Use of GPR to Detect Voids Beneath Pavements in Karst Terrane

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  - Wade Pence, PG
- GSSI
  - Robert Parrillo

Objective

- **Can GPR be used to determine if known Karst features, located adjacent to existing pavement structures, extend beneath the paved roadway?**

Scope

- Testing was performed at 3 sites
  - All adjacent to interstate pavement structures
- Verification
  - Verified by “detecting” known voids
  - No cores/borings etc.
- Timeframe
  - March 2010

Background

- Geology from a pavement engineers perspective

- Western portion of Virginia
  - Comprised of rock layers subject to weathering and dissolution
  - Sinkholes, sinking streams, caves, springs are typical of Karst terrane

Sinkholes

- Loss of foundation
- Repair can be expensive and time consuming
- How can we determine the lateral extents without significant effort?

GPR

- Antenna transmits & receives electromagnetic energy

- Reflection at boundaries between materials having differing *dielectric constant*
  - Ability to store a molecular charge
  - The larger the difference, the greater the reflection
  - Travel time is measured
  - Subject to interpretation

Dielectric constants for typical paving materials

Scullion & Saarenketo (1997)

Material	Dielectric constant
Air	1.0
Asphalt binder	2.1
Dry aggregate	4-6
HMA	5-7
PCC	7-9
Flexible base	6-20*
Subgrade	10-25*
Water	81

***depending on moisture content**

GPR Antenna

- **A question of frequency**
  - **High frequency**
    - Good resolution of smaller objects
    - Lesser depth of penetration
  - **Low frequency**
    - Lesser resolution of smaller objects
    - Greater depth of penetration

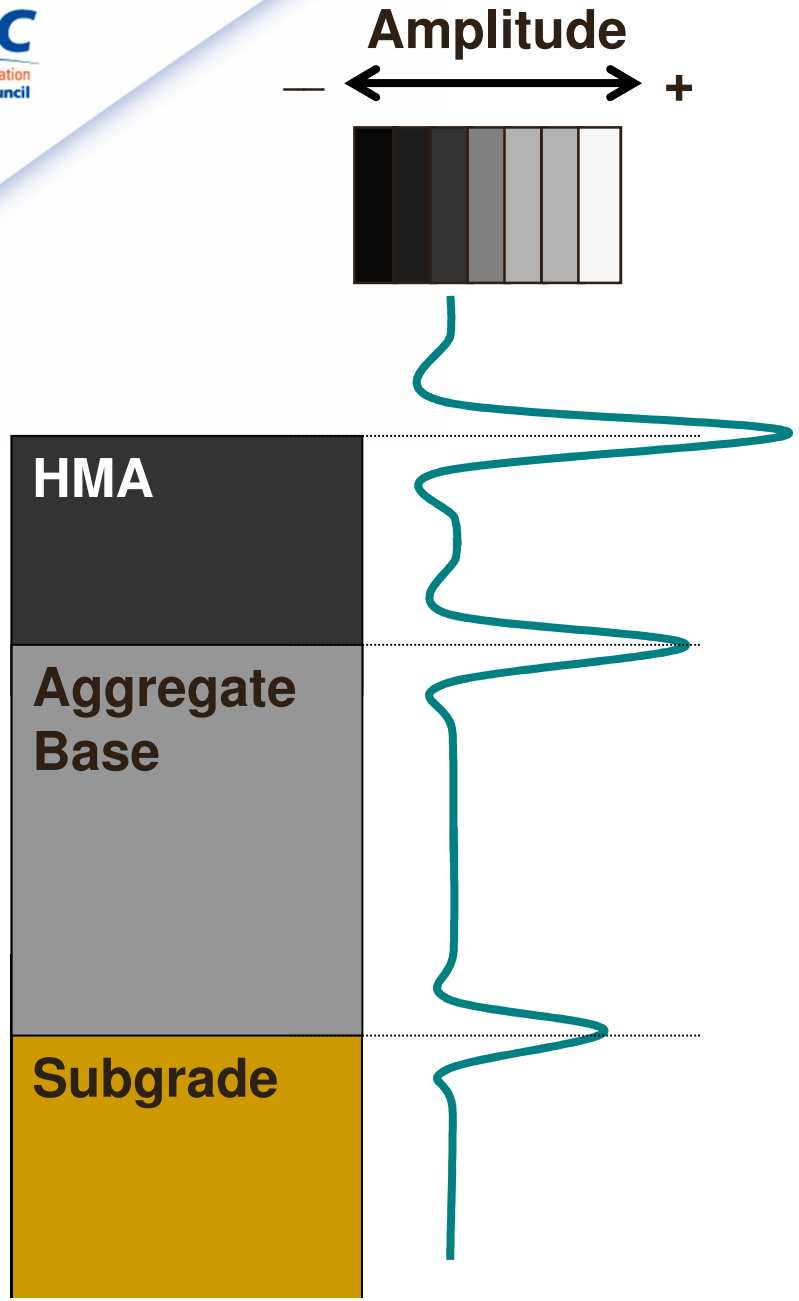
- **For this study**
  - **400 MHz, ground-coupled antenna**
    - Penetration up to 12 feet (less in clayey soils)

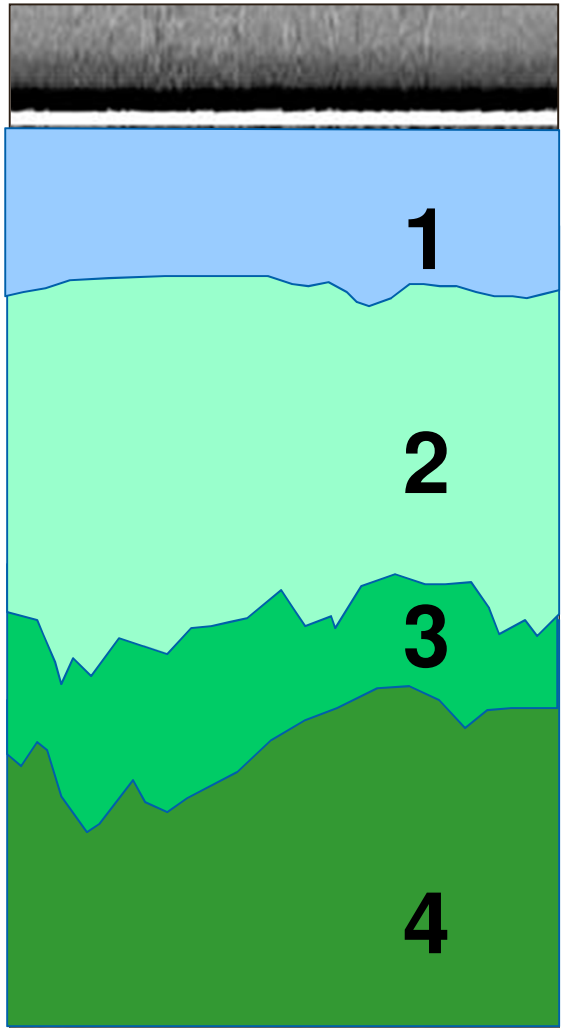
GPR Analysis

- **Location**
  - **Identify response at known voided areas**
    - Having a negative reflection
  - **Identify additional areas that show a similar response**

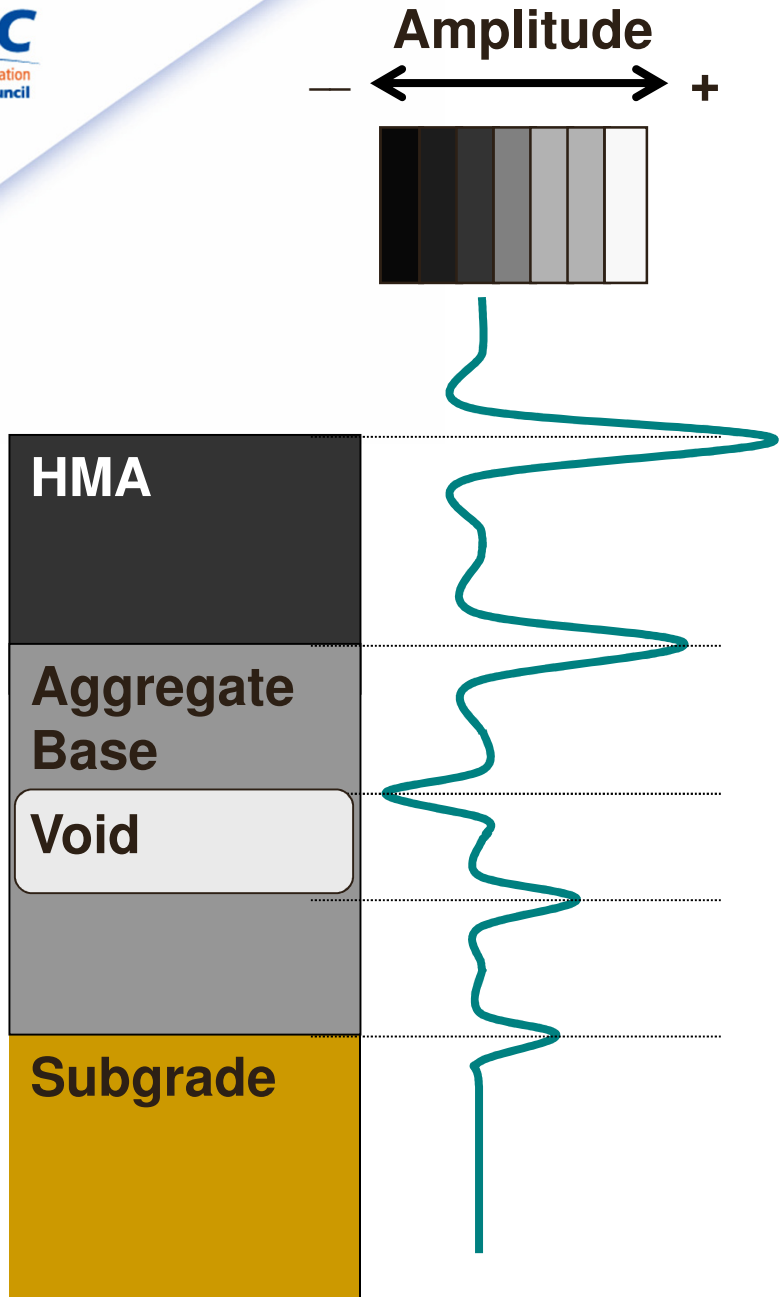
- **Depth**
  - **An estimate**
    - Heterogeneous subsurface

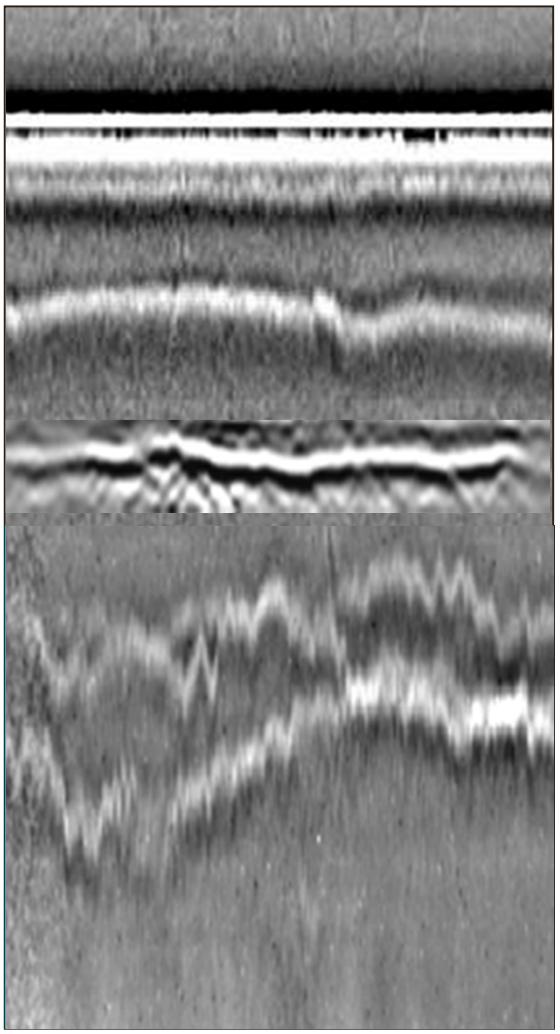
GPR Analysis (Location)





GPR Analysis (Location)





GPR Analysis (Depth)

- **Variables**
  - h = depth, m
  - c = speed of light, 3×10^8 m/s
  - t = 2-way travel time, ns
  - ε_r = dielectric constant
- **2 unknowns?**

$$h = \frac{c(\Delta t)}{2\sqrt{\varepsilon_r}}$$

GPR Equipment

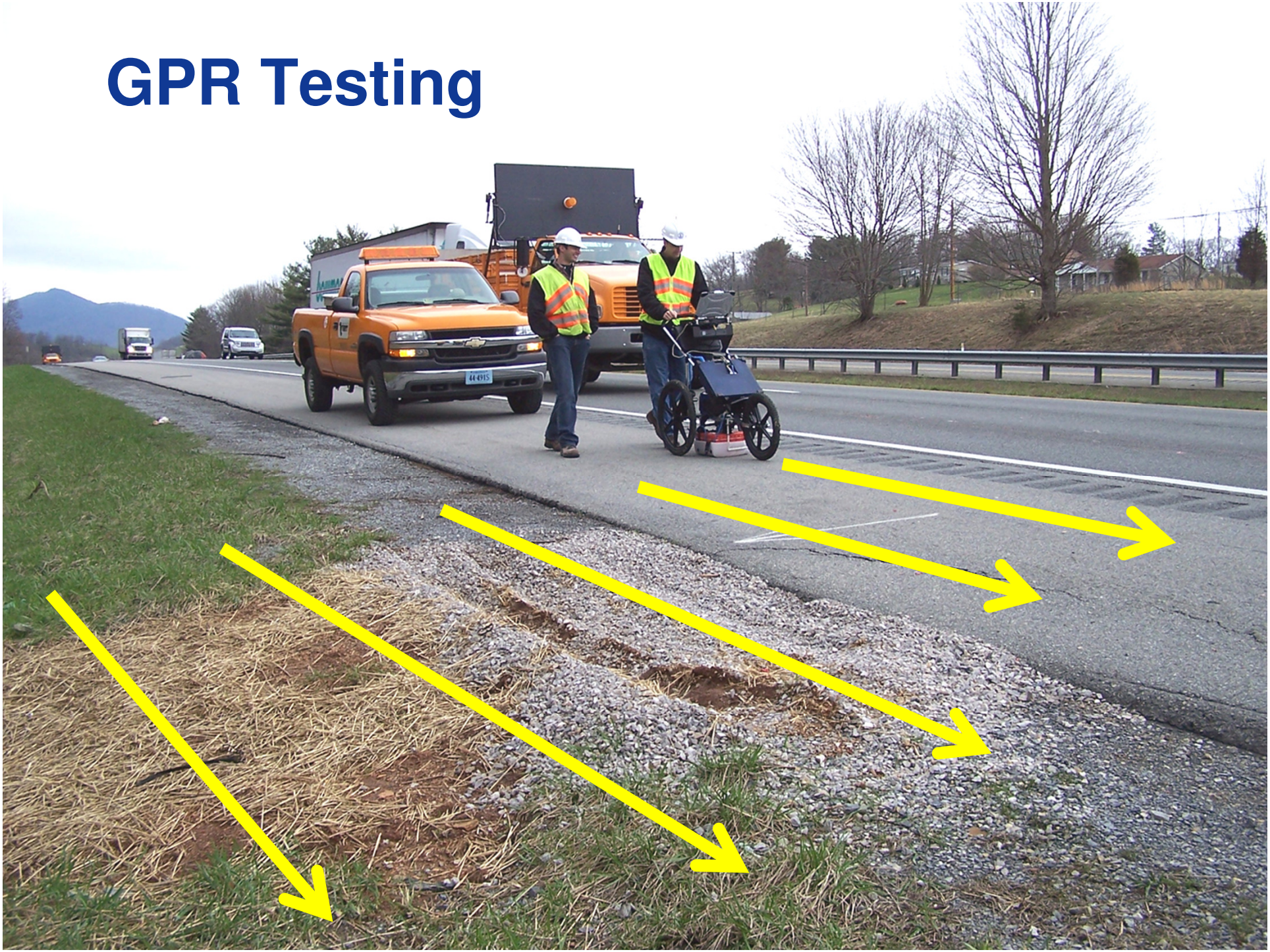
Laptop

GSSI SIR-20 Controller Unit

Antenna Cart

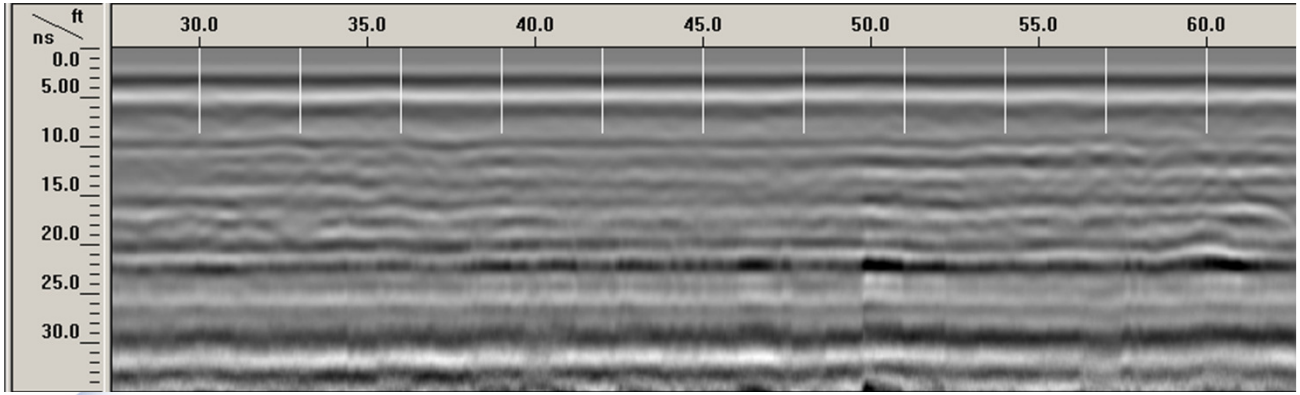
400MHz Antenna

GPR Testing

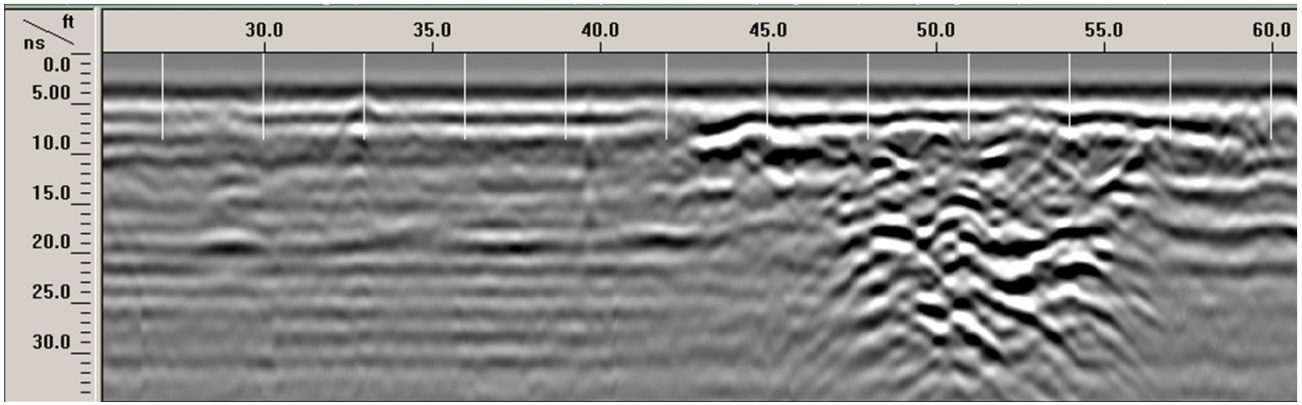


Site 1: I-581 NB

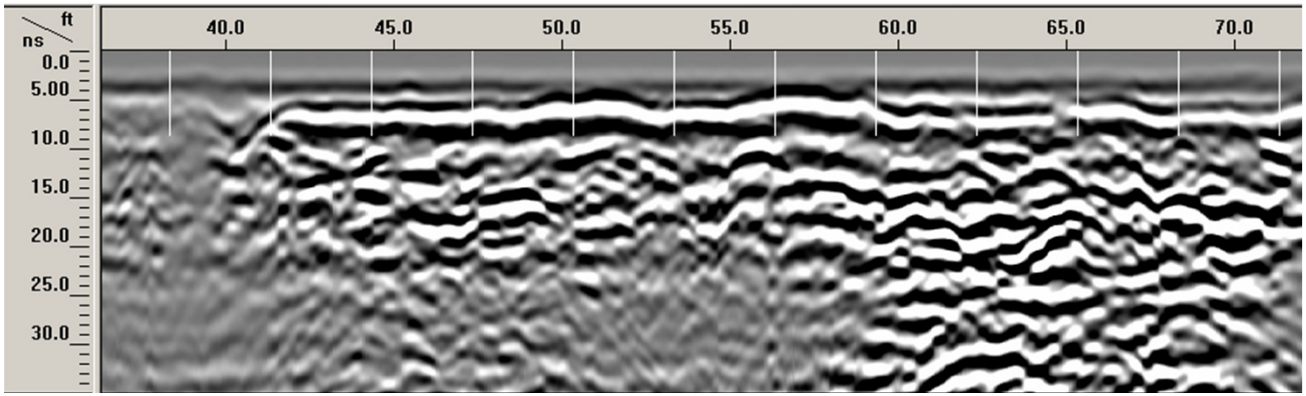
Site 1: Results



Right paved shoulder



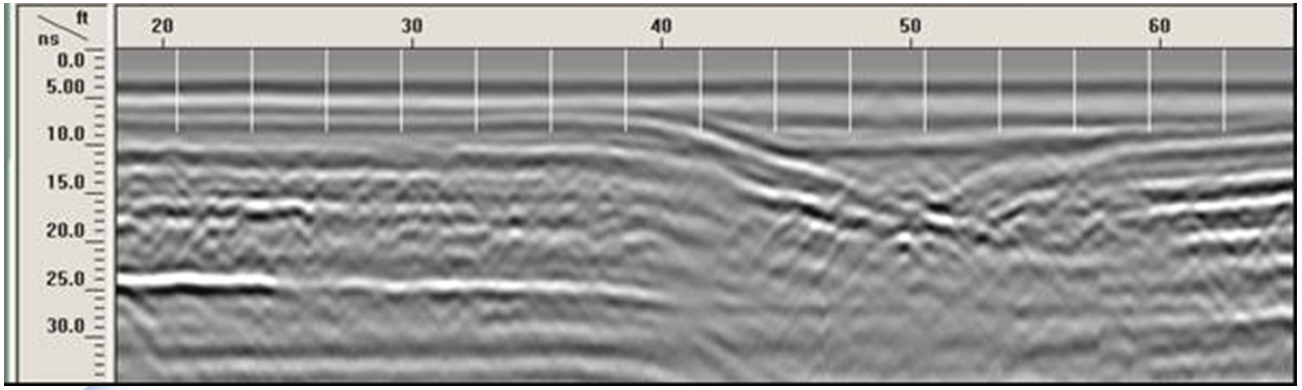
Right grassy shoulder



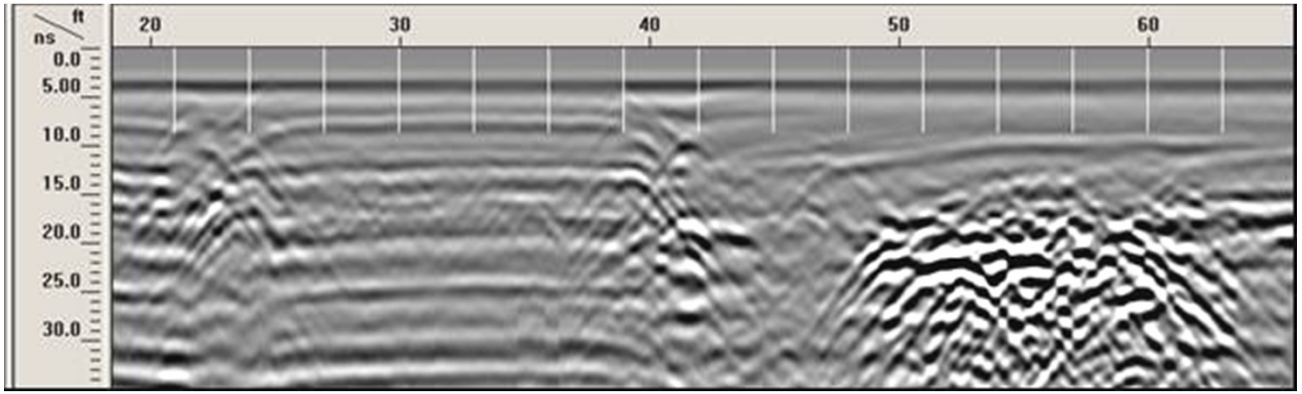
Right grassy shoulder (near ditch)


Site 2: I-81 SB
MAR 23 2010

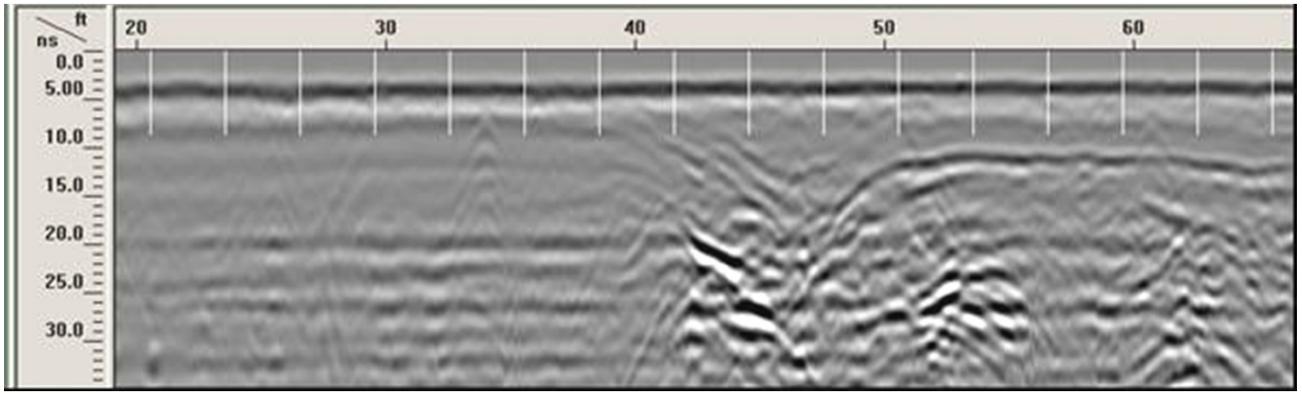
Site 2: Results



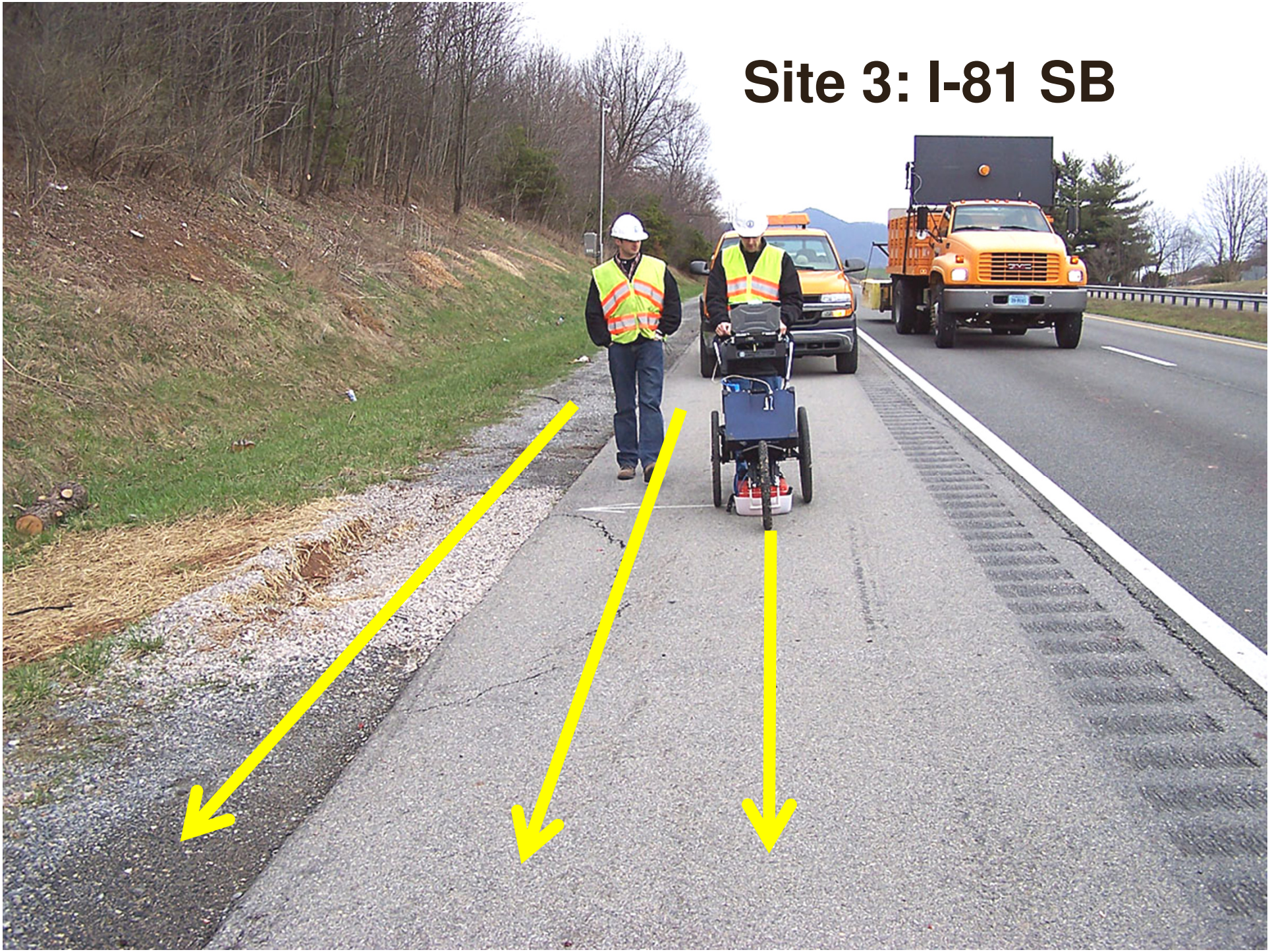
Left side of right paved shoulder



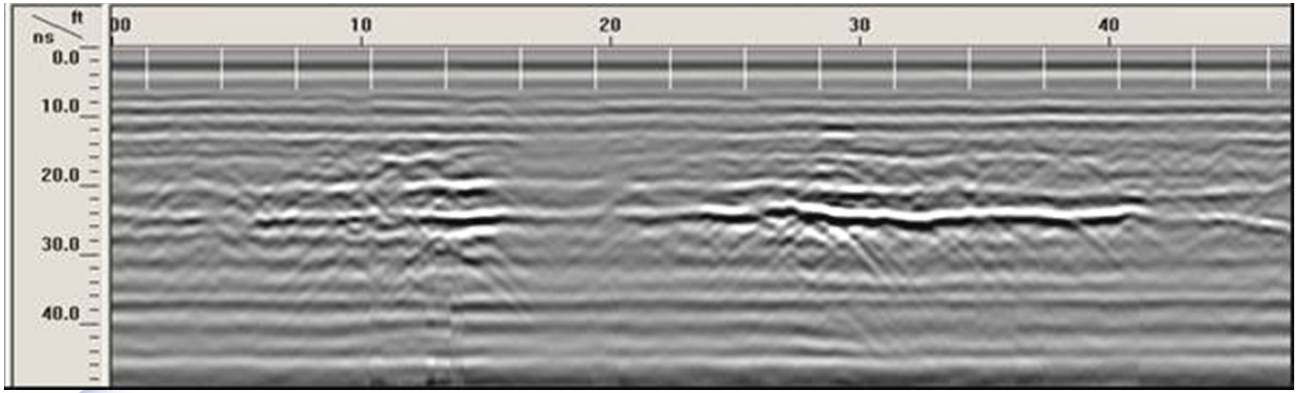
Right side of right paved shoulder



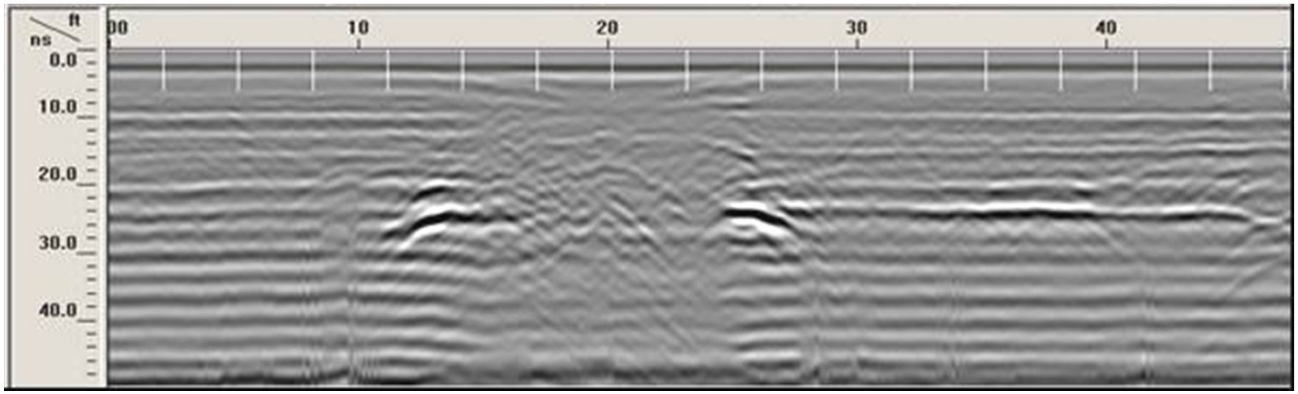
Just off right paved shoulder


Site 3: I-81 SB

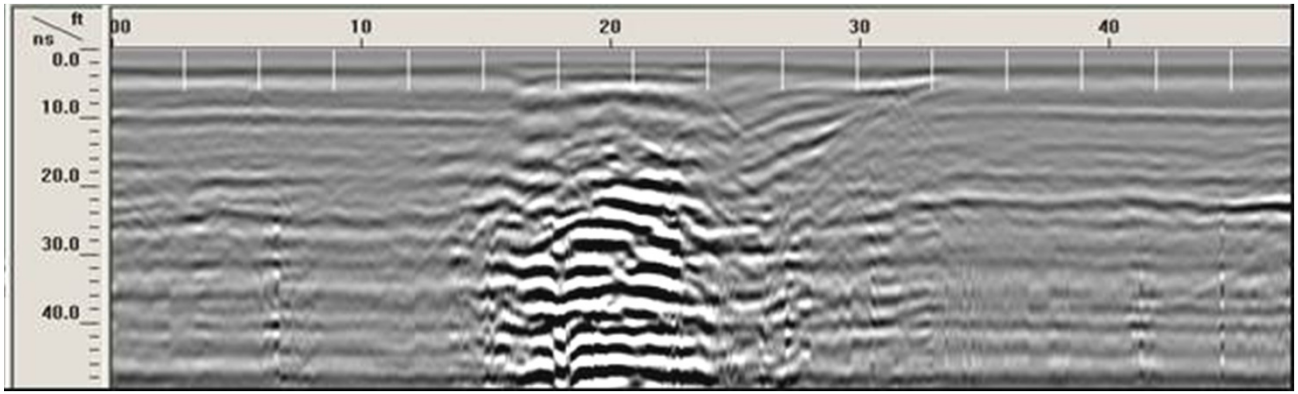
Site 3: Results



Middle of right paved shoulder



Right side of right paved shoulder



Just off right paved shoulder

Summary & Recommendations

- GPR used to identify potential voided areas
  - Identified features beneath paved roadway
  - Adjacent to known voided areas on shoulder

- Future steps
  - Are identified features newly formed voids or results of previous repairs?
  - Vertical extent of identified areas
  - Structural capacity testing by FWD

Thank you!

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