Woodward-Clyde Consultants

REVIEW OF THE MAGNITUDE OF THE JULY 16, 1936 WALLA WALLA AREA EARTHQUAKE

Report prepared for

Washington Public Power Supply System
Richland, Washington

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by

Woodward-Clyde Consultants
3 Embarcadero Center, Suite 700
San Francisco, CA 94111

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REVIEW OF THE MAGNITUDE OF THE JULY 16, 1936 WALLA WALLA AREA EARTHQUAKE

The purpose of this report is to review the methods that have been used to assess magnitudes for the July 16, 1936, Walla Walla area earthquake. The nature of each of the alternative magnitudes that have been assigned to this event is clarified, and the utility of these types of magnitudes as bases for engineering analyses of earthquake ground motions is evaluated.

Summary of Conclusions

The results of this review indicate that the 5-3/4 magnitude published by Gutenberg and Richter (1954) for the July 16, 1936 earthquake is a surface-wave magnitude, M_S. Using Gutenberg's original amplitude data and station corrections that were subsequently established, the magnitude of this event has been recomputed as M_S 5.7 ± 0.3, which is very close to the M_S of 5.8 originally computed by Gutenberg.

The magnitude value of 6.1 reported by Woodward-Clyde Consultants (1980) was determined primarily from Calfornia Wood-Anderson seismograph trace amplitudes, using the relationships developed by Gutenberg and Richter (1936), in the form of the nomogram presented by Gutenberg and Richter (1942). The Wood-Anderson data were recorded at epicentral distances between 9 degrees and 13.5 degrees, and the periods corresponding to the maximum trace amplitudes are in the range of 2 to 10 seconds. The magnitude thus computed is denoted "M", conforming with the original notation of Richter (1935) and Gutenberg and Richter (1936).

Current usage of the term "local magnitude, M_L" is reserved for magnitudes determined from Wood-Anderson data recorded at distances normally restricted to less than 5 degrees (Richter, 1958). Originally, however, the formulation for calculating

magnitudes from Wood-Anderson trace amplitudes was extended out to distances as great as 15 degrees (Gutenberg and Richter, 1936). At that time, all magnitudes (including those calculated from surface-wave data recorded at teleseismic distances) were denoted simply as "M", since the scale was originally intended to yield compatible magnitude values at all distances. It has been found, however, that magnitudes calculated within different distance ranges are not, in fact, entirely compatible. Specifically, a magnitude, M, calculated from Wood-Anderson trace data recorded at distances in the range 5 degrees to 15 degrees is not necessarily equivalent to an M_L, for two main reasons:

1) Maximum trace amplitudes recorded on Wood-Anderson instruments at distances less than 5 degrees correspond to waves having periods of approximately one second or less, for which the response of the Wood-Anderson is flat. Periods associated with maximum trace amplitudes recorded at distances between 5 degrees and 15 degrees, however, are generally in the range of 1 to 12 seconds, for which the instrument response becomes progressively less.

2) The crustal attenuation characteristics along the particular travel paths between the earthquake focus and stations in the distance range of 5 degrees to 15 degrees may not be adequately represented by the average attenuation model that is incorporated into the formulation of the original magnitude scale (Richter, 1958).

Comparison of locally computed M_L values for recent California earthquakes with M values calculated from 6- to 12-second period maximum amplitude waves recorded at Newport, eastern Washington suggests that the M values thus determined are consistently higher than M_L. The average difference for the 10 earthquakes studied is about one-half magnitude unit. Because the propagation paths from these Californian earthquakes to Newport are nearly reciprocal to the paths from the 1936 epicenter to the

California stations that were used to determine its magnitude, this difference between M and M_L may also apply to the 1936 earthquake magnitude. However, the results of the present study are not sufficient to permit estimation of a rigorous numerical correction to convert M to M_L for this earthquake.

Existing empirical relationships used for evaluation of earthquake ground motions are based on the M_L, M_S, and other magnitude scales. To our knowledge, no empirical relationships have been developed based on magnitudes determined from Wood-Anderson data in the period range of 2 to 12 seconds. Therefore, because well-calibrated, local data are insufficient to directly calculate a reliable local magnitude (M_L) for the 1936 earthquake, earthquake ground motion evaluations for this event should be based on the M_S value, which has been calculated directly.

Surface-Wave Magnitude

The 5-3/4 magnitude for the 1936 earthquake was first published in the standard reference, "Seismicity of the Earth" (Gutenberg and Richter, 1949; 2nd Edition, 1954). Geller and Kanamori (1977) have shown that the magnitudes of most shallow, "class a" (magnitude greater than, or equal to, 7-3/4) earthquakes listed in "Seismicity of the Earth" are essentially equivalent to 20-second surface-wave magnitudes, M_S, even though M_S was not formally defined until 1945 (Gutenberg, 1945), and the final version of the scale was not presented until 1956 (Gutenberg and Richter, 1956a). This equivalence to M_S of magnitudes computed for large, pre-1945 earthquakes from teleseismic observations is to be expected: the work done by Gutenberg and Richter (1936) to extend Richter's (1935) magnitude scale, M, to distances beyond 15 degrees utilized ground displacement amplitudes of surface waves and essentially established the basis for the M_S scale.

In view of this equivalence, the magnitude 5-3/4 listed in "Seismicity of the Earth" for the July 16, 1936 earthquake was assumed

to be a surface-wave magnitude. To review and verify this magnitude calculation, Gutenberg's original worksheets were retrieved from the California Institute of Technology. A copy of the worksheet for the 1936 earthquake is shown in Appendix A to this report.

This worksheet confirms that the original magnitude was calculated using ground displacement amplitudes recorded at distant stations. These data are reproduced in Table 1. The average of Gutenberg's magnitude calculations for 6 stations is 5.8, which was published in fractional form as 5-3/4 in "Seismicity of the Earth". The stations used, Pulkovo, Baku, Tashkent, Hamburg, De Bilt and Paris are distributed over an azimuthal range of approximately 45 degrees (see Table 2), which is a somewhat limited sample of the radiation pattern from the earthquake.

The magnitudes were recomputed using Gutenberg's original data and relationships for M_S presented by Gutenberg (1945):

$$M_S = \log A - \log B + C + D \qquad (1)$$

where: A is the zero-to-peak amplitude of the horizontal component of maximum ground displacement in microns,

B is the same quantity for the "zero magnitude" or "standard" shock (Richter, 1958) and is given by the following empirically derived relationship (Gutenberg, 1945):

$$-\log B = 1.818 + 1.656 \log\Delta \qquad (15° < \Delta < 130°) \qquad (2)$$

C is the individual station correction as given in Gutenberg (1945), and

D is a correction that accounts for the focal depth and radiation pattern of the earthquake and for absorption along the path.

TABLE 1

ORIGINAL MAGNITUDE COMPUTATION BY GUTENBERG
FOR THE JULY 16, 1936 EARTHQUAKE*

Station	Horizontal Ground Amplitude (microns)			Magnitude
Pulkovo	1-1/2	5.0	0.2	5.2
Baku	7	5.2	0.8	6.0
Tashkent	7	5.2	0.8	6.0
Hamburg	5	5.0	0.7	5.7
De Bilt	6	5.0	0.8	5.8
Paris	6	5.0	0.8	5.8

Average magnitude = 5.8 (± 0.3)

*See Appendix A

TABLE 2

RECOMPUTED MAGNITUDE FOR THE JULY 16, 1936 EARTHQUAKE

Station	Δ (deg)	AZ (deg)	Horizontal Ground Amplitude (microns)	-log B	log A	C	D	M_S
Pulkovo	70.9	016	1.5	4.88	0.18	+0.04	+0.1	5.20
Baku	92.8	009	7.0	5.08	0.85	-0.21	+0.1	5.82
Tashkent	92.2	354	7.0	5.07	0.85	+0.14	+0.1	6.16
Hamburg	71.0	030	5.0	4.88	0.70	-0.23	+0.1	5.45
De Bilt	70.4	033	6.0	4.88	0.78	-0.17	+0.1	5.59
Paris	71.9	037	6.0	4.89	0.78	-	+0.1	5.77

Average M_S = 5.7 ± 0.3

$$M_S = \log A - \log B + C + D$$

The results of this recomputation are presented in Table 2, which gives an average M_S of 5.7. This value is very close to the original published value. For the 1936 earthquake, it appears that Gutenberg effectively estimated D = 0.1 and set C = 0 (the station corrections had probably not yet been estimated at the time that this magnitude was originally computed); if so, the two columns following the amplitude in Table 1 correspond to " - log B + D" and "log A", respectively in Equation 1. When the station corrections are not included, over-estimation of the magnitude is by only 2 percent.

Magnitude Determined from Wood-Anderson Records

The 1936 earthquake occurred at the time when the definition of the magnitude scale was undergoing its initial development. Richter (1935) defined the magnitude, M, of an earthquake in terms of the trace amplitude, A, recorded on a standard Wood-Anderson seismograph (free-period = 0.8 second, magnification = 2800, damping = 0.8) by the relationship:

$$M = \log A - \log A_o \qquad (3)$$

The empirical part of the development of this scale consisted of determining $\log A_o$ as a function of distance ($\log A_o$ is a normalizing factor that accounts for the attenuation of seismic energy with distance). Richter (1935) accomplished this using Wood-Anderson data recorded at the Pasadena stations, and produced a table of $\log A_o$ versus distance, Δ, up to 600 km (5.5 degrees). The table was limited to this distance range at that time only because insufficient data were available for larger distances. Richter (1935) observed that the data for distances less than 600 km fit the relationship:

$$\log A = 3.37 - 3 \log \Delta \qquad (4)$$

Data subsequently collected for the distance range 200 to 1500 km (13.5 degrees) were found to be fairly well represented by this relationship. Therefore, Gutenberg and Richter (1936) used Equation (4) to extend the magnitude scale to 15 degrees. In that paper, values of log A_O derived from Equation 4 were plotted as a function of distance in the range 5 degrees to 15 degrees (Gutenberg and Richter, 1936, Figure 6). The scale was also extended beyond 15 degrees using the amplitudes of ground displacement of surface waves at teleseismic distances, thus providing the basis for the M_S scale.

A nomogram for computing magnitudes from Wood-Anderson trace amplitudes up to distances of 100 degrees was presented by Gutenberg and Richter (1942), based on Figure 6 of Gutenberg and Richter (1936). Gutenberg and Richter (1956a) gave a table of log A_O versus distance up to a distance of 1000 km (9 degrees). The distinction between local magnitudes and surface-wave magnitudes was first effectively made by Gutenberg (1945), and the terms M_L and M_S were introduced by Gutenberg and Richter in 1956 (Gutenberg and Richter, 1956a,b).

The nomogram presented by Gutenberg and Richter (1942) was used by Woodward-Clyde Consultants (1980) to calculate the magnitude of the 1936 earthquake from the seismograms that had been collected to investigate the epicentral location and focal mechanism of this event. These data include 12 Wood-Anderson seismograms, 11 of which were recorded at stations of the Pasadena and Berkeley networks. The Wood-Anderson stations used for the magnitude calculation were located at epicentral distances in the range 9 degrees to 15 degrees. Records from other types of seismographs located within the distance ranges of 5 degrees to 7 degrees and 15 degrees to 24 degrees were also used in the calculation, although the calibrations of these instruments are less certain then those of the Californian Wood-Anderson instruments. The result of this calculation is a magnitude, M, of 6.1, as reported by Woodward-Clyde Consultants (1980).

Current usage of the term "local magnitude", M_L, is restricted to magnitudes determined from Wood-Anderson trace amplitudes using Equation (3) for distances normally less than 5 degrees (Richter, 1958). Despite the fact that the scale was originally extended beyond this range, Wood-Anderson magnitudes (M) calculated from data recorded at greater distances cannot be assumed, in general, to be equivalent to locally calculated M_L magnitudes, for two reasons:

1) At distances up to 5 degrees, maximum trace amplitudes correspond to S or surface waves that have periods of about 1 second or less, which are within the flat part of the Wood-Anderson frequency response. As distance increases beyond 5 degrees, maximum amplitudes correspond to surface waves that have progressively longer periods for which the magnification of the Wood-Anderson becomes progressively smaller. However, magnitudes calculated according to the original formulation (Gutenberg and Richter, 1936) for distances less than 15 degrees use the maximum trace amplitude irrespective of the seismograph phase or period. Gutenberg and Richter (1936) observed that the variation in the period of the maximum amplitude wave and in the magnification of the Wood-Anderson seismograph is the cause of the divergence of the assumed relationship expressed by Equation 4 from the observed data in the distance range 6 degrees to 25 degrees (Gutenberg and Richter, 1936, Figure 6). Gutenberg and Richter's (1936) original data indicate systematic deviations in magnitudes determined from their adopted log A_o curve; these deviations are high by 0.07 magnitude units at 8 degrees, increasing to 0.24 units at 15 degrees.

2) As stated by Richter (1958), calculation of magnitudes using the log A_o versus distance relationship extended to distances beyond 5 degrees is subject to uncertainties arising from lack of adequate data needed to rigorously verify the relationship in this distance range, differences in seismic wave

attenuation along different paths that may not be adequately represented by the log A_o relationship, and the effects of local crustal structure.

Differences Between July 16, 1936 Calculated Magnitude, M, and M_L

It is clear, therefore, that the magnitude 6.1 calculated for the July 16, 1936 earthquake from Wood-Anderson seismograms should not be assumed to be equivalent to an M_L magnitude. Although there is no simple way to convert this magnitude (or the M_S value) to an equivalent M_L, the possible difference between this magnitude and M_L was investigated. The magnitude calculated for the 1936 earthquake might differ from a locally calculated M_L because of a combination of the two factors discussed above:

1) The magnitude was calculated using the maximum amplitudes of waves that have periods (2 seconds to 10 seconds) greater than 1 second.

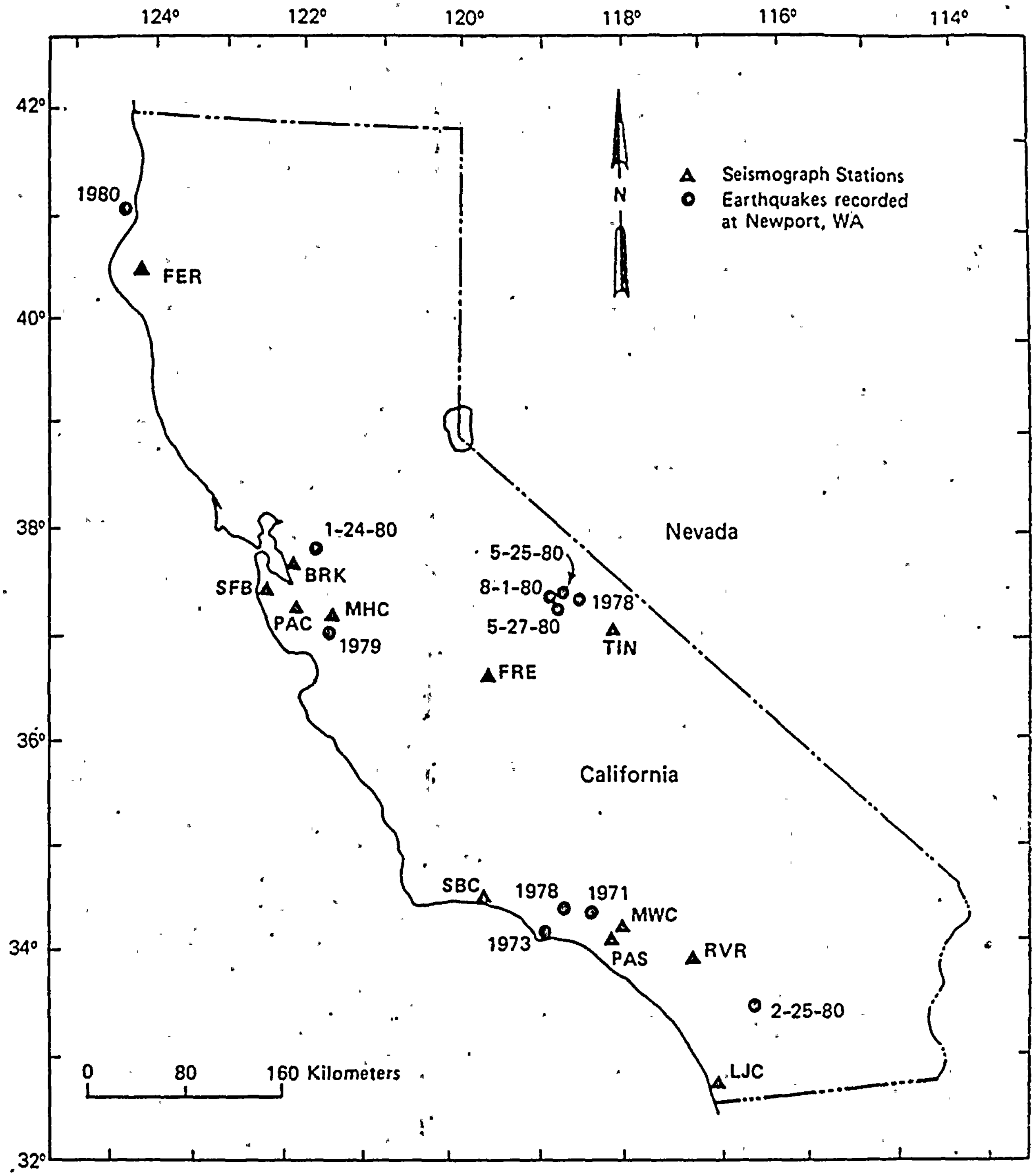
2) The propagation paths from the hypocenter to the stations used include paths, or portions of paths, outside of California and may not be adequately represented by Richter's (1936) plot of log A_o versus distance.

As discussed above, the observed data in the 10- to 15-degree distance range suggests that Factor 1 (above) may result in magnitudes that are too high by 0.07 to 0.24 units. The magnitude calculated by Woodward-Clyde Consultants (1980) relies primarily on data from 11 northern and southern California Wood-Anderson stations, which have azimuths in the range 176 degrees to 201 degrees from the epicenter (Woodward-Clyde Consultants, 1980, Tables 6 and 8). Therefore, the particular characteristics of seismic attenuation along paths within this limited range of azimuths may significantly influence the magnitude calculation. (It should be noted, however, that the magnitudes calculated

using data from stations outside this range, such as Ferndale [azimuth 220 degrees], Tucson [azimuth 155 degrees], and College [azimuth 330 degrees], are in good agreement with those calculated from the California data). By reciprocity, this path effect should be the same for waves propagating in either direction along the same path (except for the effects of local crustal structure at the receiver end of each path). This factor is investigated using data from California earthquakes recorded in eastern Washington.

Each of the earthquakes selected for this investigation occurred close to one of the groups of stations that had been used to calculate the magnitude of the 1936 earthquake. Station and earthquake locations are shown in Figure 1. The earthquakes have well-constrained Pasadena or Berkeley local magnitudes, in the range of M_L 5.0 to 7.0. The reported M_L selected for each earthquake (Table 3) is the value calculated from the network (Berkeley or Pasadena) having stations closest to the epicenter; alternative values are shown in parentheses. All of the earthquakes produced clear Wood-Anderson seismograms at the station at Newport (NEW), Washington, which is located approximately 2 degrees north of the instrumental epicenter of the 1936 earthquake. The shape of the frequency response of the NEW Wood-Anderson seismographs shown in Figure 2 is identical to the standard Wood-Anderson response, but the NEW instruments are run at a magnification of 1400, 5600, 14,000, or 140,000. The azimuths from NEW to the selected test earthquakes, from NEW to the California Wood-Anderson stations, and from the epicenter of the 1936 earthquake to the California stations are all within 10 degrees of each other.

After normalizing the maximum trace amplitudes to a gain of 2800, a magnitude, M, for each of the test events was computed from the NEW Wood-Anderson seismograms in exactly the same manner as used for the 1936 magnitude calculation. The periods of the maximum



Project No. 14940E	Hanford FSAR	EARTHQUAKES USED IN THE MAGNITUDE INVESTIGATION AND CALIFORNIA STATIONS USED TO CALCULATE THE 1936 EARTHQUAKE MAGNITUDE	Figure 1
Woodward-Clyde Consultants			

TABLE 3

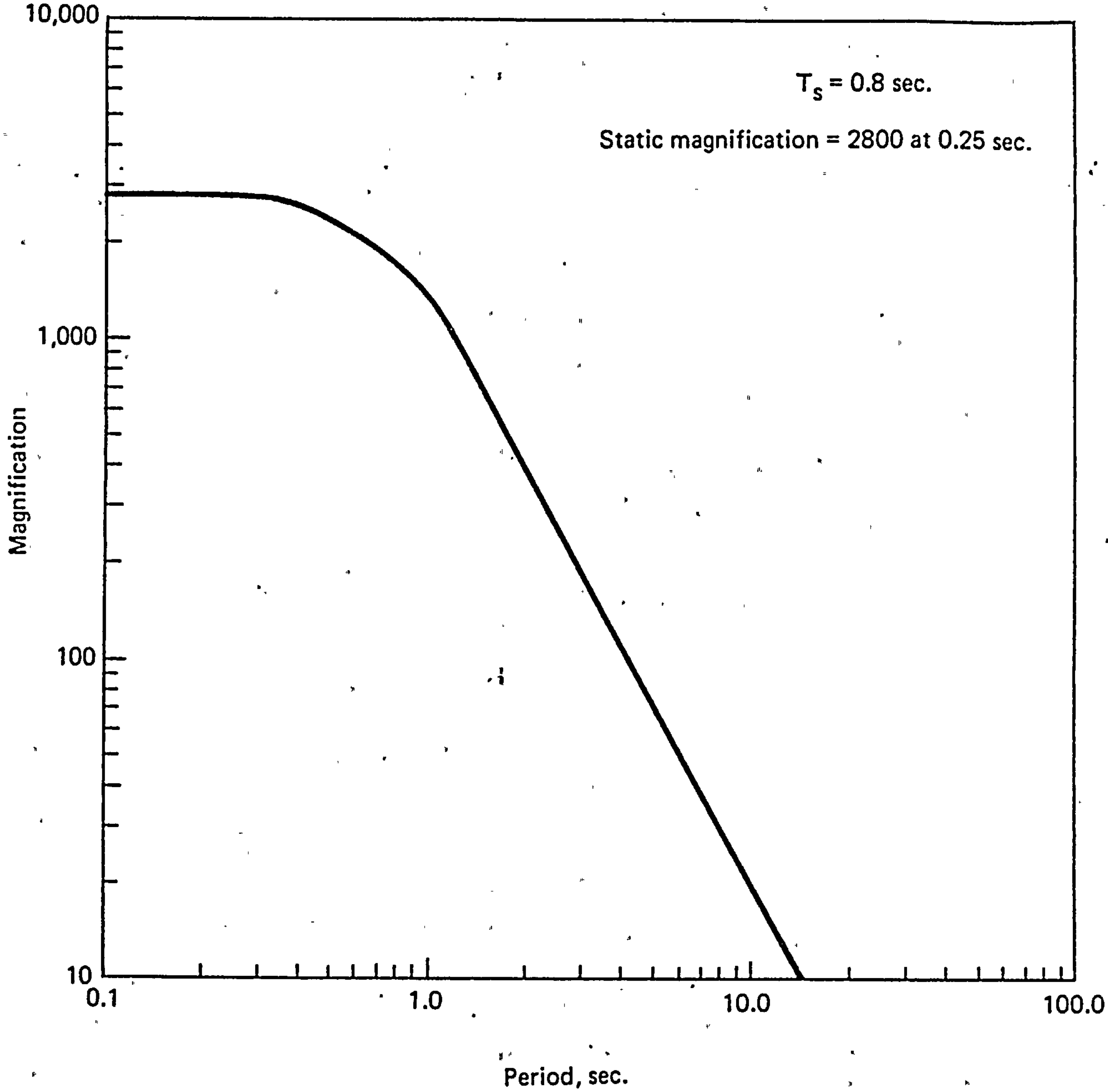
MAGNITUDE DETERMINATIONS FOR CALIFORNIAN EARTHQUAKES USING NEWPORT WOOD-ANDERSON SEISMOGRAMS

Earthquake	Epicenter LAT (Deg N)	Epicenter LON (Deg W)	Δ (Deg)	Az (Deg)	Corrected Max. Amp[1] N (mm)	Corrected Max. Amp[1] E (mm)	Average Max. Amp. (mm)	Calculated Magnitude, M	Reported M_L[2]	$M-M_L$	Period (sec)
AREA A											
San Fernando Feb. 9, 1971: 1400	34.4	118.4	13.9	004	17.2	9.5	13.4	7.3	6.4P (6.7B)	+0.9	9
Los Angeles Feb. 21, 1973: 1446	34.1	119.0	14.2	005	1.0	1.0	1.0	6.2	5.9P (5.6B)	+0.3	8
Santa Barbara	34.4	119.7	14.0	007	1.5	1.9	1.7	6.4	5.1P (5.7B)	+1.3	10
AREA B											
Bishop Sep. 4, 1978: 1643	37.53	118.63	10.8	005	1.1	1.5	1.3	6.0	5.8P,B	+0.2	8
Mammoth Lakes May 25, 1980: 1634	37.60	118.84	10.7	006	7.8	16.5	12.2	6.9	6.5P (6.1B)	+0.4	8
Mammoth Lakes May 25, 1980: 1945	37.57	118.82	10.7	006	3.9	8.2	6.1	6.6	6.7P (6.1B)	-0.1	12

TABLE 3 (continued)

Earthquake	Epicenter LAT (Deg N)	Epicenter LON (Deg W)	Δ (Deg)	Az (Deg)	Corrected Max. Amp[(1)] N (mm)	Corrected Max. Amp[(1)] E (mm)	Average Max. Amp. (mm)	Calculated Magnitude, M	Reported M_L[(2)]	$M-M_L$	Period (sec)
Mammoth Lakes May 27, 1980: 1451	37.48	118.81	10.8	006	4.3	7.6	6.0	6.7	6.3P (6.2B)	+0.4	8
Mammoth Lakes Aug. 1, 1980: 1639	37.56	118.89	10.8	006	0.4	0.7	0.6	5.7	5.3P (5.4B)	+0.4	8
AREA C											
Coyote Lake Aug. 6, 1979: 1705	37.1	121.5	11.6	015	1.6	1.9	1.8	6.2	5.9B	+0.3	6
Livermore Jan 24, 1980: 1900	37.9	121.8	10.9	017	1.6	5.0	3.3	6.4	5.5B	+0.9	8
Average, Groups A, B and C										0.50±0.41	

Notes: (1) Trace amplitudes normalized to magnification of 2800
(2) Reported M_L; P = Pasadena, B = Berkeley



Project No. 14940E	Hanford FSAR	FREQUENCY RESPONSE OF THE NEWPORT MODIFIED WOOD-ANDERSON SEISMOGRAPH: GEOTECH MODEL 17398	Figure 2
Woodward-Clyde Consultants			

amplitude waves at NEW for the test events are in the range of 6 to 12 seconds. These M magnitudes were, therefore, calculated using Wood-Anderson data recorded within the same range of azimuths and with roughly similar periods as the Wood-Anderson data used for the 1936 earthquake magnitude (M) calculation. The range of epicentral distances from NEW to the test events (10.8 to 14.2 degrees, Table 3) encompasses the distances from the 1936 epicenter to the California stations (9 to 13.4 degrees), although the distances from NEW to specific station/source localities are about 2 degrees greater than the distances from the 1936 epicenter to the same localities.

Results of Investigations

The results of this investigation are shown in Table 3. Magnitudes (M) determined from the NEW seismograms are compared with the reported M_L values by subtracting the two values, as shown in Column 11 of the table. It can be seen that, with the exception of one earthquake, the M values are consistently higher than the reported M_L values. Combining areas A, B, and C, the average difference $(M - M_L)$ is $+ 0.50 \pm 0.41$.

The results presented in Table 3 are not sufficiently definitive to permit estimation of a rigorous numerical correction to convert M values calculated using seimsic waves that have propagated along the path between California and eastern Washington (and vice versa) to M_L. Specific limitations and uncertainties in the present results are as follows:

1) There are insufficient data to assess the difference between M and M_L for each of the individual station/source localities; Area B (TIN/Mammoth Lakes) has the largest data set, and also (when the apparently anomalous result for the May 25, 1945 earthquake is neglected) gives the most consistent result (average $[M - M_L] = 0.35 \pm 0.10$).

2) Factors that probably contribute to the scatter in the results are the effects of differing source radiation patterns, focal depths and local crustal structures.

3) A station correction for NEW Wood-Anderson magnitudes has never been computed (L. Keriy, Newport Observatory; W. Person, National Earthquake Information Service, personal commmunications, February 1982). Therefore, the effect on the results of the local crustal structure at NEW has not been removed.

The potential effects of Factors 2 and 3 on the results cannot, at present, be separated from the effect of attenuation along the path between eastern Washington and the station/source localities. In applying these results to assess the relationship between M_L and the M 6.1 calculated for the 1936 earthquake, the following uncertainties also apply:

1) The effects of local crustal structure in the epicentral area of the 1936 earthquake and of the focal depth and source radiation pattern of the event have not been assessed.

2. NEW is 2 degrees farther north than the 1936 epicenter. This distance is between 15 and 20 percent of the total path distance from the California stations to the epicenter.

In summary, this study has shown that M magnitudes calculated using data from waves that have propagated along the path between California and eastern Washington appear to be consistently higher than M_L values calculated from local networks. These differences probably arise, in part, from a combination of two factors. The first factor is the systematic divergence of observed amplitudes from the log A_o curve that is used to define Richter magnitudes in the distance range of 5 to 15 degrees. The

second factor is the particular attenuation characteristics of the path between eastern Washington and California. Assuming path reciprocity, these results suggest that the M 6.1 calculated for the 1936 earthquake is probably higher than the M_L value that would be calculated from local data, if such data were available. The results of the present study are not sufficient to estimate a rigorous numerical correction for converting M to M_L either for the California - eastern Washington path in general, or for the 1936 earthquake in particular.

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APPENDIX A

COPY OF B. GUTENBERG'S WORKSHEET FOR
THE JULY 16, 1936 EARTHQUAKE

1936 July 16 7:07:47 45°57' 118°27'W USGS Near Walla Walla (Trans.

2cs -.4772
4m -.8788

46°N 118½°W

-333 -613 +717 7: 7:47

	Δ'	α	P	S-P	R-O	O	R-O	Δ	δ		r
Boz 9962	5.0	100	9:06	1:06	1:25	41	1:19	5.1	.1		
College 908	24.8	330	13:14	4:24	5:28	66	5:27	25.0	.2		
Seattle 9989	2.7	290	(8.33)	(0:43)	0:56	37	0:46	2.9	.2		
Sitka 9654	15.1	320	11:26	3:19	4:09	~~47~~	3:39	15.2	.1		
Tucs 9665	14.9	150	11:23	2:58	3:44	39	3:36	15.1	.2		
[illegible] 9915	7.5	220	9:48	1:26	1:50	58	2:01	8.2	.7		
Pasa 9792	11.9	200	10:41				2:54	11.9	.2		
Tin 9884	8.7	190	10:00				2:13	8.9	.2		
Berk 9892+	8.4	210	9:56	1:42	2:10	46	2:09	8.6	.2		
Lick		210	10:04								
Ferndale 9952	6.7	220	9:44				1:57	7.9	~~.2~~		
Florissant 928	21.4	110	12:42	3.57	4:56	46	4:55	21.8	-.1		
H-L			12:43	4:00	5:00	43					
Vict 9978	3.8	310	8:58				1:08	4.0	.2		
Pulk 317	71.5	30	(19:12)	(9:15)	11:30	42	11:25	71.7	.2	1/2	5.9 = 5.7
Sv 215	77.6	0	19:43	9:53	12:09	34	11:56	77.2	-.4	-	
Upku										7	5.8 6.0
Ukk										7	5.3 6.0
Hamb.										5	5.7
Strasb.										6	5.8 5.8
Paris										6	5.9 5.8

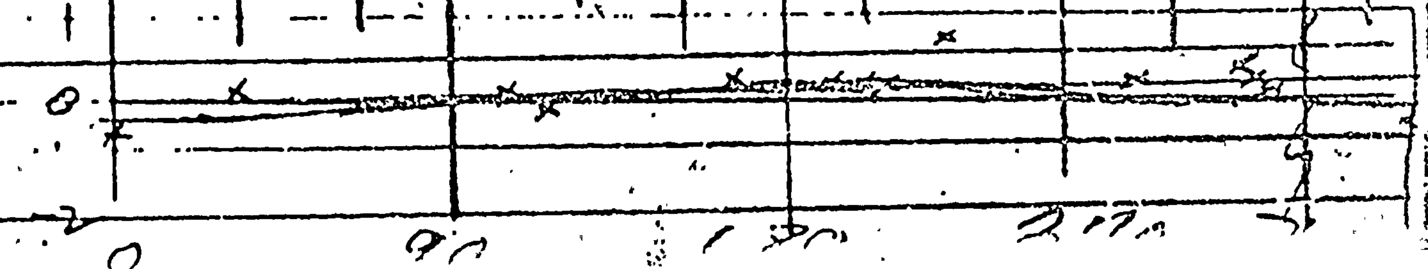
42

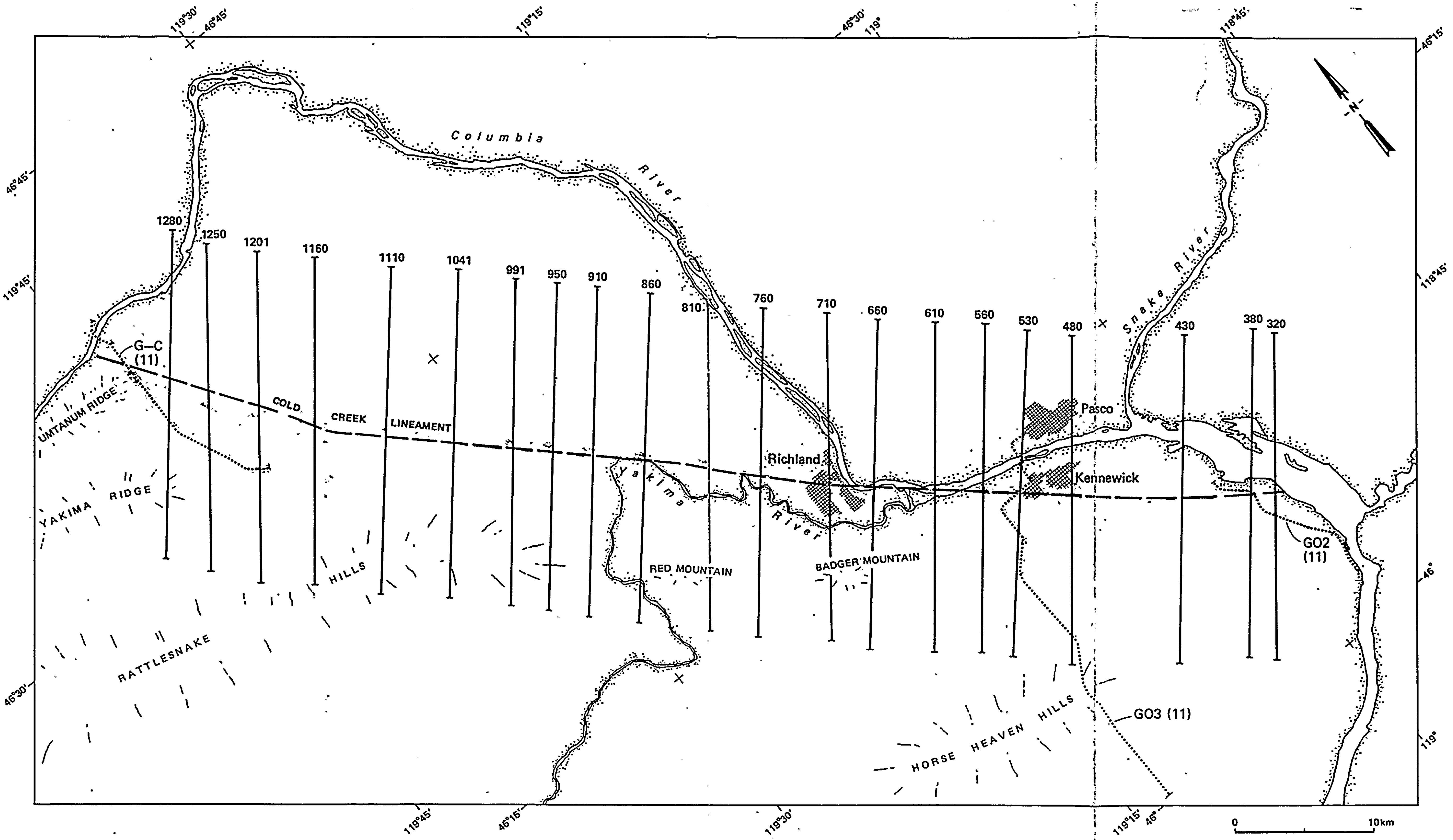
(5.8)

7:07:48

46 N 118½ W

Ad M = 5.8





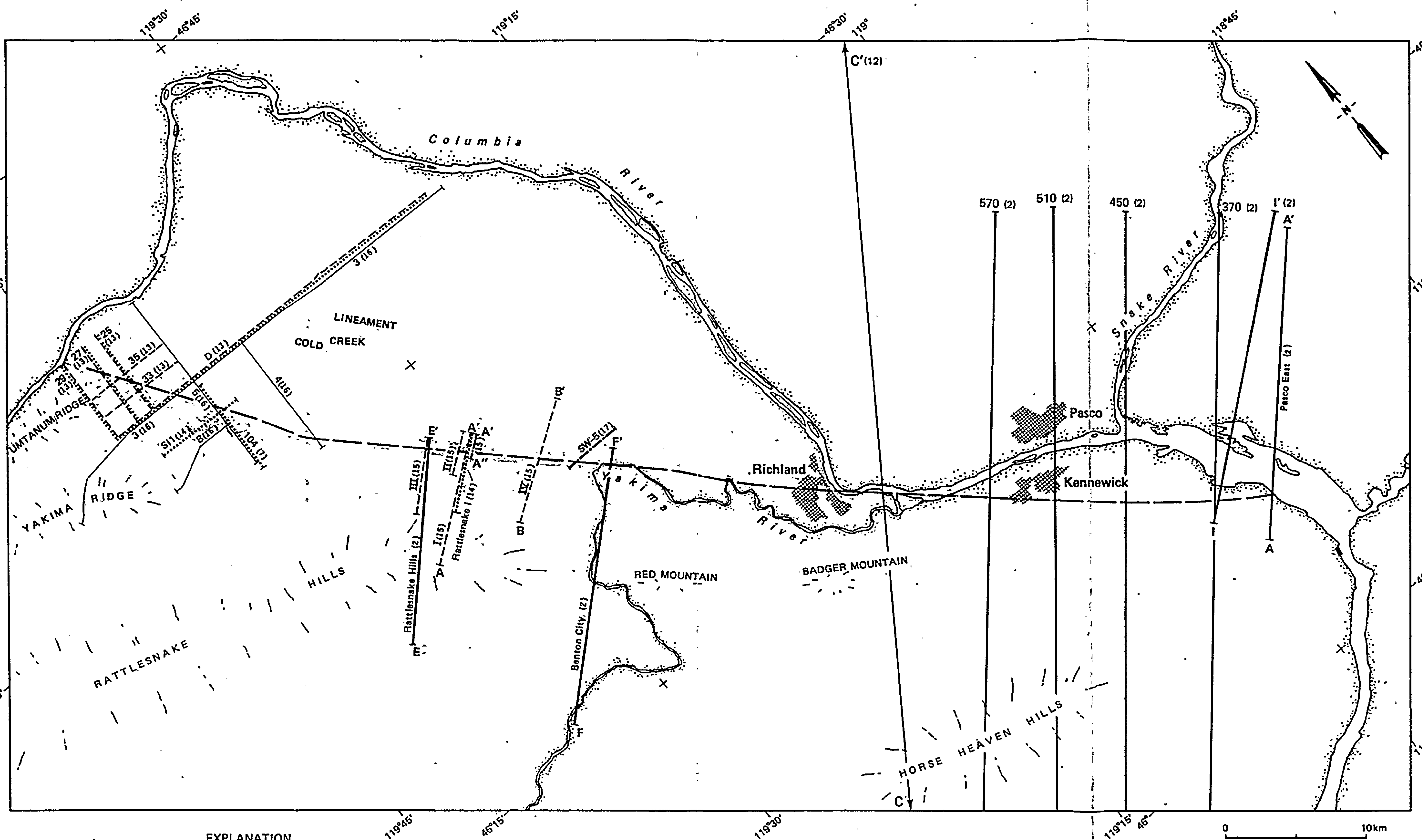
EXPLANATION

Aeromagnetic profile

Ground gravity traverse

NOTE: Profiles 320-1280 from Item (1) Table.
Profiles G-C and GO2 from Item (11) Table.

WASHINGTON PUBLIC POWER SUPPLY SYSTEM Nuclear Project No. 2	GEOPHYSICAL COVERAGE OF THE COLD CREEK LINEAMENT	Figure 10

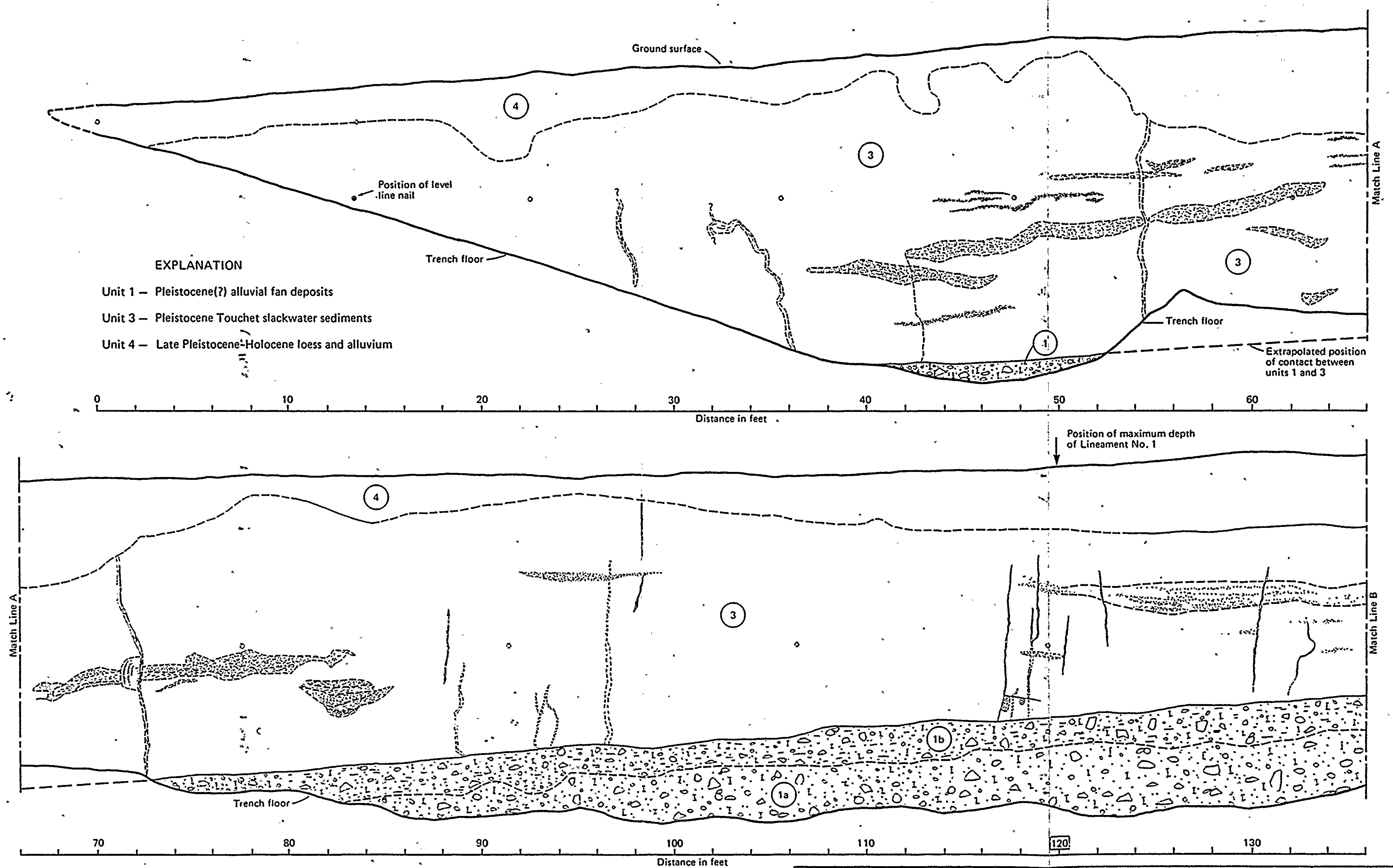


EXPLANATION

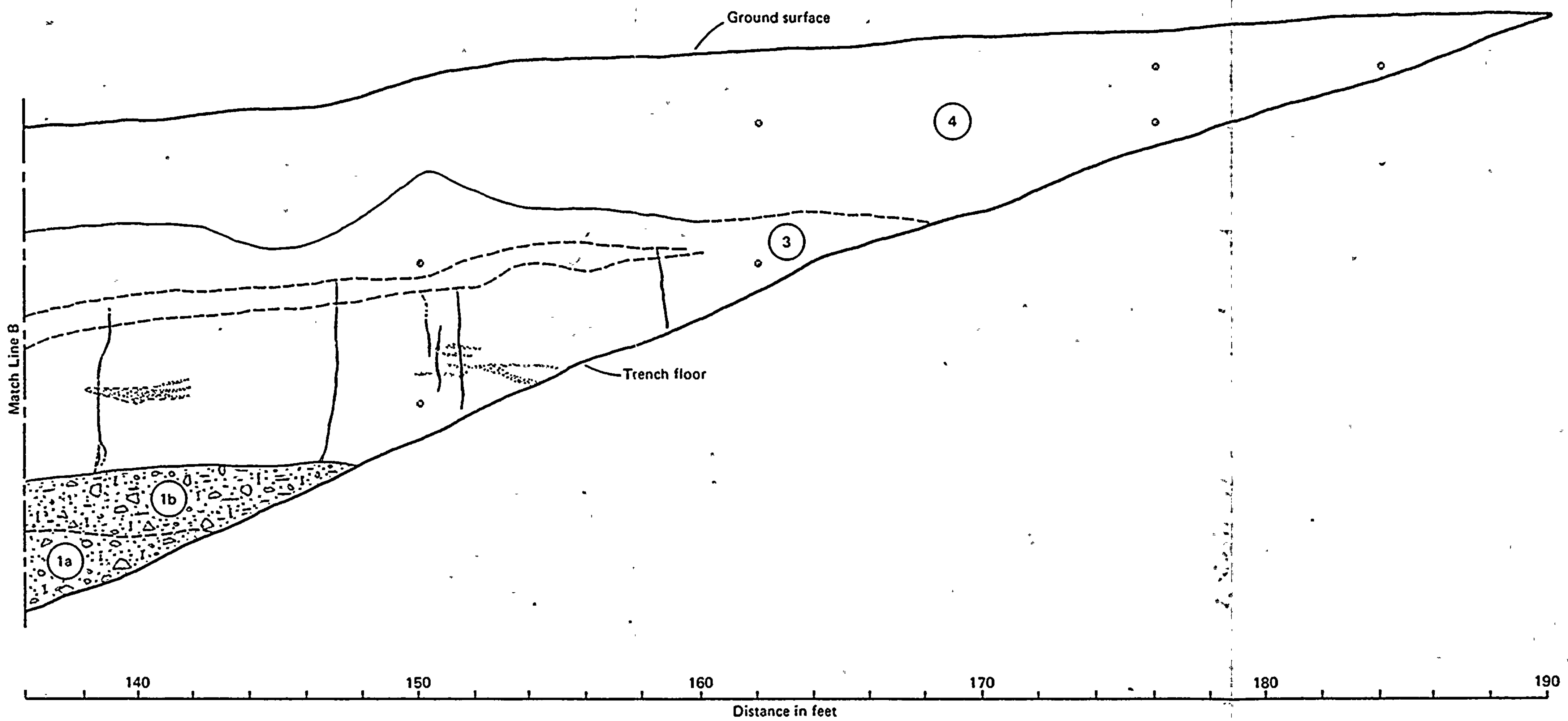
- Seismic reflection line
- Gravity traverse
- Aeromagnetic model profile
- Ground magnetic traverse
- Seismic refraction
- Gravity model profile

NOTE: Data sources indexed to Table 2. Numbers in parentheses correspond to item numbers in the table.

WASHINGTON PUBLIC POWER SUPPLY SYSTEM Nuclear Project No. 2	GEOPHYSICAL COVERAGE OF THE COLD CREEK LINEAMENT	Figure 11



WASHINGTON PUBLIC POWER SUPPLY SYSTEM Nuclear Project No. 2	LOG OF TRENCH RMT-1	Figure 6a



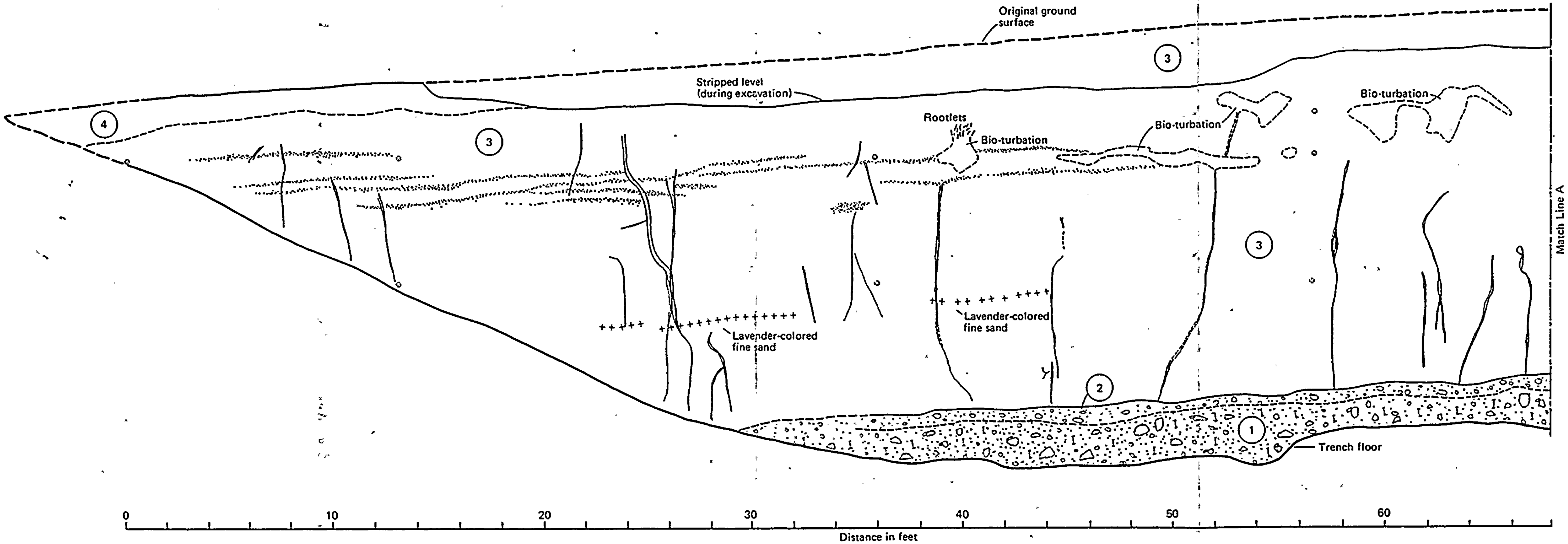
EXPLANATION

Unit 1 — Pleistocene(?) alluvial fan deposits

Unit 3 — Pleistocene Touchet slackwater sediments

Unit 4 — Late Pleistocene-Holocene loess and alluvium

WASHINGTON PUBLIC POWER SUPPLY SYSTEM Nuclear Project No. 2	LOG OF TRENCH RMT-1 (continued)	Figure 6b



EXPLANATION

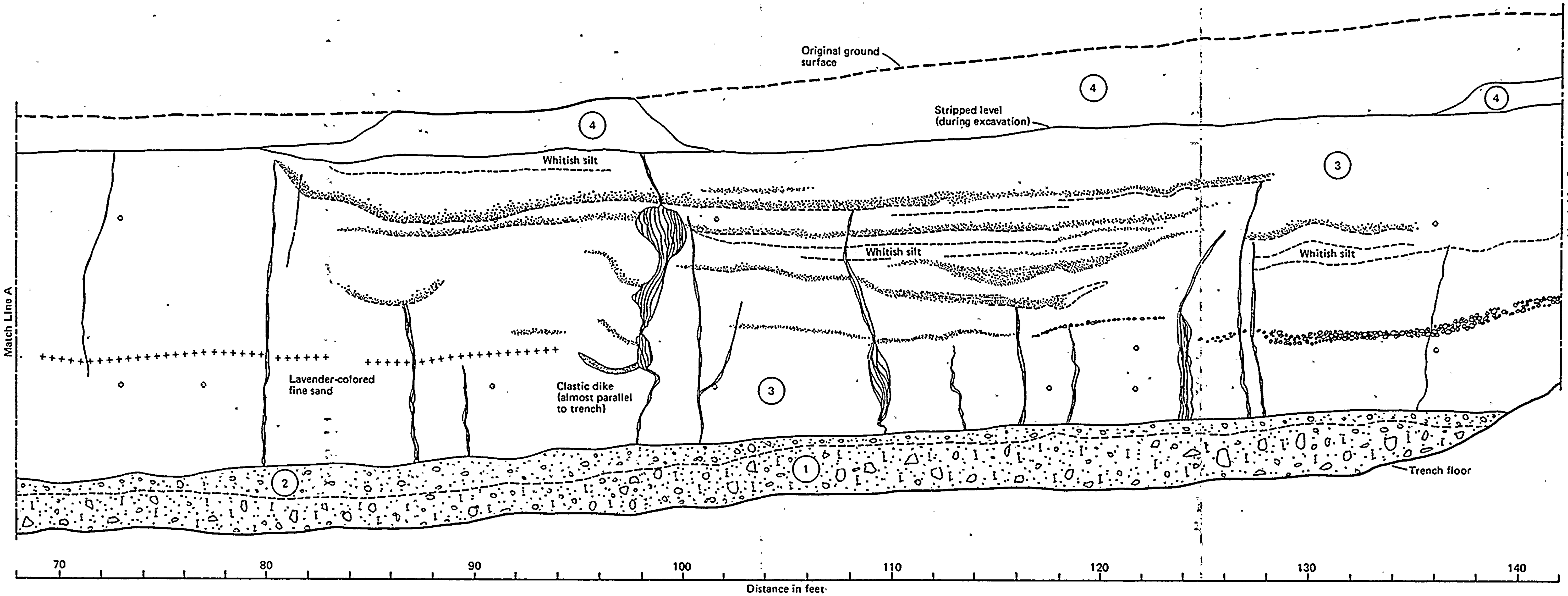
Unit 1 – Pleistocene(?) alluvial fan deposits

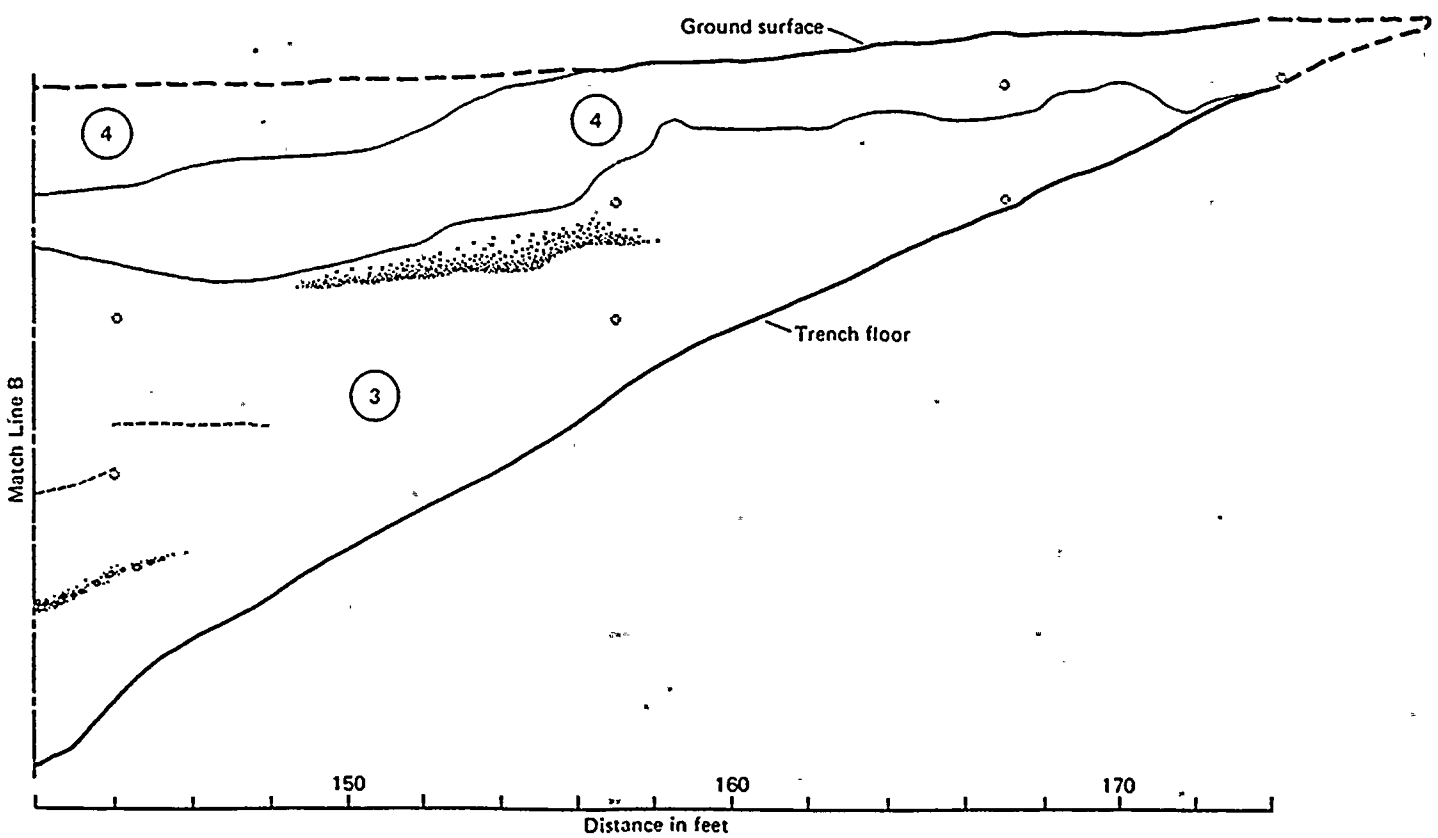
Unit 2 – Pleistocene(?) alluvial gravel

Unit 3 – Pleistocene Touchet slackwater sediments

Unit 4 – Late Pleistocene-Holocene loess and alluvium

WASHINGTON PUBLIC POWER SUPPLY SYSTEM Nuclear Project No. 2	LOG OF TRENCH RMT-4	Figure 7a





EXPLANATION

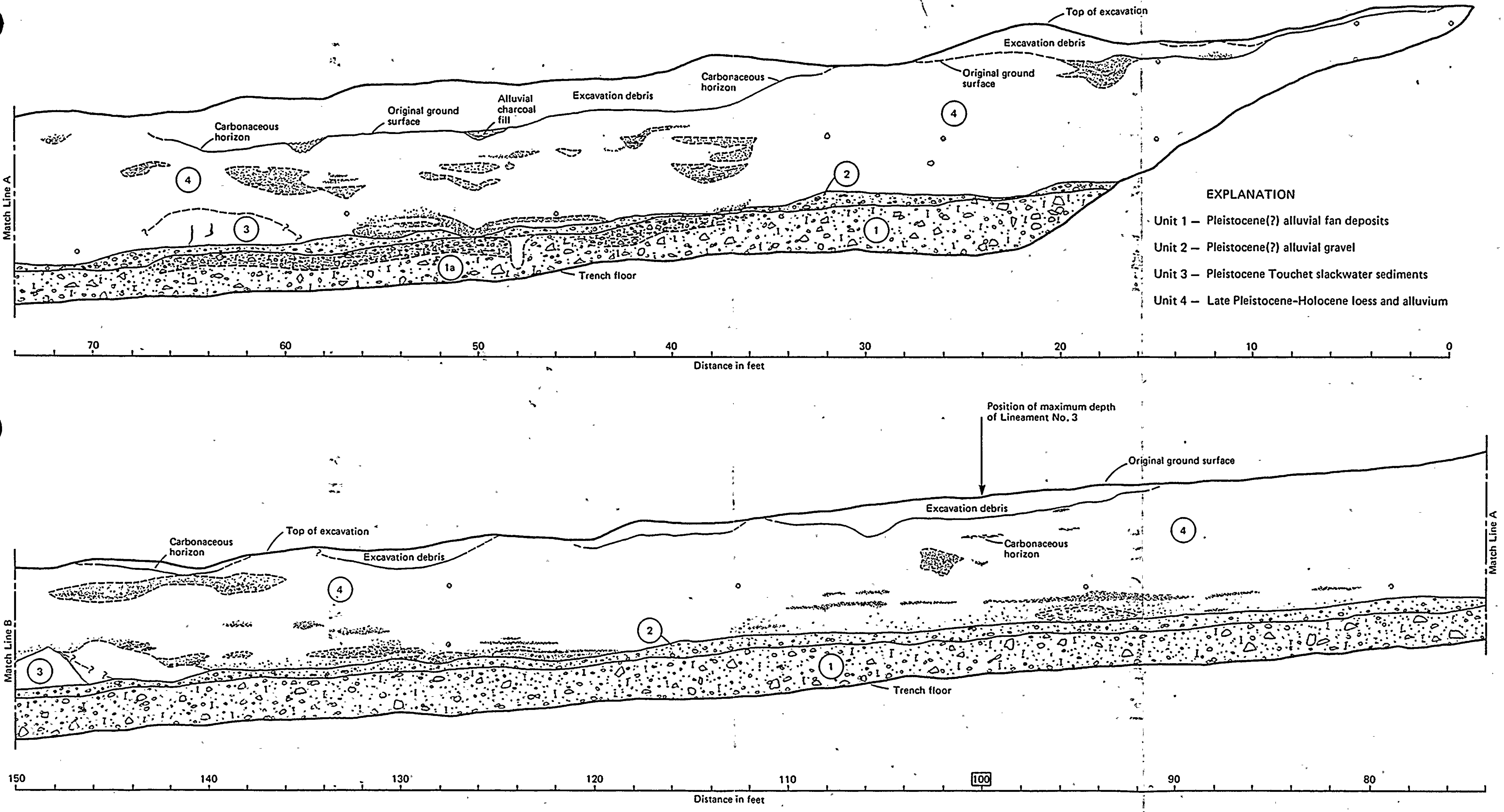
Unit 1 — Pleistocene(?) alluvial fan deposits

Unit 2 — Pleistocene(?) alluvial gravel

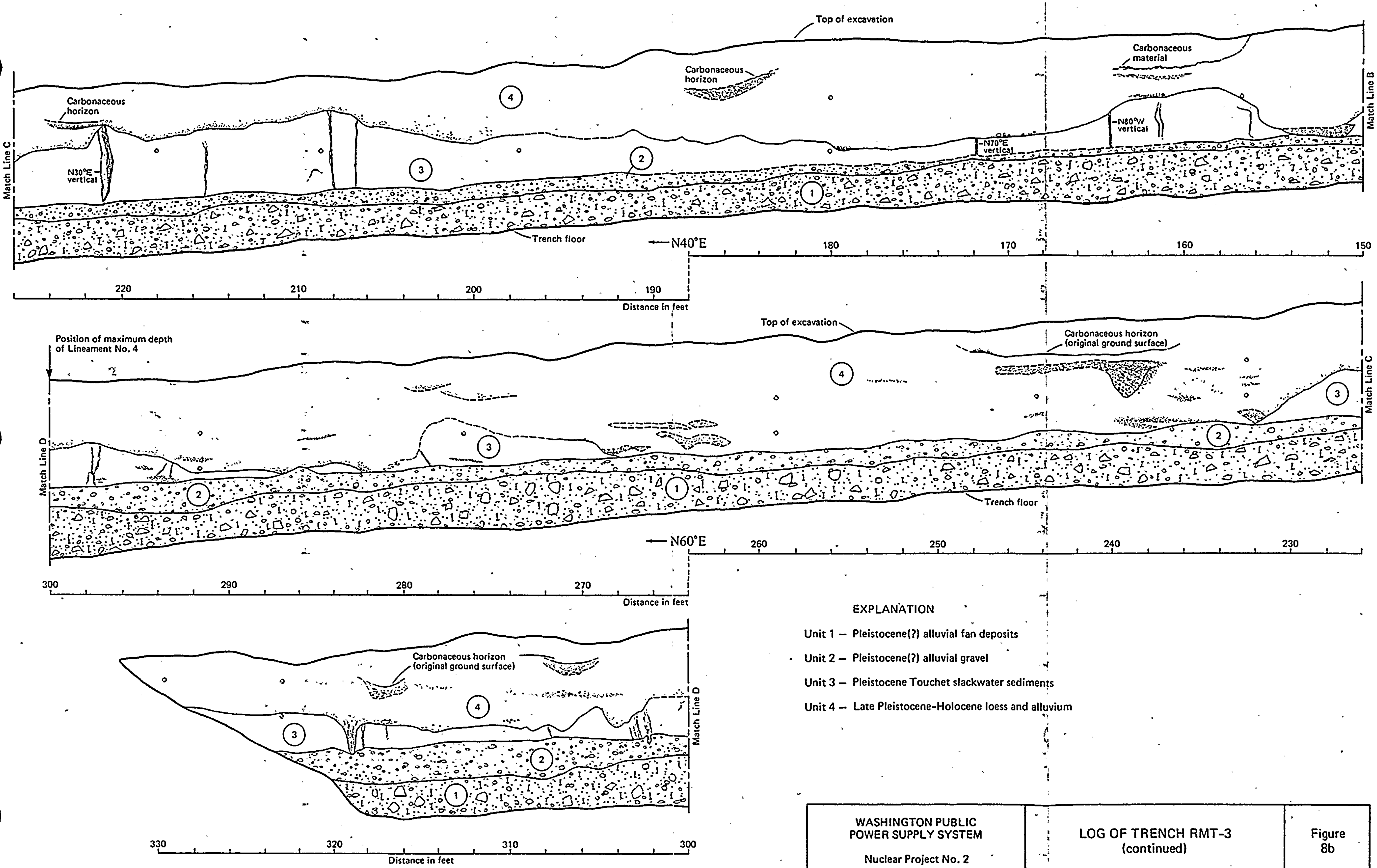
Unit 3 — Pleistocene Touchet slackwater sediments

Unit 4 — Late Pleistocene-Holocene loess and alluvium

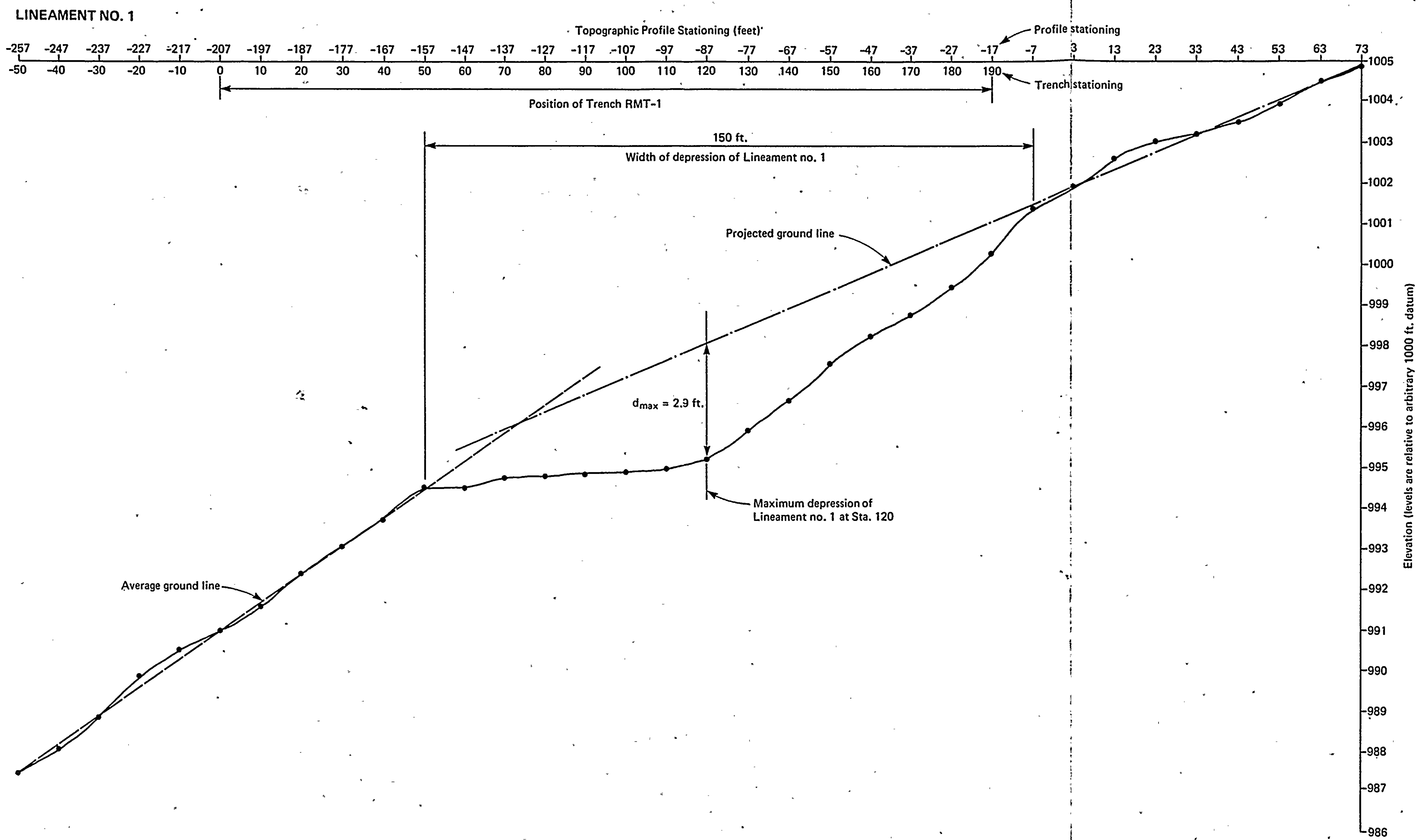
WASHINGTON PUBLIC POWER SUPPLY SYSTEM Nuclear Project No. 2	LOG OF TRENCH RMT-4 (continued)	Figure 7b



WASHINGTON PUBLIC POWER SUPPLY SYSTEM Nuclear Project No. 2	LOG OF TRENCH RMT-3	Figure 8a



WASHINGTON PUBLIC POWER SUPPLY SYSTEM Nuclear Project No. 2	LOG OF TRENCH RMT-3 (continued)	Figure 8b

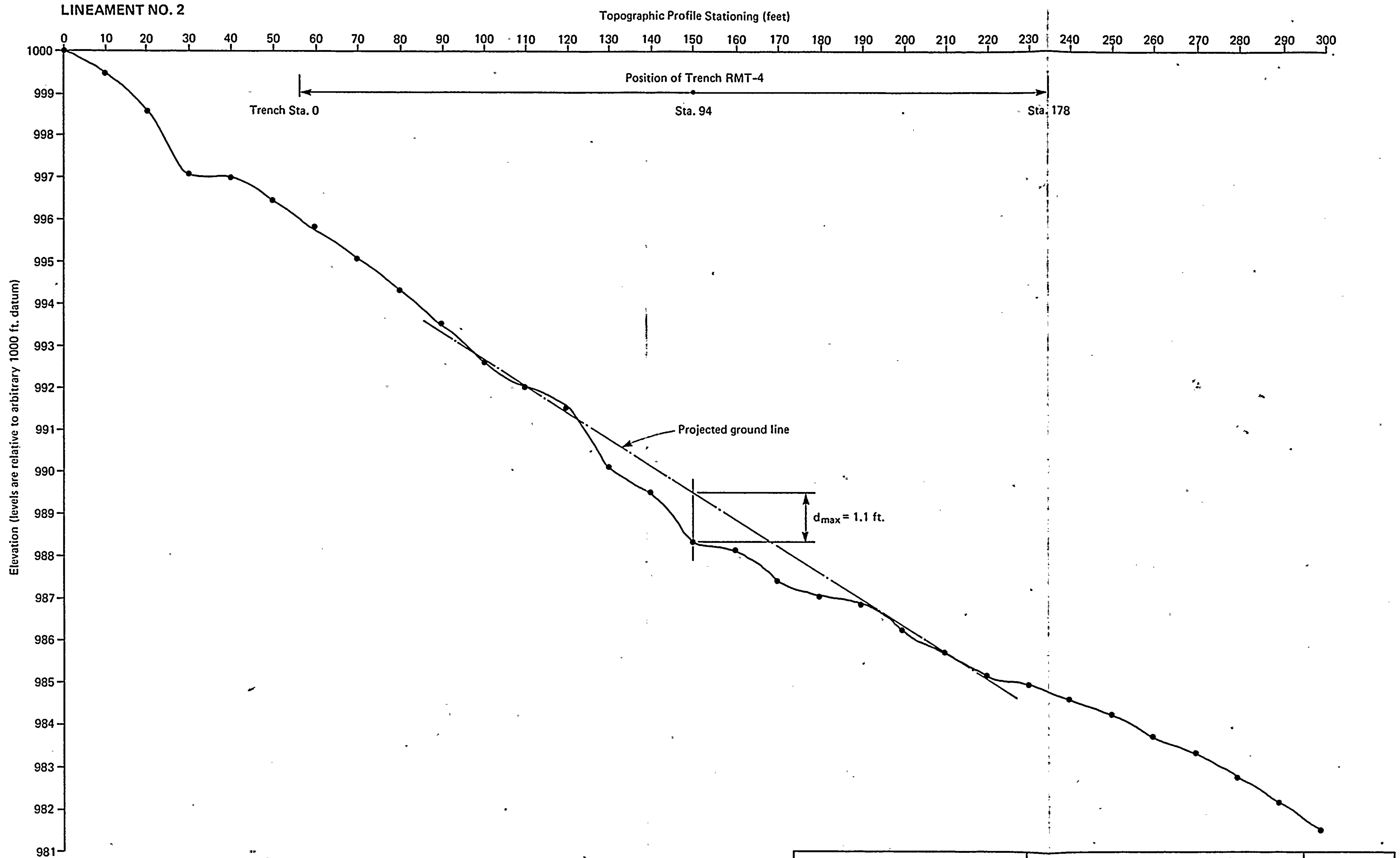


WASHINGTON PUBLIC POWER SUPPLY SYSTEM

Nuclear Project No. 2

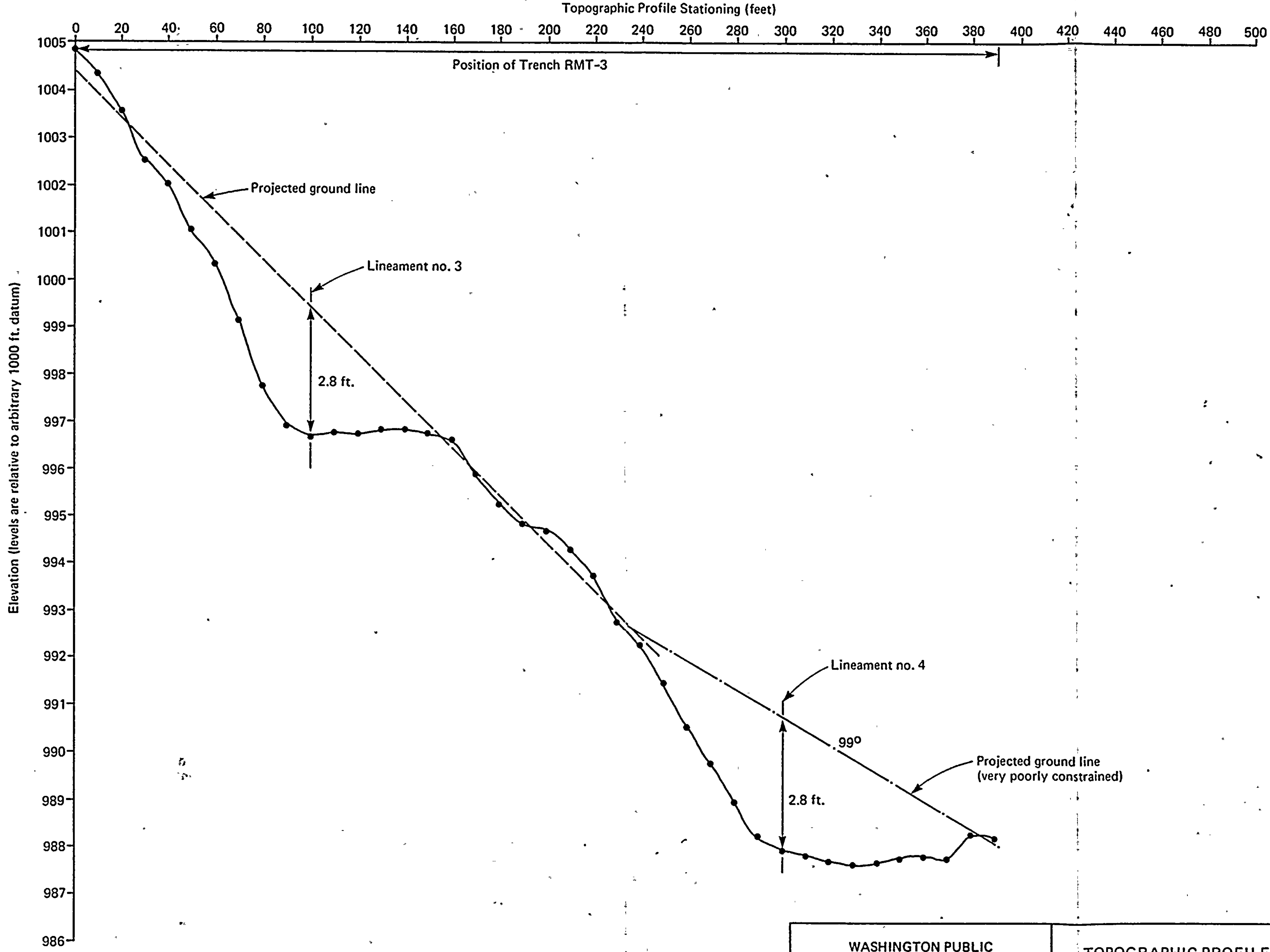
TOPOGRAPHIC PROFILE ACROSS LINEAMENT NO. 1 AT TRENCH RMT-1 SITE

Figure 10

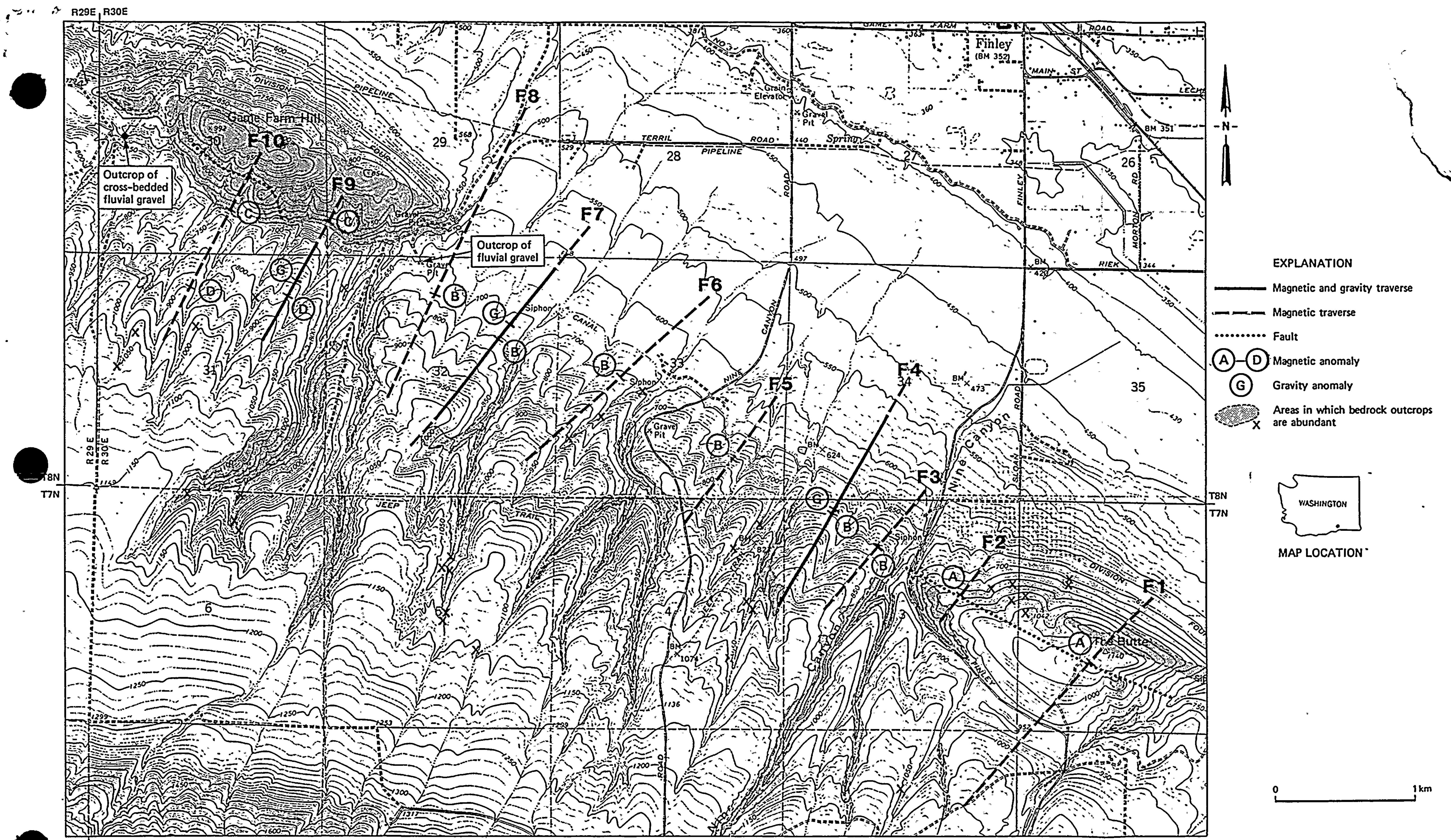


WASHINGTON PUBLIC POWER SUPPLY SYSTEM Nuclear Project No. 2	TOPOGRAPHIC PROFILE ACROSS LINEAMENT NO. 2 AT TRENCH RMT-4 SITE	Figure 11

LINEAMENTS NO. 3 AND NO. 4



WASHINGTON PUBLIC POWER SUPPLY SYSTEM Nuclear Project No. 2	TOPOGRAPHIC PROFILE ACROSS LINEAMENTS 3 AND 4 APPROXIMATELY 30 YARDS NORTH OF TRENCH RMT-3	Figure 12



Base map from Pasco and Nine Canyon 7.5′ quadrangles.
United States Geological Survey

Project No. 14940	Hanford FSAR	GEOPHYSICAL TRAVERSE AND ANOMALY LOCATIONS IN THE VICINITY OF THE BUTTE AND GAME FARM HILL	Figure 1
Woodward-Clyde Consultants			