BIRCH CREEK DAM

PHASE II
GEOLOGY & SEISMIC REPORT

PRELIMINARY

DIVISION OF WATER RESOURCES

1636 WEST NORTH TEMPLE, SUITE 310
SALT LAKE CITY, UT 84116-3156

#1075

BIRCH CREEK DAM

PHASE II
GEOLOGY & SEISMIC REPORT

PRELIMINARY

DIVISION OF WATER RESOURCES
Engineering Geology Section
1636 West North Temple
Suite 310
Salt Lake City, Utah 84116

GEOLOGY/SEISMIC REPORT

October 27, 1994

TO: Dennis Strong
Assistant Director
FROM: Ben Everitt
Chief Engineering Geologist
Dan Aubrey
Engineering Geologist
SUBJECT: Birch Creek Dam No. 2 - Phase II Geology & Seismic Report

Location & Introduction

Birch Creek Dams No. 1 & 2 are located on Birch Creek which is a tributary to Woodruff Creek, about 9 miles upstream of the town of Woodruff in Rich County, Utah, and about 3 miles directly north of Woodruff Creek reservoir (Figure 1). Birch Creek Dam No. 2 is located on the Birch Creek Reservoirs 7 1/2 minute topographic map in the NW 1/4 of the NW 1/4 of Section 19, T9N, R6E, SLB&M. The dam is operated by the Woodruff Irrigation Company.

Design work for Birch Creek Dam No. 2 was completed in 1950, following several years of site investigation. Construction was begun in the spring of 1951 and completed in January of 1952, since its completion no major modifications have been necessary (U.S.Army, 1979). The dam is described as a zoned earthfill structure (see Figure 2) with an impervious clay filled core and cutoff trench. The crest is 474 feet long, 100.4 feet above the streambed, and has a width of 24.38 feet (U.S.Army, 1979 and Figure 3).

Regional & Reservoir Basin Geology

The Quaternary units, in the area immediately around the dam, consist of various fluvial and colluvial units which vary in thickness (unit Qac on Figure 4). Marsell (1968) described similar overburden, at Woodruff Creek Dam, as "poorly sorted cobbles, gravels, sand, silt and some clay". These deposits originated as colluvium derived from the Wasatch and Twin Creek formations, which underlie adjacent slopes, and as fluvial sediments deposited as terraces (Marsell, 1968).

The Tertiary Wasatch Formation, in this area has been measured as being a thousand feet or more in thickness (Hintze, 1988). Marsell (1964 & 1968) described the Wasatch as consisting of "a coarse, thick-bedded red conglomerate with abundant cobbles and boulders of quartzite and cherty limestone embedded in a red, silty matrix". He noted that the boulders were all well rounded and were as large as 8-10 inches in diameter. The Wasatch Formation unconformably overlies the Twin Creek limestone. Birch Creek has eroded its valley through the capping Wasatch and into the underlying Twin Creek. Locally the Wasatch Formation is above the elevation of the dam and reservoir while the Twin Creek limestone forms the reservoir basin, and the abutments of the dam (Figure 4).

WOODRUFF & BIRCH CREEK #2
RESERVOIR LOCATIONS

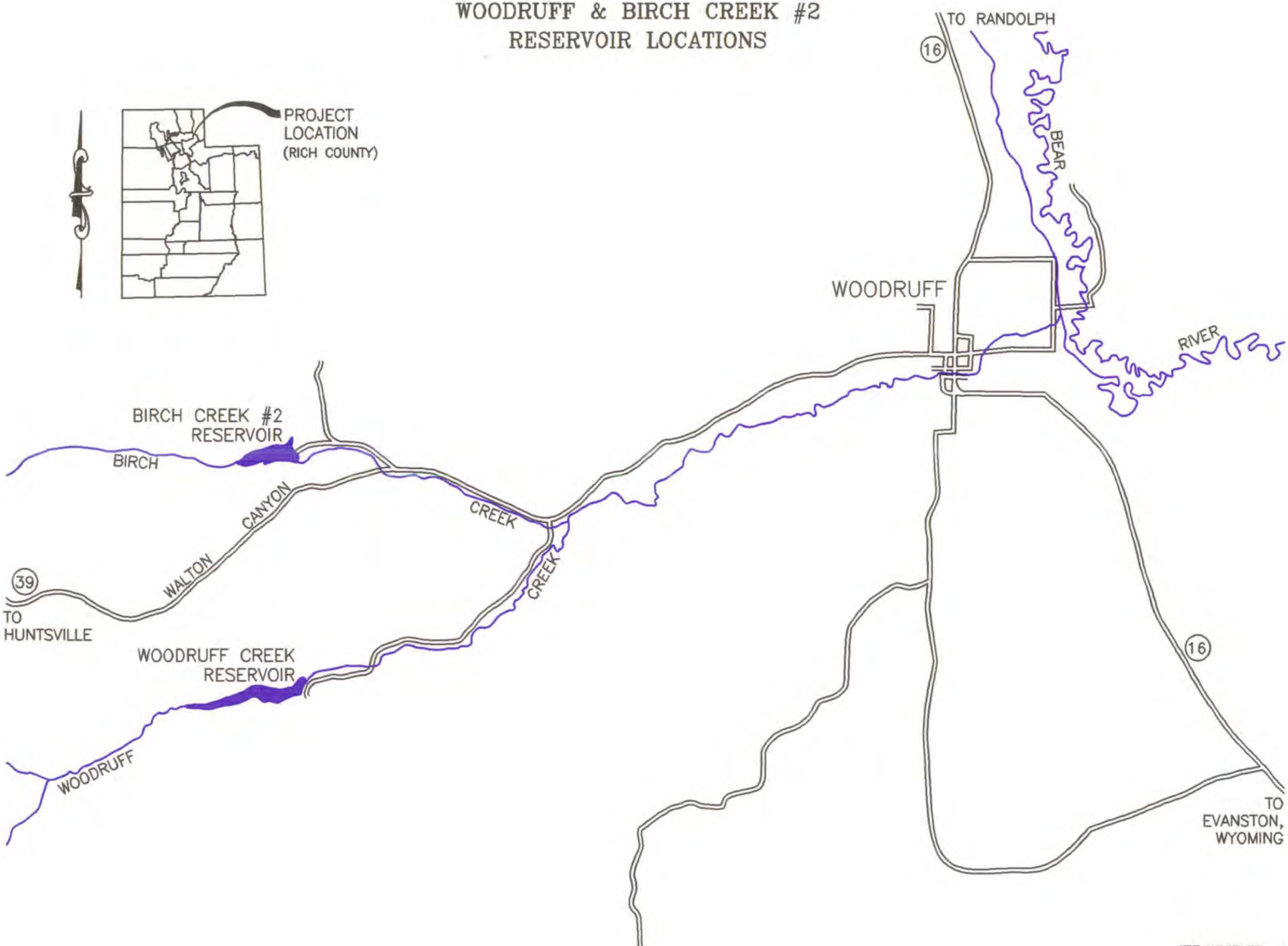
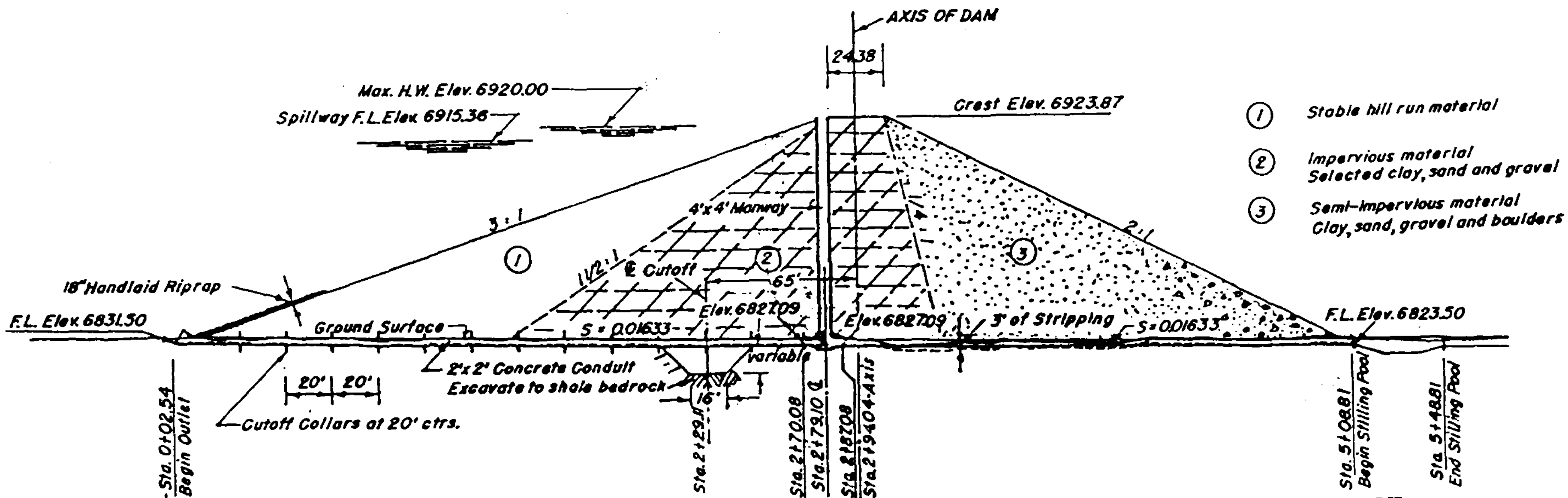
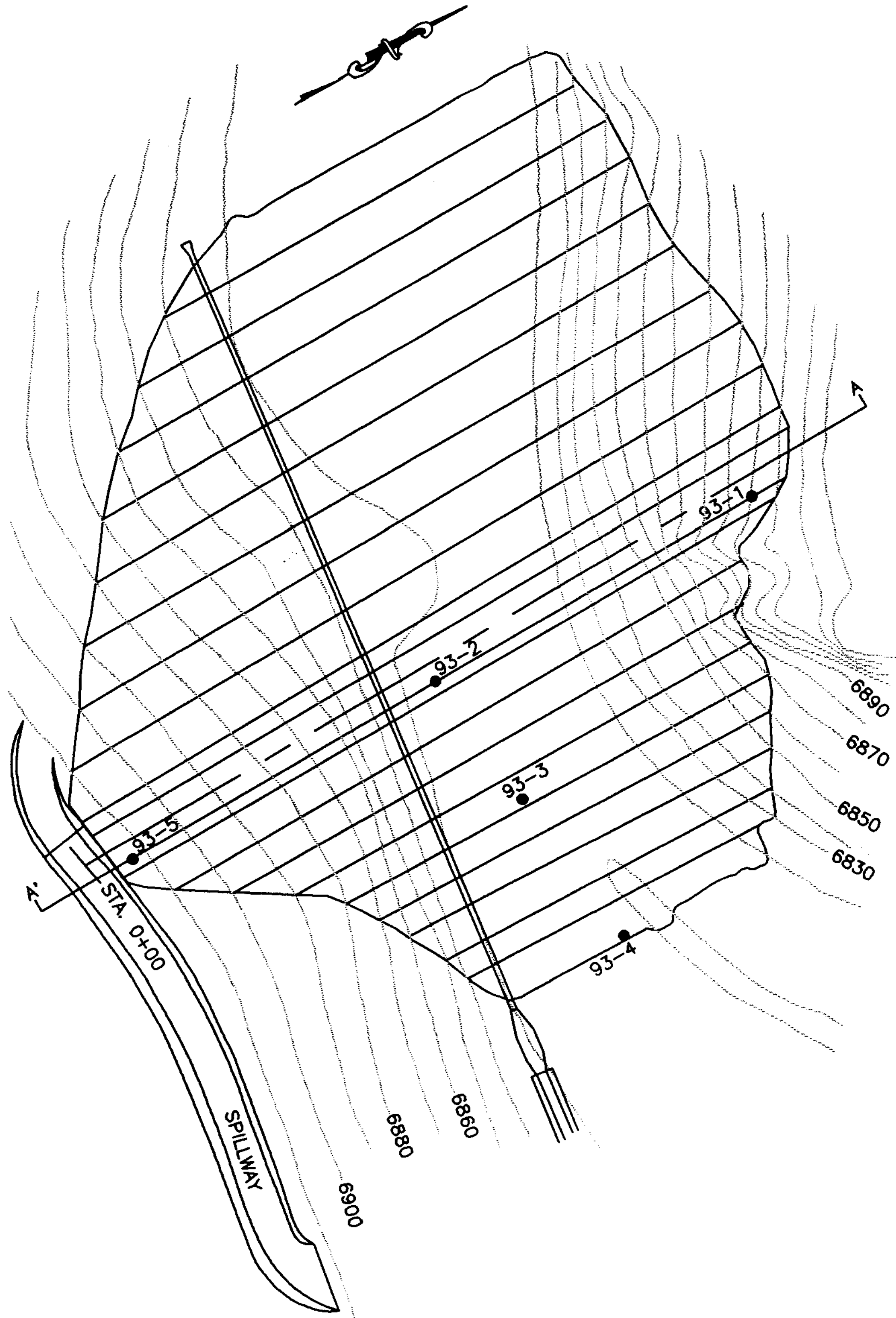


FIGURE 1



MAXIMUM AND LONGITUDINAL SECTIONS OF DAM ON CENTER LINE OF OUTLET

Figure 2

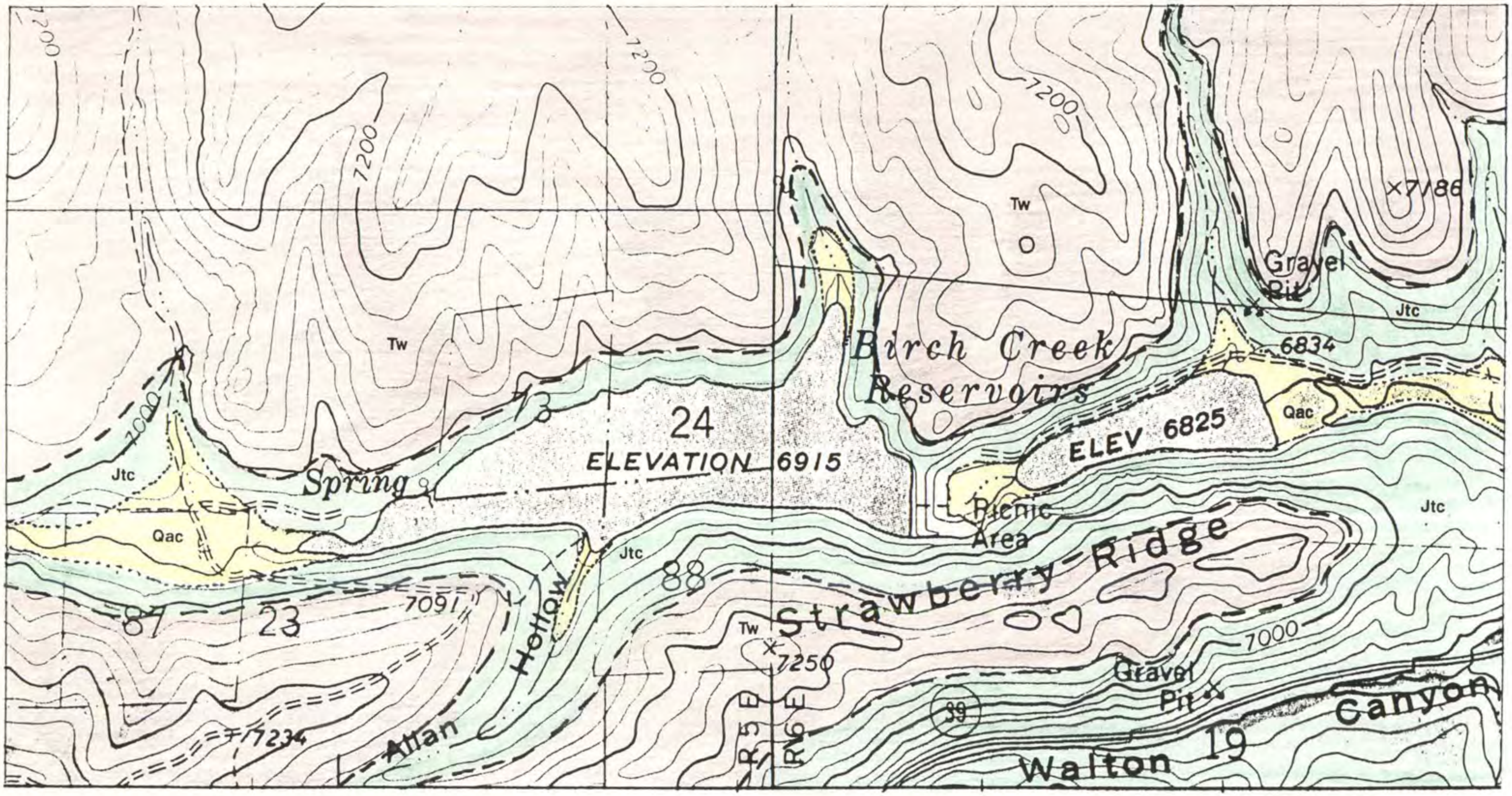


BIRCH CREEK DAM #2
WOODRUFF IRRIGATION COMPANY
RICH COUNTY, UTAH

CONTOUR INTERVAL 10 FEET
SCALE: 1" = 100'

● DRILL HOLES 93-1 THRU 93-5

FIGURE **3**



Geologic Map

Birch Creek Reservoirs

Rich County, Utah

Qac	Quaternary alluvium & colluvium
Tw	Tertiary Wasatch Formation
Jtc	Jurassic Twin Creek Formation

N

Scale 1" = 1000'

40 Foot Contour Interval

Figure 4

Geology based on aerial photo & field reconnaissance

The Jurassic Twin Creek Limestone is measured at 2,300 feet thick, and consists of both shaly limestone and calcareous shale (Hintze, 1988) that regionally is "generally highly folded, bent, crumpled, and broken" (Marsell, 1964 & 1968). Outcrops of this formation in the immediate area around the reservoir are observed to consist of thin to very thin-bedded, highly jointed to splintery, shaly limestone. The bedding at the dam dips 25° to 30° in an upstream direction, while the joints dip in a downstream direction at 60° to 65° (U.S.Army, 1979 Photo's 2 and 8).

1993 Investigation

Using a CME 55 drilling rig, RB&G Engineering Inc. of Provo, Utah started drilling at Birch Creek Dam #2 on September 24, 1993. By October 19th, five holes had been drilled (DH 93-1 through 93-5, see Figure 3) and ten piezometers installed.

The embankment was drilled dry using 4 1/2" I.D. hollow stem augers with 7 1/2" O.D. flights. Drive samples were recovered at least every 5 feet using a 2" split spoon. Where encountered (DH's 93-2, 93-3, & 93-4) the alluvium was drilled and cased using NX size, rotary wash rock bits and casing. Bedrock was drilled using an NX diamond bit and wireline core barrel. Percolation tests were conducted every 5 feet in unconsolidated foundation material (alluvium) while packer tests were run at 10 foot intervals in the consolidated foundation (Twin Creek Limestone).

Based on the drill hole logs (see Appendix A), select samples were sent to Dames & Moore for laboratory testing (Gradation & Atterburg Limits). The results are found in Appendix B and summarized in Table 1.

To allow a down hole shear wave analysis of the embankment, one of the piezometers in DH 93-2 was specially constructed using 2" PVC and bentonite as backfill. Below five feet the shear wave velocities ranged from 943 ft/sec to 1353 ft/sec with an average of 1099 ft/sec, see Appendix C for details.

Geology of the Foundation

The bedrock which occurs in the foundation and both abutments (see Figure 5) is thin bedded carbonaceous rocks of the Jurassic Twin Creek Limestone. The Twin Creek Limestone, which elsewhere in the region is steeply dipping to overturned, is more gently dipping at the damsite. In outcrop (particularly in the left abutment) numerous joint sets have broken the rock into small sliver shapes resembling pencils.

The alluvium as characterized by the drilling and laboratory testing indicate that this material is sandy silt and clay, and clayey gravel. There appears to be no loose (liquefiable) sands. K values (hydraulic conductivity) for the alluvium range from 93 feet per year to 173 feet per year (DH 93-4). K values in bedrock range from 5 feet per year to 574 feet per year. Thus the aquifer characteristics of the alluvium would be described as heterogeneous and anisotropic. Information in Tables 1 & 2 help to characterize the alluvial foundation materials as sampled in DH's 93-2, 93-3, & 93-4.

Embankment Characterization

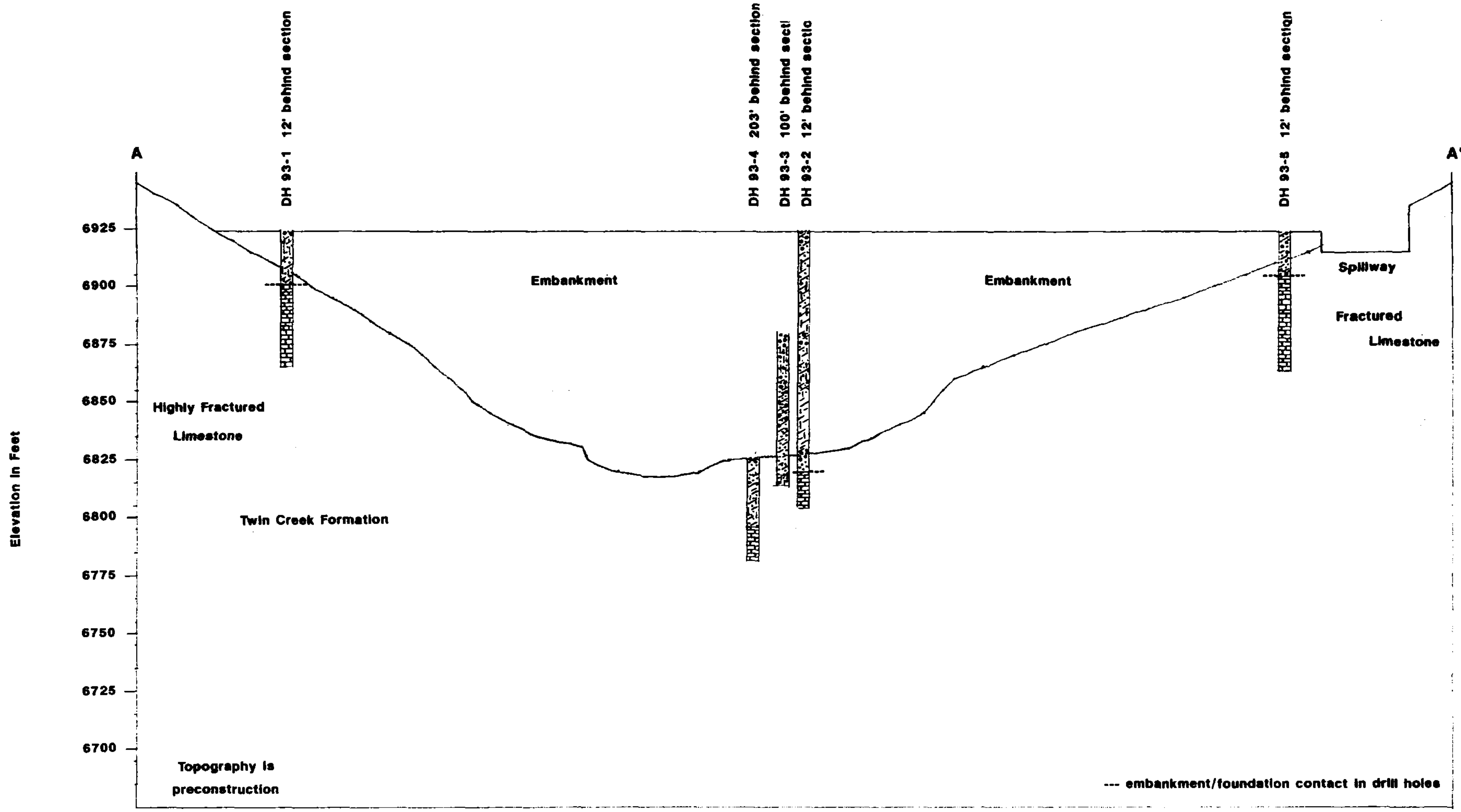
Based on the 1993 drilling and laboratory test results the embankment materials classify as dense (based on an average of 33 blows/foot) clay to sandy clay with an average of 52% fines and 29% sand (see Tables 1 & 3). DH's 93-1, 93-2, & 93-5 were located to sample impervious core material, zone 2 (see Figure's 2 & 3). DH 93-3 was located to sample the downstream shell,

TABLE 1
SUMMARY OF LABORATORY TEST DATA - BIRCH CREEK DAM #2

HOLE	DEPTH (feet)	DESCRIPTION	ATTERBERG LIMITS %*			SIEVE ANALYSIS %			UNIFIED SOIL CLASSIFICATION
			LL	PL	PI	SLT/CL	SAND	GRAVEL	
93-1	15-16.5	Embankment	30	16	14	61.3	28	10.7	CL
93-2	15-16.5	Embankment				51.8	23.1	25.1	CL
	50-51.5	Embankment	36	20	16				CL
	70-71.5	Embankment	36	19	17				CL
	100-01.5	Alluvial Foundation				21.1	36.7	42.2	GC
93-3	25-26.5	Embankment				58.8	26.5	14.7	SC
	40-41.5	Embankment	37	19	18	40.9	36.4	22.7	SC
	55-56.5	Alluvial Foundation				55.8	44.2	0	CL
	65-66.5	Alluvial Foundation	22	21	1	70.3	29.6	0.1	ML
93-4	15-16.5	Alluvial Foundation	21	20	1	75.4	24.4	0.2	ML
	24-25.5	Alluvial Foundation	24	16	8	63.4	34.3	2.3	CL
93-5	10-11.5	Embankment	32	17	15	46.6	31.8	21.6	SC

* Atterbergs performed according to ASTM 4318; on minus #40 fraction.

DIVISION OF WATER RESOURCES



BIRCH CREEK DAM #2

CROSS-SECTION A-A'

LOOKING DOWNSTREAM

Scale Vertical & Horizontal 1"=50'

0' 50' 100'

Figure 5

Cross-Section On Crest Of Dam See Figure 3

TABLE 2

Alluvial Foundation Characterization

Drill Holes	Sample Depths	Blows Per Foot	Density	USCS	Laboratory Classification % Fines	% Sand	% Gravel
93-2	90-91.5′	28	V. Stiff	ML			
	95-96.5′	30	Md. Dense	SW			
	100-101.5′	26	Md. Dense	GC	21.1	36.7	42.2
93-3	55-56.5′	14	Stiff	CL	55.8	44.2	0.0
	60-61.5′	27	Md. Dense	GW			
	65-66.5′	10	Stiff	ML	70.3	29.6	0.1
93-4	5-6.5′	8	Stiff	CL			
	10-11.5′	16	Md. Dense	GC			
	15-16.5′	6	Firm	ML	75.4	24.4	0.2
	20-21.5′	2	Soft	CL			
	24-25.5′	3	Soft	CL	63.4	34.3	2.3

zone 3 (see Figure's 2 & 3). Based on sample descriptions (see DH Logs Appendix A) and lab results (see Table 1) there appears to be no difference between materials in these two zones.

Seismotectonic Setting

Birch Creek Dam #2 is located in north-central Utah and very near the northeastern margin of the Basin and Range province. Here the intermountain seismic belt is composed of north-trending normal faults which have formed in response to east-west Neogene extension superimposed on the Cretaceous-early Tertiary compressional fold and thrust belt (McCalpin, 1992). The Uniform Building Code of 1988 assigns this area to seismic zone 3. Algermissen and others (1982) assign an acceleration of 0.40g with a 90% probability of not being exceeded in 250 years.

Historic Earthquakes

Table 4 lists all earthquakes which have occurred within a 15 mile radius of the dam. The largest earthquake to occur, at a radius of 5.93 miles, was a magnitude 2.4 in May of 1967.

Table 5 lists all earthquakes greater than magnitude 4 that have occurred within a radius of 75 miles. The largest earthquake to occur in this region, was the 1884 quake near Bear Lake, see Figure 6. Table 5 indicates this quake was estimated to have a magnitude of 6.3 and occur at a distance of 34-35 miles from the damsite. A second quake estimated at magnitude 6.3 occurred in 1909 at a distance of 72 miles from the damsite.

On February 3, 1994 a series of earthquakes, including a shock of moment magnitude (M_w) 5.8-5.9 occurred in a mountainous region near the Idaho-Wyoming border (Arabasz et. al. 1994), approximately 79 miles north of the Birch Creek Dam #2. Although beyond the 75 mile radius it is interesting to note that its correlation with known faults is uncertain (Arabasz, 1994). The nearest major Quaternary normal fault is the Star Valley fault which lies about 11 miles east of the mainshock epicenter.

Potential Seismic Sources

The following is a description of the known (mapped) faults in the vicinity of Birch Creek Dam #2, taken from Hecker (1993). See Figure 6 for the location of these faults in relation to the dam.

Crawford Mountain Fault - This fault lies on the west side of the Crawford Mountains, 11 miles east of the dam. Goter (1990) characterizes this fault as Pleistocene to late Quaternary. Hecker (1993) indicates that the age of most recent movement (involving surface rupture) is about 70,000 years ago. An earthquake swarm in 1884 (pre-instrumental) with maximum estimated magnitude of 2.0 was attributed to this fault (Cook & Smith, 1967).

Saleratus Creek Fault - This fault is the closest to the dam, its northern end lying 9 miles southeast of the dam. Evidence suggests that this fault has not experienced surface rupture since late Pleistocene (Hecker, 1993).

East Bear Lake Fault - The southern end of this fault (near Laketown) is 22 miles north of the dam. Recently completed studies which included trenching, indicate that the most recent movement on the fault was approximately 2,100 years ago. Based on the amount of surface rupture,

TABLE 3

Embankment Materials Characterization

Drill Holes	Sample Depth	Blows Per Foot	Density	USCS	Laboratory Classification % Fines	% Sand	% Gravel
93-1	5-6.5′	26	V. Stiff	ML			
	10-11.5′	13	Stiff	ML			
	15-16.5′	15	Stiff	CL	61.3	28.0	10.7
	20-21.5′	11	Stiff	ML			
93-2	5-6.5′	44	Dense	SC			
	10-11.5′	43	Dense	SC			
	15-16.5′	87	Hard	CL	51.8	23.1	25.1
	20-21.5′	35	Hard	ML			
	25-26.5′	22	V. Stiff	ML			
	30-31.5′	26	V. Stiff	ML			
	35-36.5′	22	V. Stiff	ML			
	40-41.5′	26	V. Stiff	ML			
	45-46.5′	30	Dense	SC			
	50-51.5′	29	V. Stiff	CL			
	55-56.5′	28	V. Stiff	SC			
	60-61.5′	27	V. Stiff	ML			
	65-66.5′	24	V. Stiff	ML			
	70-71.5′	17	V. Stiff	ML			
	75-76.5′	21	V. Stiff	ML			
	80-81.5′	28	V. Stiff	ML			
	85-86.5′	23	V. Stiff	ML			
93-3	5-6.5′	40	Hard	SM			
	10-11.5′	79	Hard	SM			
	15-16.5′	33	Hard	SM			
	20-21.5′	20	V. Stiff	CL			
	25-26.5′	21	Md. Dense	SC	58.8	26.5	14.7
	30-31.5′	22	Md. Dense	SC			
	35-36.5′	62	V. Dense	SC			
	40-41.5′	24	Md. Dense	SC	40.9	36.4	22.7
	45-46.5′	16	Md. Dense	SC			
	50-51.5′	41	Dense	SC			
93-5	5-6.5′	80	V. Dense	SC			
	10-11.5′	53	V. Dense	SC	46.6	31.8	21.6
	15-16.5′	34	Dense	SC			

TABLE 4

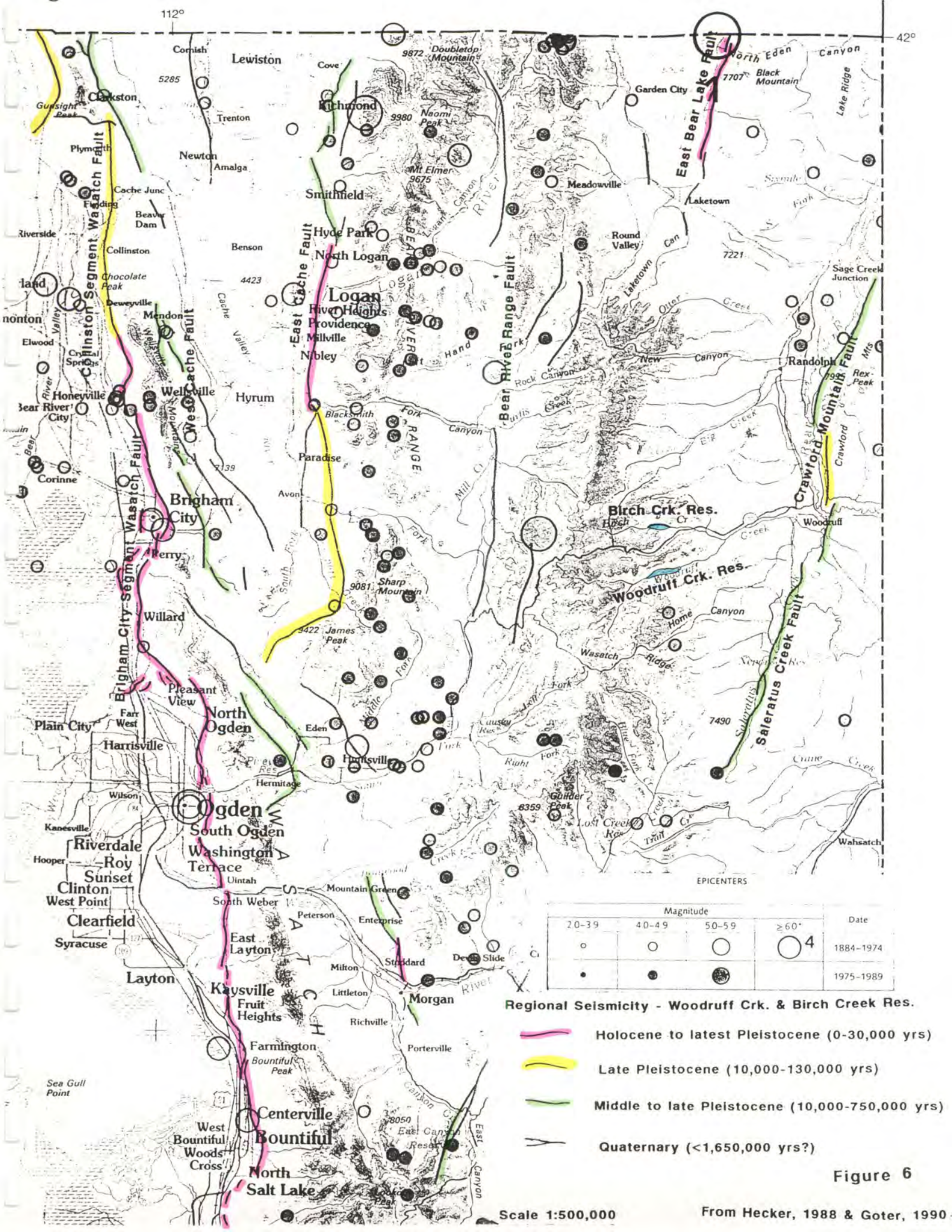
All Earthquakes >1.00 Magnitude Within A 15 Mile Radius
With Center At 473,300 East and 4,594,700 North
Indexed By Magnitude

Report From Univ. of Utah Earthquake Database

Year	Date MoDa	Latitude Deg. Min.	Longitude Deg. Min.	Magn	Radius Miles
1967	501	41 25.17	111 19.56	2.40	5.93
1991	1110	41 27.59	111 17.47	2.10	3.48
1990	710	41 23.14	111 20.68	2.00	8.36
1971	406	41 32.16	111 27.60	1.90	7.56
1984	1223	41 37.19	111 9.38	1.82	11.58
1971	822	41 24.20	111 32.57	1.80	13.54
1985	1127	41 23.00	111 25.39	1.67	9.98
1983	807	41 22.52	111 22.95	1.60	9.54
1976	313	41 34.81	111 23.58	1.60	6.40
1975	1228	41 30.07	111 29.05	1.60	8.52
1987	1119	41 37.72	111 27.48	1.52	11.11
1984	923	41 35.50	111 25.31	1.38	7.96
1982	409	41 18.24	111 22.58	1.36	14.20
1987	1129	41 38.30	111 28.35	1.25	12.11
1982	118	41 31.61	111 19.93	1.23	1.61
1971	822	41 31.35	111 27.78	1.20	7.51
1982	821	41 37.52	111 9.74	1.00	11.62

TABLE 5
All Earthquakes >4.00 Magnitude Within A 75 Mile Radius
With Center At 473,300 East And 4,594,700 North
Indexed by Radius
Report From Univ. of Utah Earthquake Database

Year	Date MoDa	Latitude Deg. Min.	Longitude Deg. Min.	Magn	Radius Miles
1966	317	41 39.66	111 33.63	4.60	16.45
1964	1018	41 43.55	111 43.77	4.10	26.09
1923	607	41 44.26	111 49.85	4.30	30.92
1884	1110	42 0.00	111 16.00	6.30	34.23
1988	1119	41 59.75	111 28.33	4.80	34.74
1950	102	41 30.00	112 0.00	4.30	35.27
1988	1119	42 0.44	111 28.62	4.30	35.57
1920	918	41 30.61	112 0.95	4.30	36.09
1920	919	41 30.61	112 0.95	4.30	36.09
1920	1120	41 30.61	112 0.95	4.30	36.09
1906	524	41 13.45	111 57.55	4.30	38.47
1894	718	41 13.45	111 57.55	5.00	38.47
1914	513	41 13.45	111 57.55	5.70	38.47
1962	830	42 2.12	111 44.46	5.70	42.54
1946	506	41 43.80	112 7.80	4.30	44.71
1909	1117	41 44.66	112 9.72	4.30	46.60
1915	730	41 44.66	112 9.72	4.30	46.60
1914	408	40 59.00	111 55.00	4.30	47.56
1955	512	40 54.82	111 52.64	4.30	50.09
1942	418	41 30.00	112 18.00	4.30	50.83
1960	820	42 18.00	111 18.00	4.30	54.83
1959	104	42 18.00	111 24.00	4.30	54.97
1989	705	41 42.40	112 22.28	4.60	56.19
1989	703	41 42.39	112 22.40	4.80	56.28
1989	621	41 42.46	112 22.40	4.10	56.30
1949	307	40 44.94	111 50.95	5.00	59.03
1910	522	40 44.94	111 50.95	5.70	59.03
1955	202	40 47.00	111 56.00	4.30	59.20
1934	414	41 30.00	112 30.00	5.60	61.21
1960	807	42 24.00	111 30.00	5.00	62.41
1983	1008	40 44.88	111 59.56	4.30	62.95
1962	905	40 42.92	112 5.33	5.20	67.67
1943	410	40 42.00	112 4.80	4.30	68.26
1943	222	40 42.00	112 4.80	5.00	68.26
1906	1019	42 30.00	111 24.00	4.30	68.74
1972	1001	40 30.36	111 20.91	4.30	68.95
1924	1125	42 30.00	111 30.00	4.30	69.24
1960	810	42 30.00	111 30.00	4.30	69.24
1953	524	40 30.00	111 30.00	4.30	69.99
1975	329	42 2.00	112 31.09	4.70	71.81
1909	1006	41 46.00	112 40.00	6.30	72.00
1978	1130	42 6.08	112 29.48	4.60	73.13
1975	328	42 3.77	112 31.48	6.00	73.14
1975	327	42 3.95	112 32.05	4.20	73.66
1975	330	42 1.99	112 34.85	4.10	74.61



Regional Seismicity - Woodruff Crk. & Birch Creek Res.

Figure 6

From Hecker, 1988 & Goter, 1990

determined from trenching, and the rupture length, this fault is thought capable of producing a 7.1 magnitude event.

Bear River Range Faults - Physiographic evidence suggests that late Quaternary displacements have occurred on these faults. The faults are located about 20 miles west of the dam.

East Cache Fault - The southern segment of this fault zone is located about 18 miles from the dam. A maximum earthquake magnitude of 7.2 has been calculated based on fault length. Hecker (1993) has indicated that the age of most recent movement is between 6,000-9,000 years ago. She has calculated a slip rate of between 0.16-0.28 mm/yr.

Brigham City Segment of the Wasatch Fault - This segment of the Wasatch fault lies due west of the dam, at a distance of 33 miles. Based on fault length a maximum earthquake magnitude of 7.1 can be calculated. Trenching studies from near the center of the segment, at Brigham City, suggests that this segment is overdue for a surface faulting earthquake (Hecker, 1993).

Weber Segment of the Wasatch Fault- This segment of the Wasatch fault lies 37 miles to the southwest of the dam. A maximum earthquake magnitude of 7.2 has been calculated based on rupture length. This segment is the longest in the Wasatch fault zone and indications are that individual faulting events may not have ruptured its entire length.

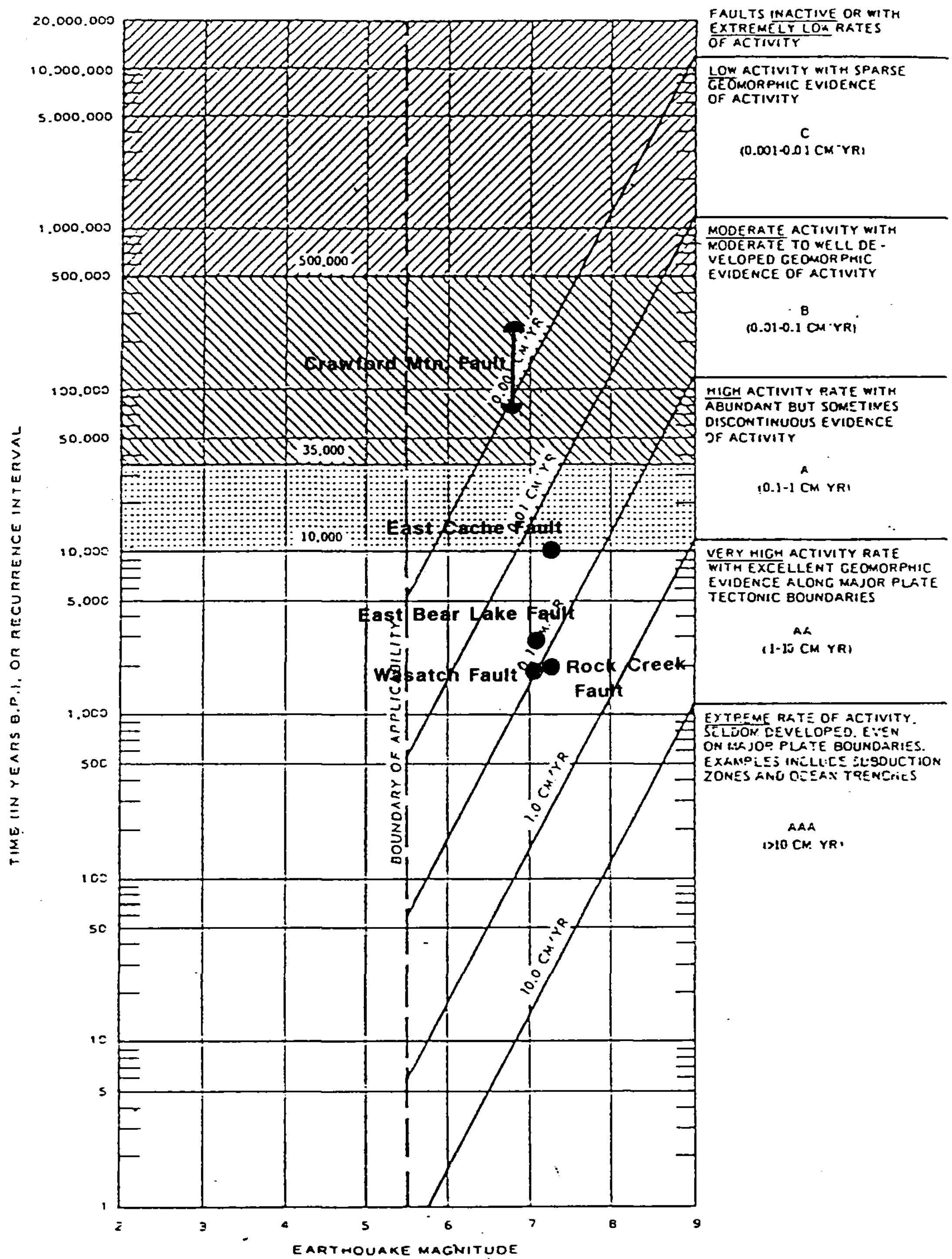
Wyoming Faults - Based on a map of seismic source zones in Wyoming (Case and others, 1990) the nearest fault known or suspected to have been active in the Quaternary is 49 miles east-northeast of the dam. This fault, called the Rock Creek fault, which is in Linclon Co., Wyoming is 21 miles long. Based on this length and offset (determined from trenching studies) it is assumed capable of producing a quake of magnitude 7.2 (McCalpin, 1992). A quake of this magnitude at a distance of 49 miles would produce ground shaking at the dam having a peak horizontal acceleration of approximately 0.10g.

Two other faults, the Star Valley and Grey's River faults fall outside the 75 mile radius but are included on Table 6 because of the recent seismicity (Feb.-Apr., 1994) in the area. Details on these faults can be found in McCalpin (1992).

<u>Deterministic Earthquakes</u>

The primary sources and their pertinent information are listed in Table 6. Mean peak site accelerations have been calculated for each source using both the curves of Seed and Idriss (1983, Figure 17), and Equation 5 of Campbell (1987, p. L-46). The two methods agree well for nearby sources, but diverge somewhat for distant sources. Campbell's relation was developed specifically for northern Utah. Both methods are based on California earthquakes, and assume California-like attenuations. The largest estimated acceleration is 0.33g, from both the Saleratus Creek Fault and the Crawford Mountain Fault (Table 6). Both faults are classified as inactive by the State Engineers criterion of no offset within 35,000 years, but do belong to the family of north-south trending normal faults, many of which have been active during that time. The largest acceleration from a fault known to have been active in late Pleistocene or Holocene time is 0.19g, from both the East Cache Fault and the East Bear Lake Fault.

The results of the deterministic estimate of the largest expected ground motion is considerably lower than the probabilistic estimate of Algermissen



Relation between time or recurrence interval (in years), strain rates across fault zones (in cm/yr), and earthquake magnitude.

From: Slemmons, 1977, Fig. 2

Figure 7

TABLE 6
Design Earthquakes

Source	Length (mi)	Offset <35,000 (yrs)	Offset Mult. Offset[1]	Quaternary Slip rate mm/yr	Activity Class.[2]	MCE	Dist. (mi)	Peak Site Acc'n(g) S&I[3]	Peak Site Acc'n(g) Campbell[4]	Duration (sec)[5]
Crawford Mountain	16	N	Y	?	low	6.8	11	0.27	0.27	5
Saleratus Creek	18	N	N	?	inactive	6.8	9	0.32	0.32	5
East Bear Lake	20	Y	Y	0.8	moderate	7.1	22	0.21	0.16	7
Bear River Range	13	N	?	?	?	6.7	20	0.19	0.13	4
East Cache	34	Y	Y	0.28	moderate	7.2	18	0.25	0.19	8
Wasatch Fault										
Brigham City Seg.	40	Y	Y	0.8-1.3	high	7.1	33	0.19		7
Weber Segment	61	Y	Y	1.0-3.0	high	7.2	37	0.20		7
Faults in Wyoming										
Rock Creek	21	Y	Y	1.27	high	7.2	49	0.10		9
Star Valley	21	Y	Y	0.63	moderate	7.2	81	0.04		11
Grey's River	35	Y	Y	1.75	high	7.3	89	0.05		12

1 Multiple offsets in the last 500,000 years (NRC active fault criterion).
2 From Figure 6.
3 Bedrock accelerations from Seed & Idriss, 1983, Figure 17.
4 Accelerations from Campbell, 1987, equation 5, using K_1=0 (normal faulting), K_2=0 (no source directivity), K_3=1 (upper bound for site effects, consolidated rock), e_3=0.41, and gamma=0.0059. Source distance taken as distance from site to nearest point on surface trace of fault.
5 Krinitzsky, 1989, Figure 23.

and others (1982), who give a value of 0.40g as the acceleration with a 90% probability on non-exceedence (in other words, a 10% probability of exceedence) in 250 years. The method of Algermissen and others divides the country into source areas on the basis of geology, and distributes earthquakes randomly within each source area. It is meant to be applied at a small scale. It may overestimate accelerations for sites like Woodruff or Birch Creek Dams which lie between, and some distance from , geologically identifiable earthquake sources. Therefore we recommend using the deterministic MCE and its associated acceleration as input to the stability and settlement analyses. It is well to keep in mind, however, that there is no reason to expect that all potential earthquake sources have been identified.

MCE

A conservative approach to the maximum credible earthquake would use the Crawford Mountain Fault as a source. The average of the 2 methods yields a site acceleration of 0.31g, which would be appropriate for new construction. Under the current State Engineer's definition of active fault, the East Cache earthquake is controlling, and produces a site acceleration of 0.19g. This earthquake has an estimated recurrence of 10,000 years (Figure 7), or a probabality of 1 in 10,000 of occurring in any given year.

OBE

The operating basis earthquake (OBE) for this site is taken from Algermissen and others (1982). This event would have an acceleration of 0.17g at the dam and a 90 percent probability of not being exceeded in 50 years, which is roughly equivalent to a return period of 475 years (Youngs and others, 1987).

Seismic Stability

The fill was compacted during construction by modern earth-moving equipment. Based on the 1993 drilling, blow counts in the dam averaged 33 blows per foot which translates on a scale of relative density to a dense classification.

Table 6 indicates that the site should only be affected by low to medium accelerations, therefore, based on the California comparative method Birch Creek Dam #2 falls into Zone 7 (Babbitt et. al., 1983, p.106) as shown in Table 7. Cases that fall into this zone will normally not present any problems.

Table 7

Density Class	Acceleration Low 0-0.2	Medium 0.21-0.39	High >0.40
Loose	1	2	4
Med. Dense	7	3	5
Dense	7	7	6
Very Dense	7	7	7

Geologic Hazards

Table 8 is a summary of those geologic hazards having the potential to impact the dam.

TABLE # 8

SUMMARY OF GEOLOGIC HAZARDS

Birch Creek Dam No. 2 & Reservoir

	Hazard Rating*			Further
	Probable Hazard	Possible Hazard	Unlikely Hazard	Study Recommended**
Earthquake				
Ground shaking	E			G-SIP
Liquefaction			AF/DST	
Surface faulting			X	
Tectonic deformation			X	
Slope failure		A,SP & RB		
Seiche			X	
Slope Failure (Non-seis)				
Rockfall		A,SP & RB		
Landslide			X	
Debris flow			X	
Found/Embank Problems				
Collapsible soils			X	
Expansive clays			NA	
Sensitive clays			X	
Organic soils			NA	
Soluble salts			NA	
Pipable/Erodible			BF	
Karst			BF	
Differential settlement			X	
Non-engineered fill			X	
Hydrologic				
Shallow ground-water			X	
Springs/Seeps			X	
Flooding				
Stream/Lake		X		H-SIP
Upstream dam failure			NA	
Spillway capacity		X		H-SIP
Dam overtopping			X	

*Hazard Rating - Probable-evidence is strong that the hazard exists and mitigation measures should be taken. Possible-hazard may exist, but evidence is uncertain and further study is recommended. Unlikely-no evidence was found to indicate that the hazard is present.

Abbreviations; E = embankment, F = foundation, AF = alluvial foundation, BF = bedrock foundation, A = abutments, RB = reservoir basin, SL = shore line, DST = down stream toe, UST = up stream toe, DSF = down stream face, USF = up stream face, SP = spillway, & NA = Not applicable.

**Further Study (S-soil/foundation, G-geotecnical/engineering, H-hydrologic, SIP-study in progress, MIP-mitigation measures in progress) is recommended to address the hazard (see Conclusions and Recommendations).

Earthquake Hazards

Ground Shaking - Due to the dam's location relative to active faults, which are capable of producing moderate to large earthquakes, it is reasonable to expect that ground shaking could affect the site. If the MCE associated with the East Cache Fault were to occur, ground shaking up to 0.25g could result. Structural damage, to the dam and/or appurtenances, as a result is considered unlikely.

Liquefaction - The current round of drilling (DH's 93-1 thru 93-5) has confirmed that the majority of the footprint of the dam rests directly upon bedrock. The alluvium which does exist under the dam, is mostly non-granular in nature (ML & CL, see Table 1). The lowest blow counts per foot in the alluvium were encountered in DH 93-4. Counts of 2 & 3 blows per foot were recorded in clay at 20.5 and 24.5 feet respectively (see Table 2).

Slope Failure - Depending on the degree of ground shaking experienced at the dam it is not unreasonable to assume that some rockfall might result. This is especially true near the left abutment, in the spillway and at various places around the reservoir basin where fractured to highly fractured bedrock (Twin Creek Limestone) is exposed in steep slopes.

Slope Failure Hazard (Non-Seismic)

Of the three categories under this heading only rockfall is considered a possible hazard.

Rockfall - High angle slopes together with moderate to intense fracturing of the bedrock (Twin Creek Limestone) combine to create a possible hazard for this category. This is viewed more as a nuisance than as a hazard capable of jeopardizing the integrity of the dam or reservoir. However, continued unraveling of steep bedrock slopes in the spillway results in an ongoing maintenance problem. The accumulation of debris in the spillway will reduce its capacity to pass flood flows.

Hazards Related to Foundation/Embankment Problems

The nine categories under this heading are all rated as unlikely hazards. The subsurface investigation to date, including laboratory testing of selected samples has not identified soils or bedrock, either in the embankment or the foundation which would present a hazard.

Hydrologic Hazards

Flooding - Two of the four categories related to flooding appear to be possible hazards:

Stream flooding, and Spillway capacity - Based on the size of the drainage basin above the reservoir and the capacity of the spillway it is possible that a flood could present a hazard to the dam. (These hazards will be dealt with in greater detail in the Hydrologic Report).

Conclusions & Recommendations

Repair - Under current conditions the structure is performing well and there is no need for immediate repair. The dam was designed to the state-of-the-art at the time, and appears with our present knowledge, to be functioning adequately. There is no immediate concern for safety.

Stability Analysis - An assessment of the static and seismic stability of the dam should wait until we have information on pore pressures in the embankment and foundation. This includes reading piezometers through at least one filling and spilling cycle.

References Cited

Algermissen, S.T., Perkins, D.M., Thenhous, P.C., Hanson, S.L., & Bender, B.L., 1982, Probabilistic estimates of maximum acceleration and velocity in rock in the contiguous United States: U.S. Geological Survey, Open-File Report 82-1033, 99p.

Arabasz, W.J., Pechmann, S.J., Nava, S.J., and Smith, R.B., 1994, The Magnitude (M_w) 5.8-5.9 Earthquake in SE Idaho of February 3, 1994, and Associated Shocks: Preliminary Earthquake Report, Univ. of Utah Seismograph Stations, 5p.

Case, J.C., Larsen, L.L., Boyd, C.S., & Cannia, J.C., 1990, Earthquake epicenters and suspected active faults with surficial expression in Wyoming, Geological Survey of Wyoming, Map, 1:1,000,000

Cook, K.L., & Smith, R.B., 1967, Seismicity in Utah, 1850 through June 1965, Bulletin of the Seismological Society of America, vol. 57, no. 4, p. 687-718.

Goter, Susan, K., 1990, Earthquakes in Utah, 1884-1989, U.S. Geological Survey, National Earthquake Data Center, 1:500,000.

Hecker, Suzanne, M., 1993, Quaternary Tectonics of Utah with Emphasis on Earthquake-Hazard Characterization, Utah Geological Survey, Bulletin 127, 157p.

Hintze, Lehi, F., 1980, Geologic Map of Utah, Utah Geological and Mineral Survey, 1:500,000.

______1988, Geologic History of Utah: Brigham Young University Geology Studies, Special Publication 7, 202p.

Krinitzsky, E.L., 1989, Empirical earthquake ground motions for an engineering site with fault sources: Tooele Army Depot, Utah. Bulletin of the Association of Engineering Geologists, vol. XXVI, no. 3, p. 283-308.

Marsell, Ray, 1964, Geologic Reconnaissance of Proposed Woodruff Creek Dam Site: Division of Water Resources, 3p.

______1968, Geology of the Upper Woodruff Creek Dam Site: Division of Water Resources, 10p.

McCalpin, J.P., 1993, Neotectonics of the northeastern Basin and Range margin, Western USA: Zertschritt fur Geormoph, Suppl.-Bd. 94, p137-157.

Slemmons, David, B., 1977, Faults and Earthquake Magnitude, Report 6 in State-of-the-art for assessing earthquake hazards in the United States, U.S. Army Corps of Engineers Waterways Experiment Station Misc. Paper S-73-1.

U.S.Army Corps of Engineers, 1979, Phase I Inspection Report National Dam Inspection Program - Birch Creek Dam No. 2 Rich Co., Utah: Utah Division of Water Rights, 38p.

Youngs, R.R., Swan, F.H,. Power, M.S., Schwartz, D.P., and Green, R.K.,Probabilistic Analysis of Earthquake Ground Shaking Hazard along the Wasatch Front, Utah: in Gori, P.L., and Hays, W.W., eds., 1987, Assessment of Regional Earthquake Hazards and Risks Along the Wasatch Front, Utah, Volume II: U.S. Geological Survey, Open-File Report 87-585.

APPENDIX A

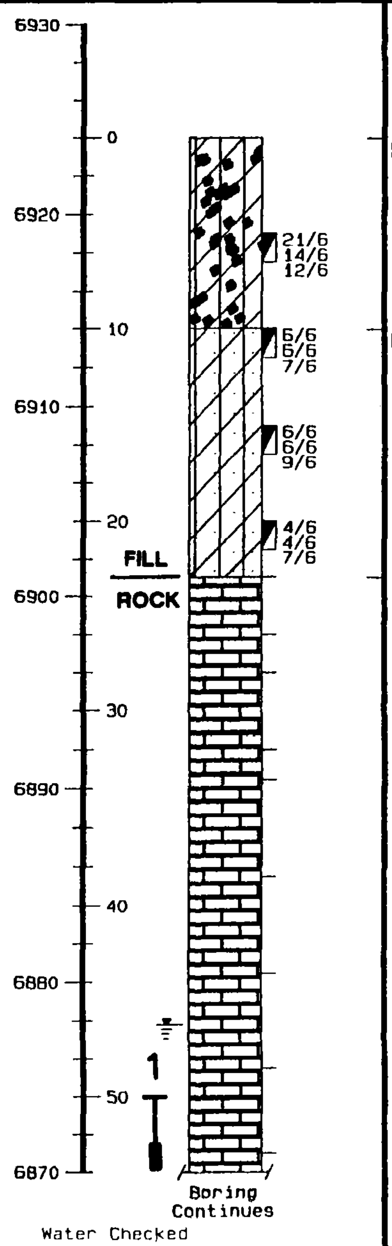
DRILL HOLE LOGS

FOR HOLES 93-1 THRU 93-5

LOG OF TEST BORING

PROJECT: BIRCH CREEK DAM No. 2 — DATE: 9/27/93
BORING NO.: 93-1 — ELEV.: 6924
BORING LOCATION: DS Edge - Crest at Left Abutment
DRILL METHOD: Auger to 23'; DC to 58'
CONTRACTOR: RB&G Engineers — LOGGED BY: TOM
DEPTH TO WATER: 46.2' — DATE CHECKED:

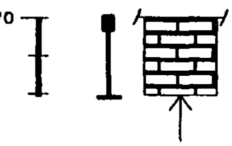
ELEV / DEPTH — SOIL SYMBOLS, SAMPLER SYMBOLS AND FIELD TEST DATA

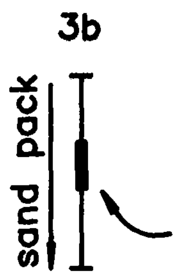


USCS	Description	Rec	Rock Qual	K ft/yr
ML	Clayey Gravelly SILT; lt gry-brn, firm, dry; <1" subang-subround gravel			
		5"		
ML	Sandy Clayey SILT; lt gry-brn, soft-firm, damp	9"		
		11"		
	..turning to dk brn	18"		
	LIMESTONE; gry, angled horiz & vert jointing; some joints filled w/white, red or yellow material	2.3/3.0	.1	
		1.8/2.0	.4	
	..nearly vertical joint 1/4" thick filled with white calcite	4.1/4.1	.7	
		1.3/1.4	.6	
		4.8/5.0	.8	25
		5.0/5.0	.7	
		4.8/5.0	.9	
		4.2/4.5	.8	
		5.0/5.1	.8	12

LOG OF TEST BORING

PROJECT: BIRCH CREEK DAM No. 2 — DATE: 9/27/93
BORING NO.: 93-1 — ELEV.: 6924
BORING LOCATION: DS Edge - Crest at Left Abutment
DRILL METHOD: Auger to 23'; DC to 58'
CONTRACTOR: RB&G Engineers — LOGGED BY: TOM
DEPTH TO WATER: 46.2' — DATE CHECKED:

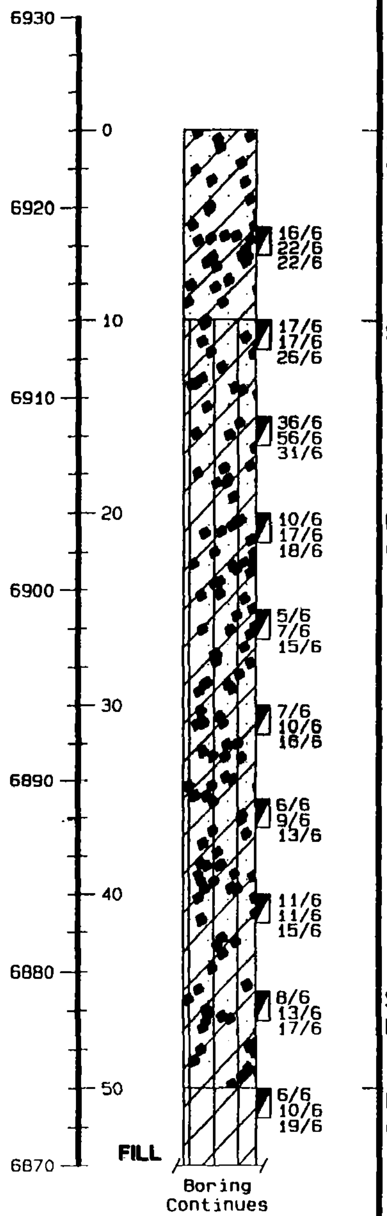
ELEV / DEPTH	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	USCS	Description	Rec	Rock Qual	K ft/yr
6870			TD -- 58.1'			



LOG OF TEST BORING

PROJECT: BIRCH CREEK DAM No. 2 — DATE: 9/28/93
BORING NO.: 93-2 — ELEV.: 6924
BORING LOCATION: DS Edge - Crest at Max Section
DRILL METHOD: Auger to 100'; TC to 104'; DC to 119.8'
CONTRAGTOR: RB&G Engineers — LOGGED BY: TOM
DEPTH TO WATER: 57.1' — DATE CHECKED:

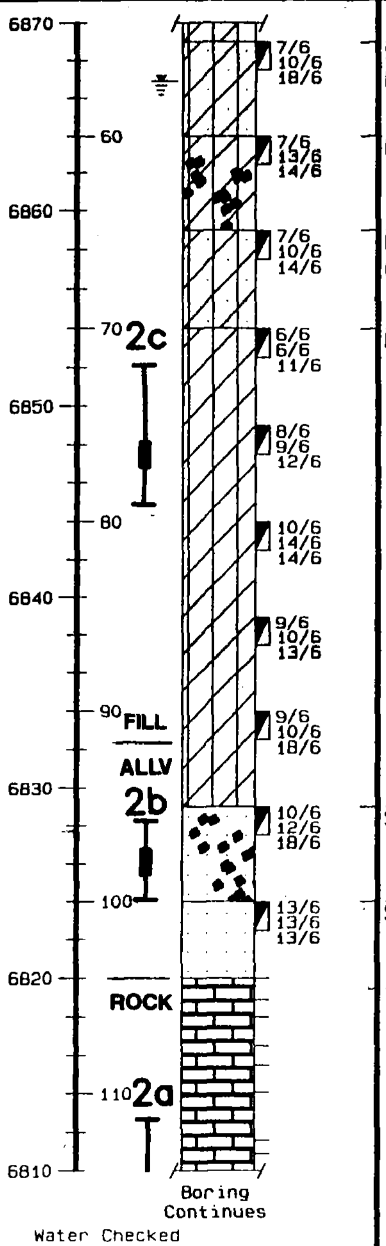
ELEV / DEPTH | SOIL SYMBOLS, SAMPLER SYMBOLS AND FIELD TEST DATA



USCS	Description	Rec	Rock Qual	K ft/yr
SP-SC	Gravelly Clayey SAND; lt gry-brn, med dense, dry; sand med-fine; gravel sub ang to sub round			
		16"		
SC	Silty Clayey SAND; lt gry-brn, med dense, dry; sand med-fine; gravel <3/4", subangular	16"		
	..turning to gravelly clayey sand, gray turning to brown, sand fine	17"		
ML-CL	Sandy Clayey SILT; lt gry-brn, med dense to stiff, damp; sand fine	9"		
		12"		
	..turning to gravelly clayey silt, lt brown; gravel <1" subangular	17"		
	Clayey SILT; red-brn turning to lt gry-brn turning to dk brn turning to lt gry-brn, firm, damp	16"		
	..alternating layers of lt gry-brn & dk gry, 1/4" wood pieces in top layer	14"		
SC-ML	Gravelly Clayey SAND; red-brn turning to gravelly clayey SILT; lt gry-brn, med dense, stiff, damp; sand med-fine	16"		
ML-CL	Clayey SILT; alternating lt gry & dk gry, firm, damp; gravel <3/4" subang	20"		

LOG OF TEST BORING

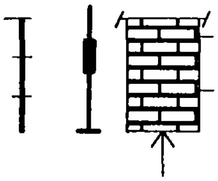
PROJECT: BIRCH CREEK DAM No. 2 DATE: 9/28/93
BORING NO.: 93-2 ELEV.: 6924
BORING LOCATION: DS Edge - Crest at Max Section
DRILL METHOD: Auger to 100'; TC to 104'; DC to 119.8'
CONTRACTOR: RB&G Engineers LOGGED BY: TOM
DEPTH TO WATER: 57.1' DATE CHECKED:

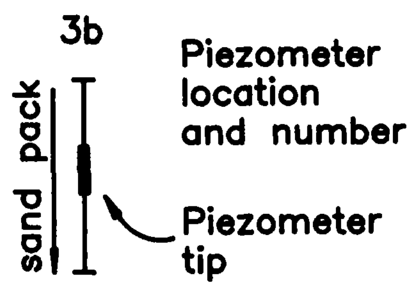


SAMPLER SYMBOLS AND FIELD TEST DATA	USCS	Description	Rec	Rock Qual	K ft/yr
7/6 10/6 18/6	SC-ML	Silty Clayey SAND; red-brn turning to clayey silt w/few gravels, lt gry-brn sand well graded, loose, firm, damp	17"		
7/6 13/6 14/6	ML	Gravelly Clayey SILT; red-brn/gry, firm, damp; <1" subang to subround gravel	19"		
7/6 10/6 14/6	ML-CL	Sandy Clayey SILT; alternating lt gry -brn & dk gry layers, firm, damp; sand well graded; gravel <1/2"	18"		
6/6 6/6 11/6	ML	Clayey SILT; gry-dk gry, firm, damp	20"		
8/6 9/6 12/6			19"		
10/6 14/6 14/6		..turning to sandy clayey silt, red-brn, and gray; gravel <1"	19"		
9/6 10/6 13/6			18"		
9/6 10/6 18/6			20"		
10/6 12/6 18/6	SW	Gravelly SAND; well graded, med dense moist; gravel <1" round-subround	8"		
13/6 13/6 13/6	SP	SAND; poorly graded #4-#30; turning to gravelly silty CLAY; dk gry, soft saturated	17"		
		LIMESTONE; med-dk gry, angled	0.7/1.1	0	
		..horiz & vert joints	0.8/1.0	0	
		..highly fragmented	1.4/1.5	.3	
		..some joints healed w/white material	1.5/2.4	0	
		..open joints 2/gry, yel or red clay material	2.0/2.5	.3	
			.6/.7	0	
			1.8/1.8	.8	650

LOG OF TEST BORING

PROJECT: BIRCH CREEK DAM No. 2 DATE: 9/28/93
BORING NO.: 93-2 ELEV.: 6924
BORING LOCATION: DS Edge - Crest at Max Section
DRILL METHOD: Auger to 100'; TC to 104'; DC to 119.8'
CONTRACTOR: RB&G Engineers LOGGED BY: TOM
DEPTH TO WATER: 57.1' DATE CHECKED:

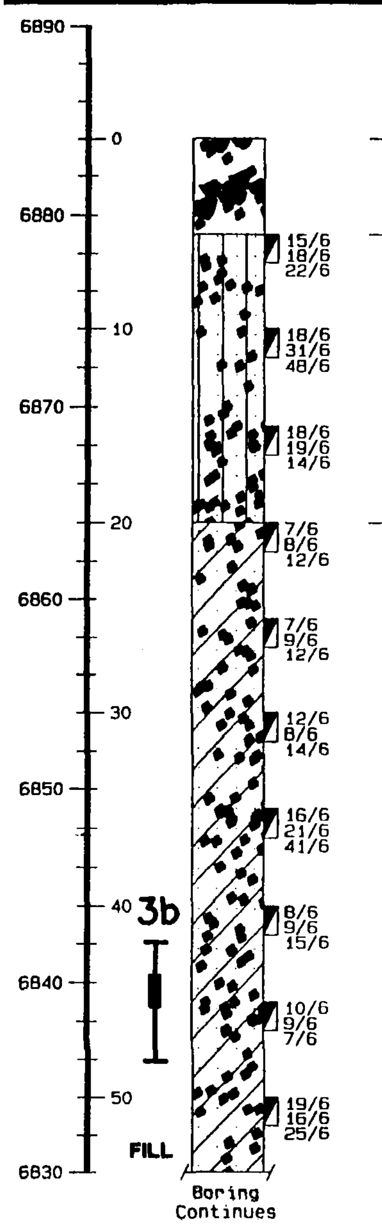
ELEV / DEPTH	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	USCS	Description	Rec	Rock Qual	K ft/yr
6810				2.5/2.8		
				.6/.6	0	
			TD -- 119.8'			



LOG OF TEST BORING

PROJECT: BIRCH CREEK DAM No. 2
DATE: 10/18-19/93
BORING NO.: 93-3
ELEV.: 6884
BORING LOCATION: Downstream Face - Midslope
DRILL METHOD: Auger to 66.5'
CONTRACTOR: RB&G Engineers
LOGGED BY: DAN
DEPTH TO WATER:
DATE CHECKED:

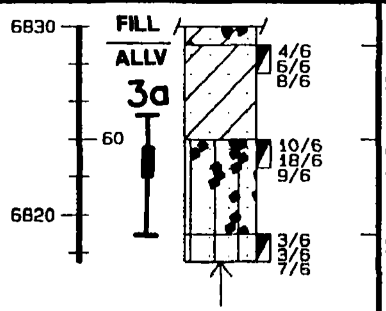
ELEV / DEPTH — SOIL SYMBOLS, SAMPLER SYMBOLS AND FIELD TEST DATA



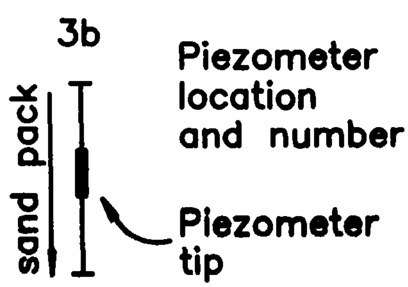
USCS	Description	Rec	Rock Qual	K ft/yr
GP	GRAVEL & COBBLES down to 7'			
SM-GM	Silty Gravelly SAND/Silty Sandy GRAVL med brn to red-brn, poorly graded, dense, dry; Sand fine, Gravel to 2"	9"		
	..gry-grn, very dense lots of gravel	15"		
	..less gravel, brn-gry to med brn gravel to 1 1/2" subrnd to angular	11"		
CL	Gravelly Sandy CLAY; med brn, plastic very stiff, damp ..less gravel	16"		
SC	Gravelly Clayey SAND; red-brn, poorly graded, med dense,	17"		
	..red-brn & grn-gry to dark gry some plant fibers	16"		
	..dk brn-gry to blk, very dense some plant fibers large cobble at 37.5'	11"		
CL/SC	Sandy CLAY; lt-med gry, interlayered & intermixed w/Sandy Clay/Clayey Sand med-dk gry-brn, poorly graded, med dense, damp, some plant fibers, gravl to 1/2", subround to angular	18" 13"		
GC-SC	Clayey Sandy GRAVEL/Clayey Gravelly SAND; med red-brn & med gry-brn, med dense, poorly graded, damp	14"		
SC	Gravelly Clayey SAND; med brn/brn-gry poorly graded, dense, dry-damp. Sand fine. Gravel to 3/4", subrnd-angular			

LOG OF TEST BORING

PROJECT: BIRCH CREEK DAM No. 2 DATE: 10/18-19/93
BORING NO.: 93-3 ELEV.: 6884
BORING LOCATION: Downstream Face - Midslope
DRILL METHOD: Auger to 66.5'
CONTRACTOR: RB&G Engineers LOGGED BY: DAN
DEPTH TO WATER: DATE CHECKED:

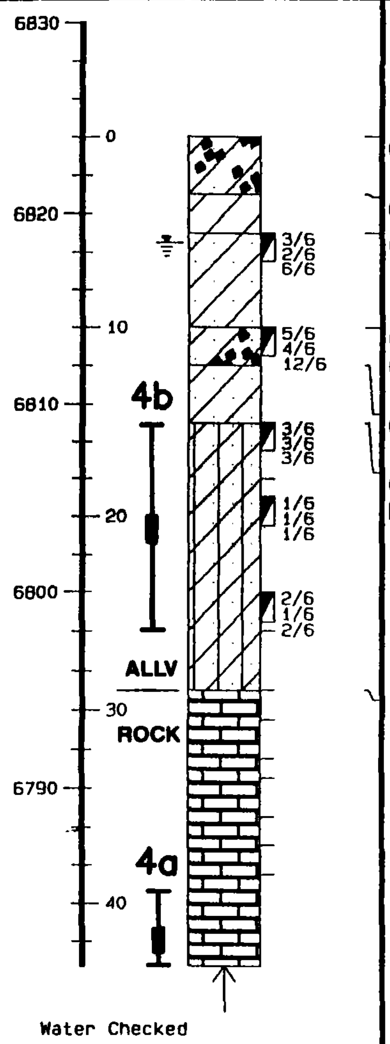


ELEV / DEPTH	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	USCS	Description	Rec	Rock Qual	K ft/yr
		SW/ SC	SAND; brn, fine-med, interlayered w/ Clayey Sand, med-dk gry-brn, well graded, med dense, moist, plant fiber	18"		
		GW- SW	Silty Sandy GRAVEL/Silty Gravelly SAND; med brn-gry, well graded, med dense, saturated	18"		
		SM	Silty SAND; med brn, poorly graded, loose to med dense, saturated. Sand fine w/carbonized organic material TD -- 66.5'	18"		

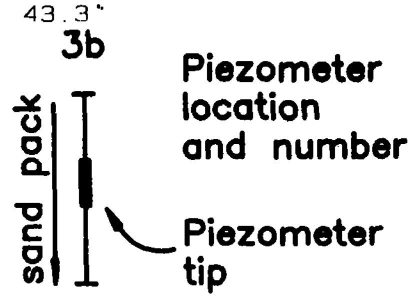


LOG OF TEST BORING

PROJECT: BIRCH CREEK DAM No. 2 — DATE: 9/24/93
BORING NO.: 93-4 — ELEV.: 6824
BORING LOCATION: Max Section - Downstream Toe
DRILL METHOD: Auger to 15'; TC to 29'; DC to 43.3'
CONTRACTOR: RB&G Engineers — LOGGED BY: DAN
DEPTH TO WATER: 5.5' — DATE CHECKED:



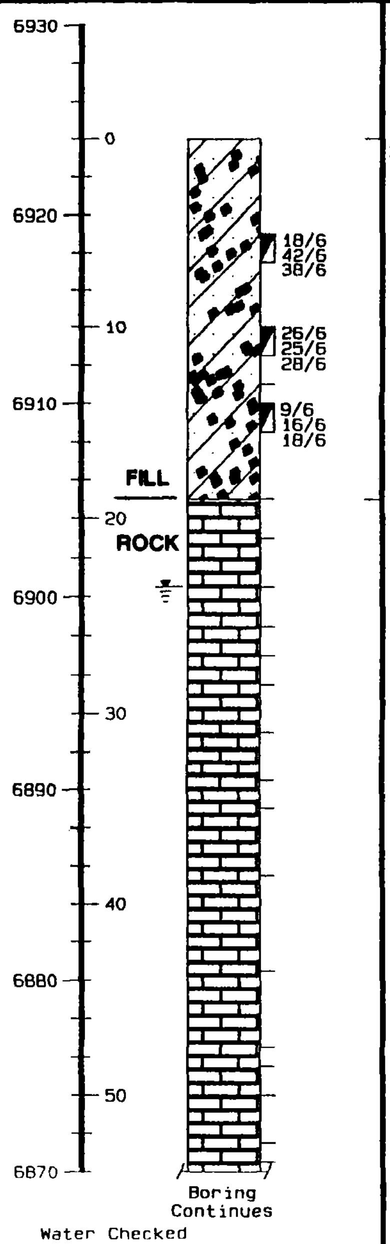
USCS	Description	Rec	Rock Qual	K ft/yr
GC	Sandy Clayey GRAVEL w/cobbles; embank ment fill.			
CL	CLAY; dk gry, damp-moist, easy dilg			
CL	Sandy CLAY; dk gry, plastic, firm, moist to very moist, minor gravel, some slender roots	8"		
GC/ CL	Clayey Sandy GRAVEL; dk gry, poorly graded, loose saturated, gravel to 3/4" rounded to sub angular; AND	5"		
CL	Sandy CLAY; dk gry, firm, sticky, saturated	18"		
CL- ML	Silty Sandy CLAY/Clayey Sandy SILT; brn to gry-brn, plasticity varies, firm, saturated	18"		94
	Silty Clayey SAND; lt-med brn, poorly graded, very loose, saturated. Sand very fine; bottom 1 1/2" coarse.	18"		
	..casing advanced by pushing			173
	..occasional gravel layers			
	LIMESTONE; of the Twin Creek Frmtn;	0.8/1.5	0.3	
	lt-med grn-gry, hi & low angle jnts,	1.5/2.0	0.2	
	some healed w/wht calcite	1.2/1.2	0.3	
	..brecciated & highly fractured	1.8/1.8	0	
	..numerous horiz-low angle jnts	3.1/3.1	0.8	
	All hi angle jnts healed w/wht			405
	calcite	4.4/4.7	0.4	
	..bottom 1' brecciated & crumbly			
	TD -- 43.3'			



LOG OF TEST BORING

PROJECT: BIRCH CREEK DAM No. 2 — DATE: 10/7 - 10/8/93
BORING NO.: 93-5 — ELEV.: 6924
BORING LOCATION: Downstream edge of crest - R Abut
DRILL METHOD: Auger to 10'; TC to 19'; DC to 60'
CONTRACTOR: RB&G Engineers — LOGGED BY: DAN
DEPTH TO WATER: 23.5' — DATE CHECKED:

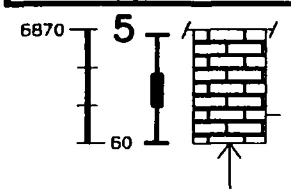
ELEV / DEPTH — SOIL SYMBOLS, SAMPLER SYMBOLS AND FIELD TEST DATA

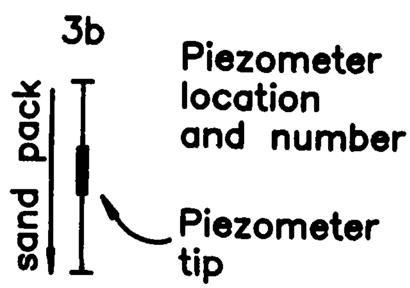


USCS	Description	Rec	Rock Qual	K ft/yr
SC	Gravelly Clayey Sand; lt grn-gry, poorly graded, very dense, dry occasional cobbles			
		18"		
		18"		
	..quartzite cobble, followed by grn-gry fill	6" 8"		
	..dense, moist, some gravel to 2 1/2" subangular to subround			
	Limestone of the Twin Creek Formation	0.9/2.0	0	
	lt pp-gry, brecciated, mostly rubble,	2.2/2.4	0	
	pink & red-brn clay on joints			
	..hi angle jts healed w/white calcite	2.0/2.1	0	
	many horiz to low angle breaks, blu	1.1/1.3	0.4	
	& brnish clay on some joint surface	1.6/1.6	0.9	
	..bottom 2" crushed rock & clay	2.5/2.5	0	
	..all jnts coated w/red & yel clay			
	..broken	2.0/2.5	0.5	
	..lt yel-brn clay on joints	4.7/4.8	0.5	
				114
		4.2/5.2	0.7	
	..numerous joints - clay coated	4.0/4.0	0.4	
		0.6/0.8	0	
	..most joints coated w/red clay	3.5/4.2	0.4	
	..several 2-3" highly fractured zones			143
		1.0/1.0	0.8	
	..1 hi angle jnt has 1/2" of grn-brn clay and rock chips	4.9/5.0	0.9	

LOG OF TEST BORING

PROJECT: BIRCH CREEK DAM No. 2 — DATE: 10/7 - 10/8/93
BORING NO.: 93-5 — ELEV.: 6924
BORING LOCATION: Downstream edge of crest - R Abut
DRILL METHOD: Auger to 10'; TC to 19'; DC to 60'
CONTRACTOR: RB&G Engineers — LOGGED BY: DAN
DEPTH TO WATER: 23.5' — DATE CHECKED:

ELEV / DEPTH	SOIL SYMBOLS SAMPLER SYMBOLS AND FIELD TEST DATA	USCS	Description	Rec	Rock Qual	K ft/yr
6870 60			..several hi angle jts have been healed w/wht calcite & red-brn Iron oxides TD -- 60'	1.2/1.4	0.7	



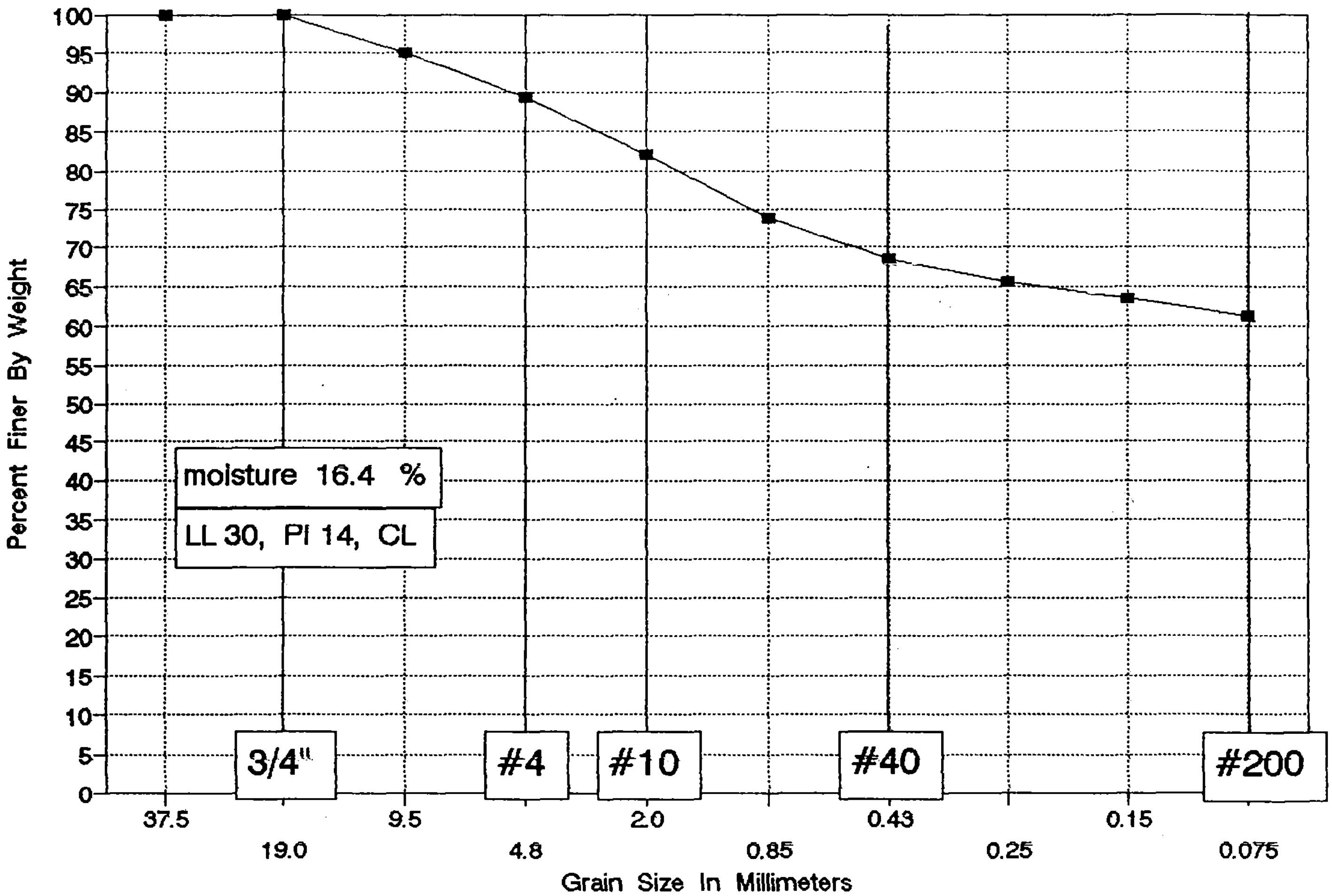
APPENDIX B

LABORATORY TEST RESULTS

DRILL HOLE SAMPLES

GRADATION CURVE

Boring DH-1, sample at 15 to 16.5 feet



ATTERBERG LIMITS TEST DATA

FIELD CLASSIFICATION ________________

LABORATORY CLASSIFICATION ____________

JOB NO. 02401-024-0001
CLIENT/OWNER UDWR
LOCATION BIRCH CREEK DAM
BORING DH-1 SAMPLE ____ DEPTH 15-16.5'

FIELD DENSITY BY ____/__/__

DETERMINATION	1	2
NUMBER OF RINGS		
WT OF RINGS + WET SOIL		
WT OF RINGS		
WT OF WET SOIL		
FIELD DENSITY		
DRY DENSITY		

DETERMINATION	1	2
DISH		
WT OF DISH + WET SOIL		
WT OF DISH + DRY SOIL		
WT OF MOISTURE		
WT OF DISH		
WT OF DRY SOIL		
FIELD MOISTURE CONTENT		

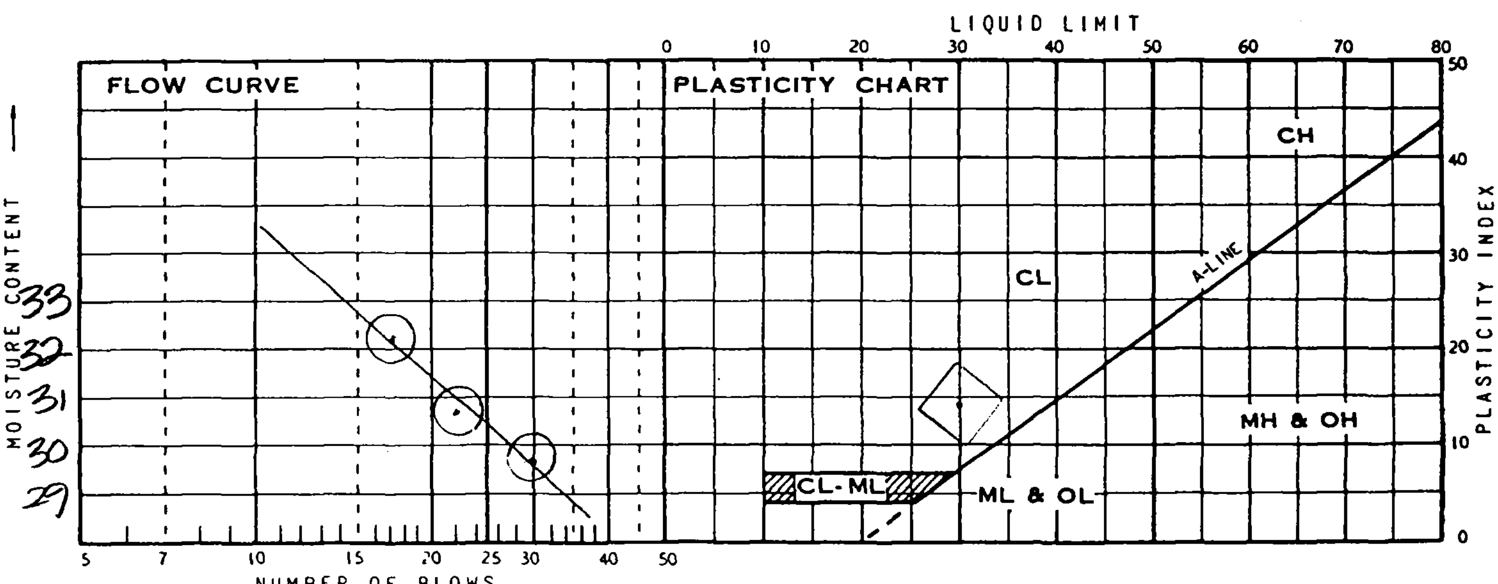
THIS IS AN 1/8-INCH THREAD

PLASTIC LIMIT BY RH 2/1/94

DETERMINATION	1	2	3	4	5	6
DISH	41	106				
WT OF DISH + WET SOIL	13.31	12.57				
WT OF DISH + DRY SOIL	11.63	11.03				
WT OF MOISTURE						
WT OF DISH	1.40	1.40				
WT OF DRY SOIL						
MOISTURE CONTENT	16.42	15.99	AV=16			

LIQUID LIMIT

DETERMINATION	1	2	3	4	5	6
DISH	183	15	75			
NUMBER OF BLOWS	30	23	18			
WT OF DISH + WET SOIL	15.15	16.07	16.19			
WT OF DISH + DRY SOIL	11.99	12.61	12.59			
WT OF MOISTURE						
WT OF DISH	1.40	1.40	1.40			
WT OF DRY SOIL						
MOISTURE CONTENT	29.84	30.87	32.17			

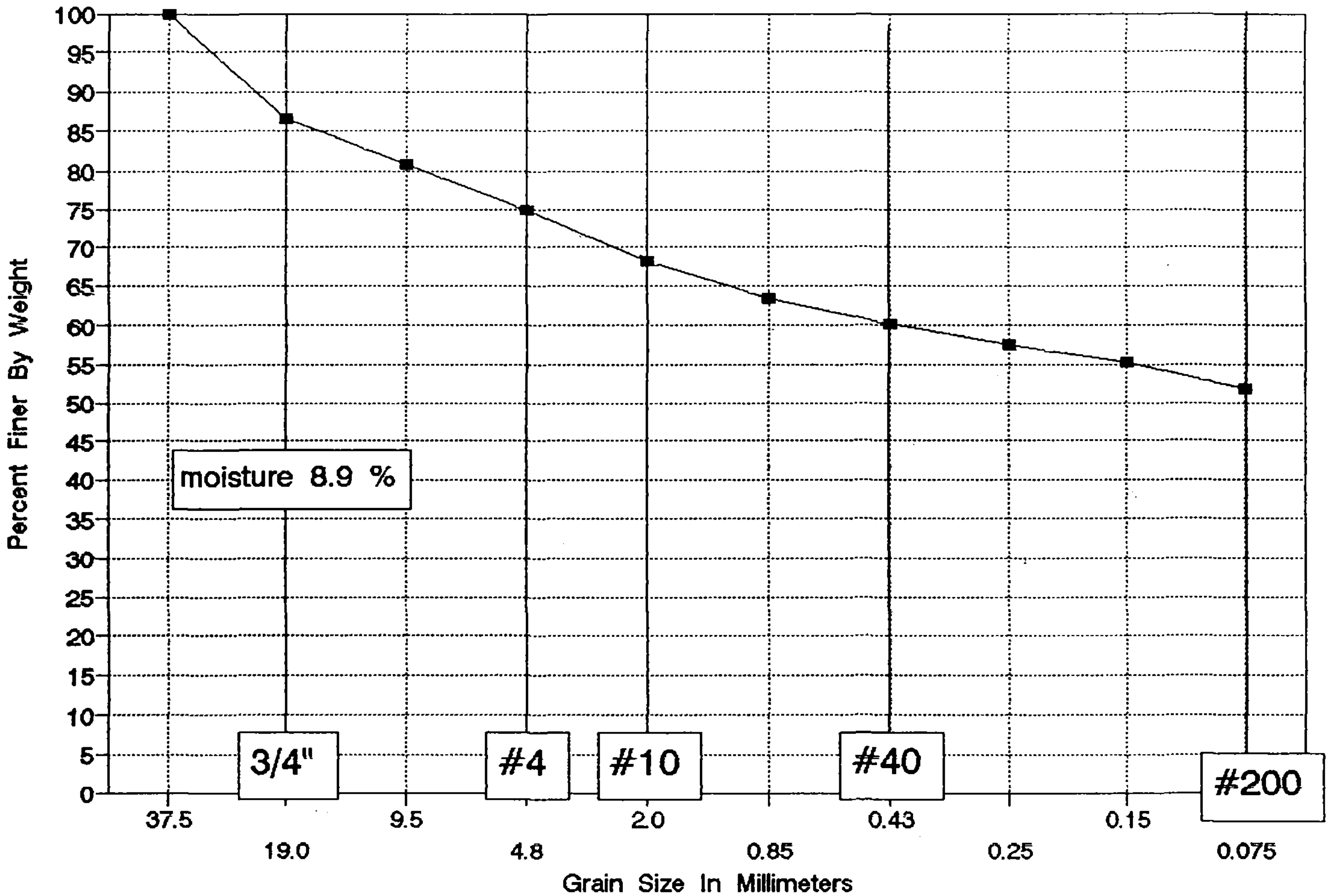


SUMMARY

DRY DENSITY	MOISTURE CONTENT	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	IDENTIFICATION	
		30	16	14	CL	

GRADATION CURVE

Boring DH-2, sample at 15 to 16.5 feet



ATTERBERG LIMITS TEST DATA

JOB NO. [illegible]
CLIENT/OWNER UDWR
LOCATION BIRCH CREEK DAM
BORING DH-2 SAMPLE – DEPTH 50-50.5'

FIELD CLASSIFICATION _______________

LABORATORY CLASSIFICATION _______________

FIELD DENSITY BY ___ /_/_

DETERMINATION	1	2
NUMBER OF RINGS		
WT OF RINGS + WET SOIL		
WT OF RINGS		
WT OF WET SOIL		
FIELD DENSITY		
DRY DENSITY		

THIS IS AN 1/8-INCH THREAD

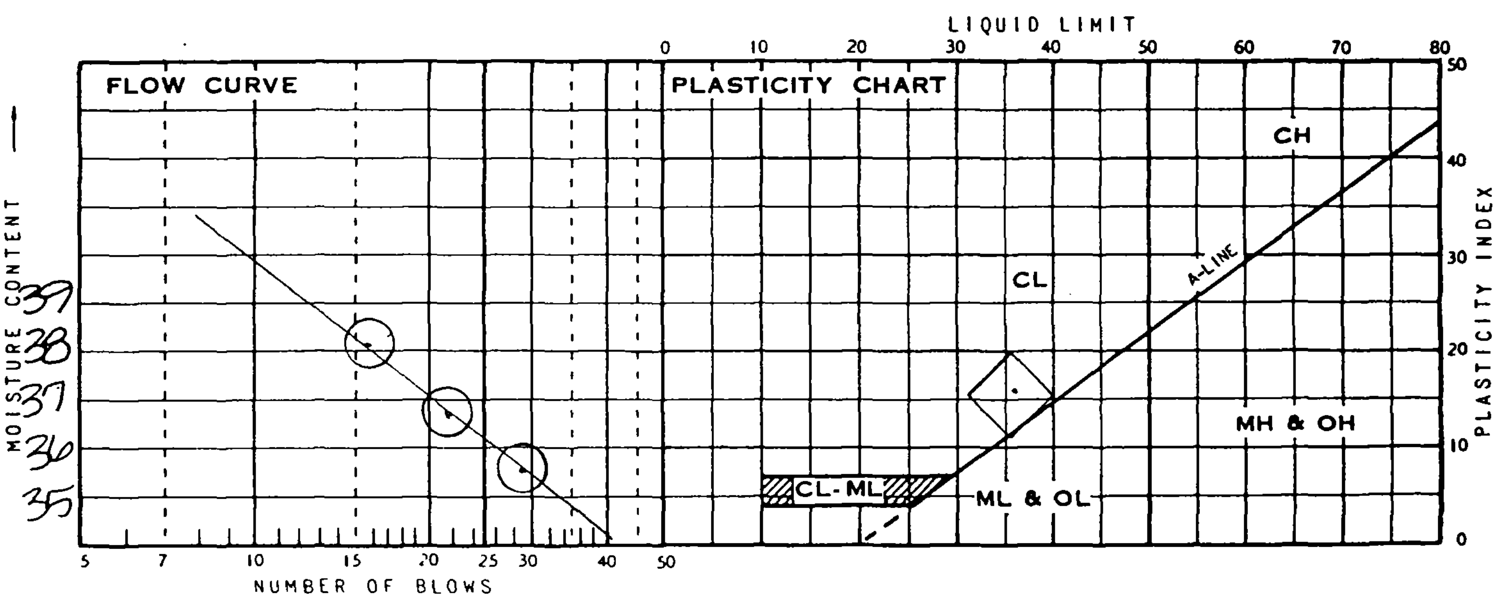
DETERMINATION	1	2
DISH		
WT OF DISH + WET SOIL		
WT OF DISH + DRY SOIL		
WT OF MOISTURE		
WT OF DISH		
WT OF DRY SOIL		
FIELD MOISTURE CONTENT		

PLASTIC LIMIT BY RH 2/1/94

DETERMINATION	1	2	3	4	5	6
DISH	131	AL-104				
WT OF DISH + WET SOIL	13.39	11.30				
WT OF DISH + DRY SOIL	11.36	9.72				
WT OF MOISTURE						
WT OF DISH	1.40	1.40				
WT OF DRY SOIL						
MOISTURE CONTENT	20.38	19.95	AV = 20			

LIQUID LIMIT

DETERMINATION	1	2	3	4	5	6
DISH	15	13	AL-121			
NUMBER OF BLOWS	29	22	16			
WT OF DISH + WET SOIL	14.06	15.24	15.34			
WT OF DISH + DRY SOIL	10.74	11.51	11.50			
WT OF MOISTURE						
WT OF DISH	1.40	1.40	1.40			
WT OF DRY SOIL						
MOISTURE CONTENT	35.55	36.89	38.02			



SUMMARY

DRY DENSITY	MOISTURE CONTENT	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	IDENTIFICATION	
		36	20	16	CL	

ATTERBERG LIMITS TEST DATA

JOB NO. UD4101-021 0001
CLIENT/OWNER UDWR
LOCATION BIRCH CREEK DAM
BORING DH-2 SAMPLE — DEPTH 70-70.5'

FIELD CLASSIFICATION

LABORATORY CLASSIFICATION

FIELD DENSITY BY ___/__/__

DETERMINATION	1	2
NUMBER OF RINGS		
WT OF RINGS + WET SOIL		
WT OF RINGS		
WT OF WET SOIL		
FIELD DENSITY		
DRY DENSITY		

DETERMINATION	1	2
DISH		
WT OF DISH + WET SOIL		
WT OF DISH + DRY SOIL		
WT OF MOISTURE		
WT OF DISH		
WT OF DRY SOIL		
FIELD MOISTURE CONTENT		

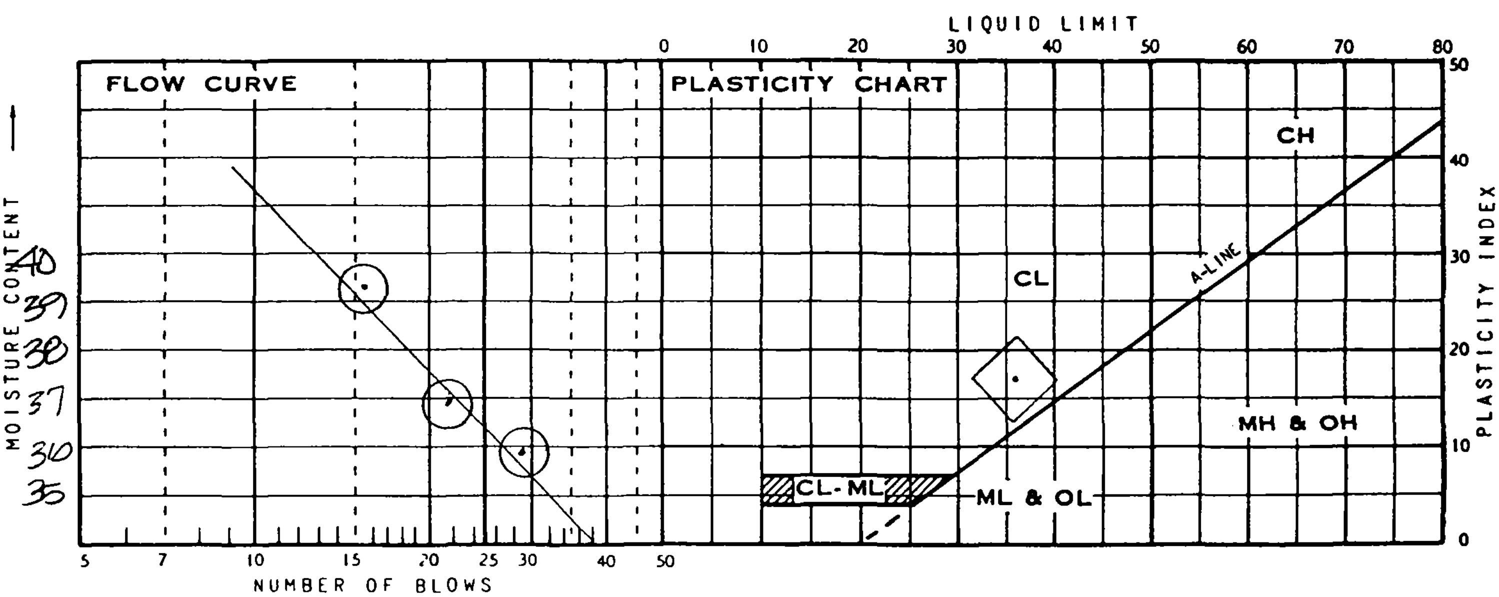
THIS IS AN 1/8-INCH THREAD

PLASTIC LIMIT BY RH 2/1/94

DETERMINATION	1	2	3	4	5	6
DISH	79	55				
WT OF DISH + WET SOIL	13.50	13.02				
WT OF DISH + DRY SOIL	11.53	11.17				
WT OF MOISTURE						
WT OF DISH	1.40	1.40				
WT OF DRY SOIL						
MOISTURE CONTENT	19.45	18.94	AV=19			

LIQUID LIMIT

DETERMINATION	1	2	3	4	5	6
DISH	5	A6	108			
NUMBER OF BLOWS	29	22	16			
WT OF DISH + WET SOIL	12.06	12.72	11.82			
WT OF DISH + DRY SOIL	9.24	9.81	8.88			
WT OF MOISTURE						
WT OF DISH	1.40	1.40	1.40			
WT OF DRY SOIL						
MOISTURE CONTENT	35.97	36.98	39.30			

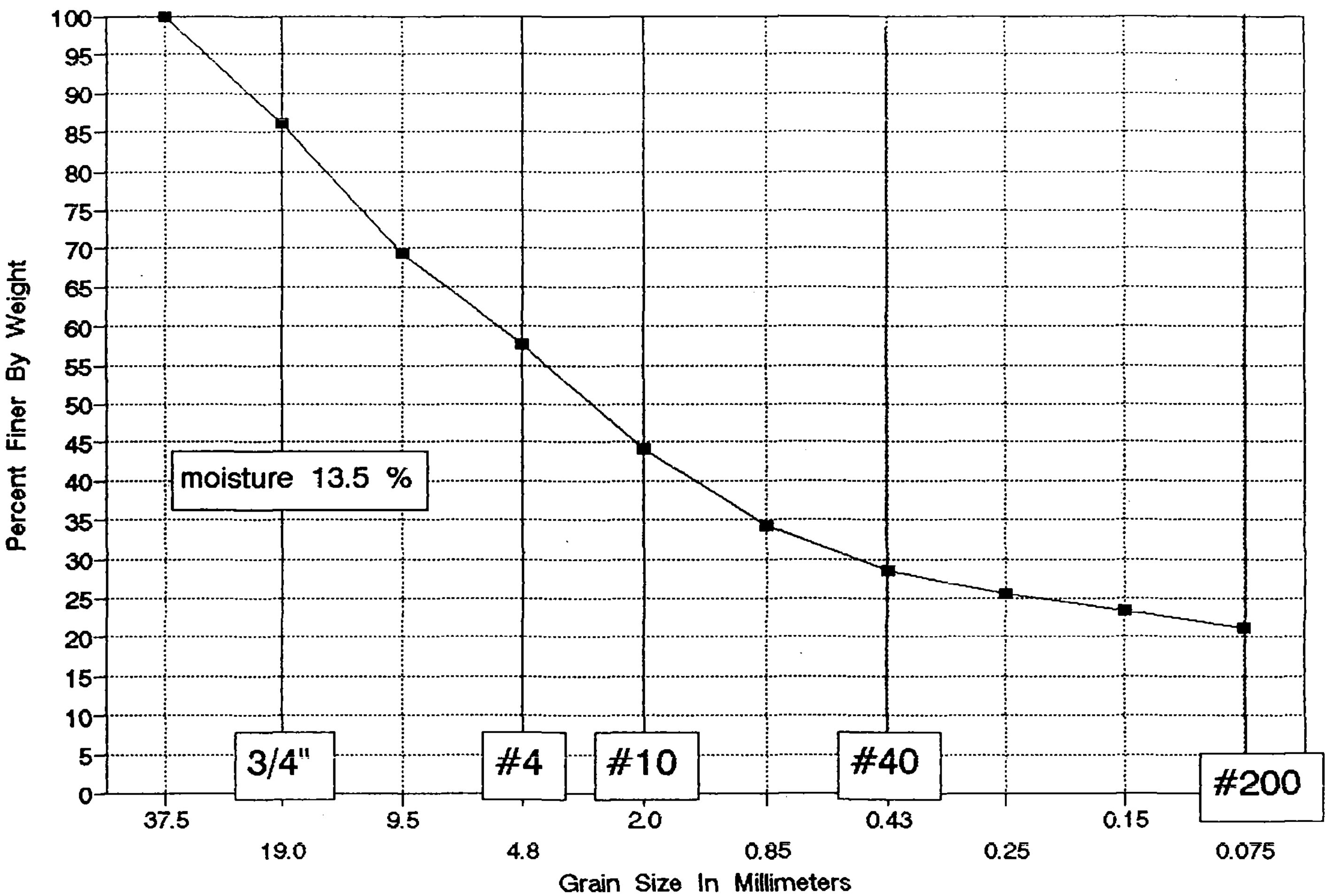


SUMMARY

DRY DENSITY	MOISTURE CONTENT	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	IDENTIFICATION	
		36	19	17	CL	

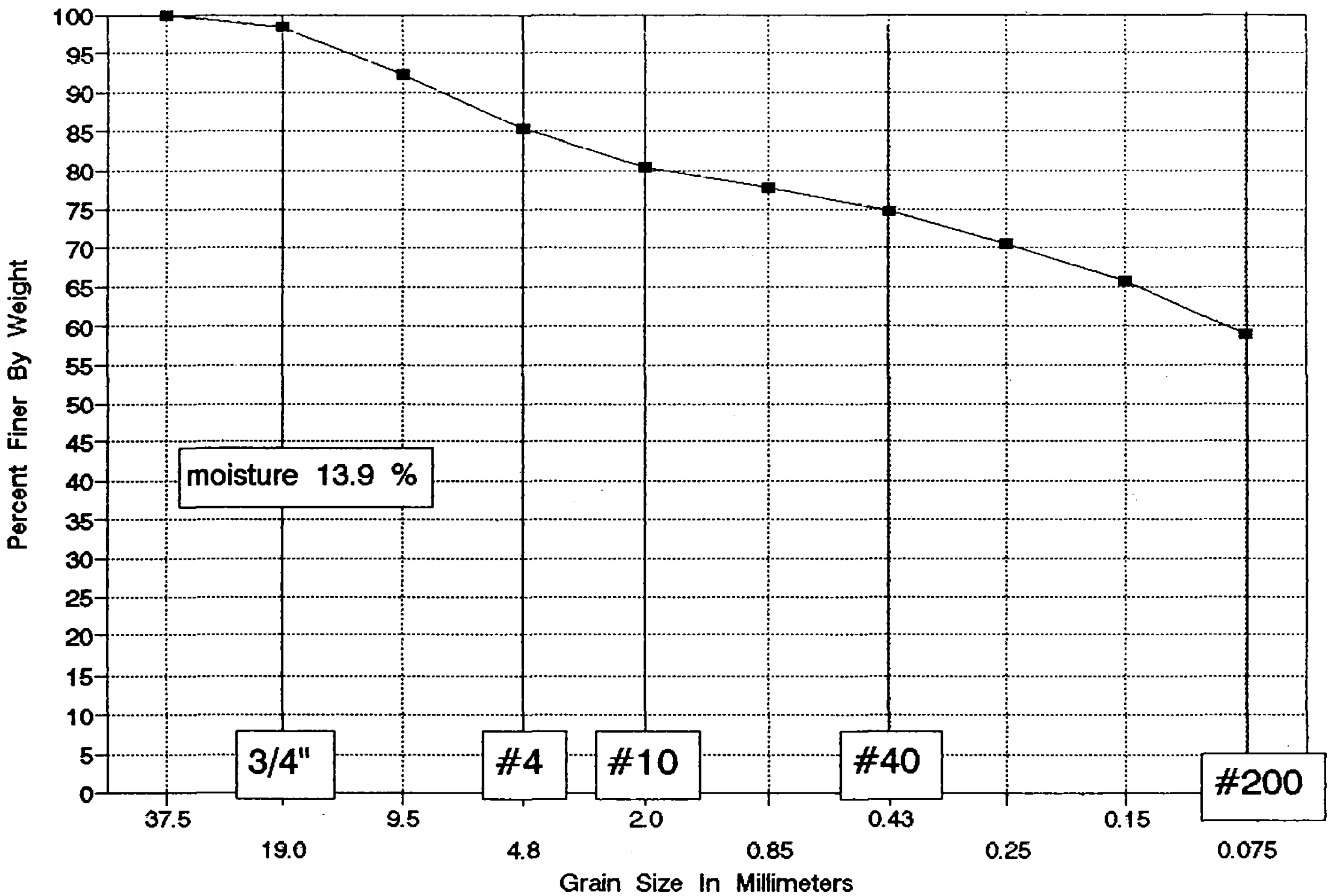
GRADATION CURVE

Boring DH-2, sample at 100 to 101.5 ft



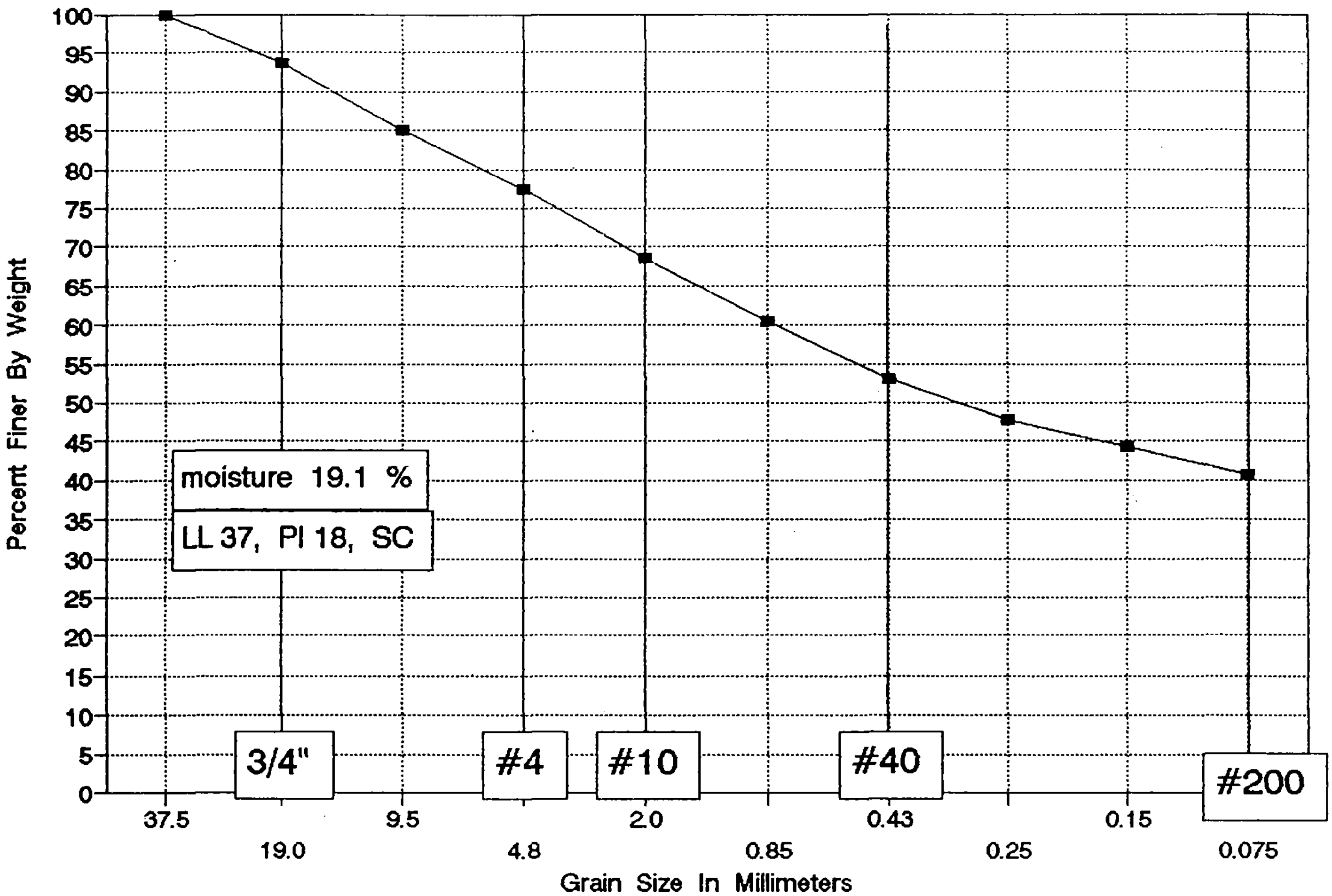
GRADATION CURVE

Boring DH-3, sample at 25 to 26.5 feet



GRADATION CURVE

Boring DH-3, sample at 40 to 41.5 feet



ATTERBERG LIMITS TEST DATA

FIELD CLASSIFICATION _______________

LABORATORY CLASSIFICATION _______________

JOB NO. [illegible]

CLIENT/OWNER UDWR

LOCATION BIRCH CREEK DAM

BORING DH-3 SAMPLE — DEPTH 40-41.5

FIELD DENSITY BY ____/__/__

DETERMINATION	1	2
NUMBER OF RINGS		
WT OF RINGS + WET SOIL		
WT OF RINGS		
WT OF WET SOIL		
FIELD DENSITY		
DRY DENSITY		

DETERMINATION	1	2
DISH		
WT OF DISH + WET SOIL		
WT OF DISH + DRY SOIL		
WT OF MOISTURE		
WT OF DISH		
WT OF DRY SOIL		
FIELD MOISTURE CONTENT		

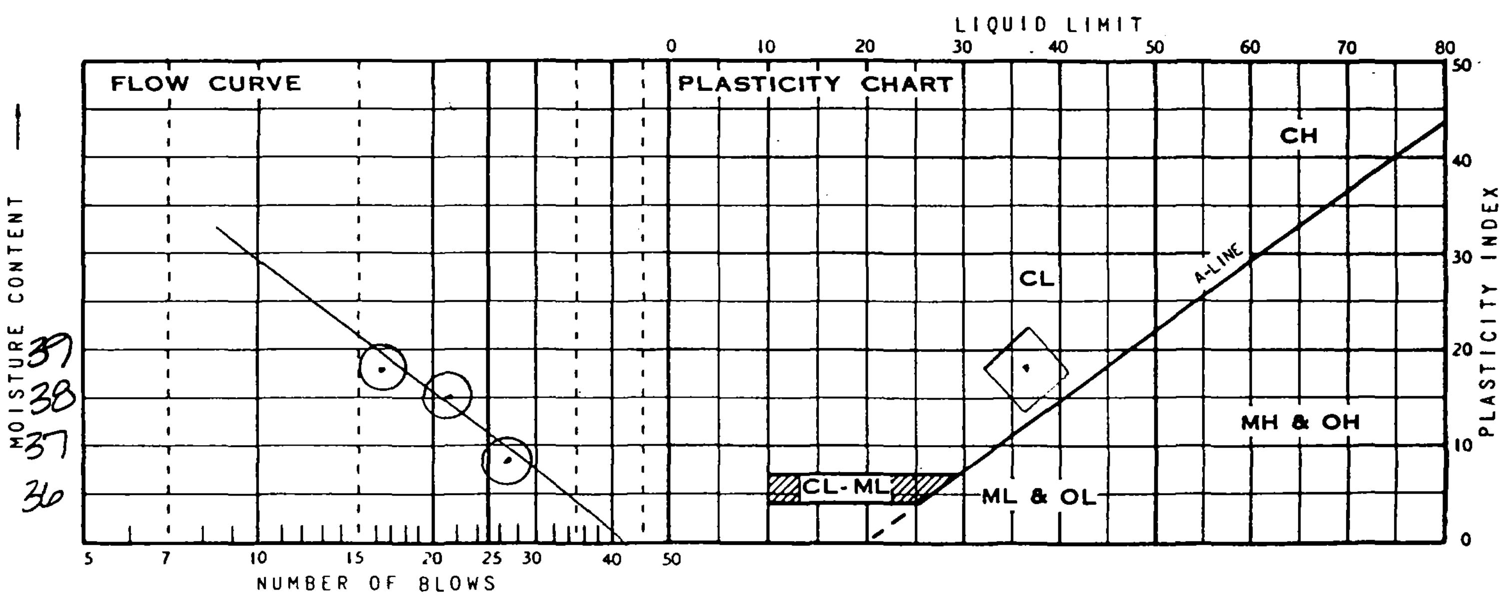
THIS IS AN 1/8-INCH THREAD

PLASTIC LIMIT BY RH 2/1/94

DETERMINATION	1	2	3	4	5	6
DISH	AL-108	AL-85				
WT OF DISH + WET SOIL	12.01	14.87				
WT OF DISH + DRY SOIL	10.31	12.66				
WT OF MOISTURE						
WT OF DISH	1.40	1.40				
WT OF DRY SOIL						
MOISTURE CONTENT	19.08	19.63	AV=19			

LIQUID LIMIT

DETERMINATION	1	2	3	4	5	6
DISH	11	107	21A			
NUMBER OF BLOWS	27	22	17			
WT OF DISH + WET SOIL	12.92	12.04	13.73			
WT OF DISH + DRY SOIL	9.82	9.11	10.29			
WT OF MOISTURE						
WT OF DISH	1.40	1.40	1.40			
WT OF DRY SOIL						
MOISTURE CONTENT	36.82	38.00	38.70			



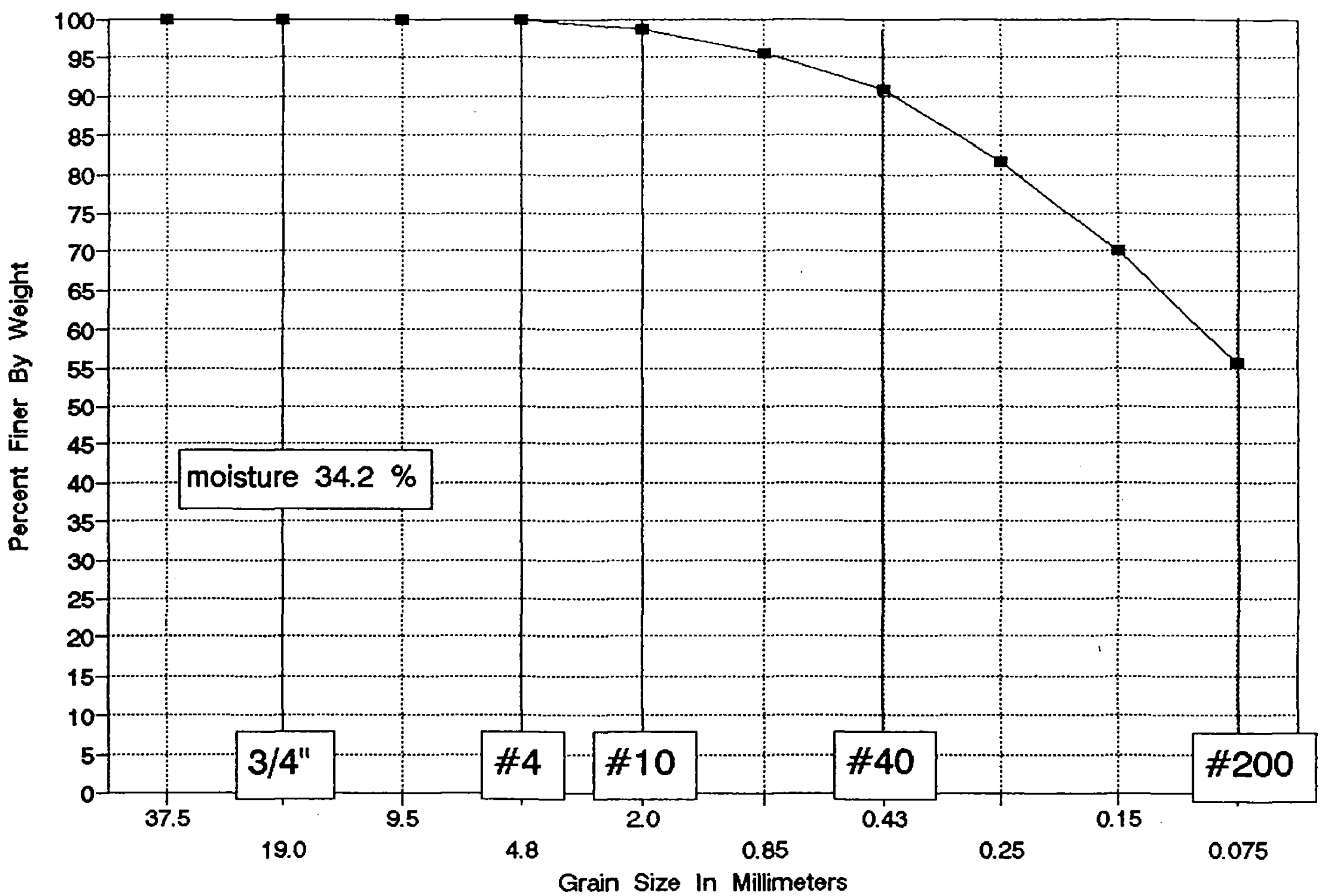
SUMMARY

DRY DENSITY	MOISTURE CONTENT	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	IDENTIFICATION	
		37	19	18	CL	

DAMES & MOORE

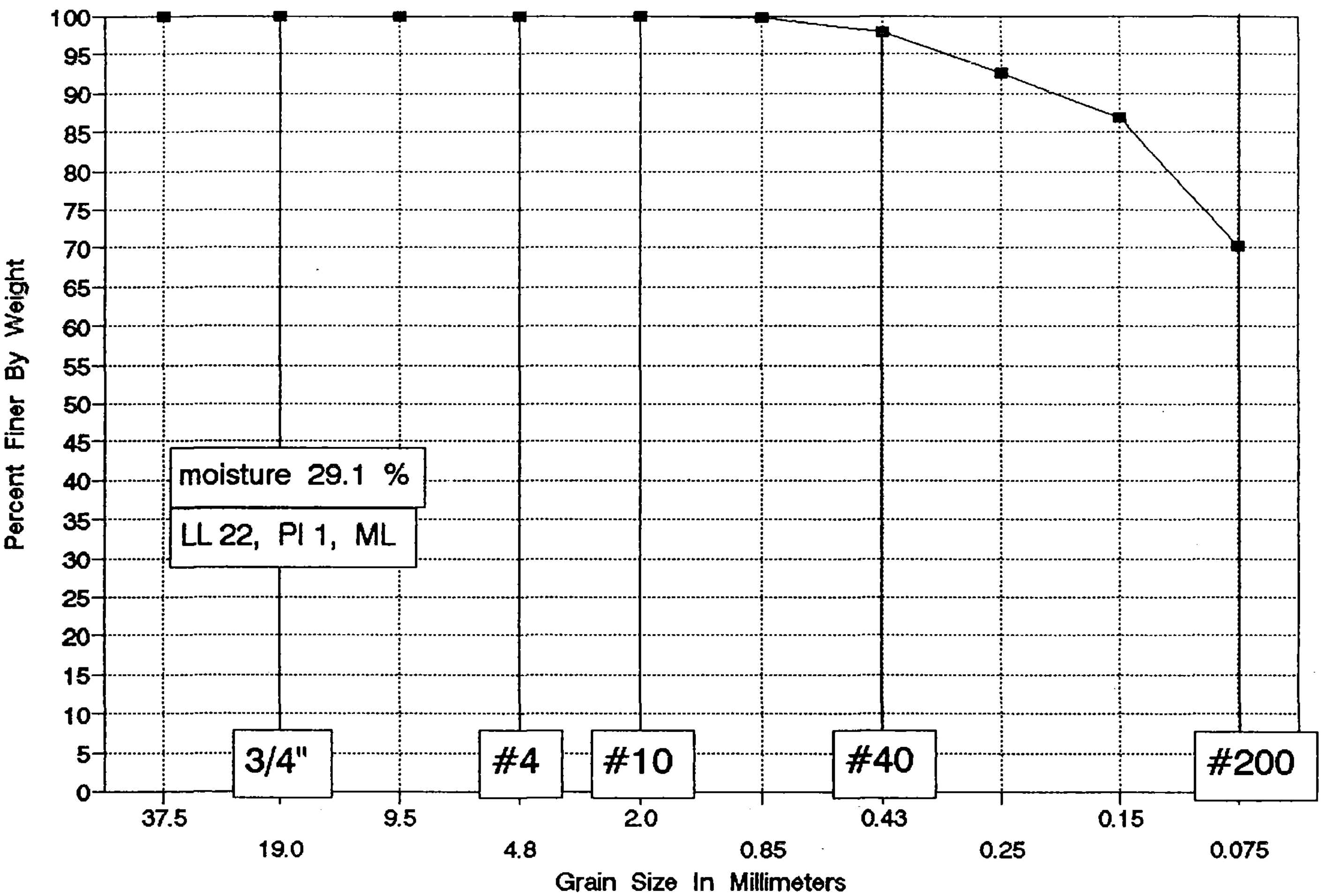
GRADATION CURVE

Boring DH-3, sample at 55 to 56.5 feet



GRADATION CURVE

Boring DH-3, sample at 65 to 66.5 feet



ATTERBERG LIMITS TEST DATA

JOB NO. 05461-027-00101
CLIENT/OWNER UDWR
LOCATION BIRCH CREEK DAM
BORING DH-3 SAMPLE ____ DEPTH 65-66.5

FIELD CLASSIFICATION ________________

LABORATORY CLASSIFICATION ________________

FIELD DENSITY BY ____ /_/_

DETERMINATION	1	2
NUMBER OF RINGS		
WT OF RINGS + WET SOIL		
WT OF RINGS		
WT OF WET SOIL		
FIELD DENSITY		
DRY DENSITY		

THIS IS AN 1/8-INCH THREAD

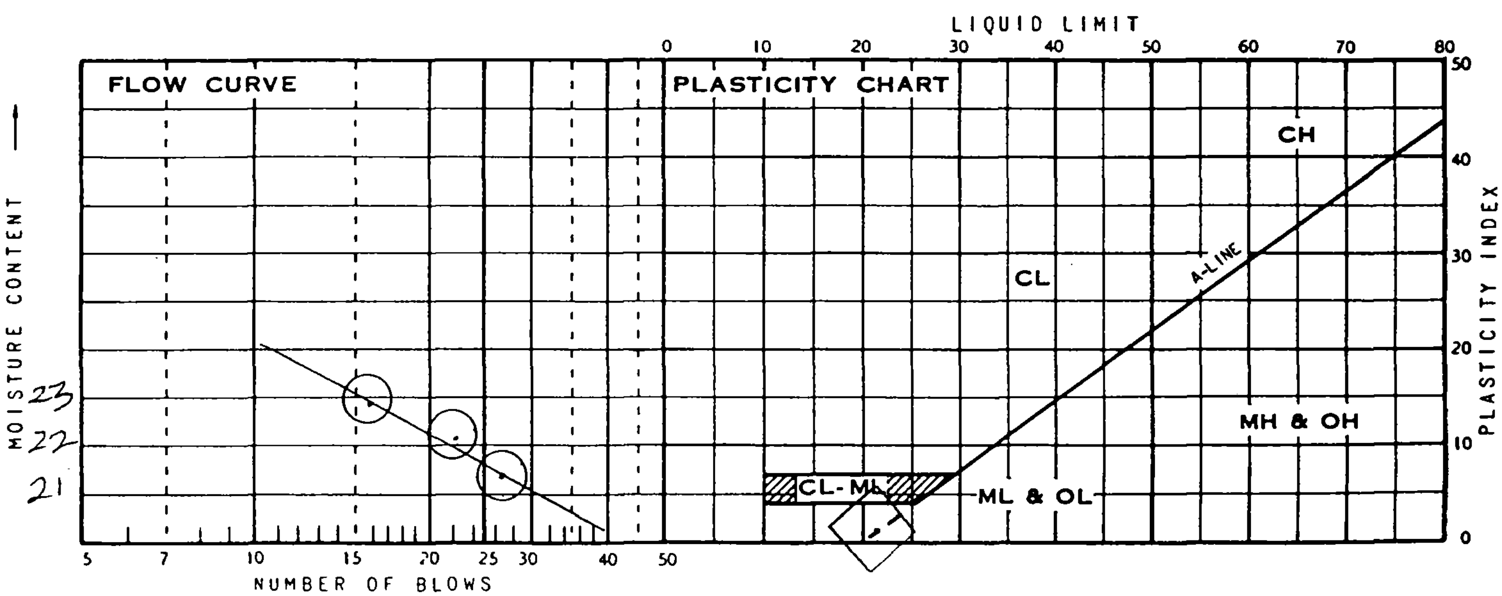
DETERMINATION	1	2
DISH		
WT OF DISH + WET SOIL		
WT OF DISH + DRY SOIL		
WT OF MOISTURE		
WT OF DISH		
WT OF DRY SOIL		
FIELD MOISTURE CONTENT		

PLASTIC LIMIT BY RH 2/1/94

DETERMINATION	1	2	3	4	5	6
DISH	A-7	105				
WT OF DISH + WET SOIL	13.17	13.50				
WT OF DISH + DRY SOIL	11.09	11.49		DIFFICULT		
WT OF MOISTURE				TO		
WT OF DISH	1.40	1.40		THREAD		
WT OF DRY SOIL						
MOISTURE CONTENT	21.47	20.91	AV=21			

LIQUID LIMIT

DETERMINATION	1	2	3	4	5	6
DISH	AL-91	AL-102	112			
NUMBER OF BLOWS	27	23	16			
WT OF DISH + WET SOIL	10.96	10.26	9.70			
WT OF DISH + DRY SOIL	9.27	8.66	8.15			
WT OF MOISTURE						
WT OF DISH	1.40	1.40	1.40			
WT OF DRY SOIL						
MOISTURE CONTENT	21.47	22.04	22.96			

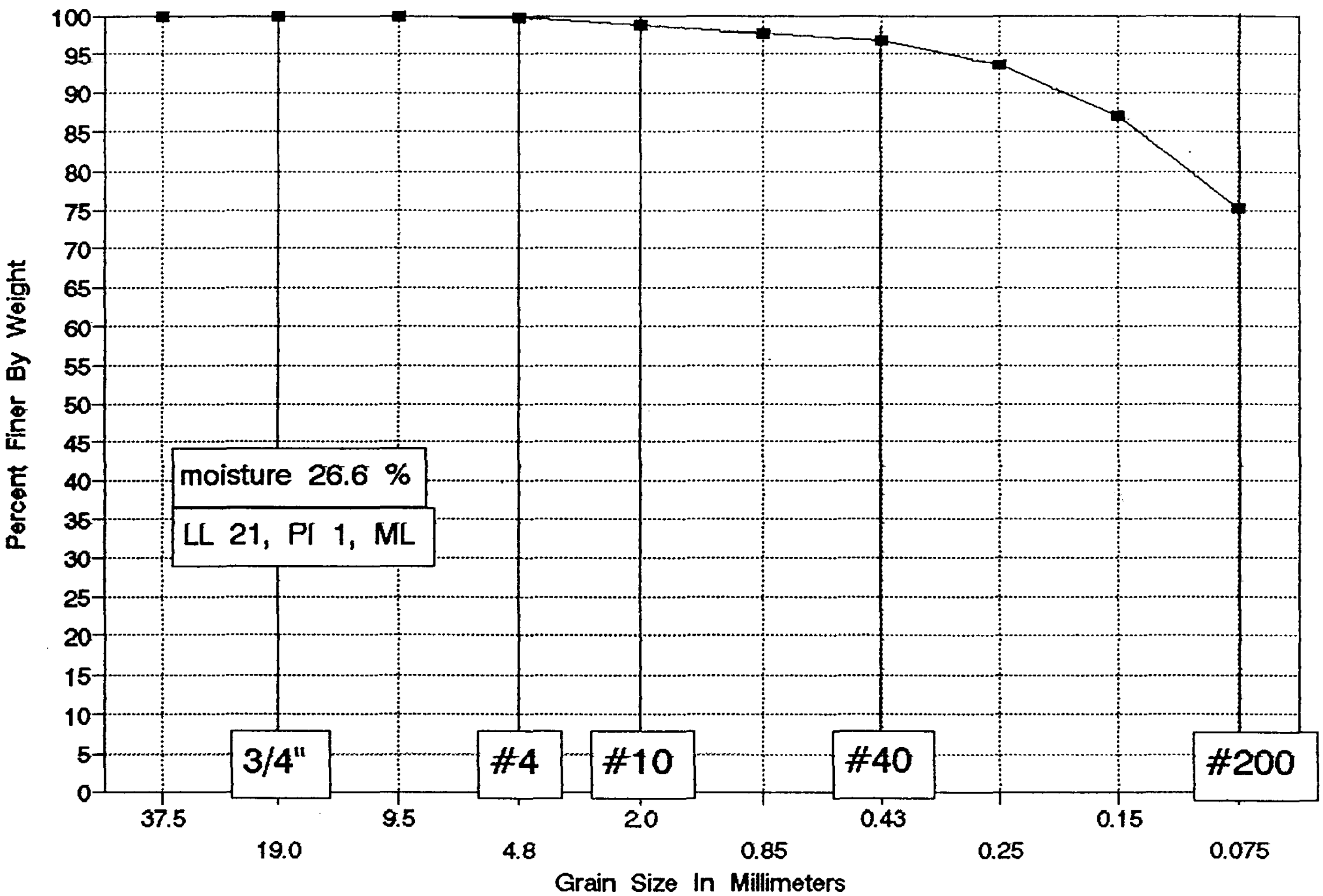


SUMMARY

DRY DENSITY	MOISTURE CONTENT	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	IDENTIFICATION
		22	21	1	ML

GRADATION CURVE

Boring DH-4, sample at 15 to 16.5 feet



ATTERBERG LIMITS TEST DATA

FIELD CLASSIFICATION _______________

LABORATORY CLASSIFICATION _______________

JOB NO. U3401-U27-0001

CLIENT/OWNER UDWR

LOCATION BIRCH CREEK DAM

BORING DH-4 SAMPLE — DEPTH 15-16.5

FIELD DENSITY BY ____/__/__

DETERMINATION	1	2
NUMBER OF RINGS		
WT OF RINGS + WET SOIL		
WT OF RINGS	—	—
WT OF WET SOIL		
FIELD DENSITY		
DRY DENSITY		

THIS IS AN 1/8-INCH THREAD

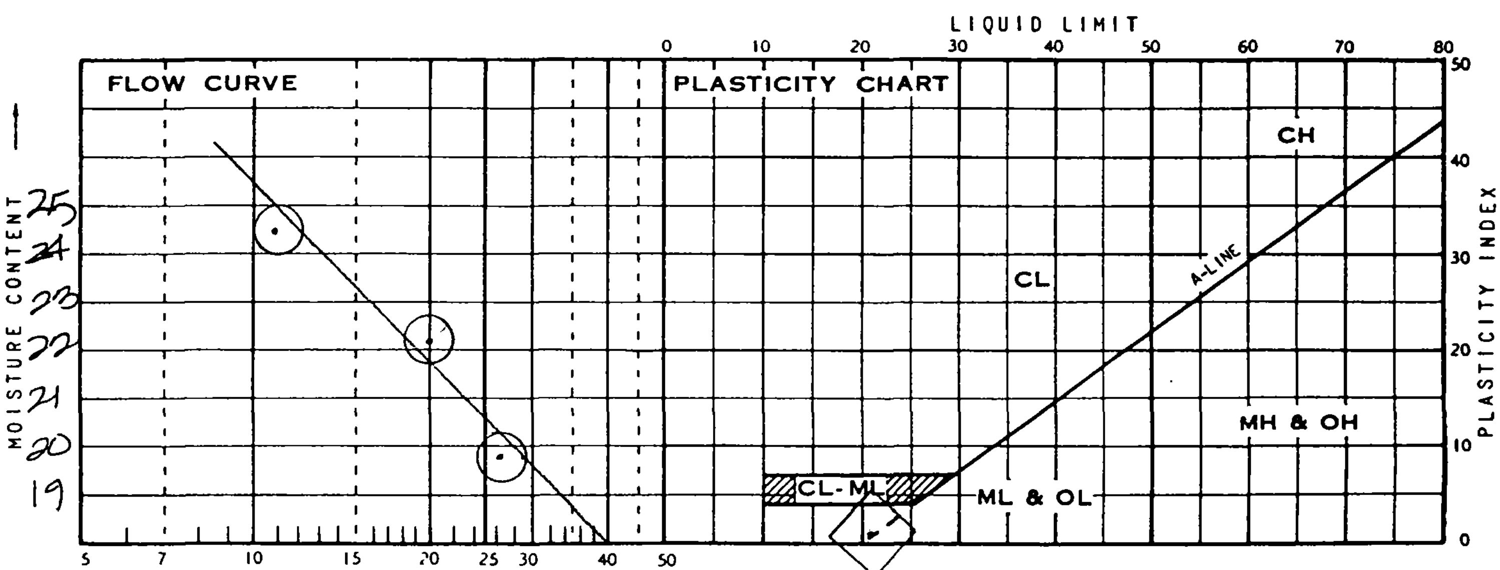
DETERMINATION	1	2
DISH		
WT OF DISH + WET SOIL		
WT OF DISH + DRY SOIL	—	—
WT OF MOISTURE		
WT OF DISH	—	—
WT OF DRY SOIL		
FIELD MOISTURE CONTENT		

PLASTIC LIMIT BY RH 2/1/94

DETERMINATION	1	2	3	4	5	6
DISH	AL-125	104				
WT OF DISH + WET SOIL	11.99	12.39	(DIFFICULT			
WT OF DISH + DRY SOIL	10.23	10.56	—	TO	—	—
WT OF MOISTURE				THREAD)		
WT OF DISH	1.40	1.40	—	—	—	—
WT OF DRY SOIL						
MOISTURE CONTENT	19.93	19.98	AV=20			

LIQUID LIMIT

DETERMINATION	1	2	3	4	5	6
DISH	10	AL-76	17			
NUMBER OF BLOWS	27	20	11			
WT OF DISH + WET SOIL	11.78	11.81	13.47			
WT OF DISH + DRY SOIL	10.06	9.92	11.10	—	—	—
WT OF MOISTURE						
WT OF DISH	1.40	1.40	1.40	—	—	—
WT OF DRY SOIL						
MOISTURE CONTENT	19.86	22.18	24.43			

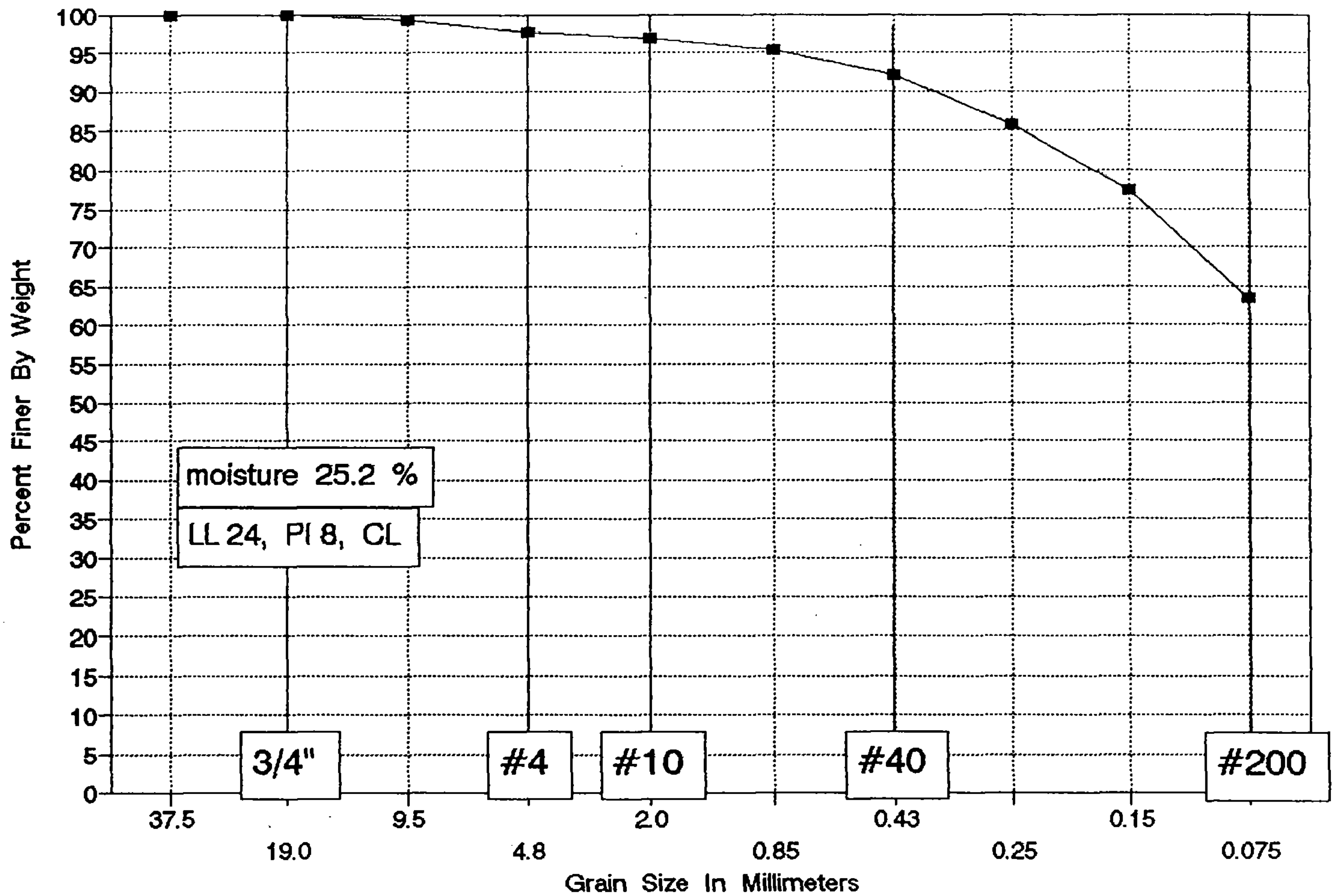


SUMMARY

DRY DENSITY	MOISTURE CONTENT	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	IDENTIFICATION	
		21	20	1	~~CL~~ ML	

GRADATION CURVE

Boring DH-4, sample at 24 to 25.5 feet



ATTERBERG LIMITS TEST DATA

FIELD CLASSIFICATION ________________

LABORATORY CLASSIFICATION ________________

JOB NO. [illegible]

CLIENT/OWNER UDWR

LOCATION BIRCH Creek DAM

BORING DH-4 SAMPLE — DEPTH 24-25.5

FIELD DENSITY BY ___/__/__

DETERMINATION	1	2
NUMBER OF RINGS		
WT OF RINGS + WET SOIL		
WT OF RINGS		
WT OF WET SOIL		
FIELD DENSITY		
DRY DENSITY		

DETERMINATION	1	2
DISH		
WT OF DISH + WET SOIL		
WT OF DISH + DRY SOIL		
WT OF MOISTURE		
WT OF DISH		
WT OF DRY SOIL		
FIELD MOISTURE CONTENT		

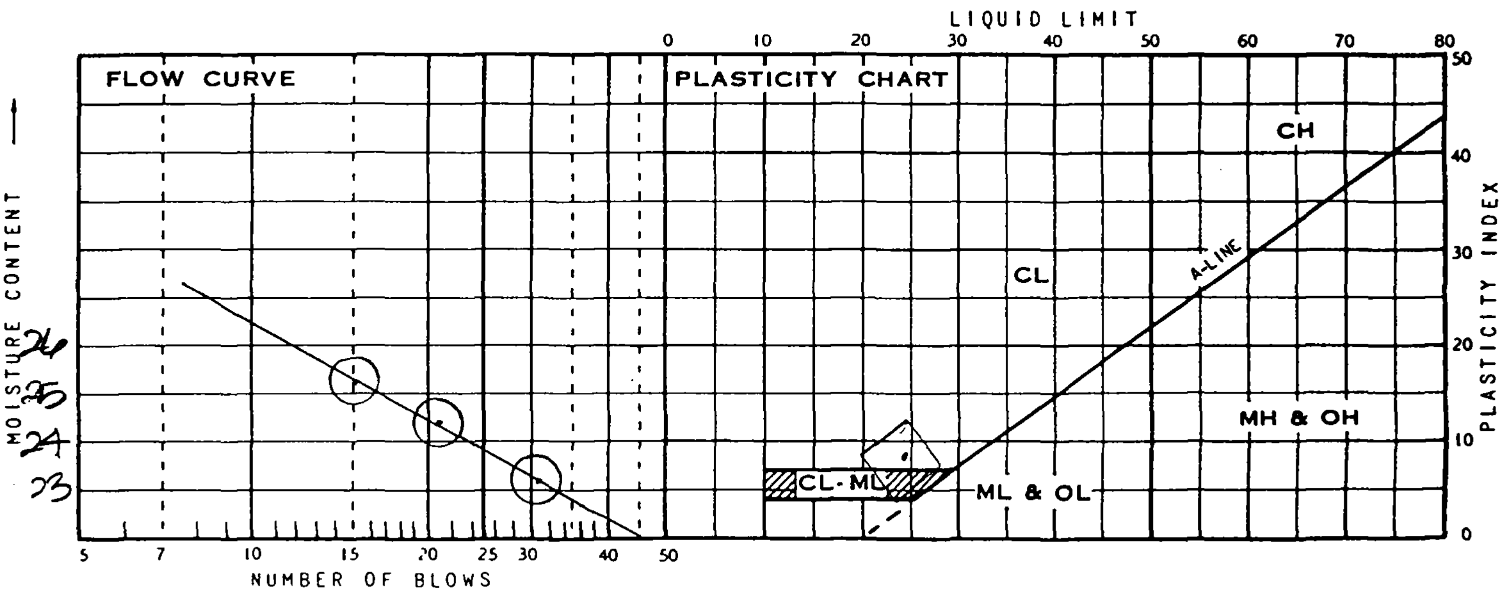
THIS IS AN 1/8-INCH THREAD

PLASTIC LIMIT BY RH 2/1/94

DETERMINATION	1	2	3	4	5	6
DISH	37	102				
WT OF DISH + WET SOIL	14.58	13.94				
WT OF DISH + DRY SOIL	12.77	12.22				
WT OF MOISTURE						
WT OF DISH	1.40	1.40				
WT OF DRY SOIL						
MOISTURE CONTENT	15.92	15.90	AV=16			

LIQUID LIMIT

DETERMINATION	1	2	3	4	5	6
DISH	A=135	130	7			
NUMBER OF BLOWS	31	21	15			
WT OF DISH + WET SOIL	16.25	14.74	13.16			
WT OF DISH + DRY SOIL	13.47	12.12	10.80			
WT OF MOISTURE						
WT OF DISH	1.40	1.40	1.40			
WT OF DRY SOIL						
MOISTURE CONTENT	23.03	24.44	25.11			

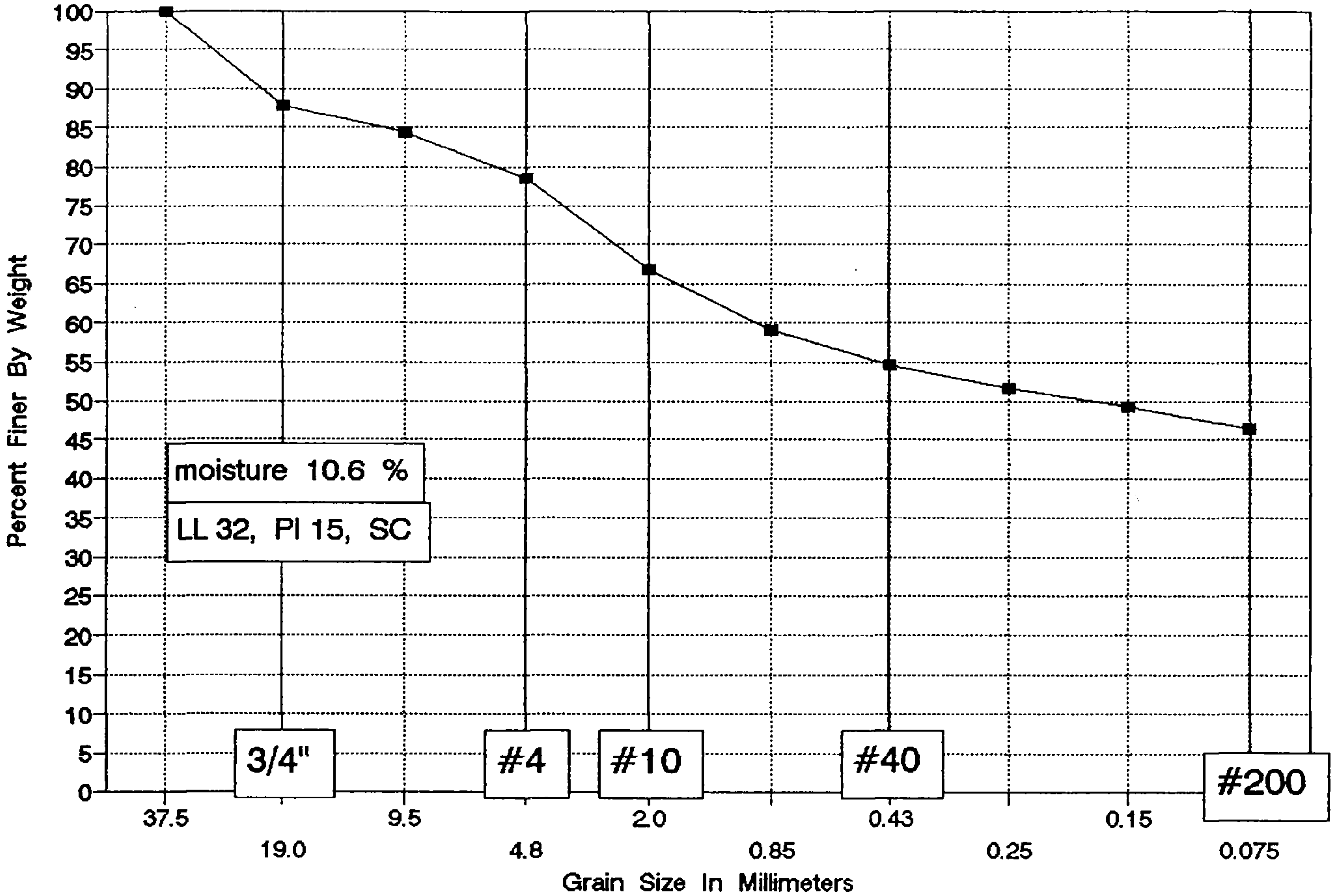


SUMMARY

DRY DENSITY	MOISTURE CONTENT	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	IDENTIFICATION	
		24	16	8	CL	

GRADATION CURVE

Boring DH-5, sample at 10 to 11.5 feet



ATTERBERG LIMITS TEST DATA

FIELD CLASSIFICATION ________________

LABORATORY CLASSIFICATION ______________

JOB NO. [illegible]

CLIENT/OWNER UDWR

LOCATION BIRCH CREEK DAM

BORING DH-5 SAMPLE — DEPTH 10-11.5'

FIELD DENSITY BY ______/__/__

DETERMINATION	1	2
NUMBER OF RINGS		
WT OF RINGS + WET SOIL		
WT OF RINGS		
WT OF WET SOIL		
FIELD DENSITY		
DRY DENSITY		

DETERMINATION	1	2
DISH		
WT OF DISH + WET SOIL		
WT OF DISH + DRY SOIL		
WT OF MOISTURE		
WT OF DISH		
WT OF DRY SOIL		
FIELD MOISTURE CONTENT		

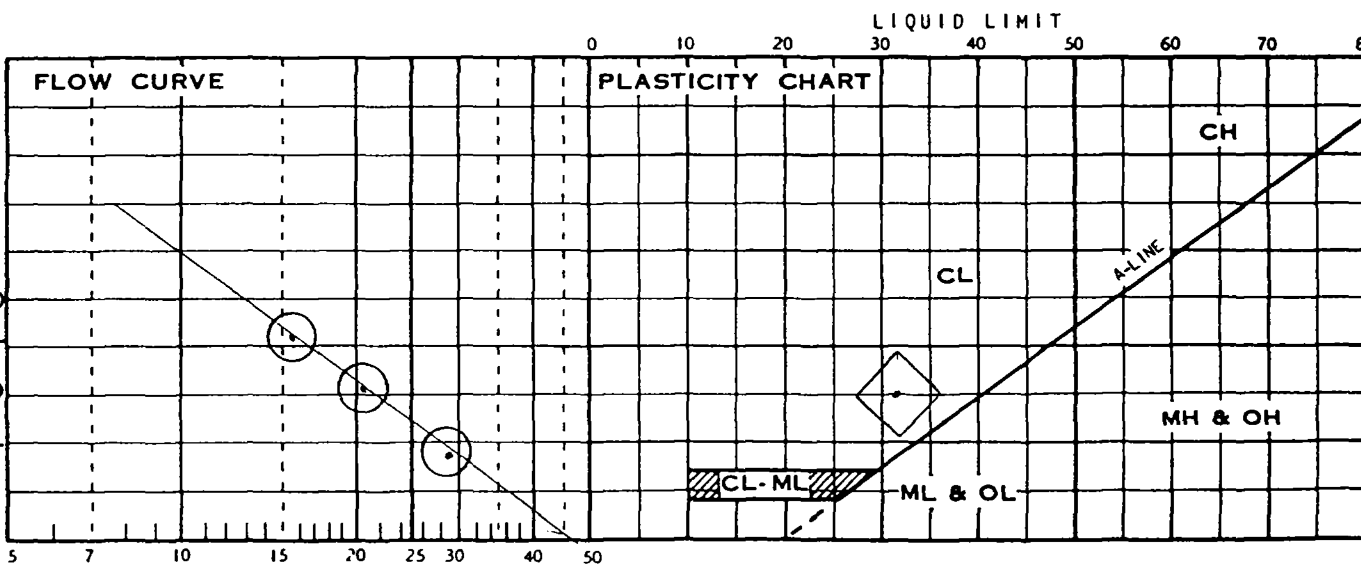
THIS IS AN 1/8-INCH THREAD

PLASTIC LIMIT BY RH 2/1/94

DETERMINATION	1	2	3	4	5	6
DISH	114	42				
WT OF DISH + WET SOIL	13.58	14.25				
WT OF DISH + DRY SOIL	11.85	12.43				
WT OF MOISTURE						
WT OF DISH	1.40	1.40				
WT OF DRY SOIL						
MOISTURE CONTENT	16.56	16.50	AV=17			

LIQUID LIMIT

DETERMINATION	1	2	3	4	5	6
DISH	35	32	115			
NUMBER OF BLOWS	29	21	16			
WT OF DISH + WET SOIL	13.98	13.65	13.08			
WT OF DISH + DRY SOIL	10.94	10.61	10.11			
WT OF MOISTURE						
WT OF DISH	1.40	1.40	1.40			
WT OF DRY SOIL						
MOISTURE CONTENT	31.87	33.01	34.10			



SUMMARY

DRY DENSITY	MOISTURE CONTENT	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	IDENTIFICATION	
		32	17	15	CL	

DAMES & MOORE

APPENDIX C

RESULTS OF DOWNHOLE SHEAR WAVE SURVEY

LGS GEOPHYSICS INC.

RESULTS OF DOWNHOLE SHEAR WAVE SURVEY AT BIRCH CREEK DAM, WOODRUFF, UTAH

Prepared For: Utah Division of Water Resources,
Salt Lake City, Utah

Prepared By: LGS Geophysics Inc.
Salt Lake City, Utah
July 5, 1994

LGS GEOPHYSICS INC.
engineering, environmental, mining geophysics

July 5, 1994

Utah Division of Water Resources
1636 W. North Temple, Suite 310
Salt Lake City, Ut 84116-3156

Attn: Bill Leeflang, P.E.

Subject: Results of Geophysical Downhole Shear Wave Survey at Birch Creek Dam, Woodruff, Utah.

Gentlemen:

Presented in this report are the results of our down hole shear wave survey conducted within drill hole DH-2, located at the crest of the above dam. The drill hole was surveyed at five foot depth increments to 83 ft., the approximate total depth of the hole. The purpose of the survey was to determine the seismic compressional and shear wave velocities, at five foot intervals, of the subsoils encountered by the drill hole. The seismic velocities thus measured form the basis for determining the elastic moduli of the subsoils investigated under dynamic, low strain (X 10-E5 in./in.) and high loading rate conditions.

Field Investigations:

Field investigations were completed in June, 1994. The drill hole had been cased with 2 in. ID, PVC casing and backfilled with grout in preparation for conducting the survey. The downhole measurements were conducted using two orthogonal geophone units, spaced five feet apart, with each unit containing a vertical, a transverse and a radially oriented geophone. The field procedure consisted of placing the two units into the cased drill hole and recording the arrival of the various components of a surface generated seismic wave or signal as they arrived, successively, at the upper and

1104 Ashton Ave. Salt Lake City, Utah 84106 • (801) 466 • 1784

lower packages. The first test location consisted of placing the upper package at 0 ft. (ground surface), within the drill hole, and the lower package at 5 ft. within the hole. A horizontally polarized seismic signal was then generated near the hole collar, using the horizontal traction method (weighted plank). The arrival time for this signal was indicated by the two geophone packages and subsequently amplified and recorded by the seismograph. The direction of the energy impact was then reversed to confirm the onset of the shear wave arrival. The geophones were then lowered five ft. and the process repeated. This procedure was followed for each successive five foot depth increment to the hole bottom.

Equipment:

A signal enhancement seismograph was used in the data collection. The enhancement feature allowed the use of a series of light hammer blows in generating the seismic signal, rather than a single heavy blow, thus minimizing the potential for unwanted signals and also aids minimizing any delay inherent in the timing switch mechanism. The seismic signals were unfiltered to minimize signal distortion. A signal voltage sampling rate of 50,000 measurements per second was used in the analog to digital convertor step to allow a high degree of accuracy (± 0.1 milliseconds) in determining the arrival times of the seismic signals of interest. The impedence values of the seismograph and geophones were within 5% to allow accurate recording of the particle velocities at the low strain levels measured. The frequency response of the vertical and the radial and transversely mounted, horizontal geophones within each of the geophone packages was 8 Hz.

Data Reduction, Comments

The compressional seismic wave was indicated as the first arrival by the vertical geophone within each of the two geophone packages; the horizontal (shear) component from the same hammer impact was indicated by the transverse/radial geophones within the packages. The shear wave arrivals were corroborated by a reversed response of the transverse/radial geophones on reversal of the direction of impact of the seismic source. Using two geophone packages, separated by a five ft. interval, enabled the measurement of interval times as well as the total travel time to the geophones from the source. Use ofinterval times in the calculations avoids the possibility of potential measurement error due to any delay inherent in the timing system and essentially eliminating the affect of different travel time paths of the seismic energy as a source of error. Corrections were made in the depth increments in determining the seismic velocities to compensate for the offset of the seismic source from the hole collar. The seismic source was located three feet from the hole collar and oriented parallel to the dam axis.

The Shear modulus (G) was computed by the relationship given below, using the shear wave velocity (Vs) measured for each depth increment and the in situ density (d) of the material.

$$G = d(Vs)^2$$

[d=soil moist unit weight (135 lbs./ft.^{3})/gravity constant(32.2 ft./sec.^{2})]

The ratio of the compressional and shear wave velocities (Vp/Vs) obtained for each depth increment was then calculated for use in determining Poissons' ratio (p) by the following relationship:

$$p = (Vp/Vs)^2-2/2(Vp/Vs)^2-2$$

Youngs' modulus was then determined for each depth increment, using the Shear modulus and Poissons' ratio for the same increment, by the following relationship:

$$E = 2G(1+p)$$

Results

The results of the calculations together with the seismic velocities measured are presented on Table I.

We have appreciated providing this service to you. Please contact us if there are any questions on the above or if we may be of further service to you.

LGS GEOPHYSICS INC.

LaMonte Sorenson
Principal

TABLE I

RESULTS OF DOWNHOLE SHEAR WAVE SURVEY IN
DRILL HOLE DH-2, BIRCH CREEK DAM, WOODRUFF, UTAH

DEPTH (ft.)	Vp (ft./sec.)	Vs (ft./sec.)	p	G (lb./ft.^{2})	E (lb./ft.^{2})
0- 5	1208	552	.37	1.28 X 10E6	3.50 X 10E6
5-10	2244	1353	.21	7.67 "	18.56 "
10-15	2178	1140	.31	5.45 "	14.27 "
15-20	2778	1250	.37	6.55 "	17.94 "
20-25	2632	1075	.40	4.84 "	13.56 "
25-30	2083	943	.37	3.73 "	10.21 "
30-35	2941	1163	.41	5.67 "	15.98 "
35-40	2500	971	.41	3.93 "	11.09 "
40-45	2500	1279	.36	6.85 "	18.64 "
55-50	2703	1064	.41	4.74 "	13.38 "
50-55	2500	1000	.40	4.19 "	11.73 "
55-60	2500	1149	.37	5.53 "	15.16 "
60-65	2273	1042	.37	4.55 "	12.47 "
65-70	2439	1075	.38	4.84 "	13.36 "
70-75	2273	1000	.40	4.19 "	11.73 "
75-80	2273	991	.38	4.11 "	11.36 "
80-83	2366	1099	.36	5.04 "	13.70 "

Vp = compressional wave velocity
Vs = shear wave velocity

p = Poissons' ratio
G = shear modulus
E = Young's modulus