# Design of Instrumentation Systems for Monitoring Geo-Hazards in Transportation

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# Systematic Approach to Planning Monitoring Programs

Without a carefully executed plan, a geotechnical instrumentation program is guaranteed to fail.

Systematic planning requires special effort and dedicated, responsible people.

Avoid taking shortcuts.

# 21 Planning Steps

## PREDICT PERFORMANCE

1. Define project conditions
2. Predict mechanisms that control behavior
3. Define questions to be answered
4. Define purpose of instrumentation
5. Select parameters to be monitored
6. Predict magnitudes of change

## DESIGN INSTRUMENTATION

7. Devise remedial actions
8. Assign tasks
9. Select instruments
10. Select locations for instruments
11. Select data collection system (including factors that may influence data)
12. Establish procedures to check data
13. List purpose of each instrument
14. Prepare budget

## DEVELOP PLANS & SPECS

15. Prepare instrumentation design report
16. Write procurement specifications
17. Plan installation
18. Plan calibration and maintenance
19. Plan data collection, management and reporting.
20. Write specs for instrumentation services
21. Update budget

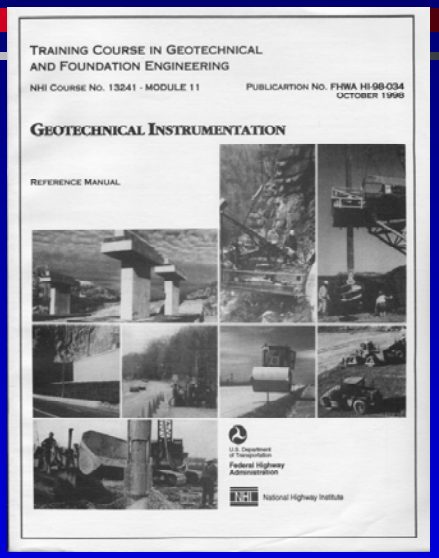
# 10 Execution Steps

1. Procure instruments
2. Perform pre-installation acceptance tests
3. Install instruments
4. Perform post-installation acceptance tests
5. Calibrate and maintain instruments
6. Collect data
7. Process and present data
8. Interpret data
9. Report conclusions
10. Implement

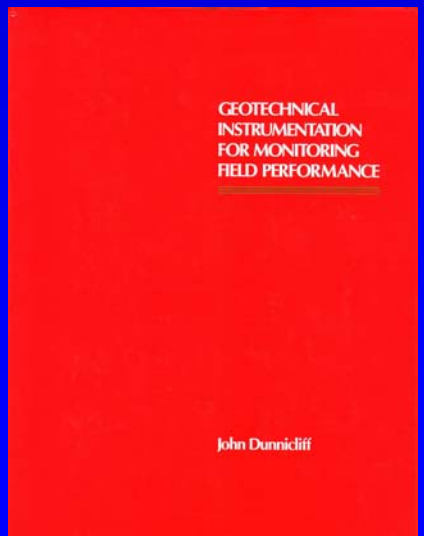
# References

- **Geotechnical Instrumentation - Reference Manual, Training Course in Geotechnical and Foundation Engineering, NHI Course No. 13241 - Module 11, Publication No. FHWA HI-98-034, October 1998**

  **www.FHWA.dot.gov/engineering**




- ***Geotechnical Instrumentation for Monitoring Field Performance*, John Dunnicliff, John Wiley & Sons, 1988.**

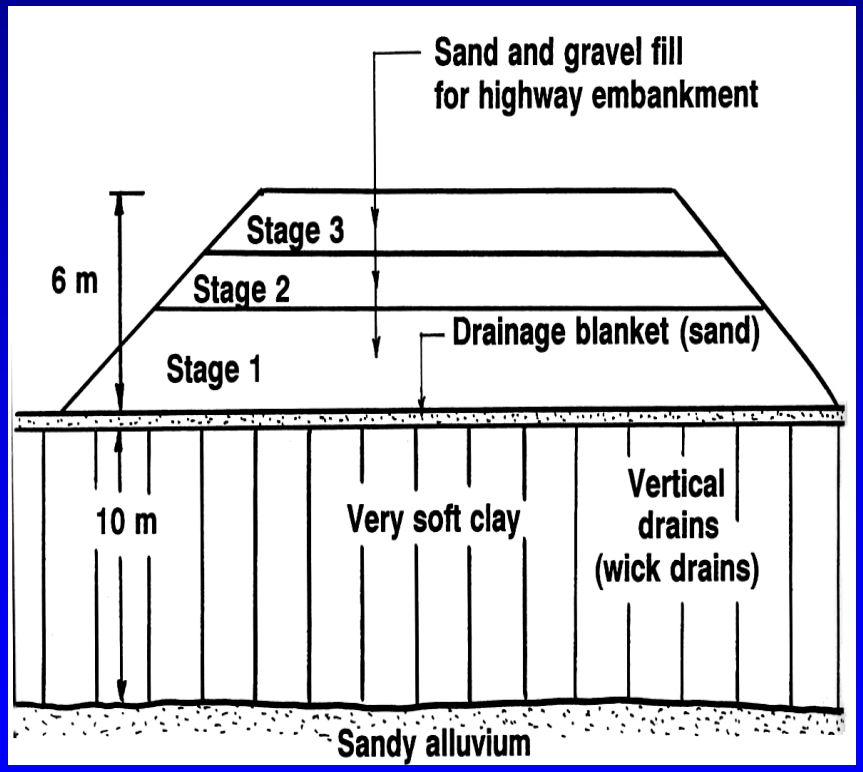


# 1. Define the project conditions

- What are the driving concerns?
- Project layout and adjacent facilities
- Critical elements
- Subsurface conditions
- Construction activities
- History of performance
- Principal parties and their responsibilities
- Risks

# 2. Identify mechanisms controlling performance

- Develop one or more working hypotheses on what mechanisms are likely to control (affect) future performance.
- Use past performance, knowledge, experience, training, advice of others, etc., to develop and test the working hypotheses.



# 3. What questions need to be answered?

- What geotechnical questions are likely to arise during design, construction and operation phases?
- Which of these questions can be answered with data from instrumentation?
- If there is no question, there should be no instrumentation.

# 4. Define the purpose(s) of the instrumentation

- **Predict and avoid failure (reveal unknowns)**
- **Evaluate critical design assumptions (reduce risks)**
- **Minimize damage to adjacent structures**
- **Assess contractor's means and methods (provide QA especially for design-build)**
- **Control construction (avoid delays)**
- **Devise remedial methods to fix problems**
- **Document performance for assessing damages**
- **Inform stakeholders (answer questions and calm fears)**
- **Help deal with politically sensitive projects**
- **Reduce litigation**
- **Advance state-of-knowledge**
- **Develop message to communicate with management**

# Why instrument?
## The real answer--

- TO SAVE MONEY
  - Save Lives
  - Minimize Damages
  - Reduce Delays
- Instrumentation answers questions to remove uncertainties

# What are the estimated costs from the risks?

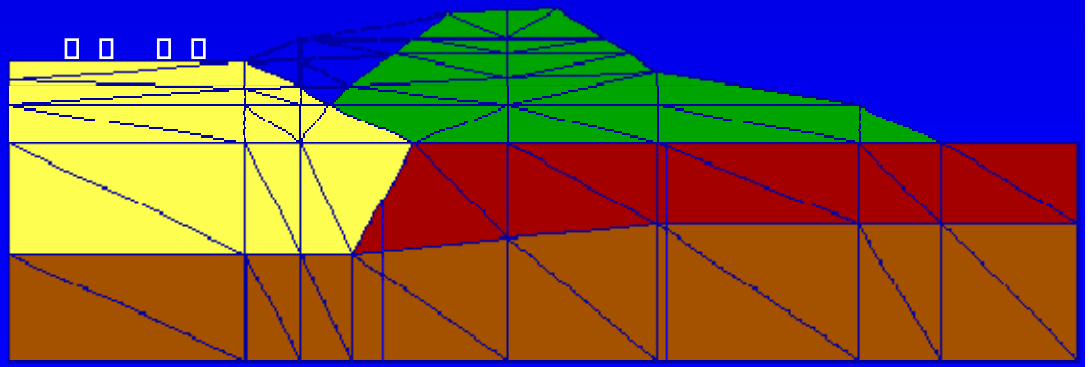
- Repair
- Delays
  - Time value of money
  - Lost user benefits
  - Liquidated damages
- Claims
  - Settlement
  - Mediation, Arbitration
  - Litigation
- Don’t underestimate these costs!

# 5. Select the parameters to be monitored

- **What can we measure?**
  - **total stress, pore water pressure, force, strain, deformation, tilt, temperature, acceleration, velocity, flow**
  - **Temperature, Humidity, Wind speed and direction, Precipitation, Sound Intensity, Light Intensity**
- **What measurements relate to the purpose of the instrumentation and the questions to be answered?**

# 6. Predict changes to be measured

- Predicted values are required to select range, sensitivity and accuracy of the instrumentation.
- Predicted values are used to establish limiting (response) values for taking action.
  - Green - all ok
  - Yellow - caution
  - Red - take remedial action



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# Golden rules

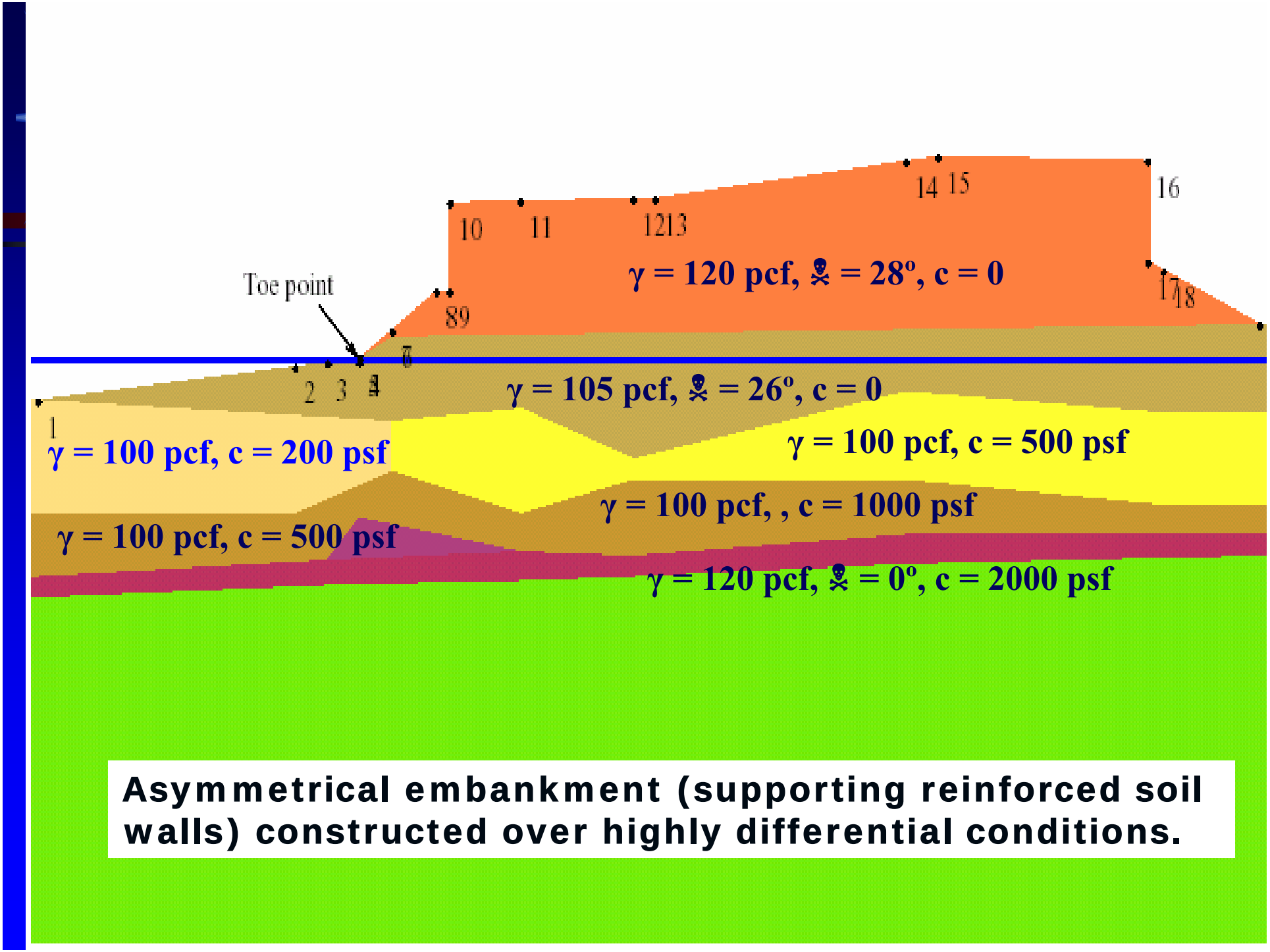
- **Key rules to a successful instrumentation project:**
  - **Every instrument must have a purpose (every instrument should provide data to help answer a question)**
  - **Instrumentation program must be planned and executed in a systematic way**
  - **Watch the details**

# Woodrow Wilson Bridge - Geotechnical Issues for Reconstruction

Aerial Photo of Existing Woodrow Wilson Bridge

# Rosalie Island

# I-95 / I-295 Interchange




**Asymmetrical embankment (supporting reinforced soil walls) constructed over highly differential conditions.**

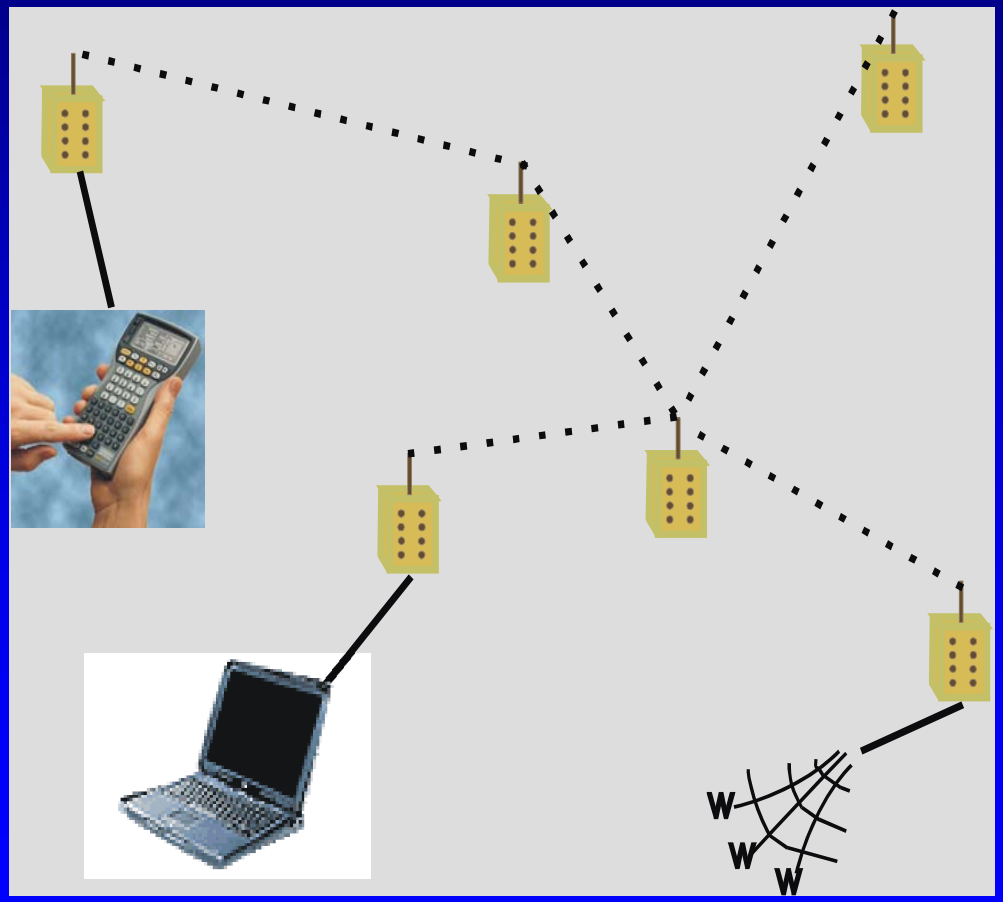

CHEVROLET
DRIGGS

# Geosynthetic Instrumentation


# *Geotechnical Instrumentation*


iSite
#22

# Remote Area Monitoring

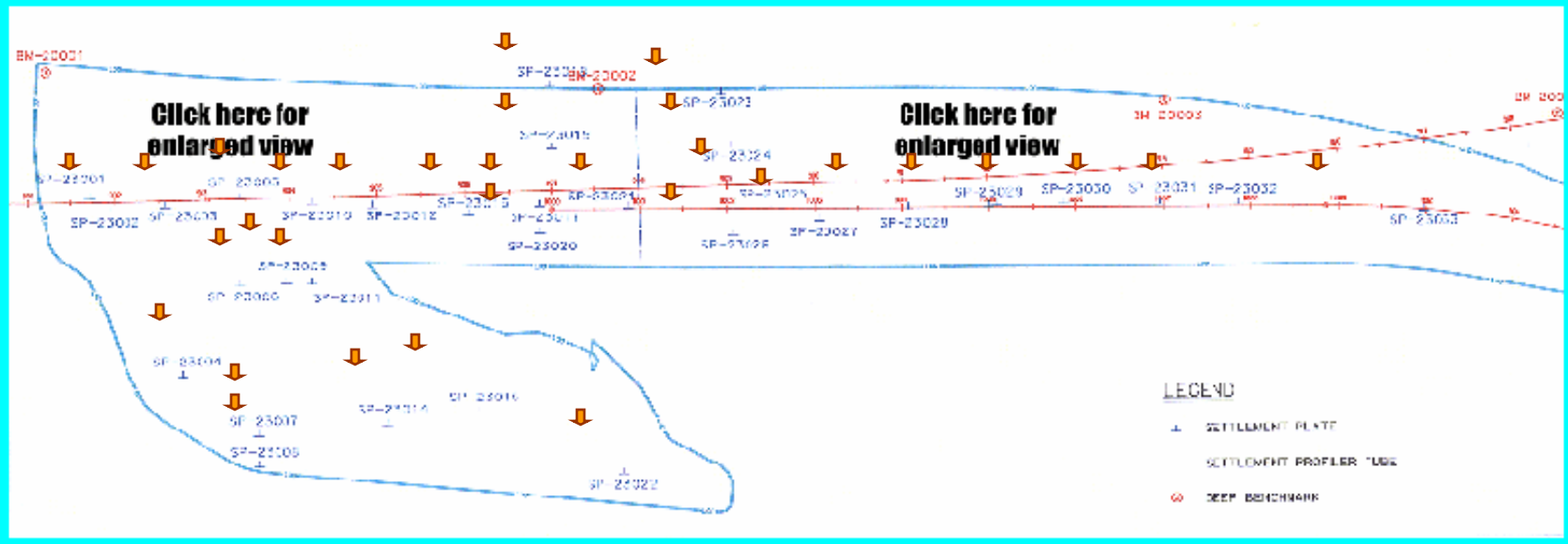



- Cells excite sensors and act as repeaters
- Remote network links by radio and/or hardwire
- Network to WEB by cell-modem
- Access data from any WEB browser

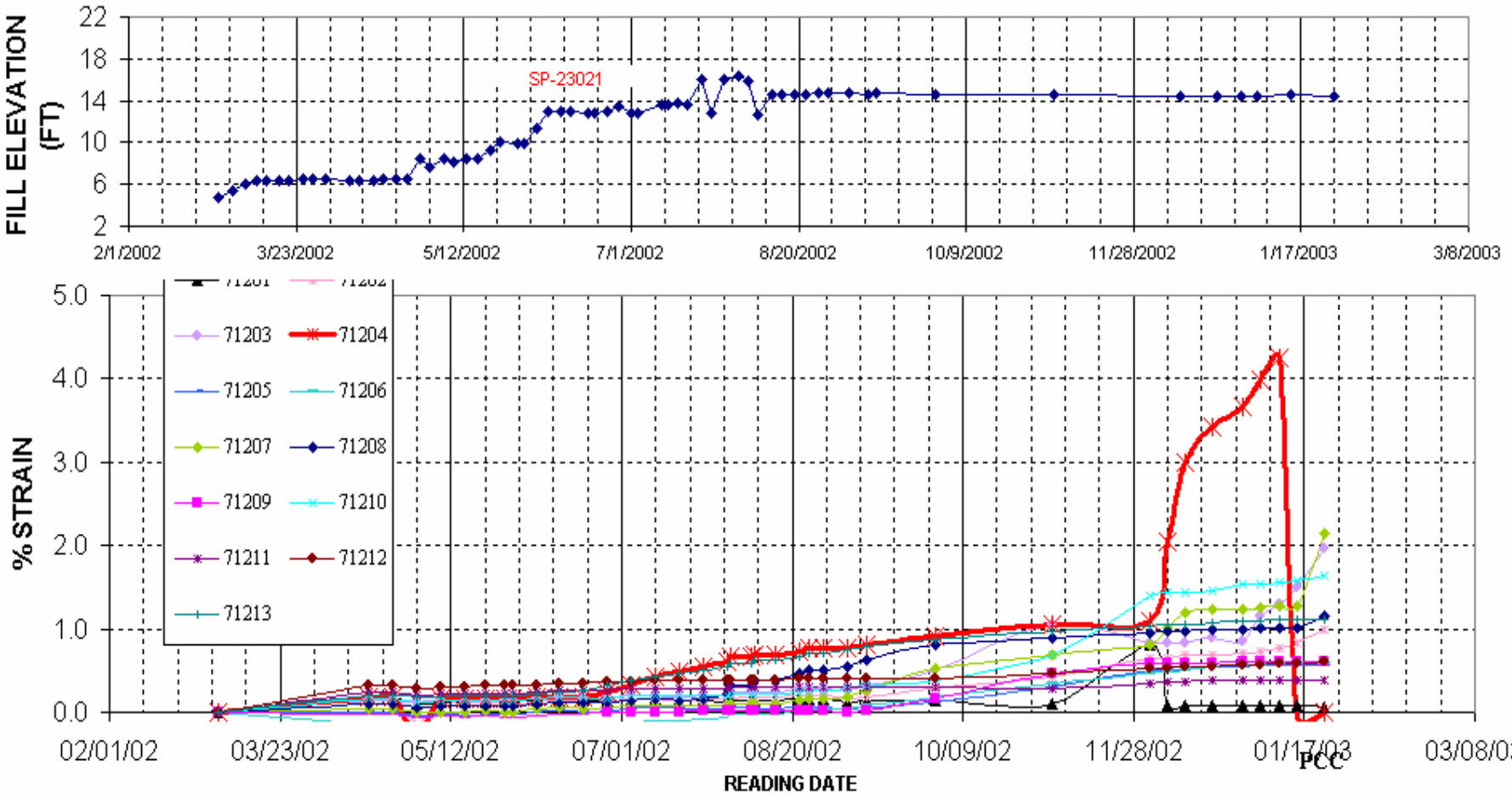
# Settlement Plates

Go Rosalie Island Main  Instrument Locations - Main  Go To Available Electronic Files

Click on either side of the map for graphs.



**Strain Gages - 71200: Includes Data Through 1/23/03**



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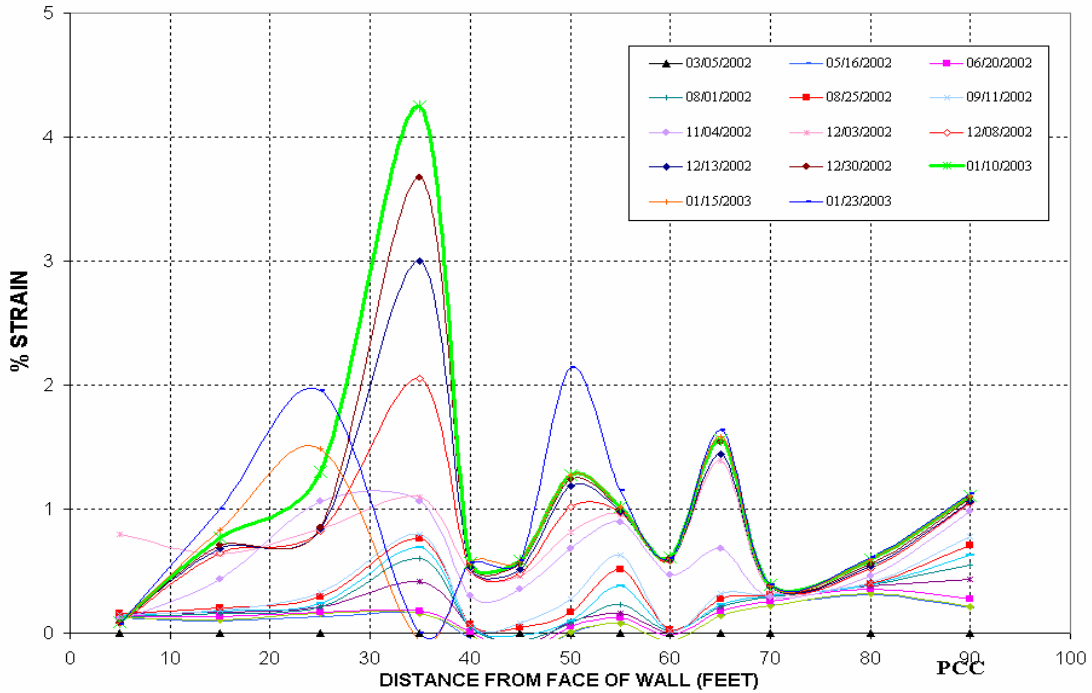
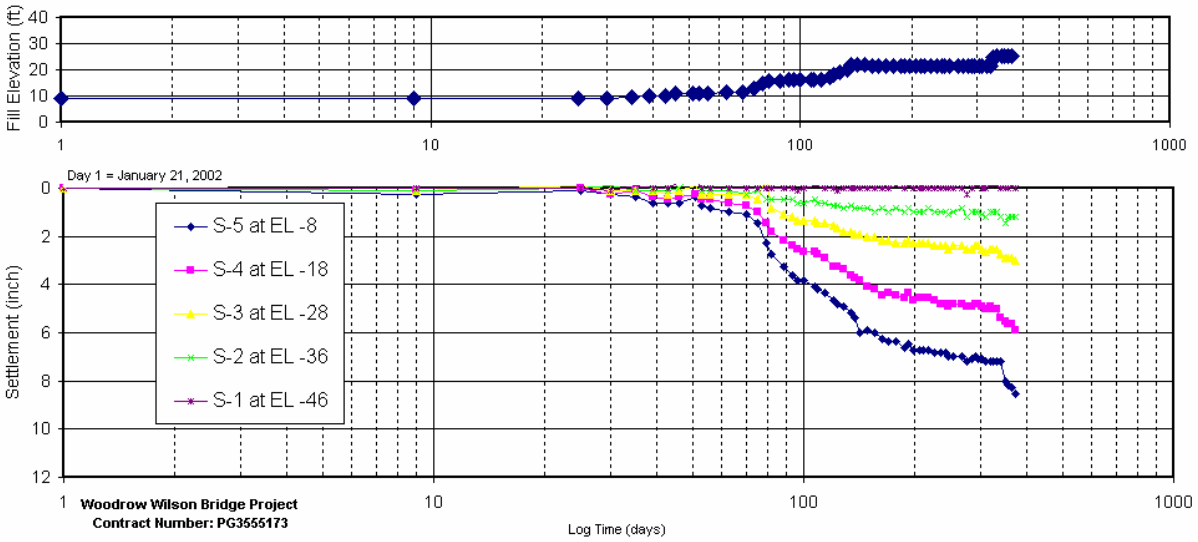
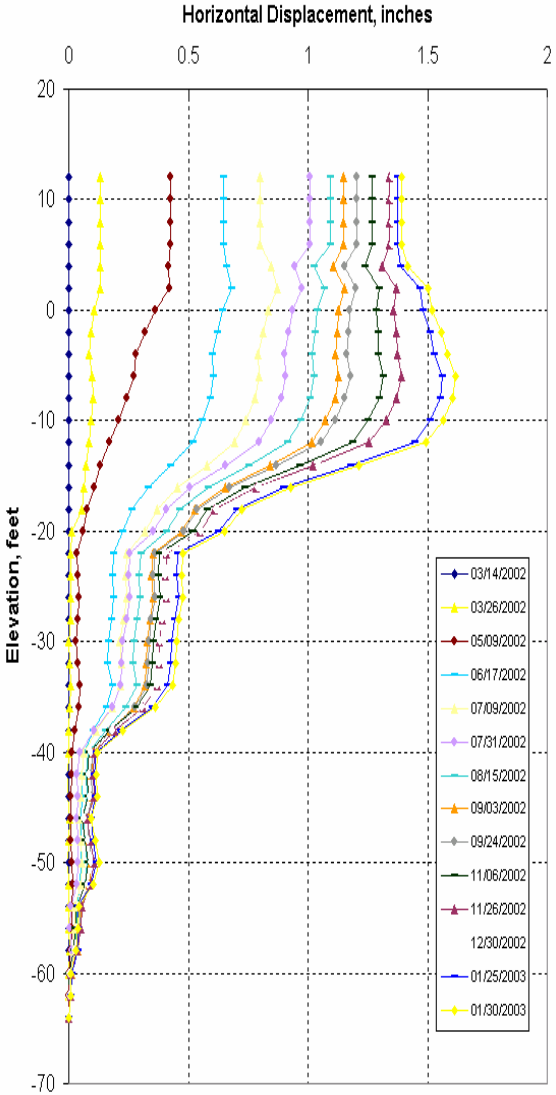
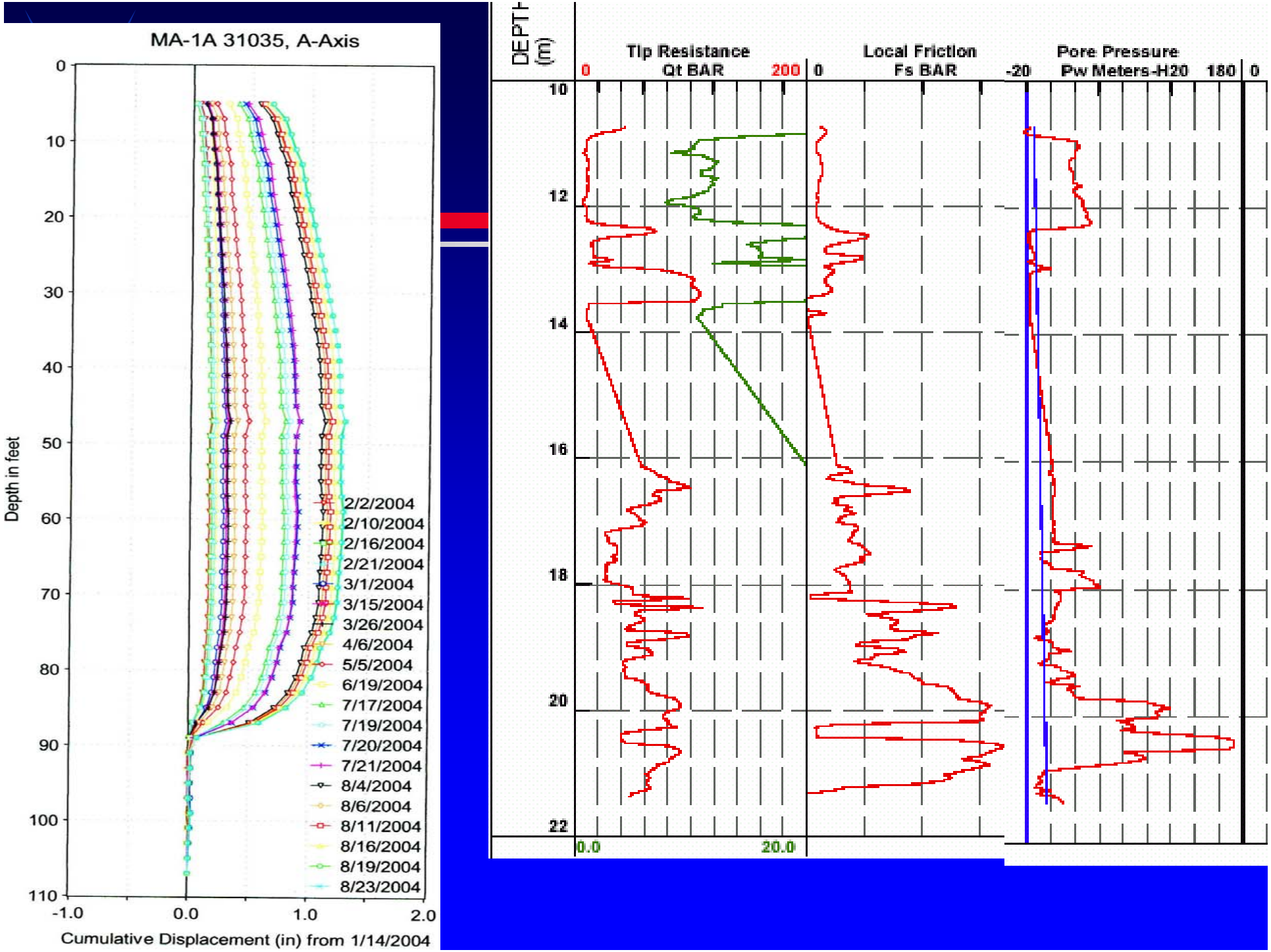



## Multi-Point Borehole Extensometer MPBX-41002
## Settlement and Fill Elevation vs. Log Time
## Sta. 902+92, 5' Right




## Inclinometer # 31022 A-Axis Cumulative Displacement
## Woodrow Wilson Bridge Project



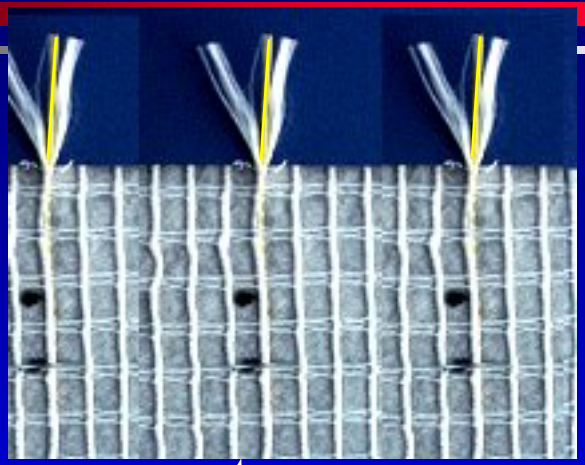

MA-1A 31035, A-Axis
Depth in feet
Cumulative Displacement (in) from 1/14/2004
2/2/2004
2/10/2004
2/16/2004
2/21/2004
3/1/2004
3/15/2004
3/26/2004
4/6/2004
5/5/2004
6/19/2004
7/17/2004
7/19/2004
7/20/2004
7/21/2004
8/4/2004
8/6/2004
8/11/2004
8/16/2004
8/19/2004
8/23/2004
DEPTH (m)
Tip Resistance
Qt BAR
Local Friction
Fs BAR
Pore Pressure
Pw Meters-H20
0.0
20.0

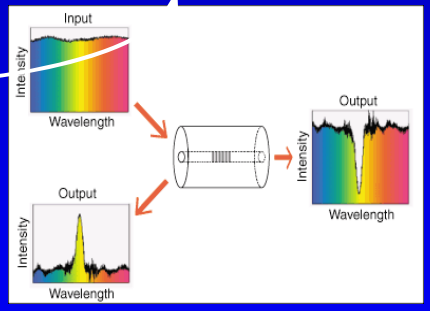
# Geofoam

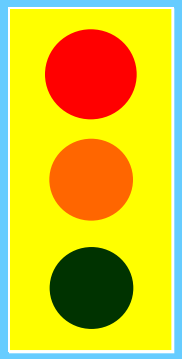
# Lessons Learned

- Instrumentation
  - Planning allowed a successful instrumentation program with clearly identifiable cost savings.
  - allowed reduction in FS for slope stability while maintaining reliability
  - Instrumentation allowed for accelerated construction
- Remote Data acquisition
  - Allowed real time involvement of all stake holders in decision making
  - Several key issues rapidly resolved
  - Prevented potential major geo-hazard issue

# Geodetect

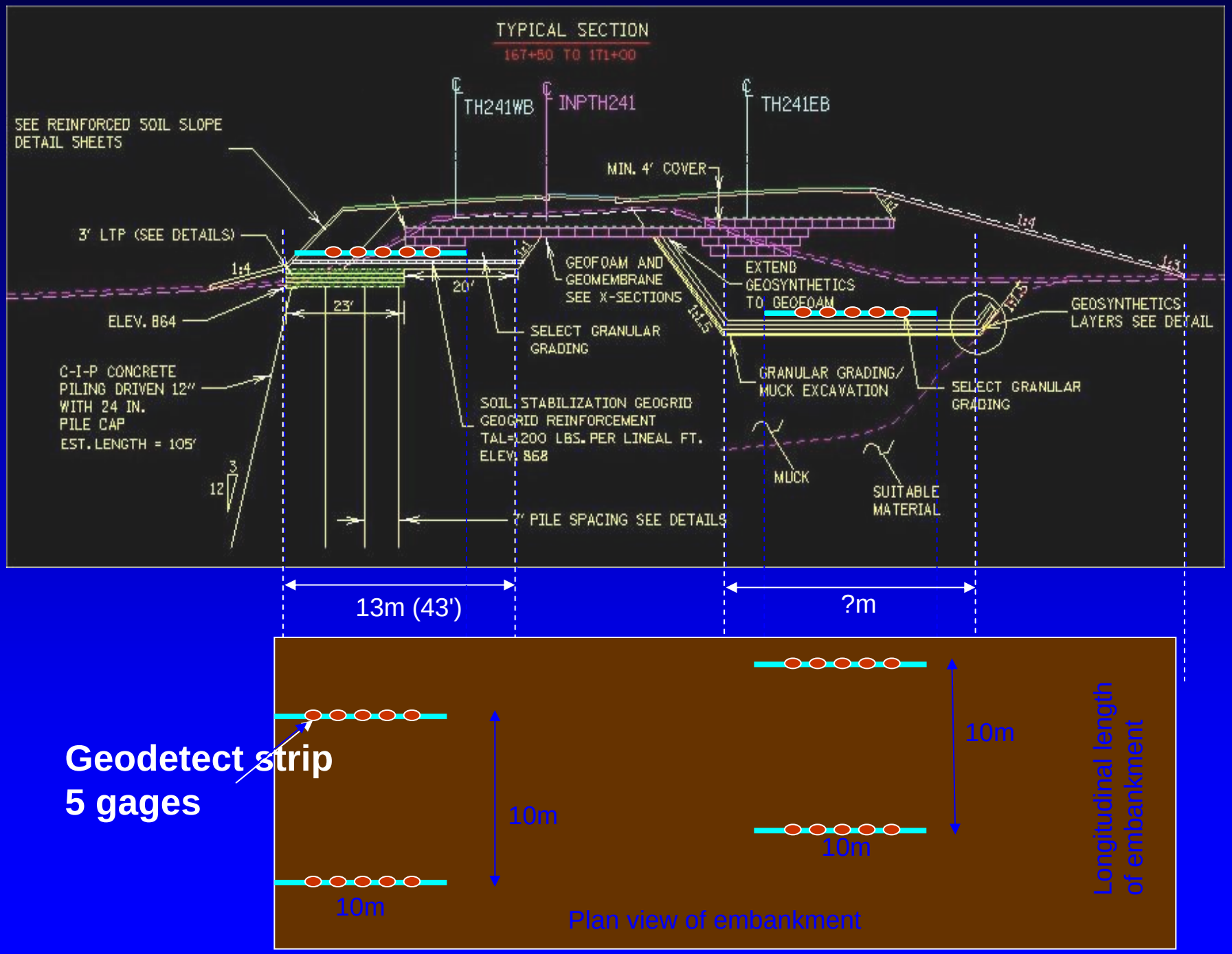



Input
Intensity
Wavelength
Output
Intensity
Wavelength
Output
Intensity
Wavelength



# Geodetect: first projects

## Railways Arbois (France) 2004-2005


TYPICAL SECTION
167+80 TO 171+00
TH241WB
INPTH241
TH241EB
SEE REINFORCED SOIL SLOPE DETAIL SHEETS
MIN. 4' COVER
3' LTP (SEE DETAILS)
1:4
ELEV. 864
23'
20'
GEOFOAM AND GEOMEMBRANE SEE X-SECTIONS
SELECT GRANULAR GRADING
EXTEND GEOSYNTHETICS TO GEOFOAM
GEOSYNTHETICS LAYERS SEE DETAIL
C-I-P CONCRETE PILING DRIVEN 12" WITH 24 IN. PILE CAP
EST. LENGTH = 105'
SOIL STABILIZATION GEOGRID
GEOGRID REINFORCEMENT
TAL=1200 LBS. PER LINEAL FT.
ELEV. 868
GRANULAR GRADING/ MUCK EXCAVATION
SELECT GRANULAR GRADING
MUCK
SUITABLE MATERIAL
7' PILE SPACING SEE DETAILS
13m (43')
?m
Geodetect strip
5 gages
10m
10m
10m
Plan view of embankment
Longitudinal length of embankment

# Questions?