

Geophysics Case Studies: Road & Embankment Collapses



Prof. Bob Whiteley
Senior Principal



Road settlement
& potential
collapses are a
major Hazard



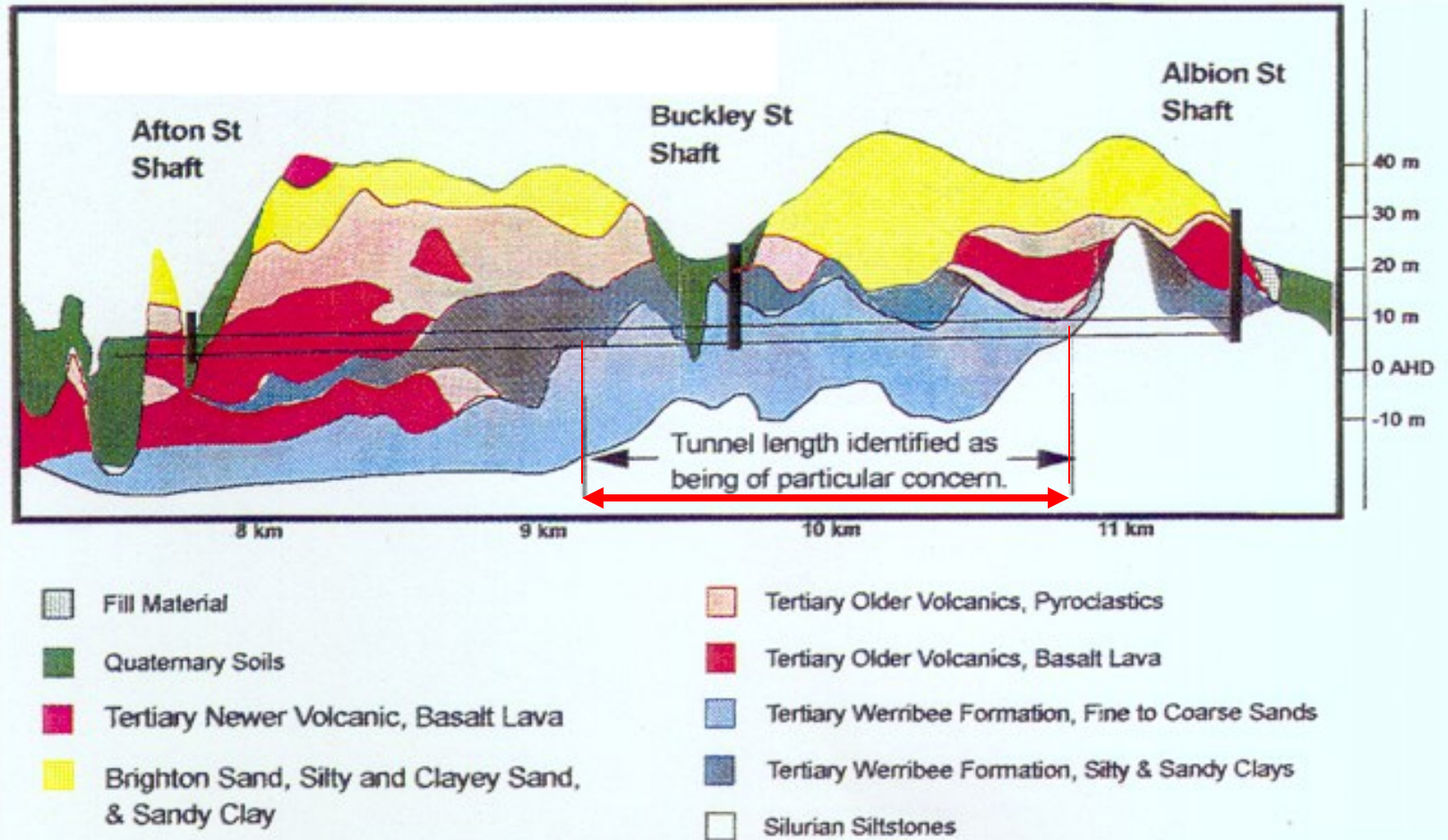
Case studies

- **Road settlement over tunnel – SUBS**
- **Embankments- MASW testing**
- **Embankment testing- Seismic imaging**
- **Soil conditions over Sewer – SEWREEL imaging**

Road Settlement during Tunnelling



Composite Geology, NW Sewer Route



DATE	9/6	20/6	21/6	24/6
GROUT (m ³)	32	12.4	7	0.65

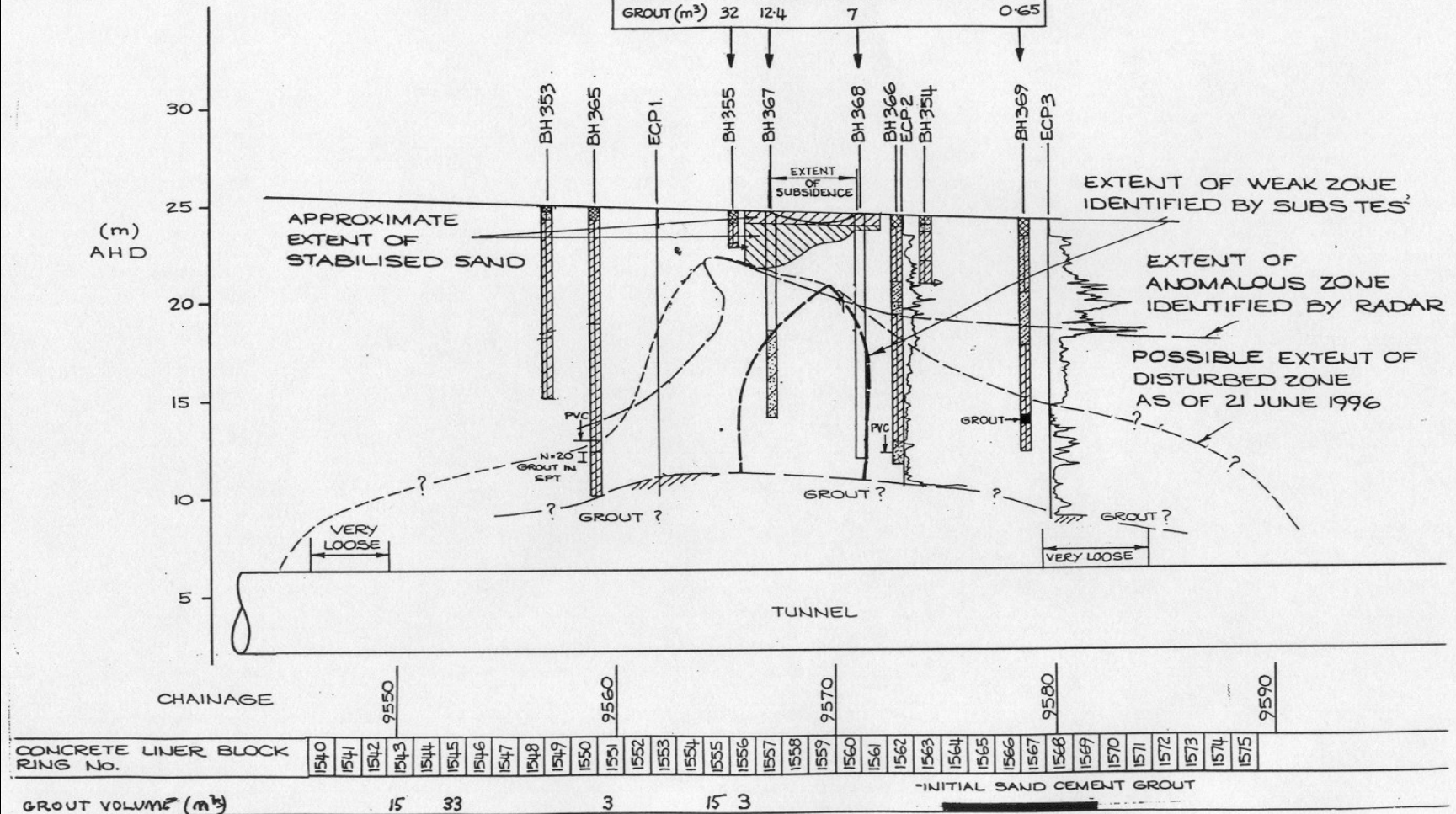
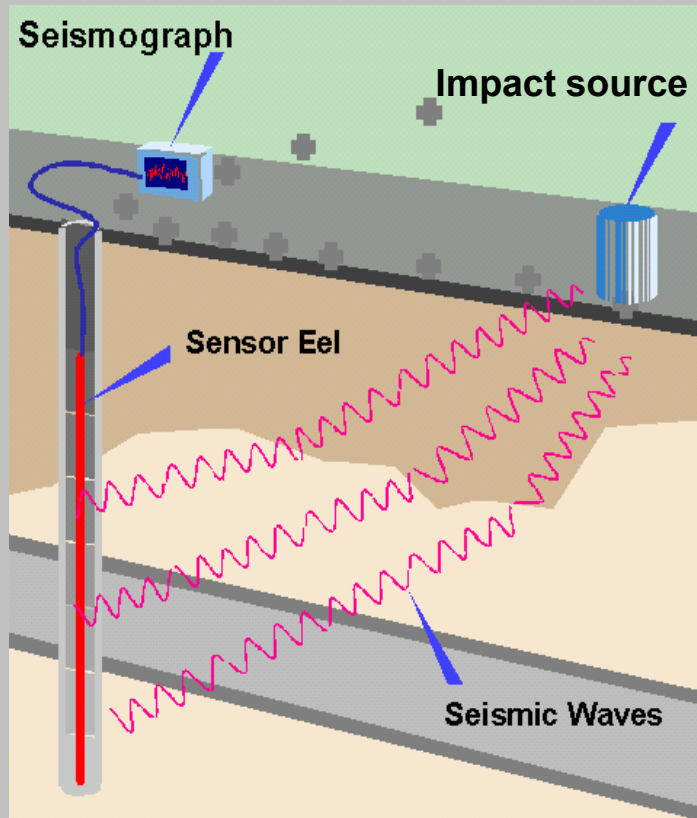


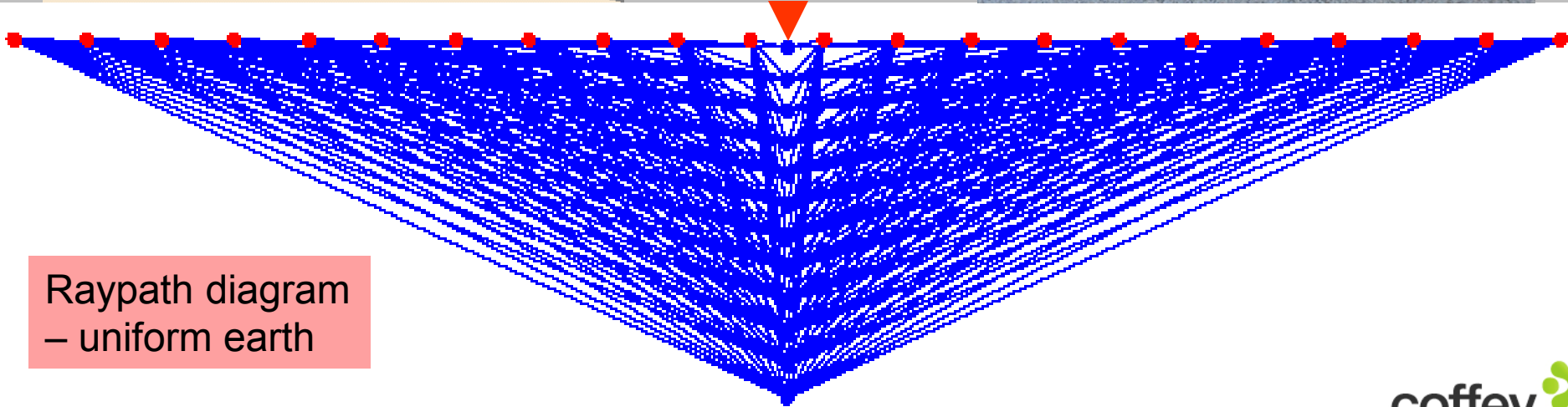
Figure : 5 Subsurface Section and Borehole Grout Takes

Site Uniformity Borehole Seismic (SUBS) Testing

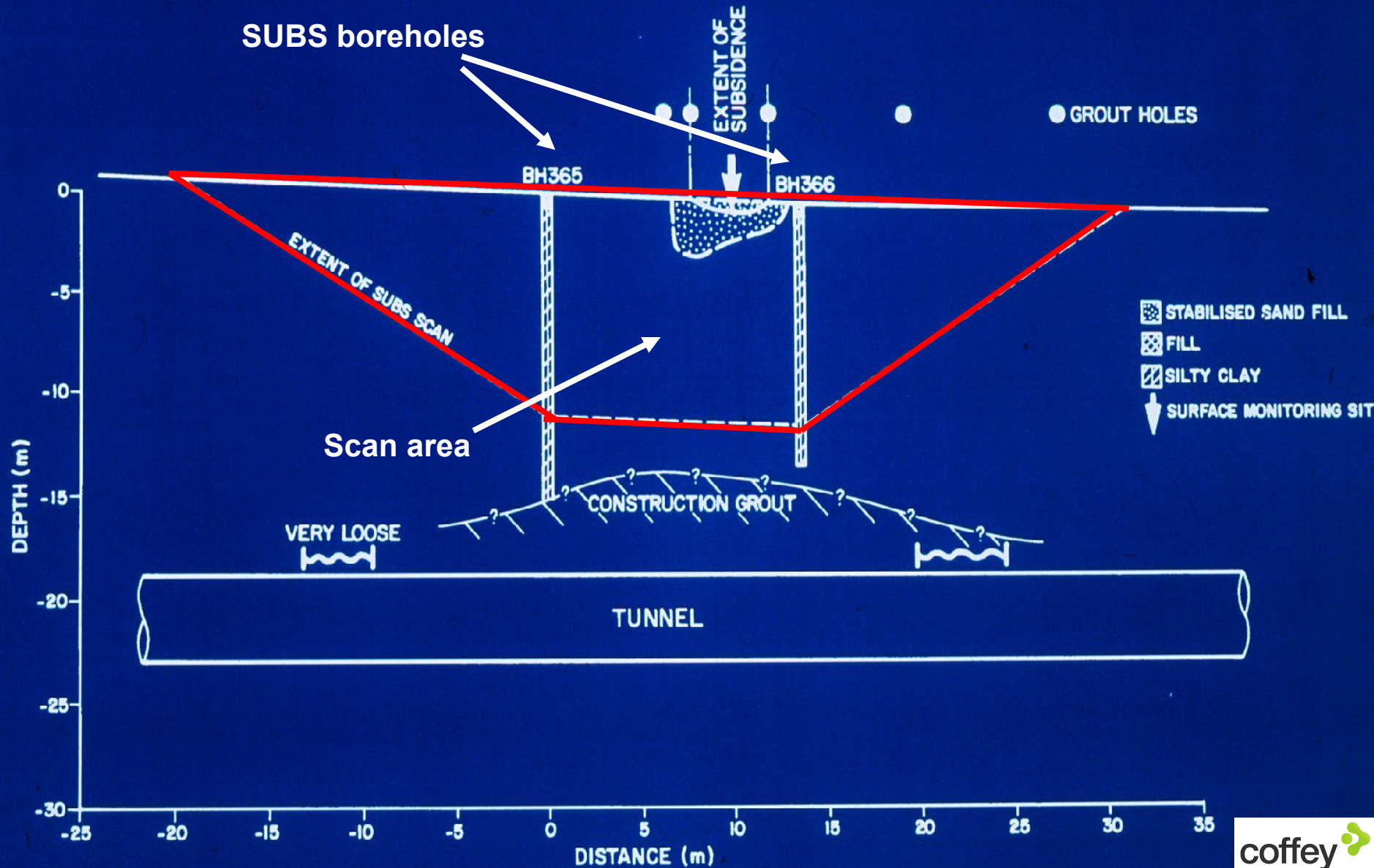


borehole

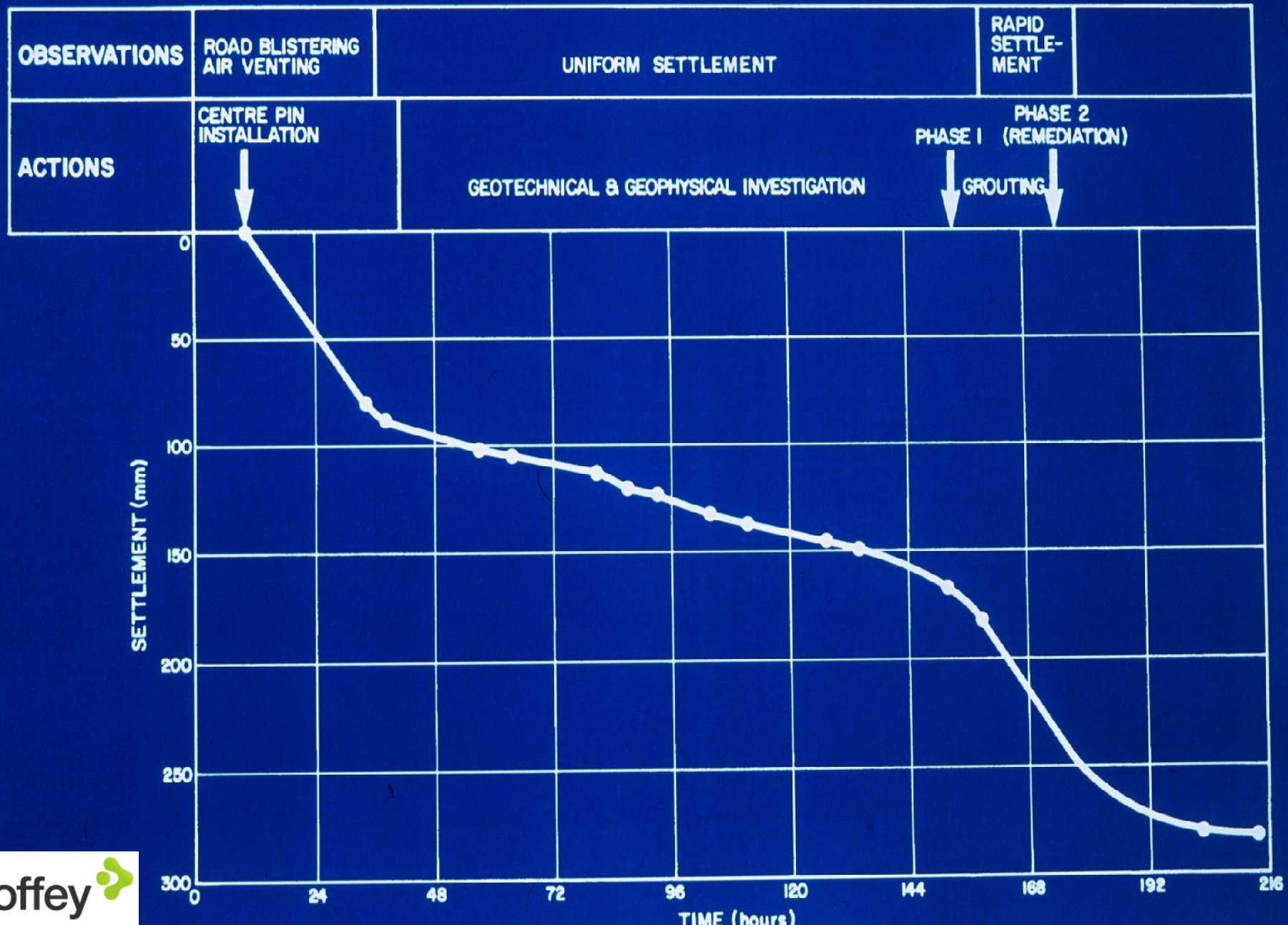
Raypath diagram
– uniform earth



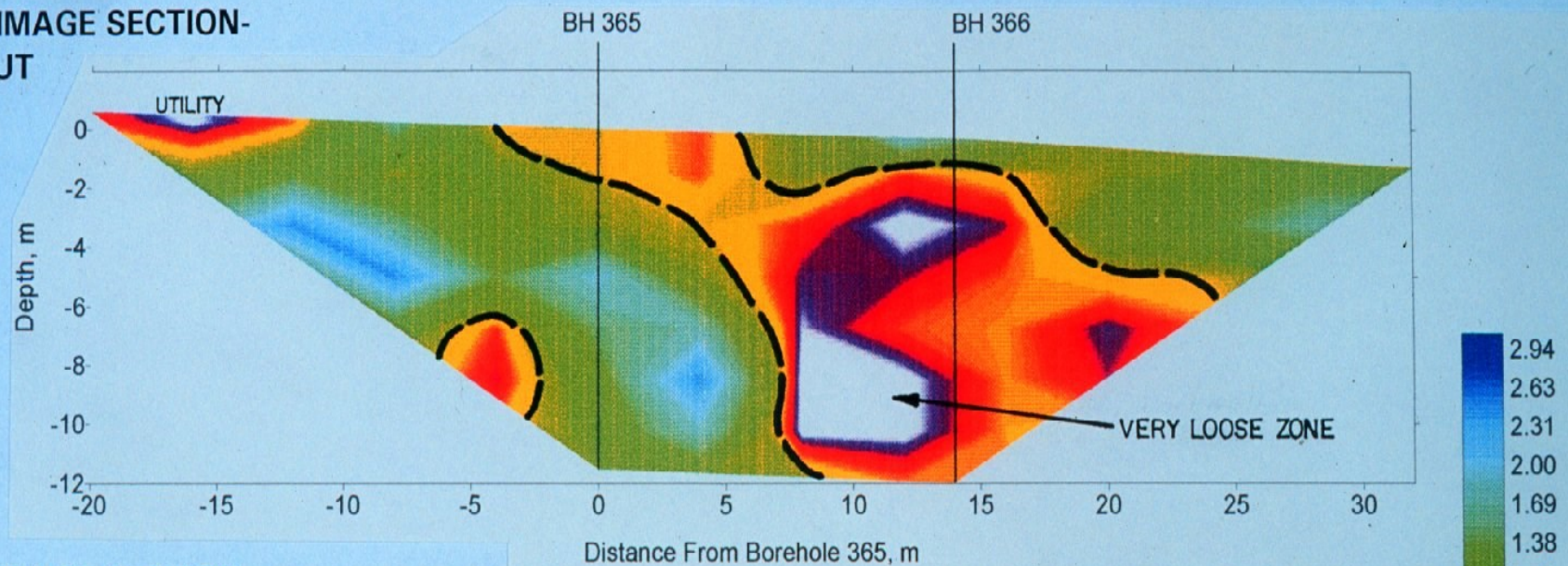
SEISMIC IMAGING OF SUBSIDENCE ZONE



ROAD SUBSIDENCE - SURFACE ELEVATION MONITORING



SEISMIC IMAGE SECTION- PRE-GROUT

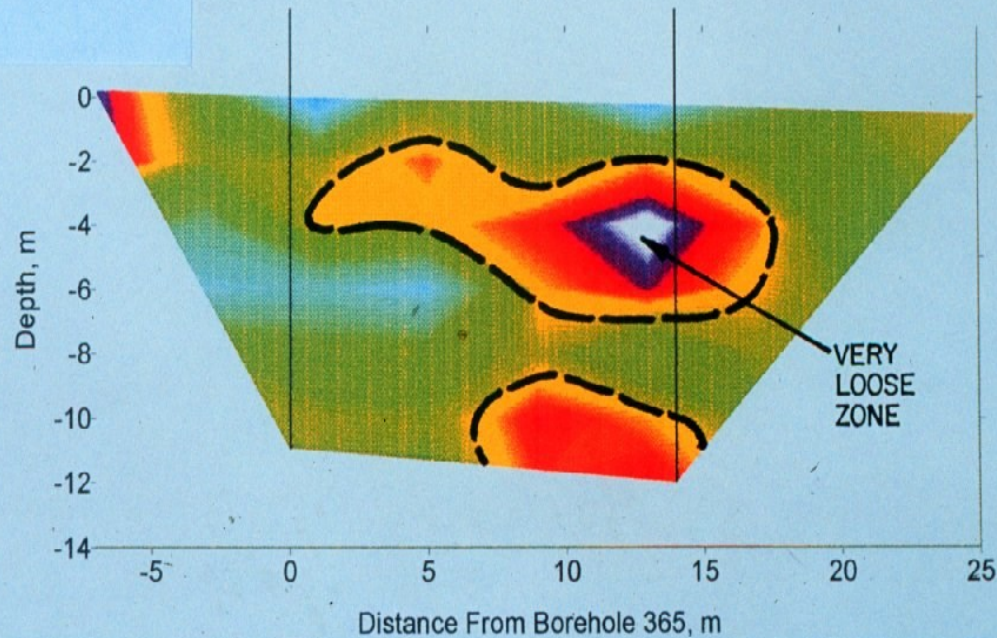


SEISMIC IMAGE SECTION- POST GROUT (PHASE 1)

Downstream

Upstream

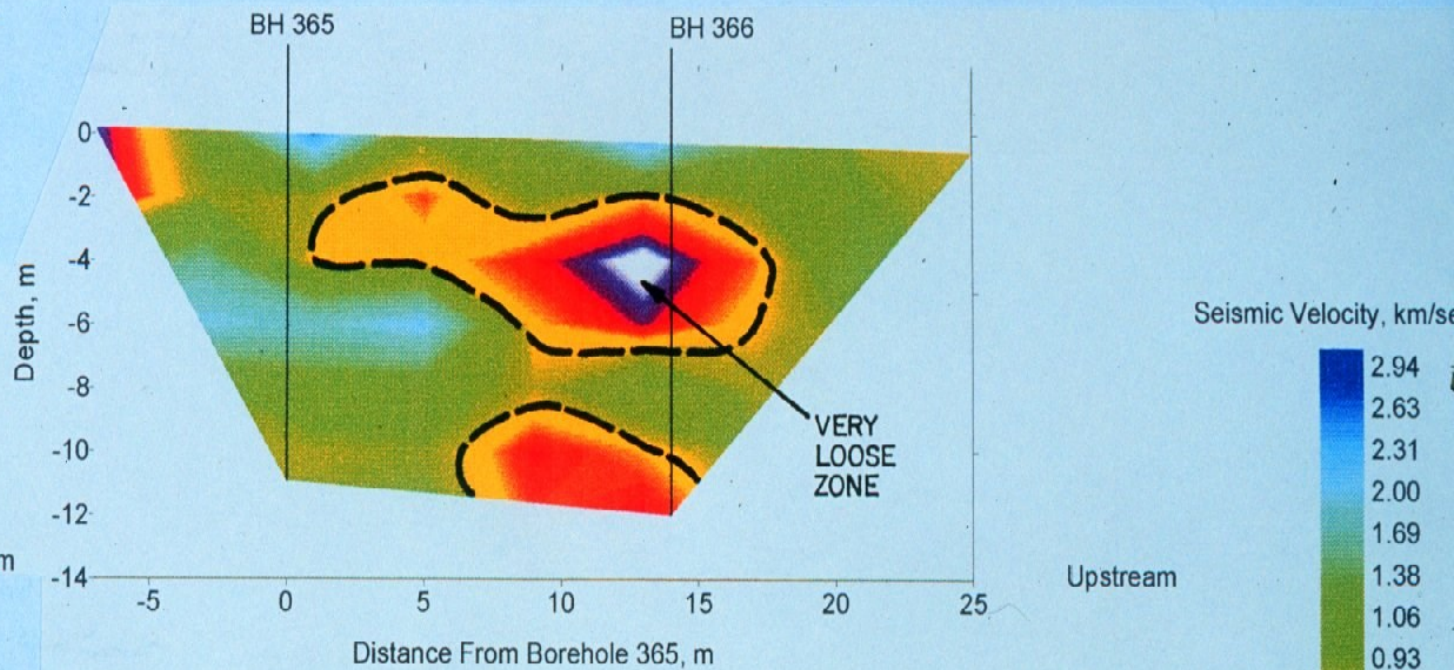
Straight Ray Interpretation
Initial model based on average velocity
no constraints



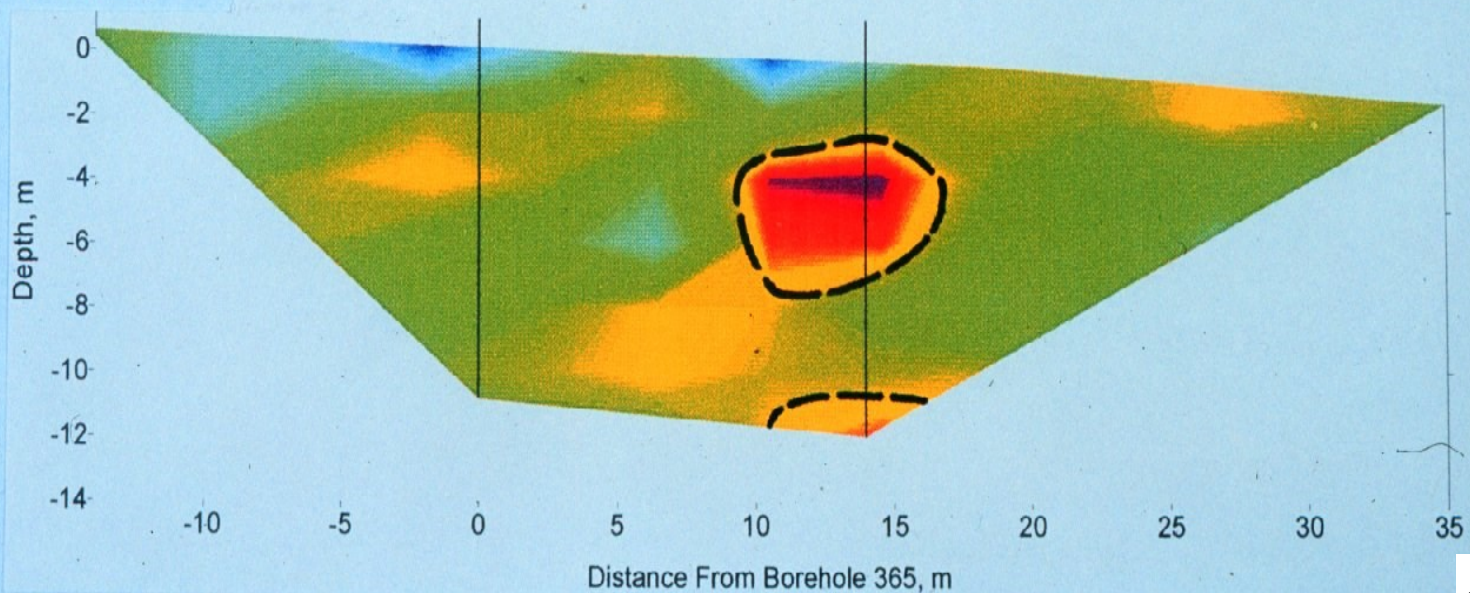
Seismic Velocity, km/sec

SEISMIC IMAGE SECTION- POST GROUT (PHASE 1)

Straight Ray Interpretation
Initial model based on
average velocity,
no constraints



SEISMIC IMAGE SECTION- POST GROUT (PHASE 2)









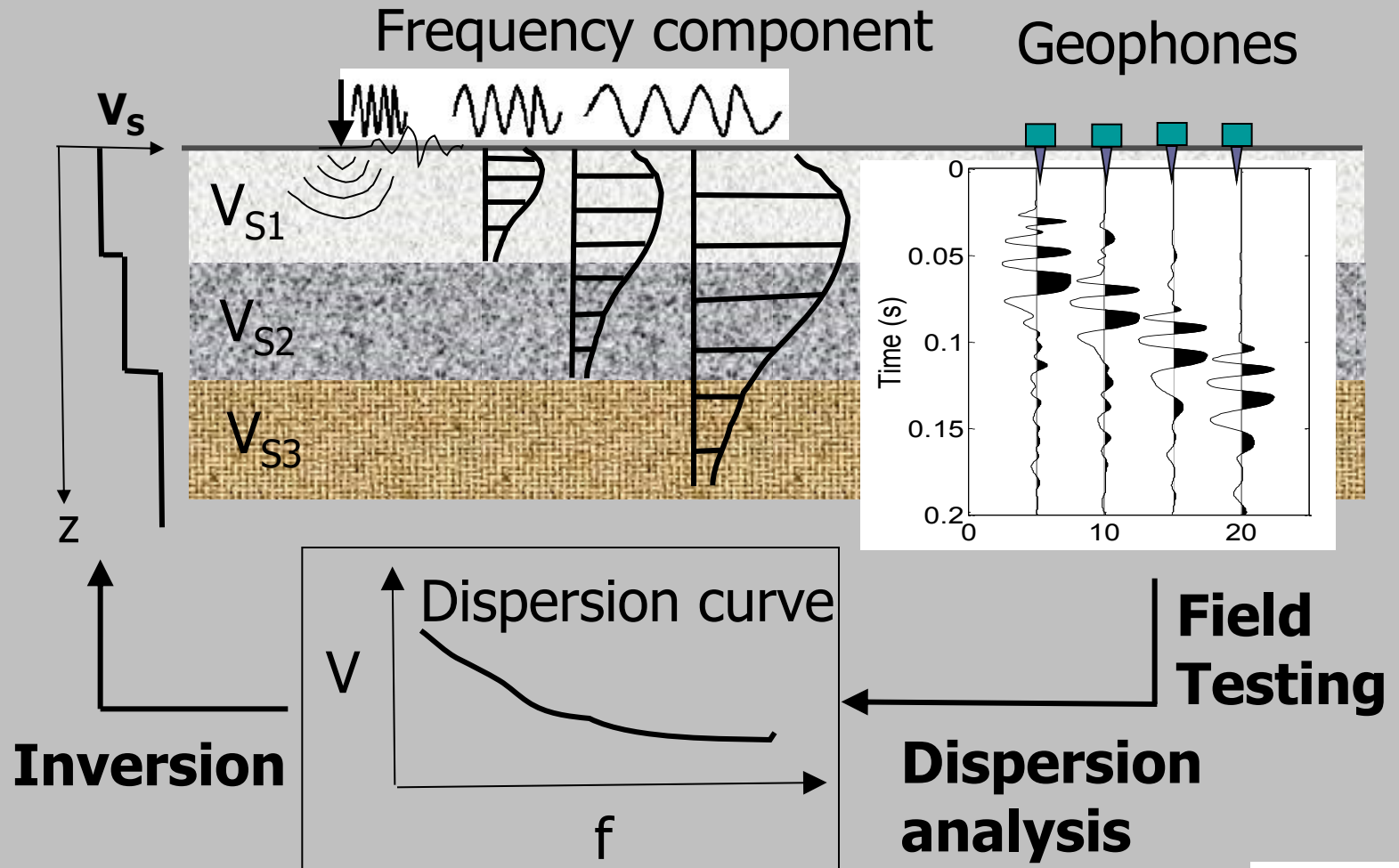
Embankment Collapse over Conduit



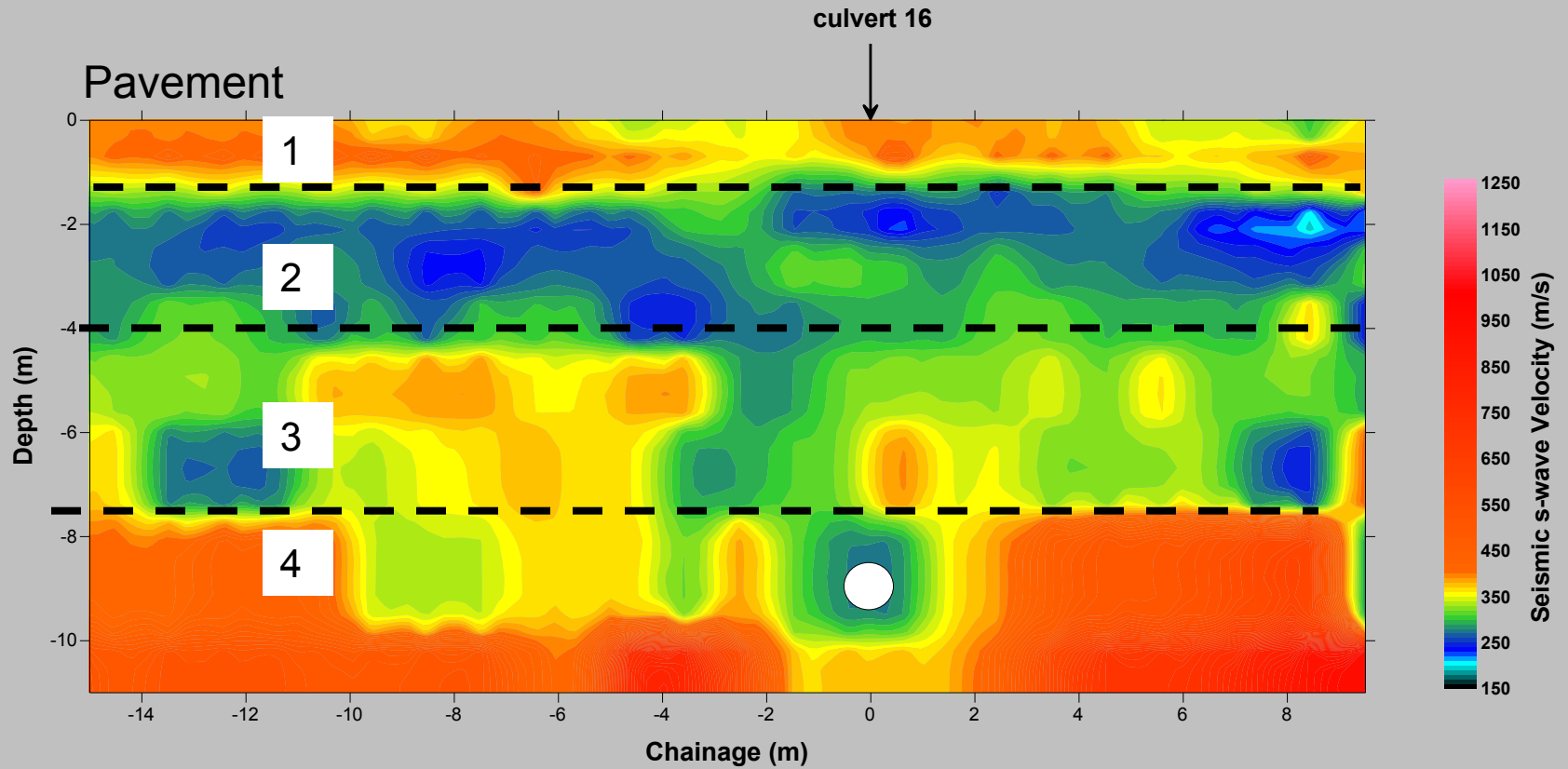
MASW & GPR Testing of Highways



Basic Principle of Surface Wave Method



Shear Wave Velocity Section - Northbound-Slow Shoulder



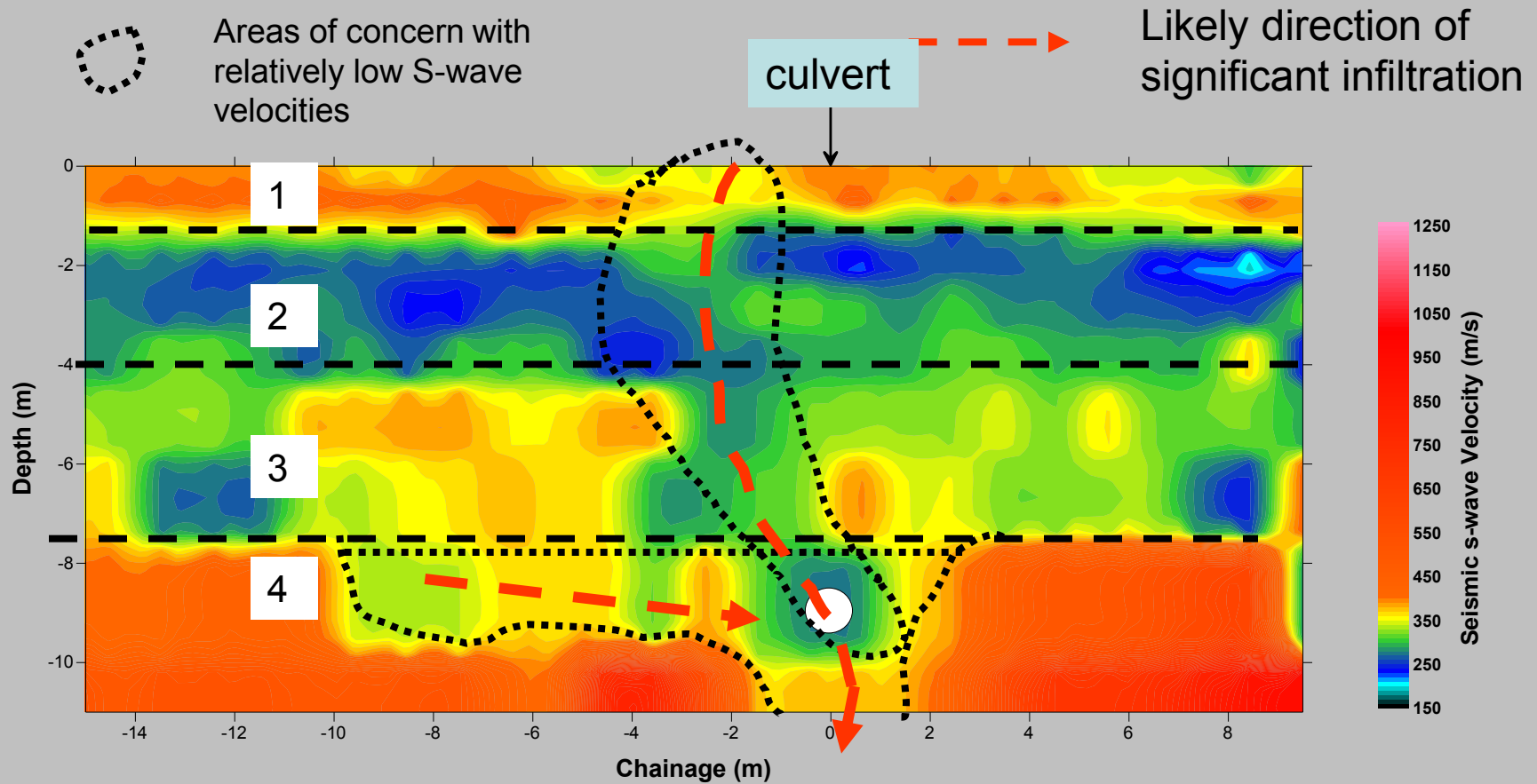
— — — Approx. depth of material property change

1 Layer No.

S-wave velocity interpretation

Layer	Approx. Depth	Description	S-wave velocity range (m/s)	Interpretation
1	0 - 1.5	Pavement construction layers	430 - 500 	generally good condition
			350 - 420 	Minor loss of dynamic stiffness
			300 - 350 	Loss of dynamic stiffness
2	1.5 - 4	Fill	300 - 340 	Generally coarse fill with some fines
			200 - 290 	Coarse voided fill (draining)
3	4 - 7.5	Fill	350 - 420 	Coarse variable fill
			300 - 340 	Generally coarse fill with some fines
			200 - 290 	Coarse voided fill (draining)
4	> 7.5	Fill / rock (?)	300 - 400 	Generally coarse fill with some fines / EW rock (?)
			410 - 900 	Coarse variable fill, EW-MW rock (?)

Shear Wave Velocity Section Northbound Slow Shoulder

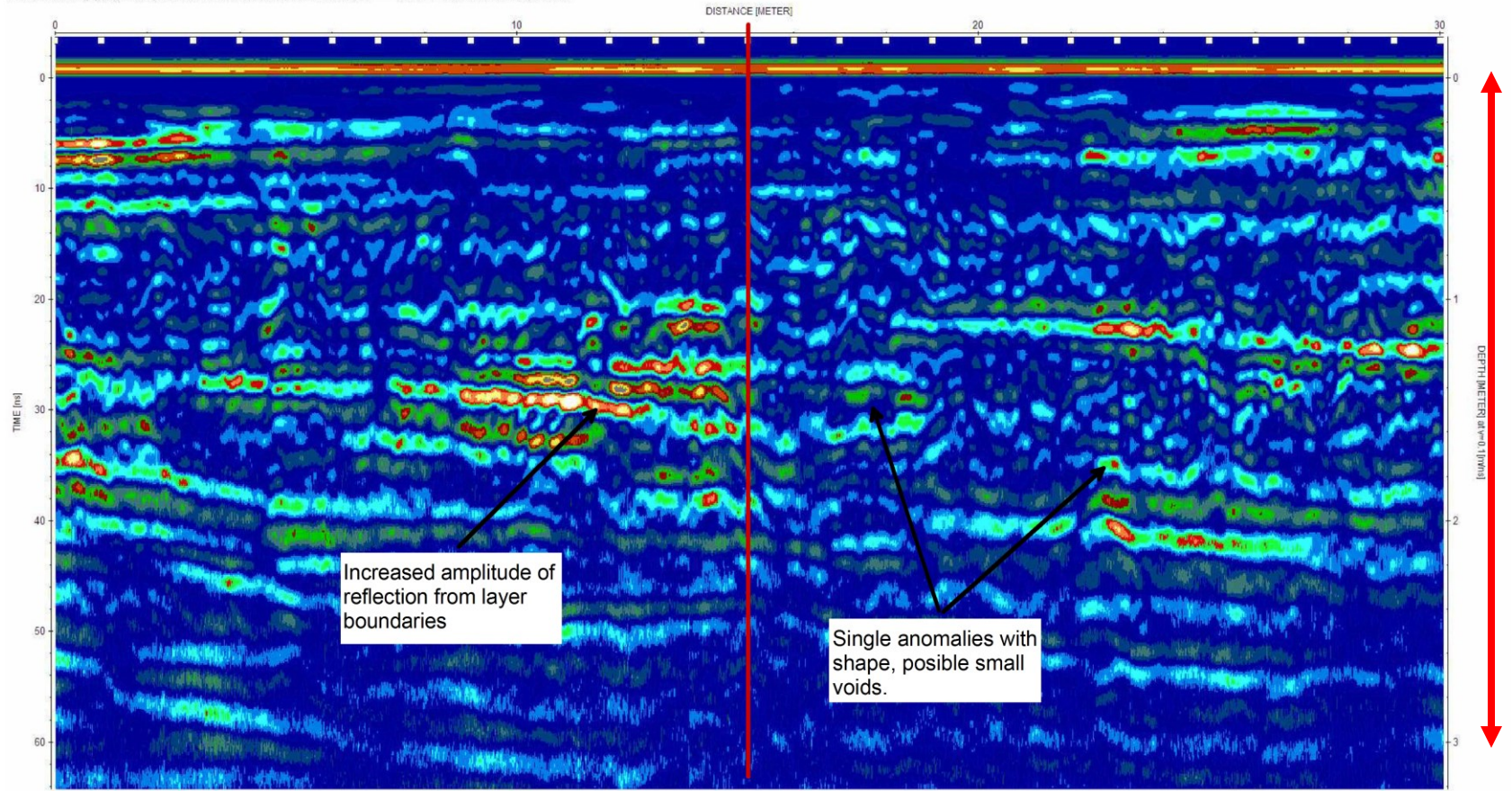


— — — Approx. depth of material property change

1 Layer No.

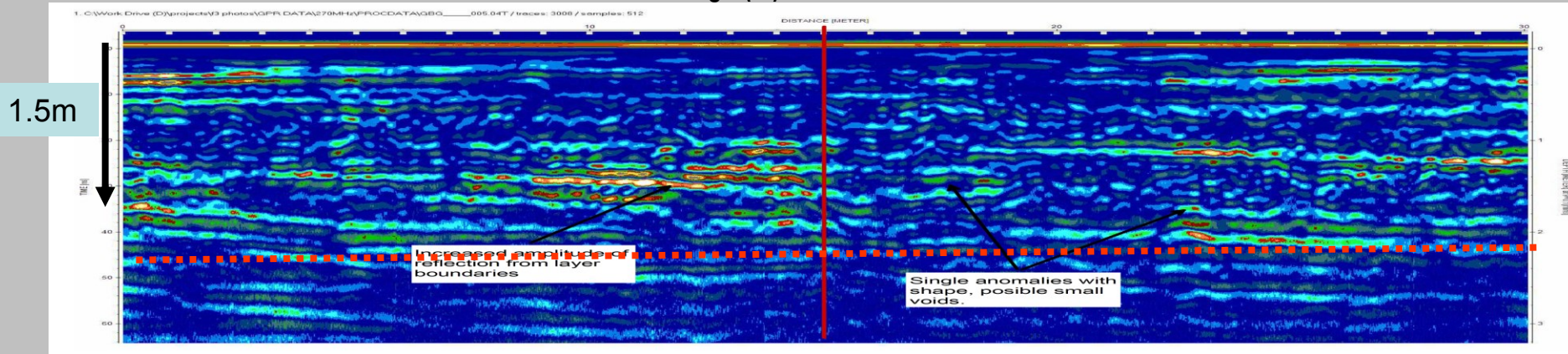
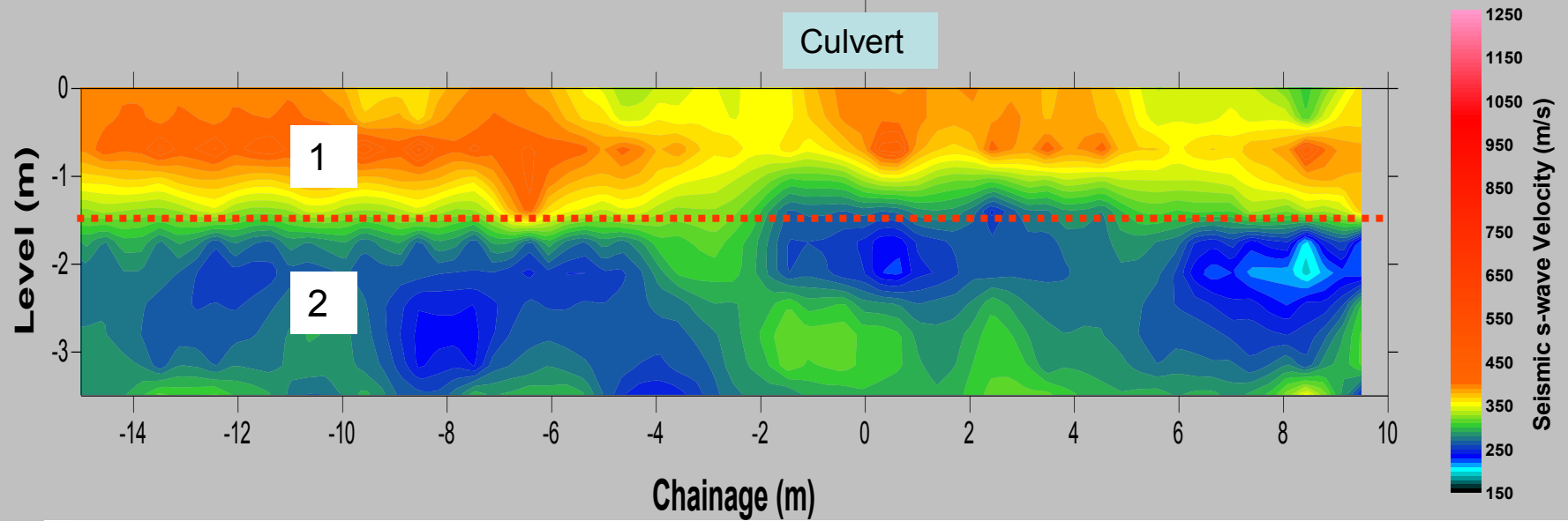
GPR Section – 250MHz antenna

1. C:\Work Drive (D)\projects\Y3 photos\GPR DATA\270MHz\PROC DATA\QBG____005.04T / traces: 3008 / samples: 512



3m

30m



Layer	Approx. Depth	Description	S-wave velocity range (m/s)	Interpretation
1	0 - 1.5	Pavement construction layers	430 - 500	generally good condition
			350 - 420	Minor loss of dynamic stiffness
			300 - 350	Loss of dynamic stiffness
2	1.5 - 4	Fill	300 - 340	Generally coarse fill with some fines
			200 - 290	Coarse voided fill (draining)



P-wave seismic imaging of embankments

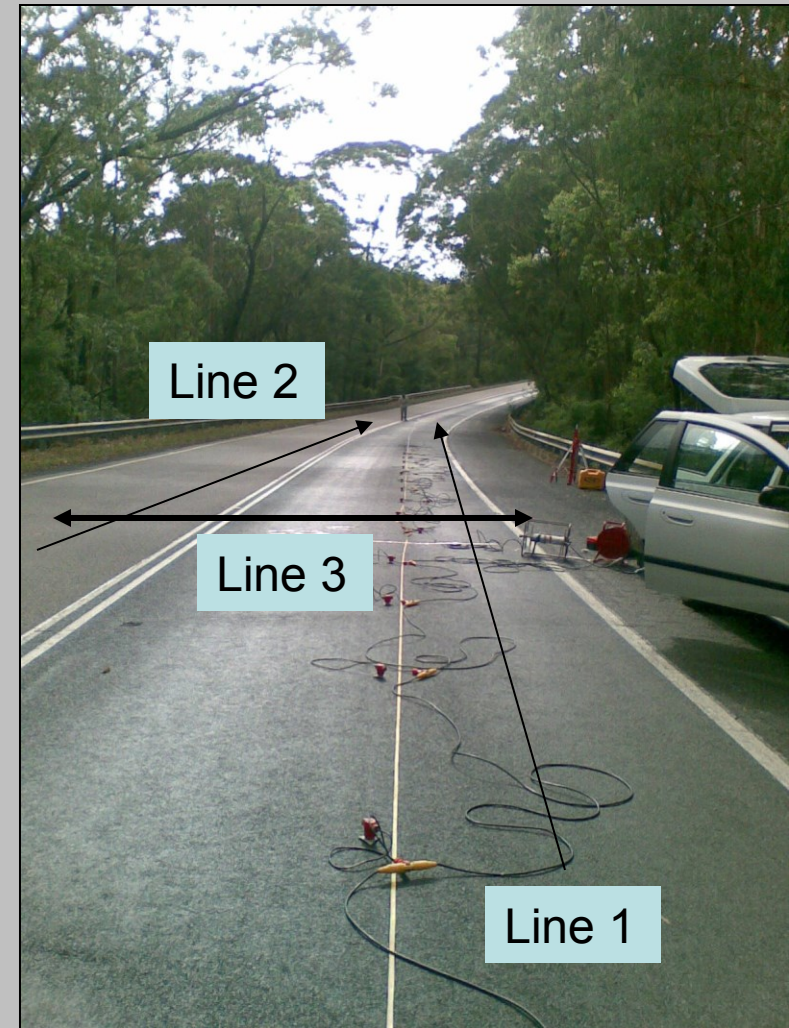


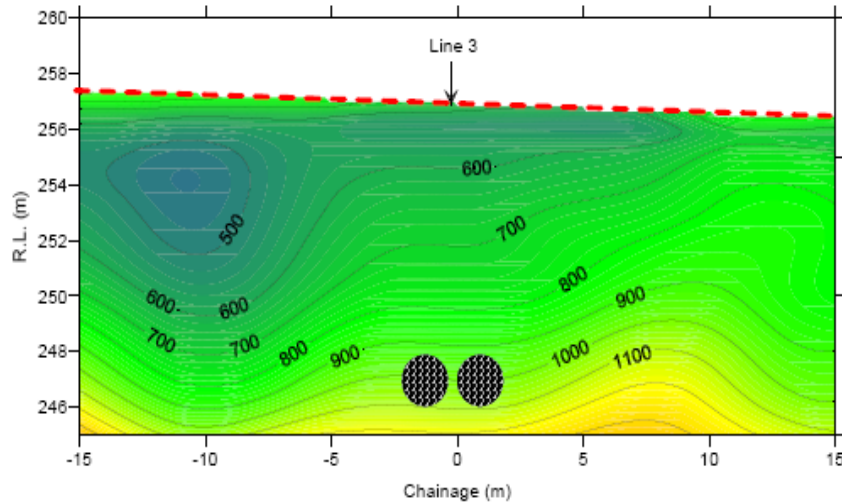
Table 1: P-wave seismic velocity and inferred geotechnical conditions

P-wave seismic velocity (m/s)*	Inferred SPT N-value	Geotechnical classification
< 350	0 to 4	Very loose Blue
350 to 500	4 to 10	Loose Blue
500 to 750	10 to 30	Medium dense to dense Green
750 to 1700	30 to 50	Dense to very dense Yellow
> 1700	>50	Very dense Yellow

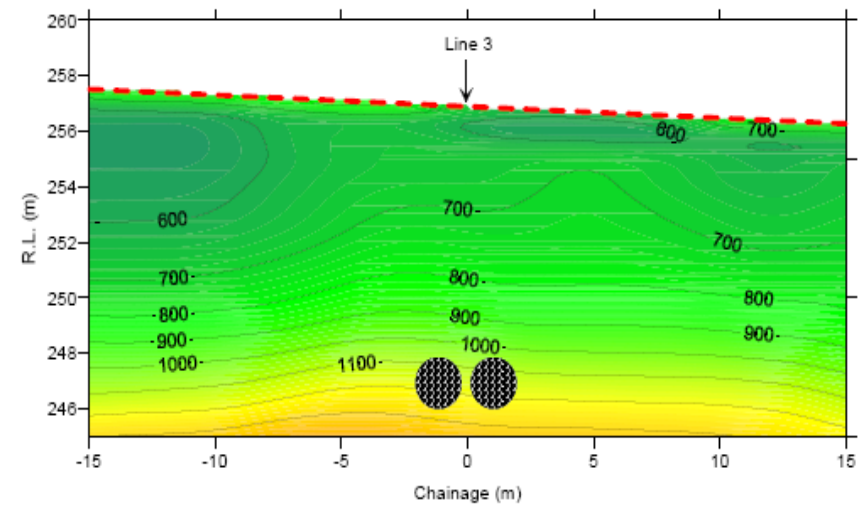
* Dry or partially saturated granular soils and fills

P-wave seismic image Sections

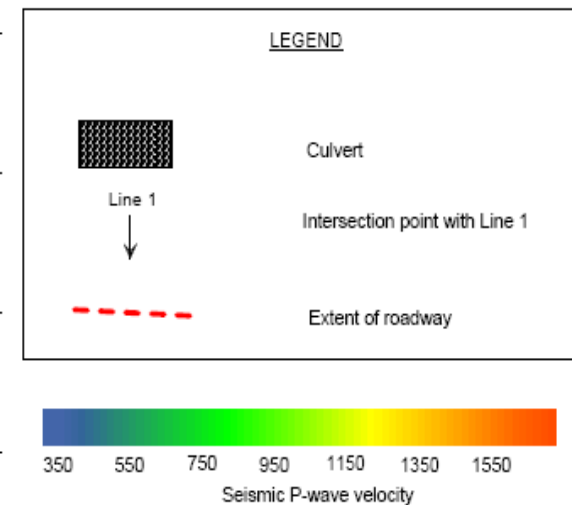
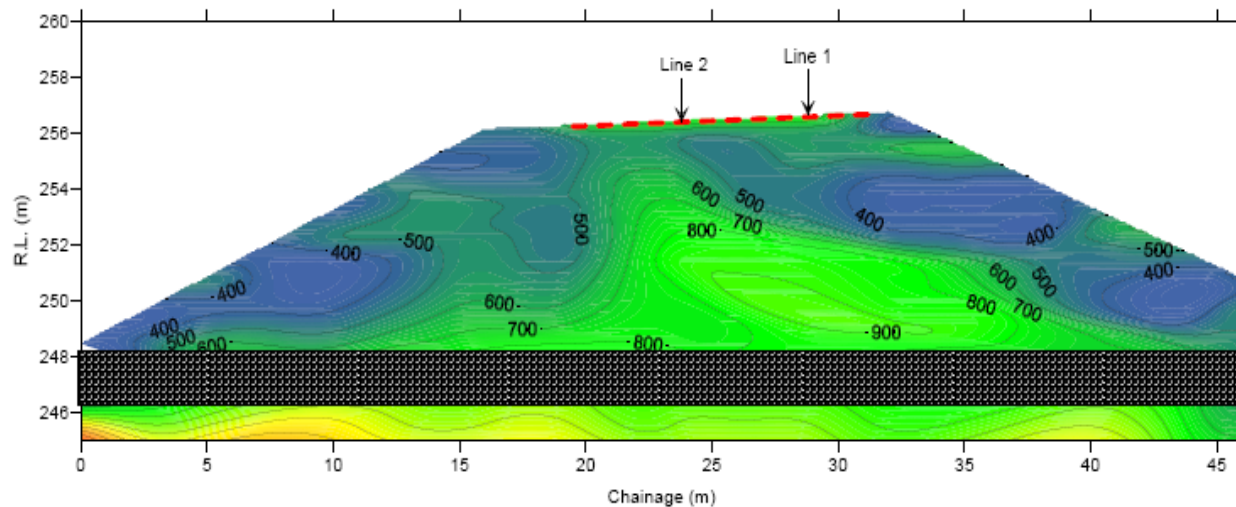
Line 1



Line 2

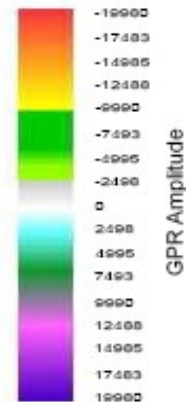
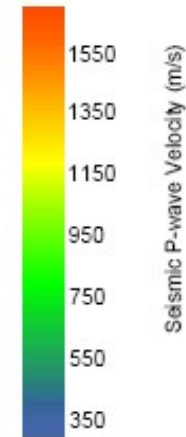
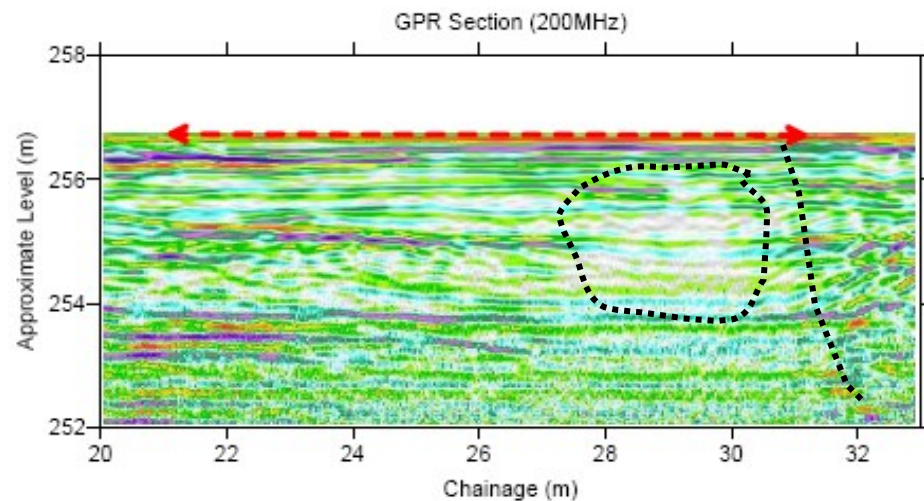
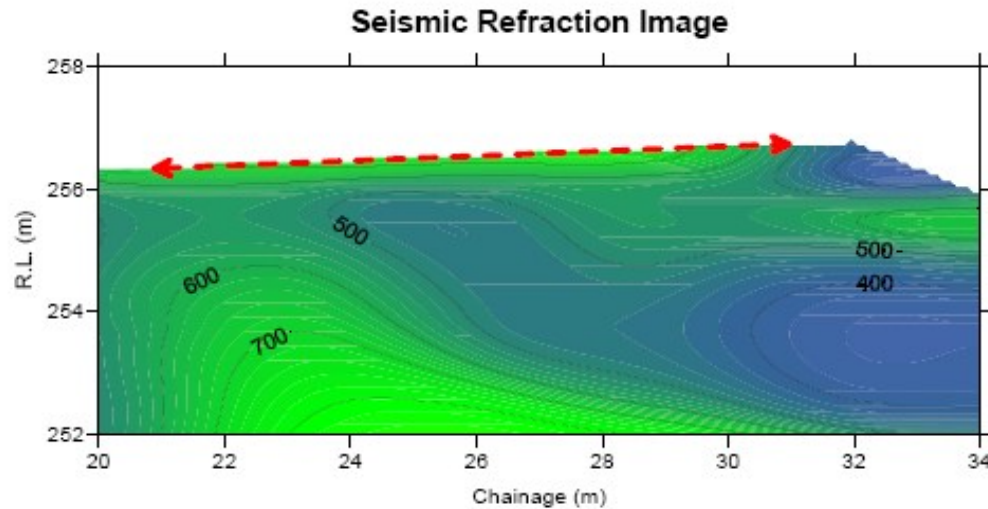


Line 3



Line 3

Comparison of GPR & Seismic Images



LEGEND



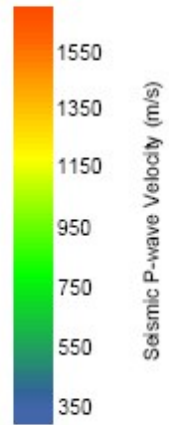
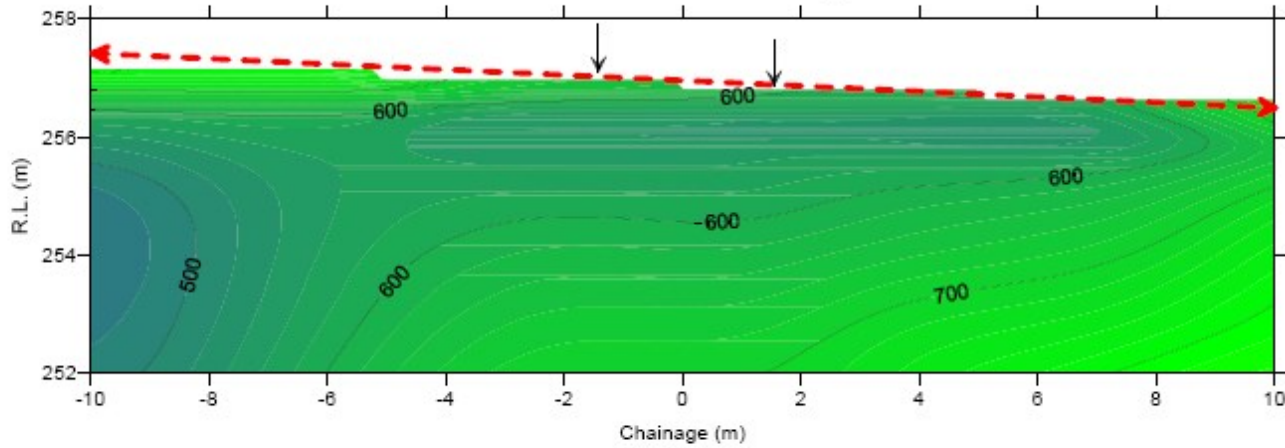
Extent of roadway



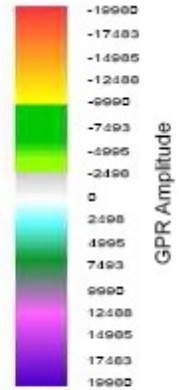
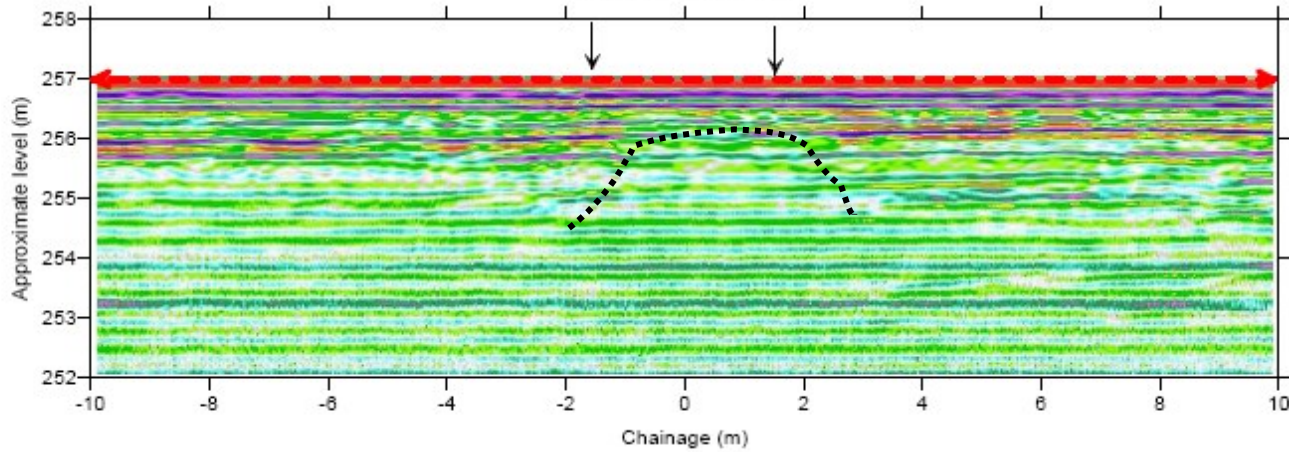
Culvert location

Line 1

Seismic Refraction Image



GPR section (200MHz)



LEGEND



Extent of roadway



Culvert location



Surface Evidence

**Distressed
Buried Sewers**

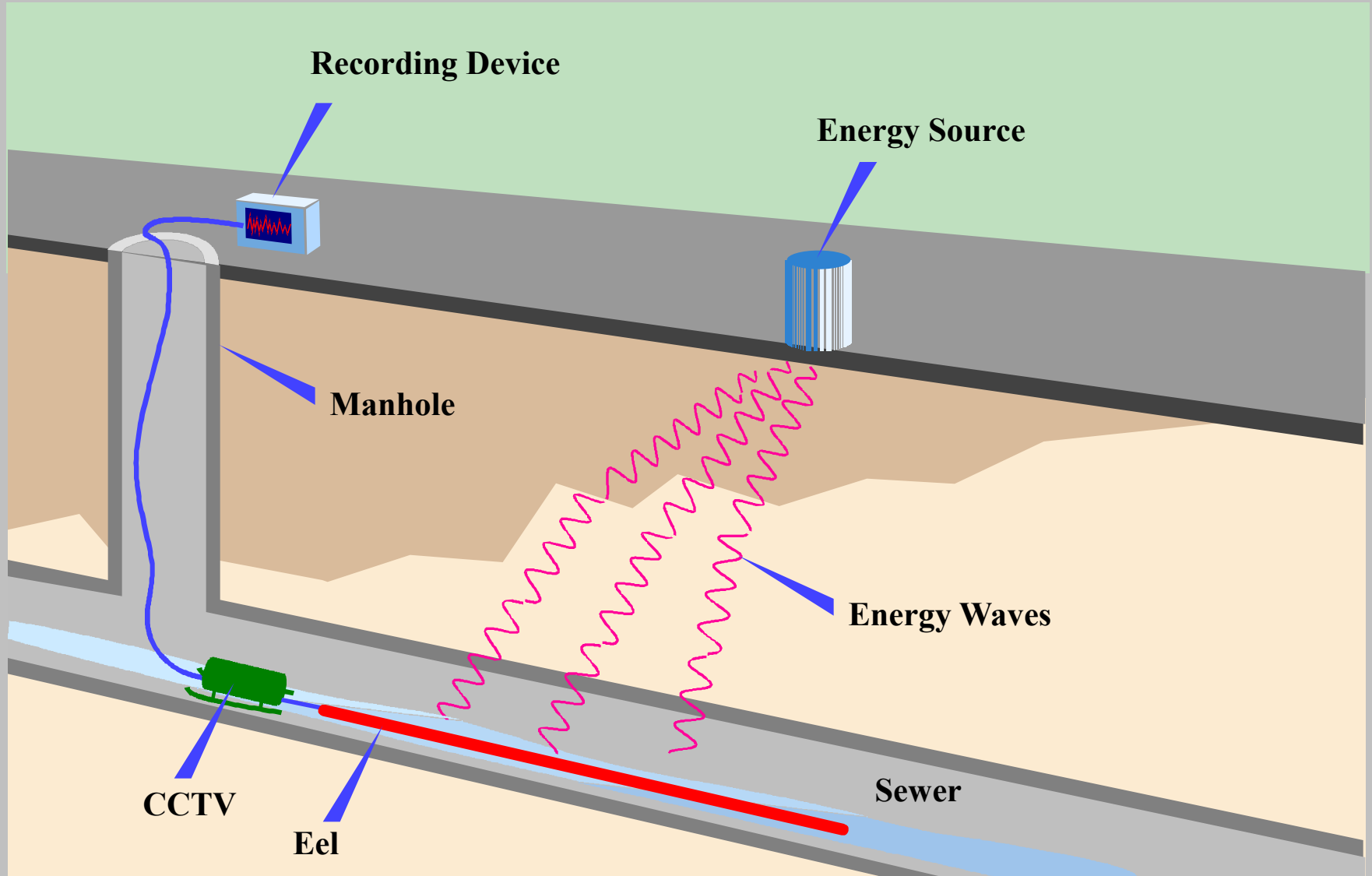


GROUND CONDITION ASSESSMENT with Seismic Testing Technology

SEWREEL - Eel in the sewer

- Objectives:
 - Detailed seismic testing of ground conditions from the conduit to the surface
 - Monitoring of distressed areas
 - Checking remediation works

SEWREEL



SEWREEL FIELD OPERATIONS - ORLANDO SITE



Energy Device: The Hiss Hammer

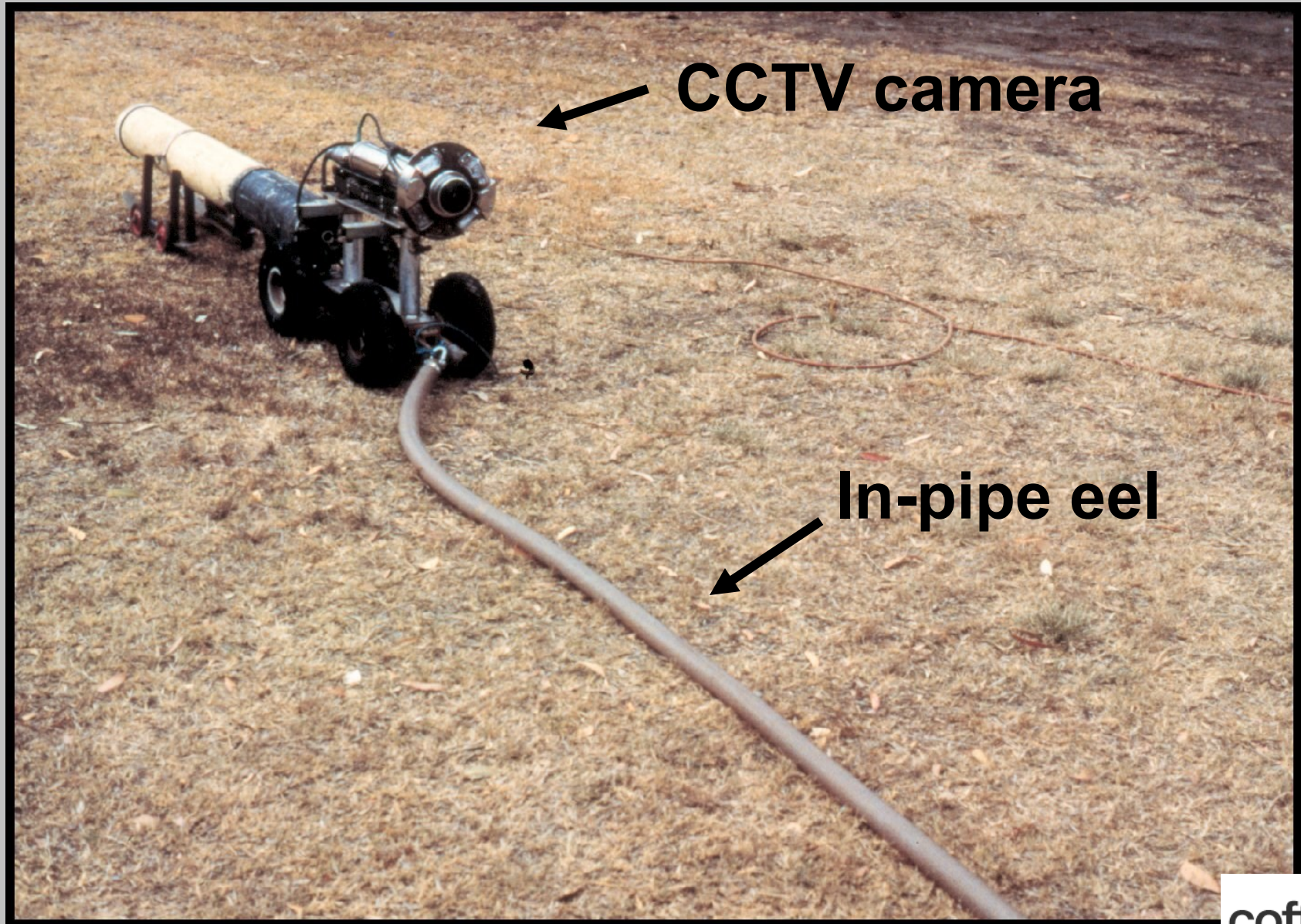


**Seismograph
Trigger**

Moving the Hiss Hammer Source



Detecting Device: The eel



← **CCTV camera**

← **In-pipe eel**

THE OUTPUT OF SEWREEL IS A SEISMIC TOMOGRAPHIC IMAGE (STI)

- A SEWREEL STI of the earth is like a medical CT scan of the body
- An STI shows the distribution of seismic velocity in the earth as a range of colours
- The velocity distribution on an STI may be related to material strength, density, SPT and CPT

SEWREEL TESTING for VOIDS & GROUT AFFECTED GROUND

**Testing Ground Conditions above a
54-72 inch RCP Gravity Main
ORLANDO, FLORIDA**

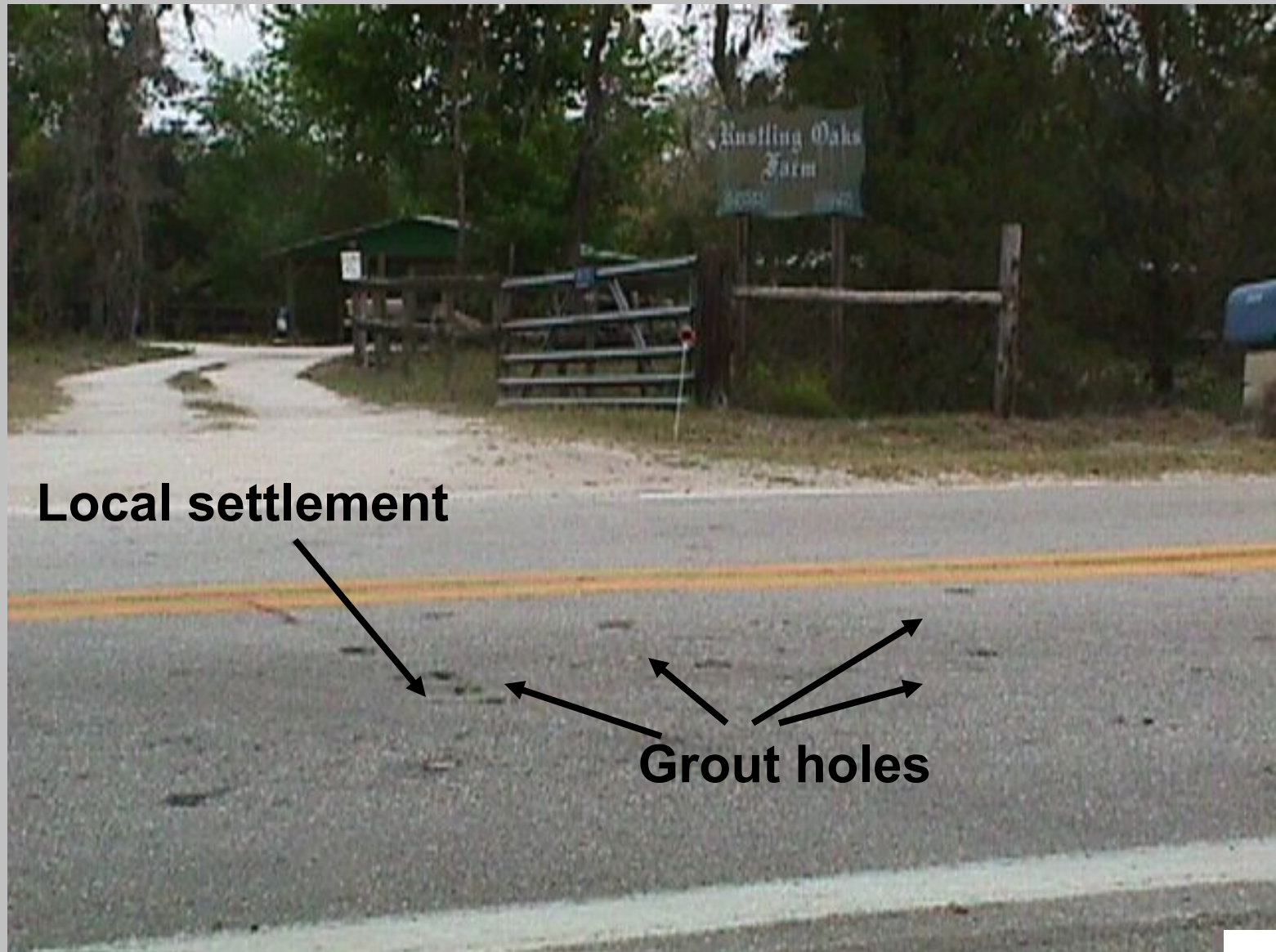
Orlando -Site Conditions



Road dips & repair

Sewer Alignment

Extensive Grouting at MH 9 + 170



2 Inch diameter Grout Holes in Pavement at MH 9 +170



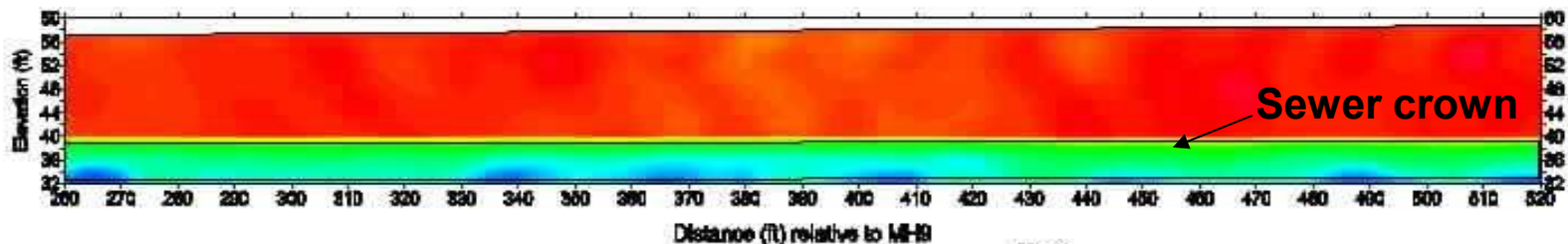
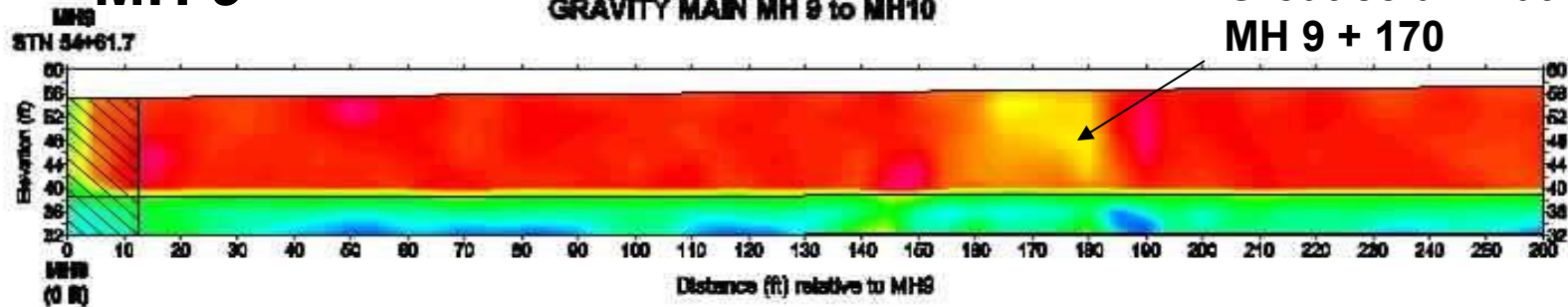
<u>SPT N-value</u>	<u>Geotechnical Classification</u>	<u>P-Wave Seismic Velocity</u> <u>m/s & (ft/s)</u>
0 – 4	Very loose	<350 – 430 (<1150 – 1400)
4 – 10	Loose	430 – 520 (1400 – 1700)
10 – 30	Medium dense	520 – 730 (1700 – 2400)
30 - 50	Dense	730 – 1680 (2400 – 5500)
>50	Very dense	>1680 (>5500)

SEWREEL Images of Grout Affected Soils

MH 9

SEWREEL IMAGE
GRAVITY MAIN MH 9 to MH10

Grout column at
MH 9 + 170



Note: This SEWREEL image is an output of a seismic test described in the accompanying report.
The seismic velocity distribution may be related to geotechnical soil density classifications as described in the report.



Seismic Velocity (ft/sec x 1000)



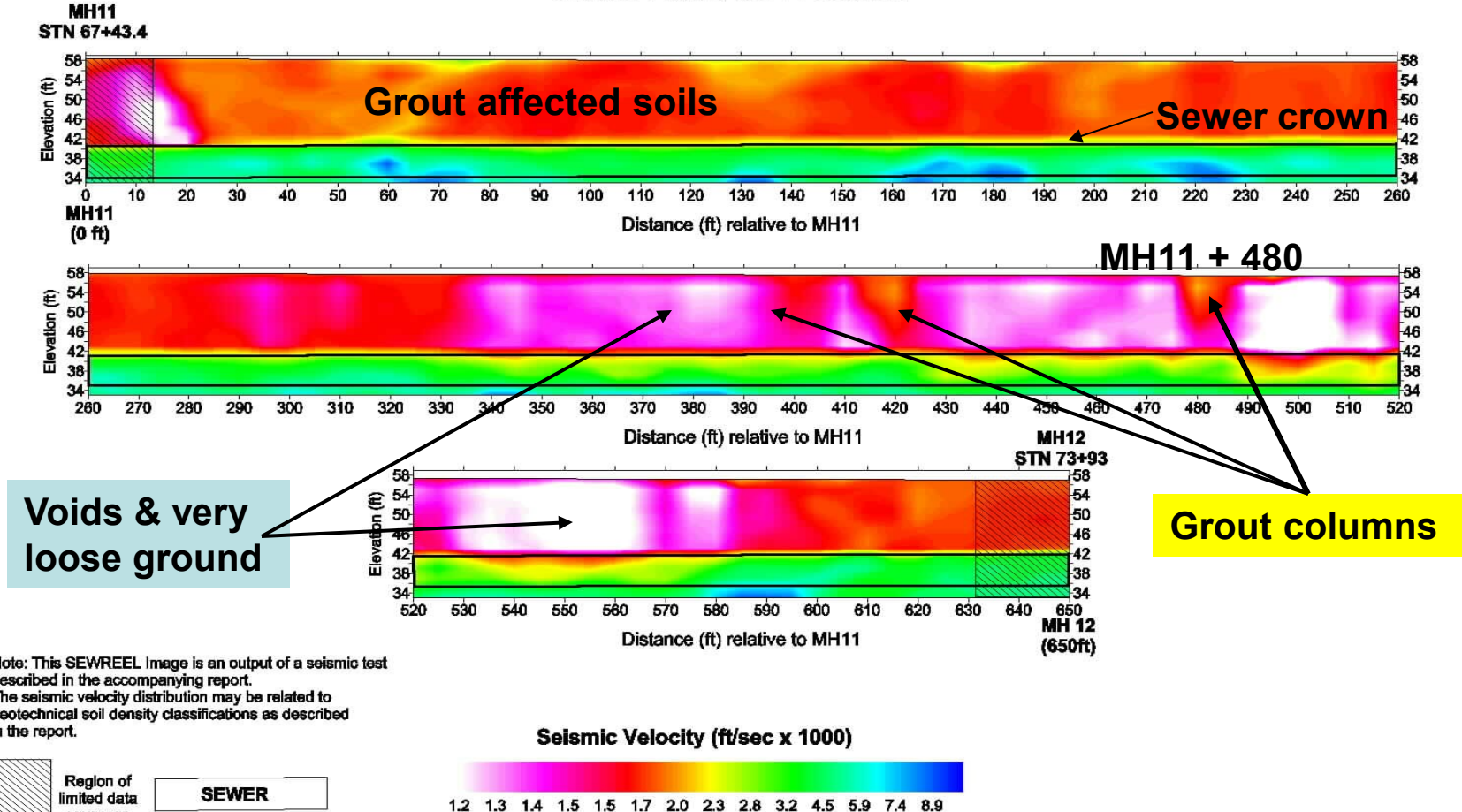
COFFEY GEOSCIENCES PTY. LTD.
SEWREEL TESTING GRAVITY MAIN
ORLANDO FLORIDA

Post-Grout Settlement: MH 11 + 480 ft.



SEWREEL Images of Voided Soils

SEWREEL IMAGES GRAVITY MAIN MH 11 to MH12



Note: This SEWREEL Image is an output of a seismic test described in the accompanying report. The seismic velocity distribution may be related to geotechnical soil density classifications as described in the report.