Boyle Engineering Corporation

191 East 100 North
P.O. Box 88
Price, Utah 84501

consulting engineers / architects

801 / 637-6121

RECEIVED
JAN 26 1982

DIVISION OF
OIL, GAS & MINING

January 25, 1982

Mr. William Wollen
Genwal Coal Company
P. O. Box 1201
Huntington, Utah 84528

Dear Mr. Wollen:

In response to Manti-Lasal National Forest's letter dated January 13, 1982 we have revised the appropriate drawings to comply with the summary of comments offered in the letter. A summary of what has been done follows:

1. A note has been added to drawing no. 007 calling for a superelevation rate equal to reverse crown of 2 percent.

2. Minimum slope rounding on drawing no. 017 has been revised to require 1.5:1. Road alignment between Station 77+00 and Station 81+16 has been revised to allow an embankment slope of 1.5:1 to be constructed without encroaching upon Crandal Creek.

3. A note has been added to drawing no. 016 indicating erosion protection measures may be necessary on the interior borrow ditch. The half round pipe has been set at subgrade elevation.

   Review of hydrology calculations indicates a 48" diameter culvert will handle the runoff from a ten year precipitation event with HW/D approximately equal to 1.1 with projecting entrance. An end section is specified on the drawings which reduces HW/D to less than 1.0. Drawing no. 019 has been revised requiring grouted rock rip-rap at outlet of 48" diameter culvert. The abrupt deflection in the 48" diameter culvert has been replaced with a smooth 100 foot alignment curve. Calculations indicate allowable soil pressures along the transition will not be exceeded.

   A concrete box has been added at the outlet of the culvert handling undisturbed runoff from the lower interceptor ditch.

   We are awaiting comments from the state damn safety engineer and DOGM concerning adequacy of design of the sediment pond.

4. A sign has been added to drawing no. 023 at Station 75+25 advising traffic of mine activities ahead.

Hopefully these revisions will complete your mine submittal package.

Very Truly Yours,

BOYLE ENGINEERING CORPORATION

David R. Ariotti, P.E.

:bt

Attach to R+M consultant binder (flush w/ colored) Sed Pond Embankment Slope Stability Analysis (Dec 22/81)

only one copy available (loaned to BCCC 6-6-84)

GENWAL COAL COMPANY

Crandall Canyon Mine Site Plan Design Narrative

RECEIVED
DEC 22 1981
DIVISION OF
OIL, GAS & MINING

INTRODUCTION

The purpose of this narrative is to substantiate the design of the Crandall Canyon Mine site plan. Economic, environmental and geographical constraints make suitable development of the mine site extremely difficult. This narrative covers only the most economical development alternative with consideration toward minimizing environmental impact.

DESIGN DESCRIPTION

Traffic

The haul road alignment has been modified to direct traffic not associated with Genwal's mine operation around the mine facilities. This minimizes potential interference with the operation. This alignment necessitates decreasing the radius of two curves to approximately 150 feet. In order to maintain the 210 feet radius as recommended in the Forest Service design criteria either shifting of the storage pile further into the hillside or forcing the 210 feet radius would be necessary. If the storage piles were shifted the result would be more excavation and more exposed cut. If the 210 feet radius was applied to the alignment the result would be encroachment of the embankment into Crandall Creek. This would force either realignment of Crandall Creek or construction of retaining structure in the creek bottom to prevent the embankment from encroaching upon the creek.

Traffic on portal access roads will be limited to underground mine equipment, man-trip, and maintenance and supply vehicles necessary for operation. Maximum size of vehicle will be two-ton trucks. Most traffic will be three-quarter to one ton pick-up trucks. Anticipated volume is ten round trips per day.

Hydrology

Culvert and ditch sizing was performed as per DOGM requirements and sound engineering practice. Undisturbed runoff from the area above the mine has been directed around the disturbed area. Erosion control and prevention measures have been taken and include installation of half round corrugated steel pipe, velocity control drop structure at the outlet of the 48 inch diameter culvert and surface culvert at station 73 + 00. The sediment pond was designed in accordance with DOGM regulations to accommodate runoff from a disturbed area of approximately 10.4 acres.

In order to reduce sediment load in Crandall Creek during construction, it is recommended a minimum of three temporary straw dams be installed downstream from the construction area. These dams should be located at points on Crandall Creek which are easily accessible and as near the actual construction as possible. Construction of the sediment pond should precede other mine site improvements. The berm and halfround corrugated steel pipe on the haul road will help direct all disturbed runoff from the mine site into the sediment pond.

Embankments

Recommendations offered in geotechnical reports prepared by Delta Geotechnical Consultants and R & M Consultants have been incorporated in the design. Careful monitoring of construction in critical areas will be necessary to identify and use the correct design section (i.e. 1:1, ½:1 or ¼:1 slopes). Embankment protection at the toe of slopes adjacent to Crandall Creek will be as per typical sections detailed in the haul road plans.

2

Reclamation

Upon completion of mining operations, regrading will be accomplished to bring the finished topography to that prior to development as nearly as is possible and practical. Reference is made to Site Plan Drawings G01-C-016 and G01-C-017. These drawings identify and correlate proposed development with reclamation plan. It should be noted that the Forest Service has expressed a desire to keep the haul road in service after reclamation. No post-reclamation topography is provided. Topography on existing pre-development plans (C-016) shall be used as reference for reclamation grading.

Boyle Engineering Corporation

consulting engineers

288 West 400 South, Suite 301
Salt Lake City, Utah 84101

801 / 355-[illegible]

December 8, 1981

Mr. William C. Wollen
Vice President
Genwal Coal Company
P.O. Box 1201
Huntington, UT 84528

Dear Mr. Wollen:

We have completed the Crandall Canyon mine site plan design as per your direction. The mine site plan design is detailed on drawing nos. G01-C-016 through G01-C-022. These drawings were done under the direction of a Registered Professional Engineer.

As per your request concerning other drawings, haul road and bridge drawing nos. G01-C-001 through G01-C-015 were also done under the direction of a Registered Professional Engineer.

A brief design narrative has been written to accompany plans and help explain and substantiate design selection.

Thank you for the opportunity to do this work.

Very Truly Yours,
BOYLE ENGINEERING CORPORATION

David R. Ariotti

David R. Ariotti, P.E.

:bt

REGISTERED PROFESSIONAL ENGINEER
No. 5617
DAVID R.
ARIOTTI
STATE OF UTAH

Boyle Engineering Corporation

consulting engineers

268 West 400 South, Suite 301
Salt Lake City, Utah 84101

801 / 355-6109

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Vice President
Genwal Coal Company
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BOYLE ENGINEERING CORPORATION

David R. Ariotti

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:bt

REGISTERED PROFESSIONAL ENGINEER
No. 5617
DAVID R.
ARIOTTI
STATE OF UTAH

R&M

R&M CONSULTANTS INC.

ENGINEERS
GEOLOGISTS

March 30, 1982

R&M No. 161031

Genwal Coal Company
P.O. Box 1201
Huntington, UT 84528

Attn: Mr. William C. Wollen

Gentlemen:

SUBJECT: Supplemental Study for Sedimentation Pond Stability at Crandall Canyon Mine

We have performed the additional slope stability analysis on the downstream slope of the pond embankment for the subject project, supplemental to our original study documented in a report entitled "Embankment Slope Stability Study, Sedimentation Pond, Crandall Canyon Mine, Huntington, Utah", dated December, 1981.

In order to improve the factors of safety of the downstream slope of the pond embankment, the typical cross-section of the pond was revised by Boyle Engineering Corp. of Price, Utah as shown in Fig. 6 attached herewith. The crest of the pond was lowered to Elev. 7787 ft, the upstream slope of the pond embankment was steepened to 1.5H:1V, and the pond floor was lowered to Elev. 7769 ft to form a V-shape. Due to those changes, the pond embankment was shifted slightly toward the hillside.

The same soil parameters as in the original study was used in the STABL2 computer program for the analysis of the slope stability of the downstream slope. For a 2H:1V slope, the factor of safety is 1.540 under static conditions and 1.314 under seismic conditions (with unassumed horizontal acceleration equal to 8% of gravity). A set of copies of the computer output is attached.

The factors of safety of the revised cross-section of the sedimentation pond, as shown in Fig. 6, provide an adequate margin against slope failure. We will be glad to answer any questions you may have regarding this supplemental study.

Prepared by:

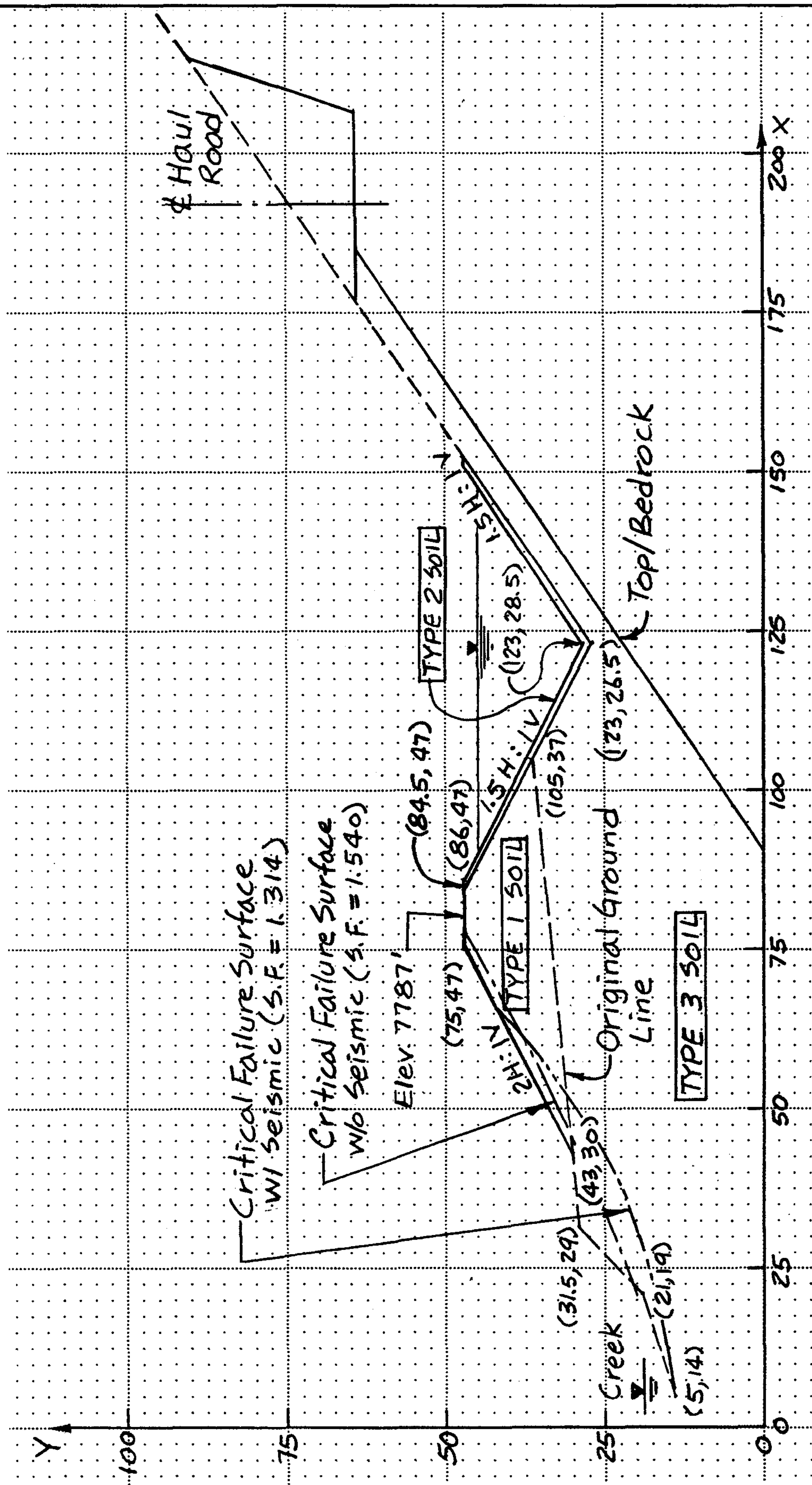
J.S. Liu, Ph.D., P.E.
Senior Geotechnical Engineer

Reviewed by:

Larry Migliaccio, P.E.
Director, Salt Lake City Office

REGISTERED PROFESSIONAL ENGINEER
LARRY MIGLIACCIO
3595
STATE OF UTAH

cc: DAriotti/Boyle Engineering Corp.
✓CWHedberg/DOGM
BBarney/U.S. Forest Service



2H:1V DOWNSTREAM SLOPE AND 1.5H:1V UPSTREAM SLOPE

WITH LOWERED CREST AND POND FLOOR

DWN.	JSL
CKD.	LGS
DATE.	3/24/82
SCALE.	1"=25'

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

GENWAL CRANDALL CANYON MINE
SEDIMENTATION POND

F.B.	
GRID.	
PROJ.NO.	161031
DWG.NO.	Fig. 6

3/23/82

--SLOPE STABILITY ANALYSIS--
SIMPLIFIED JANBU METHOD OF SLICES
IRREGULAR FAILURE SURFACES

PROBLEM DESCRIPTION JOB NO. 161031 GENWAL SEDIMENTATION POND
DOWNSTREAM SLOPE (2H TO 1V)
W/ LOWERED CREST & POND FLOOR

BOUNDARY COORDINATES

7 TOP BOUNDARIES
10 TOTAL BOUNDARIES

BOUNDARY NO.	X-LEFT (FT)	Y-LEFT (FT)	X-RIGHT (FT)	Y-RIGHT (FT)	SOIL TYPE BELOW BND
1	5.00	14.00	21.00	19.00	3
2	21.00	19.00	31.50	29.00	3
3	31.50	29.00	43.00	30.00	3
4	43.00	30.00	75.00	47.00	1
5.	75.00	47.00	84.50	47.00	1
6	84.50	47.00	86.00	47.00	2
7	86.00	47.00	123.00	28.50	2
8	84.50	47.00	105.00	37.00	1
9	43.00	30.00	105.00	37.00	3
10	105.00	37.00	123.00	26.50	3

ISOTROPIC SOIL PARAMETERS

3 TYPE(S) OF SOIL

SOIL TYPE NO.	TOTAL UNIT WT. (PCF)	SATURATED UNIT WT. (PCF)	COHESION INTERCEPT (PSF)	FRICTION ANGLE (DEG)	PORE PRESSURE PARAMETER	PRESSURE CONSTANT (PSF)	PIEZOMETRIC SURFACE NO.
1	120.0	132.0	.0	38.0	.00	.0	0
2	120.0	132.0	1000.0	20.0	.00	.0	0
3	110.0	125.0	.0	35.0	.00	.0	0

2

A CRITICAL FAILURE SURFACE SEARCHING METHOD, USING A RANDOM TECHNIQUE FOR GENERATING CIRCULAR SURFACES, HAS BEEN SPECIFIED.

100 TRIAL SURFACES HAVE BEEN GENERATED.

10 SURFACES INITIATE FROM EACH OF 10 POINTS EQUALLY SPACED ALONG THE GROUND SURFACE BETWEEN X = 6.00 FT.
AND X = 55.00 FT.

EACH SURFACE TERMINATES BETWEEN X = 60.00 FT.
AND X = 90.00 FT.

UNLESS FURTHER LIMITATIONS WERE IMPOSED, THE MINIMUM ELEVATION AT WHICH A SURFACE EXTENDS IS Y = 5.00 FT.

5.00 FT. LINE SEGMENTS DEFINE EACH TRIAL FAILURE SURFACE.

FOLLOWING ARE DISPLAYED THE TEN MOST CRITICAL OF THE TRIAL FAILURE SURFACES EXAMINED. THEY ARE ORDERED - MOST CRITICAL FIRST.

SAFETY FACTORS ARE CALCULATED BY THE MODIFIED BISHOP METHOD.

FAILURE SURFACE SPECIFIED BY 14 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	22.33	20.27
2	26.87	22.38
3	31.40	24.49
4	35.92	26.62
5	40.44	28.76
6	44.96	30.90
7	49.48	33.05
8	53.98	35.21
9	58.49	37.38
10	62.99	39.56
11	67.49	41.75
12	71.98	43.94
13	76.46	46.15
14	78.19	47.00

*** 1.540 ***

FAILURE SURFACE SPECIFIED BY 15 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	6.00	14.31
2	10.99	14.61
3	15.96	15.21
4	20.87	16.11
5	25.73	17.31
6	30.50	18.79
7	35.18	20.56
8	39.74	22.60
9	44.17	24.92
10	48.46	27.50
11	52.58	30.33
12	56.52	33.41
13	60.27	36.72
14	63.81	40.24
15	65.18	41.79

*** 1.609 ***

FAILURE SURFACE SPECIFIED BY 8 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	49.56	33.48
2	54.51	34.16
3	59.34	35.44
4	63.98	37.32
5	68.35	39.75
6	72.38	42.70
7	76.02	46.13
8	76.73	47.00

*** 1.633 ***

FAILURE SURFACE SPECIFIED BY 14 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	11.44	16.01
2	16.44	16.16
3	21.42	16.67
4	26.34	17.54
5	31.19	18.76
6	35.94	20.33
7	40.56	22.24
8	45.03	24.47
9	49.33	27.03
10	53.43	29.89
11	57.31	33.04
12	60.96	36.46
13	64.34	40.14
14	65.99	42.21

*** 1.641 ***

FAILURE SURFACE SPECIFIED BY 13 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	16.89	17.72
2	21.68	18.06
3	26.83	18.78
4	31.71	19.86
5	36.49	21.31
6	41.15	23.12
7	45.67	25.27
8	50.01	27.75
9	54.15	30.55
10	58.08	33.65
11	61.75	37.04
12	65.17	40.69
13	66.69	42.58

*** 1.657 ***

FAILURE SURFACE SPECIFIED BY 16 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	16.89	17.72
2	21.85	18.32
3	26.79	19.13
4	31.68	20.15
5	36.53	21.36
6	41.33	22.78
7	46.06	24.39
8	50.72	26.20
9	55.31	28.19
10	59.80	30.38
11	64.21	32.75
12	68.51	35.30
13	72.70	38.02
14	76.78	40.92
15	80.73	43.98
16	84.32	47.00

*** 1.689 ***

FAILURE SURFACE SPECIFIED BY 6 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	44.11	30.59
2	49.10	30.85
3	53.92	32.20
4	58.32	34.58
5	62.08	37.86
6	64.80	41.58

*** 1.722 ***

FAILURE SURFACE SPECIFIED BY 15 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	22.33	20.27
2	27.05	21.92
3	31.75	23.62
4	36.44	25.38
5	41.10	27.19
6	45.74	29.05
7	50.36	30.96
8	54.96	32.93
9	59.53	34.94
10	64.08	37.01
11	68.61	39.13
12	73.12	41.30
13	77.60	43.52
14	82.05	45.79
15	84.37	47.00

*** 1.733 ***

FAILURE SURFACE SPECIFIED BY 10 COORDINATE POINTS

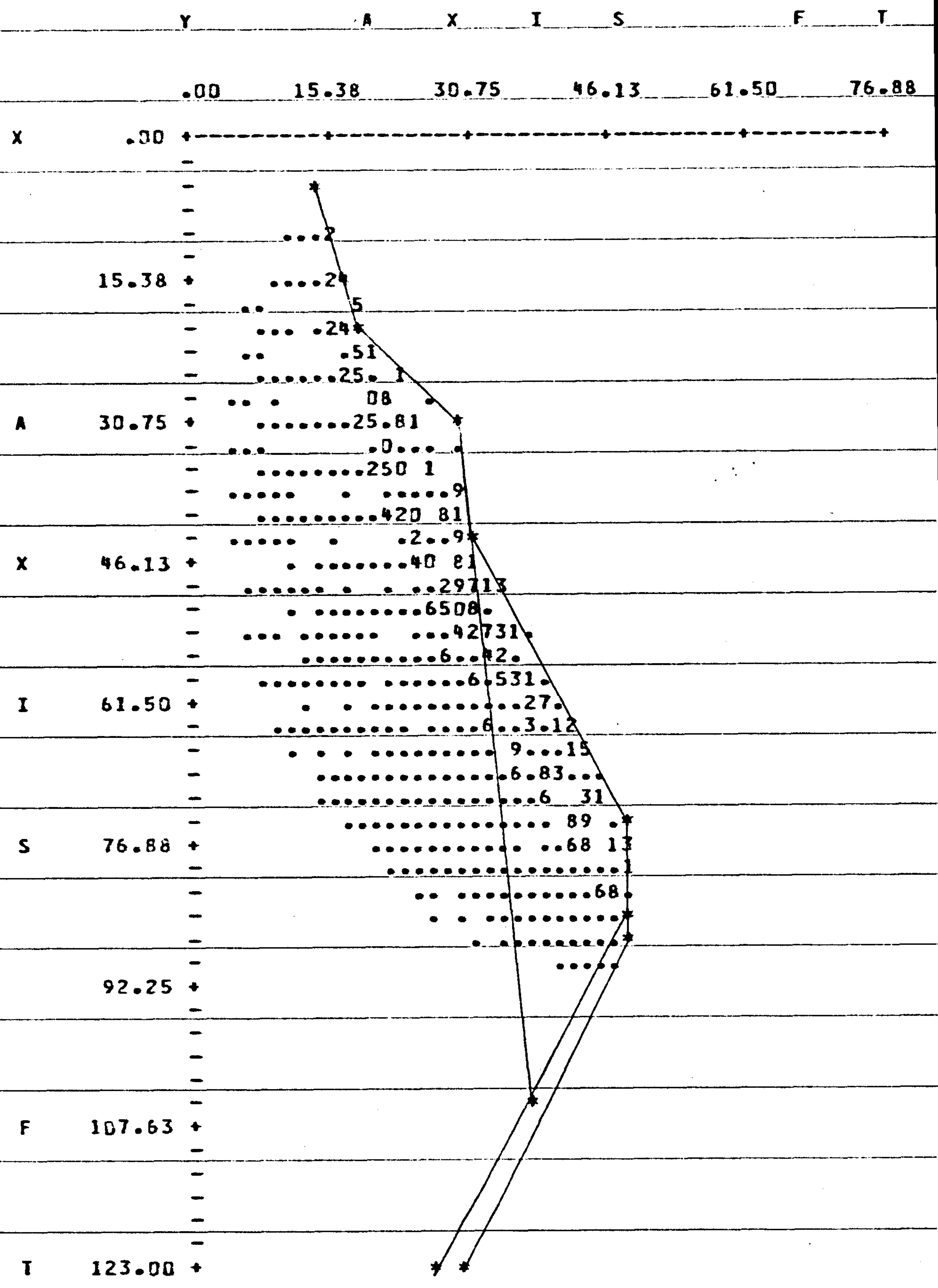
POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	38.67	29.62
2	43.59	28.73
3	48.58	28.60
4	53.54	29.25
5	58.34	30.65
6	62.87	32.78
7	67.01	35.58
8	70.67	38.98
9	73.76	42.91
10	76.06	47.00

*** 1.737 ***

FAILURE SURFACE SPECIFIED BY 12 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	22.33	20.27
2	27.31	20.74
3	32.24	21.60
4	37.08	22.85
5	41.91	24.47
6	46.39	26.47
7	50.80	28.83
8	55.01	31.53
9	58.99	34.56
10	62.71	37.89
11	66.17	41.51
12	67.31	42.91

*** 1.740 ***



Y A X I S F T
.00
15.38
30.75
46.13
61.50
76.88
X A X I S F T
.00
15.38
30.75
46.13
61.50
76.88
92.25
107.63
123.00

A HORIZONTAL EARTHQUAKE LOADING COEFFICIENT
OF .080 HAS BEEN ASSIGNED

A VERTICAL EARTHQUAKE LOADING COEFFICIENT
OF .000 HAS BEEN ASSIGNED

CAVITATION PRESSURE = .0 PSF

A CRITICAL FAILURE SURFACE SEARCHING METHOD, USING A RANDOM TECHNIQUE FOR GENERATING CIRCULAR SURFACES, HAS BEEN SPECIFIED.

100 TRIAL SURFACES HAVE BEEN GENERATED.

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AND X = 55.00 FT.

EACH SURFACE TERMINATES BETWEEN X = 60.00 FT.
AND X = 90.00 FT.

UNLESS FURTHER LIMITATIONS WERE IMPOSED, THE MINIMUM ELEVATION AT WHICH A SURFACE EXTENDS IS Y = 5.00 FT.

5.00 FT. LINE SEGMENTS DEFINE EACH TRIAL FAILURE SURFACE.

FOLLOWING ARE DISPLAYED THE TEN MOST CRITICAL OF THE TRIAL FAILURE SURFACES EXAMINED. THEY ARE ORDERED - MOST CRITICAL FIRST.

SAFETY FACTORS ARE CALCULATED BY THE MODIFIED BISHOP METHOD.

FAILURE SURFACE SPECIFIED BY 15 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	6.00	14.31
2	10.99	14.67
3	15.95	15.32
4	20.86	16.25
5	25.71	17.46
6	30.48	18.95
7	35.16	20.71
8	39.73	22.73
9	44.18	25.02
10	48.49	27.55
11	52.65	30.33
12	56.64	33.34
13	60.45	36.58
14	64.07	40.03
15	66.25	42.35

*** 1.314 ***

FAILURE SURFACE SPECIFIED BY 14 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	11.44	16.01
2	16.44	16.25
3	21.40	16.86
4	26.31	17.81
5	31.14	19.12
6	35.85	20.78
7	40.44	22.77
8	44.87	25.09
9	49.12	27.72
10	53.17	30.65
11	57.00	33.87
12	60.59	37.35
13	63.91	41.09
14	63.93	41.12

*** 1.337 ***

FAILURE SURFACE SPECIFIED BY 8 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	44.11	30.59
2	49.08	31.14
3	53.93	32.34
4	58.58	34.19
5	62.94	36.63
6	66.93	39.65
7	70.49	43.16
8	72.36	45.60

*** 1.353 ***

FAILURE SURFACE SPECIFIED BY 14 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	22.33	20.27
2	27.30	20.84
3	32.23	21.70
4	37.10	22.84
5	41.89	24.25
6	46.60	25.95
7	51.20	27.91
8	55.68	30.13
9	60.02	32.60
10	64.21	35.32
11	68.25	38.28
12	72.10	41.47
13	75.76	44.87
14	77.81	47.00

*** 1.370 ***

FAILURE SURFACE SPECIFIED BY 6 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	55.00	36.38
2	59.97	36.92
3	64.72	38.46
4	69.03	41.01
5	72.73	44.38
6	74.35	46.65

*** 1.382 ***

FAILURE SURFACE SPECIFIED BY 14 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	22.33	20.27
2	27.33	20.29
3	32.32	20.70
4	37.25	21.50
5	42.11	22.69
6	46.86	24.25
7	51.47	26.18
8	55.92	28.46
9	60.18	31.09
10	64.21	34.04
11	68.01	37.29
12	71.53	40.84
13	74.77	44.65
14	76.47	47.00

*** 1.427 ***

FAILURE SURFACE SPECIFIED BY 18 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	6.00	14.31
2	10.94	13.55
3	15.93	13.17
4	20.93	13.15
5	25.91	13.51
6	30.86	14.24
7	35.74	15.34
8	40.52	16.80
9	45.18	18.61
10	49.69	20.76
11	54.03	23.25
12	58.17	26.05
13	62.10	29.15
14	65.77	32.54
15	69.19	36.19
16	72.32	40.09
17	75.16	44.21
18	76.78	47.00

*** 1.437 ***

FAILURE SURFACE SPECIFIED BY 7 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	55.00	36.38
2	59.99	36.61
3	64.84	37.84
4	69.35	40.00
5	73.34	43.01
6	76.65	46.76
7	76.79	47.00

*** 1.442 ***

FAILURE SURFACE SPECIFIED BY 19 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	6.00	14.31
2	10.95	13.58
3	15.93	13.18
4	20.93	13.13
5	25.92	13.41
6	30.88	14.04
7	35.79	15.00
8	40.62	16.29
9	45.35	17.91
10	49.96	19.85
11	54.43	22.09
12	58.73	24.64
13	62.85	27.47
14	66.77	30.58
15	70.46	33.95
16	73.92	37.56
17	77.12	41.40
18	80.06	45.45
19	81.03	47.00

*** 1.446 ***

FAILURE SURFACE SPECIFIED BY 17 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	6.00	14.31
2	10.93	13.48
3	15.91	13.07
4	20.91	13.08
5	25.89	13.52
6	30.82	14.37
7	35.66	15.64
8	40.37	17.32
9	44.92	19.39
10	49.28	21.84
11	53.42	24.65
12	57.30	27.79
13	60.90	31.26
14	64.20	35.02
15	67.17	39.05
16	69.78	43.31
17	70.41	44.56

*** 1.458 ***

137 West 2260 South, Salt Lake City, Utah 84115 Telephone (801) 487-7754

Delta
GEOTECHNICAL CONSULTANTS INC.

December 8, 1981

Mr. William C. Wollen, Vice President
Genwal Coal Company
P. O. Box 1201
Huntington, Utah 84528

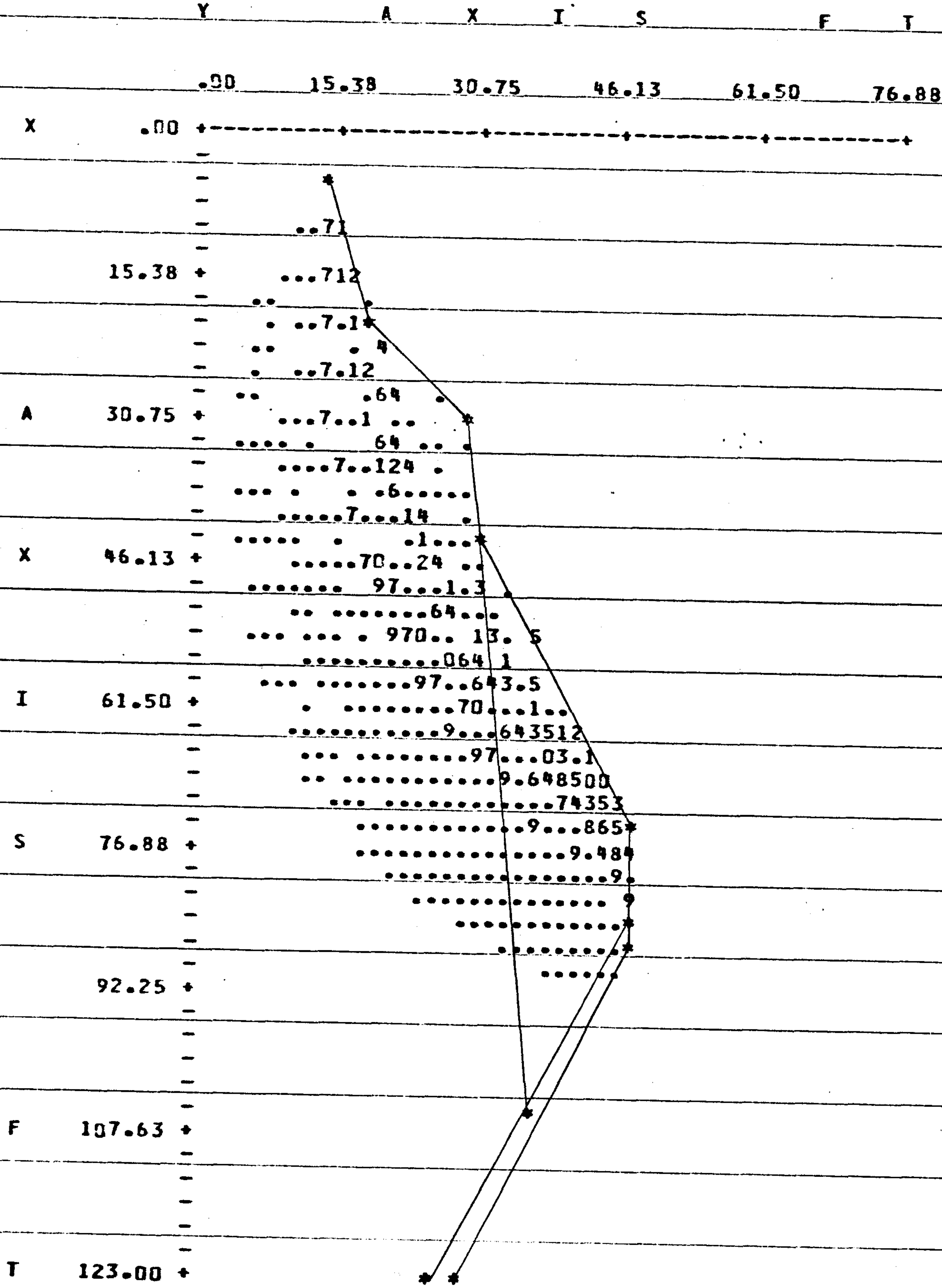
Subject: Cut Slopes and Safety Factors for Portal Pads and Access Roads to Genwal Coal Mine

Delta Job No. 1169

Dear Bill,

This letter summarizes our previous recommendations concerning cut slopes and cut slope safety factors for the proposed access roads and portal pads. Please refer to our report dated November 27, 1981 for details.

Material to be Cut	Recommended Slope	Safety Factor
Competent Bedrock	¼:1 to vertical	The dip of the potential sliding planes slope away from the proposed alignments; therefore rock cuts are considered stable and a numerical safety factor against sliding is inappropriate.
Fractured Bedrock	½:1	Same as above.
Shallow Surficial Deposits (less than 4 feet deep) Overlying Bedrock	1:1	a. 1.10 to less than 1 for the shallow surficial deposits. b. Same as above for bedrock.



DATA DOCUMENTS/INC 55-338-0

R&M
R&M CONSULTANTS, INC. BUSCH PARK • 5280 SOUTH 320 WEST, SUITE E-160 • MURRAY, UTAH 84107 • PHONE (801) 263-3419
ENGINEERS
GEOLOGISTS

December 15, 1981 R&M No. 161031

Genwal Coal Company
P.O. Box 1201
Huntington, UT 84528
ATTN: Mr. William C. Wollen

Gentlemen:

SUBJECT: Sedimentation Pond Embankment Slope Stability Study
Crandall Canyon Mine

Included herewith are six copies of the embankment slope stability study report for the subject project. This report was authorized by your Mr. Wollen on December 7, 1981.

We appreciate the opportunity of providing this geotechnical service to you on this project and will be glad to answer any questions you may have concerning this report.

Sincerely,

Larry Migliaccio, P.E.
Director

REGISTERED PROFESSIONAL ENGINEER
LARRY MIGLIACCIO
3595
STATE OF UTAH

cw

cc: Mr. Dave Ariotti/Boyle Engineering Corp. (1 copy)

EMBANKMENT SLOPE STABILITY STUDY
SEDIMENTATION POND
CRANDALL CANYON MINE
HUNTINGTON, UTAH

Prepared for

GENWAL COAL COMPANY
Huntington, Utah

by

R&M Consultants, Inc.
Salt Lake City, Utah

Proj. No. 161031

December, 1981

I. INTRODUCTION

Presented in this report are the results of our slope stability analysis of a sedimentation pond proposed by Genwal Coal Company for its Crandall Canyon Mine facilities. The Crandall Canyon Mine, located within Crandall Canyon, is approximately 16 miles northwest of Huntington, Carbon County, Utah and is approximately 1½ miles west of the junction of Crandall Creek and Huntington Creek (Fig. 1).

The proposed sedimentation pond is to be built just below the proposed haul road and above the Crandall Creek between Stations 74+50 and 76+50. The pond embankment will be constructed immediately above the creek and will adjoin the proposed haul road to form the impoundment.

This report has been prepared in accordance with a contractual agreement between Genwal Coal Co., Huntington, Utah and R&M Consultants, Inc. (R&M), Salt Lake City, Utah.

II. SCOPE

The proposed sedimentation pond is to serve as a temporary retention area for surface runoff collected from the upslope portion of the proposed coal stockpile areas and the haul road. The suspended solid particles in the retained water will be allowed to deposit onto the sedimentation pond floor before the water is discharged into the Crandall Creek.

The proposed sedimentation pond has a maximum capacity of approximately 52,000 cu ft. The crest of the pond embankment, 14 ft above bottom of the pond, is to be constructed to Elev. 7790 ft, and is approximately 14 ft below the roadbed of the haul road.

The upstream slope of the embankment is 2H:1V, while the downstream slope and the haul road embankment are $1\frac{1}{2}$H:1V. The pond is to be lined with 1-ft thick compacted impervious clay material to prevent the impounded water from seeping into the embankment. Details of the proposed pond construction are shown in Fig. 2.

The objectives of this study are to determine the stability of the embankments which form the impoundment for the proposed sedimentation pond and to present recommendations for improving their stability as deemed necessary.

The scope of work does not include field investigation nor laboratory testing. For analysis purposes, the surface conditions of the proposed pond site and the engineering characteristics of the embankment material were obtained based on two reports on related subjects furnished to R&M by Genwal Coal Company: 1) "Slope Stability Investigation, Portal Pads and Portal Access Roads, Genwal Coal Mine, Huntington, Utah" dated November 27, 1981 by Delta Geotechnical Consultants, Inc., and 2) "Soils Study, Genwal Coal Co. Crandall Canyon Mine Permit Area" by Valley Engineering Inc. These reports will be referenced as Report No. 1 and Report No. 2, respectively, herein after.

III. EXISTING SITE CONDITIONS

The description of the surface conditions pertinent to this study presented below is based on the following:

1) Topographic cross sections of the Crandall Creek drainage at the proposed pond site and an adjoining area made by R&M,

2) Topographic cross sections and subsurface investigations from Report No. 1,

3) Surficial soils classifications of the general area from Report No. 2, and

4) Design drawings of the pond and haul road by Boyle Engineering Corp., Price, Utah.

Crandall Creek is located within a narrow, V-shaped drainage with steep to very steep, bedrock controlled slopes.

The crest of the proposed pond embankment is located on a moderately north-sloping stream terrace of Crandall Creek, approximately 35 ft above and 60 ft south of Crandall Creek. Extensive, steep to very steep slopes border the terrace on the south. A 10-ft high, steep, creek embankment borders the terrace on the north.

The surficial deposits overlying the steep to very steep slopes above the proposed sedimentation pond are colluvial, consisting of heterogeneous mixtures of gravel to cobble to boulder size rock in a silty sand matrix, derived from nearby upslope weathering of the underlying sandstone bedrock. Based on Report No. 1, bedrock is estimated to be at approximate depth 4 ft in these steep to very steep slope areas.

Surficial deposits at the pond embankment site are alluvial, consisting of stream terrace deposits, and consist of sand to silty sand with lessor amounts of gravel, cobble and boulders. Bedrock underlying the pond embankment and pond site is estimated to be below the maximum depth relevant to our study.

A proposed mine haul road is located approximately 100 ft upslope from the pond embankment site and is approximately 14 ft above the embankment crest.

IV. SUBSURFACE CONDITIONS

Subsurface conditions are based on the logs of two test pits (Test Pits Nos. 1 and 2), from Report No. 1, located 100 ft left of approximate stations 76+00 and 76+50 of the proposed haul road. Both test pits are located at the proposed sedimentation pond embankment and encountered medium dense, wet to moist sand and silt to sandy silt to depths 3 and 4 ft. This was underlain by medium dense to dense, slightly moist, gravelly to silty, gravelly sand containing varying amounts of cobbles and boulders to the excavated depths of 7 and 10 ft. One of the test pits encountered a 1½-ft thick surface layer of coal waste.

Subsurface conditions in the steep slope area above the proposed pond are based on rock outcroppings mapped immediately above the site and on subsurface investigations in the general vicinity in Report No. 1. The surficial deposits, consisting predominantly of sand, gravel, cobbles and boulders, are estimated to be approximately 4-ft deep.

Ground water was not encountered in previous investigations and is not anticipated to be within the depths relevant to this study. Surface seeps occurring throughout the slope areas, indicated in Report No. 1, are considered to be localized, superficial features only, due to their occurrence up-dip from the generally uniform bedding attitude of the area.

V. ANALYSIS

A computer program entitled "STABL2", was utilized for the analysis of the sedimentation pond slope stability. STABL 2 was developed in 1975 by R.A. Siegel and subsequently revised in 1978 by E. Boutrup of Purdue University, for the Indiana State Highway Department. The program analyzes slope stability by the Modified Bishop Method, using the limiting equilibrium procedure to determine the factor of safety.

Critical cross sections of the pond embankment were obtained from design drawings furnished by Boyle Engineering Corp. (Figure 2). The natural ground surface profile was obtained from topographic map coverage, furnished by Genwal Coal Company.

A typical cross section cut through Station 75+40 of the haul road was analyzed for the slope stability (Fig. 3). Included in the analyses are three slopes: 1) the downstream slope of the pond embankment, 2) the upstream slope of the pond embankment, and 3) the haul road embankment, which forms a portion of the impoundment of the sedimentation pond. An equivalent uniform of load 100 psf covering two 11-ft lanes was used as the traffic load for the proposed haul road.

Two cases were investigated for each slope: 1) an empty pool condition, and 2) a full pool condition. The full pool condition was taken at 2 ft below the crest of the pond embankment. Analysis was made for each case with and without seismic loading. A horizontal acceleration of 8% of gravity was utilized for the seismic loading, based on recommendations from "Seismic Zones for Construction in Utah," September 1979, by the Seismic Safety Advisory Council of Utah.

The cross section of the pond embankment consists of three types of soils. Type 1 soil is the embankment material for building the pond embankment, type 2 soil is the clay liner for the pond, and type 3 soil is the natural soil upon which the pond embankment is constructed.

The pond embankment is to be built with native material available in the general vicinity of the Crandall Canyon Mine area. Based on 19 hydrometer particle size analyses for the general area, included in Report No. 1, the native soils, exclusive of gravel, cobble, stone or boulder sizes, is approximately 50% sand by weight with lessor amounts of silt and clay. General descriptions of soils in the site area, included in Report No. 1, indicate gravel and cobble size material ranging from 10-30% by weight, and stones and boulder sized material, generally confined to the surface layer, of 0-30% by weight.

The clay liner for the pond is to be built with local clay material, compacted to form an impervious membrane to cut off water seepage into the pond embankment.

The natural soils underlying the proposed embankment, as previously described in the subsurface section of this report, are predominantly sand with varying amounts of cobble, gravel, and silty to clay size material.

The bedrock, according to Report No. 1, is less than 4 ft below the existing steep slope above the proposed pond site. For analysis purposes, the bedrock was assumed to be at 4-ft depth and parallel to the existing slope above the proposed pond site. This bedrock would extend to a substantial depth below the proposed pond embankment and would have little consequence to the stability of the pond embankment.

For analysis purposes, the following soil parameters were used in the slope stability investigation:

Soil Layer	Description	Unit Wt., pcf		ϕ, degrees	c, psf
		γ_m	γ_{sat}		
Type 1	Embankment fill (granular)	120	132	38	0
Type 2	Pond Liner (cohesive)	120	132	20	1000
Type 3	Natural Soil (granular)	110	125	35	0

Because of the shallow depth to bedrock for the haul road embankment, block sliding failure is considered as the most likely failure mode for the haul road embankment which forms portion of the sedimentation pond impoundment. Due to the great depth of the alluvium deposit underneath the proposed pond embankment, circular slip failure is considered as the most likely failure mode for both the upstream and downstream slopes of the pond embankment.

One hundred failure surfaces for the circular slip failure mode and 50 failure surfaces for the block sliding failure mode were analyzed for each slope under consideration. The STABL2 computer program computes the factors of safety for these failure surfaces, prints the ten most critical factors of safety and defines the respective ten most critical failure surfaces for each slope analyzed.

According to the results of the STABL2 computer program, the design slopes of the haul road embankment (1½H:1V) and the upstream slope (2H:1V) of the pond embankment have more than adequate factors of safety against slope failure (see Table 1). The factors of safety, for the design slope (1½H:1V) of the downstream slope of the pond embankment is 1.15 without seismic load and 0.972 with seismic load, regardless of the level of water inside the pond. These are considered as inadequate.

To increase the stability of the downstream slope of the pond embankment, the slope was flattened to 1-3/4H:1V and subsequently to 2H:1V, and the stability was re-analyzed. The factors of safety are 1.198 without seismic load and 1.059 with seismic load for the 1-3/4H:1V slope; and are 1.357 without seismic load and 1.081 with seismic load for the 2H:1V slope. The 2H:1V slope is considered adequate against slope failure for the downstream slope of the pond embankment.

The most critical potential failure surfaces for each slope investigated are superimposed onto its cross section, as shown in Figs. 3 to 7. The minimum factors of safety of the most critical potential failure surfaces of each case are summarized in Table 1. The computer output of the STABL2 program for the analysis of the downstream slope of the pond embankment (2H:1V) is included in Appendix A. The printout material for the remaining analyses are not included in this report, due to their volume, but are available on file upon request.

VI. CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the slope stability analyses, utilizing the STABL2 computer program, two of the three design slopes of the sedimentation pond are considered stable. The design slope (2H:1V) of the upstream slope of the pond embankment and the design slope (1½H:1V) which forms the upstream embankment, are both determined to be more than adequate against slope failure for all cases analyzed. The design slope (1½H:1V) of the downstream slope of the pond embankment does not have adequate factors of safety and should be flattened to at least 2H:1V.

The reduced volume of the sedimentation pond, due to the flattening of the downstream slope of the pond embankment, may be compensated by steepening the upstream slope of the pond embankment to 1½H:1V and lowering the bottom of the pond till it forms a V-shape, or by cutting back the haul road embankment into the bedrock which is at very shallow depth and is capable of standing at near vertical slope.

The pond embankment should be constructed with the sandy material locally available. This material should be well graded with no particles greater than 3 in. and should be free of organic substances, debris, frozen soil and other deleterious materials. The pond embankment should be constructed in 12-in. loose horizontal lifts compacted to at least 96% of the maximum density determined by ASTM D698.

To avoid seepage loss through the pond walls and bottom, the thickness of the clay pond liner is recommended to be increased to at least 18 in. The clay liner should be constructed with local or borrow clay material free of organic substances, debris, frozen soil and other deleterious materials. This material should be 100% passing No. 200 sieve and should contain no more than 5% of silt. The clay liner should be constructed in 8-in. loose horizontal lifts and compacted to at least 96% of the maximum density determined by ASTM D698.

VII. CLOSURE

The preparation of this report did not include field investigations and laboratory testing performed by R&M. The subsurface conditions of the proposed pond site and the engineering characteristics of the pond embankment and liner materials are derived from reports prepared by others on related subjects previously referred to in this report, furnished by Genwal Coal Company. The results of the slope stability for the sedimentation pond are therefore dependent to a great degree on the accuracy of the contents of these reports.

R&M should be notified if the surface conditions, subsurface conditions or construction material properties are appreciably different from those discussed in this report, either as the results of additional surface or subsurface investigations or during construction, as additional analysis may be required.

Prepared by:

LaMonte Sorenson
Senior Engineering Geologist

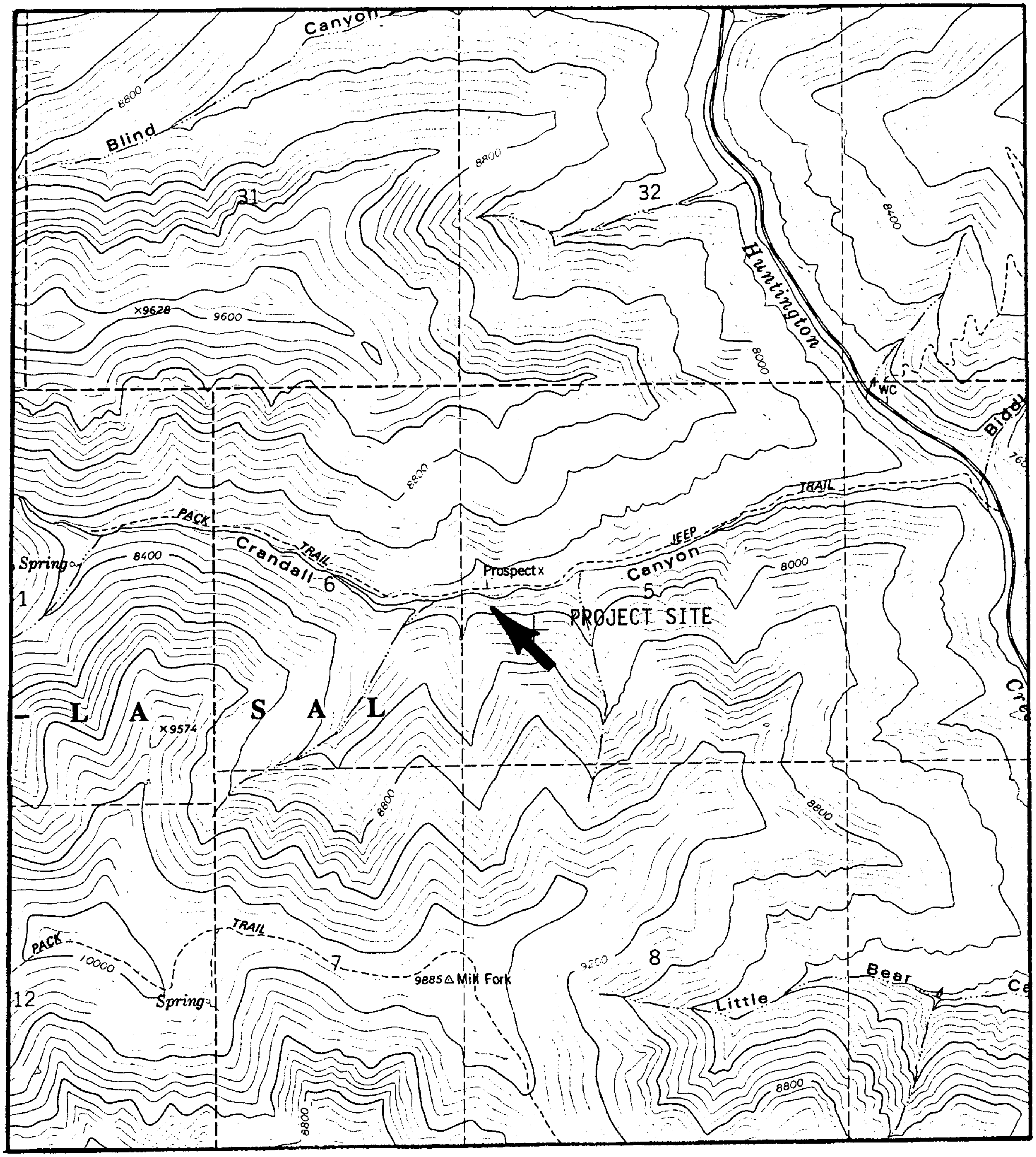
J.S. Liu, P.E., Ph.D.
Senior Geotechnical Engineer

Reviewed by:

Larry Migliaccio, P.E.
Director

TABLE 1. MINIMUM FACTORS OF SAFETY AGAINST SLOPE FAILURE

		Empty Pool		Full Pool	
		w/o seismic	w/seismic	w/o seismic	w/seismic
Downstream slope of pond embankment:	1.5:1 (design slope)	1.150	0.972	1.150	0.972
	1.75:1	1.198	1.059	1.198	1.059
	2.0:1	1.357	1.081		
Upstream slope of pond embankment:	2:1 (design slope)	2.365	1.992	5.091	3.866
	1.5:1	1.887	1.441		
Upstream slope of sedimentation pond:	1.5:1 (design slope)	1.697	1.467	2.544	2.127



VICINITY MAP

DWN.	LGS
CKD.	JSL
DATE.	12/13/81
SCALE.	1"=2000'

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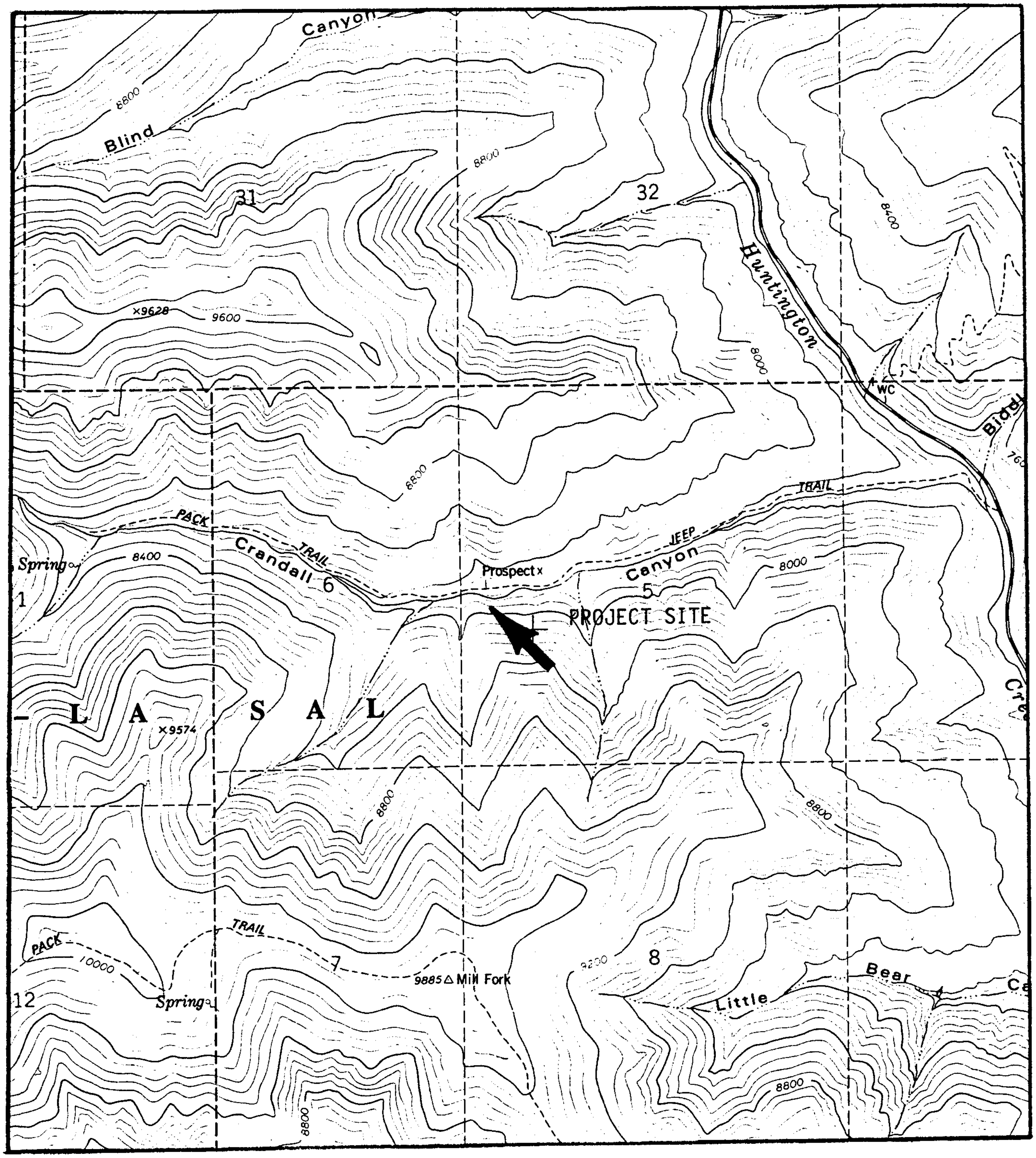
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

GENWAL COAL MINE CO.
HUNTINGTON, UTAH

F.B.	
GRID.	
PROJ.NO.	161031
Figure 1	



VICINITY MAP

DWN.	LGS
CKD.	JSL
DATE.	12/13/81
SCALE.	1"=2000'

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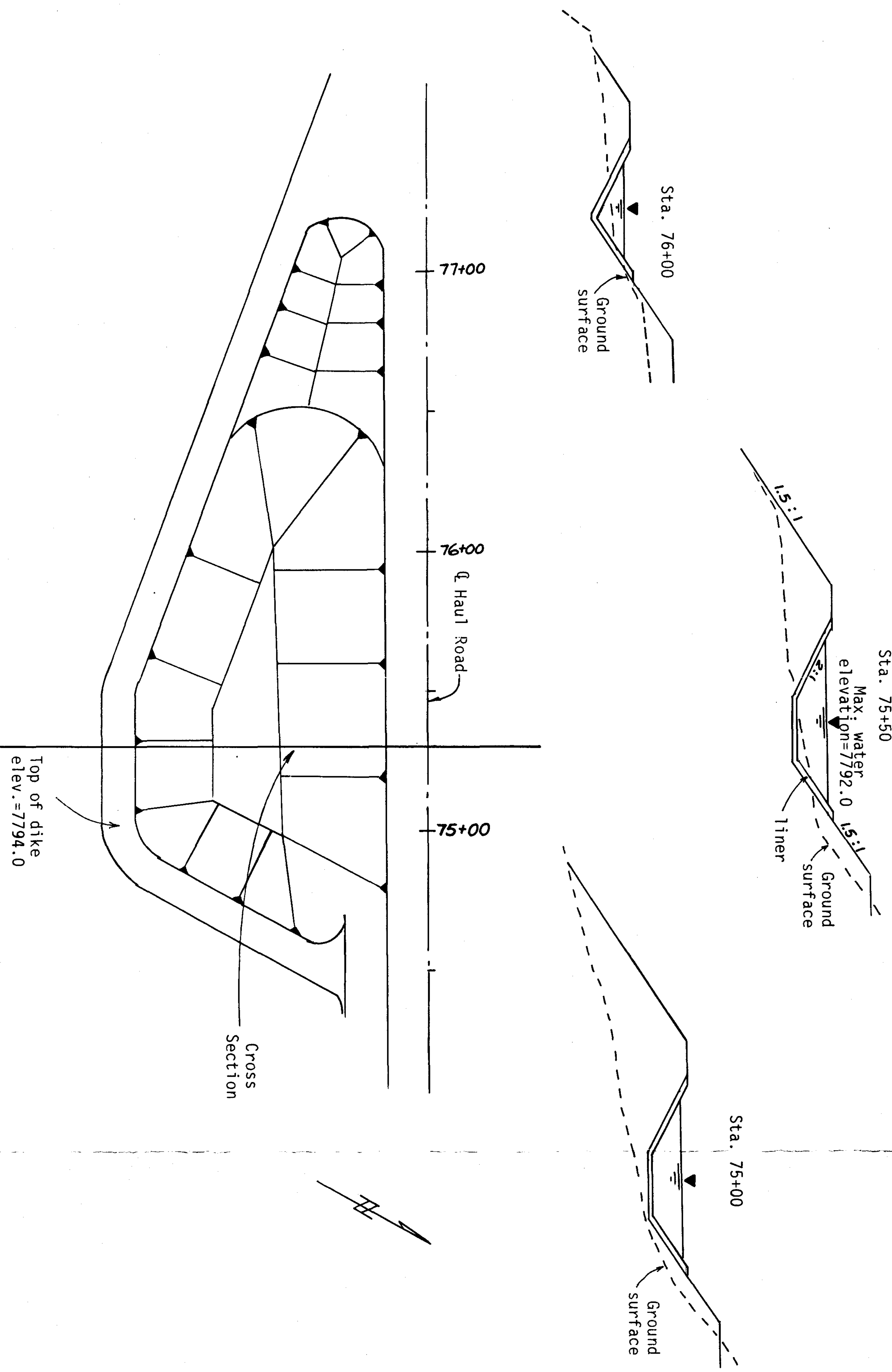
F.B.	
GRID.	
PROJ.NO.	161031
Figure 1	



SEDIMENTATION POND
CRANDALL CANYON MINE

DWN.	LGS
CKD.	
DATE.	12/11/81
SCALE	1"=40'

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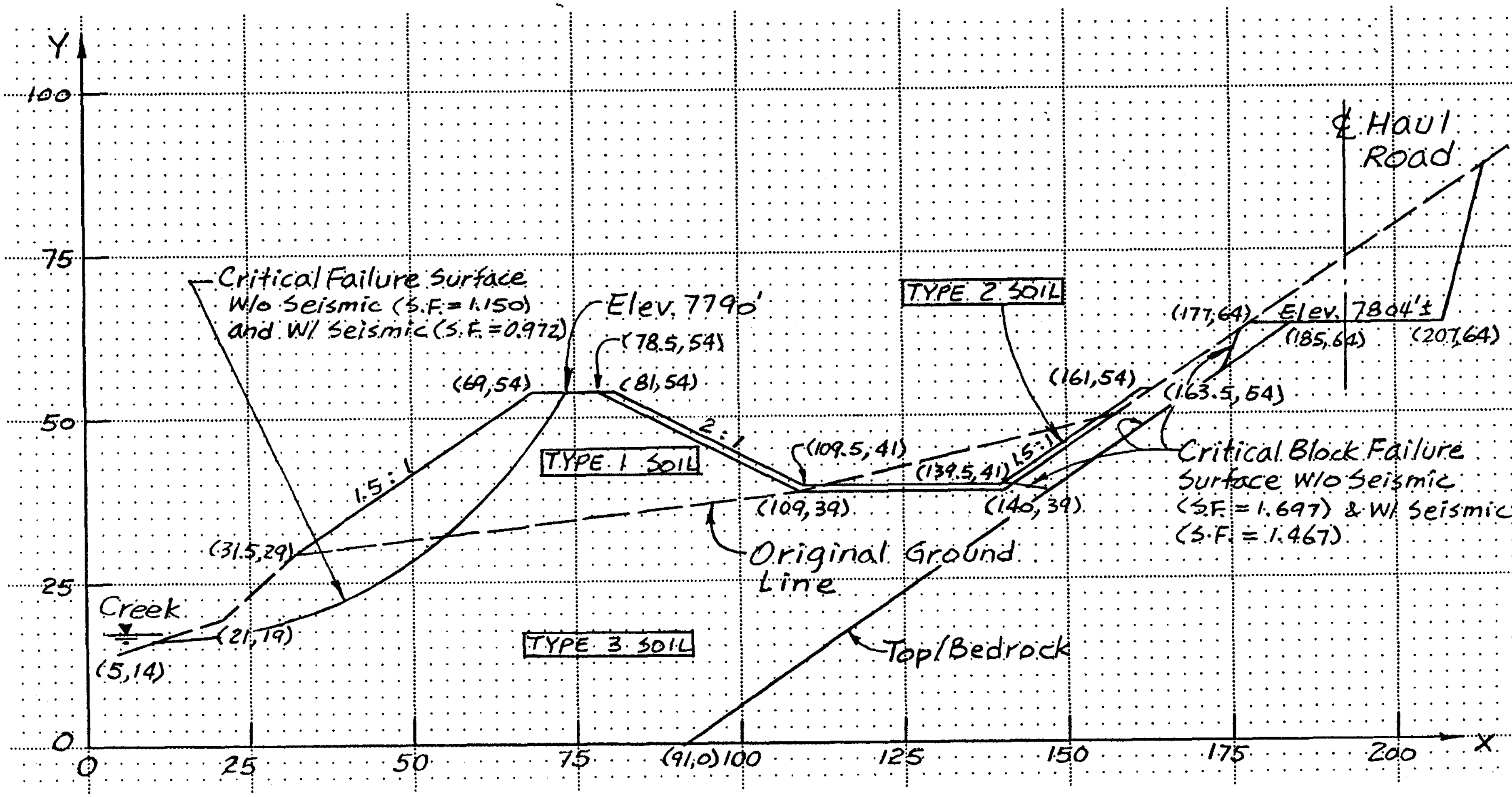
Figure 2	

TYPE 1 SOIL	TYPE 2 SOIL	TYPE 3 SOIL
γ_m = 120 pcf	γ_m = 120 pcf	γ_m = 110 pcf
γ_{sat} = 132 pcf	γ_{sat} = 132 pcf	γ_{sat} = 125 pcf
c = 0	c = 1000 psf	c = 0
ϕ = 38°	ϕ = 20°	ϕ = 35°



HAUL ROAD EMBANKMENT AND $1\frac{1}{2}$H:1V DOWNSTREAM SLOPE WITH EMPTY POND

DWN.	JSL
CKD.	LGS
DATE	12/11/81
SCALE	1"=25'

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GENWAL CRANDALL CANYON MINE
SEDIMENTATION POND

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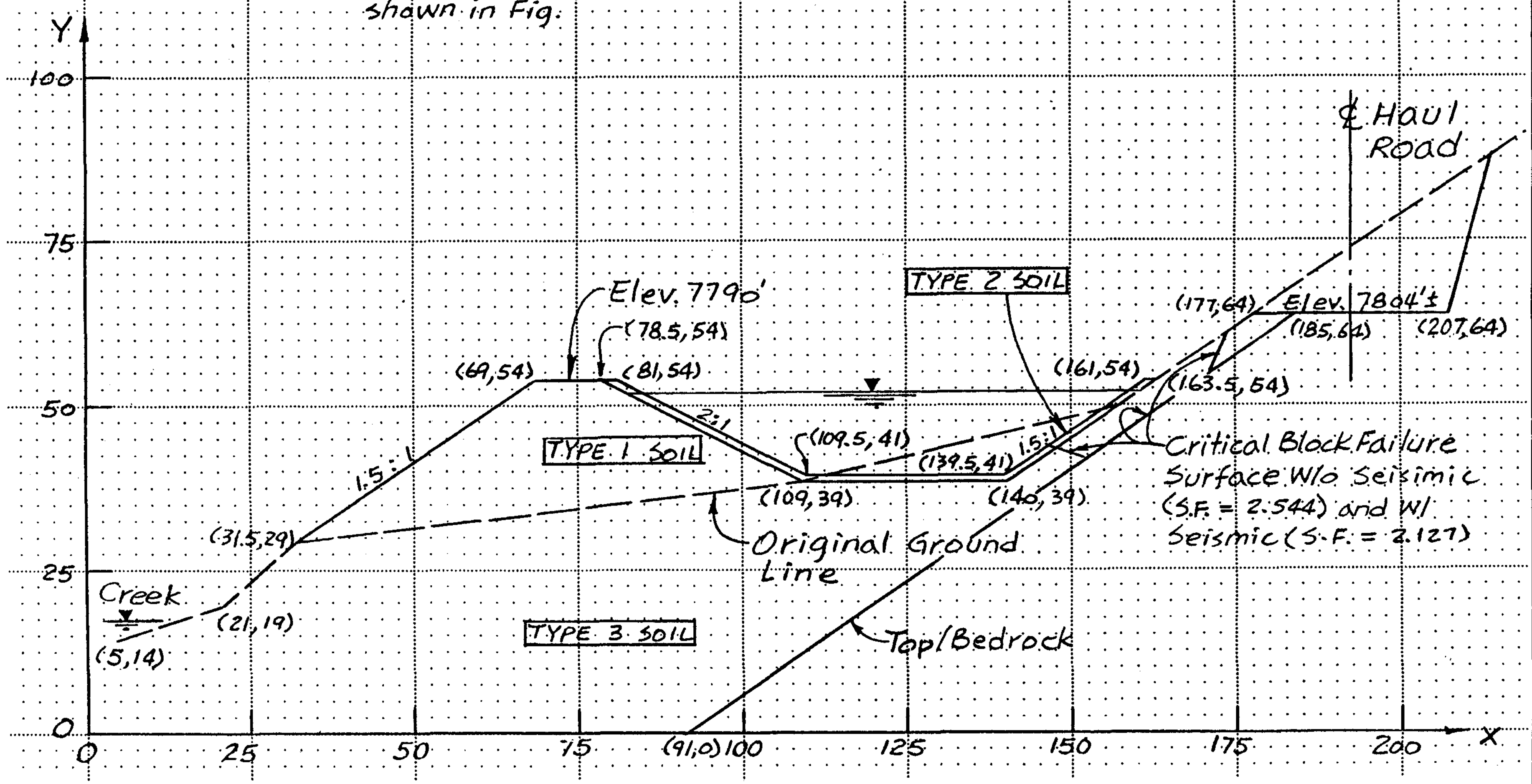
PROJ.NO.	161031
DWG.NO.	Fig. 3

Note: For downstream slope, the critical failure surfaces and their corresponding safety factors are same as those for empty pond case shown in Fig.



HAUL ROAD EMBANKMENT AND 1½H:1V DOWNSTREAM SLOPE WITH FULL POND

DWN.	JSL
CKD.	LGS
DATE.	12/11/81
SCALE	1"=25'

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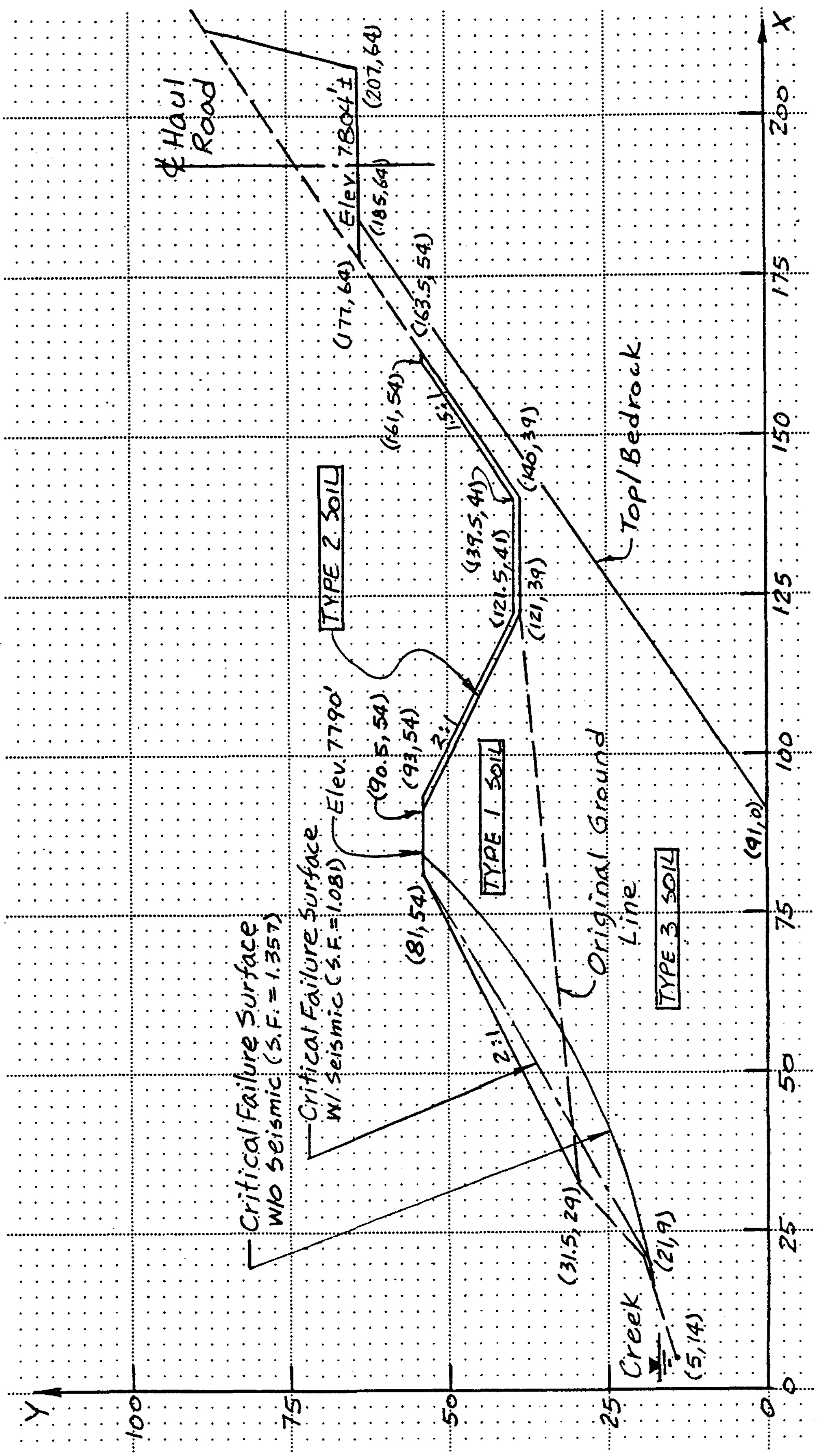
GENWAL CRANDALL CANYON MINE
SEDIMENTATION POND

F.B.	
GRID.	
PROJ.NO.	161031
DWG.NO.	Fig. 4



2H:1V DOWNSTREAM SLOPE WITH BOTH EMPTY AND FULL POND

DWN.	JSL
CKD.	LGS
DATE.	12/11/81
SCALE.	1"=25'

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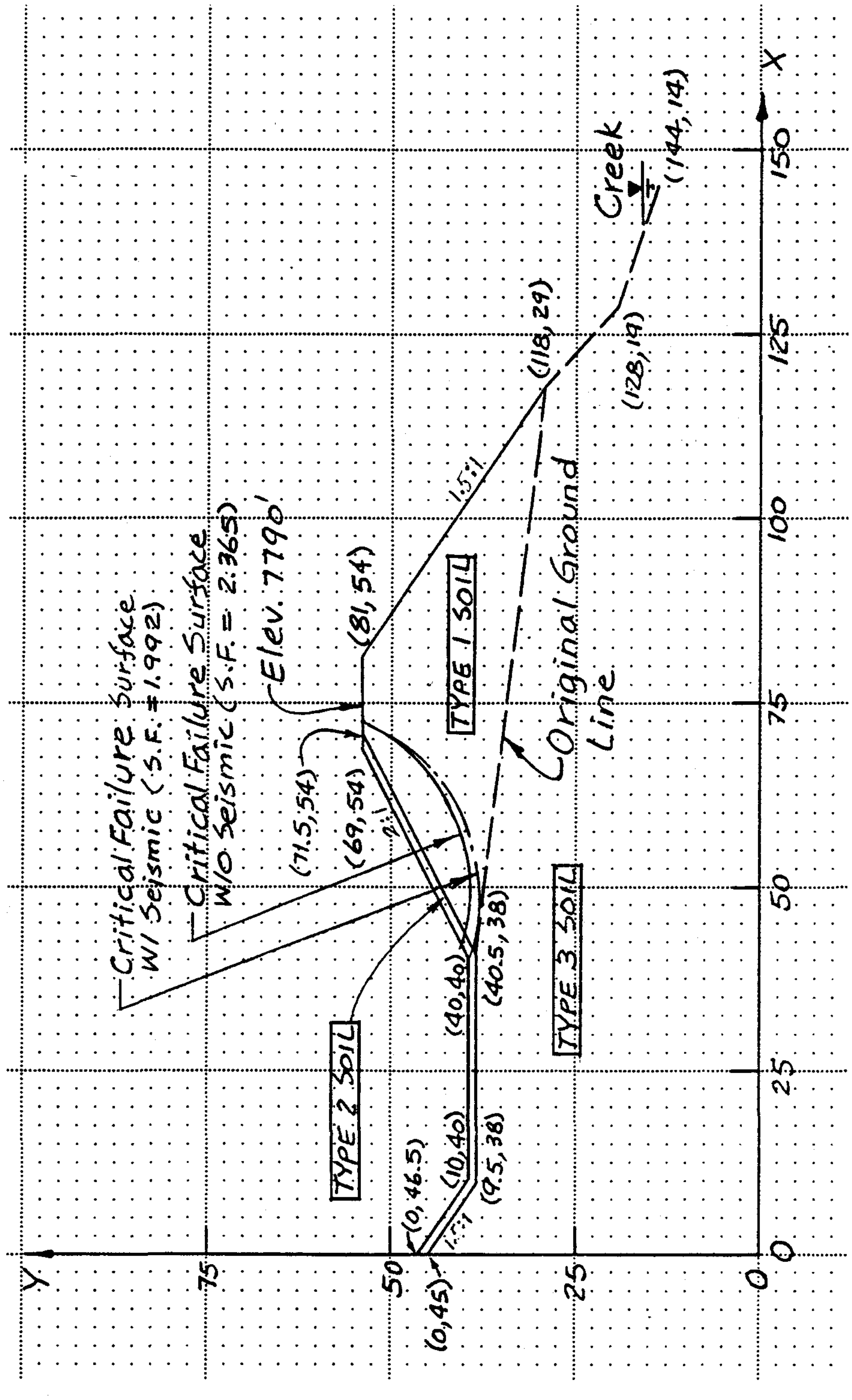
GENWAL CRANDALL CANYON MINE
SEDIMENTATION POND

F.B.	
GRID.	
PROJ.NO.	161031
	Fig. 5



UPSTREAM SLOPE WITH EMPTY POND

DWN.	JSL
CKD.	LGS
DATE.	12/11/81
SCALE	1"=25'

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GENWAL CRANDALL CANYON MINE
SEDIMENTATION POND

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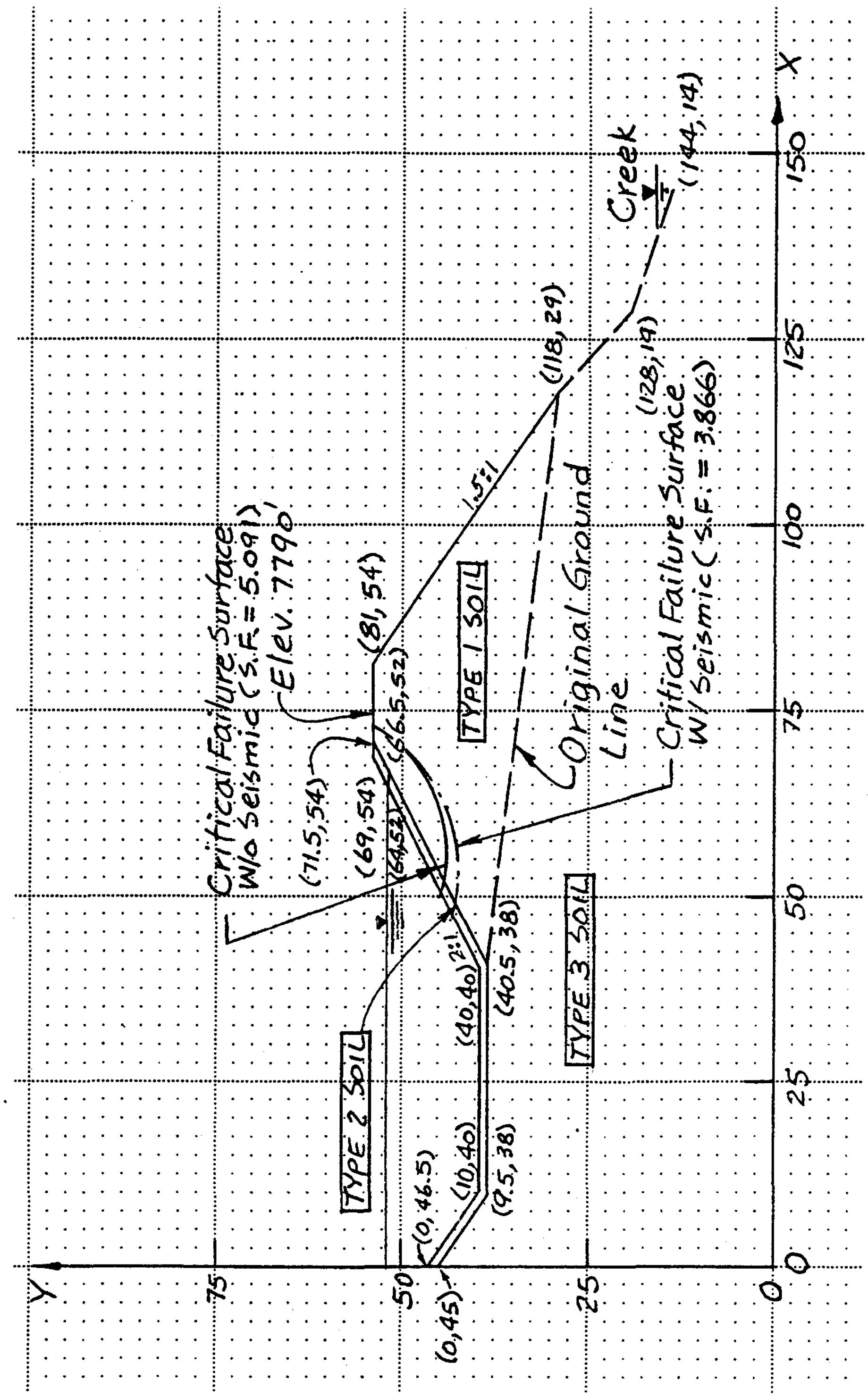
PROJ.NO.	161031
DWG.NO.	Fig. 6



UPSTREAM SLOPE WITH FULL POND

DWN.	JSL
CKD.	LGS
DATE.	12/11/81
SCALE	1"=25'

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GENWAL CRANDALL CANYON MINE
SEDIMENTATION POND

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DWG.NO.	Fig. 7

APPENDIX A - STABL2 COMPUTER PROGRAM OUTPUT

--SLOPE STABILITY ANALYSIS--
SIMPLIFIED JANBU METHOD OF SLICES
IRREGULAR FAILURE SURFACES

PROBLEM DESCRIPTION 161031 GENWAL CRANDALL CANYON MINE SED.
POND -- DOWNSTREAM SLOPE, EMPTY
(2H:1V)

BOUNDARY COORDINATES

11 TOP BOUNDARIES
15 TOTAL BOUNDARIES

BOUNDARY NO.	X-LEFT (FT)	Y-LEFT (FT)	X-RIGHT (FT)	Y-RIGHT (FT)	SOIL TYPE BELOW BND
1	5.00	14.00	21.00	19.00	3
2	21.00	19.00	31.50	29.00	3
3	31.50	29.00	81.00	54.00	1
4	81.00	54.00	90.50	54.00	1
5	90.50	54.00	93.00	54.00	2
6	93.00	54.00	121.50	41.00	2
7	121.50	41.00	139.50	41.00	2
8	139.50	41.00	161.00	54.00	2
9	161.00	54.00	163.50	54.00	2
10	163.50	54.00	177.00	64.00	3
11	177.00	64.00	185.00	64.00	3
12	90.50	54.00	121.00	39.00	1
13	31.50	29.00	121.00	39.00	3
14	121.00	39.00	140.00	39.00	3
15	140.00	39.00	163.50	54.00	3

ISOTROPIC SOIL PARAMETERS

3 TYPE(S) OF SOIL

SOIL TYPE NO.	TOTAL UNIT WT. (PCF)	SATURATED UNIT WT. (PCF)	COHESION INTERCEPT (PSF)	FRICTION ANGLE (DEG)	PORE PRESSURE PARAMETER	PRESSURE CONSTANT (PSF)	PIEZOMETRIC SURFACE NO.
1	120.0	132.0	.0	38.0	.00	.0	0
2	120.0	132.0	1000.0	20.0	.00	.0	0
3	110.0	125.0	.0	35.0	.00	.0	0

SEARCHING ROUTINE WILL BE LIMITED TO AN AREA DEFINED BY 2 BOUNDARIES
OF WHICH THE FIRST 2 BOUNDARIES WILL DEFLECT SURFACES UPWARD

BOUNDARY NO.	X-LEFT (FT)	Y-LEFT (FT)	X-RIGHT (FT)	Y-RIGHT (FT)
1	91.00	.00	185.00	64.00
2	185.00	64.00	414.00	64.00

A CRITICAL FAILURE SURFACE SEARCHING METHOD, USING A RANDOM TECHNIQUE FOR GENERATING CIRCULAR SURFACES, HAS BEEN SPECIFIED.

100 TRIAL SURFACES HAVE BEEN GENERATED.

10 SURFACES INITIATE FROM EACH OF 10 POINTS EQUALLY SPACED ALONG THE GROUND SURFACE BETWEEN X = 10.00 FT.
AND X = 35.00 FT.

EACH SURFACE TERMINATES BETWEEN X = 30.00 FT.
AND X = 120.00 FT.

UNLESS FURTHER LIMITATIONS WERE IMPOSED, THE MINIMUM ELEVATION AT WHICH A SURFACE EXTENDS IS Y = 5.00 FT.

5.00 FT. LINE SEGMENTS DEFINE EACH TRIAL FAILURE SURFACE.

FOLLOWING ARE DISPLAYED THE TEN MOST CRITICAL OF THE TRIAL FAILURE SURFACES EXAMINED. THEY ARE ORDERED - MOST CRITICAL FIRST.

FAILURE SURFACE SPECIFIED BY 16 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	18.33	18.17
2	23.26	19.03
3	28.13	20.15
4	32.95	21.50
5	37.69	23.09
6	42.34	24.91
7	46.90	26.96
8	51.35	29.24
9	55.69	31.74
10	59.89	34.44
11	63.95	37.36
12	67.87	40.47
13	71.62	43.77
14	75.21	47.26
15	78.61	50.92
16	81.21	54.00

*** 1.357 ***

FAILURE SURFACE SPECIFIED BY 16 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	21.11	19.11
2	26.09	19.54
3	31.04	20.29
4	35.92	21.35
5	40.73	22.71
6	45.45	24.38
7	50.05	26.34
8	54.51	28.59
9	58.83	31.11
10	62.97	33.91
11	66.94	36.96
12	70.70	40.25
13	74.24	43.78
14	77.56	47.52
15	80.63	51.46
16	82.36	54.00

*** 1.402 ***

FAILURE SURFACE SPECIFIED BY 16 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	21.11	19.11
2	25.64	21.22
3	30.16	23.37
4	34.65	25.56
5	39.13	27.79
6	43.59	30.05
7	43.03	32.35
8	52.45	34.69
9	56.85	37.06
10	61.23	39.47
11	65.59	41.92
12	69.93	44.40
13	74.25	46.91
14	78.55	49.46
15	82.83	52.05
16	86.00	54.00

*** 1.407 ***

FAILURE SURFACE SPECIFIED BY 18 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	15.56	17.30
2	20.55	17.57
3	25.52	18.10
4	30.46	18.90
5	35.34	19.96
6	40.17	21.27
7	44.91	22.84
8	49.57	24.66
9	54.13	26.72
10	58.57	29.02
11	62.88	31.56
12	67.05	34.31
13	71.07	37.29
14	74.92	40.47
15	78.60	43.86
16	82.10	47.43
17	85.46	51.19
18	87.62	54.00

*** 1.437 ***

FAILURE SURFACE SPECIFIED BY 15 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	23.89	21.75
2	28.85	22.37
3	33.77	23.29
4	38.62	24.49
5	43.39	25.98
6	48.07	27.75
7	52.63	29.79
8	57.07	32.10
9	61.36	34.67
10	65.49	37.48
11	69.45	40.54
12	73.22	43.82
13	76.79	47.33
14	80.14	51.03
15	82.52	54.00

*** 1.441 ***

FAILURE SURFACE SPECIFIED BY 19 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	15.56	17.30
2	20.52	16.71
3	25.52	16.48
4	30.51	16.63
5	35.49	17.15
6	40.41	18.04
7	45.25	19.29
8	49.98	20.90
9	54.59	22.85
10	59.03	25.14
11	63.29	27.75
12	67.35	30.68
13	71.18	33.89
14	74.76	37.38
15	78.07	41.13
16	81.10	45.11
17	83.82	49.31
18	86.22	53.69
19	86.36	54.00

*** 1.476 ***

FAILURE SURFACE SPECIFIED BY 14 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	26.67	24.40
2	31.55	25.43
3	36.38	26.78
4	41.14	28.29
5	45.84	30.06
6	50.46	31.92
7	54.99	34.03
8	59.42	36.35
9	63.75	38.85
10	67.96	41.54
11	72.06	44.41
12	76.02	47.46
13	79.85	50.68
14	83.46	54.00

*** 1.496 ***

FAILURE SURFACE SPECIFIED BY 18 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	21.11	19.11
2	26.11	18.92
3	31.11	19.07
4	36.06	19.56
5	41.02	20.37
6	45.88	21.52
7	50.66	22.99
8	55.33	24.77
9	59.67	26.87
10	64.26	29.26
11	68.43	31.94
12	72.52	34.90
13	76.34	38.12
14	79.94	41.59
15	83.30	45.29
16	86.40	49.21
17	89.24	53.33
18	89.64	54.00

*** 1.53[illegible] ***

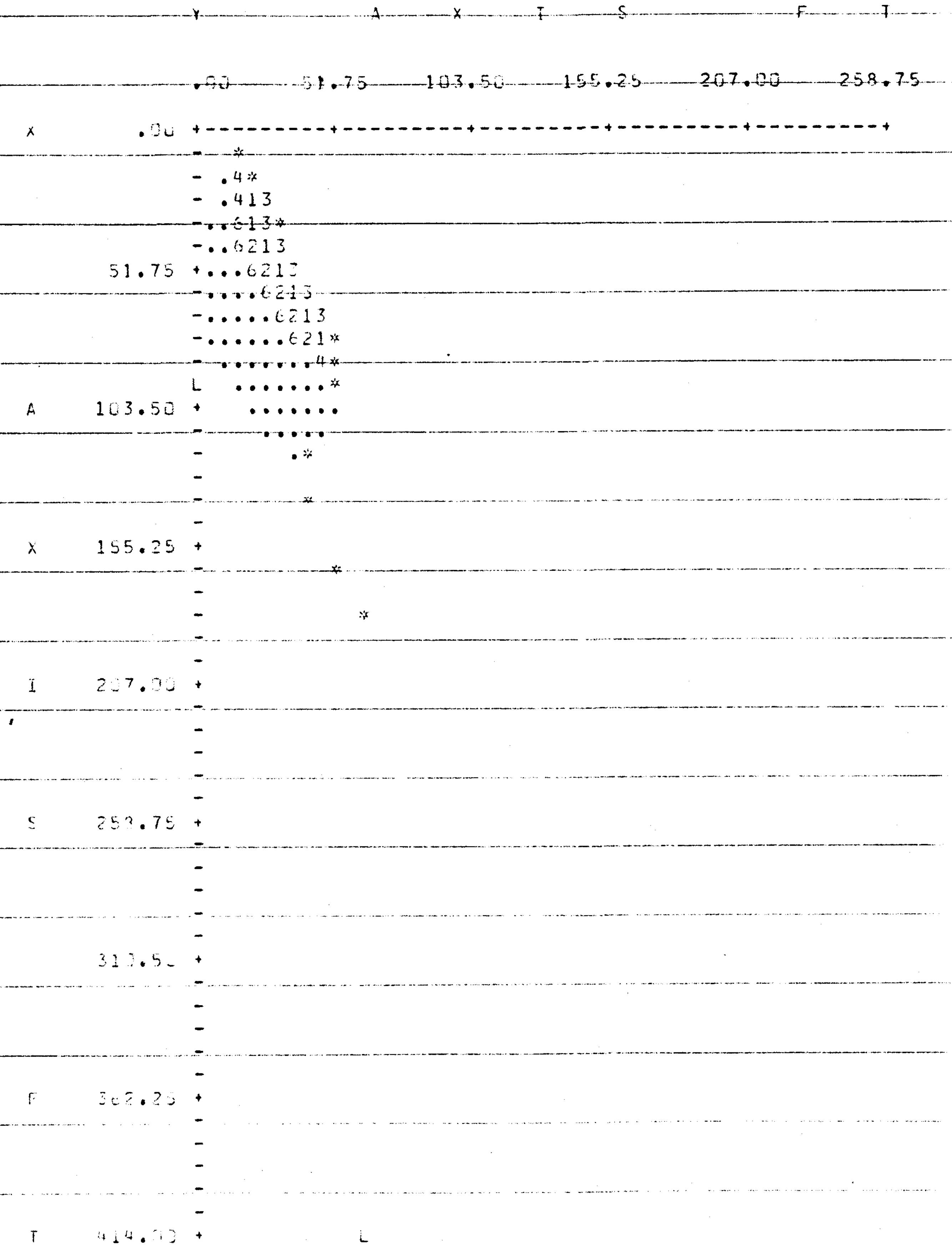
FAILURE SURFACE SPECIFIED BY 16 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	23.89	21.75
2	28.76	22.87
3	33.60	24.15
4	38.39	25.58
5	43.13	27.17
6	47.82	28.91
7	52.44	30.80
8	57.01	32.84
9	61.58	35.03
10	65.93	37.36
11	70.27	39.84
12	74.53	42.45
13	78.71	45.20
14	82.79	48.09
15	86.76	51.10
16	90.36	54.00

*** 1.551 ***

FAILURE SURFACE SPECIFIED BY 20 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	10.00	15.56
2	14.93	16.04
3	19.93	16.71
4	24.86	17.56
5	29.75	18.59
6	34.66	19.83
7	39.41	21.18
8	44.16	22.75
9	48.85	24.49
10	53.47	26.40
11	58.01	28.47
12	62.48	30.72
13	66.56	33.13
14	71.15	35.70
15	75.34	38.42
16	79.43	41.30
17	83.41	44.33
18	87.28	47.50
19	91.02	50.81
20	93.93	53.53


Y AXIS FT
.00
51.75
103.50
155.25
207.00
258.75
X AXIS FT
.00
51.75
103.50
155.25
207.00
258.75
310.50
362.25
414.00

A HORIZONTAL EARTHQUAKE LOADING COEFFICIENT
OF .080 HAS BEEN ASSIGNED

A VERTICAL EARTHQUAKE LOADING COEFFICIENT
OF .000 HAS BEEN ASSIGNED

CAVITATION PRESSURE = .0 PSF

A CRITICAL FAILURE SURFACE SEARCHING METHOD, USING A RANDOM TECHNIQUE FOR GENERATING CIRCULAR SURFACES, HAS BEEN SPECIFIED.

100 TRIAL SURFACES HAVE BEEN GENERATED.

10 SURFACES INITIATE FROM EACH OF 10 POINTS EQUALLY SPACED ALONG THE GROUND SURFACE BETWEEN X = 10.00 FT.
AND X = 35.00 FT.

EACH SURFACE TERMINATES BETWEEN X = 80.00 FT.
AND X = 120.00 FT.

UNLESS FURTHER LIMITATIONS WERE IMPOSED, THE MINIMUM ELEVATION AT WHICH A SURFACE EXTENDS IS Y = 5.00 FT.

5.00 FT. LINE SEGMENTS DEFINE EACH TRIAL FAILURE SURFACE.

FOLLOWING ARE DISPLAYED THE TEN MOST CRITICAL OF THE TRIAL FAILURE SURFACES EXAMINED. THEY ARE ORDERED - MOST CRITICAL FIRST.

FAILURE SURFACE SPECIFIED BY 15 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	21.11	19.11
2	25.45	21.58
3	29.79	24.07
4	34.13	26.56
5	38.46	29.05
6	42.79	31.55
7	47.12	34.06
8	51.44	36.57
9	55.76	39.09
10	60.08	41.61
11	64.39	44.14
12	68.70	46.68
13	73.00	49.22
14	77.31	51.77
15	81.06	54.00

*** 1.081 ***

FAILURE SURFACE SPECIFIED BY 19 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	10.00	15.56
2	15.00	15.59
3	19.99	15.92
4	24.95	16.52
5	29.87	17.42
6	34.73	18.60
7	39.51	20.06
8	44.20	21.79
9	48.79	23.79
10	53.25	26.05
11	57.57	28.57
12	61.73	31.33
13	65.73	34.33
14	69.55	37.56
15	73.18	41.00
16	76.61	44.64
17	79.81	48.48
18	82.79	52.52
19	83.77	54.30

*** 1.158 ***

FAILURE SURFACE SPECIFIED BY 15 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	23.89	21.75
2	28.54	23.59
3	33.15	25.52
4	37.73	27.53
5	42.27	29.63
6	46.76	31.82
7	51.22	34.09
8	55.63	36.44
9	60.00	38.87
10	64.32	41.39
11	68.59	43.99
12	72.82	46.66
13	76.99	49.42
14	81.11	52.25
15	83.55	54.00

*** 1.185 ***

FAILURE SURFACE SPECIFIED BY 20 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	10.00	15.56
2	15.00	15.59
3	19.99	15.85
4	24.97	16.35
5	29.91	17.09
6	34.82	18.06
7	39.67	[illegible]
8	44.47	[illegible]
9	49.19	22.33
10	53.82	24.21
11	58.36	26.30
12	62.80	28.60
13	67.13	31.11
14	71.33	33.82
15	75.39	36.73
16	79.32	39.83
17	[illegible]	43.11
18	86.71	46.56
19	90.16	50.18
20	93.33	[illegible]

*** 1.281 ***

FAILURE SURFACE SPECIFIED BY 14 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	29.44	27.04
2	34.43	27.37
3	39.39	28.03
4	44.29	29.02
5	49.11	30.34
6	53.83	31.99
7	58.43	33.95
8	62.89	36.21
9	67.16	38.78
10	71.29	41.63
11	75.20	44.75
12	78.89	48.12
13	82.34	51.74
14	84.22	54.00

*** 1.311 ***

FAILURE SURFACE SPECIFIED BY 20 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	12.78	16.43
2	17.57	15.00
3	22.46	13.98
4	27.43	13.38
5	32.42	13.21
6	37.42	13.46
7	42.37	14.14
8	47.23	15.23
9	52.02	16.74
10	56.64	18.65
11	61.08	20.95
12	65.31	23.62
13	69.30	26.63
14	73.01	29.98
15	76.43	33.63
16	79.52	37.58
17	82.27	41.73
18	84.65	46.13
19	86.65	50.71
20	87.76	54.00

*** 1.314 ***

FAILURE SURFACE SPECIFIED BY 20 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	12.78	16.43
2	17.45	14.66
3	22.28	13.34
4	27.21	12.50
5	32.19	12.13
6	37.19	12.24
7	42.16	12.84
8	47.04	13.91
9	51.80	15.44
10	56.39	17.42
11	60.77	19.84
12	64.89	22.66
13	68.73	25.87
14	72.24	29.43
15	75.39	33.31
16	78.15	37.46
17	80.50	41.90
18	82.41	46.51
19	83.87	51.30
20	84.42	54.30

*** 1.335 ***

FAILURE SURFACE SPECIFIED BY 20 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	15.56	17.30
2	20.39	15.69
3	25.15	14.52
4	30.10	13.80
5	35.09	13.54
6	40.09	13.73
7	45.05	14.36
8	49.93	15.48
9	54.66	17.02
10	59.28	18.98
11	63.68	21.36
12	67.84	24.13
13	71.73	27.27
14	75.32	30.75
15	78.57	34.55
16	81.47	38.65
17	83.98	42.95
18	86.09	47.46

19	87.77	52.19
20	88.23	54.00

*** 1.357 ***

FAILURE SURFACE SPECIFIED BY 18 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	21.11	19.11
2	25.86	17.55
3	30.76	16.52
4	35.73	16.02
5	40.73	16.06
6	45.70	16.63
7	50.57	17.74
8	55.30	19.37
9	59.83	21.50
10	64.09	24.10
11	68.06	27.15
12	71.67	30.60
13	74.89	34.43
14	77.68	38.58
15	80.01	43.00
16	81.84	47.65
17	83.16	52.48
18	83.41	54.00

*** 1.365 ***

FAILURE SURFACE SPECIFIED BY 20 COORDINATE POINTS

POINT NO.	X-SURF (FT)	Y-SURF (FT)
1	15.56	17.30
2	20.43	16.19
3	25.38	15.44
4	30.36	15.06
5	35.36	15.04
6	40.35	15.36
7	45.30	16.09
8	50.18	17.17
9	54.97	18.59
10	59.65	20.36
11	64.16	22.47
12	68.55	24.91
13	72.73	27.66
14	76.69	30.70
15	80.42	34.03
16	83.90	37.62
17	87.11	41.46
18	90.02	45.52
19	92.63	49.79
20	94.46	53.33

*** 1.392 ***

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                              Y         A         X         I         S         F         T

                             .00      51.75     103.50    155.25    207.00    258.75

      X            .00      +---------+---------+---------+---------+---------+
                            -  *
                            - .2*
                            -.7211
                            -.7421*
                            -.762511
                 51.75      +..642511
                            -..7642511
                            -...7642211
                            -.....6442*
                            -......644*
                            L  .......*
      A         103.50      +   .......
                            -     .....
                            -      .*
                            -
                            -       *
                            -
      X         155.25      +
                            -         *
                            -
                            -           *
                            -
                            -
      I         207.00      +
                            -
                            -
                            -
                            -
                            -
      S         258.75      +
                            -
                            -
                            -
                            -
                            -
                310.50      +
                            -
                            -
                            -
                            -
                            -
      F         362.25      +
                            -
                            -
                            -
                            -
                            -
      T         414.00      +           L

  @FIN
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