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December 16, 1996

Mr. Chuck Grunenfelder
CH2M Hill, Inc.
9 South Washington, Suite 400
Spokane, Washington 99204

Re: Seismic Reflection Survey, Sullivan Road Corridor, Spokane, Washington.

Dear Mr. Grunenfelder,

This report presents the results of a seismic reflection survey conducted along Sullivan Road and along parallel Progress Road, Spokane, Washington, using the SeisPulse seismic source (pat.) and the near-offset method of seismic surveying. The principal objective of the work was to map the top of bedrock below the valley fill which comprises the Spokane Valley aquifer. A secondary objective was identify stratigraphic features in the valley fill.

Bedrock consists of both Columbia River basalt and older granitic gneiss. Valley fill consists mainly of coarse clastic materials representing Lake Missoula flood deposits. Near the valley margins the flood deposits are known to contain some locally extensive intervals of fine sand and silt. Fine grained deposits of the Latah Formation also are present and can overlie the bedrock below the flood deposits.

The investigation resulted in acquisition of 253 shot points comprising four seismic lines which proceeded from south to north. Line locations are shown on Figure 1, the horizontal distribution of shot points is shown on Figure 2, and the seismic profiles of Lines 1, 2, 3, and 4 are included in Appendix A. Full access to Sullivan Road was restricted by vehicular traffic, thus Line 4 and most of Line 1 were shot on Progress Avenue, a parallel roadway to the west of Sullivan Road. Topography along the seismic lines was obtained from the USGS 7.5 minute Greenacres Quadrangle.

The results of a recent seismic refraction survey near the Sullivan Road corridor, by S.D. Schwarz & Associates, Inc. (May 10, 1994), were utilized in this study to estimate seismic velocities. Also, well logs from water wells within the Sullivan Road corridor and 1995 water level data for the area, supplied by CH2M Hill, were utilized to constrain the velocity model and the interpreted section.

DATA ACQUISITION AND PROCESSING

Data for this investigation were acquired using two active channels of a 12-channel Geometrics S-12 seismograph and two Mark Products geophones (channel 1, Mark 40A and channel 2, Mark

L28). All data were recorded at a 1/4 msec sample interval and a record length of 512 msec.

Seismic energy was generated with the SeisPulse seismic source (pat.) which allows minimal source-geophone offset and in turn permits the collection of vertical-summed single channel reflection data. The near vertical ray path eliminates the need for long cable layouts and reduces the subsequent data processing to a few basic steps, ie., appropriate temporal filtering, static correction, and amplitude scaling. Data processing was done on a microcomputer using *EavesDropper* software from the Kansas Geological Survey. A number of processing runs were applied to each line to optimize filter parameters. Data processing flow and final parameters are shown below.

1) Conversion from Geometrics to *EavesDropper* format.

2) Edit traces.

3) Sort data.

4) Scale (500 msec window).

5) Filter - bp(HZ) 30-40 50-60

6) Scale (120 msec window).

7) Residual statics (20 msec window, 5 msec max shift).

8) Final stack.

RESULTS

Seismic Profiles

A prominent, coherent reflector, ranging from approximately 140 to 250 msec arrival time, is present on the records of the four seismic lines and is believed to represent the top of bedrock in contact with valley fill, mainly flood deposits. The reflector was not tied from line to line because traffic or cultural features prevented shooting crossing seismic lines or filling data gaps. Nevertheless, the position of the reflector can be readily interpolated between lines and appears to represents a self consistent event in the time dimension. The structure section of Figure 2 shows the horizontal distribution of points along the Sullivan Road corridor with Lines 1, 2 and 3 projected to a common plane, and Line 4 shown in its relative horizontal position with respect to parallel Line 3. The reflector appears to define a valley-like profile with it deepest point (location of greatest travel time) in the vicinity of the present Spokane River.

Line 1 was initiated at granitic gneiss outcrops on Saltese Road and proceeded via Sullivan Road and 24th Avenue to Progress Road, thence north to Mission Avenue. The apparent bedrock reflector is continuous throughout the record beginning at the third shot point at 140 msec, 200 feet from shot point 1. The seismic record suggests that the bedrock-valley fill interface is relatively steep near the valley margin with a gradient of 0.7 msec/foot. Thereafter, the reflector drops off in a series of steps and hummocks to about 230 msec at the north end of the line.

Line 2 begins just north of the I-5 Freeway and proceeds with several gaps and variable shot point spacing along Sullivan Road to Upland Drive north of Trent Road. In evident continuity with Line 1, the apparent bedrock reflector drops off to the north reaching a maximum travel time of 250 msec at the location of Sullivan Park. Thereafter, it climbs irregularly to approximately 210 msec at the north end of the line.

Line 3 begins at Wellesley Avenue and extends north 1200 feet to within 150 feet of basalt outcrops. In evident continuity with Line 2, the apparent bedrock reflector climbs to the north to about 155 msec at the end of the line. Apparently, the bedrock-valley fill interface at the north end of the transect is also relatively steep with a gradient of 1.0 msec/foot. Also evident on the record of Line 3 is a prominent flat lying reflector at about 90 msec and the interval between 40 and 90 msec appears to contain similar distinctive waveforms. The 90 msec reflector can also be interpreted on Line 2, though it is much less coherent than on Line 3. The stratigraphic significance of this reflector is not known, however, one speculative possibility is that it represents an ancestral channel of the Spokane River as other investigators have identified in the vicinity of the Washington-Idaho border.

Line 4 begins at Upland Drive and proceeds north on Progress Road to a point 1200 feet north of Wellesley Avenue. Line 4, which parallels Line 3, was shot in order to bridge the data gap between Lines 2 and 3, but it could not be extended farther north on Progress Road because of vehicular traffic.

Velocity Model

Locations of seismic refraction lines done by S.D. Schwarz & Associates, Inc. in the vicinity of the Kaiser Trentwood facility are shown on Figure 1. Proximity to the Sullivan Road corridor suggest these results should be useful for estimating seismic velocities applicable to the present study. While the valley fill stratigraphy and the corresponding velocity structure is no doubt complicated in detail, from a seismic viewpoint the most significant velocity contrast is likely to exist between similar materials above and below the water table. Schwarz's refraction study confirms this assumption and identifies the following velocity ranges:

1) Dense glaciofluvial sand and gravel above water table: 2260-2915 ft/s,

2) Glaciofluvial sand and gravel below water table, may also include buried erosional remnants of older less permeable Latah formation: 5280-5685 ft/s.

The two layer velocity model, using mid-range values of 2588 ft/s and 5482 ft/s, is internally consistent because the water table is a more or less constant, known subsurface datum over the length of the seismic transect. Potential inaccuracies in calculating depth to bedrock lie in not accounting for a near surface low velocity layer and the presence of apparent fine grained deposits as seen in Schwarz's refraction lines. To a first approximation, however, their exclusion is justified because we have no basis for extrapolation beyond the refraction study boundary. In the case of the finer grained materials, for example, they are thought to be erosional remnants concentrated near the valley margins rather than laterally continuous deposits distributed predictably throughout the valley.

Interpreted Section

Figure 2 shows the entire seismic transect including horizontal shot point distribution, 2-way travel time, topography, well control, assumed water table elevation of 1940 feet (USGS datum), and calculated bedrock elevation. Depth to bedrock (D_{total}) was calculated with the following equations:

$$T_1 = V_1 / 2D_1 ,$$

$$T_{total} - T_1 = T_2$$

$$(T_2 V_2) / 2 = D_2,$$

$$D_1 + D_2 = D_{total},$$

where $V_1 = 2588$ ft/s, $V_2 = 5482$ ft/s, D_1 = Surface Elevation - Water Table Elevation (1940 feet), T_{total} = 2-way travel time to apparent bedrock reflector, T_1 = 2-way travel time to water table, T_2 = 2-way travel time from water table to apparent bedrock reflector, and D_2 = distance between water table and apparent bedrock.

The calculated bedrock profile generally reflects the time domain profile with a calculated maximum depth of valley fill of over 600 feet between the location of I-5 and Sullivan Park. The calculated profile diverges from the time domain trends somewhat between stations 5000 and 15000 feet as a function of topography (i.e., the relatively higher elevations south of I-90 result in a greater influence of V_1 on the calculated depth of bedrock). Local and overall relief on the apparent bedrock surface is consistent both qualitatively and quantitatively with the refraction results of Schwarz. The apparent bedrock-valley fill interface at the south end of the seismic transect slopes approximately 50 degrees, and at the north end it slopes an estimated 60 degrees.

LIMITATIONS

This report is based on the field geophysics as described, information from well logs, and reports and figures provided to us by the client. Interpre'Tech/SeisPulse, LLC makes no warranties either expressed or implied as to depth accuracy, nor to the identity of reflections or other features of the seismic records, without independent velocity control or ground-truth verification. Further, findings and interpretations in this report are based on limited data. The apparent nature and continuity of subsurface reflections is in part a function of data density and additional shot points or seismic profiles could reveal other or additional conditions than those presented in this report.

We appreciate the opportunity to be of service on this project. Should you have any questions regarding our report of geophysical activities, please do not hesitate to contact this office.

Very truly yours,

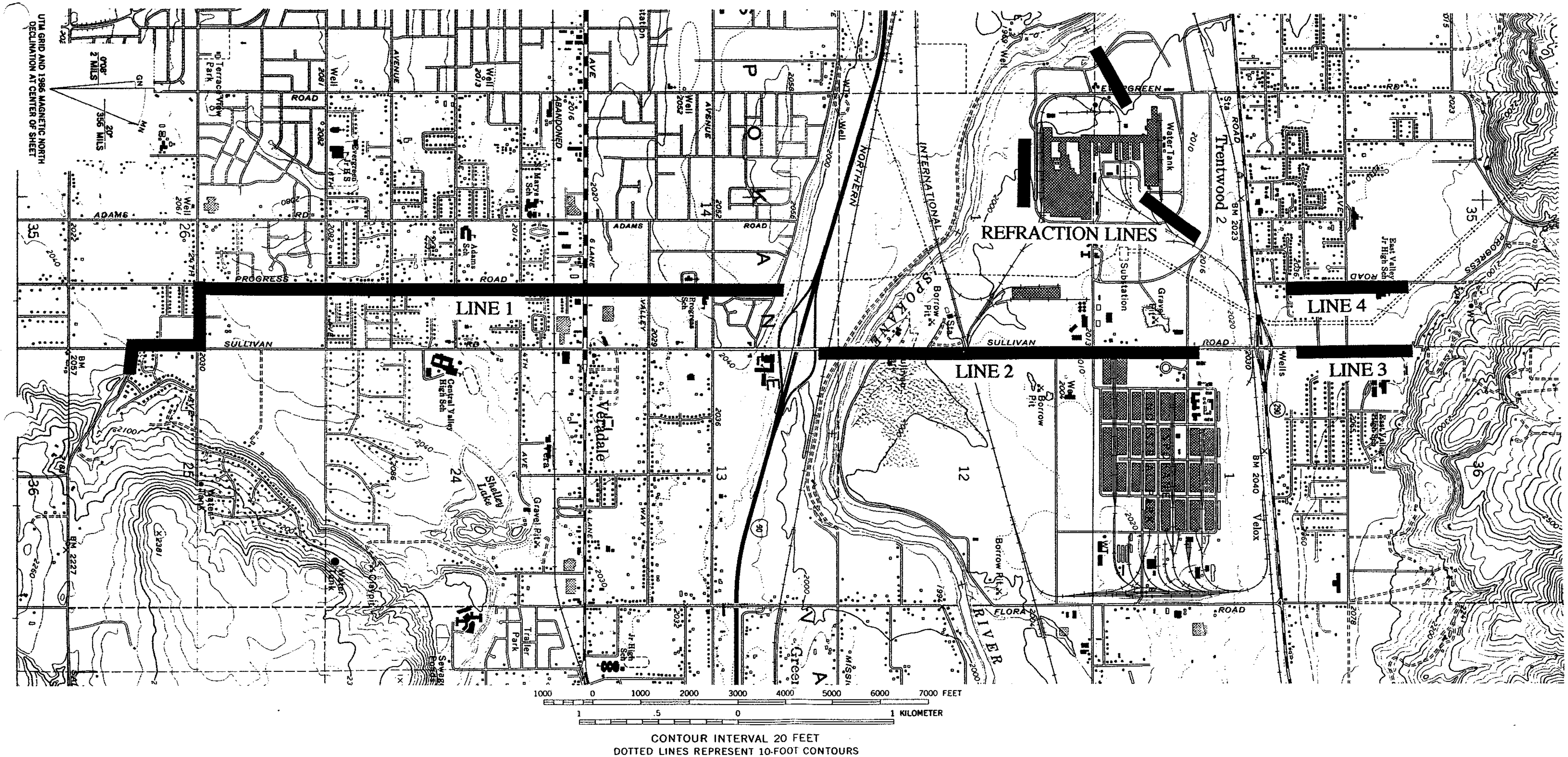
Kent McMillan, PhD.

J. Michael King, M.Sc.

President

Attachments: Figure 1
Figure 2
Appendix A

Distribution: (2) Addressee



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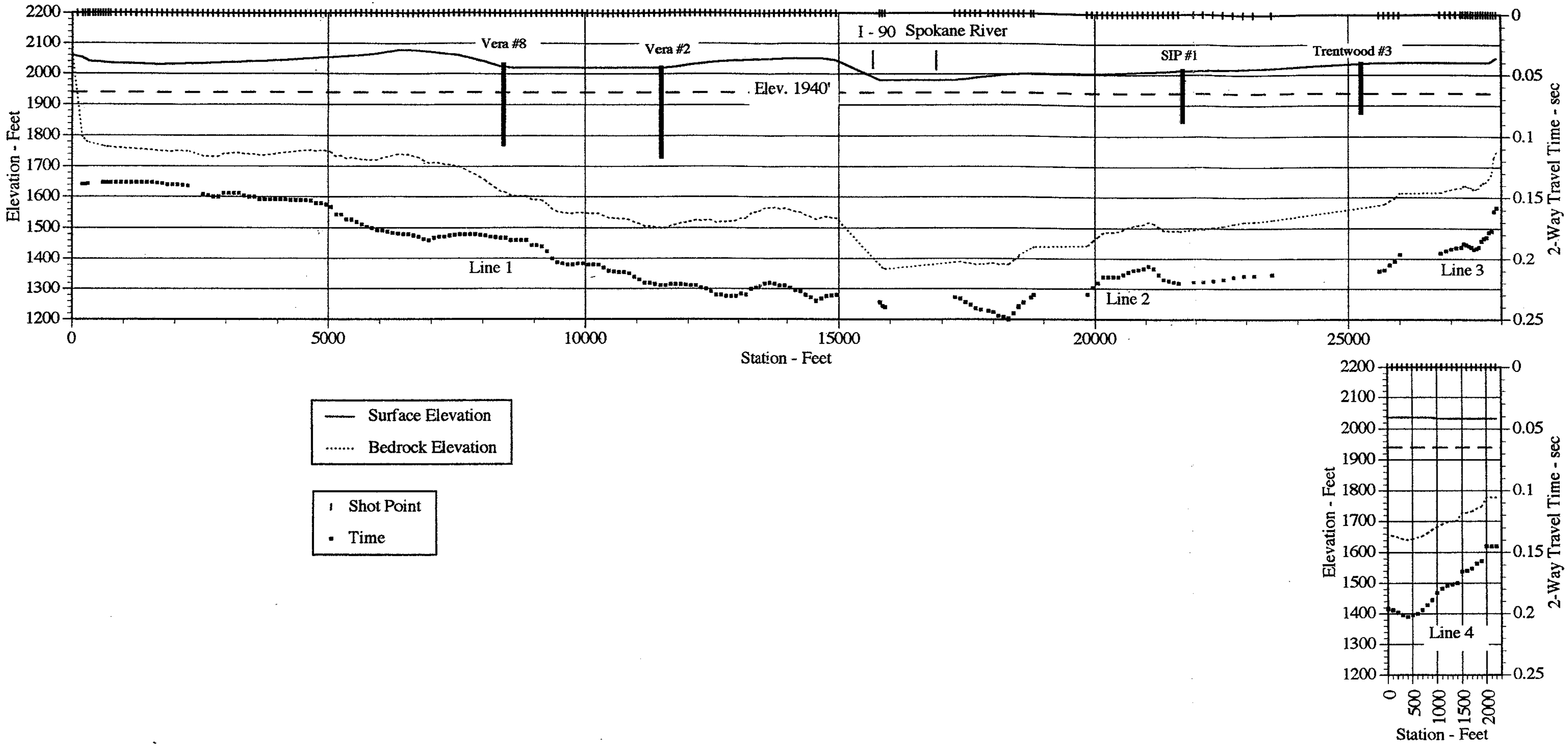
Location Plan

Figure 1



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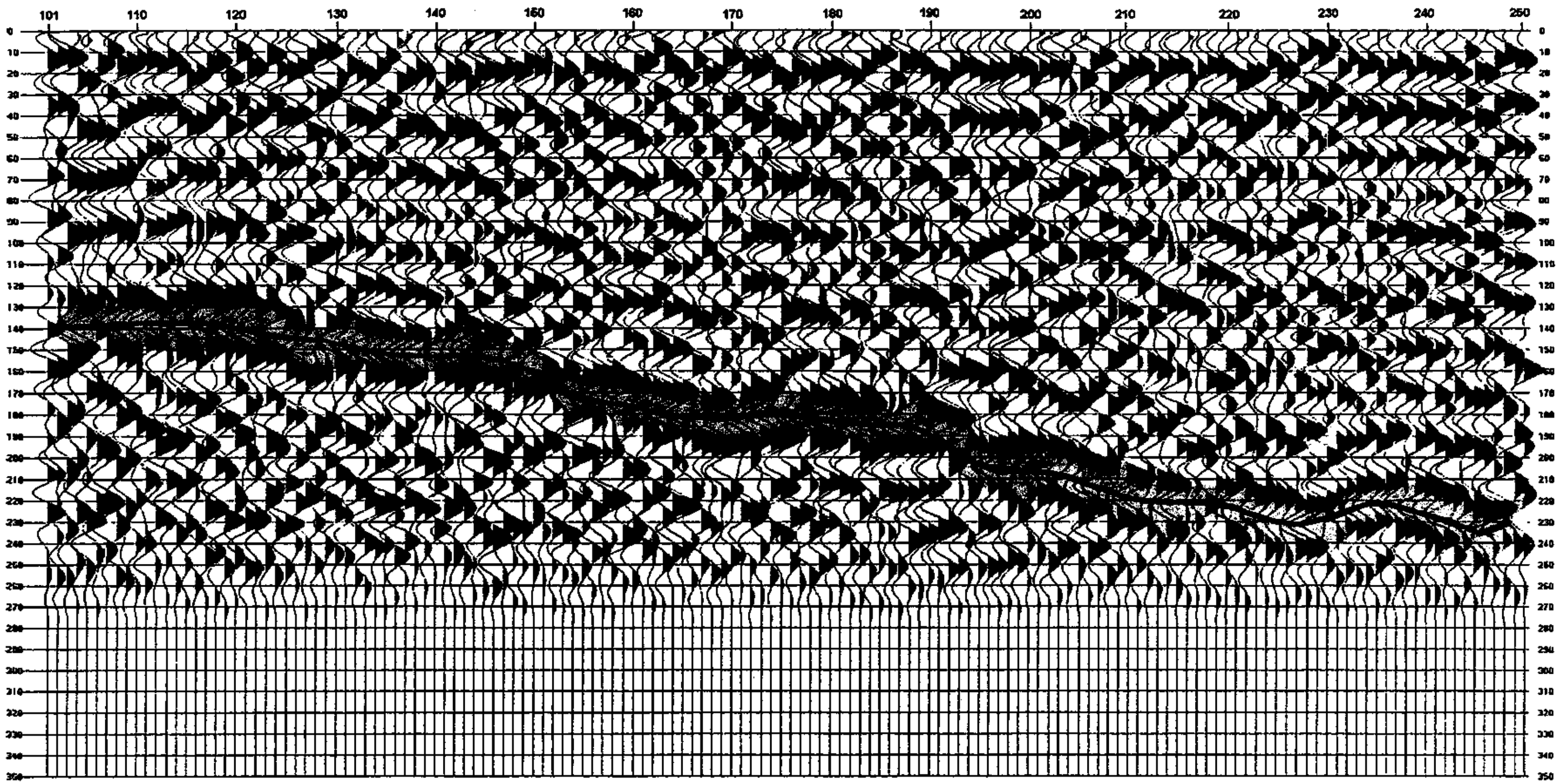
Interpretive Structure Section

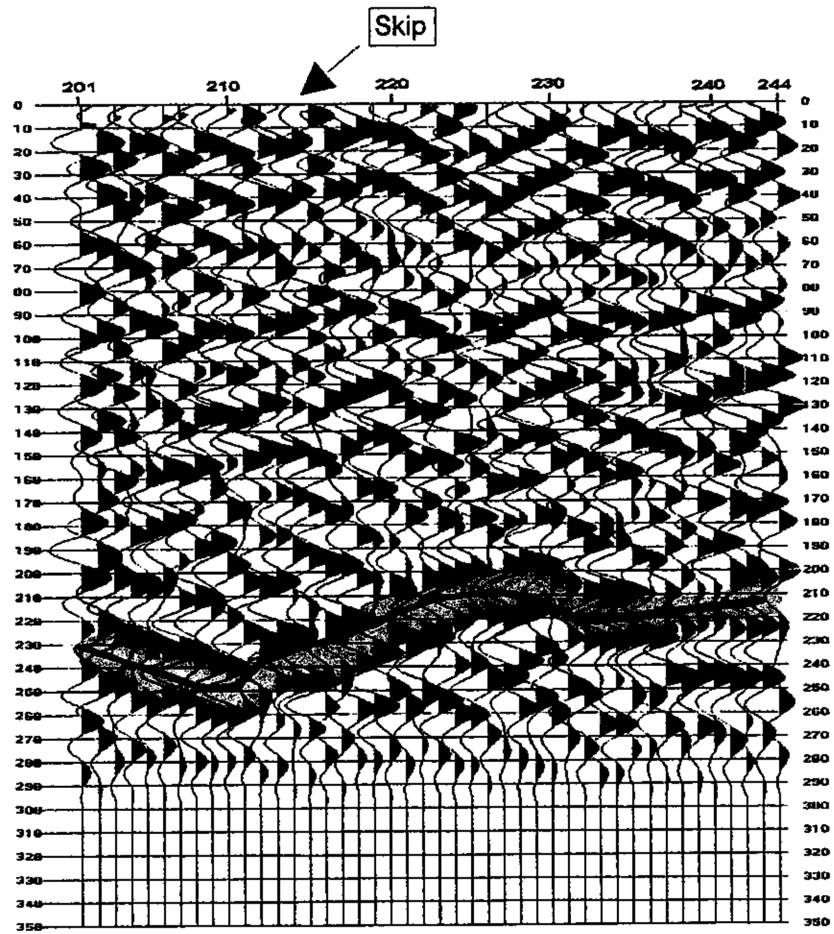
Figure 2

APPENDIX A

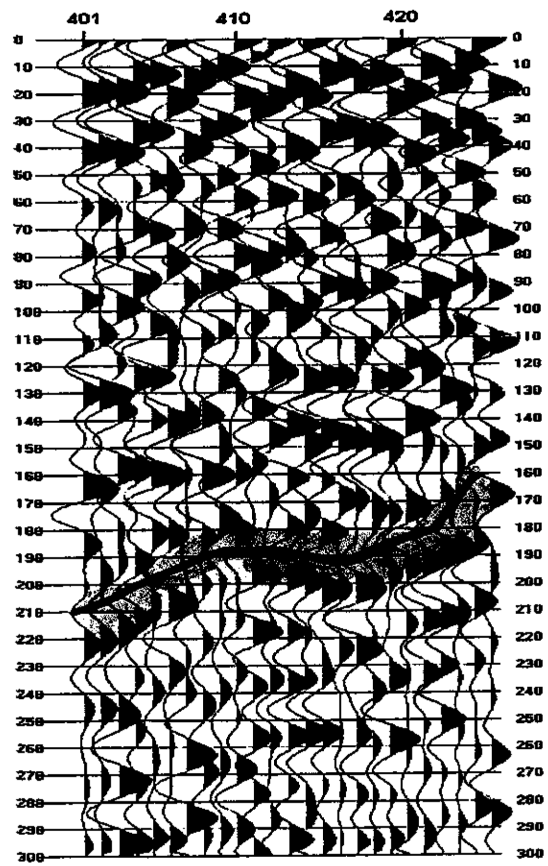
SEISMIC SECTIONS



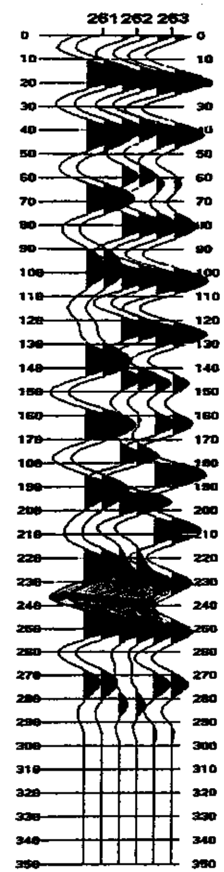
SULLIVAN ROAD - LINE 1



SULLIVAN ROAD - LINE 2



SULLIVAN ROAD - LINE 4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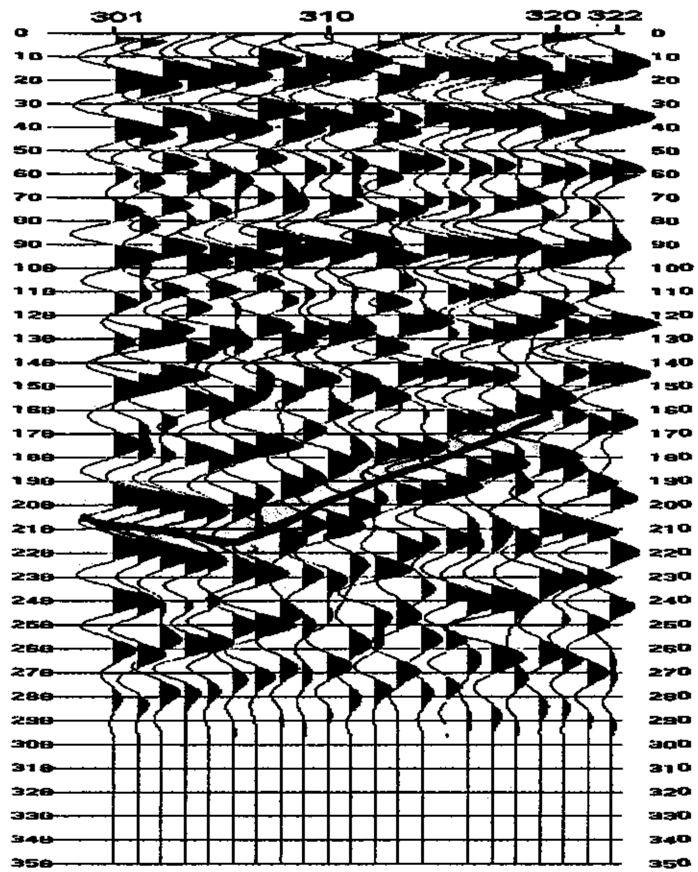
Line 2 EXT



SULLIVAN ROAD - LINE 3