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RETURN TO REGULATORY CENTRAL FILES
ROOM 016

GEOLOGY OF THE SOUTHERN HUMBOLDT BAY AREA AND THE HUMBOLDT BAY POWER PLANT SITE

APPENDICES

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Prepared for
THE PACIFIC GAS AND ELECTRIC COMPANY

77 BEALE STREET
SAN FRANCISCO, CALIFORNIA 94106

SEP 22 1972

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AUGUST 1972

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APPENDICES

A. Data from field and laboratory investigations by Earth Sciences Associates, 1972.

B. Data from geophysical investigations by Earth Sciences Associates, 1972.

C. Data from seismic reflection surveys, Humboldt Bay and offshore area.

D. Paleontologic and geologic data provided by Standard Oil Company of California, Western Operations, Inc. Exploration Department.

E. Logs of Wells.

F. Logs of test borings at the Humboldt Bay Power Plant Site by Dames and Moore.

G. Consultants Reports from previous investigations of geologic and seismic conditions pertaining to the Humboldt Bay Power Plant Site.

A. Data from field and laboratory investigations by Earth Sciences Associates, 1972.

1. Description of field investigations.
2. Logs of Earth Sciences Associates exploratory borings H-1 through H-11.
3. Logs of Earth Sciences Associates backhoe trenches.
4. Sketch geologic maps of exposures near Fields Landing.
5. Results of laboratory testing of Carlotta Formation claystone.

A-1. Description of field investigations.

A-1. Description of Field Investigations.

The field investigations for the Humboldt Bay Power Plant site geology investigation included three principal phases: 1) field reconnaissance and reconnaissance mapping, supplemented by study of stereo aerial photographs; 2) geophysical surveying in selected areas by sparker seismic reflection profiling, magnetic surveying and gravity surveying; and 3) subsurface exploration, chiefly by drilling, with some backhoe trenching.

The reconnaissance and reconnaissance mapping phase was initiated when Dr. G. H. Curtis spent four days mapping outcrops in the southern Humboldt Bay area in 1969. This work was resumed in 1972, when Curtis and D. H. Hamilton spent several more days in the field in this area. A total of about four man-weeks was spent in field mapping work. Field data were plotted on 1 inch = 2000 feet scale U.S.G.S. topographic maps, or in larger scale sketch maps.

The geophysical surveying work began with a sparker seismic reflection survey of Humboldt Bay by Alpine Geophysical Associates, Inc. of Norwood, New Jersey. This survey was made during the third week of September 1971. A detailed description of the survey is presented in Appendix C. Magnetic and gravity surveys of selected areas were performed by Earth Sciences Associates in March and April of 1972. Descriptions of those surveys are given in Appendix B.

The program of subsurface exploration for the third phase of the investigation was designed after the preliminary results of the reconnaissance mapping and the geophysical surveying programs were available. The two initial objectives of the drilling program were 1) to extend the available information indicating continuity of identifiable strata in the ground underlying the plant site, and 2) to test trends of geophysical anomalies identified previously in the King Salmon - South Spit area. Later, the scope of the drilling work was increased to permit exploring for the boundary conditions associated with the buried trace of the Little Salmon fault, under Humboldt Hill.

The drilling contract work was done by the Pitcher Drilling Company of Daly City, California using a Failing 750 rotary wash boring rig. Samples were taken at selected intervals using a Pitcher Barrel sampler. This device utilizes a toothed cutting barrel around a 3 inch I.D. steel Shelby tube. Samples are recovered as 3 inch diameter cores up to 2 feet in length. The drilling operations were monitored continuously by an E.S.A. geologist; borings were logged from core samples and washed drill cuttings. Six inch segments of each sample were preserved in glass jars for later lithologic and paleontologic studies.

A total of eleven holes were drilled during the subsurface exploration program. The borings ranged from 50 feet to 443 feet in depth, and a total of 2422 feet of drilling was done. Holes H-1 and H-2 were drilled to provide a section near the plant that was transverse to the section defined by previously drilled Dames and Moore borings 1-A and D-13, and by PG&E well No. 1. Holes H-3, H-4, H-5, H-7, H-8, and H-9 were located so as to test the stratigraphic relationships in the vicinity of the geophysical anomalies detected near King Salmon and the north end of the South Spit. Hole H-6 provided a link between stratigraphic data in the Buhne Point - King Salmon peninsula and in the Humboldt Hill - Spruce Point area. Holes H-10 and H-11 were drilled to explore the section underlying the Hookton Formation capping on Humboldt Hill. Logs of all borings are presented in part A-2 of this Appendix.

Fourteen trenches were excavated on the crest and along the base of the south slope of the terrace spur ridge located in Section 9, (T3N, R1W), immediately northeast of the juncture of Little Salmon and Salmon Creeks, using a backhoe. The trenches were entered, logged, and sampled, and then were backfilled. The logs are presented in part A-3 of this Appendix.

A-2. Logs of Earth Sciences Associates exploratory borings H-1 through H-11. Locations of borings are shown on Drawing No. 7 and Drawing No. 9.

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT HUMBOLDT 1253 DATE DRILLED 4/6- 4/10/72 HOLE NO. H-1
LOCATION ____ GROUND SURFACE ELEV. ____
DRILLING CONTRACTOR J.N. PITCHER CO. LOGGED BY RCH DEPTH TO GROUND WATER ____
TYPE OF RIG FAILING 750 HOLE DIAMETER NX HAMMER WEIGHT AND FALL ____
SURFACE CONDITIONS FLAT - FILL - MUDDY WEATHER COOL - CLOUDY

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
0	CL	0-6.5 FILL: SILTY CLAY; moderate yellowish brown; mottled with some gray.		AD	Augered to 6'; set 5½" surface casing to 6'. Set up mud tub and began rotary drilling with clean water.
5					
	CL-CH	6.5-35.0 BAY MUD: silty Clay with gradations to fine sandy clay; dark greenish gray; abundant organic fibers; firm to stiff.		RD	
10		Contains thin (¼" - ½") lenses of clayey sand.			Little or no circulation loss. Logging from cuttings between samples.
15					
20					
25			J-1	P	24.0-26. Pushed 3" Shelby Tube
				RD	
30			J-2	P	30-32 Pushed 3" Shelby Tube.
				RD	
35	CL-SC	35.0-50.0 SANDY CLAY. greenish gray; low plasticity; 40-60% fine-grained sand; silty, scattered organic fibers; stiff	J-3	P	36-38 Pushed 3" Shelby Tube.
				RD	
40		40.0 - becomes mottled with olive grey and orange.	J-4	P	40-42 Pushed 3" Shelby Tube.
				RD	
45	CL	44-46 Lens of silty clay, dark greenish gray; stiff.	J-5	P	45-47 Pushed 3" Shelby Tube.
	CL-SC	46-50 greenish gray; no mottling; scattered organic fibers.		RD	
50					

SHEET 1 OF 6

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-1
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
50	SM ML SM ML SP	50.0 - 63.0 <u>SILTY SAND</u>: greenish gray; fine-grained; up to 10% silt fines with thin (1"-3") lenses of sandy silt and clean sand; scattered organic fibers; dense.	J-6	P	50'-52' Pushed 3" Shelby Tube
			J-7	PB 1.2/2.5	52' Began coring with Pitcher barrel in 2½' runs. Recovery ratio in mode column.
55	SP (ML)	54-56' clean sand with ¼"-1" silt lenses		PB 2.0/2.5	
	SP 8 SP	56.6- clean fine- to medium-grained sand with lenses of decayed wood fragments	J-8	PB 1.8/2.5	59' Mixed bentonite mud to prevent sand caving, no circulation loss.
	8 SP		J-9		
60	ML SP			PB 2.0/2.5	
	GP	63.0 - 74.0 <u>GRAVEL</u>: pebbly sand, ¼"-1½" rounded pebbles, mostly quartz and red and black chert in medium- to coarse-grained sand matrix	J-10	PB 0.7/2.5	
65				PB 0.0/2.5	64.5-67' Rig chattering on gravel - no recovery
				RD	67-75' Rotary drill with Tricone bit.
70					
	SP-SM	74.0-110.0 <u>SAND</u>: light bluish gray; < 10% silt fines; very fine- to fine-grained; partially cemented zones; very dense.			
75				PB 0.5/2.5	75' Coring with Pitcher Bbl.
		80-85 zones of brown, and with organic fibers and ¼" organic rich silt lenses.	J-11	PB 2.0/2.5	
80			J-12	PB 1.0/2.5	
				PB 0.5/2.5	
85	SP	85 becomes clean [illegible]; very fine- to fine-grained; uncemented; dense.		PB 0.6/2.5	
			J-13	PB 1.5/2.8	
90				PB 0.6/2.5	Poor recovery in clean sand.
				PB 0.5/2.5	
95				PB 0.0/2.5	
				PB 1.6/2.5	
100					

SHEET 2 OF 6

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-1
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
100	SP	74.0'-110.0' SAND (cont'd)		PB 1.3/2.5	
				PB 0.5/2.5	4-6-72 4-7-72 Hole caved overnite, 20' of cave in bottom.
105				PB 1.4/2.5	
			J-14		
				RD	
110	CL	110.0'-135.0' SILTY CLAYSTONE: dark greenish gray (blue clay); remolds to low plastic silty clay; distinct bedding planes in the form of subhorizontal laminations; no apparent organic matter; occasional laminations of very fine-grained sand; damp; hard.			
			J-15	PB 2.1/2.5	
	(SP)		J-16	PB 1.8/2.5	
115				PB 2.0/2.5	
		114'-116' Contains thin (1/4"-1/2") lenses of clean very fine- to fine-grained sand.	J-17	PB 2.0/2.5	
120		Apparent dip of bedding ~ 10°		PB 2.0/2.5	
125		124.5' & 125.3' lenses (1/2") of clean sand. sand fills small pockets or cracks in underlying claystone to depth of 1½".		PB 1.9/2.0	
			J-18	PB 1.2/2.0	
		126'-132' thin sand laminae with lenses up to 3" in claystone		PB 2.0/2.5	
130		132.5'-135' Lens of greenish gray clean fine sand.		PB 1.9/2.5	
			J-19	PB 0.7/2.5	
135	SP	135.0-138.5 SAND: olive brown; fine-grained; rounded to sub-round; well sorted; mostly quartz and chert, uncemented but very dense; scattered rounded chert pebbles; thin (1/4") yellow gray clay lenses.	J-20	PB 0.5/2.5	
	SP (GP)	138.5- pebbly sand; fine- to medium-grained with rounded chert & qtz pebbles up to 1". 139' grades to greenish gray.	J-21	PB 1.5/1.5	Pitcher Barrel refusal at 139.5' in dense gravelly sand.
140		139'- Pebbly sand and gravel, logged from cuttings and drill action.		RD	Began rotary drilling with Tricone bit. Losing little circulation in gravel, mixing heavy mud.
145					
150					

SHEET 3 OF 6

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-1
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
150	SP-GP	138.5-170 PEBBLY SAND + GRAVEL (cont'd)		RD	
155					
					Hard drilling in dense sand and gravel.
160					
165					
		decrease in gravel content			
170	SP	170-235 SAND: dark greenish gray; clean; fine-grained; rounded; scattered coarse-grained and fine gravel; very dense.			
			J-22	DR	171-171.7 Drove standard split spoon - 140 lb hammer 120/.5 80/.2
				RD	
175					
180					
					Hard, slow drilling in very dense sand.
185					
190					
195					
200					

SHEET 4 OF 6

EARTH SCIENCES ASSOCIATES
DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-1
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
200	SP	170'-235 SAND: (contd)		RD	
205					
210					
215					
					4-7-72 4-10-72 Hole caved in to 30' depth. Cleaned out to bottom with tricone bit.
220					
		222'-235' Lenses of gravel; abundant black chert chips, 1/4" rounded gravel and sand in cuttings. rig chattering periodically on coarser gravels.			
225					
230					
235	SC-CL	235'-238' CLAYEY SAND: dark greenish gray (5GY4/1); 40-60% clay fines; fine-grained; cohesive. 237.8' lens of light olive brn clay.			softer drilling at 235', sandy clay in cuttings.
				PB 0.3/2.5	Began coring with Pitcher barrel.
	CL	238'-265.5' SILTY CLAYSTONE: dark gray (N3); abundant oyster shell fragments; thinly laminated; cross-bedded; very stiff.	J-23	PB 0.9/2.0	Pitcher tube full of caved sand, drilling mud Too thick to circulate through barrel and wash hole; Cleaned mud out of hole and recirculated clean water.
240			J-24	RD	
				PB 2.0/2.5	
			J-25		
245				PB 1.6/2.5	
				RD	
250					

SHEET 5 OF 6

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED HOLE NO. H-1
LOCATION GROUND SURFACE ELEV.
DRILLING CONTRACTOR LOGGED BY DEPTH TO GROUND WATER
TYPE OF RIG HOLE DIAMETER HAMMER WEIGHT AND FALL
SURFACE CONDITIONS WEATHER

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
250	CL	268-265.5 <u>SILTY CLAYSTONE</u> (cont'd)		RD	Drilling w/ Tricone bit
255					
260					
		265.5-268.5 <u>SAND</u>: dark gray (N3); very fine- to fine-grained; subangular, abundant dark minerals, micaceous; very dense; friable.			
265	SP		J-26	PB 0.5/2.5	Cored w/ Pitcher Barrel
			J-27	PB 0.4/1.0	Pitcher Barrel refusal in very dense sand.
270		B.H. 268.5'			Terminated hole at 268.5'
275					
280					
285					
290					
295					
300					

SHEET 6 OF 6

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT HUMBOLDT 1253 DATE DRILLED 4/11/72 HOLE NO. H-2

LOCATION ______ GROUND SURFACE ELEV. ______

DRILLING CONTRACTOR J.N. PITCHER CO. LOGGED BY RCH DEPTH TO GROUND WATER UNDET.

TYPE OF RIG FAILING 750 HOLE DIAMETER NX HAMMER WEIGHT AND FALL ______

SURFACE CONDITIONS FLAT-GRASSY-WET WEATHER RAINING

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
0	CL	0.0-7.5 SILTY CLAY: olive brown; laminated with decayed organic laminations.		AD	Augered to 6', installed 6' of 5½" surface casing.
5				RD	Cleaned out with Tricone bit to 7', began coring with Pitcher barrel.
	CL	7.5-13.0 SILTY CLAY: dark greenish gray (5GY4/1); mottled with olive brown; contains roots and decayed organic matter; fissured; no apparent bedding; firm to stiff.	J-1	PB 2.5/2.5	Recovery ratio in mode col.
10				PB 2.0/2.5	
	SC-SM	11.0-13.0 Lens of silty to clayey sand; dark greenish gray w/ oxidized layers; roots		PB 2.5/2.5	
	CL		J-2		
15		13.0-28.7 SILTY CLAY: medium bluish gray mottled w olive gray; firm to soft; moist; roots and decayed organic fibers; slight trace of bedding; most organic fibers oriented vertically		PB 2.2/2.5	
			J-3	PB 1.4/2.5	
20				PB 1.8/2.5	
		24.0 grades to sandy silty clay.		PB 2.5/2.5	
25	CL CL	25.0 silty clay, beoming stiff		PB 2.5/2.5	
		28.5 thin lenses of clayey sand		PB 2.5/2.5	
	SM	28.7-30.5 SILTY SAND: moderate olive brown mottled with orange brown; laminated; very fine- to fine-grained; deeply oxidized; dense.	J-4		
30				PB 2.0/2.5	
	SP		J-5		
	SC SP	30.5-32.6 SAND: moderate yellowish brown mottled with olive; fine grained. thin sub-horizontal oxidized lenses; slightly cohesive.		PB 2.5/2.5	
	CL	32.6-38.7 SILTY CLAY: light olive brn (5Y5/6) mottled with greenish gray; orange laminae; same as interval 13-28'; very stiff.			
35				PB 2.3/2.5	
				PB 2.0/2.5	
	SP-SM	37.0' thin sand laminae			
40	SP	38.7'-40.0' SILTY SAND: olive brn with orange oxidized laminae; v. fine grained.		PB 2.2/2.5	
			J-6		
		40.0-50.0' SAND: orange brown w/ red brn zones; fine- to coarse-grained; fine gravelly lenses. non cohesive.		PB 2.0/2.5	
45	SM-SP	44.0 Lens of fine silty sand w/ scattered rounded fine gravel and occasional coarse rounded chert gravel.	J-7	PB 0.8/2.5	Poor recovery in sand and gravel. Drilled with tricone to 50'. Terminated hole at 50'.
				RD	
50	SC SP	B.H. 50'			

SHEET 1 OF 1

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT HUMBOLDT 1253 DATE DRILLED 4/11 - 4/13/72 HOLE NO. H-3
LOCATION ____ GROUND SURFACE ELEV. ____
DRILLING CONTRACTOR J.N. PITCHER CO LOGGED BY RCH DEPTH TO GROUND WATER UNDETERMINED
TYPE OF RIG FAILING 750 HOLE DIAMETER NX HAMMER WEIGHT AND FALL ____
SURFACE CONDITIONS WET - ROCKY FILL WEATHER RAINING - SCAT. CLDS

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
0		0.0-7.0 FILL: sand with cobble to boulder size riprap		AD	Augered to 3', refusal on rocks. Drilled through fill with 6" Tricone bit, lost all circulation at 4'. Set 5½" surface casing to 10'. Began drilling, lost circulation again, drove casing to 13'.
5	FILL			RD	
	SP	7.0'-139' SAND: moderate yellowish brown (10YR5/4) with lenses of moderate brown (5YR4/4); thin- to thick-bedded; fine- to medium-grained with lenses of coarse-grained and fine rounded gravel; bedding ~ horizontal			
10					4/11/72 4/12/72
15					
	f cs f	gravel lenses generally thin (0.1'-0.5') consisting of ¼"-½" well rounded red, black and green chert, some white qtz.	J-1	PB 2.5/2.5	Began coring with Pitcher Barrel Recovery ratio in mode column
20	cs			PB 2.0/2.5	
	c cs f cs f cs f		J-2	PB 2.4/2.5	
25				PB 2.0/2.5	
				PB 1.1/2.5	
	f f			PB 1.7/2.5	
30	cs f	bedding dips ~15°	J-3	PB 1.7/2.5	
	cs			PB 1.4/2.5	
35	f			PB 1.0/2.5	
	f			PB 0.9/2.5	
40	f	fine sand grading to light olive gray (5Y4/2) with irregular orange oxidized zones		PB 0.4/2.5	
	f			PB 1.2/2.5	
45	c f f cs	sand bedding dipping ~15°-20° crossbedding?		PB 1.8/2.5	
	c cs			PB 1.1/2.5	
50					

SHEET 1 OF 3

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-3
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.		FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
50	f	SP	7.0-139' <u>SAND</u> (cont'd)		PB 1.4/2.5	
	f				PB 0.8/2.5	
55	f			J-4	PB 0.8/2.5	
	cs 000 cs	000			PB 1.2/2.5	
60	f f				PB 1.6/2.5	
	cs				PB 1.3/2.5	
65	000 cs	000			PB 0.7/2.5	
	0f00	0000	sand light olive gray (5Y4/2) with little oxide staining	J-5	PB 1.4/2.5	
70	cs 000	GP-SP 000	70.0-75.5 Lens of coarse to very coarse sand with rounded pebble gravel. Coarse rounded gravel up to 2" at 72'		PB 1.6/2.5	
	cs				PB 0.0/2.5	Sample fell out of tube at top of hole.
75	f	SP	75.5' fine-grained sand		PB 1.1/2.5	
	000	0000			PB 1.0/2.5	
80	f cs	CL	81.5'-81.6 ± 81.8-82.0' Lenses of silty clay moderate yellowish brown; with ½" lens of blue clayey sand beneath upper clay lens.	J-6	PB 2.0/2.5	
	f	SP GP	84' Lens of fine- to medium rounded gravel.		PB 1.5/2.5	
85					PB 0.0/2.5	Tube crushed in by rock in side of hole, no recovery 4-12
	?	? SP			RD	4-13 Began drilling w/ Tricone bit.
90						
95			97-98 ± 99-100 gravelly lenses			
	00	000				
100	000	000				

SHEET 2 OF 3

EARTH SCIENCES ASSOCIATES
DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-3
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.		FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
100		SP	7.0'-139' SAND (Contd)		RD	
105						
			Thin lenses of "blue sand" in olive brn sand.			
110						
	o o	o o o				
115						
	o o o	o o				
120			120' becoming mostly blue sand			
125	○	○	125' oyster shell fragments in v.f. blue sand, no trace of clay.	J-7 cuttings		
130						
	o o o	o o o	132 gravel lens			
135						
	o o	o o				Terminated hole at 139' 4/13/72
140			B. H. 139'			
145						
150						

SHEET 3 OF 3

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT HUMBOLDT 1253 DATE DRILLED 4/13/72 HOLE NO. H-4
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR J.N. PITCHER Co. LOGGED BY RCH DEPTH TO GROUND WATER UNDET.
TYPE OF RIG FAILING 750 HOLE DIAMETER NX HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.		FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
0		SP	0.0 – 13.0 FILL & SLOPEWASH: moderate brn (5YR 4/4) to dark yellowish brn (10YR 4/2); mostly clean fine-grained sand with occasional gravel and chunks of blue clay; compact to dense; damp to moist.		AD	Augered to 11'. Drove 5½" casing to 13'.
5						
10						Drilled with Tricone bit to 14'.
					RD	
		CL	13.0'–15.7' SILTY CLAYSTONE: med. dark gray (N4) grading to light olive gray (5Y 5/2); laminated, bedding dips 12°; contains lens of olive brn sand.		PB 2.5/2.5	Began coring with Pitcher Barrel. Recovery ratio in mode column.
15		SP		J-1		
			15.7- SAND: mod. yellowish brn. (10YR 5/4) generally fine-grained with lenses of coarse-grained; scattered rounded pebbles; very dense, partly cohesive.		PB 2.4/2.5	
20					PB 2.5/2.5	
					PB 2.5/2.5	
25	f	SP	24.8 thin bedded very fine sand; light olive gray (5Y 5/2) mottled with mod. brn (5YR 4/4); bedding dips 18°	J-2	PB 1.9/2.5	
					PB 2.3/2.5	
	cs	SP	28.1 coarse pebbly sand			
30	f	SP	29.0 fine sand, no pebbles		PB 0.5/2.5	
				J-3	PB 1.8/2.5	
35					PB 1.9/2.5	
	cs		35.5' Coarse-grained pebbly sand; moderate brn (5YR 4/4)			
				J-4	PB 2.2/2.5	
40					PB 2.3/2.5	
	f cs f		42.2 fine-grained, few scattered pebbles		PB 2.2/2.5	
45					PB 0.6/2.5	Loose fine sand washing from front of bit
	f				PB 1.2/2.5	
50			pebbly at 50'		PB	

SHEET 1 OF 2

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-4
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.		FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
50	f	SP	15.7-54.0 SAND: (cont'd)		cont'd 1.0/2.5	
	f-cs			J-5	PB 1.7/2.5	Terminated hole at 54' 4/13/72
55						
60						
65						
70						

SHEET 2 OF 2

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT HUMBOLDT 1253 DATE DRILLED 4/17 HOLE NO. H-5
.OCATION * GROUND SURFACE ELEV. 5'±
DRILLING CONTRACTOR J.N. PITCHER CO. LOGGED BY RCH DEPTH TO GROUND WATER 5'
TYPE OF RIG FAILING 750 HOLE DIAMETER NX HAMMER WEIGHT AND FALL —
SURFACE CONDITIONS GRASSY SAND DUNES WEATHER CLEAR - COLD - WINDY
* 100' NW OF FENCE ON BUHNE DR.; 20' SW OF LINE ON EXTENSION OF SW SIDE OF COD ST.

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
0	SP	0.0–13.0 <u>DUNE SAND</u>: olive gray (5Y4/1); fine-grained; scattered shell fragments; loose to dense; moist to wet.		AD	AUGERED TO 5½'; set 5½" casing to 5½', began rotary drilling with tricone bit.
5				RD	
10					Drilled to 14', set casing to 13'.
	CL	13.0 – 23.5 <u>SILTY CLAY</u>: med. dark gray (N4); low plasticity; slow dilatancy; scattered oyster shell fragments; soft to firm; wet. (Recent Bay mud ?)	J-1	PB 2.2/2.5	Began coring with Pitcher Barrel. Recovery ratio in mode column.
15			J-2	PB 2.5/2.5	
20	(SC)	19'-23.5' Lenses of clayey sand and peaty organic fibers; horizontally bedded.	J-3	PB 2.3/2.5	
				PB 2.3/2.5	
	SP	23.5 – 31.5 <u>SAND</u>: med. dark gray; very fine- to fine-grained; scattered shell fragments and organic fibers; compact to dense; horizontal bedding.	J-4	PB 2.4/2.5	
25	CL SP SP			PB 2.4/2.5	
30	CL SP			PB 2.5/2.5	
	CL	31.5 - <u>SILTY CLAY</u>: same as 13.0 - 23.5; soft to firm.		PB 2.5/2.5	
35				PB 2.5/2.5	
				PB 1.8/2.5	
40				PB 2.4/2.5	
	SM-ML	41.0' Lens of very fine silty sand; shell and organic fragments.	J-5	PB 2.2/2.5	
45	CL			PB 1.5/2.5	
				PB 2.5/2.5	
50				PB	

SHEET 1 OF 5

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-5
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
50	CL-ML	31.5-65.2 <u>SILTY CLAY</u>: (contd) 50' gradations to clayey silt.		2.5/2.5	
			J-6	PB 2.5/2.5	
55		55-56 thin (½") horizontal clay lenses.		PB 2.5/2.5	
				PB 2.2/2.5	
60		59- thin (⅛"-½") interbeds of clay and very fine silty sand; horizontal bedding.		PB 2.2/2.5	
				PB 2.0/2.5	
65	SP	63.2-65.2 Lens of pebbly sand, abundant shell frags.	J-7	PB 2.0/2.5	
	SP CL SP	65.2'-75.0' <u>SAND</u>: med dark gray; fine-grained; subrounded to rounded; occasional rounded pebbles; scattered shell frags.; dense		PB 1.5/2.5	
70	ML SP			PB 2.0/2.5	
			J-8	PB 1.9/2.5	
75	CL	75.0-224' <u>SILTY CLAY</u>: same as 31.5-65.2; soft to firm.		PB 2.4/2.5	
				PB 2.4/2.5	
80				PB 1.4/2.5	
			J-9	PB 2.8/2.5	
85				PB 2.4/2.5	
				PB 2.5/2.5	
90				PB 2.5/2.5	
				PB 2.5/2.5	4/17
95		95' becoming firm to stiff.		PB 1.4/2.5	
				PB 2.0/2.5	
100				PB	

SHEET 2 OF 5

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ____ HOLE NO. H-5
LOCATION ____ GROUND SURFACE ELEV. ____
DRILLING CONTRACTOR ____ LOGGED BY ____ DEPTH TO GROUND WATER ____
TYPE OF RIG ____ HOLE DIAMETER ____ HAMMER WEIGHT AND FALL ____
SURFACE CONDITIONS ____ WEATHER ____

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
100	CL	75-224' SILTY CLAY (cont'd)	J-10	2.7/2.5	
				PB 2.5/2.5	
105				PB 2.5/2.5	
				PB 2.5/2.5	
110				PB 2.5/2.5	
				PB 2.4/2.5	
115				PB 2.5/2.5	
		no sand lenses, distinct bedding or oxidation.		PB 2.5/2.5	
120				PB 2.5/2.5	
				PB 2.5/2.5	
125				PB 2.5/2.5	
				PB 2.5/2.5	
130				PB 2.3/2.5	
				PB 2.5/2.5	
135				PB 2.5/2.5	
		137' thin laminations dipping 14°	J-11	PB 2.5/2.5	
140	SP CL	139.3 Lens of fine sand with shell fragments 140' Thin laminations and irregular pockets of fine sand.		PB 2.4/2.5	
				PB 2.5/2.5	
145				PB 2.5/2.5	
				PB 2.5/2.5	
150				PB	

SHEET 3 OF 5

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED HOLE NO. H-5
LOCATION GROUND SURFACE ELEV.
DRILLING CONTRACTOR LOGGED BY DEPTH TO GROUND WATER
TYPE OF RIG HOLE DIAMETER HAMMER WEIGHT AND FALL
SURFACE CONDITIONS WEATHER

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
150	CL	75-224' <u>SILTY CLAY</u>: (cont'd)		2.5/2.5 PB 2.5/2.5 PB 2.5/2.5	
155				RD	Rotary drilled with Tricone bit.
160					
165					
170					
175					
180					
185					
190					
195					
200					

SHEET 4 OF 5

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-5
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
200	CL	75'–224' SILTY CLAY (cont'd)		RD	
205					
210					
215					
220					
225		B.H. 224'			
230					
235					
240					
245					
250					

SHEET 5 OF 5

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT HUMBOLDT 1253 DATE DRILLED 4/19- HOLE NO. H-6

.OCATION 140' NW of ℄ BROADWAY ON PURDUE GROUND SURFACE ELEV. ______

DRILLING CONTRACTOR J.N. PITCHER Co LOGGED BY RCH DEPTH TO GROUND WATER ______

TYPE OF RIG FAILING 750 HOLE DIAMETER NX HAMMER WEIGHT AND FALL ______

SURFACE CONDITIONS DIRT ROAD WEATHER CLEAR - WARM

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
0	FILL	0.0 - 3.5 ROAD FILL: mod. brn. gravelly silty sand.		AD	Augered to 4', pushed 5¼" casing to 10' in soft clay.
	CL	3.5-20.5 SILTY CLAY: blk on surface grading to dark gray (N3); low to medium plasticity; abundant organic fibers and peaty layers; soft; moist.			
5				RD	Began drilling with Tricone bit.
10					
		thin (¼"-½") lenses, horizontal; scattered small shell fragments.	J-1	PB 2.4/2.5	Coring intermittently with Pitcher Barrel.
15				RD	
20	SC-SM	20.5 - 29.5 SILTY CLAYEY SAND: pebbly; med. bluish gray (5B 5/1); grades clayey to silty fines; fine-grained with ¼" - ½" rounded pebbles, mostly chert; cohesive; dense	J-2	PB 2.5/2.5	
				RD	
25	SC-SM				
	SC-SM	25-27 color light olive brn, back to bluish gray at 27.			
30	CH	29.5 - 35.0 FAT CLAY: dark greenish gray (5GY4/1) mottled with mod. brn (5YR 4/4); high plasticity; scattered small organic fibers; stiff; sticky; moist	J-3	PB 2.5/2.5	
				RD	
35	CL	35.0 - 138.3 SILTY CLAY: dark greenish gray (5G 4/1); scattered organic fibers, laminated sporedically; thin (<1") lenses of fine sand; sand lenses dip variably; laminations horizontal; stiff to very stiff.			
40			J-4	PB 2.3/2.5	
				RD	
45					
50					

SHEET 1 OF 8

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-6
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
50	CL	35.0-138.3 <u>SILTY CLAY</u>: (cont'd) bedding dips 10° ; no apparent shell fragments.	J-5	PB 2.2/2.5	
				RD	
55					
60		Color grading to olive gray (5Y4/1) bedding Dips 10°-12°; some beds contorted		PB 2.5/2.5	
	SC	63'-64 clayey fine sand w/ decomposed wood fragments	J-6	RD	
65	CL				
70				PB 2.5/2.5	
				RD	
75					
80				PB 2.4/2.5	
				RD	
85					
90				PE 2.2/2.5	
		Thin sand seams in clay	J-7		
				RD	
95					
100					

SHEET 2 OF 8

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-6
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
100	CL	35.0'-138.3' SILTY CLAY: (cont'd)		RD	
105					
110					
115					
		color grading to dark gray (N3)		PB 2.3/2.5	
			J-8		
120				RD	
125					
130		131.5-132 wood fragment			131.5 bit advance slowed by wood fragment, firmer drilling below 132'.
135					
	SP	138.3'-190 SAND: greenish black (5G 2/1); clean; fine- to medium-grained; subangular to subrounded, mostly qtz, chert & dark minerals; dense.	J-9	PB 1.3/2.5	
140				RD	
		Contains pebbly and gravelly lenses; mostly chert.			
145					
	○○○ ○○○	large gravel at 148'			
150					

SHEET 3 OF 8

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-6

LOCATION ______ GROUND SURFACE ELEV. ______

DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______

TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______

SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
150	SP	138.3 – 190 SAND: (cont'd)		RD	
155					
				PB 1.5/1.5	Refusal on gravel
160				RD	
165					
	ooo ooo	168-190 gravel lenses			
170	oo oo				
175					
	oo ooo				
180					
	oo ooo				
185	oo oo				
	ooo ooo				
	ooo oo				
190	CL	190-203 SILTY CLAY: med. dark gray (N4); thin horizontal bedding; hard.			
				PB 2.0/2.5	
			J-10		4/19
195				RD	4/20
200					

SHEET 4 OF 8

EARTH SCIENCES ASSOCIATES
DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-6
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
200	CL	190-203 <u>SILTY CLAY</u>: (cont'd)		RD	
	GP	203-247.5 <u>PEBBLY SAND</u>: dark greenish gray (5GY 4/1); fine- to coarse-grained; 1/4"-1/2" rounded qtz & chert pebbles; lenses of coarser gravel; very dense. 203-204.5 Lens of coarse gravel with shell fragments.			
205	SP				
210					
	(GP)		J-11	PB 0.7/0.9	Pitcher Barrel refusal in pebbly sand.
215				RD	
	SP				
220					
225					
230					
235					
240					
245		pebbly sand, small wood fragments, very dense.	J-12	DR	Drove standard split spoon with 300 lb sampler jars 15" drop 150/.5 100/.2
				RD	
	CL	247.5-260 <u>SILTY CLAY</u>:			
250					

SHEET 5 OF 8

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-6
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
250	CL	247.5-260 SILTY CLAY: (cont'd) dark gray (N3); abundant oyster shell fragments; hard.		RD	
255			J-13	PB 1.4/2.5 RD	
260	SP	260-296.5 SAND: gray; fine- to medium grained with pebbly lenses.			
265	(CL)	266-272 lenses of gray clay			
270					
275	SP	277-296.5 fine- to very fine-grained gray sand; very dense			
280			J-14	PB 0.8/0.8 RD	Pitcher barrel refusal in dense sand
285					
290					
295	CL	296.5-304 SILTY CLAY: dark gray (N3); few shell fragments			
300					

SHEET 6 OF 8

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ____ HOLE NO. H-6
LOCATION ____ GROUND SURFACE ELEV. ____
DRILLING CONTRACTOR ____ LOGGED BY ____ DEPTH TO GROUND WATER ____
TYPE OF RIG ____ HOLE DIAMETER ____ HAMMER WEIGHT AND FALL ____
SURFACE CONDITIONS ____ WEATHER ____

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
300	CL	296.5-304 <u>SILTY CLAY</u> (contd)		RD	
	SP	304-307 <u>SAND</u>: fine-grained with few thin pebbly lenses			
305					
	CL	307-339.5 <u>SILTY CLAY</u>: dark gray (N3); scattered shell fragments; horizontal bedding; hard			Hole squeezing in clay section 296-304.
310				PB 1.2/2.5	
			J-15		4/20
				RD	4/21 Approx. 100' of cave or squeezed hole overnight.
315					
320	CL	320-332 sandy clay: dark greenish gray (5GY 4/1); with lenses of sand and gravelly sand.			
	SP				
	CL				
325					
	GP				
	CL				
330					
	CL	332 silty clay; dark gray			
335					
	ML	337.5 grades to dark gray silt			
340	SC-CL	339.5 - <u>CLAYEY SAND</u> with gradations to <u>SANDY CLAY</u>: greenish black (5GY 2/1); very fine- to fine-grained; very dense and cohesive; contact curved, with wood fragment at contact.	J-16	PB 1.5/1.5	Pulled Rods - took 20min Pitcher Barrel stopped at 160' by squeezing hole, had to go back in and ream out before sampling
				RD	
345		contains lenses of fine clean sand.			
350					

SHEET 7 OF 8

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-6

LOCATION ______ GROUND SURFACE ELEV. ______

DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______

TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______

SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
350	SC- SP	339.5 - <u>CLAYEY SAND</u> (contd) 350 gradations to clean sand		RD	
355					
360					
365					
		368 Lenses of coarse gravel			
370					
375					
380					
385					
		387-400 Gravelly Lenses, chert chips and fine wood fibers in cuttings.			
390					
395					
400					

SHEET 8 OF 8

4/21/72

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT HUMBOLDT 1253 DATE DRILLED 4/25/72 HOLE NO. H-7
LOCATION SOUTH JETTY SPIT GROUND SURFACE ELEV.
DRILLING CONTRACTOR J.N. PITCHER CO LOGGED BY RCH DEPTH TO GROUND WATER 4'
TYPE OF RIG FAILING 750 HOLE DIAMETER NX HAMMER WEIGHT AND FALL
SURFACE CONDITIONS SAND DUNES WEATHER SCATTERED SHOWERS

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
0	SP	0.0 – 39' DUNE SAND: fine-grained; rounded; well sorted; loose; wet at 4'.		AD	Augered to 6', set 5½" casing to 6', set up mud tub and began rotary drilling.
5					
				RD	Drilled with Tricone to 45'; reamed hole with larger bit; set casing to 45'. Tricone jetting through dune sand.
10					
15					
20					
25					
30					
35					
	CL (SP)	39.0 – 76.2 INTERBEDDED SILTY CLAY and FINE SAND: dark gray (N3); thinly bedded clay with peaty seams; stiff; very fine- to fine-grained sand, dense; clay beds and contact at 46' dip 10°.			
40					
45			J-1	PB	
	SP		J-2	1.5/2.5	
				RD	
50					

SHEET 1 OF 4

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ____ HOLE NO. H-7
LOCATION ____ GROUND SURFACE ELEV. ____
DRILLING CONTRACTOR ____ LOGGED BY ____ DEPTH TO GROUND WATER ____
TYPE OF RIG ____ HOLE DIAMETER ____ HAMMER WEIGHT AND FALL ____
SURFACE CONDITIONS ____ WEATHER ____

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
50	SP CL	39.0 – 76.2 <u>INTERBEDDED CLAY AND SAND</u> (Cont'd)		RD	
			J-3	PB 2.2/2.5	
55		thin (½"-1") lenses of very fine sand.		PB 2.1/2.5	
		dip ~ 6°		PB 2.5/2.5	
60				PB 2.3/2.5	
		scattered very fine shell fragments	J-4	PB 2.5/2.5	
65	SP SP (CL)	64.5 sand w/ abundant shell and wood fragments.	J-5	PB 2.5/2.5	
	CL	clay w/ sand seams		PB 2.4/2.5	
70				PB 2.5/2.5	
				PB 2.5/2.5	
75	SP	74.2 sand w/ abundant shells & thin clay seams	J-6	PB 2.3/2.5	
	SP	76.2 - 124.0' <u>SAND</u>: dark gray (N3); clean; fine- to medium-grained; sub-angular to subrounded; dense; homogeneous; no trace bedding		PB 1.8/2.5	
80				PB 1.8/2.5	
				RD	
85					
90		abundant wood fragments.	J-7 cuttings		
		no gravel			
95					
100					

SHEET 2 OF 4

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ________ HOLE NO. H-7
LOCATION ________ GROUND SURFACE ELEV. ________
DRILLING CONTRACTOR ________ LOGGED BY ________ DEPTH TO GROUND WATER ________
TYPE OF RIG ________ HOLE DIAMETER ________ HAMMER WEIGHT AND FALL ________
SURFACE CONDITIONS ________ WEATHER ________

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
100	SP	76.2-124' <u>SAND</u> (cont'd)		RD	
		clean, no gravel			
105					
110					
115					
120					
	SP (GP)	124-182' <u>PEBBLY SAND</u>: mostly small pebbles and chips in cuttings, lenses of coarser gravel as evidenced by rig chattering.			
125					
130					
135					
	SP	138-147 clean sand - no gravel			
140					
145					
	SP (GP)	147-158 gravelly			
150					

SHEET 3 OF 4

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-7
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
150	SP (GW)	124'-182' <u>PEBBLY SAND</u> (cont'd)		RD	
155					
	SP	158'-173' clean sand, no gravel.			
160					
165					
170					
	SP- (SC)	173-182 clean sand w/ lenses of very fine clayey sand, dark gray.			
175					
180					
		B.H. 182.0'			Terminated hole at 182' 4/25/72
185					
190					
195					
200					

SHEET 4 OF 4

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT Humboldt 1253 DATE DRILLED 4/26/72 HOLE NO. H-8
LOCATION 1000'± N70E of H-7 GROUND SURFACE ELEV.
DRILLING CONTRACTOR J.N. Pitcher Co. LOGGED BY RCN DEPTH TO GROUND WATER 4'
TYPE OF RIG Failing 750 HOLE DIAMETER NX HAMMER WEIGHT AND FALL
SURFACE CONDITIONS Sand Dunes WEATHER Clear - scat. clds

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
0	SP	0.0'–24.0' DUNE SAND		AD	Augered to 5'; set 5½" casing to 6'.
5				RD	Drilled with Tricone using heavy mud to 25'. Reamed hole and set casing to 26'.
10					
15					
20					
	CL	24.0 – 36.0 SILTY CLAY: olive blk 5Y(2/1); gradations to clayey silt; thin sand seams; strong odor H_2S; scattered shell fragments; soft to firm. peaty lenses horizontal			
25					
			J-1	PB 2.5/2.5	
30				PB 2.4/2.5	
				PB 2.1/2.2	
35				PB 2.4/2.5	
	SP	36.0 – 40.0 SAND: dark gray (N3); fine-grained with lenses of medium grained; lenses of shell concentrations and scattered fragments throughout; dense.	J-2	PB 2.5/2.5	
40	CL	40.0' SILTY CLAY: same as 24'-36'	J-3	PB 2.5/2.5	
				PB 2.5/2.5	
45		bedding ranges 0°–6° in one sample		PB 2.3/2.5	
				PB 2.4/2.5	
50					

SHEET 1 OF 4

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-8

LOCATION ______ GROUND SURFACE ELEV. ______

DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______

TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______

SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
50	CL	40.0–76.0' SILTY CLAY: (cont'd)		PB 2.0/2.5	
			J-4	PB 2.5/2.5	
55				PB 1.9/2.5	
	ML CL	gradations to silt		PB 2.5/2.5	
60		1/4" sand seams		PB 2.5/2.5	
			J-5		
				PB 2.5/2.5	
	ML CL				
65				RD	
70					
75					
	SP	76.0' – SAND: dark gray; clean; very fine- to fine-grained; lenses of shell concentrations; no gravel.			
80					
85					
			J-6	PB 1.5/2.5	
90				RD	
95					
100					

SHEET 2 OF 4

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-8

LOCATION ______ GROUND SURFACE ELEV. ______

DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______

TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______

SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
100	SP	76.0' <u>SAND</u>: (cont'd)		RD	
105					
110					
115					
120					
125					
	GP	127 gravel lens			
130					
135					
140					
145					
150					

SHEET 3 OF 4

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ____ HOLE NO. H-8
LOCATION ____ GROUND SURFACE ELEV. ____
DRILLING CONTRACTOR ____ LOGGED BY ____ DEPTH TO GROUND WATER ____
TYPE OF RIG ____ HOLE DIAMETER ____ HAMMER WEIGHT AND FALL ____
SURFACE CONDITIONS ____ WEATHER ____

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
150	SP	76.0' – 182' <u>SAND</u> (cont'd)		RD	
155	SP (GP)	155 - 161 pebbly sand			
160					
	SP	161-171 clean sand			
165					
170					
	SP (GP)	171-173 pebbly sand			
	SP				
175					
	SP (CL)	176-182 fine sand with lenses of silty clay, dark gray.			
180					Terminated hole at 182' 4/25/72
		B.H. 182.0'			
185					
190					
195					
200					

SHEET 4 OF 4

EARTH SCIENCES ASSOCIATES
DRILLING AND SAMPLING LOG

PROJECT Humboldt 1253 DATE DRILLED 4/26/72 HOLE NO. H-9
LOCATION Bunne Dr., 75' E of E. side Herring St. GROUND SURFACE ELEV. 12'±
DRILLING CONTRACTOR J.N. Pitcher Co. LOGGED BY RCH DEPTH TO GROUND WATER 6.5'
TYPE OF RIG Failing 750 HOLE DIAMETER NX HAMMER WEIGHT AND FALL
SURFACE CONDITIONS Hard packed sand-gravel road shoulder WEATHER warm clear.

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
0	SP	0.0-10.0 DUNE SAND: gravelly near surface, wet at 6.5'.		AD	Augered to 10'; set $5\frac{1}{2}$" casing to 12'.
5					
					Cleaned out w/ Tricone bit
10	CL	10.0-33.5' SILTY CLAY: olive gray (5Y 4/1); strong odor H_2S; abundant shells; thin sand seams; soft to firm.		RD	
				PB 2.5/2.5	Cored with Pitcher barrel
			J-1		
15		scattered small decomposed wood fragments			
				PB 2.2/2.5	
				PB 1.8/2.5	
			J-2		
20				PB 2.3/2.5	
				PB 2.2/2.5	
25			J-3	RD	
30					
	GP SP	33.5-52.5 SAND: dark gray; fine-grained; scattered rounded pebbles of chert and qtz; lenses of gravelly sand; dense.			
35					
				PB 1.8/2.5	
			J-4		
40				RD	
45	GP-SP	44-50 gravelly sand, gravel up to 4"			
50					

SHEET 1 OF 5

EARTH SCIENCES ASSOCIATES
DRILLING AND SAMPLING LOG

PROJECT HUMBOLDT 1253 DATE DRILLED _____ HOLE NO. H-9
LOCATION _____ GROUND SURFACE ELEV. _____
DRILLING CONTRACTOR _____ LOGGED BY _____ DEPTH TO GROUND WATER _____
TYPE OF RIG _____ HOLE DIAMETER _____ HAMMER WEIGHT AND FALL _____
SURFACE CONDITIONS _____ WEATHER _____

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
50	SP	33.5-52.5 SAND (cont'd)		RD	
	SP-SM	52.5'-117.0' SANDSTONE: dark yellowish brown (10YR 4/2) with some mod. brown (5YR 4/4) lenses; thin to thick bedded; attitude obscure; crossbedding; mostly fine-grained w/ lenses of coarse and pebbly lenses; very dense.			
55				PB 0.3/2.5	gravel cave crimped end of tube - poor recovery.
			J-5	PB 0.9/1.5	Pitcher barrel refusal at 58'.
			J-6	PB 1.5/2.5	
60				RD	
65					
70		71'-95' gravelly lenses			
75					
80					
85					
90					
95					
100					

SHEET 2 OF 6

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ____ HOLE NO. H-9
LOCATION ____ GROUND SURFACE ELEV. ____
DRILLING CONTRACTOR ____ LOGGED BY ____ DEPTH TO GROUND WATER ____
TYPE OF RIG ____ HOLE DIAMETER ____ HAMMER WEIGHT AND FALL ____
SURFACE CONDITIONS ____ WEATHER ____

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
100	SP	52.5 – 117.0' *SANDSTONE* (contd)		RD	
105	(GP)				
110					
115					
	CL	117.0 – 127.0' *CLAYSTONE*: dark gray (N3); very stiff to hard. Indurated; apparent dip of bedding 20°; no apparent shells.	S-7	PB 0.7/1.5 PB 0.2/1.5 RD	Too much sand in drilling mud to circulate through Pitcher barrel.
120					
125					
	SP	127.0' – *PEBBLY SAND*: light olive brown; gravel lenses.			
130					
135					
140					
145					
150					

SHEET 3 OF 5

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ____ HOLE NO. H-9
LOCATION ____ GROUND SURFACE ELEV. ____
DRILLING CONTRACTOR ____ LOGGED BY ____ DEPTH TO GROUND WATER ____
TYPE OF RIG ____ HOLE DIAMETER ____ HAMMER WEIGHT AND FALL ____
SURFACE CONDITIONS ____ WEATHER ____

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
150	SP	127'-255' PEBBLY SAND (cont'd)		RD	
155					
160					
		164 coarse gravel			
165	SP				
170					
175					
	SP				
190	SP				
195					
	GP	197-203 Gravelly sand.			
200					
					4/26/72
					4/27/72 Hole caved in overnight reamed out.
205					
210					

SHEET 4 OF 6

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ______ HOLE NO. H-9
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
210	SP	127'-255' <u>PEBBLY SAND</u> (cont'd)		RD	
215					
	SC-SM	217-221 blue sand w/ lenses of fine clayey sand and sandy clay			
220					
	SP (GP)	221-226 gravelly lenses			
225					
	SP (CL)	226-239 Sand with 6" lenses of blue sandy clay and thin gravelly lenses.			
230					
235					
	SP-GP	239-255 Gravelly sand			
240					
245					
250					
255		B.H. 255			Terminated hole 4/27/72
260					

SHEET 5 OF 5

EARTH SCIENCES ASSOCIATES
DRILLING AND SAMPLING LOG

PROJECT HUMBOLDT 1253 DATE DRILLED 4/27-28/72 HOLE NO. H-10
LOCATION HUMBOLDT HILL GROUND SURFACE ELEV.
DRILLING CONTRACTOR J.N. PITCHER CO LOGGED BY RCH DEPTH TO GROUND WATER
TYPE OF RIG FAILING 750 HOLE DIAMETER NX HAMMER WEIGHT AND FALL
SURFACE CONDITIONS CLEARED LOT - SANDY CLAY WEATHER OVERCAST

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
0	CL	0.0 – 9.5 SANDY CLAY: mod. yellowish brown (10YR 5/4) mottled w/ orange and light gray; low plasticity; deeply weathered and oxidized; firm to stiff; moist.		AD	Augered to 5', set 5½" casing To 6'
5		Contains lenses of rounded chert & Qtz pebbles.		RD	Drilling w/ Tricone bit
10	SM-SP	9.5 - 42.5 PEBBLY SAND: mod. yellowish brn.; fines variable 0-20%, silty; fine- To coarse-grained, variable in lenses; lenses of rounded chert pebbles ¼"-¾"; dense.			
15					
	(CL)	Contains lenses of sandy clay			
20			J-1	PB 2.0/2.5	Cored w/ Pitcher Barrel
				RD	
25					
30					
35					
40					
	CL	42.5 - 105.0 SILTY CLAY: bluish gray (5B 6/1) w/ irregular brown oxide staining; very stiff to hard; abundant organic fibers and plant remains.	J-2	PB 1.5/2.5	
45				RD	
		48 grades To greenish black (5G 2/1); stiff to very stiff			
50					

SHEET 1 OF 5

EARTH SCIENCES ASSOCIATES
DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ________ HOLE NO. H-10
LOCATION ________ GROUND SURFACE ELEV. ________
DRILLING CONTRACTOR ________ LOGGED BY ________ DEPTH TO GROUND WATER ________
TYPE OF RIG ________ HOLE DIAMETER ________ HAMMER WEIGHT AND FALL ________
SURFACE CONDITIONS ________ WEATHER ________

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
50	CL	42.5 - 105.0' <u>SILTY CLAY</u>: (cont'd) thin (¼" - ½") seams of sand crossbedding varies 0°-20°		PB 2.2/2.5	
			J-3	PB 2.5/2.5	
55		55 grading to dark gray (N3)		RO	
60					
65					
70					
75					
			J-4	PB 1.2/2.5	
				RO	
80					
85					
90					4/27 4/28
95					
		dips variable - max dip 10°	J-5	PB 1.3/2.5	
100					

SHEET 2 OF 5

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ____ HOLE NO. H-10
LOCATION ____ GROUND SURFACE ELEV. ____
DRILLING CONTRACTOR ____ LOGGED BY ____ DEPTH TO GROUND WATER ____
TYPE OF RIG ____ HOLE DIAMETER ____ HAMMER WEIGHT AND FALL ____
SURFACE CONDITIONS ____ WEATHER ____

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
100	CL	42.5'-105.0' SILTY CLAY (cont'd)		RD	
105	SP	105.0-137.0 SAND: mod. yellowish brn to mod. brn; grades from fine- to coarse-grained with lenses of rounded chert and qtz pebbles and gravel; dense.			
110					
115					
120			J-6	PB 2.0/2.0	
				RD	
125		125-137 gravelly sand			
130					
135					
	CL	137.0-190 SILTY CLAY: dark gray (N3); contains concentrations of oyster shells; thin silt lenses; very stiff; irregular contorted bedding			
140			J-7	PB 1.4/2.5	
				RD	
145					
150					

SHEET 3 OF 5

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED ____ HOLE NO. H-10

LOCATION ____ GROUND SURFACE ELEV. ____

DRILLING CONTRACTOR ____ LOGGED BY ____ DEPTH TO GROUND WATER ____

TYPE OF RIG ____ HOLE DIAMETER ____ HAMMER WEIGHT AND FALL ____

SURFACE CONDITIONS ____ WEATHER ____

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
150	CL	137.0 – 190.0 <u>SILTY CLAY</u>; (contd)		RD	
155					
160					
165					
170					
175					
180					
185					
190	SP (GP)	190-204.0' <u>GRAVELLY SAND</u>: bluish gray; contains wood fragments			
195					
		197- grades to med. brn.			
200					

SHEET 4 OF 5

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT 1253 DATE DRILLED HOLE NO. H-10

LOCATION GROUND SURFACE ELEV.

DRILLING CONTRACTOR LOGGED BY DEPTH TO GROUND WATER

TYPE OF RIG HOLE DIAMETER HAMMER WEIGHT AND FALL

SURFACE CONDITIONS WEATHER

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
200	SP (GP)	190.0 – 204.0 GRAVELLY SAND (cont'd)		RD	
205	CL	204.0 – 208.0 SILTY CLAY: dark gray (N3); contains fine wood fragments; very stiff.			
210	SP (CL)	208-224 GRAVELLY SAND: with lenses of dark gray clay.			
215					
220					Terminated hole 4/28/72
225		B.H. 224'			
230					
235					
240					
245					
250					

SHEET 5 OF 5

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

DRILLER = EARL REED,
OILER = MIKE WATSON

PROJECT HUMBOLDT 1253 DATE DRILLED 8 THRU — MAY, '72 HOLE NO. H-11

LOCATION INT HUMBOLDT HILL RD. & HILLCREST (NE COR.) GROUND SURFACE ELEV. ~320

DRILLING CONTRACTOR J.N. PITCHER CO. LOGGED BY EAN DEPTH TO GROUND WATER

TYPE OF RIG FAILING 750 HOLE DIAMETER 5" HAMMER WEIGHT AND FALL —

SURFACE CONDITIONS GRASSY GENTLY SLOPING PASTURE WEATHER CLEAR + WARM TO OVERCAST + CO

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
0	SM	0.0-2.0 SILTY SAND, DARK BROWN, DAMP, LOOSE, SLIGHTLY ORGANIC TOPSOIL		AD	AUGERED TO 4'; SET 6½' OF 5½" DIA CASING TO 5'
5	CL-SC SM-SC	2.0-17.5 SANDY CLAY GRADING TO CLAYEY SILTY SAND, MOTTLED LIGHT ORANGE BROWN & LIGHT BROWN, DAMP, FIRM-THEN MEDIUM DENSE; SILTY SANDY CLAY (~30% SAND) TO 7' THEN SLIGHTLY CLAYEY SILTY SAND; FINE-MEDIUM GRAINED SAND WITH A FEW WELL ROUNDED CHERT PEBBLES		RD	DRILLING WITH TRICONE BIT FROM 4'; STARTED [illegible] DRILLING @ 1400
10				PB 25/25	
			J-1	RD	
15					
20	SM + GM	17.5 - 55.0 INTERBEDDED SILTY SAND + SILTY SANDY GRAVEL, ORANGE BROWN, DENSE TO VERY DENSE, WELL ROUNDED CHERT (90% CHERT [illegible]) PEBBLES TO ¾" DIA. MAKE UP GRAVEL LAYERS, GRAVEL + SAND INTERBEDDED IN 1 TO 3' BED THICKNESS, SAND COARSE TO VERY COARSE GRAINED			BIT CHATTERING ON GRAVEL @ 17.5'
25					
30					
35		MORE SILTY FROM 34'-50', ORANGE BROWN MEDIUM - VERY COARSE GRAINED SAND + GRANULES WITH PEA GRAVEL INTERBEDS			
40					LOSING A LITTLE WATER ALL THE WAY DOWN; DRILLING RAPIDLY
45					
50					

SHEET 1 OF 9

EARTH SCIENCES ASSOCIATES
DRILLING AND SAMPLING LOG

PROJECT Humboldt 1253 DATE DRILLED ______ HOLE NO. H-11
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
50	SM + GM	INTERBEDDED SILTY SAND & GRAVEL (AT ABOUT; PEBBLES >90% CHERT, 5% ± A FEW OF WX GRANITICS		RD	
55	SM	55.0-115.0 ~~PEBBLY~~ SILTY TO SLIGHTLY SILTY SAND, YELLOW BROWN TO ORANGE BROWN, DENSE, INTERLAYERED FINE TO VERY COARSE GRAIN WITH SCATTERED PEA GRAVEL			
60					
65					
70					
75					BIT STILL CHATTERING ON GRAVEL STRINGERS EVERY FEW FEET TO 77
80					
85					
	SM-SW	LESS SILTY @ 77; PEBBLY SLIGHTLY SILTY SAND; MEDIUM GRAY BROWN, MEDIUM DENSE TO DENSE; INTERLAYERED FINE TO COARSE GRAINED, VERY FRIABLE, UNCEMENTED SAND WITH SCATTERED PEA GRAVEL IN THE COARSER GRAINED LAYERS; GRADES FROM FINE TO COARSE GRAINED -- NO SHARP CONTACTS, BED THICKNESS 4"-12"; SAND GRAINS ANGULAR, PEBBLES SUB-ROUNDED TO WELL ROUNDED -- TO ¾" DIA -- MAINLY CHERT	J-2	PB 19/2.0	
90					
95					
8 MAY 9 MAY					97 @ 1710 STARTED DRILLING FROM 97, 0770
100					

SHEET 2 OF 9

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT HUMBOLDT 1253 DATE DRILLED ______ HOLE NO. H-11
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
100	SM-SW	PEBBLY SLIGHTLY SILTY SAND; (AS ABOVE)		RD	
105					
					108' @ 0800
110					
	SW-SM	GRADING CLEANER -- MINOR SILT; ALSO LESS GRAVELLY - FEW GRAVEL STRINGERS			
115	SP + SW	115.0 - 131.0 CLEAN TO VERY SLIGHTLY SILTY SAND; MEDIUM GRAY BROWN, MEDIUM DENSE TO DENSE; INTERLAYERED MEDIUM GRAINED WELL SORTED SAND + MEDIUM TO COARSE GRAINED POORLY SORTED SAND WITH MINOR VERY THIN (1/16 - 1/8") SILTY CLAY INTERBEDS; DIP= 12°-15°, BREAKS TO BEDDING -- DARK MINERALS DEFINE BEDDING; VERY FRIABLE & TOTALLY UNCEMENTED; FEW CLAYEY SILT INTERBEDS			
120					
			J-3	PB 1.2/1.3	PITCHER BARREL SAMPLING @ 123 @ 0915
125				RD	RESUMED DRILLING @ 0945
130					130' @ 1005
	SM-SP	131.0 - 2885 SLIGHTLY SILTY TO CLEAN SAND; MEDIUM BROWN, DENSE TO VERY DENSE, SLIGHTLY SILTY, FINE GRAINED, WELL SORTED SAND; ANGULAR GRAINS, SAND GRAINS MAINLY LIMONITE - STAINED FELDSPAR WITH CONSIDERABLE DARK MINS.; FEW CLAYEY SILT INTERBEDS			DRILLS FIRM, SMOOTH, SLOW @ 132
135					
140					
145					
150					

SHEET 3 OF 9

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT HUMBOLDT 1253 DATE DRILLED ______ HOLE NO. H-11
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
150	SM.SP	<u></u>SLIGHTLY SILTY SAND; MEDIUM BROWN, DENSE TO VERY DENSE; FINE GRAINED, WELL SORTED SAND, ANGULAR GRAINS; LOTS OF DARK MINERALS		RD	
			J-4	PB 0.5/0.5	
				RD	CHANGED TO NEW TRI-CONE AFTER SAMPLING, + HAD TO REAM HOLE GOING BACK IN BECAUSE OF INCREASED DIAMETER
155					
160					161' @ 1340
165					
170					
		ORANGE BROWN SILTY CLAY INTERBEDS FROM 173'			
175					
	CL	DARK GRAY SILTY CLAY INTERBED			CUTTINGS DARK GRAY CLAY @177'
	SM	SILTY SAND, LIGHT YELLOW BROWN TO ORANGE BROWN, VERY DENSE, MUCH LESS FRIABLE THAN SAMPLE @ 123', BUT STILL FAIRLY FRIABLE -- COMPACTED, RATHER THAN CEMENTED; FINE TO MEDIUM GRAINED WELL-SORTED SAND WITH A FEW SCATTERED GRANULES AND VERY SMALL PEBBLES. DIP = 13° ON LIMONITE BANDING	J-5	PB 1.0/1.0	DRILLING FROM 178.5 @ 1600
180					
185					
					DRILLING SLOWLY: TOOK 10 MIN TO DRILL FROM 188' TO 190'
190					
9 MAY 10 MAY					STARTED DRILLING FROM 192' @ 0745; HOLE STANDING OPEN - GOES BACK DOWN EASILY
195					
					DRILLING SLOWLY + STEADILY -- ~ 5 MIN/FT.
		CLAYEY SILT INTERBEDS 197.0 - 198.5 3" GRAVEL LAYER @ 197.5			
200					

SHEET 4 OF 9

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT Humboldt 1253 DATE DRILLED ______ HOLE NO. H-11
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
200	SM-SP	SLIGHTLY SILTY TO CLEAN SAND (AS ABOVE); ORANGE BROWN, VERY DENSE, WELL SORTED, FINE GRAINED MASSIVE SAND; STRUCTURELESS; TOTALLY UNCEMENTED & EXTREMELY FRIABLE		RD	
			J-6 (MIXTURE OF INTERVAL)	PB 1.9/2.0	CORE WON'T HOLD TOGETHER WHEN EXTRUDED - VERY FRIABLE
205				RD	
210					
					213' @ 1120
215					
220					220' @ 1238; TAKING ~11 MIN/FT.
					222' @ 1301 - 11.5 MIN/FT
	SP	CLEAN SAND; ORANGE BROWN, VERY DENSE, WELL SORTED FINE GRAINED SAND WITH VERY FEW SCATTERED ¼" TO ½" WELL ROUNDED PEBBLES; TOTALLY UNCEMENTED & EXTREMELY FRIABLE — (I CAN'T FOR THE LIFE OF ME UNDERSTAND WHY THIS STUFF DOESN'T DRILL FAST AS HELL -- IT SHOULD PRACTICALLY WASH!)		PB 2.3/2.4	STARTED WITH NEW 10.5' ROD FROM 223' @ 1320
225			J-7		223.5 @ 1329 - COMING OUT TO SAMPLE AND SWITCH TO DRAG BIT TO SEE IF IT'S ANY FASTER
				RD	PUT A 3-FT FISHTAIL DRAG BIT ON, STARTED DRILLING FROM 225.4' @ 1432
230					GOES LIKE HELL! (~2'/MIN)
					234 @ 1443/1445 - NEW ROD
235					
240					
					244 @ 1552/ (7 MIN FOR 10')
245					
		2" THICK CLAYEY LAYER @ 249'			
250					

SHEET 5 OF 9

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT Humboldt 1253 DATE DRILLED ______ HOLE NO. H-11
LOCATION ______ GROUND SURFACE ELEV. ______
DRILLING CONTRACTOR ______ LOGGED BY ______ DEPTH TO GROUND WATER ______
TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______
SURFACE CONDITIONS ______ WEATHER ______

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
250	SP	(Clean sand as above)		(R)	
255		1" thick clayey layer @ 256'			255' @ 1502/1505 Drilling v. rapidly - + smoothly - obviously sand
260		hitting a few scattered pebbles on the way down			
265	SP	Clean sand (as above, except very fine grained vs fine grained) 2" thick clayey + gravelly layer @ 265'	J-8	PB 10	265' @ 1515 Having to ream P.B. down, since drag bit is slightly smaller dia. Could only advance PB 0.7'
270					Drilling rapidly + smoothly
	SC	Sand-clay interval			Drilling slow + hard 272.8-274.5 [illegible]
275	SP				276 @ 0805 081
					(Lost string in hole + had to fish for it)
285					286 @ 0823/0833
	GM-GC	288.5 - 302.5 Interbedded clayey to silty sand gravel + gravelly sand			Harder + gravelly 288.5-290
290	SP-GW	Gravelly sand			Drilling rapidly + evenly 290-297 - gravelly sand)
295					
	GM-GW	Silty sandy gravel; red-brown + green-gray chert			297 @ 0852 slow rod V. gravelly 297' to ———
300					

SHEET 6 OF 9

Fairly good sized gravel -
Drilling slow + rough

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT Humboldt 1253 DATE DRILLED HOLE NO. H-11
LOCATION GROUND SURFACE ELEV.
DRILLING CONTRACTOR LOGGED BY DEPTH TO GROUND WATER
TYPE OF RIG HOLE DIAMETER HAMMER WEIGHT AND FALL
SURFACE CONDITIONS WEATHER

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
300	GW-GM	Silty Sandy Gravel; well rounded pea gravel & sm. pebbles [illegible] chert		RD	Drilling intermittant [illegible] f sand [illegible] + [illegible] No coll [illegible] Losing some water Drilling [illegible] Tough @ 302.5
	CL-ML	302.5-305.0 *Silty Clay interbed, dark brown-gray, very stiff; slightly gravelly?			
305	SP	305.0- *Clean Sand *Silty Sand (interbedded); medium yellow brown, very dense, fine grained, well sorted sand; angular grains - considerable dark minerals & mica	J-9	PB 0.8/1.0	
				RD	0915 Started pulling to sample @ 303.5 - will have to go in with tri cone to get the hole through gravel above contact
310					[illegible] completed reaming & drilled with tri cone 303.5-305 1220 going back in with tri-cone 1223 started drilling from 30[illegible]
	SM + SP	Scattered pebbles, few clayey interbeds			
315					
					312' @ 1318
320					
325					
					324 @ 1353
330					
335					335.5 drilling slightly faster
					339 @ 1435 1434
340					
345					Rough @ 346.5-346.8
350					

SHEET 7 OF 9

EARTH SCIENCES ASSOCIATES

DRILLING AND SAMPLING LOG

PROJECT Humboldt 1253 DATE DRILLED ______ HOLE NO. H-11

LOCATION ______ GROUND SURFACE ELEV. ______

DRILLING CONTRACTOR ______ LOGGED BY EAW/H DEPTH TO GROUND WATER ______

TYPE OF RIG ______ HOLE DIAMETER ______ HAMMER WEIGHT AND FALL ______

SURFACE CONDITIONS ______ WEATHER ______

MAY (EAW SIGNING OFF)

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
350	SM & SP	INTERBEDDED SILTY SAND & CLEAN SAND; ORANGE BROWN TO MEDIUM YELLOW BROWN, VERY DENSE; FINE GRAINED WELL SORTED SAND — GRADES SILTY TO CLEAN ON 6"-12" BED THICKNESS; FEW SCATTERED SUB-ROUNDED GRANULES & PEA GRAVEL		PB	FINISHED DRILLING TO 350' @ 1530
			J-10	12.5	P.B. OUT OF THE HOLE @ 1630
355					
360					
				RD	
365					
	SC?				Reported "clayey" at 267'. Cuttings showed clayey fine sand.
370	SP	Clean sand; Orange brown, v. dense, fine grained, well sorted sand; scattered rounded granules to ⅛" size, essentially uniform grain size no matrix or cementation.	J-11	8"/11"	1330 - Back into hole, tricone bit.
				I.D.	
375					
380					
385					
390					
395					
400					

SHEET 8 OF 9

EARTH SCIENCES ASSOCIATES

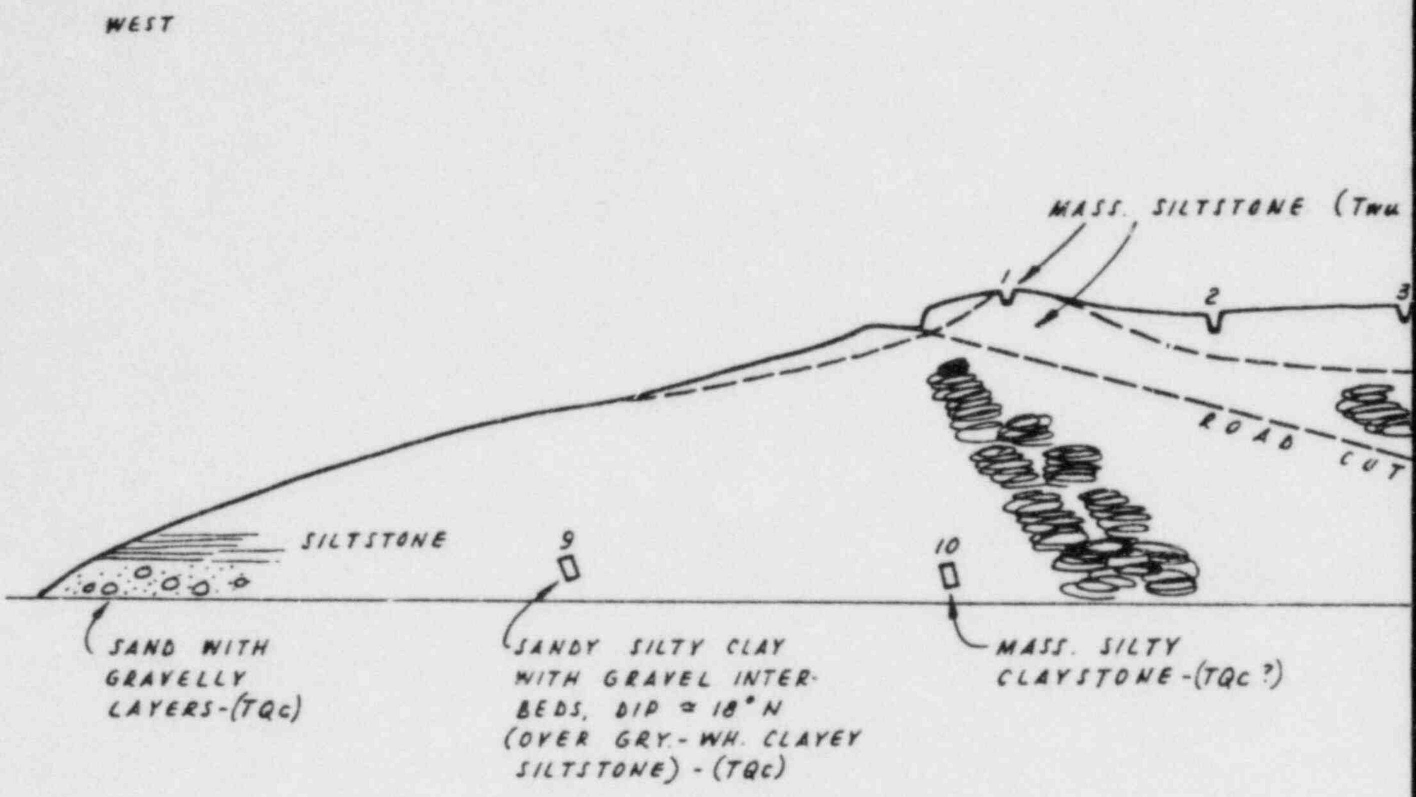
DRILLING AND SAMPLING LOG

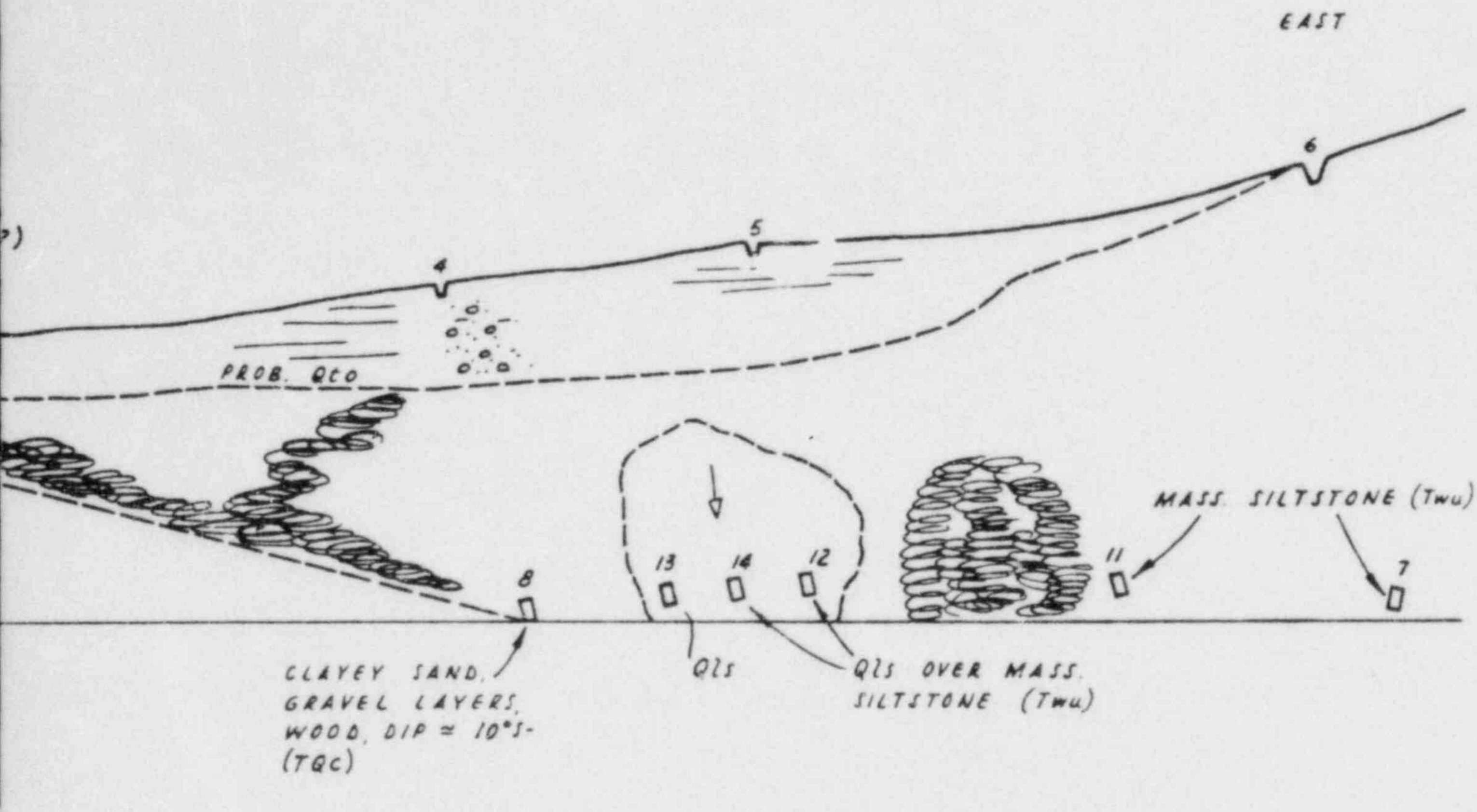
PROJECT Humboldt - 1253 DATE DRILLED ____ HOLE NO. H-11.
LOCATION ____ GROUND SURFACE ELEV. ____
DRILLING CONTRACTOR ____ LOGGED BY H/RCH DEPTH TO GROUND WATER ____
TYPE OF RIG ____ HOLE DIAMETER ____ HAMMER WEIGHT AND FALL ____
SURFACE CONDITIONS ____ WEATHER ____

DEPTH	CLASS.	FIELD DESCRIPTION	SAMPLE	MODE	REMARKS
400	SP			RD	
	SM?				Started Sat drilling with enlarged drag bit - no faster than tricone ≈ 5 min/ft
405					
	SC-(CL)	Est. top from drilling behavior. ~~Medium grey~~ Clayey sand, medium grey. v. dense, fine grained well sorted sand in a matrix of grey ~~clay~~ silty clay. Higher in this interval, found brown plastic silty clay.			
410					Very slow drilling, pulled bit, found to be fouled with grey clayey sand and brown sticky clay.
	SP	Clean sand Or brown, as in sample at 370'	(J-12A) J-12	PB 11"/12"	Tricone
415	SC	Clayey sand, greenish-grey, v. dense,			
			J-13 cuttings	Jar	
420					
					423' stopped drilling Sat, mudded hole.
425					5/15/72
430		430- 443 SANDSTONE: dark gray; cemented; hard; very fine-grained.			
435					Very hard slow drilling with tricone bit, occasional 6" thick softer lenses.
440			J-14 cuttings		442'-443' drilling rate: 12"/30 min
				PB	Attempted coring w/ Pitcher Barrel, ground off end of tube, no recovery.
445		B.H. 443.5'			Terminated hole at 443.5' 5/15/72 1530
450					

SHEET 9 OF 9

A-3. Logs of Earth Sciences Associates backhoe trenches.
Locations of trenches are shown on Drawing No. 7.


WEST
MASS. SILTSTONE (Twu
1
2
3
ROAD CUT
SILTSTONE
9
10
SAND WITH GRAVELLY LAYERS-(TQc)
SANDY SILTY CLAY WITH GRAVEL INTER-BEDS, DIP ≈ 18° N (OVER GRY.-WH. CLAYEY SILTSTONE) - (TQc)
MASS. SILTY CLAYSTONE -(TQc ?)



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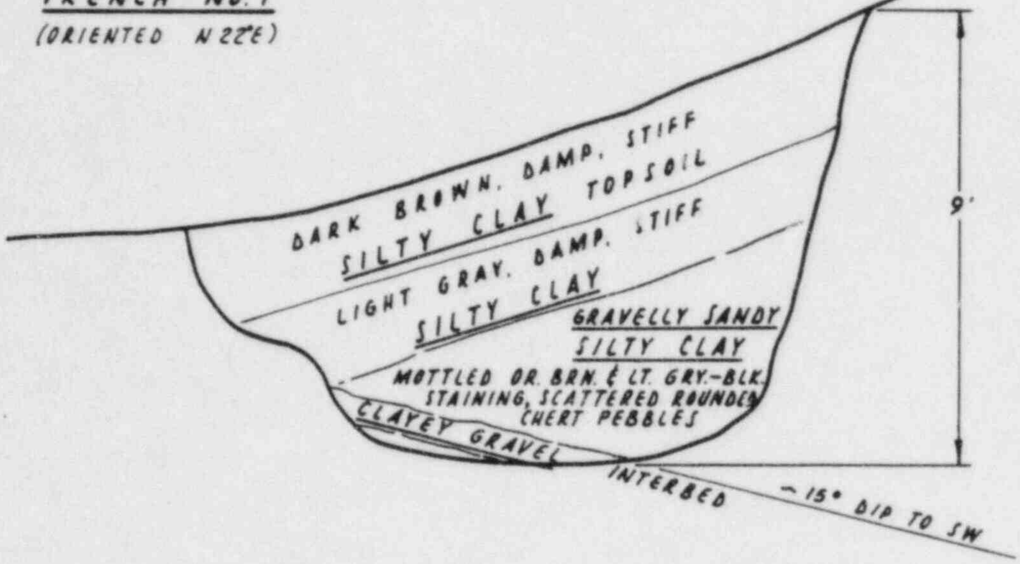
SKETCH PROFILE SHOWING LOCATIONS
OF BACKHOE TRENCHES IN SECTION 9
HELGERSON PROPERTY, NORTH OF SALMON CREEK

FIGURE NO. A-3

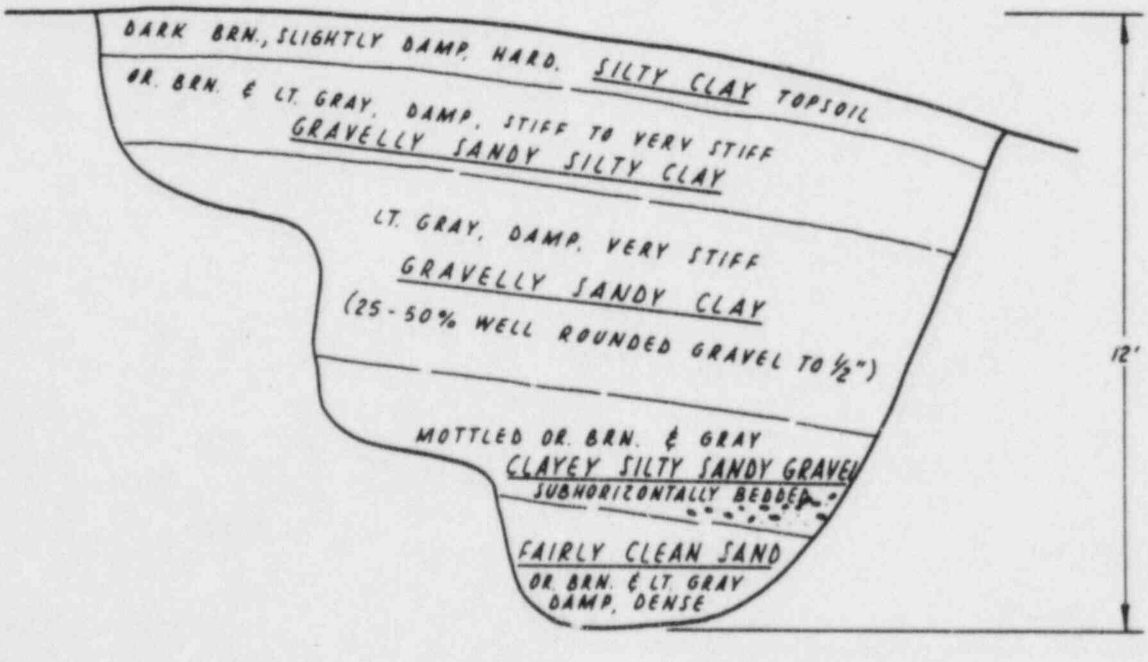
ESA 8-30-72

TRENCH NO. 1

(ORIENTED N22°E)

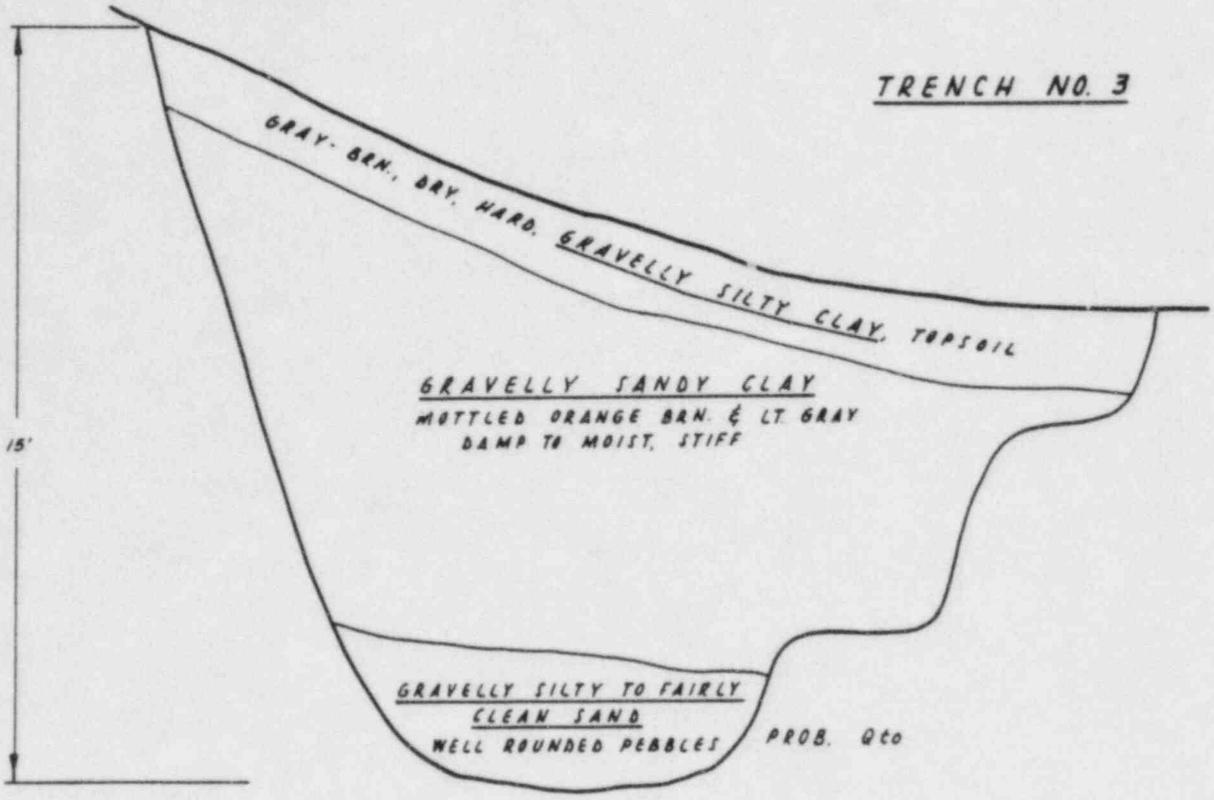


TRENCH NO. 2

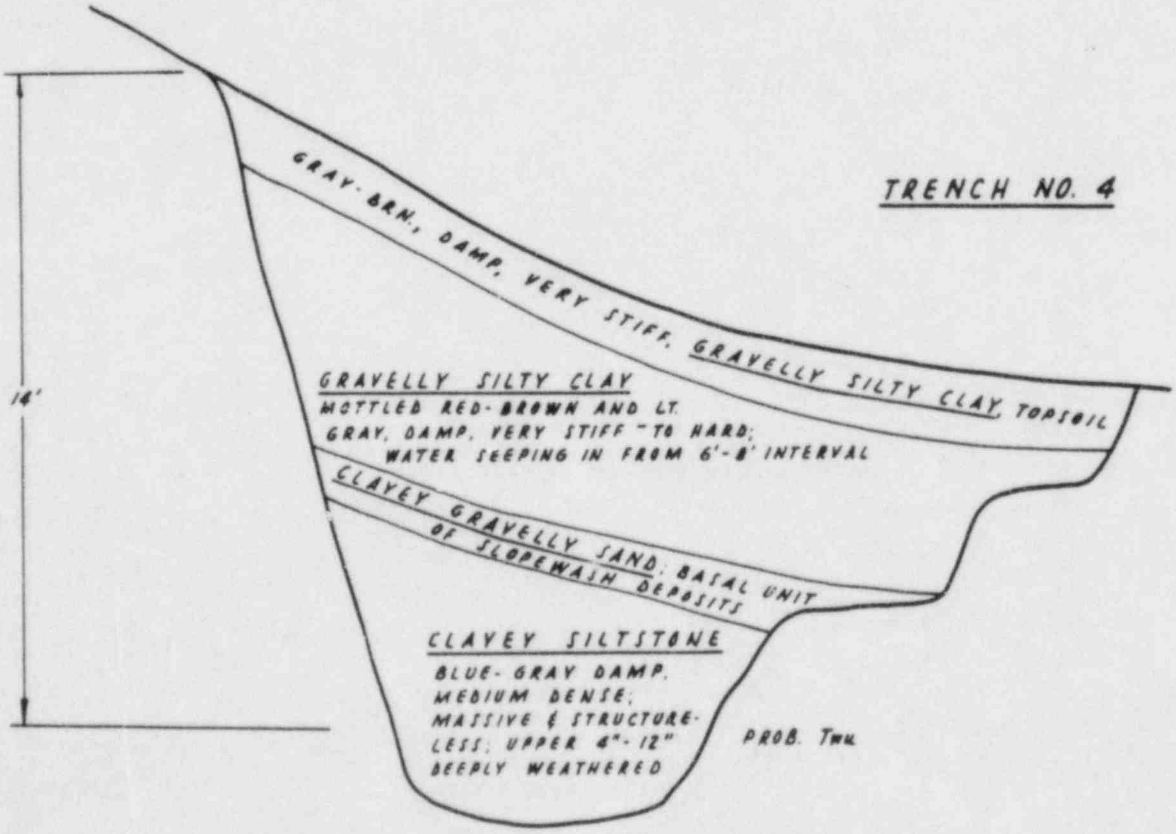


43A 1253

TRENCH NO. 3

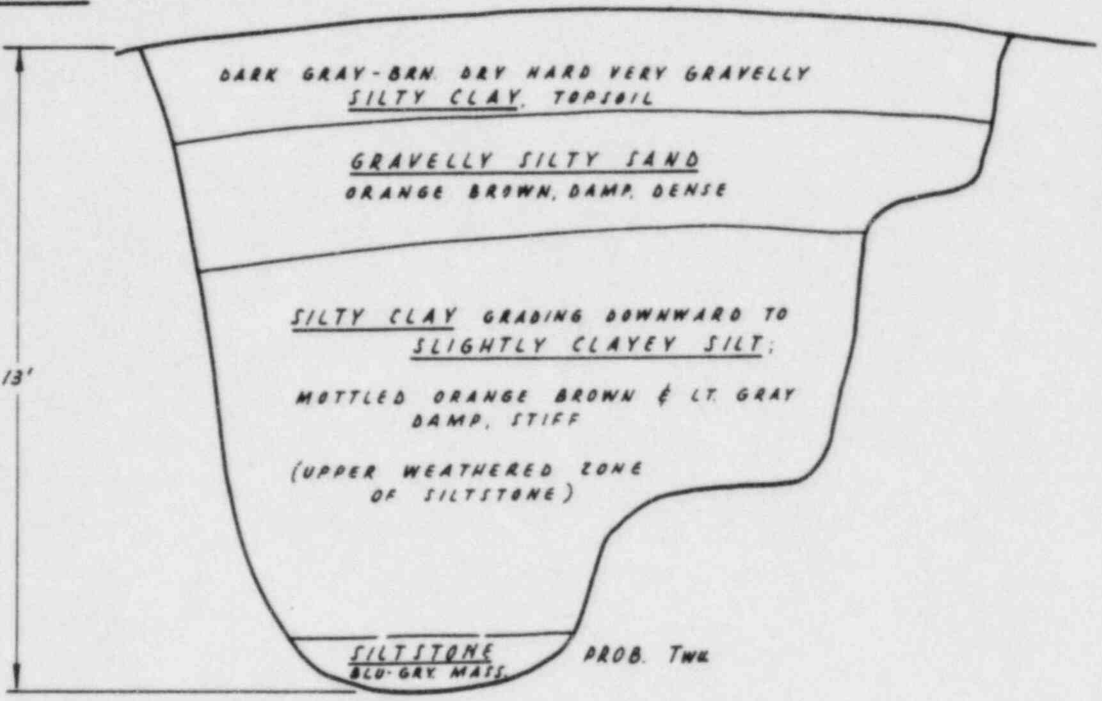


TRENCH NO. 4

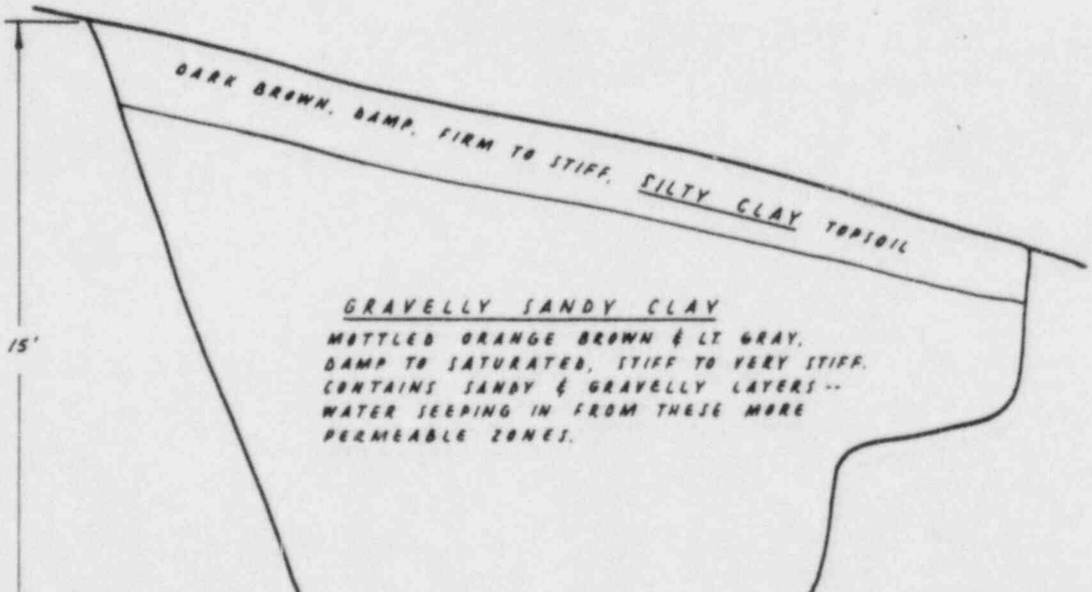


CIA1253

TRENCH NO. 5

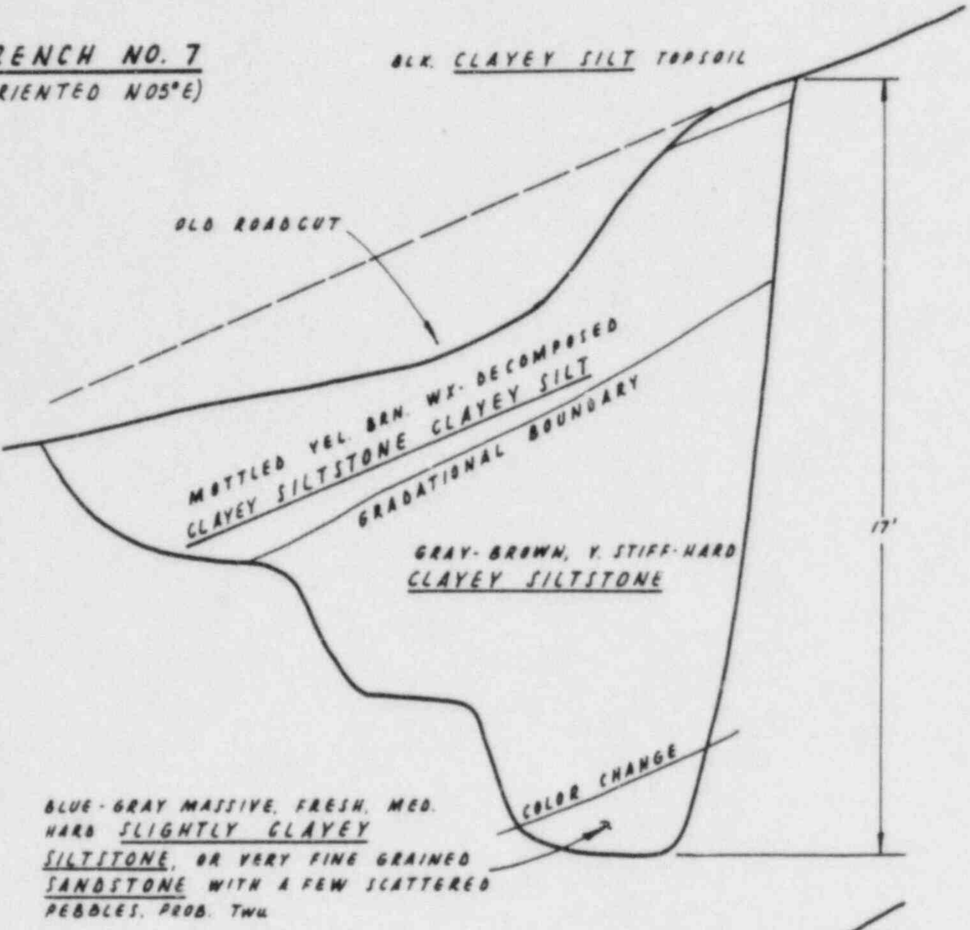


TRENCH NO. 6



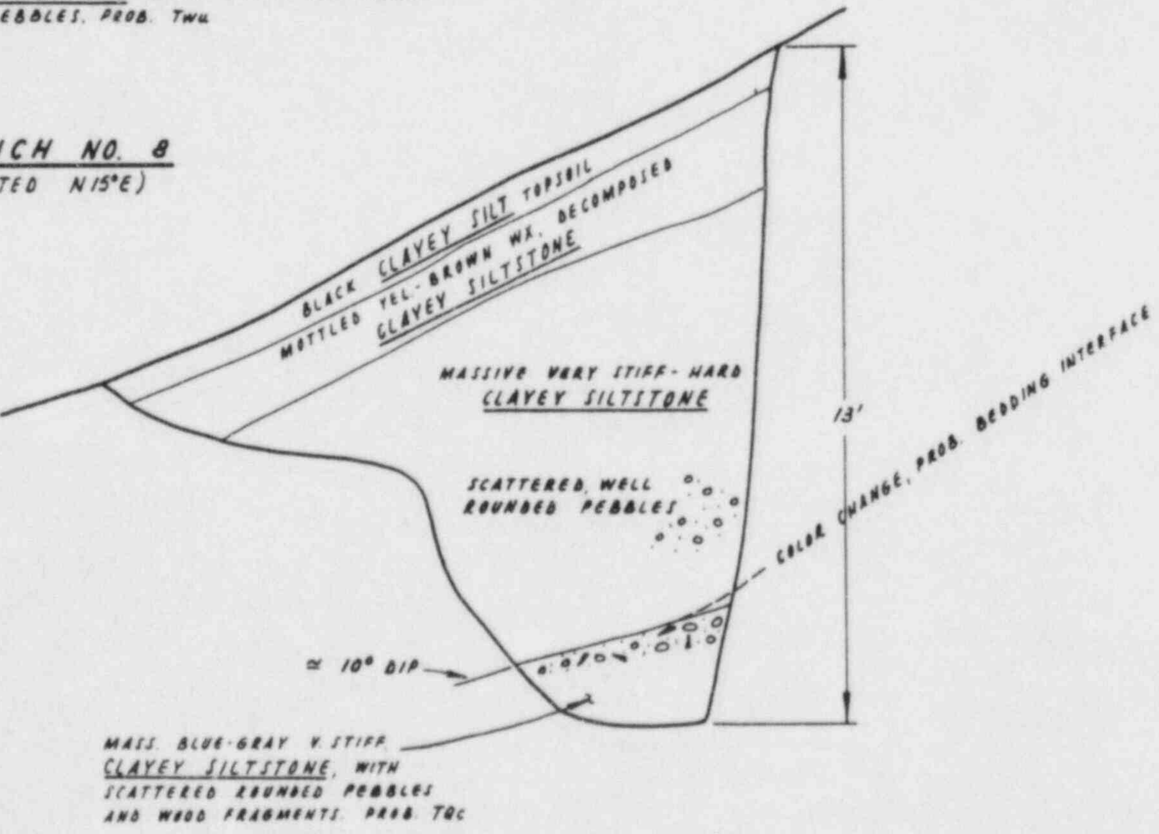
TRENCH NO. 7

(ORIENTED N05°E)



TRENCH NO. 8

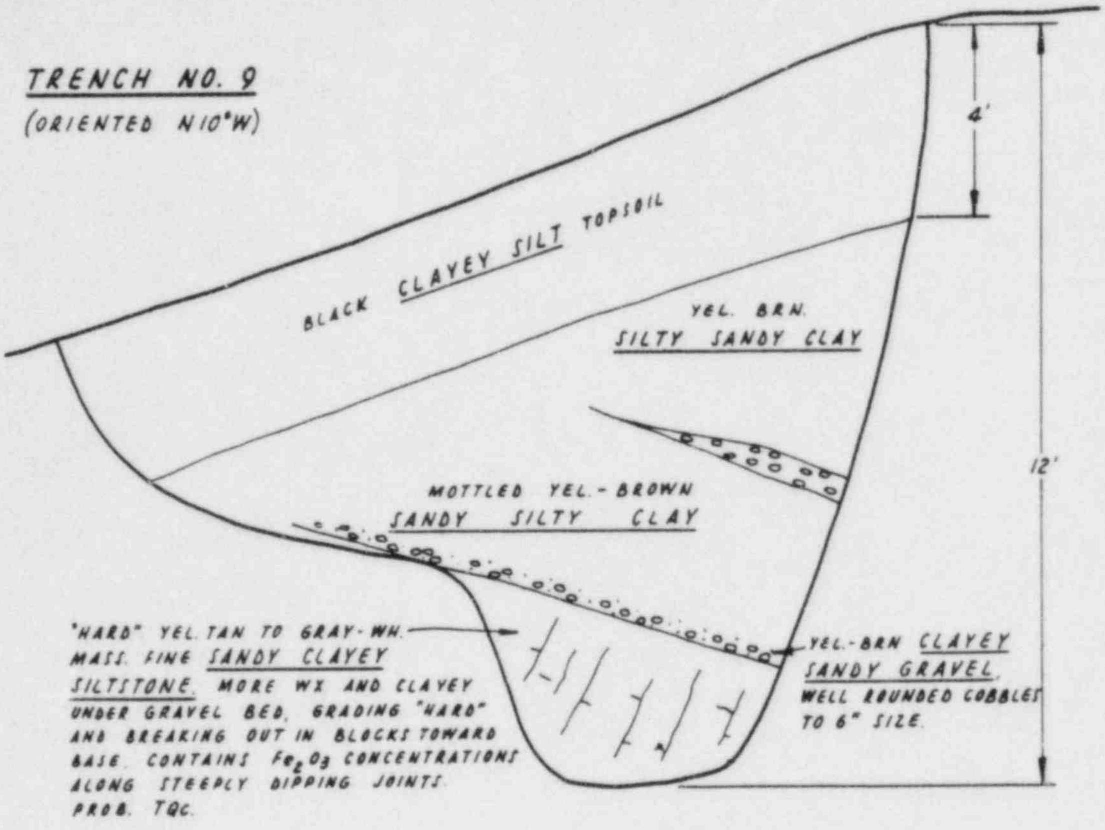
(ORIENTED N15°E)



ETA 1853

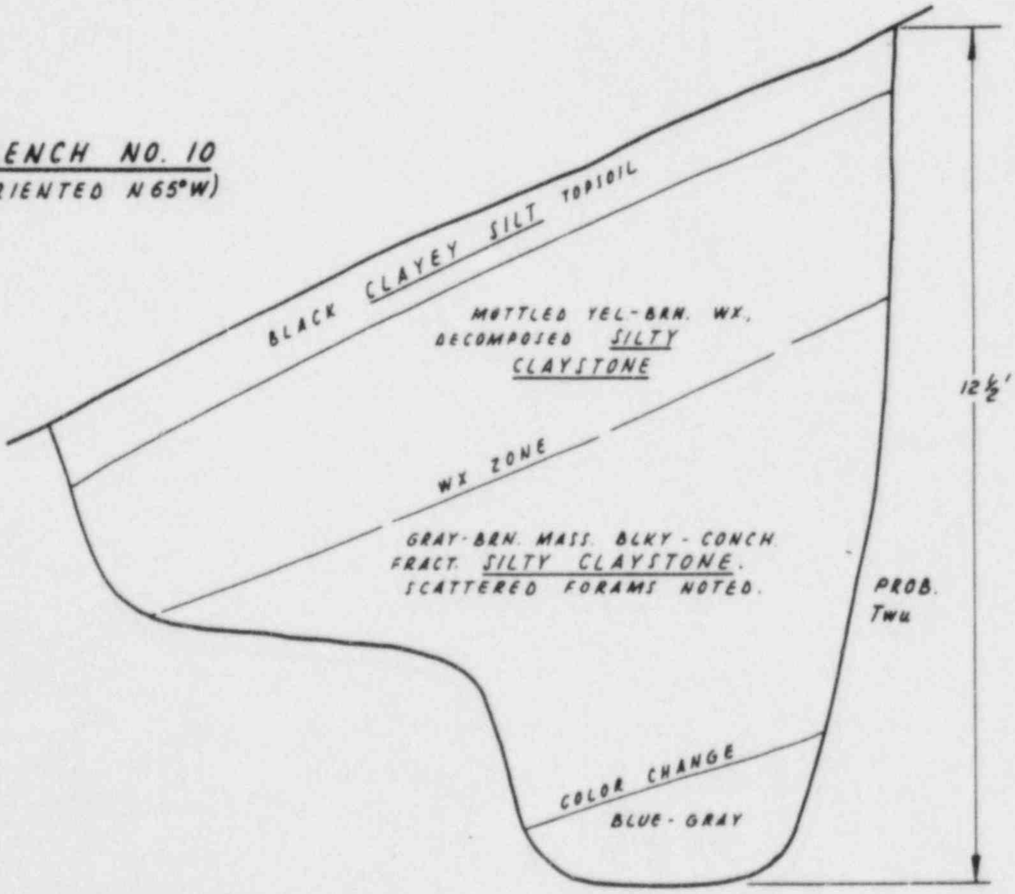
TRENCH NO. 9

(ORIENTED N10°W)



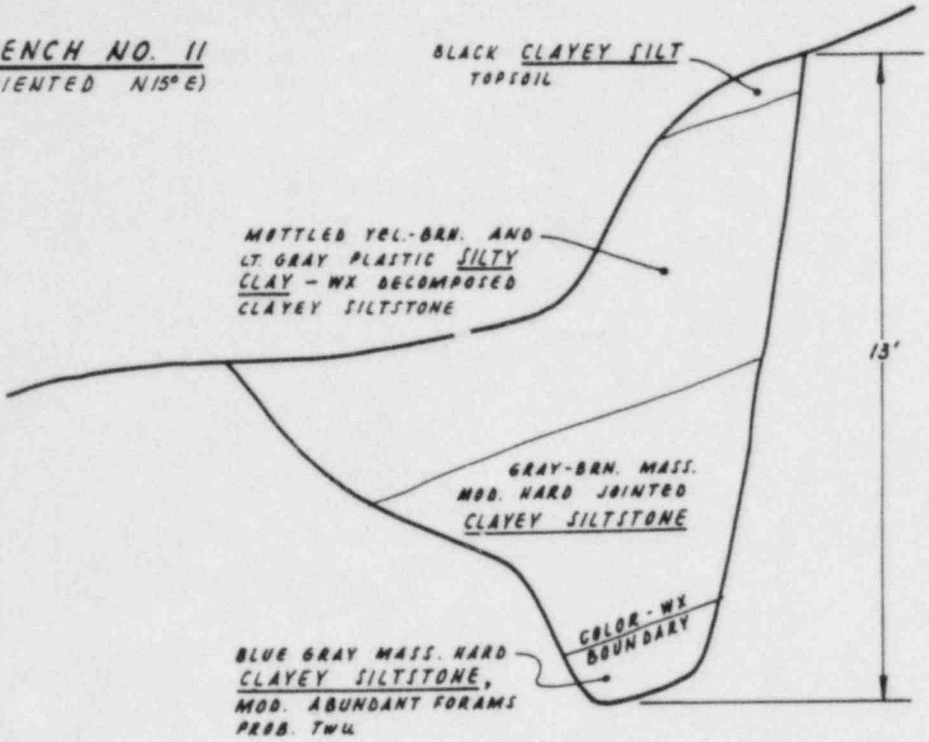
TRENCH NO. 10

(ORIENTED N65°W)

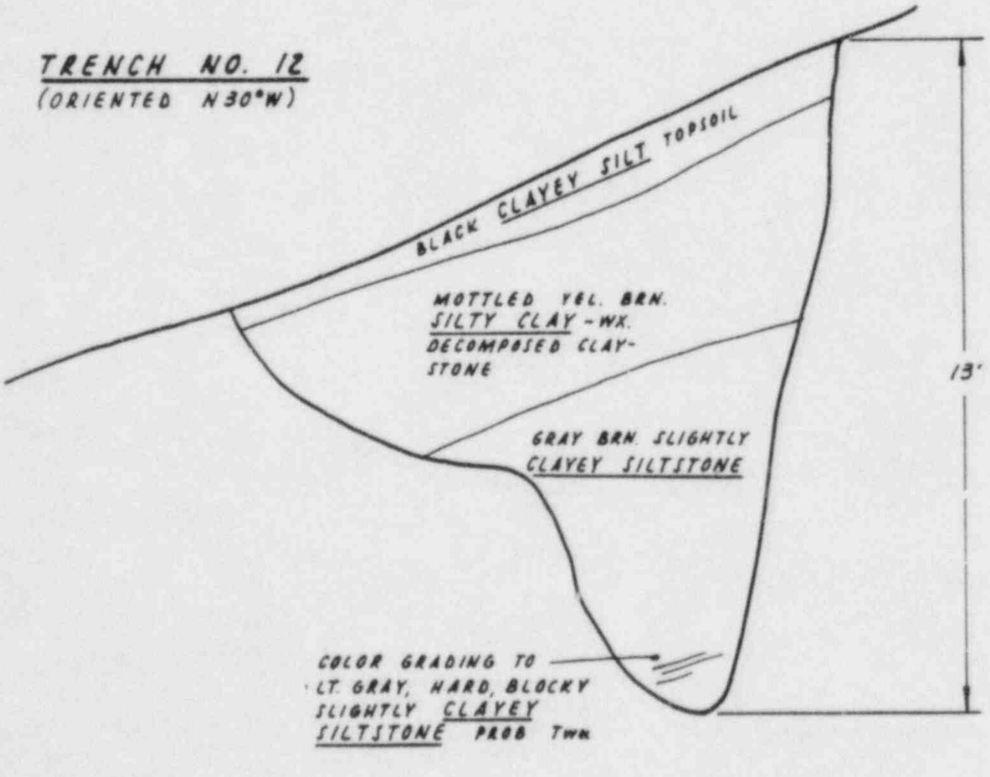


ELA 1253

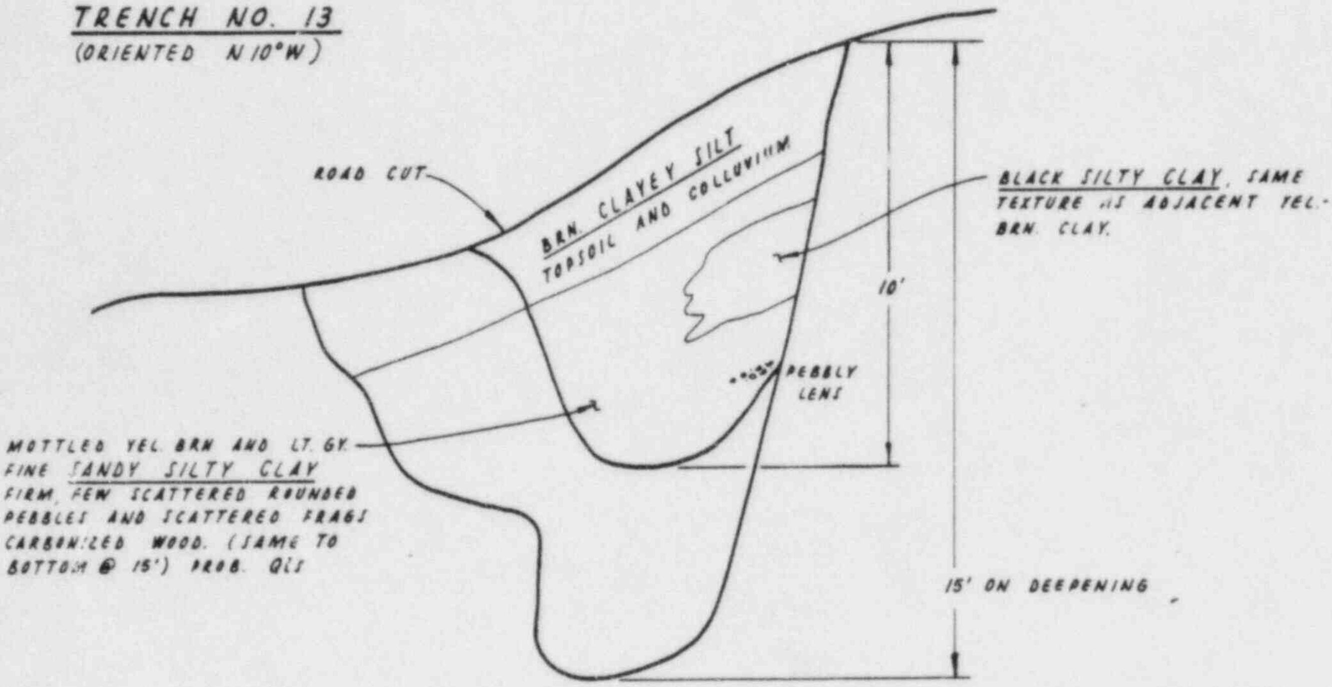
TRENCH NO. 11
(ORIENTED N15° E)



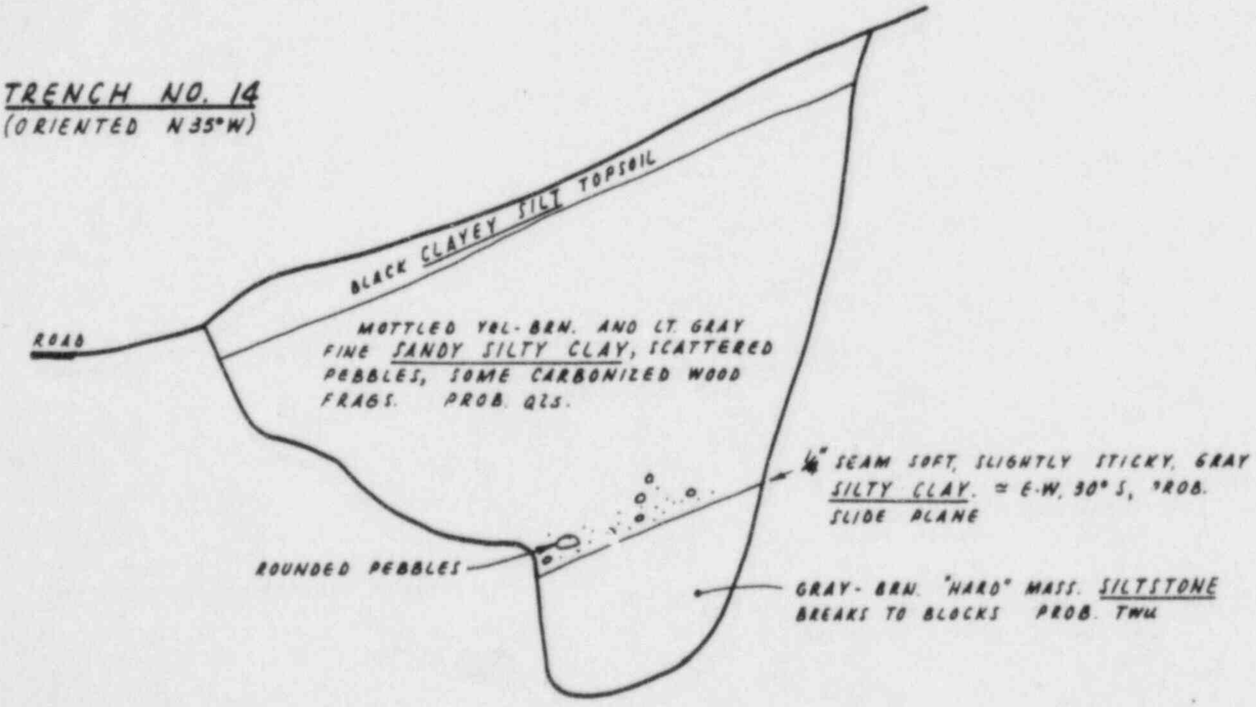
TRENCH NO. 12
(ORIENTED N30°W)



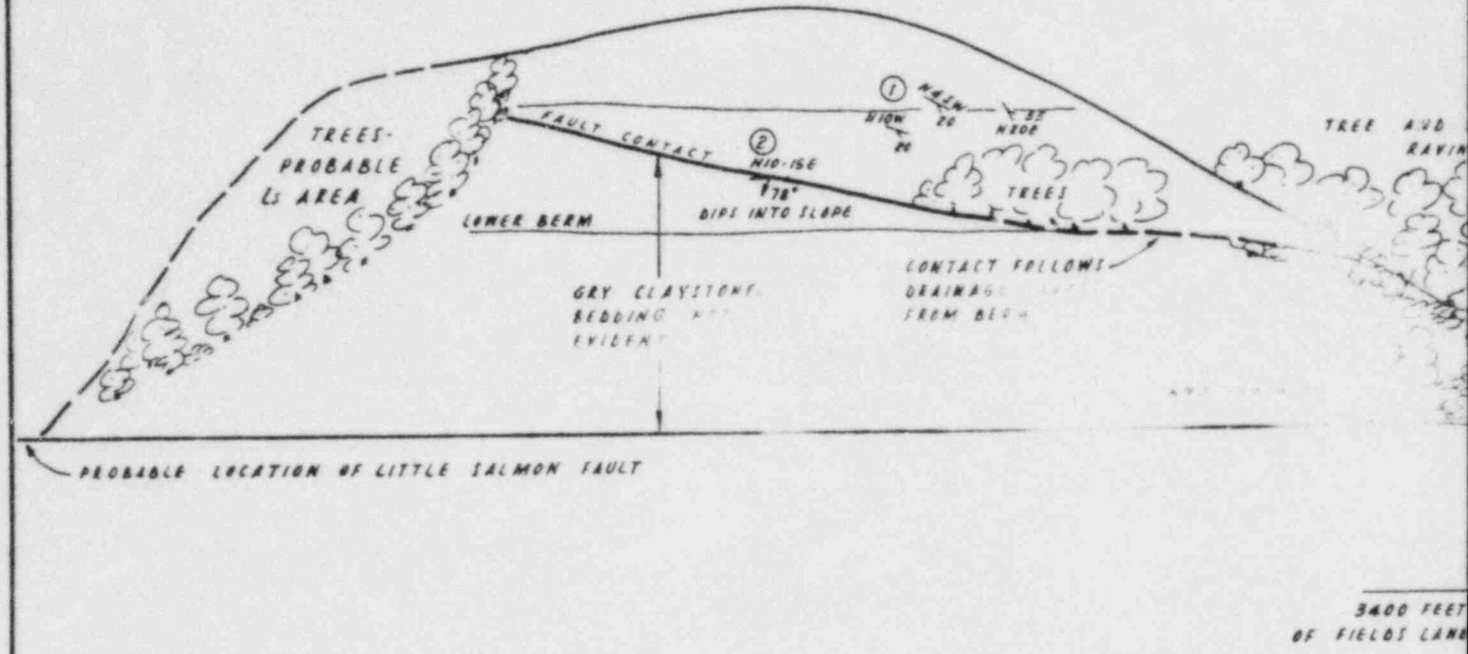
TRENCH NO. 13
(ORIENTED N 10°W)



TRENCH NO. 14
(ORIENTED N 35°W)



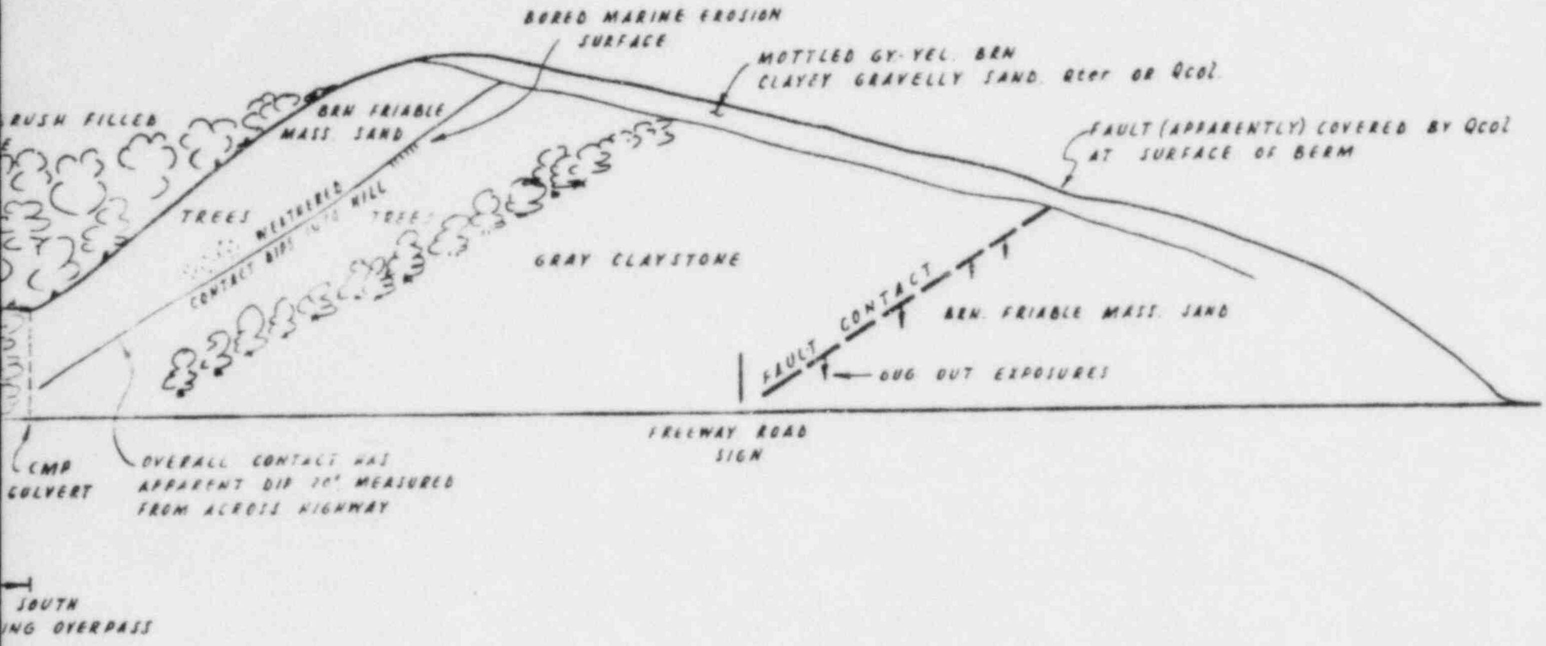
A-4. Sketch geologic maps of exposures near Fields Landing.



<u>NOTES</u> ① BERM AND UPPER HIGHWAY CUT NORTH OF FAULT EXPOSURE - MASSIVE FRIABLE BROWN SAND, N20W - N45W - N80E, 55 SE = 20SW

② CONTACT BETWEEN BROWN SAND AND GRAY CLAYSTONE EXPOS IN LOWER HIGHWAY CUT IS N10-15E, 78° SE, ⊄ N-S, 40°E IN TWO DUG OUT EXPOSURES - PROBABLE FAULT.

ESA 1253



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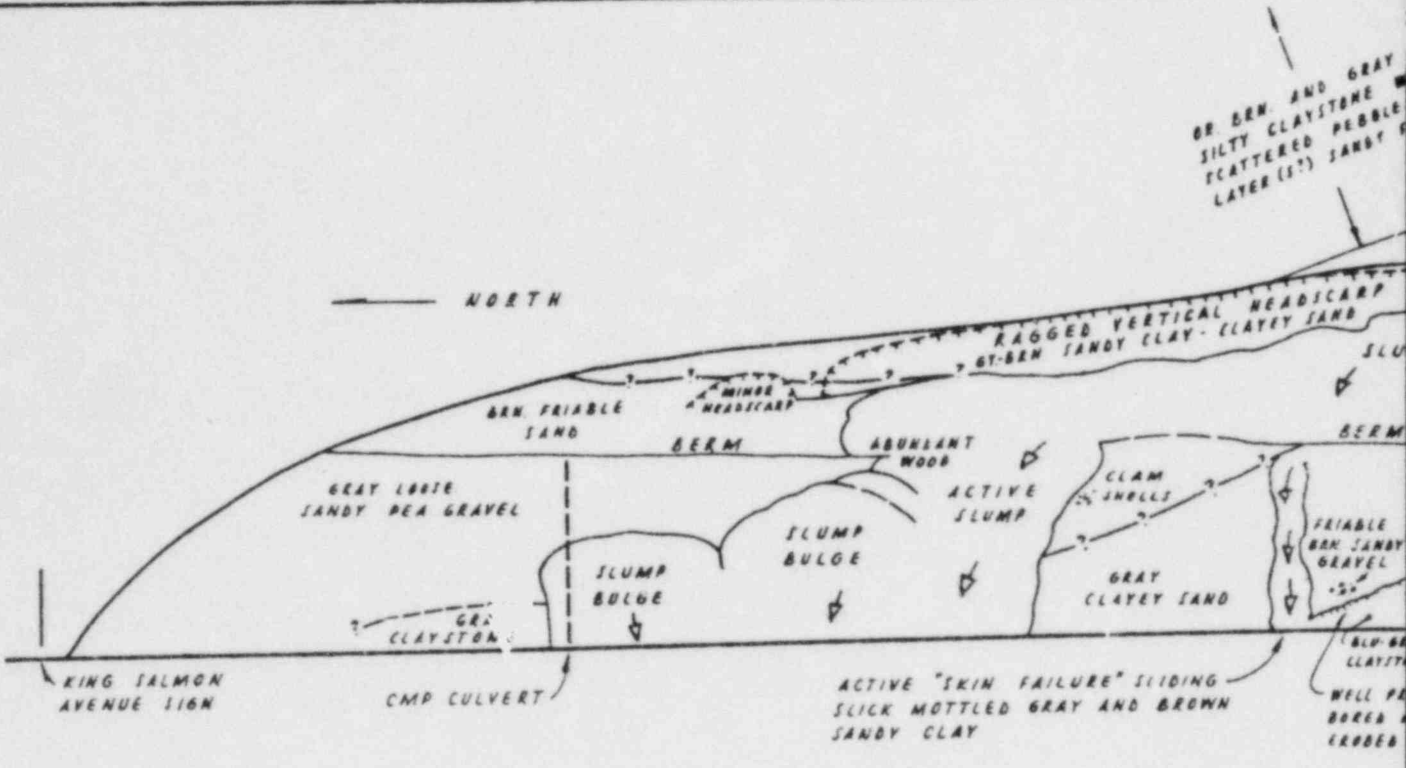
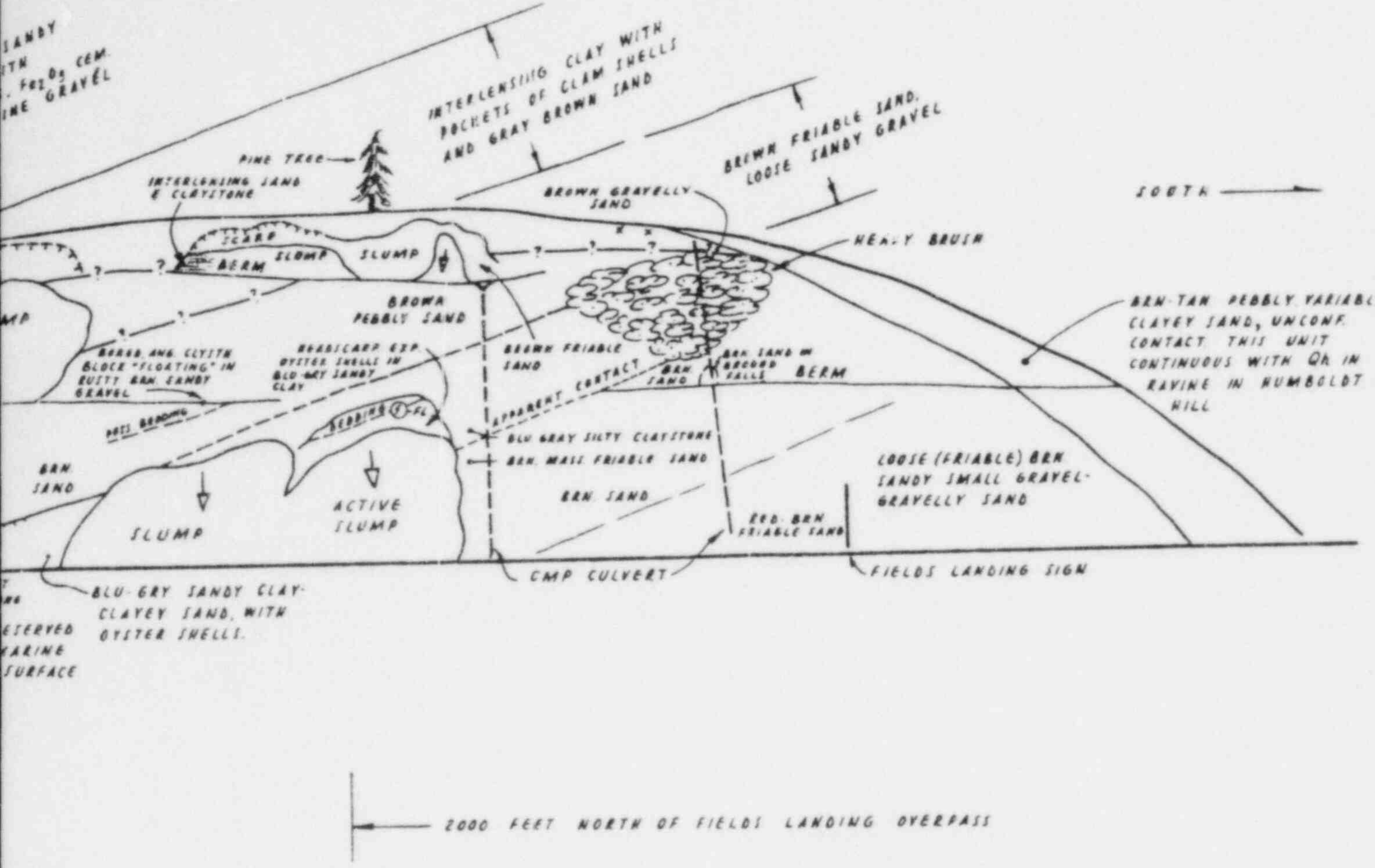
SKETCH OF GEOLOGIC FEATURES EXPOSED IN THE FREEWAY ROADCUT 3400 FEET SOUTH OF THE FIELDS LANDING OVERPASS

FIGURE NO. A-4-2

ESA 8-30-72


NORTH
DR. BRN. AND GRAY
SILTY CLAYSTONE
SCATTERED PEBBLE
LAYER (S?) SANDY
RAGGED VERTICAL HEADSCARP
GY-BRN SANDY CLAY - CLAYEY SAND
MINOR HEADSCARP
BRN. FRIABLE SAND
BERM
GRAY LOOSE SANDY PEA GRAVEL
ABUNDANT WOOD
ACTIVE SLUMP
CLAM SHELLS
SLU
BERM
FRIABLE BRN SANDY GRAVEL
SLUMP BULGE
SLUMP BULGE
GRAY CLAYEY SAND
GR
CLAYSTON
KING SALMON AVENUE SIGN
CMP CULVERT
ACTIVE "SKIN FAILURE" SLIDING SLICK MOTTLED GRAY AND BROWN SANDY CLAY
BLU-GR
CLAYST
WELL P
BORED
ERODED

ESA 1258



NO SCALE

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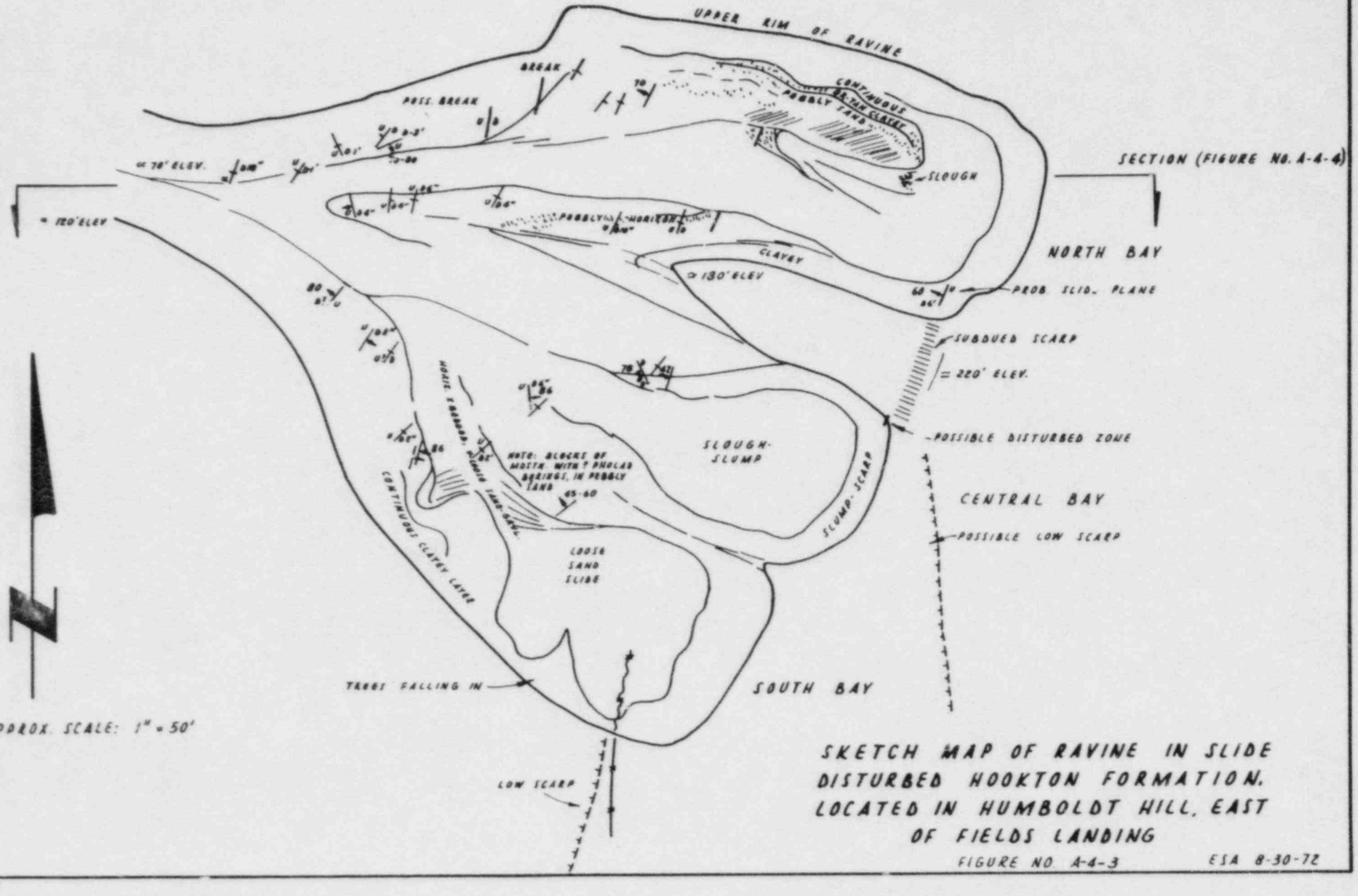
SKETCH OF GEOLOGIC FEATURES EXPOSED IN THE FREEWAY ROADCUT 2000 FEET NORTH OF THE FIELDS LANDING OVERPASS

FIGURE NO. A-4-1 8102060099-03 ESA 8-30-72

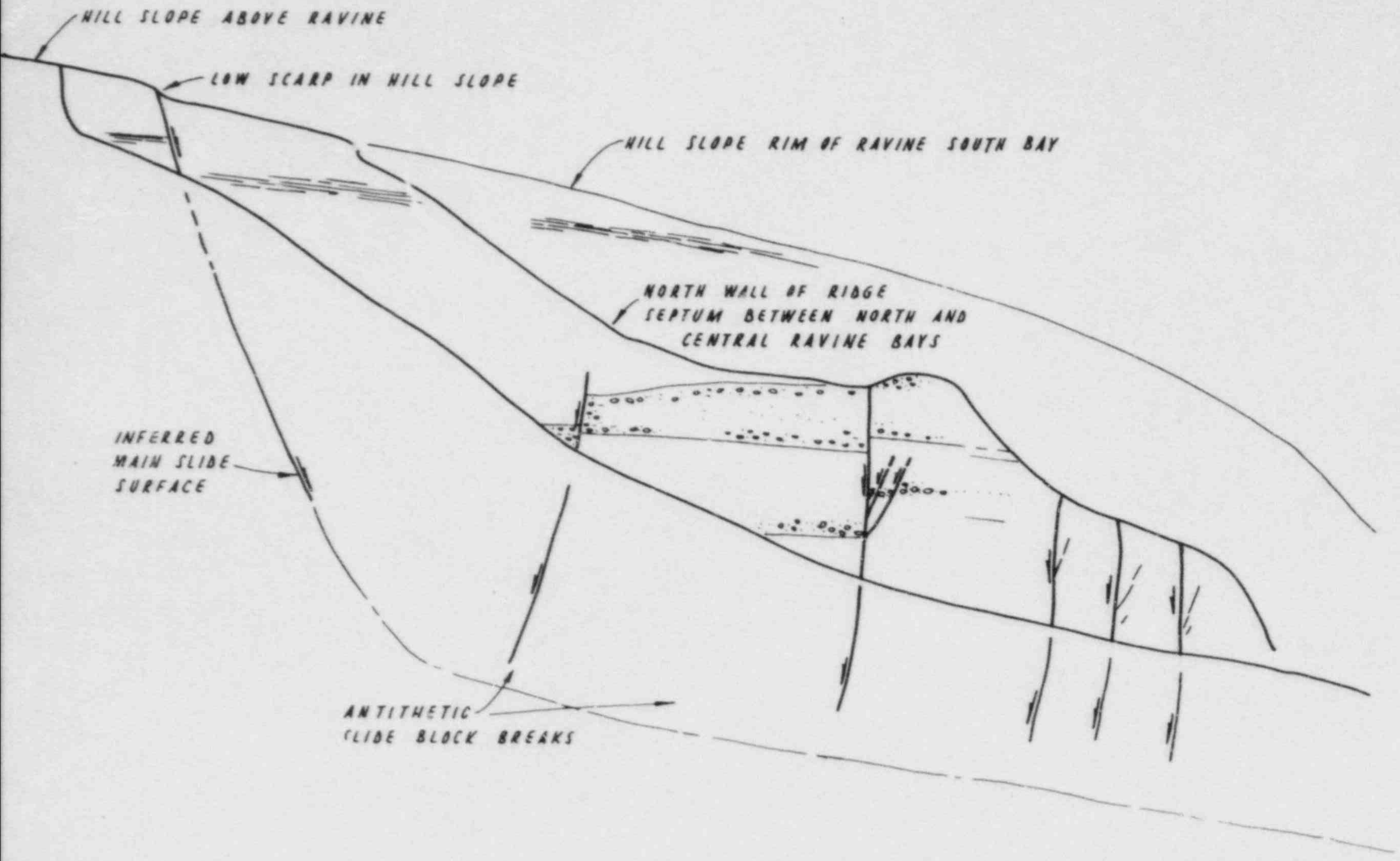


SKETCH MAP OF RAVINE IN SLIDE DISTURBED HOOKTON FORMATION, LOCATED IN HUMBOLDT HILL, EAST OF FIELDS LANDING

FIGURE NO. A-4-3

ESA 8-30-72

ESA 1253



SKETCH VIEW OF SOUTH SIDE OF NORTH BAY SHOWING GENERAL PATTERN OF BREAKS, AND INFERRED SUBSURFACE RELATIONSHIPS

FIGURE NO. A-4-4

ESA 8-30-72

A1253

A-5. Results of laboratory testing of Carlotta Formation claystone.

RESULTS OF LABORATORY TESTING OF REPRESENTATIVE SAMPLES OF CARLOTTA FORMATION CLAYSTONE

Sample H-1, J17

Depth: 119 ft.
Description: Dark greenish gray silty claystone.
Natural Water Content: 23.9%
Unit Weight: 122.8 lbs/cu.ft.
Unconfined Compressive Strength: 2.5 - 4.2 tons/sq.ft.

Sample H-1, J25

Depth: 243 ft.
Description: Dark gray silty claystone.
Natural Water Content: 27.2%
Unit Weight: 124.1 lbs/cu.ft.
Unconfined Compressive Strength: 3.5 - 5.7 tons/sq.ft.
Estimated Maximum Past Pressure: Estimated from consolidation test on undisturbed sample at less than 12 tsf; material may be normally consolidated at this depth.

Sample H-2, J3

Depth: 18 ft.
Description: Bluish gray silty clay
Natural Water Content: 23.5%
Unit Weight: 128.1 lbs/cu.ft.
Unconfined Compressive Strength: 1.6 - 3.5 tons/sq.ft.

B. Data from geophysical investigations by Earth Sciences Associates, 1972.

1. Description of Magnetic survey.
2. Magnetometer profiles.
3. Description of Gravity survey.
4. Bouguer gravity value profiles.

B-1. Description of Magnetometer survey.

B-1. Description of Magnetometer Survey.

Surveys of total magnetic field values were made along selected traverse lines in the southern Humboldt Bay area as part of the Humboldt Bay Power Plant site geology investigation. The surveys were made using proton precession magnetometers having digital readouts with an accuracy of one gamma. Two similar instruments, a Varian M-50 and a Geometrics G-806, were used at different times during the survey.

Magnetic traverse lines were laid out so as to provide magnetic field data throughout most of the southern Humboldt Bay area, and especially across possible projections of geologic structural features mapped elsewhere. On-land traverses were made on the North and South spits, on Buhne Point, and at several localities along the base of Humboldt Hill adjacent to Humboldt South Bay. Over-water traverses were made in the South Bay and Bay entrance areas.

During the course of the survey, a base station and traverse field stations were established so as to permit making of corrections for any short term drift of the total magnetic field. The field was relatively quiet during times when observations were being made. Tests were made to determine the effect at different geographic orientations of the fibreglass boat and outboard motor used during the over-water traverses. During any given over-water traverse, the boat was operated at constant heading and speed between identifiable reference points.

Data from the survey are presented on Drawings Nos. B-1 through B-4 accompanying this Appendix.

Results and Interpretation.

The magnetic survey was performed in order to provide a check of geophysical anomalies indicated by sparker seismic reflection and gravity surveys, and to determine whether magnetic anomalies existed in areas where there were no exposures, and which were not accessible to surveying by gravity and seismic reflection techniques.

In general, the objectives of the survey were most satisfactorily fulfilled by the results of the over-water traverses. The over-land traverses mostly yielded confused patterns of data which were further complicated by numerous anomalies associated with cultural features.

It was found that significant magnetic anomalies were associated with the Table

Bluff fault under the South Bay and with the trend of the possible Bay Entrance fault determined from sparker seismic reflection, gravity, and stratigraphic anomalies. At other points not along the trend noted above, where there were anomalies in the sparker seismic reflection data, no magnetic anomalies were detected. This was considered to reinforce the interpretation that those sparker anomalies do not represent bedrock geologic features.

B-2. Magnetometer profiles.

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114
118
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B-3. Description of Gravity survey.

B-3. Description of Gravity Survey.

A gravity survey for the Humboldt Bay Power Plant site geology investigation included the following operations: 1) measurement of gravity values at numerous stations along selected traverses and also at other stations scattered throughout the Humboldt Bay - lower Eel River region, 2) reduction of the measured field values to Bouguer gravity values, 3) preparation of detailed profiles of Bouguer gravity values, and 4) compilation of a regional contour map of Bouguer gravity values. The survey was carried out using a La Coste and Romberg Model G gravimeter. The gravity meter was frequently returned to a base station to remove effects of instrumental drift. The base station used was part of the California gravity base station network established by the California Division of Mines (Chapman 1966 - Gravity Base Station Network : Cal. Div. of Mines Special Report 90). To further improve instrumental precision, the meter calibration constant was checked by running the instrument through a portion of the U. S. Geological Survey's Mt. Hamilton gravity meter calibration loop. The instrument was found to be very stable with respect to drift, and to be well calibrated. Elevation control and location of gravity measurement stations for the regional map were obtained from bench mark and spot elevation data on U.S.G.S. 7½ minute topographic maps. Control for measurement stations along the detailed profiles was obtained by leveling and distance measuring wheel surveys.

Values read at the gravity measurement stations were reduced on an IBM model 360 computer. The latitude and longitudes of the gravity stations were taken from the U.S.G.S. topographic maps by means of an X-Y digitizing table. A manually computed "inner zone" terrain correction extending 1.1 kilometers from each station was calculated for stations located in areas of rugged topography. The location and terrain correction data, together with the principal facts for each gravity station, were then submitted to the computer. Tidal, latitude, elevation,and Bouguer corrections, and theoretical gravity values were computer generated and Bouguer anomalies retrieved as the computed output. The procedure outlined is highly automated to reduce to a minimum the possibility of human error in the numerous mathematical computations involved.

The gravity values determined along lines of close station spacing were plotted as profiles at scales of 2000 and 600 feet per inch. The regional contour map was prepared by linear interpolation between all available data points. No regional gradient correction was made for either the profiles or the map.

Data from the survey are presented on Drawings Nos. 5, 6, and 12 in the report and the detailed profiles are presented on Drawings Nos. B-5 and B-6 accompanying this Appendix.

Results and Interpretation.

The gravity survey was performed in order 1) to determine the relationship between measured gravity values and known geologic structures, thus providing a basis for interpreting gravity anomalies in areas where the geology is not exposed, and 2) to detect and trace extensions of known structures, especially the Little Salmon fault and other possible concealed structural features.

It was found that good correlation exists between the pattern of gravity values and large scale structural features in the area including the Little Salmon - North Spit fault system, the South Bay syncline, the trough located southwest of the Freshwater fault, and the Freshwater fault itself. Small but distinct anomalies were found associated with probable near surface juxtaposition of materials of differing density along the Table Bluff fault and the postulated Bay Entrance fault. These gravity anomalies appear to correlate with magnetic anomalies over the Table Bluff fault, and with magnetic, seismic reflection, and stratigraphic anomalies along the trend of the possible Bay Entrance fault.

Adequate data exist to permit construction of quantitative models for the structures associated with the measured pattern of gravity values in the Humboldt Bay - lower Eel River area. These data include information about average saturated bulk density values for Carlotta Formation claystone (2.0) and sandstone (2.1), for the lower units of the Wildcat Group (2.3) and for "basement" Yager Formation (2.4 to 2.6); also depths to and thicknesses of these units are known from drill hole information at several points in the surveyed area. However, because the primary purpose of the gravity study was the detection of faulting and 1) since faults are usually best indicated by a pronounced steepening of the gravity gradient in the vicinity of faulting, and 2) because of the availability of other geologic and geophysical data, it was considered adequate for the purposes of this investigation to use the gravity data qualitatively in conjunction with these other data. Because of the observed correspondence between anomalies in gravity values and known or suspected geologic structural features, it is believed to be unlikely that any significant structures cross the detailed profile lines other than the ones shown on the geologic maps presented with this report.

B-4. Bouguer Gravity Value Profiles.

C. Data from Seismic Reflection Surveys, Humboldt Bay and Offshore area.

1. Survey of Humboldt Bay by Alpine Geophysical Associates, Norwood, New Jersey, 1971.
2. Profile from the Wildcat offshore survey made from the R/V Oconostota, 1967, by Eli Silver.

C-1. Survey of Humboldt Bay by Alpine Geophysical Associates, Norwood, New Jersey, 1971.

C-1. Geophysical Survey in Humboldt Bay, California, Performed by Alpine Geophysical Associates, Norwood, New Jersey.

Introduction

A continuous seismic profile survey was carried out by Alpine Geophysical Associates, Inc. in Humboldt Bay for Pacific Gas and Electric Company during the period September 15 to September 20, 1971.

Seismic data were obtained using Alpine's continuous seismic profiler called the "Sparker". Navigation was provided by Towill, Inc. using their Hydroplotter system.

The sparker survey extended from central Arcata Bay, on the north to southern South Bay, on the south, a distance of 12 miles. The most detailed part of the survey, represented by the greatest density of traverse lines, was in an area of about 2 miles' length and 1 mile width, centered between the Bay entrance and the Buhne Point peninsula. Useful data were obtained from the survey in this area in the vicinity of the Buhne Spit shoal and from one traverse up the channel between the southern Eureka waterfront and the North Spit from the vicinity of Fairhaven south. Scattered data were obtained at a few other points in the surveyed area. In general, it appears that the sparker survey was effective only in places where younger bay filling deposits are thin or absent. Such places exist within the bay only along the major channels near the Bay entrance and over the recently eroded Buhne Spit shoal north of Buhne Point.

The traverse lines and survey points from the sparker survey are shown on the Alpine Geophysical Associates, Inc. Figures 1-A, 1-B, and 1-C. Examples of typical returns from various traverse segments and of anomalies in the sparker recordings are reproduced as Figures 2-A through 2-E.

Instrumentation

Profiler. The Alpine Sparker uses a high energy electric spark as the sound source. A portable five (5) KW generator provides the 110 volt AC to the power unit. This is transformed to 10,000 volts, rectified, and used to charge a capacitor for a maximum value of 200 joules. The capacitor is discharged through an air gap which can be keyed by the trigger circuit at a rate from eight seconds to four times per second.

The broad-band seismic signal is received at the pressure sensitive hydrophone array, amplified by Alpine's "505" pre-amplifier, filtered with active variable pass-band filters and recorded on a wet-type helix recorder.

Each revolution of the helix in the recorder triggers the sparker so that full scale on the 19-inch paper is variable from $\frac{1}{4}$ second to eight seconds.

Surveying. The Towill hydroplotter system makes use of a range and bearing technique from a known position.

A plane table is set up at the known position. The bearing arm on the table has a transit telescope mounted on top. A surveyor continuously tracks the vessel with the arm. The arm also has a screw controlled range point on its bearing line. This range point is mechanically connected to a master tellurometer where another surveyor continuously tracks the boat's range and feeds the distance to the plane table. A third operator plots the track points at stated time intervals and passes the identification information to the boat via radio.

Aboard the vessel, a fourth survey team member operates the remote tellurometer. The identifying fixes are marked and numbered directly on the seismic record.

Operations

The basic program was outlined at a meeting at Pacific Gas and Electric's offices in San Francisco, on Monday, September 13, 1971.

A boat was located and survey points spotted on September 14. The gear arrived in Eureka, California, on Wednesday, September 15, and was installed on the boat the same day. Final navigation arrangements were set up on Thursday morning and profiling commenced about noontime.

Fog was encountered each morning, lifting sufficiently between 11:00 and 12:00 to permit navigation. Profiling continued on each day of September 17, 18, 19, and 20. Field work was completed about 6:20 PM on September 20. All seismic profiles were accompanied by hydroplotter navigation except during Monday morning when some lines were re-run on topographic navigation before the fog lifted to permit hydroplotter visibility.

All lines in the South Bay area were run at least twice, once at low power and once at high power to assure both maximum penetration and resolution. The northern lines were run only once because of the better record quality in this area.

At the conclusion of the field work, a meeting was held in San Francisco on Tuesday, September 21, to discuss the survey results.

Record Quality

Record quality ranged from poor to fair. The better data were obtained using a relatively broad pass-band, from 200 Hz to 2000 Hz, with high power on the energy source and a $\frac{1}{2}$ second repetition rate.

Attempts were made to obtain data over the mud flats at high tide. These runs produced virtually no usable data. Apparently, the muds were aerated enough at low tide to produce an extremely high acoustic impedance match with the water body. This fact, together with the shallow water, allowed little to no energy penetration.

The best records were produced in the deep water channels. Penetration up to 600 feet was achieved although the average was about 300. Side reflections from the edge of the channels and from man-made structures, (jetties, wharves, etc.) were very apparent and, to some extent, detracted from record quality in the narrow channels.

Results and Interpretation

The results of the survey may be summarized as follows:

- The area of the Bay floor lying north and northwest of Buhne Point is underlain by a stratified section which has a predominant northerly component of dip. This structure probably corresponds to the southwest flank of the northwest trending Buhne Point syncline.

- Near the center of the gap between the North and South Spits, the dip appears to undergo several reversals, suggesting that two or more minor folds may be superimposed on the flank of the larger, north dipping structure.

- Anomalies in the recordings, generally consisting of zones of confused returns, sometimes with returns of differing character on opposite sides, occur at points along a west-northwest trend between King Salmon and the Bay entrance (sparker traverse points 364 and 753). Magnetic and gravity anomalies also occur along this trend. These sparker record anomalies are interpreted as possibly indicating a fault in the Carlotta Formation bedrock section.

- Other anomalies appear in the recordings from a point 600 feet northwest of Buhne Point (sparker traverse points 837 and 844), and from a point in the South Bay channel opposite King Salmon (traverse points 429-434). The anomaly from northwest of Buhne Point corresponds in location to a contact of bay fill deposits against the planed-off bedrock surface of the Buhne Spit shoal. This anomaly is interpreted as probably representing a local masking of returns from within the Carlotta Formation section by overlapping younger bay fill deposits. The anomaly from the channel opposite King Salmon may represent irregular channeling and backfill in the bay bottom. It is interpreted as probably not indicating a bedrock structure. There is no magnetic anomaly at the location of this anomaly in the sparker recording.

- The reach of the channel between the North Spit and the southern Eureka waterfront is underlain by an unbroken, gently south dipping section of strata. These strata probably represent the Hookton Formation, which is exposed in the low bluff back of the Eureka waterfront.

- Only a few scattered returns from the sub-bottom section were obtained from traverses in the South Bay and from Arcata Bay. This information was not adequate for determining the nature of structural features in the bedrock section.

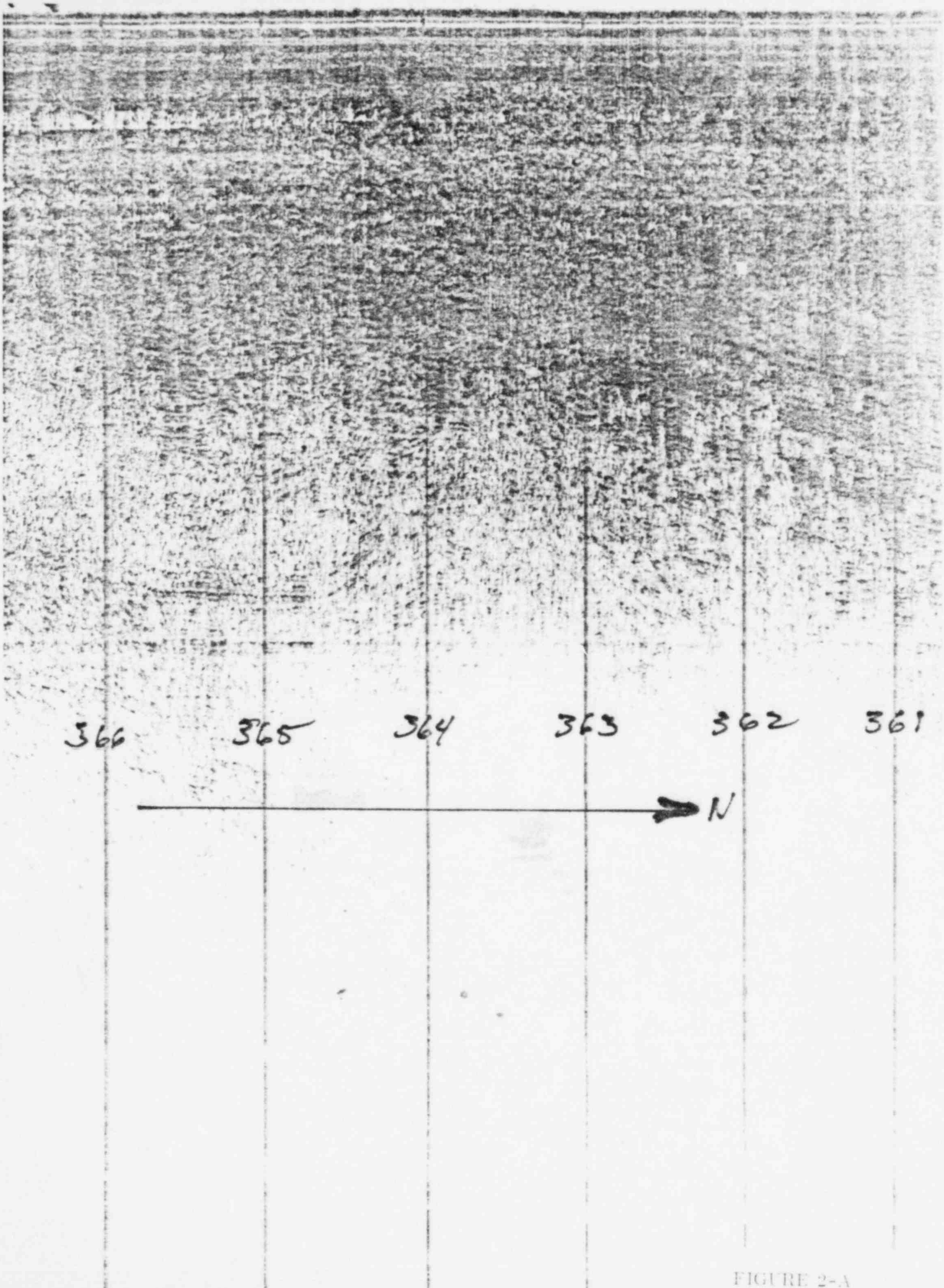


FIGURE 2-A

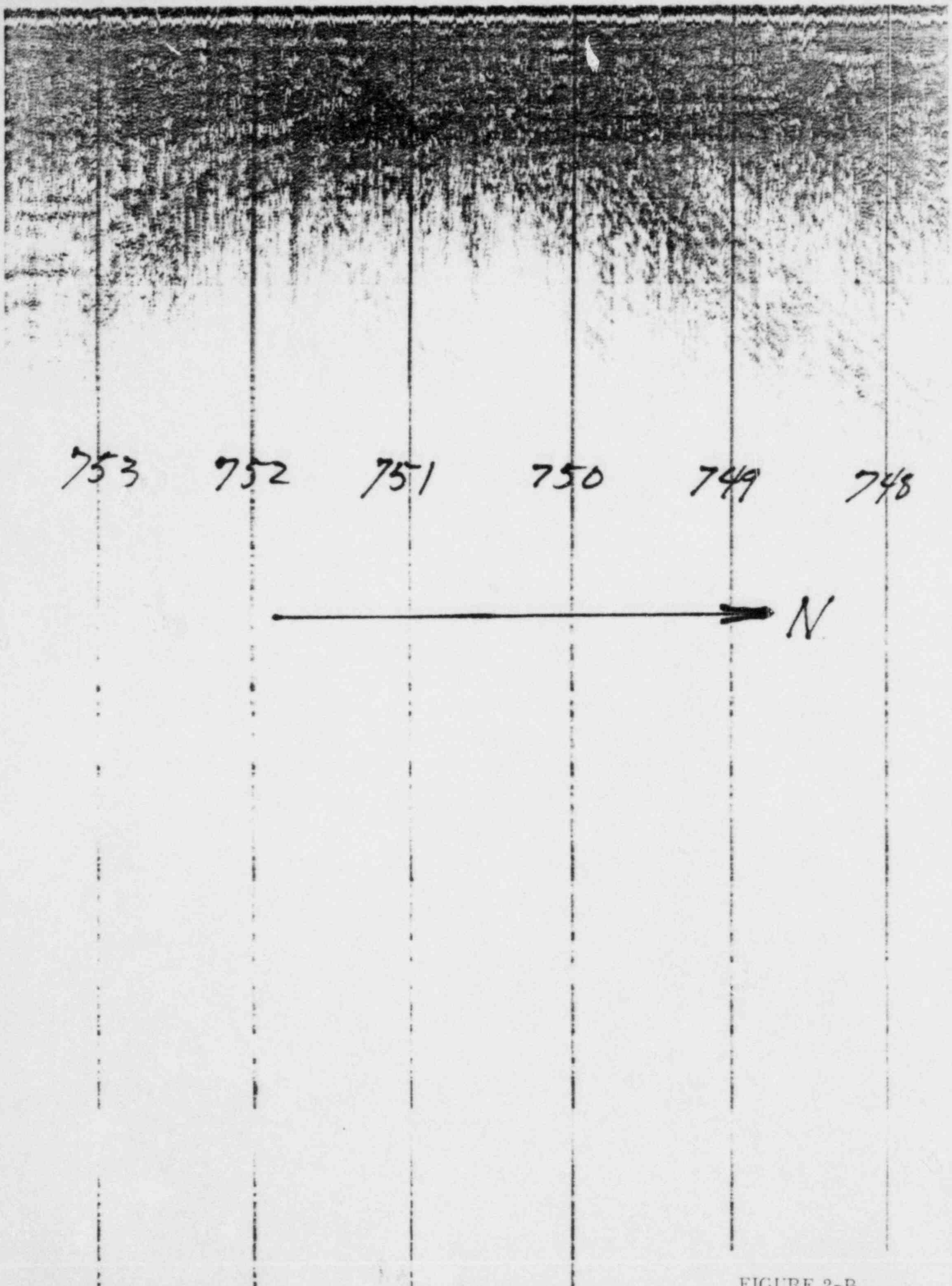


FIGURE 2-B

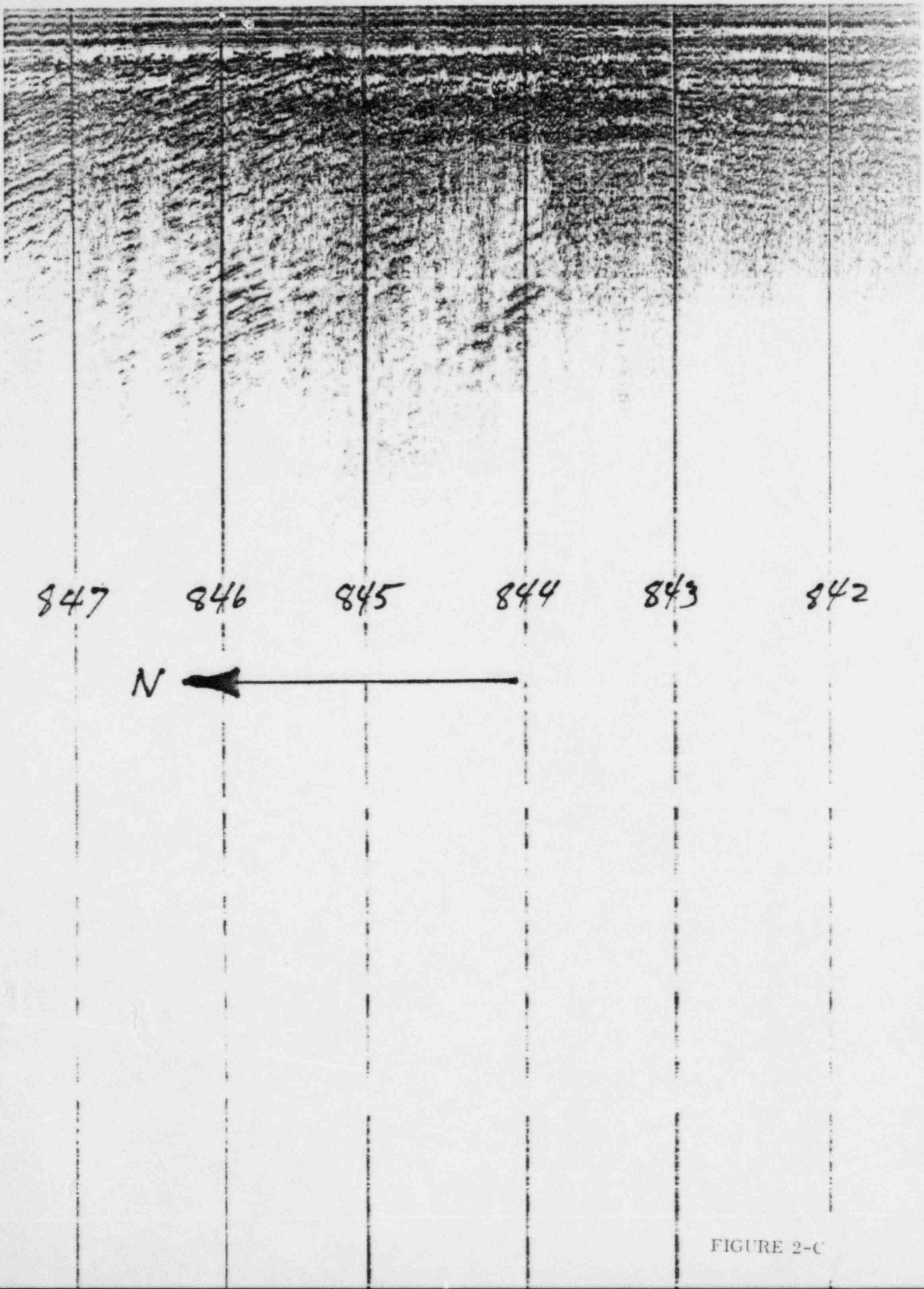


FIGURE 2-C

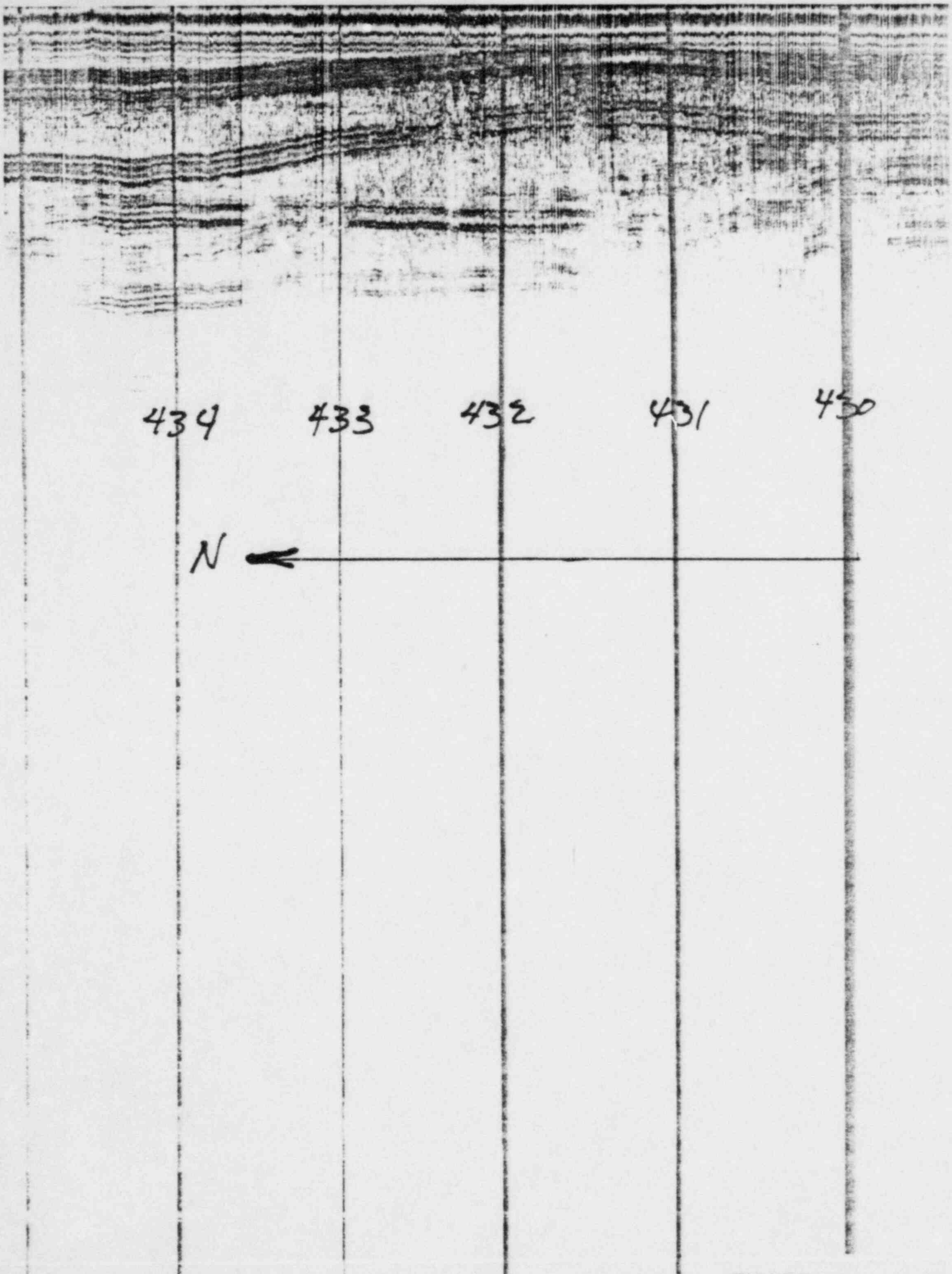


FIGURE 2-D

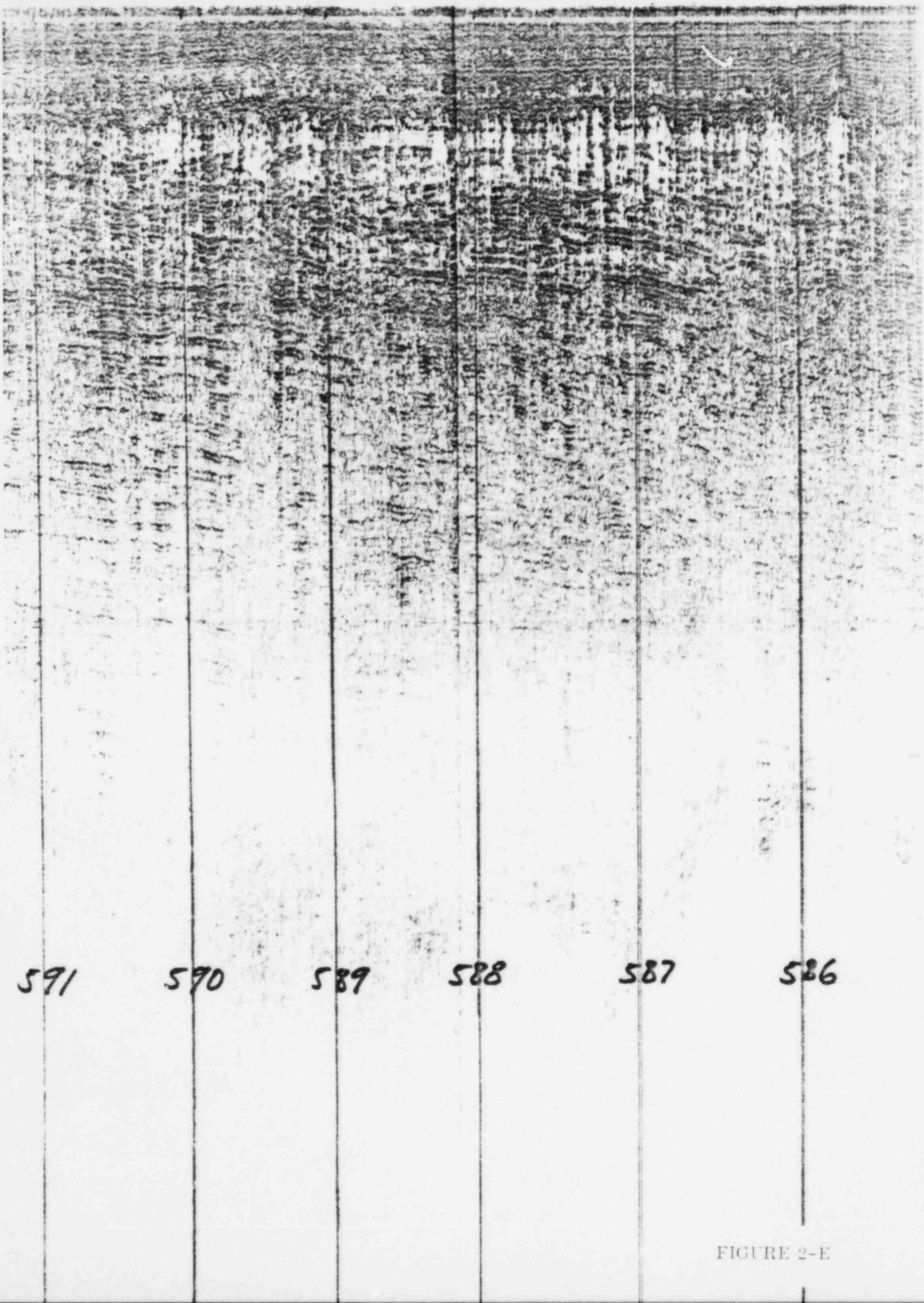


FIGURE 2-E

C-2. Data from the Wildcat offshore survey made from the R/V. Oconostota, 1967, by Eli Silver.

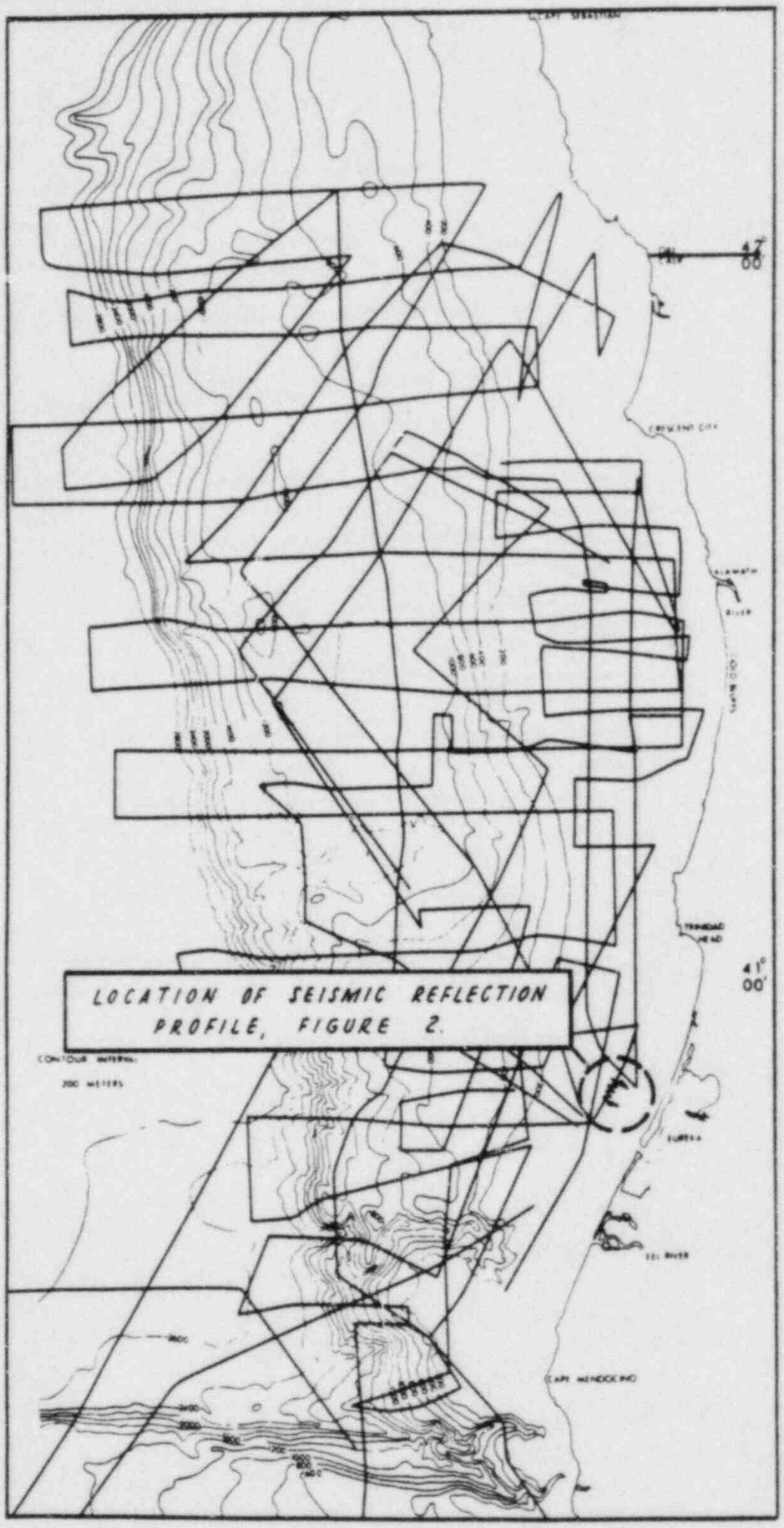
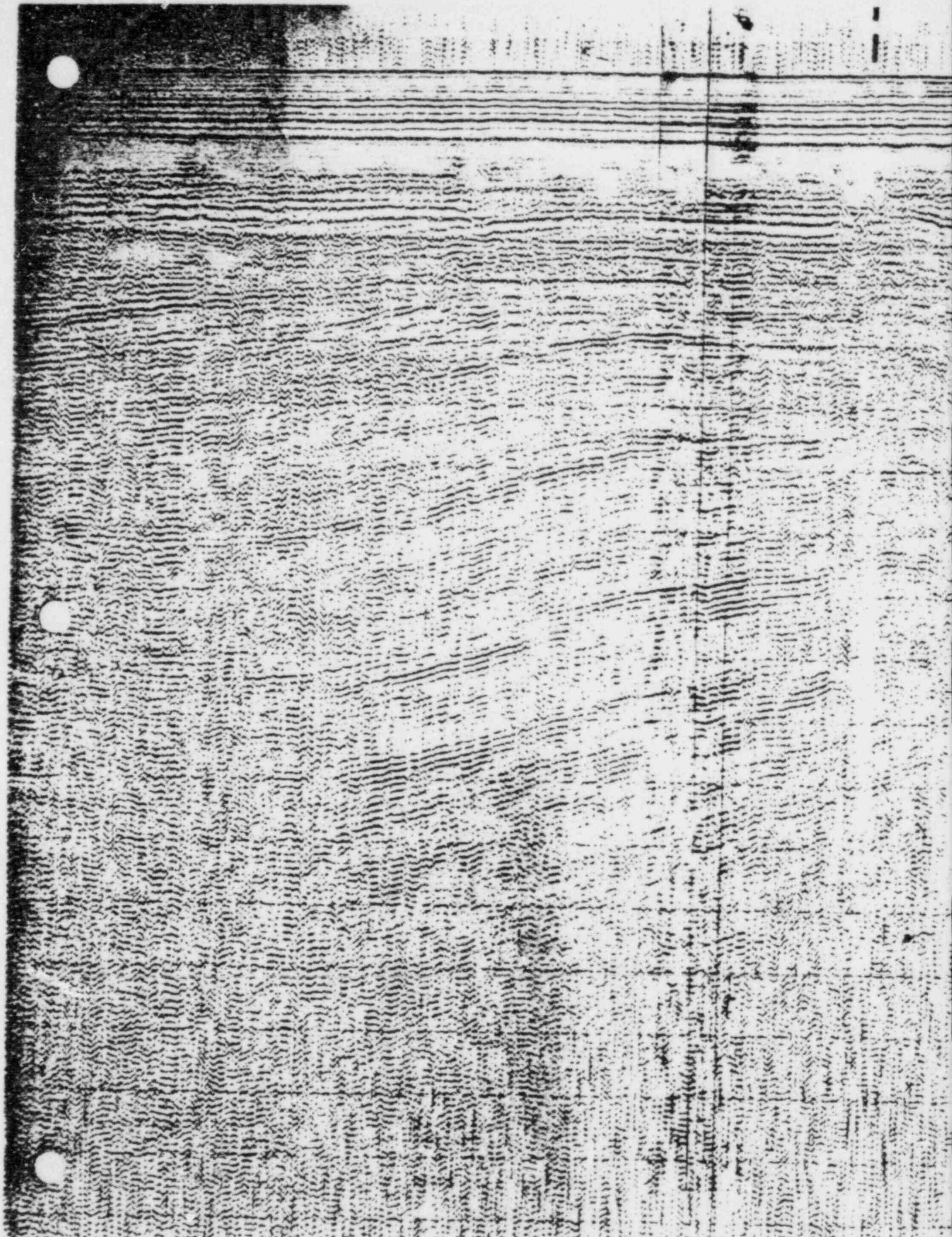
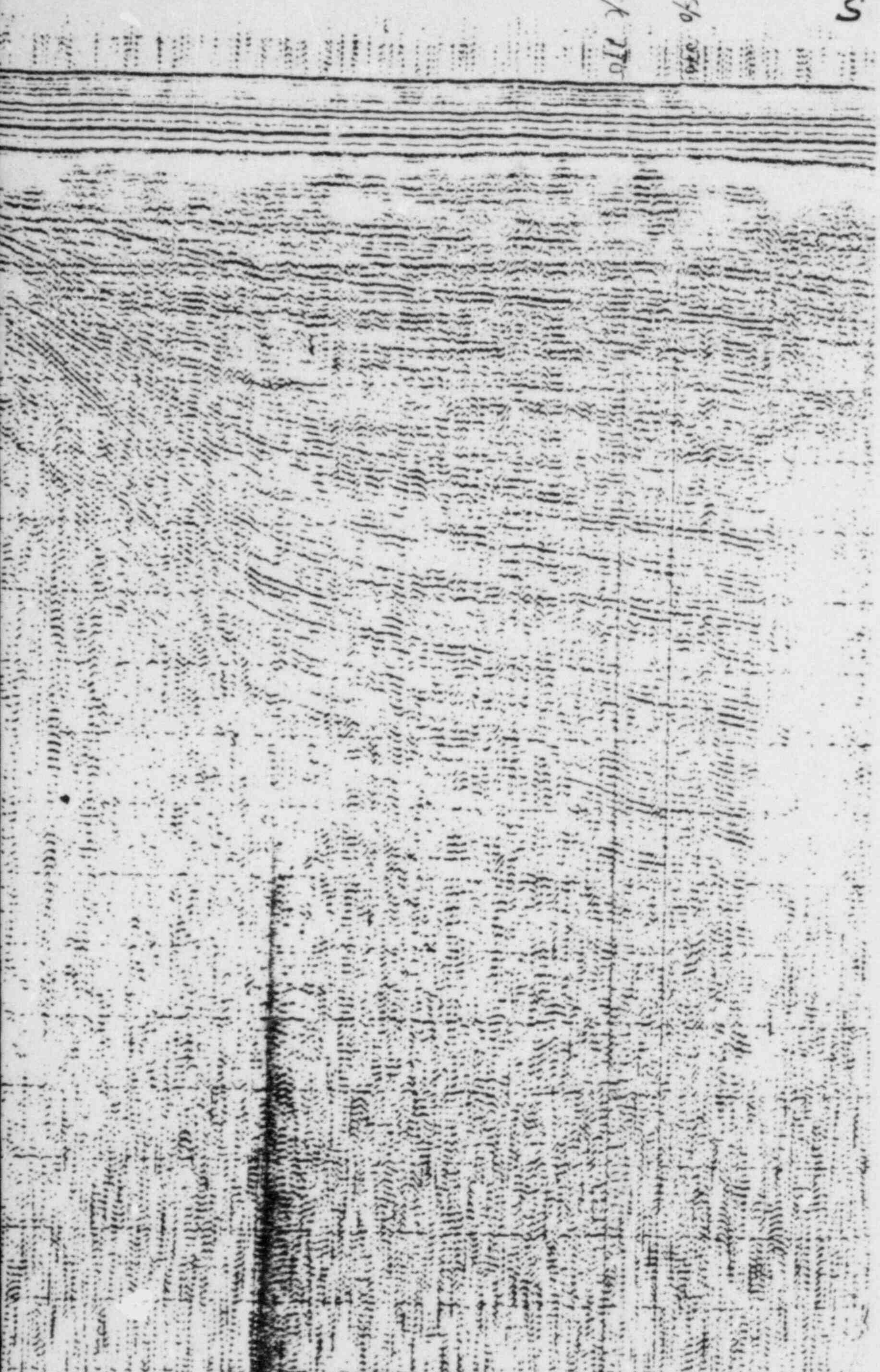


Figure 1. Track of the R/V *Oconostota* during August-September 1967, on *Wildcat*

FROM SILVER, (1971) TRANSITIONAL TECTONICS AND LATE CENOZOIC STRUCTURE OF THE CONTINENTAL MARGIN OFF NORTHERNMOST CALIFORNIA

GEOL. SOC. AMER. BULLETIN, VOL. 82, NO. 1





S
270
290

D. Paleontologic and Geologic data provided by Standard Oil Company of California, Western Operations, Inc. Exploration Department.

1. Paleontologic determinations of samples from the vicinity of Buhne Point and Fields Landing.

2. Geologic summary, Standard Oil Company Brainer No. 1 Well.

D-1. Paleontologic determinations of samples from the vicinity of Buhne Point and Fields Landing. Locations of samples are shown on Drawing No. 7.

Chevron

Standard Oil Company of California,
Western Operations, Inc.
320 Market Street, San Francisco, CA 94111

Exploration Department

April 28, 1972

Mr. Douglas H. Hamilton
Engineering Geologist
Earth Sciences Associates
701 Welch Road
Palo Alto, California 94304

Dear Mr. Hamilton:

I am sorry that analyzing the samples you left with us has taken so long, but as you may recall, we were, and still are, in the process of moving our Paleontology Lab; hence, the time delay.

Our Paleontologist has determined the following from the samples that you left with us:

Gray silty claystone carries:

Very common	Rotalia beccarri	
Very common	Elphidiella hannai	Composite sample from
Abundant	Elphidium hughesi	outcrops at Buhne Point (f BP)
Rare	Mollusk frags	and at the Freeway roadcut
Very rare	Radiolaria spp	1500 ft. N. of Fields Landing (f FL)
Scarce	Diatoms	

Depositional environment: Very shallow water marine

Age: These species are long ranging but in West Coast sequence are Pleistocene (generally assigned to Lower Pleistocene).

Based on the above, the shallow marine nature of the samples suggest that it should be placed within the Carlotta formation. Such an assignment would agree with the published mapping of B. A. Ogle.

Mr. Rod Huppi has advised that he has passed these data on to you when you phoned him earlier this week.

If we can be of any further help, please advise.

Very truly yours,

D. L. Zieglar

RECEIVED
MAY 1 1972

Chevron

Standard Oil Company of California,
Western Operations, Inc.
320 Market Street, San Francisco, CA 94111

Exploration Department

July 13, 1972

Paleontologic Summary
P. G. & E. Reactor
Humboldt Bay Area, California

Mr. Douglas H. Hamilton
Engineering Geologist
Earth Sciences Associates
701 Welch Road
Palo Alto, California 94304

Dear Mr. Hamilton:

Attached is a summary of the paleontology from the samples you recently left with us.

The Pleistocene to Recent material is probably representative of the Carlotta formation in the area. Outcrop samples No. 2 and possibly No. 4 are interpreted as being deep water sediments and, thus, may be from the Rio Dell formation.

We would appreciate it if you would furnish us with coordinates for the samples, or with a map showing the location where you collected these samples, so that we may fill out our locality cards properly and be able to retrieve these data from our computer file.

I hope these determinations will prove useful to you.

Very truly yours,

D. L. ZIEGLAR

Attachment

JUL 14 1972

MEMORANDUM

San Francisco, CA
July 6, 1972

PALEONTOLOGIC SUMMARY
CORES AND OUTCROP SAMPLES (S.O. Loc 28542)
P. G. & E. REACTOR
HUMBOLDT BAY AREA

MR. D. L. ZIEGLAR

H-1-J-24 (Depth 240 feet)

Abundant	Elphidium spp. (E. hughesi, E. granulosum, E. sp.)
Very Rare	Rotalia beccarii
Rare	Mollusk frags.

H-2-J-3 (Depth 18 feet)

Scarce	Elphidium granulosum
Rare	Radiolaria
Rare	Sponge spicules
Scarce	Fish frags.

H-5-J-9 (Depth 83 feet)

Abundant	Elphidium granulosum, E. hughesi
Very Rare	Elphidiella hannai
Very Rare	Mollusk frags.

H-6-J-13 (Depth 257 feet)

Abundant	Elphidiella hannai
Very Common	Elphidium granulosum
Rare	Rotalia beccarii
Rare	Eponides frigidus calidus
Very Rare	Ostracods
Very Rare	Mollusk frags.

H-7-J-4 (Depth 63 feet)

Abundant	Elphidiella hannai
Common	Elphidium granulosum
Very Rare	Ostracods

H-8-J-4 (Depth 53 feet)

Very Rare	Elphidium hughesi, E. granulosum

H-9-J-7 (Depth 118 feet)

Barren

H-10-J-7 (Depth 142 feet)

Common	Mollusk frags.

Outcrop #1 (Sample f -1)

One Radiolarian (reworked?)

Outcrop #2 (Sample f -2)

Rare	Cassidulina cushmani
Scarce	Frondicularia advena
Common	Urigerina hollicki
Rare	Urigerina peregrina
Common	Pulvinulinella pacifica
Rare	Eponides frigidus callidus
Common	Globigerina spp.
Scarce	Bolivina subadvena serrata
Scarce	Nonionella miocenica var.
Rare	Radiolaria spp.

Outcrop #3 (Sample f -3)

Barren

Outcrop #4 (Sample f -4)

One Pulvinulinella pacifica
Very Rare Radiolaria spp.

Depositional environment: All fossiliferous samples in "H" sequence are from shallow water marine or brackish deposits. Outcrop samples #2 and (probably) #4 are from moderately deep marine waters, probably Upper Bathyal.

Age:

"H" sequence: Pleistocene or Recent
Outcrop #2 and #4: Probably Upper Pliocene

G. E. MOLANDER

GEM/jmh

D-2. Geologic Summary, Standard Oil Company Brauner No. 1 Well.

GEOLOGIC SUMMARY - S. O. CO. "BRAUNER" #1

Location:	1050'N, 1050'W of SE corner, Sec. 20 4N/1W HBM
Elevation (D.F.):	510'
Total Depth:	7152

Lithologic Summary:

0 - 200'	multicolored coarse sand and conglomerate
200 - 260'	predominantly sand
260 - 1780'	gray-gray green claystone becoming sandy below 1650'
1780-3490'	gray-white sands, coarse and conglomeratic at top, grading to fine at the base.
3490-6440'	predominantly gray claystone and siltstone with some fine gray sands.
6440-7152'	gray claystone and siltstone with gray-white, fine-medium grained, calcite cemented sands.

Paleo Summary:

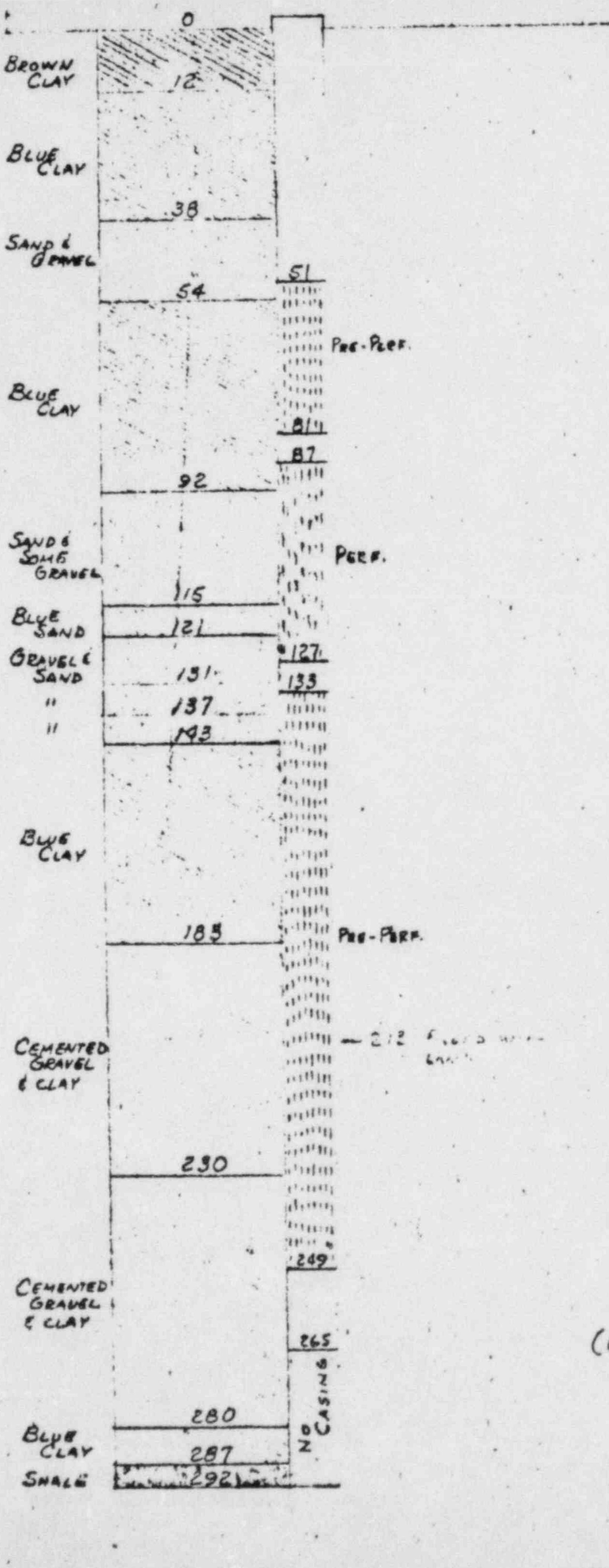
230-1780	Early Pliocene - Repettian stage
1780-2620	Possibly non-marine to brackish water; first megafossils noted at 2520
2620-4800	Late Pliocene - Upper and Middle Pico
4800-5130	" " - Lower Pico and/or Repetto
5100-6200	Early Pliocene - Repettian stage

Fault Evidence:

Thrust fault at 1780' indicated by anomalous position of Lower Pliocene Eel River Formation over Lower Pleistocene - Upper Pliocene Carlotta and Scotia Bluffs formations. Dipmeter results indicate southwesterly dips above the fault and northwest to northeast dips below the fault.

E. Logs of Wells.

Locations of wells are indicated by name, on Drawing No. 7. Well logs are placed in order of their location, going from north to south.



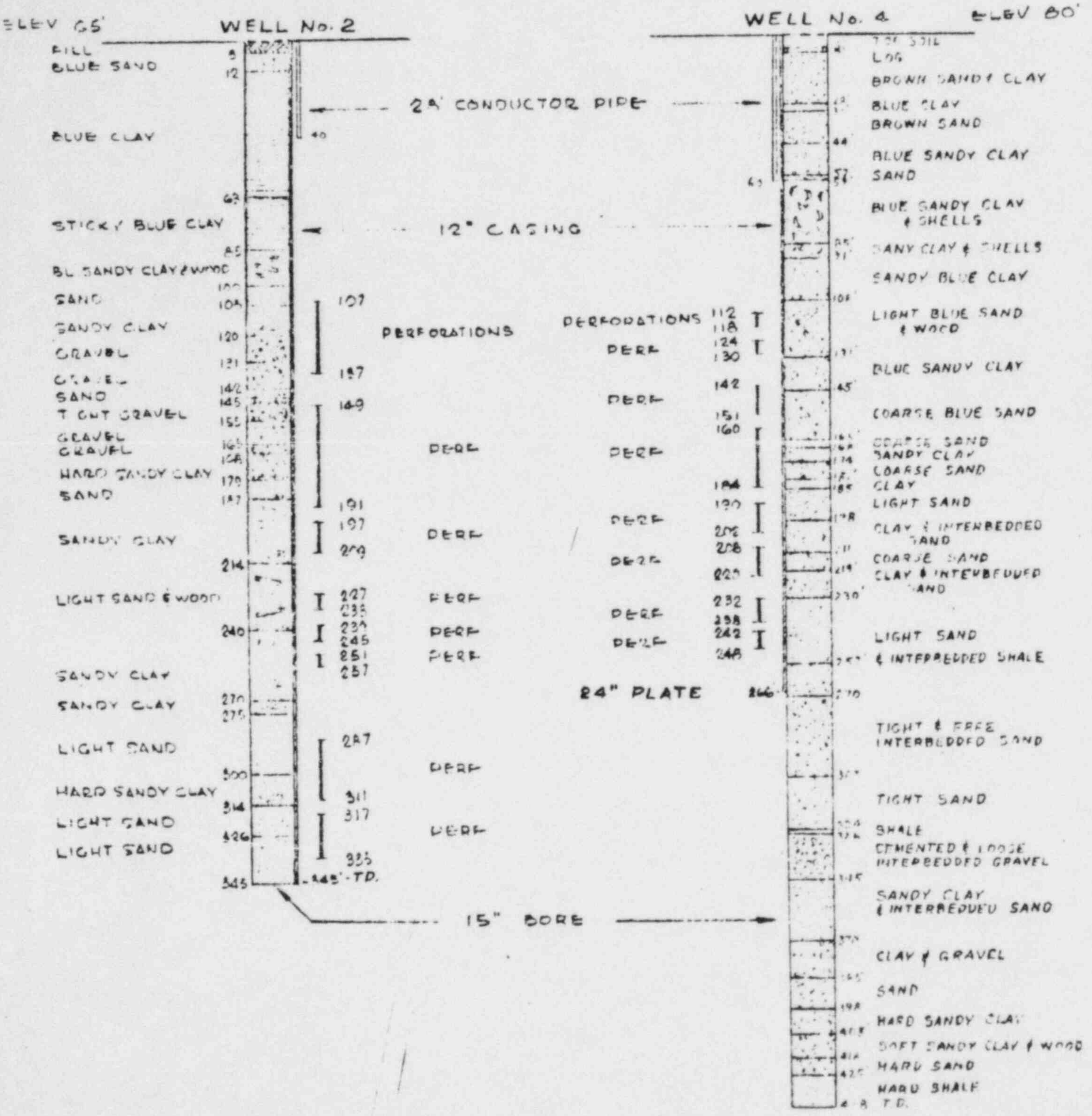
[illegible]

Pre-perf
3/32" × 1¼" perforations
or 1⅞" /lin.ft.

Perf.
Olson "Mills" Knife
8" knife blocked to 12"
3 runs @ 2' centers

Well No. 1
(Campton Rd Well)

Humboldt C.S.D.
Job 2649
1-4-55



BY JJ
DATE 9-10-55
VERTICAL SCALE 1" = 60'
JOB NO.

HUMBOLDT COMMUNITY SERVICES DISTRICT
WELL Nos 2 & 4
LITHOLOGICAL LOG

DEAN S. KINGMAN
CONSULTING ENGINEER
PALO ALTO, CALIFORNIA

Humboldt Community Services District
4135 Williams Ave.
Eureka, Calif.

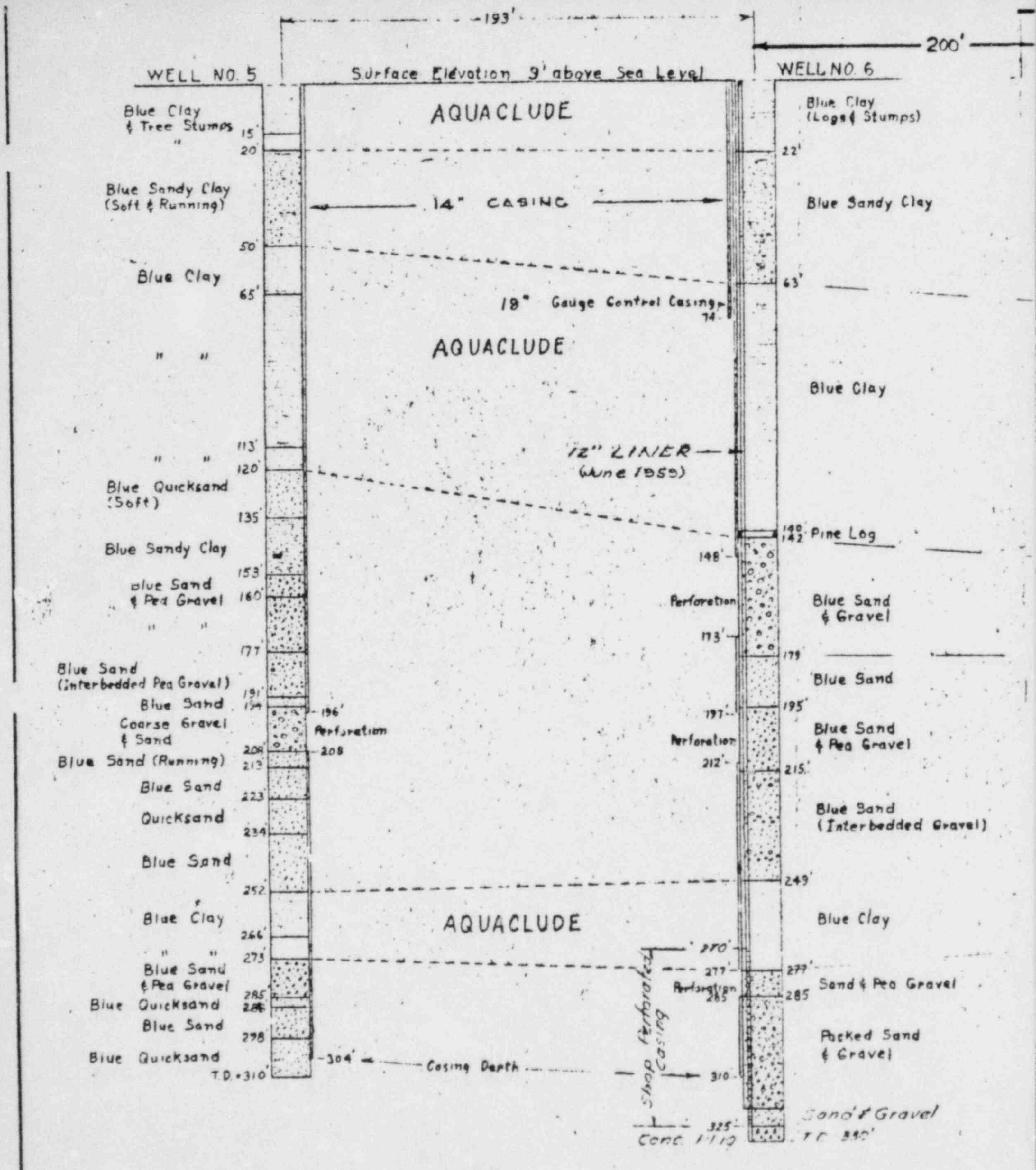
LOG OF TEST WELL No. 3

11-23-54 Started   11-26-54 Completed

From	To.	Formation
0	2	Top soil
2	8	Brown clay
8	26	Brown sand & streaks of Clay
26	32	Brown clay
32	50	Blue clay
50	125	Blue clay & shell
125	135	Light blue clay
135	140	Coarse blue sand and gravel
140	160	Light blue clay
160	220	Cemmented blue gravel
220	240	Blue clay
240	258	Cemmented blue gravel
258	300	Light blue clay
300	408	Light blue clay

Olsen Implement Co. Inc.

Drilled by W. A. Younger



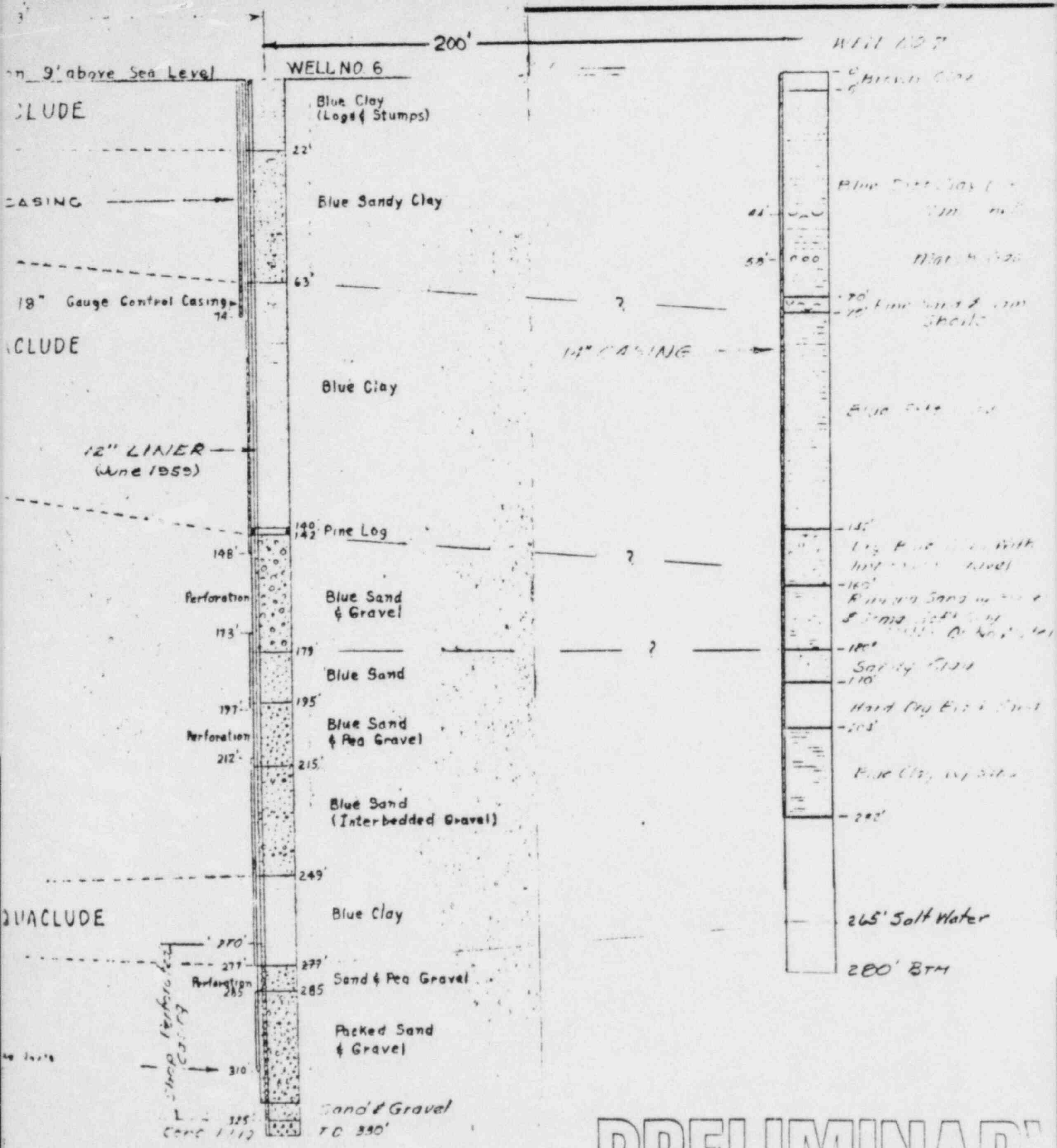
Rev 6-26-59

By J.J.J.
Date 8-31-55
VERTICAL SCALE 1"=40'
JOB NO. 2649

HUMBOLDT COMMUNITY SERVICES DISTRICT
WELLS No 5 & 6
LITHOLOGICAL LOG & CORRELATION CHART

DEAN S. KINGMAN
CONSULTING ENGINEER
PALO ALTO, CALIFORNIA

3.14-0



PRELIMINARY

... DISTRICT
... G
... CHART

DEAN S. KINGMAN
CONSULTING ENGINEER
PALO ALTO, CALIFORNIA

...ERVICES DISTRICT
7
LOG

DEAN S. KINGMAN
CONSULTING ENGINEER
PALO ALTO, CALIFORNIA

9-068
(December 1949)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

No. 4N/1W-0J1

OTHER NOS.

WELL LOG

52

State California County Humboldt Subarea

Owner Dr. Stone

Location Spruce Pt.

Drilled by Dougherty Address Hydesville

Date Casing diam. Land-surf. alt.

Source of data B. A. Ogle

(Enter type of well, perforations, yield, and drawdown at end of log)

CORRELATION	MATERIAL	THICKNESS (feet)	DEPTH (feet)
	Soil	1	0-1
	Yellow sandy clay	7	1-8
	Gray mud	6	8-14
	Yellow sandy clay	11	14-25
	Blue sandy clay	104	25-129
	Sand (with water)	6	129-135
	Blue sandy clay	10	135-145
	Coarse gravel	3	145-148
	Blue clay	5	148-153
	Coarse gravel	3	153-156
	Blue clay	74	156-230
	Sandstone	5	230-235
	Blue sandy clay and hard sand	28	235-263
	Hard stone	12	263-275
	Coarse gravel	8	275-283
	Apparently sanded up		

Sheet of

59

4N/1W-8

4N/1W-8J1

Dr. Stone well (ne¼se¼ sec. 8, 4N1W, near Bucksport School)
(1950?)

0-1	soil	
1-8	yellow sandy clay	Qh
8-14	gray mud	Qh
14-25	yellow sandy clay	Qh
25-129	blue sandy clay	Qh or QTc
129-135	sand with water	
135-145	blue sandy clay	
145-148	coarse gravel	
148-153	blue clay	
153-156	coarse gravel	
156-230	blue clay	
230-235	sandstone	probably QTc-Tsb
235-275	hard stone?	
275-283	coarse gravel	

Well produced some water from upper part but there has been trouble with "sanding up."

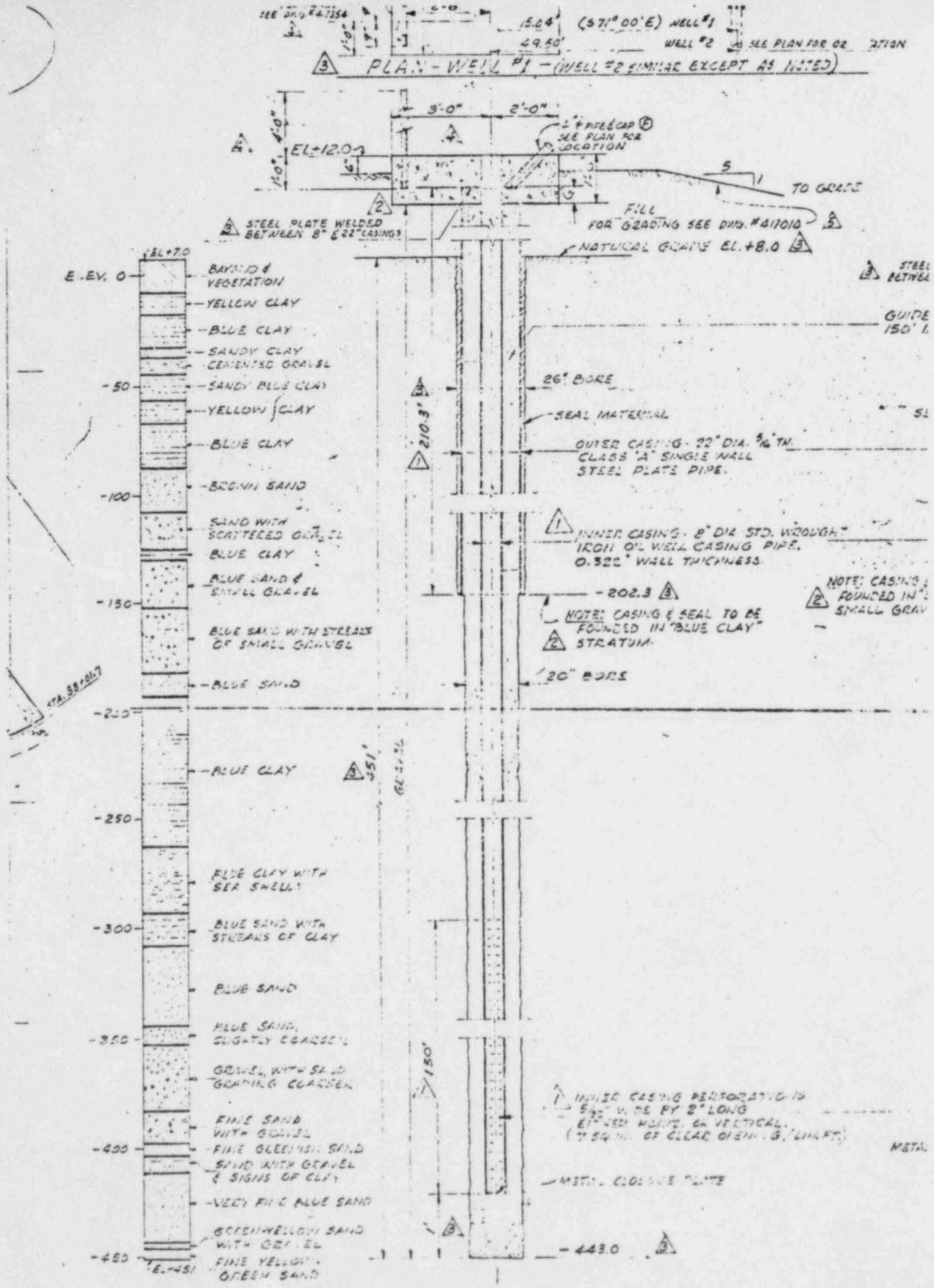
3N/2W-32N1

Cennick well #2 (sw¼se¼ sec. 32, 3N2W, drilled 1950)
sw¼

Qal alluvium

0-10	soil	
10-14	heavy blue clay	pre-Carlotta material, some appears to be very young; part may be Hookton.
30-35	water carrying sand	
35-40	gray sandy clay	
40-63	gravel (salt water)	
60-80	gray sand	
80-88	gravel	top QTc
88-142	gray sand	
142-202	blue sandy mud-like clay...	claystone-siltstone, one large *Schizothaerus* fragment
202-235	gray sand	
230-265	cemented gravel, fresh water artesian to the surface at the rate of approximately 200-300 gal./min. from this gravel. On pump produced 500-700 gal./min.	

From this well and others in the vicinity it has been shown that the upper 100 feet of sediments contain some salt water-bearing strata. This apparently encroaches from the sea to the west. The lower gravels or conglomerates are part of the Carlotta beds which dip north into the Eel River syncline. Being interbedded with claystones they are confined aquifers and are a great potential source of water for the valley. It is imperative that the upper strata be shut off in all wells penetrating this artesian aquifer in order to prevent contamination. (A few oyster fragments were found in the cuttings from the upper part of the hole; position not certain.)

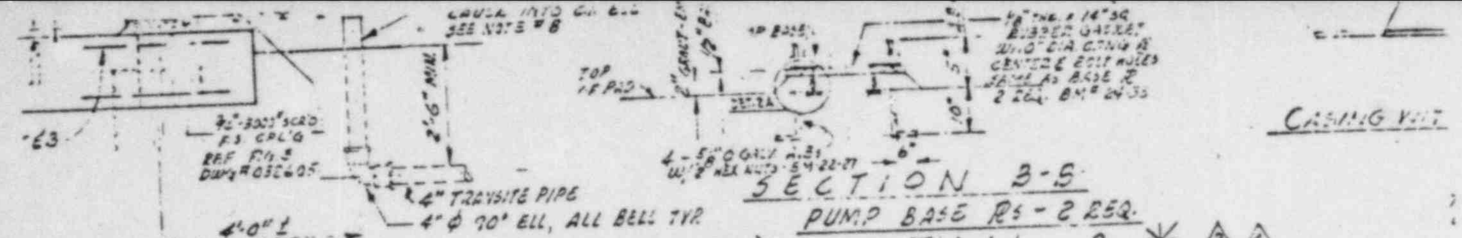


TEST WELL #1
DRILLING LOG

SCALE: 1" = 40'

WELL NO. 1

SCALE: 3/8" = 1'0"

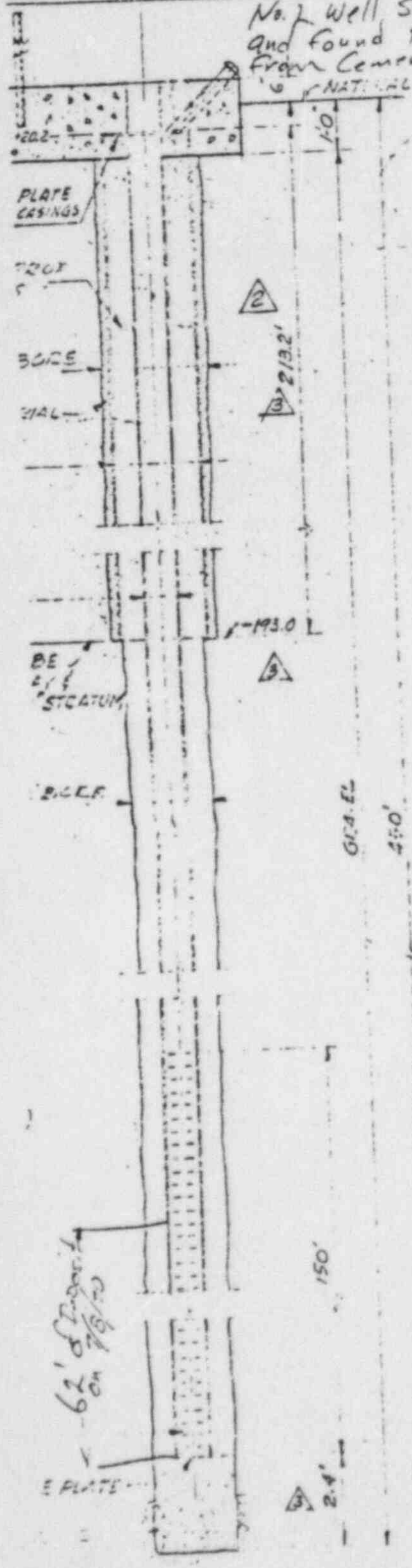


SECTION B-B
PUMP BASE R's - 2 REQ.

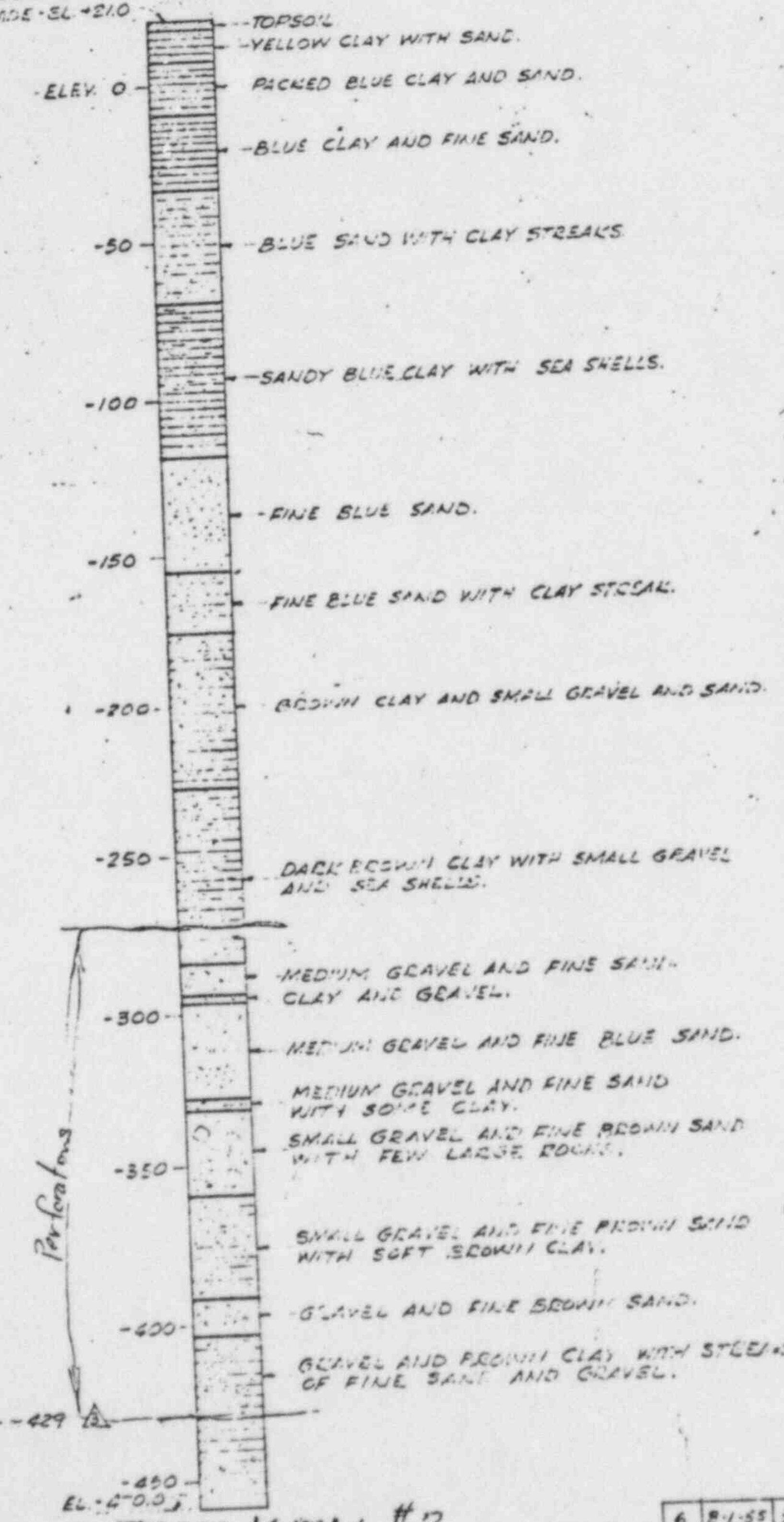
EVATION-WELL #2-(WELL #1 SIMILAR EXCEPT AS NOTED)

DETAIL-2 * △3 △4
SCALE 3/4" = 1'-0"

No. 2 Well Sounded on 7/8/70
and found to be 386 feet Deep
from Cement Base. RSC



WELL NO. 2
SCALE: 3/4" = 1'-0"



TEST WELL #2
DRILLING LOG
SCALE: 1" = 35'

AUTO

△3

1	4" Φ CLASS I
2	6" Φ "
3	6" - 90° C.I.
4	6" - 45° "
5	6" - 22 1/2° "
6	6" × 6" × 4" C.
7	6" × 4" [illegible]
8	4" Φ - 90° C.
9	4" - 45° "
10	4" - [illegible] "
11	4" Φ - [illegible]
12	4" Φ 33# S.
13	4" Φ 153# [illegible]
14	4" NL 43
15	4" NL 47
16	4" Φ SCH.
17	3/4" - 3000#
18	PRESSURE
19	3/4" × 1/2" [illegible]
20	1/2" CRISFIX
21	1/2" NL 44
22	1/2" - 300#
23	1/2" SCH. 4

△4

8. ALL BURIED [illegible] MINIMUM OF [illegible] AND [illegible] FIRST CAS[illegible] OF 2 HOURS. CAUTION - [illegible] APPLIED WI[illegible] OF SECOND [illegible]

9. FOR LAYING [illegible] WELL #1, R

6	8-1-55	[illegible]
5	6-[illegible]	[illegible]
3	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

H.M.Horton, Geologist, P.O.Box 942, Eureka, Calif.

7 3
16
16

WALTER EICH No.1 FEE   Humboldt County.

Section 16, T-4N- R 1 W
Location : Approx 500' E and 175' N of Southwest corner of section.
Elevation: Approx 230' (USGS Topog)   Drilled with rotary eq'pt made by
Total Depth: 779 D and A   operator.
Drilled 3½ hole, took 1" cores.

Spudded June 1, 1935.

LOG AND RECORD , copied from Mr. Eich's original log book by H.M.H 6/2/44.

0-42 Red brown sand and buchshot gravel
-51 Sandstone
-53 yellow clay
-75 Fine brown sand
-78 Yellow Clay
-82 Rock and yellow shale; 1" gas pocket
-84 Rocks and gravel
-92 Brown sand
-94 Rock , gravel and flint
-103 Sandstone
-105 Rock and gravel
-111 Yellow shale and fine gravel
-121 Sandstone
-122 Rock and gravel
-130 Yellow shale
-143 Sandy brown shale
-145 Rock, boulders (shot hole to move)
-153 Yellow brown shale
-171 " " "
- 177 Dark blue shale, greasy looking ; slight color with ether.
-178 CORE: Brown buckshot sand , wet with oil
-185 Hard Coarse sand and yellow clay
-198 Hard brwwn sandy shale with small gravel
-216 Brown sand and shale with fine sand
-225 Fine sand shale, easy drilling
-247 Hard S.S , brown in color, hard drilling. (Aug.25, '35)
-266 Hard S.S.
-269 Rock and ss
-271 Very hard ss
-278 Hard ss. Hit big boulder -shot hole
-280
-286 Gravel and rock, soft
--295 Small gravel and brown shale, foam of gas (shot hole at 296)
-329 Fine nrown sand
-331 CORED; Blue shale
-335 Blue -brown sand and shale
-356 Brown sand
-365 ss and boulders
-376 Hard brown ss. Hit blue shale at 376'
-378 Shale turned to dark brown, with some sand , cut oil

-382 Hard brown shale, heavy cut of oil
-384 San and Shale, brown-gray
-386 Oil sand
-391 Interbedded layers of sand and shale
-393 CORED : Oil sand 53.5 gravity
-394 Brown gray shale
-397 Oil sand , gas (3½ feet)
-399 Very hard blue shale, light cut of oil
-403 Fine rock and brown shale
-408 Gray shale
-411
-413 Gray shale, light cut of oil
-423 Dark shale, black or blue to gray
-431 Gray shale, soft. Gas and oil on sump
" to 435 CORE: Gray shale; heavy cut of oil
-439 CORED: Shale, dark blue and gray, with white spots
-448 CORED: Gray Shale ; heavy cut of oil 12% cut
-463 Blue - Black shale
-475 Brown shale, greenish, heavy cut of oil
-505 " " " ; cut of oil, 37.5 degrees gravity
-526 " " " ; " " " . At 526- 46 (?) heavy gas.
-547 Brown , dark shale. Oil 37.5 gravity
-569 Dark brown shale, some fine rocks. Heavy cut of oil
-605
-619 Black shale. Oil 47.3 gravity
-633 Very dark sticky shale. 46.2 gravity oil
-649 Darkbrown-gray shale. Test showed kerosene content. Black paraffin chunks floating, size of apple seeds.
-671
-673 Black- blue shale
-694 Gray shale, light cut of oil. Kxxixx (H.M.H. saw bit sample from 679 ;gray siltstone bearing numerous scattered large sand grains or small pebble -granules)
-716 Gray shale, light cut of oil
-720 Gray shale(silt , becomes fine sand) , extra heavy cut of black oil
-727 Gray shale, light cut of oil
-747 Gray- black shale, with silt
-779 Bluish-gray silt , very light cut of oil. Micaceous siltstone at end of hole. Strong gas odor in formation.
At 755', CORE: (HMH examined sample: Gray compact marine siltstone, mostly coarse-grained , some fine-grained , with numerous hyaline FORAMS, well preserved definite DIATOMS) HMH got sample...((Note that H.M.Horton made his own observations.)

Total Depth: 779'

These showings, with percentages and gravities, listed on the above logx , are based on the mhxxxxkxx,determination and analysis of Robert Duffy, then chemist for Skinner -Duprey Drug Co., Eureka, now believed to be in San Jose. (1944)

Mr. Eich drilled a total of four wells. However, he doent have the records of the other wells at hand.

H. M. HORTON

Number 2 Fee: Located right behind his house, about 200' west of #1. Estimated elevation is 325', and total depth about 500', junked.
Number 3 Fee: This well, on which a small derrick is still standing, is in Section 21, 4N-1W, about 800'E and 150'S of the NW cor of the section, but only a few hundred feet from the others he drilled. It's elevation is estimated to be about 260', and he states it was drilled to about 1430' total depth. He states that this well did not correlate with the others in that, at 400' this one encountered blue shale and continued in it, without a break, to its total depth.
Number 4 Fee: Located approximately between #1 and #2, it was carried only to about 463'. Its elevation would be about 275', estimated.

No logs can now be found by Mr. Eich on any of the wells except on Number 1, as given above.

TRIPLICATE
Retain this copy

WATER WELL DRILLERS REPORT

(Sections 7079, 7080, 7081, 7082, Water Code)

THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES

Do Not Fill In

№ 18954

State Well No.

Other Well No.

(1) OWNER:

Name [illegible] [illegible]icultural Corp
Address P. O. Box [illegible]5
[illegible], [illegible]

(2) LOCATION OF WELL:

County [illegible]oldt Owner's number, if any
Township, Range, and Section
Distance from cities, roads, railroads, etc. [illegible] Corporation
[illegible] Landing, Eureka, Calif.

(3) TYPE OF WORK (check):

New Well ☒ Deepening ☐ Reconditioning ☐ Destroying ☐
If destruction, describe material and procedure in Item 11.

(4) PROPOSED USE (check):

Domestic ☐ Industrial ☒ Municipal ☐
Irrigation ☐ Test Well ☐ Other ☐

(5) EQUIPMENT:

Rotary ☒
Cable ☐
Other ☐

(6) CASING INSTALLED:

STEEL: SINGLE ☐ DOUBLE ☒ OTHER:

From ft.	To ft.	Diam.	Gage or Wall	If gravel packed: Diameter of Bore	From ft.	To ft.
4[illegible]	445	6	13[illegible]		[illegible]one	

Size of shoe or well ring [illegible] Size of gravel
Describe joints [illegible]

(7) PERFORATIONS OR SCREEN:

Type of perforation or name of screen [illegible] 30'6"

From ft.	To ft.	Perf. per row	Rows per ft.	Size in. x in.
[illegible]	[illegible]			
3[illegible]	4[illegible]			
	[illegible]			

(8) CONSTRUCTION:

Was a surface sanitary seal provided? Yes ☐ No ☐ To what depth ft.
Were any strata sealed against pollution? Yes ☐ No ☐ If yes, note depth of strata
From ft. to ft.
From ft. to ft.
Method of sealing

(9) WATER LEVELS:

Depth at which water was first found, if known ft.
Standing level before perforating, if known ft.
Standing level after perforating and developing ft.

(10) WELL TESTS:

Was pump test made? Yes ☐ No ☐ If yes, by whom?
Yield: gal./min. with ft. drawdown after hrs.
Temperature of water Was a chemical analysis made? Yes ☐ No ☐
Was electric log made of well? Yes ☐ No ☒ If yes, attach copy

(11) WELL LOG:

Total depth [illegible]5 ft. Depth of completed well [illegible]45 ft.
Formation: Describe by color, character, size of material, and structure

Formation	ft. to	ft.
Sand	1	[illegible]
Blue Clay	[illegible]	[illegible]
Blue Sand	1[illegible]	110
Blue Sand-Silt	110	1[illegible]
Blue Clay	1[illegible]	2[illegible]
Bl. Cl[illegible] Grav	2[illegible]	2[illegible]5
Gravel	205	21[illegible]
Bl. Cl[illegible] & Grav	210	27[illegible]
Blue Clay	270	295
Blue Sand	295	310
Bl Cement Grav.	310	325
Yellow Sand	325	3[illegible]5
[illegible] Grav.	3[illegible]	410
Yellow Sand	410	415
Blue Clay	415	465
Blue Clay	465	475
Blue Sand-Clay-Gravel	475	525
Blue Sand hard streaks	525	60[illegible]
Bl. Sand & Grav	60[illegible]	650
Fine Grav & Blue Sand	650	810
Hard Blue Cement Gravel	810	903
Blue Shale Hard	[illegible]3	[illegible]5

Work started [illegible] 19 Completed [illegible] 19

WELL DRILLER'S STATEMENT:

This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME [illegible]
(Person, firm, or corporation) (Typed or printed)
Address [illegible] Co.
[illegible]

[SIGNED]
(Well Driller)
License No. [illegible] Dated 5-2[illegible]-69, 19

SKETCH LOCATION OF WELL ON REVERSE SIDE

Well #2 Reed Jr. College

Aug 1966

10 - 40	Sandy clay & course sand	
40 - 50	Birds eye gravel - "good"	perf. ✓
50 - 60	Coarse sand & clay blue	
60 - 70	" " " "	
70 - 80	" " " "	
80 - 90	Fine gravel 3/16"	Perf. ✓
90 - 100	Blue clay no gravel	
100 - 110	" " some sand, coarse	
110 - 120	Blue Clay " " , "	
120 - 130	" " "	
130 - 140	" " very little sand	
140 - 150	" " Better sand	
150 - 160	" " some "	
160 - 170	" " " "	
170 - 180	" " Fine "	
180 - 190	" " ______	
190 - 200	" " & Coarse sand	
200 - 210	" " & fine sand	
210 - 220	" " " "	
220 - 230	mostly sand to 1/16"	
230 - 240	" " some small gravel	
240 - 250	Clay	
250 - 260	Blue clay & fine gravel	perf - (250 - 290)
260 - 292	Fine gravel "fair to good"	perf -
292 - 330	Blue clay & gravel streaks & timber	

310 and

WINZLER & KELLY
CONSULTING ENGINEERS

WELL LOG - REDWOOD JUNIOR COLLEGE

By Pialorsi - August 64

360 feet deep - 0' - 43' = 10"
0' - 43' - 360' = 8"

0 - 9 Yellow Clay
9 -19 Grey Clay
19-20 Surface Water
20-41 Sandy Grey Clay
41-43 Gravel & Bolders
43-360 Some water - Blue Clay

QUINTUPLICATE
RETAIN THIS COPY

WATER WELL DRILLERS REPORT

(Sections 7076 … 7078 Water Code)

STATE OF CALIFORNIA

Do Not Fill In
Nº 67553
State Well No.
Other Well No.

(1) OWNER:

Name McBride Livestock Ranches
Address Rt. Box 80
Loleta, CA

(2) LOCATION OF WELL:

County Humboldt Owner's number, if any
Salmon Creek

(3) TYPE OF WORK (check):

New well ☑ Deepening ☐ Reconditioning ☐ Abandon ☐
If abandonment, describe material and procedure in Item 11.

(4) PROPOSED USE (check):

Domestic ☐ Industrial ☐ Municipal ☐
Irrigation ☑ Test Well ☐ Other ☐

(5) EQUIPMENT:

Rotary ☐
Cable ☑
Dug Well ☐

(6) CASING INSTALLED:

SINGLE ☐ DOUBLE ☐
From 0 ft. to 500 ft. 14 Diam. 250 Gage or Wall

If gravel packed
Diameter of Bore from ft. to ft.

Type and size of shoe or well ring 14"
Size of gravel
Describe joint

(7) PERFORATIONS:

Type of perforator used torch
Size of perforations 4 in. length, by 1/8 in.
From 380 ft. to ft. Perf. per row Rows per ft.
360 XXX
430 440

(8) CONSTRUCTION:

Was a surface sanitary seal provided? ☐ Yes ☐ No To what depth ft.
Were any strata sealed against pollution? ☐ Yes ☐ No If yes, note depth of strata
From ft. to ft.
Method of Sealing

(9) WATER LEVELS:

Depth at which water was first found 20 ft.
Standing level before perforating ft.
Standing level after perforating 10 ft.

(10) WELL TESTS:

Was a pump test made? ☐ Yes ☐ No If yes, by whom?
Yield 100 gpm ft. draw down after hrs.
Temperature of water Was a chemical analysis made? ☐ Yes ☒ No

(11) WELL LOG:

Total depth 500 ft. Depth of completed well ft.
Formation: Describe by color, character, size of material, and structure

0	14	Clay
14	25	SAND
25	150	Clay
150	170	Clay & GRAVEL
170	350	Clay
350	355	SAND
355	380	GRAVEL
380	430	Clay
430	440	SANDSTONE
440	498	HARD Clay
498	500	GRAVEL

Work started Feb. 14. 1967 Completed MARCH 17. 19

WELL DRILLER'S STATEMENT:
This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.

NAME
(Person, firm, or corporation) (Typed or printed)
Address

[SIGNED]
Well Driller
License No. [illegible] Dated , 19

3096

3N1W-18

Golden State Well (1950, in Golden State Creamery yard, Loleta, sec. 18, 3N1W)

This well was being drilled in the summer of 1950. Because of the presence of brackish water in some earlier wells drilled in the yard area, Golden State had sent Mr. Elmer Trone, chemist, to sample the water found. Mr. Trone kindly furnished information on the chemical content of the water in various strata in the well. Mr. Larson, superintendent for Golden State, allowed the writer to examine logs of former wells.

Ca, and Mg are expressed as $CaCO_3$ and $MgCO_3$ in parts per million (ppm). Cl is given in ppm; Mr. Trone noted that the creamery has used up to 380 ppm Cl for washing but that above 300 is poor for boilers. 350-380 ppm Cl begins to taste brackish.

0-16	yellow clay	Qh
16-21	yellow clay and fine sand	
21-28	blue clay	
28-38	sand and gravel	
38-42	yellow clay	
42-59	blue clay	
59-87	brown clay and gravel (hard)	
87-108	yellow sand	
108-177	blue clay	
177-182	sand and fine gravel	
182-198	coarse gravel	
198-224	blue clay, hard	QTc top?
224-272	(examined by the writer) .... gray, compact, blue-gray siltstone, few carbonaceous fragments.	
272-298	cobbles to 4", mostly sub-angular; poorly sorted, range to 1/2" pebbles.	
298-323	medium-gray sandstone (compact when fresh).	
323-373?	small pebbles to 1/2" ranging to medium sand, shell fragments (incomplete data) (see A6873)	

Analysis depth (in feet)		ppm Ca	Mg	Cl
20	fresh water			
30	....			(7000)
190		124	276	896
220		220	465	473
270		1120	2980	3550
278		334	516	650
290		336	616	650
294		310	530	780
312		530	1090	1314
326		480	1060	1160
336		390	840	900
352		470	990	1180
373		610	1330	1450 associated with pelecypod shell fragments

Well logs - Eureka Area 48

City of Fortuna Well (located adjacent to the NWPRR depot in Fortuna, see Plate I) drilled in 1950? 3N/1W-24J

		Notes
0-4	soil	
4-39	yellow sandy clay (water at 20')	Qr
39-90	fine gravel and sand (84-86 hard rock)	
90-104	gray coarse gravel, hard	QTc top ?
104-115	" " " "	
115-154	" " " "	
154-182	blue clay	claystone?
182-192	gray hard sand	"hard" sometimes used when grains are hard
192-197	gray sand	
197-208	blue clay	
208-214	gray coarse sand	
214-226	coarse-fine gravel	
226-227	blue clay	
227-237	coarse gravel	
237-259	blue clay	
259-265	clean fine gravel	
265-281	" " "	
281-285	blue clay	
285-288	clean gravel	
288-325	fine gravel-coarse sand	
325-328	gray rock and gravel cemented	pebbles bonded by clayey matrix
328-346	" " " " "	
346-351	blue clay	
351-356	gray hard sand	
356-361	coarse sand or fine gravel	
361-365	clean gravel	
365-500	clay, contains fragments of dense, hard wood	Typical carbonized wood fragments of the QTc in claystone

The lower part of this well was perforated in order to produce from the lower gravels. A considerable amount of water could be produced but it was found to have a high manganese and iron content. The well has not been used for the city water system, as yet, although production might be as much as 500-600 gallons/minute.

9-063
(December 1949)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

No. 3N/1W-34J1

OTHER NOS.

WELL LOG

State California County Humboldt Subarea 42

Owner City of Fortuna, Well No. 3

Location

Drilled by C. Dougherty Address Hydesville

Date 1949 Casing diam. 12 in. Land-surf. alt.

Source of data D. W. Maudlin, Fortuna Water Supt.

(Enter type of well, perforations, yield, and drawdown at end of log)

CORRELATION	MATERIAL	THICKNESS (feet)	DEPTH (feet)
	Soil	4	0-4
	Yellow sandy clay (water at 20 ft)	35	4 ~~35~~-39
	Yellow clay and fine gravel or sand	45	39- ~~45~~-84
	Hard rock or boulders	2	84-86
	Gray clay and gravel	18	86-104
	Brown clay and gravel	50	104-154
	Blue clay	28	154-182
	Blue hard sand	10	182-192
	Gray sand and clay	5	192-197
	Blue clay	11	197-208
	Gray coarse sand and clay	6	208-214
	Clay and fine gravel	12	214-226
	Sticky blue clay	33	226-259
	Com. clay and fine gravel	22	259-281
	Blue clay	4	281-285
	Fine gravel or sand	40	285-325

RECORD BY DATE SHEET 1 OF 2

U. S. GOVERNMENT PRINTING OFFICE 16—61587-1

9-063
(December 1949)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

No. 3N/1W-34J1 Cont.

Other Nos.

WELL LOG

State County Subarea

Owner City of Fortuna, Well #3

Location

Drilled by Address

Date Casing diam. Land-surf. alt.

Source of data

(Enter type of well, perforations, yield, and drawdown at end of log)

Correlation	Material	Thickness (feet)	Depth (feet)
	Larger gravel	21	325-346
	Blue clay	5	346-351
	Hard sand	5	351-356
	Coarse gravel and sand	9	356-365
	Blue clay or mud	95	365-460
	Wood in clay	20	460-480
	Blue clay or mud	16	480-496
	Perforations 182 - 226		
	Perforations 285 - 365		

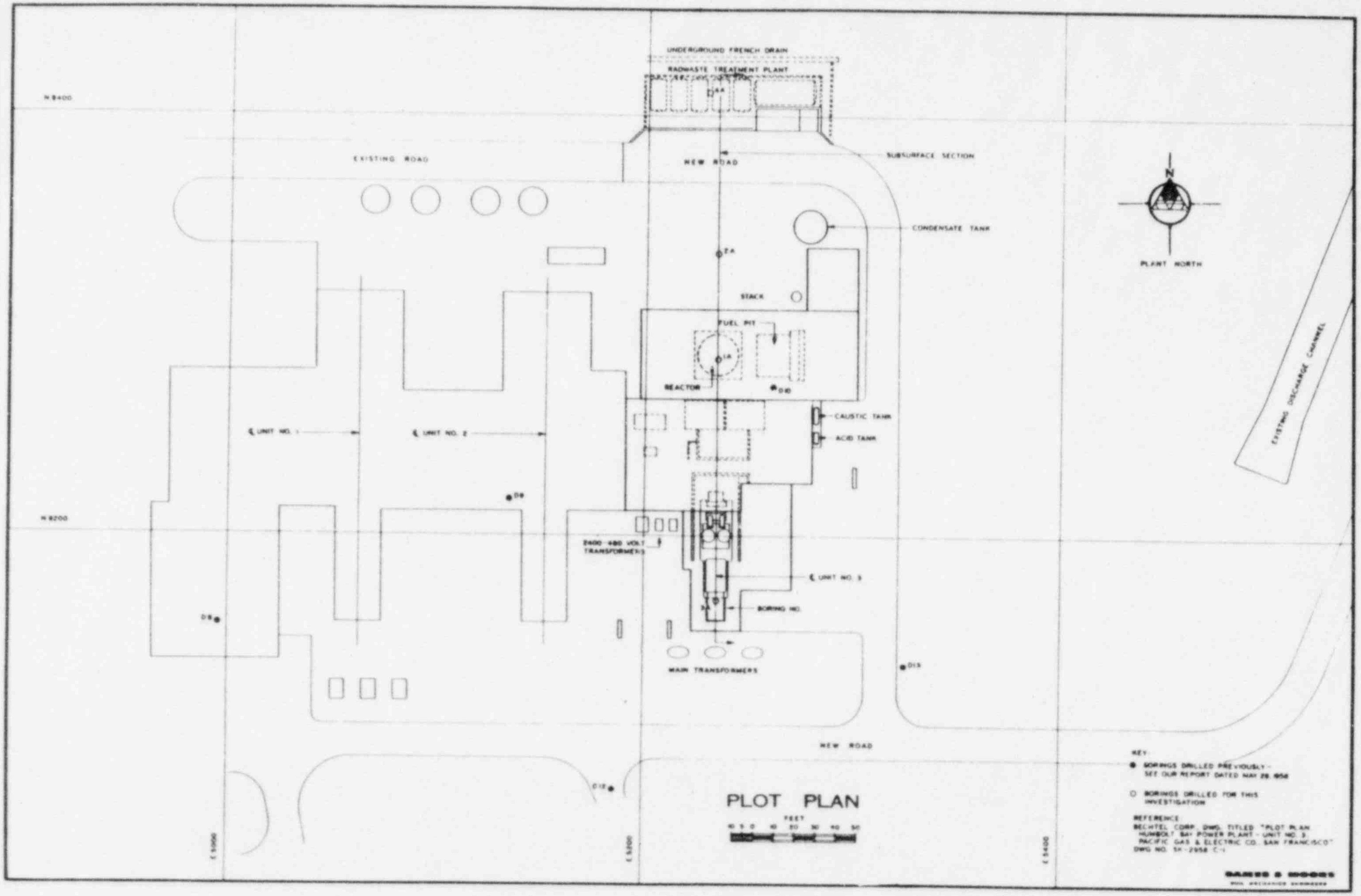
Record by Date Sheet 2 of 2

F. Logs of test borings at the Humboldt Bay Power Plant Site by Dames and Moore.

APPENDIX VI

BORINGS FOR SITE FOUNDATION INVESTIGATION

LIST OF PLATES



PLOT PLAN

KEY:

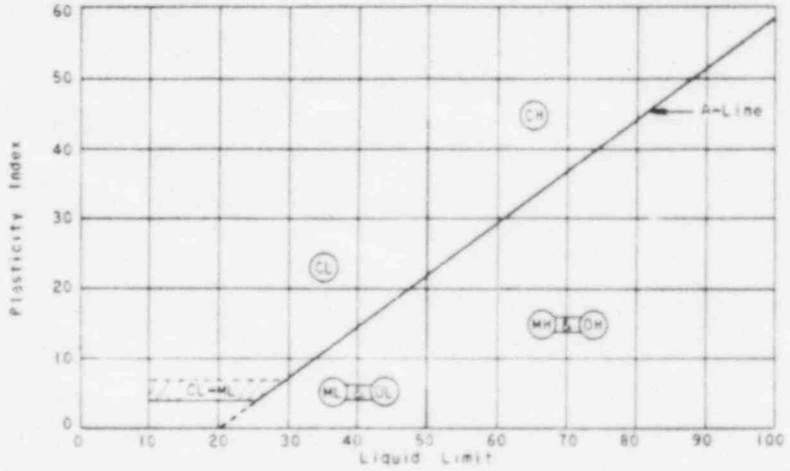
● BORINGS DRILLED PREVIOUSLY - SEE OUR REPORT DATED MAY 28, 1958

○ BORINGS DRILLED FOR THIS INVESTIGATION

REFERENCE:
BECHTEL CORP. DWG. TITLED "PLOT PLAN
HUMBOLT BAY POWER PLANT - UNIT NO. 3
PACIFIC GAS & ELECTRIC CO., SAN FRANCISCO"
DWG NO. 5K-2958 C-1

DAMES & MOORE
SOIL MECHANICS ENGINEERS

MAJOR DIVISIONS				LETTER	SYMBOL	NAME
Coarse-grained Soils More than half of material is **larger** than No. 200 sieve size. The No. 200 sieve size is about the smallest particle visible to the naked eye.	Gravels More than half of coarse fraction is larger than No. 4 sieve size.	(For visual classification, the 1/4-in. size may be used as equivalent to the No. 4 sieve size)	Clean Gravels (Little or no fines)	GW	▨	Well-graded gravels or gravel-sand mixtures, little or no fines
				GP	▨	Poorly-graded gravels or gravel-sand mixtures, little or no fines
			Gravels with Fines (Appreciable amount of fines)	GM	▨	Silty gravels, gravel-sand-silt mixtures
				GC	▨	Clayey gravels, gravel-sand-clay mixtures
	Sands More than half of coarse fraction is smaller than No. 4 sieve size		Clean Sands (Little or no fines)	SW	▨	Well-graded sands or gravelly sands, little or no fines
				SP		Poorly-graded sands or gravelly sands, little or no fines
			Sands with Fines (Appreciable amount of fines)	SM	▨	Silty sands, sand-silt mixtures
				SC	▨	Clayey sands, sand-clay mixtures
Fine-grained Soils More than half of material is **smaller** than No. 200 sieve size.	Silts and Clays LL < 50			ML	▨	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
				CL	▨	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
				OL	▨	Organic silts and organic silt-clays of low plasticity
	Silts and Clays LL > 50			MH	▨	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
				CH	▨	Inorganic clays of high plasticity, fat clays
				OH	▨	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS				Pt	▨	Peat and other highly organic soils



PLASTICITY CHART

SOIL CLASSIFICATION CHART

(UNIFIED SOIL CLASSIFICATION SYSTEM)

TESTS AT FIELD MOISTURE

TEST SURCHARGE PRESSURE IN POUNDS PER SQUARE FOOT
PER CENT FIELD MOISTURE EXPRESSED AS A PERCENTAGE OF THE DRY WEIGHT OF SOIL
DRY DENSITY EXPRESSED IN POUNDS PER CUBIC FOOT

2900 — 20.4% — 104.2

DIRECT SHEAR - STRAIN CONTROL

▭ *YIELD POINT SHEARING STRENGTH IN LBS PER SQ FT*
▤ *ULTIMATE SHEARING STRENGTH IN LBS PER SQ FT*

FRICTION OF SOIL ON CONCRETE

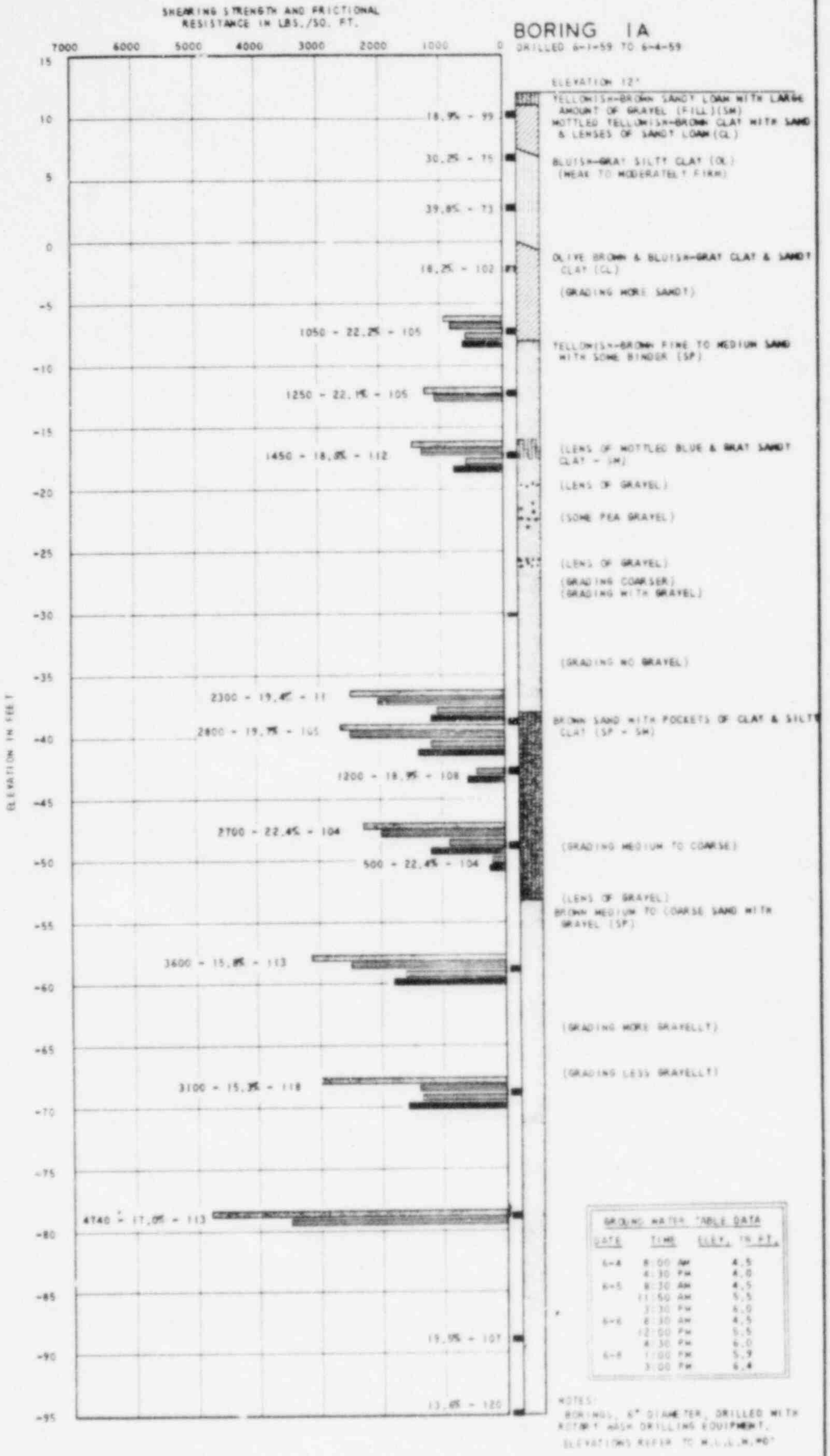
▭ *YIELD POINT IN LBS PER SQ FT*
▬ *ULTIMATE IN LBS PER SQ FT*

■ *INDICATES DEPTH AT WHICH UNDISTURBED SAMPLE WAS EXTRACTED*

KEY TO TEST DATA

DAMES & MOORE
SOIL MECHANICS ENGINEERS

5781e



GROUND WATER TABLE DATA

DATE	TIME	ELEV. IN FT.
6-4	8:00 AM	4.5
	4:30 PM	4.0
6-5	8:30 AM	4.5
	11:50 AM	5.5
	3:30 PM	6.0
6-6	8:30 AM	4.5
	12:00 PM	5.5
	4:30 PM	6.0
6-8	1:00 PM	5.9
	3:00 PM	6.4

NOTES:
BORINGS, 6" DIAMETER, DRILLED WITH ROTARY WASH DRILLING EQUIPMENT.
ELEVATIONS REFER TO M.L.L.W.MO'

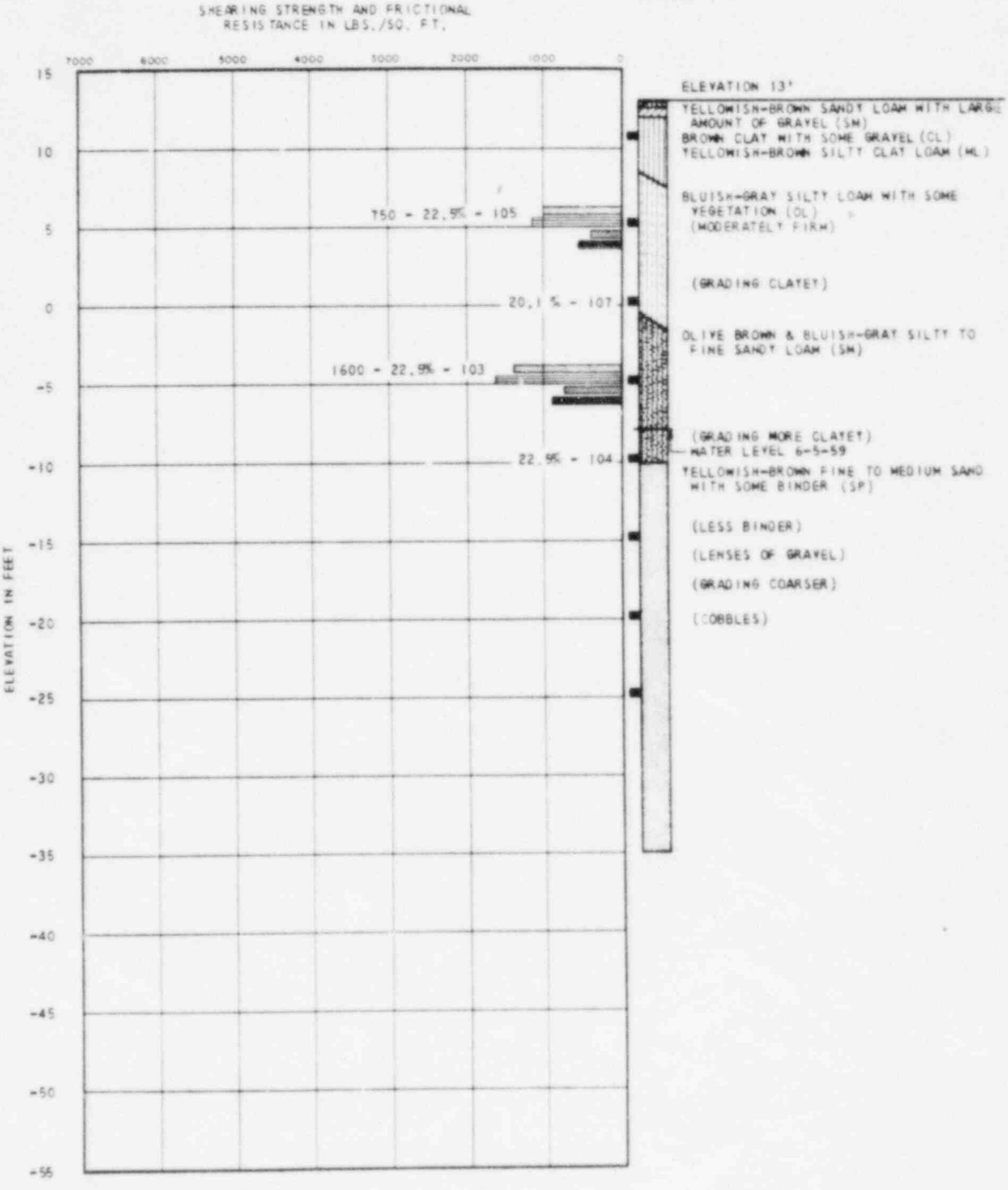
LOG OF BORING

DAMES & MOORE
SOIL MECHANICS ENGINEERS

5781e

BORING 2A

DRILLED 6-4-59



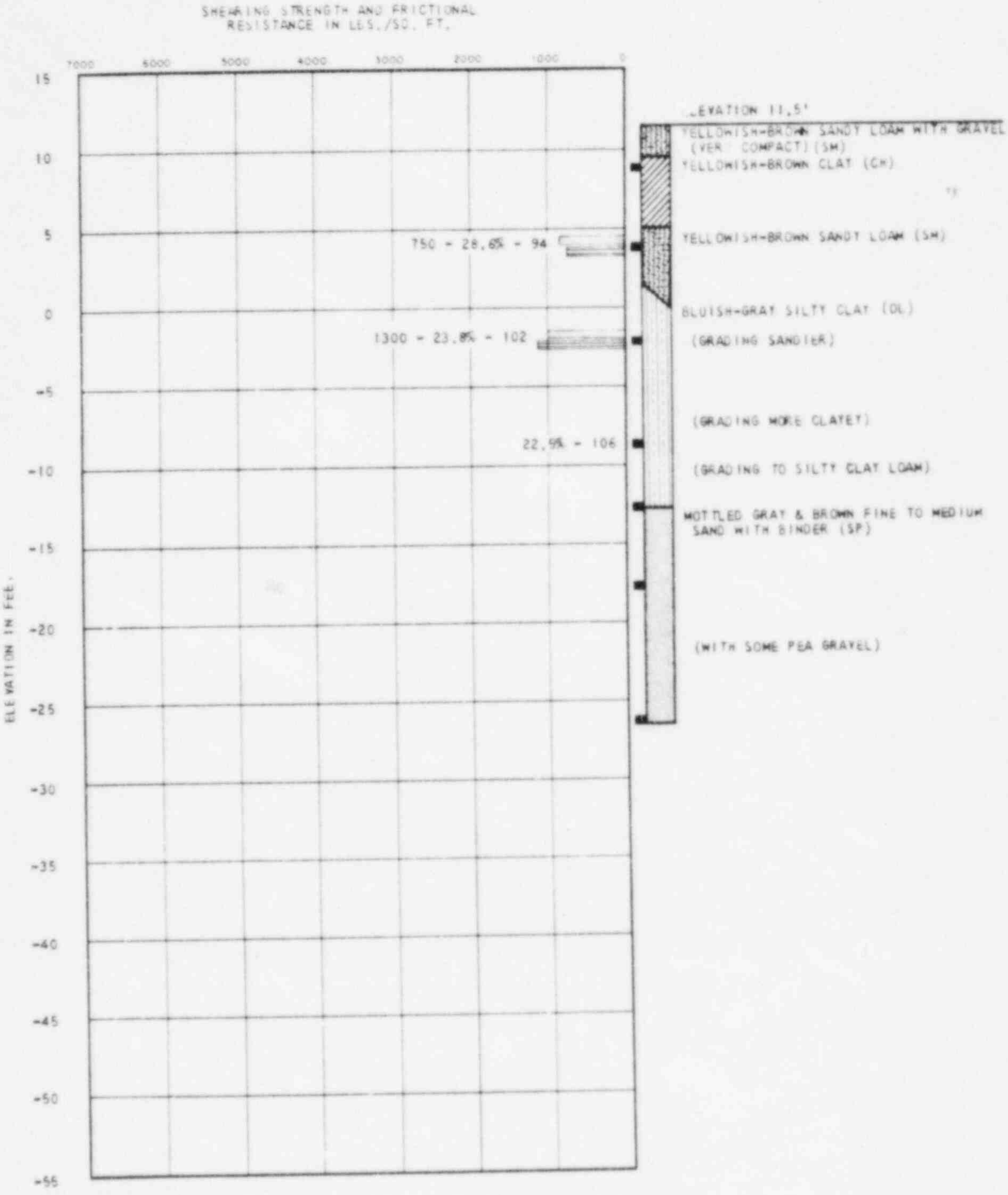
LOG OF BORING

DAMES & MOORE
SOIL MECHANICS ENGINEERS

STule

BORING 3 A

DRILLED 6-11-59



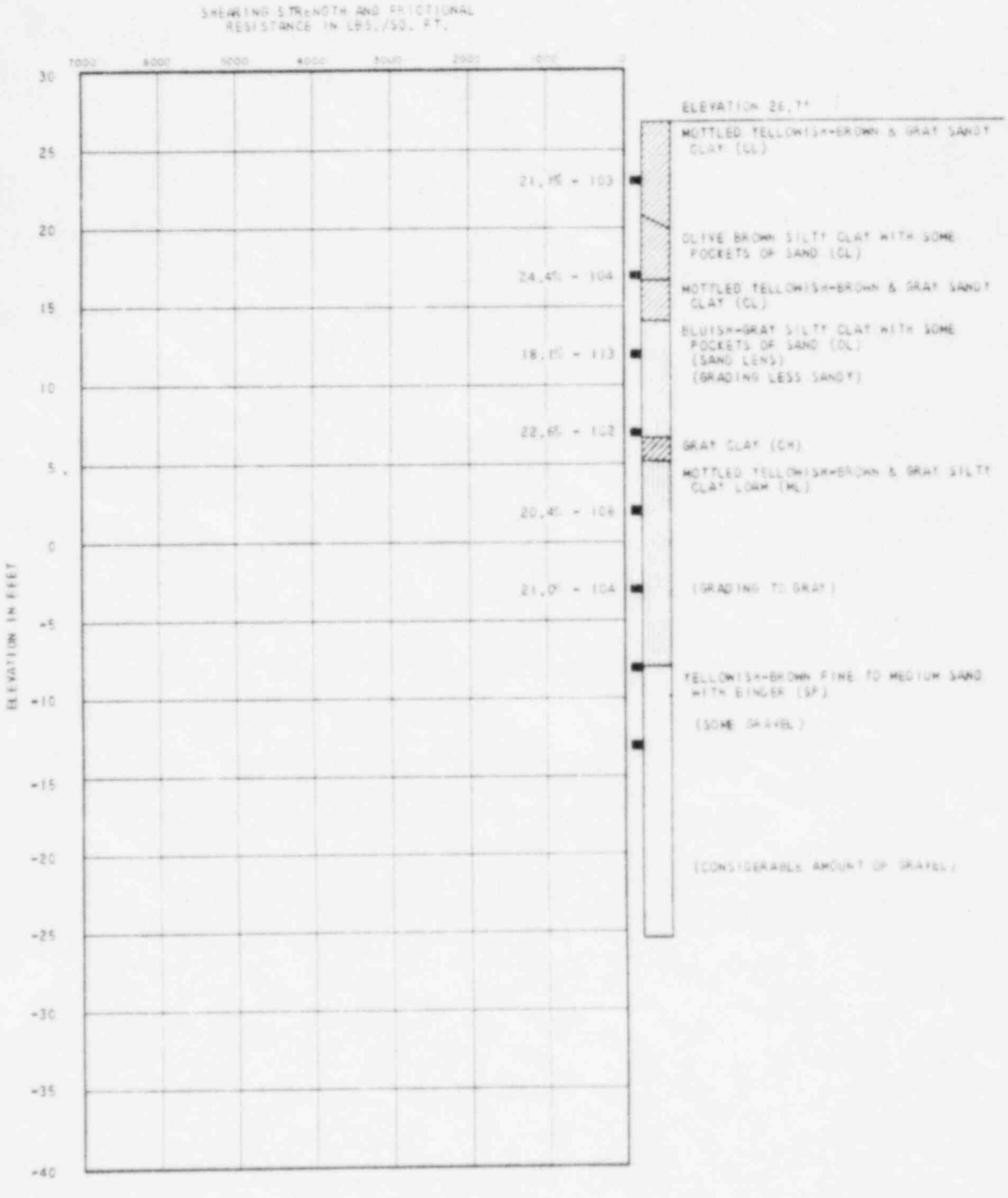
LOG OF BORING

DAMES & MOORE
SOIL MECHANICS ENGINEERS

5781e

BORING 4A

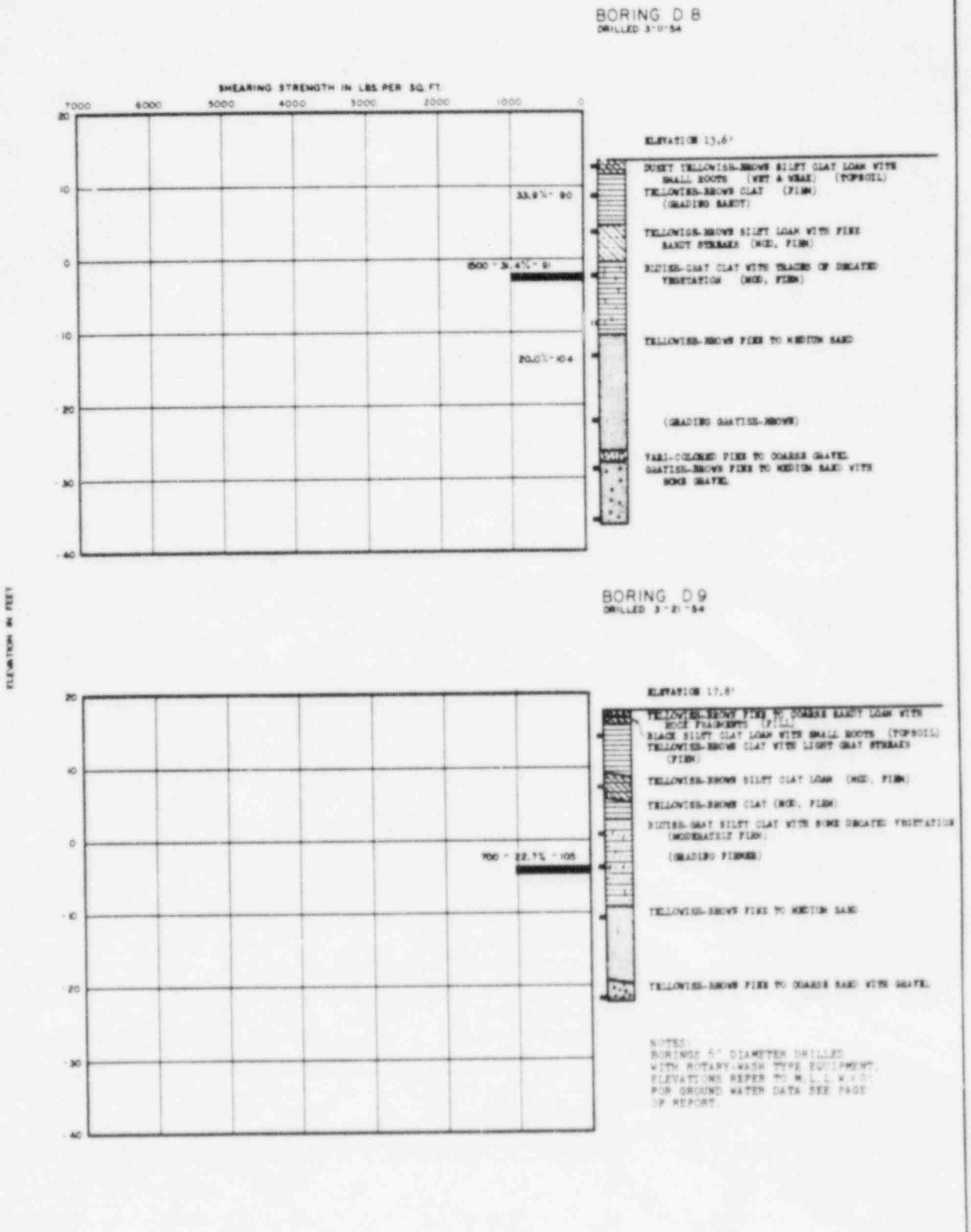
DRILLED 6-12-55



LOG OF BORING

DAMES & MOORE
SOIL MECHANICS ENGINEERS

5781e



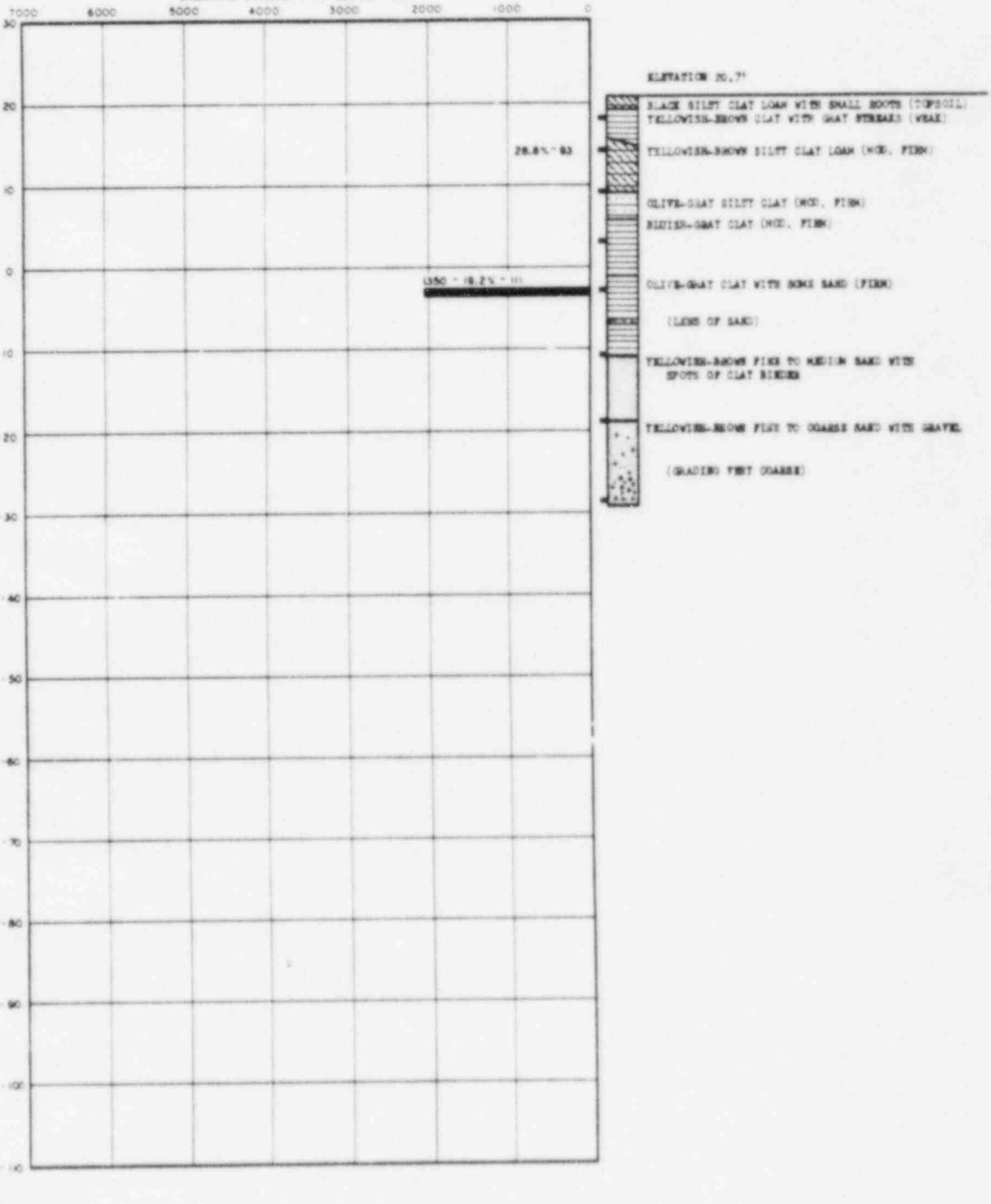
NOTES:
BORINGS 5" DIAMETER DRILLED
WITH ROTARY-WASH TYPE EQUIPMENT.
ELEVATIONS REFER TO M.L.L.W.(0)
FOR GROUND WATER DATA SEE PAGE
OF REPORT.

LOG OF BORINGS

DAMES & MOORE, Civil Engineers
FOUNDATION INVESTIGATIONS · SOIL MECHANICS ENGINEERING

5781e

BORING D10
DRILLED 3-18-54

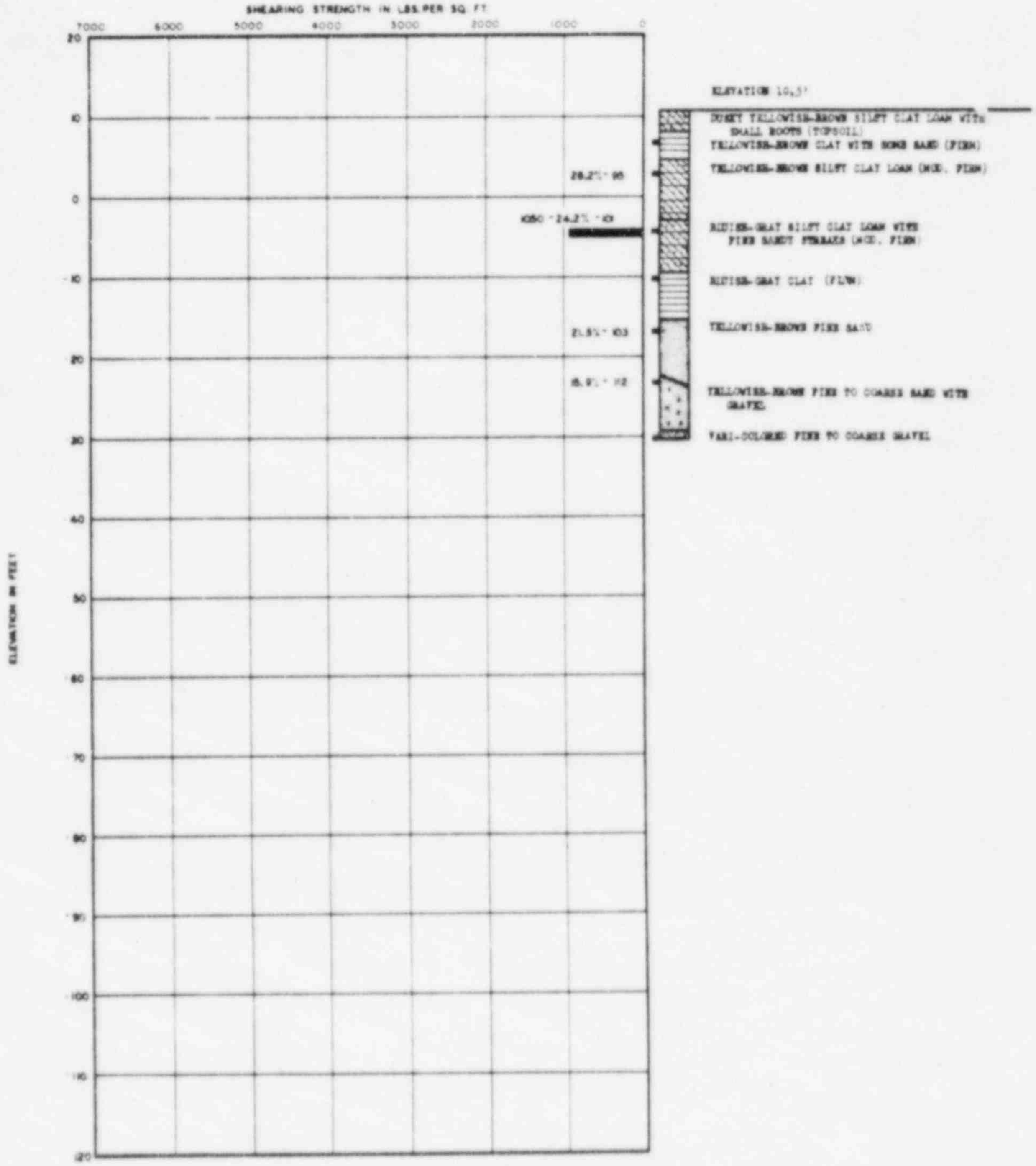


LOG OF BORINGS

DAMES & MOORE, *Civil Engineers*
FOUNDATION INVESTIGATIONS · SOIL MECHANICS ENGINEERING

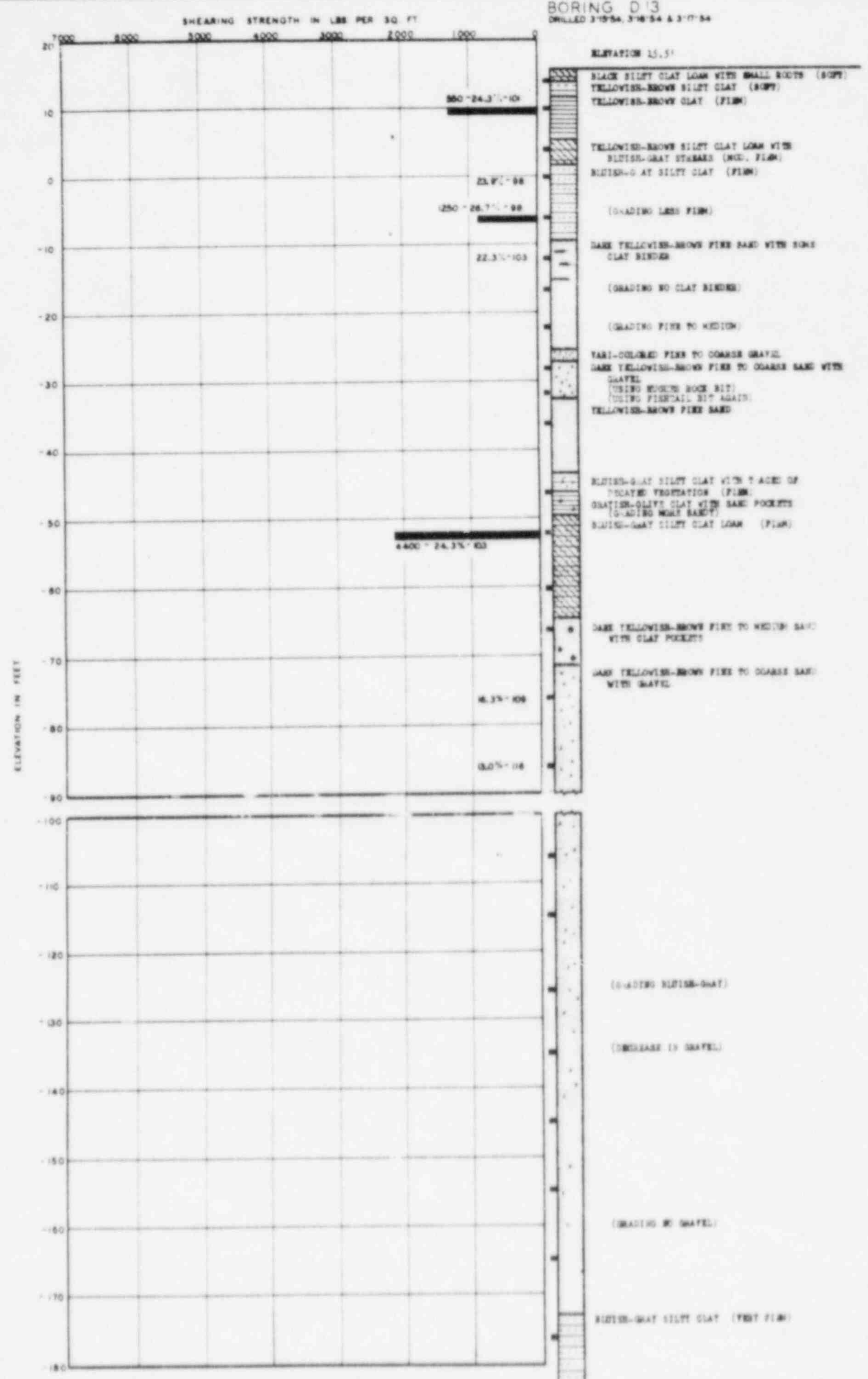
5781e

BORING D 12
DRILLED 3-11-54



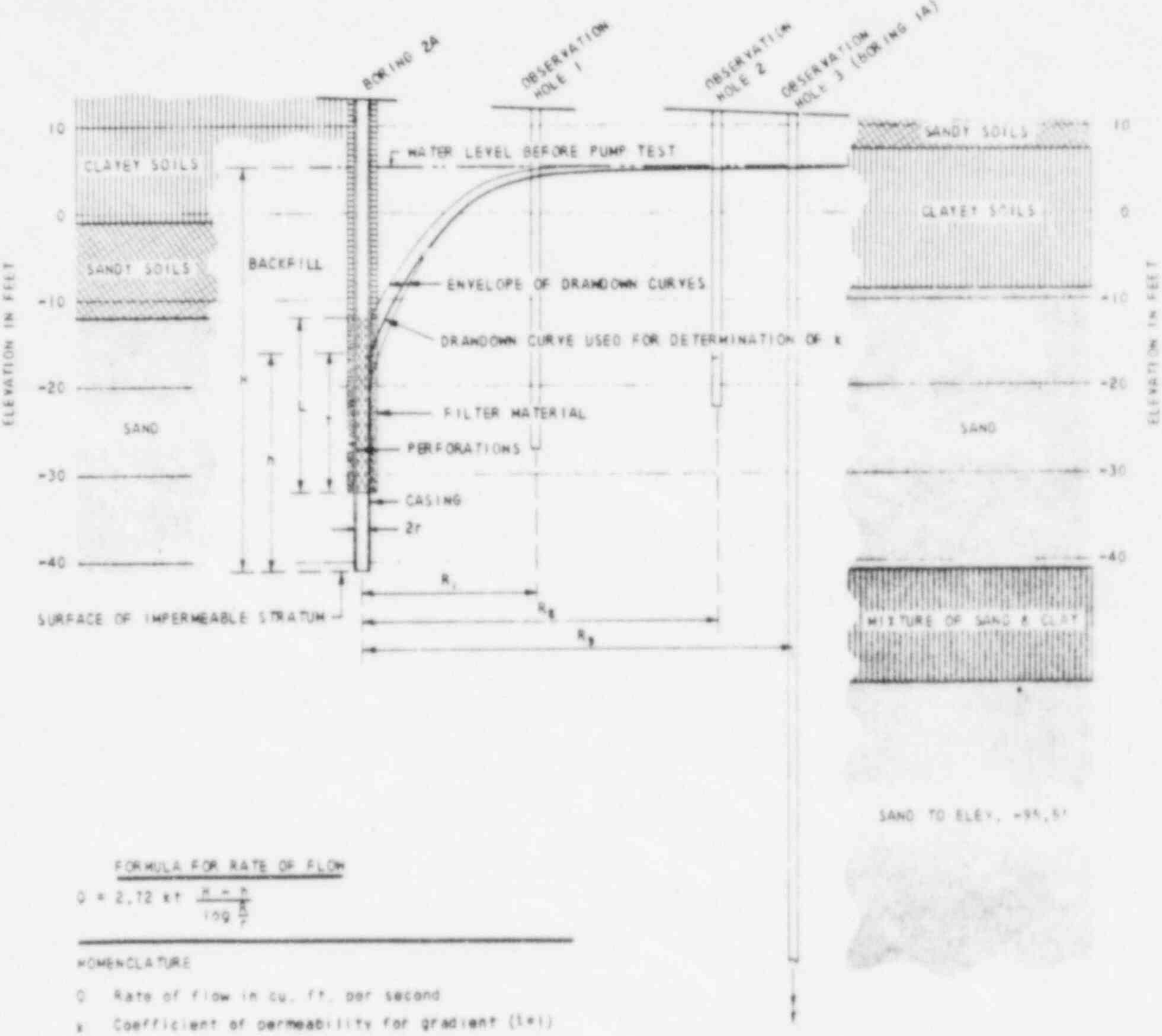
LOG OF BORINGS

DAMES & MOORE *Civil Engineers*
FOUNDATION INVESTIGATIONS · SOIL MECHANICS ENGINEERING



LOG OF BORINGS

DAMES & MOORE, *Civil Engineers*
Foundation Investigations   Soil Mechanics Engineering



FORMULA FOR RATE OF FLOW

$$Q = 2.72\,kf\,\frac{H - h}{\log \frac{R}{r}}$$

NOMENCLATURE

Q Rate of flow in cu. ft. per second

k Coefficient of permeability for gradient (i=1)

L Length in feet of perforated casing

f Effective length in feet of perforated casing

H Height in feet of ground water level above impermeable stratum

h Depth of water in well to impervious stratum in feet

R Radius of influence in feet, Assumed = 100' (influence of drawdown beyond 50' insignificant)

r Radius of perforated casing in feet

$$k = \frac{Q \log \frac{R}{r}}{2.72\,f\,(H - h)}$$

H = 46.25' R = 100' Q = 10 G.P.M. = .0222 CU. FT./SEC.

h = 25' r = $\frac{1}{3}$' f = 16'

$$k = \frac{.0222 \log \frac{100}{\frac{1}{3}}}{2.72\,(16)\,(46.25 - 25)} = .00006 \text{ cu. ft. per sq. ft. per sec. unit gradient}$$

FIELD PUMPING TEST DATA

FOR UNIT GRADIENT

k = 6 x 10^{-5} ft. per sec.

k = 41.1 gal. per sq. ft. per day

k = 2000 ft. per yr.

DAMES & MOORE
SOIL MECHANICS ENGINEERS

G. Consultants Reports from previous investigations of geologic and seismic conditions pertaining to the Humboldt Bay Power Plant Site.

1. Report of Earthquake hazard at the Humboldt Bay Power Plant, by Perry Byerly and William Quaide, 1959.

2. Geologic Reconnaissance of ground water conditions, Buhne Point, Eureka, California, by Chester Marliave, 1959, 1960.

3. The geology in the vicinity of the Pacific Gas and Electric plant at Buhne Point on Humboldt Bay, California, by G. H. Curtis, 1969.

4. Report on earthquake hazard at the Humboldt Bay plant, by Perry Byerly, 1969.

G-1. Report of Earthquake hazard at the Humboldt Bay Power Plant, by Perry Byerly and William Quaide, 1959.

7125d

Appendix III

REPORT OF EARTHQUAKE HAZARD
AT THE HUMBOLDT BAY POWER PLANT
PACIFIC GAS AND ELECTRIC COMPANY

By

Perry Byerly and William Quaide

appendix III

7125d

REPORT ON EARTHQUAKE HAZARD AT THE HUMBOLDT BAY PLANT

By Perry Byerly and William Quaide

Foreword

The investigation of earthquake hazard consists of three parts:

1) The history of earthquakes felt in the region.

2) The distribution of epicenters located from the records of seismographs.

3) A study of the geologic faults in the region.

Discussions below will be based on this classification.

Summary of Conclusions

Study of the hazards leads to:

1) No faults pass through the proposed site.

2) The geologic foundation at the proposed site is satisfactory.

3) The region is one of many fairly large earthquakes. Construction should be such as to resist an earthquake of intensity 8, Modified Mercalli Scale, which corresponds to an acceleration of about one quarter of gravity accompanying periods of 0.1 second to 0.3 second and repeated several times.

Earthquake History

The area of Humboldt Bay is quite seismic. From references cited at the end of this report, Table 1 has been compiled. The intensity of an earthquake describes the damage done and the effects on people. The intensity of a given shock is different at different localities. It depends on distance from the center of the shock, on geologic foundation, and on the type of construction of buildings.

Table 2 lists the criteria for rating the intensity. These intensities are given for the town of Eureka since it is from it that most reports are on record. Only in the later years is the location of epicenters available. Seismometry is a comparatively young subject and general location of epicenters in the area, except for very large shocks, awaited the establishment of seismographic stations at Ferndale and Arcata by the University of California.

There is only one earthquake historically recorded in the Eureka area with an observable fault break at the surface. That was the California earthquake of April 18, 1906. The report of the Earthquake Investigation Commission indicates that as well as the great fault break to the south, a fracture occurred which began at Upper Mattole (35 miles south of Eureka) and disappeared beneath the sea at Shelter Cove.

Many of the earthquake reports indicate that fissures opened in the area. These were not fault breaks but cracks due to differential settling of poorly consolidated fill. This can occur at some distance from the epicenter of a shock, and is not an indication of an active fault at the point.

The tabulation of these earthquakes shows over 275 shocks which have been felt. This list is probably incomplete in the early years, but would include all the large shocks.

The greatest damage reported is an Intensity IX on October 1, 1865. This is taken from old records, and there is some disagreement among early newspaper reports as to the extent of the damage. This may well be an exaggeration, as no recent earthquake has exceeded Intensity VIII.

There are some nine shocks of Intensity VIII listed and this is a maximum which might be expected in the future.

Intensity VIII, according to Hershberger, is to be associated with an acceleration of 0.25 gravity. It would accompany waves of period 0.1 to 0.3 seconds which would be repeated several times.

The Distribution of Epicenters

In Table 1 certain earthquakes are marked with asterisks. For these epicentral coordinates are given. These epicenters are plotted on Figure 1. The shocks marked with one asterisk had epicenters within 30 miles of Eureka. They are plotted as solid circles on the map. The shocks marked with crosses in circles centered more than 30 miles from Eureka but were felt in the city.

The "magnitude" is given for these shocks. The magnitude of an earthquake is determined from the record of a seismograph. A given shock has only one magnitude. It aims to measure the energy in the earthquake. A formula connecting energy and magnitude is

$$\log E = 11 + 1.6 M$$

where E is in ergs.

Most of the epicenters were located from the records of the University of California seismographic stations of which there are now twelve, ranging from Corvallis, Oregon on the north through Reno, Nevada on the east and Fresno, California on the south. For the larger shocks records of distant stations were also available.

Geology and Faulting

The theory that earthquakes result from breaks along faults is well substantiated. Location of faults, therefore, is one method of determining the possibility of damage from earthquake activity.

In this investigation the geology was mapped with emphasis on fault location. Field surveys were conducted as far north as Trinidad Head, 23 miles north of the proposed site, as far south as Petrolia, 29 miles distant, and inland as far as the 124 degree meridian, 15 miles away at the closest point. The area in the immediate vicinity of Buhne Point was studied in greater detail than were more distant regions.

Discussion of Faults

Nine major faults were mapped in the area investigated (Plate 2). These include, north to south, the Korbel, Crawford, Blue Lake, Falor, Freshwater, Little Salmon-Yager, Russ, Bear River, and Mattole Faults. In addition to these, breakage which occurred in the 1906 movement along the San Andreas Fault is shown. A more northerly trace of this fault has not yet been located.

None of the mapped faults pass through the proposed site. The nearest, the Little Salmon Fault, is four miles distant at its closest approach. Because of its proximity, this fault will be considered first. Subsequent discussion will concern faults at succeedingly greater distances from the site.

Little Salmon and Yager Faults

A detailed map of the trace of the Little Salmon and Yager Faults is shown in Plate 1. These faults form a northwest trending system northeast of Fortuna. Movement appears to have taken place at widely spaced times in the past. Southeast of Fortuna, rocks of the Yager formation of Jurassic-Cretaceous age have been thrust over rocks of the Rio Dell formation of Pliocene age. The exact amount of movement here can not be determined, but displacements on the order of 10,000 feet along the fault surface are likely. The fault surface here dips steeply to the northeast.

To the west, this fault can not be differentiated from the Little Salmon Fault. In this area, beds of Wildcat Group of Upper Pliocene age have been thrust over rocks of the Hookton formation of middle Pleistocene age. There is no exact measure as to the amount of displacement on the Little Salmon Fault, but due north of Fortuna, in Section 23, R1W, T3N, (Plate 1), a borehole drilled by the Texas Company started in Upper Pliocene rocks of the Wildcat Group and penetrated the Little Salmon Fault surface at 395 feet, passing into Pleistocene gravels of the Hookton formation. These data taken together with field information show that the fault surface dips at approximately 40 degrees to the northeast and that movement of the northeast block over the southwest block has not exceeded 1000 feet.

Farther to the northwest, the Little Salmon fault appears to have progressively smaller displacements until, in the center of Section 33, R1W, T4N (Plate 1), the fault dies out.

The most recent movement on this fault was after deposition of the Hookton beds of Middle Pleistocene age, but before formation of some low terraces of Upper Pleistocene age in the Beatrice region. There appears to have been no more recent activity on this fault system.

Freshwater Fault

The Freshwater Fault has been mapped at the abrupt contact between rocks of the Yager and Franciscan formations from the headwaters of the Elk River northwesterly to Arcata Bay. The trace of the fault is concealed throughout most of its extent by deposits of the Hookton formation, but occasional exposures permit its approximate location. This is an old fault which was active mainly before disposition of the Hookton beds. Some late movements along the old fault line are indicated, however. Southwest of Bayside on old Highway 101 (Plate 2) rocks of the Franciscan formation have been faulted against rocks of the Hookton formation, indicating activity since the Middle Pleistocene. Movements may be taking place along this fault at the present time.

Blue Lake, Falor, Crawford, and Korbel Faults

These four faults are discussed together because of their similarity. All occur north of Arcata and are northwest trending, near vertical faults which bound blocks of Pliocene sediments which have been faulted against rocks of the Franciscan Formation. All have large but inexactly determined displacements, probably measuring in the thousands of feet. Three of these faults are known to have been active since Middle Pleistocene time, for they have faulted Franciscan rocks against Hookton rocks. Movement on the Korbel fault, the most northerly of the four, has been greater than on the others in more recent times, for Franciscan rocks stand high above Hookton beds against which they have been faulted.

The Russ-False Cape Shear Zone-Bear River Fault System

The fault shown in Plate 2 as the Russ Fault is actually a line of contact between highly broken rocks of the False Cape Shear Zone and unaltered rocks of the Yager formation. The False Cape Shear Zone is a westerly trending zone of intensely sheared and crumpled rocks several miles wide. Movement along faults within the zone must have taken place over a long period of time. Prominent submarine structural features extend great distances offshore from this zone and from other similar zones to the south. Numerous epicenters have been located along these offshore zones of weakness, indicating that present day movements are continuing.

The southern limit of the False Cape Zone is also bounded by a near vertical fault, termed the Bear River Fault in this report. This fault branches in the vicinity of Capetown, one branch trending southwest and the other northwest. The block between the two branches is a down-dropped block of sediments of Miocene and Pliocene age. The amount of movement is large, probably measuring thousands of feet, but exact measurements are not possible. The fault has been mapped inland for 10 miles. Beyond that point the trace of the fault has not been located, not because it dies out, but because mapping control is poor there. Location of epicenters reported in the section on Seismology indicate the probable eastward extension of this fault as well as continued faulting activity.

Mattole Fault

South of Cape Mendocino another wedge of Pliocene sediments is bounded to the north and south by vertical faults. The fault pattern is much the same as that of the Bear River Fault, and movements are of the same order of magnitude. The name Mattole Fault is used in this report to describe this feature. It can be mapped with certainty only a few miles inland, but its extension up the Mattole Valley is indicated by the presence of numerous epicenters.

1906 Breakage

Known breakage along the San Andreas Fault in 1906 is confined (in this area) to a small region near Shelter Cove (Plate 2). The more northerly trace of the San Andreas is not known. The fault mapped as the Mattole in this report could be this more northerly extension, but a trace along the trend of the King Mountain Range reaching the ocean south of the mouth of the Mattole River is a much more likely one.

Geologic Conclusions

Nine major faults or fault zones were mapped in the general vicinity of Eureka (Plate 2). All these faults have large but inexactly determined displacements. Displacements of several thousands of feet are the rule. All of these faults have been active over considerable lengths of geologic time, and activity has continued into the recent on many.

North of the site, the Korbel, Blue Lake, Falor, and Freshwater Faults have been active since Middle Pleistocene time. The greatest amount of recent movement in this northern area has been on the Korbel Fault.

The Little Salmon-Yager Fault System is closest to the proposed site. It is a northwest trending thrust fault with large displacements on its southeastern extent, but with succeedingly smaller displacements to the northwest until the fault finally dies out just north of Beatrice, four miles from the proposed site. The Little Salmon-Yager System has been active over a long period of time, with the most recent activity having been after deposition of the Middle Pleistocene Hookton formation but before formation of some low-lying Upper Pleistocene terraces in the neighborhood of Beatrice.

South of the site, immediately north and south of Cape Mendocino, faults are numerous and of large displacement. All these faults have a westerly trend and are related to structures which form the Gorda and Mendocino Escarpments, submarine features of extreme magnitude extending 1000 miles or more offshore. Fault activity here started long ago, but has extended up to the present time, as indicated by geological and seismological evidence.

The proposed site is unfaulted. Present installations and the proposed site are on rocks of the Hookton formation, the same rock unit which underlies the City of Eureka. It is a fairly well indurated series of mudstones, siltstones, sandstones, and conglomcrates. Surrounding the site on all sides is recent, unconsolidated Bay-fill.

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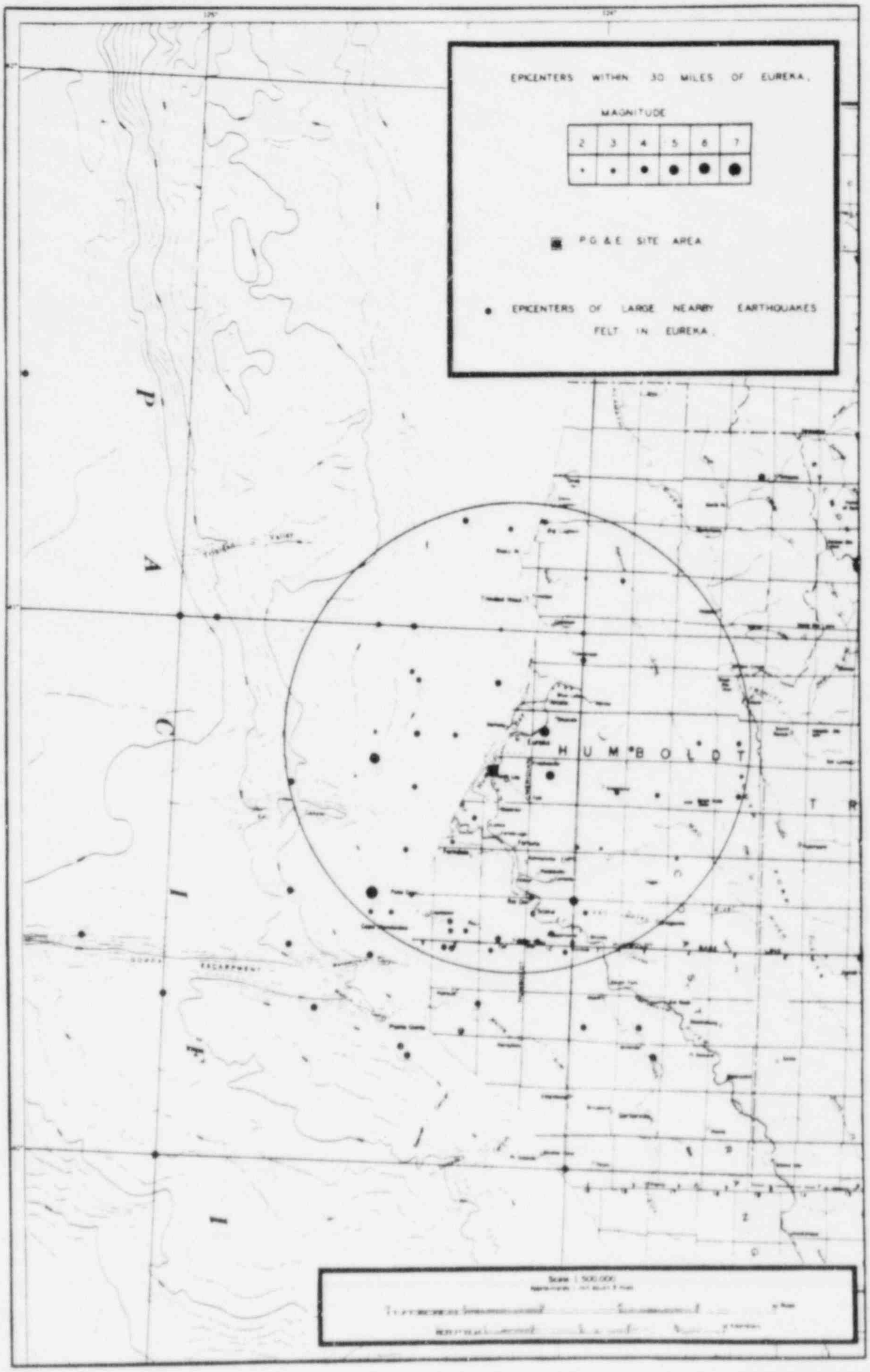
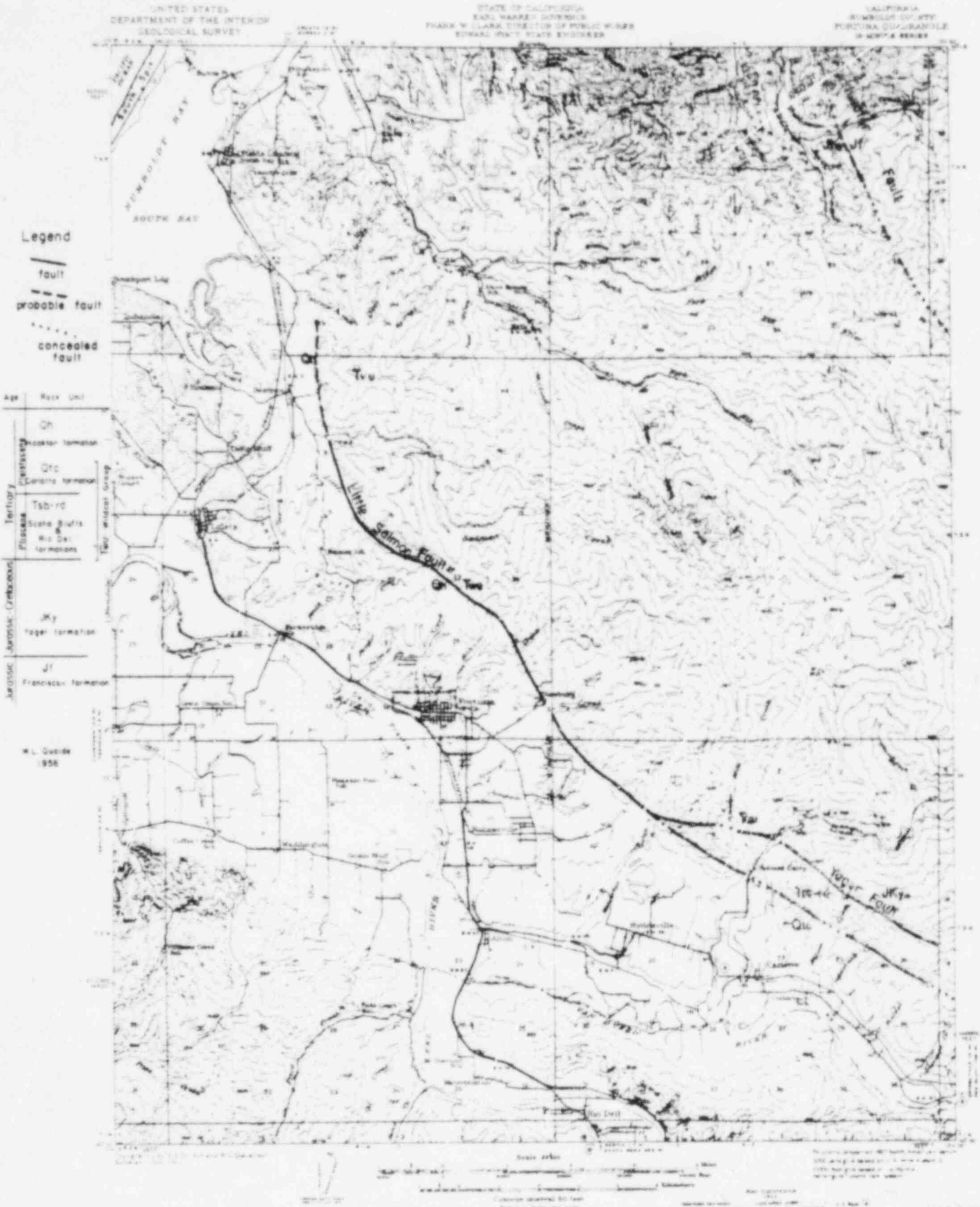
FIGURE 1.

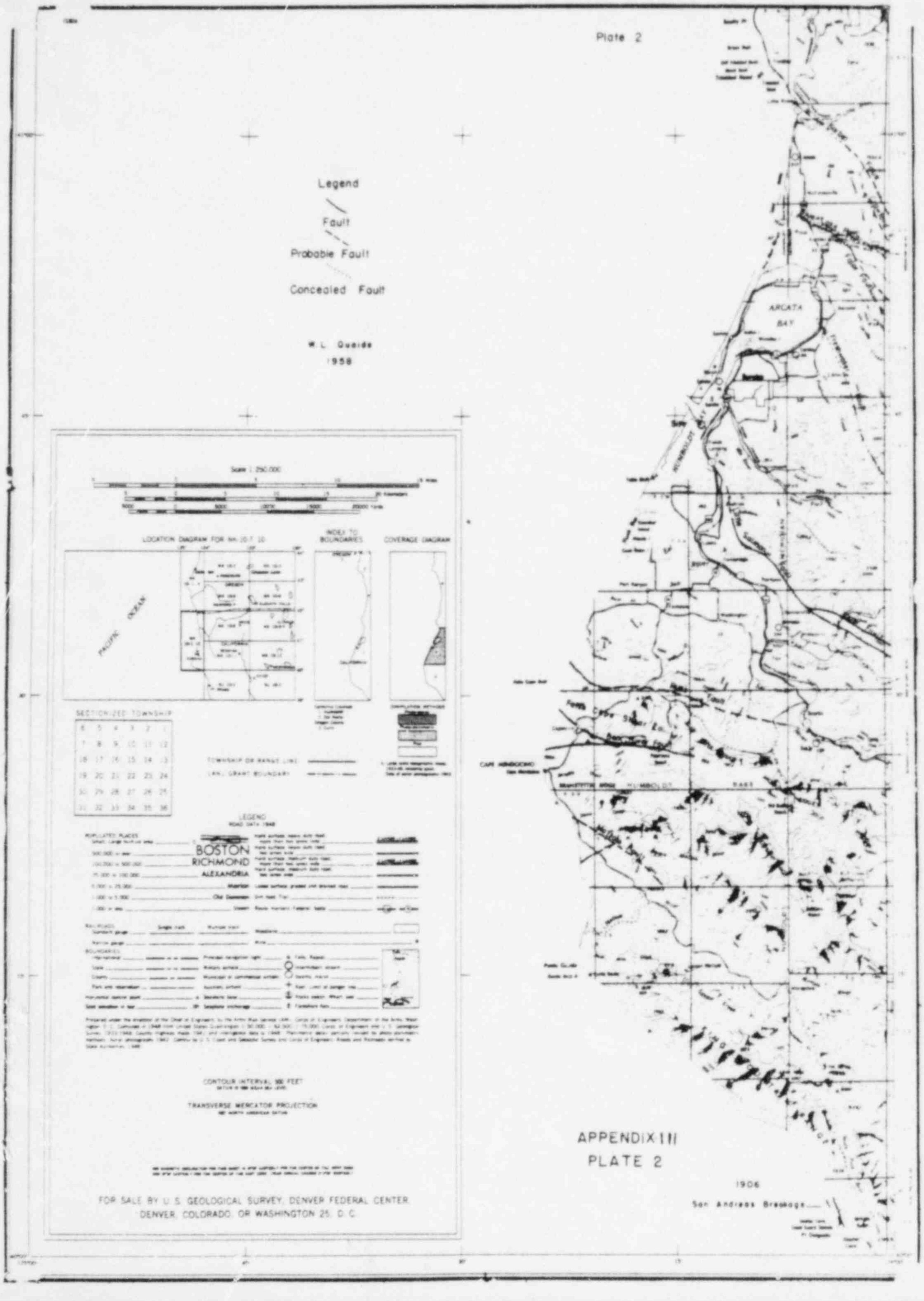


APPENDIX III
FIGURE I

PLATE I



APPENDIX III
PLATE I



APPENDIX III
PLATE 2

Table 1

EARTHQUAKES IN THE VICINITY OF EUREKA, CALIFORNIA

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1853, October 23	Humboldt Bay	(VIII)	Houses rolled like ships at sea, and the wharf sank four feet.
1855, March 19	Humboldt County	(VI)	Flow of streams affected and milk thrown out of pans.
1865, October 1	Eureka	IX	Destroyed all the brick houses. Redwood trees were uprooted. Fissures opened a few miles below Eureka on the bay.
1865, October 3	Humboldt County	V	Heavy shock.
1869, June 12	Humboldt County	V	Sharp shock.
1871, March 2	Humboldt County	(VII)	Shook cornices off some buildings.
1873, November 22	At sea north of Cape Mendocino	--	Much damage to property.
1877, August 27	Eureka	--	--
1883, January 3	Eureka	III	Light, no damage.
1884, January 27	Humboldt County	(VII)	Other reports give intensity IV.
1884, April 6	Eureka	III	Very light.
1884, April 8	Eureka	III	Very light shock(s).
1889, August 12	Eureka	--	Sharp shock.
1889, December 20	Eureka	--	Light shock.
1890, April 25	Eureka	--	Two shocks, the first light and the second sharp.
1890, July 4	Eureka	--	Quite a sharp shock.
1890, July 26	Petrolia	VI	Clocks stopped.
1890, July 27	Eureka	--	Moderate aftershock.
1891, June 20	Eureka	--	Several light shocks.
1892, January 22	Eureka	--	Light shock.
1893, January 9	Eureka	--	Sharp shock.

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Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1893, February 22	Eureka	--	Light shock.
1893, February 23	Eureka	--	Light shock.
1893, April 13	Hydesville	--	Light shock.
1894, September 30	Eureka	--	Two heavy earthquakes, but no damage.
1895, January 8	Eureka	--	Heavy shock.
1895, April 1	Eureka	--	Sharp shock.
1895, August 6	Eureka	--	No damage reported.
1895, October 5	Eureka	--	Light shock.
1895, October 15	Eureka	--	Two very light shocks.
1895, November 18	Eureka	--	Light shock.
1895, December 6	Eureka	--	Quite a heavy shock.
1896, February 13	Weaverville	--	A sharp earthquake.
1896, April 22	Eureka	--	Doors, windows, and movable objects rattled.
1896, June 9	Eureka	--	Light shock.
1897, March 6	Eureka	--	Five distinct shocks.
1897, September 17	Eureka	--	A severe shock.
1897, October 28	Eureka	--	A slight earthquake.
1897, November 25	Eureka	--	Slight--windows and doors rattled.
1897, November 27	Eureka	--	Buildings swayed and windows and doors rattled loudly.
1898, January 29	Eureka	--	Windows and doors rattled.
1898, April 14	Eureka	--	--
1898, April 14	Humboldt County and Mendocino County	--	Clocks were stopped.
1898, September 9	Eureka	--	A severe earthquake.
1898, October 19	Eureka	--	A light earthquake.
1898, November 25	Eureka	--	A light shock.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1899, April 16	Eureka	VII	The iron flue connecting the boilers and smokestack of lumber mill was loosened.
1899, April 18	Eureka	--	Light shock.
1900, January 21	Eureka	--	Light earthquake.
1900, April 14	Eureka	--	Light earthquake.
1900, April 16	Eureka	--	Very light shock.
1900, October 1	Eureka	--	Very light earthquake.
1903, February 25	Eureka	--	Slight earthquake.
1903, December 9	Eureka	VI	Two successive jolts stopped clocks.
1904, January 11	Eureka	--	Very light earthquake.
1904, March 26	Eureka	--	Quite a heavy earthquake.
1904, July 6	--	--	A light earthquake.
1904, September 14	Eureka	--	Light shock.
1904, December 4	Eureka	--	Quite a severe earthquake.
1906, April 18	San Francisco	VIII	

In Eureka several frame buildings were twisted, many chimneys toppled, several panes of glass were broken, and pendulum clocks stopped. At Field's Landing--"the shock opened a fissure over 100 feet long in the middle of the road, which six teams spent one day in filling. Pelican Island, as it is commonly called, opposite Field's landing dropt 3 feet at the point where the United States pile beacon stands." (From the Report of the State Earthquake Investigation Commission, on the California earthquake of April 18, 1906.)

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1906, April 18	Eureka(?)	III	-- (05:22 am P.S.T.)
1906, April 18	Eureka(?)	--	Slight. (12:25 pm P.S.T.)
1906, April 19	Eureka	--	Slight. (03:00 am P.S.T.)
1906, April 19	Eureka	--	Slight. (05:22 am P.S.T.)
1906, April 19	Eureka	--	Slight. (10:30 am P.S.T.)
1906, April 19	Eureka	--	-- (11:10 pm P.S.T.)
1906, April 20	Eureka	--	Slight.
1906, April 23	Eureka	V to VI	Stopped clocks.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1906, April 23	Eureka	--	Slight.
1906, April 27	Eureka	--	Sharp.
1906, April 30	Eureka	--	--
1906, May 9	Eureka	--	Shook windows.
1906, May 10	Eureka	--	Slight sudden jolt.
1906, June 7	Eureka	--	Shook buildings, most severe since April 18.
1906, June 10	Eureka	--	--
1906, June 13	Eureka	--	Very light.
1906, July 9	Eureka	--	-- (10:00 pm P.S.T.)
1906, July 9	Eureka	--	-- (11:37 pm P.S.T.)
1906, July 30	Eureka	--	Light.
1906, August 1	Eureka	--	Very light.
1906, November 7	Eureka	--	--
1906, December 25	Eureka	--	Upset vases.
1907, January 14	Eureka	--	Light.
1907, February 25	Eureka	--	--
1907, August 8	Eureka	--	Very light steady shaking of the earth for six seconds.
1907, August 11	Humboldt County	?	VI or higher at Fortuna, but Eureka lists only "quite heavy".
1907, August 12	Eureka	--	Very light earthquake shocks.
1907, August 23	Eureka	--	Light.
1907, August 26	Eureka	--	Slight.
1907, October 7	Eureka	--	Quite a heavy shock.
1907, October 14	Eureka	--	The jolt shook buildings.
1907, October 23	Eureka	--	Quite a perceptible earthquake shock.
1907, October 28	Eureka	--	Very light.
1907, November 22	Eureka	--	Slight.
1908, January 3	Eureka	--	Heavy earthquake, distinct jolt.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1908, April 18	Eureka	--	Light earthquake.
1908, July 10	Eureka	--	Light earthquake.
1908, July 18	Humboldt Bay	VIII	Several plate glass windows were cracked, a few chimneys tumbled, and statues on the roof of the courthouse were damaged.
1908, December 8	Eureka	--	A light earthquake.
1909, May 17	Upper Mattole	--	Very perceptible.
1909, June 28	Eureka	--	A light earthquake.
1909, October 28	Humboldt County (Fortuna)	VIII	Very heavy earthquake, a number of chimneys tumbled down, stores goods were thrown from the shelves, clocks stopped, and telephone and telegraph lines were put out of commission.
1909, November 1	Eureka	--	Very light.
1910, January 29	Rohnerville	--	Very light.
1910, February 14	Rohnerville	--	Very light.
1910, March 18	Humboldt County	--	Quite a heavy earthquake, continued without cessation for about 49 seconds, the longest earthquake ever felt in the city, but no damage.
1910, August 4	Eureka 42° N, 127° W	--	A sharp earthquake stopped office clocks. (Magnitude 6.8)
1910, August 26	Humboldt County	--	A light earthquake.
1910, December 12	Eureka	--	A very slight shock.
1911, March 11	Eureka	--	Light.
1912, February 2	Eureka	--	Very perceptible.
1914, April 10	Eureka	III to IV	--
1914, August 14	Eureka	IV	Rattled windows.
1914, December 10	Eureka	II	Abrupt jolt.
1914, December 12	Eureka	--	--
1915, February 18	Rohnerville	II to III	One sudden jolt.
1915, May 6	Mendocino Coast	II	--

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Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1915, July 22	Eureka	III	Chandeliers shaken.
1915, December 31	Off Humboldt Coast 41° N, 126° W.	III	Magnitude 6½.
1916, May 16	Eureka	III	Two shocks.
1916, July 4	Humboldt County (Ferndale)	V	Three distinct shocks.
1916, August 23	Eureka	V to VI	Felt by practically everyone.
1917, June 26	Eureka	IV	One bump.
1917, September 12	Eureka	IV	Rattled windows.
1917, October 26	Eureka	II	Houses creaked.
1918, January 14	Eureka	--	--
1918, February 23	Eureka	IV	Felt by many.
1918, March 2	Eureka	III	Felt by several.
1918, April 16	Eureka	V	Distinct bump.
1918, July 14	Off Humboldt Coast 41° N, 125° W	VI	Buildings swayed alarmingly. Magnitude 6½.
1918, July 21	Eureka	III	Felt by many.
1918, August 20	Eureka	IV	Awakened most.
1918, November 29	Eureka	V	--
1919, June 13	Eureka	IV	Felt by several.
1919, September 12	Eureka	V	A series of at least five shocks, the largest giving intensity V.
1919, September 15	Eureka	VII+	Four shocks. The first, and most severe, demolished some chimneys and broke windows.
1919, October 4	Eureka	III	Felt by several.
1920, March 20	Eureka	IV	Felt by many.
1920, April 19	Eureka	III+	Felt by many.
1920, October 4	Eureka	III	A bump. (05:31 am P.S.T.)
1920, October 4	Eureka	IV to V	Some alarm. (08:46 pm P.S.T.)
1921, March 22	Eureka	II to III	Bump felt by several.

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Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1921, April 24	Eureka	IV	Bump felt by many.
1921, August 28	Eureka	III	Bump felt by many.
1921, November 29	Eureka	II	Abrupt trembling.
1922, January 31	Off Cape Mendocino 41° N, 125½° W	IV	Felt over an extremely large area of northern California. Magnitude 7.3.
1922, February 4	Eureka	III+	Rattled windows.
1922, August 5	Eureka	III	-- (7:30 pm P.S.T.)
1922, August 5	Eureka	IV	Rocking motion felt by many.
1922, August 5	Eureka	III	-- (9:45 pm P.S.T.)
1922, August 17	Eureka	III	Rocking felt by many.
1922, September 18	Eureka	III?	Felt by several.
1922, November 3	Eureka	III	Rocking felt by several.
*1923, January 22	Off Cape Mendocino 40½° N, 124½° W	VI to VII	Only minor damage. Magnitude 7.2.
1923, February 9	Eureka	II	Felt by several.
1923, March 28	Eureka	III	Abrupt bumping.
1923, September 3	Eureka	IV?	Awakened nearly all sleepers.
1923, September 17	Eureka	IV?	Abrupt rocking.
1924, January 9	Eureka	IV+	Awakened all but the soundest sleepers.
1924, June 19	Upper Mattole	--	Felt.
1924, July 17	Eureka	IV	Abrupt bumping.
1924, September 7	Eureka	II to III	Rocking felt by several.
1925, January 25	Eureka	II	Felt by several.
1925, March 2	Eureka	IV	Felt by many.
1925, March 3	Eureka	III+	Felt by many.
1925, July 26	Eureka	III+	Abrupt bumping.
1926, September 21	Eureka	IV	Awakened many.
1926, October 13	--	--	Awakened many.
1926, December 27	Eureka	III	Abrupt bumping.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1927, January 3	Eureka	IV	Alarmed some.
1927, February 12	Eureka	IV	Abrupt rocking.
1927, May 16	Humboldt County	IV	Felt by many.
1927, August 10	Eureka	V+	Awakened nearly all, and alarmed many.
1927, August 20	Humboldt Bay	VIII	

In Eureka considerable damage was done in the way of cracking of walls, fall of plaster, cracking and fall of chimneys, and damage to goods which were thrown from the shelves in stores. The County Courthouse and the Federal Building suffered extensive damage in cracking of plaster and walls. Water pipes were broken in the latter building. (From Perry Byerly, The Eureka (California) Earthquake of August 20, 1927.)

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1927, September 6	Humboldt County	III	Felt by several.
1927, September 16	Eureka	V	Light fixtures swayed. Awakened all but the soundest sleepers.
1927, December 8	Eureka	V	Felt by many. (2:25 pm P.S.T.)
1927, December 8	Eureka	V	Felt by nearly all at rest. (10:13 pm P.S.T.)
1929, December 4	Garberville	IV	--
1930, March 27	--	III	--
1930, September 22	Eureka	VII	Major earthquake. Two shocks which caused considerable local damage, but little information available.
1930, December 11	--	V	No damage. (12:59 am P.S.T.)
1930, December 11	--	IV	(4:29 am P.S.T.)
1930, December 12	--	III	(12:15 pm P.S.T.)
1930, December 23	--	--	No damage. Between December 11 and December 23 there were eight shocks felt in Eureka.
*1931, March 9	40° N, 125° W	II to III	--
1931, May 19	--	III	--
*1931, September 9	40½° N, 124° W	IV	Magnitude 5.8.
1931, November 28	--	III	--
1932, January 5	--	III	--
1932, April 26	--	IV	--

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Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1932, June 5	--	II to III	--
*1932, June 6	40° 45' N, 124° 30' W	VIII	

Two large brick stacks (both 150 feet high) were damaged, almost all brick chimneys around Humboldt Bay were damaged, and most of them completely demolished. On the highway at Field's Landing a crack running in an east-west direction transverse to the road was formed, but there was no evidence that it extended farther than the edge of the concrete pavement. One person was killed and another severely injured in Eureka. Electric power was interrupted for only a few minutes, and the water system in Eureka remained intact. No fires followed the earthquake. (From Neil R. Sparks, The Eureka Earthquake of June 6, 1932.)

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1933, November 10	--	IV	Felt by many.
1934, April 20	--	IV	Bumping motion following by trembling. Awakened many.
**1934, July 6	41° 26' N, 125° 24' W	V	Hanging objects swung, clocks stopped.
1934, November 15	--	II	Walls creaked.
1934, November 17	--	III	Gentle rocking.
1935, January 2	40°.4 N, 125.7° W	IV	Windows rattled, walls creaked, and chandeliers swung.
1935, February [illegible]	--	II	Felt.
1935, October 27	--	(III)	--
1936, June 3	40.2° N, 126.0° W	IV	Slow rocking and rolling motion.
1936, August 23	--	(III)	Felt by many.
1936, September 25	--	(III)	A single surge, felt by many.
1937, February 6	--	V	Pendulum clocks stopped, bushes shook, and hanging objects swung.
**1938, September 11	40° N, 124° W	V	Felt by all; hanging objects swung.
**1938, October 17	40° N, 124° W	(II)	Felt by few.
1938, November 9	--	(III)	Mild earth tremor, felt by many.
**1939, May 1	40° N, 124° W	IV	Rattled windows; hanging objects swung.
1939, June 22	--	II	Felt by few.
1940, August 25	--	III	One vertical bump; subterranean sounds.
1940, September 27	--	IV	Moderately loud subterranean sounds, lighting fixtures swung, some alarm.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1940, October 22	--	IV	Rattled windows and doors.
1940, November 16	--	V	Objects swung, trees and bushes shook.
1940, November 19	--	V	Objects swung, dishes rattled, walls creaked, and bushes were disturbed.
1940, December 20	--	IV	Clocks stopped, objects swung, felt by nearly all.
1941, January 23	--	IV	Felt by many, awakened few.
**1941, February 9	40.7° N, 125.4° W	VI	Overturned small objects, and shook trees and bushes.
**1941, May 13	40.3° N, 125.0° W	III	Felt by few.
1941, October 3	--	VII	Plaster cracked and fell, chimneys cracked and twisted; was felt by and frightened all.
1941, October 4	--	III	Slight.
1941, November 24	--	III	Felt.
1943, November 11	--	IV	Rattled loose objects, buildings creaked, awakened few.
1944, January 12	--	V	Hanging objects swung, small objects disturbed.
1944, June 5	--	III	Felt by few.
1944, September 21	--	IV	Rattled windows.
1945, May 2	--	V	Fixtures swung, disturbed objects.
1945, May 19	40.2° N, 126.8° W	IV	Rattled windows.
*1945, October 22	40.7° N, 124.7° W	0	Not reported felt. Magnitude 4.3.
1946, August 1	--	III	Swayed light fixtures.
1946, November 23	--	V	Earthquake sounds, objects disturbed.
1946, December 18	--	V	Earthquake sounds, objects disturbed; sharpest since 1932.
1946, December 20	--	III	Felt by several.
1947, March 29	--	V	Floor lamps swayed, objects disturbed.
**1947, May 27	40.4° N, 124.7° W	V	--
**1947, September 23	40.4° N, 125.2° W	VI	Awakened all, frightened many, hanging objects swung.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
**1948, February 19	41° N, 124.9° W	III	Felt by several.
1948, April 3	--	IV	Felt by many, loose objects rattled.
*1948, August 8	40° 25' N, 124° 07' W	0	Not reported felt. Magnitude 3.0.
*1948, August 8	40° 25' N, 124° 07' W	0	Not reported felt. Magnitude 3.3.
**1948, August 18	40.5° N, 124.7° W	V	Disturbed objects.
1948, August 19	--	V	Awakened many.
**1948, September 7	40° 15' N, 124° 16' W	III	Felt by several.
*1948, November 12	40° 24' N, 124° 19' W	0	Not reported felt. Magnitude 4.5.
*1949, May 3	40.4° N, 124.3° W	III	Hanging objects swung. Magnitude 4.1.
*1949, May 12	40.7° N, 124.7° W	0	Not reported felt. Magnitude 4.3.
1949, September 6	--	?	Felt.
*1949, October 27	40.9° N, 124.2° W	V	Disturbed objects. Magnitude 4.5.
*1949, December 21	40.4° N, 124.3° W	0	Not reported felt. Magnitude 3.6.
**1950, January 14	40° 13' N, 124° 25' W	V	Shifted small objects, rattled windows.
*1950, February 10	41.2° N, 124.3° W	V	Hanging objects swayed, small objects displaced. Magnitude 4.0.
*1950, June 2	40.8° N, 124.4° W	?	Sharp at Eureka. Magnitude 4.0.
*1950, June 6	40.8° N, 123.7° W	0	Not reported felt. Magnitude 3.0.
*1951, January 13	41.2° N, 124.3° W	IV	Felt by many.
**1951, October 7	40° 17' N, 124° 38' W	V	Disturbed objects, many frightened.
*1951, October 26	41° 00' N, 124° 30' W	0	Not reported felt. Magnitude 3.9.
*1951, November 14	40° 26' N, 124° 03' W	VI	Large windows broken. Magnitude 4.7.
*1952, March 23	40° 25' N, 124° 08' W	0	Not reported felt. Magnitude 3.2.
*1952, April 27	40° 55' N, 124° 25' W	0	Not reported felt. Magnitude 3.0.
**1952, September 22	40° 12' N, 124° 25' W	V	Felt by most, disturbed objects.
*1952, October 4	40° 35' N, 124° 25' W	0	Not reported felt. Magnitude 3.7.
*1952, November 16	41° 00' N, 124° 25' W	0	Not reported felt. Magnitude 4.1.
*1952, December 17	40.4° N, 124.2° W	0	Not reported felt. Magnitude 2.8.
*1953, January 3	40.7° N, 124.4° W	0	Not reported felt. Magnitude 3.6.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
*1953, April 10	40° 26' N, 124° 18' W	0	Not reported felt. Magnitude 3.2.
*1953, May 25	40° 35' N, 123° 45' W	0	Not reported felt. Magnitude 2.8.
*1953, May 27	40.5° N, 124.4° W	0	Not reported felt. Magnitude 3.0.
*1953, May 30	40° 28' N, 124° 27' W	0	Not reported felt. Magnitude 3.6.
*1953, June 25	40.4° N, 124.3° W	0	Not reported felt. Magnitude 3.1.
*1953, July 1	40.5° N, 123.6° W	0	Not reported felt. Magnitude 2.4.
*1953, July 7	40.6° N, 124.3° W	0	Not reported felt. Magnitude 3.1.
*1953, August 6	40.6° N, 124.0° W	0	Not reported felt. Magnitude 3.1.
*1953, August 7	40.7° N, 123.8° W	0	Not reported felt. Magnitude 3.5.
*1953, August 14	40° 28' N, 124° 06' W	0	Not reported felt. Magnitude 3.0.
*1953, October 25	40° 36' N, 123° 56' W	0	Not reported felt. Magnitude 2.9.
*1953, November 17	41.2° N, 124.1° W	0	Not reported felt. Magnitude 3.2.
*1954, May 27	40° 28' N, 124° 30' W	0	Not reported felt. Magnitude 3.6.
*1954, July 1	40.8° N, 124.5° W	0	Not reported felt. Magnitude 2.0.
*1954, July 5	40° 26' N, 124° 16' W	III	Slight rumbling earthquake. Magnitude 3.6.
**1954, July 17	41° 13' N, 123° 34' W	III	Mild intensity.
*1954, October 20	40.4° N, 124.3° W	0	Not reported felt. Magnitude 2.5.
*1954, November 18	40.5° N, 124.1° W	IV	Felt by many.
*1954, December 21	40° 49' N, 124° 05' W	VII	Magnitude 6.5.

The old City Hall and old County Courthouse in Eureka were extensively cracked; several old poorly constructed brick walls bulged, and there was some parapet damage, but damage in the main was to chimneys, plaster, plate-glass windows, and merchandise. In the poorly consolidated ground areas north and east of Eureka there were some pipe line failure and Eureka's main water reservoir (constructed in two halves) was cracked in one half. Numerous breaks occurred in Eureka's water distribution system, but none were serious. Two tall industrial stacks, cracked in the 1932 earthquake, were again cracked. One elevated steel tank (not earthquake resistant) had broken rods. U.S. Highway 101 between Eureka and Arcata was cracked and bulged to some extent but no serious damage occurred to roads or bridges. A press report stated, "A large section of the older downtown area of Eureka settled from two to six inches. The area, bounded roughly by E Street, Fourth Street, Broadway and the Bay, at one time was a tidal mud flat and was filled to allow construction of buildings. This sector of the city has been settling gradually for many years but sank rapidly during the earthquake. .... One man fell into Humboldt Bay and was drowned and a number of people were injured by falling objects. (From the United States Coast and Geodetic Survey).

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
*1954, December 22	40° 47' N, 123° 52' W	0	Not reported felt. Magnitude 3.5.
*1954, December 24	40° 44' N, 124° 04' W	V	Frightened all, rattled dishes. Magnitude 3.5.
*1954, December 30	40° 47' N, 123° 52' W	VI	Plaster cracked windows broken, chimneys down, and water transmission lines broken. Magnitude 5¼.
*1955, January 1	40° 57' N, 124° 00' W	IV	Some plaster cracked. Magnitude 4.0.
*1955, January 1	41° 11' N, 124° 11' W	?	Included above. Magnitude 3.0.
*1955, January 8	40.9° N, 124.4° W	0	Not reported felt. Magnitude 3.0.
*1955, January 9	40.9° N, 124.4° W	0	Not reported felt. Magnitude 2.6.
*1955, January 12	41.1° N, 123.9° W	0	Not reported felt. Magnitude 3.3.
1955, January 30	--	IV	Felt by many.
1955, January 31	--	IV	Light jolt.
*1955, March 5	41.0° N, 124.0° W	III	Light earthquake. Magnitude 3.1.
*1955, March 7	40° 39' N, 124° 15' W	0	Not reported felt. Magnitude 3.5.
1955, March 15	--	III	Two light shocks.
*1955, June 7	40.8° N, 124.4° W	?	Felt.
*1955, August 26	40° 23' N, 124° 30' W	III	A minor earthquake. Magnitude 4.5.
*1955, August 29	40° 25' N, 124° 11' W	V	Floor lamps swayed, disturbed objects. Magnitude 4.1.
1955, October 11	--	III	Slight rattles.
*1955, November 4	40.8° N, 124.3° W	IV	Felt by all in home. Magnitude 3.0.
*1955, November 15	40.7° N, 123.6° W	IV	Felt by all in home. Magnitude 3.2.
*1955, November 18	40° 25' N, 124° 05' W	0	Not reported felt. Magnitude 3.6.
**1956, March 9	40° 18' N, 124° 14' W	IV	Felt by several, awakened few.
*1956, May 28	41.1° N, 124.0° W	III	Very light. Magnitude 2.5.
1956, May 31	--	III	Felt on first floor.
1956, June 1	--	III	Six light shocks.
*1956, July 12	40.8° N, 123.6° W	0	Not reported felt. Magnitude 3.5.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
*1956, July 26	40° 27' N, 124° 18' W	0	Not reported felt. Magnitude 3.2.
*1956, August 1	40° 25' N, 124° 05' W	0	Not reported felt. Magnitude 3.0.
*1956, October 6	40° 25' N, 124° 00' W	0	Not reported felt. Magnitude 3.3.
1956, October 11	40° 40' N, 125° 46' W	V	A few dishes broken.
1956, October 13	--	IV	Caused garage to tremble.
** 1956, November 10	40° 13' N, 123° 48' W	V	Rattled windows and awakened sleepers.
*1957, January 26	40° 24' N, 124° 01' W	0	Not reported felt. Magnitude 3.3.
*1957, February 18	41.0° N, 124.2° W	III	Light jolting earthquake. Magnitude 2.7.
*1957, March 13	40.7° N, 123.9° W	III	Small shock. Magnitude 3.0.
** 1957, March 14	40° 16' N, 123° 50' W	IV	Disturbed objects.
*1957, April 9	40.4° N, 124.2° W	0	Not reported felt. Magnitude 3.3.
*1957, June 5	40° 30' N, 124° 00' W	0	Not reported felt. Magnitude 3.4.
*1957, September 2	40.7° N, 123.9° W	0	Not reported felt. Magnitude 3.0.
*1957, July 28	40° 29' N, 123° 58' W	0	Not reported felt. Magnitude 3.2.
** 1958, March 14	40° 16' N, 123° 58' W	IV	Felt by many, awakened few.

* Epicenter located on map within 30 miles of Eureka.

** Epicenter located on map, beyond 30 miles, but felt in Eureka.

11-21-58

Table 2

MODIFIED MERCALLI INTENSITY SCALE OF 1931

I. Not felt except by a very few under especially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls made cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbed persons driving motor cars.

IX. Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI. Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

G-2. Geologic Reconnaissance of ground water conditions, Buhne Point, Eureka, California, by Chester Marliave, 1959, 1960.

APPENDIX II

GEOLOGIC RECONNAISSANCE OF GROUND WATER CONDITIONS, BUHNE POINT EUREKA, CALIFORNIA

by E. C. Marliave

PREFACE

After Mr. E. C. Marliave completed the original report on "Geologic Reconnaissance of Ground Water Conditions, Buhne Point, Eureka, California," the Company drilled seven test holes to determine the position and slope of the ground water table in the area. Mr. Marliave's analysis of the data obtained from the test holes is presented in his letter of December 27, 1960.

Included in this appendix are Mr. Marliave's letter of December 27, 1960 and his original report.

Appendix II

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E C MARLIAVE
CONSULTING GEOLOGIST
4466 NORTH PARK DRIVE
SACRAMENTO 21 CALIF
—
IVANHOE 9-4510

December 27, 1960

Mr. John F. Bonner
Vice President & Chief Engineer
Pacific Gas & Electric Company
245 Market Street
San Francisco, California

Subject: Unit No. 3, Eureka Plant

Attention: Mr. J. D. Worthington
Chief Civil Engineer

Dear Mr. Bonner:

In my transmittal letter for the original report dated October 28, 1958, above subject, it was suggested that your company drill a few test holes to determine the position and slope of the ground-water table in this area. In accordance with this idea seven holes were drilled during the Fall of 1960, and measurements have been taken on them allowing an approximate determination of the position and slope of water table in various parts of the adjacent area.

The location of these holes are plotted on the accompanying map which is a portion of the U.S.G.S. Fortuna quadrangle. Various water-level profiles have also been drawn and shown on the accompanying graph from the measurements taken by your office. They are numbered numerically as profiles. A study of these profiles bears out the previous thinking regarding ground-water movement and establishes the direction of movement and slope of water table.

In general, it is quite true that the water-table slope, and particularly in the main ground-water body of Elk River valley, is from the southeast to the northwest and in local cases in a more westerly direction toward the Bay. The following comments refer to the various profiles.

Profile 1

This profile trends northwesterly down Elk River valley through test holes 7, 6, and 5, and shows a water-level slope from elevation 29+ feet in hole no. 7 to elevation 4+ feet in hole no. 5 in the Fall of 1960. This is a slope of 25 feet in about two and one-fifth miles, or an average slope of about 12 feet per mile. It should be noted that this slope occurs at what is generally considered to be the low-water period of the year prior to any appreciable rainfall and recharge.

It will also be noted in your tabulation of elevations on the drawing entitled 'Ground-Water Test Holes, Humboldt Bay, Scale 1' = 400'," that in the last week of November there was a rise in water-level elevations, probably due to rainfall and recharge. The slopes remain approximately the same but the water levels are at an elevation several feet higher due to the effects of recharge.

The foregoing suggests that there is always a seaward gradient to the water table with no opporutnity for any water to work upstream into the Elk River valley to the southeast of the vicinity of hole no. 5 should any accidental discharge enter the lower portion of the stream. The stream will continue to flush out the channel sediments; particularly during the winter months when large flows occur.

Profile 2

This northeasterly trending profile, between holes 4 and 5, indicates a water-table slope to the northeast. Hole no. 4 was located where it was estimated a ground-water divide might exist and this condition seems borne out by the measurements taken. Also there is very little fluctuation in hole no. 4 indicating it probably does not receive much recharge. Hole no. 5 is in the Elk River valley and probably within the zone affected by the tidal fluctuations. There is generally an average water-level elevation difference of 3 feet in 5,700 feet, or a little less than a 3-foot per mile slope.

Profile 3

There is a slope varying from 2 to 4 feet from test hole 4 to test hole 2 in a westerly direction and generally toward the Bay and Buhne Slough. The slope from test hole 4 to 5 to the northeast, and from 4 to 2 to the west, suggests that a hydrologic divide exists in the vicinity of hole no. 4 and drainage goes in both directions to the northeast to Elk River valley and then the Bay, and to the west towards Buhne Slough. The slope between test hole 4 and test hole 2 is about 5 feet per mile.

Profile 4

There is generally a slope of about 5 feet in the 1,000 feet between test holes 4 and 3 in a northwesterly direction, which is toward Buhne Slough and also the Bay. Hole no. 3 is adjacent to Buhne Slough and is apt to be flooded during heavy rains and probably also fluctuates with the tide through a rather poor ground-water connection in tight sediments. This water-table slope is about 25 feet per mile.

Profile 5

The slope between test holes 1 and 2 indicates a slight landward gradient of about 1+ feet in 2,200 feet, or about two and one-half feet per mile during low-water stages. This is noted in the fall measurements prior to any appreciable rainfall. After rainfall occurs the gradient is reversed and a slight seaward gradient occurs.

Profile 6

A landward gradient exists between holes no. 1 and 3 on the order of 2.8 feet in 3,200 feet, or about 5 feet per mile.

Profile 7

A landward gradient exists between holes 2 and 3 on the order of 1.8 feet in 2,200 feet, or about 5 feet per mile.

Hole no. 3 was drilled at the lowest elevation of all of the test holes and is adjacent to Buhne Slough where it probably represents the effect of tidal action. Hole no. 1 is at a slightly higher elevation and may be drilled largely in tighter materials underlying a very thin skin of Recent alluvium. Hence, these measurements may not be as important to the area picture and only reflect local conditions in the tidal zone. However, it should be noted that these holes are drilled in the immediate vicinity of the plant site and are generally away from the main ground-water body of Elk River valley and are separated from this valley by what appears to be both a surface and ground-water divide.

From study of the logs of the seven test holes drilled, there is little can be said other than that the material appears to be clay and sandy clay and should have a very low permeability.

It should be indicated that the plant area will be at least, in part, paved and with certain drainage provided, which would carry any runoff to the vicinity of Buhne Slough or the plant wasteway, in either case the water being carried immediately to the Bay. While the underlying materials, as previously indicated in the original report, are quite tight and would have low percolation rates, the addition of an asphalt or other type pavement in the plant area would further reduce the opportunity for liquids on the surface to penetrate to water table.

It might be well at this time to indicate that the quantity of waste, which might be accidentally discharged, would be relatively small and in terms of a few thousands of gallons. This would not be a large quantity of liquid to control by prepared drainage at the plant site and would certainly be appreciably diluted when it reaches Buhne Slough or the Bay.

A pumping transmissibility test conducted by Dames & Moore during foundation investigations at the plant site indicated a low transmissibility coefficient.

It might also be well to quote from the U. S. Geological Survey Water-Supply Paper 1470, which was published in 1959 and is entitled 'Geology and Ground-Water Features of the Eureka Area, Humboldt County, California.'

Similar conditions of ground-water movement are believed to exist in the Elk River and Buhne Point area.

While this paper deals largely with the Mad River to the north and the Eel River to the south of this area, there are paragraphs on page 28, which indicate that water generally moves toward the Bay and ocean and is discharged naturally by subsurface flow. The following paragraphs quote the particular reference regarding discharge of ground water.

'Discharge of Ground Water

> 'Ground water in the Eureka area is discharged by natural and artificial means. Artificial discharge is considered to be the flow and pumpage from wells.

Natural Discharge

'Most ground water is naturally discharged by subsurface flow to streams and tidal estuaries in the coastal plain, by evaporation and transpiration, and by flow through spring orifices. As previously discussed in the section on recharge and movement of ground water, the discharge of ground water to the sea or to the tidal estuaries is partly controlled by the rise and fall of the tide. The magnitude of the natural discharge is no doubt large, but no data were available to estimate it. An indication of the magnitude of natural discharge from the alluvium of the Eel and Mad Rivers may be obtained from the numerical difference between total pumpage and the estimated depletion of storage during 1952. This difference indicates about 10,000 acre-feet of natural discharge per year from the Eel and Mad River alluvial deposits.

"In addition, ground-water discharge to the sea from the older water-bearing deposits probably takes place at some distance offshore, and ground water from the coastal dune sand probably discharges near the beach."

Conclusions

1. There is a pronounced seaward gradient of the water table in Elk River valley, which is the main water-bearing body near the plant, to the vicinity of test hole no. 5. The water table near hole no. 5 is above sea level but is probably affected to some extent by tidal action.

2. Regardless of the effect of tides in Elk River valley the sediments or ground water-bearing materials will be flushed out each year during the rainy season.

3. Both a ground water and slight topographic divide appear to exist between the plant site and Elk River valley in the vicinity of test hole no. 4. These features would reduce greatly the possibility of liquids moving from the plant area to the Elk River valley as subsurface or surface flow.

4. There is a small area immediately to the south and west of the plant where ground water has a slight landward gradient part of the time. This area, however, seems to be within the

zone of tidal action and there is probably little opportunity for any appreciable movement of water inland.

5. With the proposed paving and draining of the plant area, it would be almost impossible for liquid wastes to penetrate through the paving and the underlying tight sediments to the vicinity of the water table. Should this occur, it is doubtful if such wastes, even diluted, could move inland from the vicinity of the plant area.

6. The pump test conducted by Dames & Moore in the vicinity of the plant indicates, as previously estimated, a very low permeability of the underlying sediments, and since this is probably largely a horizontal permeability, it should be remembered that the vertical permeability is many times less.

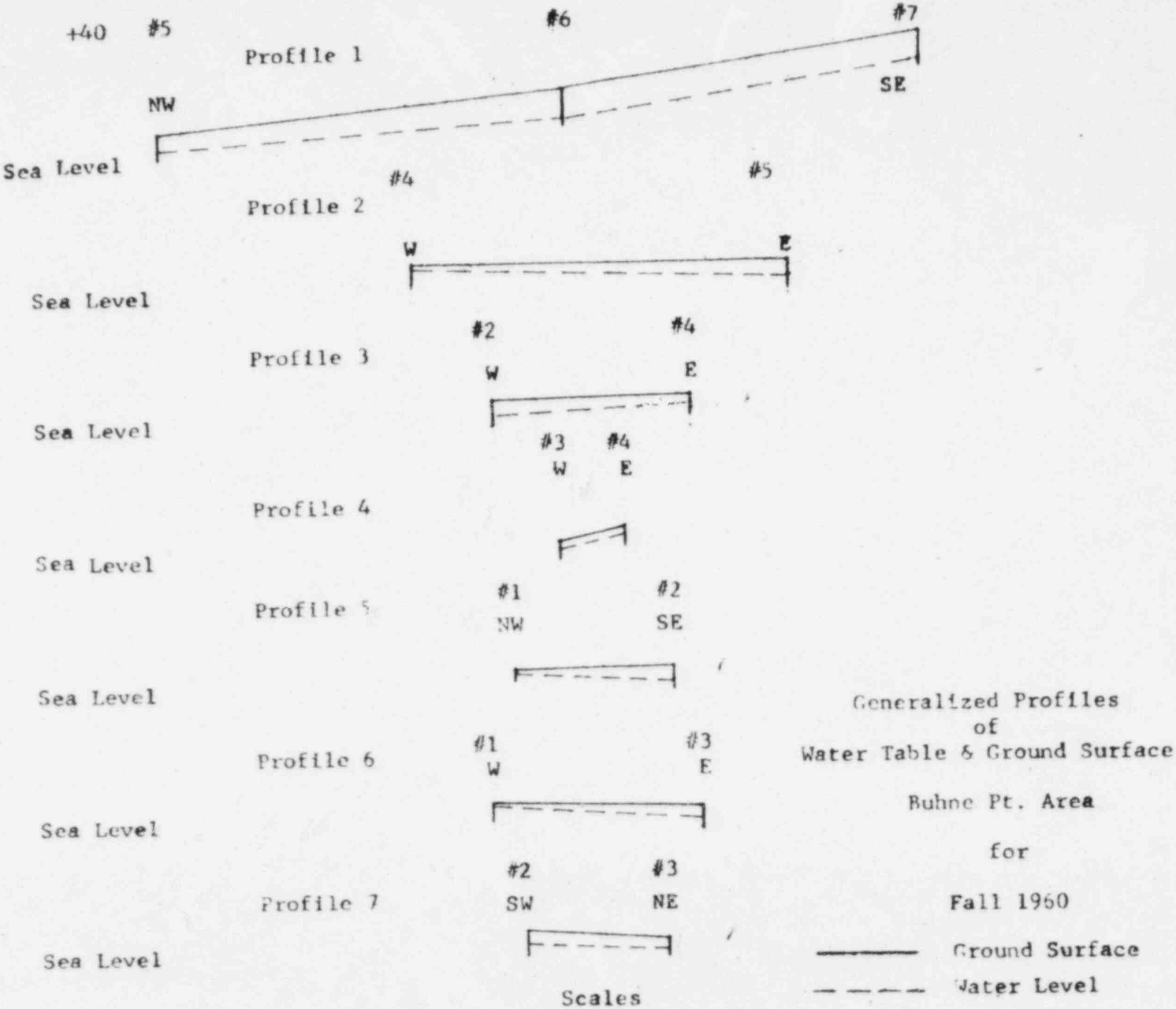
Recommendation

The test holes should be measured at least twice annually, for a period of several years. Measurements should be made in late spring when water levels are high and again in late fall when water levels are low and before there is recharge by rainfall. These measurements will give sufficient evidence over a period of time that liquids from the plant area cannot work up-gradient.

Very truly yours,

E. C. Marliave
Consulting Geologist

ECM:jh
Enclosures



Generalized Profiles
of
Water Table & Ground Surface

Buhne Pt. Area

for

Fall 1960

Scales

Horizontal 1" = 2000'
Vertical 1" = 400'

STBI.

Appendix II

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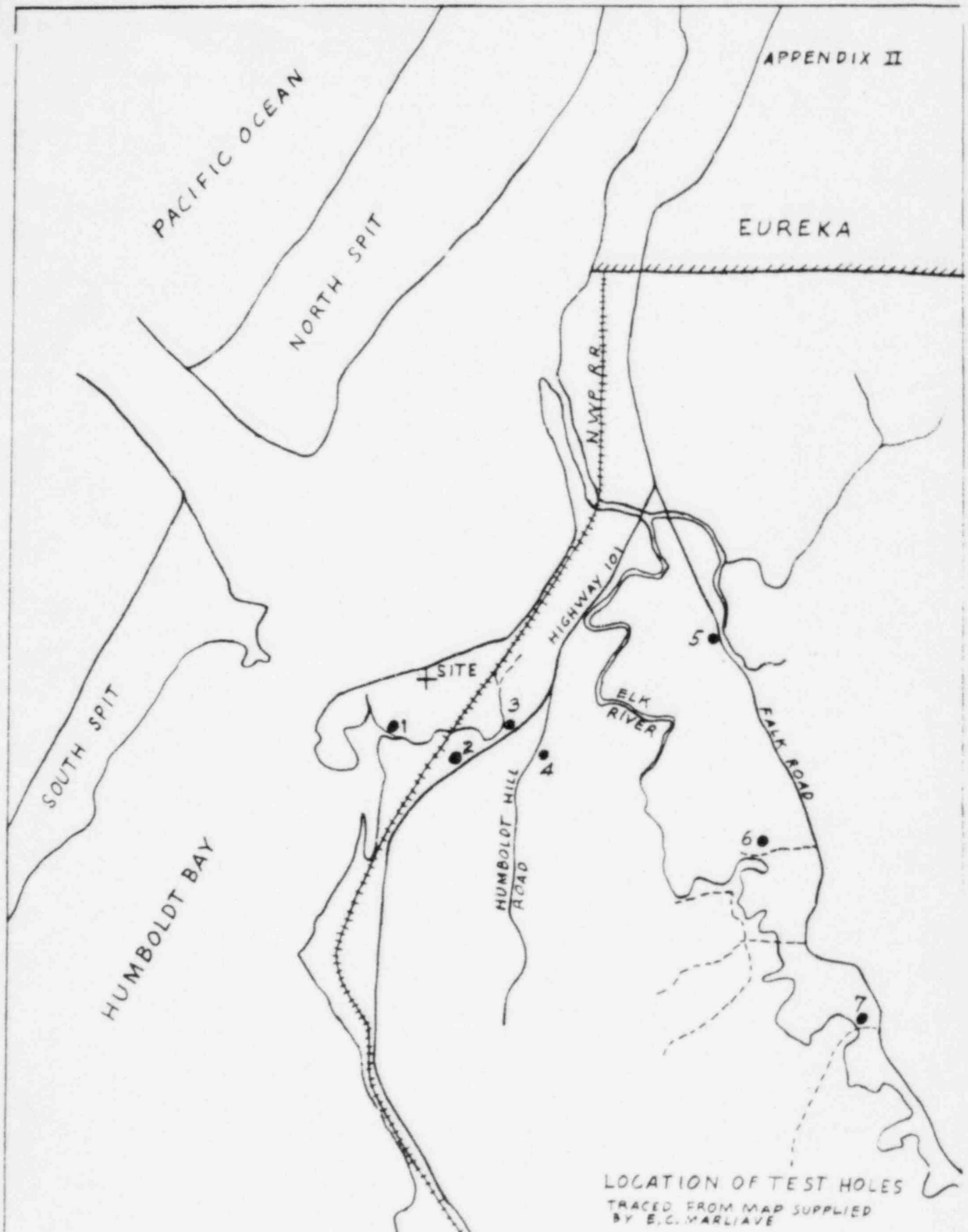
APPENDIX II



LOCATION OF TEST HOLES

TRACED FROM MAP SUPPLIED BY E.C. MARLIAVE

8166d

Appendix II

Geologic Reconnaissance
of
Ground Water Conditions
Buhne Point
Eureka, Calif.

by
E. C. Marliave
Consulting Geologist
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1959

Appendix II

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Geologic Reconnaissance of Ground Water Conditions
Buhne Point, Eurkea, Calif.

Purpose

The purpose of this report is to determine the occurrence and movement of surface and subsurface waters in the vicinity of the Eureka Plant area.

Location

The plant is located approximately in the NW 1/4 of the SW 1/4 of Section 8, T. 4 N., R. 1 W., H.B.M. This location is about 3 miles south and two and one-half miles west of the town of Eureka.

The plant is located on Buhne Point, between the Northwestern Pacific Railroad tracks and the receding north shoreline of Buhne Point. The plant area is slightly higher in elevation than the surrounding flood plain and marshy areas, as Buhne Point represents the seaward extension of a northwest southeast trending range of hills that extend from Buhne Point to the southeast.

The adjacent area of importance to this study is to the east, south and southeast of the plant area and in part in Sections 8, 9, 16, 17 and 22, T. 4 N., R. 1 W., H.B.M. Much of this area is primarily the portion of Elk River Valley and the bordering contiguous hills that extend from the southeast to the northwest toward Buhne Point.

Topography and drainage

The topography in the vicinity of this site is primarily that of low rolling erosional hills with a gently grading slope to the west toward the coast line as one descends from the mountainous area to the east. The coastal area, and particularly the valleys and flood plains, are in a mature stage of development, with broad wide valleys containing the flood plains meandering streams and sloughs. The low lying flood plain and slough areas are affected for several miles inland by tidal action, particularly at low water stages. The flood plain deposits originate from high winter and spring stream flow. The flood plain and flats are poorly drained and there is little relief in the bottom of the valleys. The hills and mountainous areas to the northeast and southeast are reasonably well drained by a dendritic stream pattern.

Locally, in the vicinity of the plant, which is on slightly higher ground than the tidelands and lowlands adjacent to Buhne Point, surface drainage can be controlled to a modest degree. Locally drainage is to the west, as exemplified by Buhne Slough, while to the east of the plant drainage is to the northwest. A tide gate installed near the mouth of Buhne Slough affords further control of waters in the Slough.

Geology

Since most of the pre-Pliocene sediments containing very little water do not occur in the nearby areas, we are concerned primarily with the post-Pliocene deposits and, in particular, with the upper Pleistocene and Recent Quaternary deposits.

These latter sediments, of the water-bearing series, are the least consolidated and most permeable members of the geologic formation and they absorb, transmit and yield water in sufficient quantities to be of economic importance. These are the materials that would transmit most of the water that may occur in the area.

There are five water-bearing formations in the vicinity of Buhne Point. First, the river channel deposits of which the coarse gravels and sands in the active channels of the river are the most recent; secondly, the alluvium, which is the unconsolidated gravels, sands, and clays underlying the alluvial plains and flats of the flood plains; thirdly, the terrace deposits which are poorly consolidated mixtures of gravel, sand and clay, on the higher benches and slopes of the hills adjacent to the flood plains and river bottom lands. These latter are slightly more consolidated in many cases than the alluvium.

The Hookton formation, described by Ogle in 1953, is a slightly consolidated series of gravels, sands and clays. These materials in general where exposed are fairly tight and consist largely of the finer constituents. Ground water in the sands and gravel throughout this formation is apparently confined. Some of the wells penetrating strata of this unit are flowing wells. The source of supply or forebay area is farther upslope to the east and to the south in the steeper hills.

Underlying the Hookton formation is the Carlotta formation, again described by Ogle in 1953, which is similar to the Hookton though more consolidated and indurated and comprised largely of conglomerates, sandstones and claystone. Again, ground water in the more permeable beds of this formation appear to be confined and give rise to artesian flows and pressure water in wells penetrating the formation.

The formations most pertinent to this study are the river gravels, alluvium, terrace deposits and, to a lesser extent, the Hookton formation.

Thus it may also be seen that the geologic units just referred to may be divided into two important parts, the alluvium and river gravels and terrace deposits, which are the most recent in age, which appear to contain free ground water and may be recharged by streamflow and penetration of rainfall on the surface.

In general, it is estimated from the well data and geologic sections available that the materials containing free ground water have a depth range of from 20 to about 70 feet below average ground surface in the flat, alluviated areas and particularly in Elk River Valley in the vicinity of Buhne Point.

Secondly, the tighter, more consolidated Hookton formation containing considerable amounts of fine materials and aquifers which are frequently under pressure. The fact that the aquifers are under pressure implies confining beds overlying permeable strata and absorption of water is primarily in a forebay area. It is important to recongize this as the confining strata and the hydrostatic pressure will probably prevent appreciable downward percolation of water and prevent surface liquids from reaching the confined water-bearing strata in the Hookton formation.

The areal geology, taken from U.S.G.S. open file report, 'Reconnaissance of the Geology and Ground Water Features of the Eureka Area, Humboldt County, California,' is indicated on the following pages. Indicated on this map are the location of two geologic sections A-A' and B-B' drawn through the plant area and also the location of the Pine Hill anticline from Ogle's report. The geologic sections follow the geologic map. The vertical scale of these sections is greatly exaggerated to show the tight surficial materials overlying the alluvium and the approximate thickness of alluvium and channel deposits in the vicinity of the plant.

Originally it was believed that surface and subsurface flow in the coarse sediments of Elk River Valley would be an important factor in controlling surface and subsurface waters originating in the plant area. Study of geologic and hydrologic data suggests that this idea should be minimized for the following reasons:

1. Water from the plant area will probably not be discharged directly into Elk River Valley.
2. The existence of a modest drainage divide between headwaters of Buhne Slough and Elk River just east of the plant site, and the possibility of a ground water divide in this area.
3. The probable importance of surface and subsurface flow toward the plant to the north from the area east of Fields Landing.
4. Buhne Slough drains to the west. Elk River may become important during periods of low stream flow and high tides, at which times stream flow reaching the bay may then move in a landward direction to the limits of tidal effects, possibly two miles inland.

Surface Flow

Elk River has a very low gradient and the lower portion for several miles of the channel to its mouth is choked with phreatophyte growth. The Geological Survey maintains a gaging station called the Falk Station about three miles upstream from the mouth where this station is believed to be out of the zone of tidal effects. Tidal effects may well extend inland from Humboldt Bay for one to two miles.

From a discussion of stream flow characteristics with personnel of the U.S.G.S., they have estimated that the maximum velocity of surface flow in Elk River would not exceed eight feet per second in the area near Buhne Point and that this maximum flow would rarely be attained. During periods of low flow and high tides, negative velocities of one to two feet per second may occur for limited periods of time and might be effective a mile or more inland from the Humboldt Bay boundary. However, eventually all water discharged by Elk River will enter into Humboldt Bay where tidal currents will take over. Hence it would seem reasonable to assume low surface velocities in Elk River on the order of one to three feet per second most of the time during low flows near Buhne Point. Since surface runoff would normally enter near the edge of such a stream, side velocities would be at a minimum at the entrance point.

This applies to surface flows only and the ground water flows below the surface will be dealt with separately.

Since a tide gate is installed near the mouth of Buhne Slough, a degree of control may be exercised over the movement of water in this slough.

Waters falling on the ground surface in the Buhne Point area would move with the drainage to lower elevations and transported to the slough area near the bay. The surface velocity would be greatest during storms and when the ground is thoroughly saturated at lower elevations.

During heavy storms with high flows, water would move rapidly overground to the channels, while at low flows and low water table, following the same local drainage, it would tend to seep to a limited extent into the alluvial fill.

Subsurface Flow

Due to many variations in soil conditions and other factors, the rates of movement of water are variable. Rates of movement might be on the order of values, as follows·

1. Vertically through clays and silts 0.01 to 0.1 ft/day.
2. Vertically through sands and sandy clay 0.1 to 10.0 ft/day

3. Vertically through sands and gravels 10 to 100 ft/day.

4. Horizontally through clays and silts 0.1 to 1.0 ft/day.

5. Horizontally through sands and gravels 100 to 500 ft/day.

6. Horizontally through mixtures sandy clay and sand 1 to 10 ft/day.

The above figures should be used with judgment, as they are only estimates of average rates of travel for various types of materials under hydraulic gradients of unity. When reducing these rates of travel to the normal water table gradients existing in the alluvial fill materials in the vicinity of Eureka, California, it is obvious that for the lower gradients the indicated values will be greatly reduced.

While data are not available to draw ground water contours in Elk River Valley and vicinity, a Water Level Profile, Eel River Valley, August 1952, has been prepared from the U.S.G.S. open file report. This profile should be indicative of water table slope in the free water body of the channel deposits and alluvium of Elk River and the profile indicates a steeper slope in the upper reaches of the valley and a much gentler slope within a few miles of the river mouth at a point on Salt River about two miles northeast of Ferndale. The profile indicates a seaward gradient and a similar gradient is believed to exist in Elk River Valley.

Confined water in sand and gravel strata of the underlying Hookton formation near the plant site exerts an upward pressure. This force and the clayey material of the confining beds would make it almost impossible for water from the surface to reach the confined zone. Since surface waters may not readily reach this zone, it is not probable that estimates of transmissibility in the confined aquifers will be needed. The vertical permeability through these materials should be very low though the horizontal permeability should be much greater.

Test drilling at Buhne Point and other well logs available indicate a thickness of several to 35 feet of tight clayey material at and near ground surface. According to Dames and Moore and others who drilled this area, the depths at plant site average 20 feet. Laboratory tests indicate this to be a clayey material that might have a vertical permeability of a fraction of a foot per day. For lower slopes the rate of travel toward the more permeable lower zone would be appreciably less. Hence it would seem logical that surface water would have a relatively difficult time in reaching the shallow free ground water zone in the plant area, and a much more difficult time in reaching the lower pressure aquifers through the confining layers.

Although topography is not detailed enough, there appears to be a surface drainage divide north of the extension of Spruce Point. Here Buhne Slough drains through the plant area to the west, while to the east of the divide there must be surface drainage to Elk River. The possibility of a ground water divide must also be considered.

Even though in a limited area near the plant ground water might move westerly for a short distance, the main mass of movement should still be toward the northwest both from the vicinity of Humboldt Hill and Elk River Valley.

While it is believed that most surface and ground water moves northwesterly, with the exception of the local westerly drainage of Buhne Slough, there are no data from water table elevations to support such a hypothesis. The block diagram indicates geologic conditions near the plant site at Buhne Point.

While a seaward hydraulic gradient exists or is believed to exist at the present time, heavy pumping in an area inland might reverse the hydraulic gradient either in the free ground water body near the surface or in the confined aquifers at depth and possibly allow for sea water intrusion or a change in direction of ground-water movement.

Since surface waters at the plant will not be discharged directly into the Elk River Valley, they would have to follow drainage channels or slowly percolate through the surface clays to reach the water table. The chances of surface water from the plant area reaching Elk River Valley are rather remote.

Because of the rather free interconnection of ground water in the permeable channel deposits and alluvium of the valley, heavy pumping might draw bay water into the channels when the gradient is reversed and the bay water might permeate the alluvial fill. This would probably be a temporary condition and high winter flows would result in a flushing action.

Seismicity.- This area has been subject to numerous earth shocks annually, some of appreciable intensity and magnitude. This hazard poses a problem as to rupture of installations with a possible attendant accidental spreading of wastes. Water-level recorders have indicated some temporary readjustment of ground-water levels during earth shocks in this area. Such shocks might also cause mud spouts and surface flows for a short period of time in areas of alluvial fill containing ground water. It is also conceivable that ground-water flow might be reversed for short periods of time.

Conclusions

1. There is a lack of factual hydrologic data.

2. A comparison of surface flow and subsurface data in Eel River area suggests that ground water moves in a northwesterly direction in both the free and confined areas of Elk River and Buhne Point.

3. Surface flows may be on the order of feet per second.

4. Vertical rates of movement of water in the plant area may be on the order of fractions of a foot per day in the tight surface clays and horizontal movement from feet to hundreds of feet per day in the more permeable aquifers at depth.

5. Movement of all surface and subsurface flow is to the bay.

6. River and tide stages will have a considerable effect on rates of surface and free ground water flow.

7. Waters on the surface of the ground in the plant area would be primarily controlled by surface drainage, as the rate of downward percolation in the surface clays and soils would be very slow.

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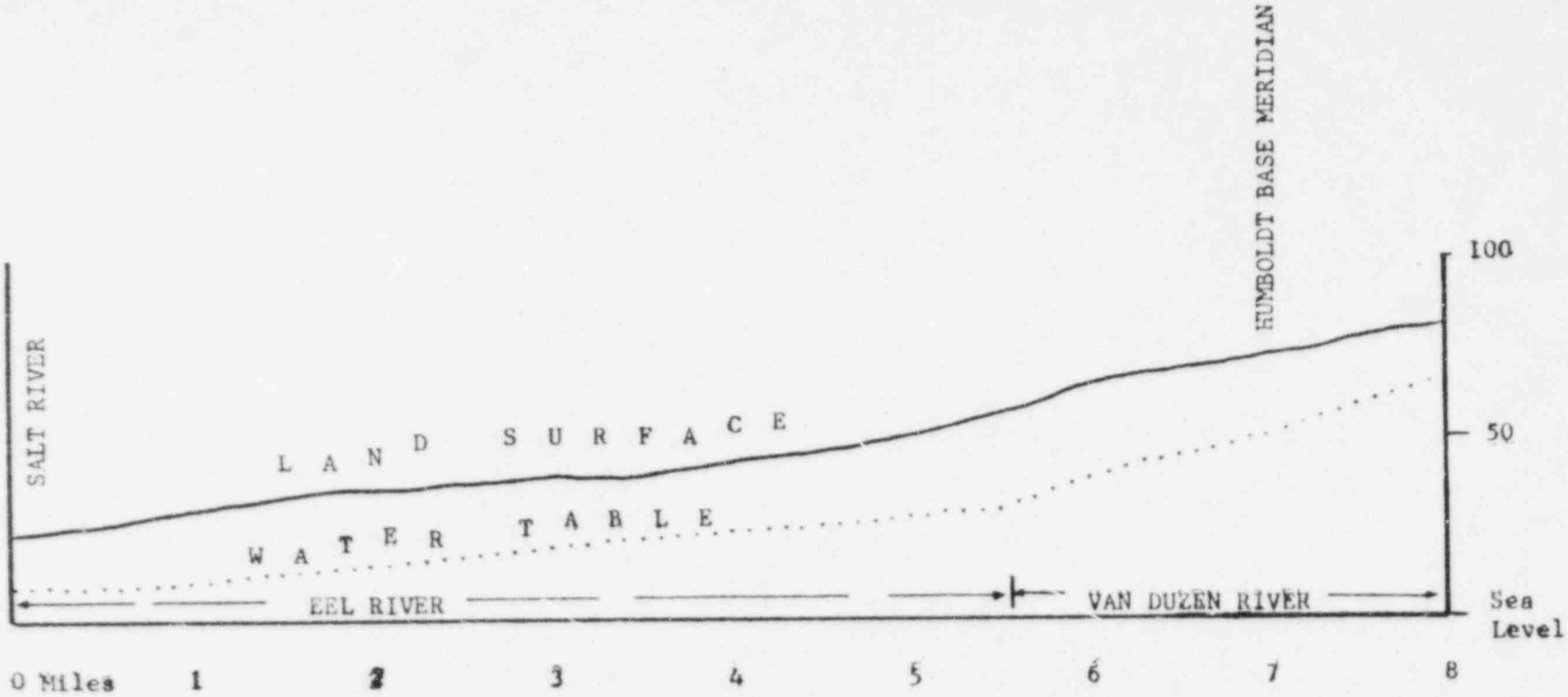

WATER LEVEL PROFILE, EEL RIVER VALLEY

AUGUST 1952

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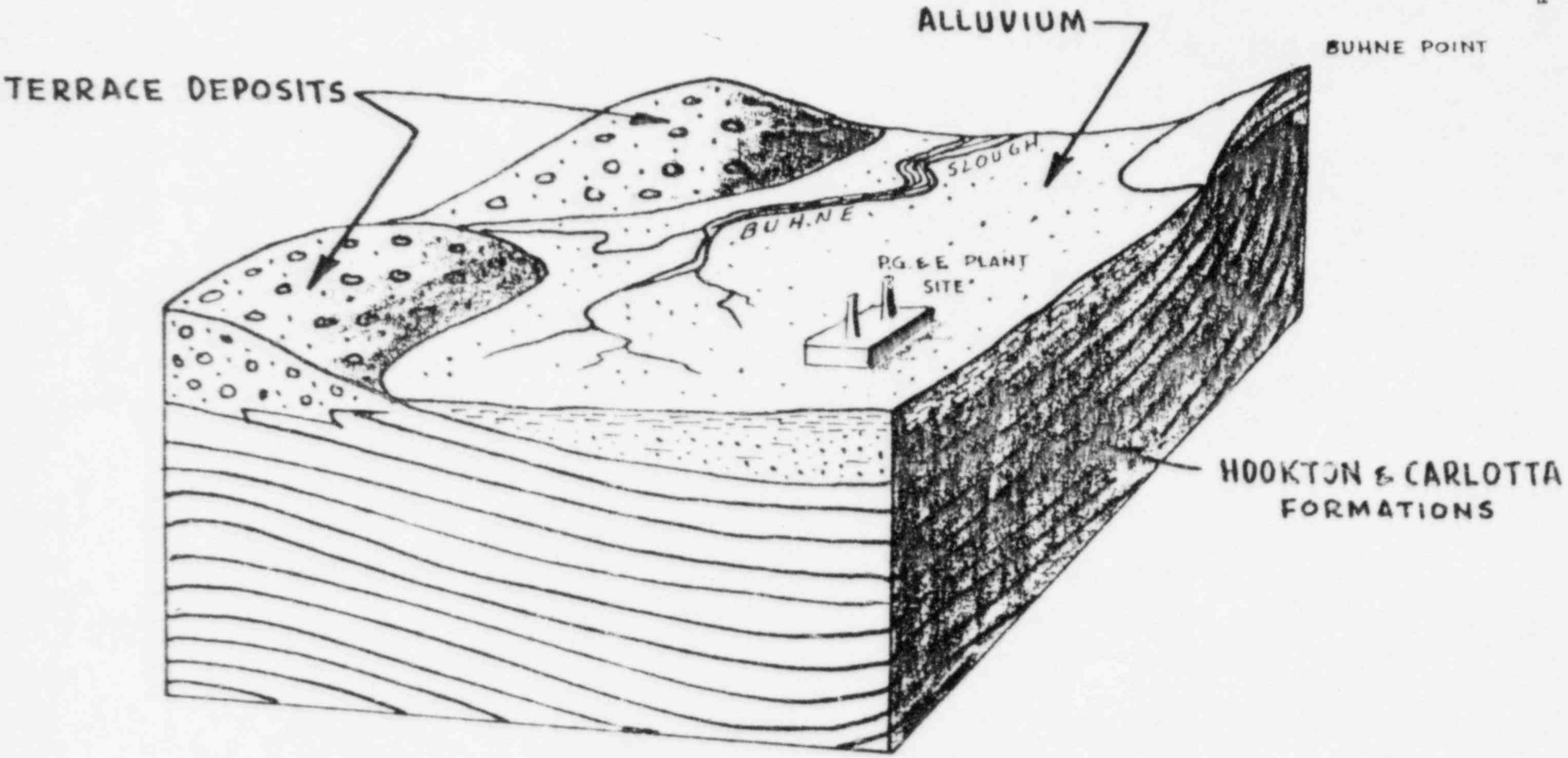
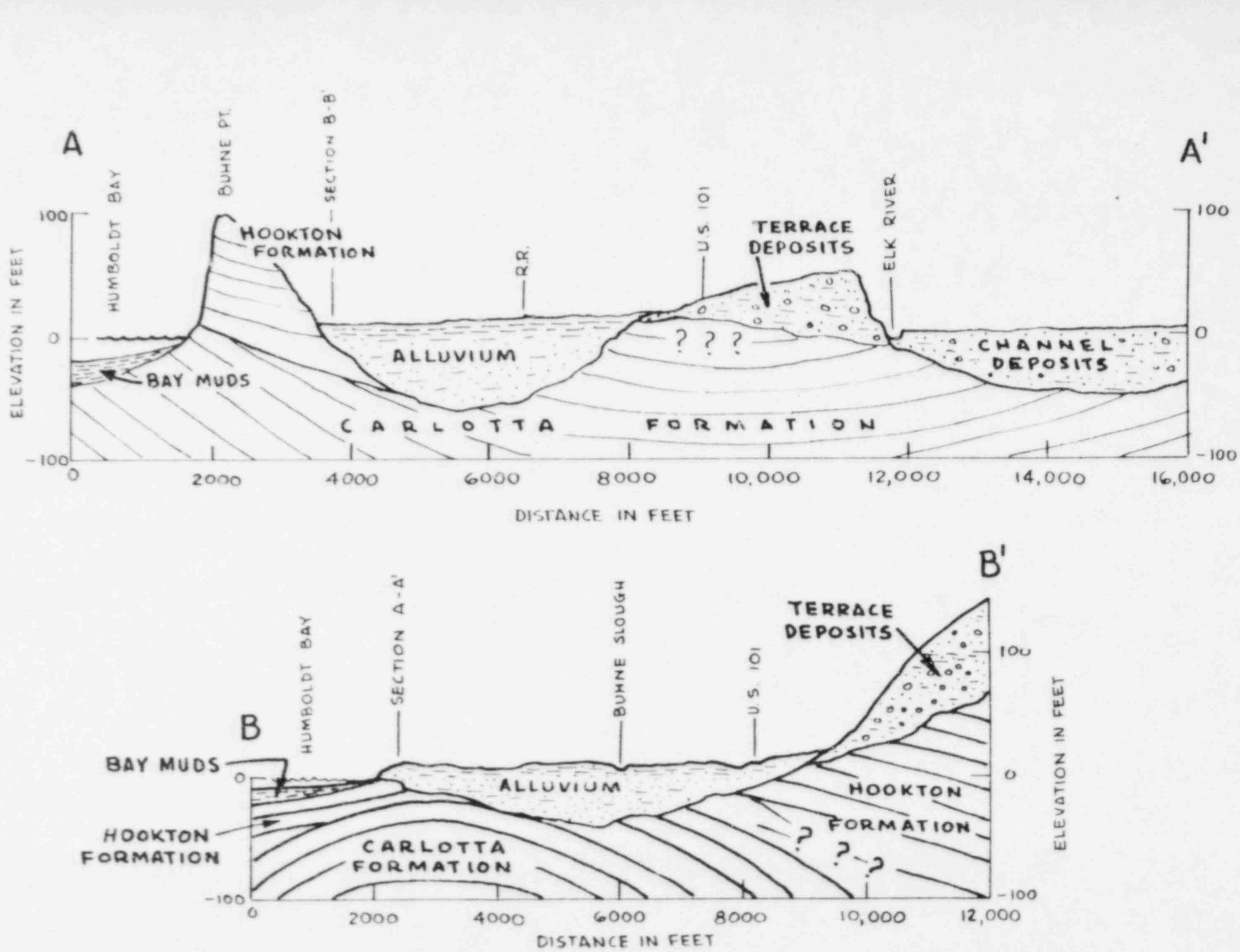


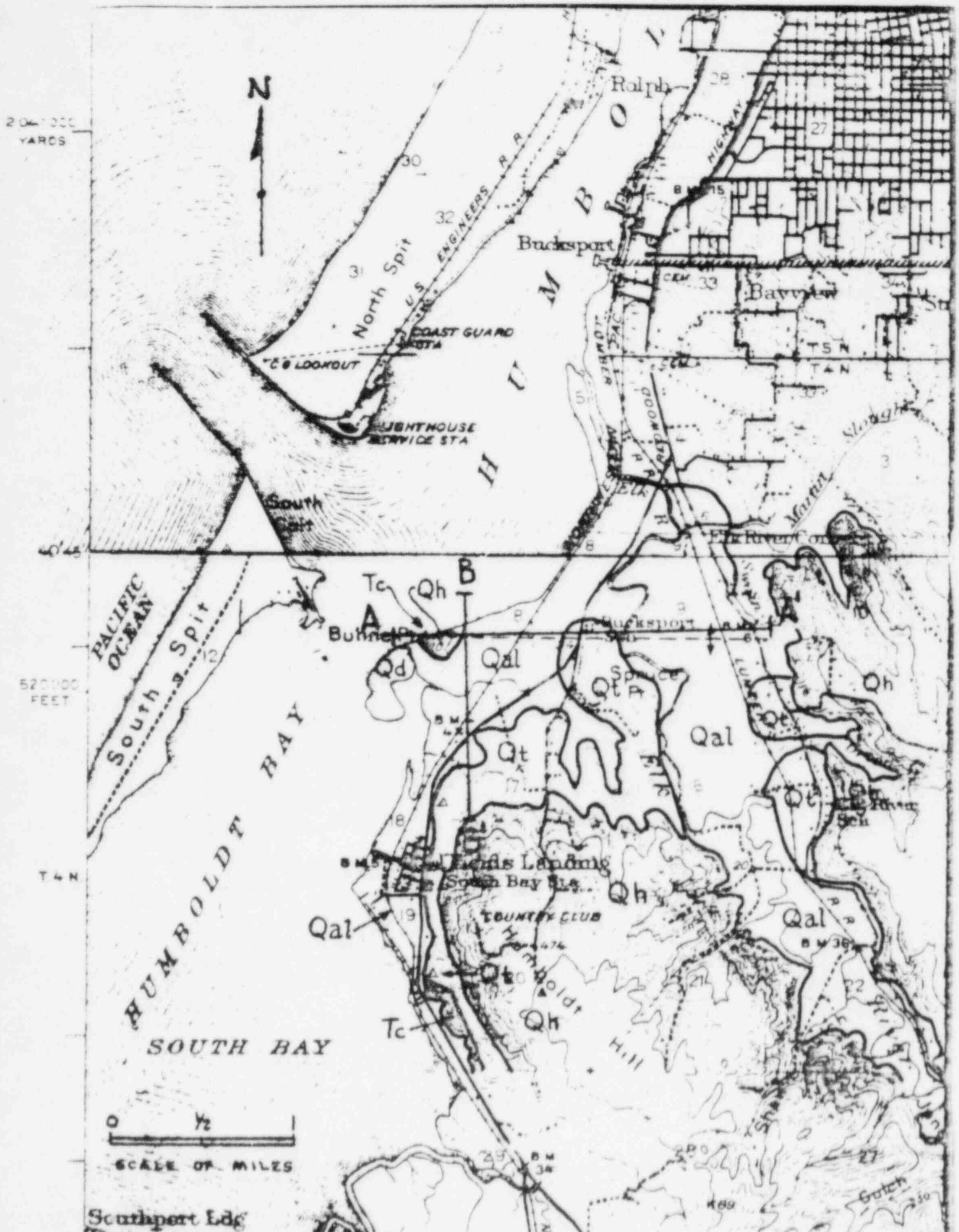
LOOKING SOUTHWEST

NOT TO SCALE

BLOCK DIAGRAM



GEOLOGIC SECTIONS A - A', B - B'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CG LOOKOUT
LIGHTHOUSE SERVICE STA
South Spit
PACIFIC OCEAN
HUMBOLDT BAY
SOUTH BAY
Elk River Corners
Martin Slough
Swain Slough
Buhne Pt
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Fields Landing
South Bay Sch
COUNTRY CLUB
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SCALE OF MILES

G-3. The geology in the vicinity of the Pacific Gas and Electric plant at Buhne Point on Humboldt Bay, California, by G. H. Curtis, 1969.

THE GEOLOGY IN THE VICINITY OF THE PACIFIC GAS AND ELECTRIC PLANT AT BUHNE POINT ON HUMBOLDT BAY, CALIFORNIA

BY

G. H. CURTIS

G. H. Curtis
G. H. Curtis

Berkeley, California
April, 1969

The Geology in the Vicinity of the Pacific Gas and Electric Plant at Buhne Point on Humboldt Bay, California

by

G. H. Curtis

Summary

The atomic reactor plant of the Pacific Gas and Electric Company at Buhne Point on Humboldt Bay is in a tectonically active region but is located on unfractured rock no closer than 7½ miles to any visible trace of a major fault or 3½ miles to any possible extension of a visible fault (the Little Salmon Fault). The Freshwater Fault, the nearest fault on which earthquakes have occurred in historic times, is 9½ miles away at its closest point to the plant. The plant appears geologically safe.

Introduction

Four days, May 15, 16, 17 and 18, 1968, were spent in the field studying the faults in the vicinity of the P. G. and E. plant on Humboldt Bay, California. The published geologic map of the Fortuna and Ferndale Quadrangles, by B. A. Ogle (1953), was used as a base, additional field data being plotted on the Fields Landing Quadrangle on a scale of 1:24,000 (Pl.1).

Particular attention was paid to the possibility that the Little Salmon Fault, or a branch of it, might extend northward to the plant site from its last occurrence shown on Ogle's map approximately four miles to the south near Willow Brook, Sect. 33, T. 4 N. R. 1 W., H. B. M. As can be seen on his map, the Little Salmon Fault turns abruptly north about a mile south of the junction of Salmon Creek and Little Salmon Creek. Although Ogle extended the fault only to the vicinity of Willow Brook, he indicates a possible bifurcation of the fault at that point, with the eastern most branch heading northward, in the general direction of Fields Landing and Buhne Point. Since fissures were reported having developed in the highway at Fields Landing at the time of the great 1906 earthquake on the San Andreas Fault and again during the Eureka Earthquake of June 6, 1932, it seemed possible that the reported fissures might mark the location of a branch of the Little Salmon Fault where it intersected the highway at Fields Landing, 1½ miles south of the plant, and that it might still be an active fault. As will be shown below, however, no such extension of the fault occurs, and the fissures at Fields Landing are probably due to slump of unconsolidated landslide debris.

General Geology

The two formations exposed at the surface within five miles of the plant in any direction are the Pliocene-age marine Wildcat and the Pleistocene-age non-marine Hookton. Within this radius of five miles, the Wildcat is composed dominantly of blue-gray silty to sandy mudstone. Thin gravel lenses are rare, constituting less than three percent of all observed exposures. Fossils of invertebrates are sparse and of marine types. Further south along the Eel River, Ogle was able to separate the Wildcat into three mappable units, but no such separation can be made in the vicinity of the Pacific Gas and Electric Company plant at Buhne Point. Ogle indicates a thickness of approximately 5,000 feet for the Wildcat formation on his structure section in the vicinity of the plant.

The Hookton formation in the area under consideration contrasts markedly with the Wildcat formation, being composed of 200 to 400 feet of yellow-orange sandstone, sandy gravel, siltstone, and claystone in approximately that order of relative abundance. Most of these lithologic types are almost as well-consolidated as the Wildcat formation, and they appear to have been deposited under fresh or brackish water conditions; however, thin lenses of fossiliferous marine blue-gray mudstone, identical in all respects to the mudstones composing the Wildcat formation, can be seen interbedded with yellow-orange sandstone and gravel typical of the Hookton formation along the freeway both north and south of Fields Landing. Ogle quite understandably mapped these as Wildcat formation. Now, however, owing to the excellent exposures afforded by the new freeway-cuts at these localities, the interbedded relationship can be clearly seen.

In the few good exposures of the contact between the Hookton and Wildcat formations within five miles of the plant the contact is unconformable; but, as described by Ogle, the unconformity is not great and the Hookton folds follow the underlying folds of the Wildcat formation closely but have somewhat less steep limbs. The near conformity of the two formations is well illustrated in the Pine Hill Anticline area east of the plant (Pl. 1), where the two formations almost lie parallel to each other for distances of two miles or more. In a few places the unconformity between the two formations is profound, and it appears that between deposition of the Wildcat and the Hookton there was local uplift and deep erosion of the Wildcat formation.

Subsequent to deposition of the Hookton formation, in probably mid-Pleistocene time, there was a general but sporadic uplift which allowed the Elk River and the Salmon and Little Salmon Creeks to cut terraces along their courses into the Hookton and Wildcat formations on which were deposited patches of coarse gravel. Ogle's map over-emphasizes the abundance and thickness of these terrace deposits, owing to the difficulty in accurately delineating them; however, he mentions in his report (1953, p. 63) that they are 5 to 25 feet thick. I have omitted them from my map, but their presence on several prominent benches along these streams at an elevation of about 75 to 90 feet indicates that folding of the area since their formation has been negligible. The presence of marine Humboldt Bay mud deposits, resting unconformably on Hookton formation at Buhne Point immediately adjacent to the plant, probably represents eustatic rise of the sea consequent upon ending of the last great glaciation and melting of ice approximately 12,000 years ago.

Detailed Geology

The plant rests on the Hookton formation. Owing to cut and fill immediately around the plant itself, no rocks are presently visible in contact with the building. Drill-hole data obtained by Dames and Moore previous to plant construction, however, indicate that to a depth of approximately 20 to 35 feet at the plant site the strata are compact clayey sand and sandy siltstone. Almost certainly these same strata are exposed on the cliff facing Humboldt Bay about 150 yards north of the plant, where they dip gently (10-12°) eastward and southeastward. Below 20 to 35 feet at the plant site are increasing amounts of interbedded gravel of pea to cobble size which occur in thin discontinuous lenses to a depth of approximately 90 feet below the surface. Probably the same sandy gravels are also exposed along the cliff mentioned above, west of the sandy siltstone and dipping eastward below the sandy siltstone. Ogle (1953, p. 61) believes that a prominent gravel bed overlying blue clay at Buhne Point, approximately 1,200 feet northwest of the plant, marks the contact between the Hookton and Wildcat formations. This interpretation is probably correct and places the contact of these two formations a little under 90 feet below sea-level at the plant site, or just below the deepest test-hole put down. Confirmation of this is afforded by a test well, put down about 600 feet southeast of the plant by Bechtel Corporation, which shows sand with scattered gravel lenses to a depth of 130 feet and mostly blue clay below that depth, indicating that the Wildcat formation had been reached. (Marliave, 1959 & 1960; and Bechtel Corporation, 1954).

Although the cliff-section of strata north of the plant is not perfectly exposed, owing to debris having been dumped there locally during construction of the plant, most of the section is well-exposed, and nowhere are there indications of even minor faulting.

Faulting

In their 1958 report of earthquake hazard at the Humboldt Bay Power Plant of Pacific Gas and Electric Company, Byerly and Quaide dealt with the nine known faults in the Eureka Fortuna area. With the exception of the Little Salmon Fault, which I discuss below, all of these are more than 9½ miles from the plant at Humboldt Bay. As I have nothing more to add to the known geology of these other faults than was given by Byerly and Quaide, I have simply reproduced their comments about these faults, verbatim, in Appendix I.

The Little Salmon Fault, as mentioned earlier, appears from study of Ogle's geologic map to have a probable northward extension that might bring it into the vicinity of the Pacific Gas and Electric Company Plant. An effort was therefore made to trace it carefully from where it deviates sharply from its N65°W trend to its N20°W trend, near the west central edge of Sect. 15, T. 3N., R. 1W., H. B. M. South of this deviation in strike there are both surface and subsurface data (Appendix I), indicating that the Little Salmon Fault and its branch (the Yager Fault) are high-angle reverse or thrust faults with their fault planes dipping northeastward. North beyond the deviation in strike, however, it becomes apparent that the contact between the Hookton formation and the Wildcat formation, which Ogle evidently believed was a fault contact, dips southwest at angles varying between 20 and 35 degrees. Such a change in attitude implies that the fault suddenly changed from reverse movement to normal movement where it changed strike! This is highly unlikely.

There appears to me to be only two possible interpretations to this sudden marked change in dip of the northern part of the Little Salmon Fault:

1. The north-trending section of the Little Salmon Fault is not the Little Salmon Fault but is a completely separate normal fault that has been intersected by the Little Salmon Fault.

2. The north-trending contact between the Hookton formation and the Wildcat formation is not a fault contact at all but is a depositional contact along a steep slope cut into the Wildcat formation after its deposition and before deposition of the Hookton formation.

In either of the above cases, the Little Salmon Fault probably continues its N65°W trend out through the southern part of Humboldt Bay, or dies out quickly in that direction.

The field evidence supports the second interpretation. In most places exposures of the Hookton-Wildcat contact are poor, owing to heavy vegetation cover; however, sufficient good exposures can be found in several gulches to show that the contact is depositional and unsheared. Furthermore, Hookton formation overlying Wildcat formation extends up ridgecrests for several hundred yards to the east of where Ogle shows the "fault," and in adjacent gulches the Wildcat formation can be found several hundred yards to the west of the "fault" lying beneath a cover of Hookton (Pl. 1).

If the Little Salmon Fault does not die out as it approaches Humboldt Bay, its most reasonable extension northwestward would place it along the southernmost end of the bay no closer than 3½ miles from the Pacific Gas and Electric Company Plant. It should be noted that no epicenters occur anywhere in the southern part of Humboldt Bay to indicate recent activity of this fault.

Fields Landing Slump

Immediately east of Highway 101, at the town of Fields Landing, is a sand quarry cut into the Hookton formation. It was here that Ogle (1953, p. 65) found several faults of small displacement. Probably some of these were removed or obscured by quarrying operations, because at the time of my visit only 4 hairline cracks could be observed, two of which showed virtually no displacement and two showed a maximum of about 12 inches of normal movement which seemed to die out along strike. The "faults" vary in dip from 47° to vertical and in strike from about N15°E to N75°E, being markedly at odds with the prevailing northwesterly trend of all major faults in this region and showing no consistent pattern of their own. The dips of the Hookton formation on the western edge of the quarry are much steeper (35°) than on the eastern edge (5-10°) and much steeper than 200 yards to the south. In addition, the N20°E strike of the beds in the quarry contrasts with the almost east-west strike of bedding both north and south of the quarry.

The location of this quarry, with its anomalous structural features, is along the crest of a small unnamed anticline shown on Ogle's geologic map running through Humboldt Hill. It appeared to me that all of the anomalous features of the quarry can be explained in terms of its position on the plunging anticline, together with westward slumping along a bedding plane down the plunge of the anticline. Before the highway was located immediately west of where the quarry now is, there is evidence that there was a wave-cut cliff facing the town of Fields Landing, which was modified somewhat when the highway was placed at its base. The quarry-area seems to have slumped somewhat along this old cliff face;

and doubtless when the first road was constructed it was laid over the unconsolidated debris at the toe of the slide. Almost certainly the ruptures in the highway observed in 1906 and again in 1932 occurred at this point as a result of further slight movement of this large slump or slide. Similar landslides of this kind are very frequent in this region, as inspection of Ogle's geologic map will attest.

Conclusions

The exposed rocks of the Hookton formation near the power plant of the Pacific Gas and Electric Company at Buhne Point on Humboldt Bay, California, are firm and well-consolidated and without visible fault-fractures. They appear to be a stable foundation for the plant.

There are no visible major faults within 7½ miles of the plant and there are no reasons to suspect that any major fault in the entire area comes closer than 3½ miles to the plant-site. There appears to be no geologic threat to the safety of the P. G. and E. power plant.

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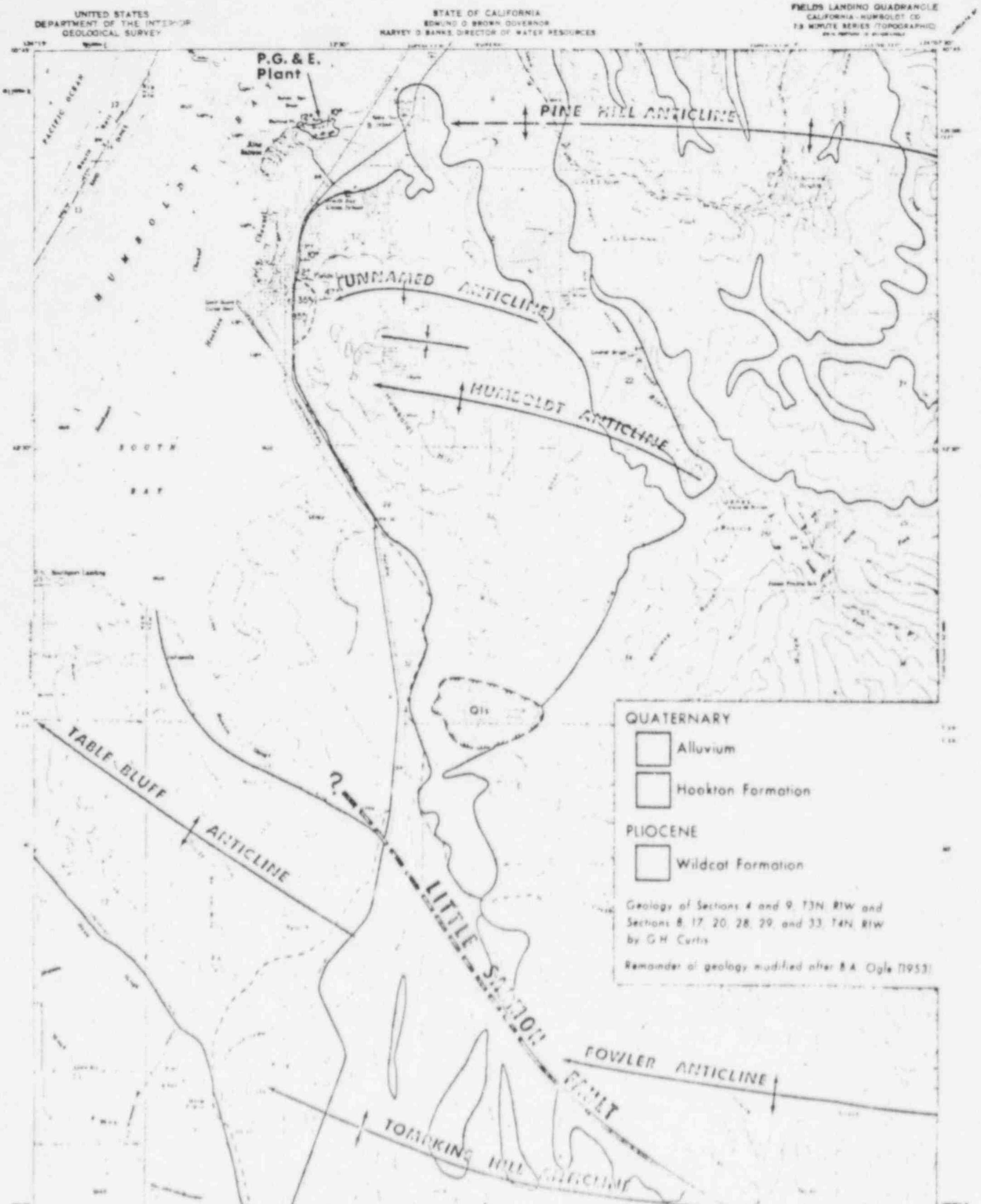
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Qls
?
TABLE BLUFF ANTICLINE
LITTLE SALMON FAULT
FOWLER ANTICLINE
TOMPKINS HILL ANTICLINE
QUATERNARY
Alluvium
Hookton Formation
PLIOCENE
Wildcat Formation
Geology of Sections 4 and 9, T3N, R1W and Sections 8, 17, 20, 28, 29, and 33, T4N, R1W by G.H. Curtis
Remainder of geology modified after B.A. Ogle (1953)

G-4. Report on earthquake hazard at the Humboldt Bay plant, by Perry Byerly, 1969.

REPORT ON EARTHQUAKE HAZARD AT THE HUMBOLDT BAY PLANT

Pacific Gas and Electric Company

By Perry Byerly

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Berkeley, California
April 8, 1969

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Report on Earthquake Hazard at the Humboldt Bay Plant, Pacific Gas and Electric Company.

By Perry Byerly.

An earlier report was submitted in 1958. This report presents additional data and conclusion.

Foreword.

The investigation of the earthquake hazard consists of these parts:

1) The history of earthquakes in the region.

2) The distribution of instrumental epicenters located from the records of seismographs.

3) A study of the geology of the site, including faults in the region (see report of Dr. Garniss Curtis):

   a) To see if any pass through the site;

   b) To see if the distribution of epicenters indicates that any of these faults are active.

Summary of Conclusions.

1) No faults pass through the site, and the geology of the site is suitable.

2) The region is one of frequent moderately large earthquakes.

3) For design basis an acceleration of 40% g is recommended.

4) For operational basis I recommend 25% g which was the single acceleration recommended in my earlier report.

Re California Earthquakes and Faulting.

A fault is a surface in the earth's crust where breakage has occurred in the past. It is recognized by a field geologist both by discordancies in the rock types across the fault trace at the earth's surface and by physiographic evidence such as displacement of streams and ridges, indicating horizontal movement, and linear scarps, indicating vertical motion. It takes a trained geologist to recognize all but the most obvious recent faults.

The continued program of locating epicenters of California earthquakes confirms the earlier conclusions of Harry Wood (Ref. 1) and Perry Byerly (Ref. 2) that many of the epicenters of smaller shocks do not lie on recognized faults although those of the larger shocks do.

Here we are speaking of "instrumental epicenters", those located by use of a group of seismographic stations. Such epicenters are supposed to indicate the point on the surface of the earth above the point where the earthquake disturbance started--if a fault is the source it is the place where the fault began to break. In contradistinction, there is the "field epicenter", the place where the earthquake had the greatest intensity--did the most damage. This may well be at some distance from the fault, on the alluvial fill of a valley.

Wood wrote: "As with the large earthquakes, many of the smaller shocks, say from Magnitude M = 5 or M = 4.5 downward, are or may reasonably be associated with the more important faults which emerge at the surface. However, from the beginning of the systematic work of locating shocks by means of the data furnished by seismograms it has been conspicuous that some of these shocks, ultimately many of them, for which good locations have been determined cannot reasonably be associated with these more important faults. Moreover, a considerable number of these epicenters cannot reasonably be associated with any known fault . . ."

When the epicenters of small earthquakes do lie on recognized fault outcrops,or very near them, we may conclude that the fault is "active". However, if the epicenters are scattered over a considerable area we are slow to say that they represent a network of faults covering the area. (In the location of these epicenters we have taken it that we know the velocity of seismic waves in the region and that they are the same in all directions from the source.)

The San Andreas Fault.

Regarding the San Andreas Fault, Maxwell Allen pointed out to a Seismological Society meeting in the early 1930's that the portions of the fault on which major displacements occurred at the times of the very great earthquakes of 1857 and 1906 are very quiet, whereas the regions at either end of these breaks are the seat of many moderate and small shocks, i.e. the Imperial

Valley, the area from San Luis Obispo County to San Francisco, and the Cape Mendocino region. Byerly in 1937 (Ref. 3) drew attention to this and opined less transverse compression in the regions where the fault was freer to slip--more moderate shocks, but no very large ones. In 1967 Clarence Allen (Ref. 4) writes, "In summary, the author suggests that those two segments of the San Andreas fault that have been characterized by great earthquakes within the historic record, in 1857 and 1906, have likewise generated infrequent great shocks throughout the recent geologic past, and that the present absence of small earthquakes and creep is typical of the past and probable future behavior between large shocks. The three remaining segments of the fault, on the other hand, are currently the sites of abundant small and moderate earthquakes, together with fault creep, and it is suggested that this behavior stays relatively constant with time; truly great earthquakes are unlikely in these areas."

The phenomenon of creep on the fault has been generally recognized only in the last ten years.

Regarding the Cape Mendocino area, the record of the period for which magnitude is available shows eleven earthquakes of magnitude 6 or greater. They are:

Date	M	North Latitude	West Longitude
Aug. 4, 1910	6.8	42°	127°
Dec.31, 1915	6.5	41°	126°
Jan.31,1922	7.3	41°	125.5°

Date	M	North Latitude	West Longitude
Jan. 22, 1923	7.2	40°.5	124°.5
June 6, 1932	6.4	40°.7	124°.5
Feb. 9, 1941	6.0	40°.7	125°.4
May 13, 1941	6.0	40°.3	125°.0
Oct. 3, 1941	6.4	40°.4	124°.8
Dec. 21, 1954	6.5	40°.8	124°.1
Oct. 11, 1956	6.0	40°.7	125°.8
Aug. 8, 1960	6.2	40°.3	127°.1

It seems reasonable to conclude that no earthquake of magnitude over 7.5 need be feared off Cape Mendocino.

Earthquake History.

(See Ref. 5 to 13)

The Humboldt Bay area is subject to frequent moderately large earthquakes. Tables 1, A, and B present the history. Table 1 is essentially that presented in my first report except for some changes from Rossi-Forel intensities to Modified Mercalli intensities. The intensity is given most frequently for Eureka, which is only a few miles (about 8), from the site, because it has the most complete record. Map 1 plots the data from Table 1. Map B plots only instrumental epicenters of earthquakes of magnitude 5 or greater, unless the intensity at a city near the site was VI or greater, in which case the epicenter is plotted even though the magnitude was less than 5.

Table B lists the data on which Map B is based.

Table A lists the earthquakes of intensities VI or greater which occurred before instrumental epicenters were available.

There is only one earthquake historically recorded in the Eureka area with an observed surface fault break. This was the great earthquake of April 18, 1906. The report of that earthquake indicates that as well as the great fault break to the south, a fracture occurred which began at Upper Mattole, 35 miles south of Eureka, and disappeared beneath the sea at Shelter Cove.

Many of the earthquake reports indicate fissures in the area. These were not fault breaks but cracks due to differential settling of poorly consolidated fill. This can occur at some distance from the epicenter of the shock, and does not indicate an active fault at the place.

The Distribution of Epicenters

On Map 1 is plotted all the instrumental epicenters available, as listed in Table 1. The large circle on the map represents the area within 30 miles of Eureka.

We now look to see if any of these epicenters tend to indicate that any of the faults shown on the map included in the report of field geologist Dr. Garniss Curtis are active. In view of the discussion in the above paragraphs we are not surprised at the scatter of epicenters of the smaller earthquakes, plotted as open circles. We conclude that the False Cape shear zone near the Humboldt Base Line is active, and probably the Freshwater Fault. The latter conclusion is based almost wholly on the epicenter of the earthquake of December 21, 1954.

The plethora of epicenters off the coast (which extend to sea beyond our maps) are often vaguely referred to as the San Andreas Fault Zone.

Design Basis Earthquake * (DBE)

Inspection of the history indicates that a Modified Mercalli intensity of high VII in the site area (Eureka) describes all of them except perhaps that of October 1, 1865. The fullest report of this shock is from a Petaluma paper and is given in Table A. The description of the effects on structures would place it in the VII category. But we have the statement of "many a majestic tree uprooted" which seems inconsistent with no reports of collapse of masonry walls and the like. Cracks in the bayshore fill have been commonly reported, but here it is said to be "two miles wide"! (Ref. 5 and 6) I feel that a high VII or low VIII should be used to describe this earthquake in the vicinity of the site.

I suggest that a strong VIII with an acceleration of 40% g be used for design basis -- safe shutdown.

Hershberger's Correlation:

Regarding the use of Hershberger's correlation of

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* DBE, the earthquake (larger than any on record) for which Class I structures should not lose their functional capabilities, including safe shutdown.

intensity with acceleration in the higher ranges, see attached graph on which Hershberger's curve is the steeper of the two. The other is the Gutenberg-Richter correlation.

1) Note that there is no good theoretical reason that the logarithm of acceleration and the intensity should have a linear relationship.

2) Note that for the strong intensity VIII where Hershberger gives us 40% of g, Gutenberg and Richter's correlation gives us 17% of g.

3) Note that for intensity average VIII Hershberger's formula gives 33% of g but the observed point on the graph is 25% of g. His formula is overshooting his observations.

4) Note that intensity X which has been assigned to the El Centro earthquake of 1940 would be correlated with 70% of g by Gutenberg-Richter, while Hershberger's curve prolonged to that intensity would exceed 200% of g, whereas the famed El Centro accelerogram of this shock gave 33% g.

It is clear that when we get to high intensities we have to give up the straight line relation.

If we grant that correlation of accelerations and intensity as given by Hershberger or Gutenberg-Richter is a fair approximation in the lower ranges, we seem to be forced to the conclusion that once the structures of man begin to fail the

Hershberger, John "A Comparison of Earthquake Accelerations with Intensity Ratings", Bulletin of the Seismological Society of America, Vol. 46, No. 4, October, 1956.

of all the ratings published for a single severe earthquake. The earthquake chosen for this purpose was the big Kern County shock of July 21, 1952. For this shock 1,151 ratings have been published, and the analysis is shown in curve C. This curve, too, has a sharp peak similar to the others, with 465 ratings at the top, but this time the peak comes at intensity 6.

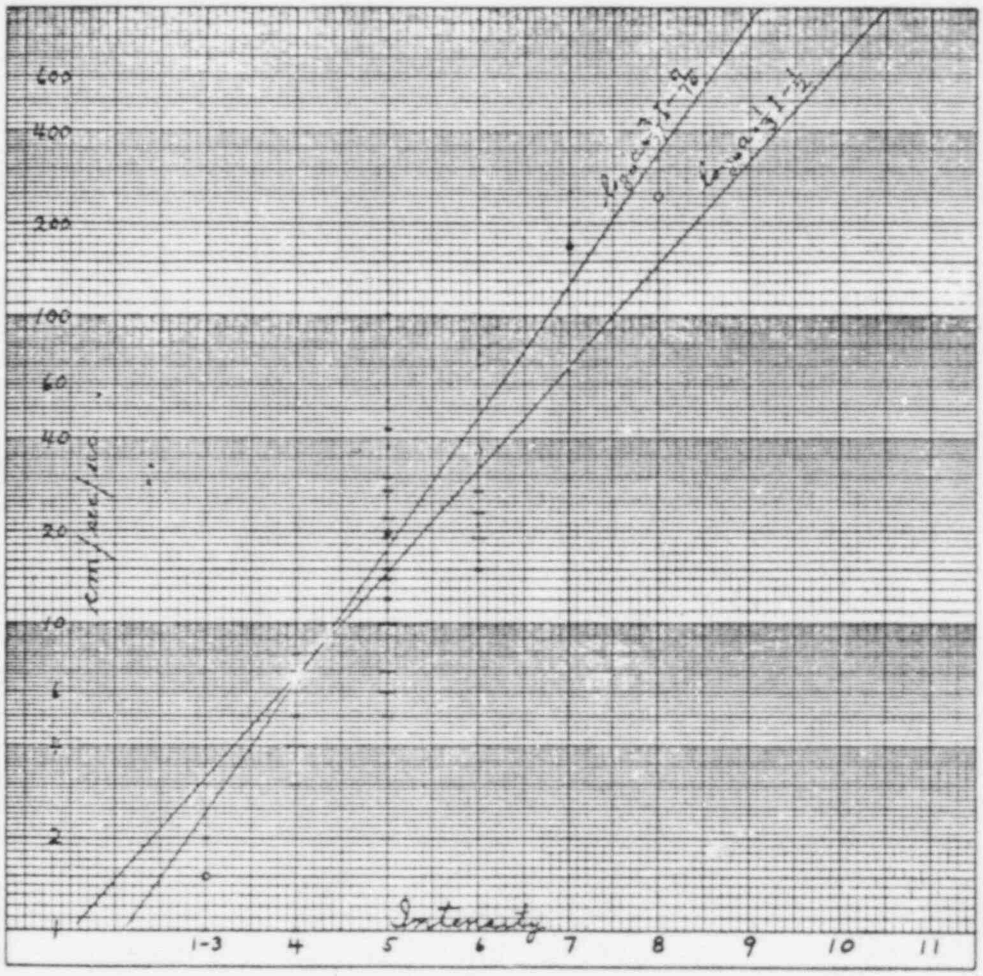


Fig. 2.

Finally, curve D shows an analysis of the same ratings as those in curve C, and on the same scale, except that deletions have been made so as to include only one rating from each locality. Evidently these deletions have not had any important effect on the shape of the curve.

These analyses and curves may not prove that my method of selecting the data was absolutely foolproof, but, in any event, I do not know of a better method.

Getting back to the main subject, that of comparing accelerations with intensities, the comparisons made are shown in figure 2. Each dot in the figure, except the circled ones, represents one comparison; that is, it represents an acceleration increment of acceleration necessary to produce much greater damage (i.e. to increase the intensity by a unit) decreases.

If it is desired to tie this hypothetical maximum earthquake to a fault we can proceed as follows:

The Freshwater Fault has been presumed to be active (see geological report) because several epicenters have been located very near it, as shown on the maps. It is the nearest such fault to the site.

The largest earthquake assigned to this fault since instrumental records are available is that of December 21, 1954. It had a magnitude of 6.5 and its intensity in the site area was VII. The maximum acceleration for this shock was 0.23 g at Eureka and 0.16 g at Ferndale. Let us assume an earthquake of magnitude 7 on this fault. At its nearest point the fault is 15 km. from the site. From Gutenberg and Benioff (Ref. 14) we find they advise an intensity VIII at distances between 10 km. and 25 km. from a source of magnitude 7. Therefore a fairly high VIII may be taken and correlated with 40% g as design basis.

Operational Basis Earthquake (OBE)

For the operational basis earthquake I recommend 25% g, as I did in my 1958 report. In getting this single value I had put in my own factor of safety, and I do not feel that it should be doubled for the design basis earthquake (DBE), for which I think the value 40% g is ample.

Spectra

As a starting base for drawing the spectra, I advise the use of the Ferndale acceleration spectrum (corresponding to maximum ground acceleration 0.16 g) of the September 11, 1938 earthquake as presented by Alford, Housner and Martel in "Spectrum Analyses of Strong-Motion Earthquakes", Caltech Report, August 1951, Revised, August 1964, Figure 64.

We select this because Ferndale is near the site (about 10 miles) and the geologic underground foundation on record for it is the same as for the site (both taken from Ogle).

This spectrum should be smoothed allowing the numerous spikes to lie on either side of it. The maximum ground acceleration for this record was 0.16 g, according to Housner, Bull. Seis. Soc. America, 43, pg. 101, 1953.

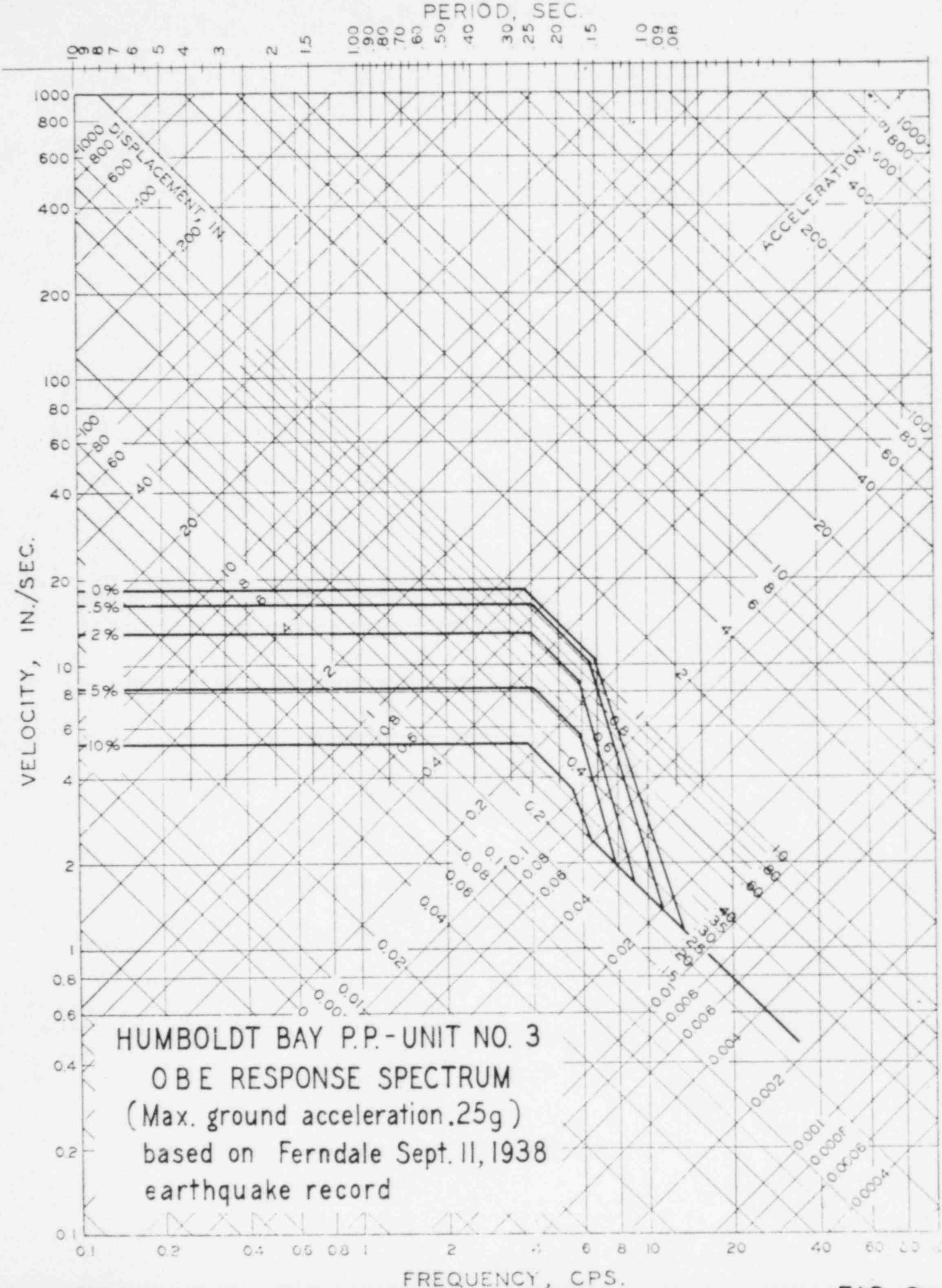
The accelerations read from these smoothed spectra should be normalized by multiplying each acceleration by 0.25/0.16 for the operational base, and 0.40/0.16 for the design basis spectra.

Plot these on a tripartite graph.

Since the earthquake on which these spectra are based had a magnitude of only 5.5, and shocks we fear will be larger and therefore contain more long period motion, adjust for this on the tripartite graph by not allowing the velocity to decrease for longer periods following its maximum value. This is a customary procedure. It results in a higher acceleration for longer periods than would the directly normalized spectra. (It also requires a continued increase in displacement which may be questioned, but which seems unimportant in this connection.)

The response spectrum for OBE is given on Fig. 3.

We may safely assume that the vertical component of the ground acceleration will be two-thirds the horizontal.



HUMBOLDT BAY P.P. - UNIT NO. 3
OBE RESPONSE SPECTRUM
(Max. ground acceleration .25g)
based on Ferndale Sept. 11, 1938
earthquake record

FIG. 3

Conclusion.

The adoption of 40% of gravity for "design basis", or greatest plausible earthquake, is conservative.

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6) Petaluma Journal and Argus, October 12, 1865.

7) Bulletins of the Seismographic Stations, University of California.

8) "United States Earthquakes", Coast and Geodetic Survey and "Abstracts of Earthquake Reports."

9) Lawson, A. C., "Report of the State Earthquake Investigation Commission," "The California Earthquake of April 18, 1906."

10) Gutenberg, B., and Richter, C. F., "Seismicity of the Earth", Princeton University Press, 1949.

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References (continued)

12) Byerly, Perry, "Earthquakes Off the Coast of Northern California", Bulletin, Seismological Society of America, 27, p. 73, 1937.

13) Sparks, N. R., "The Eureka Earthquake of June 6, 1932", Bulletin, Seismological Society of America, 26, p.13, 1936.

14) Gutenberg, B., and Benioff, H. "General Introduction to Seismology", California Division of Mines' Bulletin 171, (1955) p. 133.

Table A.

Earthquakes of Intensity MM VI or Greater, in the Period before Instrumental Epicenters were Available.

Date	Intensity at Eureka	Effects at Eureka
1853, Oct. 23	VII ?	Houses rolled like ships at sea, and the wharf sank four feet.
1855, Mar. 19	VI ?	Flow of streams affected and milk thrown out of pans.
1865, Oct. 1	VIII ?	*The Petaluma Journal and Argus* for October 12, 1865, reports scarcely a house in town (Eureka) escaped fracture in its brickwork. Most of this seems to have been chimneys down. "The steeple of the 1st Cong. Church swayed to and fro. . . and in the forests of redwood which lie adjacent to the town many a majestic tree was uprooted". At Fort Humboldt, a few miles south of Eureka, the soldiers had a "crevice of about two miles in width . . (open) beneath their feet."
1871, Mar. 2	VII	Shook cornices off some buildings.
1899, Apr. 16	VI?	The iron flue connecting the boilers and smokestack of lumber mill was loosened.
1906, Apr. 18	VII	In Eureka several frame buildings were twisted, many chimneys toppled, several panes of glass were broken, and pendulum clocks stopped. At Field's Landing--"the shock opened a fissure over 100 feet long in the middle of the road, which six teams spent one day in filling. Pelican Island, as it is commonly called, opposite Field's Landing dropt 3 feet at the point where the United States pile beacon stands." (From the Report of the State Earthquake Investigation Commission, on the California Earthquake of April 18, 1906.)
1907, Aug. 11	VI	VI at Fortuna, but Eureka lists only "quite heavy".
1908 Aug. 18	VI	Several plate glass windows were cracked, a few chimneys tumbled, and statues on the roof of the courthouse were damaged.
1909, Oct. 28	VII	Very heavy earthquake, a number of chimneys tumbled down, store goods were thrown from the shelves, clocks stopped, and telephone and telegraph lines were put out of commission. (VIII at Fortuna)

Date	Intensity at Eureka	Effects at Eureka
1918, July 14	VI	Buildings swayed alarmingly. Magnitude 6.5.
1919, Sep. 15	VII	Four shocks. The first, and most severe, demolished some chimneys and broke windows.
1927, Aug. 20	VII	Considerable damage was done in Eureka in the way of cracking of walls, fall of plaster, cracking and fall of chimneys, and damage to goods which were thrown from the shelves in stores. The County Courthouse and the Federal Building suffered extensive damage in the cracking of plaster and walls. Water pipes were broken in the latter building. (From Perry Byerly, "The Eureka, California, Earthquake of August 20, 1927.") VI at Ferndale.
1930, Sep. 22	VII	Chimneys down, dishes thrown from shelves. Field's Landing: chimneys cracked and dishes thrown from shelves.

Table B.

Earthquakes with Instrumental Epicenters -- Magnitude 5 or Greater -- or Intensity VI or Greater.

Date	M	---Epicenters--- Degrees N. Lat.	Degrees W.Long.	Intensities; and Maximum Acceleration at Ferndale in g, when available
1922, Jan. 31	7.3	41	125½	V in Eureka. Felt over an extremely large area of northern California.
1923, Jan 22	7.2	40½	124½	VI at Eureka. Only minor damage. VII at Ferndale, Petrolia.
1931, Sep, 9	5.8	40½	124	VI at Ferndale. IV at Eureka.
1932, June 6	6.4	40°45'	124°30'	VII in Eureka. Two large brick stacks (both 150 feet high) were damaged, almost all brick chimneys around Humboldt Bay were damaged, and most of them completely demolished. On the highway at Field's Landing a crack running in an east-west direction transverse to the road was formed, but there was no evidence that it extended farther than the edge of the concrete pavement. One person was killed and another severely injured in Eureka. Electric power was interrupted for only a few

		---Epicenters---		
Date	M	Degrees N. Lat.	Degrees W.Long.	Intensities; and Maximum Acceleration at Ferndale in g, when available.
				minutes, and the water system in Eureka remained intact. No fires followed the earthquake. (From Neil R. Sparks, The Eureka Earthquake of June 6, 1932.)
1935, Jan. 2	5.8	40°.4	125.7	IV at Eureka. Windows rattled, walls creaked, and chandeliers swung. V at Alderpoint.
1936, June 3	5	40.2	126.4	IV at Eureka. Slow rocking and rolling motion. V at Ferndale.
1937, Feb. 6	5.8	40.5	125.2	V at Eureka. Pendulum clocks stopped, bushes shook, and hanging objects swung.
1938, Sep. 11	5	40.3	124.8	V at Eureka. Felt by all; hanging objects swung. VI at Ferndale.
1940, Nov. 19		Offshore		Objects swung, dishes rattled, walls creaked, and bushes were disturbed. V at Eureka. VI at Field's Landing.
1941, Feb. 9	6	40.7	125.4	Overturned small objects, and shook trees and bushes. V at Field's Landing. VI at Eureka. Maximum acceleration at Ferndale in g: 0.05
1941, May 13	6	40.3	125.0	III at Eureka. Felt by few. Maximum Acceleration at Ferndale: 0.001 g.
1941, Oct. 3	6.4	40 3/4	125	VI at Eureka. Plaster cracked and fell, chimneys cracked and twisted; was felt by and frightened all. Maximum acceleration at Ferndale in g: 0.12
1944, Jan. 12	5.1	40.3	124.9	V at Eureka. Hanging objects swung, small objects disturbed.
1944, Jan. 16	5.1	40.3	125.1	IV at Ferndale.

		---Epicenters---		
Date	M	Degrees N. Lat.	Degrees W.Long.	Intensities; and Maximum Acceleration at Ferndale in g, when available.
1945, May 2	5.0	41.2	123.5	V at Eureka. Fixtures swung, disturbed objects. (Acceleration 0.004 g at Eureka.)
1947 May 27	5.2	40.4	124.7	V at Eureka. VI at Upper Mattole. Maximum acceleration at Ferndale: 0.03.
1947 Sep. 23	5.3	40.4	125.1	V at Eureka. Awakened all, frightened many, hanging objects swung. Maximum acceleration at Ferndale: 0.02 g.
1948 Aug. 18	5.0	40.5	124.7	V at Eureka. Disturbed objects. V at Ferndale. Maximum acceleration at Ferndale 0.02
1951 Apr. 1	5	40.5	125.3°	
1951 Oct. 7	5.8	40°17'	124°38'	V at Eureka. Disturbed objects. many frightened. V at Ferndale and Field's Landing. Maximum acceleration at Ferndale in g: 0.02
1951 Nov. 14	4.7	40°26'	124°03'	VI at Eureka. Large windows broken. VI at Ferndale. Maximum acceleration, Ferndale, in g: 0.02.
1952 Sep. 22	5.2	40°12'	124°25'	V at Eureka. Felt by most, disturbed objects. Maximum acceleration at Ferndale: 0.05 g
1954 Dec. 21	6.5	40°49'	124°05'	VII at Eureka. VII at Field's Landing. Maximum acceleration at Eureka 0.23 g. Maximum acceleration at Ferndale, 0.16 g

The old City Hall and old County Courthouse in Eureka were extensively cracked; several old poorly constructed brick walls bulged, and there was some parapet damage, but damage in the main was to chimneys, plaster, plate glass windows, and merchandise. In the poorly consolidated ground areas north and east of Eureka there were some

Date	M	---Epicenters--- Degrees N. Lat.	Degrees W.Long.	Intensities; and Maximum Acceleration at Ferndale in g, when available.
1954 Dec. 21 (continued)	6.5			pipe line failures and Eureka's main water reservoir (constructed in two halves) was cracked in one half. Numerous breaks occurred in Eureka's water distribution system, but none were serious. Two tall industrial stacks, cracked in the 1932 earthquake, were again cracked. One elevated steel tank (not earthquake resistant) had broken rods. U.S. Highway 101 between Eureka and Arcata was cracked and bulged to some extent, but no serious damage occurred to roads or bridges. A press report stated, "A large section of the older downtown area of Eureka settled from two to six inches. The area bounded roughly by E Street, Fourth Street, Broadway and the Bay at one time was a tidal mud flat and was filled to allow construction of buildings. This sector of the city has been settling gradually for many years, but sank rapidly during the earthquake . . One man fell into Humboldt Bay and was drowned, and a number of people were injured by falling objects." (From the U.S. Coast and Geodetic Survey.) Maximum acceleration at Eureka 0.23 g. Maximum acceleration at Ferndale 0.16 g.
1954 Dec. 30	5.3	40.8	123.9	VI at Eureka. Plaster cracked, windows broken, chimneys down, and water transmission lines broken. Maximum acceleration at Ferndale in g: 0.02.
1956 Oct. 11	6.0	40.7	125.8	V at Eureka. A few dishes broken. Maximum acceleration at Ferndale, 0.02 g.
1958 May 24	4.8	40.3	124.1	VI at Ferndale. V at Field's Landing, Alton, Fortuna, Loleta. Maximum acceleration at Ferndale, 0.02 g.
1959 July 23	5.8	41.1	125.3	IV at Eureka.
1959 Dec. 5	5.1	40.3	125.4	V at Alton, Ferndale, Field's Landing.
1960 June 5	5.7	40.7	124.9	VI at Eureka, Ferndale. V at Alton, Field's Landing, Fortuna, Loleta. Maximum acceleration at Ferndale, 0.07 g.

Date	M	---Epicenters--- Degrees N. Lat.	Degrees W.Long.	Intensities; and Maximum Acceleration at Ferndale in g, when available.
1960 Aug. 8	6.2	40.3	127.1	V at Ferndale, Fortuna. IV at Field's Landing, Eureka. Maximum acceleration at Ferndale, 0.06.
1960 Dec. 27	5.4	41.5	125.0	V at Ferndale. Reported not felt at Field's Landing.
1961 Apr. 20	5.	40.1	124.8	V at Eureka, Ferndale, Field's Landing, Loleta.
1962 July 14	5.0	40.3	124.7	V at Field's Landing, Fortuna. IV at Loleta, Ferndale, Alton. Maximum acceleration at Ferndale 0.02 g.
1962 Aug. 23	5.6	41.9	124.6	V at Ferndale. IV at Field's Landing, Eureka, Loleta,Fortuna.
1962 Sep. 4	5.0	41.0	124.4	VI at Eureka. V at Ferndale and Field's Landing.
1965 Sep. 15	5.6	40.4	125.7	IV at Eureka, Ferndale. III at Fortuna.
1967 Dec. 10	5.8	40.5	124.6	VI at Ferndale. V at Field's Landing and Scotia.
1968 June 25	5.8	40.4	124.5	V at Eureka, Ferndale, Field's Landing, Loleta. IV at Humboldt Bay Power Plant.

Table 1.

Earthquakes in the Vicinity of Eureka, California, to June 25, 1968

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1853, October 23	Humboldt Bay	VII ?	Houses rolled like ships at sea, and the wharf sank four feet.
1855, March 19	Humboldt County	VI ?	Flow of streams affected and milk thrown out of pans.
1865, October 1	Eureka	VIII	

The Petaluma Journal and Argus for October 12, 1865, reports scarcely a house in town (Eureka) escaped fracture in its brickwork. Most of this seems to have been chimneys down. "The steeple of the 1st Cong. Church swayed to and fro . . . and in the forests of redwood which lie adjacent to the town many a majestic tree was uprooted". At Fort Humboldt, a few miles south of Eureka, the soldiers had a "crevice of about two miles in width . . (open) beneath their feet."

1865, October 3	Humboldt County	V	Heavy shock.
1869, June 12	Humboldt County	V	Sharp shock.
1871, March 2	Humboldt County	VII	Shook cornices off some buildings.
1873, November 22	At sea north of Cape Mendocino	VII	Much damage to property.
1877, August 27	Eureka	—	--
1883, January 3	Eureka	III	Light, no damage.
1884, January 27	Humboldt County	IV	Moderate.
1884, April 6	Eureka	III	Very light.
1884, April 8	Eureka	III	Very light shock(s).
1889, August 12	Eureka	--	Sharp shock.
1889, December 20	Eureka	—	Light shock.
1890, April 25	Eureka	—	Two shocks, the first light and the second sharp.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1890, July 4	Eureka	—	Quite a sharp shock.
1890, July 26	Petrolia	VI	Clocks stopped.
1890, July 27	Eureka	—	Moderate aftershock.
1891, June 20	Eureka	—	Several light shocks.
1892, January 22	Eureka	—	Light shock.
1893, January 9	Eureka	—	Sharp shock.
1893, February 22	Eureka	—	Light shock.
1893, February 23	Eureka	—	Light shock.
1893, April 13	Hydesville	—	Light shock.
1894, September 30	Eureka	—	Two heavy earthquakes, no damage.
1895, January 8	Eureka	—	Heavy shock.
1895, April 1	Eureka	—	Sharp shock.
1895, August 6	Eureka	—	No damage reported.
1895, October 5	Eureka	—	Light shock.
1895, October 15	Eureka	—	Two very light shocks.
1895, November 18	Eureka	—	Light shock.
1895, December 6	Eureka	—	Quite a heavy shock.
1896, February 13	Weaverville	—	A sharp earthquake.
1896, April 22	Eureka	—	Doors, windows, and movable objects rattled.
1896, June 9	Eureka	—	Light shock.
1897, March 6	Eureka	—	Five distinct shocks.
1897, September 17	Eureka	—	A severe shock.
1897, October 28	Eureka	—	A slight earthquake.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1897, November 25	Eureka	--	Slight--windows and doors rattled.
1897, November 27	Eureka	--	Buildings swayed and windows and doors rattled loudly.
1898, January 29	Eureka	--	Windows and doors rattled.
1898, April 14	Eureka	--	--
1898, April 14	Humboldt County and Mendocino County	--	Clocks were stopped.
1898, September 9	Eureka	--	A severe earthquake.
1898, October 19	Eureka	--	A light earthquake.
1898, November 25	Eureka	--	A light shock.
1899, April 16	Eureka	V ?	The iron flue connecting the boilers and smokestack of lumber mill was loosened.
1899, April 18	Eureka	--	Light shock.
1900, January 21	Eureka	--	Light earthquake.
1900, April 14	Eureka	--	Light earthquake.
1900, April 16	Eureka	--	Very light shock.
1900, October 1	Eureka	--	Very light earthquake.
1903, February 25	Eureka	--	Slight earthquake.
1903, December 9	Eureka	V	Two successive jolts stopped clocks.
1904, January 11	Eureka	--	Very light earthquake.
1904, March 26	Eureka	--	Quite a heavy earthquake.
1904, July 6	--	--	A light earthquake.
1904, September 14	Eureka	--	Light shock.
1904, December 4	Eureka	--	Quite a severe earthquake.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1906, April 18	San Francisco	VII	

In Eureka several frame buildings were twisted, many chimneys toppled, several panes of glass were broken, and pendulum clocks stopped. At Field's Landing--"the shock opened a fissure over 100 feet long in the middle of the road, which six teams spent one day in filling. Pelican Island, as it is commonly called, opposite Field's Landing dropt 3 feet at the point where the United States pile beacon stands." (From the Report of the State Earthquake Investigation Commission, on the California Earthquake of April 18, 1906.)

1906, April 18	Eureka (?)	III	-- (05:22 a.m. P.S.T.)
1906, April 18	Eureka (?)	--	Slight. (12:25 p.m. P.S.T.)
1906, April 19	Eureka	--	Slight. (03:00 a.m. P.S.T.)
1906, April 19	Eureka	--	Slight. (05:22 a.m. P.S.T.)
1906, April 19	Eureka	--	Slight. (10:30 a.m. P.S.T.)
1906, April 19	Eureka	--	-- (11:10 p.m. P.S.T.)
1906, April 20	Eureka	--	Slight.
1906, April 23	Eureka	V to VI	Stopped clocks.
1906, April 23	Eureka	--	Slight.
1906, April 27	Eureka	--	Sharp.
1906, April 30	Eureka	--	--
1906, May 9	Eureka	--	Shook windows.
1906, May 10	Eureka	--	Slight sudden jolt.
1906, June 7	Eureka	--	Shook buildings, most severe since April 18.
1906, June 10	Eureka	--	--
1906, June 13	Eureka	--	Very light.
1906, July 9	Eureka	--	-- (10:00 p.m. P.S.T.)
1906, July 9	Eureka	--	-- (11:37 p.m. P.S.T.)
1906, July 30	Eureka	--	Light.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1906, August 1	Eureka	--	Very light.
1906, November 7	Eureka	--	--
1906, December 25	Eureka	--	Upset vases.
1907, January 14	Eureka	--	Light.
1907, February 25	Eureka	--	--
1907, August 8	Eureka	--	Very light steady shaking of the earth for six seconds.
1907, August 11	Humboldt County	VI	VI at Fortuna, but Eureka lists only "quite heavy".
1907, August 12	Eureka	--	Very light earthquake shocks.
1907, August 23	Eureka	--	Light.
1907, August 26	Eureka	--	Slight.
1907, October 7	Eureka	--	Quite a heavy shock.
1907, October 14	Eureka	--	The jolt shook buildings.
1907, October 23	Eureka	--	Quite a perceptible earthquake shock.
1907, October 28	Eureka	--	Very light.
1907, November 22	Eureka	--	Slight.
1908, January 3	Eureka	--	Heavy Earthquake, distinct jolt.
1908, April 18	Eureka	--	Light earthquake.
1908, July 10	Eureka	--	Light earthquake.
1908, August 18	Humboldt Bay	VI	Several plate glass windows were cracked, a few chimneys tumbled, and statues on the roof of the courthouse were damaged.
1908, December 8	Eureka	--	A light earthquake.
1909, May 17	Upper Mattole	--	Very perceptible.
1909, June 28	Eureka	--	A light earthquake.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1909, October 28	Humboldt County (Fortuna)	VII	Very heavy earthquake, a number of chimneys tumbled down, store goods were thrown from the shelves, clocks stopped, and telephone and telegraph lines were put out of commission.
1909, November 1	Eureka	—	Very light.
1910, January 29	Rohnerville	—	Very light.
1910, February 14	Rohnerville	--	Very light.
1910, March 18	Humboldt County	—	Quite a heavy earthquake, continued without cessation for about 49 seconds, the longest earthquake ever felt in the city, but no damage.
1910, August 4	Eureka 42° N, 127° W	--	A sharp earthquake stopped office clocks. (Magnitude 6.8)
1910, August 26	Humboldt County	--	A light earthquake.
1910, December 12	Eureka	—	A very light shock.
1911, March 11	Eureka	—	Light.
1912, February 2	Eureka	--	Very perceptible.
1914, April 10	Eureka	III to IV	--
1914, August 14	Eureka	IV	Rattled windows.
1914, December 10	Eureka	II	Abrupt jolt.
1914, December 12	Eureka	--	—
1915, February 18	Rohnerville	II to III	One sudden jolt.
1915, May 6	Mendocino Coast	II	—
1915, July 22	Eureka	III	Chandeliers shaken.
1915, December 31	Off Humboldt Coast 41° N, 126° W	III	Magnitude $6\frac{1}{2}$
1916, May 16	Eureka	III	Two shocks.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1916, July 4	Humboldt County (Ferndale)	V	Three distince shocks.
1916, August 23	Eureka	V	Felt by practically everyone.
1917, June 26	Eureka	IV	One bump.
1917, September 12	Eureka	IV	Rattled windows.
1917, October 26	Eureka	II	Houses creaked.
1918, January 14	Eureka	—	--
1918, February 23	Eureka	IV	Felt by many.
1918, March 2	Eureka	III	Felt by several.
1918, April 16	Eureka	V	Distinct bump.
1918, July 14	Off Humboldt Coast 41° N, 125° W	VI	Buildings swayed alarmingly. Magnitude 6½
1918, July 21	Eureka	III	Felt by many.
1918, August 20	Eureka	IV	Awakened most.
1918, November 29	Eureka	V	--
1919, June 13	Eureka	IV	Felt by several.
1919, September 12	Eureka	V	A series of at least five shocks, the largest giving intensity V.
1919, September 15	Eureka	VII	Four shocks. The first, and most severe demolished some chimneys and broke windows.
1919, October 4	Eureka	III	Felt by several.
1920, March 20	Eureka	IV	Felt by many.
1920, April 19	Eureka	III+	Felt by many.
1920, October 4	Eureka	III	A bump. (05:31 a.m. P.S.T.)
1920, October 4	Eureka	IV to V	Some alarm. (08:46 p.m. P.S.T.)
1921, March 22	Eureka	II to III	Bump felt by several.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1921, April 24	Eureka	IV	Bump felt by many.
1921, August 28	Eureka	III	Bump felt by many.
1921, November 29	Eureka	II	Abrupt trembling.
1922, January 31	Off Cape Mendocino 41° N, 125½° W	VI	Felt over an extremely large area of northern California. Magnitude 7.3.
1922, February 4	Eureka	III+	Rattled windows.
1922, August 5	Eureka	III	— (7:30 p.m. P.S.T.)
1922, August 5	Eureka	IV	Rocking motion felt by many.
1922, August 5	Eureka	III	— (9:45 p.m. P.S.T.)
1922, August 17	Eureka	III	Rocking felt by many.
1922, September 18	Eureka	III?	Felt by several.
1922, November 3	Eureka	III	Rocking felt by several.
*1923, January 22	Off Cape Mendocino 40½° N, 124½° W	VI	Only minor damage. Magnitude 7.2
1923, February 9	Eureka	II	Felt by several.
1923, March 28	Eureka	III	Abrupt bumping.
1923, September 3	Eureka	IV?	Awakened nearly all sleepers.
1923, September 17	Eureka	IV?	Abrupt rocking.
1924, January 9	Eureka	IV+	Awakened all but the soundest sleepers.
1924, June 19	Upper Mattole	—	Felt.
1924, July 17	Eureka	IV	Abrupt bumping.
1924, September 7	Eureka	II to III	Rocking felt by several.
1925, January 25	Eureka	II	Felt by several.
1925, March 2	Eureka	IV	Felt by many.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1925, March 3	Eureka	III+	Felt by many.
1925, July 26	Eureka	III+	Abrupt bumping.
1926, September 21	Eureka	IV	Awakened many.
1926, October 13	—	—	Awakened many.
1926, December 27	Eureka.	III	Abrupt bumping.
1927, January 3	Eureka	IV	Alarmed some.
1927, February 12	Eureka	IV	Abrupt rocking.
1927, May 16	Humboldt County	IV	Felt by many.
1927, August 10	Eureka	V+	Awakened nearly all, and alarmed many.
1927, August 20	Humboldt Bay	VII	

In Eureka considerable damage was done in the way of cracking of walls, fall of plaster, cracking and fall of chimneys, and damage to goods which were thrown from the shelves in stores. The County Courthouse and the Federal Building suffered extensive damage in cracking of plaster and walls. Water pipes were broken in the latter building. (From Perry Byerly, The Eureka, California, Earthquake of August 20, 1927.)

1927, September 6	Humboldt County	III	Felt by several.
1927, September 16	Eureka	V	Light fixtures swayed. Awakened all but the soundest sleepers.
1927, December 8	Eureka	V	Felt by many. (2:25 p.m. P.S.T.)
1927, December 8	Eureka	V	Felt by nearly all at rest. (10:13 p.m. P.S.T.)
1929, December 4	Garberville	IV	—
1930, March 27	—	III	—
1930, September 22	Eureka	VII	Major earthquake. Two shocks which caused considerable local damage, but little information available.
1930, December 11	--	V	No damage. (12:59 a.m. P.S.T.)
1930, December 11	--	IV	(4:29 a.m. P.S.T.)

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1930, December 12	--	III	(12:15 p.m. P.S.T.)
1930, December 23	--	--	No damage. Between December 11 and December 23 there were eight shocks felt in Eureka.
**1931, March 9	40° N, 125° W	II to III	--
1931, May 19	--	III	--
*1931, September 9	40½° N, 124° W	IV	Magnitude 5.8.
1931, November 28	--	III	--
1932, January 5	--	III	--
1932, April 26	--	IV	--
1932, June 5	--	II to III	--
*1932, June 6	40° 45'N 124° 30' W	VII	

Two large brick stacks (both 150 feet high) were damaged, almost all brick chimneys around Humboldt Bay were damaged, and most of them completely demolished. On the highway at Field's Landing a crack running in an east-west direction transverse to the road was formed, but there was no evidence that it extended farther than the edge of the concrete pavement. One person was killed and another severely injured in Eureka. Electric power was interrupted for only a few minutes, and the water system in Eureka remained intact. No fires followed the earthquake. (From Neil R. Sparks, The Eureka Earthquake of June 6, 1932.) Magnitude 6.4.

1933, November 10	--	IV	Felt by many.
1934, April 20	--	IV	Bumping motion followed by trembling. Awakened many.
*1934, July 6	41° 26' N, 125° 24'W	V	Hanging objects swung, clocks stopped.
1934, November 15	--	II	Walls creaked.
1934, November 17	--	III	Gentle rocking.
1935, January 2	40°.4'N, 125.7° W	IV	Windows rattled, walls creaked, and chandeliers swung.
1935, February 3	--	II	Felt.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1935, October 27	--	III?	--
1936, June 3	40.2° N, 126.0° W	IV	Slow rocking and rolling motion.
1936, August 23	--	III?	Felt by many.
1936, September 25	--	III?	A single surge, felt by many.
1937, February 6	--	V	Pendulum clocks stopped, bushes shook, and hanging objects swung.
**1938, September 11	40° N, 124° W	V	Felt by all; hanging objects swung.
**1938, October 17	40° N, 124° W	II?	Felt by few.
1938, November 9	--	III?	Mild earth tremor, felt by many.
**1939, May 1	40° N, 124° W	IV	Rattled windows; hanging objects swung.
1939, June 22	--	II	Felt by few.
1940, August 25	--	III	One vertical bump; subterranean sounds.
1940, September 27	--	IV	Moderately loud subterranean sounds, lighting fixtures swung, some alarm.
1940, October 22	--	IV	Rattled windows and doors.
1940, November 16	--	V	Objects swung, trees and bushes shook.
1940, November 19	--	V	Objects swung, dishes rattled, walls creaked, and bushes were disturbed.
1940, December 20	--	IV	Clocks stopped, objects swung, felt by nearly all.
1941, January 23	--	IV	Felt by many, awakened few.
1941, February 9	40.7° N, 125.4° W	VI	Overturned small objects, and shook trees and bushes.
**1941, May 13	40.3° N, 125.0° W	III	Felt by few. Magnitude 6.0

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1941, October 3	40 3/4°N, 125°W	VI	Plaster cracked and fell, chimneys cracked and twisted; was felt by and frightened all. Magnitude 6.4
1941, October 4	--	III	Slight
1941, November 24	--	III	Felt
1943, November 11	--	IV	Rattled loose objects, buildings creaked, awakened few.
1944, January 12	--	V	Hanging objects swung, small objects disturbed.
1944, June 5	--	III	Felt by few.
1944, September 21	--	IV	Rattled windows.
1945, May 2	--	V	Fixtures swung, disturbed objects.
1945, May [illegible]	40.2° N, 126.8° W	IV	Rattled windows.
*1945, October 22	40.7° N, 124.7° W	0	Not reported felt. Magnitude 4.3.
1946, August 1	--	III	Swayed light fixtures.
1946, November 23	--	V	Earthquake sounds, objects disturbed.
1946, December 18	--	V	Earthquake sounds, objects disturbed; sharpest since 1932.
1946, December 20	--	III	Felt by several.
1947, March 29	--	V	Floor lamps swayed, objects disturbed.
**1947, May 27	40.4° N, 124.7° W	V	--
**1947, September 23	40.4° N, 125.2° W	VI	Awakened all, frightened many, hanging objects swung. Magnitude 5.3.
**1948, February 19	41° N, 124.9° W	III	Felt by several.
1948, April 3	--	IV	Felt by many, loose objects rattled.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
*1948, August 8	40° 25' N, 124° 07'W	0	Not reported felt. Magnitude 3.0.
*1948, August 8	40° 25' N, 124° 07' W	0	Not reported felt. Magnitude 3.3.
**1948, August 18	40.5° N, 124.7° W	V	Disturbed objects.
1948, August 19	--	V	Awakened many.
**1948, September 7	40° 15' N, 124° 16' W	III	Felt by several.
*1948, November 12	40° 24' N, 124° 19' W	0	Not reported felt. Magnitude 4.5.
*1949, May 3	40.4° N, 124.3° W	III	Hanging objects swung. Magnitude 4.1.
*1949, May 12	40.7° N, 124.7° W	0	Not reported felt. Magnitude 4.3.
1949, September 6	--	?	Felt.
*1949, October 27	40.9° N, 124.2° W	V	Disturbed objects. Magnitude 4.5.
*1949, December 21	40.4° N, 124.3° W	0	Not reported felt. Magnitude 3.6.
**1950, January 14	40° 13' N, 124° 25' W	V	Shifted small objects, rattled windows.
*1950, February 10	41.2° N, 124.3° W	V	Hanging objects swayed, small objects displaced. Magnitude 4.0.
*1950, June 2	40.8° N, 124.4° W	?	Sharp at Eureka. Magnitude 4.0.
*1950, June 6	40.8° N, 123.7° W	0	Not reported felt. Magnitude 3.0.
*1951, January 13	41.2° N, 124.3° W	IV	Felt by many.
**1951, October 7	40° 17' N, 124° 38' W	V	Disturbed objects, many frightened.
*1951, October 26	41° 00' N, 124° 30' W	0	Not reported felt. Magnitude 3.9.
*1951, November 14	40° 26' N, 124° 03' W	VI	Large windows broken. Magnitude 4.7.
*1952, March 23	40° 25' N, 124° 08' W	0	Not reported felt. Magnitude 3.2.
*1952, April 27	40 55' N, 124° 25' W	0	Not reported felt. Magnitude 3.0.
**1952, September 22	40° 12' N, 124° 25' W	V	Felt by most, disturbed objects.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
*1952, October 4	40° 35' N, 124° 25' W	0	Not reported felt; Magnitude 3.7.
*1952, November 16	41° 00' N, 124° 25' W	0	Not reported felt. Magnitude 4.1.
*1952, December 17	40.4° N, 124.2° W	0	Not reported felt. Magnitude 2.8.
*1953, January 3	40.7° N, 124.4° W	0	Not reported felt. Magnitude 3.6.
*1953, April 10	40° 26' N, 124° 18' W	0	Not reported felt. Magnitude 3.2.
*1953, May 25	40° 35' N, 123° 45' W	0	Not reported felt. Magnitude 2.8.
*1953, May 27	40.5° N, 124.4° W	0	Not reported felt. Magnitude 3.0.
*1953, May 30	40° 28' N, 124° 27' W	0	Not reported felt. Magnitude 3.6.
*1953, June 25	40.4° N, 124.3° W	0	Not reported felt. Magnitude 3.1.
*1953, July 1	40.5° N, 123.6° W	0	Not reported felt. Magnitude 2.4.
*1953, July 7	40.6° N, 124.3° W	0	Not reported felt. Magnitude 3.1.
*1953, August 6	40.6° N, 124.0° W	0	Not reported felt. Magnitude 3.1.
*1953, August 7	40.7° N, 123.8° W	0	Not reported felt. Magnitude 3.5.
*1953, August 14	40° 28' N, 124° 06' W	0	Not reported felt. Magnitude 3.0.
*1953, October 25	40° 36' N, 123° 56' W	0	Not reported felt. Magnitude 2.9.
*1953, November 17	41.2° N, 124.1° W	0	Not reported felt. Magnitude 3.2.
*1954, May 27	40° 28' N, 124° 30' W	0	Not reported felt. Magnitude 3.6.
*1954, July 1	40.8° N, 124.5° W	0	Not reported felt. Magnitude 2.0.
*1954, July 5	40° 26' N, 124° 16'W	III	Slight rumbling earthquake. Magnitude 3.6.
**1954, July 17	41° 18' N, 123° 34' W	III	Mild intensity.
*1954, October 20	40.4° N, 124.3° W	0	Not reported felt. Magnitude 2.5.
*1954, November 18	40.5° N, 124.1° W	IV	Felt by many.
*1954, December 21	40° 49' N, 124° 05' W	VII	Magnitude 6.5.

The old City Hall and old County Courthouse in Eureka were extensively cracked; several old poorly constructed brick walls bulged, and there was some parapet damage, but damage in the main was to chimneys, plaster, plate-glass windows, and merchandise. In the poorly consolidated ground areas north and east of Eureka there were some pipe line failures and Eureka's main water reservoir (constructed in two halves) was cracked in one half. Numerous breaks occurred in Eureka's water distribution system, but none were serious. Two tall industrial stacks, cracked in the 1932 earthquake, were again cracked. One elevated steel tank (not earthquake resistant) had broken rods. U.S. Highway 101 between Eureka and Arcata was cracked and bulged to some extent, but no serious damage occurred to roads or bridges. A press report stated, "A large section of the older downtown area of Eureka settled from two to six inches. The area, bounded roughly by E Street, Fourth Street, Broadway, and the Bay, at one time was a tidal mud flat and was filled to allow construction of buildings. This sector of the city has been settling gradually for many years, but sank rapidly during the earthquake. . . . One man fell into Humboldt Bay and was drowned, and a number of people were injured by falling objects." (From the United States Coast and Geodetic Survey.)

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
*1954, December 22	40° 47' N, 123° 52' W	0	Not reported felt. Magnitude 3.5.
*1954, December 24	40° 44' N, 124° 04' W	V	Frightened all, rattled dishes. Magnitude 3.5.
*1954, December 30	40° 47' N, 123° 52' W	VI	Plaster cracked, windows broken, chimneys down, and water transmission lines broken. Magnitude 5¼.
*1955, January 1	40° 57' N, 124° 00' W	IV	Some plaster cracked. Magnitude 4.0.
*1955, January 1	41° 11' N, 124° 11' W	?	Included above. Magnitude 3.0.
*1955, January 8	40.9° N, 124.4° W	0	Not reported felt. Magnitude 3.0.
*1955, January 9	40.9° N, 124.4° W	0	Not reported felt. Magnitude 2.6.
*1955, January 12	41.1° N, 123.9° W	0	Not reported felt. Magnitude 3.3.
1955, January 30	--	IV	Felt by many.
1955, January 31	--	IV	Light jolt.
*1955, March 5	41.0° N, 124.0° W	III	Light earthquake. Magnitude 3.1.
*1955, March 7	40° 39' N, 124° 15' W	0	Not reported felt. Magnitude 3.5.
1955, March 15	--	III	Two light shocks.
*1955, June 7	40.8° N, 124.4° W	?	Felt.

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
**1955, August 26	40° 23' N, 124° 30' W	III	A minor earthquake. Magnitude 4.5.
*1955, August 29	40° 25' N, 124° 11' W	V	Floor lamps swayed, disturbed objects. Magnitude 4.1.
1955, October 11	—	III	Slight rattles.
*1955, November 4	40.8° N, 124.3° W	IV	Felt by all in home. Magnitude 3.0.
*1955, November 15	40.7° N, 123.6° W	IV	Felt by all in home. Magnitude 3.2.
*1955, November 18	40° 25' N, 124° 05' W	0	Not reported felt. Magnitude 3.6.
**1956, March 9	40° 18' N, 124° 14' W	IV	Felt by several, awakened few.
*1956, May 28	41.1° N, 124.0° W	III	Very light. Magnitude 2.5.
1956, May 31	--	III	Felt on first floor.
1956, June 1	--	III	Six light shocks.
*1956, July 12	40.8° N, 123.6° W	0	Not reported felt. Magnitude 3.5.
*1956, July 26	40° 27' N, 124° 18' W	0	Not reported felt. Magnitude 3.2.
*1956, October 6	40° 25' N, 124° 05' W	0	Not reported felt. Magnitude 3.0.
*1956, October 6	40° 25' N, 124° 00' W	0	Not reported felt. Magnitude 3.3.
1956, October 11	40° 40' N, 125° 46' W	V	A few dishes broken.
1956, October 13	--	IV	Caused garage to tremble.
** 1956, November 10	40° 13' N, 123° 48' W	V	Rattled windows and awakened sleepers.
*1957, January 26	40° 24' N, 124° 01' W	0	Not reported felt. Magnitude 3.3.
*1957, February 18	41.0° N, 124.2° W	III	Light jolting earthquake. Magnitude 2.7.
*1957, March 13	40.7° N, 123.9' W	III	Small shock. Magnitude 3.0.
*1957, March 14	40° 16' N, 123° 50' W	IV	Disturbed objects.

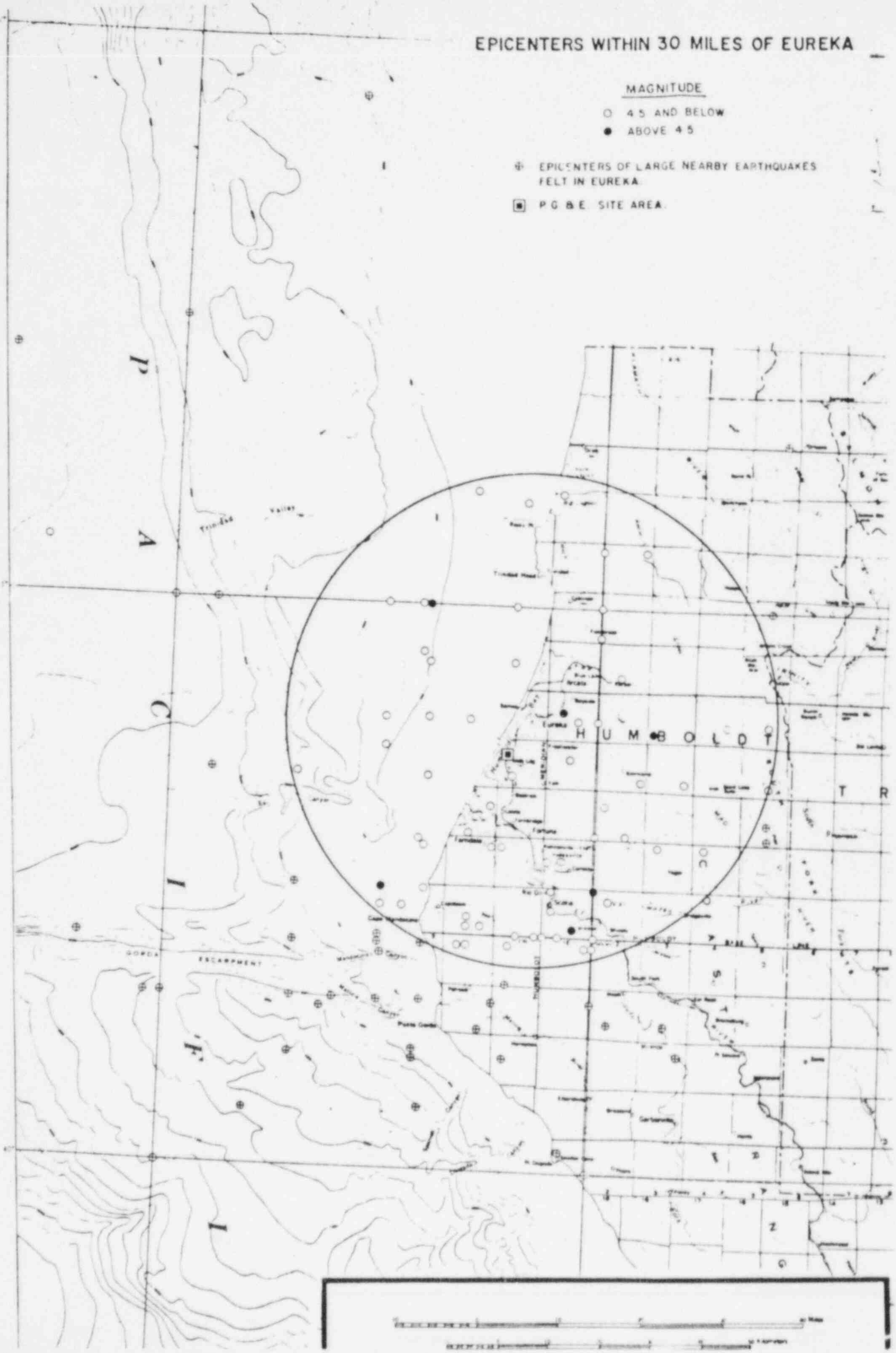
Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
*1957, April 9	40.4°N, 124.2°W	0	Not reported felt. Magnitude 3.3
*1957, June 5	40° 30'N, 124° 00'W	0	Not reported felt. Magnitude 3.4
*1957, September 2	40.7°N, 123.9°W	0	Not reported felt. Magnitude 3.0
*1957, July 28	40° 29'N, 123° 58'W	0	Not reported felt. Magnitude 3.2
**1958, March 14	40° 16'N, 123° 58'W	IV	Felt by many; awakened few.
1958, March 21	40°.98N, 123°.60W	--	Not reported felt. Magnitude 3.6
1958, May 24	40°.33N, 124°.2W	--	VI at Ferndale; V at Fields Landing, Alton, Fortuna, Loleta. Magnitude 4.8
1958, June 11	40°.65N, 123°.98W	III	Magnitude 3.6
1958, December 2	40°.2N, 124°.7W	--	V in Briceland, Ferndale, Fields Landing, Loleta. Magnitude 4.3
1959, January 21	40°.88N, 123°.95W	II	Magnitude 3.2
1959, July 23	41°.1N, 125°.3W	IV	Magnitude 5.8
1959, August 19	40°.3N, 124°.4W	--	V at Rio Dell. Magnitude 4.2
1959, December 5	40°.3N, 125°.4W	--	V at Alton, Ferndale, Fields Landing. Magnitude 5.1
1959, December 21	40°.3N, 124°.5W	--	V at Ferndale, Fields Landing, Lolet IV at P.G.& E. Humboldt Bay Power House. Magnitude 4.7
1960, May 20	40°.63N, 123°.60W	--	Magnitude 2.0
1960, June 5	40°.7N, 124°.9W	VI	VI at Eureka, Ferndale. V at Alton, Fields Landing, Fortuna Loleta. Magnitude 5.7
1960, June 8	40°.57N, 124°.22W	III	Magnitude 4.3
1960, July 24	40°.57N, 124°.40W	--	Not reported felt. Magnitude 3.0
1960, August 8	40°.3N, 127°.1W	IV	V at Ferndale, Fortuna. IV at Fields Landing, Eureka. Magnitude 6.2
1960, December 12	40°.55N, 124°.08W	IV	Magnitude 3.7
1960, December 27	41°.5N, 125°.0W	--	V at Ferndale. Reported not felt a Fields Landing. Magnitude 5.4

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1961, March 14	40°.5N, 124°.0W	--	"Sharp earthquake shook the Fortuna-Rio Dell area." Magnitude 3.1
1961, April 20	40°.1N, 124°.8W	V	V at Eureka, Ferndale, Fields Landing, Loleta. Magnitude 5.
1961, November 9	40°.4N, 124°.0W	V	V at Eureka, Ferndale, Fields Landing, Fortuna, Loleta. Magnitude 3.8
1962, March 5	40°.3N, 125°.0W	--	V at Fields Landing. IV at Ferndale. Reported not felt at Fortuna. Magnitude 4.6
1962, June 10	40°.4N, 124°.4W	--	V at Alton, Ferndale, Fortuna. Reported not felt at Fields Landin Magnitude 3.8
1962, July 14	40°.3N, 124°.7W	--	V at Fields Landing, Fortuna. IV at Loleta, Ferndale, Alton. Magnitude 5.0
1962, July 20	40°.3N, 124°.4W	--	V at Ferndale. IV at Fortuna. Reported not felt at Fields Landin Magnitude 4.1
1962, August 23	41°.9N, 124°.6W	IV	V at Ferndale. IV at Fields Landing, Eureka, Loleta, Fortuna. Magnitude 5.6
1962, September 4	41°.00N, 124°.40W	VI	VI at Eureka. V at Ferndale and Fields Landing. Magnitude 5.0
1962, November 16	40°.60N, 124°.00W	--	Not reported felt. Magnitude 3.0
1963, May 9	40°.55N, 124°.11W	IV	IV at Eureka. Magnitude 4.0
1963, June 6	40°.6N, 124°.3W	--	Slight shock felt at P.G.& E. Humboldt Bay Power Plant. Magnitude 4.0
1964, February 26	40°.3N, 124°.4W	--	V at Ferndale. IV at Fortuna, Loleta. Reported not felt at Fields Landin Magnitude 4.6
1964, December 9	40°.80N, 124°.00W	--	No felt reports. Magnitude 3.5

Date	Epicentral Region	Intensity at Eureka	Effect at Eureka
1965, March 16	40°.80N, 123°.70W	IV	IV at Eureka. Magnitude 3.2
1965, April 25	40°.57N, 124°.24W	--	Not reported felt. Magnitude 3.1
1965, April 27	40°.3N, 124°.6W	IV	IV at Eureka. Magnitude 3.6
1965, June 29	40°.2N, 124°.2W	--	Not reported felt. Magnitude 3.6
1965, July 19	40°.9N, 125°.5W	IV	IV at Eureka. Magnitude 4.5
1965, September 15	40°.4N, 125°.7W	IV	IV at Eureka, Ferndale. III at Fortuna. Magnitude 5.6
1966, January 10	40°.3N, 124°.0W	--	Not reported felt. Magnitude 3.4
1966, March 23	40°.4N, 124°.5W	--	Not reported felt. Magnitude 4.0
1966, April 29	40°.3N, 124°.7W	--	Not reported felt. Magnitude 3.2
1966, July 3	40°.6N, 123°.6W	--	Felt at Rio Dell. Magnitude 3.6
1966, October 15	40°.7N, 124°.2W	V	V at Eureka, Ferndale, Fortuna. Magnitude 4.0
1967, February 25	40°.3N, 123°.1W	--	Reported not felt at Ferndale, Fields Landing, Loleta. Magnitude 4.0
1967, March 1	40°.3N, 124°.5W	--	Felt at Eureka, Ferndale, Fortuna. Magnitude 3.6
1968, June 25	40°.4N, 124°.5W	V	V at Eureka, Ferndale, Fields Landing, Loleta. IV at Humboldt Bay Power Plant. Magnitude 5.8

* Epicenter located on Map 1 within 30 miles of Eureka.
** Epicenter located on Map 1, beyond 30 miles, but felt in Eureka.

EPICENTERS WITHIN 30 MILES OF EUREKA



MAP B

EPICENTERS WITHIN 30 MILES OF EUREKA