#9

ADDENDUM TO

BOKUM RESOURCES CORPORATION

GROUND WATER DISCHARGE PLAN

TO THE

NEW MEXICO ENVIRONMENTAL IMPROVEMENT DIVISION

FEBRUARY 5, 1979

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WATER POLLUTION
CONTROL

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INTRODUCTION

Included in this addendum report to Bokum Resources Corporation's Ground Water Discharge Plan submittal of August, 1978 are the responses to requests for additional information raised by the Environmental Improvement Division's letter of October 25, 1978 to Bokum Resources. The report is organized sequentially in sections by number corresponding to the questions in the memorandum from John Dudley and Bruce Gallaher of the Water Pollution Control Section of the EID which was included in the October 25, 1978 letter to Bokum Resources Corporation.

Bokum Resources Corporation (BRC) and its consultants Stears Roger (SR), Woodward-Clyde Consultants (WCC), and Science Applications, Inc. (SAI) have maintained close liason with each other and the EID in order to proceed as expeditiously as possible with the additional investigation that has been required. That liason has involved several meetings with EID and consultants to discuss and evaluate the suitability and criteria for additional investigations conducted by the above mentioned organizations.

In general, the concern expressed by the EID in their October 25, 1978 letter and attached memorandum may be divided into four general areas which include:

- definition of the shallow ground water flow in and adjacent to the proposed tailings impoundment area
- the proposed diversion of Canon de Marquez and Arroyo Hondo surface and ground water flow upstream of the tailings impoundment area to Canon de Santa Rosa

which is north-northeast of the tailings area.

— the integrity of the proposed seepage cutoff trench to prevent ground water flow from entering the tailings impoundment area and to prevent tailings liquids from exiting the impoundment area.

— adequacy of monitoring efforts to assure detection of any potential seepage from the tailings impoundment area.

The remainder of this report includes detailed descriptions of additional investigative efforts of BRC, SR, WCC and SAI to respond to those specific questions raised by the EID related to the four aforementioned general areas of concern.

Each following section is numbered to correspond to the 23 questions raised by EID. Each section is prefaced by the question raised by the EID from their October 25, 1978 correspondence.

Preface to Questions B-1 through 4 Raised by the EID

The first four questions raised by the EID from the October 25, 1978 letter deal with a more detailed evaluation of the shallow ground water system in and adjacent to the proposed Marquez tailings impoundment area. Specifically, the questions are related to providing more detailed maps showing areal extent of alluvial materials under and adjacent to the impoundment area, saturated thicknesses of alluvial materials, potentiometric surface of the alluvial system, and hydraulic characteristics of the alluvial materials.

Because BRC proposes to construct a compacted clay seepage cutoff trench to intercept ground water entering the impoundment area and prevent seepage from exiting the same area, definition of the shallow ground water within the impoundment area becomes less critical than in those areas immediately upstream and downstream of the impoundment area. As an alternative, SAI suggested that intensive field investigation in the areas where ground water flow is proposed to be intercepted by the cutoff trench would be of greater value in evaluating the shallow ground water system adjacent to the tailings impoundment area. Thus, two critical areas of ground water flow evaluation were defined as existing: (1) upstream of the tailings impoundment area where the proposed diversion ditch and adjacent seepage cutoff trench intersect Canon de Marquez, and Arroyo Hondo and (2) east of the downstream toe of the tailings dam and parallel to its axis.

On November 20, 1978, members of the Water Pollution Control Section of EID met to discuss with SAI the proposed field investigative effort to define the shallow ground flow regime in the aforementioned two critical areas. Details of well/piezometer completions, locations and testing efforts were discussed. At that time EID agreed that these two areas were indeed critical and would require the greatest effort.

In an effort to supplement the more detailed investigations of the two critical areas, SAI has reviewed in considerable detail the logs and cross sections prepared by WCC in their geotechnical investigations. Those logs and cross sections prepared by WCC have been included in two previous submitalls to the EID (Appendix J of BRC mill license application and Appendix A of BRC's Ground Water Discharge Plan submittal of August, 1978). Thus, in addition to SAI's intensive investigation in the two critical ground water areas, a map detailing the areas of saturation, saturated thicknesses and ground water elevations as discerned from WCC investigations throughout the tailings impoundment area is presented in Figure 1-1. It must be noted, that although the WCC borings are adequate for delineating saturated versus non-saturated areas, these borings were not intended for hydrological investigation. Thus, interpretation of the information on water level from the uncased WCC borings must be considered only in general. They are presented here because they are available, not because they are entirely suitable.

SAI's ground water investigation report to BRC is included as Appendix A to this report. This report gives details of field investigations in the two critical ground water flow areas. Specific responses to question B-1 through 4 follow.

B-1: A MAP SHOWING THE AREAL EXTENT AND THICKNESS OF ALLUVIAL MATERIALS UNDER AND ADJACENT TO THE TAILINGS DISPOSAL AREA.

As mentioned previously in the introduction to this section, details of the water level determinations conducted by SAI and WCC are compiled on Figure 1-1 (note that data presented by the two studies are shown by different symbols). The map shows areas of shallow ground water saturation, alluvial thickness (alluvium is defined as all materials including claystone, sand, sand and gravel, and silty sands overlying the competent unweathered Mancos Shale), saturated thickness, and ground water elevations. Use of the term alluvium is not meant to imply all materials are water-deposited nor that all material is interconnected as a single aquifer throughout the area of the tailings impoundment. In fact, it is likely that although ground water exists across the impoundment area, the groundwater between the two major aquifers (Canon de Marquez and Canon de Santa Rosa) is not a continuous aquifer connecting the two canons. It represents a small amount of perched ground water.

FIGURE 1-1
SATURATION ZONE
AND
DRILL HOLE MAP

B-2: A MAP SHOWING THE SATURATED THICKNESS OF ALLUVIAL MATERIALS IN THE SAME AREA SPECIFIED IN B-1.

Again, the reader is referred to Figure 1-1 and Appendix A for more detailed evaluations of the saturated thickness of the alluvial materials in and adjacent to the tailings impoundment area. It should also be noted here that comparison of ground water elevations and saturated thickness between those piezometers drilled by SAI (DD and TD locations - Figure 1-1) and the water levels of the WCC drilling (TH locations - Figure 1-1) are complicated by two factors:

— Drilling by WCC occurred August, 1977 to March, 1978 prior to any construction activity. Excavation of the seepage cutoff trench has significantly altered water levels adjacent to the proposed tailings dam in borings and piezometers subsequent to the water level measurements made by WCC.

— Interpretation of water level elevations in uncased weathered materials may be of questionable accuracy.

However, Figure 1-1 does provide insight to the horizontal extent of saturation in the tailings impoundment area. SAI studies indicate that in the diversion ditch area and downstream toe of the tailings dam, saturated thickness is controlled by proximity of the sand and gravel in and adjacent to Canon de Marquez (and Arroyo Hondo in the diversion ditch area) to the underlying dry unweathered Mancos Shale. Saturated thicknesses in the confined ground water condition sites were generally one to three feet and controlled primarily by the occurrence of fractures and gypsiferous layers in the weathered claystone overlying the unweathered Mancos Shale. In all drilling, the perched nature of both the unconfined and confined ground water systems was confirmed by recovery of hard, dry, competent shale under the water bearing zone with split spoon sampling through the hollow stem auger (see Appendix A). That is, the drilling results indicate water did not penetrate the unweathered shale.

In almost all cases saturated thicknesses are small and average about five feet, and range from less than one foot to as much as seven feet in the diversion ditch area and one to four feet in the tailings dam area. TH-18 drilled by WCC in September, 1977 showed a saturated thickness of 20 feet which when compared to the other ground water occurrences and ground water elevations appears anamolous for the area near Arroyo Hondo approximately midway between the diversion ditch and the tailings dam, and suggests that the level does not represent the true ground water elevation for the area.

B-3: A MAP CONTOURING THE POTENTIOMETRIC SURFACE WITHIN THE SATURATED ALLUVIUM IN THE SAME AREA

As mentioned previously, ground water elevations for WCC borings are not strictly comparable to water levels obtained more recently by SAI. However, Figure 1-1 does show ground water elevations for WCC borings reporting ground water. Figure 4 in Appendix A shows a more detailed potentiometric map for the shallow alluvium in the diversion ditch area. This potentiometric map was prepared using ground water elevations in the DD piezometer array in the diversion ditch area for purposes of assessing the shallow ground water baseflow in that area.

As mentioned in Appendix A, the hydraulic gradient in the diversion ditch area varies from 0.013 to 0.031 ft/ft. Prior to conducting the hydraulic investigation in the diversion ditch area, a small dam had been constructed across Arroyo Hondo for purposes of impounding water for construction purposes. This dam was drained prior to initiating the field investigations discussed herein. It is thought that much of the variability in saturated thicknesses and hydraulic gradient in this area may be attributable to residual effects of the impounded water in Arroyo Hondo.

The equipotential lines shown in Figure 4, Appendix A indicate flow moving parallel to the channels of Arroyo Hondo and Canon de Marquez in an east-southeasterly direction.

Elsewhere in the tailings impoundment area, it is not as easy to discern as precisely the potentiometric surface. In the tailings dam area, ground water flow directions have undoubtedly been affected by construction activity in the seepage cutoff trench. However, it is apparent that the ground water flow is to the east in the alluvial and confined claystone units as evidenced by ground water elevations throughout the area. The absence of ground water in WCC borings north from Canon de Marquez and Arroyo Hondo paralleling the diversion ditch alignment (TH-44, 53, 56) suggests that the saturated area reported in the La Laguna basin and eastward is a result of recharge from the playa lake basin of La Laguna and not the result of recharge from west of the tailings impoundment area.

B-4: A MAP UPON WHICH FIELD AND/OR LABORATORY SATURATED PERMEABILITIES ARE PLOTTED FOR ALLUVIAL SANDS AND GRAVELS IN THE SAME AREA AS ABOVE.

As discussed in the introduction to the sections dealing with shallow ground water flow (B-1 through 4), the two critical areas of ground water flow adjacent to the diversion ditch and tailings dam near Canon de Marquez and Arroyo Hondo are considered to be the most important in terms of providing quantitative description of ground water flow.

In order to accomplish this goal, part of SAI's field investigation included a pump test analysis of the shallow ground water flow in the sands and gravels of Canon de Marquez. As discussed in Section 3.0, Appendix A, a range of permeabilities of 585 to 1200 gallons/day/ft^2 (29,000 to 59,000 ft/yr) were determined from those tests. Based on ground water gradients and saturated cross sectional areas as discerned from the DD piezometer array, shallow ground water baseflow is estimated to be approximately 30 to 70 gallons per minute in the Canon de Marquez/Arroyo Hondo drainage.

B-5: DETAILED LITHOLOGIC LOGS FOR THE EXISTING MONITORING WELLS AND FOR ANY ADDITIONAL HOLES DRILLED TO GENERATE THE INFORMATION REQUESTED ABOVE.

Drilling logs of the piezometers (and BRMW monitor wells) are included in SAI's Hydrologic Investigation Report included as Appendix A of this addendum report. Drilling logs and cross sections of the WCC Geotechnical report have been submitted in BRC license application (Appendix J). Also included with the logs of SAI's piezometer installations are schematic representations of the piezometers showing lithologies and piezometer completion information.

B-6: RESULTS OF A SUFFICIENT NUMBER OF FIELD AND/OR LABORATORY SATURATED PERMEABILITY TESTS CONDUCTED ON SO-CALLED "ZONE I" MATERIALS TO ADEQUATELY DEFINE THE RANGE OF PERMEABILITIES FOR THESE MATERIALS.

The reader is here referred to Appendix B containing the WCC report on Zone I material testing. This report contains information and calculations pertaining to questions B-6, 7, 8, 11, and 12 of the EID memo of Octboer 25, 1978.

Tests were performed by WCC on twelve samples representative of Zone I material from selected borrow area locations. It was considered that the selection of a range of representative samples would be more expeditious and as valid a technique for determining the range of permeabilities of compacted Zone I material as testing 50 to 100 random samples.

Results of the permeability tests conducted by WCC indicate permeability values for compacted Zone I materials considerably lower than the values assumed for purposes of seepage calculations. Tests were done with both demineralized water and simulated acidic raffinate liquid. Permeability determinations were in accordance with U.S. Bureau of Reclamation Permeability and Settlement of Soils, Designation E-13, USBR Earth Manual, 1974 (see Appendix B for test description). Average water permeability for the Zone I material was 0.026 ft/yr (2.6 X 10^{-8} cm/sec). Permeability values for artificial raffinate tests were below equipment sensitivity (<.001 ft/yr), indicating that the interaction of raffinate and Zone I materials will produce some solid precipitate such as gypsum or induce additional clay swelling to produce lower permeabilities. The presence of slightly calcareous soils in the borrow areas suggests precipitation of hydrated calcium sulphate (gypsum) would be likely when Zone I materials are mixed with the acidic (sulfuric acid) raffinate.

B-7: DETAILED DESCRIPTION OF WHERE "ZONE I" SAMPLES WERE COLLECTED, HOW THEY WERE PREPARED, AND/OR HOW THE PERMEABILITY TESTS WERE PERFORMED.

Table I of Appendix B contains a summation of test results of permeabilities for the twelve selected Zone I samples. The locations of sample collection are also reported in the same table. The samples were selected from borrow areas near the tailings dam excavation stockpile and the diversion ditch excavation area.

Tests were performed on the -3/4 inch fraction of the twelve representative Zone I samples. Appendix B provides complete details on the USBR procedures followed in making the permeability determinations on the twelve Zone I material samples.

B-8: A DETAILED LITHOLOGIC DESCRIPTION OF EACH ZONE I SAMPLE TESTED.

Again, the reader is referred to Table I of Appendix B for a lithologic description of the Zone I samples selected. Lithologies of these samples, borings by WCC, and descriptions used by SAI in their field investigations were made using the Unified Soils Classification System (USCS). Figure 8-1 shows the lithologic description of USCS descriptions. Ranges of lithologies from sandy silty gravel (GP-GM) to silty lean clay (CL) are reported for the Zone I material samples which were tested.

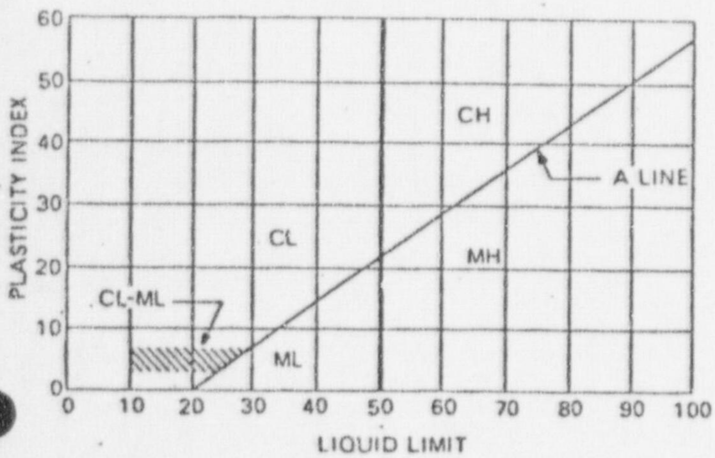
UNIFIED SOIL CLASSIFICATION SYSTEM

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

FIGURE 8-1

B-9: INFORMATION ON THE CHEMICAL QUALITY OF THE TAILINGS EFFLUENT.

Table 9-1 shows the estimated chemical quality of the tailings effluent. The references for sources of quality data are shown on the table. Water quality determinations for the tailings effluent will be monitored and reported as discussed in Section 18.

ANTICIPATED TYPICAL ANALYSIS OF WASTE
LIQUORS SENT TO TAILINGS DAM
(g/l)

U_3O_8	0.01	Al	0.4	Zn	0.01
V_2O_5	0.01	Mn	0.4	SO_4	2.0
Mo	0.003	Mg	0.2	PO_4	1.0
As	0.004	Ti	0.01	Cl	0.3
Ca	0.8	Cu	0.01	Ra-226	3000 pCi/l
Fe (total)	4	Ni	0.002	Se	0.006
Fe +2	1	Cr	0.001	pH	2
Si	1	Sn	0.004		
Na	0.7	Pb	0.005		

TABLE 9-1

ANTICIPATED TAILINGS EFFLUENT QUALITY

Reference

1. Hazen Research, Inc. (raffinate tests on BRC ore leach)
2. Environmental Survey of Uranium Fuel Cycle, Report-1248, U. S. Atomic Energy Commission Division of Licensing, Washington, D. C., April, 1974.
3. L. Storm, Marquez Mill Superintendent, personal communication, Janaury, 1979.

B-10: A DETAILED EXPLANATION OF THE SOURCES OF PROCESS LIQUIDS GOING TO THE TAILINGS PILE, AS WELL AS QUANTITIES TO BE RECYCLED TO THE MILL.

Figure 10-1 shows the maximum capacity mill process flow chart. Included on that flow chart are the estimated process liquids (acid, flocculant, make-up water, chemicals, etc.). Figure 10-2 shows the estimated liquids to tailing, stage capacity curve, stage time curve. From that drawing the following liquids to tailings rates are anticipated:

262 gpm, tailings
155 gpm, raffinate (85% recycle)
103 gpm, annual precipitation (Stages I & II)
132 gpm, annual precipitation (Stages III, IV and V)

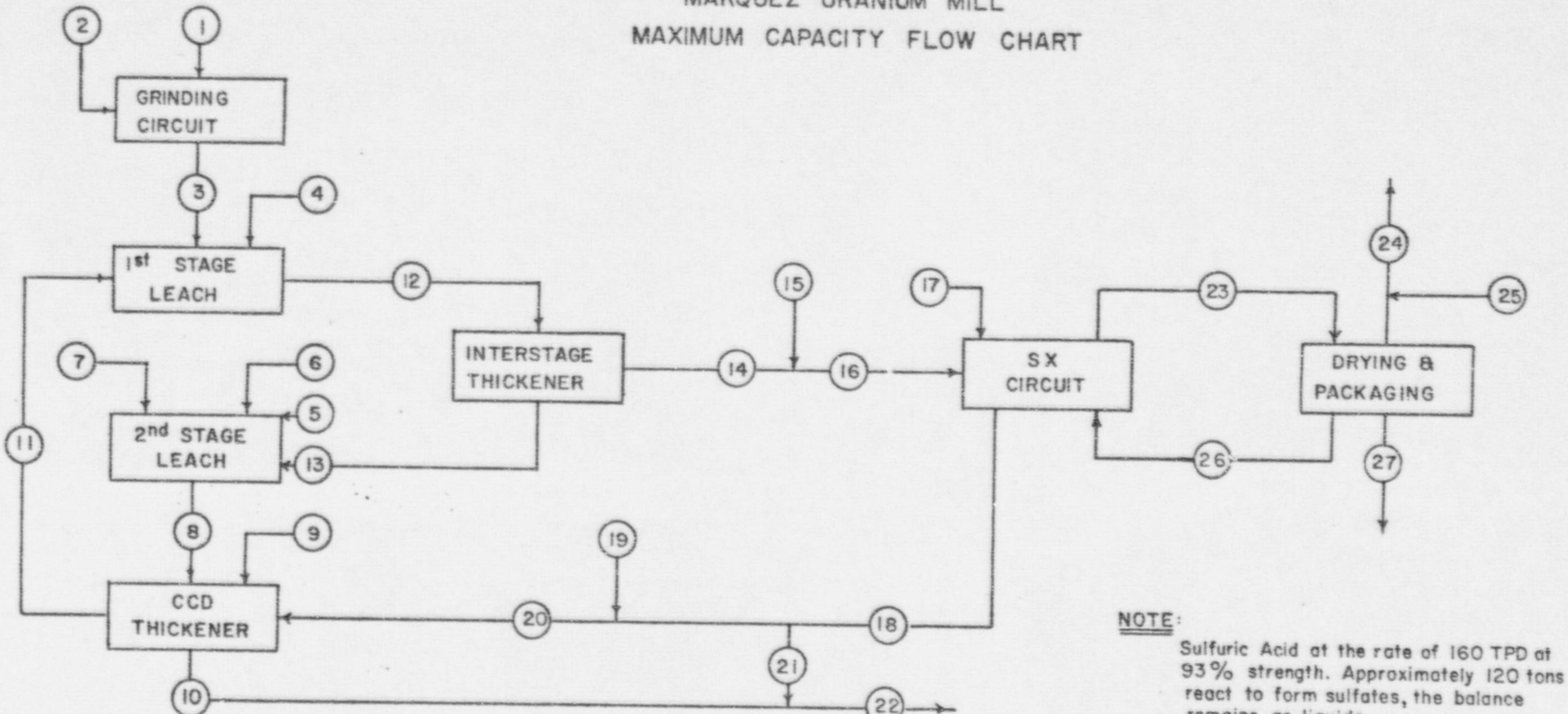
Based on investigations summarized in Appendix A of this addendum

50 gpm, shallow ground water inflow

Activation of Stage II dam construction is initiated when the liquid pool elevation reaches 6540 ft (MSL). The entire seepage cutoff trench will be completed at the end of Stage II construction. Thus, shallow baseflow from Canon de Marquez and Arroyo Hondo will be blocked and diverted upon completion of Stage II construction.

MARQUEZ URANIUM MILL

MAXIMUM CAPACITY FLOW CHART



NOTE:

Sulfuric Acid at the rate of 160 TPD at 93% strength. Approximately 120 tons react to form sulfates, the balance remains as liquids.

DESCRIPTION	TONS/DAY SOLID	TONS/DAY LIQ.	DESCRIPTION	TONS/DAY SOLID	TONS/DAY LIQ.	DESCRIPTION	TONS/DAY SOLID	TONS/DAY LIQ.	DESCRIPTION	TONS/DAY SOLID	TONS/DAY LIQ.	DESCRIPTION	TONS/DAY SOLID	TONS/DAY LIQ.
(1) ORE	2200	388	(7) SULFURIC ACID	0	40	(13) THICKENER UNDERFLOW	2200	1728	(18) RAFFINATE	0	6063	(24) STEAM	0	5
(2) MINE WATER	0	797	(8) CCD FEED	2197	1976	(14) THICKENER OVERFLOW	0	5836	(19) MAKE - UP WATER	0	946	(25) WATER SCRUBBER	0	6
(3) NEUTRAL PULP	2200	1185	(9) FLOCCULANT	0	73	(15) FLOCCULANT	0	62	(20) WASH SOLUTION	0	6050	(26) DRIER RETURN	0	6
(4) WATER SCRUB	0	6	(10) THICKENER UNDERFLOW	2197	1726	(16) PREGNANT SOLUTION	0	5898	(21) BLEED	0	959	(27) PRODUCT	3	0
(5) STEAM	0	190	(11) THICKENER OVERFLOW	0	6383	(17) SODIUM CARBONATE	0	164	(22) TO TAILINGS	2197	2685			
(6) SODIUM CHLORATE	0	16	(12) THICKENER FEED	2200	7568				(23) NEUTRAL STRIP	3	5			

FIGURE 10-1

FIGURE 10-2
LIQUID TO TAILINGS
AND
TAILINGS POOL ELEVATION

B-11: SEEPAGE CALCULATIONS, ASSUMED PERMEABILITIES, AND MODELS USED TO ARRIVE AT THE ESTIMATED 0.01 CFS. SEEPAGE LOSS.

B-12: SEEPAGE LOSS CALCULATIONS FOR THE COLLECTION DITCH AND EVAPORATION POND

The reader is again referred to Appendix B containing the WCC Zone I testing report. It should be noted that althought the permeability tests performed by WCC indicate average permeabilities of 0.026 ft/yr, the calculations regarding seepage losses used a permeability value of 1 ft/yr. Thus, the reported seepage loss values are considered to be conservative by a factor of approximately 40X.

The results of the seepage calculations using the permeability value of 1 ft/yr are summarized below:

— seepage through dam cutoff trench	= 0.0063 cfs
— seepage under dam filter blanket	= 0.0005 cfs
— seepage through collection ditch lining	=<0.0001 cfs
— seepage through evaporation pond	= 0.0035 cfs
— seepage through "reservoir" cutoff trenches	= 0.0014 cfs
TOTAL SEEPAGE	= 0.0118 cfs

Detailed calculation of seepage through these zones is presented in Appendix B.

B-13: A COMPLETE SET OF DESIGN DRAWINGS FOR THE REDESIGNED DIVERSION DITCH AND DAM TO BE LOCATED UPSTREAM OF THE TAILINGS DISPOSAL AREA.

The diversion channel was redesigned following a meeting between EID, NRC, BRC and consultants on October 3, 1978. The resulting modifications included widening the channel to 40 feet at the bottom, decreasing the channel slope to 0.2%, and riprapping the channel to above the level of the probable maximum flood flow. Subsequently, the geomorphologic aspects of the diversion channel have been investigated by Dr. Peter F. Lagasse (consultant to the EID) and Dr. Stanley A. Schumm (consultant to BRC).

Dr. Schumm has proposed that the diversion channel be constructed essentially as orginally planned, then allowed to degrade to its natural gradient (approximately 1.8%), with BRC insuring that the channel be brought to this gradient by mechanical means, if necessary.

The present design concept incorporates the natural erosion concept specifically as follows:

1. Elimination of riprap on the floor and west slope of the diversion channel.
2. Addition of a ten foot wide by four foot deep cut at the centerline of the diversion channel as a "starter cut" for natural erosion.
3. Addition of a 200 foot radius approach to the diversion channel for Canon de Marquez, resulting in a wide transition section.

4. Reduction of the "n" value for the diversion channel and approach channel at PMF to 0.025. The result is higher velocities at lesser depth of flow. Calculated depth of the PMF flood at the point of diversion is 23.6 feet leaving a freeboard of 8.4 feet with a dam height of 32 feet. Calculated depth through curves #1, #2, and #3 is 26.3 feet, leaving a freeboard of 5.7 feet.

5. Riprap was re-evaluated at the point of diversion, using USBR chart for stone sizing below stilling basins. Twenty-four inch stone size was selected with blanket thickness of 36 inches.

Applicable diversion channel design drawings included as a part of this report, are 08-2-24, 08-2-26, and 08-2-38. Additionally, applicable design computations are included (see Appendix C). Also included in Appendix C are the additional following materials:

1. Dr. Stanley Schumm's report to Stearns Roger.
2. Stearns Roger's calculations pertaining to modifications of the diversion ditch as discussed above.

If required, as an alternative to stabilization of the channel by natural erosion, BRC will mechanically achieve the ultimate channel section and gradient (approximately 1.8%) during the first five years of mill operation.

B-14: A DETAILED TOPOGRAPHIC MAP SHOWING THE ROUTE OF THE TAILINGS SLURRY LINE FROM THE THICKENERS TO THE INFLECTION LINE OF THE TOPOGRAPHY EAST OF THE MILL SITE,

a. DETAILS OF HOW A TAILINGS SLURRY SPILL IN THIS AREA WOULD BE CONTAINED AND PREVENTED FROM FLOWING NORTH AND WEST INTO MARQUEZ CANYON UPSTREAM OF THE PROPOSED DIVERSION DAM,

b. DESCRIPTION OF HOW RUNOFF FROM THE MILL AREA IS DIVERTED AND CONTROLLED.

Appendix D at the back of this report contains design drawings for the tailings distribution system, and descriptions of piping, energy dissipators, pipe flow capacities etc. The key plan and drawing index map shows the route of the tailings line from the mill area to the mesa "inflection point" and routes of the line to distribution spigots on the tailings dam and diversion ditch embankment.

As may be discerned from the key map, at all points along the slurry line route, drainage will flow into the tailings impoundment area. Thus, an uncontrolled slurry line break at any point on the slurry line will flow to the tailings impoundment area. The additional drawings in Appendix C contain detail line grades and profiles for the tailings line distribution system.

Stearns Roger drawing number 08-2-31 (Appendix D) shows a plan view of the mill area. As noted on the drawing, the north side of the mill area shows a runoff interception ditch which will be used for diverting precipitation runoff from the mill area. This ditch daylights on the east side of the mill area approximately 30 feet north of the inflection point for the tailings slurry line. The entire mill area is graded to prevent runoff from draining off the mesa to its northern side. Additionally, all leach tanks, solvent extraction tanks, and other chemical storage facilities have primary containment structures surrounding the particular vessels. Grading in the mill area will provide drainage to the northern collection ditch.

B-15: DESCRIPTION OF SAMPLE COLLECTION AND HANDLING PROCEDURES FOR ALL SURFACE AND GROUND WATER DATA PRESENTED, AND A SAMPLE COLLECTION DATE AND LOCATION FOR SAME.

Since August, 1978 when the BRC Ground Water discharge plan was filed, two additional water quality sampling trips were made in September and December to the Marquez area. Table 15-1 presents the results of the most recent water quality analyses from the Marquez area. Analytical results for the sampling trip in December, 1978 are not yet complete.

Table 15-2 includes a description of the sample collection, handling and location for the water quality data presented in Appendices B and C of the Ground Water Discharge Plan submittal of August, 1978.

	BRSR-1	BRSR-2	BRSR-3
Ra-226 (pCi/l) (total)	<.6	1.1 ± 0.4	1.7 ± 0.6
*Th-230(pCi/l)(total)	1.1 ± 0.5	0.7 ± 1.2	0.0 ± 0.9
U (total)	0.003	0.013	0.011
Ra-226 (pCi/l)	0.7 ± 0.3	0.9 ± 0.3	1.4 ± 0.5
*Th-230 (pCi/l)	5.3 ± 2.1	<.8	<.6
U	0.006	0.022	0.016
As	<.01	<.01	<.01
Ba	<.1	<.1	<.1
Cd	0.001	<.001	0.001
Co	<.01	<.01	<.01
Fe	0.23	0.08	0.04
Pb	<.001	<.001	<.001
Mn	0.013	0.011	0.004
Mo	0.001	0.001	0.001
Ni	<.01	<.01	<.01
Se	<.01	<.01	<.01
NO_3 as N	<.01	0.2	0.1
Cl	7.0	32.	30.
F	0.33	0.66	0.64
SO_4	309.	407.	411.
TDS	340.	1080.	1052.
pH	8.4	8.9	8.9
TSS	19.	23.	31.

(all analyses, handling and collection as per specifications in Table 18-1 all concentrations in mg/l except where noted)

*NOTE: Radiometric analyses reporting counts <20 pCi/l typically show levels which are higher in dissolved fraction than in the total determination because of high analytical errors in ranges approaching limits of detection.

TABLE 15-1

SURFACE WATER QUALITY DATA COLLECTED 9/8/78

Water Level	BRMW-2	BRMW-3	BRMW-4	BRMW-5	BRMW-6
(Ft below Land Surface	10.2	3.50	6.03	3.20	10.00
Ra-226 (total)	1. ± 0.3	7.8 ± 1.6	1. ± 1.6	7.5 ± 2.1	1.3 ± 0.3
Th-230 (total)	8. ± 4.4	<.6	<.6	2.5 ± 0.8	0.6 ± 0.2
U (total)	0.009	0.02	0.011	0.012	0.012
Hg (total)	0.002	0.0011	<.0004		<.0004
Ra-226	<.6	2.3 ± 0.3	<.6	<.6	<.6
Ra-228	1. ± 1.	3. ± 1.	3. ± 1.	1 ± 1	1 ± 1
Th-230	7.1 ± 3.1	2.8 ± 1.	1.1 ± 0.8	3.4 ± 0.9	2.1 ± 1.
U	0.009	0.010	0.017	0.013	0.018
Al	<.1	0.4	0.2	<.1	0.2
As	<.01	<.01	<.01	<.01	<.01
Ba	<.1	<.1	<.1	<.1	<.1
Cd	0.003	0.003	0.002	0.002	0.001
Cr	0.067	<.001	<.001	<.001	<.001
Cu	0.006	0.006	0.006	0.005	0.007
Pb	0.001	<.001	0.001	0.001	0.002
Fe	0.02	0.07	0.07	0.07	0.07
Mn	0.16	0.95	0.072	0.016	0.044
Co	<.01	<.01	<.01	<.01	<.01
Mo	0.002	0.003	0.003	0.003	0.003
Ni	<.01	<.01	<.01	<.01	<.01
Ag	<.01	<.01	<.01	<.01	<.01
Zn	0.07	0.04	0.04	0.03	0.04
Se	<.01	<.01	<.01	<.01	0.01
Cl	45.	48.	13.	44.	15.
F	0.76	0.69	0.58	0.76	0.46
SO_4	1000.	768.	2110.	1980.	2030.
TDS	1889.	1590.	3410.	1070.	3420.
NO_3	0.2	0.2	1.1		0.2
pH	7.7	7.5	7.7	7.9	7.7

(all sample collection, handling as per specification on Table 18-1)
(all concentrations in mg/l also except Ra-226, Th-230, Ra-228 in pCi/l)

TABLE 15-1 (CONT'D)

GROUND WATER QUALITY COLLECTED 9/7/78

SAMPLE IDENTIFICATION	DATE(S) OF COLLECTION	SAMPLING TECHNIQUE	HANDLING	LOCATION DESCRIPTION
BRW-1	9-8-77	1	6	Spring discharge from base of Point Lookout Sandstone (Ojo Marquez) in headwaters of Canon de Marquez.
BRW-2	9-8-77	2	6	Artesian well tapping Point Lookout Sandstone at the head of Canon de Marquez.
BRW-4	9-8-77	1	6	Marquez Mine discharge; reportedly major water production in shaft at the time from Tres Hermanos Sandstone.
BRW-5	9-8-77	1	6	Canon de Marquez immediately upstream of mine
BRW-6	9-8-77	1	6	Road crossing in Canon de Marquez immediately south of townsite.
BRW 7A - 7G	10-5-77	1	6	Equally spaced sampling locations in Canon de Marquez from immediately downstream of mine to the tailings impoundment area.
BRSR-1	3-6-78, 4-3-78 5-1-78, 9-5-78 12-12-78	1	6	Immediately upstream of mine in Canon de Marquez (same as BRW-5 above)
BRSR-2	3-6-78, 4-3-78 5-1-78, 9-5-78 12-12-78	1	6	Immediately downstream of mine in Canon de Marquez.
BRSR-3	3-6-78, 5-1-78 5-1-78, 9-5-78 12-12-78	1	6	Same as BRW-6
BRMW-2	3-6-78, 4-3-78 5-1-78, 9-5-78 12-12-78	3	6	In Canon de Marquez immediately upstream of the proposed diversion ditch.
BRMW-3	3-6-78, 4-3-78 5-1-78, 9-5-78 12-12-78	3	6	In Canon de Marquez downstream of the proposed seepage evaporation dam.

TABLE 15-2

SAMPLE LOCATION

SAMPLE IDENTIFICATION	DATE(S) OF COLLECTION	SAMPLING TECHNIQUE	HANDLING	LOCATION DESCRIPTION
BRMW-4	3-6-78, 4-3-78 5-1-78, 9-5-78 12-12-78	3	6	In Canon Seco upstream of its confluence with Canon de Marquez.
BRMW-5	3-6-78, 4-3-78 5-1-78, 9-5-78 12-12-78	3	6	In Canon de Marquez immediately downstream of its confluence with Canon Seco.
BRMW-6	3-6-78, 4-3-78 5-1-78, 9-5-78 12-12-78	3	6	In Canon de Santa Rosa east of the northwest corner of the tailings dam.
Table 2.6.1C previous Disc. Plan Submittal	4-19-76	4	7	Exploration well uncased (see coordinate location Table 2.6.1C of Ground Water Discharge Plan.
Mine Well	4-19-76	5	7	Mine supply well completed in Gallup Sandstone (MAR-131B sheet 2 of 2 of Ground Water Discharge Plan).

COLLECTION

1. Rinse new sample container and submerge or dip from stream with acid rinsed and washed polyethylene cup.
2. Artesian flow to new container after rinse with sample.
3. Water level measure, bail dry, return next day and bail sample after rinsing bailer and new sample container with ground water sample.
4. Swab.
5. Submersible pump.

HANDLING

6. As per specifications in Table 18-1.
7. Unknown

TABLE 15-2 (CONT'D)

B-16: ADDITIONAL DATA (I.E. GEOPHYSICAL LOGS, PREPARED CROSS SECTIONS, ETC.) WHICH DOCUMENT THE PRESENCE OR ABSENCE OF FAULTS IN THE TAILINGS DISPOSAL AREA.

As noted of Figure 2.3 of the Ground Water Discharge Plan submittal of August, 1978, an inferred fault has been located based on geophysical logs obtained from BRC. Copies of these geophysical logs for exploration holes 392-B, 396-B, 439-B 390-B, and 394-B are included as Appendix E of this document.

The second fault area discerned from the State Geologic Map is shown traversing the Mesa Marquez area near the mill site. On November 2, 1978, Jay Lazarus of the EID made walking traverses of the faulted area on Mesa Marquez to examine the area. He reported that no apparent large vertical displacement was evident, but that jointing and minor faulting of the Gallup Sandstone which caps the mesa was apparent. There is no additional evidence to infer that the fault extends further north into the tailings impoundment area either from visual observation from atop the mesa or from exploration logs of the area. As discussed in Sections 18 and 20, monitoring of the upper Tres Hermanos Sandstone in the vicinity of the fault zone east of the tailings dam is proposed.

B-17: MAPS, LEGAL COVENANTS, LEASES AND NARRATIVE DETAILING THE LAND OWNERSHIP, LAND USAGE PATTERNS, LAND USE RESTRICTIONS, AND PRESENT/PROJECTED SHALLOW GROUND WATER WITHDRAWALS ALONG THE MARQUEZ CANYON-SALADO CREEK DRAINAGE SYSTEM FROM MARQUEZ TO GOTERA VILLAGE

Bokum Resources Corporation controls land ownership and usage in the vicinity of the Marquez tailings impoundment area as detailed in two agreements: (1) Lease by and between Bokum Resources Corporation and the Juan Tafoya Land Grant (see Appendix F-1); (2) Purchase agreement by and between Bokum Resources Corporation and the Juan Tafoya Land Corporation, successor to the heirs of Juan Tafoya Land Grant (see Appendix F-2).

The lease with the Juan Tafoya Land Grant covering lands as shown on plate attached to Appendix F-1 provides for the following which relate to this ground water discharge plan addendum:

— Term of Lease - Lease shall extend for a primary term of five (5) years from March 31, 1975, and shall be automatically renewed for a second five (5) year term at the option of Bokum Resources Corporation upon payment of value in cash and so long thereafter as Bokum Resources is conducting mining operations or an active exploration program upon the property.

— Bokum Resources has the exclusive right and privilege to (1) explore for, develop, extract, mill, store, and market all minerals, metals and ores: (2) to use so much of the surface as may be necessary in connection with the foregoing operations; and (3) to use said production facilities installed on the property for the additional purpose of producing metals, ores, minerals or materials from lands which are owned, operated or controlled by Bokum Resources adjacent to or nearby the property. Such right to use said production facilities may continue after the expiration of the lease so long as use is required by Bokum Resources in connection with operations on said adjacent or nearby lands.

— Bokum Resources shall have the right to drill and maintain water wells upon the property and shall have the right to use all of the water developed without charge.

The purchase agreement, dated May 3, 1978, by and between Bokum Resources Corporation and the Juan Tafoya Land Corporation (formerly known as the Juan Tafoya Land Grant) provides for the purchase of surface rights to land as shown on plat attached as Appendix F-3 and specifically relates to the ground water discharge plans as follows:

— Bokum Resources Corporation is the fee title holder of the deeded property (approximately 1,000 acres). There is no reversion in the agreement during the first initial 20 years and Bokum Resources Corporation can continue ownership with notice and exercise of option with the result of continuing ownership for two additional one year periods. At the expiration of the 20 years, plus two option periods of ten years each, title to the property will revert to the Juan Tafoya Land Grant corporation upon "discontinuance of the ownership of the property or the mill operations thereon."

- Bokum agrees to construct a fence encompassing the acreage purchased to prevent animal entrance.
- Bokum Resources is permitted to reroute certain roads which presently exist and which presently run through or into the property, as well as certain waterways presently existing upon the premises. The Juan Tafoya Land Corporation grants the authority to Bokum to reroute any of said roads and waterways around the property conveyed to Bokum.
- The Juan Tafoya Land Corporation agrees to cooperate with Bokum in its aim of constructing and maintaining facilities upon said property, including ingress and egress, without interruption from any of the Corporation's stockholders or officers and the Corporation agrees to exercise reasonable efforts to prevent any stockholders from constructing any buildings, whether domestic or commercial, within one-half (½) mile of the outside boundaries of the tailings pond.
- Bokum agrees that upon discontinuance of ownership of said property or the milling operations thereon, Bokum shall restore the property by complying with all federal and state law and regulations pertaining to restoration but not less than the placing of top soil upon said property where top soil is required for vegetation growth.
- Upon expiration of ownership under this agreement when Bokum discontinues mill operation and use of the property for that purpose, the lease of March 31, 1975, referred to above shall remain in full force and effect unless otherwise terminated as provided in said lease.

There are certain private tracts of land located within the boundaries of the Juan Tafoya Land Grant and certain of these private tracts are within one-half mile of the exterior boundaries of the ultimate tailings pile. For purposes of elaboration, these tracts will be considered in two groups. The first group lies within one-half mile and upstream of the tailings area, and the second group lies within one-half mile and downstream of the tailings area.

The tracts that are located one-half mile and upstream of the tailings area are described as Tracts 3A, 4A, 6A, 7A, 63 and the La Joya Tract. Bokum Resources Corporation has mineral leases on Tracts 3A, 4A, 6A and 7A. Copies of those leases are attached hereto as Appendix F-4.

The tracts downstream and within one-half mile of the tailings area are known as the El Bosque Tract and the Loma Larga Tract. The El Bosque Tract is owned by Bokum Resources Corporation with title vested in them with the subsequent agreement that only after discontinuance of all mill operationswill the tract be reconveyed to the previous grantors or their heirs and assigns. Copies of the purchase agreement survey and deed are attached hereto as Appendix F-5. Bokum Resources Corporation has no contractural agreement or lease agreement with the tract known as Loma Larga.

All private tracts, whether upstream or downstream, within the one-half mile perimeter of the tailings area, are presently not being used for any residential purposes and if any grazing is taking place on those lands, it is to a very limited extent. No water wells exist on any of these private tracts. It is also important to point out that regardless of the ownership of the private tracts of the land grant itself, no residences are located within one-half mile of the perimeter of the proposed tailings area.

For reference only, note is made of Tract 5A which is located on the eastern boundary of the Juan Tafoya Land Grant and is outside the one-half mile perimeter of the tailings area. Bokum Resources Corporation has a mineral lease on Tract 5A, and is attached as Appendix F-6.

All land east of the eastern boundary of the Juan Tafoya Land Grant along the Salado Creek drainage is owned by Sohio and Reserve Oil and Minerals for approximately two and three-quarters (2-3/4) of a mile.

Present and future downstream potential shallow ground water use between the tailings dam and the property boundaries in Canon de Marquez is unlikely as Bokum intends to intercept and divert both shallow ground and surface water runoff upstream of the tailings impoundment area and divert this to Canon de Santa Rosa. Thus, the area between the tailings dam and the confluence of Canon de Marquez with Canon Seco and Canon de Santa Rosa (coinciding closely with the eastern Juan Tafoya Land Grant) will be deprived of previous recharge sources which would normally provide shallow ground water to this area and ground water in Canon de Santa Rosa will increase by an equivalent amount. The extent of the ground water recharge diversion has been estimated (based on baseflow rate at the diversion ditch) to be approximately 30 to 70 gallons per minute (≈100 ac-ft/yr). Bokum Resources Corporation currently has water rights to divert this diminished ground water recharge source. Thus, it would be advantageous for any potential future land owner to seek shallow ground water supply in the Canon de Marquez/Salado Creek area downstream from the tailings dam at points east of the property boundary where the shallow ground water recharge of Canon Seco and Canon de Santa Rosa has been added to the Salado Creek shallow ground water system. The principles of the Juan Tafoya Land Grant will be advised of this situation so that in the future they in turn may advise any potential ground water developers of the depleted shallow ground water resource in the area immediately downgradient of the tailings impoundment area.

The two ground water discharge sites identified on the Salado Creek drainage downstream of the tailings dam site on the La Gotera 7½ minute USGS topographic map were visited by members of the EID on November 2, 1978 with SAI staff. It was noted that the well located slightly west of the Evans Ranch was abandoned and in a state of disrepair. The well/spring at the Evans Ranch was not visited. Efforts to contact the occupants of Evans Ranch for the intent of obtaining well information and water quality samples have been unsuccessful to date. John Nixon of the New Mexico State Engineer's Office was contacted on January 19, 1979 to inquire if drillers logs or other well information on the two above mentioned wells (Section 34, T13N, R4W) were available from the State Engineer's Office. Mr. Nixon reported that the Water Rights Division of the SEO had no information on those two well locations. As noted above, it is stated that the proposed monitoring plan will detect any seepage from the tailings dam early enough that remedial action can be taken to collect any contaminated ground water prior to its exiting the Juan Tafoya Land Grant. Therefore, it is not considered that further documentation of ground water use/withdrawals further east in the Salado drainage are necessary. Bokum will intercept any contaminated ground water exiting the impoundment area prior to its moving off the property boundary.

B-18: A DESCRIPTION OF THE RATIONALE USED IN DESIGNING THE GROUND WATER MONITORING PROGRAM.

In designing the ground water monitoring system for the Marquez tailings impoundment system, the following areas are of importance:

— In the vicinity of the diversion ditch and the adjacent seepage cutoff trench approximately 300 to 400 feet east of the ditch.

— To the east of the downstream toe of the tailings impoundment dam.

— Directly east of and approximately parallel to the axis of the tailings dam near an inferred fault which has been tentatively located based on exploration borings (see Section 16 for discussion and Figure 18-1).

— In the southeast corner of the tailings impoundment area where the tailings dam is separated by a knoll.

In order to accomplish the goals outlined in the four areas mentioned above, a selected number of existing and proposed piezometers and wells were chosen as the most suitable sites for ground water monitoring. A more detailed description of the selected sites for monitoring, a summary of measured water quality parameters, sampling frequency, field techniques and ancillary surface monitoring follows. The reader is here referred to Figure 18-1 for the location of monitoring sites.

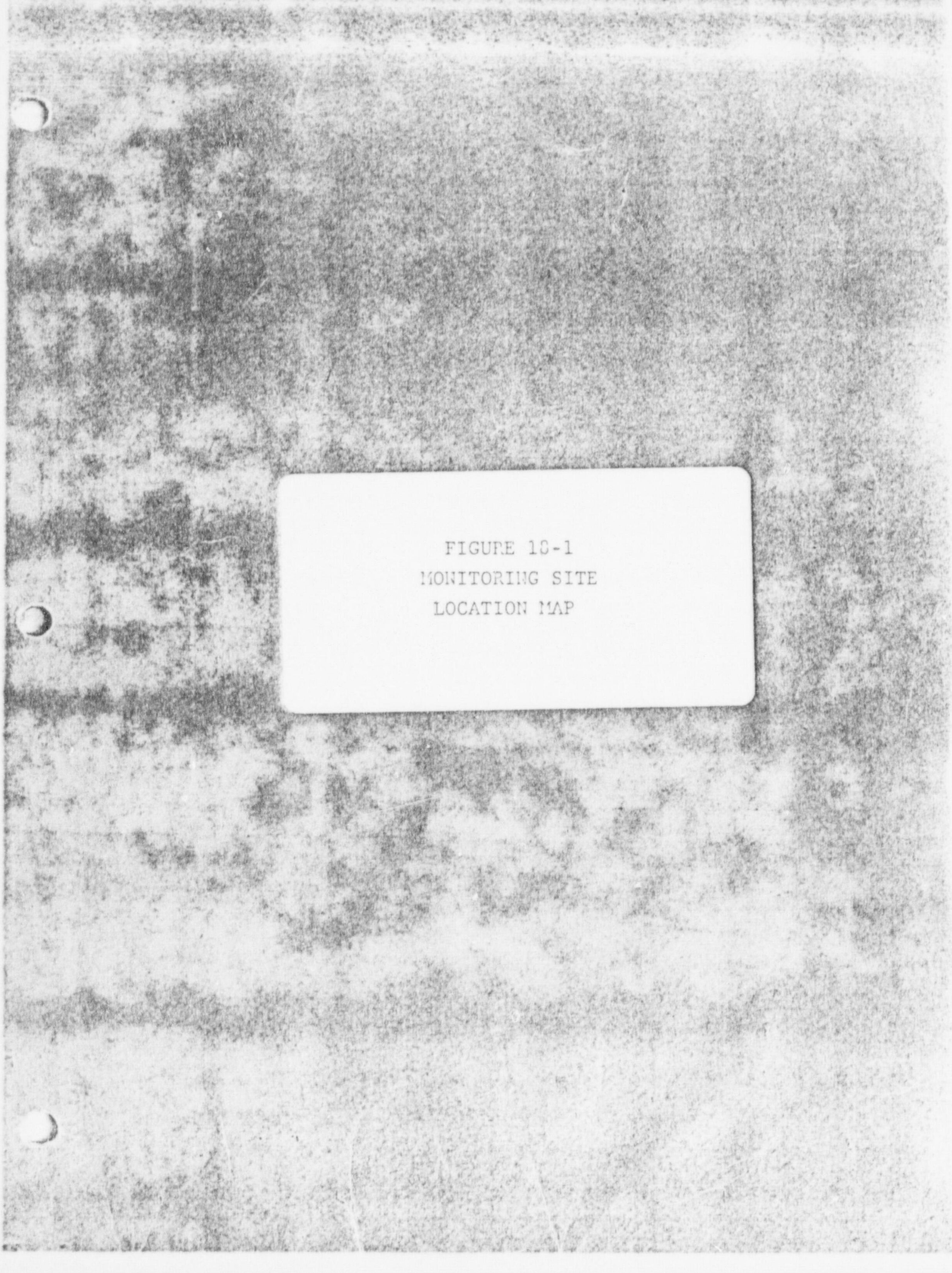


FIGURE 18-1
MONITORING SITE
LOCATION MAP

OVERSIZE DOCUMENT PAGE(S) PULLED

SEE APERTURE CARD FILES

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ACCESSION NUMBERS OF OVERSIZE PAGES:

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DRP-08

Diversion Ditch Area

— Monitoring Sites: DD-8, BRMW-2

— Purpose: To monitor baseflow water levels and water quality upstream of the diversion ditch and seepage cutoff trench.

— Monitoring Sites: DD-1, 2, 3, 9, 16, 18

— Purpose: To monitor water levels adjacent to Canon de Marquez upstream of the seepage cutoff trench.

— Monitoring Site: DD-11

— Purpose: To monitor water levels and water quality between the diversion ditch and the seepage cutoff trench in Canon de Marquez.

— Monitoring Site: DD-10

— Purpose: To monitor water levels until seepage cut-off construction; follow by water level and water quality after cutoff trench construction in Canon de Marquez.

East of Tailings Dam

— Monitoring Sites: TD-3, 4, 5, 6, 10, 11 and 13

— Purpose: To monitor water levels and water quality directly east of tailings dam adjacent to Canon de Marquez.

— Monitoring Sites: BRMW-3, BRMW-5

— Purpose: To monitor water levels and water quality in Canon de Marquez downstream of the seepage cutoff trench, tailings dam and evaporation basin.

Southeast Knoll Abutment (proposed)

— Monitoring Sites: TD-14, 15

— Purpose: To monitor potential seepage from the knoll and saddle dam segment in the southeast corner of the tailings impoundment area.

Canon Seco and Canon de Santa Rosa

— Monitoring Sites: BRMW-4 and 6

— Purpose: To monitor ground water baseflow from the two tributary drainages to Canon de Marquez exiting the BRC property boundary.

Upper Tres Hermanos Sandstone (proposed)

— Monitoring Site(s): TH-1, (2)

— Purpose: To monitor Tres Hermanos sandstone downstream of the tailings dam, east of the inferred normal fault. Second well to be completed pending on Tres Hermanos permeability (see Section 20).

Surface Water Monitoring

- Monitoring Sites: BRS-1 and 2
- Purpose: To monitor surface flow in Canon de Marquez immediately upstream and downstream of the Marquez mine.

- Monitoring Site: BRS-3
- Purpose: To monitor mine discharge as per specifications in NPDES permit no. NM0028215

- Monitoring Site: BRS-4
- Purpose: To monitor surface flow at diversion ditch seepage face resulting from interception of shallow ground water baseflow

- Monitoring Sites: BRS-5 and 6
- Purpose: To monitor tailings effluent to spigot outlets (BRS-5) and ponded water in tailings pile (BRS-6).

- Monitoring Site: BRS-7
- Purpose: To monitor seepage from tailings dam toe prior to entering the evaporation basin.

WATER QUALITY PROCEEDURES

MONITORING AREA	MONITORING SITES	SAMPLING & REPORTING FREQUENCY	MEASURED PARAMETERS
DIVERSION DITCH	DD - 1,2,3,9,16,18	Quarterly for one year and then semiannual.	WATER LEVEL ONLY
	BRMW - 2 DD - 8, 10, 11	SAME AS ABOVE (*NOTE:* DD-10 will be sampled for quality parameters only after cut-off trench construction is completed.)	— ALL SAMPLES — SPLIT "A" Ra - 226, U, Mo, Na, Cd Ra - 228, Cr, Ag, As, Mn Th - 230, Pb, Zn, Co, Ca Pb - 210, Fe, Se, Mg FIELD PRESERVATION: Filtration to $< 0.45\mu$, Reagent grade HNO_3 to $pH < 3$ SPLIT "B" Cl, F, SO_4, TDS FIELD PRESERVATION: Filtration to $< 0.45\mu$, Cool to 4° C SPLIT "C" Total Ra-226, Total Pb-210, Total Th-230, Total U, Total Hg FIELD PRESERVATION: Reagent grade HNO_3 to $pH < 3$ FIELD DETERMINATIONS $HCO_3^-/CO_3^=$, Conductivity, Temperature, Water Level (*NOTE:* 1. All filtration and preservation performed in field on site 2. All sample bottles are new and rinsed with sample prior to preservation and shipment 3. All GW samples obtained after measuring the water level and bailing the well dry then returning the following day for sample collection 4. All analyses in accordance with Sect. 3-107B of the NMWQCC)
EAST TAILINGS DAM	BRMW - 3,5 TD - 3,4,5,6,10,11, and 13	SAME AS ABOVE	
SE. TAILINGS DAM	TD - 14, 15	SAME AS ABOVE	
UPPER TRES HERMANOS SANDSTONE	TH - 1	SAME AS ABOVE	
CANON SECO	BRMW - 4	SAME AS ABOVE	
CANON de SANTA ROSA	BRMW - 6	SAME AS ABOVE	
SURFACE and EFFLUENT	BRS - 1,2,3,4,5,6,7	SAME AS ABOVE	
MILL PROCESS WATER	Mill water makeup volumes and ore moisture content will be reported on a semiannual basis.		

TABLE 18-1

B-19: DESCRIPTION OF PLUGGING PROCEDURES THAT HAVE BEEN, OR WILL BE FOLLOWED IN PLUGGING BRMW-3, AND ALL OTHER TEST HOLES AND EXPLORATION HOLES WITHIN OR ADJACENT TO THE TAILINGS DISPOSAL AREA.

All of the shallow test borings and piezometers drilled by WCC and SAI have not or are contemplated to be plugged. All of these shallow borings have been completed generally less than ten to twenty feet into competent unweathered Mancos Shale. Because these borings do not penetrate aquifers other than the shallow alluvial ground water, plugging is not considered to be necessary.

However, the uncased exploration borings made by BRC in their uranium development and exploration drilling programs did penetrate deeper lying water bearing zones (Tres Hermanos, Dakota and Westwater Canyon Sandstones) that could potentially be impacted by tailings seepage. All exploration holes drilled by BRC in their exploration programs throughout the lease area have been plugged according to specifications of the New Mexico State Engineers Office. Specifications for plugging with high gel strength drilling mud or cement are shown in Appendix G. Exploration holes in the area have utilized both techniques (mud or cement) for hole plugging.

B-20: CONSTRUCTION DETAILS OF THE PROPOSED TRES HERMANOS WELLS INCLUDING DRILLING METHOD, CASING PERFORATION PROGRAM, METHOD OF EMPLACING CEMENT AND GRAVEL PACK, AND DESCRIPTION OF THOSE ZONES WHICH ARE TO BE CEMENTED, GRAVEL PACKED, OR LEFT AS OPEN ANNULUS.

Figure 20-1 illustrates the proposed construction details for the Tres Hermanos monitoring well(s). The sequence of completion details follows:

1. Based on geophysical logs of exploration holes 392-B, 396-B, 439-B, 390B, and 394B, (see Section 16 and Appendix E), the fault is inferred to occur about 350 feet west of 390-B. The well will be set 150 to 250 feet west of 390-B (east of fault on upthrown side of fault). Air rotary drill a 4½" hole one to two feet into the upper Tres Hermanos Sandstone. After topping the upper Tres Hermanos Sandstone, ream the hole (air) to 9 5/8" diameter.
2. Install six inch I.D. steel casing with centering guides to the top of the upper Tres Hermanos.
3. Displace grout through 6" casing into annulus. Grout continuously from the top of the upper Tres Hermanos to the surface.
4. Depending upon water production in the upper Tres Hermanos Sandstone, rotary drill (air or mud) 5½" hole 25 to 30 feet through upper Tres Hermanos Sandstone.
5. Perform grain size analysis on cutting return from Tres Hermanos to determine proper screen slot size.
6. Install 4" I.D. continuous wire wrap screen through 6" casing with neoprene self sealing packer to T.D.

7. Develop well by air lift and/or bailing until fine material washed from well bore.

Upon final completion, this well (TH-1) will be tested to determine if the Tres Hermanos sand is permeable enough to warrant a second well on the west side of the inferred fault. The second well will be drilled after discussion with EID and presentation of water quality and well performance data to determine if the Tres Hermanos should be further monitored. If needed, the second well would be completed in a similar manner to TH-1.

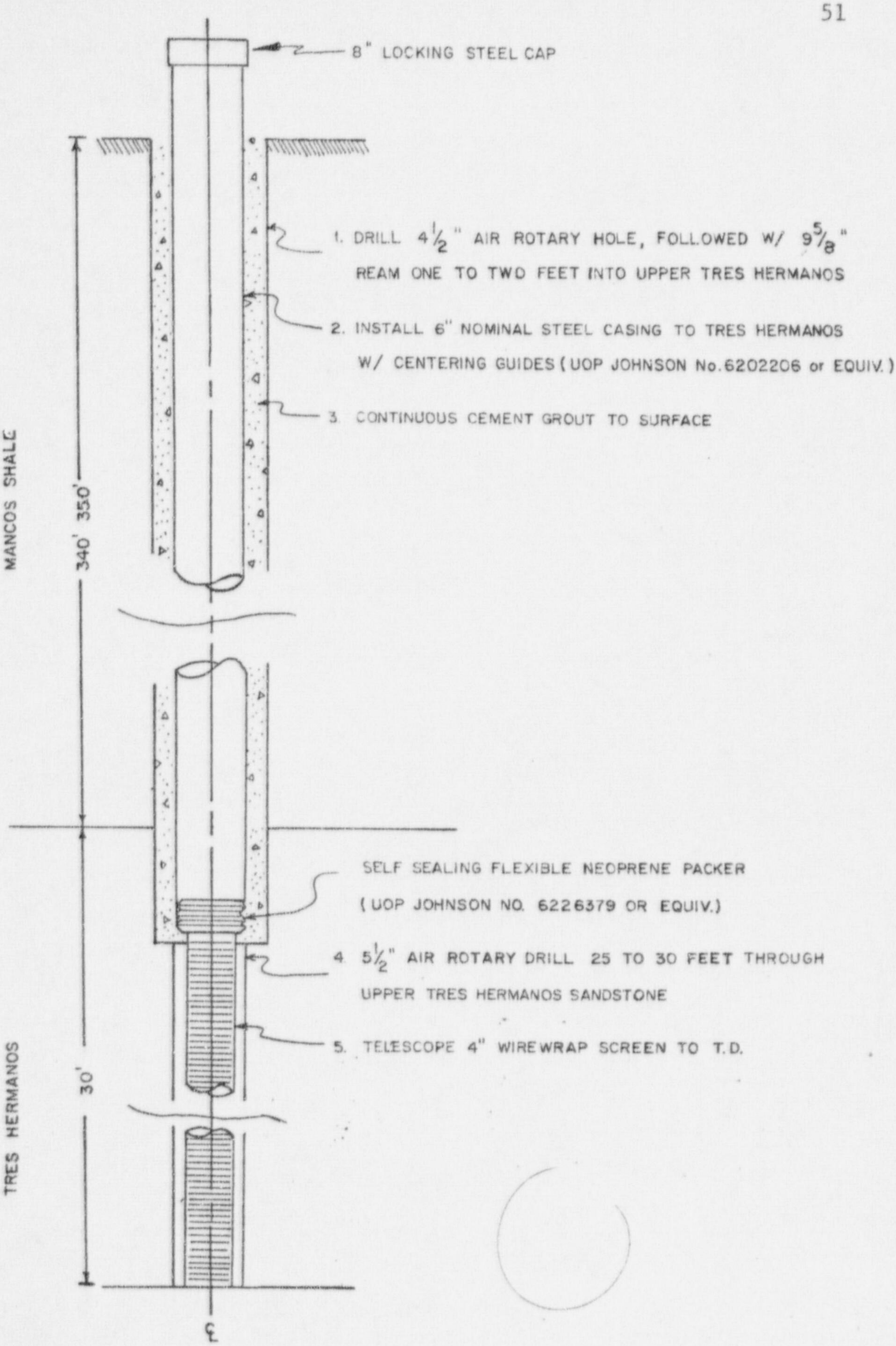

FIGURE 20-1

UPPER TRES HERMANOS SANDSTONE MONITORING WELL

B-21: WITH REGARD TO MONITORING, THE FOLLOWING GENERAL COMMENTS ARE OFFERED:

A: TAILINGS EFFLUENT MONITORING SHOULD ALSO BE CONDUCTED AT THE TAILINGS POND, THE SEEPAGE COLLECTION DITCH, AND THE EVAPORATION POND ON A QUARTERLY BASIS.

B: ALL TAILINGS SAMPLES SHOULD BE PRESERVED WITH APPROPRIATE ACIDS REGARDLESS OF THE pH OF THE FLUID AT THE TIME OF COLLECTION.

C: ALL EFFLUENT AND GROUND WATER SAMPLES COLLECTED FOR DISSOLVED SPECIES SHOULD BE FILTERED AND ACIDIFIED IN THE FIELD.

D. THE PROPOSED LIST OF PARAMETERS FOR CHEMICAL AND RADIOLOGICAL ANALYSIS REQUIRES SOME ADJUSTMENT. CERTAIN OF THE CONSTITUENTS LISTED IN TABLE 3.1 OF THE DISCHARGE PLAN MAY NOT BE NECESSARY TO INCLUDE IN THE ANALYTICAL PROGRAM. OTHER CONSTITUENTS SHOULD BE ADDED TO ADEQUATELY CHARACTERIZE THE TAILINGS EFFLUENT. MOST SIGNIFICANT OMISSIONS INCLUDE MAJOR CATIONS AND ANIONS SUCH AS BICARBONATE, CALCIUM, POTASSIUM, SODIUM AND MAGNESIUM. IN ADDITION LEAD-210 SHOULD BE ADDED TO THE LIST FOR RADIOLOGICAL ANALYSIS.

The reader is here referred to Section 18 which provides guidelines and rationale for the proposed ground and surface water monitoring program at the Marquez tailings impoundment area. Specific responses to the above questions follow:

A. Both tailing effluent to the tailings impoundment area and ponded tailings water will be sampled (see Section 18). In the seepage collection ditch/

evaporation pond, it is necessary to collect only one sample at the evaporation pond inlet (BRS-6).

B. All samples will be preserved according to specifications in Table 18-1.

C. All samples are filtered and preserved in the field prior to shipment to the laboratory for analysis.

D. As noted in Table 18-1 the dissolved species: aluminum, barium, copper, and nickel have been deleted from the proposed list of quality parameters for monitoring. The major ions: bicarbonate, calcium, magnesium and sodium have been added, and lead-210 has been added for both dissolved and total determination.

B-22: PREOPERATIONAL MONITORING

Preoperational monitoring for sites identified in the previous Ground Water Discharge Plan (BRMW and BRSR monitoring sites) will continue for a pre-operational data base quarterly for one year from sampling commencement and then to a semi-annual basis according to descriptions in Section 18.

The new piezometers drilled by SAI and additional proposed sites which are discussed in Section 18 have been added to the preoperational monitoring program.

These new DD, TD, TH and BRS sampling sites will also be sampled quarterly for one year followed by semi-annual sampling and reporting. These sites discussed here and in Section 18 constitute the preoperational, operational and postoperational monitoring plans for the Marquez tailings impoundment area.

B-23: POSTOPERATIONAL MONITORING

The proposed ground and surface water quality monitoring program as outlined in Section 18 is anticipated to be continued throughout the operational phase of the mill life of twenty to thirty years. Modifications of the pre-operational, operational and postoperational phase of monitoring the ground and surface water quality may be necessary by mutual consent of BRC and EID in the future depending upon the results of those future data. BRC will continue the operational monitoring of the ground and surface water quality according to the description provided in Section 18 or modifications thereof which are mutually agreed upon by the EID and BRC for a period of three years after shutdown of the Marquez mill.

Contigency

- BRC will contain any seepage contamination on their leased acreage of the Juan Tafoya Land Grant, by means of seepage collection ditches or wells, grouting of seepage zones, or pond lining.
- Should future shallow ground water production in the Canon Seco, Canon de Marquez or Canon de Santa Rosa on the BRC leased property show contamination resulting from seepage from the tailings impoundment area, then those well owners will be provided with deeper wells or alternate water supply sources.

HYDROLOGIC INVESTIGATIONS AT THE MARQUEZ URANIUM MILL TAILINGS DISPOSAL AREA

TO

BOKUM RESOURCES CORPORATION

BY

SCIENCE APPLICATIONS, INC.
HYDRO & GEOENGINEERING DIVISION

JANUARY 16, 1979

Stuart E. Faith, P.E. 6396

Keith Kennedy, Hydrogeologist

TABLE OF CONTENTS

1.0 INTRODUCTION

The purpose of this report is to provide Bokum Resources Corporation with a report of findings based on SAI's recent investigations at the Marquez Uranium Mill Tailings Disposal Site near Marquez, New Mexico.

SAI has reviewed the results of previous geotechnical investigations at the site area and has conducted specific site investigations to determine in more detail, the geohydrologic characteristics of near-surface water bearing units in the site area. Site work has been done near the diversion ditch and near the tailings dam. Drilling and installation of piezometers has been accomplished at 19 locations in the vicinity of the diversion ditch and at 16 locations in the tailings dam vicinity. Locations are shown on Figure 1. Current drilling activity was terminated on January 13, 1979.

Concurrent with the drilling, a field well/piezometer testing program has been conducted. Final results from this program have been used to define hydraulic conductivity. hydraulic gradients and saturated thicknesses of the main water bearing units. Results are presented in this report.

2.0 GEOHYDROLOGIC CHARACTERISTICS OF WATER BEARING UNITS

2.1 Diversion Ditch Area

Figure 2 shows the stratigraphy in a south-north cross-section approximately parallel to the proposed diversion ditch. Sand, sand and gravel, clay and claystone units overlie the Mancos Shale in this area. The sand and gravel is the principal water bearing strata, but water was also found in the claystone and at the claystone/shale contact. Both confined artesian and water table conditions were encountered in this area.

Sand and Gravel Units

A continuous sand and gravel unit extends from at least 400 feet south of Canon de Marquez to at least 100 feet north of Arroyo Hondo. It is not continuous with the sand and gravel deposit in the unnamed arroyo north of Hondo between DD-18 and DD-16 as shown on Figure 2.

Water was encountered in the sand and gravel unit at each location drilled except at DD-9, midway between Canon de Marquez and Arroyo Hondo drainages. Saturated thicknesses vary from one to ten feet with the most saturation occurring in the center of the drainages. In the channel, the dry hard Mancos Shale is typically overlain by ten to twenty feet of the sand and gravel units.

The shale contact beneath the sand and gravel is sharp and distinct and, as shown on the sections, is based both on drilling characteristics and samples. The shale in this area is characteristically dry and hard within six inches to one foot below the saturated sand and gravel unit contact.

The sand and gravel unit is not continuously saturated between Canon de Marquez and Arroyo Hondo (Figure 2). However, there appears to be a hydraulic connection between the saturation in the two units extending through a claystone unit which overlies the shale in that vicinity (DD-9, Figure 2).

Figure 3 illustrates the continuous nature of the sand and gravel unit parallel to the Canon de Marquez channel. The water table slopes eastward as is generally shown on this west-east section. Actual gradients, however, are derived from the potentiometric surface map shown in Figure 4.

Claystone/Shale Unit

Water was encountered at three locations, DD-5/DD-7, DD-9, and DD-18 in the claystone or at the claystone/shale contact. The presence of water at DD-9 and DD-18 is related to drainage channels laterally recharging into this unit away from the main channel areas (Figure 2).

The conditions of saturation at DD-5 and DD-7 (Figure 5), however, are not similar to DD-9 and DD-18. The sand and gravel unit was not encountered at this location. Sand directly overlies claystone which in turn overlies the shale. Water was encountered in a one to two feet thick layer at the claystone/shale contact at a depth of about 51 feet below ground surface (BGS). The zone of saturation was observed and determined to be approximately one to two feet based on dry material encountered at approximately this depth above the unweathered Mancos Shale contact. After penetrating the claystone at DD-5 water rose 17 feet above the confined saturated zone in the boring to about 34 feet BGS. An additional hole (DD-7) was drilled ten feet away using air rotary and confirmed there was no water in the sand overlying the claystone. Both DD-7 and DD-5 currently show water levels about 34 feet below ground surface.

The conditions encountered at DD-5 and DD-7 indicate a one to two foot thick, confined water bearing zone existing between the dry, hard Mancos Shale and an overlying dry, moderately hard claystone unit. A large head difference exists between the confined unit and the adjacent unconfined zones in DD-3 and DD-4. Also, the specific conductance value at DD-5 is 4500 μmhos/cm; about three and a half times greater than the specific conductance at DD-4. These data and the absence of any spring discharge on the northern side of Mesa Marquez indicate that this unit is not hydraulically connected to the shallow unconfined system in Canon de Marquez and Arroyo Hondo.

Hydraulic Gradient/Unconfined System

Figure 4 is a potentiometric surface map for the unconfined water bearing units in the vicinity of Canon de Marquez and Arroyo Hondo near the diversion ditch. Figure 2 shows the water table in the south-north section parallel to the diversion ditch. Based on this figure, both Canon de Marquez and Arroyo Hondo streams appear to be locally recharging the ground water system in the immediate vicinity of the channel banks.

Using currently available data, the hydraulic gradient in the unconfined system varies from about 0.013 ft/ft to 0.031 ft/ft in a southeasterly direction approximately parallel to the Marquez/Hondo channels. However, the gradient appears to be somewhat variable in its direction north of Marquez. This gradient variation may be showing residual effects of the impounded water to the east, near DD-2. The water has been impounded in Canon de Marquez and Arroyo Hondo immediately prior to SAI's field work for purposes of construction and soil wetting.

Water levels at DD-2 and DD-1 have shown a consistent decline since installation. This decline may be related to the removal of the dam structure and impounded water in that vicinity about one week prior to completion of these wells. Observations over a longer period will be needed to more accurately establish the natural static levels.

2.2 Tailings Dam Area

Figure 6 shows the stratigraphy in a south-north cross section parallel to the axis of the tailings dam on the downstream side. Sand, sand and gravel, and claystone overlie the Mancos Shale in this area. Water bearing units in this area include the sand and gravel, and claystone. Both confined artesian and water table conditions exist in this area, but several holes are dry near Canon de Marquez and near the northwest-southeast trending part of the tailings dam eastward from La Laguna (Figure 1).

Coordinate and elevation survey control are not completed for the wells in this vicinity. Therefore no estimates are made of hydraulic gradient or ranges of values for hydrologic characteristics of the water bearing units.

Sand and Gravel Units

In the tailings dam vicinity, the sand and gravel unit has lithologies and physical characteristics similar to that observed in the diversion ditch area. It extends from about 100 feet south of Canon de Marquez northward about 2000 feet. It thins northward and and pinches out adjacent to the topographic and bedrock high in the vicinity of TD.7

The sand and gravel unit is dry immediately south and north of Canon de Marquez. As seen on Figure 6, the unit is above the elevation of the stream. The channel has been incised into the shale and currently stream flow is directly over the bedrock.

The temporary construction cutoff and the permanent cutoff trenches have undoubtedly intercepted flow in some near surface water bearing units west of the trenches near our south-north line of drilling. Flow into the trenches may be draining the sand and gravel units north and adjacent to Canon de Marquez to a distance of about 1000 feet north of the stream. The shale in this area was both dry and hard to a depth of 35 feet below the contact (see TD-1 drilling log and Figure 6 cross section).

About 400 feet north of TD-2, saturation occurred in the sand and gravel where it again overlies hard, dry, and what has been referred to in earlier geotechnical reports as "unweathered" shale. Beyond TD-3, the sand and gravel unit extends another 1200 feet northward but was dry at depths of 19 and 15 feet at TD-4/TD-12 and TD-5, respectively (Figure 6). At these two locations, the sand and gravel unit overlies weathered, gypsiferous, fractured claystone. Water was encountered below the sand and gravel in the claystone bedrock at these locations as described below.

Hydrologic properties for the sand and gravel unit near the tailings dam are believed to be similar to those for the unit in the diversion ditch area.

Claystone/Shale Unit

In the vicinity of the tailings dam, the claystone/ shale unit consists of both weathered and unweathered zones underlying the sand and sand and gravel units. The claystone is differentiated from shale in this area but may be a weathered product from shale. Compared to the claystone in the diversion ditch area, the claystone in the tailings dam area is more gypsiferous and fractured with gypsum seams appearing to fill fractures in the bedrock. The claystone unit contains interlayers of more competent less weathered shale. The contact with the hard, dense and dark gray shale "unweathered" bedrock is sharp and distinct from the claystone. It should be noted that the absence of fracturing and gypsum seams is one of the criteria to be used in determining the depth of the seepage cutoff trench. Thus, water bearing zones in the weathered claystone will be assured of being intercepted.

Hard, dry and "unweathered" shale underlies the sand and gravel to a distance of about 1800 feet north of Canon de Marquez. The shale is dry within one foot below its contact with the sand and gravel in this area. At TD-1 the shale was moderately hard to hard and dry to a depth of 60 feet BGS.

Farther to the north near TD-4 the "unweathered" shale is overlain by about 35 to 55 feet of claystone.

Ground water was found in the claystone although it was dry at TD-7, TD-8 and TD-9 (Figure 6). Unconfined water table conditions are present at the locations where ground water is in the claystone. The ground water occurs in fractured, gypsiferous layers which commonly displayed iron staining and were softer than the overlying rock. At several piezometers completed in the claystone, water bearing units were only moist in the samples taken and these moist zones seeped water to the boring during drilling (TD-5 and 6). At several other locations water could be heard flowing into the boring after it had been penetrated by the auger or the sampler (TD-14).

Confined artesian conditions exist in the claystone/shale unit at several locations along the tailings dam area. They are most noticeable at TD-4 about 2000 feet north of Canon de Marquez (Figure 6). TD-4 was drilled into hard dry shale to a depth of 50 feet, about three feet below the claystone/shale contact. Water was encountered at 28 feet, 9 feet below the base of the sand and gravel unit. Water rose 18 feet in the boring to a depth of about ten feet BGS after completion of the hole. The TD-4 piezometer installed with screen to 28 feet BGS currently shows the water level at 9.8 feet BGS.

TD-12 drilled next to TD-4 confirms the sand and gravel overlying the shale is dry. The TD-12 piezometer with a screen depth of about 19 feet shows no water. Thus, the claystone unit has a confined artesian water unit.

The elevation of the confined water level at TD-4 is similar to unconfined water levels northward at TD-5 and TD-6. However, accurate elevations on the wells are needed before exact hydraulic gradients can be determined.

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FIGURE 1

SITE LOCATION MAP

AND

FIGURE 4

POTENTIOMETRIC MAP

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3.0 BASEFLOW TO THE TAILINGS AREA

3.1 Pump Test Analysis

From January 9, 1979 to January 13, 1979, a combined pumping test and recovery test was conducted on piezometers DD-11, DD-12, DD-13, DD-14 and DD-15 located in the alluvium of Canon de Marquez near the proposed diversion ditch. The locations of the piezometers are shown on Figure 4 attached to this report. The test consisted of a 1560 minute pumping phase at an average rate of 5.88 gal/min and a subsequent 4260 minute recovery phase. The data from this test are presented in Appendix B attached to this report.

The pump test results from the observation piezometers (DD-11, DD-12, DD-13 and DD-14) were analyzed both as if the aquifer was infinite and as if a constant head existed at the north edge of the stream in Canon de Marquez. Log-log plots of the drawdown data for the piezometers are presented in Figure 7, Figure 8, Figure 9, and Figure 10. The drawdown data were corrected for flow zone thinning by using Jacob's correction:

$$S' = S - S^2/2D$$

where S' = Jacob's corrected drawdown (ft)

S = observed drawdown (ft)

D = saturated thickness of the aquifer (ft)

The largest difference between the observed drawdown and Jacob's drawdown was 0.05 feet for an observed drawdown of 0.71 feet in piezometer DD-14. This is

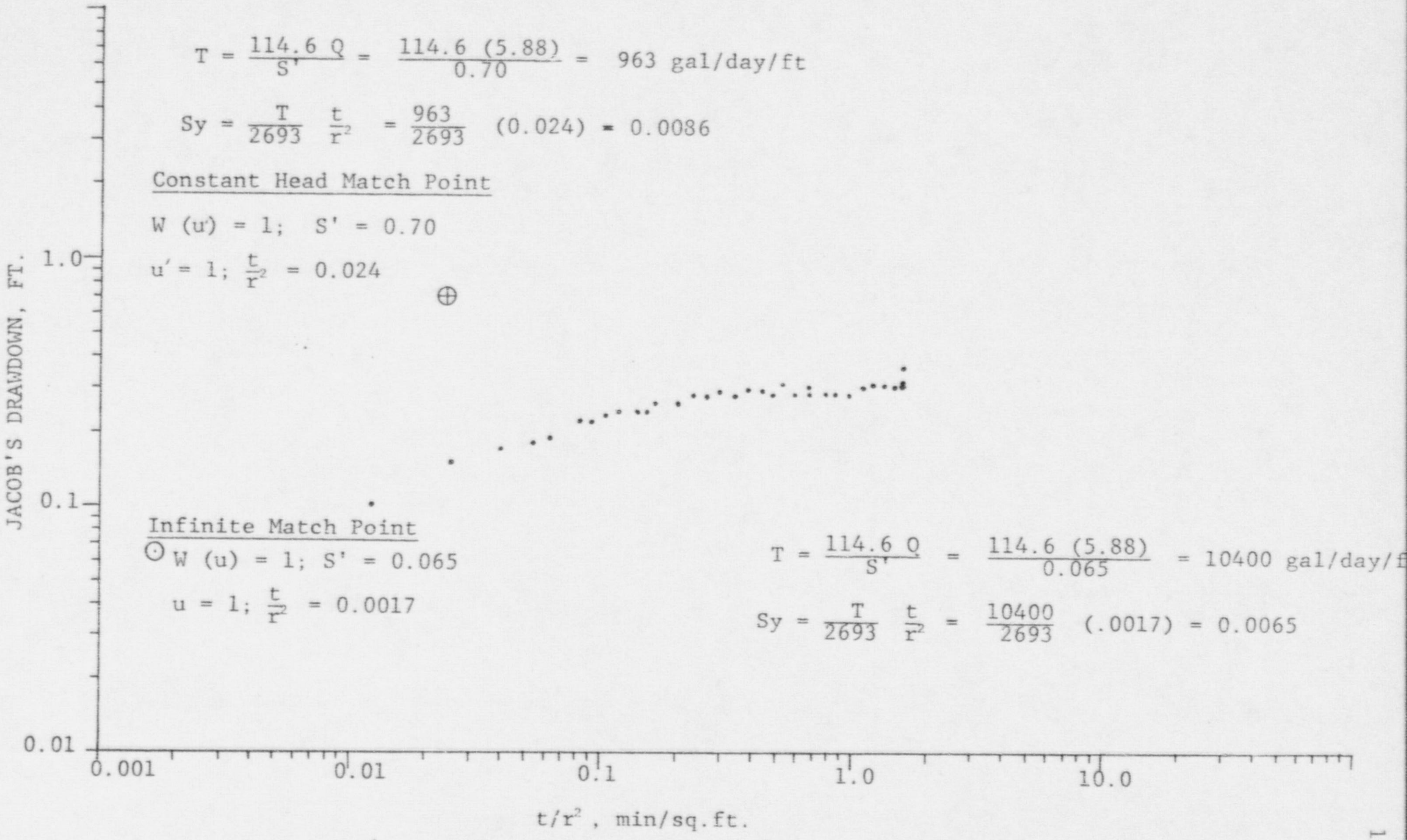


FIGURE 7: LOG-LOG DRAWDOWN FOR DD-11

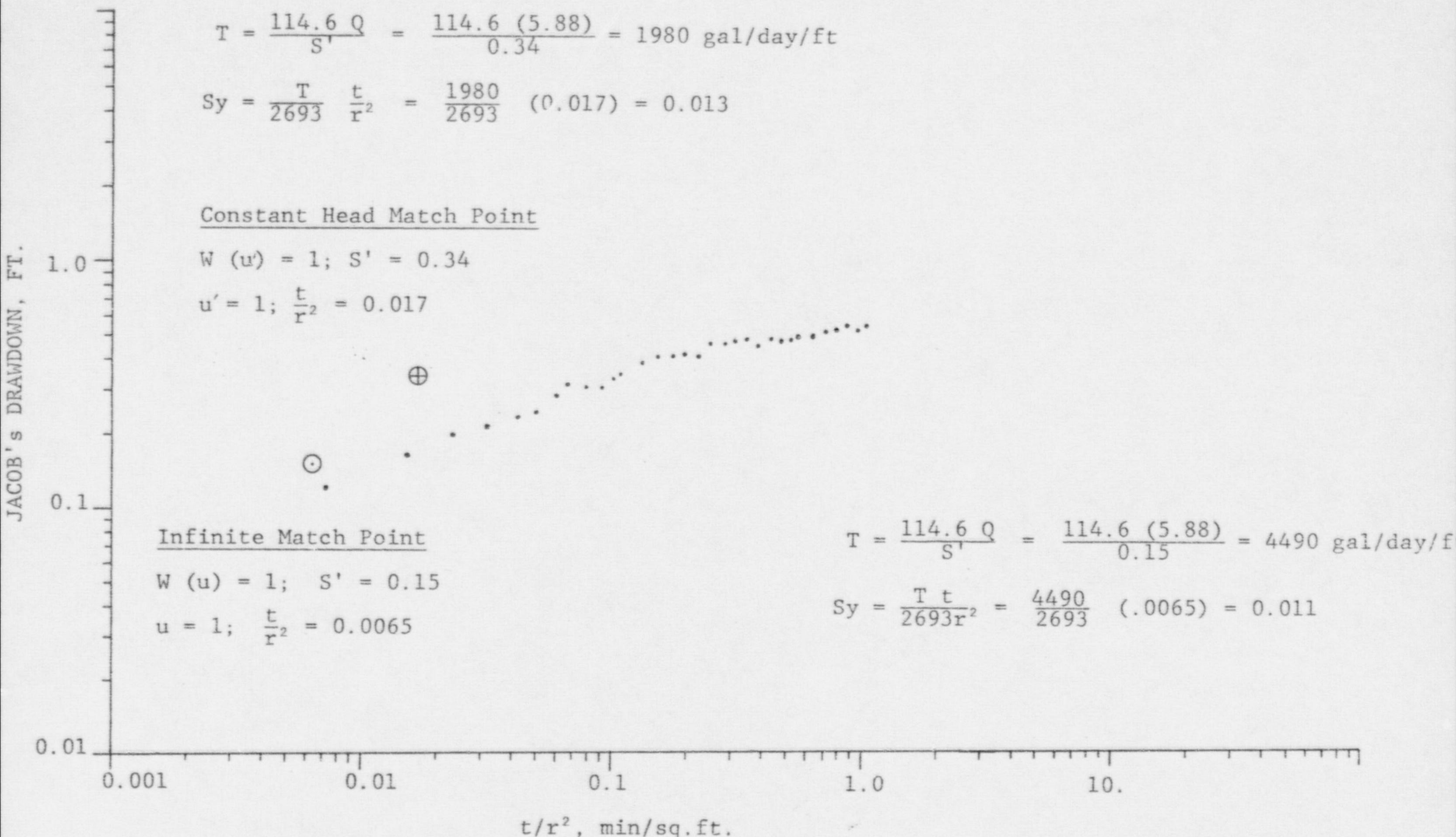


FIGURE 8: LOG-LOG DRAWDOWN FOR DD-12

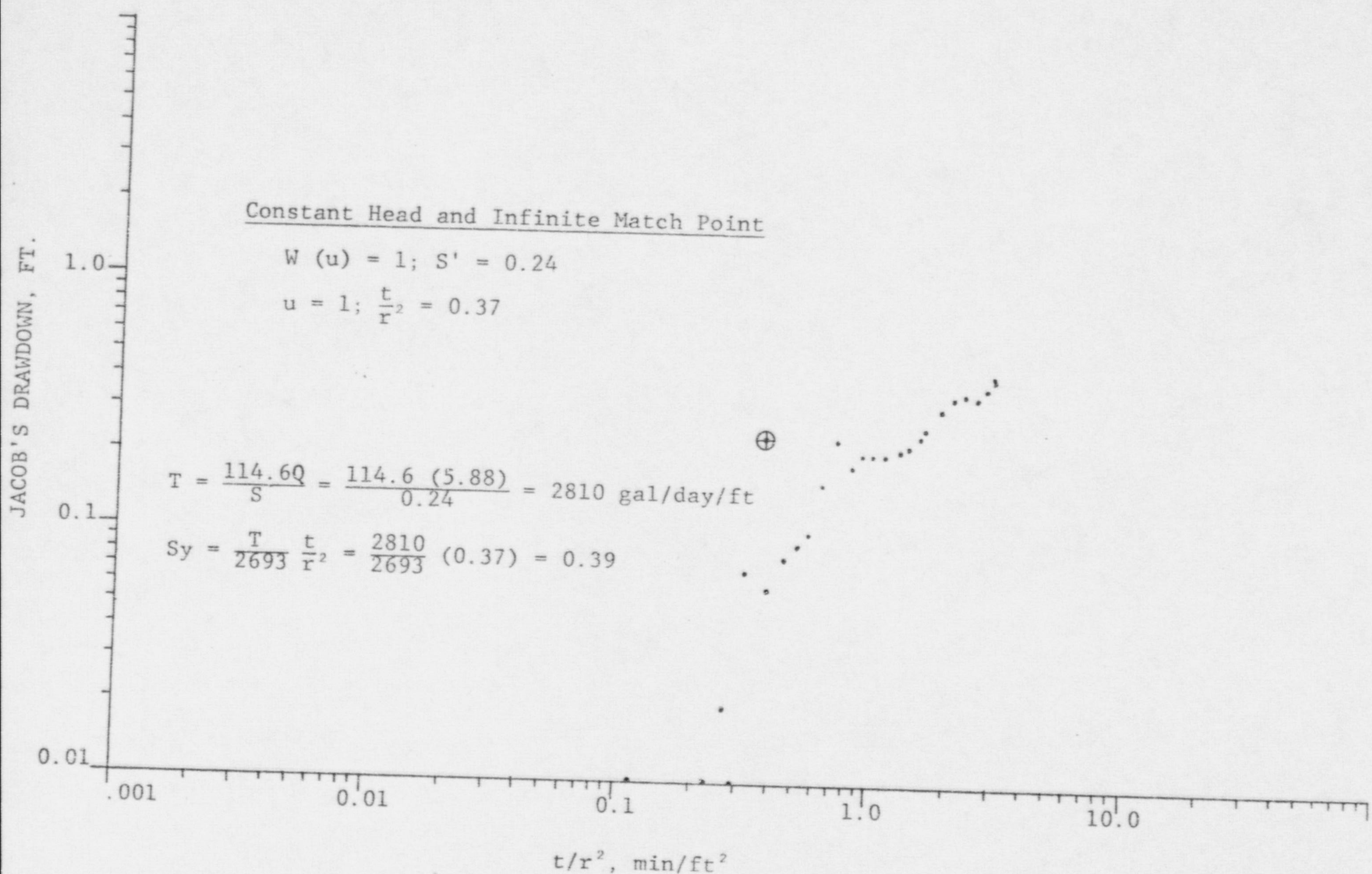


FIGURE 9: LOG-LOG DRAWDOWN FOR DD-13

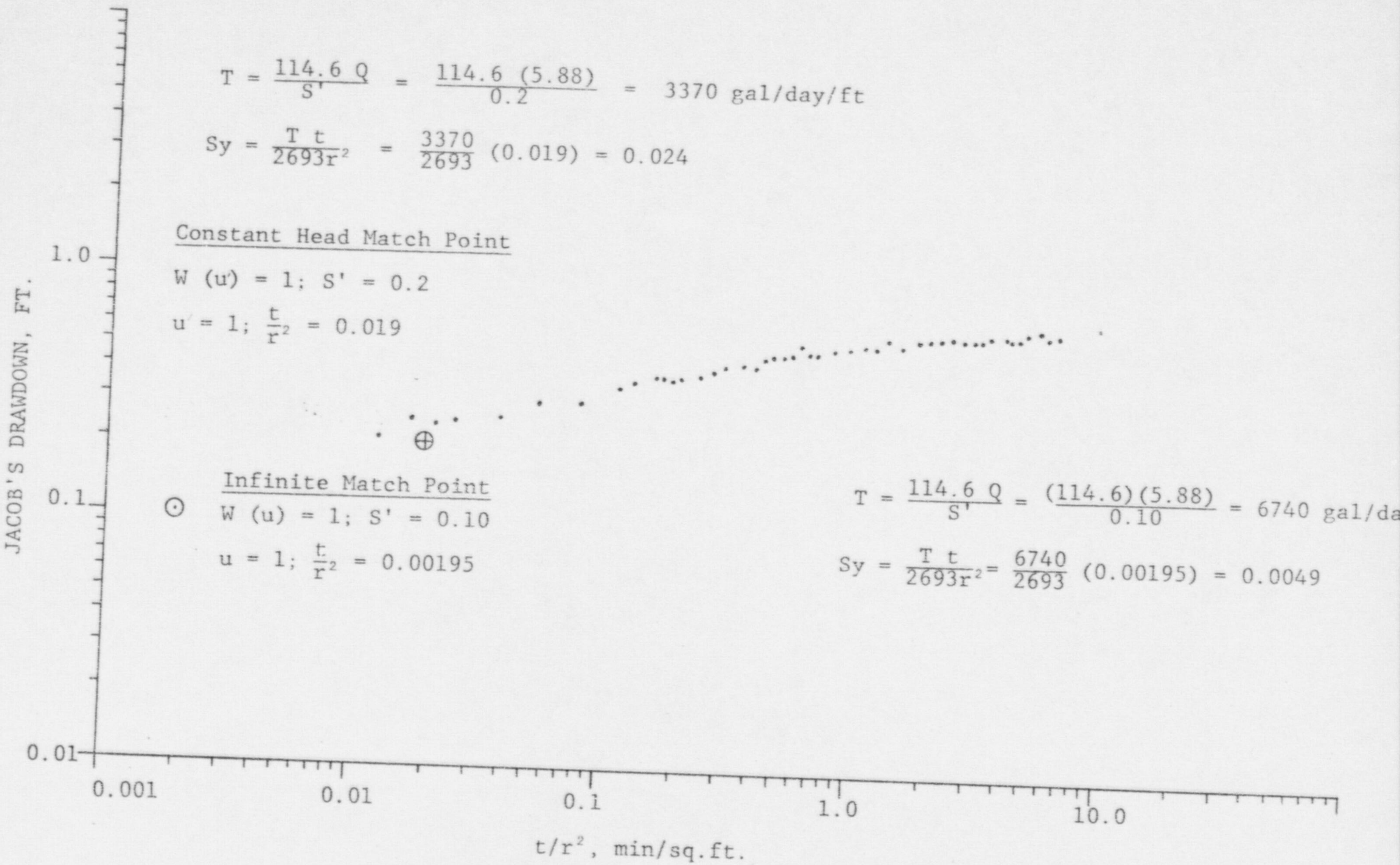


FIGURE 10: LOG-LOG DRAWDOWN FOR DD-14

primarily due to the larger drawdowns measured in this piezometer due to it being the closest piezometer to the pumping piezometer, DD-15. Data on the saturated thickness of the alluvial aquifer at each piezometer are presented in Table 1.

Type curves for the constant head aquifer were generated by using the relationship

$$W(u') = W(u) - W\{\frac{r_i^2}{r_p^2} u\}$$

where $W(u')$ = well function for constant head aquifer for the argument u

$u = 2693\ r_p^2\ Sy/Tt$

Sy = specific yield

T = transmissivity (gal/day/ft)

t = elapsed time since start of pumping (min)

r_i = distance between piezometer and image recharge well (ft)

r_p = distance between piezometer and pumping well (ft)

The above equation is the superposition relationship for a semi-infinite aquifer with a constant head. Distances between the piezometers and the pumping and recharge wells are presented in Table 1.

The drawdown plots for the infinite aquifer and the constant head aquifer were matched to type curves generated for each particular case. The match point for the infinite aquifer is shown as an ⊙ and the match point for the constant head aquifer is shown as a ⊕ on Figure 7, Figure 8, Figure 9, and Figure 10.

TABLE 1: PUMP TEST RESULTS SUMMARY

PIEZOMETER	SATURATED THICKNESS (FT)	DISTANCE TO PUMPING WELL (FT)	DISTANCE TO IMAGE WELL (FT)	INFINITE AQUIFER RESULTS T (GAL/DAY/FT)	INFINITE AQUIFER RESULTS Sy	CONSTANT HEAD AQUIFER RESULTS T (GAL/DAY/FT)	CONSTANT HEAD AQUIFER RESULTS Sy
DD-11	5.9	31.55	39.55	10400	0.0065	963	0.0086
DD-12	5.8	38.50	80.85	4490	0.011	1980	0.013
DD-13	4.8	23.00	94.10	2810	0.39	2810	0.39
DD-14	5.6	15.45	72.76	6740	0.00049	3370	0.024
DD-15	4.8	Pumping well	71.00				

The equations and calculations to determine transmissivity and specific yield are presented on the figures. The results are summarized in Table 1. Transmissivity values ranged from 2810 gal/day/ft to 10400 gal/day/ft for the infinite aquifer and from 963 gal/day/ft to 3370 gal/day/ft for the constant head aquifer. Specific yield values for the aquifer were quite variable ranging from 0.0049 to 0.39 for the infinite aquifer and from 0.0086 to 0.39 for the constant head aquifer.

A comparison of the drawdown data for piezometer DD-13 with the infinite aquifer type curve and DD-13's constant head type curve showed that DD-13 is essentially free from any constant head effects caused by the stream. This condition probably sets a lower value of transmissivity of the alluvial aquifer at 2810 gal/day/ft. A plot of drawdown of piezometers DD-12 and DD-14 with respect to t/r_p^2 show that these drawdowns match exactly for t/r_p^2 greater than 0.08 (see Figure 11). This indicates that possibly the alluvial aquifer may be considered infinite and that the transmissivity may be as high as 6740 gal/day/ft. A comparison of drawdowns from the four observation piezometers with respect to t/r_p^2 to the infinite type curve fitted through the drawdown curve for DD-13 shows that the drawdown curves from these piezometers may merge at t/r_p^2 equal to 7.0 (see Figure 11). This curve seems to almost intersect the last drawdown points of the DD-12 and DD-14 curves. If this is so, the transmissivity and specific yields obtained from the data from piezometer DD-13 may yield best values of the hydraulic characteristics of the aquifer.

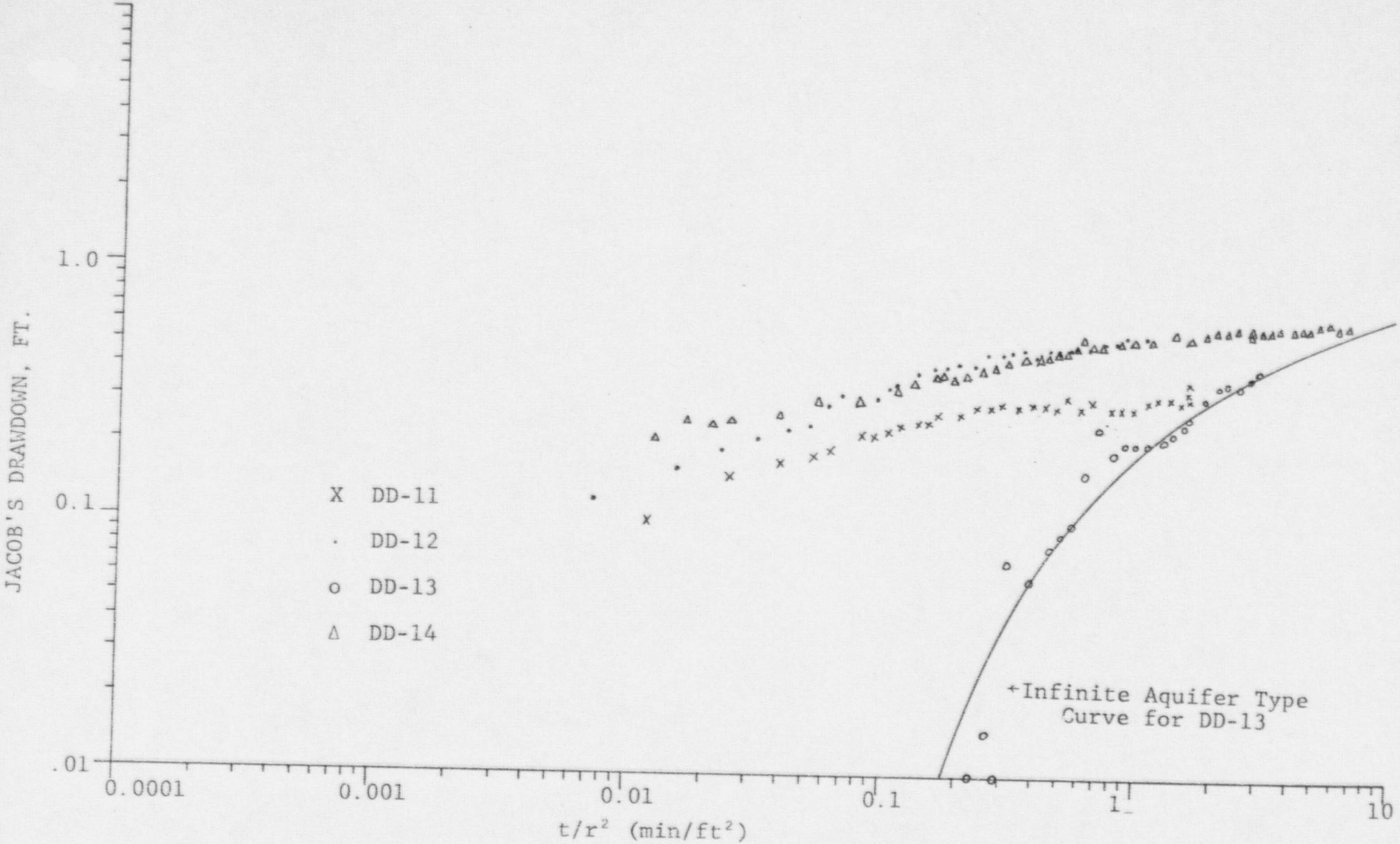


FIGURE 11: COMPARISON OF DRAWDOWNS FROM ALL PIEZOMETERS

3.2 Flow Through Saturated Alluvium

Based on data presented in the previous section and other sections of this report it is possible to calculate the baseflow occurring in Canon de Marquez. Baseflow may be calculated from the equation:

$$Q = K\ i\ A/1440$$

where Q = baseflow (gal/min)

K = hydraulic conductivity (gal/day/ft)

i = hydraulic gradient

A = saturated area (ft^2)

Hydraulic conductivity may be calculated from transmissivity by the equation:

$$K = T/D$$

where T = transmissivity (gal/day/ft)

D = saturated thickness (ft)

Referring to the previous section and Table 1, the hydraulic conductivity ranges from 585 gal/day/ft^2 to 1200 gal/day/$ft.^2$

The hydraulic gradient for the aquifer can be obtained from Figure 4. Figure 4 shows that the hydraulic gradient between piezometer DD-9 and the pump test area is 0.0234 ft/ft and that the hydraulic gradient between the pump test area and piezometer DD-10 is 0.0294 ft/ft. The weighted average gradient is 0.0255 ft/ft.

A cross-section through the diversion ditch area of the alluvial aquifer is shown on Figure 2. From this figure, saturated cross-sectional area through sand and gravel can be determined to be approximately 3000 ft^2 in Canon de Marquez, Arroyo Hondo and an unnamed arroyo between piezometers DD-18 and DD-16.

Based on the above mentioned numbers, baseflow can be calculated as follows:

A. For maximum hydraulic conductivity and hydraulic gradient:

$$Q = K\ i\ A/1440$$
$$= 1200\ (0.0294)(3000)/1440$$
$$= 74\ \text{gal/min}$$

B. For minimum hydraulic conductivity and hydraulic gradient:

$$Q = K\ i\ A/1440$$
$$= 585\ (0.0234)(3000)/1440$$
$$= 29\ \text{gal/min}$$

4.0 CONCLUSIONS

4.1 Baseflow Adjacent to Diversion Ditch

A. The baseflow occurs primarily in the sand and gravel unit extending from about 400 feet south of Canon de Marquez to a point about 200 feet north of Arroyo Hondo.

B. Additional baseflow is occurring in the sand and gravel unit underlying the unnamed arroyo north of Arroyo Hondo. Neither the sand and and gravel nor the ground water under the unnamed arroyo are continuous with the flow to the south.

C. A pump test was conducted in the alluvial aquifer from which the hydraulic conductivity of the aquifer was determined to range from 585 gal/day/ft to 1200 gal/day/ft . A drilling program instituted in the diversion ditch area showed that there is approximately 3000 ft of saturated area in the diversion ditch area. The unconfined hydraulic gradient in the sand and gravel is parallel to Canon de Marquez with a slope ranging from 0.0234 ft/ft to 0.0294 ft/ft. Calculated estimate of baseflow into the proposed tailings impoundment area ranges from 29 gal/min to 74 gal/min.

4.2 Ground Water in the Tailings Dam Vicinity

A. In the vicinity of the tailings dam and immediately downstream, the Canon de Marquez channel is incised down to the shale bedrock and lies below the sand and gravel unit adjacent to the channel. This sand and gravel unit immediately north and south of Canon de Marquez is unsaturated.

B. Both confined artesian and unconfined water table conditions exist in the claystone/shale unit along the face of the tailings dam. At only one location the sand and gravel unit was partially saturated (TD-3). There appears to be a ground water system underlying parts of currently proposed tailings disposal area distinct from the primary ground water flow regime adjacent to Canon de Marquez and its tributaries. There also exist layers of saturation confined in the claystone unit near the tailings and diversion dams. However, design specifications for the seepage cutoff trench calling for ten feet penetration into unweathered (no fractures or gypsum seams) shale will intercept both these zones along the face of the tailings dam.

C. At three locations (between TD-7 and TD-9) directly east of La Laguna the claystone/shale unit is dry to depths of 60 feet into the claystone/shale unit. This unsaturated area extends about 1200 feet to the northwest of a topographic high in the unweathered shale. This topographic high appears as a barrier separating two areas of saturation in the claystone/shale unit.

Elevation of confined ground water in the clay/stone will be accurately determined in order to ensure that the seepage cutoff trench excavation elevation are well below the water bearing zones.

4.3 Confined Ground Water Conditions

A. Ground water was encountered in the claystone/ unit under confined artesian conditions in both the diversion ditch area and in the tailings dam area. Hydraulic heads are about 5 to 20 feet above the zone of saturation in both areas.

B. At the diversion ditch, the confined condition exists about 300 feet south of Canon de Marquez (DD-5/DD-7). The zone is at a depth of about 50 feet and is considered to be hydraulically isolated from nearby zones of saturation in the sand and gravel unit adjacent to the Canon de Marquez channel. Source of water to this zone may be from Mesa Marquez or from saturated deposits upstream from the diversion ditch.

C. At the tailings dam area, confined conditions exist at several locations. About 2000 feet north of Canon de Marquez at TD-4, the zone is a depth of about 25 to 35 feet and appears hydraulically connected to the saturated zones encountered about 400 to 800 feet further north at TD-5 and TD-6. Other confined conditions exist at TD-13, south of Canon de Marquez and at TD-11 near the northwest end of the tailings dam.

D. As stated earlier, these confined zones are above the unweathered shale. The cutoff will be emplaced below these zones and thus intercept them along the face of the tailings dam.

APPENDIX A

DRILLING LOGS

DRILLING LOG

Client: Bokum Resources Corporation

Piezometer #: BRMW-2

Job: 1-100-05-237-C0

Sheet 1 of 1

Start: 2/ 24 /78

Finish: 2/ 24 /78

Drill Type: CME-45

Location: N:
E:

Elevation: Ft (LSD)

Hole: 6" straight flight auger

Fluid: None

SAI by: Faith

Completion: 4" PVC to TD with hacksaw slots on lower 15'; cement collar; plastic well caps on bottom and surface.

TD: 25 FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	0								
		Silty sand, gravels, large cobbles				GP			
	5								
	10								
		Hard dark shale to TD				SH			
	15								
	20								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: BRMW-3 (old location)

Sheet 1 of 1

Start: 2/ 23 / 78

Finish: 2/ 23 / 78

Drill Type: CME-45

Location: N:
E:

Elevation: Ft (LSD)

Hole: 6: Straight flight auger

Fluid: None

SAI by: Faith

Completion: 4" PVC casing with hacksaw slots on lower 15'; cement collar, well caps on bottom and surface

TD: 25 FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	0								
		Poorly graded, silty sand and gravel	-	-	-	SP GP			Encountered H_2O at ≈ 8 ft.
	5								
	10								
		Dark, dry shale to TD Some sandstone stringers	-	-	-	SHS			Muddy return, dark clay shale fragments
	15								
	20								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: BRMW-4

Sheet 1 of 1

Start: 2/ 24 /78

Finish: 2/ 24 /78

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" Straight flight auger

Fluid: None

SAI by: Faith

Completion: 4" PVC to TD with hacksaw slots on lower 15"; cement collar, well caps on bottom and surface.

TD: 25 FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	0								
	5	Large cobbles and silty gravel	-	-	-	SP GP	-		
	10								
	15	Shale to TD				SHS			
	20								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: BRMW-5

Sheet 1 of 1

Start: 2/ 23 /78

Finish: 2/ 23 /78

Drill Type: CME-45

Location: N:
E:

Elevation: Ft (LSD)

Hole: 6" straight flight auger

Fluid: None

SAI by: Faith

Completion: 4" PVC casing with hacksaw slot on lower 15'; cement collar, well caps on bottom and surface.

TD: 25 FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	0								
		Fine grained silty sands and coarse gravel	-	-	-	SP	-		
	5								
		Dark dry shale to TD	-	-	-	SH	-		
	10								
	5								
	20								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: BRMW-6

Sheet 1 of 1

Start: : 2/ 23 /78

Finish: : 2/ 23 /78

Drill Type: CME-45

Location: N:
E:

Elevation: Ft (LSD)

Hole: 6" Straight Flight auger

Fluid: None

SAI by: Faith

Completion: 4" PVC to TD with hacksaw slots lower 15'; cement collar; well caps bottom and surface.

TD: 25 FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	0								
						GP			
	5	Coarse gravel, silty sand, few cobbles				SP			
	10								
		Dark gray shale				SHS			
	15								
	20								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: DD-1

Sheet 1 of 2

Start: 12:30 12/ 4 /78

Finish: 14:30 12/ 4 /78

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" H/S Auger 3¼" with SS

Fluid: None- Auger

SAI by: Kennedy

Completion: 10' Well Screen set to 32.0'
Sand to 2' above screen, 23.5' to surface

TD: 33.3FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	0	Organic Soil Layer				SC	IG	M	
	5	Silt and very fine sand, med. brown loose, Tr. organic	12/55	100	/12	SM	IG	L	
	10	Silt/Sand, light to medium brown, dry	12/55	100	/12	SM	IG	L	
	15	As above, but clayey in tip of sampler	12/55	100	/12	SM	IG	M	
	20								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 2 of 2 | Hole #: DD-1

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20	Bldrs/Cobbles to 6" diameter; with finer grain matrix	12/55	100	/12	SM	IG	M	
	23								
	25	Finer Gravel	12/22	70	/12	GP	IG	H	
	29	Contact based on drilling shale				SH			
	30	Shale; med. gray, dry, slight fracturing, weathered but no staining or gypsum.	5/55	100	50/5	SH			Hard drill at 31'
	33.3	Shale, dry, tight, deuse, dark gray		100	60/3	SH			
	5								
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: DD-2

Sheet 1 of 2

Start: 8:15 12/5/78

Finish: 11:15 12/6/78

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" HS Auger 3¼" ID, with S/S Sample

Fluid: None

SAI by: D. Updegraff

Completion: 10' Screen; 15½' casing; 12' sand pack

LOCATION PLOT

TD: ____ FT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	0								
	5	Sand; brown, very fine grained, clayey	12/55	100		SC/SM	IG	L	
	10	Same as above but less clay	12/55	100	8/12	SM	IG	M	
	13	Gravel				GP			
	15	Sand, fine grained, minor clay.	12/55	100	8/12	SP/SM	IG	M	
	20								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 2 of 2 | Hole #: DD-2

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Pe .d.	NOTES
	20	Sand and Gravel, wet	12/55	100	33/12	GP	IG	H	∇ ≈ hit while driving
	23	Shale, gray to black, dry, hard	4/55	75	50/4	SH	IB	VL	
	25	Shale, gray to black, dry, hard	3/55	100	50/3	SH	IB	VL	
	0								
	5								
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation	Piezometer #: DD-3
Job: 1-100-05-237-00	Sheet 1 of 2
Start: 11:30 12/ 6 /78 Finish: : / /	Drill Type: CME-45
Location: N: E:	Elevation: Ft (LSD)
Hole: 6" HS Auger 3¼" ID; with Split Spoon Sample	Fluid: None
SAI by: D. Updegraff, /Kennedy	Completion:
LOCATION PLOT	TD: ____ FT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	0	Very fine sand with clay				SM			
	4.5	Sand, light brown, fine grained, some calcite	13/55	40	18/33	SM/SC	IG	M	SA/GR Mix SS Pebb.
	5								
	9.5 10	Sand, fine grained, very silty iron staining	18/55	100	28/18	SM/ML	IG	S	≈3" of soil in SS before driving
	12.5	Hitting same hard stuff, balling of fines, some clay							
	14.5	Sand, some clay balls appearing, some shale fragments							
	15	Fine grained, very silty, 35% clay, some caliche, a few pebbles	18/55	90	25/18		IG	L	≈2" of slough
	17	Sand, fine grained with silt, clay 35% Si lenses, lt-md red brown with caliche and organic mire	18/36		32/18	SC/SM		L	≈3" of slough Hard drilling to 19.5
	20								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 2 of 2 | Hole #: DD-3

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20	Sand, med. brown, very fine grained with 25% clay; 15-20% Si; coal, Fe-St pebbles from weathering	18/55	90	43/18	SC	IG	LT	
	25	Silt, med. brown, 30% very fine sand 20% clay.	18/55	100	50/18	SM/ML	IG	L	4" slough Drilling still hard H_2O to cuttings
	28.5	Sand/Gravel							
	29.5	Pebbles & cobbles to 3-4" w̄ Sa, matrix SA/GR							Contact with gravel no slough
	30								
	32	SA (Drilling)							Layered GR & SA in zone to 35'
	35	Sand, gravel, Fe stain in SA with magic ext. bldr. and gravel, getting moist.	18/55	90	100 18	GP	IG	M/H	(Sampler bouncing)
	38	Shale							
	39.8	Shale, dry, fissle, black/gray, dense				SH	FR	VL	Hit dense material at 38' drilling
	40	Boring DD-3 completed at 39.8 @1500 hr. 12/6/78							
		Water level 38 ft. 1' saturation above top of							15:15 WL Meas. @ 37.3 BGS through PVC Pipe
	45								
	0								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: DD-4

Sheet 1 of 2

Start: 10:30 12/ 11 /78

Finish: 13:30 12/ 11 /78

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: Hollow Stem with 6" Auger sampling every 5'

Fluid: None

SAI by: Kennedy

Completion: 2' Solid Sub; 8' Spiral Screen; 32' Solid Casing Coarse Sand from bottom of hole to 22' below MP

TD: 41.7FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	0								
	4.5	Sand, very silty							
	5	Silty sand, fine-medium grained, lt. yellow brown, very silty (≈30%)	18/55	50		SM/SC	IG	IG	
	9.5	Sand; very silty and clayey							
	10	Silty sand; med-fine grained, med. brown, silted clay ≈20%, poorly sorted	18/55	99	28/10	SM/SC	IG	IG	
		Gypsum ≈5%							
	14.5	Silty Sand, fine grained, med. brown							
	5	Silt ≈30% fine sand ≈10%, poorly sorted, Tr. gypsum	18/55	99	28/18	SM/SC	IG	IG	
	19.5	Silty sand, fine grained, med. brown							
	20								

Client: Bokum Resources Corp. | Job #: 01-100-237-00 | Sheet 2 of 2 | Hole #: DD-4

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20	poorly sorted silt 20%; gypsum 5%	18/55	100	42/18	SC	IG	IG	
	24.5	SAND: med. gray brown with high							
	25	(40%) clay and Si content, very	18/55	100	44/18	SC	IG	L	
		fine sand, Fe stain, small grained							
		(10%), roots, minor organics							
	29.5	SILT, dry brown, clayey, sandy							
	30	moist, some caliche	18/55	100	32/18	SC/GL	IG	L	
	32.5	CONTACT - drilling				GP			32.5 boulders, cobbles
	34.5	GRAVEL AND SAND: dark to med. brown							33.65' BGS WL Measured
	35	wet, basalt material to 2" 60%	18/55	50	44/18	GP	IG	H	
		Cobbles to 5" at surface from return							Hard driving in boulders
	39.5	CONTACT							
	40	SHALE, dark gray, fractured but only	9/55	90	50/8	SH	IB	L	
		slightly moist							Slough passed easily
	41.5	SHALE, dry, dark-med. gray, (Photo)		100	50/3	SH	IB	L	
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: DD-5

Sheet 1 of 2

Start: 14:00 12/ 11 /78

Finish: 13:00 12/ 11 /78

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" H/S Auger with 3¼" ID split spoon

Fluid: None

SAI by: D. Updegraff

Completion: 4.7' Sub; 5' Spiral Screen; 45' Solid Casing - Packed with pea gravel from 37.74 below top of casing to bottom at hole. Dirt fill from LSD to top of gravel; Cap on bottom of sub.

TD: 52.5 FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	0	Sand, light brown, fine grained, silty, a few gray clay balls mixed with sand							
	4.5	Sand, light brown, fine grained,							
	5	silty, a few clay balls, pebbles	18/55	100	29/18	SM/ML	IG	M	
	9.5	Same; some small basalt gravel							
	10		18/55	70	29/18	SM/ML	IG	M	
	15	Same; some caliche appearing	18/55	70	61/18	SM/ML	IG	M	
		Gray clay balls with sand up to 1½" long - Noticed some reddish brown soft sandstone							
	20								

Client: Bokum Resources Corp.	Job #: 01-100-05-237-00	Sheet 2 of 2	Hole #: DD-5

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20	Sand, brown, silty, sticking together very well, 60-70% clay, some dampness, caliche very visible, some carbon specks	18/55	100	60/18	SM/ML	IG	M	
	23	Drilling becomimg harder							
	25	Sand, slightly moist, brown, fine grained, silty, clayey, caliche not as visible	18/55	100	48/18	SM	IG	M	
	30	Same only caliche is disappearing	18/55	100	49/18	SC	IG	M	
	35	Clay, brown, black, gray clay with iron visible, slightly damp	6 /55	100	50/6	CH	IB	VL	4 gal into hole for drilling
1/12/78	40	Clay, brown to gray, hard, some iron visible, some gypsum in lower half of sample, slightly damp	6½/55	100	50/6½	CH	IB	VL	3 gal into hole for drilling
	44.5	Brown to brownish yellow clay, gypsum very persistent							
	45		6/55	100	50/6	CH	IB	VL	
	47	Shale, pebbles coming out of hole, well rounded clay is soft & moist				WSH	IG	M	
	50	Shale, soft, gray, some gypsum slightly damp, wet clay on top of shale	7/55	100	50/7	SH	IB	VL	
	52.5	Gray shale, some moisutre, lot of coming out of SS	2/55	100	50/2	SH	IB	VL	

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: DD-6

Sheet 1 of 2

Start: 13:30 12/ 12 /78

Finish: : 12/ 13 /78

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" OD Auger with 3¼" H/S Split Spoon Sample

Fluid: None

SAI by: Kennedy/D. Updegraff

Completion: 3' Solid Sub; 12½ Spiral Screen, 15' Solid Casing, one sack of sand at bottom; sand to above screen

TD: 30.2FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
12/12/78	0								
	5	Sand, very fine grained, med. reddish brown, roots, silt (20-25%0	18/55	100	6/9/8 18"	SM	IG	L	
	10	Sand, reddish brown, fg, roots, silt 20% becoming clayey towards the bottom of sample	18/55	100	28/18	SM	IG	M	Slightly moist
	15	Sand, med. yellow brown, fine to med. grained, minor silt, no clay	18/	100	18/18	SP	IG	M	
		Clayey sand				SC			
		Contact Gravel, Boulder, sand							19.5' water sat. mtrl.
	20								bitting on boulder

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 2 of 2 | Hole #: DD-6

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20	No sample available	0/						
	25	Gravel, boulders (to 2"), basalt with		90	50/9	GP	IG	H	
		iron, stain							
		Contact							
		Shale, med, gray, dry	2/	100	50/2	GP	IB	H	27.5 even drilling
	30	Shale, gray, dry	3/55	100	80/3	SH		VL	smooth
	5								
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: DD-7

Sheet 1 of 3

Start: : / /

Finish: : / /

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: Air Rotary

Fluid: Air Rotary

SAI by:

Completion:

LOCATION PLOT

TD: ____ FT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	0	NO SAMPLES TO 32 FEET							
	5								
	10								
	15								
	20								

Client: | Job #: | Sheet of | Hole #: DD-7

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20								
		Gravel/Sand or just hard drilling							Lost circulation at 25'
	25								
	30	Sand, light brown, fine grained, some clay	12/55	12	60/12	SM/CH			Air rotary to 45'
		Claystone, brown to gray, some Fe staining, sl., moisture	6/55	100	50/6				
	35								
	40								
	45	Claystone/Shale; med. gray friable moist with gypsum, minor Fe-stain in zones	9/55	100	50/9				Moist sample but not wet
		Cuttings became darker							Cuttings turned to gray color
	0								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 3 of 3 | Hole #: DD-37

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	50	Clay, dark to light gray, mottled, gypsum present and shale, dark gray, fractured from driving, moisture	6/55	100	50/6				Confined water intersected while driving
		Continued air rotary drilling. Noted 1' of saturation							at about 50.4' to 51.4'
	54.5 55	Shale, dark gray, dry, fissle, not wet except for caved material			50/5				Water heard entering the hole hole
		Air rotary completed at 54.5'							
	0								
	5								
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation	Piezometer #: DD-8
Job: 1-100-05-237-00	Sheet 1 of 1
Start: 10:00 12/15/78 Finish: 11:30 12/15/78	Drill Type: CME-45
Location: N: E:	Elevation: Ft (LSD)
Hole: H/S Auger	Fluid: None
SAI by: Kennedy	

LOCATION PLOT

Completion: 3' Sub; 10' Spiral Screen, 10.9 Solid casing, pea gravel from bottom of hole to 11.4' below LSD, Sand to about 8' BGS 10' screen/3' sub. TD: 23.3FT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
12/15/78	0	Sand, silt, very fine grained				SM	IG	M	
	4.5	Sand, med. grained lenses				SP			
	5	Clay contact	18/55	80	52/18	CL	IB	VL	2" Slough
	9.5	Clay; med. yellow brown, scattered							
	10	pebbles and sand, stiff, tight, dry	18/55	80	34/18	CL		VL	Clean
		sand throughout							
		Contact; gravel (drilling)				GP			
	14.5	Gravel with sand	18/55	40	27/18	GP	IG	M/H	
	15								Rapid drilling 17.5 to 19.5
		Boulders to 4" from cuttings							
		Mixed lith. with sandstone, basalt							
	19.5	Gravel, pebbles, sand							
	20	Contact; shale, dark gray, moist							1½" slough hit shale
	23.5	Shale, dry, dark gray/black							in bottom of drive

DRILLING LOG

Client: Bokum Resources Corporation

Piezometer #: DD-9

Job: 1-100-05-237-00

Sheet 1 of 2

Start: 12:00 12/ 15 /78

Finish: 9:30 12/ 20 /78

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" H/S Auger with SS Sampler

Fluid: None

SAI by: K. Kennedy/D. Updegraff

Completion: 7' Solid Sub; 5' Spiral screen; 30' Solid Casing Packed from 24' below LSD to hole bottom with 10-20 sand

TD: 39.7 FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	0	Sand, med. brown, dense				SM			
	4.5 / 5	Sand, med. yellow brown, very fine to med. grained gravel, Fe stain	18/55	100	20/18	SP	IG	M	
	10	Contact sand in top of sampler							
		Clay, Fe stain, med. brown, sandy, dense, tight	18/55	100	21/18	CH	IG	VL/L	
	14.5 / 15	Sand, clayey, fine grained, Fe stain, dry, gypsum, caliche, roots	18/55	100	29/18	SC	IG	M/L	
		Pebbles coming up with sand				GP			
	19	Contact; gravel							
	19.5 / 20	Sand, fine grained, light brown; sandstone, pebbles, caliche	6/55	100	50/6	SC	IG	H	

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 2 of 2 | Hole #: DD-9

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
12/18/78	20								
	21	Cobbles, basalt coming out with cuttings - Switch to 4" auger				GP			
	23	Contact				CLS			
	25	Claystone, gray, Fe stain, slightly damp	7/50	100	50/7			VL	
	30	Claystone, gray, some Fe stain, slightly damp - Drilling got soft	6/55	100	50/6	CH		VL	
	33	Contact: shale, gray, dry; soft clay at top of sample	3/55	100	50/3				
	34.5	Shale, gray, soft, crumbly, slightly	3/55	100	50/3	WSH			
	35	slightly moist							
	37.5	Shale, gray, hard in some spots, soft in others may be shale	3"	100	50/3	WSH			
	39.5	Shale, gray	2½"	100	50/2½	SH			
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: DD-10

Sheet 1 of 1

Start: 13:00 12/21/78

Finish: 13:30 12/21/78

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" H/S Auger with SS

Fluid: None

SAI by: Kennedy

Completion: 2.17' Sub; 4' screen, 4' blank to top, sand pack to 2'

TD: 10.3FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	0	Gravel, Boulders; alluvial fill material with irregular lenses of sand mixed with silt and clay. Scattered cobbles to 6" size with sand and silt				GP	IG	H	
	5								
	7.5	Shale contact				SH			
	10								
	5								
	20								

DRILLING LOG

Client: Bokum Resources Corporation

Piezometer #: DD-11

Job: 1-190-05-237-00

Sheet 1 of 1

Start: 09:30 12/20/78

Finish: 12:00 12/20/78

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: H/S Auger - 6" with S/S Samples

Fluid: None

SAI by: Kennedy/D. Updegraff

Completion: 2' Sub; 5' Screen; 5' Solid casing Stickup = above G.S.

LOCATION PLOT

TD: 12.3 FT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
12/20/78	0	Boulders, gravel to 24"							
		Boulder - cored				GP			
	5	Sand, Gravel, silty, clayey	6"/	100	50/6	GP	IG	H	
		Scattered sand and gravel							
	8.5	Contact				SH			Soft drilling
	10	Shale, dark gray, moderately moist, partly fractured in layers, tight	4/55	100	50/4	SH		VL	
	12		3/55	100	50/3	SH			
	15	Cleaned auger with cal. spn.							
	20								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: DD-12

Sheet 1 of 1

Start: 12:30 12/ 20 / 78

Finish: 14:00 12/ 20 / 78

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" H/S Auger with SS Samples

Fluid: None

SAI by: Kennedy/D. Updegraff

Completion: 3' Sub' 5' Screen, 7.00' Solid Casing Natural Gravel Pack

LOCATION PLOT

TD: 15.2 FT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
12/20/78	0	Gravel, boulders with sand, silty (alluvium)				GP			
	5	Gravel, Sand, med.-coarse grained, dark brown, Fe Stain	14/55		50/14	SP	IG		
									Hit water
	10	Gravel, basalt, Sand, brown, med. grained, some clay, iron staining, wet	11/55	11	50/11	GP	IG	H	
	12	Shale, gray, soft, dry	3/55		50/3	SH			Contact
	15	Shale, gray, hard, dry	2/55	2"	50/2	SH			
	20								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: DD-13

Sheet 1 of 1

Start: 14:15 12/20/78

Finish: 15:39 12/20/78

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" H/S Auger with S/S Samples

Fluid: None

SAI by: D. Updegraff

Completion: 3' Sub; 5' Screen, 7' Top casing Natural packing

LOCATION PLOT

TD: 13.3FT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
12/20/78	0								
	5	Gravel, basalt, sand, fine to med. grained, brown, damp, iron staining	6/55	5"	50/6	GP	IG	H	
	7								Hit water
	10	Gravel, basalt, Sand, fine to med. grained, saturated	18/55		36/18				Bottom 3" of sample is soft shale
		Contact - Shale, gray, soft, damp				GH			
		Shale, gray, soft, dry	3/55	3"	50/3	SH			
	5								
	20								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: DD-14

Sheet 1 of 1

Start: 15:45 12/ 20 /78

Finish: 16:45 12/ 20 /78

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" H/S Auger with S/S Samples

Fluid: None

SAI by: Kennedy

Completion: 2' Sub; 5' Screen, 7' Blank to 1.3' AGS Sand Pack to 1.5' BGS

TD: 13.3FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
12/20/78	0	Scattered Sand, Gravel, Boulders				GP			
	5	In boulders/no sample				GP			Hit water
		Scattered sand, gravel, boulders							
	10	Gravel, sand, basalt lith, med. to	15/55	100	50/15	GP	IG	H	
						SH	IB		
	11	Contact - shale, dry, flashy, med. gray							
	13		3/55	100	50/3	SH			
	5								
	20								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: DD-15

Sheet 1 of 2

Start: 10:00 12/ 21 /78

Finish: 12:45 12/ 21 /78

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: Overdrilled with 6" H/S Auger and S/S sampler

Fluid: None; hole then spun with REVERT

SAI by: C. Culver

Completion: 10' Sub; 6' screen; 6' top piece all 2"; 10-20 sand pack from bottom of casing to 36 below LSD

TD: 25 FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	0	SAND, poorly, sandy gravel, dominantly basalt, boulders/gravel - grades into silty sand - FME grained,				GP	IG	H	
	5	Grades into silty sand - fine, med. grained, yellow brown							
	10	CONTACT - SHALE; gray, soft, dry	2/55		50/2				
		SHALE, olive black, soft, thin bedded, wthrd, Contact shows traces of Fe staining.							
	15								
	20								

Client: Bokum Resources Corp | Job #: 01-100-05-237-00 | Sheet 2 of 2 | Hole #: DD-15

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20								
	25	Shale as at 10.5							
	0								
	5								
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: DD-16

Sheet 1 of 2

Start: 14:30 12/21/78

Finish: 10:30 12/22/78

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" H/S Auger with S/S Samples

Fluid: None

SAI by: D. Updegraff/Kennedy

Completion: 2.11' Sub; 5' Screen 10' Solid Top piece Gravel - 16.3' below LSD to hole bottom; sand 10-20 from gravel to 6' below LSD; Piezometer sits at top of gravel

TD: 23.3FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	0	Sand, fine, brown							
12/20/78	2	Gravel, basalt lithology, sand				GP			
	5	No sample							
						SP			
	10		4/55	100	50/4				
	14	Volcanics				SC			Water hit
	15	Claystone, gray; iron staining	18/55	100	55/18				
	20								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 2 of 2 | Hole #: DD-16

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20	Claystone, gray; iron staining	8/55	100	50/8	SH			Contact
		Shale, gray, slightly moist							
	23	Shale, gray, dry, hard	3/55	100	50/3	SH			
	5								
	0								
	5								
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation	Piezometer #: DD-18
Job: 1-100-05-237-00	Sheet 1 of 2

Start: 12:30 12/22/78 Finish: 15:00 12/22/78	Drill Type: CME-45	Location: N: E: Elevation: Ft (LSD)
Hole: 6" H/S Auger with S/S Sample	Fluid: None	SAI by: D. Updegraff
Completion: 10' Screen at BGS		TD: 30 FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
12/22/78	0	SAND, lt. brown, fine, dry SAND, clayey, damp, dark brown							
									Caliche appearing
	5	SAND, fine grained, clean, lt. brown some gypsum	18/55	18"	27/18	SP	IG	H	
		Contact - gravel							
		Contact - clayey sand							
	10	SAND, fine grained, lt. brown, slightly damp, fairly clean	18/55	4"	39/18	SP	IG	H	
									Soft clay
	15	SAND, fine grained, lt. brown, clayey, damp	18/55	18"	19/18	CH	IG	L	Fine sand, fine gravel, cobbles, sand
		CLAY, soft, lt. brown to gray, some sand, moist							
	20								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 2 of 2 | Hole #: DD-18

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20	SHALE, brown to gray, gypsum, presently moist	14/55	14"	50/14	WSH	IB	L	
	25	SHALE, gray, soft, mixed with clay; alot of gypsum present	7/55	7"	50/7	WSH	IB FR	L	
	30	SHALE, gray, hard, dry	2/55	2"	50/2	SH	IB	VL	
	5								
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: DD-19

Sheet 1 of 2

Start: 10:00 1 / 13 /79

Finish: 12:00 1 / 13 /79

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" H/S Auger with Split Spoon Samples

Fluid: None

SAI by: D. Updegraff

Completion: 10' Screen set at 22'; 14' Solid top 10-20 Sand: T.D. - 11.1 below MP

LOCATION PLOT

TD: 25 FT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
1/13/79	0	SAND, fine grained, lt. brown, Tr. organics				SM			
						SC			
	5	SAND, fine grained, lt. brown, silty, clayey	18/55	100	25/18	SC	IG	M	
						GP			
	10	SAND & GRAVEL, fine grained sand, basalt, cobbles	9/55	100	50/9	GP	IG	H	
	15	SAND; lt. brown, fine grained, clean GRAVEL, iron staining	18/55	100	30/18	GP	IG	H	
	20								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 2 of 2 | Hole #: DD-19

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20	SAND & GRAVEL, iron staining, saturated	18/55	100	38/18	GP	IG	H	
		SHALE, gray, dry, crumbly	3/55	100	50/6	SH	IB	VL	Contact
	25	SHALE, gray, dry, crumbly	2/55	100	50/2	SH	IB	VL	
	0								
	5								
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: TD-1

Sheet 1 of 3

Start: 10:00 12/ 27 /78

Finish: 13:30 12/ 27 /78

Drill Type: CME-45

Location: N:
E:

Elevation: Ft (LSD)

Hole: 6" H/S Auger (3¼")

Fluid: None

SAI by: Kennedy

Completion:

TD: ____ FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
12/27/78	0	SAND; med. brown with silt, fine grained				SM SC	IG	M	
	5	SAND, med. gray brown, very fine grained, silty, dry	18/55	100	18/18	SM	IG	M	
	10	SAND, lt. yellow brown, fine to med. grained, <15%, silt, small gravel (<5%)	18/55	100	19/18	SP	IG	H	
		CONTACT - Scattered gravel with sand							
	15	SAND, GRAVEL, mixed lithology	12/55	85	50/12	GP	IG	H	Sampler hit rock (Short drive)
	18.5	CONTACT (drilling)							
		SHALE				WSH			
	20								

Client: Bokum Resources Corp | Job #: 01-100-05-237-00 | Sheet 2 of 3 | Hole #: TD-1

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Porcs.	Perm.	NOTES
	20	SHALE; dark gray black, moist, soft , friable, blocky, (Wthrd)	12/55	100	34/12	W3H	IB	L	
		SHALE	20/55	100	50/10	WSH	IB	L	
	25	SHALE, dark blue gray, very salt in parts, non-friable	8/55	100	50/8	WSH	IB	L	
						SH			
	30	SHALE, med. gray, flaky, friable slightly moist	4/	100	50/4	SH	IB	L	
	35	SHALE, med. gray, slightly moist, flaky	5/55	100	50/5	SH	IB	L	
	40	SHALE, med. gray, ≈dry, flaky	3/55	100	50/3	SH	IB	VL	
		Scattered (Ls and (siltstone layers n shale (drilling)							
	45	SHALE, med. gray, ≈ dry, flaky, with some gypsum <1%	4/55	100	50/4	SH	IB	VL	
	0								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 3 of 3 | Hole #: TD-1

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	50	SHALE; med. gray, dry, flaky	3/55	100	50/3	SH	IB	VL	
	55	(PHOTO) SHALE; med. gray, soft, slightly moist, flaky with 3" soft layer of talc-like substance	9/55	100	50/9	SH	IB	L	
	60	SHALE, dry, flaky, hard	4/55	100	50/4	SH		L	Dry
	5								
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation	Piezometer #: TD-2
Job: 1-100-05-237-00	Sheet 1 of 2
Start: 13:30 12/27/78	Drill Type: CME-45
Finish: : / /	Location: N: E:
	Elevation: Ft (LSD)
Hole: 3¼" H/S Auger 6" SS Samples	Fluid: None
SAI by: Kennedy	
Completion:	TD: ____ FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
12/27/78	0	SAND, med. to fine grained, dark yellow brown, minor silt, gravel <10%, some caliche				SM	IG	M	
	5	SAND, med. grained, lt. yellow brown well sorted, loose, no fines	18/55	100	25/18	SP			
	10	SAND, fine to med. grained with 15% Si, 10% clay, med. brown, Fe stain (minor)	18/55	100	22/18	SP			
	15		18/55	100	16/18	SP			
	20								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 2 of 2 | Hole #: TD-2

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20			100	24/18	SP			
	25	CONTACT, gravel layers with sand and silt (Channel deposits)		100	23/18	GP			
		SAND							
		GRAVEL							
	30	GRAVEL, SAND, wet but not saturated Fe stain	9/55	90	50/9	GP	IG	H	
		CONTACT - Shale							Drilling change @ 33'
	35	SHALE	5/55		50/5				
	38								38' - No recovery
	39	SHALE			50/5				
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation

Piezometer #: TD-3

Job: 1-100-05-237-00

Sheet 1 of 2

Start: 15:30 12/ 27 /78

Finish: 17:30 12/ 27 /78

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 3½" HS Auger with SS Sampler

Fluid:

SAI by: Kennedy

Completion: 10' Screen, 10' Blank, 20' Blank cut at 16'

LOCATION PLOT

TD 38.3 FT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
12/27/78	0	SAND, fine grained, Tr. organics				SM			
	5	SAND, med. yellow brown, silty (20%) very fine to fine grained, more clay	18/55	100	18/18	SP/SC	IG	M	
	10	SAND, med. reddish brown, silty with clay (10%), organic, fine to med. grained with Fe stain	18/55	100	18/18	SP/SC	IG	M	
	15	SAND, lt. yellow brown, with small gravel (15%), med. grain with fine and very fine	18/55	100	33/18	SP	IG	M	
		CONTACT - scattered gravel with sand mixed lithologies				GP			
	20								

Client: Bokum Resources Corp.	Job #: 01-?00-05-237-00	Sheet 2 of 2	Hole #: TD-3

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20	GRAVEL & SAND, med. to fine grained, med. yellow brown	18/55	100	32/18	SP	IG	H	
	23	SAND, with scattered gravel							
	25	SAND, gravelly, med. grained, med. brown, slightly moist	18/55	100	32/18	GP	IG	H	
	30	GRAVEL SAND, as above but saturated med. brown	18/55	100	32/18	GP	IG	H	
		CONTACT, shale (drilling)				GP			
	35	SHALE, med. gray, platy, dry	5/55	100	50/5	SH			
	38		4/55	100	50/4	SH			
	38.5	Completed							
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: TD-4

Sheet 1 of 2

Start: 10:30 12/28/78

Finish: 10:30 1/3/79

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" H/S Auger with S/S Samples

Fluid: None

SAI by: D. Updegraff

Completion:

LOCATION PLOT

TD: 50.3FT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
12/28/78	0	SAND, silty, lt. brown, Tr. organics				SM			
									Contact
	5	CLAY, silty, brown, slightly damp, some gypsum, (Wthrd)	18/55	100	50/18	SC/CH	IG	VL	
									Contact
	10	SAND, gray to light brown; 10% clay	18/55	100	28/18	SC	IG	H	
									Cobbles
	15	SAND & GRAVEL; fine, lt. brown gypsum, iron staining	18/55	100	38/18	GP	IG	H	
		CONTACT							Drilling contact
	20								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 2 of 2 | Hole #: TD_4

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
1/3/79	20	SHALE, gray, gypsum, iron, sulfur	17/55	100	50/17	WSH	IB	VL	
									Cuttings are wet
	25	SHALE, gray, soft, gypsum, iron present (Wthrd)	9/55	100	50/9	WSH	IB	VL	
									Water coming out of hole at good rate
	30	SHALE, gray, soft, gypsum, iron sulfur, (Wthrd)	9/55	100	50/9	WSH	IB	VL	Measured, WL at 12.0' below LSD when lifting to spin
									No more water coming out of hole
	35	SHALE, gray, soft, damp (Wthrd)	6/55	100	50/6	WSH	IG	VL	
	40	SHALE, gray, medium hard, slightly damp to dry (Wthrd)	9/55	100	50/9	WSH	IG	VL	
	45	SHALE, gray, medium hard, slightly	7/55	100	50/7	WSH	IG	VL	
									Contact based on drilling & Driving Char
	50	SHALE, dark gray, medium hard, dry	4/55	100	50/4	SH	IG	VL	

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: TD-5

Sheet 1 of 3

Start: 12:30 1/ 3 /79

Finish: 5:30 1/ 3 /79

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" H/S Auger with S/S samples

Fluid: None

SAI by: D. Updegraff

Completion: 10' Screen; 33' Solid Top piece

LOCATION PLOT

TD: 54.8FT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
1/3/79	0	SAND, silty				SC			
	5	SAND, lt. brown, fine grained, 10% clay, caliche	18/55	50	36/18	SC	IG	H	
	10	SAND, fine grained, lt. brown GRAVEL, sand in layers	9/55	100	50/9	GP	IG	H	Hit while augering
		CONTACT							Driller says out of sand, gravel
	15	SHALE, lt. brown, dry, crumbly (Wthrd)	10/55	100	50/10	WSH	IG	L	
	20								

Client: Bokum Resources Corp.	Job #: 01-100-05-237-00	Sheet 2 of 3	Hole #: TD-5

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20	SHALE, lt. brown, dry, gypsum (Wthrd)	8/55	100	50/8	WSH	IG	L	
	25	CLAYSTONE, lt. brown to gray, gypsum (Wthrd)	9/55	100	50/9	WSH	IG	L	
	30	SHALE, brown to gray, gypsum, sulfur, iron present	9/55	100	50/9	WSH	IG	L	
									Contact ≈3.5'
	35	SHALE, brown to gray, gypsum iron present; gray-brown shale inter-bedded with gray shale, dry (Wthrd)	10/55	100	50/10	WSH	IG	L	
									Driller thinks he hit ≈½" of saturation
	40	SHALE, brown to gray; soft, gypsum sulfur, iron present, dry (Wthrd)				WSH	IB	L	Noticed water in hole after drive. Unable to get measurement.
	45	SHALE, brown to gray; soft gypsum sulfur, iron present (Wthrd)	5/55	100	50/5	WSH	IB	L	
									Driller contact
	0								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 3 of 3 | Hole #: TD-5

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	50	SHALE, gray, dry, slightly hard	4/55	100	50/4	WSH	IB	L	
		NOTE: Driller thinks he hit harder shale at 47'							
	55	SHALE, gray, dry, brittle, platy	4½/55	100	50/4½	SH	IB	L	
	0								
	5								
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: TD-6

Sheet 1 of 3

Start: 9:00 1/ 4 /79

Finish: 13:00 1/ 4 /79

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" H/S with 3¼" ID SS Sampler

Fluid: None

SAI by: Kennedy

Completion:

LOCATION PLOT

TD:55.3 FT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
1/4/79	0	SAND, silty, Tr. organics, fine to very fine grained, med. yellow brown, dry				SC			
		SAND, med. yellow brown (gray), fine grained, dry with roots					IG		
	5	CONTACT - SHALE, med. brown with Fe stain, silty in part, gypsum ≈25%, Fe stain, dry, (Wthrd)	12/55	100	50/12	SC WSH	IB IG	M	
	10	SHALE, med. gray brown, dry, gypsum (10%), Fe stain, (Wthrd) throughout	12/55	100	50/12	WSH	IB FR	M/L	
	15	SHALE, med. gray brown, dry, gypsum (25%), Fe stain, organics in partings, silty in parts, (Wthrd)	11/55	100	50/11	WSH	IB FR	M	
	20								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 2 of 3 | Hole #: TD-6

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20	SHALE, med. gray brown, dry, gypsum (10%), Fe stain throughout, silty in parts, (Wthrd)	10/55	100	50/10	WSH	IB FR	L	
	25	SHALE, med. gray, dry, gypsum (20%) Fe stain (decreasing), fossiliferous remnants	13/55	100	50/13	WSH	FR IB	M	
	30	SHALE (CLAYSTONE), med. gray, gypsum (15%), Fe stain (decreasing, dry, (Wthrd)	14/55	100	50/14	WSH	FR	L/M	
		NB vertical gypsum seams, X-cutting natural layering							32' - drilling got harder
	35	SHALE, dark gray, dry, with gypsum (5%), sulfur, harder than above (Wthrd)	6/55	100	50/6	WSH	FR	L/M	Sulfur may be dep. from gypsum.
	40	SHALE, dark gray, dry, with gypsum (10%), sulfur on partings, minor Fe stain, (Wthrd)	7/55	100	50/7	WSH	FR	L/M	Good cuttings recovery to this point
	45	SHALE, dark gray, moist with gypsum (15%), minor sulfur, soft in parts fractures filled with gypsum, silty very fine-med. sand layers (Wthrd) Drilling much harder at ≈48'	9/55	100	50/3	WSH	FR	L/M	Cutting <u>not</u> coming out well now - need water
	0	Gradational contact							

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 3 of 3 | Hole #: TD-6

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	50	SHALE, dark gray, black, minor gypsum, dry, hard, brittle, no Fe stain	9/56	100	50/3	WSH	FR	L/M	Added 3 gal. water to move cutting up hole
	55	SHALE, dark gray, balck, 1% gypsum, dry, hard, platy on partings of layering	4/55	100	50/4	SH	IB	L	
	0								
	5								
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: TD-7

Sheet 1 of 3

Start: 13:30 1/4/79

Finish: 16:00 1/4/79

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" H/S with 3¼" ID SS Samples

Fluid: Air

SAI by: Kennedy

Completion: 10'2" screen, blank from 49' to above ground, gravel screen 49-50'

TD 65.3 FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
1/4/79	0	SAND, very fine fragment, yellowish brown, silty, organics, loose				SM SC	IG	M	
		CONTACT				WSH			Drilling contact
	5	SHALE, lt. brown, gypsum (25%) brittle, minor Fe stain, dry (Wthrd)	15/55	100	50/15	WSH		M	
	10	As above but more Fe stain and browner in color, dry	15/55	100	50/15	WSH	FR	M	
	15	SHALE, med. gray, gypsum (15%), Fe stain in partings, dry (Wthrd)	14/55	100	50/14	WSH	FR/IB	M	
	20								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 2 of 3 | Hole #: TD-7

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20	SHALE, silty layers, med. yellow brown-gray, mottled with Fe stain and gypsum (<10%), dry, (Wthrd)	12/55	100	50/12	WSH			
	25	SHALE, sand and silty, layers ≈15%, X-cuttings gypsum seams (15%), med. brown, brittle and parting easily, dry, (Wthrd)	13/55	100	50/13	WSH	IB	M	
	30	SHALE (CLAYSTONE), med. orange brn. mod. soft, Fe stain and gypsum, interlayered with siltstone and sandstone, dry (Wthrd)	8/55	100	50/8	WSH	IB/FR	L	Drilling harder at 32'
		CONTACT, hard layer limestone chips							
	35	SHALE, med. gray, hard, dry with no Fe stain, gypsum xals, cross cutting patterns of gypsum, brittle (<15%) and Fe stain	14/55	100	50/14	WSH	IB/FR	L	
	40	SHALE, dark gray, hard, brittle, X-cut, gypsum (<10%), dry, no Fe stain, platy along track and bedding	6/55	100	50/6	WSH	IB/FR	L	
	45	SHALE, dark gray, hard, brittle, platy, minor gypsum and Fe stain. X-cutting bedding, dry	4/55	100	50/4	WSH	IB	L	
	0								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 3 of 3 | Hole #: TD-7

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	50	SHALE, dark gray, hard, brittle, <3% gypsum, no Fe stain, drills hard, dry				WSH	IB	L	
	55	Inferred Contact SHALE, dark gray-black, brittle, dry, hard, no Fe stain, (Unwthrd)	½"/55	100	50/½	SH	IB	VL	
	60	No sample - but S. A. Above	2/55	100	50/2	SH	IB	VL	
	65	SHALE, dark gray, brittle, platy dry, fractured along bedding planes	3/55	100	50/3	SH		VL	
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation	Piezometer #: TD-8
Job: 1-100-05-237-00	Sheet 1 of 3
Start: 9:30 1/5/79	Drill Type: CME-45
Finish: 12:00 1/5/79	Location: N: E:
	Elevation: Ft (LSD)
Hole: 6" Hollow Stem Auger with 3¼" I.D. Split Spoon	Fluid: None
	SAI by: Culver/Kennedy
Completion: Sample	
See screen completion diagrams	TD: 65.2 FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	0	Sand, salty, Tr. organics				SC			
1/5/78									
	4'9" / 5	Silt, sandy, reddish brown, Tr. organics Tr. gypsum	18"/55	100	42/18"	ML	JG	M	Drilling contact
	6'5"	Contact (Damp) Shale (Claystone)							
	9'9" / 10	Shale, Olive brown, thin bedded	18"/55	100	50/18	Wsh	FR	M/L	
	14'9" / 15	Shale, soft, gray, thin bedded, highly fractured, fresh surfaces, dark gray with Fe staining along select beds. Fr. gypsum, ca Traces fossils (wthrd)	14/55	100	51/14	Wsh	FB	M	
	19'9" / 20	Shale, med. gray, thin bedded, Tr. organics, gypsum (5-10%) soft, dry Fe stain, (Wthrd)	9/55	100	50/9"	Wsh	F/B	L/M	

Client: Bokum Resources Corp. | Job #: 1-100-05-237-00 | Sheet 2 of 3 | Hole #: TD-8

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20								
	24'9"	Shale, med. brown, bray thin bedded dry, gypsum (5-10%), Tr. Fe oxides (wthrd)							
	25		12"/55	100	50/12"	Wsh	F/B	L	
	29'9"	Shale, med. gray brown, gypsum (5-10%) Fe stain along beds, thin bedded, dry (Wthrd)							
	30		11"/55	80	50/11"	Wsh	F/B	L	
	34'9"	Shale, hard, lt. brown, olive green Tr. gypsum intergrowth. Fe stain along bedding, dry (wthrd)							
	35		14"/55	70	50/14	Wsh	F	M/L	Soft drilling starts
		Limestone ≈6" thick							
	40	Shale, med. gray, gypsum (10%) fractured, platy, Mo Fe stain, dry (wthrd)	14"/55	80	50/14	Wsh	Fr	M/L	Harder drilling at 42'
	45	Shale, med. gray, gypsum (<5%) fractured, Fe stain in partings, harder than above; platy, denser (wthrd) than above, dry	6"/55	80	50/60	Wsh	Fr	M/L	Soft drilling
	50	Shale, med. dark gray, blockier, dry minor gypsum (<5%), platy Near contact to unweathered	4/55	100	50/4	Wsh	Fr	L	

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 3 of 3 | Hole #: TD-8

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	0								
	55	No Samples Lost	2"/55	0	50/2	SH			56'-1' of Hard drilling (Limestone)
	60	Shale, hard, dark gray, Fe stain along fractures, no gypsum, dry	2"/55	100	80/3"	SH	L	IB FR	
	65	As above at 60' with fossils	3"/55	<5	80/3"	SH	L	F	
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: TD-9

Sheet 1 of 3

Start: 12:30 1 / 5 /79

Finish: 15:30 1 / 5 /79

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" Auger w̄ 3¼" H/S

Fluid: None

SAI by: Kennedy

Completion:

LOCATION PLOT

TD: 6.3 FT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
1/5/79	0	Sand, silty, clayey, lt. gray brown, dry				SC			
	5	Sand, clayey, lt. yellow brown, friable, organics, caliche, mottled weathering, dry gypsum (5%)	18"/55	100	42/18	SC	40	IB/JL	
									Drilling Contact
	10	Shale, med. brown gray, soft dry, platy, minor Fe-stain, minor gypsum (wthrd)	11"/55	100	50/11	WSH	FR	L	
	15	Shale, med. brown gray, mod. hard, dry, minor Fe stain, no gpysum, platy in part, (wthrd), Hard Ls. layer	9"/55	100	50/9	WSH	FR	L	
				GRAB SAMPLE					
	20								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 2 of 3 | Hole #: TD-9

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20	Shale, med. brown gray, mod hard, dry, minor Fe stain and gymsum, platy in part, (Wthrd)	9"/55	100	50/9	WSH	FR	L	
	25	Shale, med. brown, mod. hard, dry, platy in parts, zone of Fe stain, minor gypsum (Wthrd)	17"/55	100	50/17	WSH	FR	L	
	30	Shale, med. gray, platy w̄ fractures filled with gypsum, dry, mod. hard; minor Fe stain, (Wthrd)	8"/55	100	50/8	WSH	L/M	L	BLOWS
	35	Shale, med. gray, platy, hard, minor gypsum, fractured with gypsum, (wthrd), dry	7"/55	100	50/7	WSH	L/M	L	
	40	Shale, dark gray, platy, very soft in parts, fractured with gypsum, dry Fe stain, (Wthrd)	5"/55	100	50/5	WSH	L/M	L	
	CONTACT								
	45	Shale, dark gray/black, platy, but soft and moist in parts, gypsum (10%) not visibly fractured	9"/55	100	50/9	WSH	L	L	Moist Sample
	0								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 3 of 3 | Hole #: TD-9

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	50	Shale, dark gray/black, platy and disc-like, dry, hard to brittle, <1% gypsum	3"/55	100	50/3	SH	L	VL	
	55	Shale, dark gray/black, platy in part but some blocky and soft, dry	2"/55	100	50/2	SH	L	VL	
	60	Shale, dark gray/black, hard, dry, dense	3"/55	100	50/3	SH	L	VL	
	5								
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: TD-10

Sheet 1 of 3

Start: 13:00 1/7/79

Finish: 09:30 1/7/79

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" Hollow Stem Auger with 3¼" I.D. Split Spoon

Fluid:

SAI by: Clay Culver

Completion:

LOCATION PLOT

TD: 60.2FT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	0	Sand, silty, clayey, Tr. organics				SC			
	5	Shale, gypsifeious layer and Xals, gray, dry (Wthrd)	13"/55	100	42/13	WSH	FR	H	
	10	Shale, brownish olive gray, gypsum (15%) as irregular growths disrupting bedding, hard, dry thin bedded (Wthrd)	15"/55	100	50/15	WSH	FR	M/L	
	5	Shale, brownish gray, soft, thin bedded, Fe staining along bedding, dry, gypsum (5-10%) seams disrupts bedding, (Wthrd)	13/55	100	50/13	WSH	FR	FR	
	20								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 2 of 3 | Hole #: TD-10

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20	Shale, soft, brownish lt. gray, with layers of med. gray clt, Fe stain (Tr) along brown/gray shale contacts	11/55	100	50/11	FR	L	FR	
		Gypsum as intergrowths 40%, dry (Wthrd)							
	25	Shale, gray brown, thin bedded, dry Tr. organics, Fe stain along bedding planes, gypsum as intergrowths (8%) (Wthrd)	13/55	100	50/13	WSH	FR	L	
	30	Shale, lt. brown gray, dry, Fe stain along bedding, gypsum as intergrowths (5-10%) (Wthrd)	18"/55	100	50/13	WSH	L	FR	
	35	Shale, lt. brown gray, harder than above, Gypsum (5-8%), (Wthrd)	8"/55	70	50/8	WSH	FR	L	
	40	Shale, soft, damp, dark gray, gypsum intergrowths (20%) locally disrupt bedding (Wthrd)	13"/55	100	50/13	WSH	F	M/H	
	45	As above except more moist	15/55	100	50/15	WSH	FR	H	
	0								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 3 of 3 | Hole #: TD-10

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	50	Shale, damp, dark gray: hard, gypsum (2-5%) disturbing bedding.	3/55	100	50/3	WSH	FR	H	
	55	Shale, dark gray, dry thin bedded, Tr. gypsum, platy	3/55	150	50/3	SH	B	L	
	60	Shale, very wet, dark gray, Tr. gypsum as intergrowths, thin bedded, fractured	3/55	100	50/3	SH	JG	H	
	5								
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: TD-11

Sheet 1 of 3

Start: 10:00 1/ 8 /79

Finish: 16:30 1/ 8 /79

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" Auguer w̄ 3/4" H/S SS Samples

Fluid: None

SAI by: Kennedy

Completion: Not backfill to 55'; sand to 31' BGS; gravel to 52.5' Natural fill to 1' BGS, 10' screen 52.5' to 42.5'

TD 65.2 FT

LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
1/8/79	0								
	5	Sand, silty, light gray, mottled, caleche, hardened with weathering, dry	10/55	100	50/14	SP	IG	L/M	
	10	Shale, dark gray, soft, fractured, gypsum (10%), Fe stain, dry (Wthrd)	17/55	100	50/17	WSH	FR	L	
	15	Shale, med. brown gray, 50 ft. but platy (gypsum ≈ 2%), minor Fe stain fractured, dry, (Wthrd)	18/55	100	38/18	WSH	FR	L	
	20								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 2 of 3 | Hole #: TD-11

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20	Shale, med. brown gray, mod. hard and platy, fractured, gypsum (5%), gypsum in fractures. (Wthrd)	18/55	100	43/18	WSH	FR	L	
	25	Shale, as above but less gypsum and soft throughout and minor Fe stain. Mottled weathering pattern (Wthrd)	12/55	100	50/12	WSH	FT/IB	L	
	30	Shale, med. gray, platy, hard but fractured with gypsum seams (10%) not as highly weathered as above (wthrd) dry	13/55	100	50/13	WSH	L	L	
	35	Shale, med/dark gray, platy, hard, dry, gypsum (10%), fractured with seams of gypsum (Wthrd)	12/55	100	50/12	WSH	L	L	
	40	Shale, dark gray, soft, moist, with gypsum seams (10%), loose and fissle in parts (Wthrd)	18/55	100	50/12	WSH	L/M	L	
	45	Shale , dark gray, soft, moist gypsum seams (5%) to 3/8" thick, possiblly infilled fractures, non-platy (Wthrd)	4/55	100	50/4	WSH	L/M	L	
	0								

Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 3 of 3 | Hole #: TD-11

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	50	Shale, dark gray, soft, slightly moist, gypsum seams (10%), no visible fracture (Wthrd)	7/55	10[illegible]	0/7	WSH	L	L	
	55	Shale, dark gray, dry, platy, competent, dense	3/55	100	50/3	SH	L	L	
	60	Shale, dark gray/black, hard, dry, dense, platy (unweathered)	3/55	80	50/3	SH	L	VL	
	65	Shale, dark gray,black, hard, dry, dense, platy	2½/55	100	50/2½	SH	L	VL	
	0								
	5								
	0								

DRILLING LOG

Client: Bokum Resources Corporation	Piezometer #: TD-12
Job: 1-100-05-237-00	Sheet 1 of 1

Start: 11:30 1/ 9 /79 Finish: : / /	Drill Type: CME-45	Location: N: E: Elevation: Ft (LSD)
Hole: 6" Auger with Hollow Stem with SS Samples	Fluid:	SAI by: Kennedy
Completion:		

LOCATION PLOT

TD: 20.5 FT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
1/9/79	0	SAND, organic plan debris							
	5	NO Sample Taken							
	10	SAND, fine-very fine, med. yellow brown, dry, 40% Si, clean	18/55	100	29/18	SM	IG	M	
		Scattered gravel to 1" diameter layers in cuttings							
	15	SAND/GRAVEL, dark yellow brown, dry some caliche	18/55	100	38/18	GP	IG	M/L	Hit rock blouder on drive
	19	CONTACT - shale, dark black with Fe stain throughout, soft to mod. hard				WSH	FR	M	
	20	slightly moist but not wet, (Wthrd)							

DRILLING LOG

Client: Bokum Resources Corporation

Job: 1-100-05-237-00

Piezometer #: TD-13

Sheet 1 of 2

Start: 09:45 1/10/79

Finish: 14:00 1/10/79

Drill Type: CME-45

Location: N: E:

Elevation: Ft (LSD)

Hole: 6" H/S Auger 3¼"

Fluid: NONE

SAI by: Kennedy/ D. Updegraff

Completion: 10' capped spiral screen; 33' solid casing to ground

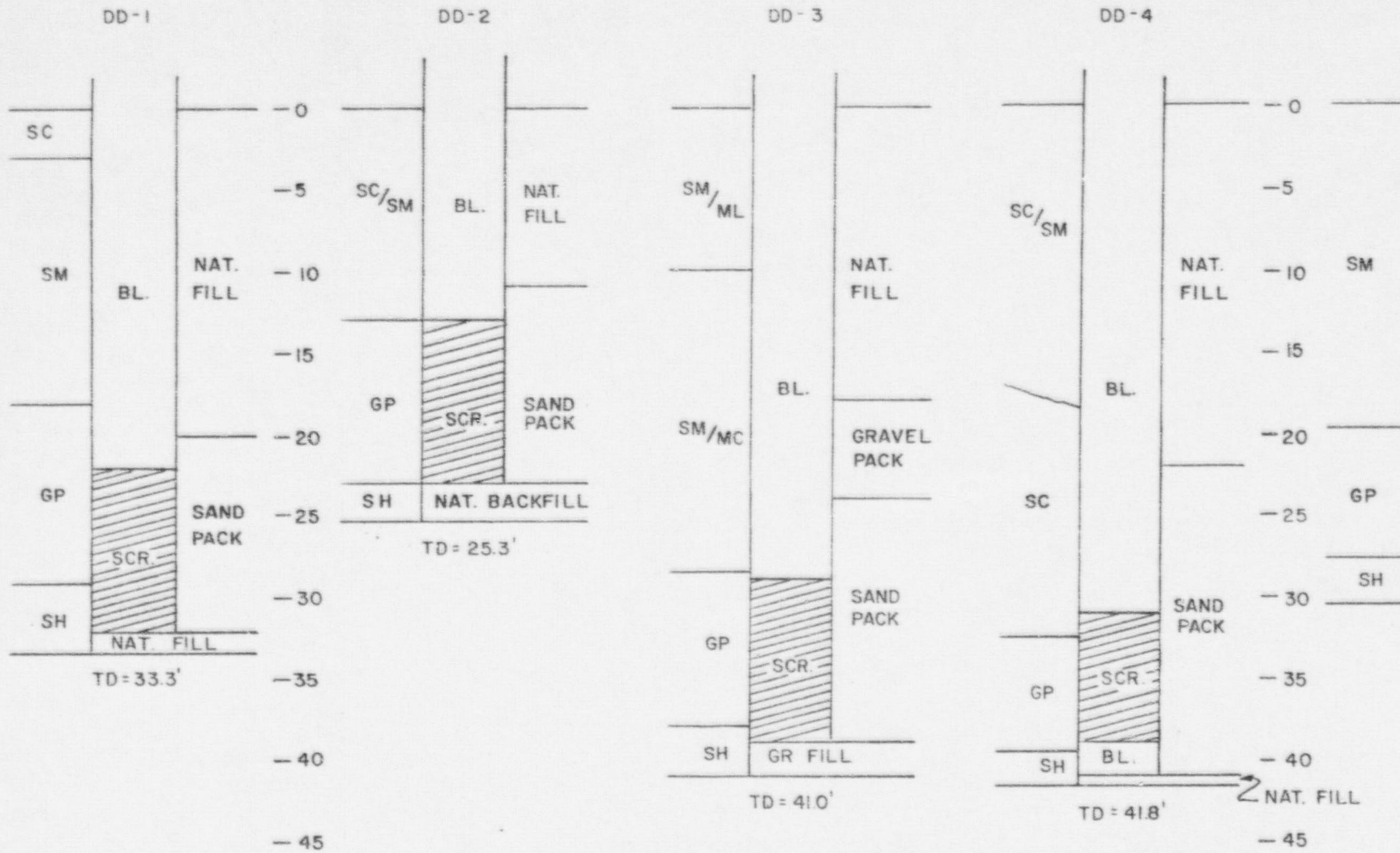
TD: 50.6FT

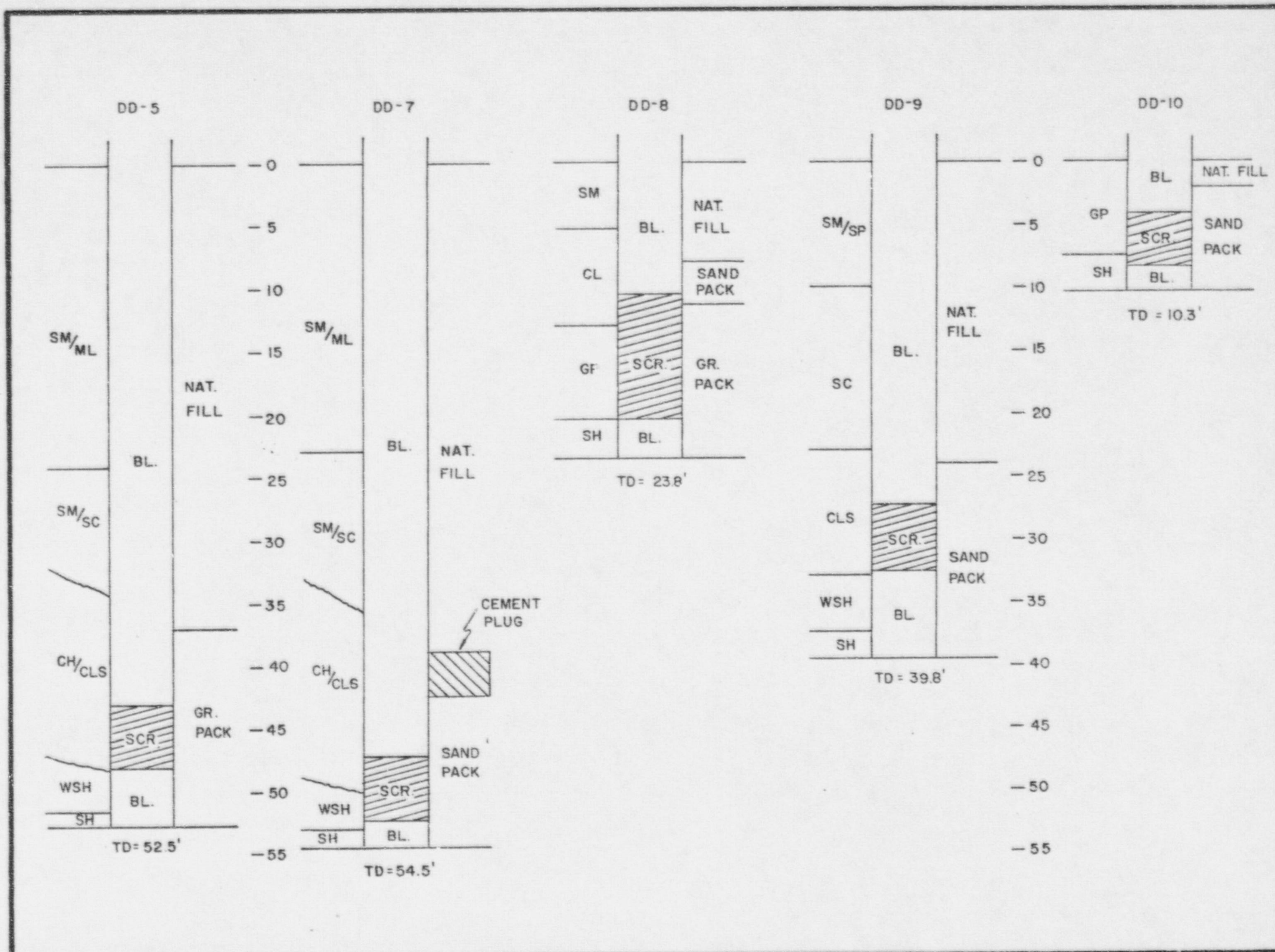
LOCATION PLOT

Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
1/10/79	0	Sand, clayey, silty, fine grained, dry				SC	IG	M	
	5	Sand, mosture zone (frost?) light brown, fine grained with Si, dry, some clay	18/55	100	33/18	SC	IG	M	
	10	Sandy Clay/Clayey Sand, light brown lighter with 10% gypsum, interlayered dry	18/4	100	32/18	SC	IG	L	
	14	Scattered gravel							
	15	Sand, light yellow brown, very fine to fine gravel, some clay, dry	18/55	80	25/18	SC	IG	M	
		Gravel (cuttings to 4" diameter)				GC			
	20								

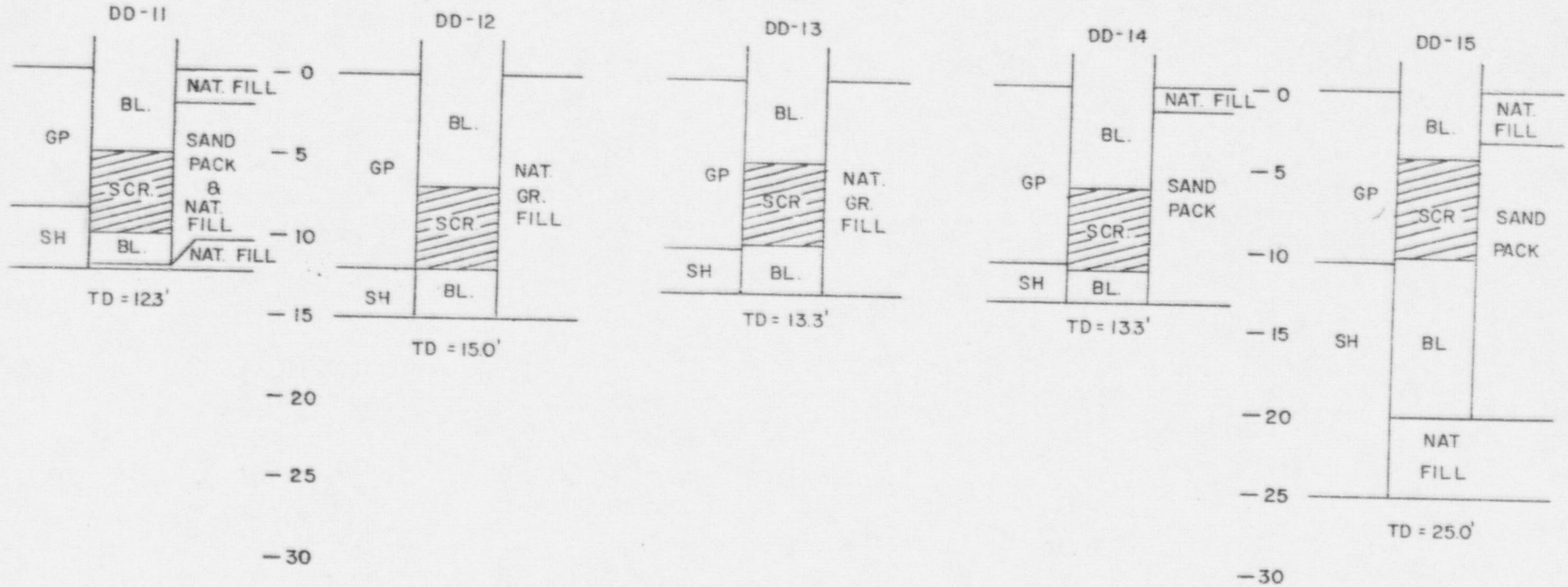
Client: Bokum Resources Corp. | Job #: 01-100-05-237-00 | Sheet 2 of 2 | Hole #: TD-13

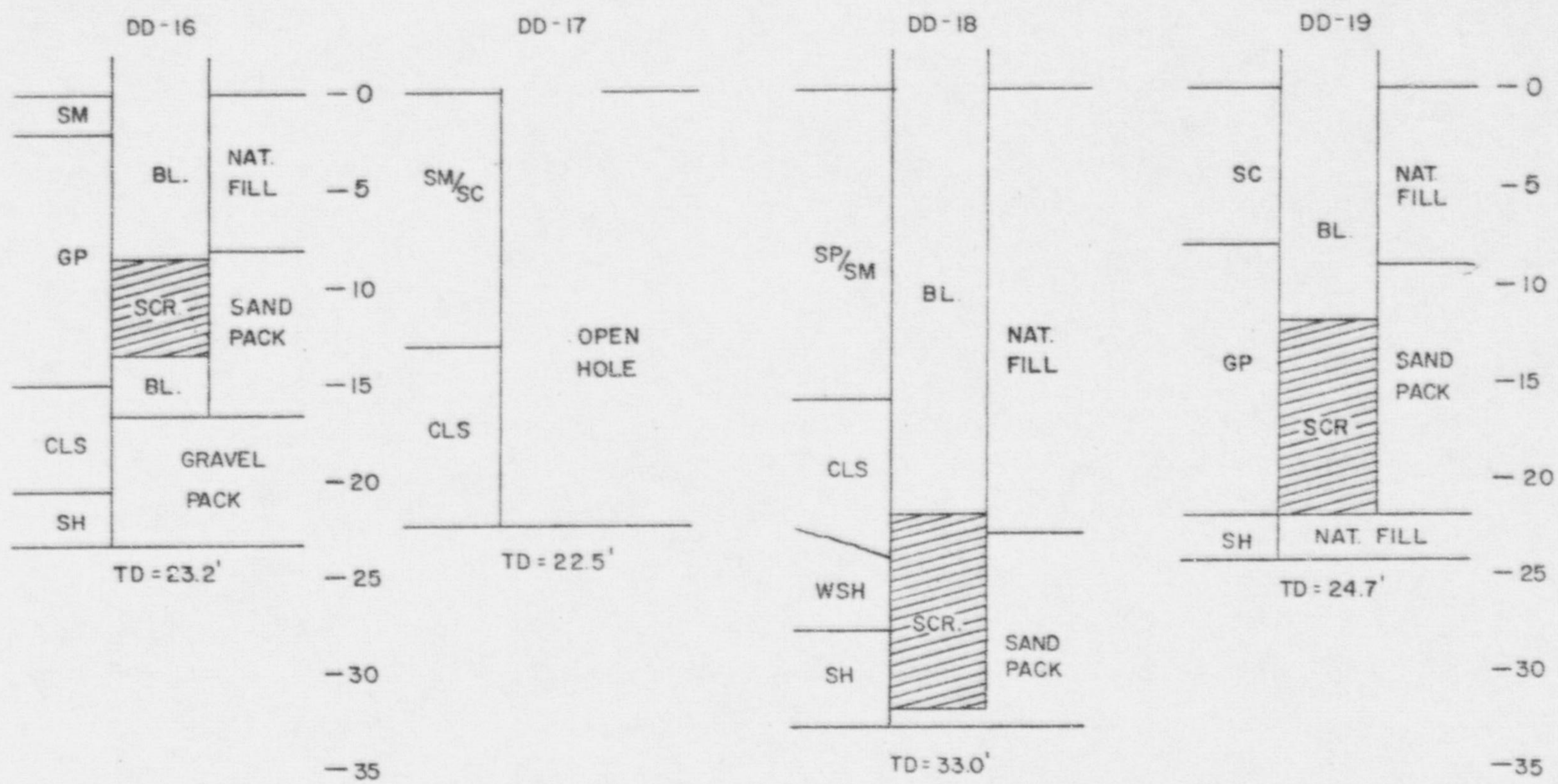
Date	Depth	DESCRIPTION	Sample	Recovery	Blows	Symbol	Poros.	Perm.	NOTES
	20	Gravel/Sand, mixed volcanic, slightly moist, some clay, wthrd gravel, grading to sand interval	18/55	100	15/18	GC SC	IG	M	
		Gravely to 4" diameter - Contact some clay misture				GC			
	25	Shale, gray, dry, slightly damp (wthrd)	14/55	100	50/14	WSH	FR	L/M	Moisture at 18' below LSD
	30	Shale, gray, dry, fossils, (Wthrd)	4/55	100	50/14	WSH	FR	L	Hit rock at 13", hit shale on drive, top of drive
	35	Shale, gray, dry, gypsum seams (Wthrd)	5/55	100	50/5			L	
	40	Shale, gray, dry, limestone at top of drive	5/55	100	50/5			L	
	45	Shale, gray, dry, platy	3/55	100	50/3	SH		L	
	50	Shale, gray, dry, some limestone	3/55	100	50/3			L	

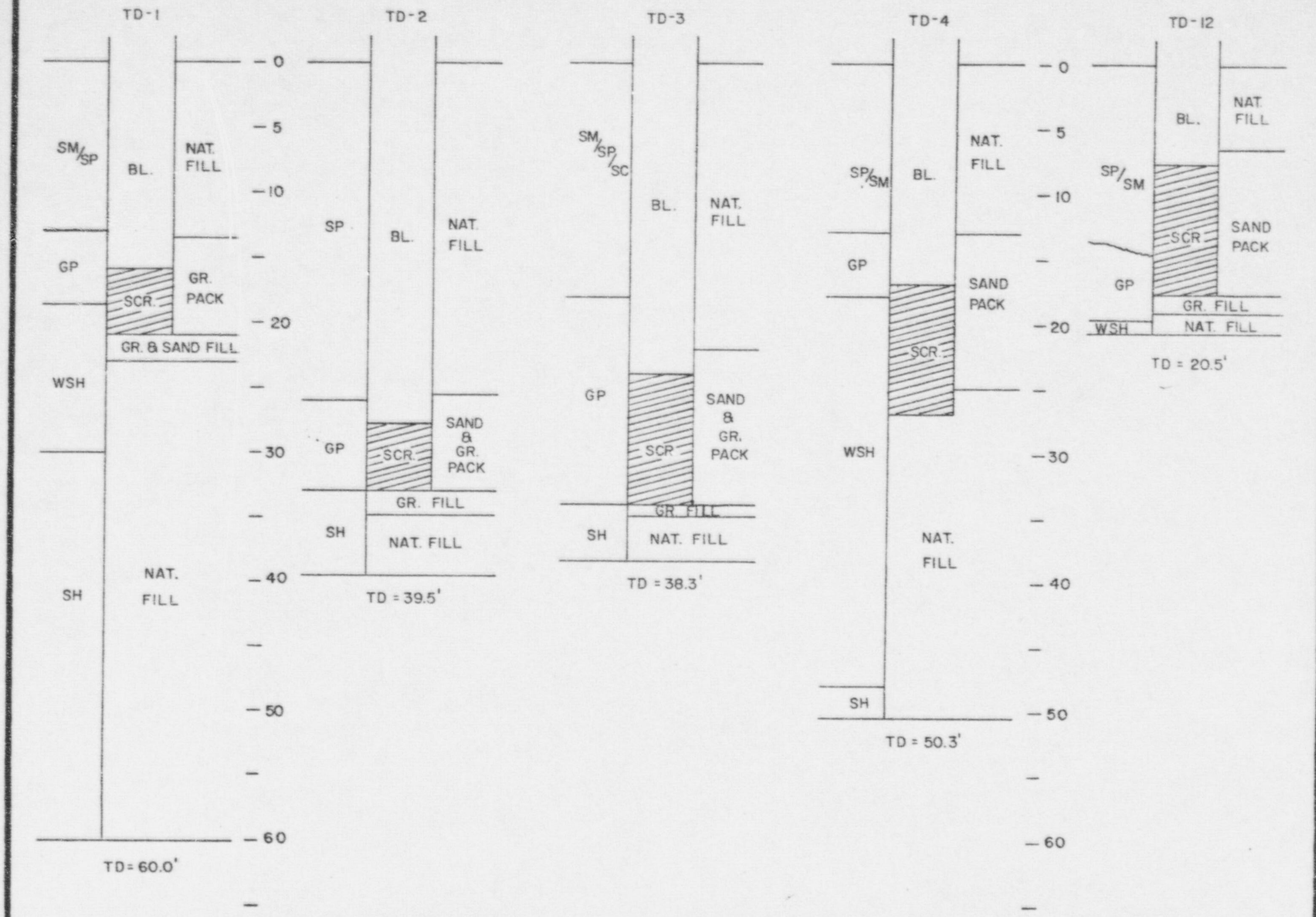

DD-1
SC
SM
BL.
NAT. FILL
GP
SAND PACK
SCR.
SH
NAT. FILL
TD = 33.3'
DD-2
SC/SM
BL.
NAT. FILL
GP
SCR.
SAND PACK
SH
NAT. BACKFILL
TD = 25.3'
DD-3
SM/ML
NAT. FILL
BL.
SM/MC
GRAVEL PACK
SAND PACK
GP
SCR.
SH
GR FILL
TD = 41.0'
DD-4
SC/SM
NAT. FILL
BL.
SC
SAND PACK
GP
SCR.
SH
BL.
NAT. FILL
TD = 41.8'
DD-6
SM
BL.
NAT. FILL
GP
SCR
SAND & NAT. FILL PACK
SH
BL.
TD = 30.3'
0
5
10
15
20
25
30
35
40
45



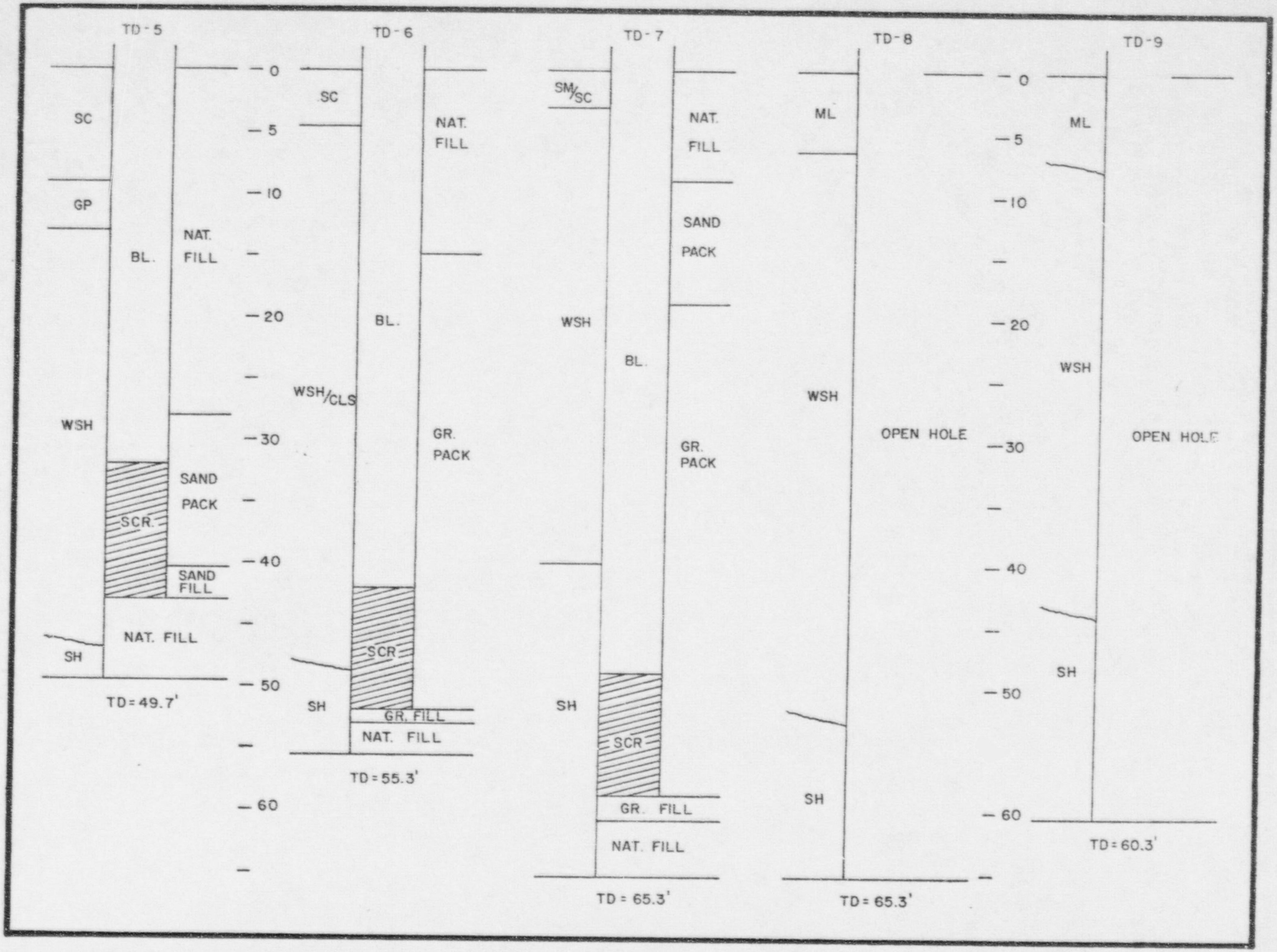
DD-5
SM/ML
SM/SC
CH/CLS
WSH
SH
BL.
SCR.
BL.
NAT. FILL
GR. PACK
TD= 52.5'
0
5
10
15
20
25
30
35
40
45
50
55
DD-7
SM/ML
SM/SC
CH/CLS
WSH
SH
BL.
SCR.
BL.
NAT. FILL
CEMENT PLUG
SAND PACK
TD=54.5'
DD-8
SM
CL
GF
SH
BL.
SCR.
BL.
NAT. FILL
SAND PACK
GR. PACK
TD= 23.8'
DD-9
SM/SP
SC
CLS
WSH
SH
BL.
SCR.
BL.
NAT. FILL
SAND PACK
TD = 39.8'
DD-10
GP
SH
BL.
SCR.
BL.
NAT. FILL
SAND PACK
TD = 10.3'


DD-11
NAT. FILL
BL.
GP
SAND
PACK
&
NAT.
FILL
SCR.
SH
BL.
NAT. FILL
TD = 12.3'
DD-12
BL.
GP
NAT.
GR.
FILL
SCR.
SH
BL.
TD = 15.0'
DD-13
BL.
GP
NAT.
GR.
FILL
SCR.
SH
BL.
TD = 13.3'
DD-14
NAT. FILL
BL.
GP
SAND
PACK
SCR.
SH
BL.
TD = 13.3'
DD-15
NAT.
FILL
BL.
GP
SCR.
SAND
PACK
SH
BL
NAT
FILL
TD = 25.0'
0
5
10
15
20
25
30

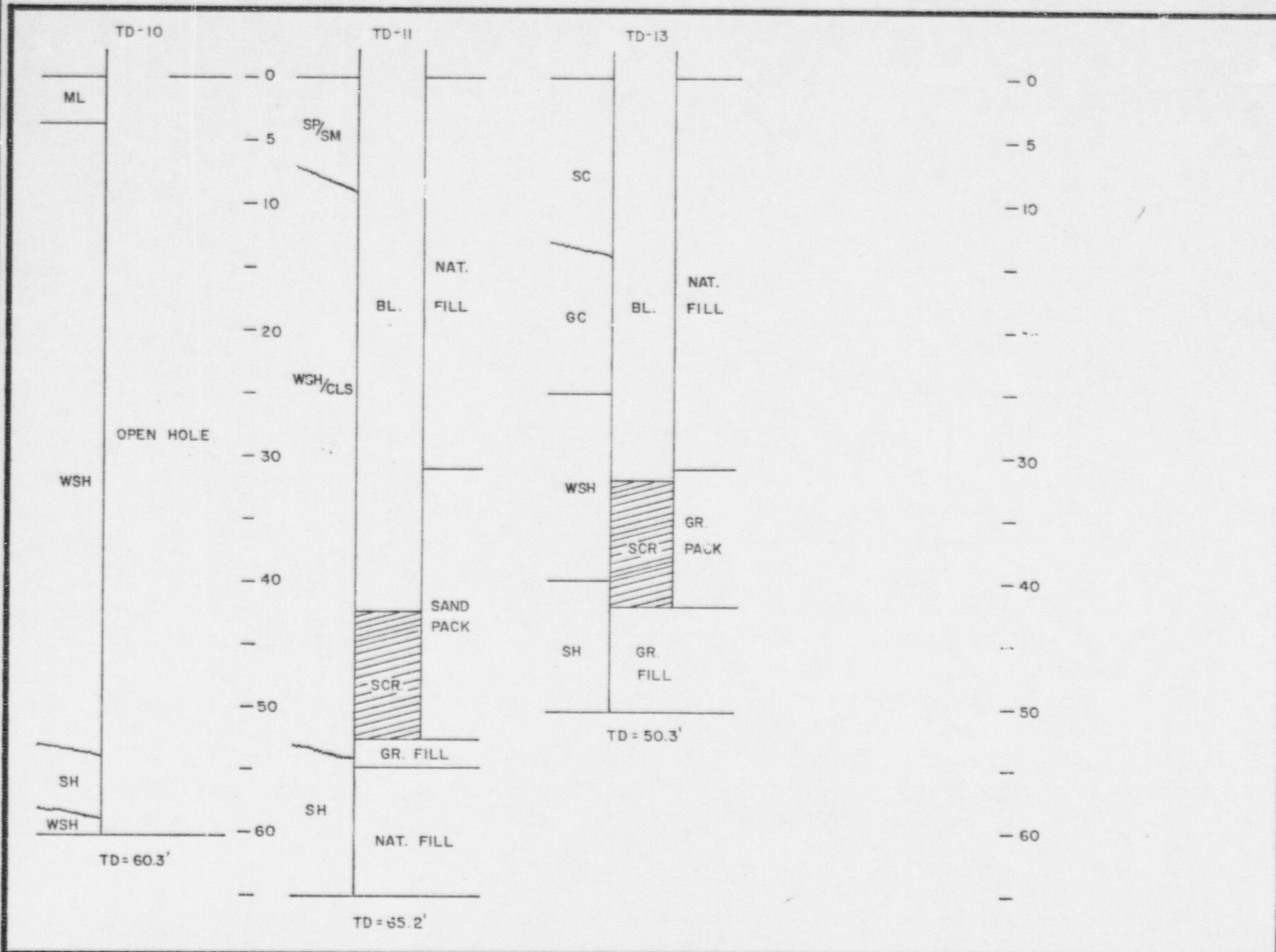

DD-16
SM
BL.
NAT. FILL
GP
SCR
SAND PACK
BL.
CLS
GRAVEL PACK
SH
TD = 23.2'
DD-17
SM/SC
OPEN HOLE
CLS
TD = 22.5'
DD-18
SP/SM
BL.
NAT. FILL
CLS
WSH
SCR.
SAND PACK
SH
TD = 33.0'
DD-19
SC
NAT. FILL
BL.
GP
SAND PACK
SCR
SH
NAT. FILL
TD = 24.7'
0
5
10
15
20
25
30
35



TD-1
SM/SP
BL.
NAT. FILL
GP
SCR.
GR. PACK
GR. & SAND FILL
WSH
SH
NAT. FILL
TD = 60.0'
TD-2
SP
BL.
NAT. FILL
GP
SCR.
SAND & GR. PACK
GR. FILL
SH
NAT. FILL
TD = 39.5'
TD-3
SM/SP/SC
BL.
NAT. FILL
GP
SCR.
SAND & GR. PACK
GR. FILL
SH
NAT. FILL
TD = 38.3'
TD-4
SP/SM
BL.
NAT. FILL
GP
SAND PACK
SCR.
WSH
NAT. FILL
SH
TD = 50.3'
TD-12
BL.
NAT. FILL
SP/SM
SCR.
SAND PACK
GP
GR. FILL
WSH
NAT. FILL
TD = 20.5'
0
5
10
20
30
40
50
60



TD-5
SC
GP
WSH
SH
BL.
SCR.
NAT. FILL
SAND PACK
SAND FILL
NAT. FILL
TD=49.7'
0
5
10
20
30
40
50
60
TD-6
SC
WSH/CLS
SH
BL.
SCR
NAT. FILL
GR. PACK
GR. FILL
NAT. FILL
TD=55.3'
TD-7
SM/SC
WSH
SH
BL.
SCR
NAT. FILL
SAND PACK
GR. PACK
GR. FILL
NAT. FILL
TD=65.3'
TD-8
ML
WSH
SH
OPEN HOLE
TD=65.3'
TD-9
ML
WSH
SH
OPEN HOLE
TD=60.3'



TD-10
ML
WSH
OPEN HOLE
SH
WSH
TD = 60.3'
TD-11
SP/SM
WSH/CLS
BL.
NAT. FILL
SAND PACK
SCR
GR. FILL
SH
NAT. FILL
TD = 65.2'
TD-13
SC
GC
WSH
SH
BL.
NAT. FILL
SCR
GR. PACK
GR. FILL
TD = 50.3'
0
5
10
20
30
40
50
60

APPENDIX B

PUMP TEST DATA

FIELD WELL TESTING DATA

Piezometer: DD-11, page 1 of 4 Job: 1-100-05-237-00 Client: Bokum Resources Corp.

SAI by: K. Kennedy/D. Updegraff/ C. Culver Location: Marquez, New Mex.

Date: January 9, 1979

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN)	TIME SINCE PUMPING STOPPED (MIN)	t/r^2 (MIN/FT^2)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	JACOB'S DRAW-DOWN (FT)	COMMENT
1/9/79	9:51	--	---	--	--	4.85	--	--	Static water
	10:16	0	---	0.00	--	--	--	--	Pump started
	10:28	12	---	0.0121	--	4.95	0.10	0.10	
	10:41	25	---	0.0251	--	5.00	0.15	0.15	
	10:55	39	---	0.0392	--	5.02	0.17	0.17	
	11:09	53	---	0.0532	--	5.03	0.18	0.18	
	11:18	62	---	0.0623	--	5.04	0.19	0.19	
	11:37	81	---	0.0814	--	5.07	0.22	0.22	
	11:47	91	---	0.0914	--	5.07	0.22	0.22	
	11:58	102	---	0.102	--	5.08	0.23	0.23	
	12:12	116	---	0.117	--	5.09	0.24	0.24	
	12:31	135	---	0.136	--	5.10	0.25	0.24	
	12:44	148	---	0.149	--	5.10	0.25	0.24	
	12:57	161	---	0.162	--	5.12	0.27	0.26	
	13:34	198	---	0.199	--	5.12	0.27	0.26	
	14:05	229	---	0.230	--	5.14	0.29	0.28	

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN)	TIME SINCE PUMPING STOPPED (MIN)	t/r^2 (MIN/FT^2)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	JACOB'S DRAW-DOWN (FT)	COMMENT
	14:37	261	---	0.262	--	5.14	0.29	0.28	
	15:06	290	---	0.291	--	5.15	0.30	0.29	
	15:48	332	---	0.334	--	5.14	0.29	0.28	
	16:31	375	---	0.377	--	5.15	0.30	0.29	
	17:22	426	---	0.428	--	5.15	0.30	0.29	
	18:06	470	---	0.472	--	5.14	0.29	0.28	
	13:48	512	---	0.514	--	5.17	0.32	0.31	
	19:52	576	---	0.579	--	5.14	0.29	0.28	
	21:07	651	---	0.654	--	5.16	0.31	0.30	
	21:14	658	---	0.661	--	5.14	0.29	0.28	
	23:07	771	---	0.775	--	5.14	0.29	0.28	
1/10/79	00:08	832	---	0.836	--	5.14	0.29	0.28	
	2:07	951	---	0.955	--	5.14	0.29	0.28	
	4:09	1073	---	1.08	--	5.16	0.31	0.30	
	3:34	1178	---	1.18	--	5.17	0.32	0.31	
	8:10	1314	---	1.32	--	5.17	0.32	0.31	
	10:05	1429	---	1.44	--	5.16	0.31	0.30	
	12:07	1551	---	1.56	--	5.22	0.37	0.36	
	12:08	1552	---	1.56	--	5.19	0.34	0.33	
	12:11	1555	---	1.56	---	5.17	0.32	0.31	

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN)	TIME SINCE PUMPING STOPPED (MIN)	t/r^2 (MIN/FT^2)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	JACOB'S DRAW-DOWN (FT)	COMMENT
	12:16	1560	0	1.57	--	--	--	--	Pump Stopped
	12:23	1567	7	-	224.	5.16	0.31	0.30	
	12:34	1578	18	--	87.7	5.12	0.27	0.26	
	12:50	1594	34	--	46.9	5.11	0.26	0.25	
	12:51	1603	43	--	37.3	5.14	0.29	0.28	
	13:00	1604	44	--	36.5	5.12	0.27	0.26	
	13:01	1605	45	--	35.7	5.12	0.27	0.26	
	13:13	1617	57	--	28.4	5.07	0.22	0.22	
	13:35	1639	79	--	20.7	5.05	0.20	0.20	
	13:50	1654	94	--	17.6	5.05	0.20	0.20	
	14:08	1672	112	--	14.9	5.02	0.17	0.17	
	14:35	1699	139	--	12.2	5.02	0.17	0.17	
	14:51	1715	155	--	11.1	5.01	0.16	0.16	
	15:25	1749	189	--	9.25	5.01	0.16	0.16	
	16:00	1784	224	--	7.96	5.00	0.15	0.15	
	20:29	2053	493	--	4.16	4.98	0.13	0.13	
1/11/79	00:18	2282	722	--	3.16	4.93	0.08	0.08	
	9:17	2821	1261	--	2.24	4.90	0.05	0.05	
	14:55	3159	1599	--	1.98	4.90	0.05	0.05	

Piezometer: DD-11, page 4 of 4

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN)	TIME SINCE PUMPING STOPPED (MIN)	t/r^2 (MIN/FT^2)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	JACOB'S DRAW-DOWN (FT)	COMMENT
	17:41	3325	1765	--	1.88	4.89	0.04	0.04	
1/12/79	9:06	4250	2690	--	1.58	4.83	-0.02	-0.02	
1/13/79	11:11	5815	4255	--	1.37	4.69	-0.16	-0.16	

FIELD WELL TESTING DATA

Piezometer: DD-12, page 1 of 3 JOB: 1-100-05-237-00 Client: Bokum Resources Corp.

SAI by: K. Kennedy/D. Updegraff/C. Culver Location: Marquez, New Mex.

Date: January 9, 1979

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN)	TIME SINCE PUMPING STOPPED (MIN)	t/r^2 (MIN/FT^2)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	JACOB'S DRAW-DOWN (FT)	COMMENT
1/9/79	9:50	--	--	---	---	6.77	--	--	Static
	10:16	0	--	0.00	---	--	--	--	Pump started
	10:27	11	--	0.00742	---	6.89	0.12	0.12	
	10:39	23	--	0.0155	---	6.93	0.16	0.16	
	10:51	35	--	0.0236	---	6.96	0.19	0.19	
	11:03	47	--	0.0317	---	6.98	0.21	0.21	
	11:19	63	--	0.0425	---	7.00	0.23	0.23	
	11:32	76	--	0.0513	---	7.01	0.24	0.24	
	11:46	90	--	0.0607	---	7.06	0.29	0.28	
	11:56	100	--	0.0675	---	7.09	0.32	0.31	
	12:14	118	--	0.0796	---	7.08	0.31	0.30	
	12:34	138	--	0.0931	---	7.08	0.31	0.30	
	12:48	152	--	0.103	---	7.11	0.34	0.33	
	12:59	163	--	0.110	---	7.12	0.35	0.34	
	13:36	200	--	0.135	---	7.16	0.39	0.38	
	14:07	231	--	0.156	---	7.18	0.41	0.40	
	14:39	263	--	0.177	---	7.18	0.41	0.40	
	15:07	291	--	0.196	---	7.20	0.43	0.41	
	15:47	331	--	0.223	---	7.19	0.42	0.40	
	16:30	374	--	0.252	---	7.24	0.47	0.45	
	17:24	428	--	0.289	---	7.24	0.47	0.45	

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN)	TIME SINCE PUMPING STOPPED (MIN)	t/r^2 (MIN/FT^2)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	JACOB'S DRAW-DOWN (FT)	COMMENT
	18:04	468	---	0.316	--	7.25	0.48	0.46	
	18:54	518	---	0.349	--	7.26	0.49	0.47	
	19:50	574	---	0.387	--	7.23	0.46	0.44	
	21:10	654	---	0.441	--	7.26	0.49	0.47	
	22:11	715	---	0.482	--	7.25	0.48	0.46	
	23:18	782	---	0.528	--	7.26	0.49	0.47	
1/10/79	00:05	829	---	0.559	--	7.27	0.50	0.48	
	2:05	949	---	0.640	--	7.27	0.50	0.43	
	4:07	1071	---	0.723	--	7.29	0.52	0.50	
	5:58	1182	---	0.797	--	7.30	0.53	0.51	
	8:07	1311	---	0.884	--	7.33	0.56	0.53	
	10:08	1432	---	0.966	--	7.30	0.53	0.51	
	10:09	1433	---	0.967	--	7.31	0.54	0.51	
	12:05	1549	---	1.045	--	7.33	0.56	0.53	
	12:16	1560	0	1.052	--	--	--	--	Pump stopped
	12:26	1570	10	---	157.	7.26	0.49	0.47	
	12:30	1574	14	---	112.	7.23	0.46	0.44	
	12:37	1581	21	---	75.3	7.20	0.43	0.41	
	12:51	1595	35	---	45.6	7.17	0.40	0.39	
	13:02	1606	46	---	34.9	7.18	0.41	0.40	
	13:17	1621	61	---	26.6	7.12	0.35	0.34	
	13:36	1640	80	---	20.5	7.08	0.31	0.30	
	13:42	1646	86	---	19.1	7.06	0.29	0.28	
	14:12	1676	116	---	14.4	7.05	0.28	0.27	
	14:32	1696	136	---	12.5	7.02	0.25	0.24	

Piezometer: DD-12, page 3 of 3

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN)	TIME SINCE PUMPING STOPPED (MIN)	t/r^2 (MIN/FT^2)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	JACOB'S DRAW-DOWN (FT)	COMMENT
	14:51	1715	155	--	11.1	7.04	0.27	0.26	
	15:24	1748	188	--	9.30	6.98	0.21	0.21	
	16:03	1787	227	--	7.87	6.96	0.19	0.19	
	20:22	2046	486	--	4.21	6.95	0.18	0.18	
1/11/79	00:21	2285	725	--	3.15	6.92	0.15	0.15	
	9:07	2811	1251	--	2.25	6.79	0.02	0.02	
	14:52	3156	1596	--	1.98	6.84	0.07	0.07	
	17:40	3324	1764	--	1.88	6.87	0.10	0.10	
1/12/79	9:01	4245	2685	--	1.58	6.85	0.08	0.08	
1/13/79	11:13	5817	4257	--	1.37	6.77	0.00	0.00	

FIELD WELL TESTING DATA

Piezometer: DD-13, page 1 of 3 JOB: 1-100-05-237-00 Client: Bokum Resources Corp.

SAI by: K. Kennedy/D. Updegraff/C. Culver Location: Marquez, New Mexico

Date: January 9, 1979

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN)	TIME SINCE PUMPING STOPPED (MIN)	t/r^2 (MIN/FT²)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	JACOB'S DRAW-DOWN (FT)	COMMENT
1/9/79	9:48	--	--	---	--	9.05	--	--	Static
	10:16	0	--	0.0000	--	--	--	--	Pump Started
	10:26	10	--	0.0189	--	9.04	-0.01	-0.01	
	10:36	20	--	0.0378	--	9.05	0.00	0.00	
	10:49	33	--	0.0624	--	9.04	-0.01	-0.01	
	10:58	42	--	0.0794	--	9.03	-0.02	-0.02	
	11:17	61	--	0.115	--	9.06	0.01	0.01	
	11:31	75	--	0.142	--	9.05	0.00	0.00	
	11:44	88	--	0.166	--	9.05	0.00	0.00	
	11:49	93	--	0.176	--	9.04	-0.01	-0.01	
	12:17	121	--	0.229	--	9.06	0.01	0.01	
	12:36	140	--	0.265	--	9.07	0.02	0.02	
	12:50	154	--	0.291	--	9.06	0.01	0.01	
	13:01	165	--	0.312	--	9.12	0.07	0.07	
	13:40	204	--	0.386	--	9.11	0.06	0.06	
	14:12	236	--	0.446	--	9.13	0.08	0.08	
	14:41	265	--	0.501	--	9.14	0.09	0.09	
	15:10	294	--	0.556	--	9.15	0.10	0.10	
	15:45	329	--	0.622	--	9.21	0.16	0.16	
	16:29	373	--	0.705	--	9.30	0.25	0.24	
	17:23	427	--	0.807	--	9.24	0.19	0.19	

Piezome[illegible]r: DD-13, page 2 of 3

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN)	TIME SINCE PUMPING STOPPED (MIN)	t/r^2 (MIN/FT^2)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	JACOB'S DRAW-DOWN (FT)	COMMENT
	18:05	469	---	0.887	--	9.26	0.21	0.21	
	18:50	514	---	0.972	--	9.26	0.21	0.21	
	19:52	576	---	1.09	--	9.27	0.22	0.21	
	21:12	656	---	1.24	--	9.28	0.23	0.22	
	22:08	712	---	1.35	--	9.29	0.24	0.23	
	23:20	784	---	1.43	--	9.31	0.26	0.25	
1/10/79	00:03	827	---	1.56	--	9.33	0.28	0.27	
	2:09	953	---	1.80	--	9.38	0.33	0.32	
	4:05	1069	---	2.02	--	9.43	0.38	0.36	
	5:57	1181	---	2.23	--	9.44	0.39	0.37	
	8:08	1312	---	2.48	--	9.43	0.38	0.36	
	10:06	1430	---	2.70	--	9.46	0.41	0.39	
	12:06	1550	---	2.93	--	9.49	0.44	0.42	
	12:16	1560	0	2.95	--	--	--	--	Pump stopped
	12:24½	1568½	8½	--	185.	9.43	0.38	0.36	
	12:31	1575	15	--	105.	9.48	0.43	0.41	
	12:32½	1576½	16½	--	95.5	9.44	0.39	0.37	
	12:38	1582	22	--	71.9	9.42	0.37	0.36	
	12:39	1583	23	--	68.8	9.50	0.45	0.43	
	12:40	1584	24	--	66.0	9.51	0.46	0.44	
	12:41	1585	25	--	63.4	9.49	0.44	0.42	
	12:53	1597	37	--	43.2	9.45	0.40	0.38	
	12:54	1598	38	--	42.1	9.44	0.39	0.37	
	13:04	1608	48	--	33.5	9.44	0.39	0.37	

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN)	TIME SINCE PUMPING STOPPED (MIN)	t/r^2 (MIN/FT^2)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	JACOB'S DRAW-DOWN (FT)	COMMENT
	13:19	1623	63	--	25.8	9.40	0.35	0.34	
	13:38	1642	82	--	20.0	9.39	0.34	0.33	
	13:55	1659	99	--	16.8	9.37	0.32	0.31	
	14:16	1680	120	--	14.0	9.36	0.31	0.30	
	14:28	1692	132	--	12.8	9.37	0.32	0.31	
	14:56	1720	160	--	10.8	9.35	0.30	0.29	
	15:22	1746	186	--	9.39	9.34	0.29	0.28	
	16:06	1790	230	--	7.78	9.32	0.27	0.27	
	20:24	2048	488	--	4.28	9.26	0.21	0.21	
1/11/79	00:15	2279	719	--	3.17	9.20	0.15	0.15	
	9:11	2815	1255	--	2.24	9.34	0.29	0.28	
	14:49	3153	1593	--	1.98	9.12	0.07	0.07	
	17:44	3328	1768	--	1.88	9.09	0.04	0.04	
1/12/79	8:57	4241	2681	--	1.58	9.08	0.03	0.03	
1/13/79	11:05	5809	4249	--	1.37	9.03	-0.02	-0.02	

FIELD WELL TESTING DATA

Piezometer: DD-14, page 1 of 4 Job: 1-100-05-237-00 Client: Bokum Resources Corp.

SAI by: K. Kennedy/ D. Updegraff/C. Culver Location: Marquez, New Mex.

Date: January, 9, 1979

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN)	TIME SINCE PUMPING STOPPED (MIN)	t/r^2 (MIN/FT^2)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	JACOB'S DRAW-DOWN (FT)	COMMENT
1/9/79	9:46	--	---	---	---	6.27	--	--	Static
	10:16	0	---	0.0000	---	--	--	--	Pump started
	10:19	3	---	0.0126	---	6.48	0.21	0.21	
	10:20	4	---	0.0168	---	6.53	0.26	0.25	
	10:21	5	---	0.0209	---	6.52	0.25	0.24	
	10:22	6	---	0.0251	---	6.53	0.26	0.25	
	10:25	9	---	0.0377	---	6.54	0.27	0.26	
	10:29	13	---	0.0545	---	6.58	0.31	0.30	
	10:35	19	---	0.0796	---	6.58	0.31	0.30	
	10:37	21	---	0.0880	---	6.96	0.69	0.65	?
	10:41	25	---	0.105	---	6.96	0.69	0.65	?
	10:43	27	---	0.113	---	6.63	0.36	0.35	
	10:47	31	---	0.129	---	6.65	0.38	0.37	
	10:54	38	---	0.159	---	6.67	0.40	0.39	
	10:57	41	---	0.172	---	6.67	0.40	0.39	
	11:00	44	---	0.184	---	6.66	0.39	0.38	
	11:04	48	---	0.201	---	6.67	0.40	0.39	
	11:13	57	---	0.239	---	6.69	0.42	0.40	
	11:21	65	---	0.272	---	6.71	0.44	0.42	
	11:28	72	---	0.302	---	6.73	0.46	0.44	

Piezometer: DD-14, page 2 of 4

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN)	TIME SINCE PUMPING STOPPED (MIN)	t/r^2 (MIN/FT^2)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	JACOB'S DRAW-DOWN (FT)	COMMENT
	11:41	85	---	0.356	---	6.74	0.47	0.45	
	11:51	95	---	0.398	---	6.76	0.49	0.46	
	11:59	103	---	0.431	---	6.77	0.50	0.48	
	12:09	113	---	0.473	---	6.78	0.51	0.49	
	12:19	123	---	0.515	---	6.78	0.51	0.49	
	12:29	133	---	0.557	---	6.80	0.53	0.50	
	12:41	145	---	0.607	---	6.85	0.58	0.55	
	12:51	155	---	0.649	---	6.81	0.54	0.51	
	13:03	167	---	0.700	---	6.81	0.54	0.51	
	13:32	196	---	0.821	---	6.83	0.56	0.53	
	14:03	227	---	0.951	---	6.84	0.57	0.54	
	14:35	259	---	1.09	---	6.85	0.58	0.55	
	15:05	289	---	1.21	---	6.87	0.60	0.55	
	15:41	325	---	1.36	---	6.89	0.62	0.59	
	16:27	371	---	1.55	---	6.86	0.59	0.56	
	17:21	425	---	1.78	---	6.90	0.63	0.59	
	18:07	471	---	1.97	---	6.91	0.64	0.60	
	18:59	523	---	2.19	---	6.91	0.64	0.60	
	19:57	581	---	2.43	---	6.92	0.65	0.61	
	21:04	648	---	2.71	---	6.89	0.62	0.59	
	21:06	650	---	2.72	---	6.91	0.64	0.60	
	22:07	711	---	2.98	---	6.91	0.64	0.60	
	23:04	768	---	3.22	---	6.91	0.64	0.60	

Piezometer: DD-14, page 3 of 4

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN)	TIME SINCE PUMPING STOPPED (MIN)	t/r^2 (MIN/FT^2)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (MIN)	JACOB'S DRAW-DOWN (MIN)	COMMENTS
1/10/79	00:01	825	---	3.46	---	6.93	0.66	0.62	
	2:11	955	---	4.00	---	6.93	0.66	0.62	
	2:57	1001	---	4.19	---	6.92	0.65	0.61	
	4:02	1066	---	4.47	---	6.92	0.65	0.61	
	5:53	1177	---	4.93	---	6.96	0.69	0.65	
	8:02	1306	---	5.47	---	6.98	0.71	0.66	
	10:02	1426	---	5.97	---	6.94	0.67	0.63	
	12:09	1553	---	6.51	---	6.95	0.68	0.64	
	12:16	1560	0	6.54	---	--	--	--	Pump stopped
	12:22	1566	6	--	261.	6.78	0.51	0.49	
	12:27	1571	11	--	143.	6.73	0.46	0.44	
	12:35	1579	19	--	83.1	6.70	0.43	0.41	
	12:42	1586	26	--	61.0	6.66	0.39	0.38	
	12:58	1602	42	--	38.1	6.54	0.27	0.26	
	13:11	1615	55	--	29.4	6.53	0.26	0.25	
	13:33	1637	77	--	21.3	6.53	0.26	0.25	
	13:48	1652	92	--	18.0	6.53	0.26	0.25	
	14:06	1670	110	--	15.2	6.50	0.23	0.23	
	14:26	1690	130	--	13.0	6.49	0.22	0.22	
	14:48	1712	152	--	11.3	6.48	0.21	0.21	
	15:21	1745	185	--	9.43	6.46	0.19	0.19	
	16:08	1792	232	--	7.72	6.43	0.16	0.16	
	20:25	2049	489	--	4.19	6.35	0.08	0.08	
1/11/79	00:17	2281	721	--	3.16	6.34	0.07	0.07	

Piezometer: DD-14, page 4 of 4

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN)	TIME SINCE PUMPING STOPPED (MIN)	t/r^2 (MIN/FT^2)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	JACOB'S DRAW-DOWN (FT)	COMMENT
	9:15	2819	1259	---	2.24	6.35	0.08	0.08	
	14:57	3161	1601	---	1.97	6.31	0.04	0.04	
	17:39	3323	1763	---	1.88	6.30	0.03	0.03	
1/12/79	9:04	4248	2688	---	1.58	6.25	-0.02	-0.02	
1/13/79	11:09	5813	4253	---	1.37	6.17	-0.10	-0.10	

FIELD WELL TESTING DATA

Piezometer: DD-15, page 1 of 7 Job: 1-100-05-237-00 Client: Bokum Resources Corp.

SAI By: K. Kennedy/D. Updegraff/ C. Culver Location: Marquez, New Mex.

Date: January 9, 1979

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN:SEC)	TIME SINCE PUMPING STOPPED (MIN:SEC)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	PUMPING RATE (GAL/MIN)	GALLONS PUMPED (GAL)	COMMENTS
1/9/79	9:34	---	---	--	6.07	--	---	0	
	10:00	---	---	--	--	--	---	---	Pump started
	10:02	---	---	--	6.10	0.03	---	---	
	10:04	---	---	--	6.10	0.03	---	---	
	10:06	---	---	--	6.08	0.01	---	---	
	10:08	---	---	--	6.07	0.00	---	---	
	10:09	---	---	--	6.09	0.02	---	---	
	10:11	---	---	--	--	--	---	---	Pump surging
	10:12	---	---	--	6.24	0.17	---	---	
	10:13	---	---	--	--	--	---	---	Pump surging
	10:14	---	---	--	6.13	0.06	---	---	Pump surging
	10:15	---	---	--	6.10	0.03	---	1½	
	10:16	---	---	--	--	--	---	---	Pump constant
	10:17	1:00	---	--	7.72	1.65	6.	---	
	10:18	2:00	---	---	--	--	6.5	---	
	10:19	3:00	---	---	7.70	1.63	---	---	
	10:20	4:00	---	---	7.70	1.63	---	---	
	10:21	5:00	---	---	7.71	1.64	---	---	
	10:22	6:00	---	---	7.76	1.69	---	---	
	10:23	7:00	---	---	7.79	1.72	6.6	---	
	10:24	8:00	---	---	7.84	1.77	---	---	

Piezometer: DD-15, page 2 of 7

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN:SEC)	TIME SINCE PUMPING STOPPED (MIN:SEC)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	PUMPING RATE (GAL/MIN)	GALLONS PUMPED (GAL)	COMMENTS
	10:25	9:00	---	--	7.88	1.81	---	---	
	10:26	10:00	---	--	7.87	1.80	---	---	
	10:28	12:00	---	--	7.83	1.76	---	---	
	10:30	14:00	---	--	7.96	1.89	---	---	
	10:32	16:00	---	--	8.08	2.01	6.7	---	
	10:34	18:00	---	--	8.10	2.03	---	---	
	10:37	21:00	---	--	8.10	2.03	---	---	
	10:40	24:00	---	--	8.16	2.09	---	---	
	10:43	27:00	---	--	8.15	2.08	---	---	
	10:47	31:00	---	--	8.26	2.19	---	---	
	10:50	34:00	---	--	8.39	2.32	---	---	
	10:51	35:00	---	--	8.34	2.27	---	---	
	10:54	38:00	---	--	8.35	2.28	6.8	---	
	10:57	41:00	---	--	8.48	2.41	---	---	
	11:00	44:00	---	--	8.50	2.43	---	---	
	11:04	48:00	---	--	8.57	2.50	---	---	
	11:08	52:00	---	--	8.62	2.55	---	---	
	11:12	56:00	---	--	8.84	2.77	---	---	
	11:17	61:00	---	--	9.00	2.93	6.7	---	
	11:20	64:00	---	--	9.03	2.96	---	---	
	11:25	69:00	---	--	8.97	2.90	---	---	
	11:30	74:00	---	--	9.46	3.39	---	---	
	11:31	75:00	---	--	9.33	3.26	---	---	
	11:35	79:00	---	--	9.03	2.96	---	---	
	11:40	84:00	---	--	9.28	3.21	---	---	
	11:45	89:00	---	--	9.46	3.39	6.72	---	

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN:SEC)	TIME SINCE PUMPING STOPPED (MIN:SEC)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	PUMPING RATE (GAL/MIN)	GALLONS PUMPED (GAL)	COMMENTS
	11:50	94:00	---	--	9.63	3.56	---	---	
	11:55	99:00	---	--	9.67	3.60	---	---	
	12:00	104:00	---	--	9.77	3.70	---	---	
	12:05	109:00	---	--	--	--	6.39	---	
	12:10	114:00	---	--	9.61	3.54	---	---	
	12:20	124:00	---	--	9.96	3.89	---	---	
	12:25	129:00	---	--	--	--	6.67	---	
	12:30	134:00	---	--	10.12	4.05	---	---	
	12:40	144:00	---	--	10.00	3.93	---	---	
	12:50	154:00	---	--	10.21	4.14	---	---	
	13:00	164:00	---	--	10.31	4.24	---	---	
	13:10	174:00	---	--	10.45	4.38	6.30	---	Temp=8.5°C; Cond = 780
	13:20	184:00	---	--	10.72	4.65	---	---	
	13:30	194:00	---	--	10.84	4.77	---	---	
	13:45	209:00	---	--	10.06	3.99	6.40	---	
	14:00	224:00	---	--	10.90	4.83	---	---	
	14:30	254:00	---	--	10.87	4.80	---	---	
	14:45	269:00	---	--	--	--	6.30	---	
	15:03	287:00	---	--	10.71	4.64	---	---	
	15:15	299:00	---	--	--	--	---	---	Temp=8.0°C: Cond=800 pH = 7.7
	15:36	320:00	---	--	10.65	4.58	---	---	
	15:45	329:00	---	--	--	--	6.21	---	
	15:55	339:00	---	--	10.76	4.69	---	---	
	16:00	344:00	---	--	--	--	---	2230	
	16:20	364:00	---	--	--	--	6.4	---	

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN:SEC)	TIME SINCE PUMPING STOPPED (MIN:SEC)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	PUMPING RATE (GAL/MIN)	GALLONS PUMPED (GAL)	COMMENTS
	16:35	379:00	---	--	10.87	4.80	---	---	
	17:00	404:00	---	--	--	--	---	2595	
	17:25	429:00	---	--	10.98	4.91	6.1	---	
	18:C	464:00	---	--	11.13	5.06	---	2955	
	18:15	479:00	---	--	--	--	---	---	Temp=7.4°C; Cond=80 Sal=1.0; pH = 7.7
	19:00	524:00	---	--	--	--	---	3318	
	19:04	528:00	---	--	11.11	5.04	---	---	
	19:58	582:00	---	--	10.87	4.80	---	---	
	20:00	584:00	---	--	--	--	---	3678	
	21:00	644:00	---	--	--	--	---	4026	
	21:02	646:00	---	--	10.49	4.42	---	---	
	21:15	659:00	---	--	--	--	---	---	Temp=6.8°C; Cond=80 Sal 0.8; pH = 7.8
	22:00	704:00	---	--	--	--	---	4374	
	22:04	708:00	---	--	11.05	4.98	---	---	
	22:56	760:00	---	--	11.83	5.76	---	---	
	23:00	764:00	---	--	--	--	---	4721	
	23:58	822:00	---	--	10.76	4.69	---	---	
1/10/79	00:00	824:00	---	--	--	--	---	5065	Temp = 5.5; Cond=83 pH = 7.8
	1:00	884:00	---	--	--	--	---	5414	
	1:02	886:00	---	--	11.23	5.16	---	---	
	2:00	944:00	---	--	--	--	---	5755	
	2:02	946:00	---	--	10.73	4.66	---	---	

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN:SEC)	TIME SINCE PUMPING STOPPED (MIN:SEC)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	PUMPING RATE (GAL/MIN)	GALLONS PUMPED (GAL)	COMMENTS
	2:20	964:00	---	--	--	--	5.5	---	
	2:55	999:00	---	--	10.66	4.59	---	---	
	3:00	1004:00	---	--	--	--	---	6194	
	3:06	1010:00	---	--	--	--	---	---	Temp = 5.0; Cond = 850; pH = 7.8
	3:55	1059:00	---	--	10.73	4.66	---	---	
	4:00	1064:00	---	--	--	--	---	6431	
	4:35	1099:00	---	--	10.69	4.62	---	---	
	5:00	1124:00	---	--	--	--	---	6766	
	5:03	1127:00	---	--	11.19	5.12	6.1	---	Opened flow valve slightly
	6:00	1184:00	---	--	--	--	---	7100	
	6:04	1188:00	---	--	10.85	4.78	---	---	Temp = 7.0; Cond = 810; Sal = 1.0; pH = 7.8
	7:00	1244:00	---	--	11.27	5.20	---	7440	
	8:00	1304:00	---	--	--	--	---	7774	
	8:04	1308:00	---	--	11.36	5.29	---	---	
	8:50	1354:00	---	--	--	--	---	---	Temp = 6.8; Cond = 800; Sal = 0.8; pH = 8.0
	8:55	1359:00	---	--	11.03	4.96	---	---	
	9:00	1364:00	---	--	--	--	5.53	8096	
	9:58	1422:00	---	--	10.50	4.43	---	---	
	10:00	1424:00	---	--	--	--	---	8427	
	10:15	1439:00	---	--	--	--	5.49	---	

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN:SEC)	TIME SINCE PUMPING STOPPED (MIN:SEC)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	PUMPING RATE (GAL/MIN)	GALLONS PUMPED (GAL)	COMMENTS
	10:54	1478:00	---	--	10.98	4.91	---	---	
	11:00	1484:00	---	--	--	--	---	8753	
	11:01	1485:00	---	--	--	--	5.5	---	
	11:04	1488:00	---	--	--	--	---	---	Flow to 1-2 gpm for a few seconds
	11:05	1489:00	---	--	--	--	5.52	---	
	12:11	1555:00	---	--	11.31	5.24	---	---	
	12:16	1560:00	0:00	--	--	--	---	9172	Pump off
		1560:05	0:05	18700	10.00	3.93	---	---	
		1560:36	0:36	2600	7.00	0.93	---	---	
		1561:50	1:50	852.	6.74	0.67	---	---	
		1563:15	3:15	481.	6.72	0.65	---	---	
		1564:30	4:30	348.	6.69	0.62	---	---	
		1566:00	6:00	261.	6.64	0.57	---	---	
		1567:30	7:30	209.	6.62	0.55	---	---	
		1569:15	9:15	170.	6.61	0.54	---	---	
		1570:45	10:45	146.	6.58	0.51	---	---	
		1572:30	12:30	126.	6.57	0.50	---	---	
		1574:00	14:00	112.	6.54	0.47	---	---	
		1576:00	16:00	98.5	6.53	0.46	---	---	
		1578:30	18:30	85.3	6.51	0.44	---	---	
		1581:00	21:00	75.3	6.49	0.42	---	---	
		1586:10	26:10	60.6	6.44	0.37	---	---	
		1593:11	33:11	48.0	6.45	0.38	---	---	
		1593:40	33:40	47.3	6.43	0.36	---	---	
		1599:03	39:03	41.0	6.37	0.30	---	---	

DATE (M/D/Y)	TIME (H:M)	TIME SINCE PUMPING STARTED (MIN:SEC)	TIME SINCE PUMPING STOPPED (MIN:SEC)	RECOVERY RATIO	DEPTH TO WATER (FT BELOW MP)	DRAW-DOWN (FT)	PUMPING RATE (GAL/MIN)	GALLONS PUMPED (GAL)	COMMENTS
		1600:11	40:11	39.8	6.42	0.35	---	---	
		1601:15	41:15	38.8	6.43	0.36	---	---	
		1610:00	50:00	32.2	6.43	0.36	---	---	
		1610:33	50:33	31.9	6.41	0.34	---	---	
		1611:05	51:05	31.5	6.41	0.34	---	---	
		1627:00	67:00	24.3	6.37	0.30	---	---	
		1648:20	88:20	18.7	6.36	0.29	---	---	
		1663:30	103:30	16.1	6.35	0.28	---	---	
		1684:20	124:20	13.5	6.31	0.24	---	---	
		1703:00	143:00	11.9	6.31	0.24	---	---	
		1710:00	150:00	11.4	6.30	0.23	---	---	
		1725:00	165:00	10.5	6.30	0.23	---	---	
	15:19	1743:00	183:00	9.52	6.28	0.21	---	---	
	15:33	1757:00	197:00	8.92	5.38	-0.69	---	---	Disconnect pump and pull pipe
	16:12	1796:00	236:00	7.61	6.15	0.08	---	---	
	20:28	2052:00	492:00	4.17	6.08	0.01	---	---	
1/11/79	00:20	2284:00	724:00	3.15	6.08	0.01	---	---	
	9:20	2824:00	1264:00	2.23	6.02	-0.05	---	---	
	14:50	3154:00	1594:00	1.98	6.02	-0.05	---	---	
	17:43	3327:00	1767:00	1.88	6.03	-0.04	---	---	
1/12/79	9:03	4247:00	2687:00	1.58	5.99	-0.08	---	---	
1/13/79	11:07	5811:00	4251:00	1.37	5.89	-0.18	---	---	

2909 West 7th Avenue
Denver, Colorado 80204
303-573-7882

Woodward-Clyde Consultants

January 10, 1979

Stearns-Roger, Inc.
P. O. Box 5888
Denver, Colorado 80217

Attention: Mr. John R. Stryker

Re: Additional Geotechnical Services, Bokum Resources, Canyon de Santa Rosa Tailing Dam, near Marquez, New Mexico.
S-R Project No. 7007 C19620
Job No. 19535-18971

Gentlemen:

As requested, we have prepared the following answers to questions numbered 6, 7, 8, 11 and 12 posed in the State of New Mexico Environmental Improvement Division memorandum from Bruce Gallaher and John G. Dudley to Maxine S. Goad dated October 25, 1978.

Zone 1 Material Characterization

Twelve additional field samples were taken at random locations to represent the range of borrow area or stockpiled soils available for selection of the materials to be used in the dam Zone 1 and the cutoff trench. These samples were secured to be representative of the materials which would be selected for Zone 1 and cutoff trench backfill construction. Inasmuch as these samples represented the range of materials to be used, it was not considered necessary to conduct tests on a very large number of additional samples for statistical analysis purposes. Proper selection of representative materials provides a better assessment of permeability conditions than a large number of randomly selected samples without consideration of representativeness. We concucted gradation, consistency, compaction and permeability tests on these samples and classified the soils in accordance with the Unified Soil Classification System. The results of the laboratory tests are presented in Table 1, attached, which also includes sample location and classification information.

Plots of the gradation, compaction and permeability test data are given in Appendicies A, B and C respectively. The tests were conducted in accordance with the following standard test procedures:

Gradation:	ASTM Particle Size Analysis of Soils, D-422
Consistency:	ASTM Liquid Limit of Soils, D-423 ASTM Plastic Limit and Plasticity Index of Soils, D-424
Compaction:	ASTM Moisture-Density Relations of Soils, D-698
Permeability:	U. S. Bureau of Reclamation Permeability and Settlement of Soils, Designation E-13, USBR Earth Manual, 1974. (Copy of Test Procedure included in Appendix C.)
Classification:	ASTM Classification of Soils for Engineering Purposes, D-2487

If the soils contained gravel particles (+No. 4 screen size), the compaction and permeability tests were made on the -3/4 inch fraction.

After completion of the compaction tests, the twelve soil samples were compacted to a depth of 3 inches in the 8-inch diameter steel permeameter molds at 100 percent maximum density and optimum moisture to optimum +2 percent, based upon the compaction test results. Loads of 32 psi (about the average fill load) were then applied to the specimens and initial consolidations were allowed to take place. Water was placed on the top of the specimens to the overflow levels, and the constant head tanks filled and connected to the bottom of the permeameters (flows are upward through the soil specimens). Measurements of the quantity of water permeating through each specimen and the amount of consolidation (vertical movement) were made at least once per day during the test periods, which were at least 10 days. The applied water head was 5 to 6 feet providing a percolation gradient of 20 to 24. Demineralized water was used as the permeant liquid.

After completion of the above permeability tests, four of the specimens being tested, which had been selected for special permeant testing, were further tested using a simulated raffinate solution as the permeant liquid. This solution was obtained from the Hazen Research Inc. laboratories, Golden, Colorado. These tests were continued for an additional ten days. The test data collection procedures were as described above for the regular permeability tests. Prior to placing the soils selected for the special raffinate tests in the permeameters, the metal parts of the four permeameters were coated with a primer and paint to protect them from undesirable reactions with the acidic raffinate.

All calculations of permeability rates were made in accordance with formulas (1) through (7) presented in Designation E-13 (see Appendix C).

The results of the permeability tests with water show that the tested samples of materials proposed for Zone 1 (and cutoff trench refill) of the dam had permeability rates which varied from 0.113 to 0.002 and averaged 0.026 ft/yr (av=2.6×10^{-8} cm/sec), being very tight (see Table I). For earth dam construction, the U. S. Bureau of Reclamation considers soils which have permeability rates less than 1 ft/yr impervious and suitable for impervious Zone 1 and cutoff trench refill construction when compacted to 98 percent of maximum density of ASTM D-698, or equivalent. The important engineering properties and relative desirability for earth dam uses are shown on Table II which was reproduced from the USBR Earth Manual. For the tests in which the simulated raffinate solution was used as the permeant liquid, the amount of liquid permeated was too small to be measured with our equipment. This means that the permeability rates were less than 0.001 ft/yr. Evidence of gas formation was noted as tests progressed.

There seems to be some misunderstanding about the impermeability of certain types of gravelly soils. When there are sufficient sand, silt or clay fractions, or combinations of these, to form a soil matrix around the gravel particles, the permeability of the total mixture is reduced, over that of the matrix alone, because the impervious gravel particles take up volume and thus block water flow where they are located. When the gravel content (+No. 4 screen size) of a soil material is about 45 to 55 percent or less, there normally is sufficient matrix material to surround the gravel particles, and the permeability of the total mixture should be less than that of the matrix material (-No. 4 sieve size) alone. For instance, it will be noted from the "Use Chart", Table II, that clayey gravel (GC) is considered to be one of the best materials for Zone 1 earth dam construction.

For the twelve samples recently tested, only two samples had significant amounts of gravel, being 45 and 56 percent. The samples tested were classified as Silty Gravel-Clay (GC), Sandy-Silty Gravel (GP-GM), Sandy Clay (SC), Silty Sand (SM), Silty Lean Clay (CL), Clayey-Silty Sand (SC-SM) and Sandy Silt-Clay (ML-CL) and are representative of the materials which will be available for selection for Zone 1 and cutoff trench refill construction. The specification requirements are that materials for this construction have at least 20 percent finer than the No. 200 sieve size.

During the design investigations for the project, 92 samples were brought to the laboratory for inspection and for various laboratory tests[1]. Three samples, representative of proposed Zone 1 materials, were selected for permeability testing. All of these permeability samples were classified as lean clays (CL).

Seepage Estimates

Estimates have been made of the quantity of seepage that would pass through the alluvial soils and weathered bedrock, other than the seepage through the dam which is collected in the dam drainage system and diverted to the evaporation pond. Computations for the seepage analyses are given in Appendix D. The results are briefly summarized as follows:

Seepage through dam cutoff trench	=	0.0063 cfs
Seepage under dam filter blanket	=	0.0005 cfs
Seepage through collection ditch lining	=	<0.0001 cfs
Seepage through evaporation pond	=	0.0035 cfs

[1] Woodward-Clyde Consultants report, "Geotechnical Services, Tailing Dam, Bokum Resources Corporation, near Marquez, New Mexico, April 1978, Job No. 19253-18971.

Seepage through "reservoir" cutoff trenches	=	0.0014 cfs
Total estimated seepage into ground	=	0.0118 cfs
Total estimated seepage through dam, collected and diverted to evaporation pond	=	0.0122 cfs

An analysis was made of the stability of the upstream natural bank of Canyon de Marquez, giving consideration to groundwater saturation of the bank toe. The soil property parameters used in this analysis were based on determinations made during previous studies reported in reference 1. We used the values of 125 pcf wt weight, cohesion - 500 psf and friction angle $\Phi=18^{\circ}$ which are very conservative. Our static and pseudo-static circular arc stability analyses were performed on a computer using the Applied Geodata Systems, Inc., "LEASE" program after the Modified Bishop Method.

The Soil Parameters used and the analyses are shown on Figure E-1, Appendix E. Based on the conservative parameters and conditions selected, the minimum theoretical safety factors computed were 2.1 for the static state and 1.6 for the dynamic state, assuming an earthquake with 0.1 g acceleration.

If you have questions on the above information, please call.

Yours truly,

Frank J. Holliday
Vice President

REGISTERED PROFESSIONAL ENGINEER 5376 NEW MEXICO FRANK J. HOLLIDAY

WGH/prf

(12 copies sent)

Enclosures (5)

Woodward-Clyde Consultants

TABLE I

Samples of Available Borrow Materials -- Tailing Disposal Dam Near Marquez, New Mexico -- Bokum Resources Corp.

Sample No.	Sample Description	United Soil Classification	Gradation: Silt-Clay %-#200	Gradation: Sand % #200 to #4	Gradation: Gravel % + #4	Plasticity: Liquid Limit	Plasticity: Plastic Index	Compaction: Optimum Moisture (%)	Compaction: Maximum Dry Density (pcf)	Permeability: Applied Load (psf)	Permeability: Settlement (%)	Permeability: Permeability Rate (ft/yr)
1	Gravel Pocket, Stage 1 Excavation, Sta. 37+00 to 40+00	Sandy Silty Gravel (GP-GM)	11	33	56		NP	10.7	127.0	4600	2.0	0.110(2) <0.001(1)
2	Stockpiled from Stage 1 Excavation, Tailing Dam	Sandy Clay (SC)	42	37	21	22	10	14.1	111.8	"	3.7	0.020(2)
3	(Same as 2)	Sandy Silt-Clay (ML-CL)	61	37	2	21	7	14.6	113.2	"	4.9	0.008(2)
4	Sta. 28+00 to 28+50 Diversion Ditch Excavation	Sandy Lean Clay (CL)	73	25	2	24	12	13.5	115.4	"	3.3	0.006(2) <0.001(1)
5	Sta. 14+00 to 14+50 Diversion Ditch Excavation	Silty Lean Clay (CL)	92	4	4	40	22	18.2	105.8	"	2.8	0.003
6	Sta. 7+00 to 8+00 Diversion Ditch Excavation	Silty Lean Clay (CL)	74	24	2	30	18	14.6	110.2	"	2.7	0.005 <0.001(1)
7	(Same as 2)	Silty Lean Clay (CL)	68	24	8	30	16	14.8	114.4	"	3.1	0.002(2)
8	(Same as 2)	Sandy Silt-Clay (ML-CL)	57	41	2	24	9	14.6	114.4	"	2.4	0.004(2) <0.001(1)
9	Weathered Shale, Cutoff Trench, Sta. 44+00	Silty Gravelly Clay (GC)	48	7	45	45	24	18.2	106.9	"	3.0	0.005(1)
10	(Same as 2)	Sandy Silt (SM)	34	58	8	22	3	14.9	115.2	"	2.7	0.027
11	(Same as 2)	Clayey Sand-Silt (SC-SM)	48	49	3	22	7	14.8	116.2	"	1.4	0.113
12	(Same as 2)	Sandy Silt (SM)	45	54	1	19	1	13.7	115.6	"	1.7	0.005
									Water Permeant Average			0.026

Notes: Gravel sizes are largely claystone and sandstone chips
(1) Raffinate solution used as permeant liquid.
(2) Permeability specimens placed at optimum +2% moisture, all others at optimum moisture
Permeability specimens compacted at 100% maximum dry density

Job No. 19535-18971

Job No. 19535-18971

TYPICAL NAMES OF SOIL GROUPS	GROUP SYMBOLS	IMPORTANT ENGINEERING PROPERTIES				
		PERMEABILITY WHEN COMPACTED	SHEAR STRENGTH WHEN COMPACTED AND SATURATED	COMPRESSIBILITY WHEN COMPACTED AND SATURATED	WORKABILITY AS A CONSTRUCTION MATERIAL
WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	GW	PERVIOUS	EXCELLENT	NEGLIGIBLE	EXCELLENT
POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	GP	VERY PERVIOUS	GOOD	NEGLIGIBLE	GOOD
SILTY GRAVELS, POORLY-GRADED GRAVEL-SAND-SILT MIXTURES	GM	SEMIPERVIOUS TO IMPERVIOUS	GOOD	NEGLIGIBLE	GOOD
CLAYEY GRAVELS, POORLY-GRADED GRAVEL-SAND-CLAY MIXTURES	GC	IMPERVIOUS	GOOD TO FAIR	VERY LOW	GOOD
WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	SW	PERVIOUS	EXCELLENT	NEGLIGIBLE	EXCELLENT
POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	SP	PERVIOUS	GOOD	VERY LOW	FAIR
SILTY SANDS, POORLY-GRADED SAND-SILT MIXTURES	SM	SEMIPERVIOUS TO IMPERVIOUS	GOOD	LOW	FAIR
CLAYEY SANDS, POORLY-GRADED SAND-CLAY MIXTURES	SC	IMPERVIOUS	GOOD TO FAIR	LOW	GOOD
INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS WITH SLIGHT PLASTICITY	ML	SEMIPERVIOUS TO IMPERVIOUS	FAIR	MEDIUM	FAIR
INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS	CL	IMPERVIOUS	FAIR	MEDIUM	GOOD TO FAIR
ORGANIC SILTS AND ORGANIC SILT-CLAYS OF LOW PLASTICITY	OL	SEMIPERVIOUS TO IMPERVIOUS	POOR	MEDIUM	FAIR
INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS	MH	SEMIPERVIOUS TO IMPERVIOUS	FAIR TO POOR	HIGH	POOR
INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS	CH	IMPERVIOUS	POOR	HIGH	POOR
ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY	OH	IMPERVIOUS	POOR	HIGH	POOR
PEAT AND OTHER HIGHLY ORGANIC SOILS	PT	—	—	—	—

Engineering use chart.

RELATIVE DESIRABILITY FOR VARIOUS USES (NO. 1 IS CONSIDERED THE BEST)									
ROLLED EARTHFILL DAMS			CANAL SECTIONS		FOUNDATIONS		ROADWAYS		
							FILLS		
HOMOGENEOUS EMBANKMENT	CORE	SHELL	EROSION RESISTANCE	COMPACTED EARTH LINING	SEEPAGE IMPORTANT	SEEPAGE NOT IMPORTANT	FROST HEAVE NOT POSSIBLE	FROST HEAVE POSSIBLE	SURFACING
—	—	1	1	—	—	1	1	1	3
—	—	2	2	—	—	3	3	3	—
2	4	—	4	4	1	4	4	9	5
1	1	—	3	1	2	6	5	5	1
—	—	3 IF GRAVELLY	6	—	—	2	2	2	4
—	—	4 IF GRAVELLY	7 IF GRAVELLY	—	—	5	6	4	—
4	5	—	8 IF GRAVELLY	5 EROSION CRITICAL	3	7	8	10	6
3	2	—	5	2	4	8	7	6	2
6	6	—	—	6 EROSION CRITICAL	6	9	10	11	—
5	3	—	9	3	5	10	9	7	7
8	8	—	—	7 EROSION CRITICAL	7	11	11	12	—
9	9	—	—	—	8	12	12	13	—
7	7	—	10	8 VOLUME CHANGE CRITICAL	9	13	13	8	—
10	10	—	—	—	10	14	14	14	—
—	—	—	—	—	—	—	—	—	—

Engineering use chart.

Woodward-Clyde Consultants

TABLE II

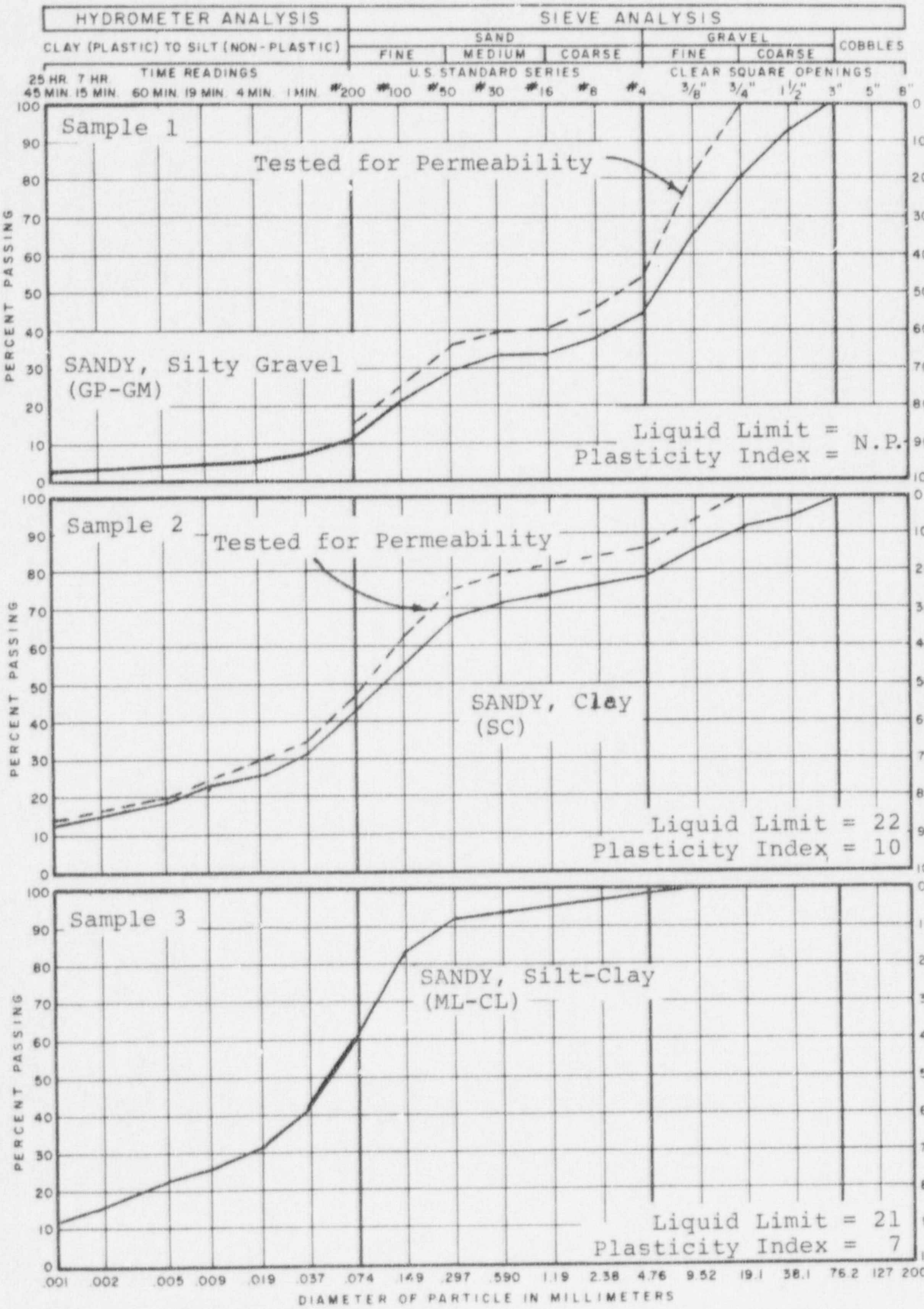
APPENDIX A

GRADATION, CONSISTENCY AND CLASSIFICATION TEST DATA

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

ROCKY MOUNTAIN REGION



GRADATION ANALYSIS

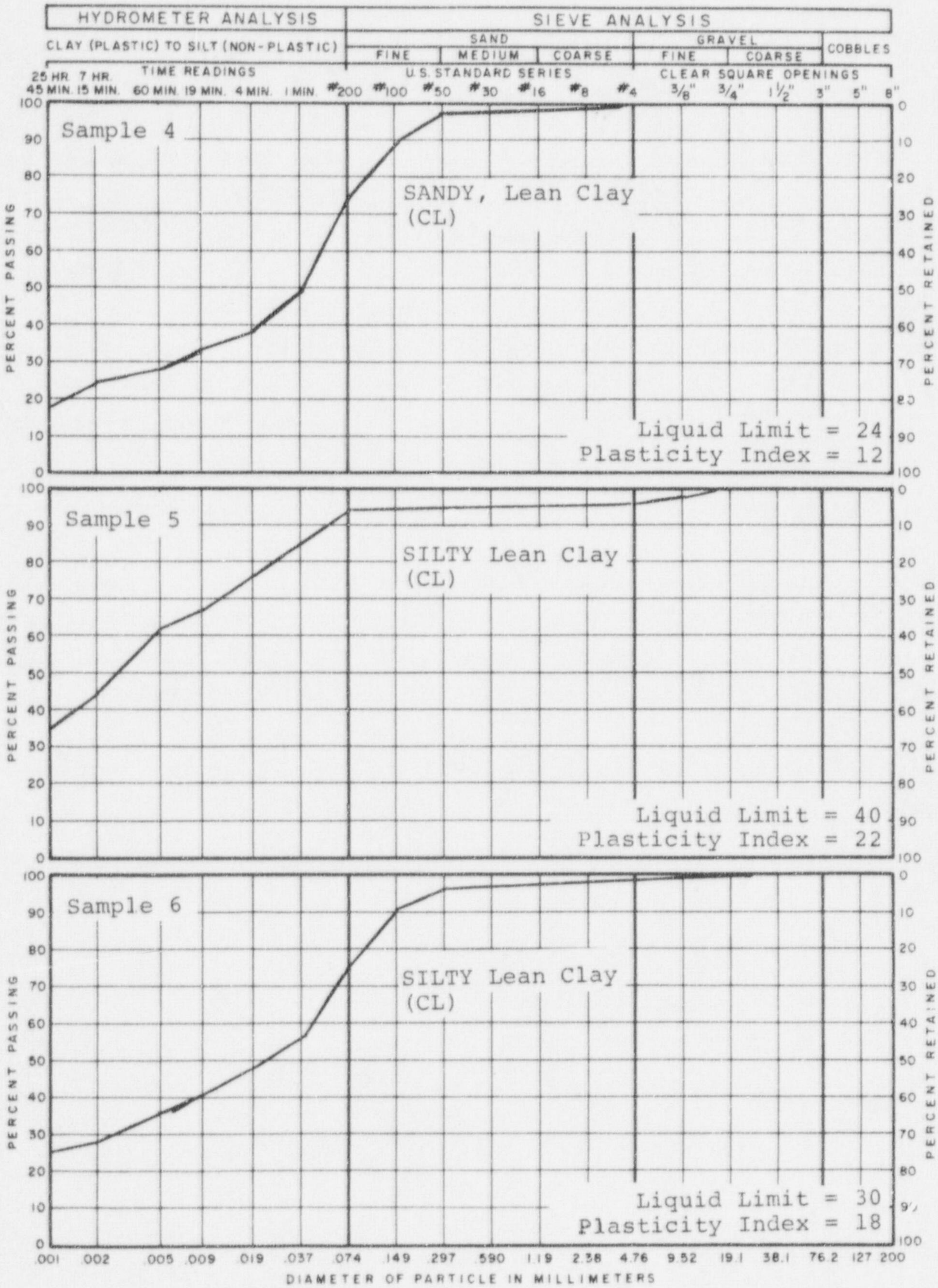
JOB NO. 19535-18971

FIG. A-1

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

ROCKY MOUNTAIN REGION



GRADATION ANALYSIS

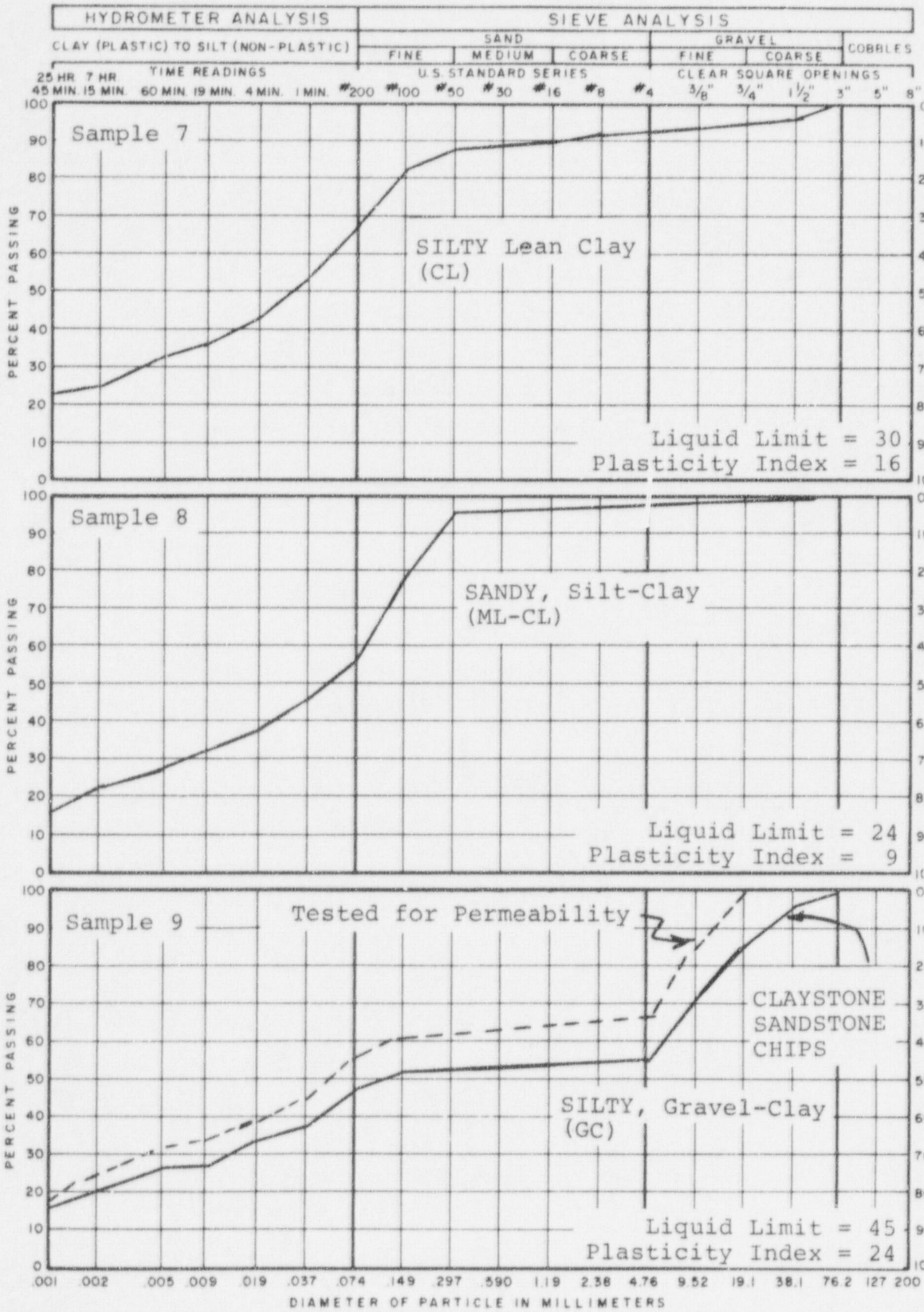
JOB NO. 19535-18971

FIG. A-2

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

ROCKY MOUNTAIN REGION



GRADATION ANALYSIS

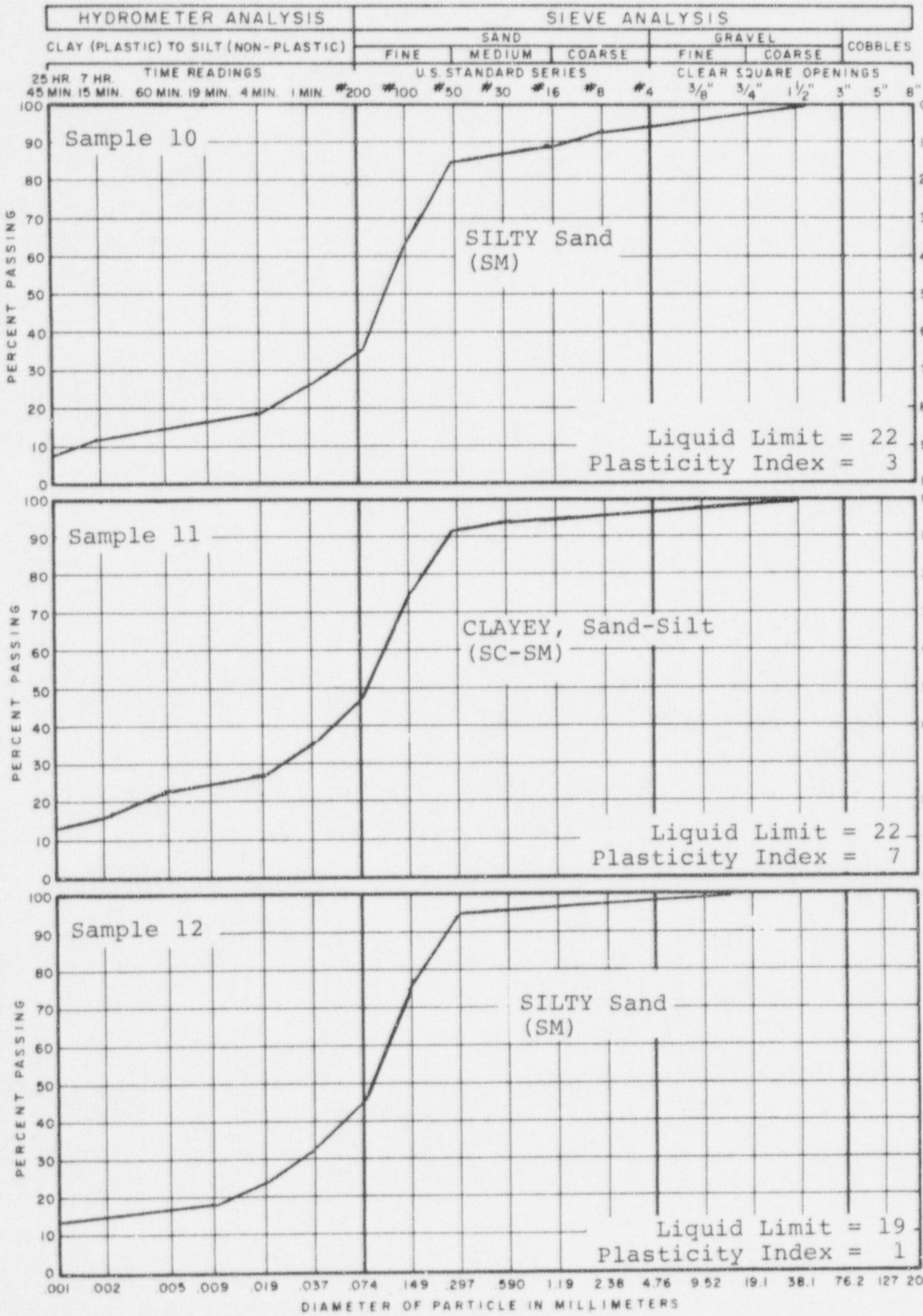
JOB NO. 19535-18971

FIG. A-3

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

ROCKY MOUNTAIN REGION



GRADATION ANALYSIS

JOB NO. 19535-18971

FIG. A-4

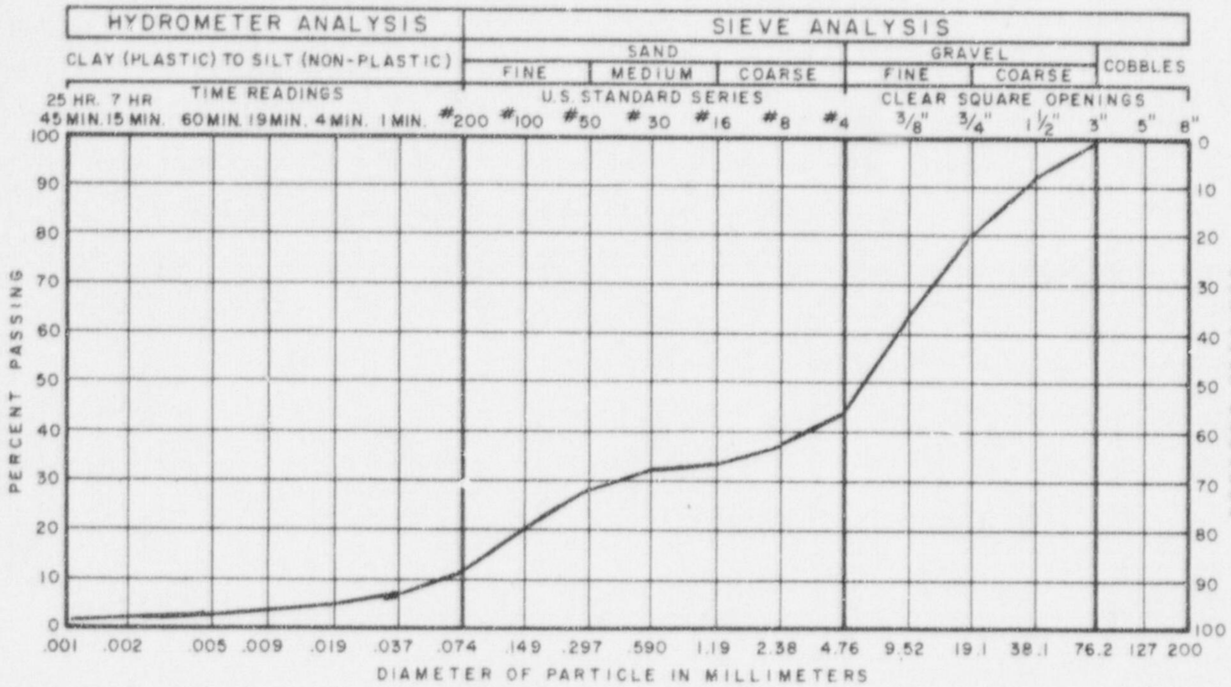
APPENDIX B

COMPACTION TEST DATA

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

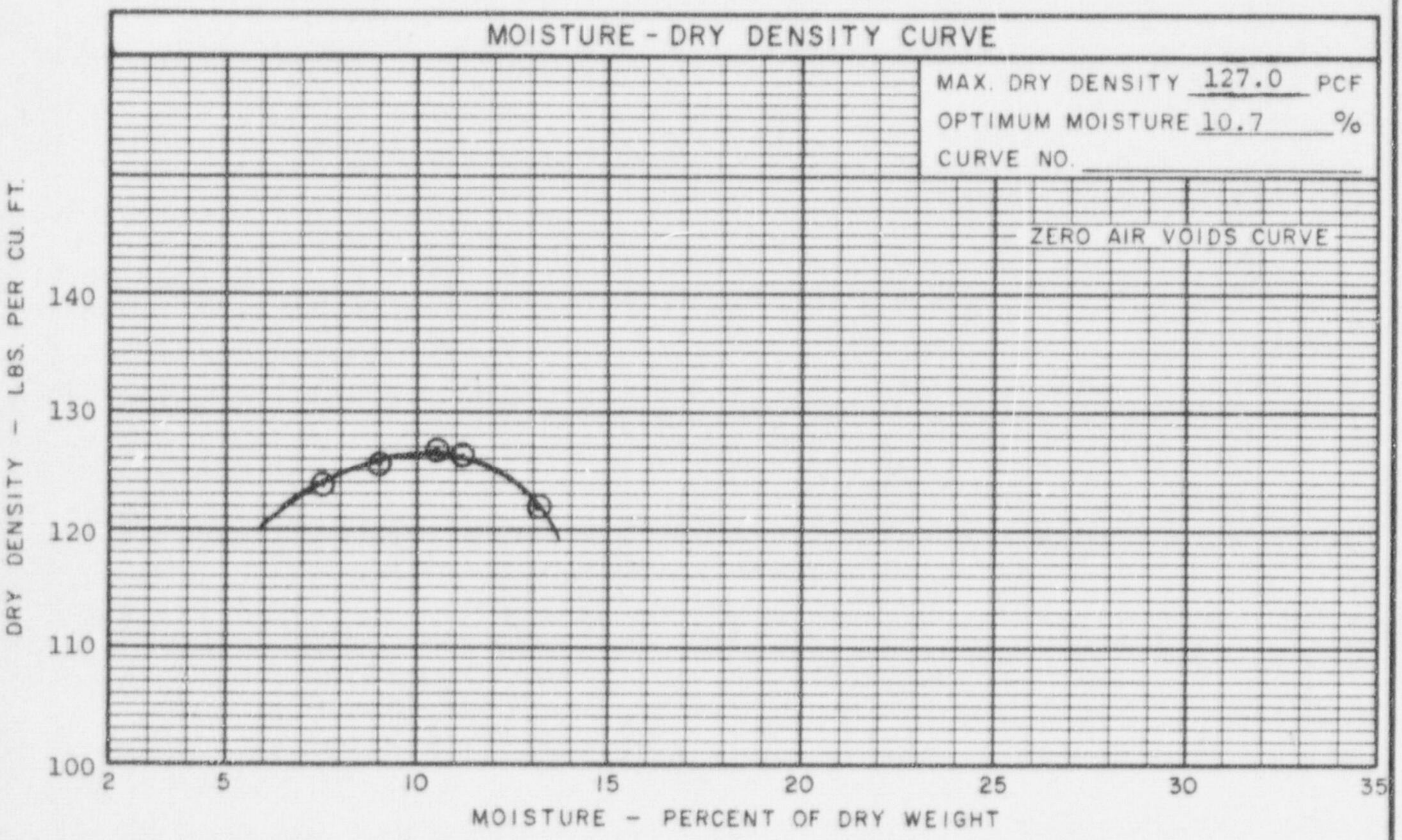
ROCKY MOUNTAIN REGION



GRAVEL 55.3 % SAND 33.8 % SILT AND CLAY 10.9 %

LIQUID LIMIT NP % PLASTICITY INDEX ______ %

GRADATION TEST RESULTS



COMPACTION TEST PROCEDURE ASTM-D-698-70 METHOD "C"

JOB NO. 19535-18971

COMPACTION TEST RESULTS

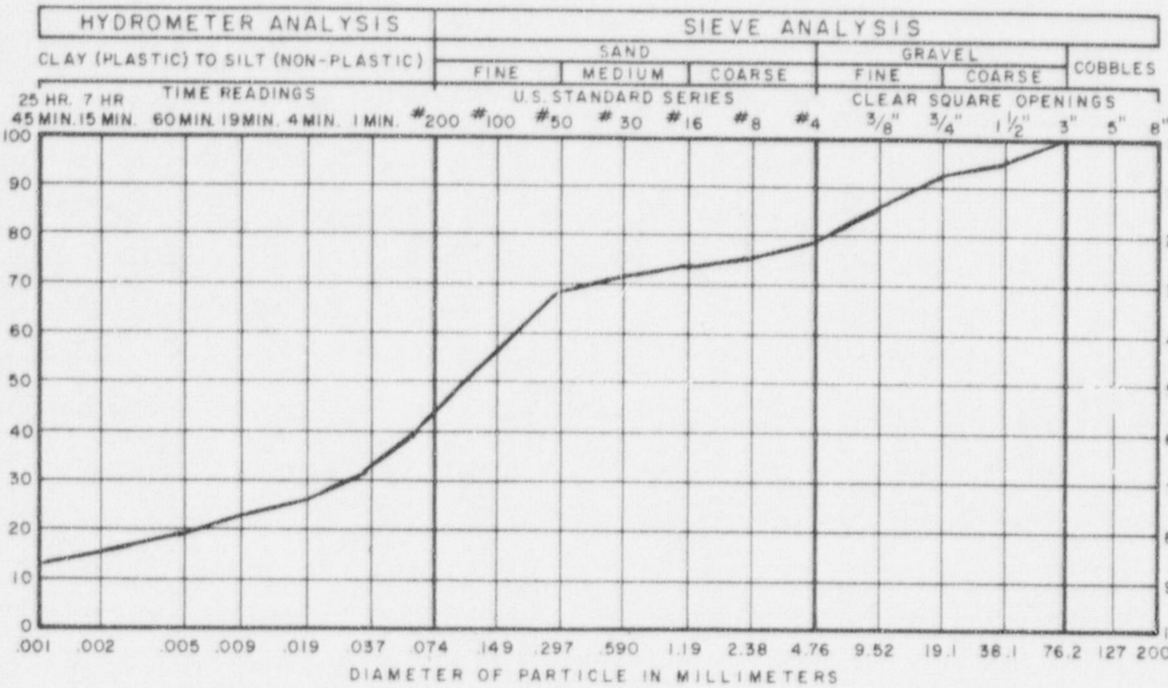
SAMPLE OF Borrow Material FROM Sample No. 1 DEPTH ______

FIG. B-1

WOODWARD - CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

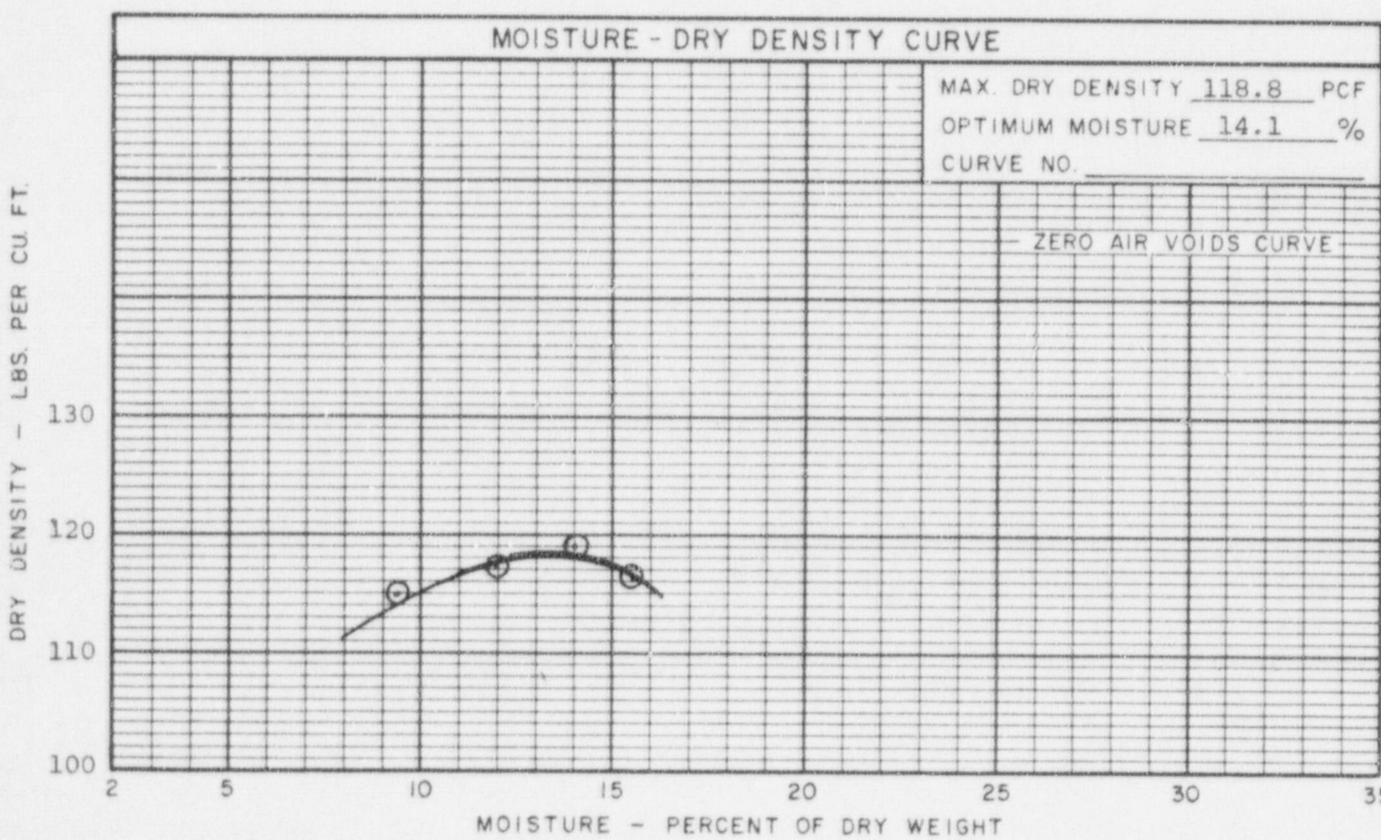
ROCKY MOUNTAIN REGION



GRAVEL 20.3 %   SAND 38.8 %   SILT AND CLAY 40.9 %

LIQUID LIMIT 22 %   PLASTICITY INDEX 10 %

GRADATION TEST RESULTS



COMPACTION TEST PROCEDURE ASTM-D-698-70   METHOD "C"

JOB NO. 19535-18971

COMPACTION TEST RESULTS

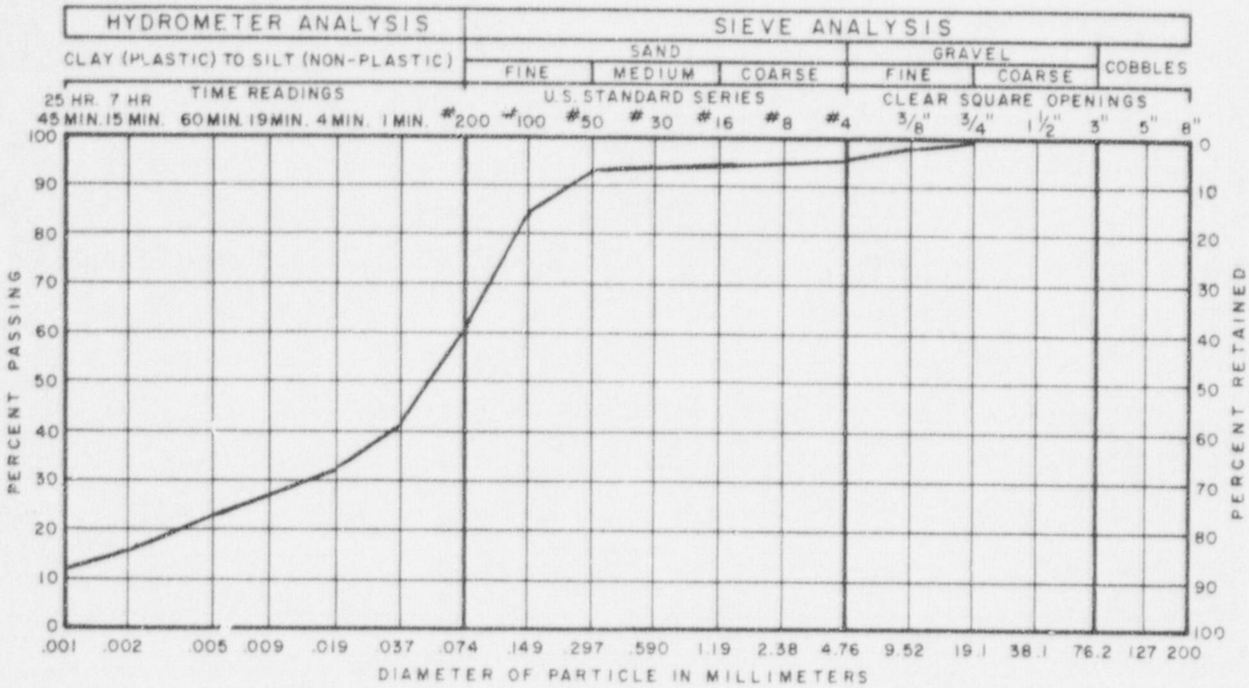
SAMPLE OF Borrow Material   FROM Sample No. 2   DEPTH

FIG. B-2

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

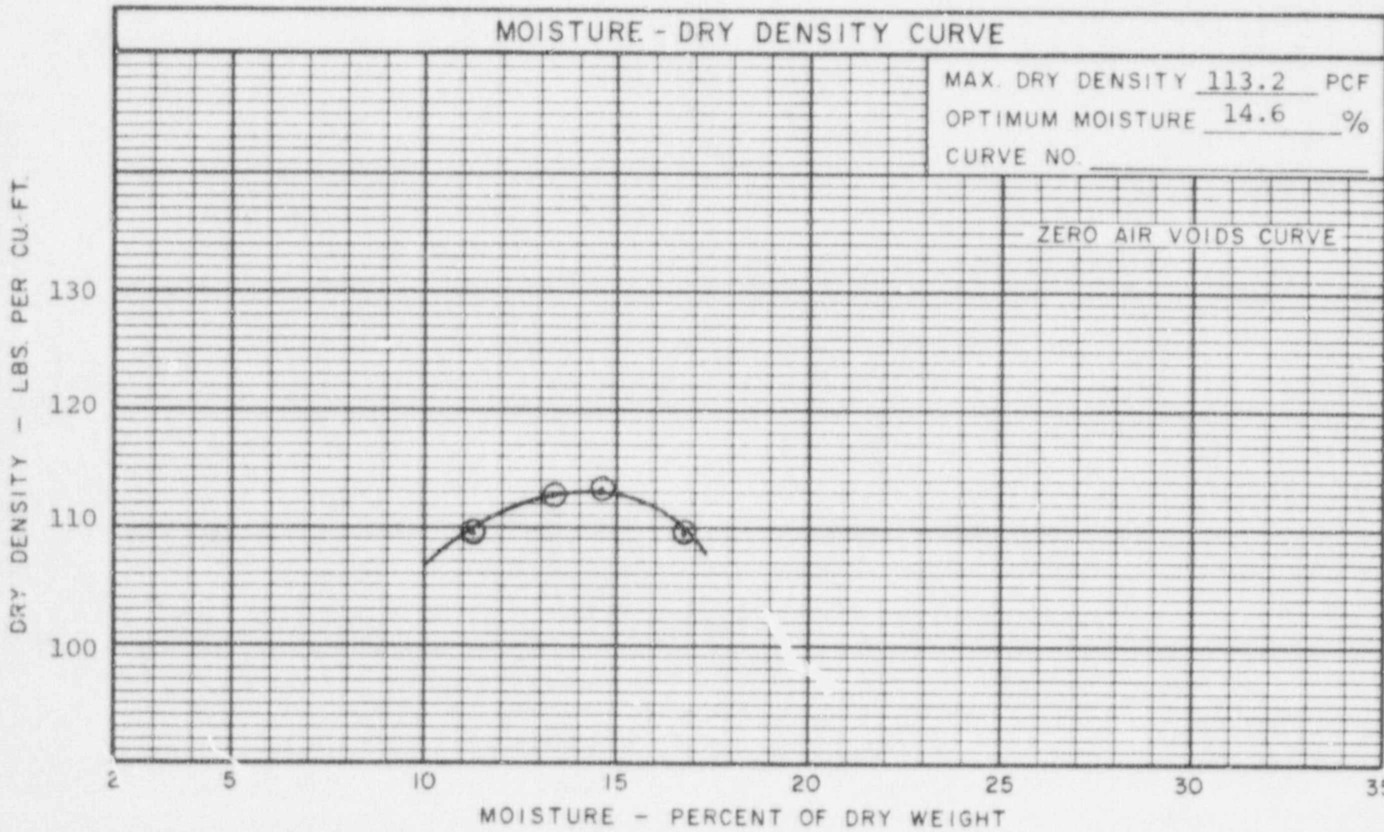
ROCKY MOUNTAIN REGION



GRAVEL 3.8 % SAND 35.8 % SILT AND CLAY 60.4 %

LIQUID LIMIT 21 % PLASTICITY INDEX 7 %

GRADATION TEST RESULTS



COMPACTION TEST PROCEDURE ASTM-D-698-70 METHOD "A"

JOB NO. 19535-18971

COMPACTION TEST RESULTS

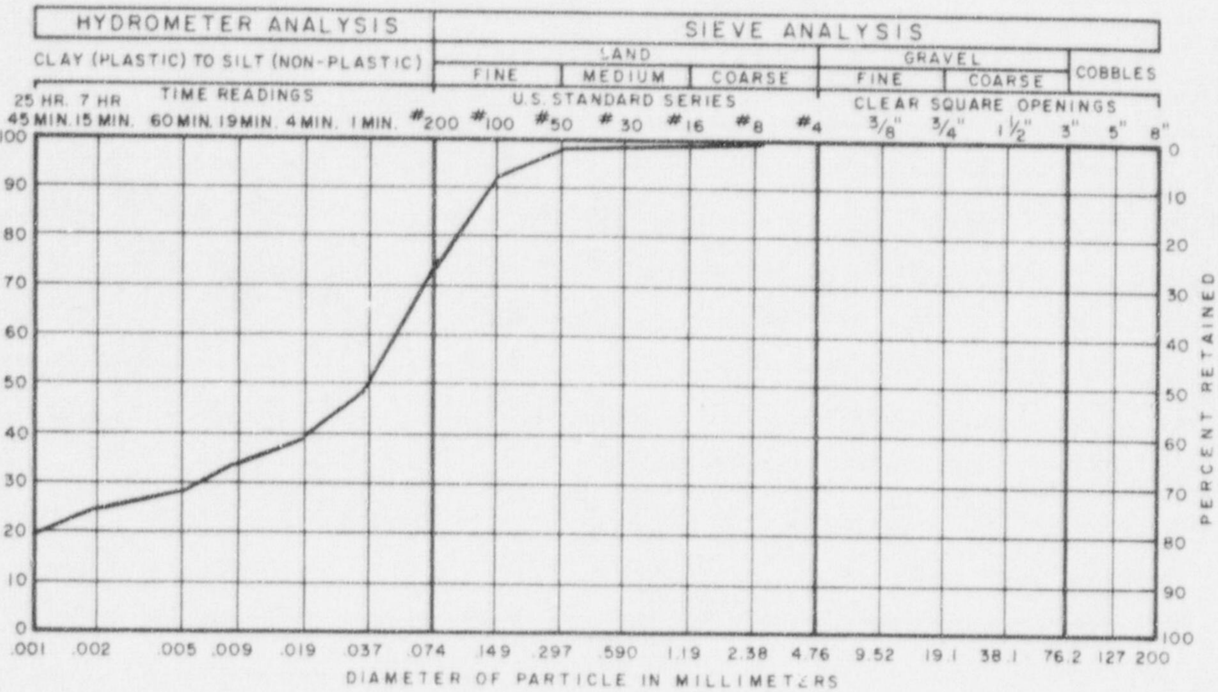
SAMPLE OF Borrow Material FROM Sample No. 3 DEPTH

FIG. B-3

WOODWARD - CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

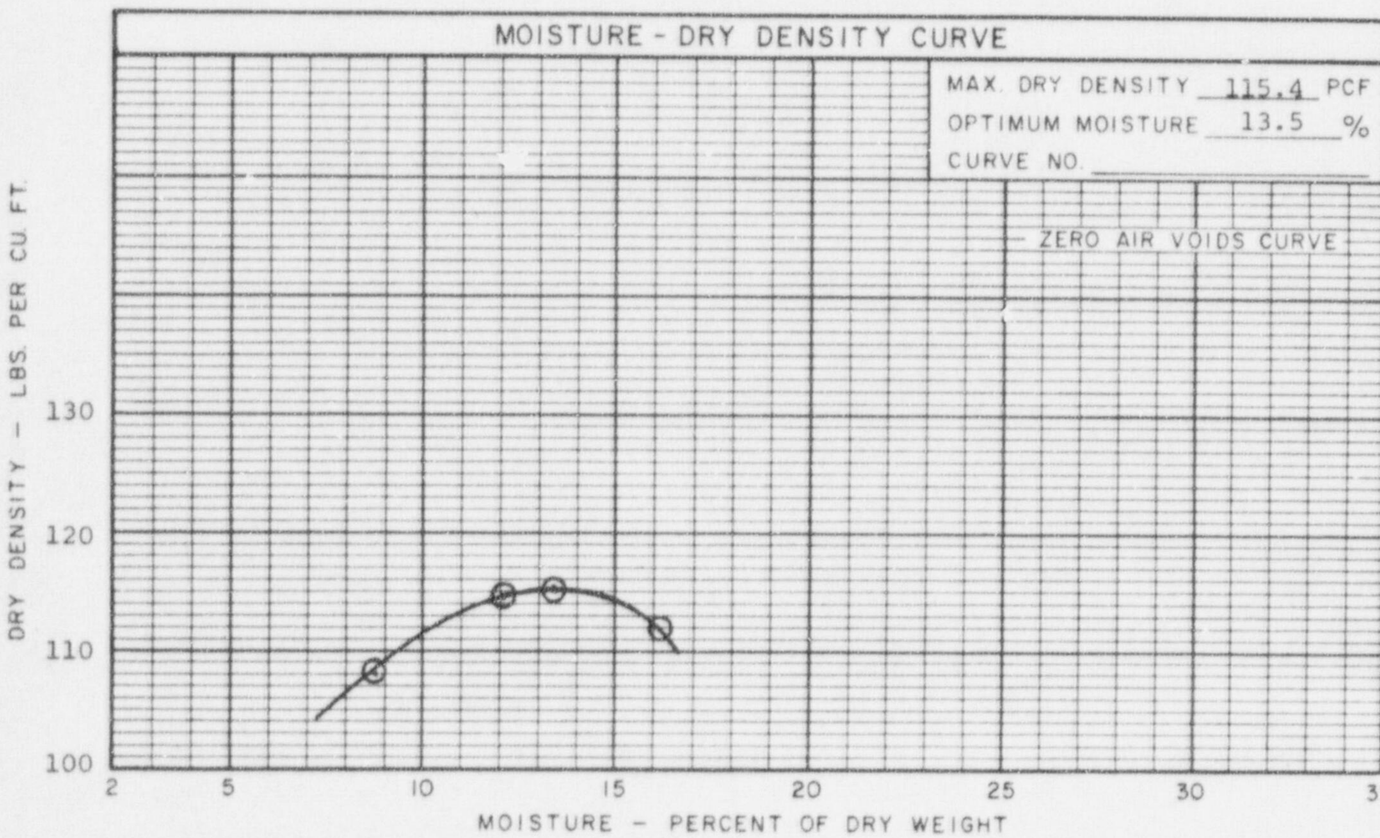
ROCKY MOUNTAIN REGION



GRAVEL 0.4 % SAND 25.6 % SILT AND CLAY 74.0 %

LIQUID LIMIT 24 % PLASTICITY INDEX 12 %

GRADATION TEST RESULTS



COMPACTION TEST PROCEDURE ASTM-D-698-70 METHOD "A"

JOB NO. 19535-18971

COMPACTION TEST RESULTS

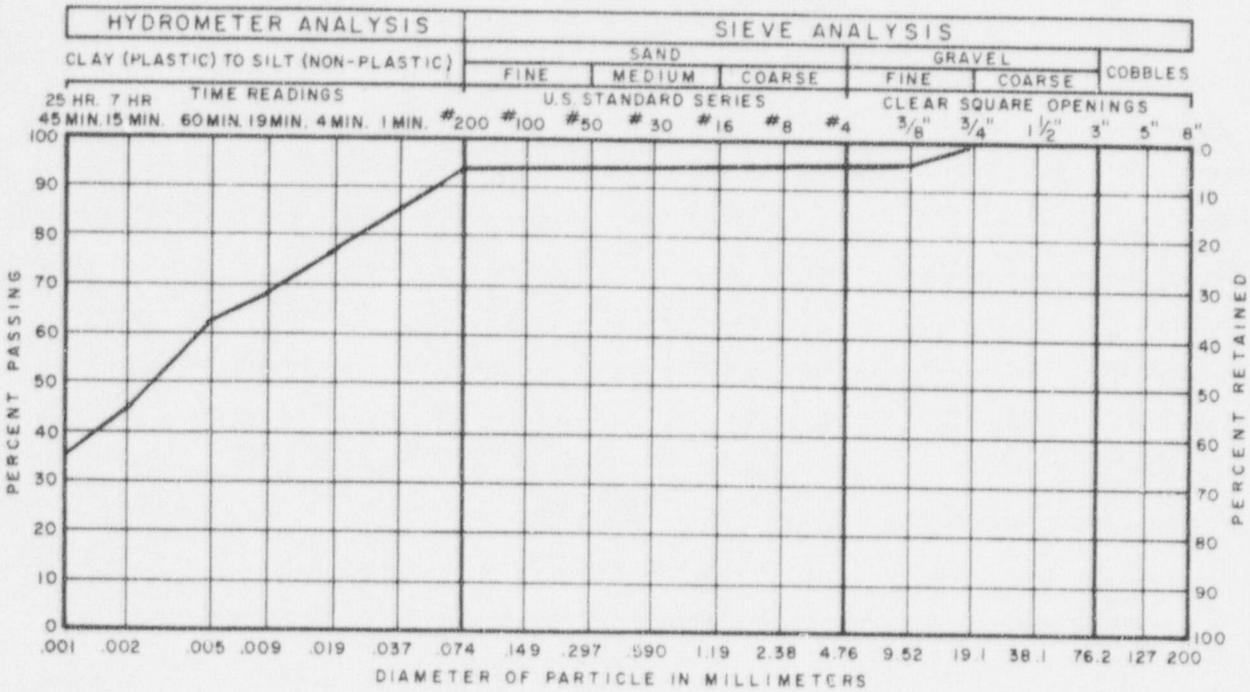
SAMPLE OF Borrow Material FROM Sample No. 4 DEPTH

FIG. B-4

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

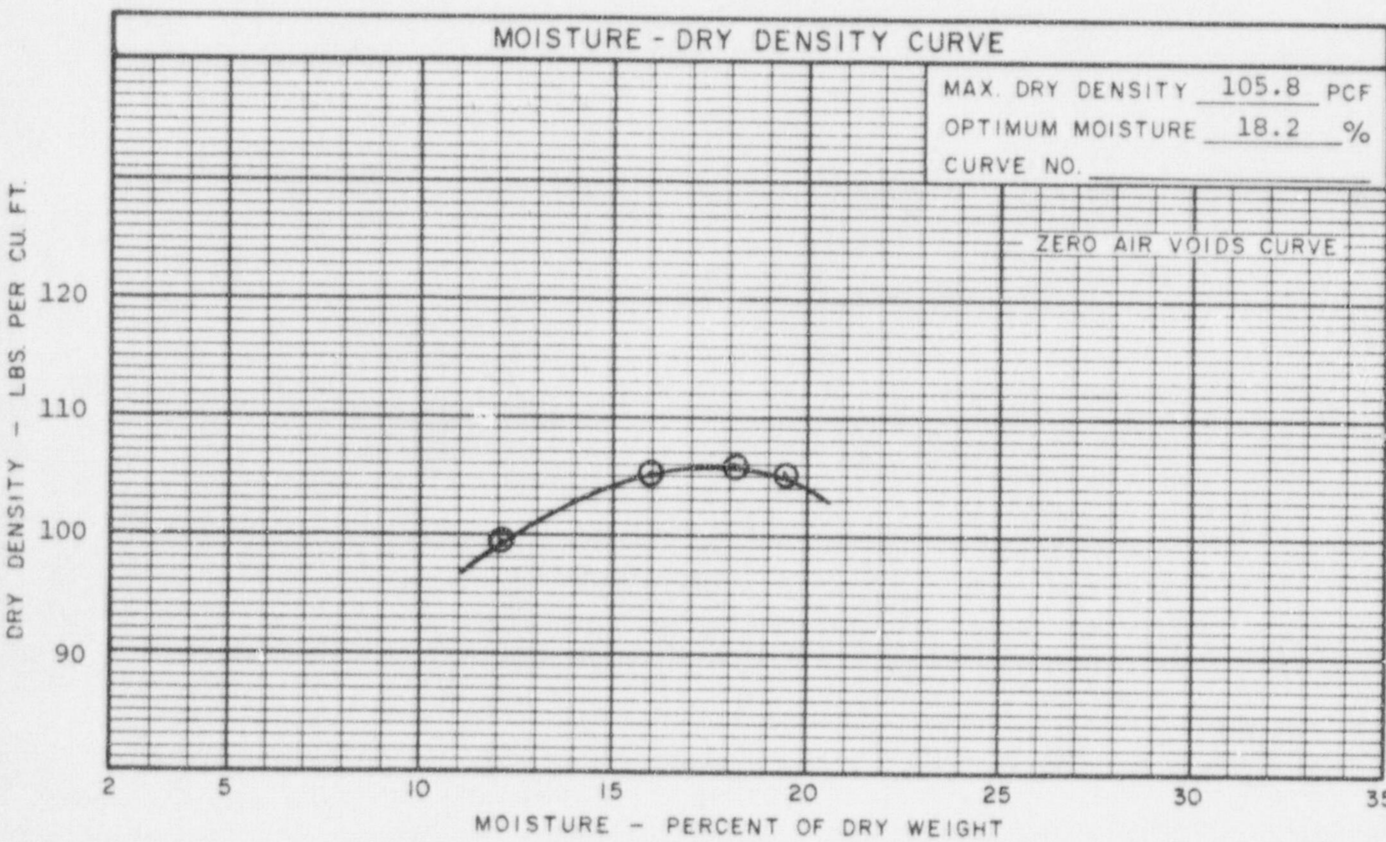
ROCKY MOUNTAIN REGION



GRAVEL 3.1 % SAND 2.4 % SILT AND CLAY 94.5 %

LIQUID LIMIT 40 % PLASTICITY INDEX 22 %

GRADATION TEST RESULTS



COMPACTION TEST PROCEDURE ASTM-D- 698-70 METHOD "A"

JOB NO. 19535-18971

COMPACTION TEST RESULTS

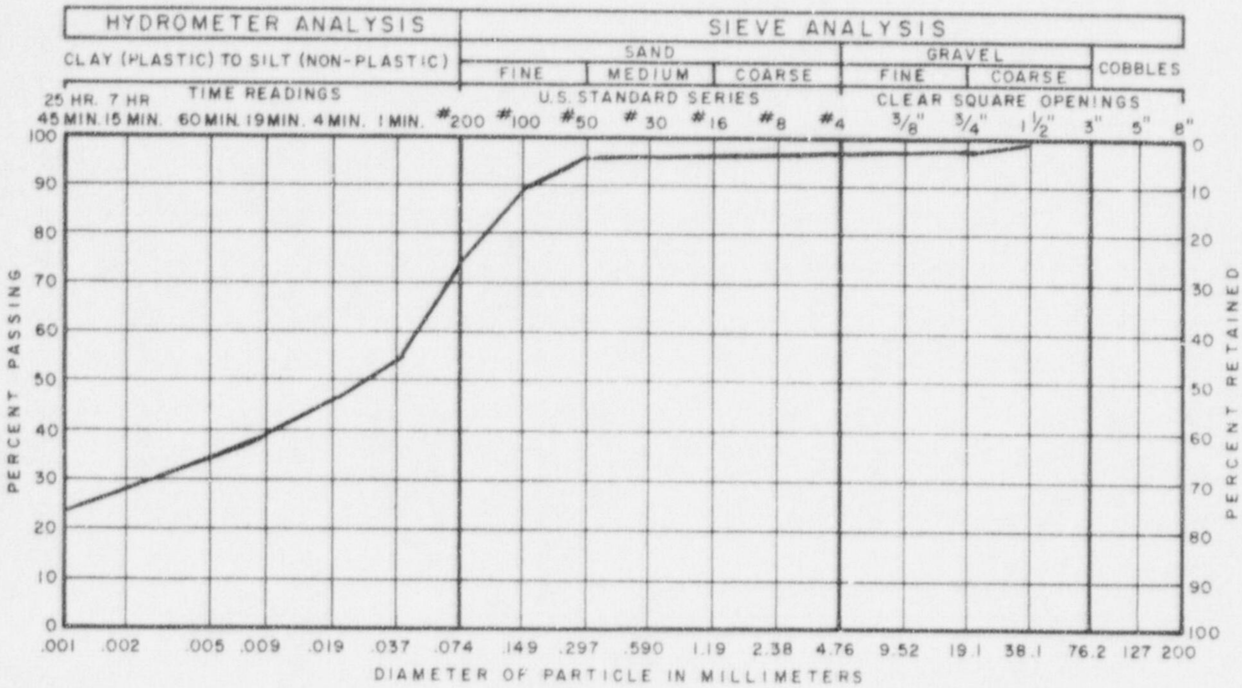
SAMPLE OF Borrow Material FROM Sample No. 5 DEPTH

FIG. B-5

WOODWARD - CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

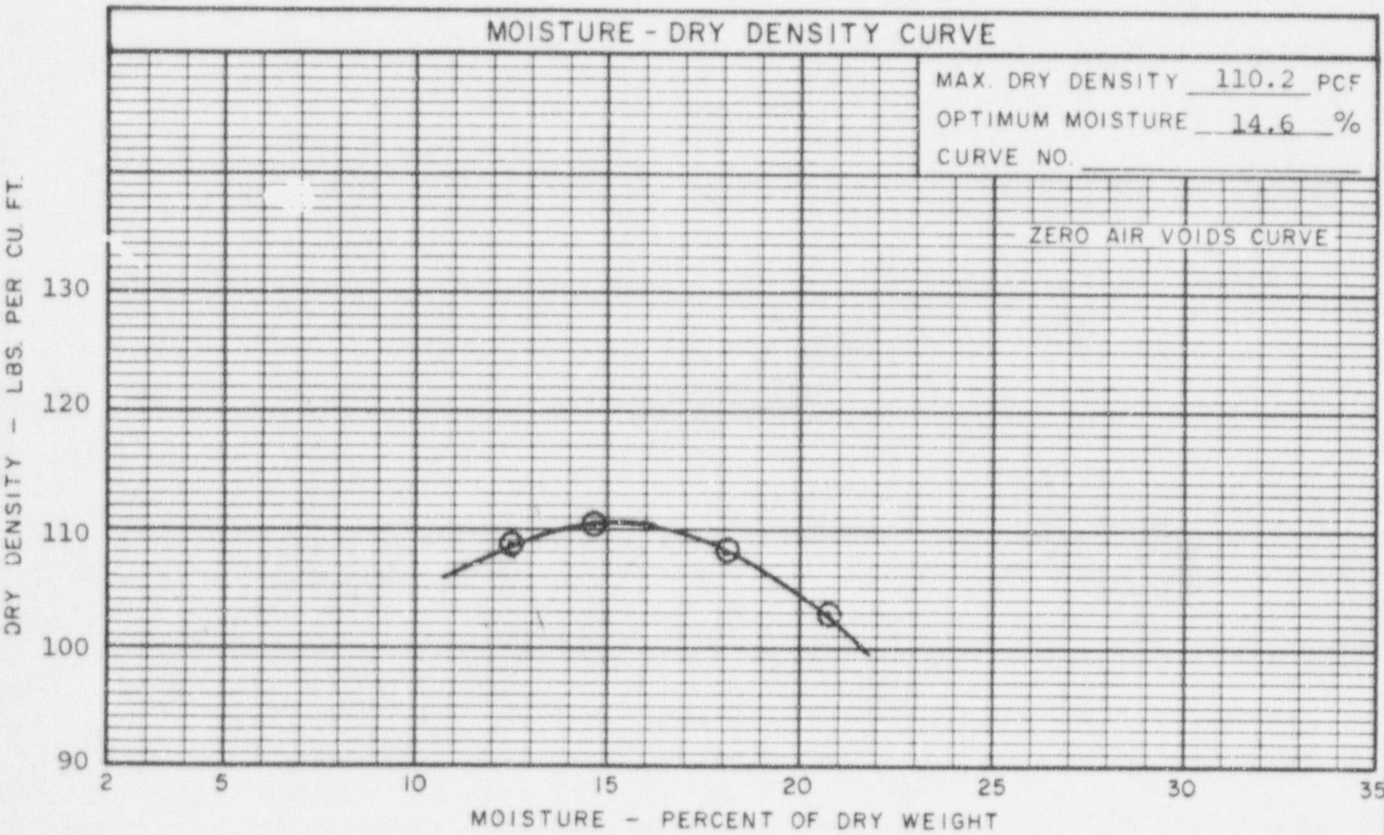
ROCKY MOUNTAIN REGION



GRAVEL 2.6 % SAND 23.2 % SILT AND CLAY 74.2 %

LIQUID LIMIT 30 % PLASTICITY INDEX 18 %

GRADATION TEST RESULTS



COMPACTION TEST PROCEDURE ASTM-D-698-70 METHOD "A"

JOB NO. 19535-18971

COMPACTION TEST RESULTS

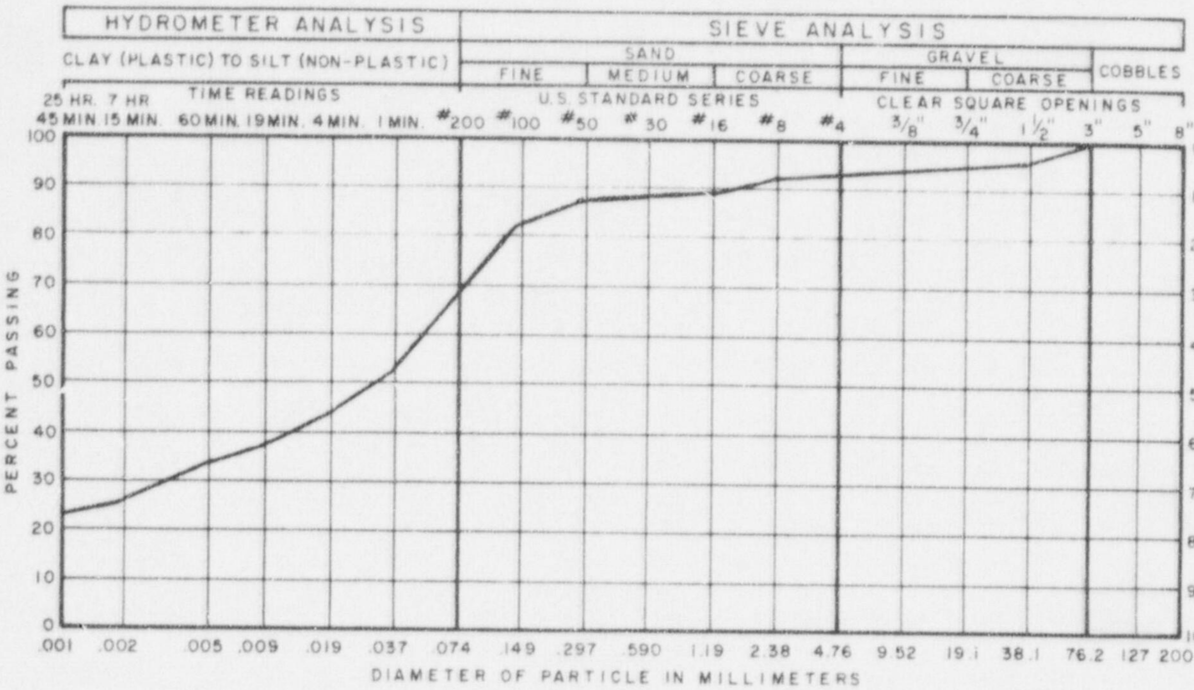
SAMPLE OF Borrow Material FROM Sample No. 6 DEPTH

FIG B-6

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

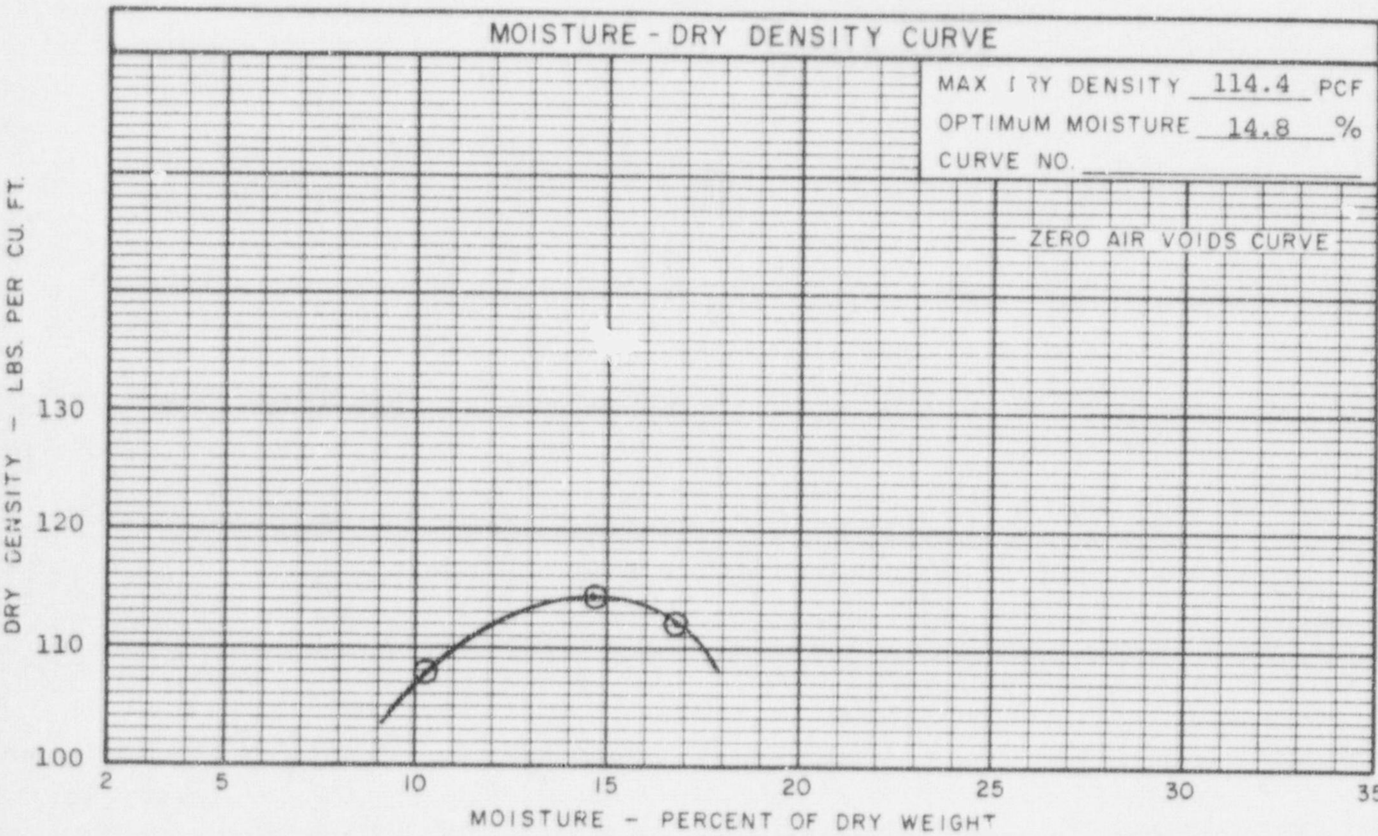
ROCKY MOUNTAIN REGION



GRAVEL 9.0 % SAND 24.0 % SILT AND CLAY 67.0 %

LIQUID LIMIT 30 % PLASTICITY INDEX 16 %

GRADATION TEST RESULTS



COMPACTION TEST PROCEDURE ASTM-D-698-70 METHOD "A"

JOB NO. 19535-18971

COMPACTION TEST RESULTS

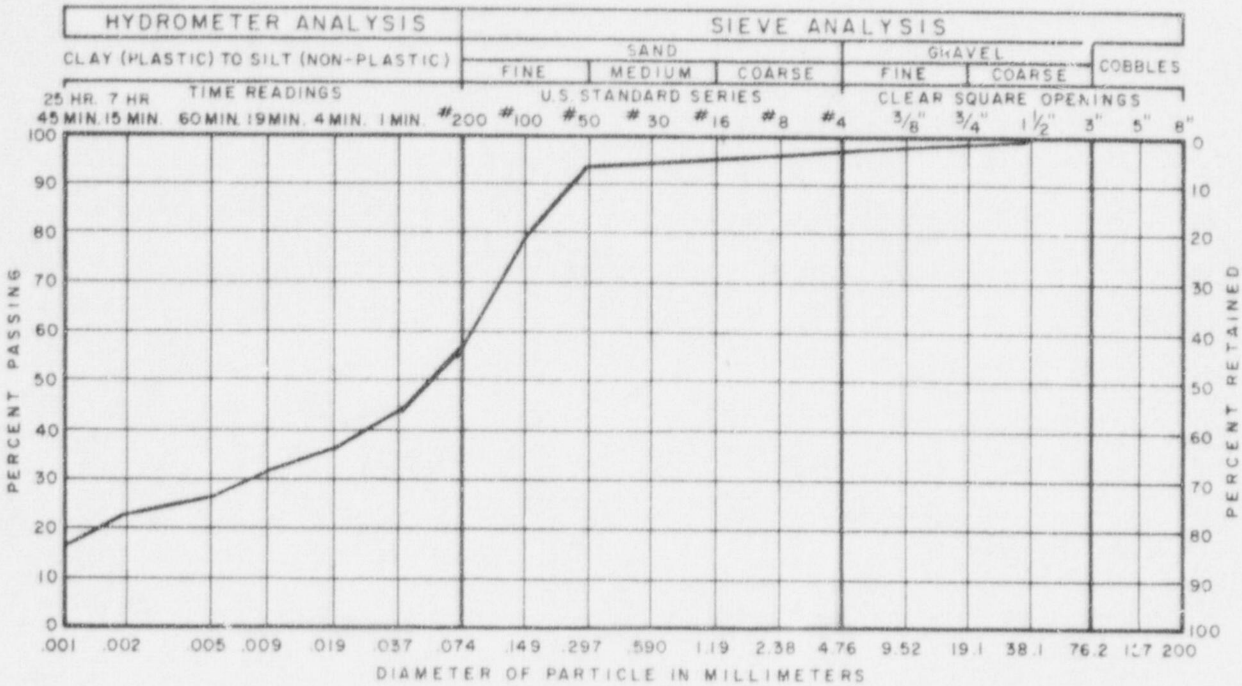
SAMPLE OF Borrow Material FROM Sample No. 7 DEPTH

FIG. B-7

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

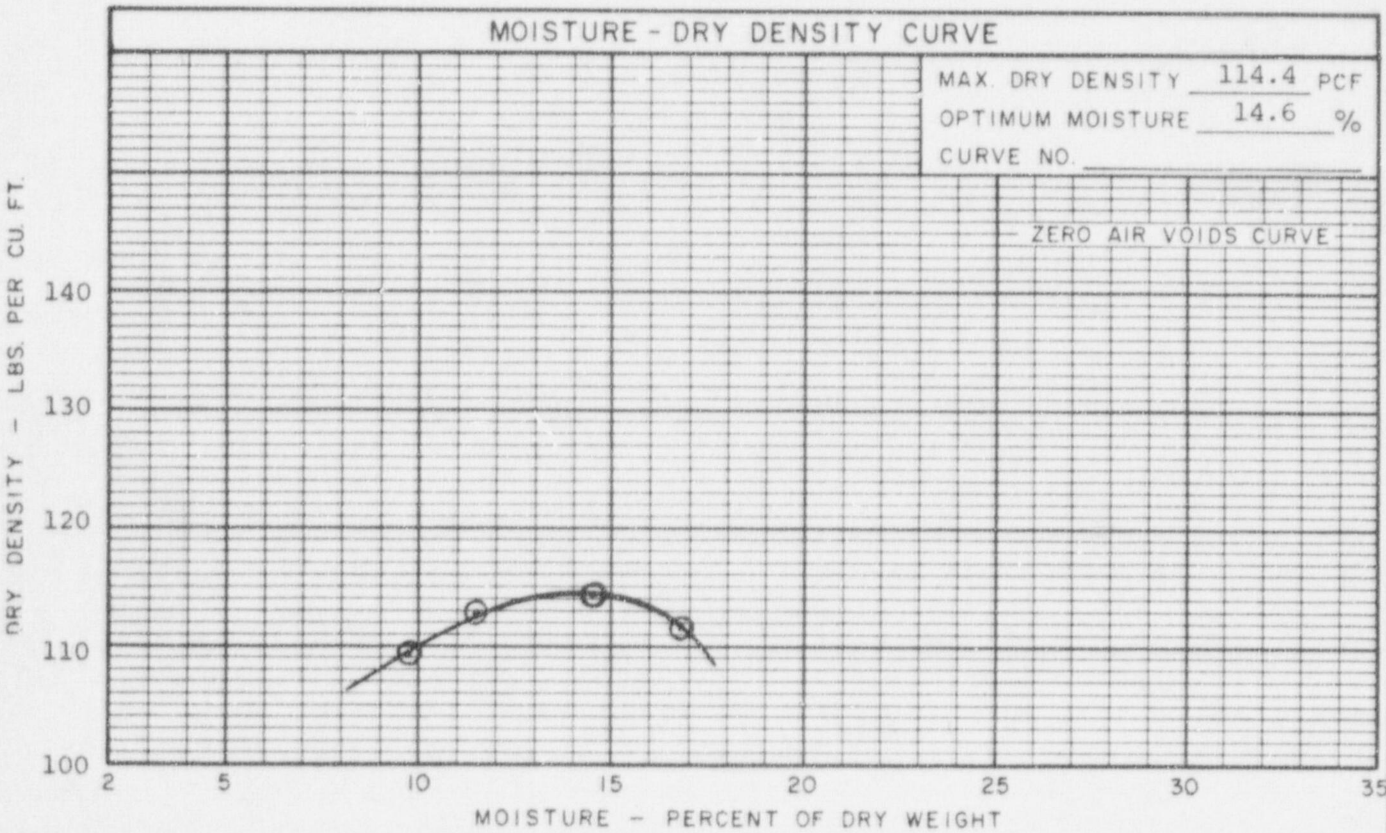
ROCKY MOUNTAIN REGION



GRAVEL 1.7 % SAND 42.0 % SILT AND CLAY 56.3 %

LIQUID LIMIT 24 % PLASTICITY INDEX 9 %

GRADATION TEST RESULTS



COMPACTION TEST PROCEDURE ASTM-D-698-70 METHOD "A"

JOB NO. 19535-18971

COMPACTION TEST RESULTS

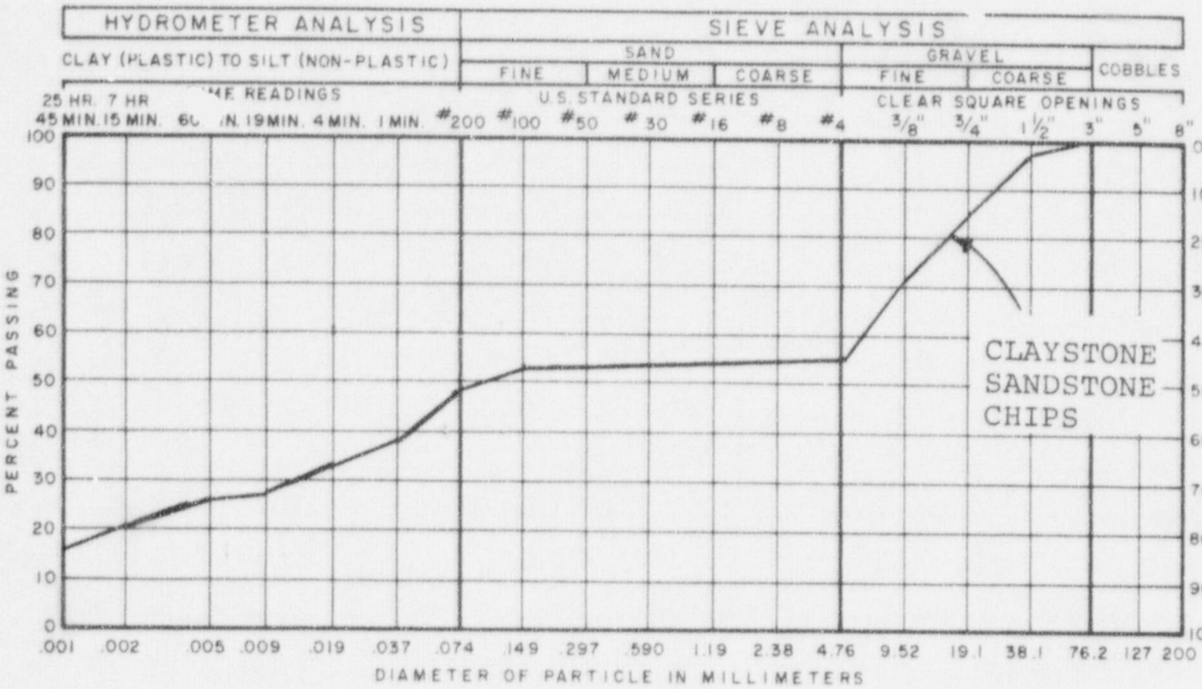
SAMPLE OF Borrow Material FROM Sample No. 8 DEPTH

FIG. B-8

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

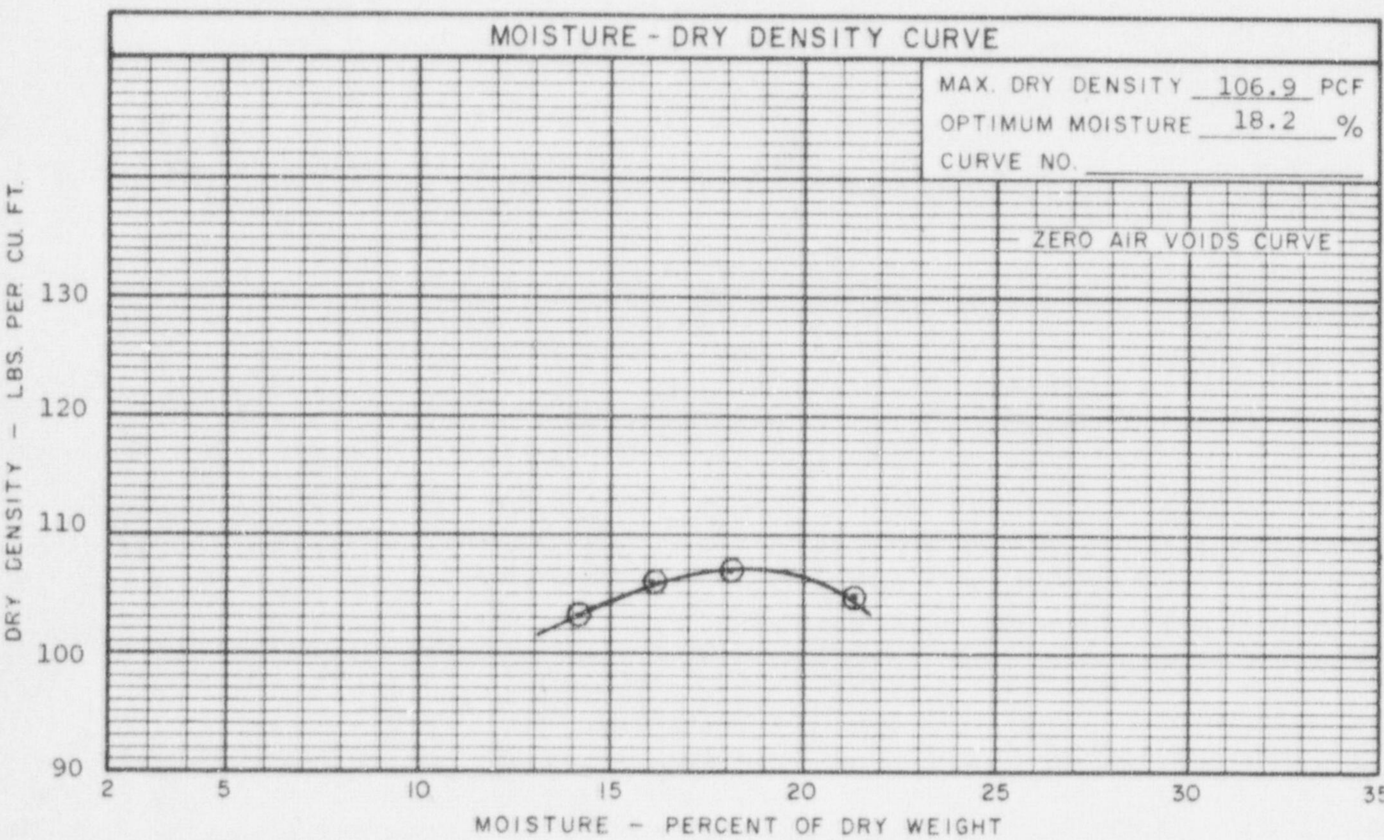
ROCKY MOUNTAIN REGION



GRAVEL 45.4 % SAND 6.8 % SILT AND CLAY 47.8 %

LIQUID LIMIT 45 % PLASTICITY INDEX 24 %

GRADATION TEST RESULTS



COMPACTION TEST PROCEDURE ASTM-D-698-70 METHOD "C"

JOB NO. 19535-18971

COMPACTION TEST RESULTS

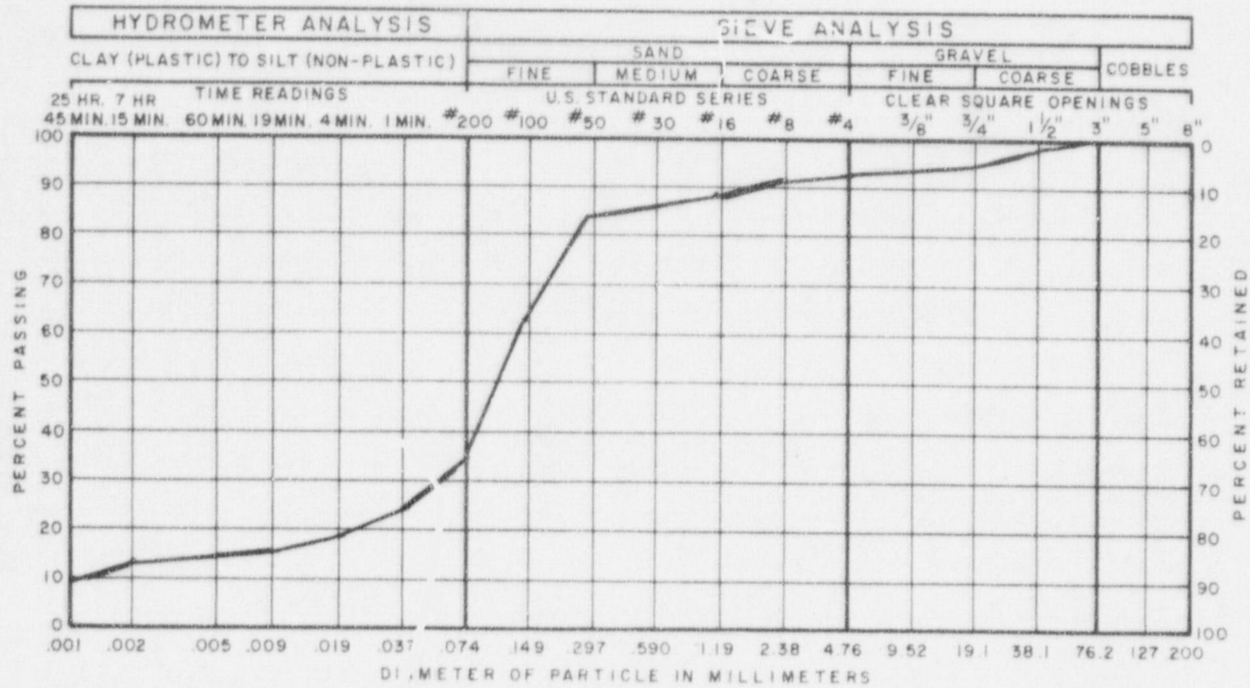
SAMPLE OF Borrow Material FROM Sample No. 9 DEPTH

FIG. B-9

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

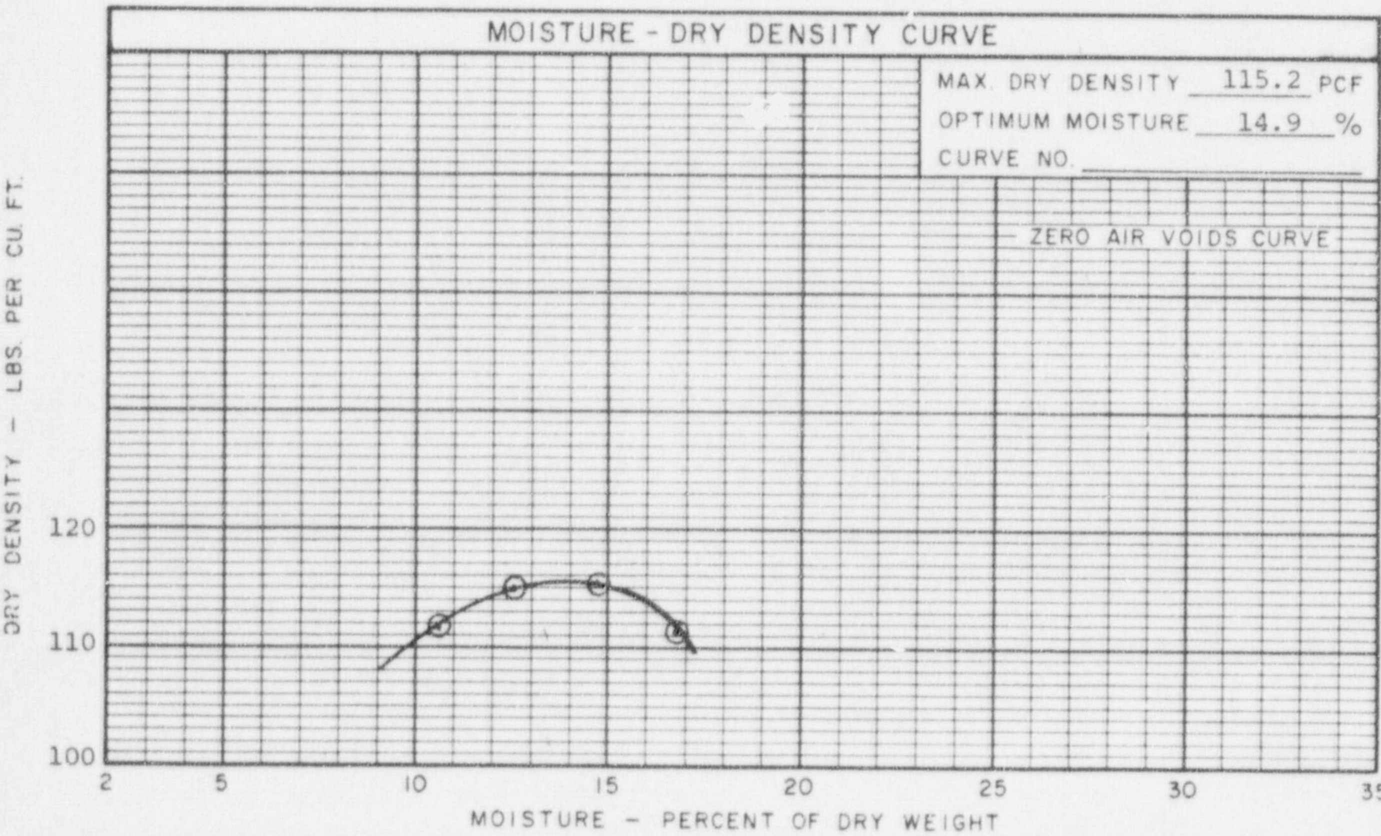
ROCKY MOUNTAIN REGION



GRAVEL 8.8 % SAND 57.1 % SILT AND CLAY 34.1 %

LIQUID LIMIT 22 % PLASTICITY INDEX 3 %

GRADATION TEST RESULTS



COMPACTION TEST PROCEDURE ASTM-D-698-70 METHOD "A"

JOB NO. 19535-18971

COMPACTION TEST RESULTS

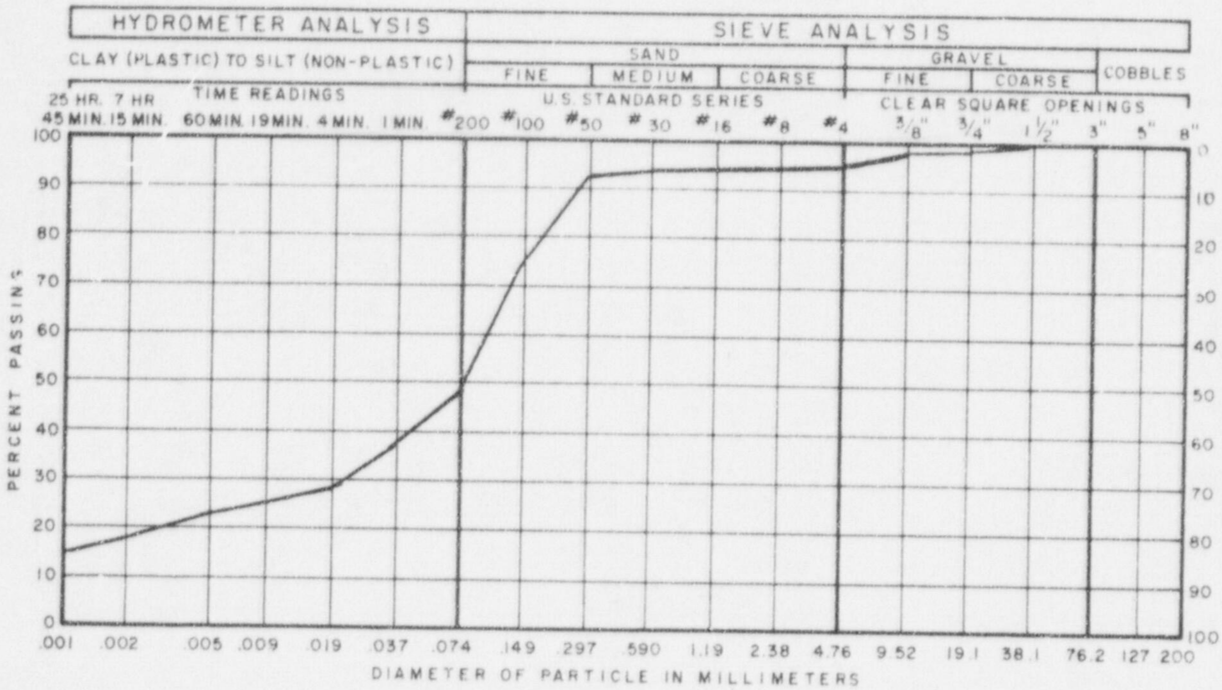
SAMPLE OF Borrow Material FROM Sample No. 10 DEPTH

FIG. B-10

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

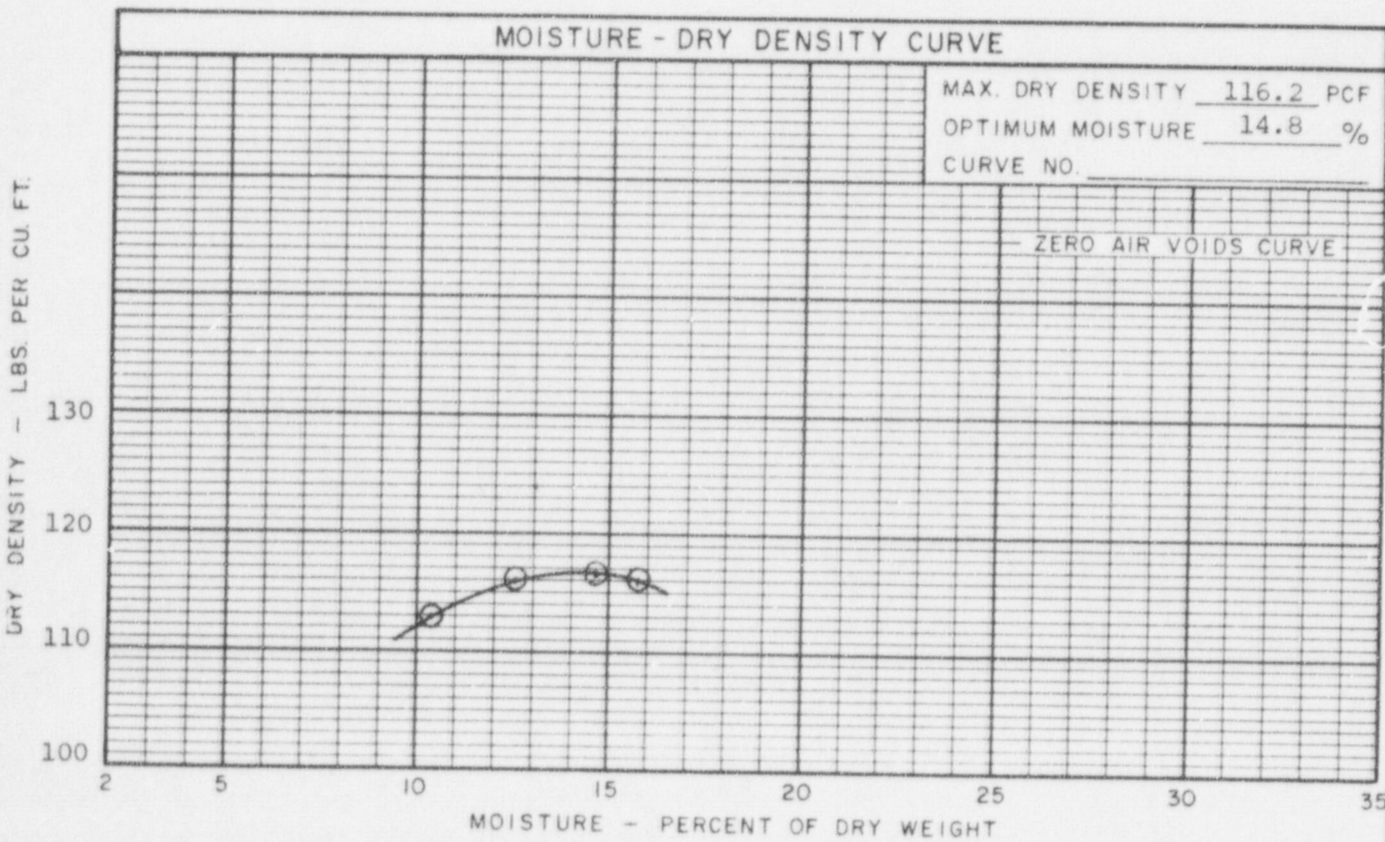
ROCKY MOUNTAIN REGION



GRAVEL 3.7 % SAND 49.3 % SILT AND CLAY 47.0 %

LIQUID LIMIT 22 % PLASTICITY INDEX 7 %

GRADATION TEST RESULTS



COMPACTION TEST PROCEDURE ASTM-D-698-70 METHOD "A"

JOB NO. 19535-18971

COMPACTION TEST RESULTS

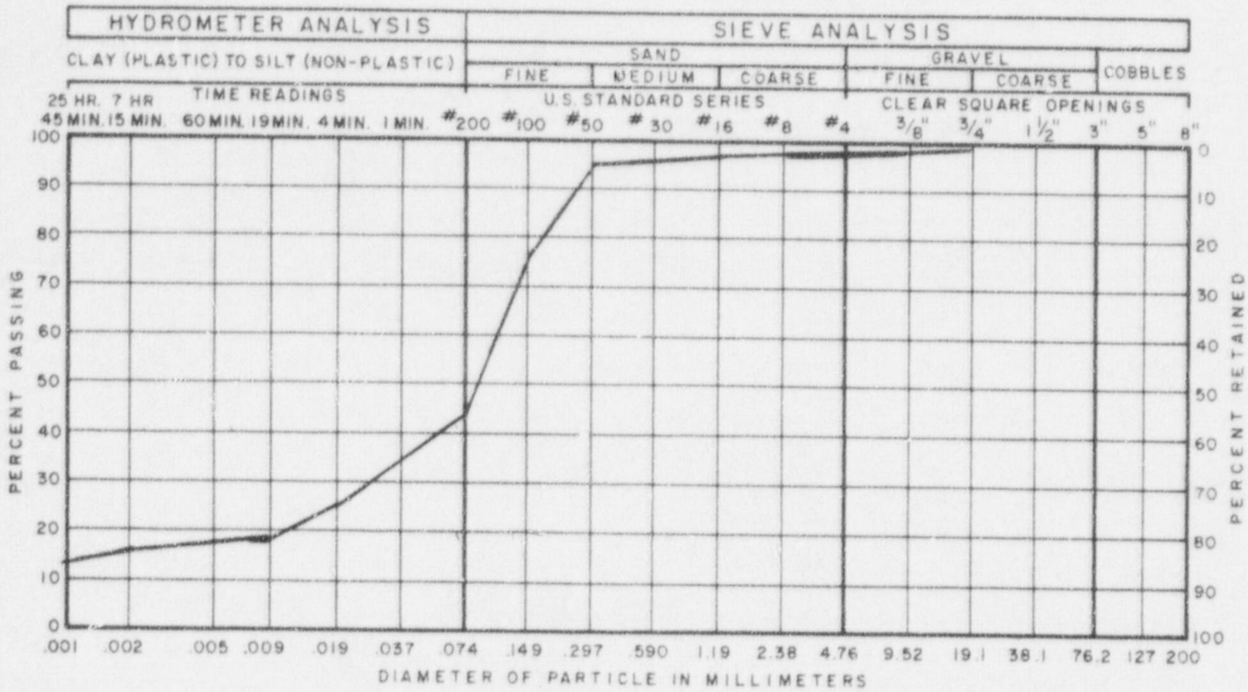
SAMPLE OF Borrow Material FROM Sample No. 11 DEPTH

FIG. B-11

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

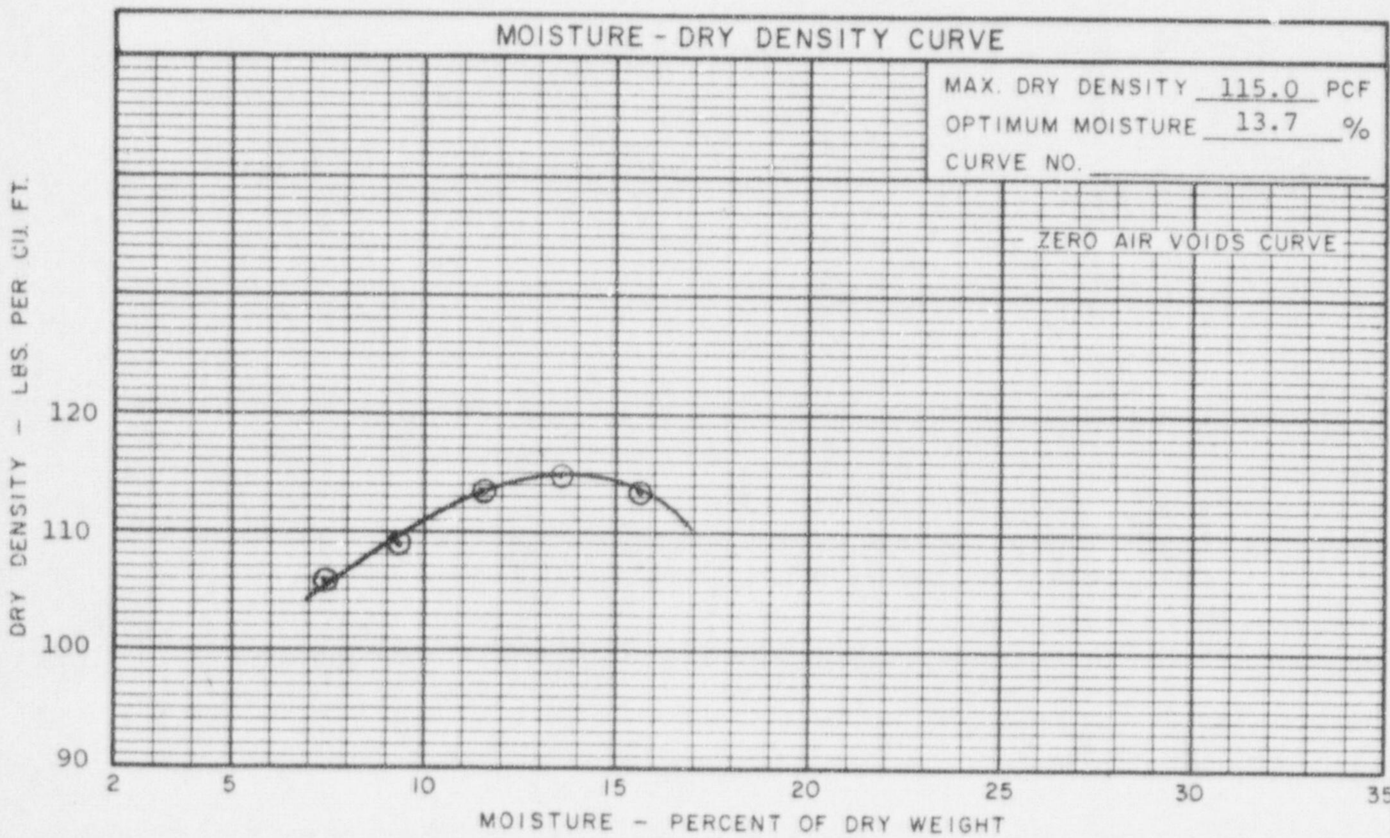
ROCKY MOUNTAIN REGION



GRAVEL 1.2 % SAND 55.1 % SILT AND CLAY 43.7 %

LIQUID LIMIT 19 % PLASTICITY INDEX 1 %

GRADATION TEST RESULTS



COMPACTION TEST PROCEDURE ASTM-D-698-70 METHOD "A"

JOB NO. 19535-18971

COMPACTION TEST RESULTS

SAMPLE OF Borrow Material FROM Sample No. 12 DEPTH

APPENDIX C

PERMEABILITY TEST DATA
AND
TEST PROCEDURE INFORMATION

PERMEABILITY AND SETTLEMENT OF SOILS

Designation E–13

1. Scope.—This designation describes the method for determining the coefficient of permeability and the amount of settlement of remolded soils passing the No. 4 sieve, and the permeability of fine-grained undisturbed soils.

2. Apparatus.—The apparatus shall consist of the following (see designation E–4 and figs. 13–1 and 13–2):

Cans, item 14.
Clamps, item 18.

[4] Numbers in parentheses refer to lines on form 7–1709, figure 12–5.

Cylinder, permeability, 8-inch, item 24.
Discs, porous, item 31.
Gages, dial indicator, with holders, item 35.
Gage, block, dial indicator reference, item 35B.
Gage, ring specimen, thickness, item 36.
Loading device, item 45.
Pan, mixing, item 61.
Sampling tube, item 73.
Scale, item 75.
Scoops, items 76 and 77.
Springs, loading, item 88.
Square, combination, item 89.
Straightedge, metal, item 92.
Supports, head tank, item 95.
T-connectors, item 96.
Tamper, 9-pound, item 97A.
Tanks, head, item 99.
Tubing, item 107.

3. **Calibration of Constant Head Tanks.**—Each constant head tank shall be calibrated to determine the number of cubic centimeters per inch. The head tank is filled with water, then the air intake tube is placed in the head tank and the water level lowered to the bottom of the air intake tube. The water shall be drained slowly from the bottom of the tube into a graduated cylinder or container suitable for weighing, allowing air to enter the tank through the air intake tube as in normal operation.

The water level shall be lowered to near the bottom graduation of the tank and the volume, or weight in grams, and the temperature of the water recorded. A temperature correction (table 10-1, designation E-10) shall be made when the volume is determined by weighing. From these data the volume in cubic centimeters of the calibrated portion of the head tank shall be determined. The calibration factor, *F*, in cubic centimeters per inch shall be determined by dividing the volume in cubic centimeters by the length in inches for the portion calibrated, which is usually 30 inches. Once this factor has been determined, it need not be redetermined unless the air intake tube is replaced.

4. **Sample.**—A 15-pound sample shall be taken from the thoroughly mixed portion of the material passing the No. 4 sieve, which has been obtained in accordance with the method for "Preparation of Soil Samples for Testing," designation E-5.

5. **Procedure.**—(a) The water content of the 15-pound sample shall

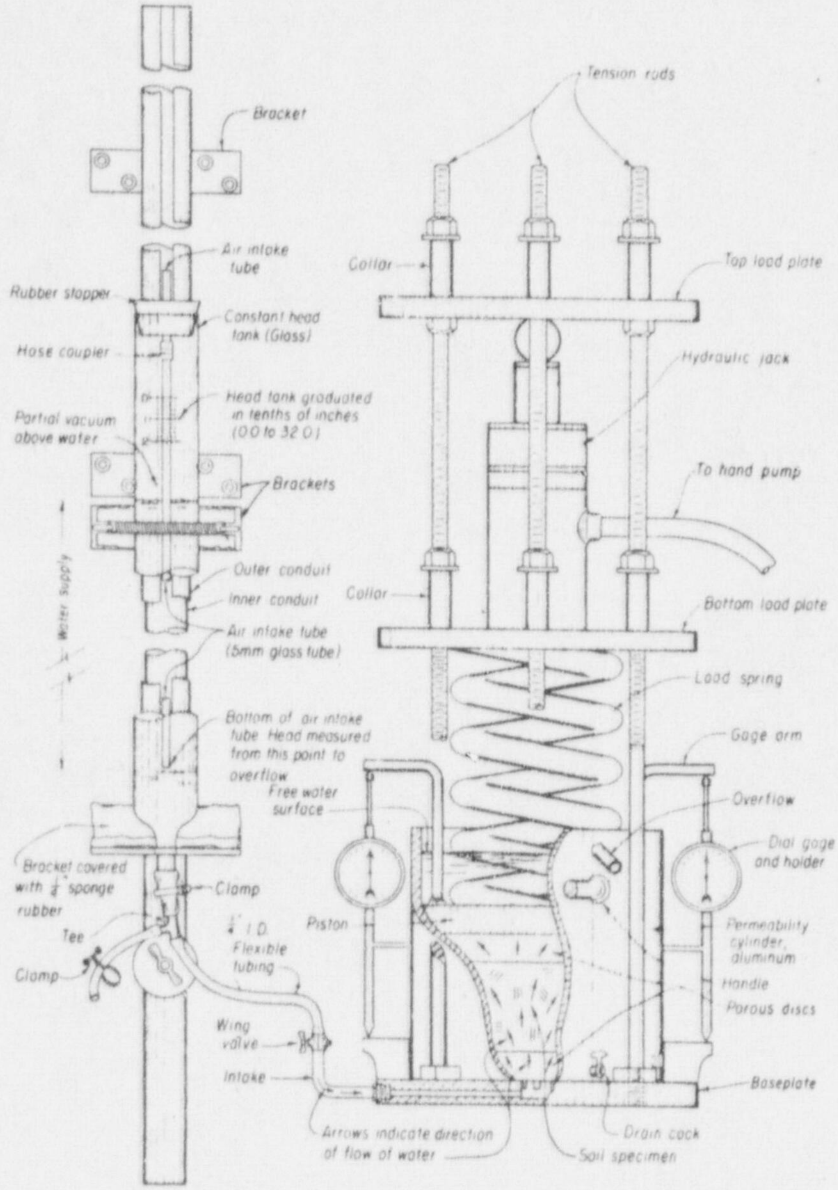


Figure 13-1.—Standard 8-inch permeability apparatus. 101-D-110.

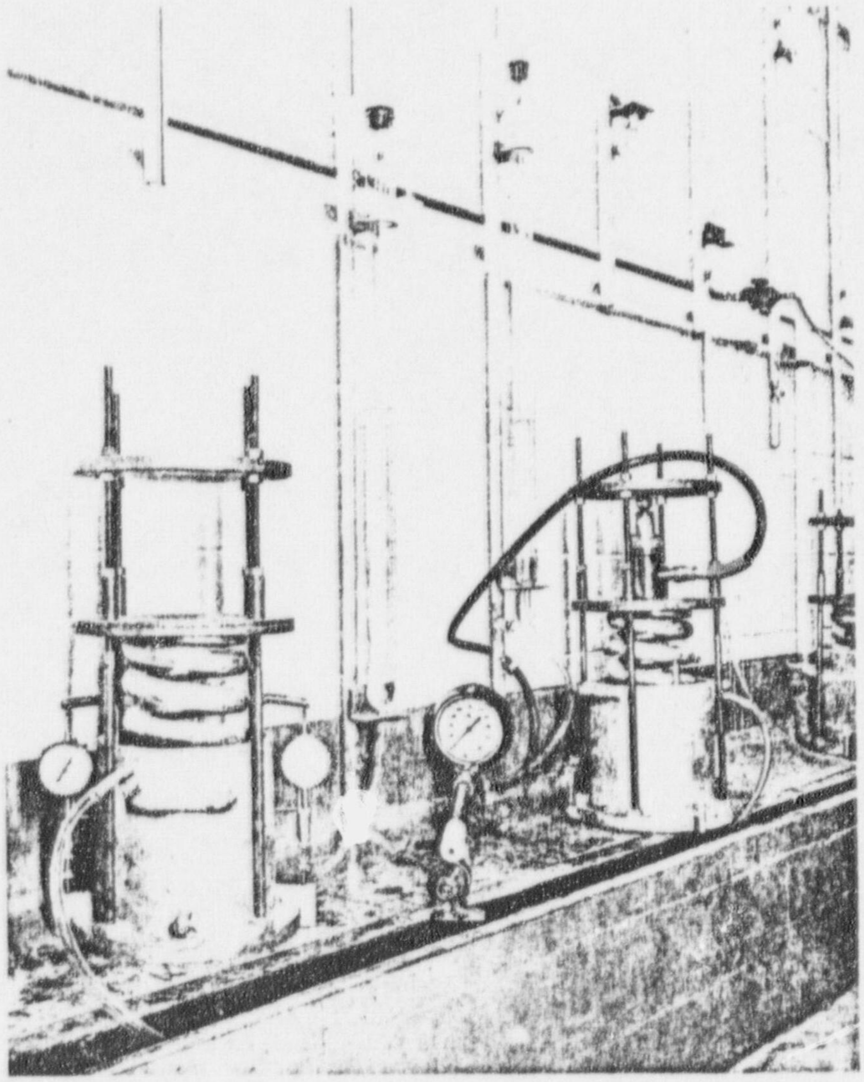


Figure 13-2.—Standard 8-inch permeability test being performed in the laboratory. E-2246-6NA.

be determined in accordance with designation E-9, and the sample placed in an airtight storage can. The quantity of water to be added to the stored sample to give the desired water content shall be computed using the determined initial water content and the wet weight of the stored sample (form 7-1454, cols. 1 to 6, fig. 13-3). This computed quantity of water shall be spread evenly over the sample, and after thoroughly mixing, the material shall again be placed in the storage can.

7-1454 (1-52)

PREPARATION OF MATERIAL FOR REMOLDED SPECIMEN

PROJECT *Example* FEATURE SAMPLE NO *11J-X90*

COMPUTED BY CHECKED BY DATE

SAMPLE NO	PREPARATION OF SAMPLE							DATA FOR PACKING				
	WATER CONTENT %			WEIGHT (POUNDS)			CC.	PCF	%	PCF	LB.	LB.
	WATER CONTENT IN CAN (1)	WATER CONTENT DESIRED (2)	WATER CONTENT DIFF (3)	WET WT SAMPLE IN CAN (4)	DRY WT SAMPLE IN CAN (5)	WT OF WATER TO ADD (6)	VOL OF WATER TO ADD	DESIRED DRY DENSITY (7)	WATER CONTENT OBTAINED (8)	WET DENSITY (9)	WET WEIGHT REQUIRED (10)	WET WT OF EACH LAYER (11)
11J-X90	8.3	14.3	6.3*	15.69	14.49	.91	413	113.3	14.5	129.73	11.34	3.78
	OVEN DETERMINATION	FROM COMPACTION CURVE	COL (2) − COL (1) + EST EVAP	TOTAL WEIGHT − WEIGHT CAN	COL (4) / (1 + COL (1)/100)	COL (5) × COL (3)/100	COL (6) × 453.6	FROM COMPACTION CURVE	OVEN DET. NOT TO VARY OVER 0.5% FROM COL (2)	COL (7) [1 + COL (8)/100]	** COL (9) × 0.0873	COL (10) / NO. OF LAYERS

* Estimated evaporation loss is 0.3%
** For specimen 3-inches in height.

Figure 13-3.—Recording preparation of sample data for permeability test. 101-D-261.

The water content of the sample shall again be determined (designation E-9) and the entire process repeated until the actual water content is within 0.5 percent of that desired.

(b) The porous discs shall be placed in a pan of water and then removed and the free water allowed to drain for 10 to 15 minutes. A porous disc shall be placed in the bottom of the permeability cylinder. The 3-inch thickness ring gage shall be placed on the bottom porous disc, the top porous disc placed on the ring gage, and the piston placed over the top disc so that the dial indicator gage arms are directly above the dial indicator supports. The positions of the piston and cylinder are matchmarked so they may be identically reassembled. The coil spring shall be placed on top of the piston to hold it firmly in place. Dial gage readings (A and B) shall be taken simultaneously and recorded as "Ring" readings on form 7-1455, figure 13-4. The total of these two readings shall be recorded as "Dial readings A + B, w/ring." The coil spring, piston, top disc, and ring thickness gage shall then be removed prior to placing the specimen. The drain cock shall be open.

(c) The soil shall be compacted into the cylinder in three 1-inch

7-1455
(5-62)
BUREAU OF RECLAMATION

PERMEABILITY-SETTLEMENT TEST, DATA SHEET 1

PROJECT Example FEATURE ______ SAMPLE NO 11J-X90

TESTED BY ______ COMPUTED BY ______ CHECKED ______ DATE ______

CYLINDER NO 14

PLACEMENT DATA

GPO 854150

WT CONTAINER + WET SOIL 21.42 LB	FINAL WT CONTAINER	SAMPLE AREA 50.27 SQ IN
WT 1ST LAYER 3.78 LB	+ WET SOIL 10.08 LB	INTENSITY OF LOAD 20 PSI
WT CONTAINER + WET SOIL 17.64 LB	WT WET SOIL 11.34 LB	OR 22 FEET OF FILL
WT 2ND LAYER 3.78 LB	WET DENSITY 129.73 PCF	LOAD ON SPECIMEN 1005 LBS
WT CONTAINER + WET SOIL 13.86 LB	PLACEMENT WATER CONT 14.5 %	JACK NO 845
WT 3RD LAYER 3.78 LB	PLACEMENT DRY DENSITY* 113.3 PCF	GAGE READING 340
	DESIRED WATER CONT 14.3 %	

	TOTAL	1/2 TOTAL	SPECIMEN THICKNESS (INCHES)		
DIAL READING A+B, W/RING	0.718	0.3590			
DIAL READING A+B, NO LOAD	0.717	0.3585			
DIFFERENCE		0.0005	3.0000 ⊕ 0.0005	3.0005	INITIAL
DIAL READING A+B, W/L, WET			3.0005 ⊖ 0.044	2.9565	(C) CONSOL., WET

SETTLEMENT DATA

DATE 19	HOUR OBSERVED	LOAD LB/SQ FT	TRAVEL: DIAL AT A, READING	TRAVEL: DIAL AT A, AMOUNT	TRAVEL: DIAL AT B, READING	TRAVEL: DIAL AT B, AMOUNT	SETTLEMENT: AVERAGE AMOUNT	SETTLEMENT: PERCENT
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
9-7	7:40	Ring	0.377		0.341			
9-7	8:10	No Load	0.291	0.000	0.426	0.000	0.000	0.000
	8:20	2880	0.316	0.025	0.471	0.045	0.035	1.166
	9:20	"	0.320	0.029	0.483	0.057	0.043	1.433
	10:20	"	0.322	0.031	0.489	0.063	0.047	1.566
9-8	8:00	w/Load	0.322	0.031	0.489	0.063	0.047	1.566
9-10	8:30	W/L, Wet	0.317	0.026	0.488	0.062	0.044	1.466
9-11	8:30	"	0.317	0.026	0.487	0.061	0.044	1.466
9-12	8:00	"	0.316	0.025	0.488	0.062	0.044	1.466
9-13	8:00	"	0.315	0.024	0.486	0.060	0.042	1.400
9-16	7:45	"	0.312	0.021	0.485	0.059	0.040	1.333
9-17	7:45	"	0.310	0.019	0.485	0.059	0.039	1.300
9-18	7:45	"	0.310	0.019	0.485	0.059	0.039	1.300
9-19	8:00	"	0.310	0.019	0.485	0.059	0.039	1.300
9-20	8:00	"	0.310	0.019	0.485	0.059	0.039	1.300 ▲
9-20	10:00	No Load	0.311	0.020	0.482	0.056	0.038	1.266
REBOUND								

AFTER PERCOLATION DATA

SAMPLE NO 11J-X90
LOCATION NO 6

WATER CONTENT DETERMINATION		CONSOLIDATED DRY DENSITY
PAN NUMBER	4	
WT PAN + WET SOIL	15.03	= PLACEMENT DRY DENSITY / ((100 − % SETTLEMENT)/100) = 113.3 / ((100 − 1.30)/100) ▲
WT PAN + DRY SOIL	13.55	
WT PAN	3.74	
WT WATER	1.48	= 114.8 PCF
WT DRY SOIL	9.81	
WATER CONTENT	15.1	NEEDLE READ 47 NEEDLE AREA 40 PEN RES 1880

WATER CONTENT 15.1 % PENETRATION RESISTANCE 1880 PSI CONSOLIDATED DRY DENSITY 114.8 PCF

* MAXIMUM STANDARD DRY DENSITY OR OTHER AS SPECIFIED

REMARKS ______

Figure 13-4.—Recording compaction and settlement test data. 101-D-539.

layers. The weight of wet soil required for each layer shall be computed using the volume of the cylinder for the 1-inch depth, the desired dry density, and the moisture content of the stored sample. This information shall be recorded on form 7-1454. (See columns 7 through 11, fig. 13-3.) The soil shall be placed at the Proctor maximum dry density and optimum water content as determined by the Proctor compaction test, designation E-11. (*Note:* Other densities and water contents shall be specified as required to simulate particular field placement conditions.)

The amount of soil required for each 1-inch layer recorded on form 7-1455 is placed in the cylinder, carefully leveled while in a loose state, and compacted with the 9-pound tamper forced downward by hand from the top of the permeability cylinder. Compaction shall be continued until each soil layer is within 1/64 inch of the required 1-inch thickness. The depth of the layer is determined with a metal straightedge and combination square. The surface of each layer shall be scarified to a depth of 1/8 to 1/4 inch before placing the next layer.

The third layer, after being compacted and leveled, is scarified, the porous disc and piston placed on top, and the piston tapped into final position with the handle of the tamper. The coil spring shall be placed on top of the piston to hold it firmly in place. The dial gage readings (A and B) shall be taken simultaneously and recorded as "no load" readings. The total of these two shall be recorded as "Dial reading A + B, no load." The final specimen thickness indicated by the dial gages shall be within ± 0.005 inch of that indicated by the 3-inch thickness gage.

(d) The assembly of the permeability apparatus shall be completed as shown in figure 13-1, making sure that the tension rods are securely screwed into the base of the permeability cylinder.

(e) The load to be applied to the soil specimen shall be as follows:

(1) For investigation of materials:

Earth dams:

For soils that are manifestly impervious, the normal load shall be 100 pounds per square inch.

For soils that are of doubtful imperviousness, the normal load shall be 20 pounds per square inch.

Canals:

For canal embankments the normal load shall be 20 pounds per square inch; and for canal linings, the normal load shall be zero if tested as shown in figure 13-6, or 1 pound per square inch if tested in a standard 8-inch permeability cylinder.

Other purposes:

The intensity of load shall be equivalent to the expected height of fill expressed as pounds per square inch.

(2) For control testing:

Earth dams:

The load applied to the specimen in the 8-inch-diameter cylinder shall be equivalent to the weight of fill, calculated as follows:

$$L = H\gamma_w(0.3491)$$

where: L = load on specimen, in pounds,
H = height of fill above, in feet, and
γ_w = wet density of soil, in pounds per cubic foot.

Canals or other purposes:

The load shall be equivalent to that imposed by the structure.

(f) The load shall be applied with a hydraulic jack and hand pump, and the nuts tightened fingertight on the bottom load plate. Immediately after the load is applied, dial gage readings (A and B) shall be taken and recorded. The load shall be checked every hour for the first 2 hours, and daily thereafter, to insure that the load maintained by the spring remains constant. Dial gage readings (A and B) shall be taken and recorded until the initial consolidation is less than 0.002 inch during a 16-hour period. The final reading is identified as "w/Load".

(g) After initial consolidation, water under a low head shall be permitted to flow upward through the specimen, using a constant head tank.

(*Note:* The size of head tank is chosen according to the anticipated permeability of the specimen, so that a full tank of water will flow through the specimen in approximately a 24-hour period under the head selected for the test.)

The head tank shall be filled from the bottom by forcing water through the tubing connecting the head tank to the permeameter intake. It is necessary that the stopper which holds the air intake tube be released before filling. After filling the head tank, the tubing shall be clamped and the lower end slipped over the intake of the permeability cylinder. With the drain cock opposite the bottom porous disc open, the head tank stopper shall be carefully and tightly inserted. Then the hose clamp on the connecting flexible tubing shall be removed, allowing water to fill the tubing and flow through the bottom porous disc. The cylinder shall be tipped so that air bubbles can escape through the drain cock. The flow of water shall be continued until all evidence of air in the system has disappeared. The drain cock shall be closed to permit water at a low head to permeate slowly upward through the specimen. The head to be used depends upon the porosity of the material as placed; it should range from 1 inch or less for specimens having high permeability, to 1 foot or more for those having low permeability. This slow permeation shall be continued until the specimen is thoroughly wetted, that is, until the top porous disc and piston are completely covered with water, or for a period of 3 days, whichever occurs first.

(*Note:* It is possible that a specimen may leak or "pipe" up the side of the cylinder and show water above the piston much earlier than the apparent permeability of the specimen would indicate. If this happens, the test shall be stopped and another specimen prepared. When testing granular cohesionless soils, special precautions should be observed. For fine sands, a water-pump grease should be applied to the cylinder wall to prevent piping between the specimen and the wall. For the coarser sands, ¼-inch-thick sponge rubber cemented to the cylinder wall has been found to be satisfactory. This will require a reduction in the diameter of the permeability cylinder for computations of soil density; a ¼-inch sponge rubber will usually compress to about ⅛ inch. The head for pervious soils should be as low as possible, usually below the critical gradient. The critical gradient is reached when the head of water on the specimen is approximately equal to the thickness of the specimen.)

(h) After the specimen is thoroughly wetted or has been wetted for 3 days, dial gage readings (A and B) shall be taken, recorded and identified as "w/L, wet".

(i) Water shall then be poured into the top of the cylinder until it flows out of the overflow. The connecting tubing between the tank and the cylinder shall then be clamped, and the head tank adjusted to the desired height and refilled in the same manner as in the initial filling, except that water shall be introduced through the bleeder tee connection just below the bottom of the head tank.

After the head tank has been completely filled and the stopper replaced, the water level in the head tank shall be lowered to the 0.0 mark or below by carefully opening and closing the clamp on the bleeder connection. The time shall be noted, the exact head tank reading observed and recorded on form 7-1394, figure 13-5, and the clamp between the head tank and the specimen released, thus starting the permeability test.

(*Note:* When readings cannot be made daily, e.g., on weekends or holidays, the head should be reduced so that the permeability test is not interrupted.) Care should be taken to see that the water in the head tank is maintained at the same temperature as the specimen, or preferably at a slightly higher temperature, about 5 degrees above that of the specimen. When water which is colder than the specimen is used, it has been found that the air dissolved in the water will come out of solution and become trapped in the voids of the specimen as air bubbles, thus resulting in an erroneously low permeability.

7-1394
(1-64)
Bureau of Reclamation

PERMEABILITY-SETTLEMENT TEST DATA SHEET 2

PROJECT *Example* FEATURE ______ SAMPLE NO *11J-X90*

TESTED BY ______ COMPUTED BY ______ CHECKED BY ______ DATE ______

CYLINDER NO *14*

TIME INSTALLED		HEAD TANK		HEAD (H_{wc}) (SEE REMARKS COLUMN)	CONSOLIDATION THICKNESS (L) (DATA SHEET NO 1)	CONSTANT	CONSTANT
DATE 19—	HOUR	NO	CALIBRATION FACTOR F	FEET	INCHES	$C = 0.0738 \frac{L}{H_{wc}}$	CF
9-10	8:24	208	6.06	5.00	2.9565	0.0436	0.2642
9-13	8:24	208	6.06	1.67	2.9565	0.1307	0.7920
9-16	8:00	208	6.06	5.00	2.9565	0.0436	0.2642

TIME OF OBSERVATION		ELAPSED TIME (t')	HEAD TANK READING	DIFFERENCE IN READING	R/t'	COEF OF PERM ($K = CF \frac{R}{t'}$)	REMARKS (RECORD HEAD IN FEET, CHANGES IN HEAD, AND OTHER OBSERVATIONS)
19—	HOUR	HOURS	INCHES	INCHES		FEET/YEAR	
9-10	8:24		1.00				Head at 5.00' - test
9-11	8:30	24.10	24.80	23.80	0.99	0.26	started.
	8:45		1.60				
9-12	8:00	23.25	26.60	25.00	1.08	0.29	
	8:12		1.50				
9-13	8:00	23.80	22.60	21.10	0.89	0.24	
	8:24		1.40				Head lowered to 1.67'
9-16	7:45	71.35	23.00	21.60	0.30	0.24	
	8:00		1.90				Head raised to 5.00'
9-17	7:45	23.75	22.00	20.10	0.85	0.22	
	8:00		1.80				
9-18	7:45	23.75	21.70	19.90	0.84	0.22	
	8:00		1.00				K(ave) = 0.22
9-19	8:00	24.00	21.30	20.30	0.85	0.22	
	8:12		1.00				
9-20	8:00	23.80	21.70	20.70	0.87	0.23	

CYLINDER LOCATION NO

Figure 13-5.—Recording permeability test data. 101-D-540.

If a head tank is operating properly, the air intake tube will remain empty. A rise in water level in the air intake tube usually indicates leakage between the large stopper and head tank or air intake tube that must be corrected. Occasionally, a slight rise in water level in the air intake tube may be caused by changes in temperature or atmospheric pressure. Observations should not be recorded unless the water level is very near the bottom of the air intake tube.

(j) The test shall be continued for a minimum of 10 days and daily settlement and permeability readings taken until the permeability rate becomes practically constant.

(k) Final dial gage readings shall be taken. The connecting tubing shall be clamped and removed from the permeability cylinder intake. The consolidating load on the specimen shall be released by means of the hydraulic jack until the load is zero. After allowing sufficient time for complete expansion of the specimen, the dial gages shall again be read and the data recorded as "no load" readings.

(l) Surplus water on top of the specimen shall be poured off; and the load plates, tension rods, spring, piston, and top porous disc shall be removed. Penetration resistance needle readings shall be taken on the specimen and recorded. A representative portion from the center of the specimen shall be removed for water content determination.

6. Calculations.—(a) The initial specimen thickness in inches shall be determined by computing the difference between one-half the total "Dial reading A + B, w/ring" and one-half the total "Dial reading A + B, no load," form 7-1455, figure 13-4. The difference shall be added to or subtracted from 3 inches.

The consolidated thickness, L′, in inches shall be computed by adding to or subtracting from the initial specimen thickness the maximum "average amount" of settlement, column 8, figure 13-4, which occurred due to load and wetting (dial gage readings identified as "w/L, wet").

(b) The amount of settlement, column 5, figure 13-4, shall be computed by subtracting the "no load" reading, column 4, from subsequent readings in column 4; the same procedure is used for columns 7 and 6. The average values of columns 5 and 7 are recorded in column 8.

(c) The settlement expressed as a percentage of the initial thickness of the specimen, column 9, figure 13-4, is determined by the following equation:

$$\text{Settlement, } \% = \frac{\text{settlement, inches (column 8)}}{\text{initial specimen thickness, inches}} \times 100 \qquad (1)$$

(d) The consolidated dry density corresponding to the particular settlement is calculated by the following equation:

Consolidated dry density, in pounds per cubic foot (p.c.f.)

$$= \frac{\text{placement dry density, p.c.f.}}{\frac{(100 - \text{settlement, \%})}{100}} \qquad (2)$$

(e) The coefficient of permeability shall be calculated as follows:

$$k = \frac{V}{At} \div \frac{H_{wc} \text{ (for constant head)}}{L} \text{ or,} \qquad (3)$$

$$k = \frac{V\,L}{At\,H_{wc}} \qquad (4)$$

where: k = coefficient of permeability, in feet per year,
V = volume of discharge, cubic feet in time t,
L = thickness (or length) of specimen, in feet,
A = area of specimen, in square feet,
t = elapsed time during measurement, in years, and
H_{wc} = constant head = difference between headwater and tailwater levels, in feet.

In order to simplify computations, the general equation given above has been partially solved and constants introduced as follows:

$$V\text{, cubic feet} = \frac{RF}{28{,}320}$$

where R is the difference in reading of head tank levels measured in inches, and F is the calibration factor for the head tank, expressed in cubic centimeters per inch.

$$L\text{, feet} = \frac{L'}{12}$$

where L' is the consolidated thickness of specimen measured in inches.

$$t\text{, years} = \frac{t'}{8{,}760}$$

where t' is the elapsed time between head tank readings expressed in hours.

A, square feet = 0.3491 for an 8-inch cylinder.

Substituting these constants in equation (4) above,

$$k = 0.0738 \frac{RF\,L'}{t'\,H_{wc}} \qquad (5)$$

Since the value $\frac{L'}{H_{wc}}$ is constant for any particular head, let

$$C = 0.0738 \frac{L'}{H_{wc}} \qquad (9)$$

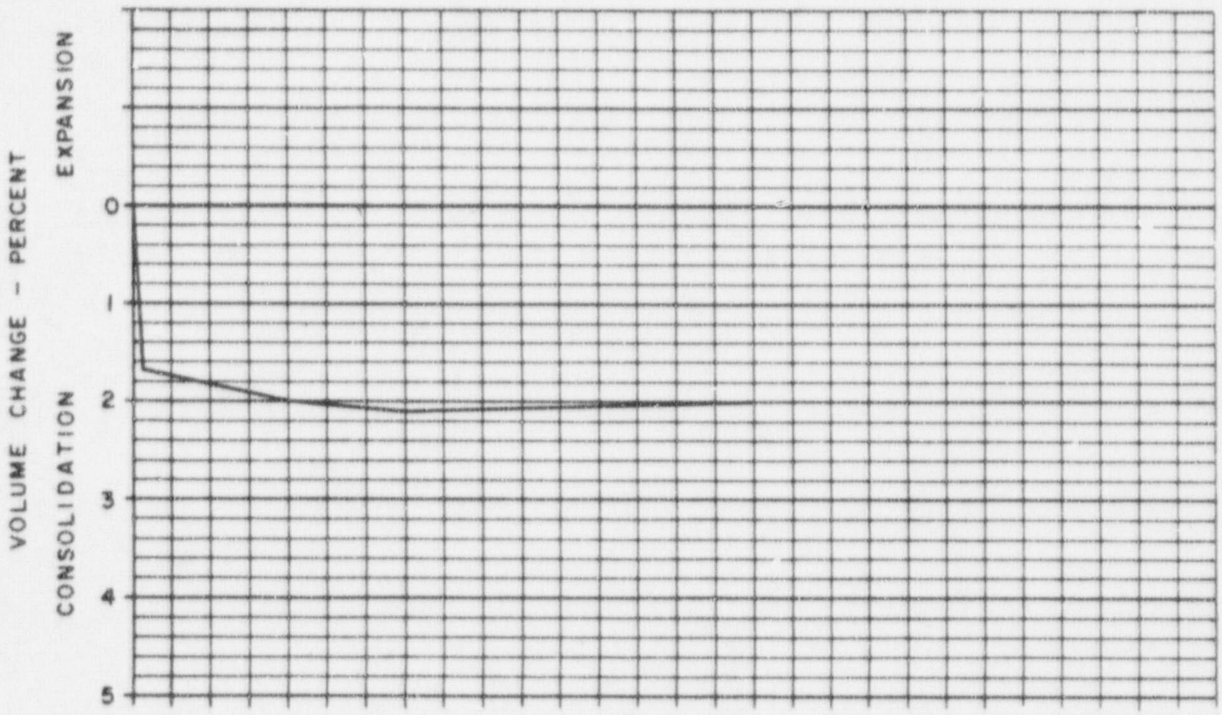
Then

$$k = CF\frac{R}{t} \qquad (7)$$

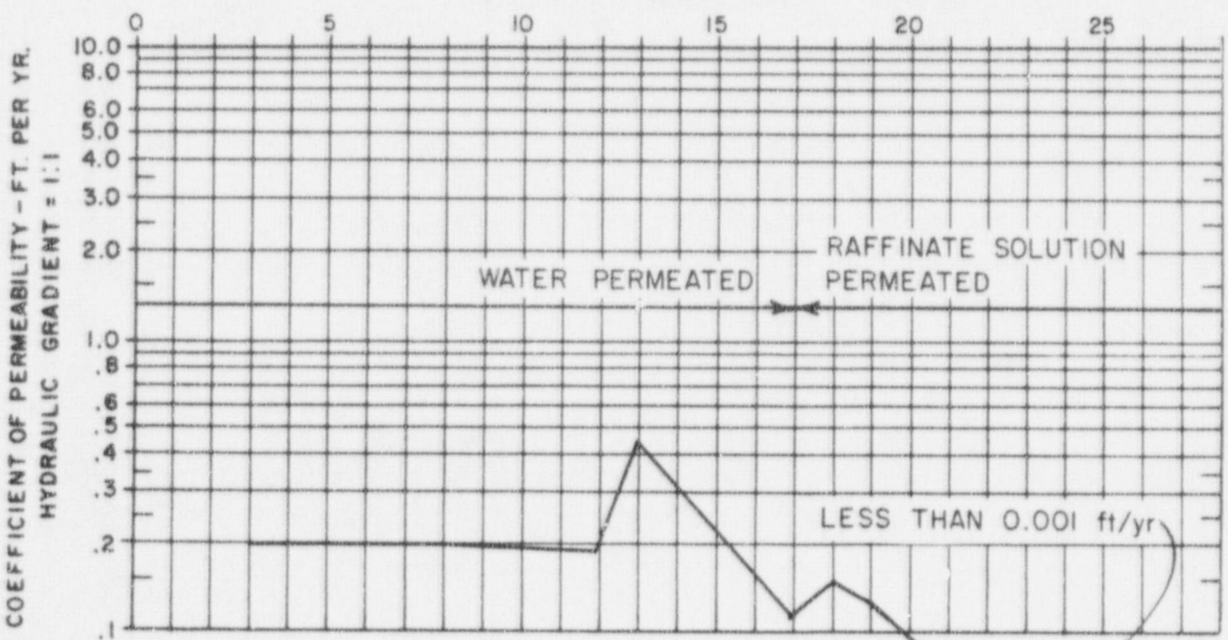
Equations (6) and (7) are shown on figure 13-5 and are used to compute the coefficient of permeability in feet per year.

(*Note:* This method for determining the permeability is based on the use of a constant head. If a "falling head" is used for special tests, the rate may be calculated on the basis of a formula presented in designation E-15.)

INITIAL CONDITION		FINAL CONDITION	
PLACEMENT USED	100% D-698	CONSOLIDATION (%)	2.0
DRY DENSITY (PCF)	127.0	CONSOLIDATED, DRY DENSITY (PCF)	129.6
MOISTURE CONTENT (%)	10.7 (opt.)	MOISTURE CONTENT (%)	---
CONSOLIDATION LOAD (PSI)	32	PENETRATION RESISTANCE (PSI)	
(DEPTH OF FILL)		COEFFICIENT OF PERMEABILITY (FT. PER YR.)	0.11
CLASSIFICATION	GP-GM		
SIZE OF SPECIMEN	4" x 8"	WITH RAFFINATE	<0.001 ft/yr



TIME IN DAYS



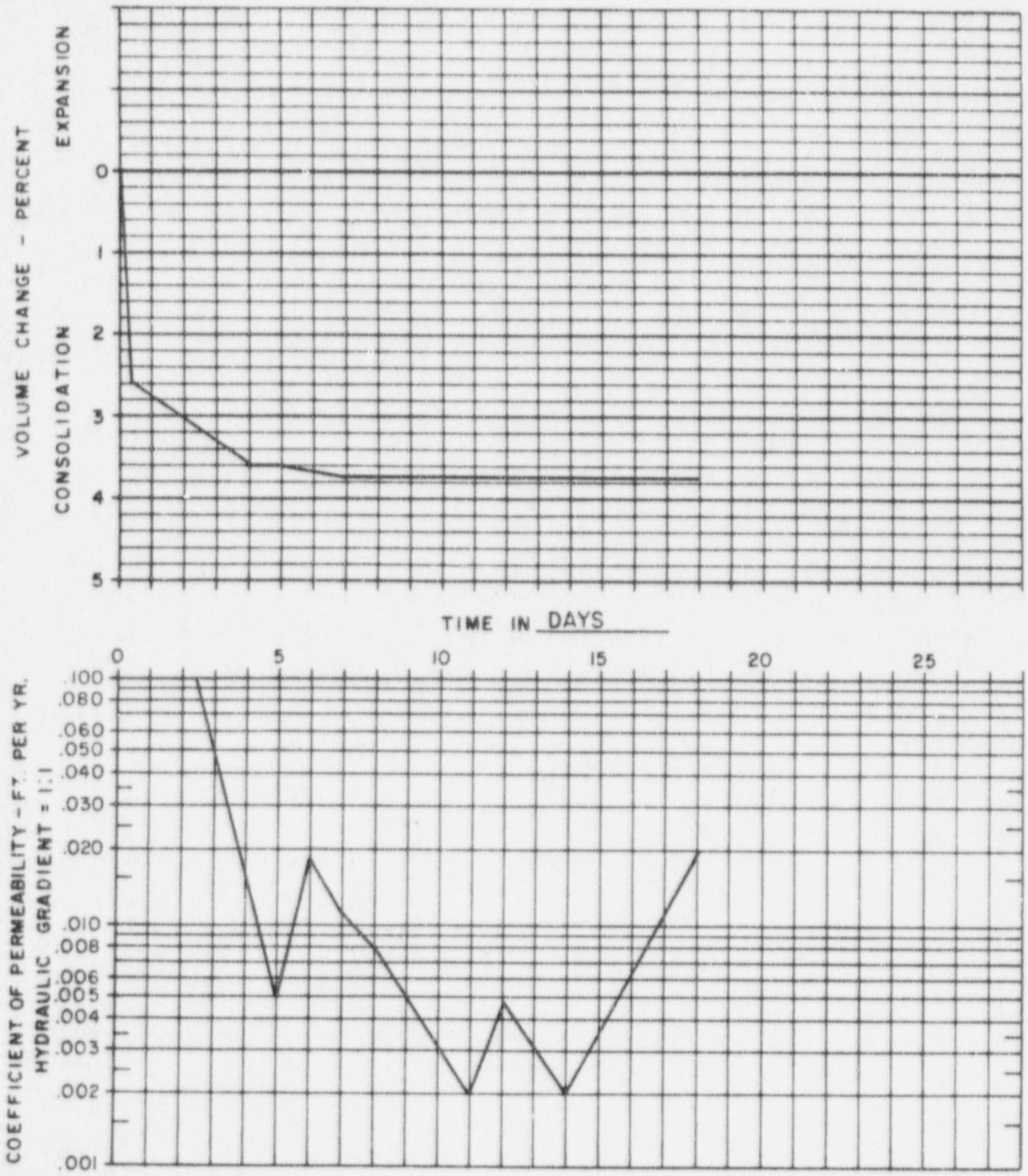
PERMEABILITY AND SETTLEMENT TEST

JOB NO. 19535-18971

LABORATORY SAMPLE NO. 1 EXCAVATION NO. BORROW DEPTH ______ STATION 37+40

FIG. C-1

INITIAL CONDITION		FINAL CONDITION	
PLACEMENT USED	100% D-698	CONSOLIDATION (%)	3.7
DRY DENSITY (PCF)	116.2	CONSOLIDATED, DRY DENSITY (PCF)	118.4
MOISTURE CONTENT (%)	16.1 (opt. + 2%)	MOISTURE CONTENT (%)	13.7
CONSOLIDATION LOAD (PSI)	32	PENETRATION RESISTANCE (PSI)	
(DEPTH OF FILL)		COEFFICIENT OF PERMEABILITY (FT. PER YR.)	0.02
CLASSIFICATION	SC		
SIZE OF SPECIMEN	4" x 8"		



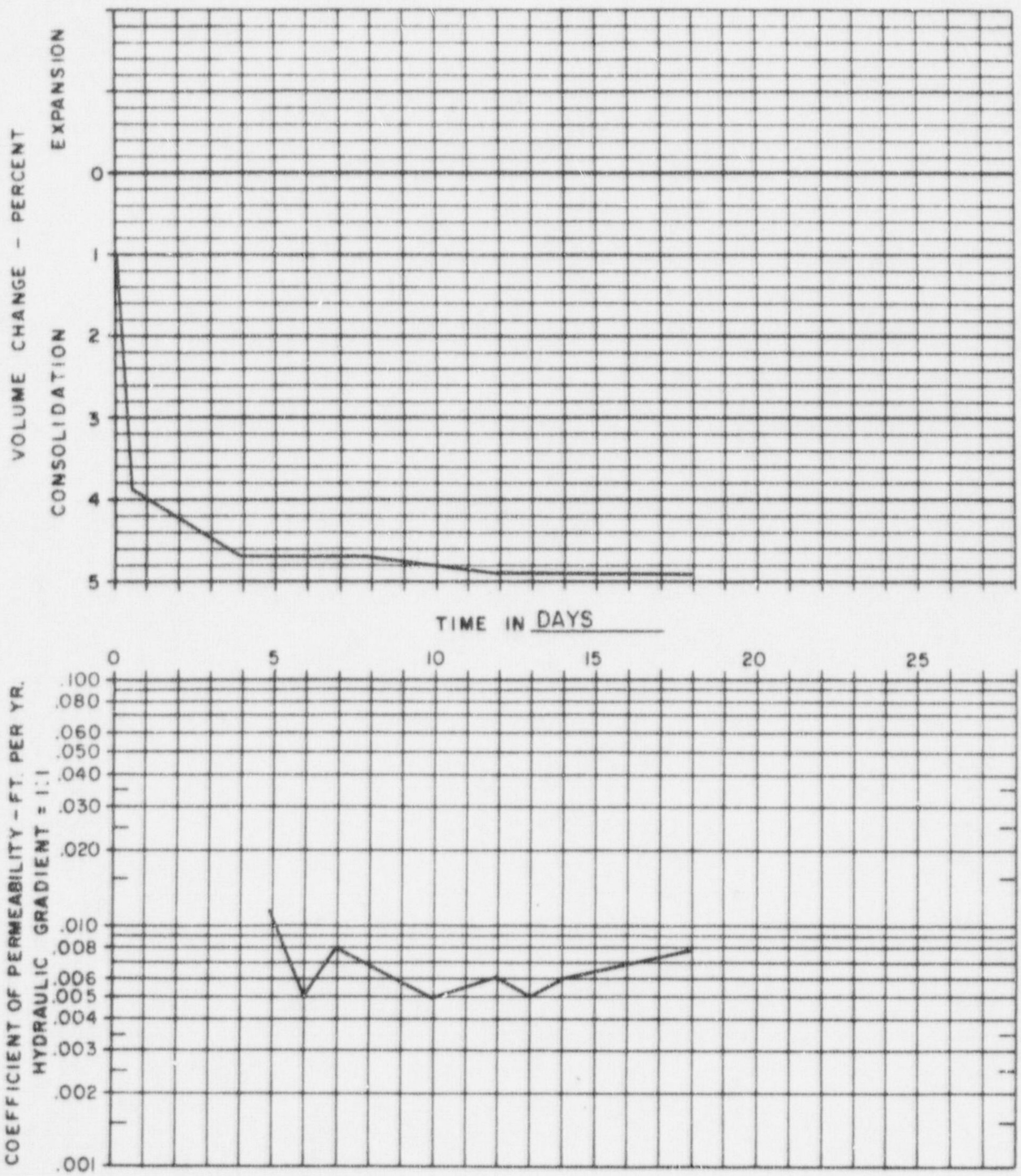
JOB NO. 19535-18971

PERMEABILITY AND SETTLEMENT TEST

LABORATORY SAMPLE NO. 2 EXCAVATION NO. BORROW DEPTH STAGE 1

FIG. C-2

INITIAL CONDITION		FINAL CONDITION	
PLACEMENT USED	100% D-698	CONSOLIDATION (%)	4.9
DRY DENSITY (PCF)	113.2	CONSOLIDATED, DRY DENSITY (PCF)	119.0
MOISTURE CONTENT (%)	16.6 (opt. + 2%)	MOISTURE CONTENT (%)	---
CONSOLIDATION LOAD (PSI)	32	PENETRATION RESISTANCE (PSI)	
(DEPTH OF FILL)		COEFFICIENT OF PERMEABILITY (FT. PER YR.)	0.008
CLASSIFICATION	ML-CL		
SIZE OF SPECIMEN	4" x 8"		



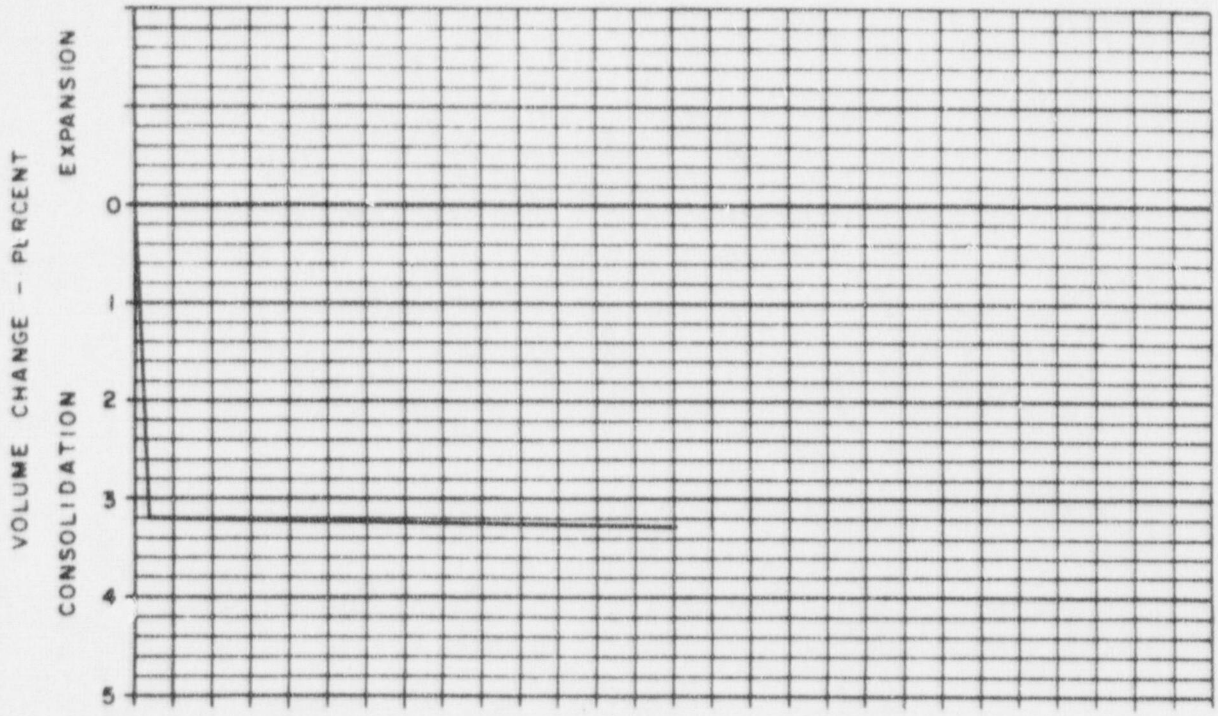
PERMEABILITY AND SETTLEMENT TEST

JOB NO. 19535-18971

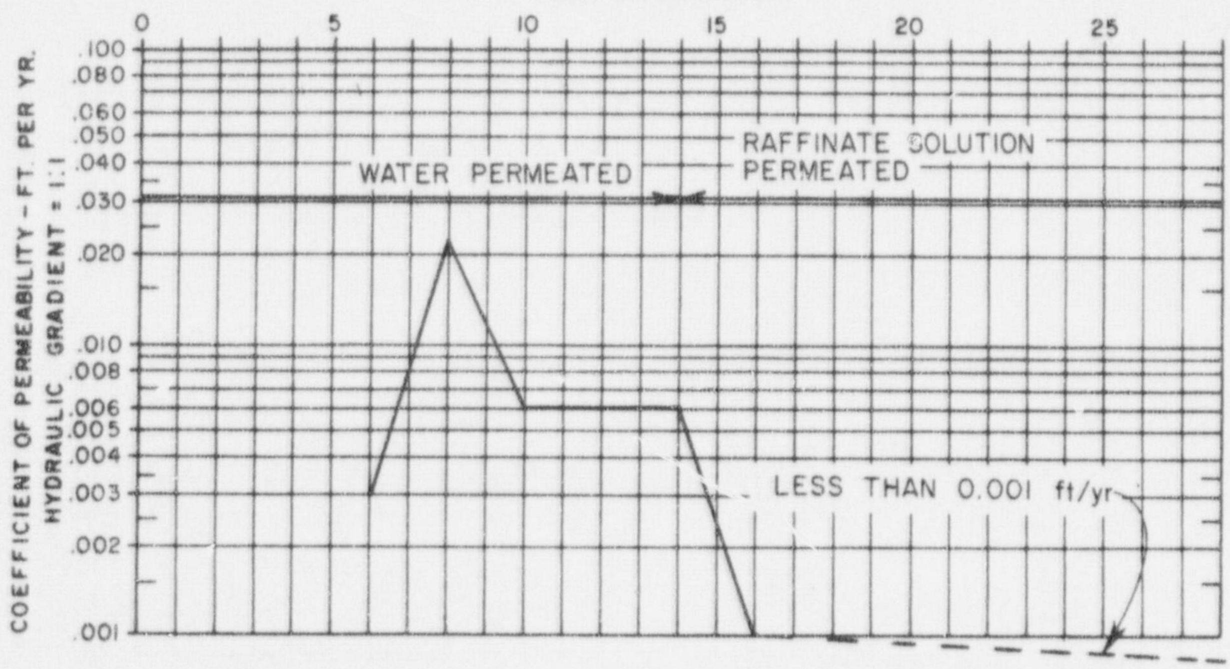
LABORATORY SAMPLE NO. 3 EXCAVATION NO. BORROW DEPTH ELEVATION

FIG. C-3

INITIAL CONDITION		FINAL CONDITION	
PLACEMENT USED	100% D-698	CONSOLIDATION (%)	3.3
DRY DENSITY (PCF)	115.4	CONSOLIDATED, DRY DENSITY (PCF)	119.3
MOISTURE CONTENT (%)	15.5 (opt. + 2%)	MOISTURE CONTENT (%)	---
CONSOLIDATION LOAD (PSI)	32	PENETRATION RESISTANCE (PSI)	
(DEPTH OF FILL)		COEFFICIENT OF PERMEABILITY (FT. PER YR.)	0.006
CLASSIFICATION	CL	WITH RAFFINATE	<0.001 ft/yr
SIZE OF SPECIMEN	4" x 8"		



TIME IN DAYS



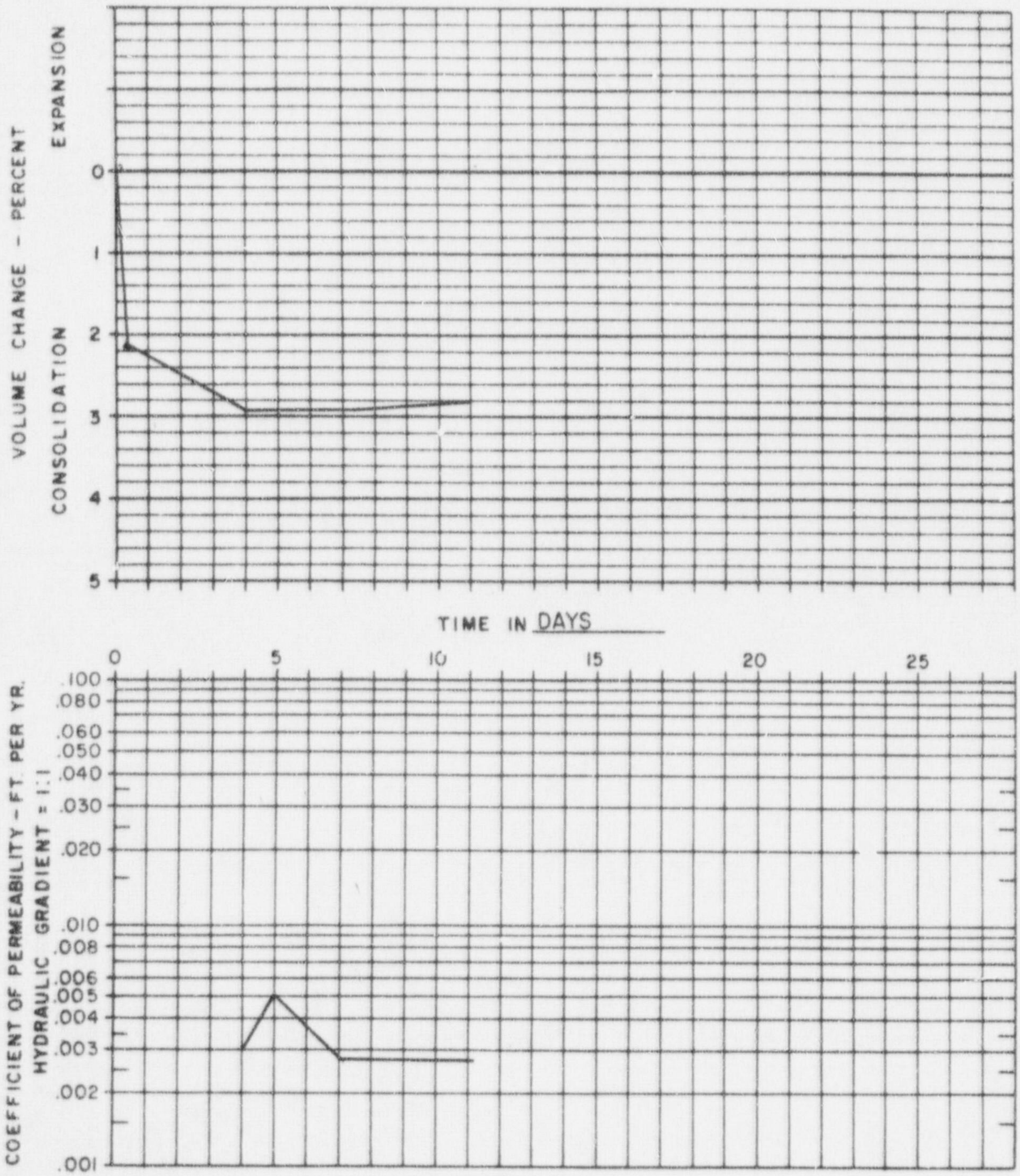
PERMEABILITY AND SETTLEMENT TEST

JOB NO. 19535-18971

LABORATORY SAMPLE NO. 4 EXCAVATION NO. BORROW DEPTH DIV. DITCH ELEVATION

FIG. C-4

INITIAL CONDITION		FINAL CONDITION	
PLACEMENT USED	100% D-698	CONSOLIDATION (%)	2.8
DRY DENSITY (PCF)	105.8	CONSOLIDATED, DRY DENSITY (PCF)	108.8
MOISTURE CONTENT (%)	20.2 (opt. +2%)	MOISTURE CONTENT (%)	20.5
CONSOLIDATION LOAD (PSI)	32	PENETRATION RESISTANCE (PSI)	
(DEPTH OF FILL)		COEFFICIENT OF PERMEABILITY (FT. PER YR.)	0.0027
CLASSIFICATION	CL		
SIZE OF SPECIMEN	4" x 8"		



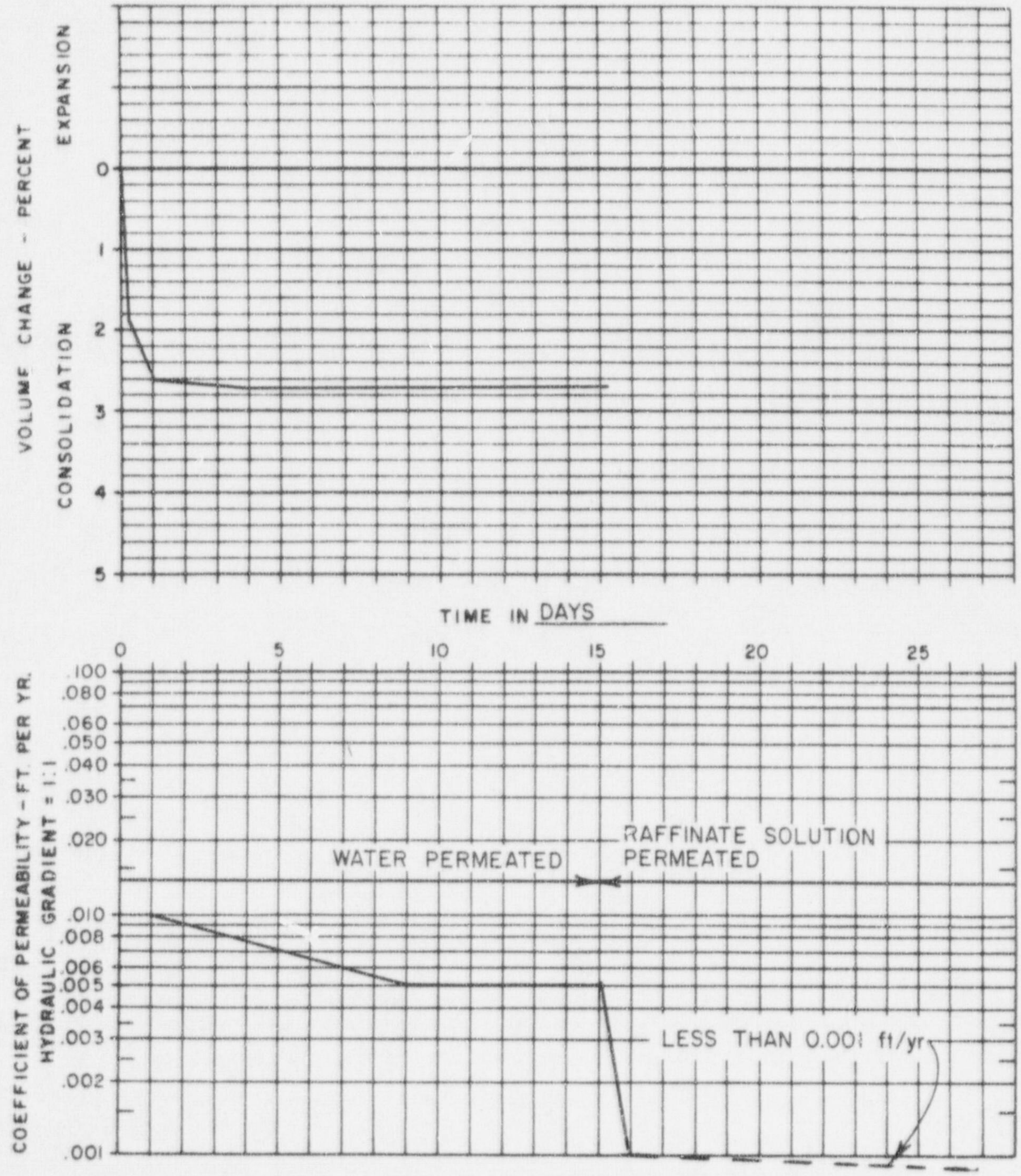
PERMEABILITY AND SETTLEMENT TEST

JOB NO. 19535-18971

LABORATORY SAMPLE NO. 5 EXCAVATION NO. BORROW DEPTH DIV. DITCH ELEVATION ______

FIG. C-5

INITIAL CONDITION		FINAL CONDITION	
PLACEMENT USED	100% D-698	CONSOLIDATION (%)	2.7
DRY DENSITY (PCF)	110.2	CONSOLIDATED, DRY DENSITY (PCF)	113.3
MOISTURE CONTENT (%)	14.6 (opt.)	MOISTURE CONTENT (%)	---
CONSOLIDATION LOAD (PSI)	32	PENETRATION RESISTANCE (PSI)	
(DEPTH OF FILL)		COEFFICIENT OF PERMEABILITY (FT. PER YR)	0.005
CLASSIFICATION	CL	WITH RAFFINATE	<0.001 ft/yr
SIZE OF SPECIMEN	4" x 8"		



PERMEABILITY AND SETTLEMENT TEST

JOB NO. 19535-18971

LABORATORY SAMPLE NO. 6 EXCAVATION NO. BORROW DEPTH DITCH ELEVATION

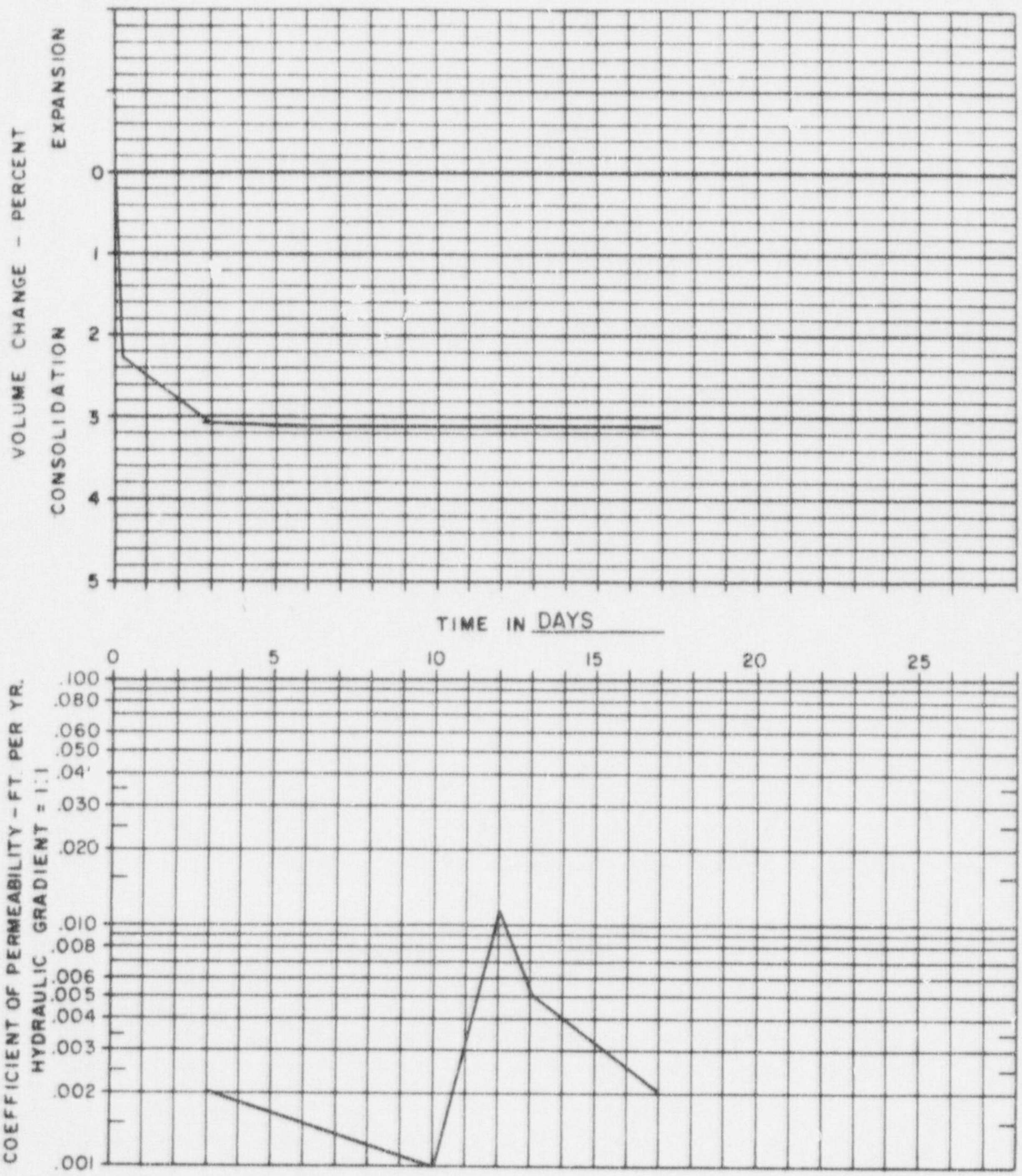
FIG. C-6

INITIAL CONDITION

PLACEMENT USED 100% D-698
DRY DENSITY (PCF) 114.4
MOISTURE CONTENT (%) 16.8 (opt. + 2%)
CONSOLIDATION LOAD (PSI) 32
(DEPTH OF FILL)
CLASSIFICATION CL
SIZE OF SPECIMEN 4" x 8"

FINAL CONDITION

CONSOLIDATION (%) 3.1
CONSOLIDATED, DRY DENSITY (PCF) 118.1
MOISTURE CONTENT (%) 16.5
PENETRATION RESISTANCE (PSI)
COEFFICIENT OF PERMEABILITY
(FT. PER YR.) 0.002



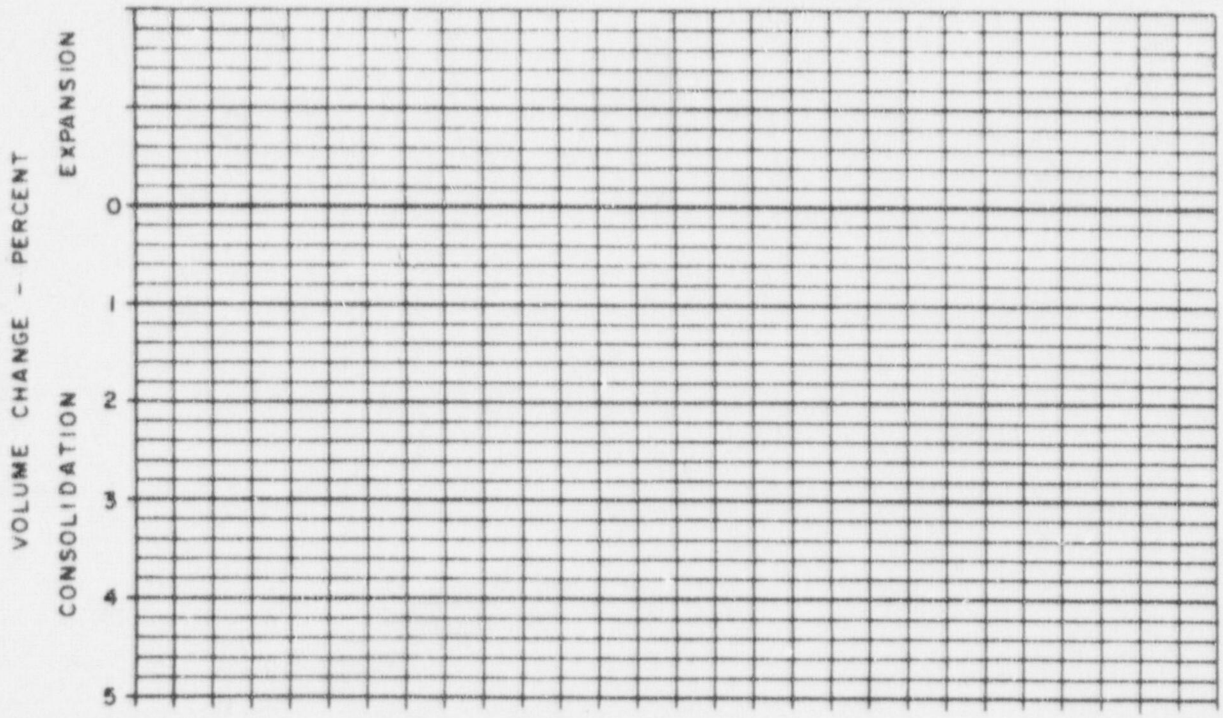
PERMEABILITY AND SETTLEMENT TEST

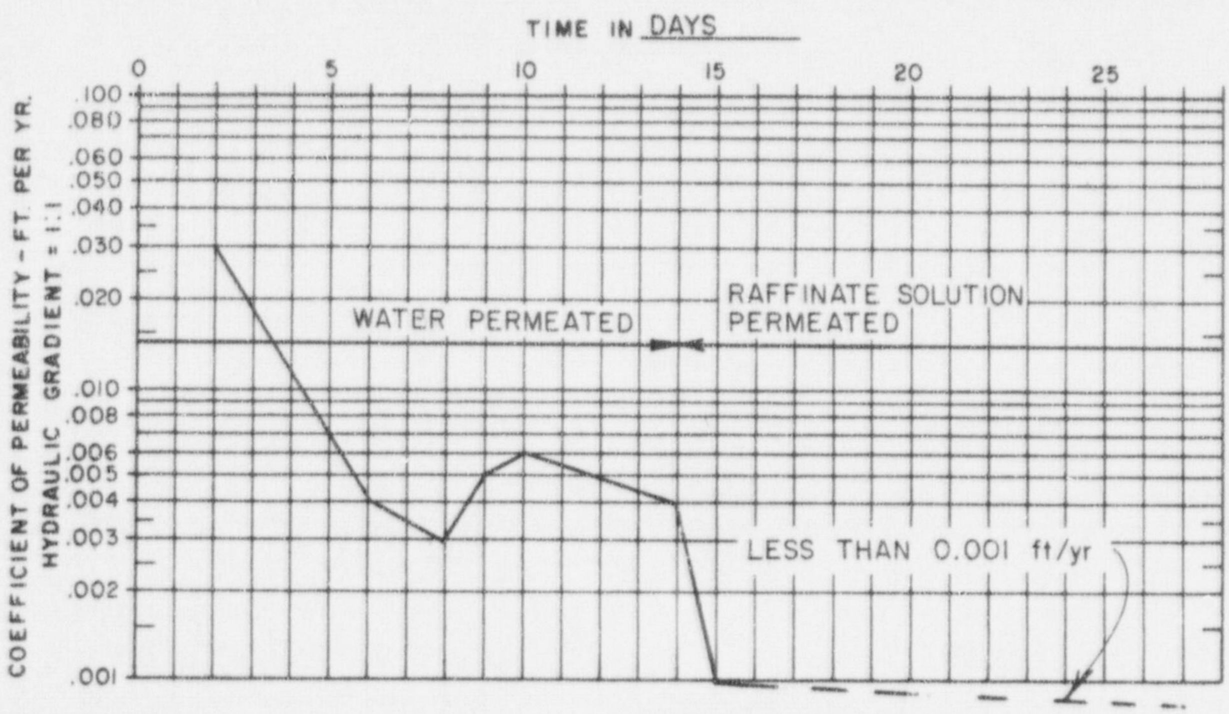
JOB NO. 19535-18971

LABORATORY SAMPLE NO. 7 EXCAVATION NO. BORROW DEPTH ELEVATION

FIG. C-7

INITIAL CONDITION		FINAL CONDITION	
PLACEMENT USED	100% D-698	CONSOLIDATION (%)	2.9
DRY DENSITY (PCF)	114.4	CONSOLIDATED, DRY DENSITY (PCF)	117.8
MOISTURE CONTENT (%)	16.6 (opt. +2%)	MOISTURE CONTENT (%)	---
CONSOLIDATION LOAD (PSI)	32	PENETRATION RESISTANCE (PSI)	
(DEPTH OF FILL)		COEFFICIENT OF PERMEABILITY (FT. PER YR)	0.004
CLASSIFICATION	ML-CL	WITH RAFFINATE	<0.001 ft/yr
SIZE OF SPECIMEN	4" x 8"		





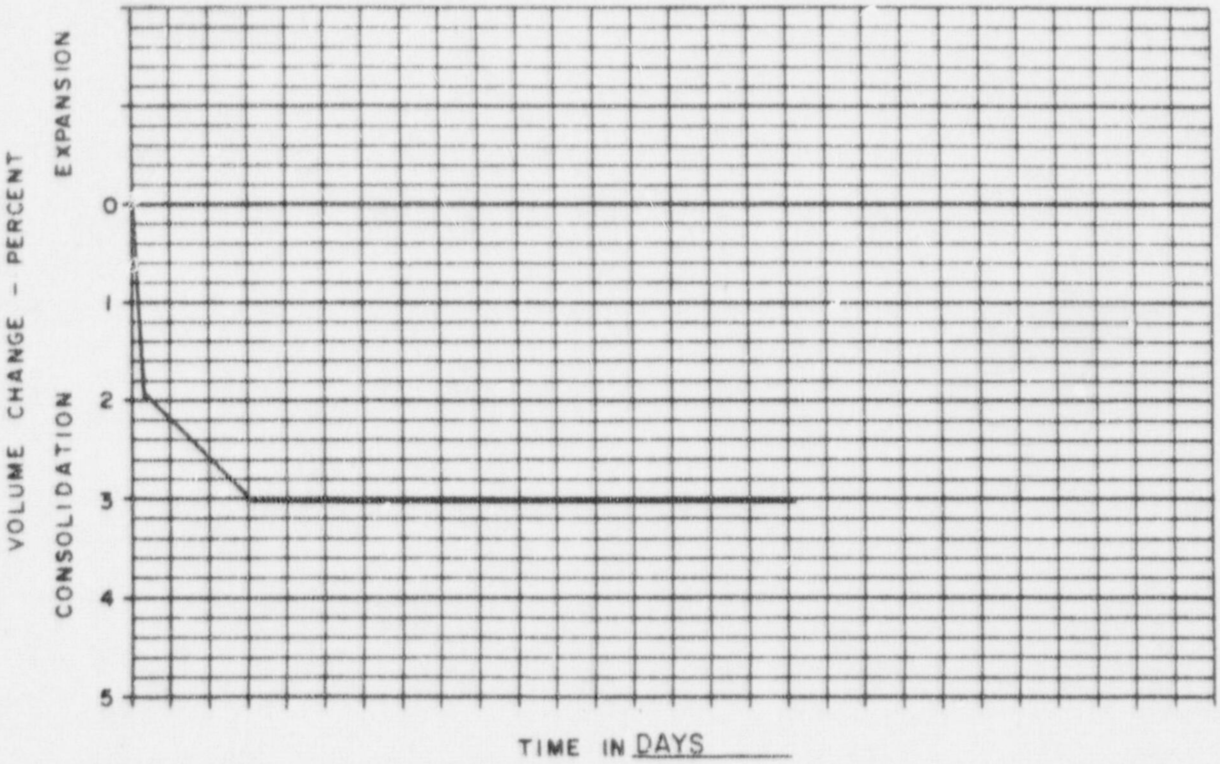
PERMEABILITY AND SETTLEMENT TEST

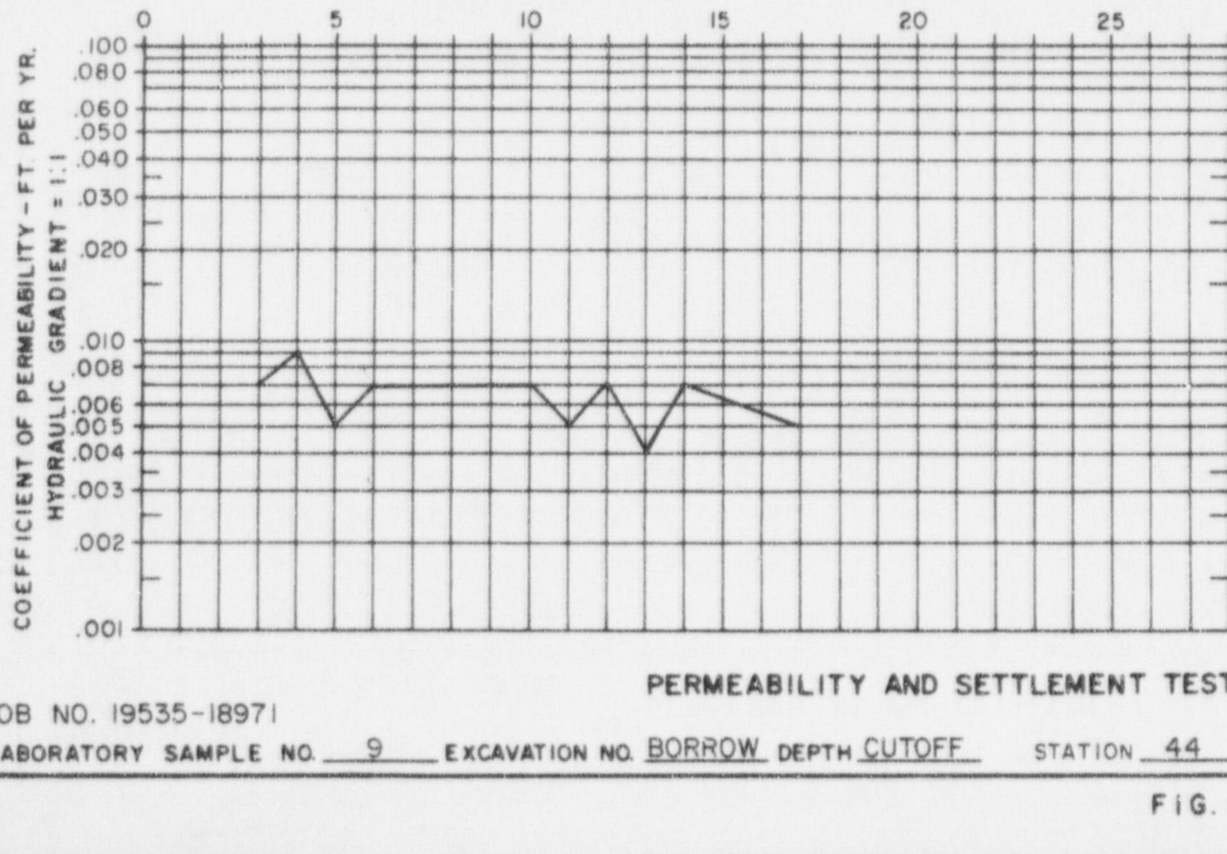
JOB NO. 19535-18971

LABORATORY SAMPLE NO. 8 EXCAVATION NO. BORROW DEPTH ELEVATION

FIG. C-8

INITIAL CONDITION		FINAL CONDITION	
PLACEMENT USED	100% D-698	CONSOLIDATION (%)	3.2
DRY DENSITY (PCF)	106.9	CONSOLIDATED, DRY DENSITY (PCF)	110.2
MOISTURE CONTENT (%)	20.2 (opt. + 2%)	MOISTURE CONTENT (%)	22.5
CONSOLIDATION LOAD (PSI)	32	PENETRATION RESISTANCE (PSI)	
(DEPTH OF FILL)		COEFFICIENT OF PERMEABILITY (FT. PER YR.)	0.005
CLASSIFICATION	GC (Weathered fill)		
SIZE OF SPECIMEN	4" x 8"		





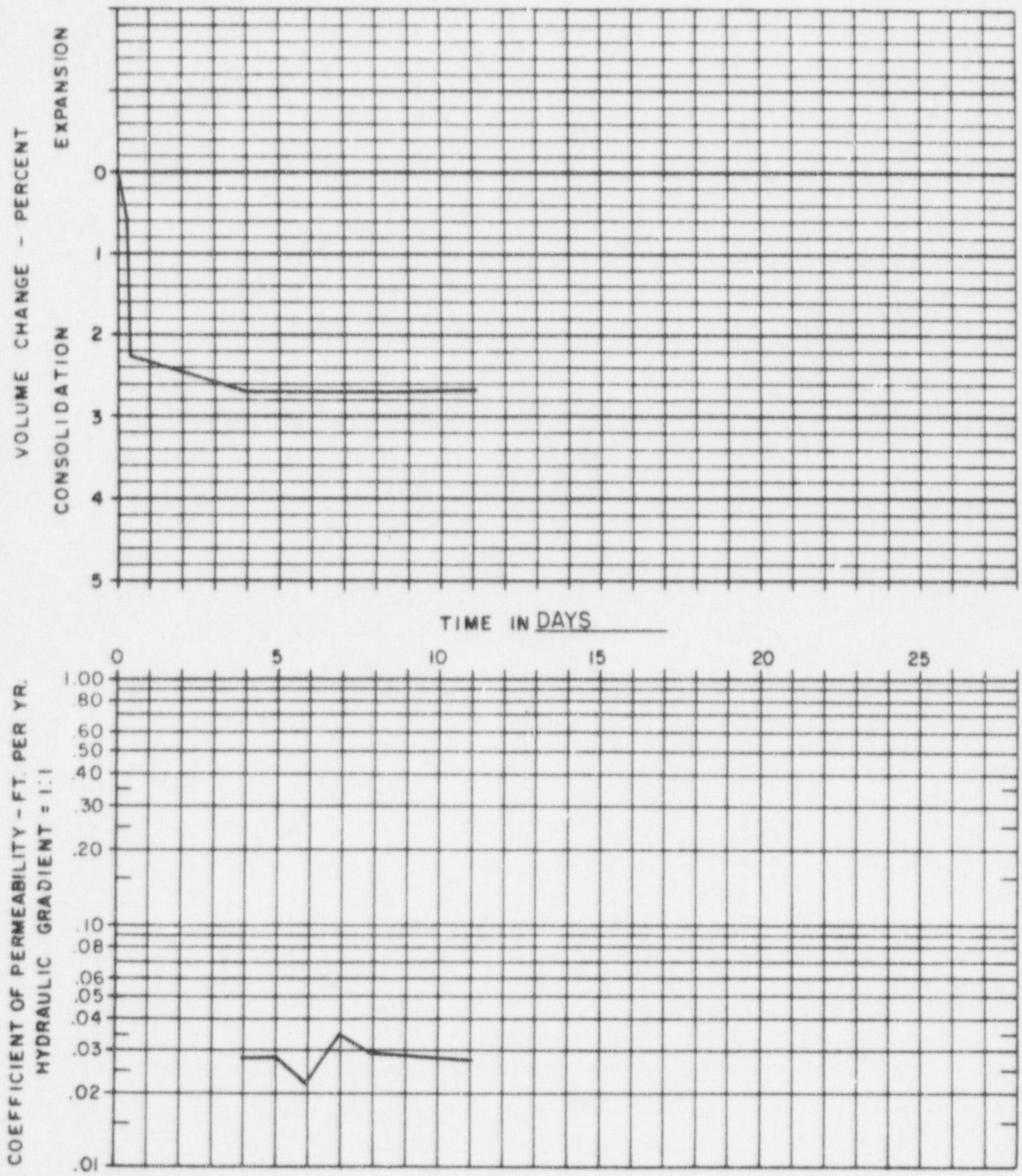
PERMEABILITY AND SETTLEMENT TEST

JOB NO. 19535-18971

LABORATORY SAMPLE NO. 9 EXCAVATION NO. BORROW DEPTH CUTOFF STATION 44

FIG. C-9

INITIAL CONDITION		FINAL CONDITION	
PLACEMENT USED	100% D-698	CONSOLIDATION (%)	2.67
DRY DENSITY (PCF)	115.2	CONSOLIDATED, DRY DENSITY (PCF)	118.4
MOISTURE CONTENT (%)	14.9 (opt.)	MOISTURE CONTENT (%)	14.8
CONSOLIDATION LOAD (PSI)	32	PENETRATION RESISTANCE (PSI)	
(DEPTH OF FILL)		COEFFICIENT OF PERMEABILITY (FT. PER YR.)	0.027
CLASSIFICATION	SM		
SIZE OF SPECIMEN	4" x 8"		



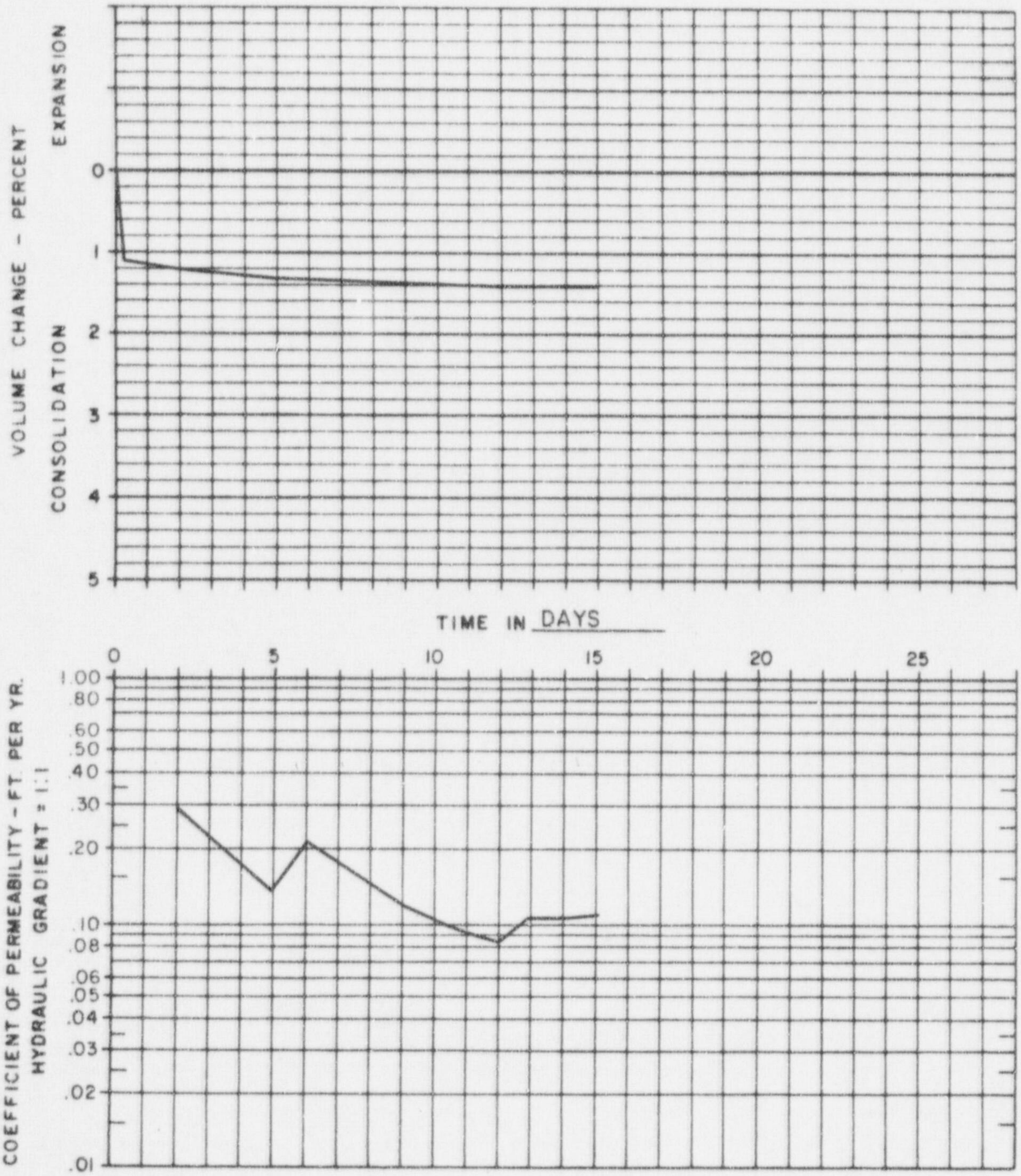
PERMEABILITY AND SETTLEMENT TEST

JOB NO. 19535 - 18971

LABORATORY SAMPLE NO. 10 EXCAVATION NO. BORROW DEPTH ELEVATION

FIG. C-10

INITIAL CONDITION		FINAL CONDITION	
PLACEMENT USED	100% D-698	CONSOLIDATION (%)	1.4
DRY DENSITY (PCF)	116.2	CONSOLIDATED, DRY DENSITY (PCF)	
MOISTURE CONTENT (%)	14.4 (opt.)	MOISTURE CONTENT (%)	
CONSOLIDATION LOAD (PSI)	32	PENETRATION RESISTANCE (PSI)	
(DEPTH OF FILL)		COEFFICIENT OF PERMEABILITY (FT. PER YR.)	0.113
CLASSIFICATION	SC-SM		
SIZE OF SPECIMEN	4" x 8"		



PERMEABILITY AND SETTLEMENT TEST

JOB NO. 19535-18971

LABORATORY SAMPLE NO. 11 EXCAVATION NO. BORROW DEPTH ELEVATION

FIG. C-11

INITIAL CONDITION

PLACEMENT USED 100% D-698

DRY DENSITY (PCF) 115.6

MOISTURE CONTENT (%) 13.7 (opt.)

CONSOLIDATION LOAD (PSI) 32

(DEPTH OF FILL) ____

CLASSIFICATION SM

SIZE OF SPECIMEN 4" x 8"

FINAL CONDITION

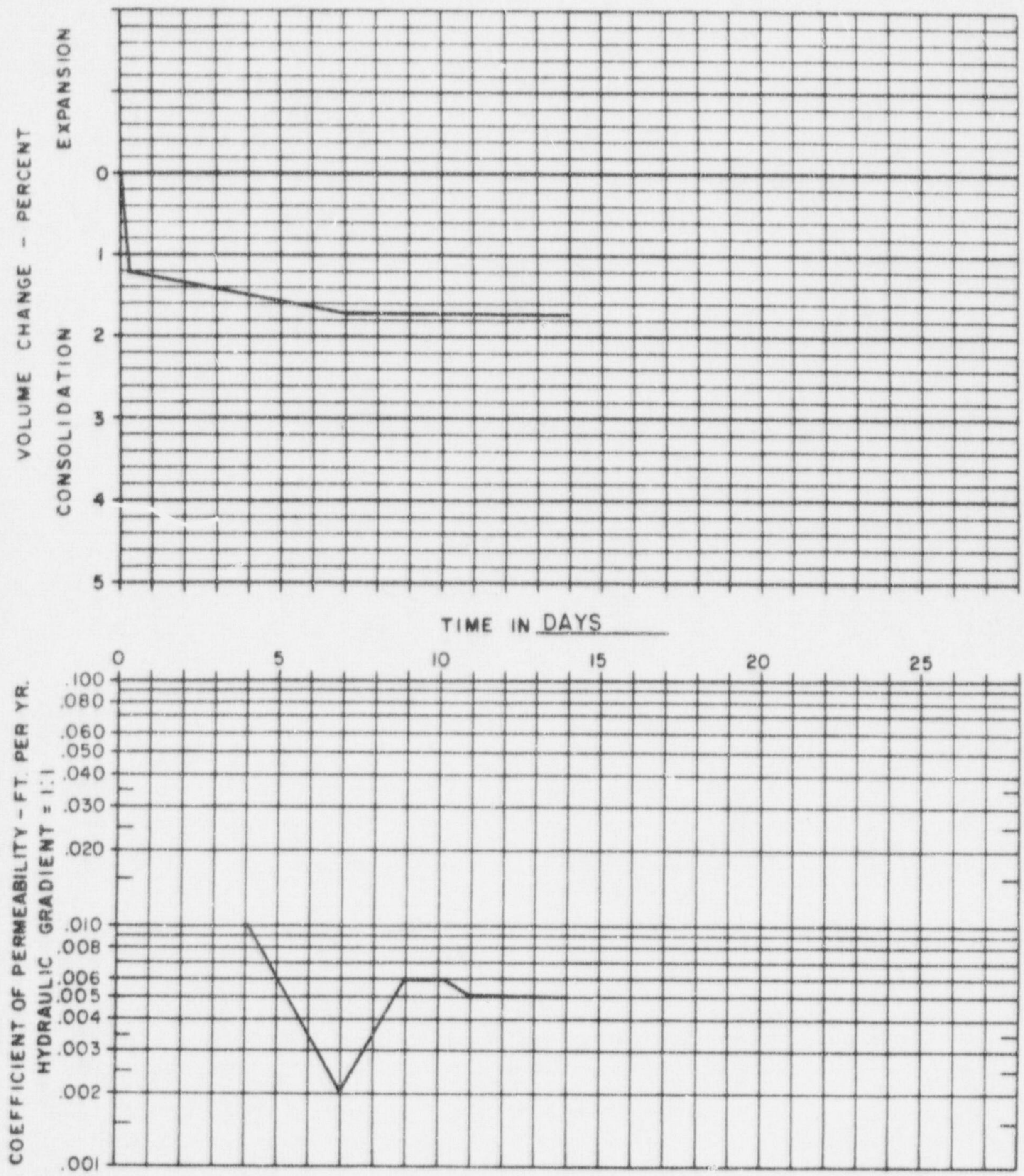
CONSOLIDATION (%) 1.7

CONSOLIDATED, DRY DENSITY (PCF) 117.6

MOISTURE CONTENT (%) 13.9

PENETRATION RESISTANCE (PSI) ____

COEFFICIENT OF PERMEABILITY (FT. PER YR) 0.005



PERMEABILITY AND SETTLEMENT TEST

JOB NO. 19535-18971

LABORATORY SAMPLE NO. 12 EXCAVATION NO. BORROW DEPTH ____ ELEVATION ____

FIG. C-12

APPENDIX D

COMPUTATIONS OF SEEPAGE

APPENDIX D

Woodward-Clyde Consultants

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SUMMARY OF COMPUTATIONS OF SEEPAGE INTO FOUNDATION AREAS NOT PICKED UP IN COLLECTION DRAINS

Part A--Seepage through dam cutoff trench =	0.0063 cfs
Part B--Seepage under dam filter blanket =	0.0005 cfs
Part C--Seepage through collection ditch =	< 0.0001 cfs
Part D--Seepage through evaporation pond =	0.0035 cfs
Part E--Seepage through "reservoir" cutoff trenches =	0.0014 cfs
Total =	0.0118 cfs

Contents:

Part A

Estimate of seepage through dam cutoff trench

1. Dam is divided into segments A, B, C and D. (Figure D-1) For each segment Avg. dam height, water depth & cutoff is estimated.
2. For purpose of computation, unit value of soil permeability (K) is assumed so that results can be proportionatly adjusted on the basis of permeability tests in progress. K assumed = 1 ft/yr (1×10^{-6} cm/sec)
3. The following dimensions are assumed:-

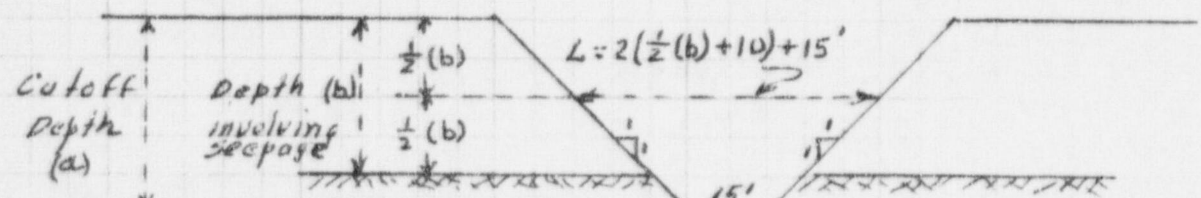
Dam Segment	Avg. Dam Height	Water Depth	Avg. Cutoff Depth	1) Cutoff less 10' in shale	Segment Length	2) Cutoff Area (A)	3) Avg. Length of Flow (L)	4) Head at Avg. Cutoff Depth (H)
A	± 20'	± 17'	50'	40'	3800'	152,000 ft²	75'	$17 + \frac{40}{2} = 37.0$
B	± 73'	± 70'	40'	30'	2350'	70,500 ft²	65'	$70 + \frac{30}{2} = 85.0$
C	N.A.	0	60'	50'	1300'	65,000 ft²	85'	$0 + 50/2 = 25.0$
D	± 7'	± 4'	55'	45'	920'	41,400 ft²	80'	$4 + 45/2 = 26.5$

1) Since bedrock (Shale) is assumed not to pass water, the 10' of cutoff in bedrock is not included in permeability computation for effective area.
2) Area is cutoff depth − 10' x segment length.
3) Length of flow is midpoint through cutoff.*
4) Head is water depth + depth to midpoint flow length.

$$Q = \text{Quantity of flow} = \frac{KAH}{L}$$

Dam Segment	$\frac{KAH}{L}$	Q (cu.ft./yr.)	Q (cu.ft/sec.)	Total Q (cu ft/sec)
A	(1)(152,000)(37.0) ÷ 75	74,990	0.0024	
B	(1)(70,500)(85.0) ÷ 65	92,192	0.0029	
C	(1)(65,000)(25.0) ÷ 85	19,120	0.0006	
D	(1)(41,400)(26.5) ÷ 80	13,710	0.0004	0.0063

*Note: Midpoint flow is length computed from standard cutoff with 1:1 side slopes and 15 ft. bottom width



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Part B

Estimate of Seepage under dam filter blanket

1. Assumed that 75% of area under dam will have collapseable soil removed for an average depth of at least 8 ft. and replaced with compacted clayey soil.
2. Assumed that 25% of area under dam will not have collapseable soil, but will have a minimum of 3 ft. layer of compacted clayey soil placed under the embankment blanket.
3. Assumed unit permeability rate, K = 1 ft/yr.
4. Drainage blanket thickness = 3 ft, as per design.
5. Granular pervious drainage blanket assumed density = 100 pcf, which then will have a porosity of $\frac{(2.65)(62.4)-100}{(2.65)(62.4)} = 40\%$
6. Permeability of blanket = 50,000 ft/yr (See Figure D-2)
7. Assumed head of water in drain = 1 ft. at start of drain.
8. Computed seepage through dam = 0.012 cfs. (See Part B, Cont'd).

Approximation of area under dam:

From Drg. No. 08-2-27, Sheet 7 of 9, Estimated quantity of Zone II material = 120,000 cu. yds. Assume compaction shrinkage factor = 0.14.

Volume of Zone II drain = 120,000 × 0.74 × 27 = 2405,592 cu. ft.

Area under Zone II drain = 2,405,592 ÷ 3 = 801,900 ft²

Length of dam = 7,000 ft.

Avg. width of sand drain blanket (assumed length of flow, L) = 801,900 ÷ 7,000 = 115 ft.

Capacity of drain, $Q = \frac{KAH}{L} = \frac{(50,000)(3 \times 7,000)}{115}$

$= 9,130,000$ cu. ft./yr $= 0.29$ cfs -- say 0.25 cfs

Seepage through dam = 0.012 cfs

Avg. head of flow in drain = 0.012 ÷ 0.25 = 0.14 ft.

Seepage from drain through compacted clayey soil layer

$Q = \frac{KAH}{L}$ Assume weighted L for variable thickness of compacted clayey soil = 25% × 3' + 75% × 8' = 6.75'

$Q = \frac{(1)(80,1900)(0.14)}{6.75} = 16,632$ cu. ft/yr

$= \underline{0.00053 \text{ cfs}}$

Part B (Continued)

Estimate of Seepage through main dam into drains

1. Dam is divided into segments as shown on profile (see Figure D-1 of Part A calculations). Segments A, B and D.
2. For purpose of calculations, unit value of permeability assumed for Zone I material so that results can be proportionatly adjusted on basis of permeability tests in progress. (K = 1 ft/yr.)
3. See assumed cross-section sketches for dam segments attached Figure D-2. Length of flow (L) is assumed to be estimated average distance to nearest drain.
4. The following dimensional values were assumed for the quantity of flow equation:

Dam Segment	Avg. Dam Height	Depth of Water	Segment Length	Area = Water depth × 3.16 × length (A)	Estimated Avg. Flow Length (L)	Head at Avg. Flow Length (H)
A	±20'	±17'	3800'	204,140 ft²	57'	17÷2 = 8.5'
B	±73'	±70'	2350'			
		Upper 40'	2350'	297,040 ft²	30'	40÷2 = 20'
		Lower 30'	2350'	222,780 ft²	80'	40 + 30/2 = 55'
D	±7'	±4	920'	11,630 ft²	38'	4÷2 = 2'

Quantity of seepage to collection ditch via drain

$$= Q = \frac{KAH}{L}$$

Dam Segment	$\frac{KAH}{L}$	Q cu. ft./yr.	Q c.f.s.	Total
A	(1)(204,140)(8.5) ÷ 57	30,440	0.0010	
B-Upper 40'	(1)(297,040)(20) ÷ 30	237,630	0.0063	
B-Lower 30'	(1)(222,780)(55) ÷ 80	153,160	0.0049	
D	(1)(11,630)(2) ÷ 38	612	0.00002	0.0122 cfs

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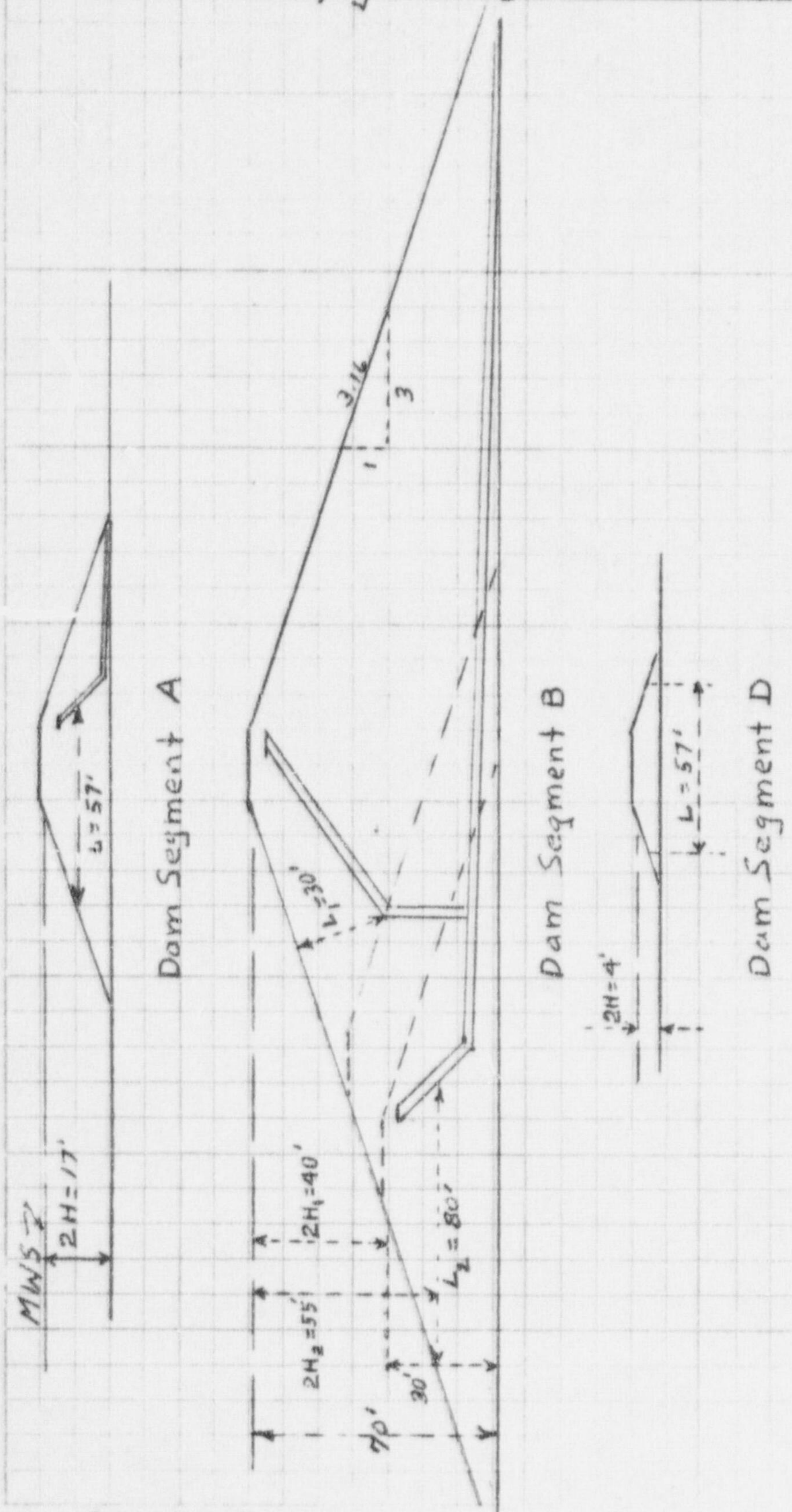
Part B
Estimate of Seepage through main dam into drains



Part C

Estimate of Seepage through Collection Ditch

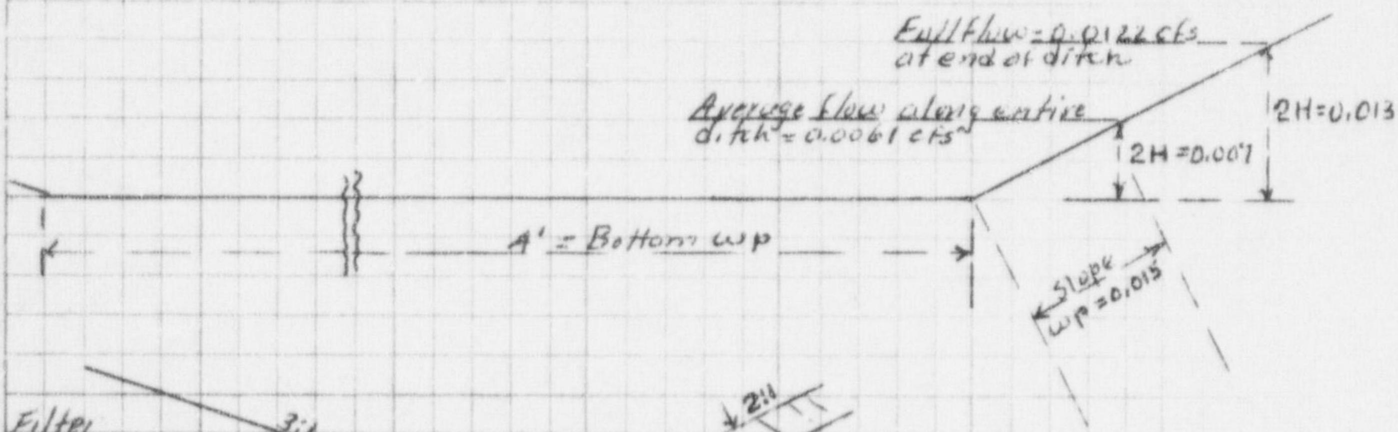
1. Assumed seepage through ditch bottom and left side (right of bottom included in Part B)
2. Assumed ditch bottom width = 4ft, side slope = 2:1
3. Lining depth = 3 ft.
4. Length of ditch = 6100 ft.
5. Grade of ditch = 70 ÷ 6100 = 0.0115
6. Computed dam seepage flow = 0.0122 cfs (at end of ditch)
7. For above flow maximum (end) water depth = 0.013 ft.
8. Wetted perimeter = 4 + 0.030 = 4.03 ft²/ft
9. Unit permeability rate for compacted clayey soil lining (K = 1 ft/yr)
10. Ditch evaporation and seepage ignored in computing water depth and wetted perimeter of ditch
11. In (7) above maximum wetted perimeter and water depth would be at end of collection ditch. Assumed average flow values at midpoint of ditch.

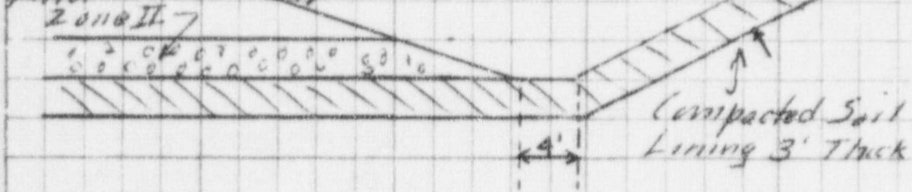
Therefore

$2H = 0.007$ ft $\qquad wp = 4' + 0.015$ ft²/ft

Wetted area $A = wp \times$ ditch length $= 4.015 \times 6100 = 24{,}492$

$$\text{Seepage} = Q = \frac{KAH}{L} = \frac{(1)(24{,}492)(0.0035)}{3} = 28.6 \text{ cu.ft./yr} = <0.0000009$$





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Part D

Estimate of Seepage through Evaporation Pond Lining

1. Compacted Clayey soil lining, see Drg. No. 08-2-26, Sheet 6 of 9, Section E-E, & Drg. 08-2-23, Sheet 3 of 9. Excerpts of these are attached as Figures D-3 and D-4
2. Assumed high water elevation = 6474 as shown. Assumed Section E-E has average water depth for pond (Maximum average depth = 5.1 ft.)
3. For purpose of computation, unit value of permeability rate (K) is assumed so that results can be proportionately adjusted on basis of permeability tests in progress. (Assumed K = 1 ft/yr = (1x10⁻⁶ cm/sec).
4. Area calculation for three segments into which the pond was divided (Figure D-3) is as follows:

Pond Segment	High Water Width	Average Width	Factor for Wetted Perimeter (Fig.)	Wetted Perimeter Width	Pond Segment Length (Fig.)	Area (ft²)
Sec. 1 (at Dam) to Sec. 2	100' 96'	98	1.04	102'	287'	29,274
Sec. 2 to Sec. 3	96 50	73	1.04	76'	330'	25,080
Sec 3 to Sec 4	50 20	35	1.04	36.5	260'	9,490
					Total	63,844
					Say	63,800

Average depth taken at Section E-E = 5.1'
(See computations, Figure D-2)

Lining Seepage loss = $Q = \frac{KAH}{L}$

where $A = 63{,}800\ ft^2$, $H = 5.1$, L = lining thickness = 3'

$$Q = \frac{(1)(63800)(5.1)}{3} = 108{,}460\ cu.ft./yr = \underline{0.0034 cfs}$$

Note: The above calculation is based on a maximum water level. Based on the dam seepage calculations this level will probably never be nearly reached.

JOB Bokum Res CALC: Seepage of Disposal Facility SHT. 7 OF 10
BY HJG DATE 12/78 CHKD BY WGH DATE 12/78 JOB NO. 19535-18971

Part D (continued)
Seepage Through Pond Dam

1. Crest length = 100' (Assumed upstr. Slope Length = 25 ft (See Figure), therefore area = 25x100 = 2500 ft^2
2. Assumed maximum upstr. section depth = (See Fig D-5) Therefore: Avg. upstr. section depth = ½ (14) = 7 ft.
3. Assumed maximum water depth on upstr. face = 10 ft (Fig. D-3) Therefore: Avg. water depth on upstr. face = ½ (10) = 5.0 ft.
4. Downward seepage on upstream face using equation

$Q = \frac{KAH}{L}$, computation made at midpoint of slope

Assumed K = 1 ft./yr.*, A = 2500 ft^2, H = ½ x 5.0 = 2.5 ft. and L = ½ x 7.0 = 3.5 ft.

$Q = \frac{(1)(2500)(2.5)}{3.5} = 1{,}786$ cu.ft./yr = 0.00006 cfs

---

Total pond loss = 0.0034 + 0.00006, say 0.0035 cfs

* Note: For purpose of calculation unit value of permeability was assumed so that results can be proportionally adjusted on basis of permeability tests in progress (K = 1 ft/yr.).

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Part E

Estimate of Seepage through "reservoir" cutoff trenches

(Includes cutoffs east and west of the south dike)

Section 1 (See Page 10 of 10) 100% in natural soils

Assumptions:

1. No drop in phreatic surface between disposal area and cutoff trench
2. Cutoff trench has 15 ft. bottom width and 1:1 side slopes
3. Cutoff trench refilled with compacted clayey soils and unit permeability rate assumed (K = 1 ft./yr) (Also Section 2 fill)
4. Average head (H) = 16 ft or ½ times distance from MWS to bedrock.
5. Total length of trench = 5600 ft. (D)
   Section 1 trench = total − Section 2 length = D_1 = 5600 − 800 = 4800 ft.
6. Average width of cutoff trench at average head = L = 65 ft.
7. Total area through which seepage could occur = A = 4800 × 32 = 153,600 ft²

$$\text{Seepage} = Q = \frac{KAH}{L} = \frac{(1)(153,600)(16)}{65} = 37,810 \text{ cu.ft/yr} = \underline{0.0012 \text{ cfs}}$$

Section 2 (See Figure E-1) Arroyo Section -- Cut and Fill

Assumptions

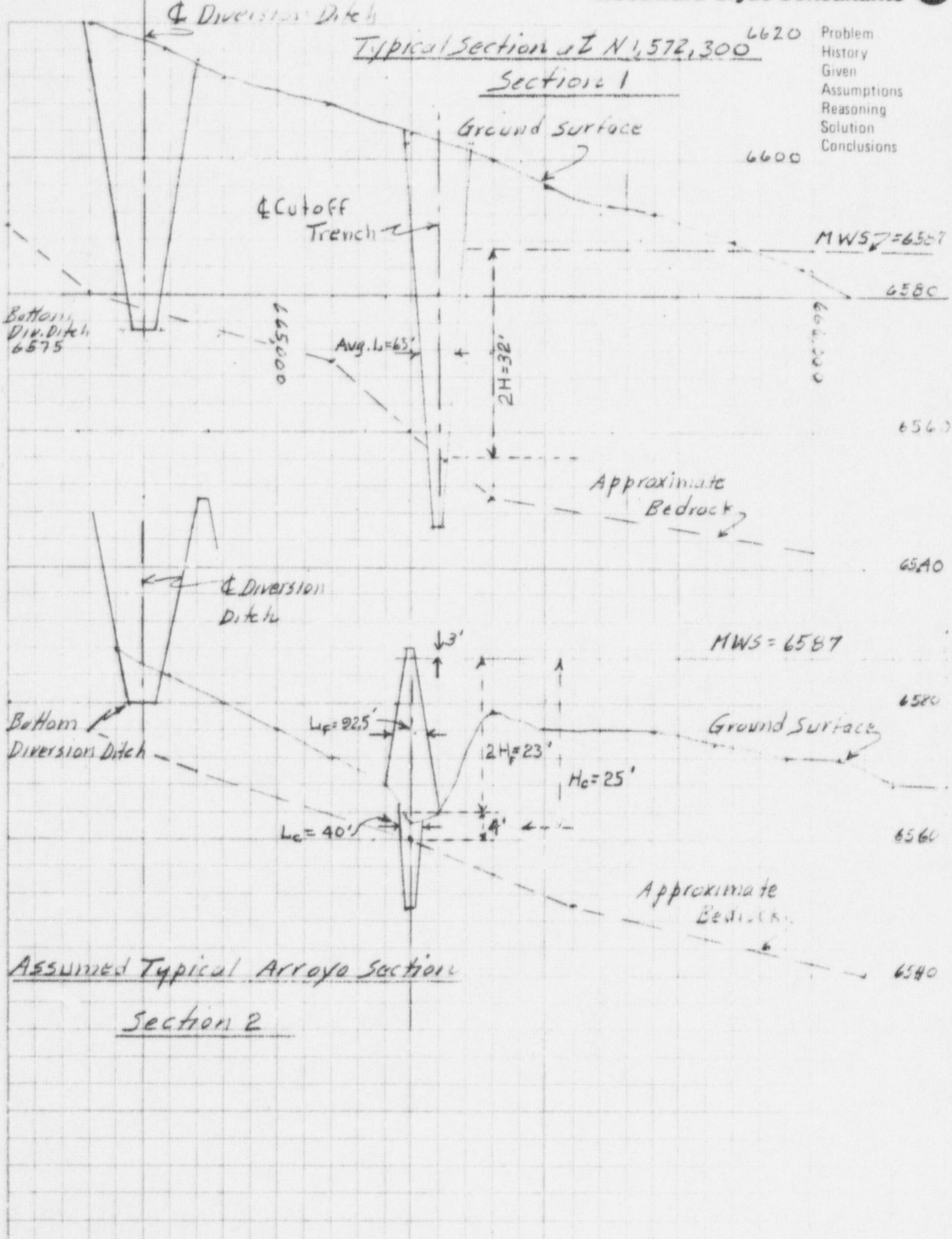
1-3 Same as 1, 2, and 3 above.

4. Average head: Fill Section H_F = 11.5 ft.
   Cutoff Section H_C = 25.0 ft
5. Average length percolation path (Average width at average head depth.)
   Fill Section: L_F = 92.5 ft
   Cutoff Section L_C = 40 ft
   } Total distance for both Arroyos = 800 ft.
6. Total area through which seepage could occur = A =
   Fill Section = A_F = 800 × 23 = 18,400 ft²
   Cutoff Section = A_C = 800 × 4 = 3,200 ft²
7. Cutoff trenches refilled and fills constructed with compacted clay soils and unit permeability rate assumed (K = 1 ft/yr)
8. Fill has 20 ft top width and 2½:1 side slopes.

$$\text{Seepage} = Q = \frac{KA_FH_F}{L_F} + \frac{KA_CH_C}{L_C} = \frac{(1)(18,400)(11.5)}{92.5} + \frac{(1)(3200)(25)}{40}$$

$$= 2288 + 2000 = 4288 \text{ ft/yr} = \underline{0.0002 \text{ cfs}}$$

Total Seepage both sections = 0.0014 cfs


℄ Diversion Ditch
Typical Section at N 1,572,300
Section 1
6620
Ground Surface
6600
℄ Cutoff Trench
MWS ▽ = 6587
6580
Bottom Div. Ditch 6575
E 675,000
Avg. L = 65'
2H = 32'
E 677,000
6560
Approximate Bedrock
6540
℄ Diversion Ditch
MWS = 6587
3'
6580
Bottom Diversion Ditch
L_f = 92.5'
Ground Surface
$2H_f$ = 23'
H_c = 25'
L_c = 40'
4'
6560
Approximate Bedrock
6540
Assumed Typical Arroyo Section
Section 2

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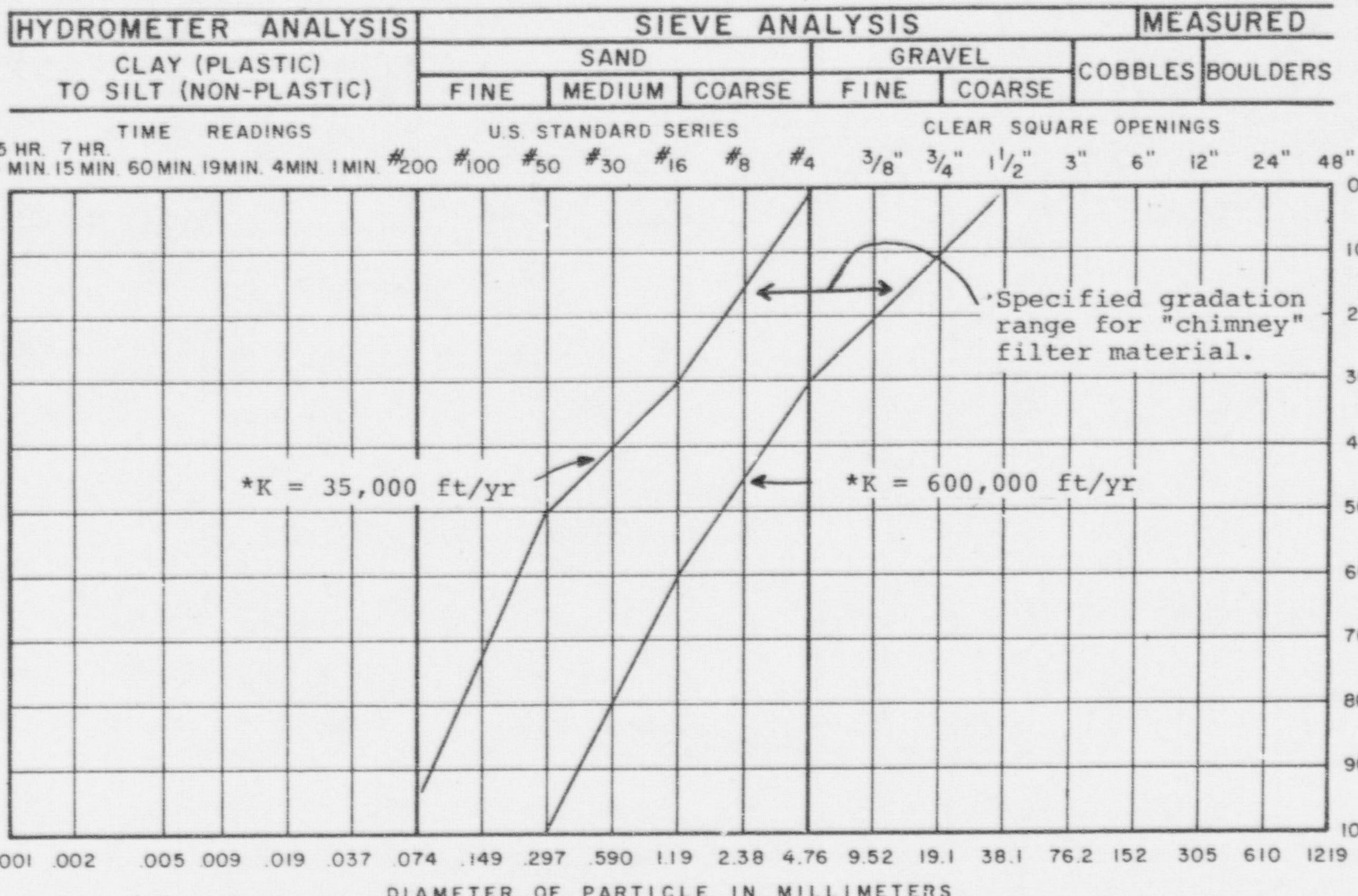


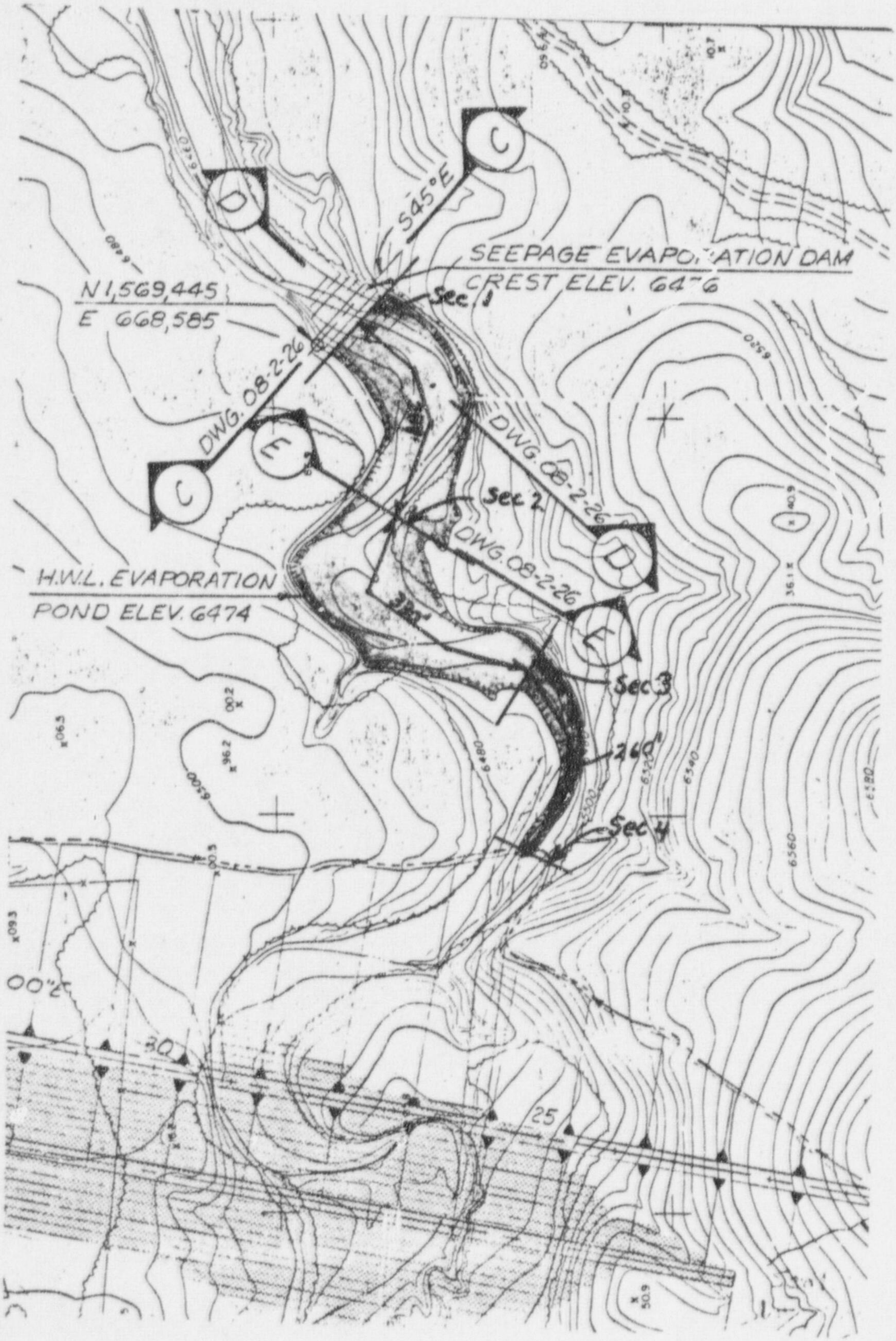
*Based on laboratory tests by Bureau of Reclamation

GRADATION ANALYSIS

FILTER MATERIALS

JOB NO. 19535-18971

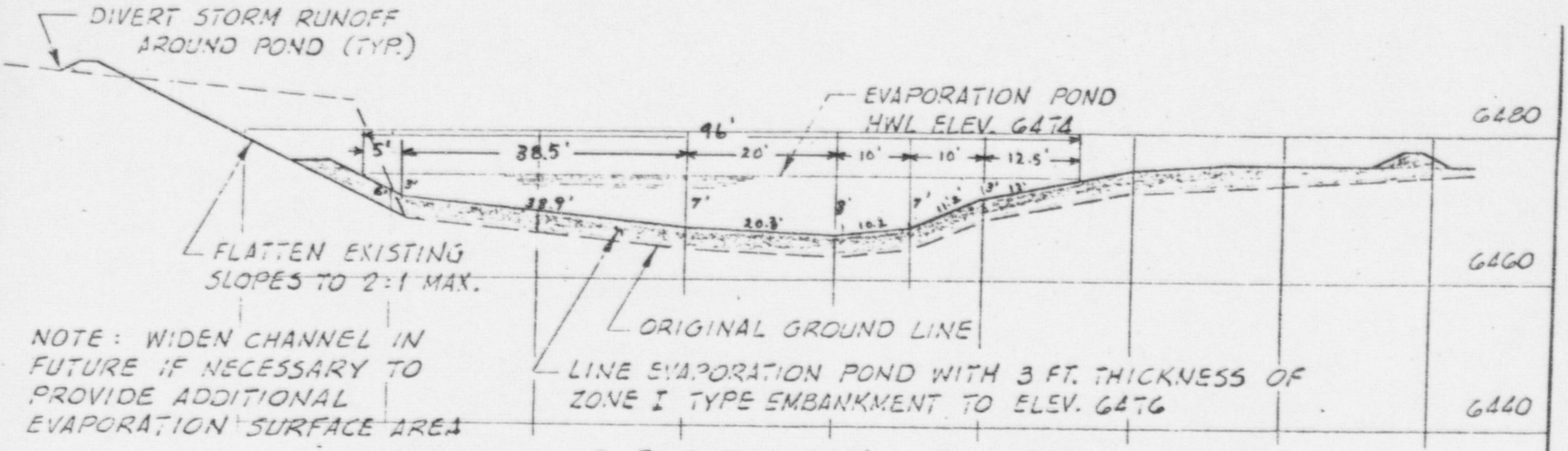
FIG. D-2



Scale: 1" = 200'

Evaporation Pond

Fig D-3



SECTION E - E

(DWG. 08-2-23)
SCALE 1" = 20'

Ave. water depth computations:

$\frac{1}{2}(5)(3) = 7.5$
$\frac{1}{2}(38.5)(3+7) = 192.5$
$\frac{1}{2}(20)(7+8) = 150.0$
$\frac{1}{2}(10)(8+7) = 75.0$
$\frac{1}{2}(10)(7+3) = 50.0$
$\frac{1}{2}(12.5)(3) = 18.75$
Total: 493.75

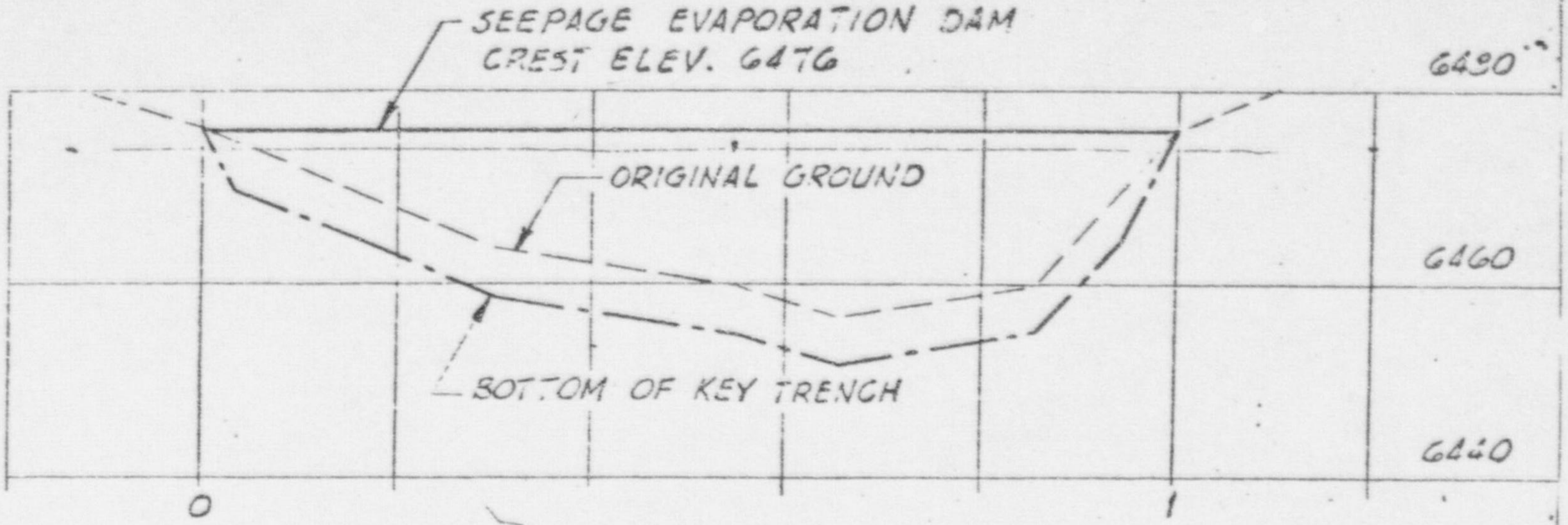
Ave depth = 493.75/96 = 5.1'

Perimeter Factor Computations:

Perimeter = sum of 6.0, 38.9, 20.3, 10.2, 11.2, 13.0
Total: 99.6'

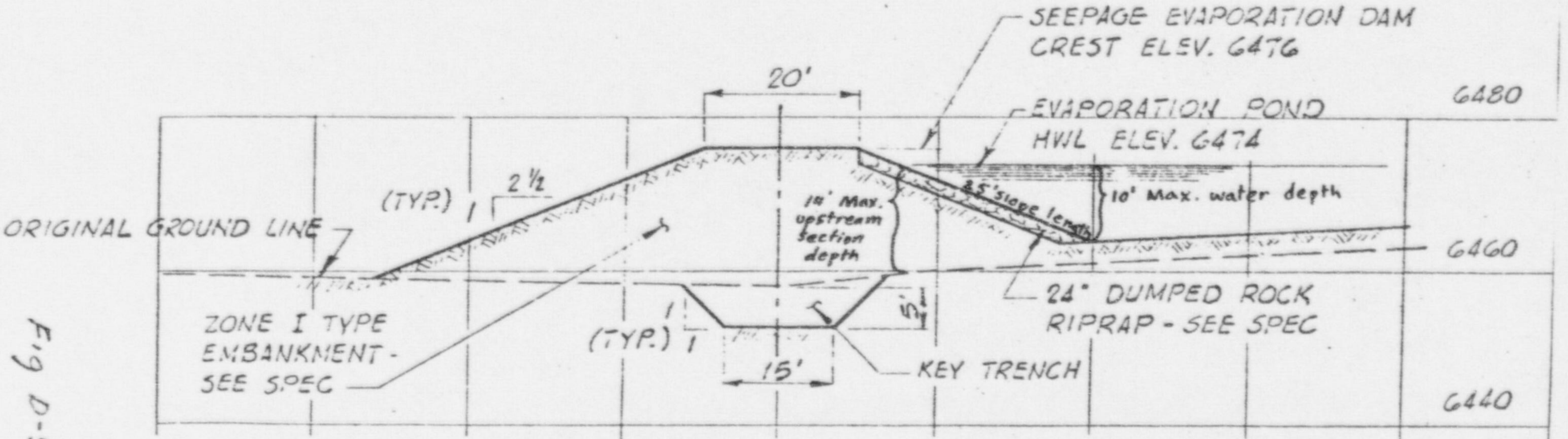
Perimeter factor = 99.6/96 = 1.04

Fig. D-4



SECTION C - C

(DWG. 08-2-23)
SCALE 1" = 20'



SECTION D - D

(DWG. 08-2-23)
SCALE 1" = 20'

Fig D-5

APPENDIX E

SUMMARY OF STABILITY ANALYSIS
CANYON DE MARQUEZ BANK

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A GEOMORPHIC-ENGINEERING APPROACH TO THE DRAINAGE DIVERSION SYSTEM, BOKUM RESOURCES CORPORATION URANIUM PROJECT MARQUEZ, NEW MEXICO

By

Stanley A. Schumm

For

Stearns-Roger Incorporated

Environmental Sciences Division

January, 1979

SUMMARY AND RECOMMENDATIONS

In order to ensure the integrity of the tailings disposal site that is associated with the Bokum Resources Corp. mill on Mesa Marquez, it is necessary to divert Canon de Marquez and Arroyo Hondo across the pediment at the foot of Mesa del Canoncito and into an unnamed tributary of Canon de Santa Rosa. A diversion channel will be constructed to carry the flow of Canon de Marquez and Arroyo Hondo at the Probable Maximum Flood (PMF).

A strictly engineering design and solution to the problems involved in the diversion and the long-term stability of the diversion channel could disregard the natural dynamics of rivers and the empirical relations that have been established between river morphology and water and sediment discharge.

The proposed drainage diversion channel should be permitted to develop its own morphology by allowing it to adjust to the controlling variables of discharge and sediment load. In light of this concept, the following recommendations are made:

a. The final gradient of the diversion channel should be similar to that of the Canon de Marquez (about 1.7%). This gradient should be established by permitting natural degradation of the channel by erosion, mechanically excavating the channel to the recommended gradient, or a combination of these.

b. To accelerate the degradation process and to minimize sediment accumulation, the diversion channel should be cut to a gradient of at least one percent during initial construction or during the first few years of project operation.

c. An alternative to cutting the channel gradient to one percent would be the mechanical removal of sediments from the channel whenever accumulations reduce the capacity of the channel to safely pass the Probable Maximum Flood. The mechanical removal of sediments will not be necessary once the channel has developed its own final gradient.

d. To accelerate erosion in the diversion channel and the tributary channel downstream from the diversion channel outlet, the floor of these channels should be ripped or disrupted by blasting.

e. The tributary channel into which the diversion channel will discharge is poorly defined in its upper reach. The channel should be mechanically widened and deepened so that headward erosion has a definite path to follow.

f. The west slope and floor of the diversion channel should not be armored with riprap so that the channel is permitted to erode vertically and laterally to the west as it develops its own morphology. However, the eastern bank (as designed), as well as the top of the eastern bank of the diversion channel should be armored with riprap. The riprap will protect the eastern flank of the channel from raindrop impact and flood-flow degradation, and will force channel erosion away from the tailings disposal area.

Once the diversion channel is at a gradient similar to that of Canon de/Marquez, neither aggradation or degradation will take place under present climatic conditions. Lateral erosion will be inhibited, and the diversion will not pose a hazard to the tailings disposal site.

The effects of the diversion on Canon de Marquez and Arroyo Hondo will be minimal.

The Canon de Santa Rosa channel will enlarge and adjust to the increased discharge provided by the diversion, but lateral erosion of bedrock will be minimal, and the tailings impoundment will not be affected.

NATURAL CHANNEL MORPHOLOGY

Although the channels in the Marquez area are ephemeral and subjec to natural periods of degradation and aggradation, streams that have a large water discharge will be deeper, wider and gentler than streams with lower discharge. Streams that transport larger bedloads will be wider, shallower, straighter and steeper for a given annual discharge than streams that transport small quantities of bedload.

These relationships can be displayed simply by relationships 1 and 2 below, which show by + and - exponents how a channel will respond to changes of average water discharge (Qw) and average sediment (bed) load (Qs). The morphologic variables are bankfull width (w), bankfull depth (d) meander wavelength (l), gradient (s), and sinuosity, the ratio of channel length to valley length (P) and width-depth ratio (F)

1) $Qw^+ \approx w^+ \quad d^+ \quad l^+ \quad S^-$

2) $Qs^+ \approx w^+ \quad d^- \quad l^+ \quad S^+ \quad P^- \quad F^+$

These qualitative relations are based on quantitative relations developed for rivers in many parts of the world (Schumm, 1977). The relations show that with an increase in water discharge the channel will enlarge and the gradient will decrease. This is frequently accomplished by an increase of sinuosity. That is, the river develops meanders, thereby increasing its length and decreasing its gradient. An increase of bed load (sediment of sand size and larger) will cause a widening of the channel and an increase of gradient among other changes.

The above relations have been developed for channels in alluvium. The size of bedrock channels depends largely on the resistance of the rock, but in most cases large valleys (w,d) with large valley meanders (l) are associated with large water discharge.

The importance of the above relations for the Marquez diversion is that they show that a stream will establish a channel in a valley both of which will be related to the water and sediment conveyed through the channel. Therefore, in order to ensure long-term channel stability a diversion channel should be fashioned or permitted to develop in such a way that it conforms to the existing geomorphic relations. That is, the channel could be permitted to develop its own morphology in relation to these independent variables over a period of time. The final diversion form will, therefore, be very similar to the natural channel above the point of diversion. Of perhaps most importance, the gradient of the diversion should be comparable to the gradient of the natural channel above the diversion. This permits transport of sediment through the diversion and ensures relative stability of the diversion channel.

NATURAL CHANNEL INCISION

Dramatic alluvial channel adjustments have been documented worldwide (Schumm, 1972, 1977; Gregory, 1977), but the erosion of a channel into bedrock is usually too slow to be measured and reported in the scientific literature. Nevertheless, experimental studies in the hydraulic laboratory provide information on channel incision into cohesive materials. In materials that simulate Mancos Shale bedrock, lowering of base level causes a channel to incise at the point of base level lowering, and then the scour or incision is propagated upstream at a rate depending on the water discharge and the resistance of the material being eroded. The rejuvenation of the channel and subsequent degradation to a new level can take place in two ways. Either a vertical headcut is formed, which maintains itself as it migrates upstream, or the vertical headcut becomes gentler, and it is replaced by a steeper reach of channel, a knickpoint, that lengthens as it moves upstream (Fig. 1).

Usually the vertical headcut is maintained in alluvial valleys, where the sod of the valley floor provides a "cap rock" effect that protects and maintains the vertical headcut (Fig. 1a). In homogeneous material the headcut will usually decline as it moves upstream, and it will be converted to a zone of steeper gradient (Fig. 1b).

Throughout the southwestern United States these types of erosion have been documented in the alluvium that forms the floor of the valleys. The Rio Puerco is a notorious example of the type. Erosion in the Rio Puerco valley commenced in about 1880 and now a deep erosional trench exists through the valley. It has been estimated that most of this erosion took place during the 43-year period between 1885 and 1928 (Leopold et. al., 1964, p. 447). If the arroyo extended upstream for 150 miles in 43 years the annual rate of upstream headcut movement was 3.5 miles per year. This is a very rapid rate of retreat in a large drainage basin. Experimental studies show an exponential decline in the velocity of headcut migration through time (Parker, 1976; Begin, 1978), and in small drainage basins rates of headcut retreat may average only a few feet per year.

Both in experimental studies (Shepherd and Schumm, 1974; Gardner, 1975) and in the field (Cooke and Reeves, 1976), it has been observed that erosion progresses upstream following the existing channel or depression. For example, Cooke and Reeves (1976) note that anomalously straight reaches of arroyos followed trails, roads or irrigation ditches. Obviously a channel cut into bedrock will be very unlikely to depart from the pre-existing flow lines. For a summary of the experimental studies see Schumm (1977, p. 188-203).

GEOMORPHIC-ENGINEERING APPROACH TO CHANNEL DESIGN

The proposed diversion channel must not only be capable of withstanding and containing the PMF but equally important, it must transport a large range of sediment sizes, from boulders to silt and clay, during normal annual discharge events and during flood events of lesser magnitude than the PMF. In order to ensure that this is the case, the diversion channel should be morphologically similar to Canon de Marquez and yet capable of containing the PMF. Of most importance, the gradient of the diversion channel should be similar to that of Canon de Marquez (about 1.7%).

In addition to the above requirement, the diversion channel should join the Canon de Santa Rosa without major changes of gradient. For example, if the diversion channel terminates at the head of the unnamed tributary to Canon de Santa Rosa approximately 100 feet above the Santa Rosa channel, deep incision will occur that will drastically alter the stability of the diversion channel as designed.

It is proposed that a combined geomorphic-engineering approach to the diversion channel be used. That is, the diversion channel as planned should be dug, but it should not be protected either on its west side or on its floor. The diversion of Canon de Marquez water into the channel and into the unnamed tributary will cause incision of the channel to a gradient similar to that of Canon de Marquez above the diversion.

The advantage of this plan is that the new channel will develop according to the geomorphic relations between channel morphology and water and sediment discharge. Therefore, it will be a natural channel with a degree of stability commensurate with its environment. In addition, if climate fluctuations over long periods of time induce aggradation the deeply incised channel will still contain the PMF. Further degradation is unlikely because most of the Marquez area channels have incised to bedrock and are armored with cobbles and boulders.

This scheme is based on a philosophy of river and land management that involves working with the fluvial system rather than by forcing it to conform to artificial standards established by man (Schumm, 1977). Further discussions of how the channel will develop under this scheme are presented below.

NATURAL EVOLUTION OF THE DIVERSION CHANNEL

Uncontrolled Evolution

If the diversion channel is permitted to establish itself the experimental studies and field observations reviewed above and below permit prediction of the manner in which the channel will develop.

Figure 2 summarizes the evolution of an unprotected diversion channel in very general terms. If the gradient of the diversion channel will stabilize at about 2 percent over the approximately 6200 feet between the point of diversion and the junction of the unnamed tributary with the Santa Rosa channel then a maximum of about 60 feet of degradation will take place at the end of the presently designed diversion channel. The unnamed tributary is already deeply incised, and upstream from the point of maximum incision the amount of incision will decrease to zero at the point of diversion.

Based on observations of incised gullies and irrigation channels in the Mancos Shale deep vertical incision will follow the diversion of Marquez water into the channel (Fig. 1). Depending on the resistance of the Mancos Shale, incision may be unchecked or it may pause as more resistant layers are encountered.

With time, natural vertical incision will be complete, and the channel will begin to erode laterally to widen its new valley (Fig. 2-c). Widening will continue until the base of the trench is about 60 feet wide, at which time deposition of alluvium will form a narrow inner floodplain. Vegetation will colonize these deposits and stabilize them (Fig. 2-d), and with time the channel will continue to erode the unprotected walls and to enlarge the "valley."

At many locations in the Colorado Plateau region high vertical slopes of Mancos Shale and other shales can be observed, where they are protected by a sandstone caprock or by a gravel armor, such as the Mancos Shale pediments near Grand Junction, Colorado and Price, Utah (Schumm and Chorley, 1966). In regions where precipitation is low and vegetation is sparse, the least erosion occurs on vertical slopes because on these slopes raindrop impact and runoff are at a minimum (Schumm et. al., 1970). Therefore, the most stable Mancos Shale slope is a very steep one with a sandstone or gravel cap.

Where the Mancos shale slopes are not protected by a cap, they will decline in angle, and very steep (70%) slopes near Montrose, Colorado are typical of the form and erosional characteristics of such slopes. A seven-year study of erosion of Mancos Shale slopes near Mack and Montrose, Colorado showed an average rate of erosion of 0.03 feet per year, on straight slopes with an average inclination of 71 percent. Convex slopes with an average inclination of 36 percent eroded at a rate of 0.02 feet per year, and concave slopes with an inclination of 46 percent eroded at an average rate of 0.002 feet per year (Schumm, 1964). None of these measured slopes were protected by a caprock. The slopes were almost bare of vegetation and yet erosion was relatively low as compared with rates of slope retreat of up to 0.1 feet per year in siltstone badlands elsewhere.

Based on the above discussion, the walls of the new valley will be stable, but as the shale is eroded it is assumed that they will decline to a slope of about 70 percent. On such slopes, erosion is expected to be about 0.03 feet per year. The upper slope, unless stabilized artificially (Fig. 2-d), will retreat toward the tailings pile 400 feet in 13,000 years, under present climatic conditions. However, as the slope angle decreases, the rate of erosion will decrease exponentially (Schumm, 1964).

Semi-controlled Evolution

Figure 3 summarizes the evolution of a partially protected diversion channel assuming that natural degradation is allowed to occur.

The new channel in its new bedrock valley will be a naturally stable channel. However, in order to ensure long-term stability of the tailings pile, it is recommended that the east slope of the diversion channel be riprapped, when the initial cut is made for the diversion channel. When the channel incises, some riprap from the east bank will fall into the channel, stabilizing the toe of the east bank and deflecting the flow to the west bank away from the tailings pile. The result will be an asymmetrical valley with a stable east side if riprap of appropriate size is placed not only on the east side of the diversion channel but also on top of the east bank. The riprap will provide a protective cap that will simulate the sandstone cap rock of the adjacent mesas. Therefore, even if the riprap were to slide into the channel through time a vertical shale cliff would form with a protective cap rock (Fig. 3-e). The self-armoring effect of the riprap in the diversion channel and the cap-rock effect of the riprap on the top and side slope will produce a very stable eastern wall of the diversion channel. Neither aggradation nor further degradation will affect the tailings because the channel will be in a deep bedrock valley that has self-armoring capabilities.

The end result will be a channel and valley with a natural morphology that is based on the channel and scarp morphology of the region. The channel will be adjusted to the normal flood discharge, and it will have the dimensions and gradient required to transport the normal sediment loads. Higher floods will inundate the new channel and floodplain, but they will be completely contained within the new valley, thereby ensuring the long-term stability of the tailings disposal site.

ADDITIONAL CONSIDERATIONS

If natural erosion is permitted to erode the diversion channel then several additional factors that may pose a threat to the tailings need consideration.

Control of Incision

The diversion channel cross-section is presently designed as a flat-floored trapezoid. The floor is about 40 feet wide. Natural incision could occur at any point in that width depending on irregularities of the channel floor. Therefore, it is recommended that a shallow center-line channel be dug (Figure 3-b). Natural incision will follow this, and maximum incision will be centered in the channel. Deeply incised bedrock channels such as the Goosenecks of the San Juan River and highly sinuous reaches of the Rio Puerco indicate that headward erosion will follow the pre-existing channel thalweg.

Side-slope Stability

The Mancos Shale when dry is a stable rock that will stand in high vertical cliffs. Vertical exposure of the Mancos Shale below the Mesa

Verde Sandstone caprock along the Book Cliffs and Mesa Verde provide clear evidence of its stability. Ground water investigations indicate that the slope should not be affected by seepage at any significant depths and the ephemeral flows will not induce significant mass movement. Unprotected walls of shale will erode due to creep, sheetwash and raindrop impact at a maximum rate of about 0.03 feet per year. Therefore, to protect the tailings pile, the eastern bank of the channel should be protected by riprap whereas the western bank can be permitted to erode naturally.

Basal Erosion

After achieving a gradient of about 2 percent the channel undoubtedly will begin to develop a sinuous thalweg. This process will undercut the shale slopes locally. Riprap will protect the eastern side of the valley and the erosion on the western side can be permitted as it will enlarge the valley. Due to the steep slope of the channel lateral migration of the channel will be minimal.

Rejuvenation of Tributary Channels and Dissection of Mesa del Canoncito Pediments

Although incision of the diversion channel will hasten erosion west of the tailings pile, this appears to be inevitable in any case. The unnamed tributary of the Santa Rosa is presently eroding into this undissected area. The additional erosion to the west of the diversion channel will not affect the stability of the channel.

Tributaries could develop to the east of the deep channel, which would endanger the tailings, but the drainage area that will supply such channels is minimal and it is unlikely that gully erosion will occur on the east side of the channel. It certainly will be prevented if the top of the east slope is stabilized with riprap or if water is prevented from draining over the top of the slope into the diversion channel.

Aggradation in Diversion Channel

As the diversion channel will be artificially cut to a relatively flat slope, aggradation will undoubtedly occur in the upper part of the diversion channel prior to its incision. This sediment can be removed mechanically, or the diversion channel can be cut to a steeper slope initially. As the Canon de Marquez gradient varies from about 1.3 percent to 1.7 percent directly above the point of diversion, cutting the initial diversion channel to a slope of one percent would, because of the initially narrow inner channel, convey the sediment delivered from the Marquez channel.

Time Factor

Although relatively rapid erosion of alluvium in semiarid valleys has been documented, it is difficult to predict the rate of erosion of the diversion channel into Mancos Shale. The shale is tight and probably initially resistant to erosion at depth. When weathered the shale is erodible. Therefore, in order to guarantee that the desired erosion will take place, the shale should be ripped or shattered by explosives placed in the thalweg. Cutting of a steeper channel, as suggested above, will also accelerate the erosional process. Diversion of excess mine waste water through the channel will also weaken the shale and accelerate channel incision.

It is recommended that some steps be taken to accelerate the erosion process in the channel, as the flows from the small Marquez drainage basin may not accomplish the cutting of the channel during the life of the project.

Effect on Canon de Marquez

If the diversion channel cuts to a gradient of about 1.5 to 2.0 percent it is unlikely that the Marquez channel above the diversion will be affected. Incision at the upper end of the diversion channel will be negligible, and because the Marquez channel is either very close to or already on bedrock and is armored with cobbles and boulders the effect of the diversion will be slight.

Effect on Canon de Santa Rosa

The gradient of the Santa Rosa channel at its junction with the unnamed tributary, which will be the lower end of the diversion channel, is about one percent or about one half that of the diversion channel. However, this is the approximate gradient of Salado Creek below the confluence of Canon de Marquez and Canon de Santa Rosa; therefore, the gradient of Canon de Santa Rosa is essentially that required for the transport of the additional flow and sediment load.

The increased sediment discharge from the eroding diversion channel may initially cause aggradation in the Santa Rosa Channel, but this will not affect the tailings pile.

The increased flow in the lower Santa Rosa channel will probably cause some meander cutoffs and enlargement of the channel until it assumes the morphology of Salado Creek below the Marquez-Santa Rosa junction. The long-term effect of the diversion, therefore, will be a reduction in size of the lower Marquez channel and enlargement of the Santa Rosa channel.

A channel with the morphology of the present Salado Creek will extend upstream in the Santa Rosa Valley to the junction with the diversion channel.

As the Santa Rosa channel is currently armored with cobbles and boulders, and is on or near bedrock, incision will not be expected either above or below the junction of the diversion channel.

<u>Summary</u>

A change in the sediment load or discharge of a river causes an adjustment of the channel to a new stable morphology. With this basic concept in mind, it is recommended that the Marquez diversion channel be permitted to establish itself and to evolve to a condition similar to that of the channels above the diversion. This will be a condition of relative stability that will ensure long-term stability of the tailing pile. The incised channel will be in bedrock over most of its length, and with self-armoring riprap protection on the eastern side, the diversion channel will not be a threat to the tailings pile. In fact, the channel will assume a morphology in its new valley that is in adjustment with the controlling variables of discharge and sediment load.

The combined geomorphic-engineering approach to the development of the diversion channel has the advantage of economy, efficiency and long-term stability. If necessary, erosion of the channel can be accelerated by mechanical means or by water diversion to ensure that at the close of the mining operation the permanent diversion channel will be functioning naturally.

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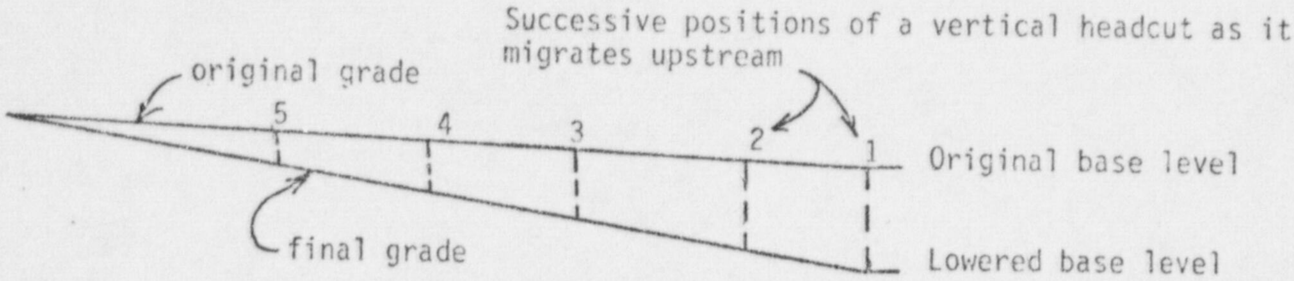
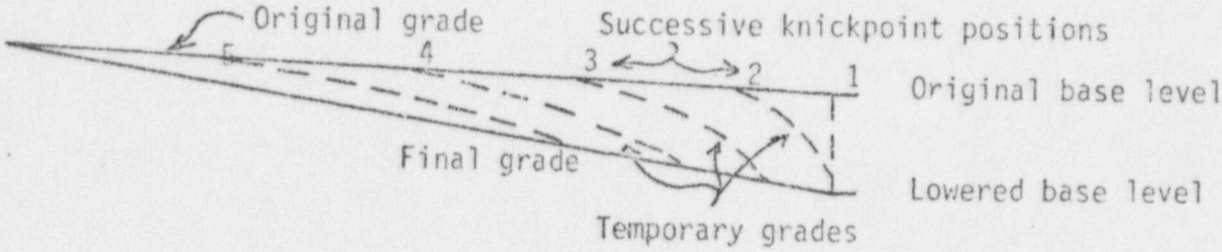


a.



b.

Figure 1. Generalized illustration of headcut migration in a shale bedrock channel due to a lowering of base level. Migration of a headcut can take place in two ways:

a. A vertical headcut forms and maintains itself as it migrates upstream, or

b. The initial vertical headcut erodes to a more gentle slope and is replaced by a steeper reach of channel that progressively lengthens upstream.

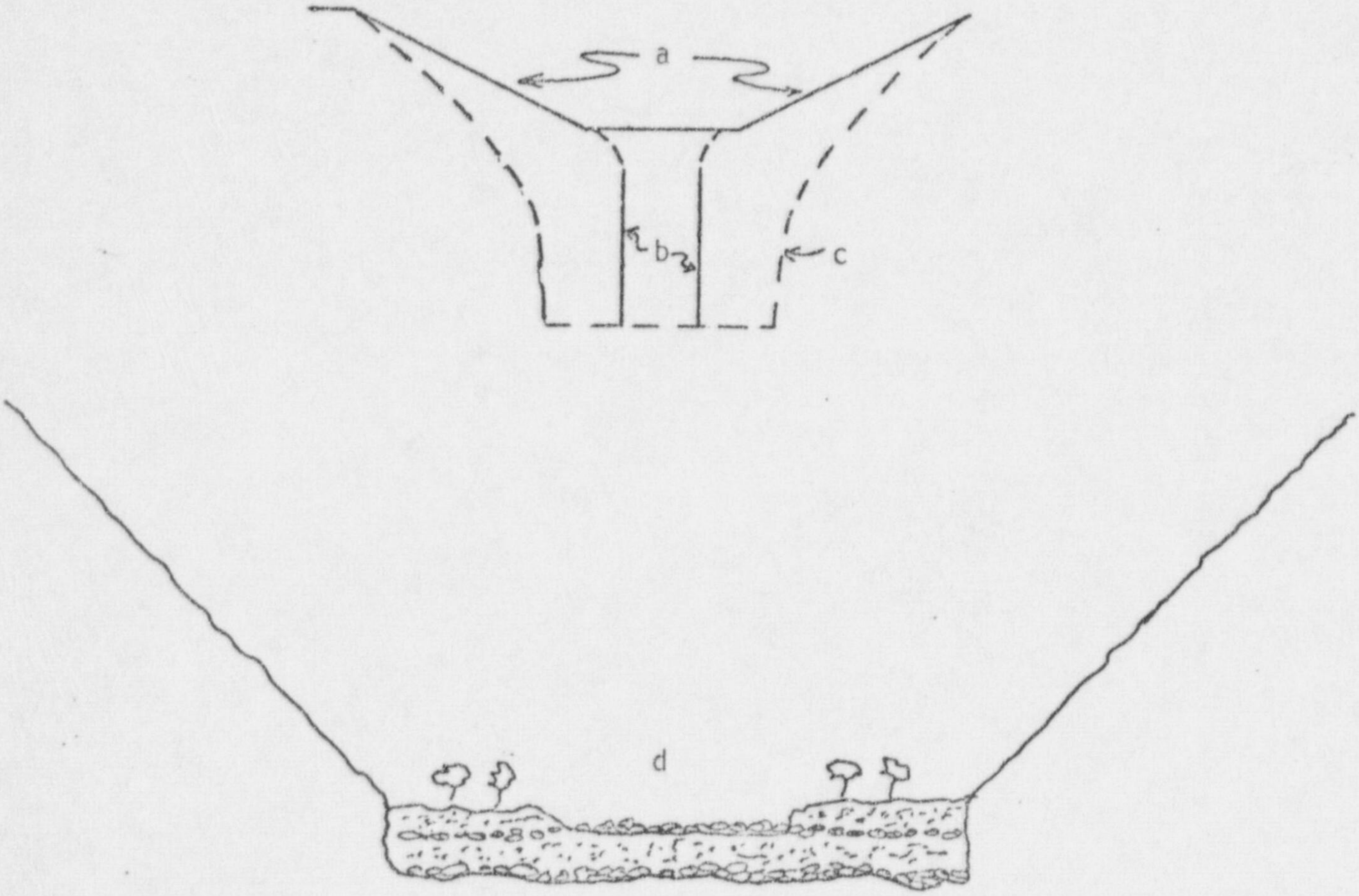


Figure 2. Generalized illustration of the natural evolution of the diversion channel without engineering control (not to scale).

a. Diversion channel as designed.
b. Deep channel formed by vertical incision in shale bedrock during the first stage of degradation.
c. Progressive widening of the channel by basal erosion and sheet/rill erosion will follow the initial incision. A valley will evolve.
d. Ultimately an alluvial channel and floodplain will form on the shale valley floor and vegetation will stabilize the alluvium.

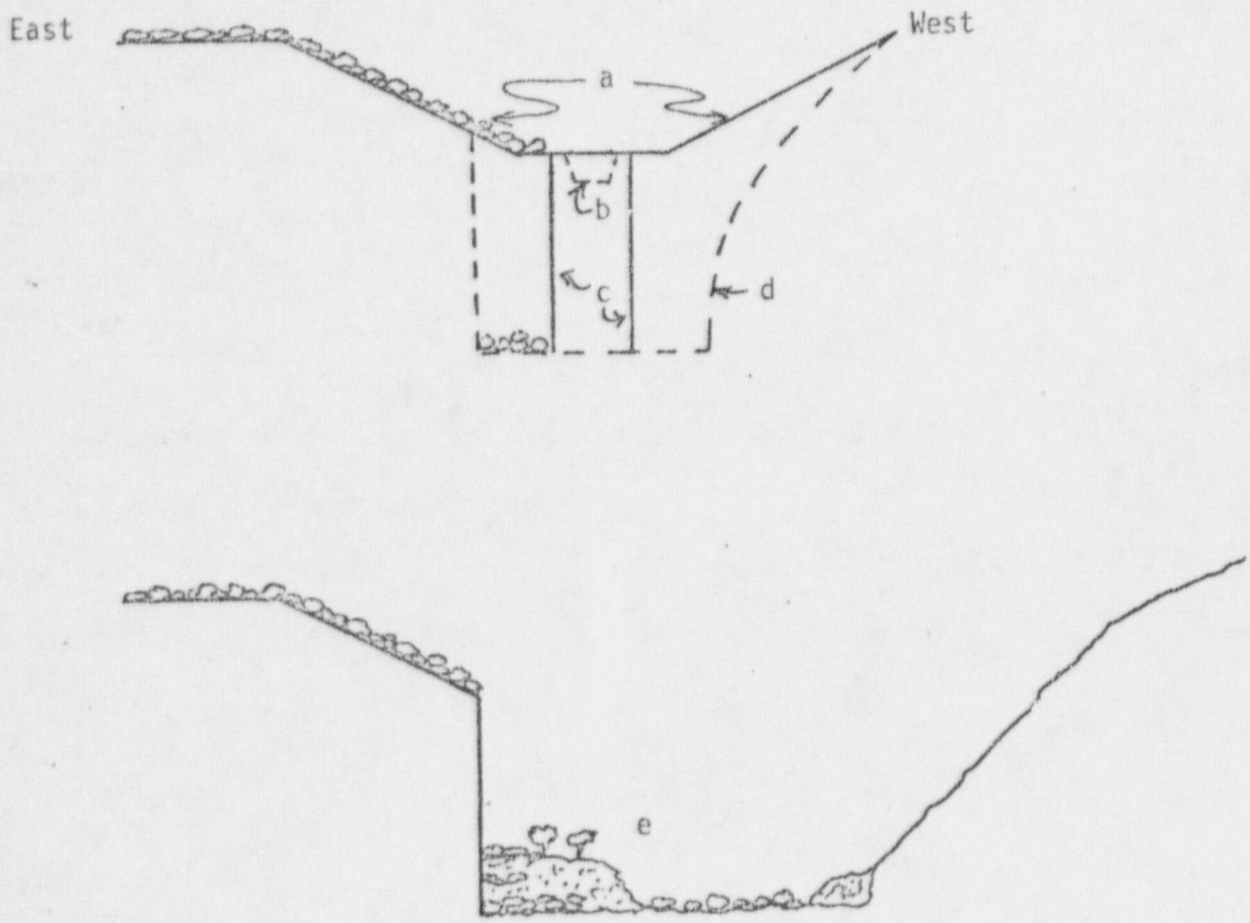


Figure 3. Generalized illustration of the projected evolution of the diversion channel with protective riprap placed on the east flank (tailings side).

a. Diversion channel as designed.
b. A trench at least 3 feet deep should be excavated along the center line of the channel floor to control the path of headward erosion.
c. Deep channel formed in shale bedrock at the discharge end of the channel during the first stages of degradation. The depth of the incision will decrease upstream and become negligible at the point of diversion.
d. Progressive widening of the channel by basal erosion and sheet/rill erosion will follow the initial incision. The riprap armor on the east flank will retard lateral erosion in an eastward direction.
e. Ultimately an alluvial channel and floodplain will form on the floor of the asymmetrical bedrock valley.

Stearns-Roger
INCORPORATED

February 1, 1979

Mr. William P. Biava
Bokum Resources Corporation
P. O. Box 2470
Santa Fe, New Mexico 87501

Reference: Marquez Uranium Mill
Our C-19780

Subject: Tailing Area Diversion Channel
Design Modifications

Dear Mr. Biava:

We have attached a copy of Jerry Knight's memo dated January 31, and supporting calculations pertaining to design modifications to the diversion channel to conform with the recommendations of Dr. Schumm.

Very truly yours,

John R. Stryker

JRS:lh
cc: Dr. Schumm
Bokum - L. Storm
Mine Tailings International
Geocon, Ltd.
Fenco Consultants, Ltd.
Woodward-Clyde Consultants
SAI, Inc.
D. L. Bradfield w/o att.
G. M. Knight w/o att.
P. E. Lantis w/o att.
R. B. Olson w/o att.

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INTEROFFICE MEMORANDUM

TO: J. R. Stryker

January 31, 1979

FROM: J. Knight

SUBJECT: Tailing Area Diversion Channel
Marquez Uranium Mill

The diversion channel design has been modified to conform with the "natural erosion" recommendations of Dr. Stanley A. Schumm. In addition, modifications were made to Canon de Marquez approach channel resulting in a stilling basin effect above the point of diversion. PMF flows were re-evaluated, using a "n" value of 0.025.

The basic modifications are as follows:

1. Elimination of riprap on floor and west slope of diversion channel.

2. Addition of a 10 ft. wide by 4 ft. deep cut at the centerline of the diversion channel as a "starter cut" for natural erosion.

3. Addition of a 200 ft. radius approach to the diversion channel from Canon de Marquez, resulting in a wide transition section.

4. Reduction of the "n" value for the diversion channel and approach channel at PMF to 0.025. The result is higher velocities at lesser depth of flow. Calculated depth of the PMF flood at the point of diversion is 23.6 ft. leaving a freeboard of 8.4 ft. with a dam height of 32 feet. Calculated depth through curves #1, #2 and #3 is 26.3 ft., leaving a freeboard of 5.7 ft.

5. Riprap was re-evaluated at the point of diversion, using USBR chart for stone sizing below stilling basins, 24 inch stone size was selected with blanket thickness of 36 inches.

J. Knight

J. Knight

JK:lh

PAGE 1/12

JOB NO. C-19620 DATE 1-25-79 BY AMK CH'K.

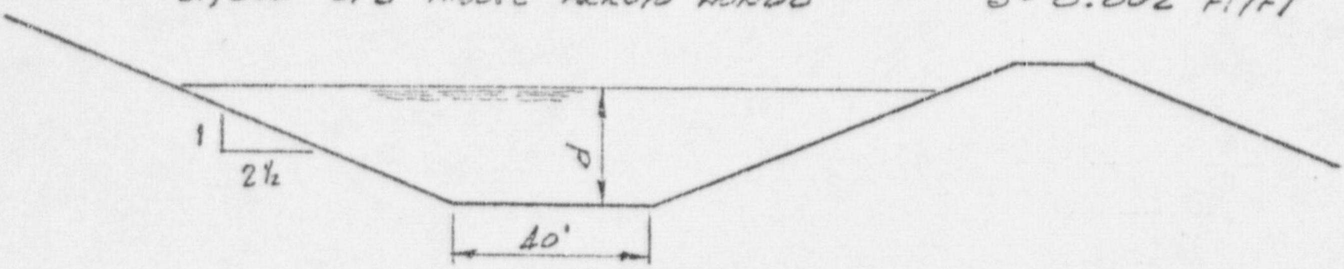
CUSTOMER Bokum PROJECT MARQUEE

SUBJECT DIVERSION CHANNEL HYDRAULICS

1. DIVERSION CHANNEL HYDRAULICS

Q = 35,500 CFS BELOW ARROYO HONDO — n = 0.025

31,800 CFS ABOVE ARROYO HONDO — S = 0.002 FT/FT



d	R	A	V	Q
18	11.17	1530.0	13.3 FPS	20,300 CFS
19	11.68	1662.5	13.7	22,750
20	12.19	1800.0	14.1	25,800
21	12.69	1942.5	14.5	28,100
22	13.19	2090.0	14.8	31,000
23	13.69	2242.5	15.2	34,100
24	14.18	2400.0	15.6	37,400
25	14.67	2562.5	15.9	40,800
26	15.17	2730.0	16.3	44,500
30	17.12	3450.0	17.7	60,900

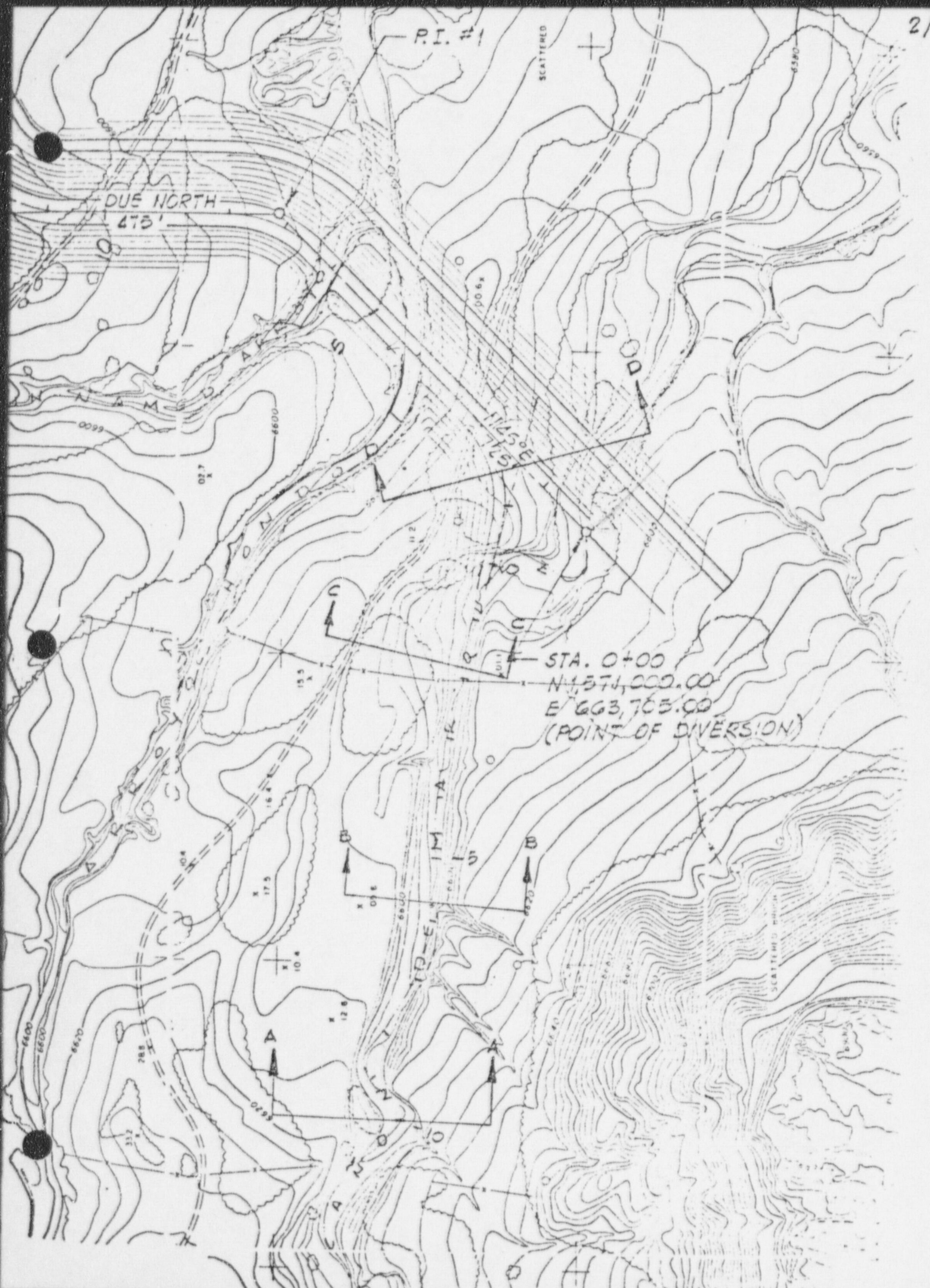
ABOVE ARROYO HONDO: d = 22.3'; V = 14.9 FPS

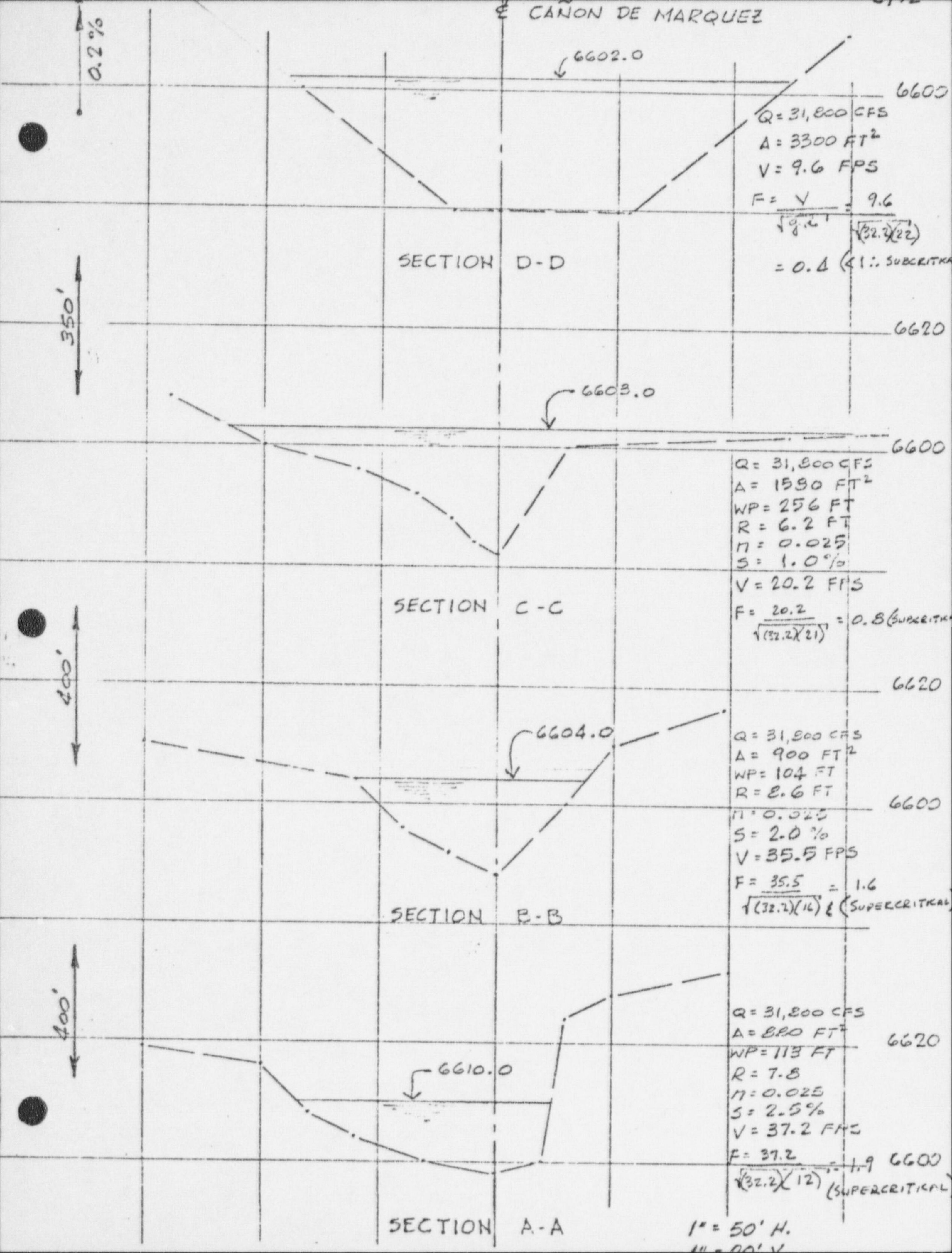
BELOW ARROYO HONDO: d = 23.4'; V = 15.4 FPS

FROUDE NUMBER & FLOW CONDITION:

ABOVE ARROYO HONDO: $F = \frac{V}{\sqrt{gd}} = \frac{14.9}{\sqrt{(32.2)(22.3)}} = 0.56$ (< 1 ∴ SUBCRITICAL)

BELOW ARROYO HONDO: $= \frac{15.4}{\sqrt{(32.2)(23.4)}} = 0.56$ (< 1 ∴ SUBCRITICAL)


P.I. #1
DUE NORTH
473'
SCATTERED
STA. 0+00
N 1,571,000.00
E 663,705.00
(POINT OF DIVERSION)
A
B
C
D
6600
6620
SCATTERED



℄ CAÑON DE MARQUEZ
0.2%
6602.0
6600
Q = 31,800 CFS
A = 3300 FT²
V = 9.6 FPS
F = V / √(g·d) = 9.6 / √((32.2)(22))
= 0.4 (<1 ∴ SUBCRITICAL
SECTION D-D
350'
6620
6603.0
6600
Q = 31,800 CFS
A = 1590 FT²
WP = 256 FT
R = 6.2 FT
n = 0.025
S = 1.0%
V = 20.2 FPS
F = 20.2 / √((32.2)(21)) = 0.8 (SUBCRITICAL
SECTION C-C
400'
6620
6604.0
Q = 31,800 CFS
A = 900 FT²
WP = 104 FT
R = 8.6 FT
6600
n = 0.025
S = 2.0%
V = 35.5 FPS
F = 35.5 / √((32.2)(16)) = 1.6 (SUPERCRITICAL
SECTION B-B
400'
Q = 31,800 CFS
A = 880 FT²
WP = 113 FT
R = 7.8
6620
n = 0.025
S = 2.5%
V = 37.2 FPS
6610.0
F = 37.2 / √((32.2)(12)) = 1.9 (SUPERCRITICAL)
6600
SECTION A-A
1" = 50' H.

SECTION A-A: V = 37.2 FPS
F = 1.9
Y = 12'
} SEE X-SECTION

$E = \frac{V^2}{2g} + y = 33.6$ FT (TOTAL ENERGY)

SECTION B-B: V = 35.5 FPS
F = 1.6
Y = 16'
E = 35.6 FT.

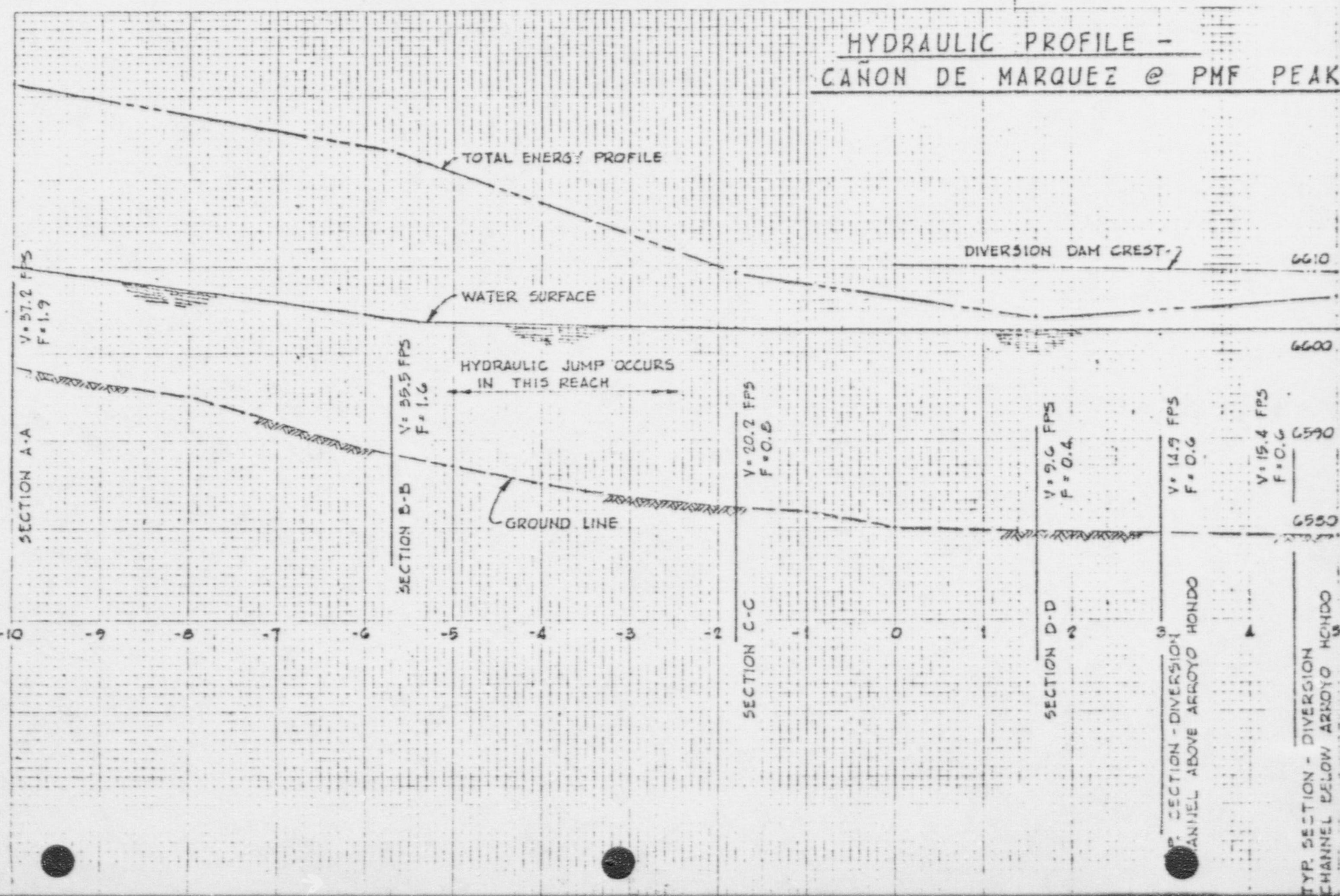
SECTION C-C: V = 20.2 FPS
F = 0.8
Y = 21'
E = 27.4'

SECTION D-D: V = 9.6 FPS
F = 0.4
Y = 22'
E = 23.4'

DIVERSION CHANNEL: (ABOVE ARROYO HONDO)
V = 14.9 FPS
F = 0.6
Y = 22.3'
E = 25.9'

DIVERSION CHANNEL: (BELOW ARROYO HONDO)
V = 15.4 FPS
F = 0.6
Y = 23.4'
E = 27.1'

HYDRAULIC PROFILE - CAÑON DE MARQUEZ @ PMF PEAK



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CUSTOMER BOKUM PROJECT MARQUEZ

SUBJECT DIVERSION CHANNEL HYDRAULICS

HYDRAULIC JUMP OCCURS BETWEEN SECTION B-B AND SECTION C-C

$F_1 = 1.6$ $D_1 = 16$ FT. (@ SECTION B-B)
$F_2 = 0.8$

PER USBR ENGINEERING MONOGRAPH NO. 25, $F_1 < 2.5$ INDICATES THE EFFECT OF HYDRAULIC JUMP WILL BE A SLIGHT RUFFLE ON WATER SURFACE OR A SERIES OF SMALL ROLLERS DEVELOPING ON THE SURFACE.

ASSUME JUMP OCCURS AT SECTION B-B;

$$D_2 = D_1 \left[\tfrac{1}{2} \left(\sqrt{1+8F_1^2} - 1 \right) \right] = 29 \text{ FT.}$$

LENGTH OF JUMP (USBR MONO. NO. 25 - FIG. 7)

$L/D_2 = 3.8$; $L = 110$ FT.

JUMP OCCURS IN NATURAL CHANNEL AT LEAST 400 FT. UPSTREAM OF POINT OF DIVERSION. EFFECT ON DIVERSION CHANNEL IS NEGLIGIBLE.

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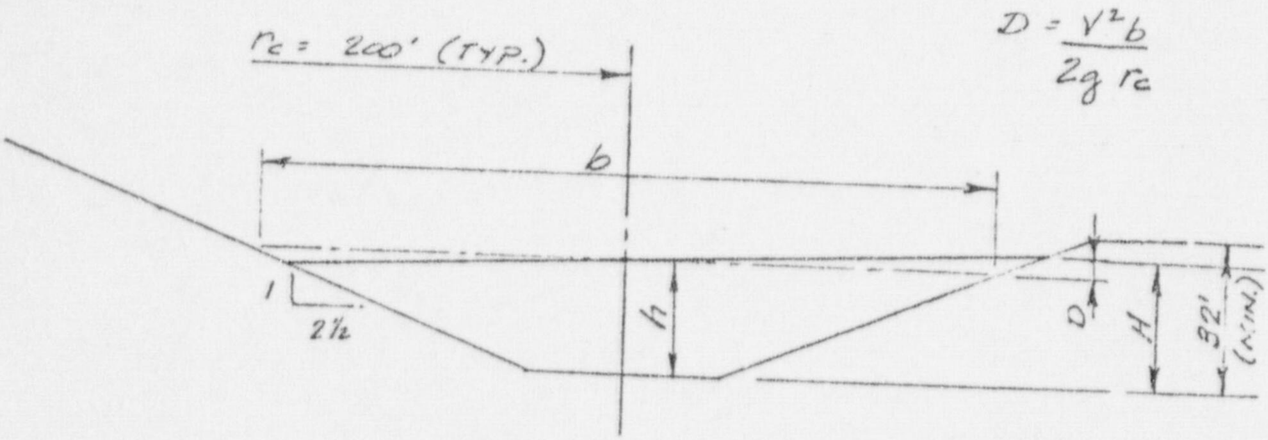
BY GMK CH'K.

CUSTOMER Bokum PROJECT Marquez

SUBJECT Diversion Channel Hydraulics

SUPERELEVATION THROUGH BENDS

SUBCRITICAL FLOW - (REF. KING p8-29)



CURVES #1, #2, & #3:

h = 23.4'
b = 157'
V = 15.4 FPS
D = 2.9'
H = 26.3' (5.7' FREEBOARD @ PMF)

POINT OF DIVERSION (SECTION D-D)

h = 22'
b = 220' (SCALED)
V = 9.6 FPS
D = 1.6'
H = 23.6' (8.4' FREEBOARD @ PMF)

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BY ADHK CH'K.
CUSTOMER Bokum PROJECT MARQUEZ
SUBJECT DIVERSION CHANNEL

RIPRAP BELOW POINT OF DIVERSION (SAY STA. 6+00)

TRACTIVE FORCE DESIGN FROM COLO. HIGHWAY DEPT. DESIGN MANUAL, CONDENSED FROM HIGHWAY RESEARCH BOARD REPORT 108.

$\tau = 62.4\ CRS$, where τ IS UNIT SHEAR ACTING ON CHANNEL
C = COEFFICIENT FROM FIG. 805-5B
R = HYDRAULIC RADIUS
S = CHANNEL SLOPE (FT/FT)

CONSIDER PMF CONDITION BELOW ARROYO HONDO:
$R \cong 13.9$
$S = 0.002$ '/'
$W/Y = 40 \div 23.4 = 1.7$
$C_s = 1.33$ (SIDES)
$C_b = 1.43$ (BOTTOM)
$C_c = 2.4$ (BENDS)
{T = 157', R = 200'} T/R = 0.785

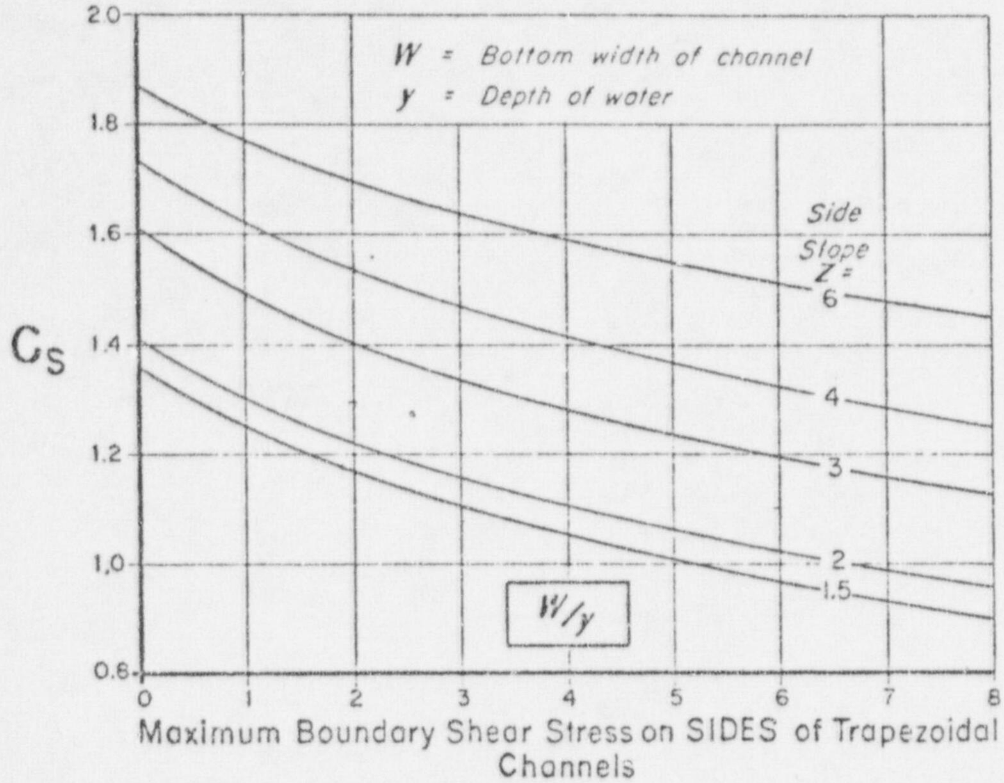
$\tau = 62.4\ CRS =$ 2.31 PSF (SIDES)
2.48 PSF (BOTTOM)
4.16 PSF (BENDS)

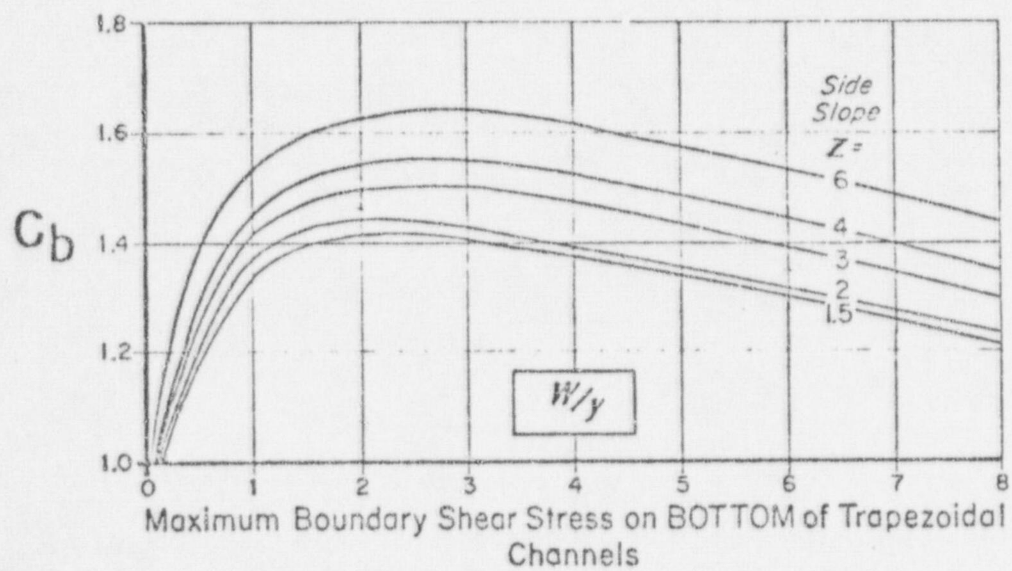
$d_{50} = \frac{\tau_R}{K4}$ where d_{50} = MEAN STONE SIZE, BY MASS
τ_R = RESISTIVE SHEAR
K = REDUCTION FACTOR (Fig. 805-5B1)

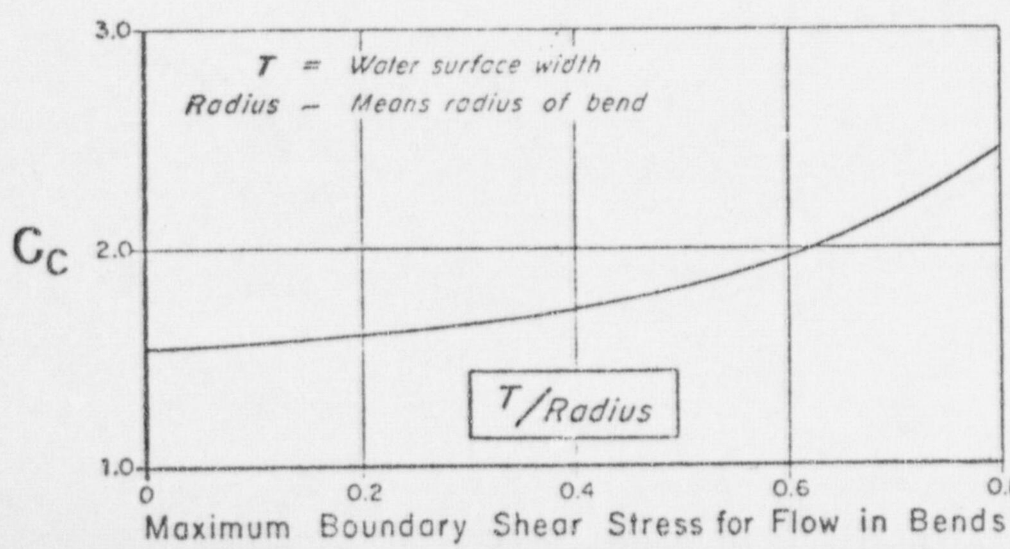
THRU CURVES, $d_{50} = 4.16 \div (0.8)(4) = 1.3$ FT = 16 INCHES
THRU TANGENTS, SIDES: $d_{50} = 2.31 \div (0.8)(4) = 0.72$ FT = 9 INCHES
BOTTOM: $d_{50} = 2.48 \div (1.0)(4) = 0.62$ FT = 7 INCHES

USING 24" RIPRAP, FS = 1.5 (BENDS)
2.7 (TANGENTS)

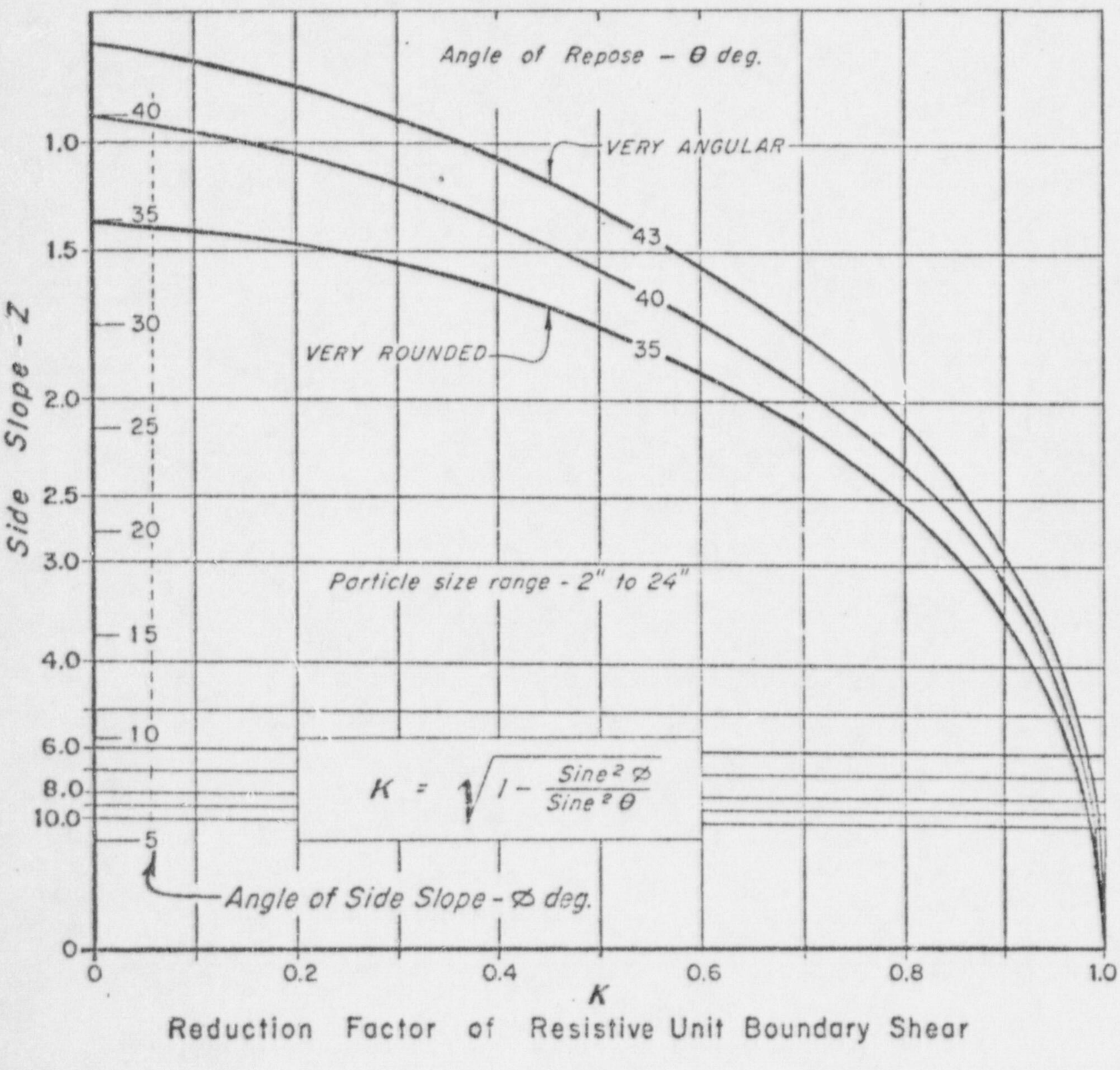
FLOW SHEAR


W = Bottom width of channel
y = Depth of water
Side Slope Z =
6
4
3
2
1.5
C_s
2.0
1.8
1.6
1.4
1.2
1.0
0.8
W/y
0
1
2
3
4
5
6
7
8
Maximum Boundary Shear Stress on SIDES of Trapezoidal Channels


Side Slope Z =
6
4
3
2
1.5
C_b
1.8
1.6
1.4
1.2
1.0
W/y
0
1
2
3
4
5
6
7
8
Maximum Boundary Shear Stress on BOTTOM of Trapezoidal Channels


T = Water surface width
Radius – Means radius of bend
C_c
3.0
2.0
1.0
T/Radius
0
0.2
0.4
0.6
0.8
Maximum Boundary Shear Stress for Flow in Bends

LINING SHEAR



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CUSTOMER BOKUM PROJECT MARQUEZ

SUBJECT DIVERSION CHANNEL

RIPRAP AT POINT OF DIVERSION

REFERENCE ATTACHED USBR CHART:

V = 9.6 FPS (SEE PAGE 3)

REQUIRED STONE DIAMETER IS 14 INCHES

USE 24" STONE SIZE (F.S. = 1.7)

THERE IS POSSIBILITY OF HEAVY IMPACT OF DEBRIS

∴ ADD 12 INCHES EXTRA BLANKET THICKNESS

USE 24" STONE SIZE

36" TOTAL THICKNESS (WHERE SUBJECT TO IMPACT)

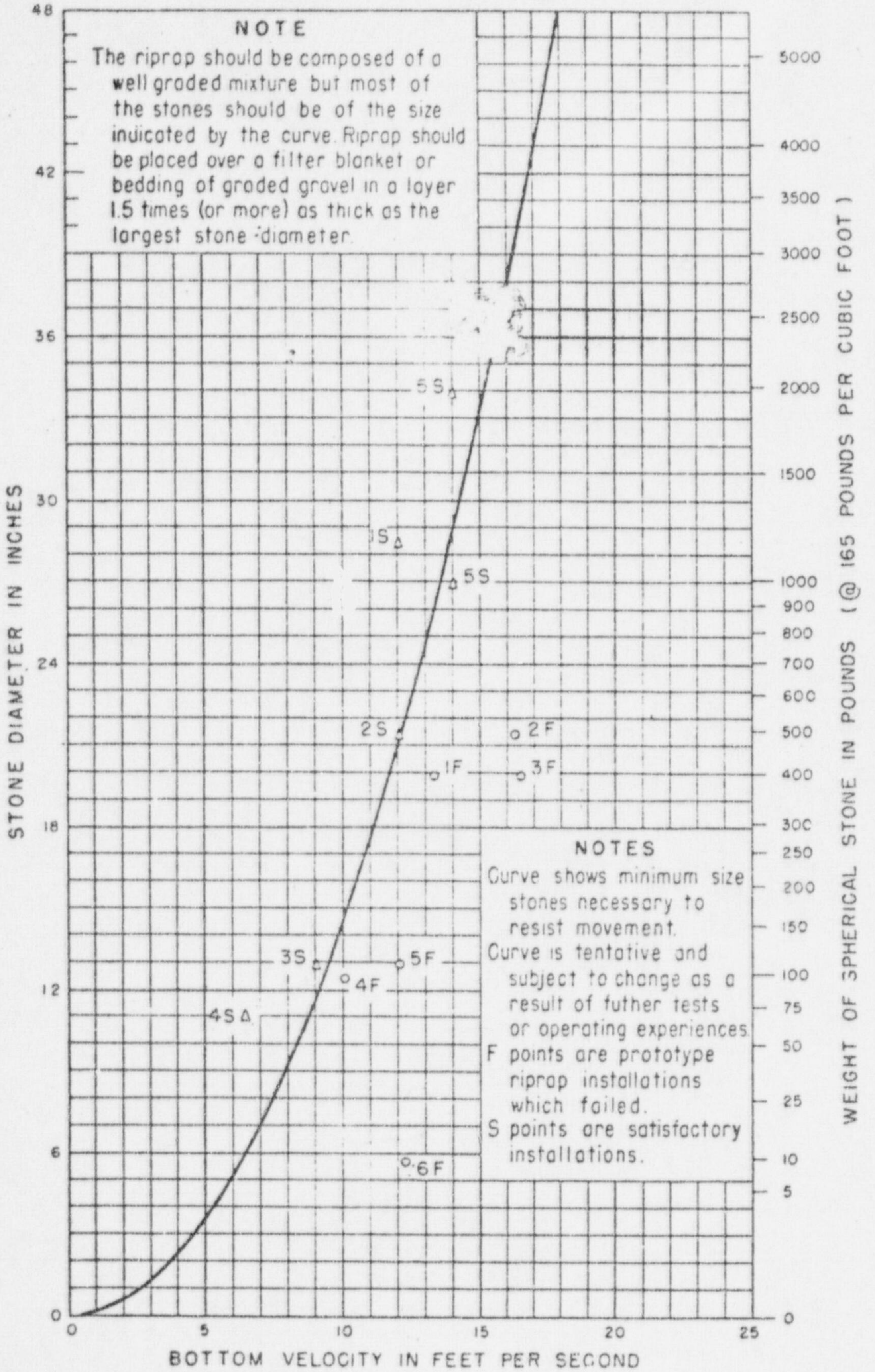

FIGURE 165.—*Curve to determine maximum stone size in riprap mixture.*

APPENDIX C

DIVERSION DITCH MODIFICATION

OVERSIZE
DOCUMENT
PAGE(S) PULLED

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