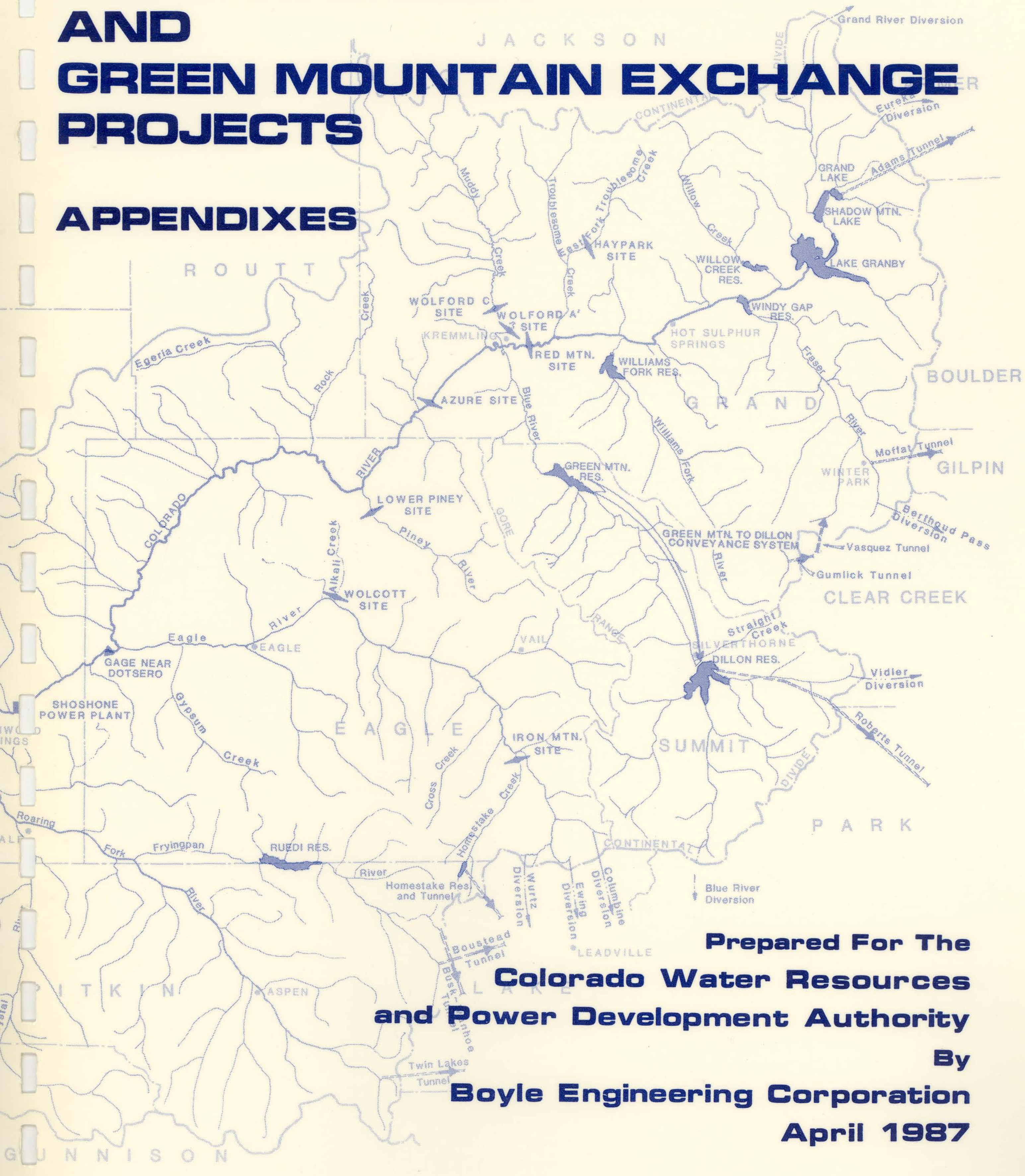
JOINT-USE RESERVOIR AND GREEN MOUNTAIN EXCHANGE PROJECTS

APPENDIXES



Prepared For The

Colorado Water Resources

and Power Development Authority

By

Boyle Engineering Corporation

April 1987

TECHNICAL APPENDIXES

JOINT-USE RESERVOIR
and
GREEN MOUNTAIN EXCHANGE PROJECTS

prepared for

COLORADO WATER RESOURCES
and
POWER DEVELOPMENT AUTHORITY

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A.1.0 HYDROLOGIC SIMULATION STUDIES

Supplemental information about the hydrologic simulation studies are provided in this section. The subjects that are covered include: the model configuration, virgin flow estimations, operation studies, and estimates of divertable flow based on daily flow analyses.

A.1.1 MODEL CONFIGURATION

To effectively perform the analysis of the complex hydrologic conditions of the Upper Colorado River Basin and reliably compare various water development alternatives, the application of a hydrologic simulation model was sought as part of this Study. A review was made of several existing hydrologic simulation models. Most of these models were developed for site-specific purposes or do not have the capability of handling the unique hydrologic and river operating conditions encountered in the study area. An exception was the Colorado River Simulation Model (CORSIM) developed by the David E. Flemming Company and Brinckerhoff, Quade & Douglas, Inc., in the early 1970's. However, the assumptions and logic included in CORSIM were not readily available for review and validation. Also the model is proprietary. The Boyle Engineering Simulation Model, (BESTSM) has unique capabilities for handling the various hydrologic conditions encountered in the study area. It was selected with the approval of the Authority. BESTSM accounts for monthly water volumes for inflows, diversions, return flows, river gains and losses, and outflows of each segment of the stream system and allocates water based on the Colorado water rights priority system and other legal and institutional arrangements.

BESTSM was applied to the Upper Colorado River Basin to estimate storable flows for each of the proposed reservoir sites. The modeling area covers over 8000 square miles and ranges in elevation from 4800 feet to over 14,000 feet. To accurately simulate the hydrologic characteristics of the basin, the mainstem and tributaries were divided up into 53 segments, bounded by 45 river nodes and 8 reservoir nodes. Figure A.1.1 displays the location of the nodes and reservoirs simulated in the model. Approximately 1600 water rights are operated in the model. These rights divert from over 800 major diversion structures.

TABLE A.1.1

AVERAGE MONTHLY VIRGIN FLOWS
UPPER COLORADO RIVER BASIN
(1951 - 1983)

(1000 af)

STAT. NO.	STATION NAME	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1050	COLORADO RIVER BELOW BAKER GULCH	1.4	.9	.6	.5	.4	.5	1.6	11.0	26.3	13.5	4.2	1.9	62.8
1900	COLORADO RIVER BELOW LAKE GRANBY	5.0	2.7	3.1	3.1	2.6	2.9	9.9	51.9	104.9	49.9	16.6	7.9	260.6
2100	WILLOW CREEK BELOW WILLOW CREEK RESERVOIR	1.4	1.0	.8	1.0	.7	.9	3.7	20.6	19.2	5.5	2.2	1.3	58.2
2405	FRASER RIVER BELOW MEADOW CREEK	3.6	2.7	2.2	1.9	1.6	1.7	3.1	16.7	40.7	20.0	7.8	4.6	106.4
3400	FRASER RIVER AT GRANBY	4.5	3.6	2.9	2.5	2.3	3.2	10.4	31.8	47.1	22.4	9.3	5.4	145.4
3425	COLORADO RIVER AT WINDY GAP	11.6	8.0	7.3	7.0	6.1	7.9	26.2	107.5	173.6	77.4	28.9	15.2	476.8
3600	WILLIAMS FORK NEAR LEAL	2.4	1.8	1.5	1.3	1.1	1.2	2.0	10.1	29.4	15.0	5.1	2.8	73.6
3850	WILLIAMS FORK RIVER AT WILLIAMS FORK RESERVOIR	3.4	2.8	2.4	2.1	1.8	2.1	4.2	12.9	29.9	12.2	5.7	3.6	83.1
4050	TROUBLESOME CREEK NEAR TROUBLESOME	1.4	1.3	1.2	1.2	1.1	1.3	3.2	11.8	10.7	3.1	1.7	1.3	39.2
4060	COLORADO RIVER AT RED MOUNTAIN SITE	16.4	12.1	11.0	10.2	9.0	11.3	33.6	132.2	214.1	92.7	36.3	20.1	599.1
4150	MUDDY CREEK AT KREMMLING	.9	.8	.7	.6	.5	.9	4.7	26.0	21.9	4.3	1.4	.8	63.6
4660	BLUE RIVER NEAR DILLON	3.1	2.1	1.8	1.6	1.3	1.4	2.2	11.1	23.6	14.3	7.6	4.5	74.5
5070	BLUE RIVER BELOW DILLON RESERVOIR	6.7	4.7	4.3	3.9	3.3	3.7	7.0	34.9	73.6	36.9	16.8	9.3	204.9
5100	STRAIGHT CREEK NEAR DILLON	.4	.3	.3	.2	.2	.2	.3	1.2	3.2	1.9	.9	.5	9.7
5750	BLUE RIVER BELOW GREEN MOUNTAIN RESERVOIR	12.5	9.0	8.0	7.2	6.2	7.5	15.3	60.5	120.9	68.7	33.3	17.6	366.8
5755	BLUE RIVER AT CONFLUENCE	12.5	9.0	8.0	7.2	6.2	7.5	15.3	60.5	120.9	68.7	33.3	17.6	366.8
5760	COLORADO RIVER BELOW BLUE RIVER AND MUDDY CREEK	29.8	21.9	19.7	18.0	15.7	19.7	53.6	218.8	357.0	165.7	71.0	38.5	1029.5
5800	COLORADO RIVER NEAR KREMMLING	33.7	26.0	23.6	22.2	19.6	24.4	62.3	227.1	360.2	170.8	75.9	41.6	1087.5
5810	COLORADO RIVER ABOVE PINEY RIVER	33.7	26.0	23.6	22.2	19.6	24.4	62.3	227.1	360.2	170.8	75.9	41.6	1087.5
5950	PINEY RIVER NEAR STATE BRIDGE	1.1	1.0	.9	.8	.7	.9	2.9	14.9	21.0	7.0	1.9	1.0	54.1
6000	COLORADO RIVER BELOW PINEY RIVER	34.9	27.0	24.5	23.0	20.3	25.3	65.3	242.0	381.2	177.8	77.8	42.6	1141.6
6050	ROCK CREEK NEAR TOPONAS	.7	.5	.5	.4	.4	.5	2.9	8.9	6.8	2.1	1.1	.7	25.5
6077	ROCK CREEK NEAR MCCOY	1.3	1.1	.9	.9	.7	1.1	5.8	17.8	13.6	4.3	2.2	1.5	51.0
6200	COLORADO RIVER ABOVE EAGLE RIVER	48.7	39.3	34.5	32.2	30.7	39.1	87.7	303.9	450.9	202.2	93.5	54.4	1416.9
6300	EAGLE RIVER AT RED CLIFF	.9	.7	.6	.6	.5	.6	1.5	8.2	13.0	3.8	1.7	1.0	33.2
6400	HOMESTAKE CREEK BELOW HOMESTAKE RESERVOIR	.7	.4	.3	.3	.2	.3	1.3	8.1	17.0	7.5	2.1	.9	39.2
6450	HOMESTAKE CREEK NEAR RED CLIFF	.9	.6	.5	.4	.4	.5	2.3	12.8	22.3	9.5	2.9	1.2	54.3
6730	ALKALI CREEK NEAR WOLCOTT	.0	.0	.0	.0	.0	.1	.5	.7	.2	.1	.0	.0	1.6
6750	EAGLE RIVER AT EAGLE	9.2	7.4	6.5	6.1	5.4	6.4	15.0	72.4	107.3	34.1	15.1	10.0	295.0
7000	EAGLE RIVER BELOW GYPSUM	15.2	14.0	12.1	11.1	9.5	11.1	19.6	77.9	144.6	65.3	23.9	15.7	420.0
7050	COLORADO RIVER NEAR DOTSERO	63.9	53.4	46.6	43.3	40.2	50.2	107.3	381.7	595.4	267.5	117.4	70.1	1836.9
7250	COLORADO RIVER AT GLENWOOD SPRINGS	69.4	57.8	49.8	46.9	43.2	54.6	113.1	397.5	614.6	275.0	122.3	75.0	1919.2
7350	ROARING FORK RIVER NEAR ASPEN	2.8	2.1	1.8	1.6	1.4	1.5	3.0	19.3	43.3	18.9	5.5	3.2	104.5
7400	HUNTER CREEK NEAR ASPEN	.8	.6	.5	.4	.4	.4	1.1	7.9	16.6	6.2	1.5	.9	37.4
8020	FRYINGPAN RIVER BELOW RUEDI RESERVOIR	4.2	2.9	2.4	2.2	1.9	2.3	6.7	35.4	62.9	26.5	9.2	5.0	161.6
8500	ROARING FORK RIVER AT GLENWOOD SPRINGS	37.9	32.4	27.6	24.2	20.2	23.9	43.6	154.4	301.4	157.5	58.2	39.2	920.4
8750	ELK CREEK NEAR NEWCASTLE	.7	.9	1.0	1.0	1.0	1.2	1.6	7.7	9.0	2.2	.8	.4	27.5
9100	WEST DIVIDE CREEK	.8	.9	1.0	1.0	1.0	1.3	1.7	8.0	9.4	2.3	.8	.4	28.7
9210	RIFLE CREEK	.8	1.0	1.1	1.1	1.1	1.4	1.8	8.4	9.9	2.4	.8	.5	30.1
9350	PARACHUTE CREEK AT PARACHUTE	.8	1.0	1.2	1.1	1.1	1.5	1.9	9.0	10.5	2.6	.9	.5	32.1
9370	COLORADO RIVER NEAR DEBEQUE	111.5	96.1	84.2	77.5	70.3	87.5	168.4	608.0	980.3	447.0	183.1	115.2	3029.0
9380	ROAN CREEK	7.2	7.0	7.4	6.4	5.7	5.9	7.1	10.1	8.7	6.3	6.5	6.8	85.2
9550	COLORADO RIVER NEAR CAMEO	118.5	103.0	91.5	83.9	75.7	93.2	175.0	617.0	986.2	451.3	189.5	121.6	3106.4
10500	PLATEAU CREEK NEAR CAMEO	1.4	.9	.6	.5	.4	.5	1.6	10.1	19.1	7.0	2.2	1.6	45.7
10510	COLORADO RIVER BELOW PLATEAU CREEK	119.9	103.8	92.1	84.3	76.1	93.7	176.6	627.1	1005.3	458.3	191.7	123.2	3152.1

TABLE A.1.2

AVERAGE MONTHLY HISTORIC FLOWS
UPPER COLORADO RIVER BASIN
(1951 - 1983)

(1000 af)

STAT. NO.	STATION NAME	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
1050	COLORADO RIVER BELOW BAKER GULCH	1.4	.9	.6	.5	.4	.5	1.6	10.1	19.1	7.0	2.2	1.6	45.7
1900	COLORADO RIVER BELOW LAKE GRANBY	1.7	1.4	1.4	1.4	1.3	1.6	2.0	5.3	7.4	8.7	2.7	1.5	36.5
2100	WILLOW CREEK BELOW WILLOW CREEK RESERVOIR	.5	.4	.5	.7	.5	.7	1.6	6.9	7.9	3.6	1.1	.3	24.8
2405	FRASER RIVER BELOW MEADOW CREEK	1.9	1.7	1.5	1.3	1.1	1.3	2.3	9.8	24.3	10.8	3.3	1.9	61.2
3400	FRASER RIVER AT GRANBY	2.9	2.6	2.2	2.0	1.8	2.8	9.6	24.9	30.7	13.2	4.8	2.7	100.3
3425	COLORADO RIVER AT WINDY GAP	5.8	5.2	4.7	4.4	4.1	5.8	15.5	40.4	48.4	25.2	9.5	5.1	174.1
3600	WILLIAMS FORK NEAR LEAL	2.2	1.7	1.4	1.3	1.1	1.2	2.0	9.3	27.8	13.7	4.3	2.5	68.3
3850	WILLIAMS FORK RIVER AT WILLIAMS FORK RESERVOIR	3.2	2.7	2.3	2.0	1.8	2.1	4.1	12.1	28.3	11.0	4.9	3.3	77.8
4050	TROUBLESOME CREEK NEAR TROUBLESOME	1.4	1.3	1.2	1.2	1.1	1.3	3.2	11.8	10.7	3.1	1.7	1.3	39.2
4060	COLORADO RIVER AT RED MOUNTAIN SITE	14.8	13.9	11.7	11.2	10.3	12.3	21.5	58.9	71.0	37.6	20.3	16.0	299.3
4150	MUDDY CREEK AT KREMMLING	.9	.8	.7	.6	.5	.9	4.7	26.0	21.9	4.3	1.4	.8	63.6
4660	BLUE RIVER NEAR DILLON	2.8	2.1	1.8	1.6	1.3	1.4	2.2	10.1	20.5	12.7	6.5	3.8	66.9
5070	BLUE RIVER BELOW DILLON RESERVOIR	6.5	4.8	4.4	4.2	3.6	3.9	6.6	25.5	49.4	28.7	14.7	8.9	161.1
5100	STRAIGHT CREEK NEAR DILLON	.4	.3	.3	.2	.2	.2	.3	1.2	3.2	1.9	.9	.5	9.7
5750	BLUE RIVER BELOW GREEN MOUNTAIN RESERVOIR	24.4	17.4	17.8	18.5	16.3	19.7	23.6	33.2	37.4	45.4	36.6	30.2	320.6
5755	BLUE RIVER AT CONFLUENCE	24.4	17.4	17.8	18.5	16.3	19.7	23.6	33.2	37.4	45.4	36.6	30.2	320.6
5760	COLORADO RIVER BELOW BLUE RIVER AND MUDDY CREEK	40.1	32.2	30.2	30.3	27.2	32.9	49.8	118.1	130.3	87.3	58.3	47.1	683.6
5800	COLORADO RIVER NEAR KREMMLING	44.0	36.3	34.0	34.4	31.0	37.7	58.6	126.4	133.4	92.4	63.2	50.1	741.6
5810	COLORADO RIVER ABOVE PINEY RIVER	44.0	36.3	34.0	34.4	31.0	37.7	58.6	126.4	133.4	92.4	63.2	50.1	741.6
5950	PINEY RIVER NEAR STATE BRIDGE	1.1	1.0	.9	.8	.7	.9	2.9	14.9	21.0	7.0	1.9	1.0	54.1
6000	COLORADO RIVER BELOW PINEY RIVER	45.1	37.3	34.9	35.2	31.7	38.6	61.5	141.4	154.4	99.4	65.1	51.2	795.7
6050	ROCK CREEK NEAR TOPANAS	.7	.5	.5	.4	.4	.5	2.9	8.9	6.8	2.1	1.1	.7	25.5
6077	ROCK CREEK NEAR MCCOY	1.3	1.1	.9	.9	.7	1.1	5.8	17.8	13.6	4.3	2.2	1.5	51.0
6200	COLORADO RIVER ABOVE EAGLE RIVER	58.9	49.6	44.9	44.5	42.1	52.3	83.9	203.2	224.1	123.8	80.8	62.9	1071.0
6300	EAGLE RIVER AT RED CLIFF	.9	.7	.6	.6	.5	.6	1.5	7.1	10.1	3.0	1.4	1.0	28.1
6400	HOMESTAKE CREEK BELOW HOMESTAKE RESERVOIR	.7	.4	.3	.3	.2	.3	1.3	8.1	17.0	7.5	2.1	.9	39.2
6450	HOMESTAKE CREEK NEAR RED CLIFF	1.0	.7	.5	.5	.4	.5	2.3	10.6	15.0	6.3	2.7	1.3	41.9
6730	ALKALI CREEK NEAR WOLCOTT	.0	.0	.0	.0	.0	.1	.5	.7	.2	.1	.0	.0	1.6
6750	EAGLE RIVER AT EAGLE	9.3	7.5	6.5	6.2	5.5	6.5	15.0	69.1	97.1	30.2	14.6	10.0	277.5
7000	EAGLE RIVER BELOW GYPSUM	15.3	14.1	12.2	11.1	9.6	11.2	19.6	74.5	134.4	61.4	23.4	15.7	402.5
7050	COLORADO RIVER NEAR DOTSERO	74.3	63.7	57.1	55.6	51.7	63.5	103.5	277.8	358.5	185.1	104.1	78.6	1473.5
7250	COLORADO RIVER AT GLENWOOD SPRINGS	79.8	68.2	60.3	59.2	54.7	67.9	109.3	293.6	377.7	192.6	109.1	83.5	1555.7
7350	ROARING FORK RIVER NEAR ASPEN	2.2	1.7	1.6	1.4	1.2	1.4	2.6	11.5	22.8	9.9	3.0	2.2	61.6
7400	HUNTER CREEK NEAR ASPEN	.8	.6	.5	.4	.4	.4	1.1	7.7	15.8	5.9	1.5	.9	36.0
8020	FRYINGPAN RIVER BELOW RUEDI RESERVOIR	4.2	2.9	2.4	2.2	1.9	2.3	6.7	35.4	62.9	26.5	9.2	5.0	161.6
8500	ROARING FORK RIVER AT GLENWOOD SPRINGS	38.9	34.0	30.0	26.7	22.5	26.4	44.3	137.3	256.2	141.9	55.1	38.7	852.0
8750	ELK CREEK NEAR NEWCASTLE	.7	.9	1.0	1.0	1.0	1.2	1.6	7.7	9.0	2.2	.8	.4	27.5
9100	WEST DIVIDE CREEK	.8	.9	1.0	1.0	1.0	1.3	1.7	8.0	9.4	2.3	.8	.4	28.7
9210	RIFLE CREEK	.8	1.0	1.1	1.1	1.1	1.4	1.8	8.4	9.9	2.4	.8	.5	30.1
9350	PARACHUTE CREEK AT PARACHUTE	.8	1.0	1.2	1.1	1.1	1.5	1.9	9.0	10.5	2.6	.9	.5	32.1
9370	COLORADO RIVER NEAR DEBEQUE	122.8	108.0	97.1	92.2	84.1	103.3	165.4	486.9	698.2	349.0	166.8	123.2	2597.2
9380	ROAN CREEK	7.2	7.0	7.4	6.4	5.7	5.9	7.1	10.1	8.7	6.3	6.5	6.8	85.2
9550	COLORADO RIVER NEAR CAMEO	129.8	114.9	104.5	98.6	89.5	109.0	172.0	496.0	704.1	353.4	173.2	129.7	2674.6
10500	PLATEAU CREEK NEAR CAMEO	1.4	.9	.6	.5	.4	.5	1.6	10.1	19.1	7.0	2.2	1.6	45.7
10510	COLORADO RIVER BELOW PLATEAU CREEK	131.2	115.8	105.1	99.1	89.9	109.5	173.6	506.1	723.2	360.4	175.3	131.2	2720.4

A.1.2 VIRGIN FLOWS

Virgin flows were estimated at each of the 45 nodes displayed in Figure A.1.1. Tables A.1.1 and A.1.2 present the estimated average monthly virgin and historic flows at each model node. These estimates were made by considering effects due to reservoirs, transbasin diversions, in-basin diversions and return flows. The general formula used to estimate virgin flows at any node is:

$$Q_V = Q_H + D_T + D_I - R + \text{Reservoir Effects}$$

where Q_V represents virgin flows; Q_H is equal to historic flows; D_T is equal to upstream transbasin diversions; D_I represents upstream in-basin diversions; and R is equal to upstream return flows. Reservoir effects were estimated according to the following formula:

$$\text{Reservoir Effects} = I_H - O_H$$

where I_H represents historic inflow to the reservoirs and O_H is equal to historic outflow from the reservoirs. Computed inflow records were corrected for net evaporation losses from the reservoirs.

Historic flow records were obtained on computer tape from the U.S. Geological Survey (USGS). Incomplete records were filled in by correlation with flow records at nearby gaging stations. Historic transbasin diversion records, reservoir inflows and reservoir outflow data were collected from USGS Water Resources Data books, and Bureau of Reclamation Annual Operating Plans. Homestake Reservoir inflow, outflow and tunnel diversions were obtained from the City of Colorado Springs, Department of Utilities.

In-basin diversion records were obtained from the State Engineer. The information was provided on magnetic tape for the years 1975 through 1983, and as hardcopy for the years 1951 through 1974. Incomplete records were filled in by inspection of trends occurring in the existing data and by correlation against records at nearby diversions.

Return flows were estimated by applying techniques described in the USGS Open-File Report titled "Techniques for Computing Rate and Volume of Stream Depletions by Wells," (USGS, 1967). The Procedure was utilized to develop a monthly return flow schedule for each stream node. Average distances between the irrigated areas and the stream were used in the calculations.

A.1.3 OPERATION STUDIES

Six basic operation studies were conducted utilizing the Boyle Engineering Simulation Model (BESTSM). For each level of basin development (Existing, Moderate Future, and High Future), the model was run under the "without pumpback" and the "with pumpback" condition. The "with pumpback" condition refers to the operation of the Green Mountain conveyance system with the full contents of the reservoir (except for water needed to meet minimum flow requirements below the reservoir) available for exchange. The "without pumpback" condition refers to the operation of Green Mountain Reservoir according to Senate Document No. 80 and subsequent stipulations and decrees.

Proposed reservoir yields were estimated utilizing a supplemental reservoir operations model. The storable flows estimated at each site in the BESTSM simulations were used as input to the model. Reservoir firm yields were estimated by operating the model for each reservoir at various constant demands. Firm annual yield is defined for the purpose of this study as the constant volume of water that can be supplied every year without shortage during the study period of 1951 through 1983. Table A.1.3 presents the estimated reservoir firm yields. The firm yields of Wolford Mountain A' Reservoir, Wolcott Reservoir and the reservoir combinations that include Wolcott Reservoir were estimated under two conditions. The first assumes unlimited pumping capacities from the Colorado and Eagle Rivers. In the second condition, the following pipeline capacities were utilized based on an optimization analysis.

DIVERSION SOURCE	PUMPING CAPACITY	OFF-STREAM STORAGE SITE
Colorado River	150 cfs	Wolford A'
Eagle River	600 cfs	Wolcott
Colorado River	600 cfs	Wolcott

The storable flows that could be diverted with respect to the above limitations were estimated through daily flow analyses. The next section describes these analyses.

A.1.4 DIVERTABLE FLOW ANALYSES

Wolcott Reservoir was analyzed for two diversion alternatives: diversions from both the Eagle River and the Colorado River or from the Colorado River only. Wolford Mountain A' was analyzed for diversions from the Colorado River for supplementary storage. Limiting the divertable flow on an average monthly flow basis does not produce the same results as if the restrictions are made on a daily basis. Less flow will be divertable on a daily basis because peak flows often exceed the diversion capacity.

To accurately account for divertable flow, daily flow analyses were performed. The analyses required the development of daily available flow hydrographs at each of the diversion sites. This was accomplished by skimming the peaks off of the daily historic hydrograph, keeping track of the total volumes skimmed and comparing the volumes to the monthly available flow. A daily available flow hydrograph for each month was defined as the daily flow above the line where the total skimmed volume equaled the monthly available flow. The daily available flows were compared against the reservoir diversion capacity, and the divertable flows were summed up into monthly values. These flows were then used in the reservoir yield operation studies of Wolcott and Wolford Mountain A' Reservoirs.

Historic daily flows were taken from the stream gages at Colorado River near Dotsero, at Eagle River near Gypsum and at Colorado River near Kremmling.

TABLE A.1.3

ESTIMATED RESERVOIR FIRM ANNUAL YIELD 1) (1000 af/yr)

RESERVOIR	CAPACITY (1000 af)	PROJECTED EXISTING		MODERATE FUTURE		HIGH FUTURE	
		W/O PUMPBACK	W/ PUMPBACK 2)	W/O PUMPBACK	W/ PUMPBACK 2)	W/O PUMPBACK	W/ PUMPBACK 2)
Wolford Mountain A' 3) w/ Div Above Blue	120	54	44	50	42	50	42
	80	42	35	38	32	38	32
	60	33	27	29	25	29	25
Wolford Mountain A' 3) w/ Div Below Blue	120	56 (54)	49 (47)	51 (49)	46 (44)	51 (49)	45 (43)
	80	43	36	39	34	39	33
	60	35	28	31	26	30	26
Wolford Mountain A' Muddy Cr. only	120	41	41	40	40	40	39
Wolford Mountain C	80	32	31	31	30	31	29
	60	26	24	25	24	25	23
Red Mountain	140	59	58	58	56	56	54
	110	52	51	49	48	47	47
	84	43	42	39	38	36	36
Wolcott w/ 3) Eagle & Colo.	350	183 (155)	175 (149)	178 (151)	168 (143)	163 (138)	159 (135)
	220	132	126	129	122	121	112
	160	99	97	95	89	90	82
Wolcott w/ 3) Eagle only	160	96 (83)	88 (75)	93 (81)	81 (70)	80 (69)	75 (65)
	140	89	83	85	75	74	68
	100	65	58	63	54	57	49

TABLE A.1.3 (continued)

ESTIMATED RESERVOIR FIRM ANNUAL YIELD [1] (1000 af/yr)

		PROJECTED EXISTING		MODERATE FUTURE		HIGH FUTURE	
RESERVOIR	CAPACITY (1000 af)	W/O PUMPBACK	W/ PUMPBACK [2]	W/O PUMPBACK	W/ PUMPBACK [2]	W/O PUMPBACK	W/ PUMPBACK [2]
Azure	85	53	53	51	51	48	48
	60	38	38	36	36	33	33
	40	26	26	24	24	20	20
Una	196	150	150	150	150	150	150
	150	105	105	105	105	105	105
	100	55	55	55	55	55	55
Red Mountain [3] & Wolcott (Eagle)	300	111 (98)	103 (90)	109 (97)	101 (90)	106 (95)	98 (89)
Azure & [3] Wolcott (Eagle)	245	146 (133)	134 (121)	141 (129)	132 (121)	131 (120)	124 (114)
Red Mountain & Una	336	209	208	208	206	206	204

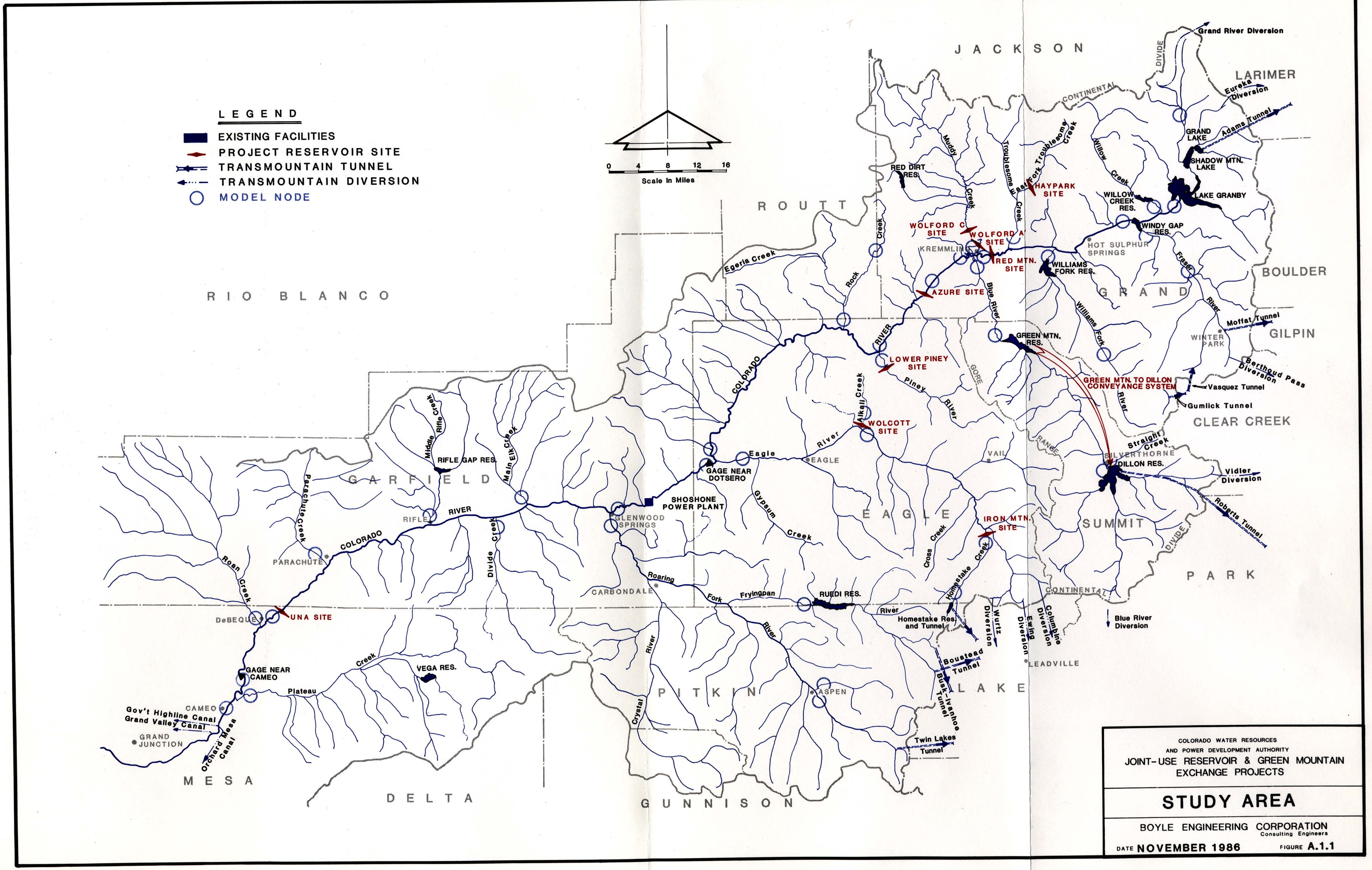
---

1) Firm Annual yield is defined as the quantity of water that can be supplied constantly every year without shortage during the study period of 1951 through 1983. Quantity expressed in thousands of acre-feet per year.

2) Based on conveyance system pumpback to Dillon Reservoir drawing upon 152,000 af available storage in Green Mountain Reservoir.

3) Firm annual yields presented without parenthesis are based on unlimited pumping capacities for river diversions. Yield figures in parenthesis are based on the following pumping capacities.

DIVERSION SOURCE	PUMPING CAPACITY	OFF-STREAM STORAGE SITE
Colorado River	150 cfs	Wolford A'
Eagle River	600 cfs	Wolcott
Colorado River	600 cfs	Wolcott



COLORADO WATER RESOURCES
AND POWER DEVELOPMENT AUTHORITY
JOINT-USE RESERVOIR & GREEN MOUNTAIN
EXCHANGE PROJECTS

STUDY AREA

BOYLE ENGINEERING CORPORATION
Consulting Engineers

DATE NOVEMBER 1986 FIGURE A.1.1

A.2.0 PROBABLE MAXIMUM FLOOD STUDIES

To size the spillways for Una and Red Mountain Dams, it was necessary to estimate the probable maximum flood (PMF) at each site. Estimates were made through the use of procedures outlined in Hydrometeorological Report No. 49, (National Weather Service, 1984), in the report Safety of Existing Dams (Committee on Safety of Existing Dams, 1983) and the HEC-1 Flood Hydrograph Model (COE, 1981).

Hydrometeorological Report No. 49 was used to estimate general storm probable maximum precipitation (PMP). The report covers the region between the crest of the Sierra Nevada on the west and the Continental Divide on the east. The region extends north to the southern limits of the Columbia River drainage and to the south to the U.S. border.

The HEC-1 model was used to compute basin runoff and to route the resulting sub-basin hydrographs down to the dam sites. The Soil Conservation Service's curve number approach for estimating direct runoff is included as an option in HEC-1. This option was utilized to generate the precipitation excess over each sub-basin. The precipitation excess values were then applied to the SCS Dimensionless Unit Graph to obtain sub-basin hydrographs at each concentration point. Routing of the resulting hydrographs was performed using the Muskingum routing techniques built into HEC-1.

A.2.1 BASIN PARAMETERS

The drainage areas above the Una and Red Mountain Dam Sites were divided into 15 and 3 sub-basins, respectively. The sub-basin areas varied from about 200 to 900 square miles. The total drainage area above Una was estimated to be about 7300 square miles. Above Red Mountain, the drainage area was estimated to be about 1400 square miles. Basin lags were computed from the following equation:

$$tp = 24n\ (L\ Lc/\sqrt{S})^{0.38}$$

where n is the Manning's roughness coefficient for overland flow, L is the length of the main stream from the sub-basin outlet to its divide, Lc is the distance from the outlet to a point on the stream nearest the centroid of the basin, and S is the average slope of the main water course.

Runoff curve numbers were estimated from the Soil Conservation Service's (SCS) National Engineering Handbook (SCS, 1969), using hydrologic soil group and vegetation information.

Travel times through river reaches were estimated by applying channel geometry and slope estimates to Manning's equation at various discharges. The resulting velocities and the measured reach lengths were then used to compute the travel times.

A.2.2 PROBABLE MAXIMUM PRECIPITATION

Two types of general-storm PMP were estimated for each site: orographic and convergence PMP. Convergence precipitation is due to atmospheric processes not affected by terrain, and orographic precipitation is caused by moist air forced upward by mountain slopes. Convergence PMP values were adjusted for barrier elevation, durational variation, areal reductions. The orographic PMP values were adjusted for area reductions and seasonal variations. Estimates of both types of PMP were made for both the Una and Red Mountain Dam Sites.

A.2.3 HEC-1 SIMULATIONS

The HEC-1 model was run separately to estimate PMF's at the Una and Red Mountain Dam Sites. At the Una Dam Site, the hydrograph computed by HEC-1 due to the PMP was superimposed onto an estimate of the 100-year flood hydrograph. Superimposing the 100-year flood provides for the consideration of 100-year snowpack conditions in the basin. Areas subject to snow accumulation require the evaluation of snowmelt as added contributions to flood flows. The procedure used is the method most often applied by the Bureau of Reclamation. The incorporation of snowmelt into the PMF estimate is also recommended by the Committee on Safety of Existing Dams (1983) and the Corps of Engineers HEC-1 documentation (1981).

The 100-year flood at the Una Dam Site was estimated using the Corp of Engineer's Flood Flow Frequency Analysis program (COE, 1982). Historic instantaneous peak annual discharge records were used in the analysis. These discharges were taken from gage records at: Colorado River near DeBeque (1967-1984) and Colorado River near Cameo (1935-1966). The results of the analysis indicate that the 100-year peak flood discharge at the Una Dam Site is about 42,000 cfs.

A total 15-day volume was estimated for the 100-year flood by extrapolation of a curve dipicting historic 15-day volumes versus peak discharge. This volume was then used to estimate a 15-day hydrograph by distributing the 100-year volume according to the historic distributions of several historic events that come close to the estimated 100-year peak discharge. This hydrograph was then superimposed (with peaks matching with respect to time) with the hydrograph generated by HEC-1 due to the PMP estimates. The PMF at the Una Reservoir Site has an estimated peak discharge of 340,000 cfs, and a total volume of 1,900,000 af. Figure A.2.1 presents the estimated PMF hydrograph at the Una Reservoir Site.

The PMF at the Red Mountain Site was computed through a similar procedure. The nearest gaging station to the site is Colorado River near Kremmling. The period of record at this station is short. Therefore, the flood frequency estimates made at this station were adjusted to reflect the flood experience at the Cameo and DeBeque gages. The 100-year peak discharge at Colorado near Kremmling was reduced by the ratio of the square root of the drainage areas to get the 100-year peak discharge at the Red Mountain Dam Site. The estimated 100-year peak discharge at the site was estimated to be 15,100 cfs. The hydrograph of the 100-year event was estimated in the same way as the 100-year hydrograph at the Una Site. The 100-year hydrograph was then superimposed with the hydrograph generated by HEC-1 due to the PMP estimates.

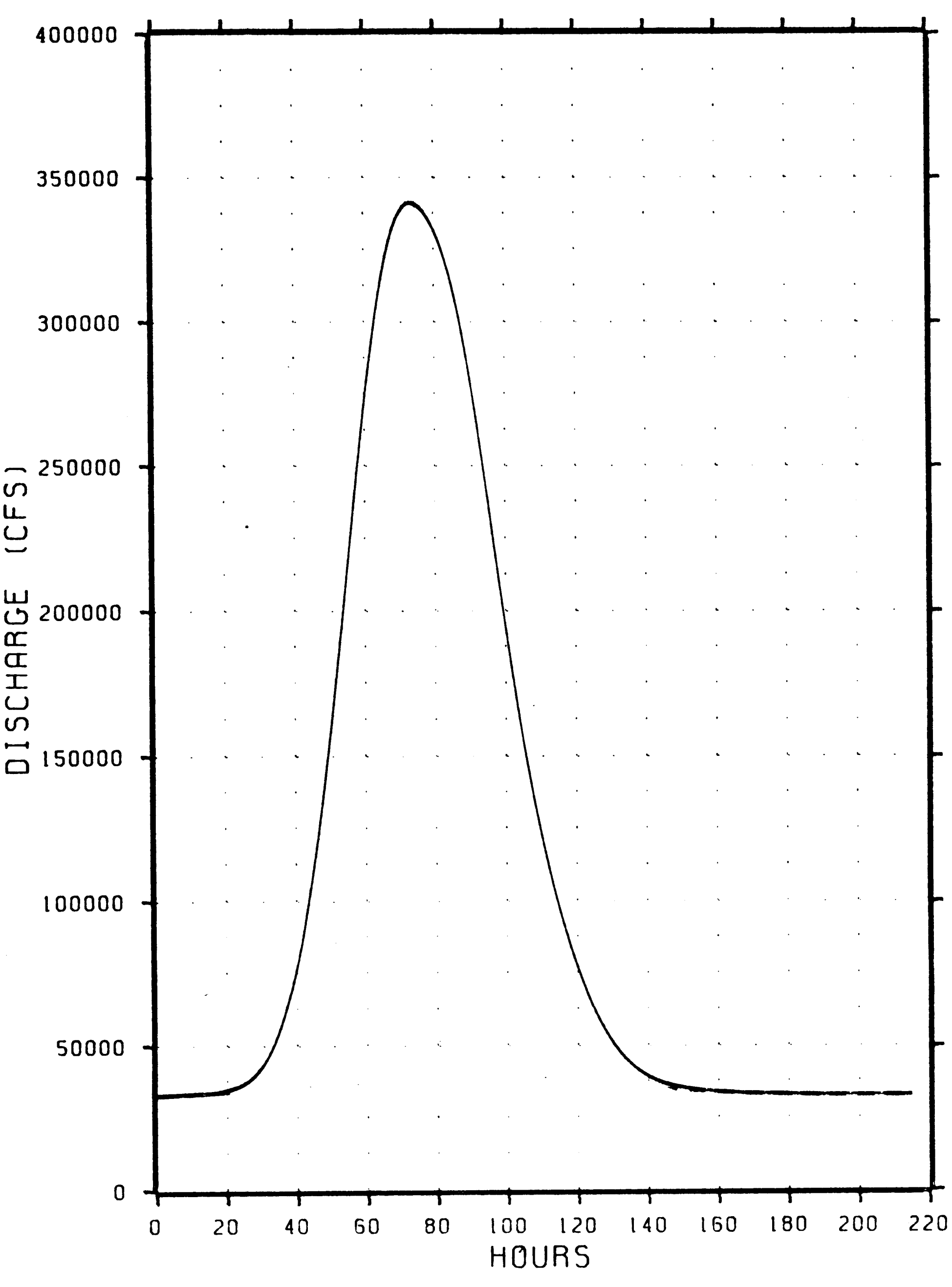
The estimated peak discharge for the PMF estimated at the Red Mountain Dam Site equals 240,000 cfs and the total volume is 680,000 af. Figure A.2.2 presents the estimated PMF hydrograph at the Red Mountain Dam Site.

Figure A.2.3 presents a comparison of the probable maximum peak discharges at the Una and Red Mountain Dam Sites against previously estimated peak discharges at the Wolcott, Wolford and Azure Dam Sites. The graphs depicts peak discharges per square mile versus drainage area. It can be seen that the estimated peak discharges at the Una and Red Mountain sites compare favorably against the Creager Envelope Curve. The Creager formula describes an empirical relationship between drainage basin characteristics and peak flood discharges:

$$q = 46CA^{(0.894A^{-0.048} - 1)}$$

where C is dependent on geographic climatological and hydrological characteristics of the basin, and A is the drainage area in square miles. The value of q is in cfs per square mile. (Committee on Safety of Existing Dams, 1983). It was estimated that a C value of 45 is representative of the Upper Colorado River Basin.

FIGURE A.2.1



PROBABLE MAXIMUM FLOOD
UNA RESERVOIR SITE
DISCHARGE (CFS)
400000
350000
300000
250000
200000
150000
100000
50000
0
0
20
40
60
80
100
120
140
160
180
200
220
HOURS

FIGURE A.2.2

PROBABLE MAXIMUM FLOOD

RED MOUNTAIN RESERVOIR SITE

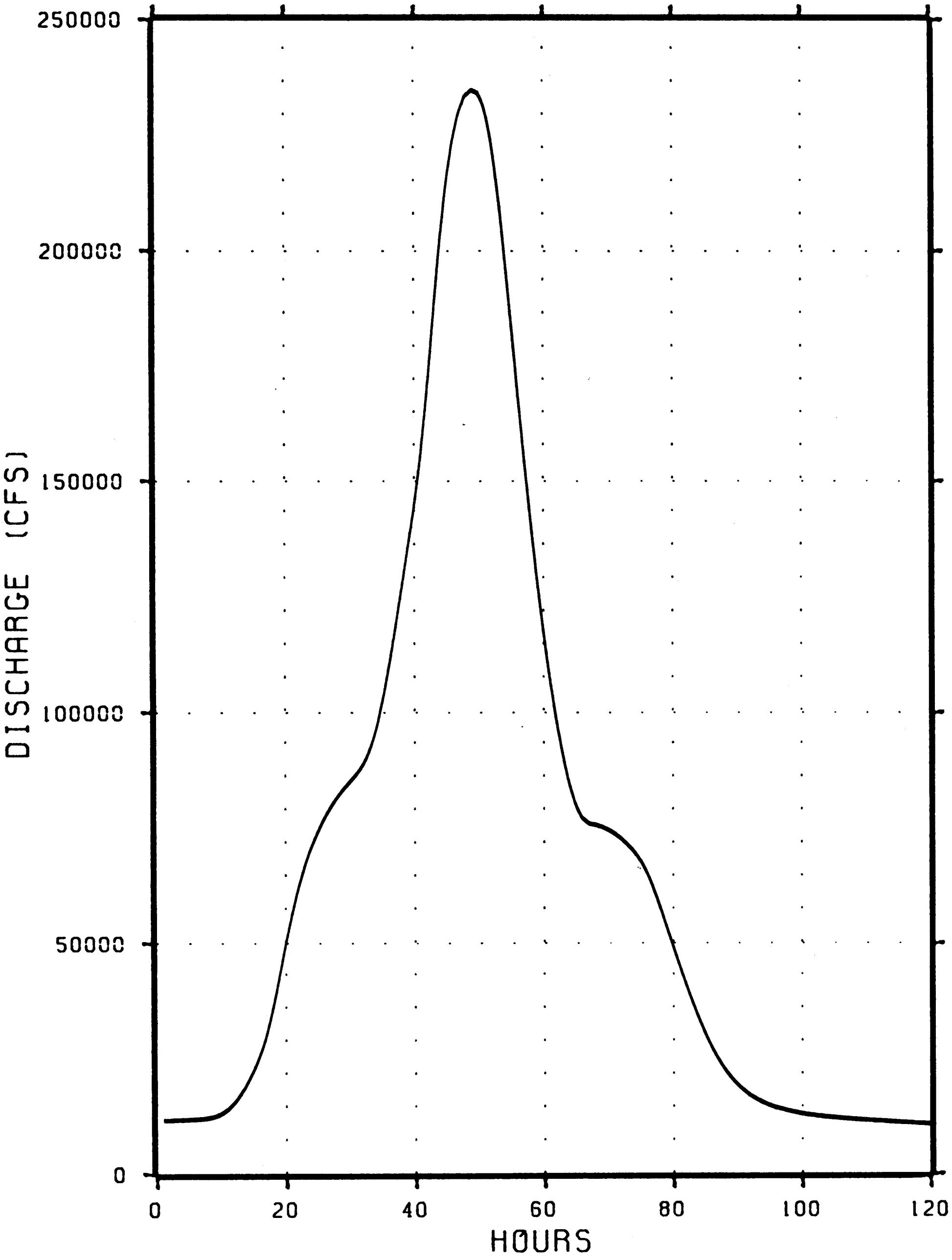
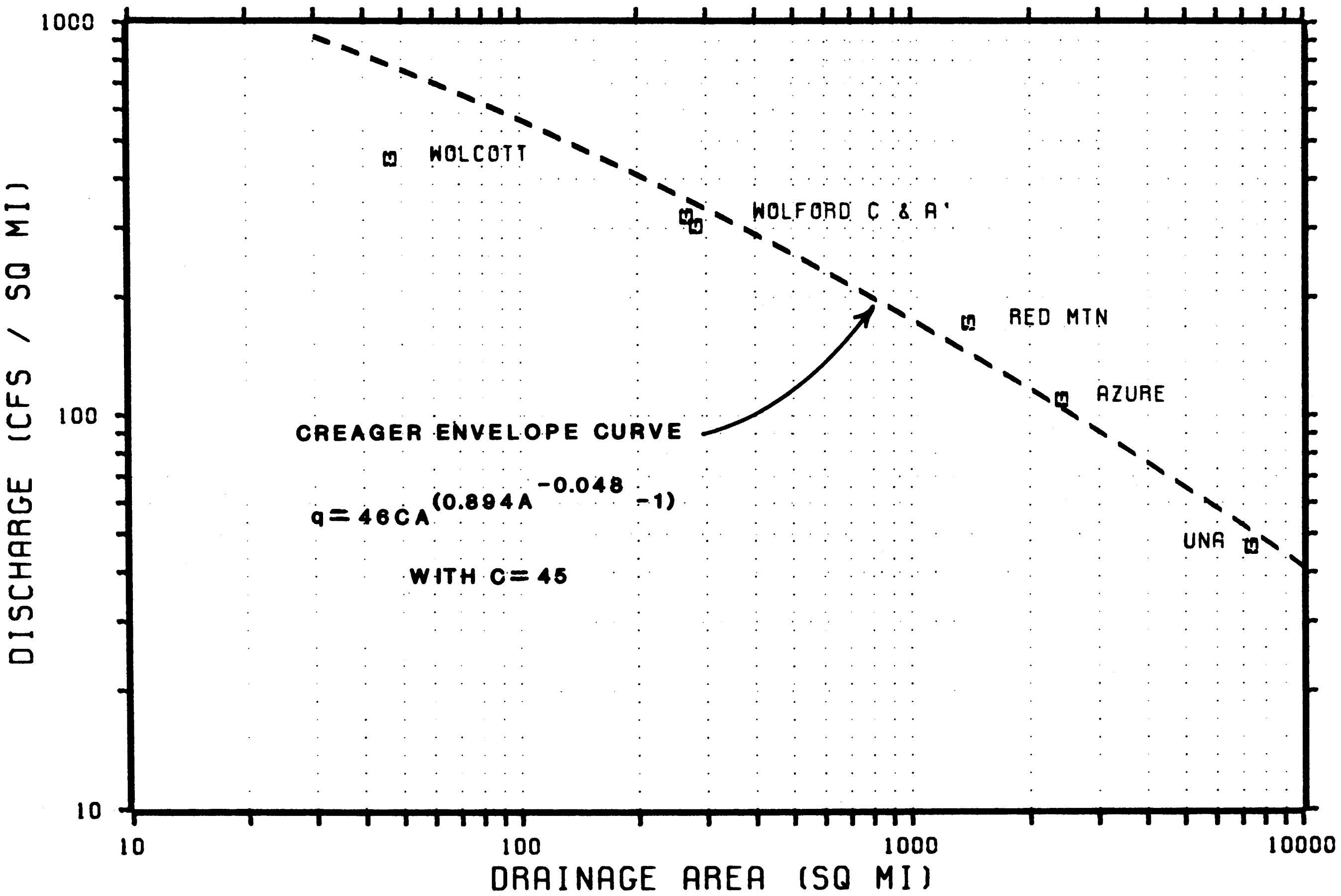


FIGURE A.2.3

PROBABLE MAXIMUM PEAK DISCHARGES

UPPER COLORADO RIVER BASIN



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APPENDIX B

APPENDIX B

PRELIMINARY DAM DESIGN, RESERVOIRS
AND
CONVEYANCE SYSTEM

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APPENDIX C

APPENDIX C

SUMMARY OF THE GEOTECHNICAL INVESTIGATIONS

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Tables and Figures are reproduced from Chen and Associates, 1986. Preliminary Report of Geotechnical Investigations of Wolford Mountain Site A', Red Mountain Site and the Conveyance System Route.

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C.1.0 INTRODUCTION

This report presents a summary of preliminary geotechnical investigations for the following projects:

- o Wolford Mountain Site A' Dam and Reservoir
- o Red Mountain Dam and Reservoir
- o Conveyance System to Dillon Reservoir from Green Mountain Reservoir

The investigations were carried out by the geotechnical firm Chen & Associates to provide geotechnical and geological information as a basis for the reconnaissance level study of the dams and reservoirs and conveyance system pipeline and pump stations. Each investigation included a review of available information, geological reconnaissance, field investigation, laboratory testing and analyses.

Dam and Reservoirs

Geologic studies of the dam and reservoir areas employed aerial photographs, published information and field observations. Detailed geologic maps were developed from geological reconnaissance of the site.

Samples of the soil and bedrock obtained from the exploratory program were tested in the laboratory. Standard properties and strength characteristics of the dam foundation materials were evaluated.

Conveyance System

A generalized soil profile was obtained along the alignment by drilling at selected locations to develop opinions on the potential impacts of geotechnical factors such as shallow ground water, rock excavation and existing landslides on the proposed construction. Material samples obtained during the field exploration were tested in the laboratory for classification and gradation characteristics.

C.2.0 WOLFORD MOUNTAIN SITE A' DAM AND RESERVOIR

Wolford Mountain Site A' Dam and Reservoir would be constructed on Muddy Creek near Kremmling, Colorado, shown on Figure C.2.1. The information in this section is from "Preliminary Geotechnical Investigation Wolford Mountain Dam and Reservoir Site A' Kremmling, Colorado, Chen & Associates, September, 1986.

C.2.1 FOUNDATION CONDITIONS

Three exploratory holes, 1 through 3, were drilled at the preliminary dam axis. Hole locations and surface geology are shown on Figure C.2.2a. The legend for the surface geology map is presented in Figure C.2.2b. After the field investigation was completed, a revised dam axis was identified slightly upstream of the original dam axis. No holes were drilled at the revised dam axis. The following discussion of the dam foundation conditions is for the original axis. Very similar conditions are expected for the revised dam axis with the exception that the terrace gravels on the left abutment probably will have less impact on the dam.

Soils

A layer of alluvial soil up to approximately 30 feet in thickness can be anticipated overlying the bedrock in the valley bottom based on the conditions encountered in Hole 2 and Holes B-1 and B-3. Valley bottom soils consist of interlayered silty sands, clayey sands with scattered gravels, and sandy clay.

On the left abutment, Hole 1 encountered 38 feet of terrace sands and gravel overlying bedrock. Boring 3 on the right abutment encountered 15 feet of colluvial soils overlying bedrock.

Rock

The Cretaceous-age Pierre Shale underlies the overburden soils. This material consists of dark-gray shales and claystones with several fine-grained, thinly-bedded sandstone beds from 20 to 50 feet in thickness. The sandstone is generally moderately cemented. Rock quality designation (RQD) in the bedrock was generally high, averaging greater than 90 percent below 10 feet from the bedrock surface.

Laboratory test results on samples of the bedrock indicate unconfined compressive strengths ranging from 8,400 psi to 13,300 psi. A soft clay seam, 3 inches in thickness, was encountered in Hole 2 at a depth of 75 feet. Based on the laboratory test results, this may be a layer of bentonite.

The rock mass rating (RMR) classification of the bedrock was calculated. This rating system provides a quantitative method of categorizing the engineering character of the rock mass based on core hole information. The classification system is based on six parameters; (1) the uniaxial compressive strength of the intact core; (2) the rock quality designation (RQD); (3) the joint or fracture spacing; (4) the joint or fracture orientation; (5) the joint or fracture condition; and (6) the ground water condition. Relative weighting factors are attached to each of the six parameters which are summed to obtain a RMR on a scale of 0 to 100 (Class 1 to Class 5). An average RMR of 50 was obtained. This values indicates the rock is generally fair. Based on the RMR value, a rock mass strength envelope with a friction angle of 35^{o} and a cohesion of 30^{o} psi may be used for modeling the foundation materials.

Ground Water

Free water was measured in Hole 1 on the left abutment at a depth of 53 feet below the ground surface when checked on August 28, 1986. Free water was not encountered in Hole 3 on the right abutment. Free water was encountered in Hole 2 at a depth of 6 feet in the valley bottom. The water levels appear to indicate the ground water regime is recharging Muddy Creek.

Foundation Permeability

In-place packer permeability tests were conducted in the shale and sandstone bedrock in Holes 1 and 2. Results of the 12 tests indicate variable permeabilities from 0 feet per year to 361 feet per year.

Spillway

No exploratory borings were drilled in the proposed spillway location on the left abutment. Based on the conditions encountered in Hole 1, a layer of terrace gravels should be anticipated consisting of silty sand and gravel to a depth of approximately 30 feet along the spillway alignment where it cuts through the existing ridge. Beneath the gravels, Pierre Shale will be encountered. Pierre Shale outcrops were noted on the north side of the ridge where the spillway will discharge into Muddy Creek.

Outlet Works

No exploratory borings were drilled for possible outlet works alignments. For an outlet works location on one of the abutments, the bedrock will consist of Pierre Shale with possible layers of sandstone.

C.2.2 SUBSURFACE EXPLORATION PROGRAM

The field investigation included nineteen exploratory borings in the dam, remote spillway, tunnel and borrow areas. Locations of the borings are shown on Figure C.2.2. The exploratory drilling was conducted with a Mobile B-80 drill rig and a CME-45 drill rig. Drilling was conducted in general accordance with ASTM D-1452 and D-2113 procedures.

In the dam foundation, Hole 1 through 3 were advanced through the overburden soils with a 7-inch diameter hollow stem auger. Exploration of the underlying bedrock in Hole 1 and 2 was accomplished with NX diamond bits which obtained a 1 7/8-inch diameter core sample. Continuous test hole logs were made.

Samples of the overburden soils were obtained with 2-inch and 1 3/8-inch I.D. spoon samplers. The samplers were driven into the various strata with blows from a 140-pound hammer falling 30 inches. This test is similar to the standard penetration tests described by the ASTM method D-1586. Depths at which the samples were taken are shown on the logs of exploratory holes, Figures C.2.3 through C.2.8. Figure C.2.9 contains the accompanying notes. Samples were obtained at approximate 5-foot intervals.

Bedrock core obtained from the holes was logged. A description of the core included a lithological description and a systematic classification for alteration and hardness of the material. The alteration and hardness were based on the field identification procedures. Discontinuities in the core were logged for orientation, roughness, planarity and filling. The fractures per foot were also recorded.

Rock quality designation (RQD) of each core run was calculated. The method was developed by Deere, 1966, and is used to provide a field standard for the classification of rock quality. The RQD is calculated as the total length of core pieces 4 inches in length or greater divided by the length of each core run. The RQD values were calculated immediately upon removal of the core from the core barrel. The RQD values are shown on the right sides of the boring logs.

In-place permeability throughout portions of Holes 1 and 2 were measured at 10-foot intervals by conducting single-stage packer permeability tests. The packer permeability tests were used to evaluate zones of high permeability. The tests were conducted after each 10-foot section of hole was cored. The test consisted of placing a pneumatic seal 10 feet from the bottom of the hole. Water was then pumped under pressure into the test section. The water was pumped at a measured pressure and the flow recorded until a constant flow rate was obtained. The test was conducted at an initial pressure and then the pressure was increased and the test rerun. The water pressure was then returned to the initial pressure and the test conducted for a third time. The permeability of the test section was taken as the average of the tests run for each section. Results of the packer tests are shown in Table C.2.1.

The exploratory borings drilled in the remote spillway, the tunnel outlet and the borrow area were advanced using 4-inch diameter continuous flight augers and relatively undisturbed samples of the soil and bedrock were obtained at approximate 5-foot intervals. The bedrock was cored in Hole 4.

Plastic pipe observation wells were installed in Holes 1 through 6 for continued water-level monitoring. The observation wells were installed with a perforated zone extending the entire depth of bedrock in each hole. Measurements of the water level were made with a weighted plumb line subsequent to drilling. The water levels and the date of measurement are shown on Table C.2.2.

C.2.3 LABORATORY TESTING PROGRAM

A laboratory investigation was conducted to study the standard properties and engineering characteristics of the materials obtained from the test holes. Samples obtained from the exploratory holes were examined and classified in the field by the project geologist. The samples were then returned to the laboratory for examination and visual classification by the project engineer. Samples were selected for testing and the remaining samples were placed in storage. Laboratory testing was performed on the selected samples to determine their classification, moisture content, density, strength, compaction and pinhole dispersion. Results of the testing have been filed with the Authority. The testing was conducted in general accordance with recognized test procedures, primarily those of the American Society for Testing and Materials (ASTM).

TABLE C.2.1

Summary Of Packer Permeability Tests

Project: Wolford Mt. Dam
Job No.: 1-471-86
Date: 9-1-86
Operator: Mock

Project File: WOLF
Base Program: PERM
Unsorted

Hole No.	Top Test Sec. (ft)	Bottom Test Sec. (ft)	Test Length (ft)	Hole Dia. (in)	Total Head (ft)	Water Take (gpm)	Perm. (ft/yr)	Avg. Perm. (ft/yr)	Material	Depth Ground Water (ft)
1	52	60	8	3	111	0.2	13	7	Shale	53
1	52	60	8	3	169	0.2	8	7	Shale	53
1	52	60	8	3	111	0.0	1	7	Shale	53
1	60	70	10	3	145	0.0	1	6	Shale	53
1	60	70	10	3	238	0.4	9	6	Shale	53
1	60	70	10	3	145	0.2	8	6	Shale	53
1	70	80	10	3	145	0.0	0	6	Shale	53
1	70	80	10	3	238	0.8	17	6	Shale	53
1	70	80	10	3	145	0.0	0	6	Shale	53
2	37	45	8	3	64	0.4	36	149	Shale	6.2
2	37	45	8	3	122	3.8	184	149	Shale	6.2
2	37	45	8	3	64	2.5	228	149	Shale	6.2
2	45	55	10	3	64	7.1	542	361	Shale	6.2
2	45	55	10	3	122	9.2	371	361	Shale	6.2
2	45	55	10	3	64	2.2	169	361	Shale	6.2
2	55	65	10	3	99	0.0	0	0	Shale	6.2
2	55	65	10	3	191	0.0	0	0	Shale	6.2
2	55	65	10	3	99	0.0	0	0	Shale	6.2
2	65	75	10	3	99	0.1	4	1	Shale	6.2
2	65	75	10	3	191	0.0	0	1	Shale	6.2
2	65	75	10	3	99	0.0	0	1	Shale	6.2
2	75	85	10	3	110	0.0	2	4	Shale	6.2
2	75	85	10	3	214	0.5	11	4	Shale	6.2
2	75	85	10	3	110	0.0	0	4	Shale	6.2
2	85	95	10	3	110	0.0	0	1	Sandstone	6.2
2	85	95	10	3	214	0.1	3	1	Sandstone	6.2
2	85	95	10	3	110	0.0	0	1	Sandstone	6.2
2	95	105	10	3	122	0.0	0	26	Sandstone	6.2
2	95	105	10	3	237	3.7	77	26	Sandstone	6.2
2	95	105	10	3	122	0.0	0	26	Sandstone	6.2
2	105.4	115.4	10	3	122	0.2	8	41	Sandstone	6.2
2	105.4	115.4	10	3	237	5.3	110	41	Sandstone	6.2
2	105.4	115.4	10	3	122	0.1	4	41	Sandstone	6.2
2	110	120	10	3	122	0.0	0	46	Sandstone	6.2
2	110	120	10	3	237	6.0	124	46	Sandstone	6.2
2	110	120	10	3	122	0.4	15	46	Sandstone	6.2

TABLE C.2.2

TABLE A-2
SUMMARY OF WATER LEVEL READINGS

Job No. 1 571 86

Hole	Time of Drilling	8/28/86	9/4/86	10/1/86
1	N.M.	53.0	53.0	54.0
2	N.M.	6.2	6.4	7.0
3	N.M.	N.E.	N.E.	N.E.
4	N.E.	N.E.	N.E.	N.E.
5	N.E.	N.E.	N.E.	N.E.
6	N.E.	N.E.	N.E.	N.E.
B-1	120	N.M.	N.M.	N.M.
B-2	4.0	N.M.	N.M.	N.M.
B-3	8.2	N.M.	N.M.	N.M.
B-4	7.1	N.M.	N.M.	N.M.
B-5	4.0	N.M.	N.M.	N.M.
B-6	5.0	N.M.	N.M.	N.M.
B-7	3.0	N.M.	N.M.	N.M.
B-8	N.E.	N.M.	N.M.	N.M.
B-9	4.5	N.M.	N.M.	N.M.
B-10	7.8	N.M.	N.M.	N.M.
B-11	N.E.	N.M.	N.M.	N.M.
B-12	N.E.	N.M.	N.M.	N.M.
B-13	N.E.	N.M.	N.M.	N.M.

N.M. - Not Measured
N.E. - Not Encountered

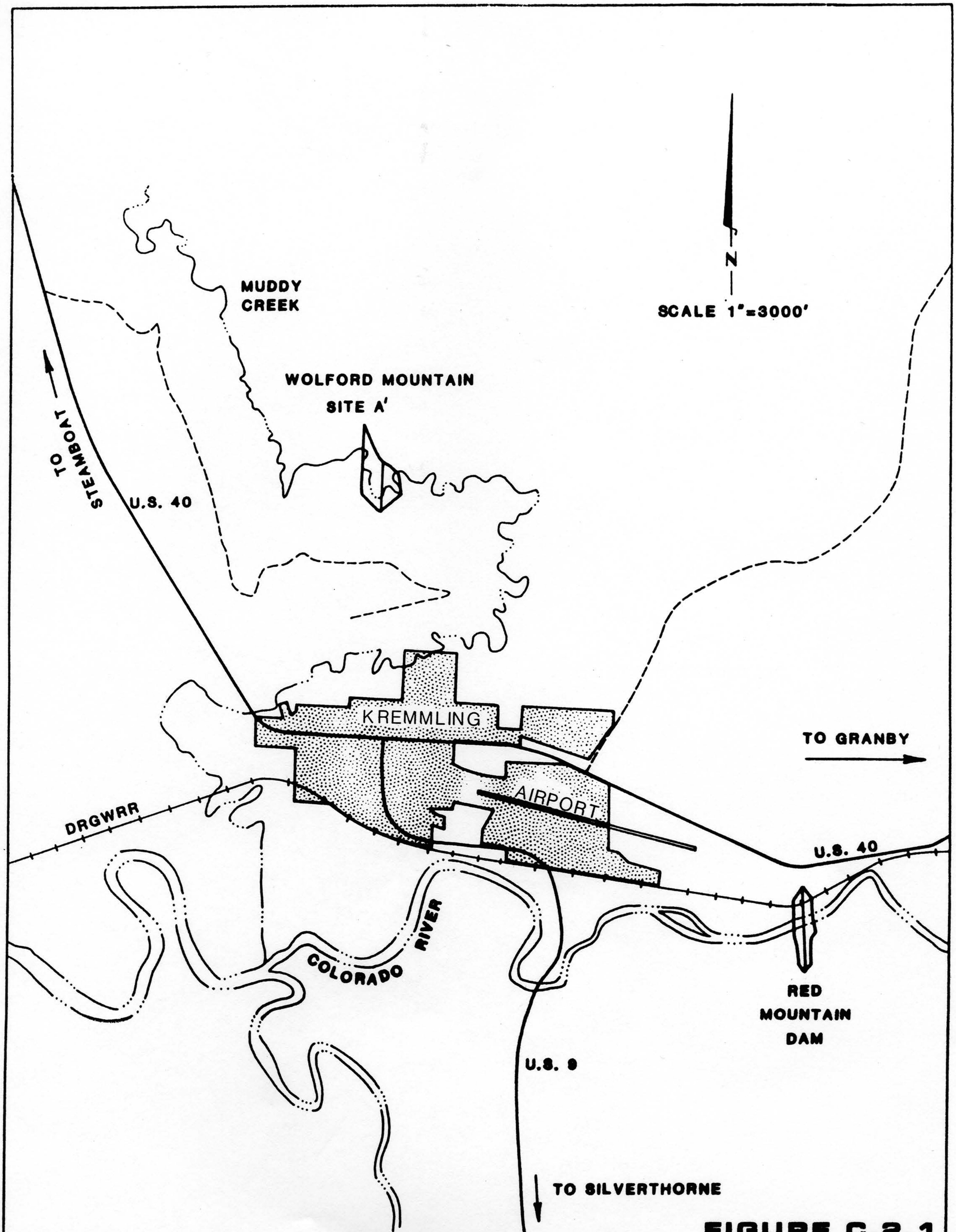
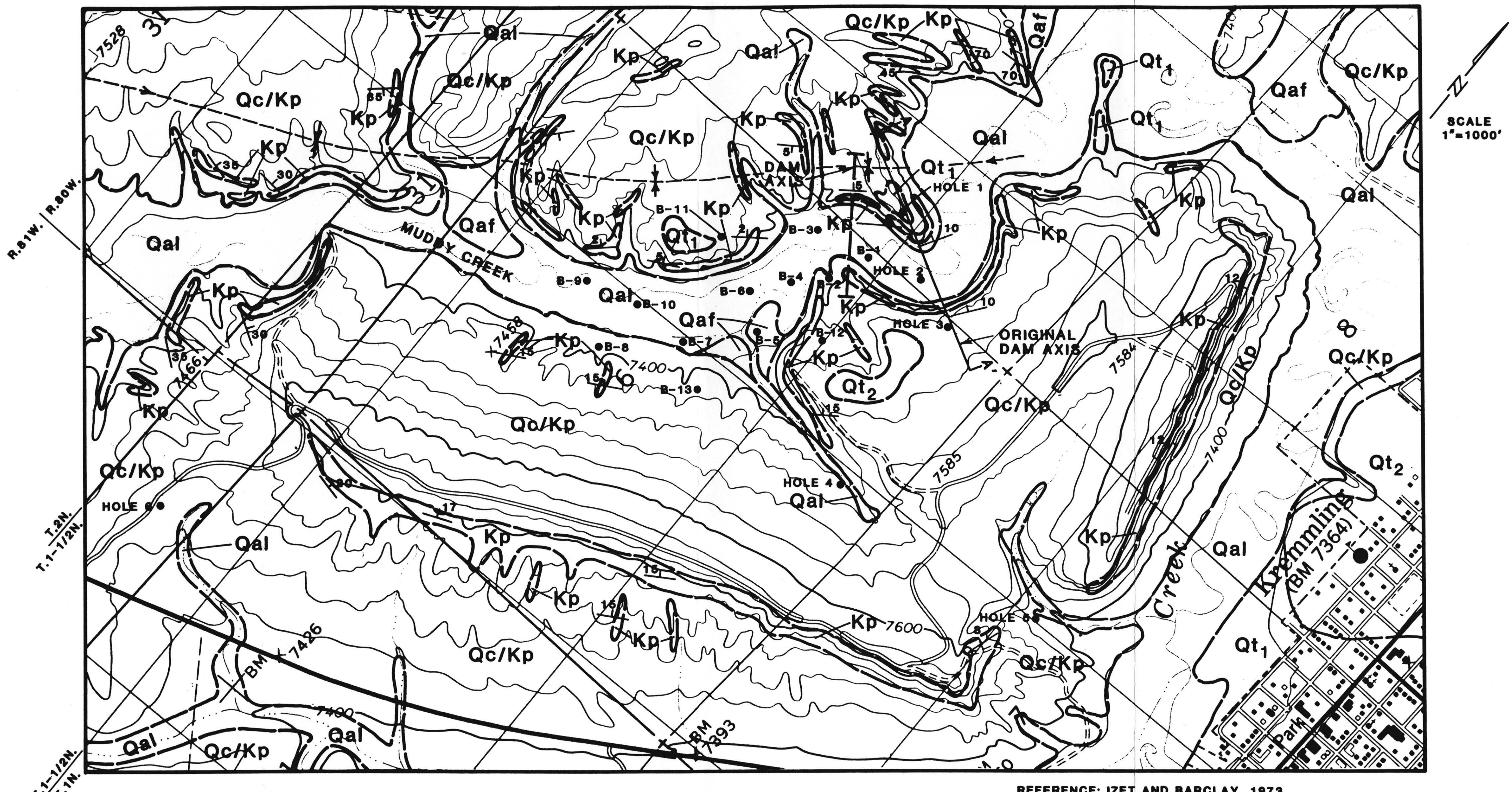


FIGURE C.2.1

1 571 86	Chen & Associates	VICINITY MAP	Fig. 1



NOTES:

1.) EXPLANATION IS ON FIG. 3.

2.) GEOLOGIC CROSS SECTION SHOWN ON FIG. 4.

REFERENCE: IZET AND BARCLAY, 1973.
GEOLOGIC MAP OF THE
KREMMLING QUADRANGLE,
GRAND COUNTY, COLORADO.

FIGURE C.2.2a

1 571 86

Chen & Associates

WOLFORD MOUNTAIN DAM SITE A'

SURFICIAL GEOLOGIC MAP

Fig. 2

EXPLANATION:

SURFICIAL DEPOSITS:

QUATERNARY

Qal
VALLEY ALLUVIUM

Qaf
ALLUVIAL FAN

$Qt_{1,2}$
TERRACE ALLUVIUM

Qc
COLLUVIUM

BEDROCK UNITS:

UPPER CRETACEOUS

Kp
PIERRE SHALE
Undifferentiated

— — — —
CONTACT
Approximate boundary
of map units

⅃ 45°
STRIKE AND DIP OF BEDS

A ├──────┤ A'
GEOLOGIC CROSS SECTION

● H-1
TEST HOLE
Approximate location

Qc/Kp
DUAL SYMBOL
Represents surficial deposit
overlying bedrock

— → — — — ✝ — — — ← —
SYNCLINE
Approximate location of
syncline axis

FIGURE C.2.2b

1 571 86
Chen & Associates
WOLFORD MOUNTAIN DAM
LEGEND FOR SURFICIAL GEOLOGIC MAP
Fig. 3

CORE LOG

Job No. 1 571 86

Sheet 1 **of** 2

Project Wolford Mountain Site A'

Location Left Abutment

Hole 1

Ground Elevation 7446'

Total Depth 80.0'

Depth of Overburden 39.0'

Angle from Horizontal -90°

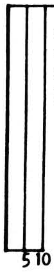
Bearing of Angle Hole

Depth of Water not encountered

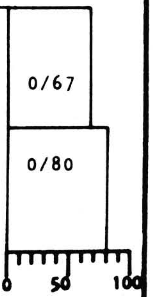
Begun 8/20/86

Finished 8/21/86

Depth	GEOLOGIC LOG	GRAPHIC LOG Test Results	DISCONTINUITY LOG Depth and Elevation (Feet)	% RQD/ % Recovery 0 50 100
0	Clays: (CL) Sandy to very sandy, low plastic, stiff, dry, brown.		Hole advanced from 0' to 40.0' by O.D. hollow stem auger.	
5		24/12		
	Sand and Gravel: (SM-GM) fine to coarse grained, silty, slightly clayey, dense to very dense, dry to moist, olive brown.			
10		50/9		
15		28/12 WC=4.3 -200=11		
20		19/6,33/6, 47/6		
25		19/6,23/6, 24/6		
30		20/6,27/6,41/6 WC=5.7 -200=19		
35		108/12		
40	Sandstone: Olive gray, bedded, fine grained, silty, friable to hard, moist, numerous thick interlayers of siltstone and shale. Iron oxide staining to 60'	84/12	Several joints along bedding, slightly rough, planar, clean. Hole advanced from 40.0' to 80.0' with NX core bit.	0/67
45		80/3		0/80
	Shale: Olive tan, low plastic to moderately hard, moist with numerous thin fine grained sandstone layers.	80/2		
50		BD=151.8 UC=8400		



Fracture/ft.



▮ Standard penetration test.

▣ Coresample tested

▨ Packer permeability test section K in ft/yr.

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LOG OF HOLE 1

1 571 86

Fig. A-1

FIGURE C.2.3a

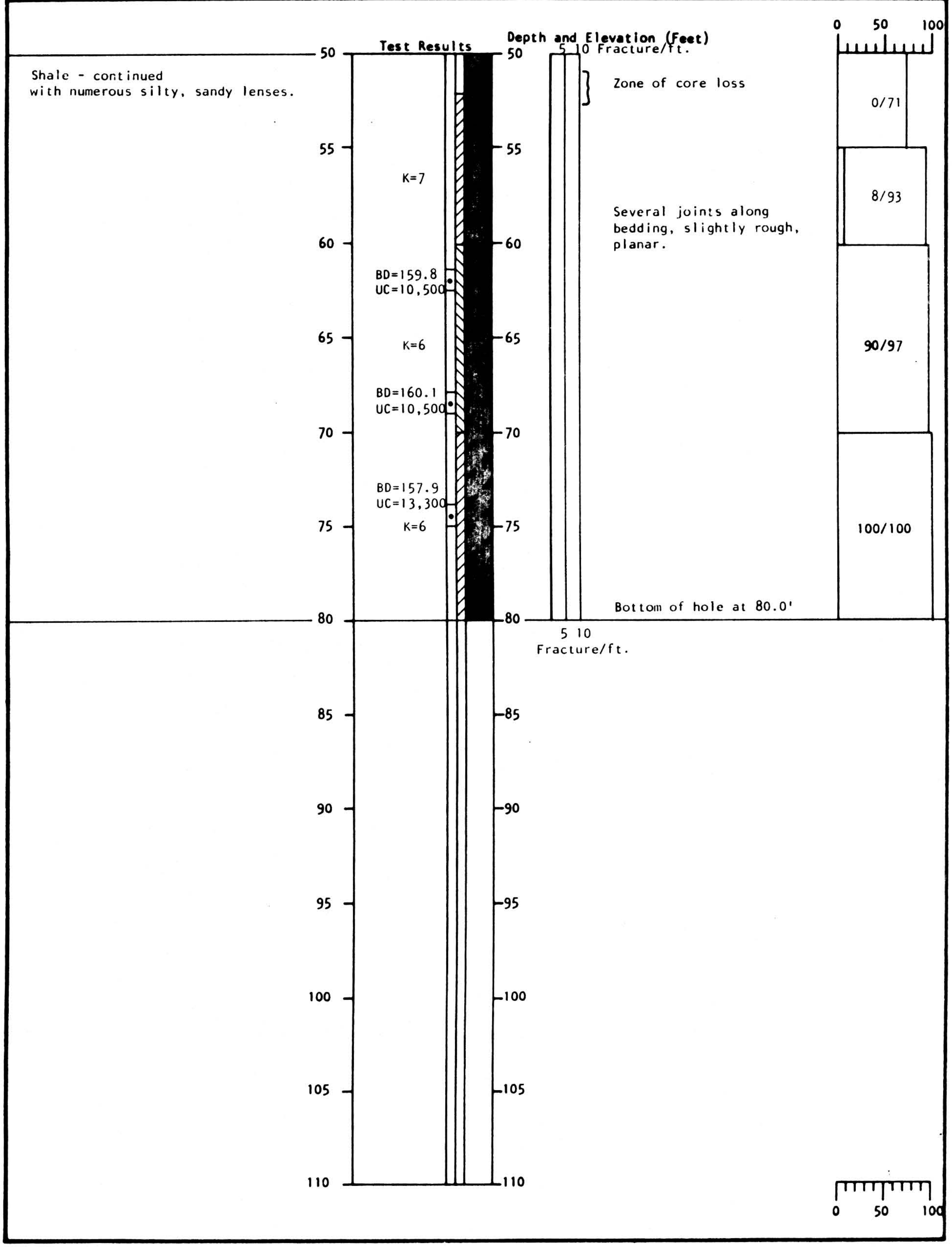
Job No. 1 571 86

CORE LOG

Sheet 2 **of** 2

Hole 1 **Continued**

GEOLOGIC LOG	GRAPHIC LOG	DISCONTINUITY LOG	% RQD/ % Recovery



Shale - continued
with numerous silty, sandy lenses.

Zone of core loss

Several joints along bedding, slightly rough, planar.

Bottom of hole at 80.0'

FIGURE C.2.3b

CORE LOG

Job No. 1 571 86

Sheet 1 of 3

Project Wolford Mountain Site A'

Location Dam Centerline

Hole 2

Ground Elevation 7346'

Total Depth 120.0'

Depth of Overburden 27.5'

Angle from Horizontal -90°

Bearing of Angle Hole

Depth of Water 8.0'

Begun 8/22/86

Finished 8/22/86

GEOLOGIC LOG	GRAPHIC LOG	DISCONTINUITY LOG	% RQD/ % Recovery

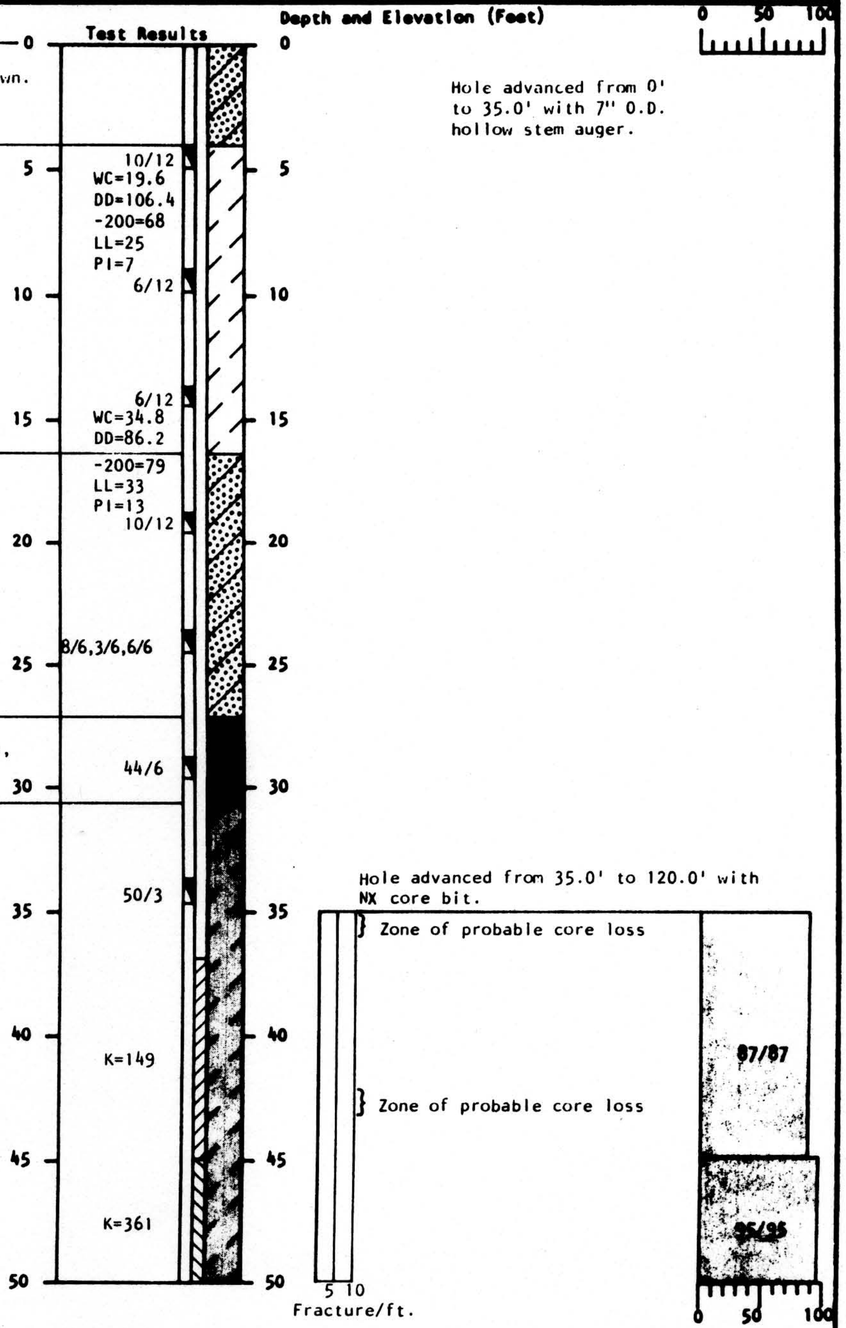
Sand: (SM) silty, stiff, moist, brown.

Clay: (CL) silty, slightly sandy, stiff, very moist, brown.

Sand: (SM) silty, dense, moist to wet, brown, scattered gravel.

Sandstone: dark gray, fine grained, moderately hard, moist.

Shale: dark gray, very low to low hardness, moist.



Hole advanced from 0' to 35.0' with 7" O.D. hollow stem auger.

Hole advanced from 35.0' to 120.0' with NX core bit.

Standard penetration test.

Core sample tested

Packer permeability test section
K in ft/yr

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LOG OF HOLE 2

1 571 86

Fig. A-2

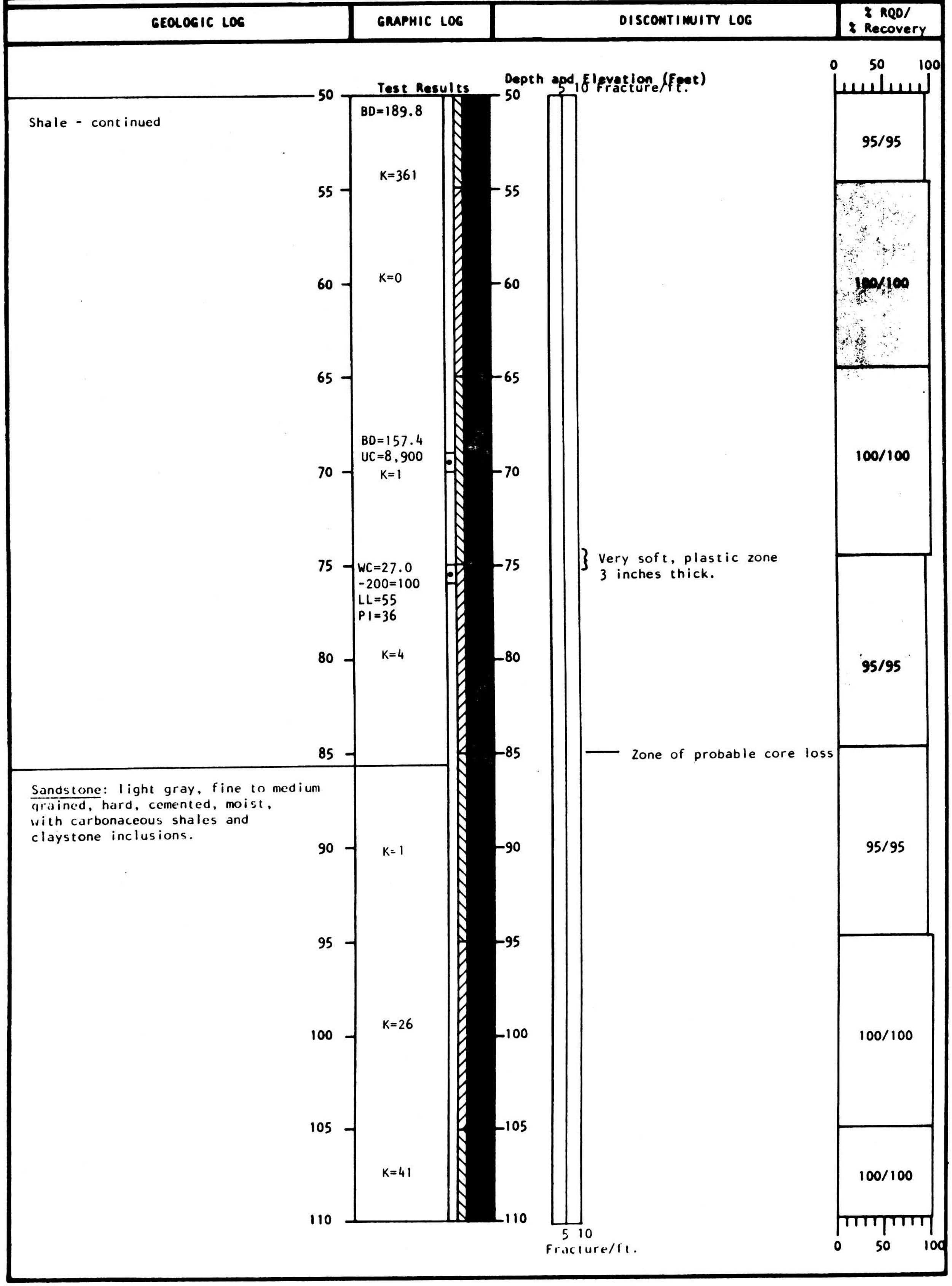
FIGURE C.2.4a

Job No. 1 571 86

CORE LOG

Sheet 2 **of** 3

Hole 2 **Continued**



Shale - continued

Sandstone: light gray, fine to medium grained, hard, cemented, moist, with carbonaceous shales and claystone inclusions.

} Very soft, plastic zone 3 inches thick.

Zone of probable core loss

FIGURE C.2.4b

Job No. 1 571 86

CORE LOG

Sheet 3 of 3

Hole 2 Continued

GEOLOGIC LOG	GRAPHIC LOG	DISCONTINUITY LOG	% RQD/ % Recovery

Sandstone:- continued

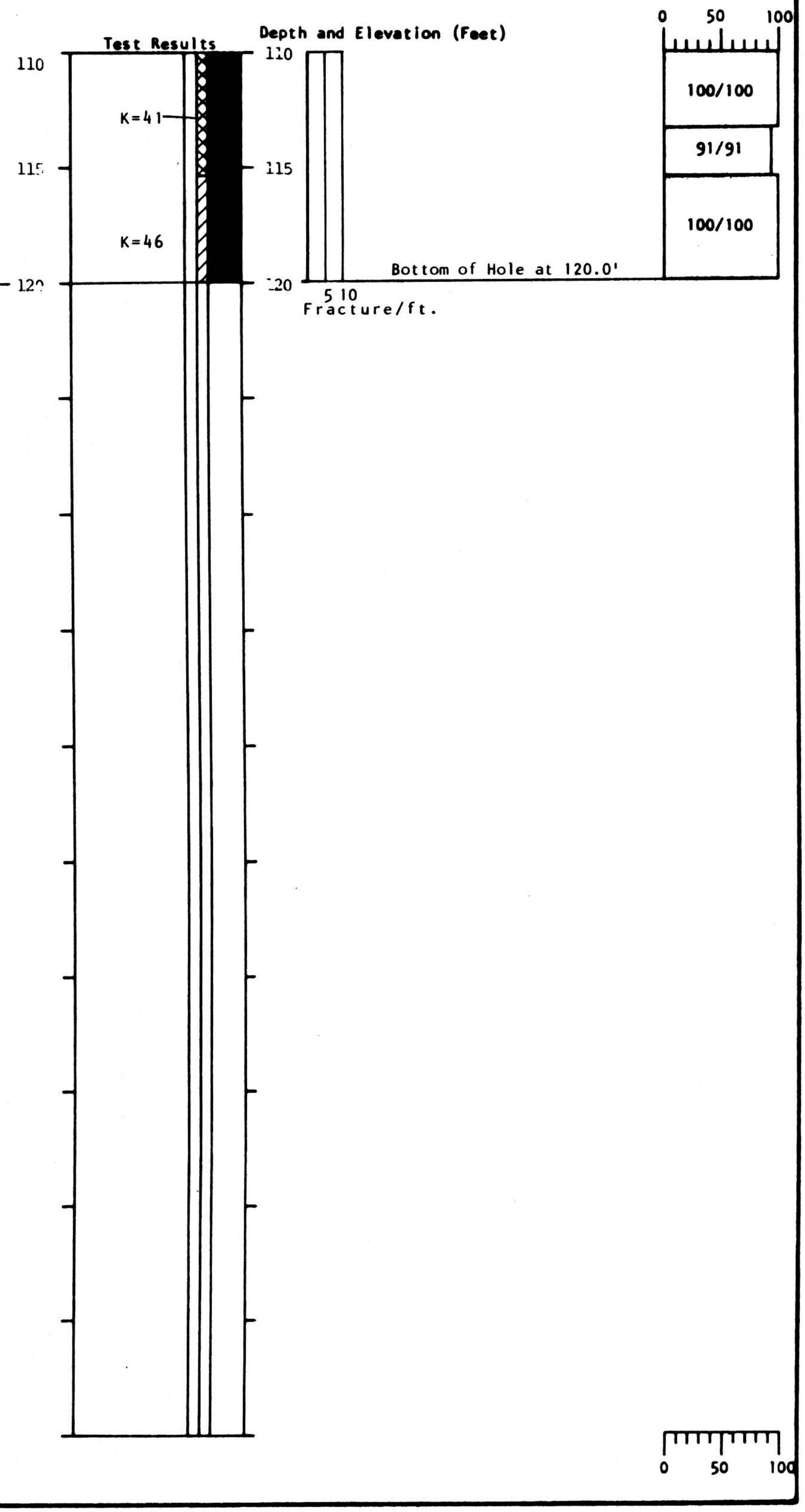


FIGURE C.2.4c

CORE LOG

Job No. 1 571 86

Sheet 1 of 1

Project Wolford Mountain Site A'

Location Right Abutment

Hole 3

Ground Elevation 7490'

Total Depth 23.0'

Depth of Overburden 15.0'

Angle from Horizontal -90°

Bearing of Angle Hole

Depth of Water not encountered

Begun 8/26/86

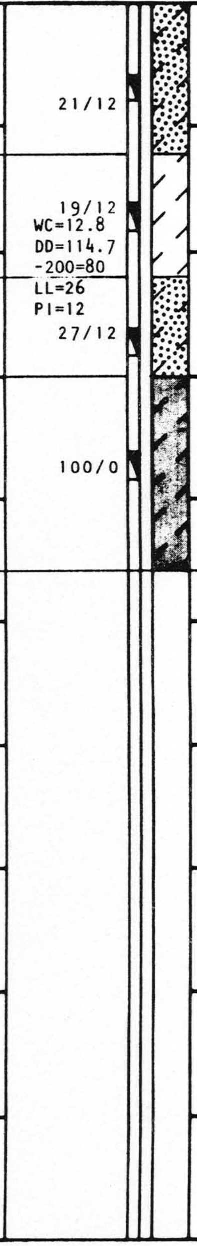
Finished 8/26/86

GEOLOGIC LOG	GRAPHIC LOG	DISCONTINUITY LOG	% RQD/ % Recovery

Depth and Elevation (Feet)

Depth (ft)	Geologic Log	Test Results
0–5.0	Sand: (SC), clayey, occasional pieces of claystone, medium dense, light moist, light brown.	21/12
5.0–10.0	Clay: (CL), sandy, very stiff, light moist, brown.	19/12 WC=12.8 DD=114.7 -200=80 LL=26 PI=12
10.0–15.0	Sand: (SC), clayey, medium dense, light moist, light brown.	27/12
15.0–23.0	Shale: gray, very hard, light moist.	100/0

Bottom of hole 23.0'



Standard penetration test.

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LOG OF HOLE 3

1 571 86

Fig. A-3

FIGURE C.2.5

CORE LOG

Job No. 1 571 86

Sheet 1 **of** 1

Project Wolford Mountain Dam

Location Along Pipelines, North end

Hole 4

Ground Elevation 7440'

Total Depth 13.0'

Depth of Overburden 12.0'

Angle from Horizontal -90°

Bearing of Angle Hole --

Depth of Water Not Encountered

Begun 9/3/86

Finished 9/3/86

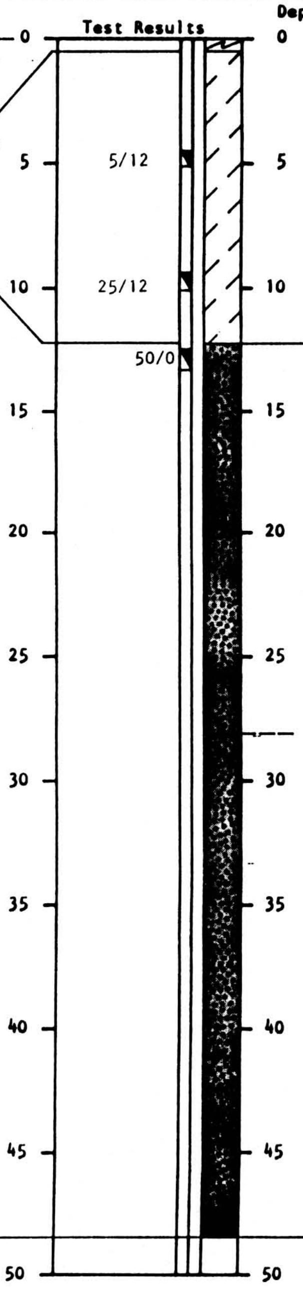
GEOLOGIC LOG	**GRAPHIC LOG**	**DISCONTINUITY LOG**	**% RQD/ % Recovery**

GEOLOGIC LOG

Clay Topsoil: sandy, soft, moist, tan.

Clay: (CL), sandy, stiff, light moist, brown.

Sandstone: (SS), well cemented, fine grained, very hard, dry, gray.



DISCONTINUITY LOG

Depth and Elevation (Feet)

Hole advanced from 0.0' to 13.0' with 4" auger.

Hole advanced from 13.0' to 48.0' with NX core bit

30° Headed

Bottom of Hole 48.0'

% RQD/ % Recovery

0 50 100

88/90
100/100
86/100
100/100
100/100
100/100
100/100

0 50 100

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LOG OF HOLE 4

1 571 86 Fig. A-4

FIGURE C.2.6

CORE LOG

Job No. 1 571 86

Sheet 1 **of** 2

Project Wolford Mountain Site A'

Location Tunnel Outlet

Hole 5

Ground Elevation 7430'

Total Depth 39.0'

Depth of Overburden 39.0'

Angle from Horizontal -90°

Bearing of Angle Hole ---

Depth of Water not encountered

Begun 8/27/86

Finished 8/27/86

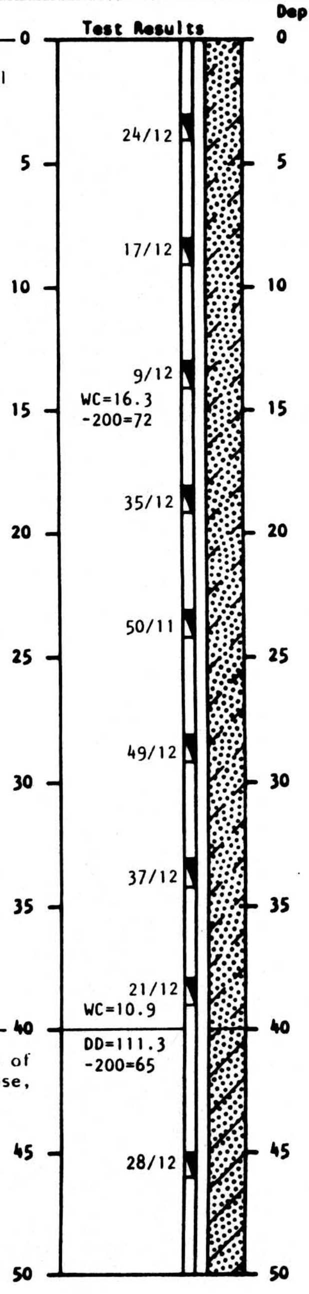
GEOLOGIC LOG	GRAPHIC LOG	DISCONTINUITY LOG	% RQD/ % Recovery

Depth and Elevation (Feet)

0 50 100

Sand: clayey (SC) silty, occasional pieces of sandstone and claystone, loose to medium dense, light moist, light brown.

Sand: silty (SM), occasional pieces of sandstone and claystone, medium dense, moist, brown.



Hole advanced from 0.0' to 70.0' with $'' auger

0 50 100

Standard Penetration TEst

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LOG OF HOLE 5

1 571 86 Fig. A-5

FIGURE C.2.7a

Job No. 1 571 86

CORE LOG

Sheet 2 **of** 2

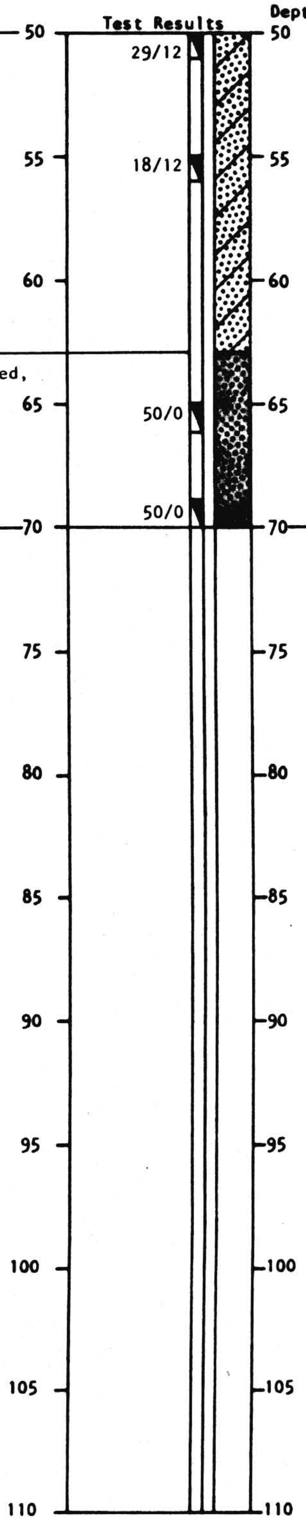
Hole 5 **Continued**

GEOLOGIC LOG	GRAPHIC LOG	DISCONTINUITY LOG	% RQD/ % Recovery

Depth and Elevation (Feet)

Sand-silty: (SM), continued.

Sandstone: well cemented, fine grained, very hard.



Bottom of Hole 70.0'

FIGURE C.2.7b

Log of Hole 5
1 571 86

Fig.________

CORE LOG

Job No. 1 571 86

Sheet 1 **of** 1

Project Wolford Mountain Site A'

Location Remote Spillway

Hole 6

Ground Elevation 7490'

Total Depth 30.0'

Depth of Overburden 2.0'

Angle from Horizontal -90°

Bearing of Angle Hole ---

Depth of Water not encountered

Begun 8/26/86

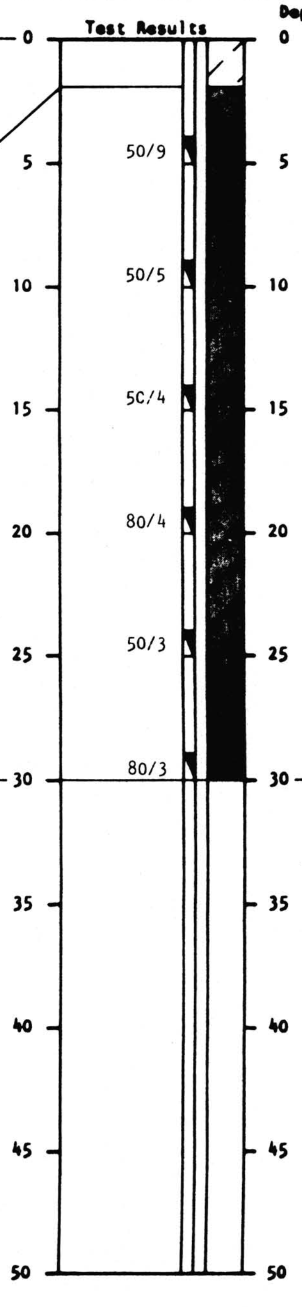
Finished 8/26/86

GEOLOGIC LOG | **GRAPHIC LOG** | **DISCONTINUITY LOG** | **% RQD/ % Recovery**

Clay: sandy (CL), stiff, light moist, light brown.

Shale: olive to gray, fine grained, very hard, light moist.

Bottom of hole 30.0'



Depth and Elevation (Feet)

Hole advanced from 0.0' to 30.0' with 4" auger

0 50 100

Standard penetration test.

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LOG OF HOLE 6

1 571 86

Fig. A-6

FIGURE C.2.8

NOTES:

1. Exploratory borings were drilled between August 20,1986 and September 19,1986 with a 4-inch diameter continuous flight power auger, a 7-inch diameter continuous flight hollow stem power auger and a NX core bit.

2. Locations of borings were measured approximately by pacing from features shown on the site plan provided.

3. Elevations of borings were obtained by interpolation between contours on the U.S.G.S $7\frac{1}{2}''$ Kremmling quadrangle. Elevations of Holes 1 and 2 were based on contours provided by Boyle Engineering Corporation.

4. The boring locations and elevations should be considered accurate only the degree implied by the method used.

5. The lines between materials shown on the boring logs represent the approximate boundaries between material types and the transitions may be gradual.

6. Water level readings shown on the logs were made at the time and under conditions indicated. Fluctuations in the water level may occur with time.

7. LABORATORY TEST RESULTS

   WC=Water Content (%);
   DD=Dry Density (pcf);
   BD=
   -200=Percentage Passing No. 200 Sieve;
   LL=Liquid Limit (%);
   PI=Plasiticity Index (%);
   UC=Unconfined Compressive Strength (psi);

8. 7/12 Drive sample blow count. Indicates that 7 blows of a 140-pound hammer falling 30 inches were required to drive the California or SPT sampler 12 inches.

FIGURE C.2.9

1 571 86

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NOTES

Fig. A-10

C.3.0 RED MOUNTAIN DAM AND RESERVOIR SITE

Red Mountain Dam and Reservoir would be constructed on the Colorado River approximately 1 mile east Kremmling, Colorado, shown on Figures C.3.1. The information in this section is from "Preliminary Geotechnical Investigation Red Mountain Dam and Reservoir Kremmling, Colorado", Chen & Associates, September, 1986.

C.3.1 FOUNDATION CONDITIONS

The preliminary subsurface configuration and physical characteristics of the foundation materials of the dam area were investigated by drilling nine exploratory borings. Figure C.3.2a shows the locations of the borings and the surface geology. Figure C.3.2b is the legend for the geology map. In-place permeabilities of the bedrock in the dam foundation were measured using packer permeability tests.

Soils

Six exploratory holes were drilled along the dam axis. The conditions encountered in the borings on the left abutment and terrace on the left side of the Colorado River consist of a layer of terrace sands and gravels, 5 to 19 feet in thickness, overlying fractured gneiss bedrock. A layer of colluvial soils was encountered in Hole 6 at the toe of the left abutment.

The valley bottom consists of alluvial sandy silt and sands and gravels. These materials were encountered in Hole 2 to a depth of 47 feet. A 6-foot thick layer of sandy silt overlying the bedrock was encountered in Hole 9. The deep silts were not encountered in Hole 2, but should be anticipated erratically in the valley alluvium. The maximum depth of alluvial soils may be greater than that encountered in the exploratory holes due to the large width of the valley bottom.

A thin deposit of terrace sands and gravels is located on the right abutment at approximately the elevation of the embankment crest. This layer of terrace gravels was encountered to a depth of 15 feet in Hole 1.

Rock

The entire dam axis is underlain by Precambrian-age gneiss. The gneiss is moderately to highly fractures due to the proximity of the dam site to the Williams Range Thrust Fault. The RQD ranged from 0 to 98 percent, with an average RQD of 43 percent. Difficult drilling conditions were encountered in Hole 3. The hole squeezed in on the drill stem during the drilling process.

Results of the unconfined compressive strength tests indicated uniaxial strengths ranging from 1,500 psi to 5,000 psi. These relatively low strengths resulted from the many healed fractures in the core which failed in the test. The average calculated RMR classification of the bedrock was 36. This values indicates the rock is of poor quality.

Ground Water

Free water was measured in Holes 1, 2, 3, 4 and 9 along the dam axis. Free water was encountered at depths ranging from 2 to 29 feet below the ground surface as shown on Table C.3.1. These water levels appear to indicate the ground water is flowing towards the Colorado River Valley at the dam site.

Foundation Permeability

In-place packer permeability tests were conducted in the gneiss bedrock in Holes 1, 2, 3 and 4 along the dam axis. Results of the permeability tests are shown on Table C.3.2. Thirty-one tests were conducted in the gneiss in the dam foundation. A majority of the tests were conducted in Holes 1 and 2. Results of the tests in the gneiss indicate variable permeabilities from 1 to 214 feet per year. In Hole 1 the permeability was low and ranged from 1 to 14 feet per year. In Hole 2 the permeability increased with depth. Above a depth of 100 feet the permeability averaged 25 feet per year whereas below 100 feet the permeability averaged 85 feet per year. No correlations were made for the tests run in Hole 3 and 4 since the number of tests was limited.

Outlet Works

The proposed outlet works may involve a conduit placed in a cut and cover excavation in bedrock in the left or right abutment. A cut may also be made for a temporary diversion of stream flow during dam construction. The conditions encountered in the cuts made in the left and right abutments will consist of highly-fractured gneiss bedrock. Free water will also be encountered in the excavation. Cuts in the bedrock should be planned at 1:1 slope. Steeper slopes may be possible in areas which are not highly fractured.

TABLE C.3.1

TABLE A-2

SUMMARY OF WATER LEVEL READINGS

Job No. 1 570 86

Hole	Time of Drilling	8/28/86	9/4/86	10/1/86
1	N.M.	24.0	23.9	25.0
2	N.M.	8.0	9.0	9.0
3	N.M.	29.3	30.2	31.0
4	N.M.	16.4	16.5	16.0
5	N.E.	N.M.	15.0	14.3
6	N.E.	N.M.	N.M.	N.M.
7	N.E.	25.5	27.6	29.6
8	N.E.	N.M.	N.M.	N.M.
9	2.0	N.M.	N.M.	N.M.

N.M. - Not Measured
N.E. - Not Encountered

TABLE C.3.2

Table A1 PERM - Page 1

Summary Of Packer Permeability Tests

Project: Red Mtn. Dam	Project File: RED2
Job No.: 1-570-86	Base Program: PERM
Date: 9-1-86	Unsorted
Operator: Mock	

Hole No.	Top Test Sec. (ft)	Bottom Test Sec. (ft)	Test Length (ft)	Hole Dia. (in)	Total Head (ft)	Water Take (gpm)	Perm. (ft/yr)	Avg. Perm. (ft/yr)	Material	Depth Ground Water (ft)
1	32	40	8	3	73	0.2	13	14	Gneiss	24
1	32	40	8	3	119	0.4	21	14	Gneiss	24
1	32	40	8	3	73	0.1	7	14	Gneiss	24
1	40	50	10	3	86	0.0	0	2	Gneiss	24
1	40	50	10	3	144	0.2	7	2	Gneiss	24
1	40	50	10	3	86	0.0	0	2	Gneiss	24
1	50	60	10	3	87	0.0	0	4	Gneiss	24
1	50	60	10	3	145	0.3	11	4	Gneiss	24
1	50	60	10	3	87	0.0	0	4	Gneiss	24
1	60	70	10	3	121	0.0	0	1	Gneiss	24
1	60	70	10	3	214	0.2	4	1	Gneiss	24
1	60	70	10	3	121	0.0	0	1	Gneiss	24
1	70	80	10	3	121	0.0	0	2	Gneiss	24
1	70	80	10	3	214	0.3	7	2	Gneiss	24
1	70	80	10	3	121	0.0	0	2	Gneiss	24
1	80	90	10	3	145	0.2	7	7	Gneiss	24
1	80	90	10	3	260	0.5	9	7	Gneiss	24
1	80	90	10	3	145	0.1	3	7	Gneiss	24
1	90	100	10	3	145	0.3	9	6	Gneiss	24
1	90	100	10	3	260	0.2	4	6	Gneiss	24
1	90	100	10	3	145	0.1	3	6	Gneiss	24
1	100	110	10	3	145	0.2	7	7	Gneiss	24
1	100	110	10	3	260	0.5	9	7	Gneiss	24
1	100	110	10	3	145	0.1	3	7	Gneiss	24
1	110	120	10	3	145	0.1	3	1	Gneiss	24
1	110	120	10	3	260	0.0	0	1	Gneiss	24
1	110	120	10	3	145	0.0	0	1	Gneiss	24
1	121	130	9	3	145	0.1	3	3	Gneiss	24
1	121	130	9	3	260	0.1	2	3	Gneiss	24
1	121	130	9	3	145	0.1	4	3	Gneiss	24
1	130	140	10	3	145	0.3	11	8	Gneiss	24
1	130	140	10	3	260	0.6	11	8	Gneiss	24
1	130	140	10	3	145	0.1	3	8	Gneiss	24

TABLE C.3.2 (continued)

Table A1 PERM - Page 2

1	138	150	12	3	147	0.1	4	3	Gneiss	24
1	138	150	12	3	262	0.2	3	3	Gneiss	24
1	138	150	12	3	147	0.1	3	3	Gneiss	24
2	52	60	8	3	66	0.4	35	38	Gneiss	8
2	52	60	8	3	124	1.0	47	38	Gneiss	8
2	52	60	8	3	66	0.3	30	38	Gneiss	8
2	60	70	10	3	100	0.3	13	13	Gneiss	8
2	60	70	10	3	193	1.7	44	13	Gneiss	8
2	60	70	10	3	100	0.0	1	13	Gneiss	8
2	70	80	10	3	112	0.0	0	13	Gneiss	8
2	70	80	10	3	216	1.6	36	13	Gneiss	8
2	70	80	10	3	112	0.1	4	13	Gneiss	8
2	80	90	10	3	112	0.0	1	26	Gneiss	8
2	80	90	10	3	216	3.3	76	26	Gneiss	8
2	80	90	10	3	112	0.0	0	26	Gneiss	8
2	90	100	10	3	124	0.0	0	46	Gneiss	8
2	90	100	10	3	239	6.7	138	46	Gneiss	8
2	90	100	10	3	124	0.0	0	46	Gneiss	8
2	100	110	10	3	124	0.0	2	51	Gneiss	8
2	100	110	10	3	239	7.2	148	51	Gneiss	8
2	100	110	10	3	124	0.1	5	51	Gneiss	8
2	110	120	10	3	124	0.0	0	52	Gneiss	8
2	110	120	10	3	239	7.5	155	52	Gneiss	8
2	110	120	10	3	124	0.0	0	52	Gneiss	8
2	120	130	10	3	124	0.8	31	106	Gneiss	8
2	120	130	10	3	239	10.4	215	106	Gneiss	8
2	120	130	10	3	124	1.8	72	106	Gneiss	8
2	130	140	10	3	124	0.9	35	71	Gneiss	8
2	130	140	10	3	239	7.9	162	71	Gneiss	8
2	130	140	10	3	124	0.4	16	71	Gneiss	8
2	140	150	10	3	124	0.3	10	12	Gneiss	8
2	140	150	10	3	239	0.7	15	12	Gneiss	8
2	140	150	10	3	124	0.3	12	12	Gneiss	8
2	150	160	10	3	124	2.5	99	121	Gneiss	8
2	150	160	10	3	239	9.0	185	121	Gneiss	8
2	150	160	10	3	124	1.9	77	121	Gneiss	8
2	160	170	10	3	124	5.3	211	214	Gneiss	8
2	160	170	10	3	158	7.0	217	214	Gneiss	8
2	160	170	10	3	124	5.3	212	214	Gneiss	8
2	168	180	12	3	124	3.4	116	55	Gneiss	8
2	168	180	12	3	216	2.4	48	55	Gneiss	8

TABLE C.3.2 (continued)

Table A1 PERM - Page 3

2	168	180	12	3	124	0.0	0	55	Gneiss	8
3	7	15	8	3	34	0.9	161	92	Gneiss	29.3
3	7	15	8	3	57	1.1	112	92	Gneiss	29.3
3	7	15	8	3	34	0.0	3	92	Gneiss	29.3
3	27	33.6	6.6	3	76	0.1	7	10	Gneiss	29.3
3	27	33.6	6.6	3	122	0.4	23	10	Gneiss	29.3
3	27	33.6	6.6	3	76	0.0	0	10	Gneiss	29.3
3	42	50	8	3	87	0.8	56	68	Gneiss	29.3
3	42	50	8	3	145	2.0	80	68	Gneiss	29.3
3	42	50	8	3	87	1.0	67	68	Gneiss	29.3
3	50	60	10	3	87	1.0	56	102	Gneiss	29.3
3	50	60	10	3	145	4.6	157	102	Gneiss	29.3
3	50	60	10	3	87	1.6	93	102	Gneiss	29.3
3	60	70	10	3	122	0.3	11	8	Gneiss	29.3
3	60	70	10	3	214	0.5	11	8	Gneiss	29.3
3	60	70	10	3	122	0.0	2	8	Gneiss	29.3
3	70	80	10	3	122	0.1	6	5	Gneiss	29.3
3	70	80	10	3	214	0.0	0	5	Gneiss	29.3
3	70	80	10	3	122	0.2	10	5	Gneiss	29.3
4	60.2	75.2	15	3	109	0.1	3	5	Gneiss	16.4
4	60.2	75.2	15	3	201	0.6	11	5	Gneiss	16.4
4	60.2	75.2	15	3	109	0.0	0	5	Gneiss	16.4
7	22	30	8	3	72	0.1	5	85	Claystone	70
7	22	30	8	3	118	2.8	140	85	Claystone	70
7	22	30	8	3	72	1.4	111	85	Claystone	70
7	30	40	10	3	81	0.9	56	116	Claystone	70
7	30	40	10	3	127	4.9	190	116	Claystone	70
7	30	40	10	3	81	1.7	102	116	Claystone	70
7	30	50	20	3	98	2.0	58	104	Claystone	70
7	30	50	20	3	156	9.1	166	104	Claystone	70
7	30	50	20	3	98	3.0	87	104	Claystone	70

C.3.2 SUBSURFACE EXPLORATION PROGRAM

The field investigation included nineteen exploratory borings in the dam, reservoir and borrow areas. The exploratory drilling was conducted with a Mobile B-80 drill rig and a CM#-45 drill rig. Drilling was conducted in general accordance with ASTM D-1452 and D-2113 procedures.

Holes 1 through 4 in the dam foundation were advanced through the overburden soils with a 7-inch diameter hollow stem auger. The remaining holes were advanced with a 4-inch auger. Exploration of the underlying bedrock in Holes 1 through 4 and 7 was accomplished with NX diamond bits which obtained a 1 7/8 inch diameter core sample. Continuous test hole logs were made.

Samples of the overburden soils were obtained with 2-inch and 1 3/8-inch I.D. spoon samplers. The samplers were driven into the various strata with blows from a 140-pound hammer falling 30-inches. This test is similar to the standard penetration test described by the ASTM method D-1586. Samples were obtained at approximate 5-foot intervals. Depths at which the samples were taken are shown on the Borings Logs, Figures C.3.3 through C.3.11. Figure C.3.12 presents the accompanying notes.

The bedrock cores obtained from holes 1 through 4 and 7 were logged. Descriptions of the cores included lithological descriptions and a systematic field classifications for alteration and hardness of the material. The alteration and hardness were determined based on the field identification procedures. Discontinuities in the cores were logged for orientation, roughness, planarity and filling. The fractures per foot were also recorded.

The RQD of each core run was calculated. The RQD values were calculated immediately upon removal of the core from the core barrel. The RQD values are shown on the right sides of the Boring Logs.

In-place permeability was measured in portions of Holes 1 and 2 in bedrock at 10-foot intervals and at selected locations in Holes 3, 4 and 7 by conducting single stage packer permeability tests. The packer permeability tests were used to evaluate zones of high permeability. Results are shown in Table C.3.2.

Plastic pipe observation wells were installed in all holes except Hole t for continued water level monitoring. The observation wells were installed with a perforated zone extending the entire depth of bedrock in each hole. Measurements of the water level were made by a weighted plumb line subsequent to drilling. The water levels and the date of measurement are shown on Table C.3.1.

C.3.3 LABORATORY TESTING PROGRAM

A laboratory investigation was conducted to access the standard properties and engineering characteristics of the materials obtained from the test holes. Samples obtained from the exploratory holes were examined and classified in the field by the project geologist. The samples were then returned to the laboratory for examination and visual classification by the project engineer. Samples were selected for testing and the remaining samples were placed in storage. Laboratory testing was performed on the selected samples to determine their classification, gradation and strength. Results of the testing have been filed with the Authority. The testing was conducted in general accordance with recognized test procedures, primarily those of the American Society for Testing and Materials (ASTM).

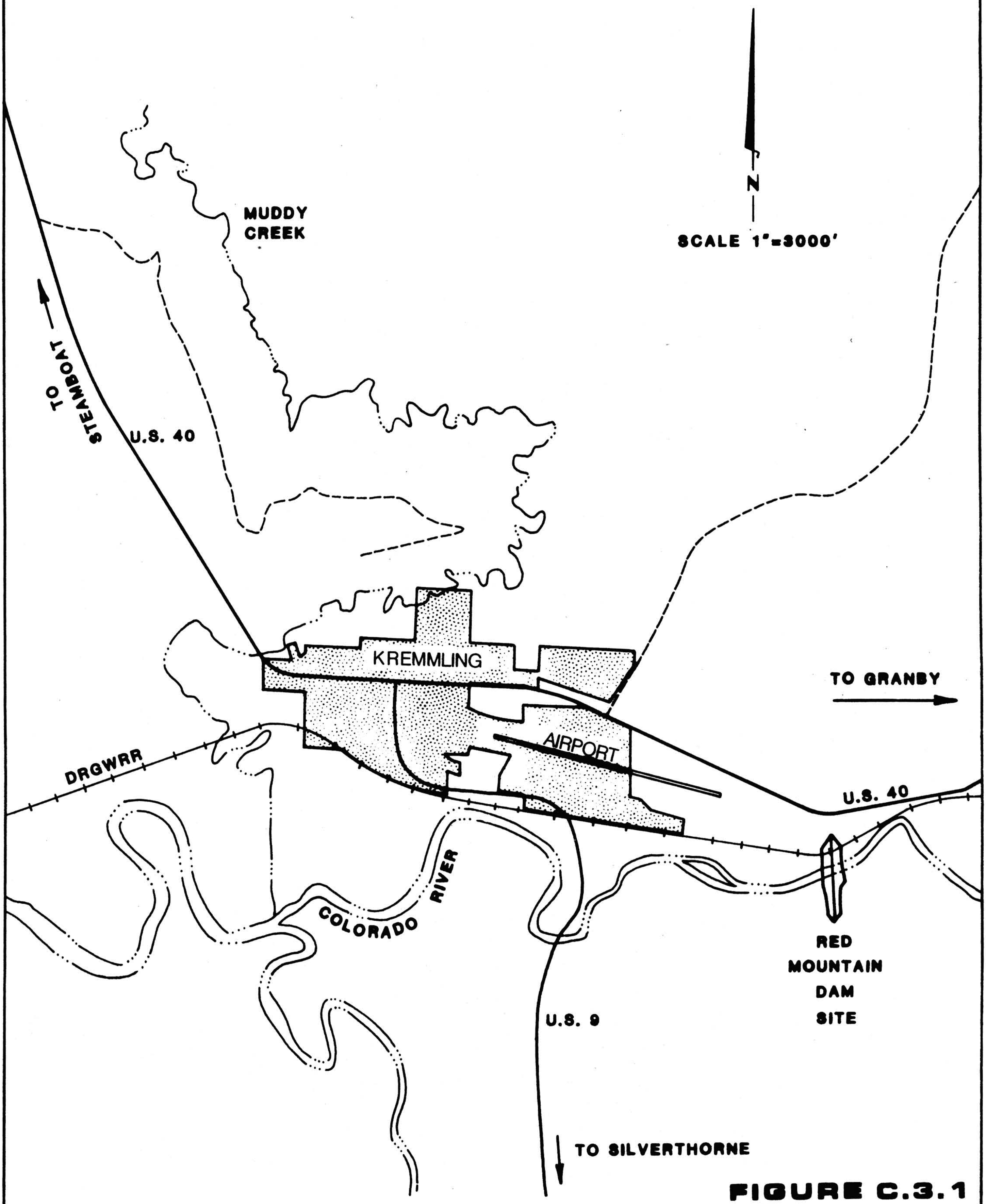
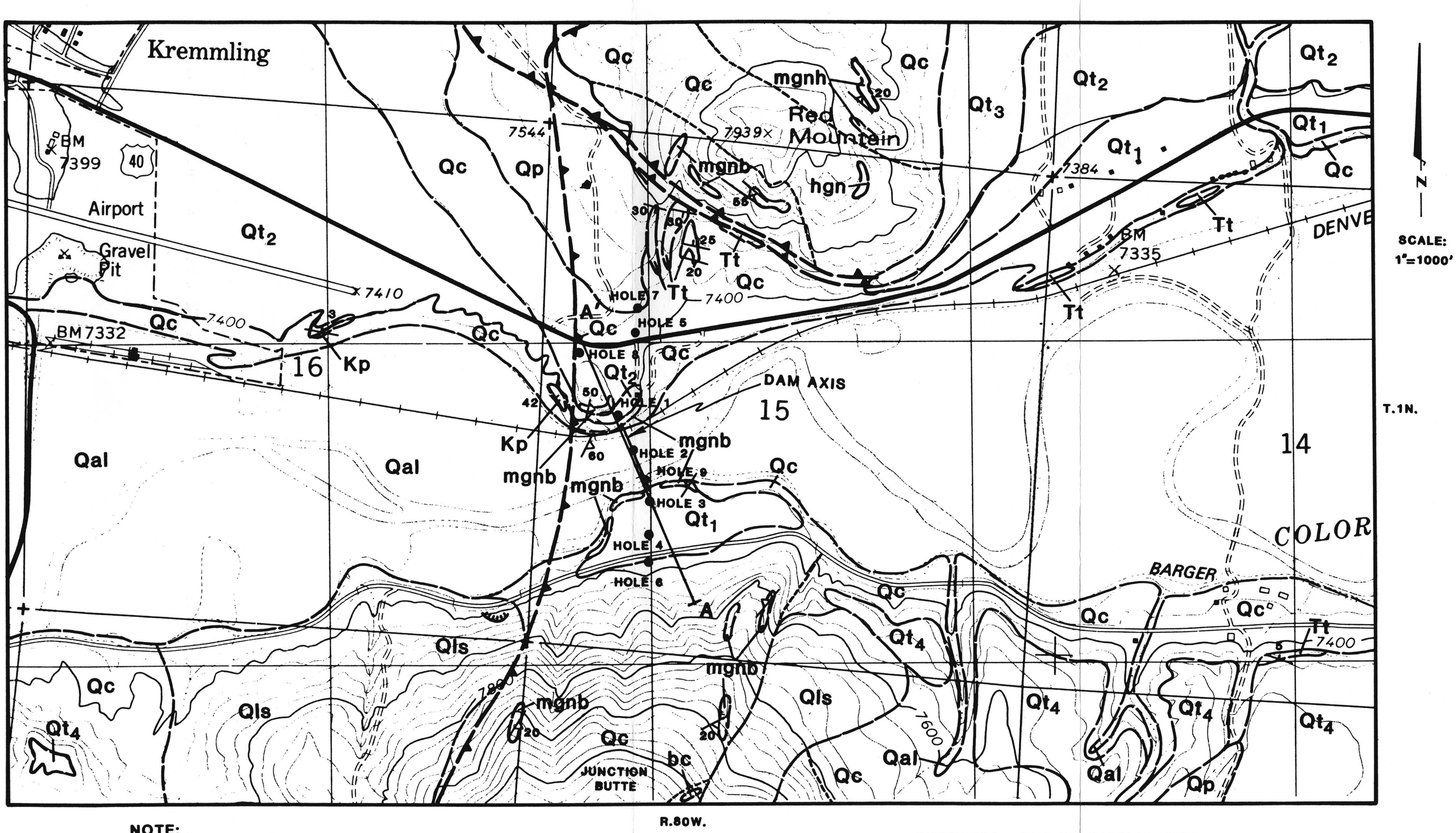


FIGURE C.3.1

1 570 86	Chen & Associates	VICINITY MAP	Fig. 1



NOTE:

EXPLANATION IS ON FIG. 3. GEOLOGIC CROSS-SECTION SHOWN ON FIG. 4.

REFERENCE: IZET AND BARCLAY, 1973
GEOLOGIC MAP OF KREMMLING QUADRANGLE
GRAND COUNTY, COLORADO

FIGURE C.3.2a

1 570 86	Chen & Associates	RED MOUNTAIN DAM	GEOLOGIC MAP	Fig. 2

EXPLANATION:

SURFICIAL DEPOSITS:

QUATERNARY

Qal

VALLEY ALLUVIUM

Qls

LANDSLIDE DEPOSITS

$Qt_{1,2,3,4}$

TERRACE ALLUVIUM

Qp

PEDIMENT DEPOSITS

Qc

COLLUVIUM

BEDROCK UNITS:

MIOCENE

Tt

TROUBLESOME FORMATION

UPPER CRETACEOUS

Kp

PIERRE SHALE

PRE-CAMBRIAN

mgnb

BIOTITE GNEISS

hgn

HORNBLENDE GNEISS

bc

BOULDER CREEK
GRANODIORITE

———

CONTACT

Approximate surface boundary
of map units

- - - - - - - - - - - -

SUBSURFACE CONTACT

Approximate subsurface boundary
of map units

THRUST FAULT

Inferred location
sawteeth on upper plate

15°

STRIKE AND DIP OF BEDS

50

STRIKE AND DIP OF FOLIATION

LANDSLIDE SCARP

A A'

CROSS-SECTION

● H-1

TEST HOLE

Approximate location

FIGURE C.3.2b

1 570 86	Chen & Associates	RED MOUNTAIN DAM	LEGEND FOR SURFICIAL GEOLOGIC MAP	Fig. 3

CORE LOG

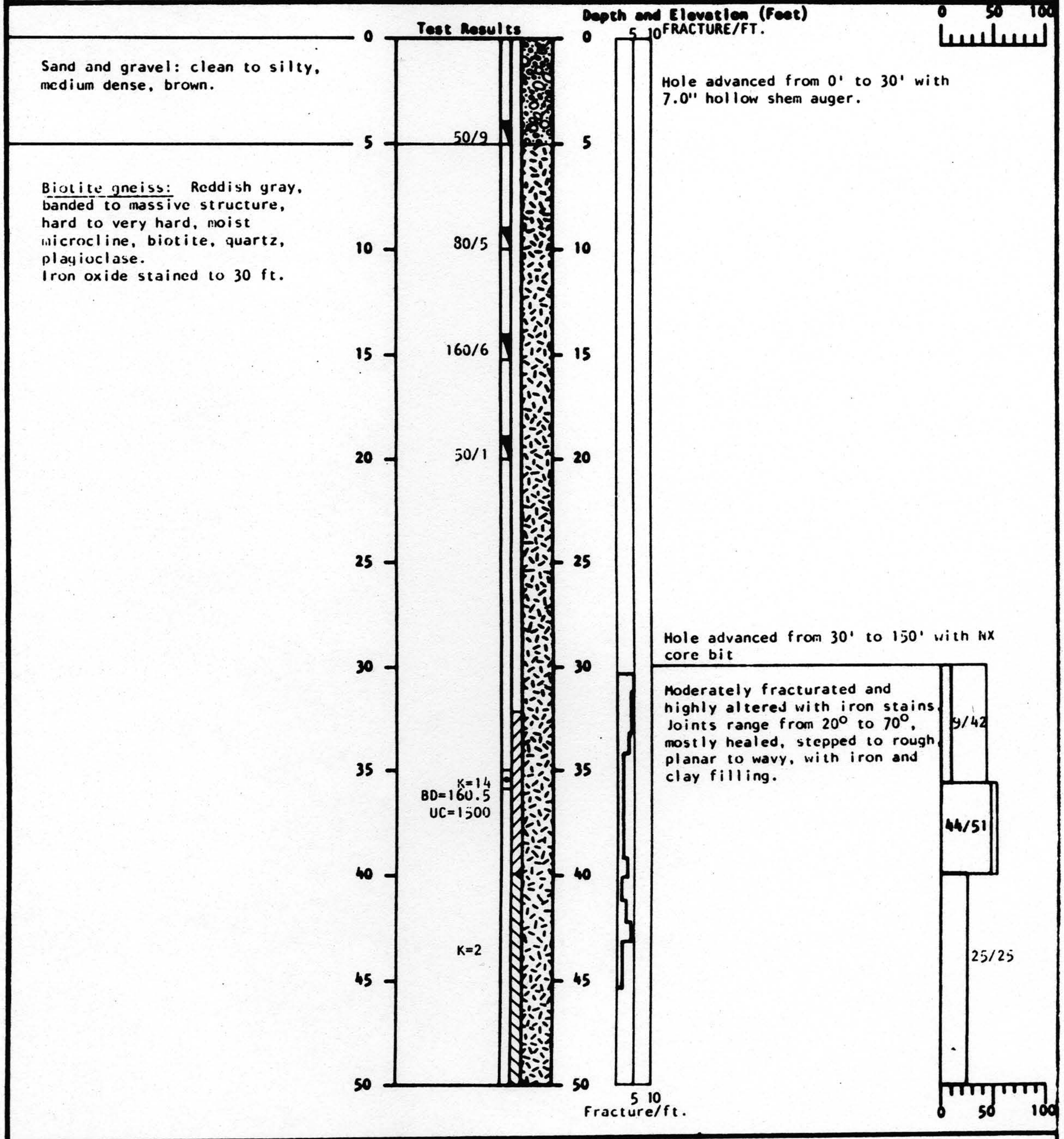
Job No. 1 570 86
Sheet 1 **of** 3

Project Red Mountain Dam
Location Right Abutment

Hole 1
Ground Elevation 7412'
Total Depth 150.0'
Depth of Overburden 5.0'

Angle from Horizontal -90°
Bearing of Angle Hole -
Depth of Water -
Begun 3/24/86
Finished 3/25/86

GEOLOGIC LOG	**GRAPHIC LOG**	**DISCONTINUITY LOG**	**% RQD/ % Recovery**



Sand and gravel: clean to silty, medium dense, brown.

Biotite gneiss: Reddish gray, banded to massive structure, hard to very hard, moist microcline, biotite, quartz, plagioclase.
Iron oxide stained to 30 ft.

Hole advanced from 0' to 30' with 7.0" hollow shem auger.

Hole advanced from 30' to 150' with NX core bit

Moderately fracturated and highly altered with iron stains. Joints range from 20° to 70°, mostly healed, stepped to rough, planar to wavy, with iron and clay filling.

▮ Standard penetration test

▨ Core sample tested

▨ Packer permeability test section
K in ft./yr.

Chen & Associates
LOG OF HOLE 1
1 570 86
Fig. A-1

FIGURE C.3.3a

Job No. 1 570 86

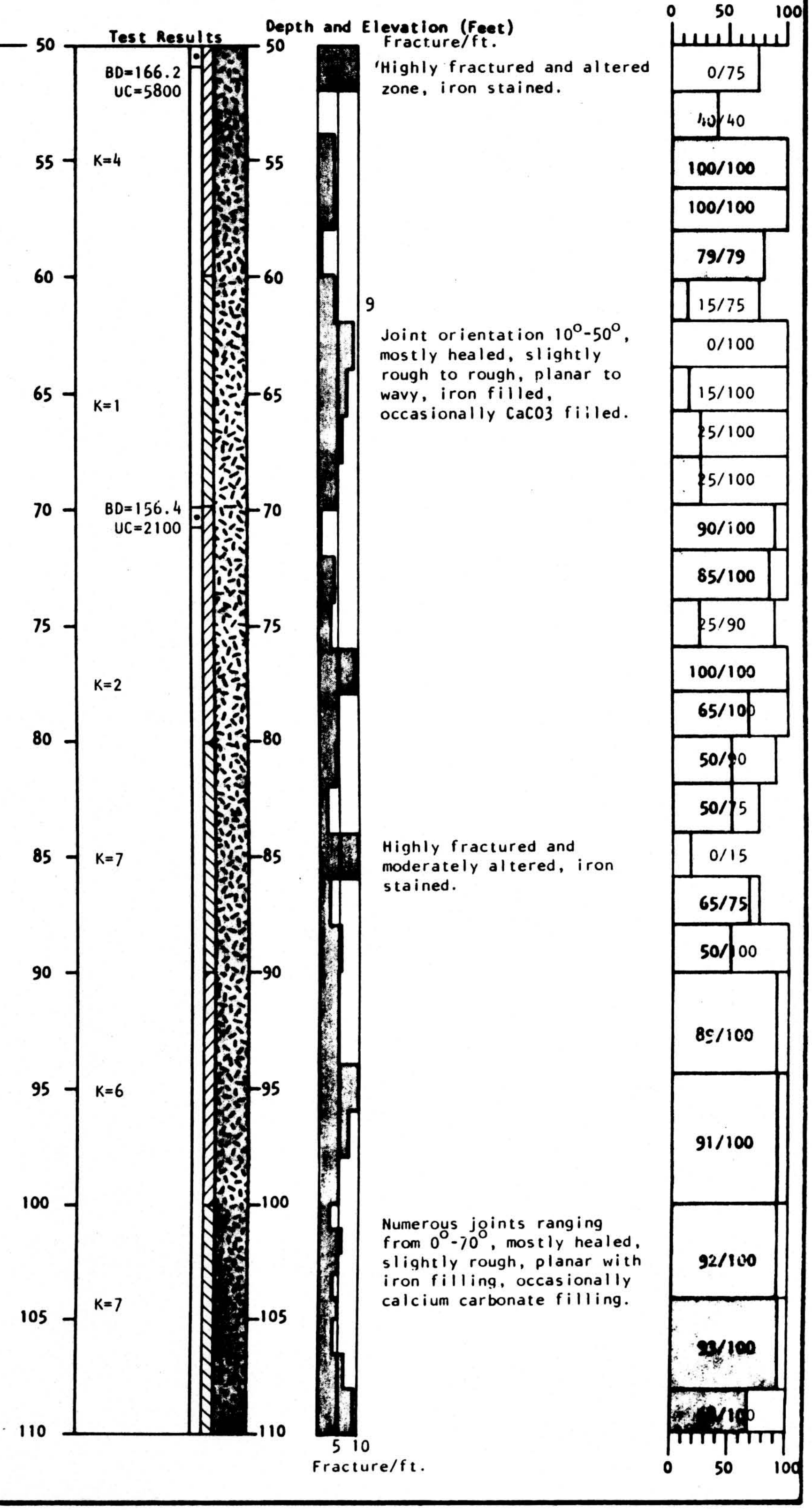
CORE LOG

Sheet 2 of 3

Hole 1 Continued

GEOLOGIC LOG	GRAPHIC LOG	DISCONTINUITY LOG	% RQD/ % Recovery

Biotite gneiss-continued
scattered pegmatite and
quartz dikes.



Highly fractured and altered zone, iron stained.

Joint orientation 10°-50°, mostly healed, slightly rough to rough, planar to wavy, iron filled, occasionally CaCO3 filled.

Highly fractured and moderately altered, iron stained.

Numerous joints ranging from 0°-70°, mostly healed, slightly rough, planar with iron filling, occasionally calcium carbonate filling.

FIGURE C.3.3b

Job No. 1 570 86

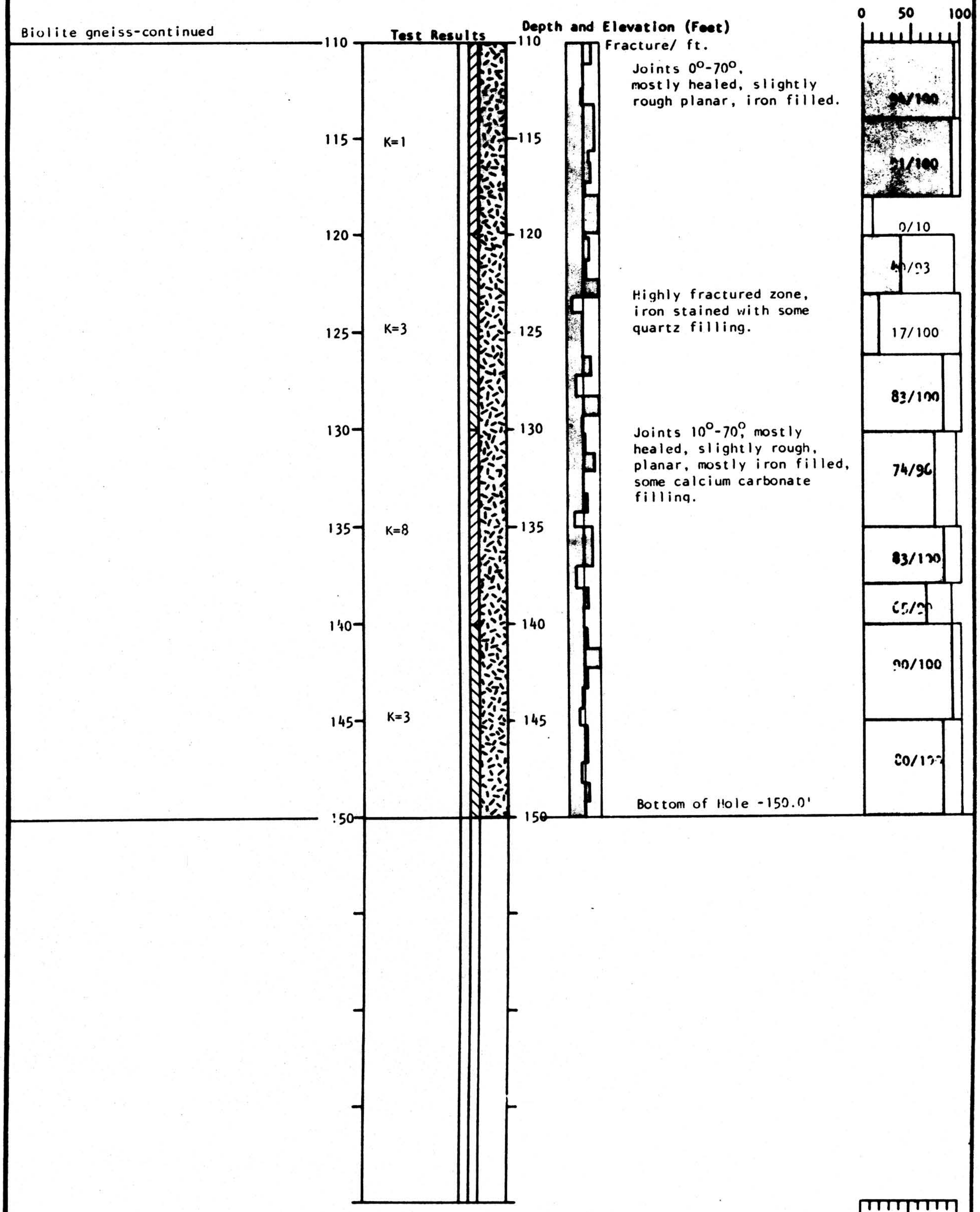
CORE LOG

Sheet 3 **of** 3

Hole 1 **Continued**

GEOLOGIC LOG	**GRAPHIC LOG**	**DISCONTINUITY LOG**	**% RQD/ % Recovery**

Biolite gneiss-continued



Joints 0°-70°, mostly healed, slightly rough planar, iron filled.

Highly fractured zone, iron stained with some quartz filling.

Joints 10°-70°, mostly healed, slightly rough, planar, mostly iron filled, some calcium carbonate filling.

Bottom of Hole -150.0'

FIGURE C.3.3c

CORE LOG

Job No. 1 570 86

Sheet 1 **of** 4

Project Red Mountain Dam

Location Dam Centerline-Channel Bottom

Hole 2

Ground Elevation 7333'

Total Depth 180.0'

Depth of Overburden 48.5'

Angle from Horizontal -90

Bearing of Angle Hole ---

Depth of Water

Begun 8/7/86

Finished 8/8/86

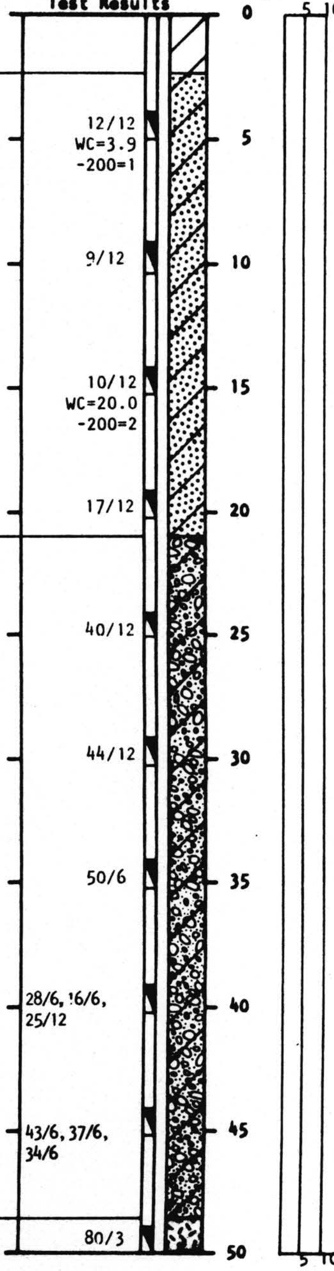
GEOLOGIC LOG	**GRAPHIC LOG**	**DISCONTINUITY LOG**	**% RQD/ % Recovery**

Test Results

Depth and Elevation (Feet)

5 10 Fracture/ft.

0 50 100



Depth	Geologic Log	Test Results	Discontinuity Log
0	Silt: (ML) sandy, fine-grained, stiff moist, brown		Hole advanced from 0' to 50.0' with 7.0" hollow stem auger.
5	Sand: (SM) clean to silty, gravelly, medium dense, moist, brown	12/12 WC=3.9 -200=1	
10		9/12	
15		10/12 WC=20.0 -200=2	
20		17/12	
	Gravel: (GM) sandy, silty, dense to very dense, wet, gray		
25		40/12	
30		44/12	
35		50/6	
40		28/6, 16/6, 25/12	
45		43/6, 37/6, 34/6	
	Biotite Gneiss: Gray to reddish-gray, banded, very hard, moist microcline, biotite, quartz, plagoclase.	80/3	Hole advanced from 50' to 180' with NX core bit.
50			

5 10

Fractures/ft.

0 50 100

Legend:

▮ Standard penetration test

▨ Packer permeability test section K in ft./yr.

▯ Core sample tested

Chen & Associates

LOG OF HOLE 2

1 570 86 Fig. A-2

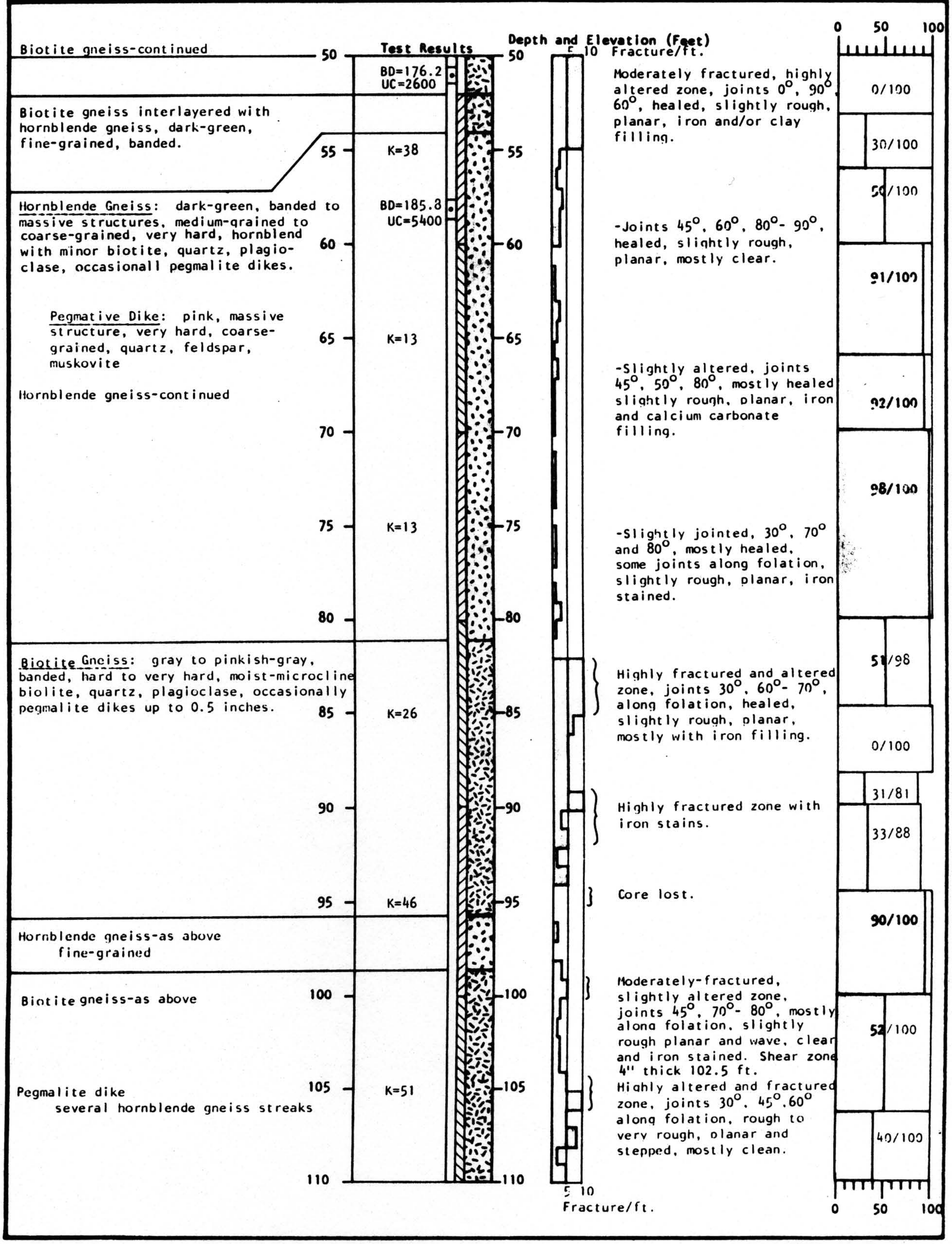
FIGURE C.3.4a

Job No. 1 570 86

CORE LOG

Sheet 2 **of** 4

Hole 2 **Continued**



Biotite gneiss-continued

Biotite gneiss interlayered with hornblende gneiss, dark-green, fine-grained, banded.

Hornblende Gneiss: dark-green, banded to massive structures, medium-grained to coarse-grained, very hard, hornblend with minor biotite, quartz, plagioclase, occasionall pegmalite dikes.

Pegmative Dike: pink, massive structure, very hard, coarse-grained, quartz, feldspar, muskovite

Hornblende gneiss-continued

Biotite Gneiss: gray to pinkish-gray, banded, hard to very hard, moist-microcline biolite, quartz, plagioclase, occasionally pegmalite dikes up to 0.5 inches.

Hornblende gneiss-as above fine-grained

Biotite gneiss-as above

Pegmalite dike several hornblende gneiss streaks

Moderately fractured, highly altered zone, joints 0°, 90°, 60°, healed, slightly rough, planar, iron and/or clay filling.

-Joints 45°, 60°, 80°- 90°, healed, slightly rough, planar, mostly clear.

-Slightly altered, joints 45°, 50°, 80°, mostly healed slightly rough, planar, iron and calcium carbonate filling.

-Slightly jointed, 30°, 70° and 80°, mostly healed, some joints along folation, slightly rough, planar, iron stained.

Highly fractured and altered zone, joints 30°, 60°- 70°, along folation, healed, slightly rough, planar, mostly with iron filling.

Highly fractured zone with iron stains.

Core lost.

Moderately-fractured, slightly altered zone, joints 45°, 70°- 80°, mostly along folation, slightly rough planar and wave, clear and iron stained. Shear zone 4" thick 102.5 ft.

Highly altered and fractured zone, joints 30°, 45°.60° along folation, rough to very rough, planar and stepped, mostly clean.

FIGURE C.3.4b

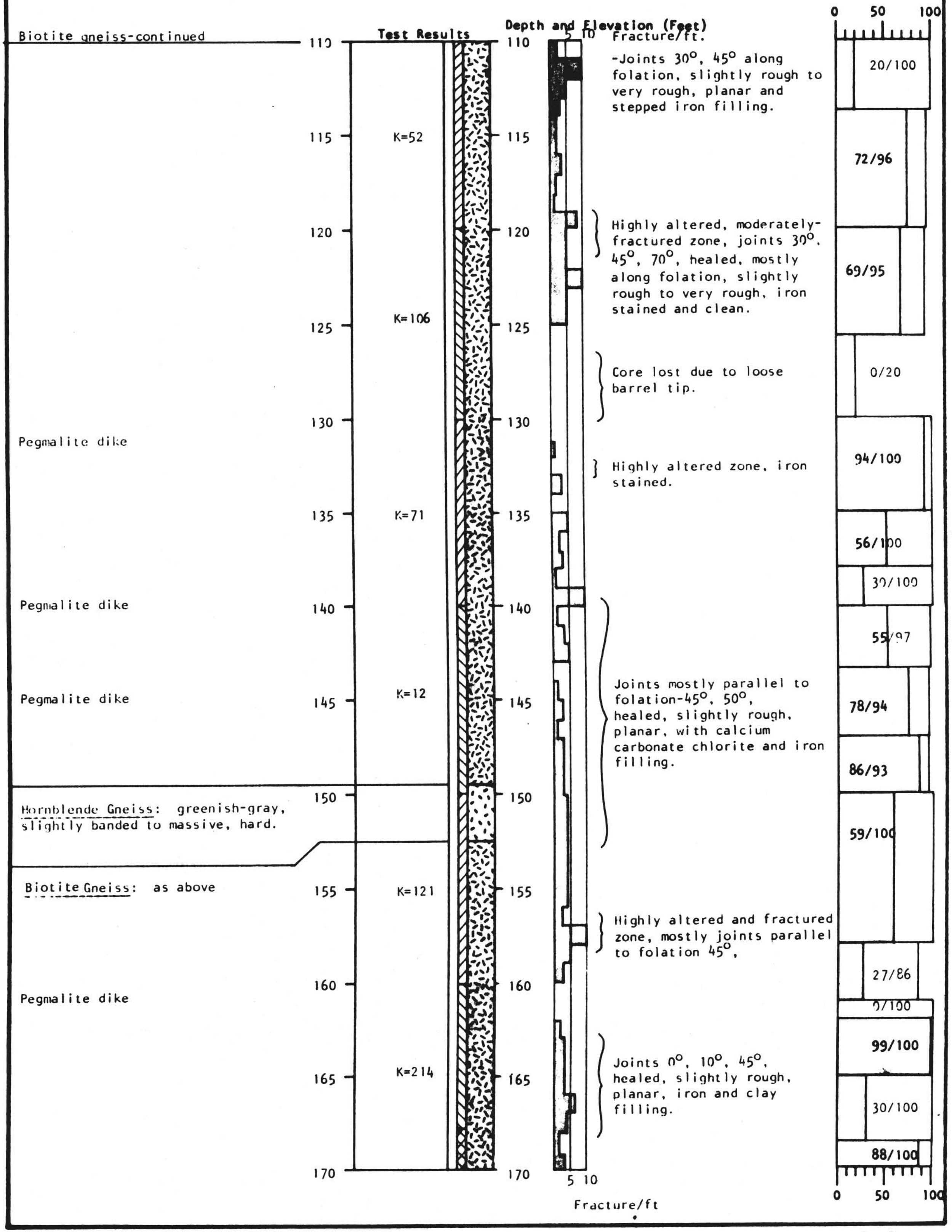
Job No. 1 570 86

CORE LOG

Sheet 3 of 4

Hole 2 Continued

GEOLOGIC LOG	GRAPHIC LOG	DISCONTINUITY LOG	% RQD/ % Recovery



Biotite gneiss-continued

Pegmalite dike

Pegmalite dike

Pegmalite dike

Hornblende Gneiss: greenish-gray, slightly banded to massive, hard.

Biotite Gneiss: as above

Pegmalite dike

-Joints 30°, 45° along folation, slightly rough to very rough, planar and stepped iron filling.

Highly altered, moderately-fractured zone, joints 30°, 45°, 70°, healed, mostly along folation, slightly rough to very rough, iron stained and clean.

Core lost due to loose barrel tip.

Highly altered zone, iron stained.

Joints mostly parallel to folation-45°, 50°, healed, slightly rough, planar, with calcium carbonate chlorite and iron filling.

Highly altered and fractured zone, mostly joints parallel to folation 45°,

Joints 0°, 10°, 45°, healed, slightly rough, planar, iron and clay filling.

FIGURE C.3.4c

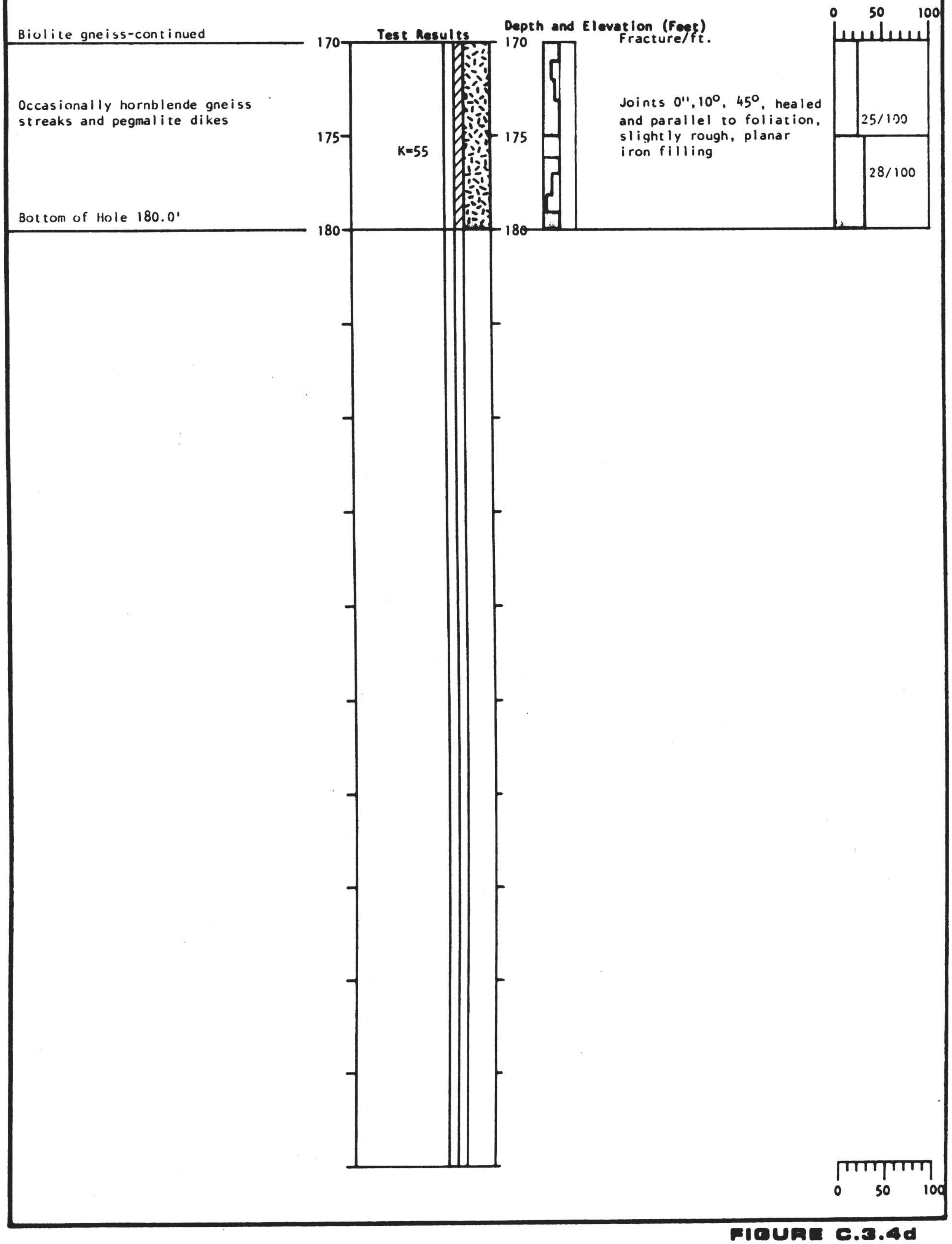
Job No. 1 570 86

CORE LOG

Sheet 4 **of** 4

Hole 2 **Continued**

GEOLOGIC LOG	GRAPHIC LOG	DISCONTINUITY LOG	% RQD/ % Recovery



Biolite gneiss-continued

Occasionally hornblende gneiss streaks and pegmalite dikes

Joints 0'',10°, 45°, healed and parallel to foliation, slightly rough, planar iron filling

Bottom of Hole 180.0'

FIGURE C.3.4d

CORE LOG

Job No. 1 570 86

Sheet 1 **of** 2

Project Red Mountain Dam

Location Terrace on left abutment

Hole 3

Ground Elevation 7379'

Total Depth 83.3'

Depth of Overburden 5.0'

Angle from Horizontal -90°

Bearing of Angle Hole -

Depth of Water -

Begun 8/13/86

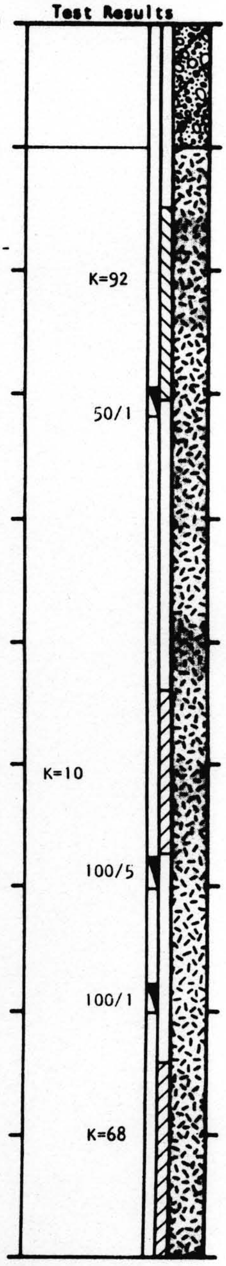
Finished 8/15/86

GEOLOGIC LOG	GRAPHIC LOG	DISCONTINUITY LOG	% RQD/ % Recovery

Depth and Elevation (Feet)

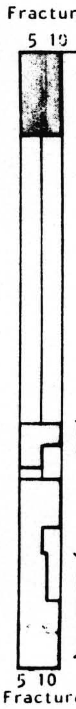
0 — Gravel: (GC) Clayey, low plastic, sandy, fine to coarse, medium dense to dense, dry, brown.

5 — Biotite Gneiss: Light gray to brownish gray, banded structure, medium grained, low hardness to hard, weathered at the top, altered and fractured, with scattered pegmatite dikes up to 4 inches thick.



0 — Hole advanced from 0.0' to 25.0' with 7" O.D. hollow stem auger.

Hole advanced from 25.0' to 83.3' with an NX core bit.



Depth (Feet)	DISCONTINUITY LOG	% RQD/ % Recovery
25	Highly fractured, with iron stains, altered several 45° joints, slightly rough, planar occasionally chlorite filling.	0/100
30–40		no recovery
40	Highly fractured and altered with several 0-10°, 80-90° joints, iron stained, slightly rough, planar.	0/100 0/50 18/100
45	Highly altered, moderately fractured, 10°, 45°, 90° joints with iron filling, occasionally calcium carbonate filling.	0/100 0/100

▮ Standard Penetration Test

▨ Packer permeability test section
K in ft./yr.

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LOG OF HOLE 3

1 570 86 Fig. A-3

FIGURE C.3.5a

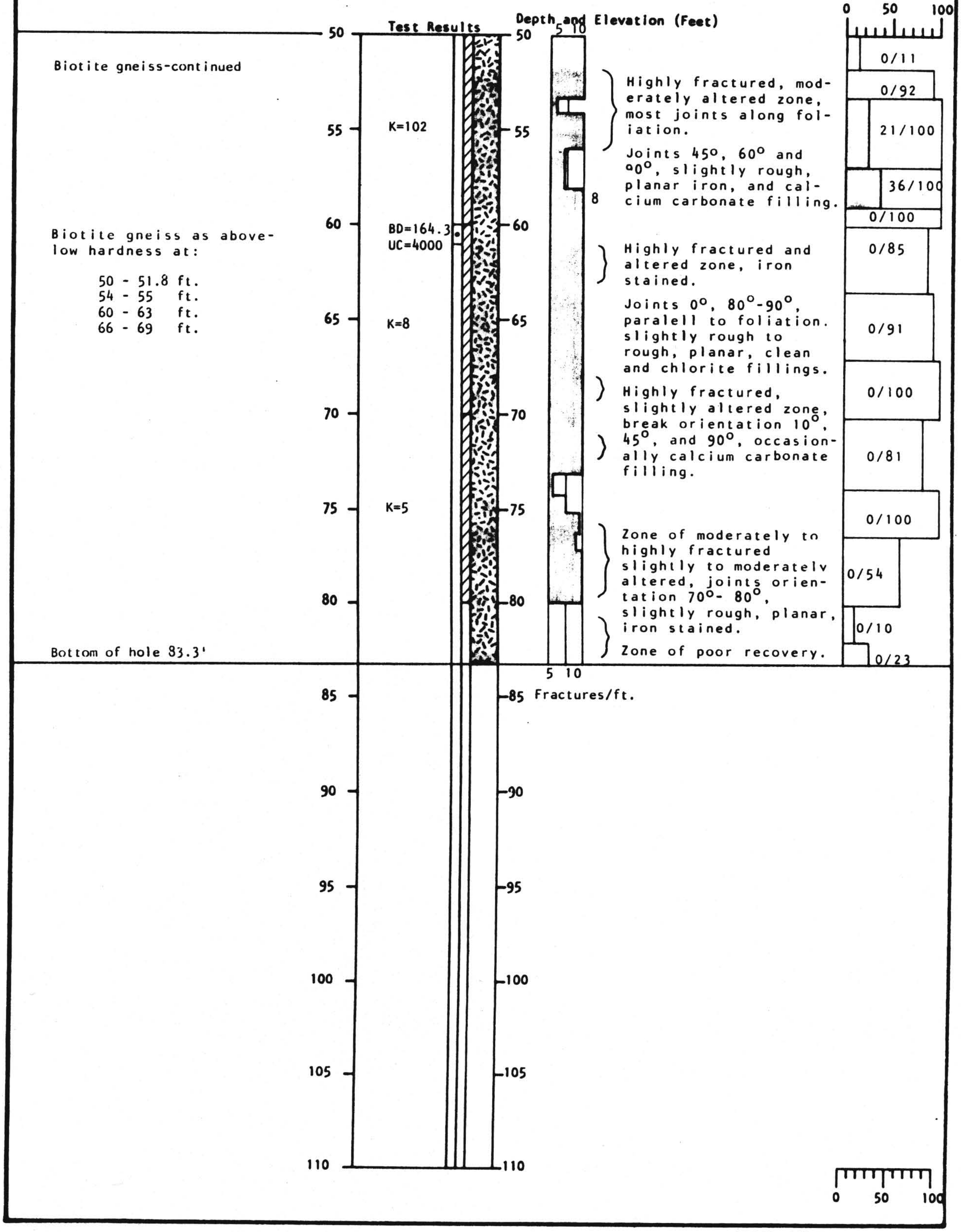
Job No. 1 570 86

CORE LOG

Sheet 2 **of** 2

Hole 3 **Continued**

GEOLOGIC LOG	**GRAPHIC LOG**	**DISCONTINUITY LOG**	**% RQD/ % Recovery**



Biotite gneiss-continued

Biotite gneiss as above-low hardness at:

50 - 51.8 ft.
54 - 55 ft.
60 - 63 ft.
66 - 69 ft.

Bottom of hole 83.3'

K=102

BD=164.3
UC=4000

K=8

K=5

Highly fractured, moderately altered zone, most joints along foliation.

Joints 45°, 60° and 90°, slightly rough, planar iron, and calcium carbonate filling.

Highly fractured and altered zone, iron stained.

Joints 0°, 80°-90°, paralell to foliation. slightly rough to rough, planar, clean and chlorite fillings.

Highly fractured, slightly altered zone, break orientation 10°, 45°, and 90°, occasionally calcium carbonate filling.

Zone of moderately to highly fractured slightly to moderately altered, joints orientation 70°- 80°, slightly rough, planar, iron stained.

Zone of poor recovery.

FIGURE C.3.5b

CORE LOG

Job No. 1 570 86

Sheet 1 **of** 2

Project Red Mountain Dam

Location Left Abutment

Hole 4

Ground Elevation 7384'

Total Depth 75.2'

Depth of Overburden 19.0'

Angle from Horizontal -90°

Bearing of Angle Hole ---

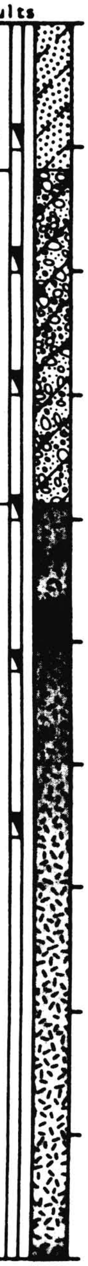
Depth of Water -

Begun 8/18/84

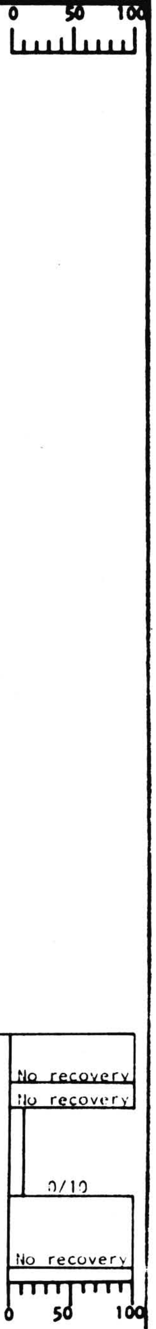
Finished 8/18/84

GEOLOGIC LOG	Depth	Test Results	Depth and Elevation (Feet)	DISCONTINUITY LOG
Sand: (SC) very silty, slightly clayey, medium dense, dry, tan	0		0	Hole advanced from 0' to 40' with 7" O.D. hollow stem auger.
	5	14/12 WC=6.7 -200=56 LL=26 PI=12	5	
Sand and Gravel: (SM-GM) fine to coarse, silty, very dense, dry, tan				
	10	12/6,26/6, 27/6	10	
	15	80/5	15	
Biotite Gneiss: greenish-gray, banded, low hardness to very hard, moist, micnocline, quartz, biolite, plagioclase, weathered	20	35/6,50/3	20	
	25	80/3	25	
	30		30	
		150/3		
	35		35	
	40		40	Hole advanced from 40' to 49.5' with NX core bit.
	45		45	Zone of poor recovery probably highly weathered and altered.
	50		50	Hole advanced from 49.5' to 58.5' with 7" O.D. hollow stem auger.

GRAPHIC LOG



% RQD/ % Recovery



Legend:

▮ Standard Penetration Test

▨ Packer permeability test section K in ft./yr.

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LOG OF HOLE 4

1 570 86 Fig. A-4

FIGURE C.3.6a

Job No. 1 570 86

CORE LOG

Sheet 2 **of** 2

Hole 4 **Continued**

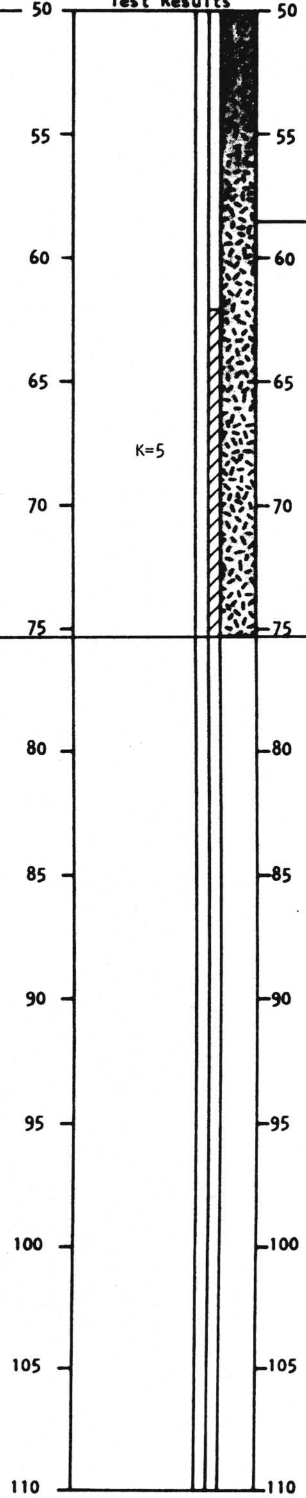
GEOLOGIC LOG	**GRAPHIC LOG**	**DISCONTINUITY LOG**	**% RQD/ % Recovery**

Test Results

Depth and Elevation (Feet)

0 50 100

Biotite gneiss- continued.



Hole advanced from 58.5' to 75.2' with NX core bit.

0/33

Probably highly altered and weathered zone

0/14

No recovery

No recovery

Bottom of Hole 75.2'

0 50 100

FIGURE C.3.6b

CORE LOG

Job No. 1 570 86

Sheet 1 of 1

Project Red Mountain Dam

Location Along U.S. Highway 40

Hole 5

Ground Elevation 7400'

Total Depth 20.0'

Depth of Overburden 15.0'

Angle from Horizontal -90°

Bearing of Angle Hole ---

Depth of Water Not encountered

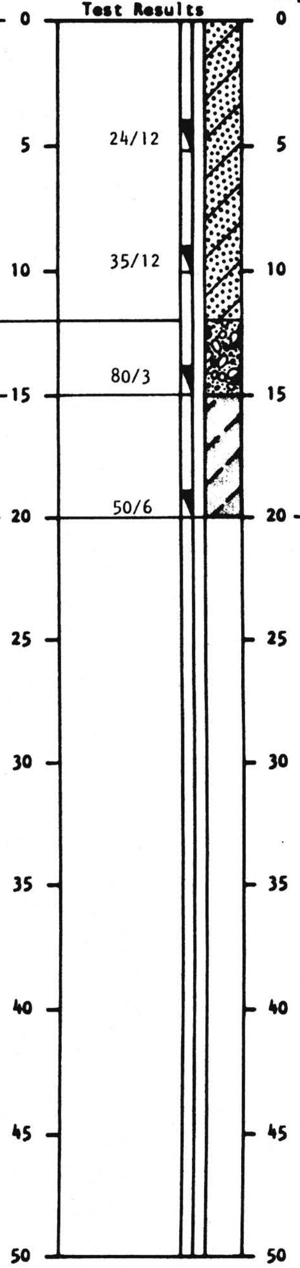
Begun 8/27/86

Finished 8/27/86

GEOLOGIC LOG	GRAPHIC LOG	DISCONTINUITY LOG	% RQD/ % Recovery

Depth and Elevation (Feet)

Depth	Geologic Log	Test Results	Discontinuity Log
0	**Sand:** (SM) silty, slightly gravelly, dense to very dense, dry, brown.		Hole was advanced from 0' to 20.0' by 4" auger.
5		24/12	
10		35/12	
12	**Gravel:** (GC) clayey, slightly silty, very dense, light moist, brown.	80/3	
15	**Claystone:** brown, low hardness to moderately hard, moist.		
20		50/6	Bottom of hole 20.0'



% RQD/ % Recovery: 0 50 100

▮ Standard Penetration Test

Chen & Associates

LOG OF HOLE 5

1 570 86

Fig. A-5

FIGURE C.3.7

CORE LOG

Job No. 1 570 86

Sheet 1 of 1

Project Red Mountain Dam

Location Left abutment along country road

Hole 6

Ground Elevation 7396'

Total Depth 30.0'

Depth of Overburden 24.0'

Angle from Horizontal -90°

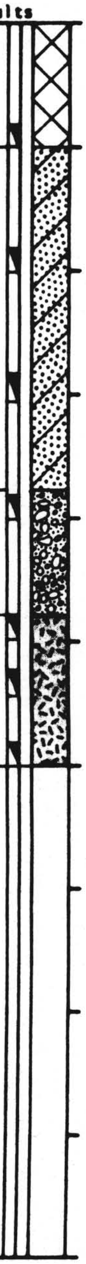
Bearing of Angle Hole -

Depth of Water not encountered

Begun 8/27/86

Finished 8/27/86

Depth and Elevation (Feet)	GEOLOGIC LOG	GRAPHIC LOG Test Results	DISCONTINUITY LOG	% RQD/ % Recovery 0 50 100
0	Fill: Silty, clayey, sand and gravel.	11/12	Hole advanced from 0'tc30.0' with 4" auger.	
5	Sand:(SM) Silty, loose, moist, brown, with scattered gravel.			
10		7/12		
15		23/12		
20	Sand and gravel:(SP-GP) Slightly silty, medium dense to dense, moist, brown	40/6,34/6, 63/6 WC=2.4 -200=5		
25	Biotite Gneiss: Gray, banded hard to very hard, moist microcline, biotite, quartz, plagioclay.	100/0 100/2		
30		100/0	Bottom of hole 30.0'	
35				
40				
45				
50				0 50 100



▮ Standard Penetration Test

Chen & Associates

LOG OF HOLE 6

1 570 86 Fig. A-6

FIGURE C.3.8

CORE LOG

Job No. 1 570 86

Sheet 1 of 1

Project Red Mountain Dam

Location Right Abutment

Hole 7

Ground Elevation 7480

Total Depth 50.0'

Depth of Overburden 11.0'

Angle from Horizontal -90

Bearing of Angle Hole ---

Depth of Water Not encountered

Begun 8/20/86

Finished 8/20/86

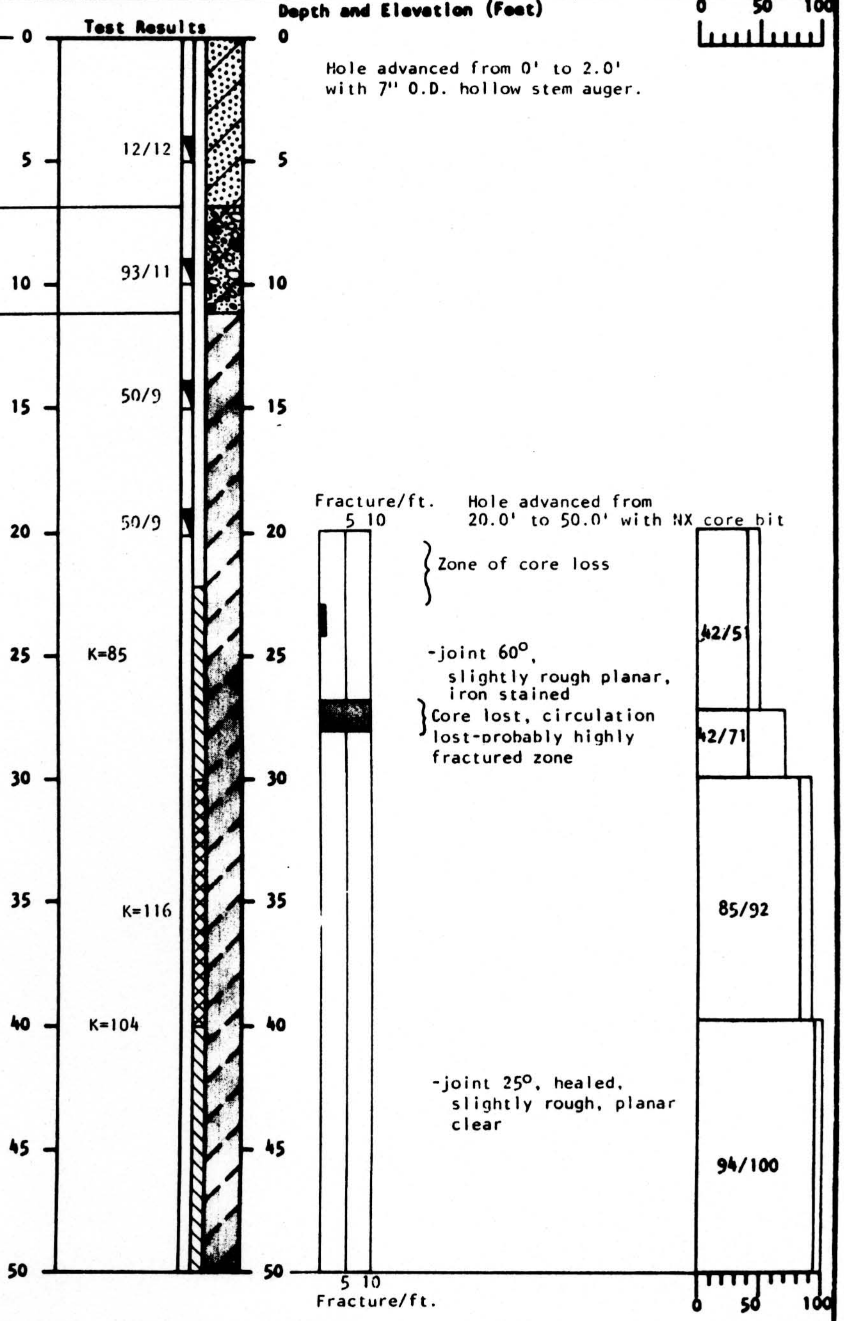
GEOLOGIC LOG	GRAPHIC LOG	DISCONTINUITY LOG	% RQD/ % Recovery

Sand: (SM) silty, medium dense, light moist, brown.

Gravel: (GM) silty, sandy, medium dense to dense, moist, brown

Claystone: brown, low to medium plasticity, low hardness to hard, blocky moist, occasionally with gray clay streaks, weakened from 11 to 15 feet.

Bottom of Hole 50.0'



Hole advanced from 0' to 2.0' with 7" O.D. hollow stem auger.

Hole advanced from 20.0' to 50.0' with NX core bit

Zone of core loss

-joint 60°, slightly rough planar, iron stained

Core lost, circulation lost-probably highly fractured zone

-joint 25°, healed, slightly rough, planar clear

Legend:

▮ Standard Penetration Test

▨ Packer permeability test section K in ft./yr.

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LOG OF HOLE 7

1 570 86

Fig. A-7

FIGURE C.3.9

CORE LOG

Job No. 1 570 86

Sheet 1 **of** 1

Project Red Mountain Dam

Location South Side of U.S. Highway 40

Hole 8

Ground Elevation 7430'

Total Depth 15.0'

Depth of Overburden 7.0'

Angle from Horizontal -90 °

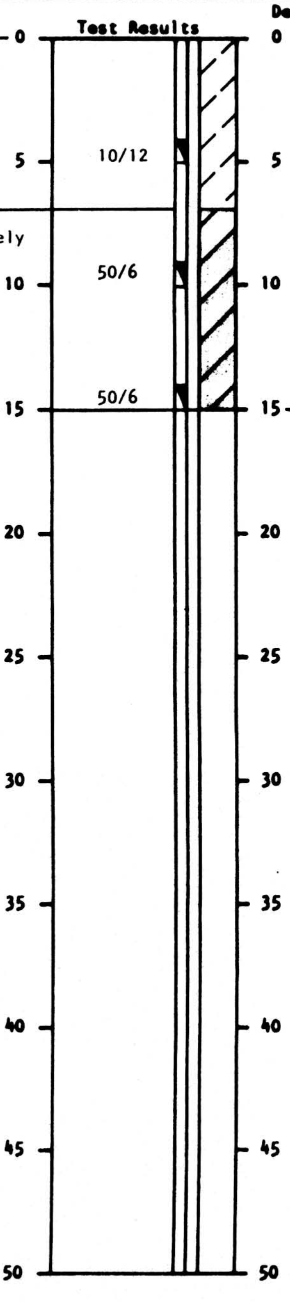
Bearing of Angle Hole ---

Depth of Water Not encountered

Begun 8/27/86

Finished 8/27/86

GEOLOGIC LOG	**GRAPHIC LOG**	**DISCONTINUITY LOG**	**% RQD/ % Recovery**
	Test Results	**Depth and Elevation (Feet)**	0 50 100



0–7.0: <u>Clay</u>: (CL) sandy, stiff, moist, brown.

7.0–15.0: <u>Siltstone</u>: Yellowish brown, moderately hard to hard, moist.

Hole was advanced from 0' to 15.0' by 4" auger.

Bottom of hole 15.0'

0 50 100

▮ Standard Penetration Test

Chen & Associates

LOG OF HOLE 8

1 570 86

Fig. A-8

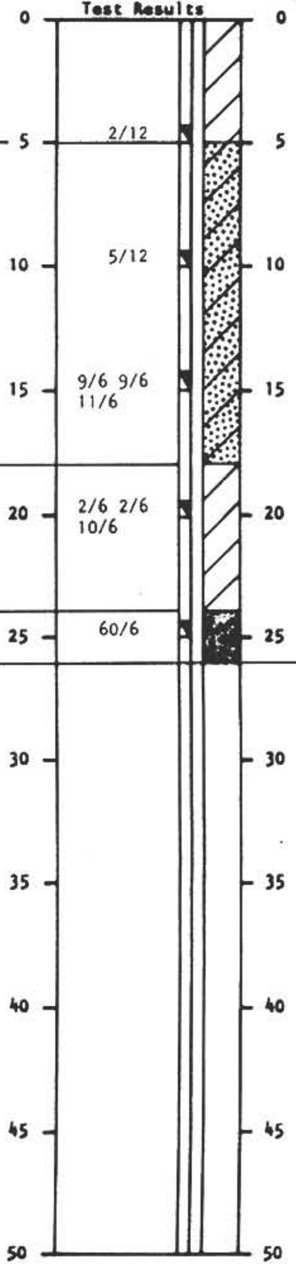
FIGURE C.3.10

CORE LOG

Job No. 1 570 86
Sheet 1 **of** 1

Project Red Mountain Dam
Location Along South Bank of Colorado River
Hole 9
Ground Elevation 7328'
Total Depth 26.0'
Depth of Overburden 24.0'
Angle from Horizontal -90°
Bearing of Angle Hole --
Depth of Water 2.0'
Begun 9/2/86
Finished 9/2/86

GEOLOGIC LOG	GRAPHIC LOG	DISCONTINUITY LOG	% RQD/ % Recovery
	Test Results	Depth and Elevation (Feet)	0 50 100
Silt: (ML) slightly sandy, very soft, moist to wet, black.	2/12	Hole advanced from 0.0' to 26.0' with 4" auger	
Sand: (SM) very silty, slightly gravelly, medium dense, wet, black.	5/12 9/6 9/6 11/6		
Silt: (ML) sandy, slightly gravelly, medium stiff, wet, black.	2/6 2/6 10/6		
Gneiss: gray, banded, very hard, wet.	60/6	Bottom of hole 26.0'	



▮ Standard Penetration Test

Chen & Associates

LOG OF HOLE 9

1 570 86 Fig. A-9

FIGURE C.3.11

NOTES:

1. Exploratory borings were drilled between March 24, 1986 and September 2, 1986 with a 4-inch diameter continuous flight power auger, a 7-inch diameter continuous flight hollow stem auger and a NX core bit.

2. Locations of borings were measured approximately by pacing from features shown on the site plan provided.

3. Elevations of borings were obtained by interpolation between contours on the U.S.G.S. 7½' Junction Buttle quadrangle. Elevations of Holes 1 through 4, 6 and 9 were based on contours provided by Boyle Engineering Corporation.

4. The boring locations and elevations should be considered accurate only to the degree implied by the method used.

5. The lines between materials shown on the boring logs represent the approximate boundaries between material types and the transitions may be gradual.

6. Water level readings shown on Table A-1 were made at the time and under conditions indicated. Fluctuations in the water level may occur with time.

7. LABORATORY TEST RESULTS

   WC=Water Content (%);
   DD=Dry Density (pcf);
   BD=Bulk Density (pcf);
   -200=Percentage Passing No. 200 Sieve;
   UC=Unconfined Compressive Strength (psi);
   LL=Liquid Limit (%);
   PI=Plasticity Index (%).

8. 7/12 Drive sample blow count. Indicates that 7 blows of a 140-pound hammer falling 30 inches were required to drive the California of SPT sampler 12 inches.

FIGURE C.3.12

1 570 86	**Chen & Associates**	NOTES	Fig. A-10

C.4.0 GREEN MOUNTAIN RESERVOIR TO DILLON RESERVOIR CONVEYANCE SYSTEM

The proposed construction would consist of an underground pipeline extending from Green Mountain Reservoir south to Dillon Reservoir. The pipeline would be approximately 26 miles in length. The inlet structure would be located adjacent to the outlet works at the toe of the dam at the north end of the Green Mountain Reservoir. The pipeline would then extend along County Road 30 to its intersection with State Highway 9. The pipeline would then parallel Highway 9 on the west side of the road to the town of Silverthorne. The pipeline be on the west side of Blue River in the area of Slate Creek where the road is approximately 1/2 to 3/4 mile east of the river. In the town of Silverthorne, The pipeline would extend under Blue River and up the right abutment to Dillon Dam with an outlet structure into Dillon Reservoir near the right abutment. The information in this section is from "Feasibility Level Geotechnical Investigation Green Mountain/Dillon Conveyance Facility Summit County, Colorado", Chen & Associates, June, 1986.

C.4.1 SUBSURFACE CONDITIONS

The general subsurface conditions along the proposed pipeline alignment were investigated by drilling ten exploratory borings at the locations shown on Figure C.4.1. Logs of the exploratory borings are shown on Figure C.4.2a. The legend and notes are shown on C.4.2b. The borings were drilled to determine the subsurface profile and approximate ground water levels. The conditions encountered in the borings generally consisted of granular soils to the maximum depth investigated. A layer of man-placed fill, 2.5 to 5 feet in thickness was encountered overlying the natural soils in Holes 1, 7 and 10. The man-placed fill consisted of sandy to very sandy gravel with scattered areas of sandy clay.

Soils

The natural granular soils consisted of clayey sand to silty to sandy gravel with cobble and boulders. Difficult drilling conditions were encountered in Holes 2, 3, 4, 5, 8, 9, and 10 with practical drill rig refusal encountered at depths ranging from 2.5 to 26.5 feet. The remaining borings were advanced to a depth of 30 feet without refusal. The results of standard penetration test in the borings indicate the N value of the soils in the upper 10 feet ranges from 7/12 to 50/0. The clayey to silty sands appear to be loose to medium-dense based on the results of standard penetration tests. The gravel materials are medium-dense to dense in consistency.

Water Levels

Free water was encountered in Hole 1 through 4, 7 and 8 at the time of drilling, at depths ranging from 3 to 27 feet below the ground surface. Slotted plastic pipe observation wells were installed in the borings for continued water level monitoring. When checked five days after drilling, free water was encountered at depths ranging from 8 to 23 feet below the ground surface. Water levels were also checked on May 22, 1986. On this date Holes 1, 3, 4, 6, 7 and 8 were checked for free water. Water was encountered in Holes 3, 4 7 and 8 at depths ranging from 4.5 to 11 feet below the ground surface.

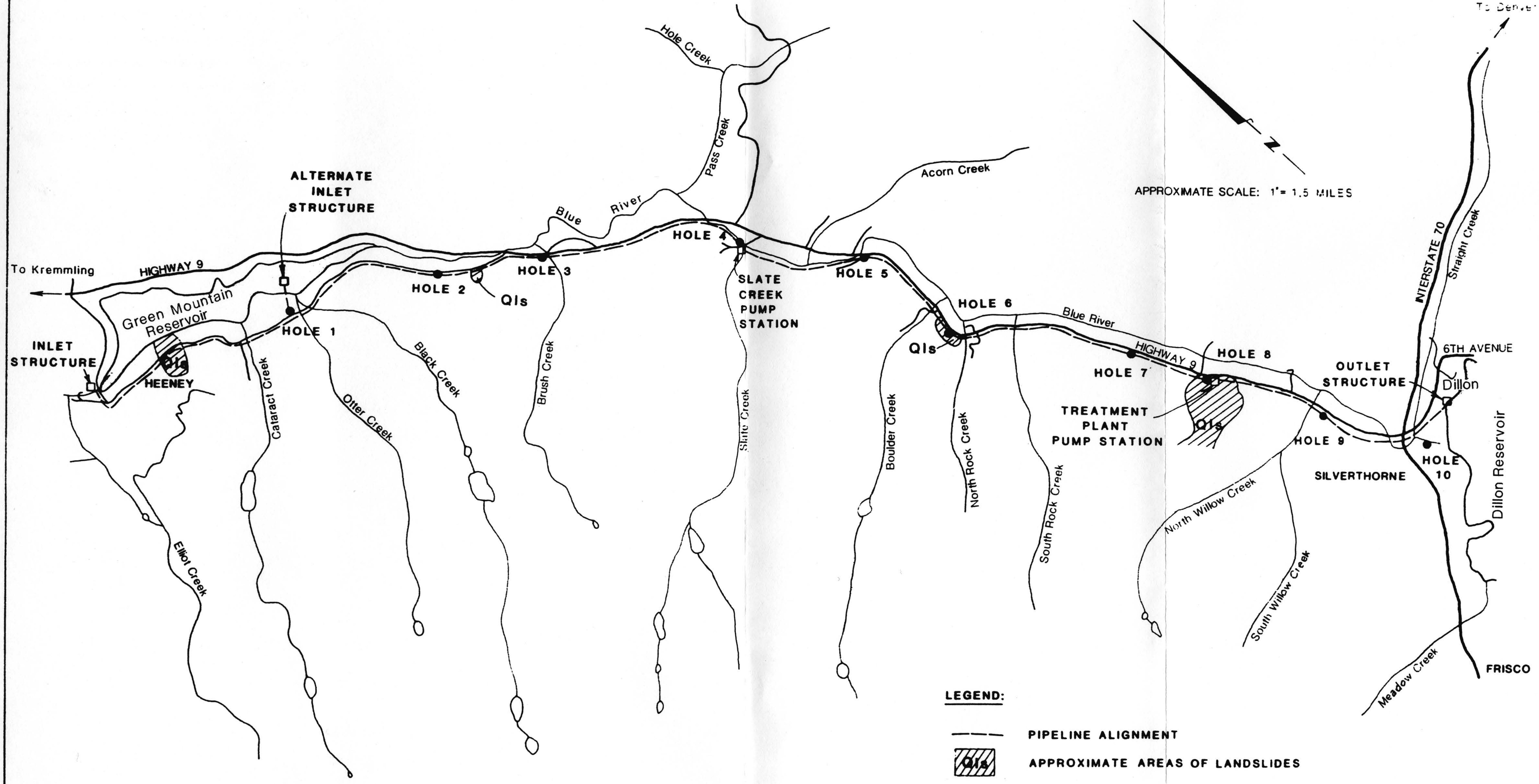


FIGURE C.4.1

1 787 85	**Chen & Associates**	GREEN MOUNTAIN/DILLON CONVEYANCE FACILITY	VICINITY MAP	Fig 1

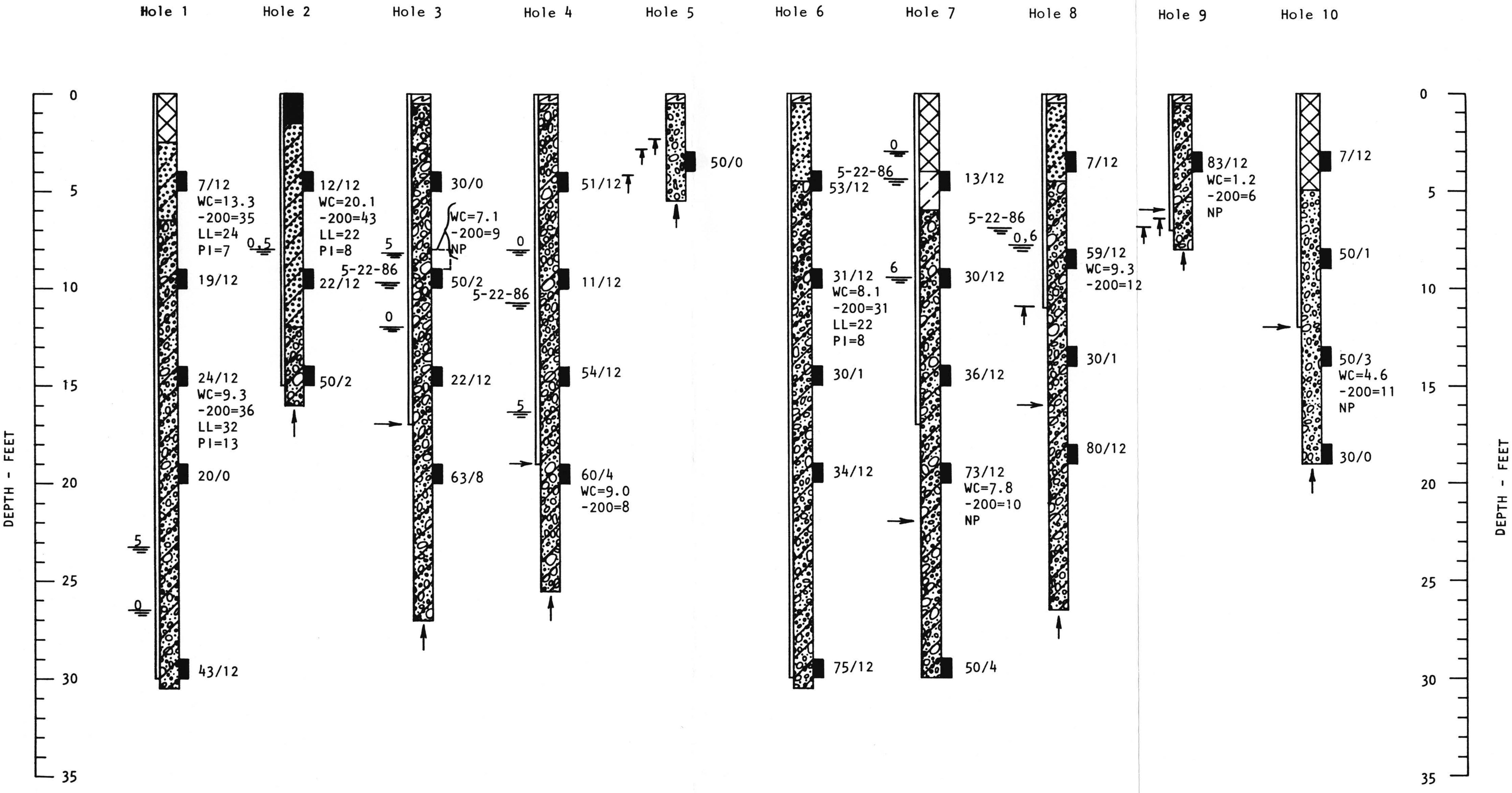


FIGURE C.4.2a

1 787 85	**Chen & Associates**	LOGS OF EXPLORATORY BORINGS	Fig. 2

LEGEND:

▨	Topsoil
■	Base Course
☒	Fill, gravel, sandy to very sandy, moist, brown, scattered areas of sandy clay.
▧	Clay (CL) sandy, silty, stiff, moist, brown.
▦	Sand (SC) clayey, scattered gravel, loose to medium dense, moist, brown.
▩	Sand (SM) silty, medium dense to dense, moist to wet, brown.
▩	Gravel (GP) sandy with cobbles, boulders dense to very dense, moist to wet, brown.
▩	Gravel (GM) silty, sandy with cobbles, boulders dense to very dense, moist to wet, brown.
▌	Drive sample, Standard Penetration Test, 1 3/8-inch I.D. split spoon sample.
7/12	Drive sample blow count, indicates that 7 blows of a 140-pound hammer falling 30 inches were required to drive the SPT sampler 12 inches.
⊏	Disturbed bulk sample.
▮	Indicates PVC pipe installed in hole to the depth shown.
5-22-86 5 ≡	Depth to water level and number of days after drilling or date measurement was taken.
→	Depth at which exploratory boring caved.
↑	Practical rig refusal.

NOTES:

1. Exploratory borings were drilled on September 19 and 20, 1985 with a 4-inch diameter continuous flight power auger.
2. Locations of exploratory borings were measured approximately by pacing from features shown on the site plan provided.
3. Elevations of exploratory borings were not measured and logs of exploratory borings are drawn to depth.
4. The exploratory boring locations should be considered accurate only to the degree implied by the method used.
5. The lines between materials shown on the exploratory boring logs represent the approximate boundaries between material types and the transitions may be gradual.
6. Water level readings shown on the logs were made at the time and under conditions indicated. Fluctuations in the water level may occur with time.
7. LABORATORY TEST RESULTS

   WC=Water Content (%);
   -200=Percentage Passing No. 200 Sieve;
   LL=Liquid Limit (%);
   PI= Plasticity Index (%);
   NP=Nonplastic (%).

FIGURE C.4.2b

1 787 85	**Chen & Associates**	LEGEND & NOTES	Fig. 3