SEISMIC REFRACTION SURVEY
RIPPABILITY STUDIES

US93, MILEPOST EL 0.00 TO MILEPOST EL 12.00
ELKO COUNTY, NEVADA

AUGUST 2005

NEVADA DOT
GEOTECHNICAL ENGINEERING

MATERIALS DIVISION

DEPARTMENT OF TRANSPORTATION

MATERIALS DIVISION

GEOTECHNICAL SECTION

SEISMIC REFRACTION SURVEY
RIPPABILITY STUDIES

US 93, MILEPOST EL 0.00 TO MILEPOST EL 12.00
ELKO COUNTY, NEVADA

SEPTEMBER 2005

EA # 73249

Prepared by

Abbas A. Bafghi, P.E.

Senior Geotechnical Engineer

Reviewed by

J er, Ph.D., P.E.

Principal Materials Engineer - Geotechnical

Approved by

Dean Weitzel, P.E.

Chief Materials Engineer

Table of Contents

General 1

Purpose and Scope 1

Project Description 1

Geology of the Slopes 1

Seismic Equipment and Field Procedure 1

Field Seismograph Records 2

Results 2

Limitations 3

Swelling Factor 3

References 4

SEISMIC REFRACTION SURVEY

General

During the month of July 2005, the NDOT Geotechnical Section conducted surface seismic refraction survey on three separate rock cuts along highway US 93, between milepost EL 0.00 and milepost EL 12.00, in Elko County, Nevada.

Purpose and Scope

The purpose of this survey investigation was to provide information regarding the rippability of the rocks in the existing rock cuts, utilizing seismic refraction techniques. The scope of this investigation included site reconnaissance, research of available geologic literature pertaining to the site, conducting surface seismic refraction survey, and report preparation.

Project Description

This section of the roadway was built under NDOT Contract No. 1190. NDOT is planning to widen both sides of the roadway by approximately three feet between mileposts EL 0.00 and EL 12.00 on US 93. The NDOT Roadway Design stated that the proposed plan might interfere with the rock cuts in this area. These rock cuts are located at mileposts 8.4, 10.4, and 10.9.

Geology of the Slopes

The slopes are mainly dark gray Andesite igneous rocks. The rocks on the slope face are narrowly spaced and tabular-shaped. The discontinuity orientation and degrees of rock weathering vary across the slopes. The slope face is comprised of strong and weak rocks that lead to diverse slope behavior. Most of the rock units are closely jointed. Spacing of joint sets at different locations varies from one millimeter to a few millimeters. Most joints are filled with fine sand and clay. Photographs of the slopes are included in the Appendix.

Seismic Equipment and Field Procedure

Bison 12-channel hand-carries seismograph, Series 9000, was used to collect seismic refraction data. The geophones were planted at 10-foot intervals on the crest of the slopes, north-south direction, and parallel to the rock slope face. The total geophone line length was 120 feet with

the estimated depth of signal penetration of about 30 to 40 feet. Sledge-hammer and metal striking plate were used to generate energy source. The layout for the seismic work included series of forward and reversed seismic lines "reversed-profile shooting" with striking plate at 10 feet from the end-geophones and 5 feet from the middle geophones. The geophone signals caused by hammer blows were digitized by the seismograph equipped with "signal enhancement". The signals were stacked 10 times for each seismic line. Due to access limitations, transverse layout of geophones was not possible.

Field Seismograph Records

The field seismograph records contain data representing the time it takes for compressional energy (P-wave) generated by the seismic source to travel a path through the subsurface and back up to the geophones on the surface. The first arrival of compressional energy including first point of movement or point of maximum curvature at each geophone is marked on the enclosed Bison Series charts and was used to determine the position of refracting surfaces. Arrival times versus shotpoint-to-geophone distance (Time-Distance) were plotted manually. The slopes of these time-distance segments are inversely proportional to the apparent velocity of sound in that layer of the Earth. The time-distance plots of the seismograph records are included in the Appendix.

Where topographical irregularities exist, elevation corrections are typically done to adjust field-derived travel time segments on the time-distance plot, associated with subsurface refractors. The total travel time from one end of the line to the other must be the same for both directions, since this time merely represents travel in opposite directions along the same path. In this survey, some degrees of accuracy have been sacrificed, as is seen on time-distance plots, since relative elevations of shotpoints and geophones on the irregular topography of the slope crests were not determined in the field.

Results

The time-distance plot is an interpretation of the seismograph records to obtain an approximate evaluation of the state of rippability of the rock slopes. It was concluded from these plots that the compressional seismic wave velocities of the near surface rocks is less than 6000 feet/second.

The velocities on the time-distance plots can be compared with the Caterpillar Tractor Company Ripper Performance Charts to determine difficulties that may be encountered in the excavation or the rock slopes. There might be more massive rocks with fewer or less continuous joints at depth into the slopes that will be difficult to excavate.

The Caterpillar Tractor Company Ripper Performance Charts for various example rippers, which are based on rock seismic refraction velocity, rock type, and the state of rippability, are included in the Appendix.

Limitations

Because of the inherent limitation in seismic refraction method, the seismic survey alone can never be considered definitive in evaluating rock slope rippability studies. Drilling borings or coring with a drill rig and/or the excavation of test trenches with a bulldozer with ripper or backhoe may be needed to provide additional information regarding rippability of the rocks at this site.

Swelling Factor

The estimating swelling factor (the overall bulking value from its initial in situ volume) for the rock cuts is about 1.3.

References

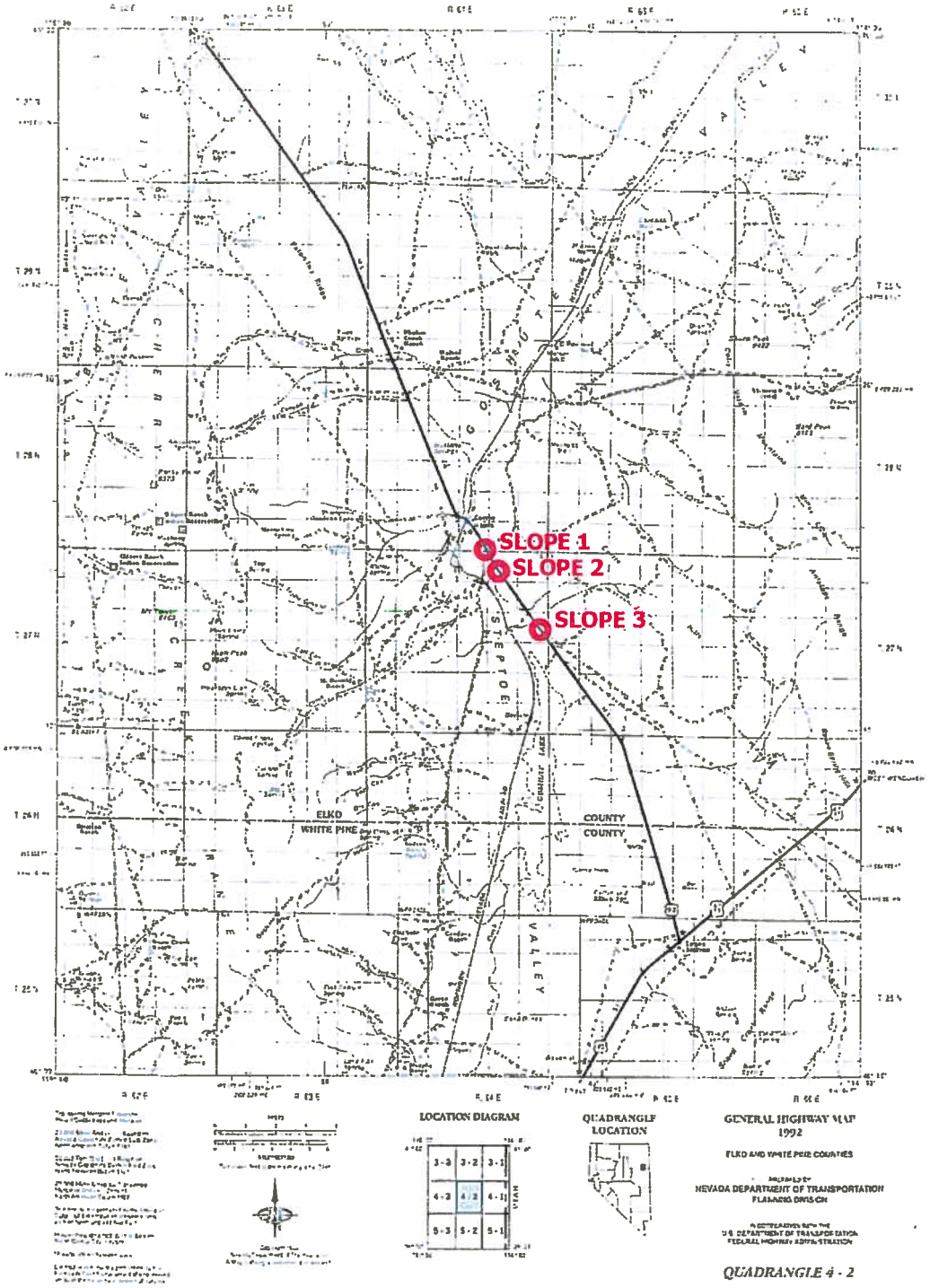
Dobrin, M.B., 1976, Introduction to Geophysical Prospecting (3d ed.): New York, McGraw-Hill.

U.S. Department of the Interior, Application of Seismic-Refraction Techniques to Hydrologic Studies, 1988, United States Government Printing Office, Washington.

Department of the Army Corps of Engineers, Geophysical Exploration, 1979, Engineering Manual, EM1110-1-1802.

Blaricom Richard, Practical Geophysics, 1980, Northwest Mining Association, Spokane, WA.

APPENDIX



Slope Locations.

SLOPE # 1

SEISMIC REFRACTION

Mile Post US93 EL 10+0.9

SLOPE # 1
Milepost US93 EL 10+0.9

(Fractured and weathered bedrocks are exposed on the slope face.)

SLOPE # 1
MILEPOST US93 EL 10+0.9

(fracture patterns in the exposed bedrock of the west face)

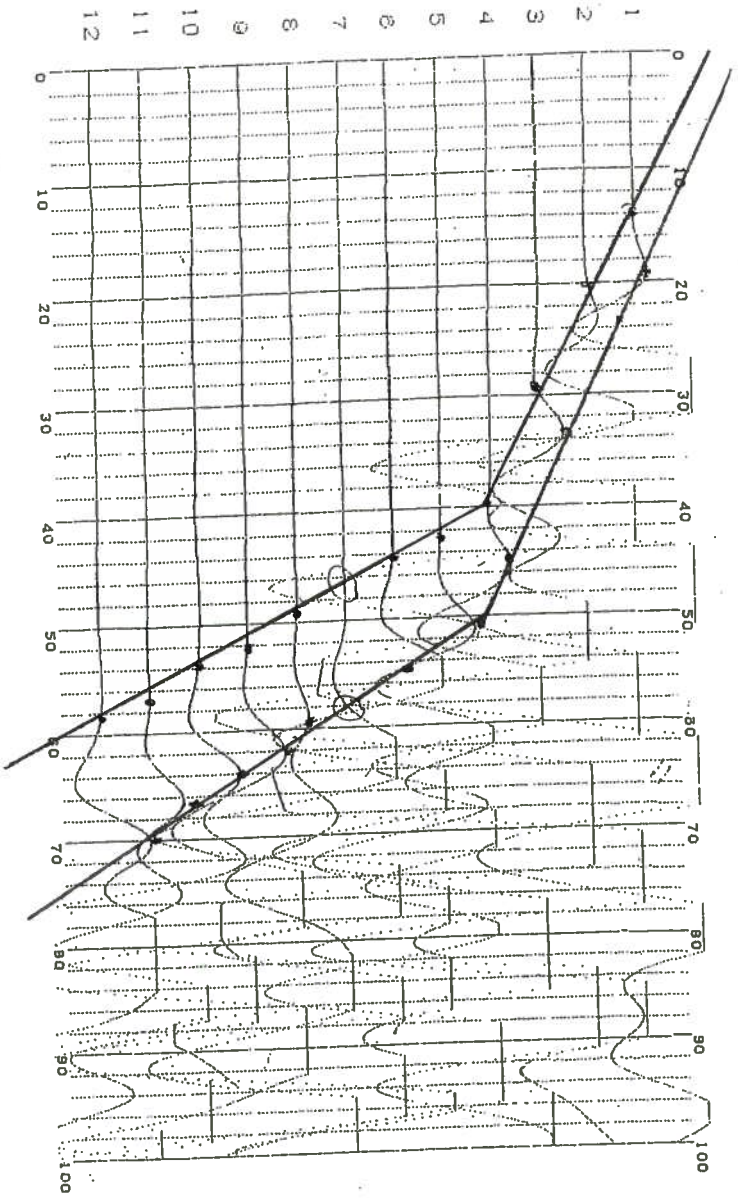
SLOPE # 1
Milepost US93 EL 10+0.9

(North side of the west face is mainly composed of soil.)

DISTANCE (x 10 ft.)

TIME (msec)

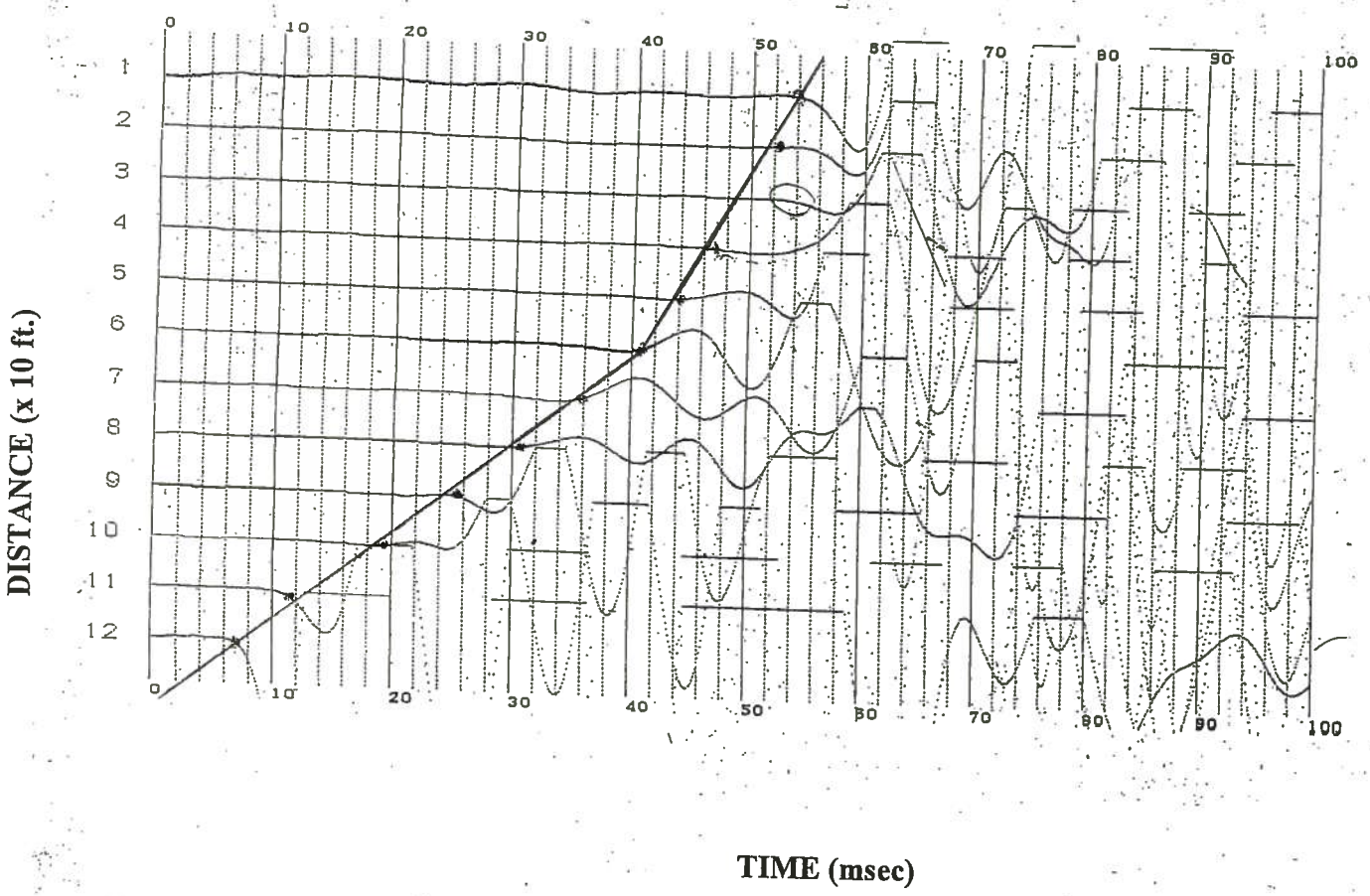
SLOPE #1



BISON 9000 SERIES

Record Name: SLPE0005
Date 06:09:05 Time 08:17
Hi-cut 125 Lo-cut 32
Sample rt .100ms Stacks 0010
Delay(ms) DFhc Out
Channels 12 DFlc Out
Samples 001000
Rec len 100ms Agc Off
Time scale = 2.0 (ms)/division.

P	CH	GN	STK	EX	P	CH	GN	STK	EX
+	01	H	0010	15	+	07	H	0010	13
+	02	H	0010	15	+	08	H	0010	13
+	03	H	0010	15	+	09	H	0010	12
+	04	H	0010	15	+	10	H	0010	11
+	05	H	0010	15	+	11	H	0010	11
+	06	H	0010	14	+	12	H	0010	10



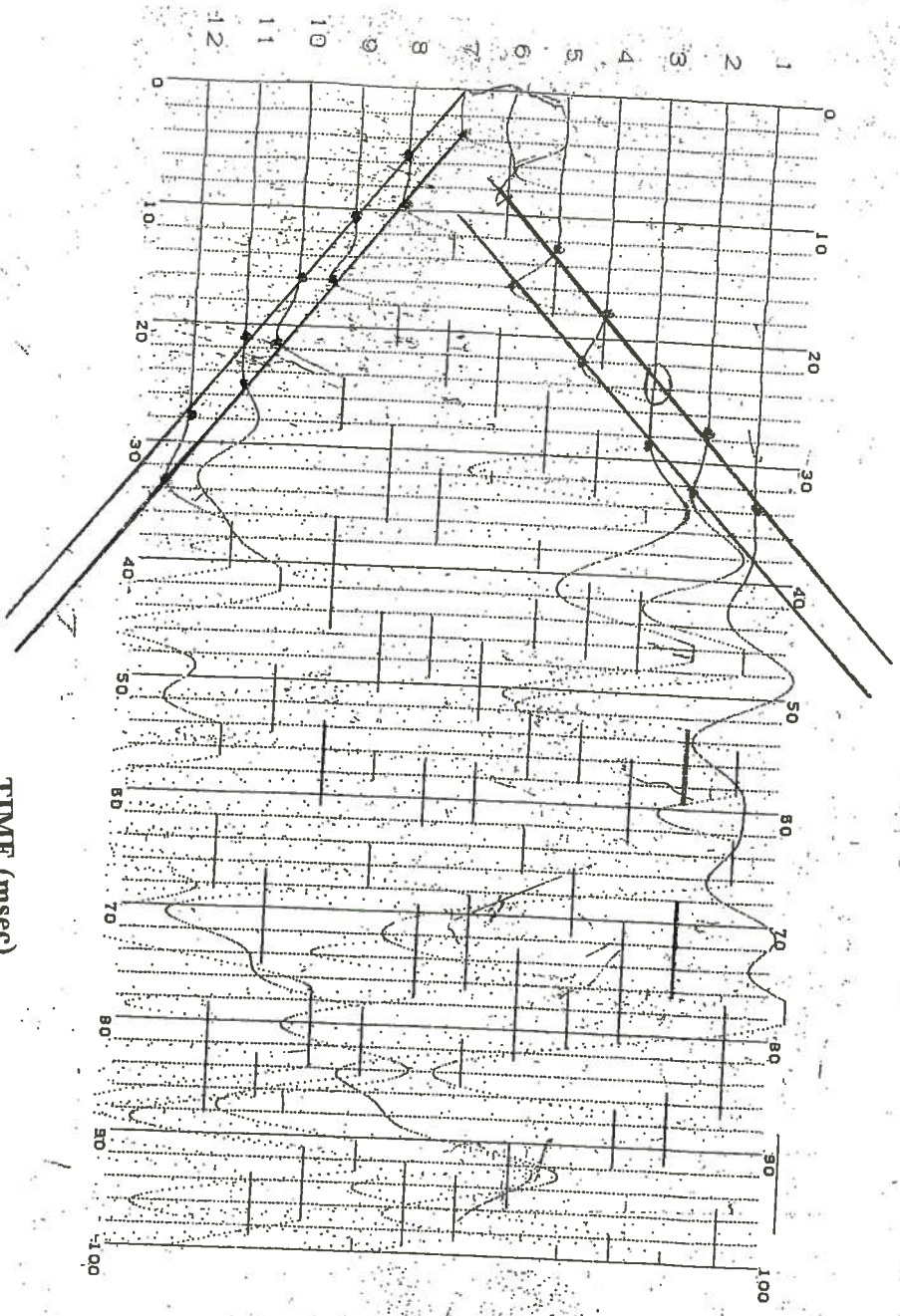
BISON 9000 SERIES

Record Name: SLPE0005
Date 06:09:05 Time 08:52
Hi-cut 126 Lo-cut 32
Sample rt .100ms Stacks 0010
Delay(ms) DFhc Out
Channels 12 DFlc Out
Samples 001000
Rec len 100ms Agc Off
Time scale = 2.0 (ms)/division.

P	CH	GN	STK	EX	P	CH	GN	STK	EX
+	01	H	0010	09	+	07	H	0010	14
+	02	H	0010	11	+	08	H	0010	15
+	03	H	0010	12	+	09	H	0010	15
+	04	H	0010	12	+	10	H	0010	15
+	05	H	0010	12	+	11	H	0010	15
+	06	H	0010	14	+	12	H	0010	15

SLOPE #1

DISTANCE (x 10 ft.)



TIME (msec)

SLOPE #1

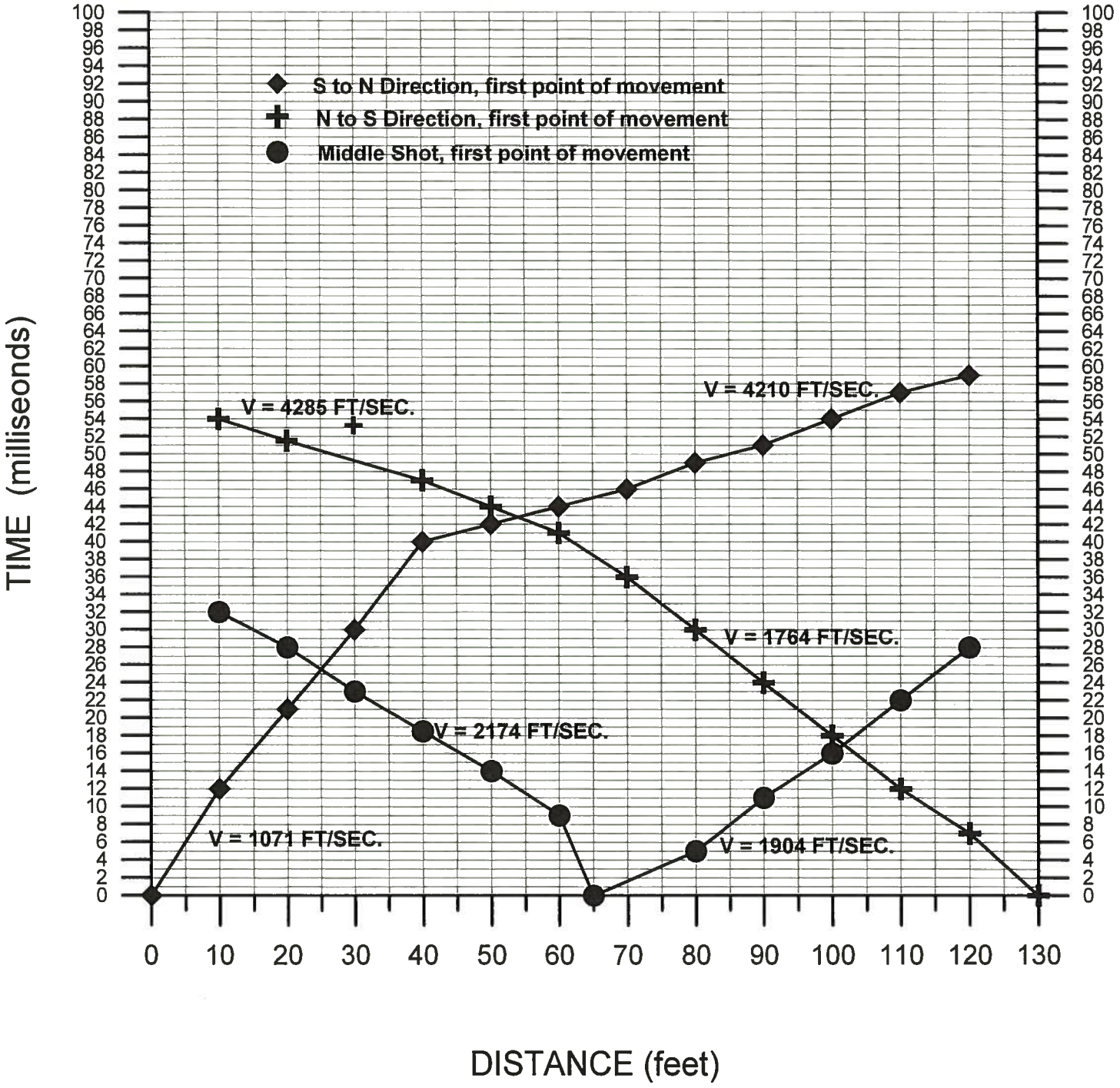
BISON 9000 SERIES

Record Name: SLPE0005
Date 06:09:05 Time 08:40
Hi-cut 125 Lo-cut 32
Sample rt .100ms Stacks 0009
Delay(ms) DFhc Out
Channels 12 DFlc Out
Samples 001000
Rec len 100ms Agc Off
Time scale = 2.0 (ms)/division.

P	CH	GN	STK	EX	P	CH	GN	STK	EX
+	01	H	0009	14	+	07	H	0009	14
+	02	H	0009	14	+	08	H	0009	14
+	03	H	0009	14	+	09	H	0009	14
+	04	H	0009	14	+	10	H	0009	14
+	05	H	0009	14	+	11	H	0009	14
+	06	H	0009	14	+	12	H	0009	13

SEISMIC REFRACTION

Mile Post US93 EL 10+0.9 (Slope #1, West Cut)



Zero distance refers to approximate station "X" 785.

SLOPE # 2

SEISMIC REFRACTION

Mile Post US93 EL 10+0.4

SLOPE # 2
Milepost US93 EL 10+0.4

(fractured and weathered bedrocks exposed on the slope face)

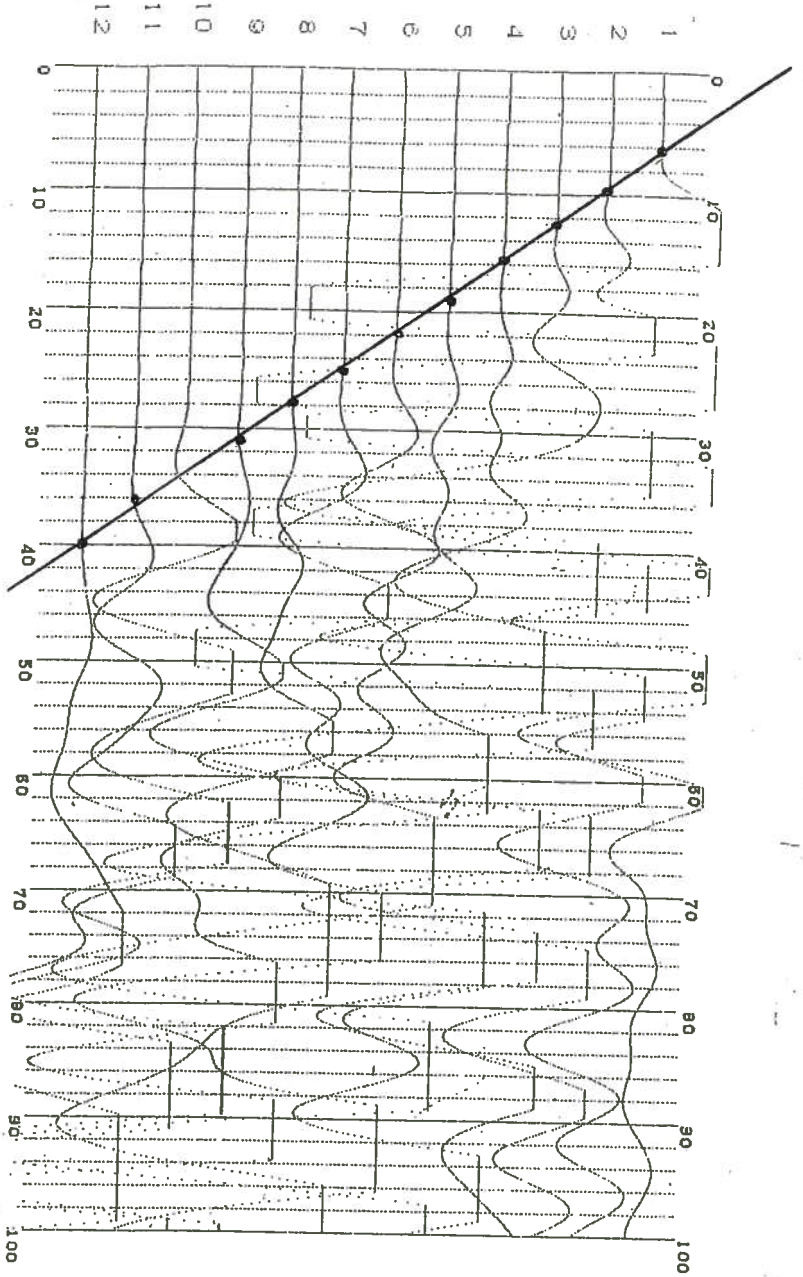
SLOPE # 2
Milepost US93 EL 10+0.4

(fractured bedrocks exposed on the slope face)

SLOPE # 2
Milepost US93 EL 10+0.4

(weathered bedrocks exposed on the slope face)

DISTANCE (x 10 ft.)



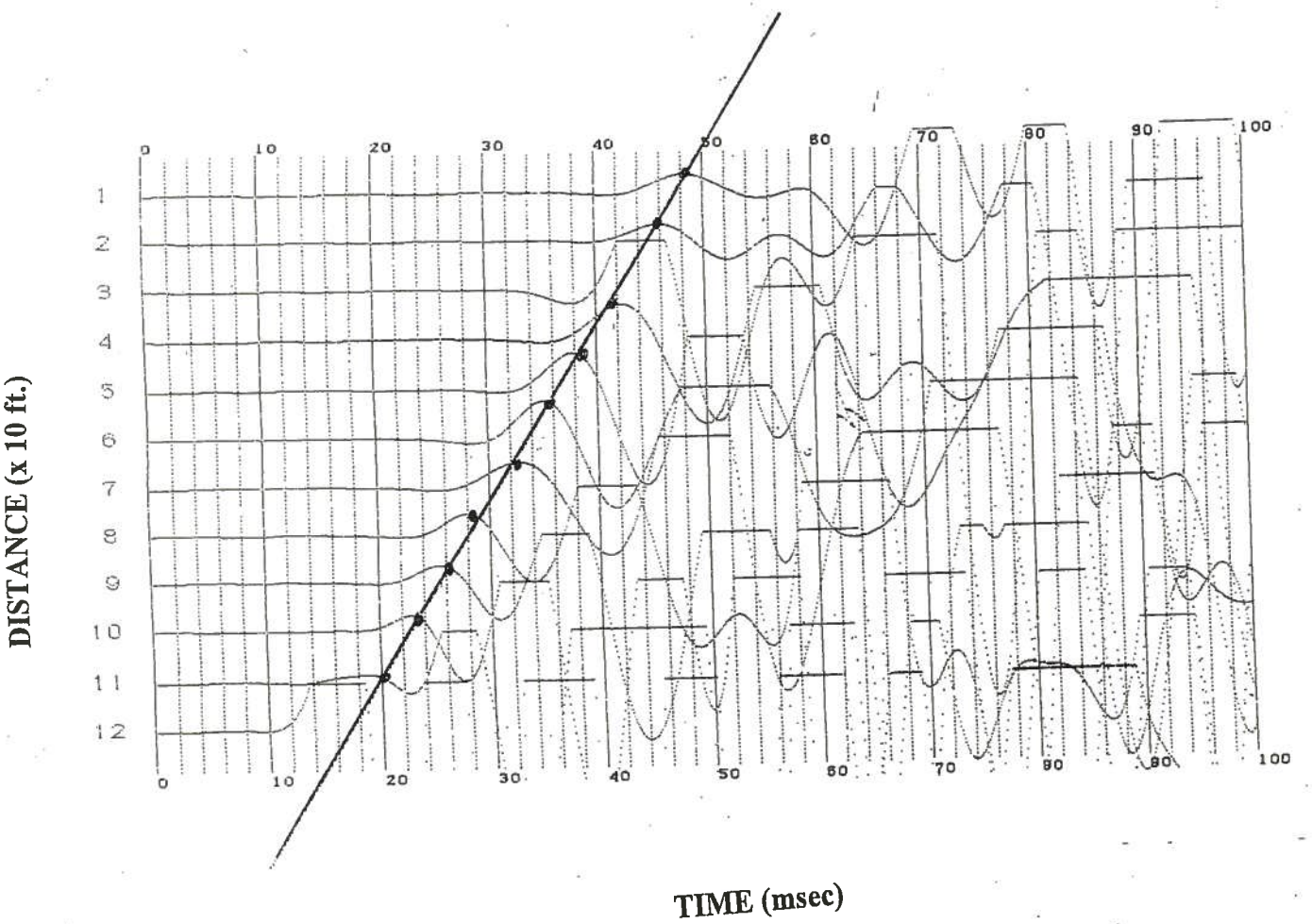
TIME (msec)

SLOPE #2

BISON 9000 SERIES

Record Name: SLPE0002
Date 06:08:05 Time 10:51
Hi-cut 125 Lo-cut 32
Sample rt .100ms Stacks 0010
Delay(ms) DFhc Out
Channels 12 DFlc Out
Samples 001000
Rec len 100ms Agc Off
Time scale = 2.0 (ms)/division.

P	CH	GN	STK	EX	P	CH	GN	STK	EX
+	01	H	0010	15	+	07	H	0010	13
+	02	H	0010	15	+	08	H	0010	12
+	03	H	0010	15	+	09	H	0010	12
+	04	H	0010	15	+	10	H	0010	11
+	05	H	0010	15	+	11	H	0010	11
+	06	H	0010	14	+	12	H	0010	11



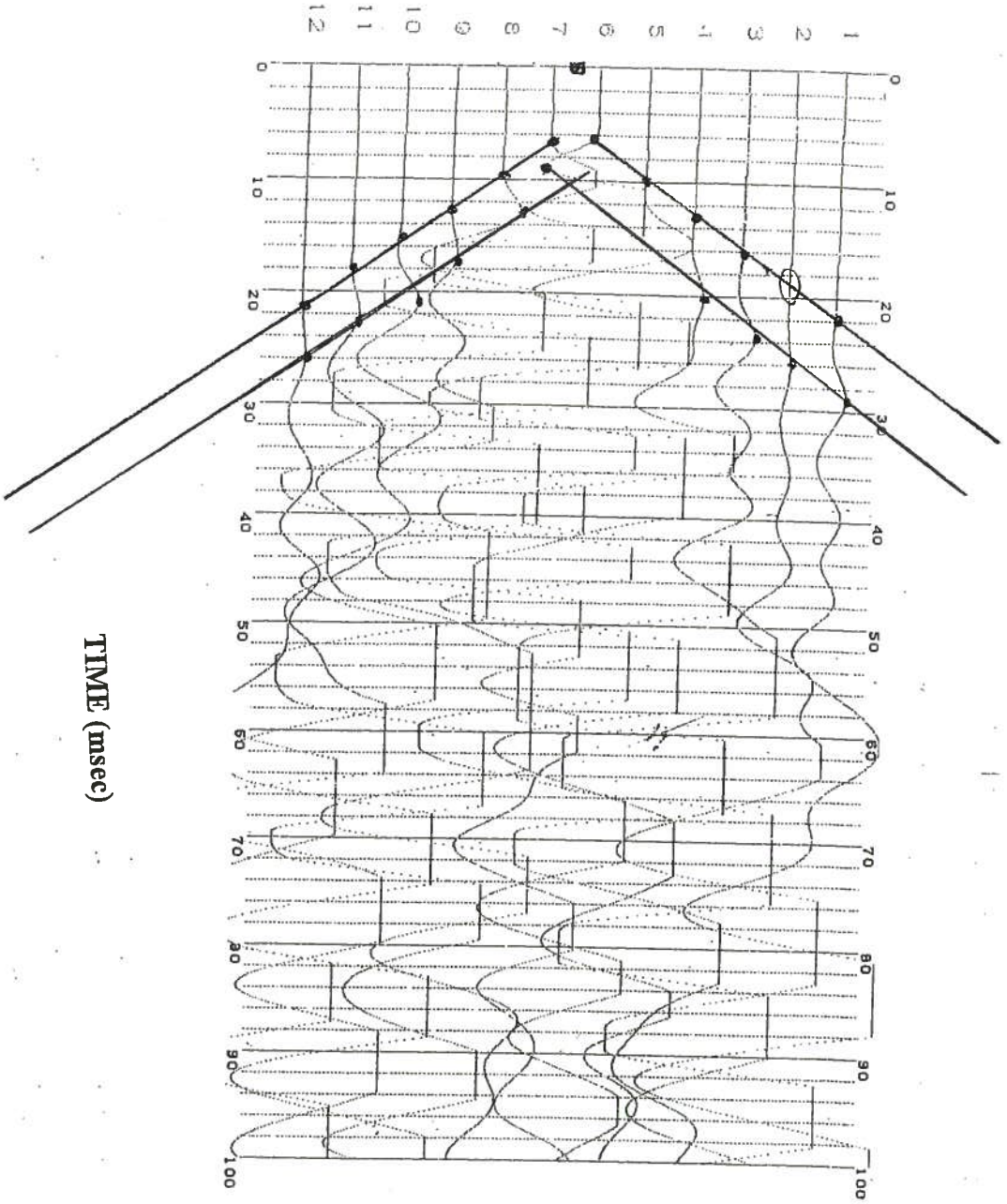
BISON 9000 SERIES

Record Name: SLPE0004
Date 06:08:05 Time 11:16
Hi-cut 125 Lo-cut 32
Sample rt .100ms Stacks 0010
Delay(ms) DFhc Out
Channels 12 DFlc Out
Samples 001000 Agc Off
Rec len 100ms (ms)/division.
Time scale = 2.0

P	CH	GN	STK	EX	P	CH	GN	STK	EX
+	01	H	0010	11	+	07	H	0010	13
+	02	H	0010	11	+	08	H	0010	13
+	03	H	0010	10	+	09	H	0010	14
+	04	H	0010	12	+	10	H	0010	15
+	05	H	0010	12	+	11	H	0010	15
+	06	H	0010	13	+	12	H	0010	15

SLOPE #2

DISTANCE (x 10 ft.)



TIME (msec)

SLOPE #2

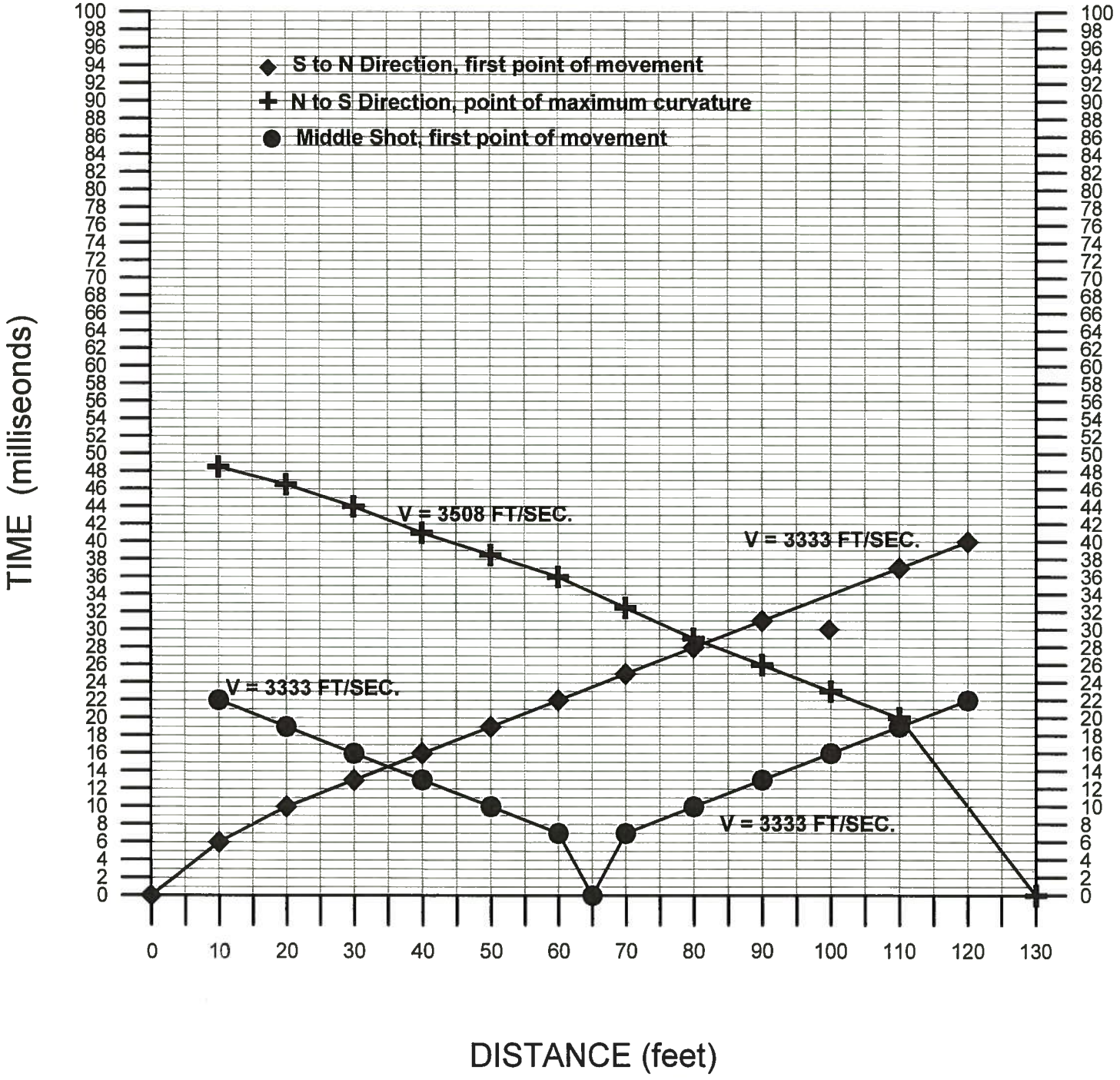
BISON 9000 SERIES

Record Name: SLPE0004
Date 06:08:05 Time 11:04
Hi-cut 125 Lo-cut 32
Sample rt .100ms Stacks 0010
Delay(ms) DFhc Out
Channels 12 DFlc Out
Samples 001000
Rec len 100ms Agc Off
Time scale = 2.0 (ms)/division.

P	CH	GN	STK	EX	P	CH	GN	STK	EX
+	01	H	0010	15	+	07	H	0010	16
+	02	H	0010	16	+	08	H	0010	16
+	03	H	0010	16	+	09	H	0010	16
+	04	H	0010	16	+	10	H	0010	16
+	05	H	0010	16	+	11	H	0010	15
+	06	H	0010	16	+	12	H	0010	15

SEISMIC REFRACTION

Mile Post US93 EL 10+0.4 (Slope #2, East Cut)



Zero Distance refers to approximate station "X" 755.

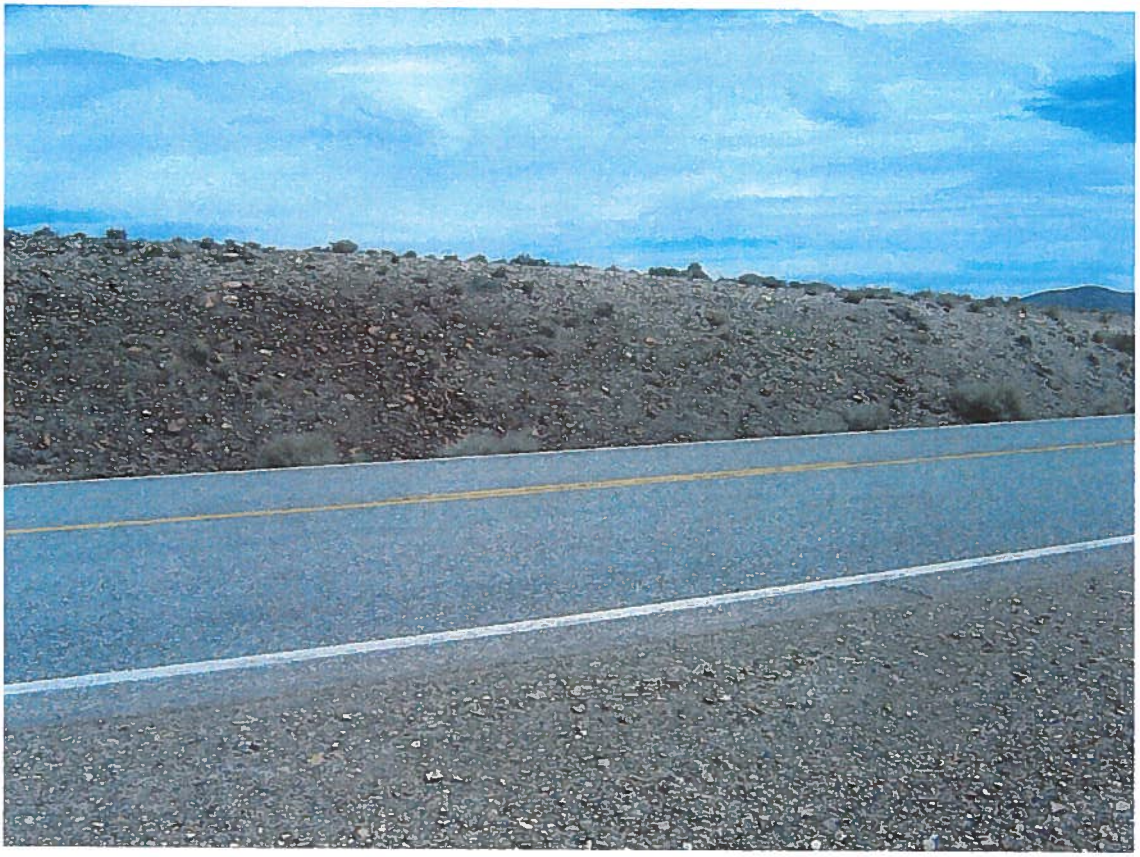
SLOPE # 3

SEISMIC REFRACTION

Mile Post US93 EL 8+0.7

SLOPE # 3
Milepost US93 EL 8+0.7

(weathered bedrocks exposed on the slope face)

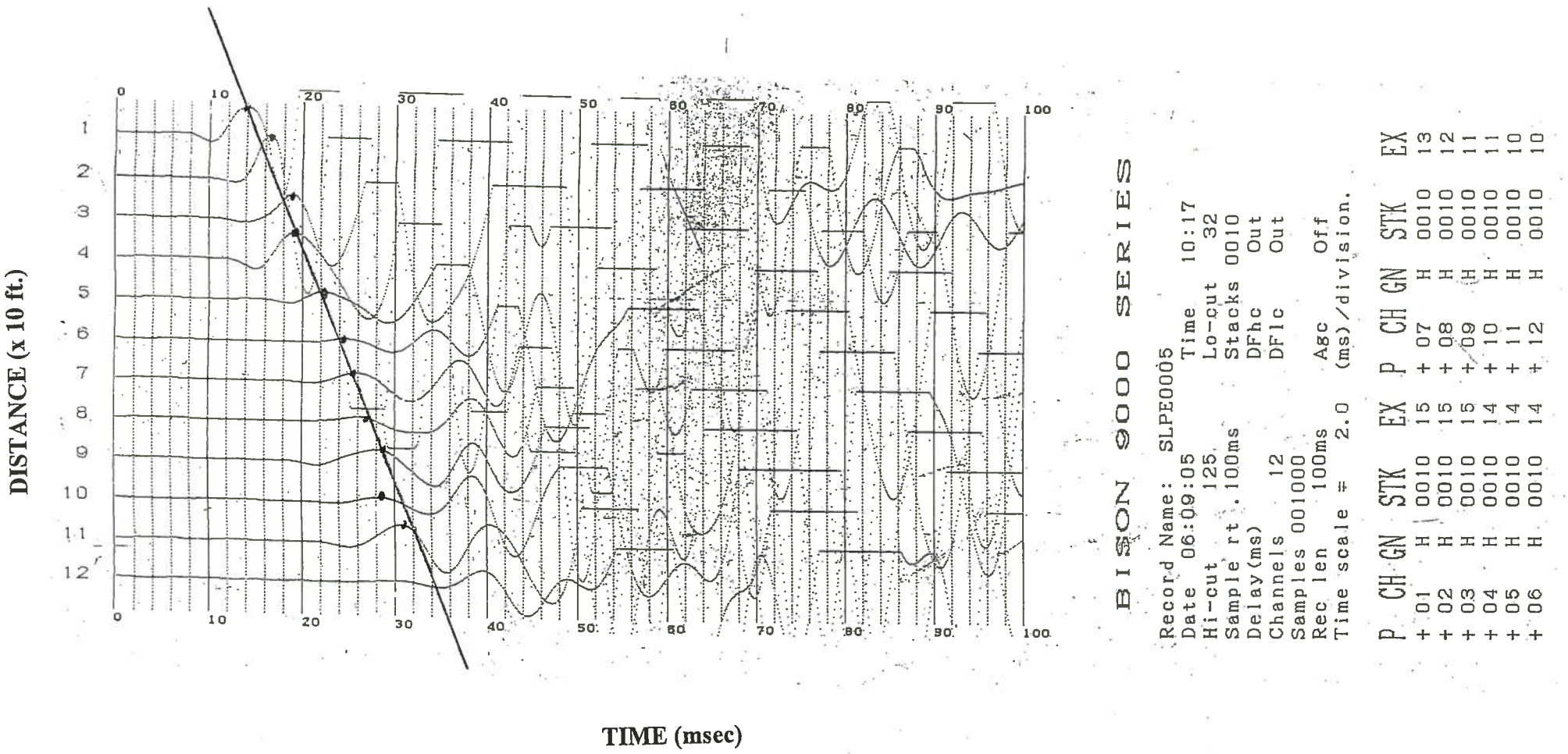


SLOPE # 3
Milepost US93 EL 8+0.7

(south section of the slope is mostly comprised of soil)

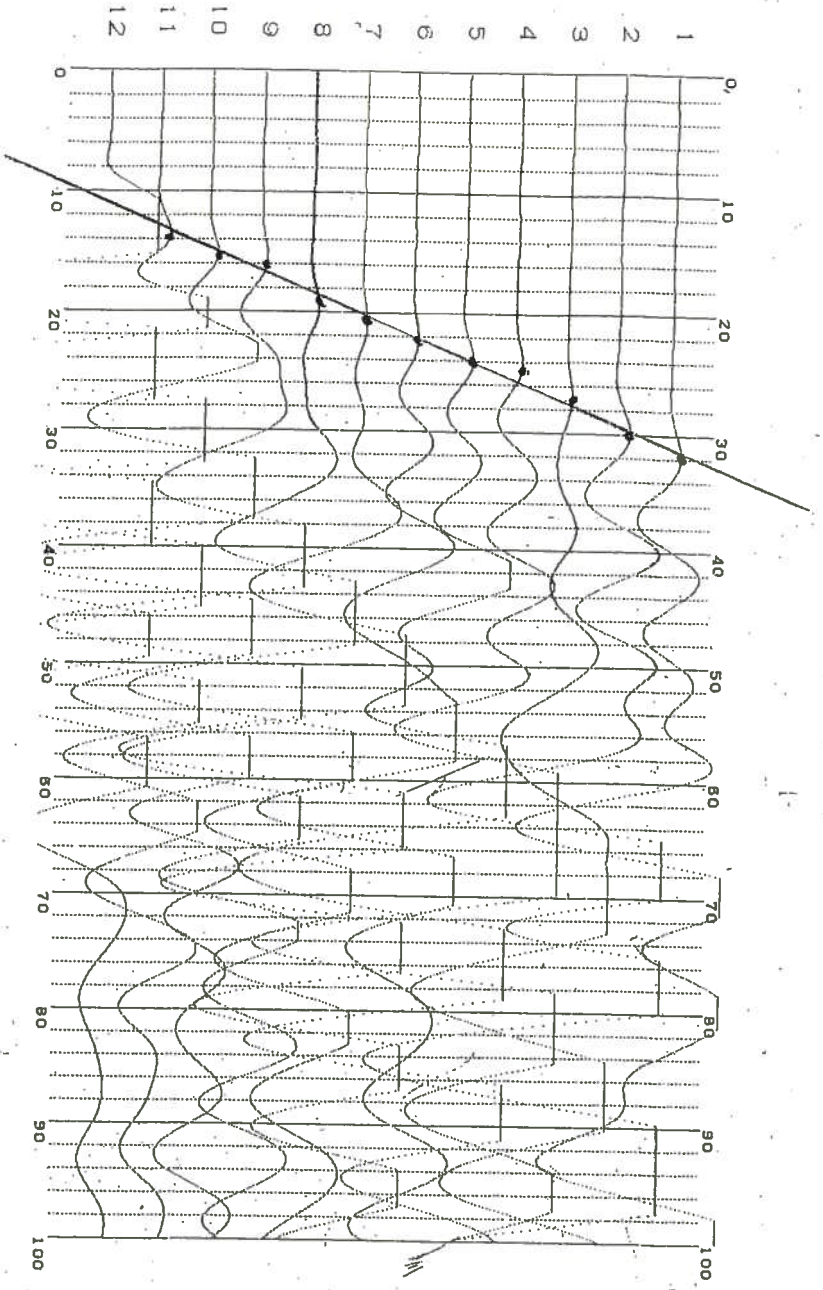
SLOPE # 3
Milepost US93 EL 8+0.7

(fractured bedrocks exposed on the slope face)


DISTANCE (x 10 ft.)
TIME (msec)
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7
8
9
10
11
12
BISON 9000 SERIES
Record Name: SLPE0005
Date 06:09:05 Time 10:17
Hi-cut 125 Lo-cut 32
Sample rt .100ms Stacks 0010
Delay(ms) DFhc Out
Channels 12 DFlc Out
Samples 001000
Rec len 100ms Agc Off
Time scale = 2.0 (ms)/division.
P CH GN STK EX P CH GN STK EX
+ 01 H 0010 15 + 07 H 0010 13
+ 02 H 0010 15 + 08 H 0010 12
+ 03 H 0010 15 + 09 H 0010 11
+ 04 H 0010 14 + 10 H 0010 11
+ 05 H 0010 14 + 11 H 0010 10
+ 06 H 0010 14 + 12 H 0010 10

SLOPE #3

DISTANCE (x 10 ft.)



TIME (msec)

SLOPE #3

BISON 9000 SERIES

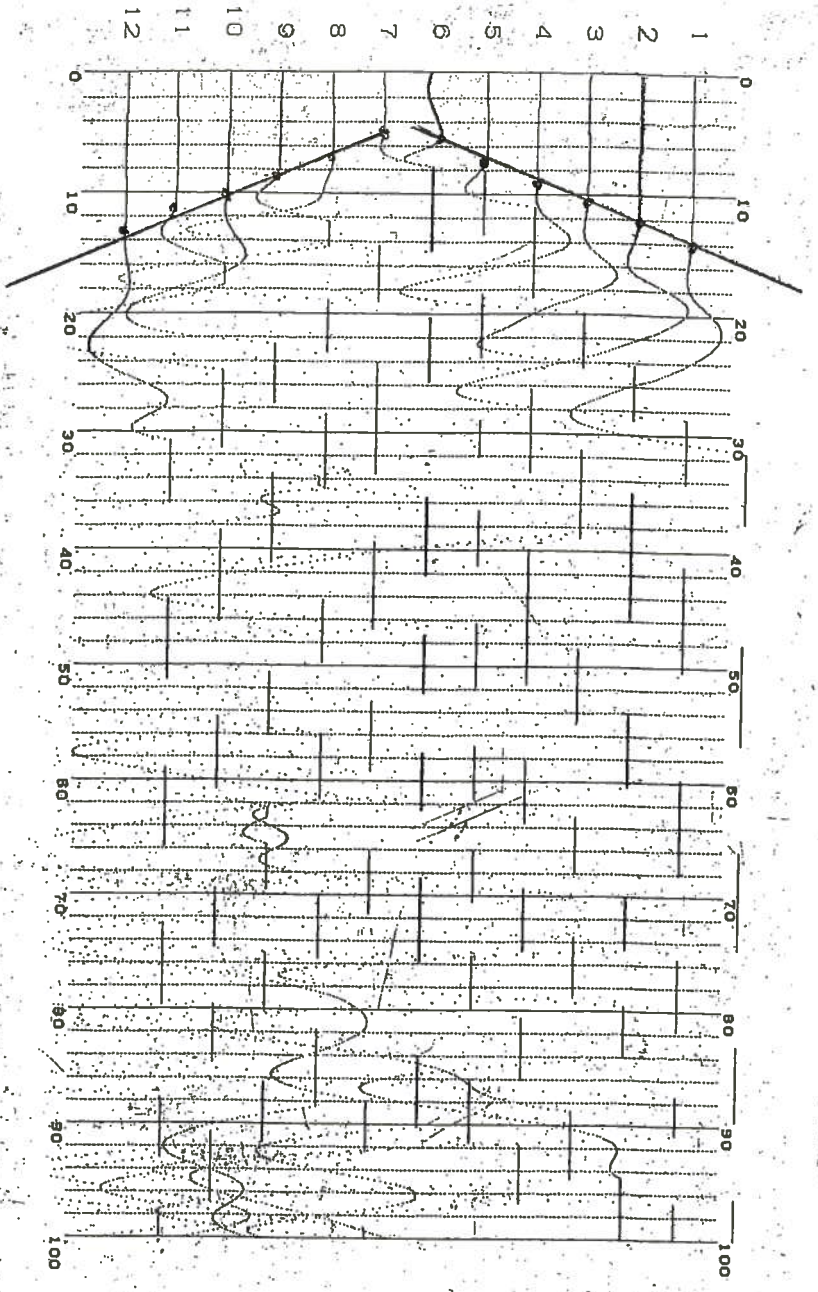
Record Name: SLPE0005
Date 06:09:05 Time 10:52
Hi-cut 125 Lo-cut 32
Sample rt .100ms Stacks 0010
Delay(ms) DFhc Out
Channels 12 DFlc Out
Samples 001000
Rec len 100ms Agc Off
Time scale = 2.0 (ms)/division.

P	CH	GN	STK	EX	P	CH	GN	STK	EX
+	01	H	0010	12	+	07	H	0010	15
+	02	H	0010	12	+	08	H	0010	15
+	03	H	0010	13	+	09	H	0010	15
+	04	H	0010	13	+	10	H	0010	16
+	05	H	0010	14	+	11	H	0010	16
+	06	H	0010	15	+	12	H	0010	16

SLOPE #3

DISTANCE (x 10 ft.)

TIME (msec)



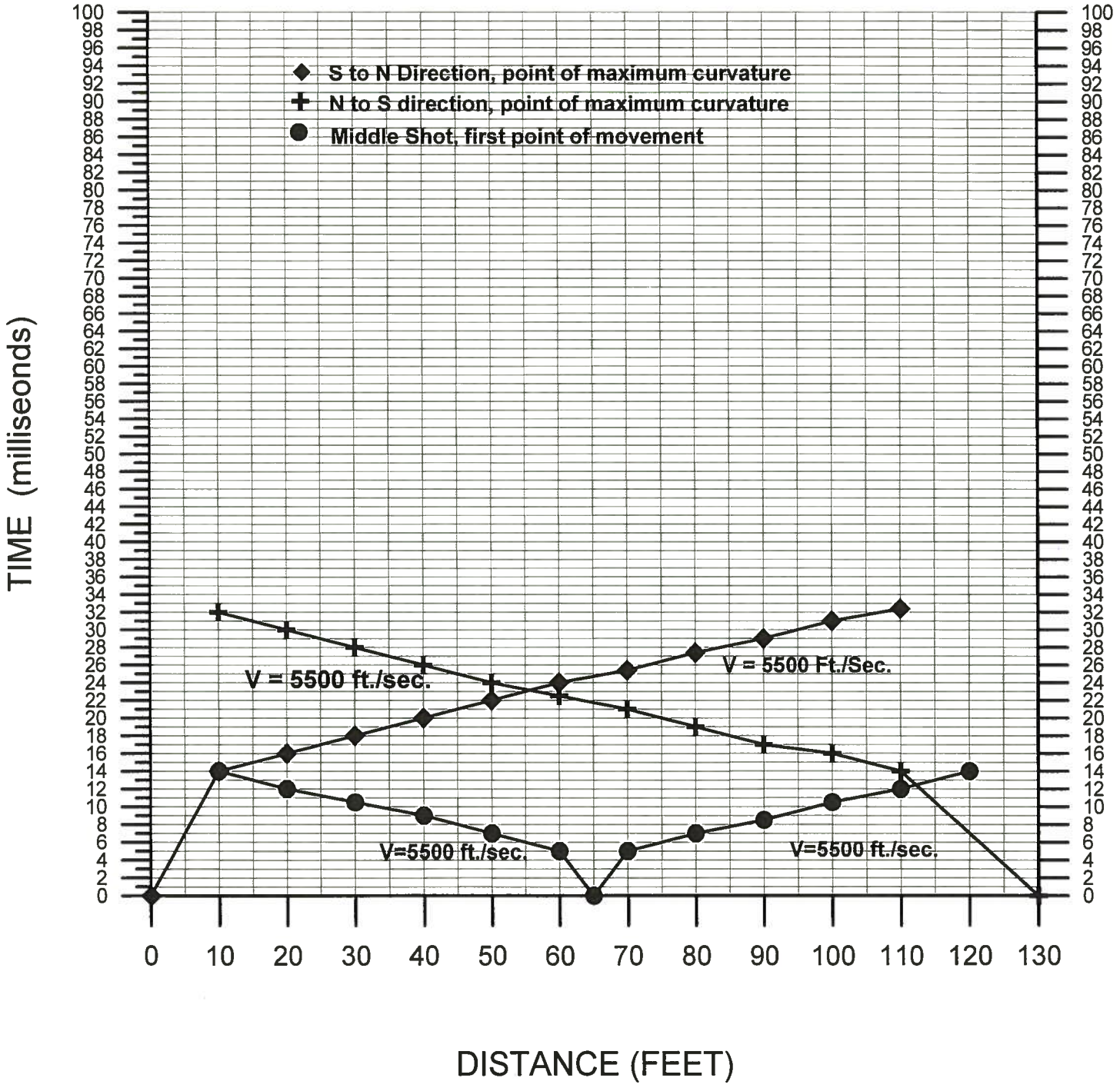
BISON 9000 SERIES

Record Name: SLPE0005
Date 06:09:05 Time 10:43
Hi-cut 125 Lo-cut 32
Sample rt .100ms Stacks 0010
Delay(ms) DFhc Out
Channels 12 DFlc Out
Samples 001000
Rec len 100ms Agc Off
Time scale = 2.0 (ms)/division.

P	CH	GN	STK	EX	P	CH	GN	STK	EX
+	01	H	0010	12	+	07	H	0010	13
+	02	H	0010	12	+	08	H	0010	13
+	03	H	0010	13	+	09	H	0010	13
+	04	H	0010	13	+	10	H	0010	12
+	05	H	0010	13	+	11	H	0010	11
+	06	H	0010	13	+	12	H	0010	11

SEISMIC REFRACTION

Mile Post US93 EL 8 +0.7 (Slope #3, East Cut)



Zero distance refers to approximate station "X" 670.

SEISMIC RIPPABILITY CHART

(Courtesy of Caterpillar Tractor Company)

D8L Ripper Performance

- Multi or Single Shank Ripper
- Estimated by Seismic Wave Velocities

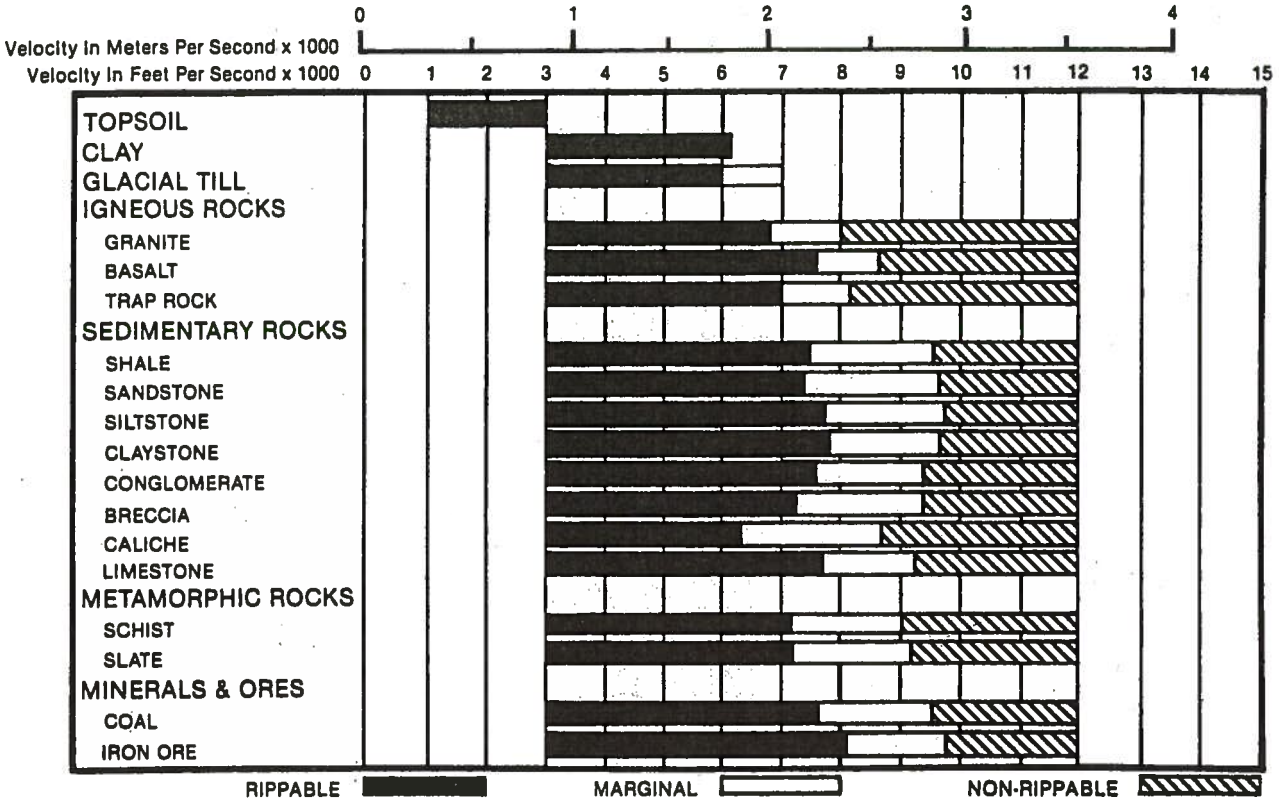


Figure 10.33 D8L Ripper Performance

D9L Ripper Performance

- Multi or Single Shank Ripper
- Estimated by Seismic Wave Velocities

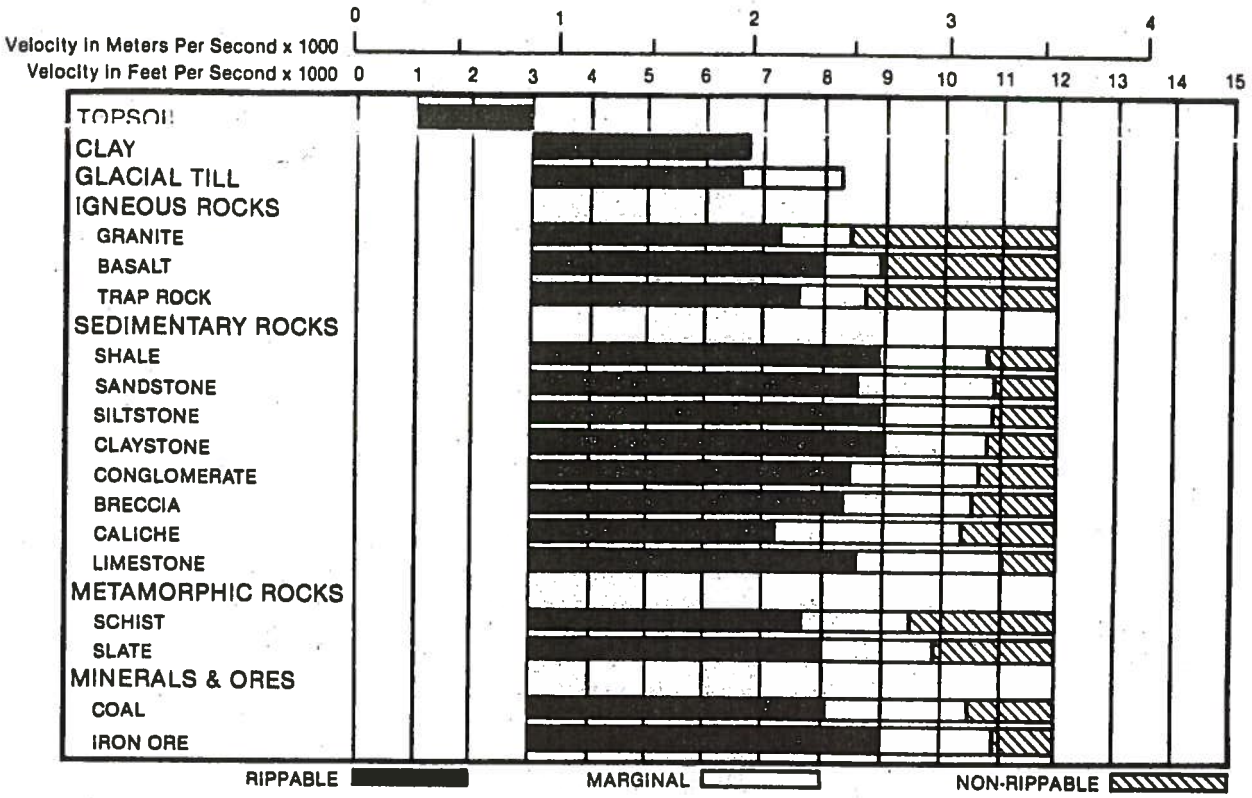


Figure 10.34 D9L Ripper Performance

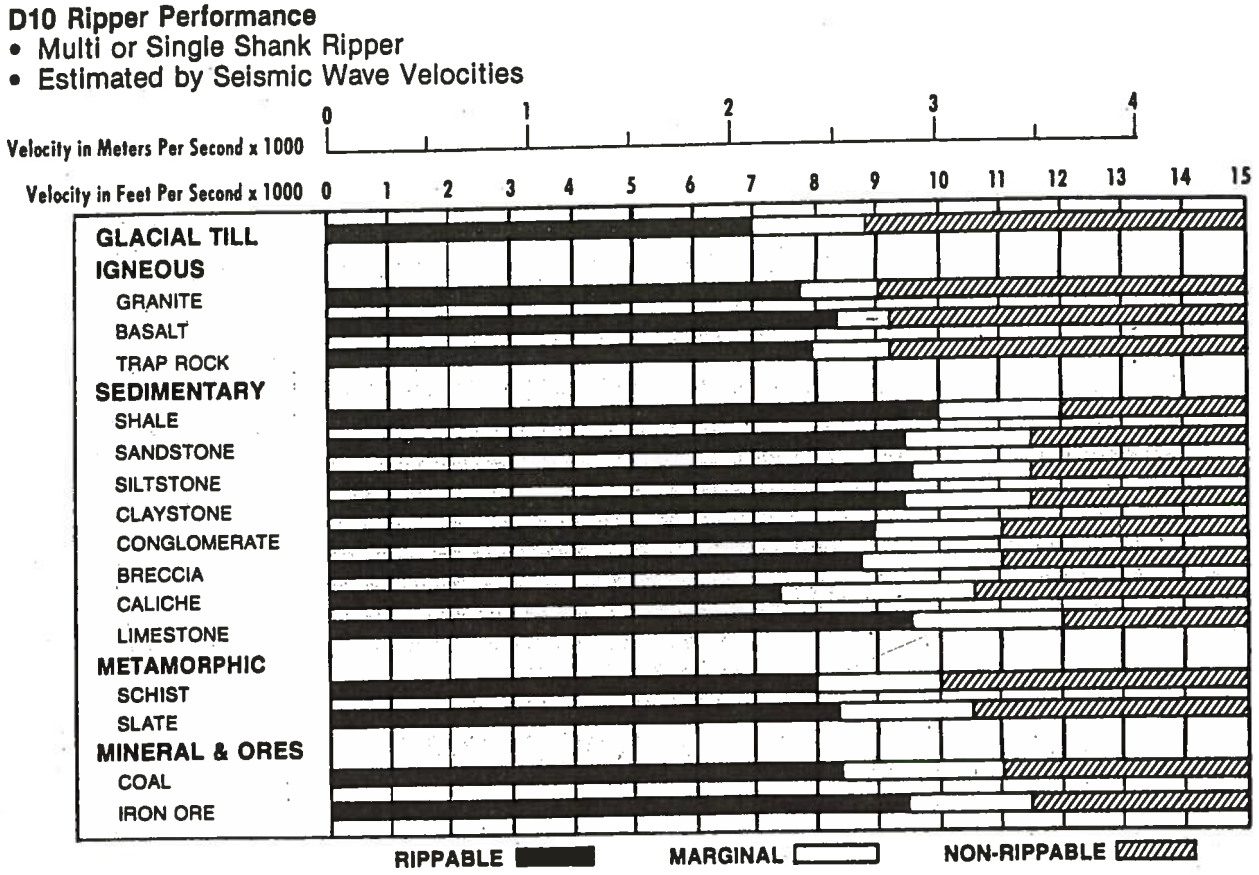


Figure 10.35 D10 Ripper Performance