TABLE 3-2

MAGNITUDE 5 AND LARGER EARTHQUAKES WITHIN 160 KILOMETERS (100 MILES) OF THE HB-ISFSI SITE, 1850 THROUGH APRIL 2002

Pacific Gas and Electric Company
Humboldt Bay ISFSI

Date	Origin Time (GMT)	Latitude (deg. min.)	Longitude (deg. min.)	*Depth (km)	Location References	§Magnitude	Magnitude References
		41 15	-125 25.2	0	Geomatrix, 1995	M_L 5.5	Geomatrix, 1995
01/02/1935	22:40	40 15	-125 15	0	Geomatrix, 1995; CNSS, 2002; Toppozada and others, 2000	M_L 5.7; M_L 5.8	Geomatrix, 1995; UCB, 2002; Toppozada and others, 2000
06/03/1935	17:08	41	-124	0, 14.8	CNSS, 2002; Geomatrix, 1995	M_L 5.0	UCB, 2002; Geomatrix, 1995
06/03/1936	09:15	40	-125 30	0	Ellsworth, 1990	$M_{G\text{-}R}$ 5.9; *M* 5.9	Bakun, 2000; Ellsworth, 1990
		40 9.6	-126 27	0	Bolt and Miller, 1975	M_L 5.8	Bolt and Miller, 1975
		40 19.8	-125 24	0	Geomatrix, 1995	M_L 5.9	Geomatrix, 1995
10/10/1936	01:25	41	-125	0	CNSS, 2002	M_L 5.0	UCB, 2002
02/07/1937	04:41	40 30	-125 15	0	Geomatrix, 1995; CNSS, 2002; Toppozada and others, 2000	M_L 5.8; $\underline{M}$ 5.8; M_L 5.7	UCB, 2002; Toppozada and others, 2000; Geomatrix, 1995
07/01/1938	18:13	41	-124	0, 14.8	CNSS, 2002; Geomatrix, 1995;	M_L 5.0	UCB, 2002; Geomatrix, 1995;

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MAGNITUDE 5 AND LARGER EARTHQUAKES WITHIN 160 KILOMETERS (100 MILES) OF THE HB-ISFSI SITE, 1850 THROUGH APRIL 2002

Pacific Gas and Electric Company
Humboldt Bay ISFSI

Date	Origin Time (GMT)	Latitude (deg. min.)	Longitude (deg. min.)	*Depth (km)	Location References	§Magnitude	Magnitude References
09/12/1938	06:10	40	-124	0	CNSS, 2002; Toppozada and others, 2000	M_L 5.5; $\underline{M}$ 5.5	UCB, 2002; Toppozada and others, 2000
		40 12	-124 37	0	Geomatrix, 1995	M_L 5.5	Geomatrix, 1995
10/22/1940	11:00	40 30	-124 6	0, 15.8	Bolt and Miller, 1975; Geomatrix, 1995	M_L 5.5	Bolt and Miller, 1975; Geomatrix, 1995
12/20/1940	23:40	40	-124	0	CNSS, 2002; Toppozada and others, 2000	M_L 5.5; $\underline{M}$ 5.5	UCB, 2002; Toppozada and others, 2000
02/09/1941	09:44	40 42	-125 24	0	CNSS, 2002; Ellsworth, 1990; Toppozada and others, 2000	$M_{G\text{-}R}$ 6.6; M_L 6.4; M 6.6; $\underline{M}$ 6.6	Bakun, 2000; UCB, 2002; Ellsworth, 1990; Toppozada and others, 2000
		40 30	-125 21.6	0	Geomatrix, 1995	M_L 6.5	Geomatrix, 1995
10/03/1941	16:13	40 24	-124 48	0	CNSS, 2002; Ellsworth, 1990; Toppozada and others, 2000	$M_{G\text{-}R}$ 6.4; M_L 6.4; M 6.4; $\underline{M}$ 6.4	Bakun, 2000; CNSS, 2002; Ellsworth, 1990 & Toppozada and others, 2000
		40 32.4	-125	0	Geomatrix, 1995	M_L 6.4	Geomatrix, 1995

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MAGNITUDE 5 AND LARGER EARTHQUAKES WITHIN 160 KILOMETERS (100 MILES) OF THE HB-ISFSI SITE, 1850 THROUGH APRIL 2002

Pacific Gas and Electric Company
Humboldt Bay ISFSI

Date	Origin Time (GMT)	Latitude (deg. min.)	Longitude (deg. min.)	*Depth (km)	Location References	[§]Magnitude	Magnitude References
10/06/1941	06:59	40 24	-125	0	CNSS, 2002	M_L 5.0	UCB, 2002
01/12/1944	15:02	40 18	-124 54	0	Geomatrix, 1995; CNSS, 2002	M_L 5.1	Geomatrix, 1995; UCB, 2002
01/16/1944	02:20	40 18	-125 6	0	CNSS, 2002	M_L 5.1	CNSS, 2002
05/02/1945	19:47	41 12	-123 30	30.1, 0	Geomatrix, 1995; UCB, 2002	M_L 5.3; M_L 5.0	Geomatrix, 1995; UCB, 2002
05/27/1947	20:58	40 24	-124 42	0	CNSS, 2002	M_L 5.2	CNSS, 2002
		40 18	-124 13	10.0	Geomatrix, 1995	M_L 5.2	Geomatrix, 1995
09/23/1947	13:53	40 24	-125 12	0	CNSS, 2002	M_L 5.3	CNSS, 2002
		40 27	-125 9	0	Geomatrix, 1995	M_L 5.3	Geomatrix, 1995
08/18/1948	19:12	40 30	-124 42	0	CNSS, 2002	M_L 5.0	CNSS, 2002
		40 22.2	-124 19.8	10.4	Geomatrix, 1995	M_L 5.0	Geomatrix, 1995
04/01/1951	19:21	40 28.2	-125 18	0	CNSS, 2002	M_L 5.0	CNSS, 2002
		40 24	-125	0	Geomatrix, 1995	M_L 5.0	Geomatrix, 1995
10/08/1951	04:10	40 15	-124 30	0	Ellsworth, 1990; Toppozada	M_{G-R} 6.0; M 6.0;	Bakun, 2000; Ellsworth, 1990;

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MAGNITUDE 5 AND LARGER EARTHQUAKES WITHIN 160 KILOMETERS (100 MILES) OF THE HB-ISFSI SITE, 1850 THROUGH APRIL 2002

Pacific Gas and Electric Company
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Date	Origin Time (GMT)	Latitude (deg. min.)	Longitude (deg. min.)	*Depth (km)	Location References	§Magnitude	Magnitude References
					and others, 2000	$\underline{M}$ 6.0	Toppozada and others, 2000
		40 21	-124 36	0	Geomatrix, 1995	M_L 5.9	Geomatrix, 1995
		40 16.8	-124 48	0	CNSS, 2002	M_L 5.8	CNSS, 2002
09/22/1952	11:41	40 12	-124 25.2	0	CNSS, 2002; Geomatrix, 1995	M_L 5.2	CNSS, 2002; Geomatrix, 1995
11/25/1954	11:16	40 16.2	-125 37.8	0	CNSS, 2002; Ellsworth, 1990; Toppozada and others, 2000	M_{G-R} 6.5; M_L 6.1; M 6.5; $\underline{M}$ 6.5	Bakun, 2000; CNSS, 2002; Ellsworth, 1990; Toppozada and others, 2000
		40 28.8	-125 27.6	0	Geomatrix, 1995	M_L 6.0	Geomatrix, 1995
12/21/1954	19:56	40 55.8	-123 46.8	0	Ellsworth, 1990; Toppozada and others, 2000	M_{G-R} 6.6; M 6.6; $\underline{M}$ 6.6	Bakun, 2000; Ellsworth, 1990; Toppozada and others, 2000
		40 56.4	-123 47.4	17.5	Geomatrix, 1995	M_L 6.6	Geomatrix, 1995
		40 46.8	-123 52.2	0	CNSS, 2002	M_L 6.5	CNSS, 2002
10/11/1956	16:48	40 40.2	-125 46.2	0	CNSS, 2002; Ellsworth,	M_L 6.0, M 6.0,	Bakun, 2000 & CNSS, 2002; Ellsworth,

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MAGNITUDE 5 AND LARGER EARTHQUAKES WITHIN 160 KILOMETERS (100 MILES) OF THE HB-ISFSI SITE, 1850 THROUGH APRIL 2002

Pacific Gas and Electric Company
Humboldt Bay ISFSI

Date	Origin Time (GMT)	Latitude (deg. min.)	Longitude (deg. min.)	*Depth (km)	Location References	§Magnitude	Magnitude References
					1990; Toppozada and others, 2000	M 6.0	1990; Toppozada and others, 2000
		40 35.4	-126 4.8	0	Geomatrix, 1995	M_L 6.0	Geomatrix, 1995
07/24/1959	01:23	41 7.8	-125 18	0	CNSS, 2002; Toppozada and others, 2000; Geomatrix, 1995	M_L 5.8; M 5.8	CNSS, 2002 Geomatrix, 1995; Toppozada and others, 2000;
12/05/1959	08:13	40 18	-125 25.2	0	CNSS, 2002; Geomatrix, 1995	M_L 5.1	CNSS, 2002; Geomatrix, 1995
06/06/1960	01:17	40 49.2	-124 52.8	0	CNSS, 2000	M_L 5.7	CNSS, 2002
		40 52.7	-124 30	10.1	Geomatrix, 1995	M_L 5.7	Geomatrix, 1995
12/27/1960	10:35	41 31.2	-125 3	0, 2.0	CNSS, 2002; Geomatrix, 1995	M_L 5.4	CNSS, 2002; Geomatrix, 1995
04/06/1961	04:04	40 10.8	-124 45	0	CNSS, 2002	M_L 5.0	CNSS, 2002
04/14/1962	07:53	40 16.2	-125 19.2	0	CNSS, 2002; Geomatrix, 1995	M_L 5.0; M_L 5.4	CNSS, 2002; Geomatrix, 1995
07/14/1962	19:43	40 25.8	-125 31.2	0	CNSS, 2002	M_L 5.1	CNSS, 2002
08/23/1962	19:29	40 51	-124 19.8	0	Geomatrix, 1995; CNSS,	M_L 5.6, M_L 5.2,	CNSS, 2002; Geomatrix, 1995;

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MAGNITUDE 5 AND LARGER EARTHQUAKES WITHIN 160 KILOMETERS (100 MILES) OF THE HB-ISFSI SITE, 1850 THROUGH APRIL 2002

Pacific Gas and Electric Company
Humboldt Bay ISFSI

Date	Origin Time (GMT)	Latitude (deg. min.)	Longitude (deg. min.)	*Depth (km)	Location References	§Magnitude	Magnitude References
					2002; Toppozada and others, 2000	$\underline{M}$ 5.6	Toppozada and others, 2000
		41 51	-124 20	0	Bolt and Miller, 1975	M_L 5.6	Bakun, 2000
09/16/1965	04:10	40 30	-125 48	0	CNSS, 2002; Geomatrix, 1995	M_L 5.0	CNSS, 2002; Geomatrix, 1995
12/10/1967	12:06	40 30	-124 42	0	CNSS, 2002; Toppozada and others, 2000	M_L 5.6; $\underline{M}$ 5.6	CNSS, 2002; Toppozada and others, 2000
		40 33.6	-124 34.8	4.6	Geomatrix, 1995	M_L 5.0	Geomatrix, 1995
06/26/1968	01:42	40 13.8	-124 16.2	0	Ellsworth, 1990; CNSS, 2002	M 5.4; M_L 5.9	Ellsworth, 1990; CNSS, 2002
		40 21.6	-124 3.6	14.4	Geomatrix, 1995	M_L 5.7	Geomatrix, 1995
09/13/1970	21:10	40 7.8	-125 4.8	0	UCB, 2002	M_L 5.4	UCB, 2002
02/27/1971	00:31	40 16.2	-124 49.8	0	UCB, 2002	M_L 5.2	UCB, 2002
03/01/1972	09:28	40 40.2	-125 15	0	UCB, 2002	M_L 5.2	UCB, 2002

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MAGNITUDE 5 AND LARGER EARTHQUAKES WITHIN 160 KILOMETERS (100 MILES) OF THE HB-ISFSI SITE, 1850 THROUGH APRIL 2002

Pacific Gas and Electric Company
Humboldt Bay ISFSI

Date	Origin Time (GMT)	Latitude (deg. min.)	Longitude (deg. min.)	*Depth (km)	Location References	§Magnitude	Magnitude References
06/15/1973	19:18	41 30	-125 31.8	0	UCB, 2002	M_L 5.0	UCB, 2002
08/09/1973	02:18	40 15.6	-124 14	2.0	CNSS, 2002	mb 5.1	CNSS, 2002
12/21/1973	19:12	40 37.5	-124 35.8	30.0	CNSS, 2002	mb 5.2	CNSS, 2002
07/03/1974	05:00	40 25.44 40 20.4	-125 8.16 -125 12.6	12 0	CNSS, 2002 UCB, 2002	mb 5.4 M_L 5.1	CNSS, 2002 UCB, 2002
07/13/1974	11:09	40 22.3	-125 10.92	1.00	CNSS, 2002	mb 5.0	CNSS, 2002
01/28/1975	13:53	40 24.9	-125 26.76	10.0	CNSS, 2002	mb 5.0	CNSS, 2002
06/07/1975 (Ferndale)	08:46	40 32.49 40 31.68	-124 16.56 -124 17.88	23.6 3.27	CNSS, 2002 Geomatrix, 1995	M_L 5.3; M_C 5.3; M_L 5.2	UCB, 2002; CNSS, 2002 Geomatrix, 1995
11/26/1976	11:19	41 17.34 41 14.82	-125 42.5 -125 37.08	15.0, 0 15	CNSS, 2002; Toppozada and others, 2000 Geomatrix, 1995	M_S 6.8; $\underline{M}$ 6.8; M_L 6.0	CNSS, 2002; Toppozada and others, 2000 Geomatrix, 1995
12/03/1978	06:48	40 37.2	-125 50.8	98.47	CNSS, 2002	M_C 5.0	CNSS, 2002
02/03/1979	09:58	40 52.15	-124 19.03	23.6	CNSS, 2002	M_L 5.2	UCB, 2002
04/07/1979	06:18	41 8.17	-125 2.56	5.00	CNSS, 2002	M_C5.4	CNSS, 2002
03/03/1980	14:17	40 24.83	-125 07.39	11.6	CNSS, 2002	M_L 5.1	UCB, 2002

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MAGNITUDE 5 AND LARGER EARTHQUAKES WITHIN 160 KILOMETERS (100 MILES) OF THE HB-ISFSI SITE, 1850 THROUGH APRIL 2002

Pacific Gas and Electric Company
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Date	Origin Time (GMT)	Latitude (deg. min.)	Longitude (deg. min.)	*Depth (km)	Location References	§Magnitude	Magnitude References
11/08/1980 (Trinidad)	10:27	41 4.44	-124 36.60	15.1	CNSS, 2002	M_S 7.2, M_C 6.7, M_L 6.9	NEIC, 2002; CNSS, 2002; UCB, 2002
		41 7.2	-124 40.2	0, 6	Ellsworth, 1990; Toppozada and others, 2000; Eaton, 1989	M_S 7.2 , *M* 7.2, $\underline{M}$ 7.4	Bakun, 2000; Ellsworth, 1990; Toppozada and others, 2000
		41 2.46	-124 36.72	21.2	Geomatrix, 1995	M_L 7.0	Geomatrix, 1995
		41 5.84	-124 44.35	19.8	Tera Corporation, 1982	M_L 7.0	Tera Corporation, 1982
11/08/1980	11:20	40 14.8	-124 44.5	15.0	CNSS, 2002	mb 5.0	CNSS, 2002
11/08/1980	22:47	40 39.0	-125 15.6	0	UCB, 2002	M_L 5.0	UCB, 2002
11/08/1980	23:07	40 32.1	-124 47.04	15.00	CNSS, 2002	M_S 5.0	CNSS, 2002
11/09/1980	04:09	40 30.06	-125 20.58	15.00	CNSS, 2002	M_L 5.4	UCB, 2002
12/07/1980	02:56	40 54.2	-126 1.86	15	CNSS, 2002	mb 5.0	CNSS, 2002
12/24/1980	13:29	41 17.76	-124 44.97	3.2	CNSS, 2002	M_L 5.0	UCB, 2002

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MAGNITUDE 5 AND LARGER EARTHQUAKES WITHIN 160 KILOMETERS (100 MILES) OF THE HB-ISFSI SITE, 1850 THROUGH APRIL 2002

Pacific Gas and Electric Company
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Date	Origin Time (GMT)	Latitude (deg. min.)	Longitude (deg. min.)	*Depth (km)	Location References	§Magnitude	Magnitude References
02/06/1982	12:02	41 04.30	-125 08.58	9.2	CNSS, 2002	M_L 5.2	UCB, 2002
05/29/1983	06:55	40 27.4	-125 26.64	10.0	CNSS, 2002	M_L 5.4; mb 5.1	UCB, 2002; CNSS, 2002
08/24/1983	13:36	40 22.39	-124 55.36	11.9	CNSS, 2002	M_L 5.5	UCB, 2002
		40 22.8	-124 49.8	0	Toppozada and others, 2000	$\underline{M}$ 5.6	Toppozada and others, 2000
		40 21.3	-124 51.9	7.87	Geomatrix, 1995	M_L 5.6	Geomatrix, 1995
12/20/1983	10:41	40 25.10	-125 47.56	9.5	CNSS, 2002	M_L 5.6	UCB, 2002
		40 20.16	-125 33.54	10.0	Geomatrix, 1995	M_L 5.8	Geomatrix, 1995
02/28/1984	15:16	40 25.59	-125 16.53	4.0	CNSS, 2002	M_L 5.2	UCB, 2002
02/11/1986	01:15	41 38.04	-125 21.18	10.0	CNSS, 2002	mb 5.0	CNSS, 2002
11/21/1986	23:33	40 22.39	-124 37.77	0.36	CNSS, 2002	M_L 5.1, **M** 5.2	UCB, 2002; Bakun, 2000
11/21/1986	23:34	40 21.62	-124 23.72	16.0	CNSS, 2002	M_L 5.1	UCB, 2002
		40 21.66	-124 25.68	7.51	Geomatrix, 1995	M_L 5.9	Geomatrix, 1995
07/31/1987	23:56	40 24.97	-124 23.02	17.5	CNSS, 2002	M_S 6.0; M_L 5.6	NEIC, 2002; UCB, 2002

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MAGNITUDE 5 AND LARGER EARTHQUAKES WITHIN 160 KILOMETERS (100 MILES) OF THE HB-ISFSI SITE, 1850 THROUGH APRIL 2002

Pacific Gas and Electric Company
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Date	Origin Time (GMT)	Latitude (deg. min.)	Longitude (deg. min.)	*Depth (km)	Location References	§Magnitude	Magnitude References
		40 25.2	-124 24.6	0	NEIC, 2002; Toppozada and others, 2000	M_S 6.0; $\underline{M}$ 6.0	NEIC, 2002 & Bakun, 2000; Toppozada and others, 2000
		40 25.5	-124 23.04	7.2	Geomatrix, 1995	M_L 5.9	Geomatrix, 1995
01/16/1990	20:08	40 14.05	-124 18.69	13.0	CNSS, 2002	M_L 5.4	UCB, 2002
01/18/1990	11:45	41 11.04	-123 46.08	39.9	UCB, 2002	M_L 5.2	UCB, 2002
		41 11.04	-123 46.2	1.58	Geomatrix, 1995	M_L 5.2	Geomatrix, 1995
08/16/1991	22:26	41 41.82	-125 23.10	10.0	CNSS, 2002	M_S 6.3; M_L 6.0; mb 5.5	NEIC, 2002; UCB, 2002; CNSS, 2002
		41 37.98	-125 51.66	0	Toppozada and others, 2000	$\underline{M}$ 6.3	Toppozada and others, 2000
08/17/1991 (Honeydew)	19:29	40 16.90	-124 14.64	9.6	CNSS, 2002	M_L 6.0; M_S 6.2	UCB, 2002; NEIC, 2002
		40 17.23	-124 14.28	0	Toppozada and others, 2000	$\underline{M}$ 6.2	Toppozada and others, 2000
08/17/1991	22:17	41 49.26	-125 23.82	13.5	CNSS, 2002	M_S 7.1, M_L 6.4,	Bakun, 2000; NEIC, 2002; UCB, 2000;

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Pacific Gas and Electric Company
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Date	Origin Time (GMT)	Latitude (deg. min.)	Longitude (deg. min.)	*Depth (km)	Location References	[§]Magnitude	Magnitude References
						mb 6.2	CNSS, 2002
		41 42.6	-125 37.8	0	Toppozada and others, 2000; Bakun, 2000	M 7.0, **M** 7.0	Toppozada and others, 2000; Bakun, 2000
		41 36.6	-125 30.6	4	Geomatrix, 1995	M_L 7.2	Geomatrix, 1995
03/08/1992	03:43	40 15.35	-124 13.98	11.1	CNSS, 2002	M_L 5.2	UCB, 2002
04/25/1992 (Petrolia)	18:06	40 19.94	-124 13.69	10.6	Oppenheimer and others, 1993	M_S 7.1	Oppenheimer and others, 1993
		40 19.96	-124 13.77	0	Toppozada and others, 2000	M 7.2	Toppozada and others, 2000
		40 20.03	-124 13.78	10.3	CNSS, 2002	m_B 6.3	UCB, 2002
04/26/1992	07:41	40 26.13	-124 34.43	19.3	Oppenheimer and others, 1993	M_S 6.6	NEIC, 2002
		40 25.86	-124 34.00	19.5	CNSS, 2000	M_L 6.5	UCB, 2002, CNSS, 2002
		40 25.63	-124 35.79	0	Toppozada and others, 2000	M 6.6	Toppozada and others, 2000

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Pacific Gas and Electric Company
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Date	Origin Time (GMT)	Latitude (deg. min.)	Longitude (deg. min.)	*Depth (km)	Location References	§Magnitude	Magnitude References
04/26/1992	11:18	40 23.38	-124 34.30	21.7	Oppenheimer and others, 1993	M_S 6.6	NEIC, 2002
		40 25.03	-124 49.92	14.2	CNSS, 2000	M_L 6.4; M_L 6.6	UCB, 2000; CNSS, 2002
		40 22.51	-124 35.12	0	Toppozada and others, 2000	$\underline{M}$ 6.6	Toppozada and others, 2000
09/01/1994	15:15	40 24.12	-125 40.8	10.1	CNSS, 2002	**M** 7.0, mb 6.6, M_L 7.0	Bakun, 2000; NEIC, 2002; CNSS, 2002
		40 26.7	-125 53.8	21.3	UCB, 2002	M_W 6.9	UCB, 2002
		40 24	-125 40.8	0	Toppozada and others, 2000	$\underline{M}$ 7.0	Toppozada and others, 2000
12/26/1994	14:10	40 44.30	-124 18.28	23.5	CNSS, 2000	M_w 5.4; **M** 5.4	UCB, 2000; Dengler and others, 1995
02/19/1995	04:03	40 33.36	-125 32.34	10.0	CNSS, 2002	M_S 6.8; M_L 6.3	CNSS, 2002; UCB, 2000
01/22/1997	07:17	40 16.32	-124 23.64	0	Toppozada and others, 2000	$\underline{M}$ 5.6	Toppozada and others, 2000
		40 15.42	-124 29.22		CNSS, 2002	M_W 5.6	CNSS, 2002
10/04/1997	10:57	41 03.0	-125 21.72	7.3	USGSb, 2002	M_L 5.1; M_W 5.6; M_W 5.5	UCB, 2002; CNSS, 2002; UCB, 2002

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MAGNITUDE 5 AND LARGER EARTHQUAKES WITHIN 160 KILOMETERS (100 MILES) OF THE HB-ISFSI SITE, 1850 THROUGH APRIL 2002

Pacific Gas and Electric Company
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Date	Origin Time (GMT)	Latitude (deg. min.)	Longitude (deg. min.)	*Depth (km)	Location References	§Magnitude	Magnitude References
10/26/1997	10:44	41 00.13	-125 09.85	5.7	CNSS, 2002	M_L 5.2	UCB, 2002
11/26/1998	19:49	40 37.43	-122 24.39	23.4	CNSS, 2002	M_L 5.2	UCB, 2002
11/27/1998	00:43	40 39.80	-125 18.68	5.4	CNSS, 2000	M_L 5.5	UCB, 2002
		40 40.02	-125 23.04	0	Toppozada and others, 2000	$\underline{M}$ 5.6	Toppozada and others, 2000
03/16/2000	15:19	40 22.96	-125 16.23	5.1	CNSS, 2002	M_L 5.8; M_C 4.8	UCB, 2000; CNSS, 2002
01/13/2001	13:08	40 44.39	-125 17.06	5.6	CNSS, 2002	M_L 5.2	CNSS, 2002

Notes:
Earthquakes from this table are shown on Figure 3-13, except the 1700 Cascadia and 18 April1906 San Francisco earthquakes. When more than one location or magnitude is given, the first one listed is used in the figure.
*Zero (0) depths are depths that have not been calculated.

§ Magnitude symbol explanations:

Mb Body wave magnitude
M_c Coda magnitude
$M_{G\text{-}R}$ Gutenberg and Richter magnitude
M_L Richter local magnitude

M_S 20-second surface-wave magnitude
M_W Magnitude generally from moment tensor computation.
M Moment magnitude (Hanks and Kanamori, 1979)
(MI) Pre-instrument (before 1900) intensity magnitude from Toppozada and others (1981) estimated from the size of the areas shaken at various levels of intensity.
[MI] Pre-instrumental (before about 1935) intensity magnitude from Bakun (2000), calibrated to equal moment magnitude.
{MI} Pre-instrumental (before about 1935) intensity magnitudes from Geomatrix (1995), calibrated to local magnitudes, are from the Decade of North America catalog (DNAG) as described in (Engdahl and Reinhart, 1991)
(M_L) Pre-instrumental (pre-1900) local magnitude estimate reported by Dengler and others (1992a).
[ML] Local magnitude estimated using intensity data and instrumentally determined ground motion amplitudes, as described in Toppozada and others (1978).
M Summary magnitude from Ellsworth (1990). The summary magnitude characterizes the relative size of all events listed on his table of major California and Nevada earthquakes, 1769-1989. When choices are available, summary magnitudes are weighted toward long-period estimates of magnitude (e.g., reliable M_S and M_{G-R}).
$\underline{M}$ Magnitudes from Toppozada and others (2000). Magnitude types not specified.

TABLE 3-3

EARTHQUAKES THAT PRODUCED GROUND MOTIONS GREATER THAN 10%g AT HUMBOLDT BAY POWER PLANT, 1975 THROUGH 1994

Pacific Gas and Electric Company

Humboldt Bay ISFSI

(Source parameters from Table 3-2)

EQ Number & Name	Date	Origin Time (GMT)	Distance (km)/ Direction from HBPP	Latitude (deg min)	Longitude (deg min)	Magnitude *	Depth (km)	Free-Field Ground Accelerations Recorded at HBPP**	Effects at HBPP
1 Ferndale	07 June 1975	846	22/ SSW	40N 32.41	124W 16.56	M_L 5.3	23.6	0.03g vert. 0.30g e/w 0.18g n/s (1)	Units 1 & 2 tripped. Unit 3 relay tripped; Unit 3 down for refueling (1). Choppy waves in spent fuel pond, 9"-12" high (1). Strong-motion duration a few seconds (1). No damage (1).
2 Trinidad	08 November 1980	1027	50/ NW	41N 4.44	124W 36.60	M_S 7.2	15.1	0.076g vert. 0.495g e/w 0.143g n/s (2,4)	No structural damage (3). Tools fell from storage rack, glassware broke, separation of paint over previous surface cracks in concrete walls (3).

TABLE 3-3

EARTHQUAKES THAT PRODUCED GROUND MOTIONS GREATER THAN 10%g AT HUMBOLDT BAY POWER PLANT, 1975 THROUGH 1994

Pacific Gas and Electric Company

Humboldt Bay ISFSI

(Source parameters from Table 3-2)

EQ Number & Name	Date	Origin Time (GMT)	Distance (km)/ Direction from HBPP	Latitude (deg min)	Longitude (deg min)	Magnitude *	Depth (km)	Free-Field Ground Accelerations Recorded at HBPP**	Effects at HBPP
3 Petrolia main shock	25 April 1992	1806	55/ S	40N 19.94	124W 13.69	M_S 7.1	10.6	0.05g vert. 0.22g e/w 0.22g n/s (6)	No structural damage (5,7,8). Unit 2 offline. Water splashed out of spent fuel pond (6). New hairline cracks in walls of refueling building, caisson access shaft, and grouted areas near top of spent fuel pond (7). Cracks and leaks in water line to Unit 2 (7).
4 Petrolia aftershock	26 April 1992	0741	55/ SW	40N 26.13	124W 34.43	M_S 6.6	19.3	0.052g vert. 0.25g e/w 0.23g n/s (6).	No Damage (7). Additional electrical problems to fuse parts (6).

TABLE 3-3

EARTHQUAKES THAT PRODUCED GROUND MOTIONS GREATER THAN 10%g AT HUMBOLDT BAY POWER PLANT, 1975 THROUGH 1994

Pacific Gas and Electric Company

Humboldt Bay ISFSI

(Source parameters from Table 3-2)

EQ Number & Name	Date	Origin Time (GMT)	Distance (km)/ Direction from HBPP	Latitude (deg min)	Longitude (deg min)	Magnitude *	Depth (km)	Free-Field Ground Accelerations Recorded at HBPP**	Effects at HBPP
5 Petrolia aftershock	26 April 1992	1118	70/ SW	40N 23.38	124W 34.30	M_S 6.6	21.7	0.031g vert. 0.13g e/w 0.10g n/s (6).	No damage (6).
6	26 December 1994	1410	8/ W	40N 44.30	124W 18.28	M_W 5.4	23.5	0.17g vert. 0.48g e/w 0.55g n/s (10). CSMIP recorded 0.41g to 0.56g in Eureka area (10).	Strongly felt (10). Unit 2 was offline. Unit 1 tripped offline from quake relay response (9). Fuses of startup transformer fell (9). Leak in Unit 1 stem air drip tank condensate return line to main condenser (9).

*See Table 3-2 for explanation of magnitude symbols.

**Component orientation: vert.= vertical; n/s= horizontal, oriented plant north-south; e/w= horizontal, oriented plant e/w.
(1) Bechtel Power Corporation, 1975
(2) Terra Technology Services, 1980
(3) Nuclear Regulatory Commission, 1980
(4) Pacific Gas and Electric Company, 1984
(5) Nuclear Regulatory Commission, 1992
(6) Pacific Gas and Electric Company, 1992a
(7) Pacific Gas and Electric Company, 1992b
(8) Pacific Gas and Electric Company, 1992c
(9) Pacific Gas and Electric Company, 1994
(10) Pacific Gas and Electric Company, 1995

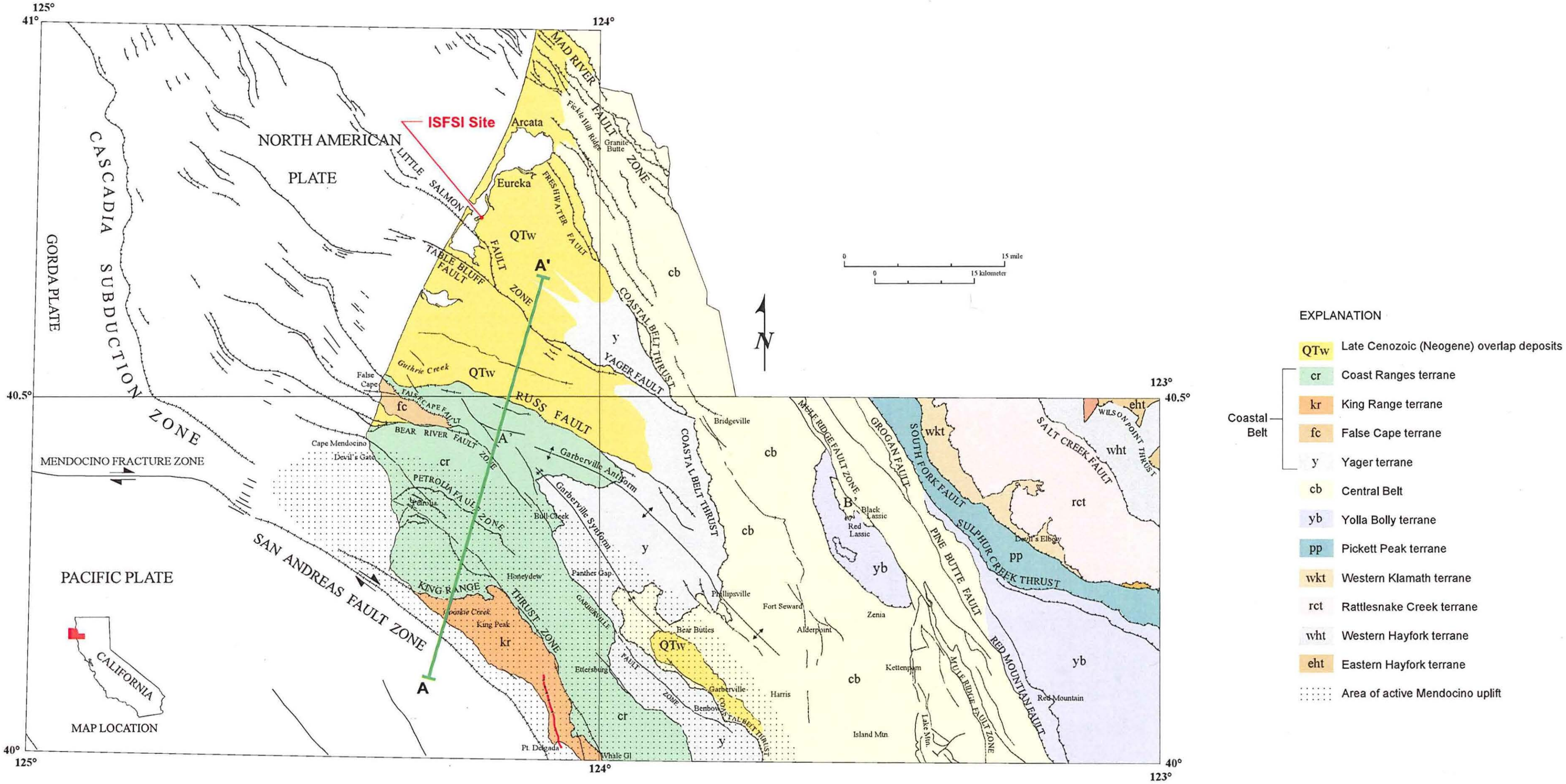
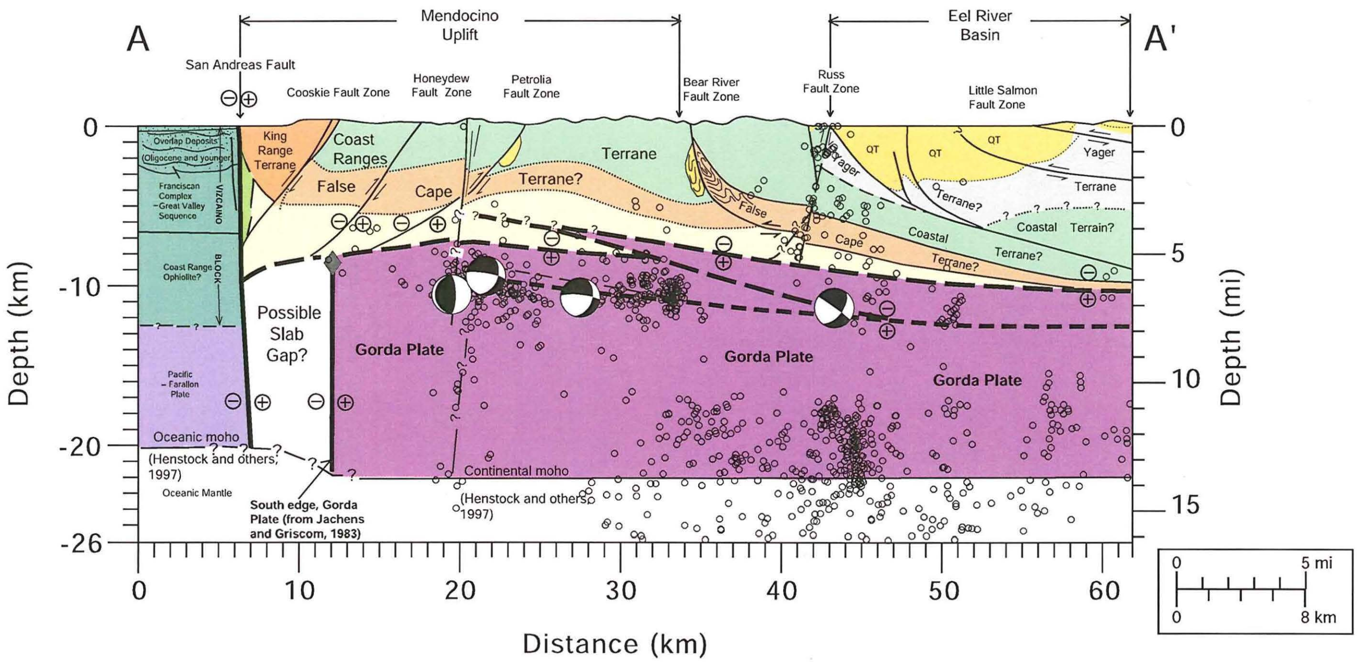


Figure 3-1 Generalized regional geologic map showing principal faults and folds, area of active Mendocino uplift (stippled pattern), and major plates *(after McLaughlin and others, 2000)*. Cross section A-A' is shown on Figure 3-2. Details of faulting in the vicinity of Humboldt Bay area shown on Figures 3-3 and 3-7.



Notes:
Focal mechanisms are depicted as spheres viewed from the southeast; black sectors are tensional, white sectors compressional. Location data and focal mechanisms from M. Magee, Stanford University/USGS (1994).

Figure 3-2 Generalized regional structure section A-A' showing depth distribution of epicenters (open circles) and selected focal mechanisms (beach balls) of earthquakes from M. Magee (Stanford University and USGS), 1994 *(after McLaughlin and others, 2000).* The location of cross section A-A' is shown on Figure 3-1.

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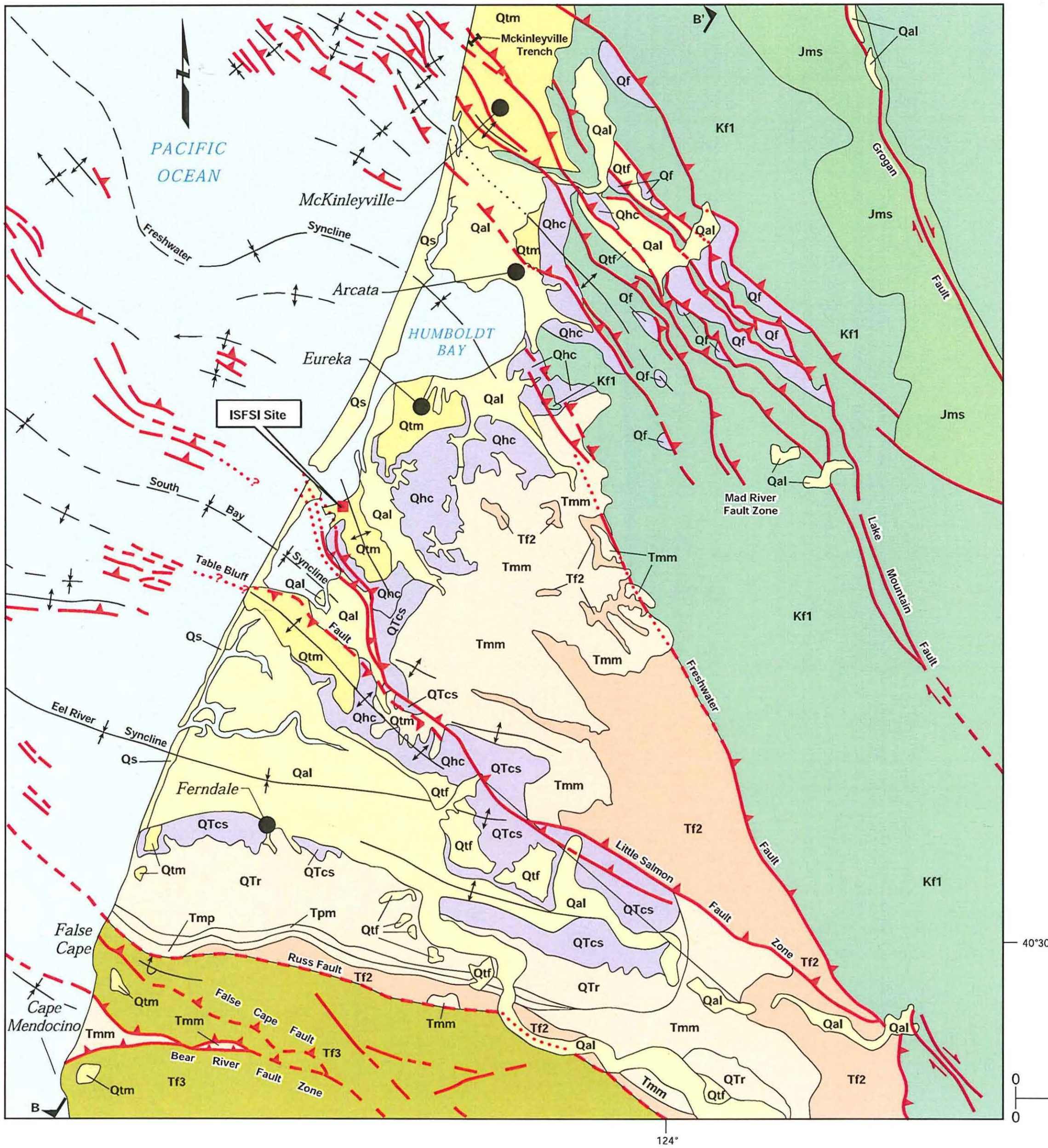

EXPLANATION

Faults: teeth on upper plate of thrust fault; arrows indicate sense of strike slip; dashed where location uncertain; dotted where buried or concealed

Anticline

Anticline, overturned

Syncline

Location of geologic cross section (Figure 3-4)

Location of McKinleyville trench (Woodward-Clyde Consultants, 1980)

COASTAL BELT AND OVERLYING SEDIMENTS

QUATERNARY
- Qs — upper Pleistocene and/or Holocene dune and beach sand
- Qal — upper Pleistocene and Holocene alluvium
- Qtf — upper Pleistocene fluvial terraces
- Qtm — middle and upper Pleistocene marine terraces
- Qhc — Pleistocene nonmarine and shallow water marine sediments (Hookton Formation and/or Carlotta Formation)

QUATERNARY AND TERTIARY
- QTcs — Plio-Pleistocene nonmarine sediments (Carlotta Formation and/or Scotia Bluffs Formation)
- QTr — upper Pliocene and lower Pleistocene marine sediments (Rio Dell Formation)

TERTIARY
- Tpm — lower and middle Pliocene marine sediments (Eel River Formation)
- Tmm — upper Tertiary marine sediments (lower Wildcat Group)
- Tmp — upper Miocene marine sediments (Pullen Formation)
- Tf2 — lower Tertiary Coastal Belt Franciscan Complex and Yager Formation

Wildcat Group (Qhc through Tmp)

CRETACEOUS

PRE-CRETACEOUS

ADJACENT AREAS

- Qs — upper Pleistocene and/or Holocene dune and beach sand
- Qal — upper Pleistocene and Holocene alluvium
- Qtf — upper Pleistocene fluvial terraces
- Qtm — middle and upper Pleistocene marine terraces
- Qf — lower and middle Pleistocene marine and nonmarine (Falor Formation)
- Qc — Pleistocene nonmarine sediments (Carlotta Formation)
- Tmm — upper Tertiary marine sediments (lower Wildcat Group)
- Tf3 — lower to middle Tertiary Coastal Belt Franciscan Complex
- Kf1 — Cretaceous Central Belt Franciscan Complex
- Jms — Pre-Cretaceous (Jurassic ?) metasedimentary rocks (South Fork Mountain Schist)

Figure 3-3 Geologic map of the Humbolt Bay Region.

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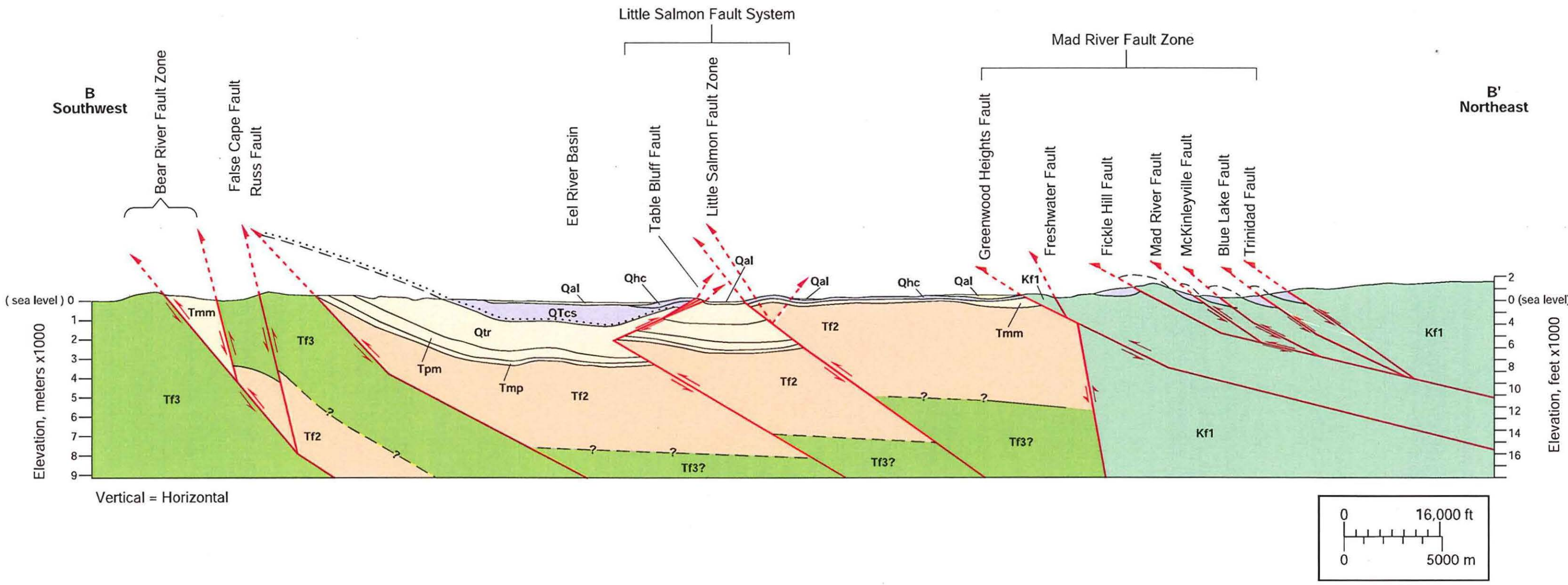

Figure 3-4 Geologic cross section of the Humboldt Bay Region. See Figure 3-3 for description of stratagraphic units. The location of cross section B-B' is shown on Figure 3-3.

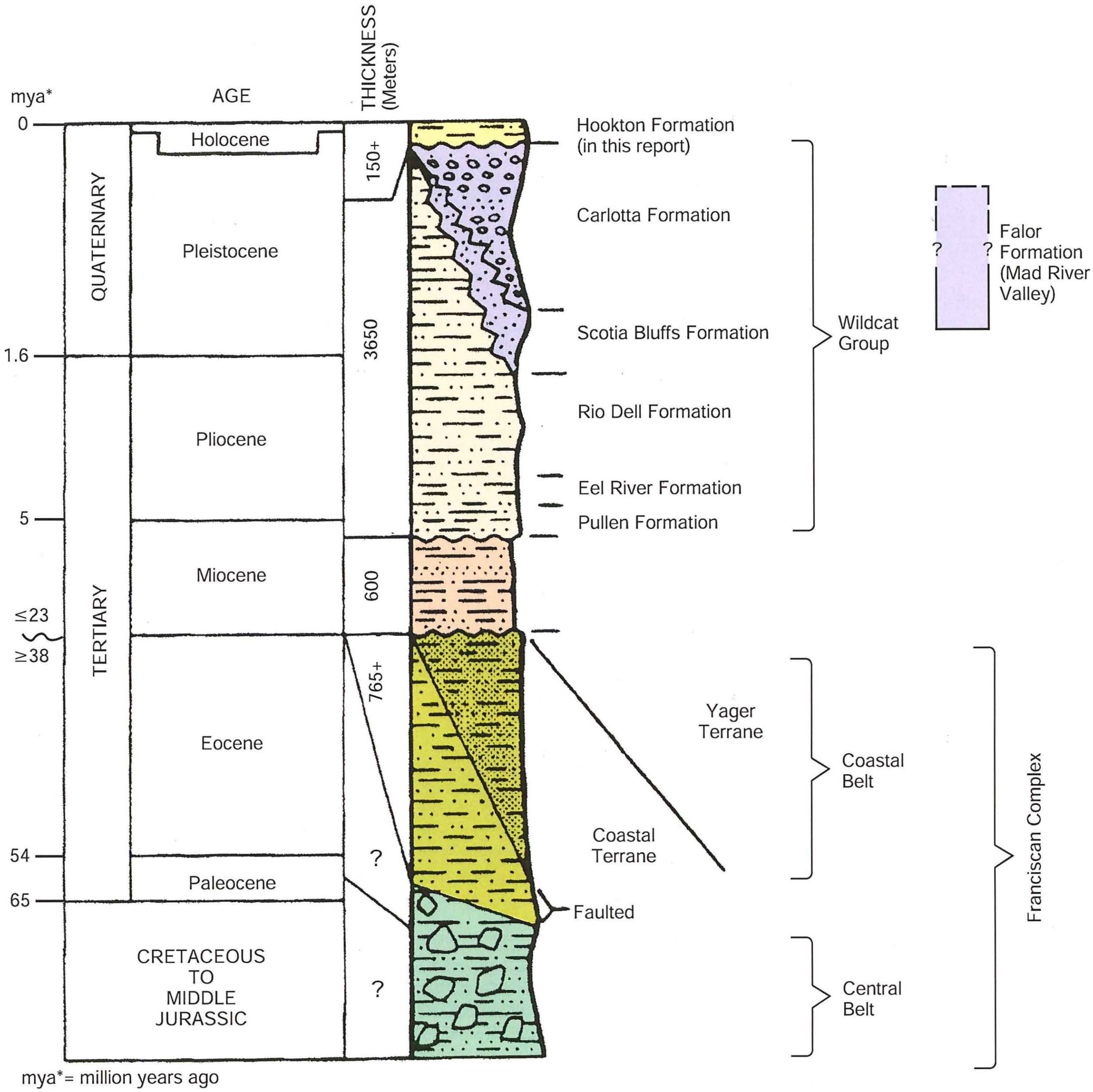

Figure 3-5 Composite stratigraphic column, onshore Eel River basin *(after Clarke, 1992).*

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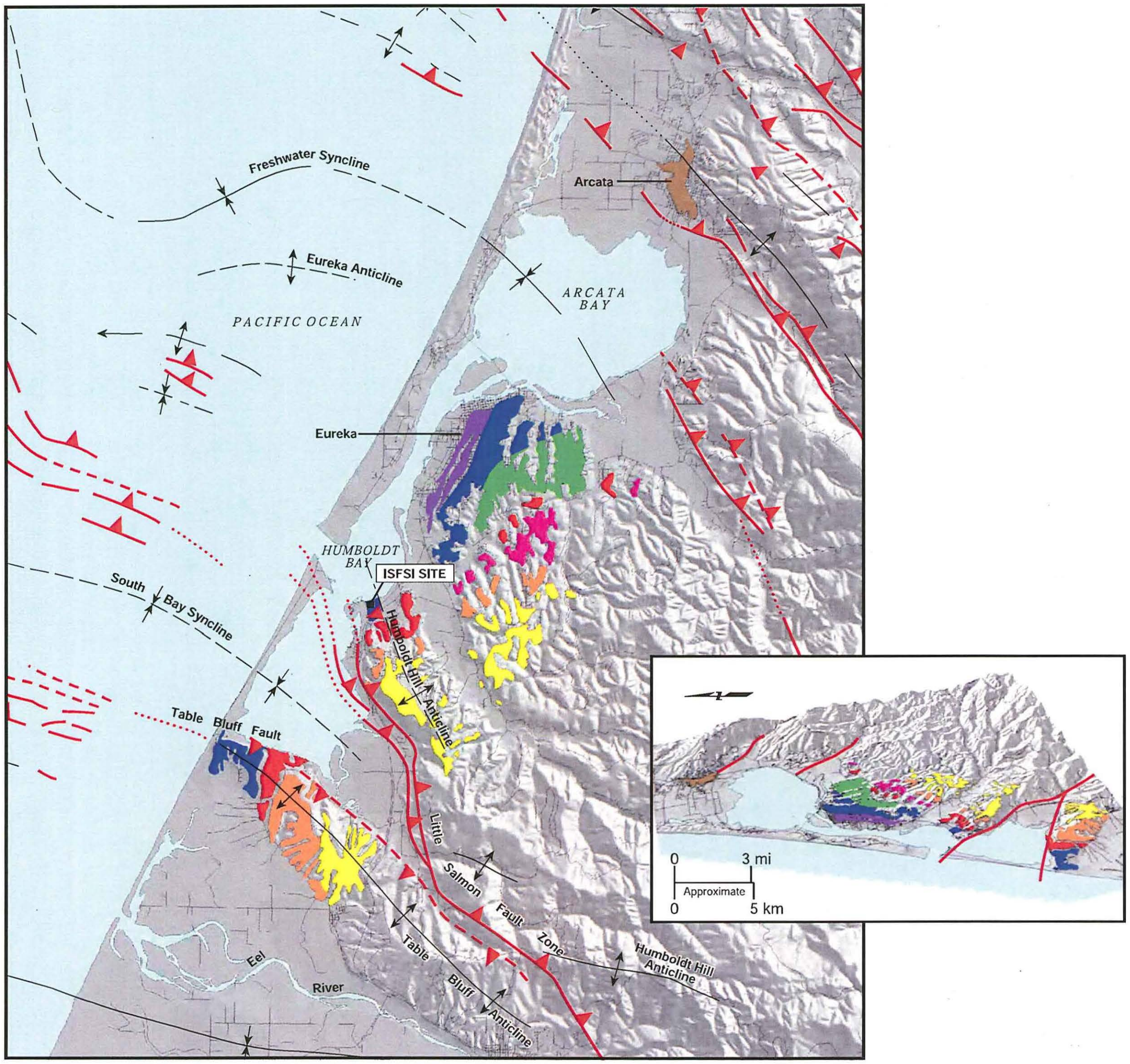

EXPLANATION

Faults: teeth on upper plate of thrust fault; arrows indicate sense of strike slip; dashed where location uncertain; dotted where buried or concealed

Anticline

Anticline, overturned

Syncline

Terrace Name	Isotope Stage	Approximate Age (x 1000 yrs.)
Patricks Point	4a	64
Savage Creek	5a	83
McKinleyville	5b	96
Westhaven	5c	103
Fox Farm	5d	120
Sky Horse	5e	130
A - Line	7a?	176
Older and much older Terraces		200+

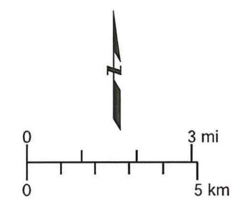

Figure 3-6 Marine terrace map of the Humboldt Bay region.

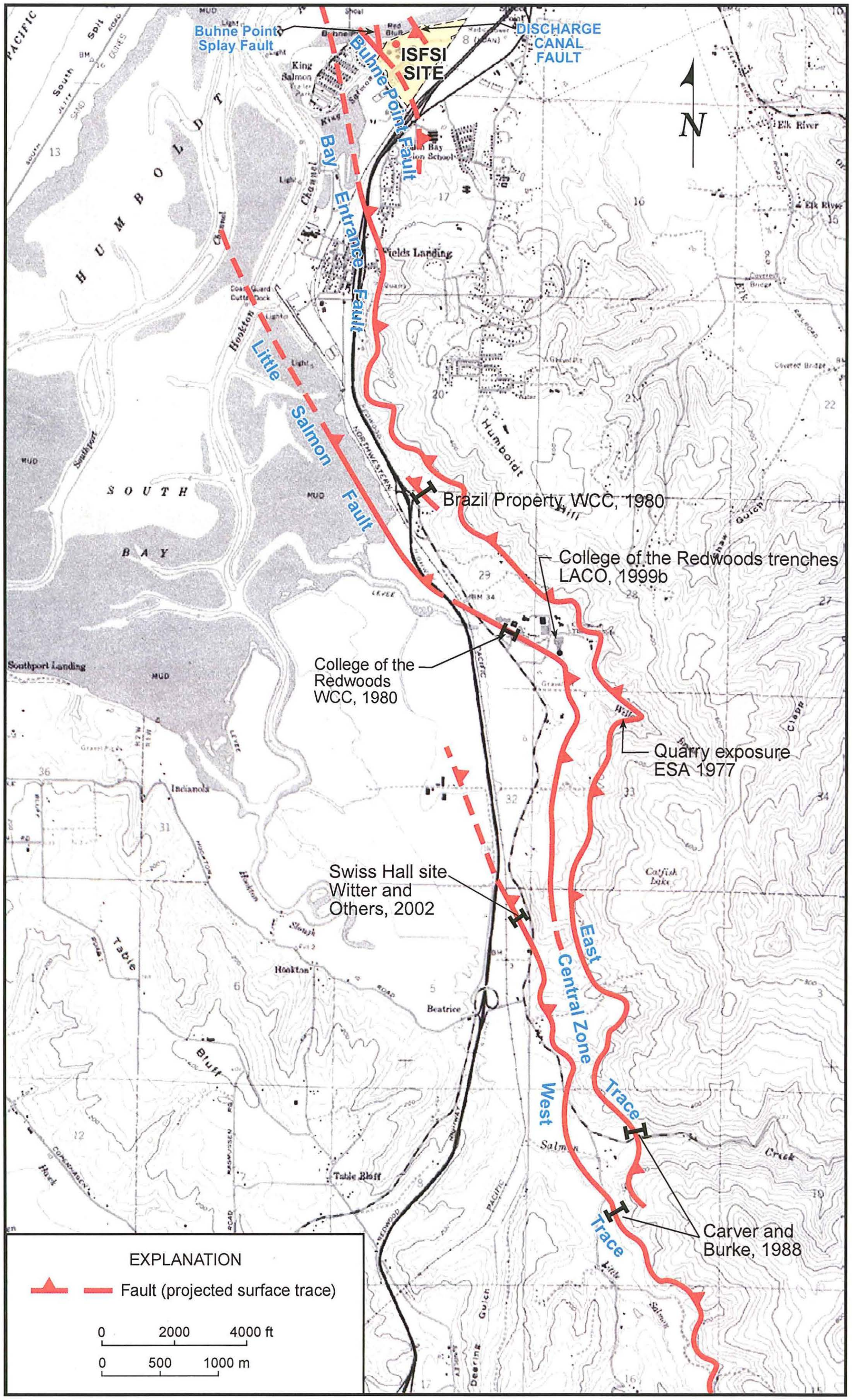

Figure 3-7 Surface traces of the Little Salmon fault zone south of the ISFSI site.

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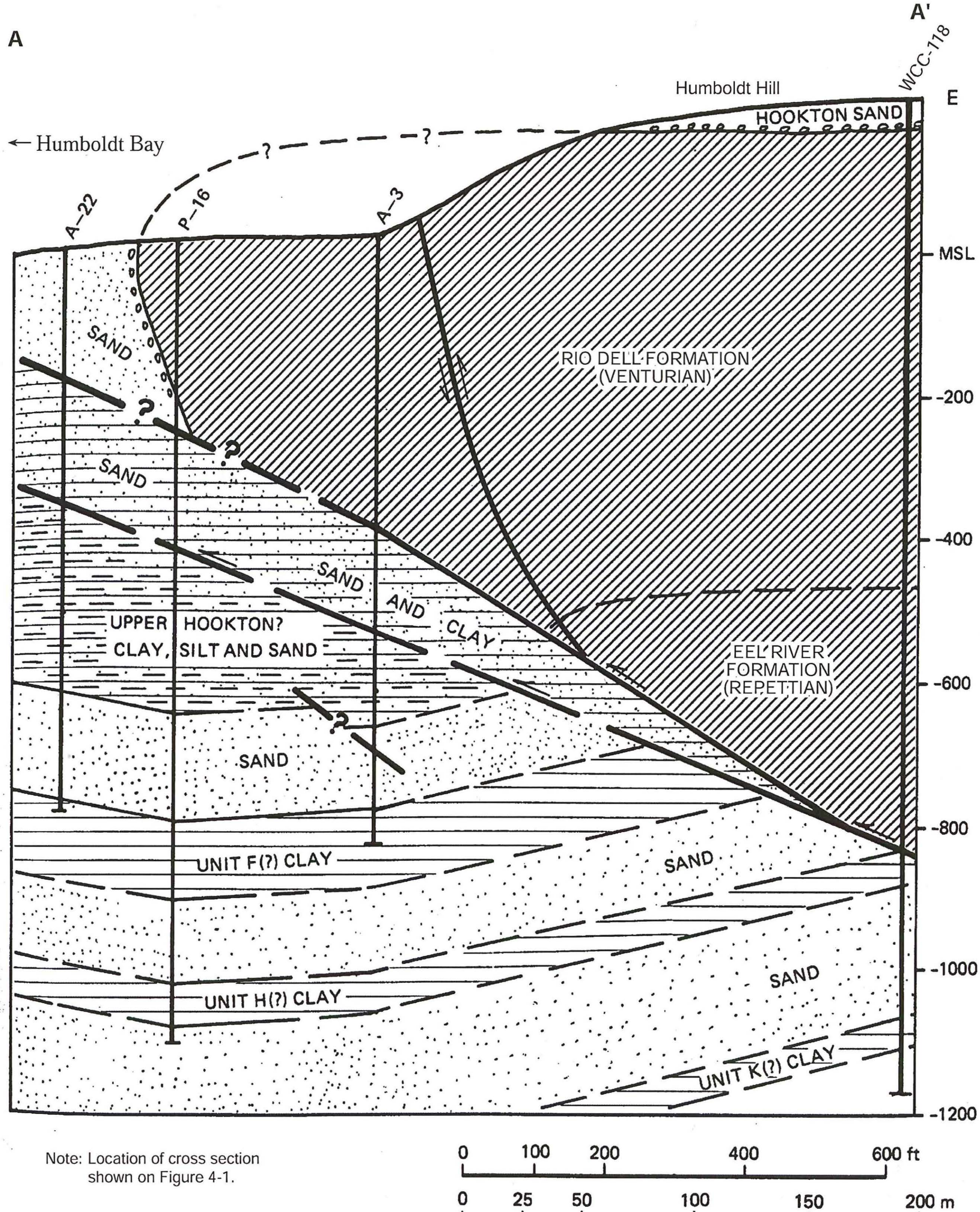

Note: Location of cross section shown on Figure 4-1.

Figure 3-8 Cross section A-A' across the Little Salmon fault zone at Humboldt Hill *(after Woodward-Clyde Consultants, 1980, Figure C-15).*

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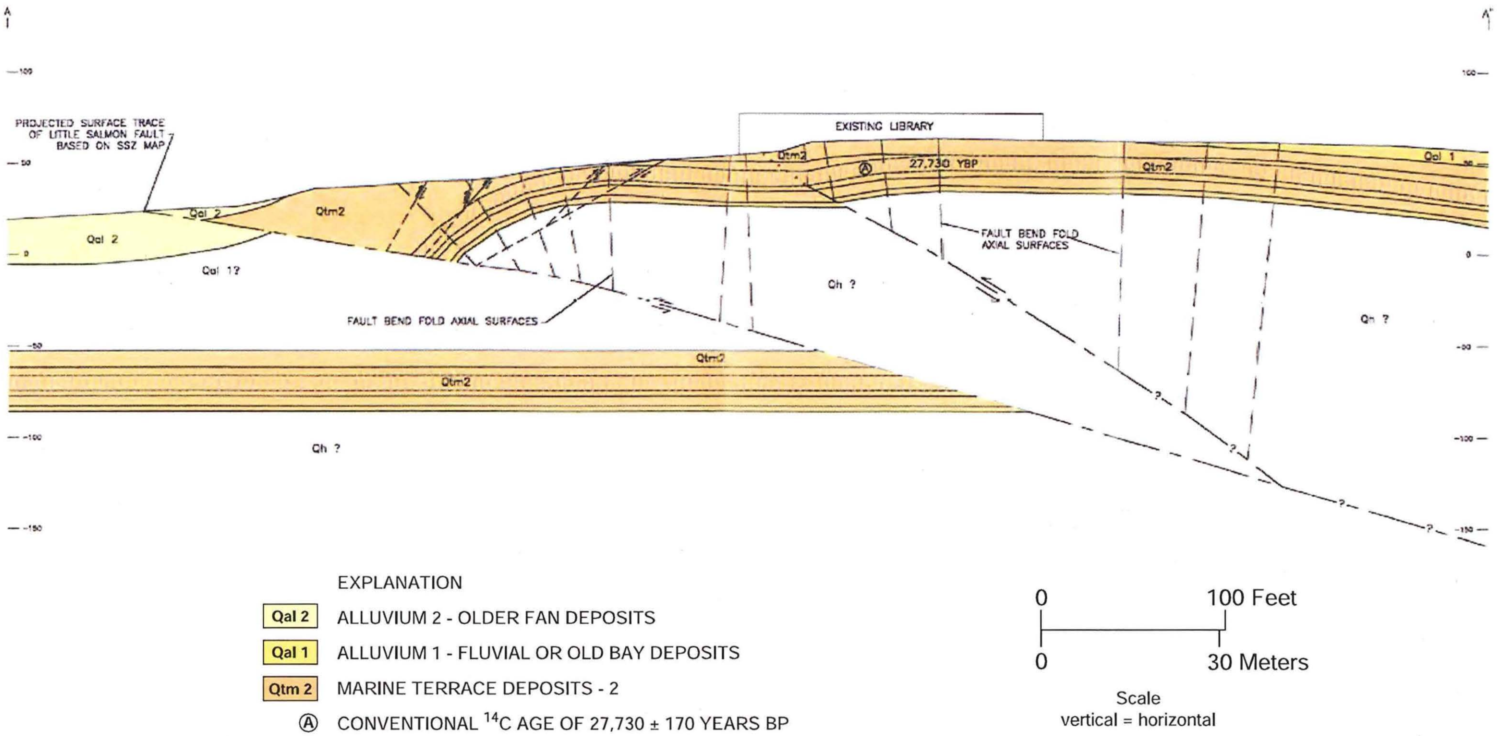

Figure 3-9 Geologic cross section A-A' across a trace of the Little Salmon fault zone at College of the Redwoods, 5 kilometers south of Humboldt Bay ISFSI site *(after LACO Associates, 1999b, Figure 5)*. Location of cross section shown on Figure 3-7.

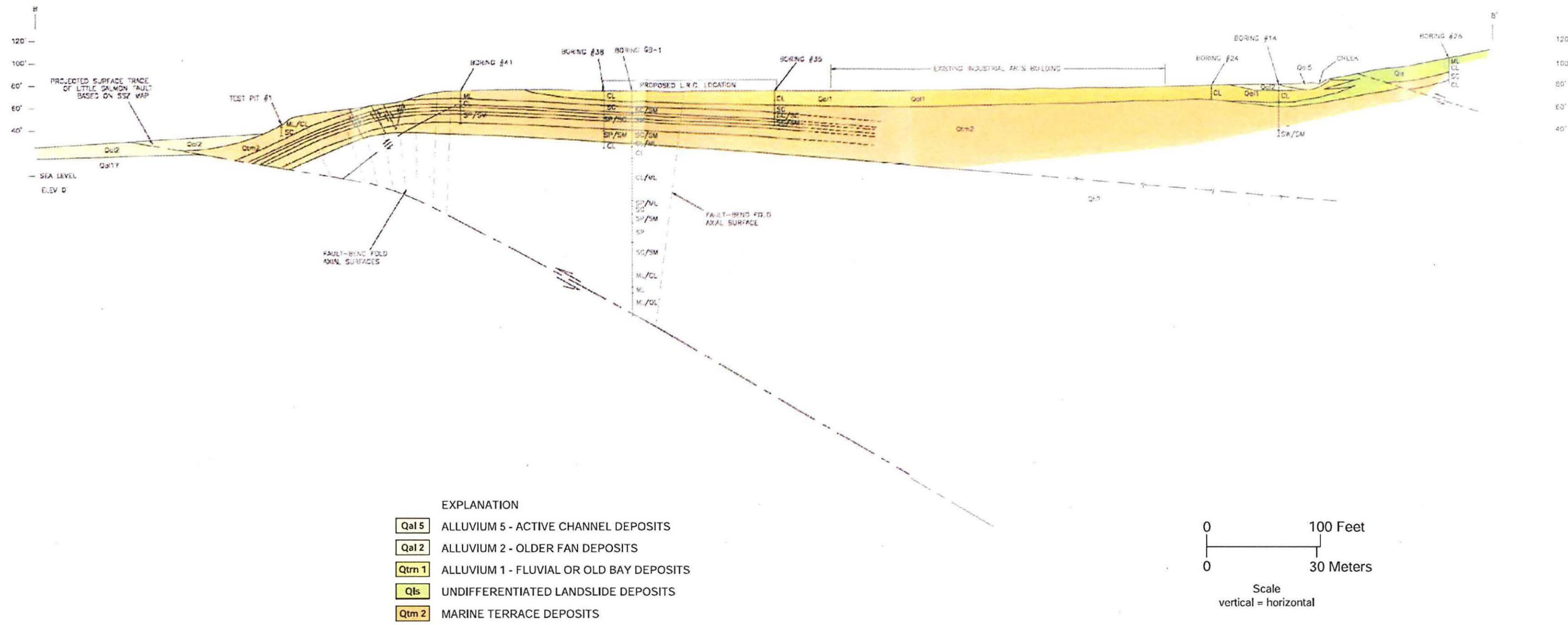

Figure 3-10 Geologic cross section B-B' across a trace of the Little Salmon fault zone at College of the Redwoods, 5 kilometers south of Humboldt Bay ISFSI site *(after LACO Associates, 1999b, Figure 6)*. Location of cross section shown on Figure 3-7.

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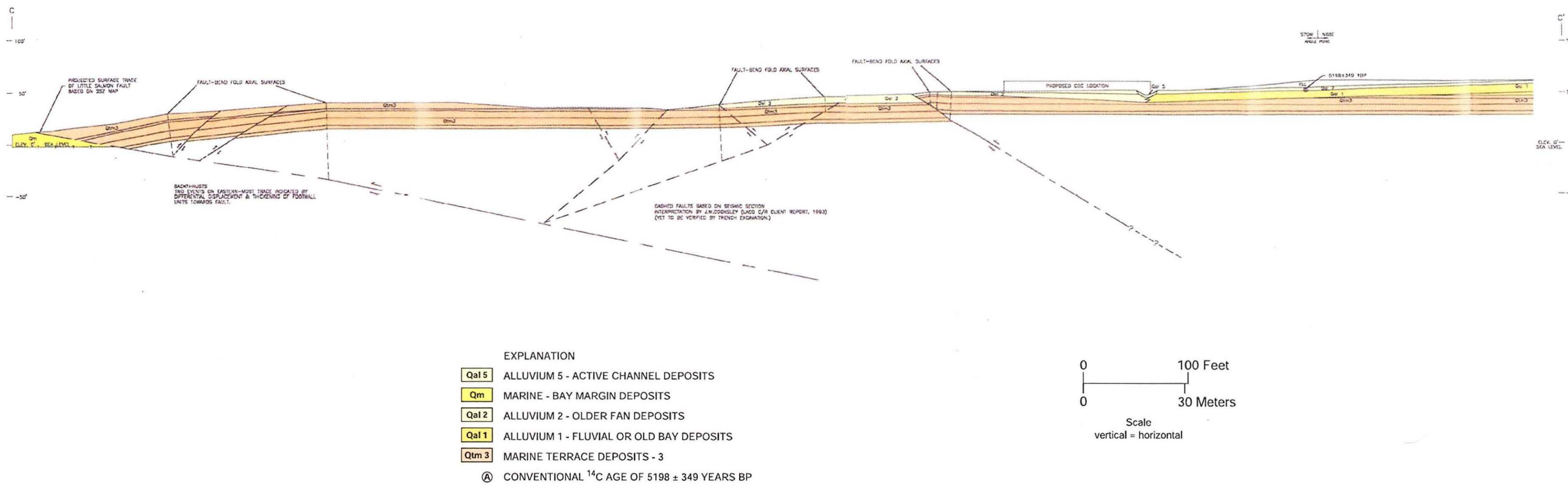

Figure 3-11 Geologic cross section C-C' across a trace of the Little Salmon fault zone at College of the Redwoods, 5 kilometers south of Humboldt Bay ISFSI site *(after LACO Associates, 1999b, Figure 7)*. Location of cross section shown on Figure 3-7.

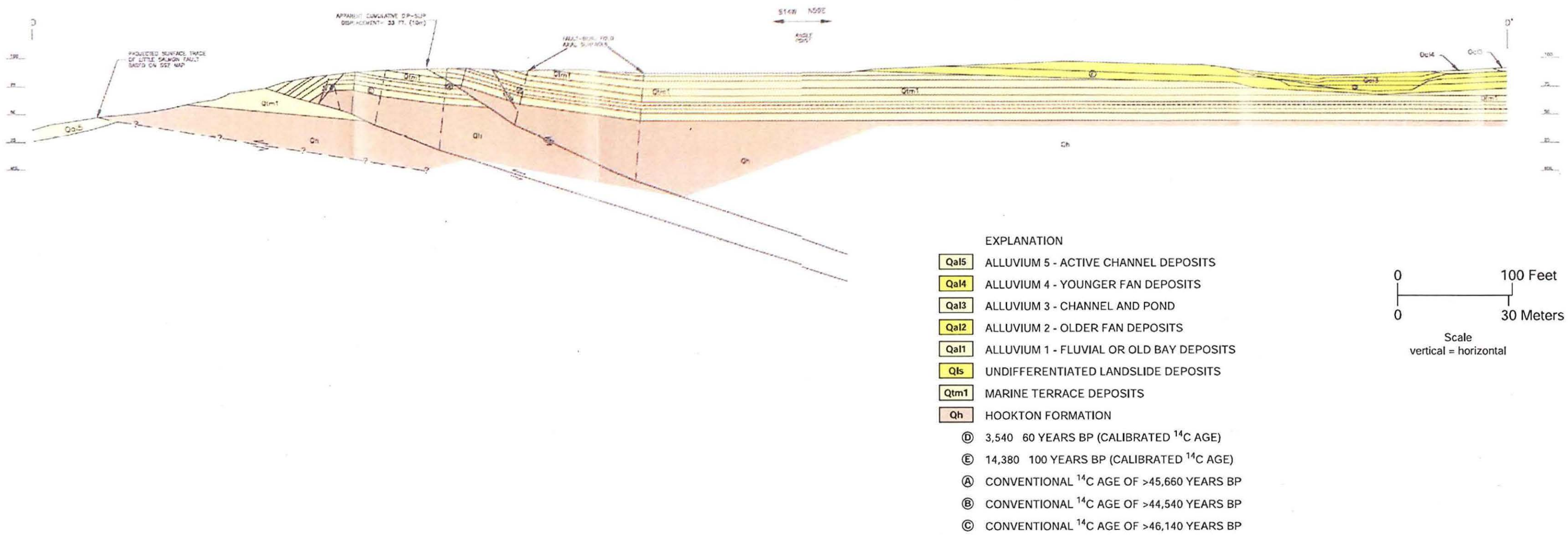

Figure 3-12 Geologic cross section D-D' across a trace of the Little Salmon fault zone at College of the Redwoods, 5 kilometers south of Humboldt Bay ISFSI site *(after LACO Associates, 1999b, Figure 8).* Location of cross section shown on Figure 3-7.

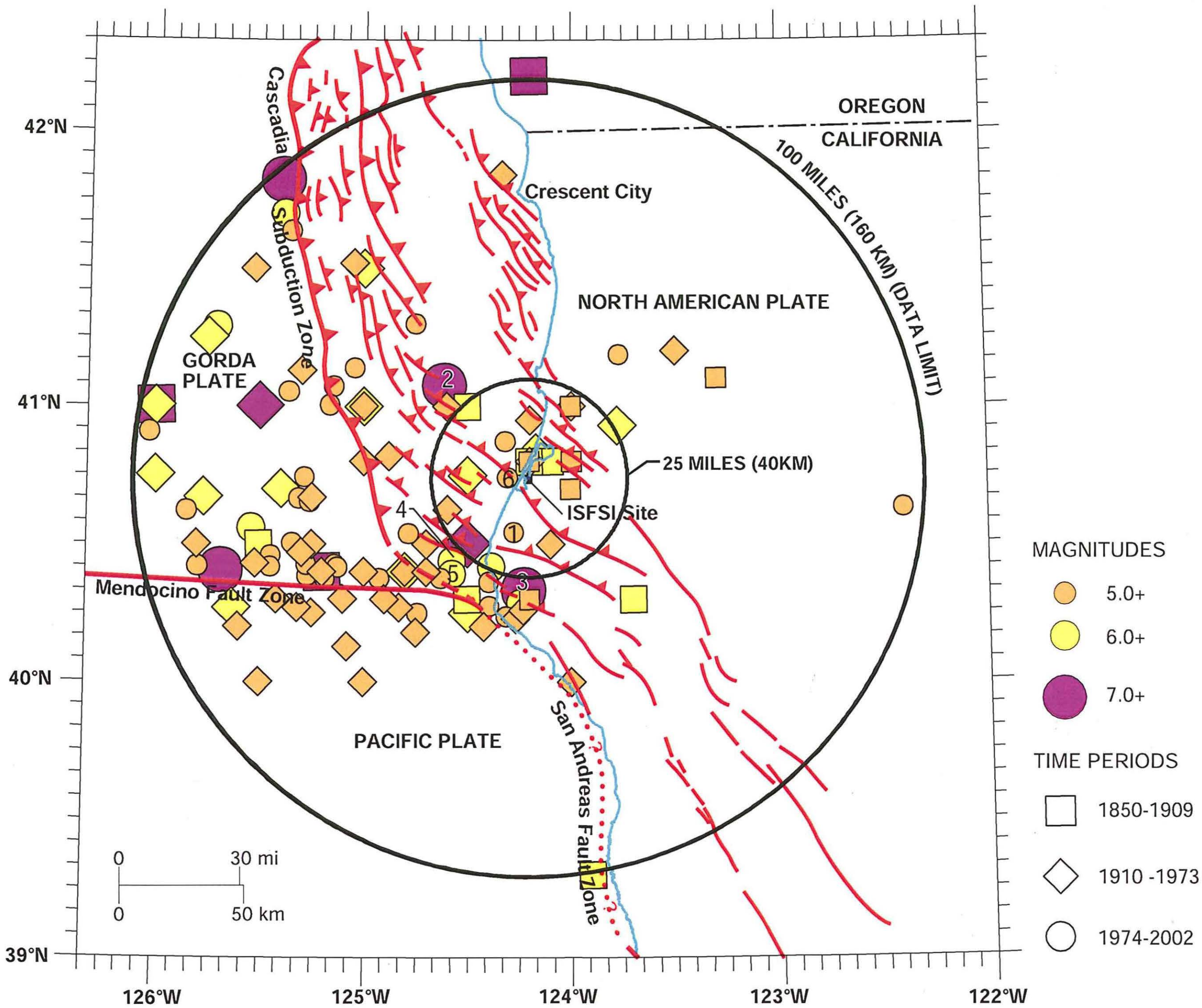

Figure 3-13 Magnitude 5 and larger earthquakes for the period 1850 through April 2002 within 160 kilometers (100 miles) of the site. Earthquakes are scaled by magnitude and differentiated by time periods. Locations are listed in Table 3-2. Numbered earthquakes are included in Table 3-3. Earthquakes within 25 miles (40 kilometers) of the site are included in Figure 3-16.

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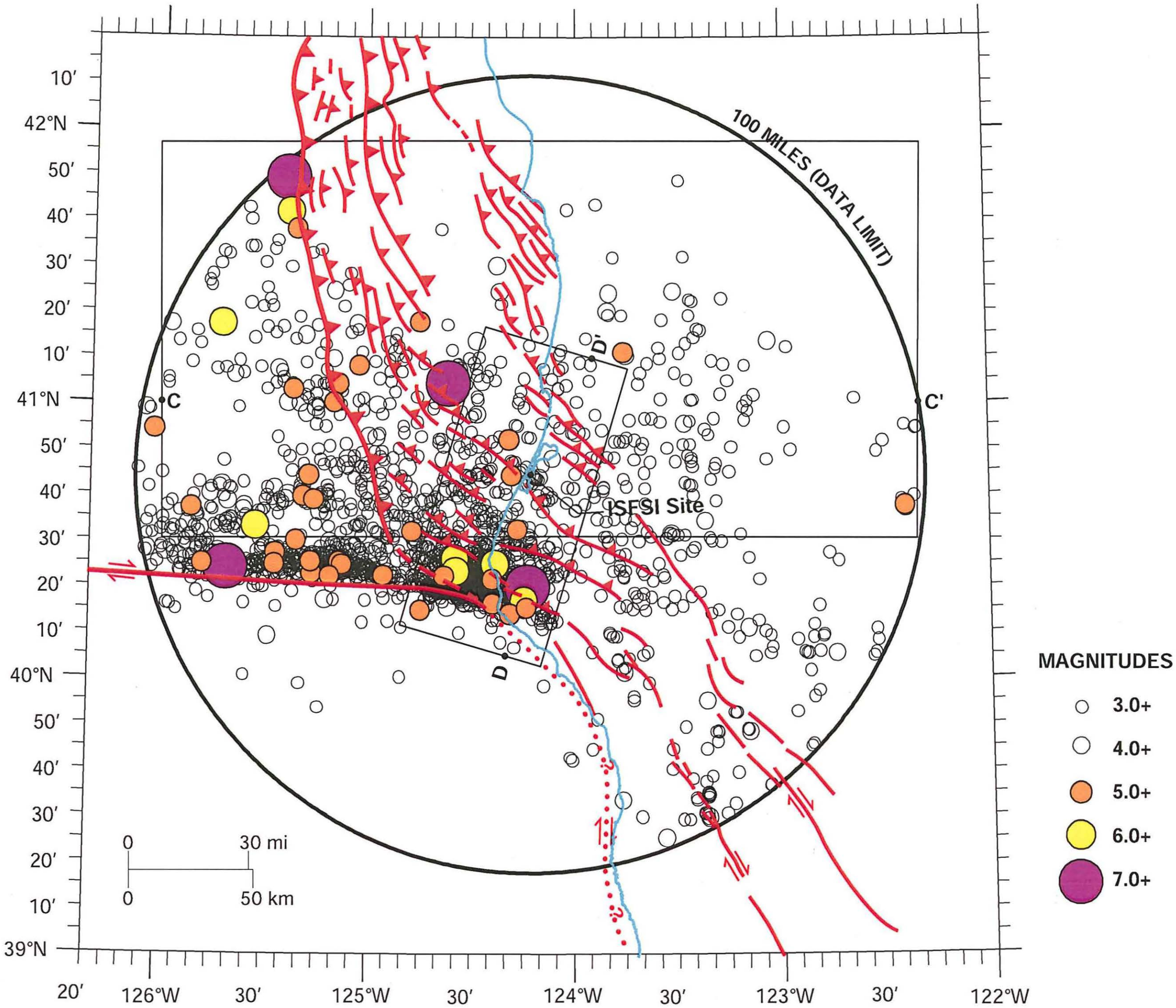

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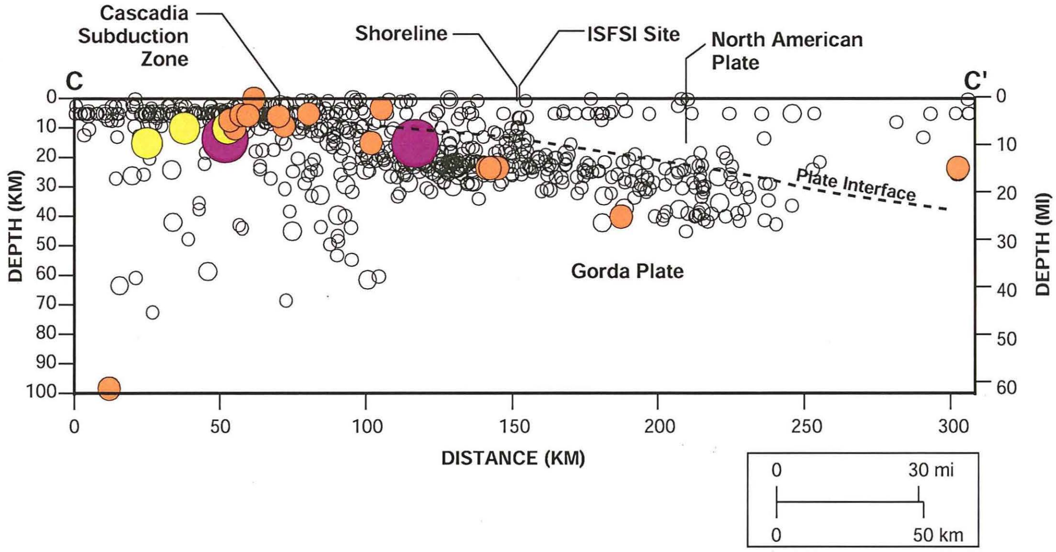
Figure 3-14 Magnitude 3 and larger earthquakes from the period 1974 through April 2002 within 160 kilometers (100 miles) of the site. The locations of cross sections C-C' and D-D' (Figure 3-15) also are shown. Locations of magnitude 5 and larger earthquakes are listed in Table 3-2.



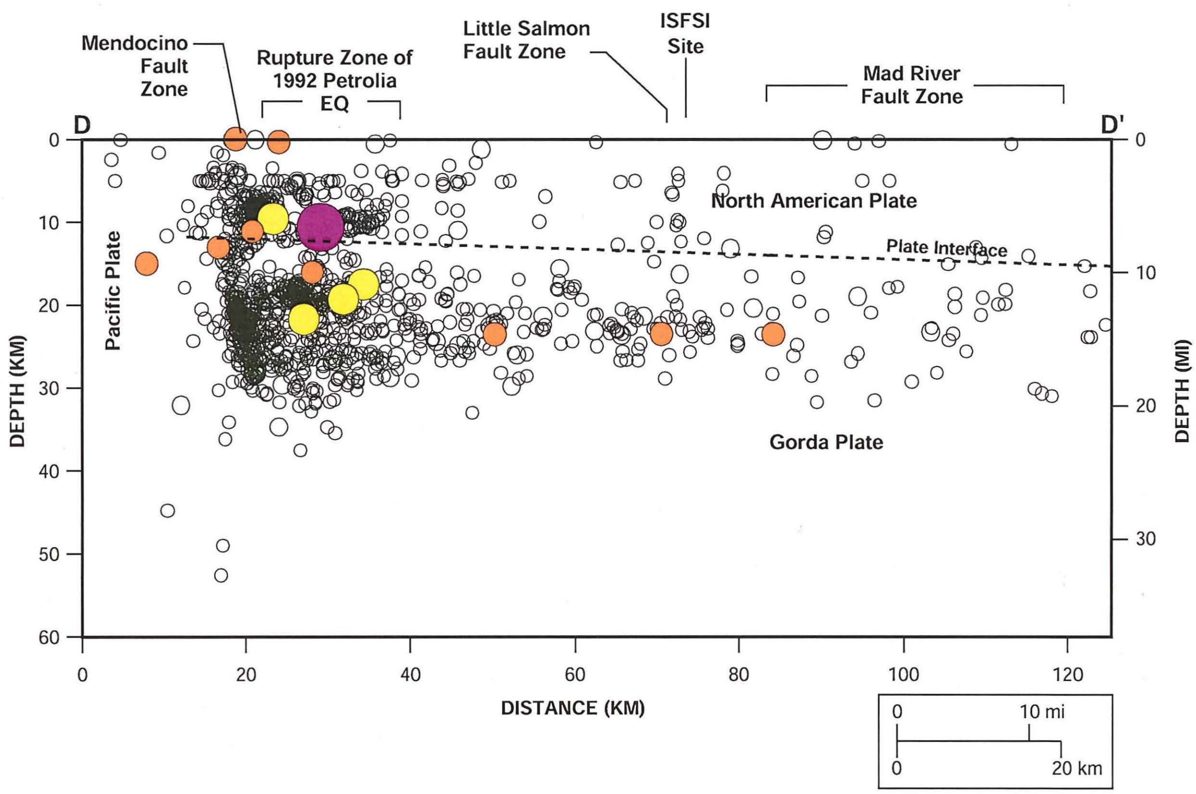


Figure 3-15 Seismic cross sections of magnitude 3 and larger earthquakes from the period 1974 through April 2002. The locations of cross sections C-C' and D-D' and earthquakes symbol legend are shown on Figure 3-14. The location of the plate interface (dashed line) is based on Figure 3-2 and Geomatrix (1994).

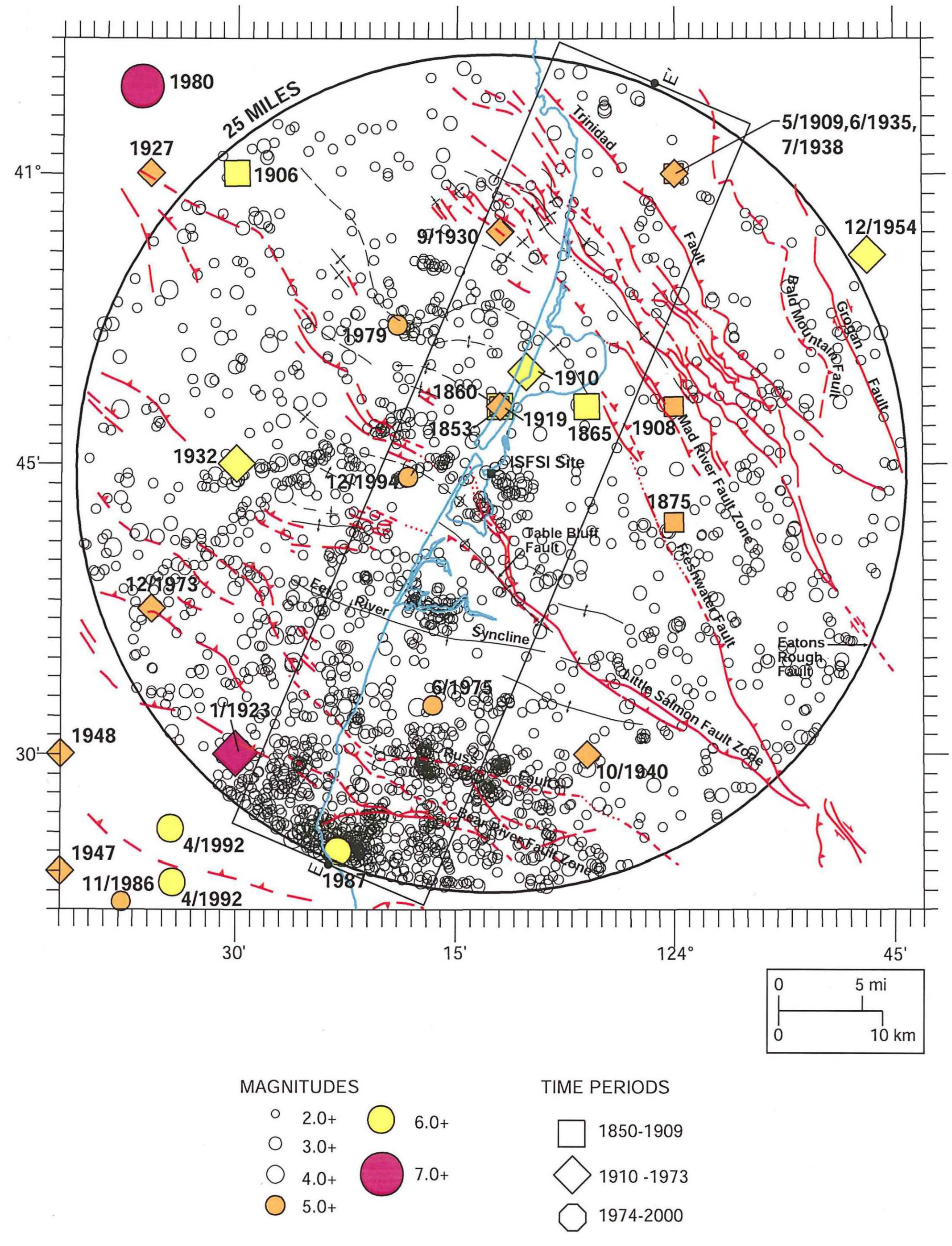


Figure 3-16 Magnitude 2 and larger earthquakes from the period 1974 through April 2002, within 40 kilometers (25 miles) of the site, and earthquakes of magnitude 5 and larger from 1850 through 1973 within the map boundary. Locations of magnitude 5 and greater earthquakes are listed in Table 3-2.

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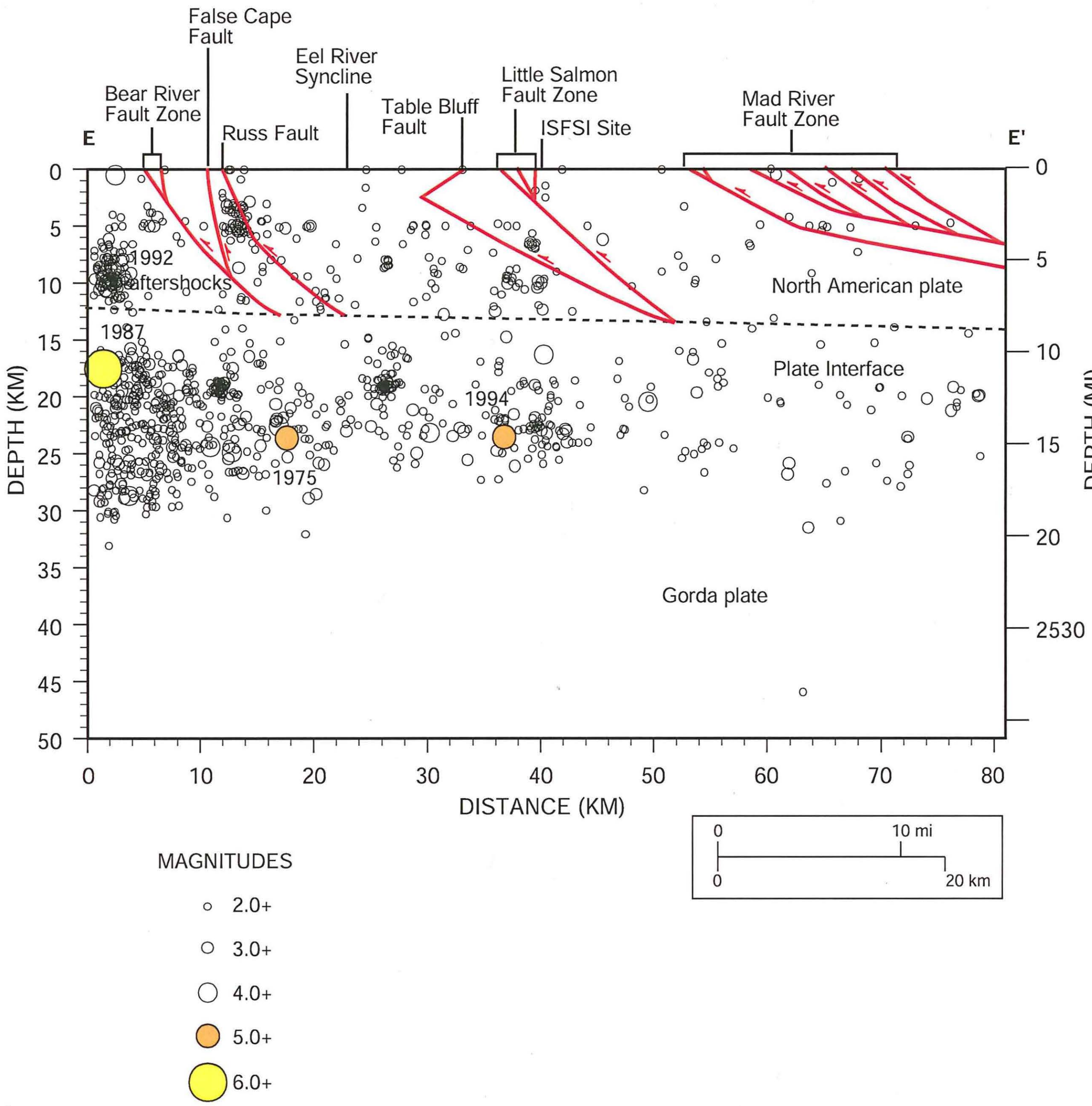

Figure 3-17 Seismic cross section of magnitude 2 and larger earthquakes from the period 1974 trough April 2002. The location of cross section E-E' is shown on Figure 3-16. Fault locations are based on Figure 3-4; location of the plate interface (dashed line) is based on Figure 3-2 and Geomatrix (1994).

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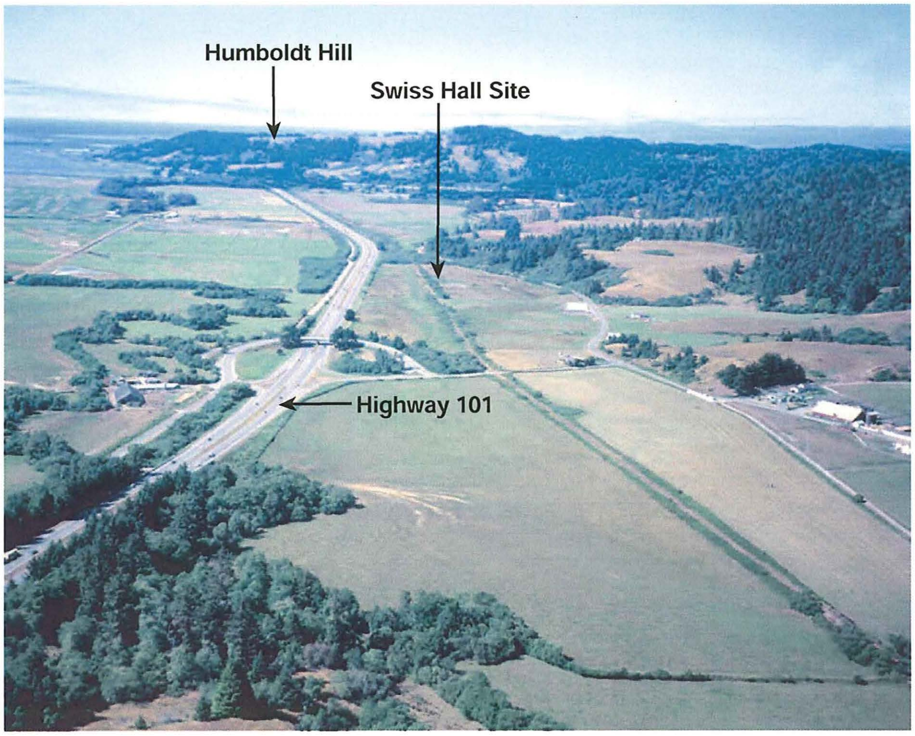
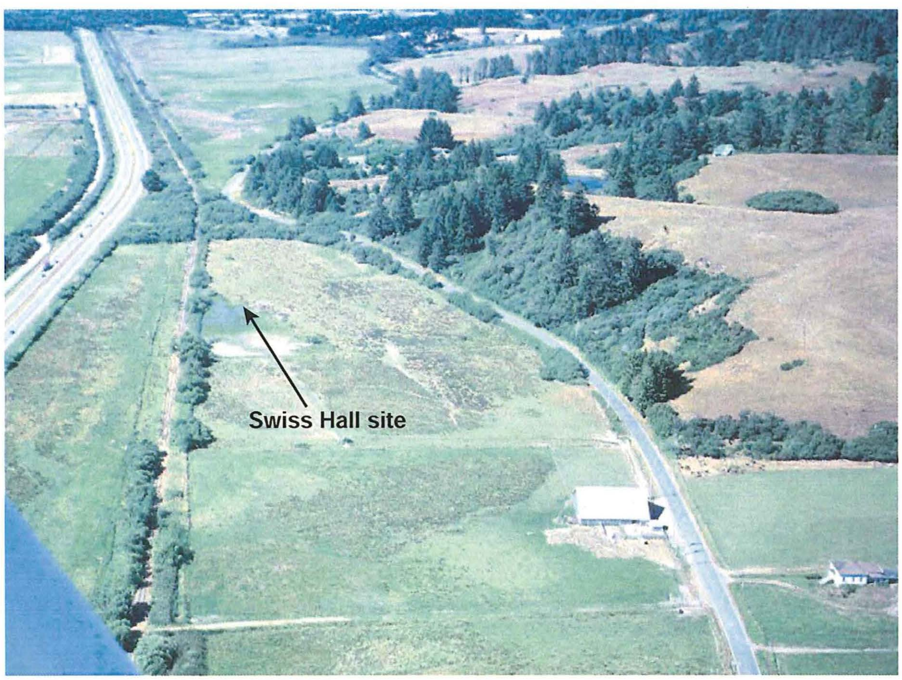


A) View north along Highway 101 with Humboldt Hill in the distance.



B) Closer view of the Swiss Hall paleoseismic study site.

Photo 3-1 Oblique aerial views looking north along the Humboldt Hill anticline and the Little Salmon fault zone. (Photographs taken July 25, 2000, by W.D. Page).

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Section 4.0
Site Geology

4.1 INTRODUCTION

Humboldt Bay Power Plant and the ISFSI site lie on the east flank of Buhne Point, a small headland on the eastern shore of Humboldt Bay (Photos 4-1a and 4-1b). The site is underlain by a thick sequence of late Tertiary[1] and Quaternary sedimentary rocks capped by a late Pleistocene terrace. Buhne Point, which is situated within the Little Salmon fault zone, has been uplifted and tilted to the northeast by displacement on the fault. The results of mapping, borehole, trenching, and dating studies at and near the site are used in the current study to characterize site geology.

Trenches and borehole data developed by Earth Sciences Associates (ESA; 1975, 1977) and Woodward-Clyde Consultants (1980) (Figure 4-1) are used to demonstrate the continuity of strata beneath the Humboldt Bay ISFSI site, and to document the locations of tectonic and nontectonic deformation in the site vicinity. Also analyzed and incorporated are data from two new trenches and borehole data from the recent geotechnical study performed to evaluate liquefaction susceptibility and slope stability at the ISFSI site (Section 7.0).

Figure 4-2 is a geologic map that shows the locations of the previous and new trenches and borings near the ISFSI site. Data from these investigations were used to demonstrate the continuity of individual stratigraphic horizons across the site and to identify stratigraphic and structural discontinuities that may indicate active faults near the site. For the current evaluation, the stratigraphic and structural data obtained during the extensive investigations for the Humboldt Bay Power Plant in the late 1970s (Earth Sciences Associates, 1975; 1977; Woodward-Clyde Consultants, 1980) were reexamined, along with the results of subsequent studies that included trenching investigations of the Little Salmon fault for College of the Redwoods (LACO Engineering Consultants, 1997, 1999a, b) and for the U.S. Geological Survey (Carver and Burke, 1988; Clarke and Carver, 1992).

Field mapping was conducted in March 2000 at and near the ISFSI site to identify geologic features, such as unstable slopes, deformational zones, soil/weathering profiles, and other

[1] The geologic time scale is presented in Table 1-1.

features that may be important to assessing the potential for ground deformation or fault rupture at the ISFSI site. As part of that work, the lithostratigraphy, soil stratigraphy, structure, and slope features associated with the terrace on Buhne Point and the hillslopes along the periphery of the terrace were mapped (Figure 4-2). Topographic profiles were measured, and the deposits and soils exposed in the escarpments on the north and south sides of the uplifted terrace at Buhne Point were described in detail. In August 2000, Geomatrix excavated two new trenches, which have a combined length of 75 meters. These trenches, and trenching conducted by Woodward-Clyde Consultants (1980), provided continuous exposure of the near-surface Quaternary deposits at the site (Figure 4-3).

Section 4.2 describes the physiographic setting of the ISFSI site. Section 4.3 describes site stratigraphy. Particular attention is paid to the nature of the deposits that underlie the ISFSI site and the soil profiles developed on the Buhne Point terrace. The well-bedded middle to late Pleistocene estuarine and fluvial deposits that underlie the site provide the means for identifying late Quaternary faulting and related deformation. The soils on the terrace surface were used to assess the minimum age of near-surface deposits.

Section 4.4 describes faulting related to the Little Salmon fault zone, including the Bay Entrance and Buhne Point fault traces. Because the site is on the hanging wall of the Buhne Point fault, particular attention was paid to the potential for hanging-wall deformation (secondary faulting, folding, and tilting) related to slip on the Bay Entrance, Buhne Point, and Discharge Canal faults. Section 4.5 addresses the continuity of the middle to late Pleistocene deposits beneath and directly adjacent to the ISFSI site.

4.2 PHYSIOGRAPHIC SETTING

The ISFSI site is located on a low hill, referred to in this report as Buhne Point hill, on the eastern side of Humboldt Bay opposite the entrance of the bay (Photo 4-1a). The hill, which has a maximum elevation of about 23 meters, extends east of Buhne Point for about 480 meters, and is 50 to 180 meters wide (Figure 4-2). The hill, capped by an erosional remnant of an uplifted terrace, is an outlier of Humboldt Hill, a northwest-trending ridge that extends southeast of the site (Photo 4-2). Humboldt Hill is a large fault-ramp anticline situated along the leading edge of the hanging wall of the Little Salmon fault zone. Buhne Point hill, where the ISFSI site is located, is bordered on the north by a coastal bluff that drops off steeply (graded slope of about 1:1) to the shore of Humboldt Bay. The eastern and southern sides of the hill are bordered by a low tidal marsh. The western side of the hill is bordered by the village of King Salmon, which is built on fill over tidal marsh and beach deposits that extend more than 500 meters into the bay. The westernmost part of the hill forms Buhne Point.

Comparison of historical and modern maps indicates that the present hill is only a remnant of a much larger hill that existed in 1850 when Buhne Point was first described as a navigational aid into the entrance of the bay. The first detailed map of the area, made in 1858 (Figure 4-4), shows a flat-iron-shaped hill having steep bluffs along its northern and southwestern sides. The flat terrace surface slopes gently away from the bluffs to the southeast. The present shoreline is about 400 meters southeast of the 1858 shoreline (Figure 4-4). The dramatic coastal retreat and loss of most of Buhne Point hill to wave erosion began when the entrance to the bay was deepened, and jetties (Photo 4-2) were placed adjacent to the entrance to provide a permanent deep-water access for ships during the late 1800s. The bluff retreat was arrested when riprap was placed along the base of the bluff in the early 1950s to prevent further wave erosion (Photo 4-3).

Buhne Point hill was formed by tectonic uplift associated with the Little Salmon fault zone combined with wave erosion. The escarpment along the southwest side of the hill is interpreted to be the eroded fault scarp produced by down-on-the-southwest displacement along the Buhne Point trace of the Little Salmon fault zone. The northeast margin of the hill that is apparent on the 1858 map (Figure 4-4) appears to be related, at least in part, to down-to-the-northeast displacement on a small secondary fault, the Discharge Canal fault. The bluff that existed on the northwest side of Buhne Point hill in 1858 was the eroded sea cliff that faced the ocean across from the natural entrance to the bay. This bluff has since retreated to its present position at the northern side of the plant area.

An approximately east-west topographic profile and geologic cross section along Buhne Point hill parallel to the coast (Figure 4-5) indicates two distinct terrace surfaces along this profile. The higher terrace, the Buhne Point terrace (Qpht on Figure 4-2), is a planar geomorphic surface having a gentle (2 to 4 degrees) southeast tilt (Photo 4-4). The small inset terrace below this surface on the western end of the hill (Figure 4-5) appears to have been man made, because it is not evident on the 1858 survey map. Also, the strata at the present ground surface are not weathered, indicating that the soils were removed.

The surface of the Buhne Point terrace was modified in several places during construction of the power plant. For example, low-angle oblique aerial photographs in PG&E's archives (Photos 4-5a and 4-5b) show grading activities from south of the old security fence to the edge of the bluff on the north side of the terrace. Parts of the Buhne Point terrace surface (Qpht on Figure 4-2) in the vicinity of the ISFSI site may have been lowered by as much as 2 to 3 meters; the most significant lowering occurred along the edge of the bluff, decreasing toward the security fence. In several places, the disturbed areas are underlain by about a meter of fill. The ISFSI site is located near the old security fence in the area of disturbed ground.

4.3 STRATIGRAPHY

As described in Section 3.2.1, the ISFSI site is underlain by more than 900 meters of late Pliocene and Quaternary deposits. Three lithostratigraphic formations separated by unconformities were encountered at the site, as shown on Figure 4-6. From oldest to youngest, these are the Rio Dell Formation, the Scotia Bluffs Formation and the Hookton Formation, which is divided into lower and upper members. The following descriptions of the Rio Dell, Scotia Bluffs, and lower Hookton formations are based on Woodward-Clyde Consultants (1980). In addition to data from the Woodward-Clyde study, the description of the upper member of the Hookton Formation includes information obtained from geotechnical borings and trenches at the ISFSI site and from surface outcrops in the Buhne Point area.

At Buhne Point, a coastal terrace surface is formed in the upper Hookton sediments; this surface appears to be conformable with the upper Hookton sediments. Remnants of a relict paleosol described in Section 4.3.4 are preserved in undisturbed areas on the terrace surface. The characteristics of this paleosol enable correlation with the regional soil chronosequence (Burke and others, 1986; Carver and others, 1986b; Carver and Burke, 1992) and assignment of an age for the terrace. Around Buhne Point hill, the Hookton deposits are unconformably overlain by Holocene colluvial, landslide, alluvial, and estuarine deposits. Extensive areas of the site have been graded, and in most places the natural soils/surface weathering profile have been removed or buried by man-made fill.

4.3.1 Rio Dell Formation (Late Pliocene to Early Pleistocene)

The Rio Dell Formation is a homogeneous marine mudstone that is encountered in boreholes at 520 meters beneath the site. The formation is about 600 meters thick. Regionally, the Rio Dell Formation is time-transgressive—marine fossils indicate age ranges from late Pliocene to Pleistocene. Near the site, the uppermost Rio Dell Formation is estimated to be 1.1 ± 0.2 million years old (Woodward-Clyde Consultants, 1980), making its age early Pleistocene.

4.3.2 Scotia Bluffs(?) Formation (Early Pleistocene)

At the site, the Rio Dell Formation is unconformably overlain by more than 340 meters of shallow-water sandy marine sediments that probably are correlative with the Scotia Bluffs Formation [2]of Ogle (1953). The deposits consist mostly of silty sand and sandy silt interbedded with clayey sediment. The clay beds provide excellent marker horizons that can be recognized on geophysical logs, particularly the natural gamma-ray logs. In the site area, Woodward-Clyde Consultants (1980) subdivided the formation into eight units, labeled O though V (from youngest to oldest). The precise age of the Scotia Bluffs(?) Formation has not been determined, but it probably was deposited between about 1.1 million years ago (the estimated age of the upper Rio Del Formation) and about 780,000 years ago (older than the Brunhes/Matuyama magnetic reversal[3] that was identified by Woodward-Clyde Consultants [1980] from borehole and outcrop samples at Centerville Beach). Therefore, the Scotia Bluffs(?) Formation is early Pleistocene in age.

4.3.3 Hookton Formation (Middle to Late Pleistocene)

As described in Section 3.2.1, (the Hookton Formation consists of middle to late Pleistocene interbedded shallow marine, estuarine, and fluvial deposits that unconformably overlie Scotia Bluffs(?) and older formations. In the vicinity of Buhne Point, the Hookton Formation is divided into a lower and an upper unit (Figures 4-6 and 4-7). The lower Hookton Formation deposits consist of alternating sand, silty sand, gravelly sand, silty clay, and clay about 265 to 275 meters thick. The thickness of the Hookton Formation varies near the site because of active faulting and folding during deposition of the unit. For example, deep boreholes and cross sections in Woodward-Clyde Consultants (1980) show that the thickness of the lower Hookton beds increases from the hanging-wall blocks (upthrown sides) to the footwall blocks (downthrown sides) across the Buhne Point, Bay Entrance, and Little Salmon faults, indicating that folding and faulting occurred during deposition of the lower Hookton Formation. In addition, tectonic thickening (i.e., duplication/stacking of stratigraphic section by superposition of older units over younger units by reverse faulting) accounts for apparent stratigraphic thickening near the site.

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[2] Following the nomenclature used by Woodward-Clyde Consultants (1980), a querry is used after Scotia Bluffs to indicate that correlation of this unit, where it is encountered in borings, to Ogle's (1953) type locality for the Scotia Bluffs Formation is uncertain. The querry is not used on geologic maps, where the deposits are exposed at the surface and the correlation is more reliable.

[3] Woodward-Clyde Consultants (1980) used an age of about 700,000 years for the polarity transition between the Matuyama and Brunhes polarity epochs. Based on recent dating using advanced potassium-argon techniques, the date of this transition is now placed at 780,000 years (Baksi and others, 1992). Previously, this boundary was thought to be at 760,000 years (Izett and others, 1988), and before that was placed at 730,000 years (Mankinen and Dalrymple, 1979).

Laterally persistent clay beds, typically overlain by gravelly sands, provide useful marker horizons. A distinctive clay bed, Unit F, near the top of the lower Hookton Formation is a particularly useful marker horizon that has been identified in borings across the site and in the western end of Trench 11-T6c at the northwest end of Buhne Point. The age of the uppermost part of the lower Hookton Formation is about 160,000 ± 40,000 years, based on amino acid racemization dates on fossil shell material collected from clayey sediment in a Caltrans road cut near the northern end of Humboldt Hill about 900 meters south of the site (Woodward-Clyde Consultants, 1980). The age of the Unit F clay is estimated to be 310,000 ± 70,000 years, based on average rates of deposition between the dated clay (top of the lower Hookton Formation) above Unit F and the basal sediments of the Hookton Formation that are estimated to have been deposited between 600,000 ±100,000 years ago (Woodward-Clyde Consultants, 1980).

Upper Hookton Formation deposits consist primarily of silt and clay alternating with thinner sand and gravel lenses. No distinctive marker horizons were identified in the upper Hookton Formation that could be correlated across the Little Salmon and Bay Entrance faults, but the deposits are significantly thicker on the downthrown sides of these faults. As exposed in trenches and in the sea cliff along the north side of the Buhne Point terrace, the deposits underlying the terrace commonly contain distinctive layers having sharp contacts (Photo 4-6). The textures of the strata vary somewhat laterally, but individual layers commonly can be traced for several meters. The clayey bay mud deposits tend to be more laterally persistent than the interbedded sandy and silty layers. However, both sandy and clayey marker horizons in the upper Hookton Formation deposits exposed in trenches were traceable across the ISFSI site. Lithologic contacts could be mapped with sufficient resolution to preclude any fault displacements larger than a few centimeters (typically 2 centimeters or less), as shown on the logs of trench walls (Figures 4-8 and 4-9).

Correlation of the stratigraphy in boreholes to the strata exposed in the sea cliff and local trenches indicates that the boundary between the lower and upper members of the Hookton Formation is at the base of the very dense sandy gravel 16 to 23 meters below the ISFSI site. Geologic cross sections X-X^5 and Y-Y^1 (Figures 4-5 and 4-10) depict the position of this contact beneath the site, as well as the correlation of two distinctive estuarine mud units in the upper Hookton Formation. The upper part of the lower Hookton Formation consists of very dense, poorly to well-graded sand and silty sand with occasional gravel overlying the Unit F clay bed, which occurs at a depth of 46 meters in borehole GMX-99-2. The two layers of bay mud (clay and silt) in the upper Hookton Formation are separated by a 9- to 10-meter-thick sandy and silty deposit, the texture of which ranges laterally from silty sand to low- to high-plasticity silt. These lateral variations are interpreted to be facies changes. Deposits overlying the uppermost clay bed are predominately sandy and silty clay, well to poorly graded sand, and silty and clayey sand. These deposits, as well as the upper part of the highest bay mud clay and silt beds, were exposed in trenches WCC-11-T6a, GMX-T1, and GMX-T2 (Figures 4-3, 4-8, and 4-9). A layer of clayey man-made fill overlies the upper Hookton Formation across most of the ISFSI site. The fill ranges from 0 to 3.2 meters thick, but typically is 0.6 to 1 meter thick.

4.3.4 Buhne Point Terrace and Paleosol (Late Pleistocene)

The uppermost Hookton deposits are conformable with a planar geomorphic surface, the Buhne Point terrace (Qpht on Figure 4-2), which dips gently (2 to 4 degrees) to the southeast. A strongly developed soil has formed in the near-surface deposits. This paleosol crops out in exposures on the steep slopes northeast and southwest of the ISFSI site, and in the southwest end of trench GMX-T2. Based on these exposures, the paleosol appears to be concordant with the tilted terrace surface. It has a well-developed argillic horizon, reddish brown (7.5YR hue) color, clay films, and strong structure (Figure 4-11 and Table 4-1). The presence of a relatively thick, strongly developed argillic horizon (Bt horizon) and the reddish color indicate that the soil on the Buhne Point terrace is correlative with Class II (80,000- and 105,000-year-old) soils developed on marine terraces in the Humboldt Bay area (Carver and Burke, 1992). In particular, the degree of soil development on the terrace surface at Buhne Point is similar to the soil at the South Port Landing quarry on Table Bluff, where a thermoluminescence age of 103,000 years was obtained for sediments underlying the terrace (Berger and others, 1991).

The Buhne Point terrace is interpreted to have formed during a high stand of sea level in the late Pleistocene, most likely during marine oxygen-isotope Stage 5c or 5a. The ages of oxygen-isotope Stage 5 marine terraces along the California coast are well documented (for example, Hanson and others, 1994); Stage 5e marine terraces are dated at 120,000 to 125,000 years, Stage 5c terraces are approximately 105,000 years old, and Stage 5a formed approximately 80,000 years ago. The soils data described above suggest that the terrace has been emergent since at least Stage 5a and possibly longer. This conclusion is consistent with previous estimates of the age of the Buhne Point terrace by Woodward-Clyde Consultants (1980), who interpreted it as post-upper Hookton Formation sediment deposited after deposition of a clay bed containing shell material having a 160,000 ± 40,000-year-old amino acid racemization age, and prior to 37,000 years ago, as determined from radiocarbon dating of wood samples from Trench 11-T6a. This date is older than the effective range of radiocarbon dating in 1980. A wood sample from upper Hookton deposits collected from trench GMX T2 (Figure 4-9) yielded a radiocarbon age of

>45,730 radiocarbon years B.P., confirming that the upper Hookton deposits are older than the effective age range for radiocarbon dating (Geomatrix, 2002e). The strongly developed soil on the Buhne Point terrace supports an age of more than 80,000 years.

4.3.5 Surficial Deposits (Holocene)

Holocene surficial deposits in the Buhne Point area include alluvial/estuarine marsh sediments, colluvium on the slopes, and shallow landslides (Figure 4-2). The alluvial/estuarine deposits underlie the flat area southwest of the Buhne Point terrace in the King Salmon Avenue area and east of the Discharge Canal. Colluvium derived from the eroded fault scarp along the southwest side of Buhne Point terrace probably interfingers with the alluvial/estuarine sediments.

Small landslides along the bluffs that border the Buhne Point terrace (Figure 4-2) are most abundant on the sea cliff adjacent to Humboldt Bay on the north side of the terrace. Most of the landslides are shallow (< 2 meters thick), translational landslides. However, the two northwesternmost landslides along the sea cliff appear to be somewhat deeper (5 to 7 meters) and to have rotational movement. This landsliding postdates the grading of the sea cliff and placement of riprap along the shoreline, which were completed during the late 1950s. No large landslides were observed along the bluff and, based on geologic conditions underlying the bluff, no large, deep-seated landslides are expected.

4.4 FAULTING IN THE SITE VICINITY ASSOCIATED WITH THE LITTLE SALMON FAULT ZONE

As described in Section 3.2.2 and shown on Figure 3-7, four traces of the Little Salmon fault zone are mapped in the vicinity of the Humboldt Bay ISFSI site. These include two primary fault traces, the Little Salmon and Bay Entrance faults, and two subsidiary faults in the hanging wall of the Bay Entrance fault, the Buhne Point and Discharge Canal faults. The Little Salmon fault corresponds to the middle trace of the Little Salmon fault zone to the southeast, and the Bay Entrance fault corresponds to the eastern trace of the Little Salmon fault zone to the southeast. The Little Salmon, Bay Entrance, and Buhne Point faults all dip to the northeast and displace the late Pleistocene Hookton Formation down to the southwest (Figures 4-12, 4-13, and 4-14). The Discharge Canal fault dips steeply to the southwest and has down-to-the-northeast displacement.

4.4.1 Little Salmon Fault

The location of the Little Salmon fault near the site is based on borings and seismic lines conducted by Woodward-Clyde Consultants (1980) (Figure 4-1). The fault strikes about N45°W and dips about 25°NE (Figure 4-12). The fault projects to the surface about 2.2 kilometers southwest of the ISFSI site. Projection of the structure contours shown on Figure 4-12 to the northwest places the fault about 1,300 meters beneath the western boundary of the Humboldt Bay Power Plant site. However, the fault was not encountered in boring WCC-4 (Figure 4-12), indicating that this trace either dies out south of the site, or its dip steepens at depth, placing the fault more than 1,600 meters below the ISFSI site. In either case, the Little Salmon fault was not encountered in site area borings or trenches. As described in Section 3.2.2, the Little Salmon fault displaces the entire lower Hookton section at the northern end of Humboldt Hill, placing Rio Dell Formation over Hookton sediments (Figure 4-15). It appears that, north of Humboldt Hill, slip on the Little Salmon trace of the Little Salmon fault zone is transferred to the Bay Entrance fault.

4.4.2 Bay Entrance Fault

The Bay Entrance fault is the closest of the main traces of the Little Salmon fault zone to the ISFSI site. As inferred from borings, the fault strikes N5-10°W and dips approximately 50° to 60°E (Figure 4-13). The fault projects to the surface about 500 meters west of the ISFSI site (Figure 4-16). The closest distance to the fault (fault-normal distance measured to the center of the site) is between about 410 and 470 meters. The fault appears to have a right-slip component that is about 50 percent of the dip-slip separation, based on analysis of boring and geophysical data (Woodward-Clyde Consultants, 1980).

The base of the Hookton Formation is displaced about 440 meters (dip-slip), and the upper Hookton Formation is displaced about 270 meters (Woodward-Clyde Consultants, 1980, their Figure C-10 and Table 2). Progressive separation of the older beds in the Hookton Formation indicates the fault was active during deposition of the Hookton Formation. The long-term, dip-slip displacement rate on the Bay Entrance fault southwest of the ISFSI site is believed to be 1 to 2 millimeters per year.

South of the plant site, the Bay Entrance fault corresponds to the east trace of the Little Salmon fault zone (Figure 3-7). In a quarry exposure directly south of College of the Redwoods, this trace displaces lower Wildcat sedimentary rocks (Pullen Formation) over late Pleistocene and Holocene sediments (Carver and Burke, 1988). To the south, at Salmon Creek, this trace deforms a late Holocene alluvial terrace. Based on the displaced terraces, Carver and Burke (1987) estimate the late Holocene slip rate to be 2 to 3 millimeters per year.

4.4.3 Buhne Point Fault

The location of the Buhne Point fault is based on analysis of site borings (Figures 4-14 and 4-16). The fault strikes about N45-70°W. The fault dips about 35°NE down to elevation -900 feet (-275 meters), where the dip flattens to less than 20° (Figure 4-16). Below elevation -300 meters (-1,000 feet), the dip of the fault steepens to about 45° and probably continues to steepen until the fault merges with the Bay Entrance fault. The fault plane lies about 140 to 160 meters beneath the ISFSI site.

The projected surface trace of the Buhne Point fault is parallel to and southwest of the southwest margin of the Buhne Point terrace, about 180 meters southwest of the ISFSI site (Figure 4-14). The 5- to 15-meter-high scarp along the southwest side of the Buhne Point terrace is interpreted to be a wave-eroded fault scarp associated with the Buhne Point fault. Although erosion and grading during plant construction modified the scarp, it reflects the general trend of the surface trace.

The Buhne Point fault shows progressively greater vertical separation of older horizons. It displaces the Scotia Bluffs(?) Formation 71 meters (vertical separation on Unit Q); the base of the Hookton Formation 49 meters; and the Unit L clay in the lower part of the Hookton 21 meters (Woodward-Clyde Consultants, 1980, Figure C-8). Structure contours on the top of Unit F in the vicinity of the ISFSI site (Figure 4-17) indicate the vertical displacement on the top of this unit in the upper part of the lower Hookton Formation ranges from 6 to 10 meters.

The upper Hookton underlying the terrace at Buhne Point is tilted 2 to 4 degrees to the southeast, indicating continued deformation and faulting on the Bay Entrance and Buhne Point faults during the late Pleistocene (the past 80,000 years). Based on the displacement of Unit F (160,000 ± 40,000 years old), the long-term-average slip rate on the Buhne Point fault (dip slip) is about 0.1 millimeter per year. This slip rate is an order of magnitude lower than the slip rate for the Little Salmon and Bay Entrance traces of the fault zone.

Woodward-Clyde Consultants (1980) excavated trenches 11-T6b and 11-T6c across the scarp that borders the Buhne Point terrace (Figures 4-2, 4-18, and 4-19). Both trenches exposed zones of fractures and small-displacement faults in the upper part of the lower Hookton Formation. The fractures and small faults are similar to those observed in the hanging wall of other reverse faults that were investigated during regional fault studies (Woodward-Clyde Consultants, 1980; Carver, 1987b). For example, Woodward-Clyde Consultants (1980) mapped similar features in the hanging wall of the McKinleyville fault, about 25 kilometers north of the plant site (Figure 4-

20). The fractures and small-displacement faults are inferred to represent deformation in the hanging wall along the leading edge of a reverse fault, suggesting that a fault lies within a few tens of meters of the present topographic scarp. Based on the structure contours on the top of the Unit F clay (Figure 4-17), a small splay branches from the main trace of the Buhne Point fault to the northwest toward Buhne Point. The vertical displacement on the splay fault is about 3 meters.

Interpretation of the structure contour map of the top of the Unit F clay (Figure 4-17) and geologic cross section W-W[1] (Figure 4-21) indicate this marker horizon is displaced 6 to 10 meters down on the southwest across the Buhne Point fault. The relatively small displacement on this fault is not enough to account for the total uplift of the Buhne Point terrace, which, at its highest point, is about 20 meters above mean lower low water. Faulting on the Bay Entrance fault must accommodate part of the uplift.

4.4.4 Discharge Canal Fault

A small fault, informally referred to as the Discharge Canal fault, displaces the upper Hookton Formation with a vertical separation of three meters or more. The fault is partly exposed in a hand-dug pit in the sea cliff about 75 meters west of the discharge canal for the power plant (outcrop JW-7; Figures 4-2 and 4-22). In this exposure, a sand layer is clearly displaced down on the northeast by numerous closely spaced, steeply dipping to near-vertical (70°S to 90°) faults that generally strike N50°W. The fault is associated with a monoclinal flexure exposed in trenches BP-2 and BP-3, east of the ISFSI site and directly west of the discharge canal (Figure 4-2). Logs of these trenches (Earth Sciences Associates, 1977) show a sand layer in the upper Hookton Formation that is deformed into a steep "monocline" (down on the northeast) that trends N70°W (Figures 4-23 and 4-24). The vertical separation across the feature is greater than or about equal to 3 meters (the limit of the exposure in trench BP-2). The surface trace defined by these exposures corresponds to a 3-meter down-to-the-northeast step in the top of Unit F (Figure 4-17). Based on the location of the offset in Unit F relative to the surface trace, the fault dips 70° to 80° to the southwest. The Discharge Canal fault is interpreted to be a backthrust on the hanging wall of the Buhne Point fault (Figure 4-16). The "monocline" represents either folding above the tip of a blind reverse fault, or hanging-wall deformation above a backthrust that daylights (or is covered by young bay sediments) to the northeast. Another small fault crops out in the sea cliff about 45 meters east of the mapped trace of the Discharge Canal fault (Figure 4-2), where a 10- to 20-centimeter-thick sand layer in the upper Hookton Formation is abruptly truncated by a zone of faint, closely space shears. The fault strikes N32°W and dips 77°SW.

Assuming reverse slip, the displacement exceeds about 1.5 meters (and exceeds the height of the exposure).

4.4.5 Other Minor Faults

As shown on Figure 4-2, the only stratigraphic displacements observed near the site were exposed in trench WCC-11-T6a, more than 30 meters west of the ISFSI site, where a small, rootless, graben-shaped feature is located in bedded silts (Appendix 4A, Figure 4A-12, Sheet 3, Station 160 m). Two narrow zones of antithetic faults that are spaced about 30 centimeters apart form a depression about 15 centimeters deep in the silt bed; there is no apparent vertical separation across the feature. Woodward-Clyde Consultants (1980) attributes the feature to soft-sediment deformation during deposition of the Hookton sediments, because the underlying and overlying sediments were not similarly disturbed. The bounding shears, however, have characteristics that are similar to the "monocline" exposed in trenches BP-2 and BP-3 and in the sea cliff exposure (Figure 4-2). Therefore, the feature probably represents minor secondary deformation (bending-moment normal faulting) in the hanging-wall block of the Buhne Point fault. As described above, zones of small faults and fractures also are evident in trenches WCC-11-T6b and WCC-11-T6c (Figures 4-2, 4-18, and 4-19).

4.5 CONTINUITY OF STRATA BENEATH THE SITE

This section discusses the continuity of the strata beneath the ISFSI site, both the Unit F clay of the upper lower Hookton Formation, and upper Hookton strata.

4.5.1 Unit F Clay (Upper Lower Hookton Formation)

The potential for detecting small faults in the Unit F marker horizon is affected by (1) the accuracy of the stratigraphic picks in individual boreholes (typically less than 0.3 to 0.6 meters); (2) the spacing of the boreholes in the site vicinity that penetrate to Unit F (which varies, as shown on Figure 4-17); (3) the possibility of erosional irregularities in the top of Unit F; and (4) the possibility of broad folding (non-brittle deformation) of Unit F. Considering these factors, the limit of resolution for detecting faults in Unit F beneath the ISFSI site is estimated to be about 2 meters.

Figure 4-17 shows a structure contour map based on the lithologic picks for the elevation of the top of Unit F encountered in site area boreholes and in trench WCC-11-T6c (Geomatrix, 2002a, 2002b). Unit F is about 40 meters below the ISFSI site, where the contact between Unit F and the overlying sand and gravel generally strikes N30-40°E and dips 5°SE. The dip is shallower to the east adjacent to the Discharge Canal fault; southeast of the site, the strike rotates to trend more eastward. This rotation in strike may reflect erosion of the upper contact of Unit F, the presence of a southwest-verging thrust fault at depth, or broad folding of Unit F. The available data indicate that erosion and/or broad synclinal folding probably account for the swing in structure contours, although faulting at depth cannot be ruled out. If a southwest-verging reverse fault was present at depth, its subsurface trace would project to the northeast of the site, and the up-dip projection of the fault plane would be approximately toward the site. However, slip on this hypothetical fault would die out along strike to the northwest, based on the decreased to no deflection in the structure contour at and northeast of the site. As described below, the absence of faulting in near-surface sediments (i.e., strata of the upper Hookton Formation) at and near the ISFSI site is documented in trenches of this and previous studies. For comparison, the deformation of the upper Hookton Formation strata by the Discharge Canal fault is readily identifiable in trenches and test pits. The absence of significant faulting in the trenches indicates that the fault does not exist, does not project through the site, or has not been active for more than 80,000 years.

Evidence of erosion on the top of Unit F is indicated in an alignment of five closely spaced boreholes that are from 2.4 to 3.6 meters apart. These boreholes were drilled about 200 meters east-southeast of the ISFSI site as part of a cross-hole shear-wave-velocity experiment (boreholes WCC80-CH-1 through WCC80-CH-5 on Figure 4-17). The lithologic logs for these boreholes indicate 1.5 meters of local relief in the top of the Unit F clay. Figures 4-25a and b are geologic cross sections at the top of Unit F that show two alternative interpretations of the CH series boreholes. As shown, the variability in the elevation of the top of Unit F could be due to either a small fault (Figure 4-25a), or a cut-and-fill channel (Figure 4-25b). If it were a fault, the vertical separation between boreholes WCC80-CH4 and WCC80-CH3 would be between 1.2 and 1.7 meters down to the east. However, given the negligible (~0.3 meter) net vertical separation across the series of boreholes, and the anomalous apparent west dip of the top of Unit F between boreholes WCC80-CH3 and WCC80-CH5 compared to the trend of the Unit F surface (Figure 4-17), the relief probably reflects a cut-and-fill channel.

Geologic cross section W-W^1 (Figure 4-21) trends northeast/southwest, approximately perpendicular to the strike of the northeastern splay of the Buhne Point and the Discharge Canal faults. Unit F can be traced continuously across the uplifted block between these faults, which displace the Unit F clay 6 to 10 meters and 3 to 5 meters (vertical separation), respectively.

There are no discernable faults (faults having a vertical separation greater than 2 meters) in this 310,000-year-old clay marker horizon beneath the ISFSI site.

4.5.2 Upper Hookton Strata

Geologic cross section Y-Y[1] (Figure 4-10), which extends north/south through the ISFSI site, illustrates the stratigraphic relations in the upper Hookton deposits beneath the site. Based on the borings and observations made in the sea cliff exposure, the upper Hookton deposits are continuous; there is no evidence these deposits, which are at least 80,000 year old, are faulted beneath the site.

Trenches WCC-11-T6a and GMX-T1 cross the ISFSI site in a N75°W direction (see Figures 4-3 and 4-8, Photo 4-7, and Appendix 4A). Trench GMX-T2 crosses the site in a N24-37°E direction, which is approximately perpendicular to the trend of the Buhne Point and Discharge Canal faults (Photo 4-8). These trenches provided continuous exposure in upper Hookton Formation bay mud deposits across the ISFSI site. Trench WCC-11-T6a extended for more than 200 meters along the uplifted block (Buhne Point terrace) that lies between the northeast-dipping Buhne Point fault and the southwest-dipping backthrust near the Discharge Canal (Figure 4-2). The trench exposures provide direct evidence for the absence of faulting beneath the ISFSI site with a high degree of resolution (typically less than 2 centimeters) in the exposed deposits, which are at least 80,000 years old (Photo 4-9).

Several thin fractures lined with roots and fine sand were observed in trenches GMX-T1 and GMX-T2 (Figures 4-8 and 4-9; Photos 4-10, 4-11 and 4-12). The fractures, which cut thinly laminated silt, clayey silt, and fine sand, show no discernable displacement, and prominent marker horizons in the upper Hookton Formation deposits can be traced across the upward (and downward) projections of the fractures with no displacement.

The strata exposed in trenches WCC-11-T6a, GMX-T1, and GMX-T2 provide direct evidence for no significant faulting (more than about 2 centimeters) in strata at the foundation level of the ISFSI site since the late Pleistocene (during at least the past 80,000 years). No displacements were observed, and the stratigraphic contacts exposed in trench walls are sharp enough to preclude vertical fault displacements greater than about 2 centimeters.

4.6 SUMMARY OF SITE GEOLOGY

Knowledge of site geology is based on extensive studies of the stratigraphy beneath the site, regional mapping of the Little Salmon fault zone, trenching at the site, analysis of the geomorphology of the Buhne Point terrace, and review of recent studies of the Little Salmon fault. The primary elements of site geology are summarized below.

- The ISFSI site is underlain by a well-bedded sequence of Tertiary and Quaternary sedimentary rocks that contain excellent planar datums that record deformation on the Little Salmon fault zone and allow for estimation of deformation rates.
- Based on its relative topographic position and the presence of a strongly developed relict paleosol, the raised and tilted terrace surface (the Buhne Point terrace) at the ISFSI site formed during an interglacial high stand of sea level, and is correlated to either the 80,000- or the 105,000-year-old (Stage 5a or 5c marine terraces that are well preserved at other places along the northern California coast.
- The ISFSI site is on the hanging wall of the Little Salmon fault zone. Three branches of this fault zone—the Little Salmon, Bay Entrance, and Buhne Point faults—dip to the northeast beneath the site.
- The Little Salmon fault projects to the surface about 2.2 kilometers southwest of the ISFSI site. This fault either dies out south of, or is more than 1,600 meters below, the site.
- The Bay Entrance fault is the closest main splay of the Little Salmon fault zone to the Humboldt Bay ISFSI site. The fault projects to the surface about 500 meters west of the ISFSI site, and is about 410 to 470 meters from the site at its closest approach (fault-normal distance measured to the center of the site).
- The Buhne Point fault, a secondary splay in the hanging wall of the Bay Entrance fault, projects to the surface about 180 meters southwest of the ISFSI site and lies about 140 to 160 meters below the site. The southwest-dipping Discharge Canal fault splays off the Buhne Point fault daylighting near the Discharge Canal about 150 meters northeast of the site.
- Displacement on the Bay Entrance and Buhne Point faults uplifted the hanging-wall block between the main trace of the Buhne Point and Discharge Canal faults, tilting the Buhne Point terrace 2 to 4 degrees to the southeast. The tilted terrace surface reflects the tectonic deformation on the hanging wall of the Little Salmon fault zone, including ruptures

associated with multiple earthquakes on the Cascadia subduction zone during the past 80,000 years.

- Despite the close proximity of the ISFSI site to active traces of the Little Salmon fault zone, the upper part of the lower Hookton Formation (about 310,000 years old) and the upper Hookton Formation deposits (>80,000 years old) are not faulted, as evidenced by continuous, unbroken upper Hookton strata in the near surface beneath the ISFSI site. These strata can be traced continuously across the ISFSI site with a high degree of resolution.

TABLE 4-1

DESCRIPTIONS OF SOIL PROFILES

Pacific Gas and Electric Company
Humboldt Bay ISFSI

Horizon[1]	Depth (cm)	Color[2]		Texture[3]	Structure[4]	Consistence[5]		Clay Films[6]	Boundary[7]
		Moist	Mottles (moist)			Moist	Wet		
PROFILE JW-11* ~ 100 M WEST OF ISFSI SITE									
A	0-35	10YR 2/2	--	l	2 f g	fr	ss, ps	N.O.	a-c, s
BAt	35-52	7.5YR 4/4	--	l-scl	2-3 m-c sbk	fi	ss-s, p	1-2 n pf & po	c, s
Bt	52-96	7.5YR 4/6	--	scl	2-3 c pr breaking to 2-3 m-c sbk	fi	s, p	2-3 n-mk po & pf	c, w
2Bt2	96-130	7.5YR 4/6	--	scl	2-3 c pr breaking to 2-3 m sbk	fi-vfi	s, p	2-3 mk-k pf & po	c-g, s
2Bt3	130-180	7.5YR 5-6/8	c 1-2 d, 7.5YR 7/4	scl	1-2 c pr	fi	ss-s, p	1-2 n pf 3-4 mk-k po	c-g, s
3Bt	180-230	10-7.5YR 5/8	c 1-2 d-p, 10YR 7/4	sicl	1-2 c pr	fi-vfi	s, p	1-2 n pf 2-3 n-mk po	a-c, w
3Cox	230-	10YR 7/4	f 2 d, 10YR 6/8 &	sicl	M	fi	ss-s, p	v1 n-mk po	--

TABLE 4-1

DESCRIPTIONS OF SOIL PROFILES

Pacific Gas and Electric Company
Humboldt Bay ISFSI

Horizon[1]	Depth (cm)	Color[2]		Texture[3]	Structure[4]	Consistence[5]		Clay Films[6]	Boundary[7]
		Moist	Mottles (moist)			Moist	Wet		
	270+		7.5YR 6/8						
PROFILE JW-12 ~130 M EAST OF ISFSI SITE**									
A	0-20	10YR 2/1	--	sicl	1 m gr	fr	ss-s, p	--	c, s
A2	20-43	10YR 3/1	--	sicl	1 m sbk breaking to 2 m gr	fi	s, p	v1 n pf	c, w
B	43-75	7.5YR 4/6	--	sicl-sic	1-2 c-vc pr breaking to 1 m sbk	fi-vfi	s-vs, p-vp	1 n pf	c, s
2Bt	75-140	7.5YR 5-6/8	m 2 d, 7.5YR 7/3	sic	2 m pr breaking to 3 m sbk	fi	s-vs, vp	3 mk-k pf & po	c-g, s
2Bt	140-197	7.5YR 6/6	f 2 d, 7.5YR 7/3	sic	1 c pr breaking to 2 m	vfi	s-vs, p-vp	2-3 k pf & po	g, s

TABLE 4-1

DESCRIPTIONS OF SOIL PROFILES

Pacific Gas and Electric Company
Humboldt Bay ISFSI

Horizon[1]	Depth (cm)	Color[2]		Texture[3]	Structure[4]	Consistence[5]		Clay Films[6]	Boundary[7]
		Moist	Mottles (moist)			Moist	Wet		
					abk				
2BCtc	197-232	7.5YR 6/6	f-c 2 f, 7.5YR 6/4	c	1 c pr & abk	vfi-efi	vs, vp	3 k pf & po	a-c, s
3Cox	232-257	10YR 5-6/4	--	sl	m	fi	ss, ps	--	a, s
4Cox	257-327+	10YR 6/4	c-m 2-3 d-p, 7.5YR 5/8	sicl	m	fi	s, p	--	--
PROFILE GMX-T2* SOUTHWEST CORNER OF ISFSI SITE**									
A	0-5 mostly stripped	10YR 3/4	--	sil-sl	1 m gr	fr	ss, ps	--	a, ir
A/B	5-28	10YR 4/4	--	sl	1 m sbk	fi	so, ps	2, n, po	c-g, ir
Bt	28-75	10YR 3/6	m 2 d, 10YR 7/3 m 2 d, 10YR 3/6	scl	2 c-vc cpr breaking to 1 m sbk	fi	ss, p	3; mk; po	g, ir
Bt2	75-110	10YR 6/8	7.5YR 5/8 c m p, 7.5YR 8/2	scl	2 c cpr breaking to 3 m	fi	s, p	3 mk-k pf & po	g; ir

TABLE 4-1

DESCRIPTIONS OF SOIL PROFILES

Pacific Gas and Electric Company
Humboldt Bay ISFSI

Horizon[1]	Depth (cm)	Color[2]		Texture[3]	Structure[4]	Consistence[5]		Clay Films[6]	Boundary[7]
		Moist	Mottles (moist)			Moist	Wet		
					abk				
B/C	110-145	10YR 6/8	m 1-2, d 7.5YR 6/8 m 1-2 d, 5YR 7/1	sc	1-2 f abk	fi	s, p	3-4 k pf	a, s
2Cox	145-213	7.5YR 4.5/8	--	s-ls	m	fi	so, po	--	va, s
3Cox	213-235	7.5YR 5.5/8 7.5YR 6.5/2	--	sil	m	fi	ss, p	--	a, s
4Cox	235-362	7.5YR 5.5/8 7.5YR 6.5/2	--	sil & s	m	fi	ss, p so, po	--	va, w
4C	362-369	7.5YR N4/0	--	s	m	fr	so, po	--	a, s
5C	369-420+	7.5YR N4/0	--	sic	m	--	s, p	--	--

* Soil profile exposed in steep south-southwest-facing escarpment below the Buhne Point terrace. Location shown on Figure 4-2.
** Soil profile exposed in steep north-northwest-facing escarpment below the Buhne Point terrace. Location shown on Figure 4-2.
*** Soil profile exposed in northwest wall of trench GMX-T2 (station 180 ft); relict paleosol formed on the Buhne Point terrace. Location shown on Figure 4-2.

Explanation of Soil Descriptions

[1] Master horizons: A = a surface horizon characterized by the accumulation of organic matter and typically as a zone of elluviation of clay, sesquioxides, silica, gypsum, carbonate, and/or salts; B = a subsurface horizon characterized as having a redder color, stronger structure development, and/or accumulation of secondary illuvial materials, such as clay, sesquioxide, silica, gypsum, and/or salts; C = a subsurface horizon that may appear similar or dissimilar to the parent material and includes unaltered material and material in various stages of weathering. Modifiers of master horizons: b = buried soil horizon; c = concretions or nodules; j = used in conjunction with other modifiers to denote incipient development of that particular feature or property; ox = oxidized (for C horizon only); p = plowing or other disturbance; t = accumulation of clay; w = color or structural B horizon.

[2] Color: From Munsell soil color chart (Munsell Color Company, 1988); dry colors were difficult to determine given very wet weather during fieldwork; -- = not observed. Abundance: f = few, c = common, m = many. Size: 1 = fine, 2 = medium, 3 = large. Contrast: f = faint, d = distinct, p = prominent.

[3] Texture: sl = sandy loam; ls = loamy sand; s = sand; l = loam; scl = sandy clay loam; sc = sandy clay; cl = clay loam; sil = silt loam; sicl = silty clay loam; sic = silty clay.

[4] Structure: Grade: m =?massive; sg = single grain; v1 = very weak; 1 = weak; 2 = moderate; 3 = strong. Size: f = fine; m = medium; c = coarse; vc = very coarse. Type: pl = platy; gr = granular; abk = angular blocky; sbk = subangular blocky; cpr = columnar; pr = prismatic.

[5] Consistence Moist consistence: lo = loose; vfr = very friable; fr = friable; fi = firm; vfi = very firm; efi = extremely firm. Wet consistence: so = nonsticky; vss = very slightly sticky; ss = slightly sticky; s = sticky; vs = very sticky; po = nonplastic; vps = very slightly plastic; ps = slightly plastic; p = plastic; vp = very plastic.

[6] Clay Films: Frequency: v1 = very few; 1 = few; 2 = common; 3 = many; 4 = continuous. Thickness: n = thin; mk = moderately thick. Location: br = clay bridges holding mineral grains together; pf = faces of peds; po = lining or filling tubular or interstitial pores; co = colloidal stains on mineral grains; N.O. = none observed; -- = not observed.

[7] Boundary with lower horizon. Distinctness: va = very abrupt; a = abrupt; c = clear; g = gradual; d = diffuse. Topography: s = smooth; w = wavy; i = irregular; b = broken.

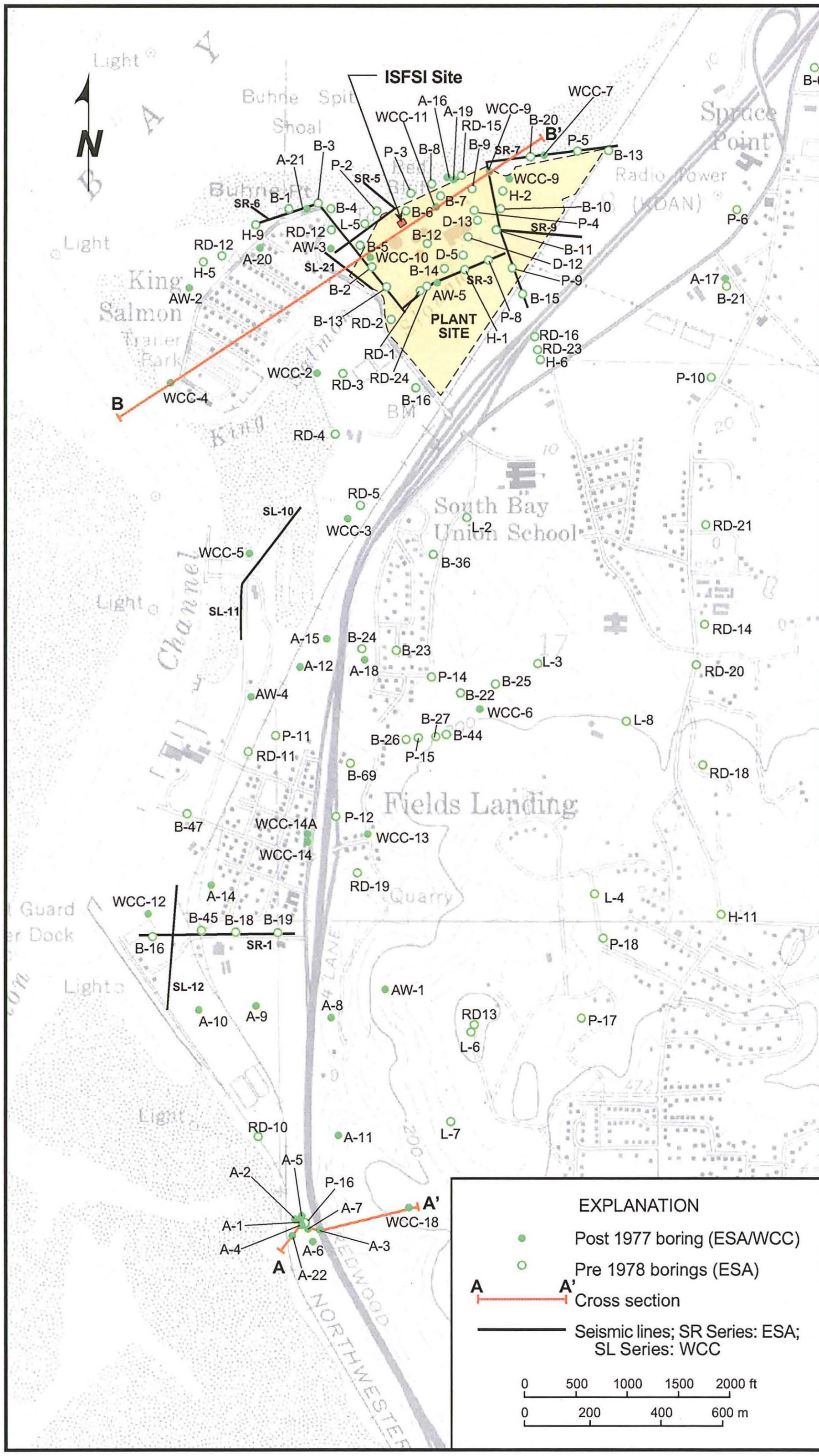

Figure 4-1 Locations of borings, cross sections, and seismic reflection lines used in the 1980 Woodward-Clyde Consultants report. *(after Woodward-Clyde Consultants, 1980, Figure C-2).* Cross section A-A' is shown on Figure 4-15 and cross section B-B' is shown on Figure 4-16.

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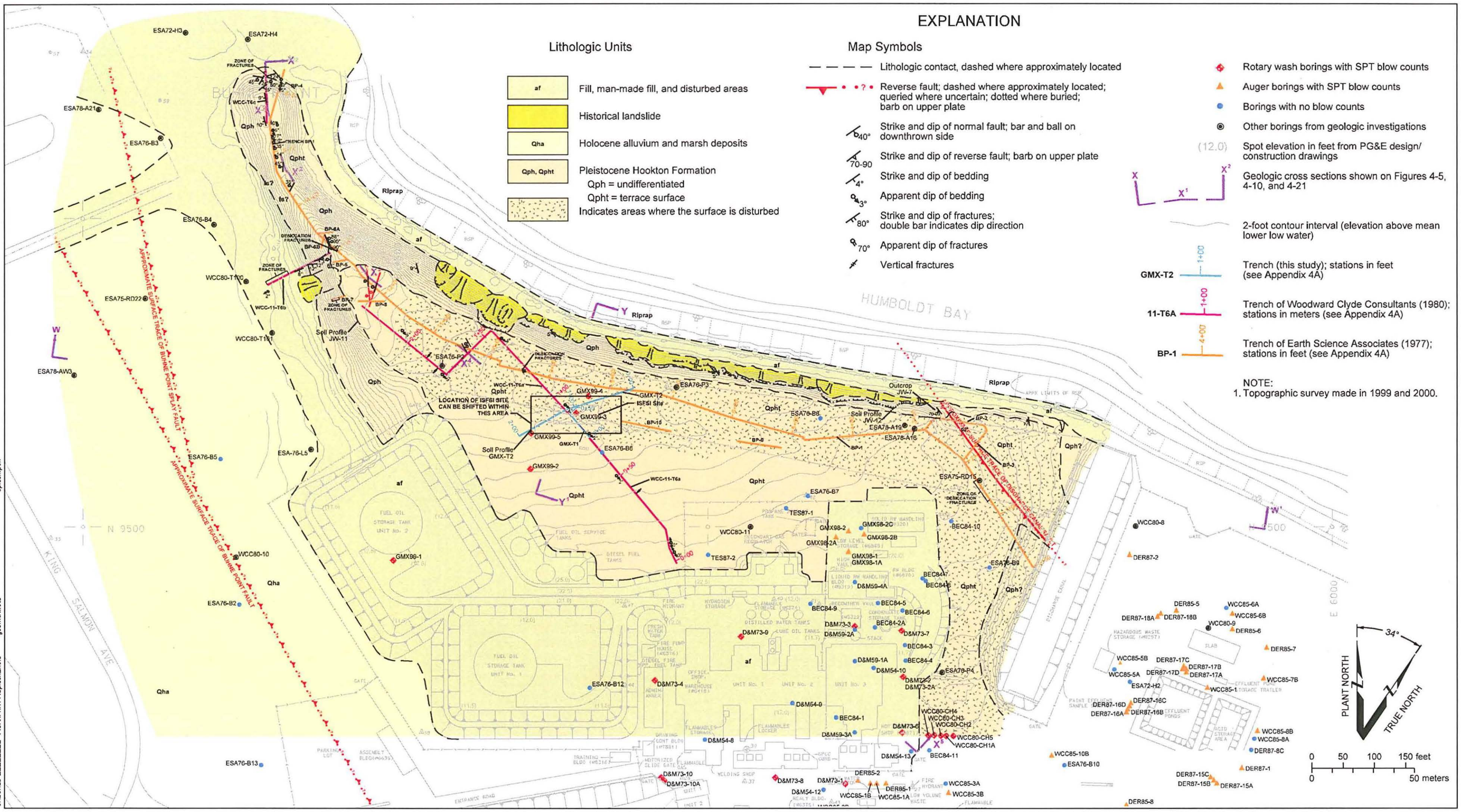


Figure 4-2 Geologic map of the ISFSI site.

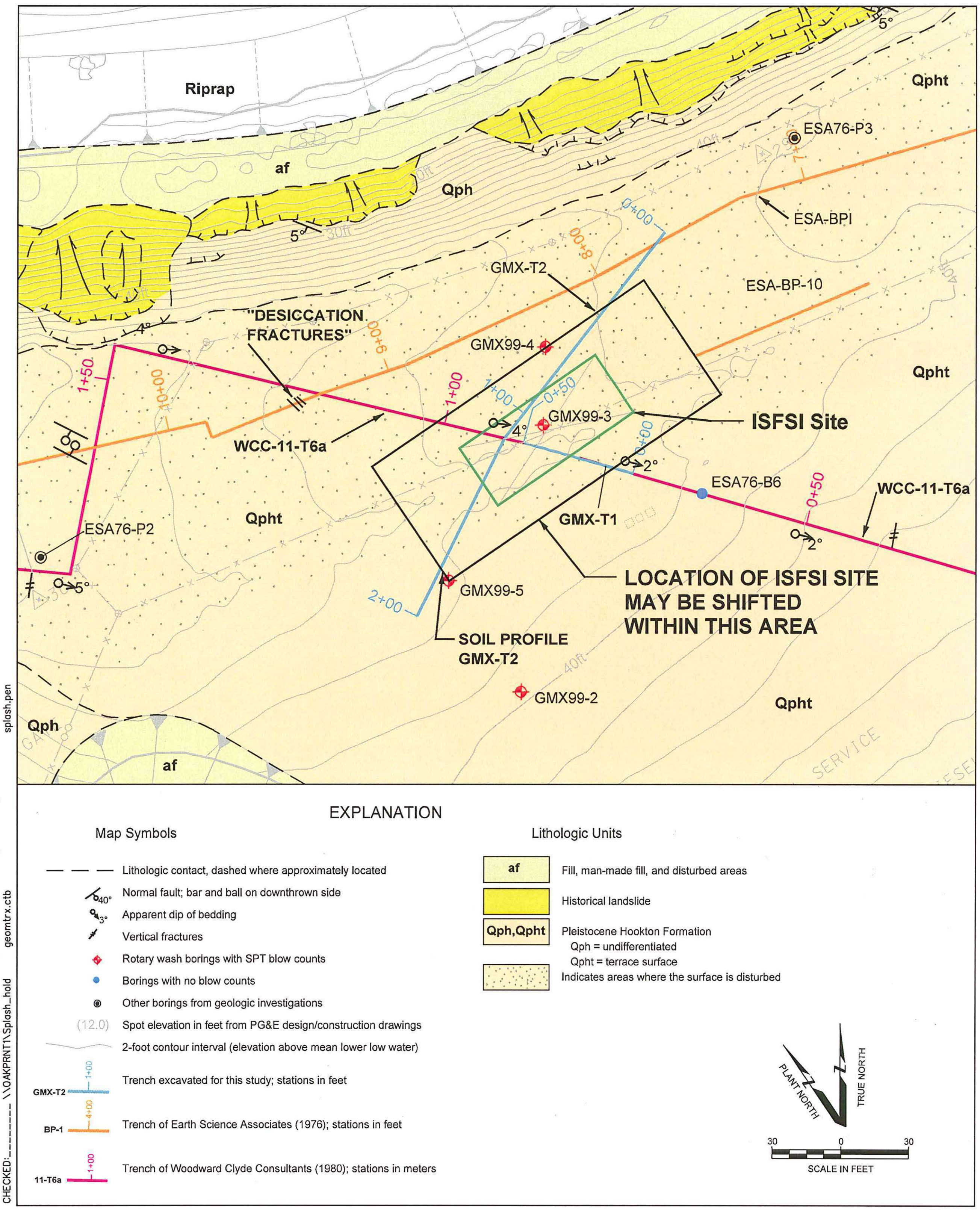
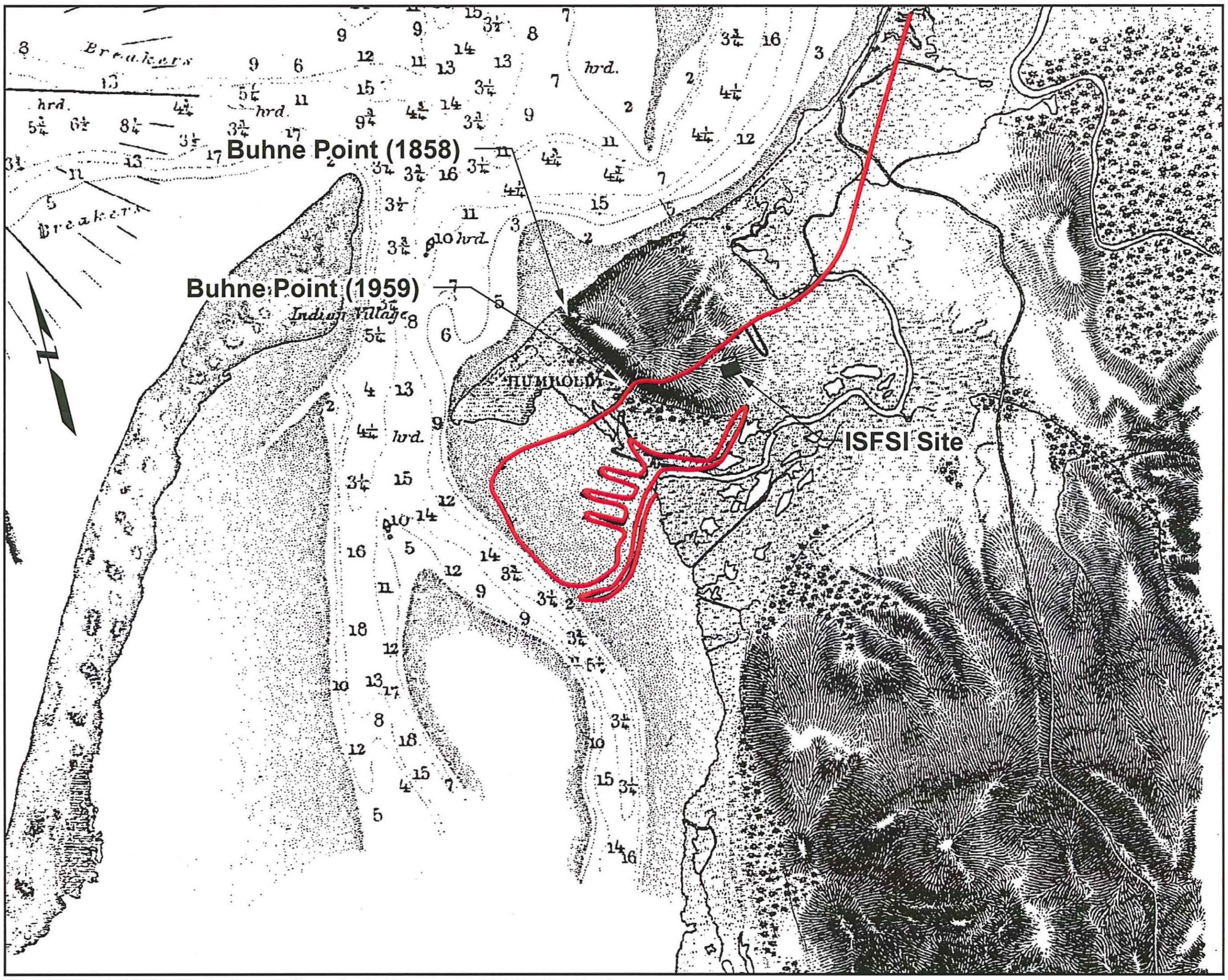


Figure 4-3 Locations of geologic trenches and borings near the ISFSI site.



Base map: U.S. Coast and Geodetic Survey, 1858, Preliminary survey map of Humboldt, California.

EXPLANATION

Coastline from U.S.Geological Survey (1959) Fields Landing 7.5' Quadrangle, California

Figure 4-4 Comparison of the shoreline shown on 1858 and 1959 surveys. The 1959 shoreline is superimposed on the 1858 map to show the extensive coastal erosion and the retreat of Buhne Point that occurred prior to placement of riprap along the shoreline of Humboldt Bay.

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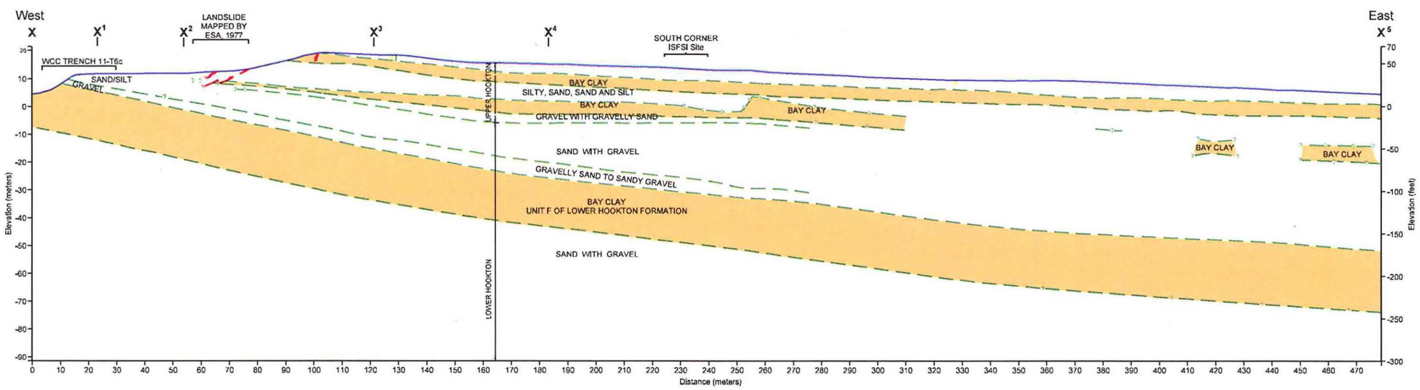

— — — ? Lithologic contact, dashed where approximate, queried where inferred.

Note: Location of cross section is shown on Figure 4-2. Unit F location based on structure contour map (Figure 4-17). Stratigraphy above Unit F based on correlation of boreholes (ESA76-P2, GMX99-2, ESA76-6) and trenches (11-T6a, 11-T6b, 11-T6c).

Figure 4-5 Geologic cross section X-X5.

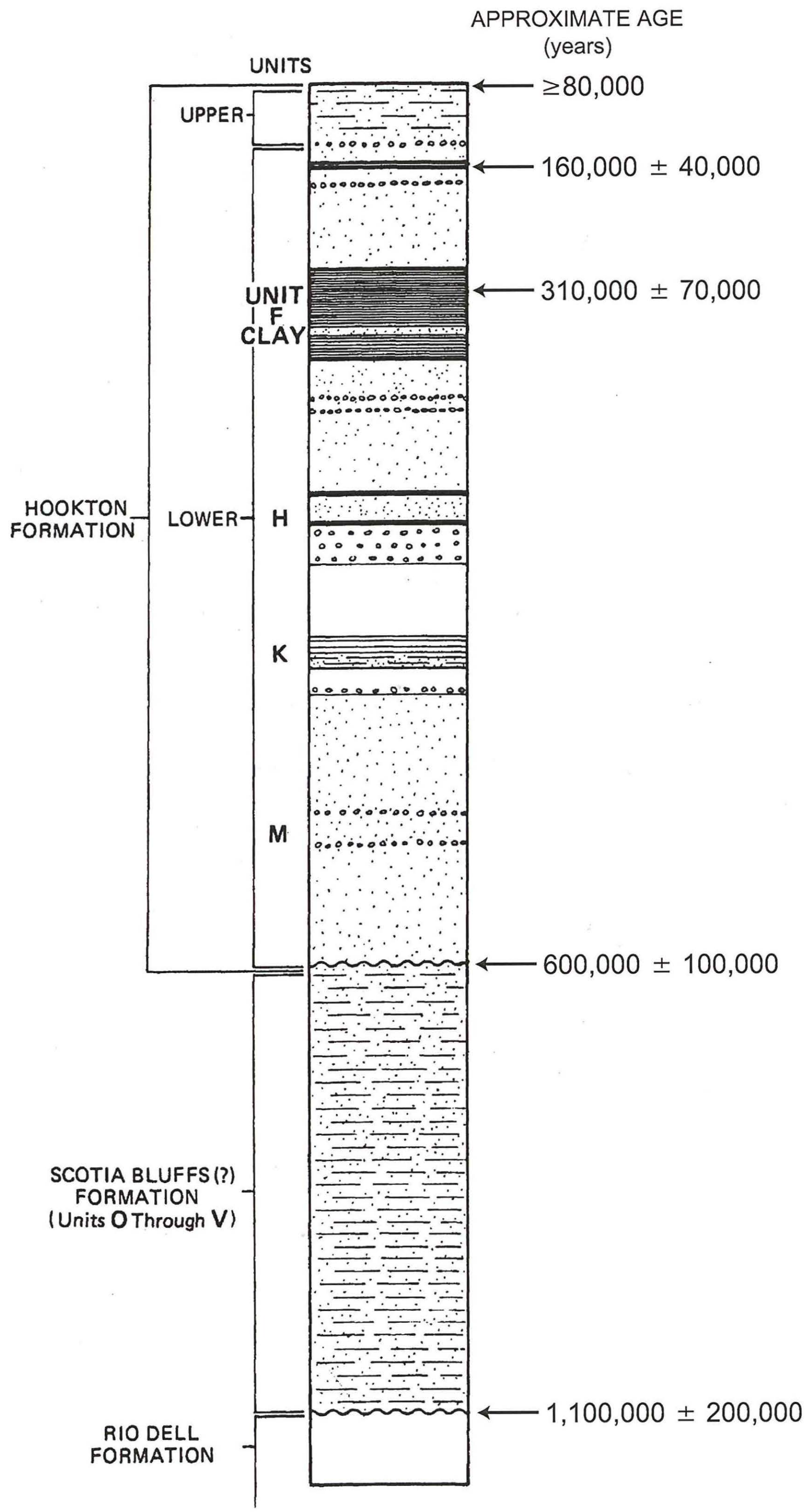

Figure 4-6 Generalized stratigraphic section at the ISFSI site. See Sections 3.2.1 and 4.3 for basis of age estimates. *(after Woodward-Clyde Consultants, 1980, Figure 7).*

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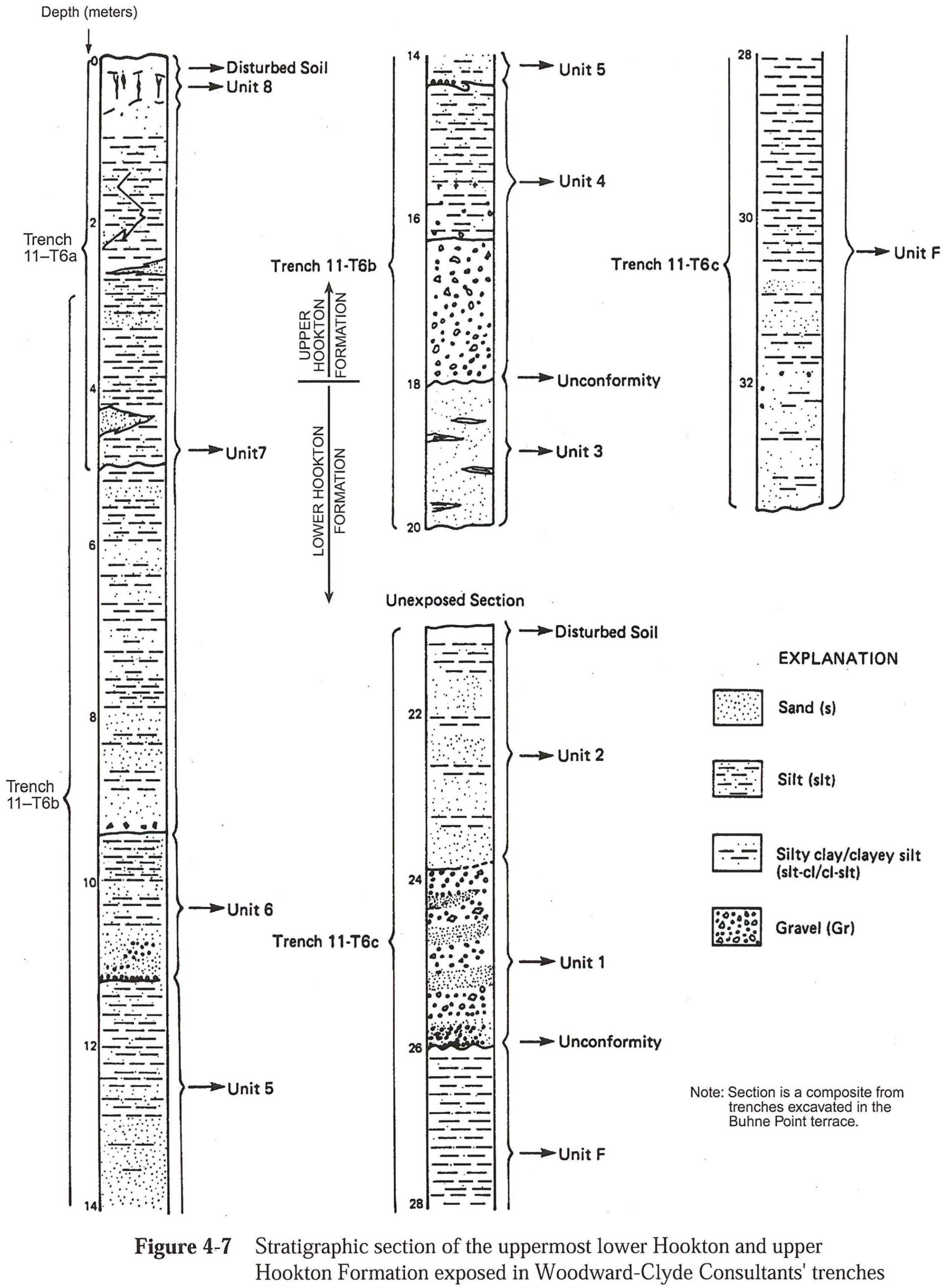

Figure 4-7 Stratigraphic section of the uppermost lower Hookton and upper Hookton Formation exposed in Woodward-Clyde Consultants' trenches 11-T6a, 11-T6b, and 11-T6c *(after Woodward-Clyde Consultants, 1980, Figure C-28).*

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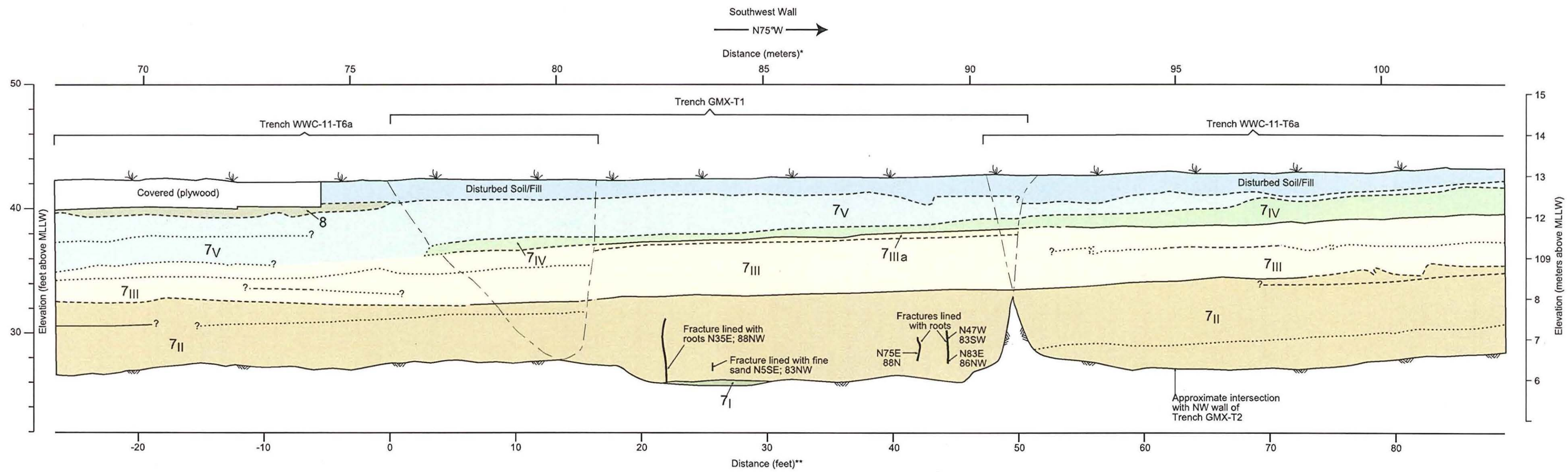

DESCRIPTION OF LITHOLOGIC UNITS

Upper Hookton Formation (Late Pleistocene)

Younger ↑ ↓ Older

Unit 8:

8 — Gleyed silty and sandy clay. Light gray to gray (10 YR 6/1 moist) and strong brown (7.5 YR 5/8 moist); some pebbles; moderately developed ped structure.

Unit 7:

7_{V} — Silty clay and clayey silt with some fine sand. Strong brown (7.5 YR 5/8 dry) with pinkish white (7.5 YR 8/2 dry) coatings along columnar and blocky ped faces; sand content increases with depth; very poorly stratified to massive; strongly oxidized; locally contains manganese-oxide nodules.

7_{IV} — Moderately sorted fine sand with silt and some clay. Mottled very pale brown (10 YR 7/3 dry) and reddish yellow (7.5 YR 6/8 dry) with light gray (5 Y 7/1) to gray (5 Y 6/1) coatings along ped faces; predominantly subrounded to subangular quartz sand; locally contains stringers of manganese-oxide nodules; A/B indicates transition between A soil horizon, which has been stripped in most places (not mapped), and a Bt soil horizon developed on Unit 7_{V} (see Table 4-1 for detailed soil profile description).

7_{IIIa} — Silty clay layer at the top of unit 7_{III}.

7_{III} — Fining-upward sequence of interbedded sand and silt. Dark grayish brown (2.5 YR 4/2) to gray (5 Y 5/2 moist) and strong brown (2.5 YR 5/2 moist) where oxidized; layers of well-sorted fine to medium sand interbedded with thin (<1 cm) lenses of silt grading upwards to clayey silt and silty clay; locally contains fine gravel along the basal contact; locally contains woody material.

7_{II} — Silt interbedded with some fine sand and clayey silt. Dark gray; massive to weakly stratified layers of sandy silt and clayey silt with some lenses of fine sand and silty clay; bedding is discontinuous laterally.

7_{I} — Silty clay. Dark gray; generally massive.

EXPLANATION

Lithologic contact; solid line where resolution is less than 2 cm, dashed line where 2 to 5 cm; dotted line where 5 to15 cm.

Fracture

NOTES:

*Values correspond to station numbers on original log of Trench 11-T6a (Woodward Clyde Consultants, 1980, Figure C-29). See Appendix 4A, Figure 4A-12.

**Values correspond to station numbers on Trench GMX-T1. (Geomatrix, 2002d).

See Figure 4-2 for locations of trenches and ISFSI site.

Figure 4-8 Composite log of trenches WCC-11T6a and GMX-T1.

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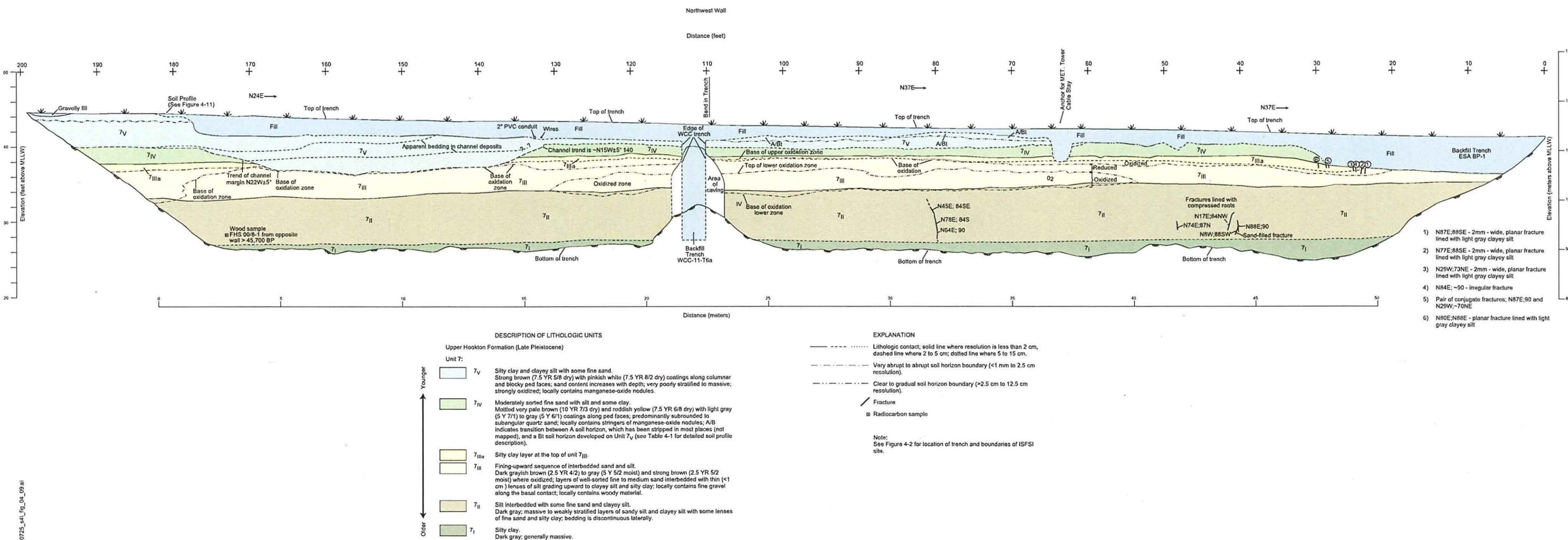

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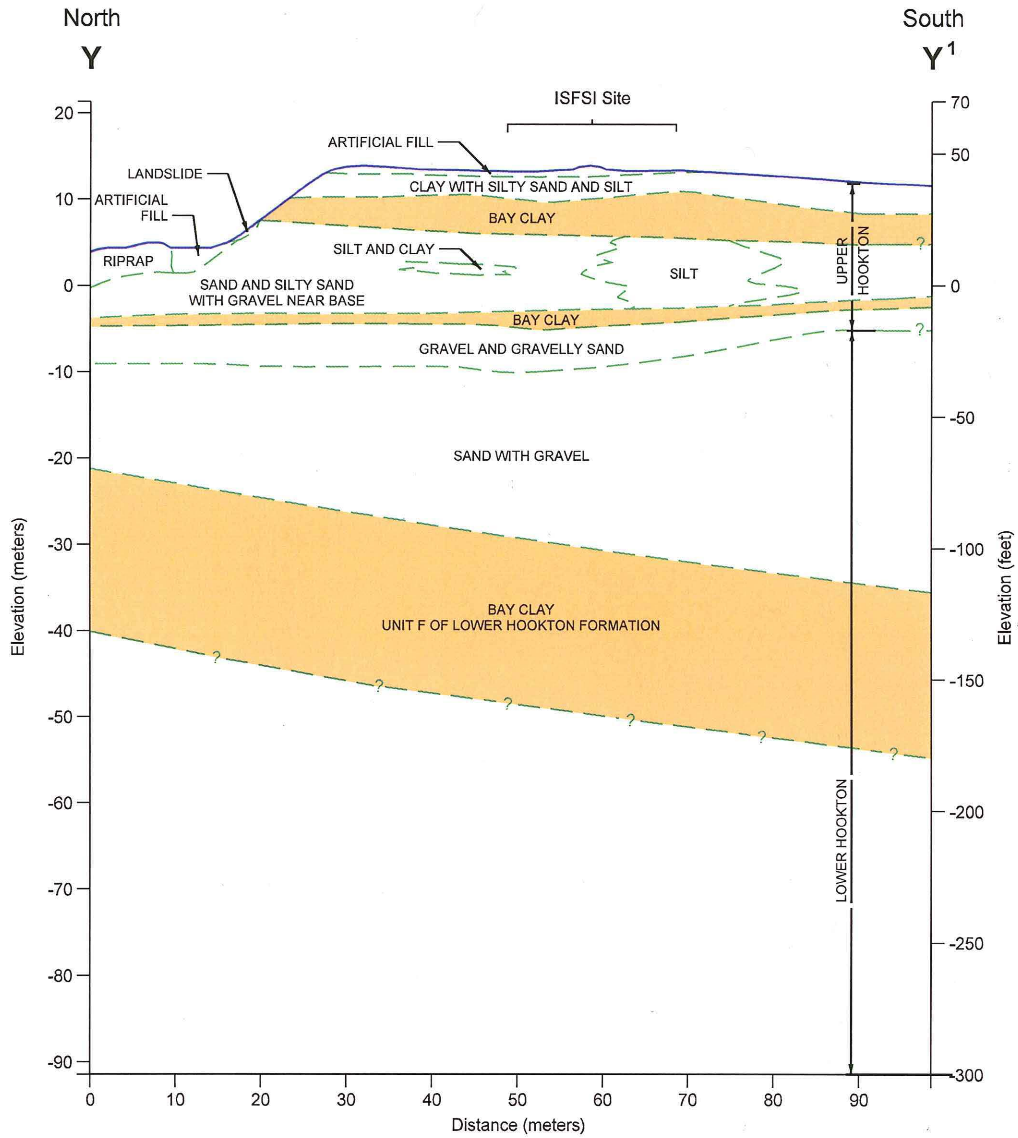
Figure 4-9 Log of trench GMX-T2.



?   Lithologic contact, dashed where approximate, queried where inferred.

Notes: Unit F location based on structure contour map (Figure 4-17).
Stratigraphy above Unit F based on correlation of boreholes (GMX99-2 through -5) and trenches, and outcrop exposure in bluff.

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Figure 4-10 Geologic cross section Y-Y1.
Location of cross section and boreholes are shown on Figure 4-2.

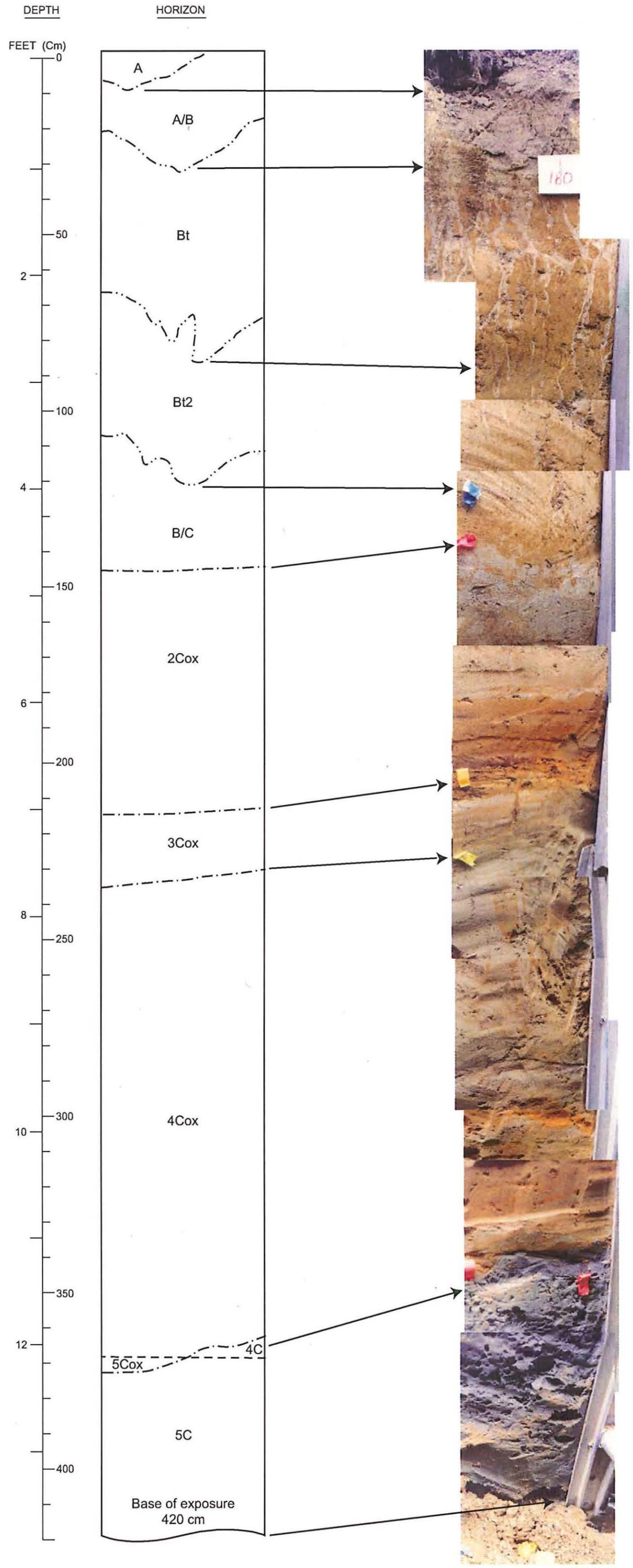

Figure 4-11 Relict soil and upper Hookton Formation deposits exposed in trench GMX-T2 (NW wall at station 180 ft.). See Table 4-1 for description of soil horizons. (Photographs FHS00/8-2#3 through FHS00/8-2#12 taken on August 1, 2000.)

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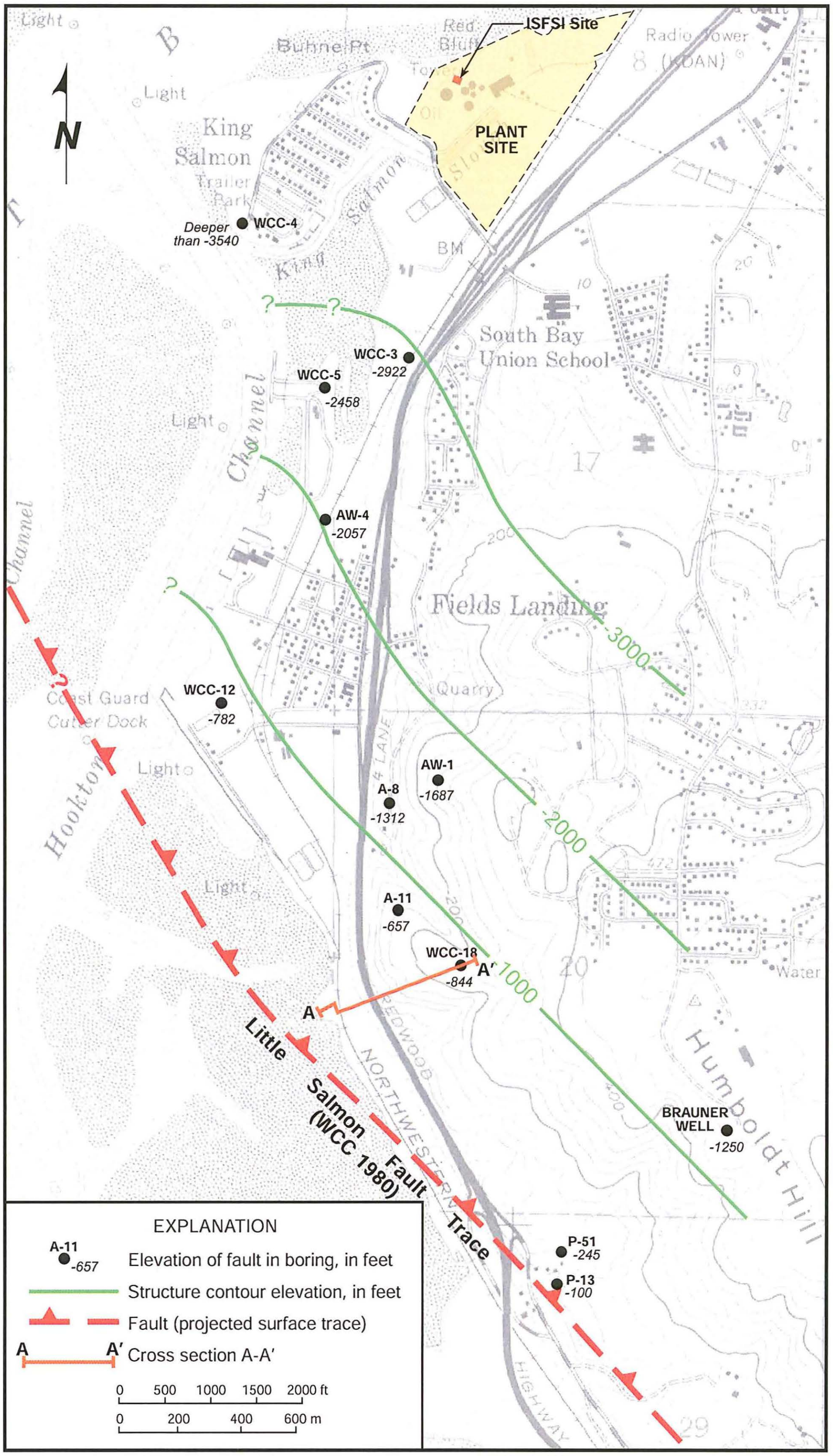

Figure 4-12 Structure contour map of the Little Salmon fault north of Humboldt Hill *(after Woodward-Clyde Consultants, 1980, Figure C-14)*. Cross section A-A' shown on Figure 4-15.

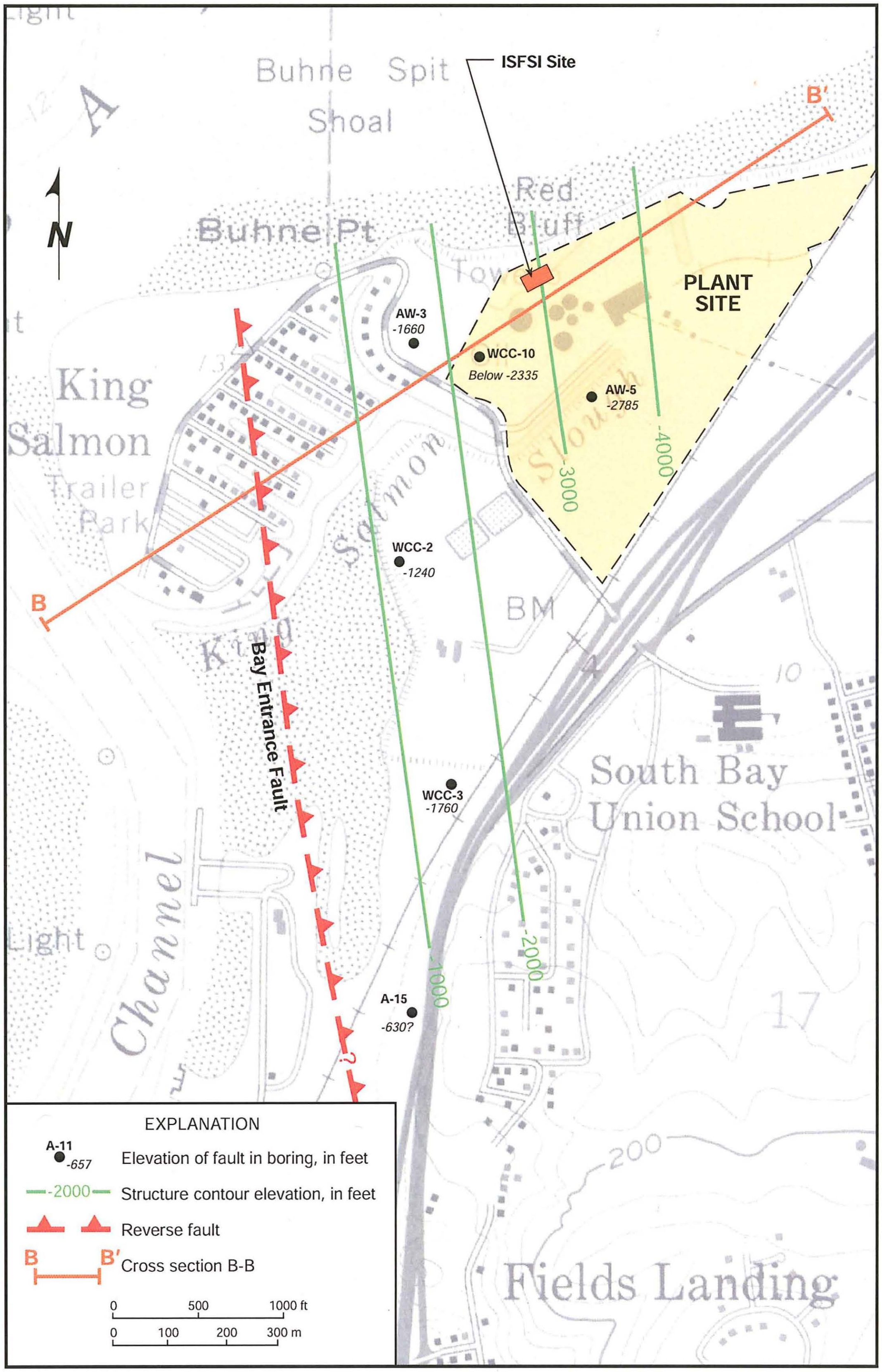

Figure 4-13 Structure contour map of the Bay Entrance fault *(modified from Woodward-Clyde Consultants, 1980, Figure C-18)*. Cross section B-B' is shown on Figure 4-16.

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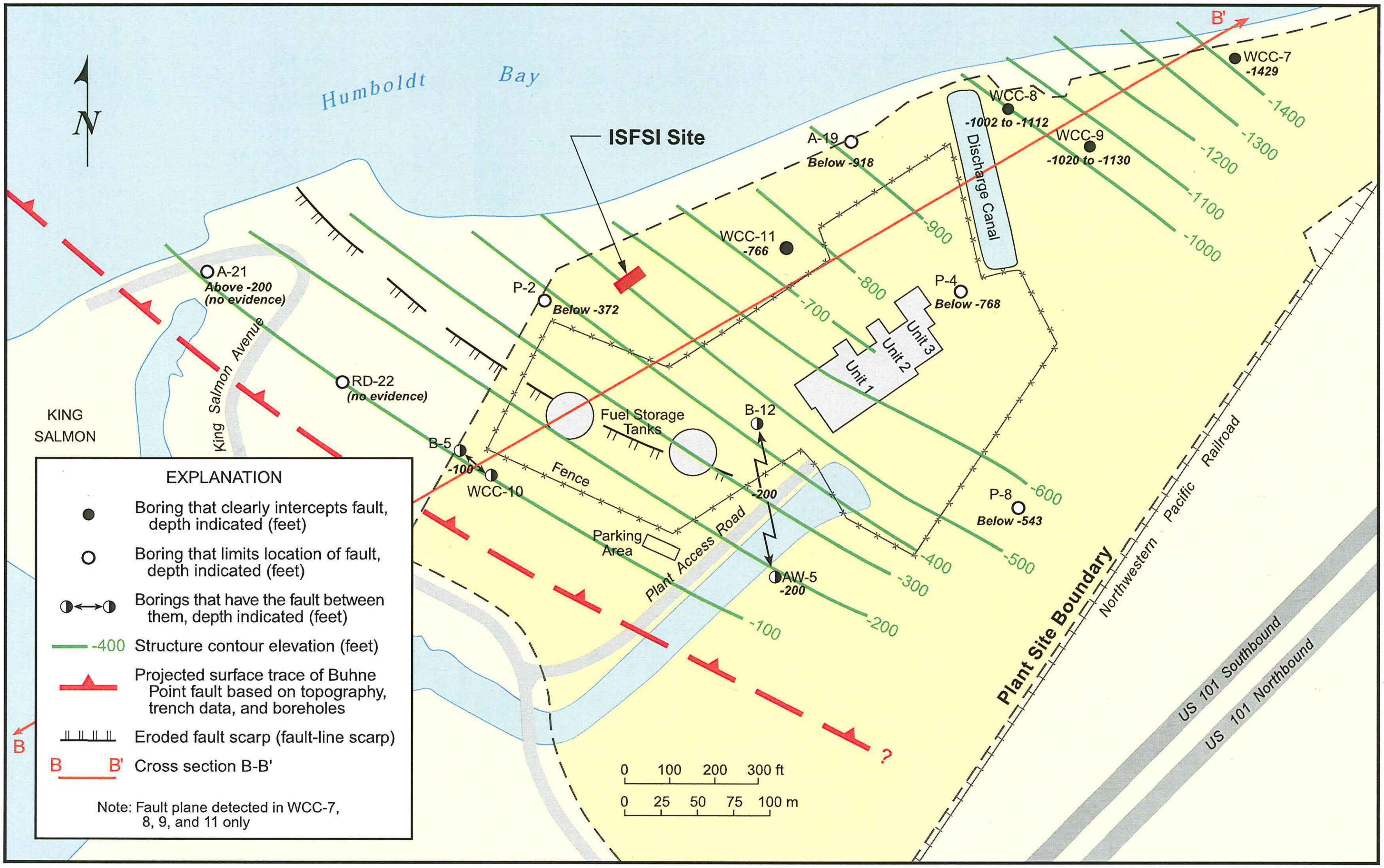

Figure 4-14 Structure contour map of the Buhne Point fault *(reinterpretation of data presented on Woodward-Clyde Consultants, 1980, Figure C-25).* Cross section B-B' is shown on Figure 4-16.

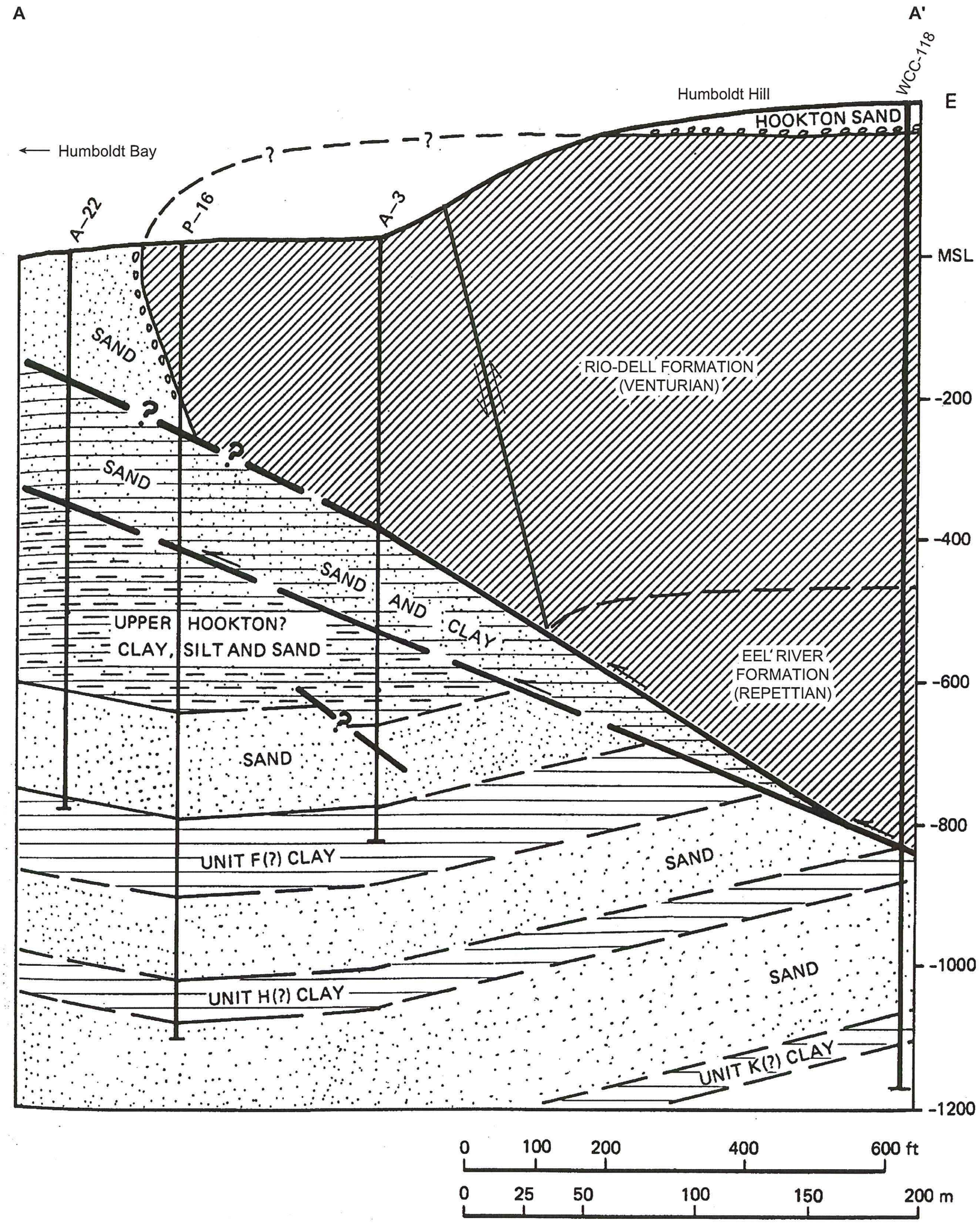

Figure 4-15 Cross section A-A' across the Little Salmon fault zone at Humboldt Hill *(modified from Woodward-Clyde Consultants, 1980, Figure C-15).* Location of cross section A-A' is shown on Figures 4-1 and 4-12.

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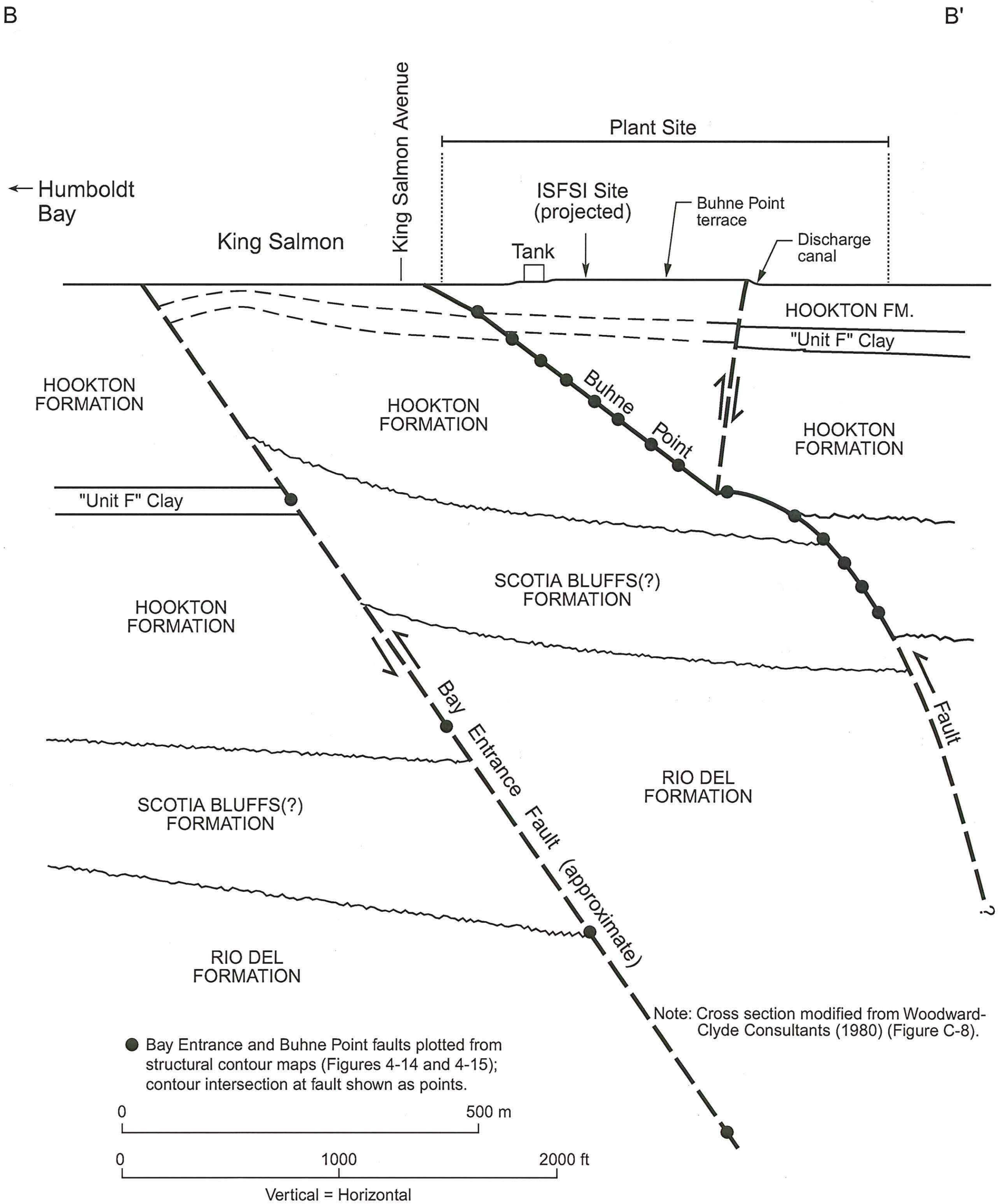

Figure 4-16 Cross section B-B' across the Bay Entrance and Buhne Point faults. Location of cross section is shown on Figures 4-1 and 4-13.

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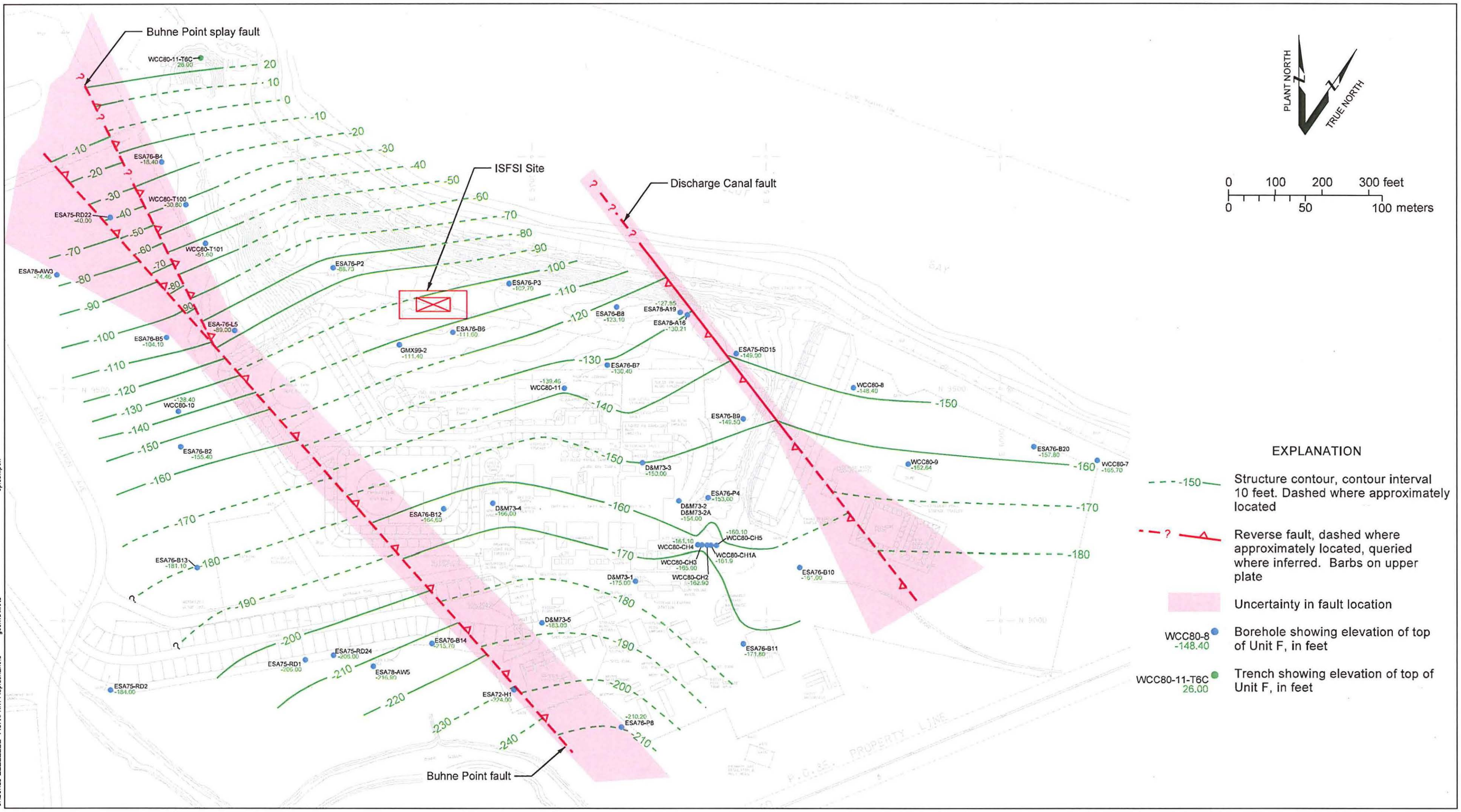
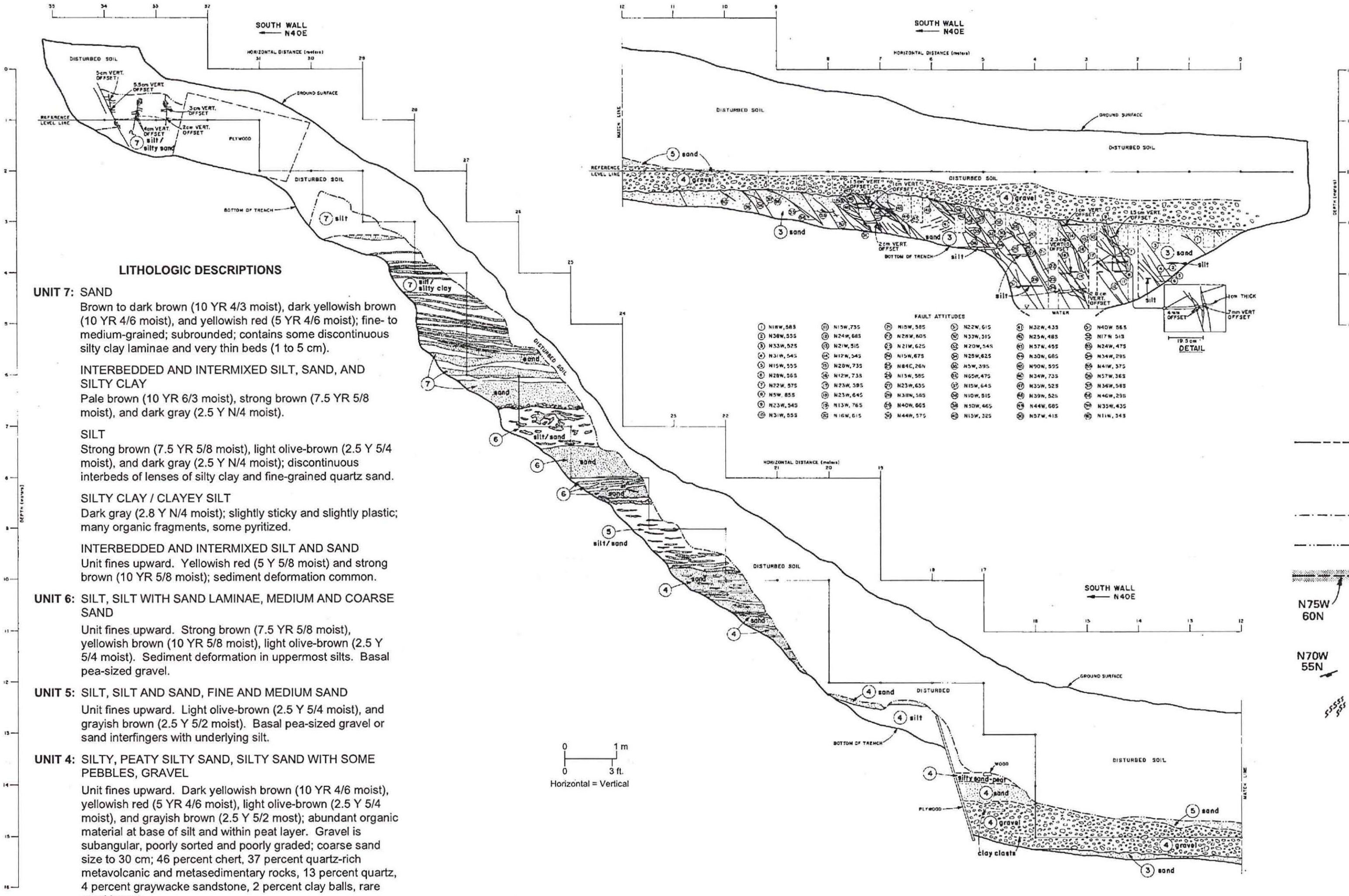


Figure 4-17 Structure contour map of top of Unit F.



LITHOLOGIC DESCRIPTIONS

UNIT 7: SAND

Brown to dark brown (10 YR 4/3 moist), dark yellowish brown (10 YR 4/6 moist), and yellowish red (5 YR 4/6 moist); fine- to medium-grained; subrounded; contains some discontinuous silty clay laminae and very thin beds (1 to 5 cm).

INTERBEDDED AND INTERMIXED SILT, SAND, AND SILTY CLAY

Pale brown (10 YR 6/3 moist), strong brown (7.5 YR 5/8 moist), and dark gray (2.5 Y N/4 moist).

SILT

Strong brown (7.5 YR 5/8 moist), light olive-brown (2.5 Y 5/4 moist), and dark gray (2.5 Y N/4 moist); discontinuous interbeds of lenses of silty clay and fine-grained quartz sand.

SILTY CLAY / CLAYEY SILT

Dark gray (2.8 Y N/4 moist); slightly sticky and slightly plastic; many organic fragments, some pyritized.

INTERBEDDED AND INTERMIXED SILT AND SAND

Unit fines upward. Yellowish red (5 Y 5/8 moist) and strong brown (10 YR 5/8 moist); sediment deformation common.

UNIT 6: SILT, SILT WITH SAND LAMINAE, MEDIUM AND COARSE SAND

Unit fines upward. Strong brown (7.5 YR 5/8 moist), yellowish brown (10 YR 5/8 moist), light olive-brown (2.5 Y 5/4 moist). Sediment deformation in uppermost silts. Basal pea-sized gravel.

UNIT 5: SILT, SILT AND SAND, FINE AND MEDIUM SAND

Unit fines upward. Light olive-brown (2.5 Y 5/4 moist), and grayish brown (2.5 Y 5/2 moist). Basal pea-sized gravel or sand interfingers with underlying silt.

UNIT 4: SILTY, PEATY SILTY SAND, SILTY SAND WITH SOME PEBBLES, GRAVEL

Unit fines upward. Dark yellowish brown (10 YR 4/6 moist), yellowish red (5 YR 4/6 moist), light olive-brown (2.5 Y 5/4 moist), and grayish brown (2.5 Y 5/2 most); abundant organic material at base of silt and within peat layer. Gravel is subangular, poorly sorted and poorly graded; coarse sand size to 30 cm; 46 percent chert, 37 percent quartz-rich metavolcanic and metasedimentary rocks, 13 percent quartz, 4 percent graywacke sandstone, 2 percent clay balls, rare sand lenses.

UNIT 3: SAND

Olive-brown (2.5 Y 4/4 moist); medium-grained; subrounded to subangular; contains discontinuous thin (2 mm to 4 cm) silt lenses.

EXPLANATION

Lithologic contact; solid line where resolution is less than 2 cm, dashed line where 2-5 cm, dotted line where 5-15 cm.

Soil contact

Disturbed soil contact

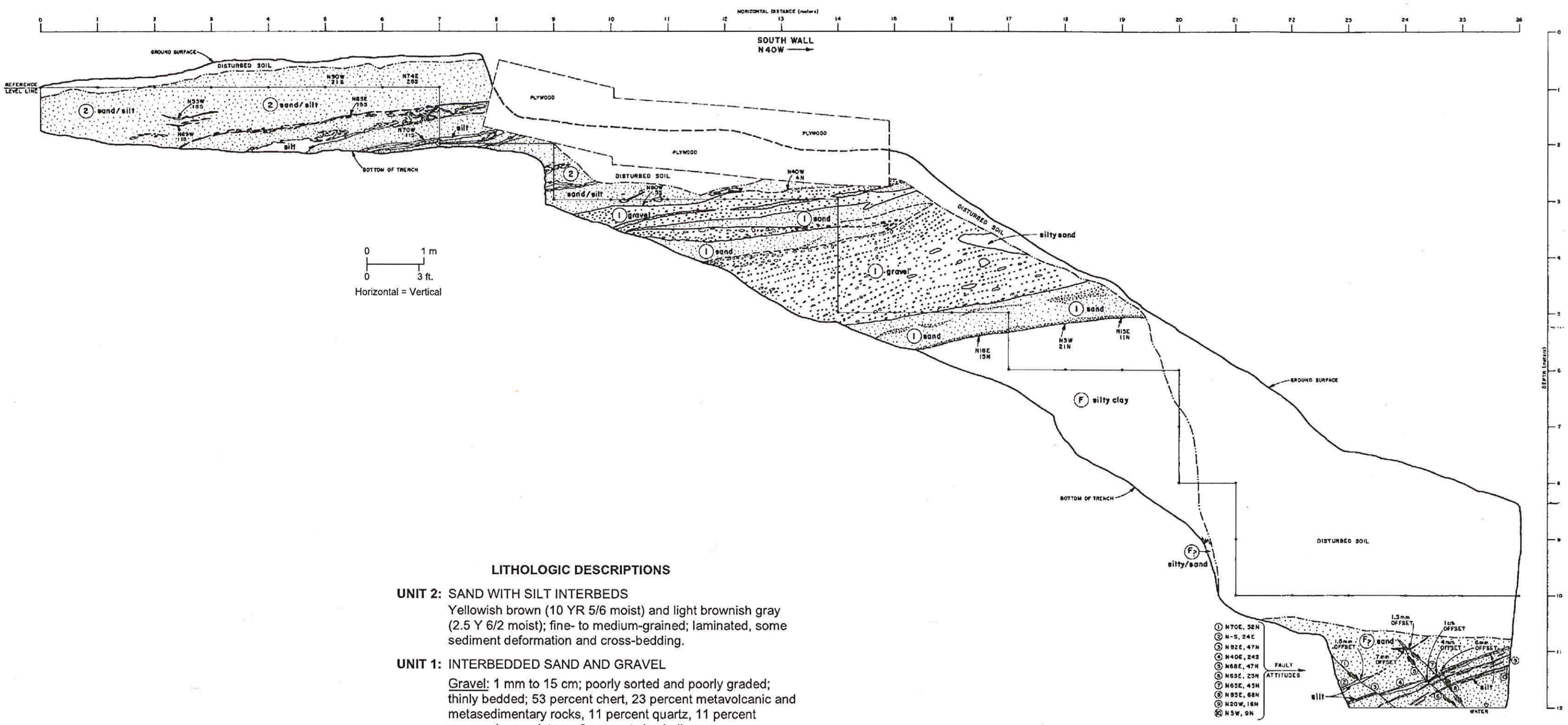
N75W 60N — Fault; solid line where resolution is less than 2 cm, dashed line where 2-5 cm, dotted line where 5-15 cm; strike and dip of fault plane indicated; arrows indicate sense of relative displacement.

N70W 55N — Strike and dip of jointing

Shears

Log of trench 11-T6b showing small faults of the Buhne Point fault in the lower Hookton Formation *(from Woodward-Clyde Consultants, 1980, Figure C-35).* Location of trench is shown on Figure 4-2.

Figure 4-18 Log of WCC trench 11-T6b.



LITHOLOGIC DESCRIPTIONS

UNIT 2: SAND WITH SILT INTERBEDS
Yellowish brown (10 YR 5/6 moist) and light brownish gray (2.5 Y 6/2 moist); fine- to medium-grained; laminated, some sediment deformation and cross-bedding.

UNIT 1: INTERBEDDED SAND AND GRAVEL
Gravel: 1 mm to 15 cm; poorly sorted and poorly graded; thinly bedded; 53 percent chert, 23 percent metavolcanic and metasedimentary rocks, 11 percent quartz, 11 percent graywacke sandstone, 2 percent clay balls.
Sand: Strong brown (7.5 YR 4/6 moist); massive; medium-grained; subangular.

UNIT F: SILTY CLAY
Very dark gray (10 YR 3/1 moist); slightly sticky and slightly plastic silty clay; rare shattered sea shells. Grades to interbedded and intermixed silt and sand. Unit fines upward. Interbedded and intermixed silt and sand is dark brown (7.5 YR 3/4 moist) and dark grayish brown (10 YR 4/2 moist). Sand is olive-brown (2.5 Y 4/4 moist); medium-grained; subrounded to subangular; contains some discontinuous, thin (2 mm to 4 cm) silt lenses.

EXPLANATION

Lithologic contact; solid line where resolution is less than 2 cm, dashed line where 2-5 cm, dotted line where 5-15 cm.

Soil contact

Disturbed soil contact

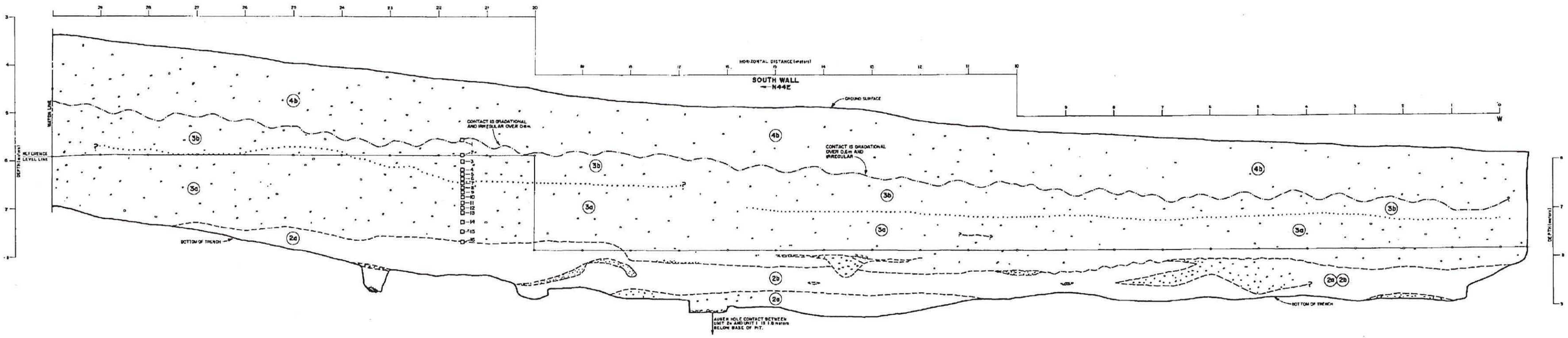
N75W 60N — Fault; solid line where resolution is less than 2 cm, dashed line where 2-5 cm, dotted line where 5-15 cm; strike and dip of fault plane indicated; arrows indicate sense of relative displacement.

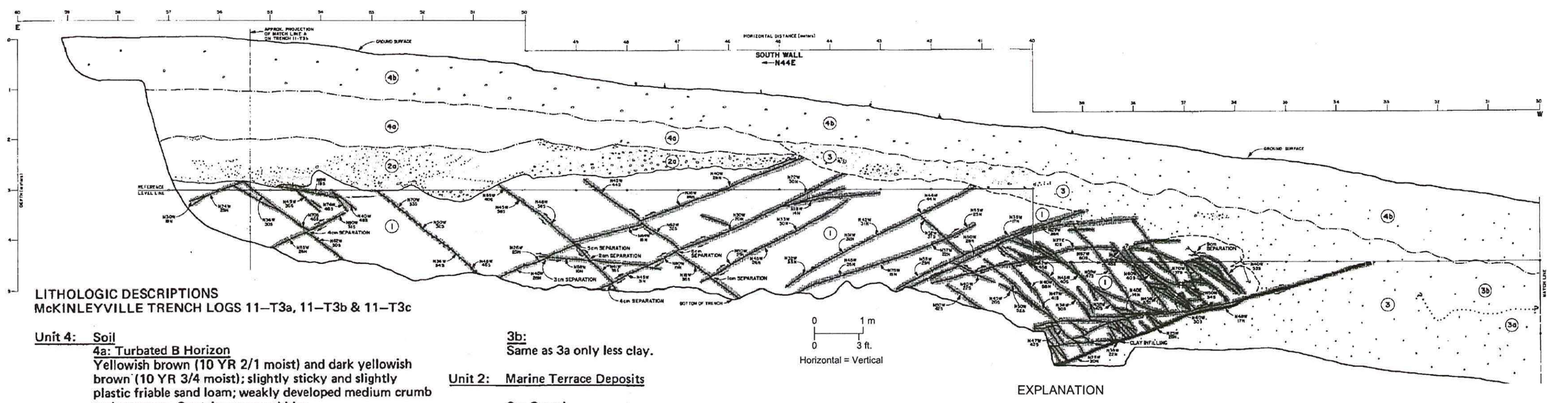
N70W 55N — Strike and dip of jointing

Shears

Log of trench 11-T6c showing small faults of the Buhne Point fault in the lower Hookton Formation *(from Woodward-Clyde Consultants, 1980, Figure C-35).* Location of trench is shown on Figure 4-2.

Figure 4-19 Log of WCC trench 11-T6c.





0 1 m
0 3 ft.
Horizontal = Vertical

LITHOLOGIC DESCRIPTIONS
McKINLEYVILLE TRENCH LOGS 11–T3a, 11–T3b & 11–T3c

Unit 4: Soil

4a: Turbated B Horizon
Yellowish brown (10 YR 2/1 moist) and dark yellowish brown (10 YR 3/4 moist); slightly sticky and slightly plastic friable sand loam; weakly developed medium crumb ped structure. Contains some pebbles.

4B: A Horizon
Black (10 YR 2/1 moist), slightly sticky and slightly plastic, friable to loose sand loam. Ped structures weakly developed. Contains burrows and roots.

Unit 3: Colluvium

3a:
Olive-yellow (2.5 YR 6/6 moist), fine-to medium-grained subangular, moderately sorted, friable to slightly indurated sand; randomly oriented pebbles and cobbles.

3b:
Same as 3a only less clay.

Unit 2: Marine Terrace Deposits

2a: Gravel
Pebbles and cobbles in a light olive-brown (2.5 Y 5/4 moist), fine- to medium-grained sand matrix (approximately 15 percent of unit); moderately sorted.

2b: Terrace Sand
Pale olive (5 YR 6/4 moist); fine-grained; subangular; moderately to well sorted; friable; cross-bedded.

Unit 1: Crannell Brown Sand
Yellowish brown (10 YR 5/6 moist); fine-grained; subangular, 70 to 80 percent quartz and 20 to 30 percent lithic fragments; moderately to well sorted; friable to slightly indurated.

EXPLANATION

Lithologic contract; solid where resolution is less than 2 cm, dashed line where 2–5 cm, dotted line where 5–15 cm.

Soil contact

Disturbed soil contact

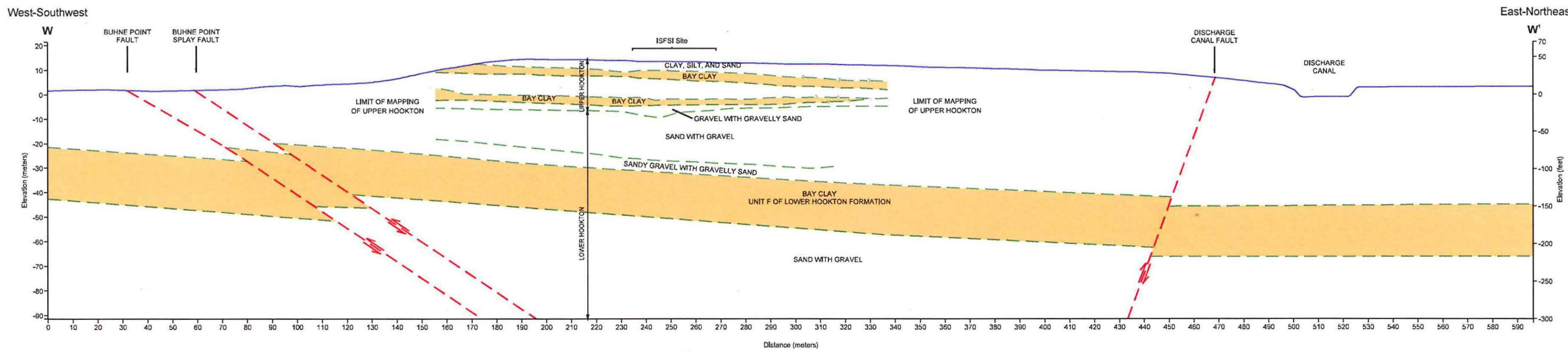
Fault; solid line where resolution is less than 2 cm, dashed line where 2–5 cm, dotted line where 5–15 cm; strike and dip of fault plane indicated; arrows indicate sense of relative displacement.

55N Strike and dip of jointing

Shears

McKinleyville trench *(from Woodward-Clyde Consultants, 1980, Figure B-19a).* Location of trench shown on Figure 3-3.

Figure 4-20 Log of WCC (1980) trench at McKinleyville.

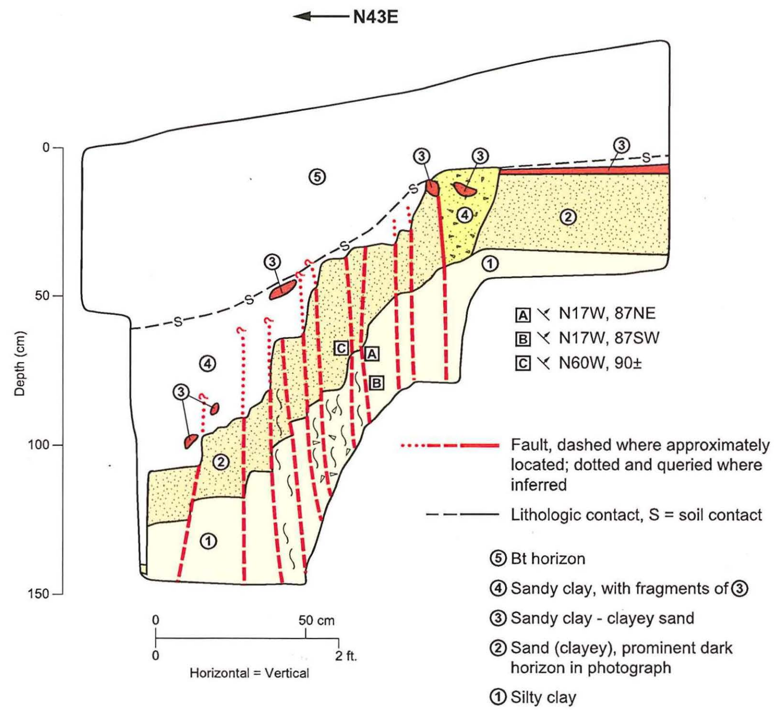


Fault, dashed where inferred, arrows show sense of displacement.

Lithologic contact, dashed where approximate, queried where inferred.

Note: Location of cross section is shown on Figure 4-2. Unit F location based on structure contour map (Figure 4-17). Stratigraphy above Unit F based on correlation of boreholes (ESA76-P2, GMX99-2, ESA76-6 through -8) and trenches. See Figure 4-2 for locations of boreholes.

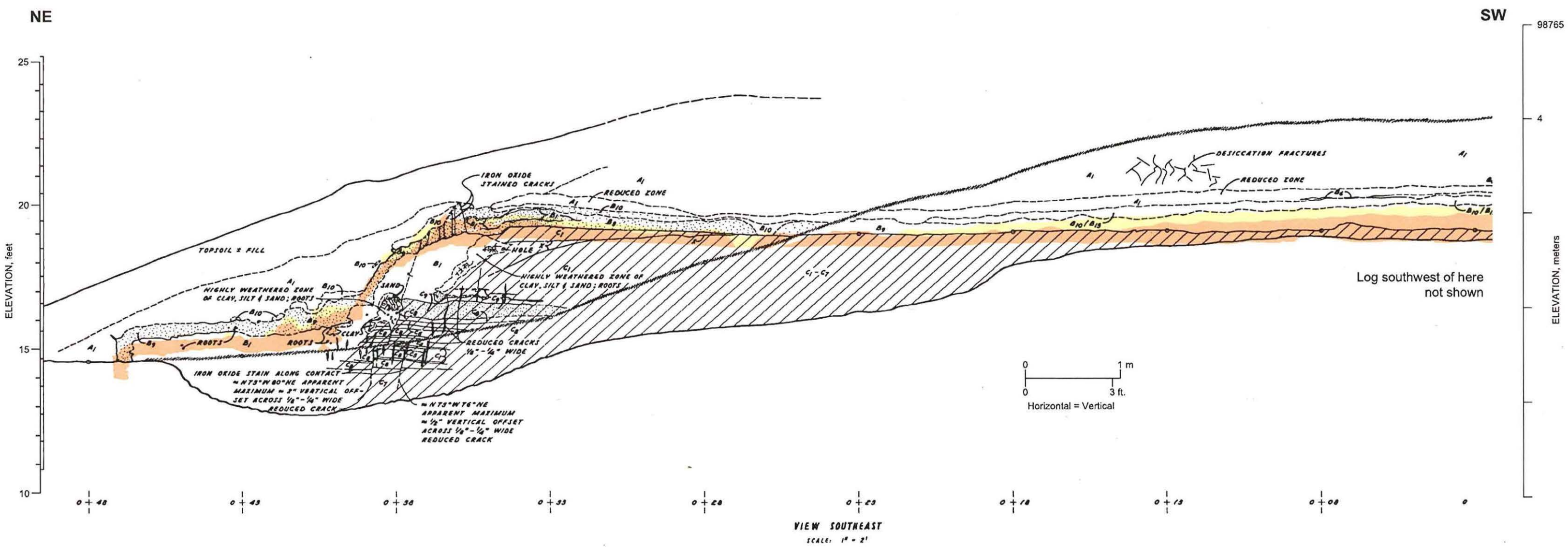
Figure 4-21 Geologic cross section W-W'



Cross trench strike of zone (shearing) ~N50W

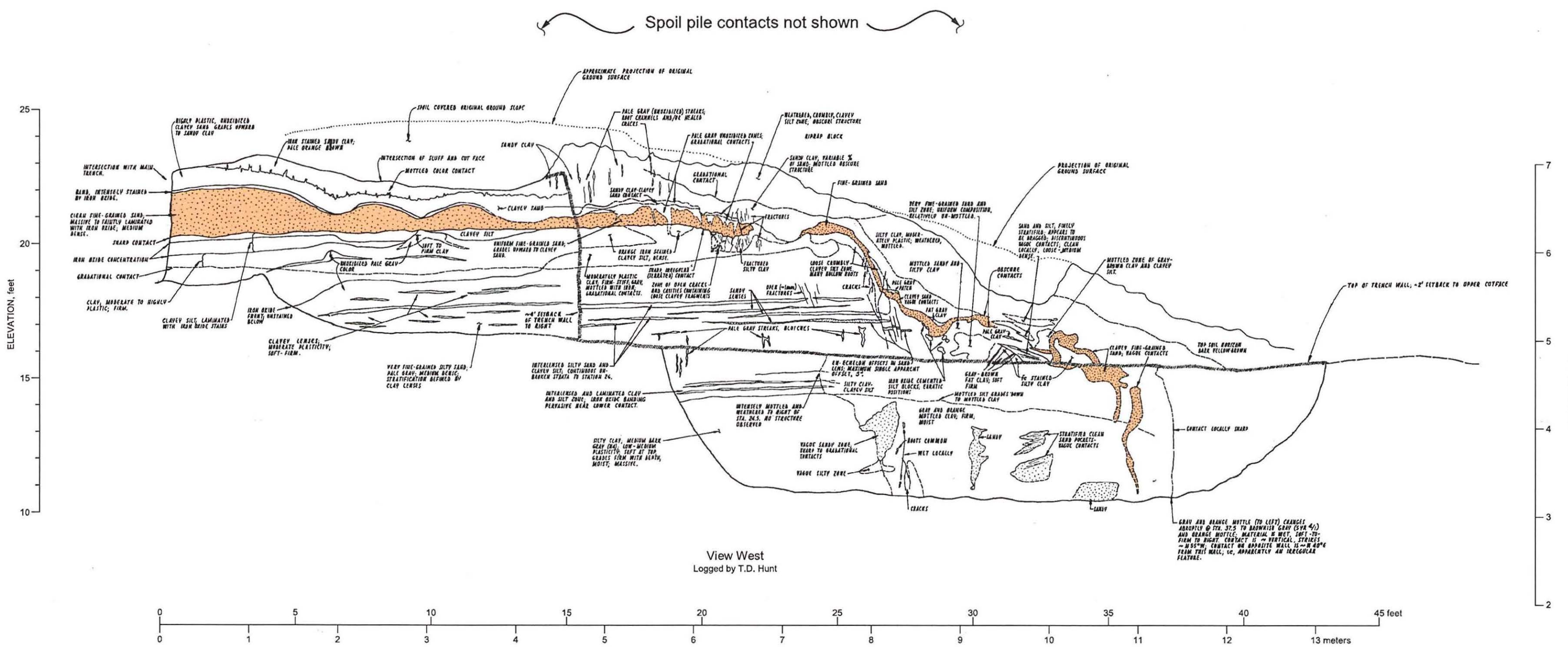
Exposure of Discharge Canal fault in sea cliff west of Discharge Canal. The vertical string line in the middle of the photograph is 100 cm long. (Photographs JW-3-23 and 24; taken on March 21, 2000). Location of exposure is shown as outcrop JW-7 on Figure 4-2.

Figure 4-22 Exposure of Discharge Canal fault.



Log of northeastern part of trench BP-2 *(from Earth Sciences Associates, 1977, Figure C37 [colors added for emphasis])*. Station numbers are in feet. Location of trench is shown on Figure 4-2.

Figure 4-23 Log of ESA (1977) trench BP-2.



Log of trench BP-3 *(from Earth Sciences Associates, 1977, Figure C37 [colors added for emphasis]).* Station numbers are in feet. Location of trench is shown on Figure 4-2.

Figure 4-24 Log of ESA (1977) trench BP-3.

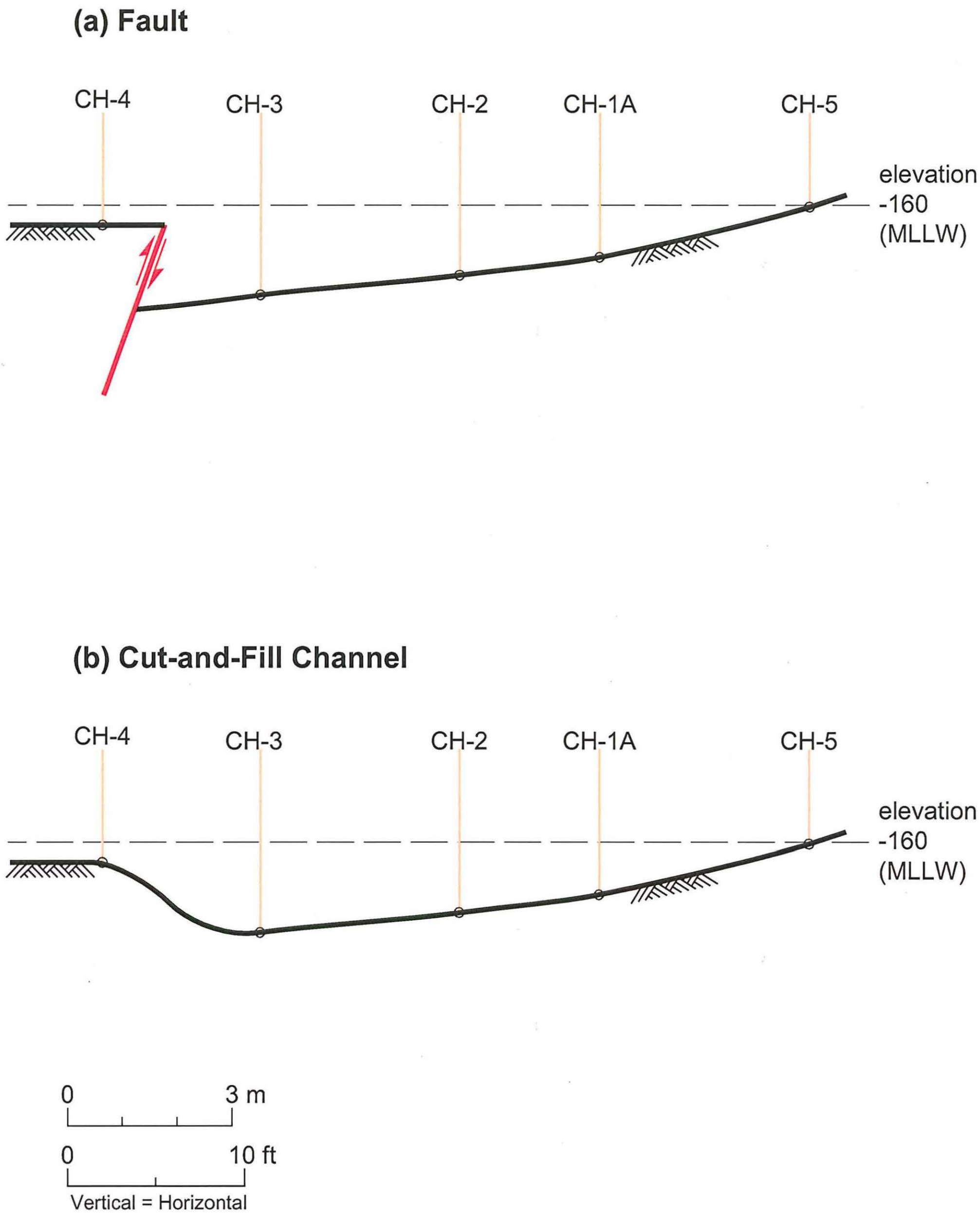


Figure 4-25 Alternative interpretations of the irregularities in the top of the Unit F clay between boreholes WCC80-CH4 and WCC80-CH5. Locations of boreholes shown on Figure 4-2.

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A) View toward the southwest.

B) View toward the west-southwest.

Photo 4-1 Oblique aerial view of the Humboldt Bay ISFSI site.
(Photographs taken July 25, 2000, by W. D. Page.)

Photo 4-2 Oblique aerial view looking northwest from above Humboldt Hill toward the entrance of Humboldt Bay. (Photograph taken July 25, 2000, by W. D. Page.)

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Photo 4-3 View looking west from Buhne Point showing the escarpment along the north side of the Buhne Point terrace and riprap along the shoreline of Humboldt Bay. (Photograph JW-2-1 taken March 9, 2000.)

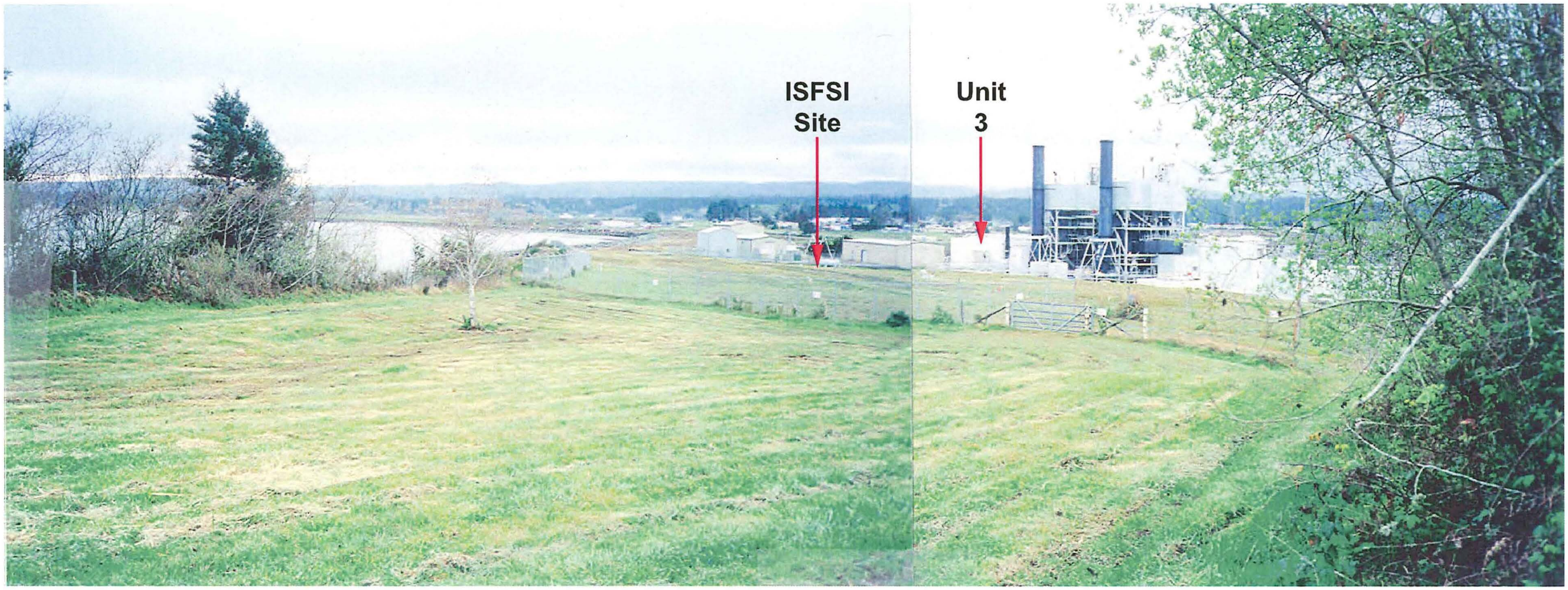
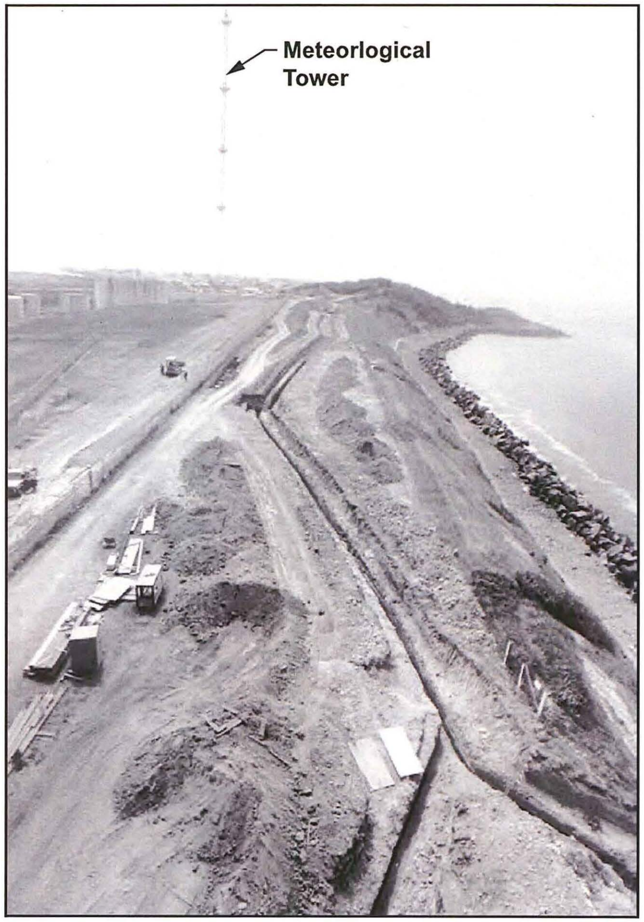


Photo 4-4 View to east of Buhne Point terrace surface and ISFSI site. (Photographs JW-2-5 and JW-2-8 taken March 10, 2000.)

(A)



(B)

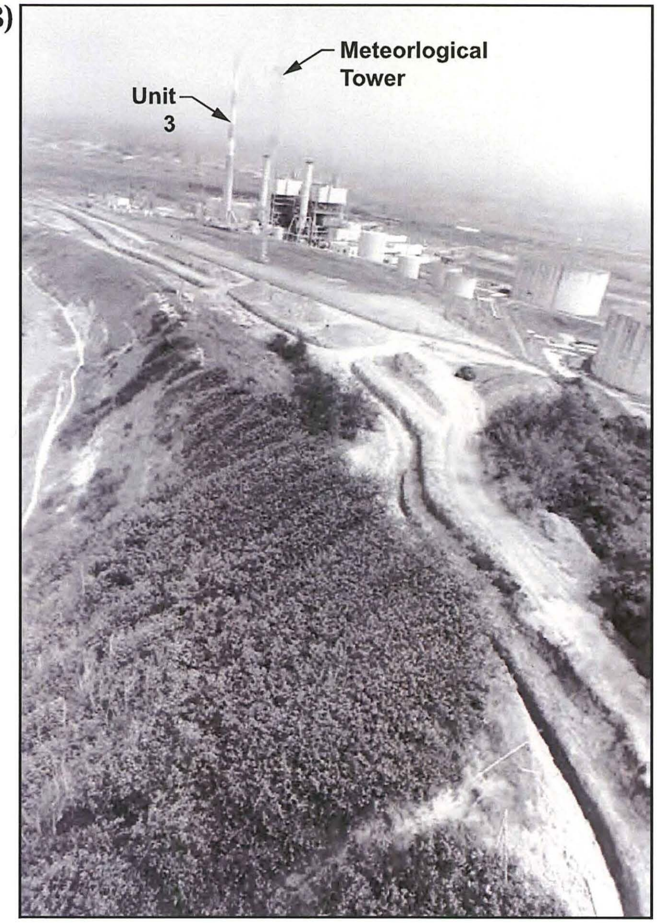


Photo 4-5 Oblique aerial photographs showing disturbance of Buhne Point terrace during trenching activities by Earth Sciences Associates (circa 1975). (A) View to the west-southwest. (B) View to the east-southeast.

Photo 4-6 Outcrop of sand with interbedded silt (light layers) in sea cliff north of ISFSI site. Scale is in tenths of feet. View to the south-southeast. (Photograph JW-1-9 taken March 2, 2000.)

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Photo 4-7 Trench GMX-T1, view east-southeast. View along trench with Humboldt Bay Power Plant in the background. Part of trench GMX-T2 is in the foreground. (Photograph FHS-00/8-1 #29 taken August 1, 2000.)

Photo 4-8 Surveying geologic contacts in trench GMX-T2. View is toward the south. (Photograph FHS-00/7-4 #9 taken August 1, 2000.)

Photo 4-9 Artificial fill overlying sand and silt layers of the upper Hookton Formation in northwest wall of trench GMX-T2 between station 36 ft. and station 44 ft. (Photograph FHS-00/7-4 #19 taken August 1, 2000.)

Photo 4-10 Clay fractures in upper Hookton Formation in trench GMX-T2. Fractures are at station ~25 ft., depth ~5 ft. Note continuous bedding across fractures below where they have been bleached in the weathered silty clay. (Photograph FHS-00/8-3 #32 taken August 3, 2000.)

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Photo 4-11 Fracture lined with black compressed rootlets in clayey-silt bed in trench GMX-T2. Fracture is at station 40 ft., depth ~11 ft. (Photograph FHS-00/7-3 #21 taken August 3, 2000.)

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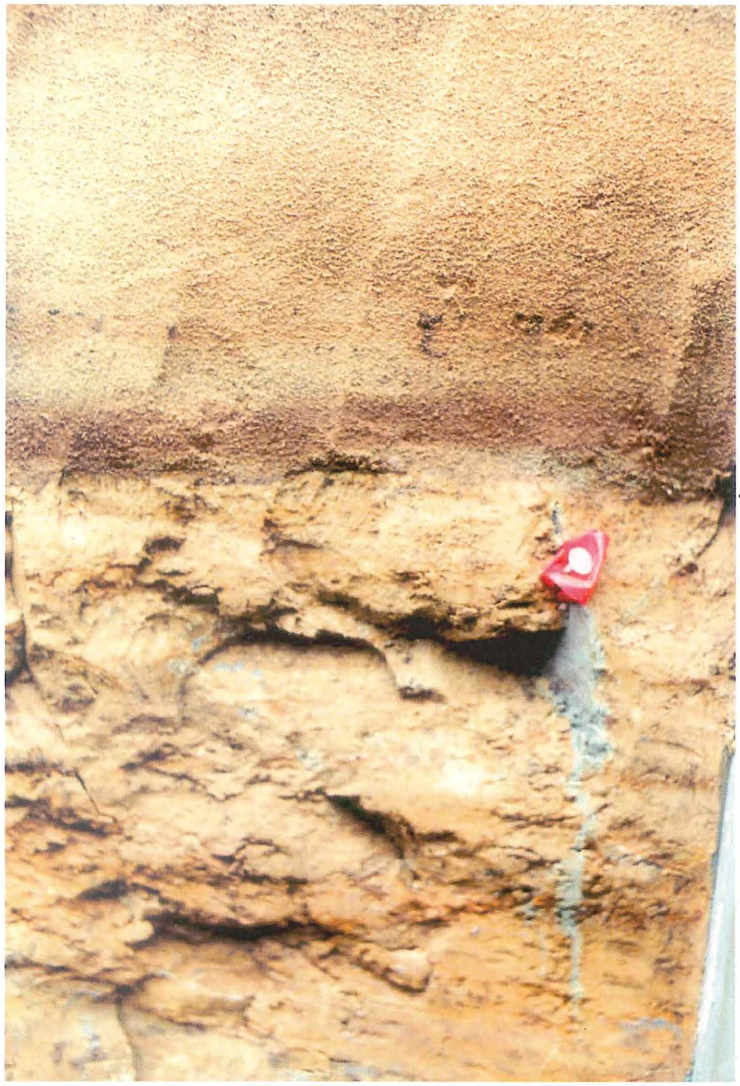


Photo 4-12 Continuous bedding across bleached fracture in silty clay in trench GMX-T2. Fractures are at station 30 ft., depth ~4 ft. (Photograph FHS-00/8-3 #26 taken August 3, 2000.)

Section 5.0
Seismic Source Characterization

5.1 INTRODUCTION

Interpretations of the tectonic framework of the Mendocino triple junction region have evolved rapidly during the past few decades as new geologic, seismologic, and crustal structure information has become available. In particular, the characterization of the Cascadia subduction zone has changed dramatically (see Section 2.0). Prior to the mid 1980s, the Cascadia subduction zone was judged not to be seismically active by the majority of seismologists and geologists, and was interpreted not to have the capability of producing significant earthquakes. As new geologic evidence was identified during the mid and late 1980s, the perception of the capability of the subduction zone changed, and by the mid 1990s, a new scientific consensus that the subduction zone is capable of generating great earthquakes had evolved (Atwater and others, 1995).

Because the scientific community increasingly accepted the Cascadia subduction zone as a potential source for earthquakes, the California Seismic Safety Commission, along with the California Department of Transportation (Caltrans) and the Oregon Department of Transportation, sponsored studies to define the characteristics and assess the consequences of a Cascadia subduction earthquake. In California, the California Division of Mines and Geology (CDMG) prepared a Cascadia earthquake scenario analysis (Toppozada and others, 1995). The CDMG scenario earthquake was defined as a "Gorda segment" rupture, involving slip on the southern 240 kilometers of the Cascadia interface and generating a magnitude 8.4 earthquake[1]. Additionally, the CDMG scenario event included slip on the Little Salmon fault zone that was triggered by slip on the subduction interface. The Little Salmon fault zone was interpreted to be

[1] Earthquake magnitudes are moment magnitudes, **M**, unless otherwise stated.

a crustal thrust fault above the Cascadia interface. The scenario earthquake was also considered to be a source for generating a local tsunami.

5.2. DESIGN INPUTS

5.2.1 Width Approaches for Cascadia Interface

The width of the Cascadia interface depends on the location of the updip (shallowest point) and downdip (deepest point) limits of potential seismogenic rupture. Geomatrix (1995, page 2-21) gives two alternative models for the location of the updip limit and two alternative models for the location of the downdip limit.

The updip extent is defined by either the location of the deformation front or the location of the change in structural trends near the slope break (change in fold trends). Geomatrix (1995, p 2-21) estimates that fault width using the change in fold trends boundary is 25 km less than using the deformation front boundary. Geomatrix (1995, page 2-21) gives relative weights of 0.7 to the change in fold trends model and 0.3 to the deformation front model.

The downdip extent is defined by either the location of the zero isobase line or the midpoint of the transition zone defined by the thermal and geodetic modeling. Geomatrix (1995, page 2-21) gives relative weights of 0.6 to the zero isobase model and 0.4 to the thermal-geodetic model.

On page 2-21 of Geomatrix (1995), the width of the Cascadia interface is given for the four combinations of the locations of the updip and down-dip limits, but the values are not correct. It appears that they incorrectly used the location of the change in fold trends as the location of the deformation front and the change in the fold trends was placed 25 km east of the misplaced deformation front. The result of this error is that interface widths listed in Geomatrix (1995) are too small. New calculations of the width of the interface are made in section 5.4.1 below.

5.2.2 Dimensions of the Cascadia Interface

Rupture Lengths

Carver (2002c) models the Cascadia interface as a combination of the Cascadia interface, Little Salmon fault zone, and Table Bluff fault. The alternative models for the lengths of the Cascadia interface ruptures and the weights for the alternatives given by Carver (2002c) are listed in Table 5-1.

Dip

Cohee et al. (1991, p. 37, caption to Figure 3) give the dip of the interface of 11° in Washington and 21° in Oregon. The average value of 16° degrees is used for the fault rupture.

5.2.3 Little Salmon Fault Zone

Rupture Length

Carver (2002c) defines the Little Salmon fault zone as extending from the Yager fault to the Thompson Ridge fault (PG&E, 2002a, Figure 2-5). The length of the zone is 310 km (Carver 2002c, pg 5A-6).

Dip

Carver (2002c) gives three possible dips of the fault of 40, 45, and 50 degrees; weights on each are 0.2, 0.6 and 0.2, respectively.

Crustal Thickness

The thickness of the crust in the HBIP region is given as 15 km (Carver, 2002c).

Displacement per Event

The fault displacement is given as 7m or 9.3m (equally likely) (Carver, 2002c).

Style of Faulting

The Little Salmon fault is a reverse slip fault (Carver, 2002c).

5.3 METHOD AND EQUATION SUMMARY

5.3.1 Method

The magnitude of the Maximum Credible Earthquake is computed based on the mean magnitude determined for the maximum rupture area or fault displacement

5.3.2 Equations

Magnitude-Area Relations

The Wells and Coppersmith (1994; Table 2A, p. 990) scaling relation for magnitude as a function of rupture area for crustal faults (using all fault types) is given by

$$M = 0.98 \, \text{Log}(A) + 4.07 \tag{5-1}$$

where A is the rupture area in km^2 and M is moment magnitude.

The Abe (1981;1984) relation for magnitude as a function of rupture area for subduction zones is given by (Geomatrix, 1995, p. 2-29)

$$M = \text{Log}(A) + 3.99. \tag{5-2}$$

The Geomatrix (1993) relation for magnitude as a function of rupture area for subduction zones is given by (Geomatrix, 1995, p. 2-29)

$$M = 0.81 \, \text{Log}(A) + 4.7 \tag{5-3}$$

Magnitude-Displacement Relations

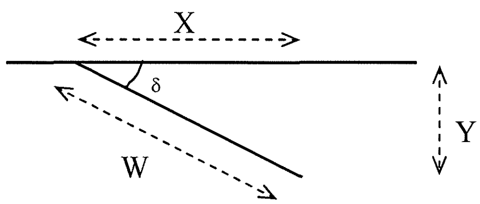
The Wells and Coppersmith (1994; Table 2B, p. 991) scaling relation for magnitude as a function of average fault displacement for crustal faults (using all fault types) is given by

$$M = 0.82 \, \text{Log}(D) + 6.93 \tag{5-4}$$

where D is the average displacement over the rupture surface in m.

Downdip Width

The following illustration is used for Eqns. 5-5 and 5-6.



For a fault with dip δ and horizontal extent X, the downdip width, W, is given by

$$W = \frac{X}{\cos(\delta)} \tag{5-5}$$

For a fault with dip δ and vertical extent Y, the downdip width, W, is given by

$$W = \frac{Y}{\sin(\delta)} \tag{5-6}$$

Eq. (5-5) and (5-6) are well known trigonometric relations.

Weighted Average

Given N values X_i with weights wt_i, the weighted mean is (Bevington, 1969, p. 73)

$$Mean = \frac{\sum_{i=1}^{N} X_i \, wt_i}{\sum_{i=1}^{N} wt_i} \tag{5-7}$$