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Subsurface Void Detection for the Foundation Performance Association

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Causes of subsurface voids

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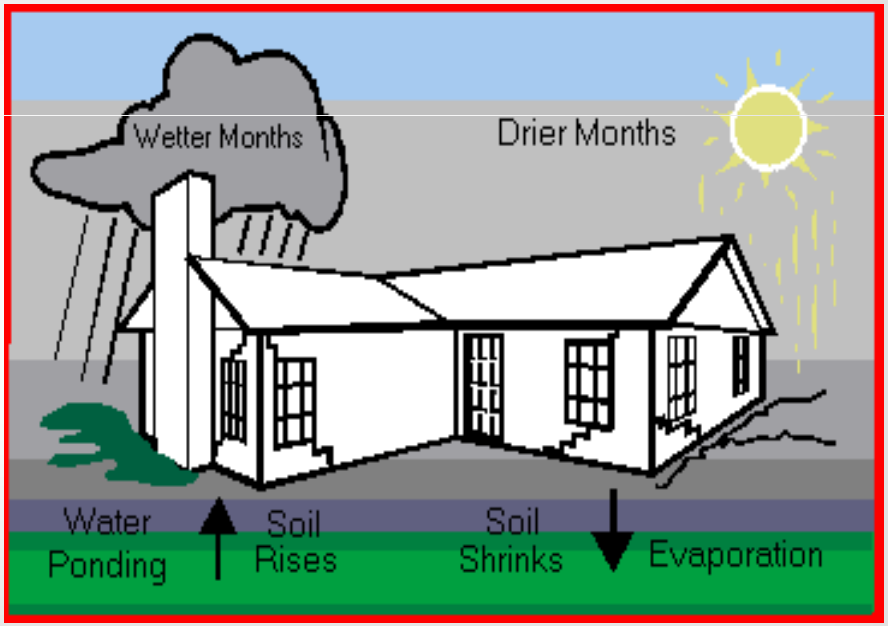
Causes of subsurface voids

- Expansive soils



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Causes of subsurface voids

- Poor drainage

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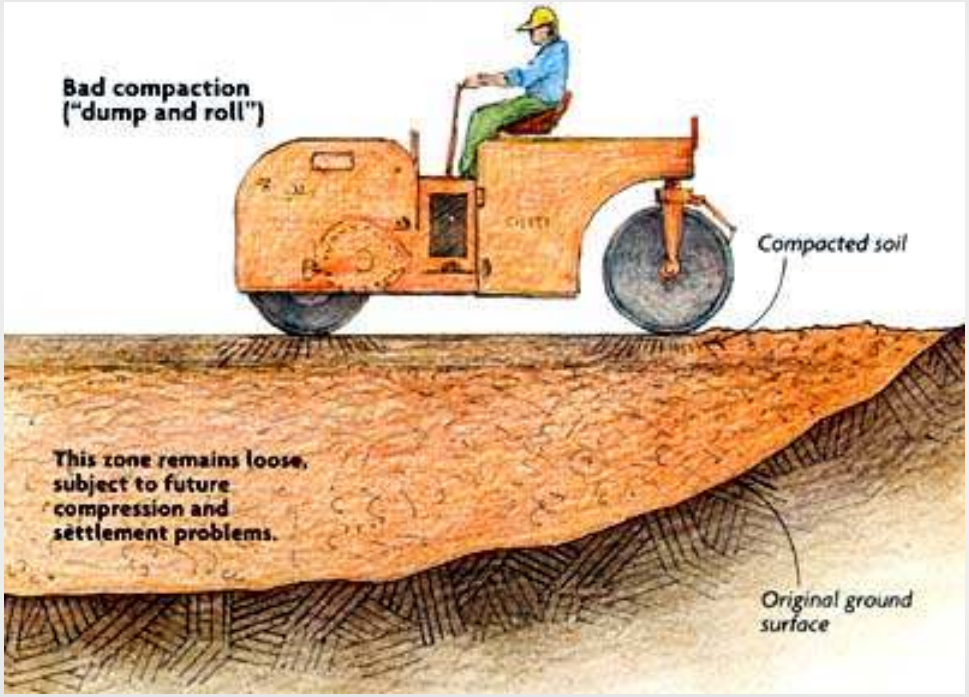
Causes of subsurface voids

- Poor compaction of soil - wrong way



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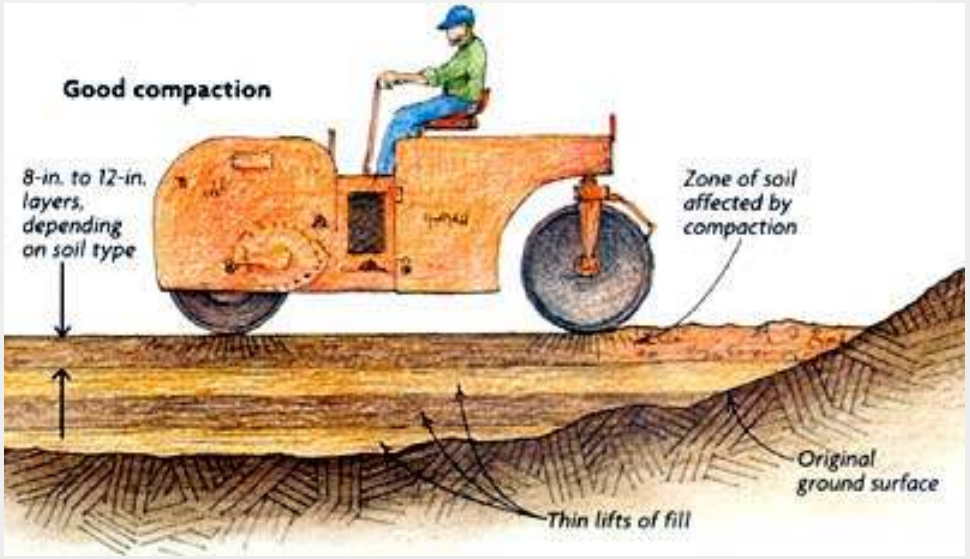
Causes of subsurface voids

- Poor compaction of soil – right way



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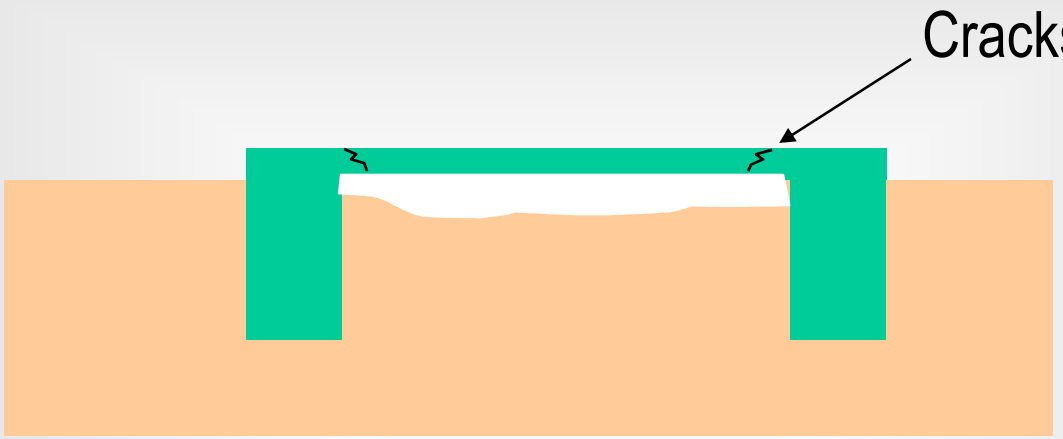
Causes of subsurface voids

- Poor compaction of soil - effect



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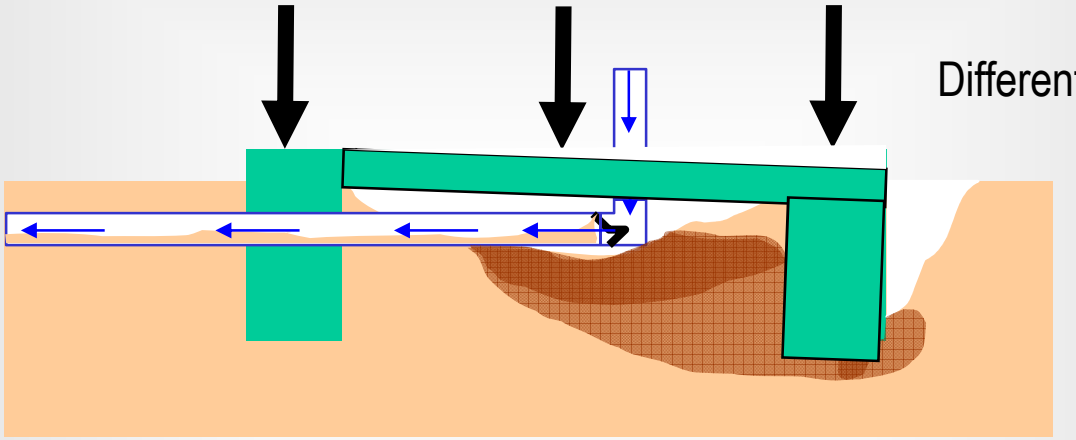
Causes of subsurface voids

- Leaking Utilities / drainage systems



Differential Settlement

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Causes of subsurface voids

- Leaking Utilities / drainage systems

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Causes of subsurface voids

- Leaking Utilities / drainage systems

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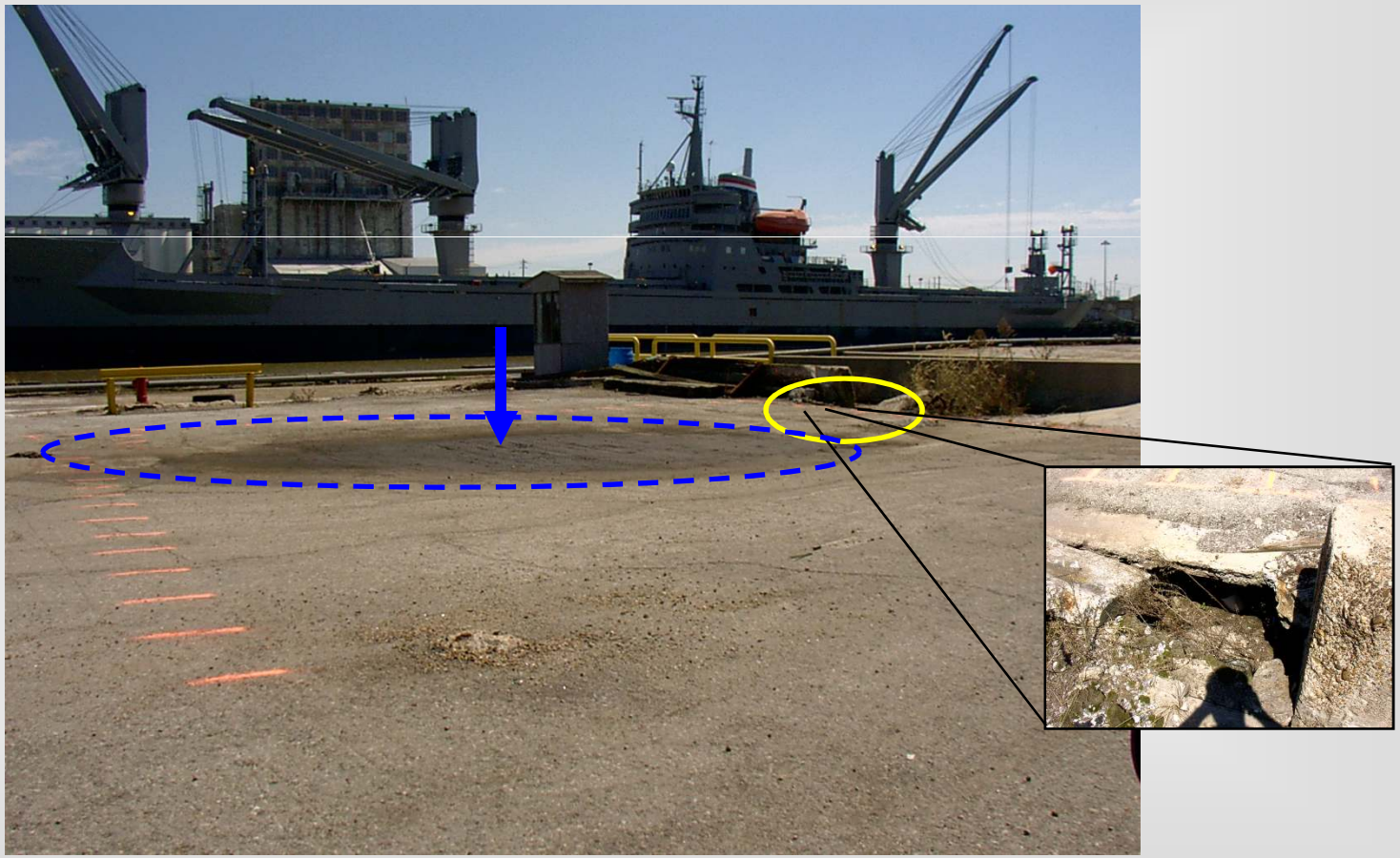
Causes of subsurface voids

- Leaking Utilities / drainage systems



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Detection Methods

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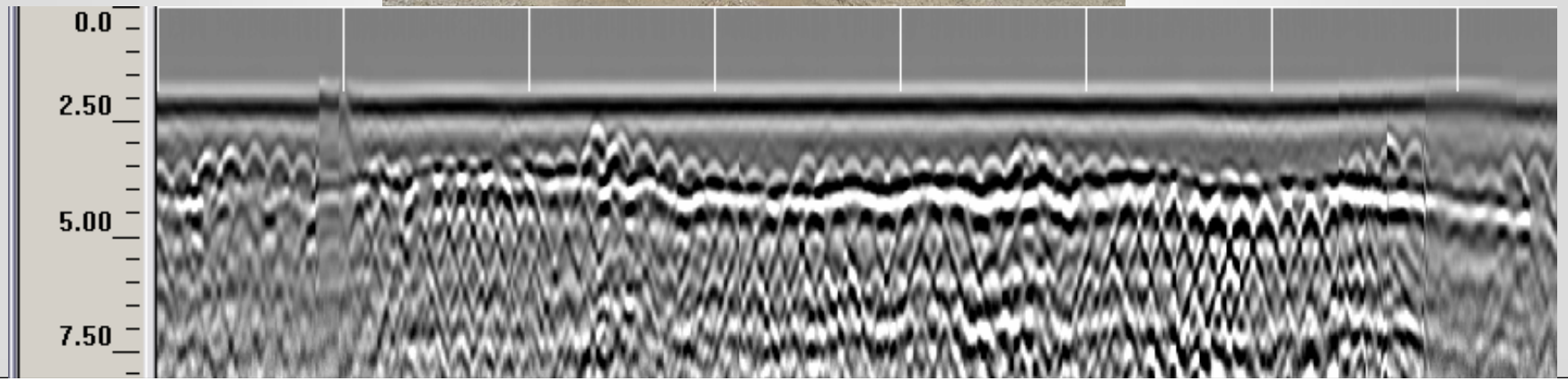
Detection Methods

- Ground Penetrating Radar (GPR)



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Detection Methods

Introduction to GPR

- Early usage: Austria 1929, Military 1950's
- 1st commercial system developed in the early 1970's for use in Geotechnical applications
- Advanced 3D Software developed in the late 1990's
- Uses Electromagnetic Wave Propagation to measure changes in electrical and magnetic properties
- Allows Non-Intrusive look into or through low-conductivity materials
- Used in Geophysical, Structural, Civil, and other industries

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Detection Methods

Two electrical properties of importance to GPR surveys

- Electrical Conductivity – effects penetration
- Electrical Permittivity “Dielectric Constant” – effects the reflected signal strength

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Detection Methods

Forms of GPR

- Single and two-channel systems are most commonly used for foundations, bridges, buildings, short road sections
- Multi-channel and phased array systems are used for high speed long sections of highways

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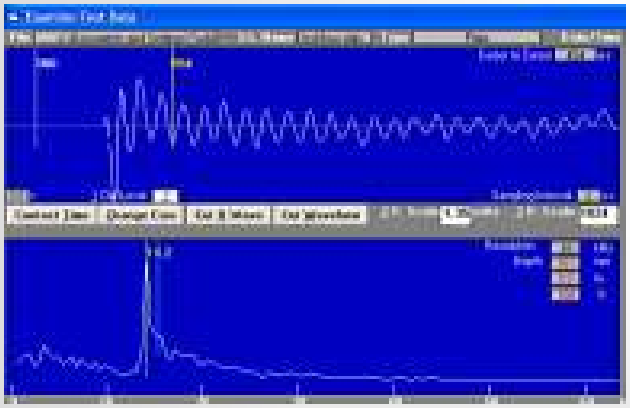
Detection Methods

- Impact-Echo



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Detection Methods

Introduction to Impact-Echo

- Research began as early as 1983 at the National Bureau of Standards (NBS) now known as National Institute of Standards and Technologies (NIST)
- The first thesis research was performed at NIST and accepted in 1986 by Cornell University
- 1st commercial system was available in 1992
- Uses Impact-generated stress waves that propagate through a concrete and masonry structures
- Used in Structural, Civil, and other industries

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Detection Methods

Impact-Echo

- Stress (sound) waves that propagate through concrete and masonry are reflected by internal flaws and external surfaces
- Primarily used to determine defects in concrete structures. It can also locate voids in the subgrade directly beneath slabs and pavements.
- Accurate method, but slower than GPR for voids surveys

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Detection Methods

Core Drilling

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Detection Methods

Core Drilling

- Core Drilling – effective to verify a suspect location but would require many holes in order to “Survey” an area for voids.
- Will not give a true indication of the void size in sq. ft.
- Destructive – effects aesthetics, carpet, flooring, cuts PT cables, rebar & utilities

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Detection Methods

Order of use:

1. Void survey: GPR
   - Used to quickly screen larges areas, providing an accurate plan view map of voids as well as determine the depth
2. Localized prove-up:
   - Core Drilling

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Other Detection Methods

Dynamic Cone Penetrometer – works reasonably well, however it is labor intensive and inefficient. ASTM STP-399

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Detection Methods

Proof of concept demonstration

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Detection Methods

Warehouse floor

- **Heavy trucks cracking the slab**
- **Proof of concept void detection and sizing**
- **NDE technologies:**
  - **GPR**
  - **Laser Elevation survey**

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Detection Methods

Slab failure near exterior grade beam due a large void.

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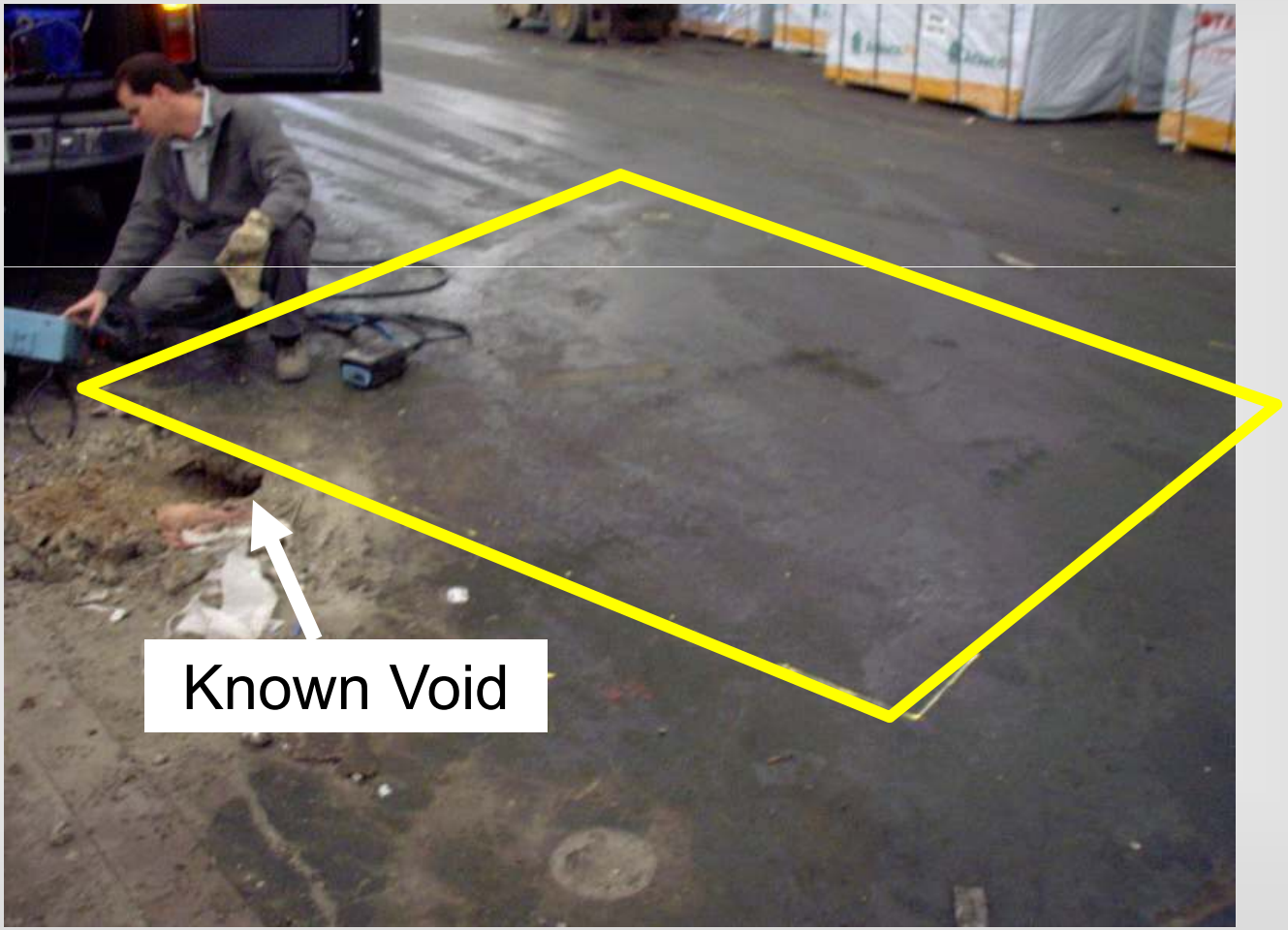
Detection Methods

Scan Area



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Detection Methods

Known Void vertical depth:

Approximately 3” as measured

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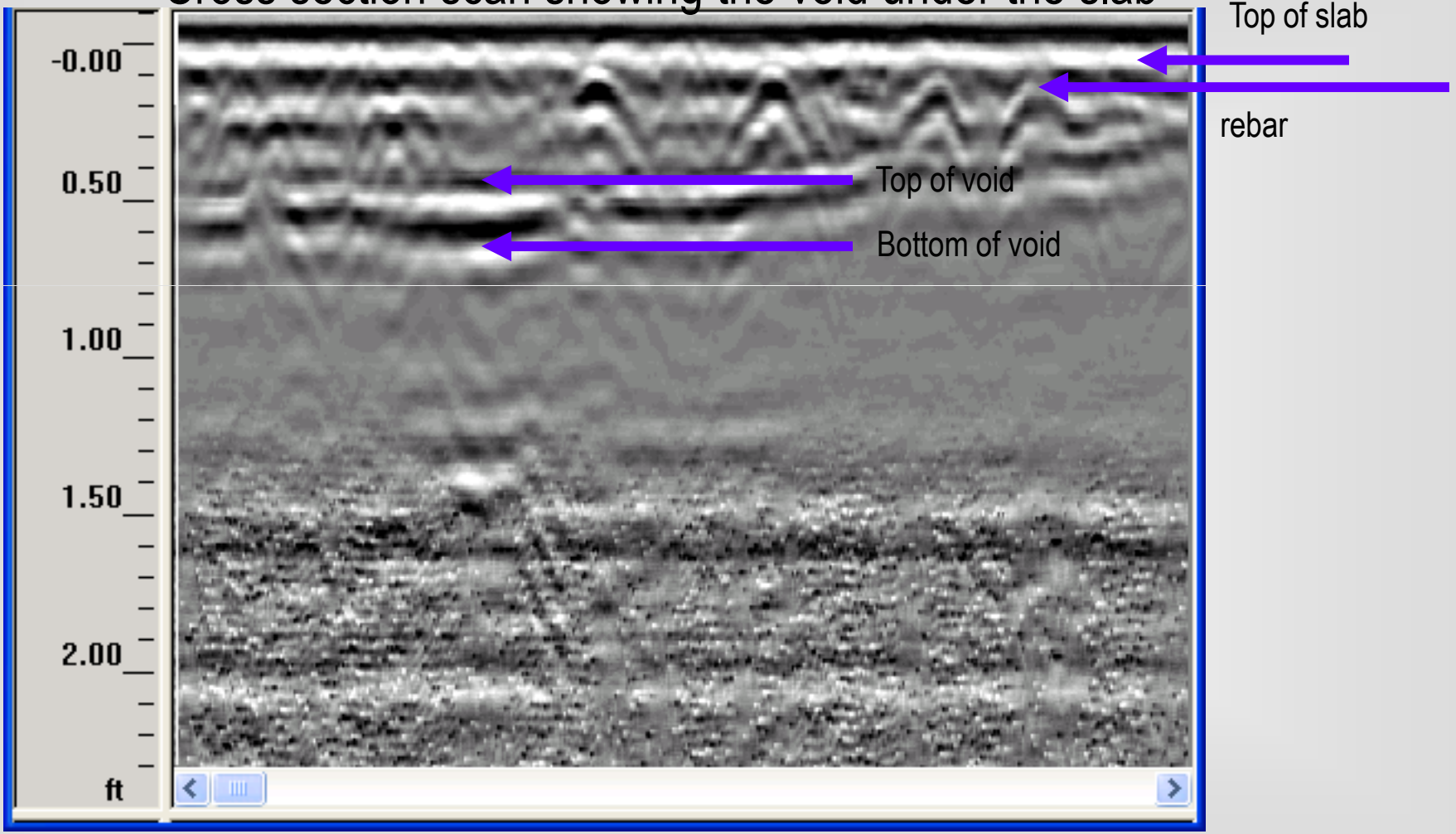
Detection Methods

Cross section scan showing the void under the slab



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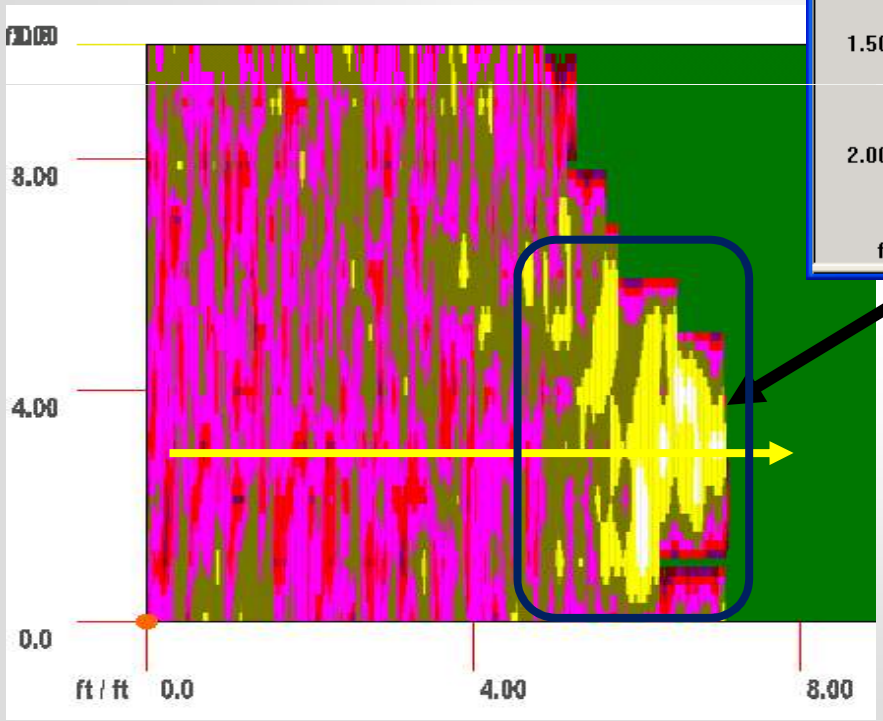
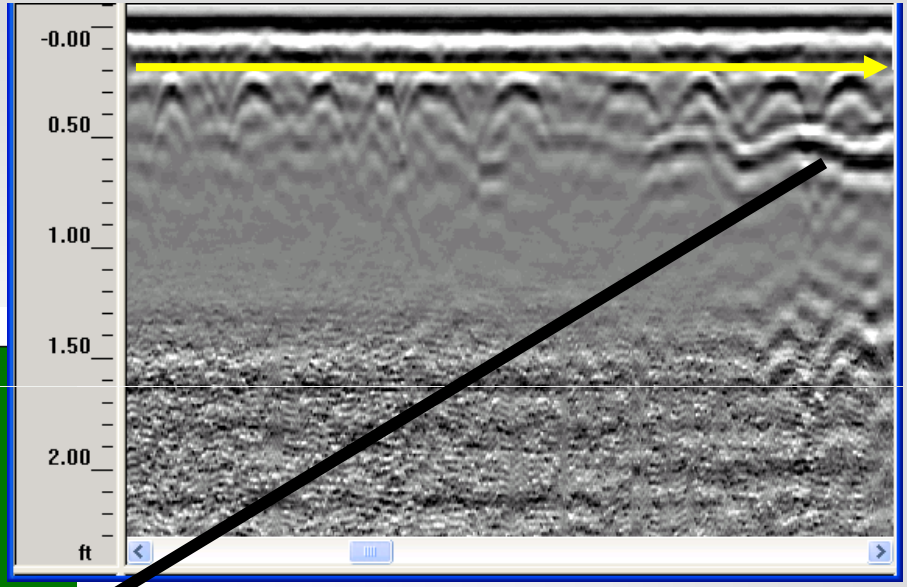
Detection Methods

Cross section scans merged into plan view to show the void.





Yellow arrows indicate scan direction

Dark blue outline indicates the area of the void

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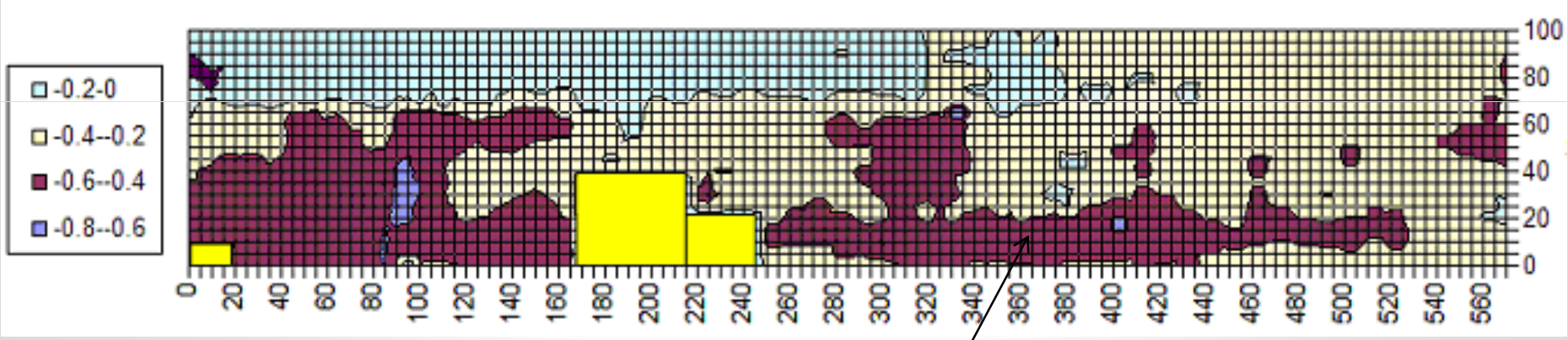
Detection Methods



560’ x 100’ void & elevation survey

Yellow: Offices in the warehouse.

The darker outlines indicate the void area

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Void Repair Options

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Void Repair Options

- Urethane Injection
- Grout Injection
- Mud Jacking

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Void Repair Options

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Void Repair Options

After lifting the slab

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Residential Void Case Study

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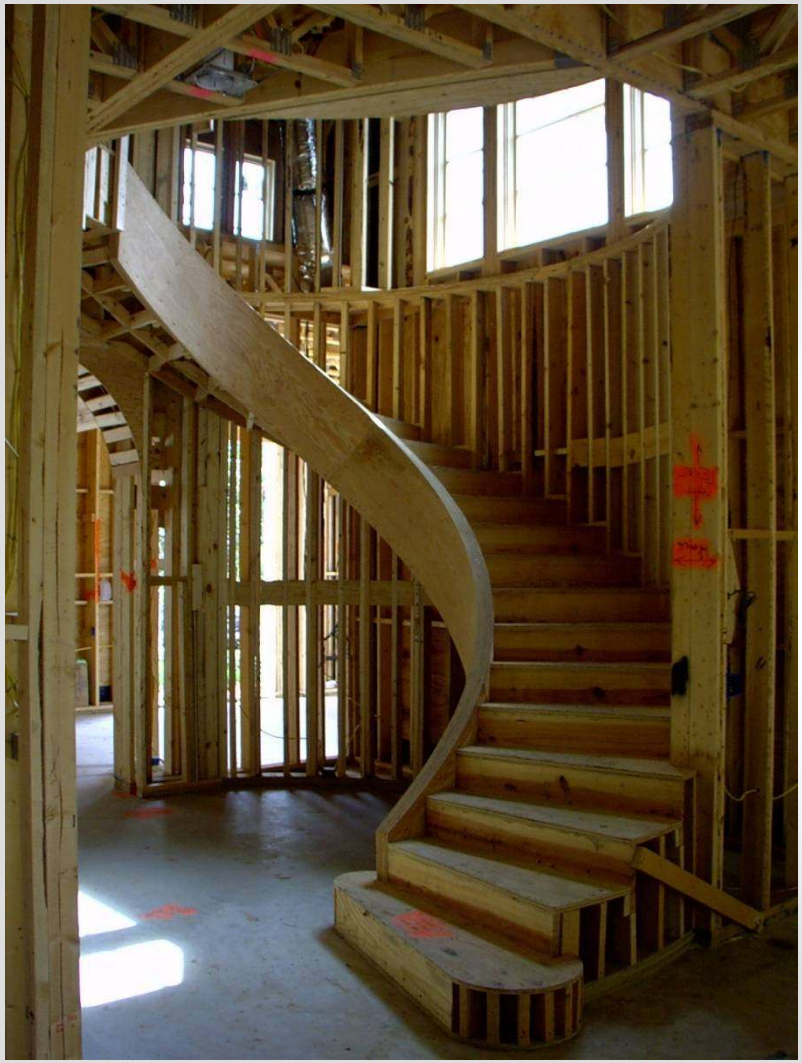
Voids beneath foundation slabs



New construction home

Problem:

Subsidence observed around the foundation perimeter of the study and foyer

Investigate for a possible void under the slab

NDT Technologies

– GPR

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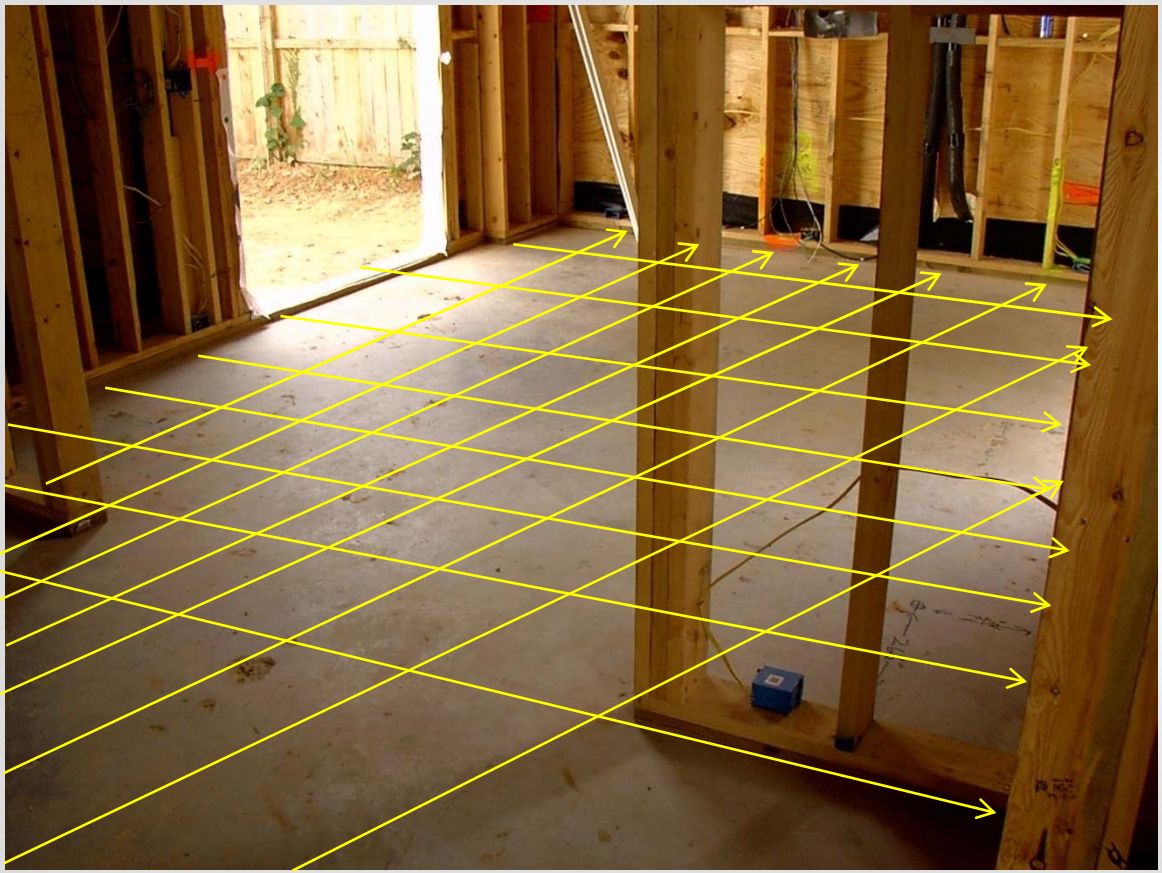
Voids beneath foundation slabs



Study and Foyer were scanned used a 6” grid pattern

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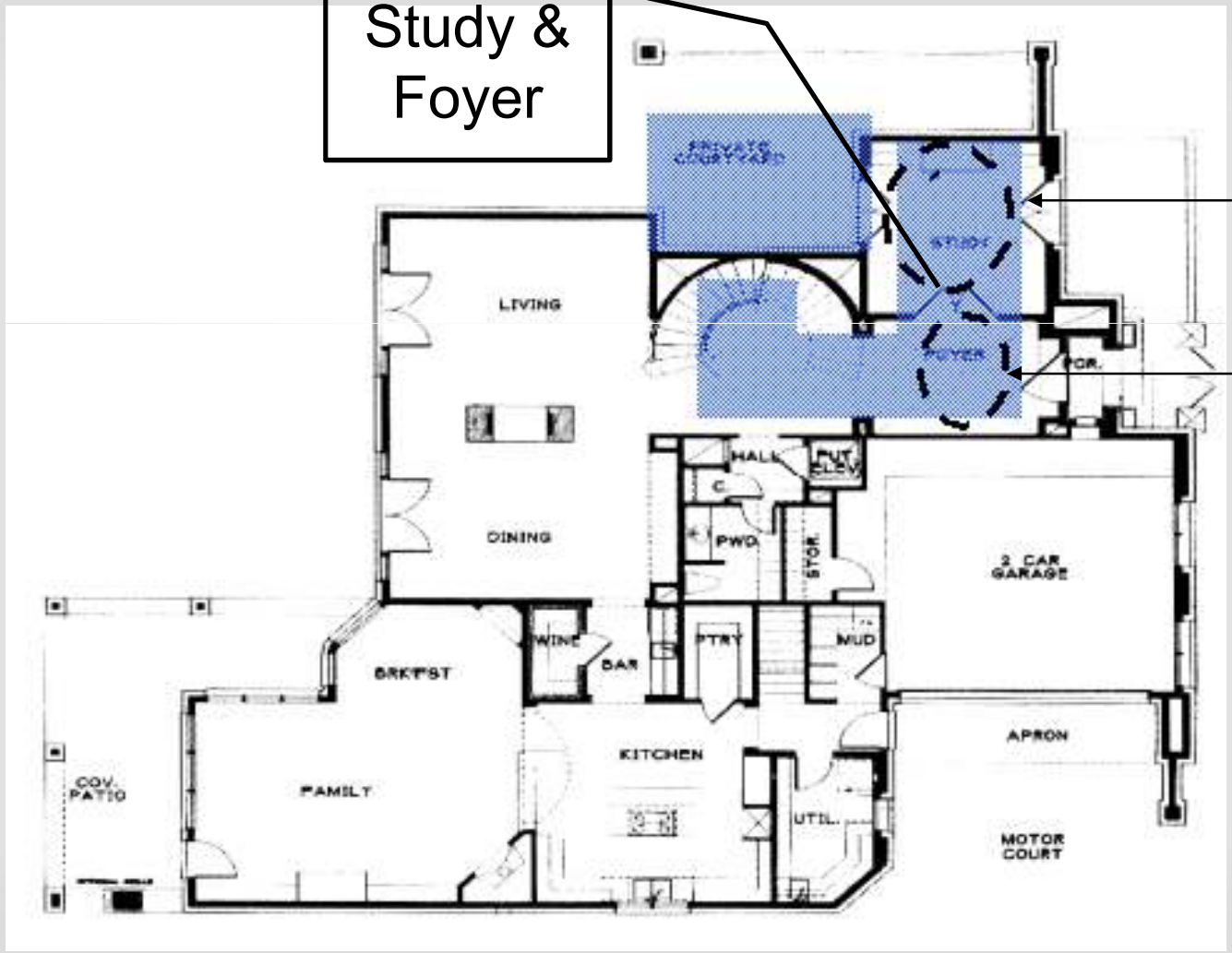
Voids beneath foundation slabs



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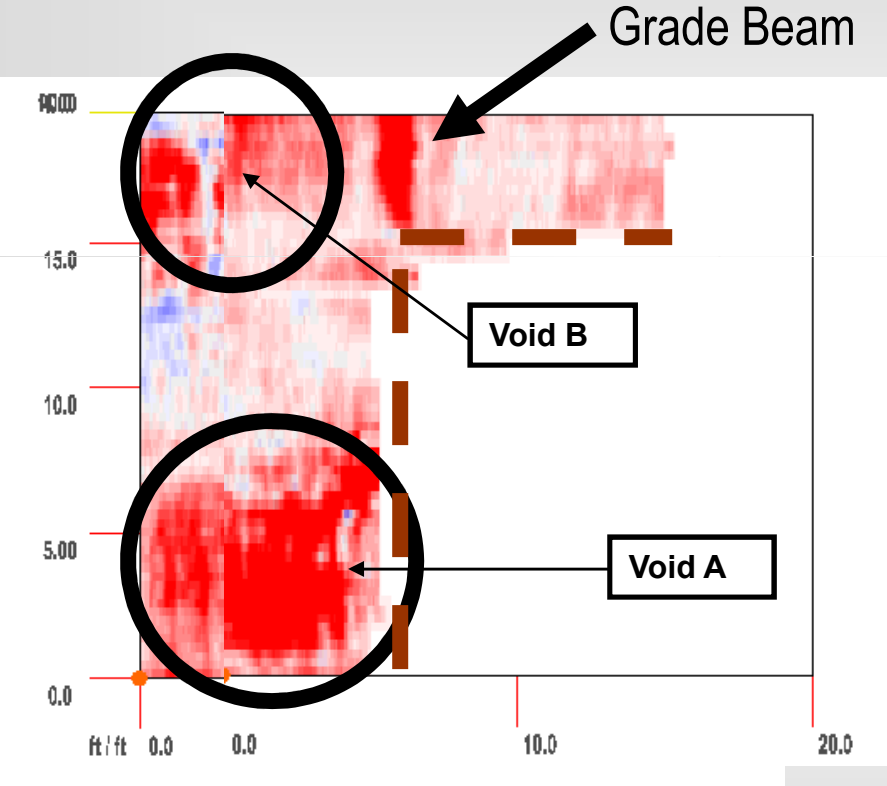
Voids beneath foundation slabs



Voids were found in two locations

Geotechnical Engineering Review
- Determined the cause to be poor compaction of fill

A contractor was mobilized to
- pump flowable fill into the voids

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Voids beneath foundation slabs

Void detection inside a small office/warehouse

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Voids beneath foundation slabs

Problem:

Client observed settlement in the offices and warehouse floor. The visible settlement was about 1-2”.

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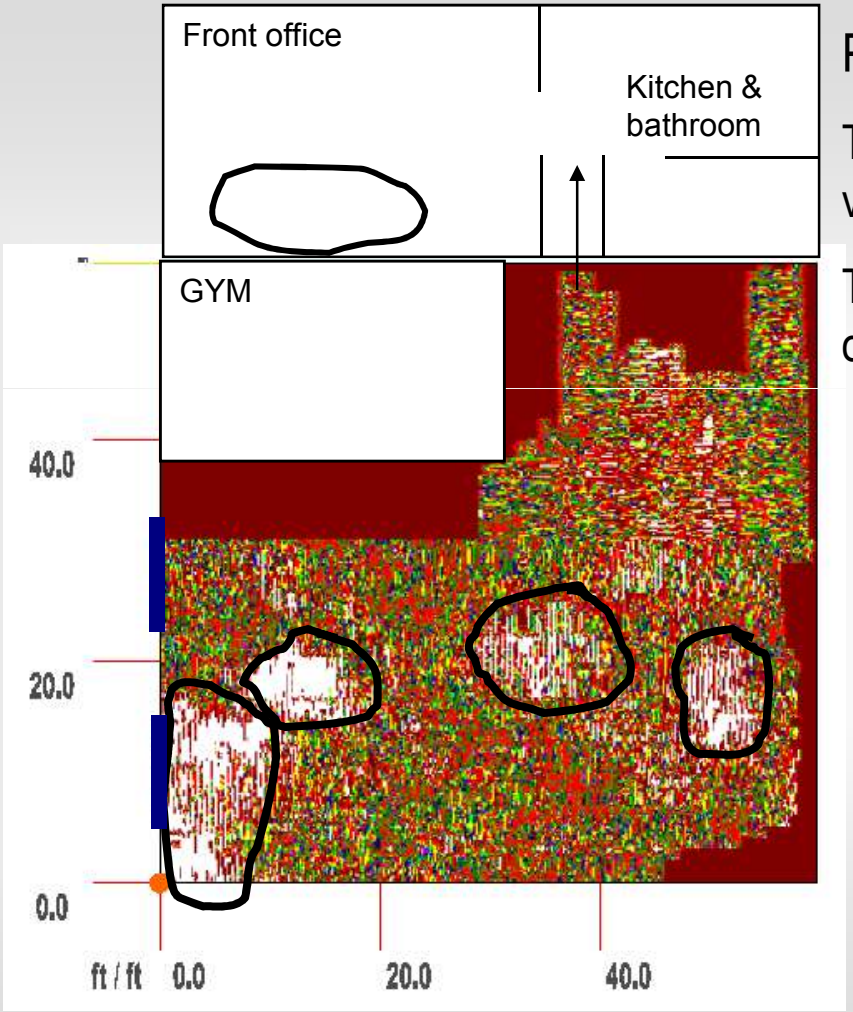
Voids beneath foundation slabs



Problem:

The black outlines indicate the void locations.

The front office void is detailed on the following slide.

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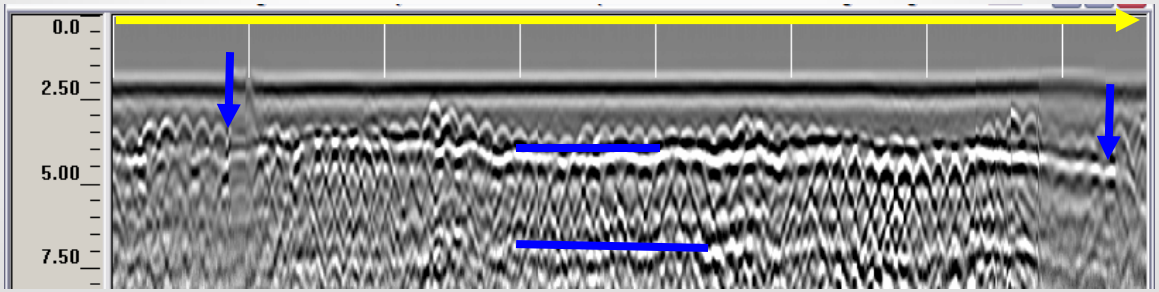
Voids beneath foundation slabs

Front office slab was broken out to verify the void and repair utilities.

Voids are evident throughout the scan (2-3" deep).



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Proposed foundation location for a new industrial control room building.

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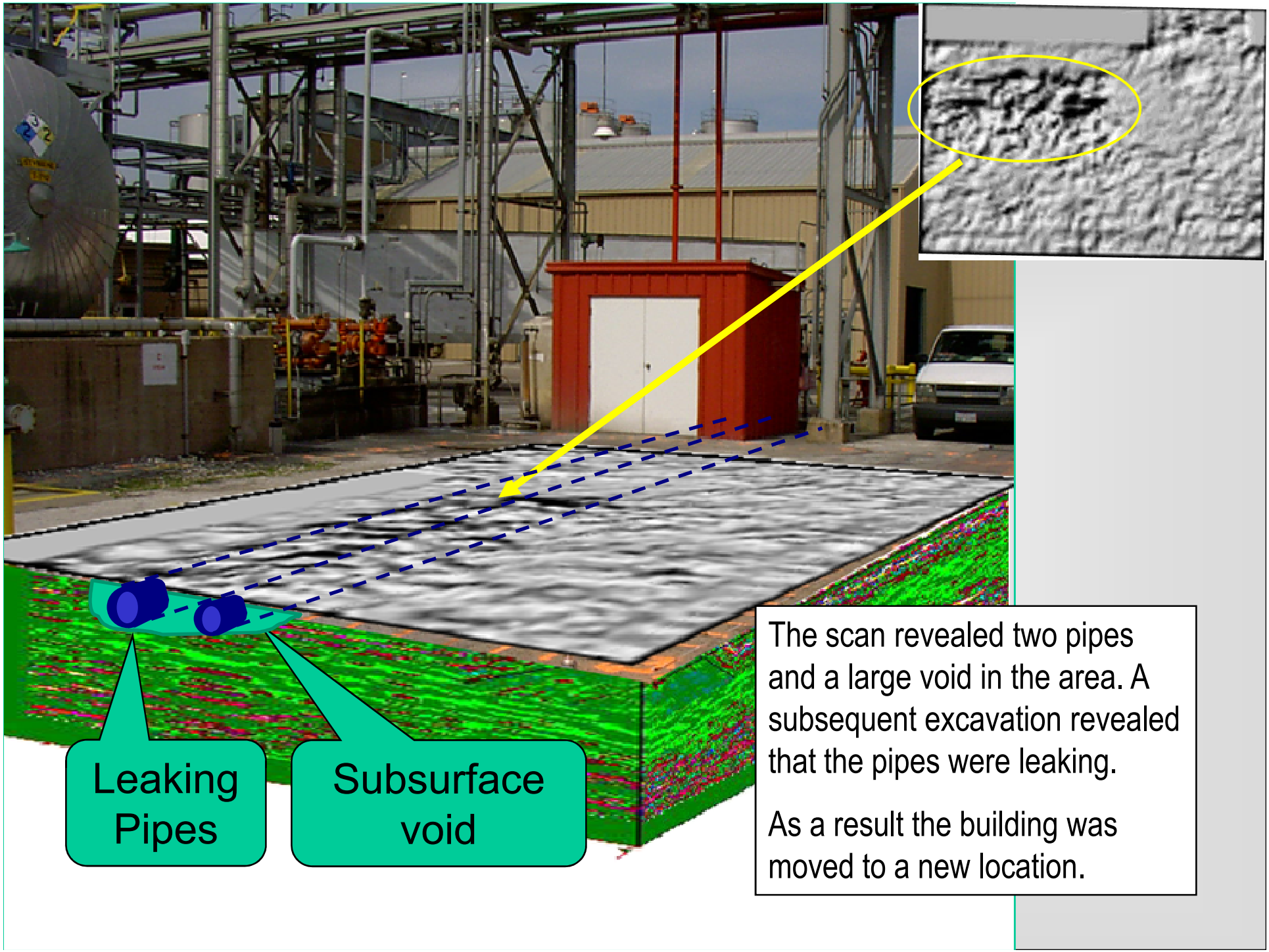
Proposed foundation location

The orange paint outline shows the area to be examined.



The scan revealed two pipes and a large void in the area. A subsequent excavation revealed that the pipes were leaking.

As a result the building was moved to a new location.

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Pavement Evaluation

Effects of voids on pavement

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Pavement Evaluation

Pavement within an industrial facility

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Pavement Evaluation

The area to be examined is outlined above.

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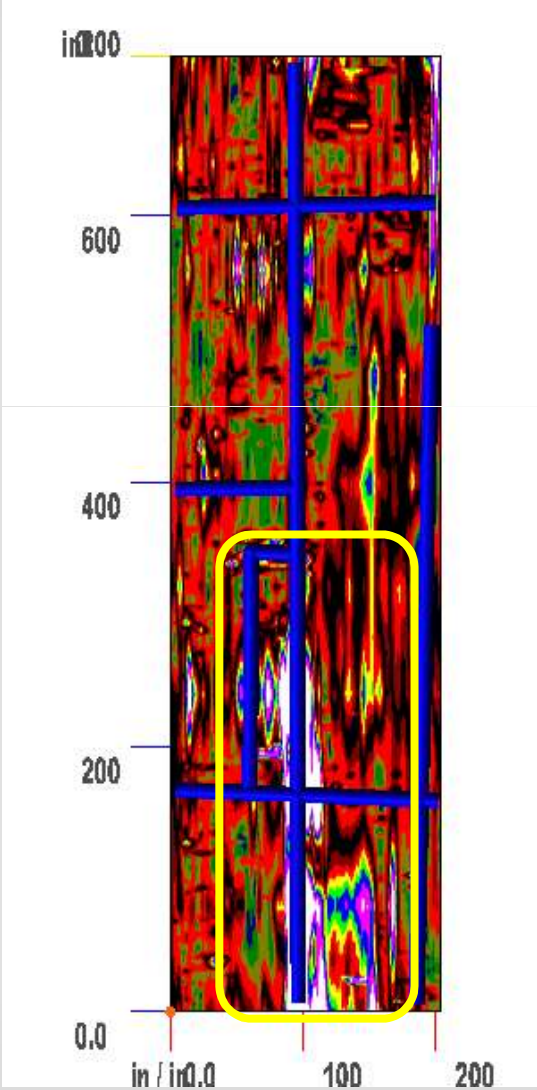
Pavement Evaluation



The image to the left shows pipes detected as well as a leaking connection and void.

The void and saturated soil from the leak are outlined in yellow.

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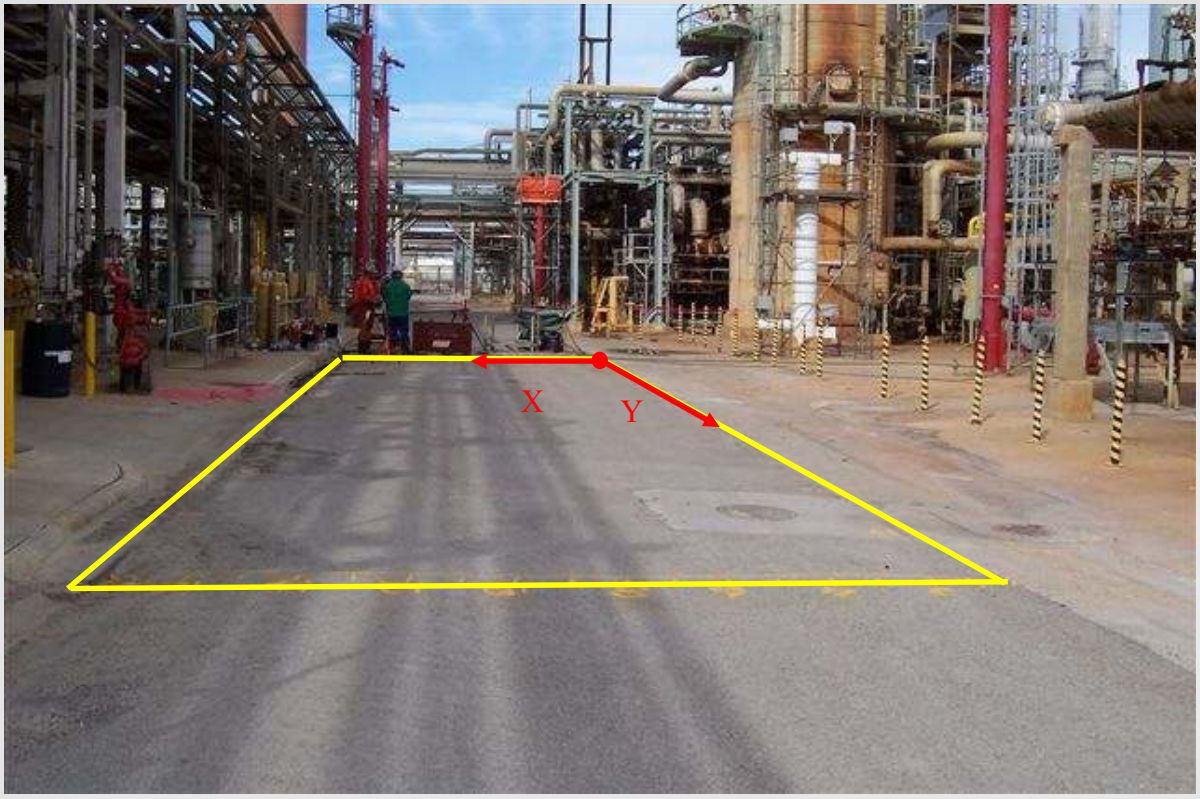
Pavement Evaluation



The area to be examined is outlined above.

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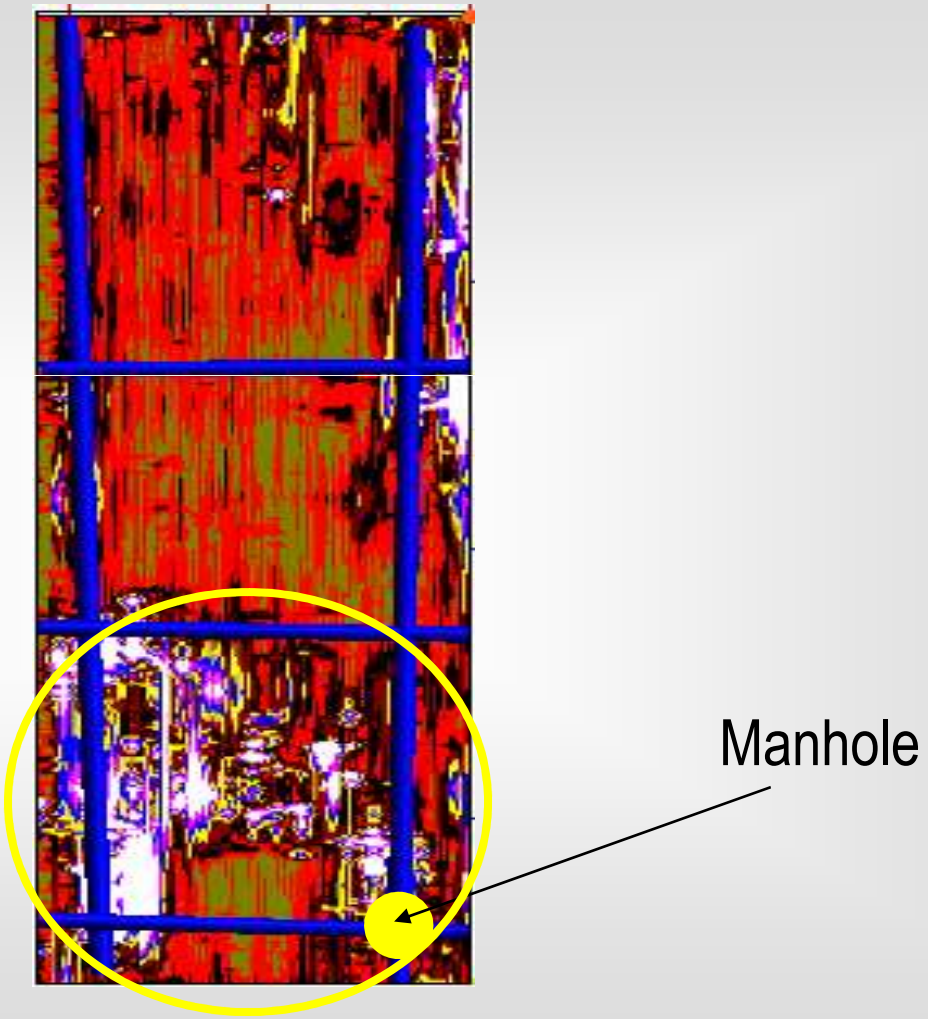
Pavement Evaluation

The image to the right shows the pipes detected as well as a leaking manhole and void.

The void and saturated soil from the leak are outlined in yellow.



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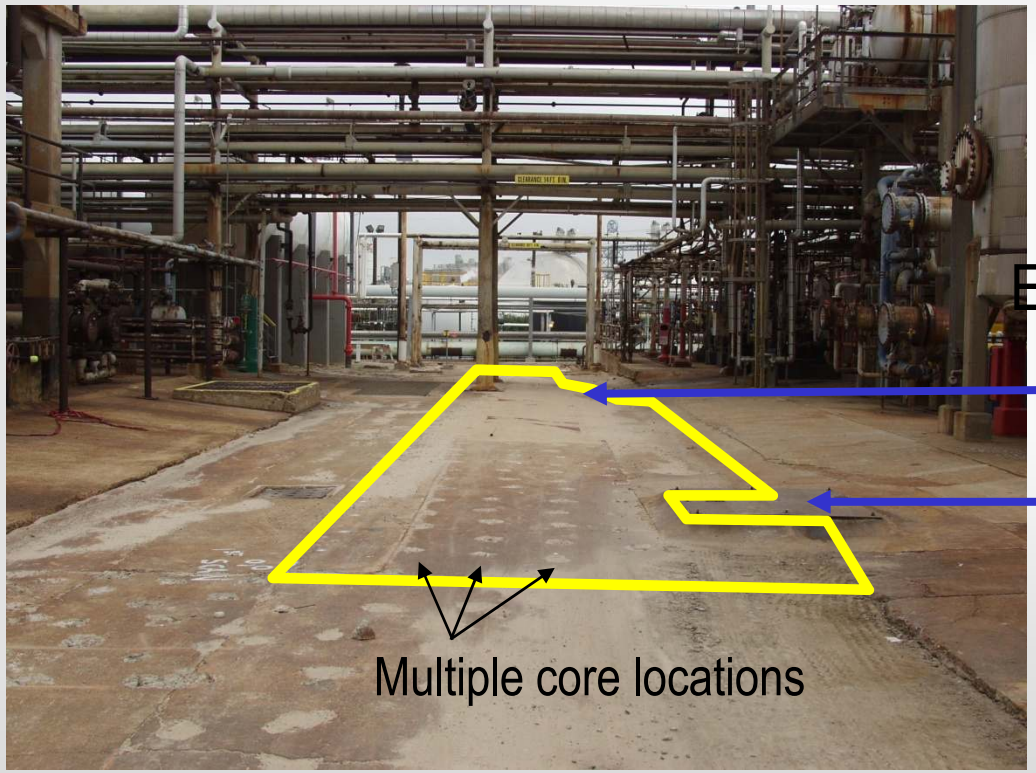
Pavement Evaluation

Problem: Concern about placement of a large crane in the roadway and general vehicular traffic safety due to a pothole. The pothole was the least of the problems. A core sample program was started first and did not find any problems. The client heard about our void imaging services and requested a 2nd look.



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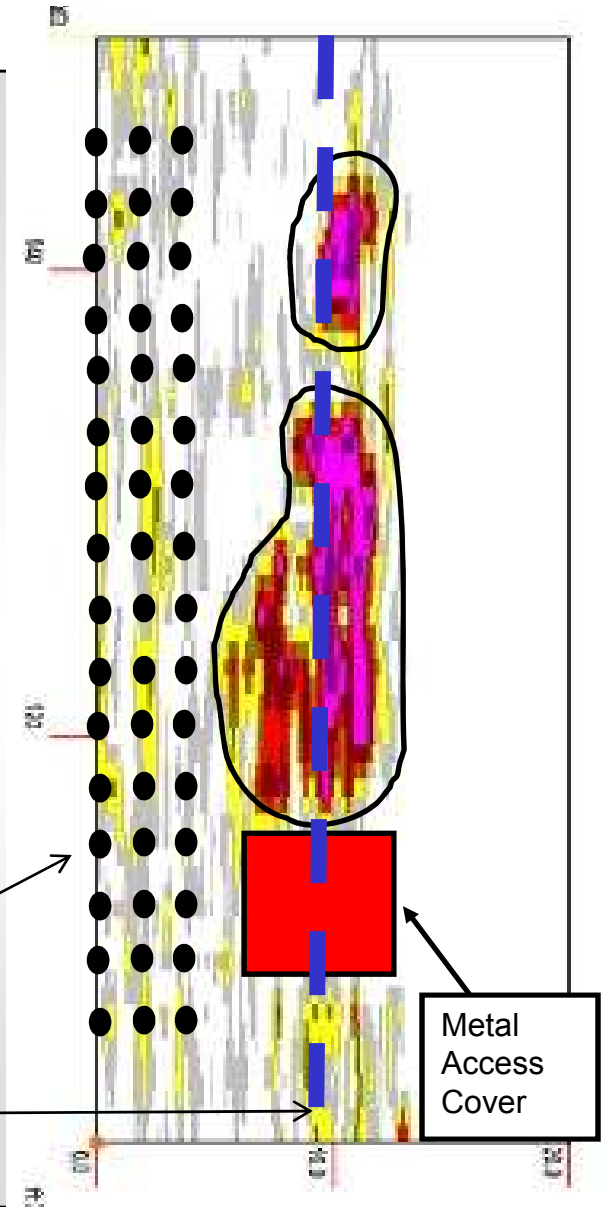
Pavement Evaluation

As evident in the image, the core sample program missed the large voids entirely.

Voids Found

5’ x 2’ x 2’ deep

18’ x 7’ x 2’ deep



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Pavement Evaluation

Settlement of pavement around storage tanks within an industrial facility

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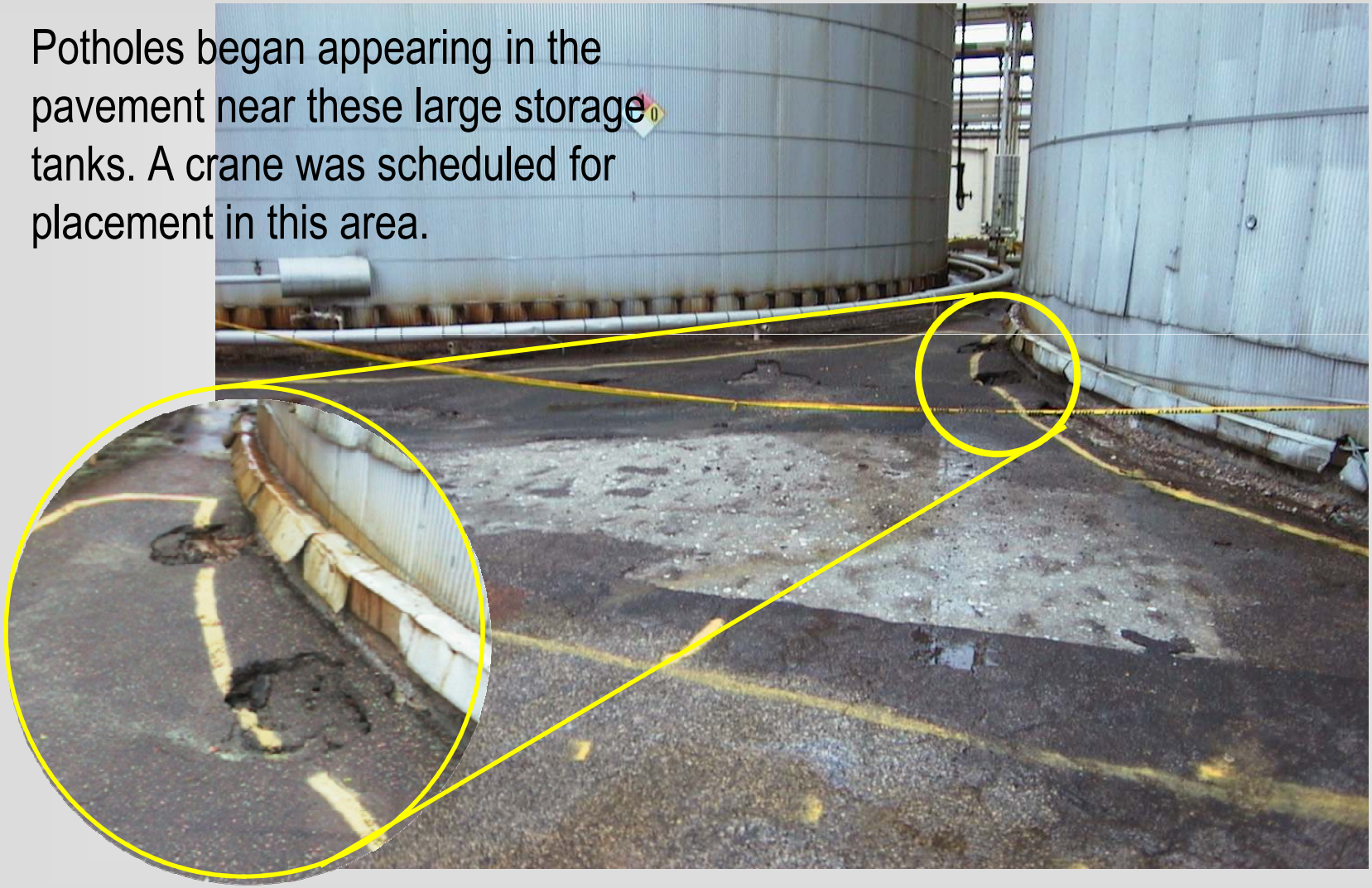
Pavement Evaluation

Potholes began appearing in the pavement near these large storage tanks. A crane was scheduled for placement in this area.



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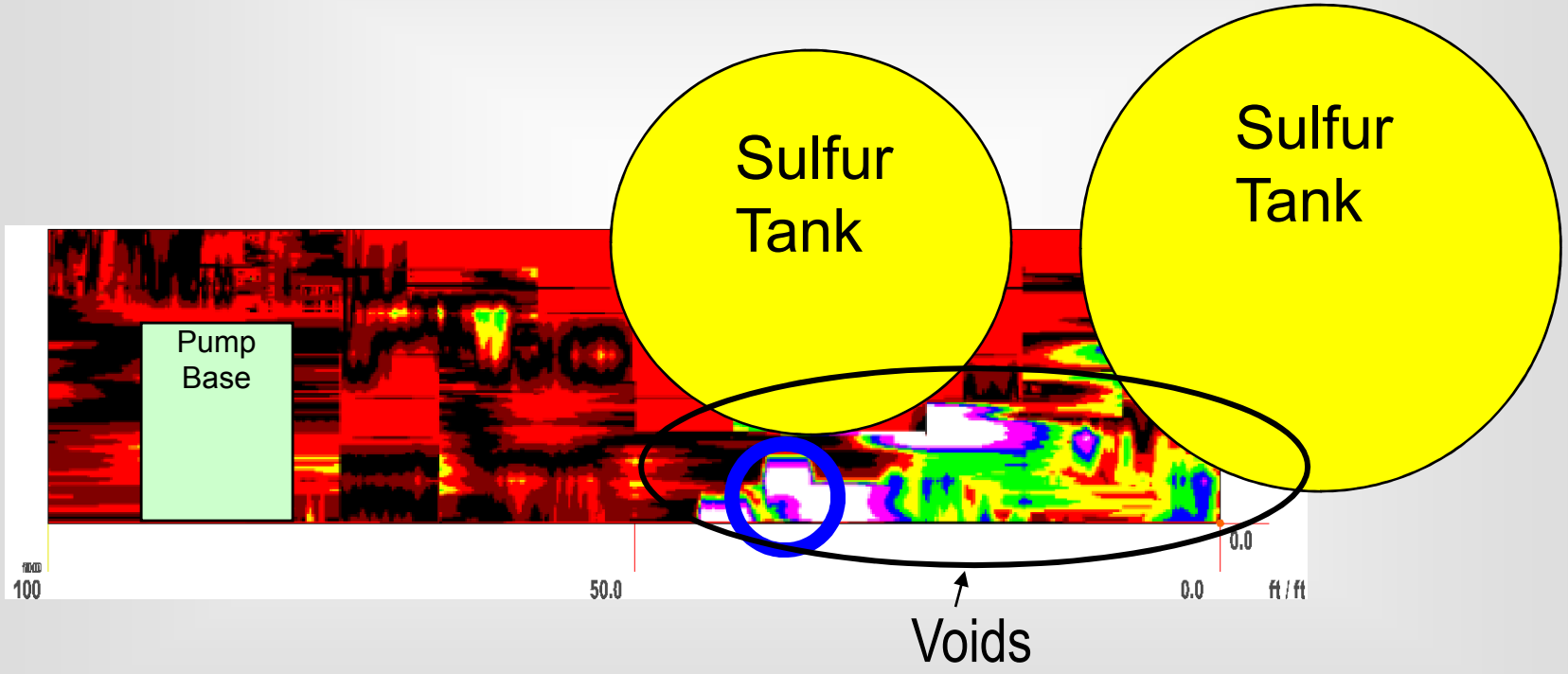
Pavement Evaluation

The outline below shows the intermittent void area detected beneath the pavement. Erosion of soil from a nearby leaking acid cooling tower was the cause.



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Pavement Evaluation

Leaking Cooling Unit eroded the soil underneath the pavement and deteriorated the concrete as well.

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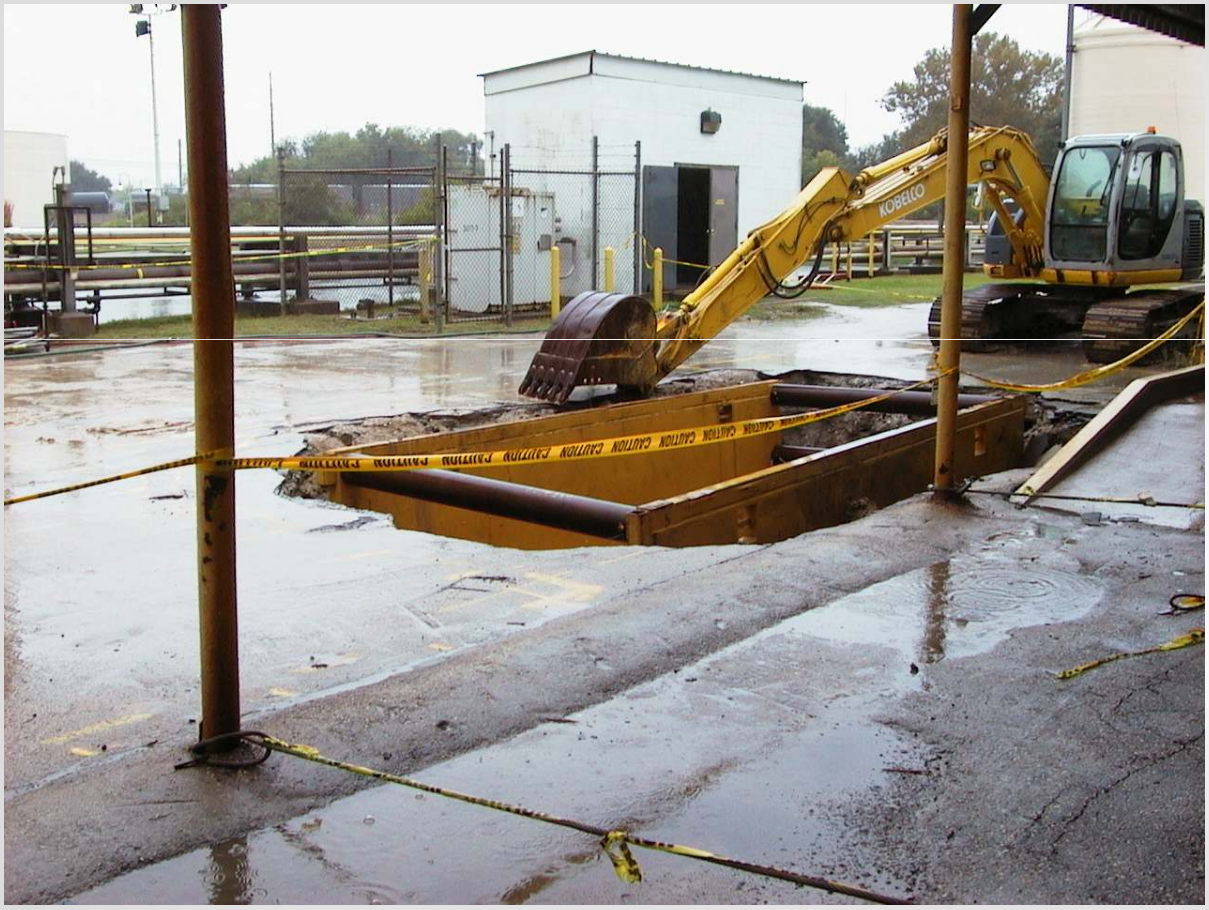
Consequences of unknown voids / sinkholes



- Safety
- Environmental
- Structures

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Consequences of unknown voids / sinkholes

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Consequences of unknown voids / sinkholes

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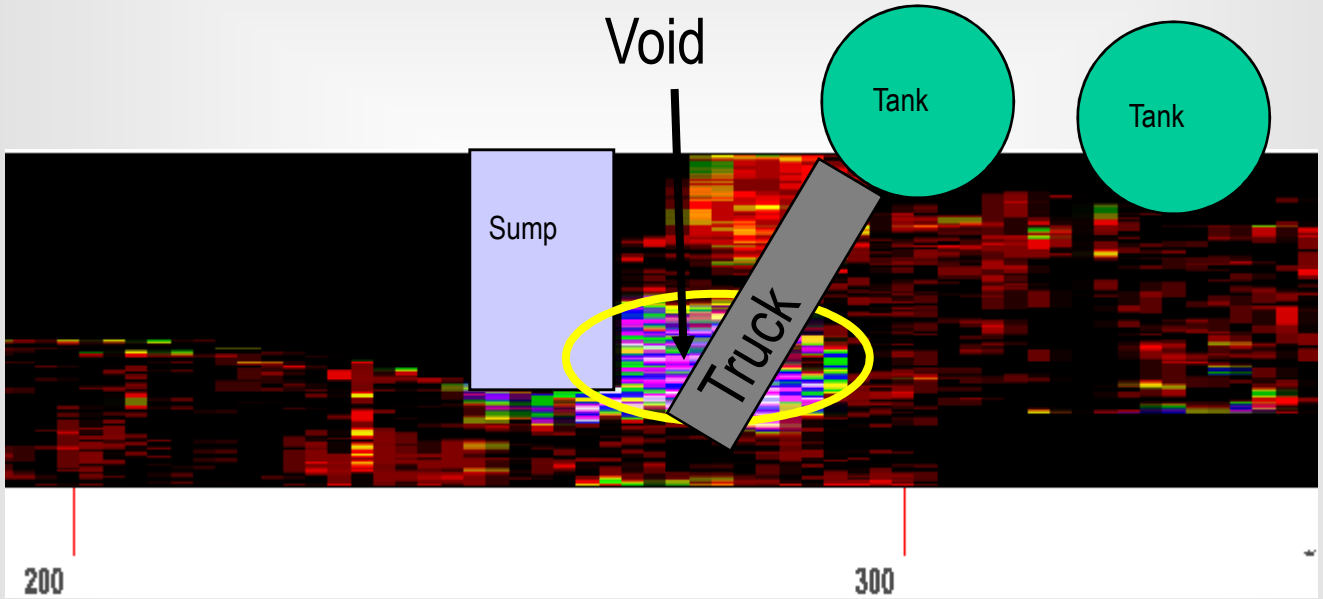
Consequences of unknown voids / sinkholes

The truck that was shown two slides before is outlined below. Another large void was detected where the truck was parked.



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Wharf & bulkhead surveys

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Wharf Surveys / bulkhead walls

This wharf had some visible depressions present and one pothole. The owner had leased the spaced for 3 new cement silos. Concern about the heavy loads prompted a void survey.

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Wharf Surveys / bulkhead walls

Pot holes tell you that a larger problem may exist below ground.
Note the heavy truck traffic in the area.

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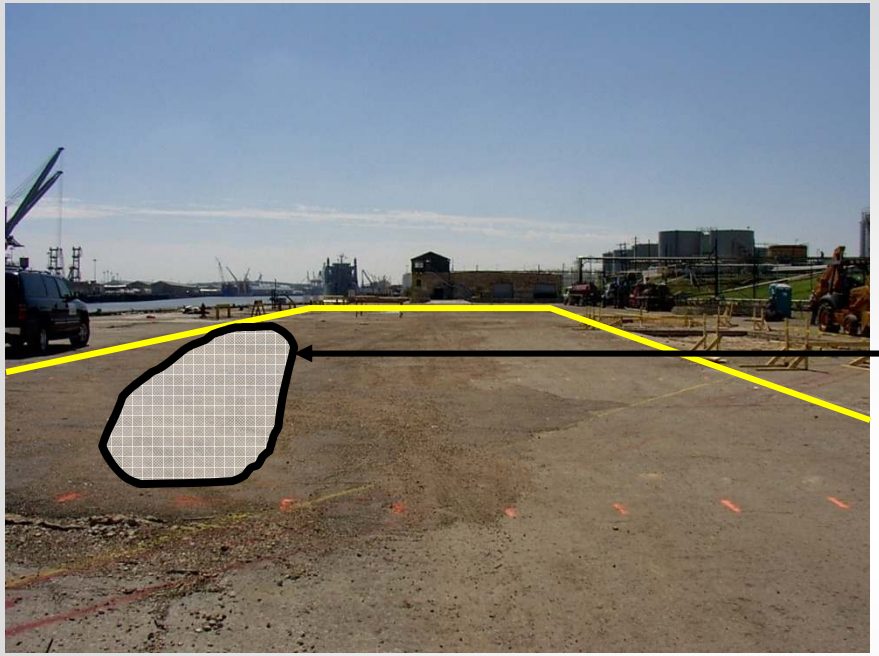
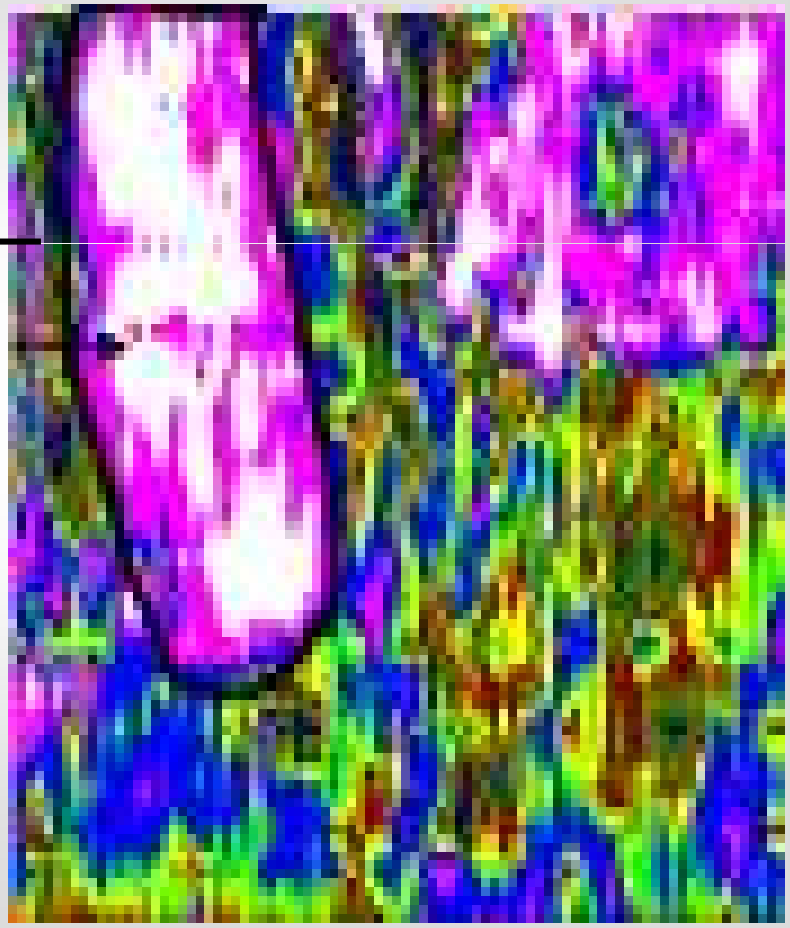
Wharf Surveys / bulkhead walls



Void



There was a void over 100ft x 25 ft in area. Only the pot hole indicated there was a problem. 6 months after this survey, a crane fell through the pavement. The owner had not repaired the void.

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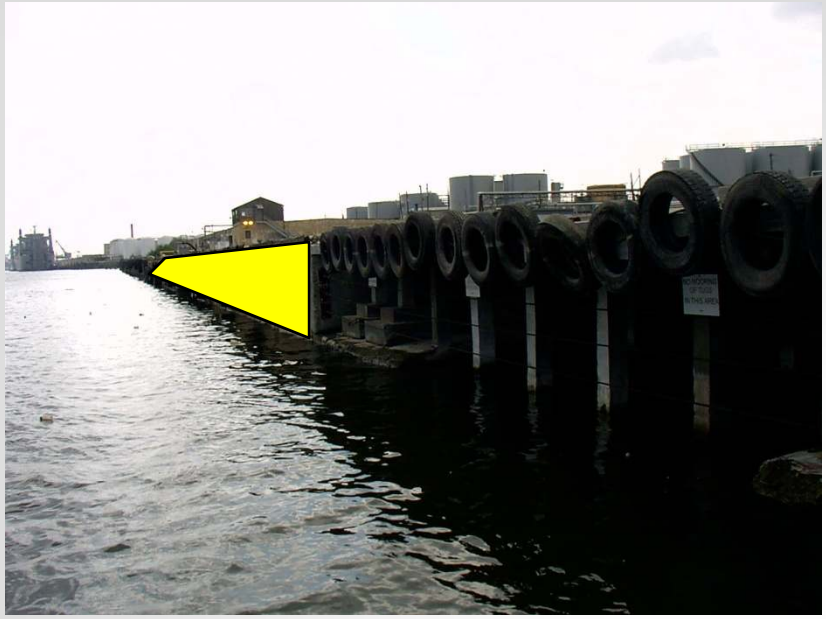
Wharf Surveys / bulkhead walls



This concrete bulkhead was examined for voids – work was performed from a boat. The area in yellow to the left was examined and the data image below shows the void in an elevation view.

Concrete Bulkhead Wall

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Concrete Thickness

- GPR
- Impact-Echo
  - –ASTM Standard C 1383-98a

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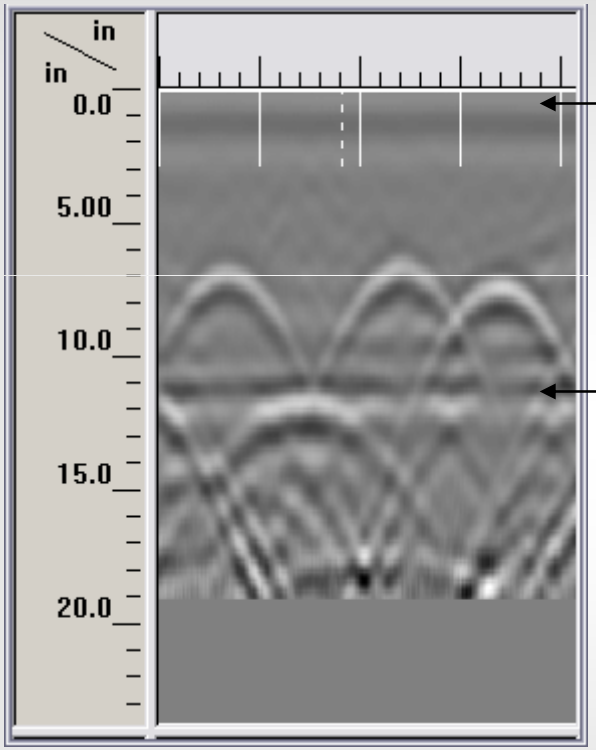
Concrete Thickness



Surface

Bottom of slab - 11” thick

Elevation View

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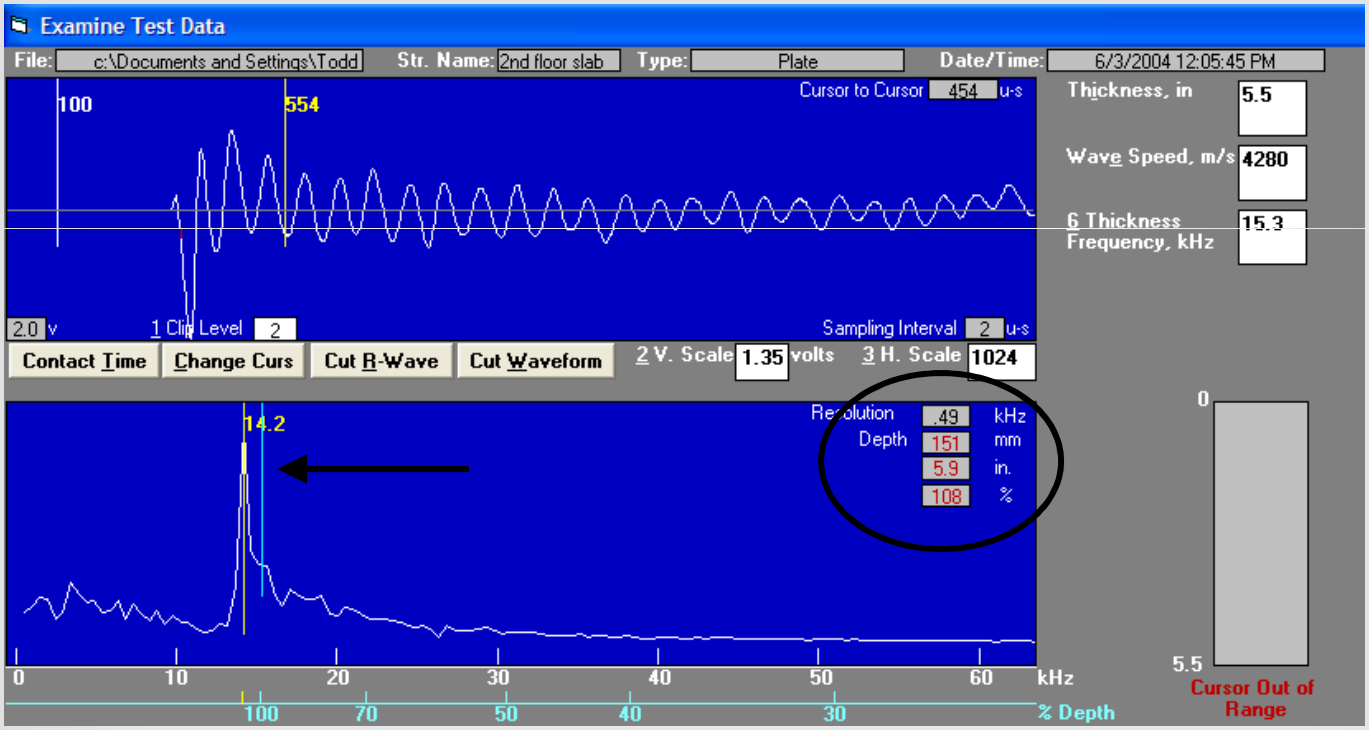
Concrete Thickness



Thickness frequency analysis > 14.2 kHz > 5.9” thick

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Locating poor consolidation/honeycombs

- **Impact-Echo**
  - **–ASTM Standard C 1383-98a**

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Locating poor consolidation/honeycombs

When the forms were removed from this concrete wall, it was apparent that there were quality problems with the concrete mix.

Honeycombs/voids were seen visually. An examination was requested to see if the entire wall was affected.
In the end the wall was repaired by injection with epoxy.

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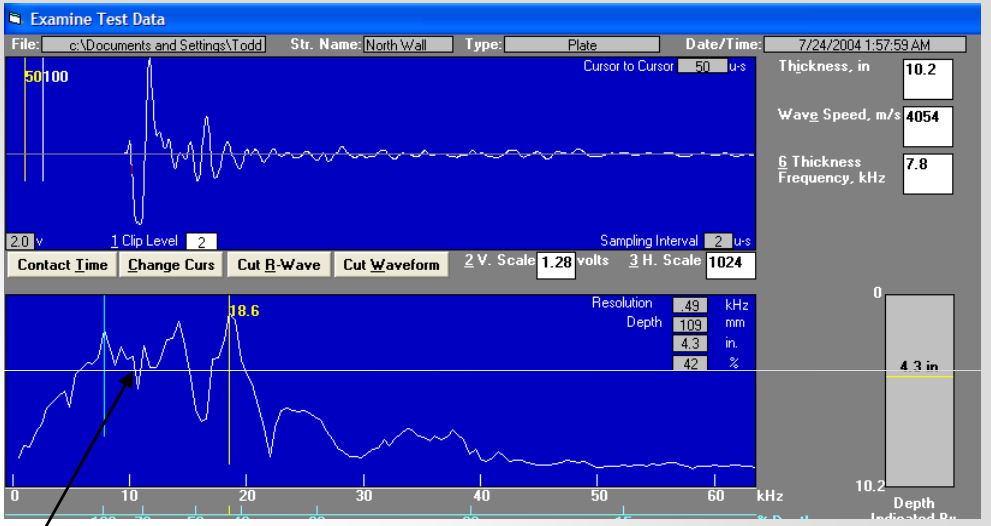
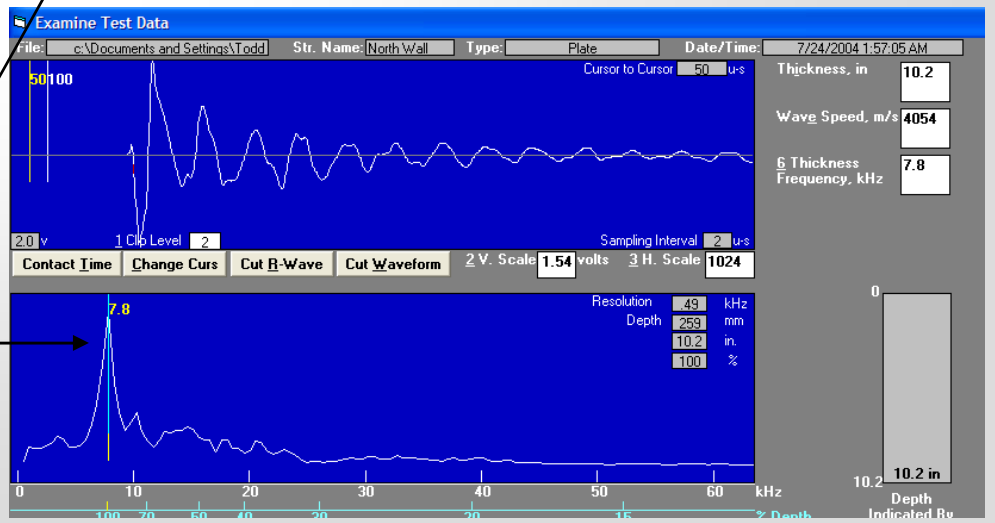
Locating poor consolidation/honeycombs

Examples of data from the examination.





Poor consolidation

Well consolidated concrete

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