Subsurface Investigation and Conceptual Alternatives

Mitigation of Gypsum Mine Voids Under SR-2 in Ottawa County, Ohio

Presented By: Ohio Department of Transportation
CH2M HILL
CTL Engineering
Technos, Inc.
Workhorse Technologies

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U.S. GYPSUM CO.

History

- Gypsum mined from 1902 to 1977
- Section under SR-2 mined 1950's – 1960's
- SR-2 constructed in 1965
- Mines flooded in 1979
- Active sinkholes since Dec. 2004

Location


Lake Erie
Sandusky Bay
Mine Area
Port Clinton
Gypsum
Danbury
Hickory Grove
Violet
East Harbor State Park
OHIO
OTTAWA
W Harbor Rd
W Lake Shore Dr
E Harbor Rd
E Sand Rd
E Perry St
E 2nd St
E 3rd St
W 3rd St
W 6th St
E 10th St
Alice St
Ottawa Dr
Township Road 281
E Lockwood Rd
W Darr Hopfinger Rd
S Schau Rd
S Steeper Rd
Marsh
Helendale Ln
S Hyde Rd
S Wormell Rd
Fulton St
Anderson
Gypsum Rd
E Kirk Rd
CR 135A
Yetter Rd
E Bay Shore Rd
E Danbury Rd
Bridge Rd
Church Rd
Township Hwy 229
CR 6
E Marino Ave
E Mugav Rd
NW Catawba Rd
W Catawba Rd
SE Catawba Rd
S Lightner Rd
Stalay
Grand Pass
Bailey St
Barrett Rd
1 miles

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Difficult Mine Conditions

- Lower mine seam covers 500 acres
- Gypsum mine seam 16 feet
- Mine voids average 10 feet, but locally may be up to 15 feet in height
- Deepest section (Ahrens) 85 feet
- Room and pillar, with 15’x15’ pillars and rooms span 20 feet
- Overlain by 10-15 feet of dolomite, shale, and gypsum

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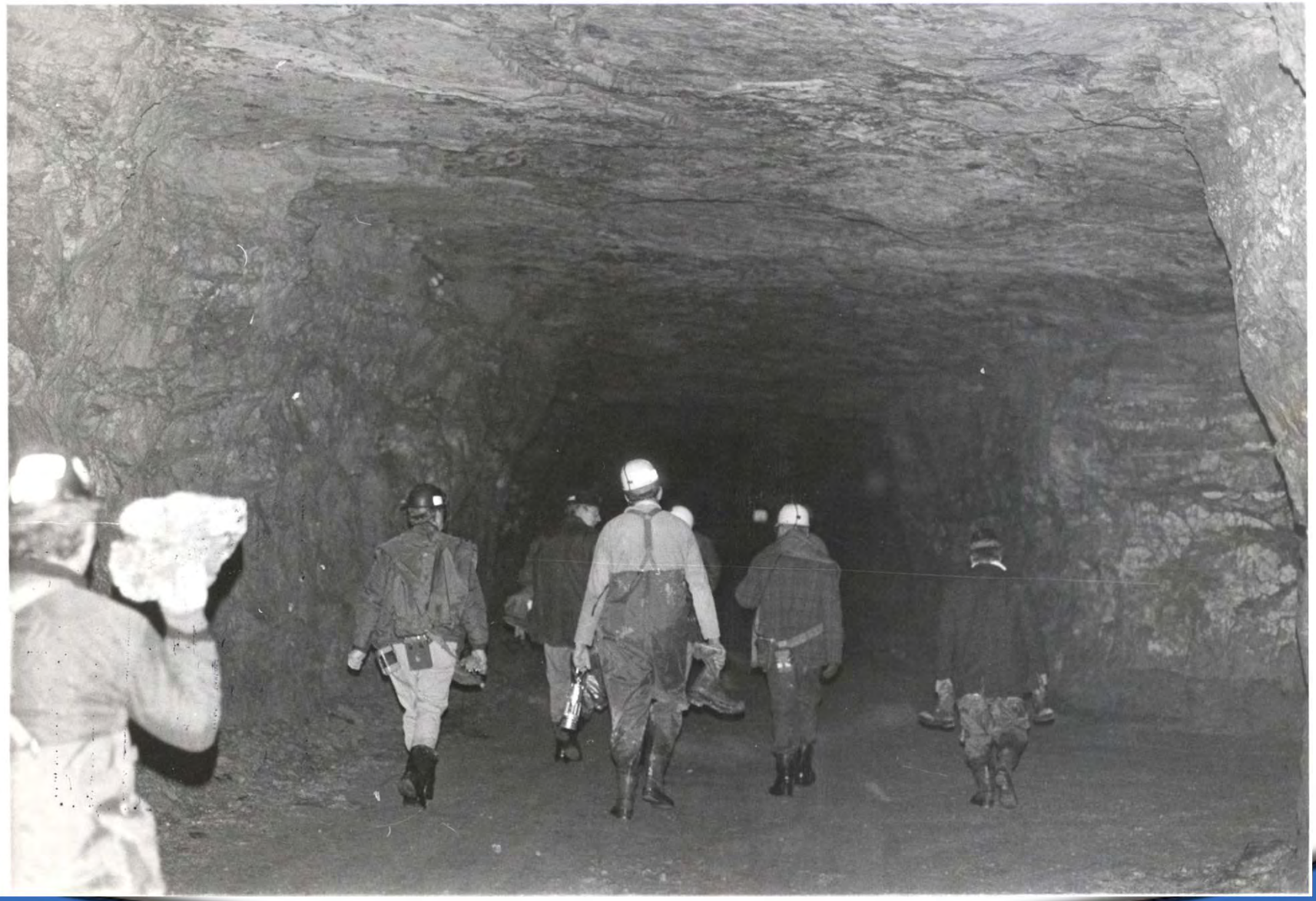

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2
53

Purpose & Need Goals

<u>Minimize Community Impacts</u>

- Airport, residential properties, large-scale camping facilities, cemeteries and municipal properties in project area
- Minimize environmental impacts
- Project be consistent with existing local plans

Purpose & Need Goals

<u>Minimize Peak Season Traffic Disruptions</u>

- SR-2 carries 18,000 vpd
- SR-2 is vital to tourist industry along Lake Erie
- Primary access to Marblehead peninsula and Ferry access to Middle & South Bass
- Secondary access to Cedar Point
- Minimize construction duration

Purpose & Need Goals

<u>Retain Limited Access Functionality</u>

- SR-2 is important east-west corridor
- Limited access facility throughout Ottawa County
- Maintain Norfolk & Southern Rail

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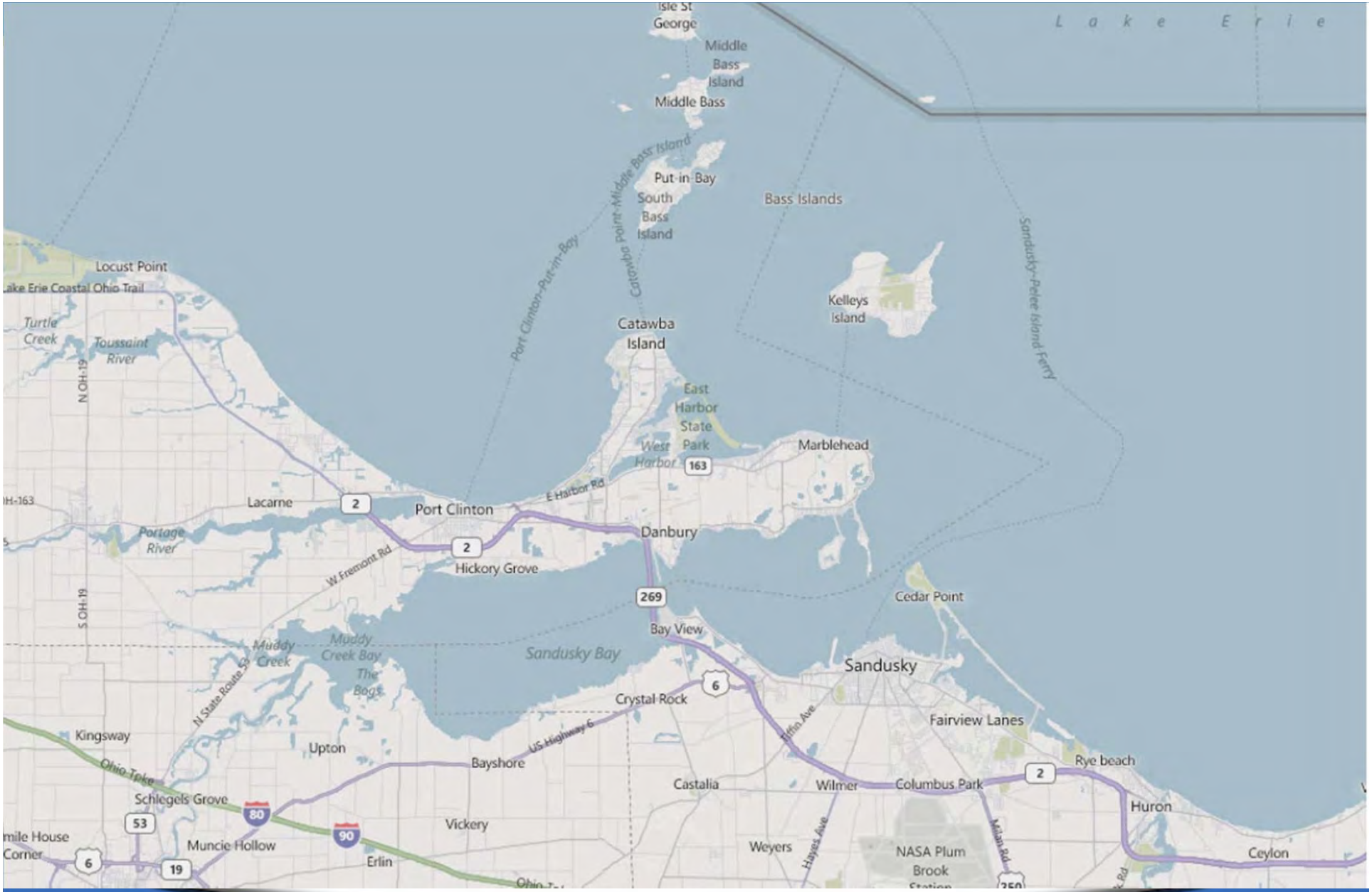

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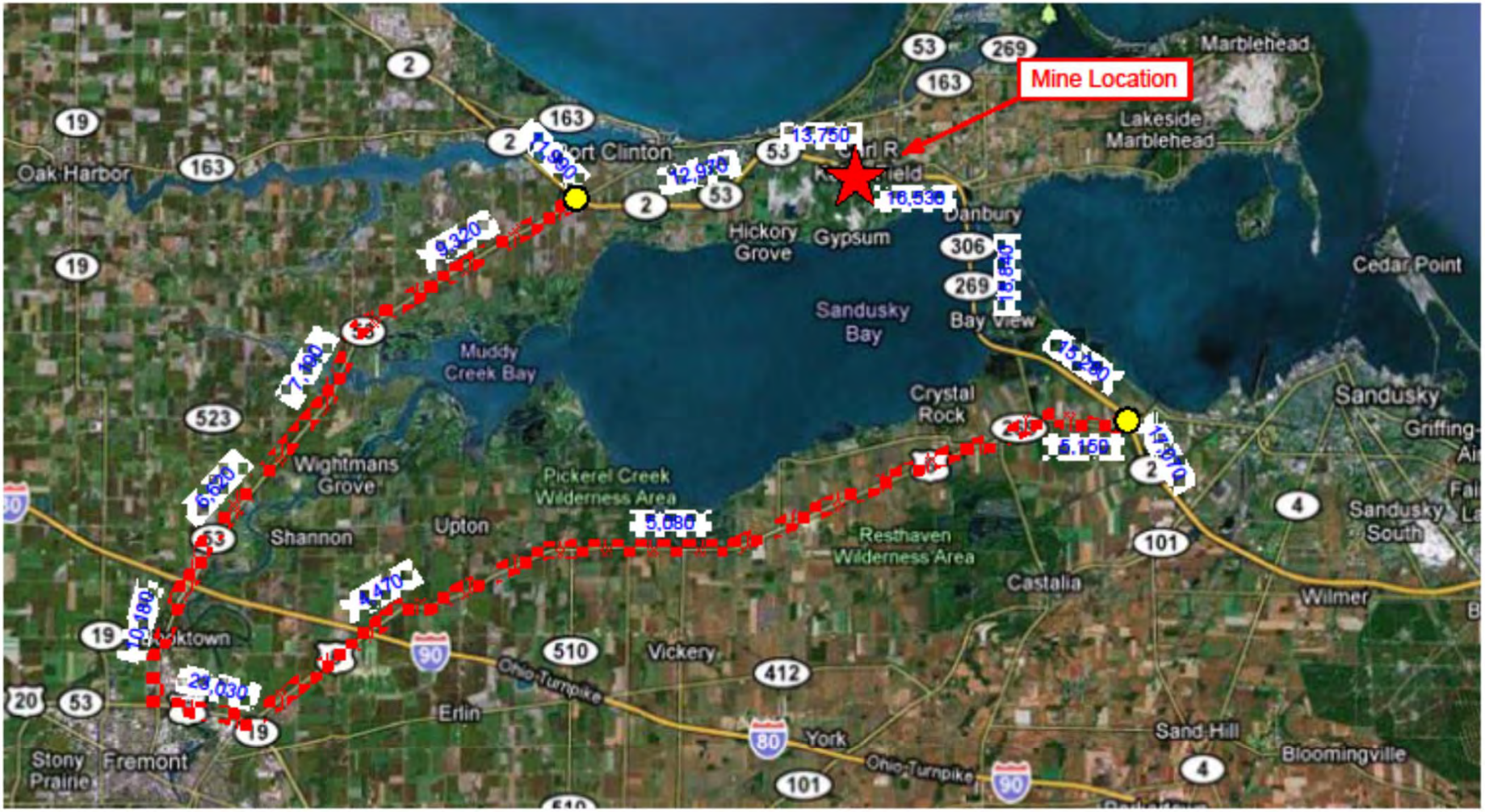
OTT-2 Detour Route and Traffic Volumes



Traffic Counts in Erie (2006), Ottawa (2009) and Sandusky (2009) Counties are from ODOT Traffic Survey Report

Detour will add 19 miles to a one-way trip from SR-2/SR-53 interchange to SR-2/US-6 interchange

2/5/10

Detour Cost

	Closure Duration (Days)	Cost to SR-2 Motorists
A	30	$5,401,222.20
B	180	$32,407,333.20
C	365	$65,714,870.10
D	365	$65,714,870.10

Project Goals

- Understand the existing geologic conditions
- Verify and define the approximate limits of the mine
- Understand the risks involved with mitigating the existing conditions

Project Goals

- Develop and evaluate conceptual alternatives based on the Purpose & Need
  - Remediate existing mines (SR-2 maintains current alignment)
  - Land bridge (SR-2 maintains current alignment)
  - Relocate/Shift SR-2

Geotechnical Investigation

- Surface geophysical
- Confirmation borings (21 Total)
- Laboratory testing
- Sonar modeling

Surface Geophysics to Help Identify Mine Boundaries

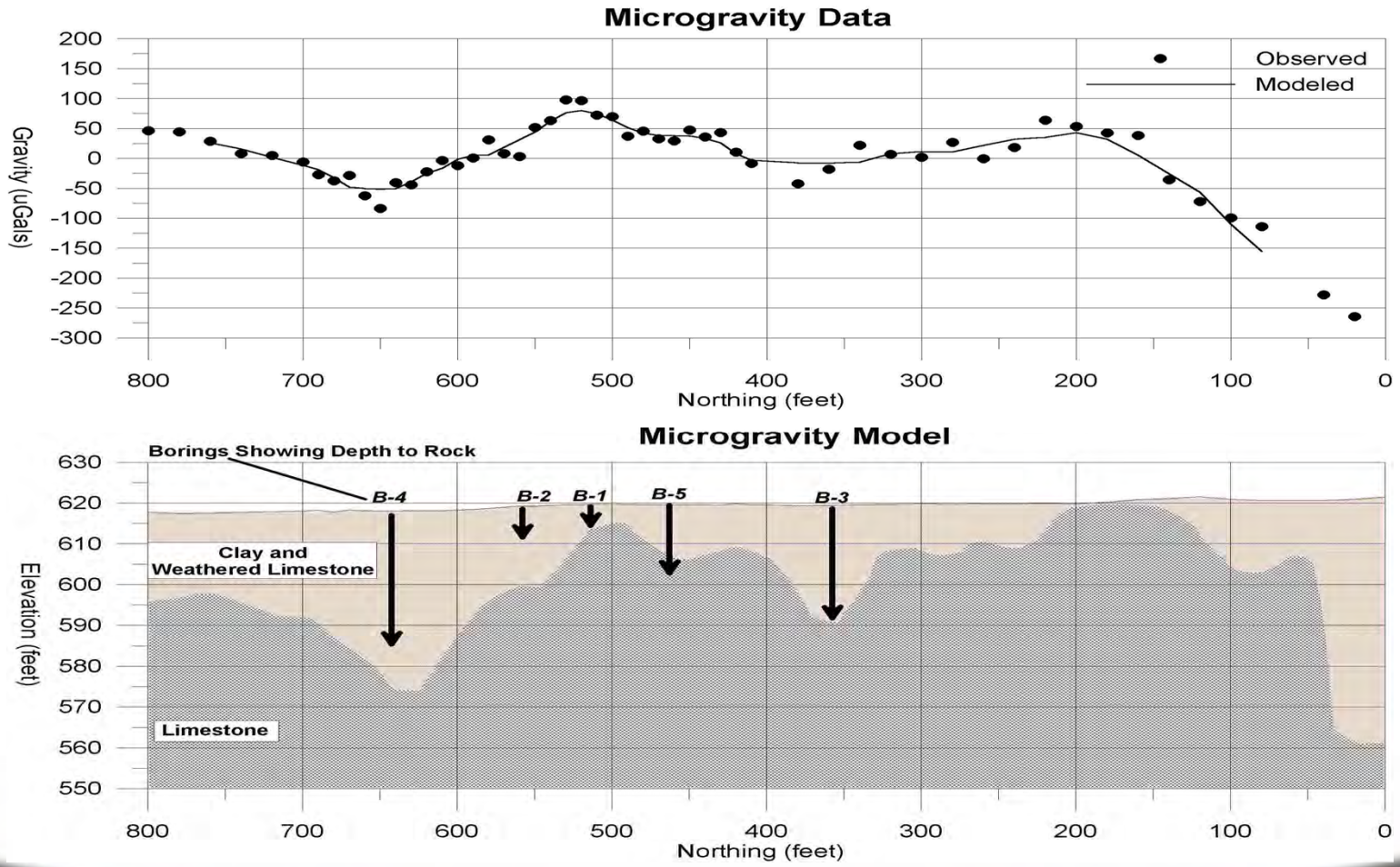
Approach included two surface geophysical methods:

- Microgravity – primarily to map mine boundaries
- Resistivity Imaging – primarily to identify other geologic variability and to aid in interpreting the gravity data

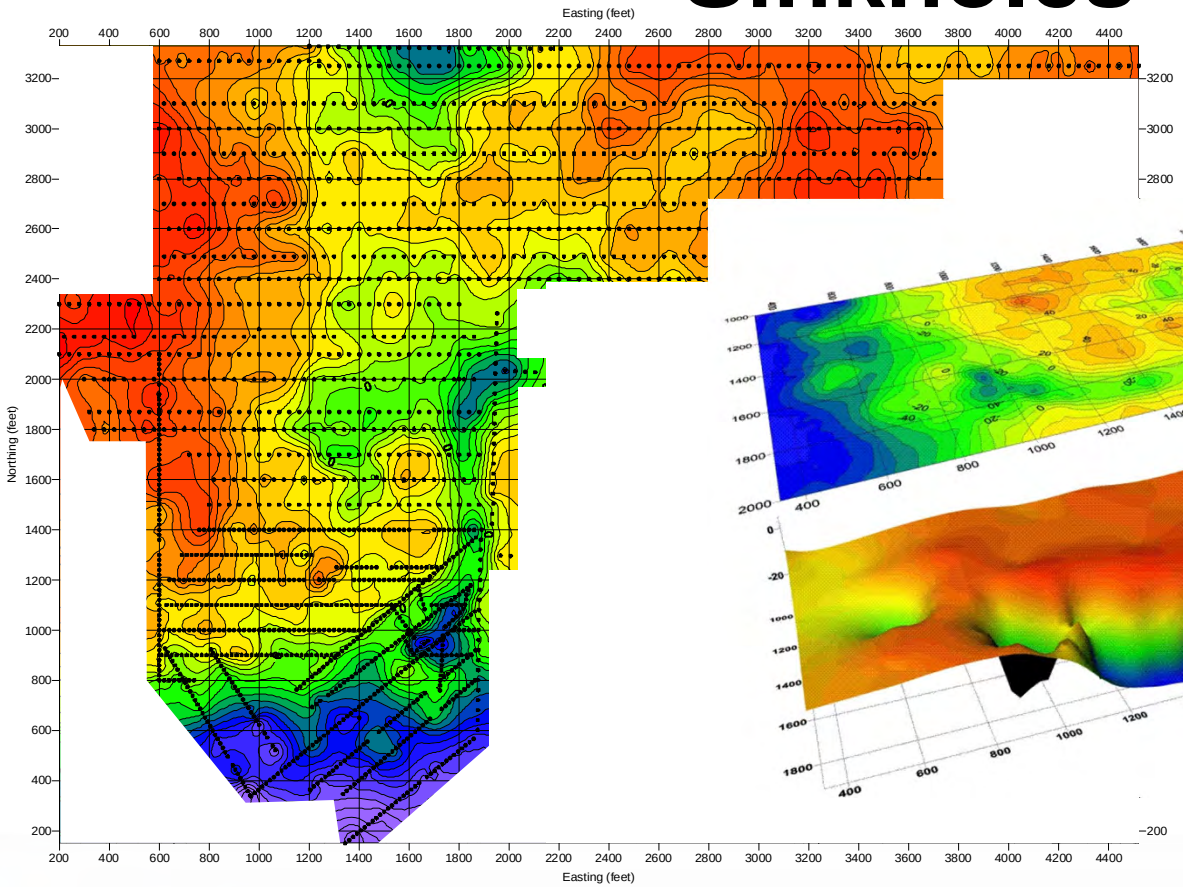
Microgravity

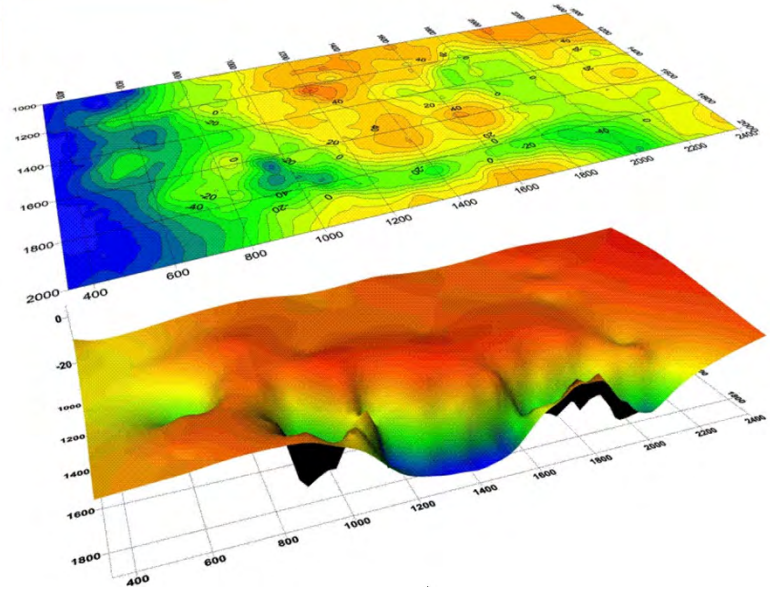
Gravity measurements detect changes in the earth's gravitational field caused by local changes in the density of the soil and rock or engineered structures.

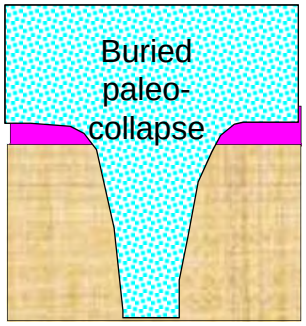
Mapping of Top of Rock



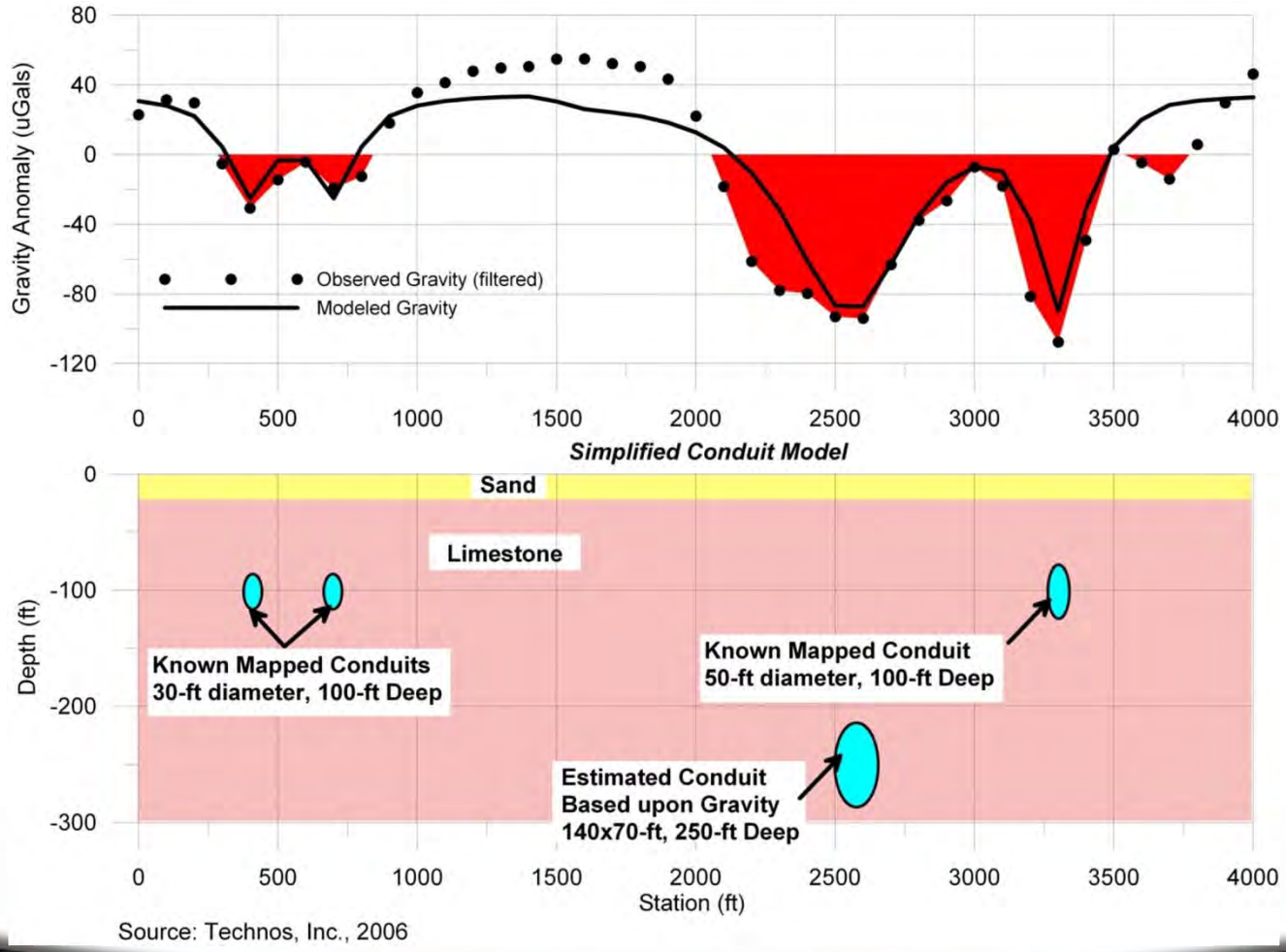
Mapping Old Paleo-Collapse Sinkholes



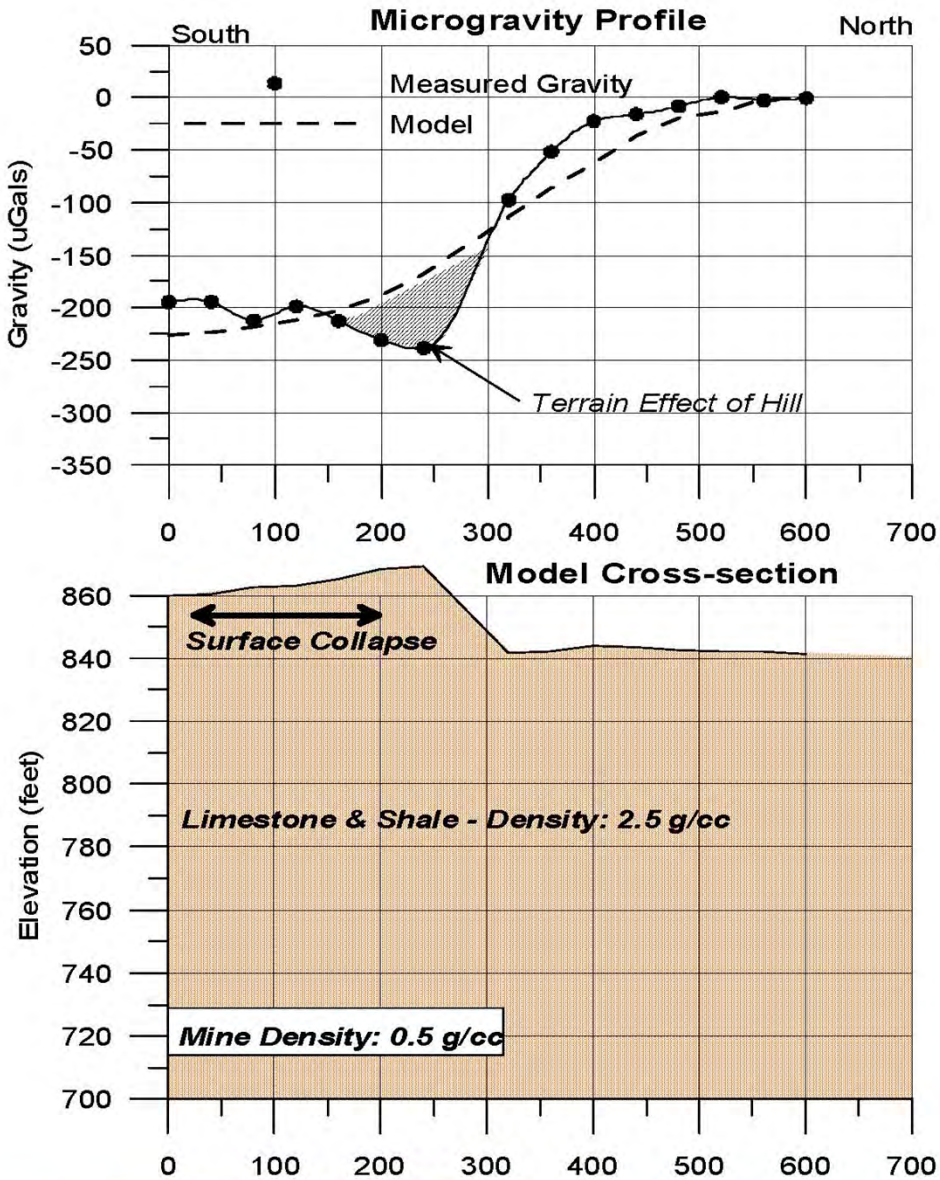




Detection of Large Conduits



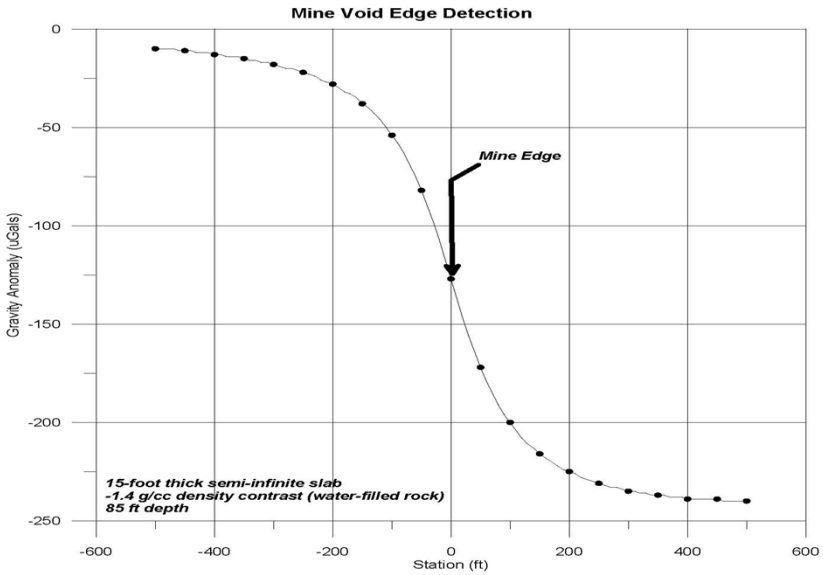
Source: Technos, Inc., 2006



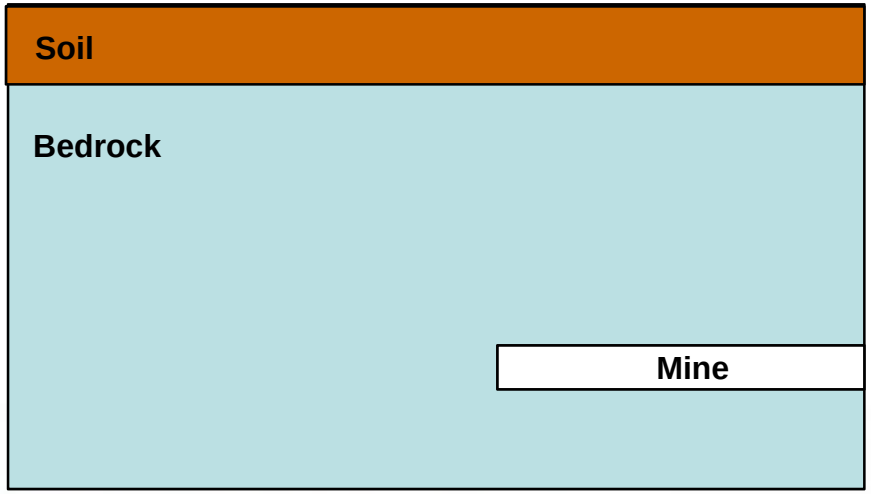
Map the Presence of Mines

Limitations

- Only detects features with a density contrast
- Supporting data must be used to constrain gravity models (non-unique modeling)
- Vibrations can produce noise in data (e.g. distant earthquakes, wind, waves, vehicles, construction, etc.)
- Nearby topography can introduce noise if not accounted for in the data processing

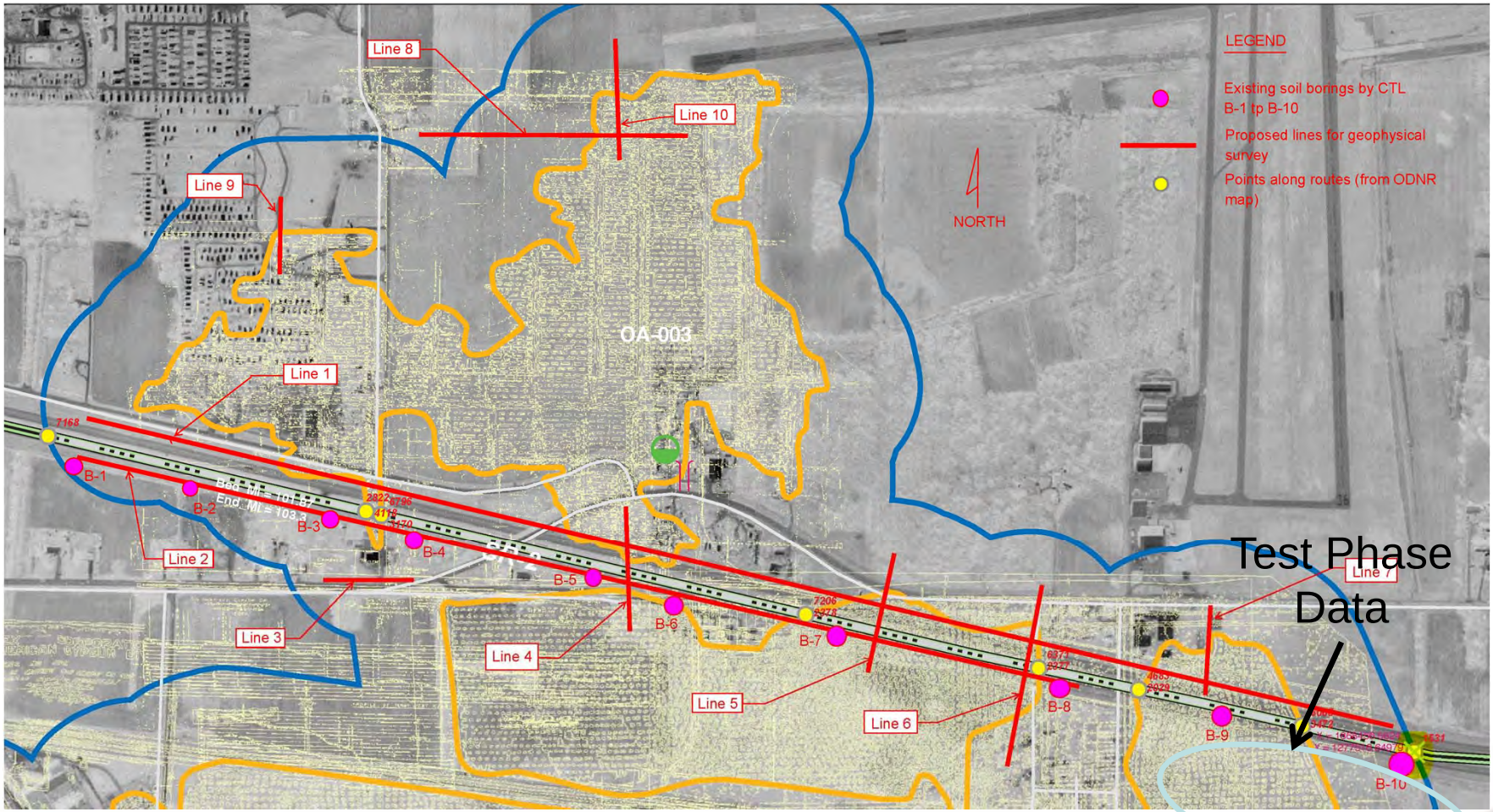


Forward Model of Gravity Response Over Expected Mine Conditions



85 ft deep,
15 ft high

Planned Geophysical Lines



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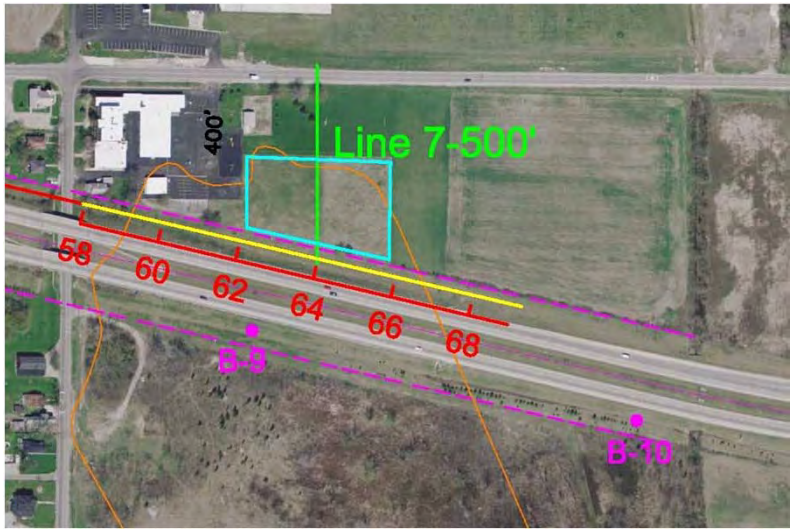
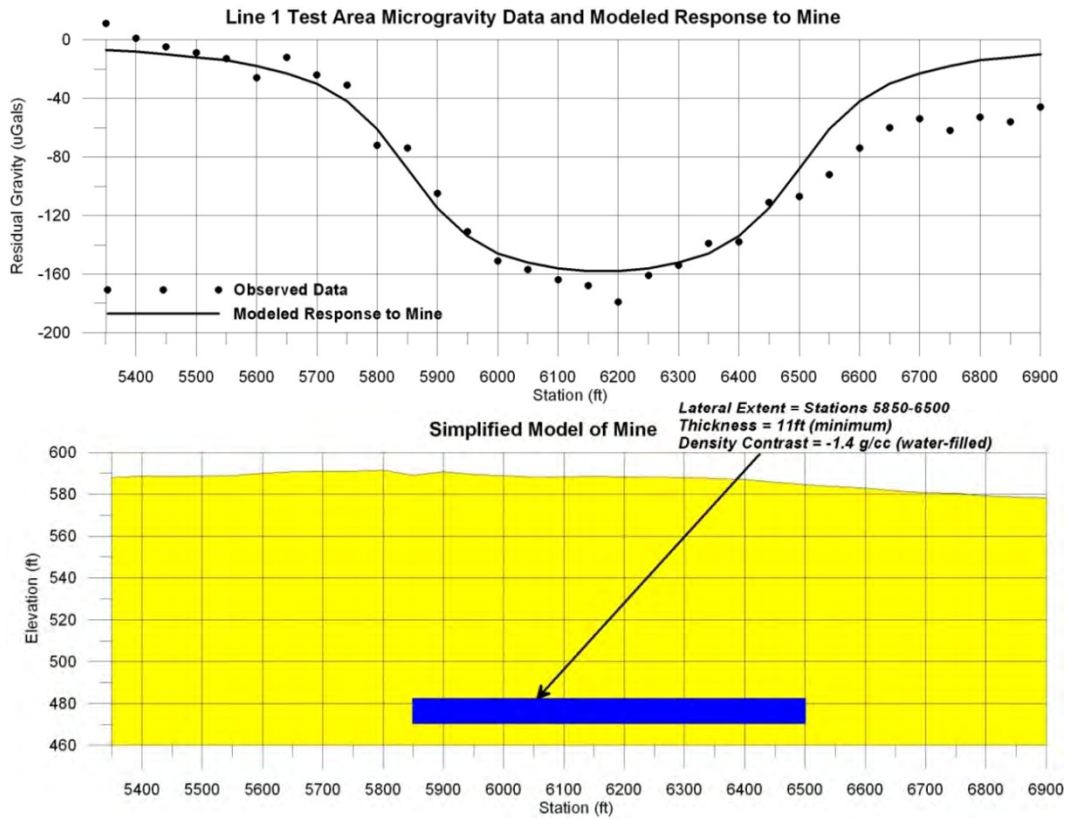
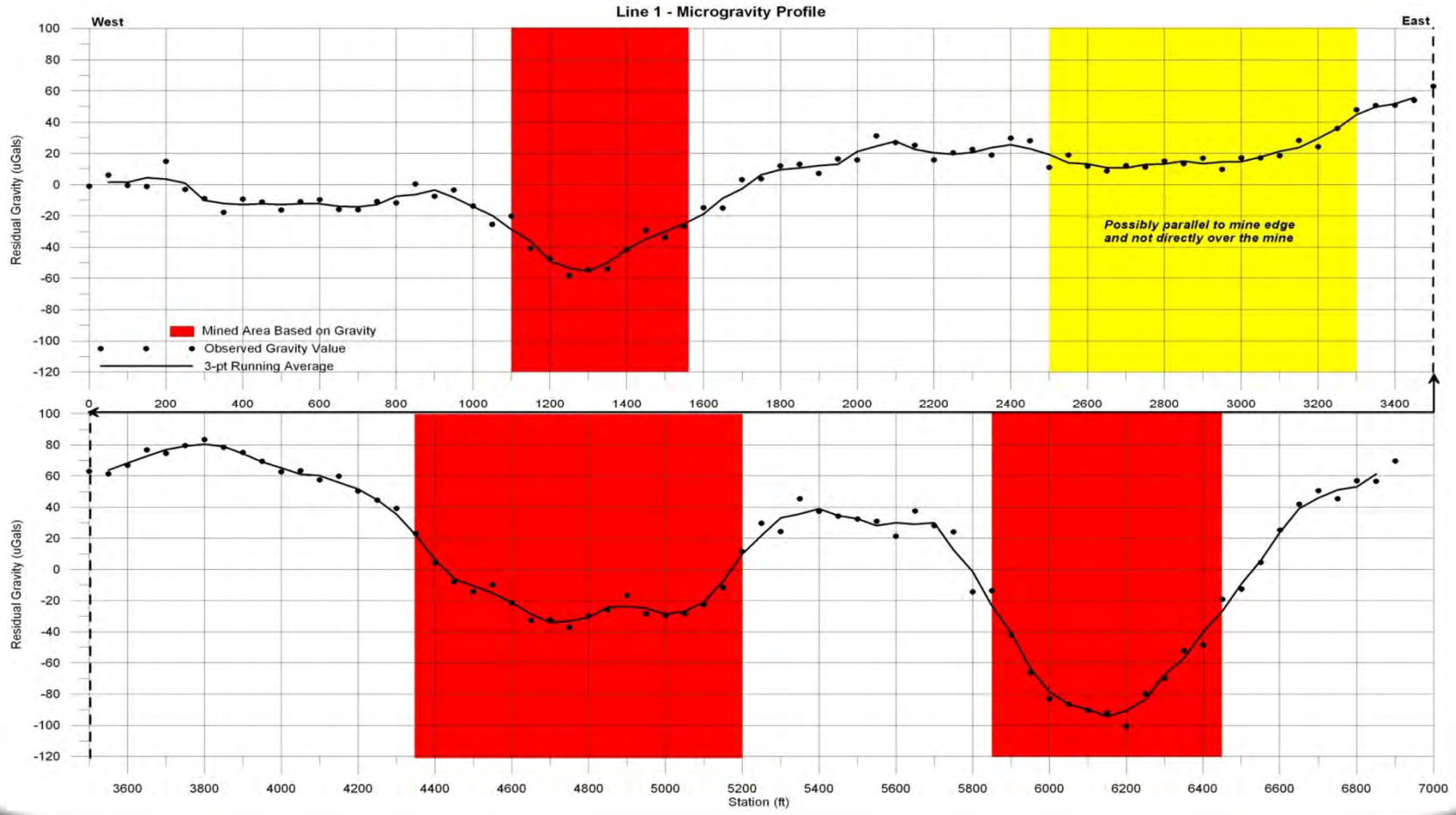
Microgravity Test Data



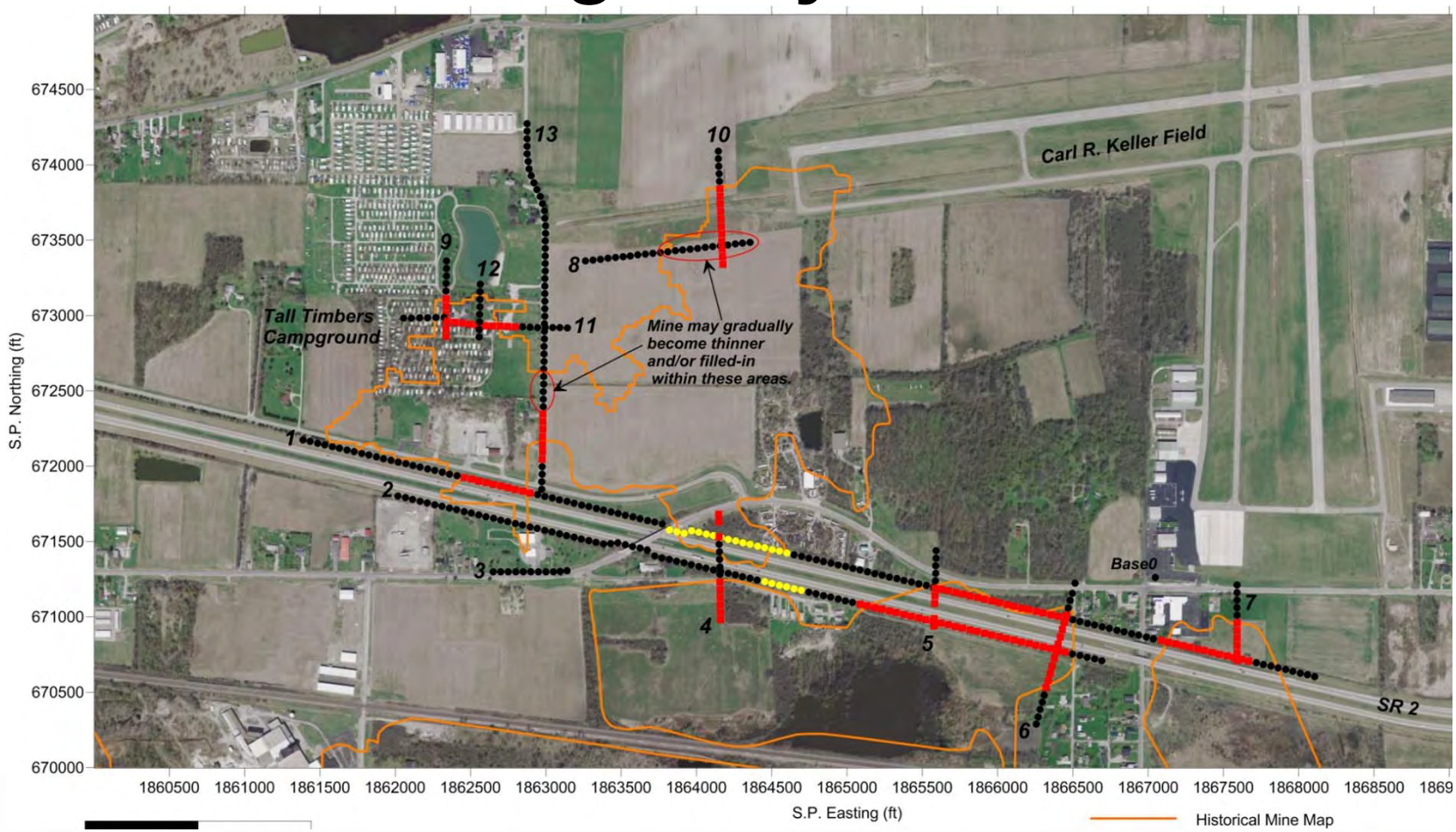


- Fairly insensitive to depth due to large planar target
- Very sensitive to thickness – 11 ft assumes water-filled, could be up to 15 ft or as little as 7 ft, if air-filled

Microgravity Data – Line 1



Microgravity Results



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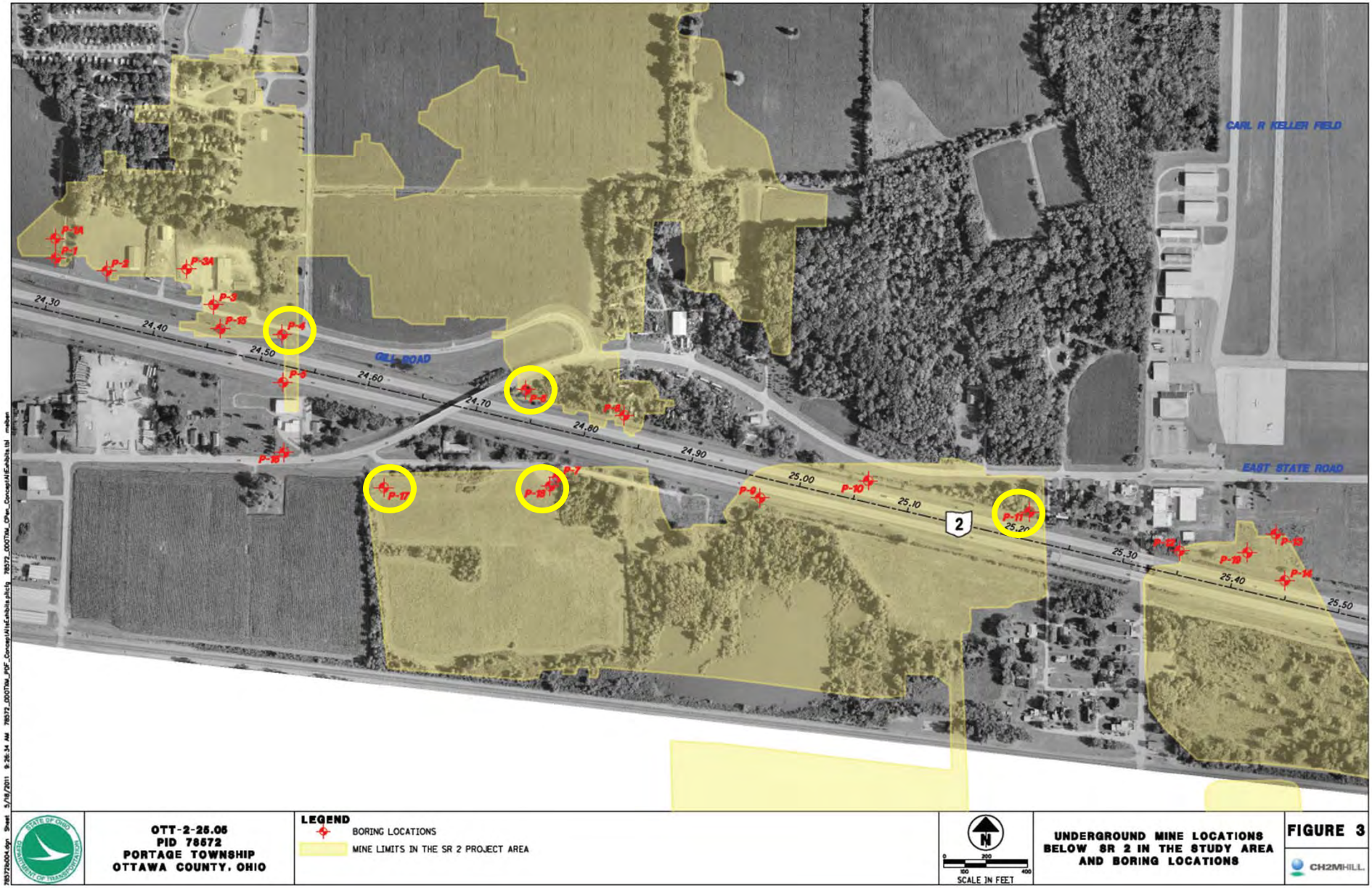
Results from Microgravity Alone

- Response from mine, even at deepest provided a good target for microgravity
- Top of rock is deeper to east
- Mine is deeper to east
- Thickness of mine varies – 2 to 12 ft, getting thinner to northwest

SUBSURFACE INVESTIGATION PLAN



OTT-2-25.06
PID 78572
PORTAGE TOWNSHIP
OTTAWA COUNTY, OHIO

LEGEND
BORING LOCATIONS
MINE LIMITS IN THE SR 2 PROJECT AREA

N
0 100 200 400
SCALE IN FEET

UNDERGROUND MINE LOCATIONS BELOW SR 2 IN THE STUDY AREA AND BORING LOCATIONS

FIGURE 3

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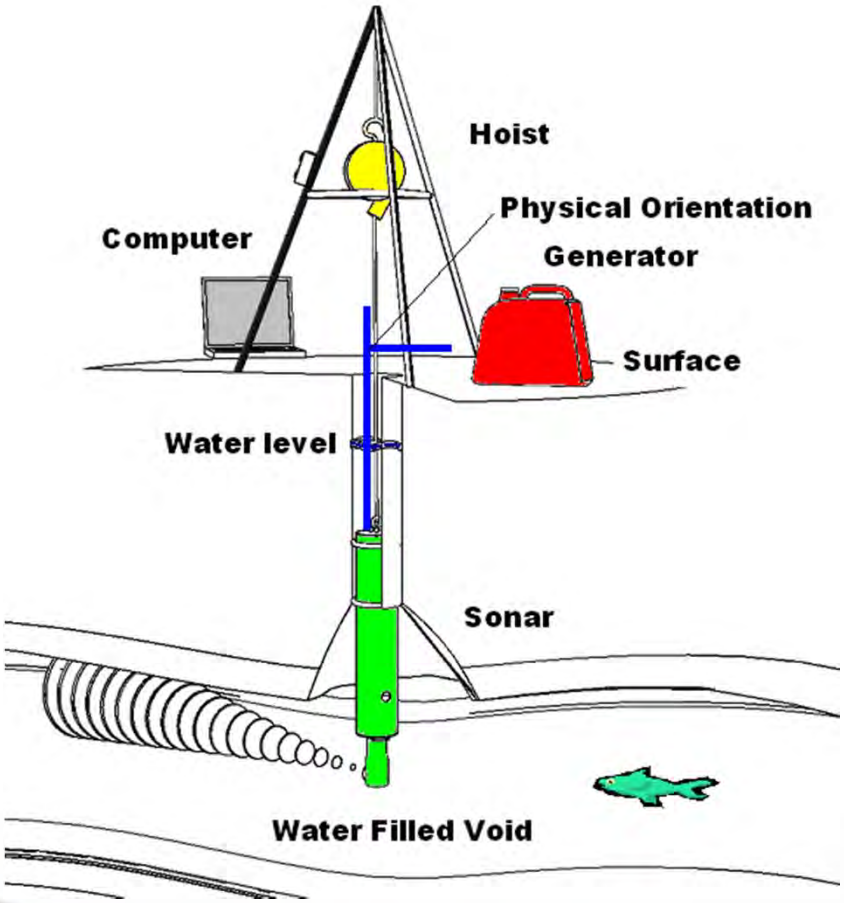
Sonar Deployment



- Sonar deployed by hoist from tripod
- Sonar linked mechanically to the surface providing a physical orientation
- Horizontal sonar scans are collected at 1 ft or less incremental elevations
- Computer controls and logs data from sonar unit

Statistics

- 200,000 cu ft of void modeled
- 1800 linear ft of mine corridor modeled
- Mine conditions revealed in models

Hole	P-4	P-6	P-11	P-17	P-18
Date of Sonar	11/17/2010	11/19/2010	11/17/2010	11/20/2010	11/20/2010
North	671861.68	671599.10	671017.05	671133.77	671139.71
East	1862851.85	1864014.87	1866416.33	1863336.13	1864129.80
Surface Elev	579.86	579.15	587.66	585.03	584.52
Water Elev	571.4	569.9	571.1	571.4	570.4
Top of Void	531.7	527.7	524.5	547.4	543.5
Bottom of Void	526.5	524.0	514.5	537.3	532.0
Volume	9083 cu ft	3537 cu ft	38314 cu ft	64039 cu ft	80648 cu ft

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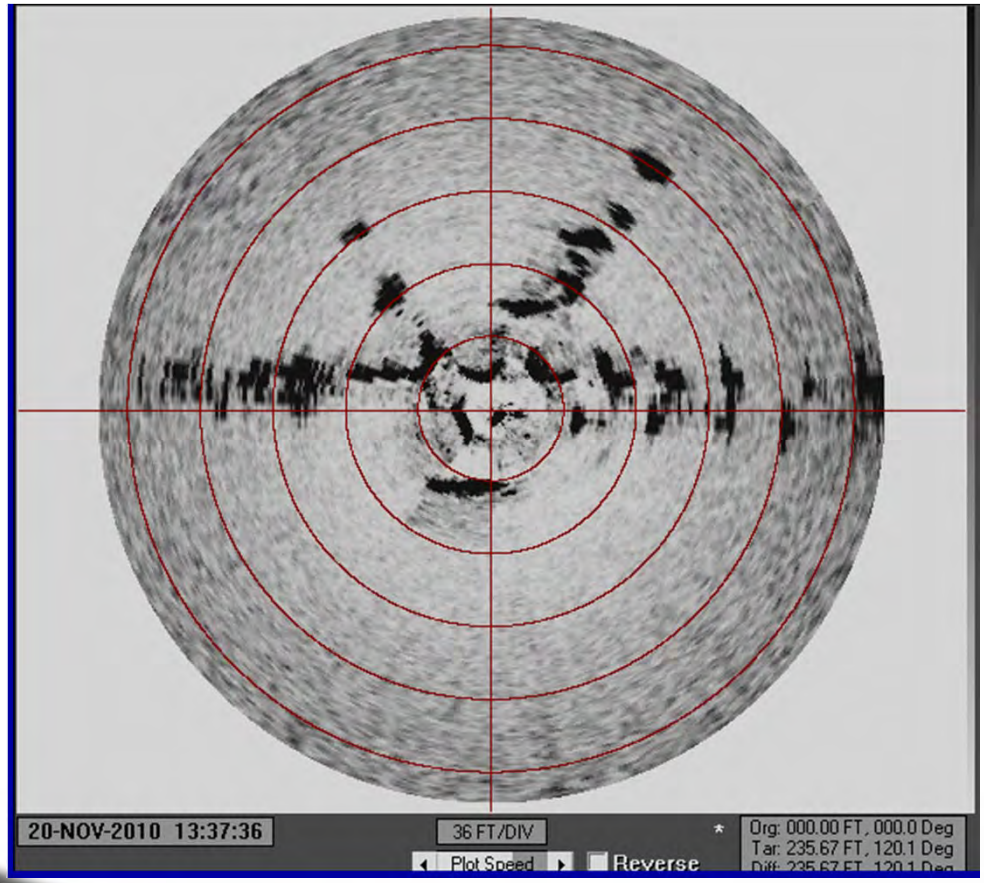
Sonar Modeling Process

- Collect horizontal sonar scans in small vertical increments in the field
- Combine scans to create a 3 dimensional model of the flooded void
- Translate and orient the model into site coordinates
- Produce plots, models, and analyze the model for volume
- View 2-D and 3-D data to access the remaining mine structures
- Align the features in the model with the mine map features

Sonar plot from field P-18



Sonar plot for 1 elevation as viewed in the field

Red circles represent 36 ft per division in this scan

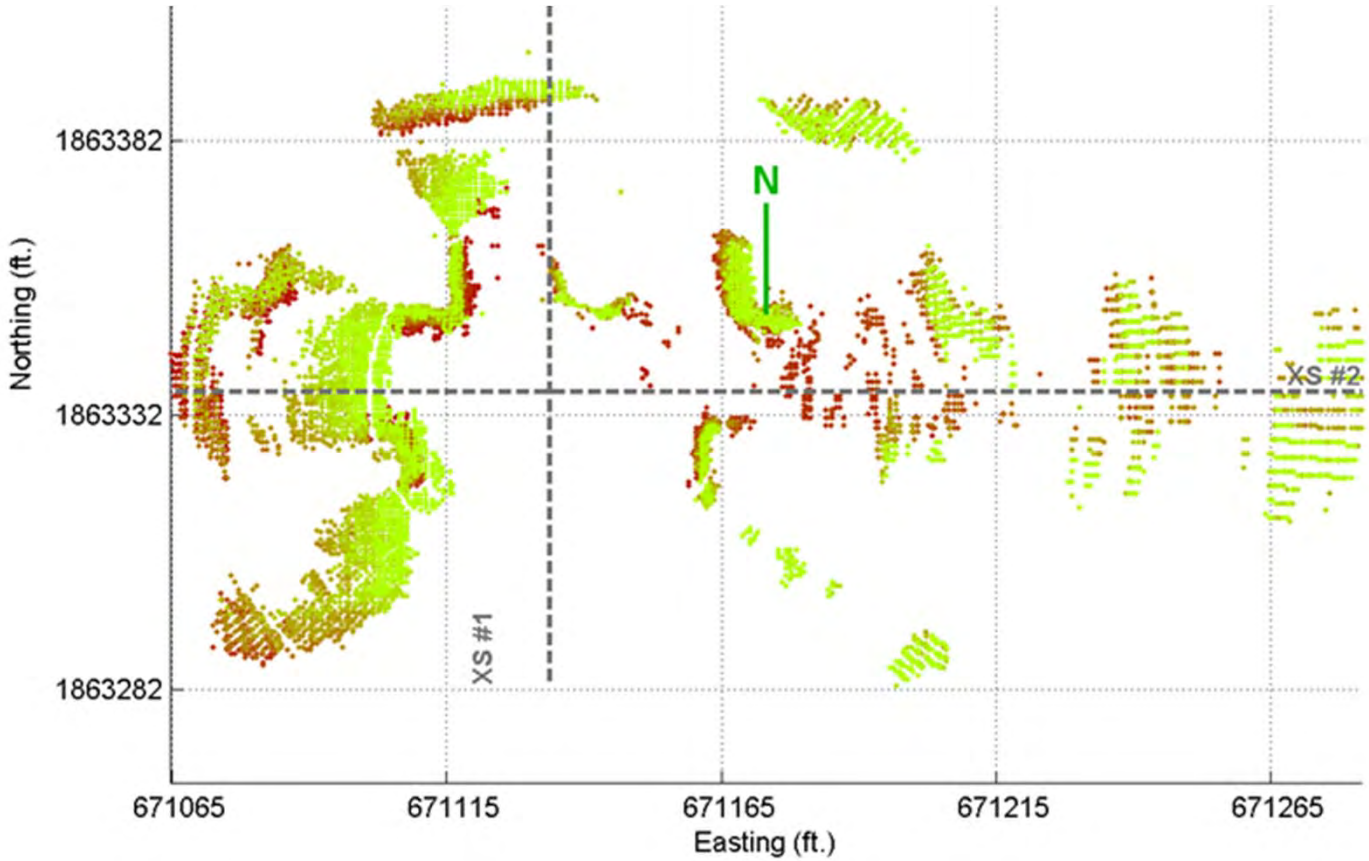
Red cross hairs show the borehole location center of the scan

Center to edge is approximately 200 ft

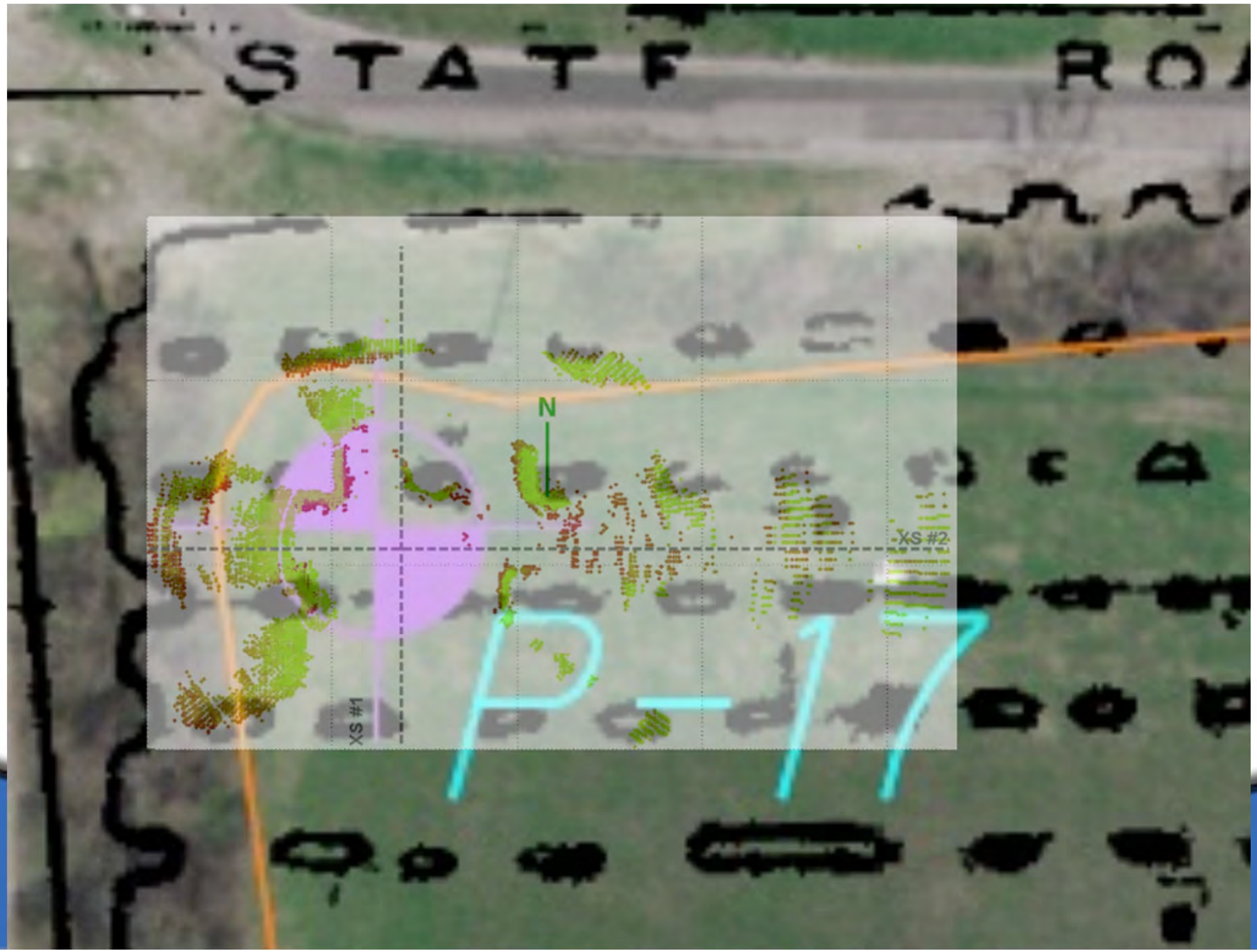
Dark areas are reflections from surfaces in the mine.

Crisp black lines are from vertical surfaces and fuzzy lines like shown to the left show slope of roof.

Composite plot of sonar scans P-17



P-17 sonar aligned on mine map



Sonar Results

- Confirmation and orientation of old mine maps through feature matching with sonar models
- Revealed areas of collapse and areas where pillars are still intact
- Larger models verified dip of the seam where both roof and floor were visible

Sonar data was gathered 200 ft from some of the boreholes

The water was filled with suspended particles and visibility was minimal. The camera was only useful to verify the water level and to confirm blockage or bottom.

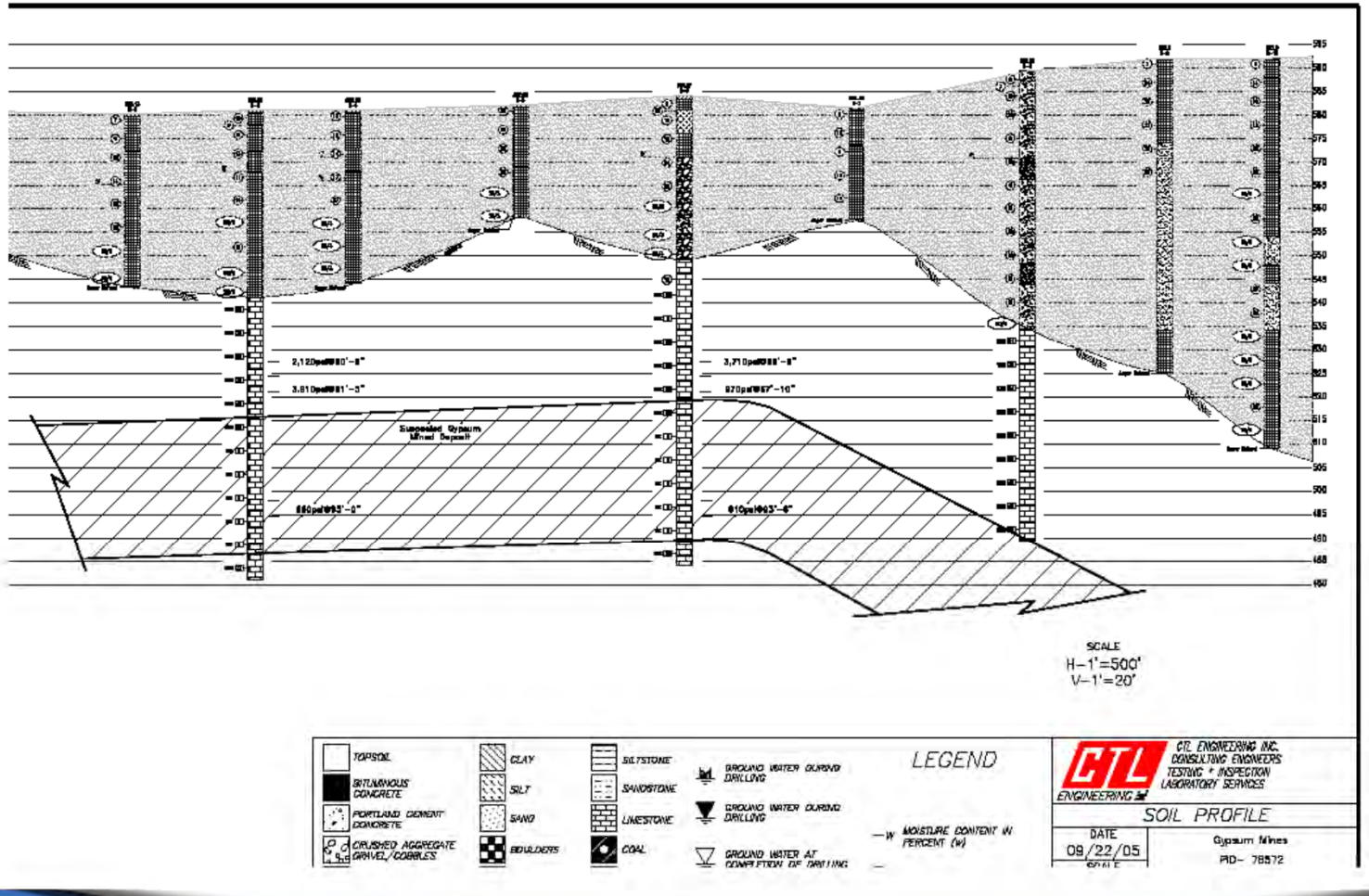
Alternative Development

- Minie Stabilization (SR-2 maintains current alignment)

- Land bridge (SR-2 maintains current alignment)

- Relocate/Shift SR-2

SR 2 – GENERAL SUBSURFACE PROFILE



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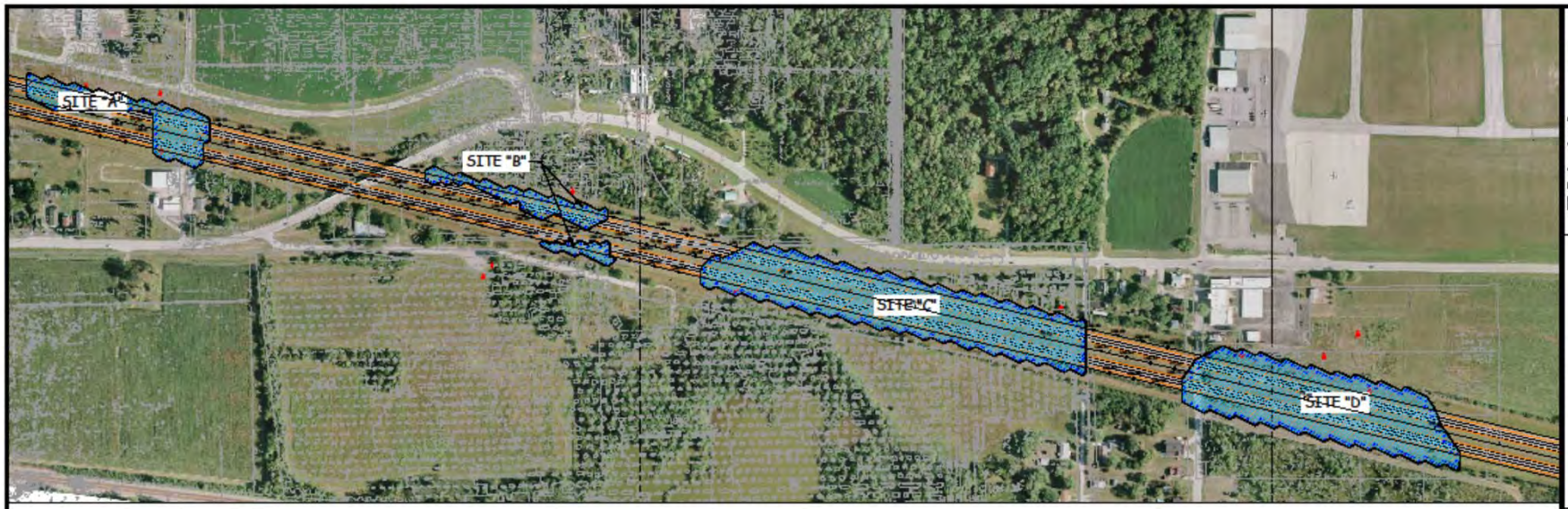
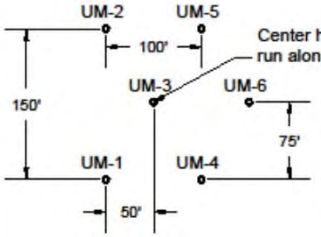
BORING INJECTION PLAN



LEGEND

UM-1 UNMAPPED AREAS OF GYPSUM EXPLORATORY BORINGS

MAPPED GYPSUM MINE GROUT INJECTION AREA



TYPICAL EXPLORATORY HOLE LAYOUT

ENGINEERS ESTIMATE
(UNMAPPED GYPSUM EXPLORATORY BORINGS)

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL PRICE
Drilling 70 Unmapped Exploratory Holes	4,900	L.F.	$12.00	$58,800
Casing Unmapped Exploratory Holes	2,450	L.F.	$3.00	$7,350
Purchasing, Handling and Placing Grout	10,000	C.Y.	$125.00	$1,250,000
Sediment Control	100	L.F.	$3.00	$300
Revegetation	1	L.S.	$10,000	$10,000
			Total	$1,326,450

SCALE 1" = 400'

0 400 800 1200

CTL Engineering of West Virginia, Inc.

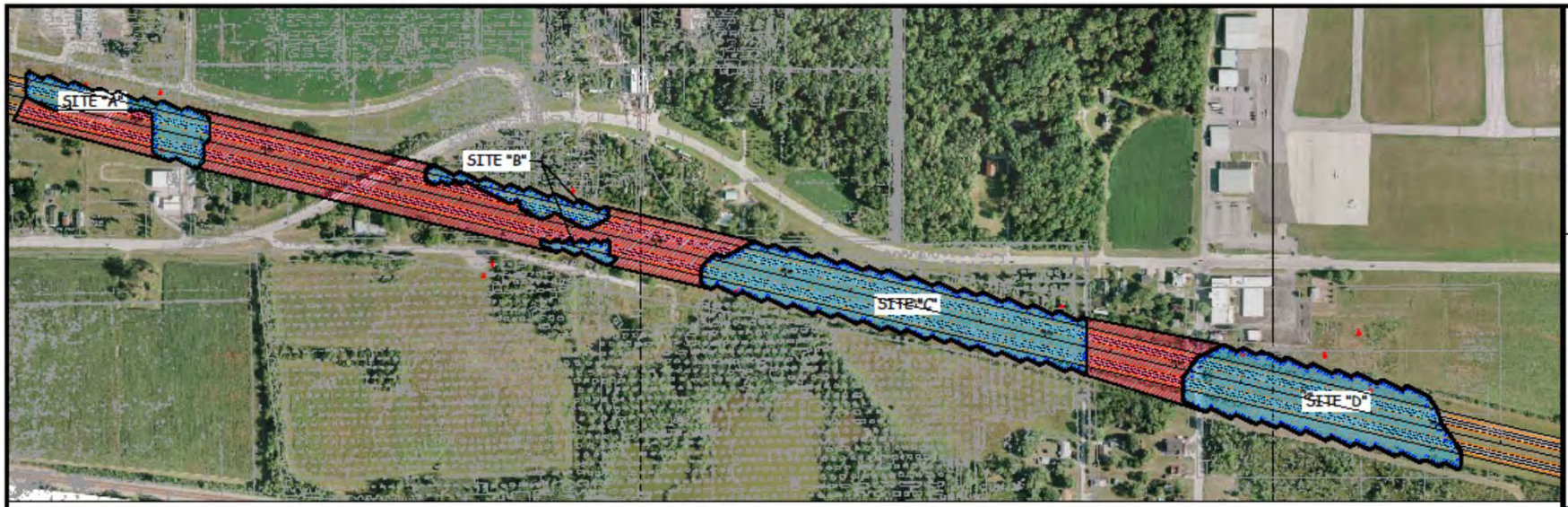
OTT-2-26.06

UNMAPPED EXPLORATORY BORINGS

POCAHONTAS TERRACE, OTTAWA COUNTY, OHIO

Date	Description	Approved

MINE STABILIZATION PLAN



SITE "A"

Grouted coverage area 87,146 ft²
x Mine Depth 11 ft / 27 ft³/yd³ x
40% Void volume = 14,200 yd³

SITE "B"

Grouted coverage area 61,775 ft²
x Mine Depth 11 ft / 27 ft³/yd³ x
40% Void volume = 10,100 yd³

SITE "C"

Grouted coverage area 318,072 ft²
x Mine Depth 11 ft / 27 ft³/yd³ x
40% Void volume = 51,834 yd³

SITE "D"

Grouted coverage area 273,217 ft²
x Mine Depth 13 ft / 27 ft³/yd³ x
40% Void volume = 52,620 yd³

UNMAPPED AREAS OF GYPSUM EXPLORATORY BORINGS

70 Exploratory Holes x 70 ft Average
Depth = 4900 lf

10,000 yd³ Grout

LEGEND

MAPPED GYPSUM MINE
GROUT INJECTION AREA

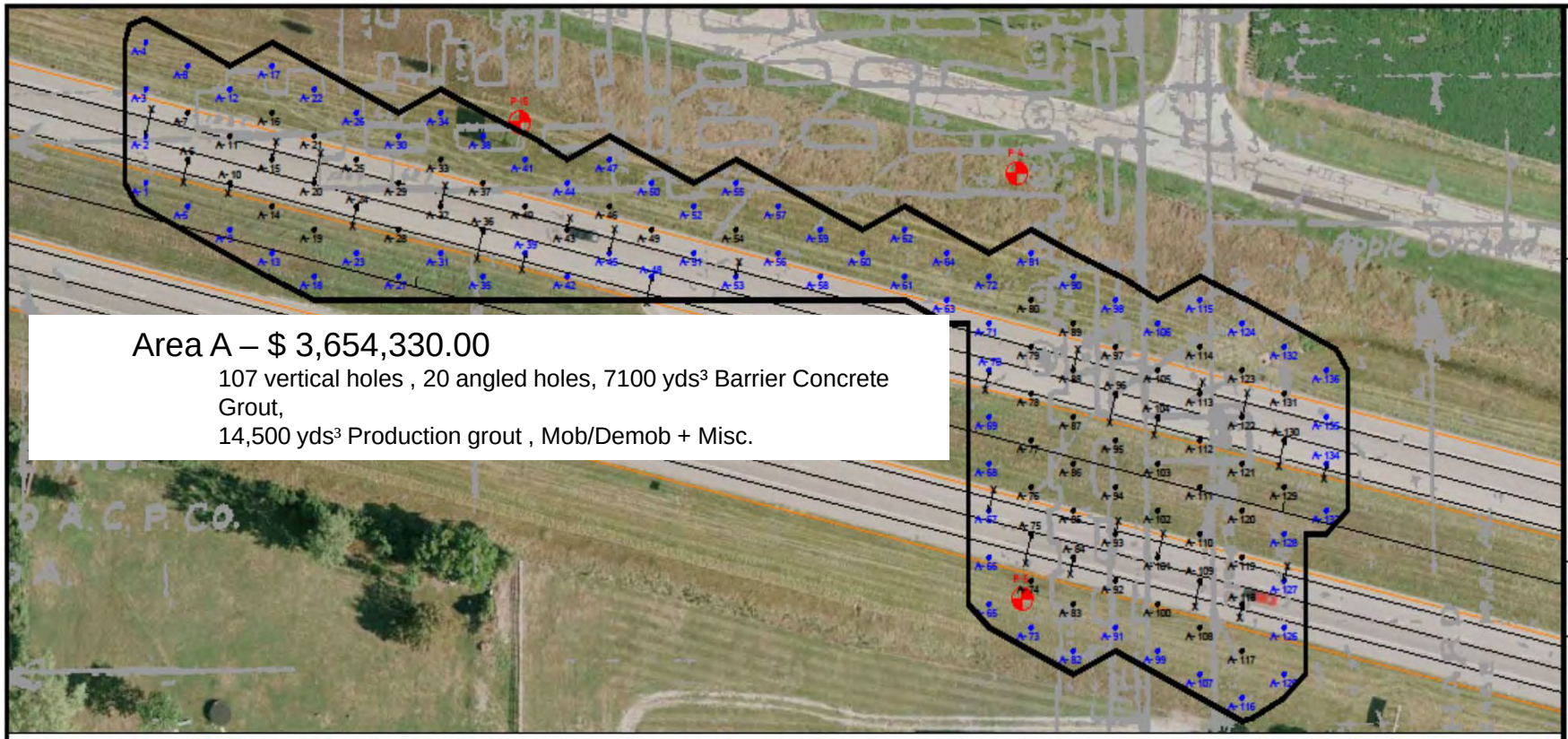
UNMAPPED GYPSUM MINE
EXPLORATORY BORING AREA

SCALE 1" = 400'

0 400 800 1200

OTT-2-28.06

OVERALL SITE PLAN



Area A – $ 3,654,330.00

107 vertical holes , 20 angled holes, 7100 yds³ Barrier Concrete Grout,
14,500 yds³ Production grout , Mob/Demob + Misc.

LEGEND

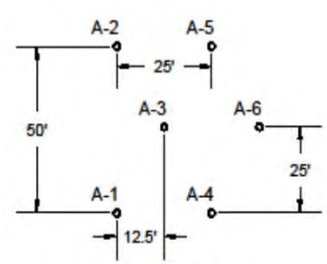
- VERTICAL GROUT INJECTION HOLE
- ANGLED GROUT INJECTION HOLE
- BARRIER INJECTION HOLE
- BORE HOLE

SCALE 1" = 60'

0 60 120 180

ENGINEERS ESTIMATE
(SITE "A" ONLY)

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL PRICE
Mobilization and Demobilization	1	L.S.	$80,000	$80,000
Construction Layout	1	L.S.	$5,000	$5,000
Quality Control	1	L.S.	$10,000	$10,000
Drilling 107 Vertical Injection Holes	6,420	L.F.	$12.00	$77,040
Casing Vertical Injection Holes	3,210	L.F.	$3.00	$9,630
Drilling 20 Angled Injection Holes	1,773	L.F.	$18.00	$31,914
Casing Angled Injection Holes	887	L.F.	$3.00	$2,661
Purchasing, Handling and Placing Concrete	710	C.Y.	$95.00	$67,450
Purchasing, Handling and Placing Grout	14,200	C.Y.	$125.00	$1,775,000
Confirmation Drilling	240	L.F.	$35.00	$8,400
Borehole Photography	10	HRS.	$40.00	$400
Sediment Control	100	L.F.	$3.00	$300
Dewatering	1	L.S.	$37,500	$37,500
QA-Program Inc. some regrouting	1	L.S.	$375,000	$375,000
Revegetation	1	L.S.	$10,000	$10,000
			Total	$3,654,330
			Grouted Area	87,146 ft²
			Price per ft²	$41.93/ft²



TYPICAL GROUT
INJECTION HOLE LAYOUT

CTL Engineering of West Virginia, Inc.

OTT-2-26.06

SITE "A" STA. 445+-454

PUTNAM COUNTY, OHIO

Approved

Description

Date

Drawn By: RAH

Approved By: PSE

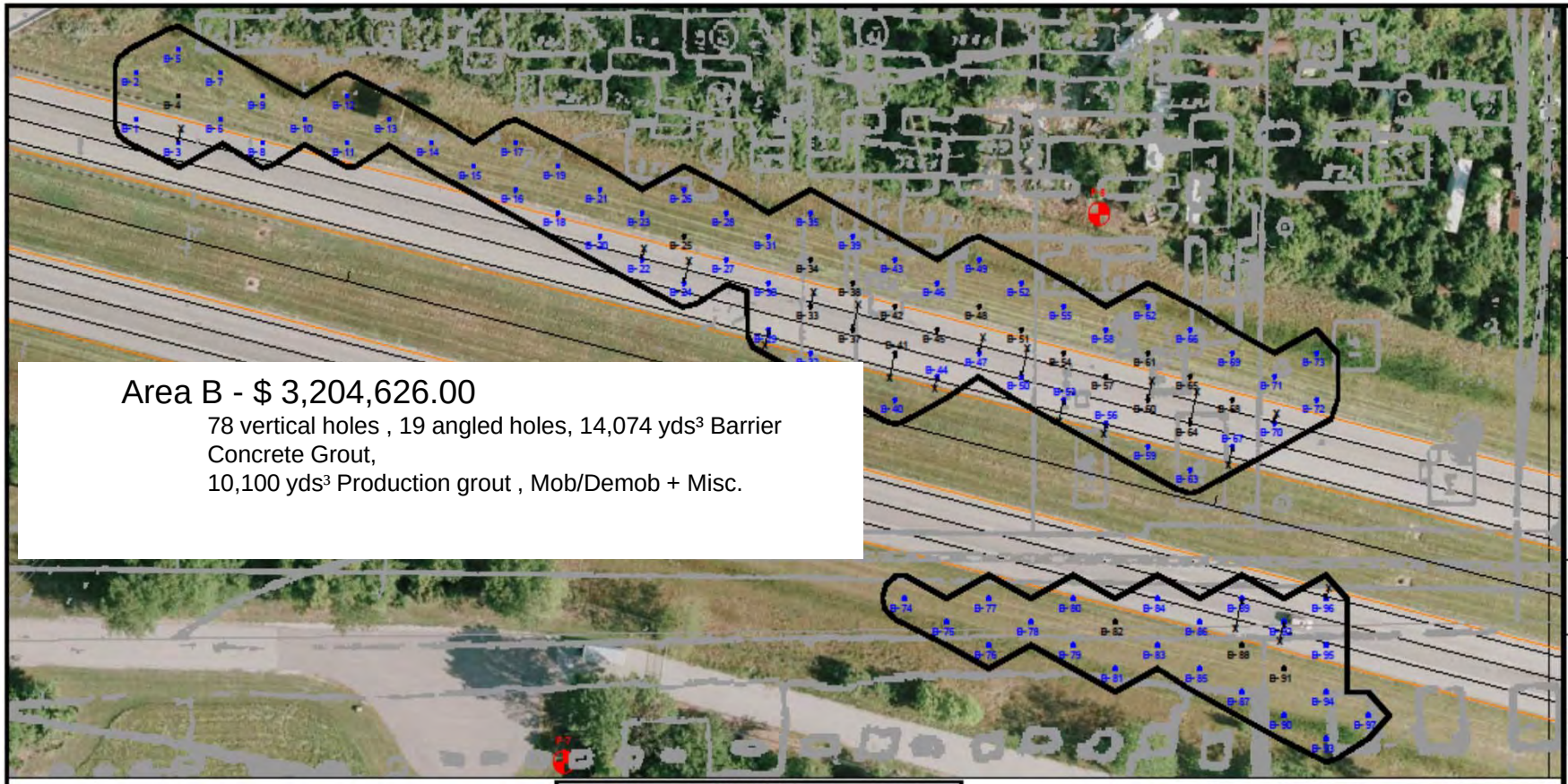
Date: 8/17/11

Scale: NO SCALE

Project No.

Drawing Name: GROUT SERVICES 8-17-11

Sheet No. 2 of 2



Area B - $ 3,204,626.00

78 vertical holes , 19 angled holes, 14,074 yds³ Barrier Concrete Grout,
10,100 yds³ Production grout , Mob/Demob + Misc.

LEGEND

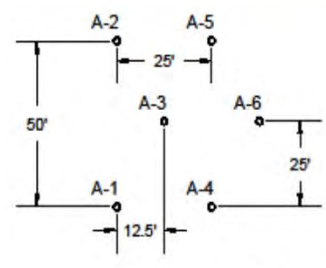
- VERTICAL GROUT INJECTION HOLE
- ANGLED GROUT INJECTION HOLE
- BARRIER INJECTION HOLE
- BORE HOLE

SCALE 1" = 60'

0 60 120 180

ENGINEERS ESTIMATE
(SITE "B" ONLY)

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL PRICE
Mobilization and Demobilization	1	L.S.	$80,000	$80,000
Construction Layout	1	L.S.	$5,000	$5,000
Quality Control	1	L.S.	$10,000	$10,000
Drilling 78 Vertical Injection Holes	4,311	L.F.	$12.00	$51,732
Casing Vertical Injection Holes	2,132	L.F.	$3.00	$6,396
Drilling 19 Angled Injection Holes	1,045	L.F.	$18.00	$18,810
Casing Angled Injection Holes	520	L.F.	$3.00	$1,560
Purchasing, Handling and Placing Barrier Material	14,074	C.Y.	$95.00	$1,337,030
Purchasing, Handling and Placing Grout	10,100	C.Y.	$125.00	$1,262,500
Confirmation Drilling	240	L.F.	$35.00	$8,400
Borehole Photography	10	HRS.	$40.00	$400
Sediment Control	100	L.F.	$3.00	$300
Dewatering	1	L.S.	$37,500	$37,500
QA-Program Inc. some regrouting	1	L.S.	$375,000	$375,000
Revegetation	1	L.S.	$10,000	$10,000
			Total	$3,204,628
			Grouted Area	61,775 ft²
			Price per ft²	$51.88/ft²



TYPICAL GROUT
INJECTION HOLE LAYOUT

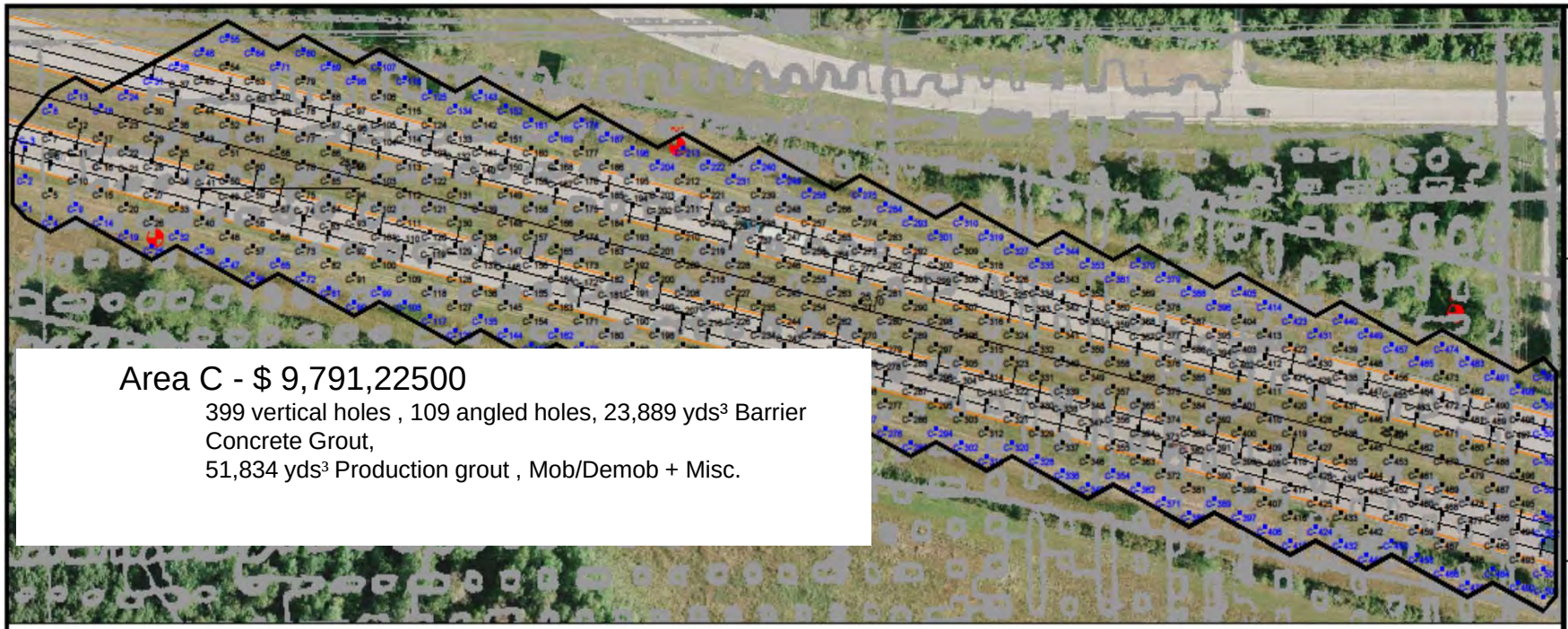
GTL Engineering of West Virginia, Inc.

077-2-26.06

SITE "B" STA. 461+470

PUTNAM TOWNSHIP, PUTNAM COUNTY, OHIO

Drawn By: RAH
Approved By: FBE
Date: 8/17/11
Scale: NO SCALE
Project No.
Drawing Name: GROUT SERVICES 8-24-11
Sheet No. 4 of 10



Area C - $ 9,791,22500

399 vertical holes , 109 angled holes, 23,889 yds³ Barrier Concrete Grout,
51,834 yds³ Production grout , Mob/Demob + Misc.

LEGEND

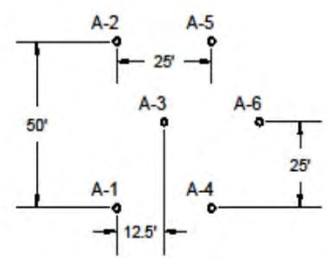
- VERTICAL GROUT INJECTION HOLE
- ANGLED GROUT INJECTION HOLE
- BARRIER INJECTION HOLE
- BORE HOLE

ENGINEERS ESTIMATE
(SITE "C" ONLY)

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL PRICE
Mobilization and Demobilization	1	L.S.	$80,000	$80,000
Construction Layout	1	L.S.	$5,000	$5,000
Quality Control	1	L.S.	$10,000	$10,000
Drilling 399 Vertical Injection Holes	23,940	L.F.	$12.00	$287,280
Casing Vertical Injection Holes	15,960	L.F.	$3.00	$47,880
Drilling 109 Angled Injection Holes	6,760	L.F.	$18.00	$121,680
Casing Angled Injection Holes	4,360	L.F.	$3.00	$13,080
Purchasing, Handling and Placing Barrier Material	23,889	C.Y.	$95.00	$2,269,455
Purchasing, Handling and Placing Grout	51,834	C.Y.	$125.00	$6,479,250
Confirmation Drilling	1,200	L.F.	$35.00	$42,000
Borehole Photography	40	HRS.	$40.00	$1,600
Sediment Control	500	L.F.	$3.00	$1,500
Dewatering	1	L.S.	$37,500	$37,500
QA-Program Inc. some regrouting	1	L.S.	$375,000	$375,000
Revegetation	1	L.S.	$20,000	$20,000
			Total	$9,791,225
			Grouted Area	318,072 ft²
			Price per ft²	$30.79/ft²

SCALE 1" = 100'

0 100 200 300



TYPICAL GROUT
INJECTION HOLE LAYOUT

CTL Engineering of West Virginia, Inc.

OTT-2-26.06

SITE "C" STA. 473+00

PUTNAM COUNTY, OHIO

Approved

Revisions

Date | Description

Drawn By: RAH

Approved By: PSE

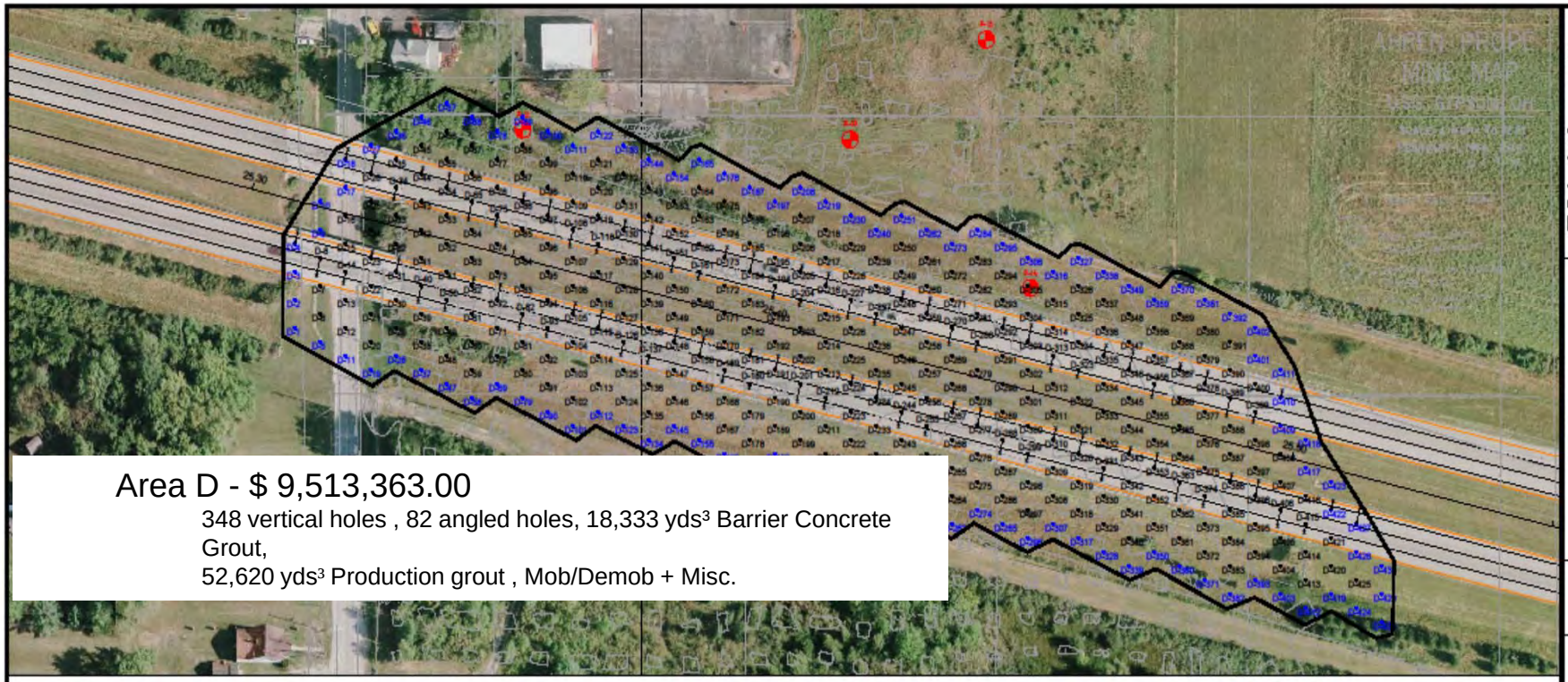
Date: 8/17/11

Scale: AS SHOWN

Project No.

Drawing Name: GROUT SEQUENCE 8-17-11

Sheet No. 2 of 2



Area D - $ 9,513,363.00

348 vertical holes , 82 angled holes, 18,333 yds³ Barrier Concrete Grout,
52,620 yds³ Production grout , Mob/Demob + Misc.

LEGEND

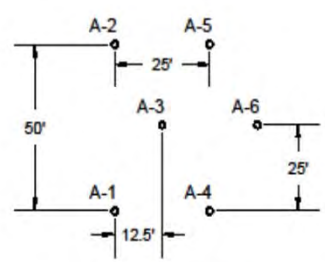
- VERTICAL GROUT INJECTION HOLE
- ANGLED GROUT INJECTION HOLE
- BARRIER INJECTION HOLE
- BORE HOLE

ENGINEERS ESTIMATE
(SITE "D" ONLY)

DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL PRICE
Mobilization and Demobilization	1	L.S.	$80,000	$80,000
Construction Layout	1	L.S.	$5,000	$5,000
Quality Control	1	L.S.	$10,000	$10,000
Drilling 348 Vertical Injection Holes	33,060	L.F.	$12.00	$396,720
Casing Vertical Injection Holes	24,012	L.F.	$3.00	$72,036
Drilling 82 Angled Injection Holes	8,036	L.F.	$18.00	$144,648
Casing Angled Injection Holes	5,658	L.F.	$3.00	$16,974
Purchasing, Handling and Placing Barrier Material	18,333	C.Y.	$95.00	$1,741,635
Purchasing, Handling and Placing Grout	52,620	C.Y.	$125.00	$6,577,500
Confirmation Drilling	950	L.F.	$35.00	$33,250
Borehole Photography	40	HRS.	$40.00	$1,600
Sediment Control	500	L.F.	$3.00	$1,500
Dewatering	1	L.S.	$37,500	$37,500
QA-Program inc. some regrouting	1	L.S.	$375,000	$375,000
Revegetation	1	L.S.	$20,000	$20,000
			Total	$9,513,363
			Grouted Area	273,217 ft²
			Price per ft²	$34.82/ft²

SCALE 1" = 100'

0 100 200 300



TYPICAL GROUT
INJECTION HOLE LAYOUT

CTL Engineering of West Virginia, Inc.

OTT-2-26.06

SITE "D" STA. 492+50

POCAHONTAS TOWNSHIP, OTTAWA COUNTY, OHIO

Grouting Costs

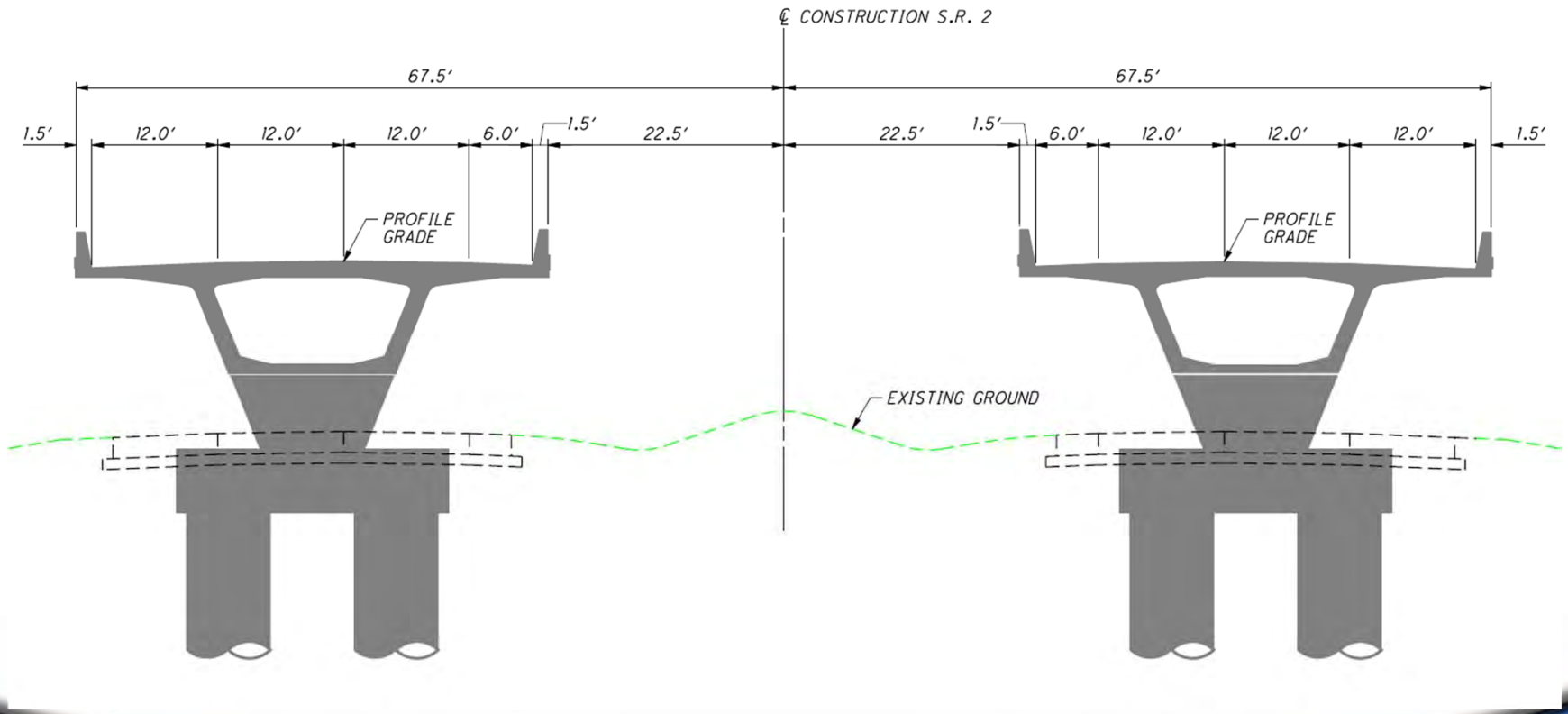
- Area A – $ 3,654,330.00
  - 107 vertical holes , 20 angled holes, 7100 yds^3 Barrier Concrete Grout,
  - 14,500 yds^3 Production grout , Mob/Demob + Misc.
- Area B - $ 3,204,626.00
  - 78 vertical holes , 19 angled holes, 14,074 yds^3 Barrier Concrete Grout,
  - 10,100 yds^3 Production grout , Mob/Demob + Misc.
- Area C - $ 9,791,22500
  - 399 vertical holes , 109 angled holes, 23,889 yds^3 Barrier Concrete Grout,
  - 51,834 yds^3 Production grout , Mob/Demob + Misc.
- Area D - $ 9,513,363.00
  - 348 vertical holes , 82 angled holes, 18,333 yds^3 Barrier Concrete Grout,
  - 52,620 yds^3 Production grout , Mob/Demob + Misc.

TOTAL MINE REMEDIATION

$ 26,163,544

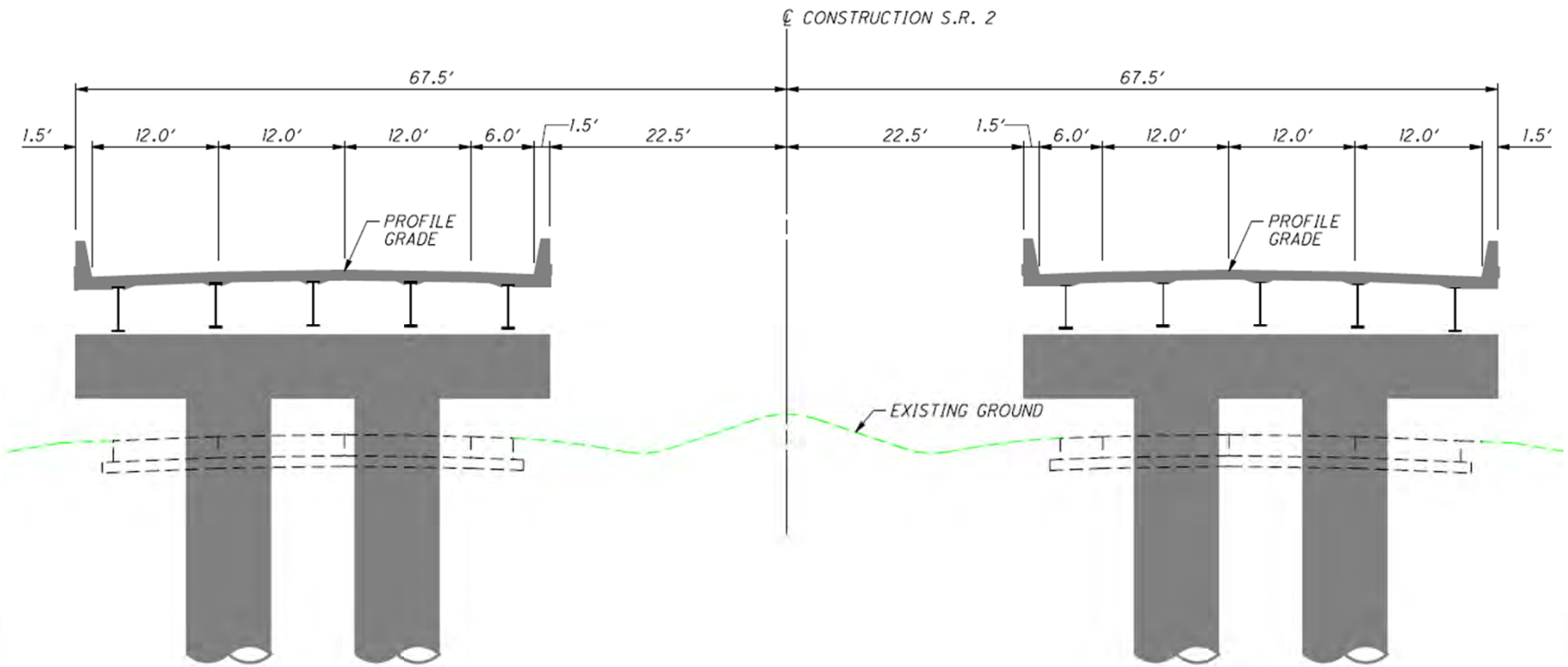
Land Bridge Alternative

- Segmental Concrete Box Girder

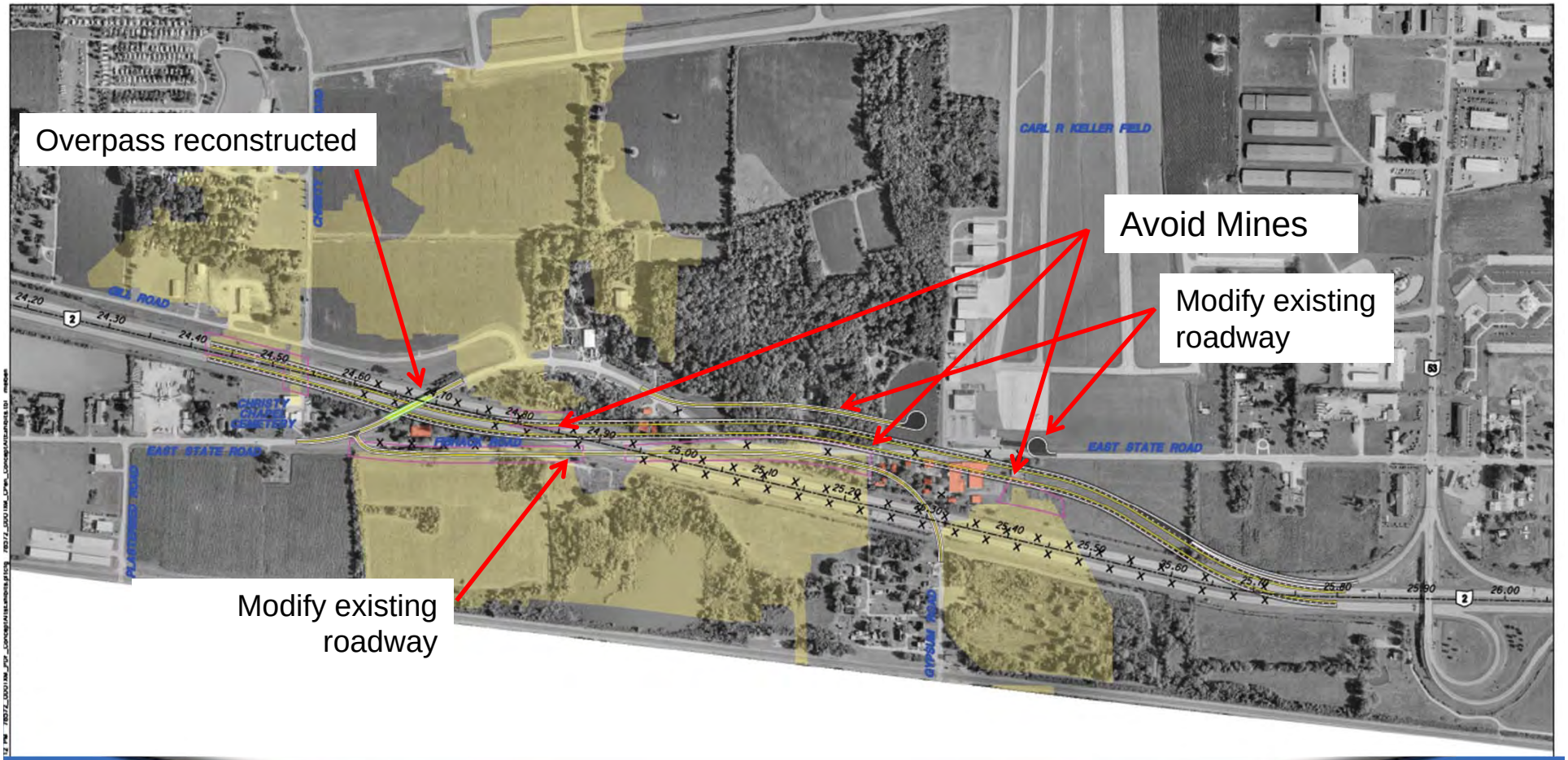


Land Bridge Alternative

- Steel Plate Girder



Shift SR-2: Alternative 3A



WORKHORSE TECHNOLOGIES

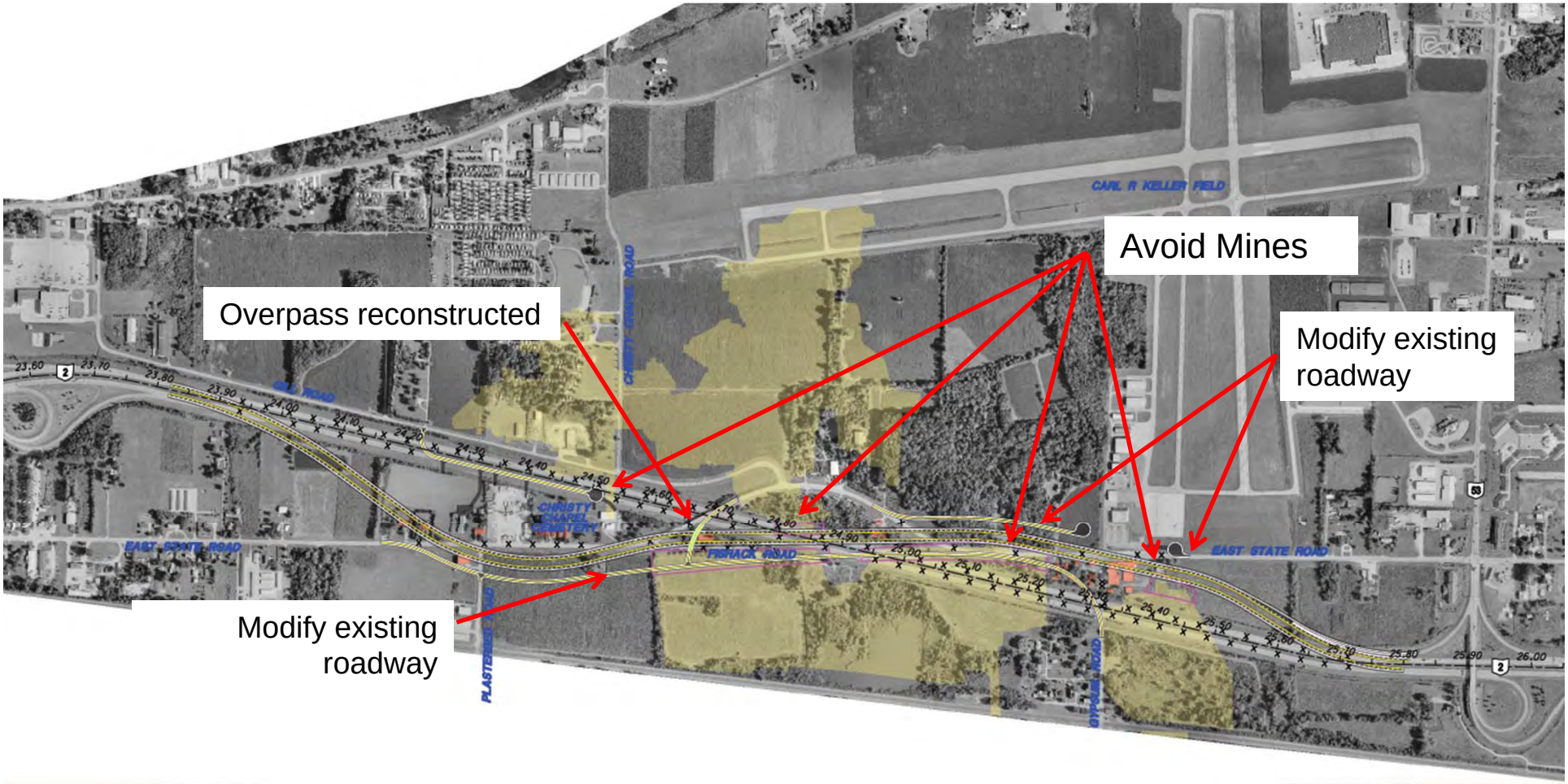
TECHNOS INC.

CTL

CH2MHILL

STATE OF OHIO DEPARTMENT OF TRANSPORTATION

Shift SR-2: Alternative 3B



WORKHORSE TECHNOLOGIES

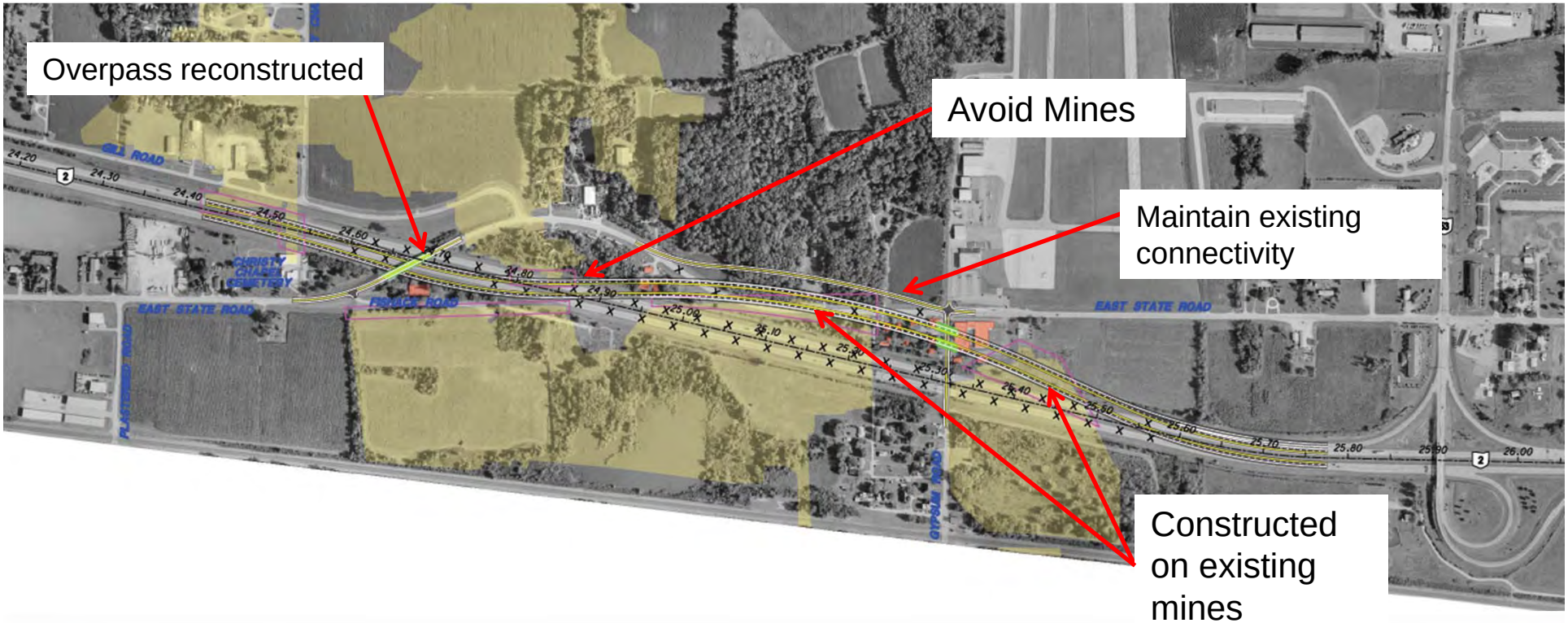
TECHNOS INC.

CTL

CH2MHILL

STATE OF OHIO DEPARTMENT OF TRANSPORTATION

Shift SR-2: Alternative 3C



WORKHORSE TECHNOLOGIES

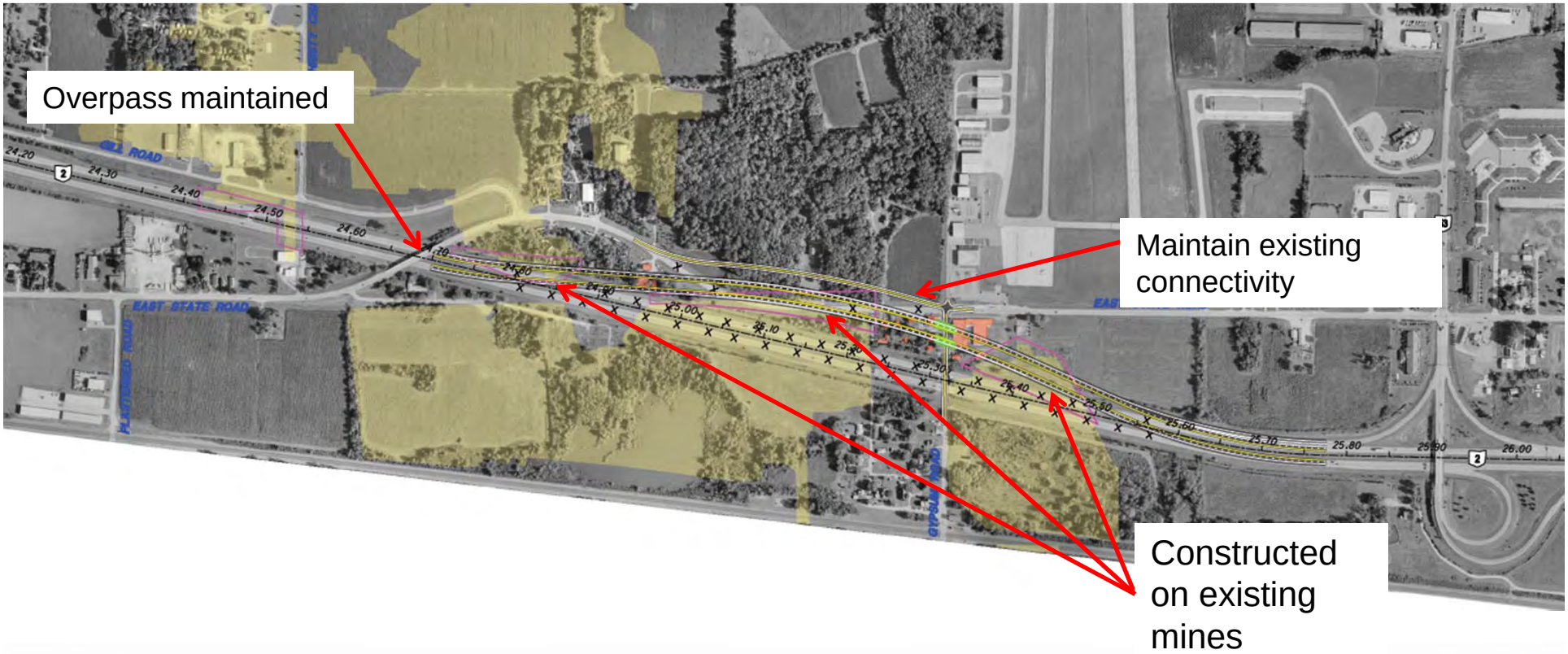
TECHNOS INC.

CTL

CH2MHILL

STATE OF OHIO DEPARTMENT OF TRANSPORTATION

Shift SR-2: Alternative 3D



WORKHORSE TECHNOLOGIES

TECHNOS INC.

CTL

CH2MHILL

STATE OF OHIO DEPARTMENT OF TRANSPORTATION

Conclusions and Recommendations

- Land Bridge – Eliminated from further consideration
  - High construction cost
  - Long construction schedule
  - High impact to existing traffic

- Mine Stabilzation – Continued for further consideration
  - Minimally satisfy all key elements of the Purpose & Need

Conclusions and Recommendations

- Shift SR-2: Alt. 3A and 3B – Eliminated from further consideration
  - High right-of-way needs
  - Long construction schedule
  - Alter existing roadway network

- Shift SR-2: Alt. 3A and 3B– Continued for further consideration
  - Minimally satisfy all key elements of the Purpose & Need

Next Steps

- PREPARE A DESIGN FOR A SMALL PILOT PROJECT, THERE IS A CONCERN REGARDING THE GROUTING AND BARRIERS FOR VOIDS POSSIBLY EXCEEDING 13 FEET IN HEIGHT
- EVALUATE THE RESULTS OF THE PILOT PROJECT TO DETERMINE THE MOST FEASIBLE APPROACH TO STABILIZING THESE MASSIVE VOIDS
- DEVELOP DESIGN DOCUMENTS IN ACCORDANCE WITH THE BEST ALTERNATIVE

QUESTIONS?