# Geophysics Case Studies: Road & Embankment Collapses

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SPECIALISTS MANAGING THE EARTH

**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**

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# Road Settlement during Tunnelling


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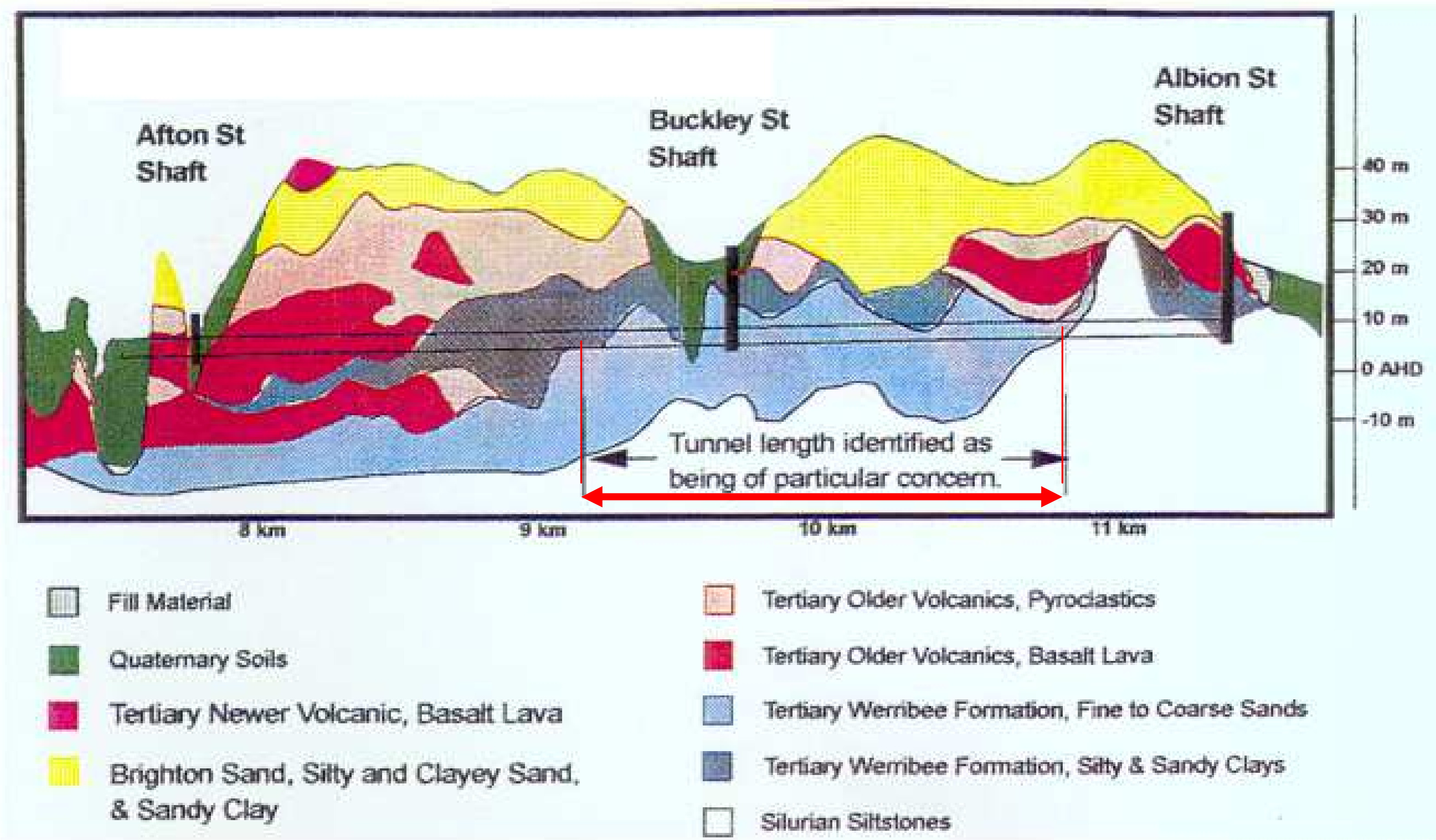
# Composite Geology, NW Sewer Route

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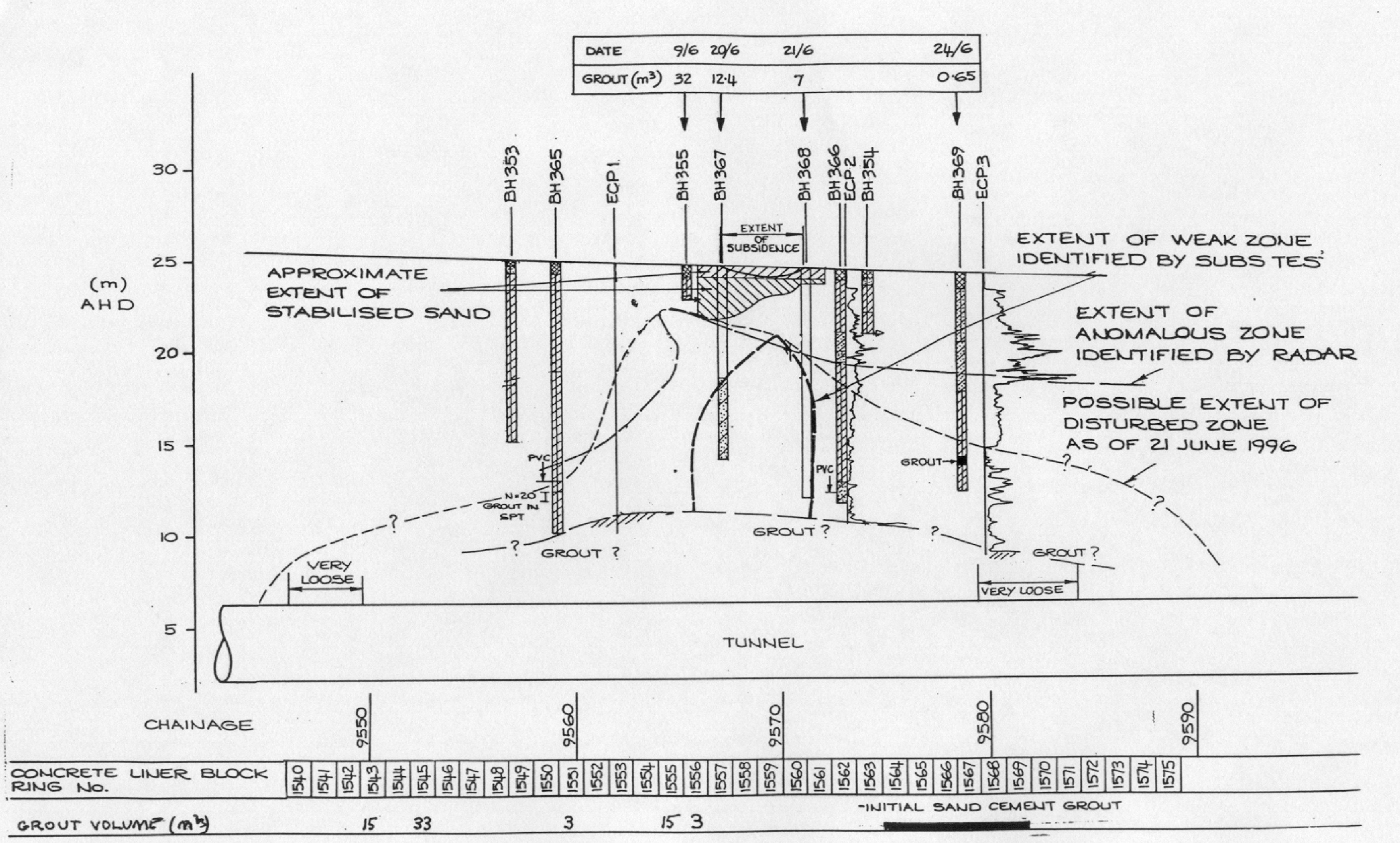
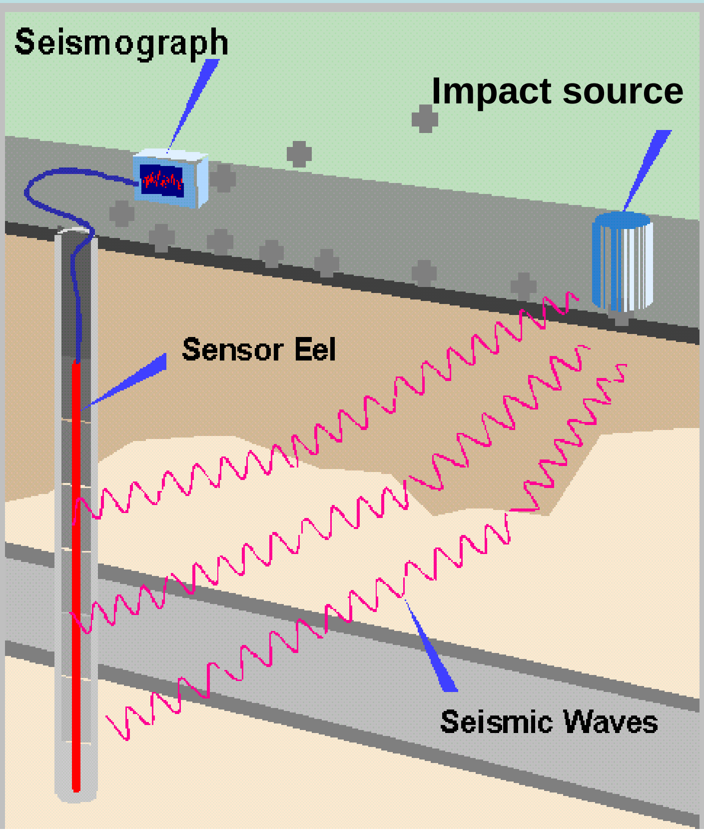
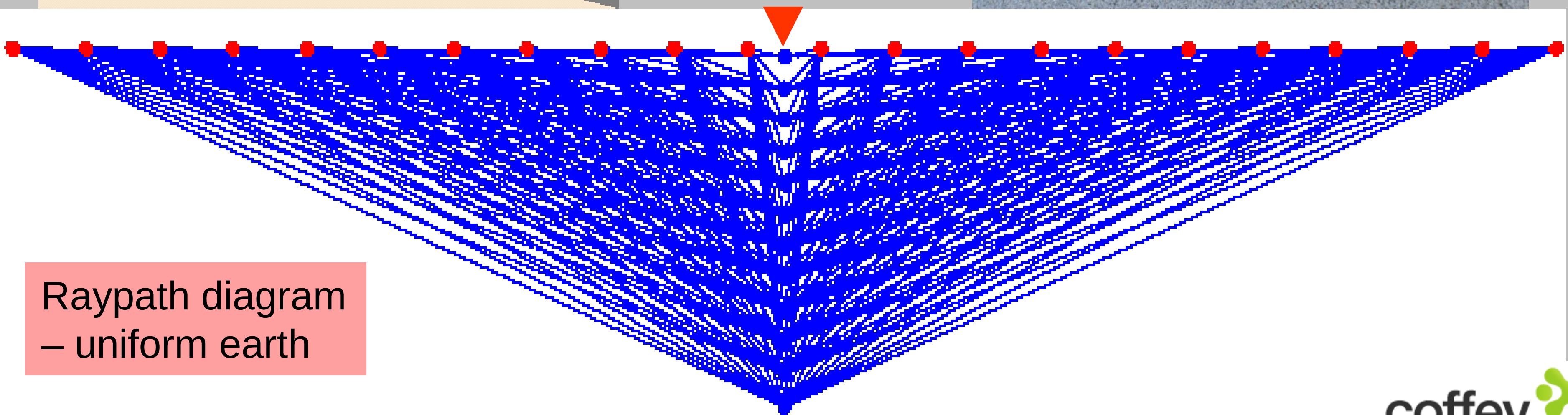



Figure : 5 Subsurface Section and Borehole Grout Takes

# Site Uniformity Borehole Seismic (SUBS) Testing




borehole



Raypath diagram
– uniform earth

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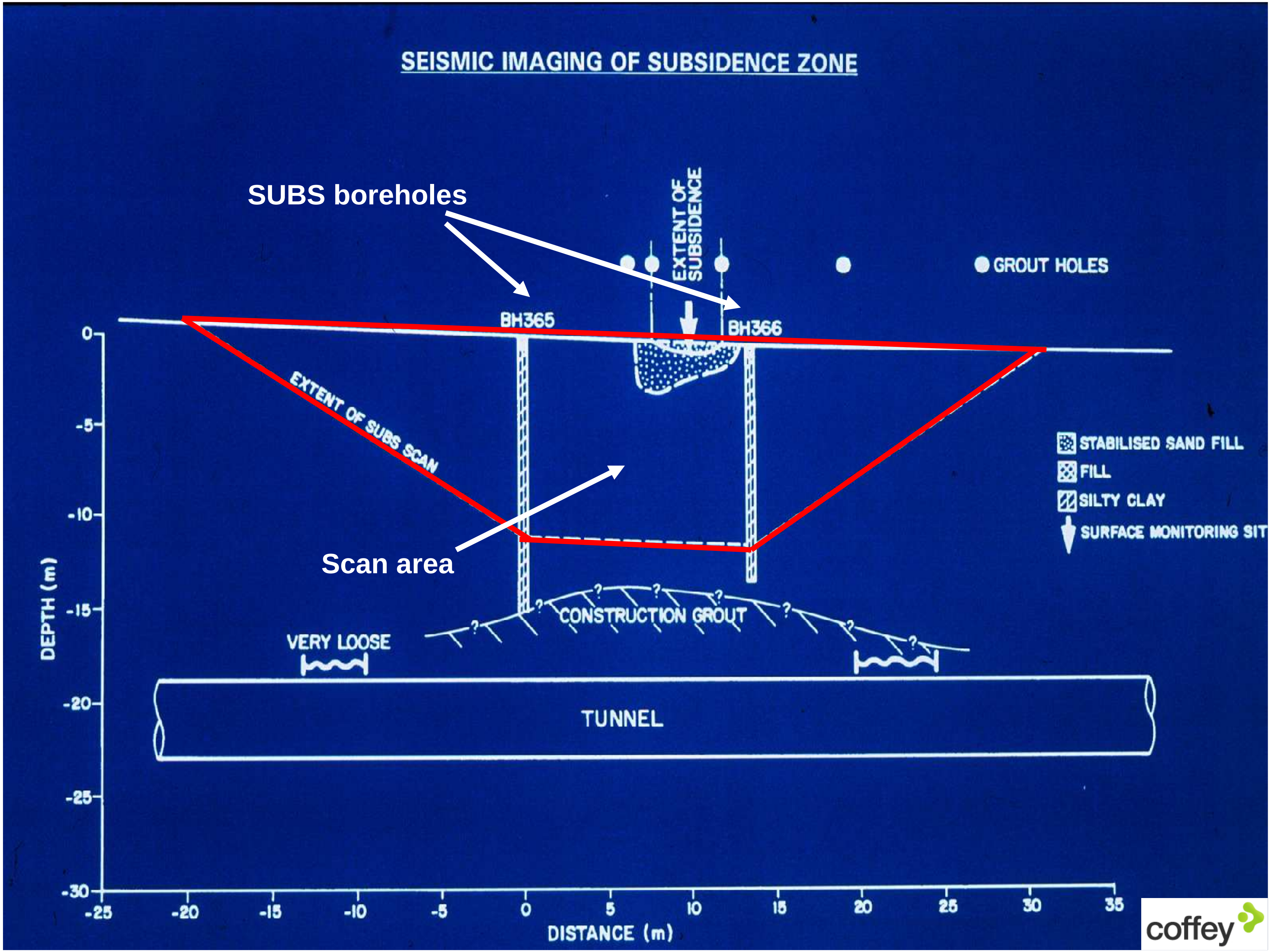
SEISMIC IMAGING OF SUBSIDENCE ZONE
SUBS boreholes
EXTENT OF SUBSIDENCE
GROUT HOLES
BH365
BH366
EXTENT OF SUBS SCAN
STABILISED SAND FILL
FILL
SILTY CLAY
SURFACE MONITORING SIT
Scan area
CONSTRUCTION GROUT
VERY LOOSE
TUNNEL
DEPTH (m)
0
-5
-10
-15
-20
-25
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
35
DISTANCE (m)
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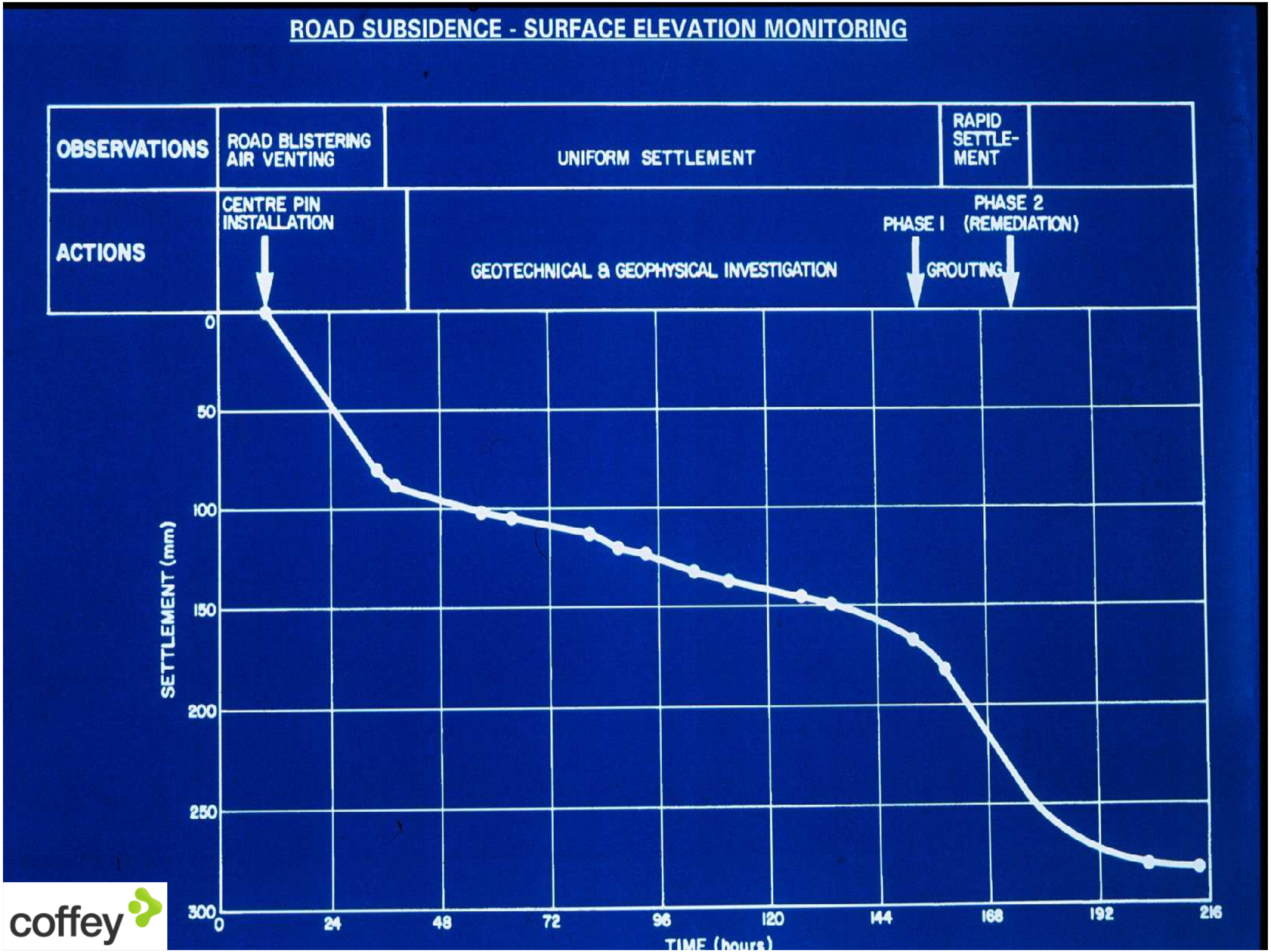
ROAD SUBSIDENCE - SURFACE ELEVATION MONITORING
OBSERVATIONS
ROAD BLISTERING AIR VENTING
UNIFORM SETTLEMENT
RAPID SETTLE-MENT
ACTIONS
CENTRE PIN INSTALLATION
GEOTECHNICAL & GEOPHYSICAL INVESTIGATION
PHASE I
PHASE 2 (REMEDIATION)
GROUTING
SETTLEMENT (mm)
0
50
100
150
200
250
300
0
24
48
72
96
120
144
168
192
216
TIME (hours)
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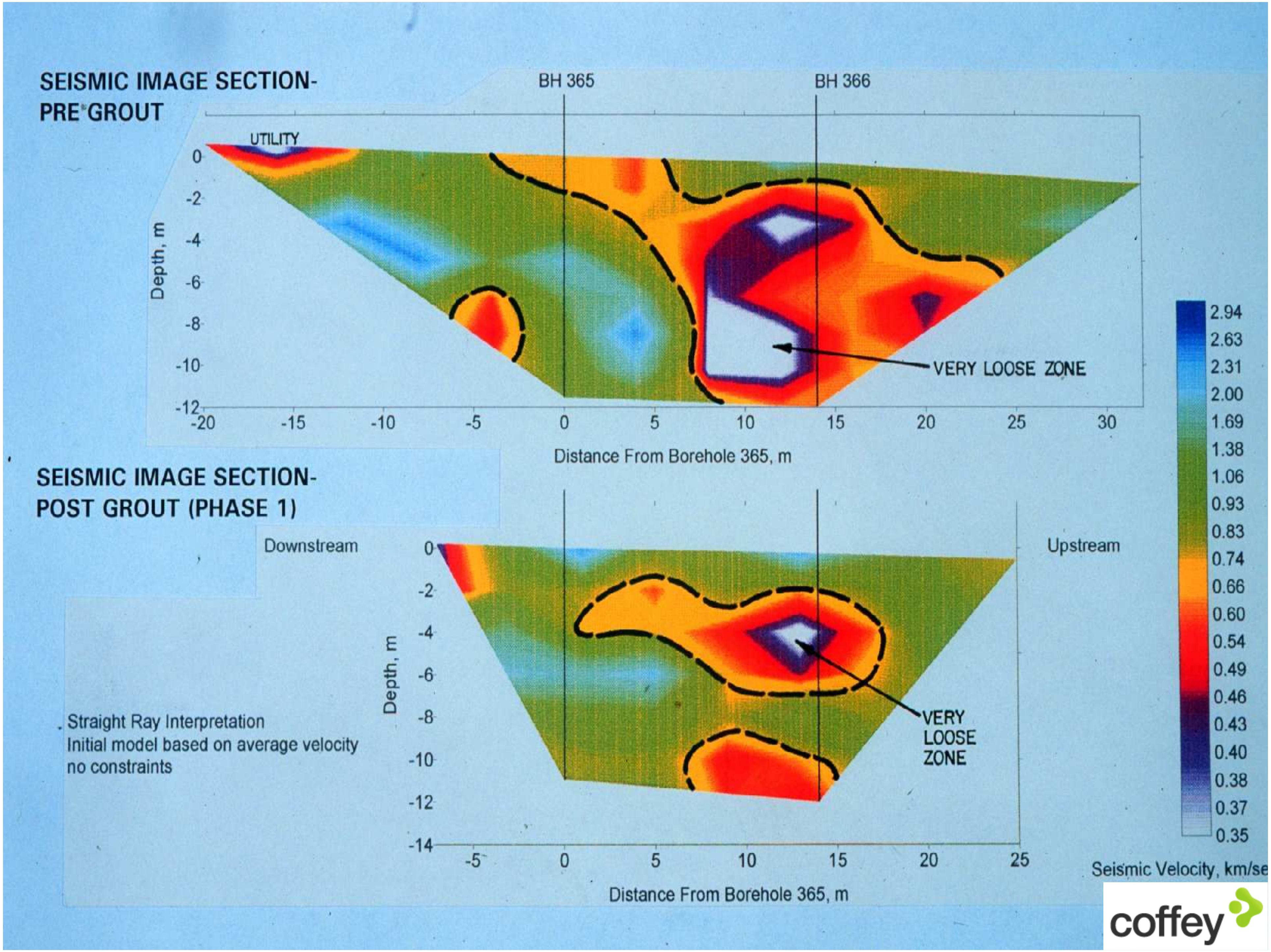
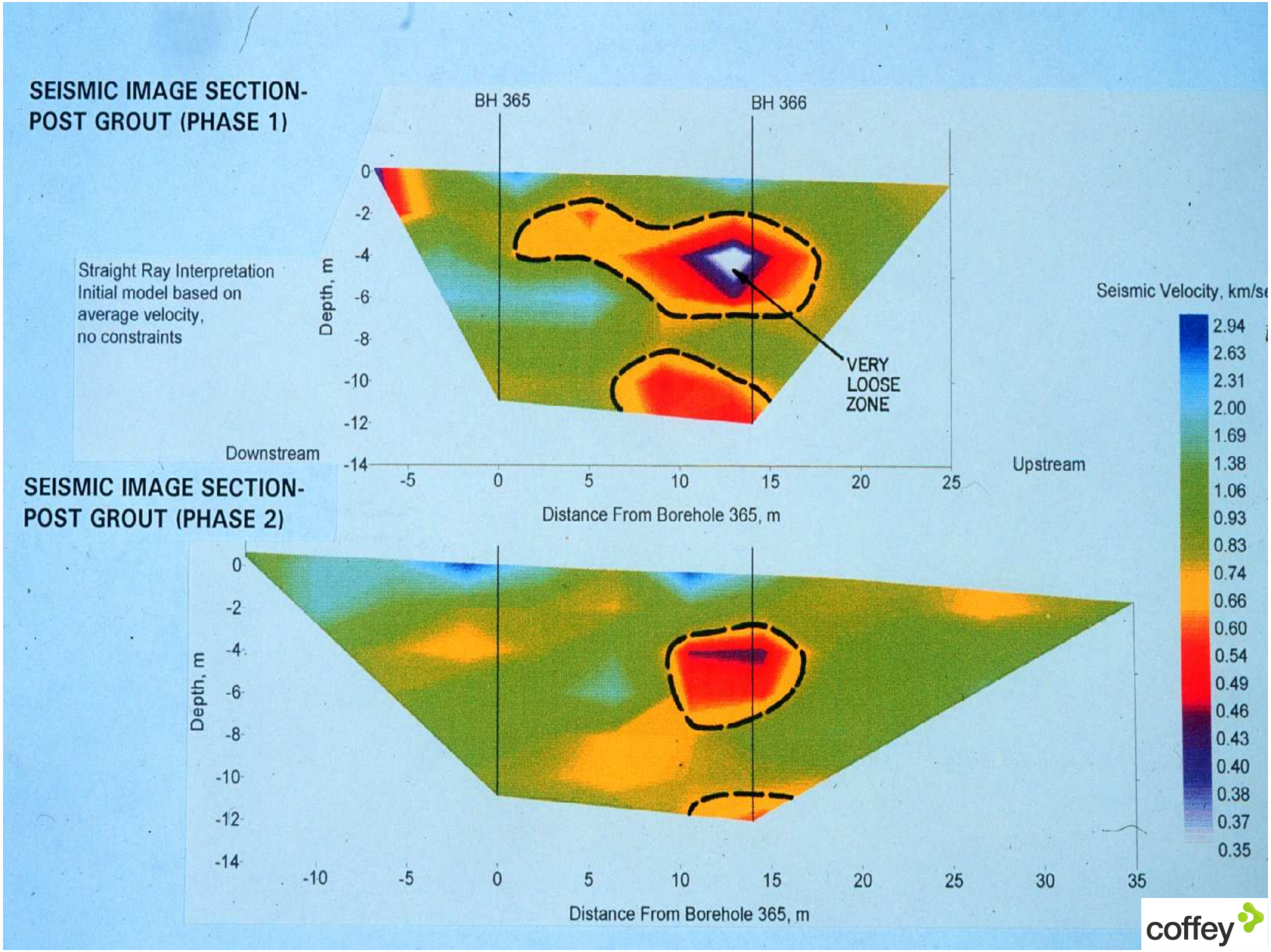


SEISMIC IMAGE SECTION-
PRE GROUT
BH 365
BH 366
UTILITY
Depth, m
0
-2
-4
-6
-8
-10
-12
-20
-15
-10
-5
0
5
10
15
20
25
30
VERY LOOSE ZONE
Distance From Borehole 365, m
SEISMIC IMAGE SECTION-
POST GROUT (PHASE 1)
Downstream
Upstream
Depth, m
0
-2
-4
-6
-8
-10
-12
-14
-5
0
5
10
15
20
25
VERY
LOOSE
ZONE
Straight Ray Interpretation
Initial model based on average velocity
no constraints
Distance From Borehole 365, m
2.94
2.63
2.31
2.00
1.69
1.38
1.06
0.93
0.83
0.74
0.66
0.60
0.54
0.49
0.46
0.43
0.40
0.38
0.37
0.35
Seismic Velocity, km/se


SEISMIC IMAGE SECTION-
POST GROUT (PHASE 1)
BH 365
BH 366
Straight Ray Interpretation
Initial model based on
average velocity,
no constraints
Depth, m
0
-2
-4
-6
-8
-10
-12
-14
VERY
LOOSE
ZONE
Downstream
Upstream
-5
0
5
10
15
20
25
Distance From Borehole 365, m
SEISMIC IMAGE SECTION-
POST GROUT (PHASE 2)
Depth, m
-10
-5
0
5
10
15
20
25
30
35
Distance From Borehole 365, m
Seismic Velocity, km/se
2.94
2.63
2.31
2.00
1.69
1.38
1.06
0.93
0.83
0.74
0.66
0.60
0.54
0.49
0.46
0.43
0.40
0.38
0.37
0.35
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# Embankment Collapse over Conduit

# MASW & GPR Testing of Highways


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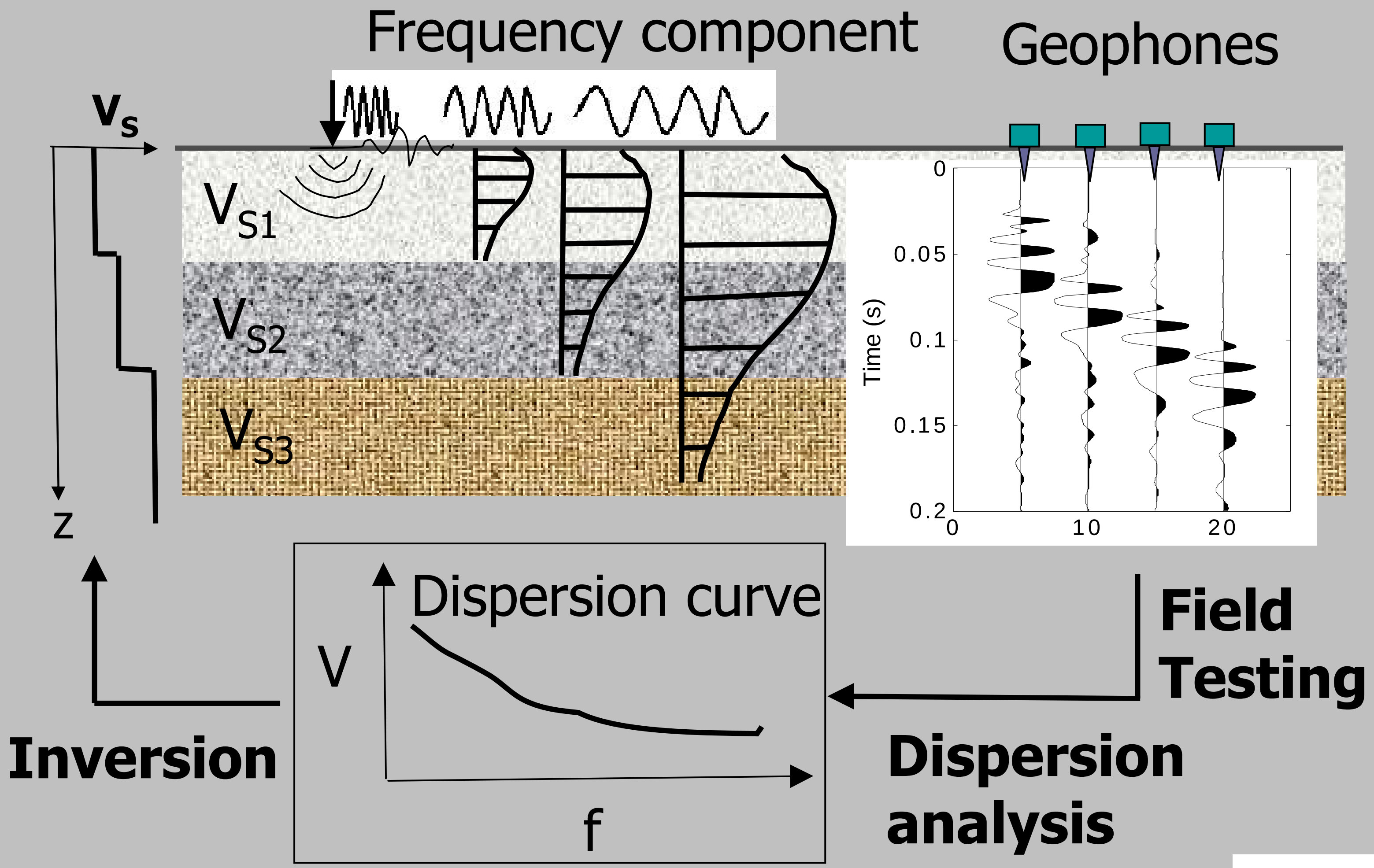
# Basic Principle of Surface Wave Method

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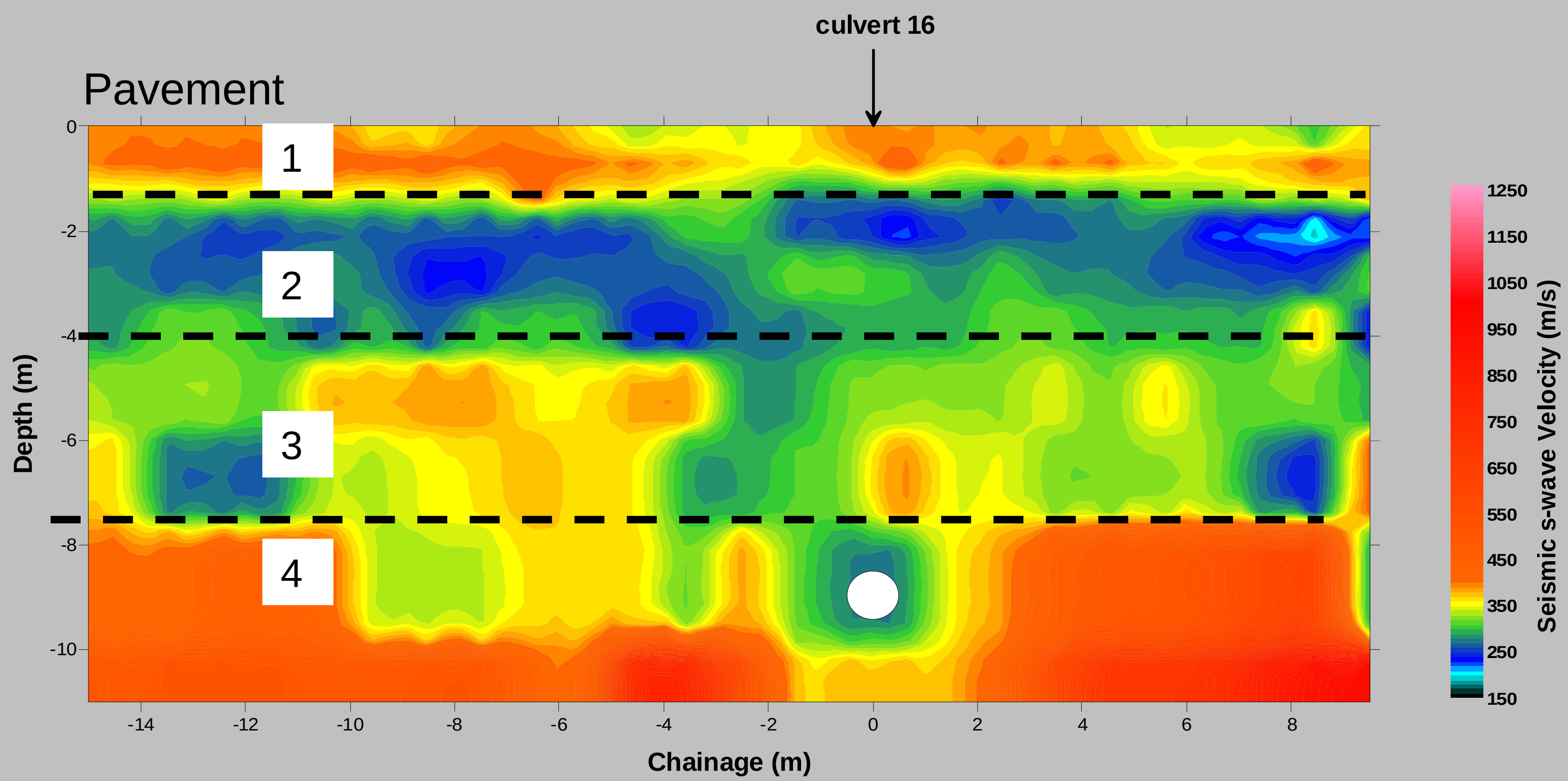
# Shear Wave Velocity Section - Northbound-Slow Shoulder




Approx. depth of material property change

1 Layer No.

# S-wave velocity interpretation

| Layer | Approx. Depth | Descripton | 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 (?) |

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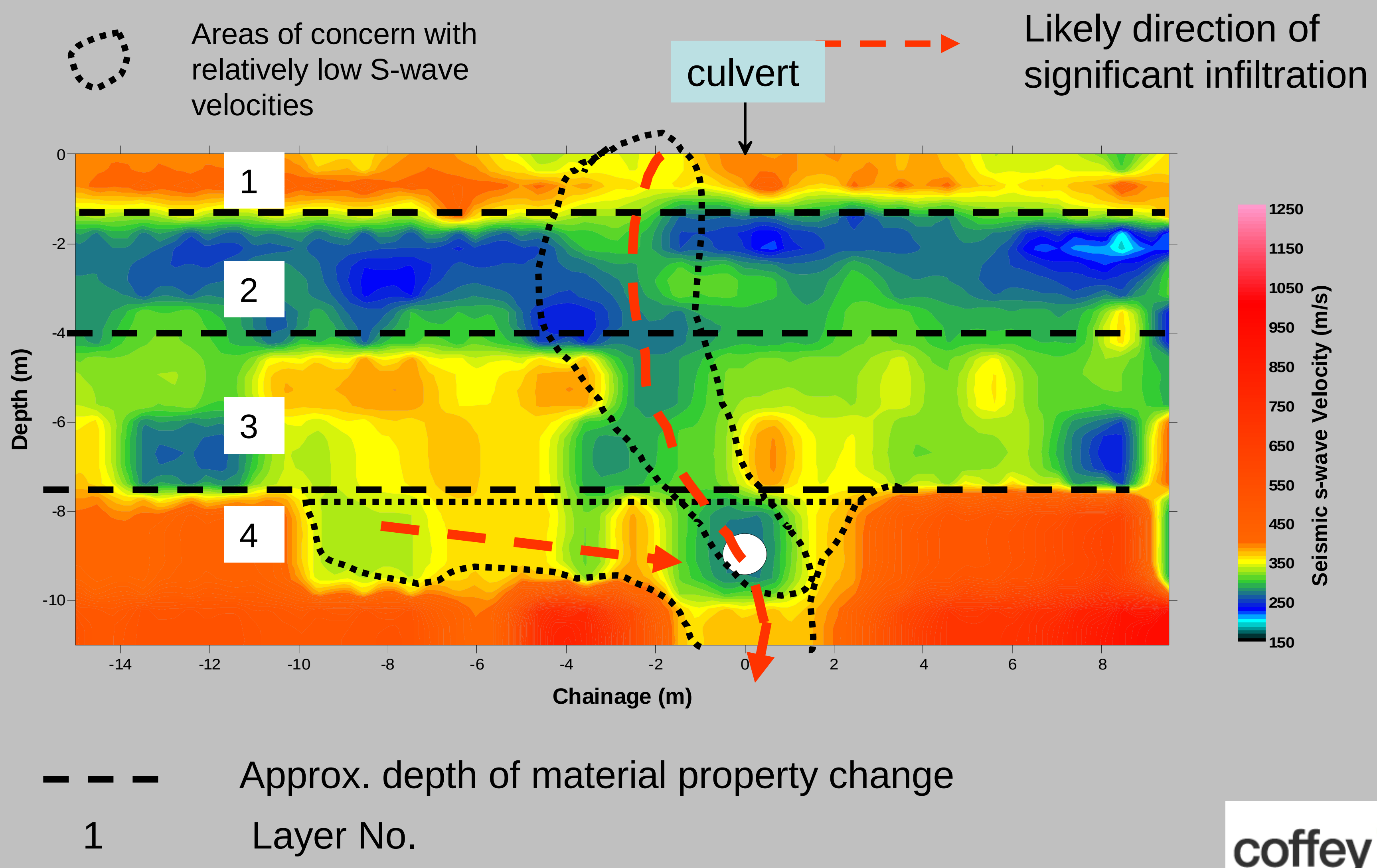
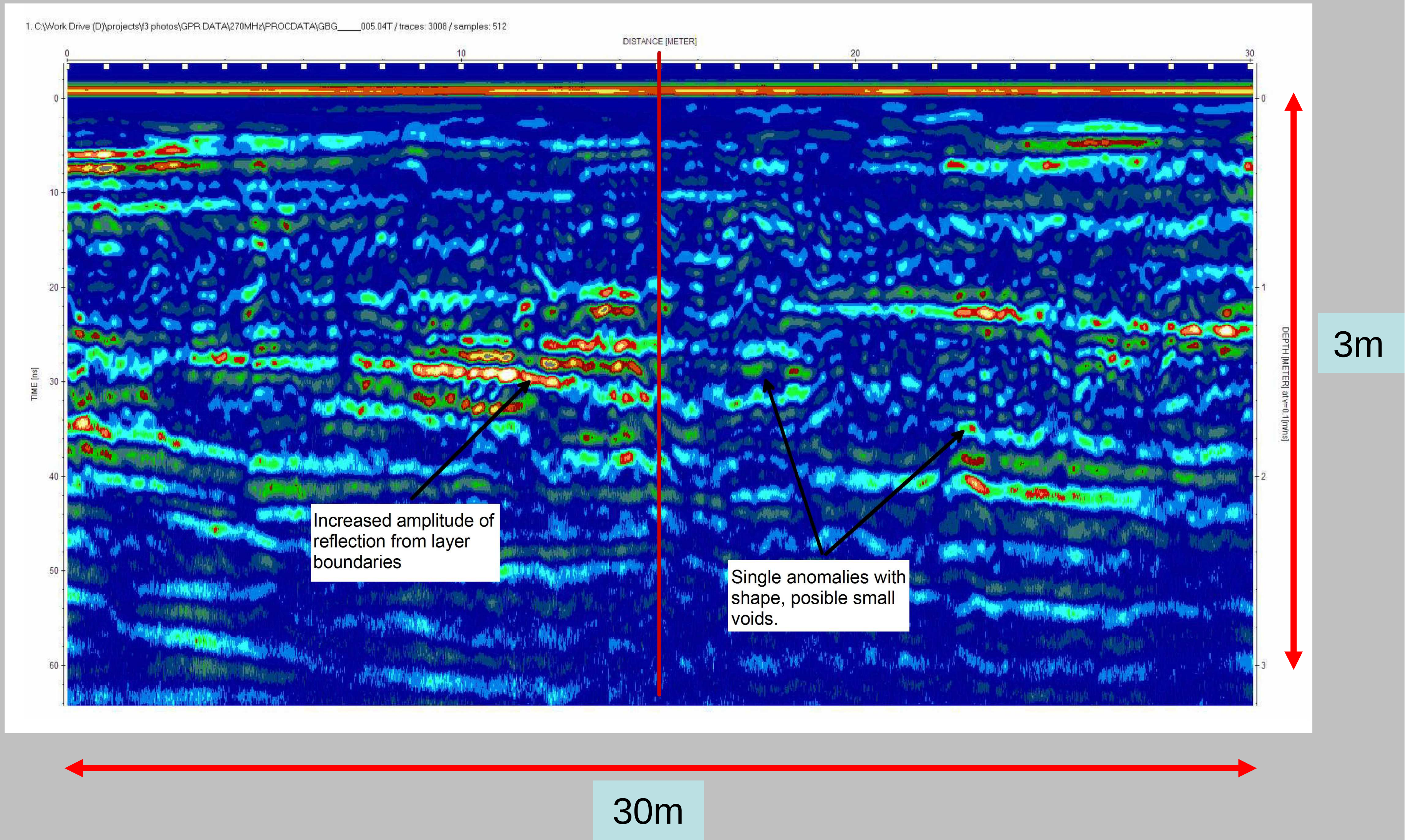
# Shear Wave Velocity Section
# Northbound Slow Shoulder



# GPR Section – 250MHz antenna

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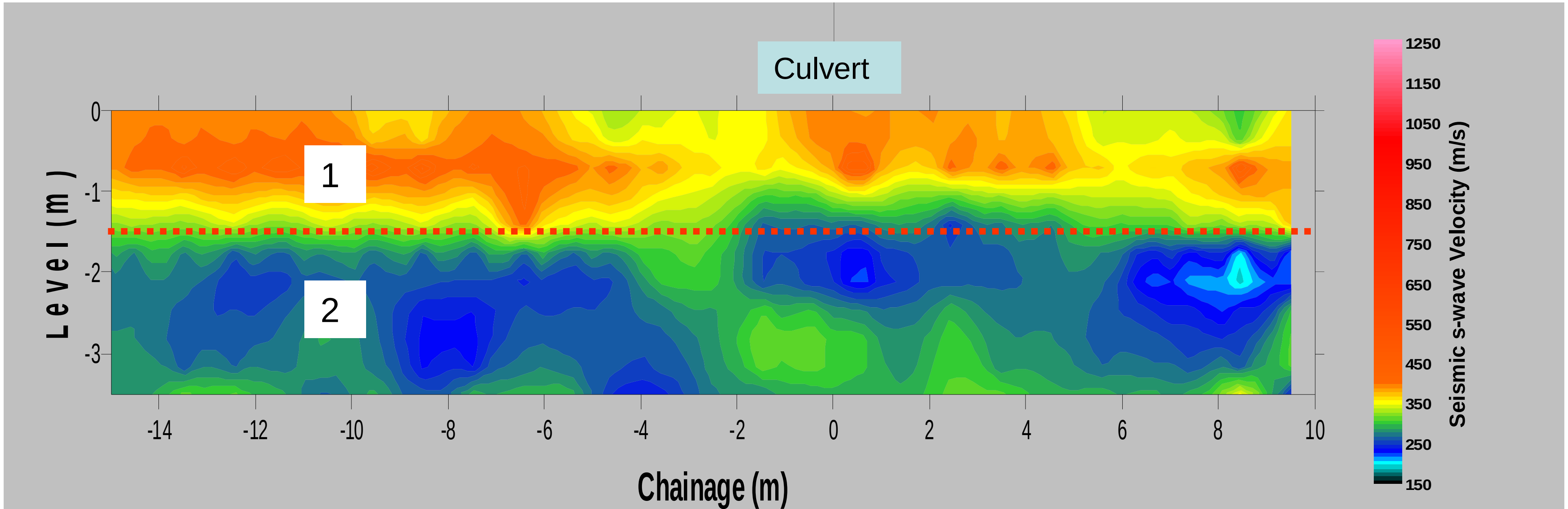
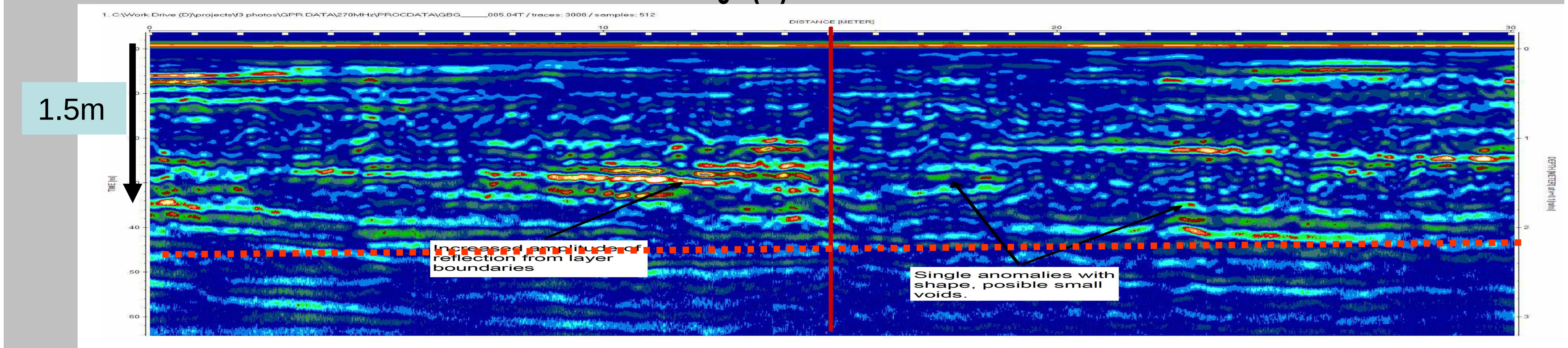
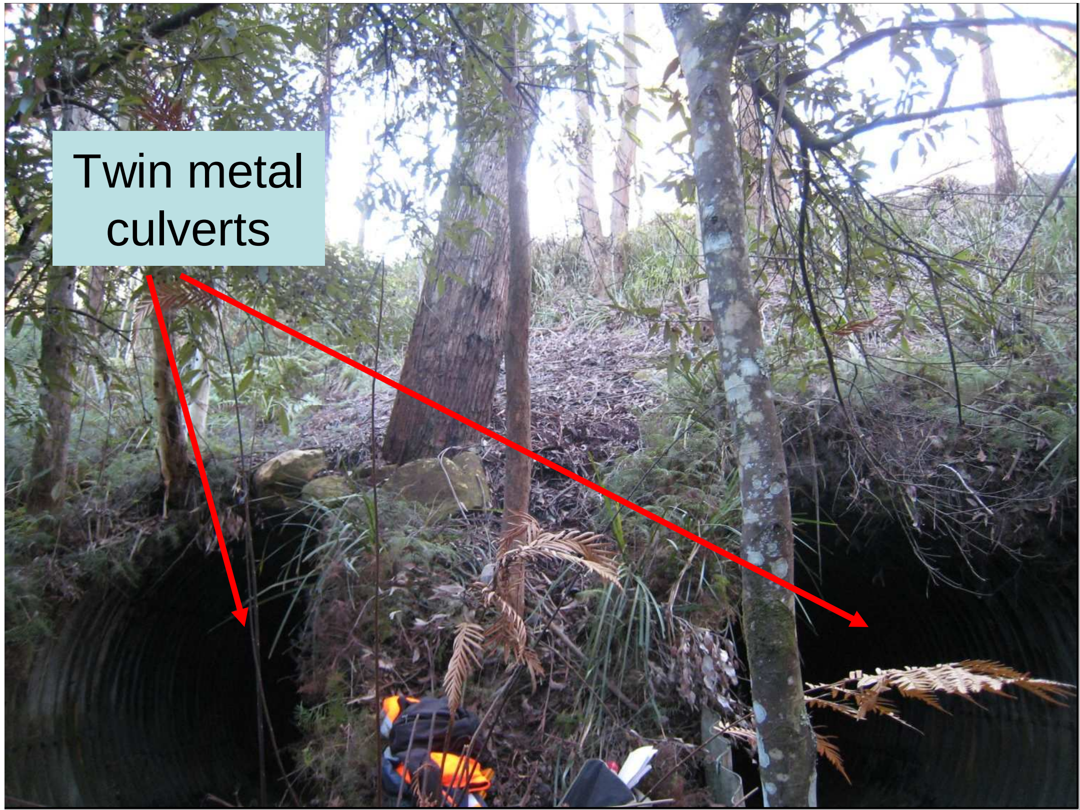



| Layer | Approx. Depth | Descripton | S-wave velocity range (m/s) | Interpretation |
|---|---|---|---|---|
| 1 | 0 - 1.5 | Pavement construction layers | 430 - 500 | generally good condition |
| | | | 350 - 420 | Minor loss of dynamic stiffness |
| | | | 300 - 350 | Loss of dynamic stiffness |
| 2 |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




# P-wave seismic imaging of embankments

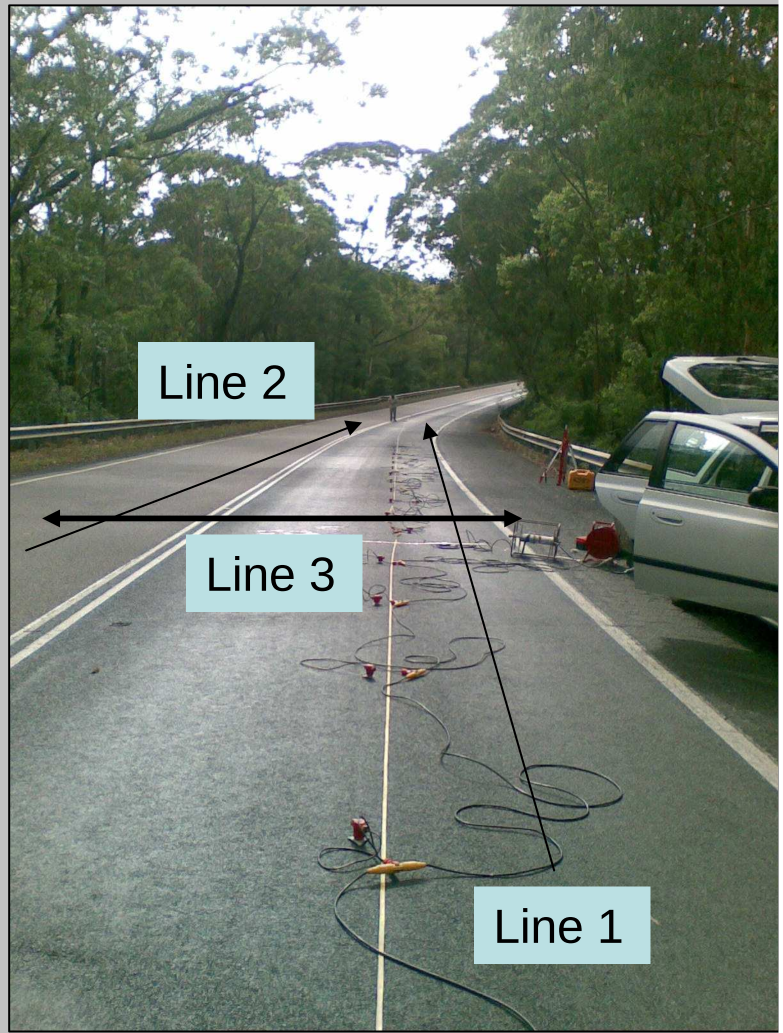



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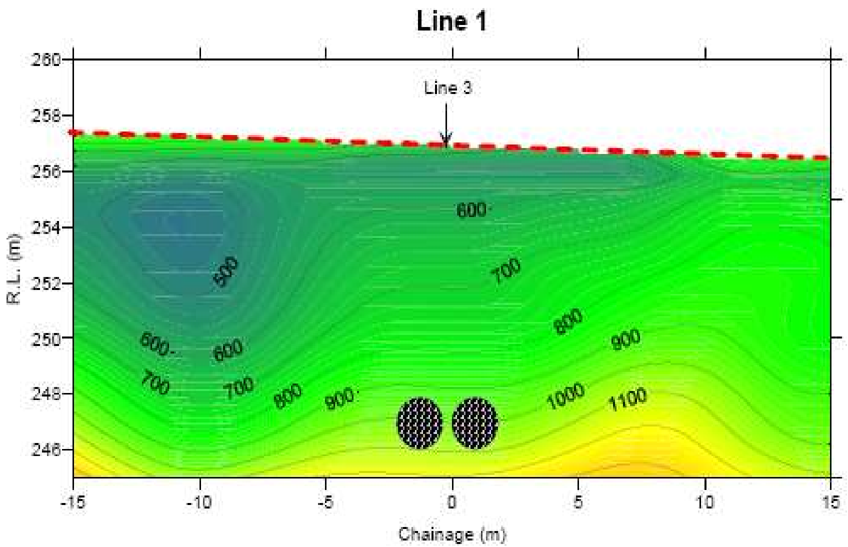
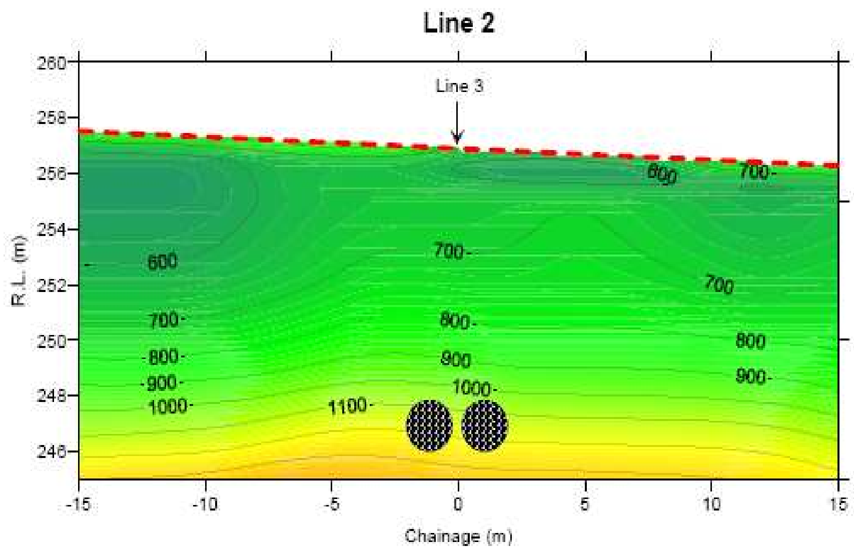
Table 1: P-wave seismic velocity and inferred geotechnical conditions

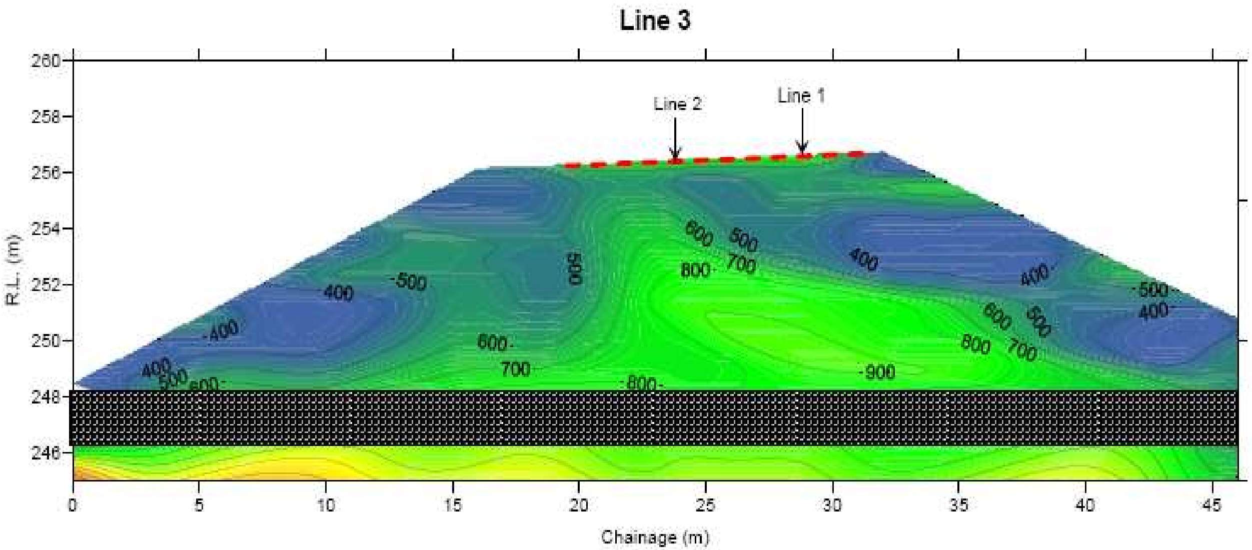
| P-wave seismic velocity (m/s)* | Inferred SPT N-value | Geotechnical classification | |
|---|---|---|---|
| < 350 | 0 to 4 | Very loose | Blue |
| 350 to 500 | 4 to 10 | Loose | Blue |
| 500 to 750 | 10 to 30 | Medium dense to dense | Green |
| 750 to 1700 | 30 to 50 | Dense to very dense | Yellow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

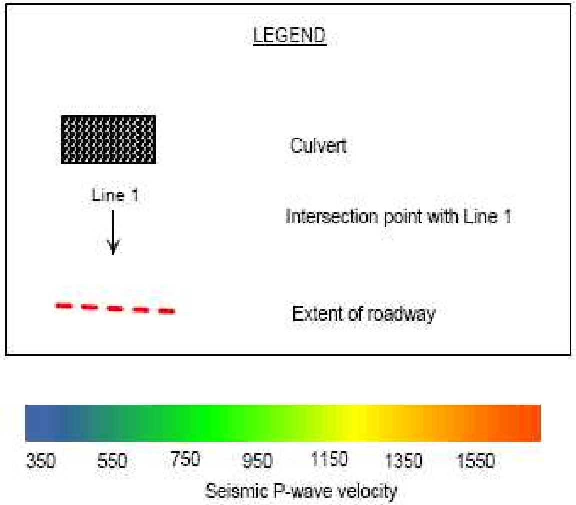
* Dry or partially saturated granular soils and fills

# P-wave seismic image Sections



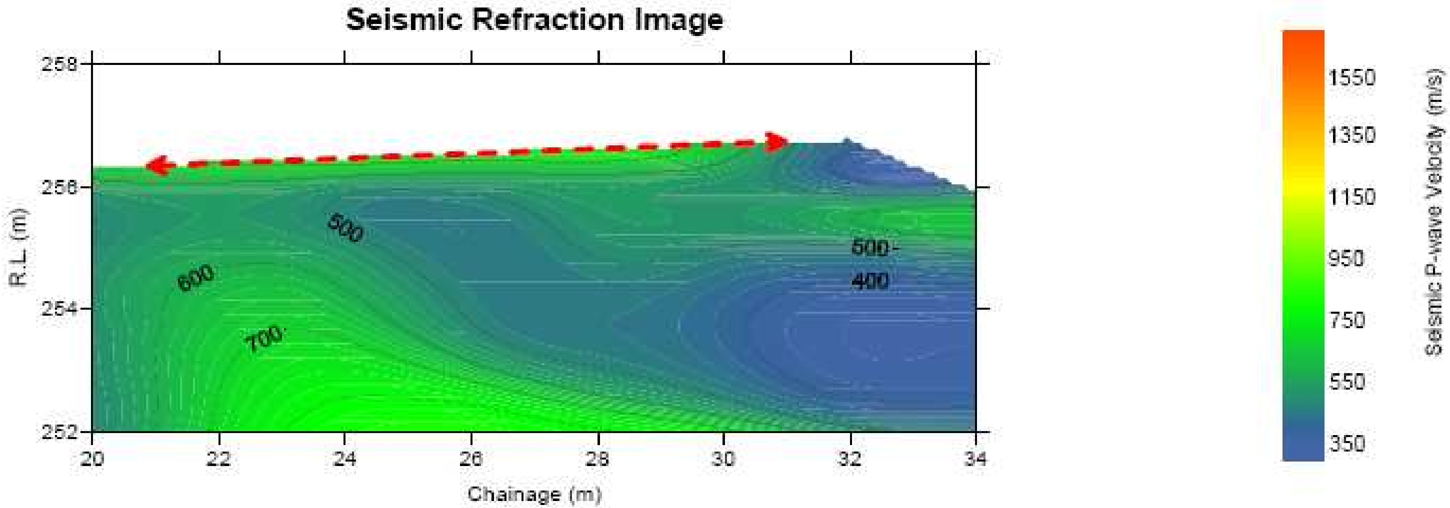



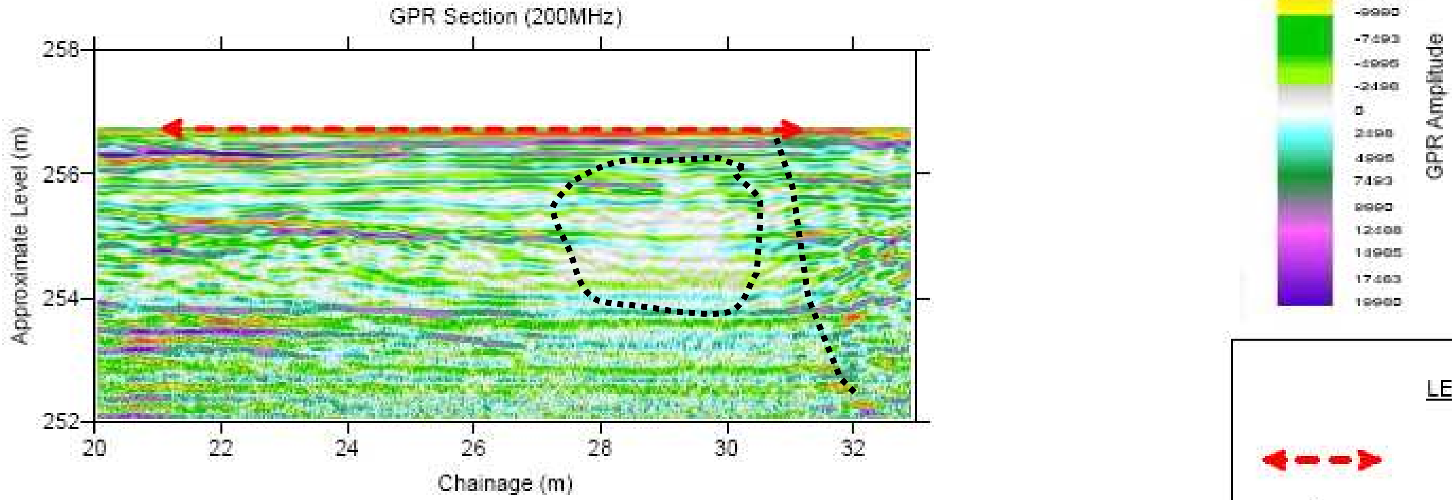



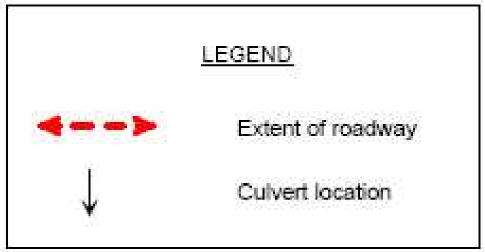



# Line 3

## Comparison of GPR & Seismic Images

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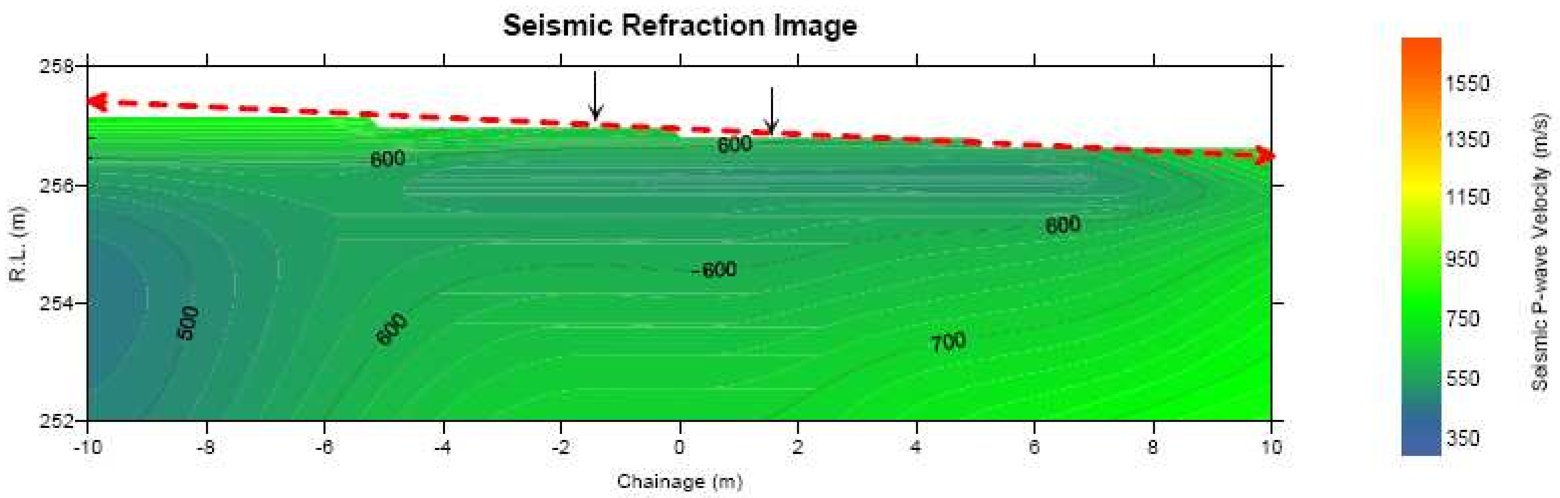
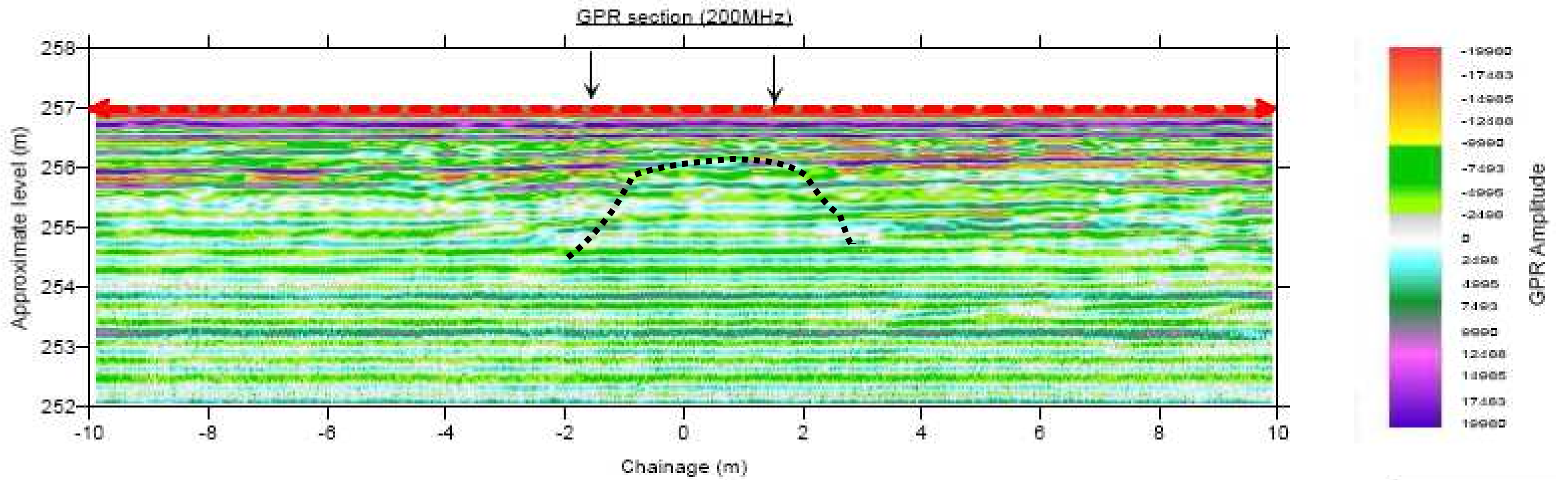
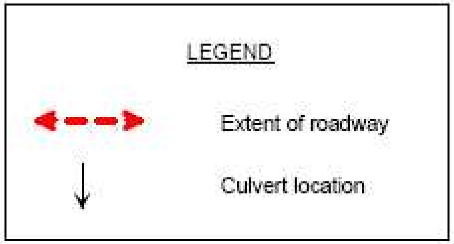
## Line 1



Seismic Refraction Image
R.L. (m)
Chainage (m)
600
600
600
600
600
500
700
Seismic P-wave Velocity (m/s)
1550
1350
1150
950
750
550
350

GPR section (200MHz)
Approximate level (m)
Chainage (m)
GPR Amplitude

LEGEND
Extent of roadway
Culvert location

# Surface Evidence


**Distressed Buried Sewers**

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# 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

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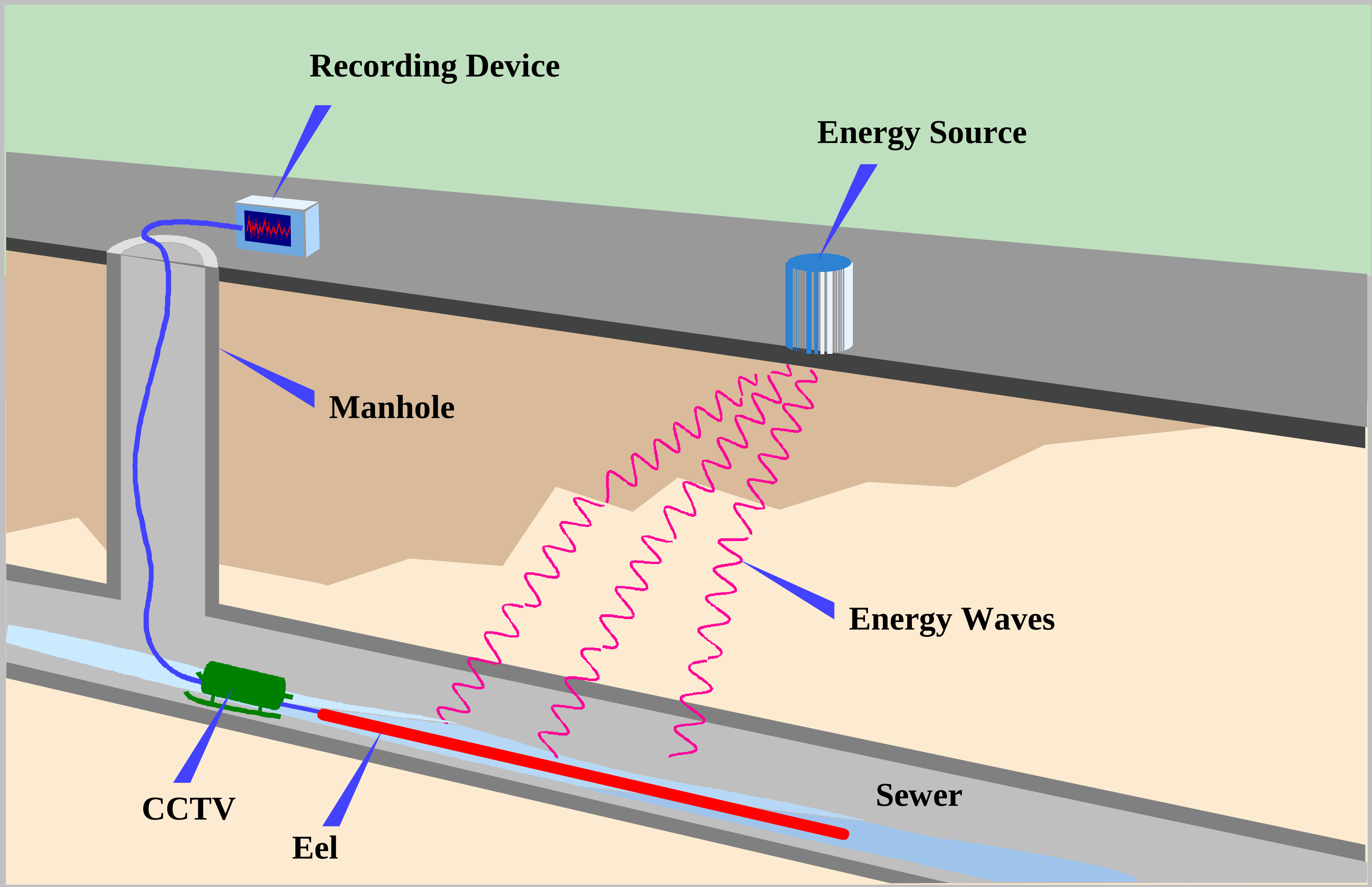
# SEWREEL

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# SEWREEL FIELD OPERATIONS - ORLANDO SITE

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# Energy Device:
# The Hiss Hammer



**Seismograph Trigger**

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# Moving the Hiss Hammer Source

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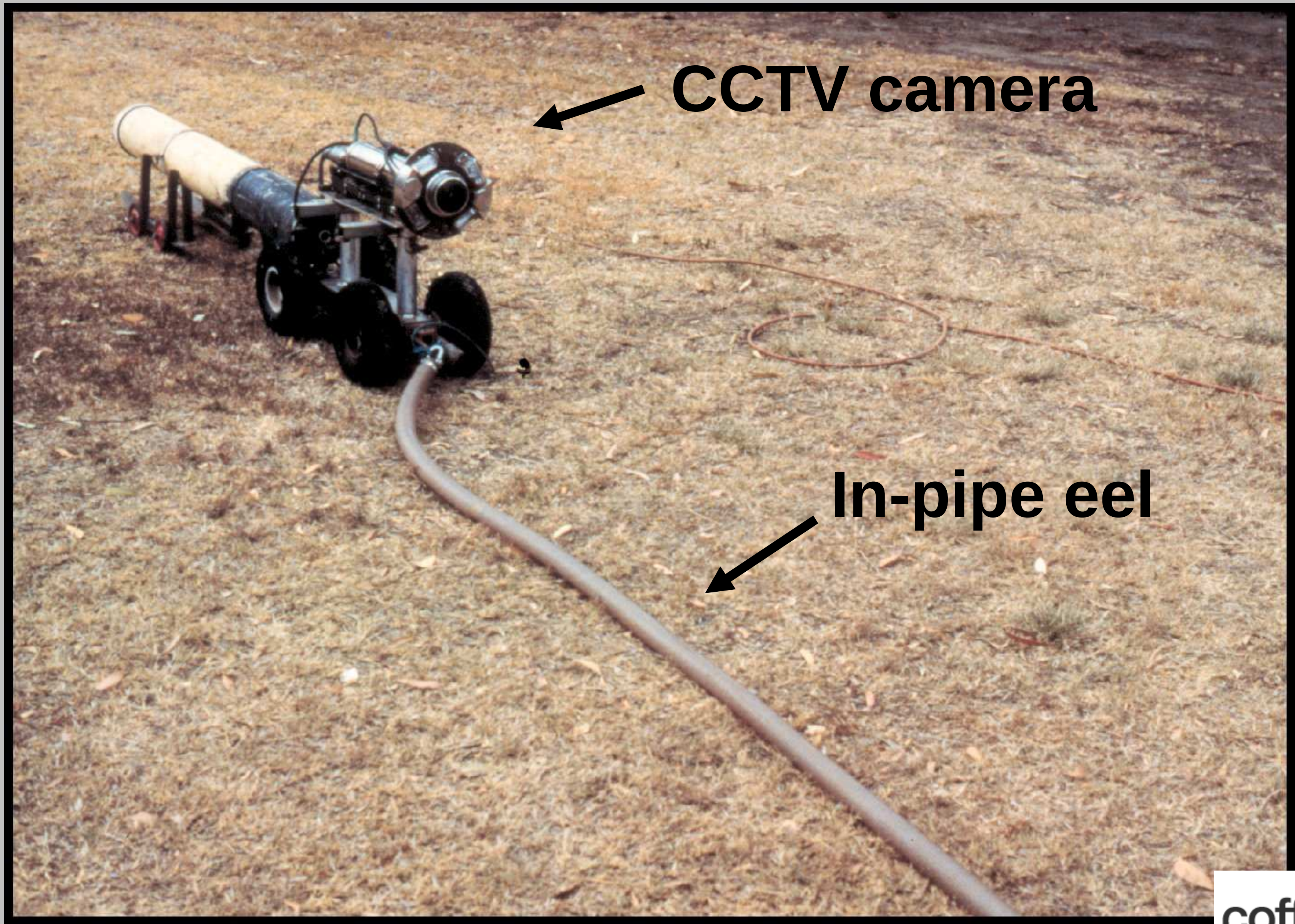
# Detecting Device: The eel

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# 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

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# SEWREEL TESTING
# for
# VOIDS & GROUT AFFECTED GROUND

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

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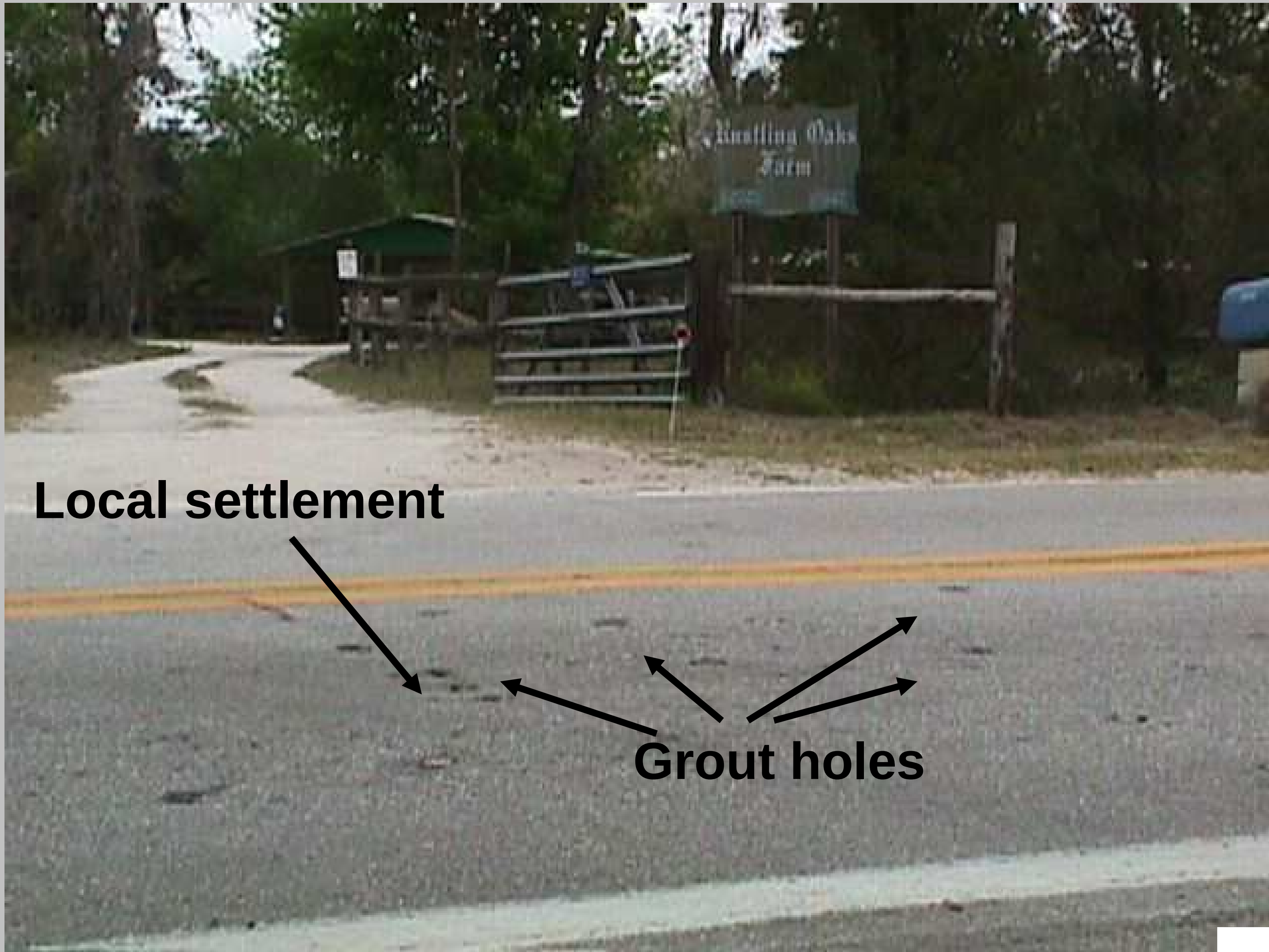
# Orlando -Site Conditions

# Extensive Grouting at MH 9 + 170

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

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| SPT N-value | Geotechnical Classification | P-Wave Seismic Velocity m/s & (ft/s) |
| --- | --- | --- |
| **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)** |

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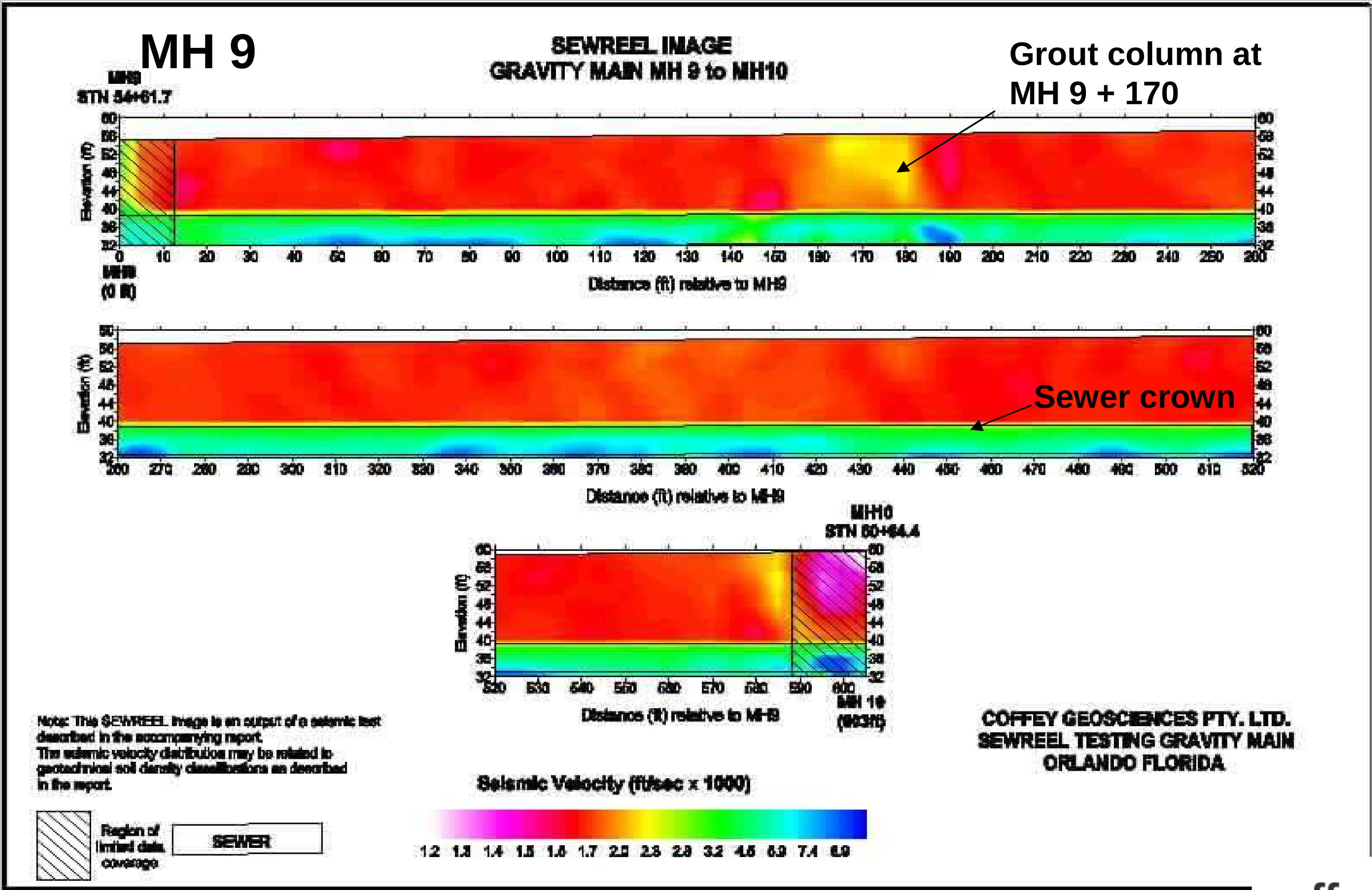
# SEWREEL Images of Grout Affected Soils

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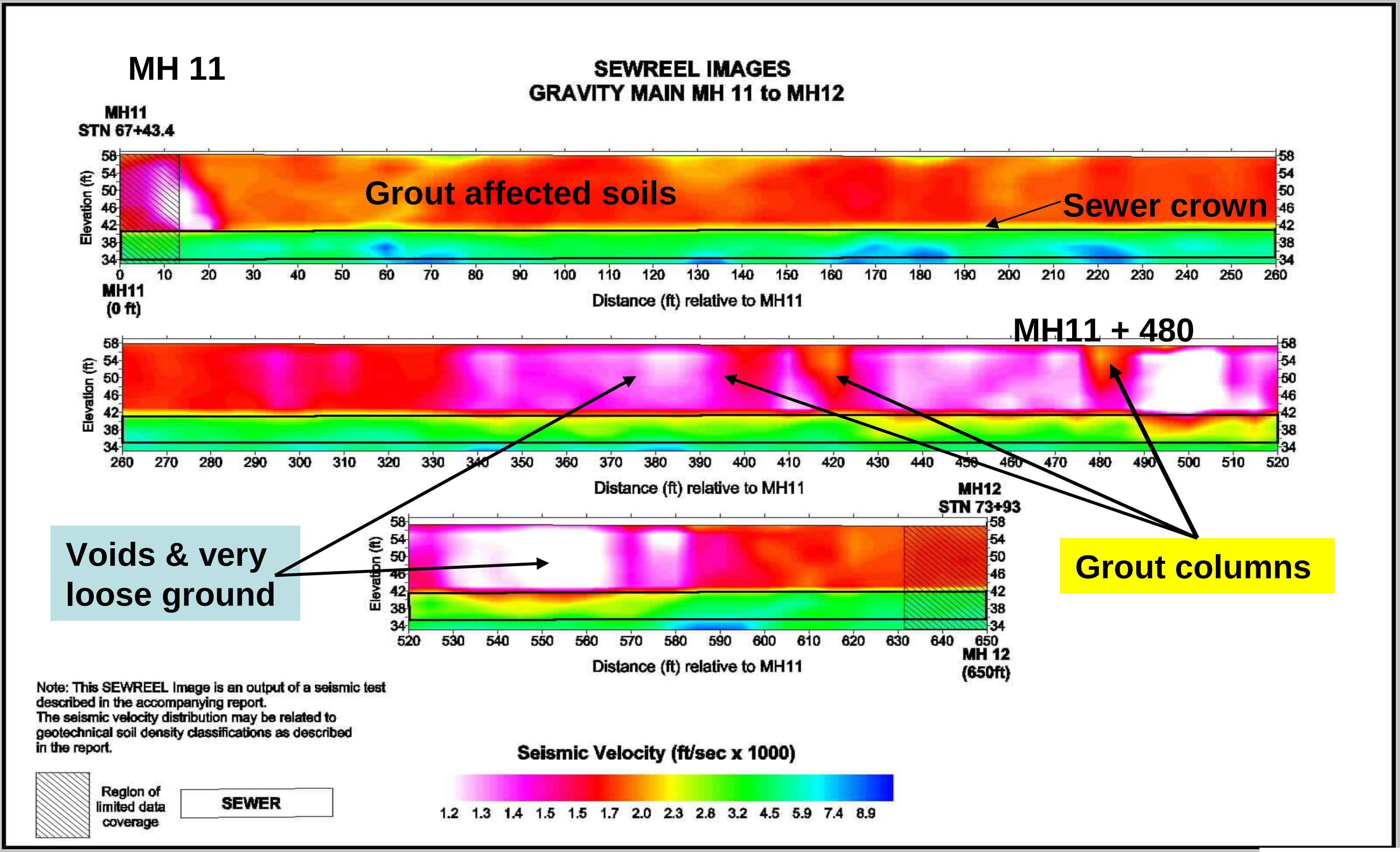
# Post-Grout Settlement: MH 11 + 480 ft.

# SEWREEL Images of Voided Soils

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