

Geophysical Determination of the Engineering Soil Profile by Joint Inversion of Dispersion and Amplitudes

**Interim Report
Idaho SBOE Research Grant 691-A037**

(July 1994 to December 1994)

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**Technical Report BSU CGISS 95-05
15 December 1994**

Acknowledgements

The author would like to thank the Idaho Transportation Department, District 3, for their permission to use the geotechnical boreholes surveyed in this research. In particular, Mr. Keith Nottingham, district 3 geologist, has been very helpful in providing not only access to the boreholes, but also geotechnical and other survey data where available. Thanks also go to the Center for Geophysical Investigation of the Shallow Subsurface (CGISS) for providing the Bison Engineering seismograph and the Idaho State Board of Education for providing the funds supporting this research.

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SUMMARY

This research project consists of three major phases. These phases are:

- * Design and build recording equipment and seismic sources.
- * Acquire the geophysical data.
- * Analyze the geophysical data for soil properties.

The first two phases of the project have been completed. The following summary provides a detailed description of the accomplishments made during the period covered by this report:

1. The borehole wireline, reference phone, and associated equipment were constructed.
2. Two repeatable seismic sources were designed and built to generate the SH-wave and P-wave data for the project.
3. A total of 6 boreholes have been logged using the above equipment. These holes were geotechnical boreholes generously provided by the Idaho Transportation Department, District 3.
4. The tool orientation at each level in each borehole was determined by hodogram analysis of the recorded 3-component waveforms.
5. The seismic data have been converted to a standard geophysical exchange format (SEGY). This format combines the survey information, tool orientation analysis, and the seismic waveforms into data sets that can be exchanged with other scientists. These data sets have been archived on floppy diskettes.
6. Preliminary analysis of the data has begun:
 - a. The reference phone signals are being examined for repeatability and dynamic analysis of the source.
 - b. Preliminary interpretation of the travel times and geologic profile analysis has begun.
 - c. The data have also been used for instruction in the Seismic Methods class (GP330/597).

The project is on schedule despite the loss of the graduate student originally chosen to work on the project. The student, Louis Orndorff, requested to be released from the project so that he could accept a commission in the U.S. Air Force. A replacement, Claudine LaCasse, has been chosen. She will be working on the project starting in January, 1995.

Future work on the project will include analysis of each site for the major

lithologic boundaries. This will be followed by a zoned inversion of the elastic and inelastic soil properties from the waveform data. The results will be disseminated in publications in the appropriate technical literature, once the work is completed.

DESIGN OF RECORDING EQUIPMENT

The recording equipment consists of a down-hole tool, wireline, reference phone, and cables for connection to a BISON 9600 digital engineering seismograph. The down-hole tool is a Mark Products L-10-3D SWC (sidewall clamping geophone). It contains 3 orthogonal 10 Hz velocity phones with 70% damping. The tool clamps to the borehole with a bowspring that is released at the bottom of the hole. The clamping mechanism was found to work well in holes with a casing diameter of 2.5 inches (schedule 40 PVC). The wireline consists of a geophone cable breast reel which has been mounted on to a utility dolly. The cable (65 meters long) is routed through a snatch block suspended from a tripod by a pulley and winch system. The reference phone is a Mark Products L-10AR, with 70% damping.

DESIGN OF SEISMIC SOURCES

The original source concept was to be a railroad tie struck on the ends by an operator using a sledge hammer. This turned out to be unsatisfactory, since the method quickly exhausted the operator, and resulted in inconsistent waveforms. Furthermore, considerable damage occurred to the railroad tie from the use of excessive force by the operator.

Two alternative seismic sources were developed. For a SH-wave source, the railroad tie was modified by adding angle irons to support the sledge hammers at each end. Holes were drilled into the ends of the hammers, and a 3/8 inch rod was used to form a pivot for the hammers, suspended from the angle iron. The bottom of the railroad tie was fitted with angle iron strips which acted as treads to increase the frictional contact with the ground. Figure 1 shows the resulting seismic source. The source was weighted with sand bags, and the hammers operated by use of ropes attached to the hammer heads. In general, a very modest and highly repeatable blow was achieved with little damage to the railroad tie. The hammers were oriented to strike the wood with the side of the hammer. A draw back of about 0.65 meters was typically used prior to releasing the hammer. The hammer is easily caught on the rebound by the operator, thus avoiding multiple bounces. Typically 15 to 20 blows from this source were stacked to overcome noise from traffic and other sources.

The second seismic source consisted of a vertical hammer which was attached to a redwood board. A wooden strike plate was glued to the top of the board, and the hammer pivoted at the end of the handle. Figure 2 shows this second source. It was also operated with a rope attached to the handle at the head.

Horizontal Hammer SH - Wave Source

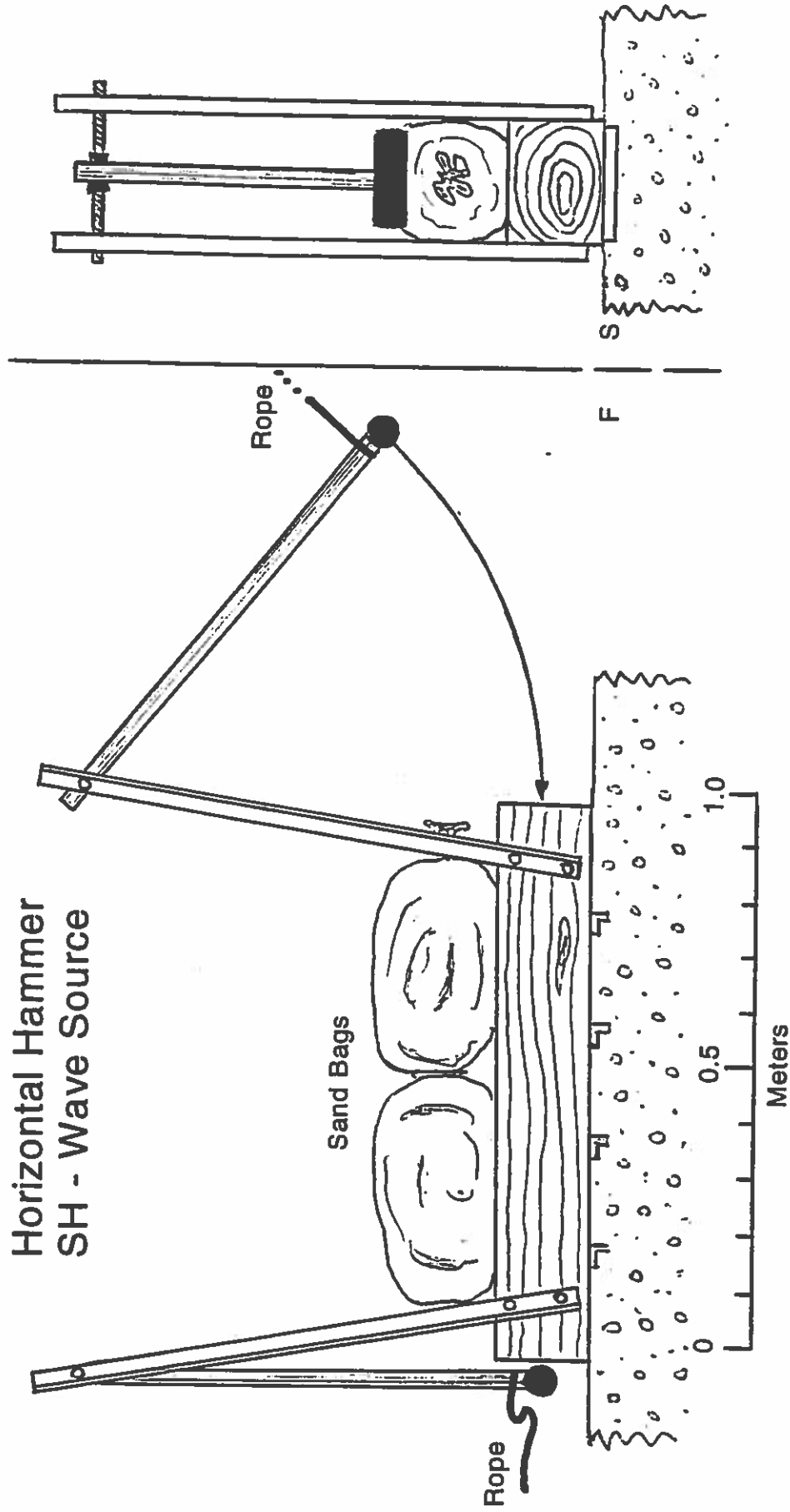


Figure 1: Horizontal seismic source for generating SH-Waves. A railroad tie forms the base. The railroad tie is struck directly with the broadside of a sledge hammer. The hammer is first drawn back with a rope, released, and then caught on the rebound by the operator. Angle iron is used to support the hammer pivots. By stacking many soft blows, quality recordings are made without any detectable damage to the railroad tie.

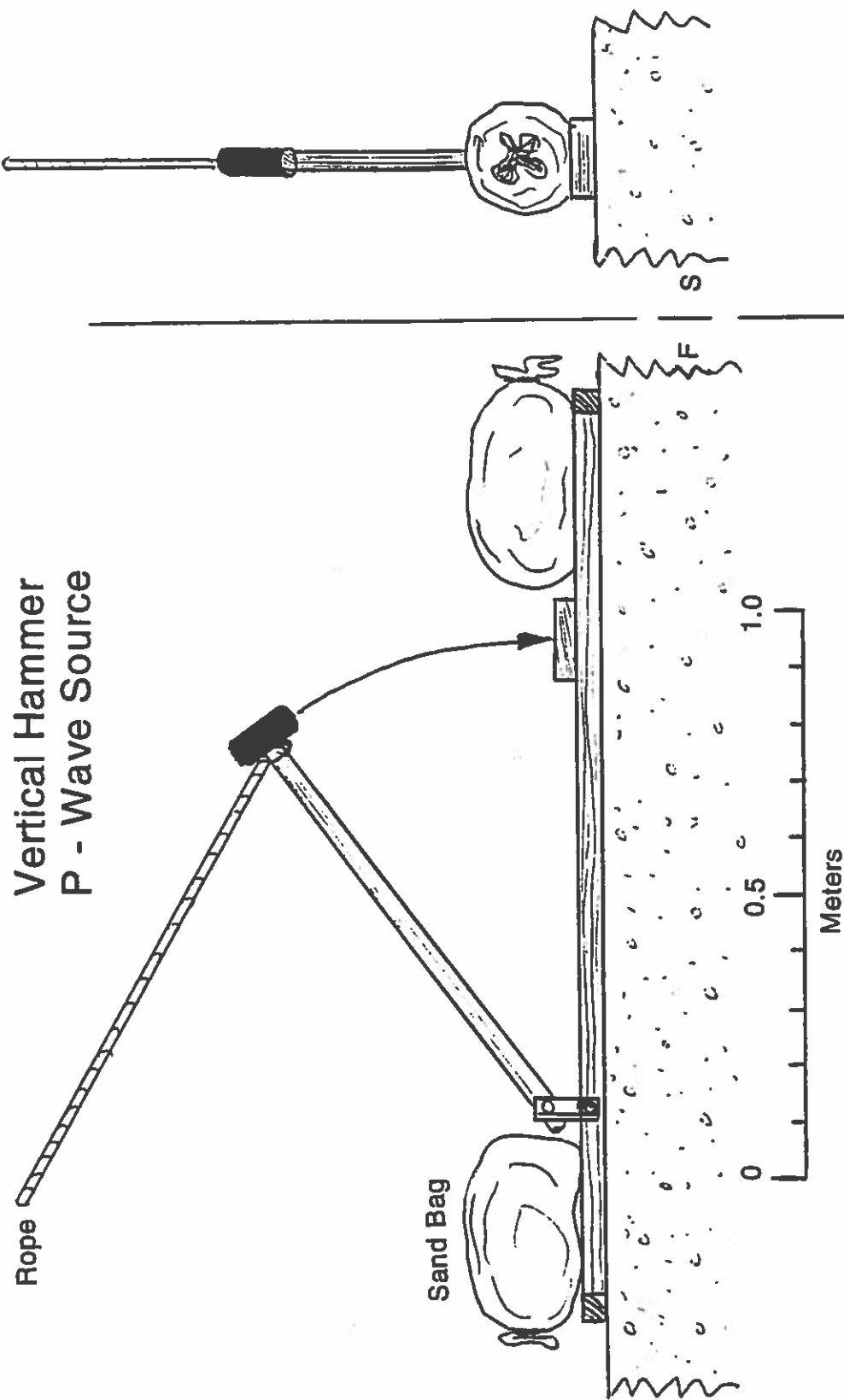


Figure 2: Vertical hammer source for generating P-waves. A 2x6 redwood board forms the base. The strike plate is formed from the same wood and glued to the base. Here, the hammer strikes the wood in a normal orientation, rather than broadside. Again, a rope is used to draw back the hammer, and then catch it on the rebound. This source has only been used on one survey to date.

Data Acquisition

Equipment Deployment

Figure 3 shows the typical experimental setup in plan view. First, a compass bearing is taken to determine north. Coordinate axes are placed with the borehole at the origin. The Y-axis is taken positive to the north. The X-axis is taken positive to the east. The center of the seismic source and reference phone are placed on the Y-axis, as space permits. To avoid ray bending, the source is kept close to the borehole (1 to 4 meters is typical). The reference phone is placed symmetrically with respect to the source center, and aligned with the radial component arrow to the north (0 degrees azimuth). The transverse component of the reference phone points to the west (270 degrees azimuth). The reference phone vertical component arrow points up (zenith).

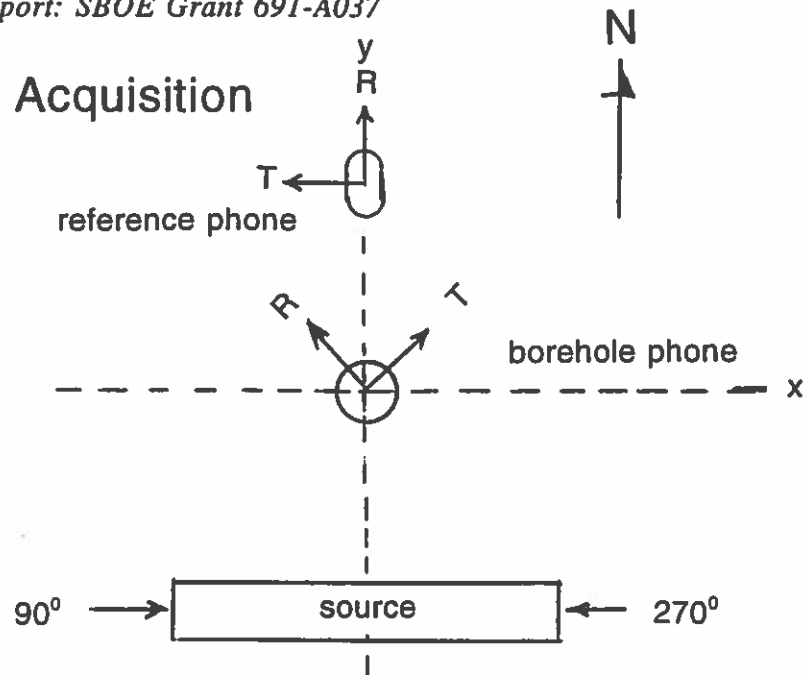
Sign Convention

The long axis of the horizontal hammer source is oriented along east-west strike. When the horizontal hammer is struck on the east face of the timber, this is represented by an arrow pointing west. Such a blow is designated as a source azimuth of 270 degrees, with an angle of 90 degrees from the vertical (ie. a horizontal blow). Similarly, a blow on the west face of the timber is indicated by an arrow pointing east (source azimuth of 90 degrees, 90 degrees from the vertical). Both the reference phone, and the borehole phone are wired to produce a negative voltage when the source and receiver arrows point in the same direction. On a waveform plot, such a voltage plots below the trace line and is colored white. Conversely, when the source and receiver arrows point toward each other (ie. in opposite directions), a positive voltage is produced, and this is plotted as a deflection above the trace line. Positive peaks are colored black on the variable area plots.

Since the borehole phone twists as it moves along the hole, its orientation must be determined by hodogram analysis of the particle motion. Once the tool orientation is determined in this way, the signals are rotated to an equivalent tool orientation with the transverse component arrow pointing west, and the radial component arrow pointing south. The SEG Y headers are updated by the rotation program to always indicate the current status of the effective tool orientation. However, the archived data are saved as recorded (no rotations applied). The archived data headers have been updated to indicate the results of the hodogram analysis. The vertical element of the borehole phone is represented by an arrow which points downward. The bottom half of Figure 3 shows the rotated orientation of the horizontal data as displayed in this report.

When the vertical hammer is used, its long axis is also oriented along the east-west strike. This provides maximum beam divergence in the direction of the hole. The vertical hammer is represented by an arrow pointing downward, toward the center of the earth.

During Acquisition



After Rotation

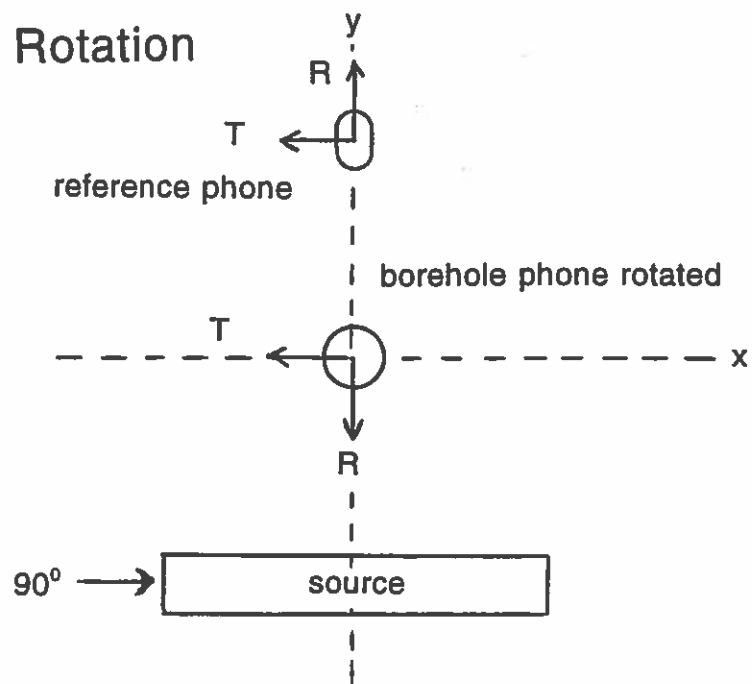


Figure 3: Plan view of coordinate system and equipment deployment. The upper drawing shows a typical recording configuration. The bottom drawing shows the final rotation of the down-hole data. The SH-data are enhanced by subtracting the 270 degree source azimuth from the 90 degree source azimuth recordings. Thus, after rotation, the SH-Wave first motion will be a positive voltage.

Data Acquisition Protocol

A tripod is erected over the borehole. A pulley and snatch block is suspended from the tripod. The dummy tool (1-1/4 inch PVC pipe filled with gravel, 0.91 meters long, weight 17.8 N) is lowered through the snatch block on a measuring tape to determine if the borehole is clear. At this time, a measurement of the water table level is made and recorded. Then the dummy tool is removed.

The clamping spring on the SWC borehole tool is compressed and engaged in the spud release rod. A slight tapping of the spud on the end of the tool can be used to establish sensitive triggering. The tool is then lowered through the snatch block into the hole. The tool is lowered to the bottom of the hole. The impact with the bottom of the hole depresses the trigger spud which then releases the clamping spring. The cable is pulled to determine clamping has occurred. A significant resistance will be felt when the tool is clamped in 2-1/2 inch PVC schedule 40 casing. [Note: The tool will not hold in 3 inch casing. Also, the tool is too large for 2 inch casing if the casing is of schedule 40 wall thickness].

The tool is then pulled up to the first cable marking that permits the tool to be positioned off the bottom of the hole. The cable is slacked off. If the tool holds its position, the first data level is recorded. Typically, 15 to 20 source efforts are stacked vertically for each level.

The tool is then pulled up to the next level and the process repeated. In all the surveys recorded thus far, a 0.5 meter station interval has been used. Once the tool emerges at the surface, the orientation of the R mark on the tool is recorded for use in controlling the hodogram analysis.

The Bison 9048 Engineering seismograph is set to the following recording parameters:

Sample interval=.0002 sec.
Low Cut Filter=8Hz
High Cut Filter=1000 Hz
Number of samples/trace=2500 (0.5second record)
K-Gain=20dB, all channels
Number of Channels=6

Channel definitions are:

Channel 1=downhole Vertical
Channel 2=downhole Radial
Channel 3=downhole Transverse
Channel 4=reference Vertical
Channel 5=reference Radial
Channel 6=reference Transverse

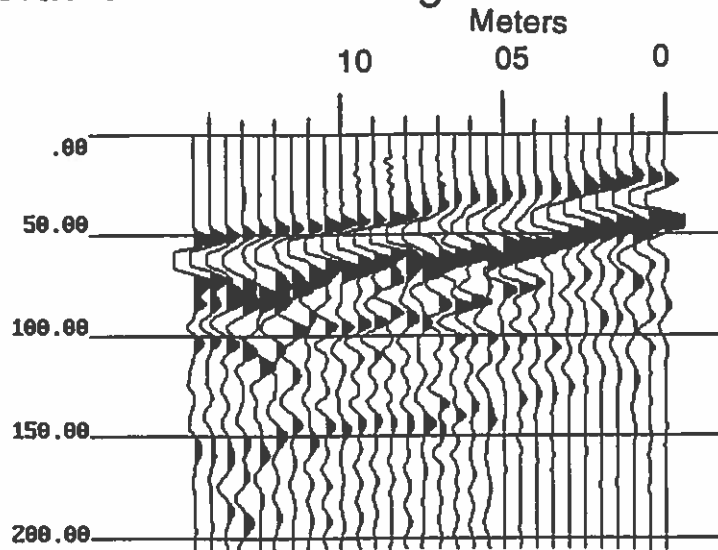
APPENDIX I

Displays of Data and SH-Wave Time-Depth Curves

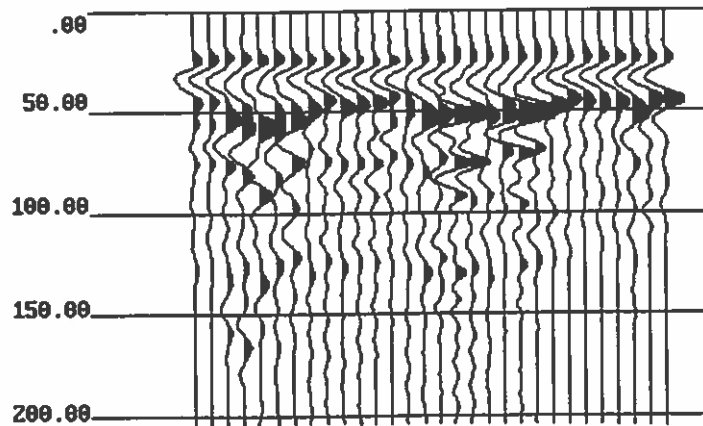
The following displays are for quality control. The borehole seismic signals have been normalized to remove the normal amplitude decay with increasing distance from the source. This permits one to observe the waveform consistency for evaluation of the hodogram derived rotations. The first break picks are evaluated by aligning the data on the .02 second timing line. A misaligned signal would indicate a bad pick. The reference phone signal is shown for the T-component. Comparison of the flattened (aligned) data with the reference permits one to observe the gross changes in waveform due to the inelastic properties of the soil. In general, the waveform will stretch with increasing depth. The greater the change in waveform, the more damping and less elastic the soil. These changes in waveform are direct evidence of the body wave dispersion effects that will be measured in the next phase of the project. However, the measurement of this effect will require waveform separation of the up and down-going wavefields. At this stage, the up-going back scatter interferes with a clear expression of the downgoing wave.

North Glenwood Bridge

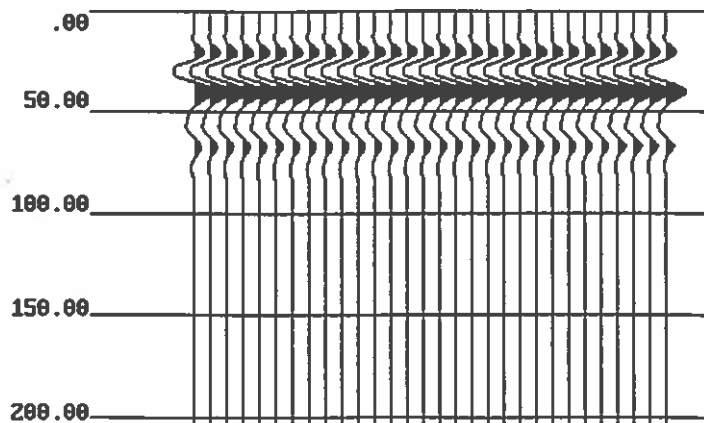
Rotated Down-Hole
Data (T-component)



Down-Hole Data
Flattened on First Break
Picks

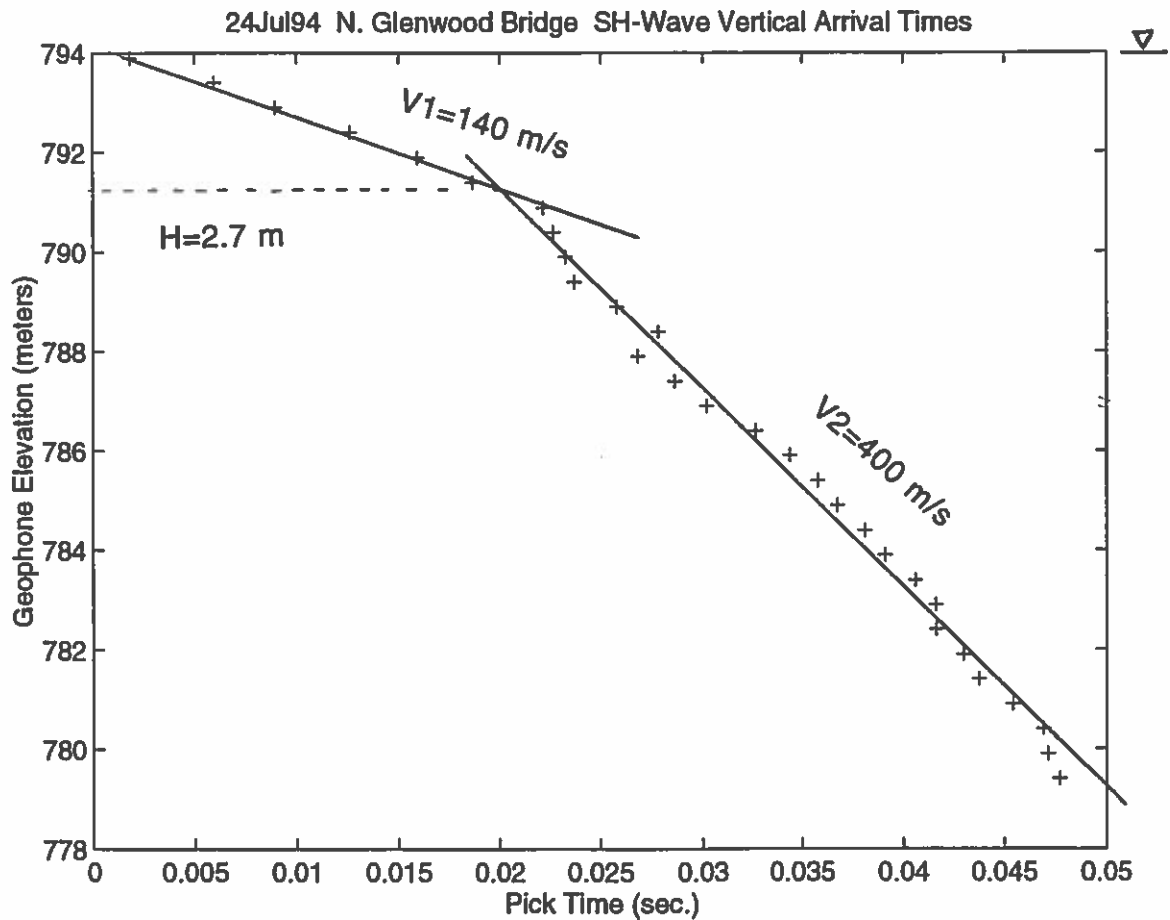


Reference Phone
T-Component



North Glenwood Bridge

SH-Wave Vertical Travel Times
and
Velocity Measurements



SEGY Header Dump

North Glenwood Bridge
Shows Tool Azimuth Determinations
Last Two Columns

PARTIAL SEG Y HEADER DUMP

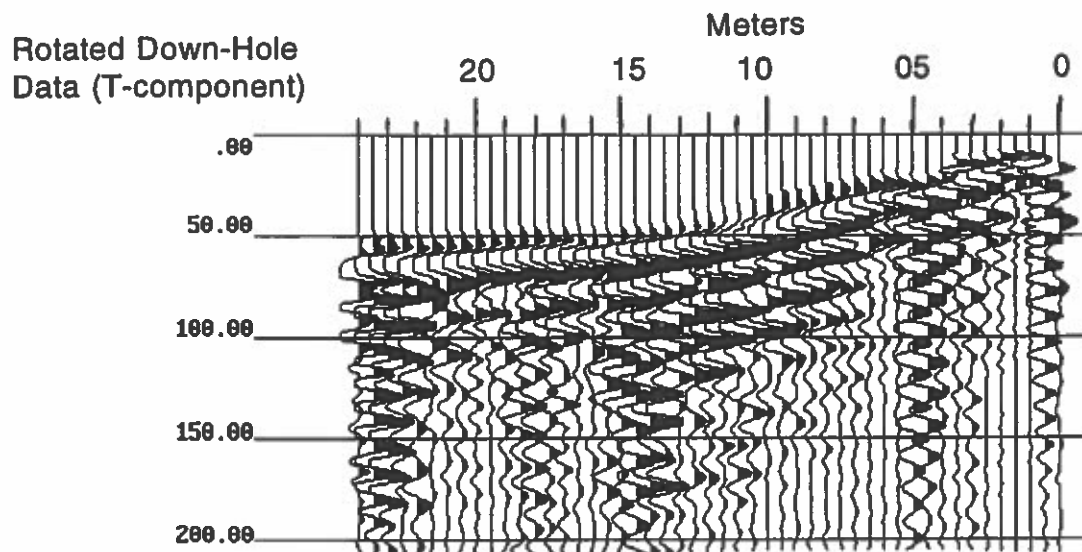
N. Glenwood Bridge 24Jul94
T-Component

Length = 2500 samples
Sample Interval = .00020 sec.
Delay Time = 0 msec.
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High Cut Filter = 1000 Hz.
Line ID: DHA3
Shot Orientation:
Azimuth= 90 Deg. Vertical= 90 Deg.

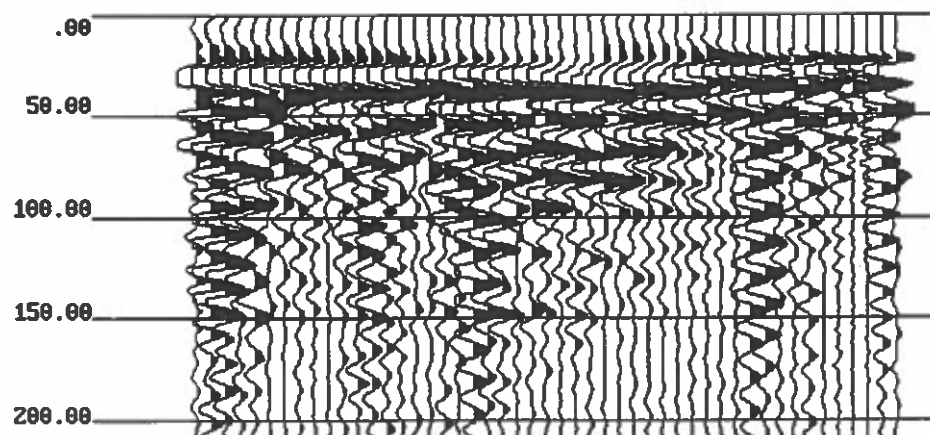
Shot Elevation = 794.1
Shot Depth = .0
Up Hole Time = 0 msec
Shot X-COORD = .0
Shot Y-COORD = -2.0
Shot Date (year.day) = 1994.724
Shot Time (hr:min) = 07:05
Charge Size (grams)= 0

TRACE #	SHOT REC.	STATION SHOT REC	OFFSET	RECEIVER		VERT	1STBRK	K-GAIN	AZI	VER
				ELEV.	X-COORD	Y-COORD	FOLD	(SEC.)	(dB)	
1	1	001 003	14.8	779.4	.0	.0	10	.0000	20	184 90
2	3	001 009	14.3	779.9	.0	.0	10	.0000	20	178 90
3	5	001 015	13.8	780.4	.0	.0	15	.0000	20	183 90
4	7	001 021	13.3	780.9	.0	.0	15	.0000	20	183 90
5	9	001 027	12.8	781.4	.0	.0	15	.0000	20	187 90
6	11	001 033	12.4	781.9	.0	.0	15	.0000	20	193 90
7	13	001 039	11.9	782.4	.0	.0	15	.0000	20	194 90
8	15	001 045	11.4	782.9	.0	.0	15	.0000	20	185 90
9	17	001 051	10.9	783.4	.0	.0	15	.0000	20	175 90
10	19	001 057	10.4	783.9	.0	.0	15	.0000	20	174 90
11	21	001 063	9.9	784.4	.0	.0	15	.0000	20	184 90
12	23	001 069	9.4	784.9	.0	.0	15	.0000	20	186 90
13	25	001 075	8.9	785.4	.0	.0	15	.0000	20	170 90
14	27	001 081	8.4	785.9	.0	.0	15	.0000	20	172 90
15	29	001 087	7.9	786.4	.0	.0	15	.0000	20	196 90
16	31	001 093	7.5	786.9	.0	.0	15	.0000	20	208 90
17	33	001 099	7.0	787.4	.0	.0	15	.0000	20	226 90
18	35	001 105	6.5	787.9	.0	.0	15	.0000	20	210 90
19	37	001 111	6.0	788.4	.0	.0	15	.0000	20	215 90
20	39	001 117	5.6	788.9	.0	.0	15	.0000	20	207 90
21	41	001 123	5.1	789.4	.0	.0	15	.0000	20	218 90
22	43	001 129	4.6	789.9	.0	.0	15	.0000	20	228 90
23	45	001 135	4.2	790.4	.0	.0	15	.0000	20	218 90
24	47	001 141	3.8	790.9	.0	.0	15	.0000	20	220 90
25	49	001 147	3.4	791.4	.0	.0	15	.0000	20	228 90
26	51	001 153	3.0	791.9	.0	.0	15	.0000	20	223 90
27	53	001 159	2.6	792.4	.0	.0	15	.0000	20	218 90
28	55	001 165	2.3	792.9	.0	.0	15	.0000	20	223 90
29	57	001 171	2.1	793.4	.0	.0	15	.0000	20	230 90
30	59	001 177	2.0	793.9	.0	.0	15	.0000	20	221 90

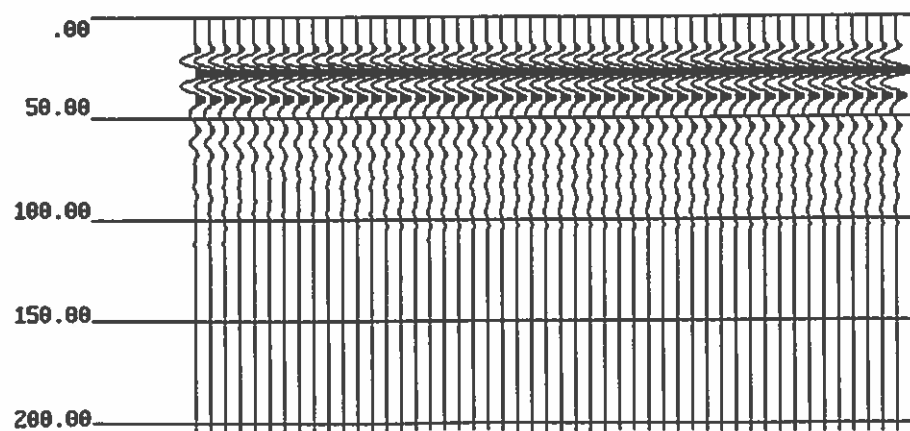
New York Canal



Down-Hole Data
Flattened on First Break
Picks

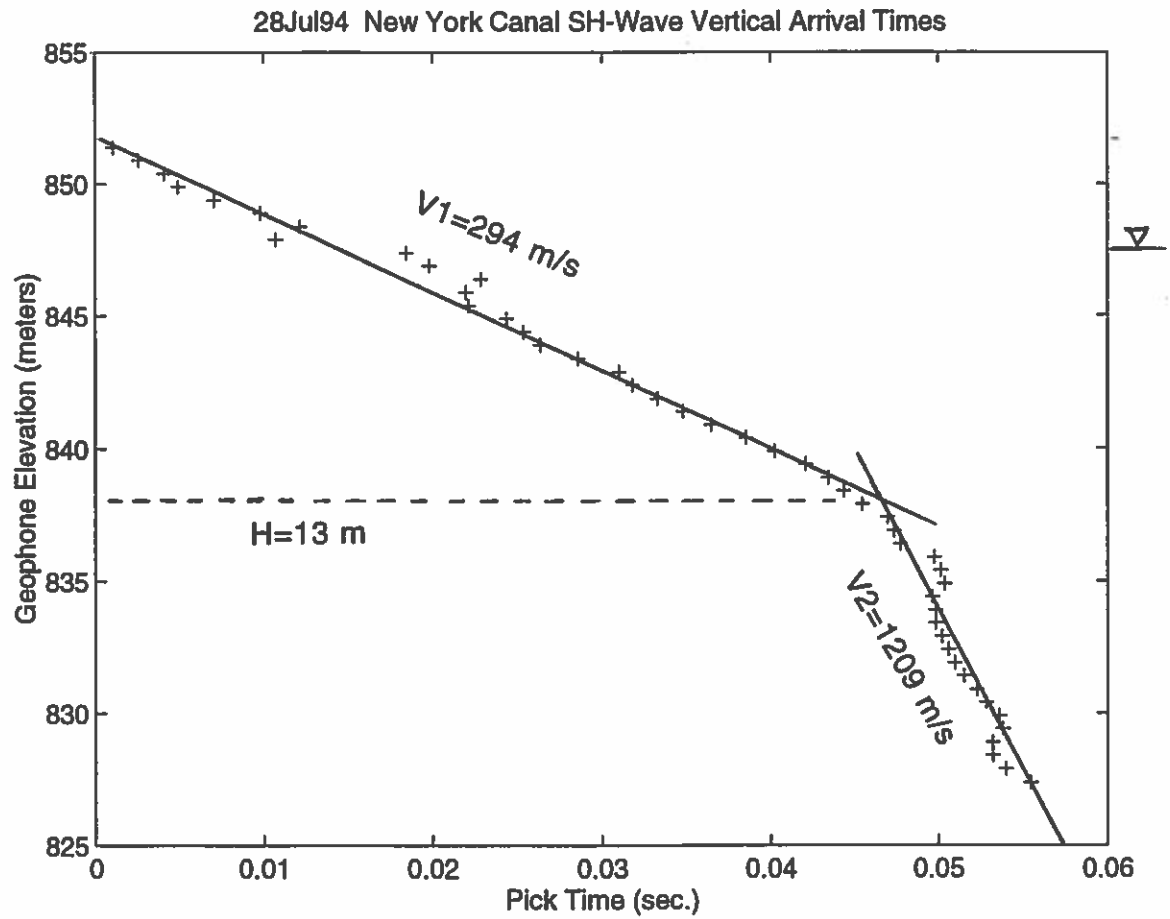


Reference Phone
T-Component



New York Canal

SH-Wave Vertical Travel Times
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Velocity Measurements



SEGY Header Dump

New York Canal
Shows Tool Azimuth Determinations
Last Two Columns

PARTIAL SEG Y HEADER DUMP

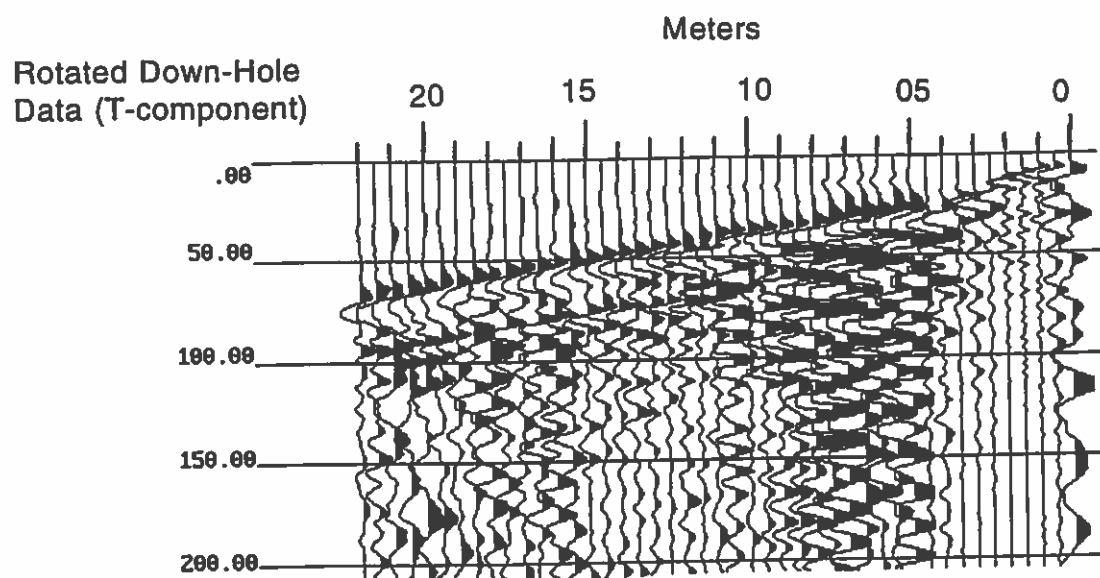
New York Canal 28 July 1994
T-Component

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High Cut Filter = 1000 Hz.
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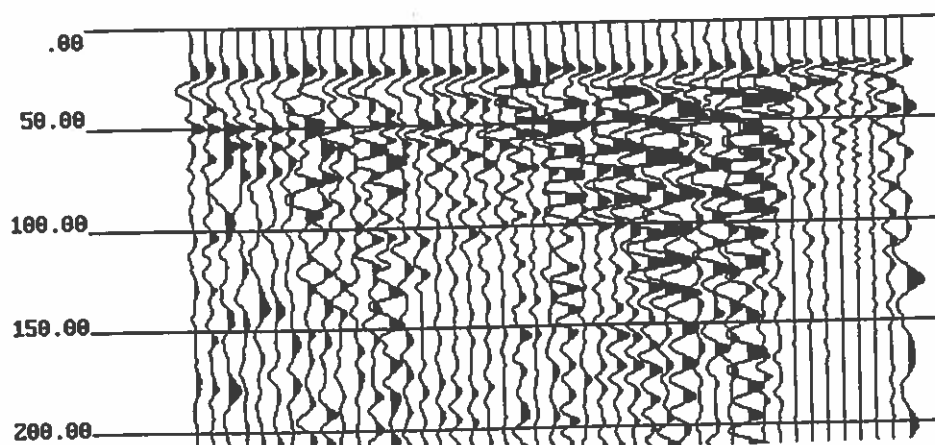
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Shot X-COORD = .0
Shot Y-COORD = 1.6
Shot Date (year.day) = 1994.728
Shot Time (hr:min) = 07:37
Charge Size (grams)= 0

TRACE #	SHOT REC.	STATION SHOT REC	OFFSET	RECEIVER			VERT FOLD	1STBRK (SEC.)	K-GAIN (dB)	AZI	VER
				ELEV.	X-COORD	Y-COORD					
1	1	001 003	23.9	827.4	.0	.0	15	.0000	20	318	90
2	3	001 009	23.4	827.9	.0	.0	15	.0000	20	290	90
3	5	001 015	22.9	828.4	.0	.0	15	.0000	20	292	90
4	7	001 021	22.4	828.9	.0	.0	15	.0000	20	300	90
5	9	001 027	21.9	829.4	.0	.0	15	.0000	20	324	90
6	11	001 033	21.4	829.9	.0	.0	15	.0000	20	328	90
7	13	001 039	21.0	830.4	.0	.0	15	.0000	20	323	90
8	15	001 045	20.5	830.9	.0	.0	15	.0000	20	321	90
9	17	001 051	20.0	831.4	.0	.0	15	.0000	20	330	90
10	19	001 057	19.5	831.9	.0	.0	15	.0000	20	324	90
11	21	001 063	19.0	832.4	.0	.0	15	.0000	20	325	90
12	23	001 069	18.5	832.9	.0	.0	15	.0000	20	328	90
13	25	001 075	18.0	833.4	.0	.0	15	.0000	20	325	90
14	27	001 081	17.5	833.9	.0	.0	15	.0000	20	318	90
15	29	001 087	17.0	834.4	.0	.0	15	.0000	20	317	90
16	31	001 093	16.5	834.9	.0	.0	15	.0000	20	345	90
17	33	001 099	16.0	835.4	.0	.0	15	.0000	20	302	90
18	35	001 105	15.5	835.9	.0	.0	15	.0000	20	318	90
19	37	001 111	15.0	836.4	.0	.0	15	.0000	20	301	90
20	39	001 117	14.5	836.9	.0	.0	15	.0000	20	294	90
21	41	001 123	14.0	837.4	.0	.0	15	.0000	20	296	90
22	43	001 129	13.5	837.9	.0	.0	15	.0000	20	292	90
23	45	001 135	13.0	838.4	.0	.0	15	.0000	20	290	90
24	47	001 141	12.5	838.9	.0	.0	15	.0000	20	273	90
25	49	001 147	12.0	839.4	.0	.0	15	.0000	20	259	90
26	51	001 153	11.5	839.9	.0	.0	15	.0000	20	256	90
27	53	001 159	11.0	840.4	.0	.0	15	.0000	20	258	90
28	55	001 165	10.5	840.9	.0	.0	15	.0000	20	267	90
29	57	001 171	10.0	841.4	.0	.0	15	.0000	20	266	90
30	59	001 177	9.5	841.9	.0	.0	15	.0000	20	278	90
31	61	001 183	9.0	842.4	.0	.0	15	.0000	20	274	90
32	63	001 189	8.5	842.9	.0	.0	15	.0000	20	273	90
33	65	001 195	8.1	843.4	.0	.0	15	.0000	20	283	90
34	67	001 201	7.6	843.9	.0	.0	16	.0000	20	287	90
35	69	001 207	7.1	844.4	.0	.0	15	.0000	20	294	90
36	71	001 213	6.6	844.9	.0	.0	15	.0000	20	283	90
37	73	001 219	6.1	845.4	.0	.0	15	.0000	20	286	90
38	75	001 225	5.6	845.9	.0	.0	15	.0000	20	280	90
39	77	001 231	5.1	846.4	.0	.0	15	.0000	20	278	90
40	79	001 237	4.7	846.9	.0	.0	15	.0000	20	270	90
41	81	001 243	4.2	847.4	.0	.0	15	.0000	20	255	90
42	83	001 249	3.7	847.9	.0	.0	15	.0000	20	275	90
43	85	001 255	3.3	848.4	.0	.0	15	.0000	20	267	90
44	87	001 261	2.9	848.9	.0	.0	15	.0000	20	259	90
45	89	001 267	2.5	849.4	.0	.0	15	.0000	20	267	90
46	91	001 273	2.1	849.9	.0	.0	15	.0000	20	270	90
47	93	001 279	1.8	850.4	.0	.0	15	.0000	20	269	90
48	95	001 285	1.6	850.9	.0	.0	15	.0000	20	267	90
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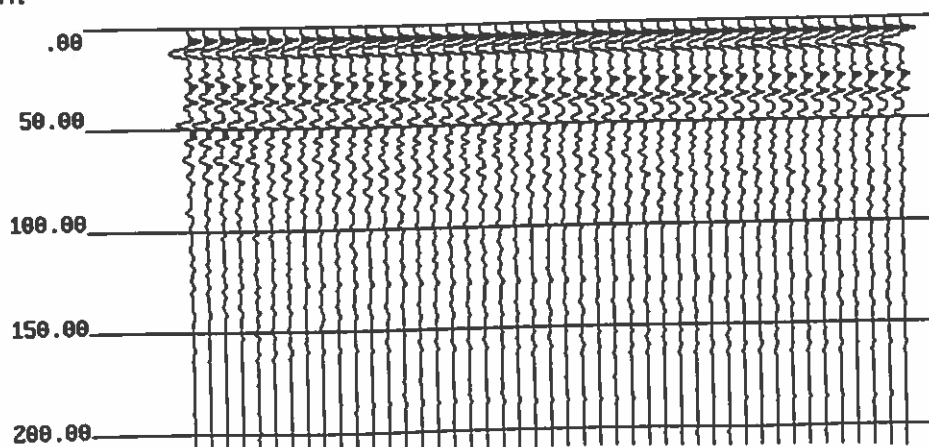
S. Glenwood Bridge



Down-Hole Data
Flattened on First Break
Picks

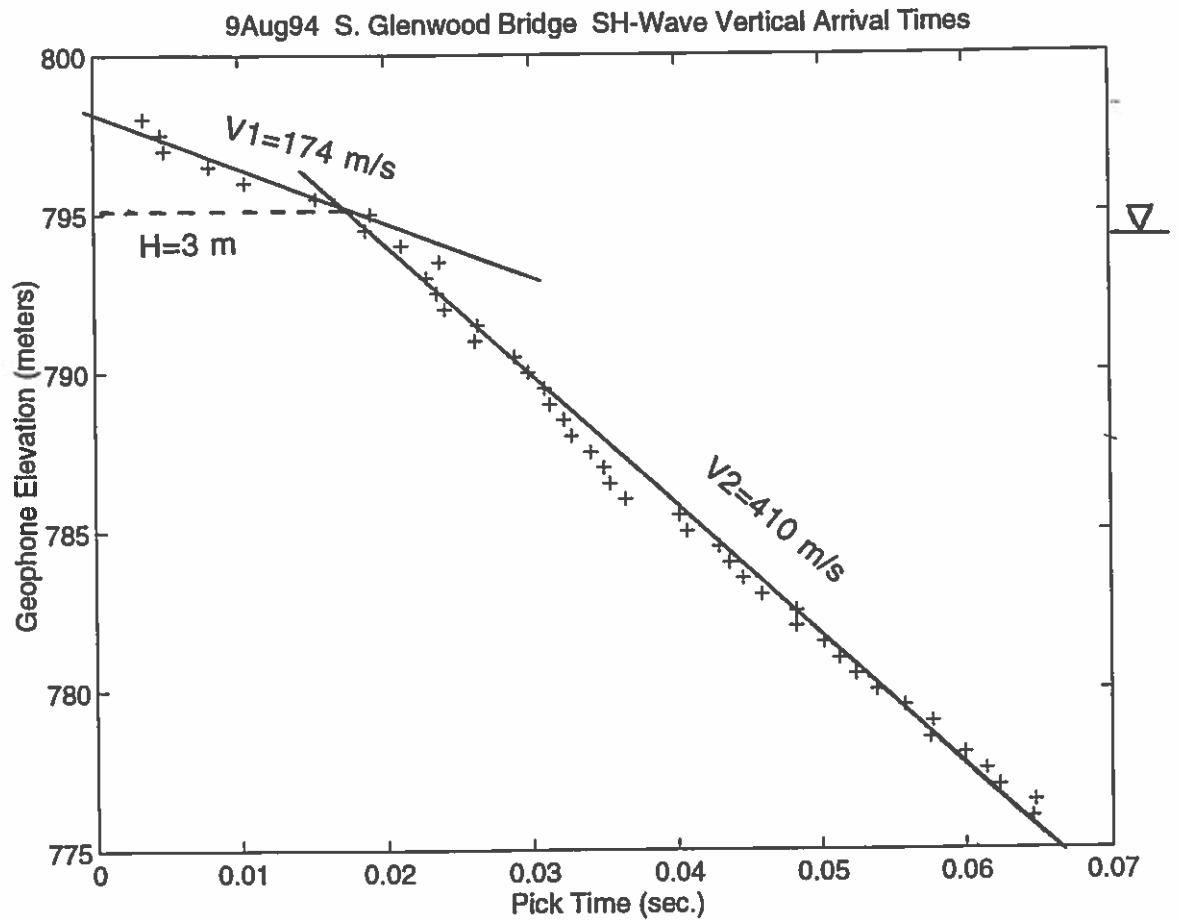


Reference Phone
T-Component



S. Glenwood Bridge

SH-Wave Vertical Travel Times
and
Velocity Measurements



SEGY Header Dump

S. Glenwood Bridge
Shows Tool Azimuth Determinations
Last Two Columns

PARTIAL SEG Y HEADER DUMP

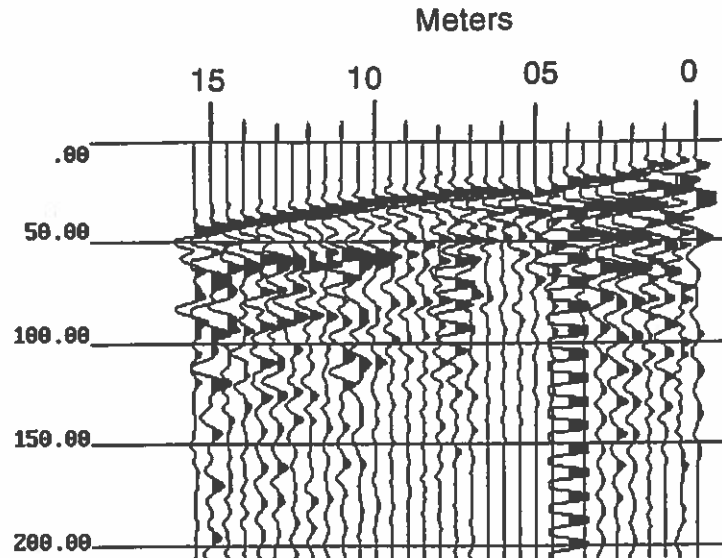
9Aug94 South Glenwood Bridge
Transverse Component

Length = 2500 samples Shot Elevation = 798.2
Sample Interval = .00020 sec. Shot Depth = .0
Delay Time = 0 msec. Up Hole Time = 0 msec
Low Cut Filter = 8 Hz. Shot X-COORD = .0
High Cut Filter = 1000 Hz. Shot Y-COORD = -.3
Line ID: DHAL Shot Date (year.day) = 1994.809
Shot Orientation: Shot Time (hr:min) = 08:57
Azimuth= 90 Deg. Vertical= 90 Deg. Charge Size (grams)= 0

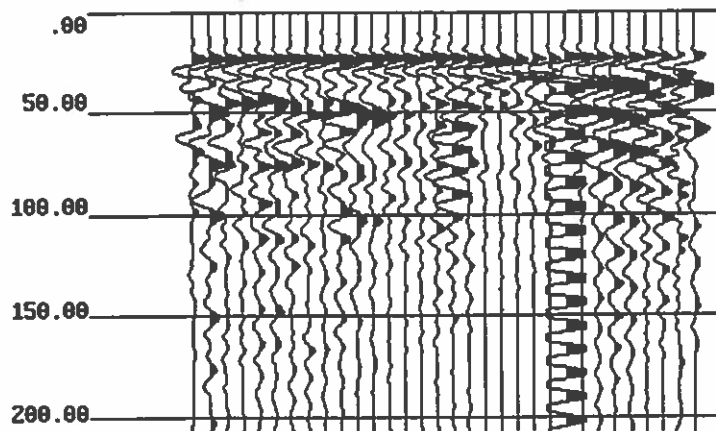
TRACE #	SHOT REC.	STATION		OFFSET	RECEIVER			VERT FOLD	1STBRK (SEC.)	K-GAIN (dB)	AZI	VER
		SHOT	REC		ELEV.	X-COORD	Y-COORD					
1	1	001	003	22.2	776.0	.0	.0	15	.0000	20	323	90
2	3	001	009	21.7	776.5	.0	.0	15	.0000	20	315	90
3	5	001	015	21.2	777.0	.0	.0	15	.0000	20	332	90
4	7	001	021	20.7	777.5	.0	.0	20	.0000	20	330	90
5	9	001	027	20.2	778.0	.0	.0	20	.0000	20	321	90
6	11	001	033	19.7	778.5	.0	.0	20	.0000	20	330	90
7	13	001	039	19.2	779.0	.0	.0	20	.0000	20	323	90
8	15	001	045	18.7	779.5	.0	.0	20	.0000	20	306	90
9	17	001	051	18.2	780.0	.0	.0	20	.0000	20	334	90
10	19	001	057	17.7	780.5	.0	.0	20	.0000	20	321	90
11	21	001	063	17.2	781.0	.0	.0	20	.0000	20	324	90
12	23	001	069	16.7	781.5	.0	.0	20	.0000	20	329	90
13	25	001	075	16.2	782.0	.0	.0	20	.0000	20	328	90
14	27	001	081	15.7	782.5	.0	.0	20	.0000	20	345	90
15	29	001	087	15.2	783.0	.0	.0	20	.0000	20	313	90
16	31	001	093	14.7	783.5	.0	.0	20	.0000	20	302	90
17	33	001	099	14.2	784.0	.0	.0	20	.0000	20	303	90
18	35	001	105	13.7	784.5	.0	.0	20	.0000	20	302	90
19	37	001	111	13.2	785.0	.0	.0	20	.0000	20	292	90
20	39	001	117	12.7	785.5	.0	.0	20	.0000	20	310	90
21	41	001	123	12.2	786.0	.0	.0	20	.0000	20	336	90
22	43	001	129	11.7	786.5	.0	.0	20	.0000	20	312	90
23	45	001	135	11.2	787.0	.0	.0	20	.0000	20	300	90
24	47	001	141	10.7	787.5	.0	.0	20	.0000	20	293	90
25	49	001	147	10.2	788.0	.0	.0	20	.0000	20	291	90
26	51	001	153	9.7	788.5	.0	.0	20	.0000	20	280	90
27	53	001	159	9.2	789.0	.0	.0	20	.0000	20	289	90
28	55	001	165	8.7	789.5	.0	.0	21	.0000	20	289	90
29	57	001	171	8.2	790.0	.0	.0	20	.0000	20	284	90
30	59	001	177	7.7	790.5	.0	.0	20	.0000	20	274	90
31	61	001	183	7.2	791.0	.0	.0	20	.0000	20	271	90
32	63	001	189	6.7	791.5	.0	.0	20	.0000	20	275	90
33	65	001	195	6.2	792.0	.0	.0	20	.0000	20	240	90
34	67	001	201	5.7	792.5	.0	.0	20	.0000	20	293	90
35	69	001	207	5.2	793.0	.0	.0	20	.0000	20	304	90
36	71	001	213	4.7	793.5	.0	.0	20	.0000	20	350	90
37	73	001	219	4.2	794.0	.0	.0	20	.0000	20	236	90
38	75	001	225	3.7	794.5	.0	.0	20	.0000	20	264	90
39	77	001	231	3.2	795.0	.0	.0	20	.0000	20	256	90
40	79	001	237	2.7	795.5	.0	.0	20	.0000	20	256	90
41	81	001	243	2.2	796.0	.0	.0	20	.0000	20	253	90
42	83	001	249	1.7	796.5	.0	.0	20	.0000	20	246	90
43	85	001	255	1.2	797.0	.0	.0	20	.0000	20	243	90
44	87	001	261	.8	797.5	.0	.0	20	.0000	20	293	90
45	89	001	267	.4	798.0	.0	.0	20	.0000	20	301	90

Franklin Road

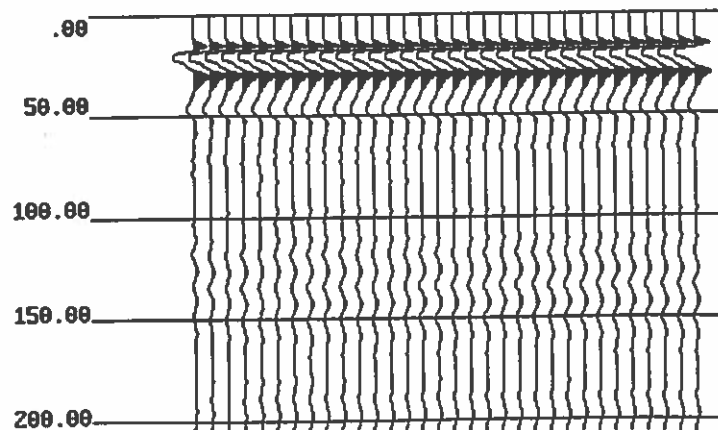
Rotated Down-Hole
Data (T-component)



Down-Hole Data
Flattened on First Break
Picks

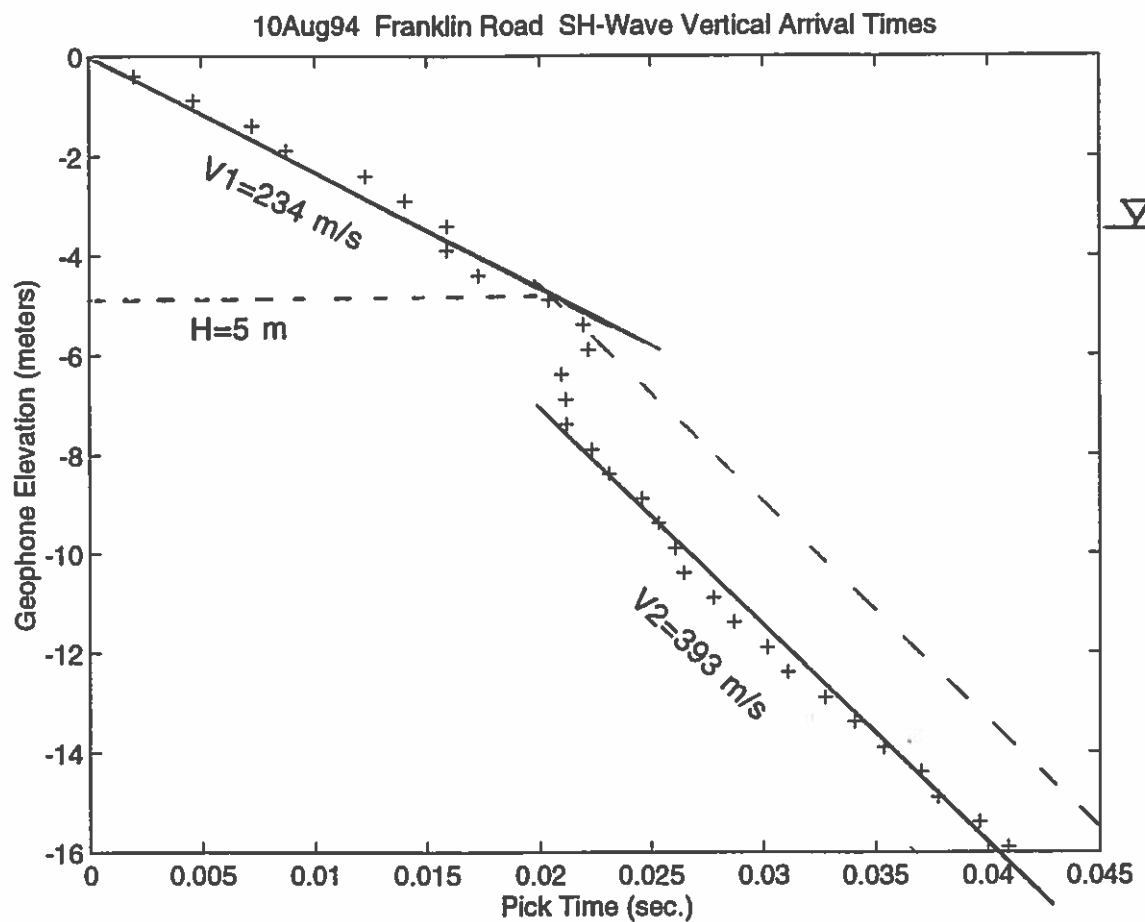


Reference Phone
T-Component



Franklin Road

SH-Wave Vertical Travel Times and Velocity Measurements



Note: This hole was drilled under an overpass. Buried concrete foundations close to the hole may have contributed to the travel time reversal that significantly decreased the travel times for the bottom half of the hole.

SEG Y Header Dump

Franklin Road
Shows Tool Azimuth Determinations
Last Two Columns

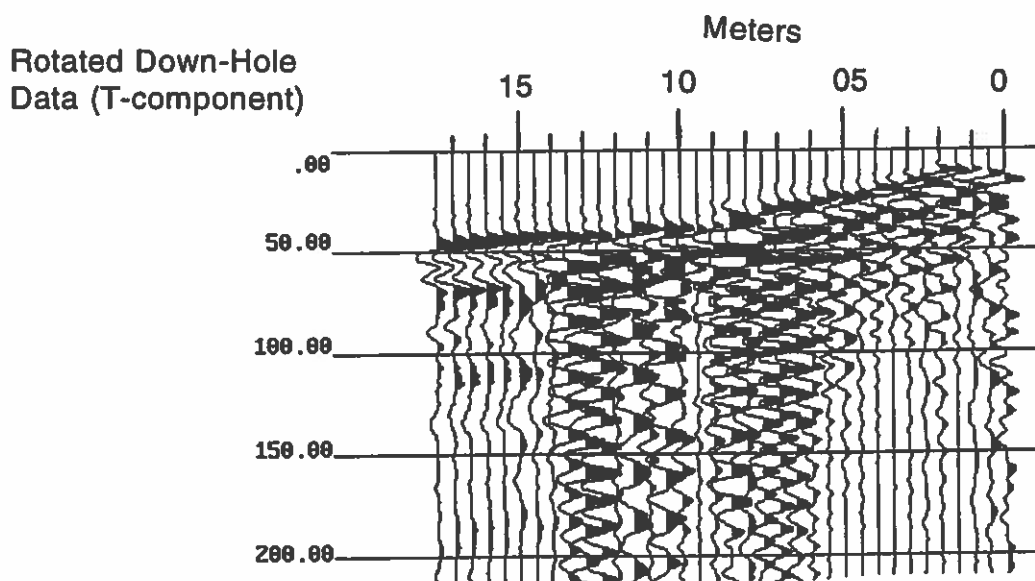
PARTIAL SEG Y HEADER DUMP
10 Aug 94 Franklin Road
T-Component

Length = 2500 samples
Sample Interval = .00020 sec.
Delay Time = 0 msec.
Low Cut Filter = 8 Hz.
High Cut Filter = 1000 Hz.
Line ID: FCL1
Shot Orientation:
Azimuth= 90 Deg. Vertical= 90 Deg.

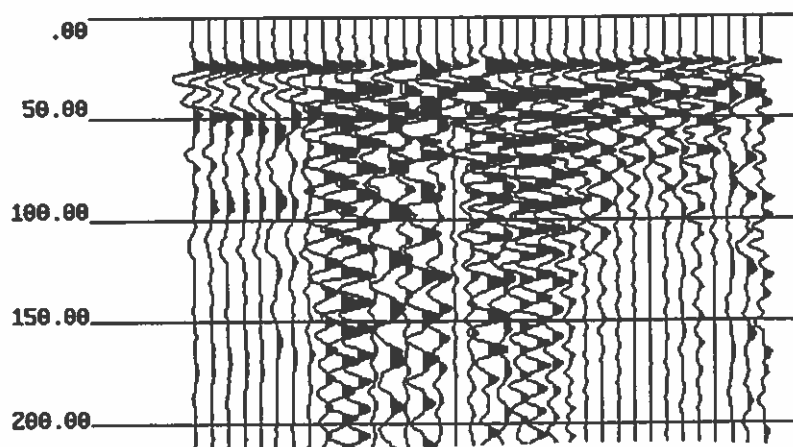
Shot Elevation = -.2
Shot Depth = .0
Up Hole Time = 0 msec
Shot X-COORD = .0
Shot Y-COORD = -1.0
Shot Date (year.day) = 1994.810
Shot Time (hr:min) = 10:13
Charge Size (grams) = 0

TRACE #	SHOT REC.	STATION		OFFSET	RECEIVER			VERT FOLD	1STBRK (SEC.)	K-GAIN (dB)	AZI	VER
		SHOT	REC		ELEV.	X-COORD	Y-COORD					
1	1	001	003	15.7	-15.9	.0	.0	20	.0000	20	292	90
2	3	001	009	15.2	-15.4	.0	.0	20	.0000	20	293	90
3	5	001	015	14.7	-14.9	.0	.0	20	.0000	20	288	90
4	7	001	021	14.2	-14.4	.0	.0	21	.0000	20	292	90
5	9	001	027	13.7	-13.9	.0	.0	20	.0000	20	134	90
6	11	001	033	13.2	-13.4	.0	.0	20	.0000	20	136	90
7	13	001	039	12.7	-12.9	.0	.0	20	.0000	20	123	90
8	15	001	045	12.2	-12.4	.0	.0	20	.0000	20	118	90
9	17	001	051	11.7	-11.9	.0	.0	20	.0000	20	126	90
10	19	001	057	11.2	-11.4	.0	.0	20	.0000	20	123	90
11	21	001	063	10.7	-10.9	.0	.0	20	.0000	20	113	90
12	23	001	069	10.2	-10.4	.0	.0	20	.0000	20	119	90
13	25	001	075	9.7	-9.9	.0	.0	20	.0000	20	114	90
14	27	001	081	9.2	-9.4	.0	.0	20	.0000	20	120	90
15	29	001	087	8.7	-8.9	.0	.0	20	.0000	20	115	90
16	31	001	093	8.3	-8.4	.0	.0	20	.0000	20	111	90
17	33	001	099	7.8	-7.9	.0	.0	20	.0000	20	113	90
18	35	001	105	7.3	-7.4	.0	.0	20	.0000	20	121	90
19	37	001	111	6.8	-6.9	.0	.0	20	.0000	20	154	90
20	39	001	117	6.3	-6.4	.0	.0	20	.0000	20	167	90
21	41	001	123	5.8	-5.9	.0	.0	20	.0000	20	182	90
22	43	001	129	5.3	-5.4	.0	.0	20	.0000	20	176	90
23	45	001	135	4.8	-4.9	.0	.0	20	.0000	20	178	90
24	47	001	141	4.3	-4.4	.0	.0	20	.0000	20	154	90
25	49	001	147	3.8	-3.9	.0	.0	20	.0000	20	181	90
26	51	001	153	3.4	-3.4	.0	.0	20	.0000	20	176	90
27	53	001	159	2.9	-2.9	.0	.0	20	.0000	20	166	90
28	55	001	165	2.4	-2.4	.0	.0	20	.0000	20	174	90
29	57	001	171	2.0	-1.9	.0	.0	20	.0000	20	151	90
30	59	001	177	1.6	-1.4	.0	.0	20	.0000	20	121	90
31	61	001	183	1.2	-.9	.0	.0	20	.0000	20	317	90
32	63	001	189	1.0	-.4	.0	.0	20	.0000	20	332	90

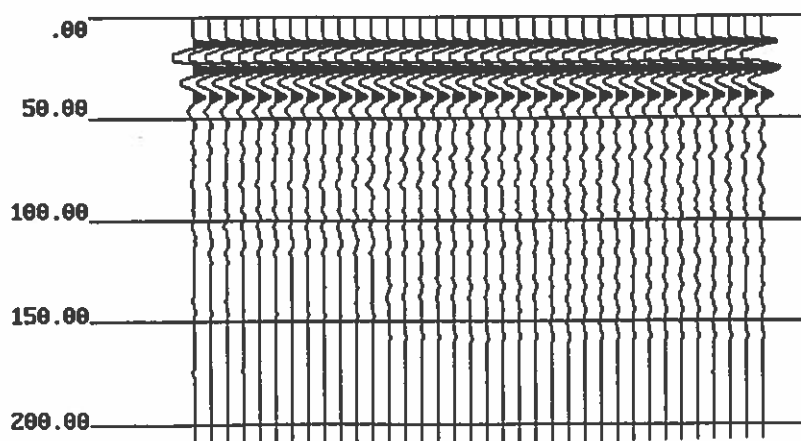
Diversion Dam



Down-Hole Data
Flattened on First Break
Picks

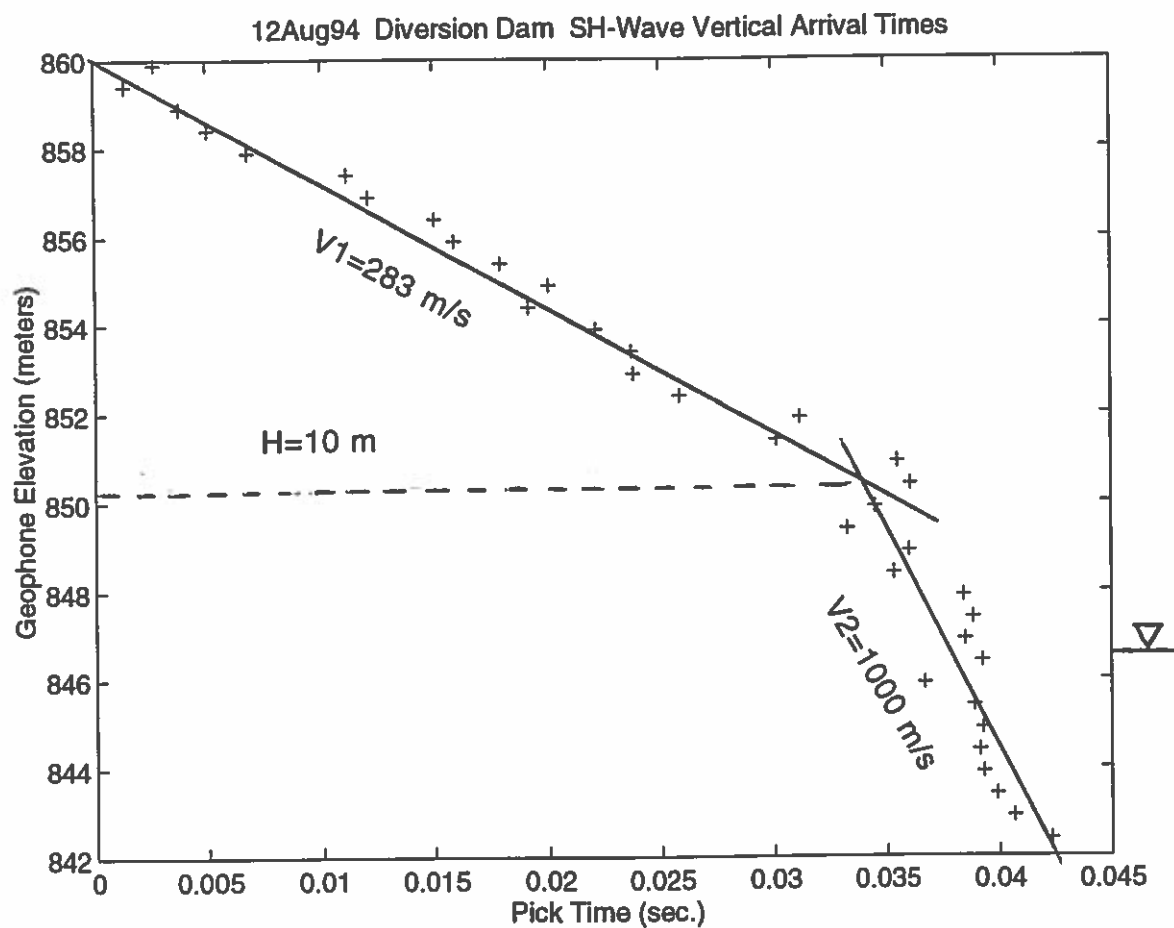


Reference Phone
T-Component



Diversion Dam

SH-Wave Vertical Travel Times and Velocity Measurements



SEGY Header Dump

Diversion Dam
Shows Tool Azimuth Determinations
Last Two Columns

PARTIAL SEG Y HEADER DUMP

12 Aug 94 Diversion Dam
Transverse-Comp.

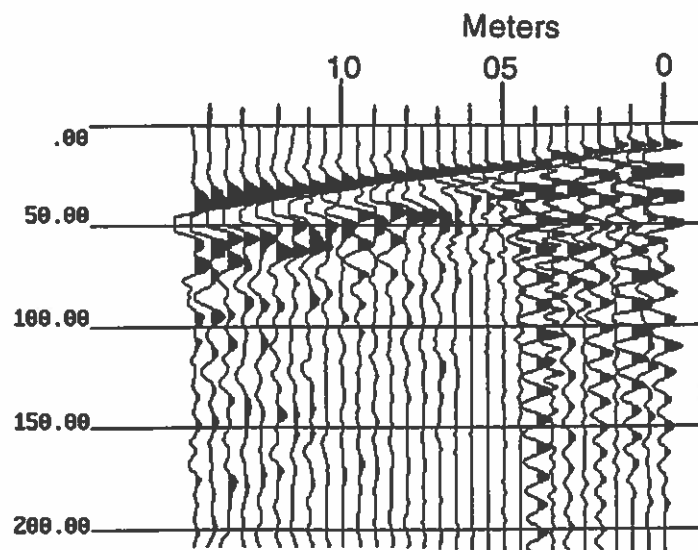
Length = 2500 samples
Sample Interval = .00020 sec.
Delay Time = 0 msec.
Low Cut Filter = 8 Hz.
High Cut Filter = 1000 Hz.
Line ID: DHA6
Shot Orientation:
Azimuth= 90 Deg. Vertical= 90 Deg.

Shot Elevation = 859.6
Shot Depth = .0
Up Hole Time = 0 msec
Shot X-COORD = .0
Shot Y-COORD = 1.5
Shot Date (year.day) = 1994.812
Shot Time (hr:min) = 08:11
Charge Size (grams)= 0

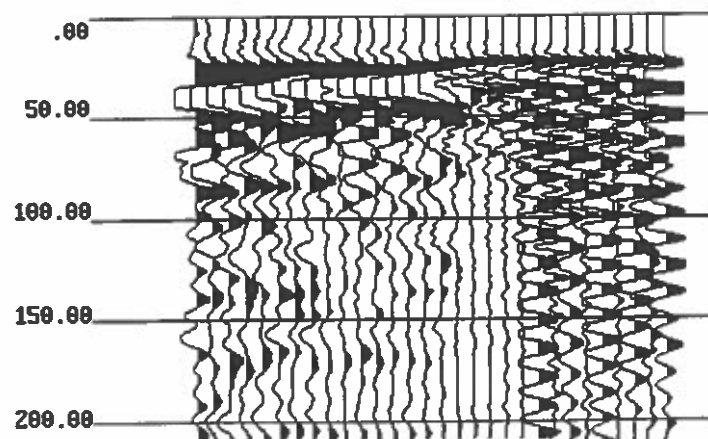
TRACE #	SHOT REC.	STATION		OFFSET	RECEIVER			VERT FOLD	1STBRK (SEC.)	K-GAIN (dB)	AZI	VER
		SHOT	REC		ELEV.	X-COORD	Y-COORD					
1	1	001	003	17.3	842.4	.0	.0	15	.0000	20	323	90
2	3	001	009	16.8	842.9	.0	.0	15	.0000	20	328	90
3	5	001	015	16.3	843.4	.0	.0	15	.0000	20	330	90
4	7	001	021	15.8	843.9	.0	.0	15	.0000	20	331	90
5	9	001	027	15.3	844.4	.0	.0	15	.0000	20	336	90
6	11	001	033	14.8	844.9	.0	.0	15	.0000	20	342	90
7	13	001	039	14.3	845.4	.0	.0	15	.0000	20	344	90
8	15	001	045	13.8	845.9	.0	.0	15	.0000	20	358	90
9	17	001	051	13.3	846.4	.0	.0	15	.0000	20	361	90
10	19	001	057	12.8	846.9	.0	.0	15	.0000	20	334	90
11	21	001	063	12.3	847.4	.0	.0	15	.0000	20	347	90
12	23	001	069	11.8	847.9	.0	.0	15	.0000	20	350	90
13	25	001	075	11.3	848.4	.0	.0	15	.0000	20	352	90
14	27	001	081	10.8	848.9	.0	.0	15	.0000	20	344	90
15	29	001	087	10.3	849.4	.0	.0	15	.0000	20	7	90
16	31	001	093	9.8	849.9	.0	.0	15	.0000	20	341	90
17	33	001	099	9.3	850.4	.0	.0	15	.0000	20	345	90
18	35	001	105	8.8	850.9	.0	.0	15	.0000	20	357	90
19	37	001	111	8.3	851.4	.0	.0	15	.0000	20	327	90
20	39	001	117	7.8	851.9	.0	.0	15	.0000	20	333	90
21	41	001	123	7.3	852.4	.0	.0	15	.0000	20	289	90
22	43	001	129	6.9	852.9	.0	.0	15	.0000	20	324	90
23	45	001	135	6.4	853.4	.0	.0	15	.0000	20	329	90
24	47	001	141	5.9	853.9	.0	.0	15	.0000	20	312	90
25	49	001	147	5.4	854.4	.0	.0	15	.0000	20	316	90
26	51	001	153	4.9	854.9	.0	.0	15	.0000	20	338	90
27	53	001	159	4.5	855.4	.0	.0	15	.0000	20	336	90
28	55	001	165	4.0	855.9	.0	.0	15	.0000	20	307	90
29	57	001	171	3.5	856.4	.0	.0	15	.0000	20	350	90
30	59	001	177	3.1	856.9	.0	.0	15	.0000	20	323	90
31	61	001	183	2.7	857.4	.0	.0	15	.0000	20	329	90
32	63	001	189	2.3	857.9	.0	.0	15	.0000	20	314	90
33	65	001	195	1.9	858.4	.0	.0	15	.0000	20	307	90
34	67	001	201	1.7	858.9	.0	.0	15	.0000	20	143	90
35	69	001	207	1.5	859.4	.0	.0	15	.0000	20	123	90
36	71	001	213	1.5	859.9	.0	.0	15	.0000	20	141	90

Cole Road

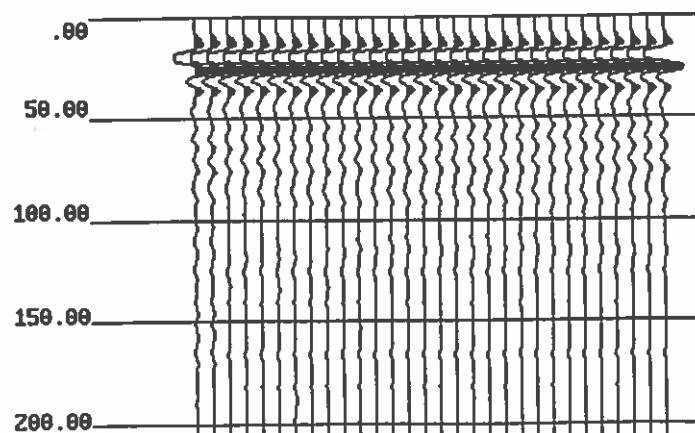
Rotated Down-Hole
Data (T-component)



Down-Hole Data
Flattened on First Break
Picks

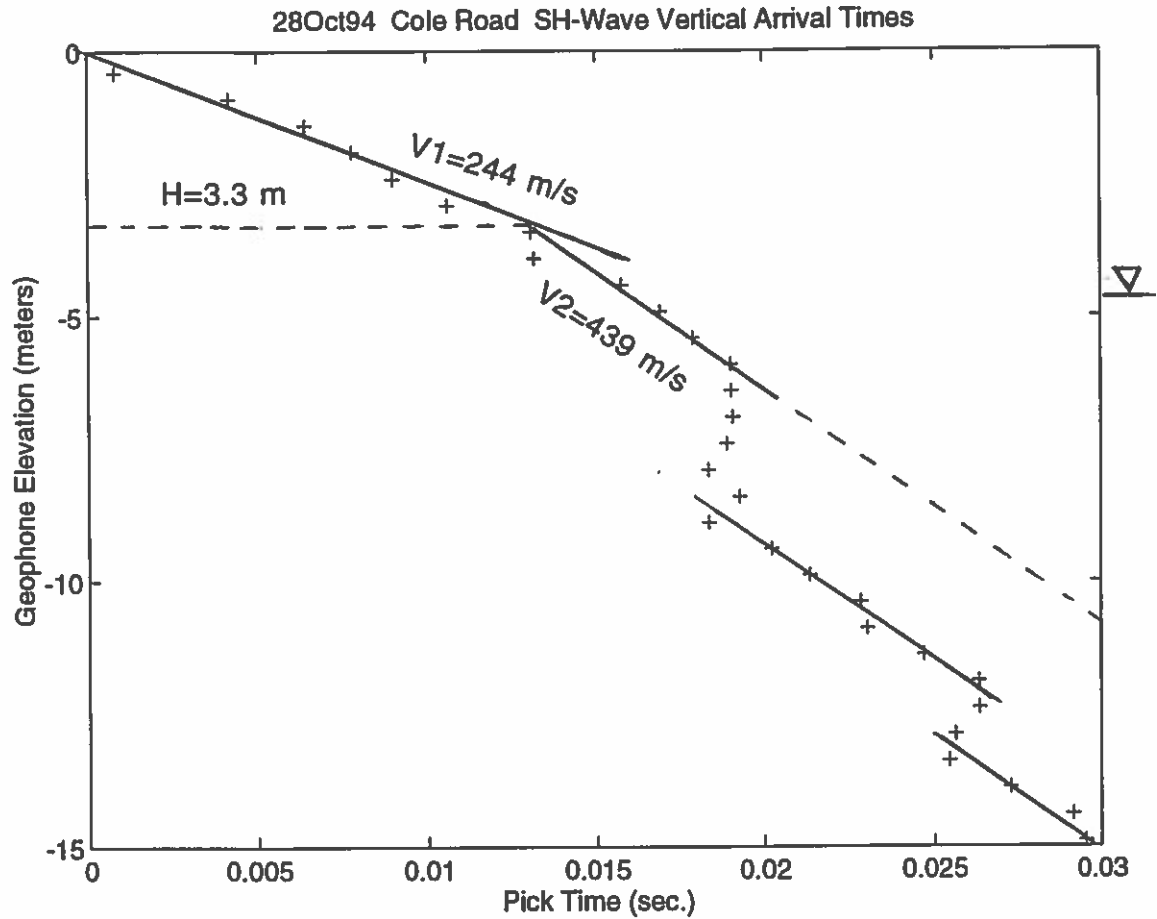


Reference Phone
T-Component



Cole Road

SH-Wave Vertical Travel Times and Velocity Measurements



Note: These data were acquired under a freeway overpass next to concrete foundations. The concrete foundations may have contributed to the travel-time anomalies.

SEGY Header Dump

Cole Road
Shows Tool Azimuth Determinations
Last Two Columns

PARTIAL SEG Y HEADER DUMP

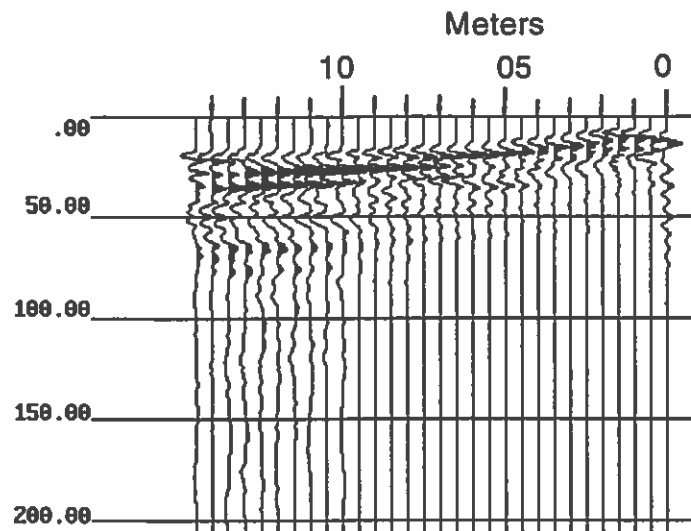
28 Oct 1994 Cole Road
Transverse Component

Length = 2500 samples				Shot Elevation = -.3			
Sample Interval = .00020 sec.				Shot Depth = .0			
Delay Time = 0 msec.				Up Hole Time = 0 msec			
Low Cut Filter = 8 Hz.				Shot X-COORD = .0			
High Cut Filter = 1000 Hz.				Shot Y-COORD = -.8			
Line ID: DHA2				Shot Date (year.day) = 1994.***			
Shot Orientation:				Shot Time (hr:min) = 10:08			
Azimuth=270 Deg. Vertical= 90 Deg.				Charge Size (grams)= 0			

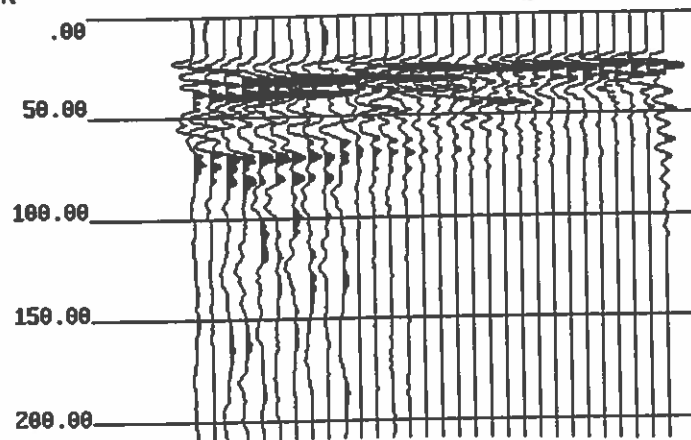
TRACE #	SHOT REC.	STATION		OFFSET	RECEIVER			VERT FOLD	1STBARK (SEC.)	K-GAIN (dB)	AZI	VER
		SHOT	REC		ELEV.	X-COORD	Y-COORD					
1	1	001	003	14.6	-14.9	.0	.0	20	.0000	20	10	90
2	3	001	009	14.1	-14.4	.0	.0	15	.0000	20	6	90
3	5	001	015	13.6	-13.9	.0	.0	15	.0000	20	352	90
4	7	001	021	13.1	-13.4	.0	.0	15	.0000	20	10	90
5	9	001	027	12.6	-12.9	.0	.0	15	.0000	20	7	90
6	11	001	033	12.1	-12.4	.0	.0	15	.0000	20	0	90
7	13	001	039	11.6	-11.9	.0	.0	15	.0000	20	353	90
8	15	001	045	11.1	-11.4	.0	.0	15	.0000	20	356	90
9	17	001	051	10.6	-10.9	.0	.0	15	.0000	20	353	90
10	19	001	057	10.1	-10.4	.0	.0	15	.0000	20	349	90
11	21	001	063	9.6	-9.9	.0	.0	15	.0000	20	357	90
12	23	001	069	9.1	-9.4	.0	.0	15	.0000	20	350	90
13	25	001	075	8.6	-8.9	.0	.0	15	.0000	20	334	90
14	27	001	081	8.1	-8.4	.0	.0	15	.0000	20	350	90
15	29	001	087	7.6	-7.9	.0	.0	15	.0000	20	343	90
16	31	001	093	7.1	-7.4	.0	.0	15	.0000	20	357	90
17	33	001	099	6.6	-6.9	.0	.0	15	.0000	20	340	90
18	35	001	105	6.2	-6.4	.0	.0	15	.0000	20	345	90
19	37	001	111	5.7	-5.9	.0	.0	15	.0000	20	358	90
20	39	001	117	5.2	-5.4	.0	.0	15	.0000	20	373	90
21	41	001	123	4.7	-4.9	.0	.0	15	.0000	20	358	90
22	43	001	129	4.2	-4.4	.0	.0	15	.0000	20	340	90
23	45	001	135	3.7	-3.9	.0	.0	15	.0000	20	264	90
24	47	001	141	3.2	-3.4	.0	.0	15	.0000	20	320	90
25	49	001	147	2.7	-2.9	.0	.0	15	.0000	20	261	90
26	51	001	153	2.2	-2.4	.0	.0	15	.0000	20	299	90
27	53	001	159	1.8	-1.9	.0	.0	15	.0000	20	266	90
28	55	001	165	1.4	-1.4	.0	.0	15	.0000	20	256	90
29	57	001	171	1.0	-.9	.0	.0	15	.0000	20	271	90
30	59	001	177	.8	-.4	.0	.0	15	.0000	20	299	90

Cole Road (Vertical Hammer)

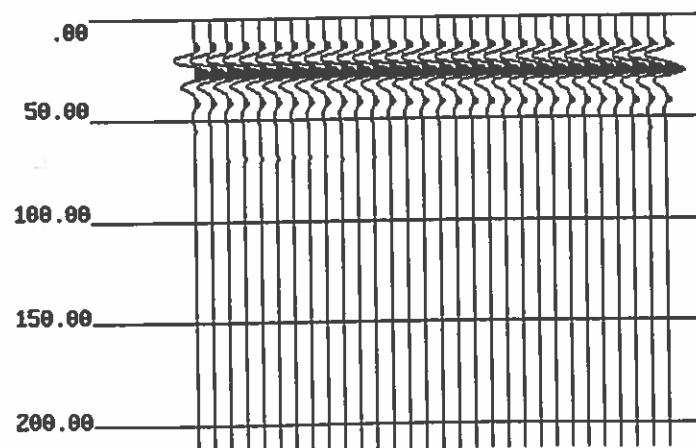
Down-Hole Data
(V-component)



Down-Hole Data
Flattened on First Break
Picks

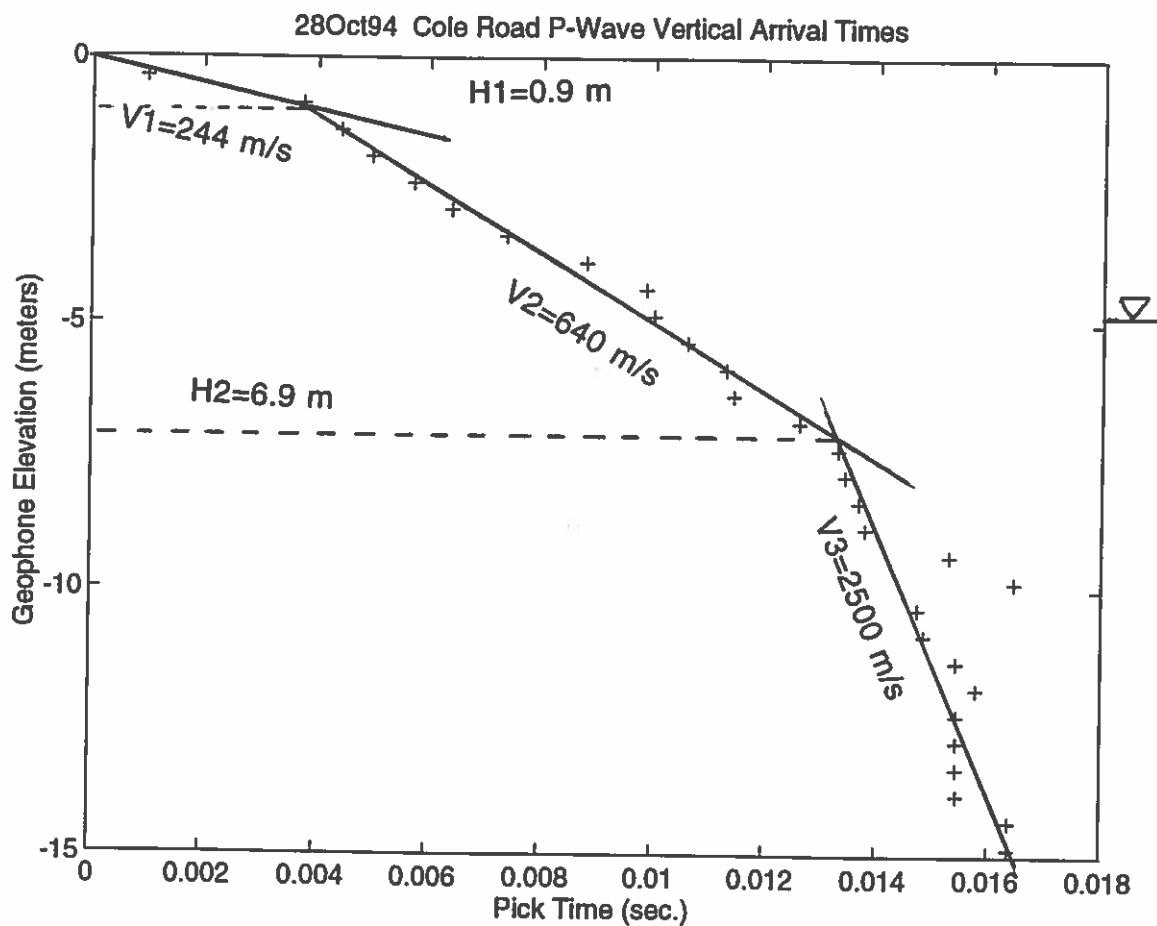


Reference Phone
V-Component



Cole Road

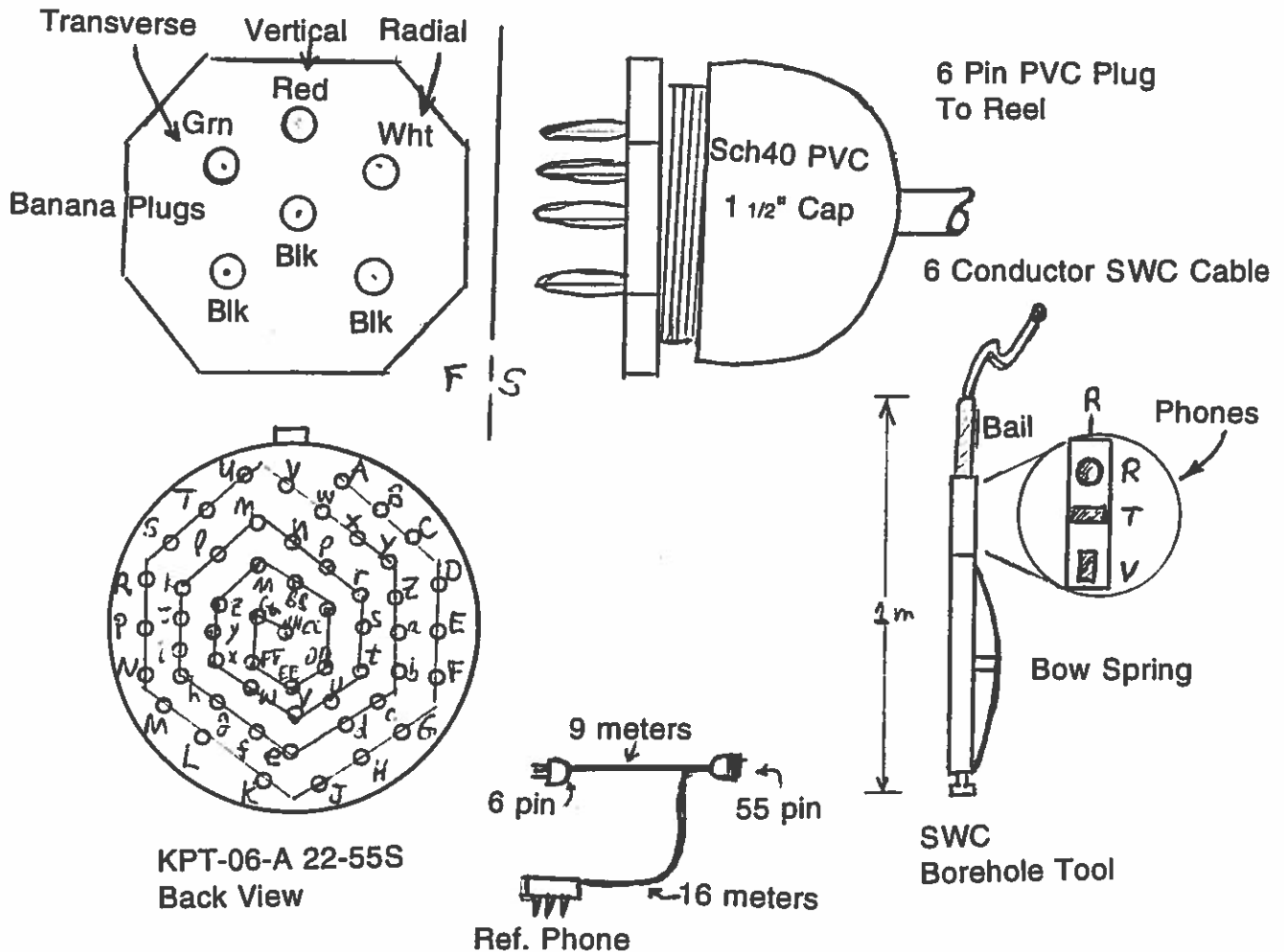
P-Wave Vertical Travel Times and Velocity Measurements



Note: These data were acquired under a freeway overpass next to concrete foundations. The concrete foundations may have contributed to the travel-time anomalies.

Appendix II

Wiring Diagrams SWC Borehole Tool and Cables



Set Bison for 6 Channel Recording, Geophone #1=1

Bendix PT06A22-55S (SR) = Cannon KPT-06-A 22-55S

Pins Channel Phone Transduction Constant=0.041(374Ω)^{1/2} volts/(in/sec)
+ - SWC Phones L10B B5 8Hz 374 ohm

AB	1	Vertical	A=black B=red
CD	2	Radial	C=black D=white
EF	3	Transverse	E=black F=green

Reference Phones L-10AR 8Hz 374 ohm 70%damping

GH	4	Vertical	G=red H=blue
JK	5	Radial	J=yellow K=black
LM	6	Transverse	L=green M=white

APPENDIX III

Selected SEGY Header Blocks

Documents Equipment Deployment and Instrument Settings

The following pages list the SEGY headers for the first source effort at each borehole location. With the exception of Cole Road, all boreholes were logged by starting with a 90 degree SH-Wave source orientation. At Cole Road, the first orientation was 270 degrees. The protocol was to alternate the source orientation, thus the odd numbered records used a 90 degree source, and the even shots used the 270 degree orientation (except at Cole Road). Cole Road is also the only one with the P-Wave source which starts with record 61.

The X, Y, and elevation of the source are given in the upper portion of the listing along with the instrument settings. The reference phone is listed as trace numbers 4, 5, and 6. The down-hole phone is listed as trace numbers 1, 2, and 3. The channel definitions are:

- 1=Down hole Vertical
- 2=Down hole Radial
- 3=Down hole Transverse
- 4=Reference Vertical
- 5=Reference Radial
- 6=Reference Transverse

Note: All Units are metric.

PARTIAL SEG Y HEADER DUMP

g001.seg
24jul94 N. Glenwood Bridge

Length = 2500 samples
Sample Interval = .00020 sec.
Delay Time = 0 msec.
Low Cut Filter = 8 Hz.
High Cut Filter = 1000 Hz.
Line ID: DHA3
Shot Orientation:
Azimuth= 90 Deg. Vertical= 90 Deg.

Shot Elevation = 794.1
Shot Depth = .0
Up Hole Time = 0 msec
Shot X-COORD = .0
Shot Y-COORD = -2.0
Shot Date (year.day) = 1994.724
Shot Time (hr:min) = 07:05
Charge Size (grams)= 0

TRACE #	SHOT REC.	STATION SHOT REC	OFFSET	RECEIVER ELEV. X-COORD Y-COORD	VERT FOLD	1STBRK (SEC.)	K-GAIN (dB)	AZI	VER
1	1	001 001	14.8	779.4 .0 .0	10	.0000	20	0	180
2	1	001 002	14.8	779.4 .0 .0	10	.0000	20	94	90
3	1	001 003	14.8	779.4 .0 .0	10	.0000	20	184	90
4	1	001 004	2.0	794.2 .0 -4.0	10	.0000	20	0	0
5	1	001 005	2.0	794.2 .0 -4.0	10	.0000	20	0	90
6	1	001 006	2.0	794.2 .0 -4.0	10	.0000	20	270	90

PARTIAL SEG Y HEADER DUMP

n001.seg
28Jul94 New York Canal

Length = 2500 samples
Sample Interval = .00020 sec.
Delay Time = 0 msec.
Low Cut Filter = 8 Hz.
High Cut Filter = 1000 Hz.
Line ID: DHA2
Shot Orientation:
Azimuth= 90 Deg. Vertical= 90 Deg.

Shot Elevation = 851.3
Shot Depth = .0
Up Hole Time = 0 msec
Shot X-COORD = .0
Shot Y-COORD = 1.6
Shot Date (year.day) = 1994.728
Shot Time (hr:min) = 07:37
Charge Size (grams)= 0

TRACE #	SHOT REC.	STATION SHOT REC	OFFSET	RECEIVER ELEV. X-COORD Y-COORD	VERT FOLD	1STBRK (SEC.)	K-GAIN (dB)	AZI	VER
1	1	001 001	23.9	827.4 .0 .0	15	.0000	20	0	180
2	1	001 002	23.9	827.4 .0 .0	15	.0000	20	228	90
3	1	001 003	23.9	827.4 .0 .0	15	.0000	20	318	90
4	1	001 004	2.4	851.2 .0 4.0	15	.0000	20	0	0
5	1	001 005	2.4	851.2 .0 4.0	15	.0000	20	0	90
6	1	001 006	2.4	851.2 .0 4.0	15	.0000	20	270	90

PARTIAL SEG Y HEADER DUMP

i001.seg
9Aug94 S. Glenwood Bridge

Length = 2500 samples
Sample Interval = .00020 sec.
Delay Time = 0 msec.
Low Cut Filter = 8 Hz.
High Cut Filter = 1000 Hz.
Line ID: DHA1
Shot Orientation:
Azimuth= 90 Deg. Vertical= 90 Deg.

Shot Elevation = 798.2
Shot Depth = .0
Up Hole Time = 0 msec
Shot X-COORD = .0
Shot Y-COORD = -.3
Shot Date (year.day) = 1994.809
Shot Time (hr:min) = 08:57
Charge Size (grams)= 0

TRACE #	SHOT REC.	STATION SHOT REC	OFFSET	RECEIVER ELEV. X-COORD Y-COORD	VERT FOLD	1STBRK (SEC.)	K-GAIN (dB)	AZI	VER
1	1	001 001	22.2	776.0 .0 .0	15	.0000	20	0	180
2	1	001 002	22.2	776.0 .0 .0	15	.0000	20	233	90
3	1	001 003	22.2	776.0 .0 .0	15	.0000	20	323	90
4	1	001 004	1.7	797.8 .0 1.4	15	.0000	20	0	0
5	1	001 005	1.7	797.8 .0 1.4	15	.0000	20	0	90
6	1	001 006	1.7	797.8 .0 1.4	15	.0000	20	270	90

PARTIAL SEG Y HEADER DUMP

f001.seg
10Aug94 Franklin Road

Length = 2500 samples
Sample Interval = .00020 sec.
Delay Time = 0 msec.
Low Cut Filter = 8 Hz.
High Cut Filter = 1000 Hz.
Line ID: FCL1
Shot Orientation:
Azimuth= 90 Deg. Vertical= 90 Deg.

Shot Elevation = -.2
Shot Depth = .0
Up Hole Time = 0 msec
Shot X-COORD = .0
Shot Y-COORD = -1.0
Shot Date (year.day) = 1994.810
Shot Time (hr:min) = 10:13
Charge Size (grams)= 0

TRACE #	SHOT REC.	STATION SHOT REC	OFFSET	RECEIVER ELEV. X-COORD	Y-COORD	VERT FOLD	1STBRK (SEC.)	K-GAIN (dB)	AZI	VER
1	1	001 001	15.7	-15.9	.0	.0	20	.0000	20	0 180
2	1	001 002	15.7	-15.9	.0	.0	20	.0000	20	202 90
3	1	001 003	15.7	-15.9	.0	.0	20	.0000	20	292 90
4	1	001 004	1.9	-.2	.0	.9	20	.0000	20	0 0
5	1	001 005	1.9	-.2	.0	.9	20	.0000	20	0 90
6	1	001 006	1.9	-.2	.0	.9	20	.0000	20	270 90

PARTIAL SEG Y HEADER DUMP

v001.seg
12Aug94 Diversion Dam

Length = 2500 samples
Sample Interval = .00020 sec.
Delay Time = 0 msec.
Low Cut Filter = 8 Hz.
High Cut Filter = 1000 Hz.
Line ID: DHA6
Shot Orientation:
Azimuth= 90 Deg. Vertical= 90 Deg.

Shot Elevation = 859.6
Shot Depth = .0
Up Hole Time = 0 msec
Shot X-COORD = .0
Shot Y-COORD = 1.5
Shot Date (year.day) = 1994.812
Shot Time (hr:min) = 08:11
Charge Size (grams)= 0

TRACE #	SHOT REC.	STATION SHOT REC	OFFSET	RECEIVER ELEV. X-COORD	Y-COORD	VERT FOLD	1STBRK (SEC.)	K-GAIN (dB)	AZI	VER
1	1	001 001	17.3	842.4	.0	.0	15	.0000	20	0 180
2	1	001 002	17.3	842.4	.0	.0	15	.0000	20	233 90
3	1	001 003	17.3	842.4	.0	.0	15	.0000	20	323 90
4	1	001 004	2.5	859.5	.0	4.0	15	.0000	20	0 0
5	1	001 005	2.5	859.5	.0	4.0	15	.0000	20	0 90
6	1	001 006	2.5	859.5	.0	4.0	15	.0000	20	270 90

PARTIAL SEG Y HEADER DUMP

c001.seg
28Oct94 Cole Road

Length = 2500 samples
Sample Interval = .00020 sec.
Delay Time = 0 msec.
Low Cut Filter = 8 Hz.
High Cut Filter = 1000 Hz.
Line ID: DHA2
Shot Orientation:
Azimuth=270 Deg. Vertical= 90 Deg.

Shot Elevation = -.3
Shot Depth = .0
Up Hole Time = 0 msec
Shot X-COORD = .0
Shot Y-COORD = -.8
Shot Date (year.day) = 1994.***
Shot Time (hr:min) = 10:08
Charge Size (grams)= 0

TRACE #	SHOT REC.	STATION SHOT REC	OFFSET	RECEIVER ELEV. X-COORD	Y-COORD	VERT FOLD	1STBRK (SEC.)	K-GAIN (dB)	AZI	VER
1	1	001 001	14.6	-14.9	.0	.0	20	.0000	20	0 180
2	1	001 002	14.6	-14.9	.0	.0	20	.0000	20	280 90
3	1	001 003	14.6	-14.9	.0	.0	20	.0000	20	10 90
4	1	001 004	1.7	-.3	.0	.9	20	.0000	20	0 0
5	1	001 005	1.7	-.3	.0	.9	20	.0000	20	0 90
6	1	001 006	1.7	-.3	.0	.9	20	.0000	20	270 90

PARTIAL SEG Y HEADER DUMP

c061.seg
28Oct94 Cole Road P-Wave

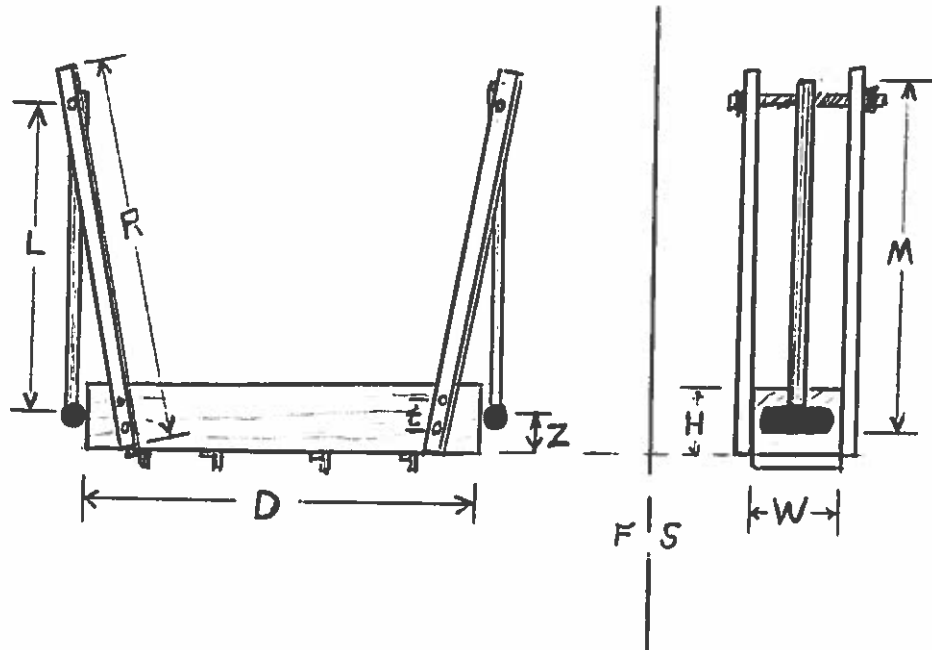
Length = 2500 samples Shot Elevation = -.3
Sample Interval = .00020 sec. Shot Depth = .0
Delay Time = 0 msec. Up Hole Time = 0 msec
Low Cut Filter = 8 Hz. Shot X-COORD = .0
High Cut Filter = 1000 Hz. Shot Y-COORD = -.8
Line ID: DHA2 Shot Date (year.day) = 1994.***
Shot Orientation: Shot Time (hr:min) = 12:01
Azimuth= 0 Deg. Vertical=180 Deg. Charge Size (grams)= 0

TRACE #	SHOT REC.	STATION SHOT REC	OFFSET	RECEIVER ELEV. X-COORD Y-COORD	VERT FOLD	1STBRK (SEC.)	K-GAIN (dB)	AZI	VER
1	61	001 181	14.6	-14.9 .0 .0	10	.0000	20	0	180
2	61	001 182	14.6	-14.9 .0 .0	10	.0000	20	0	90
3	61	001 183	14.6	-14.9 .0 .0	10	.0000	20	0	90
4	61	001 184	1.7	-.3 .0 .9	10	.0000	20	0	0
5	61	001 185	1.7	-.3 .0 .9	10	.0000	20	0	90
6	61	001 186	1.7	-.3 .0 .9	10	.0000	20	270	90

APPENDIX IV

Specifications of Seismic Sources

Horizontal Hammer for SH-Waves

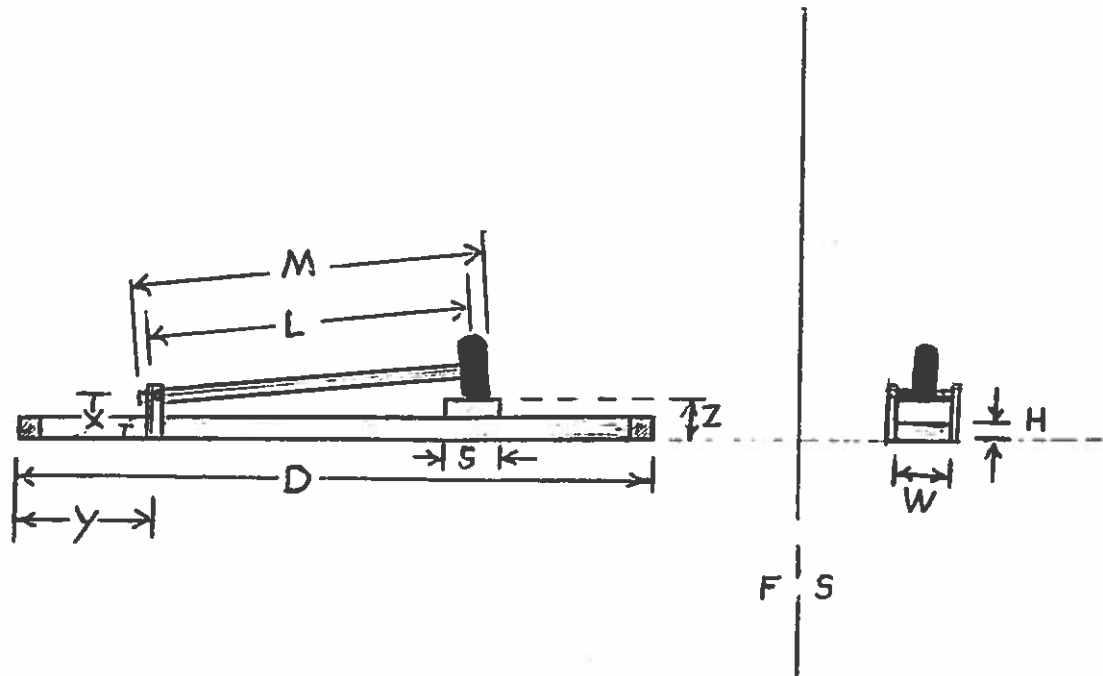


D=1.0	meters	(length of base, 1/2 railroad tie)
L=0.83	meters	(pivot to center hammer head)
R=0.99	meters	(length of angle iron)
U=0.05	meters	(top of railroad tie to first lag bolt)
T=0.10	meters	(lag bolt spacing)
X=0.14	meters	(bottom lag bolt to hammer head center)
M=0.90	meters	(hammer overall length, end handle to end of head)
Z=0.10	meters	(base of railroad tie to center of hammer head)
W=0.23	meters	(width of railroad tie)
H=0.17	meters	(height of railroad tie)

Weight of Railroad Tie=	245 Newtons
Weight of Sand Bags=	300 Newtons each bag
Weight of Angle Iron=	15 Newtons/meter

Hammer Head:		Hammer Handle:		Sand Bag:	
Diameter=	0.06 meters	Diameter=	0.035m	Diameter=	0.25m
Length=	0.18 meters	Length=	0.840m	Height=	0.35m
Weight=	53.4 Newtons				

Vertical Hammer for P-Waves



D=1.63	meters	(length of base, redwood 2x6)
L=0.82	meters	(pivot to center of hammer head)
R=0.12	meters	(length of angle iron)
X=0.10	meters	(height, base to pivot)
T=0.015	meters	(lag bolt spacing)
S=0.14	meters	(wood strike plate side length)
M=0.90	meters	(hammer overall length, end handle to end of head)
Z=0.07	meters	(height of hammer strike point above ground)
Y=0.36	meters	(horizontal distance of pivot from end of base)
W=0.135	meters	(width of base)
H=0.035	meters	(height of base)

Hammer Head:

Diameter= 0.05 m
 Length= 0.15 meters
 Weight= 26.7 Newtons

Hammer Handle:

Diameter= 0.035 m
 Length= 0.83 m