distance (ft.)	Vertical Distance (ft.)	Diagonal Distance (ft.)	Slope (%)	Velocity (ft./sec.)	Time of Conc. (hr.)
1-a	1	1200	400	1264	33	1.5	.234
1-b	5.5	3825	440	3850	11.5	4.0	.267
1-c	6	3500	260	—	7.4	4.0	.243
-d							
		9525					

ΣT_c = .744

Travel Time from Subwatershed SWS1 to Structure S2

Seg-ment	Surf. Cond.	Horizontal Distance (ft.)	Vertical Distance (ft.)	Diagonal Distance (ft.)	Slope (%)	Velocity (ft./sec.)	Travel Time (hr.)
1-1	7	420	20	—	4.8	3.7	.032
-2							
-3							

Σ ______ Σ ______ ΣT_t = .032

$\overline{V}_w$ = 3.7, X = .34, K = .032

$$X = \frac{.5\,\overline{V}_w}{1.7 + \overline{V}_w} \qquad K = \Sigma T_t$$

MUD creek
STRUCTURE 2
Subwatershed 2

WORK SHEET 2
for
Subwatershed Time of Concentration
and
Routing Hydrograph from Subwatershed Outlet to a Structure

Time of Concentration for Subwatershed SWS2
Junction J1, Branch B1, Structure S2

Seg-ment	Surf. Cond.	Horizontal Distance (ft.)	Vertical Distance (ft.)	Diagonal Distance (ft.)	Slope (%)	Velocity (ft./sec.)	Time of Conc. (hr.)
1-a	1	1444	340	1483	23.5	1.3	.317
1-b	5.5	1500	360	1542	24.0	5.8	.074
-c							
-d							

$\Sigma T_c =$ .391

Travel Time from Subwatershed SWS2 to Structure S2

Seg-ment	Surf. Cond.	Horizontal Distance (ft.)	Vertical Distance (ft.)	Diagonal Distance (ft.)	Slope (%)	Velocity (ft./sec.)	Travel Time (hr.)
1-1	7	1870	80	—	4.3	4.0	.120
-2							
-3							

Σ ______ Σ ______ $\Sigma T_t =$ .120

$\overline{V}_w =$ 4.0, X = .35, K = .120

$$X = \frac{.5\,\overline{V}_w}{1.7 + \overline{V}_w} \qquad K = \Sigma T_t$$

MUD CREEK

STRUCTURE 1 TO

STRUCTURE 2

WORK SHEET I

for

Routing Hydrographs Between Junctions and/or Structures

From Junction or Structure S1 to Structure S2

(1) Segment	(2) Surf. Cond.	(3) Horizontal Distance (ft.)	(4) Vertical Distance (ft.)	(5) Diagonal Distance (ft.)	(6) Slope (%)	(7) Velocity (ft./sec.)	(8) Travel Time (hr.)
1	7	4352	220	—	5.1	4.5	.269
2							
3							

Σ ______ Σ ______ Σ .269

$\bar{V}_w$ = 4.5 , X = .36 , K = .269

K = T_T = → Σ

$X = \frac{.5\bar{V}_w}{1.7+\bar{V}_w}$

From Junction or Structure ______ to Structure ______

Segment	Surf. Cond.	Horizontal Distance (ft.)	Vertical Distance (ft.)	Diagonal Distance (ft.)	Slope (%)	Velocity (ft./sec.)	Travel Time (hr.)
1							
2							
3							

Σ ______ Σ ______ Σ ______

$\bar{V}_w$ = ______, X = ______, K = ______

From Junction or Structure ______ to Structure ______

Segment	Surf. Cond.	Horizontal Distance (ft.)	Vertical Distance (ft.)	Diagonal Distance (ft.)	Slope (%)	Velocity (ft./sec.)	Travel Time (hr.)
1							
2							
3							

Σ ______ Σ ______ Σ ______

$\bar{V}_w$ = ______, X = ______, K = ______

$$\bar{V}_w = \sum_{i=1}^{N} \frac{\text{col. }3_{(i)} \times \text{col. }7_{(i)}}{\Sigma \text{ col. } 3}, \quad \text{OR} \quad \bar{V}_w = \sum_{i=1}^{N} \frac{\text{col. }5_{(i)} \times \text{col. }7_{(i)}}{\Sigma \text{ col. } 5};$$

where N = segment numbers

$$X = \frac{.5\bar{V}_w}{1.7+\bar{V}_w} \qquad K = \Sigma \text{ col. } 8$$

product of the rainfall excess intensity, i_e, in iph and the flow length, L, in feet is greater than 500. The equation is

$$t_c = 0.928\ (n\ L)^{0.6}/(i_e^{0.4}\ S^{0.3}) \qquad (2.57)$$

where t_c is in minutes, n is Mannings n, L is in feet, i_e is in iph and S is the slope in ft/ft. Table 2.25 presents some values for n for overland flow surfaces.

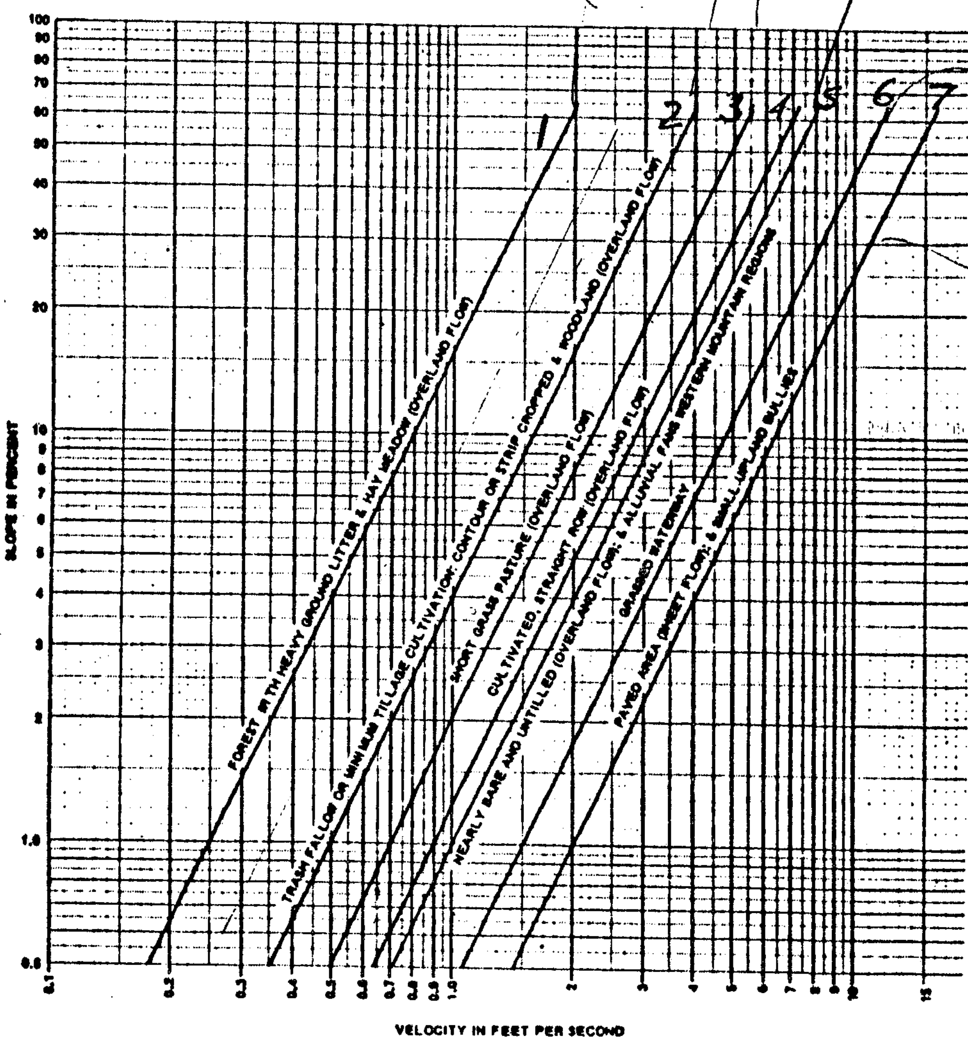

Figure 2.34. Velocities for upland method of estimating t_c.

Table 2.25. Mannings n[1].

Surface
Concrete
Asphalt
Rubble
Short grass pasture
High grass pasture
Mature row crop
Scattered brush, heavy weeds
Cleared land with stumps and no sprouts
Cleared land with stumps, heavy growth of sprouts
Heavy stand of timber, a few down trees

1. From Neyer (1981).

EXAMPLE PROBLEM 2.3a

To illustrate equation 2.57 consider a short grass with a s flow length of 200 feet. Consider that the rainfall intensity is infiltration loss of 0.5 iph. From table 2.25 n is about 0.035. Cal

Solution:

$i_e = 4.75 - 0.50 = 4.25$ iph

$S = 0.03$ ft/ft

$L = 200$ ft

$n = 0.035$

$t_c = 0.928\ (0.035 \times 200)^{0.6}/(4.25^{0.4}\ 0.03^{0.3})$

$= 4.78$ minutes

or about 5 minutes

ADDENDUM C

FIELD NOTES

Notes on field work conducted August 2, 1988 on Mud Creek channel configuration. Slopes were measured from five (5) feet above channel bottom to channel bottom. Refer to the Mud Creek Channel Location Map (Map A3) for station location.

REACH 1

Station	Bottom Width	West Slope	East Slope	% Rock Cover	Work Repair
C+20	10'	1.8	1.6	50%	1, 2
C+40	10'	1.5	1.6	60%	1, 2
C+60	8.5'	1.8	1.3	40%	1, 2
C+80	9.5'	1.9	1.5	20%	1, 2
C+100	8.0'	1.8	1.6	20%	1, 2
C+120	7.0'		1.4	30%	1, 2
C+140	9.0'	1.3	1.2	40%	1, 2
C+160	9.5'	1.4	1.2	35%	1, 2

[1] Restore east bank as designed

[2] Supplement rock on west bank

REACH 2

Station	Bottom Width	West Slope	East Slope	% Rock Cover	Work Repair
B+20	9.8'	1.5	1.5	85%	1
B+40	9.0'	1.5	1.8	95%	1
B+60	8.5'	1.7	1.5	60%	1
B+80	8.0'	1.6	1.6	70%	1
B+100	8.0'	2.1	1.4	90%	1
B+120	9.0'	1.6	1.4	80%	1
B+140	10.5'	1.3	1.8	75%	1
B+160	10.0'	1.4	1.6	50%	1
B+180	9.5'	2.0	1.5	50%	1
B+200	8.0'	6.0	6.0	20%	2
B+220	8.0'	2.1	6.5	10%	2
B+240	13'	---	---	---	

[1] Supplement rock as required

[2] Place rock as flagged by UDOGM personnel

REACH 3

Station	Bottom Width	West Slope	East Slope	% Rock Cover	Work Repair
B+20	10.7	1.6	1.4	80%	1
B+40	8.5	1.6	1.6	90%	
B+60	10.5	2	1.3	80%	1
B+80	10.0	1.6	1.6	50%	1
B+100	10.0	2	1.6	80%	1
B+120	9.0	1.6	2.2	70%	1
B+140	10.0	2.8	2.0	25%	1
B+160	----	---	---	---	2

[1] Supplement rock on east and west banks in areas where there is no rock cover

[2] Natural channel, no work required

The following pages contain the estimation of existing median rock size for the three (3) reaches of Mud Creek. Estimation is based on information gathered from field work conducted July 21, 1988.

REACH 1

Size in	R3-1	%	Cum'l %		
§4	36	36	36	%	Cum'l %
4	6	6	40	9.4	9.4
6	11	11	51	17.2	26.6
8	10	10	61	15.6	42.2
10	10	10	71	15.6	57.8
12	6	5	77	Median 9 in	
14	4	4	81		
16	2	2	83		
18	7	7	90		
20	2	2	92		
22	1	1	93		
24	4	4	97		
26	1	1	98		
28					
30	2	2	100		
	Median 9 in				

Existing median rock size estimation

REACH 1

Section 1		Section 2	
Feet	Rock Size	Feet	Rock Size
2	16	2	26
4	5	4	5
6	13	6	24
8	<4	8	8
10	<4	10	30
12	4	12	<4
14	10	14	<4
16	15	16	<4
18	18	18	5
20	4	20	<4

Section 3		Section 4	
Feet	Rock Size	Feet	Rock Size
2	22	2	9
4	4	4	15
6	<4	6	<4
8	10	8	13
10	7	10	11
12	<4	12	<4
14	8	14	15
16	<4	16	24
18	13	18	9
20	4	20	<4

Section 5		Section 6	
Feet	Rock Size	Feet	Rock Size
2	20	2	6
4	17	4	6
6	<4	6	18
8	<4	8	<4
10	20	10	<4
12	<4	12	8
14	6	14	8
16	11	16	18
18	<4	18	11
20	<4	20	6

REACH 1

Section 7		Section 8	
Feet	Rock Size	Feet	Rock Size
2	8	2	<4
4	24	4	<4
6	<4	6	6
8	<4	8	<4
10	4	10	18
12	<4	12	<4
14	10	14	10
16	18	16	18
18	14	18	10
120	<4	20	4

Section 9		Section 10	
Feet	Rock Size	Feet	Rock Size
2	12	2	12
4	18	4	24
6	10	5	10
8	<4	8	8
10	9	10	<4
12	4	12	8
14	36	14	<4
16	<4	16	6
18	12	18	6
20	<4	20	<4

REACH 1

	1	2	3	4	5	6	7	8	9	10
1	16	5x4x5	8x15x16	N	N	N	13x20x8	17x17x10	18x24x12	N
2	24x30x24	5	24	8	30	N	N	4	8x4x2	N
3	22	N	N	6x20x6	5x2x14	N	8	N	16x16x6	N
4	10x120x	14x12x20	N	16x16x4	12x10x6	6x4x2	20x12x12	24	12x4x12	4
5	30x20x12	20x20x12	N	N	20x30x12	N	6	16x12x6	N	4
6	8x8x3	8x8x3	N	N	N	12x10x2	10x12x6	18	12x12x8	6
7	8	24	N	N	4	N	12x12x6	18	16x18x8	N
8	N	N	6	3	18	N	10	18	10	4
9	12	18	10	N	12x12x3	4	36	N	12	N
10	12	24	10	8	2	8	2	6	6	N

N = No rock or less than 4 inches

REACH 2

Size in	R3-1	%	Cum'l %		
≤4	19	19	27	%	Cum'l %
4	8	8	35	9.9	9.9
6	8	8	54	9.9	19.8
8	19	19		23.5	43.3
10	9	9		11.1	54.4
12	14	14		Median 9.2 in	
14	5	5			
16	6	6			
18	3	3			
20	4	4			
22	1	1			
24	2	2			
26	1	2			
28	1	1			
30					
	100				

Existing median rock size estimation

REACH 2

Section 1 Feet	Rock Size	Section 2 Feet	Rock Size
2	<4	2	<4
4	<4	4	3
6	15	6	<4
8	<4	8	11
10	28	10	9
12	<4	12	7
14	5	14	8
16	<4	16	20
18	20	18	8
20	19	20	8

Section 3 Feet	Rock Size	Section 4 Feet	Rock Size
2	<4	2	14
4	16	4	6
6	10	6	7
8	9	8	16
10	20	10	17
12	10	12	9
14	16	14	8
16	19	16	13
18	9	18	12
20	12	20	29

Section 5 Feet	Rock Size	Section 6 Feet	Rock Size
2	<4	2	13
4	<4	4	<4
6	9	6	13
8	24	8	24
10	<4	10	<4
12	4	12	13
14	<4	14	8
16	13	16	10
18	15	18	6
20	13	20	4

REACH 2

Section 7		Section 8	
Feet	Rock Size	Feet	Rock Size
2	20	2	12
4	<4	4	4
6	18	6	27
8	15	8	17
10	12	10	6
12	4	12	4
14	8	14	10
16	8	16	12
18	12	18	8
120	8	20	10

Section 9		Section 10	
Feet	Rock Size	Feet	Rock Size
2	20	2	12
4	12	4	4
6	12	5	8
8	8	8	8
10	5	10	10
12	4	12	6
14	5	14	4
16	4	16	<4
18	8	18	8
20	4	20	12

REACH 2

	1	2	3	4	5	6	7	8	9	10
1	N	N	22x16x6	N	28	N	5	N	24x16	23x14
2	N	N	N	15x7	7x10	8x5	8	17x27	8x9	6x10
3	N	16	8x12	11x7	31x9	11x9	17x16	24x15	6x12	20x14
4	10x18	6x6	8x6	15x17	18x16	9x10	8x8	16x10	10x15	35x24
5	N	N	12x12x4	24	N	6x4x4	N	20x14x6	12x14x20	420x4x6
6	12x20x6	4	14x16x8	24	N	16x16x8	8	10	6	4
7	20	N	24x24x6	20x20x6	12	4	10x10x4	10x10x3	12	8
8	12	4	36x36x8	24x24x4	6	4	10	20x12x4	8	10
9	20	12	16x16x5	8	6x6x2	4	5	4	8	4
10	12	N	8x4x2	8	10	6	4	N	8	12

N = No rock or less than 4 inches

REACH 3

Size in	R3-1	%	Cum'l %		
≤4	7	14	14	%	Cum'l %
4	4	8	22	9.3	9.3
6	3	6	28	7.0	16.3
8	7	14	42	16.3	32.6
10	1	2	44	11.6	46.5
12	5	10	54		
14	0	0	58	4.7	51.2
16	2	4	60		
18	1	2	68		
20	4	8	70		
22	1	2	82		
24	6	12			
26	0	0			
28	0	0			
30	9	18	100		
	50				
	Median 11.5 in			Median 16 in	

Existing median rock size estimation

REACH 3

	1	2	3	4	5	6	7	8	9	10
1	20	12	36	4	N	22	4	8	12	8
2	5	5	30	12x12x2	10x10x3	12x8x8	36x18x8	12x12x4	14x14x3	24
3	24	36	N	N	N	12x12x2	12x12x4	4	6	20
4	30	30	24	24	36	N	N	12	12	24
5	5	12	36	24	18x18x12	18	21	N	8	6

N = No rock or less than 4 inches