SERGENT, HAUSKINS & BECKWITH

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

PHOENIX • ALBUQUERQUE • SANTA FE • SALT LAKE CITY • EL PASO

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Vice President & General Manager

Subsidiary of
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RECEIVED
DEC 23 1985
DIVISION OF OIL
GAS & MINING

December 18, 1985

Mr. Lowell Braxton
Mined Land Reclamation Administrator
Division of Oil, Gas & Mining
355 West North Temple
3 Triad Center, Suite 350
Salt Lake City, UT 84180-1203

Dear Mr. Braxton:

Enclosed are seven copies of Sergent, Hauskins & Beckwith's report on the final reclamation aspects for the East Spring Canyon intermittent stream. This submittal should be considered under the experimental practices provisions of OSM, 30 CFR 785.13. Section 6 of the report discusses the applicability of experimental practices to the East Spring Canyon final reclamation. Please consider this report to be an addendum to Volume 8 of SUFCo's PAP. When it is deemed acceptable, the report can be incorporated into the PAP to replace previous schemes for reclamation. This approach was used based on past difficulties in arriving at an acceptable final reclamation plan.

Sincerely,
SOUTHERN UTAH FUEL COMPANY

Ken Payne
V. P. & General Manager

WKS:cfc

STATE OF UTAH
NATURAL RESOURCES
Oil, Gas & Mining

Norman H. Bangerter, Governor
Dee C. Hansen, Executive Director
Dianne R. Nielson, Ph.D., Division Director

355 W. North Temple • 3 Triad Center • Suite 350 • Salt Lake City, UT 84180-1203 • 801-538-5340

December 23, 1985

Mr. Richard Holbrook
Office of Surface Mining
Brooks Towers
1020 15th Street
Denver, Colorado 80202

Dear Mr. Holbrook:

RE: Stream Channel Reclamation, Southern Utah Fuel Company, Convulsion Canyon Mine, ACT/041/002, Folder No. 2, 3, Sevier County, Utah

Enclosed are two copies of Southern Utah Fuel Company's (SUFCO's) plans to reclaim East Spring Canyon under an experimental practice. Two copies have also been sent to the Fish Lake National Forest with a request for them to provide any comments to you as soon as possible.

We hope to be able to provide any comments back to SUFCO by January 31, 1986. Resolution of this issue will allow a Final Decision Document for the Convulsion Canyon Mine to be forwarded to Washington for approval.

Please contact me or Tom Suchoski with questions or comments.

Sincerely,

Susan C. Linner

Susan C. Linner
Reclamation Biologist/
Permit Supervisor

jvb
cc: L. Braxton
T. Suchoski
0028R-42

STATE OF UTAH
NATURAL RESOURCES
Oil, Gas & Mining

Norman H. Bangerter, Governor
Dee C. Hansen, Executive Director
Dianne R. Nielson, Ph.D., Division Director

355 W. North Temple • 3 Triad Center • Suite 350 • Salt Lake City, UT 84180-1203 • 801-538-5340

December 23, 1985

Mr. J. Kent Taylor
Forest Supervisor
Fishlake National Forest
170 N. Main Street
P. O. Box 628
Richfield, Utah 84701

Dear Mr. Taylor:

Re: Stream Channel Reclamation, Southern Utah Fuel Company, Convulsion Canyon Mine, ACT/041/002, Folder No. 2 and 3, Sevier County, Utah

Enclosed are two copies of Southern Utah Fuel Company's (SUFCO's) plans to reclaim East Spring Canyon under an experimental practice. These plans were conceptually discussed in a meeting held October 8, 1985, between SUFCO, DOGM, Office of Surface Mining and representatives of your office.

We request that you provide comments to the Office of Surface Mining as soon as possible so that the company can be notified of any deficiencies by January 31, 1986. Please feel free to contact me or Tom Suchoski if you have questions or comments.

Sincerely,

Susan C. Linner

Susan C. Linner
Reclamation Biologist/
Permit Supervisor

jvb
cc: L. Braxton
T. Suchoski
0028R-41

SERGENT, HAUSKINS & BECKWITH CONSULTING GEOTECHNICAL ENGINEERS

APPLIED SOIL MECHANICS • ENGINEERING GEOLOGY • MATERIALS ENGINEERING • HYDROLOGY

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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)

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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.

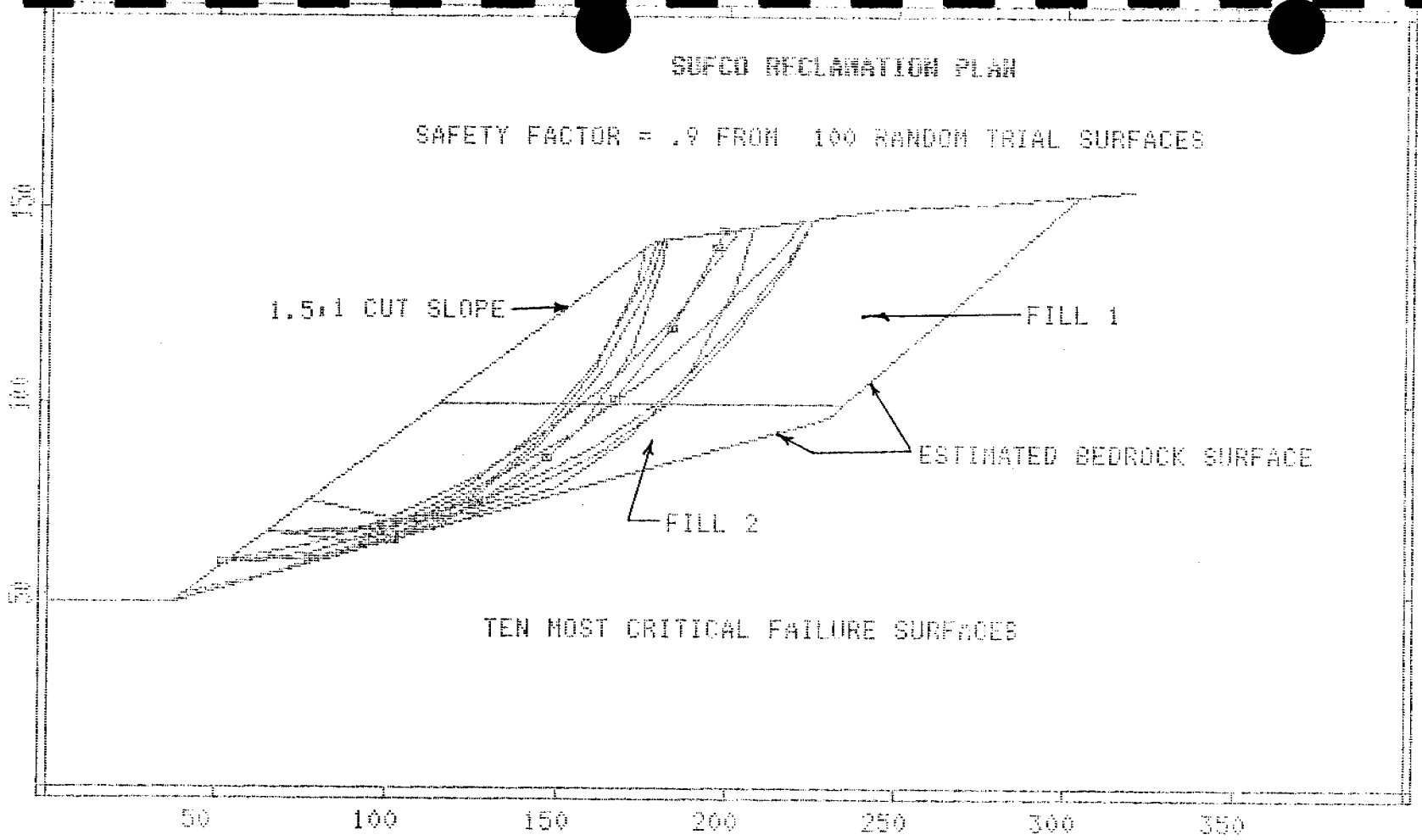
Strength parameters for the fill materials were based upon the results of laboratory testing and engineering judgement. Due to very moist soil conditions and low shear strength materials encountered at depth in Boring 6, the fill was divided into two soil layers. Two

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

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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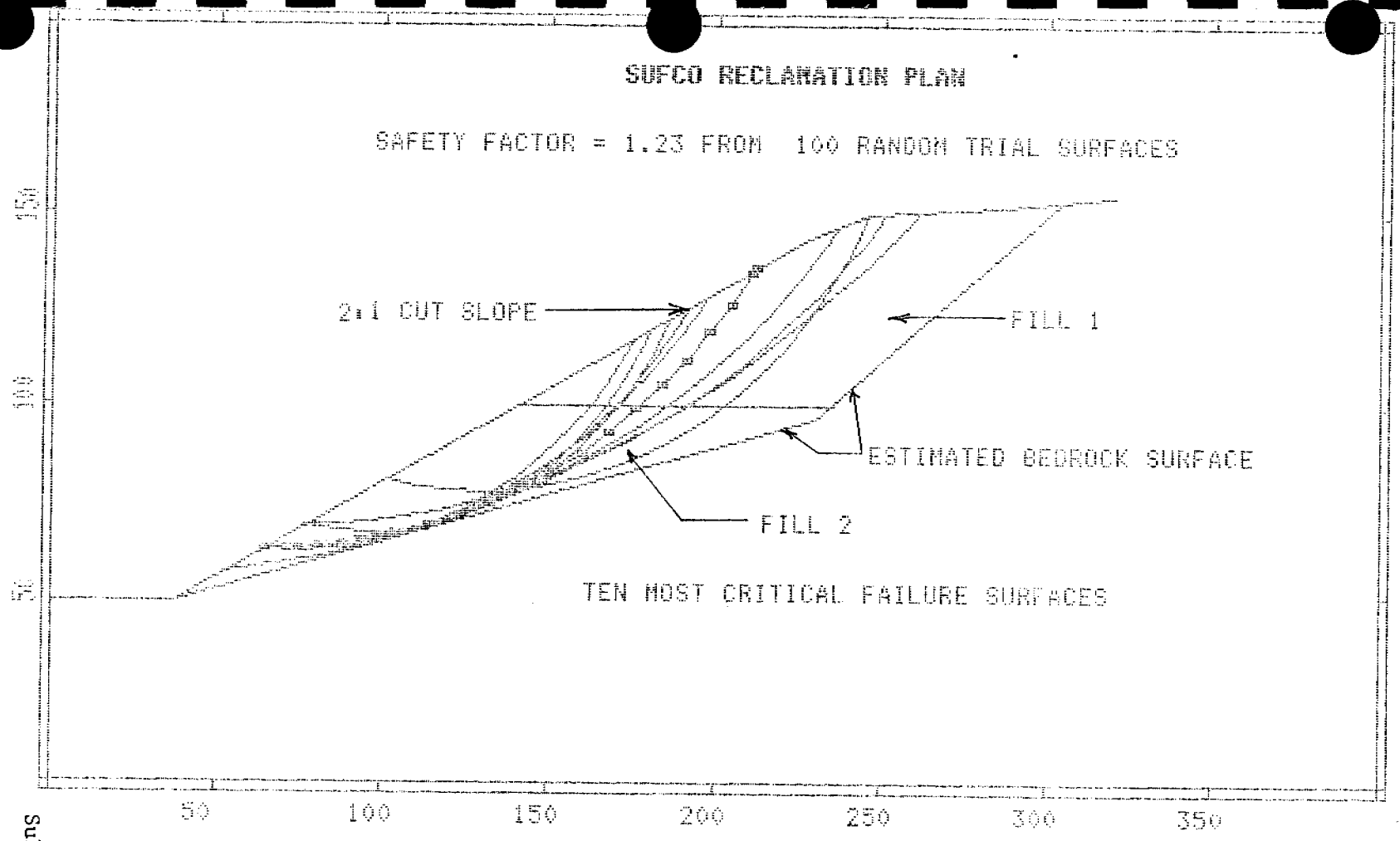

Fill 1 γ = 120 pcf
c = 500 psf
ϕ = 30°

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
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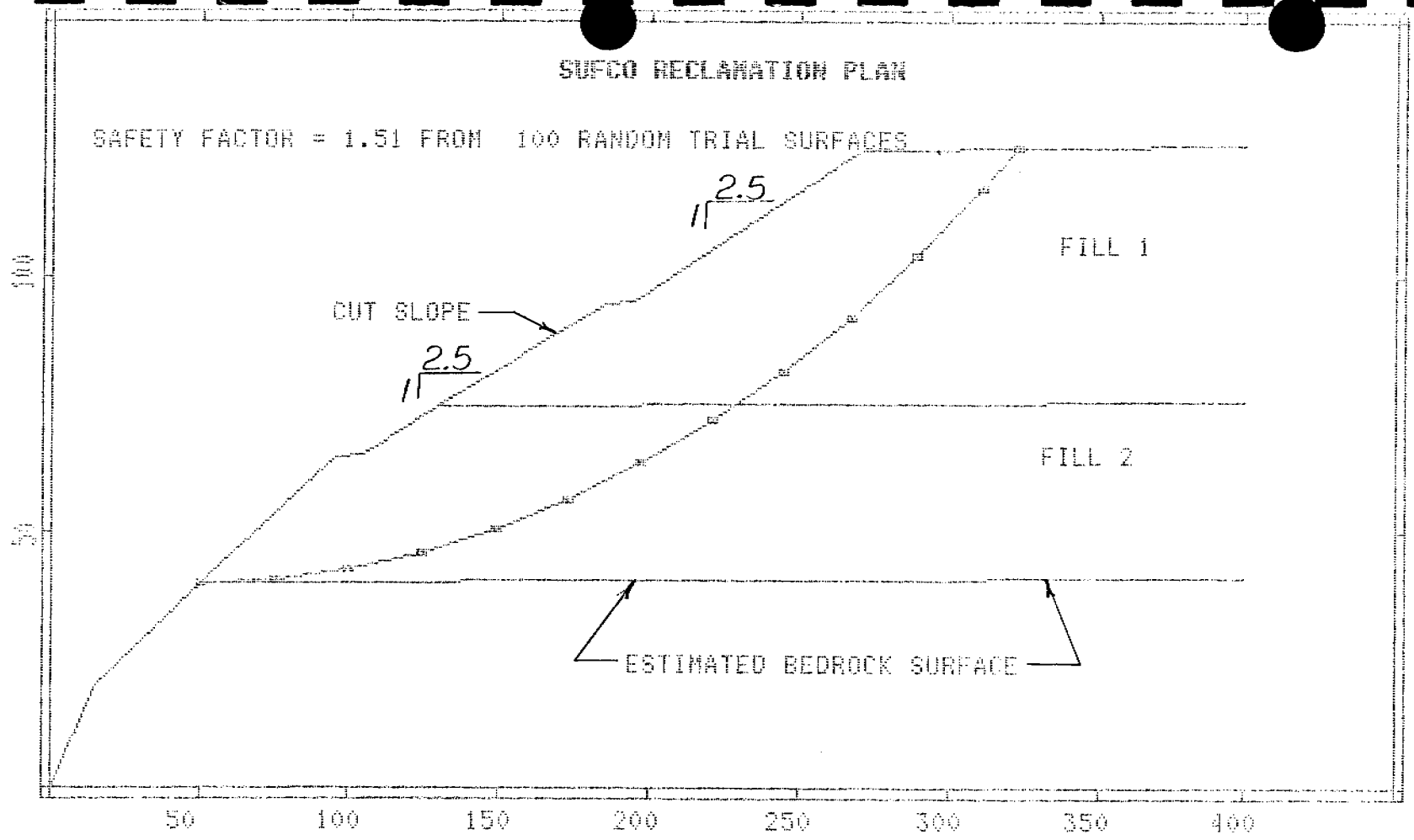
fill was modeled as a layered system as was done in Section 5.3.1. Strength parameters utilized in this analysis were the same as those utilized previously. An attempt to verify these strength paramenters was made by evaluating the existing slope. The factor of safety resulting from this analysis was 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

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

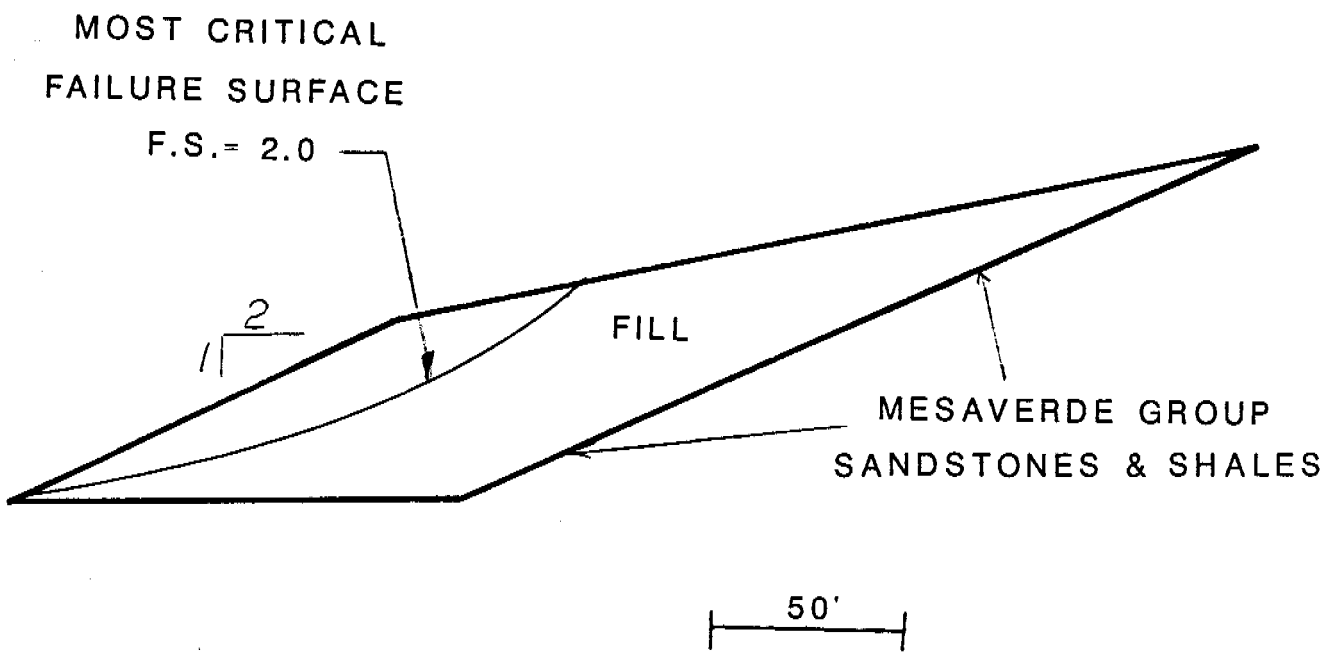
5.3.4 Hydraulic Design of Drainage Channels

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

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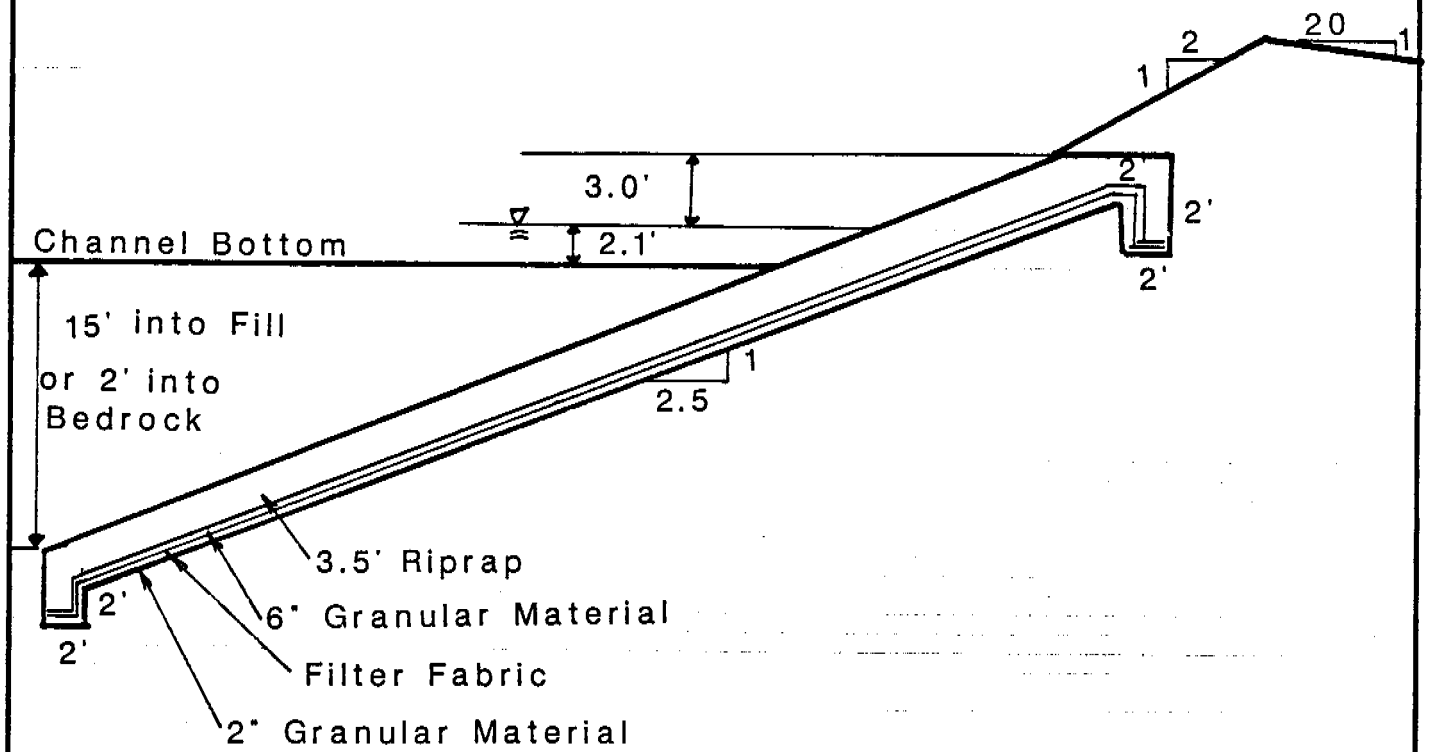
fill, and since it is not feasible to excavate through the fill to re-establish the original regime, another alternative drainage system was designed. The alternative design involves diverting runoff from Mud Spring Hollow and East Spring Hollow into a channel excavated in bedrock along the east side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

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 3.295	5.5	18.25 F/s
3	.070	20.07	3.03 3.028	5.5	20.102 F/s
4	.0063	8.69	6.10 6.087	8.5	8.7 F/s
5	.70	43.03	1.53 ? 2.184	4.7	[illegible] F/s
6	.53	39.41	1.66 2.361	4.7	44.97 F/s
7	.26	31.00	2.06 2.05	4.0	31.17 F/s
8	.25	30.60	2.09 2.07	4.0	30.7 F/s

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.

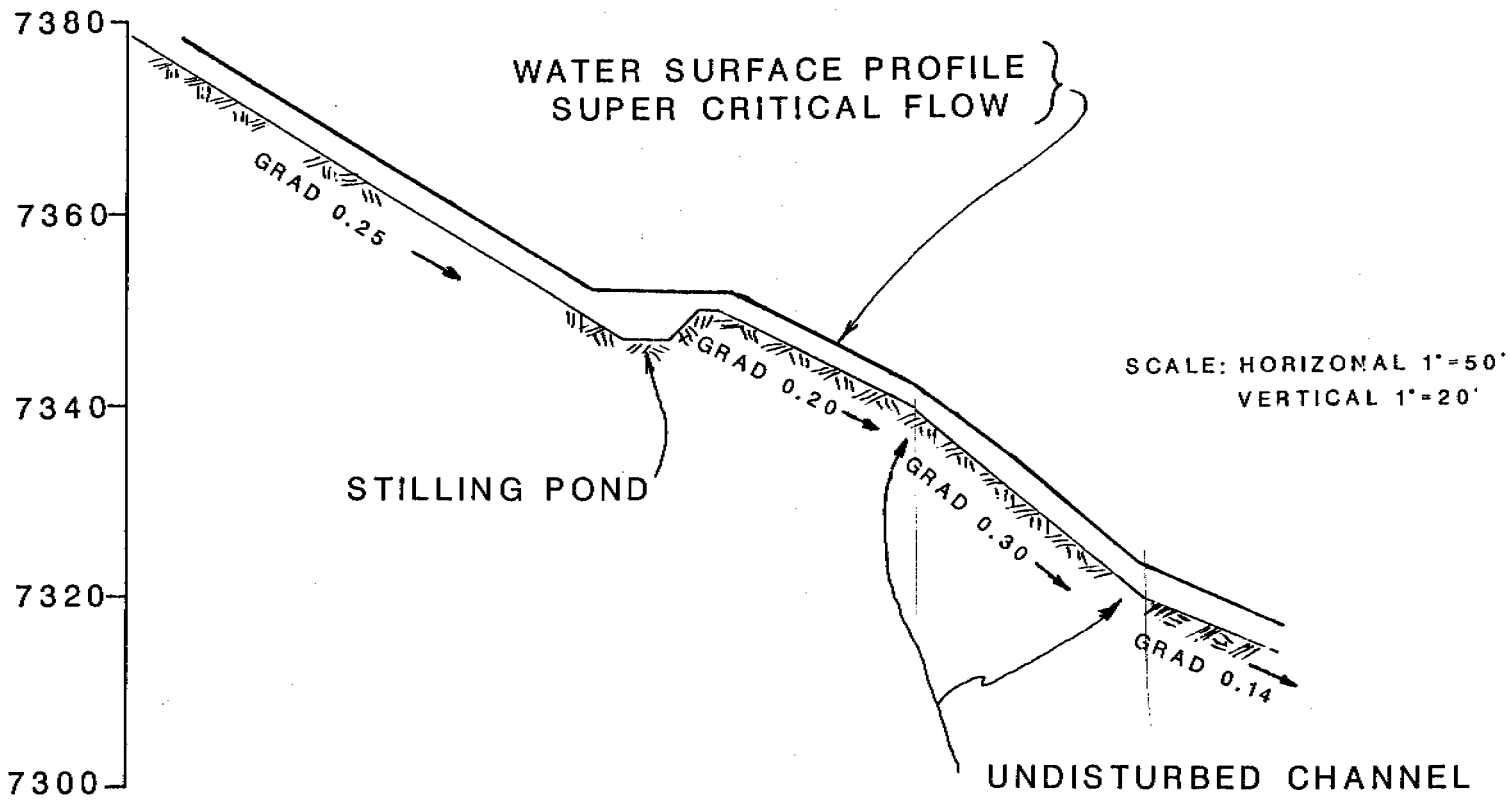

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FIGURE 6: PROFILE OF REACH NO.8, STILLING POND & TRANSITION TO UNDISTURBED STREAM

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.

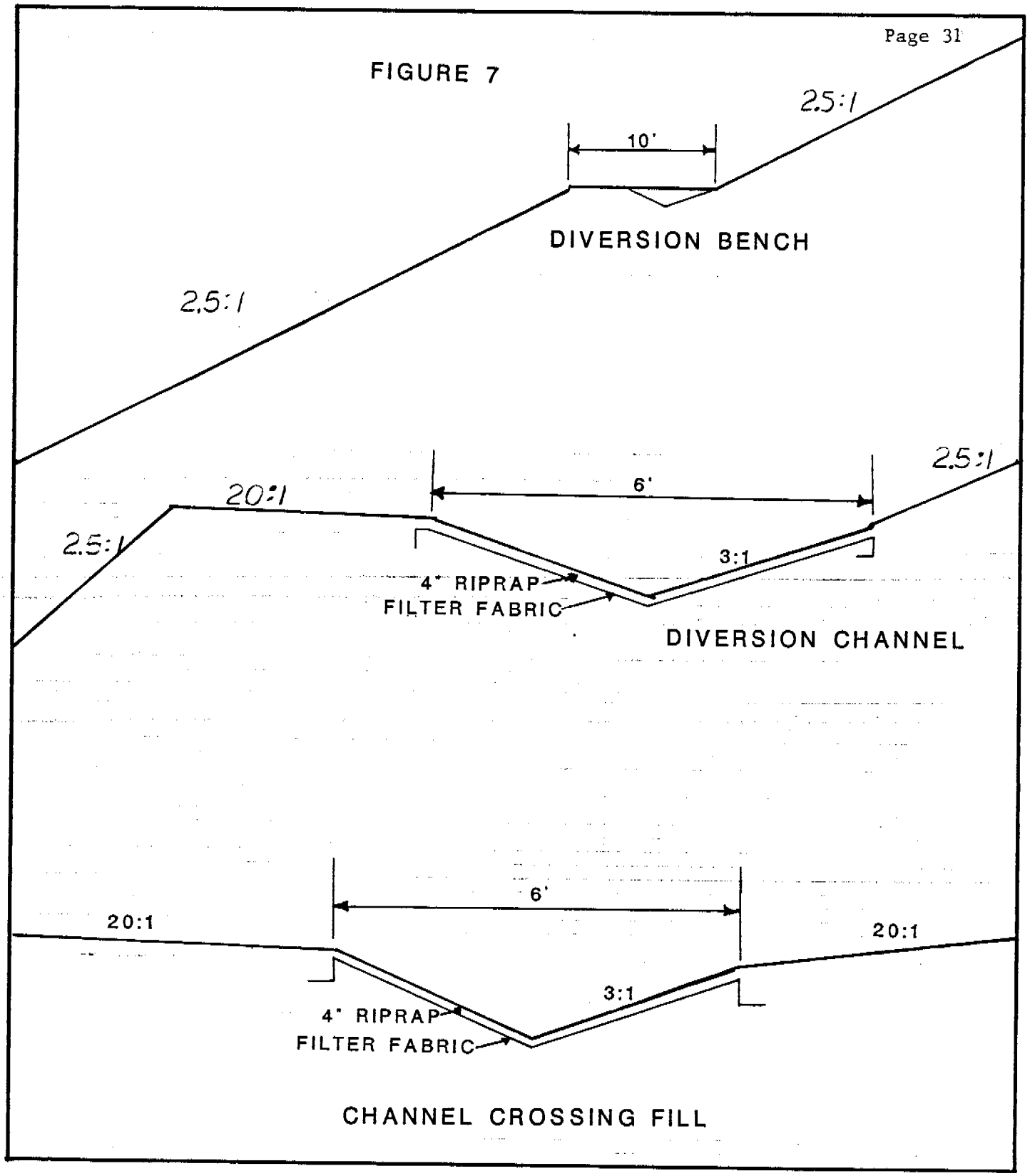
5.4 Site Grading

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

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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 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
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.

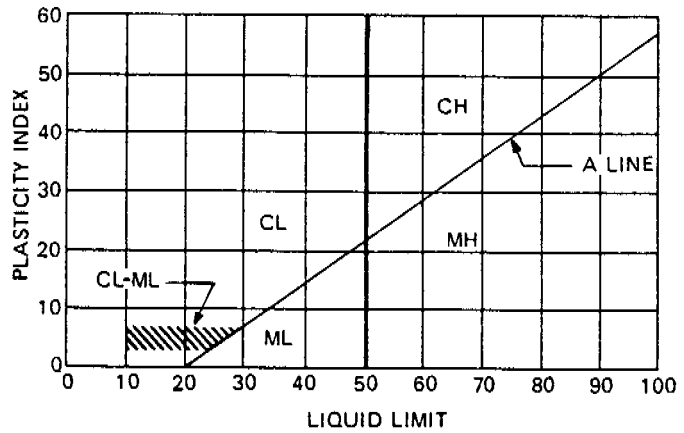
UNIFIED SOIL CLASSIFICATION SYSTEM

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 Ft.	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								GM	slightly moist	Road Base Gravel with some coal (FILL)
				S	39					
								CL	slightly moist very firm	SILTY CLAY, considerable gravel, highly stratified, low plastic, yellow and light brown (FILL)
5				S	50/2"					
								GM	slightly moist hard	SILTY GRAVEL, some sand, predominately coarse grained, subangular, strongly lime cemented, nonplastic, gray note: possible boulder at 6½' to 9' (FILL)
10				S	50/4½"					
								SM		
15				S	15		8		slight moist hard	SILTY SAND, considerable clay, trace of gravel, predominately fine to medium grained, subrounded, weakly lime cemented, nonplastic, light brown (FILL)
								CL		
20				S	15				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'
25				S	25					
30				S	20					
35				S	22		9		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'
								CL		
40				S	50/5½"					
45				S	50/5½"					
50										

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	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				S	50/4"			CL		note: color change to black at 45' to 52'
55				S	50/2⅓"			SM	slightly moist hard	SAND, considerable sandstone gravel, some silt, subrounded, weakly increasing to moderately lime cemented with depth, nonplastic, light brown
60				S	50/3"					note: apparent bedrock contact at 57'
										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				S	54				slightly moist	COAL (FILL)
5				S	13			CL	moist moderately firm to hard	GRAVELLY CLAY, some silt, weakly lime cemented, low plasticity, yellow brown (FILL)
10				S	56					
15				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				S	13				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)
				U	25		10			
25				S	14			CL		
30				S	14					
35				S	19				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'
40				S	25		4	GP-GM		
45				S	20				slightly moist firm	COAL (FILL) note: traces of wood and pine needles at 47'
50										

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			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			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	REMARKS	VISUAL CLASSIFICATION
0				S	90					COAL (FILL)
5				S	20			SC	slightly moist firm	CLAYEY SAND, considerable silt and sandstone gravel, low to medium plasticity, yellow brown (FILL)
10				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				S	12			CL		
20				S	12		13			
25				S	50/4"			SP	slightly moist hard	SAND, some gravel, predominately medium to fine grained, subrounded to rounded, non-plastic, light rust orange note: possible channel deposit
30				S	50/3"					
35										MESAVERDE FORMATION, sandstone, fine to medium grained, moderately weathered, moderately hard, weakly increasing to strongly lime cemented with depth, dark yellow
40										auger refused at 33'8"
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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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				S	50/2"			GM-GC	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'
5				S	29		6			
10				S	10				slightly moist moderately firm to firm	COAL, thin sand and clay lenses (FILL) note: traces of wood
15				S	18					
20				S	21		9		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'
								SM		
25				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)
				S	22					
5				S	8					
				U	9		16			
10				S	15					
15				S	29					
								SM		
20				S	19		19			
25				S	17					
								SM	moist to very moist hard	SILTY SAND, considerable fine gravel, rounded, nonplastic, gray to light rust
30				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	REMARKS	VISUAL CLASSIFICATION
0									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
				S	56		6			
5				S	17					
10				S	23		15	CL		
15				S	9					
20				S	17					
				U	20				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'
25				S	14		13			
30				S	9					
35				S	22		11	ML		
40				S	14					
45				S	10		13			

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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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				S	25					note: medium plasticity, sandy clay lense from 69' to 71'
55				S	15					
60				S	25		27			
								ML		
65				S	25					
70				U	82		27			
75				S	34					
80				S	45		18			
									slightly moist firm to hard	GRAVELLY SAND, considerable silt, predominately fine to medium grained, nonplastic, dark yellow
85				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)

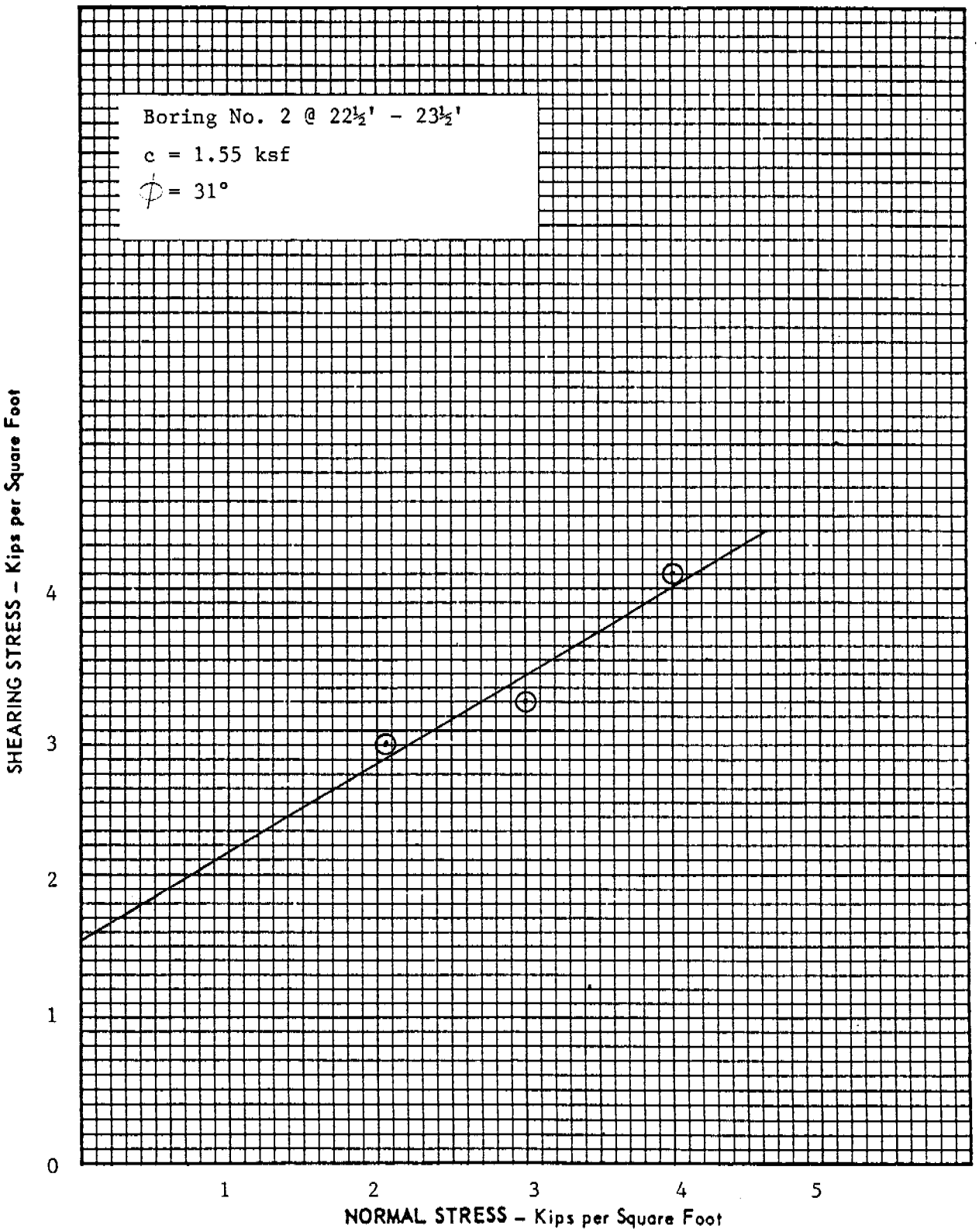
Initial Moisture Content	10.7	%
Dry Density (PCF)	122.5	
Submerged		
Final Moisture Content	-	%
Maximum Vertical Deformation @ T Max.	(+) 0.023	Inches
Shearing Stress, T Max.	3.20	KSF

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

o – INSITU
● – SUBMERGED

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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. 3-2022-2

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)

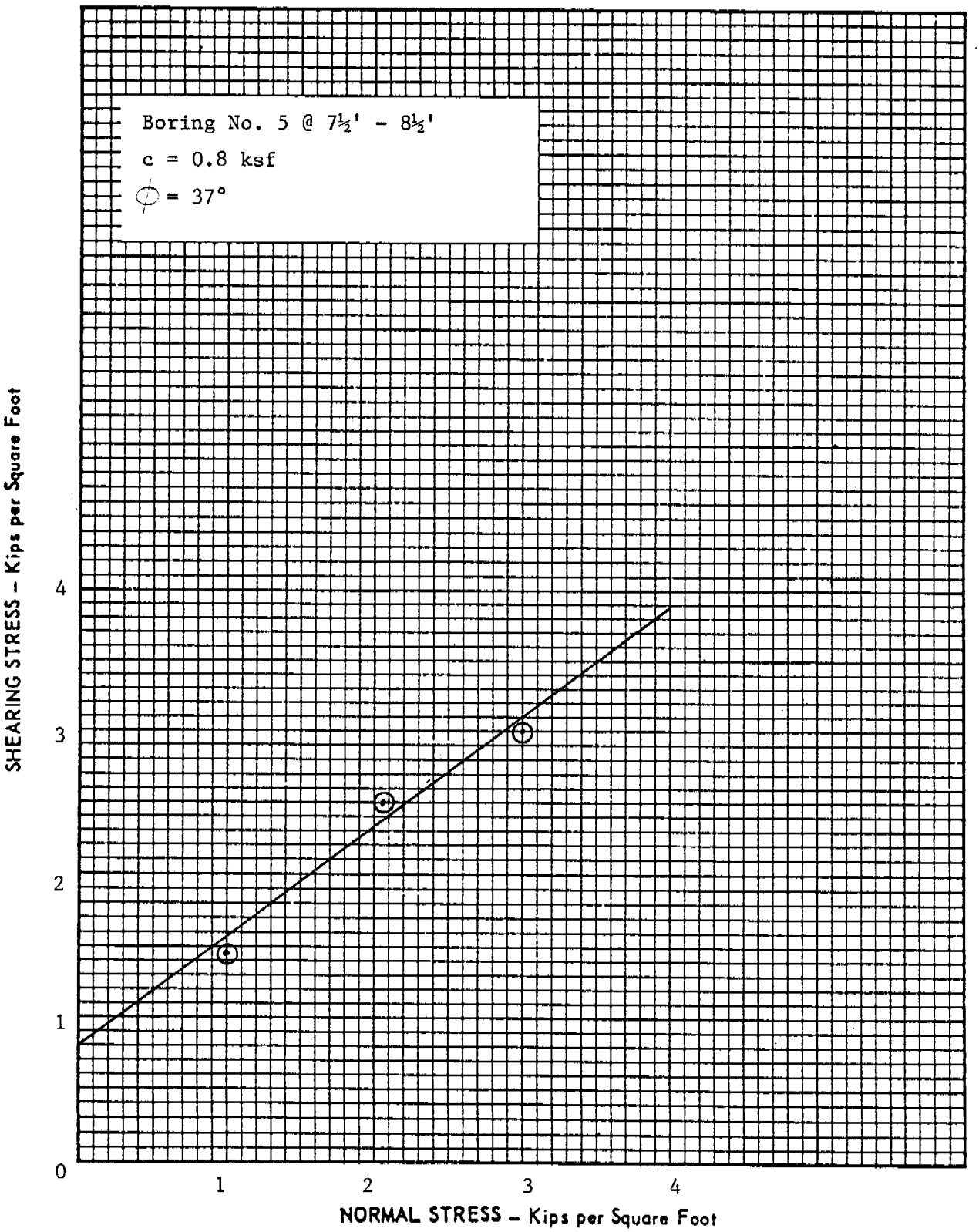
Initial Moisture Content	15.4 %
Dry Density (PCF)	91.7
Submerged	
Final Moisture Content	- %
Maximum Vertical Deformation @ T Max.	(+) 0.019 Inches
Shearing Stress, T Max.	2.50 KSF

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

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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)

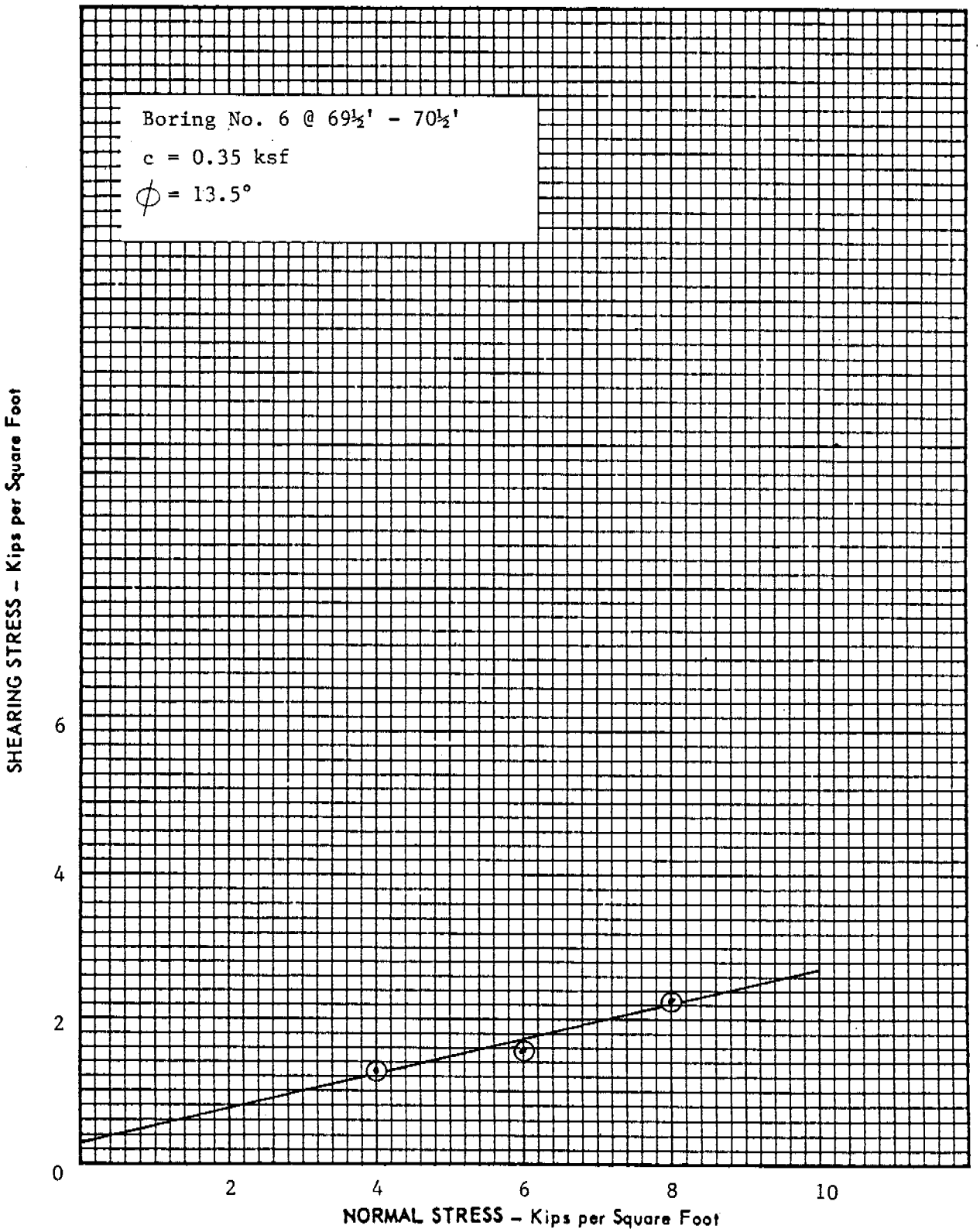
Initial Moisture Content	26.6 %
Dry Density (PCF)	91.6
Submerged	
Final Moisture Content	- %
Maximum Vertical Deformation @ T Max.	(-) 0.055 Inches
Shearing Stress, T Max.	1.58 KSF

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

○ – INSITU
● – SUBMERGED

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

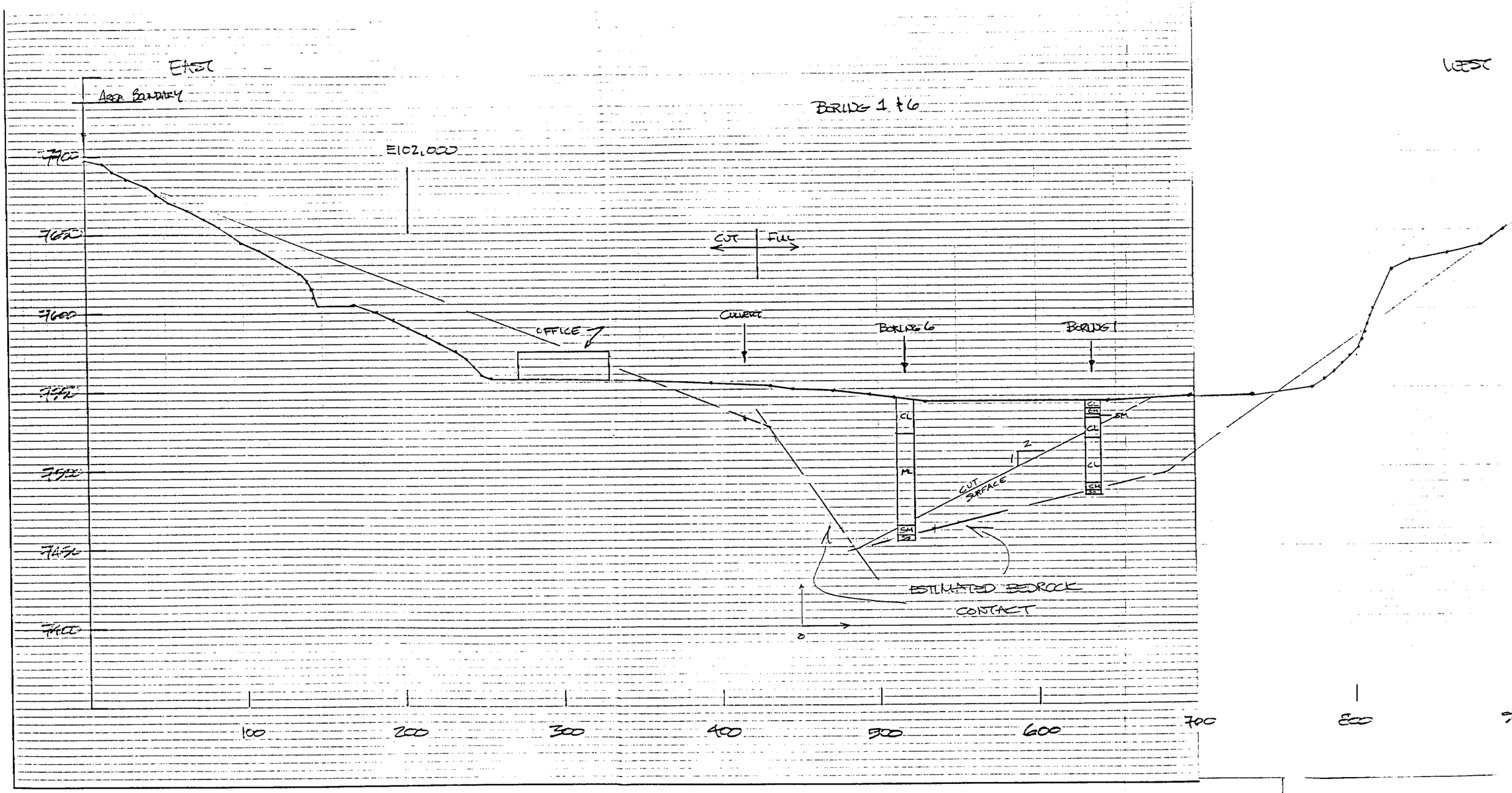
REPORT OF LABORATORY TESTS

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 ___

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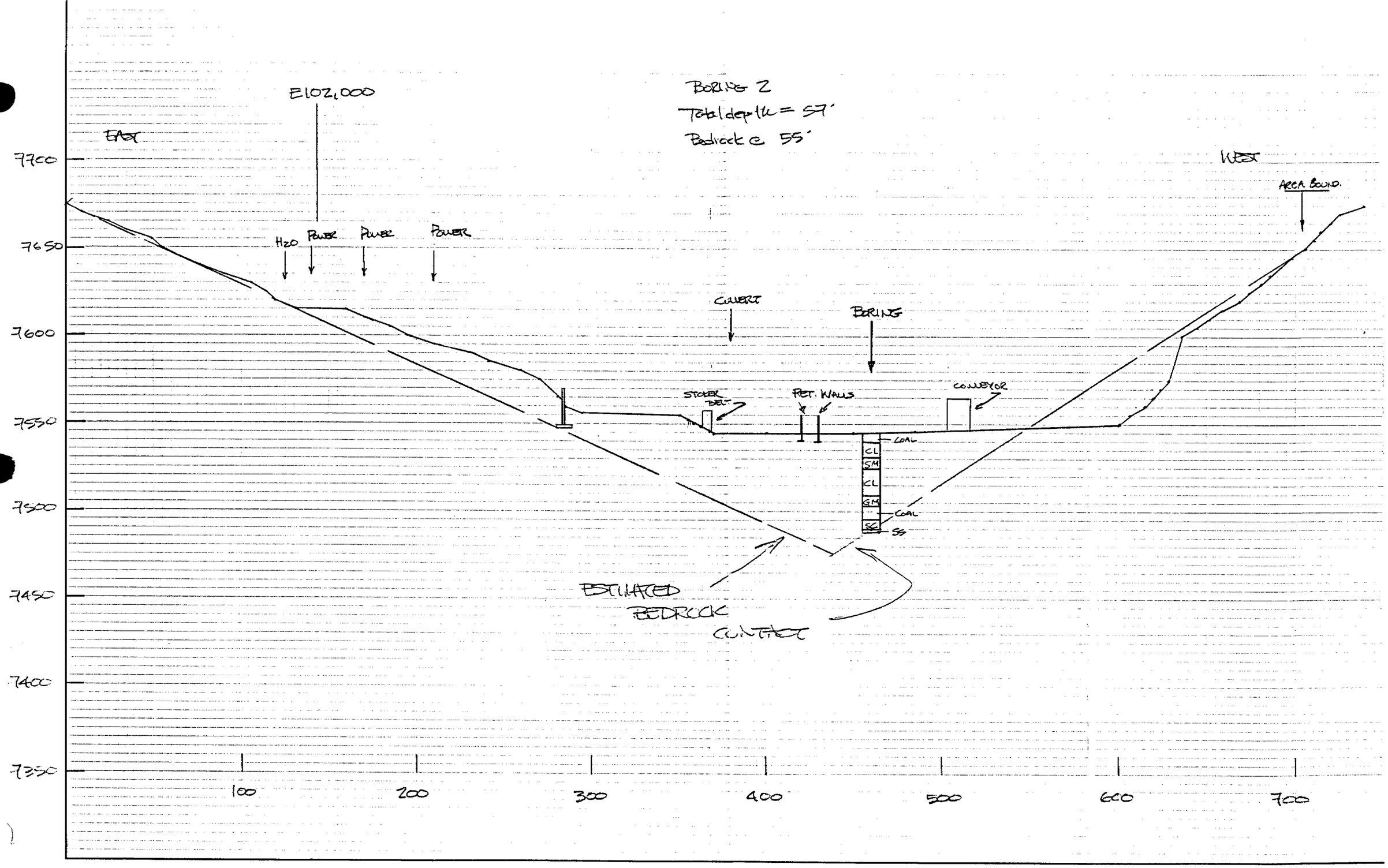

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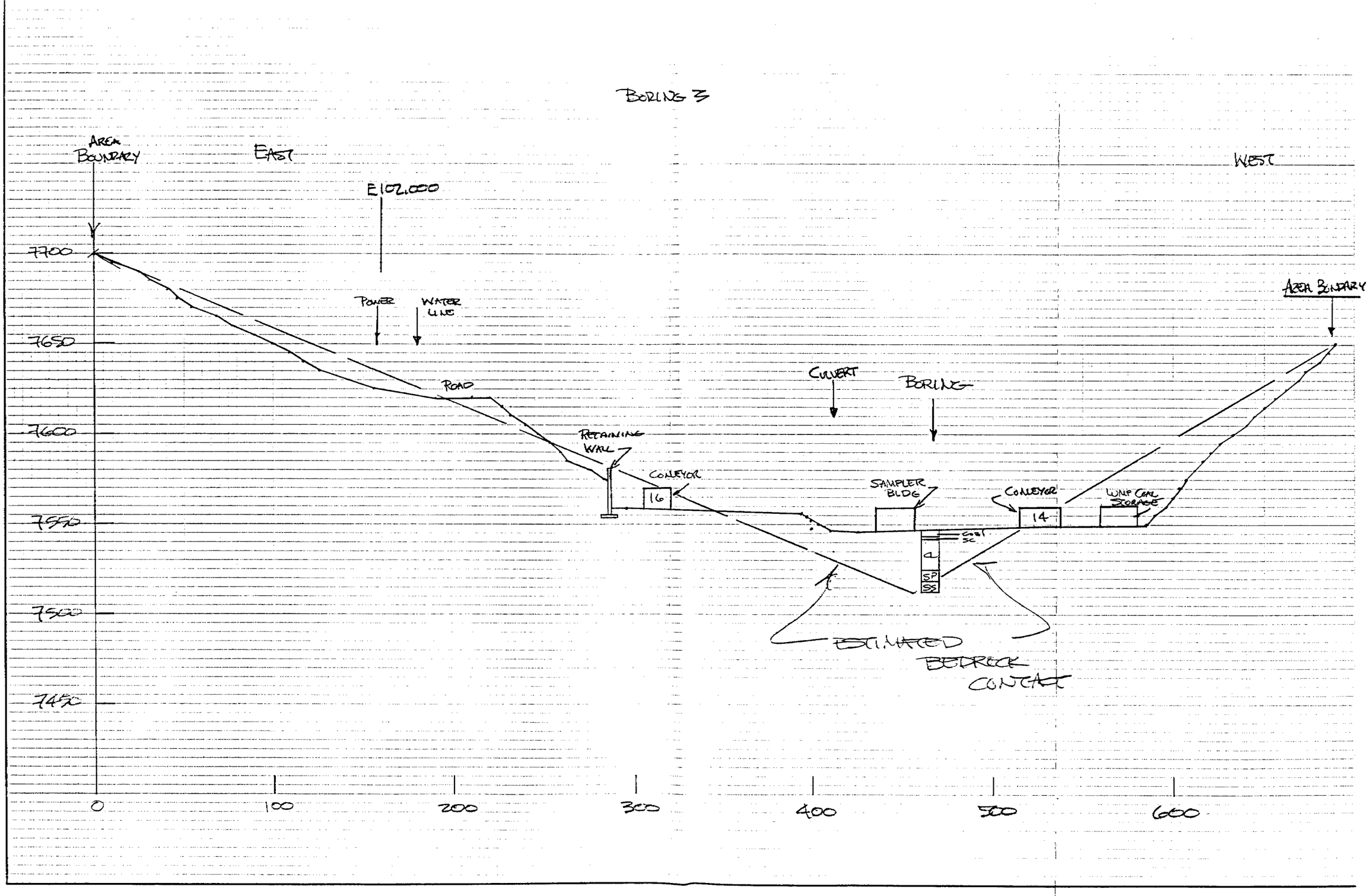

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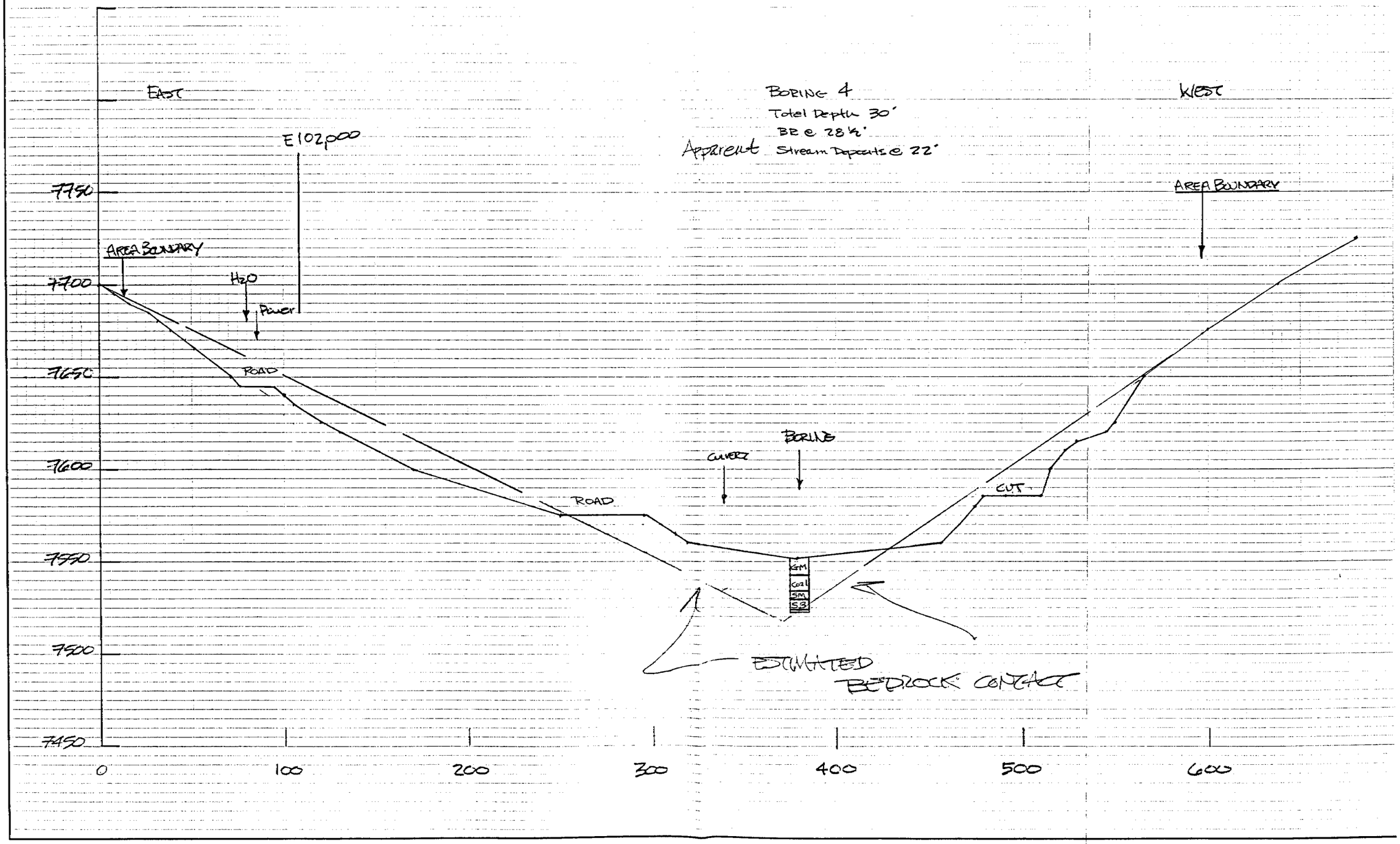

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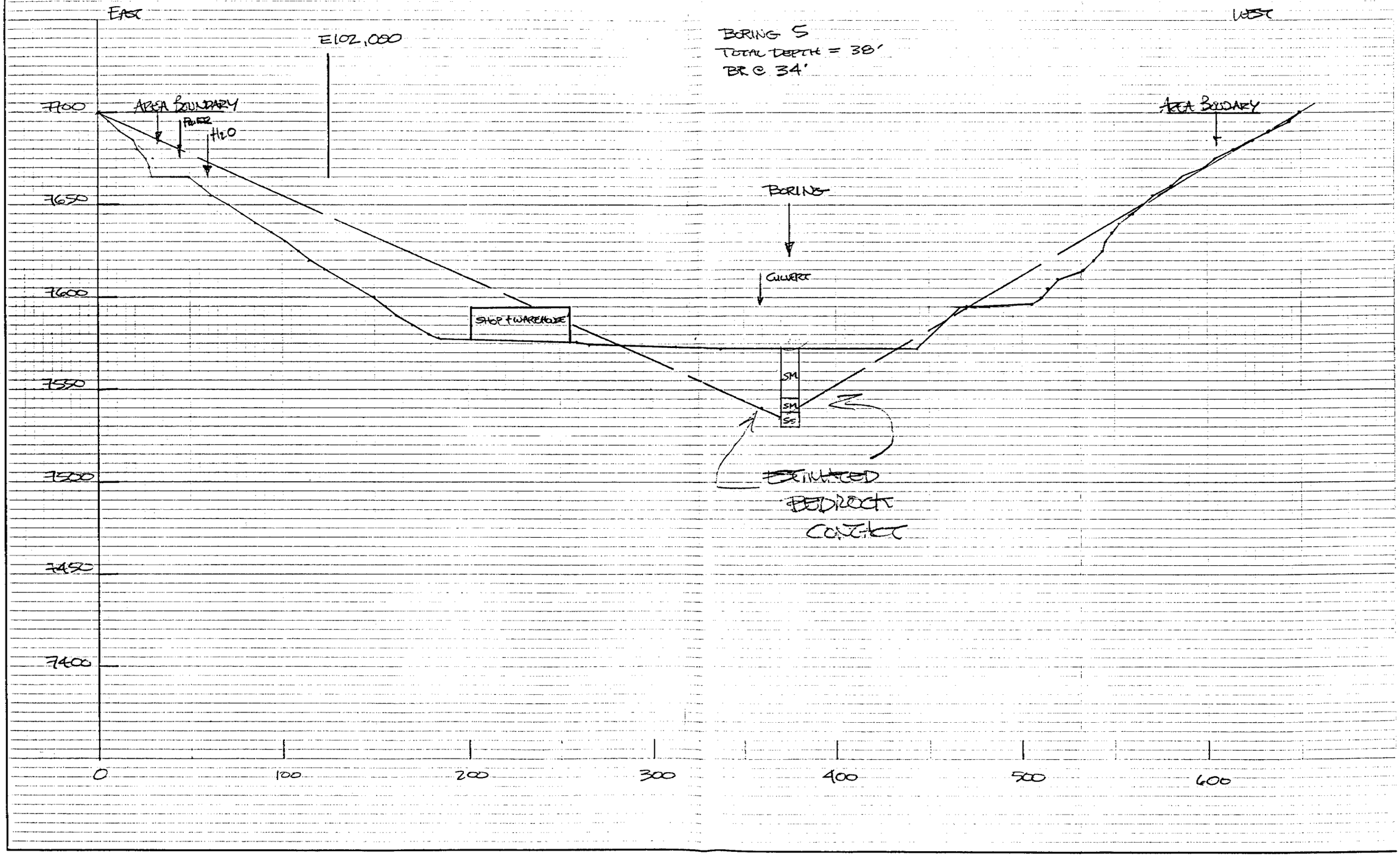

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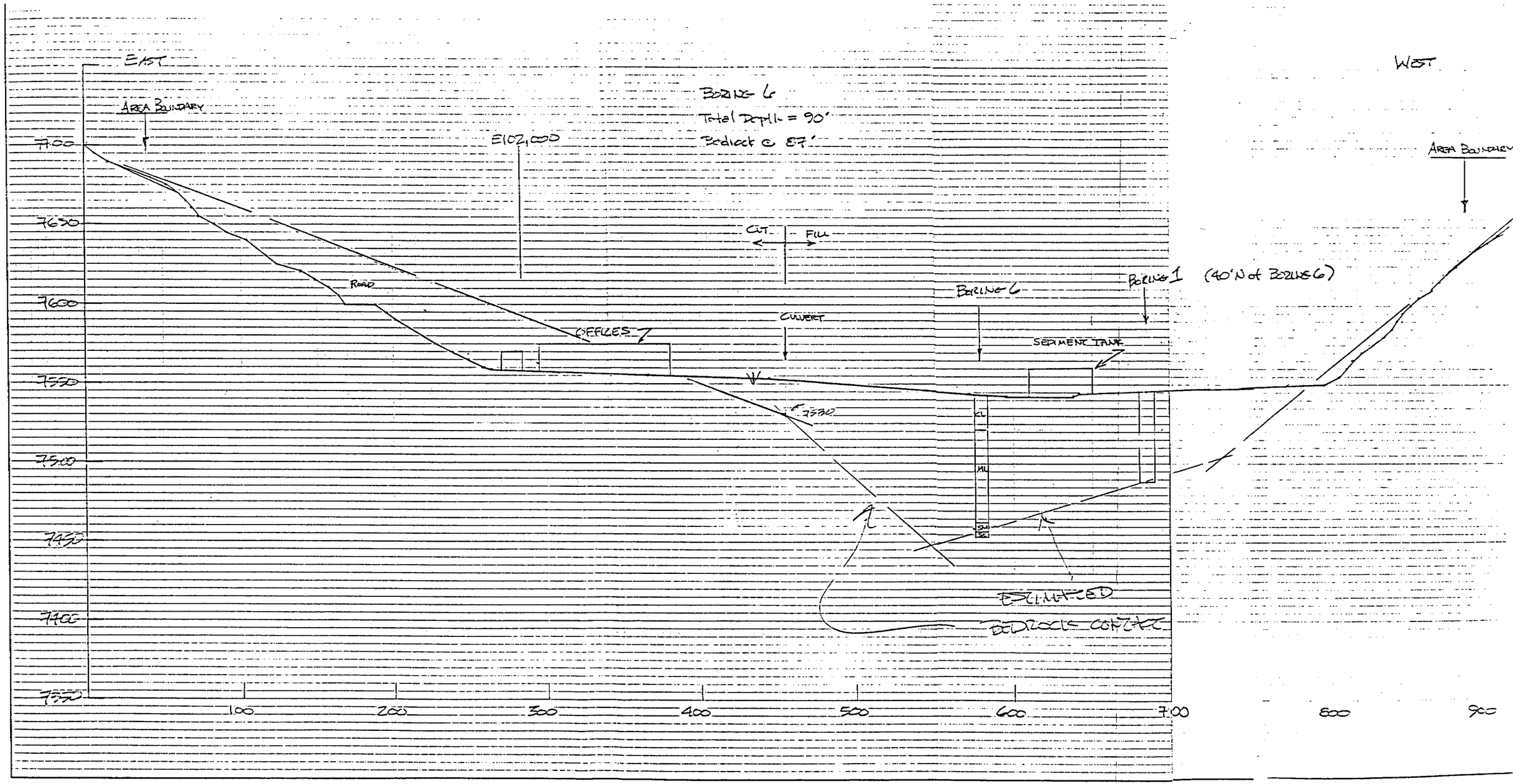

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Calculation of Slopes for Each Channel Reach

Reach 1

$$S = \frac{\Delta Z}{L} = \frac{7570 - 7562.5}{320}$$

$$= 0.0234$$

Reach 2

$$S = \frac{\Delta Z}{L} = \frac{7562.5 - 7557.5}{95}$$

$$= 0.0526$$

Reach 3

$$S = \frac{\Delta Z}{L} = \frac{7557.5 - 7542.5}{215}$$

$$= 0.070$$

Reach 4

$$S = \frac{\Delta Z}{L} = \frac{7542.5 - 7540.0}{400}$$

$$= 0.0063$$

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

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

$$= 0.246$$

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for Reclamation for Convulsion
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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

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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

$Fb = Cfb^d + 1/2\ dZ$

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No. 3 & No. 14
Sevier County, Utah
SHB Job No. E83-2022

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

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

$$n = \frac{21\ \tau_{max}}{\gamma\,(SG-1)\,D_{50}}$$

where $\tau_{max} = .75\,\gamma\,d\,S$
$= .75(62.4)(2.08)(.025)$
$= 2.43$

$SG = 2.70$

$D_{50} = 1.65$

$= 0.29$

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

$\lambda = 0$ ASSUMPTION

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

$\phi = 40°$ ANGLE OF REPOSE

$= 18.23°$

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

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

$= 0.19$

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

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

FS = 1.52

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

gradation of riprap found by curve

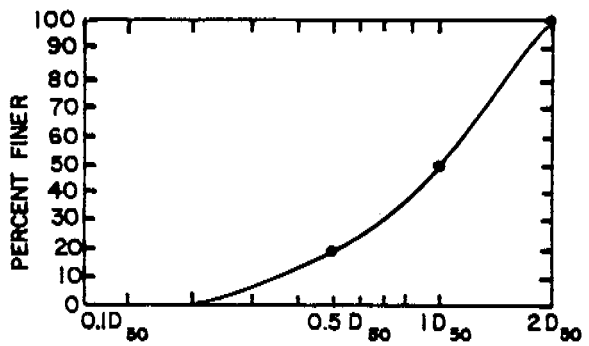


Figure 3.17. Suggested size distribution of riprap. (After Simons and Senturk, 1977).

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 Runoff Volume

100 year 24 hour Storm.

CN = 80 DISTURBED AREA

Precipitation = 2.9 INCHES (MERRICK REPORT)

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

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

$$= 1.18 \text{ INCHES}$$

$$t_c \approx 0.1 \text{ hr}$$

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

$d = .324$

$S = .015$

$T_{max} = 0.23$

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

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%

$X = \sin\theta$ $\qquad$ θ = Slope Angle

$= 0.45$ $\qquad$ $= 26.57°$

$LS = 16.53$

$CP = 0.035$ sparse grass

$= 0.015$ Wood chips (SEE SHB RPT)

$Y_{ANNUAL} = ARKLS\,CP$ (ANNUAL)

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

$$= 239 \frac{TON}{YEAR} = 5.57 \frac{TON/ACRE}{YEAR}$$

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

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

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

CHANNEL INLET & SEDIMENTATION AREA

EARTHWORK CALCULATIONS

$$\forall_1 = \frac{1}{2}(40)(56)\left(\frac{5+5+6}{3}\right)$$
$$= 5972.2 \ FT^3$$
$$= 221.2 \ YD^3$$

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

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

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

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

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

$$\forall_7 = \left(\frac{42+47}{2}\right)\left(\frac{39+36}{2}\right)\left(\frac{7+7+7+6.5}{4}\right)$$
$$= 11{,}601.6 \ FT^3$$
$$= 429.7 \ YD^3$$

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

$$\forall_9 = \frac{1}{2}(81)(92)\left(\frac{7+7+6}{3}\right)$$
$$= 25{,}760.0 \ FT^3$$
$$= 954.1 \ YD^3$$

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

$$= 447.2 \ YD^3$$

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

$$= 1093.5 \ YD^3$$

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

$$= 508.1 \ YD^3$$

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

$$= 674.1 \ YD^3$$

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

$$= 135.2 \ YD^3$$

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

$$= 261.1 \ YD^3$$

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

$$= 890.2 \ YD^3$$

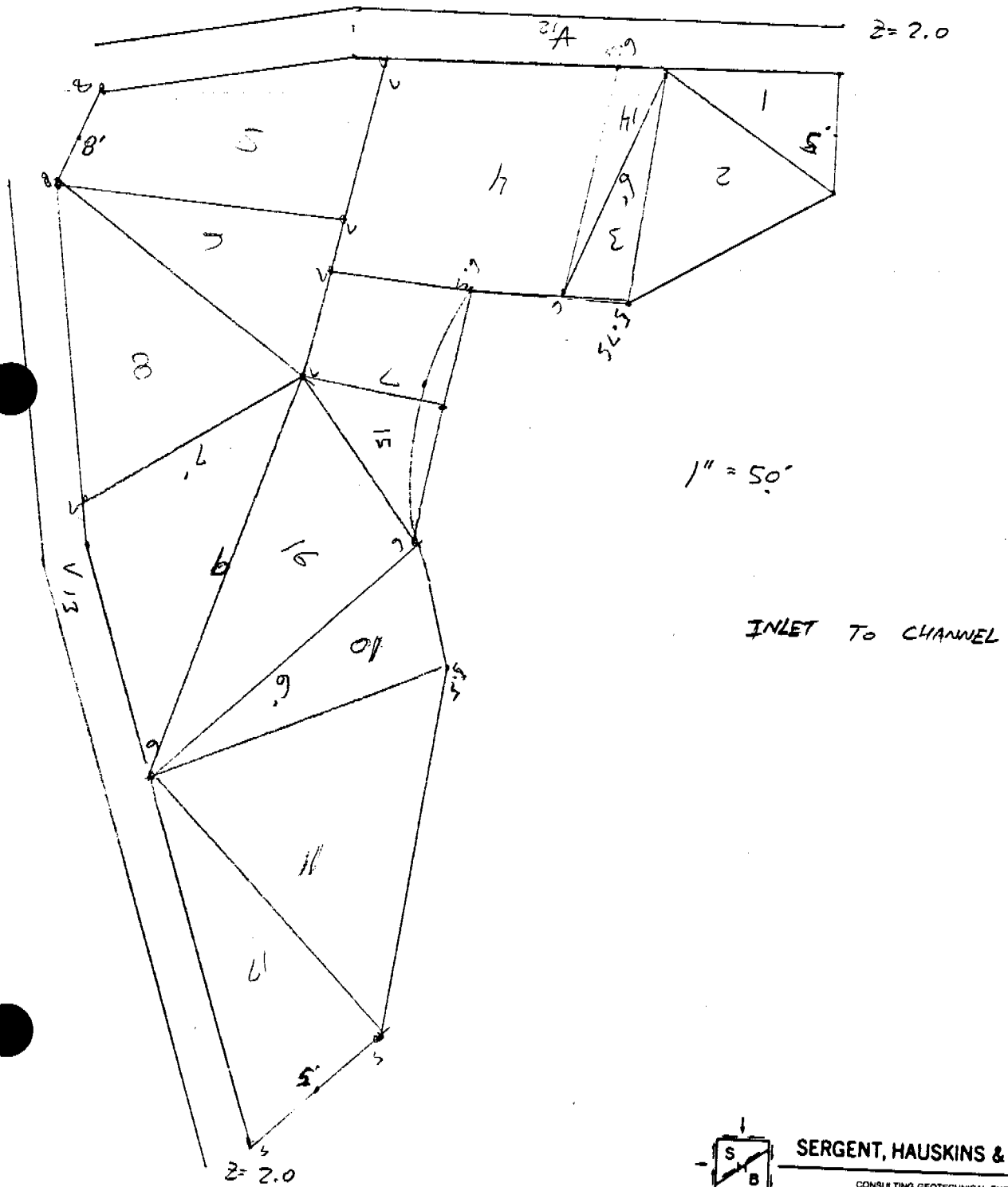
$$V_{17} = \frac{125(40)}{2}\left(\frac{6+5+5}{3}\right) = 15,333.3 \ Ft^3$$

$$= 567.9 \ YD^3$$

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

SITE PLAN

SHOWING LOCATIONS OF TEST BORINGS



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TRANSITION REACH (REACH 2)

$A_1 = (b + 2y)y = (20 + 1.0(5.5))5.5 = 140.3$

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

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

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

(REACH 3)

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

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

(REACH 4)

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

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

(REACH 5)

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

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

$= 77.7(76.5)$

$= 5941.8 \ Ft^3$

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

(REACH 6)

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

$L = 152'$

$\forall = 152(77.7) = 11{,}808.5 \ Ft^3$

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

(REACH 7)

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

$= 126.5 \quad FT^2$

$L = 105 \quad FT$

$V = (105)(126.5) = 13,282.5 \quad FT^3$

$= 491.94 \quad YD^3$

(REACH 8)

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

$= 126.5 \quad FT^2$

$L = 170'$

$V = 21,505 \quad FT^3$

$= 796.48 \quad YD^3$

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 inch² = 2500 ft²

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

12, 11

26, 25

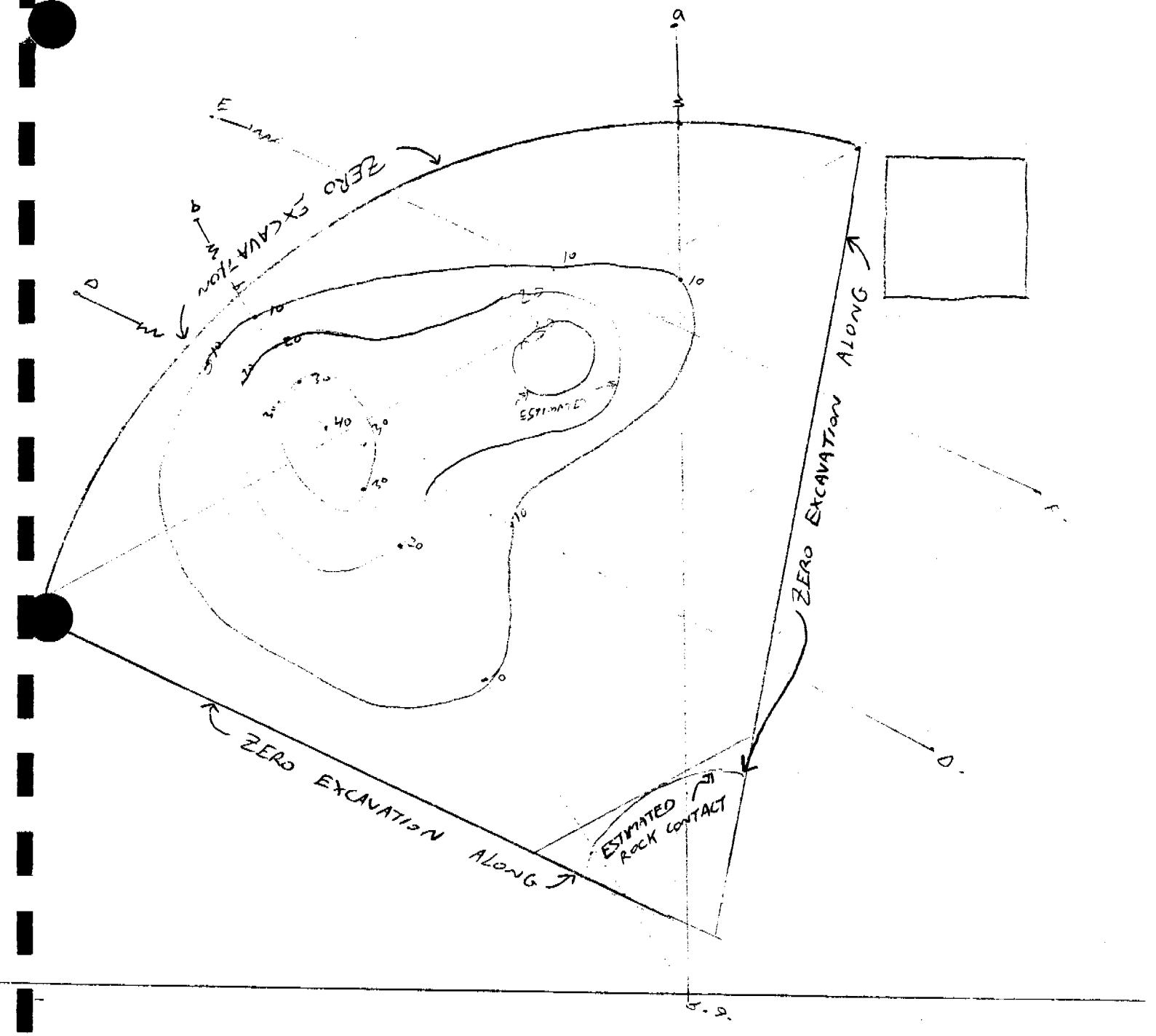
~~164~~, ~~331~~, 161, 166, 163 AVG 164

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

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Earth Work Volumes

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

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

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

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

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

$1000 + 2525$

$= 3525\ Ft^2$

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

$= 437.5 + 237.5$

$= 675.0\ Ft^2$

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

$= 300 + 412.5$

$= 712.5\ Ft^2$

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

$= 375 + 600 + 420$

$= 1395.00$

$A_J = \left(\frac{1}{2}\right)^2 (110)(60) + 26\ Ft^2 + \left(\frac{1}{2}\right)(95)(180)$

$= 1650 + 26 + 855$

$= 2541$

$$A_K = \left(\tfrac{1}{2}\right)^2(100)(25) + \left(\tfrac{1}{2}\right)^2(85)(40) - 25 + \left(\tfrac{1}{2}\right)(10.5)($$
$$= 625 + 825 + 1102.5$$
$$= 2552.50$$

$$A_L = \left(\tfrac{1}{2}\right)^2(135)(55) + \left(\tfrac{1}{2}\right)^2(65)(30) + \tfrac{1}{2}(11.5)(220)$$
$$= 1856 + 487.5 + 1265.0$$
$$= 3608.50$$

$$A_M = \left(\tfrac{1}{2}\right)^2(105)(20) + \left(\tfrac{1}{2}\right)^2(65)(20) + \left(\tfrac{1}{2}\right)(11.5)(220)$$
$$= 525 + 325 + 1265.0$$
$$= 2115.0$$

$$A_N = \left(\tfrac{1}{2}\right)^2(100)(30)$$
$$= 750 \ FL^2$$

$$A_O = \left(\tfrac{1}{2}\right)^2(70)\ 8$$
$$= 140 \ FL^2$$

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

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

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

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

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

$$\forall_{R-Q} = \frac{712.5 + 1295}{2}(50) = 1921.39$$

$$\forall_{Q-J} = \frac{1295 + 2541}{2}(50) = 3644.44$$

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

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

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

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

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

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

38,303.09

MAIN ROADWAY

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

$= 140 \text{ Ft}^2$

$L = 400 \text{ Ft}$

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

$= 2074.07 \text{ YD}^3$

LOWER ROADWAY TO EXISTING DAM

$L = 480'$

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

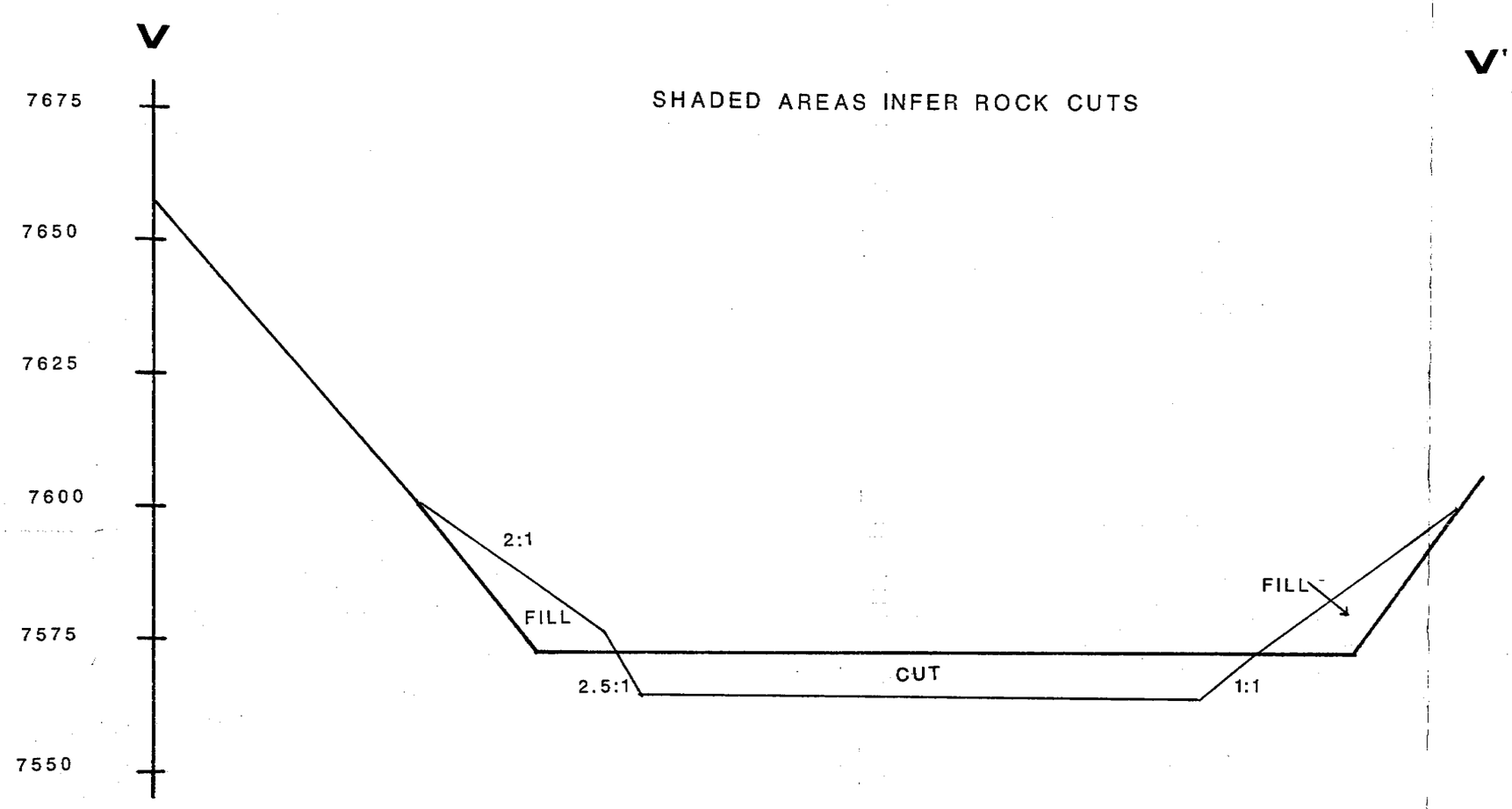
$V = 480(30) = 14{,}400 \text{ Ft}^3$

$= 533.33 \text{ YD}^3$

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	2 100
	LOWER ROADWAY	600
		41,100 yd³



HORIZONTAL SCALE 1"=50'

VERTICAL SCALE 1"=25'

LEGEND

— FINISHED GROUND SURFACE

— EXISTING GROUND SURFACE

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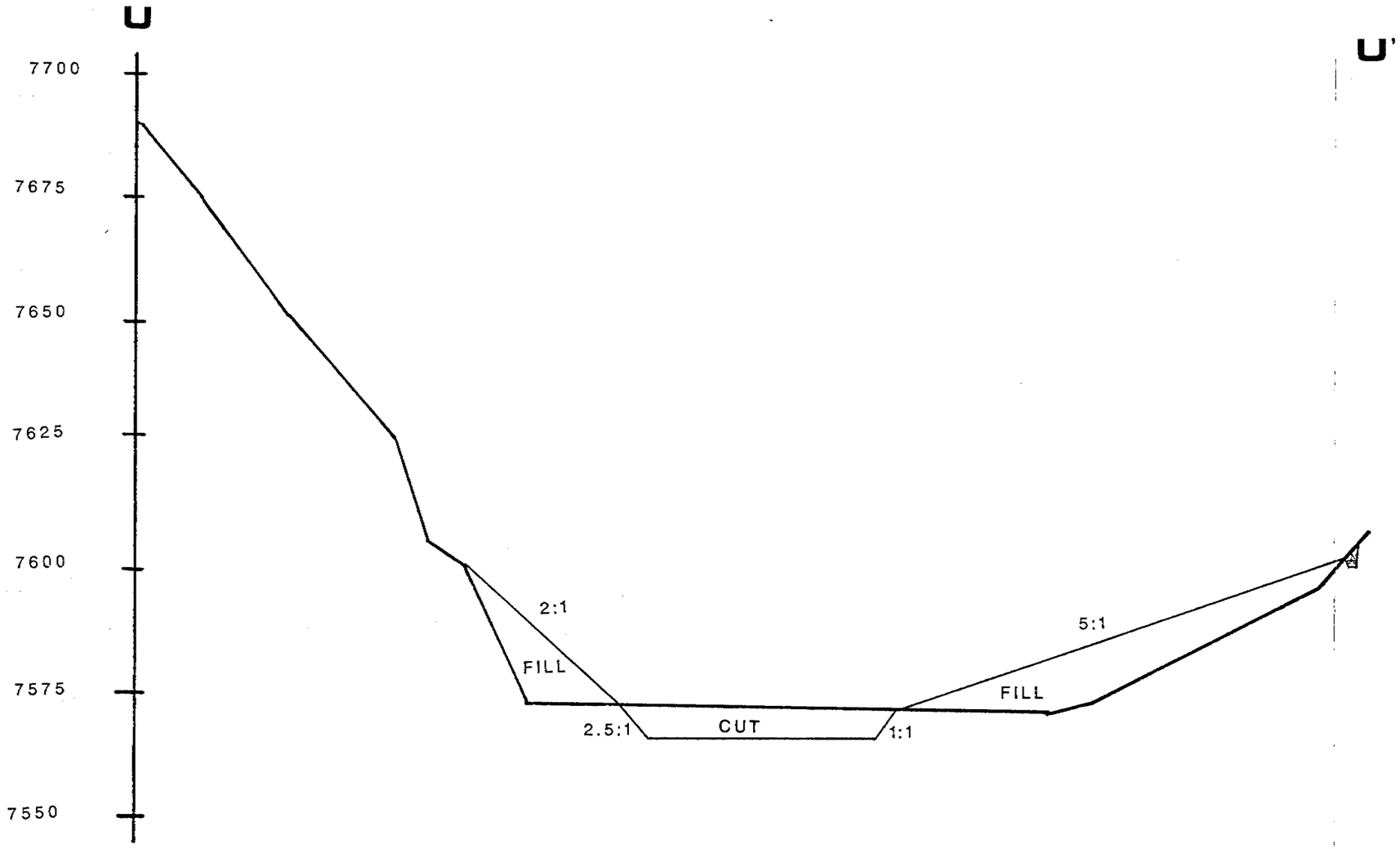

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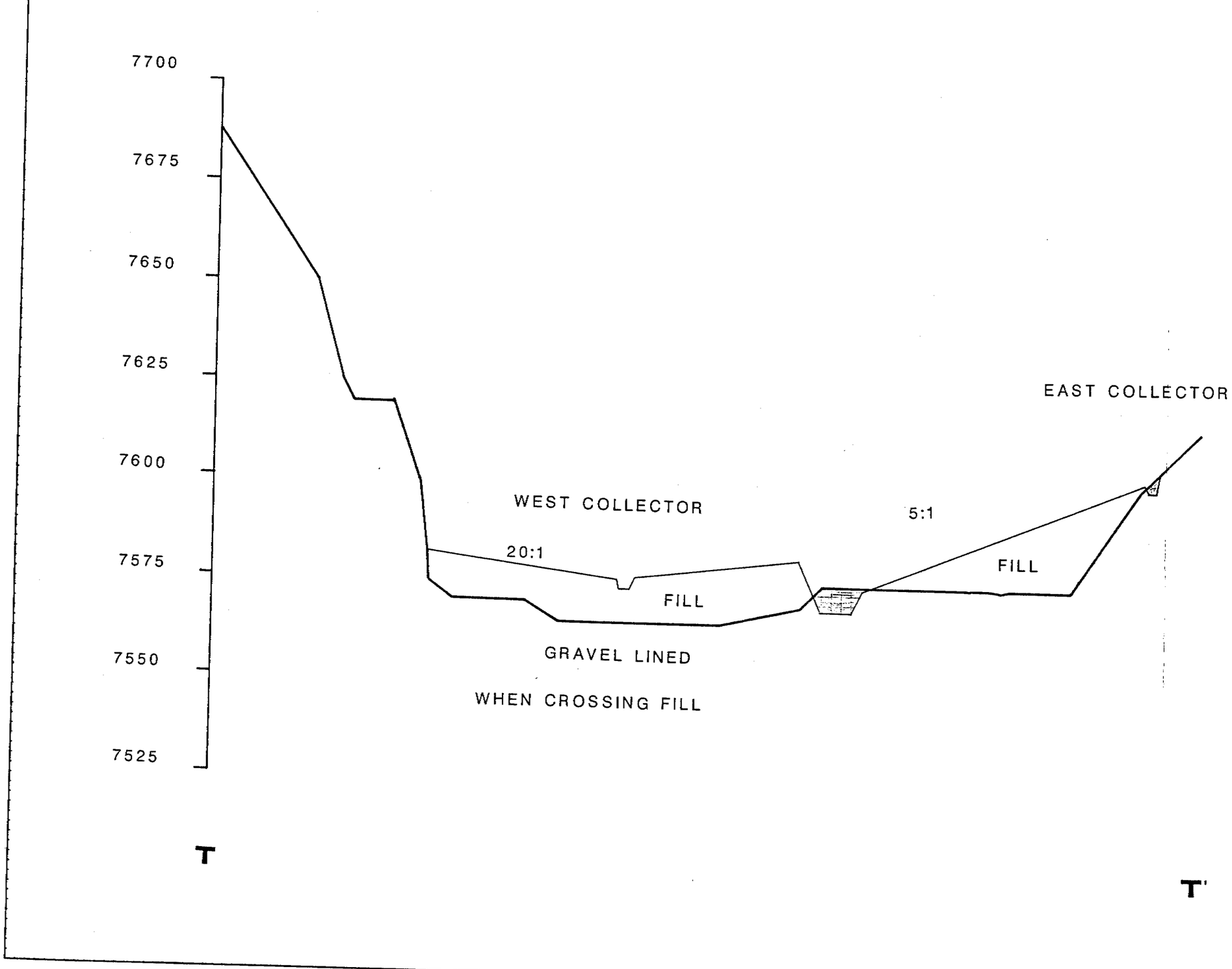

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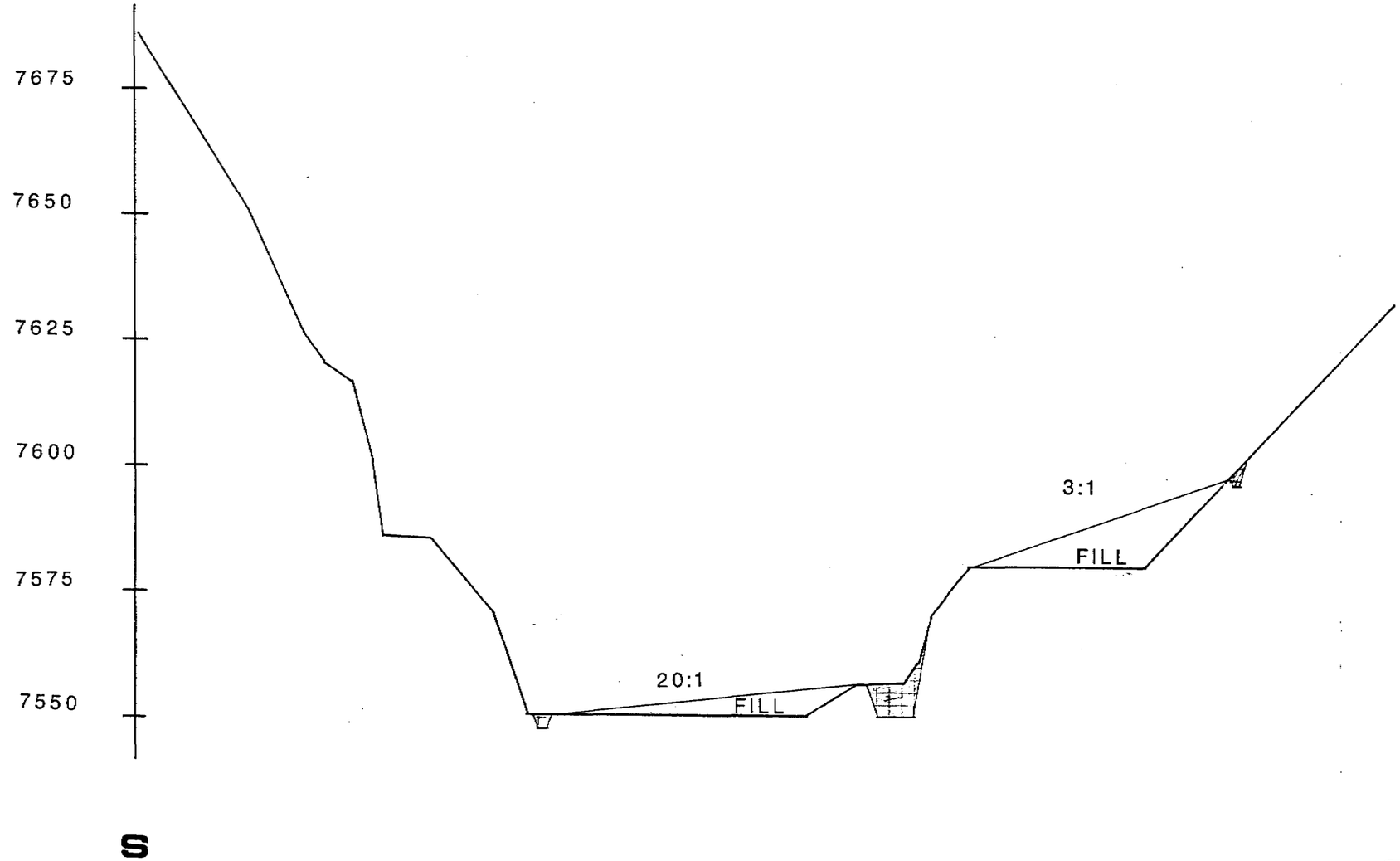

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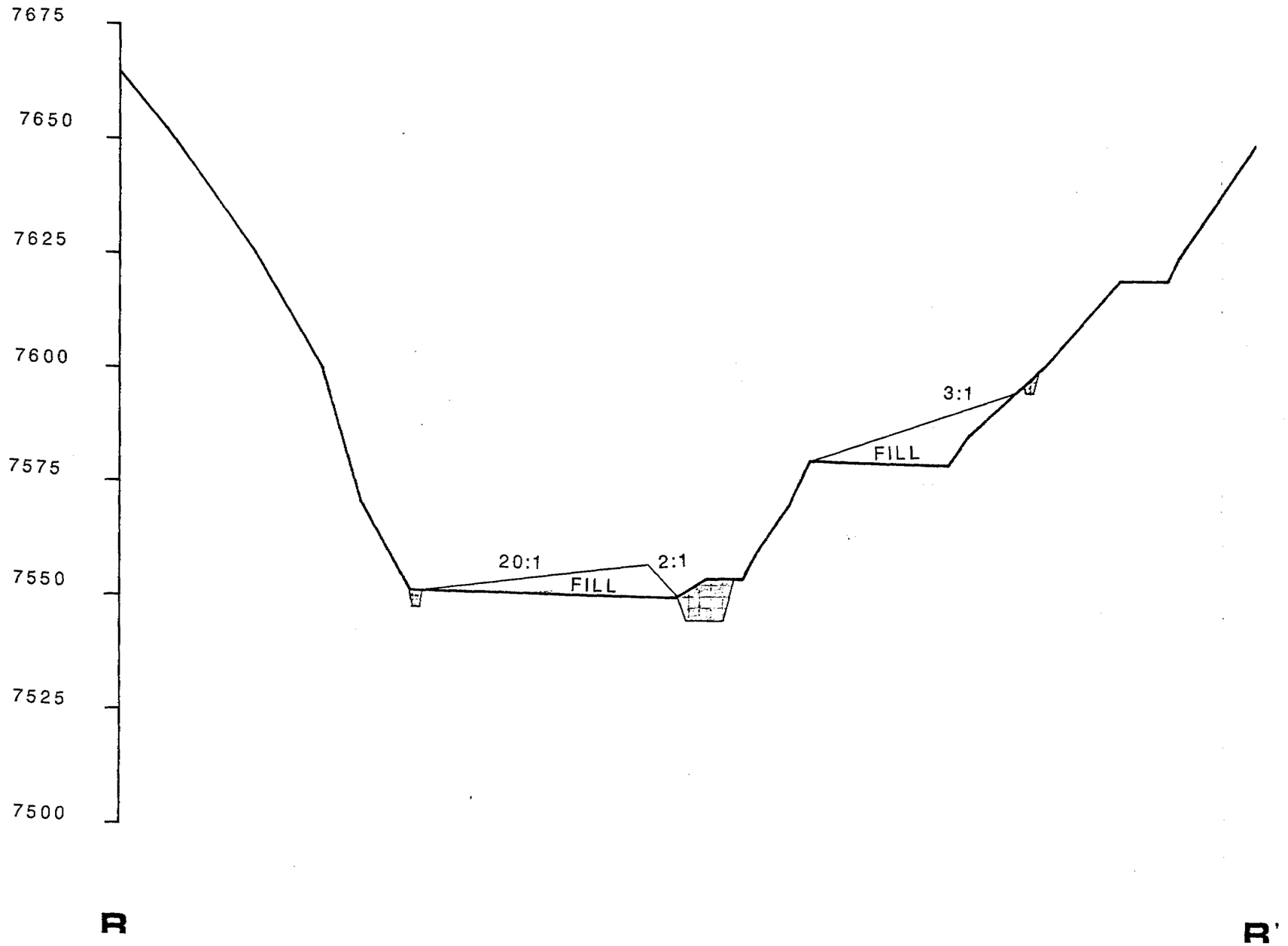

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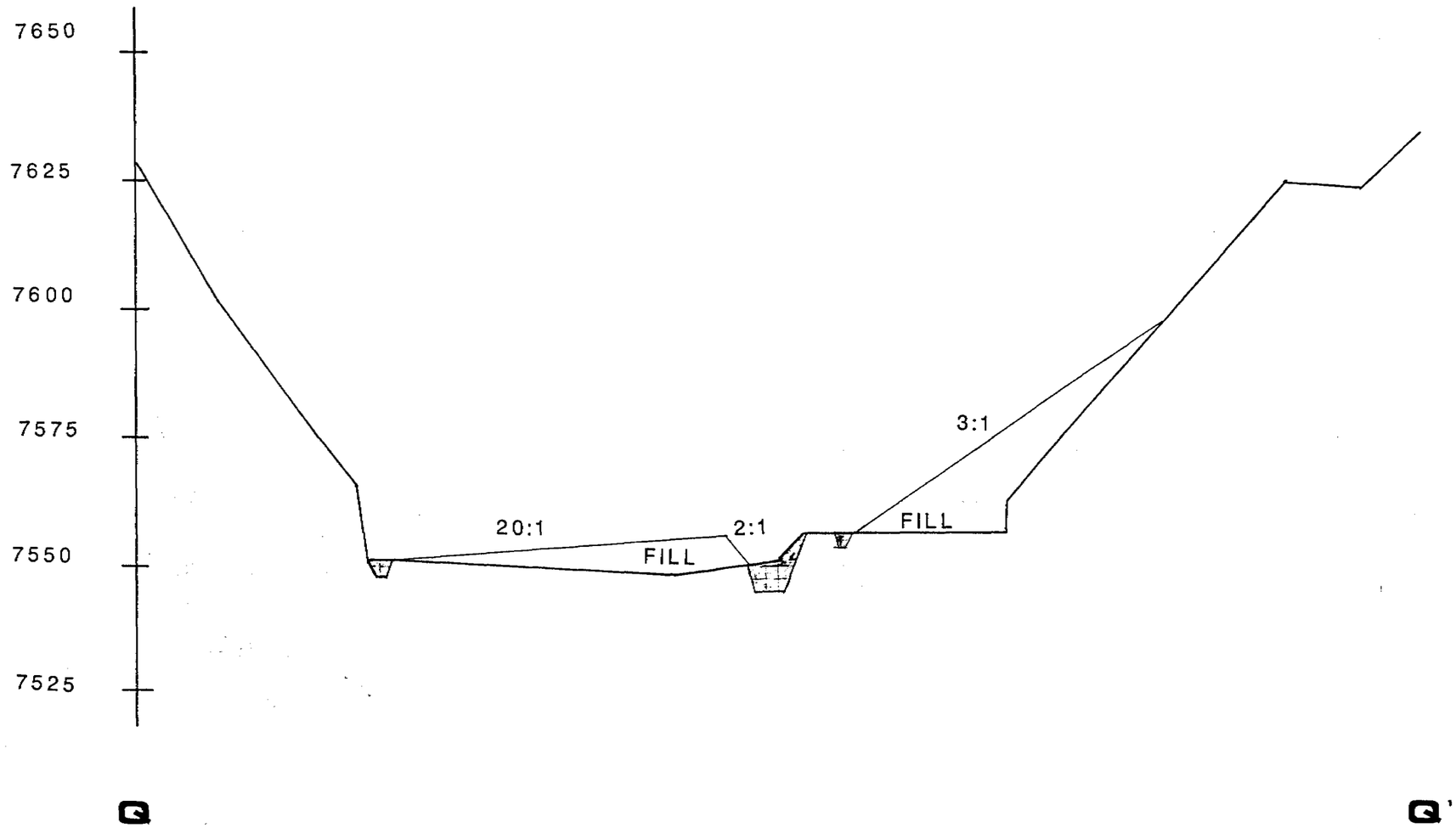

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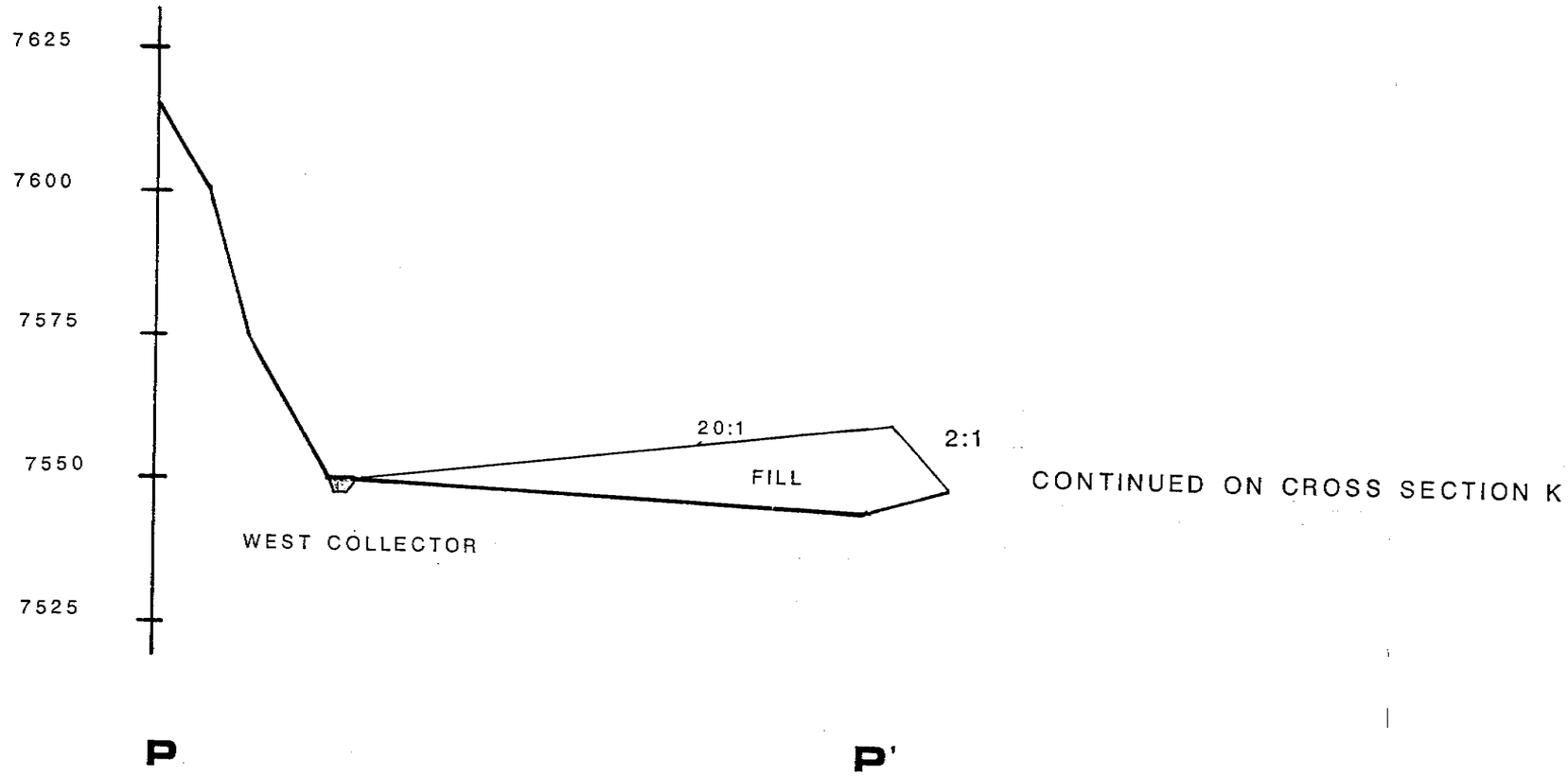

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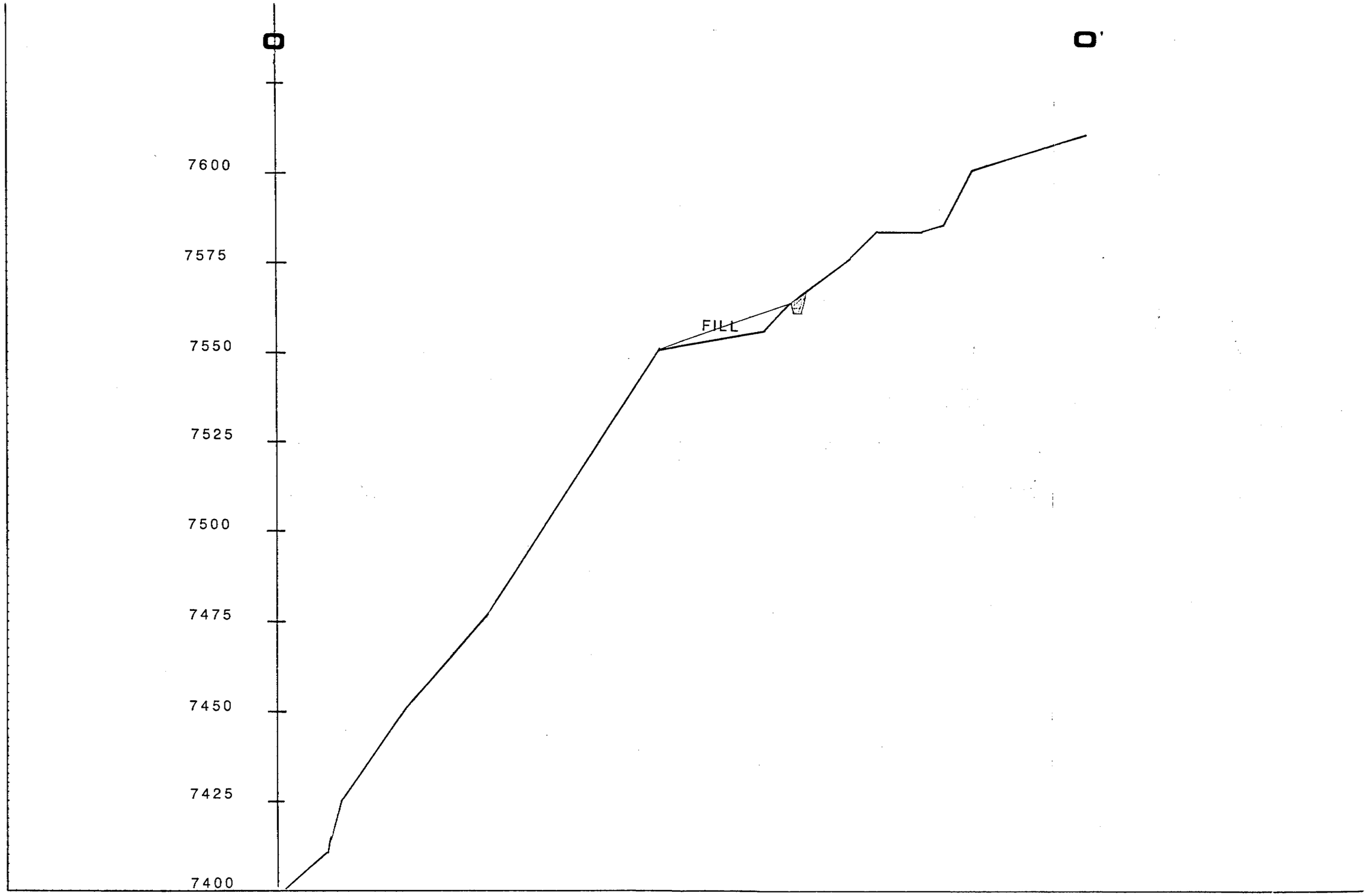

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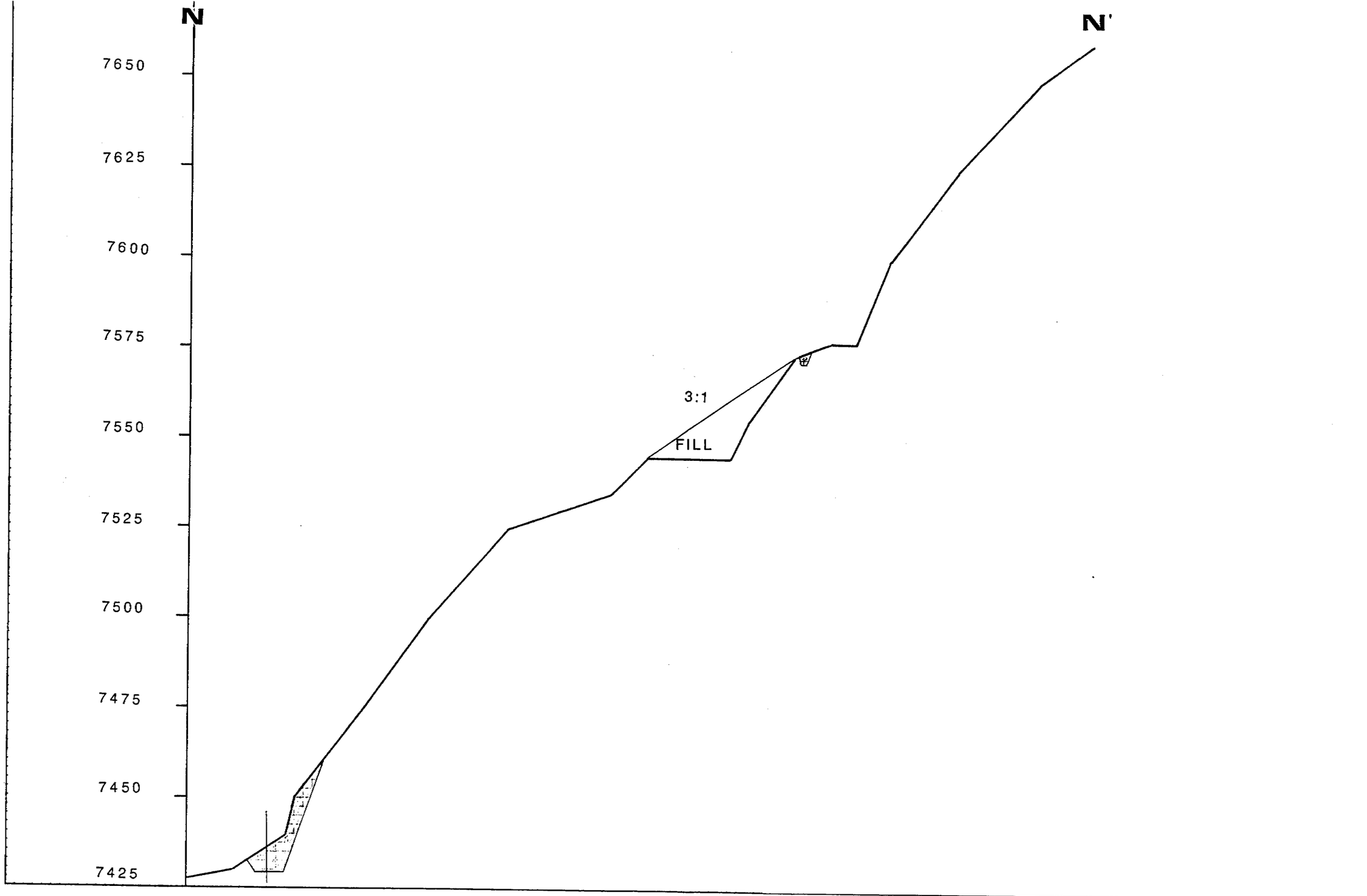

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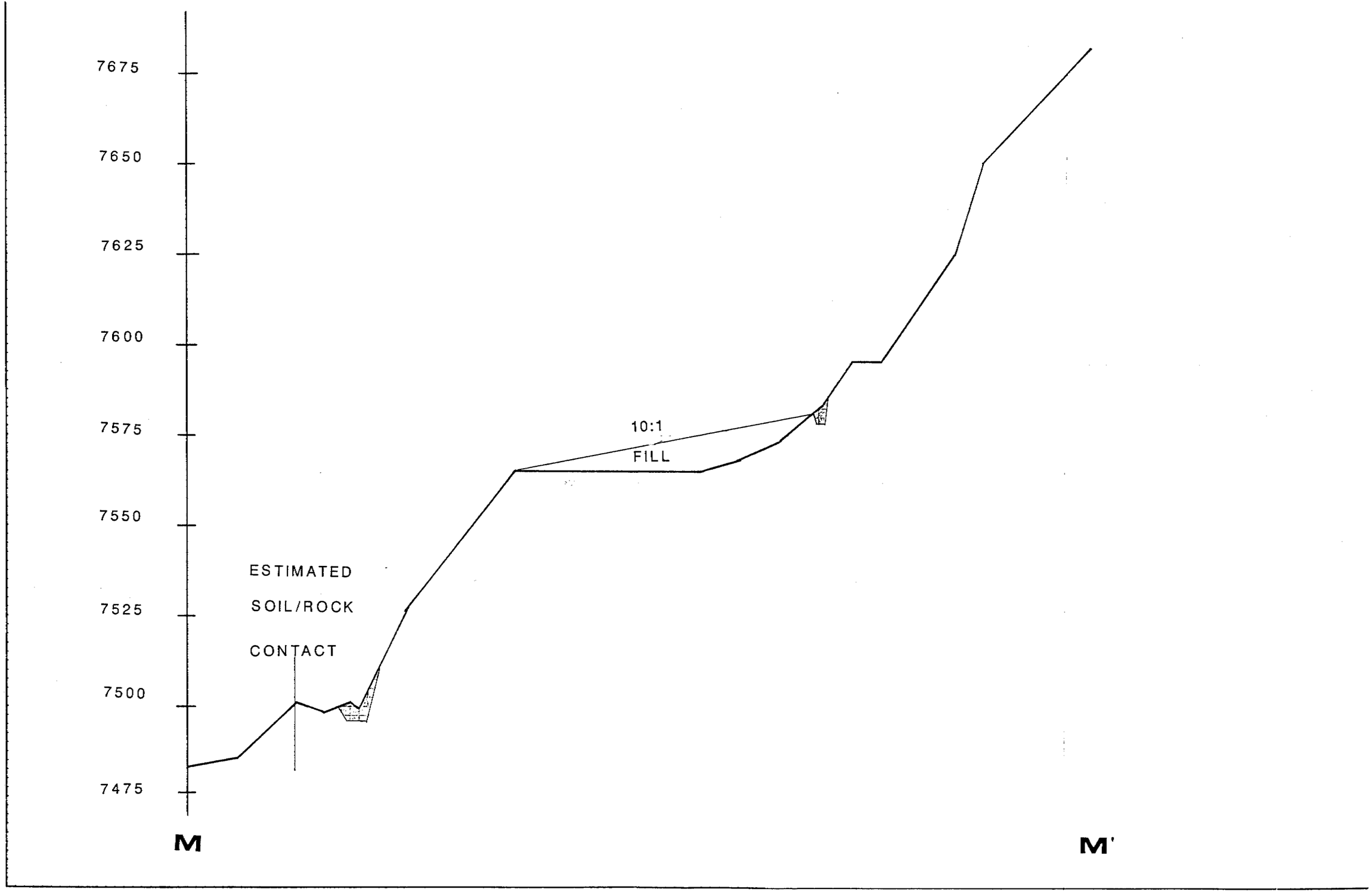

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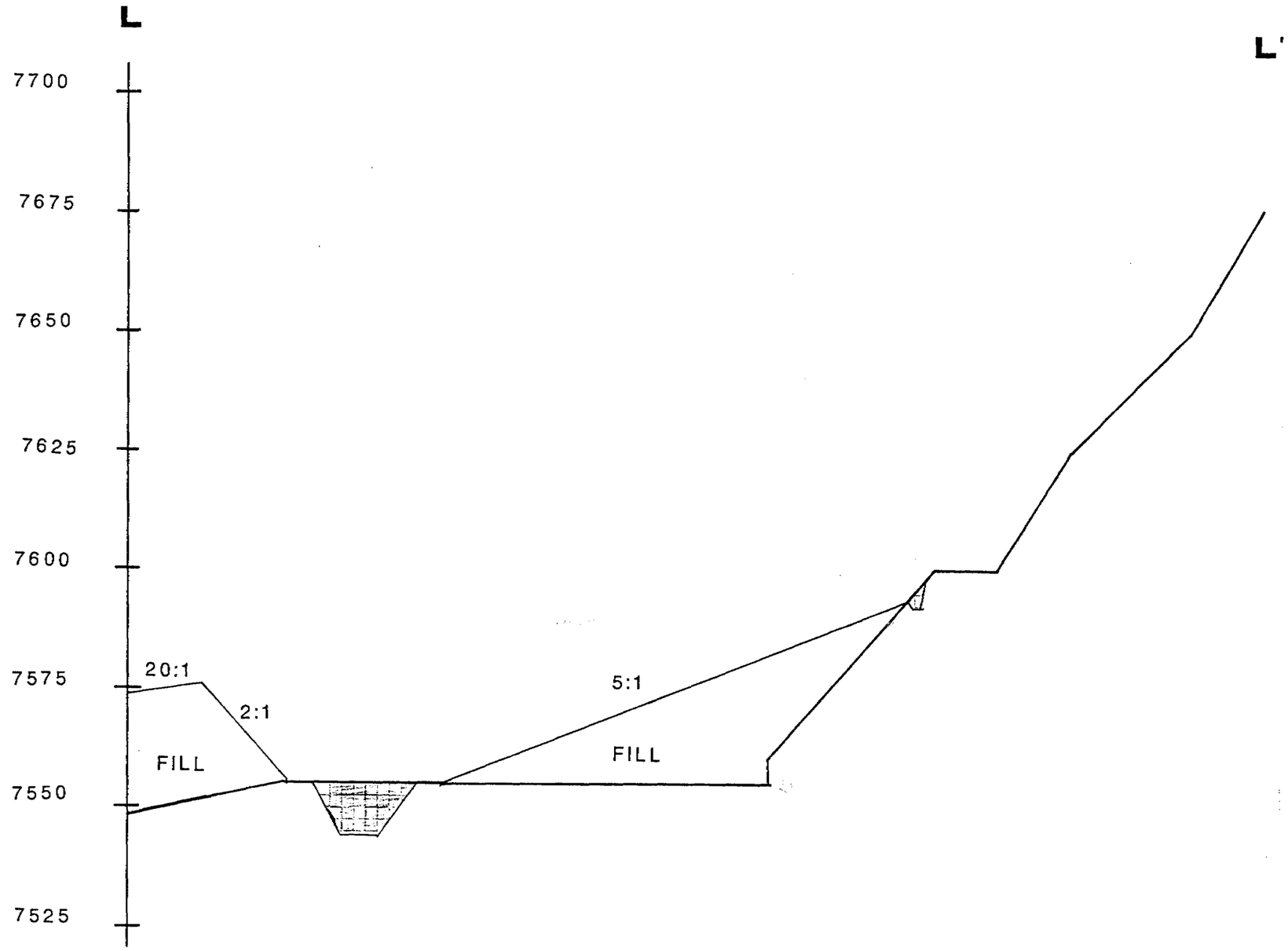

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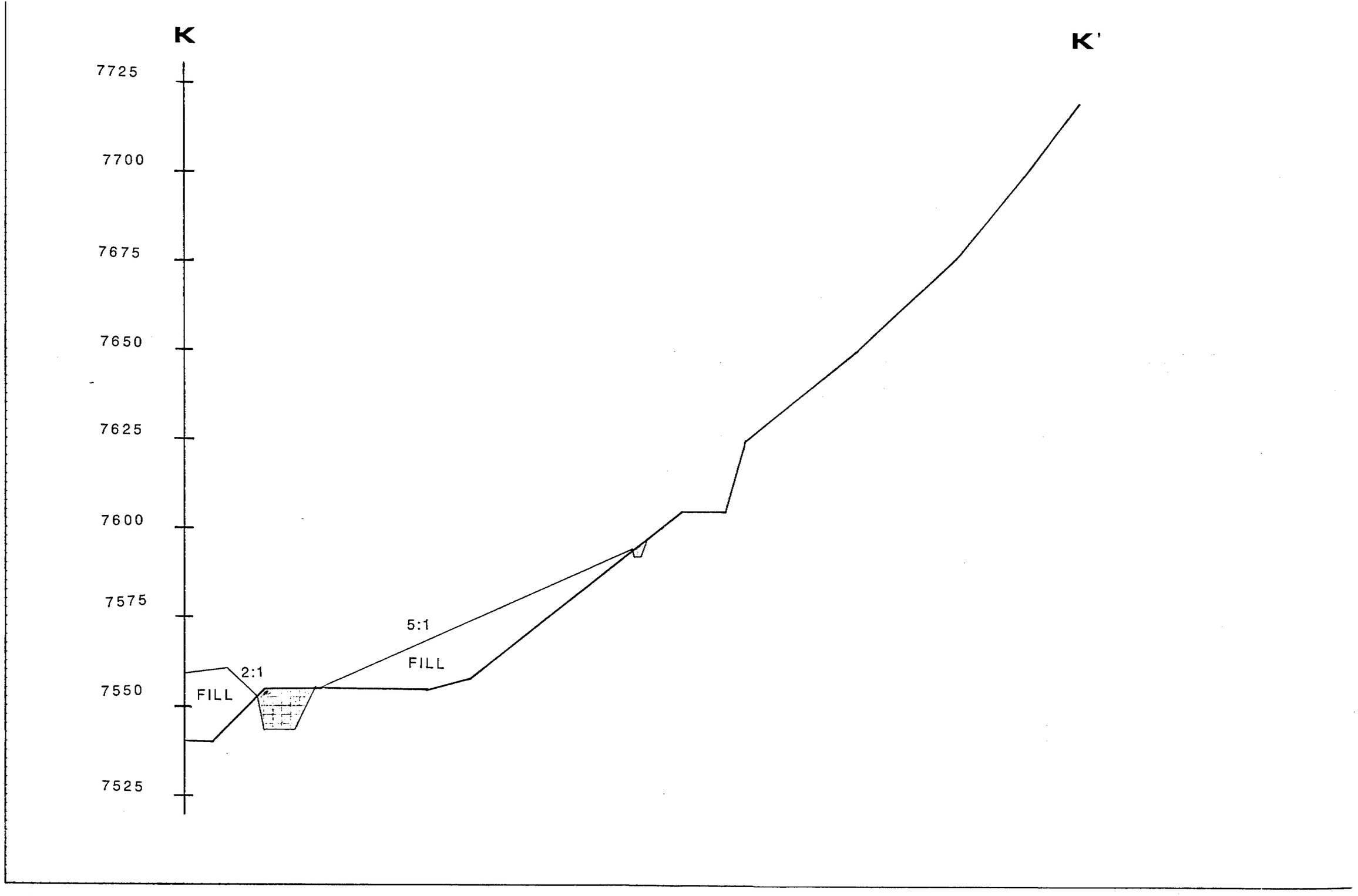

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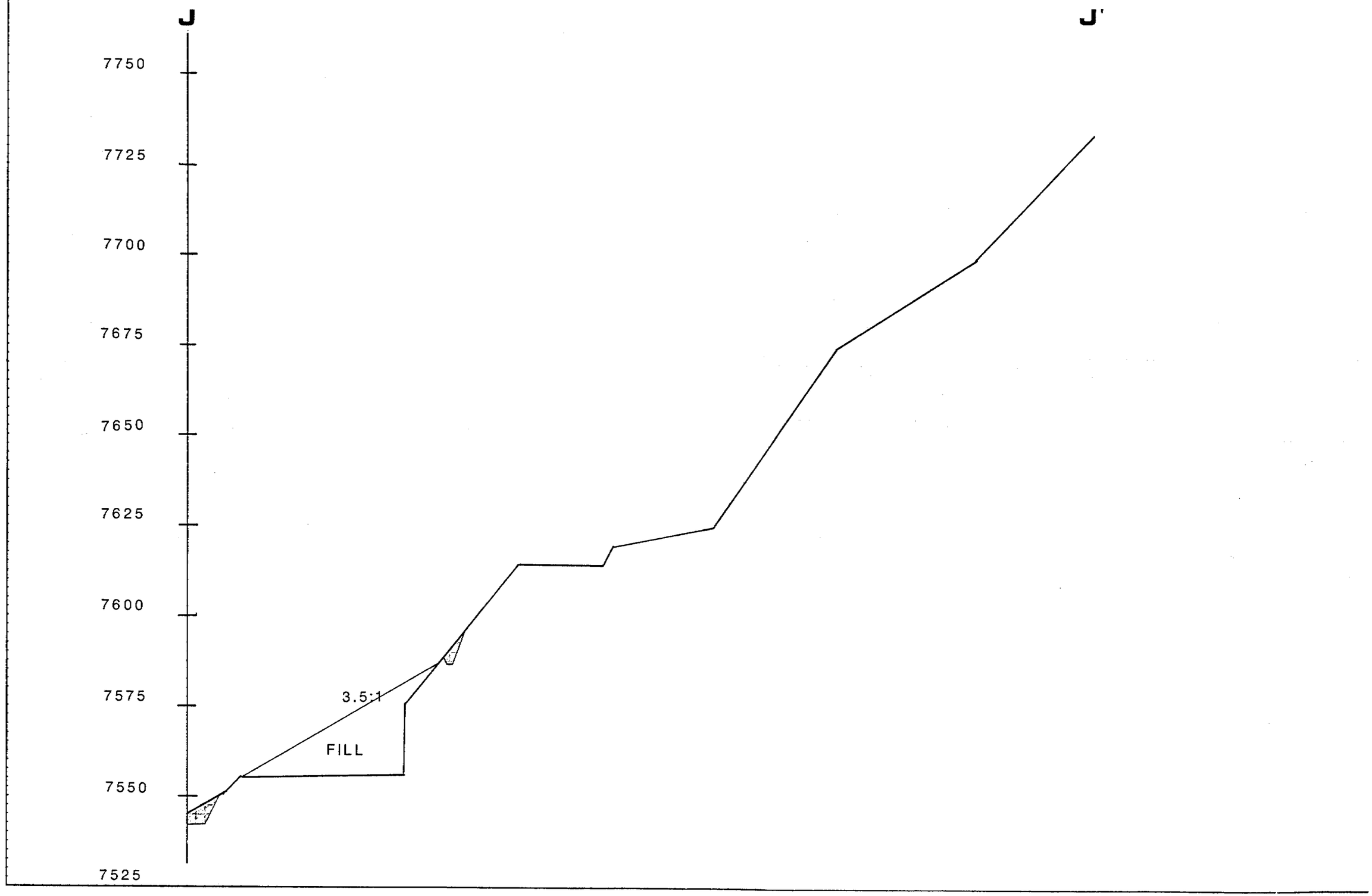

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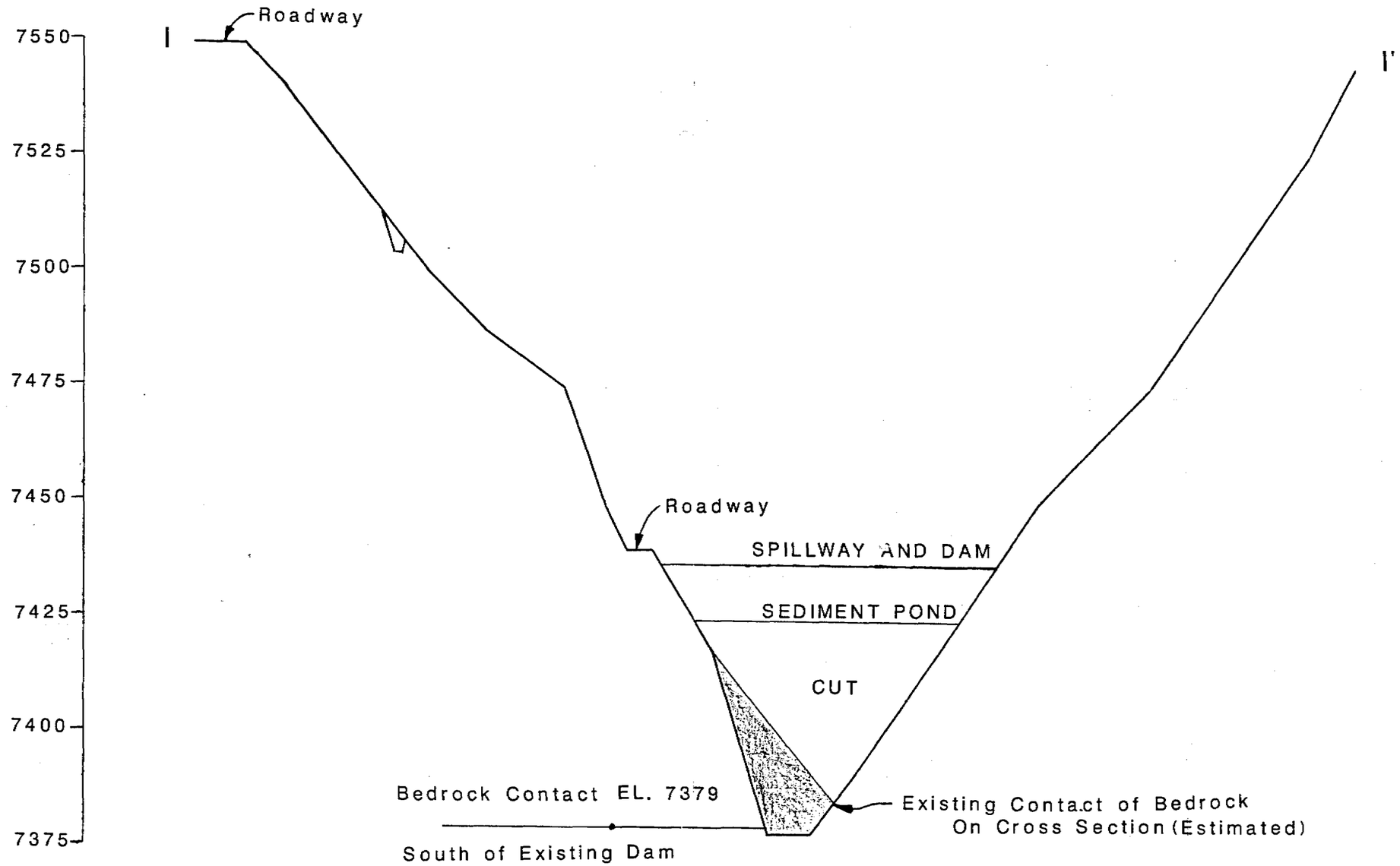

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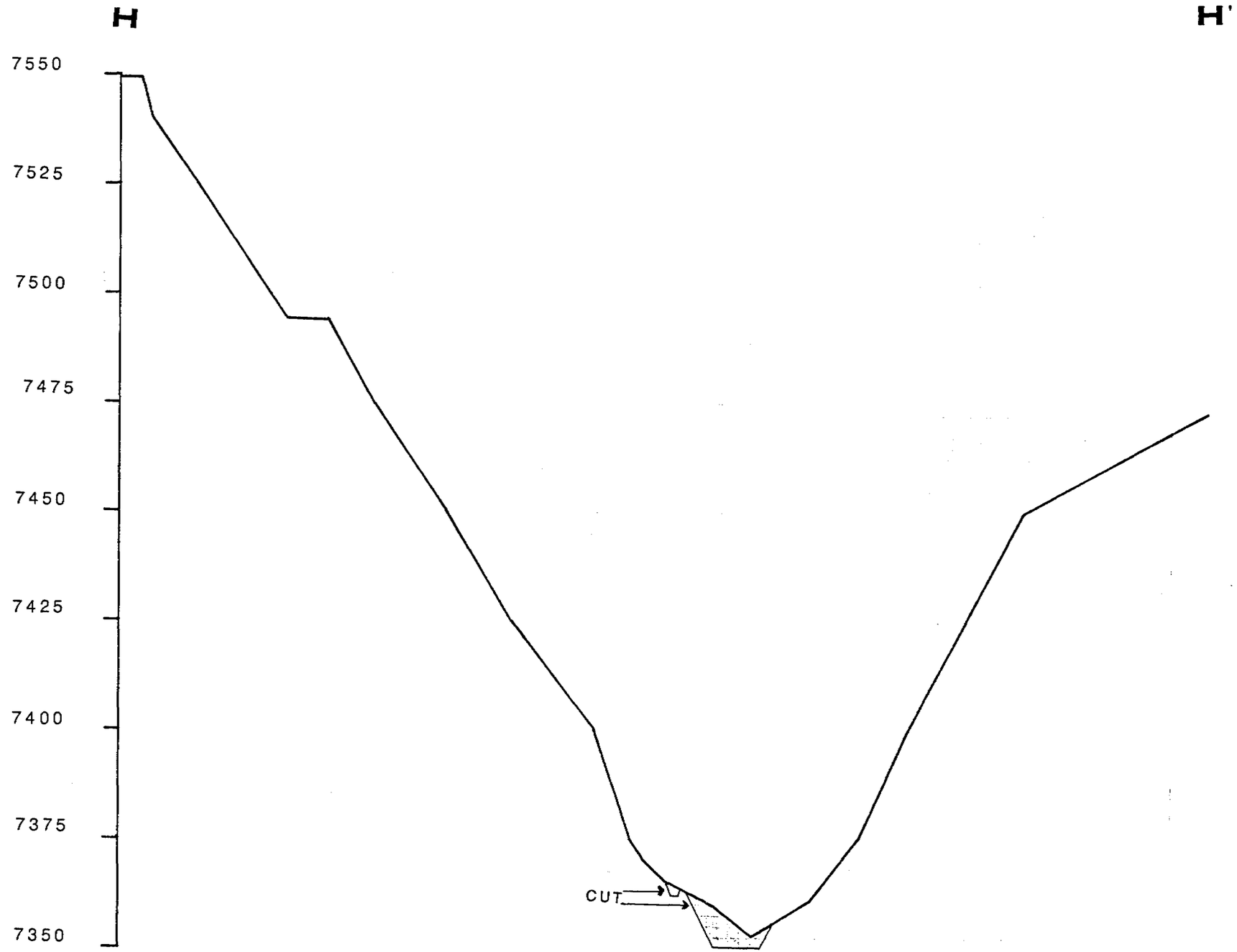

EXISTING STILLING BASIN

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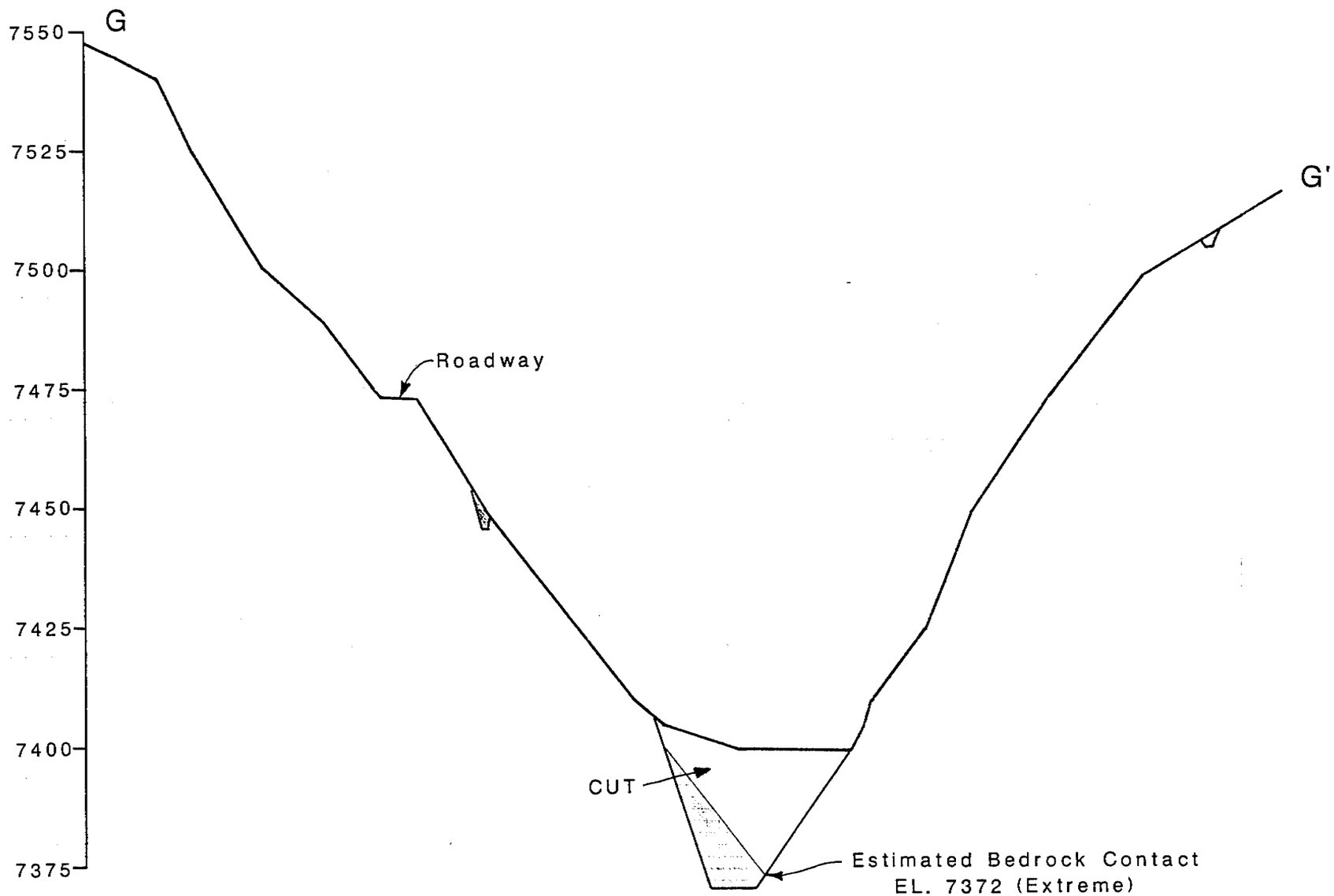

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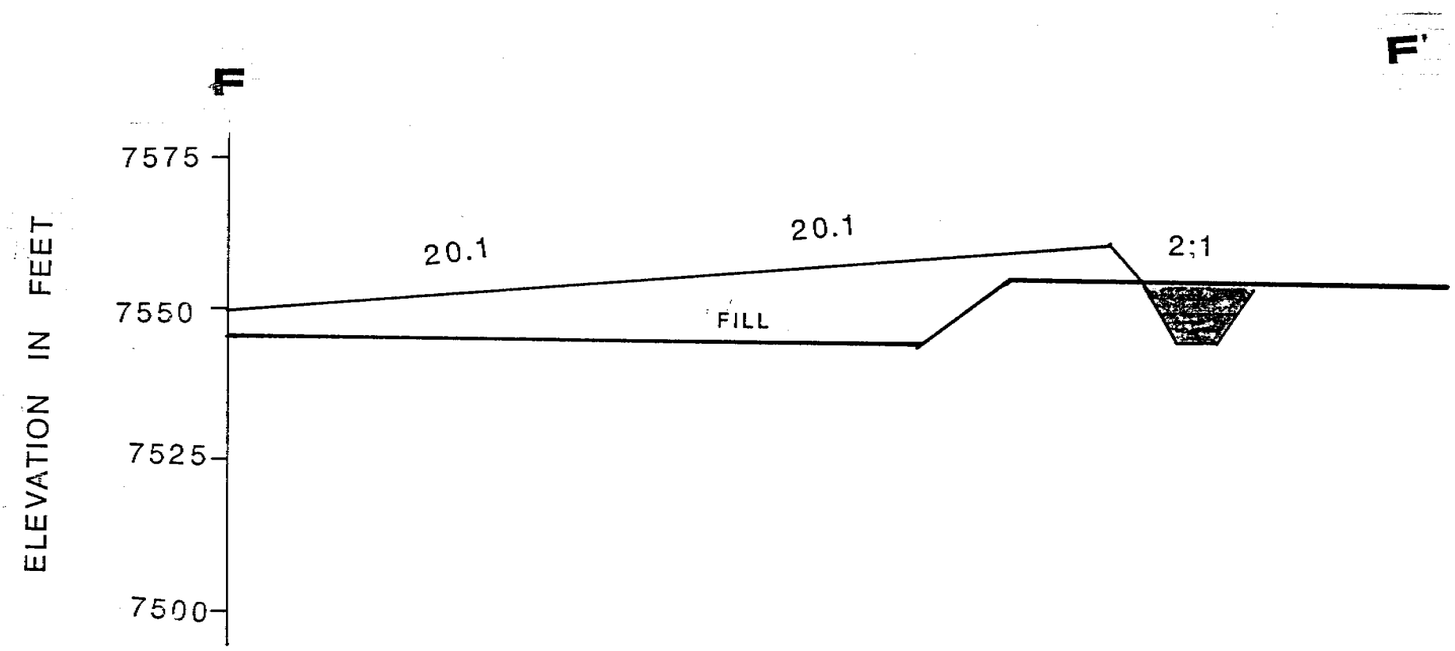

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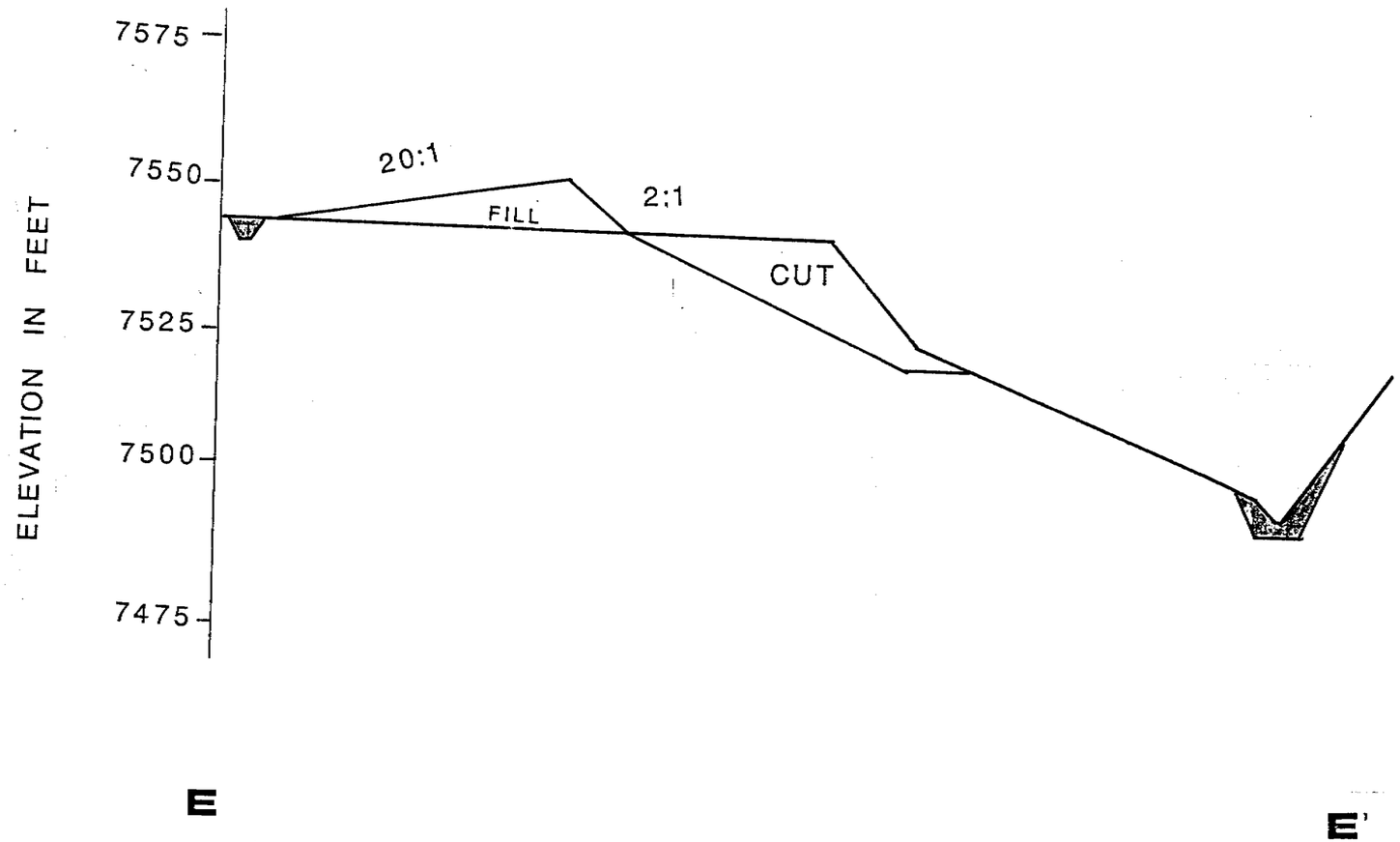

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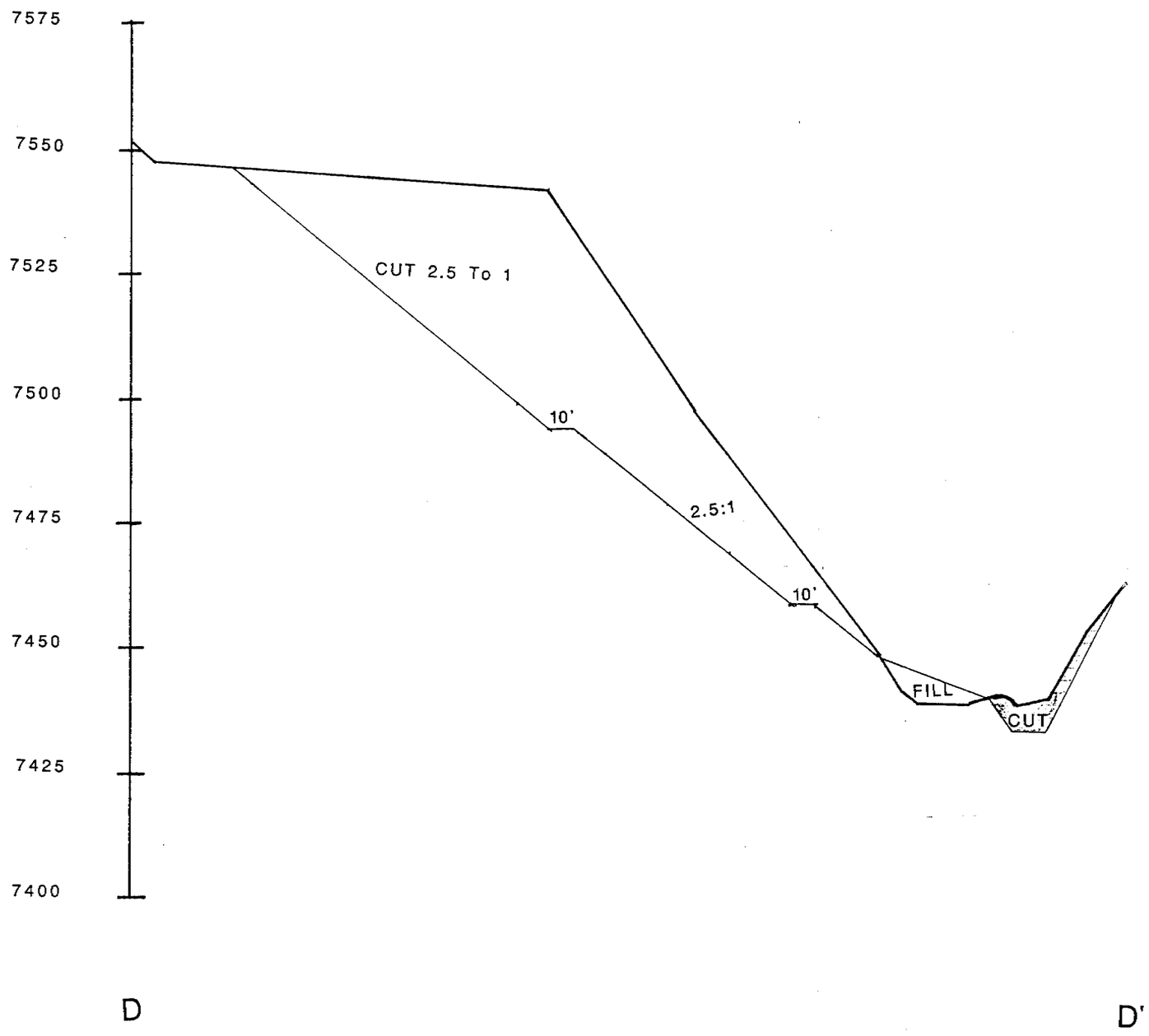

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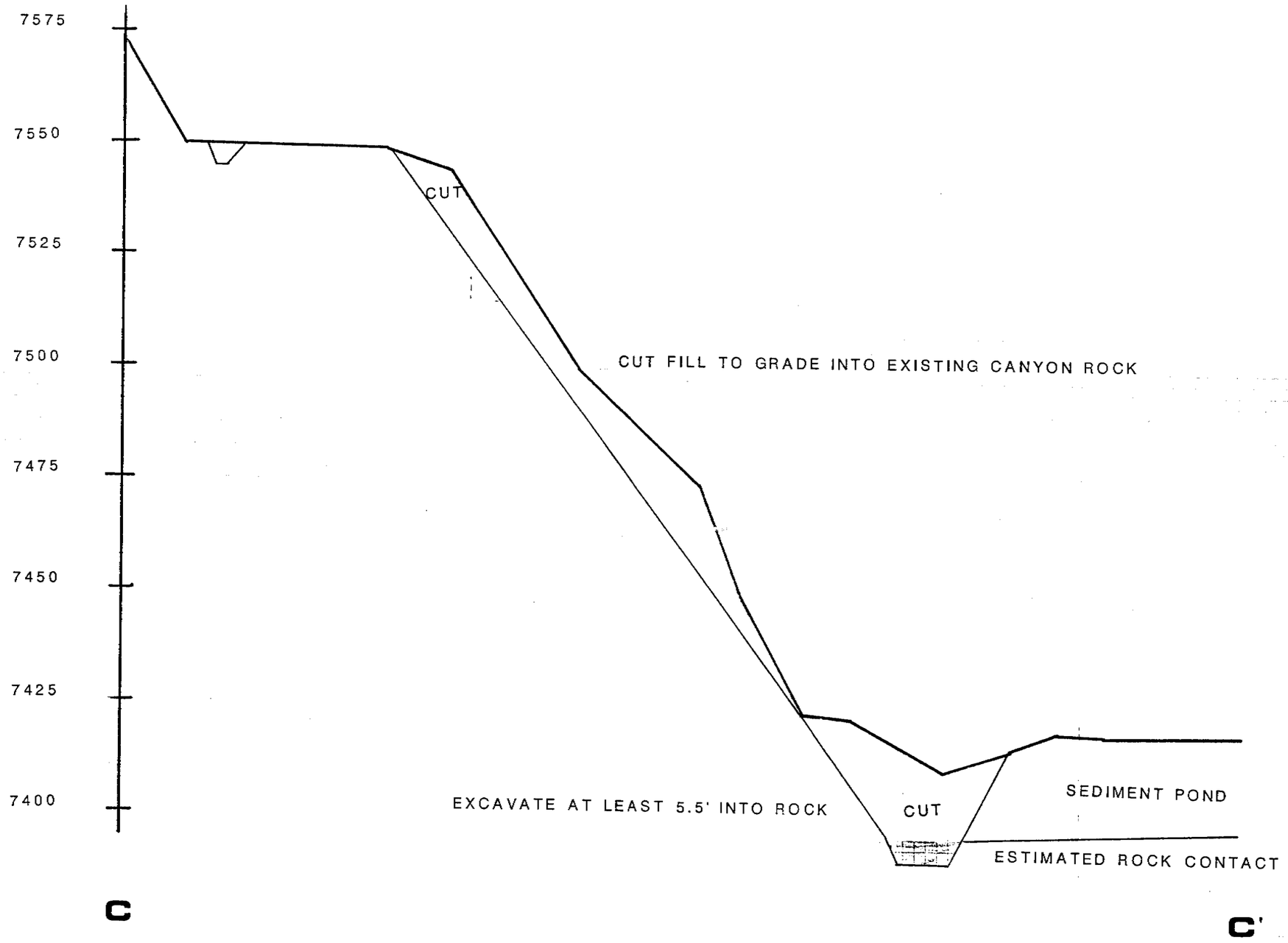

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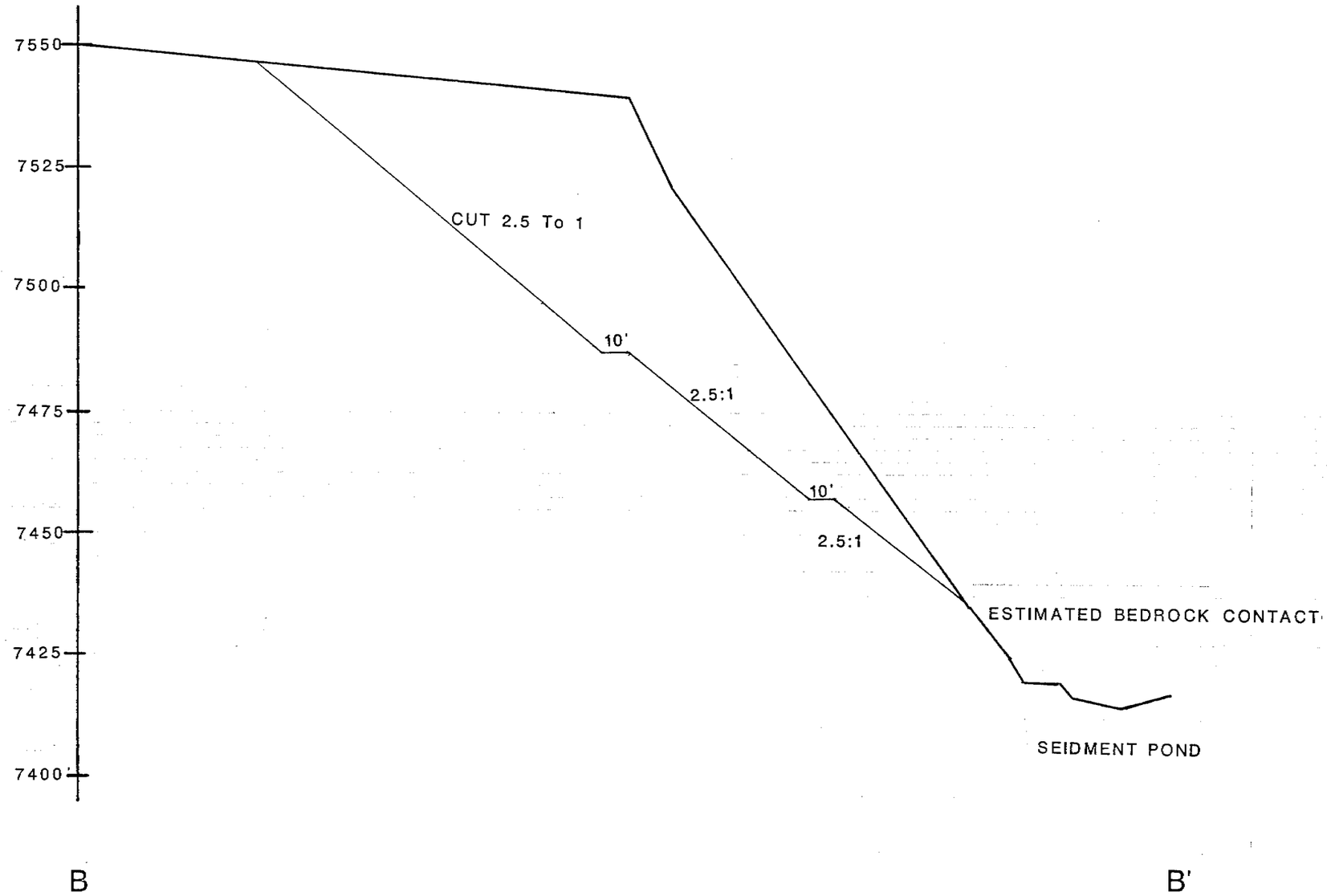

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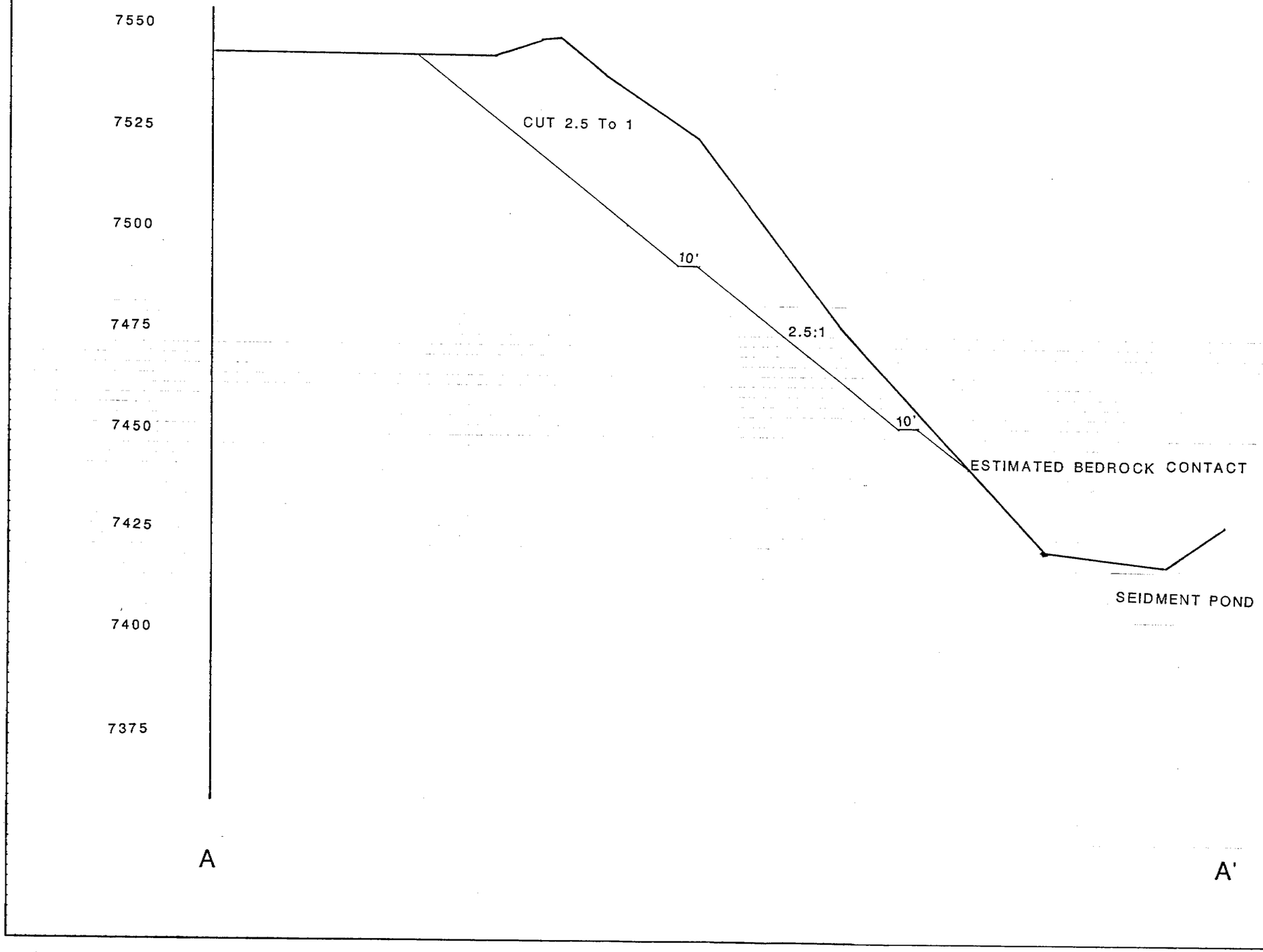

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