A P P E N D I X   V

SOILS REPORT OF THE PROPOSED
WASTE ROCK DISPOSAL SITE
CONVULSION CANYON MINE

Appendix V

SOIL PROFILE DESCRIPTIONS FOR PROPOSED WASTE DISPOSAL SITE

CONVULSION CANYON MINE SEVIER COUNTY, UTAH

Sheldon D. Nelson, Ph.D.
1180 East 700 South
Provo, Utah

On December 10, 1987 three soil profile sites were selected to represent the soil on the 7.5 acre prosposed waste disposal site located at approximately 7900 ft elevation within the Convulsion Canyon Mine. These sites are identified on Map 2 of the Underground Development Waste Disposal Site Plan. The soil pits were excavated to 24 inches and described and sampled by horizons. The soil descriptions indicate that this small area is predominated by a single soil type which is classified as Typic Torrifluvents and in land capability class V with limitations due to climate and slope. Surrounding soils have been previously classified as Typic Argixerolls and the soil on the proposed soil site is small enough to have been considered an inclusion on previous soil maps. A general description of the site and the physical and chemical properties of each soil profile is given below.

The soil within the boundaries of the 7.5 acre propsed waste rock disposal site occur in alluvium on a small flood plain which has a west aspect and moderate slopes of 5-9 percent. The parent material of the alluvium appears to be sandstone and limestone. Soils are stratified and contain evidence of relatively recent periods of depositon followed by non active periods during which plant growth has influenced soil development by forming thin A horizons. A prominent buried A horizon is found at 16-18 inches and the stratified alluvial material above has bands of organic matter accumulations about 1-3 cm in thickness indicating stable periods of surficial soil development and subsequent burial by erosional deposits. The present A horizon is about 4 inches and is underlain by 12-14 inches of stratified C horizon material. Present vegetation indicates that this is a very fertile soil on a slightly eroded landscape but present conditions suggest that this has been a stable landscape for several decades with slow runoff but which is subject to periods of erosial deposition during high storm runoff events. Present erosion hazard is slight (Class 1) with existing vegetation but could be moderate to severe if vegetation is removed. This soil is moderaley well drained, has moderate permeability and medium available water within 3 feet but has a low water holding capacity within the C horizon material from 4-18 inches. Because the buried A horizon has excellent chemical and physical properties for plant growth, this material could be mixed with the top 18 inches of soil and would make a better plant growth medium than the surficial material alone.

Detailed soil profile descriptions and data summary graphs are present in the following pages.

Averages of Disposal Pits — Tue, Dec 22, 1987 8:31 AM

SITE	HORIZON	DEPTH (in)	DRY COLOR	MOIST COLOR	ORGANIC %
PIT NO. 1	A	0-4	10YR 5/2	10YR 4/2	3.14
	Cl	4-10	10YR 6/2	10YR 4/2	1.38
	C2	10-16	10YR 6/2	10YR 4/2	1.38
	Ab	16-24	10YR 4/2	10YR 3/2	2.0
PIT NO. 2	A	0-4	10YR 6/2	10YR 4/2	4.76
	C1	4-12	10YR 4/2	10YR 4/2	1.34
	C2	12-16	10YR 4/2	10YR 4/2	1.34
	Ab	16-24	10YR 3/2	10YR 3/2	1.88
PIT NO. 3	A	0-5	10YR 6/3	10YR 4/2	2.50
	C1	5-11	10YR 5/2	10YR 4/2	1.17
	C2	11-18	10YR 5/2	10YR 4/2	1.17
	Ab	18-24	10YR 4/2	10YR 3/2	2.14
AVERAGE		6 INCHES	10YR 5/2	10YR 4/2	2.02

Averages of Disposal Pits   Tue, Dec 22, 1987 8:31 AM

	TEXTURE	SAND %	SILT %	CLAY %	STRUCTURE	CONSISTENCE
1	Sandy Loam	52.0	28.7	19.3	Granular	Very Friable
2	Sandy Loam	57.3	14.0	18.0	Granular	Loose
3	Sandy Loam	57.3	14.0	18.0	Massive	Friable
4	San Clay Loam	56.0	22.7	21.3	Granular	Firm
5						
6	Loam	42.0	30.7	27.3	Granular	Friable
7	Sandy Loam	70.7	14.0	15.3	Massive	Firm
8	Sandy Loam	70.7	14.0	15.3	Massive	Loose
9	San Clay Loam	56.0	22.7	21.3	Granular	Friable
10						
11	Loam	48.0	30.7	21.3	Granular	Friable
12	Sandy Loam	56.7	24.0	19.3	Granular	Friable
13	Sandy Loam	56.7	24.0	19.3	Massive	Loose
14	Clay Loam	41.3	31.4	27.3	Granular	Firm
15						
16	Sandy Loam	55.4	22.6	20.3	Granular	Friable

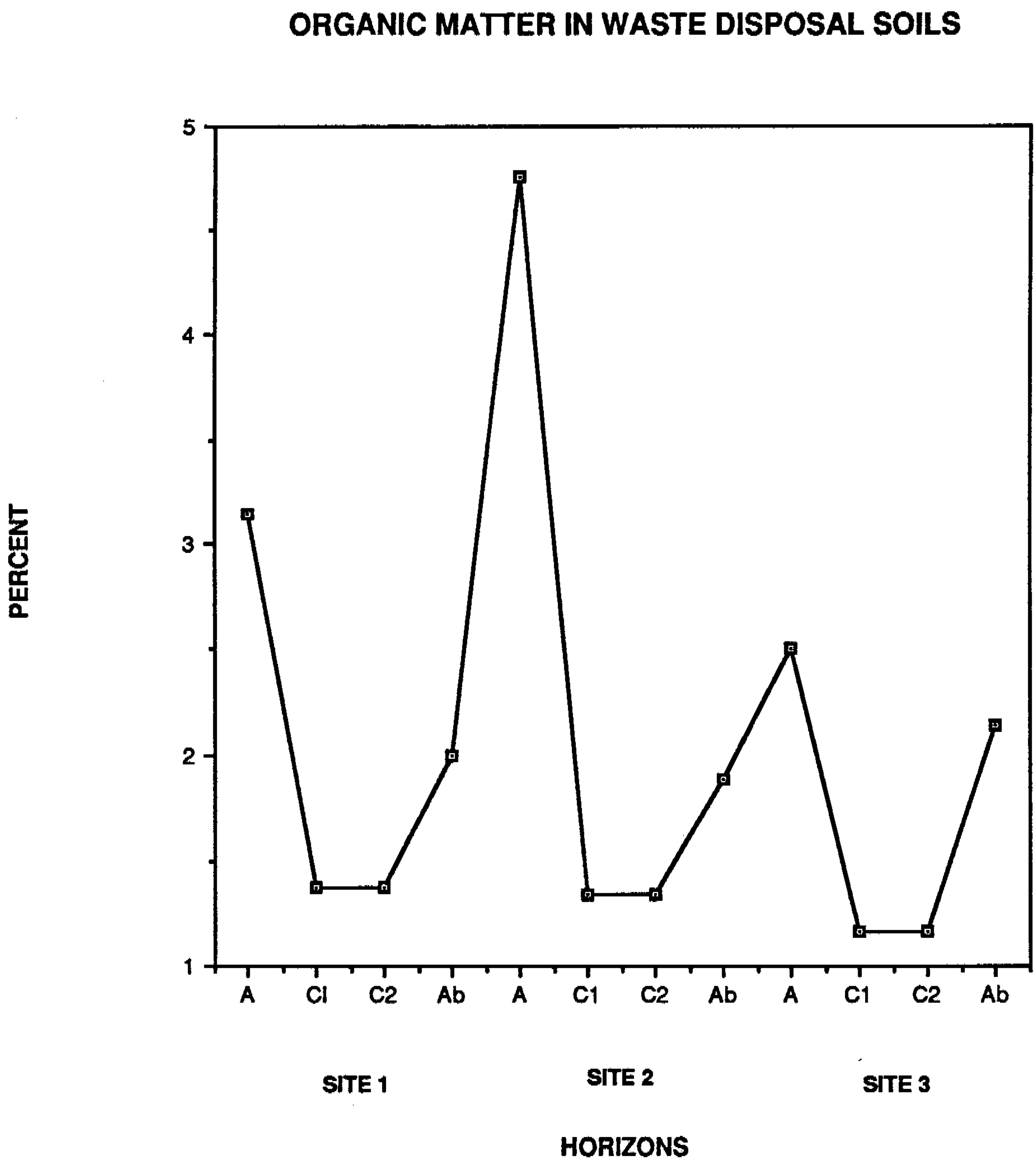
Averages of Disposal Pits   Tue, Dec 22, 1987 8:31 AM

	pH	PHOSPHORUS	POTASSIUM	CALCIUM	MAGNESIUM	SODIUM
1	7.1	13.50	512	276	29.5	9.50
2	7.0	4.62	192	183	19.5	0.50
3	7.0	4.62	192	183	19.5	0.50
4	7.4	4.41	275	68	13.0	5.50
5						
6	7.1	51.6	541	235	42.0	22.5
7	7.4	9.48	157	81	17.0	62.0
8	7.4	9.48	157	81	17.0	62.0
9	7.4	4.41	275	67	13.0	103.5
10						
11	7.2	6.31	278	150	16.5	7.50
12	7.2	2.78	163	162	20.0	2.50
13	7.2	2.78	163	162	20.0	2.50
14	7.5	3.32	275	100	16.0	5.50
15						
16	7.2	9.78	265	146	20.3	23.7

Averages of Disposal Pits

Tue, Dec 22, 1987 8:31 AM

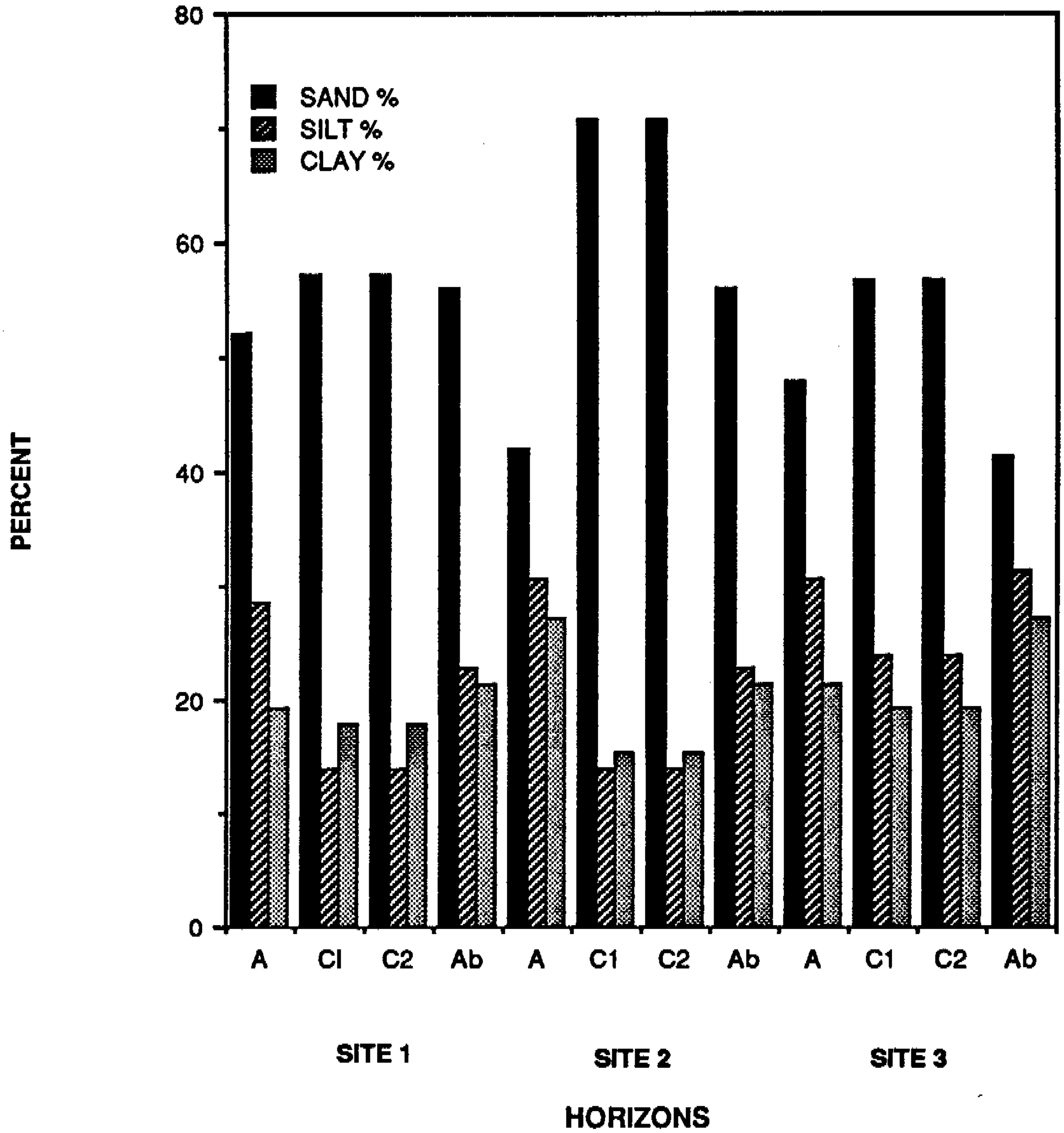
	SAR	EC (mmhos)	CaCO3 %	.3Bar Moist%	15 Bar Moist%	AVAILABLE
1	0.15	1.32	18.44	14.71	10.19	4.520
2	0.01	0.88	14.42	8.13	7.66	0.470
3	0.01	0.88	14.42	8.13	7.66	0.470
4	0.11	0.65	6.25	12.07	9.66	2.410
5						
6	0.36	1.32	13.78	20.48	15.35	5.130
7	1.63	0.67	8.82	7.17	6.07	1.100
8	1.63	0.67	8.82	7.17	6.07	1.100
9	3.01	0.65	6.25	12.07	9.66	2.410
10						
11	0.16	0.76	13.58	11.44	10.15	1.290
12	0.05	0.74	12.76	9.25	7.88	1.370
13	0.05	0.74	12.76	9.25	7.88	1.370
14	0.13	0.50	11.51	22.67	13.46	9.210
15						
16	0.61	0.82	11.82	11.88	9.31	2.57


ORGANIC MATTER IN WASTE DISPOSAL SOILS
PERCENT
5
4
3
2
1
A
Cl
C2
Ab
A
C1
C2
Ab
A
C1
C2
Ab
SITE 1
SITE 2
SITE 3
HORIZONS

Data File: SOILS ON WASTE DISPOSAL SITE

Variable:	ORGANIC %	Observations:	12
Minimum:	1.170	Maximum:	4.760
Range:	3.590	Median:	1.630
Mean:	2.017	Standard Error:	0.304
Variance:	1.111		
Standard Deviation:	1.054		
Coefficient of Variation:	52.255		
Skewness:	1.412	Kurtosis:	1.059

PARTICLE SIZE ANALYSIS OF DISPOSAL SITE SOILS



Data File: SOILS ON WASTE DISPOSAL SITE

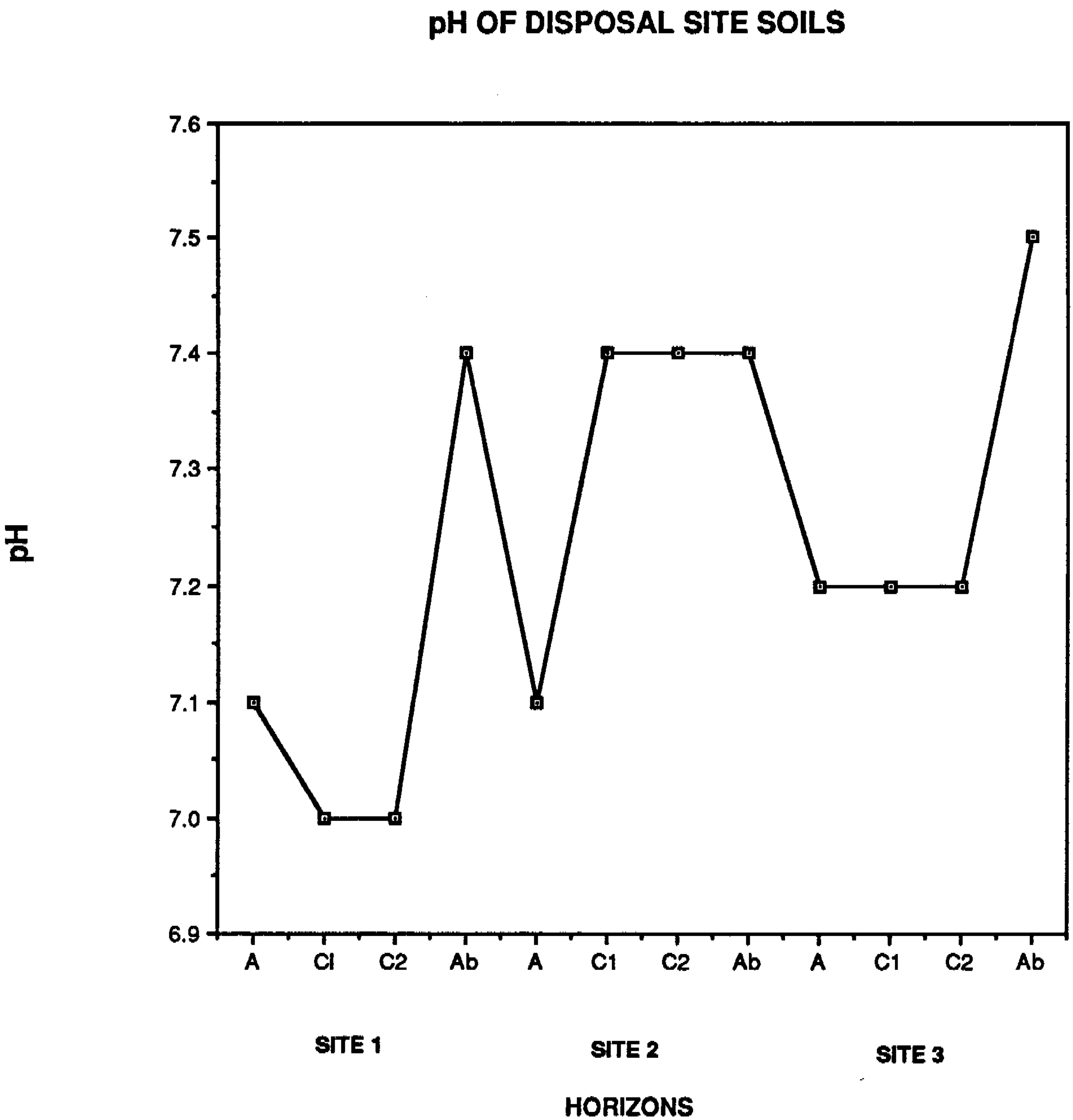
Variable:	SAND %	Observations:	12
Minimum:	41.300	Maximum:	70.700
Range:	29.400	Median:	56.350
Mean:	55.392	Standard Error:	2.646
Variance:	84.017		
Standard Deviation:	9.166		
Coefficient of Variation:	16.548		
Skewness:	0.168	Kurtosis:	-0.821

Data File: SOILS ON WASTE DISPOSAL SITE

Variable:	SILT %	Observations:	12
Minimum:	14.000	Maximum:	31.400
Range:	17.400	Median:	23.350
Mean:	22.575	Standard Error:	2.033
Variance:	49.604		
Standard Deviation:	7.043		
Coefficient of Variation:	31.198		
Skewness:	-0.126	Kurtosis:	-1.719

Data File: SOILS ON WASTE DISPOSAL SITE

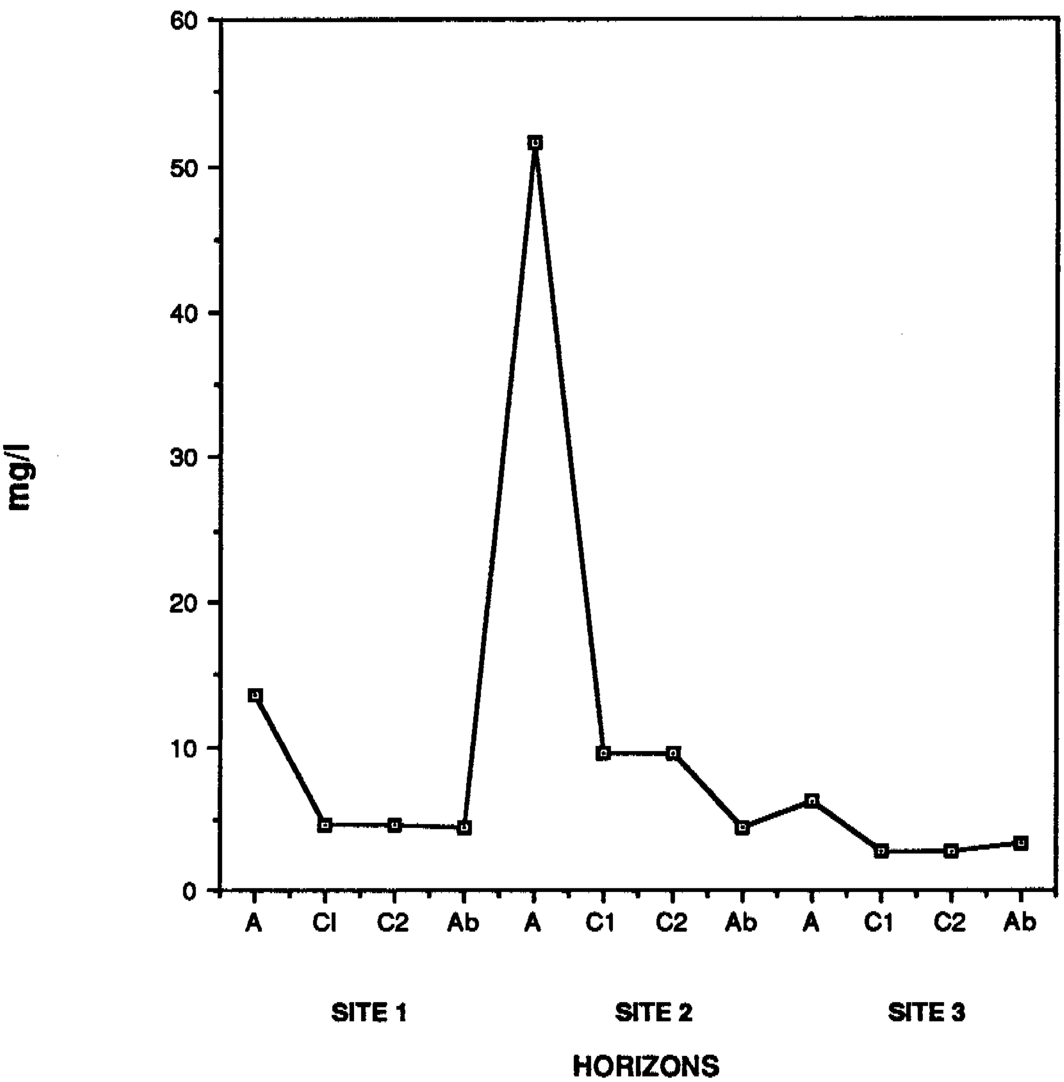
Variable:	CLAY %	Observations:	12
Minimum:	15.300	Maximum:	27.300
Range:	12.000	Median:	19.300
Mean:	20.250	Standard Error:	1.117
Variance:	14.959		
Standard Deviation:	3.868		
Coefficient of Variation:	19.100		
Skewness:	0.628	Kurtosis:	-0.692


pH OF DISPOSAL SITE SOILS
7.6
7.5
7.4
7.3
7.2
7.1
7.0
6.9
pH
A
Cl
C2
Ab
A
C1
C2
Ab
A
C1
C2
Ab
SITE 1
SITE 2
SITE 3
HORIZONS

Data File: SOILS ON WASTE DISPOSAL S-2ITE

Variable: pH	Observations: 13
Minimum: 7.000	Maximum: 7.500
Range: 0.500	Median: 7.200
Mean: 7.238	Standard Error: 0.046
Variance:	0.028
Standard Deviation:	0.166
Coefficient of Variation:	2.294
Skewness: 0.035	Kurtosis: -1.520

AVAILABLE PHOSPHORUS IN DISPOSAL SITE SOILS



Data File: SOILS ON WASTE DISPOSAL S-2ITE

Variable: PHOSPHORUS   Observations: 12

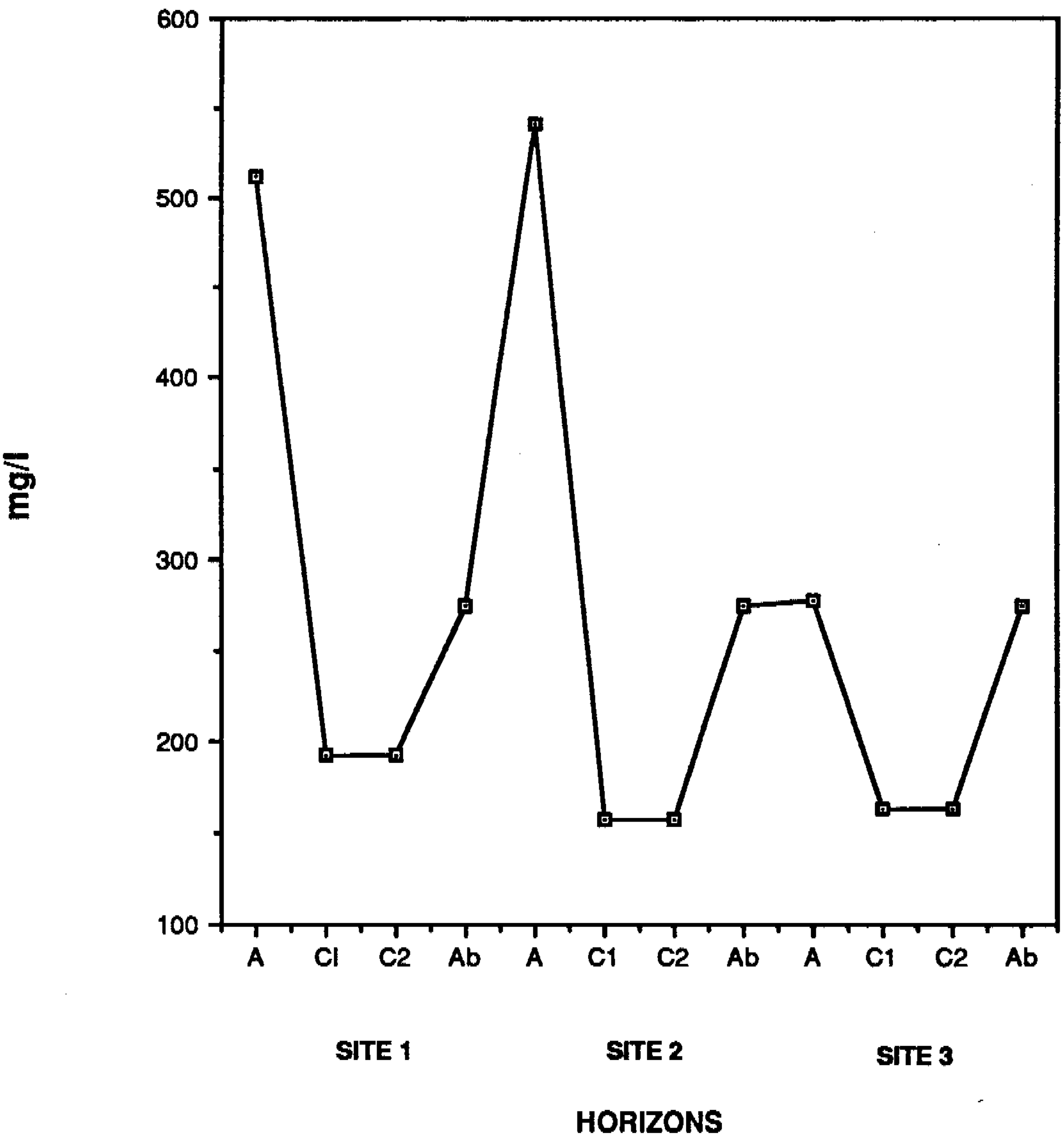
Minimum:	2.780	Maximum:	51.600
Range:	48.820	Median:	4.620

Mean:	9.776	Standard Error:	3.917

Variance:	184.148
Standard Deviation:	13.570
Coefficient of Variation:	138.813

Skewness:	2.389	Kurtosis:	4.544

AVAILABLE POTASSIUM IN DISPOSAL SITE SOILS



Data File: SOILS ON WASTE DISPOSAL SITE

Variable: POTASSIUM   Observations: 12

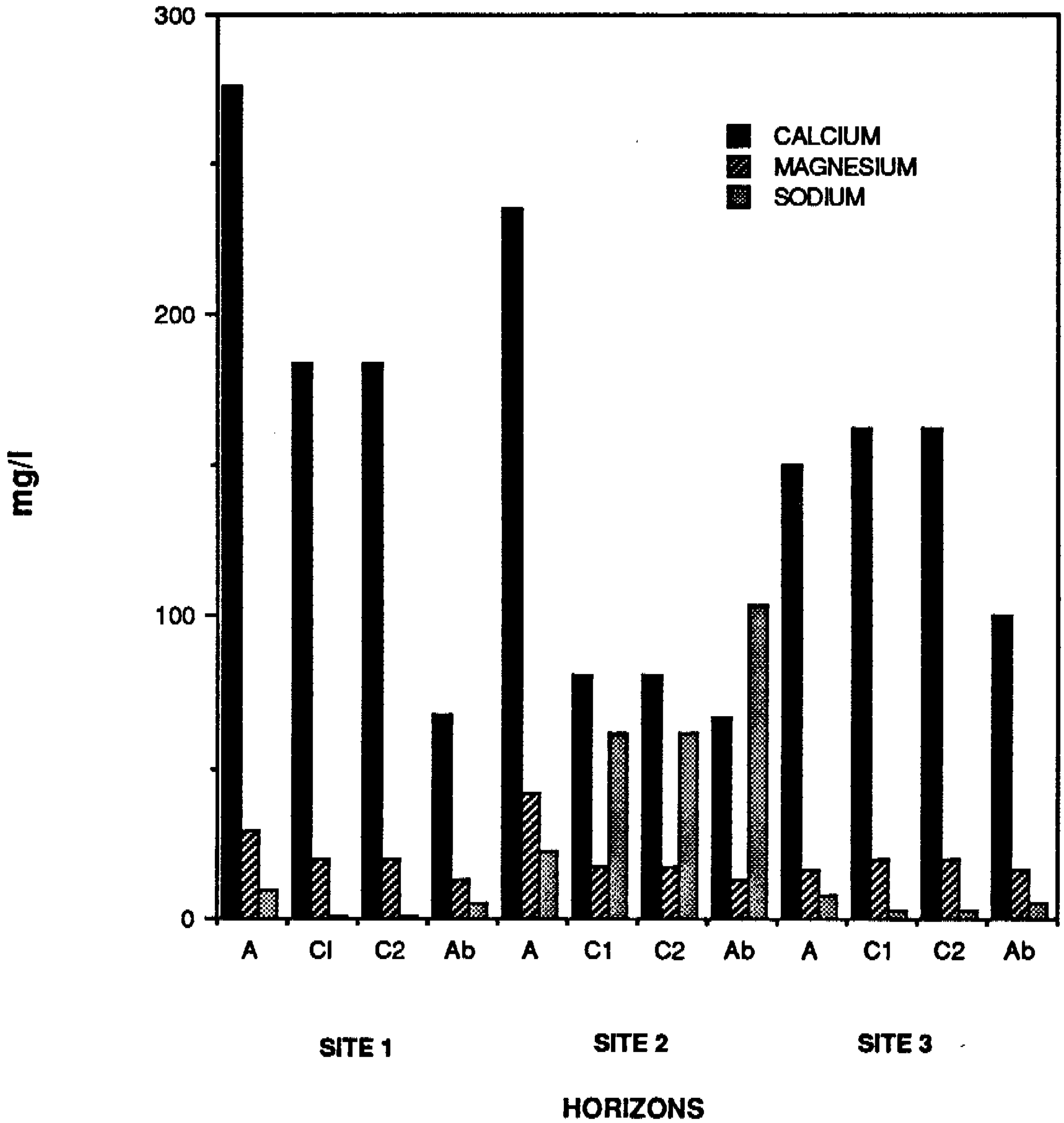
Minimum:	157.000	Maximum:	541.000
Range:	384.000	Median:	233.500

Mean:	265.000	Standard Error:	38.183

Variance:	17495.273
Standard Deviation:	132.270
Coefficient of Variation:	49.913

Skewness:	1.105	Kurtosis:	-0.258

SOLUBLE CATIONS IN WASTE DISPOSAL SOILS



Data File: SOILS ON WASTE DISPOSAL SITE

Variable: CALCIUM   Observations: 12

Minimum:	67.000	Maximum:	276.000
Range:	209.000	Median:	156.000

Mean: 145.667   Standard Error: 19.652

Variance:	4634.242
Standard Deviation:	68.075
Coefficient of Variation:	46.734

Skewness: 0.383   Kurtosis: -1.175

Data File: SOILS ON WASTE DISPOSAL SITE

Variable:	MAGNESIUM	Observations:	12
Minimum:	13.000	Maximum:	42.000
Range:	29.000	Median:	18.250
Mean:	20.250	Standard Error:	2.333
Variance:	65.295		
Standard Deviation:	8.081		
Coefficient of Variation:	39.904		
Skewness:	1.598	Kurtosis:	1.640

Data File: SOILS ON WASTE DISPOSAL SITE

Variable: SODIUM   Observations: 12

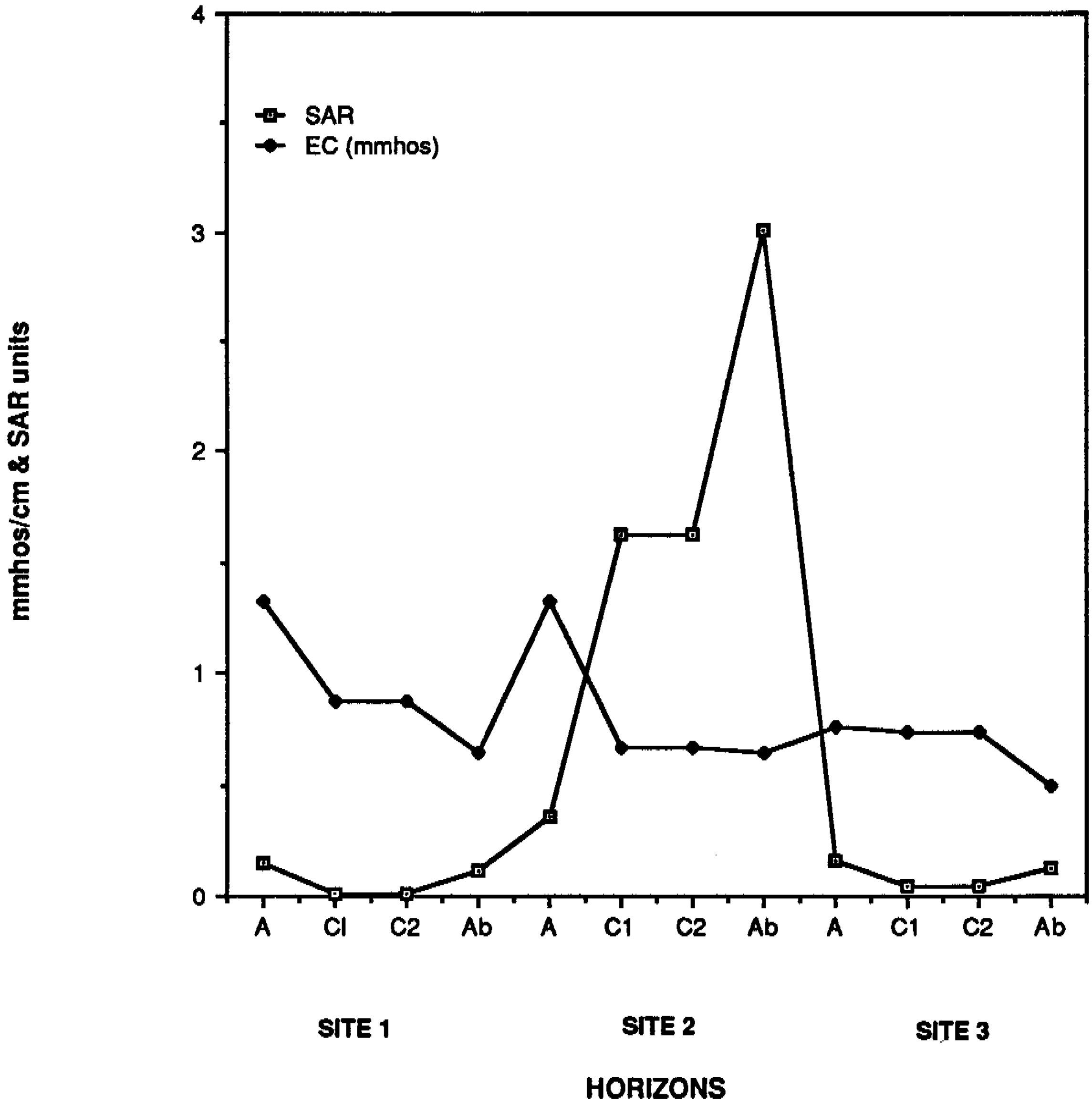
Minimum:	0.500	Maximum:	103.500
Range:	103.000	Median:	6.500

Mean: 23.667   Standard Error: 9.694

Variance:	1127.742
Standard Deviation:	33.582
Coefficient of Variation:	141.895

Skewness: 1.229   Kurtosis: 0.030

SALINITY & SODICITY OF DISPOSAL SITE SOILS

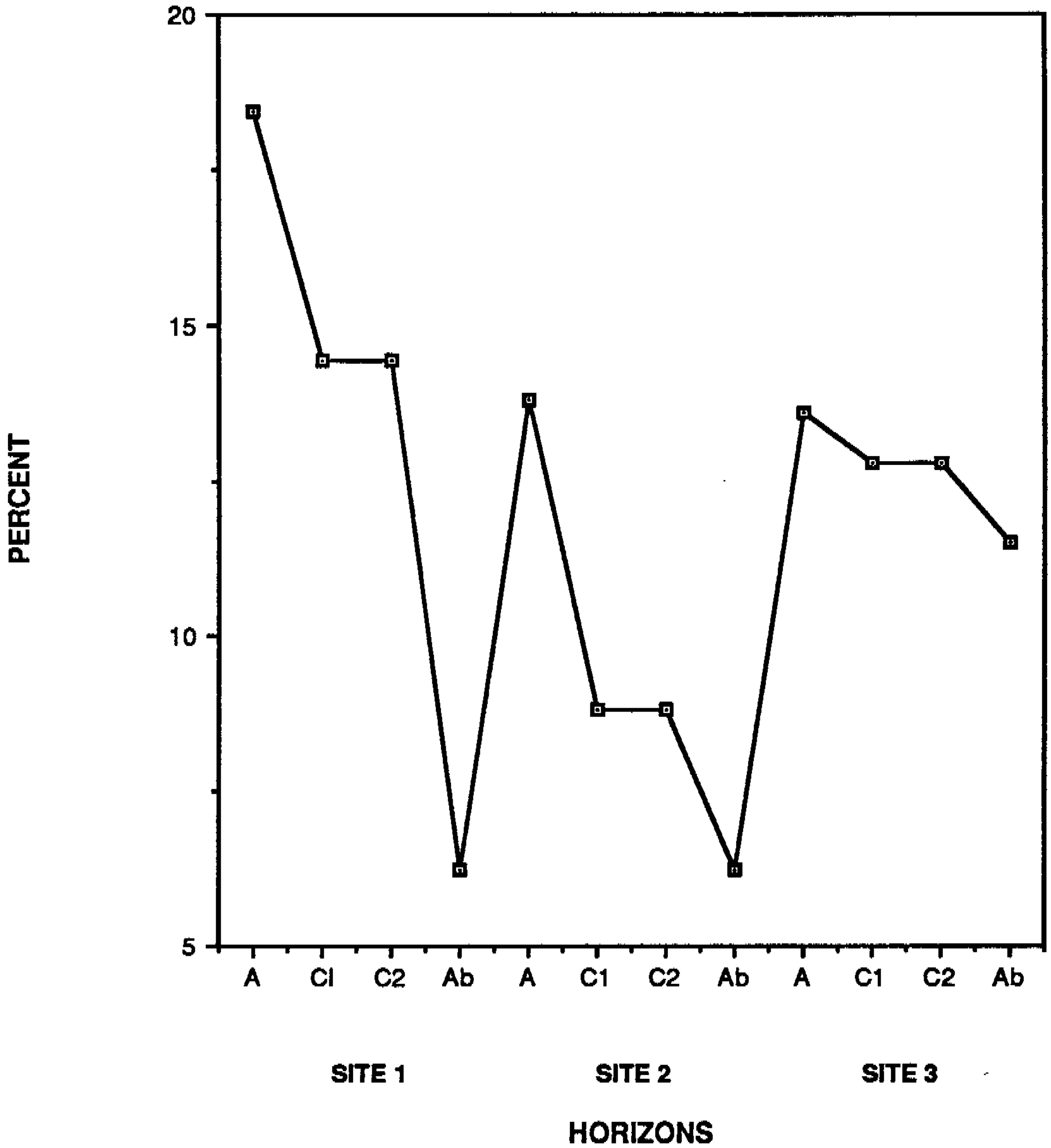


Data File: SOILS ON WASTE DISPOSAL SITE

Variable: SAR	Observations: 12
Minimum: 0.010	Maximum: 3.010
Range: 3.000	Median: 0.140
Mean: 0.608	Standard Error: 0.277
Variance:	0.922
Standard Deviation:	0.960
Coefficient of Variation:	157.866
Skewness: 1.390	Kurtosis: 0.537

Data File:	SOILS ON WASTE DISPOSAL SITE		
Variable:	EC (mmhos)	Observations:	12
Minimum:	0.500	Maximum:	1.320
Range:	0.820	Median:	0.740
Mean:	0.815	Standard Error:	0.074
Variance:		0.066	
Standard Deviation:		0.257	
Coefficient of Variation:		31.576	
Skewness:	1.031	Kurtosis:	-0.295

CALCIUM CARBONATE IN DISPOSAL SITE SOILS



Data File: SOILS ON WASTE DISPOSAL SITE

Variable: $CaCO_3$ % Observations: 12

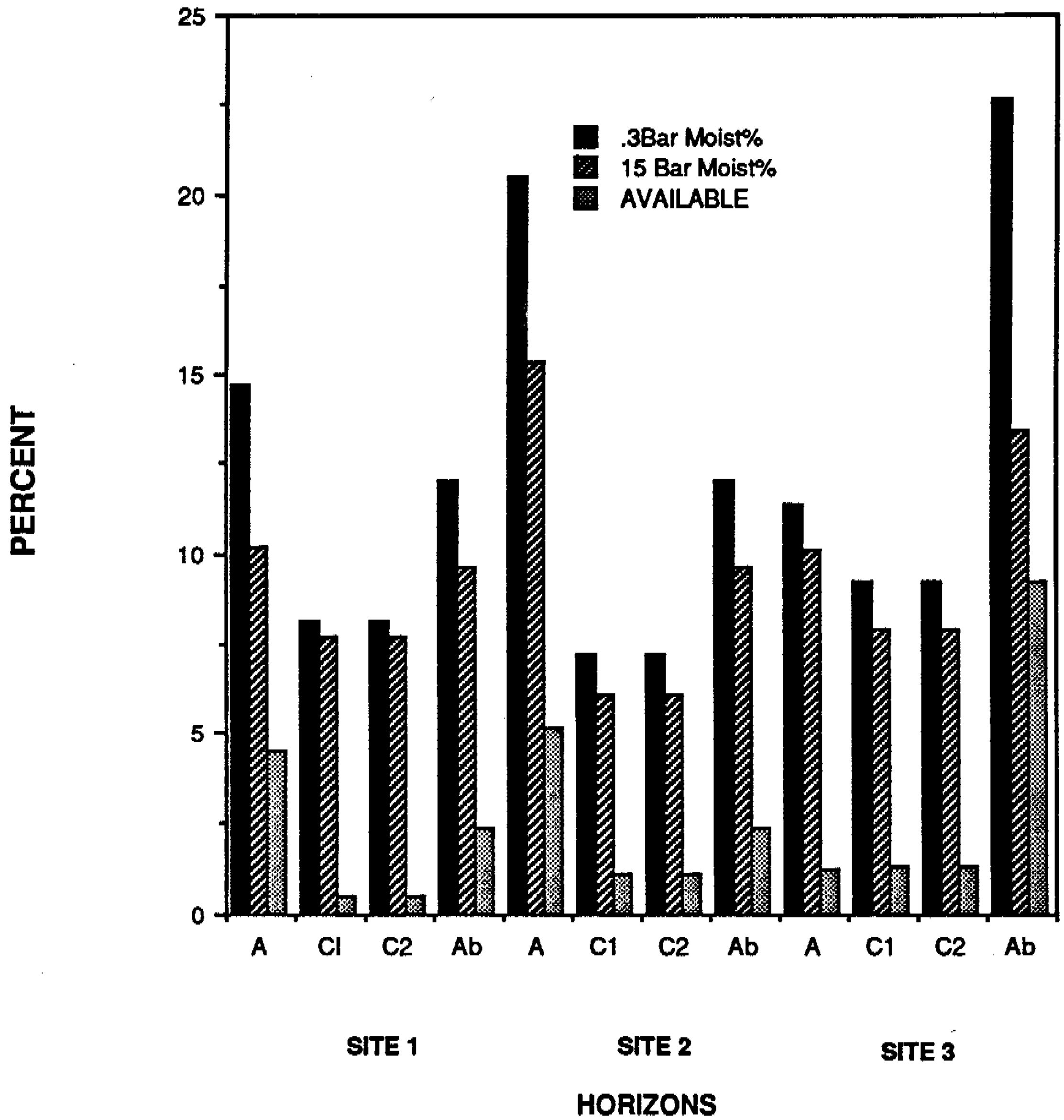
Minimum:	6.250	Maximum:	18.440
Range:	12.190	Median:	12.760

Mean:	11.818	Standard Error:	1.052

Variance:	13.291
Standard Deviation:	3.646
Coefficient of Variation:	30.849

Skewness:	-0.101	Kurtosis:	-1.054

MOISTURE CONTENTS OF DISPOSAL SITE SOILS



Data File: SOILS ON WASTE DISPOSAL SITE

Variable: .3Bar Moist% Observations: 12

Minimum:	7.170	Maximum:	22.670
Range:	15.500	Median:	10.345

Mean:	11.878	Standard Error:	1.469

Variance:	25.908
Standard Deviation:	5.090
Coefficient of Variation:	42.851

Skewness:	0.989	Kurtosis:	-0.446

Data File: SOILS ON WASTE DISPOSAL SITE
Variable: 15 Bar Moist% Observations: 12

Minimum:	6.070	Maximum:	15.350
Range:	9.280	Median:	8.770

Mean:	9.308	Standard Error:	0.807

Variance:	7.814
Standard Deviation:	2.795
Coefficient of Variation:	30.034

Skewness:	0.805	Kurtosis:	-0.442

Data File: SOILS ON WASTE DISPOSAL SITE

Variable: AVAILABLE - MOISTURE   Observations: 12

Minimum: 0.470	Maximum: 9.210
Range: 8.740	Median: 1.370

Mean: 2.571	Standard Error: 0.739

Variance:	6.560
Standard Deviation:	2.561
Coefficient of Variation:	99.625

Skewness: 1.420	Kurtosis: 0.981

ENDANGERED PLANT STUDIES, INC
129 North 1000 East
Orem, Utah 84057
(801) 225-7085

21 March 1988

Mr. Keith Welch
Coastal States Energy Company
175 East, 400 South
Suite 800
Salt Lake City, Utah 84111

Dear Mr. Welch:

Enclosed is a copy of additional soils analyses for the proposed Sufco wasterock disposal site. Response from DOGM concerning the initial completness review indicated that the soil profile described to the two foot level was insufficient and that the root content of the soils was not described. Additional concern with boron in the soil led to inclusion of that element in the analyses. A review of boron toxicity, involving irrigated soils, is included with this report. It is understood, of course, that irrigation will not be used at this site.

The additional sampling and description of the soil profile was undertaken on 3 March 1988. Work was done by Dr. Sheldon D. Nelson, soils scientist, and Mr. M. A. Franklin of this office. Analyses were carried out at the soils laboratory at Brigham Young University.

Roots were described for each of the soils subunits to a depth of 140 cm plus. The test pit was dug a week earlier than the visit by Dr. Sheldon and Mr. Franklin. The pit was dry when first excavated, but was partially filled by snow melt during the interval prior to sampling. This accounts for the "water table" in the discussion.

Procedures for determination of roots are standard for soils studies. Most roots were present in the profiles above the depth of 80 cm (i.e., about 2.5 feet).

Boron tested low to very low in concentration in the soil profiles, indicating a very low potential for production of toxic vegetation from the profile proper. Waste rock buried by 2.5 feet of the existing soil profile should be sufficient to insulate the vegetation from slightly higher concentrations of Boron in the waste rock.

There is sufficient soil materials in the profile to provide all of the topsoil necessary for burial.

If there is additional information required, please contact me.

Sincerely yours,

Stanley L. Welsh

Stanley L. Welsh

ADDENDUM

SOIL PROFILE DESCRIPTIONS FOR PROPOSED WASTE DISPOSAL SITE

CONVULSION CANYON MINE SEVIER COUNTY, UTAH

Sheldon D. Nelson, Ph.D.
1180 East 700 South
Provo, Utah

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On March 3, 1988 an additional soil profile was sampled and described to a lower depth than the December profiles. A water table was encountered at 80 cm which prevented a completely accurate description below that depth. However, each horizon was characterized in the field and horizon samples were analyzed for the physical and chemical properties requested. The profile description and laboratory analysis is summarized in Table 1.

This profile site is essentially the same as the other sites sampled with the exception that the horizons are somewhat finer in texture. The dominate root growth is in the surface A and C horizons but is not restricted to them. A buried A horizon is about 90 cm thick and overlies a light colored clay horizon of unknown depth. The buried A horizon appears to have high potential fertility and good water holding capacity. Plant roots have readily penetrated and explored the profile above the IIIC horizon which horizon appears to be a restrictive layer. However, a water table may exist in this soil during part of the growing season which may also restrict root activity.

Boron concentrations are low in all horizons but as is common in most soils values are the highest in the horizons which have higher organic matter contents. Present boron levels are not a limiting factor for plant growth. I have attached a literature review and literature references concerning boron toxicity from a 1987 BYU thesis, *The effect of power plant waste water on the growth of agricultural crops*, by Earl Hansen. Boron toxicity can be a severe problem to plant growth particularly at the germination and emergence stage and any additions of this element to soils on which wildland or domestic plants are to be grown should be carefully evaluated.

TABLE 1. COAL M[illegible]E SOIL DESC Fri, Mar [illegible] 1988

	HORIZON	DEPTH (cm)	DRY COLOR	MOIST COLOR	ORGANIC %	TEXTURE	SAND %	SILT %
1	A	0-20	10YR 6.5/2	10YR 4/2	3.02	LOAM	32.0	43.0
2	CI	20-36	10YR 6/2	10YR 5/2	1.04	SANDY LOAM	54.0	27.0
3	C2	36-53	10YR 6/2	10YR 5/2	1.42	SANDY CLAY LOAM	49.0	29.0
4	IIAb1	53-80	10YR 5/2	10YR 3/2	2.79	CLAY LOAM	39.0	31.0
5	IIAb2	80-140	10YR 5.5/2	10YR 3/1	2.51	CLAY LOAM	27.0	33.0
6	IIIC	140+	10YR 6/1	10YR 4/2	1.74	CLAY	27.0	31.0

	CLAY %	STUCTURE	CONSISTENCE	pH	BOUNDARY	ROOTS	
1	25.0	granular,wea	very friable	7.0		common,med&Coarse	many, fine & v fine
2	19.0	single grain	loose	7.5	gradual,	common, coarse	many, fine &
3	22.0	granular,wea	friable	7.1	gradual,	common fine,v fine	few, medium
4	29.0	blocky,strong	firm	7.4	clear, smooth	common, fine	few, medium
5	29.0	blocky,modera	friable	7.5	gradual,	few, medium & fine	
6	42.0	blocky,strong	firm	7.6	clear, smooth	none	

	$CaCO_3$ %	BORON ppm
1	16.5	0.85
2	11.9	0.17
3	14.0	0.02
4	9.3	0.93
5	7.8	0.71
6	16.4	0.49

REVIEW OF LITERATURE

BORON TOXICITY AND IRRIGATION MANAGEMENT

Irrigation water seldom contains enough Boron to injure plants directly. An increased concentration of B in the soil by continued use of B contaminated water and evapotranspiration eventually causes toxicity problems. Boron accumulates in soil by adsorption on clay, even though its concentration in the irrigation water is low. It is important to know the eventual B concentration of the soil solution that may result when irrigation water containing various amounts of B is applied under differing management practices. When water having high B content is being used, it is imperative to have a thorough knowledge of B distribution in the soil profile. The knowledge of factors affecting this distribution is essential for determining the maximum allowable B content in irrigation water and in facilitating efficient management of croppings systems.

When the plant uptake of B is small compared to the amounts applied in the water, the B concentration in the soil solution increases with time. Eventually an equilibrium will be reached when the amount of B added to the root zone by irrigation is equal to the amount removed from the root zone by the crop and by leaching. Thus, in order to prevent the continuous buildup of B in the root zone, it is essential that more water be applied than the plant requires so that the excess water will leach the B through the soil profile. This fraction of the applied water is referred to as the leaching fraction (LF).

At equilibrium, B concentration of the soil solution will increase gradually from a level near the soil surface equivalent to that of the irrigation water, to a level near the bottom of the root zone when the B concentration is determined primarily by the degree of leaching. When high LFs are applied, the B concentration of the soil solution will be uniform and will change relatively little with depth. In contrast, if the LF is low the resultant B concentrations will vary considerably: B concentrations near the soil surface will be close to those of the irrigation water but will increase with depth. (23).

BORON CONTENT OF SOILS

The total B content of soils will vary between 20 to 200 ppm. Most soil B is unavailable to plants. The available B fraction determined by hot water extraction (20), ranges from 0.4 to 5 ppm. Boron is present in various minerals, tourmaline (3-4% B) being the most important. In these minerals B may substitute for silicon in the tetrahedral structures of clay minerals. Soluble B in the soil consists mainly of boric acid [$B(OH)_3$]. Under normal soil pH conditions this acid is not deprotonated (dissociated); and therefore in contrast to all other essential nutrients B is mainly present in a non-ionized form in soil solution. This may be the main reason why B can be leached so easily from the soil. Gupta and Cutcliffe (19), have reported that more than 60% of applied B was not recovered in the upper layer of a podzolic soil five months after application. In addition to this, Crandall et al. (7) found that excess B in the soil disappears rapidly when adequate water is available to leach it from the root zone. Crandall et al. (7) applied high levels of B to the soil around 'Bartlett' and 'd'Anjou' pear (*Pyrus communis* L.), trees in a non-irrigated orchard. Boron levels in the soil profile and in the flowers, leaves and fruit were monitored for 6 years. Boron levels in the soil dropped to below 2 ppm within 5 years following application and all visible symptoms of toxicity had disappeared. Symptoms of toxicity were leaf tip yellowing followed by progressive necrosis. The leaves eventually dropped, and fruit was small and of poor quality. The B content of 'Bartlett' pear tissues was always higher than that of 'd'Anjou' and the symptoms of toxicity was more severe. Under conditions of this research levels in full blossom clusters and levels in the fruit at harvest time were better indicators of toxicity than were levels in leaves. Boron levels in blossom clusters above 90 and 115 ppm and in fruit above 55 and 45 ppm for 'd'Anjou' and 'Bartlett' pears respectively were considered to be detrimental to blossom and fruit development..

The aforementioned studies were conducted in humid areas, in contrast to arid regions where toxic levels of B may accumulate in the upper soil layer (33).

Boric acid does not act as a proton donor according to Parfitt (52) but rather as a Lewis acid accepting hydroxy ion (OH^-).

$B(OH)_3+H_2O=B(OH)_4^-+H^+$ pK=9.0

The high pK value indicates that the formation of the anion [$B(OH)_4^-$] is only of significance in the upper pH range. The $B(OH)_4^-$ thus formed is adsorbed by sesquioxides and clay minerals. Illites are more effective in B adsorption than kaolinites and smectites. The pH dependence of the formation of the $B(OH)_4^-$ anion may be the reason why B adsorption increases with rising soil pH. This effect of pH on borate adsorption is in marked contrast to the effect of pH on the adsorption of other anion species where adsorption is reduced as soil pH is increased. According to Hingston et al. (28) maximum B adsorption occurs at pH 9. Soil pH is one of the most important factors affecting the availability of B in soil and plants. Generally B becomes less availabile to plants with increasing soil pH. Negative correlations have been observered (20), between B uptake by plants and soil pH. It has been shown that a negative relationship occurs between soil pH and plant B when soil pH levels are greater than 6.3-6.5. The availability of B to plants decreases sharply at higher pH levels. The increase in borate adsorption with rising pH accounts for the lower B availability in high pH soil therefore overliming can induce B deficiency in crops (44). The lower rates of B leaching from neutral and alkaline soils are also a consequence of B adsorption (20).

Whiting, et al. (74) states that B may be present in soils (Chemawa loam, Parkdale loam, and Hood silt loam), in adequate amounts yet unavailabile to crops growing in those soils. Boron uptake is influenced by the equilibrium that exists between B retained by the soil particles and that which is soluble in water. Boron uptake is also reduced or prevented during dry soil conditions. Also, at low temperatures (5 C), B may be taken up by roots but because of slow translocation is essentially unavailable to the rest of the plant.

Hatcher, et al. (26) states that equilibrium exists between dissolved and undissolved B in soils. When irrigation waters having similar B concentrations are applied, injury occurs more quickly on coarse-textured than on fine-textured soils. Also, B toxicity was alleviated more rapidly on coarse-textured than on fine-textured soils when irrigation water having a lower B concentration was applied.

Goldberg and Glaubig (18) conducted a study on B adsorption on the clay minerals; kaolinite, montmorillonite, and illite. The three minerals exhibited increasing B adsorption with increasing pH. Adsorption peaks occurred at pH

8.5 to 10 and were followed by a gradual decline at higher pH levels. The assumption formed from this study was that B adsorbs by means of a ligand exchange mechanism with aluminol groups at the edges of the clay particles. They found that silicon release to the solution increased in the order: kaolinite << illite< montmorillonite and was exhibited at a minimum in the pH range 8 to 9. Adsorption of B on kaolinites was reduced only slightly in the presence of added silicate despite considerable silicate adsorption. Adsorption of B on montmorillonites was unaffected by the presence of added silicate. Goldberg and Glaubig (18), suggest that B and silicate adsorb on specific sites and that little anion competition occurs.

DETOXIFYING HIGH BORON SOILS

The recommended method, for reclaiming and detoxifying soils containing toxic levels of B is to leach them extensively with water (11, 54) or with other salt solutions (29). However, leaching of B with low mineral content water is a slow process.

Soils where soluble B contents are lowered to acceptable levels by leaching may in time regenerate toxic levels of soluble B through desorption of the more strongly sorbed B. Continued leaching prevents this. The rate of B removal by leaching is much slower for nonadsorbed salts. Reeve et al. (57) demonstrated that while 30 cm. of water per 30-cm. depth of soil reduced soil salinity by 80% of its original level, 90 cm. of water per 30 cm. of soil were required to reduce B to the same proportional level.

Chemical methods other than leaching with water have been tried for detoxifying B toxic soils. One method used involved the use of triisoproponolamine (TIPA), which acts by chelating the boric acid. This method was partially successful though uneconomical.

BORON CONCENTRATIONS IN FLY ASH

Fly ash is trapped by electrostatic precipitators as pulverized coal is burned to produce electricity. Most fly ash produced in the United States is disposed of in landfills. Fly ash has been used to a small extent in concrete and ceramics, as an alkaline amendment to coal mine spoils, as a base material in roadbeds, refuse banks, and other wasteland areas to facilitate their reclamation for growing cover crops to prevent erosion or for forage and pasture crops, (16).

The amount of fly ash produced by electric power utilities in 1978, was approximately 60 million tons (12). Concentrations of up to 600 ppm of B are common in fly ash, although concentrations up to 50,000 ppm have been reported in fine deposits of fly ash. The concentration of B in the fly ash at Hunter and Huntington is approximately 2000 ppm which is substantial and the main reason for high B levels in the irrigation waters used on the research farms. The fly ash is deposited into the irrigation storage ponds when the exhaust stacks at the power plants are washed out (blow down dishcharge water).

Elseewi et al. (12) reported the existence of a substantial fraction of water soluble B in fly ash and noted that, increased B release with increasing dilution is indicative of the presence of B in association with the innermost surfaces of fly ash and in compounds of low solubility. A common morphological feature of fly ash particles is the existence of cenospheres (spheres within spheres), which makes the migration of B and possibly other surface associated elements, from the inner to the outer spheres and into solution a time consuming process which is probably enhanced by dilution. The part of B that is water soluble, and hence immediately available is probably associated with the outer surface of the fly ash spheres and, as such, would be expected to solubilize almost immediately upon contact with solution.

When experimenting on the kinetics of B release in water it was shown that maximim release occurred during the first three hours of extraction followed by a sharp reduction and a leveling off. The apparent result of readsorption of the initially solubilized B is the reduction in the solubilization of B in water with time (12).

Of special significance in terms of water management regimes to be accepted in situations where fly ash is aquatically or terrestrially disposed, is the fact that solubilization of fly ash B is greatly diminished as more fly ash is added to solution.

Oxides that have shown an affinity for B are Fe, Al, and Mg. These fractions of B have low solubility, and exist at relatively high concentrations in fly ash.

PHYSIOLOGICAL ROLE OF BORON IN PLANTS

Although the physiological role of B in plants is less well understood than that of other nutrients, considerable progress has been made in this area. Some of the effects caused by a deficiency of B include a slower root extension, inhibition of cell division, abnormal thickening of cell walls, accumulation of callus in the conducting tissues, increased production of indoleacetic acid, and browning of plant tissue as related to the accumulation of polyphenolic compounds, (20), (44). It is well known that B unites freely with various sugars. In all studies by Eaton (10), retention of B in leaves increased as hours of sunshine increased.

Numerous investigators have studied the influence of B on membrane integrity and function. Tanada (67), has shown that B effects the plasmalemma permeability and translocation of nutrients within the plant. Pollard et al. (53) suggests that the reaction of B with polyhydroxy compounds as a possible mechanism influencing the activity and integrity of the membrane. Roth-Bejerano and Itai (60) have shown that B also plays a role in stomatal movement probably by acting at the membrane level.

Boron is probably taken up by plants as undisassocciated boric acid although the process is still not well understood. Controversy still exists as to whether the uptake process is passive or active. Kohl and Oertli (34) hypothesized that B in the leaf is a non-metabolic process. This indicates that B is carried passively in the transpiration stream of the leaf. In their effort to show the mobility of B in leaf tissue, they forced liquid exudate out of a basal section of a stem-piece of rubrum lily (*Lilium longiflorum* Thunb. var. Ace), by means of compressed air under 40 cm of mercury. The liquid that exuded from the cut end of the leaf was collected in a crucible.

When the exudate was analysized, B had been drawn from the leaf in considerable quantity. Therefore, Kohl and Oertli (34), concluded that B is more concentrated in those areas of the leaf considered to be sinks for water because mass flow of the transpiration stream ends in these areas.

It has also been reported that when plants grown in a medium with sufficient B are changed to a medium with no B, their new tissues were B deficient (34). Eaton has hypothesized the formation of large molecular B compounds which cannot pass through cell membranes to explain the phenomenon that B doesn't move from older to younger leaves. This implies that B is not carried from the leaf in the phloem and suggests that the phloem membranes are largely impermeable to B. Bowen and Nissen (5) found that the uptake of B by excised barley (*Hordeum distichon* L.), roots to be both apoplastic and symplastic. Of the total B determined, a high fraction was found to be present in the water free space or reversibly bound in the cell walls as borate polysaccharide complexes. Because of the work done in this study it would seem that the active component of B is relatively small. This indicates that B uptake under metabolic control can only be detected experimentally after it has reversibly accumulated in the free space and has then been removed. This then shows that uptake mainly follows water flow through the roots up through the xylem and is concentrated in the leaves. Evidence shows that there is little entrance into and little movement in the phloem (46). Therefore, there is not as much B moving out of the leaf as comes into it and the concentration of B builds up at this endpoint or sink. Because the main avenue of entry into the leaf is apoplastic, the B concentration in the leaf tips and leaf edges is high (46).

A possible way of determining the biochemical role of B in the metabolism of vascular plants is to determine the earliest effect that withholding B has on the physiology of the plant. If this is done, this earliest symptom is likely to indicate its primary metabolic role. The earliest effect, of B deprivation that has been determined is on nucleic acid biosynthesis in apical meristems of roots. Five day old squash plants (*Cucurbita pepo)* were transferred into a nutrient medium with no added B. After 12 hours the incorporation of [^{3}H] thymidine was reduced 66% (38). The decrease in DNA synthesis correlated temporally with inhibition of both cell division and root elongation.(38). When the B deficient squash plants were returned to a B-sufficient medium for 12 hours, autoradiographs showed that incorporation of [^{3}H] thymidine was indistinguishable from that of B-sufficient root tips. Under conditions of B deficiency, these observations suggest that DNA synthesis is rapidly, but reversibly, inhibited.

It has been concluded that B is needed for the synthesis of N-bases such as uracil (1). Boron deficiency symptoms were found to be alleviated with the additions of both uracil and orotic acid (2). This finding suggests very strongly that B is involved in uracil synthesis. Uracil is an essential component of RNA. If it is absent RNA containing assemblies such as ribosomes cannot be formed, thus protein synthesis is effected. Some of the most important processes in meristematic tissues are ribose formation, protein synthesis and ribonucleic acid synthesis. The entire process of meristematic growth is impaired if they are disturbed by a lack of B.

When uracil is deficient, a further essential consequence results. This N-base is the precursor of uridine diphosphate glucose (UDPG) which is an essential coenzyme in sucrose formation. Sucrose is the most important sugar transport form. If its synthesis is inhibited the translocation of assimilates formed in the leaves to other plant parts will be reduced.

CONDITIONS FOR A MOBILE ELEMENT

From results of various experiments, Oertli and Richardson (46), drew up the conditions for a mobile element.

1. It should not be chemically fixed, permanently in the leaf.
2. It should be able to leave the xylem because a back diffusion in the xylem against the transpiration stream is virtually impossible.
3. A sufficiently high concentration must be maintained in the phloem i.e., the element should not diffuse readily back into the xylem. A higher phloem concentration could be maintained by binding the element to less mobile compounds.

The lack of movement of B along with the transpiration stream also explains the fact that B deficiency always begins at the growing points. The lack of B behaves much like Ca, in that it is totally absent in phloem sap. However, plant organs such as anthers, stigma, and ovary contain high levels of B, which may be twice as high as in stems.

EFFECT OF BORON ON GROWTH OF PLANTS

Francois (14) determined the effect of excess B on tomato (*Lycopersicon esculentum* Mill.) yield, fruit size, and vegetative growth in large, outdoor sand cultures. Irrigation water containing 1.0, 4.0, 6,0, 8.0, 10.0, or 12.0 mg B/liter was applied. Relative yield was reduced 3.4% with each unit increase in soil solution above 5.7 mg B/liter. Increased B concentrations significantly reduced market quality of the fruit. Francois, (14) also reported that the occurence of leaf injury and reduction in vegetative growth were not reliable indicators for B tolerance unless the product is a leafy type vegetable. Fruit bearing crops and root crops need to be evaluated differently than leafy vegetables. He (14), found that Mg, K and P concentrations in the leaves tended to increase as the B concentration in the soil water increased, while the Ca concentration remained unchanged.

BORON TOXICITY

The symptoms of B toxicity are similar in most plants. They consist of marginal and tip chlorosis, which is quickly followed by necrosis. The pattern of chlorosis and necrosis follows the leaf veination; monocotyledons, for instance, show tip, not marginal necrosis.

In general, dicots have a higher B requirement and B content than monocots. In spite of the diversity among higher plants, the range in B concentration in water optimal for growth is very narrow; approximately 0.1 to 40 mg/liter B. Available B at levels that are only slightly above optimal are toxic to *C. pepo* (39), and may be similar for other plant species.

Research to determine the actual manner by which B is toxic to plants has been minimal. It has been assumed that toxic levels of B cause chlorosis and necrosis of leaf tissue resulting in a subsequent reduction in photosynthetic capacity. This may account for the eventual reduction in plant productivity. The results of Lovatt and Bates' (39) study were consistant with this hypothesis. An early effect of excess B, in the study done with *C. pepo* (39), was the failure of chlorophyll to accumulate at a normal rate in the developing leaves of plants treated with 40 mg/liter B (in solution). Five day old plants placed in this solution had 40% less chlorophyll in their oldest leaf than did control plants of the same age after 48 hours.

Changes in the rates of CO_2 fixation seemed less dramatic than changes in leaf chlorophyll content. After treatment for 48 hours at 40 mg/liter B a 30% reduction in CO_2 fixation occurred, well before the appearance of any visible symptoms of B toxcicity. This study suggested that roots may accumulate B to a level that is toxic to their metabolism before sufficient B has accummulated in the leaves to result in the appearance of visual B toxicity symptoms. The concurrent reductions in plant growth and CO_2 fixation suggest the possibility that the reduced rate of root and shoot growth might be due to limited availability of photosynthate.

INTERACTIONS

Observations made in connection with fertilizer experiments on B deficient soils have associated B deficiency symptoms with liming of the soil and certain other fertilizer practices. Frequently, observations have been recorded that the external symptoms of B deficiency and of calcium deficiency are strikingly similar. Suggestions have therefore been raised that the functions of B and Ca in the plant are intimately associated in the general metabolic activities (23).

Evidence also exists that K and B are closely related in their effects upon plant development, although this is not indicated by any similarity between external symptoms induced by deficiencies of these two elements.

In studies conducted by Reeve and Shive (57) and Tanaka (68), using tomato plants it was found that in soils which contain B in excess of that required for optimum growth and development, toxic effects may be reduced or prevented by the addition of Ca. In contradiction to this, when K was added, the effects of excess B became worse. (27). Therefore, at any given Ca and B level, within limits, the Ca/B ratio decreases markedly with increases in the K concentration of the nutrient substrate (57). This indicates the strong inhibitory influence which K exercises over the processes controlling the absorption and accumulation of Ca by the plant. Further explanation is provided then for the marked increase in severity of B toxicity at high B levels with increasing concentrations of K, (23). The severity of this type of injury increases in intensity as the Ca concentration in the nutrient substrate decreases. Cutcliffe et al. (8), reported that increasing rates of applied K tended to decrease leaf tissue B content in 3 crop studies.

The response of plants to B is determined by the direct and intimate relation between Ca and B in metabolism (57). Indirectly, K strongly influences the response of the plant to B by its effects on the absorption and accumulation of Ca. It is now known that the K ion, is much more active and mobile than the Ca ion. Potassium tends to retard the processes which determine the absorption and accumulation of Ca. Since the Ca ion is less active than the K ion its influence upon the absorption and accumulation of K is secondary, except perhaps at extremely high Ca concentrations.

In a study by Gupta et al. (23) with alfalfa (*Medicago sativa* L.) and cotton (*Gossypium hirsutum* L.), were observed to tolerate high B in calcareous soils. However, seperately, high Ca and high pH had no effect on B uptake (23), but together reduced B uptake. In another study, (23) using low levels of B, the addition of lime decreased B uptake, more because of its effect on soil pH than because of the increase in Ca or Mg availability. Gupta and MacLeod (22), later demonstrated that at equivalent rates of Ca, $CaCO_3$ reduced the B concentration more in plants than did $CaSO_4$. This indicates a pH rather than a Ca effect.

When soils are limed, (22) the exchangeable Al and hydroxy Al cations are replaced by Ca^{++} and $Al(OH)_3$ precipitates. It appears that the $Al(OH)_3$ and other related minerals are mainly responsible for B adsorption in limed soils. This sorbed B is still slowly available to plants.

Tanaka,(68) also reported that B uptake in radish was increased while Ca uptake was decreased when the P supply of the medium was increased. One other investigator however, (3) found no significant P-B interaction in a study with strawberries.

Gupta, et al. (21) conducted a greenhouse study with barley, (*Hordeum distichon* L.) and wheat (*Triticum aestivum* L.) grown on two mineral soils and fertilized with three levels of 7-yr-old compost combined with 4 different levels of nitrogen (N). They found that B toxicity was dependent on the amount of N used in combination with compost. The B concentrations of the tissues of the two crops increased with increasing rates of compost and decreased with increasing rates of N in the soil.

SALT TOLERANCE - ALFALFA

One of the problems at Hunter and Huntington Research Farms has been the poor germination and survival of seed because of the high salinity of the water. Salinity has stimulated a large amount of research on the effect of salt stress on germination and growth on agricultural crops, (40), (55), (64), (65), (69), (71). Robinson et al. (59) evaluated the germination speed and potential of two alfalfa cultivars, Mesa-Sira and Cycle 7 syn-1, (a population derived from Meas-Sira), as affected by various salt (NaCl) concentrations. The NaCl gradient provided a full range of responses (0% to 100%) germination for both cultivars. Salt concentration affected germination speed. The cultivars differed in their response to concentration and speed of germination with the Cycle 7 syn-1 being the most responsive the high salt concentrations.

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A P P E N D I X V I

REVEGETATION MONITORING GUIDELINES USED IN THE PREPARATION OF THE PERMIT APPLICATION PACKAGE WASTE ROCK DISPOSAL SITE CONVULSION CANYON MINE

Appendix VI

Appendix C

REVEGETATION MONITORING GUIDELINES

Introduction

These guidelines are intended to aid the applicant in formulating a monitoring plan, an essential part of a complete revegetation plan, which will meet the requirements and performance standards of UMC 784.13 (SMC 780.18) and UMC 817.116 (SMC 816.116.)

All revegetated areas, whether they are interim or permanent revegetation efforts, should be monitored. The frequency and type of sampling will depend on the purpose of the revegetation. For example, reconnaissance sampling may be sufficient for an interim reclamation project implemented solely for temporary land stabilization. Frequent, quantitative sampling may be desirable for test plots or an interim reclamation area being used to test the permanent reclamation seed mix.

Essential Elements of a Monitoring Plan

A. Schedule

The monitoring schedule should include frequency and season of monitoring. In general, monitoring should be conducted at least once during the growing season, preferably when the vegetation stand is at its peak which is usually during late June to August. In order to compare results between years, monitoring should occur on approximately the same dates each year. See Table 1 for recommended monitoring schedule.

B. Monitoring Methods and Parameters

Methods employed should be consistent from year to year. Plots or transects can be either randomly located each year, or randomly located and permanently marked with rebar or roof bolts to ensure that the same plots are measured each year. Individual plants can be permanently tagged and checked yearly to determine survival rate. Permanent plots are particularly useful for species composition and shrub survival data.

Two types of monitoring should occur, those being 'qualitative' or 'reconnaissance' surveys and 'quantitative' sampling. These are discussed in detail below.

1. Reconnaissance Survey. Visit each reclamation site and qualitatively record observations. No formal sampling or statistical analysis is necessary. However, the following observations are to be made:

    a. Note all species which are growing on the site, whether seeded (planted) or invading from surrounding areas. For years of quantitative sampling, this would also include all species observed outside of sample plots.

    b. Note whether or not grazing or browsing has occurred by wildlife or domestic animals and, if so, which species are being utilized.

    c. Note wind, water and mechanical (e.g. trampling) erosion.

    d. Record any special problem areas or unusual plant development as a result of disease, insect or pest infestations, etc. or areas of poor vegetation, due to toxic or acidic materials, lack or excess of fertilizer, etc.

    e. Note special conditions or circumstances, e.g. sampling conducted during drought year or during unusually wet year, plot disturbance by off road vehicles, etc.

2. Quantitative Sampling. Measure each specific parameter to be tested for the given year. Parameters sampled (cover, frequency, woody plant density, survival, etc.) depend on both the objective of a specific sampling period and the postmining land use of the revegetated area. See UMC 817.116 (SMC 816.116) for success standard parameters specific to postmining land uses and the Division's Vegetation Information Guidelines for descriptions of acceptable sampling methods.

C. Evaluation of Data

The monitoring plan must indicate the level at which revegetation would be deemed unsuccessful during early monitoring and would, therefore, prompt remedial action. The plan should refer to contingency or maintenance plans to correct problem areas.

The plan should describe reference areas or other standards to be used to determine revegetation success and indicate the level of statistical confidence which will be met (see the Division's Vegetation Information Guidelines).

D. Monitoring Report

The operator must include a summary of all reclamation activities as part of the annual report. This includes a monitoring report for all revegetated areas. The monitoring report should include at a minimum:

1. A map showing revegetated areas and test plots;

2. A table which identifies each revegetated area, the year it was seeded, and the seed mix, mulch, methods used, etc.;

3. An analysis of the data collected or the results of the reconnaissance survey; and

4. Recommendations to correct any problem areas.

0866R/11-14

Table 1. Recommended Monitoring Schedule.

QUALITATIVE OBSERVATIONS:

Reclamation type	YEAR 1	2	3	4	5	6	7	8	9	10
Permanent Reclamation	X	X	X	X	X	X	X	X	X	X
Trial Plantings	X	X	X	X	X	X	X	X	X	X
Test Plots	X	X	X	X	X	X	X	X	X	X
Interim Stabilization	X	X	X	X	X	X	X	X	X	X

QUANTITATIVE OBSERVATIONS:

Parameter	YEAR 1	2	3	4	5	6	7	8	9	10
Cover		X	X		X				X	X
Frequency		X	X		X				X	X
Woody Plant Density		X	X		X				X	X
Transplant Survival	X*	X	X							
Productivity:										
Test plots			X		X				X	X
All Other Revegetation**									X	X

* For spring planting, "year 1" sampling would occur in the fall of the planting year.

** For croplands, submit actual crop production each year (1-10).

Note: This schedule is for a mine with a 10-year extended liability period. For a mine with a 5-year period, years 9 and 10 sampling would occur during years 4 and 5 respectively.

STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF OIL, GAS AND MINING
4241 State Office Building
Salt Lake City, Utah 84114
(801) 533-5771

VEGETATION INFORMATION GUIDELINES FOR PERMANENT PROGRAM SUBMISSIONS FOR COAL MINES

* *

Pursuant to SMC 779.19 and UMC 783.19 Requirements

Please read these guidelines carefully and completely before initiating any vegetation studies.

These guidelines are only intended to provide a suggested format for the submittal of vegetation information to be included in the mining and reclamation plans for coal. The purpose of submitting such information is as follows:

1. To approximate and describe the condition of the land prior to mining.
2. To identify and describe important wildlife habitat in the mine plan area and the development of corresponding mitigation plans.
3. Identify and provide protection for any threatened and/or endangered species.
4. To aid in the prediction of revegetation potential for the site.
5. To establish the standards which must be utilized to measure the success of revegetation for the purpose of bond release. Standards must be set up for each vegetation type which has been or will be disturbed at the mine. Measurements must be taken to describe species composition, cover, density (of woody plants) and production.

These vegetation information guidelines have been drawn up at the request of coal operators in Utah. They may best be utilized as a checklist for the submittal of required information.

Should problems or questions arise concerning these guidelines, contact the Division of Oil, Gas and Mining.

For the purposes of vegetation studies the following definitions apply:

Baseline Data: The data collected to describe the "original" (pre-disturbed) community of a vegetation type or range site. It is collected using sound scientific methods and should meet statistical adequacy.

Composition: The species that occur in a given vegetation type. Species lists may be compiled from observations made while sampling other parameters.

Cover: The percent of ground covered by a species or life form (cover by species may and often does add up to more than 100% and is used to establish plant diversity. Total cover differs in that it cannot equal more than 100%, including cover by rock, litter, crytogams and bare ground).

Density: The number of plants per unit of area.

Normal Precipitation Year: A year where the effective precipitation is 90% of the 10-year average and within 90% of the 10-year monthly average of the last month of the effective precipitation period for the same time period. Effective precipitation is that which falls from October 1 of the previous year to the end of the month prior to sampling. (If productivity was to be sampled during July, 1982, the effective precipitation period would be from October 1, 1981 to June 30, 1982).

Productivity (Production): The amount of vegetation (dry weight) per unit of area (pound/acre or kilograms/hectare), per year.

Random Sample: A sample taken such that any point in the sample area has an equal chance of being sampled at any time during the sampling sequence.

Range Site: The concept of a site as an ecological entity based on climax plant communities; a distinctive kind of rangeland that has a certain potential for producing range plants.

Range Site Method: A way in which the rangeland is inventoried and classified, including not only vegetation, but soils, water, animal life, climate, topography, historical use, and the interrelationship of these components. The data and description should be correlated with the data compiled by the Soil Conservation Service for each range site.

Reference Area: An area that is similar to the community to be disturbed with respect to vegetation (cover, density, composition), soils, aspect, climate, and elevation that will be maintained and used as the standard for comparisons with the reclaimed "disturbed" area.

Vegetation Type: A plant community that is distinguished by its visually dominant species and should be described by not more than the two apparently dominant species.

Woody Plants: Those plants which are classified as sub-shrubs, shrubs, half-trees or trees.

There are options for vegetation studies pursuant to existing conditions of the permit area:

1. Existing mine (pre-law disturbance areas): The applicant may utilize the Reference Areas Method or the Range Sites Method for the revegetation standards.

2. Existing mine (new disturbance areas): The applicant may use the Baseline Data Method from the proposed disturbance sites provided that the operator demonstrates the data was collected during a "normal" precipitation year. Otherwise the Reference Area Method or the Range Site Method should be utilized.

3. New mines (new disturbance areas): Same as #2 above.

Follow the steps indicated for the method(s) you select to follow:

I. For the "Baseline Data" method, follow steps 1, 2, 3, 4, 9 and 10.

II. For the "Reference Area" method, follow steps 1, 2, 3, 4, 5, 6, 7, 9 and 10.

III. For the "Range Site" method, follow steps 1*, 2*, 3*, 4, 5**, 8, 9 and 10.

*See step 8-b.
**See step 8-e.

SUGGESTED STEPS IN PREPARING VEGETATION INFORMATION

1. Map the existing vegetation types found within the permit area and adjacent areas* (scale of 1:12,000 or larger UMC 771.23(e)). The use of aerial photography would be preferred, but should be ground truthed. Show the locations and boundaries of the presently disturbed areas as well as any areas proposed to be disturbed (UMC 784.23(b)(2)). Vegetation types should overlay the disturbance areas.

*Adjacent areas are those areas within 1 km. of any proposed disturbance. Map requirements may be altered on a case by case basis by contacting the Division in advance.

2. Map all potentially disturbed areas on contour maps of a scale approved by the Division, preferably at a scale of 1:2,400 (1"=200') scale or larger. Mark these maps so that referral may be made back to the permit area (1:12,000) map (see step 1).

3. Determine and list the acreage of each vegetation type to be disturbed (or areas of existing disturbance) and the total acreage of each type in the permit area. Also, note the total acreage of surface disturbance within the permit area.

   Vegetation types should be correlated with Wildlife Habitat Types and/or Wildlife Use Areas.

4. For each vegetation type which is found within any of the areas to be disturbed (new mines or new disturbance on existing mines):

a. Randomly sample the proposed disturbance area for cover (by species to establish diversity, and total cover, total cover is not to exceed 100%), density (of woody plants), and productivity[1]. For stands of trees, basal diameter measurements should be made[2]. Productivity measurements need not include the following: trees, officially designated weeds or noxious plants* and dense mountain shrub thickets. Number sample sites and show numbered sample locations on the map.

   Sampling methods should be approved <u>in advance</u> by the Division. (See Appendix 1).

   *A list of noxious plants may be obtained from the County Weed Supervisor, U.S.U. Extension Service or the District Agriculture Inspector.

---

1. For the baseline data method and range site method (when a reference area is not to be used): production measurements for <u>all</u> community types that are or will be disturbed is needed and should meet statistical adequacy. For shrubs, measure only the current year's growth. (Report production according to life form). Productivity measurements should not be taken prior to the latter part of June.

It should also be demonstrated that the year of sampling was a "normal" precipitation year; otherwise, reference areas should be used.

For reference areas (and the associated baseline data): productivity measurements are not critical until the time of comparison with the revegetated areas and do not need to meet statistical adequacy until that time. However, a statement of productivity should be supplied (preferably by the U.S. Soil Conservation Service). Reference areas should be in fair range condition or better.

2. If there is a noticeable stump swell, then the measurement should be taken immediately above the swell.

b. Demonstrate sample adequacy for cover, density (woody plants) and productivity. A minimum and maximum sample size has been established for each acceptable sampling method (see Appendix 1).

It is recommended that the formula, $\frac{t^2 s^2}{(d\bar{x})^2}$ be used, where:

t = the t value for a 2-tailed test,
(t = 1.645 for 90% confidence, t = 1.282 for 80% confidence)
s = the sample standard deviation,
d = the desired change in the mean,
x = the sample mean of the parameter in question.

Other formulae should be approved by the Division in advance.

All parameters should be tested at the 90% confidence level with a 10% change in the mean (d=.1) with the exception of shrublands (where shrubs contribute over 20% of the total cover) and forestlands when 80% confidence with a 10% change in the mean for all parameters should be met.

c. In a narrative, describe each vegetation type by visually dominant species, and describe the condition and relative stage of maturity of the vegetation type. Note any past perturbations in the area such as fire, chaining, reseeding, previous mining, cultivation, etc. Discuss any present use by wildlife or livestock.

d. List the species present within each vegetation type by common and botanical name. List the species by plant groupings, i.e., trees, shrubs, forbs, grasses, etc.

e. Identify, describe and show on the map the location of any endangered or threatened plants. Make a negative declaration if these are not found in the permit or disturbance areas.

5. For each vegetation type which was determined to have existed within the disturbed areas prior to mining:

Describe each by visually dominant species and list the major species assumed to have been present within each vegetation type by common and botanical name. List the species by life form of plant groupings, i.e., trees, shrubs, forbs, grasses, etc. Mark all disturbed or potentially disturbed areas on the map. (See step 2).

6. Indentify reference areas, preferably within the permit area, which will not be disturbed but which are of the same vegetation type as those which occurred on the areas of previous disturbance or areas of proposed disturbance. (RA's do not need to be established for types where less than 1 acre will be disturbed or where the community type will be greatly altered by an approved post-mining landuse.) Reference areas should be at least 1 acre in size unless otherwise approved by the Division in advance.

a. Sample randomly for cover, density (woody plants) and species composition.

b. Demonstrate sample adequacy. One reference area may represent more than one disturbance site if the reference area meets the requirements for each site. Labeled sites would allow for simplified referral between the maps and text. (UMC 700.5).

c. List the species present within each reference area by common and botanical name. List the species by life form or plant groupings, i.e., trees, shrubs, forbs, grasses, etc.

d. Productivity measurements on reference areas are not critical until they are compared to the revegetated areas. However, a statement of productivity (preferably a letter from the Soil Conservation Service) is necessary.

e. Mark off the proposed reference areas in the field with permanent markers so that they can be relocated.

f. Mark the location of the reference area(s) on the 1:12,000 vegetation map.

g. Reference areas should be in fair* or better range condition.

Range condition should be determined according to Soil Conservation Service guidelines.

*If the reference area is not in fair or better condition, describe management practices (i.e., fencing) that will be employed so that it is in fair or better condition when comparisons are made with the revegetated area.

7. Demonstrate by table, or other simplified format, the similarity between reference areas and areas of disturbance (or proposed disturbance)*. Similarity must be shown between:

a. Species composition (by a similarity index, see appendix 2), similarity should be 70% unless otherwise approved by the Division.

b. Density (woody plants) and total aerial cover (by a t-test).

c. Geology, soils, slope and aspect.

*See attached data summary sheet.

8. Range Site Method.

a. Range sites will be described in accordance with the Soil Conservation Service, 1975, National Range Handbook, U.S. Department of Agriculture.

b. Range sites will be mapped for the entire permit area and areas to be disturbed will be delineated separately (See steps 1, 2 and 3, substituting range site for vegetation type).

c. Range sites to be sampled will be in fair condition or better and representative of areas to be disturbed. They may be either within or outside the permit area.

d. Samples will not be taken in a year of below average precipitation.

e. Vegetative parameters to be measured will be:*

i. Cover,

ii. Density (for shrubs and/or trees as applicable),

iii. Productivity,

iv. Species composition.

*Follow the procedures outline in 5(a-f) substituting range site for vegetation type.

f. These measures (baseline data) will be considered the success standard for revegetation.

9. Upon request, submit to the Division the copies of the data sheets from the sampling of areas to be disturbed and potential reference sites.

Approval of reference areas by the Division may be obtained prior to approval of the permit application. If prior approval is desired, submittals should be made to allow time for field verification by the Division.

10. All technical data submitted in the application shall be accompanied by:

a. The names of persons or organizations which collected and analyzed such data.

b. The dates of the collection and analysis.

c. Descriptions of methodology used to collect and analyze the data (including means, standard deviations, formulae used, etc.).

d. The name, address and position of officials of each private or academic agency consulted by the applicant in preparation of the information (UMC 771.23).

SUMMARY TABLE OF SAMPLING ADEQUACY REQUIREMENTS

		Cover	Density (Woody Plants)	Productivity*
Base-line Data	Grass & Herb Lands	90% Confidence/d=.1	90%/d=.1	90%/d=.1
	Shrub & Forest Lands	80%/d=.1	80%/d=.1	80%/d=.1
Range Sites	Grass & Herbs	90%/d=.1	90%/d=.1	90%/d=.1
	Shrubs & Forest Lands	80%/d=.1	80%/d=.1	80%/d=.1
Refer-ence Areas	Grass & Herbs	90%/d=.1	90%/d=.1	A statement of productivity (preferably a letter from the SCS). RA should be in fair range condition or better.
	Shrub & Forest Lands	80%/d=.1	80%/d=.1	

*Production measurements need not include trees, officially designated weeds and noxious plants and dense mountain shrub thickets.

SUMMARY OF MAP GUIDELINES

A vegetation map of the entire permit area on a scale of 1:12,000 should be submitted if not otherwise exempted by the Division. Include sufficient adjacent areas to the permit area to allow for evaluation of wildlife habitat. The use of aerial photography taken prior to site disturbance would be most helpful in mapping the site. A 1:2,400 scale map should be submitted for areas of present or potential disturbance.

1. The 1:12,000 contour map should:

    a. Show the legal description of the permit area.

    b. Show the boundaries of the permit area.

    c. Show the location and boundaries of any surface area(s) already disturbed by mining and any which are proposed to be disturbed. Labeled sites would allow for simplified referral between the maps and text.

    d. Show the location and boundaries of proposed reference area(s). If reference areas will be located outside of the permit area, then submit a separate map for the reference area(s). Label the sites for referral to text.

    e. Show the boundaries of existing vegetation types, including riparian habitats, for the entire permit and adjacent areas.

    f. Show the locations of any threatened and/or endangered plants.

    g. Show the numbered locations of sampling sites.

2. The 1:2,400 (1" = 200'), or larger, contour map for the areas to be disturbed should:

    a. Give reference points back to the 1:12,000 map, including the legal description.

    b. Show the existing vegetation types. Label the sites for referral to text.

    c. Show the numbered locations of sampling sites.

The applicant is encouraged to arrange a meeting with the Division if any portion of these guidelines need further clarification.

REVISED March, 1982.
By Lynn M. Kunzler and Susan C. Linner, Reclamation Biologists.

DATA SUMMARY SHEET

VEGETATION TYPE: ____________________

	AFFECTED (Disturbance) AREA				REFERENCE AREA				
	$\bar{X}$	S	N	N_{min}	$\bar{X}$	S	N	N_{min}	t - value
Cover									
Density (plants/acre)									
Productivity									
Aspect									
Slope									
Soils									
Geology									

% Similarity: ____________________

$\bar{X}$ = Sample Mean

S = Sample Standard Deviation

N = Sample Size

N_{min} = Minimum Sample Size (for statistical adequacy)

Appendix 1

ACCEPTABLE METHODS FOR BASELINE VEGETATION STUDIES

Minimum and maximum sample sizes have been established for the various sampling methods below. One should select the most appropriate sampling method for the community to be sampled. Although a maximum sample size has been established, it may be to the company's advantage to meet sample adequacy, especially if sample adequacy will be met with just a few additional samples.

I. COVER

1. Occular Estimation

The preferred method is to estimate the percent of ground covered by vegetation (by species, life form, etc.) to the nearest 1 percent. Total vegetation cover should not exceed 100% (including cover by rock, litter, and bare ground). Each quadrat is considered one sampling unit.

Quadrat size and shape is not fixed, however the most use is made of either 1/4 M^2, M^2 or 20 x 50 cm, square or rectangle or a 1/4 M^2 circular plot. Select the quadrat size and shape that is best suited to the community being sampled.

Quadrats should be randomly placed within the study area.

Minimum sample size = 10
Maximum sample size = 40

2. Cover Classes

Cover classes may be used provided they are at least as small (range) as those listed below. One visually estimates the cover in a randomly placed quadrat and records it according to the class. When analyzing the data, the mid-point of each class is used to calculate the mean and standard deviation.

Cover Class	Range	Mid-Point	Cover Class	Range	Mid-Point
1 =	0-1.0%	.5%	8 =	35.1-45%	40%
2 =	1.1-3.0%	2.0%	9 =	45.1-55%	50%
3 =	3.1-5.0%	4.0%	10 =	55.1-65%	60%
4 =	5.1-10%	7.5%	11 =	65.1-75%	70%
5 =	10.1-15%	12.5%	12 =	75.1-85%	80%
6 =	15.1-25%	20.0%	13 =	85.1-95%	90%
7 =	25.1-35%	30.0%	14 =	95.1-100%	97.5%

Minimum sample size = 20
Maximum sample size = 40

3. Point Methods

This method employs a small frame with a rod (pin) that drops through the vegetation. Hits are recorded accordingly to what the pin intersects first (i.e., vegetation, litter, rock, bare ground). Transects of usually 50 points are counted as one sample unit. The location of the frame along the transect may be randomly or regularly placed. The location and orientation of the transect within the study site should be randomly placed.

Minimum sample size = 15
Maximum sample size = 50

4. Line Interception

Percent cover is obtained using the line intercept method by summing the distances of the transect that are covered by vegetation, litter, rock, bare ground. Transects are commonly 10-100m. long. Each transect is counted as one sampling unit. Transects should be randomly placed within the study area. (This method is best used in sparse, low vegetation).

Minimum sample size = 15
Maximum sample size = 50

II. DENSITY (SHRUBS AND/OR TREES)

1. For Semi-Dense to Dense Stands

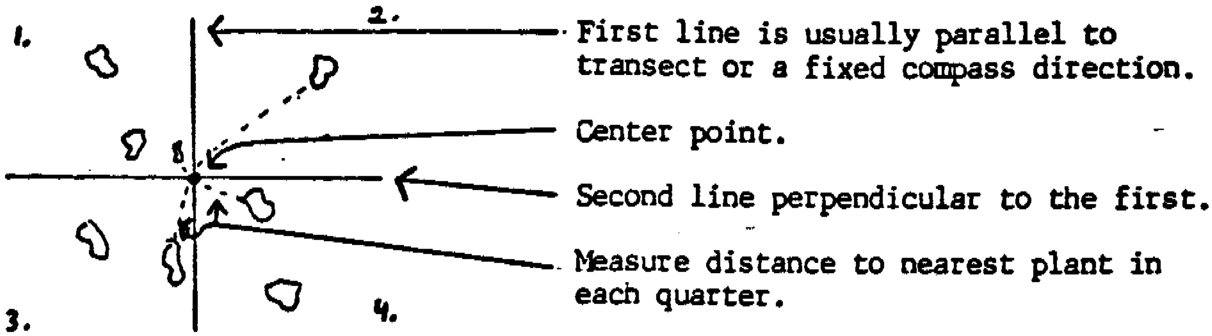
The point-quarter method as described by Cottom and Curtis (1956) is usually the preferred method.

At each point, two lines are made to divide the area into four quarters (see diagram) with the point being the center. Then, the distance from the point to the nearest plant in each quarter is measured and recorded. To determine the density, sum the 4 distances measured at each point and divide by 4. This mean distance is then squared to give the mean area per plant (this is done for each sampling point). To determine plants per acre, sum the mean area per plant of each point and divide by the number of points sampled, then divide 43,560 by this number (formulas summarized below).

Points may be randomly located in the stand or along randomly located transects.

Minimum sample size = 10
Maximum sample size = 40

DIAGRAM NO. 1



Formula:

For each point $\left(\frac{Y1 + Y2 + Y3 + Y4}{4}\right)^2 = Aj$

$$\text{Density} = 43,560 \div \frac{\Sigma Aj}{n}$$

Where: Yi = measurement from point to nearest plant in the ith quarter.

Aj = mean area/plant at the jth point.

n = sample size (number of points sampled).

Density = plants/acre.

Reference: G. Cottam and J.T. Curtis, 1956. The Use of Distance Measures in Phytosociological Sampling. Ecology 37(3):451-460.

2. For Low Density Areas

Belt transects or plots are randomly placed in the stand and the number of plants that are rooted in each plot are counted. The size of the plot is not fixed, however, those sizes commonly used are: 5'-10' x 100', 1/10 acre, 1-5m x 50m. Each plot is counted as one sample unit. Select the plot size that is best suited to the community being sampled.

To obtain the number of plants/acre, multiply the number of plants counted in the plot by 43,560 and divide the product by the size of the plot (in square feet).

Minimum sample size = 15
Maximum sample size = 40

3. For Extremely Small Stands (Usually Less than 1 Acre) or Very Low Density Areas

An exact count may be preferred as the use of an exact count is not subject to statistical tests of sample adequacy.

III. PRODUCTIVITY MEASUREMENTS

1. Exclosures:

The use of exclosures for productivity measurements is optional where domestic livestock will not be in the study area prior to sampling. If livestock are to be in the study area prior to sampling, then exclosures should be used.

When used, exclosures should be large enough to prevent animals from reaching through and grazing on the plot to be sampled. Exclosures should be randomly placed and anchored to the ground, before the growing season begins. It is recommended that the number of exclosures located in the field equal the maximum number of samples required for the method which is used even though when sampling occurs some exclosures may not be sampled because sample adequacy was met with fewer samples. Exclosures should be numbered in the order of the random numbers generated for their placement. Sampling should follow the number sequence until sample adequacy is met or all exclosures have been sampled.

2. For the Range Site Method and Reference Area Method:

It is prefered that the Soil Conservation Service be contacted to estimate productivity and evaluate range condition. Their signed statement will be sufficient for the pre-mining inventory for production.

3. Clippping

Select the quadrat size that is best suited to the community being sampled.

Randomly locate the quadrat and clip plants by life form (e.g. grass and grasslike, forbs, sub-shrubs, and shrubs). For grasses and forbs, clip all standing biomass; for shrubs, clip only current year's growth.

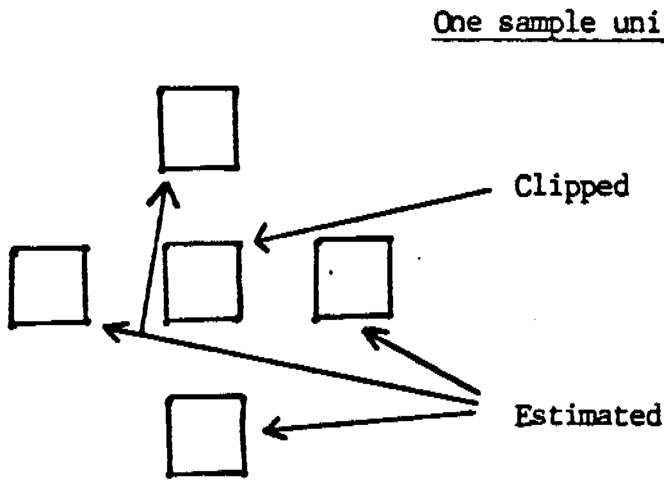
Oven dry samples and weigh to the nearest .1 gram for sample adequacy, use the combined weight of each life form at each plot. Report productivity as pounds/acre or kilograms/hectare.

Minimum sample size = 10 quadrats.
Maximum sample size = 40 quadrats.

4. Double Sampling

Select the quadrat size that is best suited to the community being sampled. 2-4 quadrats are clustered regularly around a central, randomly located quadrat. The center quadrat is clipped by life form and the "clustered quadrats are estimated (by percent) based on the clipped plot (it is necessary to estimate the other quadrats before the central quadrat is clipped). For testing purposes, each cluster is counted as one sample unit. Report productivity as pounds/acre or kilograms/hectare.

Minimum sample size = 10
Maximum sample size = 40



Appendix II

ACCEPTABLE SIMILARITY AND DIVERSITY INDICIES

A. Similarity Indicies

1. Jaccard's Community Coefficient

$$\frac{\text{common species}}{\text{total species}} \times 100 \text{ or I.S.} = \frac{c}{a + b - c} \times 100$$

Where: I.S. = Index of similarity
a = Total number of species in community a
b = Total number of species in community b
c = Number of species common to both communities

REFERENCE: Jaccard P. 1912. The Distribution of the Flora of the Alpine Zone. New Phytologist 11:37-50.

2. Ruzicka's Index of Quantitative Similarity*

$$\text{I.S.} = \frac{\Sigma \text{min}}{\Sigma \text{max}} \times 100$$

Where: ΣMin = Minimum values for any species in the two communities (zero is possible)

ΣMax = Maximum values for any species in the two communities

REFERENCE: Ruzicka, M. 1958. Anuendung Mathematisch - Statisticher Methoden in Der Geobotanik (Synthetische Bearbeitung von Aufnahmen). Biologia, Bratisl. 13:647-661.

3. Sorensen's Similarity Index

$$\text{I.S.} = \frac{2C}{A + B} \times 100$$

Where: A = Total number of species in community A
B = Total number of species in community B
C = Total number of species common to both communities

REFERENCE: Sorensen, T. 1948. A Method of Establishing Groups of Equal Amplitude in Plant Sociology Based on Similarity of Species Content. Det Kong. Danske Vidensk. Selsk. Biol. Skr. (Copenhagen) 5:1-34.

*One must have quantitative data (i.e., frequency, cover by species, etc.) to use this index.

B. Diversity Index

1. Shannon - Wiener Index

$$H' = \sum Pi \log Pi$$

Where: H' = Diversity measure

$Pi = \frac{Ni}{N}$

Ni = Cover value of species i

N = The sum of all species cover values.

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SUBMITTAL OF EXPERIMENTAL PRACTICE

FOR RECLAMATION FOR CONVULSION CANYON MINE

ACT/041/002, No. 2, No. 3, & No. 14

Sevier County, Nevada

SHB Job No. E83-2022

Consulting Geotechnical Engineers

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LAWRENCE A. HANSEN, PH.D., P.E.
RALPH E. WEEKS, P.G.
DARREL L. BUFFINGTON, P.E.
DONALD VAN BUSKIRK, P.G.
JOHN B. HAUSKINS, P.E.
DALE V. BEDENKOP, P.E.
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ROBERT W. CROSSLEY, P.E.
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JONATHAN A. CRYSTAL, P.E.
ROBERT D. BOOTH, P.E.
NORMAN H. WETZ, P.E.
ROBERT L. FREW
ALLON C. OWEN, JR., P.E.

December 6, 1985

Southern Utah Fuel Company
South Highway 89
Salina, Utah 84654

SHB Job No. E83-2022

Attention: Mr. Wesley K. Sorenson
Chief Engineer

RECEIVED
DEC 23 1985
DIVISION OF OIL GAS & MINING

Re: Submittal of Experimental Practice for Reclamation for Convulsion Canyon Mine, ACT/041/002, No. 2, No. 3 & No. 14
Sevier County, Utah

Gentlemen:

Enclosed herewith is our Submittal of Experimental Practice for the Reclamation Plan of the referenced project. The report includes the results of test drilling, laboratory analysis and recommendations for reclamation.

Should any questions arise concerning this report, we would be pleased to discuss them with you.

Respectfully submitted,

Sergent, Hauskins & Beckwith Engineers

By ____________________
Paul Kaplan, E.I.T.

Reviewed by ____________________
Allon C. Owen, P.E.

Copies: Addressee (2)

REPLY TO: 3940 W. CLARENDON, PHOENIX, ARIZONA 85019

PHOENIX (602) 272-6848 | ALBUQUERQUE (505) 884-0950 | SANTA FE (505) 471-7836 | SALT LAKE CITY (801) 266-0720 | EL PASO (915) 778-3369

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SHB Job No. E83-2022

1. INTRODUCTION

This report is submitted pursuant to a geotechnical investigation made by this firm of the canyon fill which has been placed at the portals of the Southern Utah Fuel Company, Convulsion Canyon Mine. The objective of this investigation was to evaluate the physical properties of the fill in order to provide recommendations for the design of various earthwork elements of the reclamation plan, and the location of erosion resistant bedrock units for the placement of drainage channels.

2. PROJECT BACKGROUND

The originally proposed reclamation plan consisted of regrading the disturbed area to establish a main stream channel and small side slope drainage channels. The main stream channel would have been constructed through the center of the mine site to facilitate precipitation runoff from all contributing drainage basins. Construction of the main channel could have required cuts in the existing canyon fill with 2:1 (horizontal to vertical) side slopes.

The materials from these cuts would have been placed in compacted lifts on the sides of the canyon within the mine permit area.

Design of the main channel presented unique problems due to relatively deep cuts and protection of the loose, end-dumped canyon fill as well as the very steep channel gradients which exist.

The reaches of Mud Spring Hollow and East Spring Hollow above the mining area are characterized by steep gradients, waterfalls, pools, large boulders, exposed bedrock ledges and reaches of mild slopes underlain with sand and gravel alluvium.

Within the disturbed reaches, there was likely a similar regime. The natural channel would have dropped 219 feet of elevation in 1,540 feet in length, for an average gradient of 14 percent. The canyon fill has modified the channel by flattening the upper reaches and steepening the lower reaches, and also by covering up any natural waterfalls and pools.

An attempt to assimilate the bedrock environment of the natural channel was proposed in the original submittal using grouted riprap on the steep reaches with a stilling pool at the bottom of the disturbed area (SHB; April, 1984). This proposal was rejected by regulatory agencies due to possible maintenance problems. The agencies, at that time, indicated to SUFCO that only unreinforced riprap would be suitable for a long-term reclamation project.

Based on this information, a triple-layered, boulder-size riprap was recommended (SHB; May, 1984). Subsequent to receiving this design alternative, the regulatory agencies determined that gabion-lined drop structures would be a preferable alternative to the triple-layered riprap design.

The design was then modified to include gabion-lined drop structures to break up the steep gradients and dissipate energy by use of waterfalls and stilling ponds with riprap utilized for reaches between the drop structures (SHB; January, 1985). Subsequent to receipt of this design option, regulatory agencies determined that the gradients in the lower reaches of the main channel were too steep and it would be preferable to place these reaches on bedrock.

This requirement would have necessitated large quantities of fill removal with a very limited amount of area to place the material. It was then proposed to steepen the cut slopes to minimize excavation quantities. In order to steepen the cut slopes and to evaluate the stability of these slopes, a geotechnical investigation was performed to assess the engineering properties of the existing canyon fill. The remainder of this report addresses the geotechnical investigation and subsequent analyses performed which resulted in the reclamation plan presented in this report.

The conceptual design of this reclamation plan was discussed in a meeting held at the Salt Lake City

Division of Oil, Gas and Mining offices on October 8, 1985. The meeting was attended by representatives of the Division of Oil, Gas and Mining (DOGM), Office of Surface Mining (OSM), United States Forest Service (USFS), Southern Utah Fuel Company (SUFCO) and Sergent, Hauskins & Beckwith Engineers (SHB).

3. INVESTIGATION

3.1 Geologic Reconnaissance & Mapping

A field investigation of the surface geology and geomorphology of the site area was undertaken in order to characterize pre-mine drainage patterns, to locate the limits of the fill and to locate erosion resistant bedrock units. This investigation included a study of available topographic maps and aerial photographs of the site before and after mine development.

3.2 Subsurface Investigation

A total of six exploratory borings were drilled through the canyon fill in the vicinity of the originally proposed main channel alignment. These 6 5/8-inch diameter hollow stem auger borings ranged in depth from 30 to 90 feet below the existing ground surface. All borings were advanced to bedrock or auger refusal in bedrock.

Standard penetration testing or Shelby tube sampling were performed at 5-foot intervals or less in these borings.

The locations of the borings are shown on the site plan (Plate 1), included in the map pocket at the end of this report.

All soils were classified by the Unified Soil Classification System (ASTM D2487) which is summarized in Appendix A. Terminology and coding used in the description of rock is also presented in Appendix A, along with the boring logs and a short description of drilling methods employed.

All borings were backfilled with cuttings subsequent to drilling.

3.3 Laboratory Analysis

To aid in the classification of the materials encountered, determinations of grain-size distribution and Atterberg Limits and chemical tests were performed on standard penetration and tube samples. Moisture content and dry density tests were also performed on selected samples.

Direct shear tests were performed on selected tube samples of the materials encountered.

Results of dry density and moisture content determinations are presented on the boring logs in Appendix A. Results of the other laboratory tests are presented in Appendix B.

4. SITE CONDITIONS & GEOTECHNICAL PROFILE

4.1 Topography & Surface Features

The surface facilities of the mine are situated in a narrow, steeply-sloped canyon which runs from north to south into Convulsion Canyon, a tributary to Quitchupah Creek. The steep canyon walls are made up of units of the Blackhawk Formation which are interbedded cliff formers and slope formers. The cliff formers are primarily sandstones and siltstones, and the slope formers are primarily mudstones and shales. In order to accomodate the surface facilities at the mine portals, a pad was constructed by excavating material from the canyon walls and placing the material in the bottom of the canyon. High cuts exist in the canyon walls along the pad where materials were excavated to form the canyon fill. Several of the surface mine structures were placed on sandstone benches created by the excavation. The culvert, which currently conveys canyon runoff flows past the fill, is placed on a sandstone ledge beneath the fill. The fill area is used primarily for coal stacking and loading. The approximate limits of the fill, the locations of sandstone ledges and other select surface features are presented on Plate 2.

The southern face of the fill is presently over 130 feet high with a slope of 1.4:1 (horizontal to vertical). Utilizing information gathered during the field exploration program, a series of cross sections were prepared to allow an estimate of the location of the original stream channel and bedrock surface. The location of these cross sections are shown on Plate 1 and the cross sections are presented in Appendix C.

The undisturbed canyon exposures indicate steep canyon walls with slopes on the order of 2:1 (horizontal to vertical) or steeper. Extrapolation of cross sections by correlating boring logs and undisturbed canyon slopes indicates irregular, steep natural stream gradients with the probable existence of waterfalls and pools. Estimated average natural stream gradients are presented below:

Location	Estimated Average Stream Gradient
Boring 5 to Boring 4	11%
Boring 4 to Boring 3	4%
Boring 3 to Boring 2	33%
Boring 2 to Boring 6	14%
Boring 6 to Sediment Pond	21%

The toe of the fill is near the contact of the Blackhawk Formation and the Starpoint Sandstone which is a silty mudstone, cemented with lime and gypsum. A sediment pond just downstream of the fill is keyed into the Starpoint Sandstone.

4.2 Description of Soils & Rocks

The existing canyon fill consists of a heterogenous mixture of materials which was placed by dozers and end-dumped by mine haulage trucks. The fill consists of highly variable units of clay, silt, sand, gravel, cobbles and boulders. The fill is underlain by the Blackhawk Formation.

The character of the fill materials encountered above the bedrock surface in the exploratory borings is highly variable as would be expected in a fill of this type. Silty clays, sandy clays, sandy silts and silty sands are the predominant materials encountered. Varying amounts of gravels, cobbles and boulders were present in most of these materials. Lenses of coal as well as signs of wood and metal chips were also encountered in some of the borings.

In general, the borings encountered interbedded coarse to fine gravels, sand, silt and clay of varying amounts, with signs of construction debris and coal lenses. The materials are generally well stratified and their composition may vary considerably from one layer to the next and also within layers. Frequent unpredictable changes of materials are present within the fill due to the methods employed during placement.

Most of the materials encountered during the exploratory drilling program were in a slightly moist to moist condition. However, some materials encountered in Borings 5 and 6 were in a very moist condition.

The fine grained soils encountered are, in general, moderately firm to firm, while the granular materials are generally firm to hard. However, softer layers or lenses may be present near surface and at depth (see logs of Borings 5 and 6 for examples).

Just above the bedrock surface in Borings 1, 3, 4, 5 and 6, apparent stream alluvium was encountered. These materials consisted of subrounded to rounded, nonplastic sands and gravels.

Bedrock encountered in the borings is similar to that which is exposed in natural exposures at the site and is classified as the Blackhawk Formation.

4.3 Groundwater & Soil Moisture Conditions

Although some of the fill materials were in very moist condition, no free groundwater was encountered in any of the borings. Some discontinous zones of perched groundwater may be encountered at depth due to spring activity.

4.4 Existing Drainage System

Runoff originating upstream of the fill is presently conveyed past the fill in a corrugated metal culvert.

Runoff originating on the canyon walls above the site and on the pad area is drained to a sediment control pond near the toe of the fill through ditches and culverts. All of the runoff is returned to the natural stream after passing through a boulder-lined pond near the boundary of the disturbed area as shown on Plate 2.

5. DISCUSSIONS & RECOMMENDATIONS FOR A FINAL RECLAMATION PLAN

Final recommendations for channel location and design, as well as site grading and other elements of the project are presented in this section.

5.1 Discussion

As outlined in Section 2, the purpose of this portion of the reclamation plan is to recommend the placement of the fill in a stable condition and to recommend conveyance schemes of precipitation runoff which control erosion.

Major features of the plan are shown on Plate 2. The culverts will be removed and flows from Mud Spring Hollow and East Spring Hollow will be directed into a channel excavated in a bedrock bench along the east side of the fill. Downstream of the fill the flow will be allowed to cascade down the canyon wall to approximately the natural stream bed and into the existing stilling basin.

The Starpoint Sandstone will underly the basin and the reaches of the channel downstream of the fill.

Runoff from the canyon walls will be diverted into collection ditches and conveyed to the main channel in a controlled manner. Runoff originating on the fill will drain to either the main channel or the west side collector channel. Provisions for erosion control on the fill will be discussed later.

5.2 Hydrology

There is approximately 8 square miles of contributing drainage basin area to the mine site. The two major basins, Mud Spring Hollow and East Spring Canyon, are located upstream from the mine and account for 99 percent of the contributing basin area. Two small basins, contributing basin east (CBE) and contributing basin west (CBW), are adjacent to the mine site.

Hydrologic calculations for the 10, 25 and 100-year, 24-hour precipitation events were performed by Merrick & Company (1979). Table 1 summarizes peak rainfall accumulations and discharges for each frequency event.

5.3 Design Analysis

5.3.1 Analysis of Slope Stability of Cut Slopes in Existing Fill

An alternative concept considered in this

TABLE 1

Summary of Peak Rainfal
Accumulation and Discharge
for Each Contributing Basin

Event, Year	Rainfall, Inches	Drainage Basin Discharge, cfs			
		MSH	ESC	CBE	CBW
10	1.88	147	247	5.5	9.5
25	2.25	245	412	9.3	15.8
100	2.87	453	761	17.1	29.3

MSH - Mud Spring Hollow

ESC - East Spring Canyon

CBE - Contributing Basin East

CBW - Contributing Basin West

Note: The combined 100-year peak flow used in design is 1,250 cfs investigation was to excavate through the fill and reconstruct the original stream channel. This would require cuts in excess of 100 feet in depth through the existing canyon fill.

A stability analysis was performed on the maximum fill cross section (Borings 1 and 6) which is located near the lower reaches of the channel.

The stability analysis was conducted using the computer program STABL2 developed by Siegel (1975). Determination of the factor of safety against failure utilizes a conventional method of slices approach with the modified Bishop method of analysis. The particular procedure employed generates circular-shaped slip surfaces between specified coordinate limits. The factor of safety computed by this method is conservative relative to solutions obtained by more accurate methods satisfying complete equilibrium.

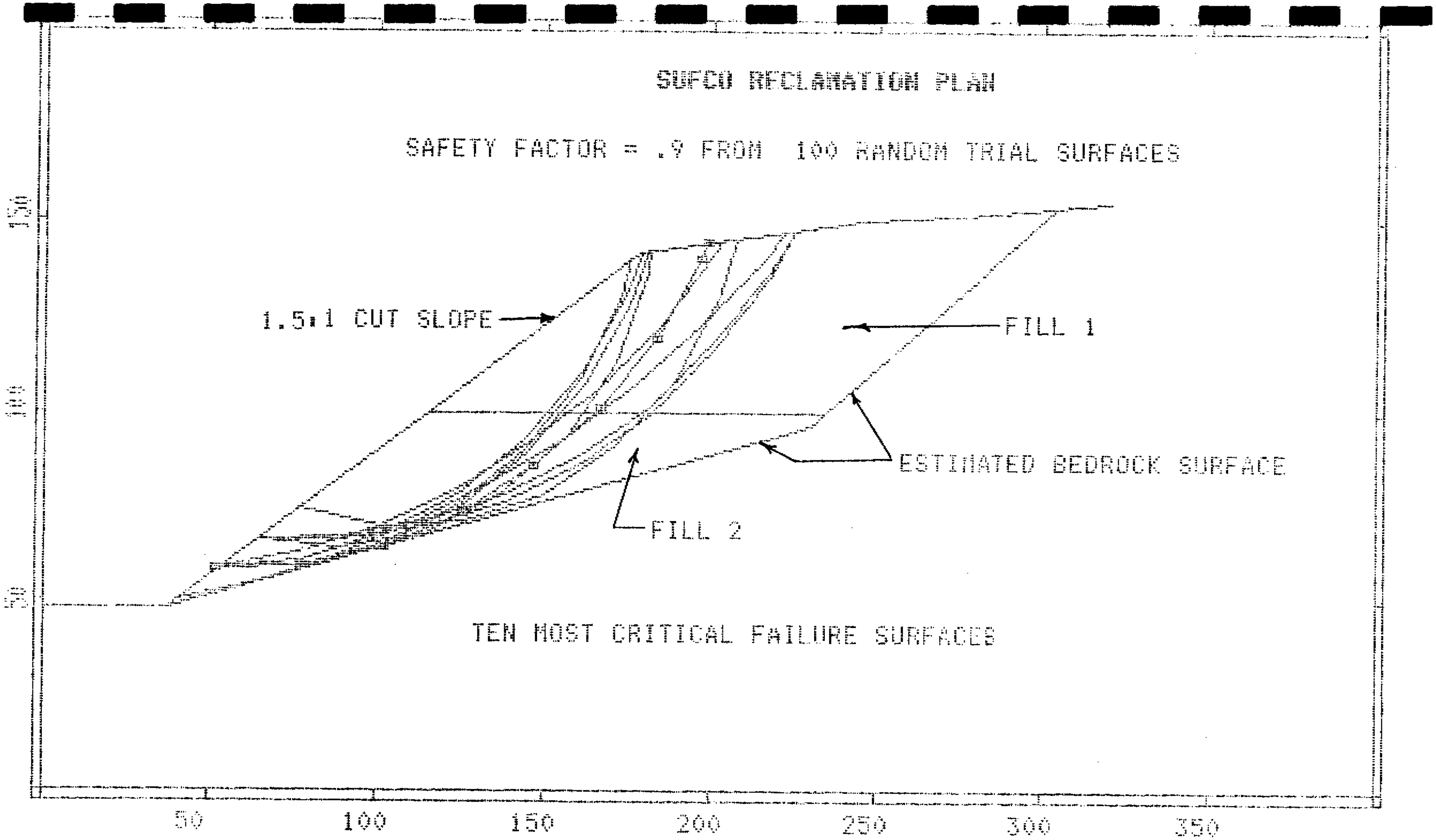
The existing canyon fill is underlain by the Blackhawk Formation. All critical shear surface search routines were directed to locate a surface above the Blackhawk Formation in the fill material.

Strength parameters for the fill materials were based upon the results of laboratory testing and engineering judgement. Due to very moist soil conditions and low shear strength materials encountered at depth in Boring 6, the fill was divided into two soil layers. Two cut slopes of 1.5:1 and 2:1 (horizontal to vertical) were analyzed. Minimum factors of safety equal to 0.9 and 1.23 were calculated for 1.5:1 and 2:1 slopes, respectively. The results of this analysis are presented in Figures 1 and 2. These low factors of safety are primarily due to the steep bedrock canyon walls which act as a plane of weakness along which the most critical failure surfaces follow. Due to these low factors of safety, it is recommended that deep cuts in this material be avoided. Slopes could be flattened to achieve a minimum factor of safety of 1.5, however, this would entail the removal of essentially all of the existing canyon fill. Due to the narrow area available for placement of excavated materials and the resulting environmental impact of this option, this alternative does not appear to be practical.

5.3.2 Analysis of Slope Stability of Existing Southern Slope

As stated in Section 4.1, the southern face of the existing canyon fill is presently over 130 feet height at a slope of approximately 1.4:1 (horizontal to vertical). This slope has been in its present condition for approximately 7 years and appears to be stable.

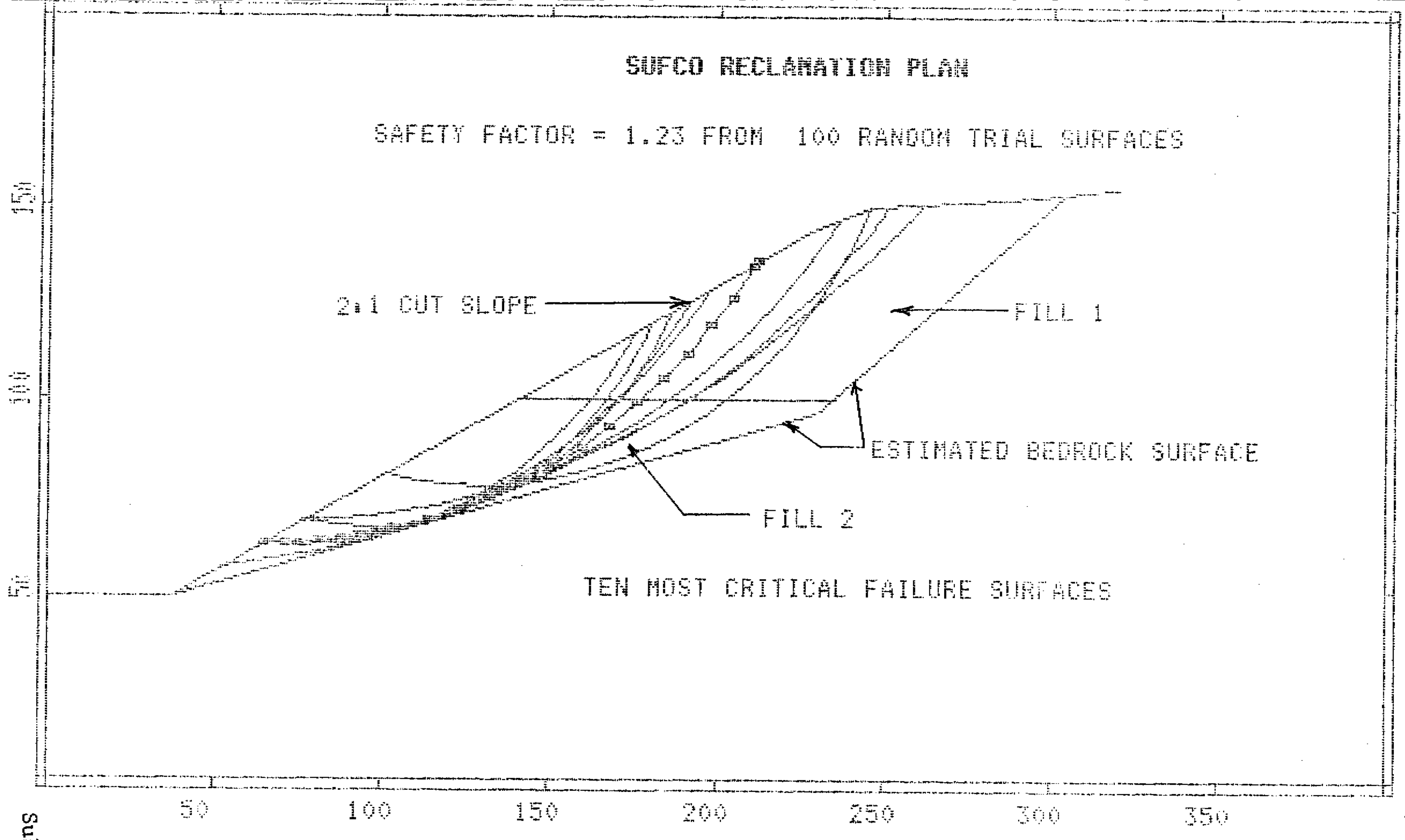
Subsurface profiles in this area were estimated from available borehole data near the exposed slope. The



Fill 1 γ = 120 pcf
c = 500 psf
ϕ = 30°

Fill 2 γ = 110 pcf
c = 350 psf
ϕ = 13.5°

FIGURE 1



Fill 1 γ = 120 pcf
c = 500 psf
ϕ = 30°

Fill γ = 110 pcf
c = 350 psf
ϕ = 13.5°

FIGURE 2

Submittal of Experimental Practice
for Reclamation for Convulsion
Canyon Mine, ACT/041/002, No. 2,
No. 3 & No. 14
Sevier County, Utah
SHB Job No. E83-2022

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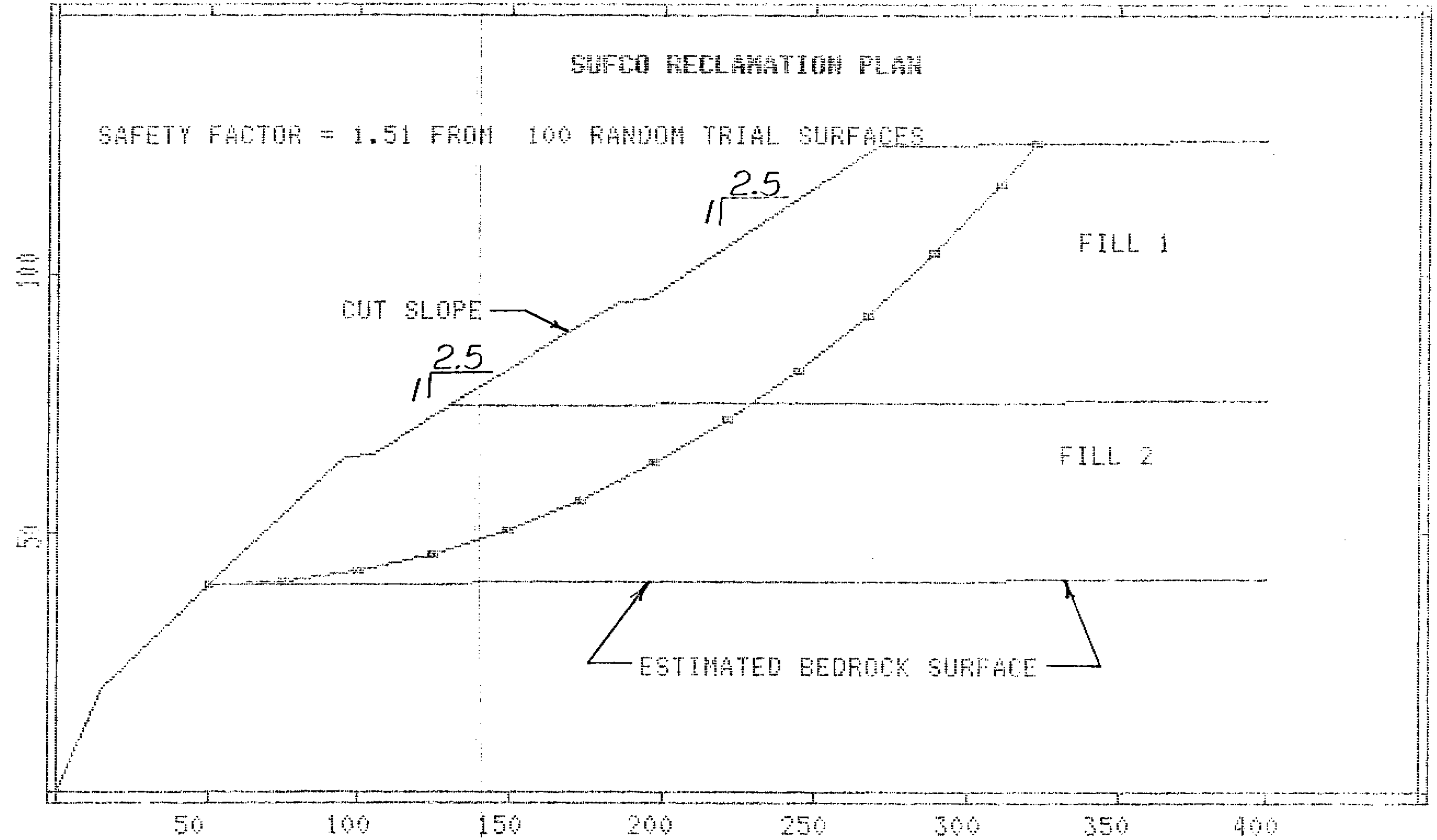
fill was modeled as a layered system as was done in Section 5.3.1. Strength parameters utilized in this analysis were the same as those utilized previously. An attempt to verify these strength paramenters was made by evaluating the existing slope. The factor of safety resulting from this analysis was equal to 1.0. This result seems reasonable since the existing slope was placed by end-dumping materials resulting in a slope at the angle of repose. The factor of safety of the existing slope is probably somewhat greater than one due to compression of the fill and aging effects. Therefore, based upon these results, the shear strength parameters utilized in these analyses may be somewhat conservative, however, they seem justified.

In order to increase the long-term stability of this slope, is is proposed the slope be cut back to a flatter angle. The grading plan consists of regrading the existing slope to a 2.5:1 (horizontal to vertical) slope with 10 foot benches on 80 centers. A typical cross-section of the regraded slope is presented in Appendix E, Section D-D'. The results of the slope stability analysis as presented on Figure 3 yielded a minimum factor of safety equal to 1.51.

The minimum allowable safety factor for long-term static conditions, as given by the Office of Surface Mining Reclamation and Enforcement, Department of the Interior (1979), is 1.5. The regraded slope has a safety factor in excess of this regulation.



Fill 1 γ = 120 pcf
c = 500 psf
ϕ = 30°

Fill 2 γ = 110 pcf
c = 350 psf
ϕ = 13.5°

FIGURE 3

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Canyon Mine, ACT/041/002, No. 2,
for Reclamation for Convulsion
Submittal of Experimental Practice

A factor which could reduce the factor of safety of the existing slope would be the presence of a phreatic surface within the mine spoil materials embankment. Since no groundwater was encountered in the borings and considering meteorological conditions at the site along with the interception of surface waters by collection ditches, the creation of a perched groundwater system in the existing mine spoil embankment appears to be remote.

5.3.3 Analysis of Slope Stability of Compacted Fills

The upper levels of the existing canyon fill consists predominantly of a silty sand and gravel mixture. This material was assigned the following strength parameters: cohesion, c, of zero and a friction angle, ϕ , of 35 degrees. The in-situ materials consist of a thin cover of silty sand and clay underlain by the Blackhawk Formation. A slope stability analysis was performed with all critical shear surfaces directed to locate a surface above this formation in the fill materials. The most critical surface, as shown on Figure 4, yielded a minimum factor of safety equal to 2.0.

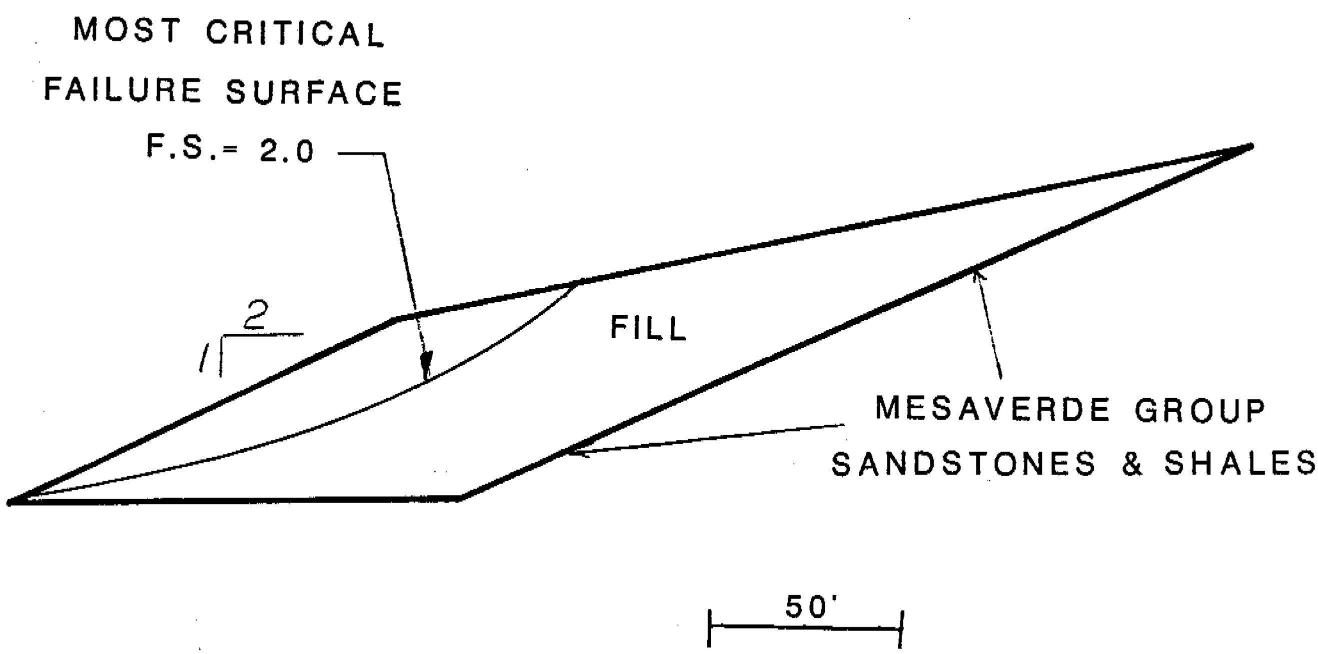
5.3.4 Hydraulic Design of Drainage Channels

5.3.4.1 Design of Main Channel

Due to many technical problems and regulatory agency concerns with placing the main channel over the

FIGURE 4

MAXIMUM FILL CROSS SECTION USED FOR STABILITY ANALYSIS



FILL

MOIST UNIT WEIGHT = 128 PCF

FRICTION ANGLE = 35

C = 0

fill, and since it is not feasible to excavate through the fill to re-establish the original regime, another alternative drainage system was designed. The alternative design involves diverting runoff from Mud Spring Hollow and East Spring Hollow into a channel excavated in bedrock along the east side of the existing fill as shown on Plate 2.

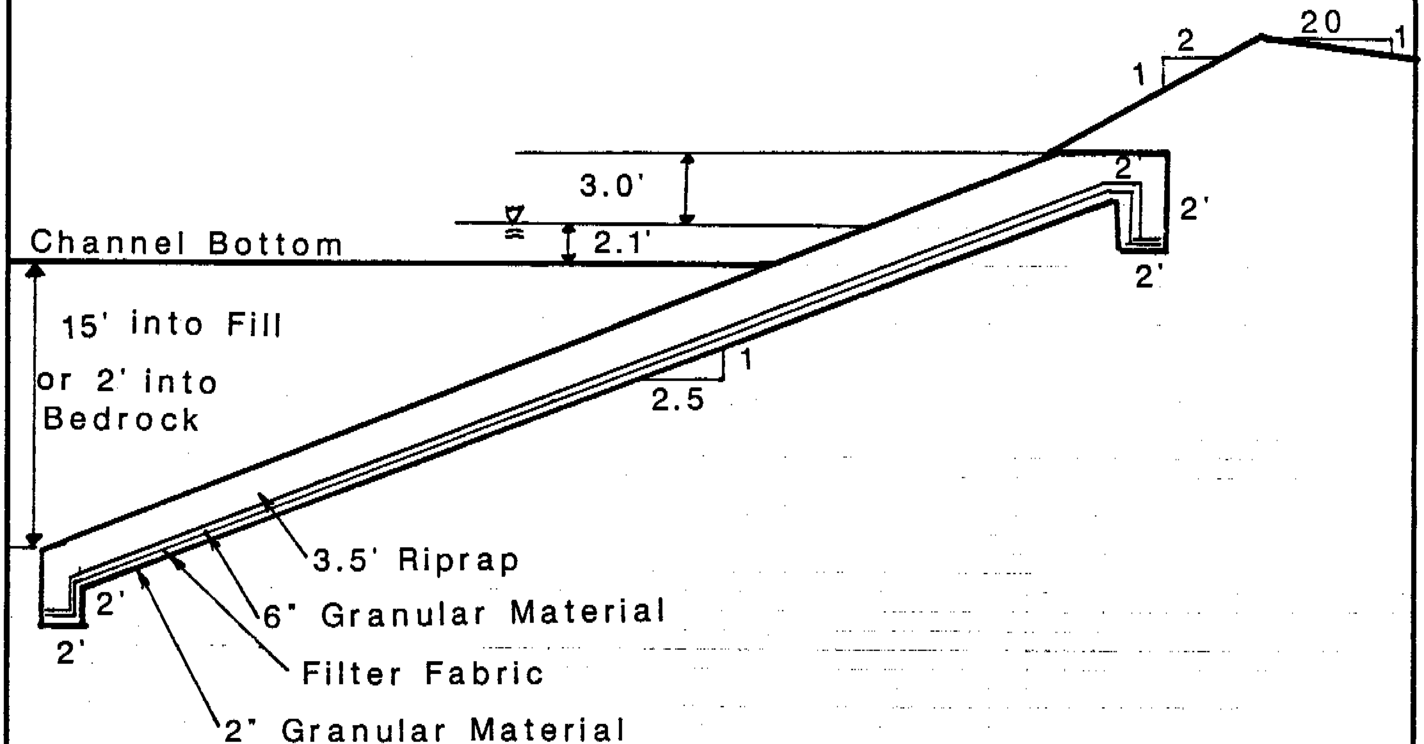
Deposition is anticipated to occur where Mud Spring Hollow and East Spring Hollow enter the excavated channel due to the abrupt change in gradients. The upstream gradients are 12 to 17 percent and the gradients in the excavated channel along the fill vary from 0.63 to 7 percent. Therefore, an inlet section identified on Plate 2 as Reach 1, was sized to provide for sediment accumulation. This transition section will direct the flows from the two natural channels to the rock-seated channel. The flows in Reach 1 will cross the upper portion of the fill, which is to be protected from scour with a riprap reinforced channel bank on the downstream side as shown in Figure 5. The channel floor should not have to be protected because the rock bottomed channel downstream of this section will control erosion depths.

? WHAT ABOUT SCOUR TO ERODE LATERALLY?

From the inlet section, the flow enters a trapezoidal rock channel. Reaches 2, 3 and 4 approximately follow the contour of the rock-fill interface and parallel the existing corrugated metal culvert which will be removed during reclamation.

FIGURE 5

REINFORCED BANK FOR CHANNEL CROSSING FILL



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Reaches 5 and 6 will convey the flow over rock ledges, down the steep canyon walls to approximately the natural channel identified as Reaches 7 and 8. The existing sedimentation pond dam and spillway will be partially removed to bedrock to create the lower two reaches.

Directly downstream of the existing spillway is a stilling basin which will be left in place. Since this basin presently handles the flow from the pond and culvert, it should continue to provide a satisfactory transition to the natural channel below the boundary of disturbed land.

Channel geometry and slopes are listed in Table 2. Calculations for design are presented Appendix D.

5.3.4.2 Hydraulics of the Stilling Pond

The existing pond is about 20 feet long by 30 feet wide by 3 feet deep and is formed in bedrock with a layer of large boulders. The downstream crest of the pond acts as a weir spillway for most flows with a weir length of about 40 feet.

Design flow would enter the pond at a depth of about 2 feet and a velocity of about 31 fps.

TABLE 2

Slope Velocity, Flow Depth, & Channel Depth in
Each Main Channel Reach for Design Peak Flow

Channel Reach	Bed Gradient	Velocity (fps)	Depth of Flow (feet)	Channel Depth (feet)
1	.025	16.9	3.18	7.0
2	.050	18.21	3.30	5.5
3	.070	20.07	3.03	5.5
4	.0063	8.69	6.10	8.5
5	.70	43.03	1.53	4.7
6	.53	39.41	1.66	4.7
7	.26	31.00	2.06	4.0
8	.25	30.60	2.09	4.0

Reach 1 is a transition section characterized by a sediment storage area with a reinforced embankment protecting the fill.

Reaches 2-4, 7 & 8 are trapezoidal sections with bottom widths of 17.5 feet and side slopes of 1:1. Reaches 5 & 6 have bottom widths of 10.0 feet and side slopes of 0.75:1. Hydraulic characteristics were calculated with Manning's equation using a roughness coefficient of 0.035.

The existing channel for 100 feet downstream of the pond narrows from about 40 feet wide to 15 feet wide with a gradient varying from 20 percent to 29 percent.

A profile of Reach 8, the stilling pond and the transition to the undisturbed channel, is presented in Figure 6. The flow will remain supercritical throughout the profile, with stream gradients varying from 14 percent to 30 percent. The pond will apparently have little impact on the energy of the design flow as it enters the undisturbed stream. However, the undisturbed stream is characterized by steep gradients and shallow coarse grained alluvium for several hundred feet downstream of the reclamation project so that degradation should not be more severe than historic conditions.

5.3.4.3 Design of the West Collector Channel

For the contributing basin on the west side of the existing mine site, there are six poorly developed channels draining runoff down the steep canyon wall. The design flow for each of these channels was taken as 5 cfs, assuming all flow occurs as stream flow as opposed to overland flow. A collector channel excavated in rock will intercept runoff from the canyon walls upstream of the fill as shown on Plate 2. Recommended dimensions for each channel reach are given in Table 3. The reaches referred to are labeled on Plate 2.

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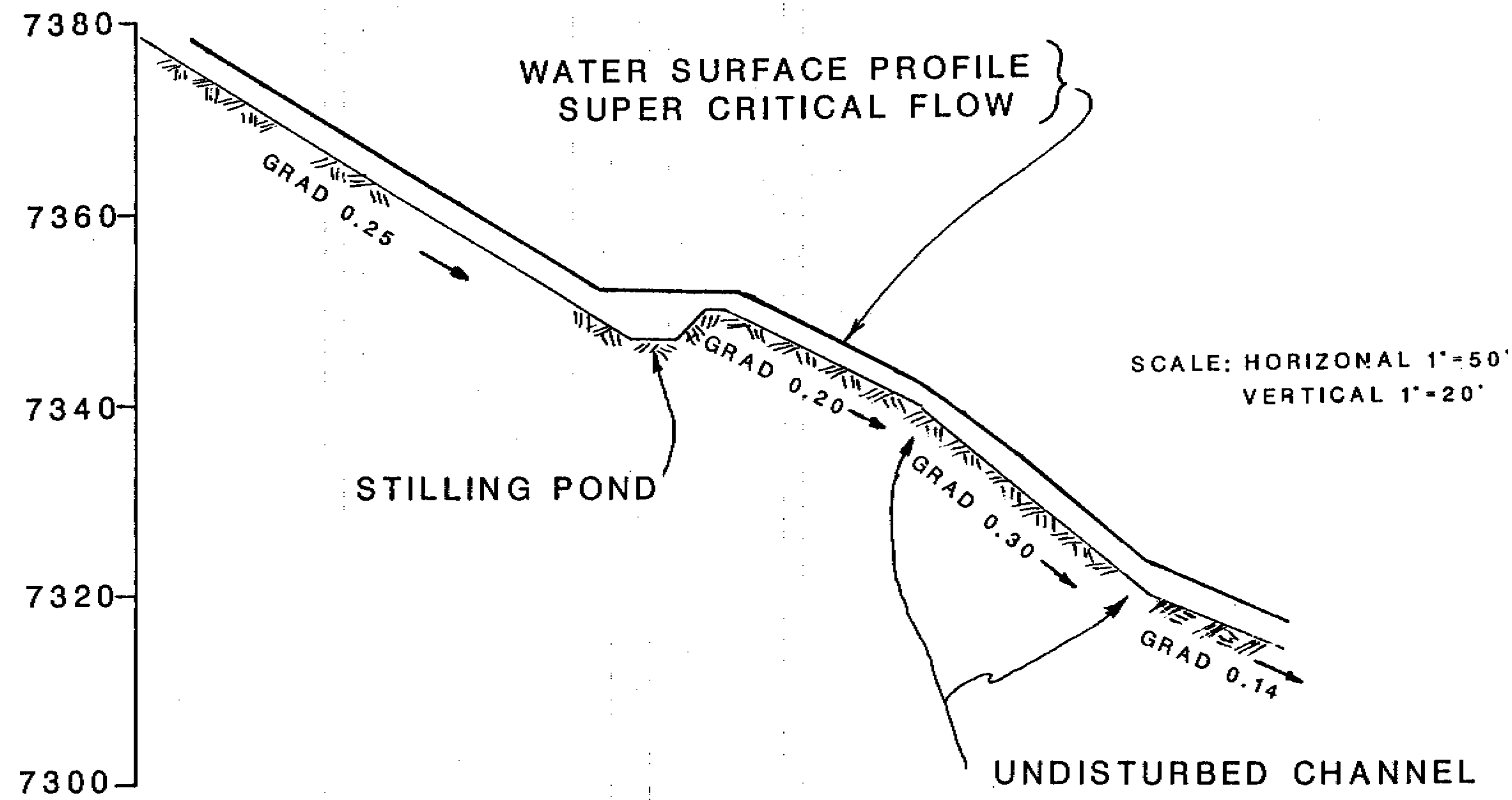


FIGURE 6: PROFILE OF REACH NO.8, STILLING POND & TRANSITION TO UNDISTURBED STREAM

TABLE 3

Select Hydraulic Design Parameters
for West Collector Channel

Channel Reach	Flow (cfs)	Slope	Depth of Flow (ft)	Channel Velocity (fps)	Channel Depth (ft)	Bottom Width (ft)
A-1	5	0.020	0.59	3.27	2.0	2.0
A-2	10	0.020	0.85	4.07	2.0	2.0
A-3	20	0.020	1.04	4.76	3.0	3.0
A-4	25	0.015	1.27	4.61	3.0	3.0
A-5	30	0.500	0.52	16.41	3.0	2.0

Note: Hydraulic parameters calculated with Manning's slope-area equation with an assumed roughness coefficient "n" of 0.035 and a trapezoidal section with side slopes of 1:1. See Appendix D for more details of calculations.

All channel sections are trapezoidal, with side slopes of 1:1, and bottom widths varying from 2 feet to 3 feet along the alignment. Manning's coefficient was assumed to be 0.035. Calculations used for design are presented in Appendix D.

5.3.4.4 Design of the East Collector Channels

There are four poorly developed channels draining the contributing basin on the east side of the mine site. The design flow for each of these channels was assumed to be 5 cfs. Recommended channel dimensions for each reach are given in Table 4.

All channel sections are trapezoidal, with side slopes of 1:1 and bottom widths varying from 2 feet to 3 feet along the alignment. Manning's coefficient was assumed to be 0.035. Calculations used for design are presented in Appendix D.

5.3.4.5 Diversion Channels for Slope Erosion Control

To limit erosion on the southern slope of the fill, intercept channels are proposed to direct surface water off the fill to the main channel. Pre-mine sediment yield in the canyon has been calculated to be approximately 10 tons per acre per year (SHB, May, 1984). Two channels are required to maintain erosion to a pre-mine yield.

TABLE 4

Select Hydraulic Design Parameters for East Collector Channel

Drainage Channel Section	Flow (cfs)	Slope	Depth of Flow (ft)	Channel Velocity (fps)	Channel Depth (ft)	Bottom Width (ft)
B-1	5	0.010	0.71	2.60	2.0	2.0
B-2	5	0.060	0.42	4.87	2.0	2.0
B-3	15	0.270	0.41	10.67	3.0	3.0
B-4	5	0.125	0.34	6.23	2.0	2.0
B-5	10	0.526	0.34	12.69	3.0	2.0

Note: Hydraulic parameters calculated with Manning's slope-area equation with an assumed roughness coefficient "n" of 0.035 and a trapezoidal section with side slopes of 1:1. See Appendix D for more details of calculations.

Two benches are proposed, spaced so that the slope is divided into thirds. These benches should be 10 feet in width with a triangular channel cut on the uphill side of the bench. The channel should be 1-foot deep, including liner and riprap, and have a 6-foot top width. The channel side-slopes should be 3:1 (horizontal to vertical). This should leave a 4-foot wide bench which is relatively level on the downhill side. Figure 7 shows the proposed dimensions of the diversion benches and channels. Calculations for hydraulics and sediment transport control of these benches are presented in Appendix E.

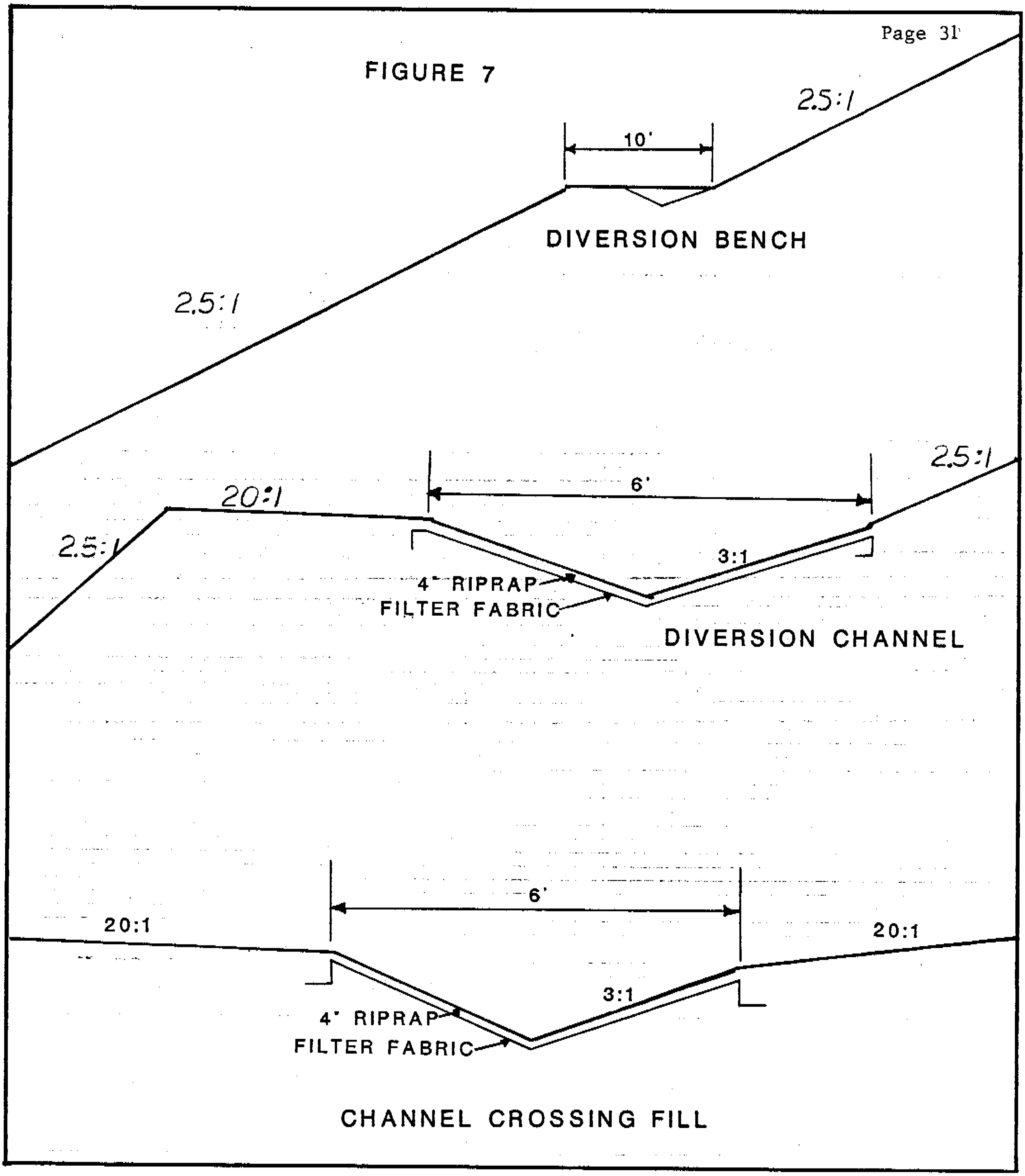
5.4 Site Grading

5.4.1 Fill Placement

The regrading plan for the existing fill and fill generated by removal of the sediment pond dam and excavation of drainage channels is shown on Plate 2 along with the cross sections presented in Appendix E. The major design considerations were directed toward balancing cut and fill quantities using conservative reconstructed slope angles and controlling erosion of the fill.

Major features of the fill placement are flattening the slope at the southern end of the fill, removal of the sedimentation pond dam, constructing an armoured embankment at the inlet of the main channel and

FIGURE 7



Submittal of Experimental Practice for Reclamation for Convulsion Canyon Mine, ACT/041/002, No. 2, No. 3 & No. 14
Sevier County, Utah
SHB Job No. E83-2022

SERGENT, HAUSKINS & BECKWITH
CONSULTING SOIL AND FOUNDATION ENGINEERS
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placing fill on the sandstone ledges along the sides of the existing fill. The maximum recommended slope for fills is 26 degrees (2:1). Due to limited information relative to the compaction characteristics of fills, no swell or shrinkage factors have been incorporated in the calculations. If excess materials are encountered, slopes can be steepened from those shown to a maximum of 26 degrees to balance cut and fill. Estimated cut is approximately 42,150 cubic yards and fill is 41,000 cubic yards. Calculations are presented in Appendix D.

5.4.2 Southern Slope Regrading

The present slope at the southern end of the mine site should be cut to a shallower angle. This will yield the required factor of safety for long-term reclamation stability. It is recommended to cut to 2.5:1 at the center of the slope and taper the cut to the existing canyon grade along the east and west sides of the slope. Cross sections showing typical cuts are shown in Appendix E.

5.4.3 Sediment Pond & Dam Removal

Partial removal of the existing sediment pond and dam is recommended to place channel Reaches 7 and 8 in rock. All of the fill material of the pond and dam that is on the western side of the channel should be removed. The material on the eastern side should be cut back to a 2:1 slope above the rock channel. Typical cross sections of the recommended cuts are shown in Appendix E.

5.4.4 <u>Constructed Fills</u>

All vegetation, organic matter, and debris should be cleared from areas to receive fill and from areas to be excavated.

The excess material from channel excavation and related earthwork should be graded to facilitate drainage from the mine site and contributing side basins. Diagrams showing locations of placement are included in Plate 2 and Appendix E. All channel embankments and placed fill should be compacted to at least 85 percent of the maximum density as determined in accordance with ASTM D698.

Side hill embankments, where the width, including the bench cuts, is too narrow to allow compaction equipment, may be constructed by end dumping, but only to a width to allow compaction equipment access. After this is achieved, the fill should be placed in lifts and compacted to specified densities.

Lifts should have a thickness when compacted of no more than 8 inches. Where the contractor demonstrates the equipment being used effectively compacts lifts greater than 8 inches, thicker lifts may be authorized by the geotechnical engineer.

Unless approved in the field by the geotechnical engineer, controlled fill should not be constructed when the ambient temperature is less than 35 degrees Fahrenheit. When the temperature falls below 35 degrees, it should be the responsibility of the contractor to protect all completed surfaces against any detrimental effects. The methods used to protect the surfaces should be approved by the geotechnical engineer. Any areas that are damaged by freezing should be reconditioned, reshaped and recompacted to specified densities.

5.4.5 Placement of Geotextile Filter & Riprap on Armoured Embankment at the Main Channel Inlet

The armoured embankment is shown in plan view on Plate 2 and in cross section in Figure 5.

The finished ground surface shall be free of all large clods, brush, roots, rocks, sod or other foreign material prior to geotextile placement. A continuous, relatively smooth surface free of protrusions of coarse rock or other abrupt irregularities shall be achieved. Asperities shall not protrude more than 1/8 inch. Selected finer soils shall be used at the near surface of the fill sections to achieve a continuous, relatively smooth surface. Pneumatic or other relatively smooth rollers shall be used in surface compaction. Dragging or hand raking the surface shall be performed, if required, to achieve a satisfactory surface. The finished surface shall be approved by the geotechnical engineer.

Where material is excavated, exposing natural subgrade soils in the side slopes, the exposed subgrade shall be observed for zones of coarse gravel and cobbles, protrusions of rock, etc., by a representative of the geotechical engineer. All such zones shall be over-excavated and backfilled with selected finer soils to achieve a continuous, relatively smooth surface approved by the geotechnical engineer.

All backfill involved in leveling shall be compacted to a minimum of 95 percent of ASTM D698 maximum dry density. The moisture content during compaction shall be maintained within the limits of 3 percent below to 3 percent above the optimum moisture content as determined in accordance with ASTM D698.

The side slopes shall have a minimum 2-inch thickness of relatively clean sand placed below the geotextile filter to act as a protective barrier during installation. There should be a 6-inch layer of granular material placed above the filter fabric to prevent damage during riprap installation. The sand shall have less than 5 percent passing the no. 200 sieve and shall be nonplastic.

The geotextile filter shall consist of Mirafi 700X or an approved equivalent.

Geotextile shall be installed such that foot traffic is minimized and no vehicle traffic crosses the geotextile. The geotextile shall have no holes or tears. Any holes or tears during installation shall be immediately marked and repaired. Repair methods shall be approved by the geotechnical engineer. Contractor shall have sufficient quality control to detect holes or tears during installation.

All seams shall be overlapped at least 2 feet. The overlap shall be so that the uphill piece overlays the downhill piece.

Rock should be carefully placed on the bedding material and filter fabric in such a manner as not to damage the fabric. If, in the opinion of the geotechnical engineer, the fabric is damaged or displaced to the extent that it cannot function as intended, he will order the contractor to remove the rock, regrade the area, if necessary, and repair or replace the filter fabric.

Gradation and specifications for the riprap are given below:

Riprap Size	Percent Finer by Weight
3.5 feet	100
1.75 feet	50-70
10 inches	10-30
4 inches	0-10

The percent of wear, when subjected to the Los Angeles abrasion test (ASTM C131), shall be no more than 45 and the percent of loss, when subjected to the sodium sulfate soundness test (ASTM C88), shall be no more than 15.

5.4.6 Placement of Geotextile Filter & Riprap in Channels Crossing Soil

For channels crossing soil, such as on the face of the slope, riprap protection will be placed and channel gradients constructed to allow self-cleaning flow velocities. A filter fabric will be placed beneath the riprap. No bedding should be needed for protection of the fabric in these areas.

Filter fabric for channels on soil should consist of Trevira 1127 or an approved equivalent. Filter fabric should be placed on prepared soil as outlined in Section 5.4.5.

The filter fabric should be installed as shown in Figure 5.7.

Gradation of the riprap for channels in soil should be as follows:

Riprap Size (inches)	Percent Finer by Weight
4	100-80
2	70-50
1	40-70
1/4	0-20

The percent of wear, when subjected to the Los Angeles abrasion test (ASTM C131), shall be no more than 45 and the percent of loss, when subjected to the sodium sulfate soundness test (ASTM C88), shall be no more than 15.

Riprap should be carefully placed as outlined in Section 5.4.5 of this report.

There is no requirement for a bedding material if the maximum size of riprap is less than 4 inches in diameter.

5.4.7 Remedial Action for Overbreaks & Areas of Non-Competent Rock in Channel Excavation

For areas of overbreakage of more than 15 percent of the neat line of the cross sectional area and for areas of unsuitable floor or side material, which in the judgement of the geotechnical engineer may be readily erodible, the following remedial action may be taken: (1) the area shall be overexcavated at least 6 inches, (2) the channel shall be filled with borrow material available on-site which has been approved by the geotechnical engineer. This material shall be compacted to 95 percent of the maximum density as determined by ASTM D698, (3) the channel shall then be cut to proper dimensions with suitable equipment, and (4) the channel surface shall then be coated with at least 3 inches of gunite. The gunite shall be placed with a perimeter toe to prevent the intrusion of water behind the gunite.

The decision to use this method should be made on a case to case basis because the undesireability of the use of gunite as lining for steep channel slopes may warrant the tolerance of a large overbreakage.

The gunite shall have a minimum ultimate 28 day compressive strength of 3000 psi. Only Type II Portland cement complying with the current issue of "Standard Specificatons for Portland Cement," A.S.T.M. C-150-67 shall be used. Aggregates shall be from an approved commercial source. A complete mix design for the gunite shall be submitted to the engineer for approval. Such approval shall not be construed to contradict the specifications listed above.

Due to potential advancements in technology which may occur prior to reclamation, remedial actions which may be required due to overbreakage should reflect state-of-the-art methods at that time.

5.5 Erosion Control

Erosion control techniques are to be utilized to reduce sediment yield of surface soils on distrubed areas to less than 20 percent of untreated soils until vegetative cover is established. It is the intent of this recommendation that a wide variety of common, cost effective techniques be considered, and that the latest technological advances be utilized. According to a comparison of methods available at the writing of these recommendations (Hittman Associates, Inc., 1976), a wood cellulose fiber as a slurry applied at a rate of 3,500 pounds per acre would provide a reduction in sediment yield of 90 percent. (SHB; April, 1984 & May, 1984).

6. REQUEST FOR EXPERIMENTAL PRACTICE

6.1 Variances from Performance Standards

The plan outlined in Section 5 varies from performance standards in 30 CFR Subchapter K in three areas:

1. The canyon fill as a non-engineered fill, which means that compaction and moisture was not properly monitored or controlled during construction of the fill.

2. Underdrains were not constructed to convey seepage water away from the fill.

3. The proposed drainage system has reaches in which velocities are extremely high and degradation of the channel is likely. The system also has abrupt changes from steep gradients to moderate gradients where sediment aggradation is likely to occur.

6.2 Environmental Protections

The lack of underdrains and proper construction control of the fill are protected against by not placing anything on the fill which would be affected by differential settlement. The southern slope, which is presently standing at the angle of repose, will be cut back to a 2.5:1 slope with two benches to provide the slope with a stability safety factor of at least 1.5. Materials which are to be regraded will be placed in a controlled manner. Precipitation runoff will be diverted away from the fill so that a dry condition will be maintained as much as possible.

The drainage channels will be placed on competent rock wherever possible. Reaches 5, 6 and A-5 will experience design velocities of 16 to 43 fps for long distances as the flows cascade down the canyon walls. At these velocities, degradation of the channels is likely; however, because the channels are seated in rock, the degradation will likely be slow.

The natural stream regime is for steep gradients. Therefore the undisturbed stream down gradient of the reclamation project is well armoured with shallow coarse grained alluvium. Exit velocities will be high from the reclamation project but not higher than historic conditions.

The most difficult issue with establishing a maintenance free system is that the proposed drainage arrangement includes flattening natural stream gradients in places, thus creating zones of aggradation. The channels are ephemeral and are subject to extreme flood events. Most of the sediment transport in such systems occurs during rare floods. Aggradation in Reaches 1, 4, A-1 to A-4, B-1, and B-2 will likely occur even during normal flow events. Large floods can be expected to scour sediment left during low flows but will deposit coarser material in its place. To accommodate this problem, a storage basin has been designed in Reach 1 and all the reaches have freeboard which can serve as sediment storage.

6.2.1 Monitoring

Two aspects of the proposed experimental practice must be monitored: 1) stability of the fill which includes lack of movement of the slopes and moisture content changes in the fill and 2) sediment transport and conveyance capacity in the surface water drainage system.

6.2.2 Monitoring of Fill

Monitoring wells are to be placed in the fill, as shown on Plate 2, to measure subsurface water conditions which could affect the hydrologic balance and the stability of the fill.

Survey monuments are to be placed adjacent to the wells to monitor movements of the surface of the fill.

6.2.3 Monitoring of the Drainage System

Ideally, the sediments of the natural stream could be characterized and monitored; however, due to the presence of significant amounts of boulders and cobbles in the natural stream, sample sizes for gradation tests would be too large (several hundred pounds, see ASTM C-136) to be practical. Therefore, the proposed monitoring scheme is to establish surveyed cross sections of the channels as indicated on Plate 2. the channels should be surveyed at least annually during the bond period.

6.2.4 Piezometer Installation

Borings shall be drilled to such a depth as to fully penetrate the fill. Standard penetration testing and sampling shall be made at 5-foot intervals, in accordance with ASTM D1586 test procedures. Minimum diameter of these borings shall be 6 inches.

Upon completion of drilling and sampling, piezometers will be installed in the borings. The piezometers shall consist of 2-inch Schedule 40 PVC pipe and 10-foot slotted PVC well screen. Tentatively, the slotted well screen shall have three rows of slots cut on 120 degree centers, with 0.01-inch wide slots being 0.25 inch apart. The bottom of the PVC screen shall have a glued cap. The top of the PVC casing shall have a slip-on cap. The annular space shall then be backfilled. Backfill material from the bottom of the piezometer to the top of the screen shall consist of a commercially-obtained graded sand. The graded sand shall be introduced into the annular space by means of a tremie pipe initially extending to the bottom of the boring and slowly raised as the backfilling progresses. A bentonite seal shall then be installed directly above the graded sand backfill. The bentonite seal shall consist of a 1-foot thickness of bentonite pellets. The pellets shall be one-half inch in diameter, with a minimum purity of 90 percent montmorillonite clay and a minimum dry bulk density of 82 pounds per cubic foot. The annular space shall then be grouted to the surface. The grout shall consist of a neat cement mix with 4 pounds of commercial bentonite and approximately 7.5 gallons of water added per 94-pound bag of cement. Mixing shall be done in a jet mixer. The grout shall be placed by pumping the mixture through a pipe or hose initially extending to the top of the bentonite seal. Grouting shall be done from this point up in one continuous operation until the annular space is completely filled. The top of the piezometer shall be protected with a standard 4- inch I.D. Schedule 40 steel pipe, 4 feet in length provided with a locking cap.

6.2.5 Survey Monuments

Survey monuments shall consist of a brass survey cap set in a 1x1x2-foot concrete pad. Monuments shall have horizontal and vertical control accurate to within 0.1 of a foot. Vertical control shall be tied to mean sea level.

6.2.6 Channel Cross Sections

Exact locations of the cross sections shall be selected in the field upon completion of channel construction to assure practical access. The limits of each cross section shall be marked with survey monuments with vertical control datum being mean sea level.

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TEST DRILLING EQUIPMENT & PROCEDURES

Drilling Equipment Truck-mounted CME-55 drill rigs powered with 4 or 6 cylinder Ford industrial engines are used in advancing test borings. The 4 cylinder and 6 cylinder engines are capable of delivering about 4,350 and 6,500 foot/pounds torque to the drill spindle, respectively. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock is performed with 6 1/2 O.D., 3 1/4 I.D. hollow stem auger or 4 1/2 inch continuous flight auger. Carbide insert teeth are normally used on the auger bits so they can often penetrate rock or very strongly cemented soils which require blasting or very heavy equipment for excavation. Where refusal is experienced in auger drilling, the holes are sometimes advanced with tricone gear bits and NX rods using water or air as a drilling fluid. Where auger and tricone gear bits cannot be used to advance the hole due to cobbles or caving conditions, the ODEX (overburden drilling with the eccentric method) is used. A percussion down-the-hole hammer underreams the hole and 5 inch steel casing is introduced into the hole during drilling. The drill bit is eccentric and can be removed from the center of the casing to allow sampling of the material below the bit penetration depth.

Sampling Procedures Dynamically driven tube samples are usually obtained at selected intervals in the borings by the ASTM D1586 procedure. In many cases, 2" O.D., 1 3/8" I.D. samplers are used to obtain the standard penetration resistance. "Undisturbed" samples of firmer soils are often obtained with 3" O.D. samplers lined with 2.42" I.D. brass rings. The driving energy is generally recorded as the number of blows of a 140 pound 30 inch free fall drop hammer required to advance the samplers in 6 inch increments. However, in stratified soils, driving resistance is sometimes recorded in 2 or 3 inch increments so that soil changes and the presence of scattered gravel or cemented layers can be readily detected and the realistic penetration values obtained for consideration in design. These values are expressed in blows per foot on the logs. "Undisturbed" sampling of softer soils is sometimes performed with thin walled Shelby tubes (ASTM D1587). Where samples of rock are required, they are obtained by NX diamond core drilling (ASTM D2113). Tube samples are labeled and placed in watertight containers to maintain field moisture contents for testing. When necessary for testing, larger bulk samples are taken from auger cuttings.

Continuous Penetration Tests Continuous penetration tests are performed by driving a 2" O.D. blunt nosed penetrometer adjacent to or in the bottom of borings. The penetrometer is attached to 1 5/8" O.D. drill rods to provide clearance to minimize side friction so that penetration values are as nearly as possible a measure of end resistance. Penetration values are recorded as the number of blows of a 140 pound 30 inch free fall drop hammer required to advance the penetrometer in one foot increments or less.

Boring Records Drilling operations are directed by our field engineer or geologist who examines soil recovery and prepares boring logs. Soils are visually classified in accordance with the Unified Soil Classification System (ASTM D2487) with appropriate group symbols being shown on the logs.

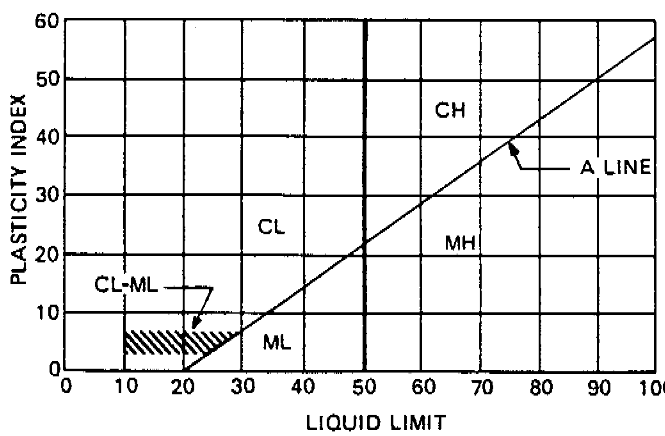
UNIFIED SOIL CLASSIFICATION SYSTEM

Soils are visually classified by the Unified Soil Classification system on the boring logs presented in this report. Grain-size analysis and Atterberg Limits Tests are often performed on selected samples to aid in classification. The classification system is briefly outlined on this chart. For a more detailed description of the system, see "The Unified Soil Classification System" Corp of Engineers, US Army Technical Memorandum No. 3-357 (Revised April 1960) or ASTM Designation: D2487-66T.

MAJOR DIVISIONS				GRAPHIC SYMBOL	GROUP SYMBOL	TYPICAL NAMES
COARSE-GRAINED SOILS (Less than 50% passes No. 200 sieve)	GRAVELS (50% or less of coarse fraction passes No. 4 sieve)	CLEAN GRAVELS (Less than 5% passes No. 200 sieve)			GW	Well graded gravels, gravel-sand mixtures, or sand-gravel-cobble mixtures.
					GP	Poorly graded gravels, gravel-sand mixtures, or sand-gravel-cobble mixtures.
		GRAVELS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart		GM	Silty gravels, gravel-sand-silt mixtures.
			Limits plot above "A" line & hatched zone on plasticity chart		GC	Clayey gravels, gravel-sand-clay mixtures.
	SANDS (More than 50% of coarse fraction passes No. 4 sieve)	CLEAN SANDS (Less than 5% passes No. 200 seive)			SW	Well graded sands, gravelly sands.
					SP	Poorly graded sands, gravelly sands.
		SANDS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart		SM	Silty sands, sand-silt mixtures.
			Limits plot above "A" line & hatched zone on plasticity chart		SC	Clayey sands, sand-clay mixtures.
FINE-GRAINED SOILS (50% or more passes No. 200 sieve)	SILTS LIMITS PLOT BELOW "A" LINE & HATCHED ZONE ON PLASTICITY CHART	SILTS OF LOW PLASTICITY (Liquid Limit Less Than 50)			ML	Inorganic silts, clayey silts with slight plasticity.
		SILTS OF HIGH PLASTICITY (Liquid Limit More Than 50)			MH	Inorganic silts, micaceous or diatomaceous silty soils, elastic silts.
	CLAYS LIMITS PLOT ABOVE "A" LINE & HATCHED ZONE ON PLASTICITY CHART	CLAYS OF LOW PLASTICITY (Liquid Limit Less Than 50)			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		CLAYS OF HIGH PLASTICITY (Liquid Limit More Than 50)			CH	Inorganic clays of high plasticity, fat clays, sandy clays of high plasticity.

NOTE: Coarse grained soils with between 5% & 12% passing the No. 200 sieve and fine grained soils with limits plotting in the hatched zone on the plasticity chart to have double symbol.

PLASTICITY CHART



DEFINITIONS OF SOIL FRACTIONS

SOIL COMPONENT	PARTICLE SIZE RANGE
Cobbles	Above 3 in.
Gravel	3 in. to No. 4 sieve
Coarse gravel	3 in. to ¾ in.
Fine gravel	¾ in. to No. 4 sieve
Sand	No. 4 to No. 200
Coarse	No. 4 to No. 10
Medium	No. 10 to No. 40
Fine	No. 40 to No. 200
Fines (silt or clay)	Below No. 200 sieve

TERMINOLOGY USED TO DESCRIBE THE RELATIVE DENSITY, CONSISTENCY OR FIRMNESS OF SOILS

The terminology used on the boring logs to describe the relative density, consistency or firmness of soils relative to the standard penetration resistance is presented below. The standard penetration resistance (N) in blows per foot is obtained by the ASTM D1586 procedure using 2" O.D., 1 3/8" I.D. samplers.

1. Relative Density. Terms for description of relative density of cohesionless, uncemented sands and sand-gravel mixtures.

N	Relative Density
0-4	Very loose
5-10	Loose
11-30	Medium dense
31-50	Dense
50+	Very dense

2. Relative Consistency. Terms for description of clays which are saturated or near saturation.

N	Relative Consistency	Remarks
0-2	Very soft	Easily penetrated several inches with fist.
3-4	Soft	Easily penetrated several inches with thumb.
5-8	Medium stiff	Can be penetrated several inches with thumb with moderate effort.
9-15	Stiff	Readily indented with thumb, but penetrated only with great effort.
16-30	Very stiff	Readily indented with thumbnail.
30+	Hard	Indented only with difficulty by thumbnail.

3. Relative Firmness. Terms for description of partially saturated and/or cemented soils which commonly occur in the Southwest including clays, cemented granular materials, silts and silty and clayey granular soils.

N	Relative Firmness
0-4	Very soft
5-8	Soft
9-15	Moderately firm
16-30	Firm
31-50	Very firm
50+	Hard

TERMINOLOGY FOR THE DESCRIPTION OF ROCK

General Property	Descriptive Term	Visual or Physical Properties
WEATHERING	VERY WEATHERED	Abundant fractures coated with oxides, carbonates, sulfates, mud, etc., thorough discoloration, rock disintegration, mineral decomposition
	MODERATELY WEATHERED	Some fracture coating, moderate or localized discoloration, little to no effect on cementation, slight mineral decomposition
	SLIGHTLY WEATHERED	A few stained fractures, slight discoloration, little to no effect on cementation, no mineral decomposition
	FRESH	Unaffected by weathering agents, no appreciable change with depth
FRACTURING	INTENSELY FRACTURED	less than 1" spacing
	VERY FRACTURED	1" to 6" spacing
	MODERATELY FRACTURED	6" to 12" spacing
	SLIGHTLY FRACTURED	12" to 36" spacing
	SOLID	36" spacing or greater
STRATIFICATION	THINLY LAMINATED	less than 1/10"
	LAMINATED	1/10" to 1/2"
	VERY THINLY BEDDED	1/2" to 2"
	THINLY BEDDED	2" to 2 feet
	THICKLY BEDDED	more than 2 feet
HARDNESS	SOFT	Can be dug by hand and crushed by fingers
	MODERATELY HARD	Friable, can be gouged deeply with knife and will crumble readily under light hammer blows
	HARD	Knife scratch leaves dust trace, will withstand a few hammer blows before breaking
	VERY HARD	Scratched with knife with difficulty, difficult to break with hammer blows

PROJECT: SUFCO Final Reclamation Plan

JOB NO.: E83-2022 DATE: 6/29/85

LOG OF TEST BORING NO. 1

RIG TYPE: CME-55
BORING TYPE: 6½" Hollow Stem Auger
SURFACE ELEV.:
DATUM:

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows per foot 140 lb. 30" free-fall drop hammer	Dry Density Lbs. per cu. ft.	Moisture Content Per Cent of Dry Wt.	Unified Soil Classification
0–2			X	S	39			GM
3								CL
5				S	50/2"			
7								GM
10				S	50/4½"			
11								SM
15			X	S	15		8	
18								CL
20			X	S	15			
25			X	S	25			
30			X	S	20			
35			X	S	22		9	
36								CL
40			X	S	50/5½"			
45				S	50/5½"			
50								

Depth (approx.)	REMARKS	VISUAL CLASSIFICATION
0–2'	slightly moist	Road Base Gravel with some coal (FILL)
2–5'	slightly moist very firm	SILTY CLAY, considerable gravel, highly stratified, low plastic, yellow and light brown (FILL)
5–12'	slightly moist hard	SILTY GRAVEL, some sand, predominately coarse grained, subangular, strongly lime cemented, nonplastic, gray note: possible boulder at 6½' to 9' (FILL)
12–24'	slight moist hard	SILTY SAND, considerable clay, trace of gravel, predominately fine to medium grained, subrounded, weakly lime cemented, nonplastic, light brown (FILL)
24–?	moist moderately firm	SILTY CLAY, considerable sand, some angular to subrounded gravel, trace of cobbles and boulders, low plasticity, yellow to gray brown (FILL) note: gravel, cobble and boulder content decreases with depth note: thin interbedded sandy clay lenses (2" lenses) from 19½' to 21' note: traces of cedar wood at 23'
–50'	moist firm	SANDY CLAY, some subangular to subrounded gravel, low plasticity, brown (FILL) note: sand lens, predominately fine to medium grained, nonplastic, light reddish yellow at 25½' to 26' note: sandstone and siltstone gravels, subangular to subrounded at 26' to 29' note: color change to gray brown-black at 35' to 45' note: coal lenses at 35' to 40' note: traces of wood at 40'

GROUND WATER

DEPTH	HOUR	DATE
none	9:15 A	6/29/85

SAMPLE TYPE
A – Auger cuttings. B – Block sample
S – 2" O.D. 1.38" I.D. tube sample.
U – 3" O.D. 2.42" I.D. tube sample.
T – 3" O.D. thin-walled Shelby tube.

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PROJECT SUFCO Final Reclamation Plan

LOG OF TEST BORING NO. 1

JOB NO. E83-2022 DATE 6/29/85

RIG TYPE CME-55
BORING TYPE 6½" Hollow Stem Auger
SURFACE ELEV.
DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows per foot 140 lb. 30" free-fall drop hammer	Dry Density Lbs. per cu. ft.	Moisture Content Per Cent of Dry Wt.	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
50			X	S	50/4"			CL		note: color change to black at 45' to 52'
55			X	S	50/2½"			SM	slightly moist hard	SAND, considerable sandstone gravel, some silt, subrounded, weakly increasing to moderately lime cemented with depth, nonplastic, light brown note: apparent bedrock contact at 57'
60			X	S	50/3"					stopped auger at 59'6" sampler refused at 59'9"

GROUND WATER

DEPTH	HOUR	DATE
none	12:00P	6/29/85

SAMPLE TYPE
A – Auger cuttings. B – Block sample
S – 2" O.D. 1.38" I.D. tube sample.
U – 3" O.D. 2.42" I.D. tube sample.
T – 3" O.D. thin-walled Shelby tube.

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JOB NO. E83-2022 DATE 6/29/85

LOG OF TEST BORING NO. 2

RIG TYPE CME-55

BORING TYPE 6½" Hollow Stem Auger

SURFACE ELEV.

DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows per foot 140 lb. 30" free-fall drop hammer	Dry Density Lbs. per cu. ft.	Moisture Content Per Cent of Dry Wt.	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0–5			X	S	54				slightly moist	COAL (FILL)
5–15			X	S	13			CL	moist moderately firm to hard	GRAVELLY CLAY, some silt, weakly lime cemented, low plasticity, yellow brown (FILL)
			X	S	56					
15–20			X	S	50/4½"			SM	slightly moist hard	SILTY SAND, considerable cobbles, predominately fine to medium grained, subrounded, moderately to strongly lime cemented, nonplastic, light brown (FILL)
20–36			X	S	13			CL	moist moderately firm	GRAVELLY CLAY, considerable silt and sand, low plasticity, gray brown to light brown note: lenses of clay, sand and sandstone gravels from 12' to 40' (FILL)
			X	U	25		10			
			X	S	14					
			X	S	14					
			X	S	19					
36–45			X	S	25		4	GP-GM	slightly moist firm	SILTY GRAVEL, considerable sand, trace of clay, predominately coarse grained, angular to subangular, nonplastic, yellow brown to tan (FILL) note: moderately lime cemented, sandstone cobbles at 40'
45–50			X	S	20				slightly moist firm	COAL (FILL) note: traces of wood and pine needles at 47'

GROUND WATER

DEPTH	HOUR	DATE
none	2:00 P	6/29/85

SAMPLE TYPE

A – Auger cuttings. B – Block sample

S – 2" O.D. 1.38" I.D. tube sample.

U – 3" O.D. 2.42" I.D. tube sample.

T – 3" O.D. thin-walled Shelby tube.

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PROJECT SUFCO Final Reclamation Plan

JOB NO. E83-2022 DATE 6/29/85

LOG OF TEST BORING NO. 2

RIG TYPE CME-55

BORING TYPE $6\frac{1}{2}$" Hollow Stem Auger

SURFACE ELEV.

DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows per foot 140 lb. 30" free-fall drop hammer	Dry Density Lbs. per cu. ft.	Moisture Content Per Cent of Dry Wt.	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
50			X	S	13		9	SC	slightly moist moderately firm	CLAYEY SAND, considerable fine grained gravel, predominately medium to fine grained, low plasticity, light red to yellowish red
55			X	S	50/5"					MESAVERDE FORMATION, sandstone, fine to medium grained, moderately weathered, moderately hard, dark yellow
										auger refused at 57'

GROUND WATER

DEPTH	HOUR	DATE
none	3:00P	6/29/85

SAMPLE TYPE

A – Auger cuttings. B – Block sample

S – 2" O.D. 1.38" I.D. tube sample.

U – 3" O.D. 2.42" I.D. tube sample.

T – 3" O.D. thin-walled Shelby tube.

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JOB NO. E83-2022 DATE 6/29/85

LOG OF TEST BORING NO. 3

RIG TYPE CME-55

BORING TYPE 6½" Hollow Stem Auger

SURFACE ELEV.

DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows per foot 140 lb. 30" free-fall drop hammer	Dry Density Lbs. per cu. ft.	Moisture Content Per Cent of Dry Wt.	Unified Soil Classification
~2–3			X	S	90			
5								SC
~6–7			X	S	20			
~11			X	S	8			
~16			X	S	12			CL
~21			X	S	12		13	
~26			X	S	50/4"			SP
~30			X	S	50/3"			

REMARKS	VISUAL CLASSIFICATION
	COAL (FILL)
slightly moist firm	CLAYEY SAND, considerable silt and sandstone gravel, low to medium plasticity, yellow brown (FILL)
slightly moist moderately firm to firm	SILTY CLAY, considerable sand, trace of fine gravel, low plasticity, grayish brown to brown (FILL) note: possible sandstone boulder from 3' to 5' and 17½' note: considerable lenses of red, yellow, graybrown, and brown clay note: traces of wood, coal, and metal chips at 23'
slightly moist hard	SAND, some gravel, predominately medium to fine grained subrounded to rounded, non-plastic, light rust orange note: possible channel deposit
	MESAVERDE FORMATION, sandstone, fine to medium grained, moderately weathered, moderately hard, weakly increasing to strongly lime cemented with depth, dark yellow
	auger refused at 33'8"

GROUND WATER

DEPTH	HOUR	DATE
none	5:00P	6/29/85

SAMPLE TYPE

A – Auger cuttings. B – Block sample

S – 2" O.D. 1.38" I.D. tube sample.

U – 3" O.D. 2.42" I.D. tube sample.

T – 3" O.D. thin-walled Shelby tube.

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JOB NO. E83-2022 DATE 6/29/85 and 6/30/85

LOG OF TEST BORING NO. 4

RIG TYPE CME-55

BORING TYPE $6\frac{1}{2}$" Hollow Stem Auger

SURFACE ELEV.

DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows per foot 140 lb. 30" free-fall drop hammer	Dry Density Lbs. per cu. ft.	Moisture Content Per Cent of Dry Wt.	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0									slightly moist firm to hard	SILTY GRAVEL AND SAND, considerable clay, predominately fine to medium grained sand, highly stratified, low plasticity, brown yellow with some black (FILL) note: thin interbedded lenses of sand, coal and clay from 5' to 8'
~3			X	S	50/2"					
~4								GM-GC		
5										
~6			X	S	29		6			
10			X	S	10				slightly moist moderately firm to firm	COAL, thin sand and clay lenses (FILL) note: traces of wood
15			X	S	18					
~18									slightly moist firm	SILTY SAND, considerable gravel, predominately fine to medium grained, moderately lime cemented, subangular to rounded, nonplastic, yellow to light rust note: interbedded sand and clay lenses note: possible boulder at 24' note: possible stream channel deposits from 22' to 28'
20										
~21			X	S	21		9			
~23								SM		
25			X	S	17					
30				S	50/0" (no recovery)					MESAVERDE FORMATION, sandstone, fine grained, moderately weathered, moderately hard, dark yellow
										stopped auger at 30' sampler refused at 30'

GROUND WATER

DEPTH	HOUR	DATE
none	7:25	6/30/85

SAMPLE TYPE

A – Auger cuttings. B – Block sample

S – 2" O.D. 1.38" I.D. tube sample.

U – 3" O.D. 2.42" I.D. tube sample.

T – 3" O.D. thin-walled Shelby tube.

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JOB NO. E83-2022 DATE 6/30/85

LOG OF TEST BORING NO. 5

RIG TYPE CME-55
BORING TYPE 6½" Hollow Stem Auger
SURFACE ELEV.
DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows per foot 140 lb. 30" free-fall drop hammer	Dry Density Lbs. per cu. ft.	Moisture Content Per Cent of Dry Wt.	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0									moist to very moist soft to firm	SILTY SAND, considerable clay, some gravel, predominately medium to coarse grained, nonplastic, black note: clayey sand lense from from 7' to 9' note: considerable coal and clayey sand lenses from 18' to 26' note: gray channel sands from 26' to 27' (FILL)
			X	S	22					
5			X	S	8					
			X	U	9		16			
10			X	S	15					
15			X	S	29					
								SM		
20			X	S	19		19			
25			X	S	17					
								SM	moist to very moist hard	SILTY SAND, considerable fine gravel, rounded, nonplastic, gray to light rust
30			X	S	55					
35				S	50/1"					MESAVERDE FORMATION, sandstone, fine to medium grained, moderately weathered, hard, dark yellow
										stopped auger at 38'

GROUND WATER

DEPTH	HOUR	DATE
none	9:25A	6/30/85

SAMPLE TYPE

A – Auger cuttings. B – Block sample
S – 2" O.D. 1.38" I.D. tube sample.
U – 3" O.D. 2.42" I.D. tube sample.
T – 3" O.D. thin-walled Shelby tube.

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JOB NO. E83-2022 DATE 6/30/85

LOG OF TEST BORING NO. 6

RIG TYPE CME-55
BORING TYPE 6½" Hollow Stem Auger
SURFACE ELEV.
DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows per foot 140 lb. 30" free-fall drop hammer	Dry Density Lbs. per cu. ft.	Moisture Content Per Cent of Dry Wt.	Unified Soil Classification
0								
3			X	S	56		6	
5			X	S	17			
10			X	S	23		15	CL
15			X	S	9			
20			X	S	17			
22			X	U	20			
25			X	S	14		13	
30			X	S	9			
35			X	S	22		11	ML
40			X	S	14			
45			X	S	10		13	

Depth	REMARKS	VISUAL CLASSIFICATION
0–22'	moist moderately firm to firm	SILTY CLAY, considerable sand and gravel, sand is predominately fine to medium grained, weakly lime cemented, low plasticity, yellow brown to light orange (FILL) note: clay is decomposed platy shale note: considerable sand and gravel lenses 1'to 2' thick with some boulders
22'–50'	moist to very moist moderately firm to very firm	SANDY SILT, some gravel, weakly lime cemented, non-plastic, light reddish yellow (FILL) note: medium plasticity, clayey gravel lens at 22' to 24'

GROUND WATER

DEPTH	HOUR	DATE
none	3:30 P	6/30/85

SAMPLE TYPE

A – Auger cuttings. B – Block sample
S – 2" O.D. 1.38" I.D. tube sample.
U – 3" O.D. 2.42" I.D. tube sample.
T – 3" O.D. thin-walled Shelby tube.

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PROJECT SUFCO Final Reclamation Plan

JOB NO. E83-2022 DATE 6/30/85

LOG OF TEST BORING NO. 6

RIG TYPE CME-55
BORING TYPE 6½" Hollow Stem Auger
SURFACE ELEV.
DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows per foot 140 lb. 30" free-fall drop hammer	Dry Density Lbs. per cu. ft.	Moisture Content Per Cent of Dry Wt.	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
50			X	S	25					note: medium plasticity, sandy clay lense from 69' to 71'
55			X	S	15					
60			X	S	25		27			
								ML		
65			X	S	25					
70			X	U	82		27			
75			X	S	34					
80			X	S	45		18			
									slightly moist firm to hard	GRAVELLY SAND, considerable silt, predominately fine to medium grained, nonplastic, dark yellow
85			X	S	23		7	SM		
				S	50/0" (no recovery)					MESAVERDE FORMATION, sandstone, fine to medium grained, moderately weathered, hard, dark yellow
90										stopped auger at 90' sampler refused at 90'

GROUND WATER

DEPTH	HOUR	DATE
none	3:30P	6/30/85

SAMPLE TYPE

A – Auger cuttings. B – Block sample
S – 2" O.D. 1.38" I.D. tube sample.
U – 3" O.D. 2.42" I.D. tube sample.
T – 3" O.D. thin-walled Shelby tube.

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LABORATORY TESTING PROCEDURES

Consolidation Tests Soiltest or Clockhouse apparatus of the "floating-ring" type are employed for the one-dimensional consolidation tests. They are designed to receive one inch high 2.5 inch O.D. brass liner rings with soil specimens as secured in the field. Procedures for the tests generally are those outlined in ASTM D2435. Loads are applied in several increments to the upper surface of the test specimen and the resulting deformations are recorded at selected time intervals for each increment. For soils which are essentially saturated, each increment of load is maintained until the deformation versus log of time curve indicates completion of primary consolidation. For partially saturated soils, each increment of load is maintained until the rate of deformation is equal or less than 1/10,000 inch per hour. Applied loads are such that each new increment is equal to the total previously applied loading. Porous stones are placed in contact with the top and bottom of the specimens to permit free addition or expulsion of water. For partially saturated soils, the tests are normally performed at in situ moisture conditions until consolidation is complete under stresses approximately equal to those which will be imposed by the combined overburden and foundation loads. The samples are then submerged to show the effect of moisture increase and the tests continued under higher loadings. Generally, the tests are continued to about twice the anticipated curve due to overburden and structural loads with a rebound curve then being established by releasing loads.

Expansion Tests The same type of consolidometer apparatus described above is used in expansion testing. Undisturbed samples contained in brass liner rings are placed in the consolidometers, subjected to appropriate surcharge loads and submerged. The loads are maintained until the expansion versus log of time curve indicates the completion of "primary swell".

Direct Shear Tests Direct shear tests are run using a Clockhouse or Soiltest apparatus of the strain-control of approximately 0.05 inches per minute. The machine is designed to receive one of the one inch high 2.42 inch diameter specimens obtained by tube sampling. Generally, each sample is sheared under a normal load equivalent to the effective overburden pressure at the point of sampling. In some instances, samples are sheared at several normal loads to obtain the cohesion and angle of internal friction. When necessary, samples are saturated and/or consolidated before shearing in order to approximate the anticipated controlling field loading conditions.

[redacted]ABU[redacted]TIO[redacted]F [redacted] RE[redacted]TS [redacted]

Job No. E83-2022 **Date**

Client: Southern Utah Fuel Company
P.O. Box P
Salina, Utah 84654

Project SUFCO Reclamation Plan Project

Material

Source

HOLE NO.	LOCATION	DEPTH	UNIFIED CLASS.	LL	PI	SIEVE ANALYSIS — ACCUM. % PASSING												LAB. NO.
						200	100	40	16	10	4	¼	⅜	¾	1	1½	2	
1	see site plan	14½'-16'	CL	21	8	53	62	72	76	78	83		88	100				3
1	see site plan	34½'-36'	CL	23	10	60	72	83	89	91	94		100					8
2	see site plan	22½'-23½'	CL	25	11	59	67	76	77	78	80	81	85	90	100			19
2	see site plan	39½'-41'	GP-GM	–	NP	7	12	18	20	21	26		33	52	63	100		23
2	see site plan	49½'-51'	SC	26	9	44	49	59	69	72	79		84	100				25
3	see site plan	19½'-21'	CL	28	12	64	71	79	86	89	97		100					31
4	see site plan	4½'-6'	GM-GC	18	5	21	30	44	49	50	57		64	71	78	100		35
4	see site plan	19½'-21'	SM	–	NP	18	24	39	50	55	70		81	87	100			38
5	see site plan	7½'-8½'	SC	33	10	45	52	61	71	76	82	85	92	96	100			43
5	see site plan	19½'-21'	SM	–	NP	34	44	58	72	77	92		93	100				46
6	see site plan	22½'-23½'	GC	27	13	46	52	61	62	63	65	66	68	71	83	100		55
6	see site plan	54½'-56'	ML	–	NP	55	67	80	84	85	89		95	100				62
6	see site plan	69½'-70½'	CL	35	16	58	72	87	90	91	92	95	97	100				65
6	see site plan	84½'-86'	SM	–	NP	28	26	42	50	52	62		71	92	100			68

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ENGINEERING ANALYSIS • PHYSICAL TESTING • QUALITY CONTROL • FIELD EXPLORATION

REPORT ON LABORATORY TESTS

DATE ________

PROJECT SUFCO Reclamation Plan JOB NO. E83-2022

LOCATION ________ LAB NO. 3-2022-1

SAMPLE Boring #2 @ 22½-23½

In Situ
DIRECT SHEAR TESTS

In Situ - Point No. 1 ($\sigma = \pm$ 2.06 KSF)

Initial Moisture Content	9.5 %
Dry Density (PCF)	120.0
Submerged	
Final Moisture Content	- %
Maximum Vertical Deformation @ T Max.	(+) 0.042 Inches
Shearing Stress, T Max.	2.90 KSF

In Situ - Point No. 2 ($\sigma = \pm$ 2.998 KSF)

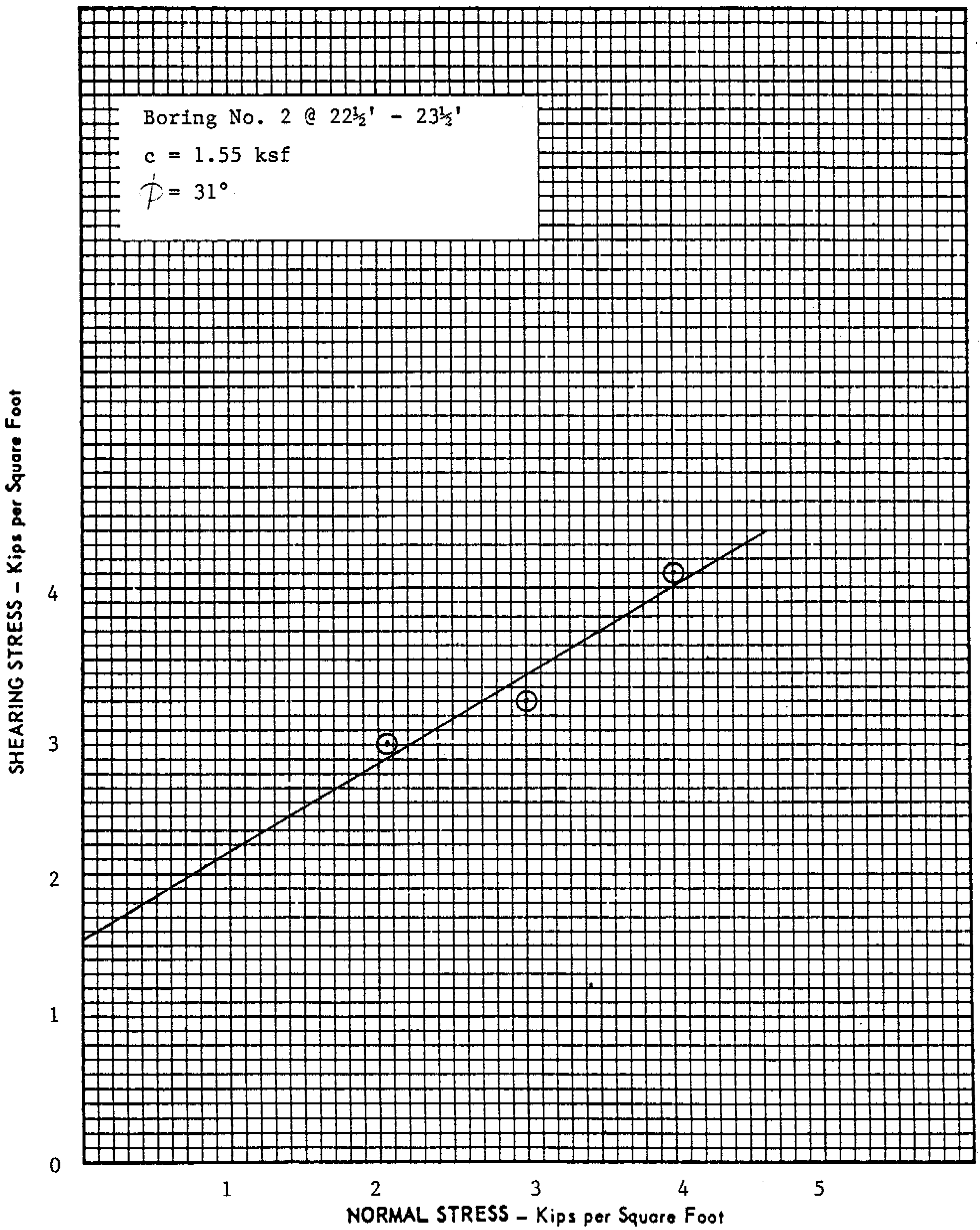
Initial Moisture Content	10.7 %
Dry Density (PCF)	122.5
Submerged	
Final Moisture Content	- %
Maximum Vertical Deformation @ T Max.	(+) 0.023 Inches
Shearing Stress, T Max.	3.20 KSF

In Situ - Point No. 3 ($\sigma = \pm$ 4.02 KSF)

Initial Moisture Content	8.8 %
Dry Density (PCF)	117.9
Submerged	
Final Moisture Content	- %
Maximum Vertical Deformation @ T Max.	(+) 0.005 Inches
Shearing Stress, T Max.	4.1 KSF

SUMMARY OF DIRECT SHEAR TESTS

PROJECT Sufco Reclamation Plan **JOB NO.** E83-2022



SOIL MOISTURE CONDITION

○ – INSITU
● – SUBMERGED

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REPORT ON LABORATORY TESTS

DATE ____________

PROJECT SUFCO Reclamation Plan JOB NO. E83-2022

LOCATION ____________ LAB NO. 3-2022-2

SAMPLE Boring #5 @ 7½-8½

In Situ DIRECT SHEAR TESTS

In Situ - Point No. 1 (σ = ± .995 KSF)

Initial Moisture Content	15.1 %
Dry Density (PCF)	85.3
Submerged	
Final Moisture Content	%
Maximum Vertical Deformation @ T Max.	(+) 0.025 Inches
Shearing Stress, T Max.	1.45 KSF

In Situ - Point No. 2 (σ = ± 2.06 KSF)

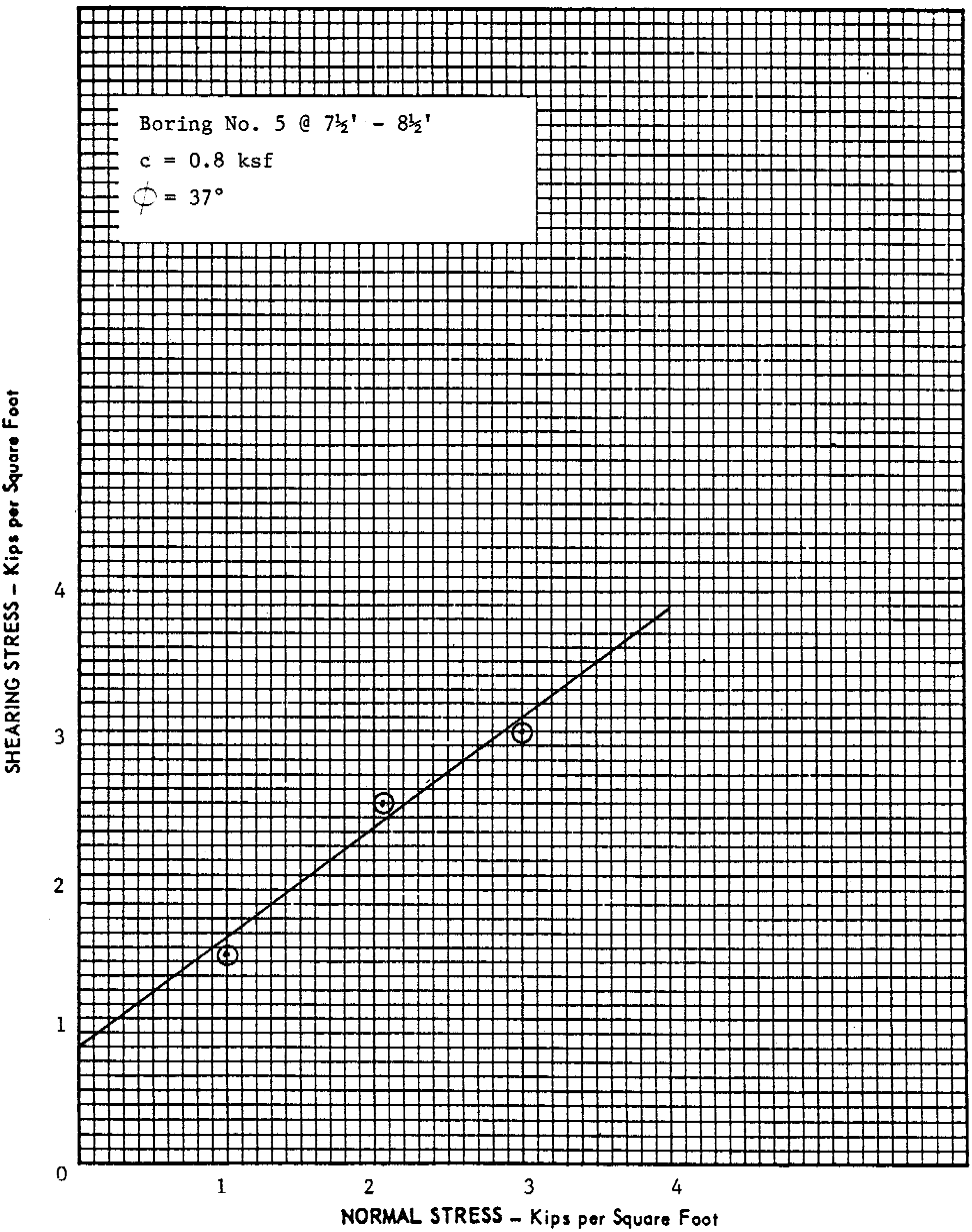
Initial Moisture Content	15.4 %
Dry Density (PCF)	91.7
Submerged	
Final Moisture Content	- %
Maximum Vertical Deformation @ T Max.	(+) 0.019 Inches
Shearing Stress, T Max.	2.50 KSF

In Situ - Point No. 3 (σ = ± 2.998 KSF)

Initial Moisture Content	16.4 %
Dry Density (PCF)	83.7
Submerged	
Final Moisture Content	- %
Maximum Vertical Deformation @ T Max.	(+) 0.009 Inches
Shearing Stress, T Max.	3.0 KSF

SUMMARY OF DIRECT SHEAR TESTS

PROJECT Sufco Reclamation Plan **JOB NO.** E83-2022



SOIL MOISTURE CONDITION

- ○ – INSITU
- ● – SUBMERGED

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REPORT ON LABORATORY TESTS

DATE ________

PROJECT SUFCO Reclamation Plan JOB NO. E83-2022

LOCATION ________ LAB NO. 3-2022-4

SAMPLE Boring #6 @ 69½-70½

In Situ
DIRECT SHEAR TESTS

In Situ - Point No. 1 (σ = ± 4.02 KSF)

Initial Moisture Content	24.6 %
Dry Density (PCF)	95.4
Submerged	
Final Moisture Content	- %
Maximum Vertical Deformation @ T Max.	(-) 0.022 Inches
Shearing Stress, T Max.	1.28 KSF

In Situ - Point No. 2 (σ = ± 6.00 KSF)

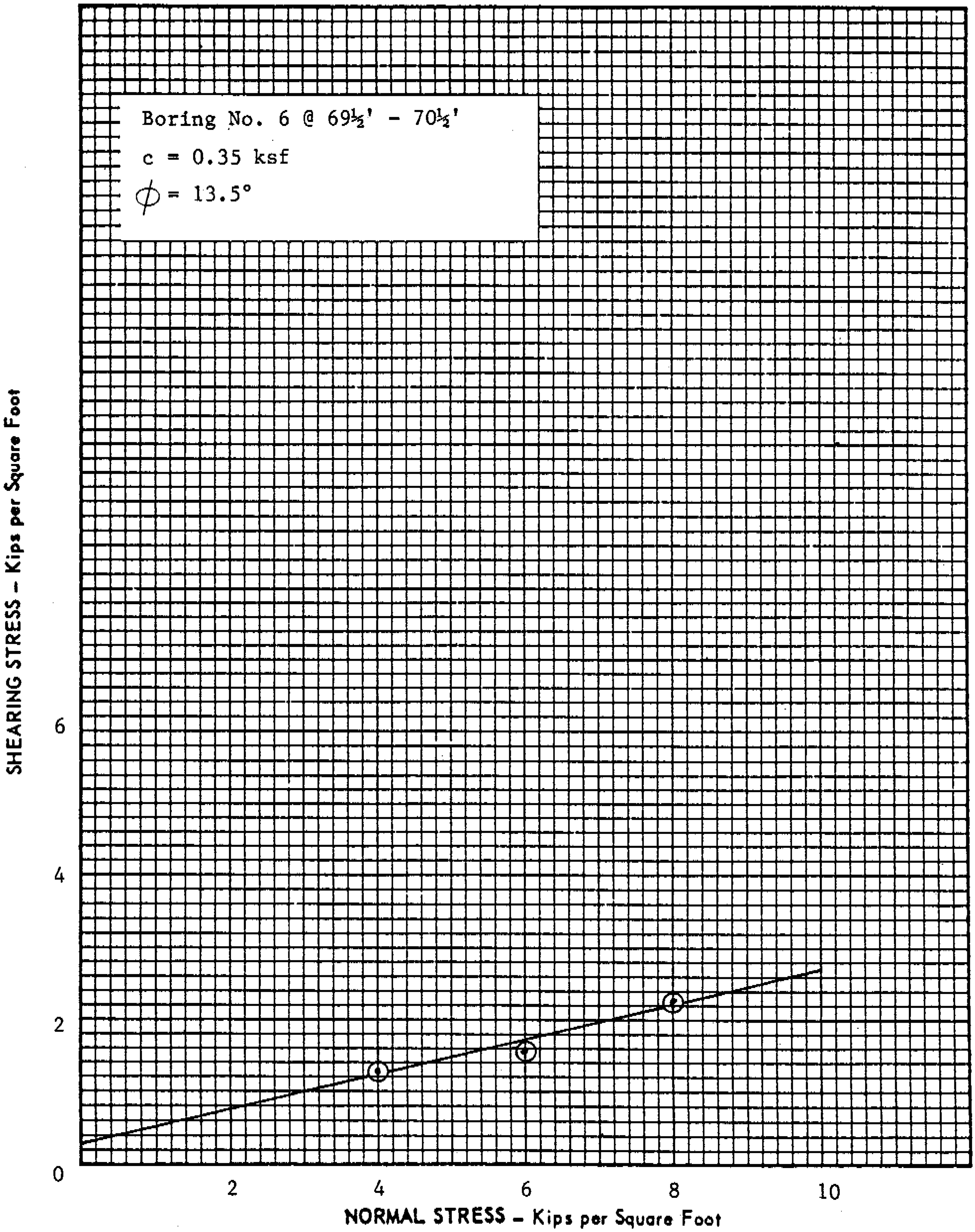
Initial Moisture Content	26.6 %
Dry Density (PCF)	91.6
Submerged	
Final Moisture Content	- %
Maximum Vertical Deformation @ T Max.	(-) 0.055 Inches
Shearing Stress, T Max.	1.58 KSF

In Situ - Point No. 3 (σ = ± 8.01 KSF)

Initial Moisture Content	28.8 %
Dry Density (PCF)	86.4
Submerged	
Final Moisture Content	- %
Maximum Vertical Deformation @ T Max.	(-) 0.034 Inches
Shearing Stress, T Max.	2.24 KSF

SUMMARY OF DIRECT SHEAR TESTS

PROJECT Sufco Reclamation Plan **JOB NO.** E83-2022



SOIL MOISTURE CONDITION

o – INSITU
● – SUBMERGED

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Submittal of Experimental Practice
for Reclamation for Convulsion
Canyon Mine, ACT/041/002, No. 2,
Sevier County, Utah
SHB Job No. E83-2022

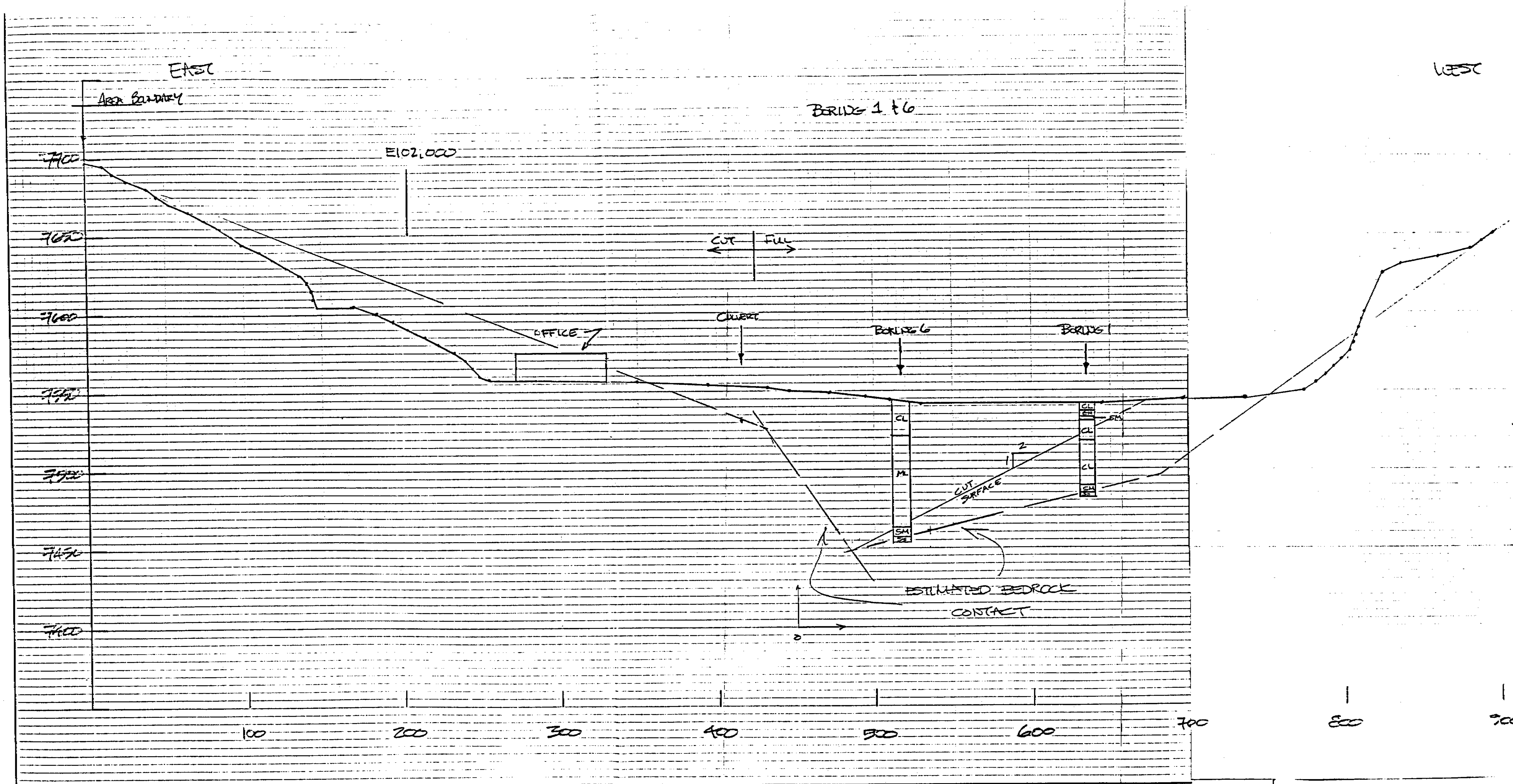
REPORT OF LABORATORY TESTS

SUMMARY OF CHEMICAL TESTS

	Boring 5 at 9-1/2' - 11'	Sample Boring 6 at 49-1/2' - 51'	Boring 6 at 74-1/2' - 76'
pH	8.15	8.21	7.99
Conductivity (μmhos/cm)	1450	1260	920
Total Chloride as Cl^- (ppm)	165	300	110
Total Water Soluble Sulfate as SO_4 (ppm)	1880*	210	250

* hydrogen sulphide (H_2S) odor present.

Note: 1000 ppm = 0.10%



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Job No: E83-2022
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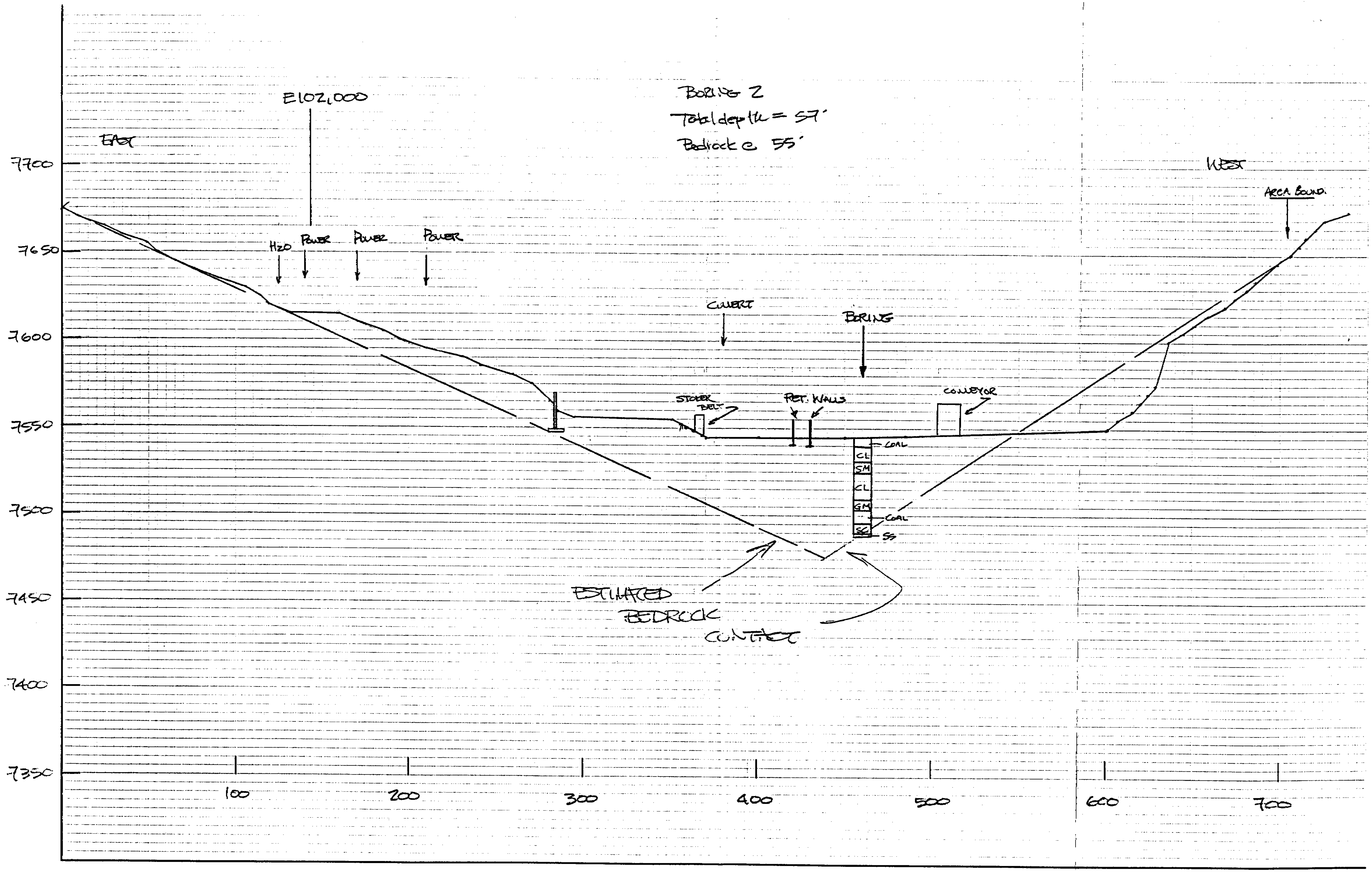
Date: 8/29/85 Page ___ of ___

C-1



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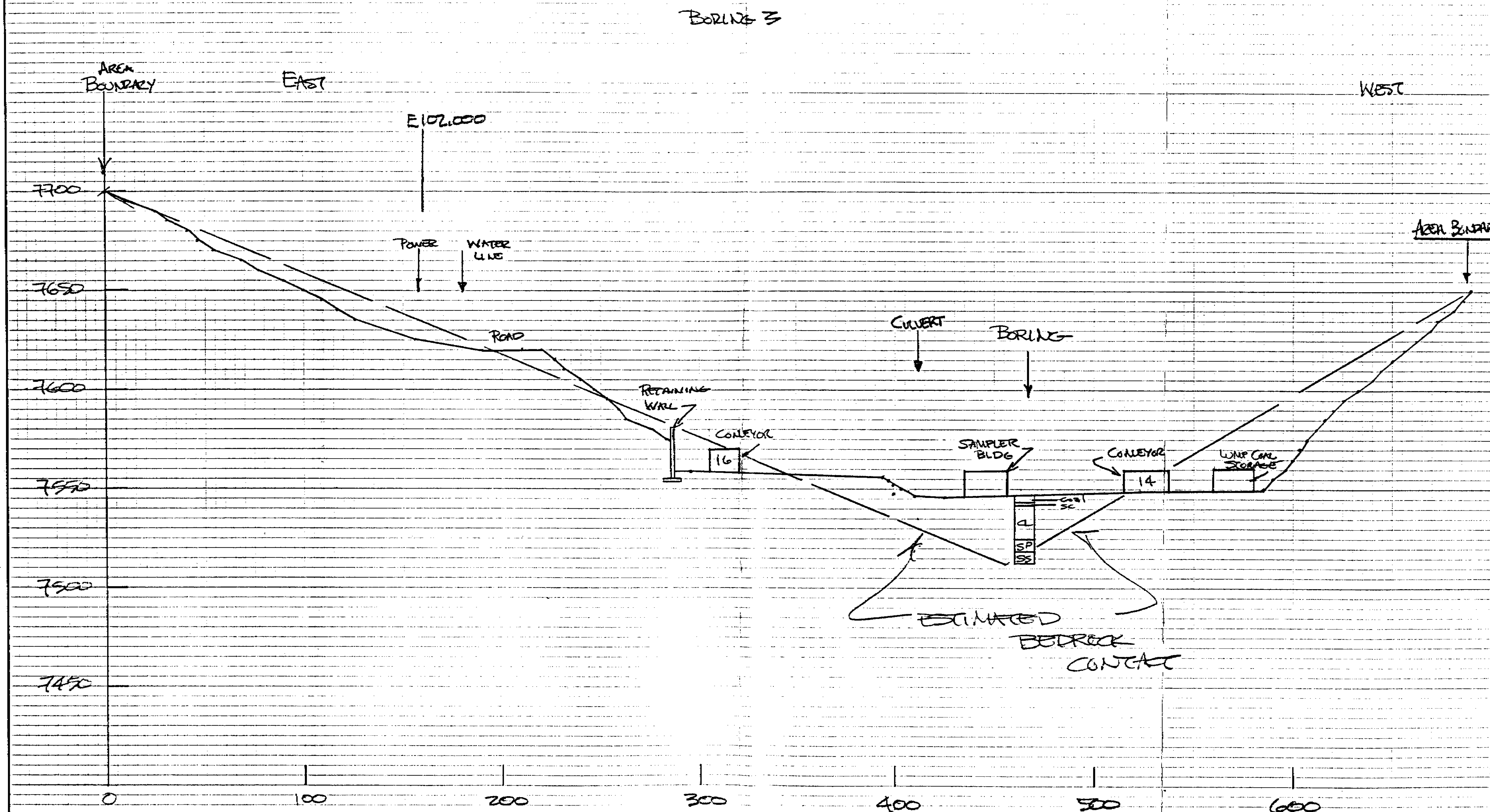
C-2



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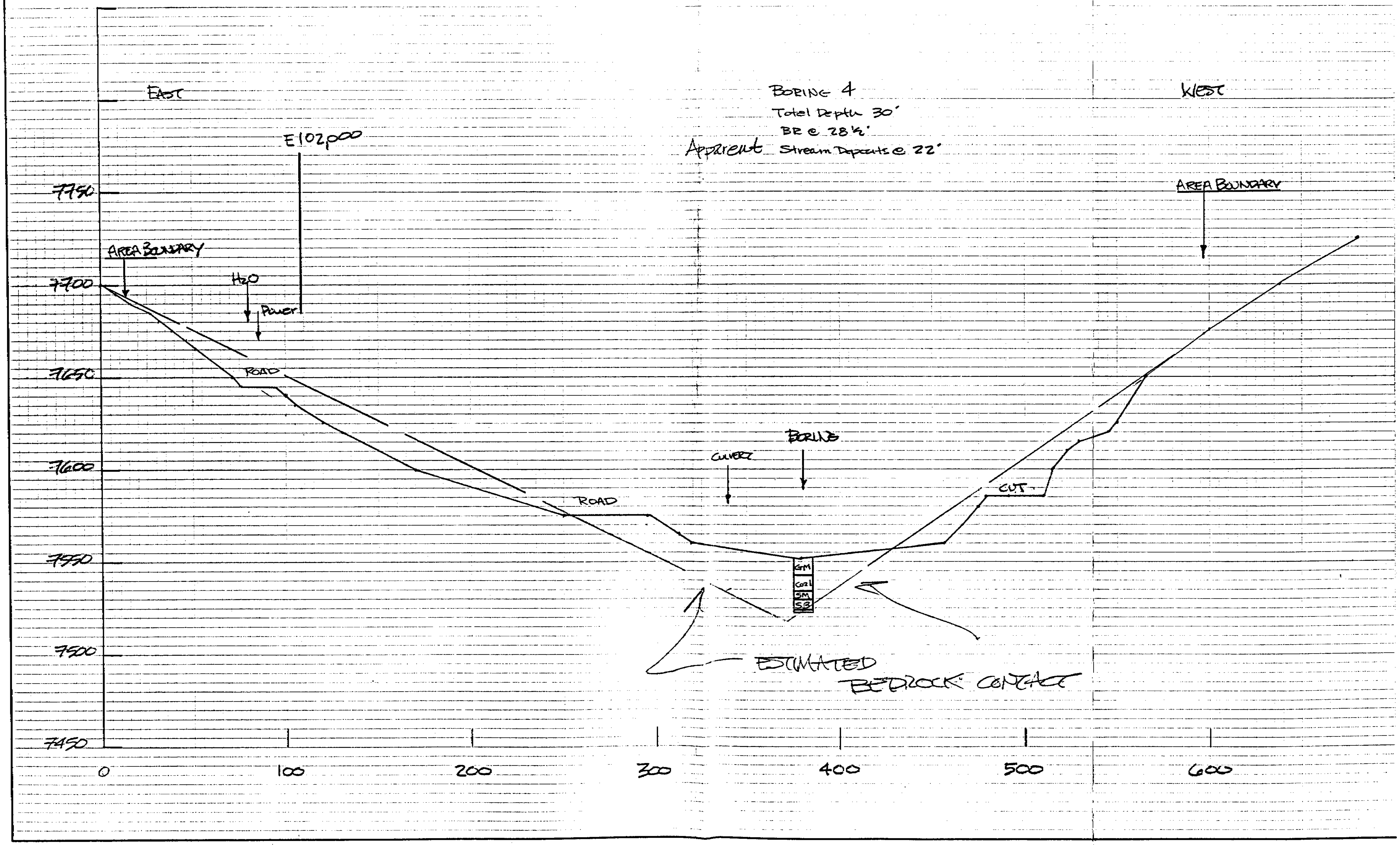

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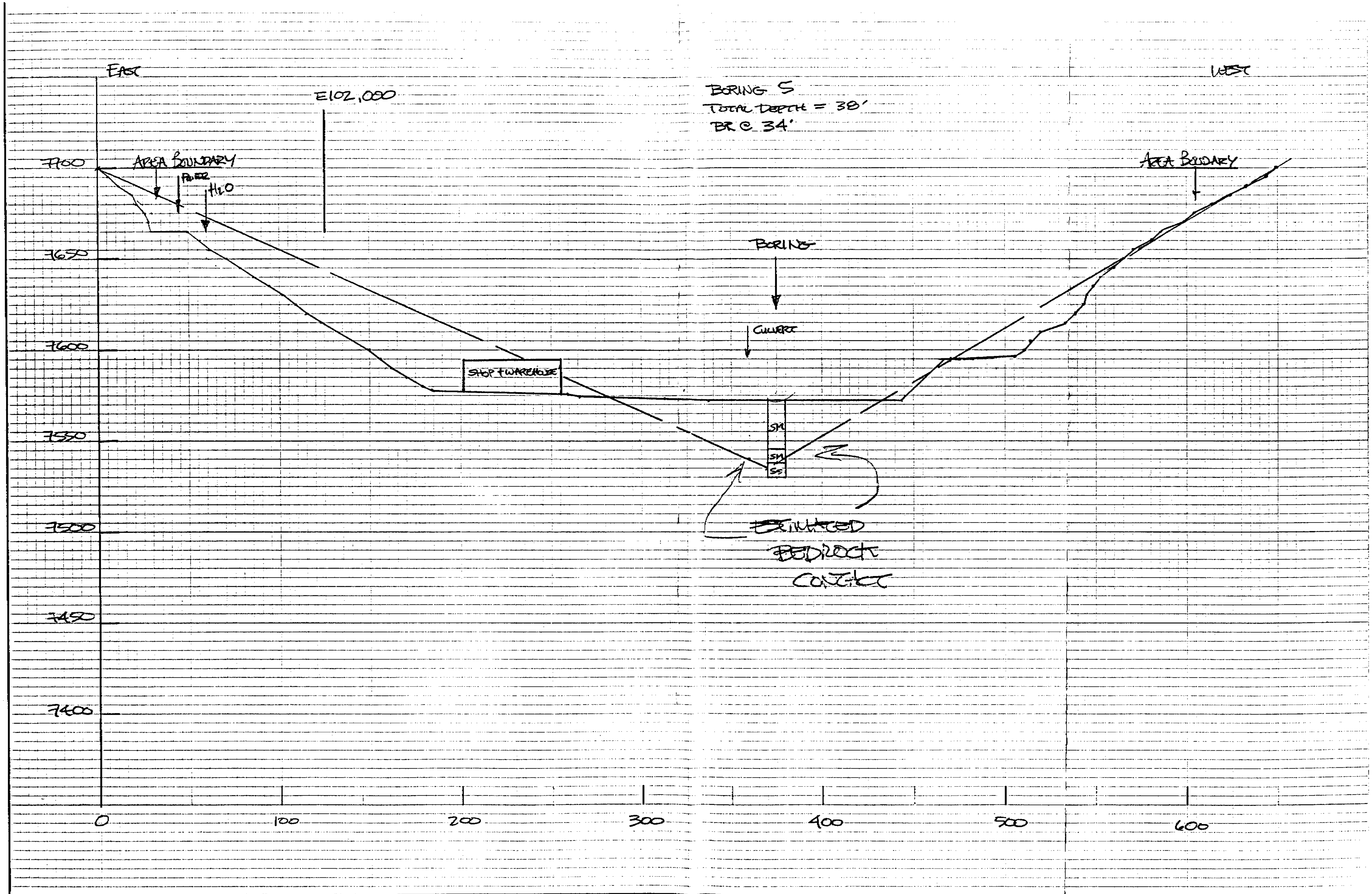

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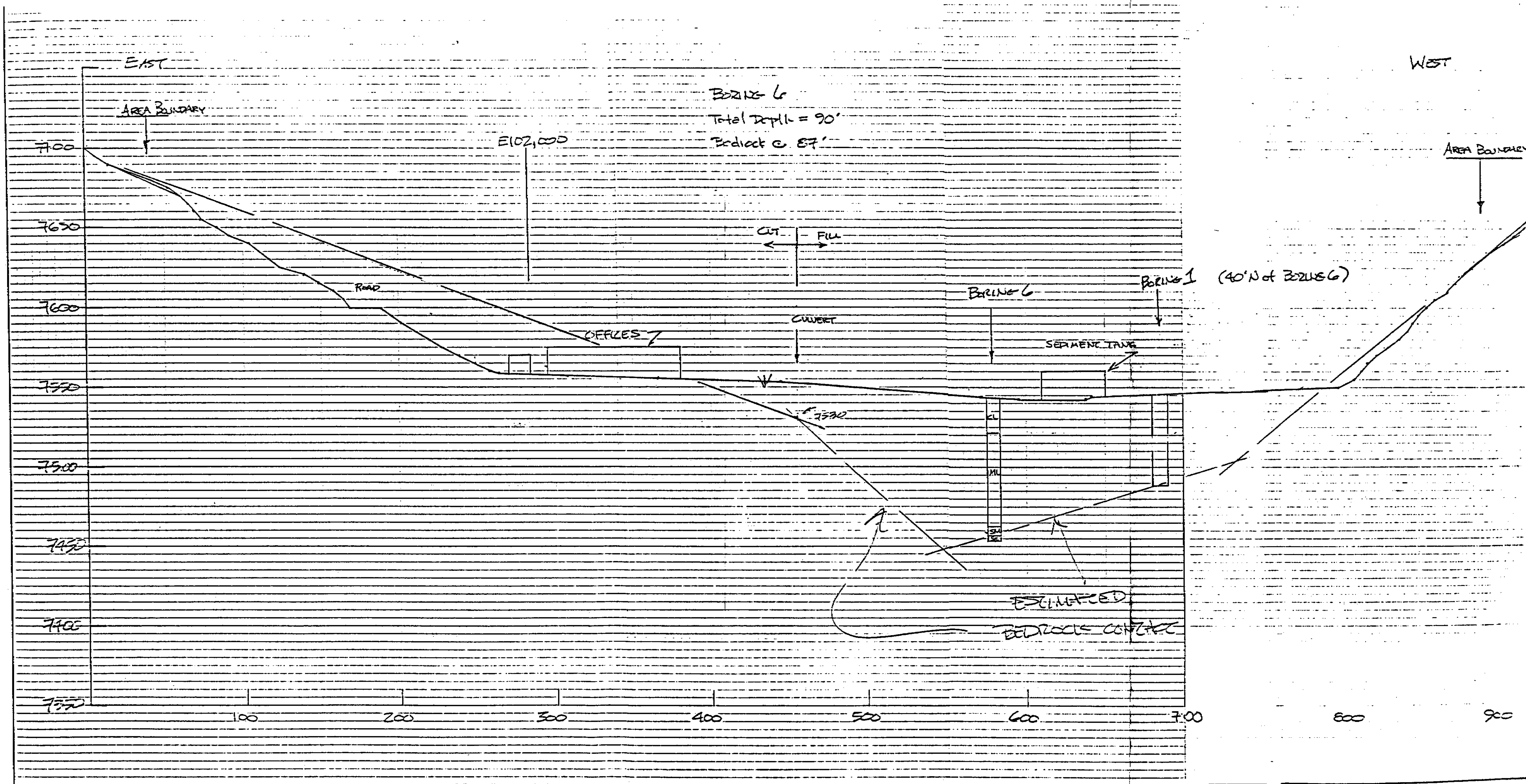
C-5



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C-6

Reach 5

$$S = \frac{\Delta z}{L} \approx \frac{7555 - 7500}{80}$$

$$\approx 0.70$$

Reach 6

$$S = \frac{\Delta z}{L} = \frac{7500 - 7420}{150}$$

$$= 0.53$$

Reach 7

$$S = \frac{\Delta z}{L} = \frac{7420 - 7379}{160}$$

$$= 0.256$$

Reach 8

$$S = \frac{\Delta z}{L} = \frac{7379 - 7347}{130}$$

$$= 0.246$$

Submittal of Experimental Practice
for Reclamation for Convulsion
Canyon Mine, ACT/041/002, No. 2,
No. 3 & No. 14
Sevier County, Utah
SHB Job No. E83-2022

Design Calculations for Channel Depths of Flow, Velocity, & Related Critical Depth & Velocity

Main Channel

Manning Formula

$$V = \frac{1.49}{n} S^{1/2} R^{2/3}$$

n = 0.035 for rock channel

Reach	Slope	Side Slope	Bottom Width	Bank Height
1	.0234	1:1	Varies	Varies
2	.0526	1:1	17.5	5.5
3	.0700	1:1	17.5	5.5
4	.0063	1:1	17.5	8.5
5	.700	.75:1	10.0	5.5
6	.530	.75:1	10.0	5.5
7	.256	1:1	17.5	5.0
8	.246	1:1	17.5	5.0

Reach	Normal Velocity (fps)	Normal Depth (feet)	Critical Velocity (fps)	Critical Depth (feet)
1	16.96	3.18	10.76	4.70
2	18.21	3.30	10.99	5.05
3	20.07	3.03	10.99	5.05
4	8.69	6.09	10.99	5.05
5	49.80	2.16	12.67	6.60
6	45.00	2.36	12.67	6.60
7	31.00	2.06	10.99	5.05
8	30.60	2.09	10.99	5.05

West Collector Channel

Q = 29.3 for entire basin

Six distinctive tributaries

Manning Equation:

$$V = \frac{1.49}{n} R^{2/3} S^{1/2}$$

n = 0.035 for rock channels. All side slopes are 1:1.

Section	Q (cfs)	Bottom Width (feet)	Bank Height (feet)	Slope
A-1	5	2.0	2.0	.020
A-2	10	2.0	2.0	.020
A-3	20	3.0	3.0	.020
A-4	25	3.0	3.0	.015
A-5	30	2.0	3.0	.501

Section	Normal Depth (feet)	Normal Velocity (fps	Critical Depth (feet)	Critical Velocity (fps)
A-1	0.59	3.27	0.54	3.65
A-2	0.85	4.07	0.82	4.33
A-3	1.04	4.76	1.02	4.88
A-4	1.27	4.61	1.16	5.18
A-5	0.52	16.39	1.29	5.42

Freeboard Calculations:

Cfb = 0.20; subcritical

Fb = Cfb^{d} + 1/2 dZ

$= .2\ (1.04) = .21'$

Allow for sedimentation

$$dZ = \frac{(4.61)^2}{32.2\ (202)}$$

$$= 0.02$$

neglect super elevation

Submittal of Experimental Practice
for Reclamation for Convulsion
Canyon Mine, ACT/041/002, No. 2,
No. 3 & No. 14
Sevier County, Utah
SHB Job No. E83-2022

East Collector Channel

Q = 17.1 cfs

Three distinctive tributaries

Manning Equation:

$$V = \frac{1.49}{n} R^{2/3} S^{1/2}$$

n = 0.035; rock-lined channel

All side slopes out to 1:1

Section	Flow (cfs)	Bottom Width	Bank Height	Slope
B-1	5	2.0	2.0	.010
B-2	5	2.0	2.0	.060
B-3	15	3.0	3.0	.270
B-4	5	2.0	2.0	.125
B-5	10	2.0	3.0	.526

Section	Normal Depth (feet)	Normal Velocity (fps	Critical Depth (feet)	Critical Velocity (fps)
B-1	.709	2.60	.542	3.63
B-2	.424	4.87	.542	3.63
B-3	.412	10.67	.858	4.53
B-4	.343	6.23	.542	3.63
B-5	.337	12.69	.821	4.32

Channel is over-sized to allow for sedimentation.

Riprap Design Summary
For Reinforced Channel Bank.

Procedure from
Applied Hydrology and Sedimentology for Disturbed Areas, Barfield, B.J. & Warner, R.C. 1981

$$\eta = \frac{21\ \tau_{max}}{\gamma\,(SG-1)\,D_{50}}$$ where $\tau_{max} = .75\,\gamma\,d\,S$

$= .75(62.4)(2.08)(.025)$

$= 2.43$

$= 0.29$

$SG = 2.70$

$D_{50} = 1.65$

$$\beta = TAN^{-1}\left(\frac{\cos\lambda}{\frac{2\sin\alpha}{\eta\,\tan\phi} + \sin\lambda}\right)$$

$\lambda = 0$ ASSUMPTION

$\alpha = TAN^{-1}\left(\frac{1}{2.5}\right) = 21.8$

$\phi = 40°$ ANGLE OF REPOSE

$= 18.23°$

$$\eta' = \eta\left[\frac{1 + \sin(\lambda + \beta)}{2}\right]$$

$$= 0.29\left[\frac{1 + \sin(18.23)}{2}\right]$$

$= 0.19$

$$FS = \frac{\cos\alpha\ \tan\phi}{\eta'\ \tan\phi + \sin\alpha\ \cos\beta}$$

$$= \frac{\cos 21.8\ \tan 40}{0.19\ \tan 40 + \sin 21.8\ \cos 18.23}$$

FS = 1.52

Factor of Saftey = 1.52
For d_{50} of 1.65

gradation of riprap found by curve

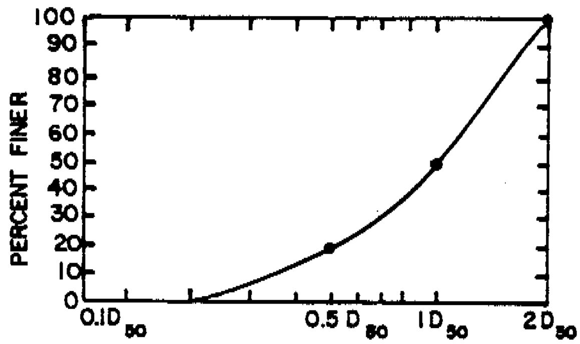

Figure 3.17. Suggested size distribution of riprap. (After Simons and Senturk, 1977).

RIP RAP SIZE (FT)	PERCENT FINER by WEIGHT
3.30	100
1.65	50
.83	20
.33	0

To provide an economical gradation, sizes were converted to inches or to nearest quarter foot.

Calculations For Diversion Channels

For Slope Face Protection

Method Used: Applied Hydrology and Sedimentology for Disturbed Areas.
Barfield and Warner, 1981

1) Calculation of Run off Volume

100 year 24 hour Storm.

CN = 80 DISTURBED AREA

Precipitation = 2.9 INCHES (MERRICK REPORT)

$$S = \frac{1000}{CN} - 10 = 2.5$$

$$Q = \frac{(P - 0.2\,S)^2}{P + 0.8\,S} = \frac{(2.9 - 0.2\,(2.5))^2}{2.9 + 0.8(2.5)}$$

= 1.18 INCHES

$t_c \approx 0.1$ hr

2) Peak Flow Rate

$$q_p = q_p'\,A\,Q$$

A = AREA OF SLOPE BETWEEN BENCHES
= (85) (220)

= .000671 SQ. MILES

$q_p' = 1000$ (MAXIMUM POSSIBLE)

$q_p = 1000(.00067)(1.18)$
$= 0.79$ CFS

DIVERSION WILL BE DESIGNED TO ACCOMADATE A PEAK FLOW OF 0.79 CFS

3) CHANNEL DESIGN
TRIANGULAR CHANNEL

MANNINGS N = 0.020
TYPICAL FOR SHALE, SANDSTONE & SILTY LOAM SPOIL.

$$V = \frac{1.49}{N} R^{2/3} S^{1/2} \qquad V = \frac{Q}{A}$$

S = .015

Z = 3 channel side slopes

Q	NORMAL DEPTH	NORMAL VELOCITY	CRITICAL DEPTH	CRITICAL VELOCITY
.79	.324	2.50	.346	2.19

CRITICAL SLOPE = 0.0097

ALLOW FOR SEDIMENTATION BETWEEN MAJOR STORM EVENTS

SO DEPTH OF CHANNEL RECOMMENDED = 1.0 Ft

Top Width = $2dz = 2(1)(3) = 6$ Ft

AREA = $3d^2 = 3$ Ft^2

4) SIZING RIPRAP FOR Diversion Channels

$S = .015$

$N = .020$

$\alpha = TAN^{-1}\left(\frac{1}{z}\right) = 18.43°$ FOR $z = 3$

$\phi = 38°$ ANGLE OF REPOSE FOR SAND

$\lambda = 0$ ANGLE OF ATTACK (ASSUMED)

$T_{max} = .75 \gamma_w d S$ critical tractive force

d = depth of flow

γ_w = UNIT WEIGHT OF WATER

$d = .324$

$S = .015$

$T_{max} = 0.23$

$\eta = \frac{21 \; T_{max}}{\gamma_w (S_G - 1) D_{50}}$

D_{50} = MEAN RIPRAP DIAMETER = .17 Ft = 2"

$= 0.26$

$\eta' = \eta \; \frac{1 + SIN \, \beta}{2} = 0.17$

$\beta = TAN^{-1}\left(\frac{1}{\frac{2 \, SIN \, \alpha}{\eta \, TAN \, \phi}}\right) = 17.81$

$FS = \frac{COS \, \alpha \; TAN \, \phi}{\eta' \, TAN \, \phi + SIN \, \alpha \; COS \, \beta}$

$= 1.71 > 1.50$

GRADATION OF RIPRAP Determined by Curve (Fig 3.17)

RIP RAP SIZE	PERCENT FINER by Weight
.33	100
.17	50
.08	20
.02	0

5) SEDIMENT YIELD OF PROTECTED Slope

USLE FACTORS FROM SHB REPORT
FINAL RECLAMATION PLAN
MAY 1984
ADDENDUM #1

$R = 26$ ANNUAL

$$R = \frac{19.25 \; P^{2.2}}{D^{0.4672}}$$ 100 year - 24 hr

$$= \frac{19.25 \; (2.9)^{2.2}}{24^{0.4672}} = 45.38$$

$K = 0.37$ Very fine sandy loam

$$LS = \left(\frac{\lambda}{72.6}\right)^m \left(\frac{430x^2 + 30x + 0.43}{6.613}\right)$$

λ = Slope length = 85'

$m = 0.5$ for Slope greater than 5%

$X = \sin\theta$ $\quad\theta$ = Slope Angle

$= 0.45$ $\quad = 26.57°$

$LS = 16.53$

$CP = 0.035$ Sparse grass

$= 0.015$ Wood chips (SEE SHB RPT)

$Y_{ANNUAL} = ARKLSCP$ (ANNUAL)

$= \frac{85(220)}{43,560}(26)(.37)(16.53)(.035)$

$= 2.39 \frac{TON}{YEAR} = 5.57 \frac{TON/ACRE}{YEAR}$

$Y_{100,24} = \frac{85(220)}{43,560}(45.38)(.37)(16.53)(.035)$

$= 4.17$ TON $= 9.71 \frac{TON}{ACRE}$

ANNUAL QUANTITY TO WASH FROM SLOPE WITH NO DIVERSIONS OR SOIL PROTECTION

$Y = \frac{220(220)}{43560}(26)(.37)(28.34)(1)$

$= 344.23 \frac{TONS}{YEAR} = 800 \frac{TONS/ACRE}{YEAR}$

$CP = 1$ For Recently graded slope with no vegetation

CHANNEL INLET

& SEDIMENTATION AREA

EARTHWORK CALCULATIONS

$$\forall_1 = \frac{1}{2}(40)(56)\left(\frac{5+5+6}{3}\right)$$
$$= 5972.3 \text{ FT}^3$$
$$= 221.2 \text{ YD}^3$$

$$\forall_2 = \frac{1}{2}(66)(69)\left(\frac{5+6+5.75}{3}\right)$$
$$= 12{,}713.3 \text{ FT}^3$$
$$= 470.9 \text{ YD}^3$$

$$\forall_3 = \frac{1}{2}(22)(78)\left(\frac{6+6+5.75}{3}\right)$$
$$= 5076.5 \text{ FT}^3$$
$$= 188.0 \text{ YD}^3$$

$$\forall_4 = (72)(75)\left(\frac{6+7+7+6.25}{4}\right)$$
$$= 35{,}437.5 \text{ FT}^2$$
$$= 1312.5 \text{ YD}^3$$

$$\forall_5 = \left(\frac{94+94}{2}\right)\left(\frac{54+35}{2}\right)\left(\frac{7+7+8+8}{4}\right)$$
$$= 31372.5 \text{ FT}^3$$
$$= 1{,}161.9 \text{ YD}^3$$

$$\forall_6 = \frac{1}{2}(53)(93)\left(\frac{7+7+8}{3}\right)$$
$$= 18{,}073.0 \text{ FT}^3$$
$$= 669.4 \text{ YD}^2$$

$$\forall_7 = \left(\frac{42+42}{2}\right)\left(\frac{39+36}{2}\right)\left(\frac{7+7+7+6.5}{4}\right)$$
$$= 11{,}601.6 \text{ FT}^3$$
$$= 429.7 \text{ YD}^3$$

$$\forall_8 = \frac{1}{2}(104)(76)\left(\frac{7+7+8}{3}\right)$$
$$= 28{,}981.3 \text{ FT}^3$$
$$= 1073.4$$

$$\forall_9 = \frac{1}{2}(84)(92)\left(\frac{7+7+6}{3}\right)$$
$$= 25{,}760.0 \text{ FT}^3$$
$$= 954.1 \text{ YD}^3$$

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$V_{10} = \frac{(115)(36)}{2}\left(\frac{6+5.5+6}{3}\right) = 12,075.0 \text{ Ft}^3$

$= 447.2 \text{ YD}^3$

$V_{11} = \frac{(122)(88)}{2}\left(\frac{5+6+5.5}{3}\right) = 29,524 \text{ Ft}^3$

$= 1093.5 \text{ YD}^3$

$V_{12} = \frac{1}{2}(16)(7)(245.0) = 13,720.0 \text{ Ft}^3$

$= 508.1 \text{ YD}^3$

$V_{13} = \frac{1}{2}(16)(7)(325) = 18200 \text{ Ft}^3$

$= 674.1 \text{ YD}^3$

$V_{14} = \frac{1}{2}(16)(75)\left(\frac{6+6+6.25}{3}\right) = 3,650 \text{ Ft}^3$

$= 135.2 \text{ YD}^3$

$V_{15} = \frac{1}{2}(47)(45)\left(\frac{6+7+7}{3}\right) = 7050.0 \text{ Ft}^3$

$= 261.1 \text{ YD}^3$

$V_{16} = \frac{(138)(55)}{2}\left(\frac{6+6+7}{3}\right) = 24,035.0 \text{ Ft}^3$

$= 890.2 \text{ YD}^3$

$V_{17} = \frac{125(40)}{2}\left(\frac{6+5+5}{3}\right) = 15,333.3 \text{ Ft}^3$

$= 567.9 \text{ YD}^3$

$V_{total} = 11,058.4 \text{ YD}^3$

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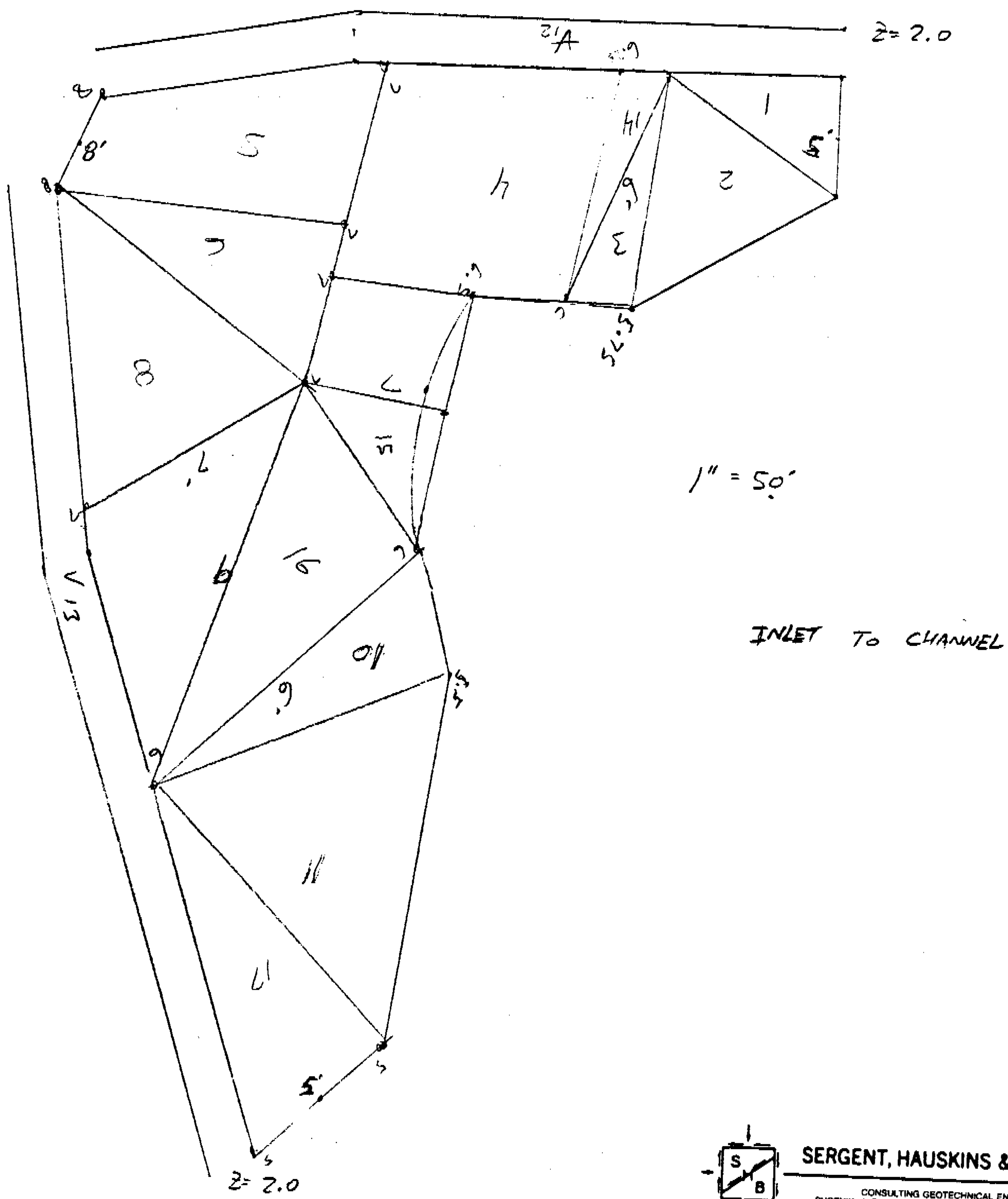
SITE PLAN

SHOWING LOCATIONS OF TEST BORINGS



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Z-17

TRANSITION REACH (REACH 2)

$A_1 = (b + zy)y = (20 + 1.0(5.5))5.5 = 140.3$

$A_2 \quad (17.5 + 5.5)5.5 = 126.5$

$A_{AVG} = 133.4 \ Ft^2$

$V = 133.4(95') = 12,673 \ Ft^3 = \underline{\underline{469.4}} \ YD^3$

(REACH 3)

$A = (17.5 + 1.0(5.5))5.5 = 126.5 \ Ft^2$

$V = 232.0(126.5) = 29,348.0 \ Ft^3 = \underline{\underline{1087.0}} \ YD^3$

(REACH 4)

$A = (17.5 + 8.5)(8.5) = 221.0 \ Ft^2$

$V = 430(221.0) = 95,030 \ Ft^3 = \underline{\underline{3,519.6}} \ YD^3$

(REACH 5)

$A = (10 + .75(5.5))(5.5) = 77.7 \ Ft^3$

$V = AL \qquad L = 76.5 \ Ft$

$= 77.7(76.5)$

$= 5941.8 \ Ft^3$

$= \underline{220.1} \ YD^3$

(REACH 6)

$A = (10 + .75(5.5))5.5 = 77.7 \ Ft^3$

$L = 152'$

$V = 152(77.7) = 11,808.5 \ Ft^3$

$= \underline{437.4} \ YD^3$

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Project: SUFCO RECLAMATION
Job No: E93-2022
Computed by: TJF Ckd. by:
Date: 24 OCT 95

(REACH 7)

$A = (17.5 + 1.0(5.5))\,5.5$

$= 126.5 \text{ FT}^2$

$L = 105 \text{ FT}$

$V = (105)(126.5) = 13{,}282.5 \text{ FT}^3$

$= 491.94 \text{ YD}^3$

(REACH 8)

$A = (17.5 + 1.0(5.5))\,5.5$

$= 126.5 \text{ FT}^2$

$L = 170'$

$V = 21{,}505 \text{ FT}^3$

$= 796.48 \text{ YD}^3$

Contour	Area (ft^2)	Total	Avg	Volume (yd^3)
0	52,530.0			
		36,567.	10	13,543
10	20,604.0			
		14,484	10	5,364
20	8364.0			
		5,151.	10	1,908
30	1938.0			
		969.	10	359
40	0			
				21,174

planimeter cts

1" = 50' ∴ $1 inch^2 = 2500 ft^2$

pln cts → 47, 51, ~~41~~, 50, 49   AVG = 49

12, 11

26, 25

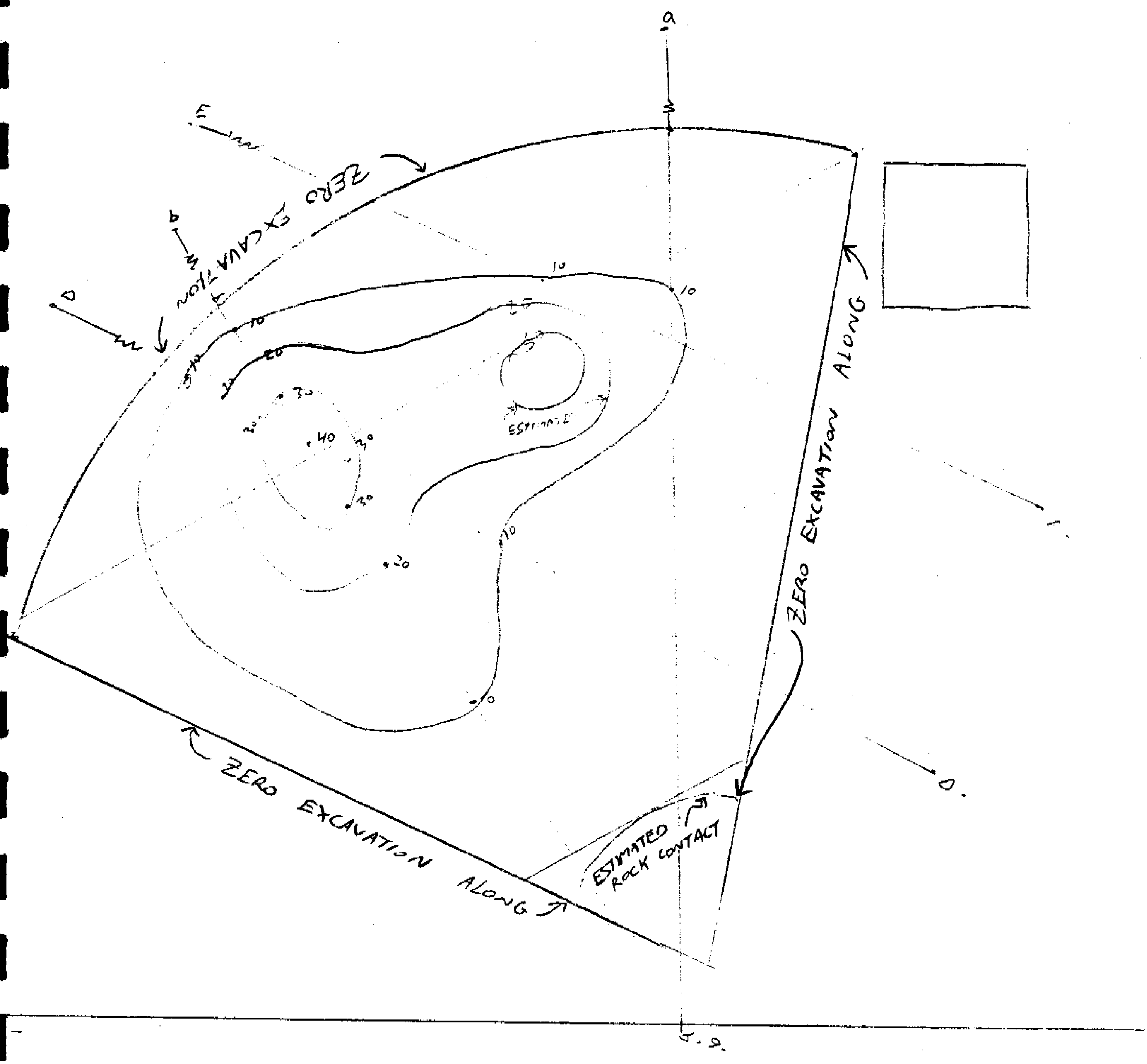
~~166~~, ~~331~~, 161, 166, 163 AVG 164

404, 403, 404 AVG 404

1030, 1028, 1030

SITE PLAN

SHOWING LOCATIONS OF TEST BORINGS



Volumes for Slope Cut Back to 2.5:1 AT CENTER & GRADED TO NATURAL ALONG SIDES

EarthWork Volumes

$A_V = \left(\frac{1}{2}\right)^2 (105)\ 25 + \left(\frac{1}{2}\right)^2 (100)\ 25$

$= 656.25 + 625 = 1281.25\ Ft^2$

$A_U = \left(\frac{1}{2}\right)^2 (195)(25) + \left(\frac{1}{2}\right)^2 (80)(25)$

$= 1218.75 + 500 = 1718.75\ Ft^2$

$A_T = \left(\frac{1}{2}\right)^2 (100)(40) + \frac{1}{2}\left[(195)(35) - \frac{1}{2}(185)(10) - 34(25)\right]$

$1000 + 2525$

$= 3525\ Ft^2$

$A_S = \left(\frac{1}{2}\right)^2 (70)(25) + \left(\frac{1}{2}\right)^2\ 95\ 10$

$= 437.5 + 237.5$

$= 675.0\ Ft^2$

$A_R = \left(\frac{1}{2}\right)^2 (60)(20) + \left(\frac{1}{2}\right)^2 (110)(15)$

$= 300 + 412.5$

$= 712.5\ Ft^2$

$A_Q = \left(\frac{1}{2}\right)^2 (75)(20) + \left(\frac{1}{2}\right)^2 (60)(40) + \left(\frac{1}{2}\right)^2 (140)(12)$

$= 375 + 600 + 420$

$= 1395.00$

$A_J = \left(\frac{1}{2}\right)^2 (110)(60) + 36\ Ft^2 + \left(\frac{1}{2}\right)(9.5)(180)$

$= 1650 + 36 + 855$

$= 2541$

$A_K = \left(\frac{1}{2}\right)^2 (100)(25) + \left(\frac{1}{2}\right)^2 (85)(40) - 25 + \left(\frac{1}{2}\right)(10.5)($

$= 625 + 825 + 1102.5$

$= 2552.50$

$A_L = \left(\frac{1}{2}\right)^2 (135)(55) + \left(\frac{1}{2}\right)^2 (65)(30) + \frac{1}{2}(11.5)(220$

$= 1856 + 487.5 + 1265.0$

$= 3608.50$

$A_M = \left(\frac{1}{2}\right)^2 (105)(20) + \left(\frac{1}{2}\right)^2 (65)(20) + \left(\frac{1}{2}\right)(11.5)(220)$

$= 525 + 325 + 1265.0$

$= 2115.0$

$A_N = \left(\frac{1}{2}\right)^2 (100)(30)$

$= 750 \ Ft^2$

$A_O = \left(\frac{1}{2}\right)^2 (70)\ 8$

$= 140 \ Ft^2$

$\forall_{V}$ (to north) $= \dfrac{625 + 0}{2}(50) = 578.70\ yd^3$

$\forall_{U-V} = \dfrac{1281.25 + 1718.75}{2}(50) = 2777.78$

$\forall_{U-T} = \dfrac{1718.75 + 3525}{2}(50) = 4855.32$

$\forall_{T-S} = \dfrac{3525 + 675}{2}(50) = 3888.89$

$\forall_{S-R} = \dfrac{675 + 712.5}{2}(50) = 1284.72$

$\forall_{R-Q} = \dfrac{712.5 + 1395}{2}(50) = 1951.39$

$\forall_{Q-J} = \dfrac{1395 + 2541}{2}(50) = 3644.44$

$\forall_{J-K} = \dfrac{2541 + 2552.5}{2}(50) = 4716.20$

$\forall_{KL} = \dfrac{2552.5 + 3608.5}{2}(50) = 5704.63$

$\forall_{LM} = \dfrac{3608.5 + 2115.0}{2}(50) = 5299.54$

$\forall_{MN} = \dfrac{2115.0 + 750}{2}(50) = 2652.78$

$\forall_{N-O} = \dfrac{750 + 140}{2}(50) = 824.07$

$\forall_{N}$ (to south) $= \dfrac{140 + 0}{2}(50) = 129.63$

38,303.09

MAIN ROADWAY

$$A_{AVG} = \frac{(\frac{1}{2})(60)(6) + (\frac{1}{2})(40)(5)}{2}$$

$= 140 \ Ft^2$

$L = 400 \ Ft$

$\forall = 140 (400) = 56,000 \ Ft^3$

$= 2074.07 \ YD^3$

LOWER ROADWAY TO EXISTING DAM

$L = 480'$

$A = \frac{1}{2}(15)(4) = 30 \ Ft^2$

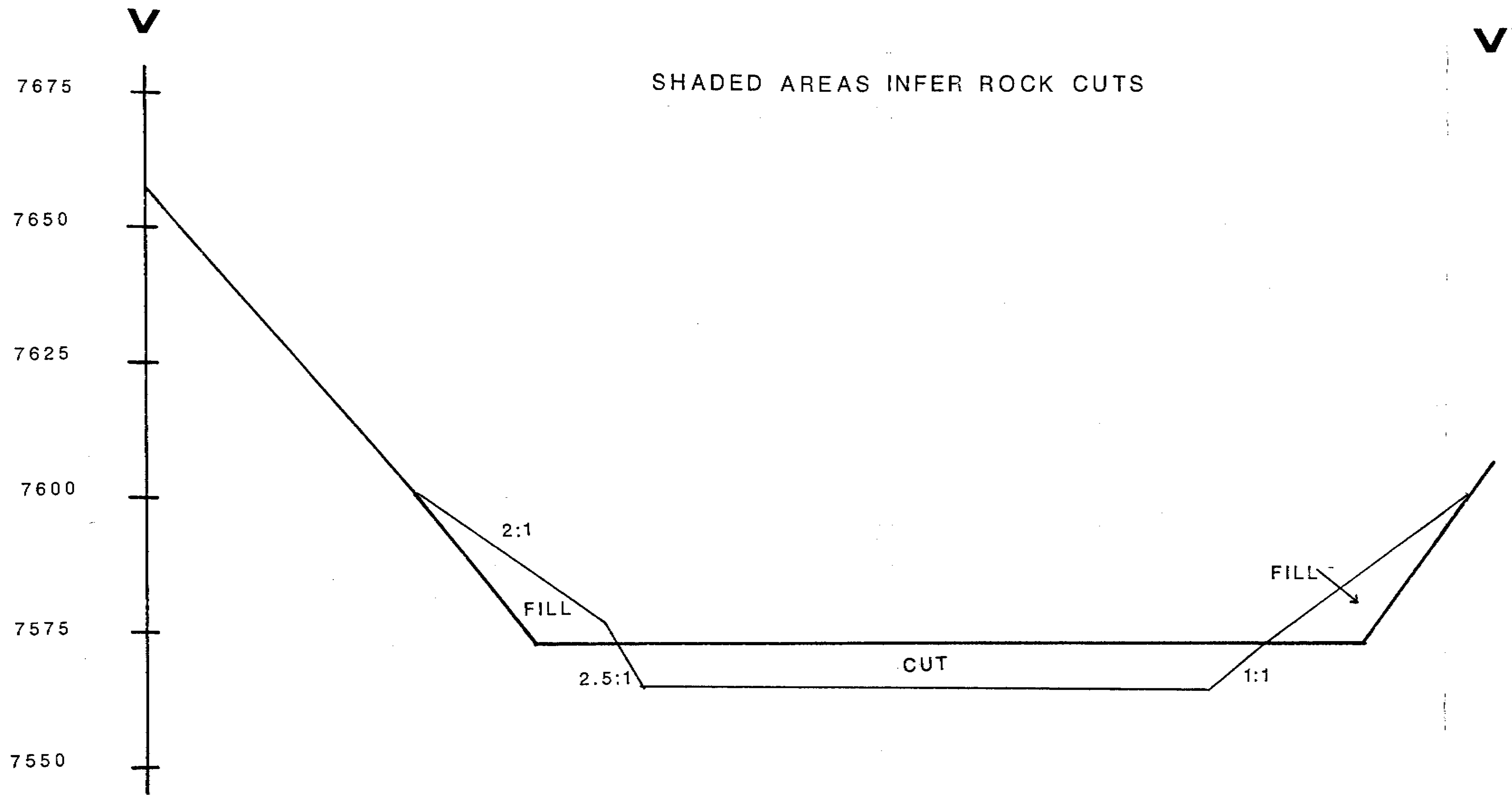
$V = 480 (30) = 14,400 \ Ft^3$

$= 533.33 \ YD^3$

TOTAL CUTS

MAIN CHANNEL	18,000
EAST COLLECTOR	650
WEST COLLECTOR	500
DAM CUT BACK	2,000
SLOPE CUT BACK	21,000
	42,150

FILL	CENTER & EAST SIDE	38,400
	ROADWAYS TO SITE	2100
	LOWER ROADWAY	600
		41,100 yd^3



HORIZONTAL SCALE 1"=50'

VERTICAL SCALE 1"=25'

LEGEND

FINISHED GROUND SURFACE

EXISTING GROUND SURFACE

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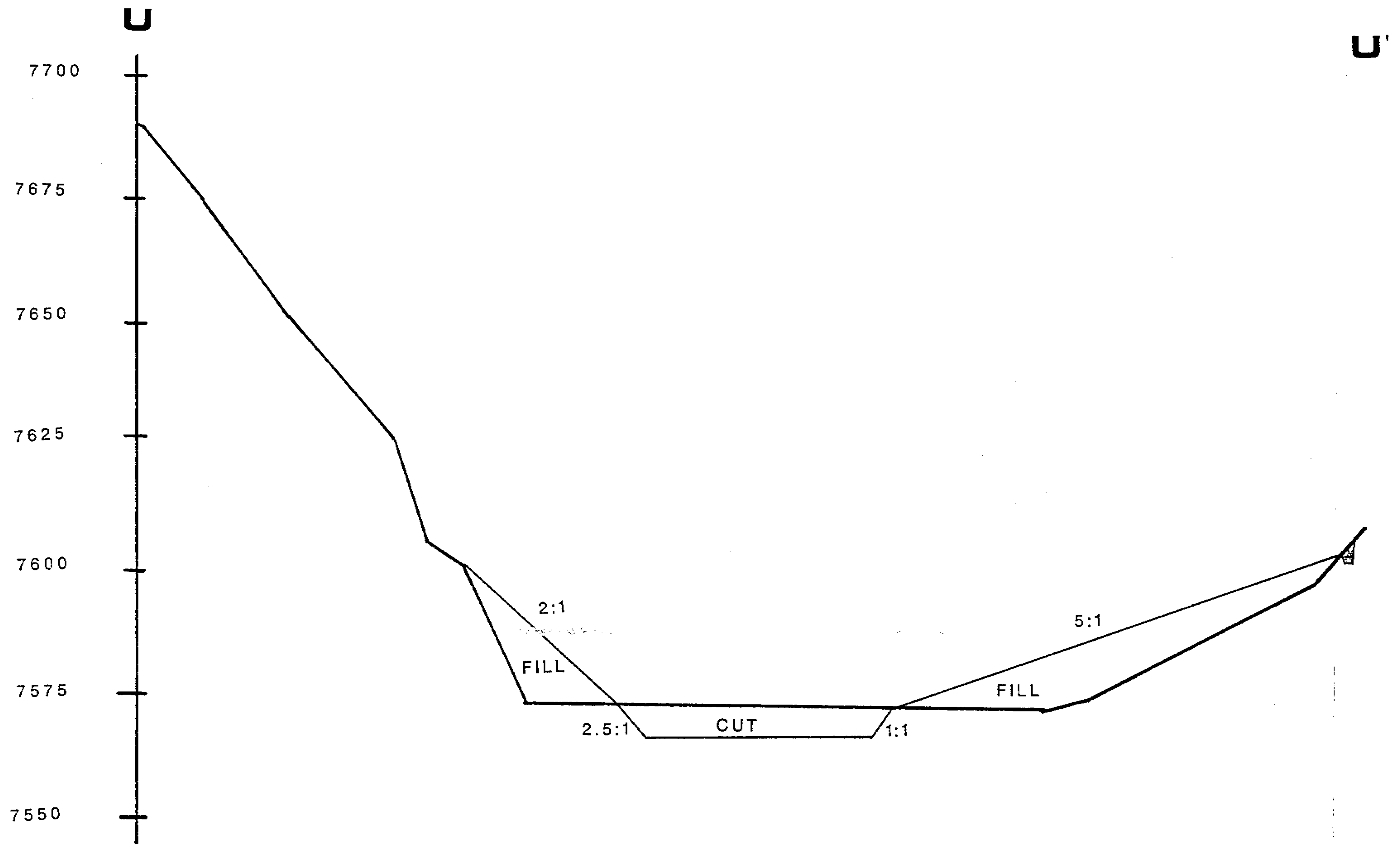

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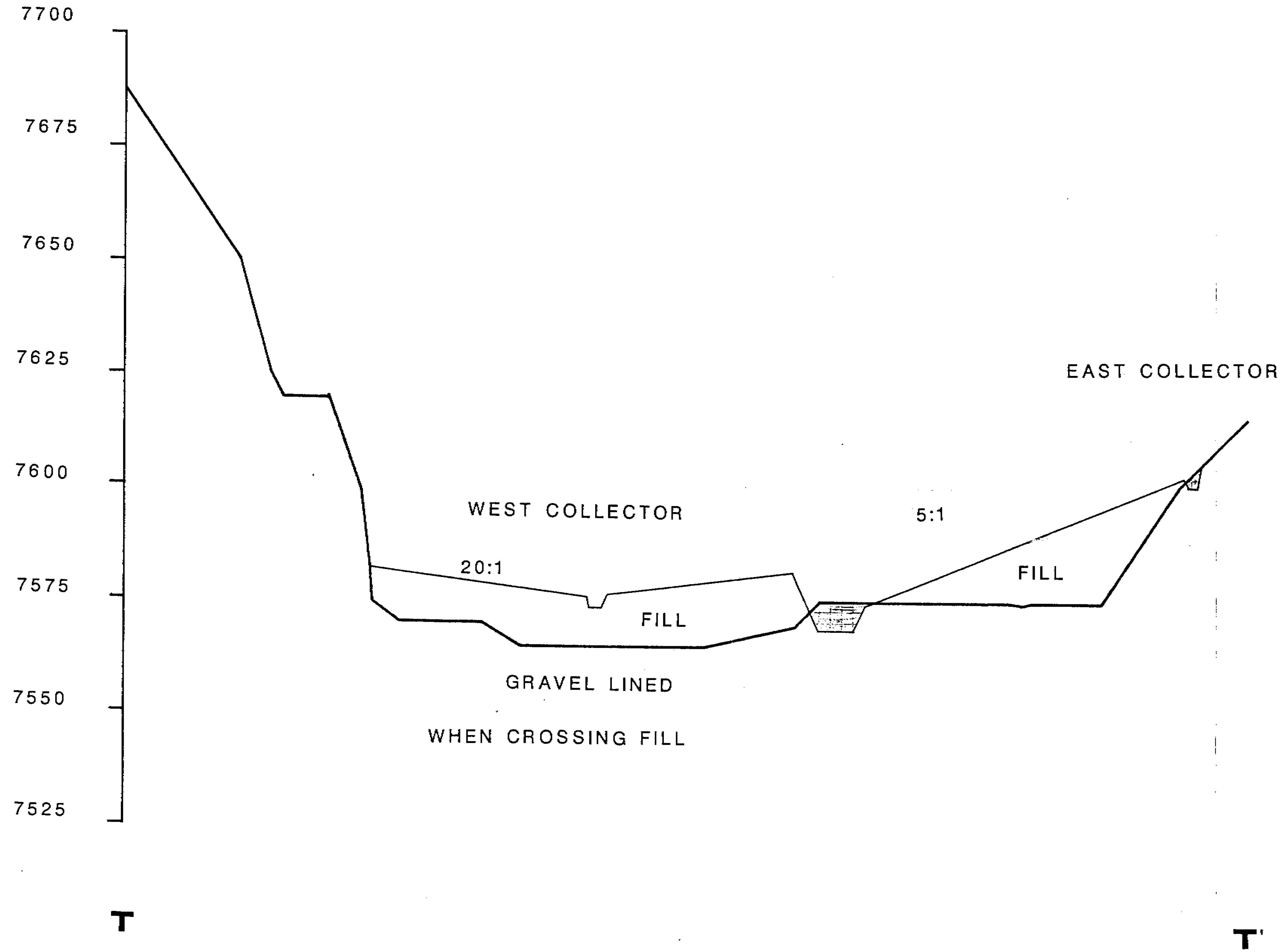
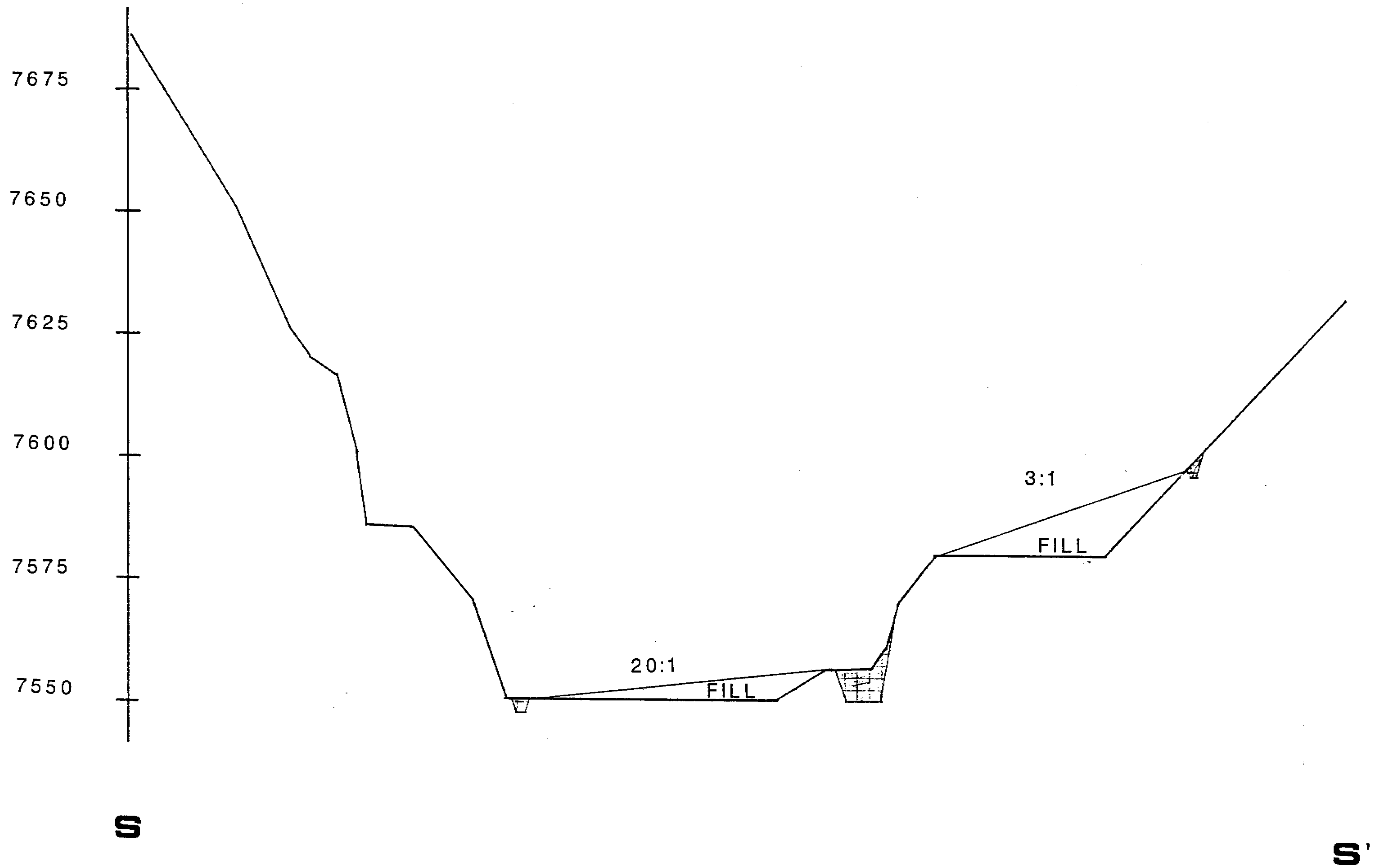

7700
7675
7650
7625
7600
7575
7550
7525
WEST COLLECTOR
20:1
FILL
GRAVEL LINED
WHEN CROSSING FILL
EAST COLLECTOR
5:1
FILL
T
T'



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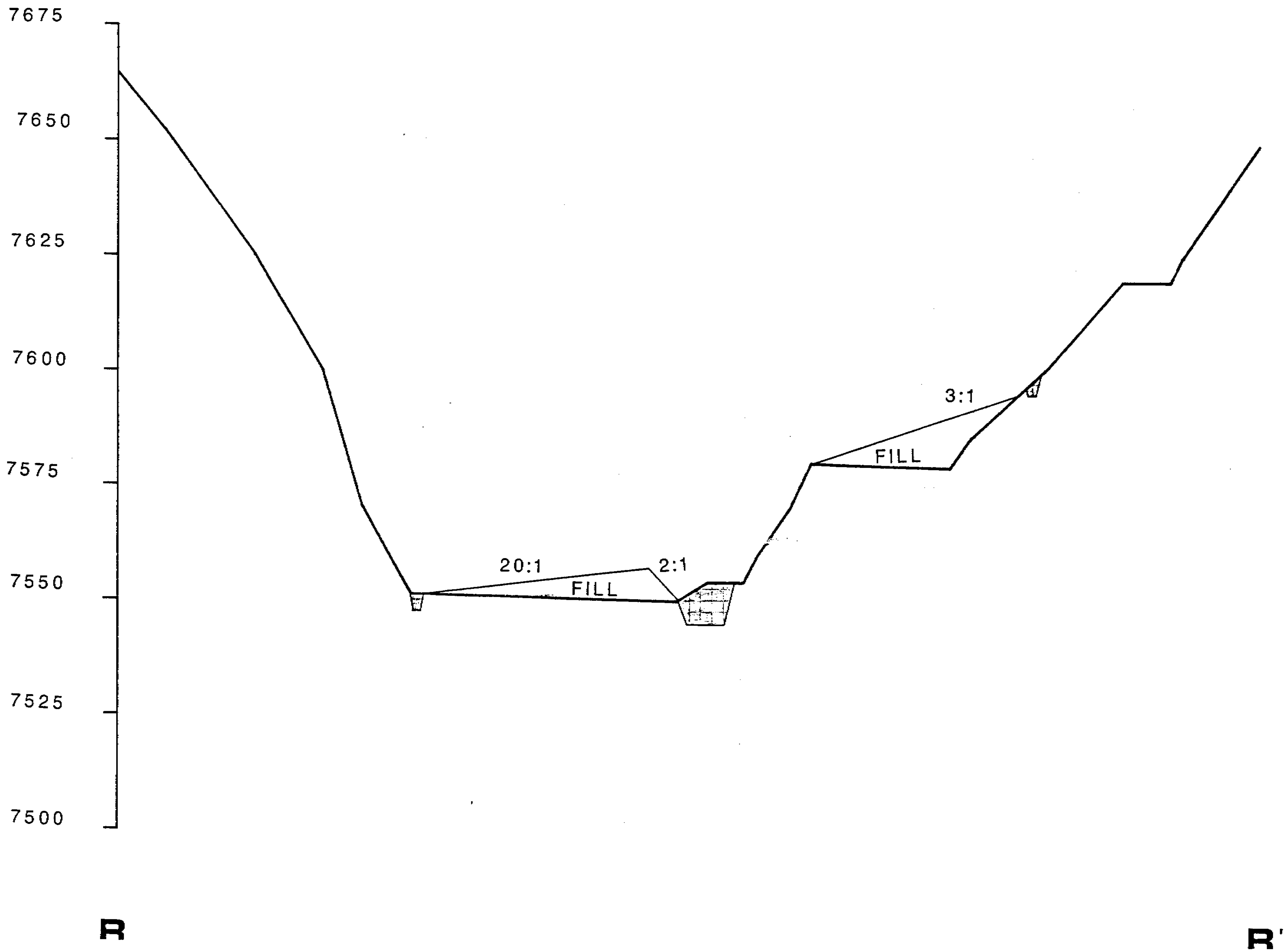

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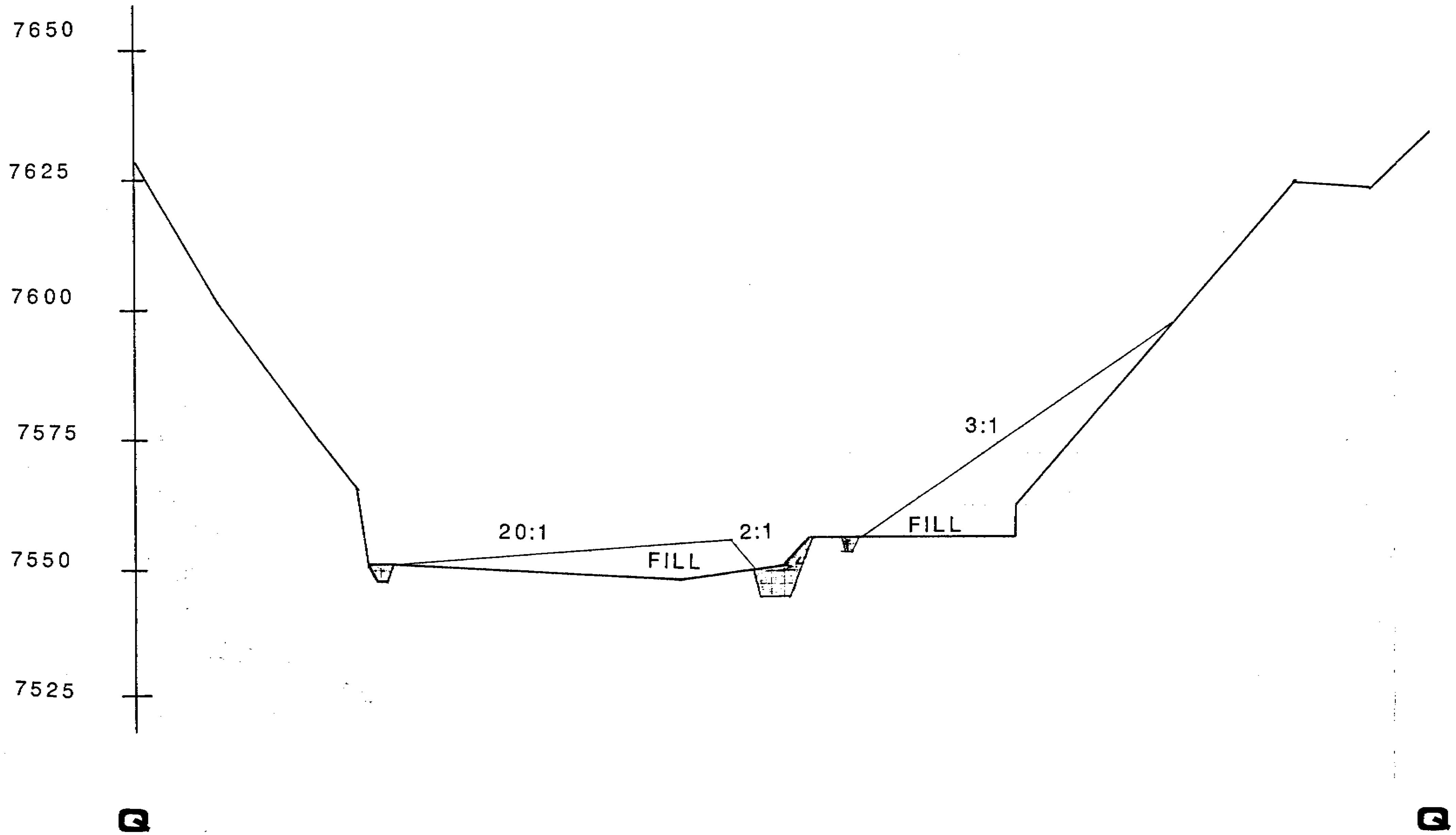

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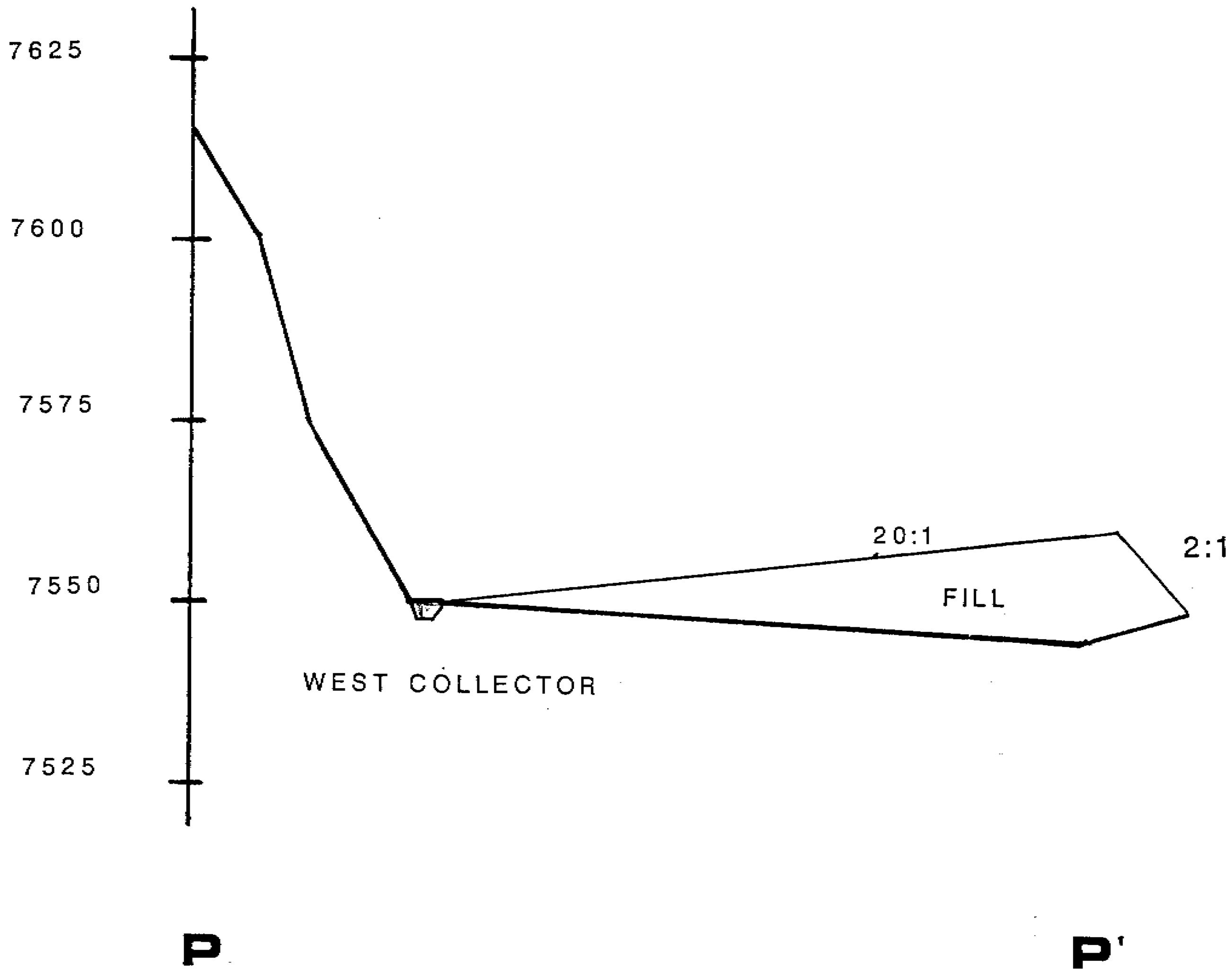

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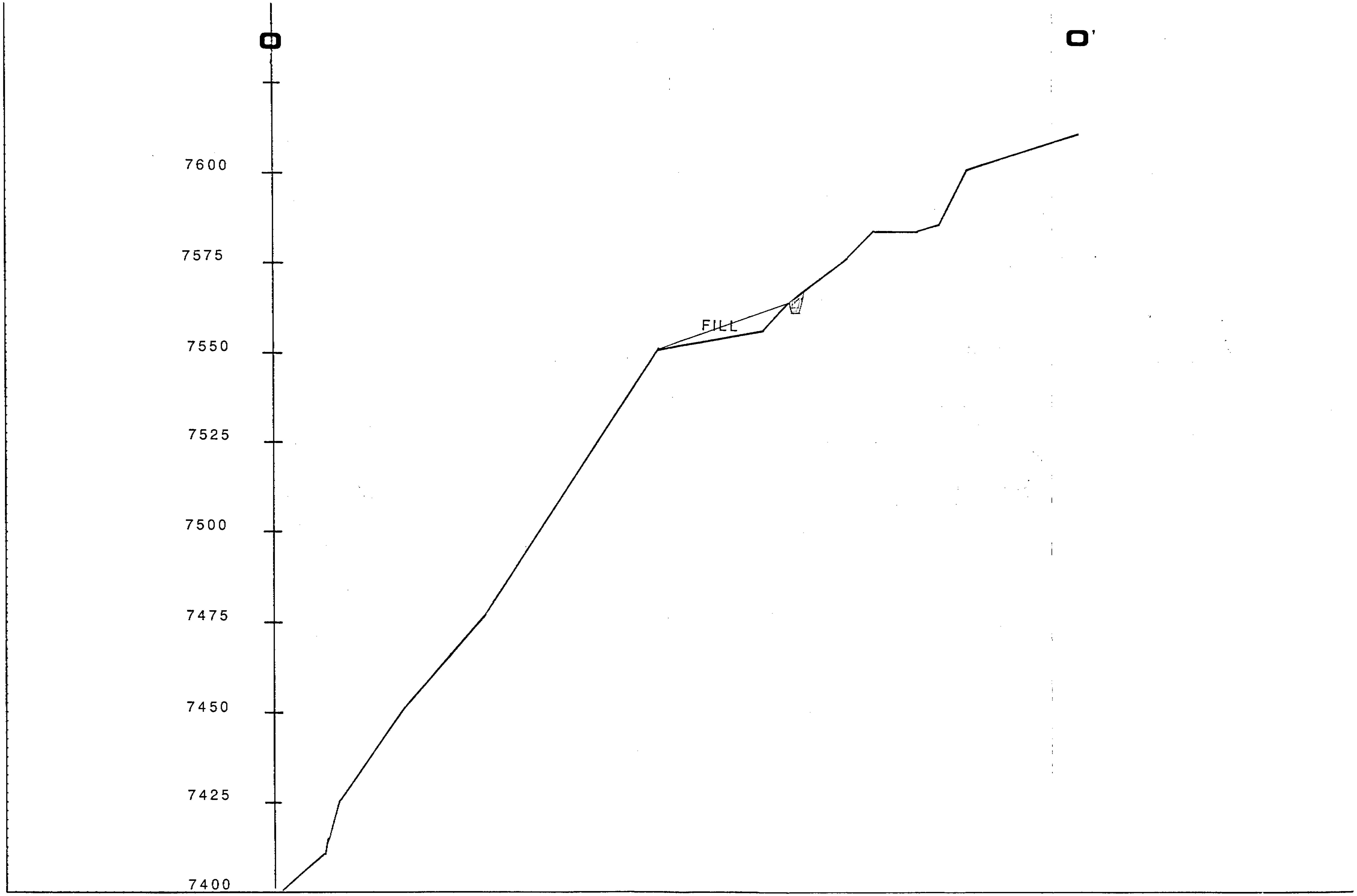

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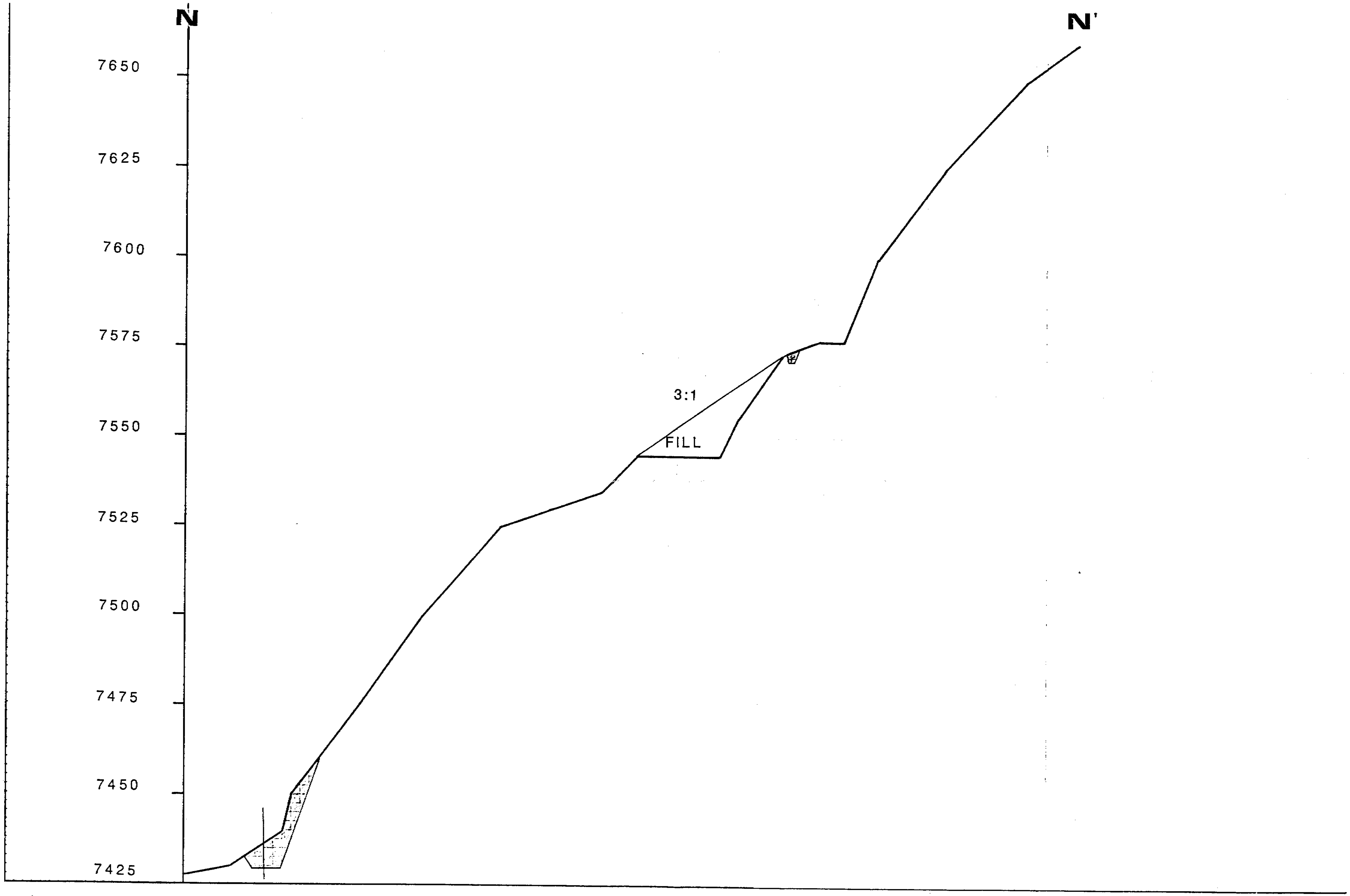

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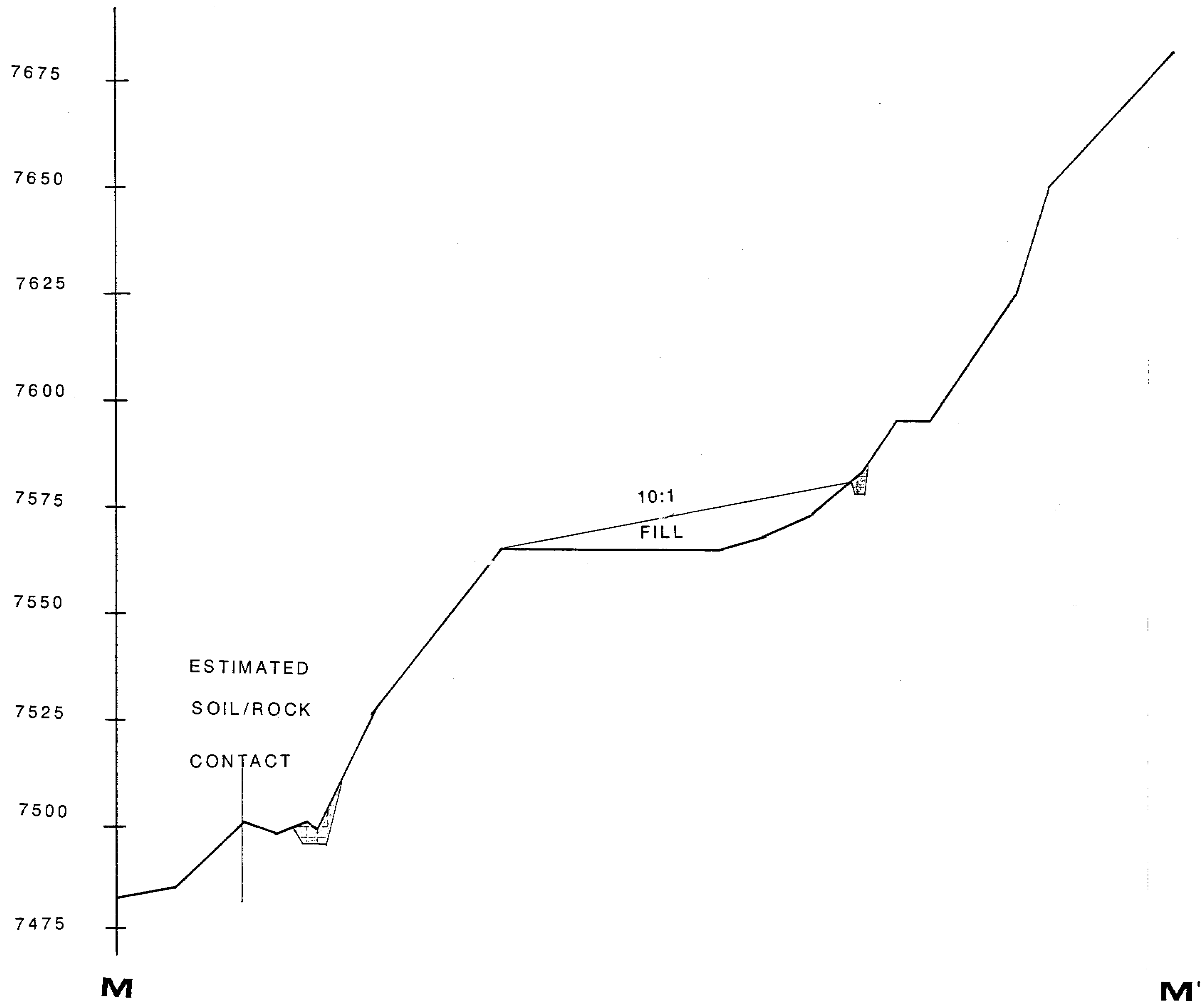

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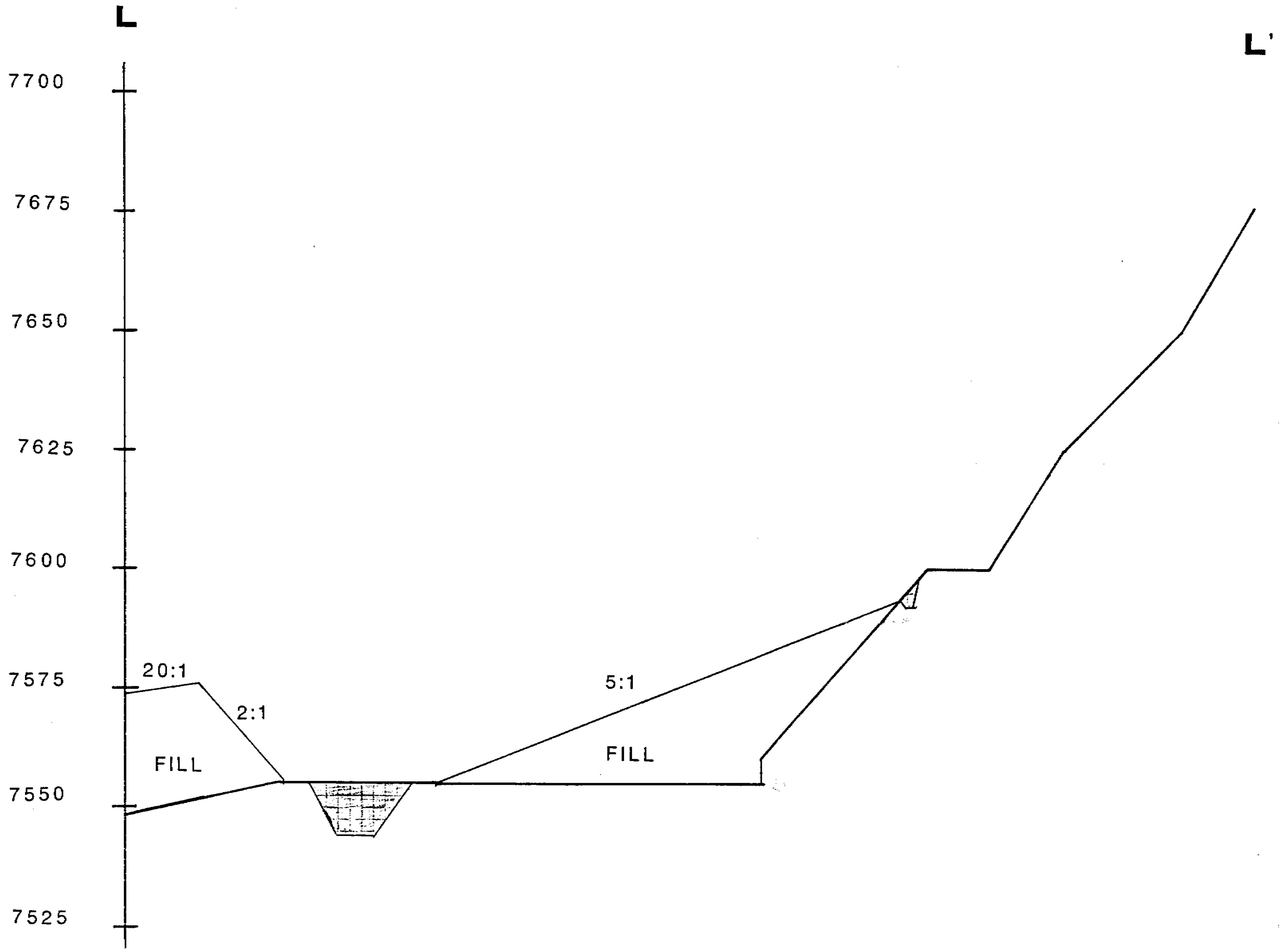

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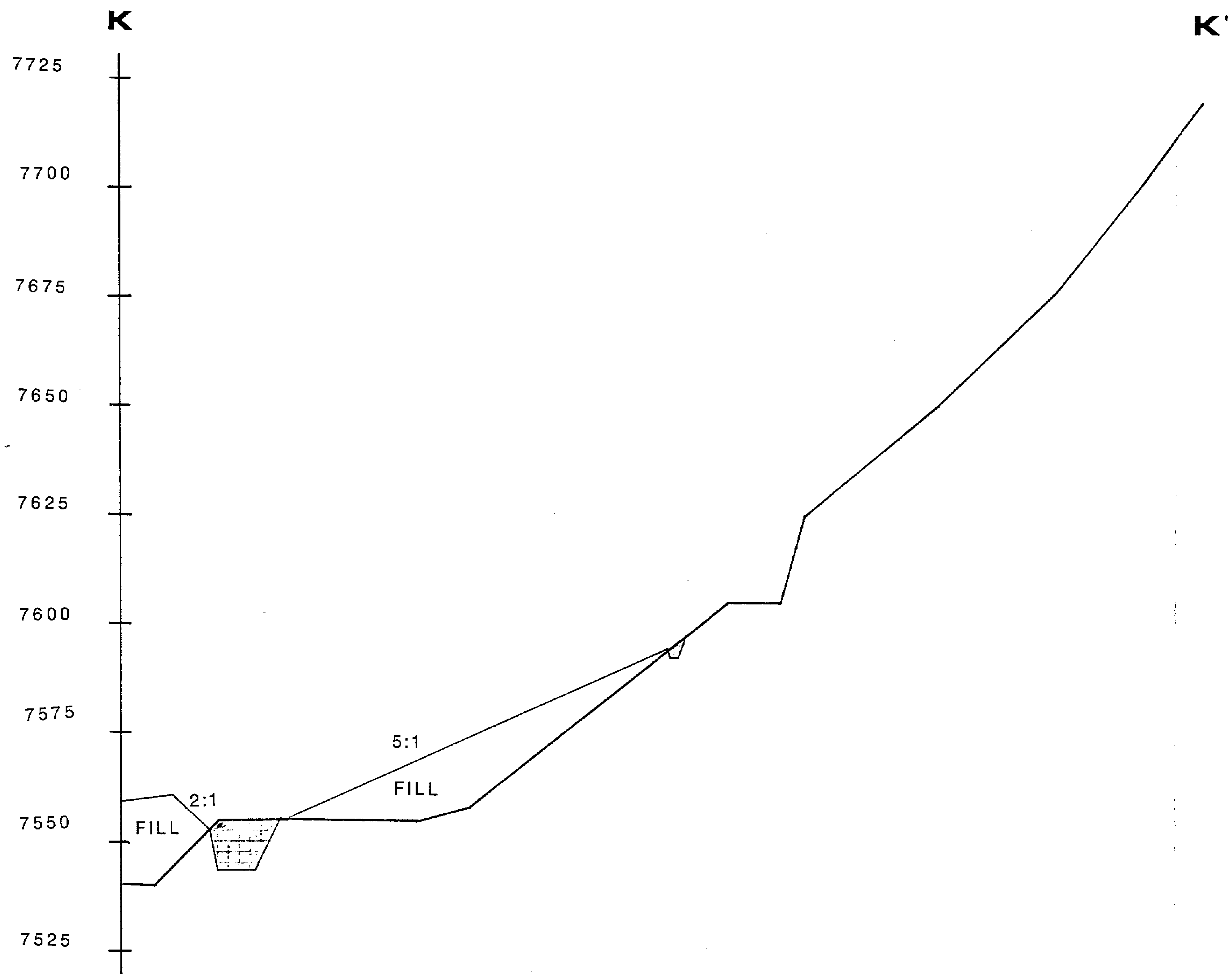

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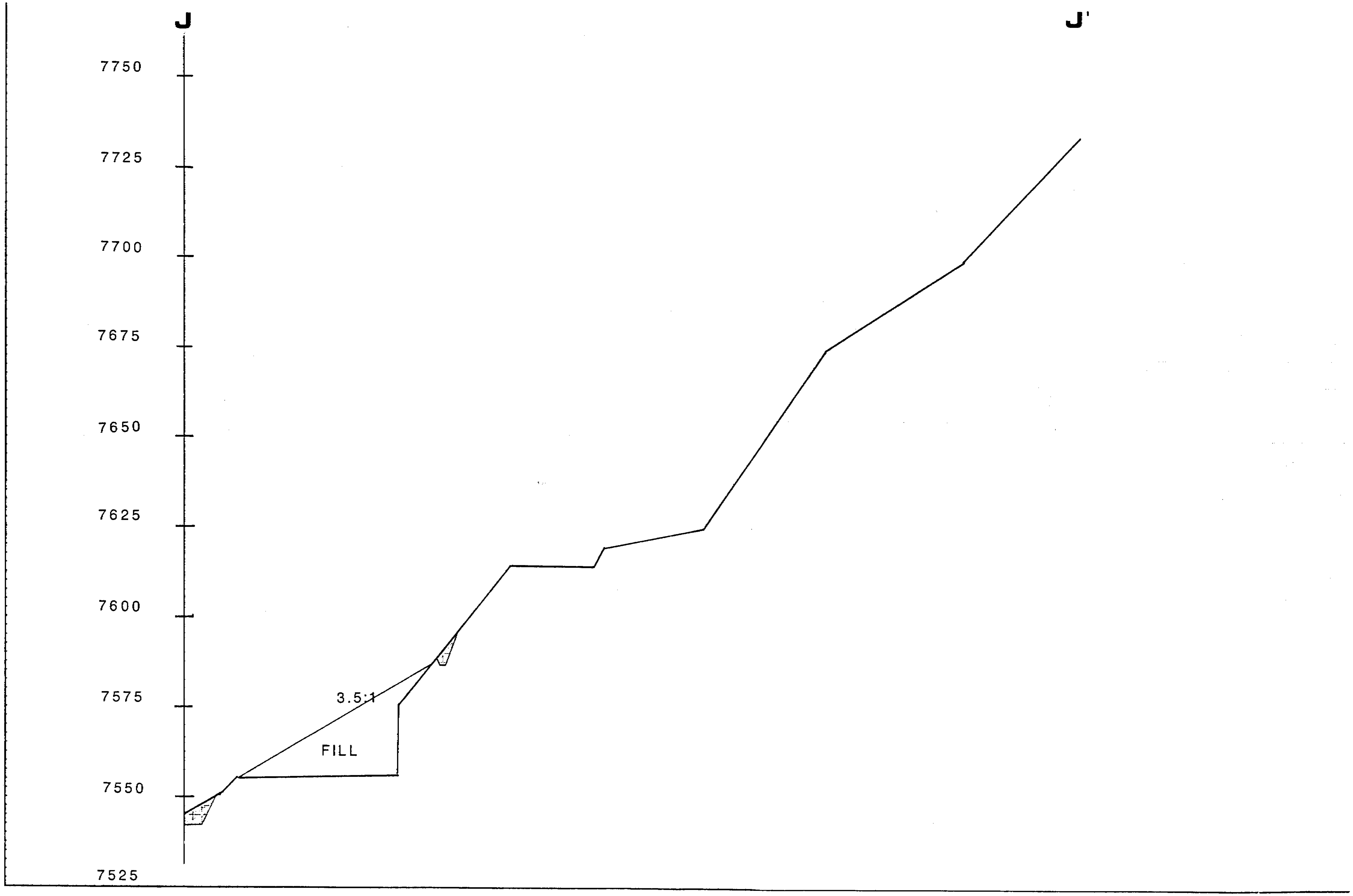

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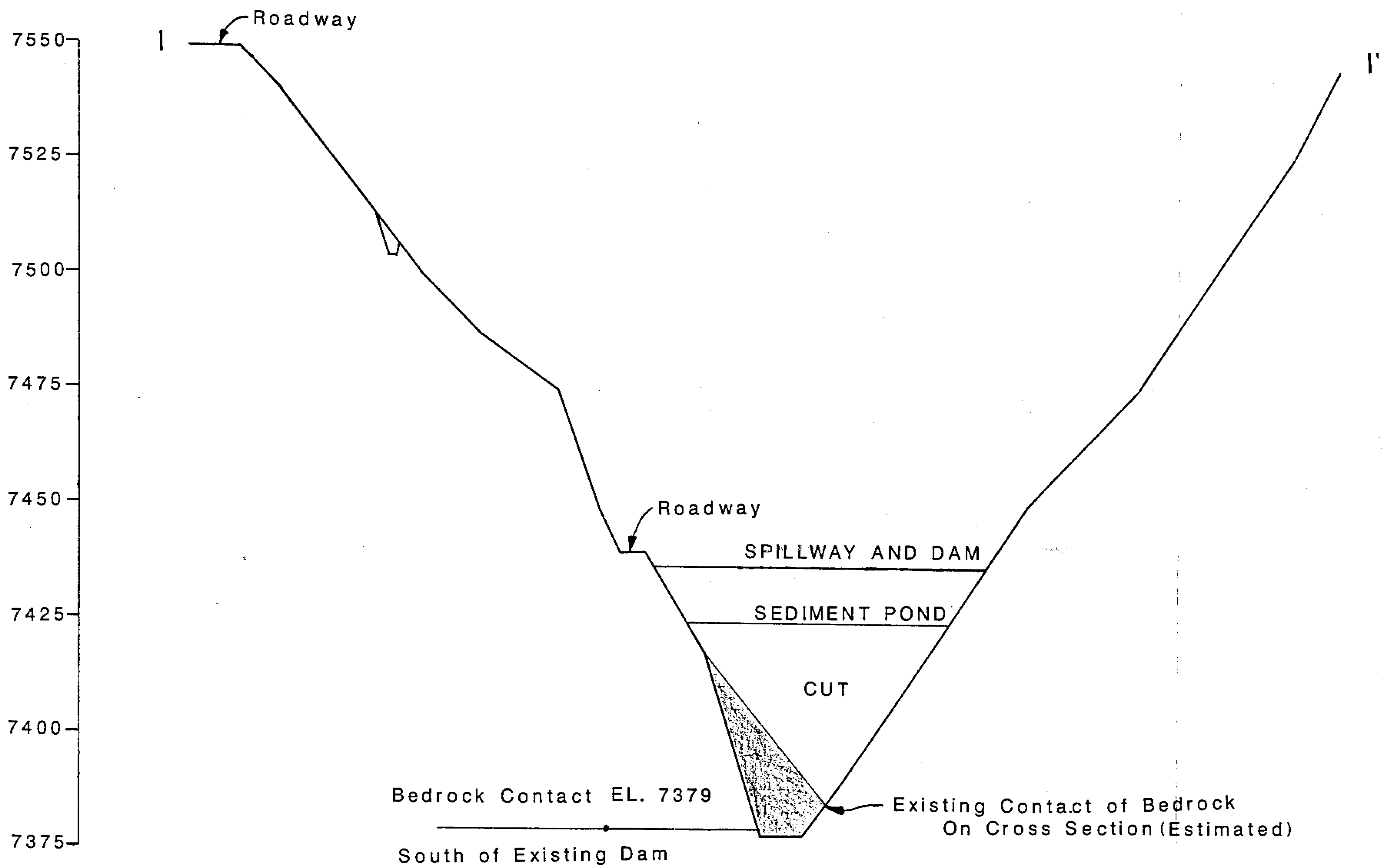

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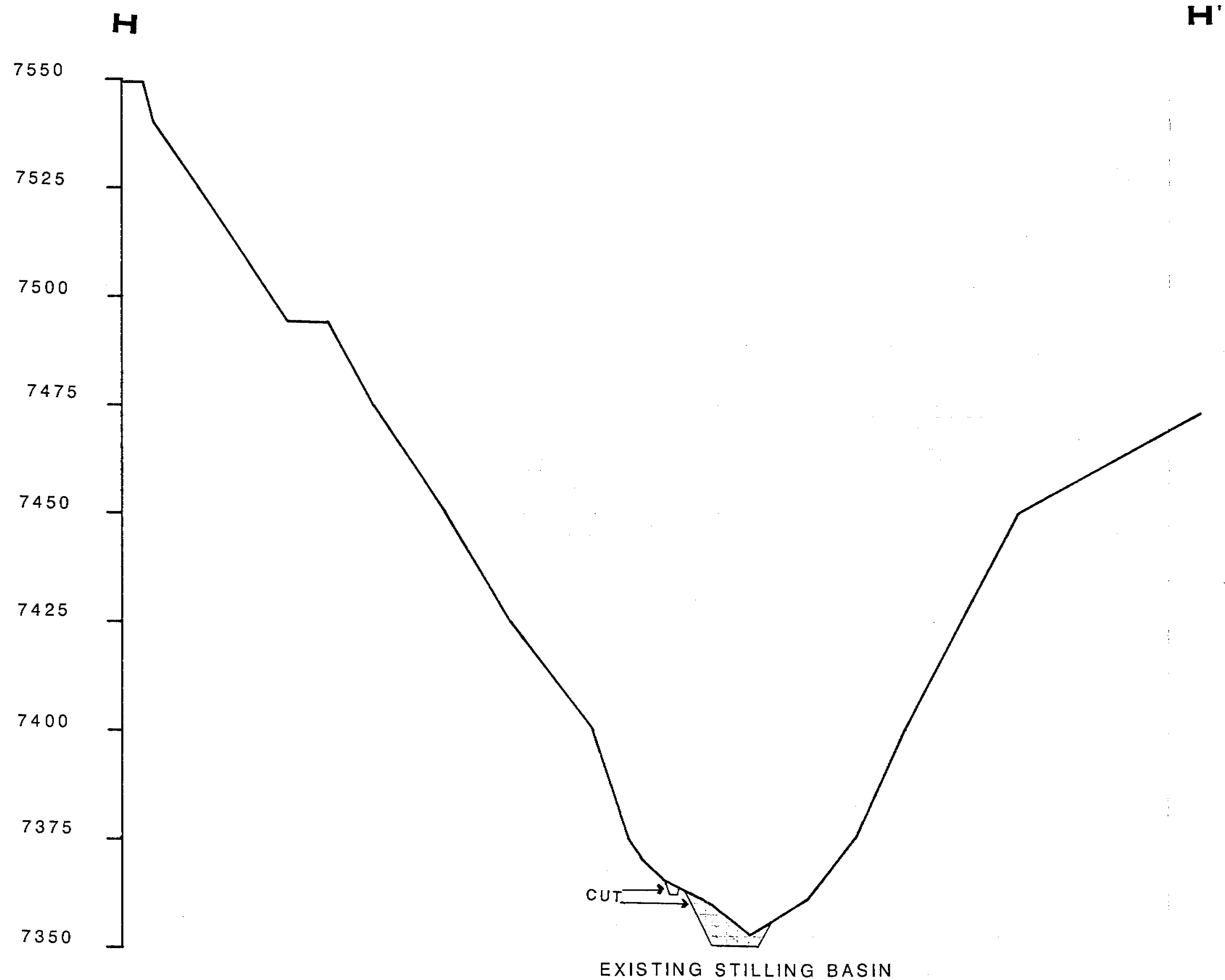

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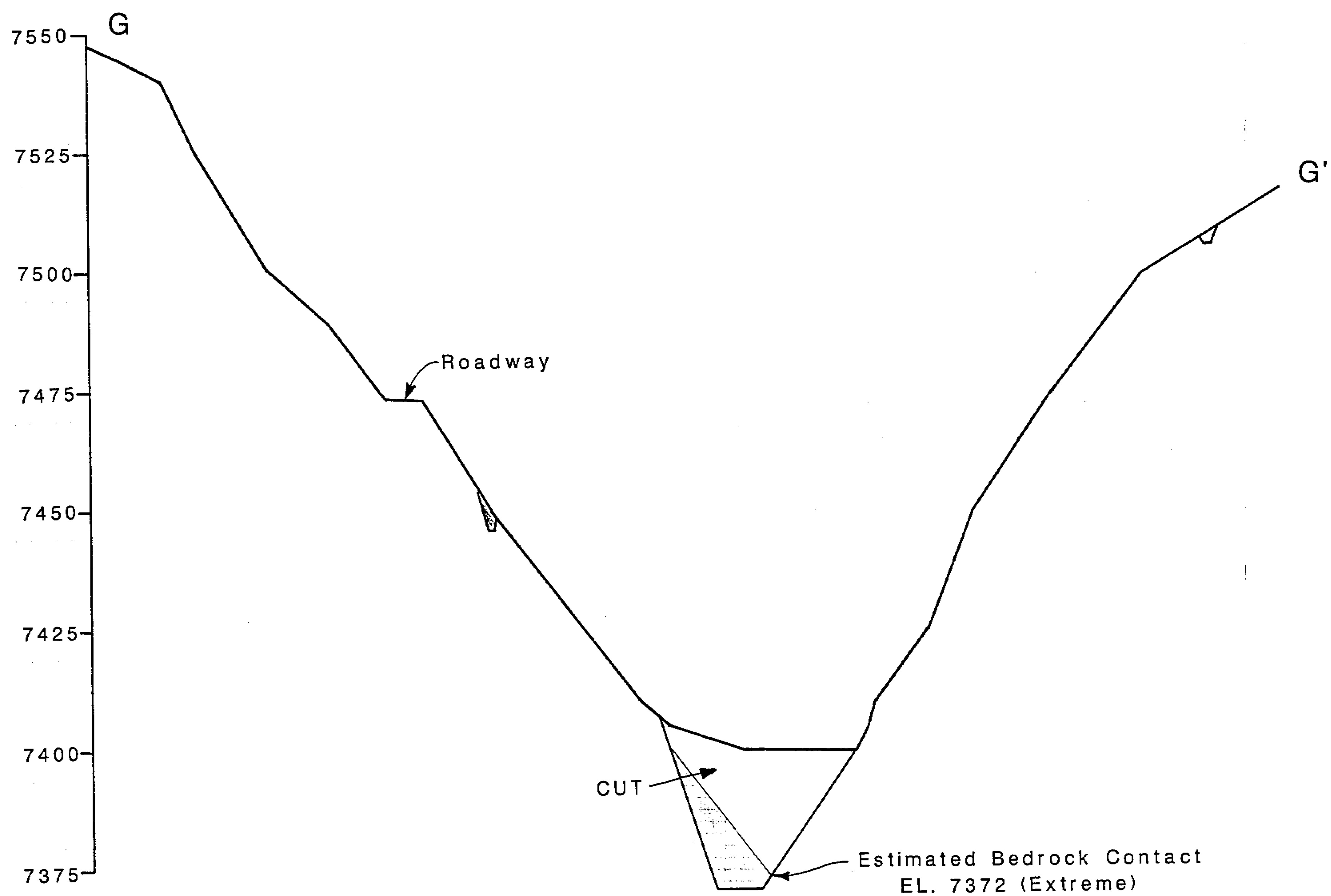

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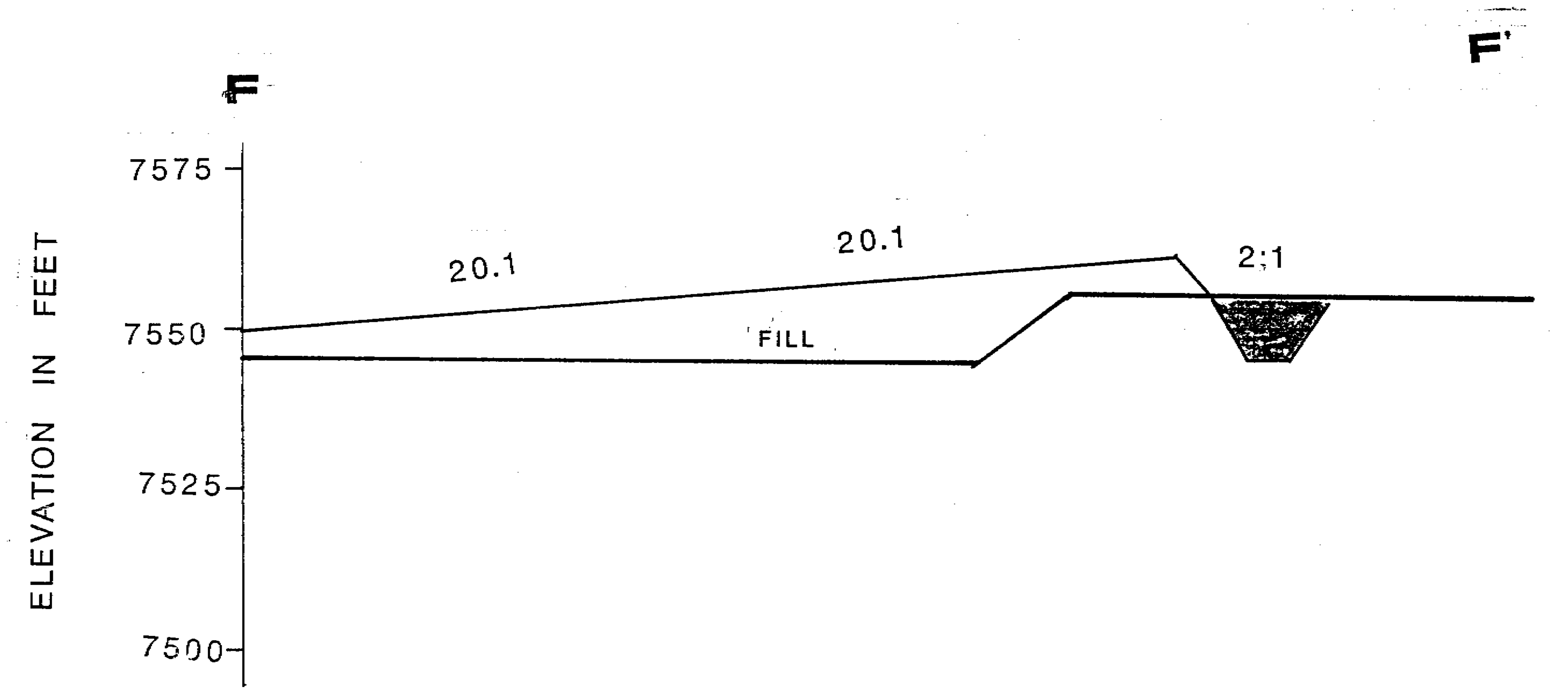

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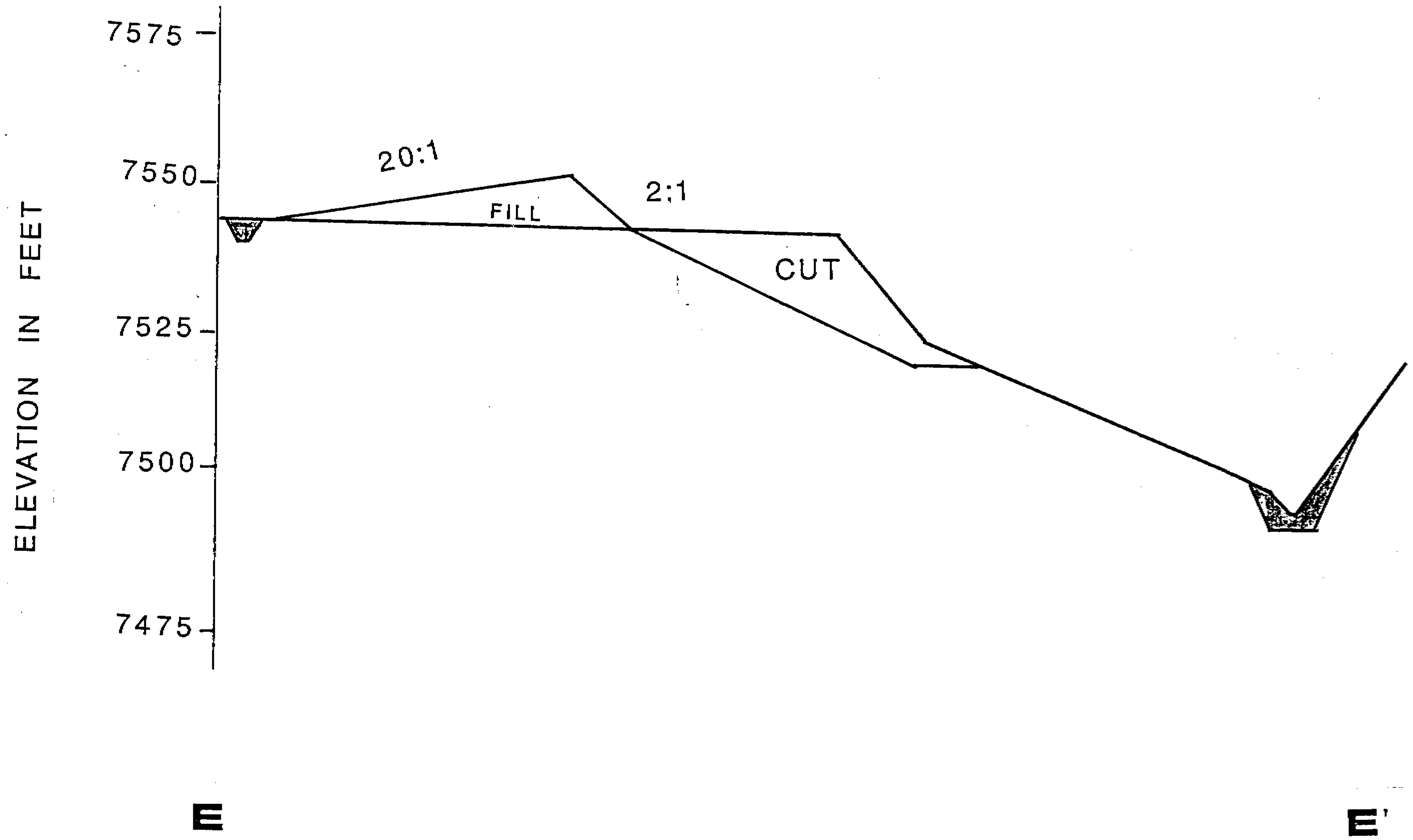
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2:1
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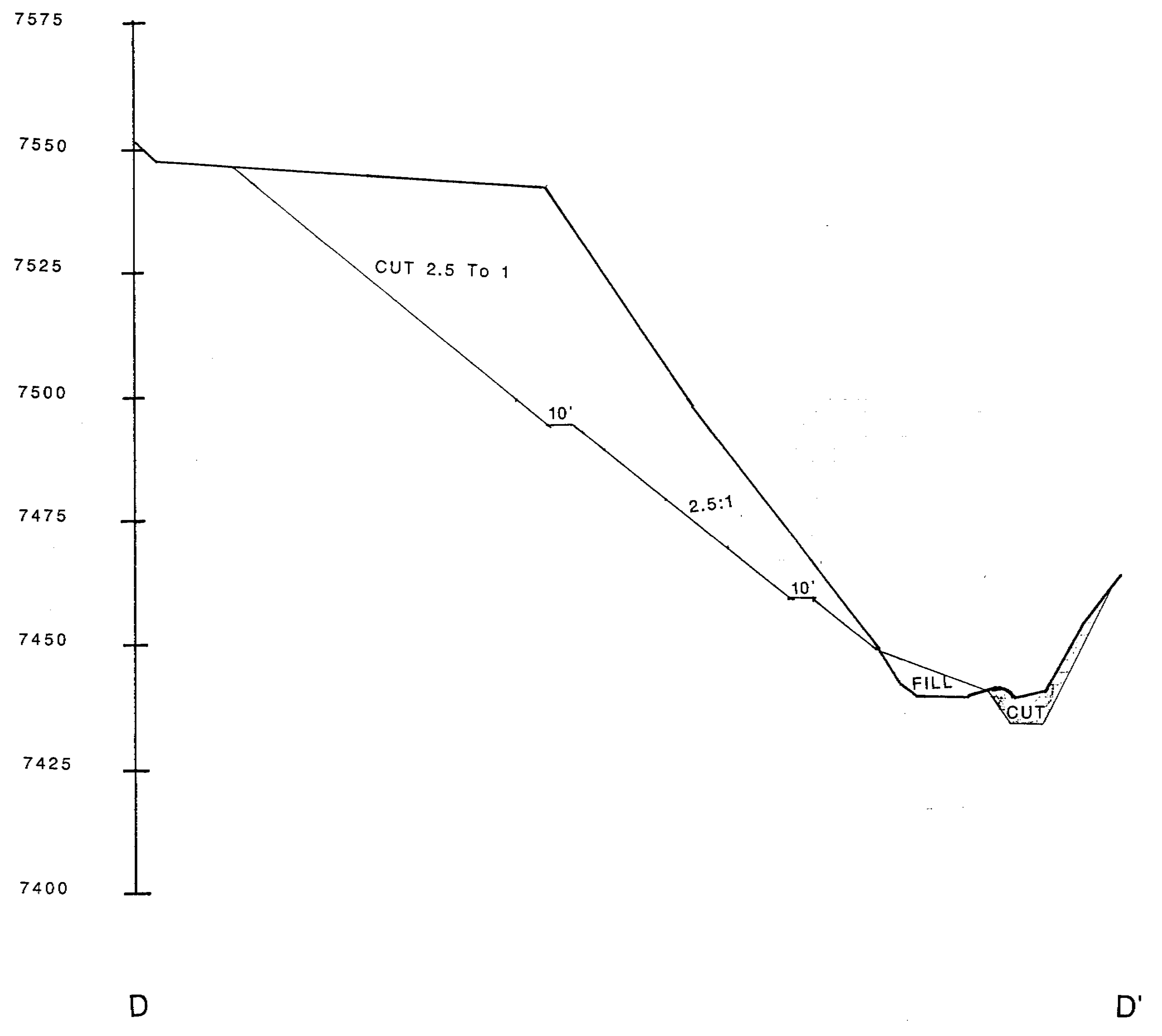
CUT
E
E'



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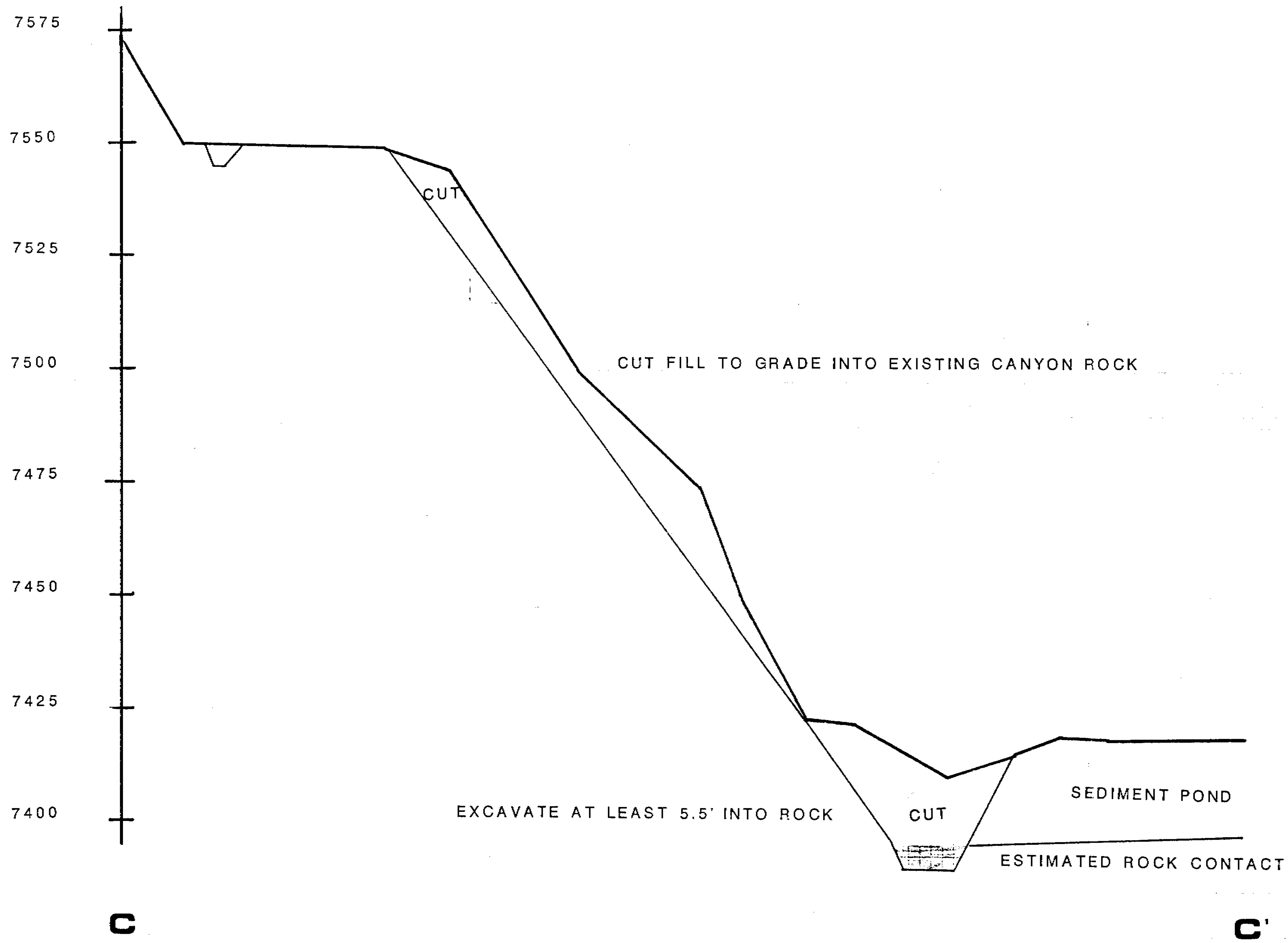

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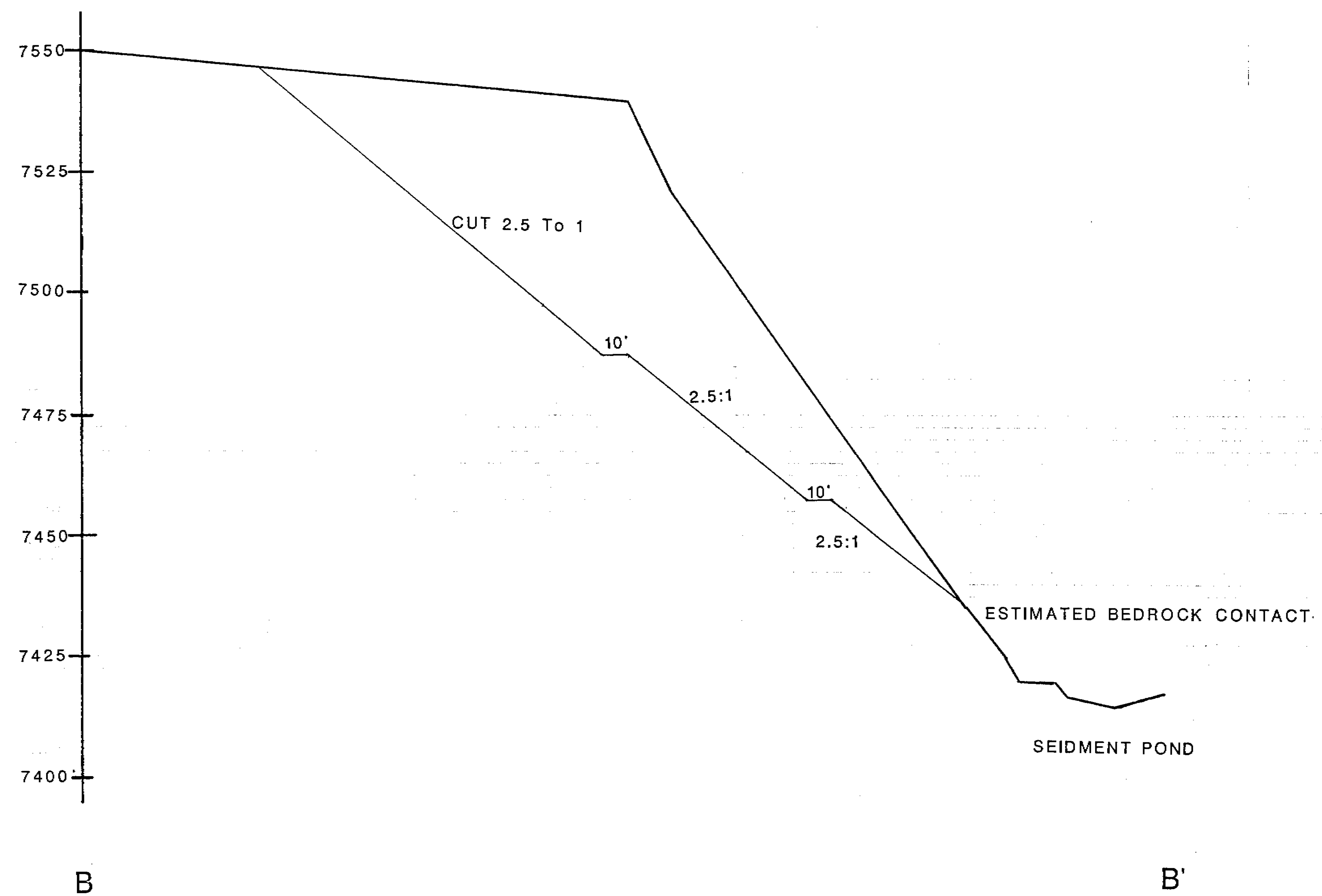

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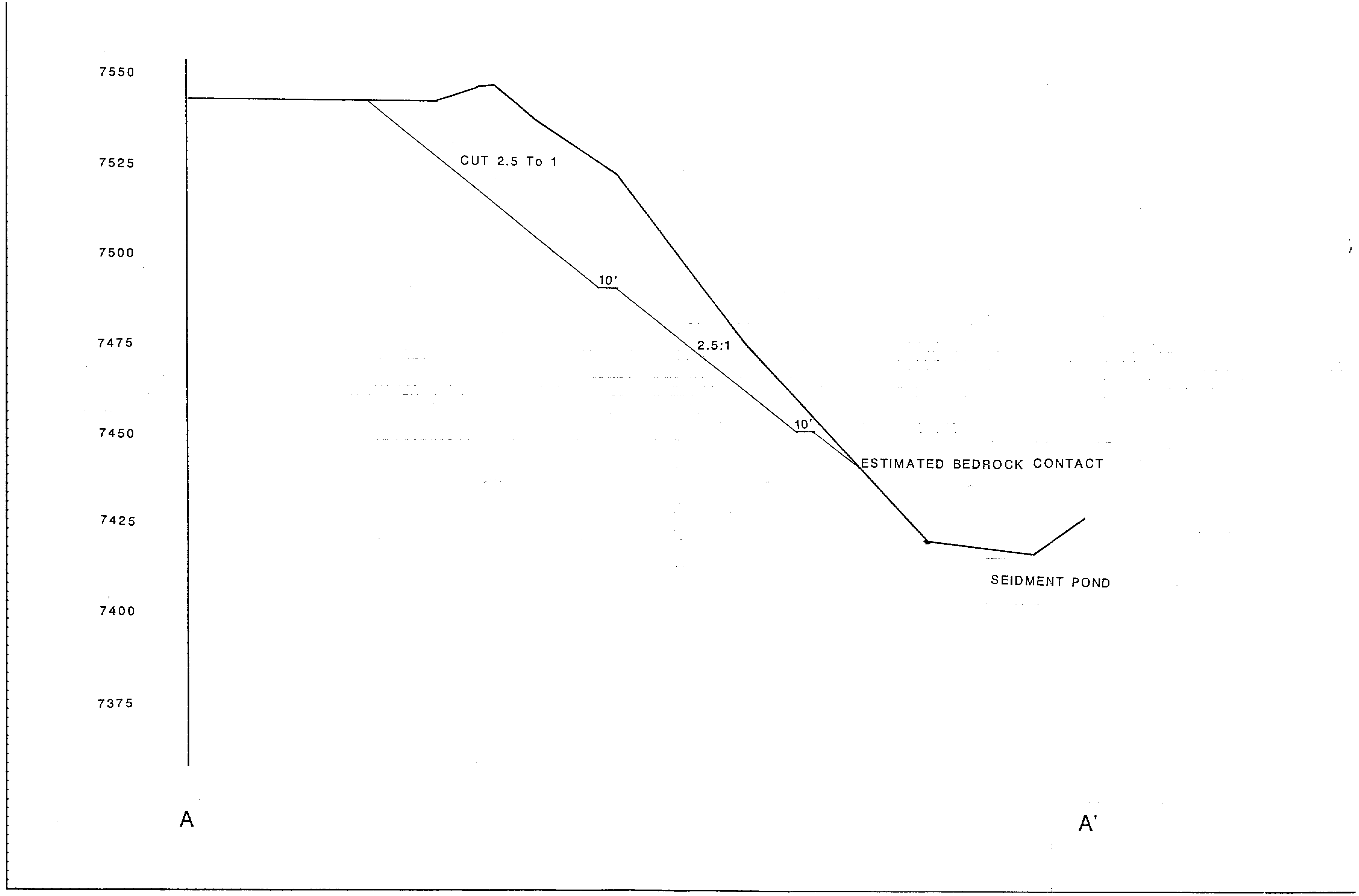

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SUBMITTAL OF DRAINAGE PLAN AND SLOPE STABILITY FOR RECLAMATION FOR CONVULSION CANYON MINE, ACT/041/002, NO. 2, NO. 3 & NO. 14 SEVIER COUNTY, UTAH

Prepared for:

Southern Utah Fuel Company
South Highway 89
Salina, Utah 84654

SHB Job No. E83-2022

SERGENT, HAUSKINS & BECKWITH

Consulting Geotechnical Engineers
PHOENIX • ALBUQUERQUE • SANTA FE • SALT LAKE CITY

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APPLIED SOIL MECHANICS • ENGINEERING GEOLOGY • MATERIALS ENGINEERING • HYDROLOGY

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LAWRENCE A. HANSEN Ph.D., P.E.
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ROBERT L. FREW
ALLON C. OWEN JR., P.E.

February 24, 1986

Southern Utah Fuel Company
South Highway 89
Salina, Utah 84654

SHB Job No. E83-2022

Attention: Mr. Wesley K. Sorenson
Chief Engineer

Re: Submittal of Drainage Plan and Slope Stability for Reclamation for Convulsion Canyon Mine, ACT/041/002, No. 2, No. 3 & No. 14
Sevier County, Utah

RECEIVED
FEB 27 1986
DIVISION OF
OIL, GAS & MINING

Gentlemen:

Enclosed herewith is our proposed drainage and slope stability plan for the Reclamation Plan of the referenced project. The report includes the results of test drilling, laboratory analysis and recommendations for reclamation.

Should any questions arise concerning this report, we would be pleased to discuss them with you.

Respectfully submitted,
Sergent, Hauskins & Beckwith Engineers

By [signature]
Paul Kaplan, E.I.T.

Reviewed by [signature]
Allon C. Owen, Jr., P.E.

Copies: Addressee (16)

REPLY TO: 4030 S. 500 WEST, SUITE 90, SALT LAKE CITY, UTAH 84123

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SHB Job No. E83-2022

1. INTRODUCTION

This report is submitted pursuant to a geotechnical investigation made by this firm of the canyon fill which has been placed at the portals of the Southern Utah Fuel Company, Convulsion Canyon Mine. The objective of this investigation was to evaluate the physical properties of the fill in order to provide recommendations for the design of various earthwork elements of the reclamation plan, and the location of erosion resistant bedrock units for the placement of drainage channels.

2. PROJECT BACKGROUND

The originally proposed reclamation plan consisted of regrading the disturbed area to establish a main stream channel and small side slope drainage channels. The main stream channel would have been constructed through the center of the mine site to facilitate precipitation runoff from all contributing drainage basins. Construction of the main channel could have required cuts in the existing canyon fill with 2:1 (horizontal to vertical) side slopes.

The materials from these cuts would have been placed in compacted lifts on the sides of the canyon within the mine permit area.

Design of the main channel presented unique problems due to relatively deep cuts and protection of the loose, end-dumped canyon fill as well as the very steep channel gradients which exist.

The reaches of Mud Spring Hollow and East Spring Hollow above the mining area are characterized by steep gradients, waterfalls, pools, large boulders, exposed bedrock ledges and reaches of mild slopes underlain with sand and gravel alluvium.

Within the disturbed reaches, there was likely a similar regime. The natural channel would have dropped 219 feet of elevation in 1,540 feet in length, for an average gradient of 14 percent. The canyon fill has modified the channel by flattening the upper reaches and steepening the lower reaches, and also by covering up any natural waterfalls and pools.

An attempt to assimilate the bedrock environment of the natural channel was proposed in the original submittal using grouted riprap on the steep reaches with a stilling pool at the bottom of the disturbed area (SHB; April, 1984). This proposal was rejected by regulatory agencies due to possible maintenance problems. The agencies, at that time, indicated to SUFCO that only unreinforced riprap would be suitable for a long-term reclamation project.

Based on this information, a triple-layered, boulder-size riprap was recommended (SHB; May, 1984). Subsequent to receiving this design alternative, the regulatory agencies determined that gabion-lined drop structures would be a preferable alternative to the triple-layered riprap design.

The design was then modified to include gabion-lined drop structures to break up the steep gradients and dissipate energy by use of waterfalls and stilling ponds with riprap utilized for reaches between the drop structures (SHB; January, 1985). Subsequent to receipt of this design option, regulatory agencies determined that the gradients in the lower reaches of the main channel were too steep and it would be preferable to place these reaches on bedrock.

This requirement would have necessitated removal of large quantities of fill with a very limited area to place the material. It was then proposed to steepen the cut slopes to minimize excavation quantities. In order to steepen the cut slopes and to evaluate the stability of these slopes, a geotechnical investigation was performed to assess the engineering properties of the existing canyon fill. The remainder of this report addresses the geotechnical investigation and subsequent analyses performed which resulted in the reclamation plan presented in this report.

The conceptual design of this reclamation plan was discussed in a meeting held at the Salt Lake City

Division of Oil, Gas and Mining offices on October 8, 1985. The meeting was attended by representatives of the Division of Oil, Gas and Mining (DOGM), Office of Surface Mining (OSM), United States Forest Service (USFS), Southern Utah Fuel Company (SUFCO) and Sergent, Hauskins & Beckwith Engineers (SHB). After this meeting a reclamation plan was submitted detailing the conceptual design (SHB, December, 1985).

Subsequent to receipt of this submittal another meeting involving the aforementioned parties was held on February 19, 1986 at SUFCO the offices which necessitated the changes reflected in this document.

3. INVESTIGATION

3.1 Geologic Reconnaissance & Mapping

A field investigation of the surface geology and geomorphology of the site area was undertaken in order to characterize pre-mine drainage patterns, to locate the limits of the fill and to locate erosion resistant bedrock units. This investigation included a study of available topographic maps and aerial photographs of the site before and after mine development.

3.2 Subsurface Investigation

A total of six exploratory borings were drilled through the canyon fill in the vicinity of the originally proposed main channel alignment. These 6 5/8-inch diameter hollow stem auger borings ranged in depth from 30 to 90 feet below the existing ground surface. All borings were advanced to bedrock or auger refusal in bedrock.

Standard penetration testing or Shelby tube sampling was performed at 5-foot intervals or less in these borings.

The locations of the borings are shown on the site plan (Plate 1), included in the map pocket at the end of this report.

All soils were classified by the Unified Soil Classification System (ASTM D2487) which is summarized in Appendix A. Terminology and coding used in the description of rock is also presented in Appendix A, along with the boring logs and a short description of drilling methods employed.

All borings were backfilled with cuttings subsequent to drilling.

3.3 Laboratory Analysis

To aid in the classification of the materials encountered, determinations of grain-size distribution and Atterberg Limits and chemical tests were performed on standard penetration and tube samples. Moisture content and dry density tests were also performed on selected samples.

Direct shear tests were performed on selected tube samples of the materials encountered.

Results of dry density and moisture content determinations are presented on the boring logs in Appendix A. Results of the other laboratory tests are presented in Appendix B.

4. SITE CONDITIONS & GEOTECHNICAL PROFILE

4.1 Topography & Surface Features

The surface facilities of the mine are situated in a narrow, steeply-sloped canyon which runs from north to south into Convulsion Canyon, a tributary to Quitchupah Creek. The steep canyon walls are made up of units of the Blackhawk Formation which are interbedded cliff formers and slope formers. The cliff formers are primarily sandstones and siltstones, and the slope formers are primarily mudstones and shales. In order to accomodate the surface facilities at the mine portals, a pad was constructed by excavating material from the canyon walls and placing the material in the bottom of the canyon. High cuts exist in the canyon walls along the pad where materials were excavated to form the canyon fill. Several of the surface mine structures were placed on sandstone benches created by the excavation. The culvert, which currently conveys canyon runoff flows past the fill, is placed on a sandstone ledge beneath the fill. The fill area is used primarily for coal stacking and loading. The approximate limits of the existing fill, the locations of sandstone ledges and other select surface features are presented on Plate 2.

The southern face of the fill is presently over 130 feet high with a slope of 1.4:1 (horizontal to vertical). Utilizing information gathered during the field exploration program, a series of cross sections were prepared to allow an estimate of the location of the original stream channel and bedrock surface. The location of these cross sections are shown on Plate 1 and the cross sections are presented in Appendix C.

The undisturbed canyon exposures indicate steep canyon walls with slopes on the order of 2:1 (horizontal to vertical) or steeper. Extrapolation of cross sections by correlating boring logs and undisturbed canyon slopes indicates irregular, steep natural stream gradients with the probable existence of waterfalls and pools. Estimated average natural stream gradients are presented below:

Location	Estimated Average Stream Gradient
Boring 5 to Boring 4	11%
Boring 4 to Boring 3	4%
Boring 3 to Boring 2	33%
Boring 2 to Boring 6	14%
Boring 6 to Sediment Pond	21%

The toe of the existing fill is near the contact of the Blackhawk Formation and the Starpoint Sandstone which is a silty mudstone, cemented with lime and gypsum. A sediment pond just downstream of the fill is keyed into the Starpoint Sandstone.

4.2 <u>Description of Soils & Rocks</u>

The existing canyon fill consists of a heterogenous mixture of materials which was placed by dozers and end-dumped by mine haulage trucks. The fill consists of highly variable units of clay, silt, sand, gravel, cobbles and boulders. The fill is underlain by the Blackhawk Formation.

The character of the fill materials encountered above the bedrock surface in the exploratory borings is highly variable as would be expected in a fill of this type. Silty clays, sandy clays, sandy silts and silty sands are the predominant materials encountered. Varying amounts of gravels, cobbles and boulders were present in most of these materials. Lenses of coal as well as signs of wood and metal chips were also encountered in some of the borings.

In general, the borings encountered interbedded coarse to fine gravels, sand, silt and clay of varying amounts, with signs of construction debris and coal lenses. The materials are generally well stratified and their composition may vary considerably from one layer to the next and also within layers. Frequent unpredictable changes of materials are present within the fill due to the methods employed during placement.

Most of the materials encountered during the exploratory drilling program were in a slightly moist to moist condition. However, some materials encountered in Borings 5 and 6 were in a very moist condition.

The fine grained soils encountered are, in general, moderately firm to firm, while the granular materials are generally firm to hard. However, softer layers or lenses may be present near surface and at depth (see logs of Borings 5 and 6 for examples).

Just above the bedrock surface in Borings 1, 3, 4, 5 and 6, apparent stream alluvium was encountered. These materials consisted of subrounded to rounded, nonplastic sands and gravels.

Bedrock encountered in the borings is similar to that which is exposed in natural exposures at the site and is classified as the Blackhawk Formation.

4.3 Groundwater & Soil Moisture Conditions

Although some of the fill materials were in a very moist condition, no free groundwater was encountered in any of the borings. Some discontinous zones of perched groundwater may be encountered at depth due to spring activity.

4.4 Existing Drainage System

Runoff originating upstream of the fill is presently conveyed past the fill in a corrugated metal culvert. Runoff originating on the canyon walls above the site and on the pad area is drained to a sediment control pond near the toe of the fill through ditches and culverts. All of the runoff is returned to the natural stream after passing through a boulder-lined pond near the boundary of the disturbed area as shown on Plate 2.

5. DISCUSSIONS & RECOMMENDATIONS FOR A FINAL RECLAMATION PLAN

Final recommendations for channel location and design, as well as site grading and other elements of the project are presented in this section.

5.1 Discussion

As outlined in Section 2, the purpose of this portion of the reclamation plan is to recommend the placement of the fill in a stable condition and to recommend conveyance schemes of precipitation runoff which control erosion.

Major features of the plan are shown on Plate 2. The culverts will be removed and flows from Mud Spring Hollow and East Spring Hollow will be directed into a channel excavated in a bedrock bench along the east side of the existing fill. Downstream of the existing fill the flow will be allowed to cascade down the canyon wall to approximately the natural stream bed and into the existing stilling basin.

The Starpoint Sandstone will underly the basin and the reaches of the channel downstream of the fill.

Runoff from the canyon walls will be diverted into collection ditches and conveyed to the main channel in a controlled manner. Runoff originating on the fill will drain to either the main channel or the west side collector channel. Provisions for erosion control on the fill will be discussed later.

5.2 Hydrology

There is approximately 8 square miles of contributing drainage basin area to the mine site. The two major basins, Mud Spring Hollow and East Spring Canyon, are located upstream from the mine and account for 99 percent of the contributing basin area. Two small basins, contributing basin east (CBE) and contributing basin west (CBW), are adjacent to the mine site.

Hydrologic calculations for the 10, 25 and 100-year, 24-hour precipitation events were performed by Merrick & Company (1979). Table 1 summarizes peak rainfall accumulations and discharges for each frequency event.

TABLE 1

Summary of Peak Rainfal
Accumulation and Discharge
for Each Contributing Basin

Event, Year	Rainfall, Inches	Drainage Basin Discharge, cfs			
		MSH	ESC	CBE	CBW
10	1.88	147	247	5.5	9.5
25	2.25	245	412	9.3	15.8
100	2.87	453	761	17.1	29.3

MSH - Mud Spring Hollow

ESC - East Spring Canyon

CBE - Contributing Basin East

CBW - Contributing Basin West

Note: The combined 100-year peak flow used in design is 1,250 cfs

5.3 Design Analysis

5.3.1 Analysis of Slope Stability of Cut Slopes in Existing Fill

As stated in Section 2, an alternative concept for reclamation was to excavate through the fill and reconstruct the original stream channel. This would require cuts in excess of 100 feet in depth through the existing canyon fill.

A stability analysis was performed on the maximum fill cross section (Borings 1 and 6) which is located near the lower reaches of the channel to assess the feasibility of this option.

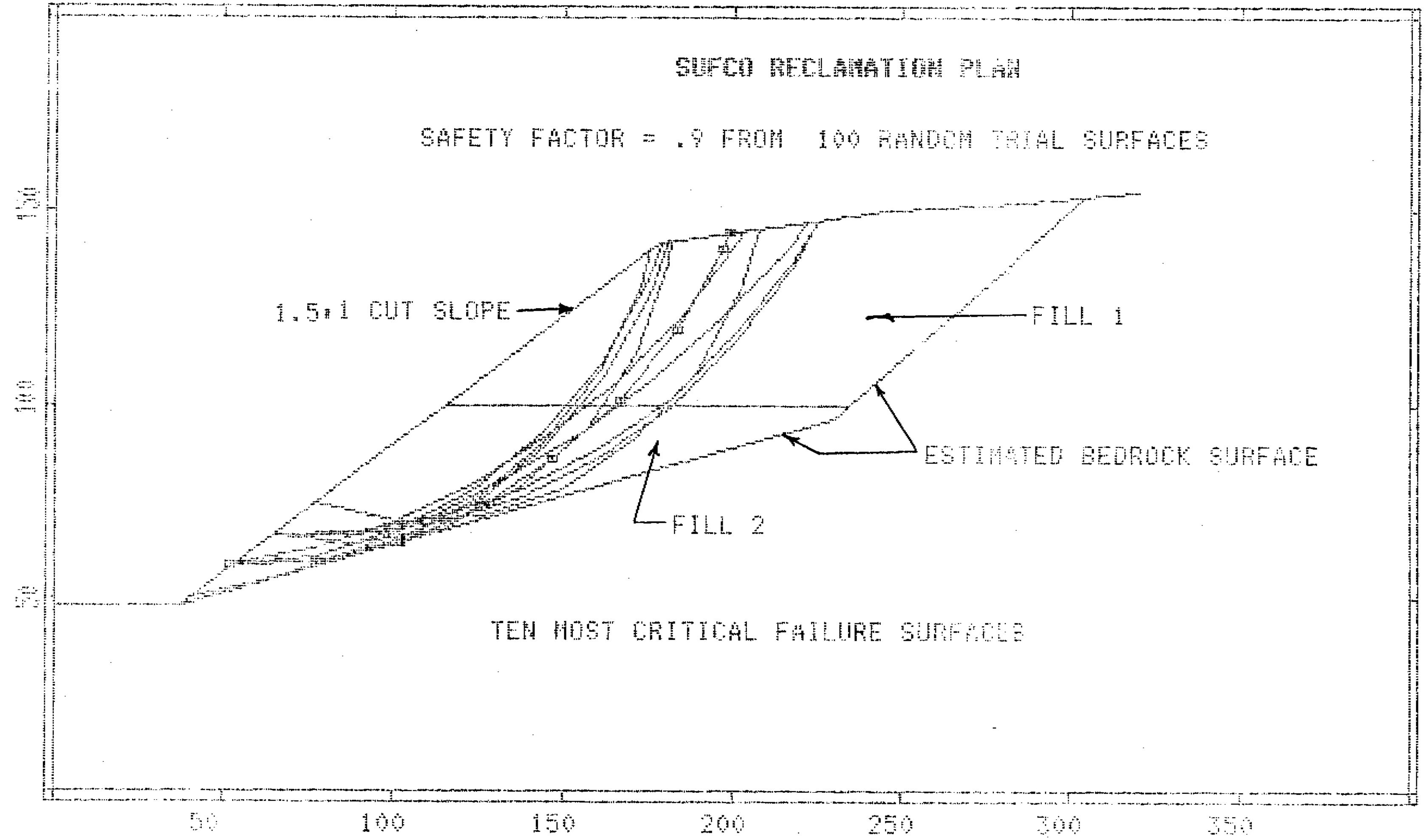
The stability analysis was conducted using the computer program STABL2 developed by Siegel (1975). Determination of the factor of safety against failure utilizes a conventional method of slices approach with the modified Bishop method of analysis. The particular procedure employed generates circular-shaped slip surfaces between specified coordinate limits. The factor of safety computed by this method is conservative relative to solutions obtained by more accurate methods satisfying complete equilibrium.

The existing canyon fill is underlain by the Blackhawk Formation. All critical shear surface search routines were directed to locate a surface above the Blackhawk Formation in the fill material.

Strength parameters for the existing fill materials were based upon the results of laboratory testing and engineering judgement. Due to very moist soil conditions and low shear strength materials encountered at depth in Boring 6, the fill was divided into two soil layers. Two cut slopes of 1.5:1 and 2:1 (horizontal to vertical) were analyzed. Minimum factors of safety equal to 0.9 and 1.23 were calculated for 1.5:1 and 2:1 slopes, respectively. The results of this analysis are presented in Figures 1 and 2. These low factors of safety are primarily due to the steep bedrock canyon walls which act as a plane of weakness along which the most critical failure surfaces follow. Due to these low factors of safety, it is recommended that deep cuts in this material be avoided. Slopes could be flattened to achieve a minimum factor of safety of 1.5, however, this would entail the removal of essentially all of the existing canyon fill. Due to the narrow area available for placement of excavated materials and the resulting environmental impact of this option, this alternative does not appear to be practical. An alternative design is presented in the following sections.

5.3.2 Analysis of Slope Stability of Existing Southern Slope

As stated in Section 4.1, the southern face of the existing canyon fill is presently over 130 feet in height at a slope of approximately 1.4:1 (horizontal



Fill 1 γ = 120 pcf
c = 500 psf
ϕ = 30°

Fill 2 γ = 110 pcf
c = 350 psf
ϕ = 13.5°

FIGURE 1

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for Reclamation for Convulsion
Canyon Mine, ACT/041/002, No. 2
No. 3 & No. 14
Sevier County, Utah

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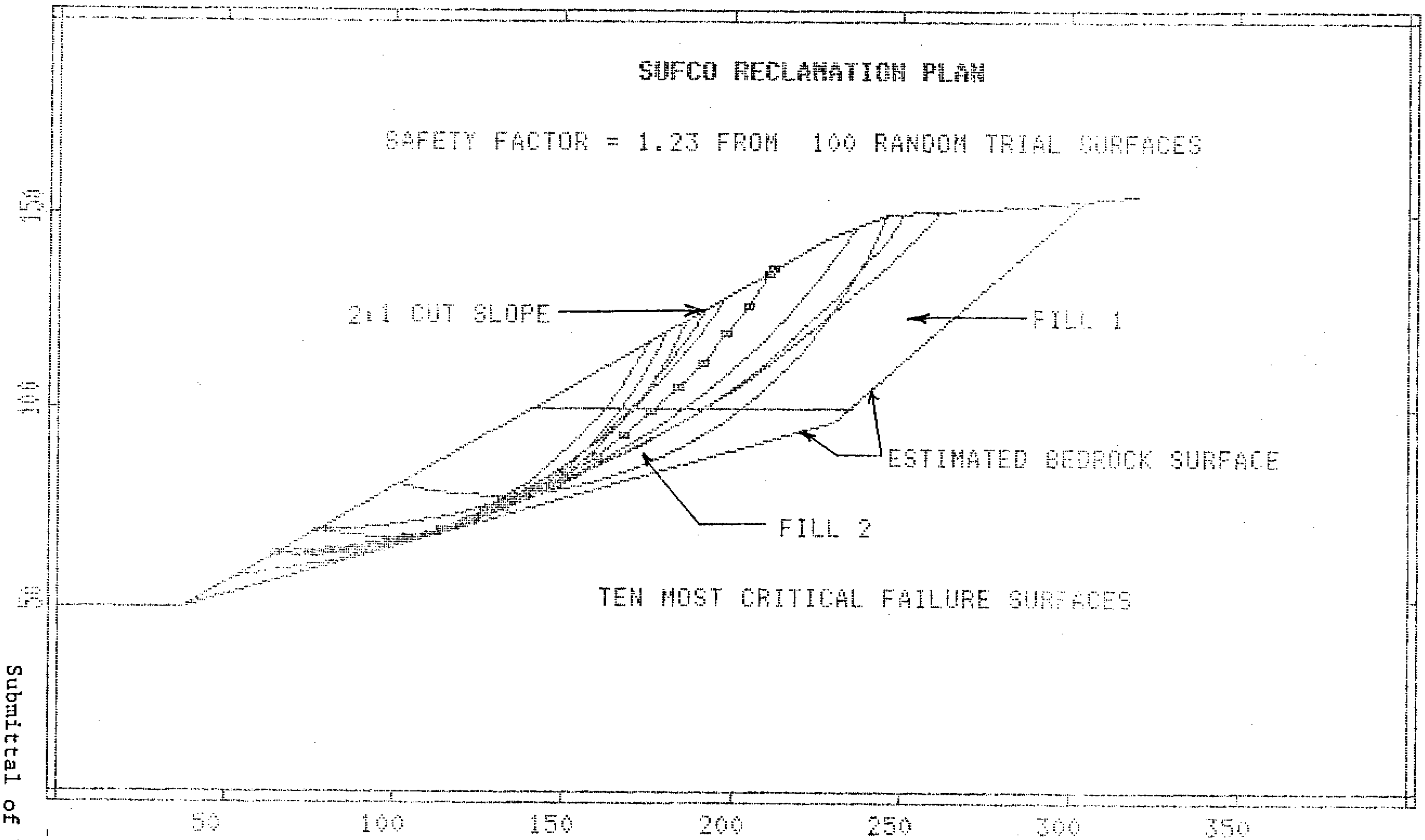


Fill 1 γ = 120 pcf
c = 500 psf
ϕ = 30°

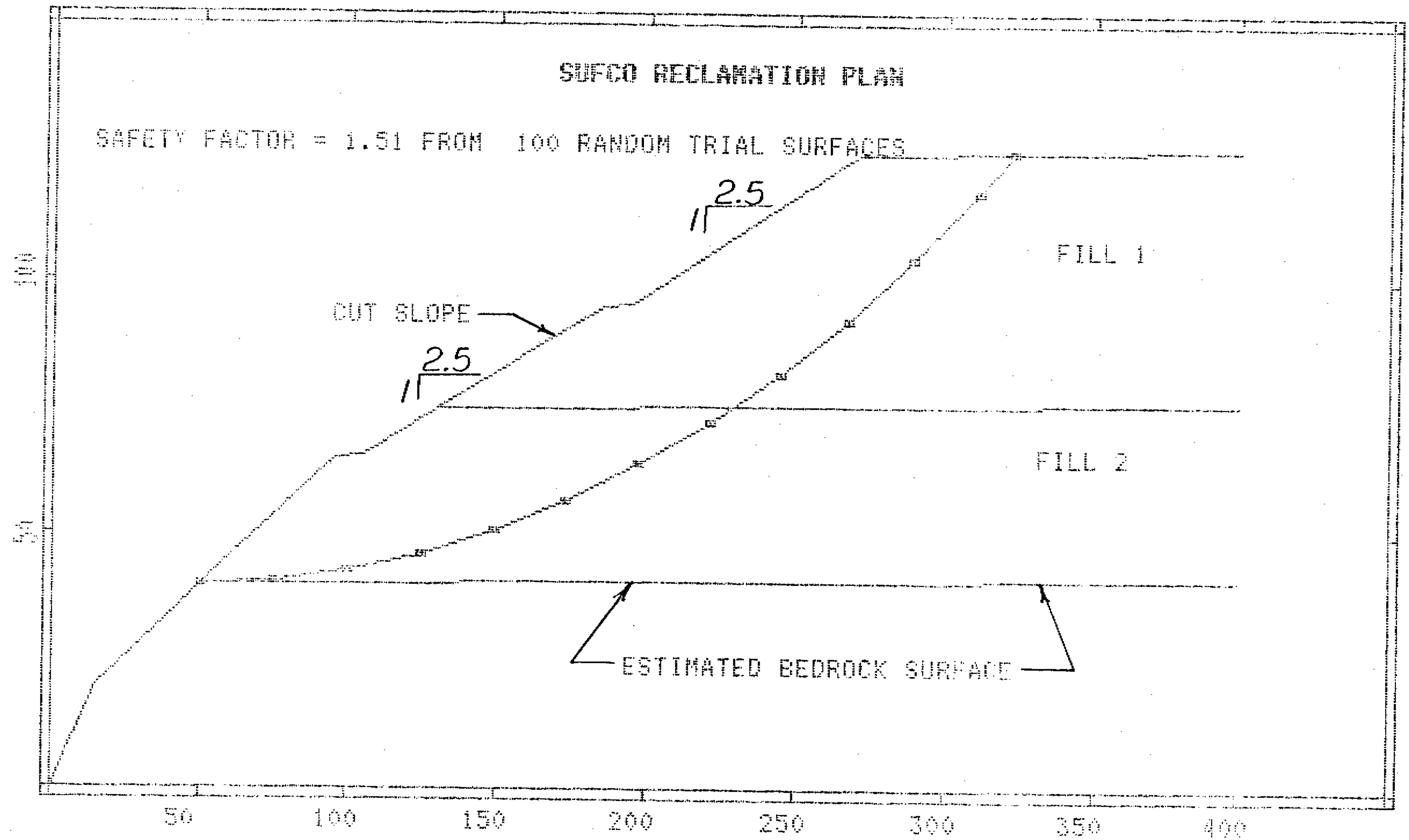
Fill γ = 110 pcf
c = 350 psf
ϕ = 13.5°

FIGURE 2

to vertical). This slope has been in its present condition for approximately 7 years and appears to be stable.

Subsurface profiles in this area were estimated from available borehole data near the exposed slope. The existing fill was modeled as a layered system as was done in Section 5.3.1. Strength parameters utilized in this analysis were the same as those utilized previously. An attempt to verify these strength parameters was made by evaluating the existing slope. The factor of safety resulting from this analysis was equal to 1.0. This result seems reasonable since the existing slope was placed by end-dumping materials resulting in a slope at the angle of repose. The factor of safety of the existing slope is probably somewhat greater than one due to compression of the fill and aging effects. Therefore, based upon these results, the shear strength parameters utilized in these analyses may be somewhat conservative, however, they seem justified.

In order to increase the long-term stability of this slope, is is proposed the slope be cut back to a flatter angle. The grading plan consists of regrading the existing slope to a 2.5:1 (horizontal to vertical) slope with 10 foot benches on 80 centers. A typical cross-section of the regraded slope is presented in Appendix E, Section D-D'. The results of the slope stability analysis as presented on Figure 3 yielded a minimum factor of safety equal to 1.51.



Fill 1 γ = 120 pcf
c = 500 psf
ϕ = 30°

Fill 2 γ = 110 pcf
c = 350 psf
ϕ = 13.5°

FIGURE 3

Submittal of Drainage Plan and Slope Stability for Reclamation for Convulsion Canyon Mine, ACT/041/002, No. 2 No. 3 & No. 14 Sevier County, Utah

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The minimum allowable safety factor for long-term static conditions, as given by the Office of Surface Mining Reclamation and Enforcement, Department of the Interior (1979), is 1.5. The regraded slope has a safety factor in excess of this regulation.

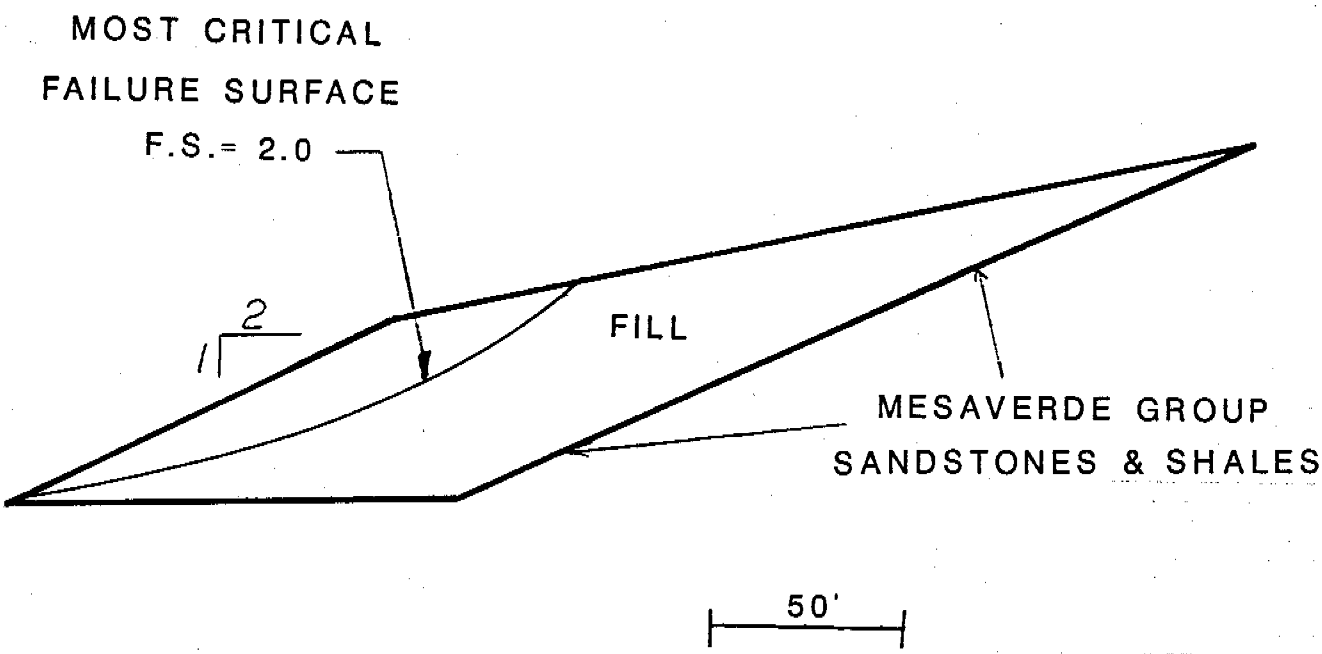
A factor which could reduce the factor of safety of the existing slope would be the presence of a phreatic surface within the mine spoil materials embankment. Since no groundwater was encountered in the borings and considering meteorological conditions at the site along with the interception of surface waters by collection ditches, the creation of a perched groundwater system in the existing mine spoil embankment appears to be remote.

5.3.3 Analysis of Slope Stability of Compacted Fills

The upper levels of the existing canyon fill consists predominantly of a silty sand and gravel mixture. This material was assigned the following strength parameters for compacted fills: cohesion, c, of zero and a friction angle, ϕ, of 35 degrees. The in-situ materials consist of a thin cover of silty sand and clay underlain by the Blackhawk Formation. A slope stability analysis was performed with all critical shear surfaces directed to locate a surface above this formation in the fill materials. The most critical surface, as shown on Figure 4, yielded a minimum factor of safety equal to 2.0.

FIGURE 4

MAXIMUM FILL CROSS SECTION USED FOR STABILITY ANALYSIS



FILL

MOIST UNIT WEIGHT = 128 PCF

FRICTION ANGLE = 35

C = 0

5.3.4 Hydraulic Design of Drainage Channels

5.3.4.1 Design of Main Channel

Due to many technical problems and regulatory agency concerns with placing the main channel over the existing fill, and since it is not feasible to excavate through the fill to re-establish the original regime, another alternative drainage system was designed. The alternative design involves diverting runoff from Mud Spring Hollow and East Spring Hollow into a channel excavated in bedrock along the east side of the existing fill as shown on Plate 2.

Deposition is anticipated to occur where Mud Spring Hollow and East Spring Hollow enter the excavated channel due to the abrupt change in gradients. The upstream gradients are 12 to 17 percent and the gradients in the excavated channel along the fill vary from 2.0 to 10.0 percent. Therefore, an inlet section identified on Plate 2 as Reach 1, was sized to provide for sediment accumulation. This transition section will direct the flows from the two natural channels to the rock-seated channel. As shown on Plate 2, Reach 1 is partially located on existing fill. As part of this reclamation plan, any existing fill in this area will be removed down to undistrubed native materials. Boring 5 which is located downstream of Reach 1, encountered approximately 35 feet of fill overlying bedrock.

After the existing fill has been removed, it may be necessary to fill any deeper cut areas with coarse rock fill to acheive the necessary gradient. The entire area should then be covered with 12-inches of grout meeting the specifications outlined in Section 5.4.8. After the fill has been removed it may be advantageous to relocate the reinforced bank and berm to the north to utilize any rock ledges which may be present. Reach 1 will be protected from scour with a riprap reinforced channel bank on the downstream side as shown in Figure 5. The channel floor will be protected, as required, with grouted riprap as outlined above.

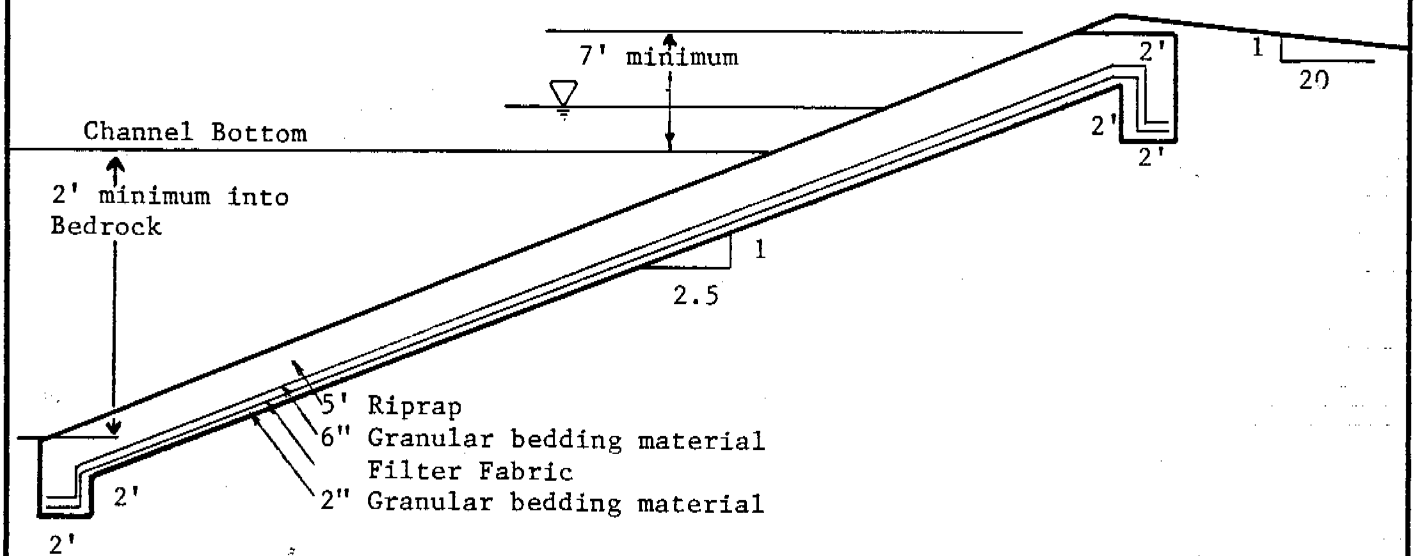
From the inlet section, the flow enters a trapezoidal rock channel. Reaches 2, 3 and 4 approximately follow the contour of the rock-fill interface and parallel the existing corrugated metal culvert which will be removed during reclamation.

Reaches 5 and 6 will convey the flow over rock ledges, down the steep canyon walls to approximately the natural channel identified as Reaches 7 and 8. The existing sedimentation pond dam and spillway will be partially removed to bedrock to create the channel within the lower two reaches.

Reaches 1 through 8 have been designed such that the flow remains supercritical throughout the profile with gradients ranging from 2 to 57 percent.

FIGURE 5

REINFORCED BANK FOR CHANNEL
IN REACH NUMBER 1



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Directly downstream of the existing spillway is a stilling basin which will be left in place. Since this basin presently handles the flow from the pond and culvert, it should continue to provide a satisfactory transition to the natural channel below the boundary of disturbed land.

Channel geometry and slopes are listed in Table 2. Calculations for design are presented Appendix D.

5.3.4.2 Hydraulics of the Stilling Pond

The existing pond is about 20 feet long by 30 feet wide by 3 feet deep and is formed in bedrock with a layer of large boulders. The downstream crest of the pond acts as a weir spillway for most flows with a weir length of about 40 feet.

Design flow would enter the pond at a depth of about 2.5 feet and a velocity of about 26 fps.

The existing channel for 100 feet downstream of the pond narrows from about 40 feet wide to 15 feet wide with a gradient varying from 20 percent to 29 percent.

A profile of Reach 8, the stilling pond and the transition to the undisturbed channel, is presented in Figure 6. The flow will remain supercritical throughout the profile, with stream gradients varying from 14 percent to 30 percent. The pond will

TABLE 2

Slope Velocity, Flow Depth, & Channel Depth in Each Main Channel Reach for Design Peak Flow

Channel Reach	Bed Gradient	Velocity (fps)	Depth of Flow (feet)	Channel Depth (feet)
1	.024	16.9	3.18	7.0
2	.100	22.67	2.73	6.0
3	.065	19.59	3.10	6.0
4	.020	13.06	4.38	7.5
5	.571	46.14	2.31	5.5
6	.546	45.41	2.34	5.5
7	.356	34.58	1.87	5.5
8	.151	26.01	2.41	5.5

Reach 1 is a transition section characterized by a sediment storage area with a reinforced embankment protecting the fill.

Reaches 2-4, 7 & 8 are trapezoidal sections with bottom widths of 17.5 feet and side slopes of 1:1. Reaches 5 & 6 have bottom widths of 10.0 feet and side slopes of 0.75:1. Hydraulic characteristics were calculated with Manning's equation using a roughness coefficient of 0.035.

Critical gradient for Reaches 1-4 = 0.018

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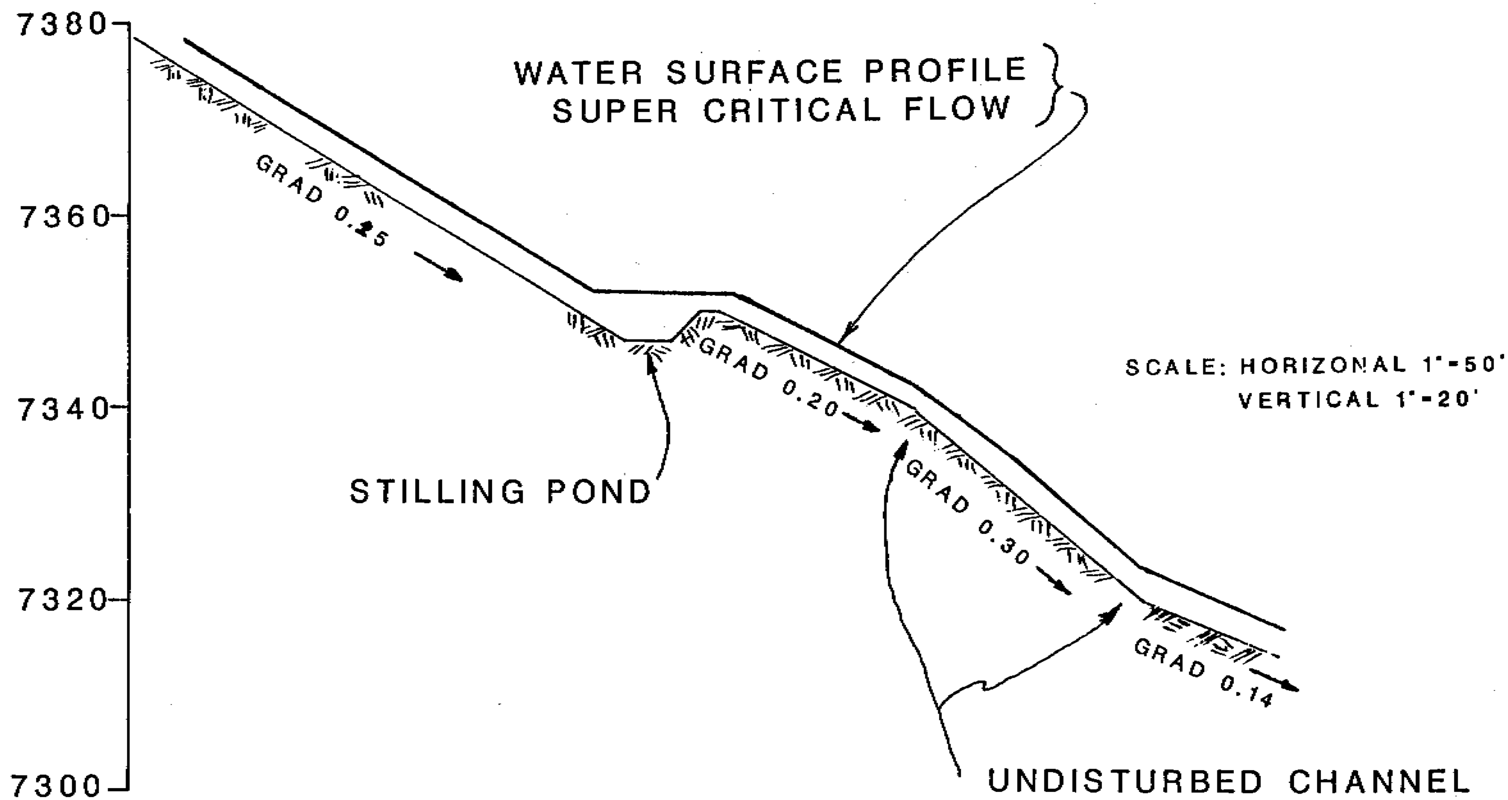


FIGURE 6: PROFILE OF REACH NO.8, STILLING POND & TRANSITION TO UNDISTURBED STREAM

apparently have little impact on the energy of the design flow as it enters the undisturbed stream. However, the undisturbed stream is characterized by steep gradients and shallow coarse grained alluvium for several hundred feet downstream of the reclamation project so that degradation should not be more severe than historic conditions.

5.3.4.3 Design of the West Collector Channel

For the contributing basin on the west side of the existing mine site, there are six poorly developed channels draining runoff down the steep canyon wall. The design flow for each of these channels was taken as 5 cfs, assuming all flow occurs as stream flow as opposed to overland flow. A collector channel excavated in rock will intercept runoff from the canyon walls upstream of the fill as shown on Plate 2. Recommended dimensions and gradients for each channel reach are given in Table 3. The reaches referred to are labeled on Plate 2. Flow throughout the profile of the west collector channel will remain supercritical.

All channel sections are trapezoidal, with side slopes of 1:1, and bottom widths varying from 2 feet to 3 feet along the alignment. Manning's coefficient was assumed to be 0.035. Calculations used for design are presented in Appendix D.

TABLE 3

Select Hydraulic Design Parameters
for West Collector Channel

Channel Reach	Flow (cfs)	Slope	Depth of Flow (ft)	Channel Velocity (fps)	Channel Depth (ft)	Bottom Width (ft)
A-1	5	0.020	0.59	3.27	2.0	2.0
A-2	10	0.020	0.85	4.07	2.0	2.0
A-3	20	0.018	1.07	4.62	3.0	3.0
A-4	25	0.015	1.27	4.61	3.0	3.0
A-5	30	0.501	0.52	16.39	3.0	2.0

Note: Hydraulic parameters calculated with Manning's slope-area equation with an assumed roughness coefficient "n" of 0.035 and a trapezoidal section with side slopes of 1:1. See Appendix D for more details of calculations.

5.3.4.4 Design of the East Collector Channels

There are four poorly developed channels draining the contributing basin on the east side of the mine site. The design flow for each of these channels was assumed to be 5 cfs. Recommended channel dimensions for each reach are given in Table 4.

All channel sections are trapezoidal, with side slopes of 1:1 and bottom widths varying from 2 feet to 3 feet along the alignment. Manning's coefficient was assumed to be 0.035. Calculations used for design are presented in Appendix D.

5.3.4.5 Diversion Channels for Regraded Slope Erosion Control

To limit erosion on the southern slope of the fill, intercept channels are proposed to direct surface water off the fill to the main channel. Pre-mine sediment yield in the canyon has been calculated to be approximately 10 tons per acre per year (SHB, May, 1984). Two channels are required to maintain erosion to a pre-mine yield.

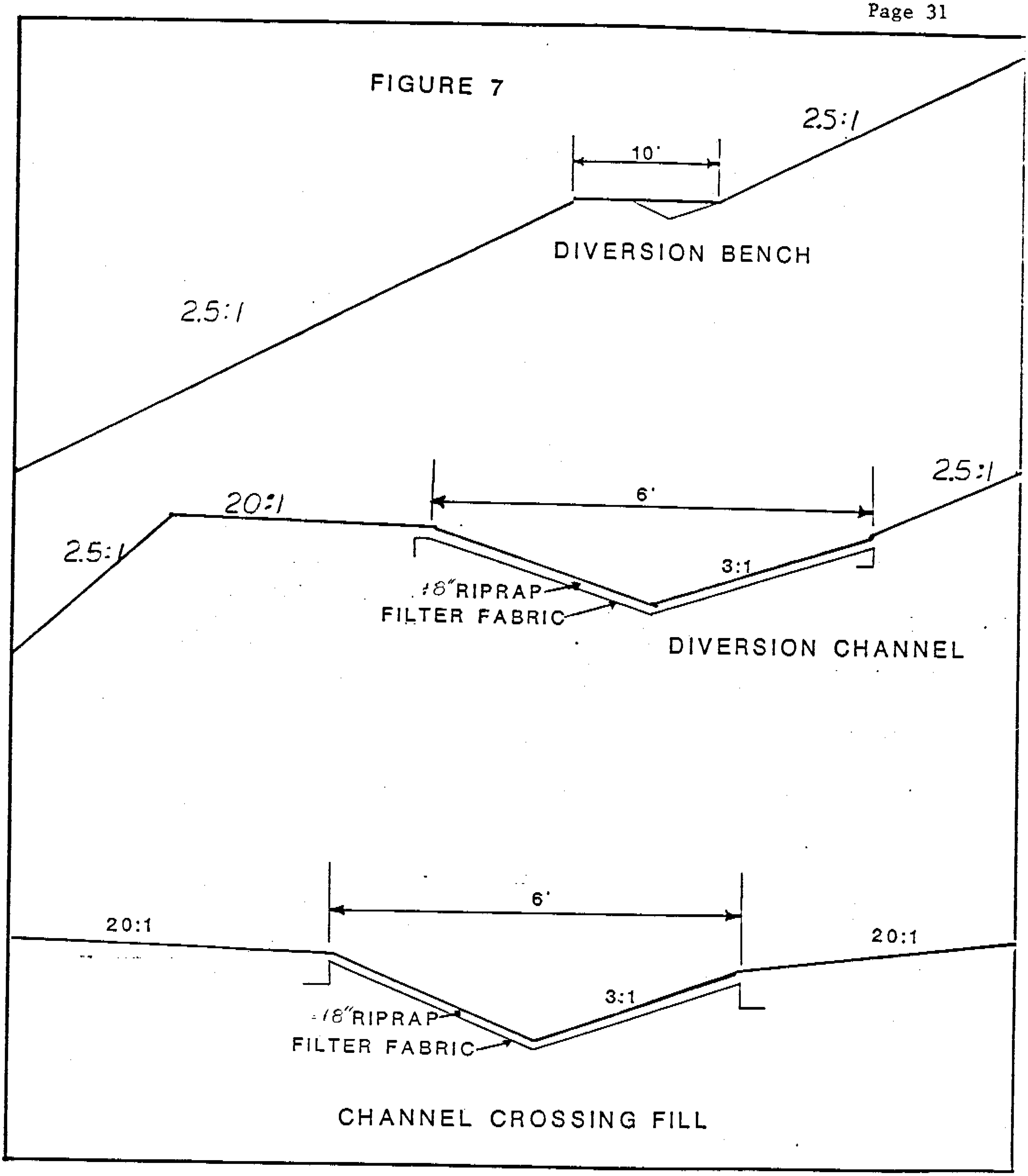
Two benches are proposed, spaced so that the slope is divided into thirds. These benches should be 10 feet in width with a triangular channel cut on the uphill side of the bench. The channel should be 1-foot deep, including liner and riprap, and have a 6-foot top width. The channel side-slopes should be 3:1 (horizontal to vertical). This should leave a

TABLE 4

Select Hydraulic Design Parameters
for East Collector Channel

Drainage Channel Section	Flow (cfs)	Slope	Depth of Flow (ft)	Channel Velocity (fps)	Channel Depth (ft)	Bottom Width (ft)
B-1	5	0.010	0.71	2.60	2.0	2.0
B-2	5	0.060	0.42	4.87	2.0	2.0
B-3	15	0.270	0.41	10.67	3.0	3.0
B-4	5	0.125	0.34	6.23	2.0	2.0
B-5	10	0.526	0.34	12.69	3.0	2.0

Note: Hydraulic parameters calculated with Manning's slope-area equation with an assumed roughness coefficient "n" of 0.035 and a trapezoidal section with side slopes of 1:1. See Appendix D for more details of calculations.



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foot wide bench which is relatively level on the downhill side. Figure 7 shows the proposed dimensions of the diversion benches and channels. Calculations for hydraulics and sediment transport control of these benches are presented in Appendix E.

5.4 Site Grading

5.4.1 Fill Placement

The regrading plan for the existing fill and fill generated by removal of the sediment pond dam and excavation of drainage channels is shown on Plate 2 along with the cross sections presented in Appendix E. The major design considerations were directed toward balancing cut and fill quantities using conservative reconstructed slope angles and controlling erosion of the fill.

Major features of the fill placement are flattening the slope at the southern end of the fill, removal of the sedimentation pond dam, constructing an armoured embankment at the inlet of the main channel and placing fill on the sandstone ledges along the sides of the existing fill. The maximum recommended slope for fills is 26 degrees (2:1). Due to limited information relative to the compaction characteristics of fills, no swell or shrinkage factors have been incorporated in the calculations. If excess materials are encountered, slopes can be steepened from those shown to a maximum of 26 degrees to balance cut and fill. Estimated cut is approximately 42,150 cubic yards and fill is 41,000 cubic yards. Calculations are presented in Appendix D.

5.4.2 Southern Slope Regrading

The present slope at the southern end of the mine site should be cut to a shallower angle. This will yield the required factor of safety for long-term reclamation stability. It is recommended to cut to 2.5:1 at the center of the slope and taper the cut to the existing canyon grade along the east and west sides of the slope. Cross sections showing typical cuts are shown in Appendix E.

5.4.3 Sediment Pond & Dam Removal

Partial removal of the existing sediment pond and dam is recommended to place channel Reaches 7 and 8 in rock. All of the fill material of the pond and dam that is on the western side of the channel should be removed. The material on the eastern side should be cut back to a 2:1 slope above the rock channel. Typical cross sections of the recommended cuts are shown in Appendix E.

5.4.4 Constructed Fills

All vegetation, organic matter, and debris should be cleared from areas to receive fill and from areas to be excavated.

The excess material from channel excavation and related earthwork should be graded to facilitate drainage from the mine site and contributing side basins. Diagrams showing locations of placement are included in Plate 2 and Appendix E. All channel embankments and placed fill should be compacted to at least 85 percent of the maximum density as determined in accordance with ASTM D698.

Side hill embankments, where the width, including the bench cuts, is too narrow to allow compaction equipment, may be constructed by end dumping, but only to a width to allow compaction equipment access. After this is achieved, the fill should be placed in lifts and compacted to specified densities.

Lifts should have a thickness when compacted of no more than 8 inches. Where the contractor demonstrates the equipment being used effectively compacts lifts greater than 8 inches, thicker lifts may be authorized by the geotechnical engineer.

Unless approved in the field by the geotechnical engineer, controlled fill should not be constructed when the ambient temperature is less than 35 degrees Fahrenheit. When the temperature falls below 35 degrees, it should be the responsibility of the contractor to protect all completed surfaces against any detrimental effects. The methods used to protect the surfaces should be approved by the geotechnical engineer. Any areas that are damaged by freezing should be reconditioned, reshaped and recompacted to specified densities.

5.4.5 Placement of Geotextile Filter & Riprap on Armoured Embankment at the Main Channel Inlet

The armoured embankment is shown in plan view on Plate 2 and in cross section in Figure 5.

The finished ground surface shall be free of all large clods, brush, roots, rocks, sod or other foreign material prior to geotextile placement. A continuous, relatively smooth surface free of protrusions of coarse rock or other abrupt irregularities shall be achieved. Asperities shall not protrude more than 1/8 inch. Selected finer soils shall be used at the near surface of the fill sections to achieve a continuous, relatively smooth surface. Pneumatic or other relatively smooth rollers shall be used in surface compaction. Dragging or hand raking the surface shall be performed, if required, to achieve a satisfactory surface. The finished surface shall be approved by the geotechnical engineer.

Where material is excavated, exposing natural subgrade soils in the side slopes, the exposed subgrade shall be observed for zones of coarse gravel and cobbles, protrusions of rock, etc., by a representative of the geotechical engineer. All such zones shall be over-excavated and backfilled with selected finer soils to achieve a continuous, relatively smooth surface approved by the geotechnical engineer.

All backfill involved in leveling shall be compacted to a minimum of 95 percent of ASTM D698 maximum dry density. The moisture content during compaction shall be maintained within the limits of 3 percent below to 3 percent above the optimum moisture content as determined in accordance with ASTM D698.

The side slopes shall have a minimum 2-inch thickness of relatively clean sand placed below the geotextile filter to act as a protective barrier during installation. There should be a 6-inch layer of granular material placed above the filter fabric to prevent damage during riprap installation. The sand shall have less than 5 percent passing the no. 200 sieve and shall be nonplastic.

The geotextile filter shall consist of Mirafi 700X or an approved equivalent.

Geotextile shall be installed such that foot traffic is minimized and no vehicle traffic crosses the geotextile. The geotextile shall have no holes or tears. Any holes or tears during installation shall be immediately marked and repaired. Repair methods shall be approved by the geotechnical engineer. Contractor shall have sufficient quality control to detect holes or tears during installation.

All seams shall be overlapped at least 2 feet. The overlap shall be so that the uphill piece overlays the downhill piece.

Rock should be carefully placed on the bedding material and filter fabric in such a manner as not to damage the fabric. If, in the opinion of the geotechnical engineer, the fabric is damaged or displaced to the extent that it cannot function as intended, he will order the contractor to remove the rock, regrade the area, if necessary, and repair or replace the filter fabric.

Gradation and specifications for the riprap are given below:

Riprap Size	Percent Finer by Weight
4.0 feet	100
2.0 feet	50-70
1.0 foot	10-30
6 inches	0-10

The percent of wear, when subjected to the Los Angeles abrasion test (ASTM C131), shall be no more than 45 and the percent of loss, when subjected to the sodium sulfate soundness test (ASTM C88), shall be no more than 15.

5.4.6 Placement of Geotextile Filter & Riprap in Channels Crossing Soil

For channels crossing soil, such as on the face of the slope, riprap protection will be placed and channel gradients constructed to allow self-cleaning flow velocities. A filter fabric will be placed beneath the riprap. No bedding should be needed between the fabric and the prepared subgrade.

Filter fabric for channels on soil should consist of Trevira 1127 or an approved equivalent. Filter fabric should be placed on prepared soil as outlined in Section 5.4.5.

The filter fabric should be installed as shown in Figure 7.

Gradation of the riprap for channels in soil should be as follows:

Riprap Size (inches)	Percent Finer by Weight
18	100-80
9	70-50
4-1/2	40-70
1	0-20

The percent of wear, when subjected to the Los Angeles abrasion test (ASTM C131), shall be no more than 45 and the percent of loss, when subjected to the sodium sulfate soundness test (ASTM C88), shall be no more than 15.

A 4-inch layer of granular material should be placed above the filter fabric for protection during riprap installation.

Riprap should be carefully placed as outlined in Section 5.4.5 of this report.

5.4.7 Remedial Action for Overbreaks & Areas of Non-Competent Rock in Channel Excavation

For areas of overbreakage of more than 15 percent of the neat line of the cross sectional area and for areas of unsuitable floor or side material, which in the judgement of the geotechnical engineer may be readily erodible, the following remedial action may be taken: (1) the area shall be overexcavated at least 6 inches, (2) the channel shall be filled with borrow material available on-site which has been approved by the geotechnical engineer. This material shall be compacted to 95 percent of the maximum density as determined by ASTM D698, (3) the channel shall then be cut to proper dimensions with suitable equipment, and (4) the channel surface shall then be coated with at least 3 inches of gunite. The gunite shall be placed with a perimeter toe to prevent the intrusion of water behind the gunite.

The decision to use this method should be made on a case to case basis because the undesireability of the use of gunite as lining for steep channel slopes may warrant the tolerance of a large overbreakage.

The gunite shall have a minimum ultimate 28 day compressive strength of 3000 psi. Only Type II Portland cement complying with the current issue of "Standard

Specificatons for Portland Cement," A.S.T.M. C-150-67 shall be used. Aggregates shall be from an approved commercial source. A complete mix design for the gunite shall be submitted to the engineer for approval. Such approval shall not be construed to contradict the specifications listed above.

Due to potential advancements in technology which may occur prior to reclamation, remedial actions which may be required due to overbreakage should reflect state-of-the-art methods at that time.

5.4.8 Grout

The grout shall be composed of Type II cement and sand conforming to the following gradation:

Screen No.	Percent Passing by Weight
8	100
16	95-100
100	10-30
200	0-5

The grout mix shall contain a minimum of seven sacks of cement per cubic yard and shall have a 28 day strength of 1800 psi. The air content shall be within 5 to 8 percent.

The grout shall be placed in such a manner as to insure the continuous filling of all voids in the riprap matrix to the full 12-inch depth. The finished surface shall be brushed with a broom to give a rough surface free from abrupt irregularities. Grout shall be cured by membrane curing using a white pigmented sealing compound conforming to ASTM C309 "Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete".

Grout shall not be placed when the descending air temperature falls below 40°F and not until the ascending air temperature rises above 35°F. Temperatures shall be taken in the shade away from artificial heat.

5.5 Erosion Control

Erosion control techniques are to be utilized to reduce sediment yield of surface soils on distrubed areas to less than 20 percent of untreated soils until vegetative cover is established. It is the intent of this recommendation that a wide variety of common, cost effective techniques be considered, and that the latest technological advances be utilized. According to a comparison of methods available at the writing of these recommendations (Hittman Associates, Inc., 1976), a wood cellulose fiber as a slurry applied at a rate of 3,500 pounds per acre would provide a reduction in sediment yield of 90 percent. (SHB; April, 1984 & May, 1984).

6. MONITORING PROGRAM

Two aspects of the proposed reclamation plan should be monitored: 1) stability of the fill which includes lack of movement of the slopes and moisture content changes in the fill and 2) sediment transport and conveyance capacity in the surface water drainage system.

6.1.1 Monitoring of Fill

Monitoring wells are to be placed in the fill, as shown on Plate 2, to measure subsurface water conditions which could affect the hydrologic balance and the stability of the fill.

Survey monuments are to be placed adjacent to the wells to monitor movements of the surface of the fill.

6.1.2 Monitoring of the Drainage System

Ideally, the sediments of the natural stream could be characterized and monitored; however, due to the presence of significant amounts of boulders and cobbles in the natural stream, sample sizes for gradation tests would be too large (several hundred pounds, see ASTM C-136) to be practical. Therefore, the proposed monitoring scheme is to establish surveyed cross sections of the channels as indicated on Plate 2. the channels should be surveyed at least annually during the bond period.

6.1.3 Piezometer Installation

Borings shall be drilled to such a depth as to fully penetrate the fill. Standard penetration testing and sampling shall be made at 5-foot intervals, in accordance with ASTM D1586 test procedures. Minimum diameter of these borings shall be 6 inches.

Upon completion of drilling and sampling, piezometers will be installed in the borings. The piezometers shall consist of 2-inch Schedule 40 PVC pipe and 10-foot slotted PVC well screen. Tentatively, the slotted well screen shall have three rows of slots cut on 120 degree centers, with 0.01-inch wide slots being 0.25 inch apart. The bottom of the PVC screen shall have a glued cap. The top of the PVC casing shall have a slip-on cap. The annular space shall then be backfilled. Backfill material from the bottom of the piezometer to the top of the screen shall consist of a commercially-obtained graded sand. The graded sand shall be introduced into the annular space by means of a tremie pipe initially extending to the bottom of the boring and slowly raised as the backfilling progresses. A bentonite seal shall then be installed directly above the graded sand backfill. The bentonite seal shall consist of a 1-foot thickness of bentonite pellets. The pellets shall be one-half inch in diameter, with a minimum purity of 90 percent montmorillonite clay and a minimum dry bulk density of 82 pounds per cubic foot. The annular space shall then be grouted to the surface. The grout shall consist of a neat cement mix with 4 pounds of commercial bentonite and approximately 7.5 gallons of water added per 94-pound bag of cement. Mixing shall be done in a jet mixer. The grout shall be placed by pumping the mixture through a pipe or hose initially extending to the top of the bentonite seal. Grouting shall be done from this point up in one continuous operation until the annular space is completely filled. The top of the piezometer shall be protected with a standard 4- inch I.D. Schedule 40 steel pipe, 4 feet in length provided with a locking cap.

6.1.4 Survey Monuments

Survey monuments shall consist of a brass survey cap set in a 1x1x2-foot concrete pad. Monuments shall have horizontal and vertical control accurate to within 0.1 of a foot. Vertical control shall be tied to mean sea level.

6.1.5 Channel Cross Sections

Exact locations of the cross sections shall be selected in the field upon completion of channel construction to assure practical access. The limits of each cross section shall be marked with survey monuments with vertical control datum being mean sea level.

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TEST DRILLING EQUIPMENT & PROCEDURES

Drilling Equipment Truck-mounted CME-55 drill rigs powered with 4 or 6 cylinder Ford industrial engines are used in advancing test borings. The 4 cylinder and 6 cylinder engines are capable of delivering about 4,350 and 6,500 foot/pounds torque to the drill spindle, respectively. The spindle is advanced with twin hydraulic rams capable of exerting 12,000 pounds downward force. Drilling through soil or softer rock is performed with 6 1/2 O.D., 3 1/4 I.D. hollow stem auger or 4 1/2 inch continuous flight auger. Carbide insert teeth are normally used on the auger bits so they can often penetrate rock or very strongly cemented soils which require blasting or very heavy equipment for excavation. Where refusal is experienced in auger drilling, the holes are sometimes advanced with tricone gear bits and NX rods using water or air as a drilling fluid. Where auger and tricone gear bits cannot be used to advance the hole due to cobbles or caving conditions, the ODEX (overburden drilling with the eccentric method) is used. A percussion down-the-hole hammer underreams the hole and 5 inch steel casing is introduced into the hole during drilling. The drill bit is eccentric and can be removed from the center of the casing to allow sampling of the material below the bit penetration depth.

Sampling Procedures Dynamically driven tube samples are usually obtained at selected intervals in the borings by the ASTM D1586 procedure. In many cases, 2" O.D., 1 3/8" I.D. samplers are used to obtain the standard penetration resistance. "Undisturbed" samples of firmer soils are often obtained with 3" O.D. samplers lined with 2.42" I.D. brass rings. The driving energy is generally recorded as the number of blows of a 140 pound 30 inch free fall drop hammer required to advance the samplers in 6 inch increments. However, in stratified soils, driving resistance is sometimes recorded in 2 or 3 inch increments so that soil changes and the presence of scattered gravel or cemented layers can be readily detected and the realistic penetration values obtained for consideration in design. These values are expressed in blows per foot on the logs. "Undisturbed" sampling of softer soils is sometimes performed with thin walled Shelby tubes (ASTM D1587). Where samples of rock are required, they are obtained by NX diamond core drilling (ASTM D2113). Tube samples are labeled and placed in watertight containers to maintain field moisture contents for testing. When necessary for testing, larger bulk samples are taken from auger cuttings.

Continuous Penetration Tests Continuous penetration tests are performed by driving a 2" O.D. blunt nosed penetrometer adjacent to or in the bottom of borings. The penetrometer is attached to 1 5/8" O.D. drill rods to provide clearance to minimize side friction so that penetration values are as nearly as possible a measure of end resistance. Penetration values are recorded as the number of blows of a 140 pound 30 inch free fall drop hammer required to advance the penetrometer in one foot increments or less.

Boring Records Drilling operations are directed by our field engineer or geologist who examines soil recovery and prepares boring logs. Soils are visually classified in accordance with the Unified Soil Classification System (ASTM D2487) with appropriate group symbols being shown on the logs.

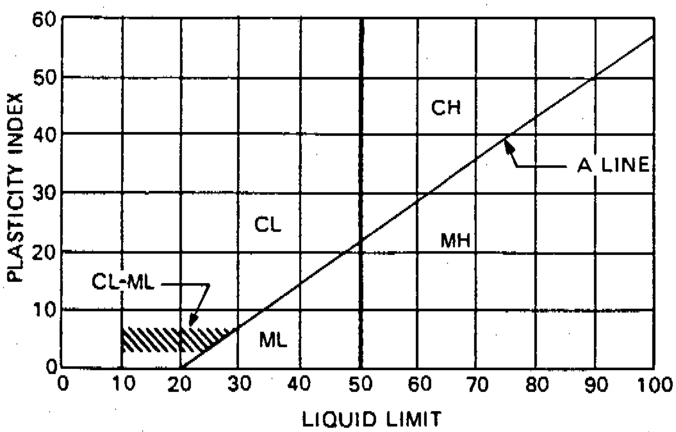
UNIFIED SOIL CLASSIFICATION SYSTEM

Soils are visually classified by the Unified Soil Classification system on the boring logs presented in this report. Grain-size analysis and Atterberg Limits Tests are often performed on selected samples to aid in classification. The classification system is briefly outlined on this chart. For a more detailed description of the system, see "The Unified Soil Classification System" Corp of Engineers, US Army Technical Memorandum No. 3-357 (Revised April 1960) or ASTM Designation: D2487-66T.

MAJOR DIVISIONS				GRAPHIC SYMBOL	GROUP SYMBOL	TYPICAL NAMES
COARSE-GRAINED SOILS (Less than 50% passes No. 200 sieve)	GRAVELS (50% or less of coarse fraction passes No. 4 sieve)	CLEAN GRAVELS (Less than 5% passes No. 200 sieve)			GW	Well graded gravels, gravel-sand mixtures, or sand-gravel-cobble mixtures.
					GP	Poorly graded gravels, gravel-sand mixtures, or sand-gravel-cobble mixtures.
		GRAVELS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart		GM	Silty gravels, gravel-sand-silt mixtures.
			Limits plot above "A" line & hatched zone on plasticity chart		GC	Clayey gravels, gravel-sand-clay mixtures.
	SANDS (More than 50% of coarse fraction passes No. 4 sieve)	CLEAN SANDS (Less than 5% passes No. 200 seive)			SW	Well graded sands, gravelly sands.
					SP	Poorly graded sands, gravelly sands.
		SANDS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart		SM	Silty sands, sand-silt mixtures.
			Limits plot above "A" line & hatched zone on plasticity chart		SC	Clayey sands, sand-clay mixtures.
FINE-GRAINED SOILS (50% or more passes No. 200 sieve)	SILTS (Limits plot below "A" line & hatched zone on plasticity chart)	SILTS OF LOW PLASTICITY (Liquid Limit Less Than 50)			ML	Inorganic silts, clayey silts with slight plasticity.
		SILTS OF HIGH PLASTICITY (Liquid Limit More Than 50)			MH	Inorganic silts, micaceous or diatomaceous silty soils, elastic silts.
	CLAYS (Limits plot above "A" line & hatched zone on plasticity chart)	CLAYS OF LOW PLASTICITY (Liquid Limit Less Than 50)			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		CLAYS OF HIGH PLASTICITY (Liquid Limit More Than 50)			CH	Inorganic clays of high plasticity, fat clays, sandy clays of high plasticity.

NOTE: Coarse grained soils with between 5% & 12% passing the No. 200 sieve and fine grained soils with limits plotting in the hatched zone on the plasticity chart to have double symbol.

PLASTICITY CHART



DEFINITIONS OF SOIL FRACTIONS

SOIL COMPONENT	PARTICLE SIZE RANGE
Cobbles	Above 3 in.
Gravel	3 in. to No. 4 sieve
Coarse gravel	3 in. to ¾ in.
Fine gravel	¾ in. to No. 4 sieve
Sand	No. 4 to No. 200
Coarse	No. 4 to No. 10
Medium	No. 10 to No. 40
Fine	No. 40 to No. 200
Fines (silt or clay)	Below No. 200 sieve

TERMINOLOGY USED TO DESCRIBE THE RELATIVE DENSITY, CONSISTENCY OR FIRMNESS OF SOILS

The terminology used on the boring logs to describe the relative density, consistency or firmness of soils relative to the standard penetration resistance is presented below. The standard penetration resistance (N) in blows per foot is obtained by the ASTM D1586 procedure using 2" O.D., 1 3/8" I.D. samplers.

1. Relative Density. Terms for description of relative density of cohesionless, uncemented sands and sand-gravel mixtures.

N	Relative Density
0-4	Very loose
5-10	Loose
11-30	Medium dense
31-50	Dense
50+	Very dense

2. Relative Consistency. Terms for description of clays which are saturated or near saturation.

N	Relative Consistency	Remarks
0-2	Very soft	Easily penetrated several inches with fist.
3-4	Soft	Easily penetrated several inches with thumb.
5-8	Medium stiff	Can be penetrated several inches with thumb with moderate effort.
9-15	Stiff	Readily indented with thumb, but penetrated only with great effort.
16-30	Very stiff	Readily indented with thumbnail.
30+	Hard	Indented only with difficulty by thumbnail.

3. Relative Firmness. Terms for description of partially saturated and/or cemented soils which commonly occur in the Southwest including clays, cemented granular materials, silts and silty and clayey granular soils.

N	Relative Firmness
0-4	Very soft
5-8	Soft
9-15	Moderately firm
16-30	Firm
31-50	Very firm
50+	Hard

TERMINOLOGY FOR THE DESCRIPTION OF ROCK

General Property	Descriptive Term	Visual or Physical Properties
WEATHERING	VERY WEATHERED	Abundant fractures coated with oxides, carbonates, sulfates, mud, etc., thorough discoloration, rock disintegration, mineral decomposition
	MODERATELY WEATHERED	Some fracture coating, moderate or localized discoloration, little to no effect on cementation, slight mineral decomposition
	SLIGHTLY WEATHERED	A few stained fractures, slight discoloration, little to no effect on cementation, no mineral decomposition
	FRESH	Unaffected by weathering agents, no appreciable change with depth
FRACTURING	INTENSELY FRACTURED	less than 1" spacing
	VERY FRACTURED	1" to 6" spacing
	MODERATELY FRACTURED	6" to 12" spacing
	SLIGHTLY FRACTURED	12" to 36" spacing
	SOLID	36" spacing or greater
STRATIFICATION	THINLY LAMINATED	less than 1/10"
	LAMINATED	1/10" to 1/2"
	VERY THINLY BEDDED	1/2" to 2"
	THINLY BEDDED	2" to 2 feet
	THICKLY BEDDED	more than 2 feet
HARDNESS	SOFT	Can be dug by hand and crushed by fingers
	MODERATELY HARD	Friable, can be gouged deeply with knife and will crumble readily under light hammer blows
	HARD	Knife scratch leaves dust trace, will withstand a few hammer blows before breaking
	VERY HARD	Scratched with knife with difficulty, difficult to break with hammer blows

LOG OF TEST BORING NO. 1

PROJECT SUFCO Final Reclamation Plan
JOB NO. E83-2022 DATE 6/29/85

RIG TYPE CME-55
BORING TYPE 6½" Hollow Stem Auger
SURFACE ELEV.
DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows per foot 140 lb. 30" free-fall drop hammer	Dry Density Lbs. per cu. ft.	Moisture Content Per Cent of Dry Wt.	Unified Soil Classification
0								GM
			X	S	39			
								CL
5			—	S	50/2"			
								GM
10			—	S	50/4½"			
								SM
15			X	S	15		8	
								CL
20			X	S	15			
25			X	S	25			
30			X	S	20			
35			X	S	22		9	
								CL
40			X	S	50/5½"			
			—	S	50/5½"			
45								
50								

REMARKS	VISUAL CLASSIFICATION
slightly moist	Road Base Gravel with some coal (FILL)
slightly moist very firm	SILTY CLAY, considerable gravel, highly stratified, low plastic, yellow and light brown (FILL)
slightly moist hard	SILTY GRAVEL, some sand, predominately coarse grained, subangular, strongly lime cemented, nonplastic, gray note: possible boulder at 6½' to 9' (FILL)
slight moist hard	SILTY SAND, considerable clay, trace of gravel, predominately fine to medium grained, subrounded, weakly lime cemented, nonplastic, light brown (FILL)
moist moderately firm	SILTY CLAY, considerable sand, some angular to subrounded gravel, trace of cobbles and boulders, low plasticity, yellow to gray brown (FILL) note: gravel, cobble and boulder content decreases with depth note: thin interbedded sandy clay lenses (2" lenses) from 19½' to 21' note: traces of cedar wood at 23'
moist firm	SANDY CLAY, some subangular to subrounded gravel, low plasticity, brown (FILL) note: sand lens, predominately fine to medium grained, nonplastic, light reddish yellow at 25½' to 26' note: sandstone and siltstone gravels, subangular to subrounded at 26' to 29' note: color change to gray brown-black at 35' to 45' note: coal lenses at 35' to 40' note: traces of wood at 40'

GROUND WATER

DEPTH	HOUR	DATE
none	9:15 A	6/29/85

SAMPLE TYPE
A – Auger cuttings. B – Block sample
S – 2" O.D. 1.38" I.D. tube sample.
U – 3" O.D. 2.42" I.D. tube sample.
T – 3" O.D. thin-walled Shelby tube.

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JOB NO. E83-2022 DATE 6/29/85

LOG OF TEST BORING NO. 1

RIG TYPE CME-55

BORING TYPE 6½" Hollow Stem Auger

SURFACE ELEV.

DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows per foot 140 lb. 30" free-fall drop hammer	Dry Density Lbs. per cu. ft.	Moisture Content Per Cent of Dry Wt.	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
50			X	S	50/4"			CL		note: color change to black at 45' to 52'
55			X	S	50/2½"			SM	slightly moist hard	SAND, considerable sandstone gravel, some silt, subrounded, weakly increasing to moderately lime cemented with depth, nonplastic, light brown note: apparent bedrock contact at 57'
60			X	S	50/3"					stopped auger at 59'6" sampler refused at 59'9"

GROUND WATER

DEPTH	HOUR	DATE
none	12:00P	6/29/85

SAMPLE TYPE

A – Auger cuttings. B – Block sample

S – 2" O.D. 1.38" I.D. tube sample.

U – 3" O.D. 2.42" I.D. tube sample.

T – 3" O.D. thin-walled Shelby tube.

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JOB NO. E83-2022 DATE 6/29/85

LOG OF TEST BORING NO. 2

RIG TYPE CME-55

BORING TYPE $6\frac{1}{2}$" Hollow Stem Auger

SURFACE ELEV.

DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows per foot 140 lb. 30" free-fall drop hammer	Dry Density Lbs. per cu. ft.	Moisture Content Per Cent of Dry Wt.	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0–5			X	S	54				slightly moist	COAL (FILL)
5–14			X	S	13			CL	moist moderately firm to hard	GRAVELLY CLAY, some silt, weakly lime cemented, low plasticity, yellow brown (FILL)
			X	S	56					
14–20			X	S	50/4½"			SM	slightly moist hard	SILTY SAND, considerable cobbles, predominately fine to medium grained, subrounded, moderately to strongly lime cemented, nonplastic, light brown (FILL)
20–36			X	S	13			CL	moist moderately firm	GRAVELLY CLAY, considerable silt and sand, low plasticity, gray brown to light brown note: lenses of clay, sand and sandstone gravels from 12' to 40' (FILL)
			X	U	25		10			
			X	S	14					
			X	S	14					
			X	S	19					
36–45			X	S	25		4	GP-GM	slightly moist firm	SILTY GRAVEL, considerable sand, trace of clay, predominately coarse grained, angular to subangular, nonplastic, yellow brown to tan (FILL) note: moderately lime cemented, sandstone cobbles at 40'
45–50			X	S	20				slightly moist firm	COAL (FILL) note: traces of wood and pine needles at 47'

GROUND WATER

DEPTH	HOUR	DATE
none	2:00 P	6/29/85

SAMPLE TYPE

A – Auger cuttings. B – Block sample

S – 2" O.D. 1.38" I.D. tube sample.

U – 3" O.D. 2.42" I.D. tube sample.

T – 3" O.D. thin-walled Shelby tube.

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JOB NO. E83-2022 DATE 6/29/85

LOG OF TEST BORING NO. 2

RIG TYPE CME-55
BORING TYPE 6½" Hollow Stem Auger
SURFACE ELEV.
DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows per foot 140 lb. 30" free-fall drop hammer	Dry Density Lbs. per cu. ft.	Moisture Content Per Cent of Dry Wt.	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
50			X	S	13		9	SC	slightly moist moderately firm	CLAYEY SAND, considerable fine grained gravel, predominately medium to fine grained, low plasticity, light red to yellowish red
55			X	S	50/5"					MESAVERDE FORMATION, sandstone, fine to medium grained, moderately weathered, moderately hard, dark yellow
										auger refused at 57'

GROUND WATER

DEPTH	HOUR	DATE
none	3:00P	6/29/85

SAMPLE TYPE

A – Auger cuttings. B – Block sample
S – 2" O.D. 1.38" I.D. tube sample.
U – 3" O.D. 2.42" I.D. tube sample.
T – 3" O.D. thin-walled Shelby tube.

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PROJECT SUFCO Final Reclamation Plan

LOG OF TEST BORING NO. 3

JOB NO. E83-2022 DATE 6/29/85

RIG TYPE CME-55

BORING TYPE 6½" Hollow Stem Auger

SURFACE ELEV.

DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows per foot 140 lb. 30" free-fall drop hammer	Dry Density Lbs. per cu. ft.	Moisture Content Per Cent of Dry Wt.	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0			X	S	90					COAL (FILL)
5			X	S	20			SC	slightly moist firm	CLAYEY SAND, considerable silt and sandstone gravel, low to medium plasticity, yellow brown (FILL)
10			X	S	8				slightly moist moderately firm to firm	SILTY CLAY, considerable sand, trace of fine gravel, low plasticity, grayish brown to brown (FILL) note: possible sandstone boulder from 3' to 5' and 17½' note: considerable lenses of red, yellow, graybrown, and brown clay note: traces of wood, coal, and metal chips at 23'
15			X	S	12			CL		
20			X	S	12		13			
25			X	S	50/4"			SP	slightly moist hard	SAND, some gravel, predominately medium to fine grained, subrounded to rounded, nonplastic, light rust orange note: possible channel deposit
30			X	S	50/3"					MESAVERDE FORMATION, sandstone, fine to medium grained, moderately weathered, moderately hard, weakly increasing to strongly lime cemented with depth, dark yellow
35										auger refused at 33'8"
40										
45										
50										

GROUND WATER

DEPTH	HOUR	DATE
none	5:00P	6/29/85

SAMPLE TYPE

A – Auger cuttings. B – Block sample
S – 2" O.D. 1.38" I.D. tube sample.
U – 3" O.D. 2.42" I.D. tube sample.
T – 3" O.D. thin-walled Shelby tube.

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PROJECT SUFCO Final Reclamation Plan

JOB NO. E83-2022 DATE 6/29/85 and 6/30/85

LOG OF TEST BORING NO. 4

RIG TYPE CME-55

BORING TYPE 6½" Hollow Stem Auger

SURFACE ELEV.

DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows per foot 140 lb. 30" free-fall drop hammer	Dry Density Lbs. per cu. ft.	Moisture Content Per Cent of Dry Wt.	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0									slightly moist firm to hard	SILTY GRAVEL AND SAND, considerable clay, predominately fine to medium grained sand, highly stratified, low plasticity, brown yellow with some black (FILL) note: thin interbedded lenses of sand, coal and clay from 5' to 8'
			X	S	50/2"			GM-GC		
5			X	S	29		6			
10			X	S	10				slightly moist moderately firm to firm	COAL, thin sand and clay lenses (FILL) note: traces of wood
15			X	S	18					
									slightly moist firm	SILTY SAND, considerable gravel, predominately fine to medium grained, moderately lime cemented, subangular to rounded, nonplastic, yellow to light rust note: interbedded sand and clay lenses note: possible boulder at 24' note: possible stream channel deposits from 22' to 28'
20			X	S	21		9			
								SM		
25			X	S	17					
				S	50/0" (no recovery)					
30										MESAVERDE FORMATION, sandstone, fine grained, moderately weathered, moderately hard, dark yellow
										stopped auger at 30' sampler refused at 30'

GROUND WATER

DEPTH	HOUR	DATE
none	7:25	6/30/85

SAMPLE TYPE

A – Auger cuttings. B – Block sample

S – 2" O.D. 1.38" I.D. tube sample.

U – 3" O.D. 2.42" I.D. tube sample.

T – 3" O.D. thin-walled Shelby tube.

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PROJECT SUFCO Final Reclamation Plan

JOB NO. E83-2022 DATE 6/30/85

LOG OF TEST BORING NO. 5

RIG TYPE CME-55

BORING TYPE 6½" Hollow Stem Auger

SURFACE ELEV.

DATUM

Depth in Feet	Sample	Sample Type	Blows per foot 140 lb. 30" free-fall drop hammer	Dry Density Lbs. per cu. ft.	Moisture Content Per Cent of Dry Wt.	Unified Soil Classification
3.5	X	S	22			
6	X	S	8			
8	X	U	9		16	
11	X	S	15			
16	X	S	29			
17.5						SM
21	X	S	19		19	
26	X	S	17			
28.5						SM
31	X	S	55			
35	—	S	50/1"			

Depth	REMARKS	VISUAL CLASSIFICATION
0–27	moist to very moist soft to firm	SILTY SAND, considerable clay, some gravel, predominately medium to coarse grained, nonplastic, black note: clayey sand lense from from 7' to 9' note: considerable coal and clayey sand lenses from 18' to 26' note: gray channel sands from 26' to 27' (FILL)
27–34	moist to very moist hard	SILTY SAND, considerable fine gravel, rounded, nonplastic, gray to light rust
34–38		MESAVERDE FORMATION, sandstone, fine to medium grained, moderately weathered, hard, dark yellow
		stopped auger at 38'

GROUND WATER

DEPTH	HOUR	DATE
none	9:25A	6/30/85

SAMPLE TYPE

A – Auger cuttings. B – Block sample

S – 2" O.D. 1.38" I.D. tube sample.

U – 3" O.D. 2.42" I.D. tube sample.

T – 3" O.D. thin-walled Shelby tube.

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PROJECT SUFCO Final Reclamation Plan

JOB NO. E83-2022 DATE 6/30/85

LOG OF TEST BORING NO. 6

RIG TYPE CME-55
BORING TYPE 6½" Hollow Stem Auger
SURFACE ELEV.
DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows per foot 140 lb. 30" free-fall drop hammer	Dry Density Lbs. per cu. ft.	Moisture Content Per Cent of Dry Wt.	Unified Soil Classification
0								
			X	S	56		6	
5			X	S	17			
10			X	S	23		15	CL
15			X	S	9			
20			X	S	17			
			X	U	20			
25			X	S	14		13	
30			X	S	9			
35			X	S	22		11	ML
40			X	S	14			
45			X	S	10		13	

REMARKS	VISUAL CLASSIFICATION
moist moderately firm to firm	SILTY CLAY, considerable sand and gravel, sand is predominately fine to medium grained, weakly lime cemented, low plasticity, yellow brown to light orange (FILL) note: clay is decomposed platy shale note: considerable sand and gravel lenses 1'to 2' thick with some boulders
moist to very moist moderately firm to very firm	SANDY SILT, some gravel, weakly lime cemented, non-plastic, light reddish yellow (FILL) note: medium plasticity, clayey gravel lens at 22' to 24'

GROUND WATER

DEPTH	HOUR	DATE
none	3:30 P	6/30/85

SAMPLE TYPE

A – Auger cuttings. B – Block sample
S – 2" O.D. 1.38" I.D. tube sample.
U – 3" O.D. 2.42" I.D. tube sample.
T – 3" O.D. thin-walled Shelby tube.

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LOG OF TEST BORING NO. 6

PROJECT SUFCO Final Reclamation Plan

JOB NO. E83-2022 DATE 6/30/85

RIG TYPE CME-55

BORING TYPE 6½" Hollow Stem Auger

SURFACE ELEV.

DATUM

Depth in Feet	Continuous Penetration Resistance	Graphical Log	Sample	Sample Type	Blows per foot 140 lb. 30" free-fall drop hammer	Dry Density Lbs. per cu. ft.	Moisture Content Per Cent of Dry Wt.	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
50			X	S	25					note: medium plasticity, sandy clay lense from 69' to 71'
55			X	S	15					
60			X	S	25		27			
								ML		
65			X	S	25					
70			X	U	82		27			
75			X	S	34					
80			X	S	45		18			
									slightly moist firm to hard	GRAVELLY SAND, considerable silt, predominately fine to medium grained, nonplastic, dark yellow
85			X	S	23		7	SM		
										MESAVERDE FORMATION, sandstone, fine to medium grained, moderately weathered, hard, dark yellow
90				S	50/0" (no recovery)					
										stopped auger at 90' sampler refused at 90'

GROUND WATER

DEPTH	HOUR	DATE
none	3:30P	6/30/85

SAMPLE TYPE

A – Auger cuttings. B – Block sample
S – 2" O.D. 1.38" I.D. tube sample.
U – 3" O.D. 2.42" I.D. tube sample.
T – 3" O.D. thin-walled Shelby tube.

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LABORATORY TESTING PROCEDURES

Consolidation Tests Soiltest or Clockhouse apparatus of the "floating-ring" type are employed for the one-dimensional consolidation tests. They are designed to receive one inch high 2.5 inch O.D. brass liner rings with soil specimens as secured in the field. Procedures for the tests generally are those outlined in ASTM D2435. Loads are applied in several increments to the upper surface of the test specimen and the resulting deformations are recorded at selected time intervals for each increment. For soils which are essentially saturated, each increment of load is maintained until the deformation versus log of time curve indicates completion of primary consolidation. For partially saturated soils, each increment of load is maintained until the rate of deformation is equal or less than 1/10,000 inch per hour. Applied loads are such that each new increment is equal to the total previously applied loading. Porous stones are placed in contact with the top and bottom of the specimens to permit free addition or expulsion of water. For partially saturated soils, the tests are normally performed at in situ moisture conditions until consolidation is complete under stresses approximately equal to those which will be imposed by the combined overburden and foundation loads. The samples are then submerged to show the effect of moisture increase and the tests continued under higher loadings. Generally, the tests are continued to about twice the anticipated curve due to overburden and structural loads with a rebound curve then being established by releasing loads.

Expansion Tests The same type of consolidometer apparatus described above is used in expansion testing. Undisturbed samples contained in brass liner rings are placed in the consolidometers, subjected to appropriate surcharge loads and submerged. The loads are maintained until the expansion versus log of time curve indicates the completion of "primary swell".

Direct Shear Tests Direct shear tests are run using a Clockhouse or Soiltest apparatus of the strain-control of approximately 0.05 inches per minute. The machine is designed to receive one of the one inch high 2.42 inch diameter specimens obtained by tube sampling. Generally, each sample is sheared under a normal load equivalent to the effective overburden pressure at the point of sampling. In some instances, samples are sheared at several normal loads to obtain the cohesion and angle of internal friction. When necessary, samples are saturated and/or consolidated before shearing in order to approximate the anticipated controlling field loading conditions.

TABULATION OF TEST RESULTS

Job No. E83-2022 **Date** ____________

Client: Southern Utah Fuel Company
P.O. Box P
Salina, Utah 84654

Project SUFCO Reclamation Plan Project

Material ____________

Source ____________

HOLE NO.	LOCATION	DEPTH	UNIFIED CLASS.	LL	PI	SIEVE ANALYSIS — ACCUM. % PASSING												LAB. NO.
						200	100	40	16	10	4	¼	⅜	¾	1	1½	2	
1	see site plan	14½'-16'	CL	21	8	53	62	72	76	78	83		88	100				3
1	see site plan	34½'-36'	CL	23	10	60	72	83	89	91	94		100					8
2	see site plan	22½'-23½'	CL	25	11	59	67	76	77	78	80	81	85	90	100			19
2	see site plan	39½'-41'	GP-GM	–	NP	7	12	18	20	21	26		33	52	63	100		23
2	see site plan	49½'-51'	SC	26	9	44	49	59	69	72	79		84	100				25
3	see site plan	19½'-21'	CL	28	12	64	71	79	86	89	97		100					31
4	see site plan	4½'-6'	GM-GC	18	5	21	30	44	49	50	57		64	71	78	100		35
4	see site plan	19½'-21'	SM	–	NP	18	24	39	50	55	70		81	87	100			38
5	see site plan	7½'-8½'	SC	33	10	45	52	61	71	76	82	85	92	96	100			43
5	see site plan	19½'-21'	SM	–	NP	34	44	58	72	77	92		93	100				46
6	see site plan	22½'-23½'	GC	27	13	46	52	61	62	63	65	66	68	71	83	100		55
6	see site plan	54½'-56'	ML	–	NP	55	67	80	84	85	89		95	100				62
6	see site plan	69½'-70½'	CL	35	16	58	72	87	90	91	92	95	97	100				65
6	see site plan	84½'-86'	SM	–	NP	28	26	42	50	52	62		71	92	100			68

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REPORT ON LABORATORY TESTS

DATE ______

PROJECT SUFCO Reclamation Plan JOB NO. E83-2022

LOCATION ______ LAB NO. 3-2022-1

SAMPLE Boring #2 @ 22½-23½

In Situ DIRECT SHEAR TESTS

In Situ - Point No. 1 (σ = ± 2.06 KSF)

Initial Moisture Content	9.5 %
Dry Density (PCF)	120.0
Submerged	
Final Moisture Content	- %
Maximum Vertical Deformation @ T Max.	(+) 0.042 Inches
Shearing Stress, T Max.	2.90 KSF

In Situ - Point No. 2 (σ = ± 2.998 KSF)

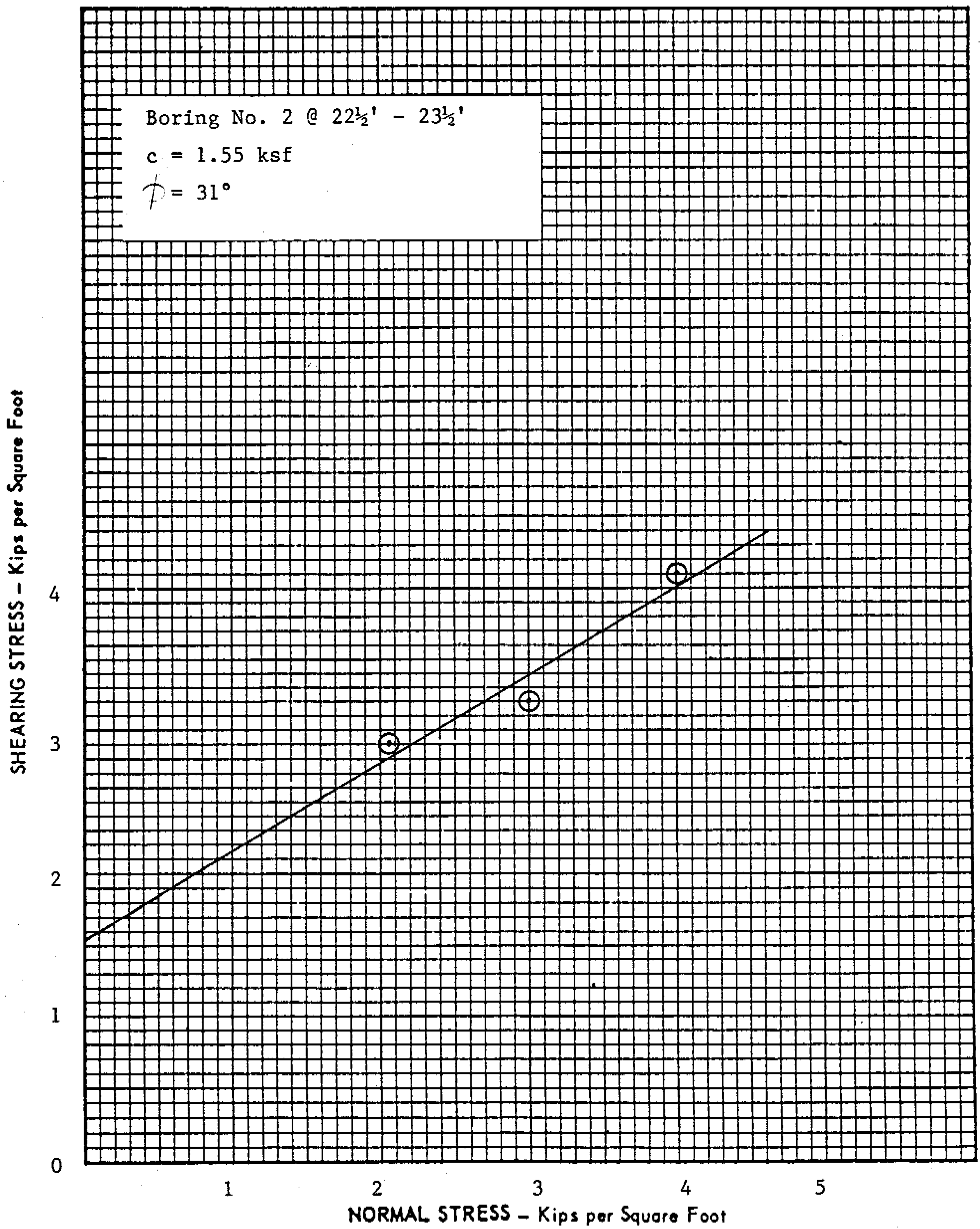
Initial Moisture Content	10.7 %
Dry Density (PCF)	122.5
Submerged	
Final Moisture Content	- %
Maximum Vertical Deformation @ T Max.	(+) 0.023 Inches
Shearing Stress, T Max.	3.20 KSF

In Situ - Point No. 3 (σ = ± 4.02 KSF)

Initial Moisture Content	8.8 %
Dry Density (PCF)	117.9
Submerged	
Final Moisture Content	- %
Maximum Vertical Deformation @ T Max.	(+) 0.005 Inches
Shearing Stress, T Max.	4.1 KSF

SUMMARY OF DIRECT SHEAR TESTS

PROJECT Sufco Reclamation Plan **JOB NO.** E83-2022



SOIL MOISTURE CONDITION

○ – INSITU
● – SUBMERGED

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REPORT ON LABORATORY TESTS

DATE ____________

PROJECT SUFCO Reclamation Plan — JOB NO. E83-2022

LOCATION ____________ — LAB NO. 3-2022-2

SAMPLE Boring #5 @ 7½-8½

In Situ
DIRECT SHEAR TESTS

In Situ - Point No. 1 (σ = ± .995 KSF)

Initial Moisture Content	15.1 %
Dry Density (PCF)	85.3
Submerged	
Final Moisture Content	%
Maximum Vertical Deformation @ T Max.	(+) 0.025 Inches
Shearing Stress, T Max.	1.45 KSF

In Situ - Point No. 2 (σ = ± 2.06 KSF)

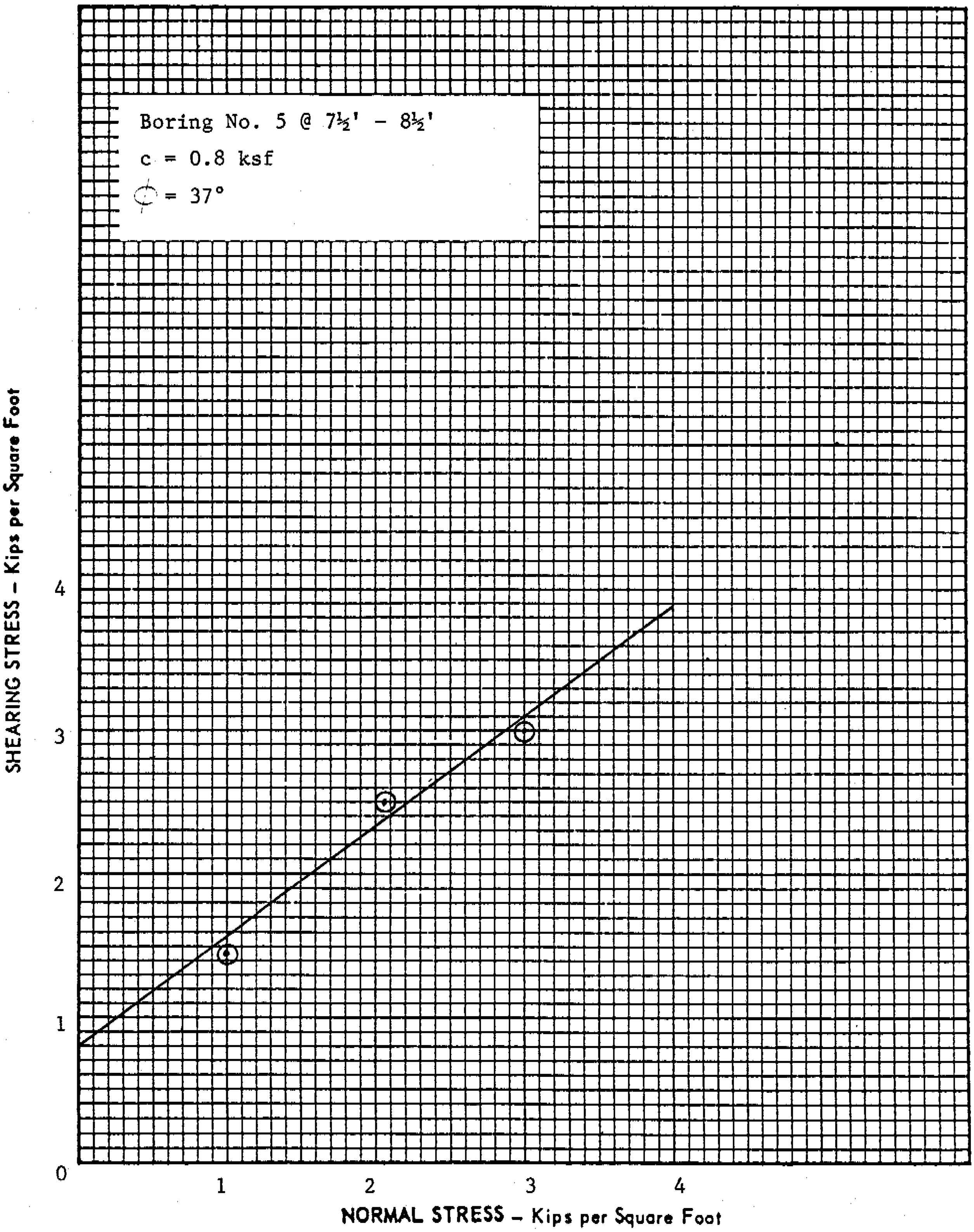
Initial Moisture Content	15.4 %
Dry Density (PCF)	91.7
Submerged	
Final Moisture Content	- %
Maximum Vertical Deformation @ T Max.	(+) 0.019 Inches
Shearing Stress, T Max.	2.50 KSF

In Situ - Point No. 3 (σ = ± 2.998 KSF)

Initial Moisture Content	16.4 %
Dry Density (PCF)	83.7
Submerged	
Final Moisture Content	- %
Maximum Vertical Deformation @ T Max.	(+) 0.009 Inches
Shearing Stress, T Max.	3.0 KSF

SUMMARY OF DIRECT SHEAR TESTS

PROJECT Sufco Reclamation Plan **JOB NO.** E83-2022



SOIL MOISTURE CONDITION

○ – INSITU
● – SUBMERGED

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REPORT ON LABORATORY TESTS

DATE ____________

PROJECT SUFCO Reclamation Plan JOB NO. E83-2022

LOCATION ____________ LAB NO. 3-2022-4

SAMPLE Boring #6 @ 69½-70½

In Situ
DIRECT SHEAR TESTS

In Situ - Point No. 1 (σ = ± 4.02 KSF)

Initial Moisture Content	24.6 %
Dry Density (PCF)	95.4
Submerged	
Final Moisture Content	- %
Maximum Vertical Deformation @ T Max.	(-) 0.022 Inches
Shearing Stress, T Max.	1.28 KSF

In Situ - Point No. 2 (σ = ± 6.00 KSF)

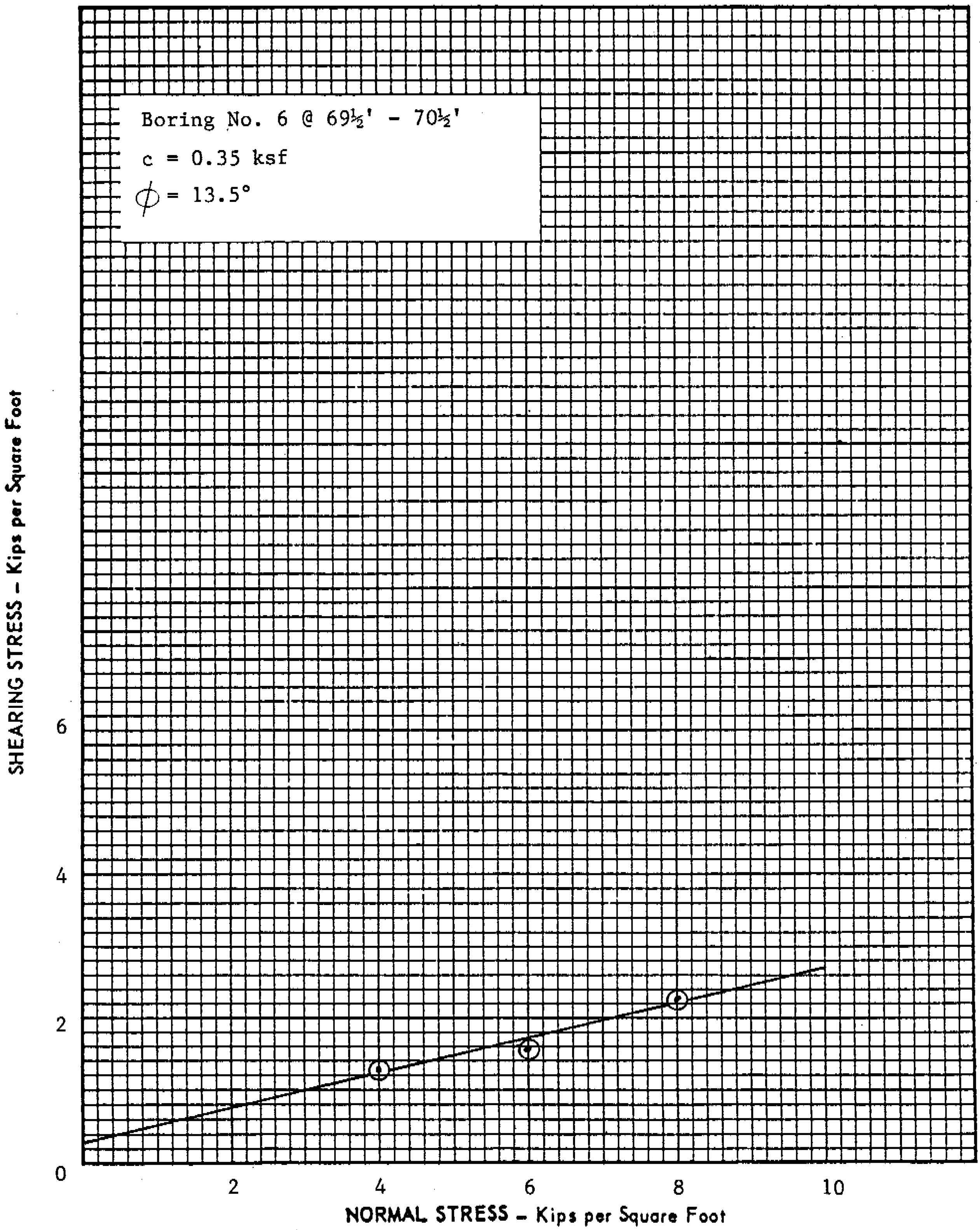
Initial Moisture Content	26.6 %
Dry Density (PCF)	91.6
Submerged	
Final Moisture Content	- %
Maximum Vertical Deformation @ T Max.	(-) 0.055 Inches
Shearing Stress, T Max.	1.58 KSF

In Situ - Point No. 3 (σ = ± 8.01 KSF)

Initial Moisture Content	28.8 %
Dry Density (PCF)	86.4
Submerged	
Final Moisture Content	- %
Maximum Vertical Deformation @ T Max.	(-) 0.034 Inches
Shearing Stress, T Max.	2.24 KSF

SUMMARY OF DIRECT SHEAR TESTS

PROJECT Sufco Reclamation Plan **JOB NO.** E83-2022



SOIL MOISTURE CONDITION

o – INSITU
● – SUBMERGED

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Submittal of Experimental Practice
for Reclamation for Convulsion
Canyon Mine, ACT/041/002, No. 2,
Sevier County, Utah
SHB Job No. E83-2022

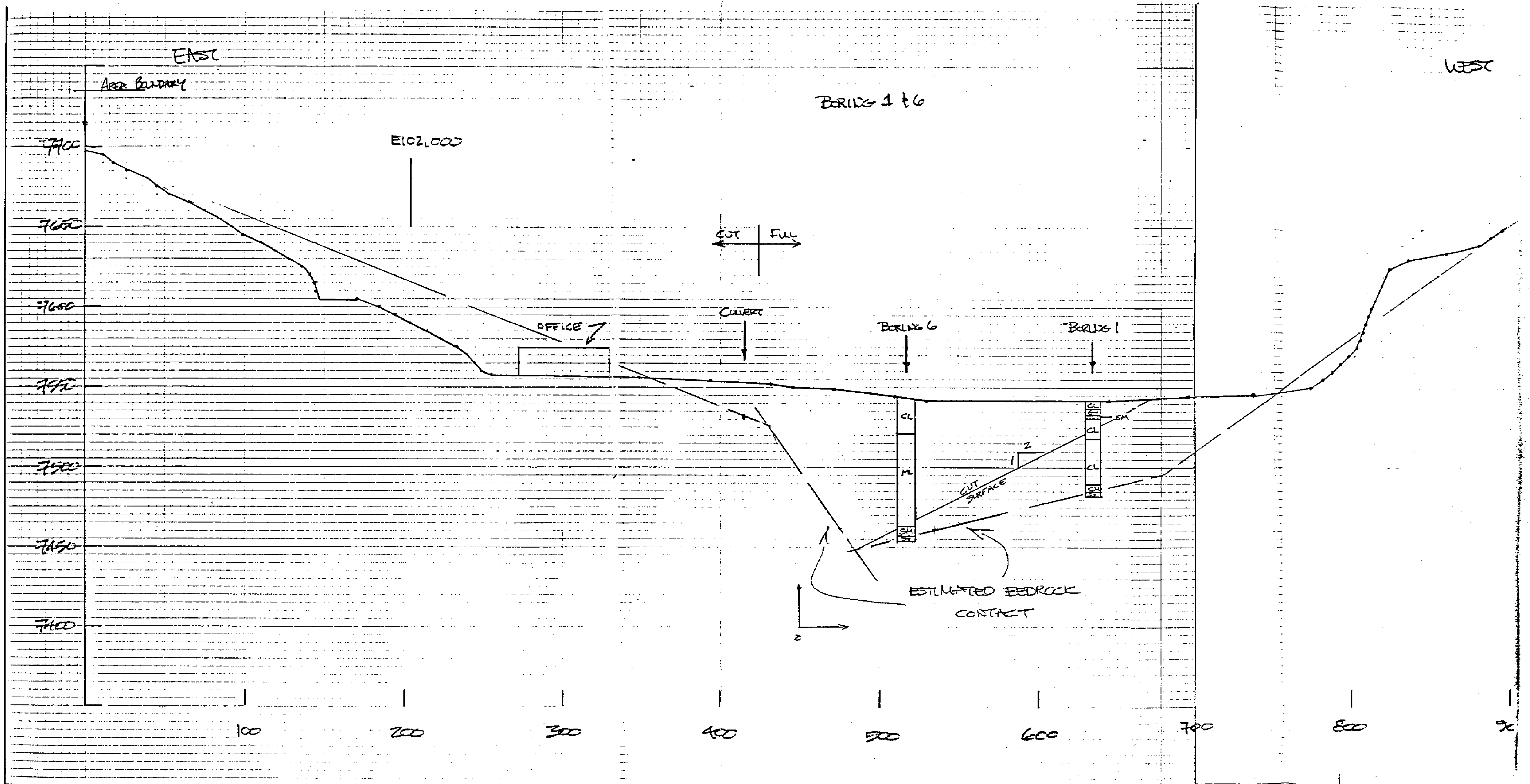
REPORT OF LABORATORY TESTS

SUMMARY OF CHEMICAL TESTS

	Boring 5 at 9-1/2' - 11'	Sample Boring 6 at 49-1/2' - 51'	Boring 6 at 74-1/2' - 76'
pH	8.15	8.21	7.99
Conductivity (μmhos/cm)	1450	1260	920
Total Chloride as Cl^- (ppm)	165	300	110
Total Water Soluble Sulfate as SO_4 (ppm)	1880*	210	250

* hydrogen sulphide (H_2S) odor present.

Note: 1000 ppm = 0.10%



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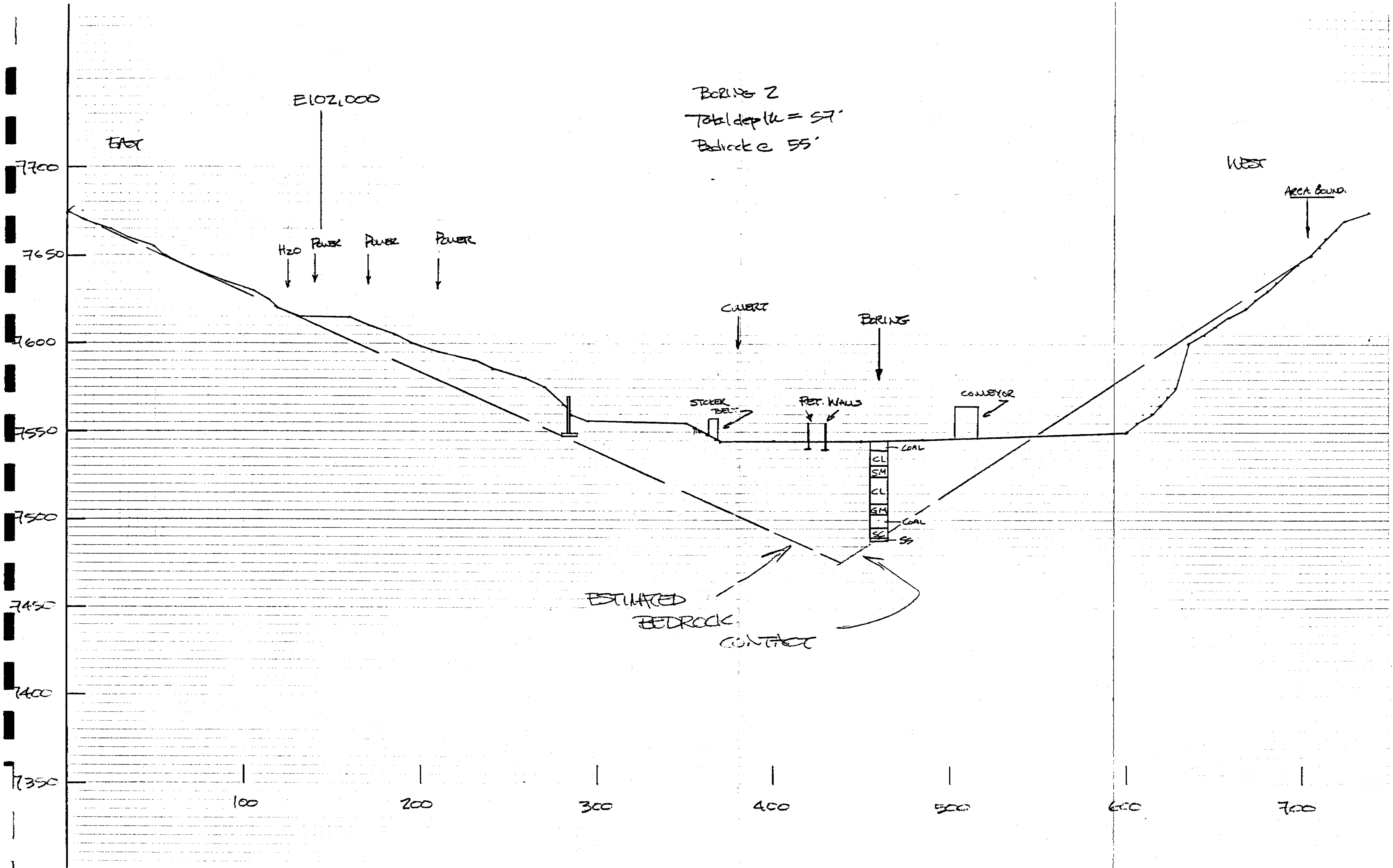
Project SUFCO RECLAMATION
Job No: E83-2022
Computed by: PK Ckd. by:
Date 8/29/85 Page ___ of ___

C-1



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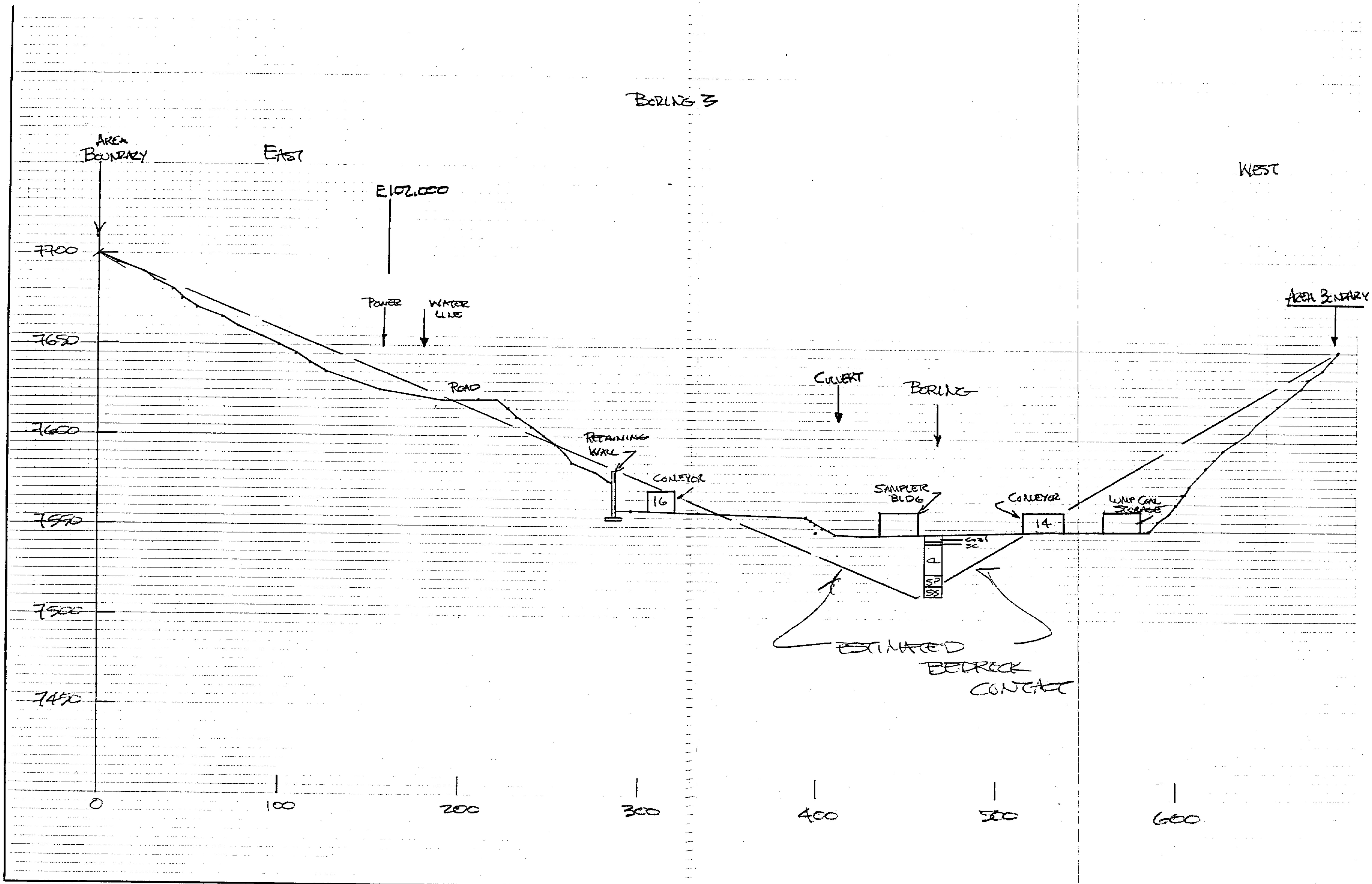
Date: 8/29/85 Page ____ of ____

C-2



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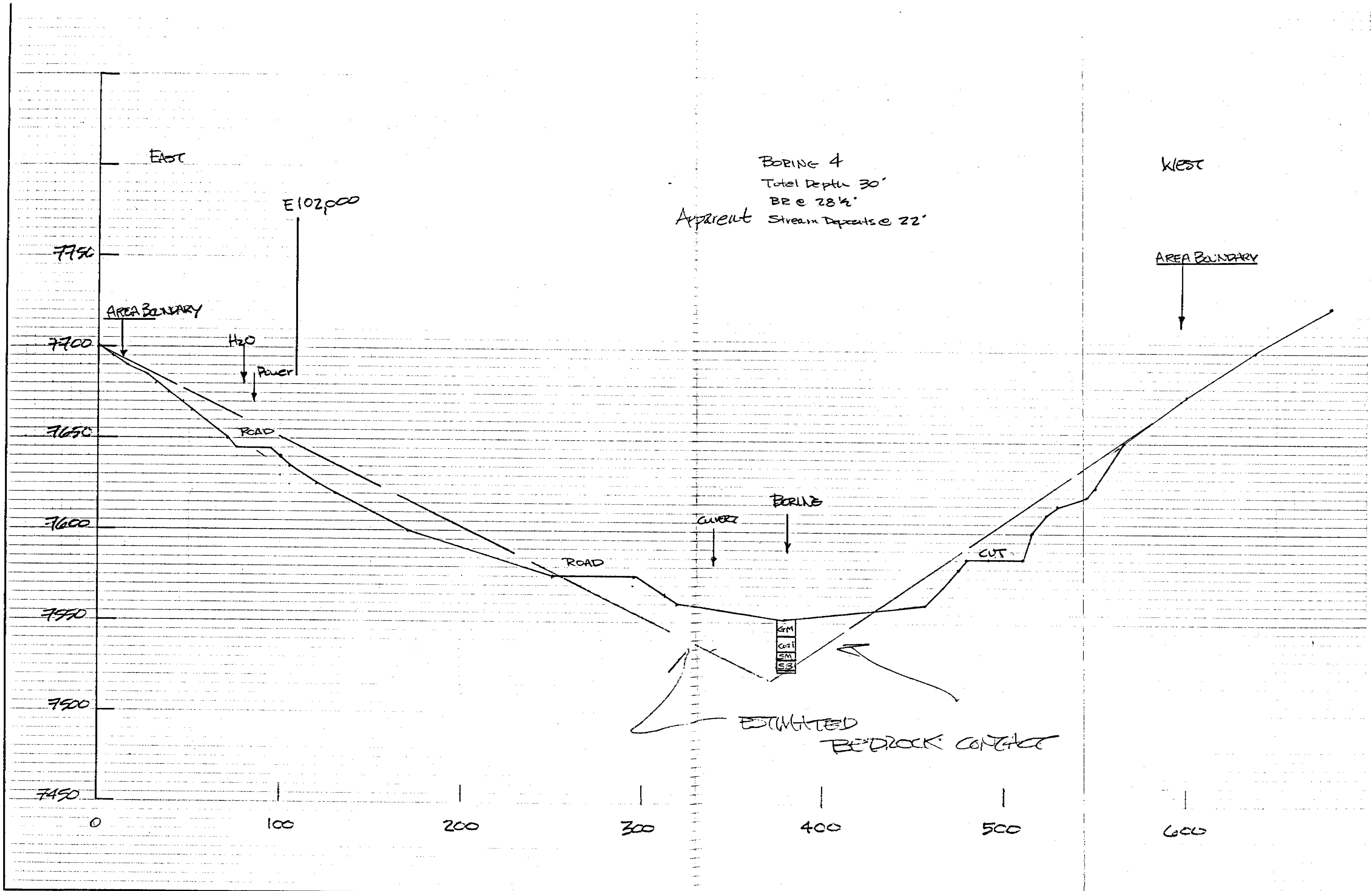

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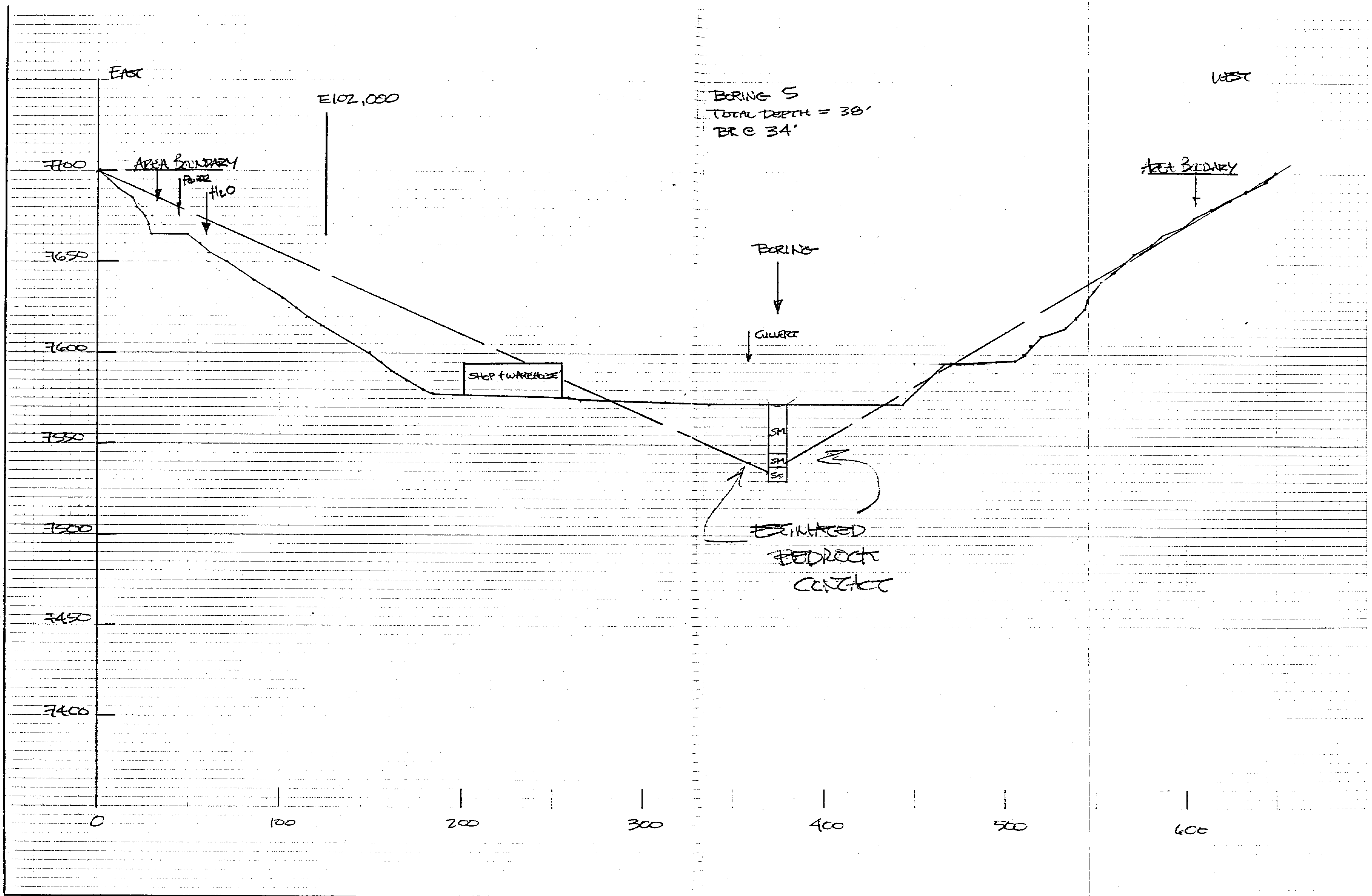

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Project SUFCO RECLAMATION
Job No: E83-2022
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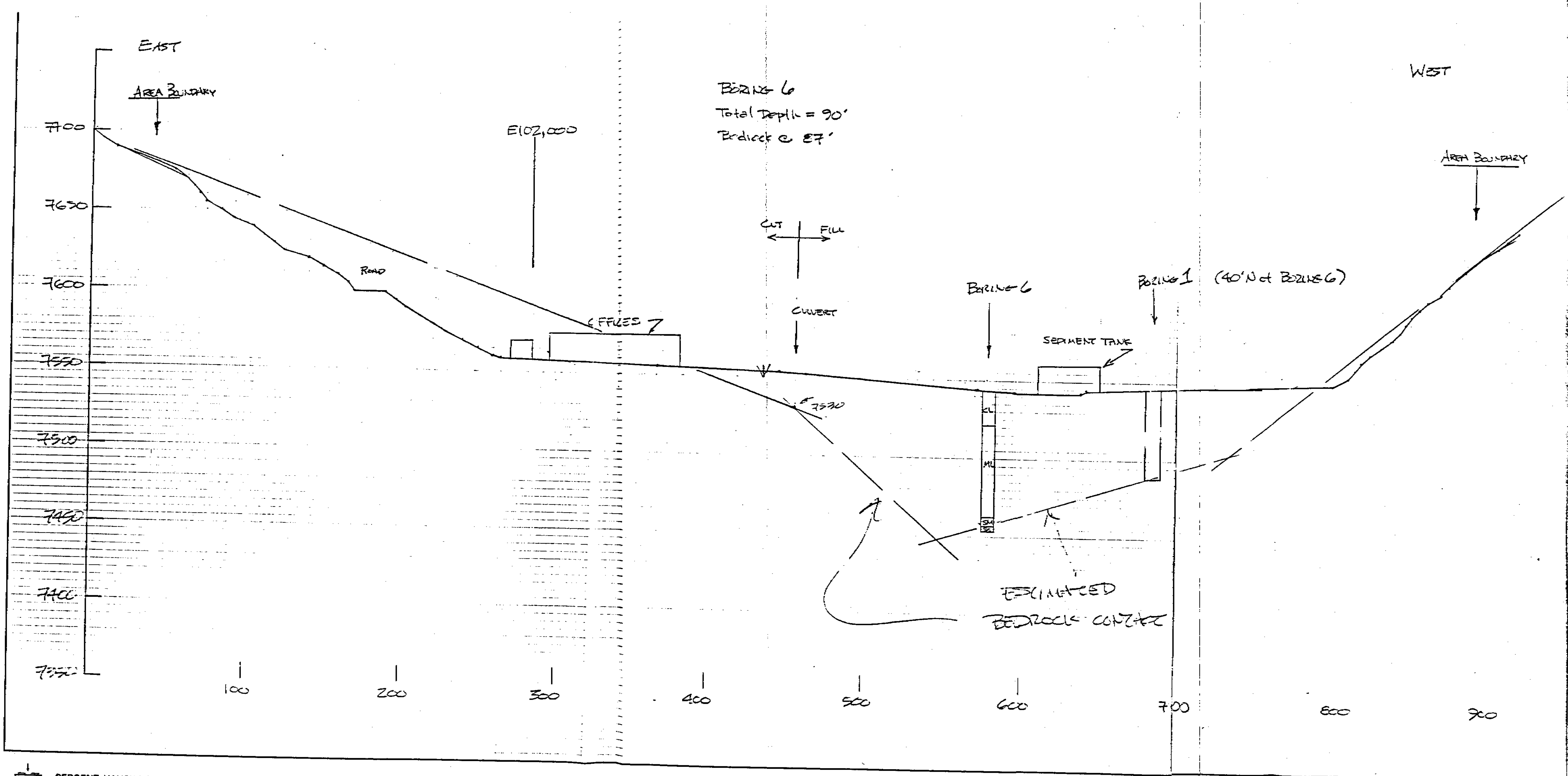

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Project SUFCO RECLAMATION
Job No: E83-2022
Computed by: PK Ckd. by:
Date 8/29/85 Page __ of __

C-6

Submittal of Drainage Plan and Slope Stability
for Reclamation for Convulsion
Canyon Mine, ACT/041/002, No. 2,
No. 3 & No. 14
Sevier County, Utah
SHB Job No. E83-2022

TABLE D-1

ELEVATION & GRADIENT FOR MAIN CHANNEL REACHES

Reach Number	Beginning Elevation	Ending Elevation	Gradient
1	7575.0	7567.0	0.025
2	7567.0	7557.5	0.100
3	7557.5	7542.2	0.065
4	7542.0	7534.0	0.020
5	7534.0	7494.0	0.571
6	7494.0	7411.0	0.546
7	7411.0	7374.0	0.356
8	7374.0	7347.0	0.151

note: critical gradient for reaches 1-4 = 0.018

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Calculation of gradient for each reach.

Reach 1

$$S = \frac{\Delta Z}{L} = \frac{7575-7567}{320} = \underline{\underline{0.025}}$$

Reach 2

$$S = \frac{7567-7557.5}{95} = \underline{\underline{0.100}}$$

Reach 3

$$S = \frac{7557.5-7542.2}{235} = \underline{\underline{0.065}}$$

Reach 4

$$S = \frac{7542.2-7534}{410} = \underline{\underline{0.020}}$$

Reach 5

$$S = \frac{7534-7494}{70} = \underline{\underline{0.571}}$$

Reach 6

$$S = \frac{7494-7411}{152} = \underline{\underline{0.546}}$$

Reach 7

$$S = \frac{7411-7374}{104} = \underline{\underline{0.356}}$$

Reach 8

$$S = \frac{7374-7347}{179} = \underline{\underline{0.151}}$$

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Project: SUFCO RECLAMATION
Job No: E83-2022
Computed by: TJF Ckd. by: PK
Date: 2/26/86 Page ___ of ___

Submittal of Drainage Plan and Slope Stability
for Reclamation for Convulsion
Canyon Mine, ACT/041/002, No. 2,
No. 3 & No. 14
Sevier County, Utah
SHB Job No. E83-2022

Design Calculations for Channel Depths of Flow, Velocity, & Related Critical Depth & Velocity

Main Channel

Manning Formula

$$V = \frac{1.49}{n} S^{1/2} R^{2/3}$$

n = 0.035 for rock channel

Reach	Slope	Side Slope	Bottom Width	Bank Height
1	0.025	1:1	Varies	7.0'
2	0.100	1:1	17.5	6.0'
3	0.065	1:1	17.5	6.0'
4	0.020	1:1	17.5	7.5'
5	0.571	.75:1	10.0	5.5'
6	0.546	.75:1	10.0	5.5'
7	0.356	1:1	17.5	5.5'
8	0.151	1:1	17.5	5.5'

Reach	Normal Velocity (fps)	Normal Depth (feet)	Critical Velocity (fps)	Critical Depth (feet)
1	16.96	3.18	10.76	4.70
2	22.67	2.73	10.99	5.05
3	19.59	3.10	10.99	5.05
4	13.06	4.38	10.99	5.05
5	46.14	2.31	12.20	6.80
6	45.41	2.34	12.20	6.80
7	34.58	1.87	10.99	5.05
8	26.01	2.41	10.99	5.05

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Submittal of Drainage Plan and Slope Stability
for Reclamation for Convulsion
Canyon Mine, ACT/041/002, No. 2,
No. 3 & No. 14
Sevier County, Utah
SHB Job No. E83-2022

West Collector Channel

Q = 29.3 for entire basin

Six distinctive tributaries

Manning Equation:

$$V = \frac{1.49}{n} R2/3S1/2$$

n = 0.035 for rock channels. All side slopes are 1:1.

Section	Q (cfs)	Width (feet)	Height (feet)	Slope
A-1	5	2.0	2.0	0.020
A-2	10	2.0	2.0	0.020
A-3	20	3.0	3.0	0.018
A-4	25	3.0	3.0	0.015
A-5	30	2.0	3.0	0.501

Section	Normal Depth (feet)	Normal Velocity (fps)	Critical Depth (feet)	Critical Velocity (fps)
A-1	0.59	3.27	0.54	3.65
A-2	0.85	4.07	0.82	4.33
A-3	1.07	4.62	1.02	4.89
A-4	1.27	4.61	1.16	5.18
A-5	0.52	16.39	1.29	5.42

Freeboard Calculations:

Cfb = 0.20; subcritical

$Fb = Cfb^{d} + 1/2\ d^{Z}$

= .2 (1.04)= .21'

Allow for sedimentation

$$dZ = \frac{(4.61)^2}{32.2\ (202)}$$

= 0.021 (critical gradient for A-4)

neglect super elevation

= 0.024 (critical gradient for A-1, A-2)

= 0.022 (critical gradient for A-3)

Submittal of Drainage Plan and Slope Stability for Reclamation for Convulsion Canyon Mine, ACT/041/002, No. 2, No. 3 & No. 14
Sevier County, Utah
SHB Job No. E83-2022

East Collector Channel

Q = 17.1 cfs

Three distinctive tributaries

Manning Equation:

$$V = \frac{1.49}{n} R^{2/3} S^{1/2}$$

n = 0.035; rock-lined channel

All side slopes cut to 1:1

Section	Flow (cfs)	Bottom Width	Bank Height	Slope
B-1	5	2.0	2.0	0.010
B-2	5	2.0	2.0	0.060
B-3	15	3.0	3.0	0.270
B-4	5	2.0	2.0	0.125
B-5	10	2.0	3.0	0.526

Section	Normal Depth (feet)	Normal Velocity (fps)	Critical Depth (feet)	Critical Velocity (fps)
B-1	.709	2.60	.542	3.63
B-2	.424	4.87	.542	3.63
B-3	.412	10.67	.858	4.53
B-4	.343	6.23	.542	3.63
B-5	.337	12.69	.821	4.32

Channel is over-sized to allow for sedimentation.

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Riprap Design Summary
for Reinforced Channel Bank (Reach 1)

Reference: Applied Hydrology & Sedimentology for Disturbed Areas, Barfield, B.J. & Warner, R.C. 1981

$$\eta = \frac{21\,\tau_{max}}{\gamma(SG-1)D_{50}}$$

$\eta = 0.41$

where:

$\tau_{max} = 0.75\,\gamma R S$

$= 0.75(62.4)(2.95)(0.025)$

$\tau_{max} = 3.5$

$SG = 2.65$

$D_{50} = 1.75$ feet

$$\beta = \tan^{-1}\left(\frac{\eta \tan\phi}{2\sin\theta}\right)$$

$\beta = 28.75°$

where:

ϕ = angle of repose of rock

$\phi = 45°$

θ = slope angle

$\theta = 21.8°$ (2.5:1)

$$\eta' = \eta\left(\frac{1+\sin\beta}{2}\right)$$

$\eta' = 0.330$

$$FS = \frac{\cos\theta \tan\phi}{\eta' \tan\phi + \sin\theta\cos\beta}$$

$FS = 1.48$

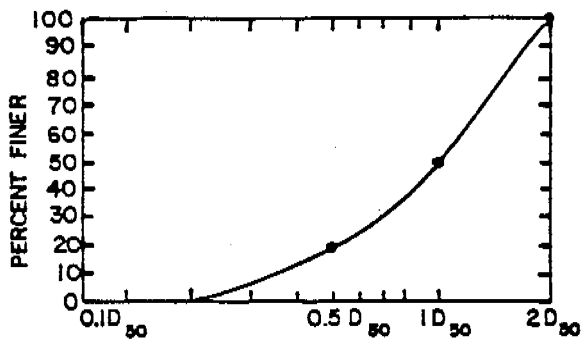

Figure 3.17. Suggested size distribution of riprap. (After Simons and Senturk, 1977).

Riprap gradation from curve:

Riprap size (ft)	percent finer
4	100
2	50
1	20
0.6	0

Riprap sizes are to nearest foot.

Calculations For Diversion Channels
For Slope Face Protection

Method Used: Applied Hydrology and Sedimentology for Disturbed Areas.
Barfield and Warner, 1981

1) Calculation of Run off Volume

100 year 24 hour Storm.

CN = 80 DISTURBED AREA

Precipitation = 2.9 INCHES (MERRICK REPORT)

$$S = \frac{1000}{CN} - 10 = 2.5$$

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} = \frac{(2.9 - 0.2(2.5))^2}{2.9 + 0.8(2.5)}$$

= 1.18 INCHES

$t_c \approx 0.1$ hr

2) Peak Flow Rate

$$q_p = q_p' A Q$$

A = AREA OF SLOPE BETWEEN BENCHES

= (85') (220')

= .000671 SQ. MILES

$q_p' = 1000$ (MAXIMUM POSSIBLE)

$$q_p = 1000(.00067)(1.18)$$
$$= 0.79 \text{ CFS}$$

DIVERSION WILL BE DESIGNED TO ACCOMADATE A PEAK FLOW OF 0.79 CFS

3) CHANNEL DESIGN

TRIANGULAR CHANNEL

MANNINGS N = 0.020

TYPICAL FOR SHALE, SANDSTONE & SILTY LOAM SPOIL.

$$V = \frac{1.49}{N} R^{2/3} S^{1/2} \qquad V = \frac{Q}{A}$$

S = .015

Z = 3 Channel Side Slopes

Q	NORMAL DEPTH	NORMAL VELOCITY	CRITICAL DEPTH	CRITICAL VELOCITY
.79	.324	2.50	.346	2.19

CRITICAL SLOPE = 0.0097

ALLOW FOR SEDIMENTATION BETWEEN MAJOR STORM EVENTS

SO DEPTH OF CHANNEL RECOMMENDED = 1.0 Ft

Top Width = 2dZ = 2(1)(3) = 6 Ft

AREA = $3d^2$ = 3 Ft^2

4) SIZING RIPRIP FOR Diversion Channels

$S = .015$

$N = .020$

$\alpha = TAN^{-1}(\frac{1}{2}) = 18.43°$ FOR $Z = 3$

$\phi = 38°$ ANGLE OF REPOSE FOR SAND

$\lambda = 0$ ANGLE OF ATTACK (ASSUMED)

$T_{MAX} = .75\, \gamma_w\, d\, S$ critical tractive force

d = depth of flow

γ_w = UNIT WEIGHT OF WATER

$d = .324$

$S = .015$

$T_{MAX} = 0.23$

$$\eta = \frac{21\, T_{max}}{\gamma_w (S_G - 1) D_{50}}$$

D_{50} = MEAN RIPRAP DIAMETER

= .17 Ft

= 2"

= 0.26

$$\eta' = \eta \frac{1 + SIN\, \beta}{2} = 0.17$$

$$\beta = TAN^{-1}\left(\frac{1}{\frac{2\, SIN\, \alpha}{\eta\, TAN\, \phi}}\right) = 17.81$$

$$FS = \frac{COS\, \alpha\; TAN\, \phi}{\eta'\, TAN\, \phi + SIN\, \alpha\, COS\, \beta}$$

$= 1.71 > 1.50$

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GRADATION OF RIPRAP Determined by Curve (Fig 3.17)

RIP RAP SIZE	PERCENT FINER by Weight
.33	100
.17	50
.08	20
.02	0

5) SEDIMENT YIELD OF PROTECTED SLOPE

USLE FACTORS FROM SHB REPORT
FINAL RECLAMATION PLAN
MAY 1984
ADDENDUM #1

$R = 26$ ANNUAL

$$R = \frac{19.25\ P^{2.2}}{D^{0.4672}}$$ 100 year – 24 hr

$$= \frac{19.25\ (2.9)^{2.2}}{24^{0.4672}} = 45.38$$

$K = 0.37$ Very fine sandy loam

$$LS = \left(\frac{\lambda}{72.6}\right)^m \left(\frac{430x^2 + 30x + 0.43}{6.613}\right)$$

λ = slope length = 85'

m = 0.5 for slope greater than 5%

$X = \sin\theta$ θ = Slope Angle

$= 0.45$ $= 26.57°$

$LS = 16.53$

CP = 0.035 sparse grass

= 0.015 Wood chips (SEE SHB RPT)

$Y_{ANNUAL} = A R K L S C P$ (ANNUAL)

$$= \frac{85(220)}{43,560}(26)(.37)(16.53)(.035)$$

$$= 2.39 \frac{TON}{YEAR} = 5.57 \frac{TON/ACRE}{YEAR}$$

$$Y_{100,24} = \frac{85(220)}{43560}(45.38)(.37)(16.53)(.035)$$

$$= 4.17 \text{ Ton} = 9.71 \frac{TON}{ACRE}$$

Annual Quantity to Wash From Slope With No Diversions or Soil Protection

$$Y = \frac{220(250)}{43560}(26)(.37)(28.34)(1)$$

$$= 344.23 \frac{TONS}{YEAR} = 800 \frac{TONS/ACRE}{YEAR}$$

CP = 1 For Recently graded slope with No Vegetation

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CHANNEL INLET

& SEDIMENTATION AREA

EARTHWORK CALCULATIONS

$\forall_1 = \frac{1}{2}(40)(56)\left(\frac{5+5+6}{3}\right)$

$= 5973.2$ FT³

$= 221.2$ YD³

$\forall_2 = \frac{1}{2}(66)(69)\left(\frac{5+6+5.75}{3}\right)$

$= 12,713.3$ FT³

$= 470.9$ YD³

$\forall_3 = \frac{1}{2}(22)(78)\left(\frac{6+6+5.75}{3}\right)$

$= 5076.5$ FT³

$= 188.0$ YD³

$\forall_4 = (72)(75)\left(\frac{6+7+7+6.25}{4}\right)$

$= 35,437.5$ FT³

$= 1312.5$ YD³

$\forall_5 = \left(\frac{94+94}{2}\right)\left(\frac{54+35}{2}\right)\left(\frac{7+7+8+8}{4}\right)$

$= 31372.5$ FT³

$= 1,161.9$ YD³

$\forall_6 = \frac{1}{2}(53)(93)\left(\frac{7+7+8}{3}\right)$

$= 18,073.0$ FT³

$= 669.4$ YD³

$\forall_7 = \left(\frac{42+47}{2}\right)\left(\frac{39+36}{2}\right)\left(\frac{7+7+7+6.5}{4}\right)$

$= 11,601.6$ FT³

$= 429.7$ YD³

$\forall_8 = \frac{1}{2}(104)(76)\left(\frac{7+7+8}{3}\right)$

$= 28,981.3$ FT³

$= 1073.4$

$\forall_9 = \frac{1}{2}(84)(92)\left(\frac{7+7+6}{3}\right)$

$= 25,760.0$ FT³

$= 954.1$ YD³

$$V_{10} = \frac{(115)(36)}{2}\left(\frac{6+5.5+6}{3}\right) = 12,075.0 \text{ Ft}^3$$

$$= 447.2 \text{ Yd}^3$$

$$V_{11} = \frac{(122)(88)}{2}\left(\frac{5+6+5.5}{3}\right) = 29,524 \text{ Ft}^3$$

$$= 1093.5 \text{ Yd}^3$$

$$V_{12} = \tfrac{1}{2}(16)(7)(245.0) = 13,720.0 \text{ Ft}^3$$

$$= 508.1 \text{ Yd}^3$$

$$V_{13} = \tfrac{1}{2}(16)(7)(325) = 18200 \text{ Ft}^3$$

$$= 674.1 \text{ Yd}^3$$

$$V_{14} = \tfrac{1}{2}(16)(75)\left(\frac{6+6+6.25}{3}\right) = 3,650 \text{ Ft}^3$$

$$= 135.2 \text{ Yd}^3$$

$$V_{15} = \tfrac{1}{2}(47)(45)\left(\frac{6+7+7}{3}\right) = 7050.0 \text{ Ft}^3$$

$$= 261.1 \text{ Yd}^3$$

$$V_{16} = \frac{(138)(55)}{2}\left(\frac{6+6+7}{3}\right) = 24,035.0 \text{ Ft}^3$$

$$= 890.2 \text{ Yd}^3$$

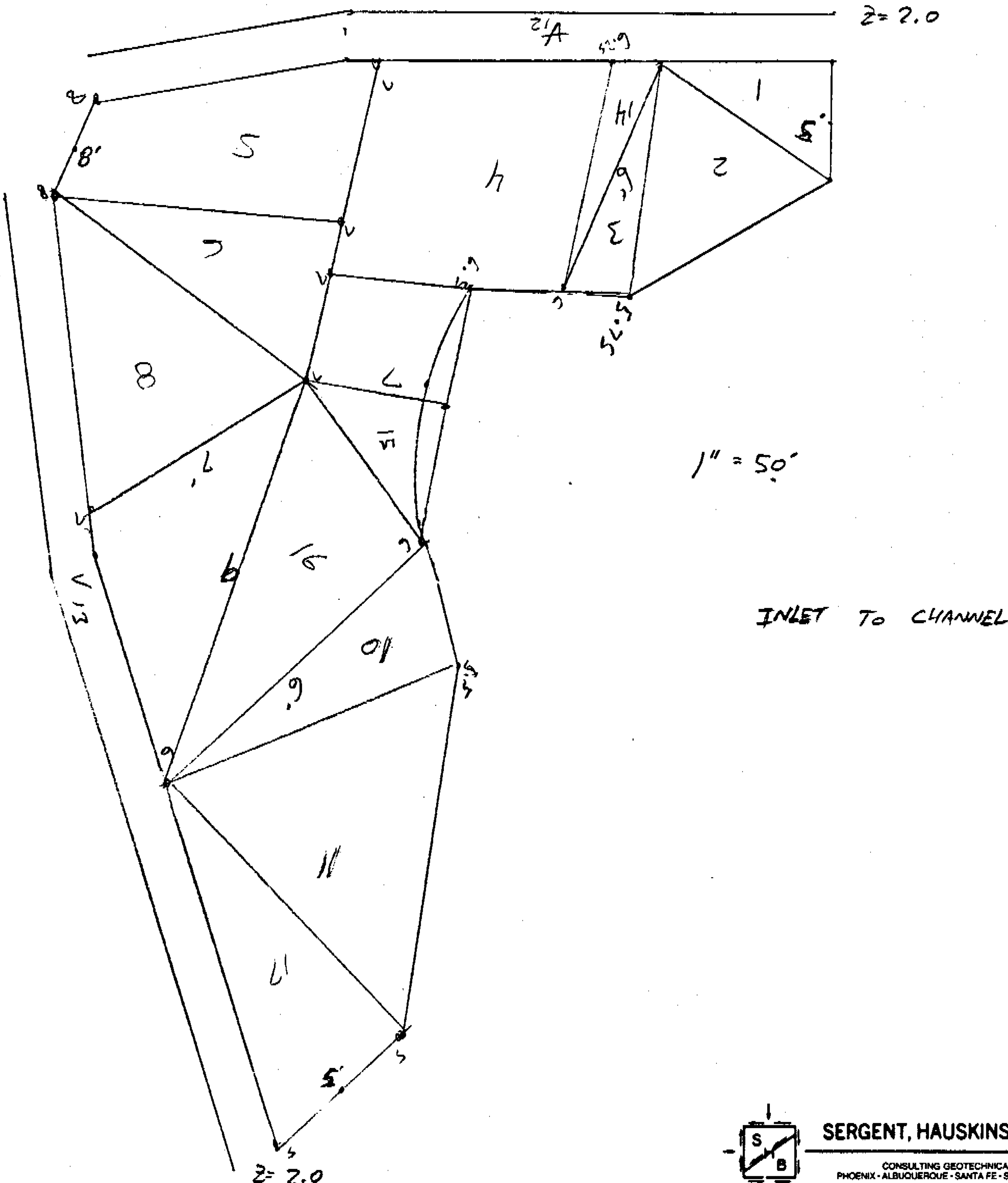
$$V_{17} = \frac{125(40)}{2}\left(\frac{6+5+5}{3}\right) = 15,333.3 \text{ Ft}^3$$

$$= 567.9 \text{ Yd}^3$$

$$V_{total} = 11,058.4 \text{ Yd}^3$$

SITE PLAN

SHOWING LOCATIONS OF TEST BORINGS



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TRANSITION REACH (REACH 2)

$A_1 = (b + 2y)y = (20 + 1.0(5.5))5.5 = 140.3$

$A_2 \quad (17.5 + 5.5)5.5 = 126.5$

$A_{AVG} = 133.4 \text{ Ft}^2$

$\forall = 133.4(95') = 12,673 \text{ Ft}^3 = \underline{\underline{469.4}} \text{ YD}^3$

(REACH 3)

$A = (17.5 + 1.0(5.5))5.5 = 126.5 \text{ Ft}^2$

$\forall = 232.0(126.5) = 29,348.0 \text{ Ft}^3 = \underline{\underline{1087.0}} \text{ YD}^3$

(REACH 4)

$A = (17.5 + 8.5)(8.5) = 221.0 \text{ Ft}^2$

$\forall = 430(221.0) = 95,030 \text{ Ft}^3 = \underline{\underline{3,519.6}} \text{ YD}^3$

(REACH 5)

$A = (10 + .75(5.5))(5.5) = 77.7 \text{ Ft}^3$

$\forall = AL \qquad L = 76.5 \text{ Ft}$

$= 77.7(76.5)$

$= 5941.8 \text{ Ft}^3$

$= \underline{220.1} \text{ YD}^3$

(REACH 6)

$A = (10 + .75(5.5))5.5 = 77.7 \text{ Ft}^3$

$L = 152'$

$\forall = 152(77.7) = 11,808.5 \text{ Ft}^2$

$= \underline{437.4} \text{ YD}^3$

(REACH 7)

$A = (17.5 + 1.0(5.5))\,5.5$

$= 126.5 \text{ FT}^2$

$L = 105 \text{ FT}$

$V = (105)(126.5) = 13,282.5 \text{ FT}^3$

$= 491.94 \text{ YD}^3$

(REACH 8)

$A = (17.5 + 1.0(5.5))\,5.5$

$= 126.5 \text{ FT}^2$

$L = 170'$

$V = 21,505 \text{ FT}^3$

$= 796.48 \text{ YD}^3$

Contour	Area (ft^2)	Total	Avg	Volume (YD^3)
0	52,530.0			
		36,567.	10	13,543
10	20,604.0			
		14,484	10	5,364
20	8364.0			
		5,151.	10	1,908
30	1938.0			
		969.	10	359
40	0			
				21,174

planimeter cts

1" = 50' ∴ 1 inch^2 = 2500 ft^2

plu cts → 47, 51, ~~41~~, 50, 49 AVG = 49

12, 11

26, 25

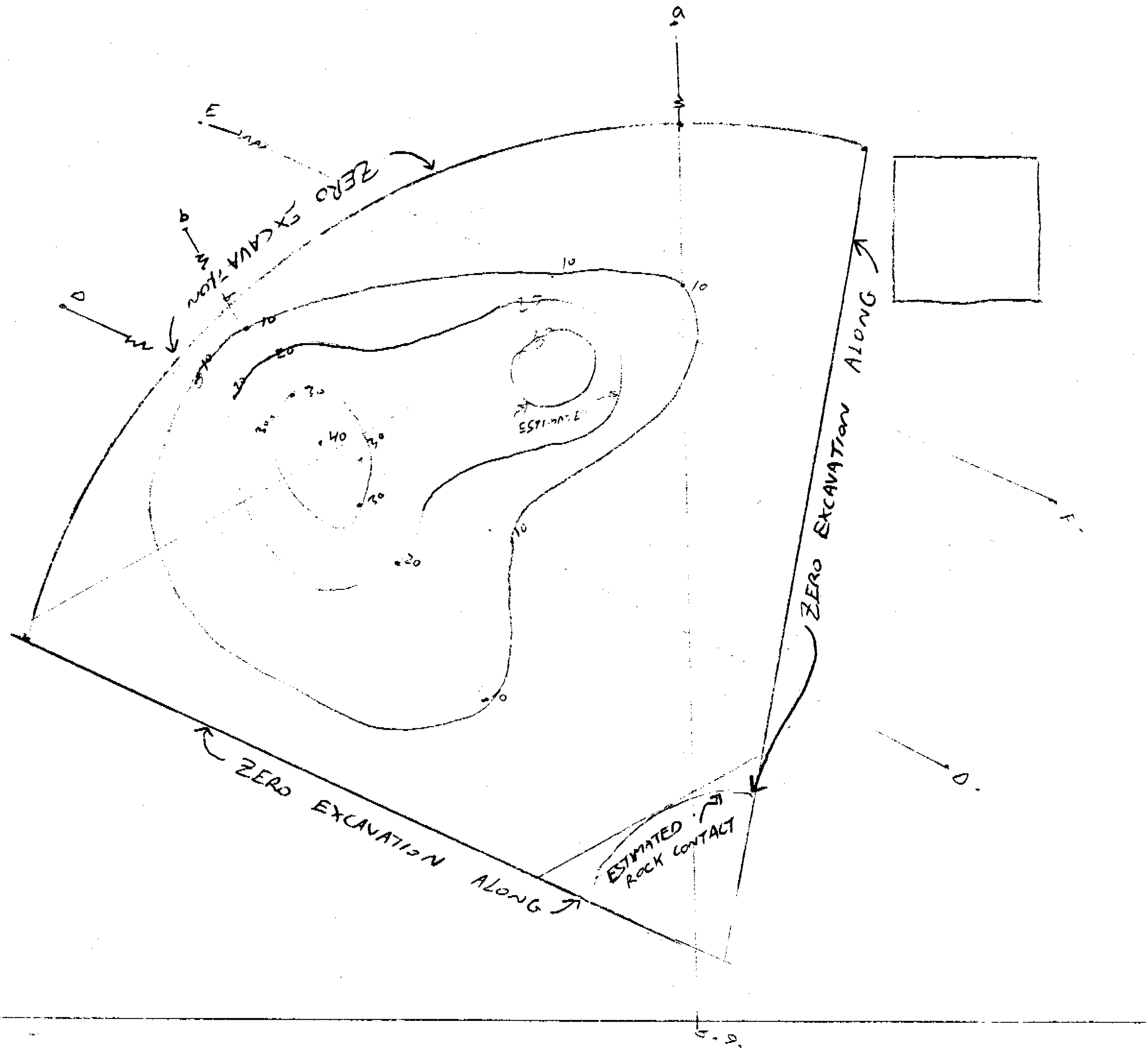
166, ~~371~~, 161, 166, 163 AVG 164

404, 403, 404 AVG 404

1030, 1028, 1030

SITE PLAN

SHOWING LOCATIONS OF TEST BORINGS



Volumes for Slope cut Back
to 2.5:1 AT CENTER
& GRADED TO NATURAL ALONG SIDES

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EarthWork Volumes

$A_V = \left(\frac{1}{2}\right)^2 (105)\ 25 + \left(\frac{1}{2}\right)^2 (100)\ 25$

$= 656.25 + 625 = 1281.25\ Ft^2$

$A_U - \left(\frac{1}{2}\right)^2 (195)(25) + \left(\frac{1}{2}\right)^2 (80)(25)$

$= 1218.75 + 500 = 1718.75\ Ft^2$

$A_T = \left(\frac{1}{2}\right)^2 (100)(40) + \frac{1}{2}\left[(195)(35) - \frac{1}{2}(185)(10) - 34(25)\right]$

$1000 + 2525$

$= 3525\ Ft^2$

$A_S = \left(\frac{1}{2}\right)^2 (70)(25) + \left(\frac{1}{2}\right)^2 95\ 10$

$= 437.5 + 237.5$

$= 675.0\ Ft^2$

$A_R = \left(\frac{1}{2}\right)^2 (60)(20) + \left(\frac{1}{2}\right)^2 (110)(15)$

$= 300 + 412.5$

$= 712.5\ Ft^2$

$A_Q = \left(\frac{1}{2}\right)^2 (75)(20) + \left(\frac{1}{2}\right)^2 (60)(40) + \left(\frac{1}{2}\right)^2 (140)(12)$

$= 375 + 600 + 420$

$= 1395.00$

$A_J = \left(\frac{1}{2}\right)^2 (110)(60) + 36\ Ft^2 + \left(\frac{1}{2}\right)(9.5)(180)$

$= 1650 + 36 + 855$

$= 2541$

$A_K = \left(\frac{1}{2}\right)^2(100)(25) + \left(\frac{1}{2}\right)^2(85)(40) - 25 + \left(\frac{1}{2}\right)(10.5)$

$= 625 + 825 + 1102.5$

$= 2552.50$

$A_L = \left(\frac{1}{2}\right)^2(135)(55) + \left(\frac{1}{2}\right)^2(65)(30) + \frac{1}{2}(11.5)(22$

$= 1856 + 487.5 + 1265.0$

$= 3608.50$

$A_M = \left(\frac{1}{2}\right)^2(105)(20) + \left(\frac{1}{2}\right)^2(65)(20) + \left(\frac{1}{2}\right)(11.5)(22$

$= 525 + 325 + 1265.0$

$= 2115.0$

$A_N = \left(\frac{1}{2}\right)^2(100)(30)$

$= 750 \text{ Ft}^2$

$A_O = \left(\frac{1}{2}\right)^2(70)\,8$

$= 140 \text{ Ft}^2$

$$\forall_{V} \text{ (to north)} = \frac{625 + 0}{2} (50) = 578.70 \text{ YD}^3$$

$$\forall_{U-V} = \frac{1281.25 + 1718.75}{2} (50) = 2777.78$$

$$\forall_{U-T} = \frac{1718.75 + 3525}{2} (50) = 4855.32$$

$$\forall_{T-S} = \frac{3525 + 675}{2} (50) = 3888.89$$

$$\forall_{S-R} = \frac{675 + 712.5}{2} (50) = 1284.72$$

$$\forall_{R-Q} = \frac{712.5 + 1395}{2} (50) = 1951.39$$

$$\forall_{Q-J} = \frac{1395 + 2541}{2} (50) = 3644.44$$

$$\forall_{J-K} = \frac{2541 + 2552.5}{2} (50) = 4716.20$$

$$\forall_{KL} = \frac{2552.5 + 3608.5}{2} (50) = 5704.63$$

$$\forall_{LM} = \frac{3608.5 + 2115.0}{2} (50) = 5299.54$$

$$\forall_{MN} = \frac{2115.0 + 750}{2} (50) = 2652.78$$

$$\forall_{N-O} = \frac{750 + 140}{2} (50) = 824.07$$

$$\forall_{N} \text{ (to south)} = \frac{140 + 0}{2} (50) = 129.63$$

38,308.09

MAIN ROADWAY

$$A_{AVG} = \frac{(\frac{1}{2})(60)(6) + (\frac{1}{2})(40)(5)}{2}$$

$= 140\ Ft^2$

$L = 400\ Ft$

$\forall = 140\,(400) = 56{,}000\ Ft^3$

$= 2074.07\ YD^3$

LOWER ROADWAY TO EXISTING DAM

$L = 480'$

$A = \frac{1}{2}(15)(4) = 30\ Ft^2$

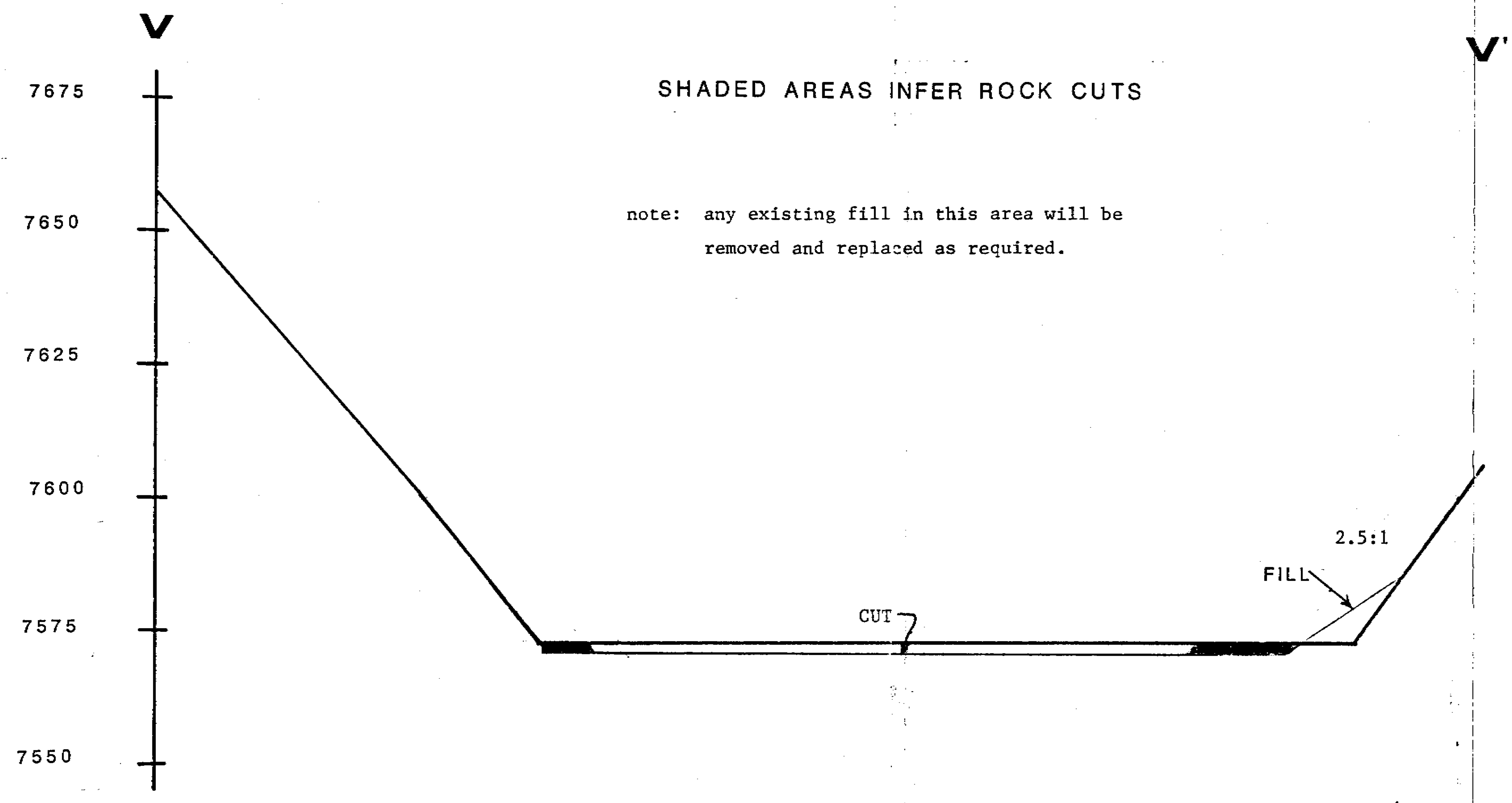
$V = 480\,(30) = 14{,}400\ Ft^3$

$= 533.33\ YD^3$

TOTAL CUTS

MAIN CHANNEL	18,000
EAST COLLECTOR	650
WEST COLLECTOR	500
DAM CUT BACK	2 000
SLOPE CUT BACK	21,000
	42,150

FILL	CENTER & EAST SIDE	38,400
	ROADWAYS TO SITE	2100
	LOWER ROADWAY	600
		41,100 YD³



HORIZONTAL SCALE 1"=50'

VERTICAL SCALE 1"=25'

LEGEND

— FINISHED GROUND SURFACE

— EXISTING GROUND SURFACE

Revised 2/26/86

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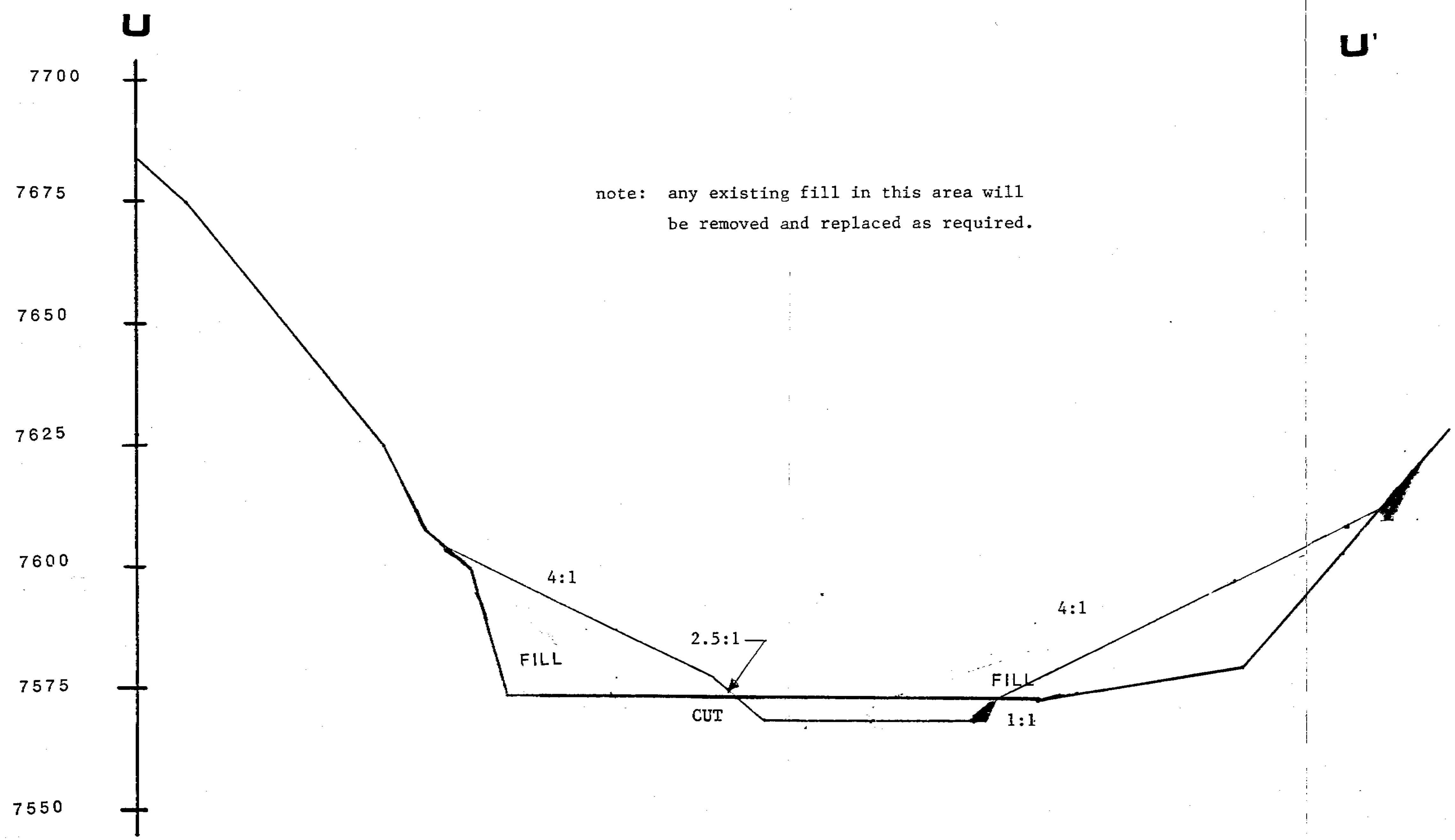

note: any existing fill in this area will be removed and replaced as required.

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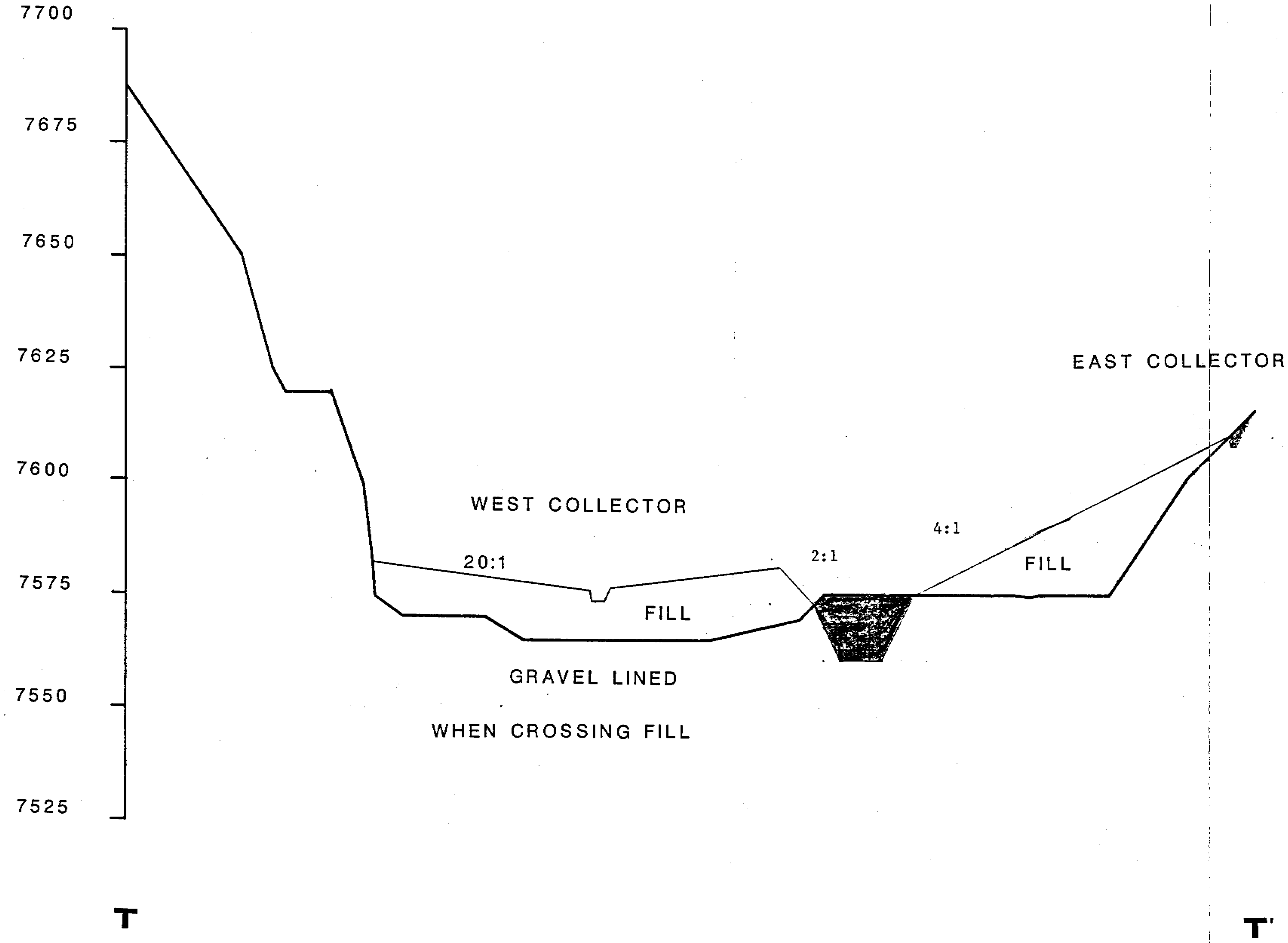

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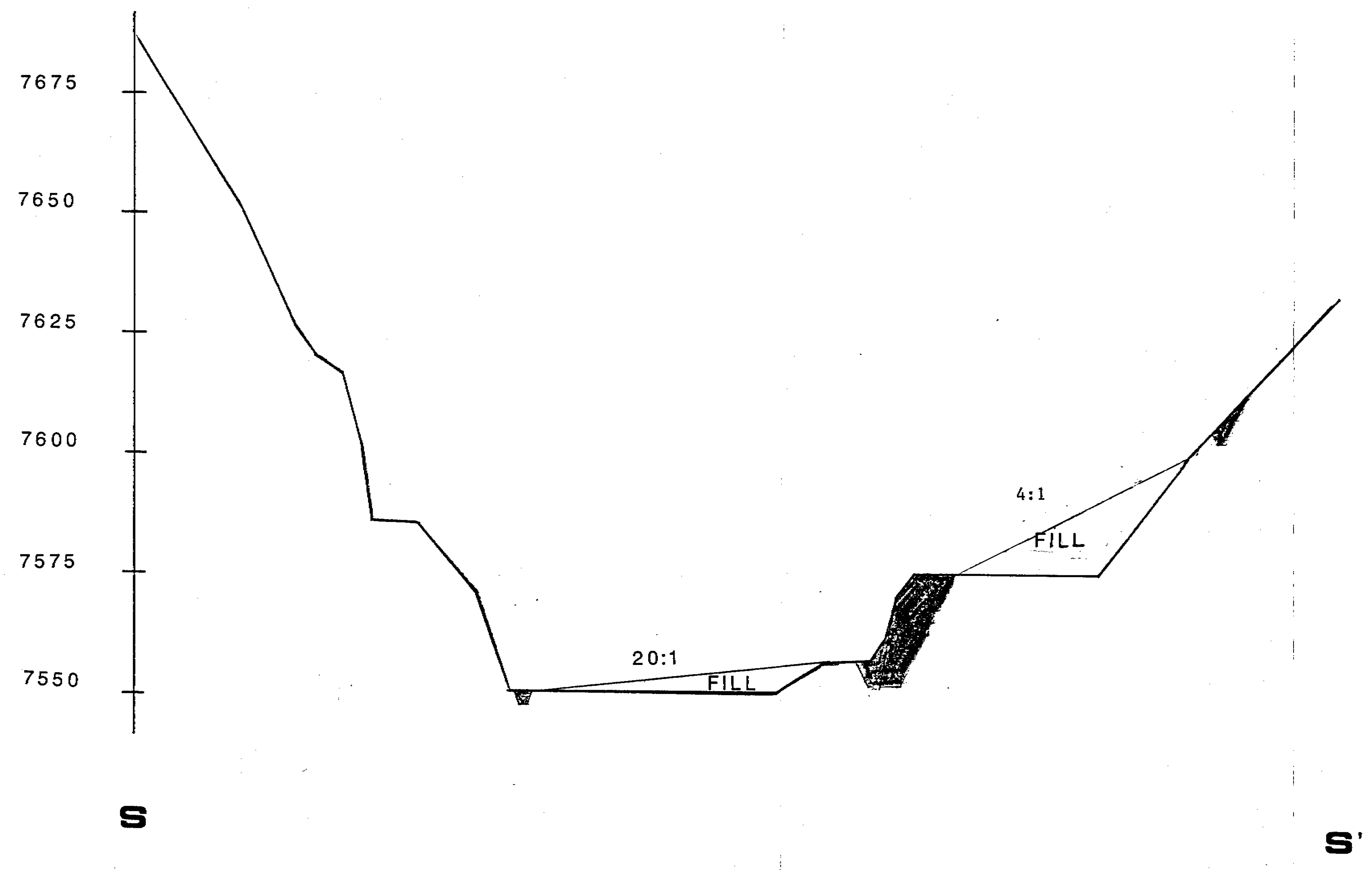

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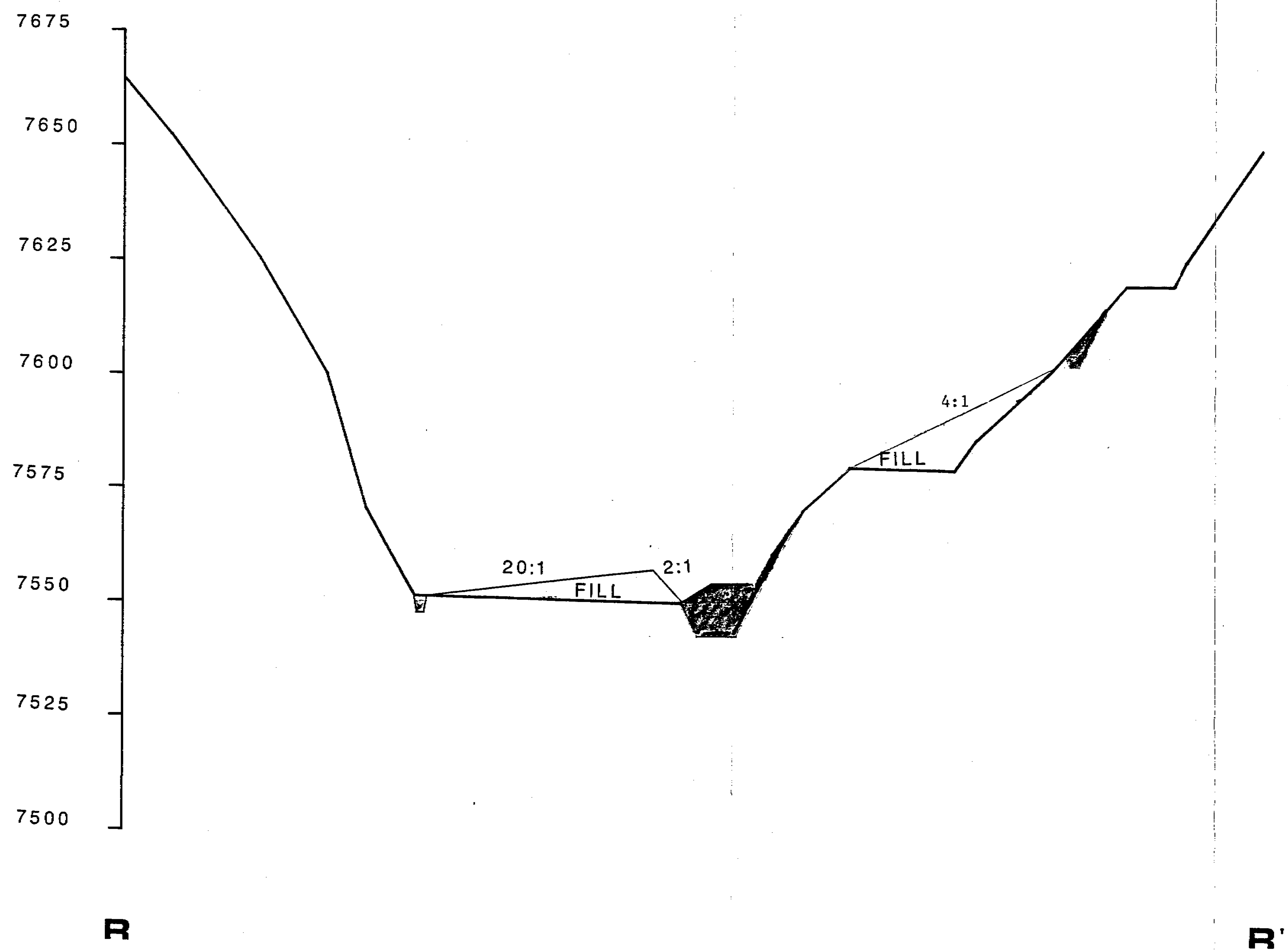

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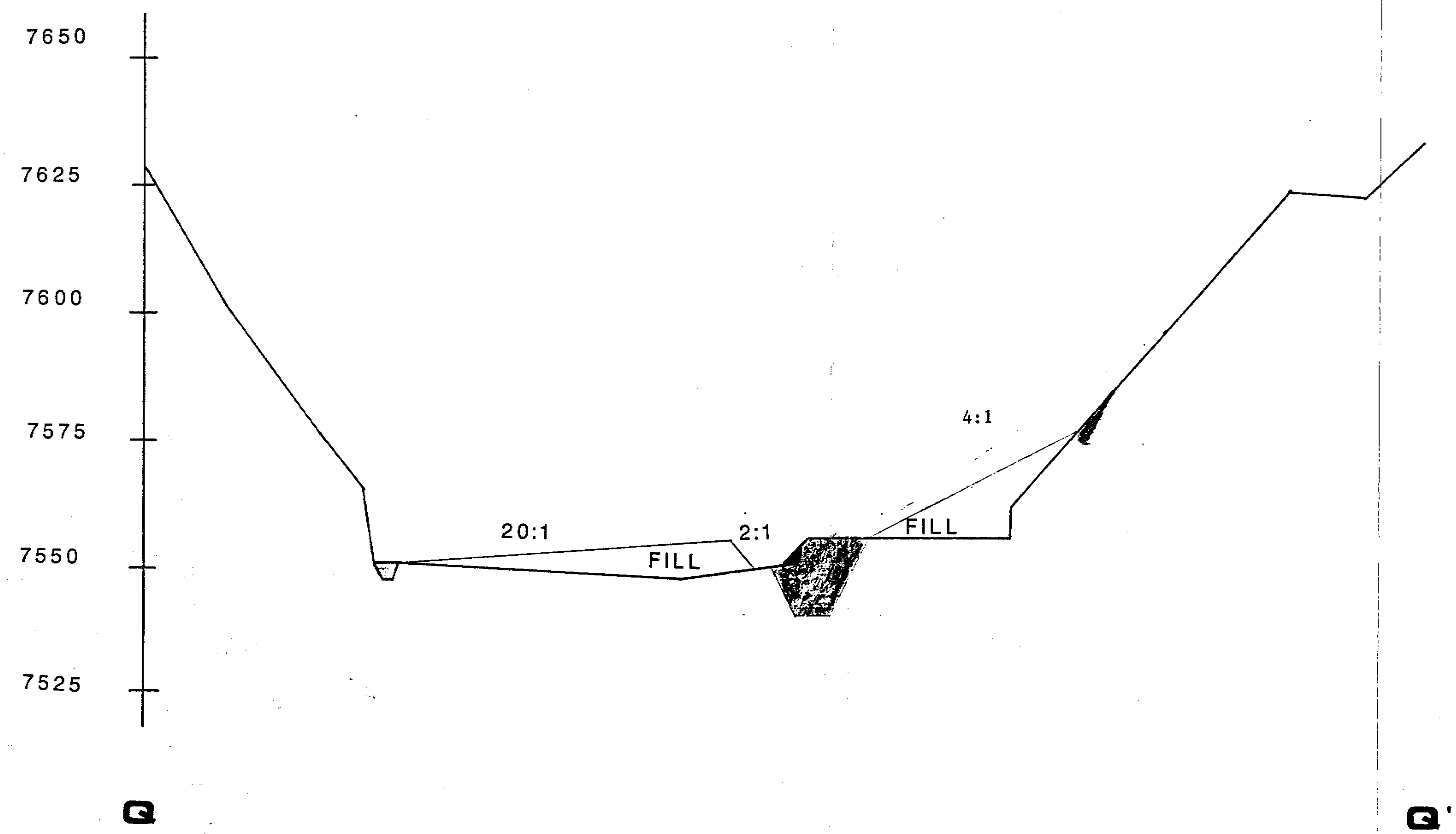

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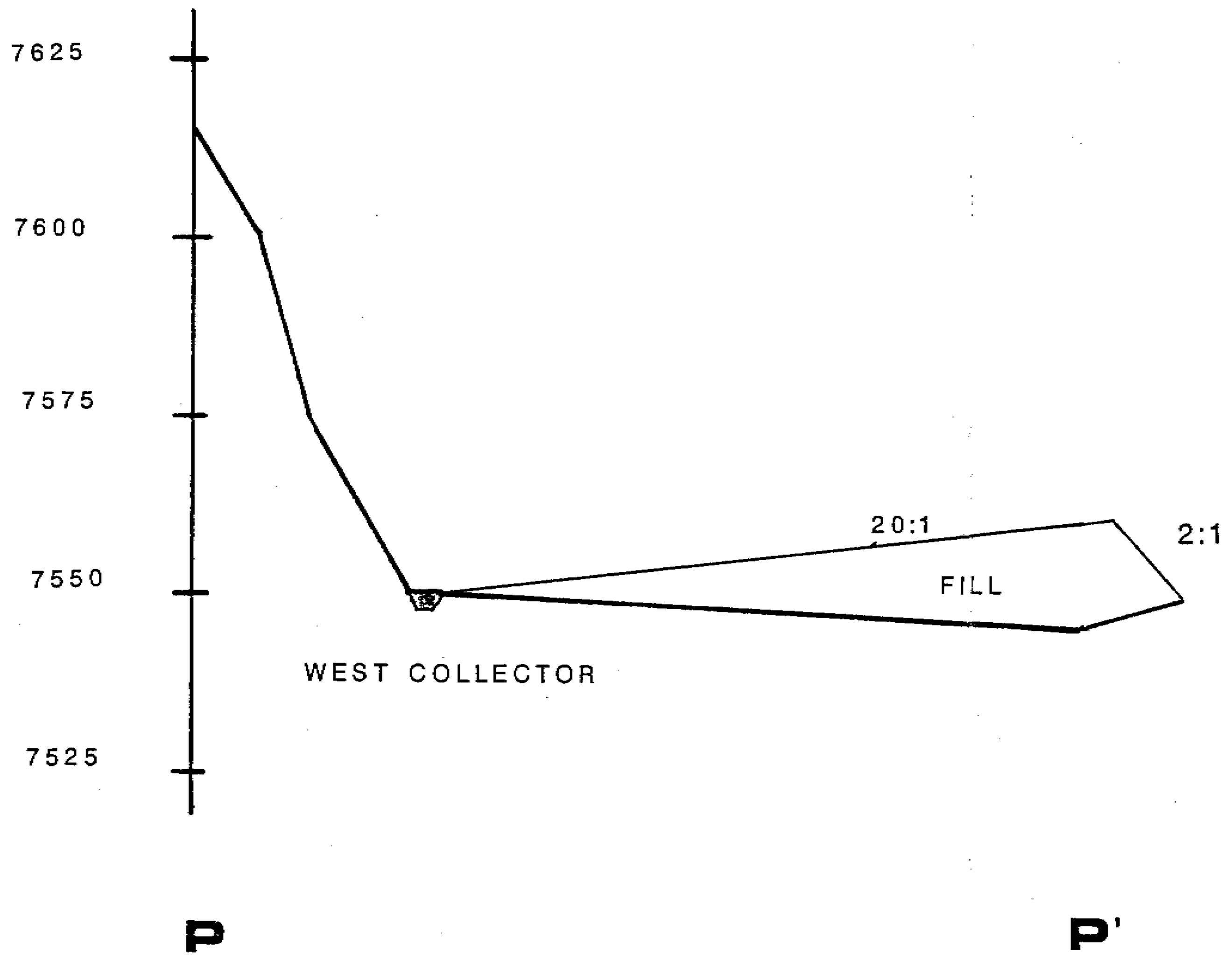

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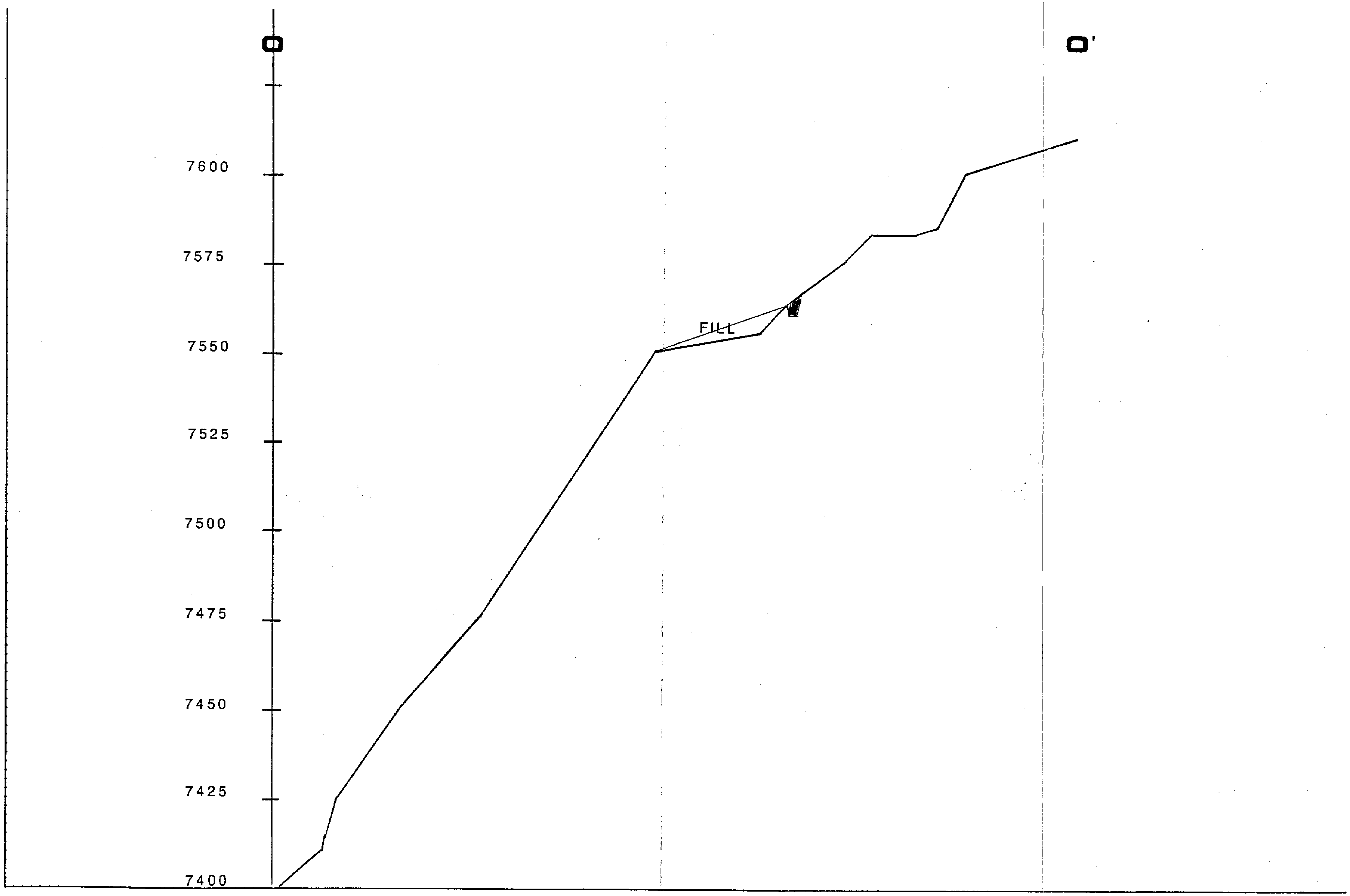

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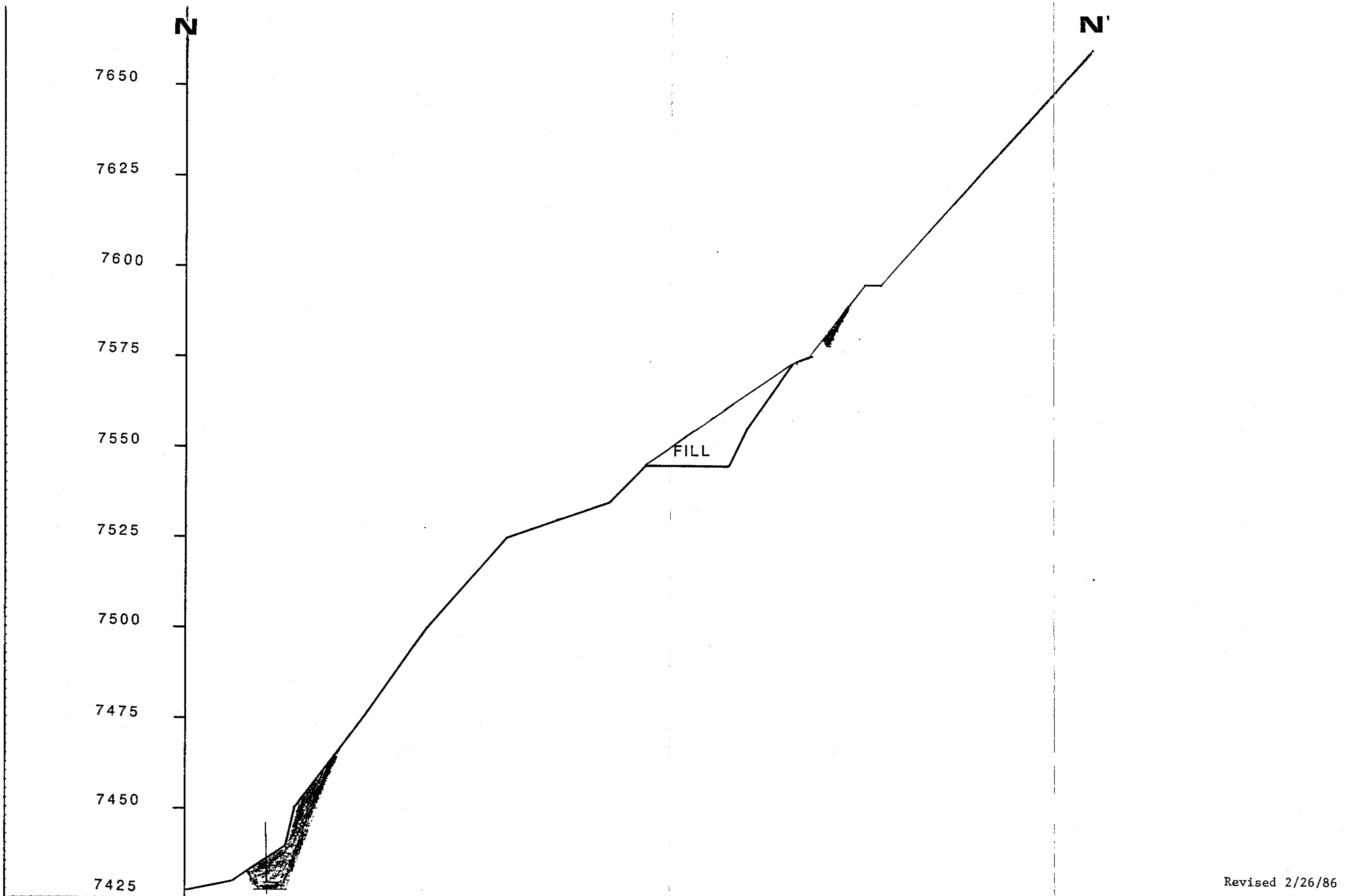

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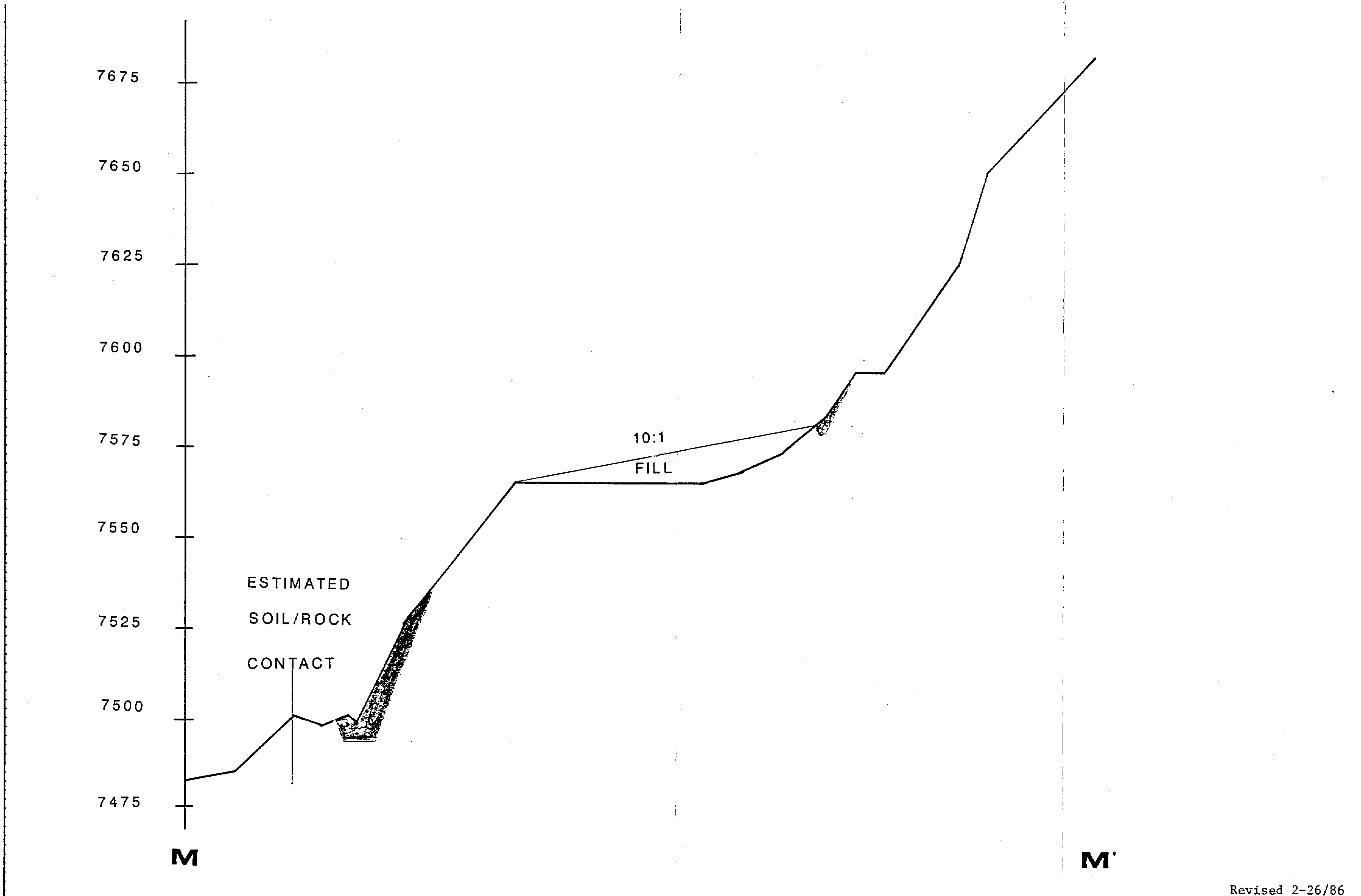

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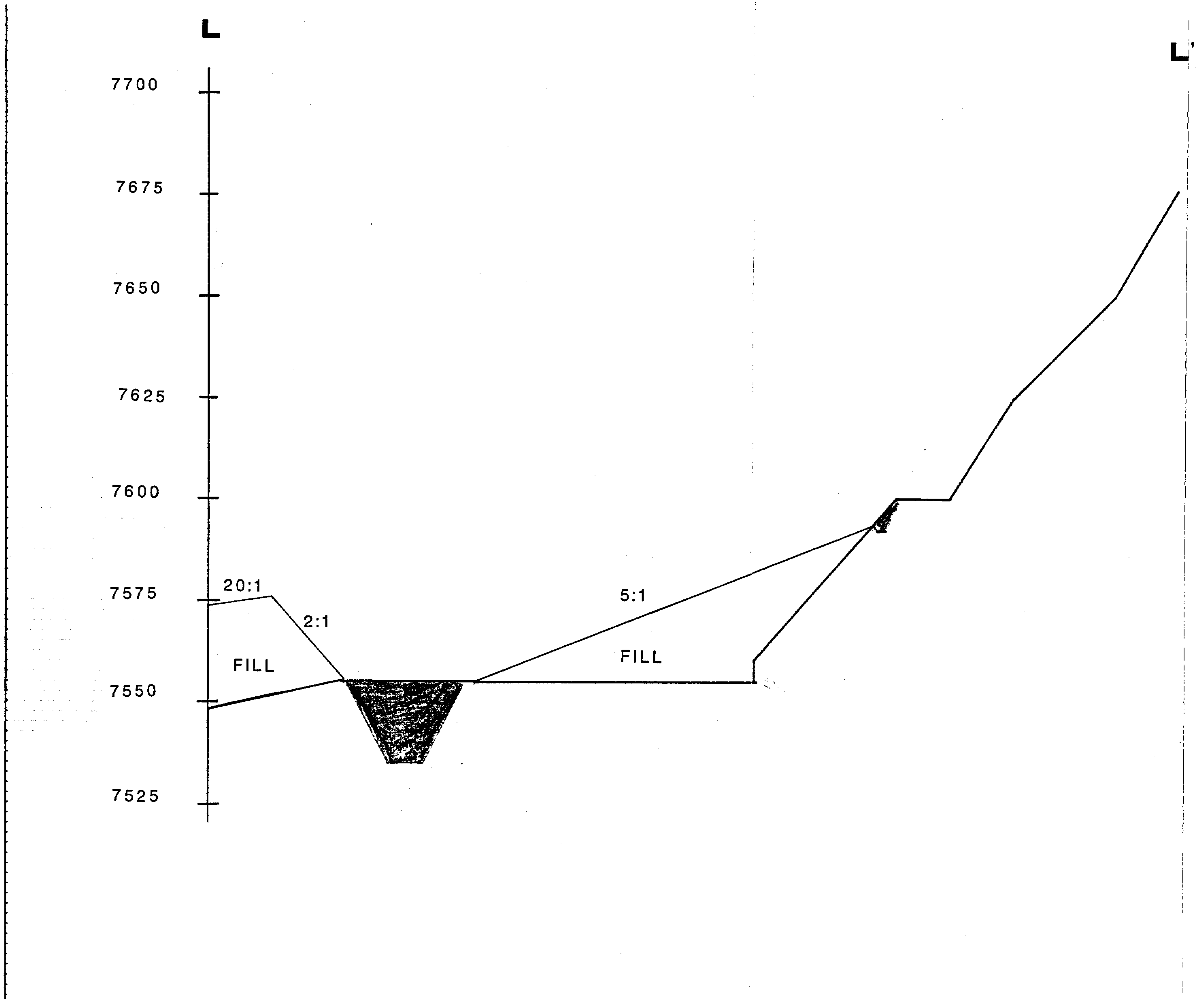

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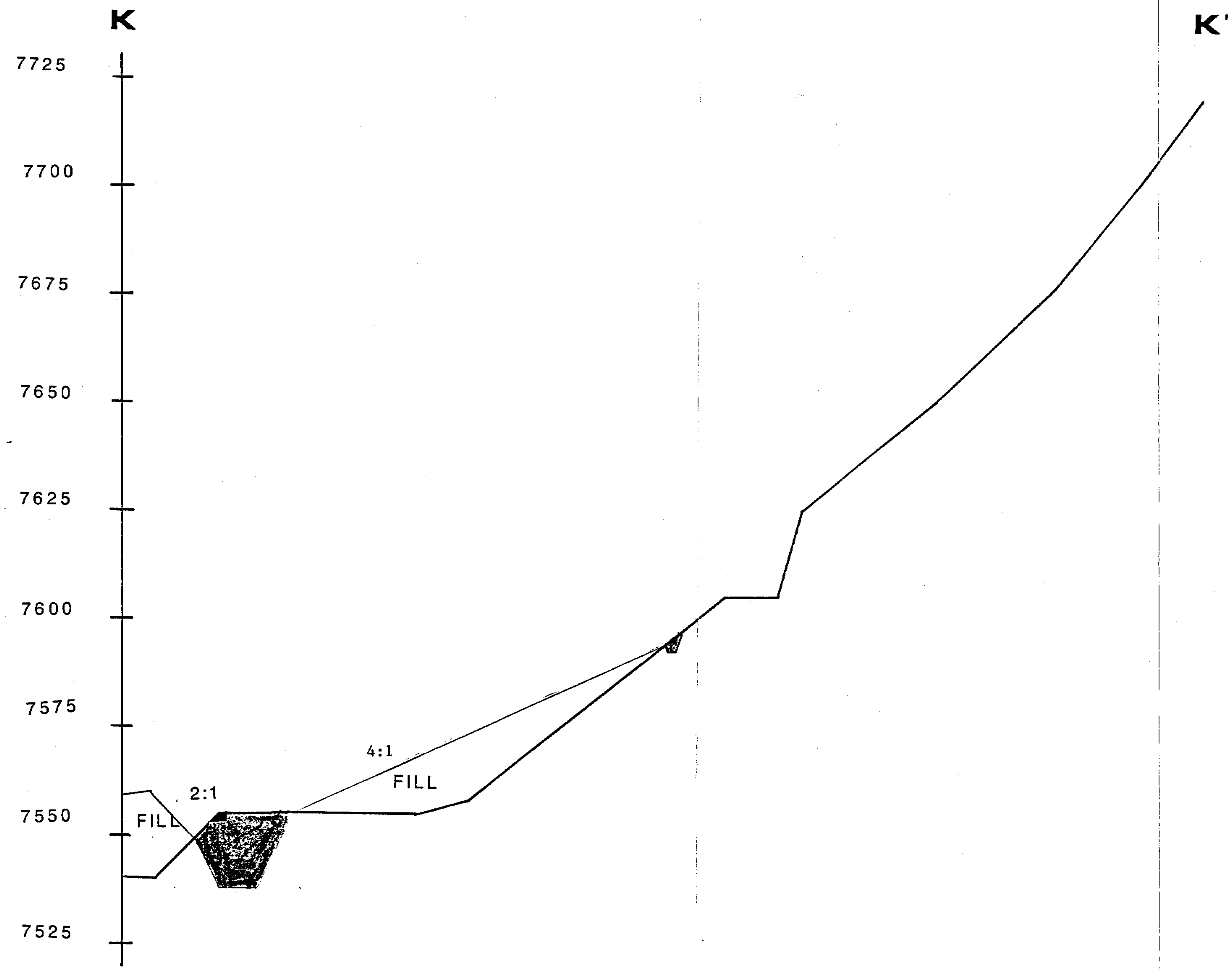

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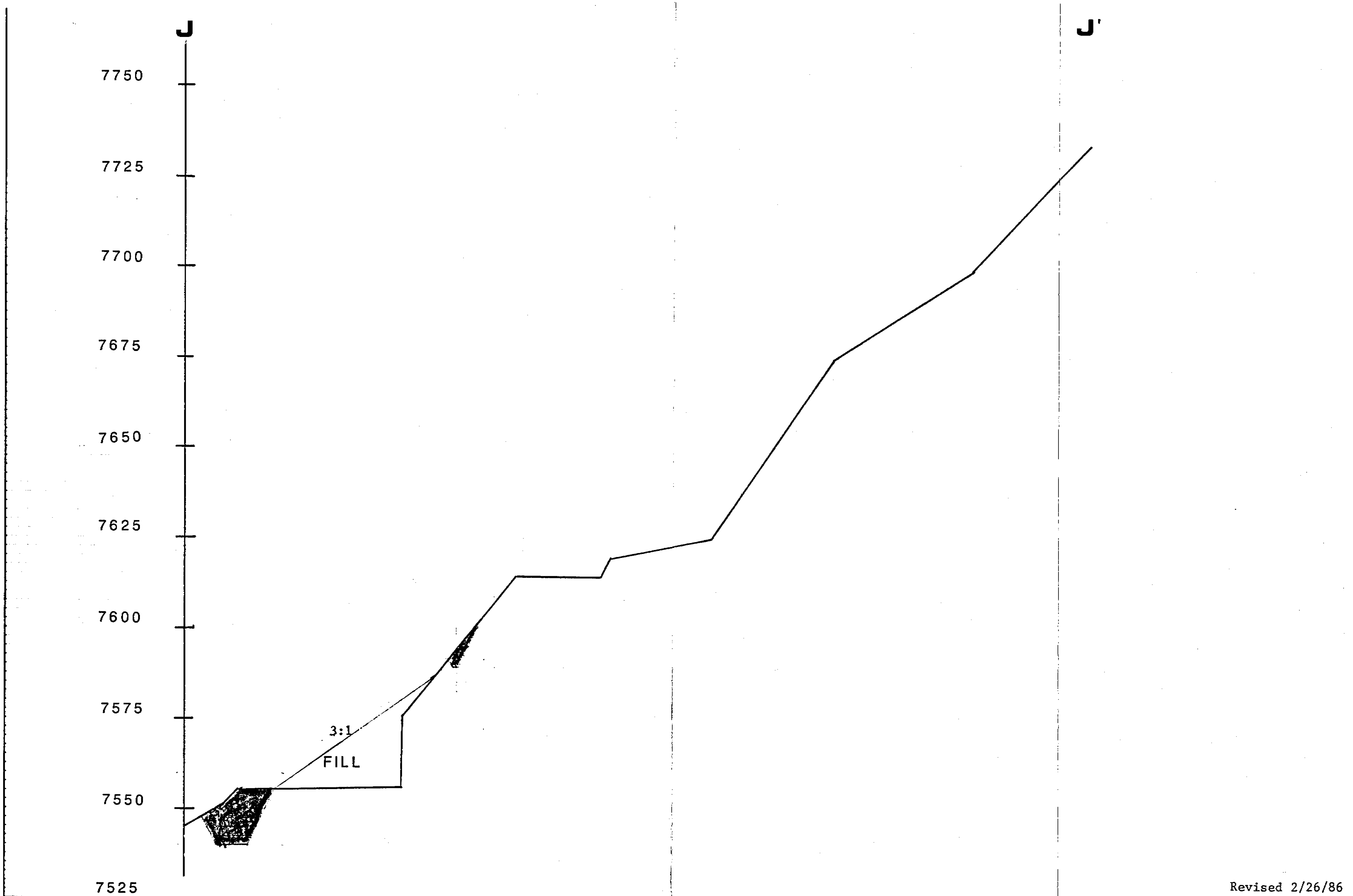

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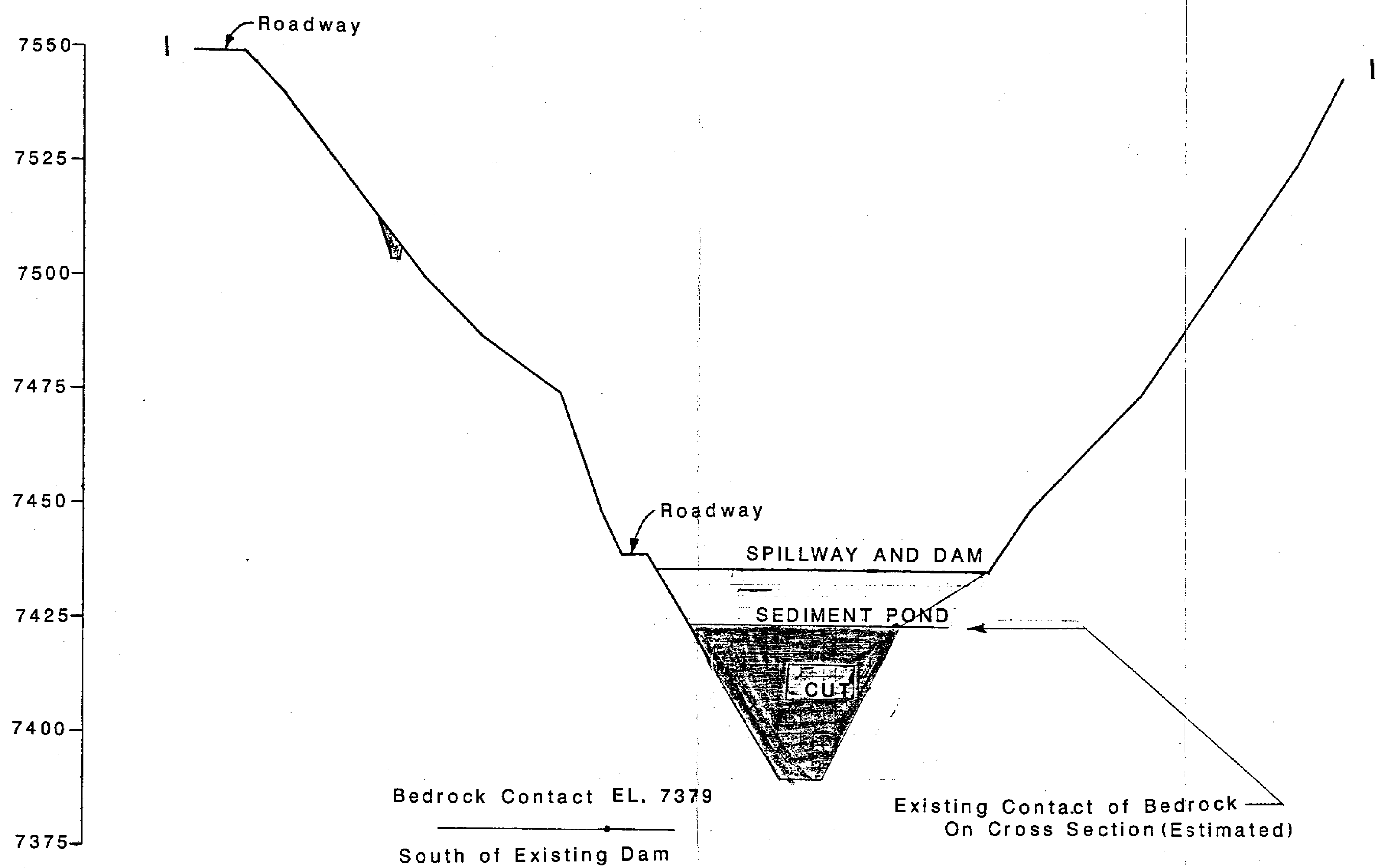

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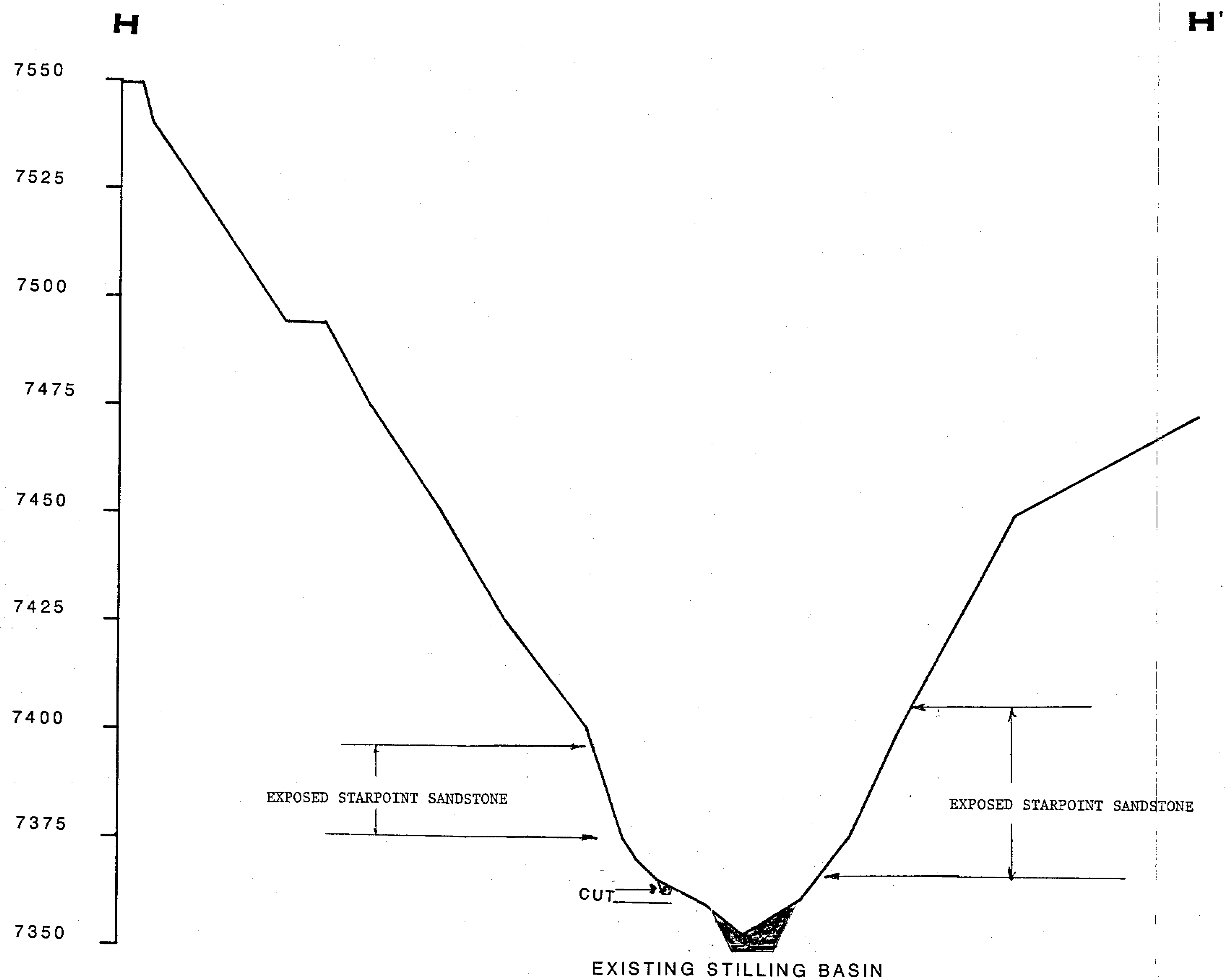

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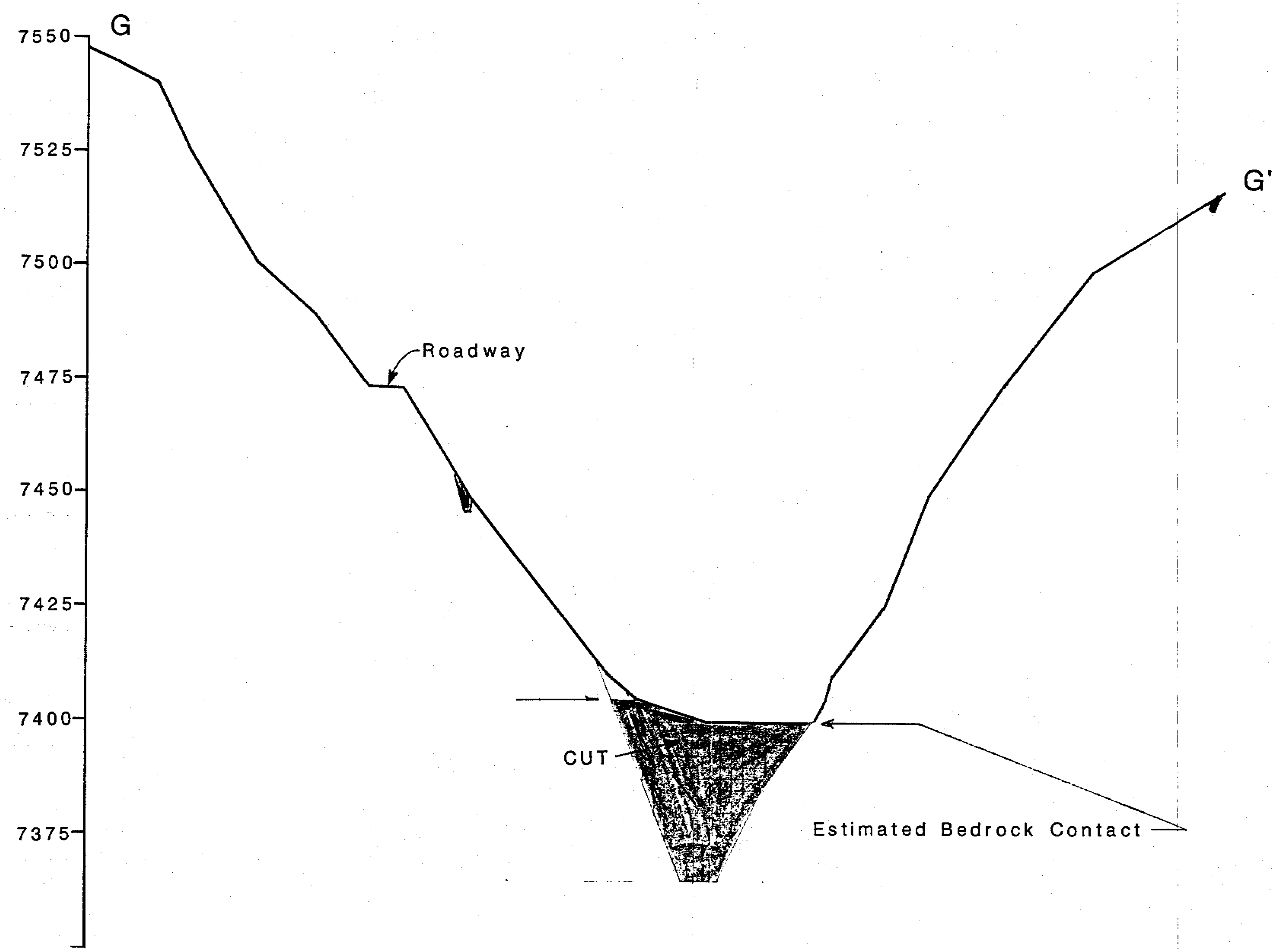

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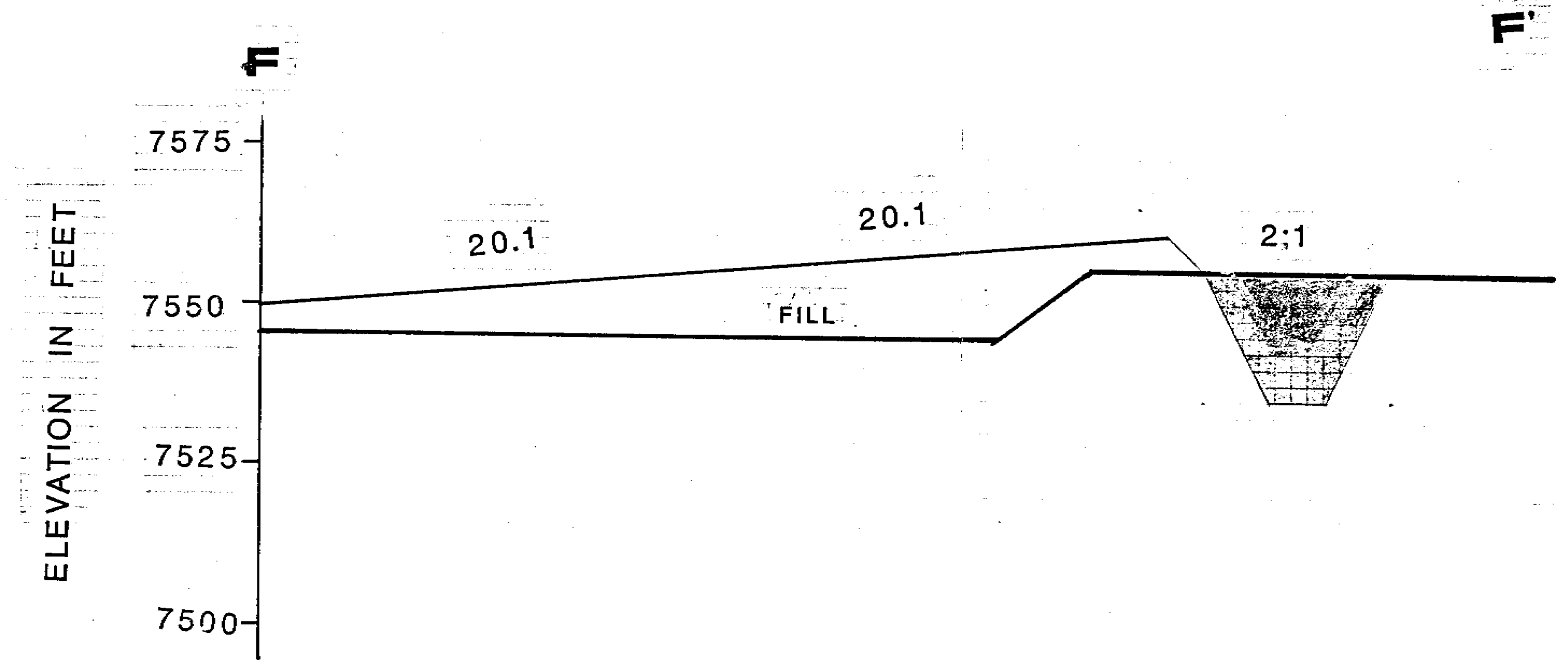

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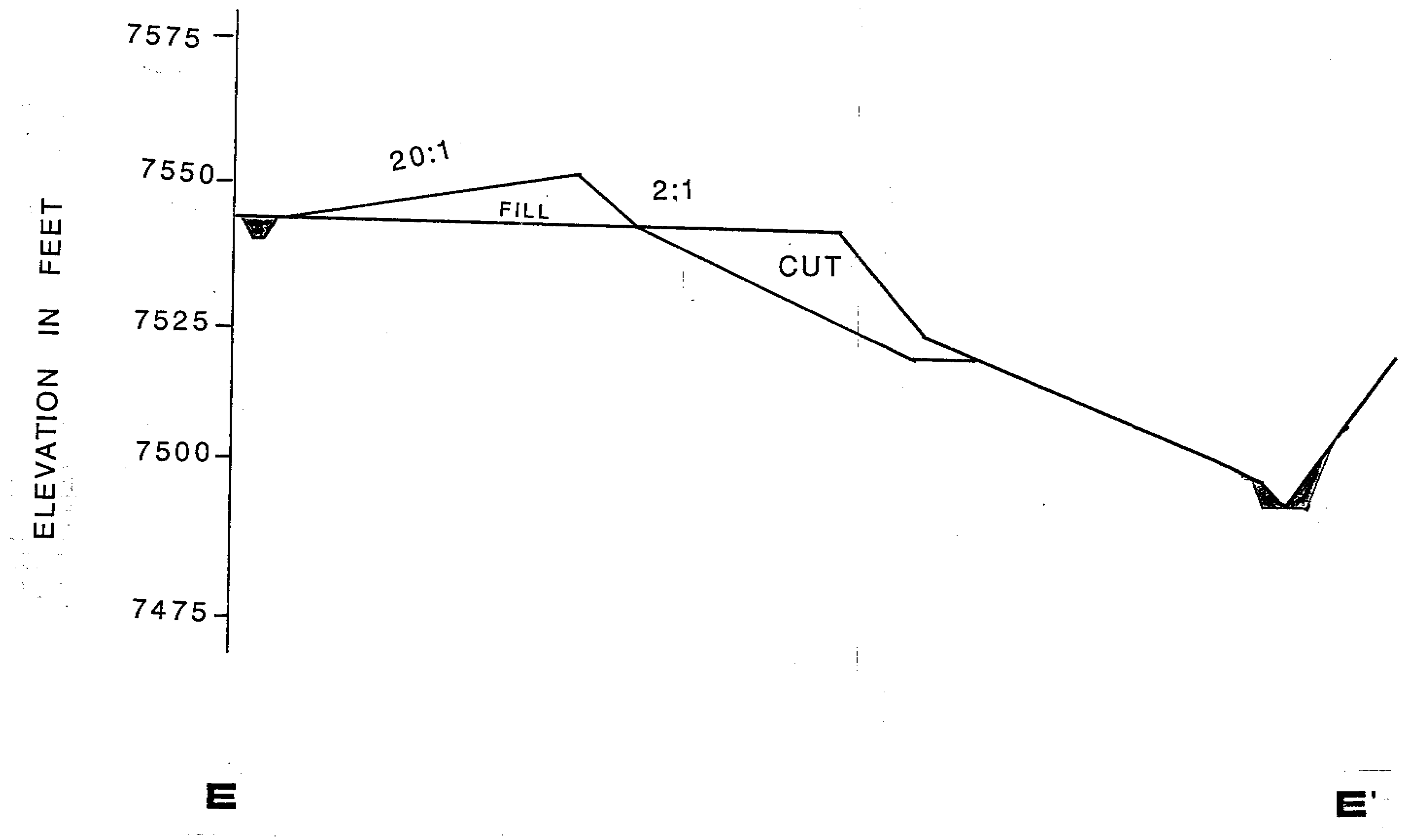

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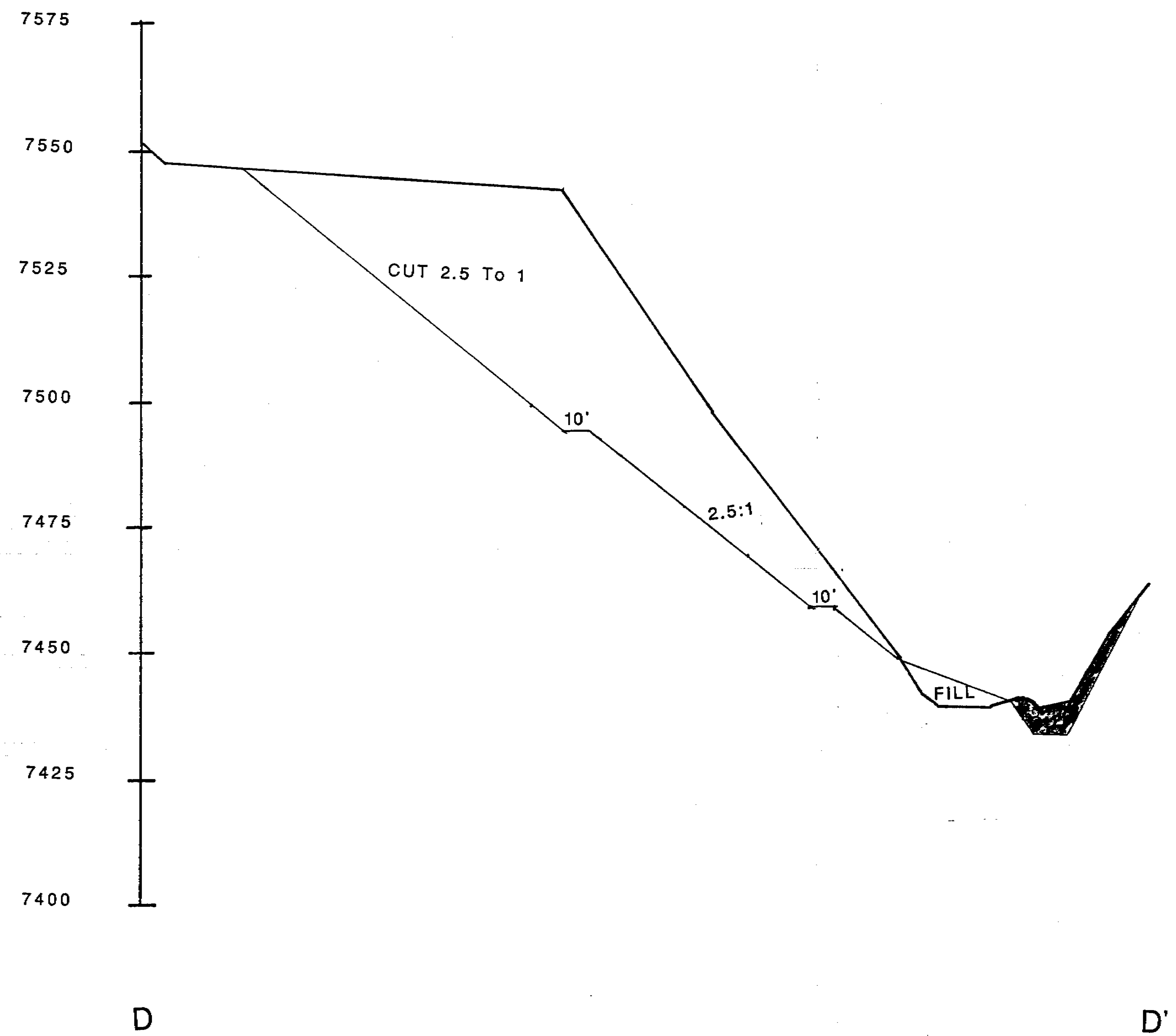

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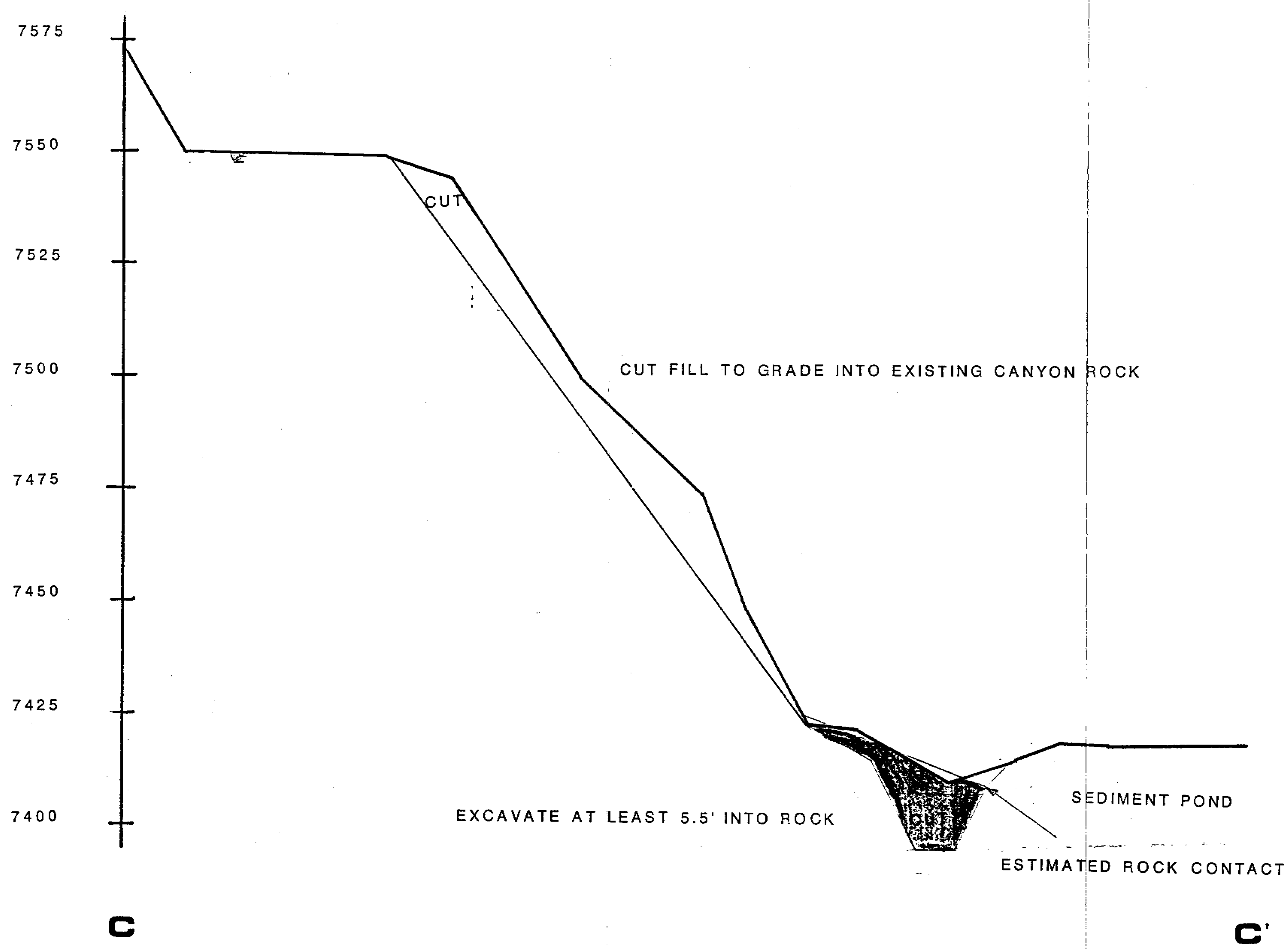

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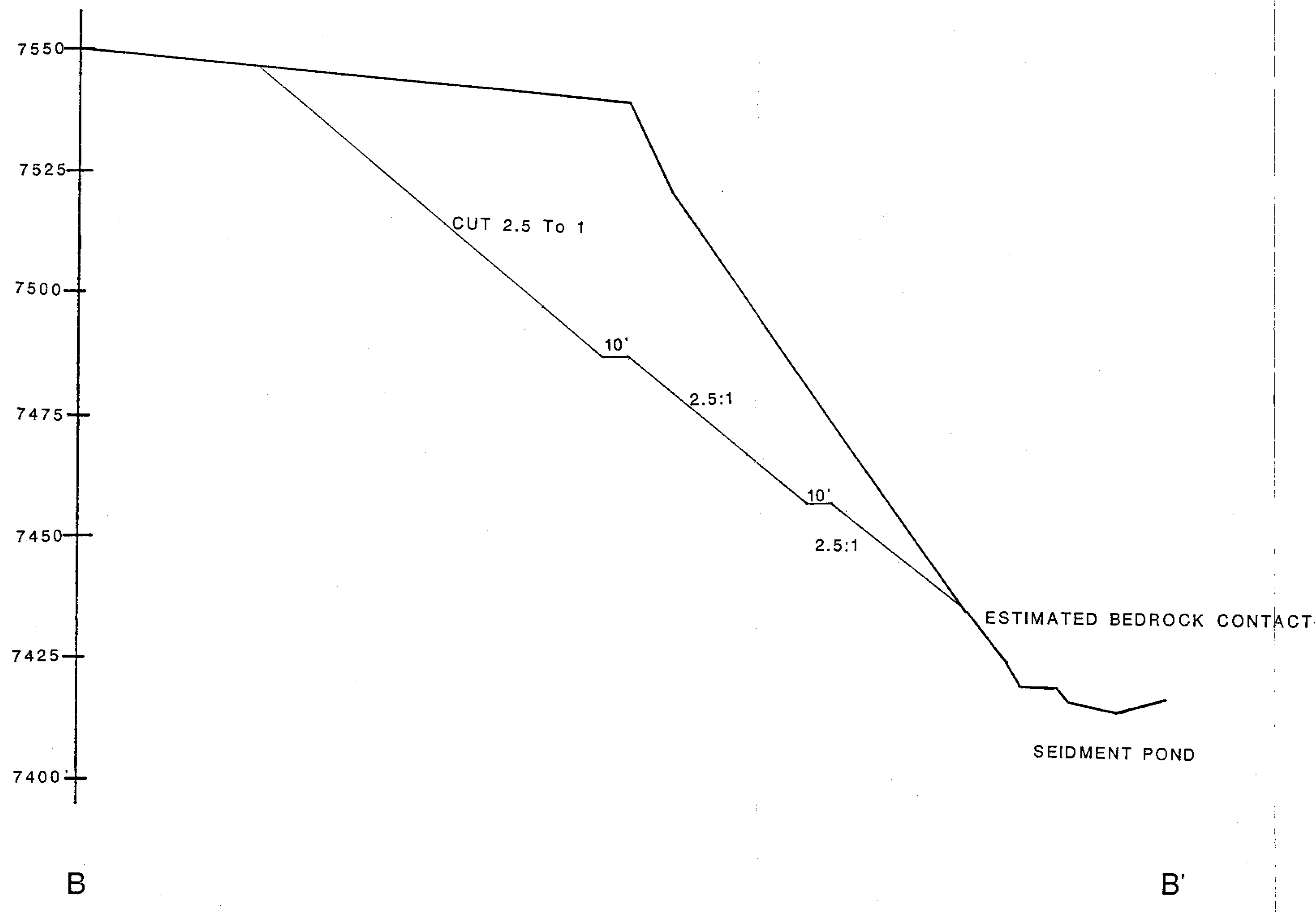

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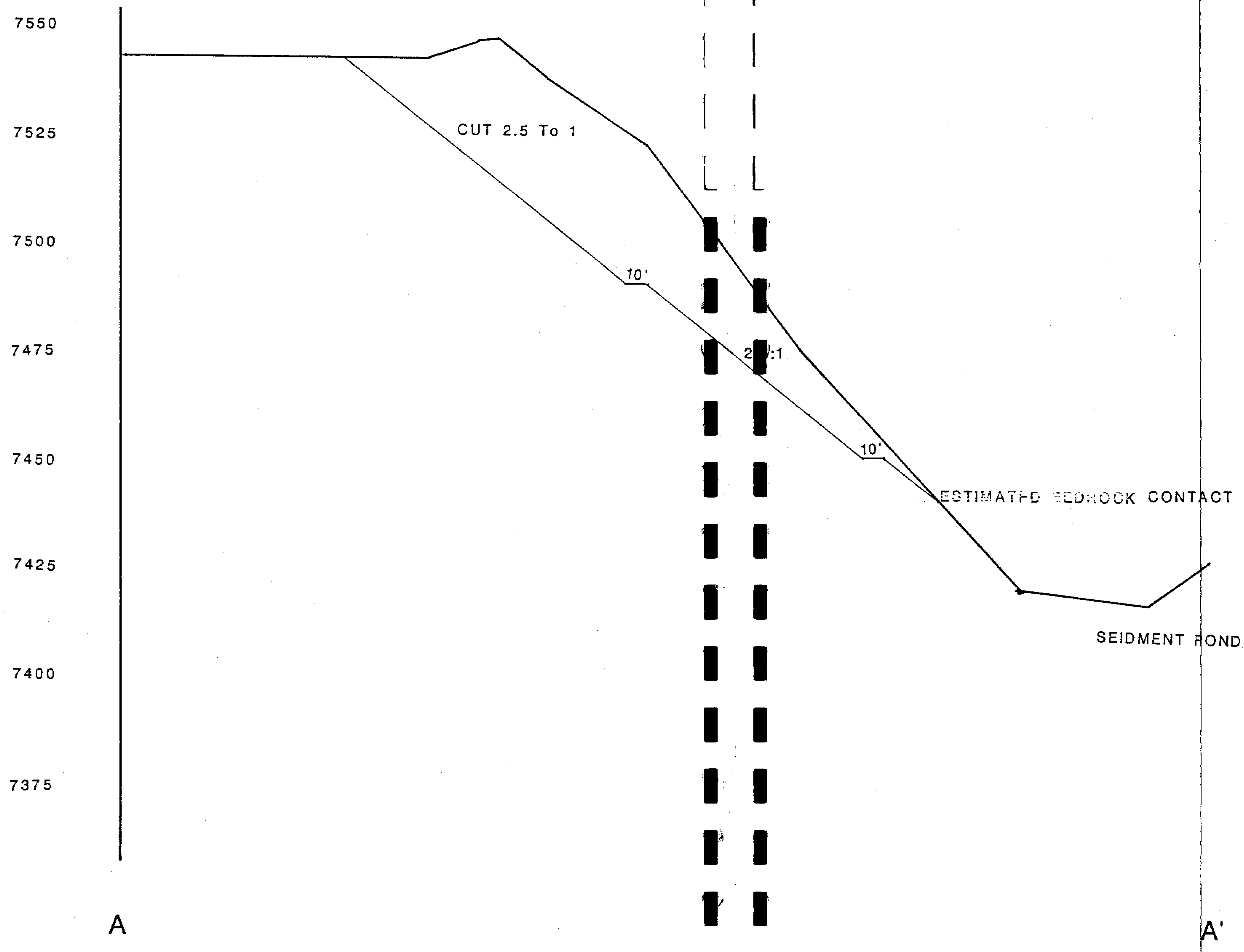

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