


# **Part 2**

# **Verifications**



## **Real World Examples**

**Comparing Shear-Wave Velocity Profiles  
from MASW with Borehole Measurements  
in Lawrence, Kansas**



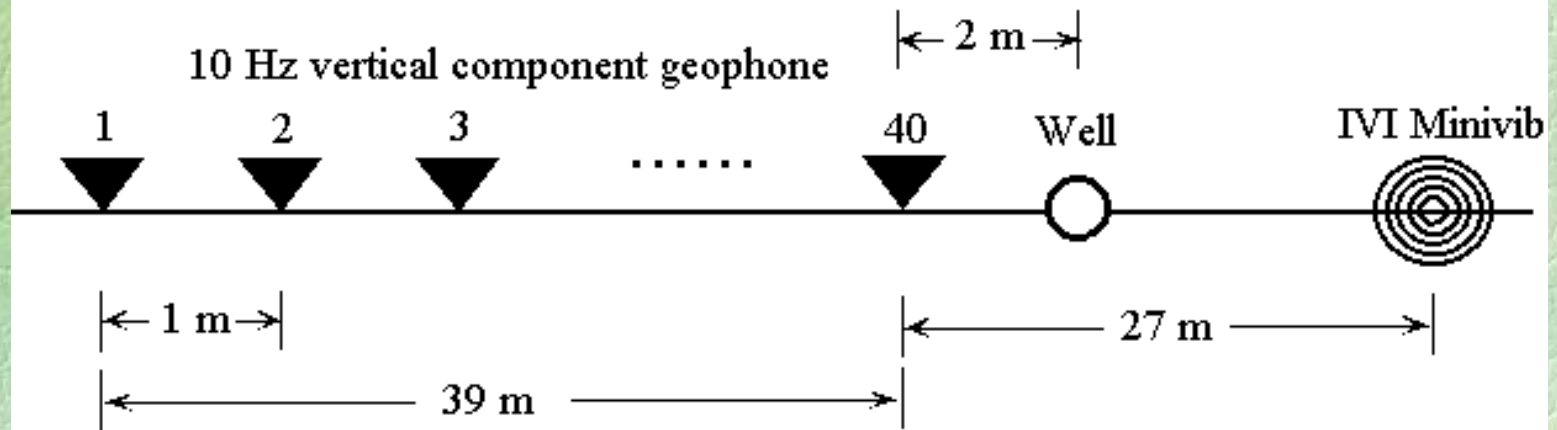
**One Detailed Real-World Example**

# Testing Site—KGS Front Yard



# Field Layout

## MASW Surface Wave Survey Line



Sweep: 10 to 200 Hz, lasting 10 seconds

# Raw Data

**Seismograph:**

*Geometrics StrataView*

**Seismic Source:**

*IVI Minivib*

**Geophone:**

*10 Hz vertical component*

**Acquisition filter:**

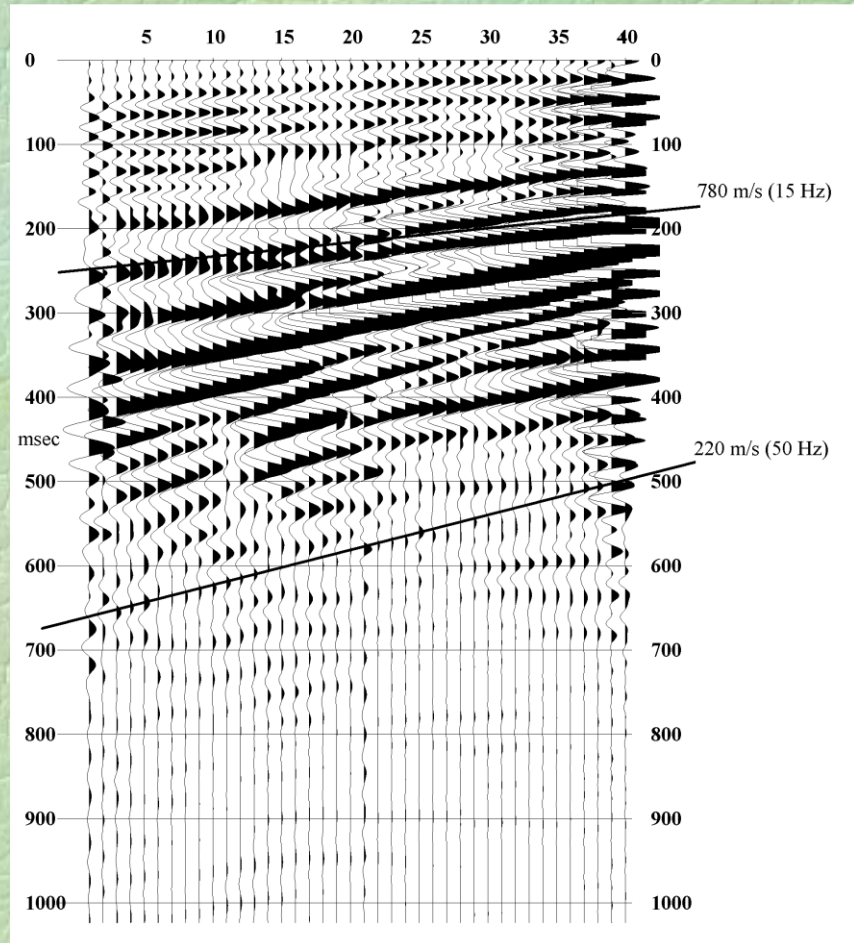
*No*

**Recording length:**

*1024 milliseconds*

**Sample interval:**

*1 millisecond*



# Layered Model for Inversion

- A ten-layer model with a one meter thick top layer gradually increasing to a 6 meter layer on the bottom.

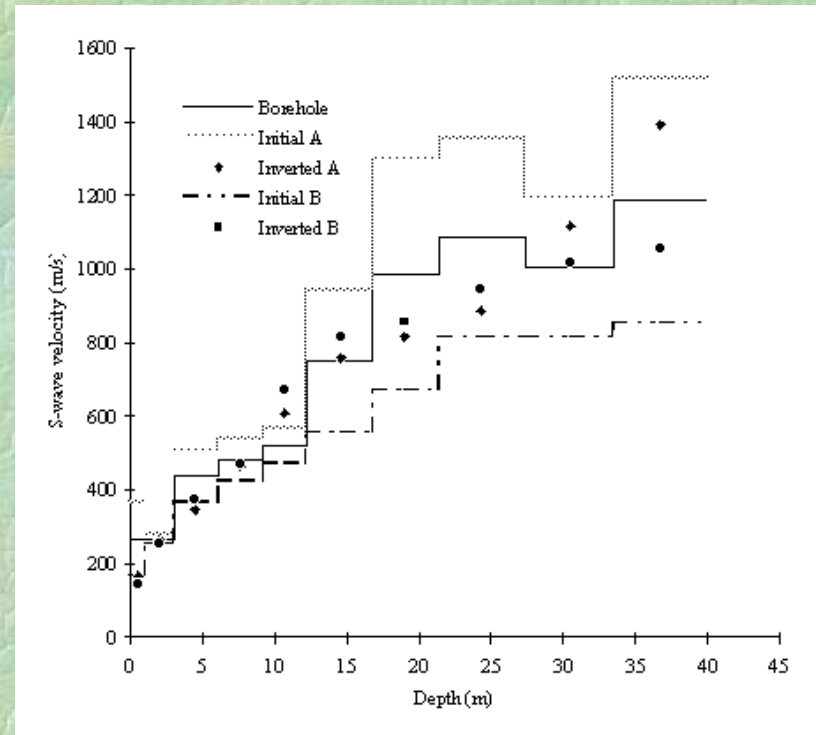
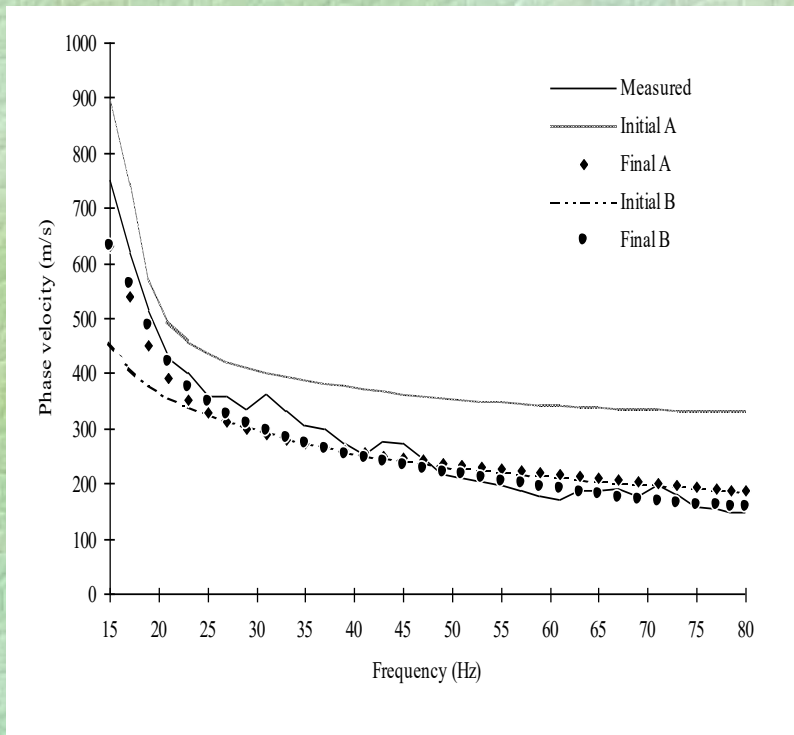
**A Layered Earth Model**

	S (m/s)	P (m/s)	d (g/cm <sup>3</sup> )
0	168	534	1.82
	254	536	1.86
6	367	791	1.91
	425	1212	1.96
12	472	1460	2.02
	558	2400	2.09
18	673	2306	2.17
	813	2226	2.26
24	813	2531	2.35
30	852	2410	2.40

Meters

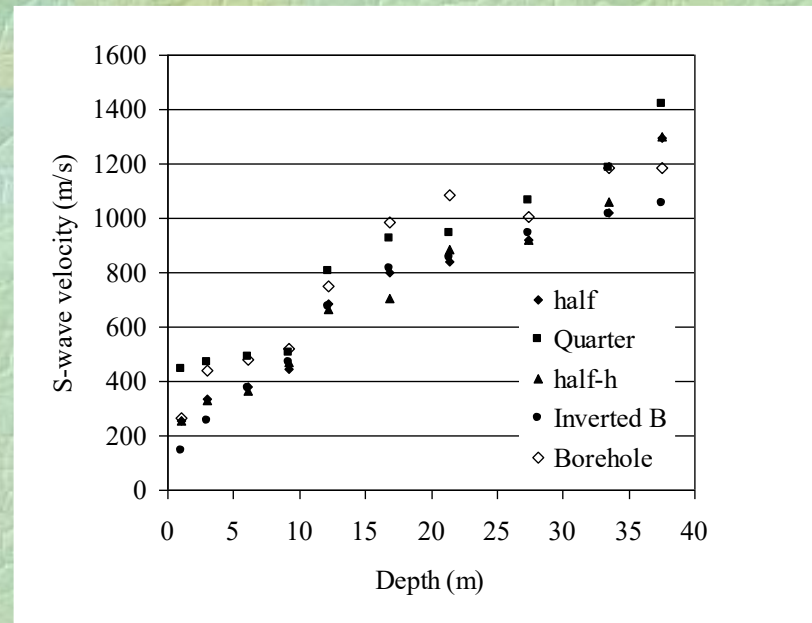
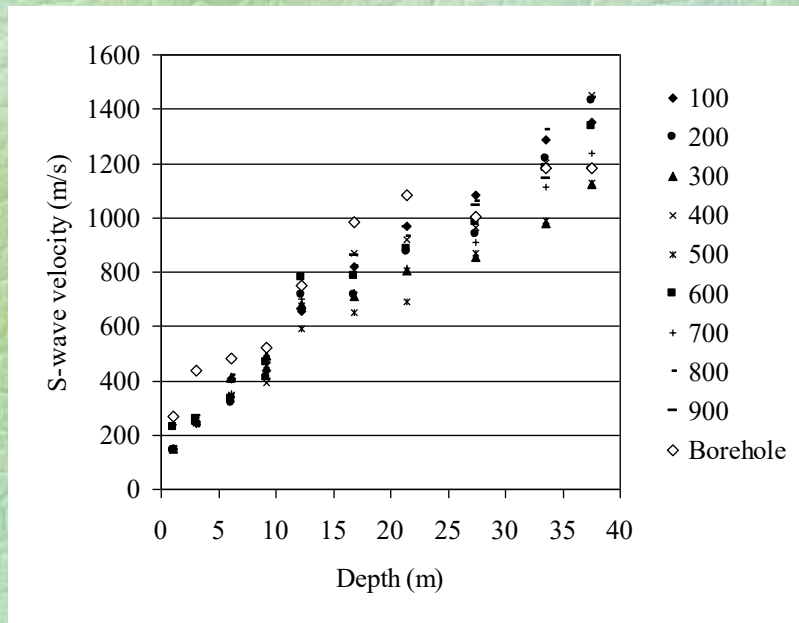
# Dispersion Curves

# S-wave Velocity Models



**Three-component borehole data were acquired. Overall error in S-wave velocity of the borehole survey is 10%.**

# Effects of Initial Models



**Initial models are blindly selected as a uniform half-space with a constant S-wave velocity from 100 m/s to 1,800 m/s.**

# Effect of the Number of Data Points

Half (*solid diamonds*):

33 points from 15 to 47 Hz;

Quarter (*solid squares*):

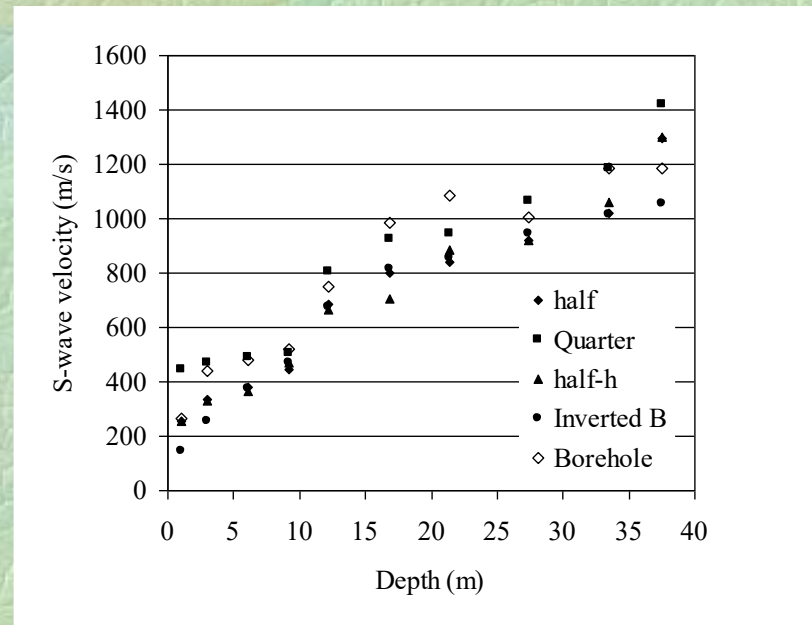
17 points from 15 to 31 Hz;

Half-h (*solid triangles*):

17 points from 15 to 47 Hz  
at 2 Hz interval, and

Inverted B (*Solid circles*):

66 points from 15 to 80 Hz.



# Summary

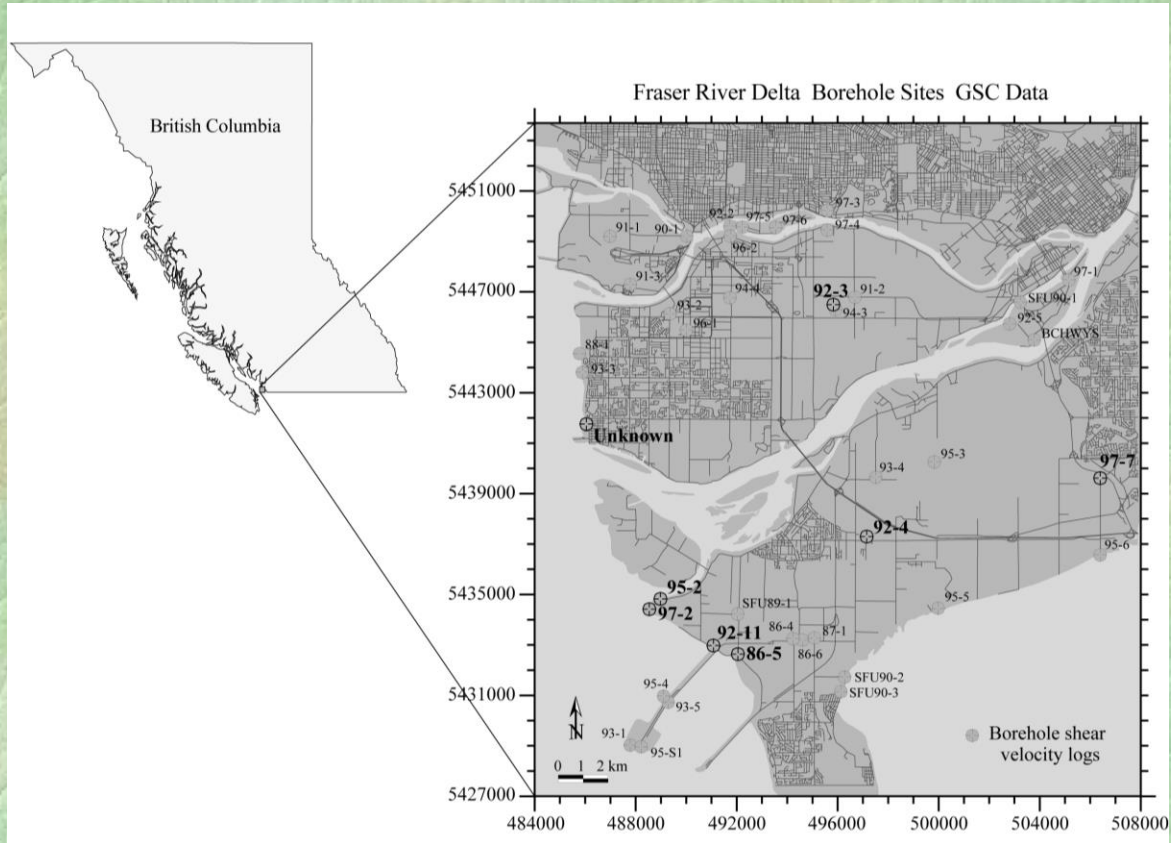
- The proposed inversion is stable. 1. Inverted models do not seem to be too sensitive to initial models; 2. The inversion is continuously improving inverted modes during inversion processing.
- Inverted S-wave velocities are reliable. A 15% difference can be expected between inverted S-wave velocities and borehole measurements.

**Comparing Shear-Wave Velocity Profiles  
from MASW with Borehole Measurements  
in the Fraser River Delta,  
Vancouver, Canada**



**Eight Real-World Examples**

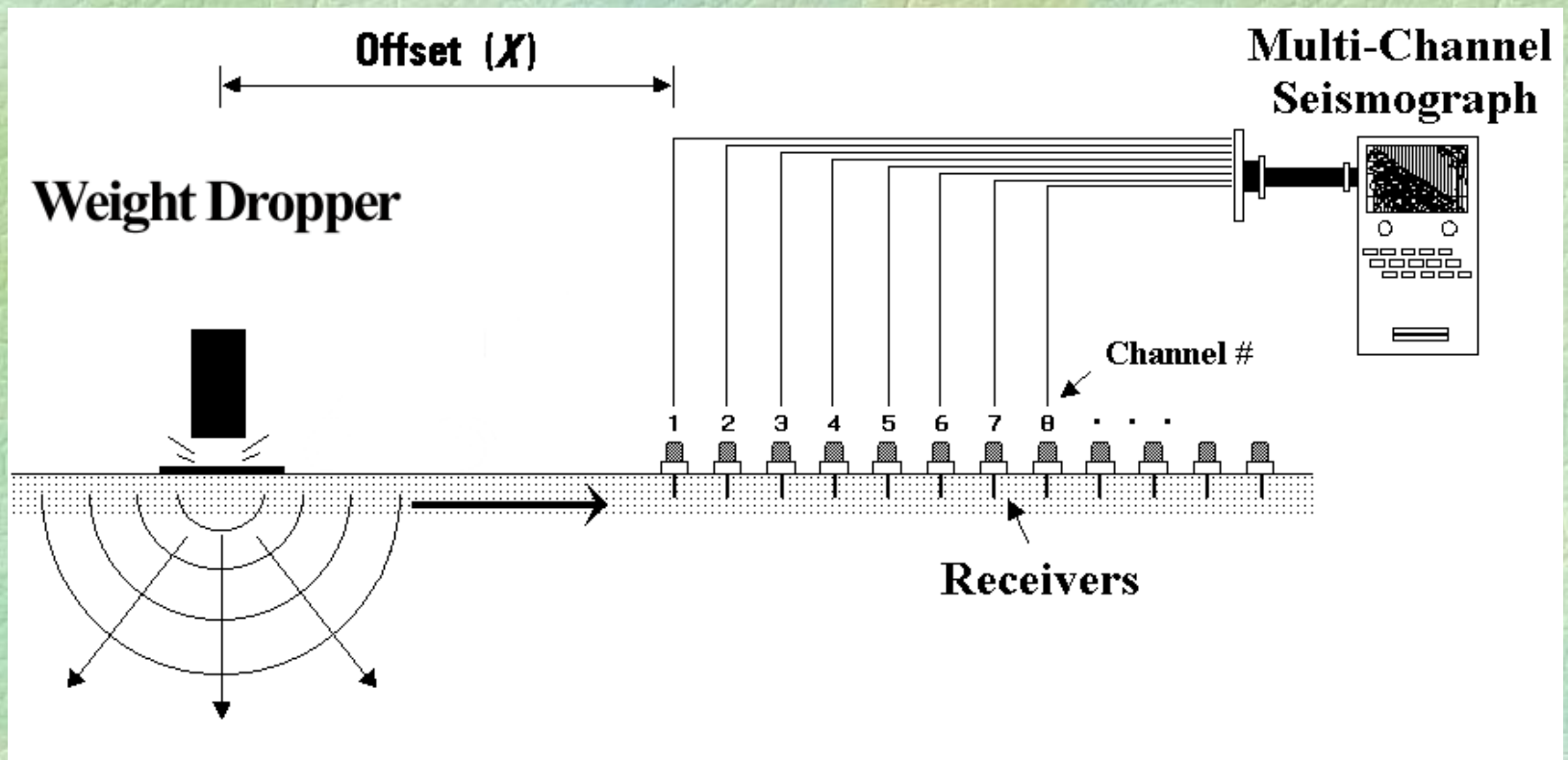
# Testing Site



# Common Parameters

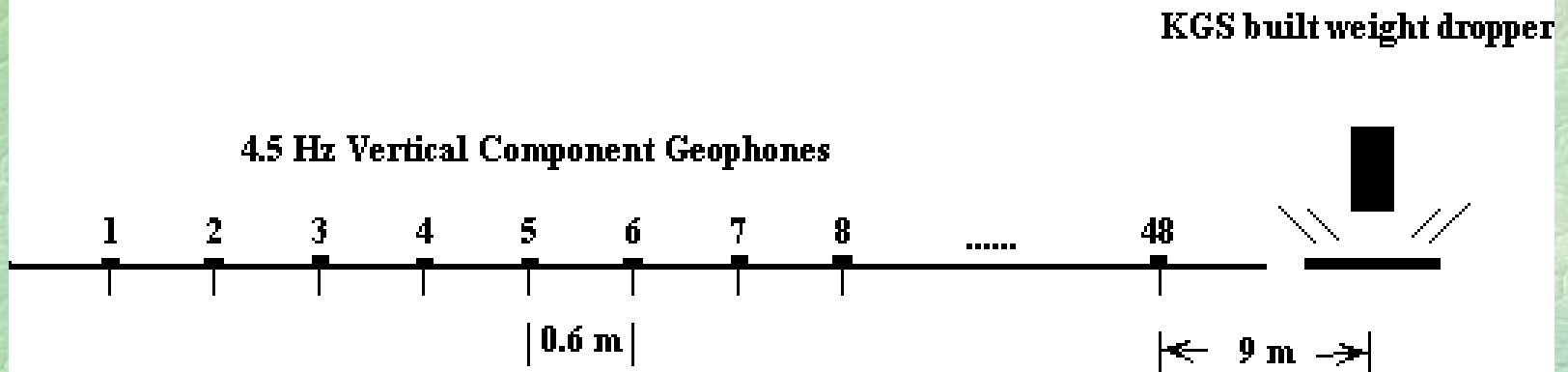
- **Seismograph:** *Geometrics StrataView*
- **Seismic Source:** *Weight dropper (built by KGS)*
- **Geophone:** *4.5 Hz vertical component*
- **Acquisition filter:** *No*
- **Recording length:** *2048 milliseconds*
- **Sample interval:** *1 millisecond*

# Field Layout

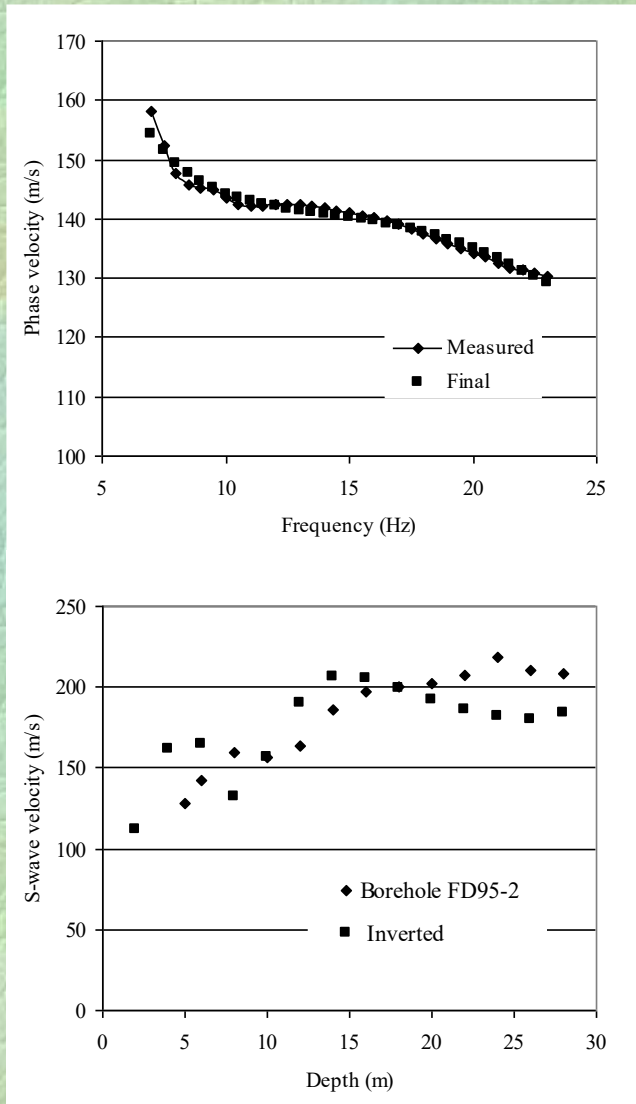
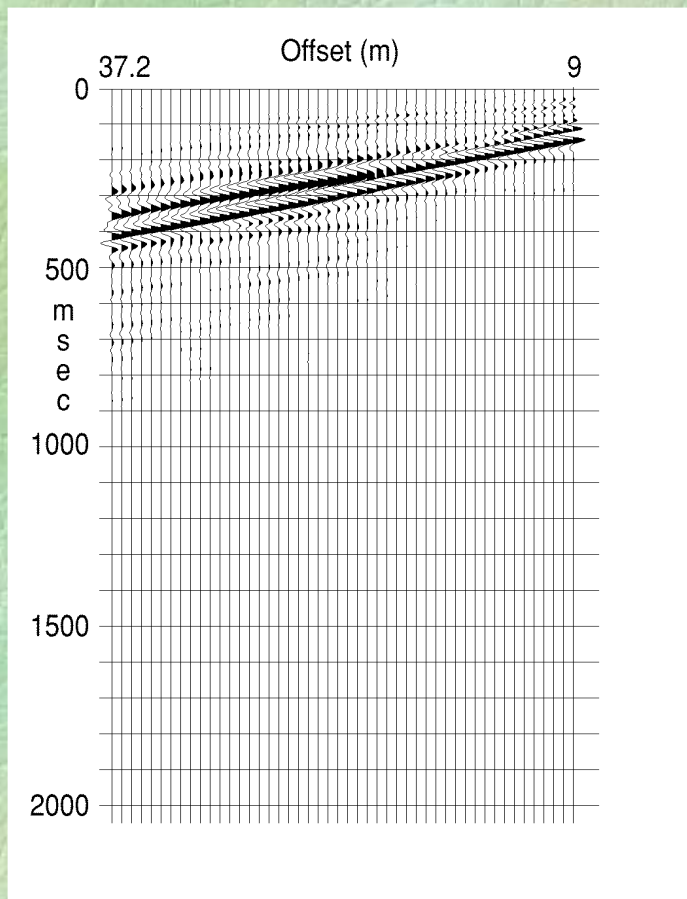


# Field Layout for Borehole FD95-2

## MASW Surface Wave Survey Line



# Borehole FD95-2

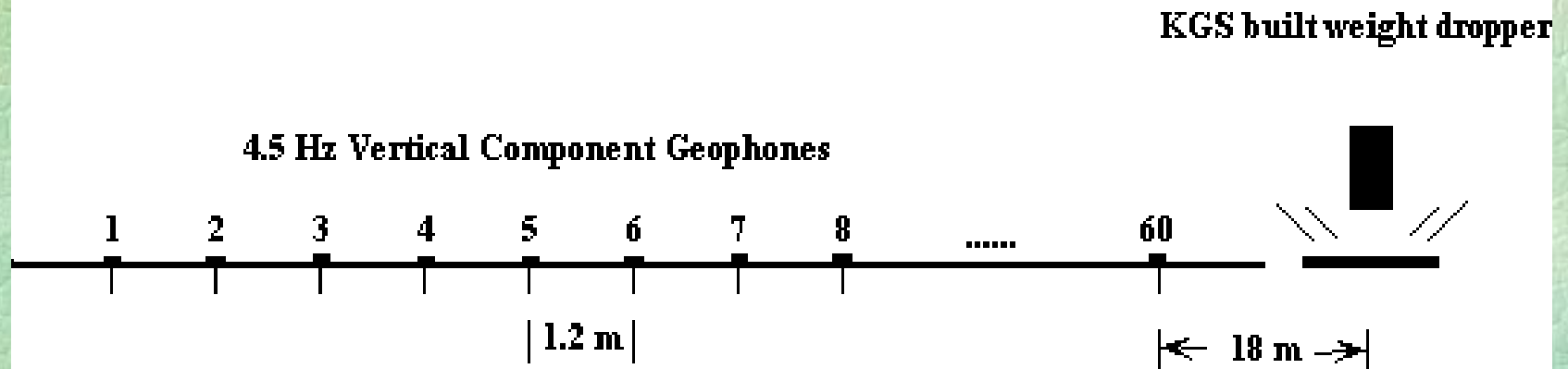


# Borehole FD95-2

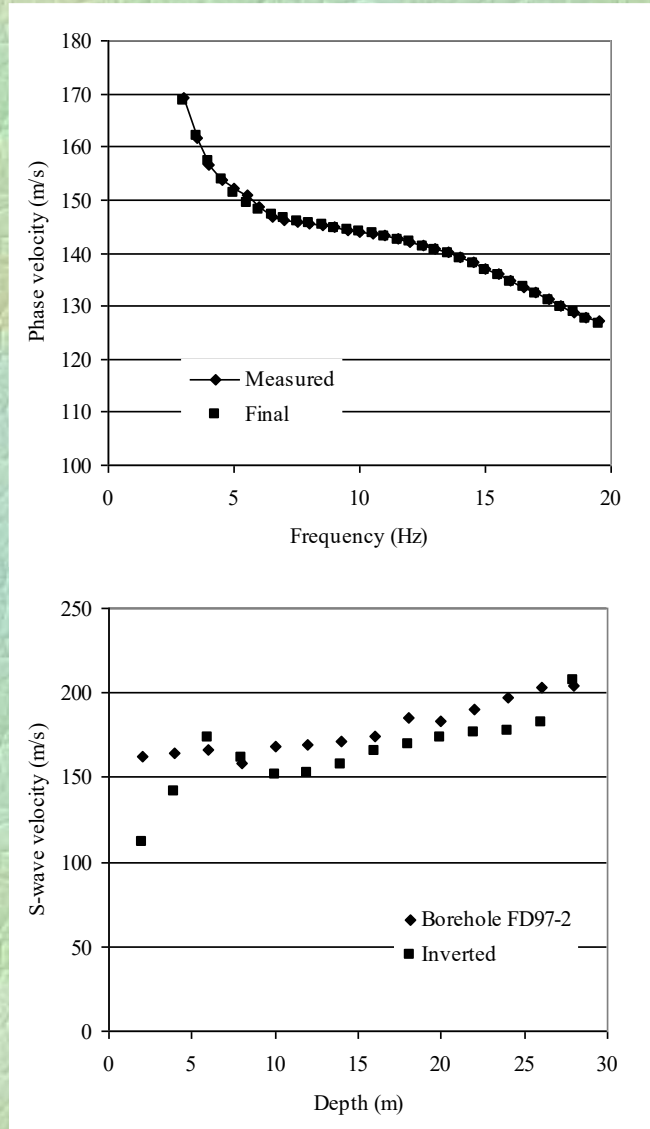
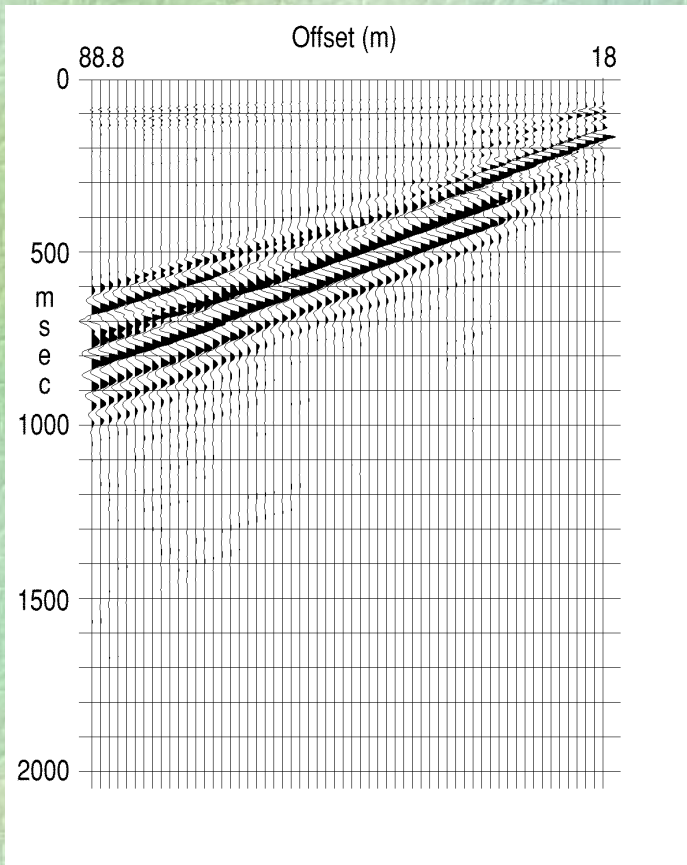
- **Wavelength Range:** *6 - 23 m*
- **Phase Velocity Range:** *130 - 158 m/s*
- **Frequency Range:** *7 - 23 Hz*
- **Depth Studied:** *30 m*
- **Inverted S-wave Velocity Range:** *111 - 206 m/s*
- **Average Relative Difference:** *10%*
- **Average Difference:** *19 m/s*

# Field Layout for Borehole FD97-2

## MASW Surface Wave Survey Line



# Borehole FD97-2



# Borehole FD97-2

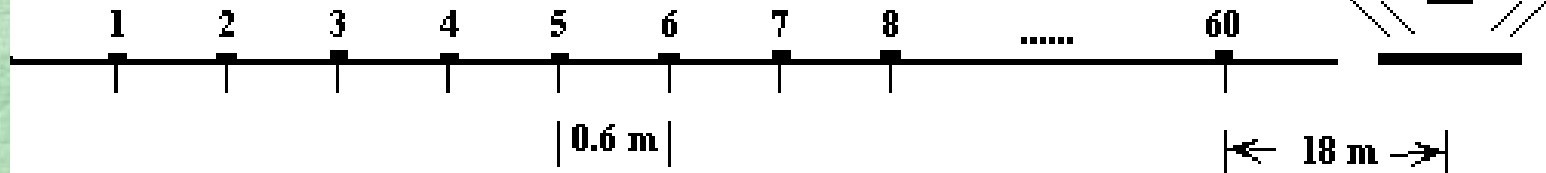
- **Wavelength Range:** *7 - 56 m*
- **Phase Velocity Range:** *127 - 169 m/s*
- **Frequency Range:** *3 - 20 Hz*
- **Depth Studied:** *30 m*
- **Inverted S-wave Velocity Range:** *111 - 207 m/s*
- **Average Relative Difference:** *9%*
- **Average Difference:** *16 m/s*

# Field Layout for Borehole FD92-11

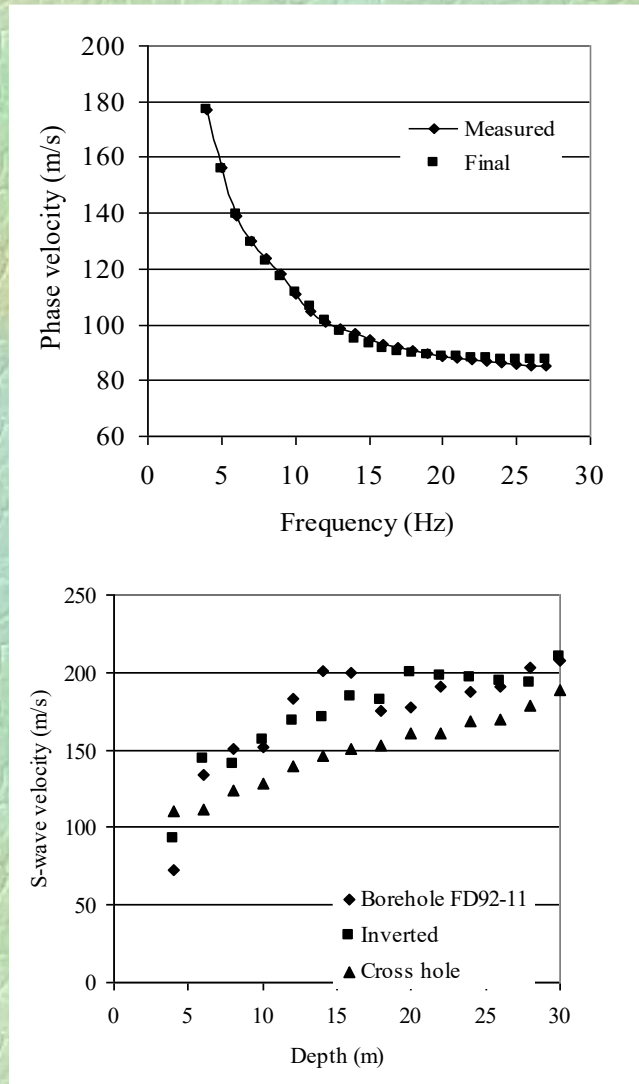
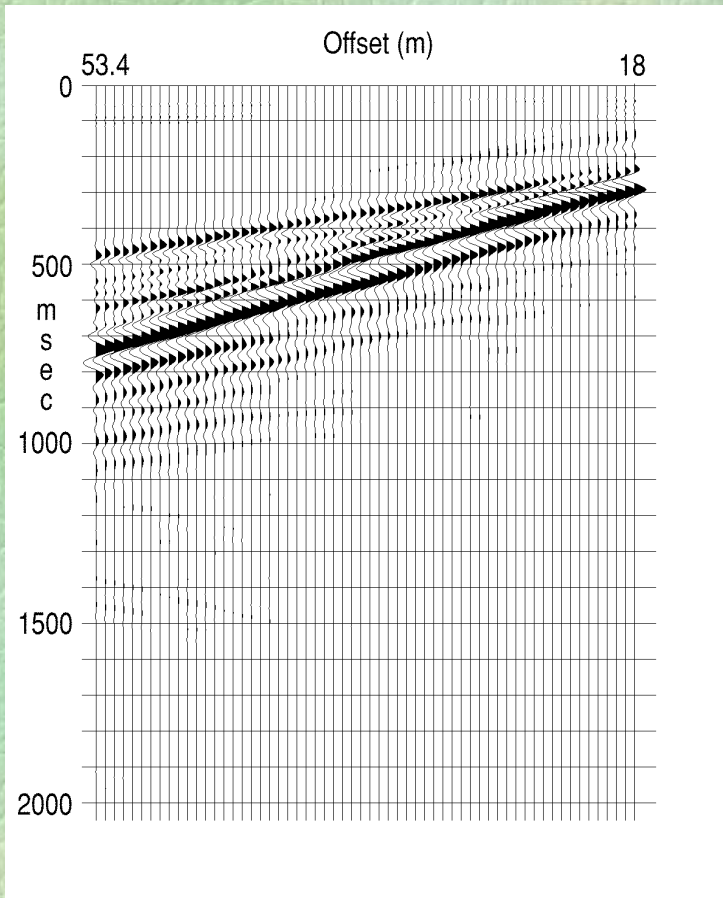
## MASW Surface Wave Survey Line

KGS built weight dropper

4.5 Hz Vertical Component Geophones



# Borehole FD92-11



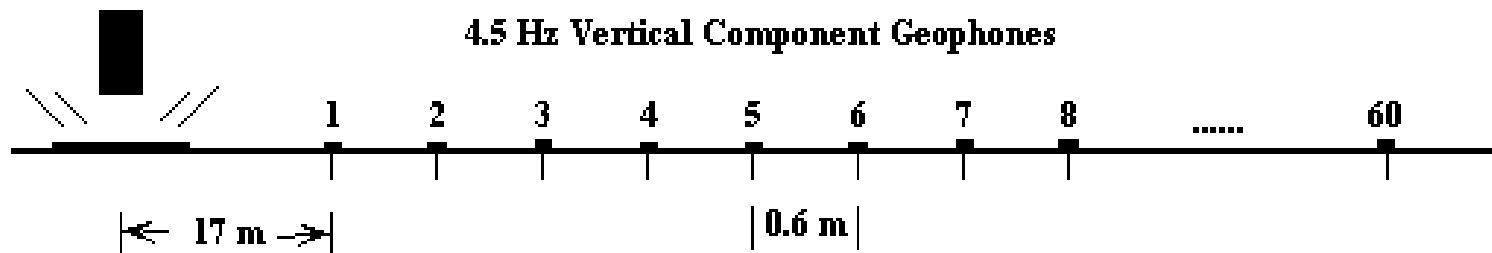
# Borehole FD92-11

- **Wavelength Range:** *3 - 44 m*
- **Phase Velocity Range:** *85 - 176 m/s*
- **Frequency Range:** *4 - 27 Hz*
- **Depth Studied:** *30 m*
- **Inverted S-wave Velocity Range:** *92 - 209 m/s*
- **Average Relative Difference:** *8%*
- **Average Difference:** *12 m/s*

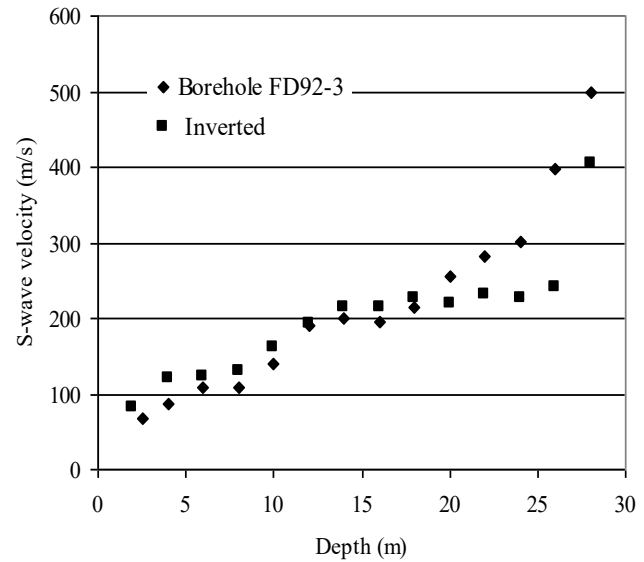
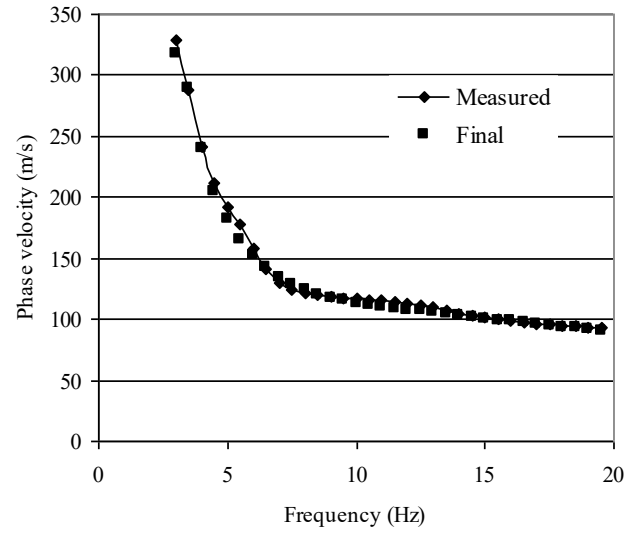
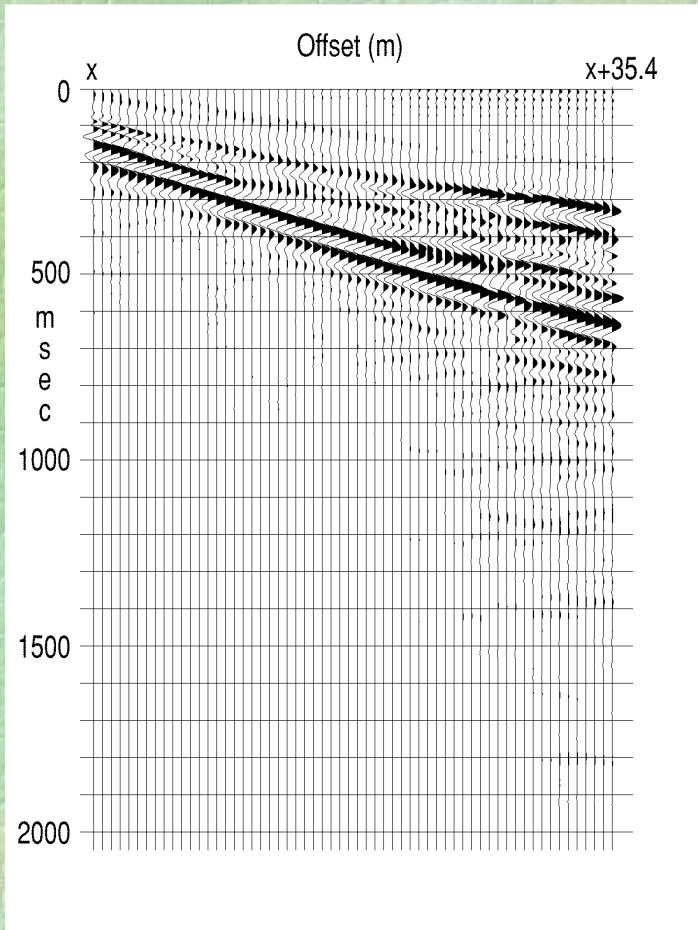
# Field Layout for Borehole FD92-3

## MASW Surface Wave Survey Line

KGS built weight dropper



# Borehole FD92-3



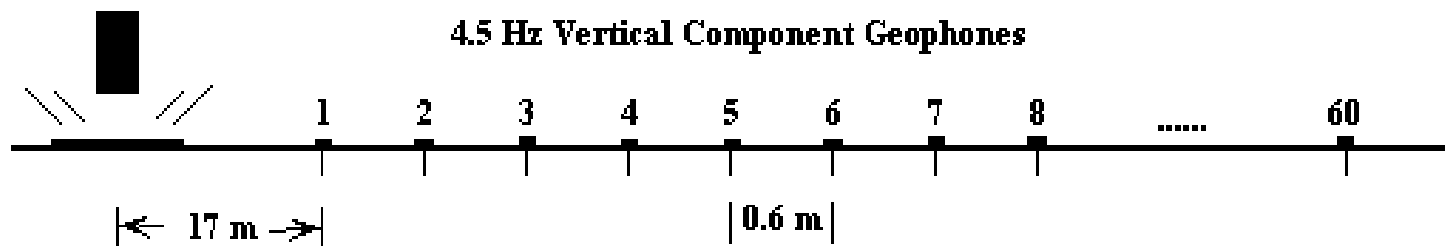
# Borehole FD92-3

- **Wavelength Range:** *5 - 110 m*
- **Phase Velocity Range:** *93 - 328 m/s*
- **Frequency Range:** *3 - 20 Hz*
- **Depth Studied:** *30 m*
- **Inverted S-wave Velocity Range:** *82 - 404 m/s*
- **Average Relative Difference:** *17%*
- **Average Difference:** *42 m/s*

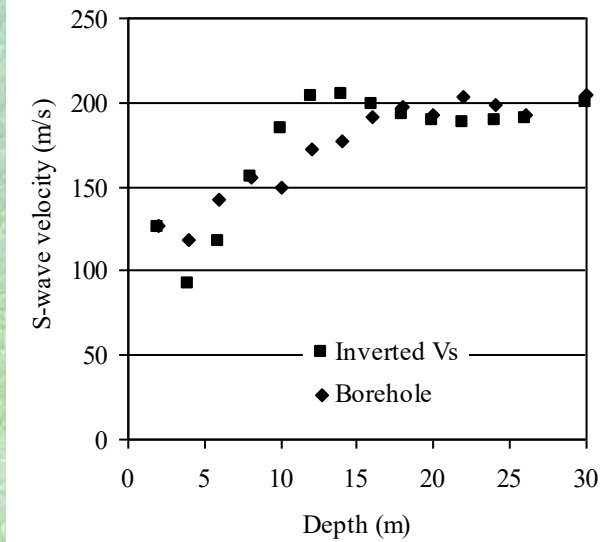
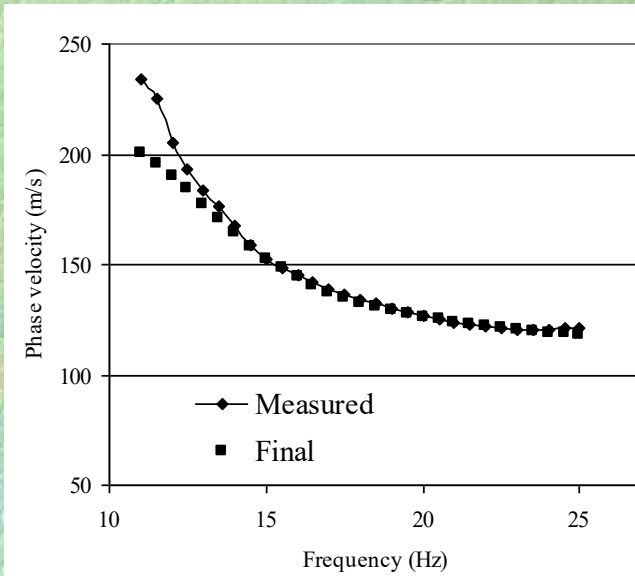
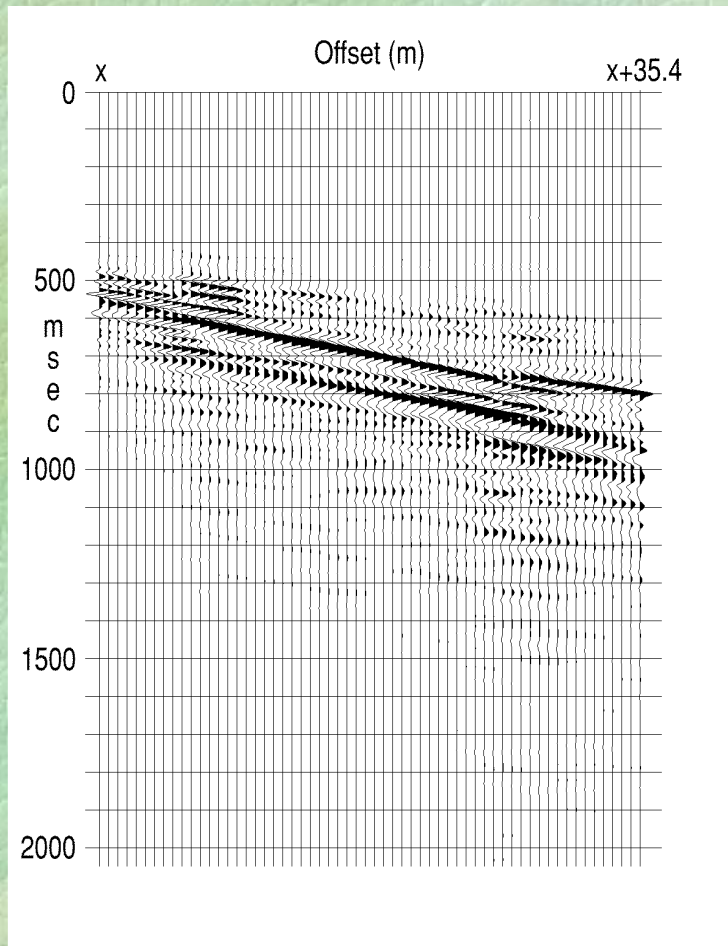
# Field Layout for Borehole Unknown

## MASW Surface Wave Survey Line

KGS built weight dropper



# Borehole Unknown



# Borehole Unknown

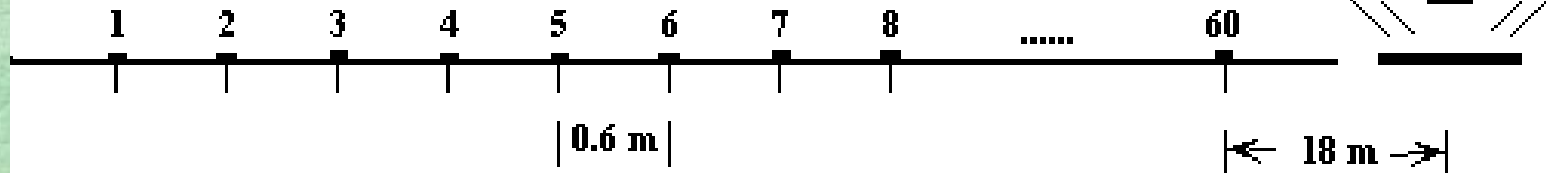
- **Wavelength Range:** *7 - 60 m*
- **Phase Velocity Range:** *107 - 179 m/s*
- **Frequency Range:** *3 - 15 Hz*
- **Depth Studied:** *30 m*
- **Inverted S-wave Velocity Range:** *92 - 205 m/s*
- **Average Relative Difference:** *9%*
- **Average Difference:** *14 m/s*

# Field Layout for Borehole FD86-5

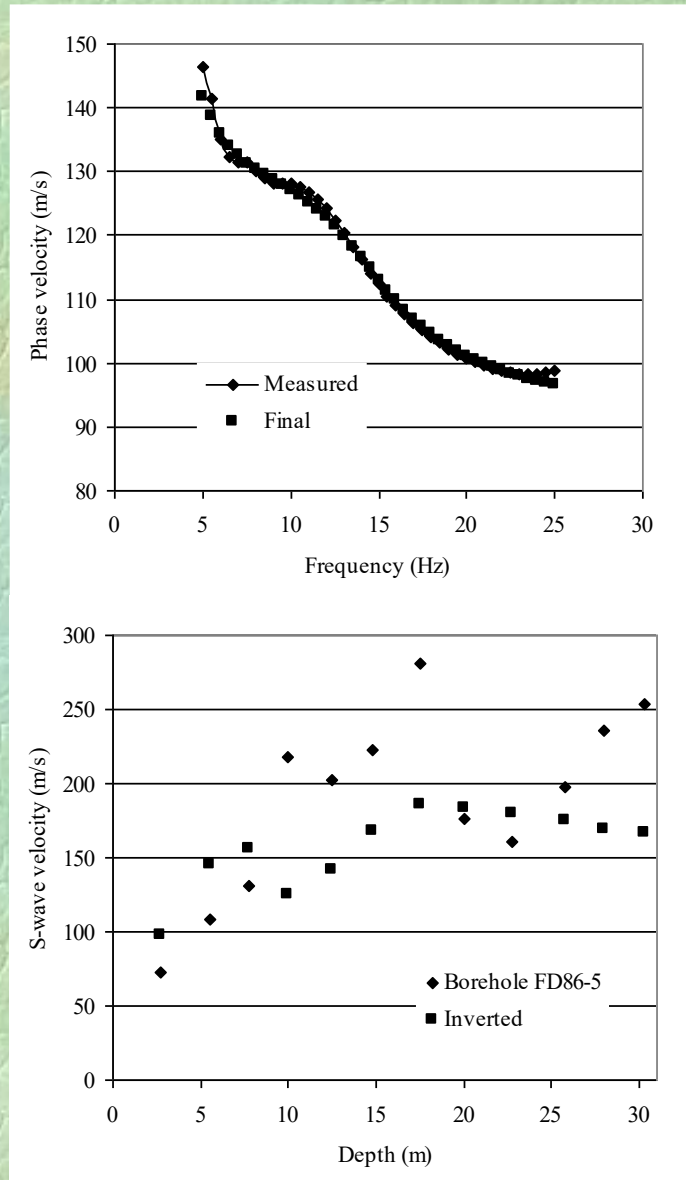
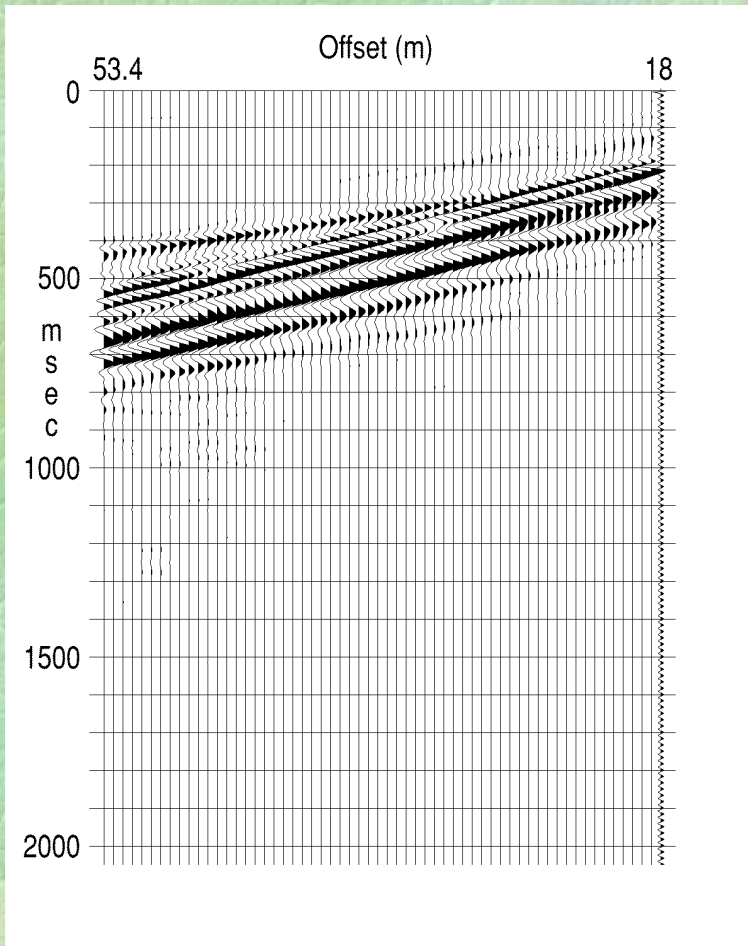
## MASW Surface Wave Survey Line

KGS built weight dropper

4.5 Hz Vertical Component Geophones



# Borehole FD86-5



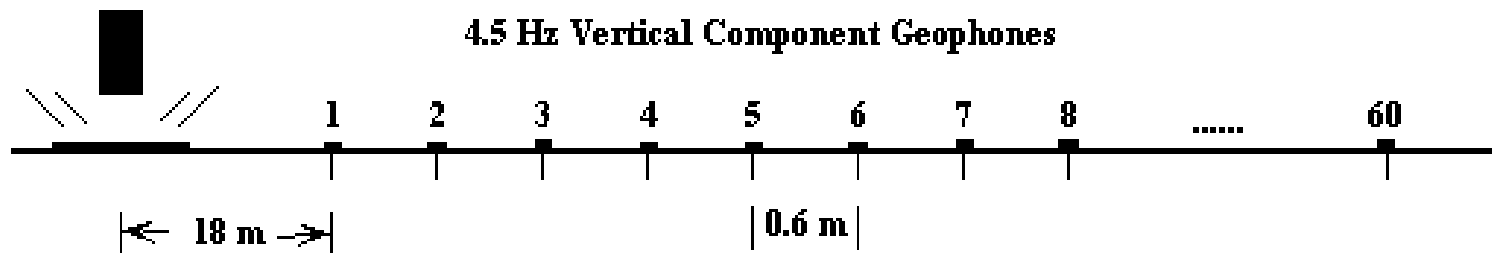
# Borehole FD86-5

- **Wavelength Range:** *4 - 29 m*
- **Phase Velocity Range:** *99 - 146 m/s*
- **Frequency Range:** *5 - 25 Hz*
- **Depth Studied:** *30 m*
- **Inverted S-wave Velocity Range:** *98 - 186 m/s*
- **Average Relative Difference:** *26%*
- **Average Difference:** *50 m/s*

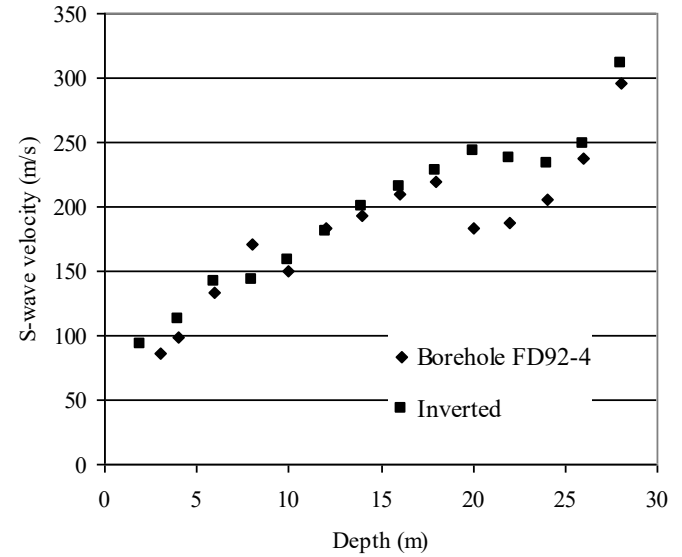
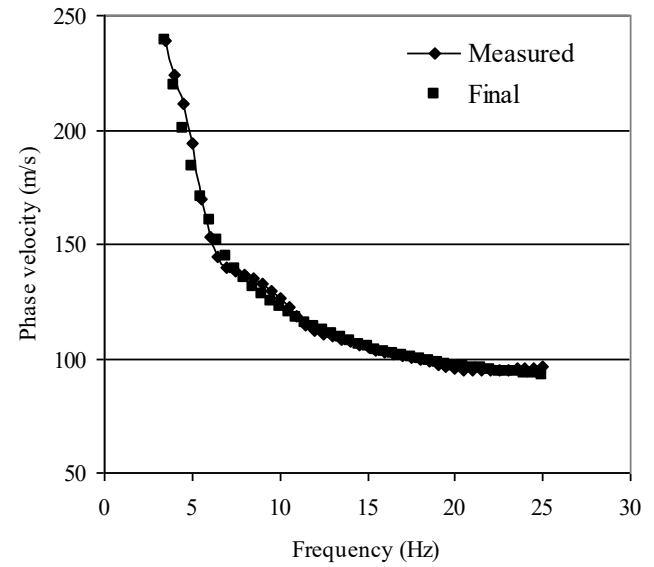
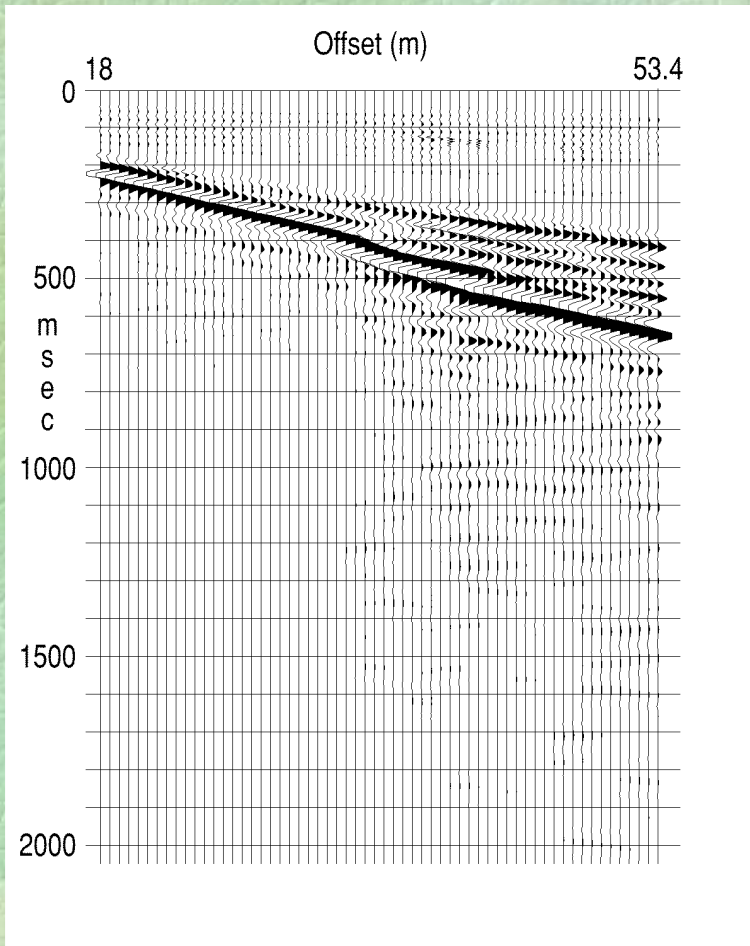
# Field Layout for Borehole FD92-4

## MASW Surface Wave Survey Line

KGS built weight dropper



# Borehole FD92-4



# Borehole FD92-4

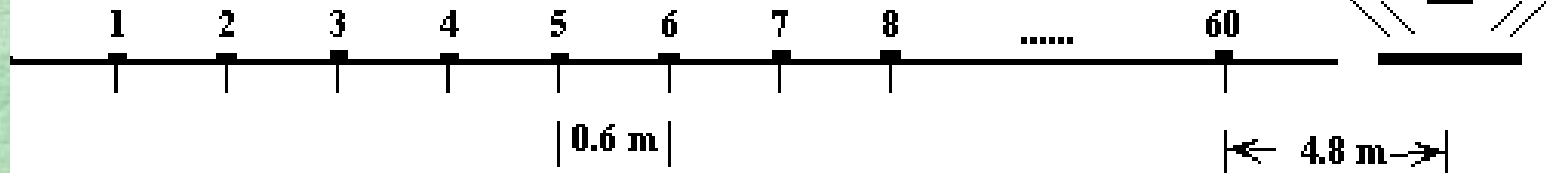
- **Wavelength Range:** *4 - 68 m*
- **Phase Velocity Range:** *96 - 239 m/s*
- **Frequency Range:** *3.5 - 25 Hz*
- **Depth Studied:** *30 m*
- **Inverted S-wave Velocity Range:** *92 - 311 m/s*
- **Average Relative Difference:** *10%*
- **Average Difference:** *19 m/s*

# Field Layout for Borehole FD97-7

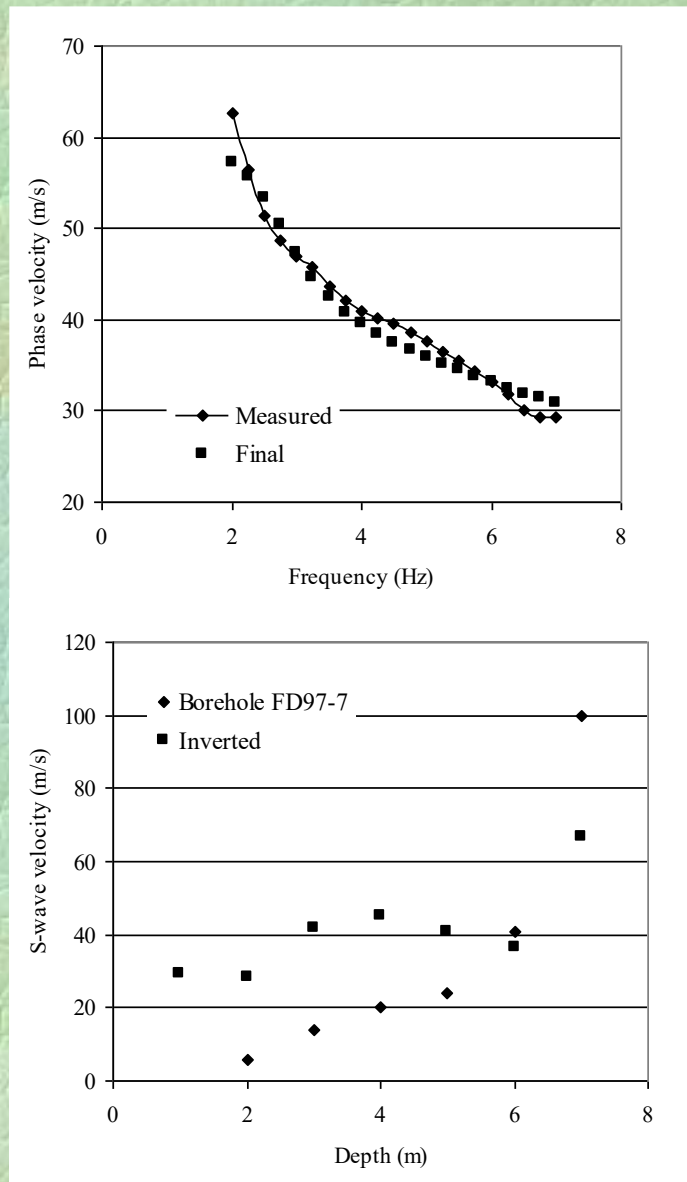
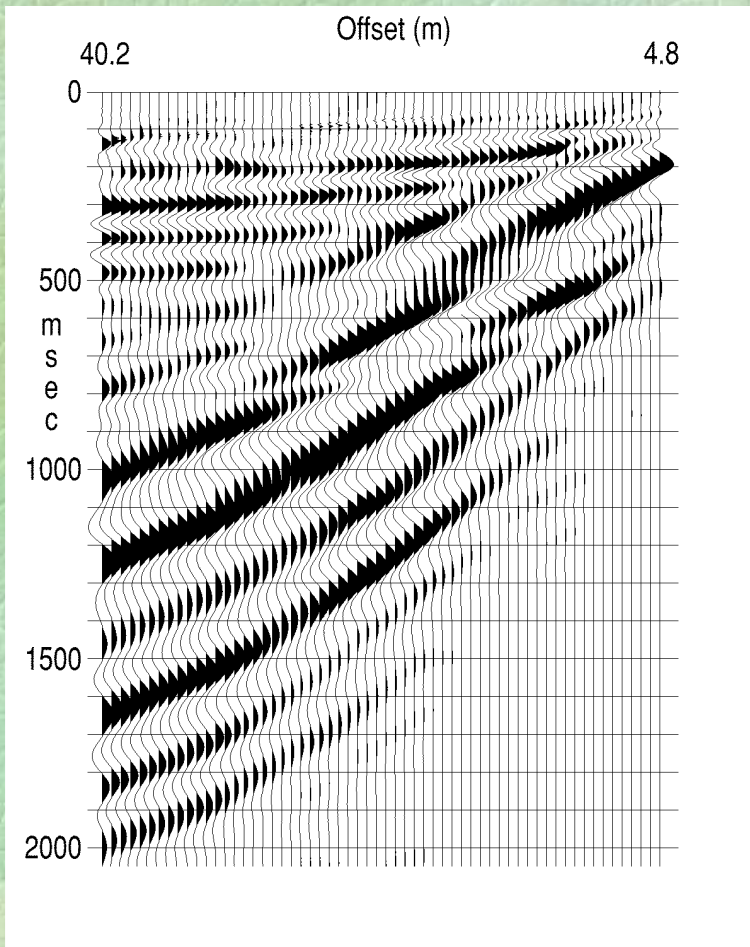
## MASW Surface Wave Survey Line

KGS built weight dropper

4.5 Hz Vertical Component Geophones



# Borehole FD97-7

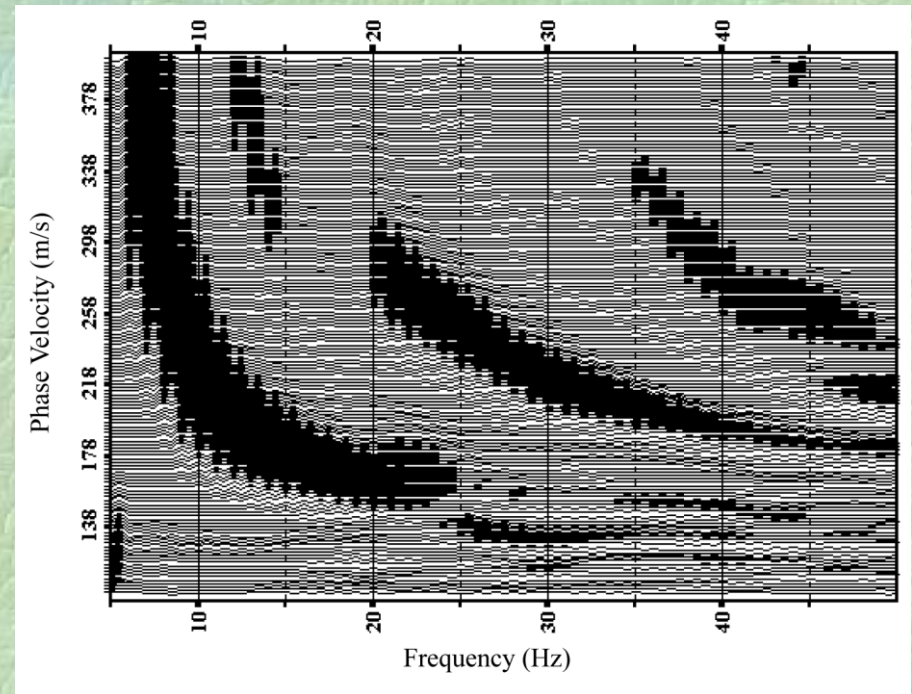


# Borehole FD97-7

- **Wavelength Range:** *4 - 31 m*
- **Phase Velocity Range:** *29 - 63 m/s*
- **Frequency Range:** *2 - 7 Hz*
- **Depth Studied:** *7 m*
- **Inverted S-wave Velocity Range:** *29 - 67 m/s*
- **Average Relative Difference:** *14%*
- **Average Difference:** *22 m/s*

# Reasons for differences

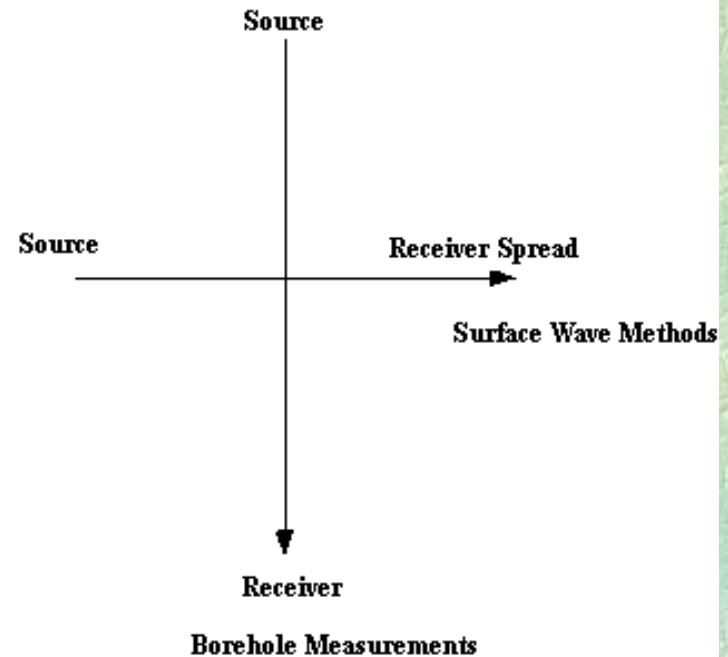
- Body waves and/or higher-mode Rayleigh waves.
- Sharpness of dispersion curve in the F-K domain.



# Reasons for differences

- Heterogeneity of the near-surface materials. Borehole measurement is in vertical direction and the MASW S-wave velocity is in horizontal direction.

**Directions of Calculated S-wave Velocity**



# Reasons for differences

- ❑ **Random noise and/or reflected ground roll.**
- ❑ **Non-uniqueness in the inversion of Rayleigh wave data and a local minimum search of the inverse algorithm.**
- ❑ **The first arrival picking on borehole data.**

# Conclusions

**The overall difference between S-wave velocities from the MASW method and borehole measurements is 15%.**

**Most errors can be associated with random and coherent noise and accuracy of borehole measurements.**

**Differences between S-wave velocities from the MASW method and borehole measurements appear to be random.**

**This comparison demonstrates the reliability and accuracy of S-wave velocities estimated from the MASW method in unconsolidated sediments.**

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