Monitoring the Threat of Sinkhole Formation US 18, Cerro Gordo Co., Iowa Using TDR

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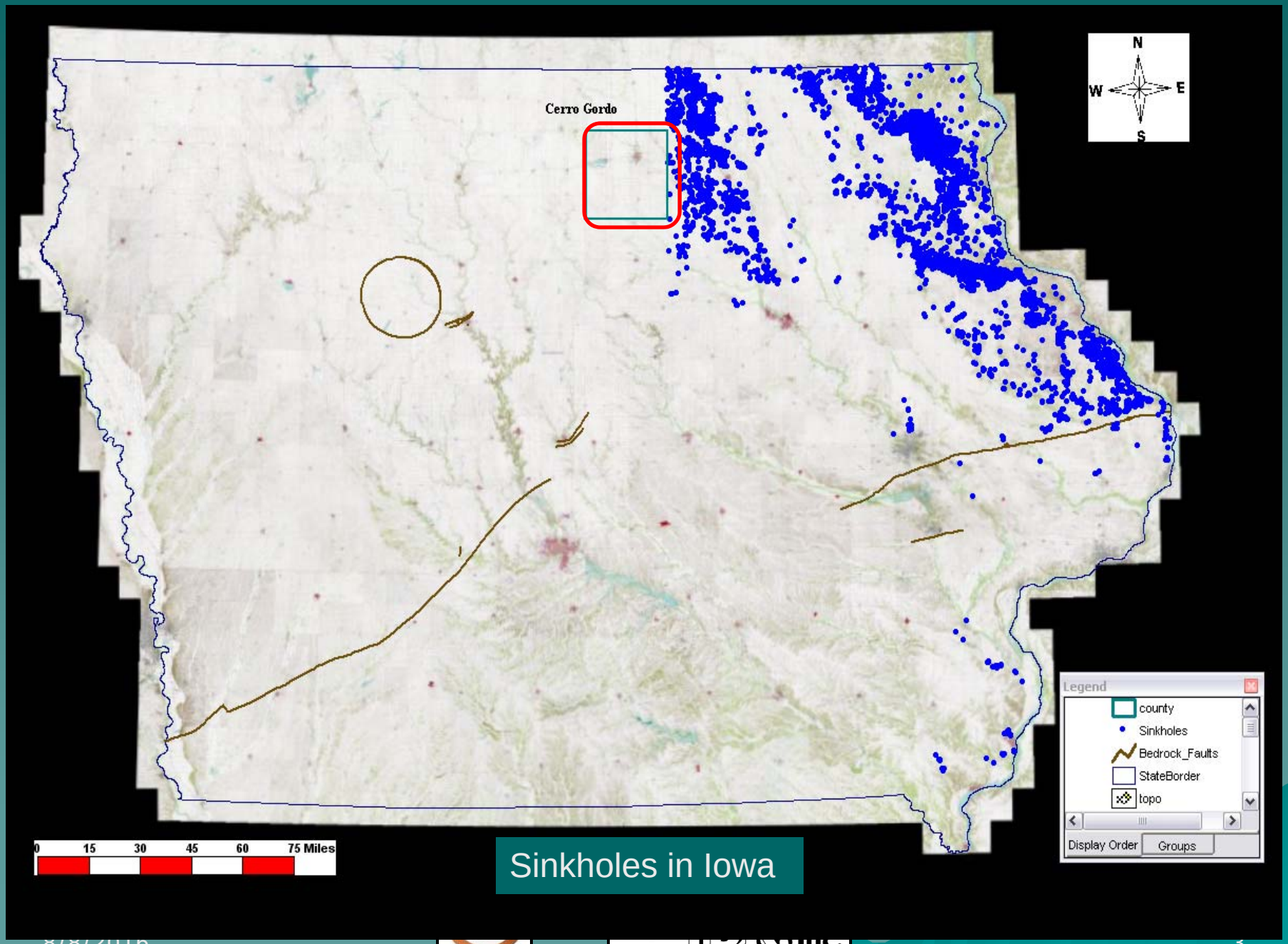
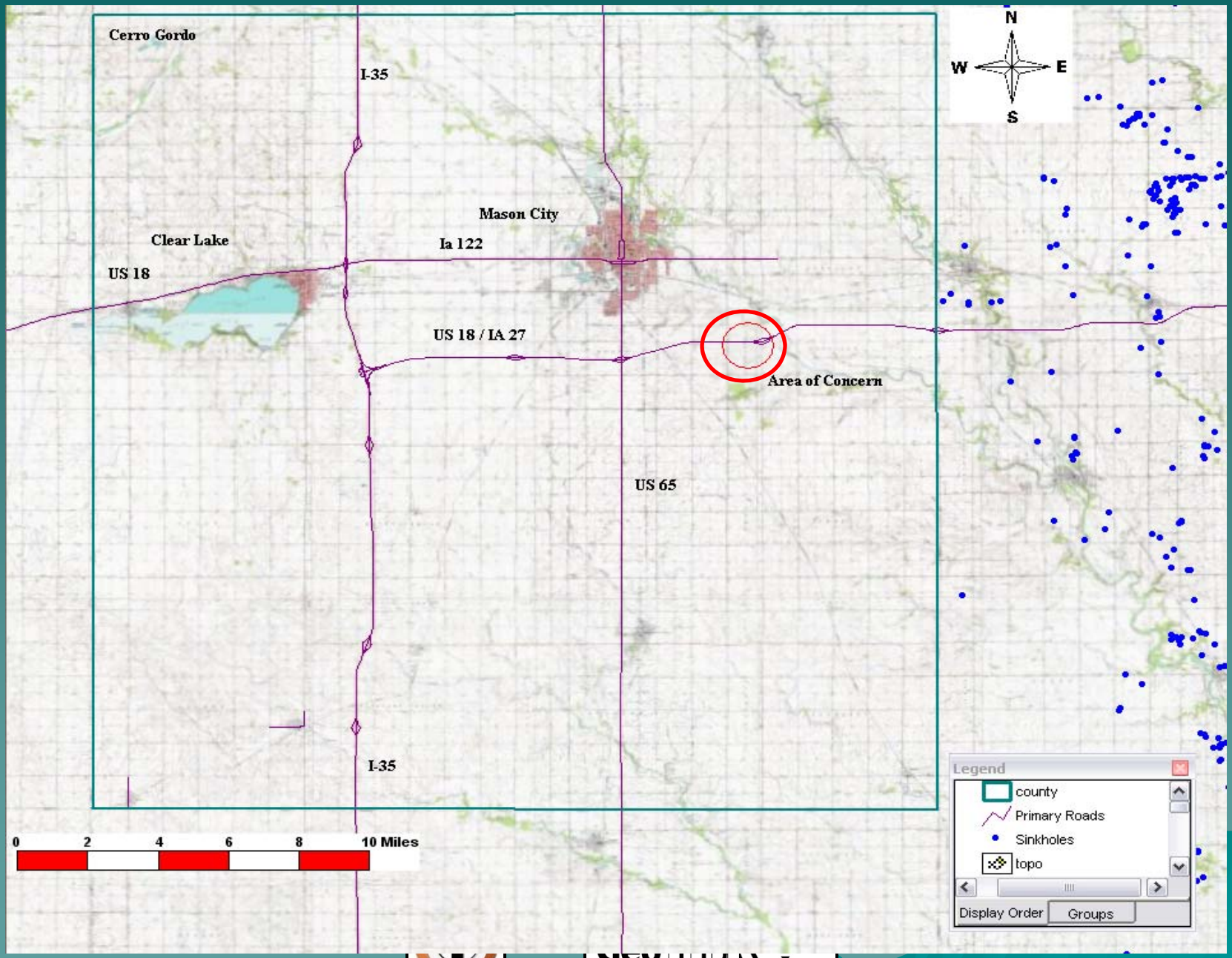
Matthew Trainum, Iowa DOT, Office of Design

16th Annual Technical Forum for
Geohazards Impacting Transportation in Appalachia
Knoxville, TN
August 2016

Site Location and Conditions



Sinkholes in Iowa


Cerro Gordo
I-35
Mason City
Clear Lake
Ia 122
US 18
US 18 / IA 27
Area of Concern
US 65
I-35
N
W
E
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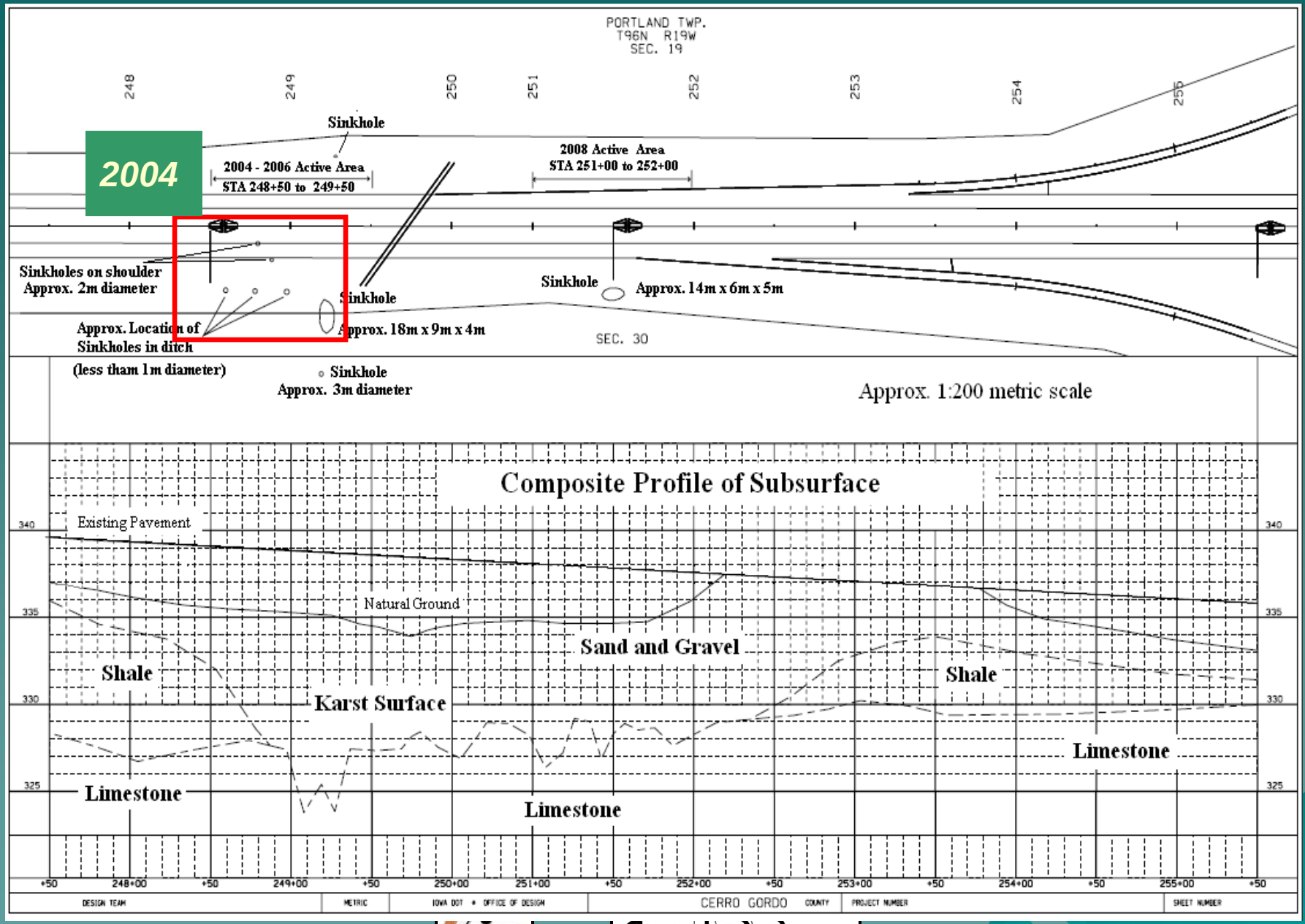
0 2 4 6 8 10 Miles
Legend
county
Primary Roads
Sinkholes
topo
Display Order
Groups


PORTLAND TWP.
T96N R19W
SEC. 19
248
249
250
251
252
253
254
255
2004
Sinkhole
2004 - 2006 Active Area
STA 248+50 to 249+50
2008 Active Area
STA 251+00 to 252+00
Sinkholes on shoulder
Approx. 2m diameter
Sinkhole
Approx. 18m x 9m x 4m
Sinkhole
Approx. 14m x 6m x 5m
Approx. Location of
Sinkholes in ditch
(less tham 1m diameter)
Sinkhole
Approx. 3m diameter
SEC. 30
Approx. 1:200 metric scale
Composite Profile of Subsurface
Existing Pavement
Natural Ground
Shale
Karst Surface
Sand and Gravel
Shale
Limestone
Limestone
Limestone
340
335
330
325
+50
248+00
249+00
250+00
251+00
252+00
253+00
254+00
255+00
DESIGN TEAM
METRIC
IOWA DOT * OFFICE OF DESIGN
CERRO GORDO
COUNTY
PROJECT NUMBER
SHEET NUMBER


EB inside

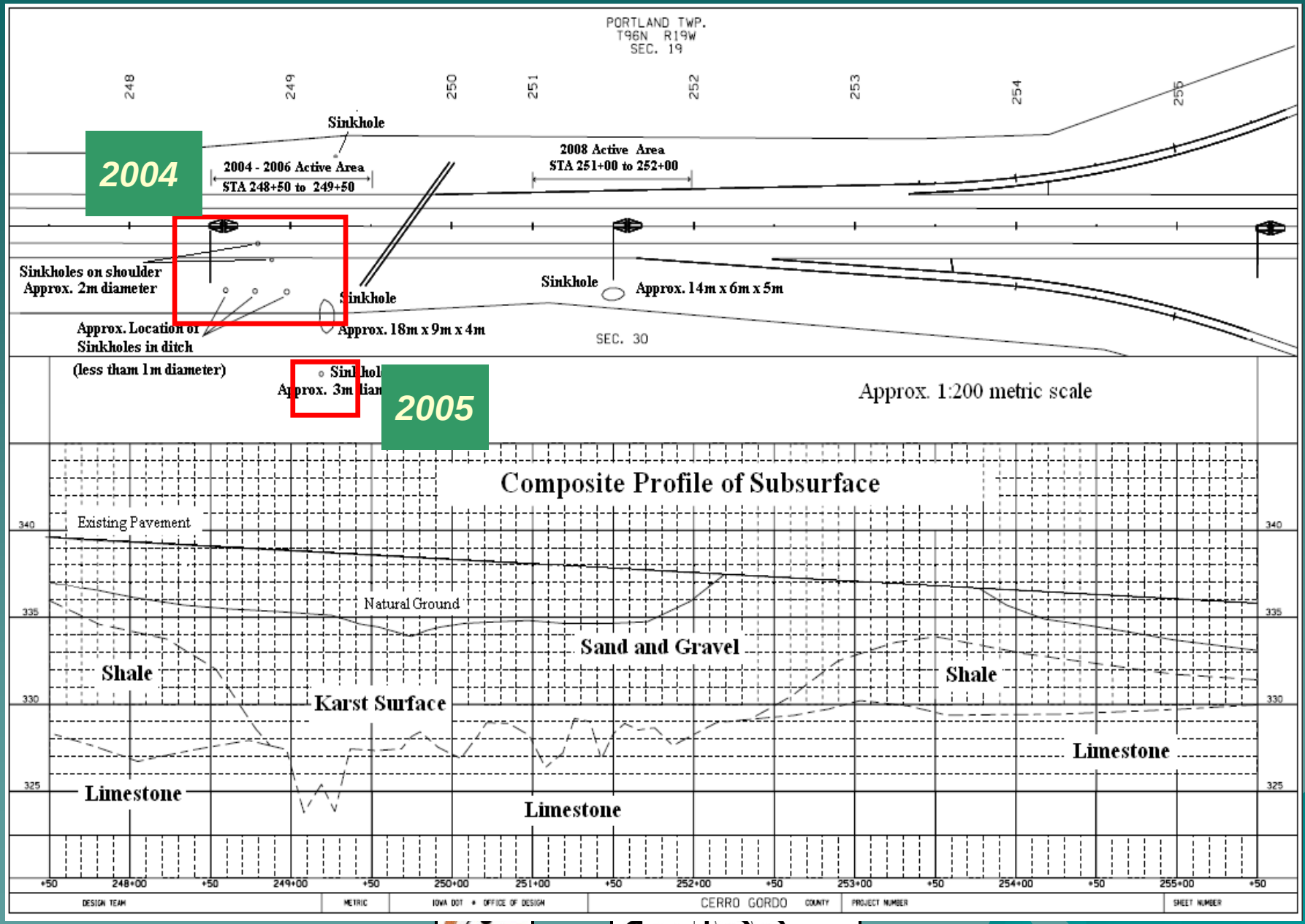
EB outside

EB outside ditch

2004 Investigation

A geophysical investigation, to determine the cause of the problem and propose options for remediation, included a Ground Penetrating Radar Survey, a Resistivity Survey, and a Soil Survey (drilling program).

No voids were identified beneath or within a couple meters of the pavement.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Limestone
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325
+50
248+00
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250+00
251+00
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253+00
254+00
255+00
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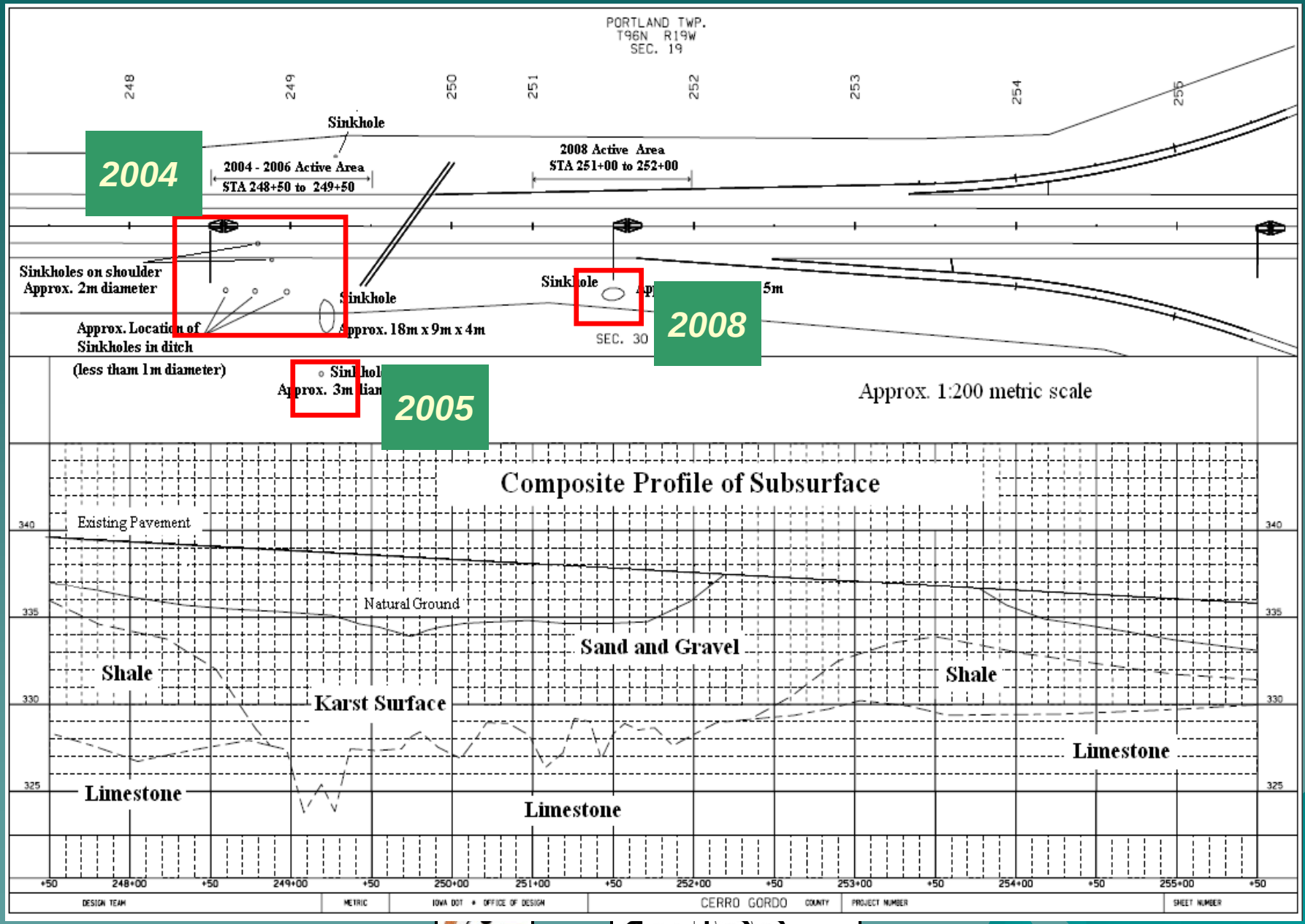
SHEET NUMBER

Outside ROW - South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254+00
255+00
DESIGN TEAM
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CERRO GORDO
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PROJECT NUMBER
SHEET NUMBER

Decision +

- In 2009, a project was designed for letting that would install a double reinforced inlay, including shoulders, for the designated area of concern on US 18 in Cerro Gordo County, Iowa.
- In addition to the inlay, the installation of a Time Domain Reflectometry System (TDR) was chosen as a real-time monitoring device for the formation of voids/sinkholes under the roadway.

NOTE 1: EASTBOUND LANE WILL BE CONSTRUCTED FIRST WITH ALL TRAFFIC IN THE WESTBOUND LANE, THEN TRAFFIC WILL BE SWITCHED AND THE WESTBOUND LANE WILL BE CONSTRUCTED.

PORTLAND TWP.
T96N R19W
SEC. 19

GEOTECHNICAL DESIGN

I hereby certify that this engineering document was prepared by me or under my direct personal supervision and that I am a duly licensed Professional Engineer under the laws of the State of Iowa.

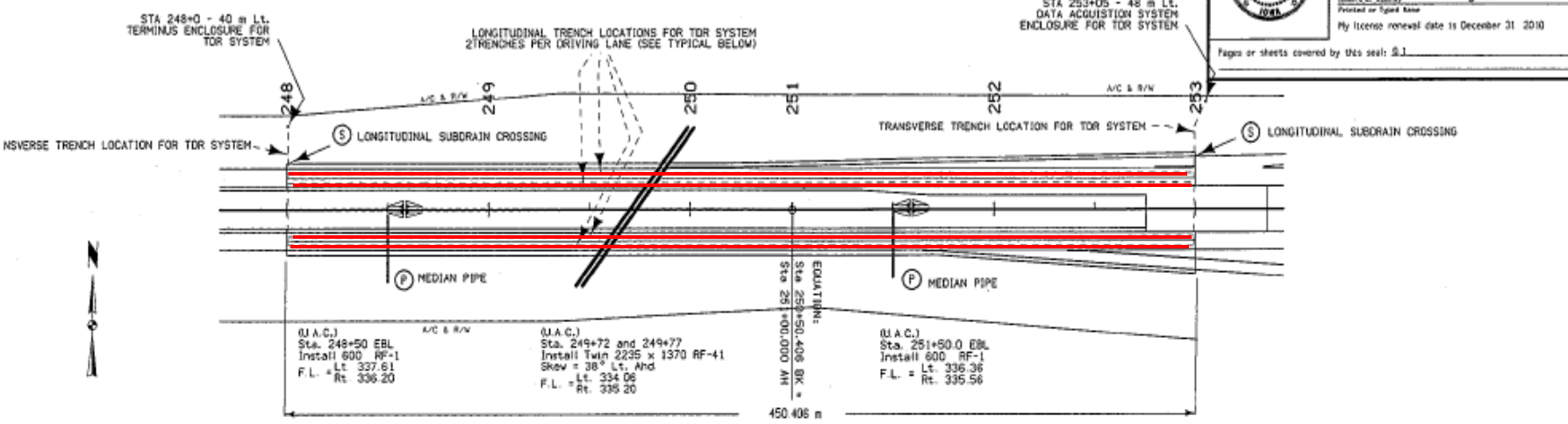
Robert L. Stanley — 08460 — 4-3-2009

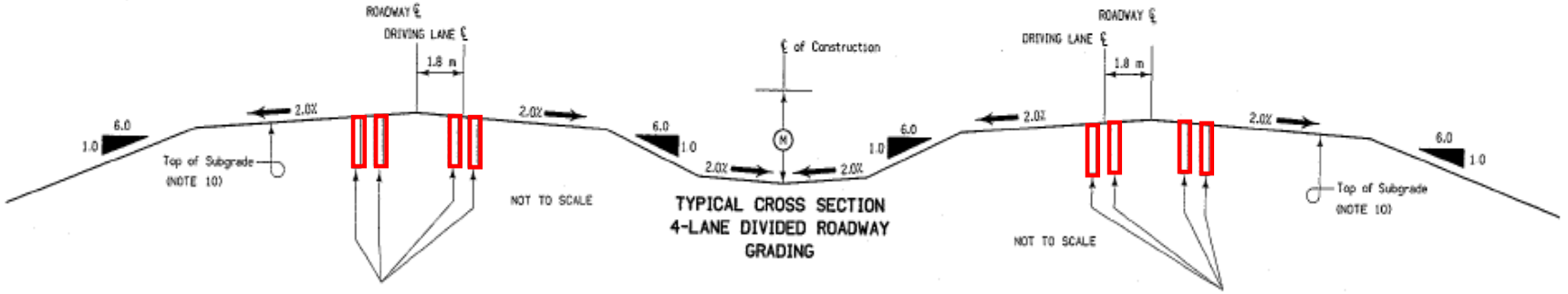
Signature — Date

Robert L. Stanley
Printed or Typed Name

My license renewal date is December 31, 2010

Pages or sheets covered by this seal: 0.1





NOTE 2: THERE ARE TWO TRENCHES PER DRIVING LANE, EACH TRENCH IS OFFSET 0.5 METER LEFT AND RIGHT OF THE CENTER LINE OF THE DRIVING LANE TRENCHES ARE 0.25 M WIDE AND 1 METER DEEP.

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NOTE 3: TRENCHING SHALL BE AS SHOWN IN DETAILS ABOVE, AND TO DEPTH AND WIDTH AS SPECIFIED WITH EXCEPTION AT MEDIAN PIPES (P).

NOTE 4: TRENCHING DEPTH SHALL BE ADJUSTED AT MEDIAN PIPE LOCATIONS (P) IN ORDER TO ALLOW INSTALLATION OVER THE TOPS OF THE MEDIAN DRAIN PIPES.

NOTE 5: ONE COAXIAL CABLE PER TRENCH, TO BE TESTED PRIOR TO GROUTING AND BACKFILL.

NOTE 6: THE COAXIAL CABLE IN THE BOTTOM OF THE TRENCH SHALL BE COVERED WITH 0.2 M OF GROUT FOLLOWED BY BACKFILLING OF THE REMAINDER OF THE TRENCH.

NOTE 7: THE DIMENSIONS OF THE TRANSVERSE TRENCH SHALL BE THE SAME AS THE LONGITUDINAL TRENCHES.

NOTE 8: TRANSVERSE TRENCH SHALL NOT BE GROUTED, THE COAXIAL CABLES SHALL BE PROTECTED BY CONDUIT.

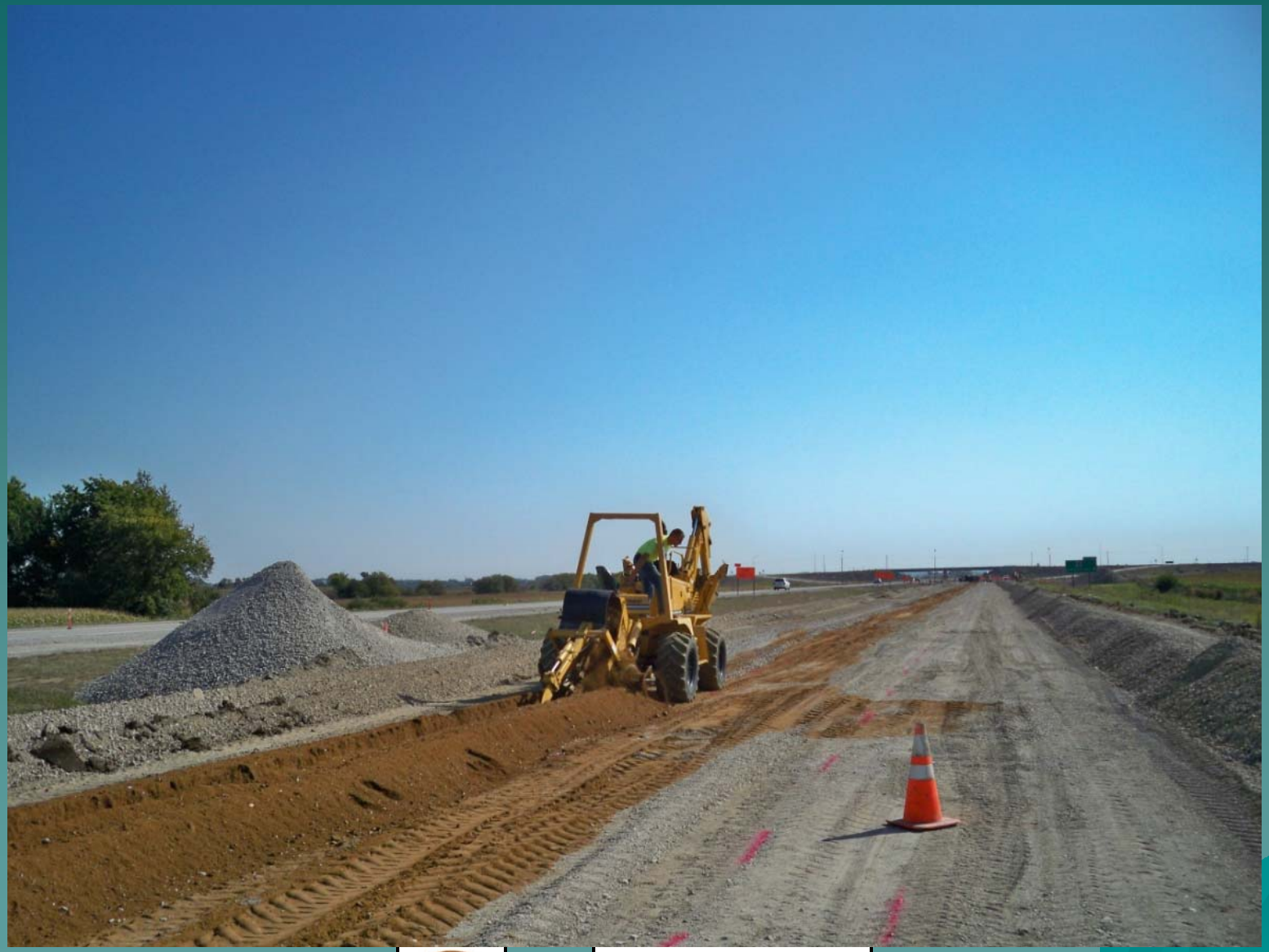
NOTE 9: THE TRANSVERSE TRENCH SHALL BE HAND-EXCAVATED THROUGH THE POINT (S) LOCATION WHERE IT ENCOUNTERS THE EXISTING SUBDRAIN ALONG THE NORTH SIDE OF THE WEST BOUNDLANE, WITH CARE TAKEN TO PRESERVE AND RE-ESTABLISH THE SUBDRAIN AFTER INSTALLATION OF THE COAXIAL CABLE THROUGH THIS AREA.

NOTE 10: TOP OF SUBGRADE REFLECTS TOP OF NOMINAL 0.15 M LAYER OF GRANULAR SUBBASE UNDERLAIN BY A NOMINAL 0.6 M THICK SUBGRADE TREATMENT LAYER CONSISTING OF SAND.

NOTE 11: TRENCHING AND ALL OTHER ACTIVITIES SHALL BE PERFORMED SO AS TO AVOID CONTAMINATION AND/OR OTHER ADVERSE EFFECTS ON THE GRANULAR SUBBASE DRAINAGE LAYER.

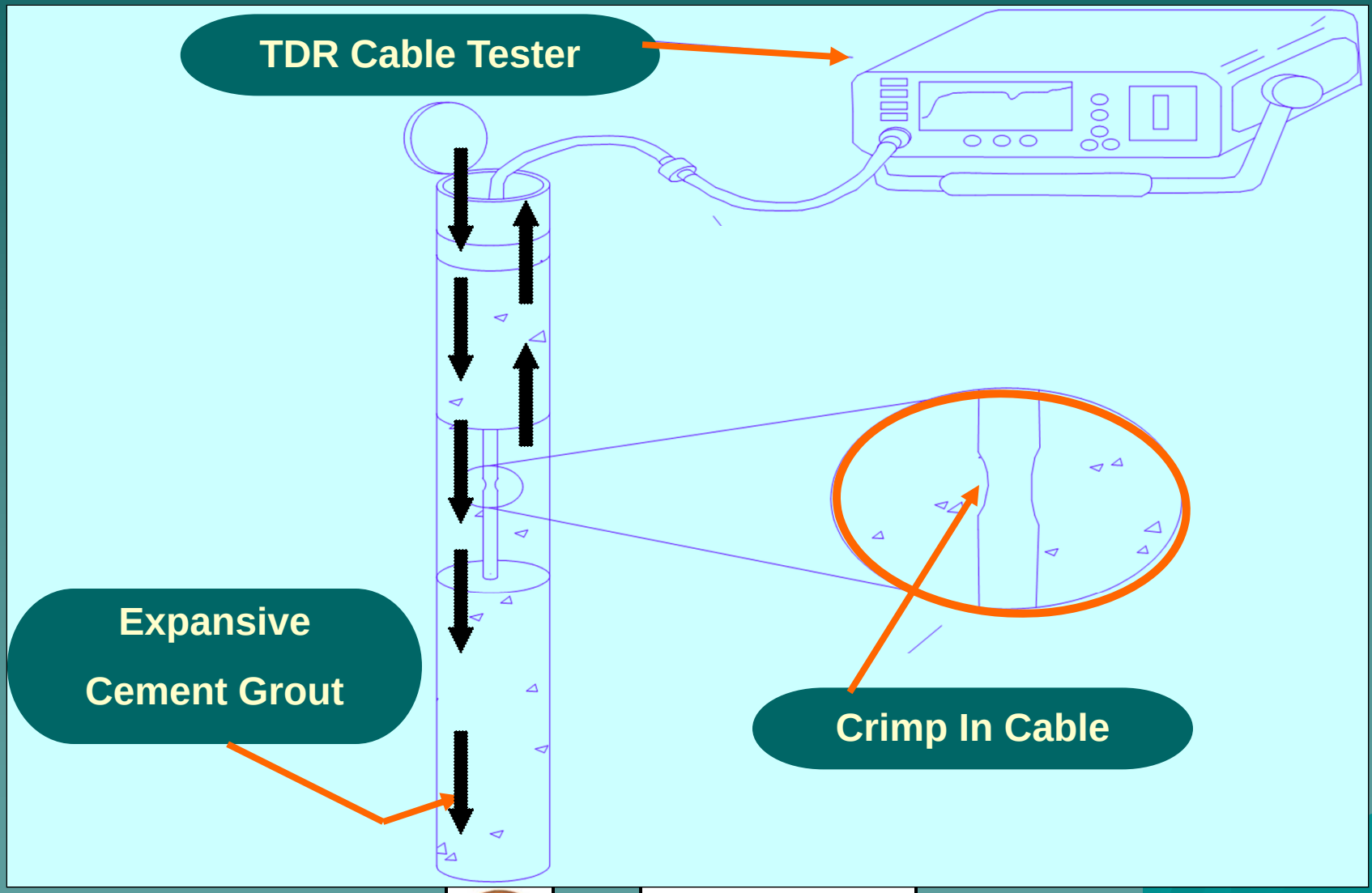
TIME DOMAIN REFLECTOMETRY SYSTEM (TDR) DETAILS

DESIGN TEAM	METRIC	IOWA DOT • OFFICE OF DESIGN	COUNTY	PROJECT NUMBER	SHEET NUMBER
Cadwell\Gansen			CERRO GORDO	NHSX-018-5(145)--3H-17	0.1



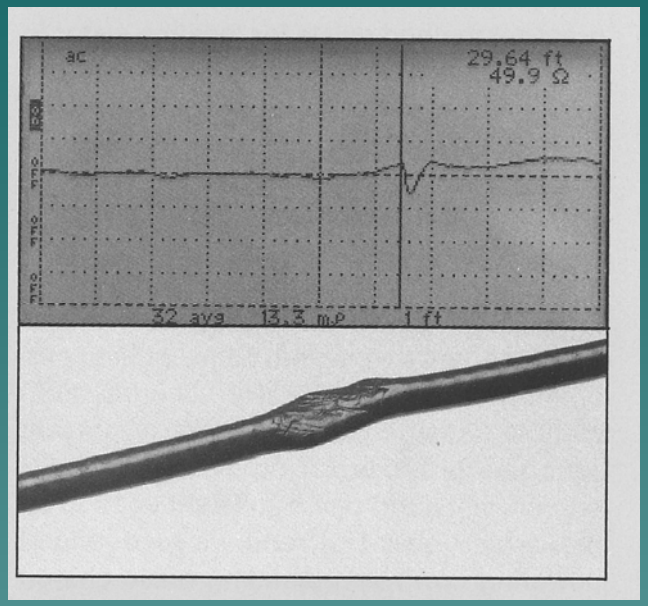
TDR Principle

Cables can be grouted into boreholes or trenches to monitor deformation

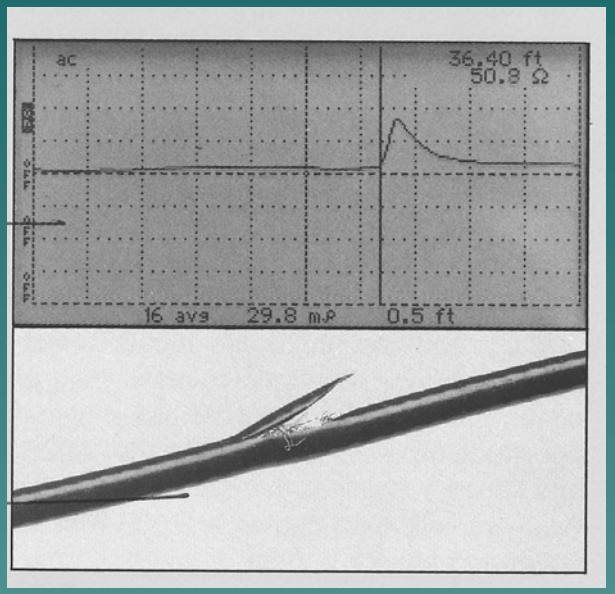


Activity up to Present Time

crimps



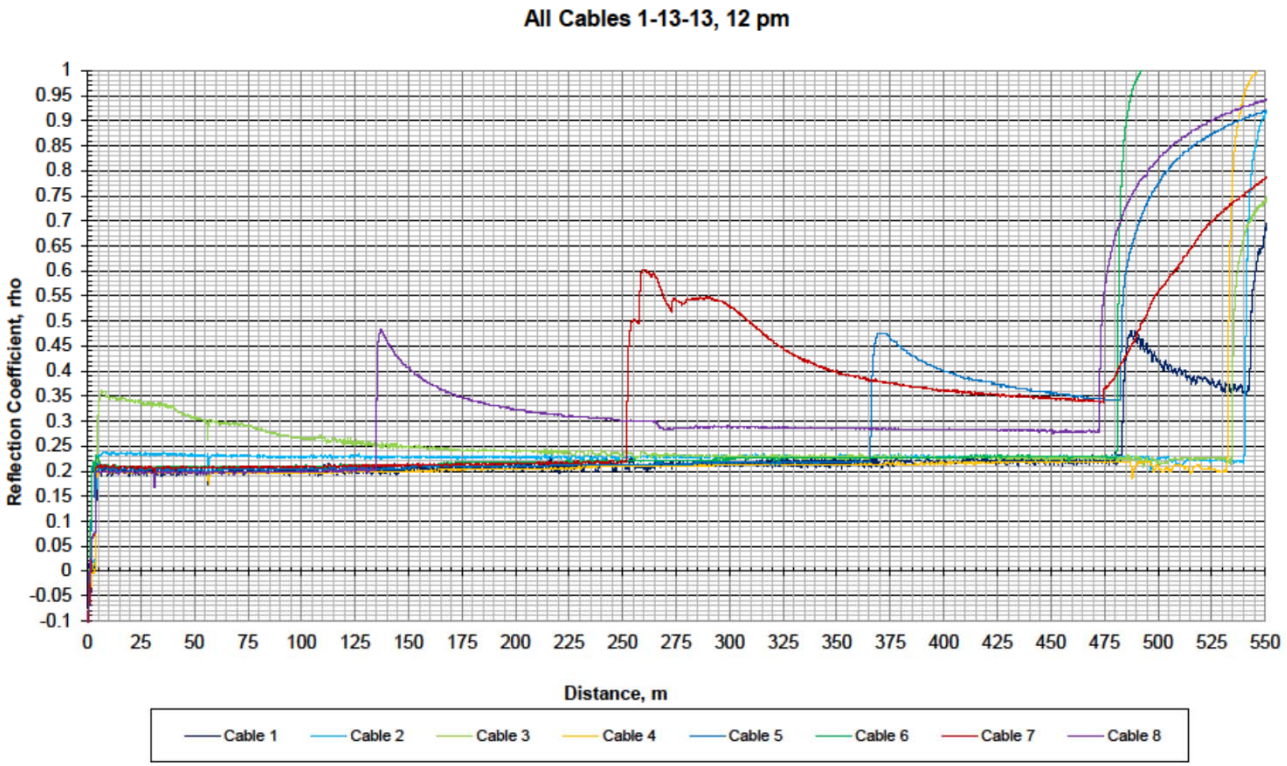
abrasion



Cable shear would produce same reflection as a crimp

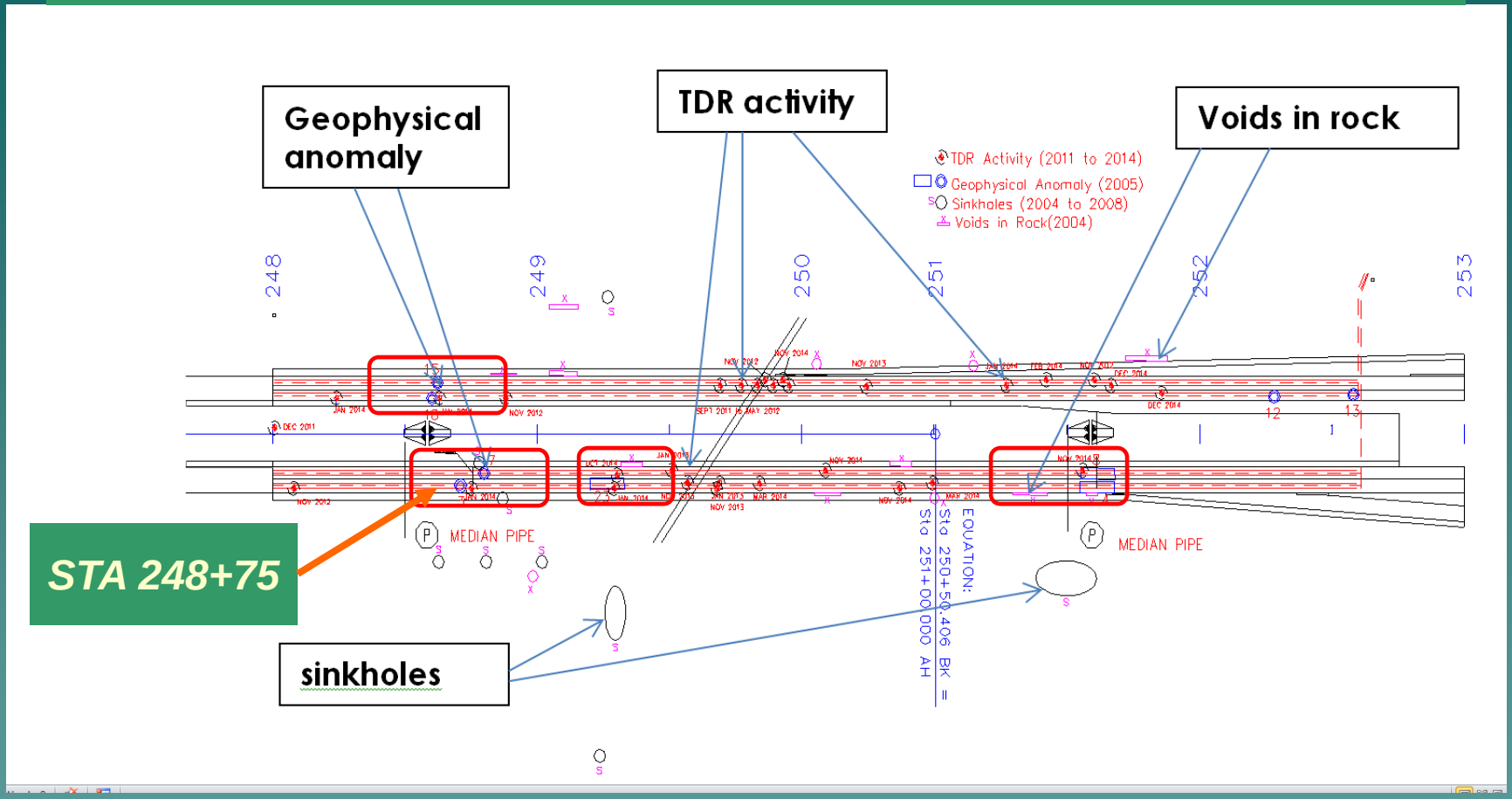
Ground movement would fracture grout then cable deformation occurs

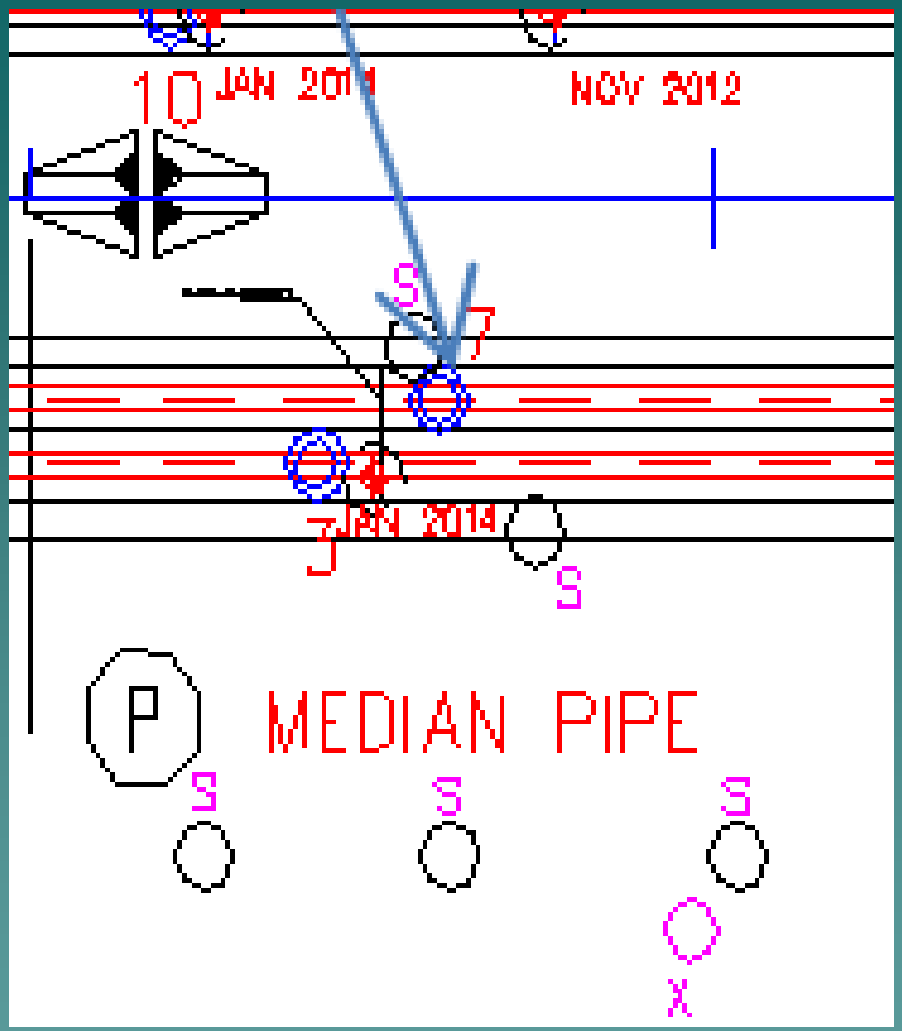
Consistent and persistent response on all eight cables



Abrasion not Shear Deformation of Cables

Limited Correlation Among TDR, Geophysics, Drilling, and Sinkholes

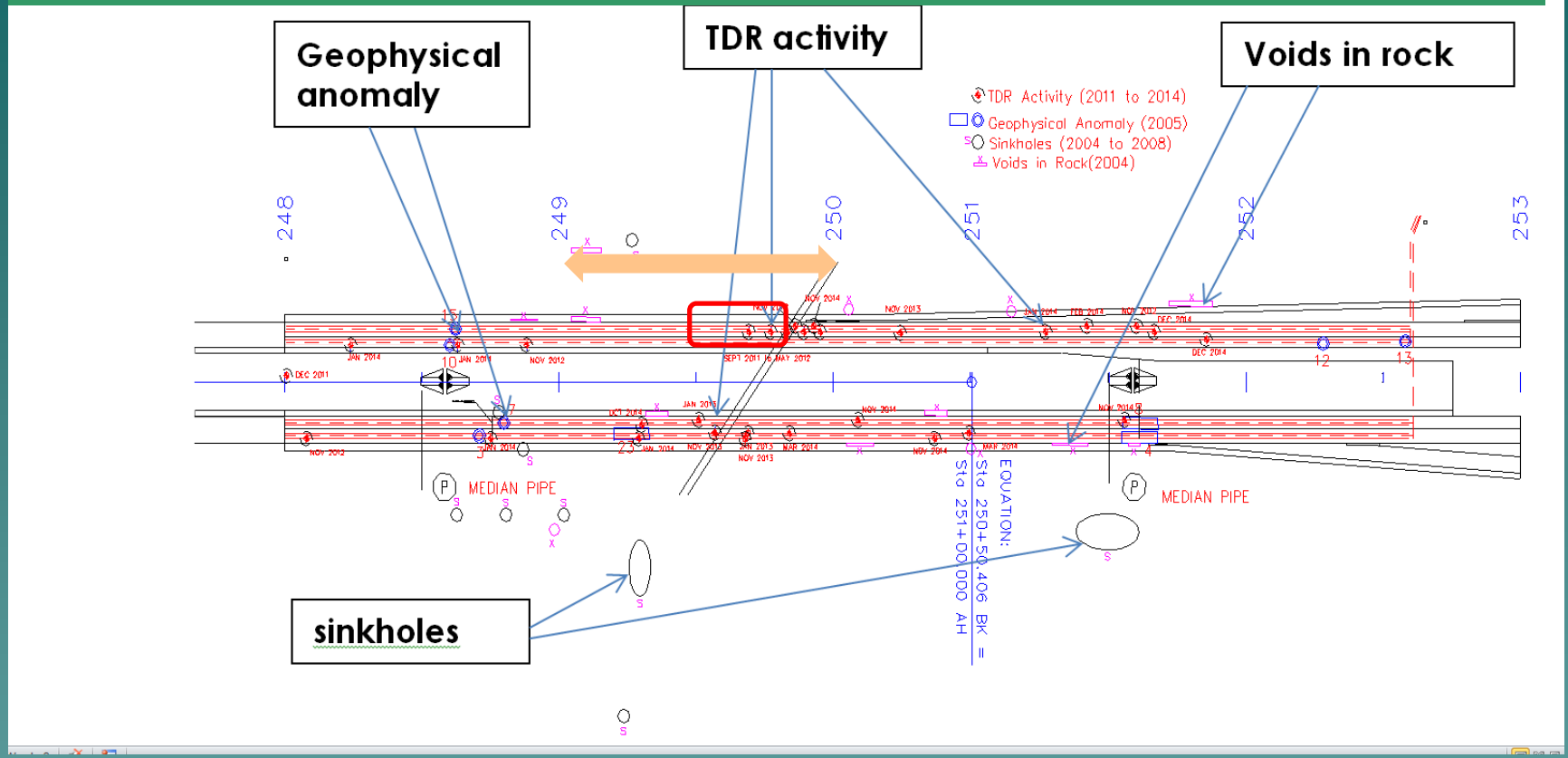




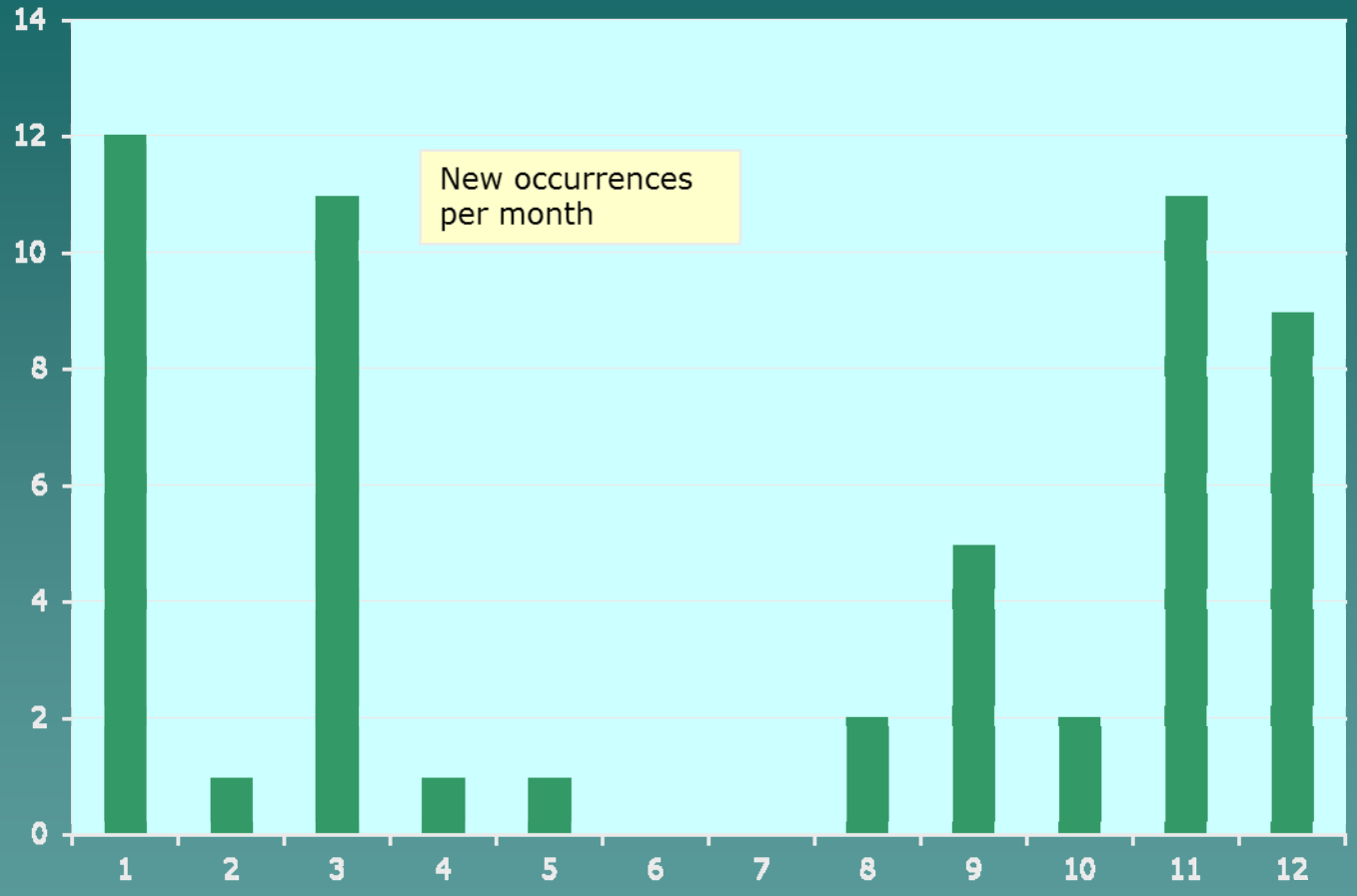
Eastbound STA 248+75

In Nov 2011 and Jan 2012

exploratory drilling and geophysics did not find voids below pavement



TIMING – new activity develops between September and March



2011, 2012, 2013, 2014, 2015, 2016

Possible Causes

- Ground Movement
  - Little or no indication of shear
  - Movement must cause abrasion
- Soil or Grout Shrinkage
  - Requires sufficient shrinkage to cause abrasion
- Frost Heave
  - Timing of TDR activity does not entirely coincide with period when frost is deepest
- Gnawing Animals
  - IS THIS EVEN A POSSIBILTY??

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NEWStalk

Gophers Cause Idaho Highway to Partially Collapse!

By John McKay May 8, 2013 11:02 AM

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(Idaho Department of Transportation photo)

Fortunately, no motorists were injured and there were no reported accidents because, but Idaho Department of Transportation crews had to work through the night to repair a large sinkhole on Highway 78 near Marsing, Idaho, just east of Hot Springs due to gophers.

Apparently a community of gophers had been burrowing into the roadbed for some time, and they caused sinkhole at least 3 to 4 in diameter. Crews were dispatched Monday night and were able to repair the hole before any accidents occurred.

Police do not currently have any of the suspects in custody as apparently they are not cooperating with authorities. Below is believed to a picture of the chief culprit.

(Photo by Steve Dykes/Getty Images)

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By STACI BARSNESS
Issaquah Reporter Reporter
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One of the benefits of living near the foothills of the
RICH BENSON
Sink hole caused by Lake Sammamish beaver colony.
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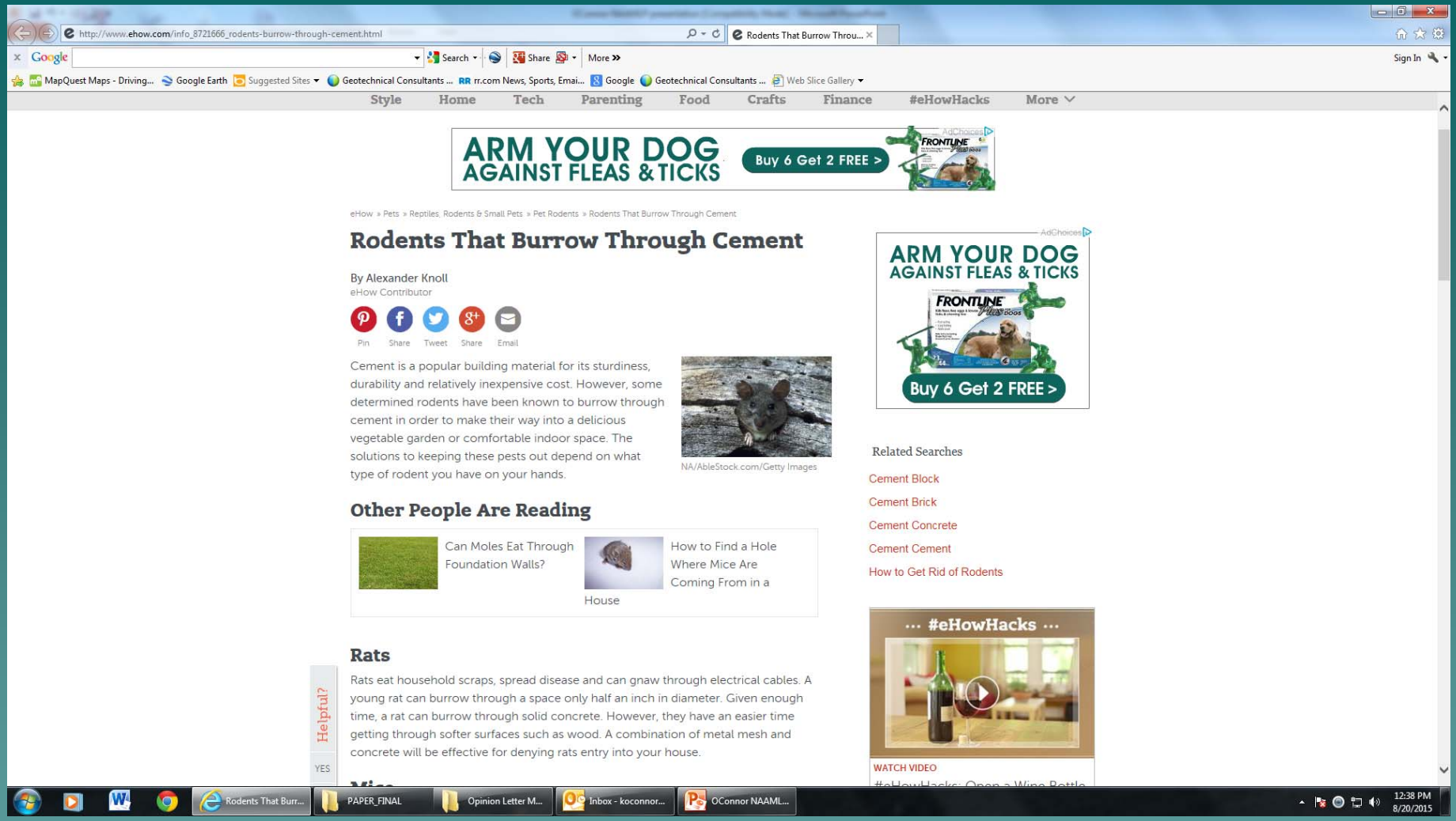
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Rodents That Burrow Through Cement
By Alexander Knoll
eHow Contributor
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Cement is a popular building material for its sturdiness, durability and relatively inexpensive cost. However, some determined rodents have been known to burrow through cement in order to make their way into a delicious vegetable garden or comfortable indoor space. The solutions to keeping these pests out depend on what type of rodent you have on your hands.
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How to Find a Hole Where Mice Are Coming From in a House
Rats
Rats eat household scraps, spread disease and can gnaw through electrical cables. A young rat can burrow through a space only half an inch in diameter. Given enough time, a rat can burrow through solid concrete. However, they have an easier time getting through softer surfaces such as wood. A combination of metal mesh and concrete will be effective for denying rats entry into your house.
Helpful?
YES
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Amphenol TFC

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RodentRepel™ Coax

RodentRepel™ Rodent Repellent Coax

Times Fiber introduces a series of cable products, which are resistant to rodent chew and damage. This offering is available for both drop and hardline cable.

The deterrent to rodent chew is achieved with the use of a non-hazardous, non-toxic, animal aversive additive. This additive is environmentally safe and is not harmful to birds or animals. It is based on an optimized blend of a synthetic animal aversive olfactory component, a bitterrant, and other proprietary additives.

The olfactory component is not detected by the human olfactory sense, but animals readily perceive it as associated to the odor of dangerous predators and read it as a signal for danger.

The bitter substances are typically used in liquid chemical products to prevent accidental human ingestion. Proprietary substances are used to develop a synergistic aversive effect. RodentRepel™ coax is safe to human skin. RodentRepel™ coaxial cables can be identified with GREEN tracers.

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- Safe for human interaction

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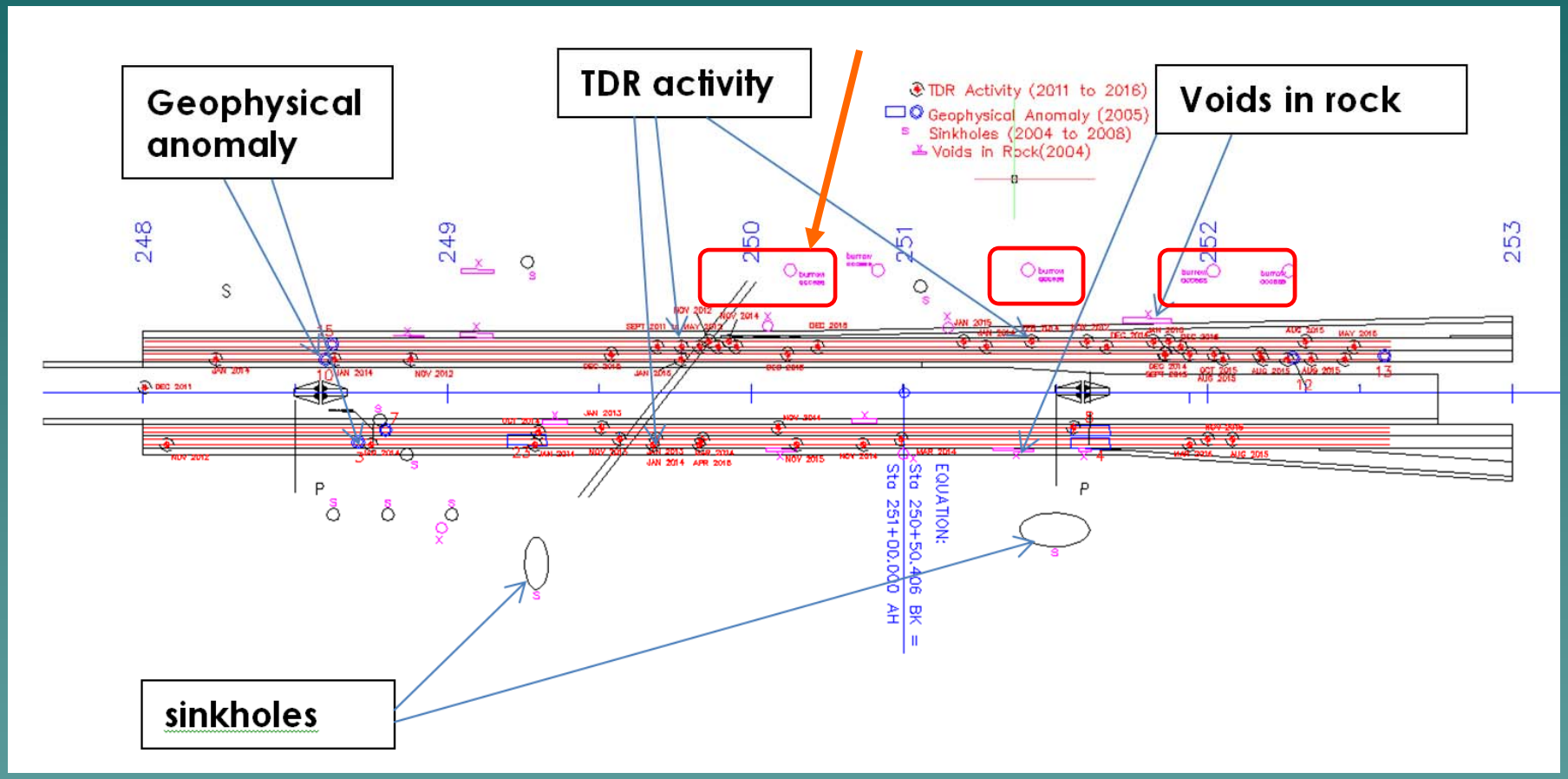
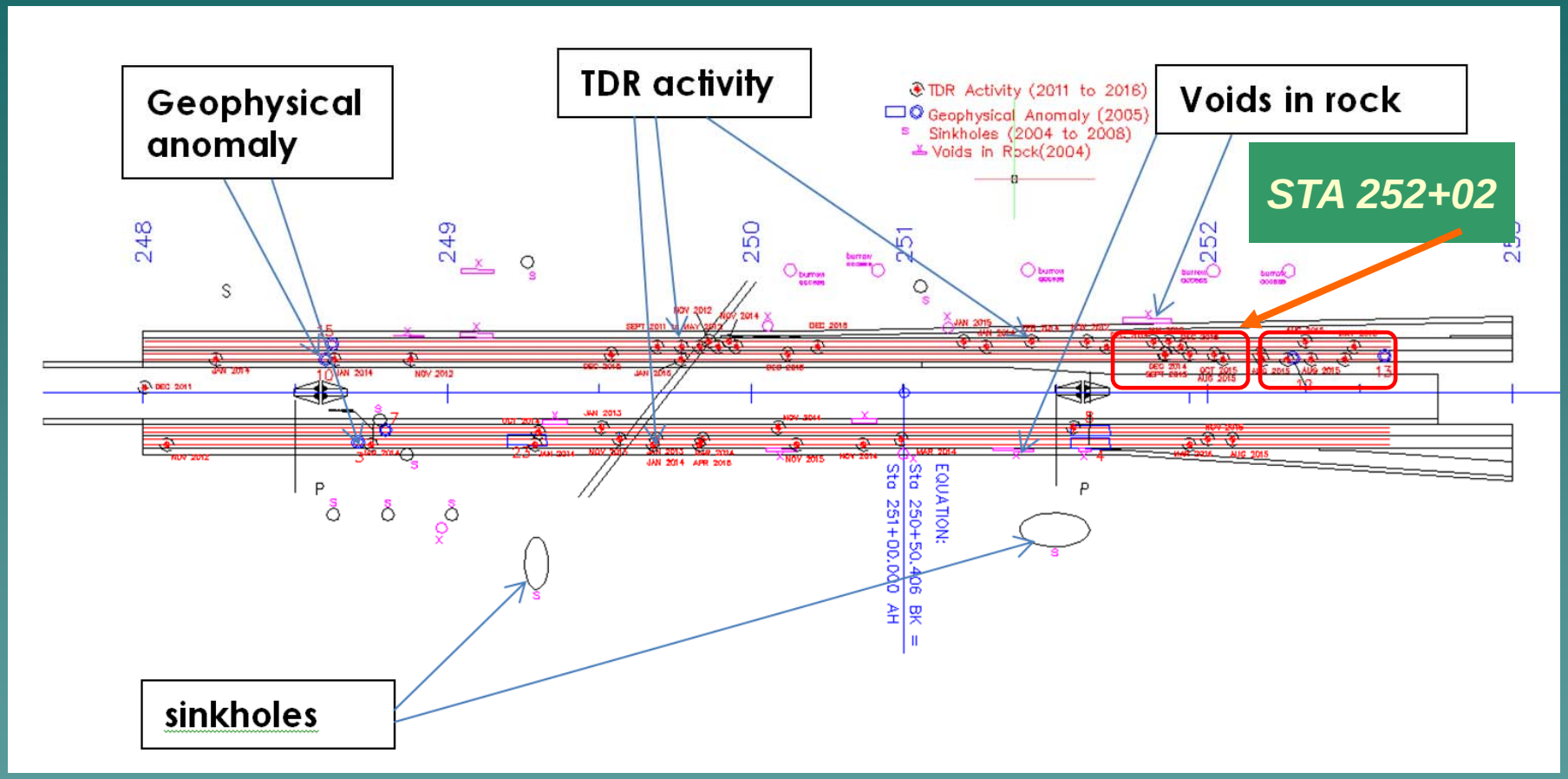
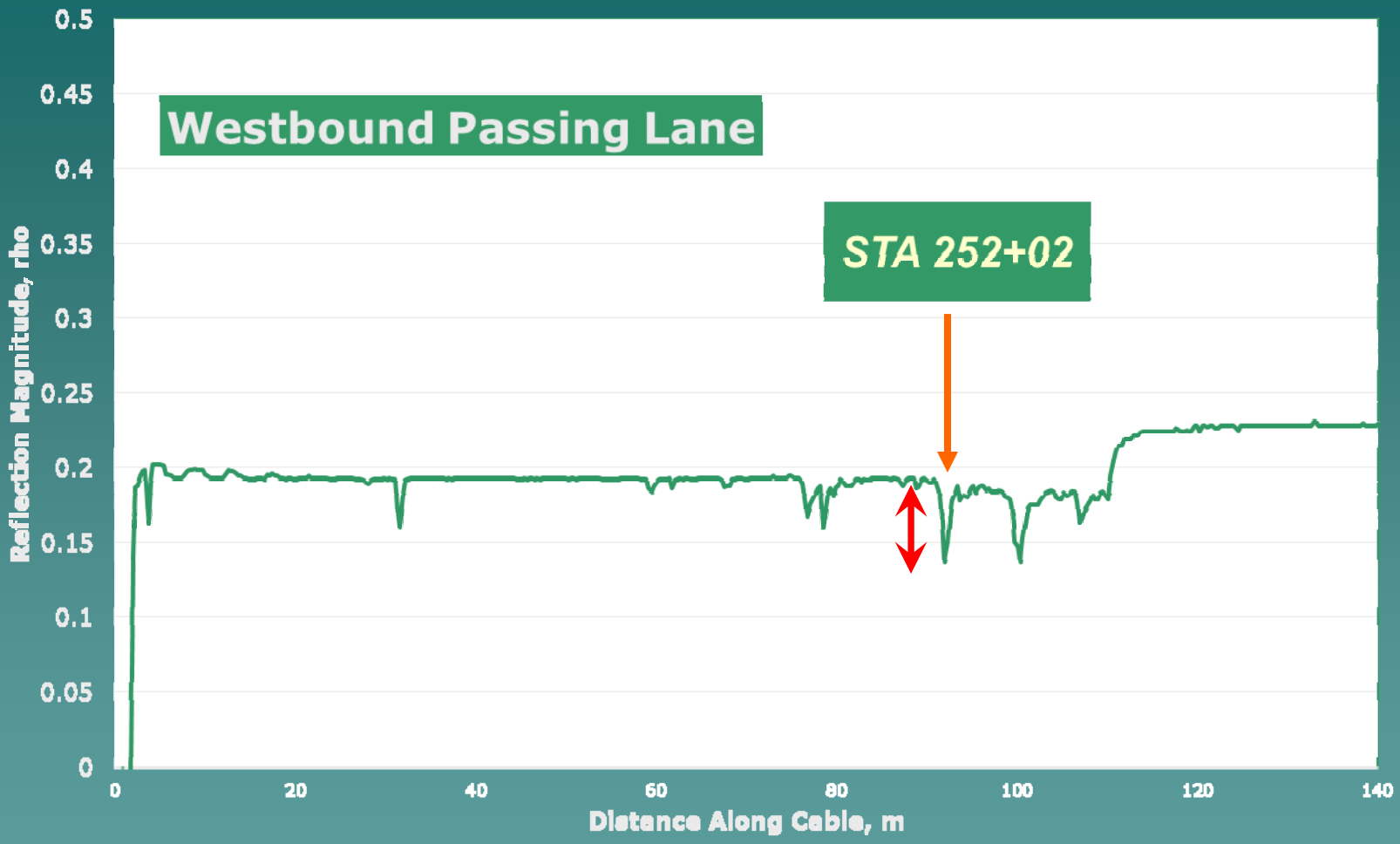
Additional Evidence of Burrowing

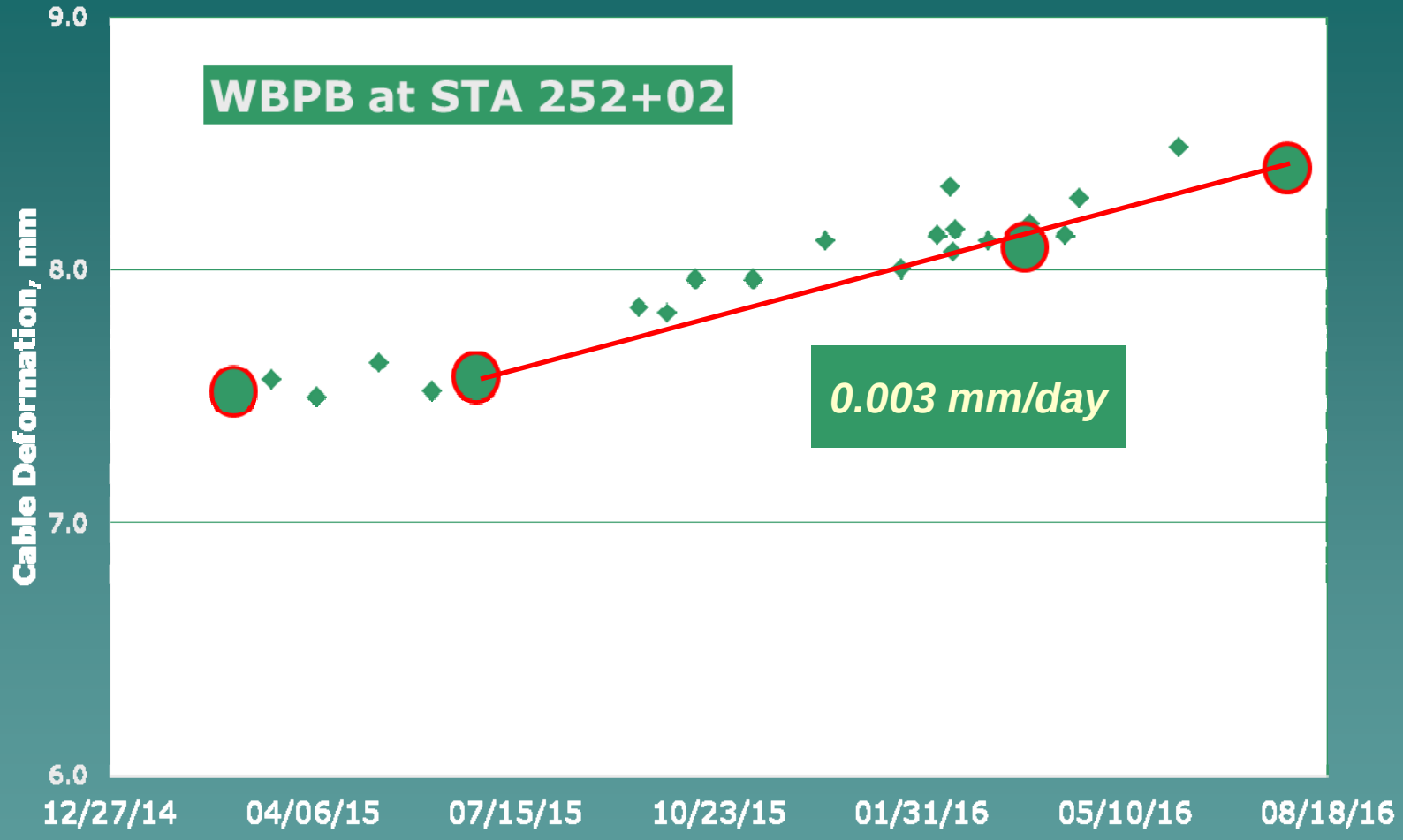


Recent TDR Activity



Westbound Passing Lane


Westbound Passing Lane
STA 252+02
Reflection Magnitude, rho
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
20
40
60
80
100
120
140
Distance Along Cable, m


WBPB at STA 252+02
0.003 mm/day
Cable Deformation, mm
9.0
8.0
7.0
6.0
12/27/14
04/06/15
07/15/15
10/23/15
01/31/16
05/10/16
08/18/16

Current Status

- The persistence and consistency indicate valid data
- The cause of cable abrasion is currently indeterminate
- Even with this uncertainty, can still detect cable deformation…so monitoring continues

Questions for You

- The cause of cable abrasion is currently indeterminate
- Has anyone seen precursor burrowing by animals in karst areas?
- Can you suggest other causes?
- Why limited to Sept-March?

Real Time Monitoring with Time Domain Reflectometry (TDR)

Kevin M. O'Connor, Ph.D., P.E.
GeoTDR, Inc.
Westerville, Ohio
www.geotdr.com