Mine and Mine Map Database Essentials
Panel II – Database Management
Amy K. Gilmer
Virginia Department of Mines, Minerals and Energy

Mine map database fields captured during cataloguing

Data Field	Data Entry Method	Brief Description
Collection Name	Dropdown list	Tracks source of maps
DMME ID	Automatically populated	Unique number used to identify maps
Map ID	Text entry box	Generally mine license number
Date of Mine Map	Text entry box	Date map was finalized
Map Scale	Text entry box	Scale of map
Company Name	Text entry box	Name of company that submitted the map
Mine Name	Text entry box	Name of the mine for which the map was submitted
Engineer	Text entry box	Certified engineer listed on map
Map Type	Dropdown list	Lists type of map
Map Quality	Dropdown list	Relative quality of the map
Vault Location	Text entry box	Permanent location of original map
Entry Date	Automatically populated	Date of map record creation
Entry Initials	Automatically populated	Initials of worker who entered the map record
Thickness Data	Checkbox	Indicates coal thickness information is available
Elevation Data	Checkbox	Indicates elevation information is available
Surface Mines	Checkbox	Indicates surface mines shown on map
Adjacent Mines	Checkbox	Indicates adjacent mines shown on map
Auger Mines	Checkbox	Indicates auger mines shown on map
Coreholes Present	Checkbox	Indicates corehole information shown on map
Gas Wells Present	Checkbox	Indicates gas wells shown on map
Water	Checkbox	Indicates water is shown in a mine
Roof Falls	Checkbox	Indicates a roof fall has occurred in mine
Final Map	Checkbox	Indicates final map
Drains	Checkbox	Indicates drains are shown
Crop Line	Checkbox	Indicates crop line is shown
Other Portals	Checkbox	Indicates other portals are shown
VVHs	Checkbox	Indicates vertical ventilation holes are shown
Comments	Text entry box	Place for specific comments about the map
Company coal bed(s)	Text entry box	Coal bed name assigned by the company
Standardized coal bed(s)	Dropdown list	DMME standardized assigned coal bed name
Georeferenced	Checkbox	Indicates the map has been geographically placed
Vectorized	Checkbox	Indicates the map has been digitized
Georeferencing Method	Dropdown list	Method by which the map was placed
State Plane Coordinates	Checkbox with text entry boxes	If map has state plane coordinates they are entered
Lat/Long Point	Checkbox with text entry boxes	If map has latitude and longitude coordinates they are entered
Company Coordinates	Checkbox	Indicates company grid or coordinates on map
Scan Information	Text entry boxes	Information about the image and hyperlink to the image
Quadrangle	Dropdown list	Quadrangle(s) of the map
County	Dropdown list	County(s) of the map
General Location	Dropdown list	Lists names of streams, rivers, towns, valleys, etc.
Mines Shown	Text entry box	Lists all mines shown on the map

Mine database fields captured during cataloguing

Data Field	Data Entry Method	Brief Description
Mine ID	Text entry box	Generally mine license number
MSHA ID	Text entry box	Federal mine number
Mine Name	Text entry box	Name of mine
Company Name	Text entry box	Name of company
Operator	Text entry box	Name of individual operator
Lessor	Text entry box	Name of lessor if applicable
Company coal bed	Text entry box	Coal bed assigned by the company
Standardized coal bed	Text entry box	DMME standardized coal bed name
Mining Method	Dropdown list	Lists mining method used in mine
Mine Size	Dropdown list	Relative mine size
Roof Falls	Checkbox	Indicates roof falls shown for mine
Water	Checkbox	Indicates water shown in mine
Mine Drains	Checkbox	Indicates mine drains shown for mine
Comments	Text entry box	Place for specific comments about the mine
Entry Date	Automatically populated	Date of mine record creation
Entry Initials	Automatically populated	Initials of worker who entered the mine record
DMME ID digitized from	Text entry box	Indicates the map from which the mine was first digitized
Quadrangle	Dropdown list	Quadrangle(s) of the mine
County	Dropdown list	County(s) of the mine
Amendment information	Text entry box(s)	Indicates what changes have been made to a mine polygon

Accuracy, Precision and Ground-Truthing of Mine Maps

By: Robert Gibson

Illinois Department of Natural Resources

Office of Mines and Minerals

AML Division

Accuracy, Precision and Ground-Truthing of Mine Maps

It’s a NAD, NAD, NAD, NAD World We Live In

Accuracy and Precision

- “Accuracy is the degree to which a measured value conforms to true or accepted values. Accuracy is a measure of correctness.”

From: ESRI GIS Dictionary, 2005

Accuracy and Precision

- “Accuracy is the degree to which a measured value conforms to true or accepted values. Accuracy is a measure of correctness.”
- “Precision measures exactness. … It is a measure of the control over random error.”

From: ESRI GIS Dictionary, 2005

Accuracy and Precision Standards

- The USGS mandates that:

From: USGS Map Accuracy Standards Fact Sheet FS-171-99 (November 1999

Accuracy and Precision Standards

- The USGS mandates that:

90% of “well-defined points” must be plotted to within 1/50th an inch accuracy on a 1:24,000 scale map (which is the equivalent of 40 feet on ground surface).

From: USGS Map Accuracy Standards Fact Sheet FS-171-99 (November 1999

The ‘uncertainty’ or ‘error’ of any point depicted on an USGS topographic map (1:24,000). In this example, shown as a 40 foot error radius encircling a benchmark location.

Accuracy and Precision Standards

- “Well-defined points are easily visible or recoverable on the ground, such as the following: monuments or markers, property boundary monuments; intersection of roads and railroads; corners of large buildings or structures (or center points of small buildings).”

From: USGS Map Accuracy Standards Fact Sheet FS-171-99 (November 1999)

Geo-Referencing and Coordinate Systems

- The Illinois mine mapping program uses USGS 7.5’ Topographic Maps as the basis for geo-referencing mine maps.

Geo-Referencing and Coordinate Systems

- The Illinois mine mapping program uses USGS 7.5’ Topographic Maps as the basis for geo-referencing mine maps.
- **For conformity with USGS topographic maps the mine maps are referenced to UTM NAD 27.**

Geo-Referencing
and
Coordinate Systems

- Section line corners and surface features common to both topographic and mine maps are used to rectify Illinois mine map images.

Geo-Referencing and Coordinate Systems

- Section line corners and surface features common to both topographic and mine maps are used to rectify Illinois mine map images.
- Topographic maps from the same time era as mining operations are used when available – to minimize location changes.

Ground-Truthing Procedures

Ground-Truthing Procedures
With Commonly Used GPS Devices

- First - validate the accuracy of geo-referenced USGS topographic map images.

Ground-Truthing Procedures
With Commonly Used GPS Devices

- First - validate the accuracy of geo-referenced USGS topographic map images.
- Then - validate accuracy of geo-referenced mine images with respect to the USGS topographic maps and ground surface.

GPS Devices Used In Study

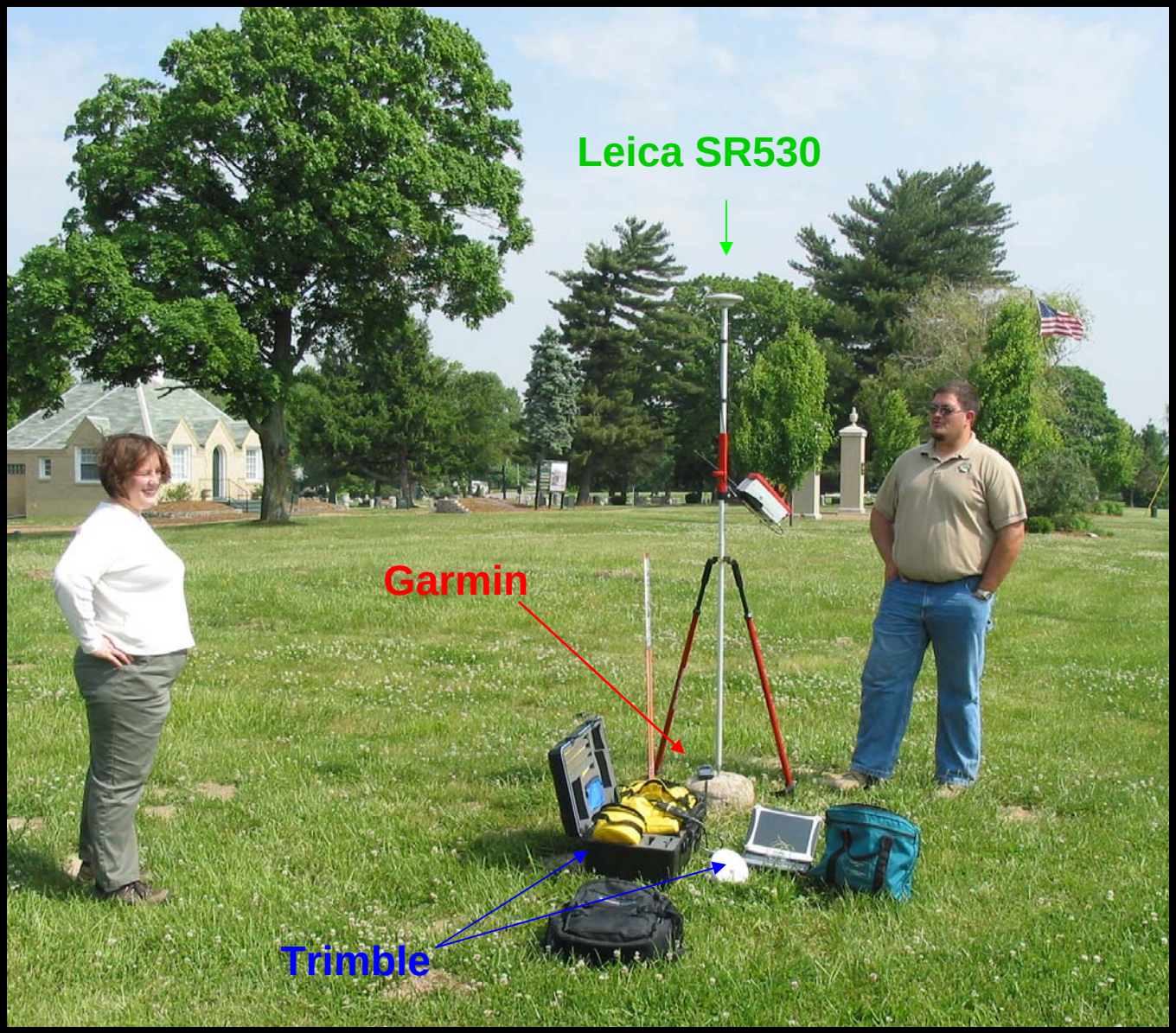
- Garmin GPSmap 76. Accuracy < 3m WAAS enabled.

GPS Devices Used In Study

- Garmin GPSmap 76. Accuracy < 3m WAAS enabled.
- Trimble with ArcPad. Accuracy < 1m

GPS Devices Used In Study

- Garmin GPSmap 76. Accuracy < 3m WAAS enabled.
- Trimble with ArcPad. Accuracy < 1m
- Leica SR 530. Survey grade accuracy 1 cm.



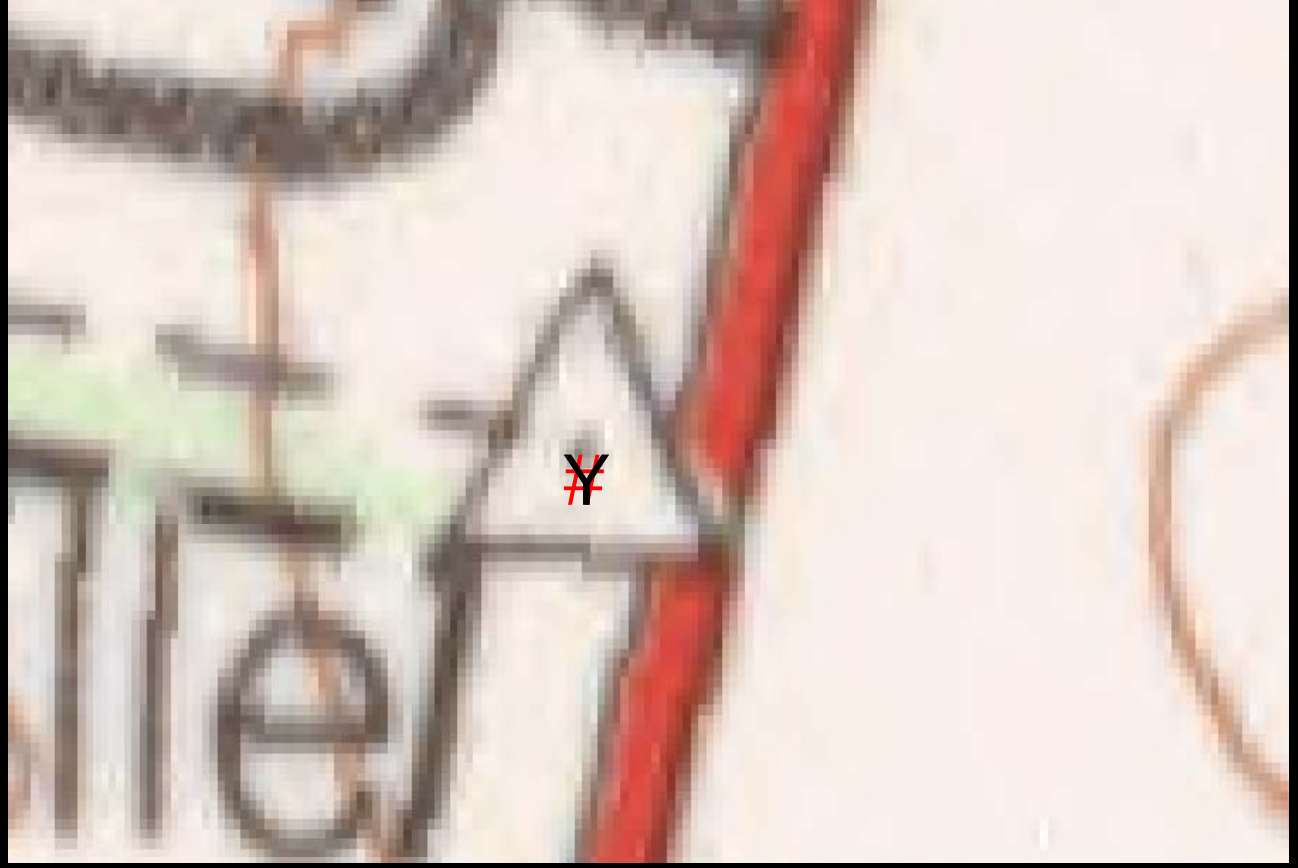
Kevin Garnett and Stephanie Self (OSMRE) provide GPS expertise. Leica SR530 shown set up over USGS monument. Trimble with ArcPad setup in foreground. Garmin GPS Map 76 resting on USGS monument.

NAD 27 and NAD 83 GPS Measurements

Projected on NAD 27 Base Maps in ArcView

Device: Garmin GPS Map 76 continuous reading

Measurement Coordinate System: NAD 27 CONUS
Map Coordinate System: NAD 27



Device: Garmin GPS Map 76 Average Position

Measurement Coordinate System: NAD 27 CONUS

Map Coordinate System: NAD 27

Distance from BM: 8.6 feet

Device: Trimble with ArcPad

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 27

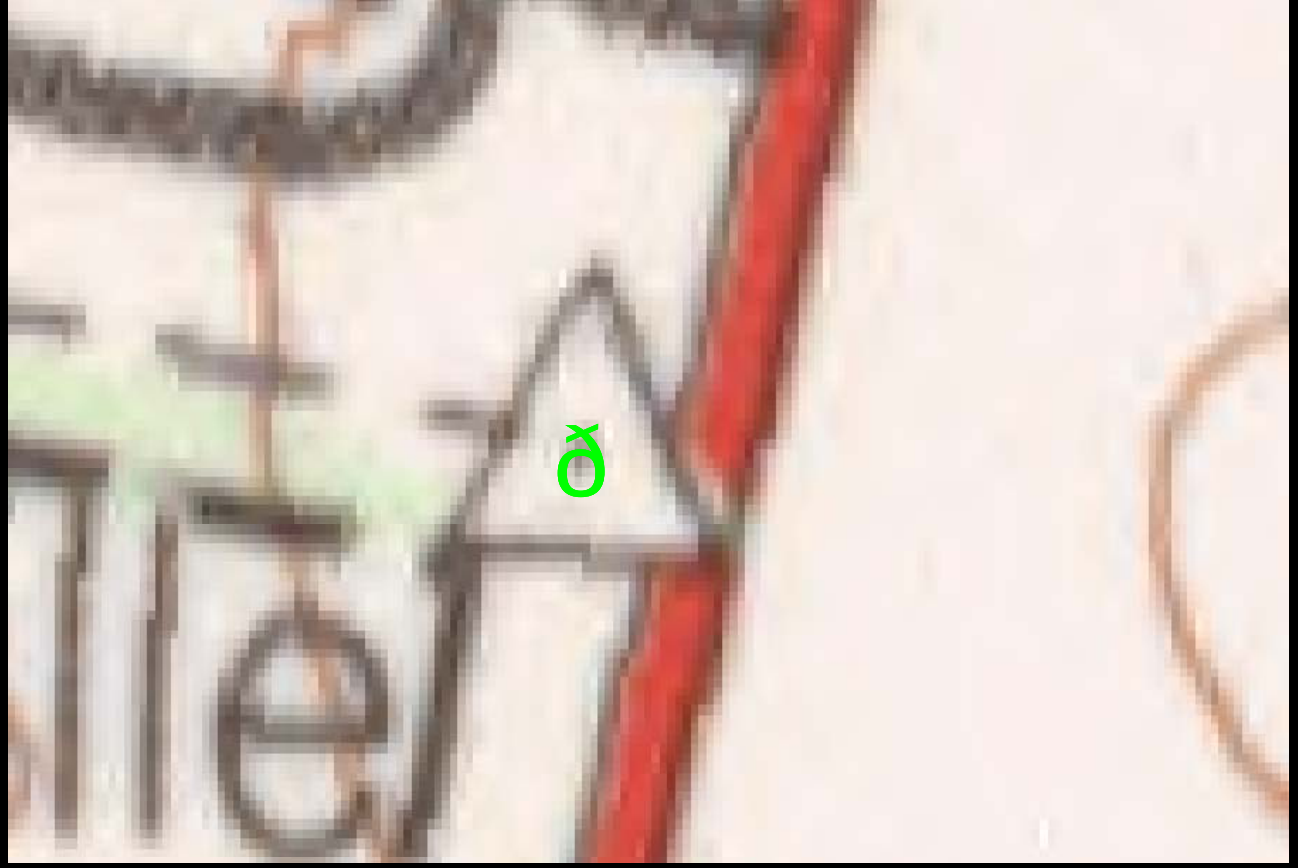
Distance from BM: 32.1 feet

Device: Leica SR530

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 27

Distance from BM: 32.8 feet



Device: Leica SR530

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 27 – AutoCad shapefile

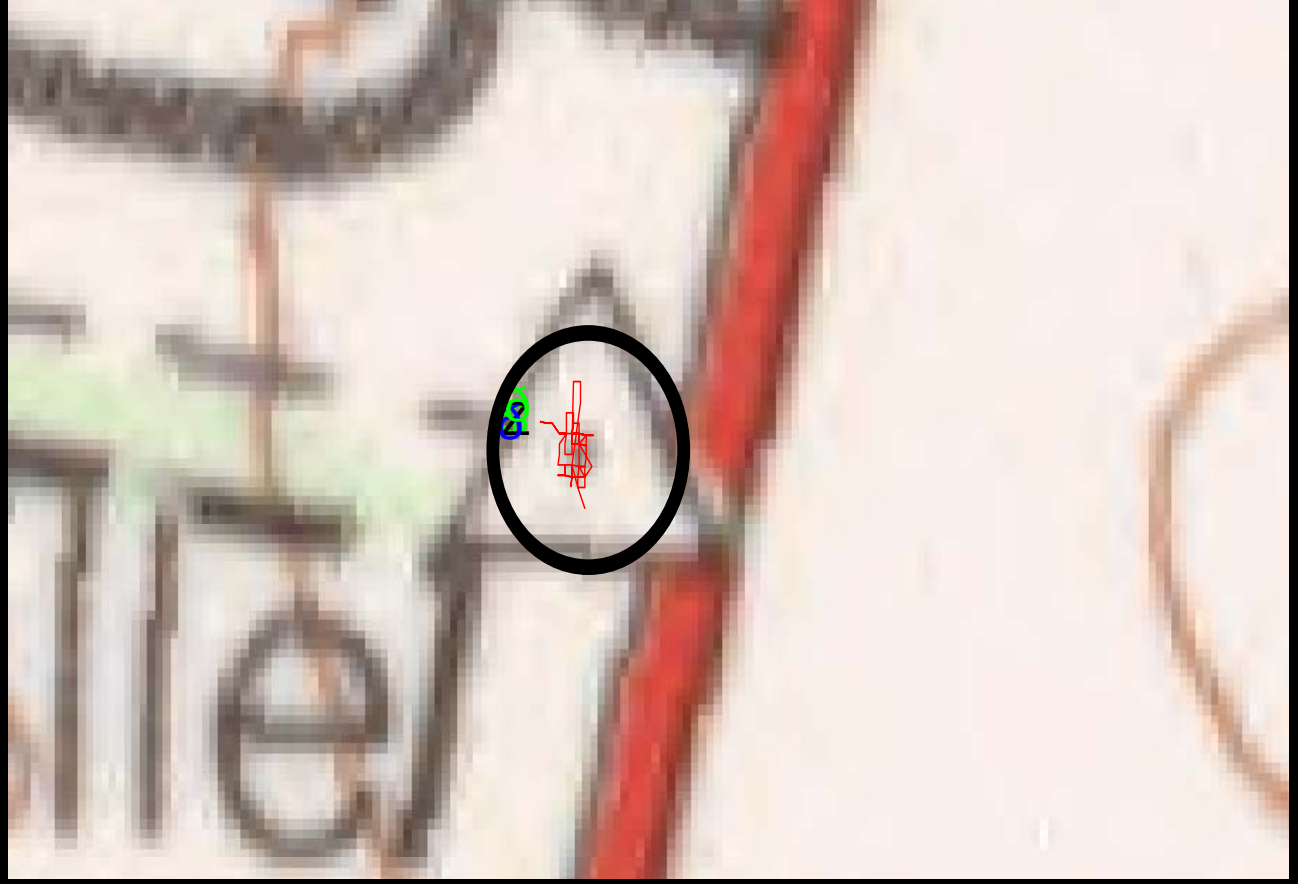
Distance from BM: 2.5 feet

National Geodetic Survey (NGS)

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 27 – NGS shapefile

Distance from BM: 31.6 feet



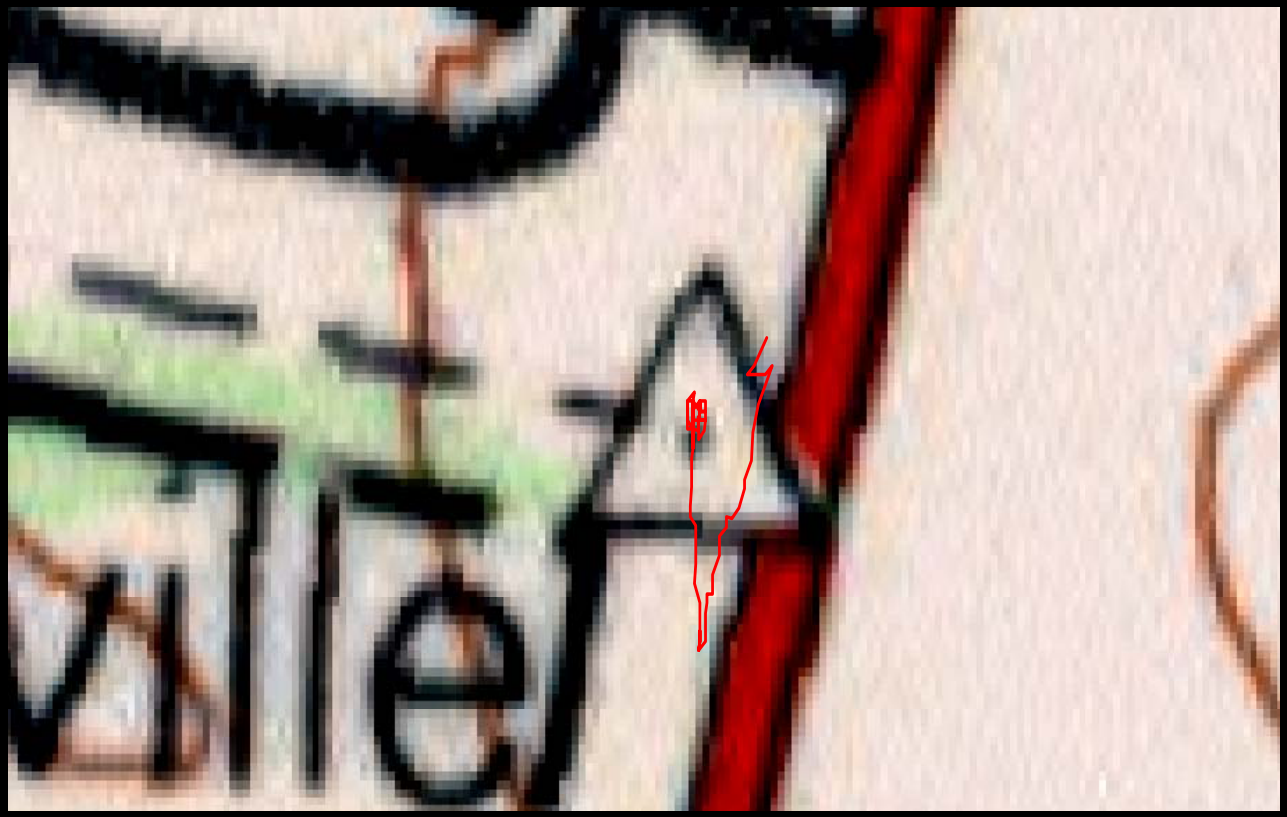
All GPS benchmark measurements fall within USGS topographical map ‘uncertainty’.

Leica SR530 Trimble with ArcPad Plot

Garmin GPS Map 76 continuous plot.

NAD 83 GPS Measurements

Projected on NAD 83 Base Maps in ArcView



Device: Garmin GPS Map 76 continuous reading

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 83

Device: Garmin GPS Map 76 Averaged Position

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 83

Distance from BM: 8.2 feet

Device: Trimble with ArcPad

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 83

Distance from BM: 6.2 feet

Device: Leica SR530

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 83

Distance from BM: 1.3 feet

Device: Leica SR530

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 83 – AutoCad shapefile

Distance from BM: 1.9 feet

National Geodetic Survey (NGS)

Measurement Coordinate System: NAD 83

Map Coordinate System: NAD 83 – NGS shapefile

Distance from BM: 2.0 feet

All GPS benchmark measurements are “spot-on” when measurements and USGS Topographic map are in NAD 83.

Leica SR530 Trimble with ArcPad Plot

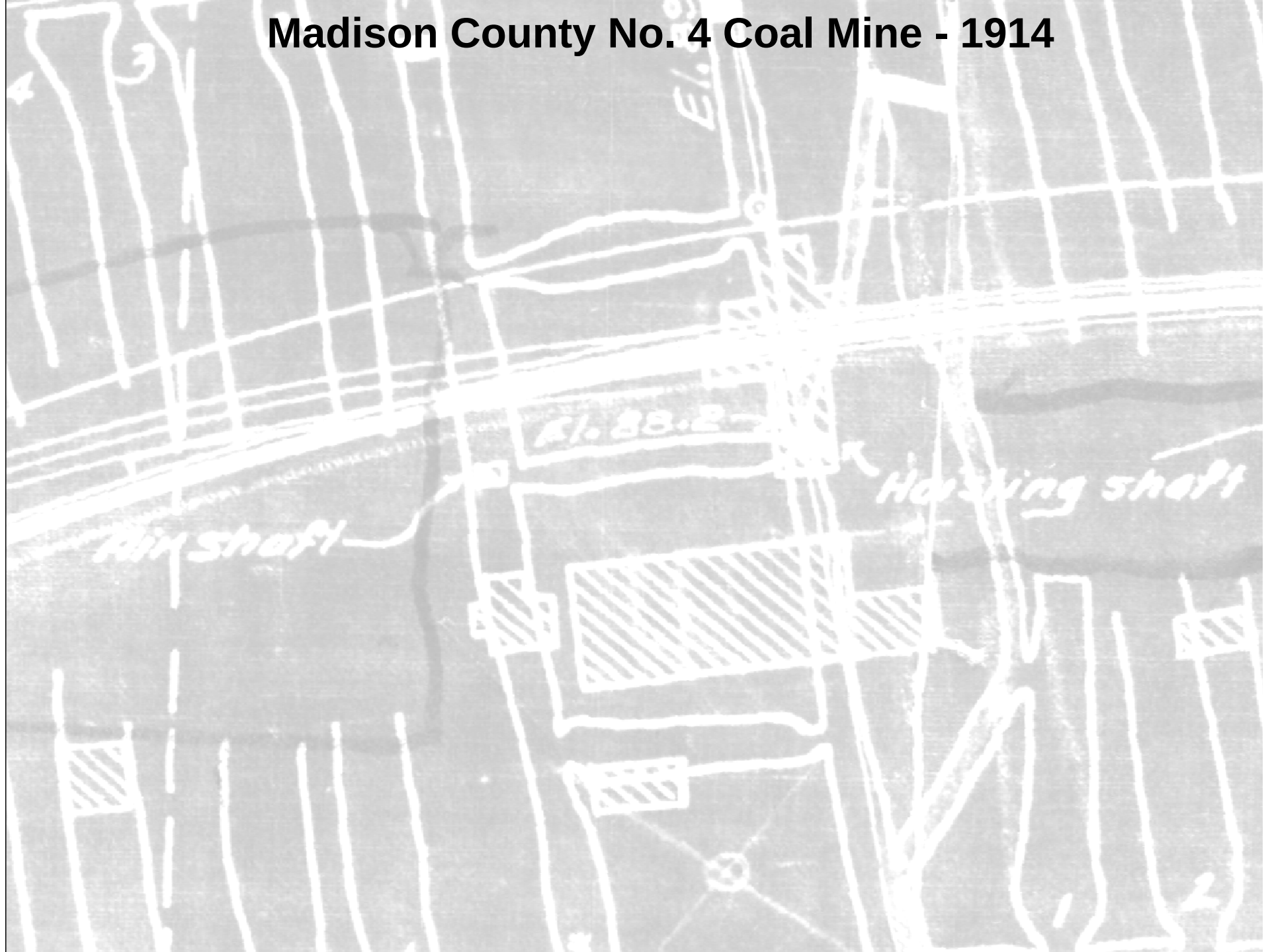
Garmin GPS Map 76 averaged position.

VIRTUAL REALITY

VS

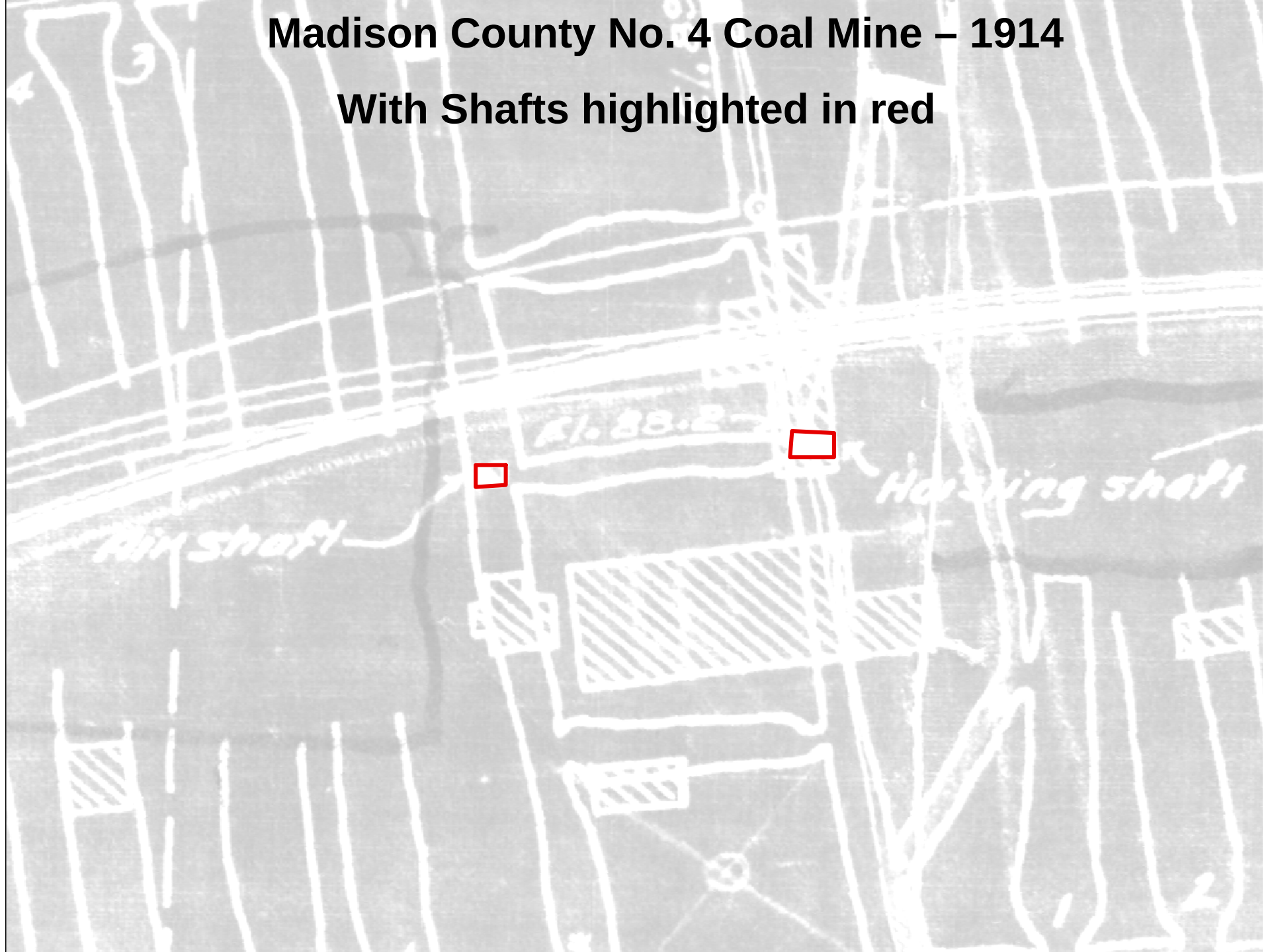
FIELD MEASUREMENT

Madison County No. 4 Coal Mine - 1914



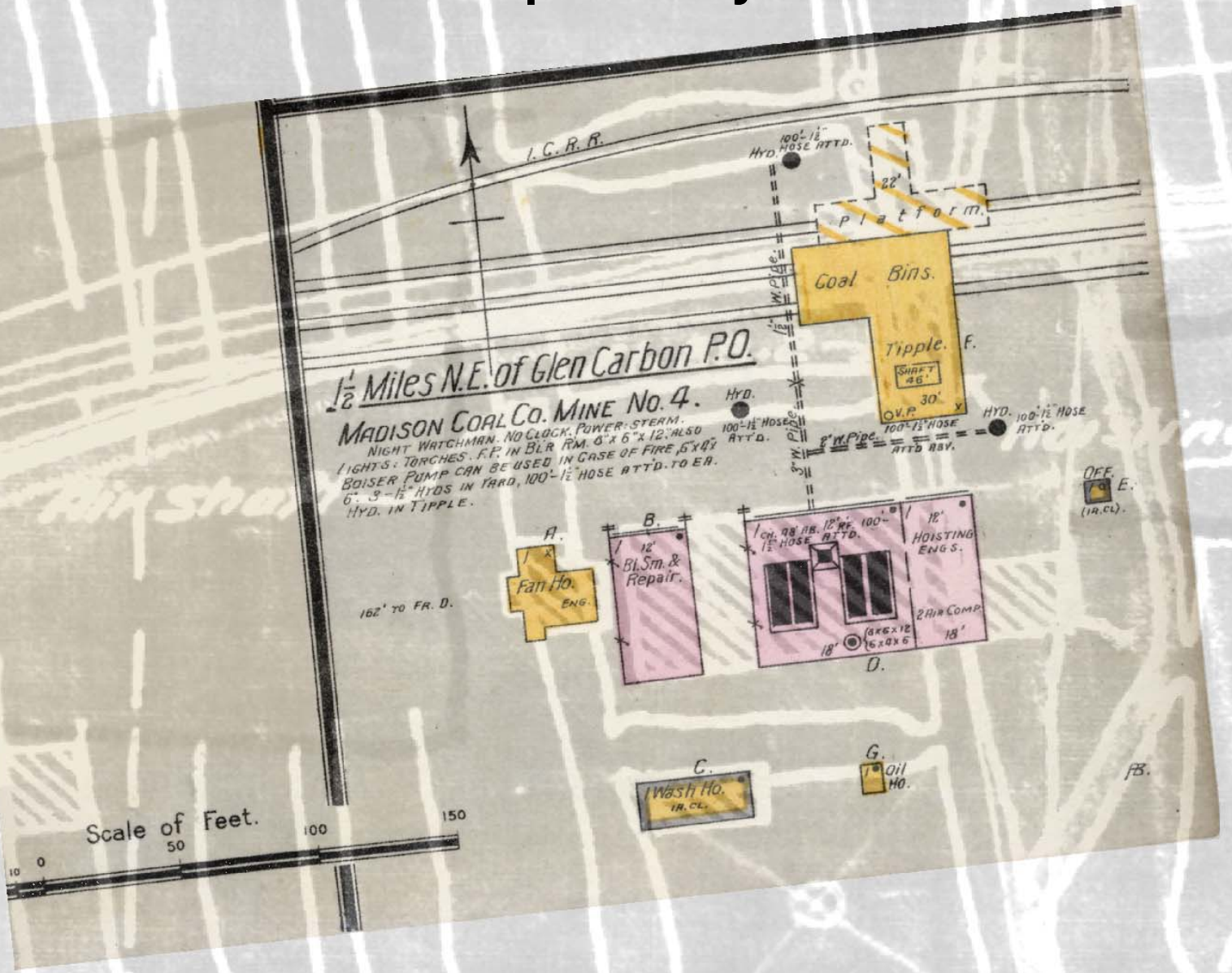
Madison County No. 4 Coal Mine – 1914

With Shafts highlighted in red



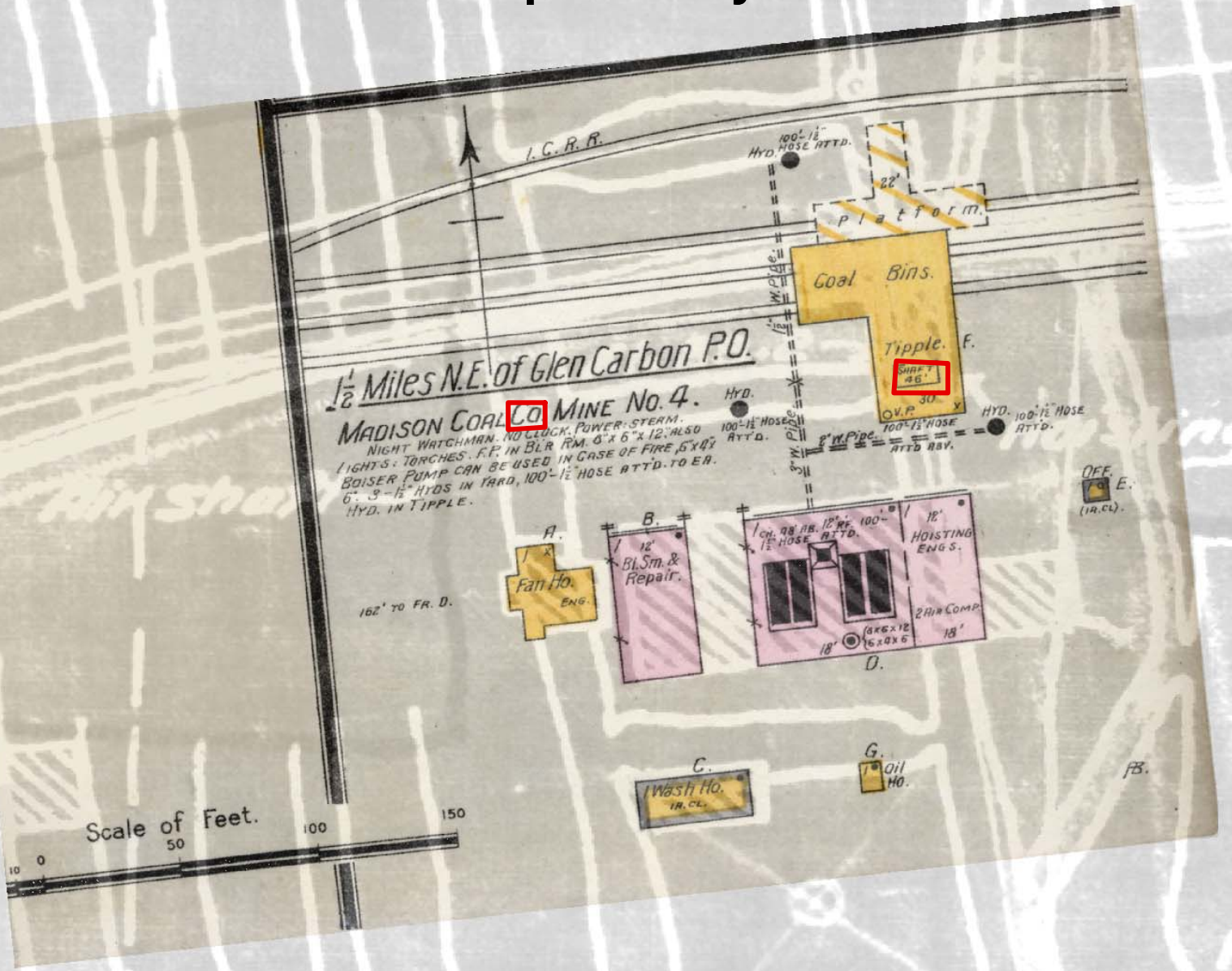
Madison County No. 4 Coal Mine - 1914

1902 Sanborn Map Overlay

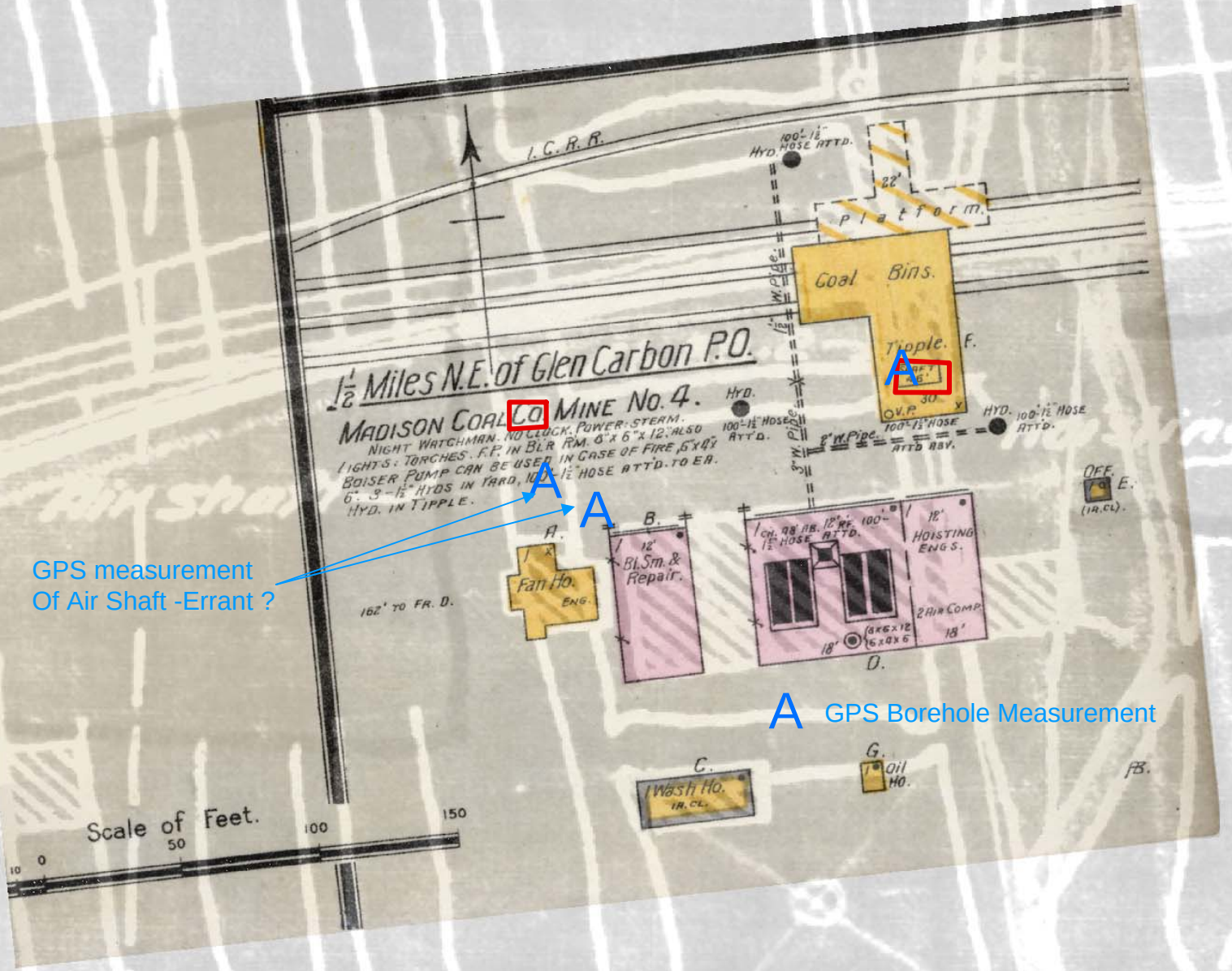


Madison County No. 4 Coal Mine - 1914

1902 Sanborn Map Overlay

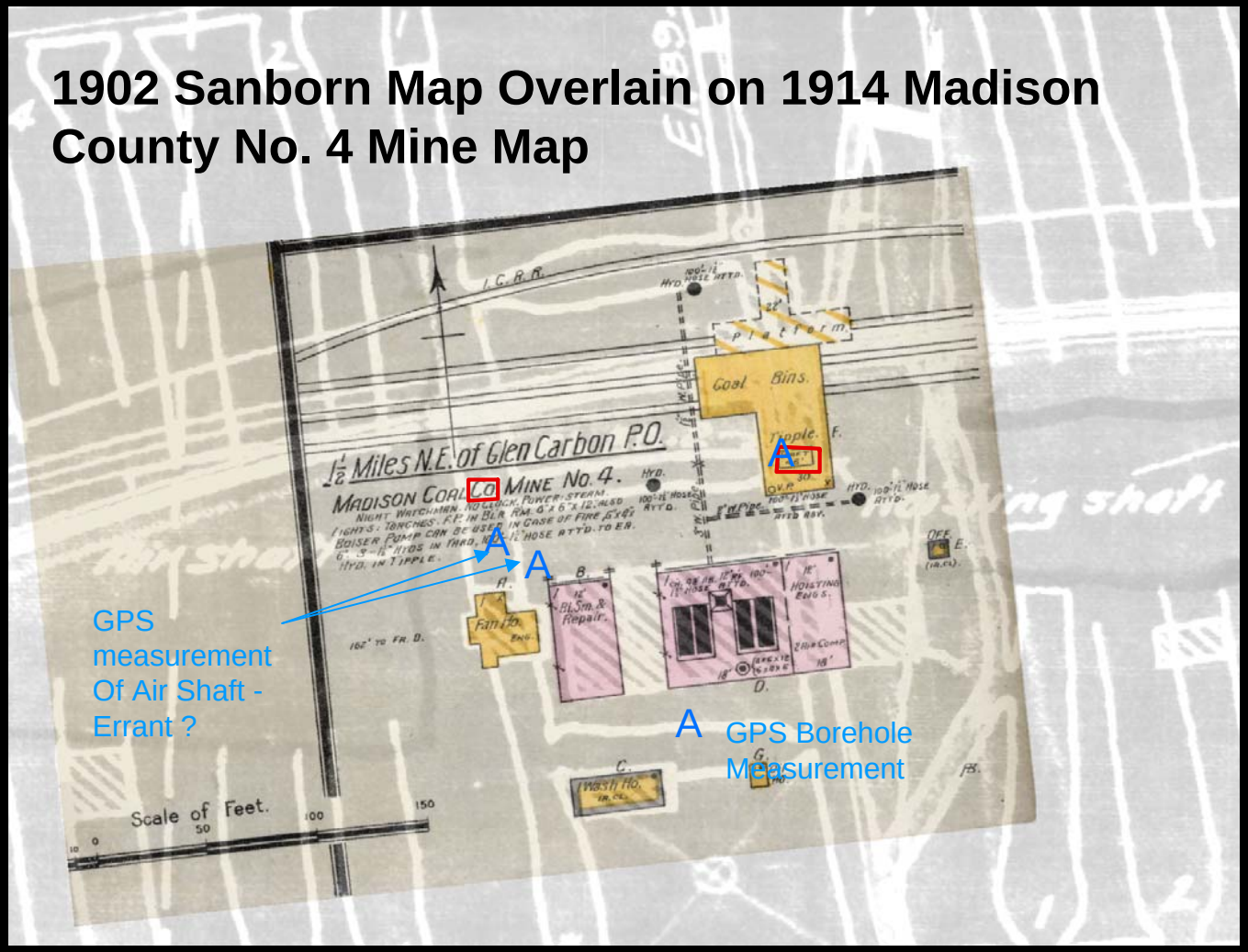


1902 Sanborn Map Overlain on 1914 Madison County No. 4 Mine Map



GPS measurement
Of Air Shaft -Errant ?

A GPS Borehole Measurement



Difference Between GPS and Map Measurement of Shaft Centroids

Main Shaft		Air Shaft	
NAD 27	38.8 ft	NAD 27	18.3 & 22.3 ft*
NAD 83	5 ft	NAD 83	25.0 & 43.9 ft *

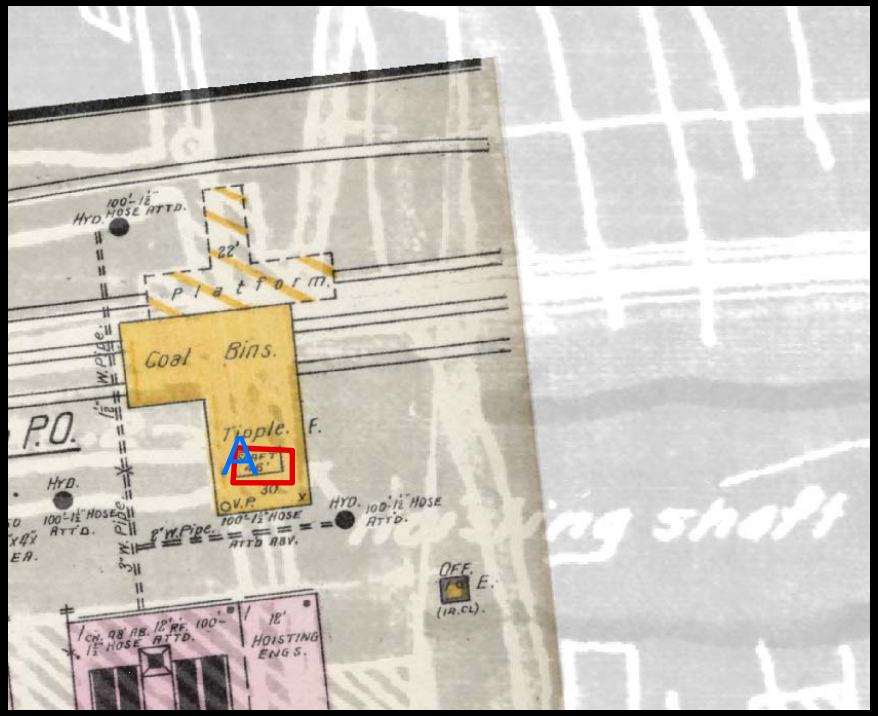
The “Real World” Challenge

Find this 1914 shaft …

X - You are here !!

In 2005
X - You are here !!

Main Shaft Found

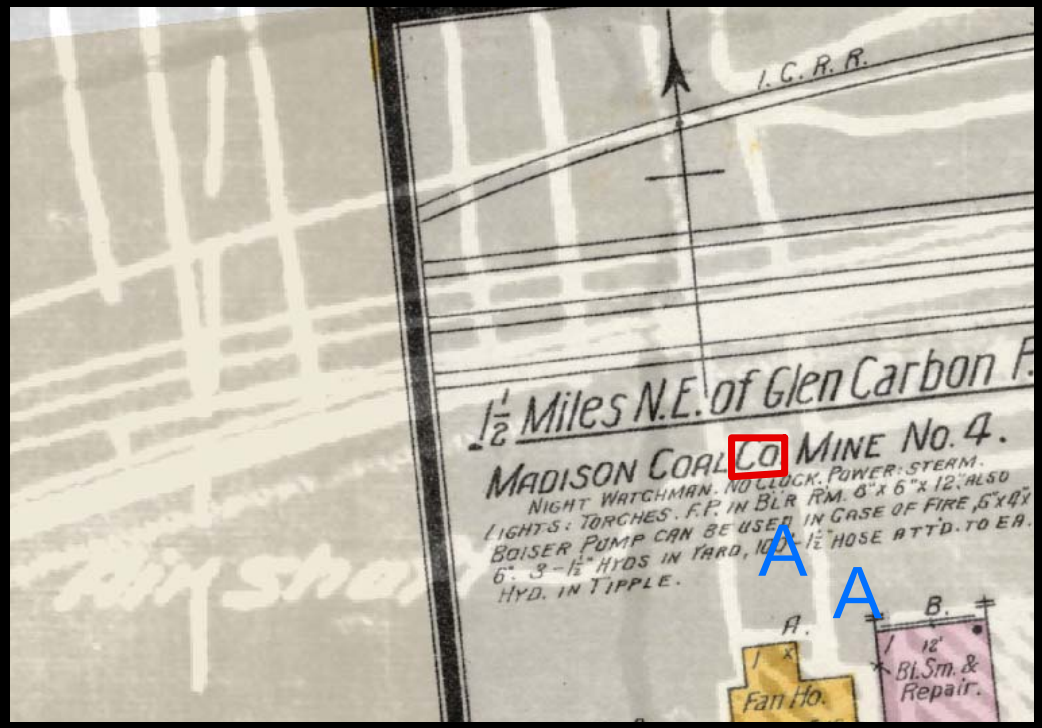


- Blue symbol shows GPS measurement.
- Vegetation too dense to photograph.

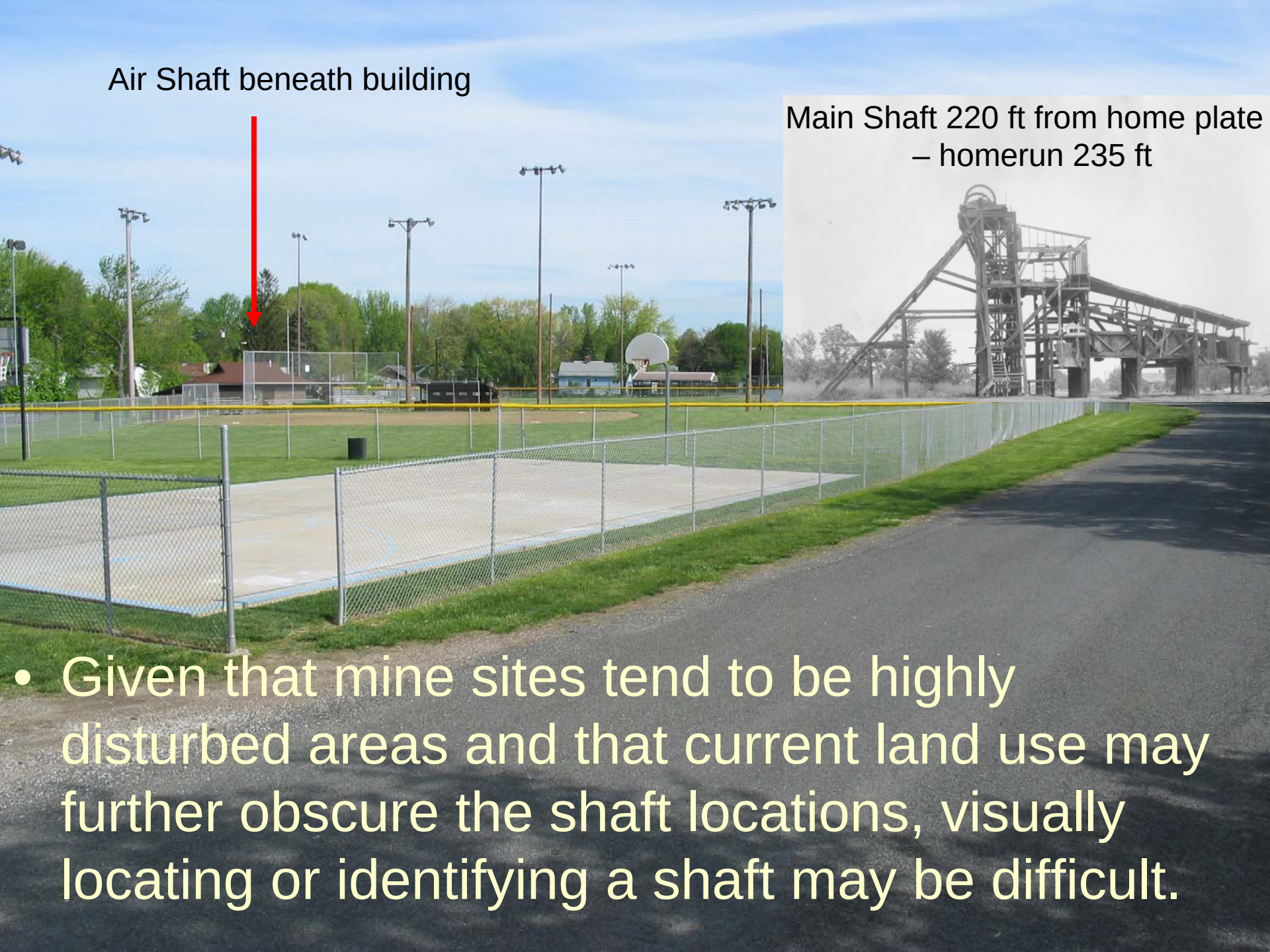
Air Shaft ?

1st guess GPS
Air Shaft ?

Could Not Locate Air Shaft Precisely



- Given dense vegetative cover and an area that is highly disturbed makes positive identification difficult when foundations and buildings have been removed.



- Given that mine sites tend to be highly disturbed areas and that current land use may further obscure the shaft locations, visually locating or identifying a shaft may be difficult.

GPS Equipment Summary

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Garmin GPSmap 76 Handheld

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- **Easy to use and download.**

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- **Sufficiently accurate in measuring shaft locations.**

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- **Waypoint navigation can be used to locate shafts.**

GPS Equipment Summary

Garmin GPSmap 76 Handheld

- Easy to use and download.
- Sufficiently accurate in measuring shaft locations.
- Projects accurately in ArcView.
- Waypoint navigation can be used to locate shafts.
- **Inexpensive to own and operate.**

GPS Equipment Summary

Trimble with Laptop and ArcPad

- **Slight ‘learning curve’.**

GPS Equipment Summary

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- **Physically cumbersome**.

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- **NAD 27 projection inaccuracies in ArcView.**

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- **‘Real-time location’ on convenient base map(s) is very useful.**

GPS Equipment Summary

Trimble with Laptop and ArcPad

- Slight ‘learning curve’.
- Physically cumbersome.
- Sufficiently accurate for measuring shaft locations.
- NAD 27 projection inaccuracies in ArcView.
- ‘Real-time location’ on convenient base map(s) is very useful.
- **Fairly expensive to own and operate.**

GPS Equipment Summary

Leica SR530

- **Significant ‘learning curve’.**

GPS Equipment Summary

Leica SR530

- Significant ‘learning curve’.
- **Physically cumbersome**.

GPS Equipment Summary

Leica SR530

- Significant ‘learning curve’.
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- **Highly precise measurement**.

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GPS Equipment Summary

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- Highly precise measurement.
- NAD 27 projection inaccuracies in ArcView.
- **Not useful in ‘finding things’.**

GPS Equipment Summary

Leica SR530

- Significant ‘learning curve’.
- Physically cumbersome.
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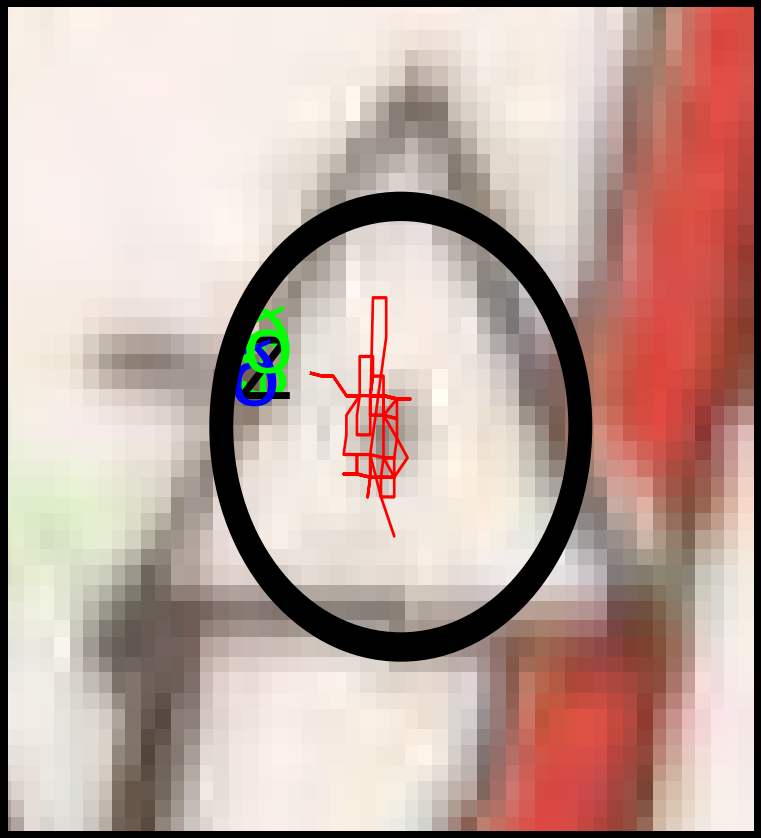
- NAD 27 projection inaccuracies in ArcView.
- Not useful in ‘finding things’.
- **Requires downloading data in office.**

GPS Equipment Summary

Leica SR530

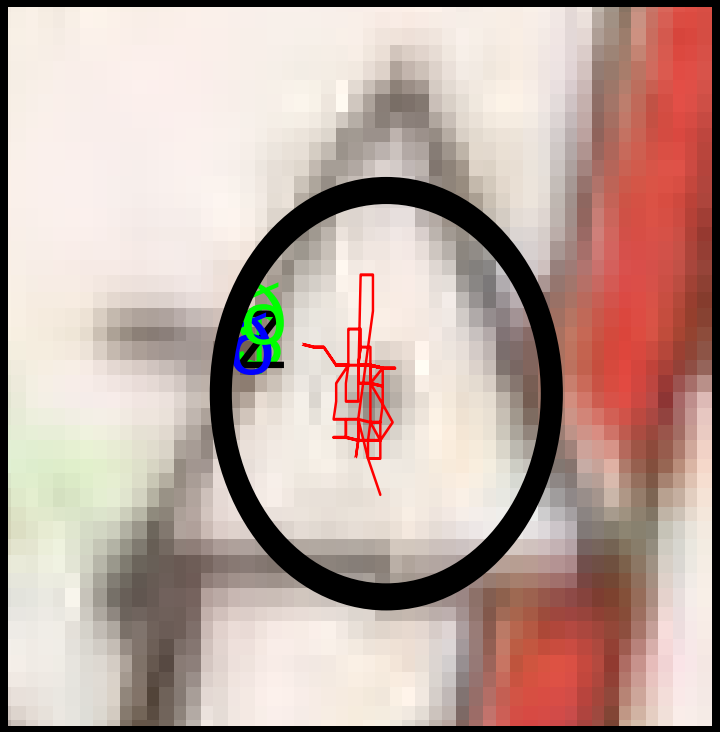
- Significant ‘learning curve’.
- Physically cumbersome.
- Highly precise measurement.
- NAD 27 projection inaccuracies in ArcView.
- Not useful in ‘finding things’.
- Requires downloading data in office.
- **Expensive to own and operate**

USGS 7.5’ Topographic Maps and Georeferencing



- **An accurate base map can be created by assigning UTM NAD 27 coordinate information to the grid marks on an USGS 7.5’ topo scanned at 350 dpi using ERDAS Imagine.**

USGS 7.5’ Topographic Maps and Georeferencing



- **Error in re-projecting UTM NAD 83 GPS measurement onto UTM NAD 27 maps in ArcView is significant for reasons unknown**

USGS 7.5’ Topographic Maps and Georeferencing

- When both GPS measurement and map projection are in NAD 83 ‘Uncertainty’ can be significantly minimized.

USGS 7.5’ Topographic Maps and Georeferencing

- When both GPS measurement and map projection are in NAD 83 ‘Uncertainty’ can be significantly minimized.
- **BM ‘uncertainty’ of USGS - GIS image was found to be about 2 ft.**

USGS 7.5’ Topographic Maps and Georeferencing

- **In short - frame of Reference is all important.**

USGS 7.5’ Topographic Maps and Georeferencing

- In short - frame of Reference is all important.
- **Ascertain that field measurement plot accurately on base map.**

Capturing ‘other’ Mine Information in a Database

By: Robert Gibson and Bruce Schottel

Illinois Department of Natural Resources

Office of Mines and Minerals

AML Division

What is ‘Other’ Mine Information ?

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- Data that facilitates mineral exploitation (covered by Nick Fedorko)

What is ‘Other’ Mine Information ?

- Data that facilitates mineral exploitation (covered by Nick Fedorko)
- **Data that facilitates safety and abandoned mine use.**

Capturing “other” Mine Information in a Database

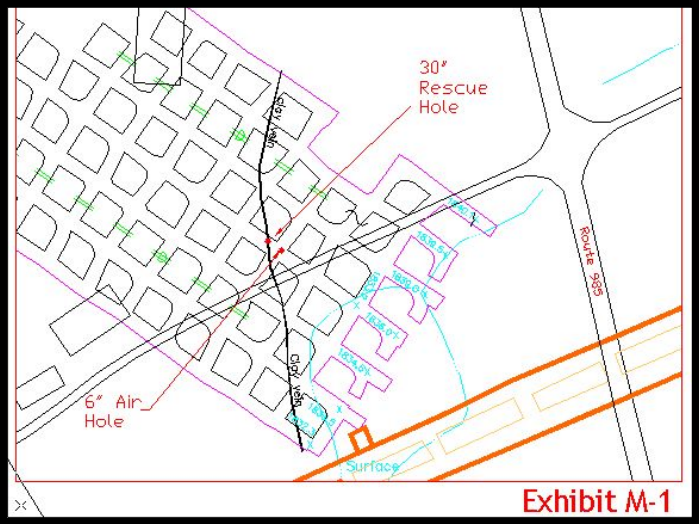
So Why Bother Collecting Mine Information ?

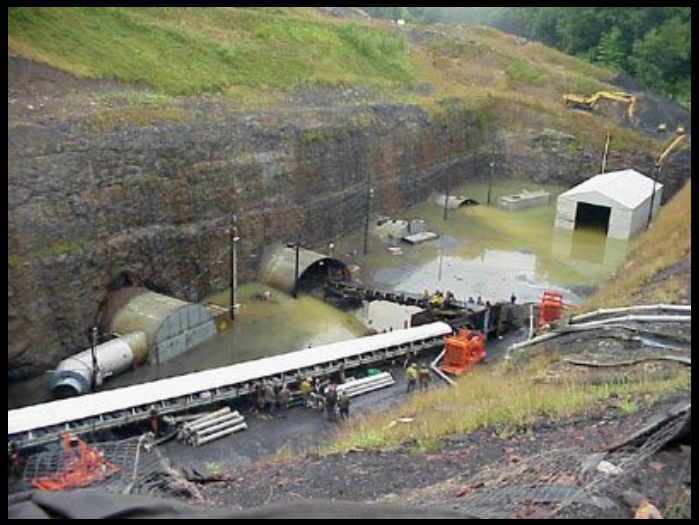
Capturing “other” Mine Information in a Database

So Why Bother Collecting Mine Information ?

Mine Safety

QueCreek





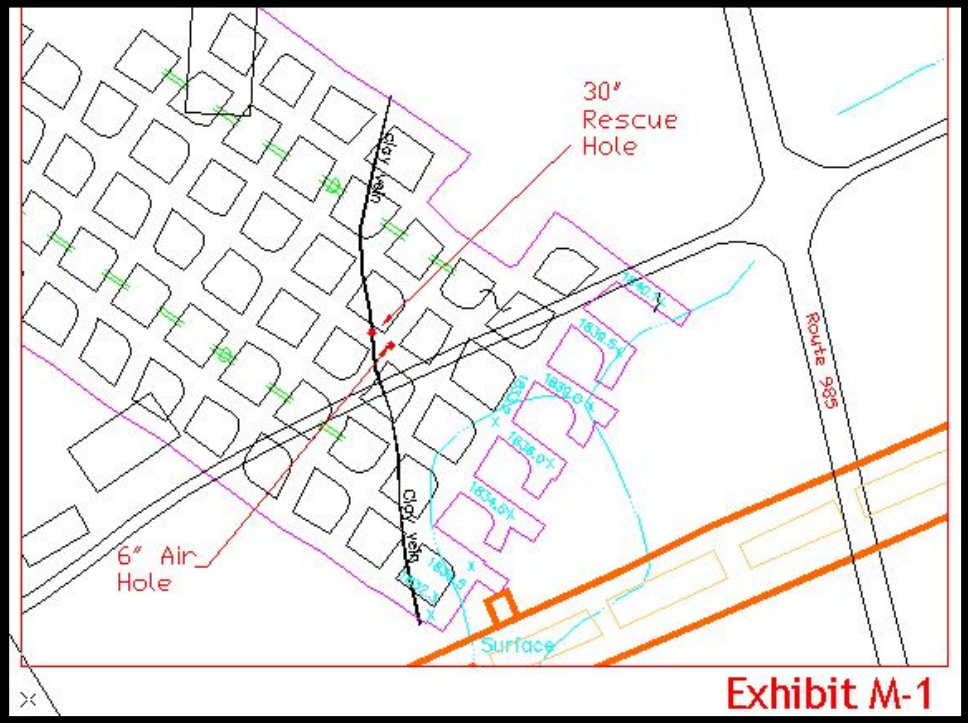
From: US Department of Labor – QueCreek Mine Rescue

And To Avoid Mine Related Land-Use Problems

Mine Safety and Land-Use Problems Share Common Needs and Concerns

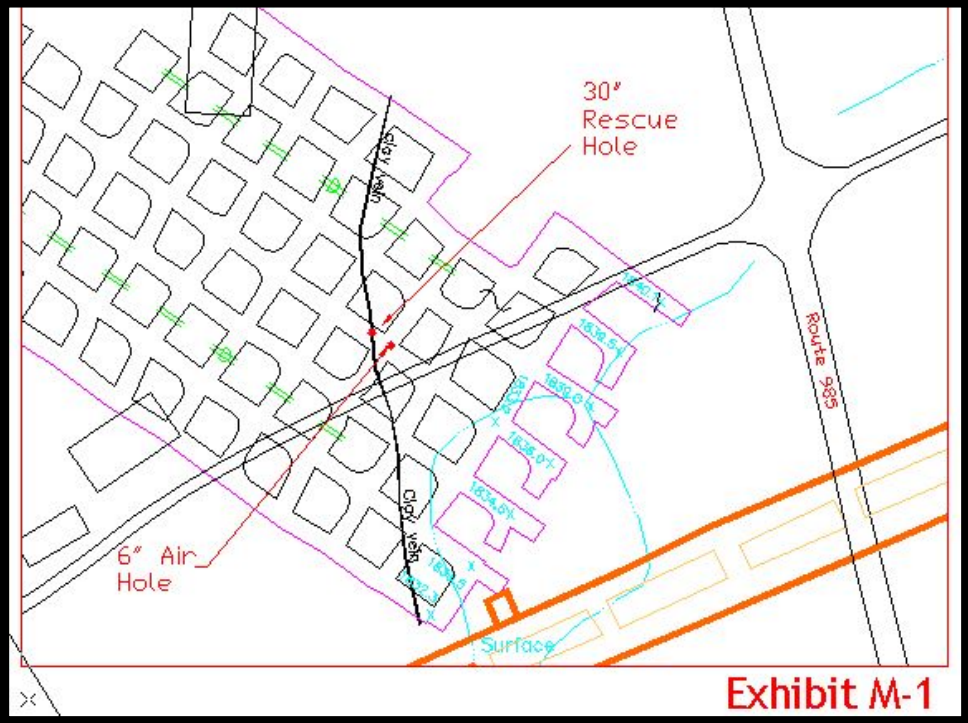
Mine Safety and Land-Use Problems Share Common Needs and Concerns

- **Precisely knowing the XYZ Coordinates of past mining.**



Mine Safety and Land-Use Problems Share Common Needs and Concerns

- Precisely knowing the XYZ Coordinates of past mining.
- **Storing mine maps in a known and accessible location.**

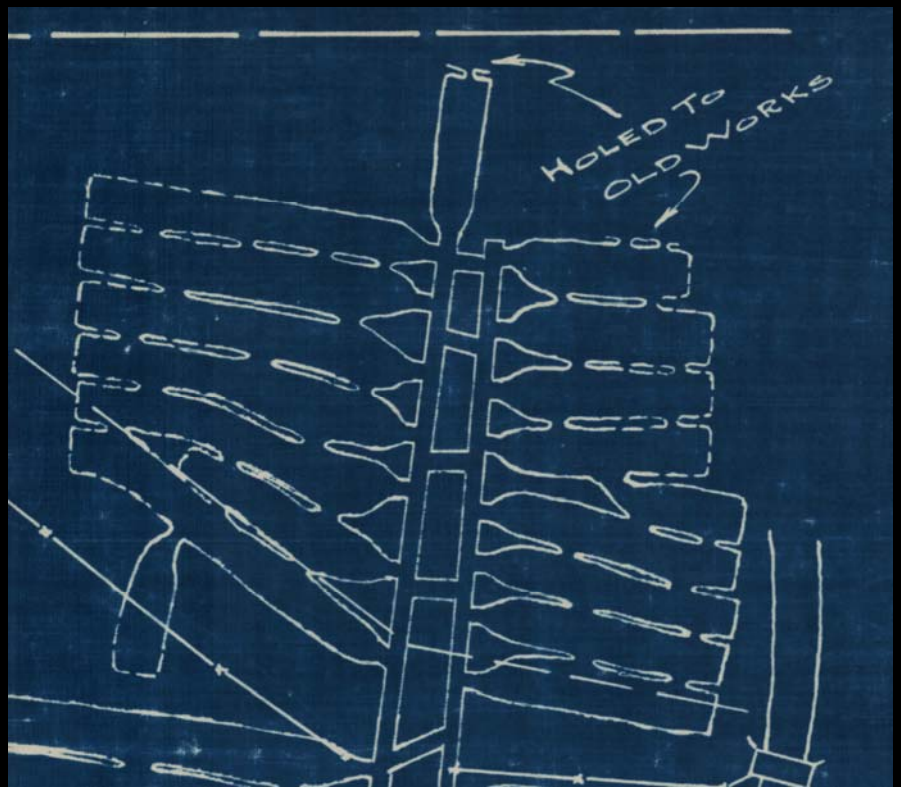


Mine Safety and Land-Use Problems Share Common Needs and Concerns

- **Knowing type, quantity and content of fluids contained in past mines.**

Mine Safety and Land-Use Problems Share Common Needs and Concerns

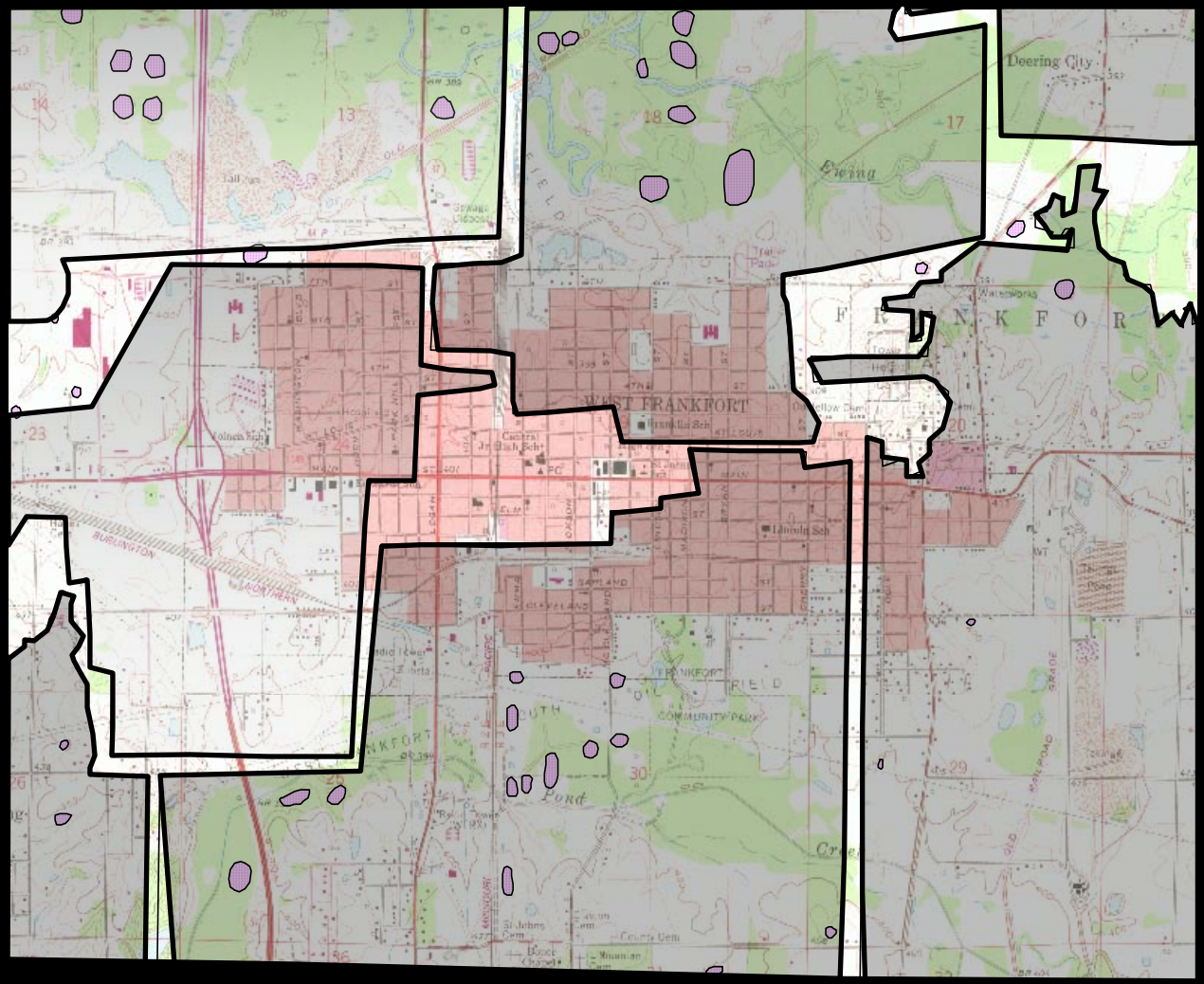
- **Knowing type, quantity and content of fluids contained in past mines.**
- **Connectivity Between Mines**



Knowing X,Y,Z Coordinates of Past Mining

- Generalized Maps and Their Use

Mined Areas Superimposed On A Topographic Map



N
W E
S

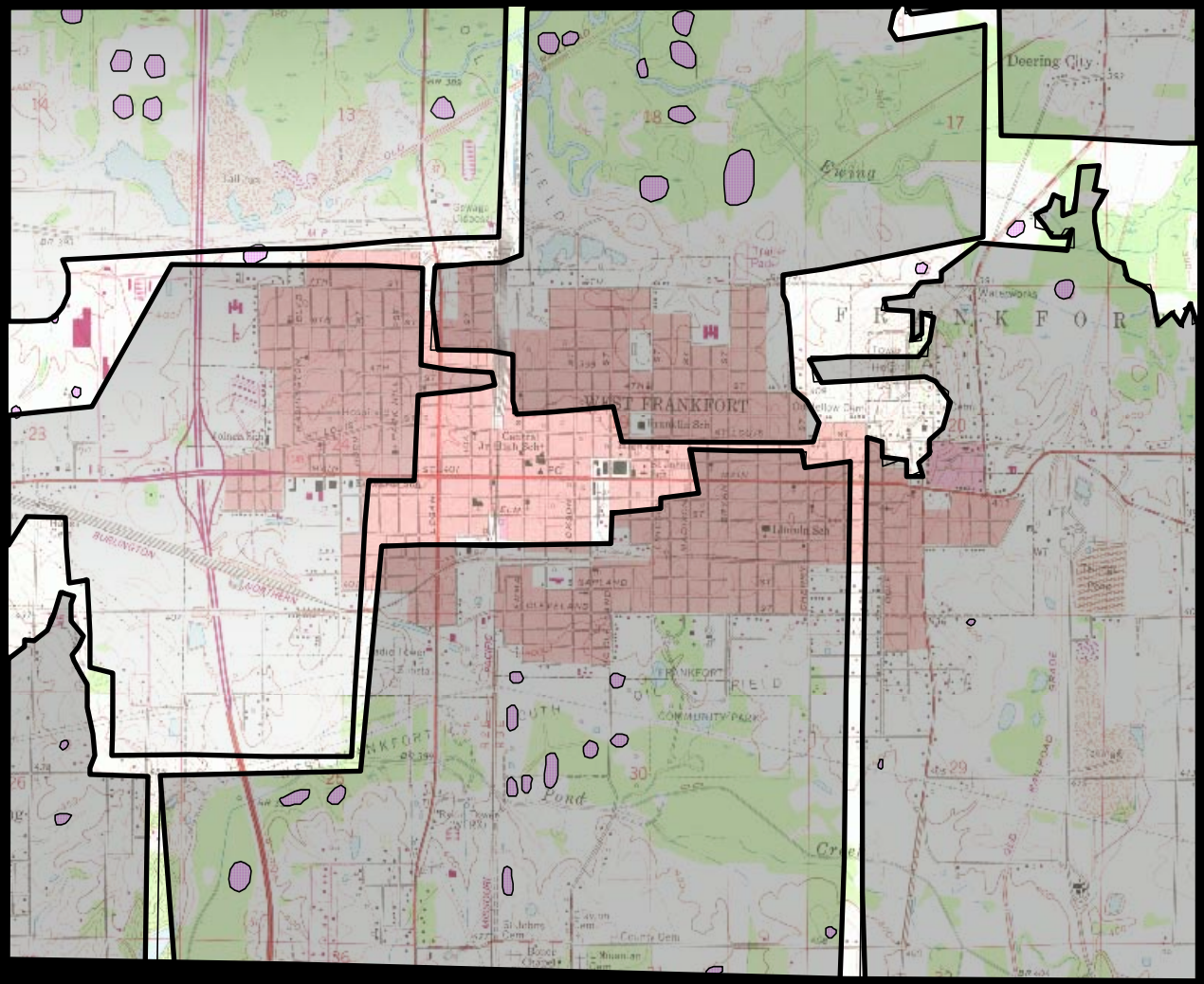
Mined Out Area

Subsidence Events

0 1 2 3 4 Miles

RDG 2005

General Map Use Examples



- City planning

Mined Out Area

Subsidence Events

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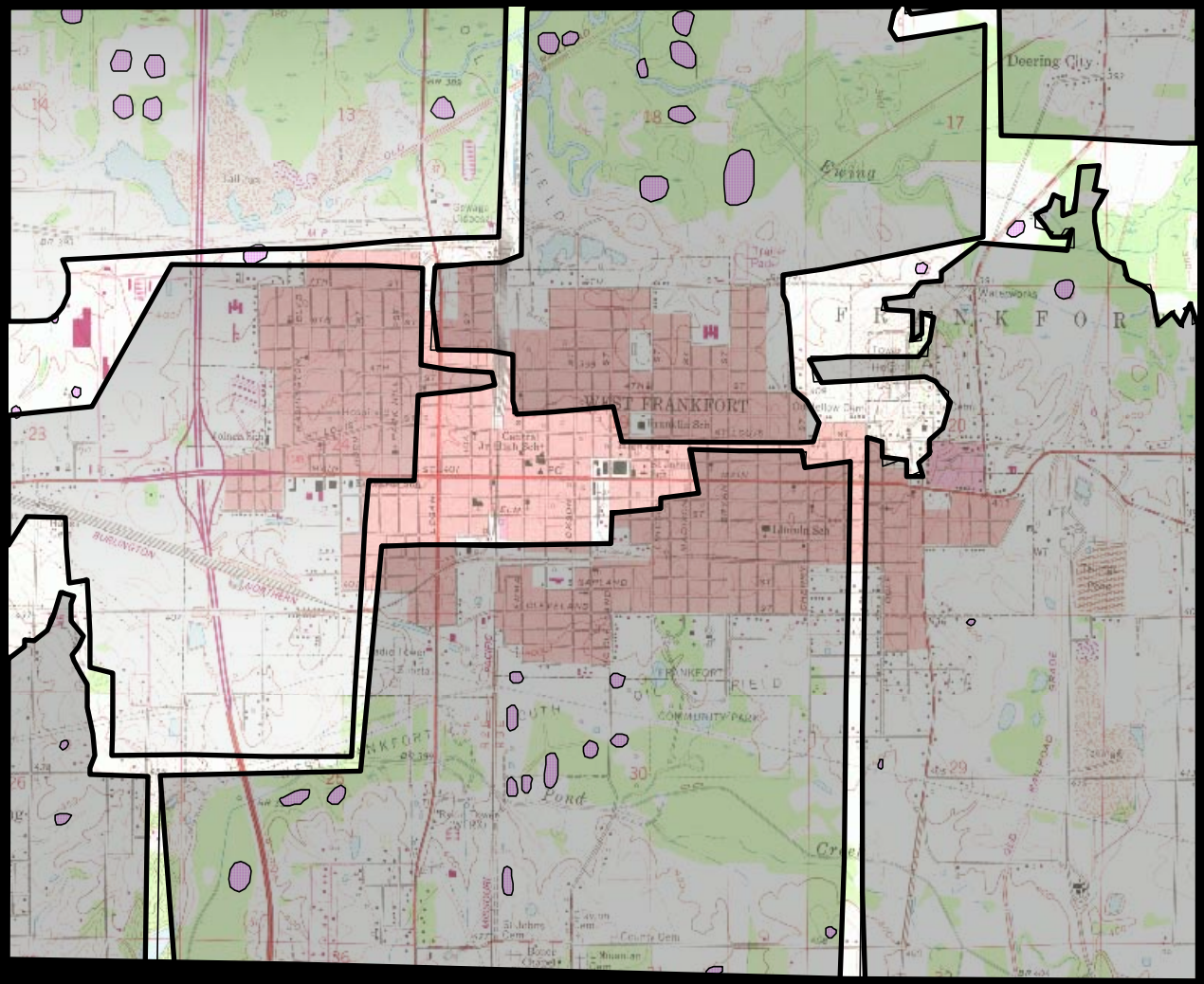
General Map Use Examples



- City planning
- Mineral depletion and speculation

Mined Out Area

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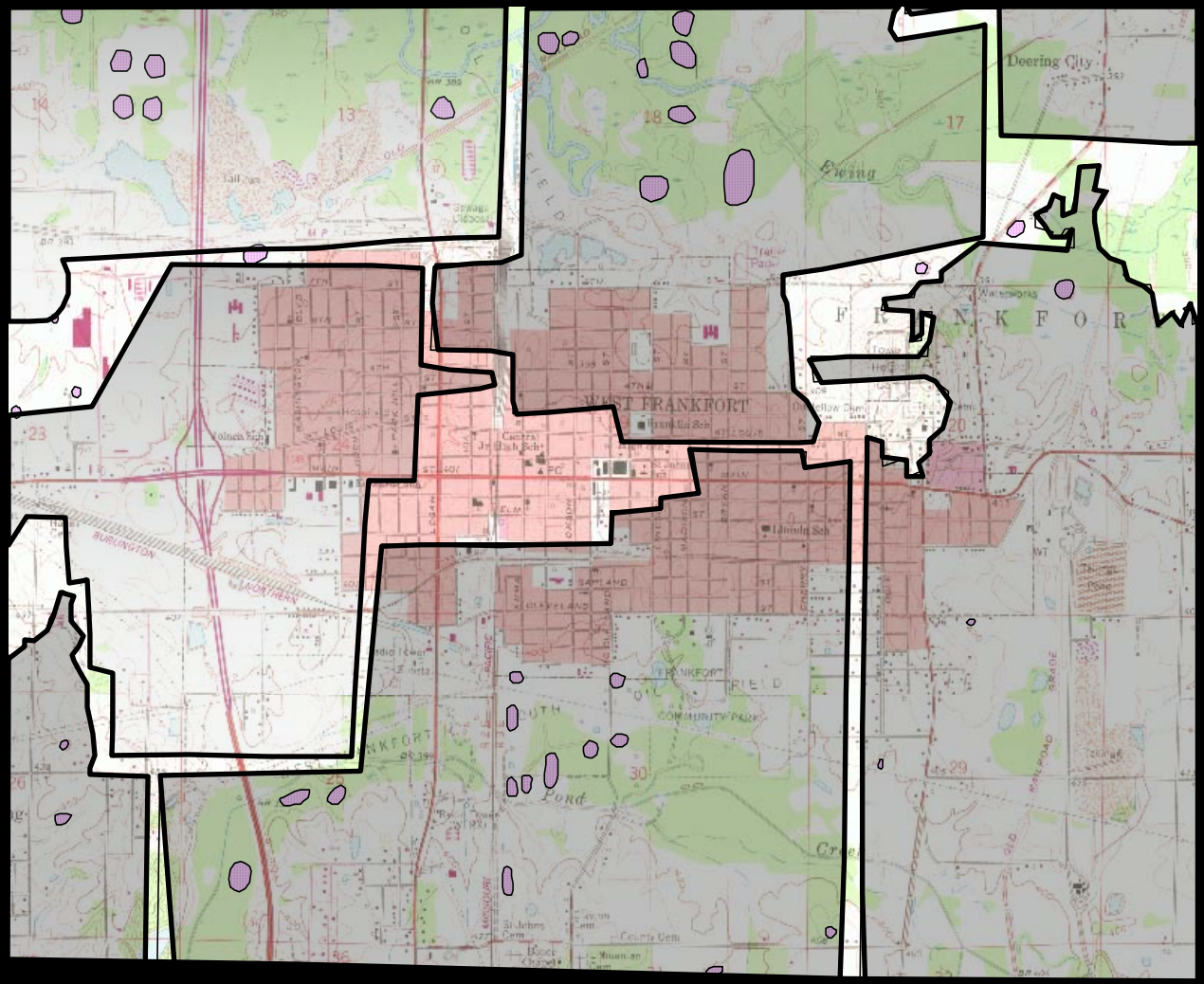

- City planning
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- Transportation

Mined Out Area

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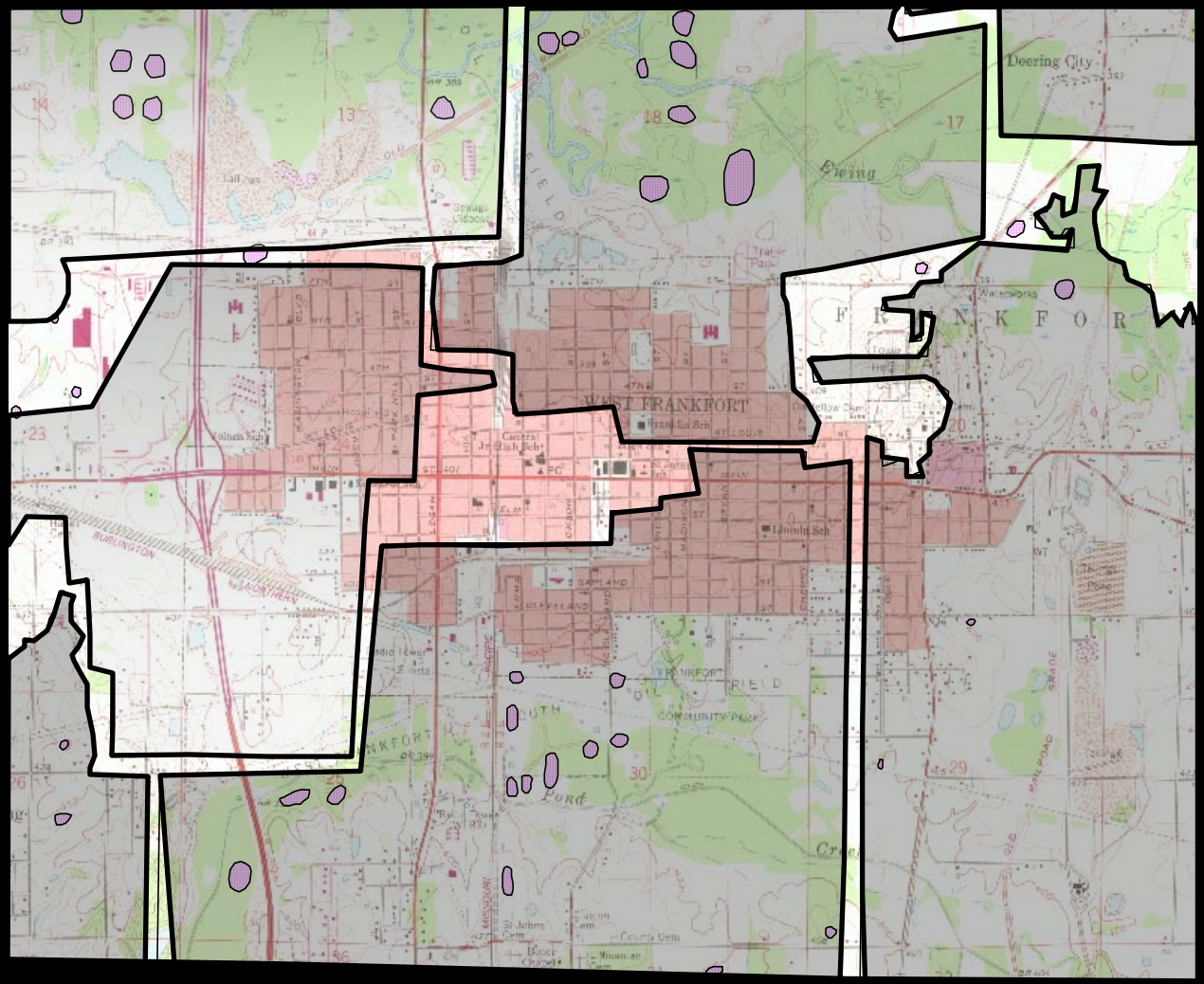
General Map Use Examples



- City planning
- Mineral depletion and speculation
- Transportation
- Emergency planning

Mined Out Area

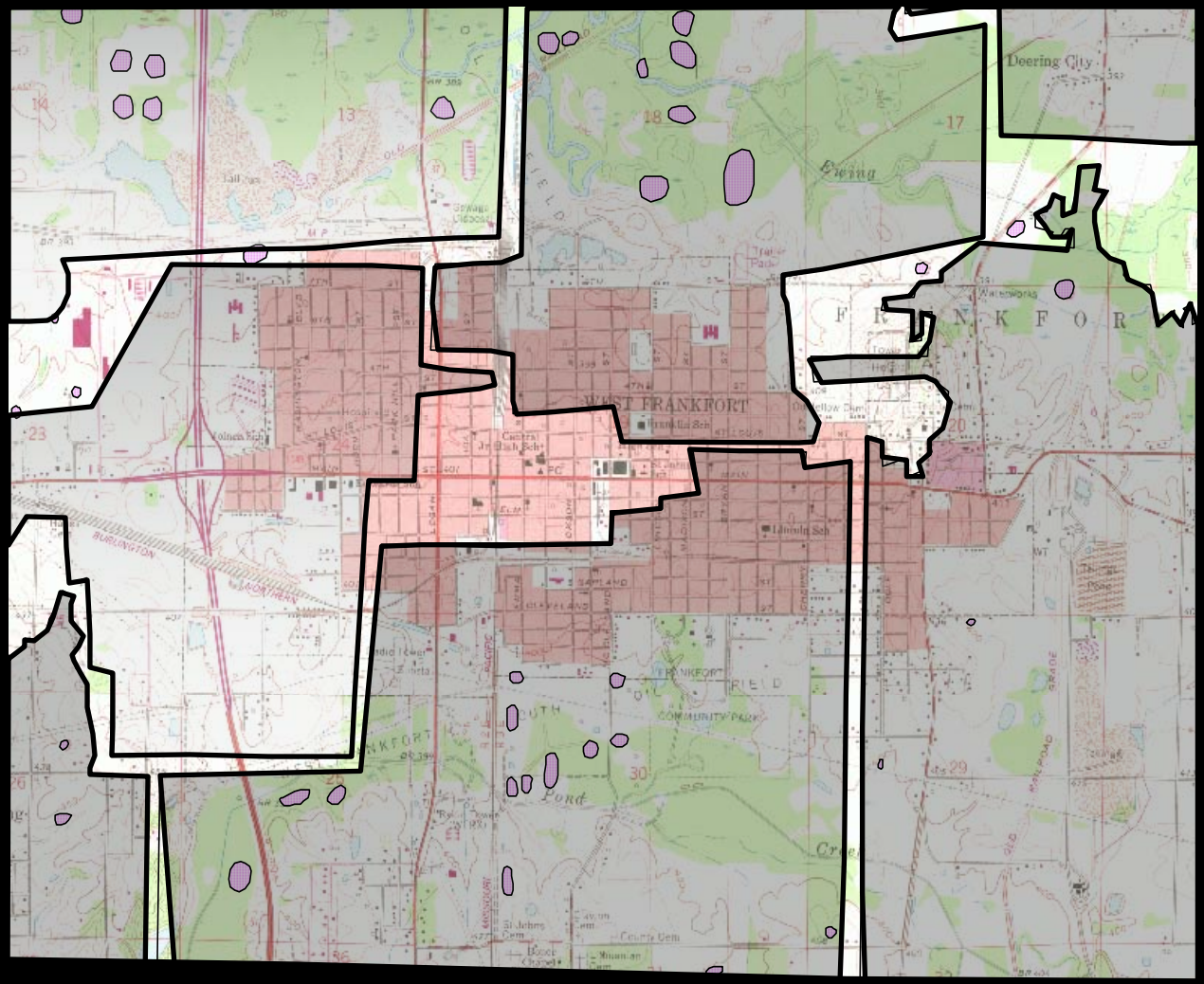
Subsidence Events

0 1 2 3 4 Miles

N
W E
S

RDG 2005

General Map Use Examples



- City planning
- Mineral depletion and speculation
- Transportation
- Emergency planning
- Waste disposal

N
W E
S

Mined Out Area

Subsidence Events

0 1 2 3 4 Miles

RDG 2005

Knowing X,Y,Z Coordinates of Past Mining

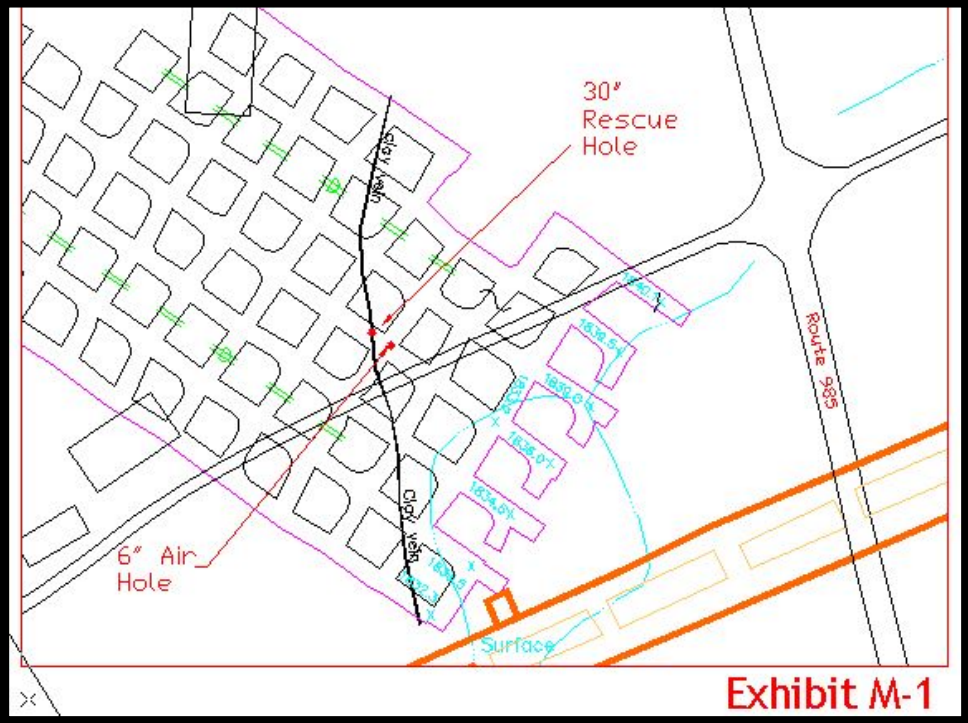
- Generalized Maps and Their Use
- Detailed Maps and Their Use.

Knowing X,Y,Z Coordinates of Past Mining

- **Modern Mine Considerations**

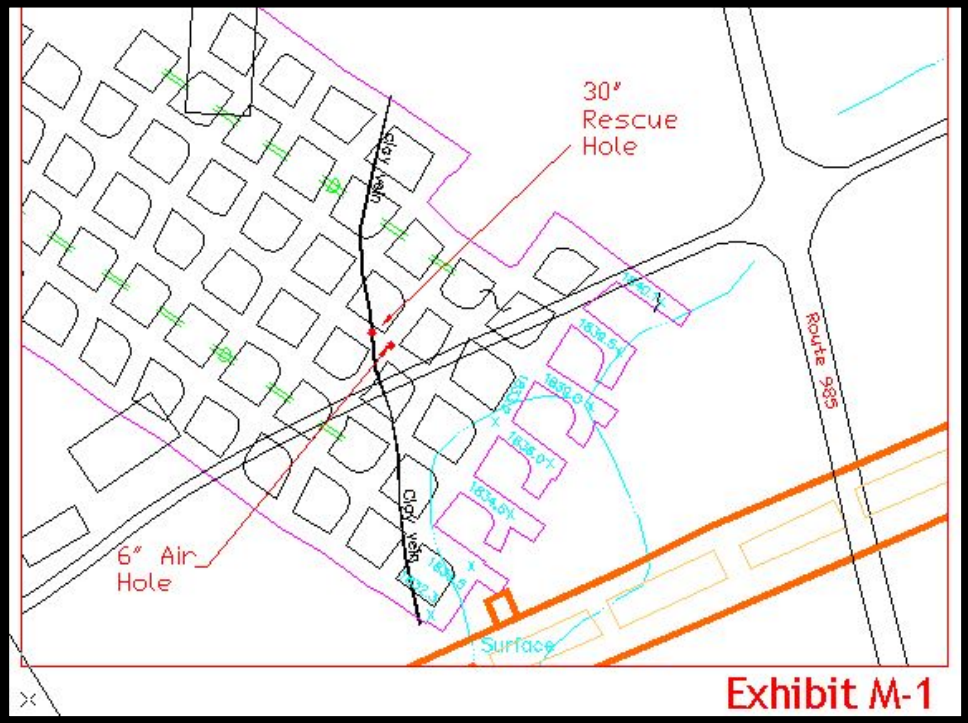
Advantages For Modern Mines

- **To avoid past mining operations.**



Advantages For Modern Mines

- **So that past mining can be avoided**
- **Or to safely use old mines for ventilation, haulage or emergency escapement purposes.**



Knowing X,Y,Z Coordinates of Past Mining

- Modern Mine Considerations
- Land-Use Development Considerations

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  - Detailed mine and land histories.

“Other” Information List

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- **Site Information**
  - Known subsidence
  - Shaft locations
  - Boreholes
  - Oil wells

“Other” Information List

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  - Seam thickness
  - Coal elevations
  - Gaseous conditions
  - Floor and roof details
  - Hydrology

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  - Floor and roof details
  - Hydrology
- Historic and Mining Information
  - Unusual mining practice and/or construction
  - Shaft construction details and closure detail
  - Mine fires
  - Past subsidence
  - Mine connectivity
  - Noting and naming of adjacent mine workings.
  - Oil well location
  - Other known problems

Mining and Potential Land-Use Conflicts

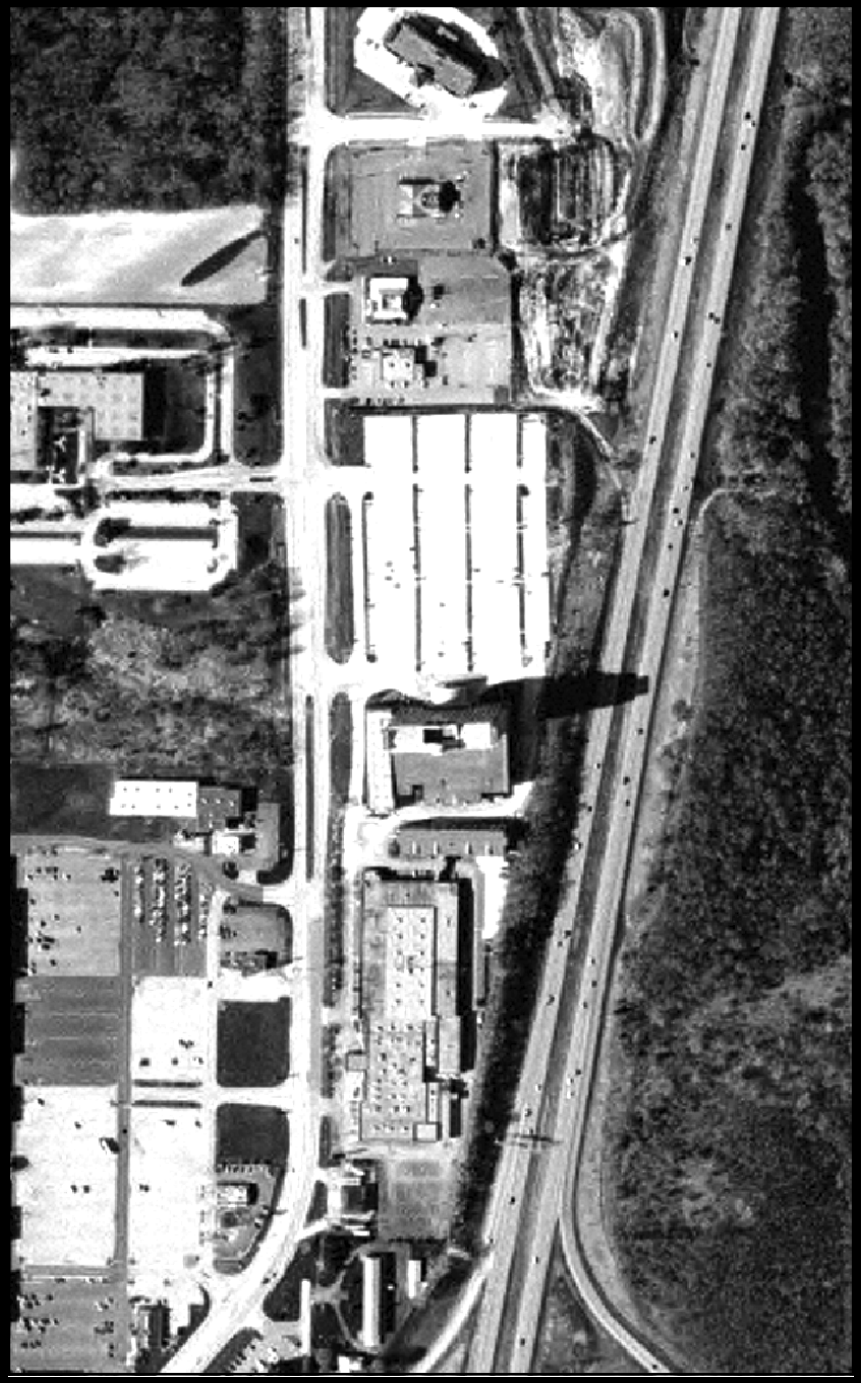
Mining and Potential Land-Use Conflicts

Typical situations and mine information needs.

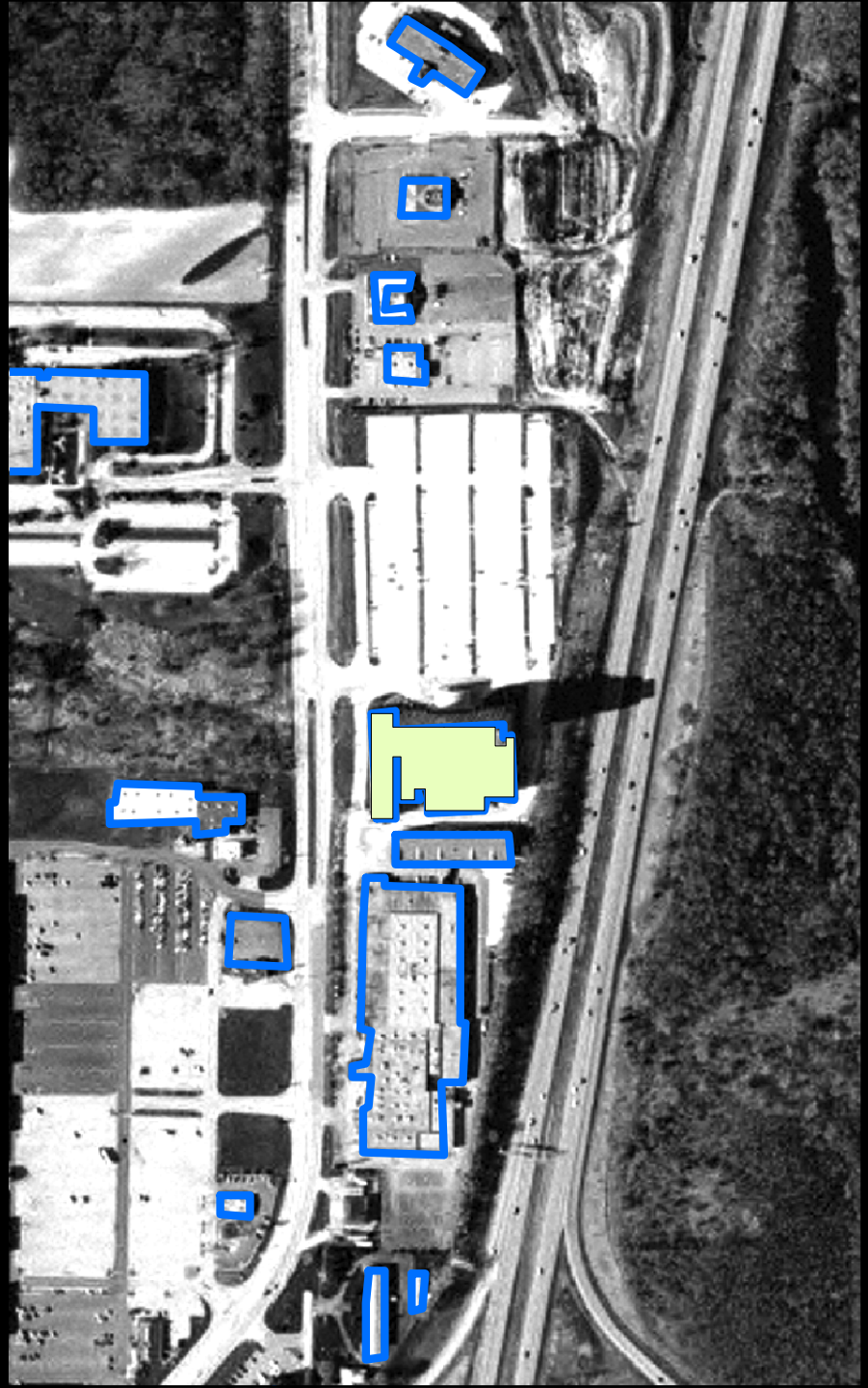
Mining and Potential Land-Use Conflicts

Typical situations and mine information needs.

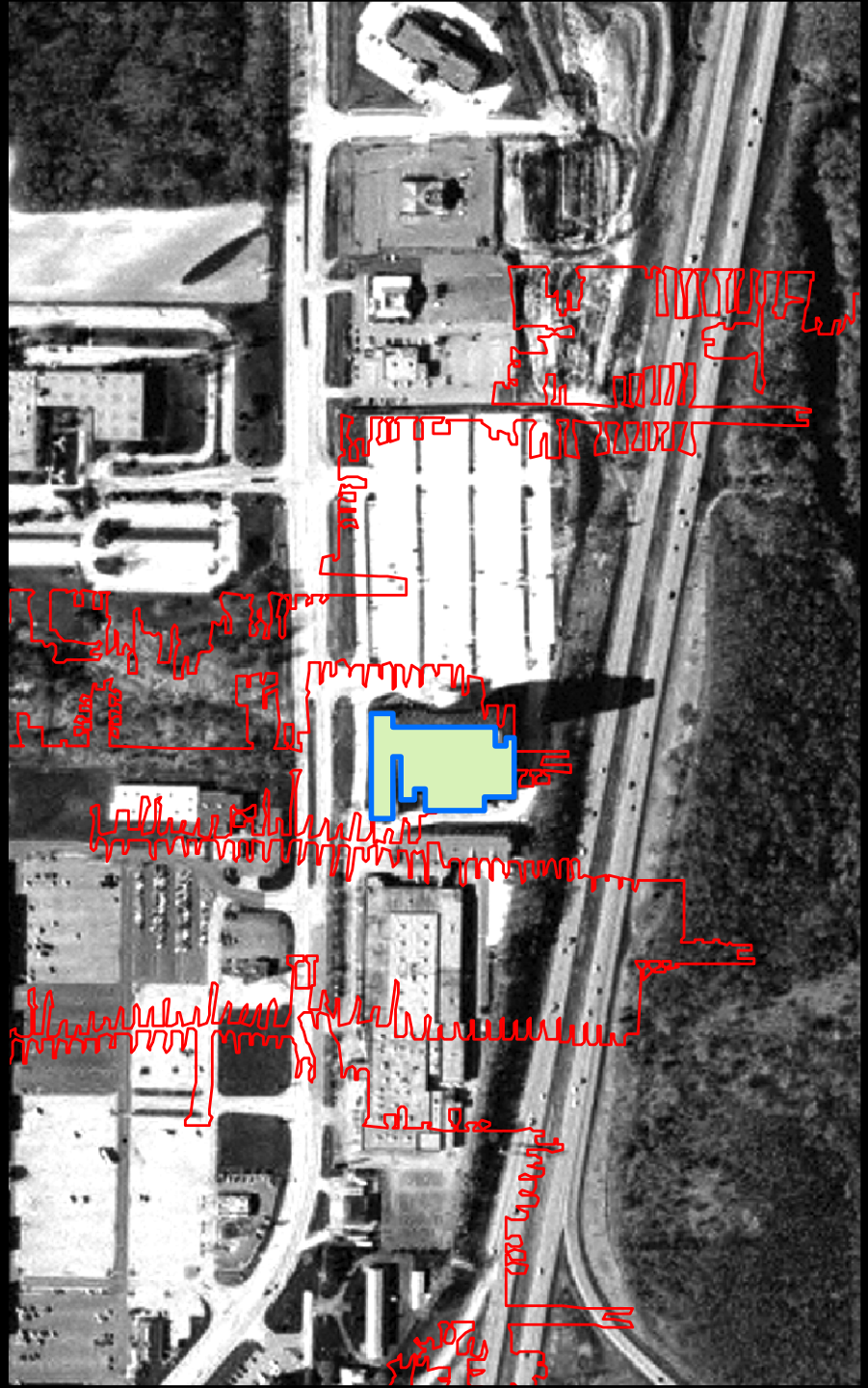
- Investigation of a large hotel complex.



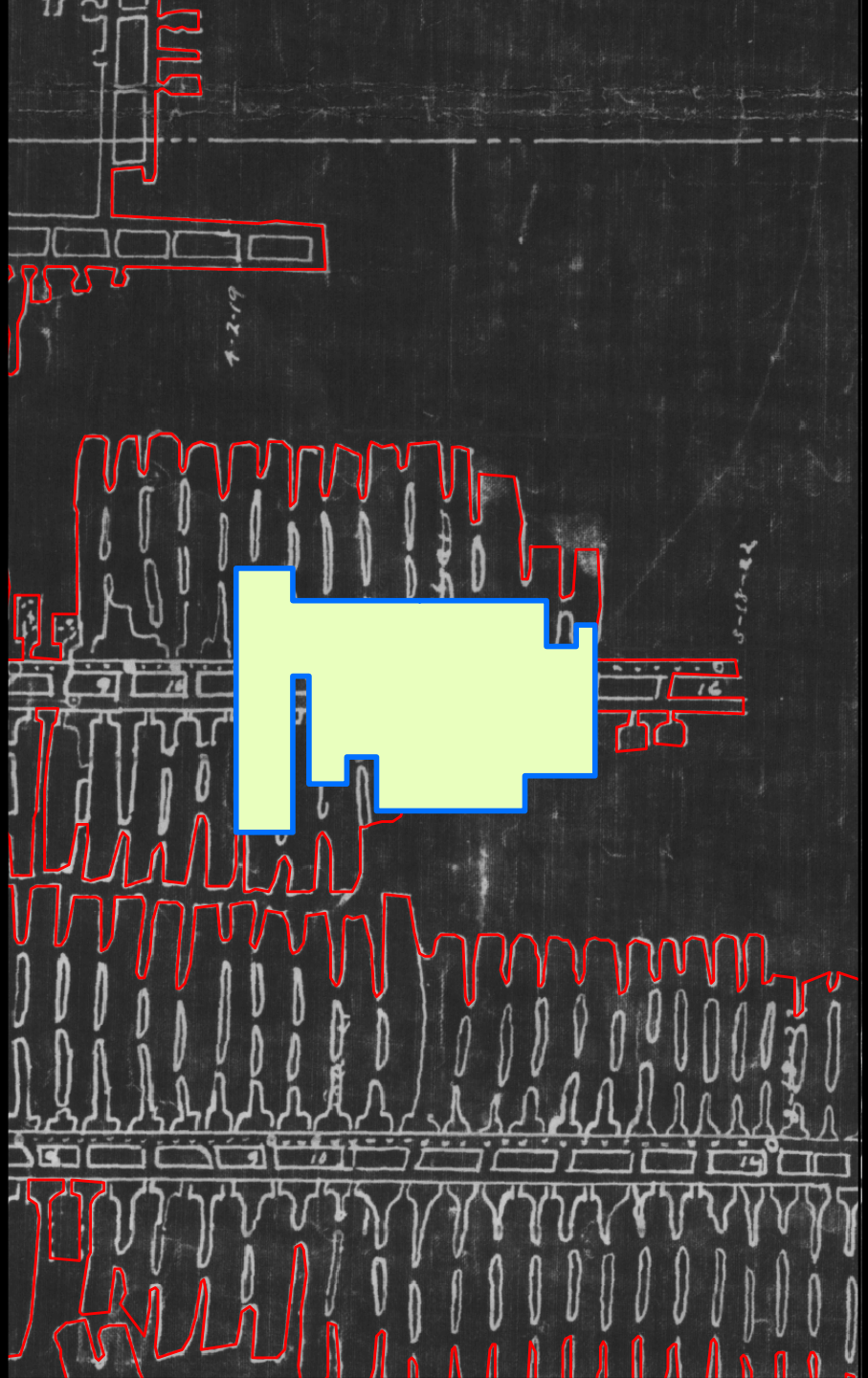
- Is this area



- Or particular building

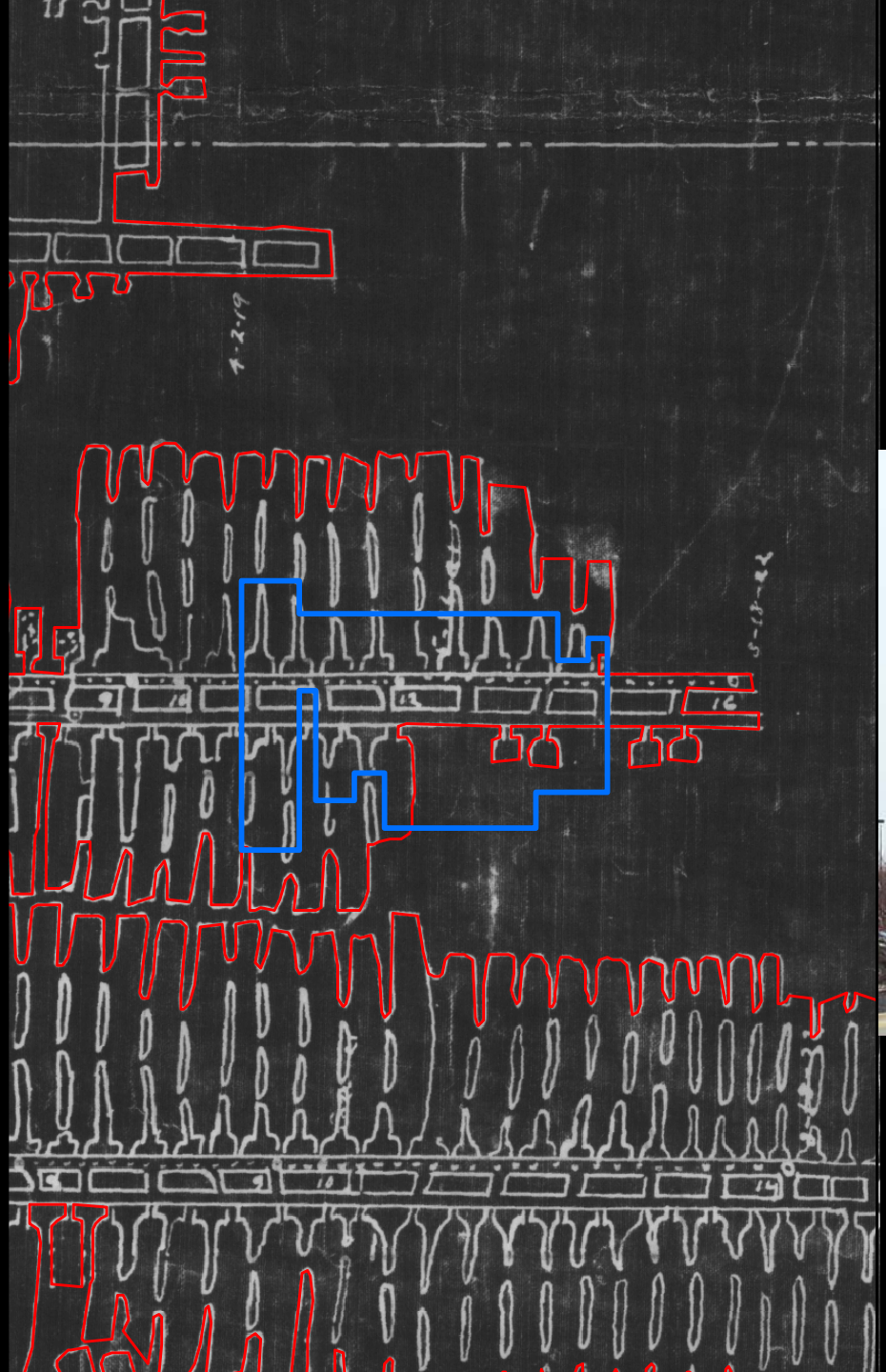


Undermined?



- IF undermined. Precisely locating surface features with respect to a detailed mine workings map

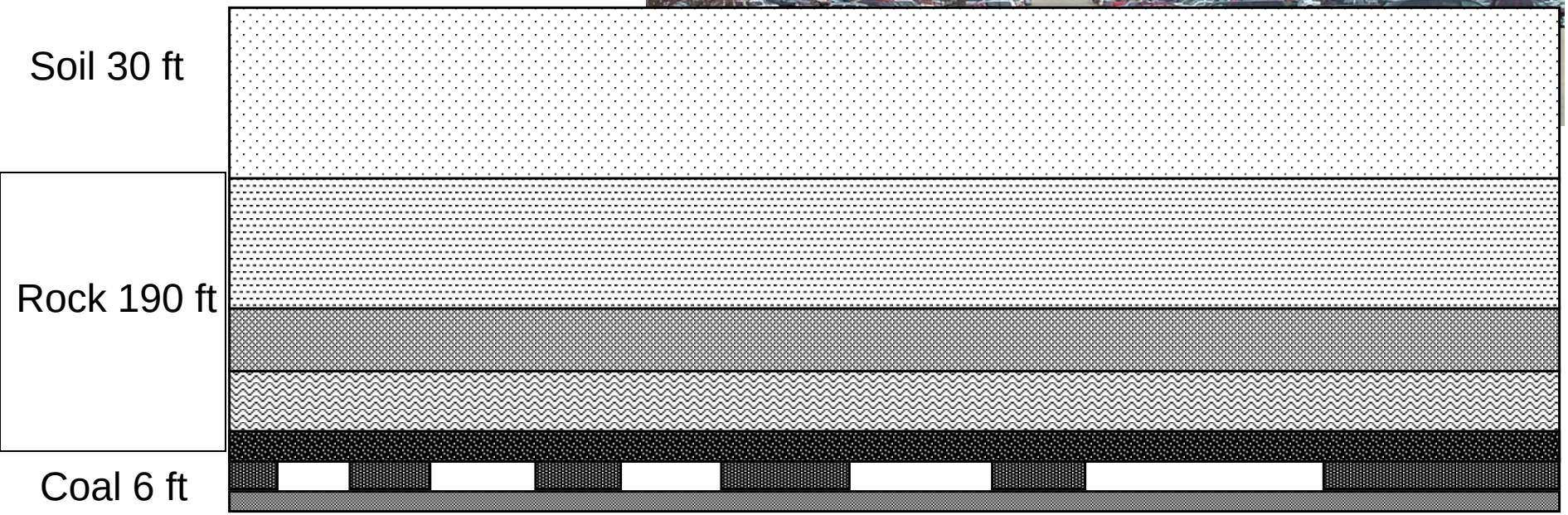
will help in identifying risks.



- What are the risks?

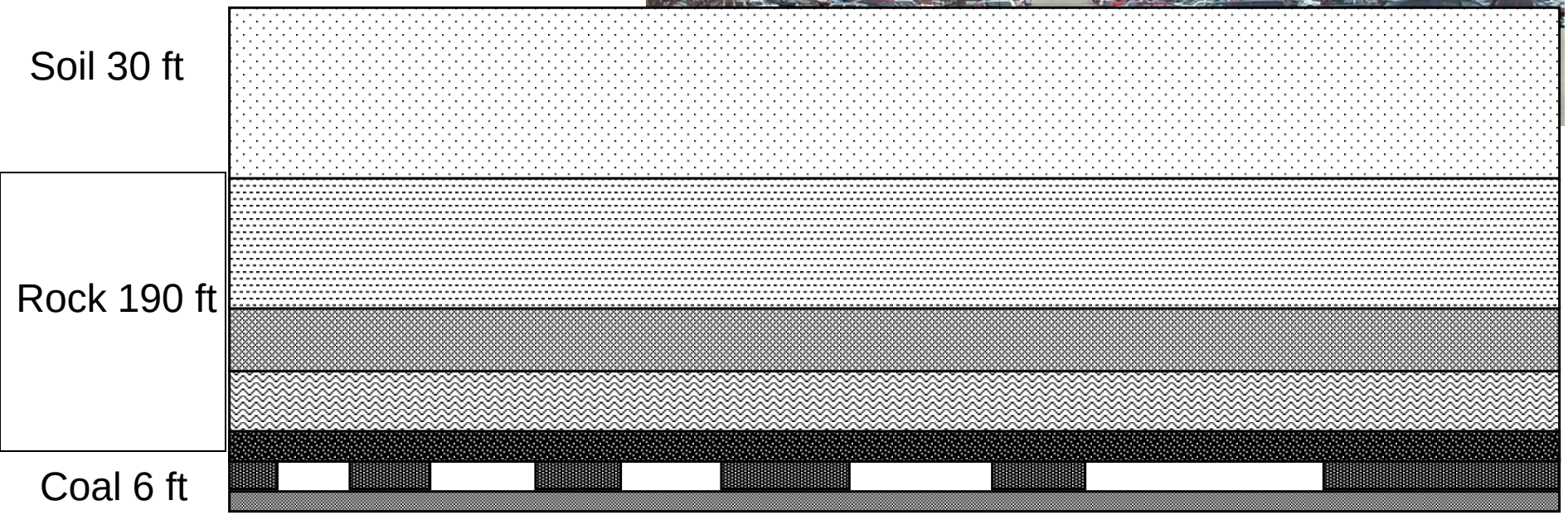
Site Information

- Evidence of previous subsidence at site ?
- Nearby subsidence ?
- Known attempts at mine stabilization?



Information Desired

- Floor thickness & lithology.
- Coal seam thickness.
- Mine hydrology
- Mine gas
- Historical mine problems



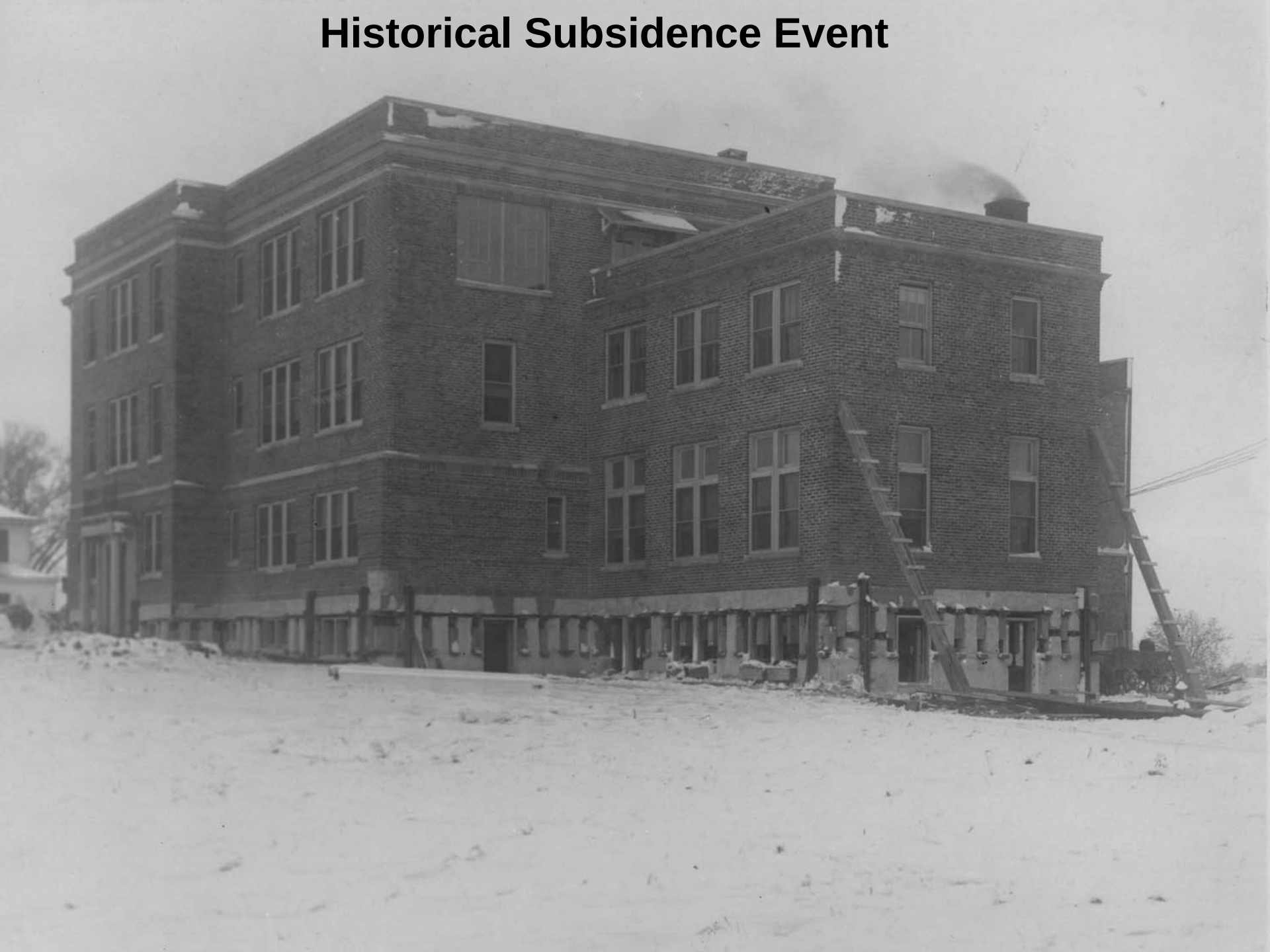
Mining and Potential Land-Use Conflicts

Typical situations and mine information needs.

- Investigation of a large hotel complex.
- Investigation for site re-development.

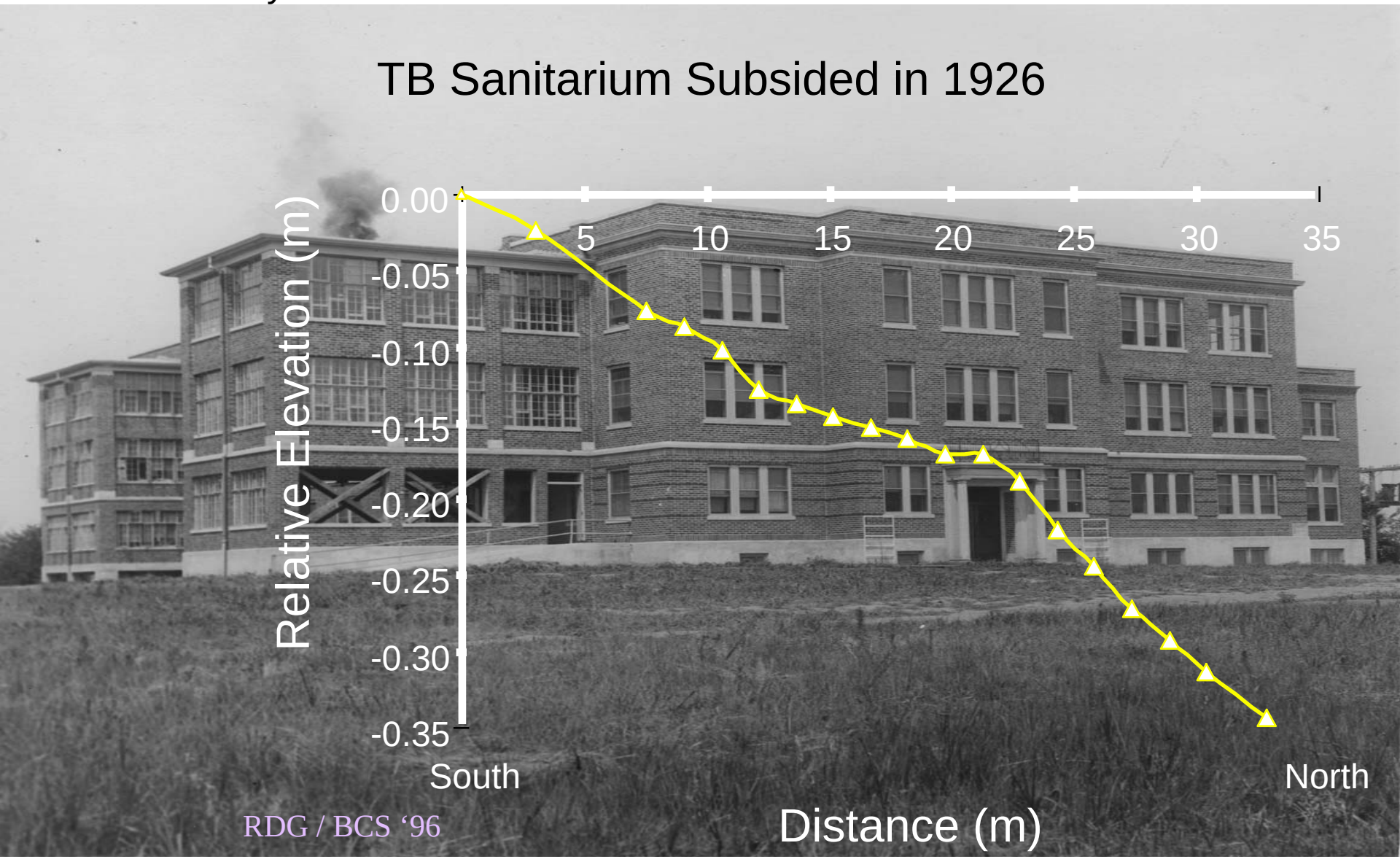
Land Being Considered for Commercial Re- Development

Historical Subsidence Event



Site Information

- Subsidence has occurred and history is known.



Donk Bros. Mine No. 4

80 Years Later – no evidence of continuing subsidence.

Subsidence Risk Summary

- The type and mechanics of subsidence is related to mine depth, seam thickness, floor characteristics, mine geometries, hydrology, and lithology.

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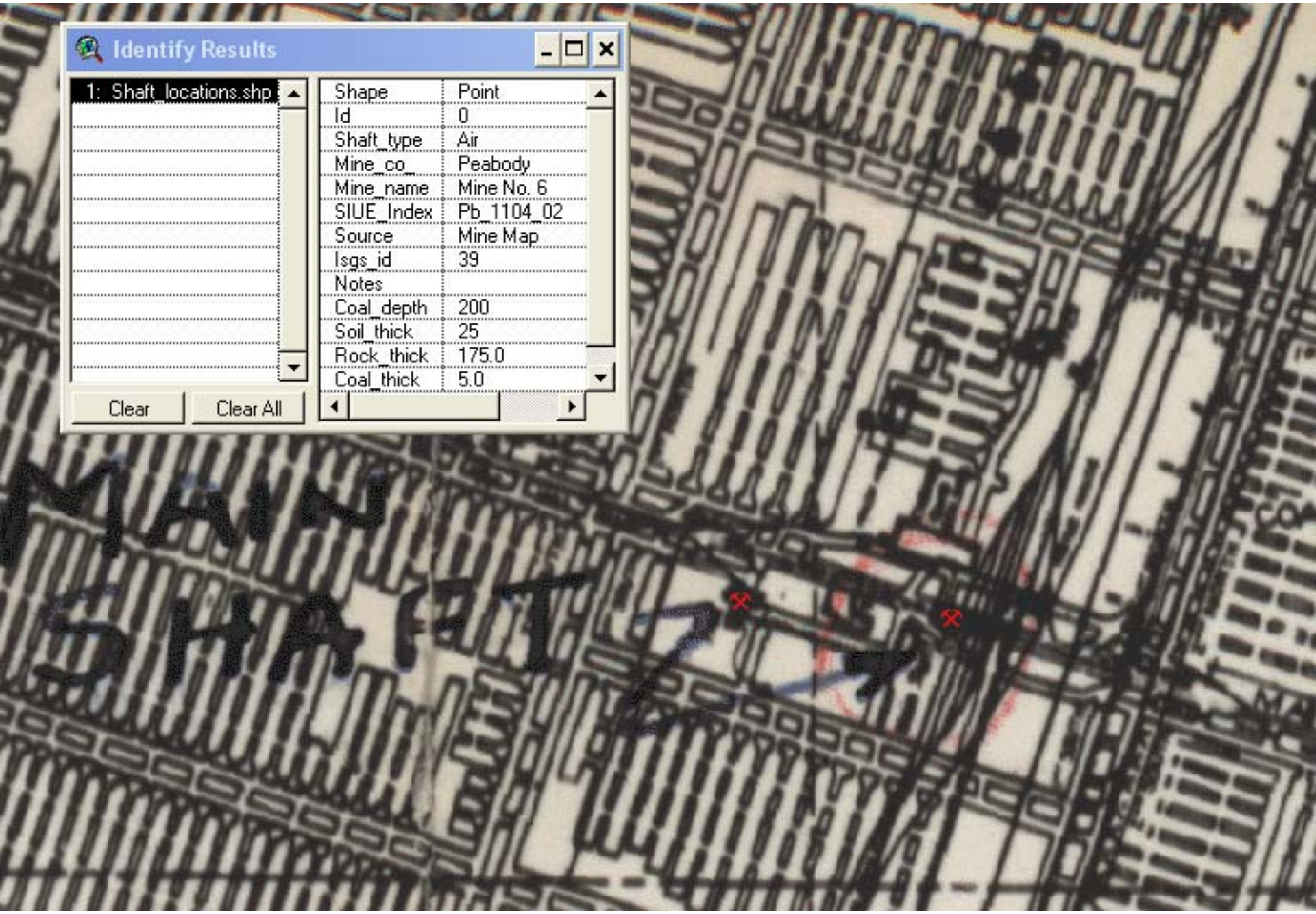
- It should be noted that adjacent mined areas may collapse and overlap boundaries of an earlier sag event.

Mining and Potential Land-Use Conflicts

Typical situations and mine information needs.

- Investigation of a large hotel complex.
- Investigation for site re-development.
- Investigation of structure for mine gas leaks.

Explosive Accumulation of Methane Gas Measured In Home.


Identify Results
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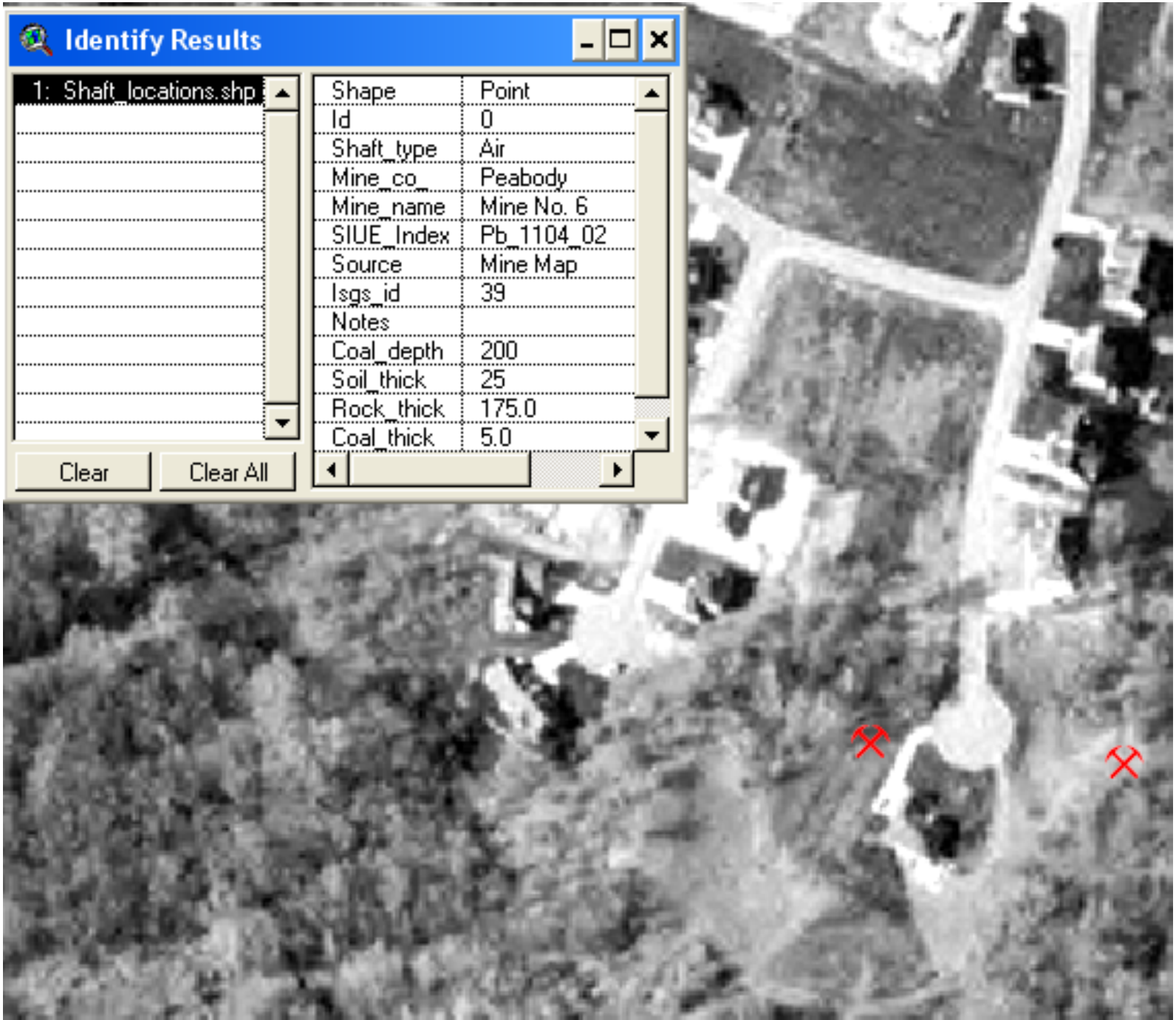
Shape Point
Id 0
Shaft_type Air
Mine_co_ Peabody
Mine_name Mine No. 6
SIUE_Index Pb_1104_02
Source Mine Map
Isgs_id 39
Notes
Coal_depth 200
Soil_thick 25
Rock_thick 175.0
Coal_thick 5.0
Clear
Clear All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Coal_depth 200
Soil_thick 25
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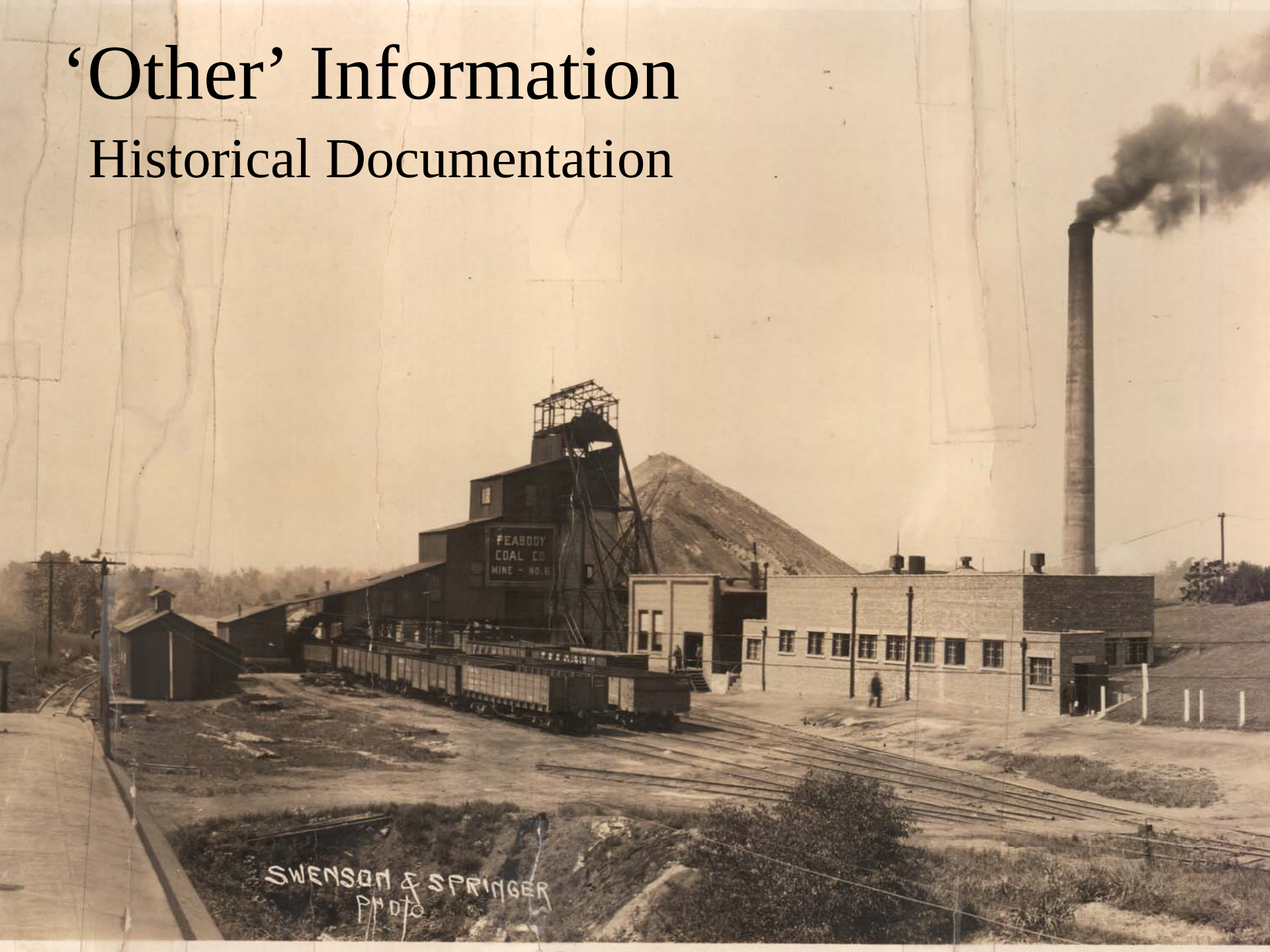
Clear
Clear All

Landscaping Conceals Location of Mine Structures

‘Other’ Information

Historical Documentation



Mine Gas Problem Summary

- Require a conduit between mine and surface

Mine Gas Risks

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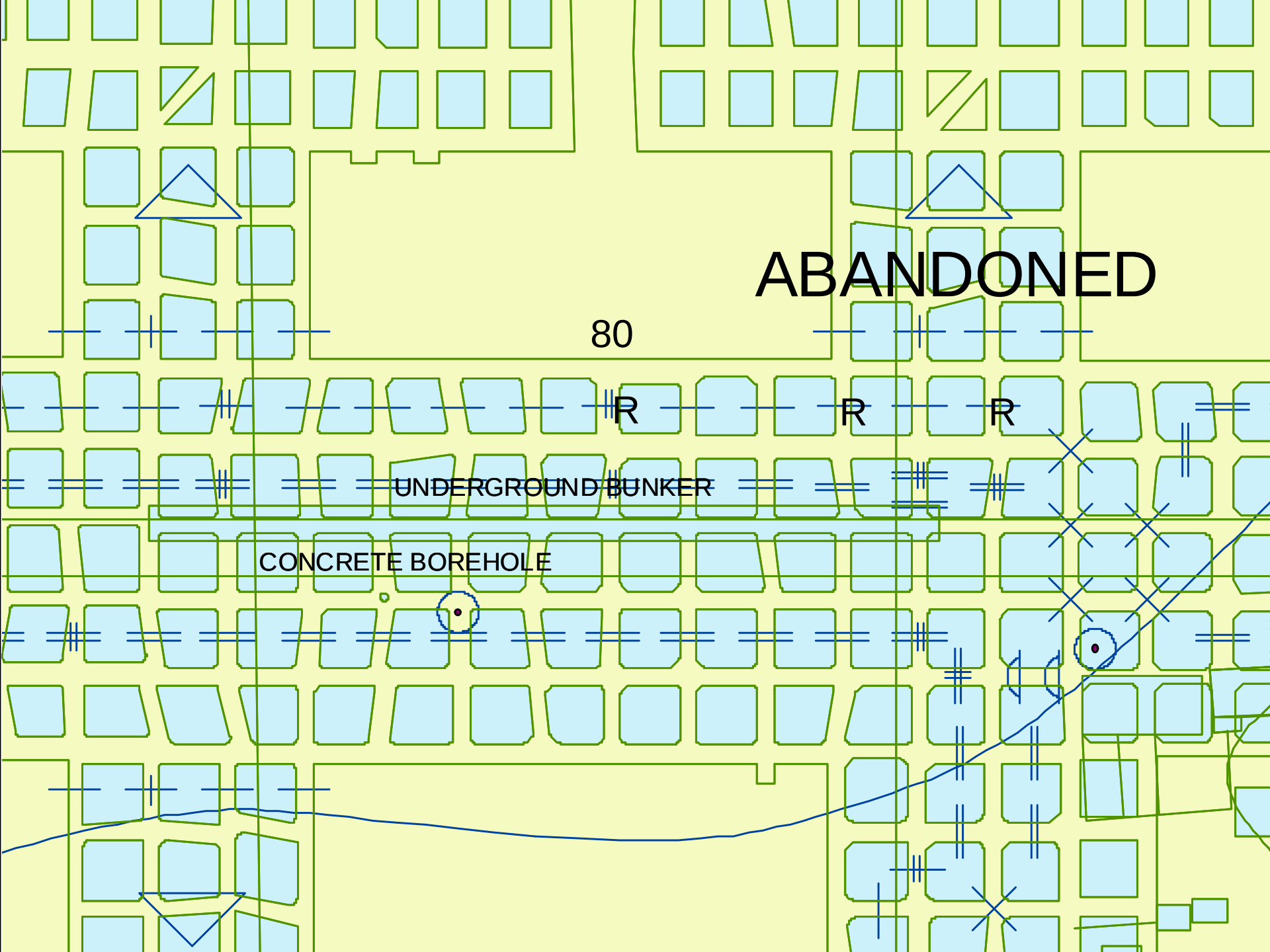
- Require a conduit between mine and surface
- Typical conduits include shafts and boreholes
- Shafts filled with porous media do not protect surface from escaping mine gases.
- Oil wells and/or interconnecting mines may significantly exacerbate mine gas pressures and volumes.

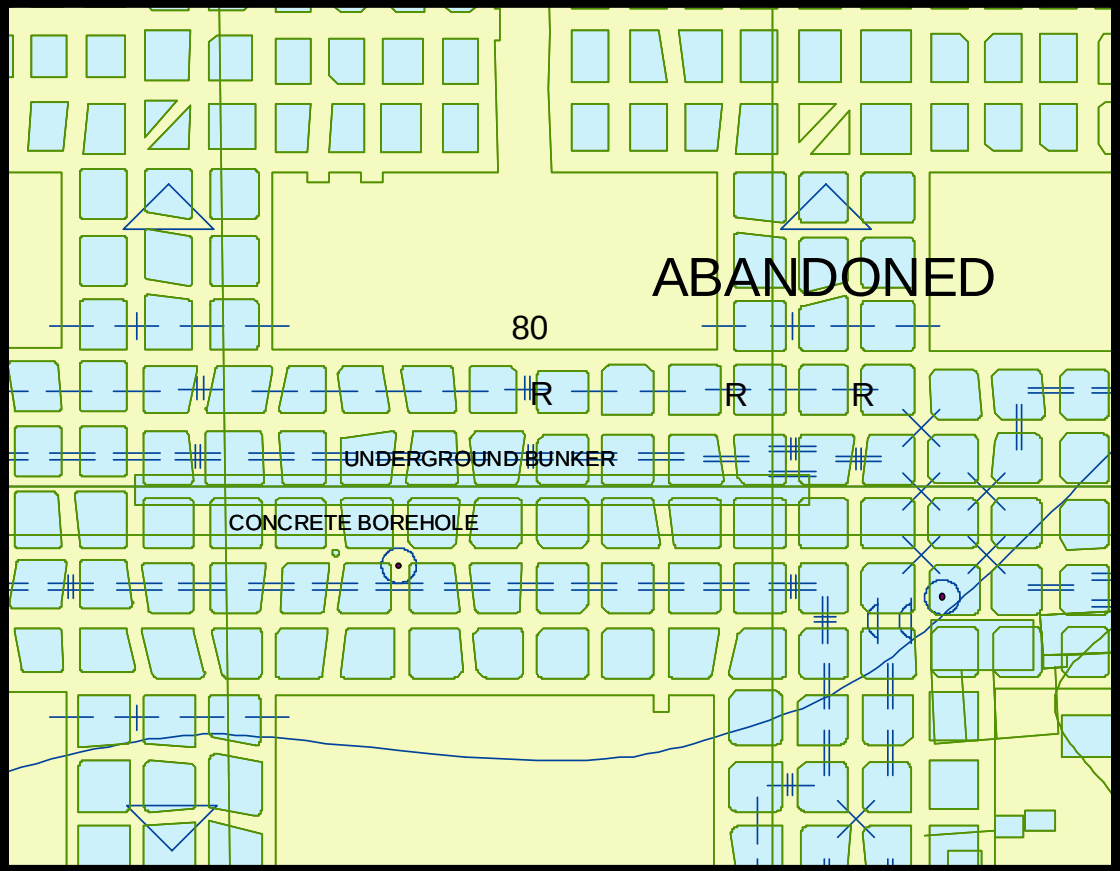
Mining and Potential Land-Use Conflicts

Typical situations and mine information needs.

- Investigation of a large hotel complex.
- Investigation for site re-development.
- Investigation of structure for mine gas leaks.
- **Unusual mining practice and/or construction**

Underground Bunker Details

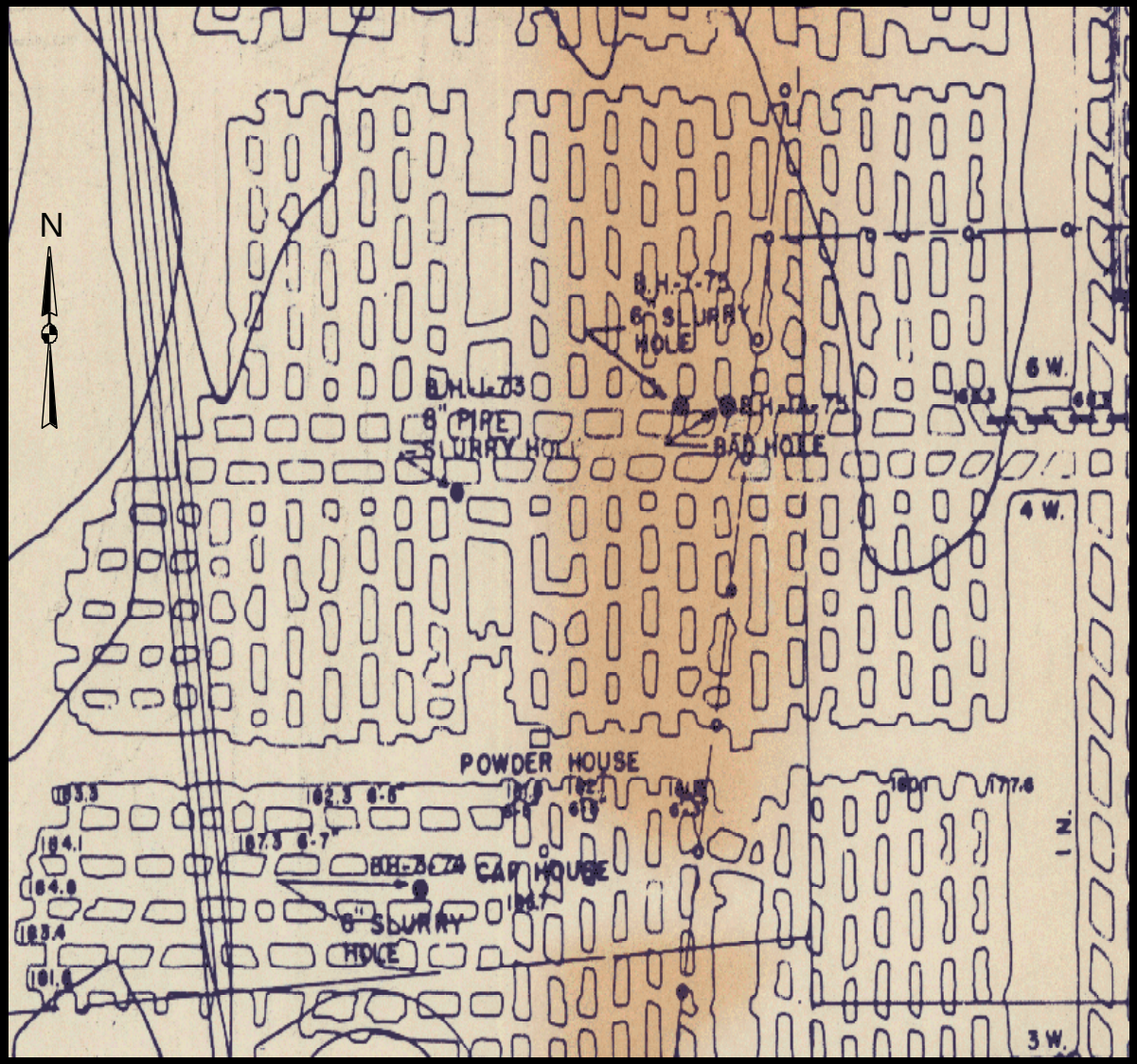

ABANDONED
80
R
R
R
UNDERGROUND BUNKER
CONCRETE BOREHOLE



Questions

- Bunker height.
- Bunker construction details
- Was bunker filled?
- Filled material Used?
- Volume of void
- Volume of fill take

Slurry Injection



Questions

- Intent of slurry
  - disposal ?
  - surface protection ?
- Cementitious ?
- Panel filled?

Mining and Potential Land-Use Conflicts

Typical situations and mine information needs.

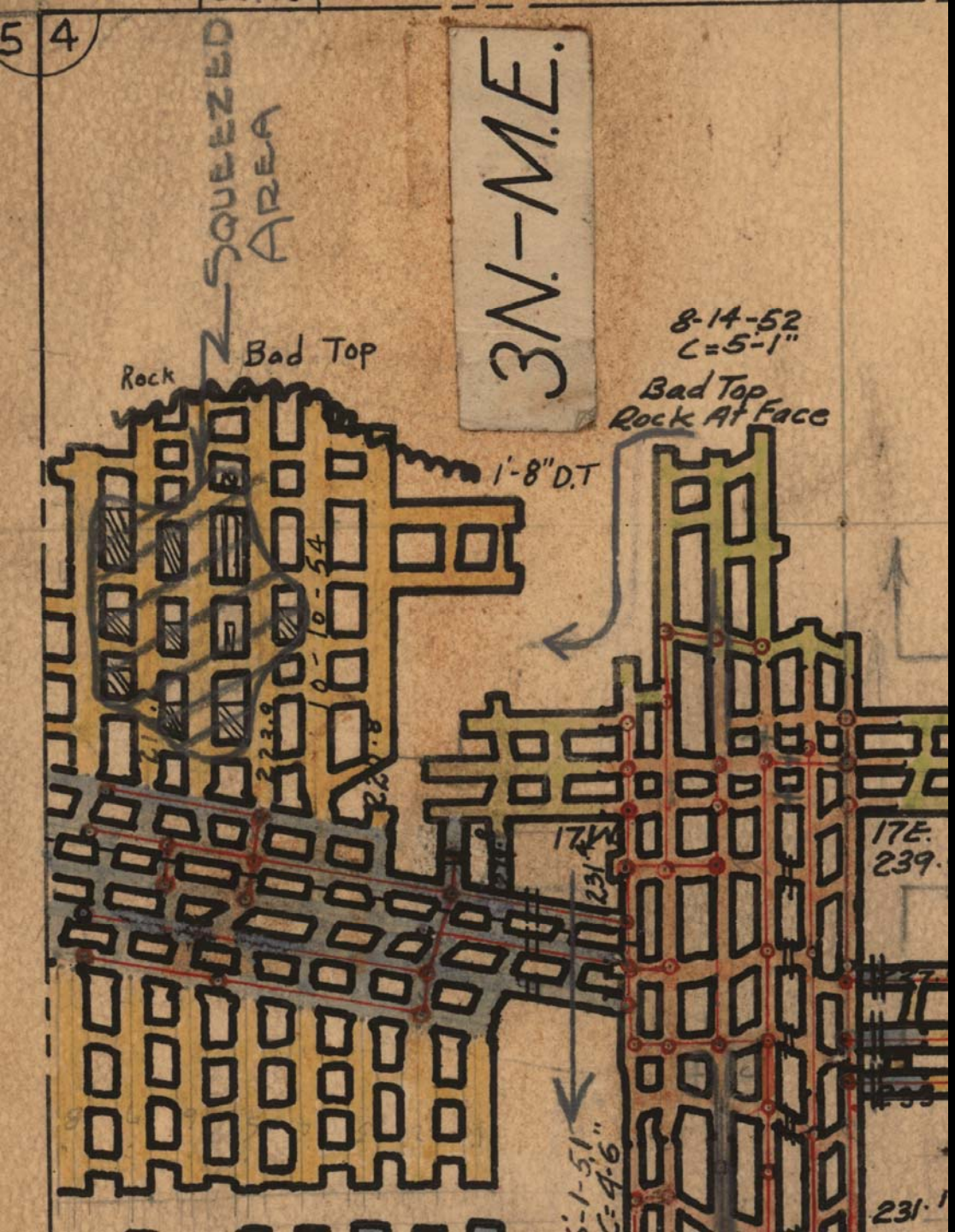
- Investigation of a large hotel complex.
- Investigation for site re-development.
- Investigation of structure for mine gas leaks.
- Unusual mining practice and/or construction
- Making and Using mine maps as a database

Examples Of Mine Maps Containing ‘Other’ Information

- Mine maps may be the only data reliably carried forward into the future.

Examples Of Mine Maps Containing ‘Other’ Information

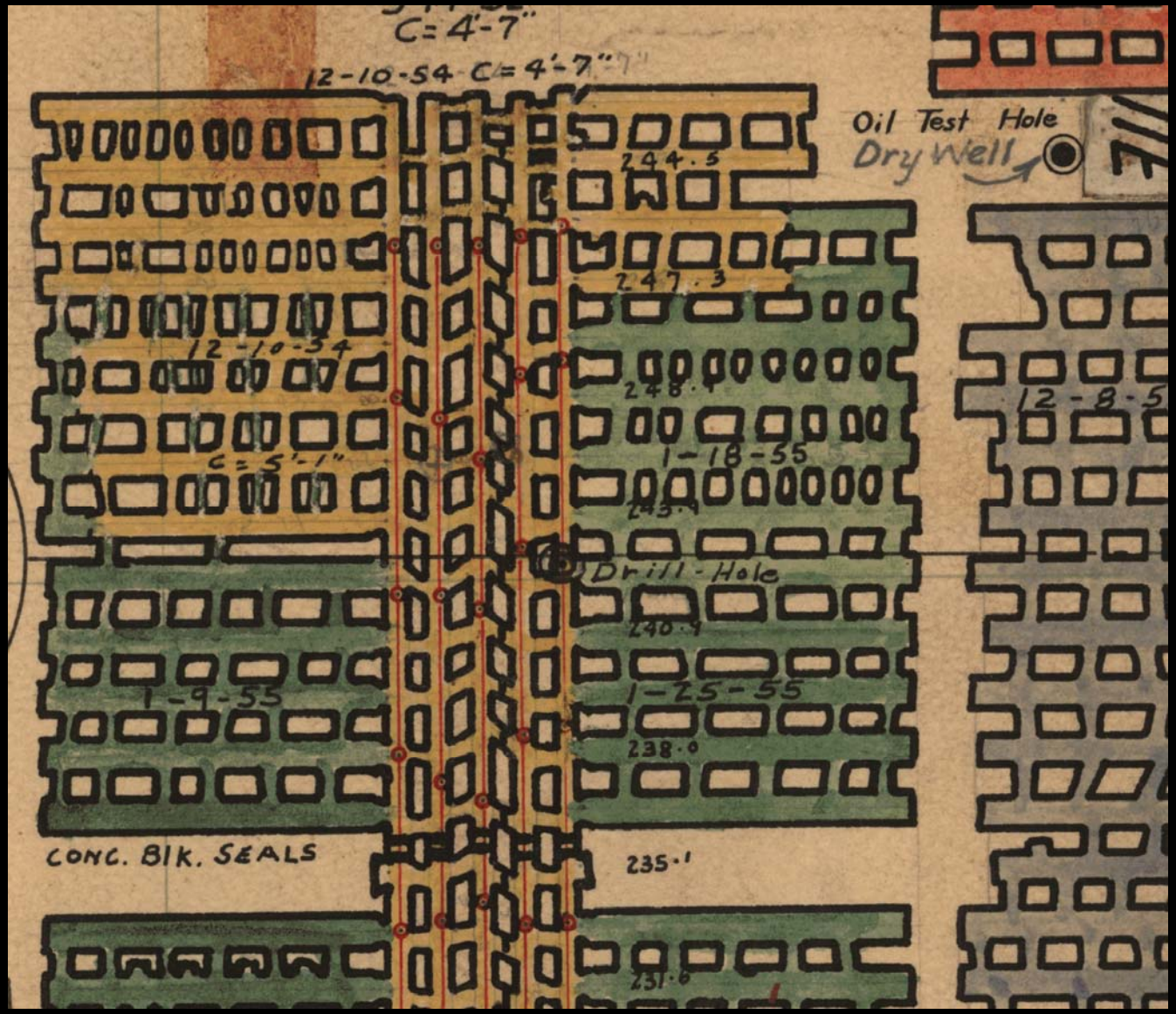
- Mine maps may be the only data reliably carried forward into the future.
- More information can be included on modern mine maps at little or no extra effort or costs. Presumably this information is commonly collected but not included on map submittal.



Questions

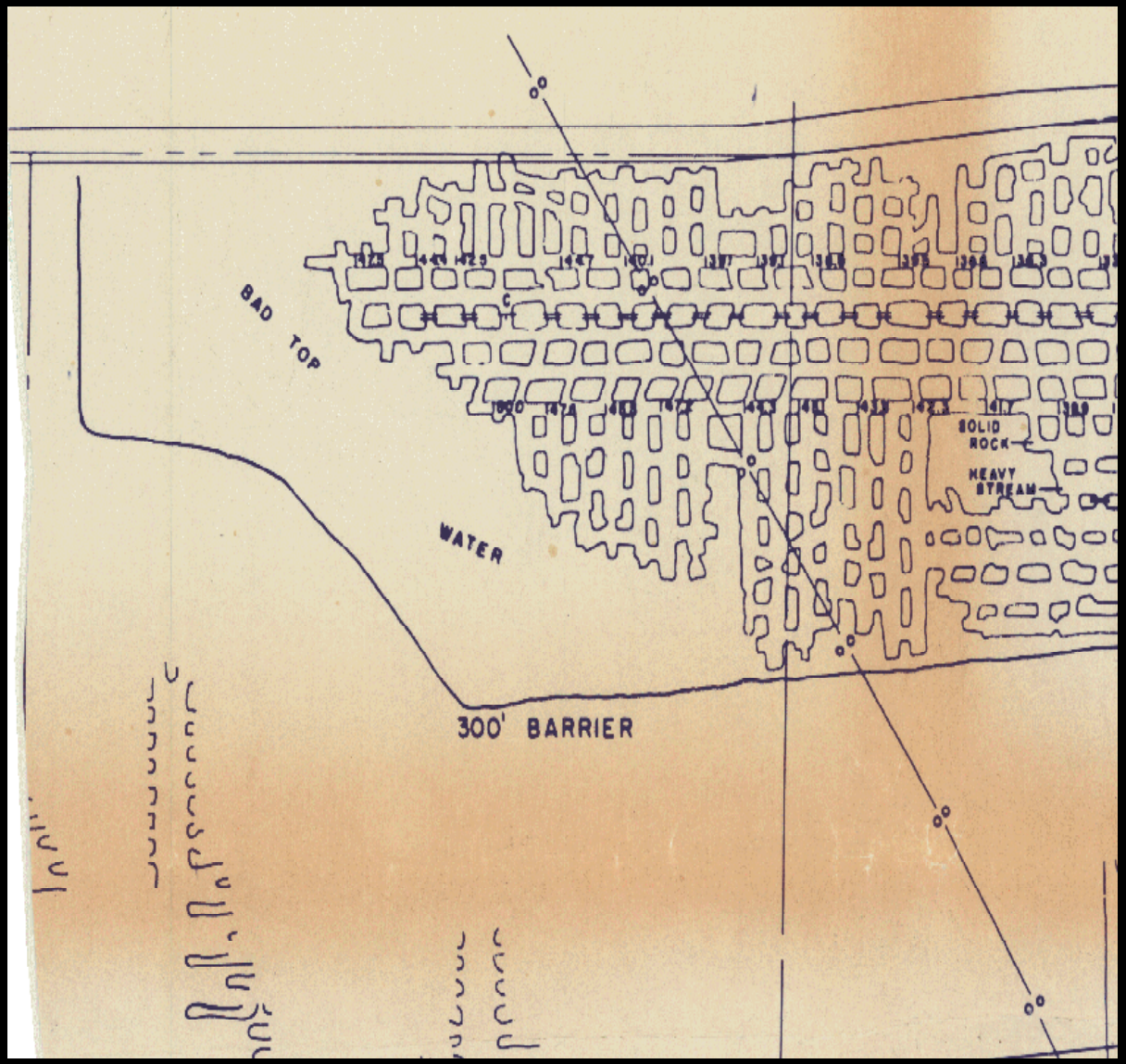
- Squeeze date?
- Complete floor/roof closure?
- Floor characteristics

Mine Gas Information



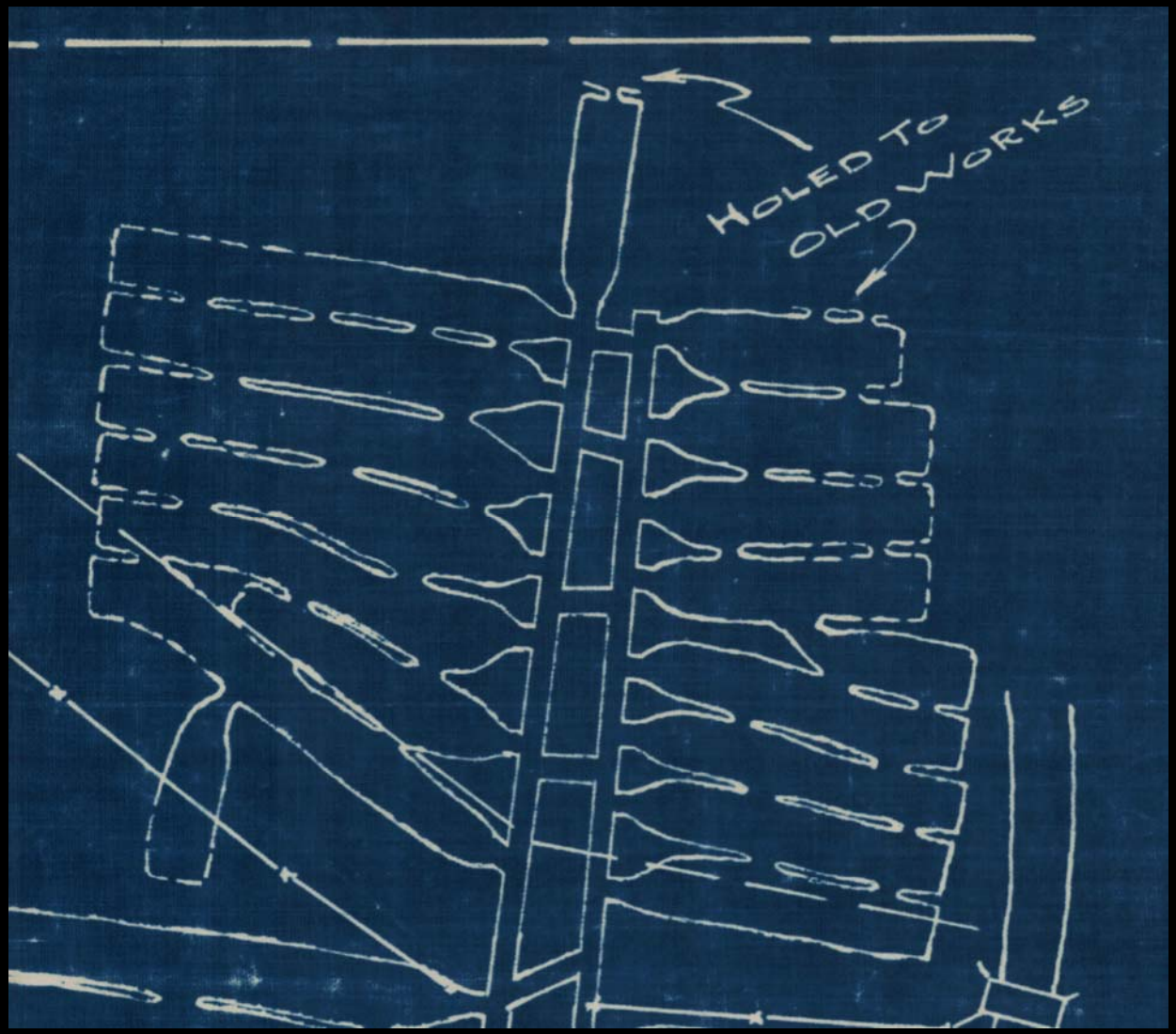
Questions

- Oil well and drill hole plugged?
- Intent of seals gas/ water ?



Questions

- Adjacent mine active? name ?
- Concerned about water in adjacent mine ?



Questions

- Accidental?
- Was hole sealed?
- Adjacent mine name

Kentucky's Mine Mapping Initiative

Processes and Procedures

Bryan W. Bunch, PLS, PG
Systems Consultant IT
Kentucky EPPC-OIS-GIS
500 Mero Street 14th FL CPT
502-564-5174
Bryan.Bunch@ky.gov

Kentucky
UNBRIDLED SPIRIT™

Kentucky Mine Mapping Status From Feb, 2004 through May, 2005

- 34,395 Total Documents Scanned
- 17,229 Mine Map Documents
- 16,051 Transmittal Documents
- 1,115 Stitch Partials
- 7,387 Geoprocessed and Deployed to Web

MAP / IMAGE FILE NAMING CONVENTIONS

APPLIES TO ALL MAPS
(UPPER CASE)

THESE TAGS MAY
APPEAR IN VARIOUS
COMBINATIONS, OR NOT AT ALL
(lower case)

12345-678_2005L_20050312_o1of2_s1of2_x1of2

STATE FILE NUMBER (SFN)

MAP YEAR

MAP DATE YYYYMMDD

SHEET TAG

STITCH PARTIAL TAG

MAP PURPOSE TAG
- F = FINAL MAP
- L = LICENSE MAP
- M = MAP YEAR (GENERIC)
- S = SUPPLEMENTAL MAP

SUPPLEMENTAL PURPOSE TAG
- o = OVERLAY
- u = UNDERLAY
- m = MISC. MAP

12345-678_2005L_20050312_t

SCANNED TRANSMITTAL DOCUMENT

KENTUCKY DEPARTMENT OF MINES AND MINERALS

MAP TRANSMITTAL LETTER

Underground Mine

License Year 2004

State File No. 18484

Map Covers Period Ending 12/9/2004

Company Name Double C Enterprises, Inc Mine No. 5

Former Company Name and Mine Hubble Mining Co. LLC Last Year Licensed 2004

Nearest Town McDowell County Floyd Map Scale 1"= 200'

Stream, branch or hollow Poplarlick of Frasure Crk Quad Name McDowell

Entry: Latitude 37° 24' 16.09190 Longitude 82° 41' 31.84377 ; see Mapping Standards document for details

Use coal seam (bed) names as found on the USGS Geologic Quadrangle and refer to the KDMM seam listing.

List coal seams being mined during this License Year:

	Average Thickness 36"	Appx. Elevation 1050'
	Average Thickness	Appx. Elevation
	Average Thickness	Appx. Elevation

CARRIER	MARTIN	05/20/04
DOUBLE "C" ENTERPRISES, INC.		0413
		NO. 5
LEONARD COLEMAN (+)		18484
P.O. BOX 249		MCDOWELL
STANVILLE, KY 41659		FLOYD
		UTC
11/21/03		15-18472

Abandonment Maps
MAP PURPOSE

18484_2004F_20041209_t

RECEIVED
APR 27 2005
DIV. OF MINE LICENSING

	YES	NO	NA
1. Are the KDMM standard data block, North Arrow, scale, and bar scale shown?	✓		
2. If using a grid is it labeled and the datum (NAD), linear units and projection indicated?	✓		
3. Is the general mining plan for the next five years indicated? (Use a different color for each year's projections.)	N/A		
4. Are pillared, worked-out and abandoned areas indicated, including major roof falls?			✓
5. Are all entries and air courses with air flow indicated by arrows shown?	N/A		
6. Are escapeways indicated?	N/A		
7. Are the required property and mineral lease lines with owners shown?	✓		
8. Are there mines above or below? If yes, information must be provided.	✓		
9. Are adjacent works and inaccessible areas shown?	✓		
10. Are surface mines, auger holes, highwall miner entries and all underground mines indicated?		NO	
11. Are water pools above? If yes, information must be provided.		✓	
12. Are oil and gas wells (producing or abandoned) indicated including owners and well numbers?	✓		
13. Is the 25 foot barrier indicated as required by KRS 352.490?	✓		
14. Are all mine fans indicated? Information must be provided.	N/A		
15. Is the watershed near the mine opening shown and named?	✓		
16. Are detailed worked-out areas within 1000 feet of future mining indicated along with precautions?			✓
17. Are all known drill holes (core holes, etc.) that penetrate the coal bed shown?	✓		
18. Is the location and description of at least two permanent base line points coordinated with the underground and surface traverses indicated? See Map Standard's document for details.	✓		
19. Is the location and description of at least two permanent elevation bench marks used in the mine elevation surveys indicated?	✓		
20. Are the elevations of tops and bottoms of shafts and slopes and the floor at the entrance to drift and tunnel openings indicated?	✓		
21. Are contour lines passing through whole number elevations of the coal bed being mined, not exceeding 10 foot intervals indicated?	✓		

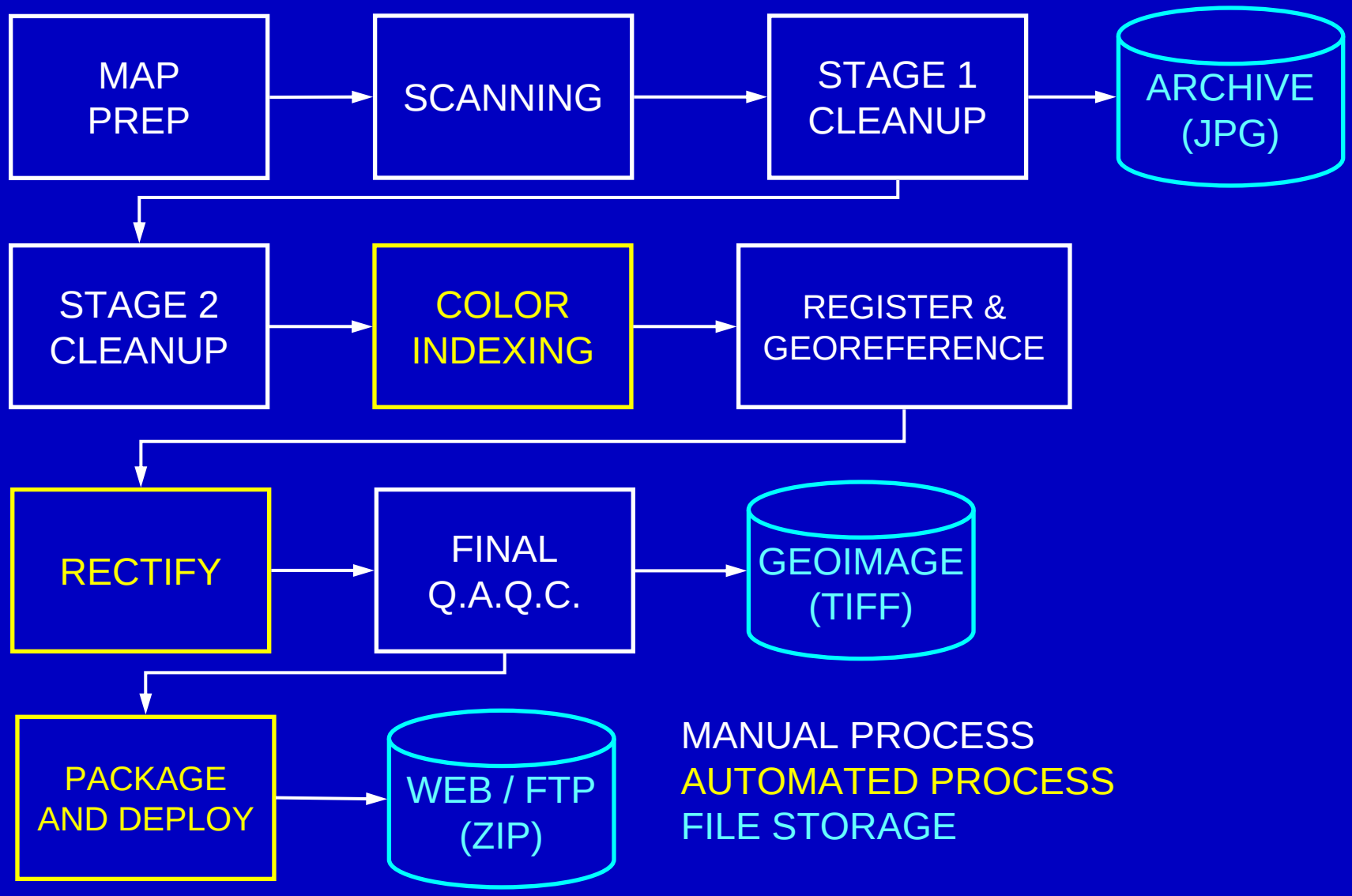
Michael Davis 4-11-05
Engineer Signature Date
Engineer Name (printed) MICHAEL DAVIS
Registration number 14203

Keith C Conley 4-20-05
Inspector Date
Randal Smith 4/21/05
District Supervisor Date

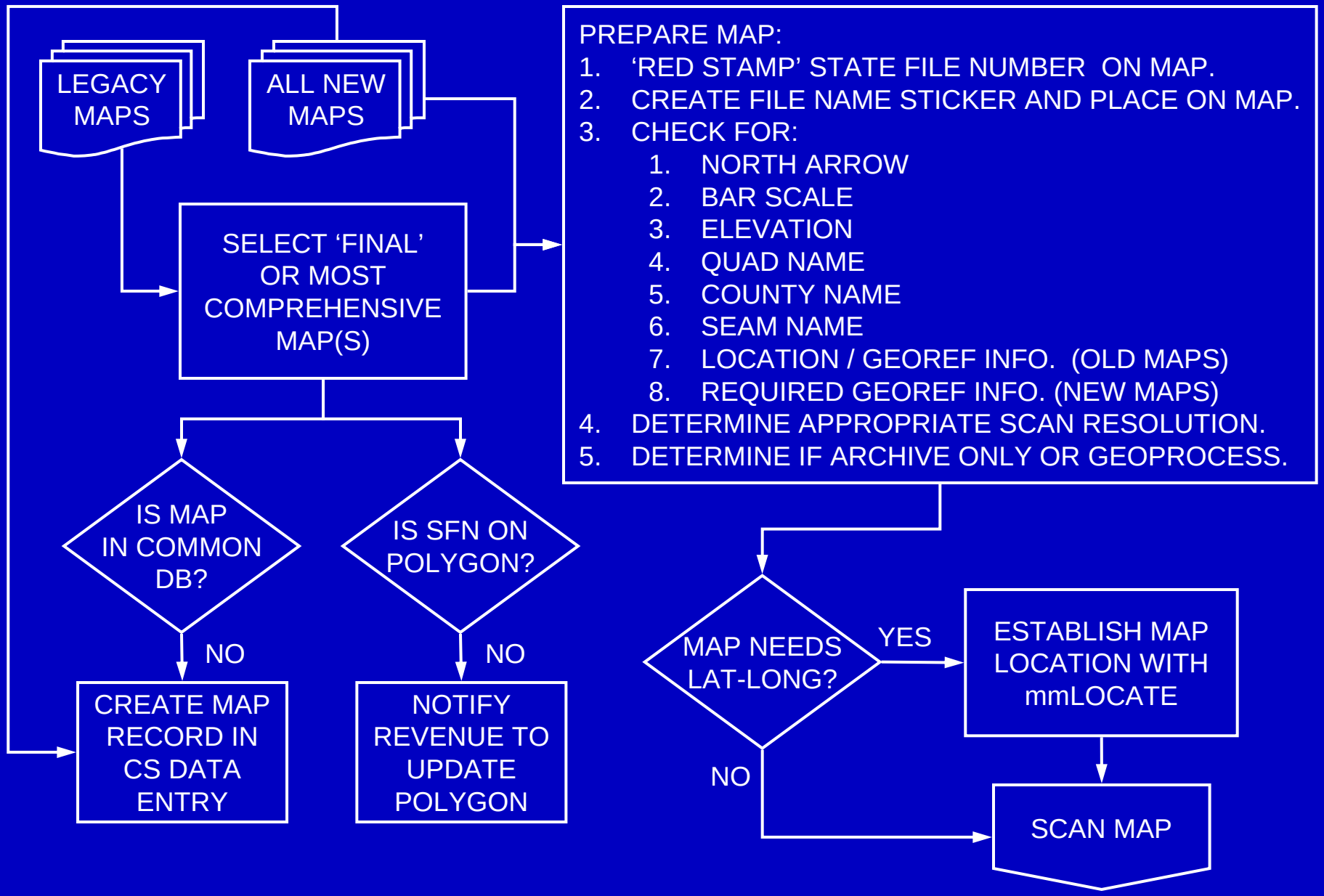
EB - 2 (11-2004) White - map, Canary - file, Pink - District, Goldenrod - Engineer

Map Transmittal Document

MINE MAPPING PROCESS



MAP PREPARATION



SCANNING

200 - 300 DPI
24 Bit Color
JPEG 90
FULL WIDTH (42”)
AUTO HEIGHT

RAW SCAN FILE

IS MAP NAME VALID?

NO

LEAVE ON SCANNER AND PLACE “INVALID MAP NAME” ENTRY IN LOG FILE.

YES

FORMAT IMAGE NAME

DUPLICATES DETECTED?

YES

MOVE TO DUPLICATES FOLDER AND PLACE “DUPLICATE MAP” ENTRY IN LOG FILE.

NO

1. COPY TO:
   ARCHIVE FOLDER
   BACKUP FOLDER
   STAGE-1 CLEANUP FOLDER
2. CREATE METADATA.
3. REMOVE IMAGE FROM SCANNER.

ARCHIVE

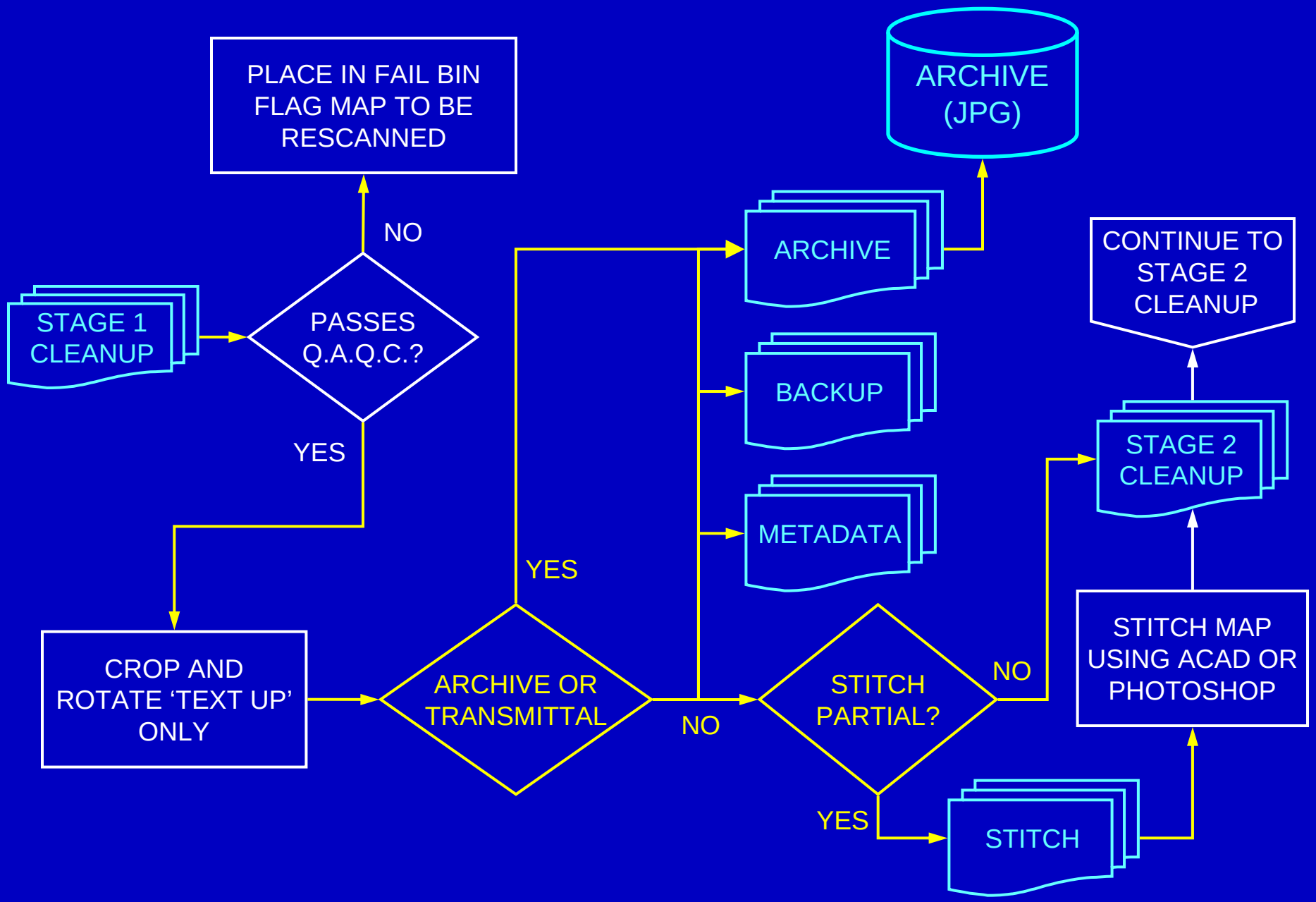
BACKUP

STAGE 1 CLEANUP

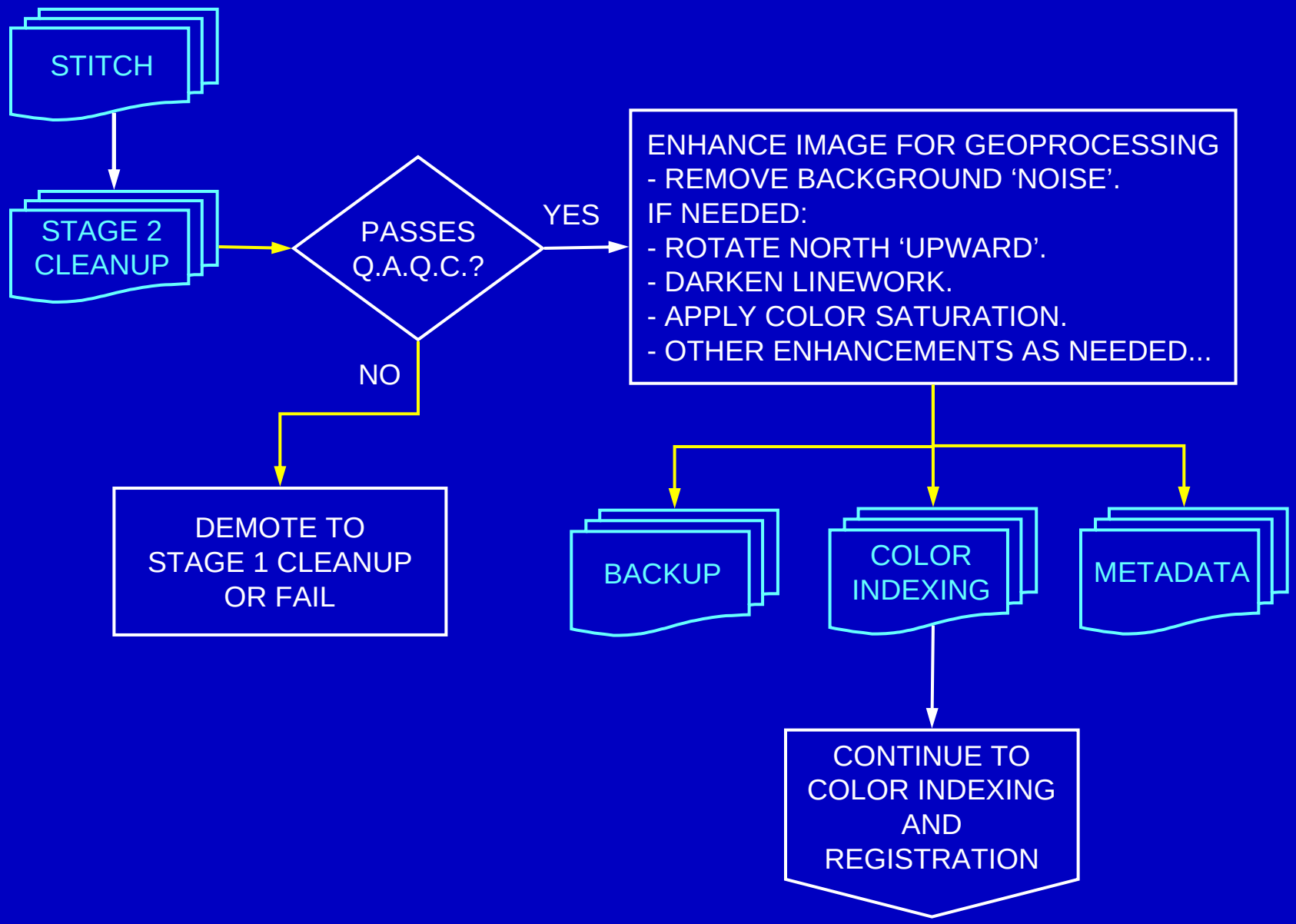
CONTINUE TO STAGE 1 CLEANUP

METADATA

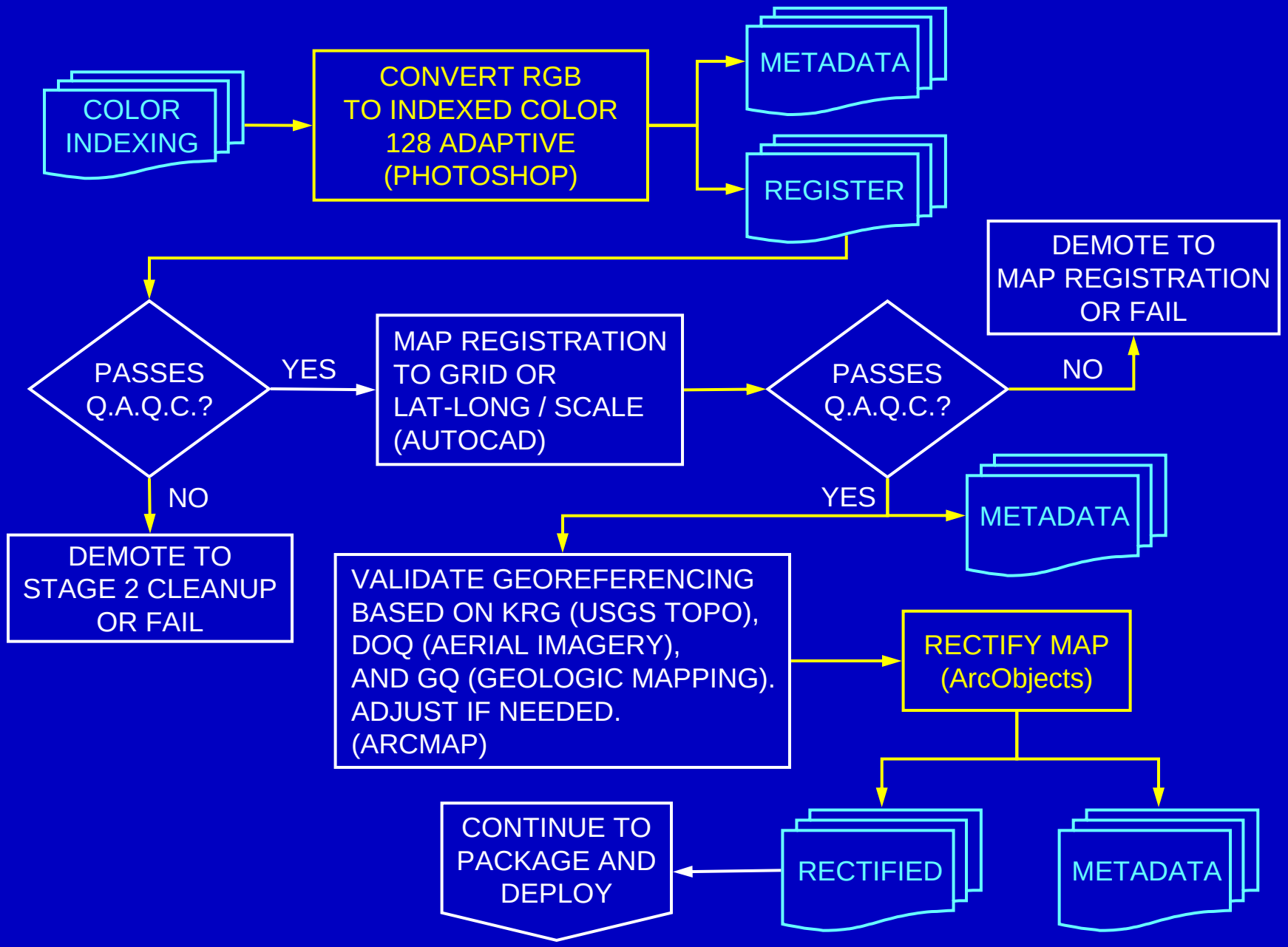
STAGE 1 CLEANUP



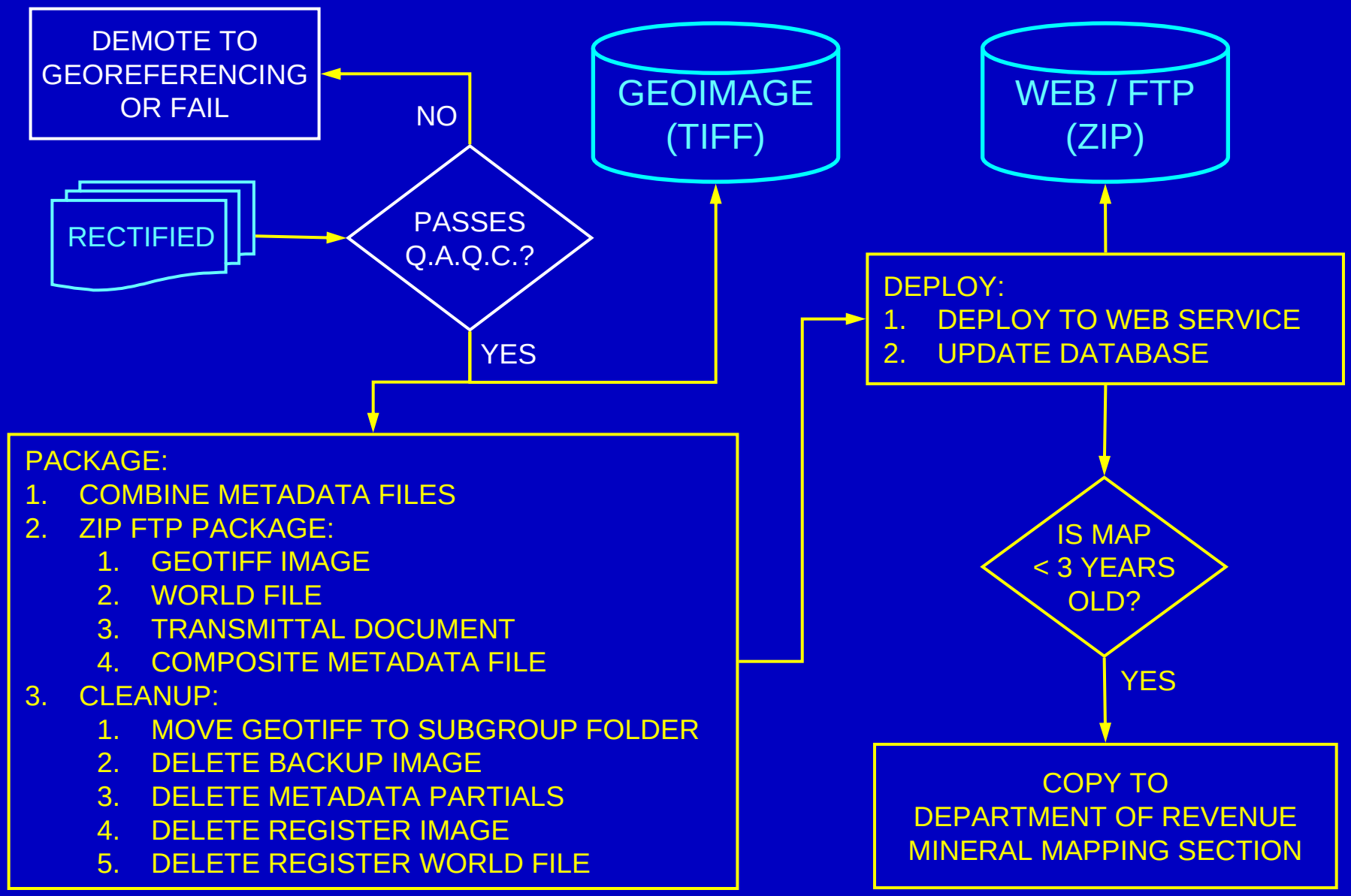
STAGE 2 CLEANUP

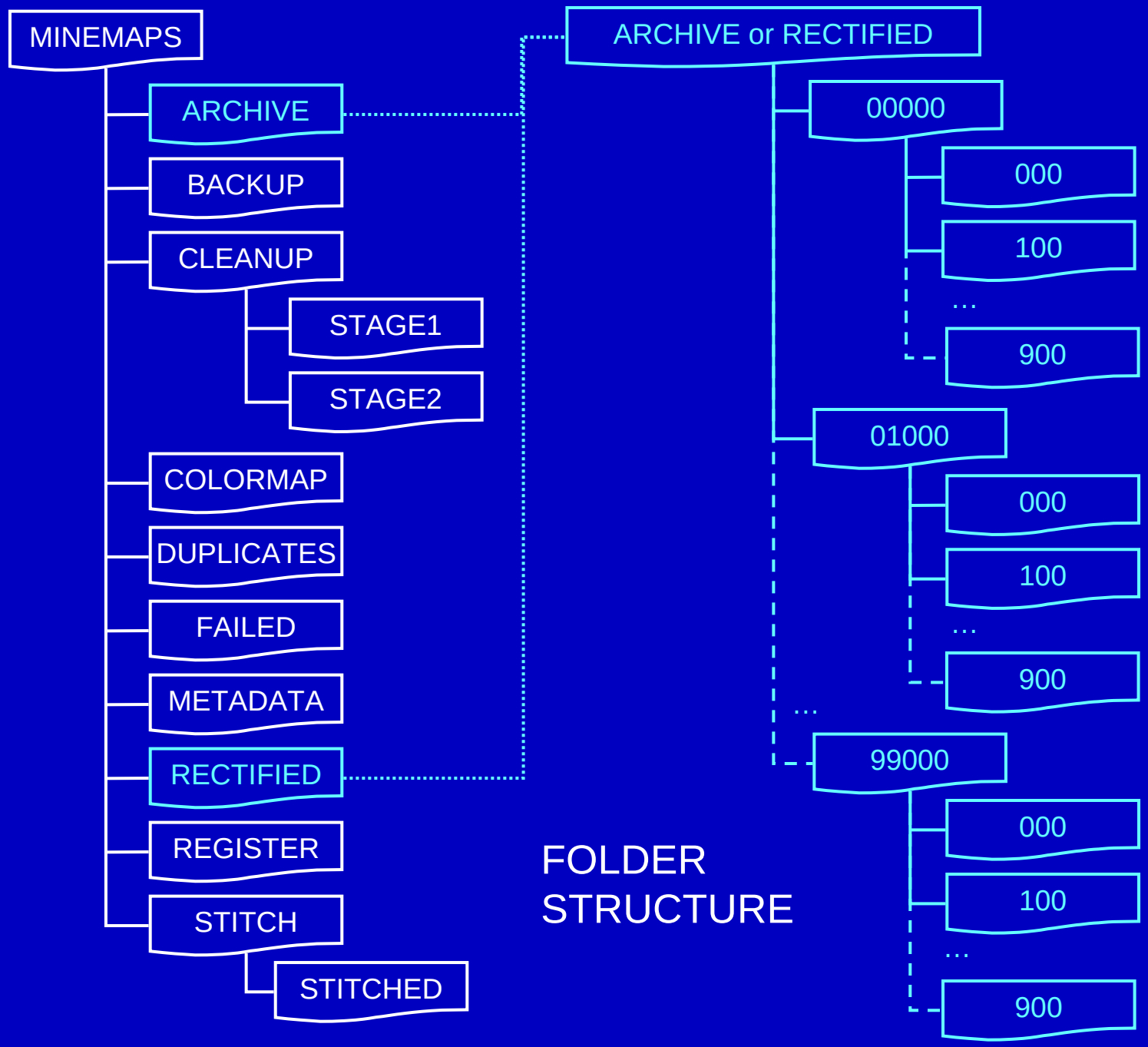


COLOR INDEXING, REGISTRATION, AND RECTIFICATION



PACKAGE AND DEPLOY





FOLDER STRUCTURE

Process Automation / ActiveX

- ADODB
- ArcGIS / ArcObjects (VBA)
- AutoCAD Object Model (VBA)
- Photoshop Type Library / Photoshop SDK

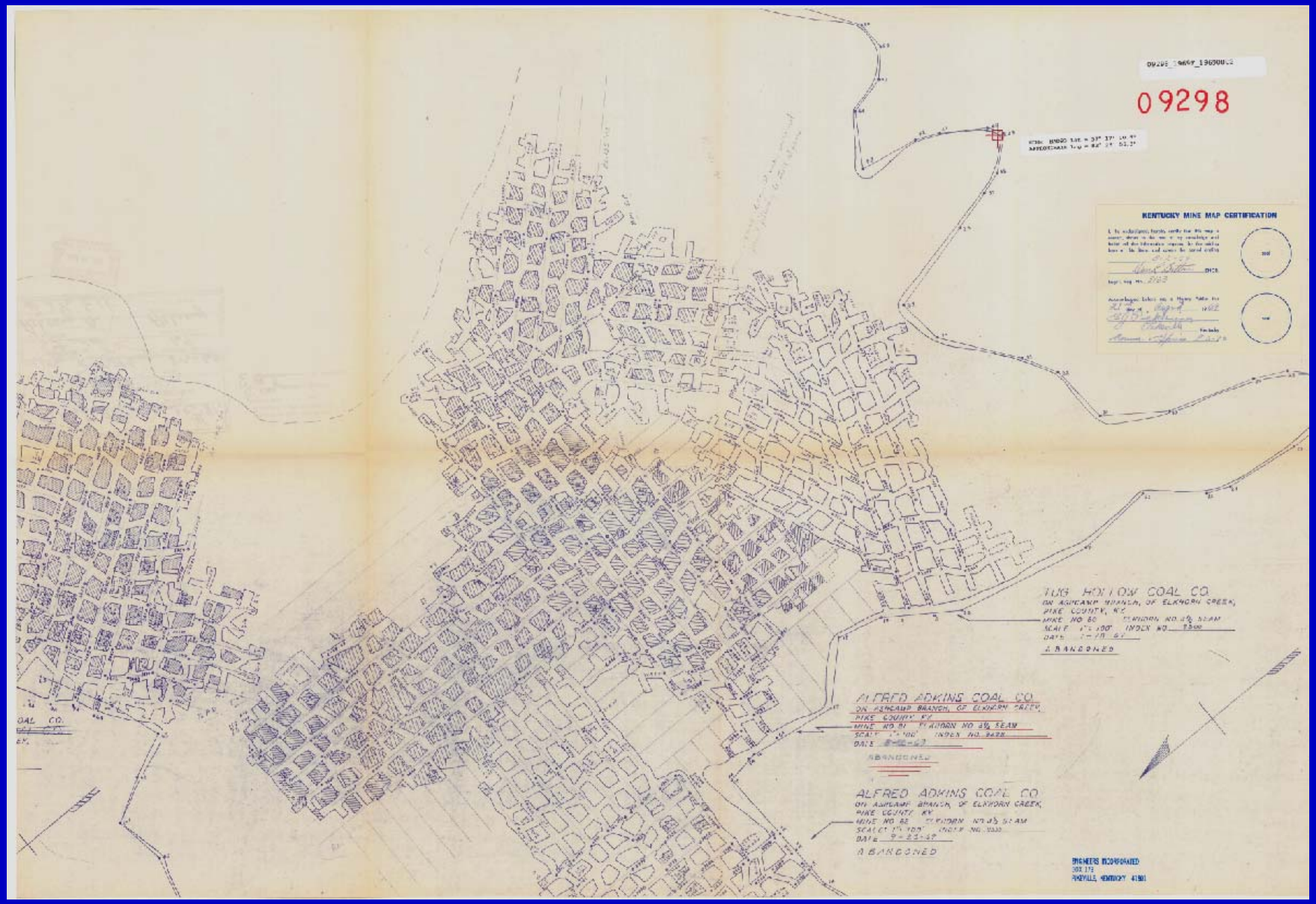
Supporting Cast: Datasets

- KYRASTER (contiguous statewide – ESRI SDE Raster)
  - Kentucky Raster Graphic (KRG) 7.5 Min. Topo
  - Kentucky Digital Ortho Quads (DOQ) 1:12,000 Aerial
  - Kentucky Geologic Quads (GQ) 7.5 min Geology
- KYVECTOR (contiguous statewide ESRI SDE Vector)
  - Kentucky County Boundaries
  - Kentucky 7.5 Minute Quadrangle Boundaries
  - Kentucky Oil and Gas Wells
- KYGNIS – Geographic Name Information System (GDB)
- MMIS5 – Kentucky Mine License Database (MDB)
- Dept. of Revenue: Mined Out Polygons (ESRI SHP)

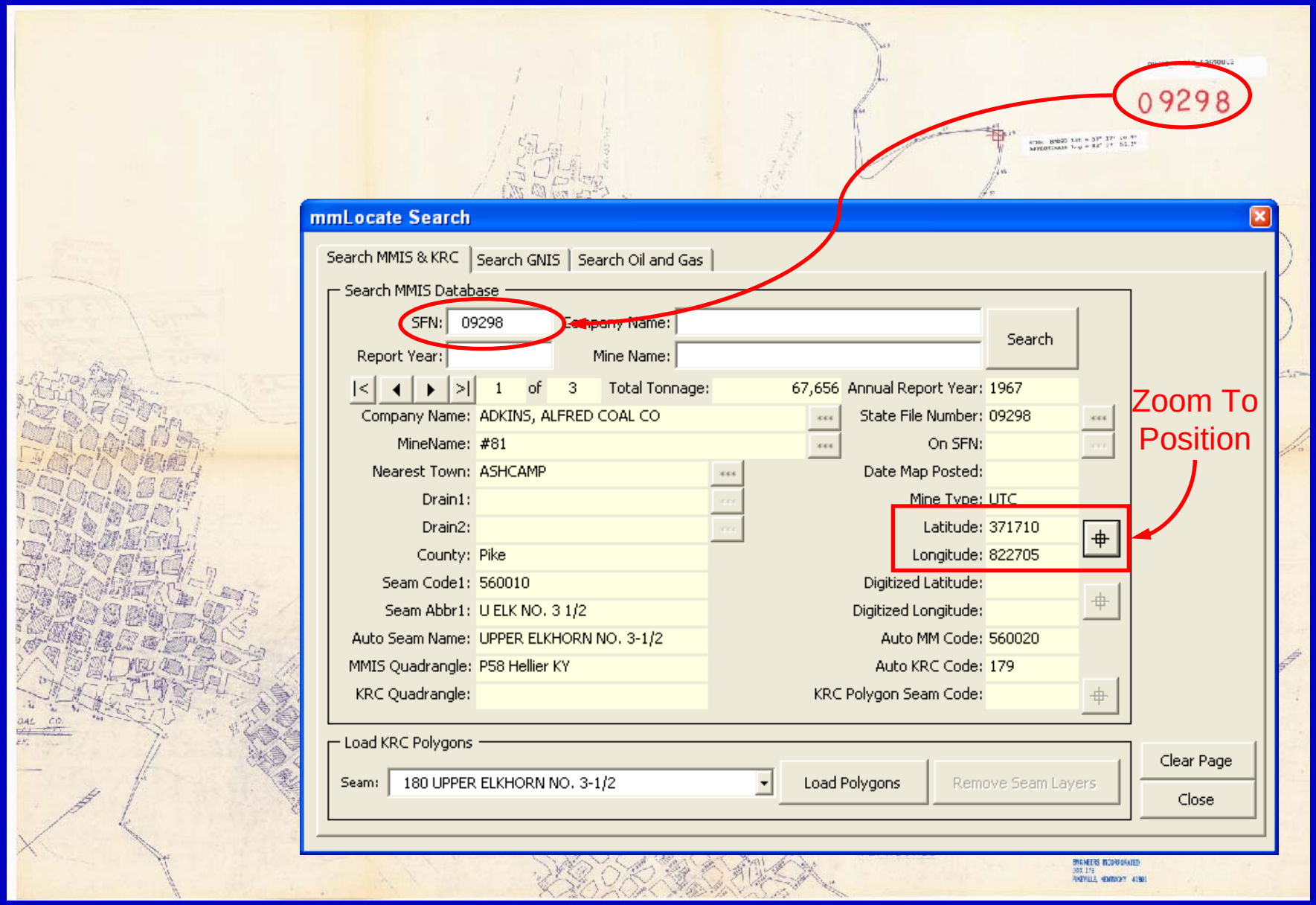
Process Automation

- File migration and management.
- Locational and geographic search (mmLocate).
- Stage 1 and 2 Cleanup (Semi-Automated).
- Color Indexing (color mapping).
- Map Registration (Semi-Automated).
- Map Georeferencing (Semi-Automated).
- Map Rectification.
- Georeferencing Q.A.Q.C. (Semi-Automated).
- Package and Deploy to MMWEB and Revenue.

Map Preparation – mmLocate (ArcMap/ArcView)



mmLocate: Search by SFN



mmLocate.mxd - ArcMap - ArcInfo

File Edit View Insert Selection Tools Window Help

1:8,931 Layer: Oil & Gas

Georeferencing Layer:

mmLocate
- Oil & Gas
- BaseMap
- DOQ
- GQ
- KRG

mmLocate Search

Search MMIS & KRC | Search GNIS | Search Oil and Gas

Search MMIS Database

SFN: 09298 Company Name: Search

Report Year: Mine Name:

1 of 3 Total Tonnage: 67,656 Annual Report Year: 1967

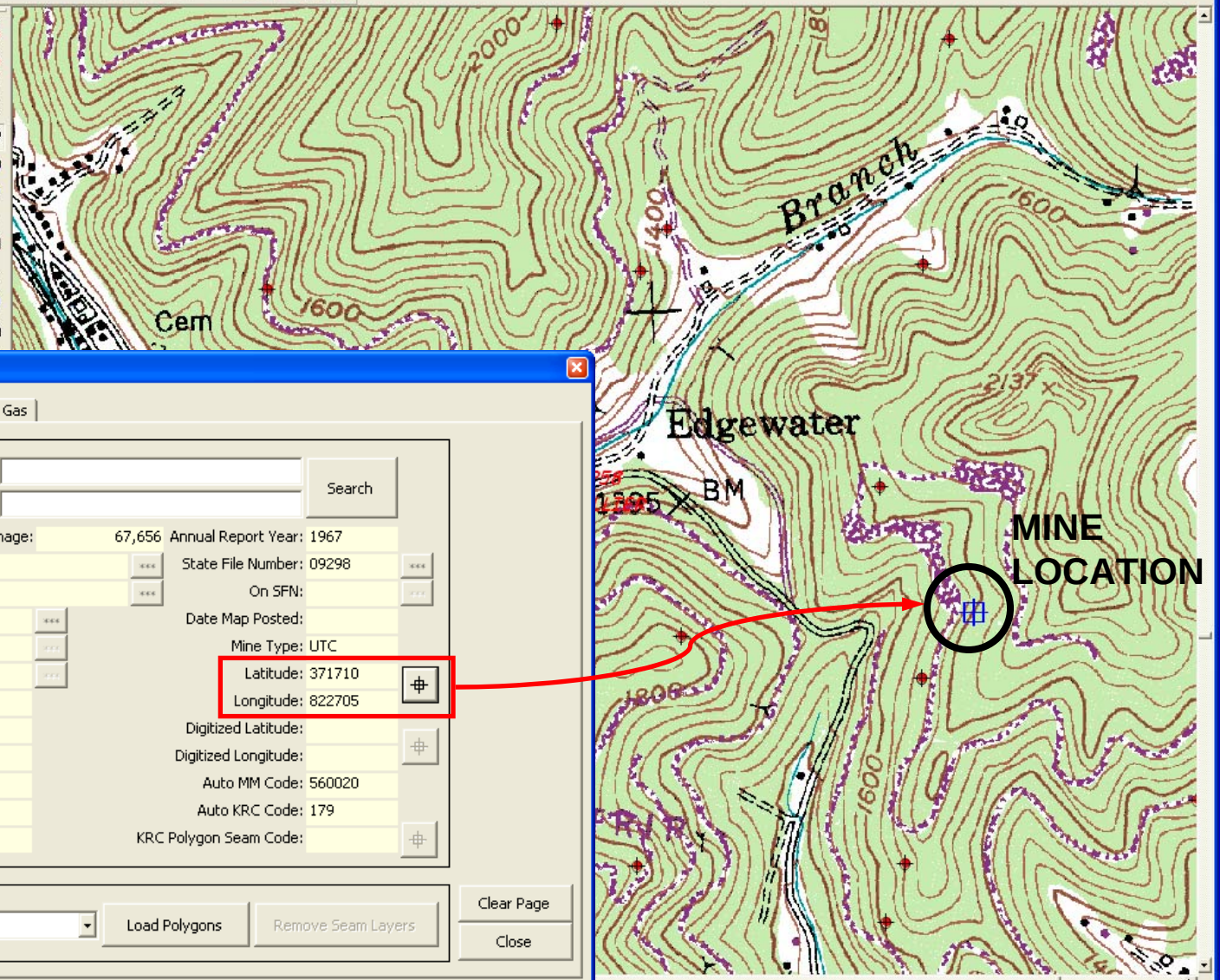
Company Name:	ADKINS, ALFRED COAL CO	State File Number:	09298
MineName:	#81	On SFN:	
Nearest Town:	ASHCAMP	Date Map Posted:	
Drain1:		Mine Type:	UTC
Drain2:		Latitude:	371710
County:	Pike	Longitude:	822705
Seam Code1:	560010	Digitized Latitude:	
Seam Abbr1:	U ELK NO. 3 1/2	Digitized Longitude:	
Auto Seam Name:	UPPER ELKHORN NO. 3-1/2	Auto MM Code:	560020
MMIS Quadrangle:	P58 Hellier KY	Auto KRC Code:	179
KRC Quadrangle:		KRC Polygon Seam Code:	

Load KRC Polygons

Seam: 180 UPPER ELKHORN NO. 3-1/2 Load Polygons Remove Seam Layers

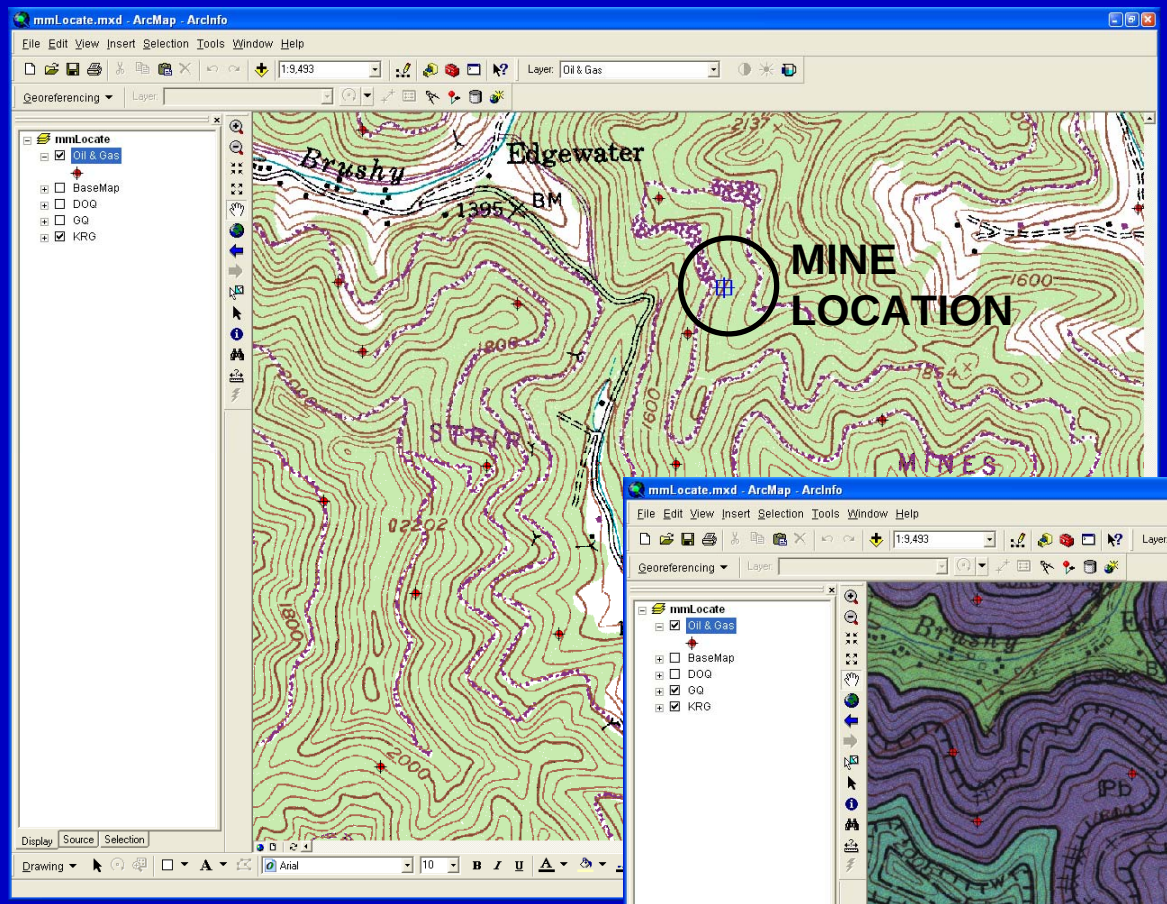
Clear Page

Close

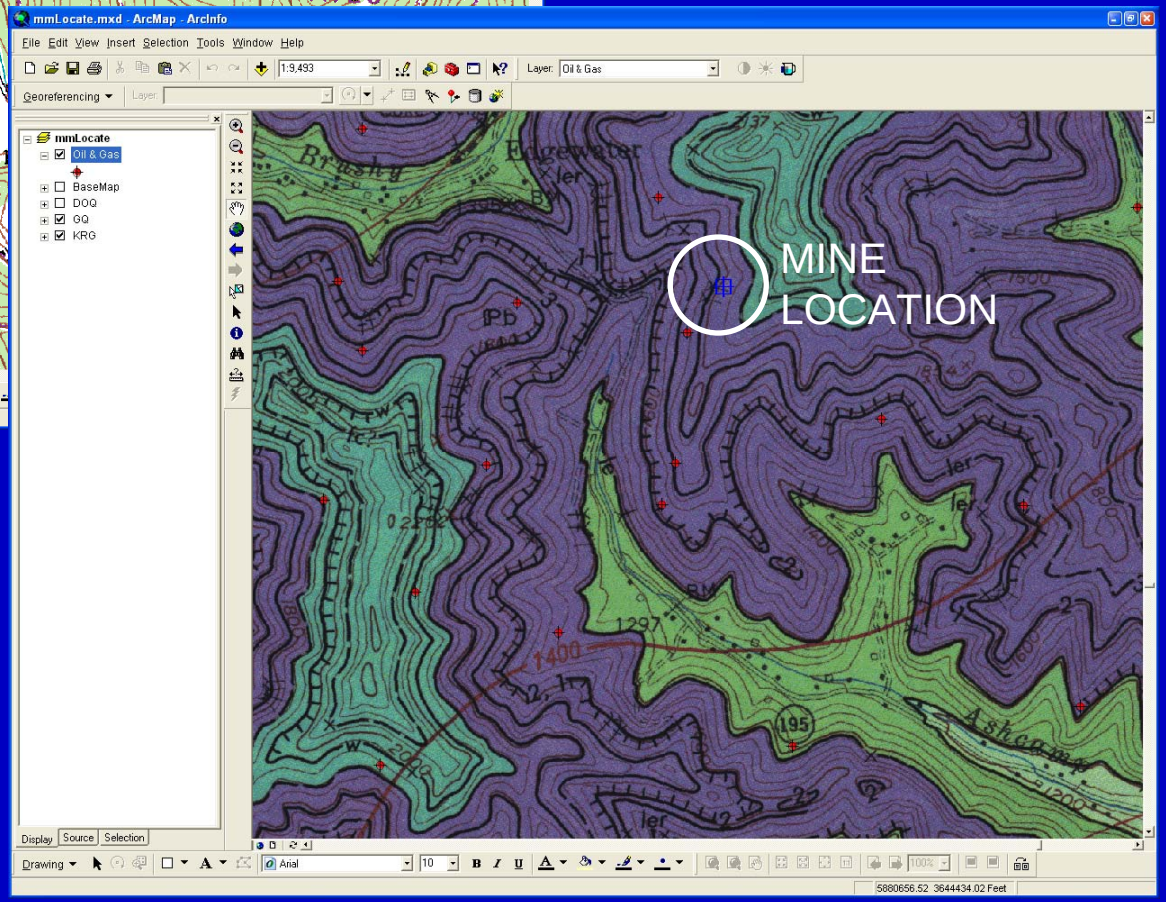


Drawing Arial 10

5879742.12 3644698.59 Feet

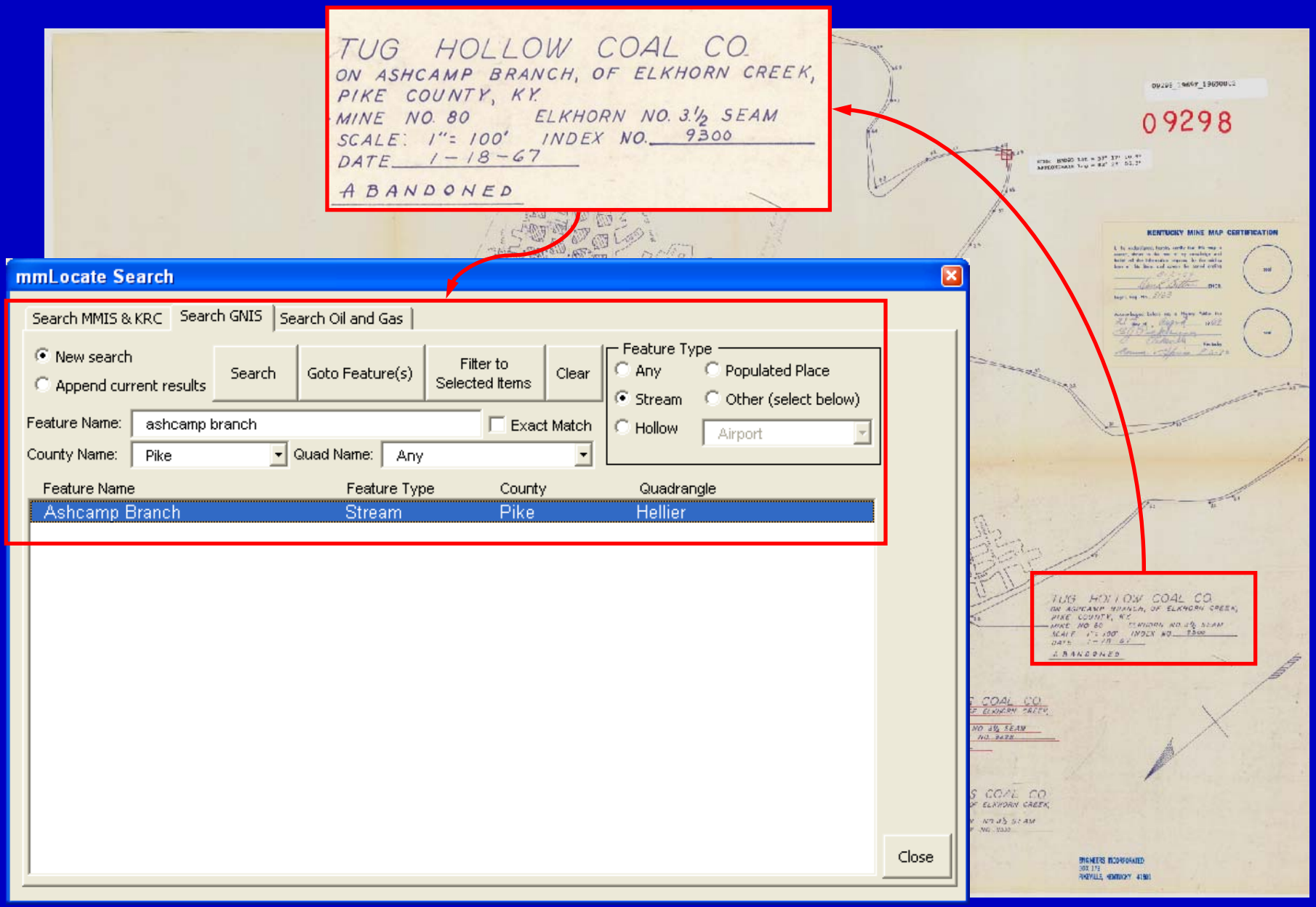


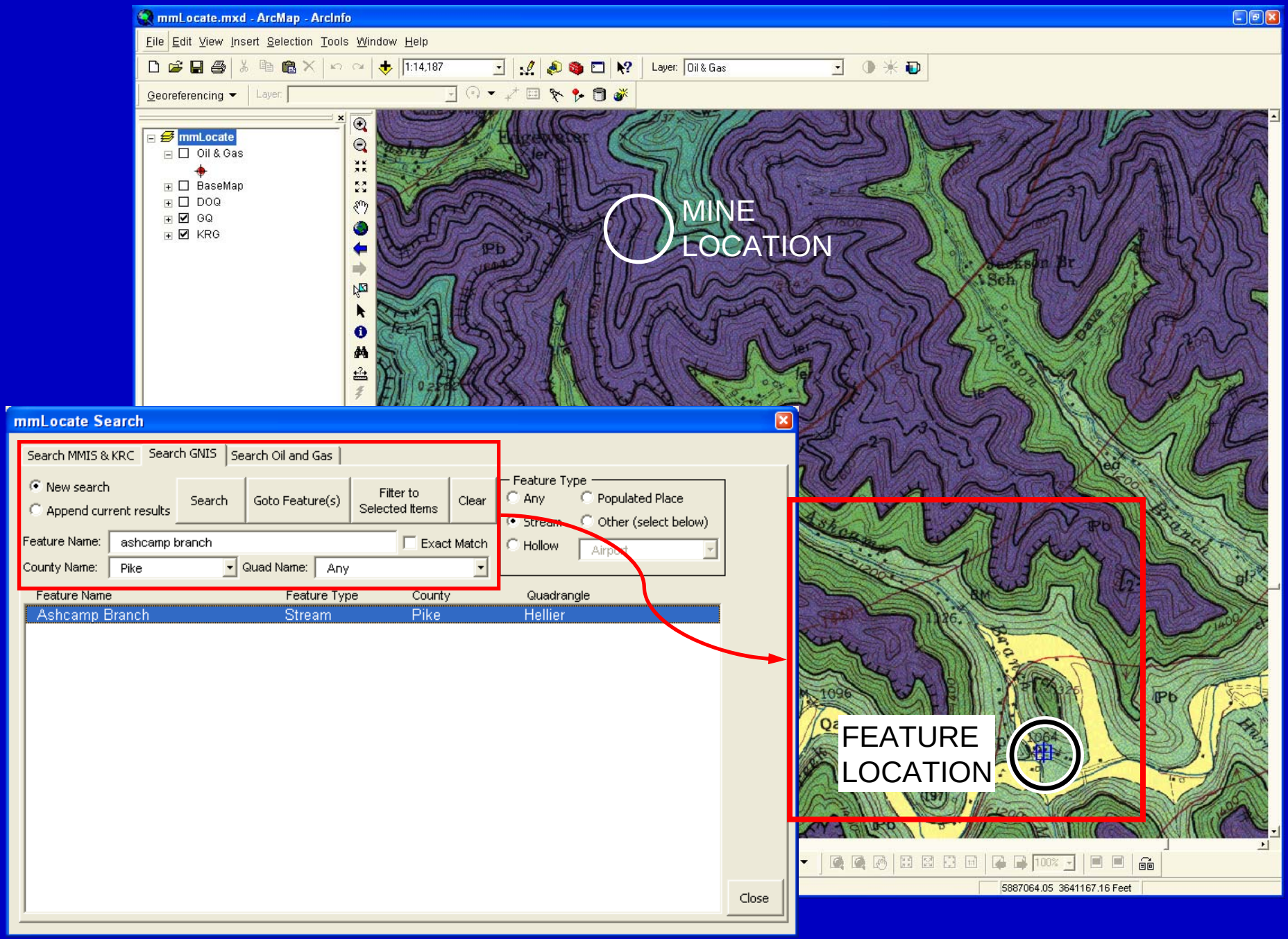
KRG Dataset

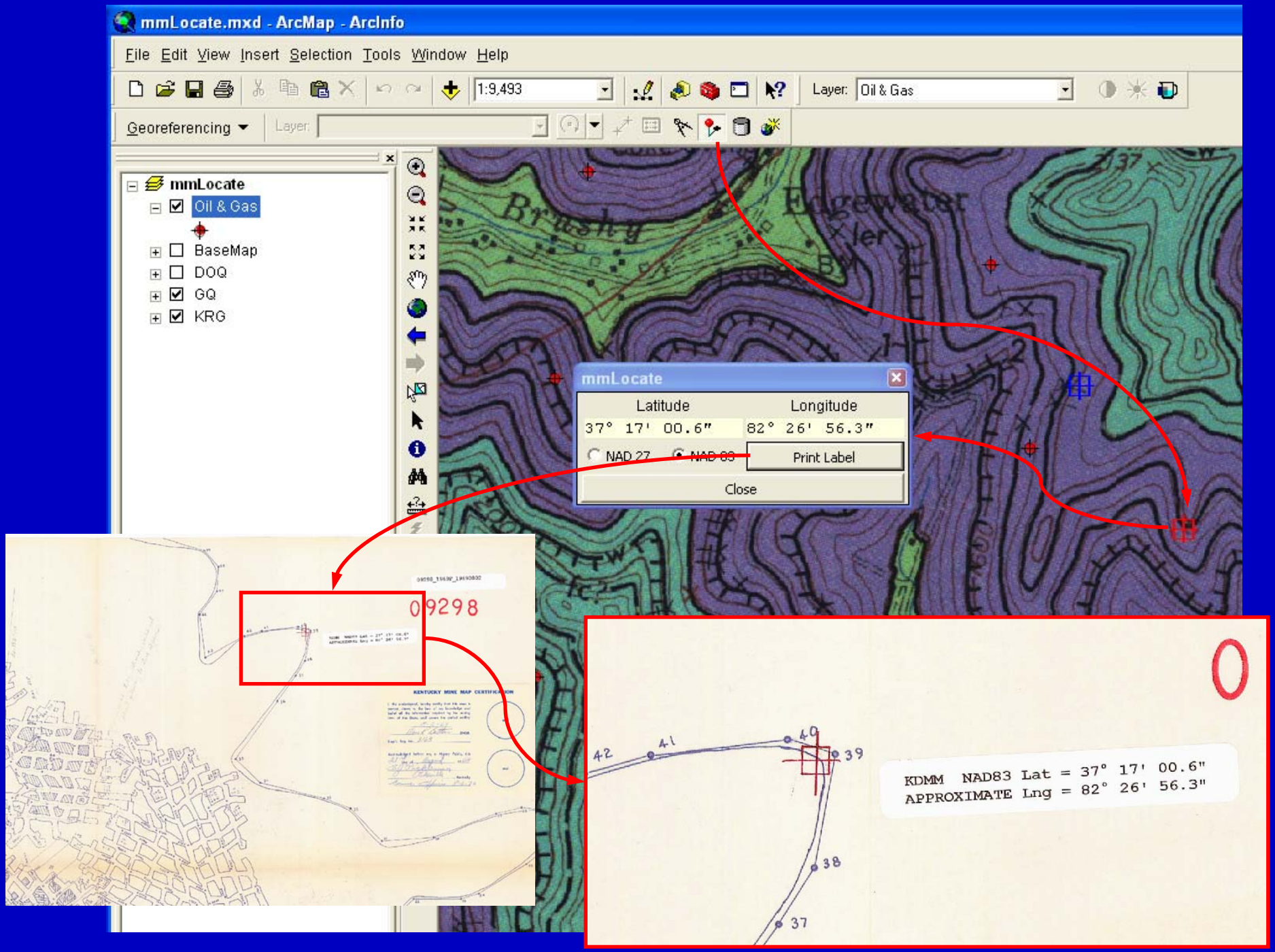


GQ Dataset

mmLocate: Search by GNS




mmLocate.mxd - ArcMap - ArcInfo
File Edit View Insert Selection Tools Window Help
1:14,187
Layer: Oil & Gas
Georeferencing
Layer:
mmLocate
Oil & Gas
BaseMap
DOQ
GQ
KRG
MINE LOCATION
mmLocate Search
Search MMIS & KRC
Search GNIS
Search Oil and Gas
New search
Append current results
Search
Goto Feature(s)
Filter to Selected Items
Clear
Feature Type
Any
Populated Place
Stream
Other (select below)
Hollow
Airport
Feature Name: ashcamp branch
Exact Match
County Name: Pike
Quad Name: Any
Feature Name
Feature Type
County
Quadrangle
Ashcamp Branch
Stream
Pike
Hellier
Close
FEATURE LOCATION
5887064.05 3641167.16 Feet


mmLocate.mxd - ArcMap - ArcInfo
File Edit View Insert Selection Tools Window Help
1:9,493
Layer: Oil & Gas
Georeferencing
Layer:
mmLocate
Oil & Gas
BaseMap
DOQ
GQ
KRG
mmLocate
Latitude
Longitude
37° 17' 00.6"
82° 26' 56.3"
NAD 27
NAD 83
Print Label
Close
09298
KENTUCKY MINE MAP CERTIFICATION
42
41
40
39
38
37
KDMM NAD83 Lat = 37° 17' 00.6"
APPROXIMATE Lng = 82° 26' 56.3"

Standardized Map Info Block (Required for All New Maps)

18525_2005L_20041231

Kentucky Department of Mines and Minerals
Mine License Map

State File No: 18525 Map Scale: 1"=200' Sheet No. 1 of 1
Federal ID No.: 15-18606 Map Covers Period Ending: 12/31/04
Mine Entry Location.: Latitude: 36°35'34.323" Longitude: 84°10'10.012"
Entry Point Quadrangle: JELLICO WEST
Nearest Named Stream: INDIAN CREEK

KDMM Seam Name	Average Thickness	Average Elevation
BLUE GEM	25"	1200'

DSMRE Permit No(s).
981-5174

18525

CARRIER BARBOURVILLE 2-14-05
GOODIN CREEK MINING CO., INC. 026
2
TIM WEBB 18525
P O BOX 103 PROCTOR HOLLOW
NEVISDALE, KY 40754 WHITLEY
UTC
1-27-03 15-18606

This map is georeferenced to NAD 83 Kentucky South State Plane Coordinates @ an accurcy standard of GPS-FGCS Class C, Order 3 or better.

KDMM Map Name Label

Map Geometry and Location:
- Map Scale
- Mine Entry Lat & Long
- USGS Quadrangle
- Nearest Named Stream

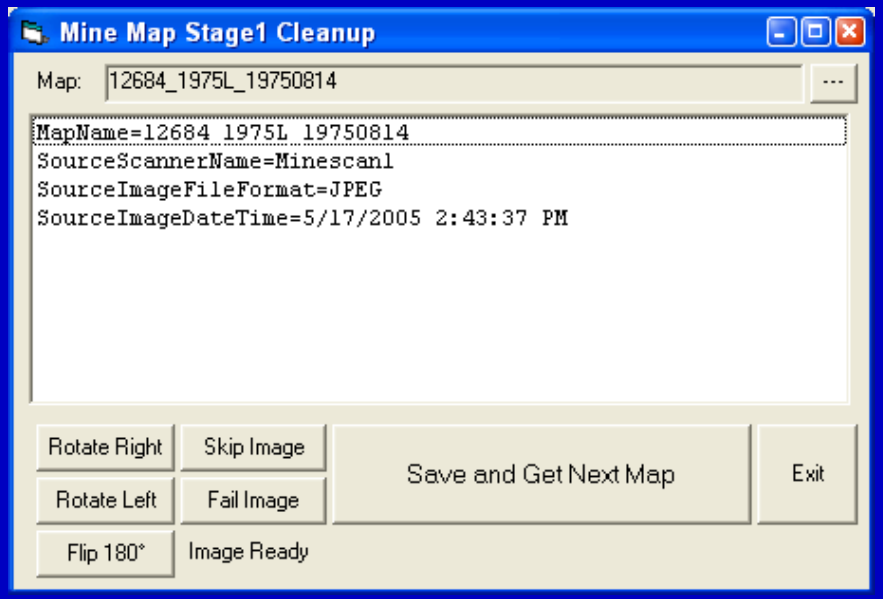
Coal Seam Information

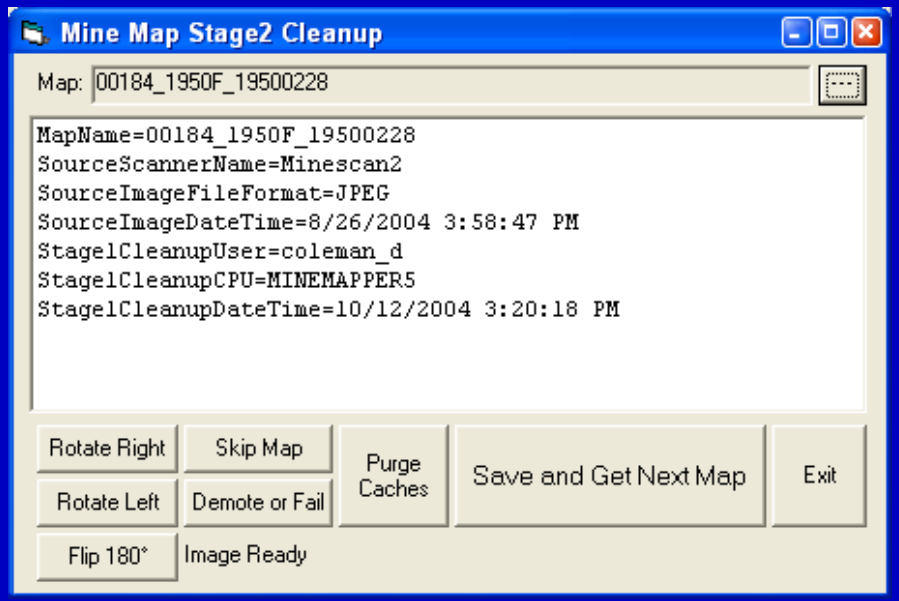
KDMM State File Number Stamp

KDMM Field Office Label

Survey Control and Georeferencing Information

Stage 1 and 2 Cleanup Application Control Panels





<u>Stage 1 Cleanup:</u>

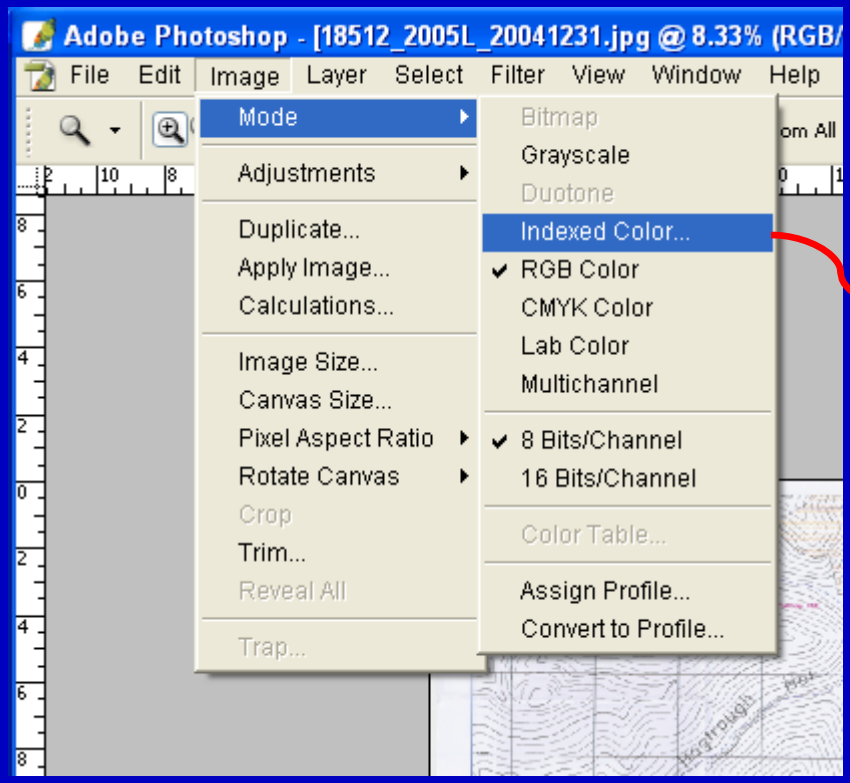
1. Q.A.Q.C. for visual quality.
2. Crop and rotate.
3. Orient map to read upward.

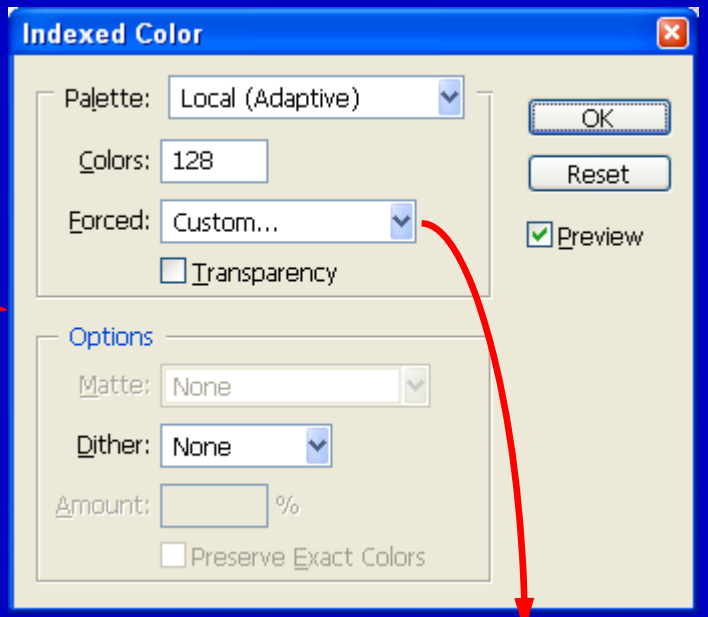
<u>Stage 2 Cleanup:</u>

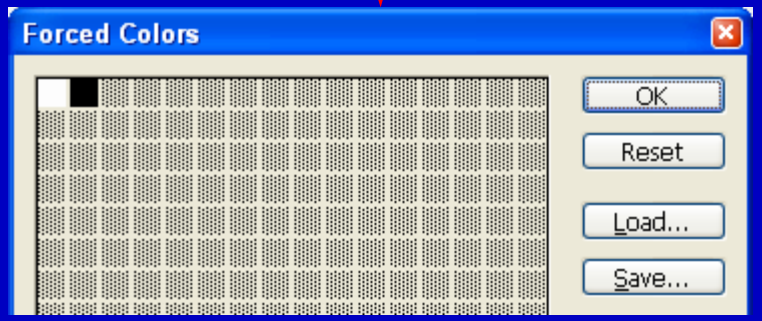
1. Q.A.Q.C. for visual quality.
2. Remove background noise.
3. Image enhancements.
4. Orient north ‘upward’.

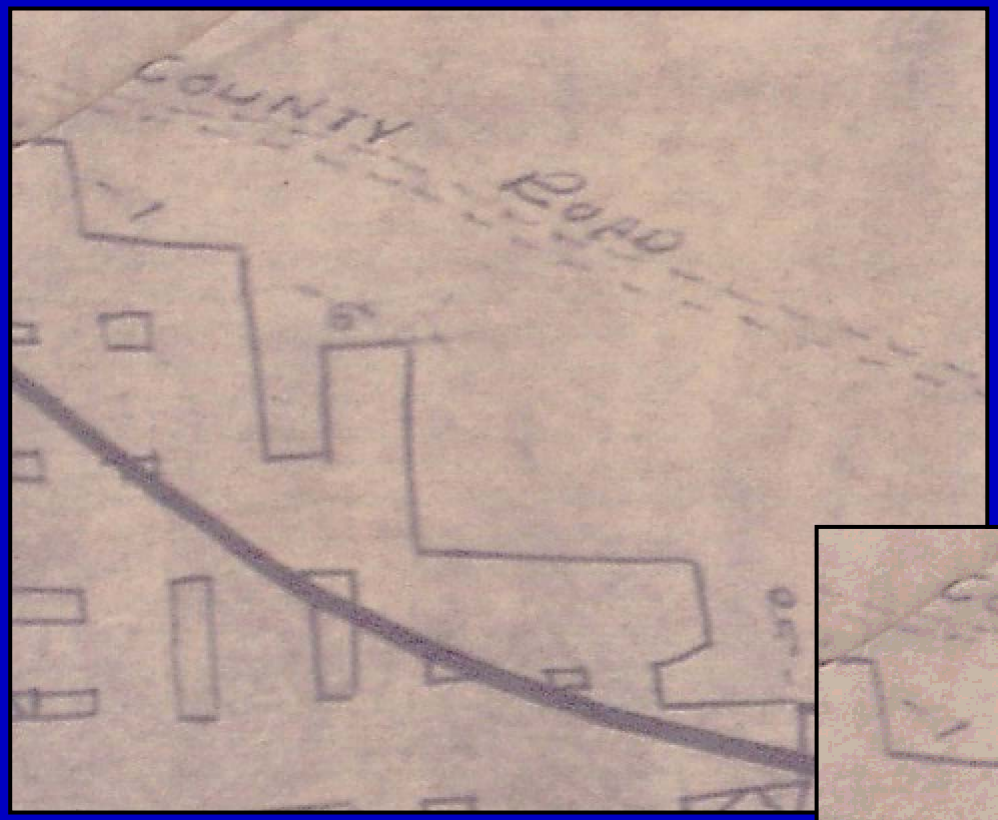
Color Indexing (Photoshop)

- Convert RGB Mode to Indexed Color
- Reduce to Best-Fit (Local Adaptive) 128 Colors
- Force White = 0 and Black = 1 (Monobit Scheme)

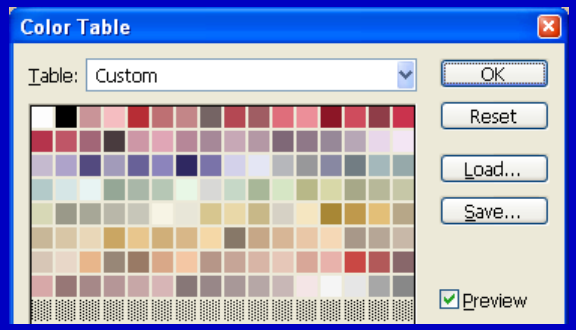


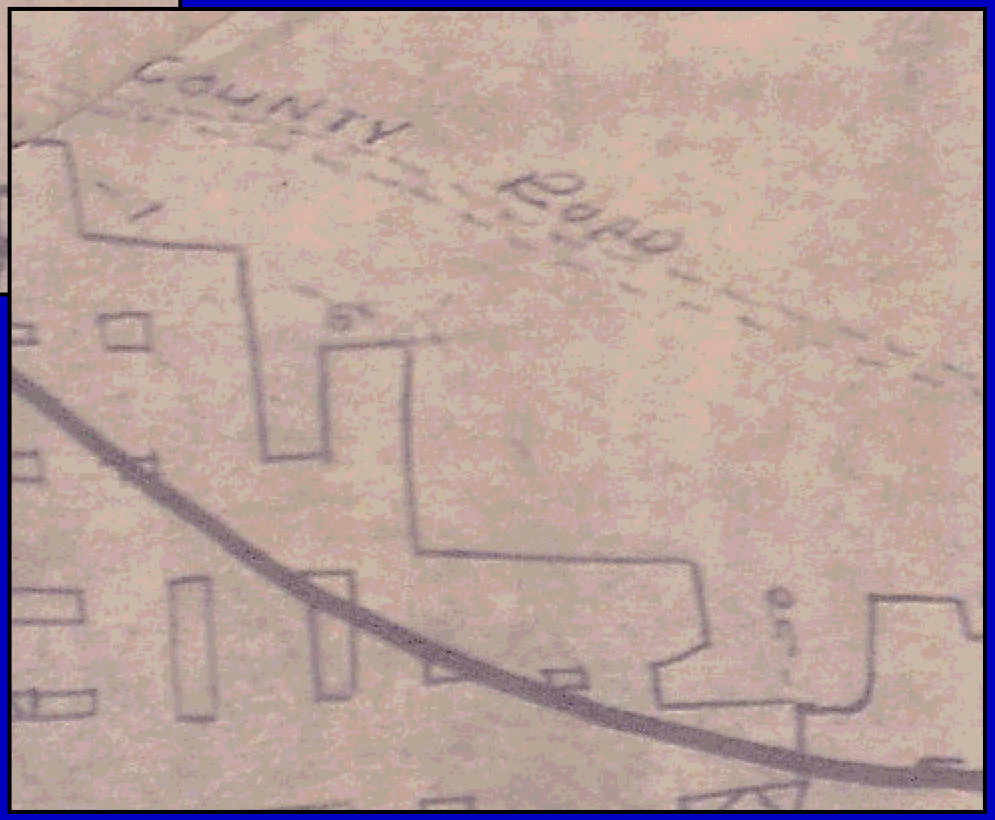




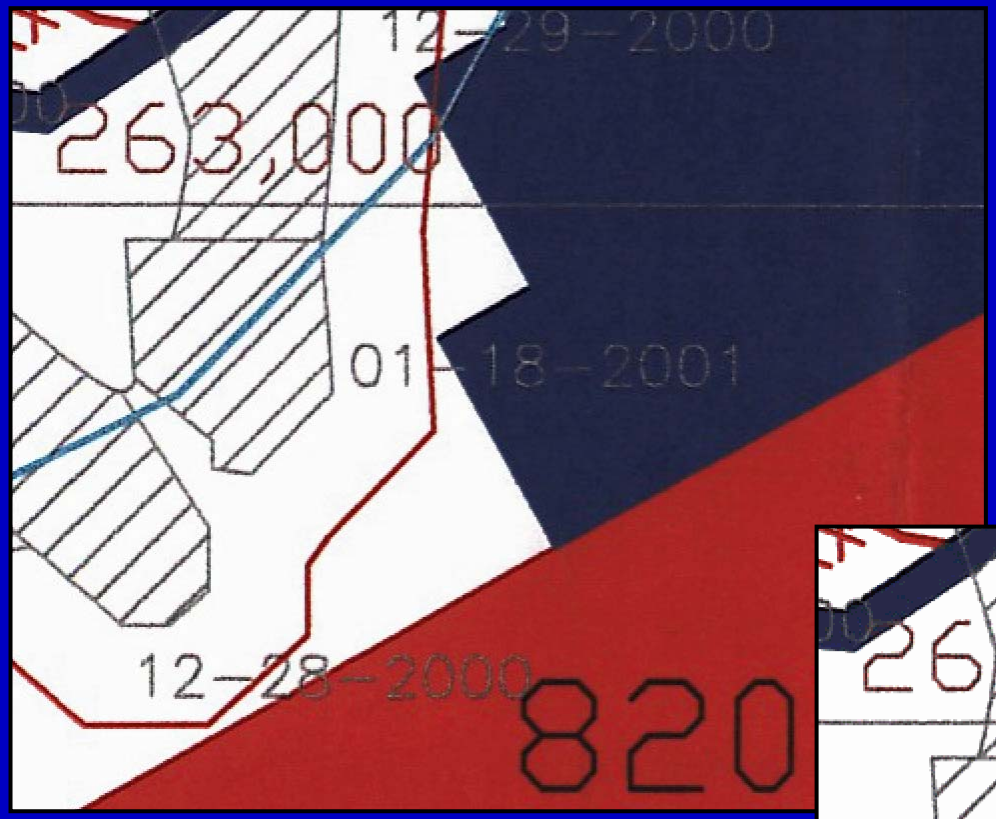


RGB Color Mode

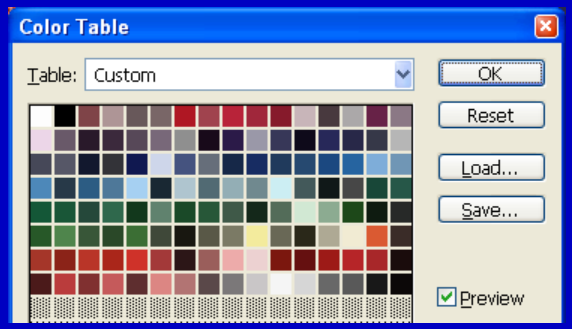




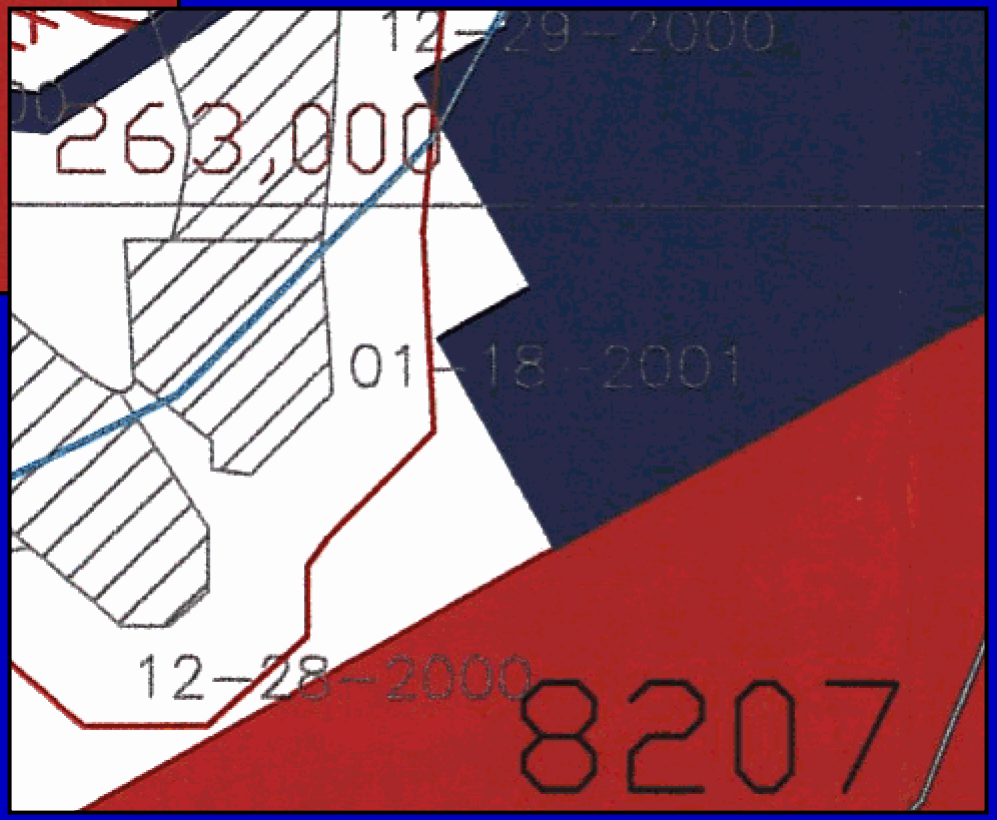
Indexed Color Mode
128 Color Adaptive



RGB Color Mode



Indexed Color Mode
128 Color Adaptive



Mine Map Registration Utility (AutoCad VBA)

Mine Map Registration Utilty

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Tonnage = 0
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SourceScannerName=Minescan1
SourceImageFileFormat=JPEG
SourceImageDateTime=9/28/2004 11:29:32 AM
Stage1CleanupUser=bemis
Stage1CleanupCPU=MINEMAPPER2
Stage1CleanupDateTime=10/12/2004 1:36:44 PM
Stage2CleanupUser=anayansi.gomez
Stage2CleanupCPU=MINEMAPPER3
Stage2CleanupDateTime=3/22/2005 11:22:36 AM
MapScanResolutionDPI=200
MapScanWidthInches=24.680
MapScanHeightInches=18.495
OriginalColorMode=RGB
ColormapCPU=C140SIS00020015
ColormapDateTime=3/23/2005 2:03:35 AM
```

Metadata Window

Grid Calibration and Scale

Simple Georeferencing

Image Orientation

Map Path: \\NRMM1\minemaps$\minemaps\register

Image File: 11838_1974L_19740923

<< Prev

Next >>

Image Calibration

Image Coordinates		Grid Coordinates		
x1	y1	N1	E1	Grid Intersection
x2	y2	N2	E2	Grid Intersection

Grid Intersection Coordinates and Spacing: Northing | Easting | Spacing:

Map Scale: 100

Register by Points

Lat-Long Registration and Locate Grid

Center on Image (Point 1 only)

Input Datum: NAD27 NAD83

Image x1	Image y1	Latitude1			Longitude1		
8.165	9.148	37	38	08	83	46	30

Image x2	Image y2	Latitude2			Longitude2		

County: Lee Quadrangle: Cobhill

Position Results	NAD 83		NAD 27	
Point #1	Northing	Easting	Northing	Easting
SPC Single Zone, USFt	3,761,106	5,493,133		
SPC South Zone, USFt	2,120,587	2,212,326	480,128	2,571,901
SPC North Zone, USFt	49,781	1,778,025	49,749	2,137,588
UTM Zone 16, Meters				
UTM Zone 17, Meters	4,169,021	255,152	4,168,807	255,139

Register Point 1

Register Point 2

Register Both Points

Rotate 90° Left

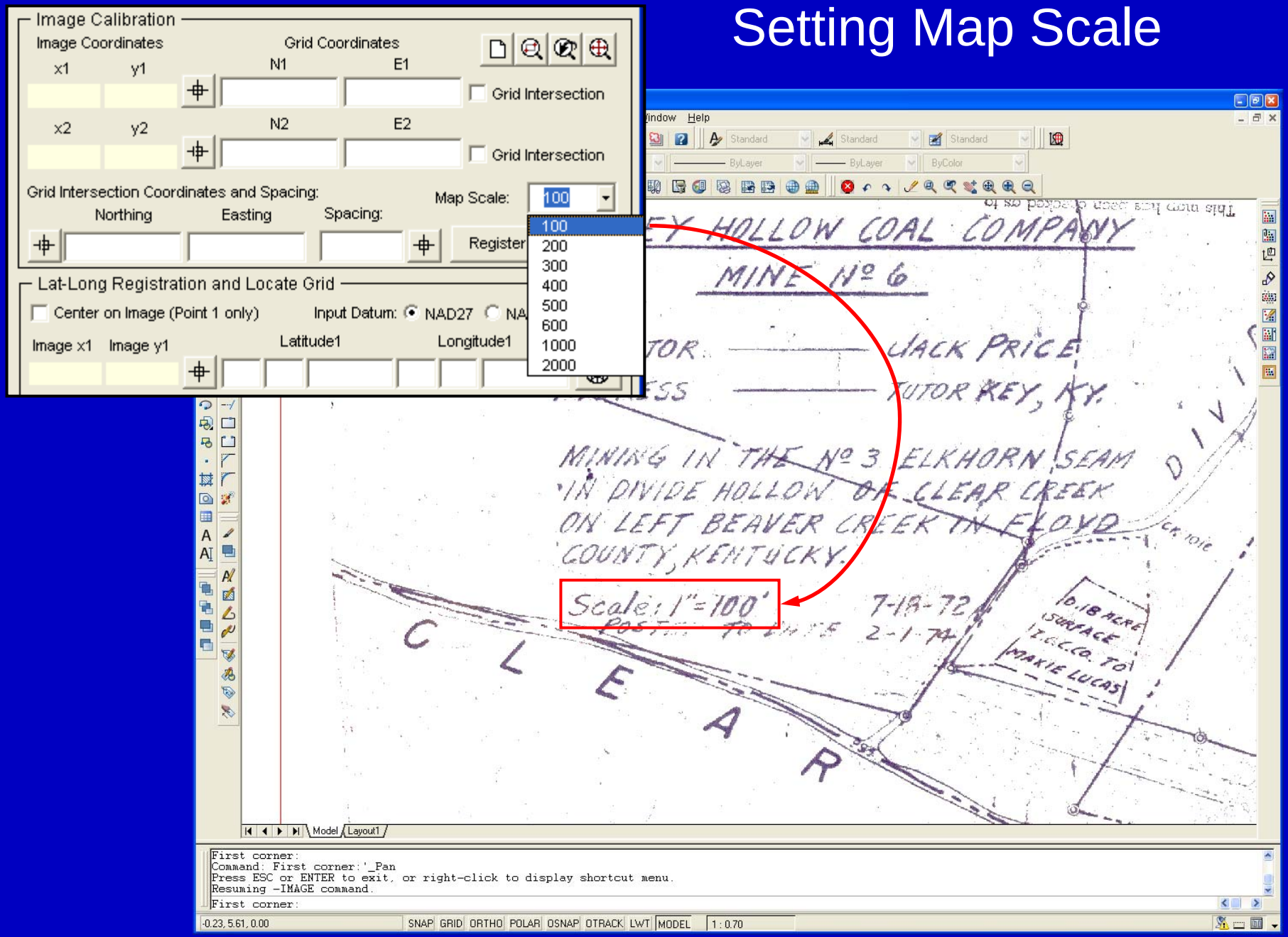
Rotate 90° Right

Rotate 180°

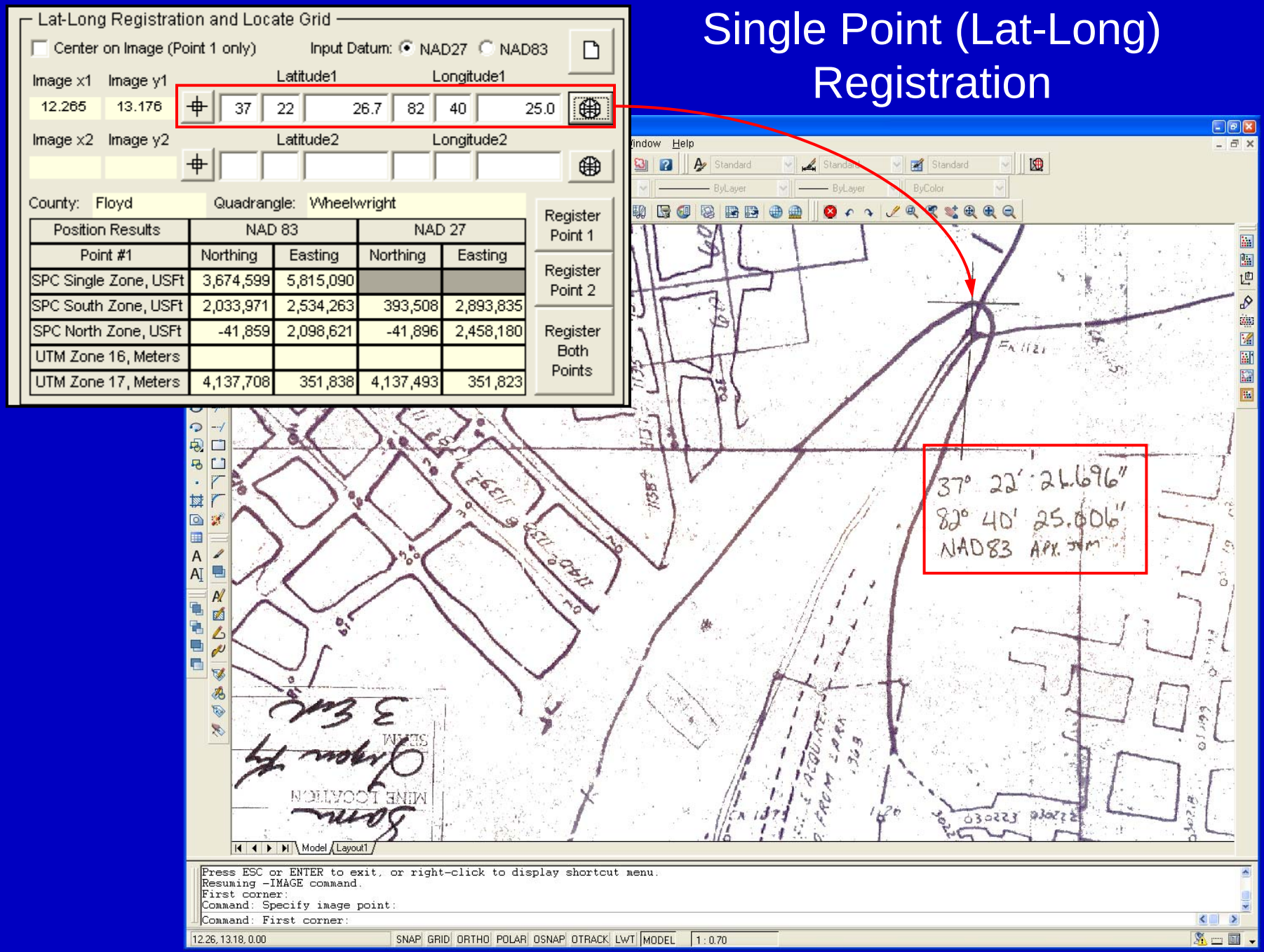
Fail Map

Exit

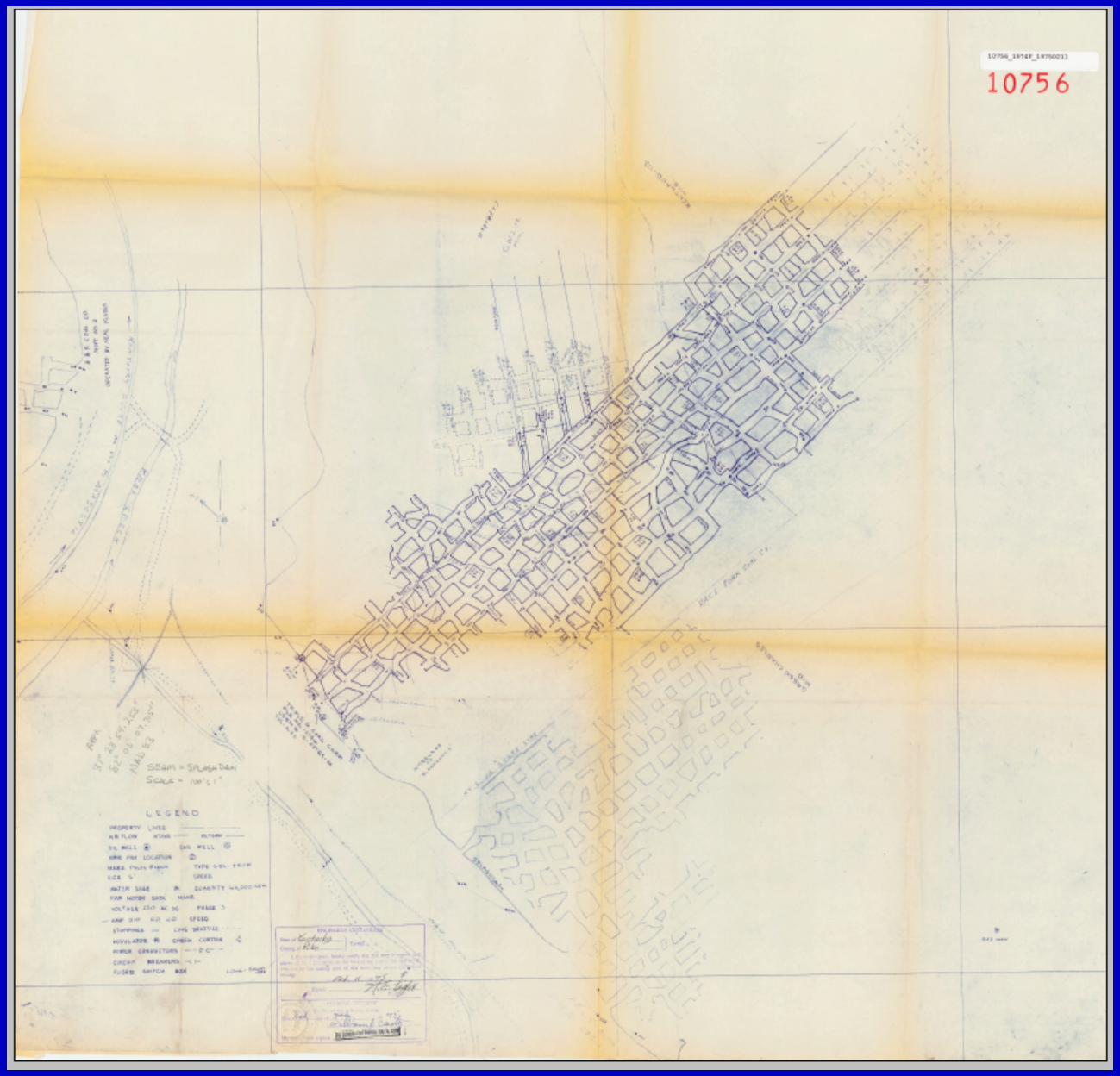
Setting Map Scale

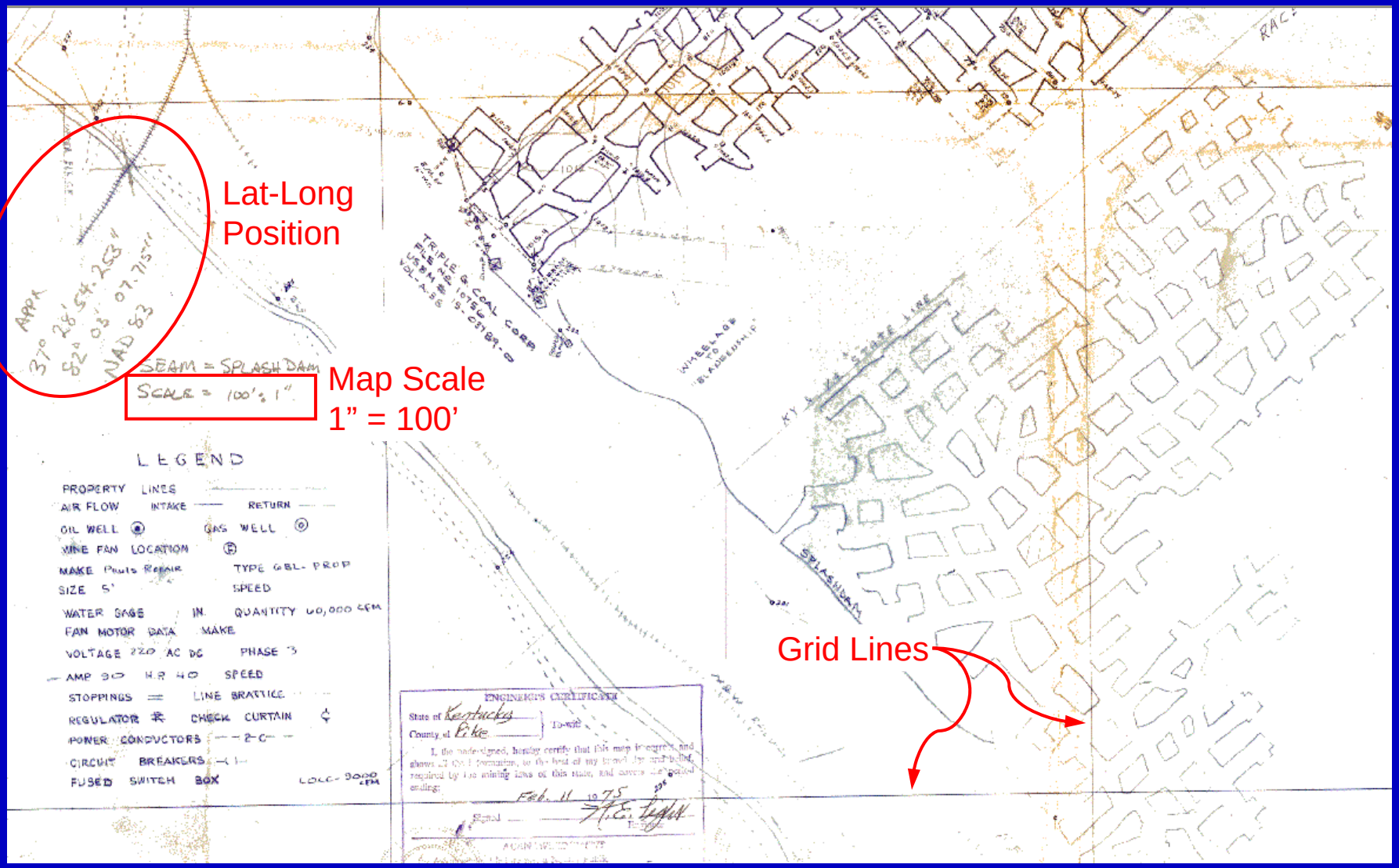


Single Point (Lat-Long) Registration

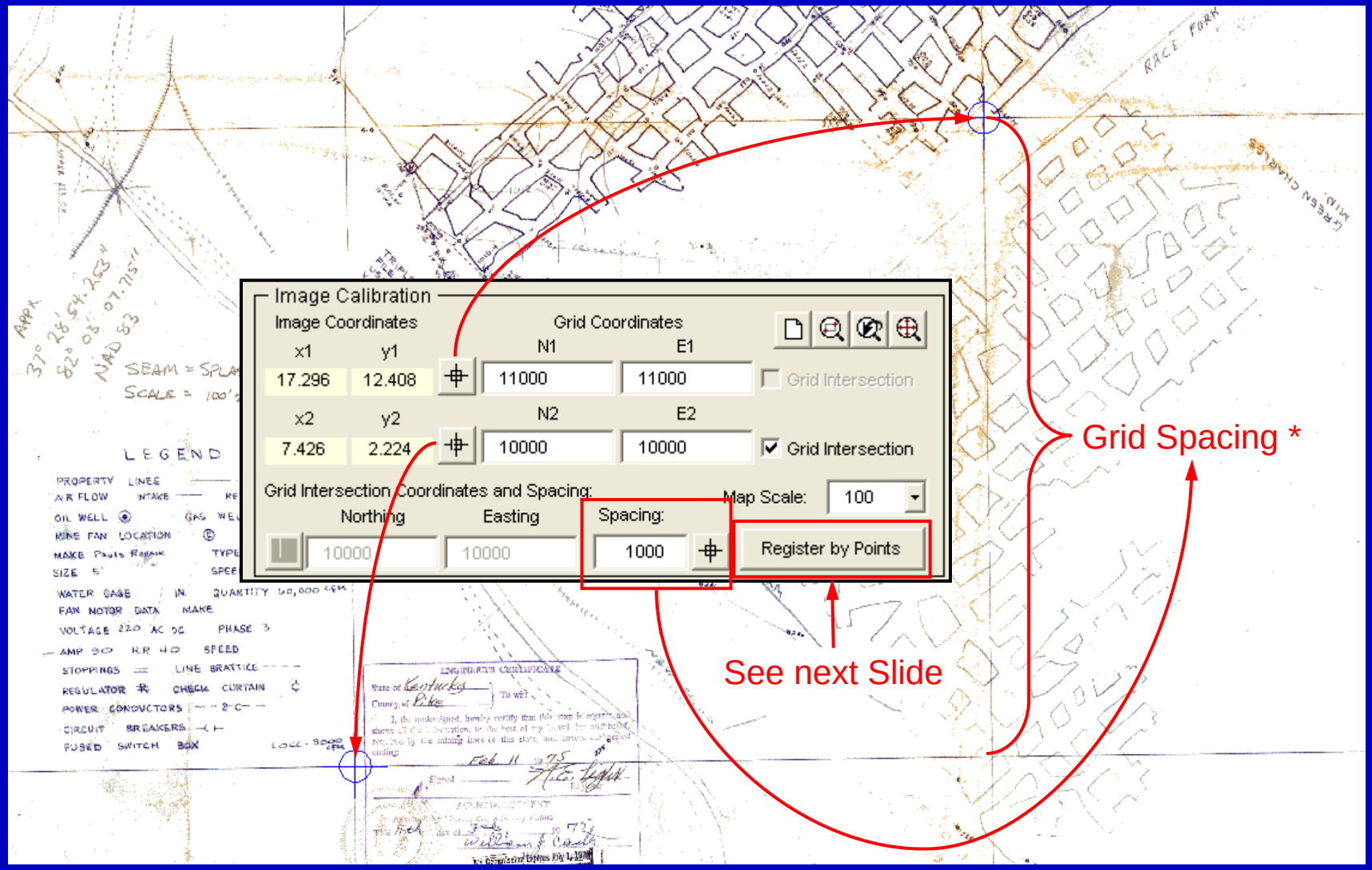


Grid Registration – Unlabeled Grid



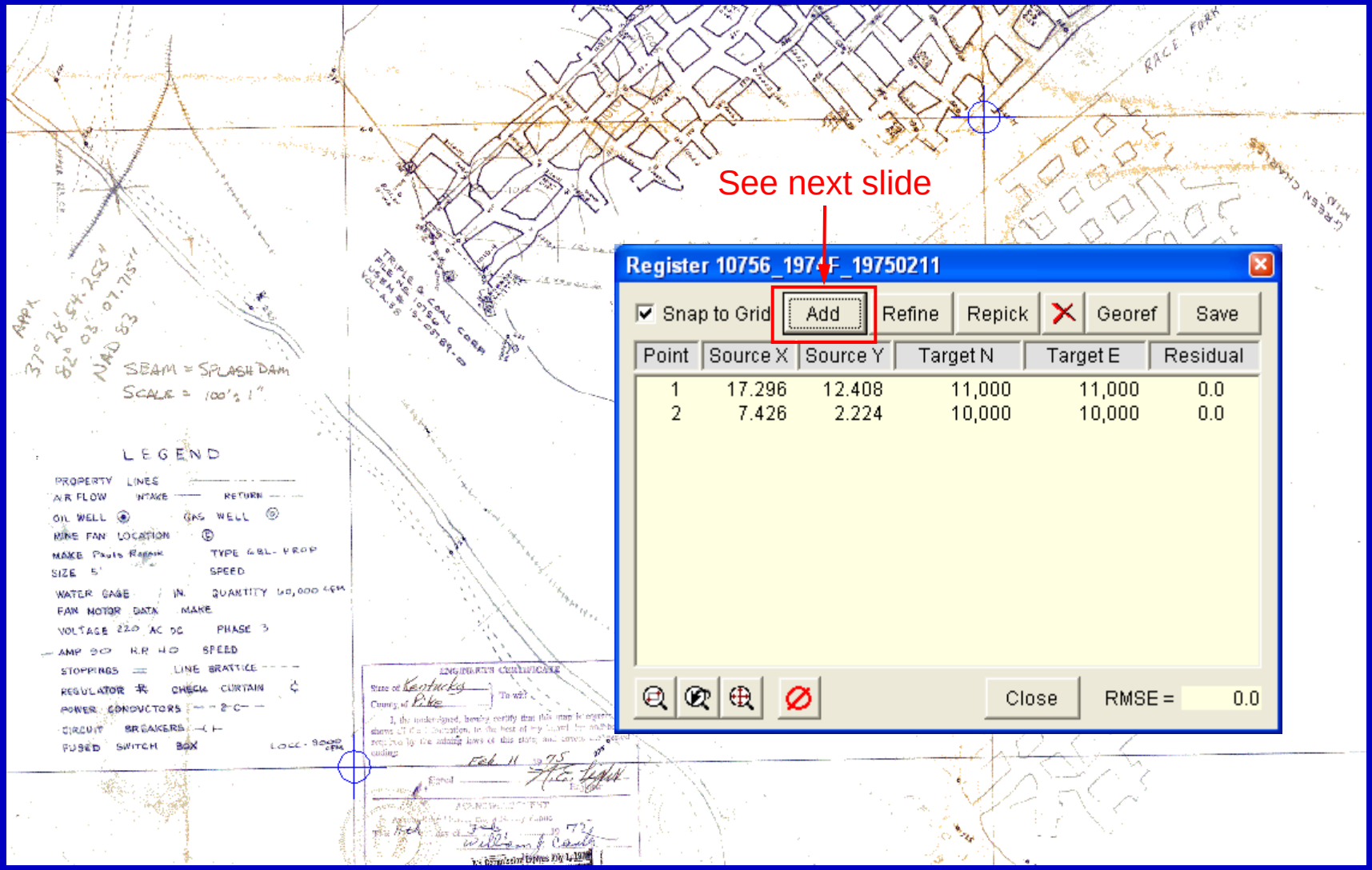

Lat-Long Position
Map Scale
1" = 100'
Grid Lines
SEAM = SPLASH DAM
SCALE = 100' = 1"
LEGEND
PROPERTY LINES
AIR FLOW INTAKE RETURN
OIL WELL
GAS WELL
MINE FAN LOCATION
MAKE Pauls Repair
TYPE GBL-PROP
SIZE 5'
SPEED
WATER GAGE IN.
QUANTITY 60,000 CFM
FAN MOTOR DATA
MAKE
VOLTAGE 220 AC DC
PHASE 3
AMP 30 H.P. 40
SPEED
STOPPINGS
LINE BRATTICE
REGULATOR
CHECK CURTAIN
POWER CONDUCTORS
CIRCUIT BREAKERS
FUSED SWITCH BOX
LOCC-9000 CFM
ENGINEER'S CERTIFICATE
State of Kentucky
County of Pike
To-wit
Feb. 11 1975
Seal
Engineer
TRIPLE G COAL CORP
WHEELAGE TO "BLADENSHIP"
KY
VA
STATE LINE
SPLASH DAM

Grid Registration – Unlabeled Grid

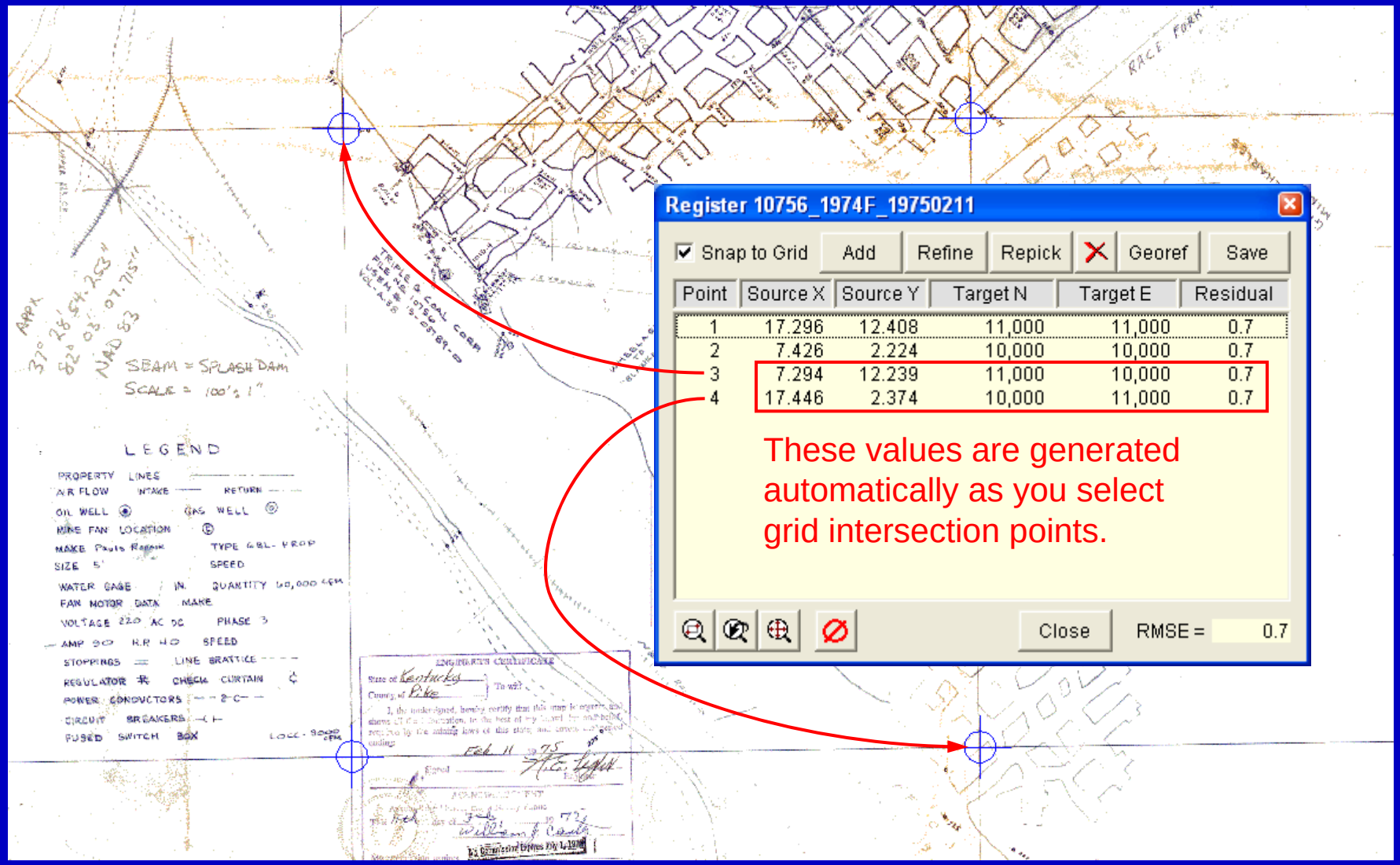


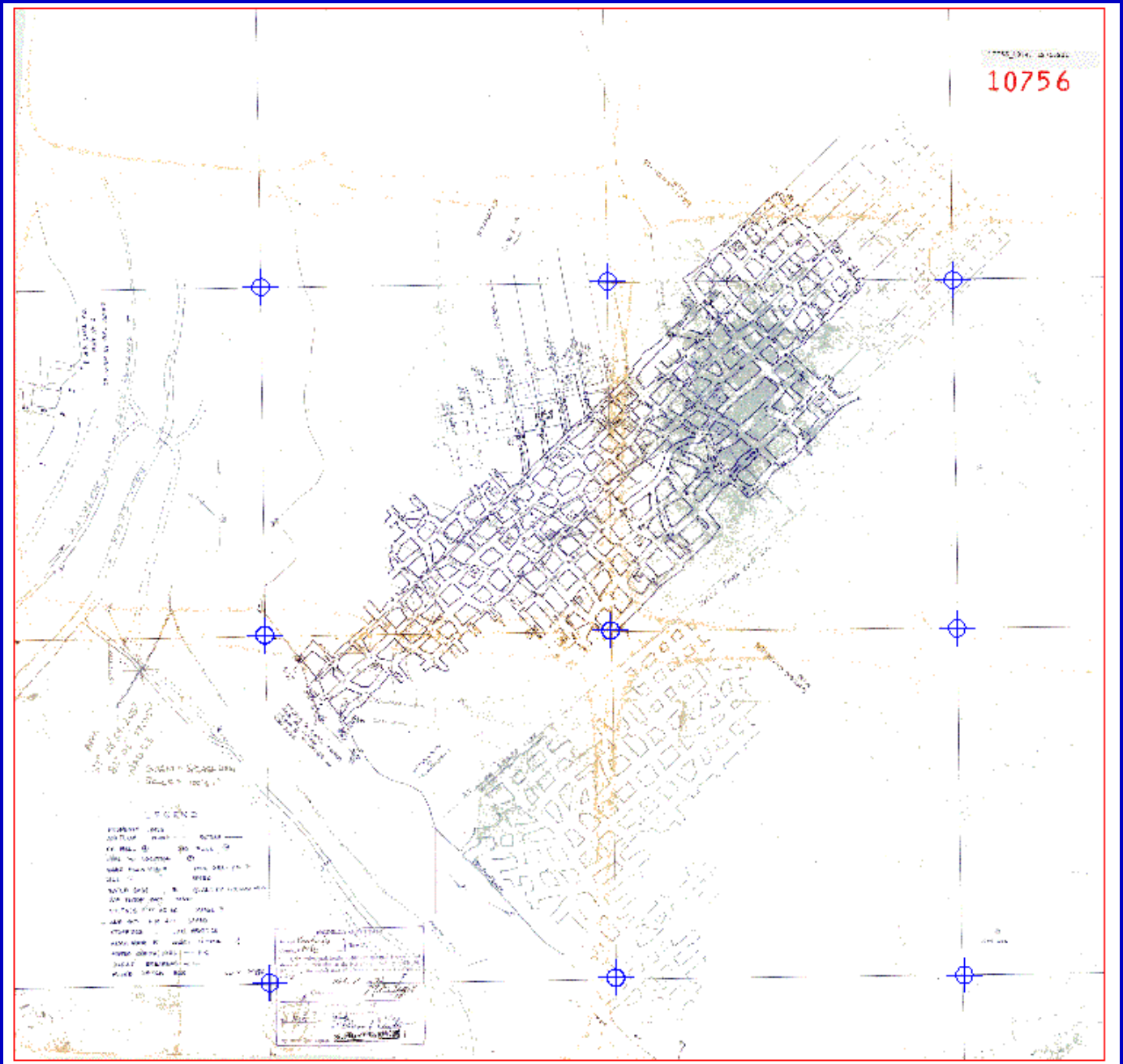
* Grid spacing for this scenario is determined by entering the map scale as provided on the map, then picking two adjacent grid intersection points.

Grid Registration – Unlabeled Grid

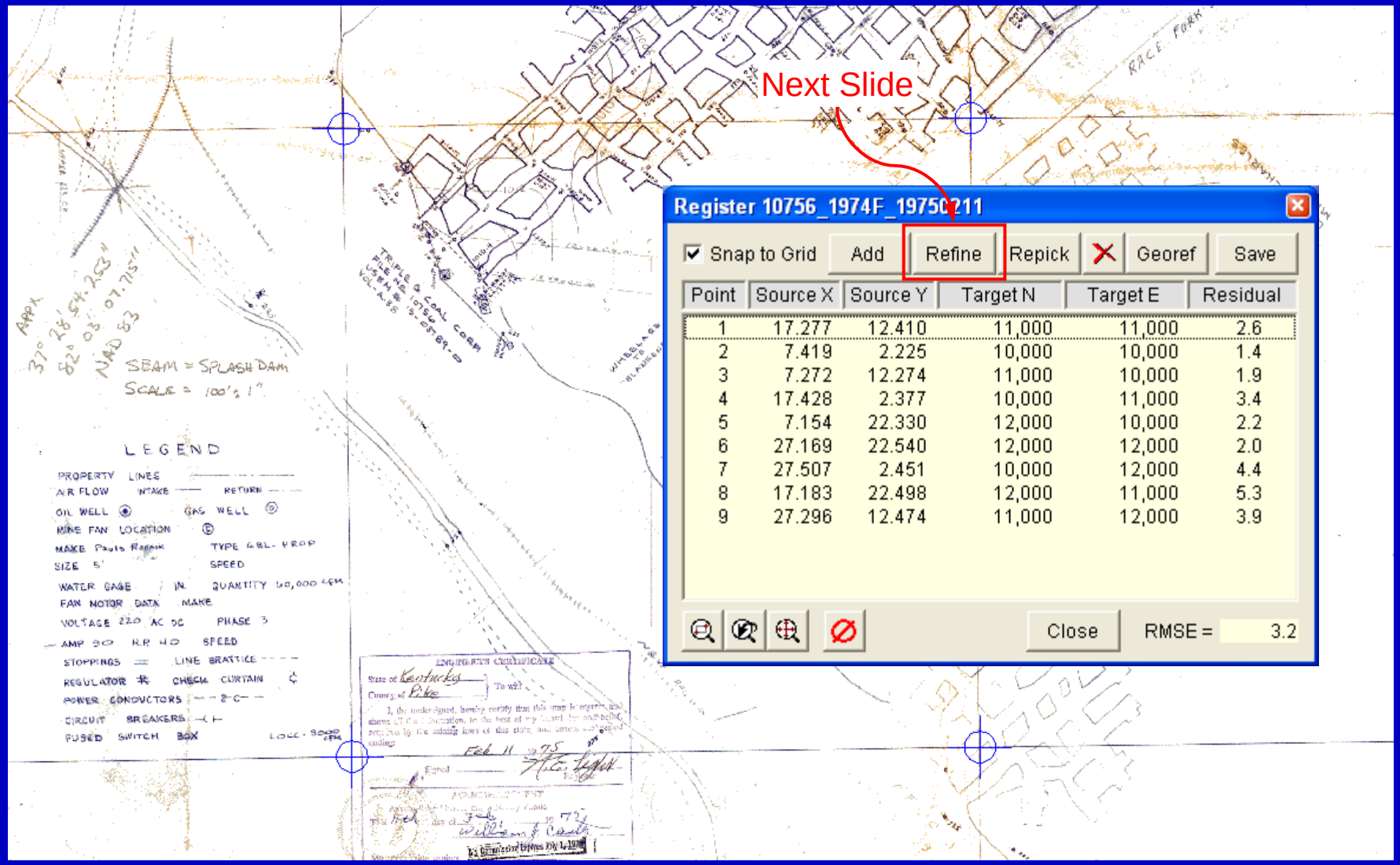


Grid Registration – Unlabeled Grid



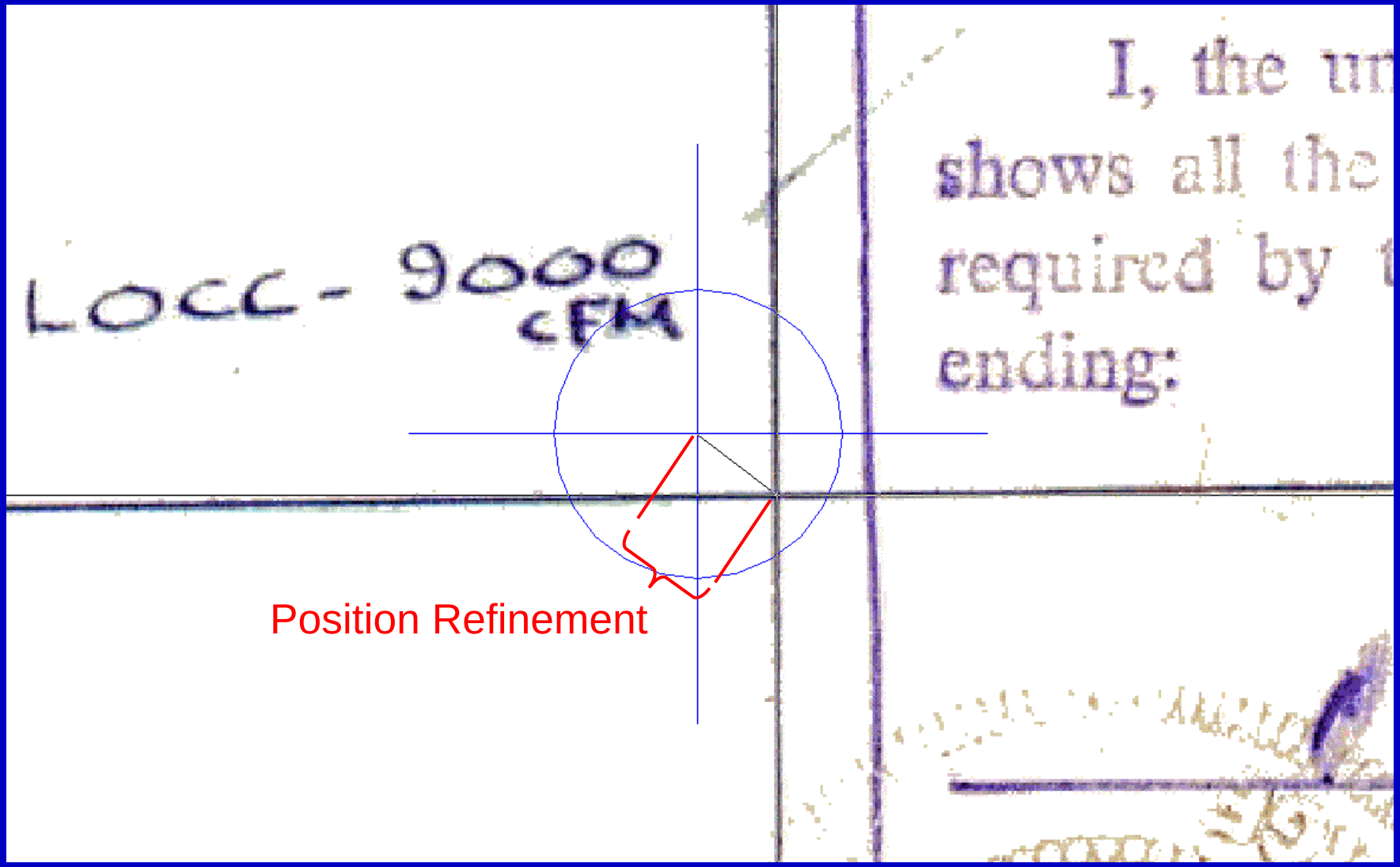

10756

Refine Registration Points

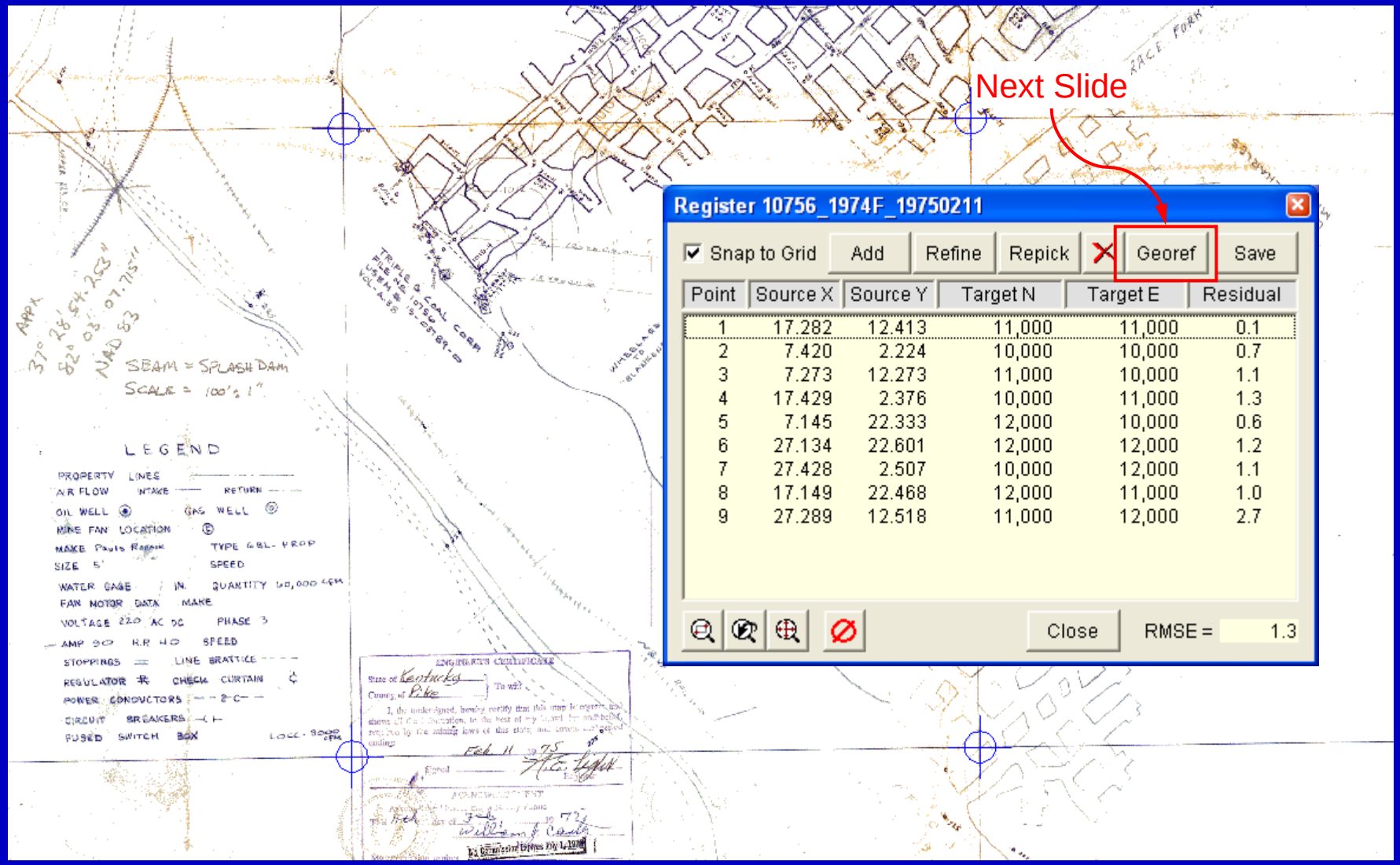


Point	Source X	Source Y	Target N	Target E	Residual
1	17.277	12.410	11,000	11,000	2.6
2	7.419	2.225	10,000	10,000	1.4
3	7.272	12.274	11,000	10,000	1.9
4	17.428	2.377	10,000	11,000	3.4
5	7.154	22.330	12,000	10,000	2.2
6	27.169	22.540	12,000	12,000	2.0
7	27.507	2.451	10,000	12,000	4.4
8	17.183	22.498	12,000	11,000	5.3
9	27.296	12.474	11,000	12,000	3.9

Refine Registration Points

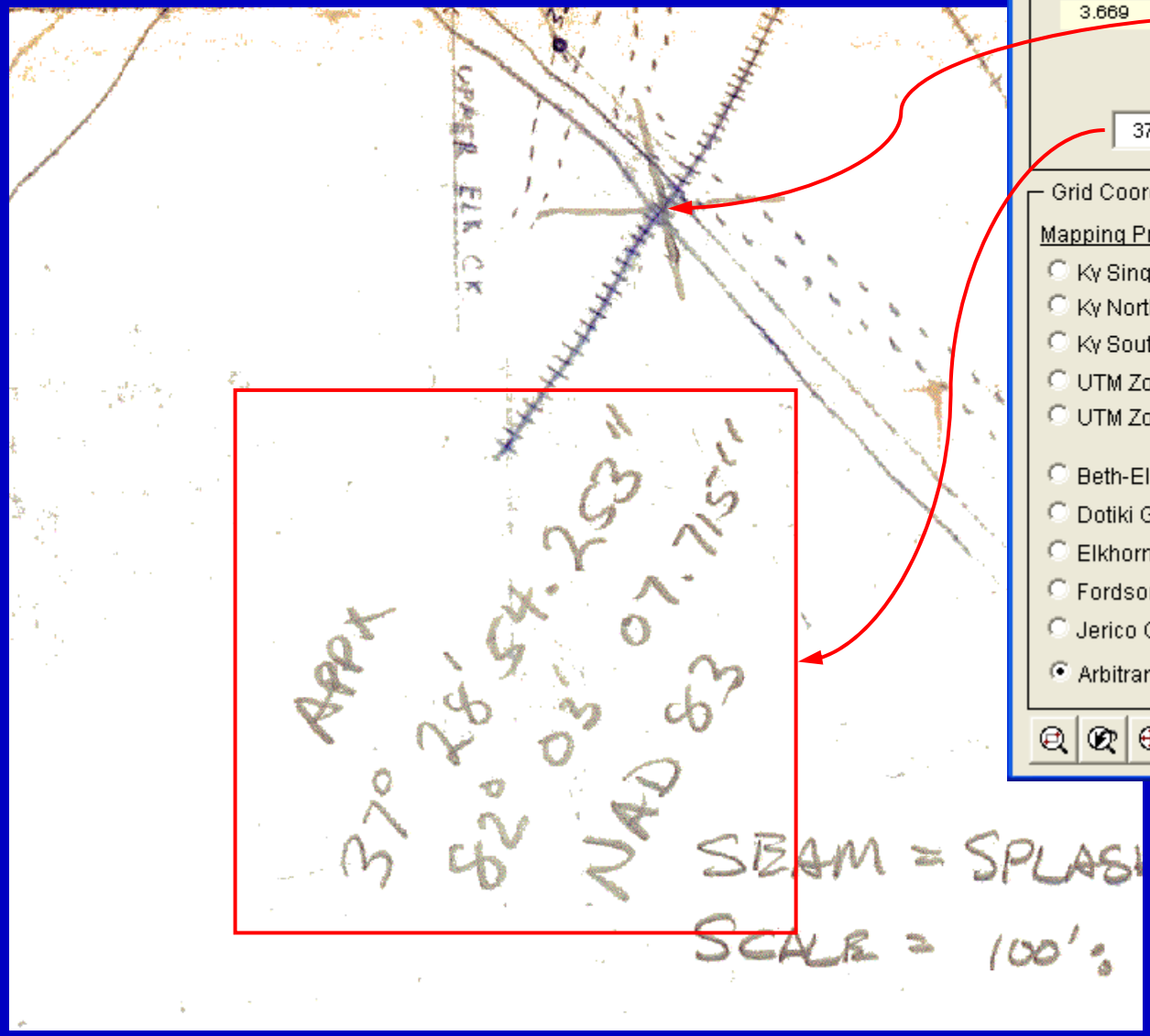


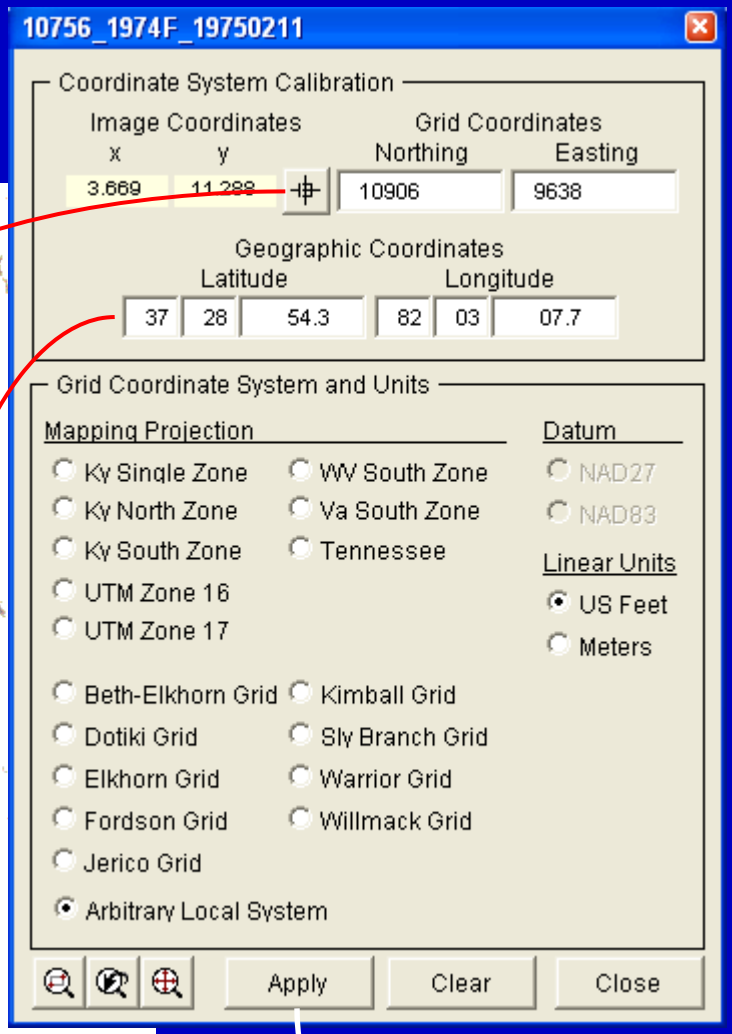
Grid Georeferencing



Point	Source X	Source Y	Target N	Target E	Residual
1	17.282	12.413	11,000	11,000	0.1
2	7.420	2.224	10,000	10,000	0.7
3	7.273	12.273	11,000	10,000	1.1
4	17.429	2.376	10,000	11,000	1.3
5	7.145	22.333	12,000	10,000	0.6
6	27.134	22.601	12,000	12,000	1.2
7	27.428	2.507	10,000	12,000	1.1
8	17.149	22.468	12,000	11,000	1.0
9	27.289	12.518	11,000	12,000	2.7

Grid Georeferencing

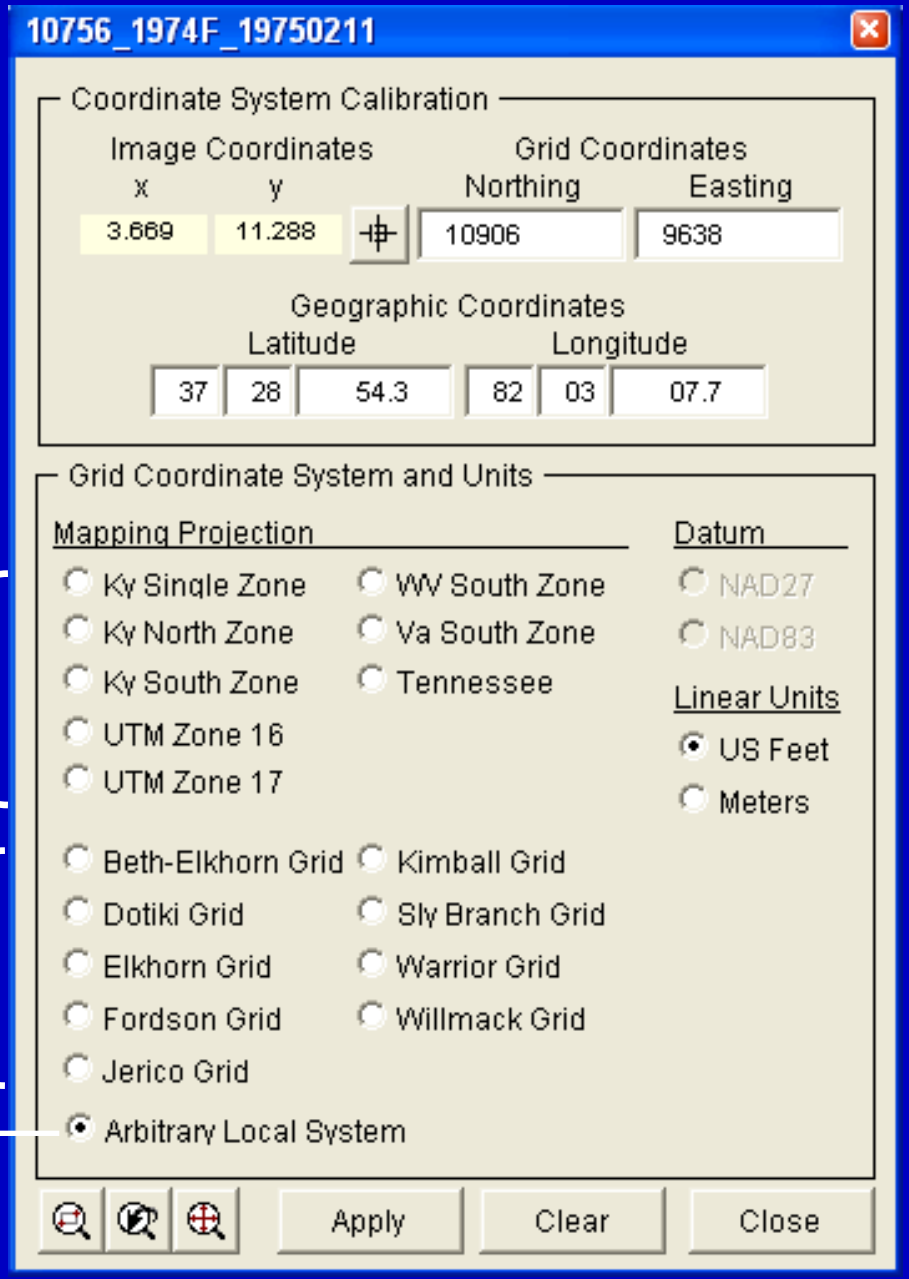




Standard Projections
(State Plane & UTM)

Known Registered
Local Grids

Arbitrary Local System



Local Grid Registration (Affine Transform Parameters)

Fordson Coal Company Coordinate System
to
Kentucky State Plane (KYSZ = NAD27 South Zone & KY1Z = NAD83 Single Zone)

Name	Fordson *v* (Northing)	Fordson *u* (Easting)	NAD27 KYSZ *y* (Northing)	NAD27 KYSZ *x* (Easting)	KYSZ Residual	NAD83 KY1Z *y* (Northing)	NAD83 KY1Z *x* (Easting)	KY1Z Residual
T/Bar No. 67	25,810.05	17,993.64	464,438.71	3,011,730.40	0.00	3,745,581.92	5,932,955.03	0.00
T/Bar No. 68	25,326.44	17,814.33	463,944.13	3,011,584.08	0.01	3,745,087.28	5,932,808.94	0.01
GW- PK 347	24,152.08	19,509.31	462,886.61	3,013,354.32	0.01	3,744,030.65	5,934,579.63	0.01
GW- PK 346	23,050.04	20,465.59	461,851.50	3,014,382.67	0.00	3,742,996.07	5,935,608.43	0.00
GW- PK 339	25,422.81	21,571.73	464,293.39	3,015,326.45	0.01	3,745,438.34	5,936,551.11	0.01
				RMSE	0.01		RMSE	0.01

NAD27 KYSZ Affine Parameters	
Tx	2995516.4079
Ux	0.99772778
Uy	-0.06736759
Ty	437475.1321
Vx	0.06736596
Vy	0.99772851

NAD83 KY1Z Affine Parameters	
Tx	5916753.1365
Ux	0.9976910831
Uy	-0.0678107478
Ty	3718611.2385
Vx	0.0678472251
Vy	0.9976681997

Fordson *(u, v)* to SPC *(x, y)* Transform Equations:

$$x = Tx + Ux\,u + Uy\,v$$

$$y = Ty + Vx\,u + Vy\,v$$

Registration World File

```
0.49979642
-0.00659989
-0.00703648
-0.49746266
5993596.88476123
3722153.31082308
```

Map Registration Metadata

```
RegistrationDateTime=5/19/2005 4:15:21 PM
RegistrationUserName=bunch_b
RegistrationCPU=C14OSIS00020015
RegistrationType=MapCoordinateSystem
MapCoordinateSystem=LocalSystem
MapDatum=None
MapUnits=AssumedFeet
X_Translation=5,984,299
Y_Translation=3,709,340
MapDatum=NAD83
MapUnits=USFt
MapScale=100
MapGridSpacing=1000
```

Image -> Map Coordinate System Registration Table

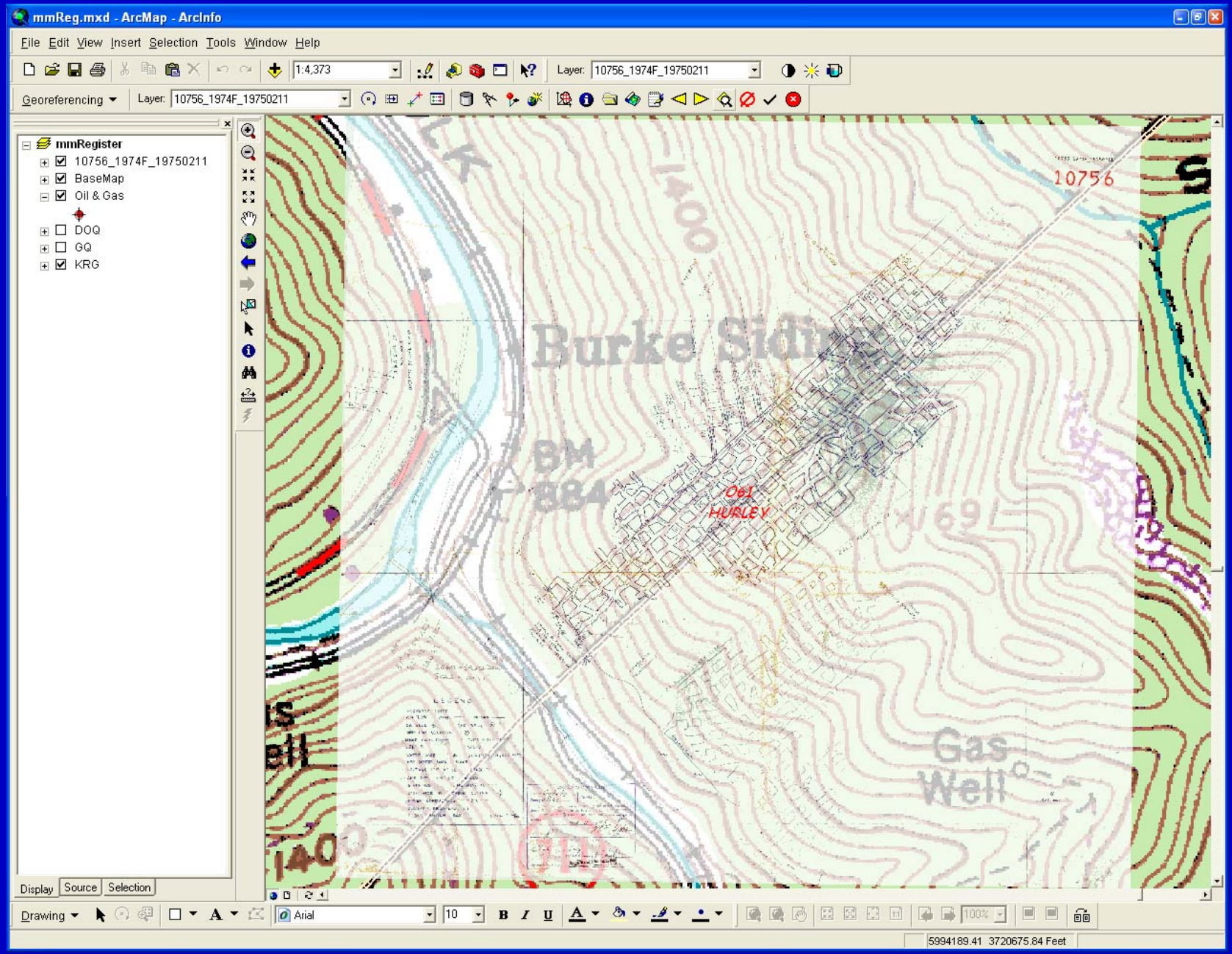
Point	Image_X pixel	Image_Y pixel	Map Northing	Map Easting	KY1Z-Ft Northing	KY1Z-Ft Easting	Residual (ft)
1	3456	3599	11000.0	11000.0	3720340.1	5995298.9	0.1
2	1483	5637	10000.0	10000.0	3719340.1	5994298.9	0.7
3	1454	3627	11000.0	10000.0	3720340.1	5994298.9	1.1
4	3485	5606	10000.0	11000.0	3719340.1	5995298.9	1.3
5	1428	1615	12000.0	10000.0	3721340.1	5994298.9	0.6
6	5426	1561	12000.0	12000.0	3721340.1	5996298.9	1.2
7	5485	5580	10000.0	12000.0	3719340.1	5996298.9	1.1
8	3429	1588	12000.0	11000.0	3721340.1	5995298.9	1.0
9	5457	3578	11000.0	12000.0	3720340.1	5996298.9	2.7
						RMSE	1.3

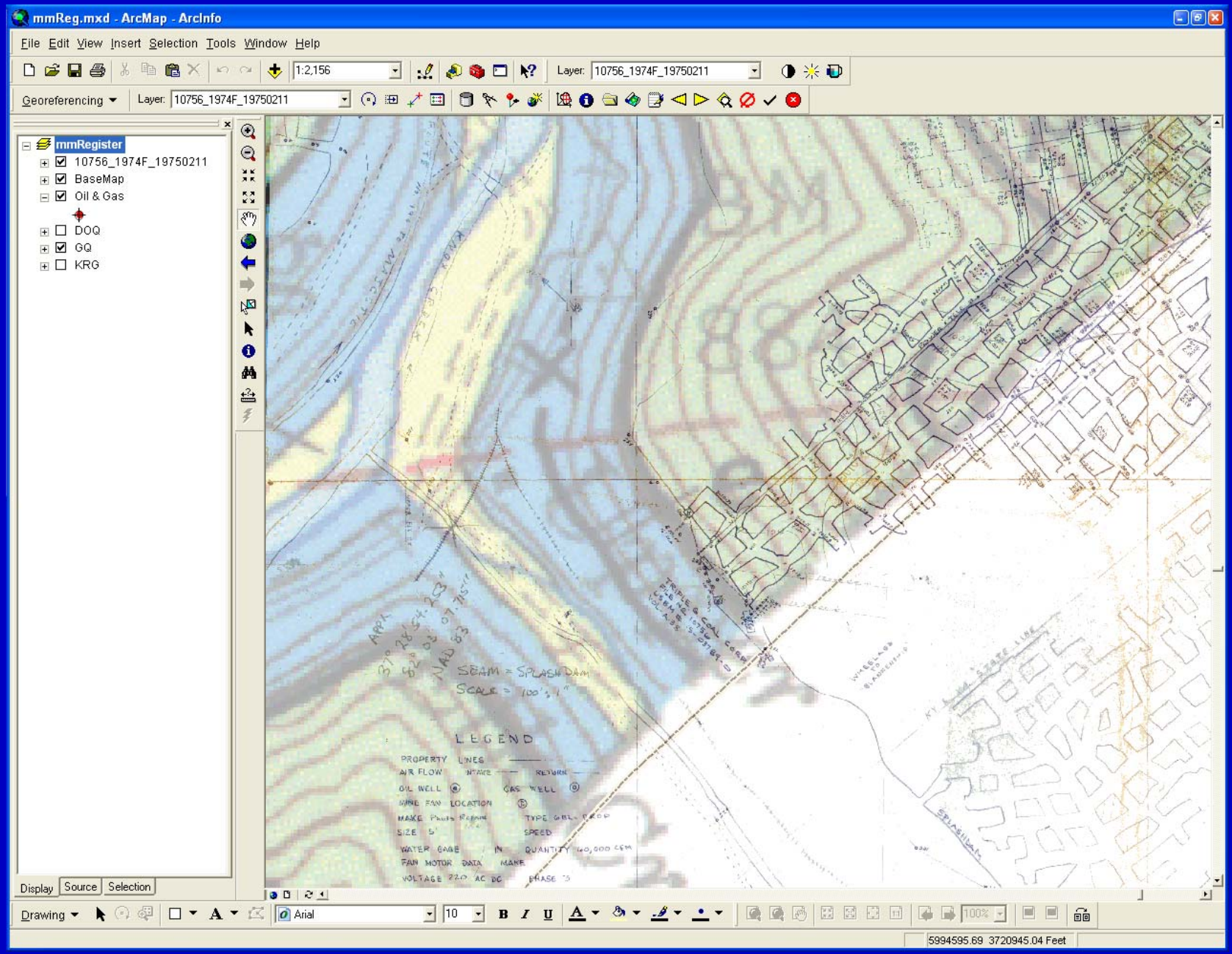
Registered Image (u,v) -> KY1Z (x,y) affine transform:

$$x = Ux * u + Uy * v + Tx$$
$$y = Vx * u + Vy * v + Ty$$

Ux = 0.49979642
Vx = -0.00659989
Uy = -0.00703648
Vy = -0.49746266
Tx = 5993596.88476123
Ty = 3722153.31082308

Check Registration / Map Georeferencing (ArcMap)




mmReg.mxd - ArcMap - ArcInfo
File Edit View Insert Selection Tools Window Help
1:2,156
Layer: 10756_1974F_19750211
Georeferencing
Layer: 10756_1974F_19750211
mmRegister
10756_1974F_19750211
BaseMap
Oil & Gas
DOQ
GQ
KRG
Display
Source
Selection
SEAM = SPLASH DAM
SCALE = 100' = 1"
LEGEND
PROPERTY LINES
AIR FLOW
INTAKE
RETURN
OIL WELL
GAS WELL
MINE FAN LOCATION
MAKE
TYPE
SIZE
SPEED
WATER GAGE
IN
QUANTITY
FAN MOTOR DATA
MAKE
VOLTAGE
PHASE
Drawing
Arial
10
5994595.69 3720945.04 Feet

mmReg.mxd - ArcMap - ArcInfo

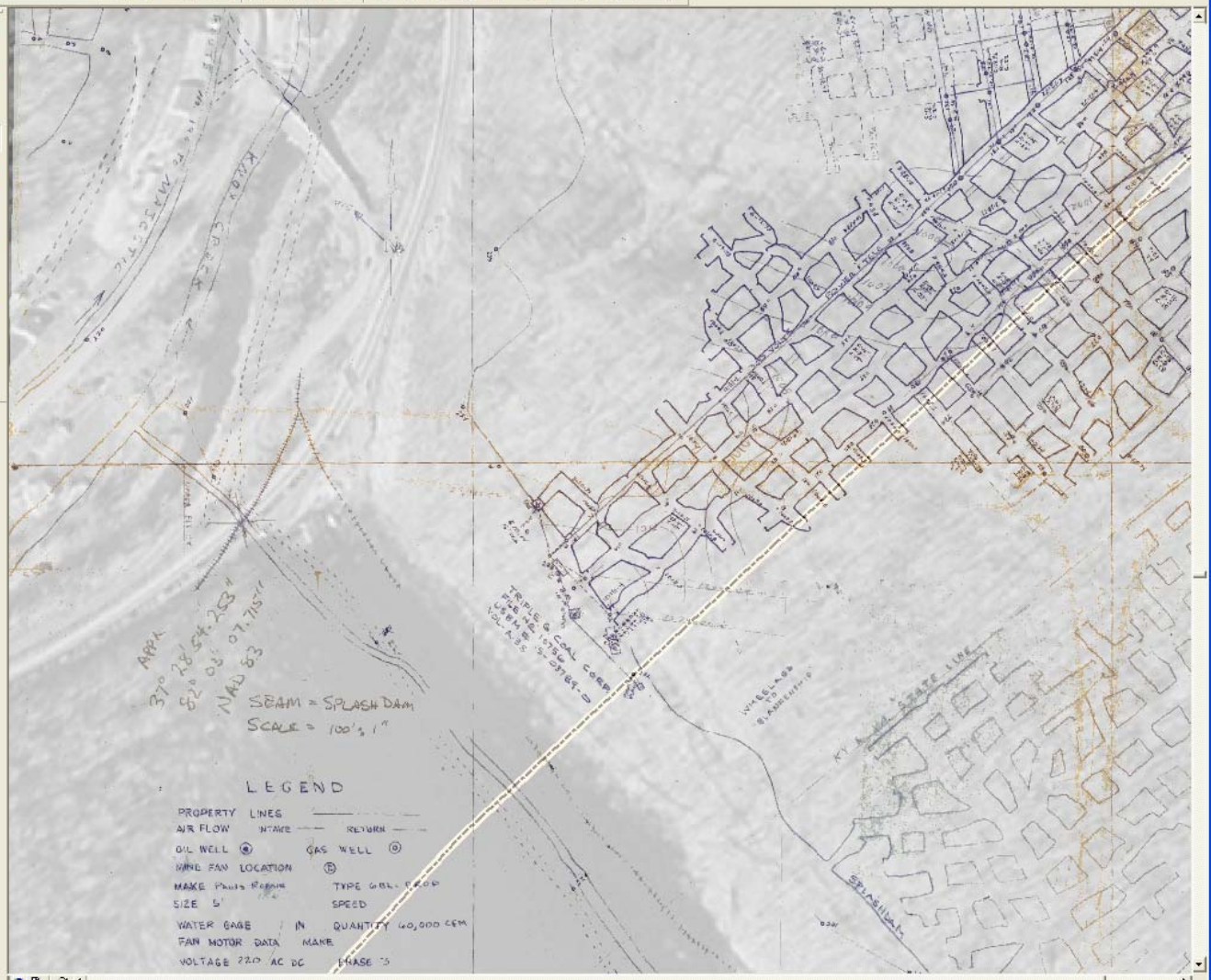
File Edit View Insert Selection Tools Window Help

1:2,156 Layer: 10756_1974F_19750211

Georeferencing Layer: 10756_1974F_19750211

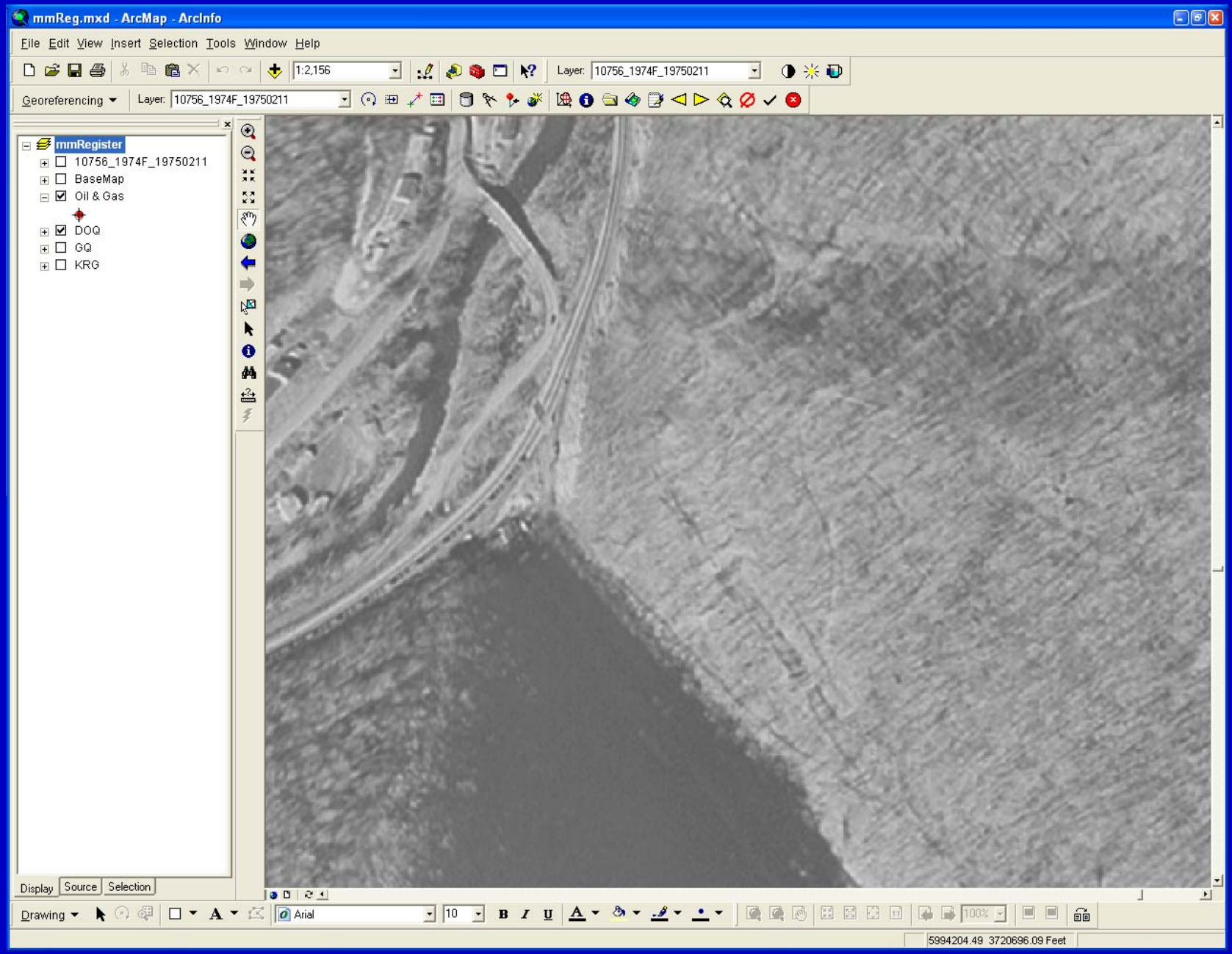
- mmRegister
  - 10756_1974F_19750211
  - BaseMap
  - Oil & Gas
  - DOQ
  - GQ
  - KRG

Display Source Selection



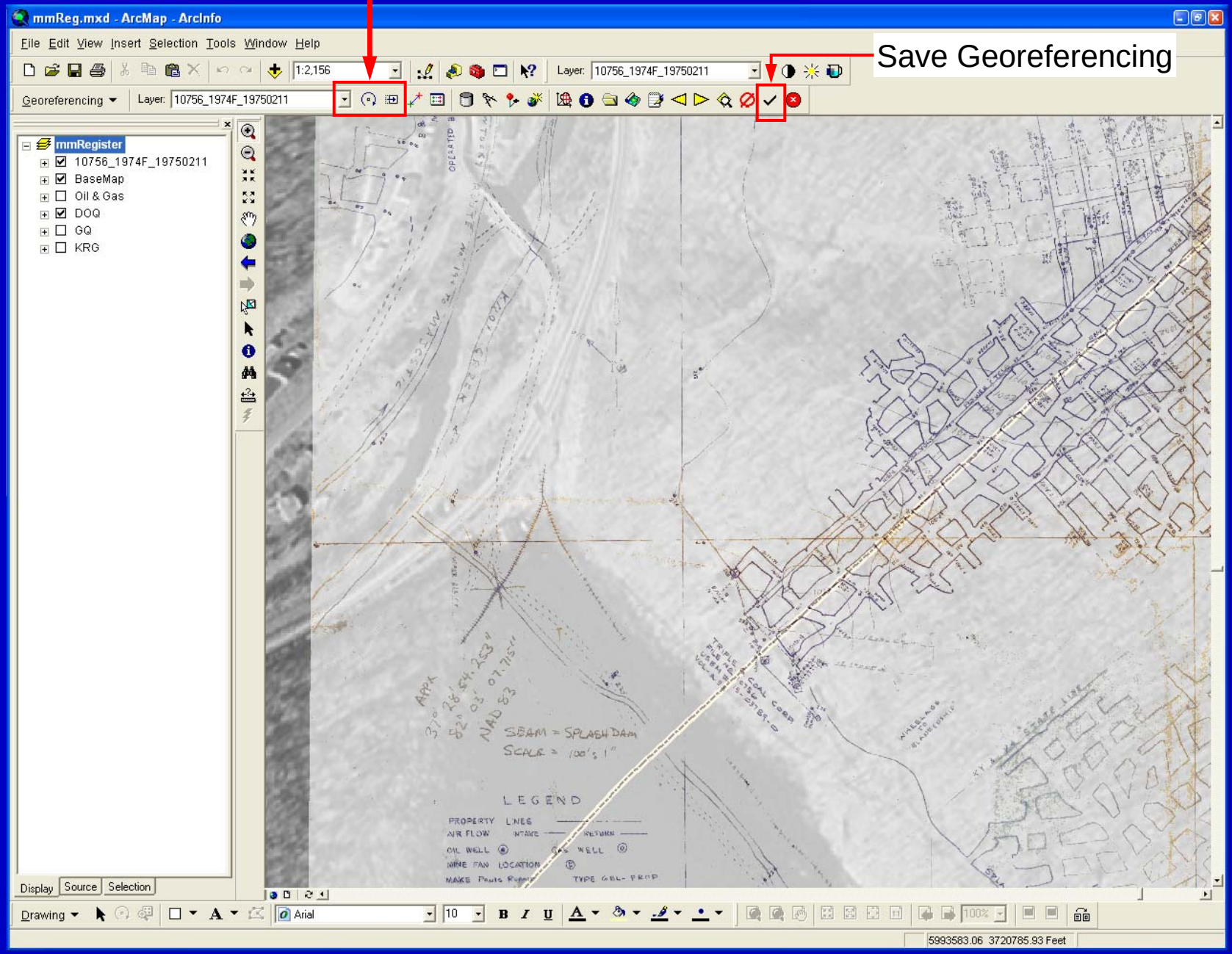
Drawing Arial 10 100%

5994475.90 3720761.60 Feet


mmReg.mxd - ArcMap - ArcInfo
File Edit View Insert Selection Tools Window Help
1:2,156
Layer: 10756_1974F_19750211
Georeferencing
Layer: 10756_1974F_19750211
mmRegister
10756_1974F_19750211
BaseMap
Oil & Gas
DOQ
GQ
KRG
Display
Source
Selection
Drawing
Arial
10
5994204.49 3720696.09 Feet

ArcMap Shift and Rotate Tools (Georeferencing)

Save Georeferencing



Registration
World File

```
0.49979642
-0.00659989
-0.00703648
-0.49746266
5993596.88476123
3722153.31082308
```

Registration Check
(Georeferencing)
World File

```
0.49982502
-0.00386936
-0.00431869
-0.49749368
5993677.40256694
3722030.85151143
```

Note:
The georeferencing world file will be the basis for final image rectification.

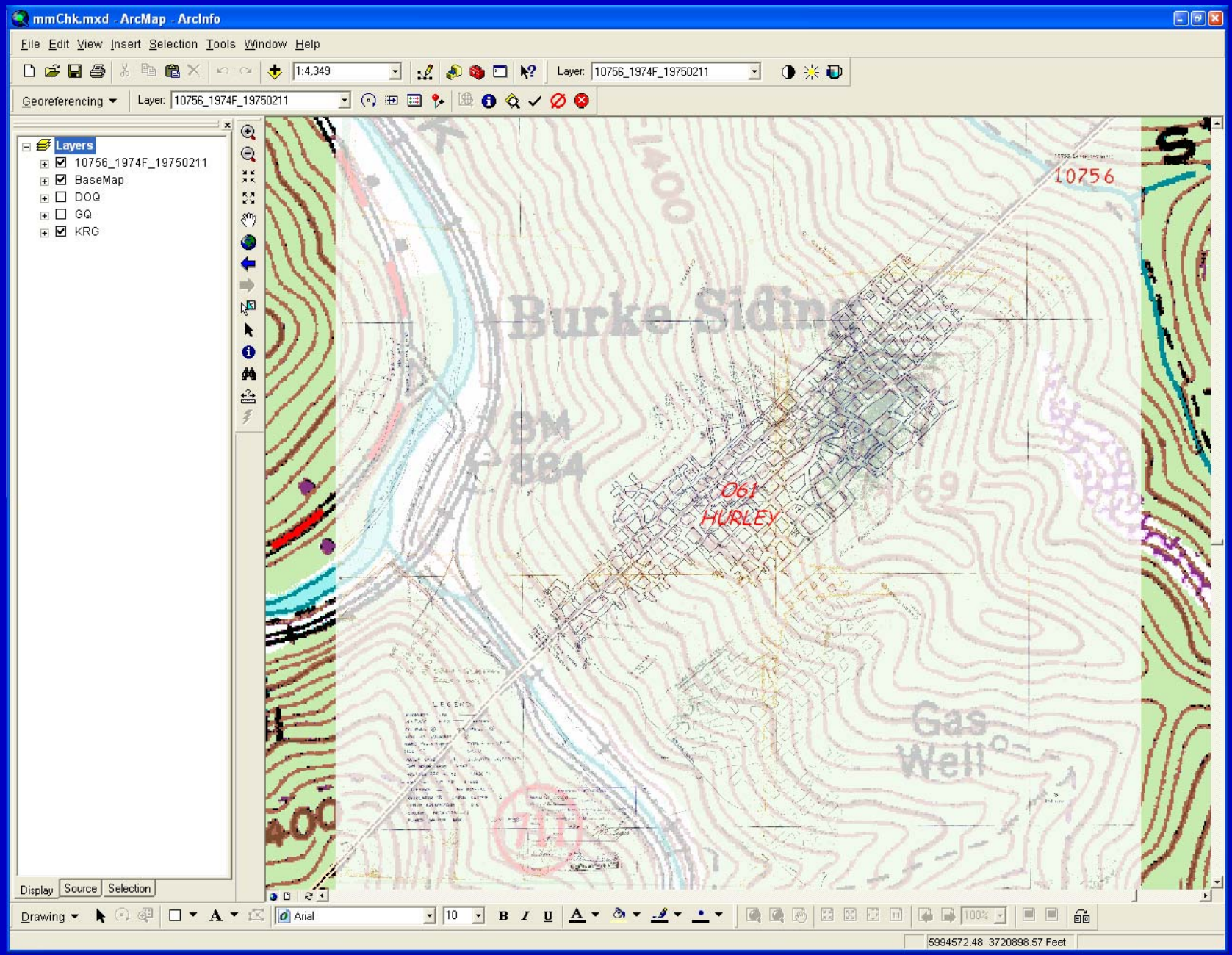
Registration Check (Georeferencing) Metadata

This section generated during grid registration (see above).

This section generated during registration check (final georeferencing).

```
...
   9     5457     3578     11000.0    12000.0  3720340.1  5996298.9      2.7
==============================================================================
                                                                RMSE      1.3
------------------------------------------------------------------------------
Registered Image (u,v) -> KY1Z (x,y) affine transform:
  x = Ux * u + Uy * v + Tx
  y = Vx * u + Vy * v + Ty
  Ux =        0.49979642
  Vx =       -0.00659989
  Uy =       -0.00703648
  Vy =       -0.49746266
  Tx =  5993596.88476123
  Ty =  3722153.31082308
------------------------------------------------------------------------------
RegistrationKRGAdjustment=True
RegistrationKRGAdjustmentType=NoLinkTableMapGridOrScaleHeldRigid
------------------------------------------------------------------------------
KRG feature based Image (u,v) -> KY1Z (x,y) affine transform:
  Ux =        0.49982502
  Vx =       -0.00386936
  Uy =       -0.00431869
  Vy =       -0.49749368
  Tx =  5993677.40256694
  Ty =  3722030.85151143
------------------------------------------------------------------------------
RegistrationCheckUserName=bunch_b
RegistrationCheckCPU=C14OSIS00020015
RegistrationCheckDateTime=5/20/2005 9:19:40 AM
```

Post-Rectification Check



Registration Check
(Georeferencing)
World File

```
0.49982502
-0.00386936
-0.00431869
-0.49749368
5993677.40256694
3722030.85151143
```

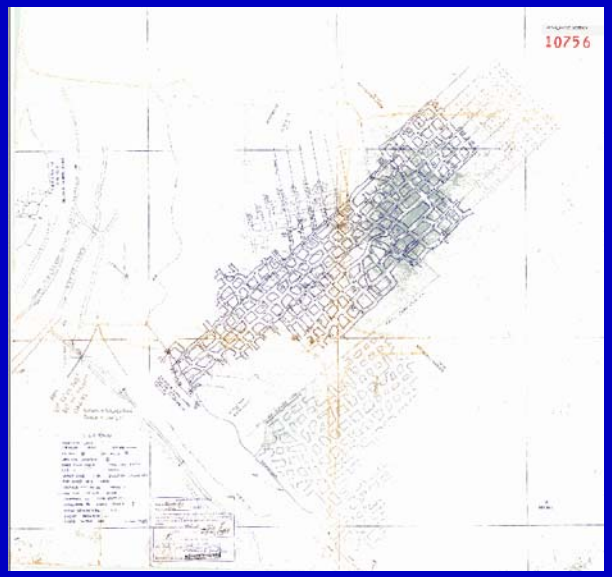
Rectified
World File

```
0.50000
0.00000
0.00000
-0.50000
5993651.00000
3722031.00000
```

Post-Rectification Metadata

```
-----------------------------------------------------------------------------
Georectified Image (u,v) -> KY1Z (x,y) world file affine transform.
  Ux =           0.50000
  Vx =           0.00000
  Uy =           0.00000
  Vy =          -0.50000
  Tx =     5993651.00000
  Ty =     3722031.00000
-----------------------------------------------------------------------------
RectifiedCellsize=0.50
RectifiedDateTime=5/20/2005 12:49:40 PM
RectifiedCPU=C14OSIS00020015
RectifiedImageFileFormat=GeoTiff/ESRI
RectifiedImageByteOrder=IBM
RectifiedImageCompressionScheme=PackBits
RectifiedImageColorMode=Indexed(8-bit)
RectifiedImageXResolution=200
RectifiedImageYResolution=200
RectifiedImageWidth=31.830
RectifiedImageHeight=30.500
RectifiedImageUnits=Inch
RectifiedCoordinateSystem=KentuckySingleZone
RectifiedCoordinateSystemFIPS=1600
RectifiedDatum=NAD83
RectifiedUnits=USFt
RectifiedUnitsToMeters=1200/3937
-----------------------------------------------------------------------------
RectifiedMapEnvelopeKentuckySingleZone:
  LowerLeftCoordinates:  x=5993651.00  y=3718981.00
  UpperLeftCoordinates:  x=5993651.00  y=3722031.00
  UpperRightCoordinates: x=5996834.00  y=3722031.00
  LowerRightCoordinates: x=5996834.00  y=3718981.00
RectifiedMapEnvelopeNAD83Geographic:
  LowerLeftCoordinates:  ddLat=37.478309N  ddLong=82.053296W
  UpperLeftCoordinates:  ddLat=37.486679N  ddLong=82.052880W
  UpperRightCoordinates: ddLat=37.486333N  ddLong=82.041918W
  LowerRightCoordinates: ddLat=37.477962N  ddLong=82.042335W
-----------------------------------------------------------------------------
```

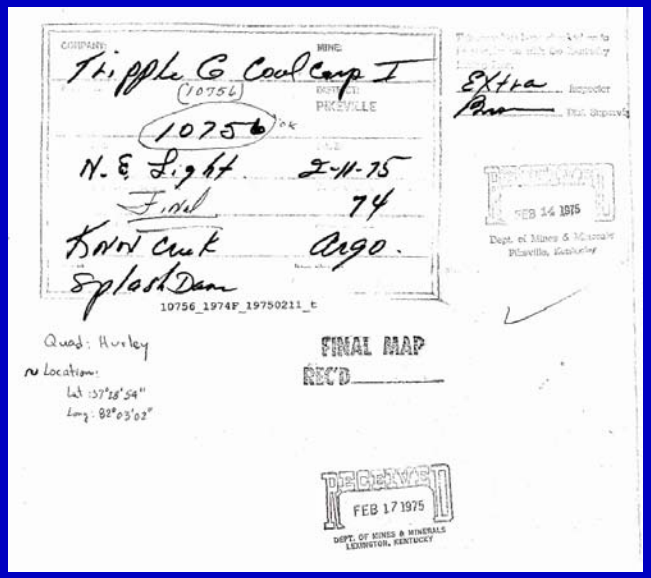
Zipped Package for Web Deployment



Rectified GeoTiff (TIF)

```
0.50000
0.00000
0.00000
-0.50000
5993651.00000
3722031.00000
```

World File (TFW)



Transmittal Information (JPG)

```
MapName=10756_1974F_19750211
SourceScannerName=Minescan1
SourceImageFileFormat=JPEG
SourceImageDateTime=11/10/2004 1:42:17 AM
Stage1CleanupUser=schubert
Stage1CleanupCPU=MINEMAPPER1
Stage1CleanupDateTime=11/10/2004 09:49:39
Stage2CleanupUser=bemis
Stage2CleanupCPU=MINEMAPPER2
Stage2CleanupDateTime=3/28/2005 2:21:41 PM
MapScanResolutionDPI=200
MapScanWidthInches=31.580
MapScanHeightInches=30.410
OriginalColorMode=RGB
ColormapCPU=C140SISO0020015
ColormapDateTime=3/29/2005 1:02:42 AM
RegistrationDateTime=5/19/2005 4:15:21 PM
RegistrationUserName=bunch_b
RegistrationCPU=C140SISO0020015
RegistrationType=MapCoordinateSystem
MapCoordinateSystem=LocalSystem
MapDatum=None
MapUnits=AssumedFeet
X_Translation=5,984,299
Y_Translation=3,709,340
MapDatum=NAD83
MapUnits=USFt
MapScale=100
MapGridSpacing=1000
```

Metadata File (TXT)

Kentucky's Mine Mapping Initiative

Map Scanning

Bryan W. Bunch, PLS, PG
Systems Consultant IT
Kentucky EPPC-OIS-GIS
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502-564-5174
Bryan.Bunch@ky.gov

Kentucky
UNBRIDLED SPIRIT™

Scanning Goals

- Capture the visual essence of the original map as best as possible within practical limitations.
- Minimize file and memory footprint while maintaining adequate visual quality.
- Result stored in a file format that can be read by a broad array of image viewers, GIS environments, and CAD applications.
- For viewing: 24 Bit JPEG, High Quality.
- For GIS/CAD: 8 Bit GeoTIFF, Packbit.

Scan Settings

- There is no one combination of scan settings that fits all scanners. The best way to establish scan settings is by vigorous trial and error. While this approach is tedious and time consuming, it also provides a good way to gain knowledge and experience on how various combinations of settings affect the output quality and file size of resulting images.

File and Memory Footprint

- The file footprint is the size of the image file stored on a digital medium and varies based upon compression method used.
- The memory footprint is the amount of memory required to load and display the image. The memory footprint is determined by the number of pixels in the image multiplied by the pixel depth.

Resolution and Memory Footprint

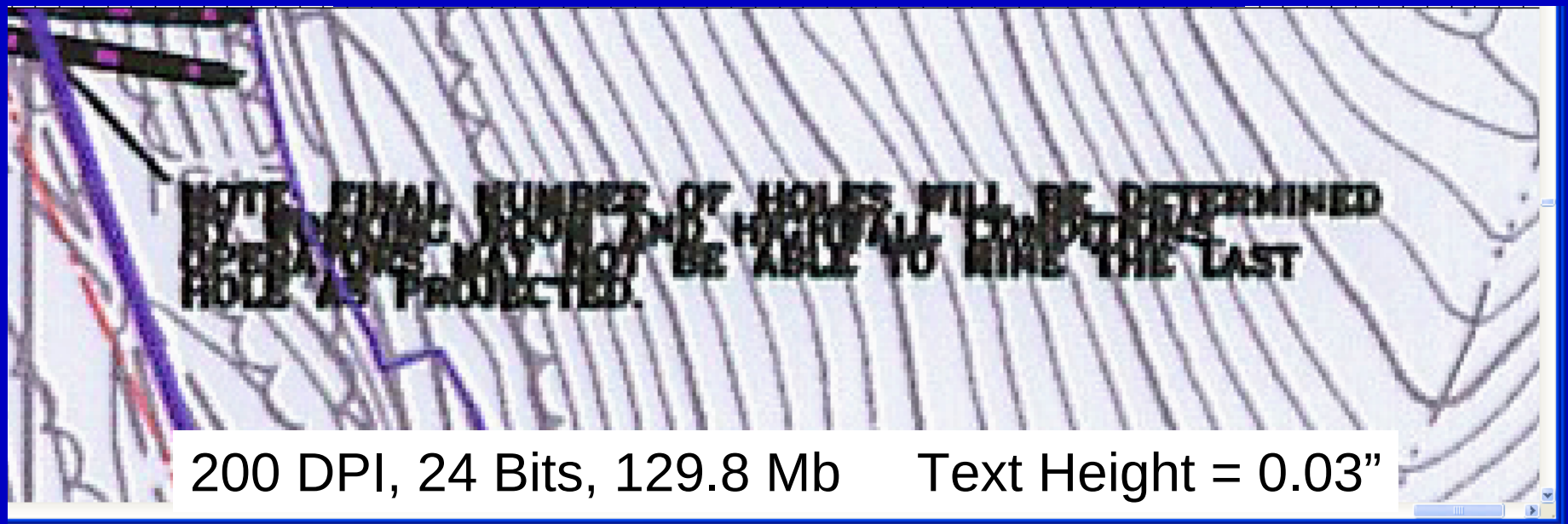
42” x 60” Map Scanned @ 24 Bits Per Pixel

100 DPI (0.01”)	72.1 Mb
200 DPI (0.005”)	288.4 Mb
300 DPI (0.003”)	648.8 Mb
400 DPI (0.0025”)	1,153.6 Mb

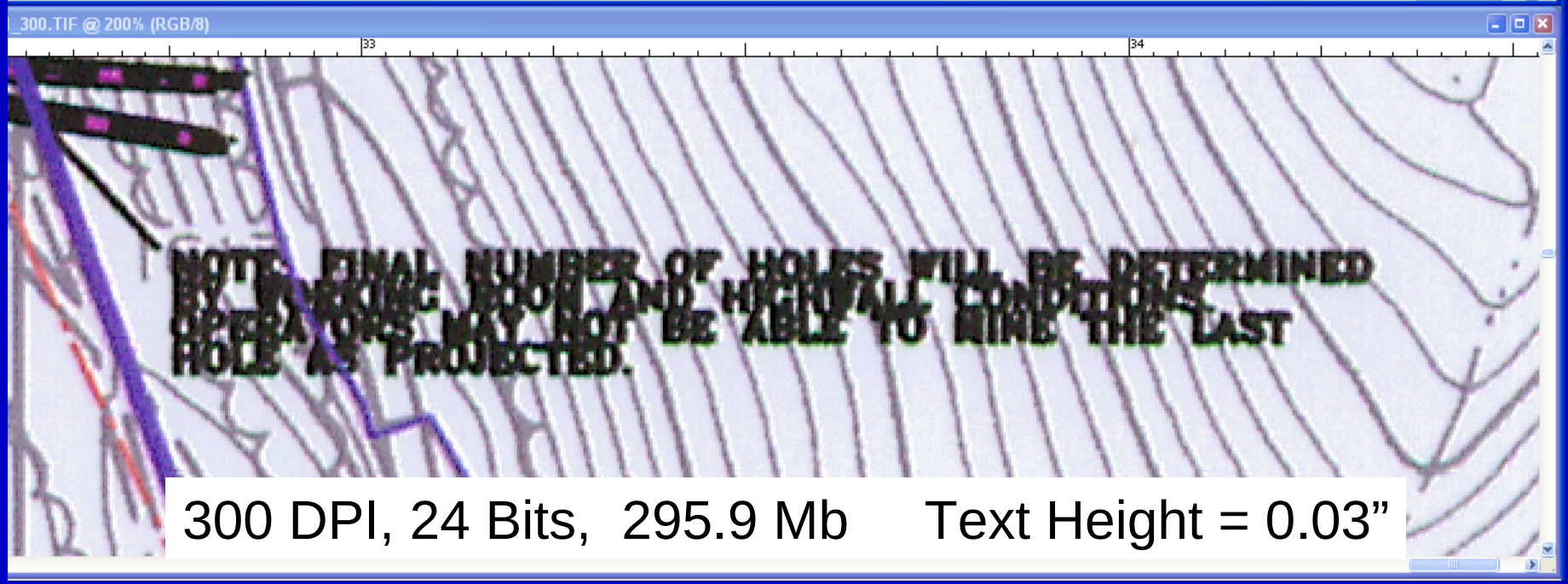
Compression Schemes

- TIFF PackBit – Lossless scheme that exploits repetition of pixel values to reduce the file footprint. The original pixel matrix is preserved when decompressed.
- JPEG – A robust scheme based on a variable quality scale that achieves far greater compression, but at the expense of preserving the original pixel matrix (lossy). JPEG lossless (full quality) is similar to PackBit, but more aggressive.

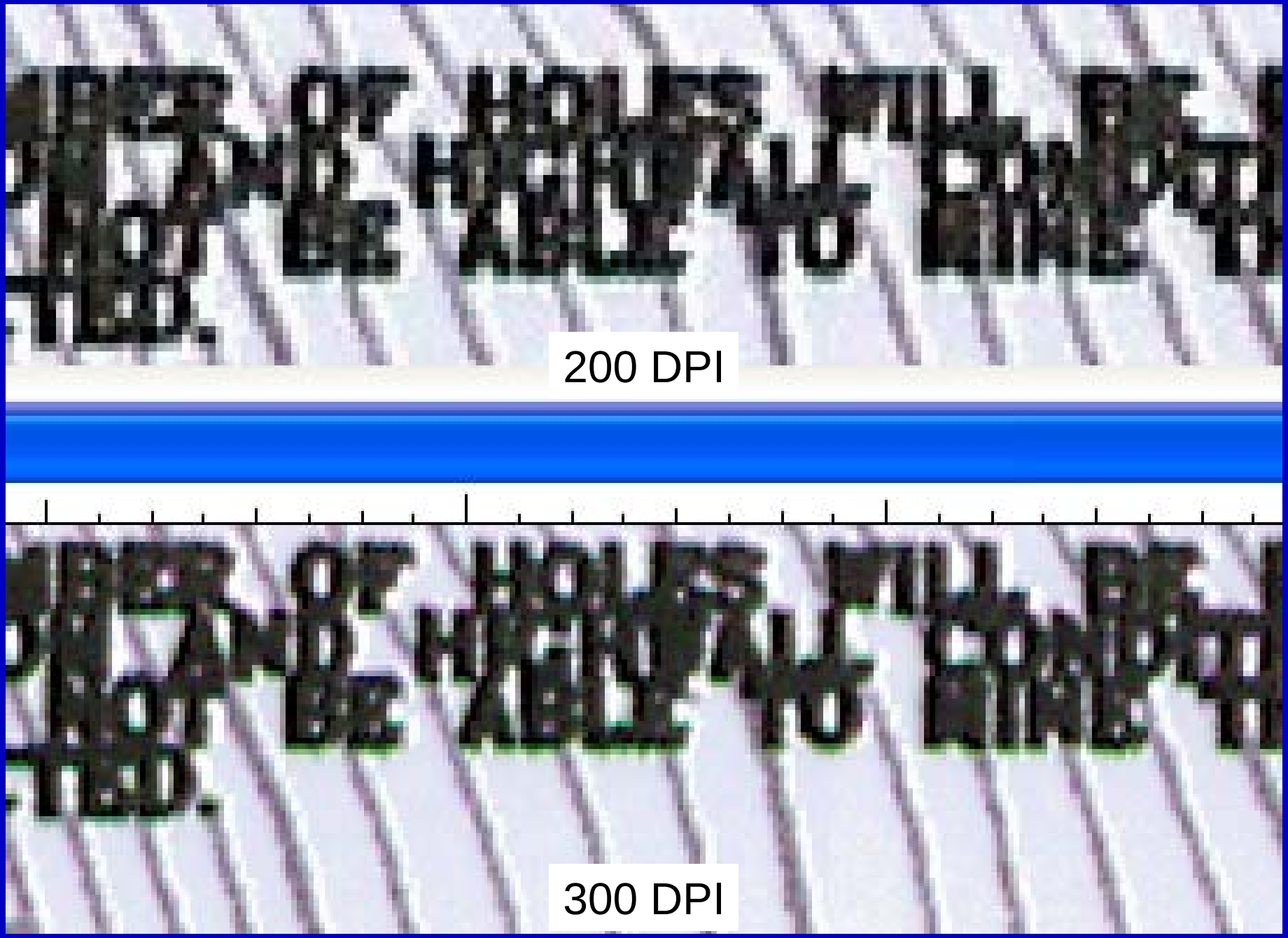
SCANNED UNCOMPRESSED TIFF



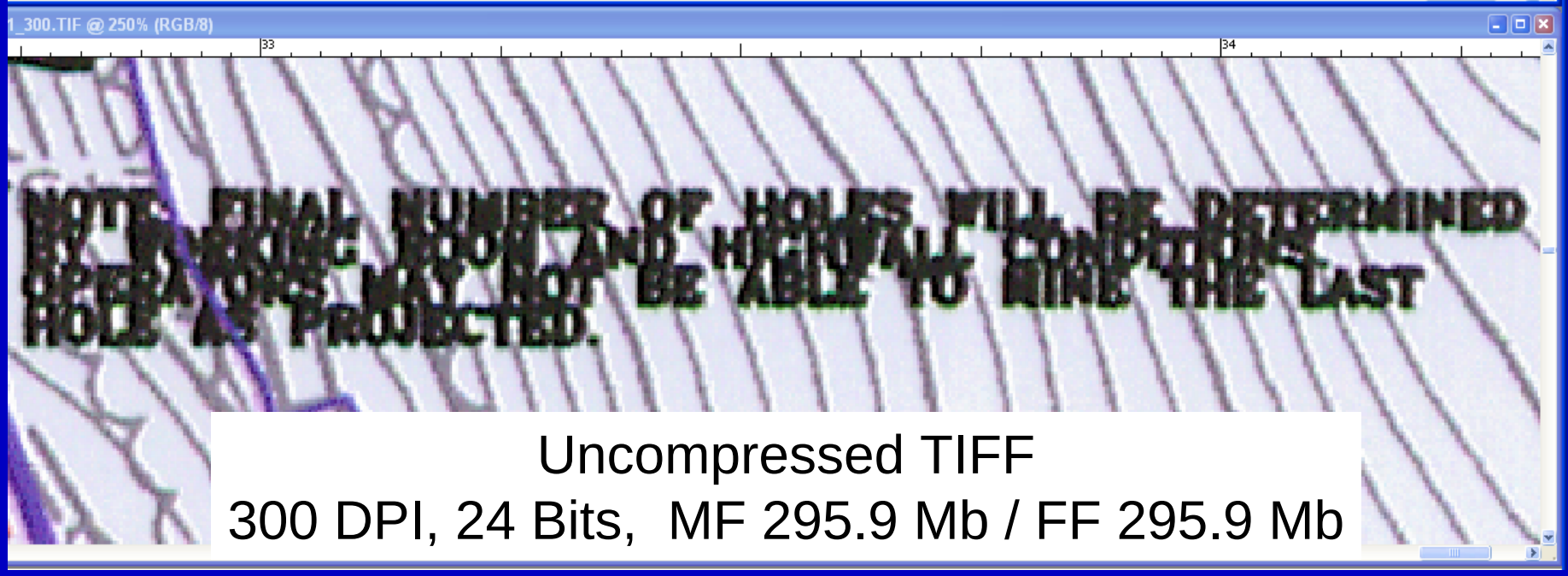
200 DPI, 24 Bits, 129.8 Mb Text Height = 0.03”



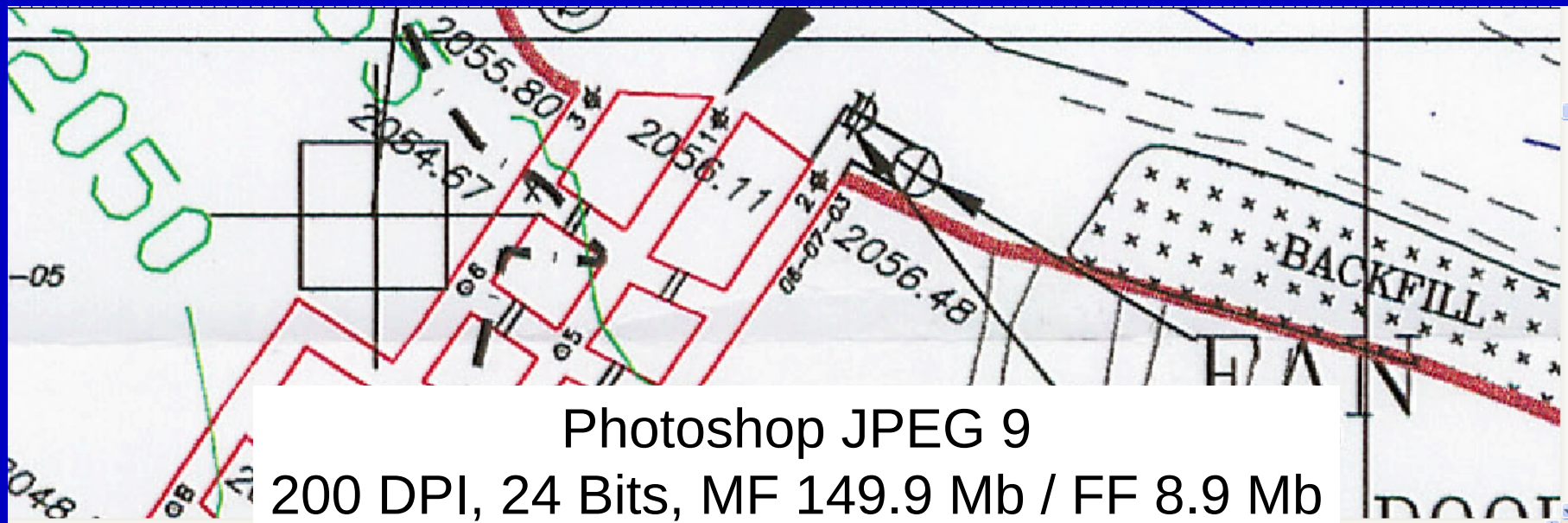
300 DPI, 24 Bits, 295.9 Mb Text Height = 0.03”


200 DPI
300 DPI

Photoshop JPEG 9
200 DPI, 24 Bits, MF 129.8 Mb / FF 19.7 Mb

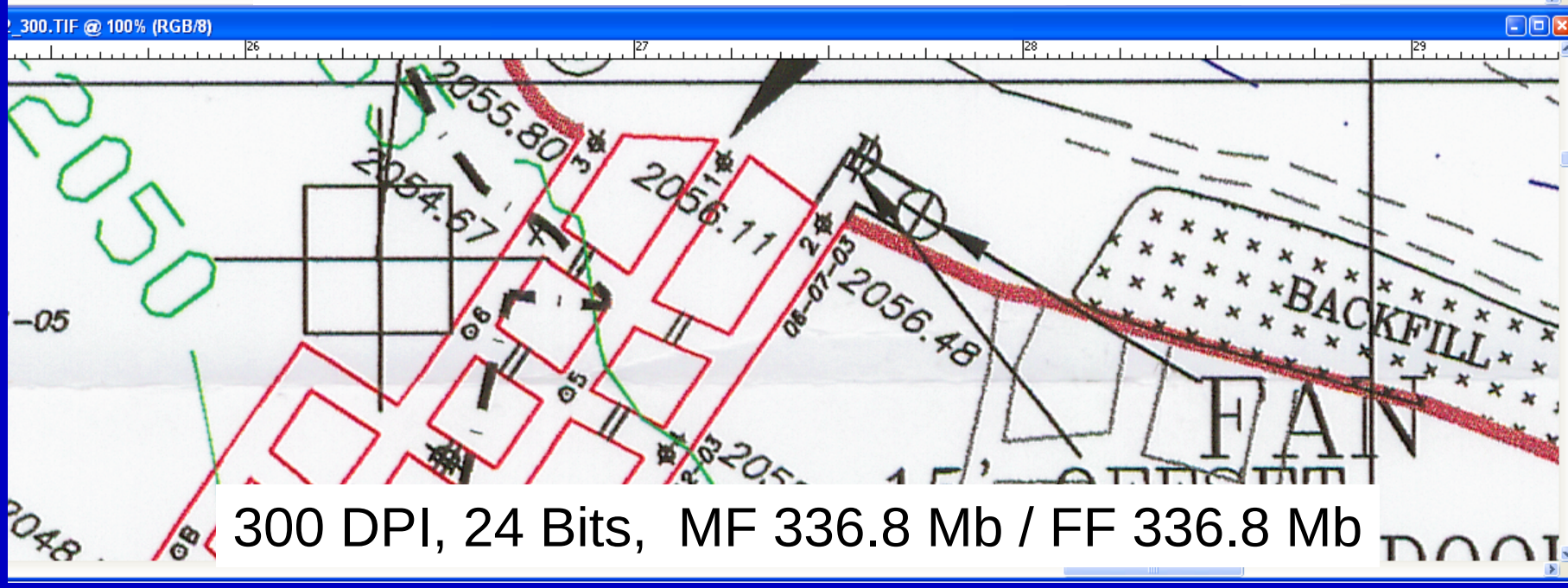


Uncompressed TIFF
300 DPI, 24 Bits, MF 295.9 Mb / FF 295.9 Mb

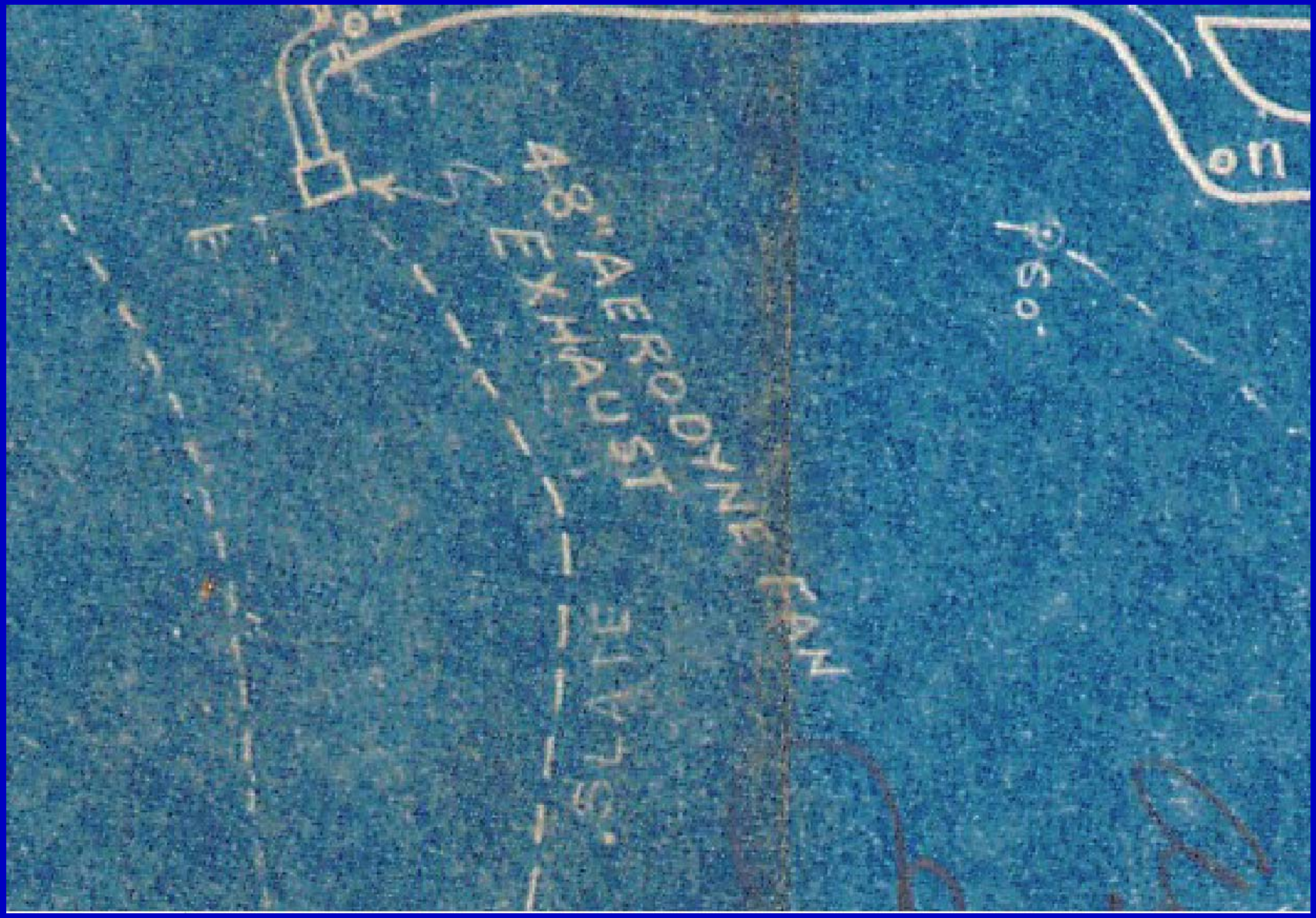


Photoshop JPEG 9

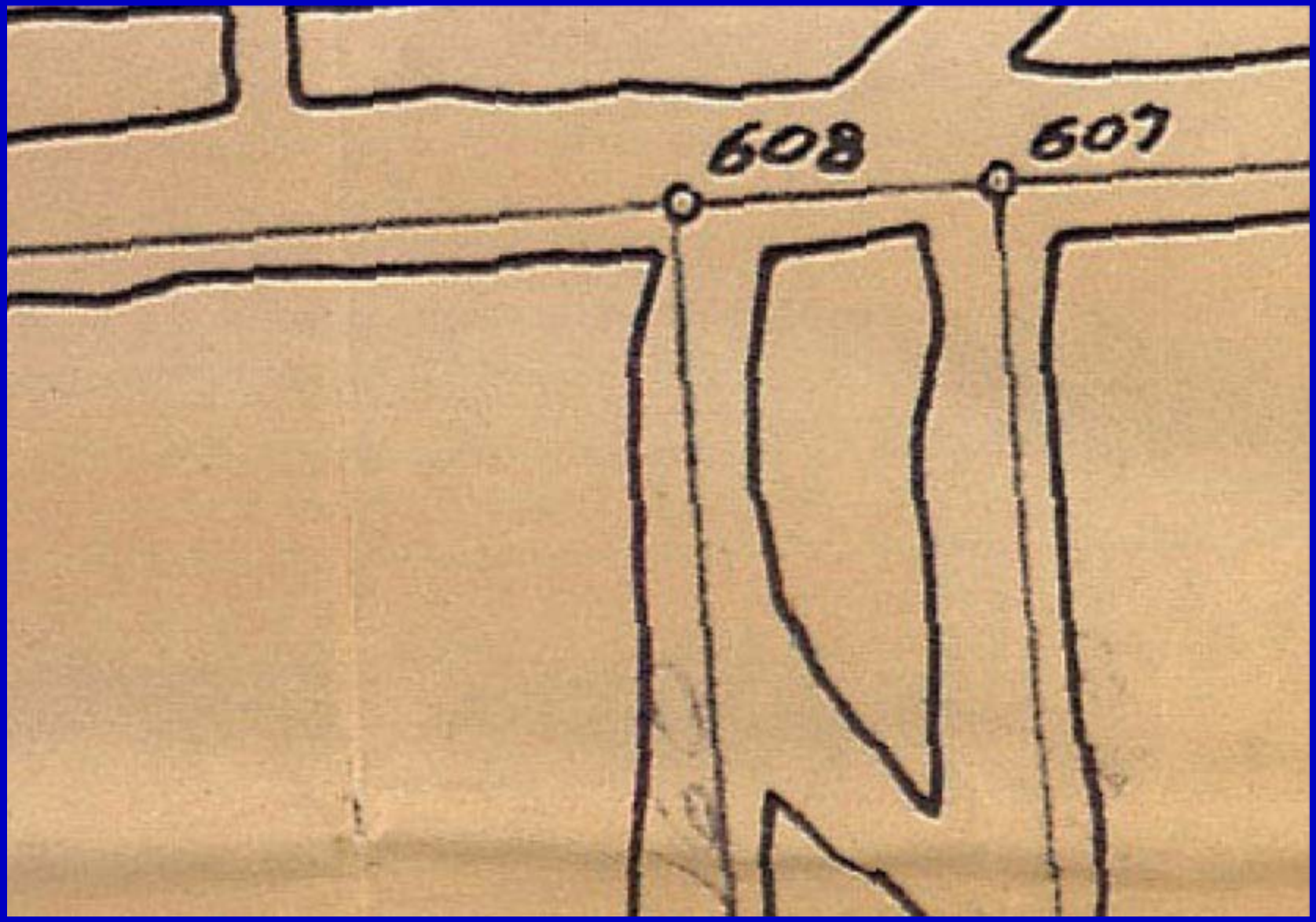
200 DPI, 24 Bits, MF 149.9 Mb / FF 8.9 Mb



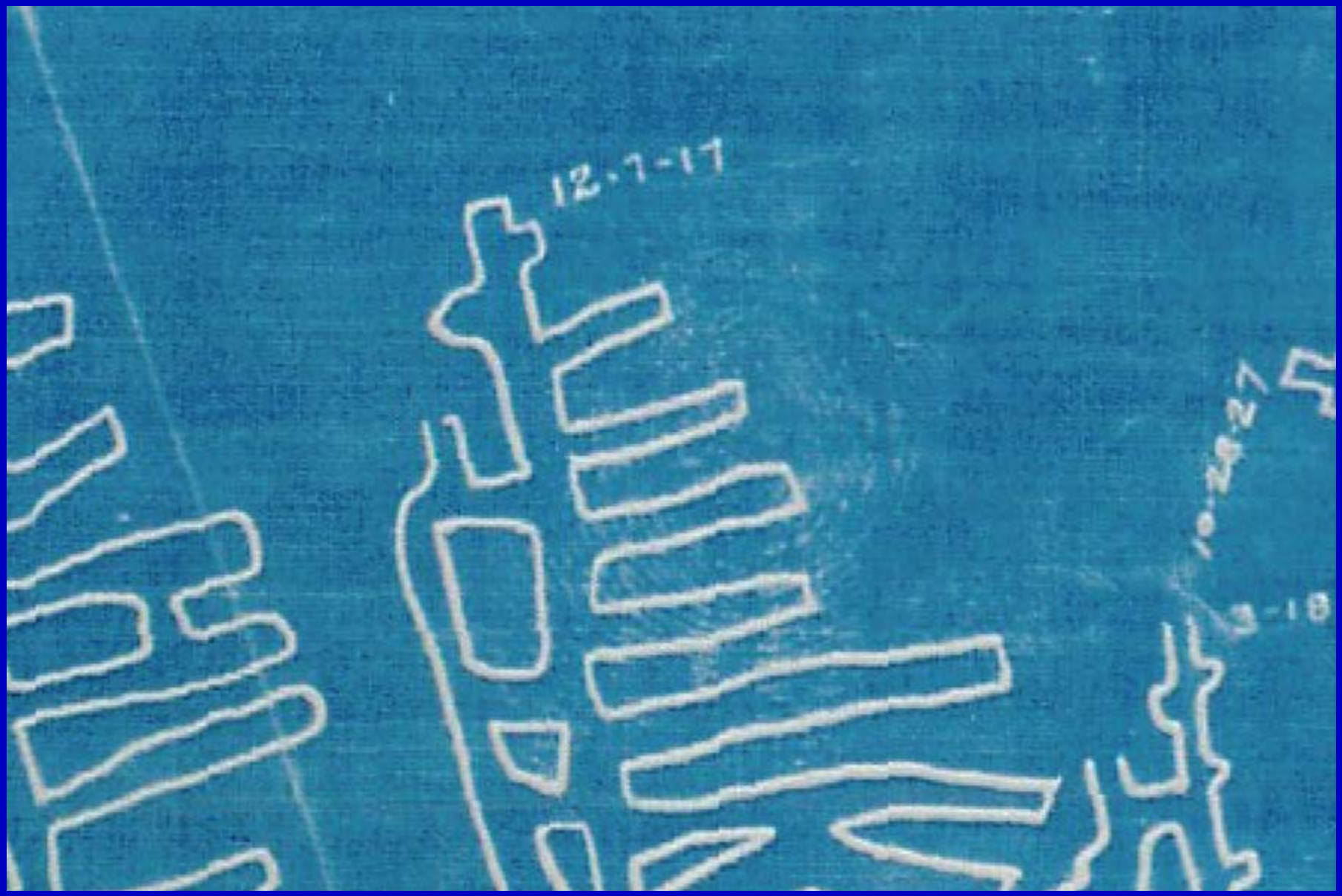
300 DPI, 24 Bits, MF 336.8 Mb / FF 336.8 Mb



200 DPI, JPEG PS9 @ 200% 55.4 Mb / 7.92 Mb

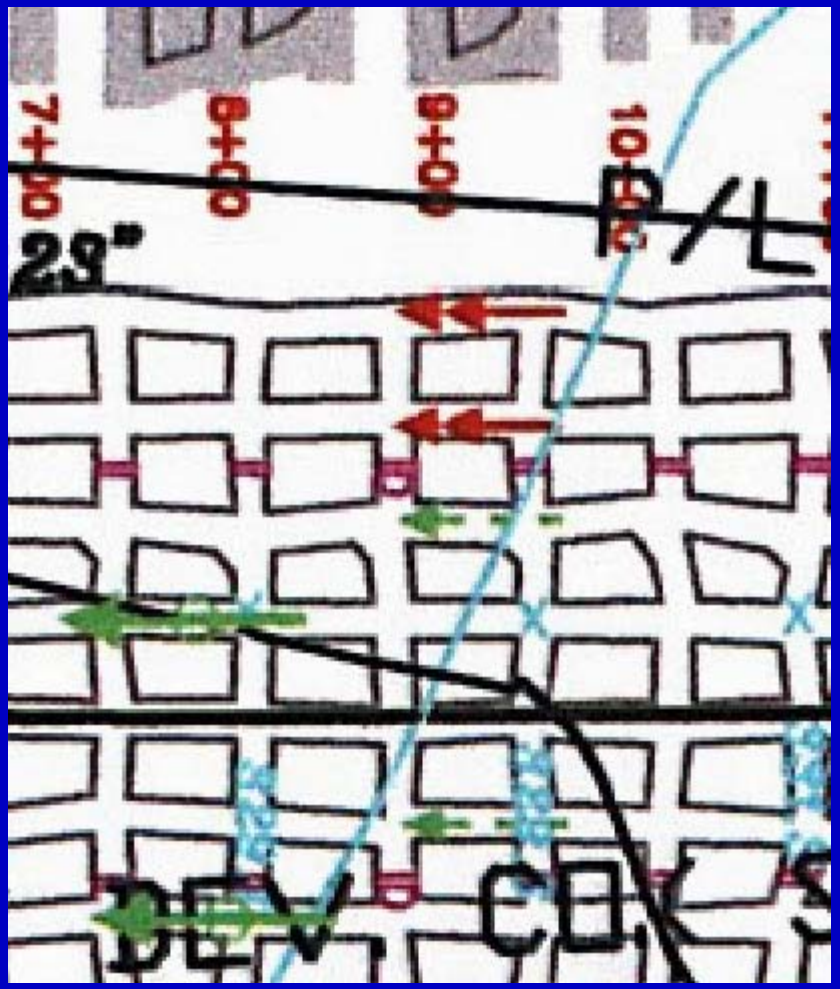


200 DPI, JPEG PS9 @ 200% 466.7 Mb / 43.0 Mb



200 DPI, JPEG PS9 @ 200% 362.9 Mb / 30.2 Mb

Post-Processing: Color Indexing



24 Bit

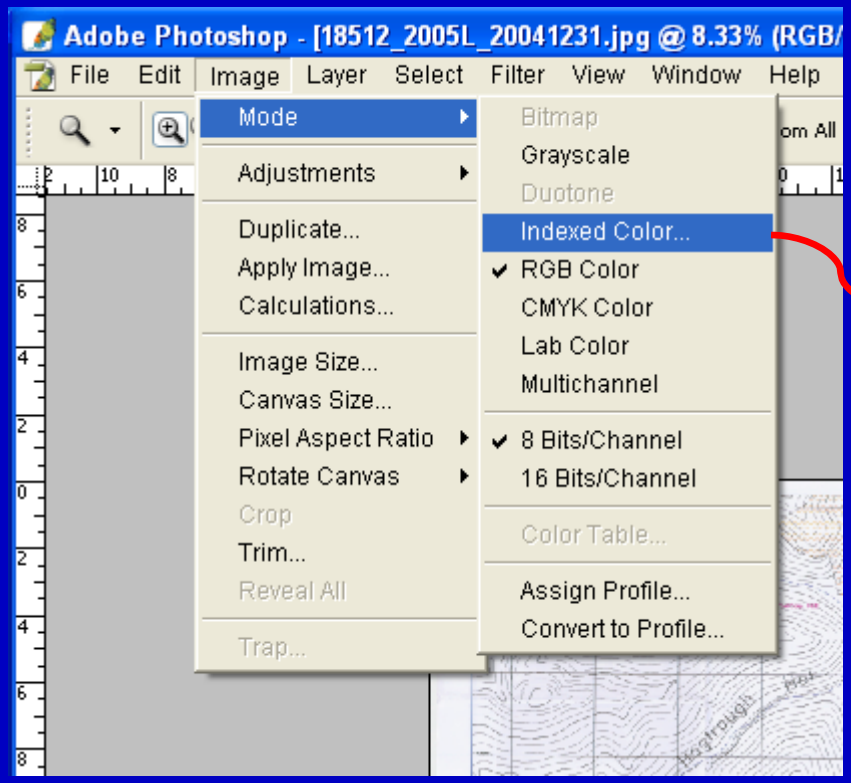
MF = 200.0 Mb

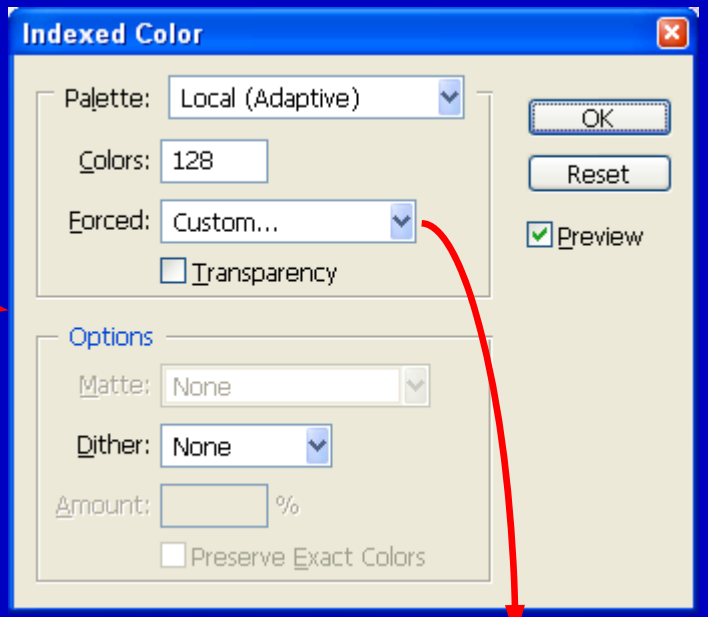
8 Bit / 128 Colors Adaptive

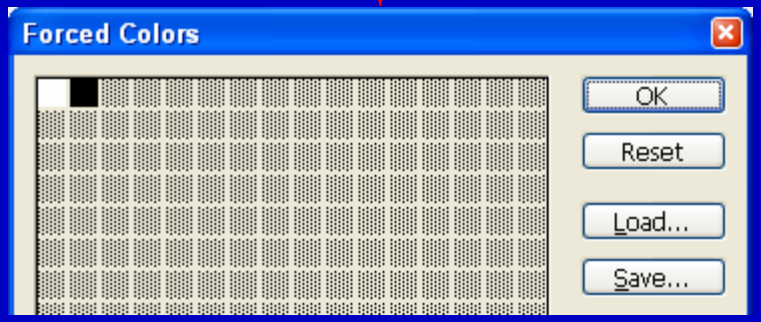
MF = 66.7 Mb / FF 29.0 Mb

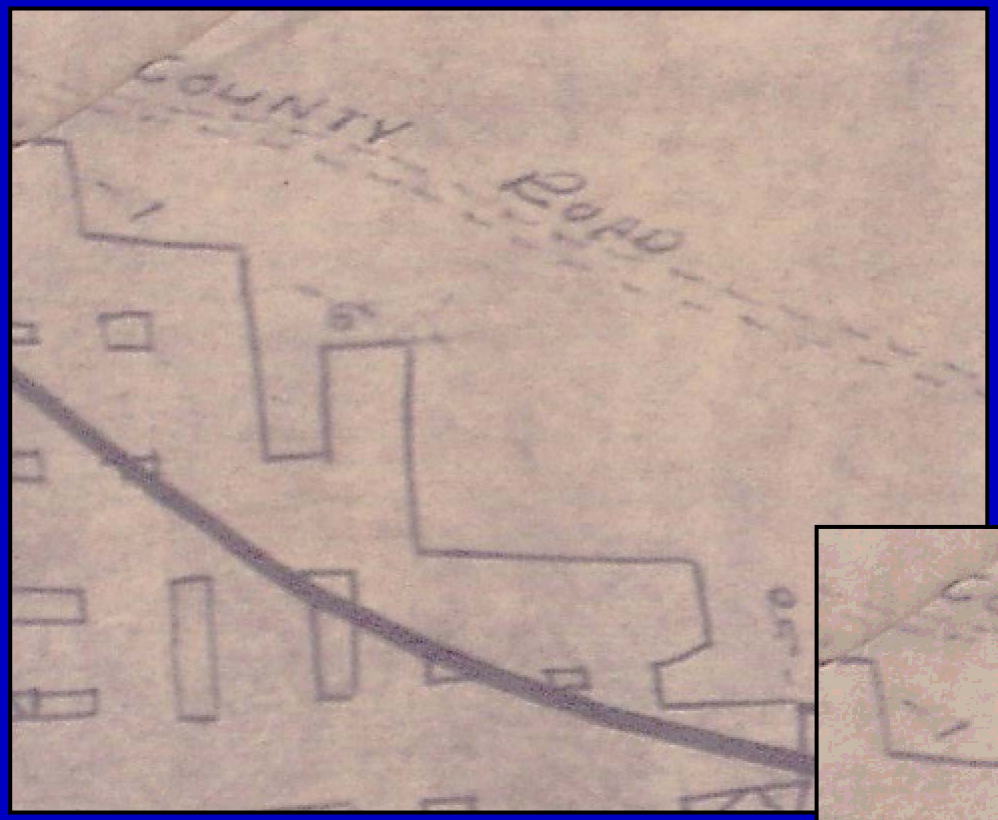
Color Indexing in Photoshop

- Convert RGB Mode to Indexed Color
- Reduce to Best-Fit (Local Adaptive) 128 Colors
- Force White = 0 and Black = 1 (Monobit Scheme)

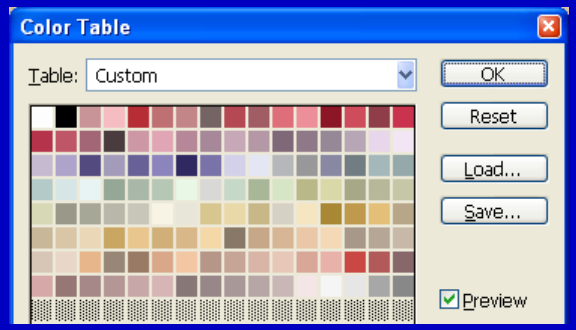


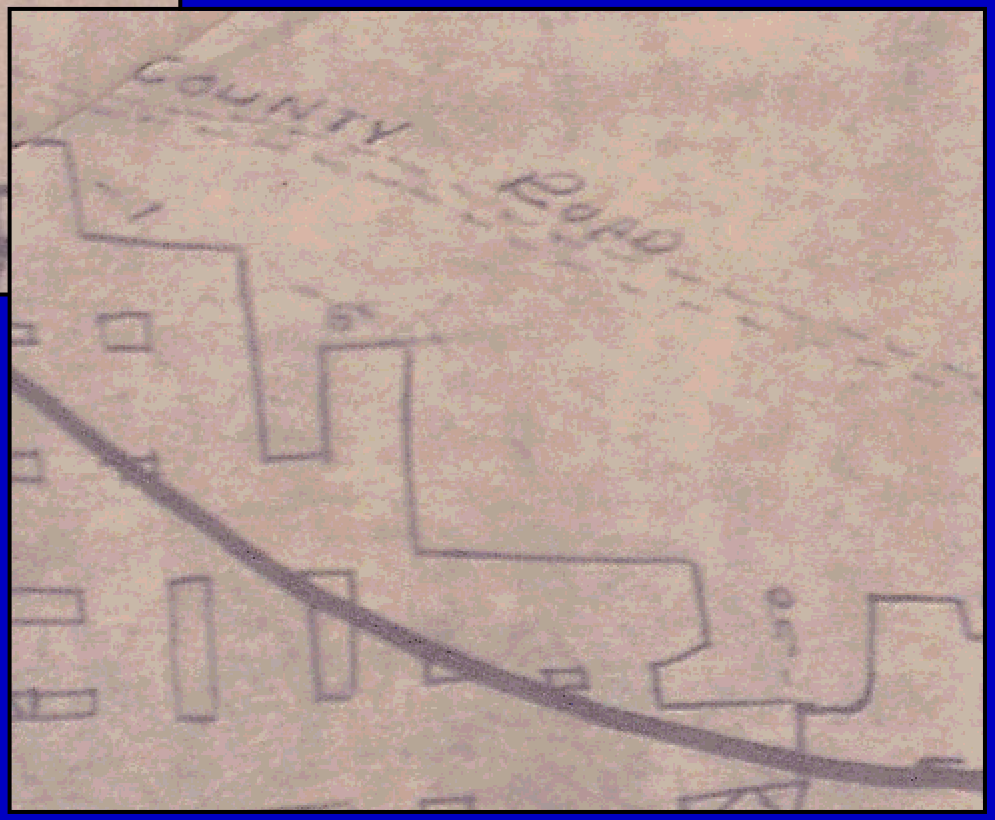




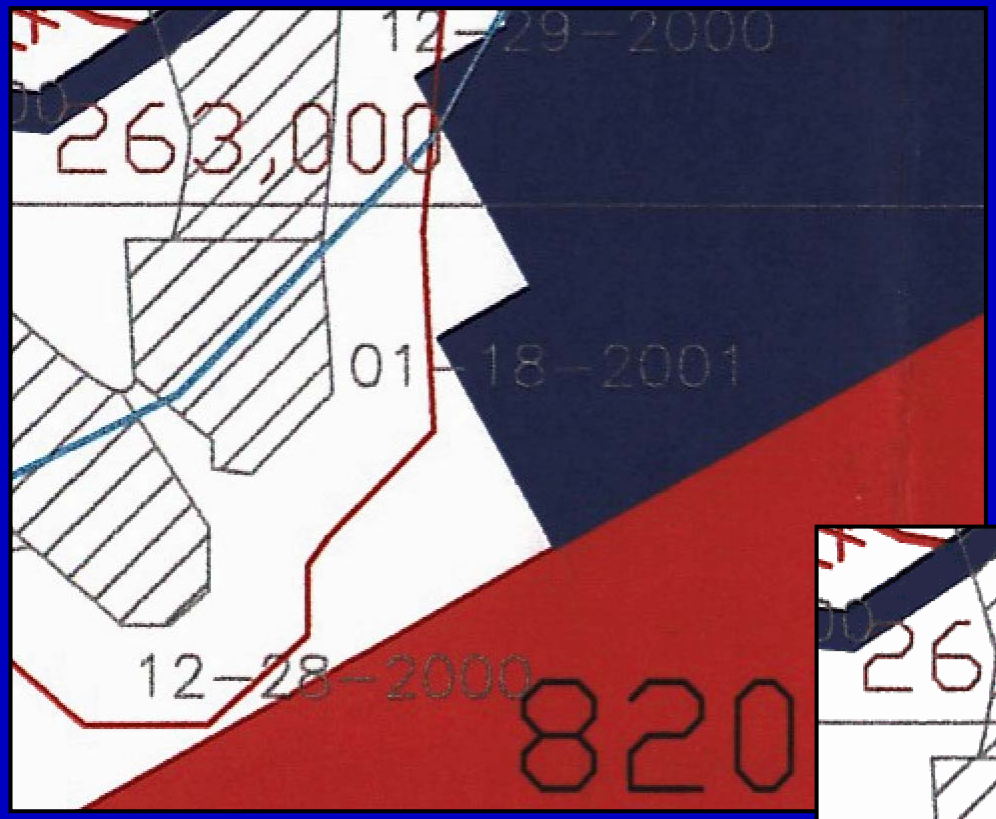


RGB Color Mode

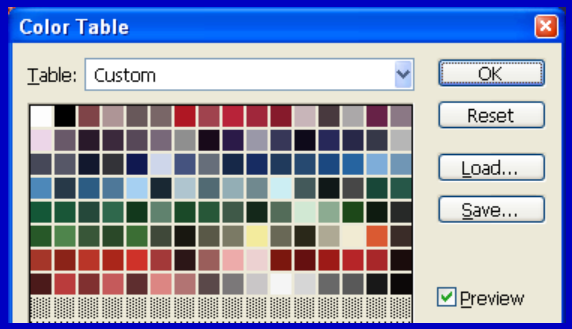




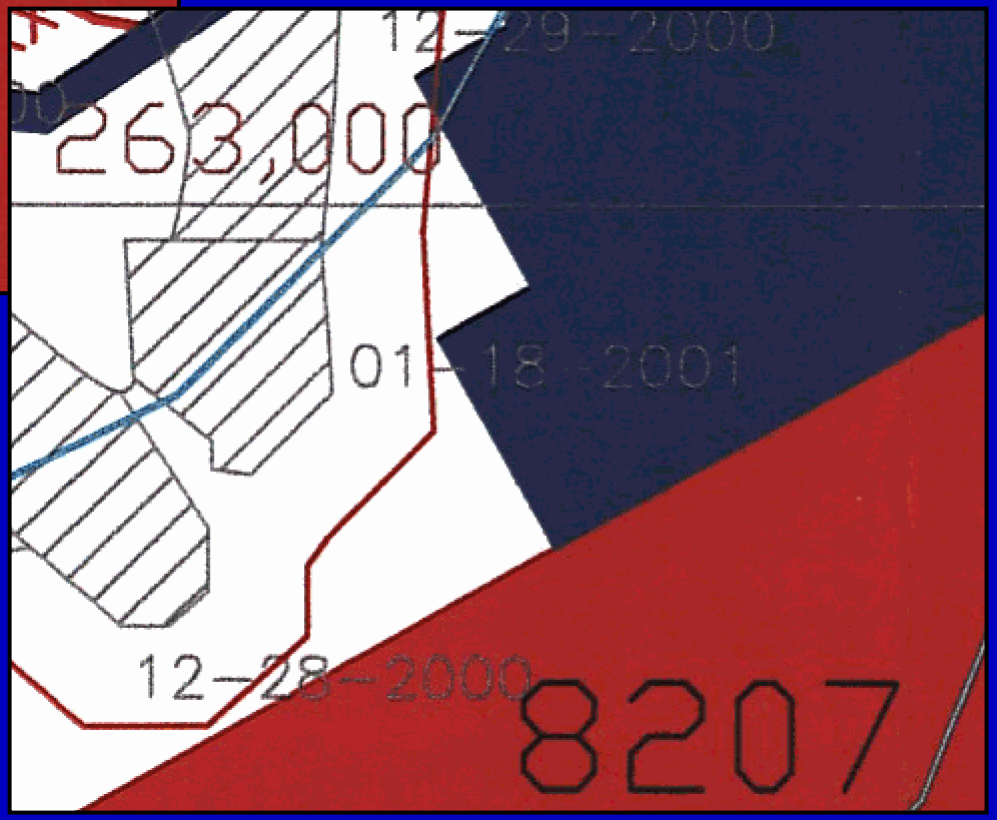
Indexed Color Mode
128 Color Adaptive

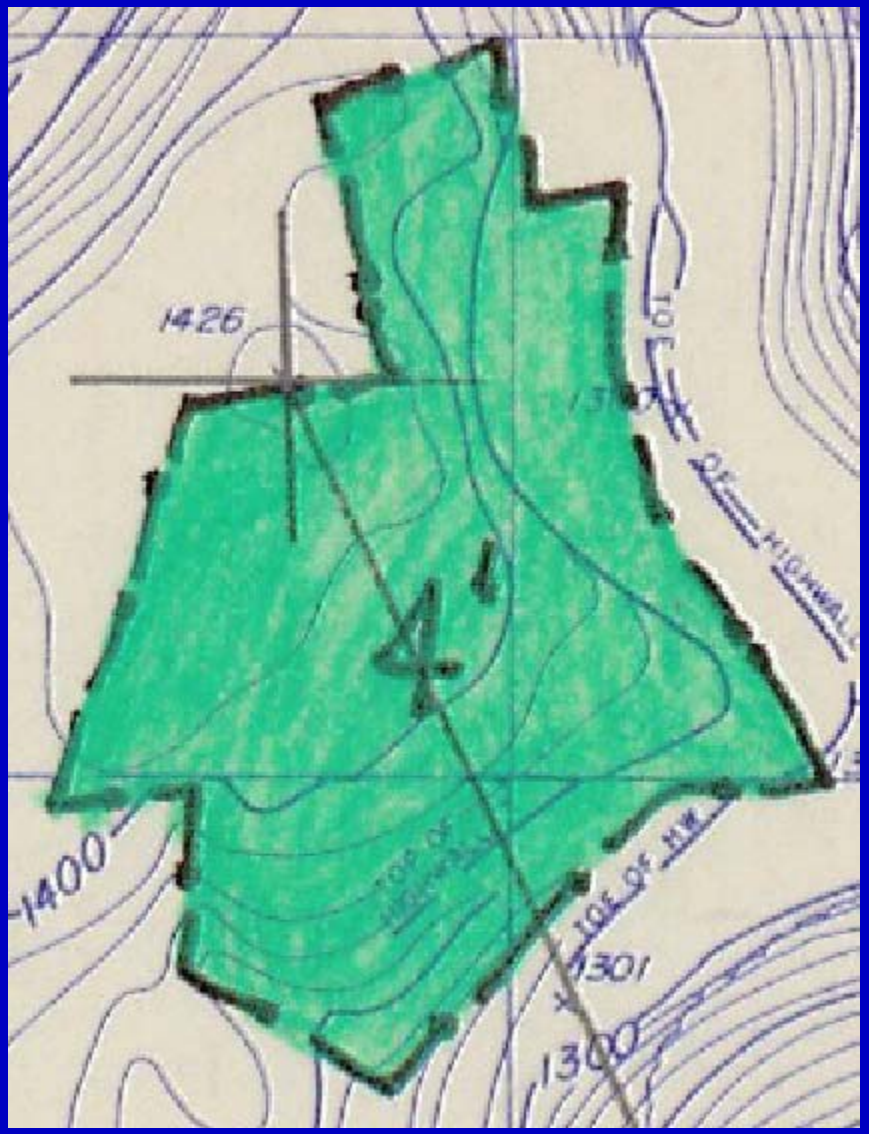


RGB Color Mode

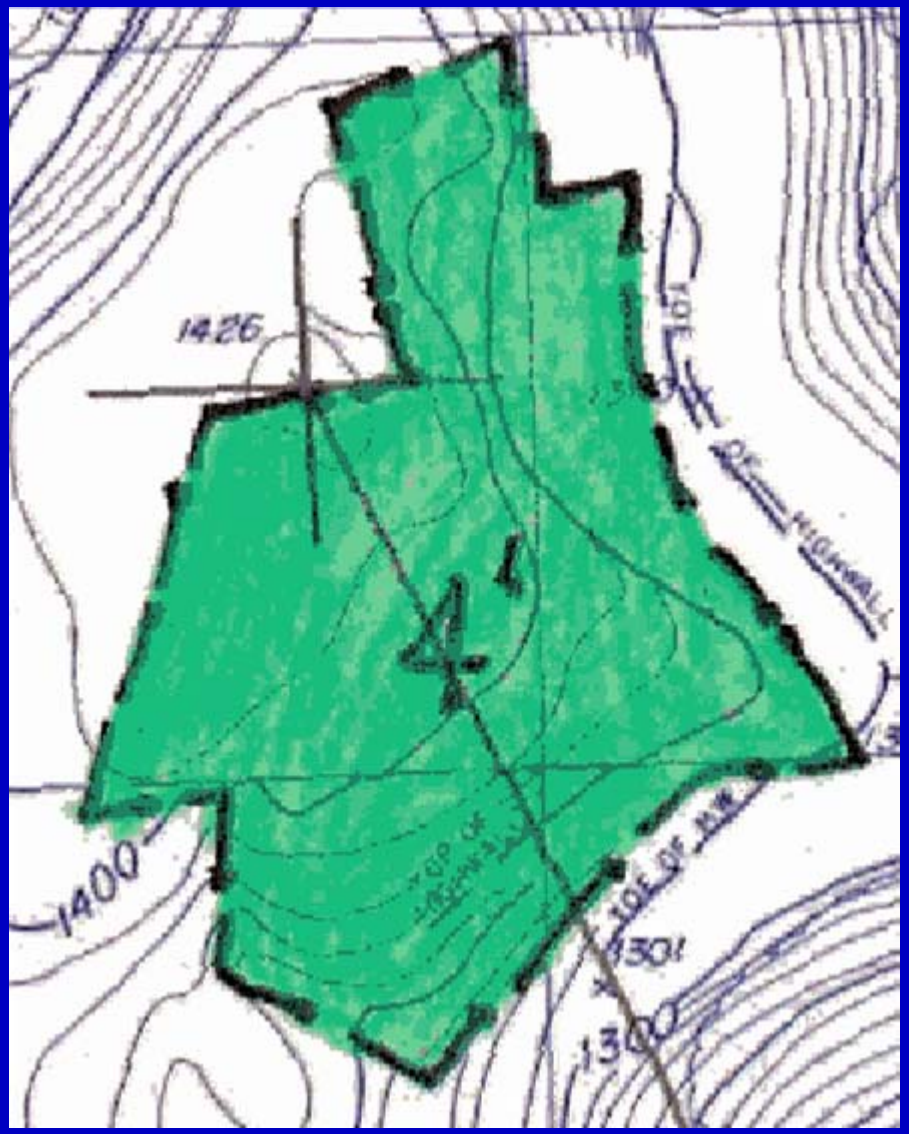


Indexed Color Mode
128 Color Adaptive





24 Bit
MF = 145.0 Mb



8 Bit / 128 Colors Adaptive
MF = 51.6 Mb / FF 17.9 Mb

PANEL IV
DATA DELIVERY

DATABASE USER INFORMATION: FORMS AND MANIPULATION

CHARLES E. BANKS --- Ohio Division of Geological Survey, Columbus, Ohio

The Underground Mine Mapping Workshop
June 1 & 2, 2005
Pittsburgh, Pennsylvania USA

DATA DELIVERY

Providing:

Project Assistance Via Contracted Work

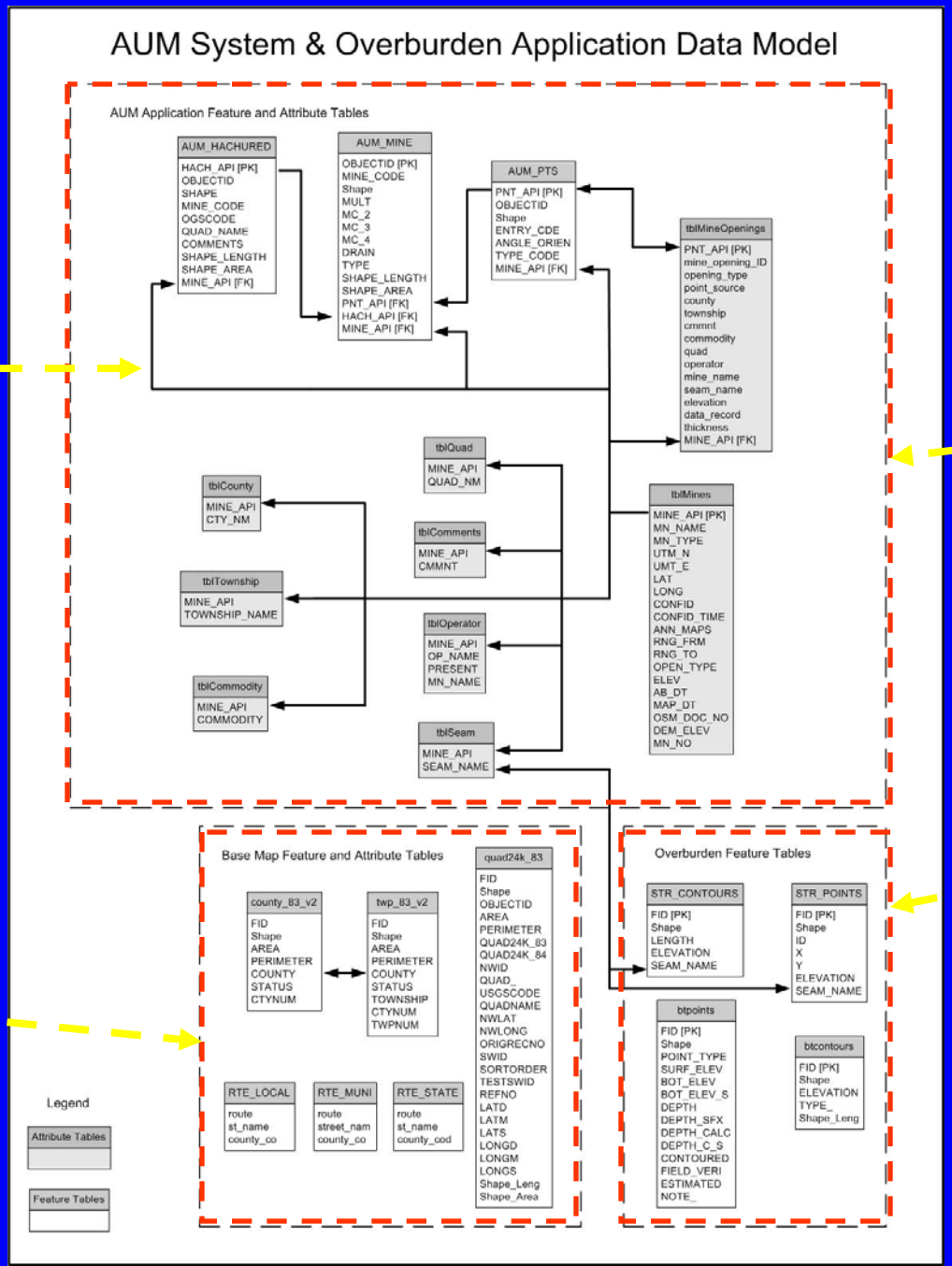
GIS and Geological Information

GIS Data

GIS Maps

to state agencies such as ODOT

AUM Data Model



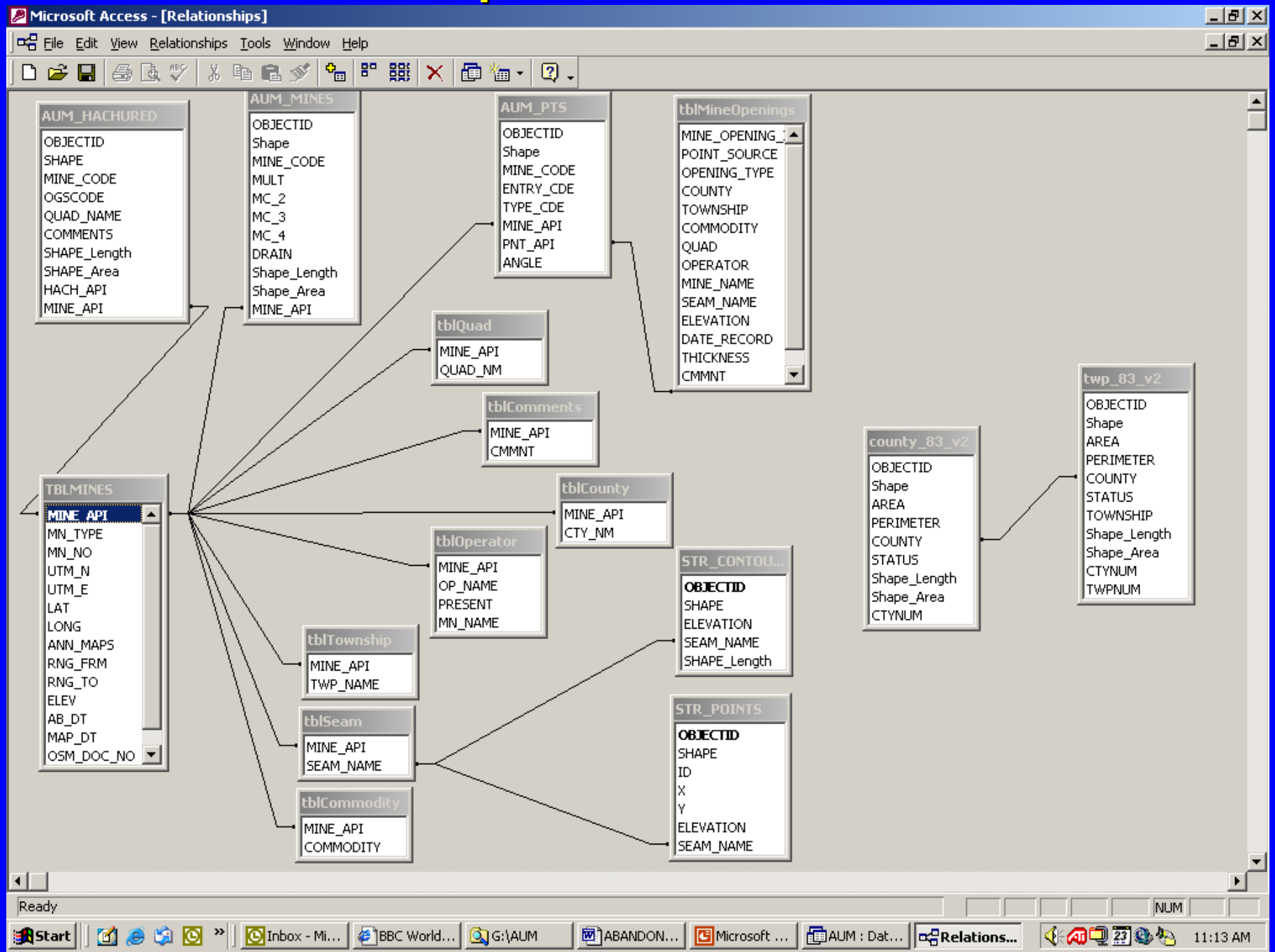
Relationship Links

AUM Feature Class and Attribute Tables

Overburden Feature Tables

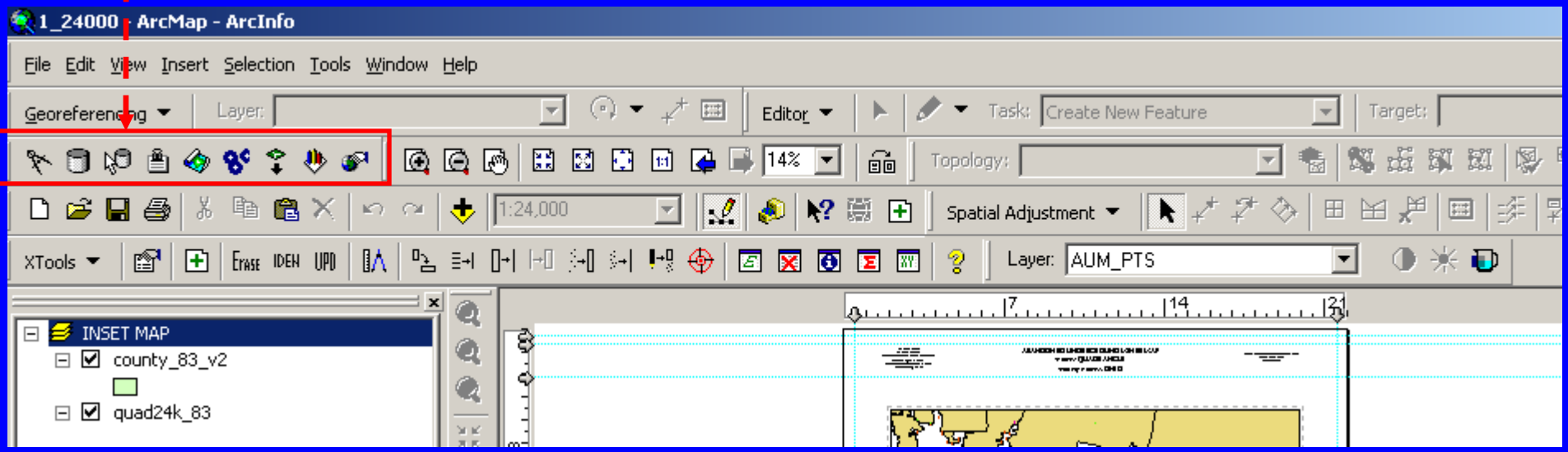
Base Map Feature Class and Attribute Tables

AUM Data Model Implementation in Microsoft Access

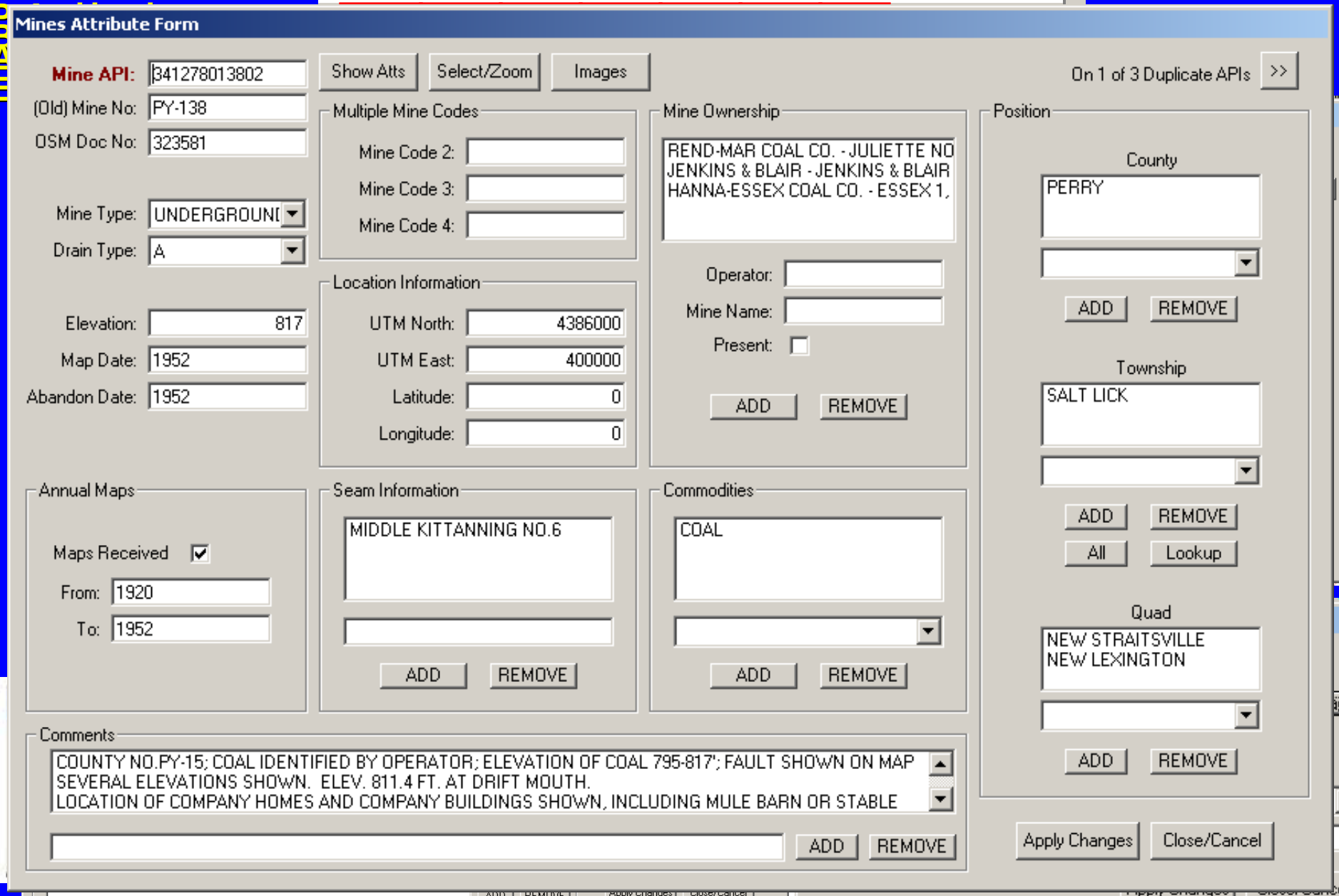


The AUM and Overburden Application Toolbar

Placement Within the ArcGIS ArcMap Environment

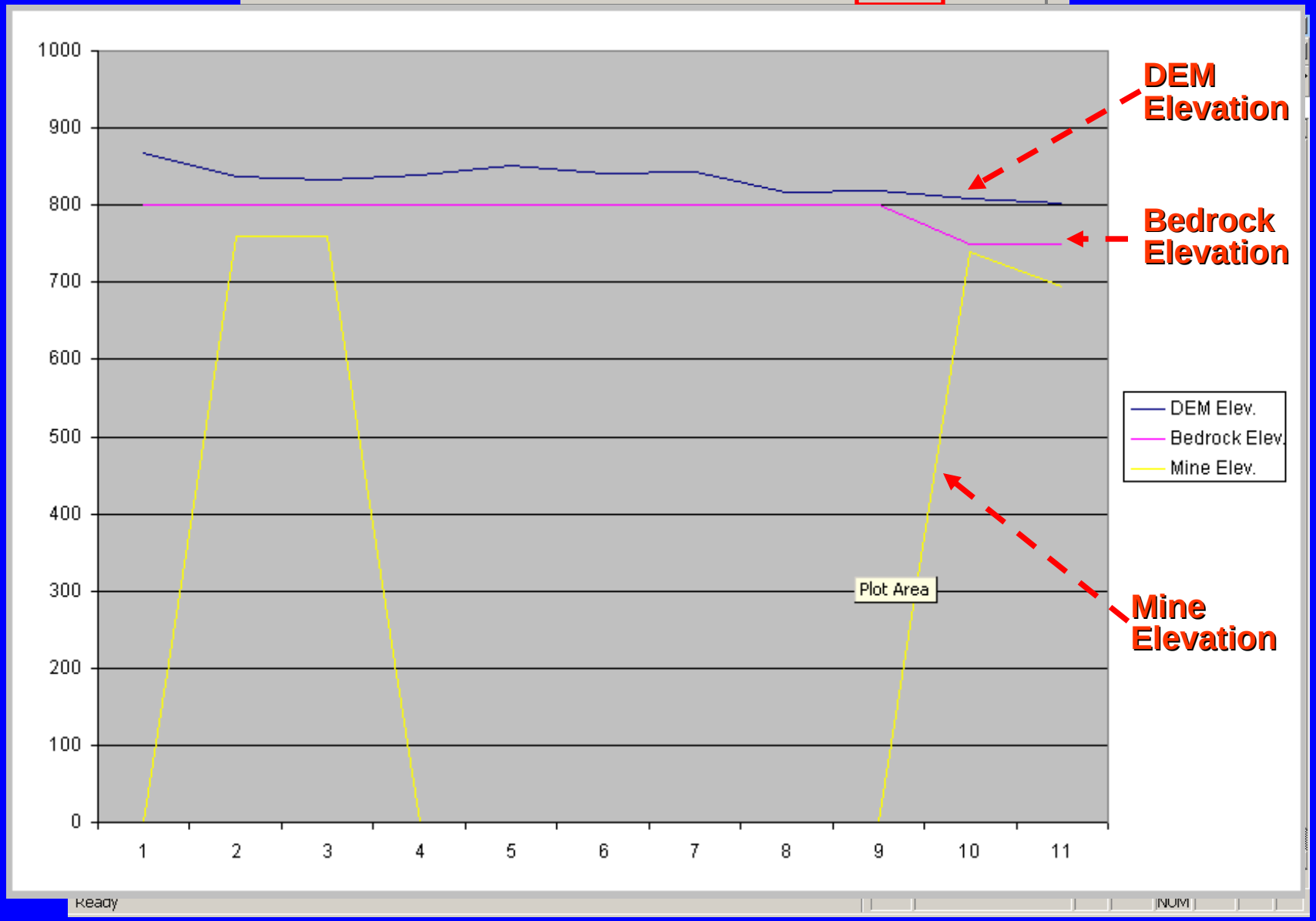


The AUM and Overburden Application Toolbar Tools



The AUM Overburden Application Tool

Query/Zoom Tool



The AUM Plotting Tools

The ‘DRG’ , 1:24000 Loader

Quadrangle Selection Box

Mine Images Tool for the 1:24000 Map

County or Region Selection Tool

Adobe Reader - [ME_001.pdf]

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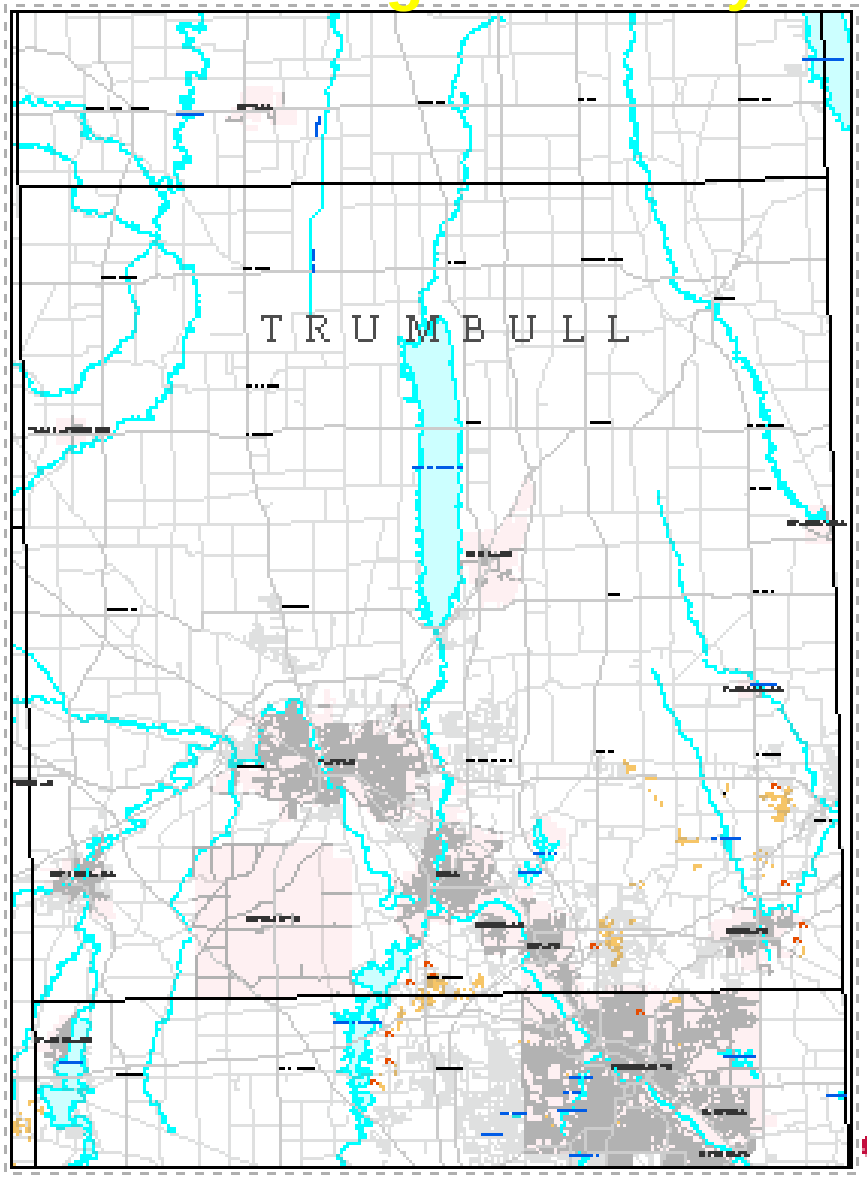
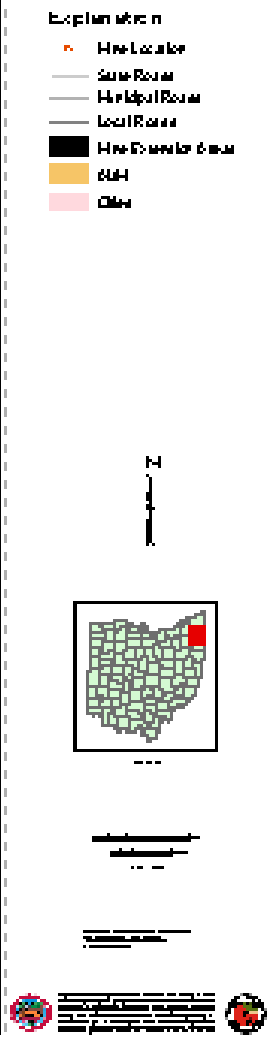
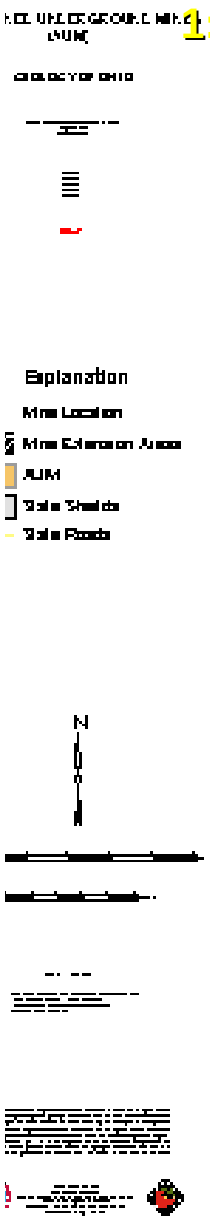
- Abandoned Underground Mine Maps Provided by the Ohio Geological Survey







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Portrait

1: 250,000

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Landscape

Locating and Accessing Mine Maps

Underground Mine Mapping Workshop

June 1st & 2nd 2005

Pittsburgh, PA

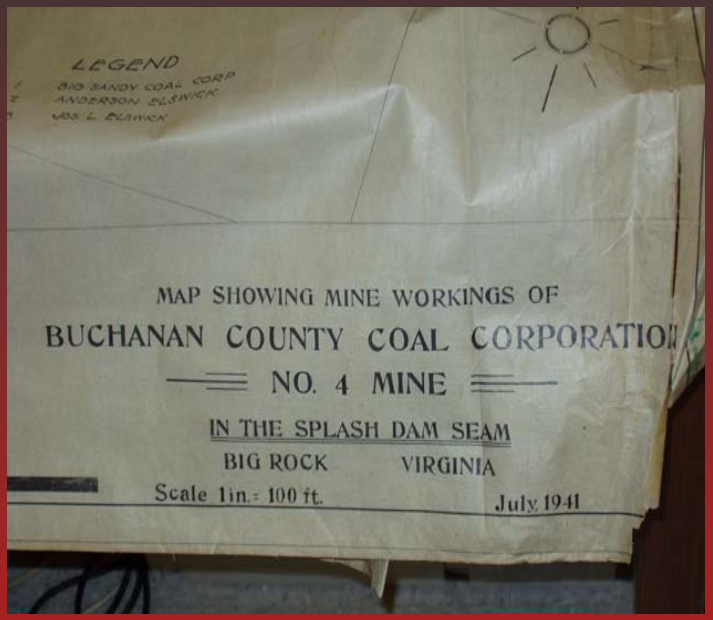
Introduction

Virginia's map acquisition process:

- Finding the mine maps – physical location and ownership
- Hardcopy acquisition – off-site & on-site scanning

Locating

- Actively pursue map collections
- Promote project
- Provide incentives

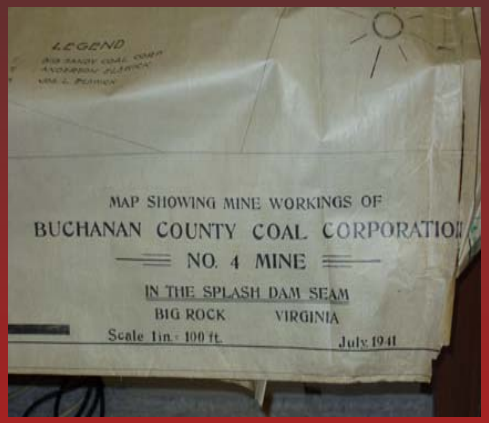


The archive is comprised of detailed underground mine maps from the mining industry, private collections, engineering firms, land offices, the Office of Surface Mining mine map repository, along with DMME existing mine map collections.

Access to Maps

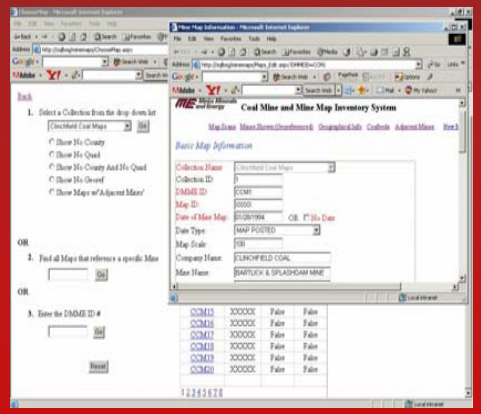
- Make it as painless as possible for lenders
- Clearly define terms of use
- Be flexible – time, location, deliverables

Virginia's Mine Map Archive contains over 40,000 mine map images that are cataloged by significant mine information, with massive information search capabilities.



Collect

Scan



Catalog

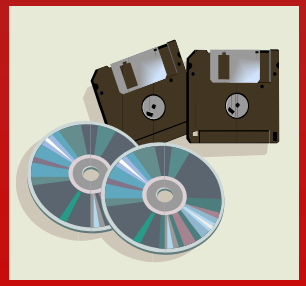
Map Information - Catalog

Deliverables

Map contributors have benefited by loaning DMME maps. Once the scanning and cataloging is complete, the maps are returned along with a digital archive, searchable spreadsheet and map inventory of their collection. The digital archive is delivered on DVD, CD, or digital down load.

F11 =

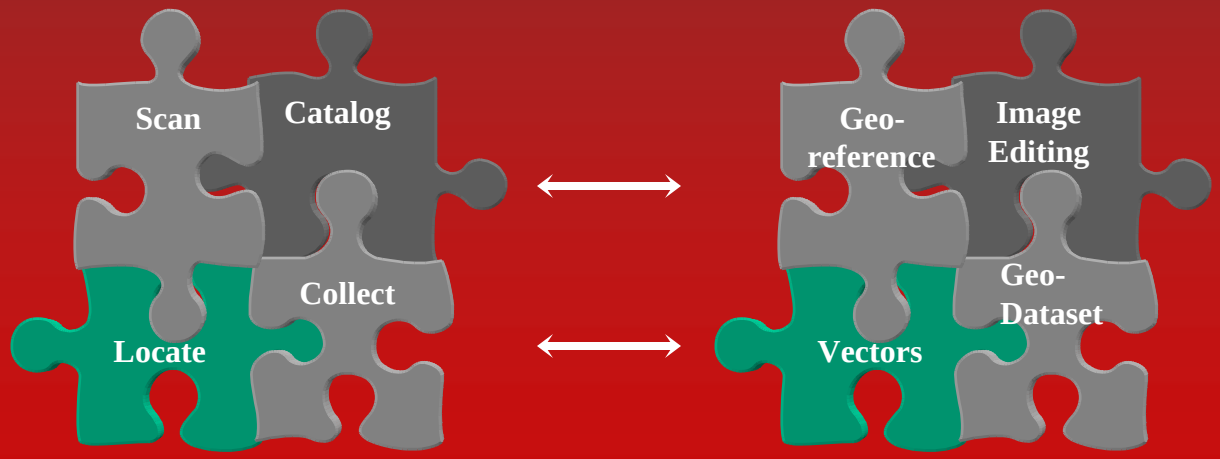
	A	B	C	D	E	F	G
1	MAP. NO	DMR NO	DM NO.	FEDERAL ID NO.	MAP DATE	COAL SEAM	COMPANY NAME
2	RAP1000		XXXXX	XXXXX	7/1/1936		Rapoca Coal
3	RAP1001		XXXXX	XXXXX			Jewell & Vansant Coal Operations
4	RAP1002		XXXXX	XXXXX			Rapoca Coal Property Owners
5	RAP1003		XXXXX	XXXXX	9/30/1970	Pond Creek	Western Pocahontas
6	RAP1004		XXXXX	XXXXX			Rapoca
7	RAP1005		XXXXX	XXXXX			Rapoca
8	RAP1006		XXXXX	XXXXX			Rapoca
9	RAP1007		XXXXX	XXXXX			Rapoca
10	RAP1008		XXXXX	XXXXX			Rapoca
11	RAP1009		XXXXX	XXXXX			Rapoca
12	RAP1010		XXXXX	XXXXX	1/24/1981	Blair	Thompson Belcher
13	RAP1011		XXXXX	XXXXX	12/31/1976		United Coal
14	RAP1012		XXXXX	XXXXX			Bull Creek
15	RAP1013		XXXXX	XXXXX			
16	RAP1014		XXXXX	XXXXX	8/7/1972		James T. Justice Heirs
17	RAP1015		XXXXX	XXXXX			
18	RAP1016_1		XXXXX	XXXXX	10/1/1987	Hagy	Harman Mining
19	RAP1016_2		XXXXX	XXXXX	10/1/1987	Hagy	Harman Mining
20	RAP1017_1		XXXXX	XXXXX	10/1/1987	Eagle	Harman Mining
21	RAP1017_2		XXXXX	XXXXX	10/1/1987	Eagle	Harman Mining
22	RAP1018_1		XXXXX	XXXXX	10/1/1987	Blair	Harman Mining
23	RAP1018_2		XXXXX	XXXXX	10/1/1987	Blair	Harman Mining
24	RAP1019_1		XXXXX	XXXXX	10/1/1987	Glamorgan	Harman Mining
25	RAP1019_2		XXXXX	XXXXX	10/1/1987	Glamorgan	Harman Mining
26	RAP1020_1		XXXXX	XXXXX	2/1/1991		Pocahontas
27	RAP1020_2		XXXXX	XXXXX	2/1/1991		Pocahontas
28	RAP1020_3		XXXXX	XXXXX	2/1/1991		Pocahontas
29	RAP1021		XXXXX	XXXXX	4/4/2003		
30	RAP1022		XXXXX	XXXXX	12/31/1977		Island Creek Coal
31	RAP1023		05926	44-01520	9/30/1979	Pocahontas No 3	Island Creek Coal
32	RAP1024		XXXXX	XXXXX			
33	RAP1025		XXXXX	XXXXX	5/22/1980		
34	RAP1026		XXXXX	XXXXX			Elkhorn Coal
35	RAP1027		XXXXX	XXXXX	4/30/1970		National Shawmut Bank of Boston



Images and catalog records are being added at the current rate of 10,000 maps per year. The number of maps projected for 2005 to 2006 is estimated to reach 11,000 maps or more as new collections are loaned.

Overview

- Fitting it all together
- Phased approach



Summary

- Locate maps
- Acquire maps
- Work on their time schedule
- Deliver a product
- Be proactive

Where to Get More Information

- Contact:
  - Daniel Kestner
  - (276) 523-8193
  - Daniel.kestner@dmme.virginia.gov
- Press Release – Request for Assistance
  - http://www.dmme.virginia.gov/DMMESeeksPre-1980UGMaps.htm

Integrating Geo-referenced Mine Map Images in a GIS

Underground Mine Mapping Workshop

June 1st & 2nd 2005

Pittsburgh, PA

Introduction

- **What is geo-referencing?**
- **Why geo-reference mine map images?**
- **Methods for geo-referencing**
- **Incorporate with existing geo-spatial datasets**

Geo-referencing Defined (ESRI)

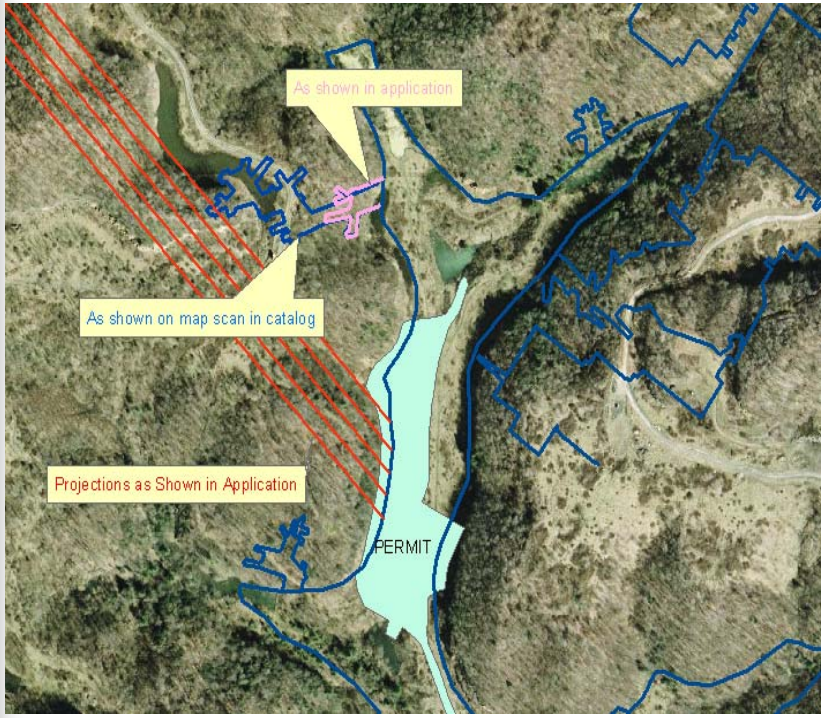
- **Georeferencing-** Assigning coordinates from a known reference system, such as latitude/longitude, UTM, or State Plane, to the page coordinates of a raster (image) or a planar map. Georeferencing raster data allows it to be viewed, queried, and analyzed with other geographic data.
- **Geometric transformation-** The process of rectifying a raster dataset to map coordinates or converting a raster dataset from one projection to another.

Why Geo-reference?

Knowing "WHERE" is the key to:

- **Identifying potential hazardous conditions**
- **Helping accurately record Virginia's mining history**
- **Assisting in efficient management of Virginia's coal reserves**
- **Facilitating economic development in Virginia's coalfields**

Vector Dataset Derived from Geo-referenced Images



The DMME Mine Map Archive is being created to better serve Virginia's citizens and mining industry. Preservation of accurate underground mine mapping is crucial. This concentrated collection of maps not only identifies hazardous conditions but also facilitates the efficient management of Virginia's coal reserves.

Geo-referencing Methods

- Printed World Coordinates
- Natural or Cultural Features
- Company Planimetrics
- Relative to other mines
- Outcrop matching
- General Location Descriptions
- Existing Geo-spatial Data

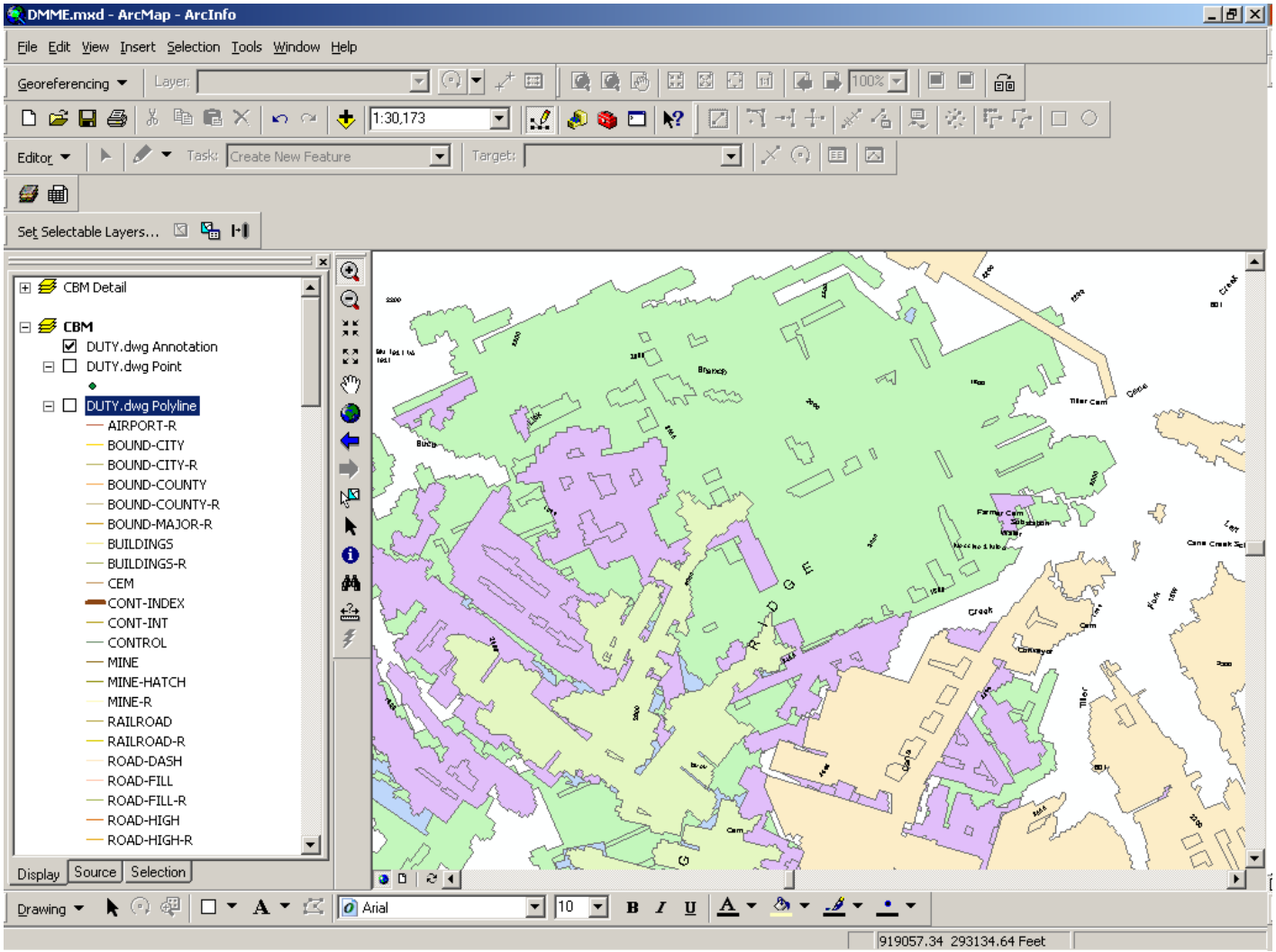
Geo-spatial Datasets

- **Vector dataset formats**
- **Geodatabase – feature classes**
- **Potential SDE raster features**
- **Raster Catalog**
  - **Rendering**

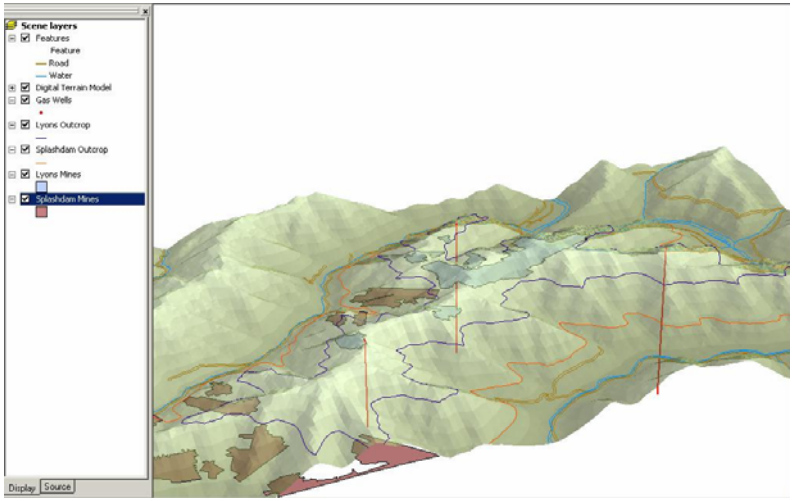
Geo-locate

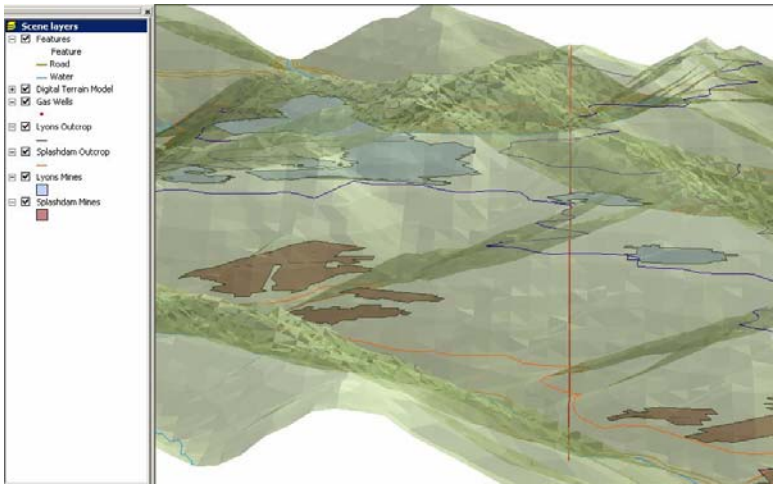
- **Tie database to location**
  - **Coordinate pairs**
- **Query by attribute and location**

Coalbed Topology

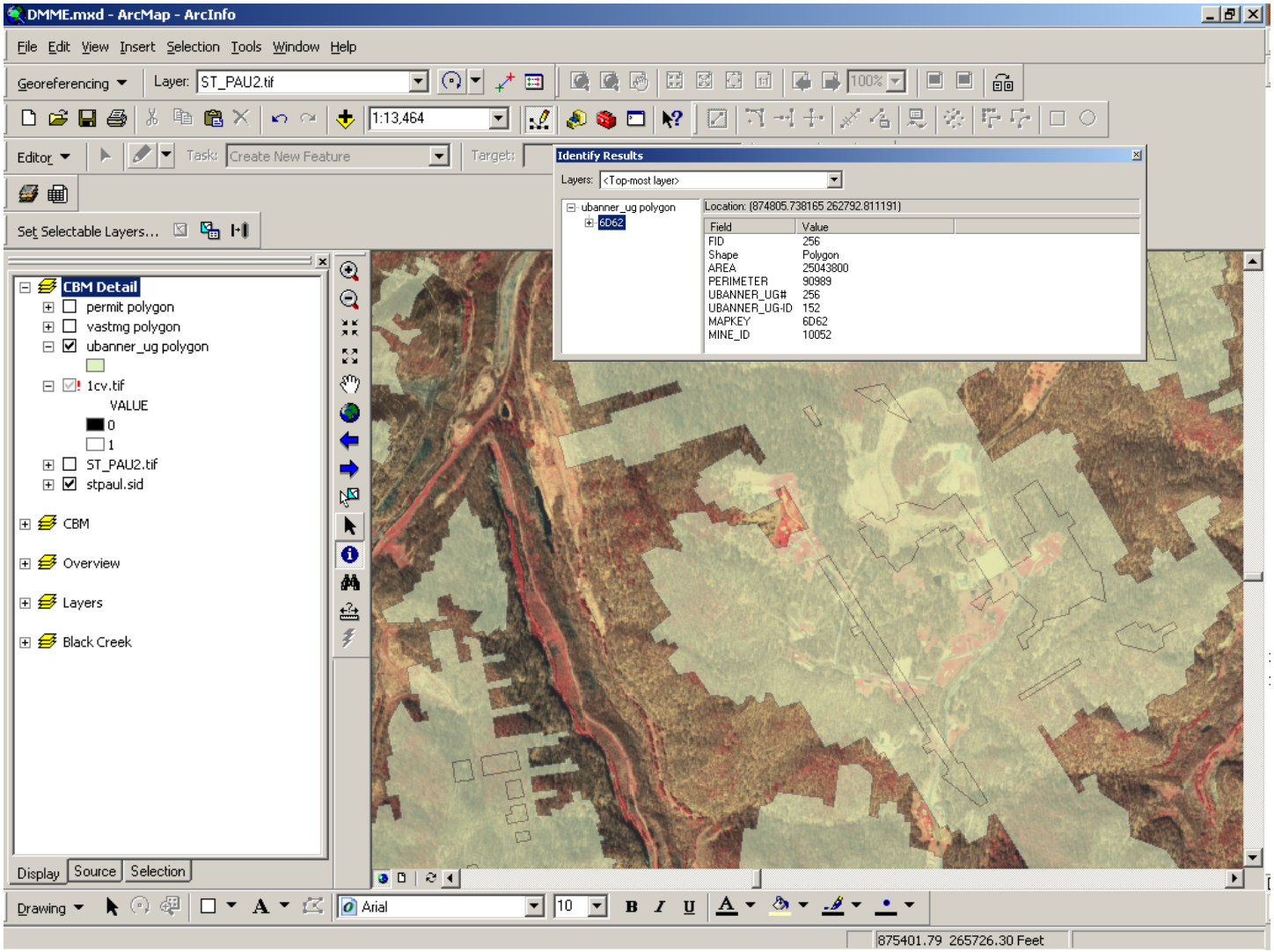


Referencing X,Y, & Z





Surface Features



Summary

- **Establish Geo-referencing method**
- **Format & Software options**
- **Establish guidelines for inclusion in GIS**

Where to Get More Information

- **Contact:**
  - **Daniel Kestner**
  - **(276) 523-8193**
  - **Daniel.kestner@dmme.virginia.gov**

Slide 1: Title Slide

Good Morning. It is my pleasure to participate in this Underground Mine Mapping Benchmarking Workshop, and to provide you with an update on the status of MSHA's void detection demonstration projects.

I have passed around a copy of the presentation, which contains more detail than I will have time to cover this morning. So please read over it at your convenience, and if you have any questions, please see me or Dr. Kelvin Wu

Slide 2: High Profile Incidents

We are all of course aware of the most prominent events – impoundment breakthroughs and mine inundations which led to this mine mapping and void detection initiative.

We had four very significant incidents where large volumes of coal processing waste broke through inadequate barriers of soil and rock passed through mines and discharged into adjacent watersheds

And then of course the infamous mine inundation and dramatic rescue at Quecreek Mine

These major problems share one element in common. They were all the result of either unavailable, incomplete, or inaccurate mine maps or inadequate characterization of the subsurface conditions above the mines.

Slide 3: Impoundment Problem

This shows the impoundment breakthrough problem in general. The question is, of course, do we actually have the barrier here that we expect, and is the quality of the soil and rock sufficient to prevent a breakthrough.

Slide 4: Martin County Overview

The Martin County breakthrough, the largest of these, resulted in the release of more than 300 million gallons of coal waste

Slide 5: Martin County Breakthrough

The processing waste broke through an inadequate barrier in the back of a refuse impoundment, passed through an unoccupied area of an active mine and discharged from two locations as depicted by these arrows.

Slide 6: Martin County Discharge at South Mains

The waste emerged at the South Mains Portal

Slide 7: Martin County Discharge at No. 2 North Belt Entry

And the No. 2 North Belt entry

Slide 8: Martin County Damage

This is typical of the environmental and property damage experienced downstream.

Slide 9: Martin County Damage

The effects were felt as far as 100 miles downstream through the Tug Fork of the Big Sandy River, and all of the way to the Ohio River

Slide 10: Martin County Public Outcry

There was the expected public outcry

Slide 11: Extent of Abandoned Mines in Appalachia

This is of course by no means an isolated situation. There are nearly 300,000 abandoned coal mines in the Appalachians, distributed as shown here.

Slide 12: Impoundments over Mines

There are 220 existing coal-mining related impoundments built over or adjacent to coal mine workings.

One of the biggest problems is to determine the extent of mining. In many instances, mine maps have proven not to be accurate, particularly in the final cut near the outcrop.

Slide 13: Congressional Study

As a result of the Martin County Breakthrough, Congress funded a study through the National Academy of Science, National Research Council, Committee on Coal Waste Impoundments. The committee ultimately wrote a report – Coal Waste Impoundments: Risks, Responses and Alternatives. Many of you have seen this report.

Slide 14: NRC Recommendation
One of the recommendations included in the report is shown here:

Among various other things, the council recommended that demonstration projects using modern geophysical techniques be funded and that results be widely conveyed to the mining industry and to government regulatory personnel through workshops and continuing education. And that is what we are doing now.

Slide 15: Quecreek Group

Shortly thereafter the Quecreek Inundation occurred.

Slide 16: Quecreek Map

The mine cut into flooded workings which were not depicted on the available mine map.

Slide 17: Quecreek Flooded Portal

The mine filled with water

Slide 18: Quecreek Trapped Miners

9 miners narrowly escaped while 9 others remained trapped for 72 hours.

Slide 19: Quecreek Rescue

And of course the dramatic rescue which ensued.

Slide 20: Inundation Statistics

This was a dramatic example of a very frequent problem.

From 1995-2002 mine operators had reported 181 mine inundation, 107 of which were unplanned cut-throughs resulting in water inundation.

Slide 21: Congressional Funding

Congress appropriated 10M to the MSHA budget to address this problem.
3.9 went to mine mapping and 6.1 to void detection demonstration projects

Slide 22: RFP

MSHA issued a request for proposals (RFP as shown here)

Slide 23: Demonstration Projects Workflow

This slide represents the detailed screening and selection process that we went through. I would especially like to point out here that each proposal was reviewed by a team of expert reviewers, generally including a representative of the COE Geophysics Branch and a recognized University Professor of Geophysics.

Slide 24: Response to RFP

We had an overwhelming response – 58 different proposals from 23 sources covering the technologies shown here.

Slide 25: Projects Underway

Of these, we selected 14 projects covering a wide range of seismic, electrical, and electromagnetic methods. These projects are now underway, and range from about 10-50% complete.

Slide 26: Surface Seismic Reflection projects

We have two demonstrations of surface seismic reflection, a technique that has been widely used in the oil and gas exploration industry to image depths from 50 to several thousand feet.

Slide 27: Surface Seismic Illustration

Seismic energy is generated at the ground surface, and reflected when the interface of zones with different seismic properties are encountered. By recording these reflected waves using geophones, and evaluating the data, the subsurface conditions can be profiled.

Slide 28: Blackhawk GeoServices - Test Layout

Here we see, the array of geophone and source locations marked out on the ground

Slide 29: Blackhawk GeoServices – Geophone

An installed geophone, embedded in the ground

Slide 30 Blackhawk GeoServices - Vibroseis

The seismic source – in this case a vibroseis device which excites the ground over a range of frequencies.

Slide 31 LM Gochioco Impact Hammer

Or in this case, a hydraulic and mechanical impact hammer that strikes a steel plate on the ground.

Slide 32 Blackhawk GeoServices Data Record

And the seismic reflection data being recorded.

Slide 33: Borehole Seismic Tomography Projects

These two projects will demonstrate borehole seismic tomography

Slide 34: Borehole Seismic Tomography Illustration

This method uses guided waves passing through a coal seam, generated in one borehole and measured using geophones or hydrophones in other boreholes.

Slide 35: Blackhawk GeoServices Cased Borehole

This is one of a series of strategically placed cased boreholes.

Slide 36: Blackhawk GeoServices Airgun

Seismic energy is generated with an airgun

Slide 37: Blackhawk GeoServices Geophones

And measured in all of the other boreholes with geophones

Slide 38: Blackhawk GeoServices Data Acquisition

And the data is acquired for processing.

Slide 39: Edgar Mine, Army Tunnel

Colorado School of Mines is doing a similar test in their Edgar Experimental Mine – an old Silver Mine. This mine was used extensively as part of the Korean Tunnel Detection Project and they will use the existing boreholes from the surface.

Slide 40: VSP Illustration

A variation of this method is Vertical Seismic Profiling. In this case, seismic energy is generated at the surface and reflections are measured in a borehole. The advantage here is that recorded waves do not pass through the surface soils which have a tendency to filter out the desired high-frequency component of the record.

Slide 41: VSP Project

This demonstration project is being conducted by LM Gochioco and Associates.

Slide 42: LM Gochioco Hydrophones

Here are the hydrophones being inserted into a cased borehole

Slide 43: LM Gochioco Impulse Hammer

The ground being struck radially at various locations.

Slide 44: LM Gochioco Data Acquisition

And the data being acquired for later processing.

Slide 45: ISS Projects

We sponsored demonstrations involving variations of inseam seismic reflection technology

Penn State is testing at anthracite and bituminous coal mines in pennsylvania and at a trona mine in Wyoming using sources and receivers in the mine.

LM Gochioco will do a similar test at bituminous coal mines in Ohio and Virginia.

Marshall Miller is using a source and receivers at a surface outcrop.

And ***Wright State University*** is attempting to evaluate seismic signals generated by the continuous miner during the mining process by measuring secondary waves at the ground surface.

Slide 46: ISS Illustration

This is a general illustration of tests conducted from within the mine. Seismic energy is generated using a blasting cap or small explosive charge in one location and the reflected signal is measured with geophones in another.

Slide 47: PSU Anthracite Mine

Here are geophones mounted in the coal rib in an anthracite mine.

Slide 48: PSU Trona Mine

And at a Soda Ash Mine.

Slide 49: PSU Data Collection

And the reflected waveforms being recorded.

Slide 50: Marshall Miller Illustration

This is from Marshall Millers project. The source (explosion) and receivers (geophones) are all at the surface outcrop

Slide 51: Marshall Miller Maps

And they are looking in two locations, one for air-filled voids and one at water-filled. They expect good results up to 1000 feet away with a precision of about 30 feet.

Slide 52: Wright State Map

Wright State University is measuring the secondary waves generated at the ground surface by a continuous miner underground, as it approaches an abandoned mine during the regular mining process.

Slide 53 Wright State Layout

Here is the geophone layout

Slide 54 : Wright State 3-Component Geophone

A 3-component geophone embedded in the ground surface

Slide 55: Wright State Data Acquisition

And Professor Hauser doing the data acquisition

Slide 56:Electrical Resistivity Illustration

A more conventional near-surface geophysical method is Electrical Resistivity,

Current is induced within the ground, and the electrical potential between two electrodes is measured along survey lines to determine variations or anomalies in the resistance of subsurface layers which could be indicative of mine voids, at shallow depths.

Slide 57: Electrical Resistivity Project

We are sponsoring one demonstration of this technology.

Slide 58: Lots Branch Aerial

In an area of uncertain mining near a coal seam outcrop around an impoundment.

Slide 59: Electrical Resistivity Photo and Explanation

Here you a survey line of electrodes, with a simple explanation.

Slide 60: TDEM and Radar Illustration

Time Domain Electromagnetics and Radar Methods involves transmitting electromagnetic waves into the ground and measuring those secondary waves that are reflected back as a result of differences in the dielectric, magnetic, and conductive properties in the subsurface.

Slide 61: TDEM and Radar Methods

We are sponsoring two projects using electromagnetic and radar methods

Slide 62: Lot's Branch Aerial

The D'Appolonia demonstration will be at the Lot's Branch Impoundment. The same site as for the electrical resistivity.

Slide 63: TDEM Photo and Explanation

Here is a shot of the transmitter and receivers. With this setup the antennas are laid out on the ground surface. Again with a simple explanation.

Slide 64: Stolar EM Gradiometer Transmitter

Stolar Research Corporation has developed a system called the Electromagnetic Gradiometer where the transmitter…

Slide 65: Stolar EM Gradiometer Receiver

And receivers are moved simultaneously along the ground surface to profile the ground beneath in real-time.

Slide 66:CSM Crosshole Radar

Colorado School of mines will deploy the electromagnetic transmitters and receivers in boreholes in a crosshole tomographic mode.

Slide 67: CSM Edgar Mine

They will again use the existing boreholes at the Edgar Experimental Mine, Army Tunnel and run this demonstration the same way as their crosswell seismic demonstration.

Slide 68: LAR Illustration

A somewhat different approach is to move the transmitter and receivers to the mine face in the look-ahead mode to again detect differences in the dielectric properties of coal and mine voids for a distance of 20 – 70 feet, as a last line of defense against an accidental cut-through.. The ultimate goal would be to have a machine mounted system.

Slide 69: LAR Project

MSHA is sponsoring the development of a hand-held unit, with the hopes that if the technology proves viable, the developer will invest additional funds to make it machine-worthy. They have already developed a similar device for measuring and controlling the mining horizon. Work on this project up to this time has been primarily development and modifying equipment.

Slide 70: MSHA Slide

And that is a very cursory overview of the work that we are doing. If anyone would like additional details, talk to me or Dr. Wu over the next couple of days and we can provide you with any additional information or details which you may want.

VOID DETECTION DEMONSTRATION PROJECT STATUS REPORT

Underground Mine Mapping Benchmarking Workshop
Interstate Mining Compact Commission (IMCC) / Office of Surface Mining (OSM)

George H. Gardner, PE
Senior Civil Engineer, Mine Waste and Geotechnical Engineering Division

Dr. Kelvin K. Wu, PE
Chief, Mine Waste and Geotechnical Engineering Division

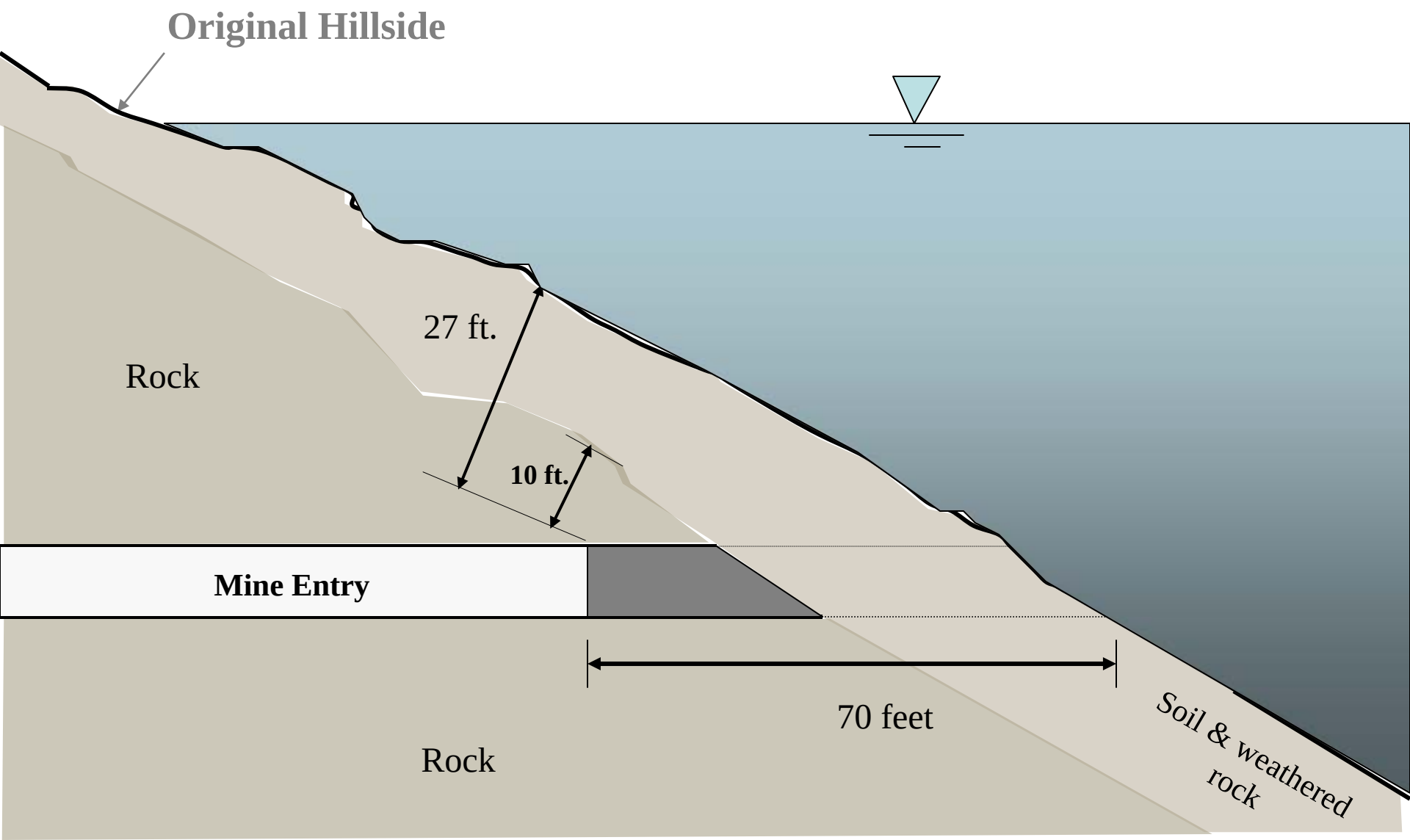
Pittsburgh Technical Support Center

Recent High-Profile Incidents Related to Underground Mines

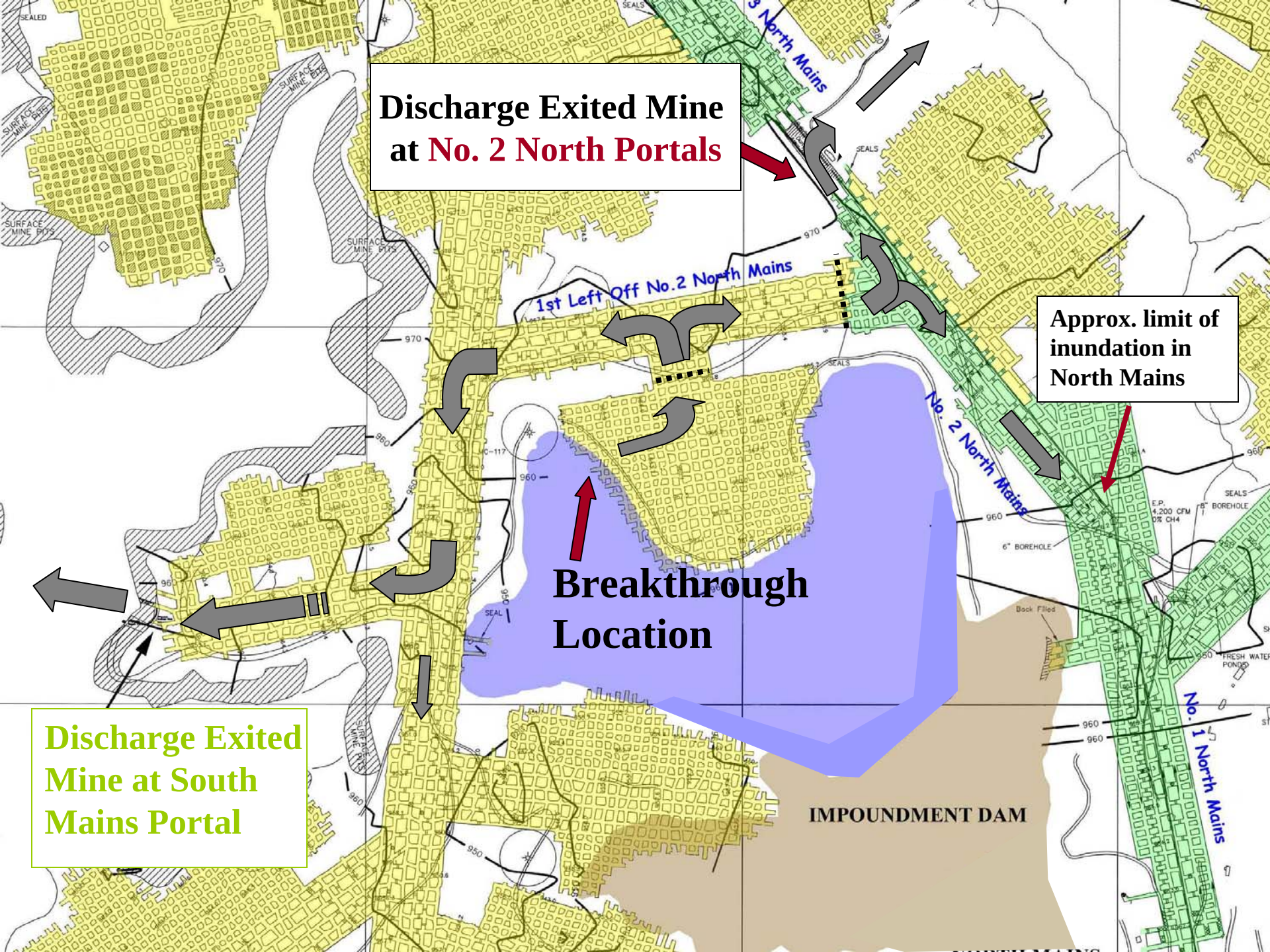
- Impoundment Breakthrough Incidents
  - Miller's Cove, Lee Co. VA, August, 1996
  - Miller's Cove, Lee Co. VA, October, 1996
  - Buchanan, Buchanan Co. VA, November, 1996
  - Big Branch, Martin Co., KY, October, 2000

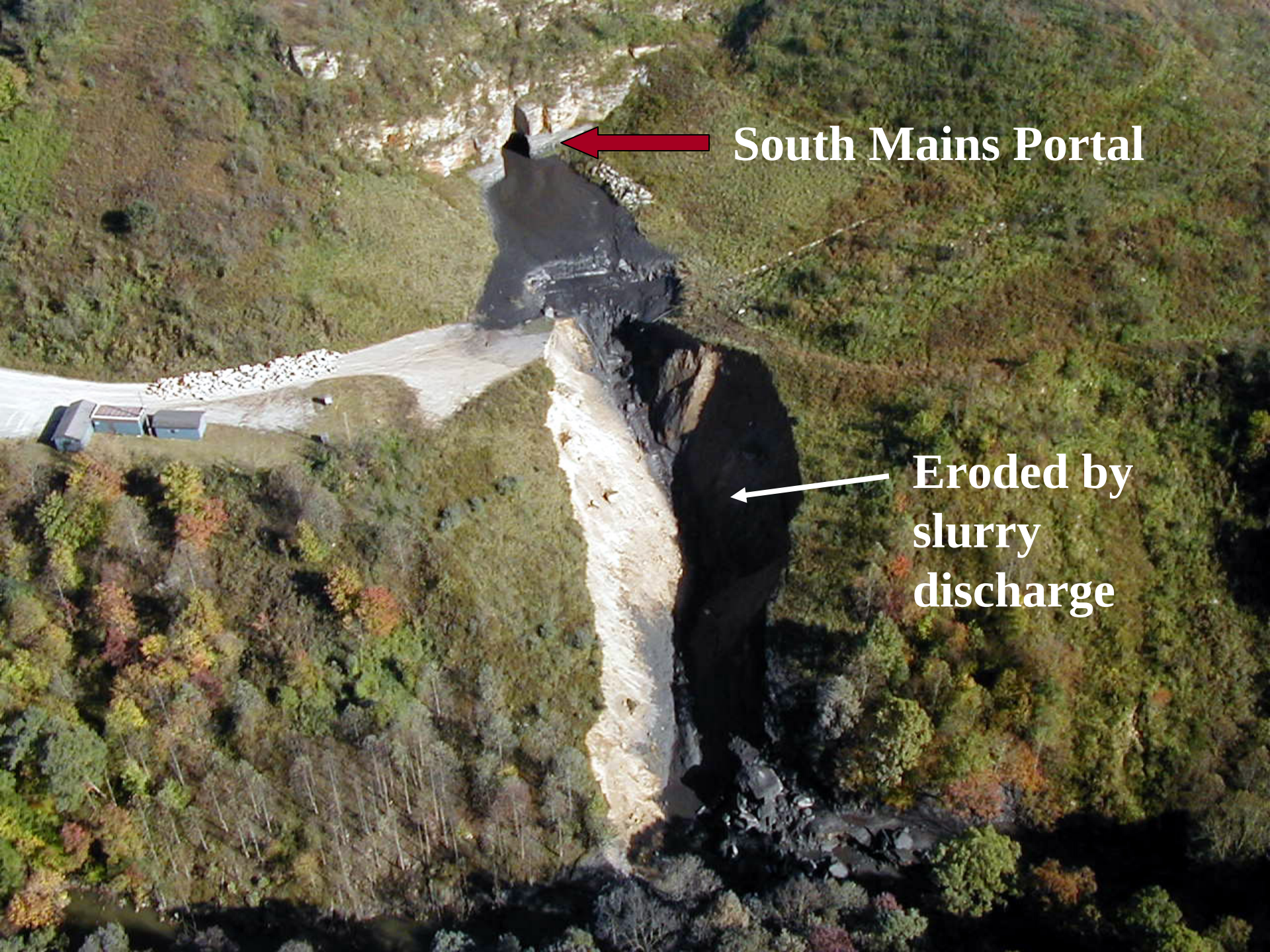
- Mine Inundation
  - Quecreek No. 1 Mine Inundation and Rescue, July 2002

Example of potential for breakthrough created by mine workings located near an impoundment.



Martin County Coal Company
Big Branch Refuse Impoundment
October 2000
Approx 300 Million Gallons Released


Discharge Exited Mine at No. 2 North Portals
Approx. limit of inundation in North Mains
Breakthrough Location
Discharge Exited Mine at South Mains Portal
1st Left Off No.2 North Mains
No. 2 North Mains
No. 1 North Mains
IMPOUNDMENT DAM
SURFACE MINE PITS
SEALS
SEAL
6" BOREHOLE
8" BOREHOLE
Back Filled
FRESH WATER POND
970
960
950


South Mains Portal
Eroded by slurry discharge

No. 2 North Belt Entry

Coldwater Creek

PITTSBURGH POST-GAZETTE

NATIONAL

Coal sludge slimes Kentucky

Mine pond collapses, pollutes streams and fouls area's water

By Roger Alford
The Associated Press

INEZ, Ky. — When Delmer Moore looks out his window in mid-October, he ordinarily sees the beautiful yellow and orange leaves of autumn.

This year, the predominant color is black.

It's been that way since a coal-mine pond gave way last week, releasing 200 million gallons of sludge into eastern Kentucky streams, killing fish, washing away roads and bridges, and fouling the region's water supply.

Moore has watched as the molasses-like substance topped the banks of Coldwater Creek and began claiming his property outside of Inez, which is 140 miles east of Lexington. The sludge covered most of

Associated Press

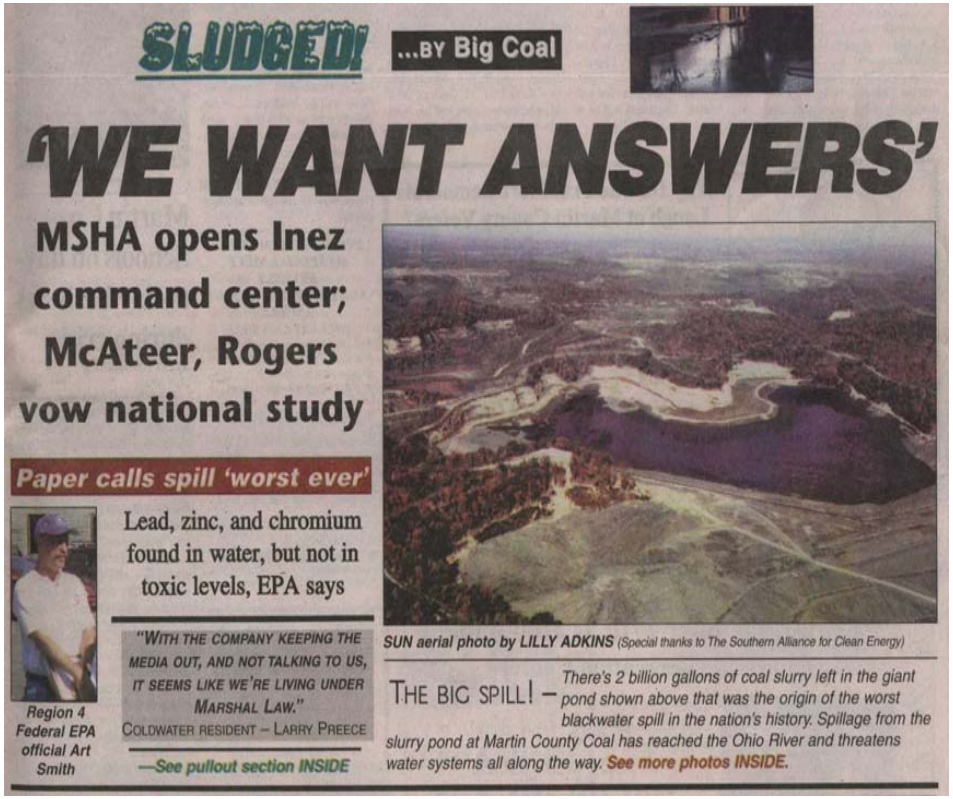
fail," said MSHA spokesman Rodney Brown. "It's just that we consider it a highly dangerous situation and it should be looked at closely."

The impoundments need to be eliminated altogether, said Hazel King, a Harlan activist who has crusaded for decades against mine ponds.

"There's just too many of them," she said. "If they know there's a potential for collapse, why do they allow it to happen in the first place? An ounce of prevention is worth of pound of cure. I've hollered that as loudly as I could. I guess the almighty dollar hollers louder."

Martin County Coal had crews working around the clock dredging the ooze from streams. The state has ordered the company, a subsidiary of A.T. Massey Coal Inc., to replace fish and other aquatic life killed and to rebuild the roads and bridges it ripped away.

Fred Stroud, a member of an emergency response team from the Environmental Protection Agency, said it could take at least five to six months to clean up the spill, a project expected to cost millions.



SLUDGED! ...BY Big Coal

'WE WANT ANSWERS'

MSHA opens Inez command center; McAteer, Rogers vow national study

Paper calls spill 'worst ever'

Lead, zinc, and chromium found in water, but not in toxic levels, EPA says

Region 4 Federal EPA official Art Smith

"WITH THE COMPANY KEEPING THE MEDIA OUT, AND NOT TALKING TO US, IT SEEMS LIKE WE'RE LIVING UNDER MARSHAL LAW."
COLDWATER RESIDENT – LARRY PREECE

—See pullout section INSIDE

SUN aerial photo by LILLY ADKINS (Special thanks to The Southern Alliance for Clean Energy)

THE BIG SPILL! – There's 2 billion gallons of coal slurry left in the giant pond shown above that was the origin of the worst blackwater spill in the nation's history. Spillage from the slurry pond at Martin County Coal has reached the Ohio River and threatens water systems all along the way. See more photos INSIDE.

Reuter - Oct. 18th - "A massive spill of slowly spreading coal slurry triggered water shortages and school closings across eastern KY...**prompting the governor to declare a state of emergency."**

"Communities throughout the affected 10 county area were forced to close off water intake pipes.

"Some public schools were forced to close indefinitely pending restoration of safe water supplies...

Anatomy of a disaster

A step-by-step analysis of what occurred in nation's worst coal waste spill

BY GARY BALL
CITIZEN EDITOR

INEZ — Uncertainty looms in the wake of the nation's worst coal slurry spill. Everyone is on edge after 250 million gallons of sludge poured out of Martin County Coal's Big Branch impoundment in the early morning hours of Oct. 11, stranding homeowners, destroying bridges,

Abandoned Coal Mines

State	No. of Abandoned Mines
Kentucky	150,000
West Virginia	100,000
Pennsylvania	40,000
Virginia	6,000

Impoundments and Mining

- 220 Impoundments in Appalachia built over or adjacent to mine workings
- MSHA rated and prioritized impoundments in terms of potential and consequences of failure
- 54 Sites had a high potential for breakthrough
- Mine Operators were required to evaluate potential for breakthroughs and design against them

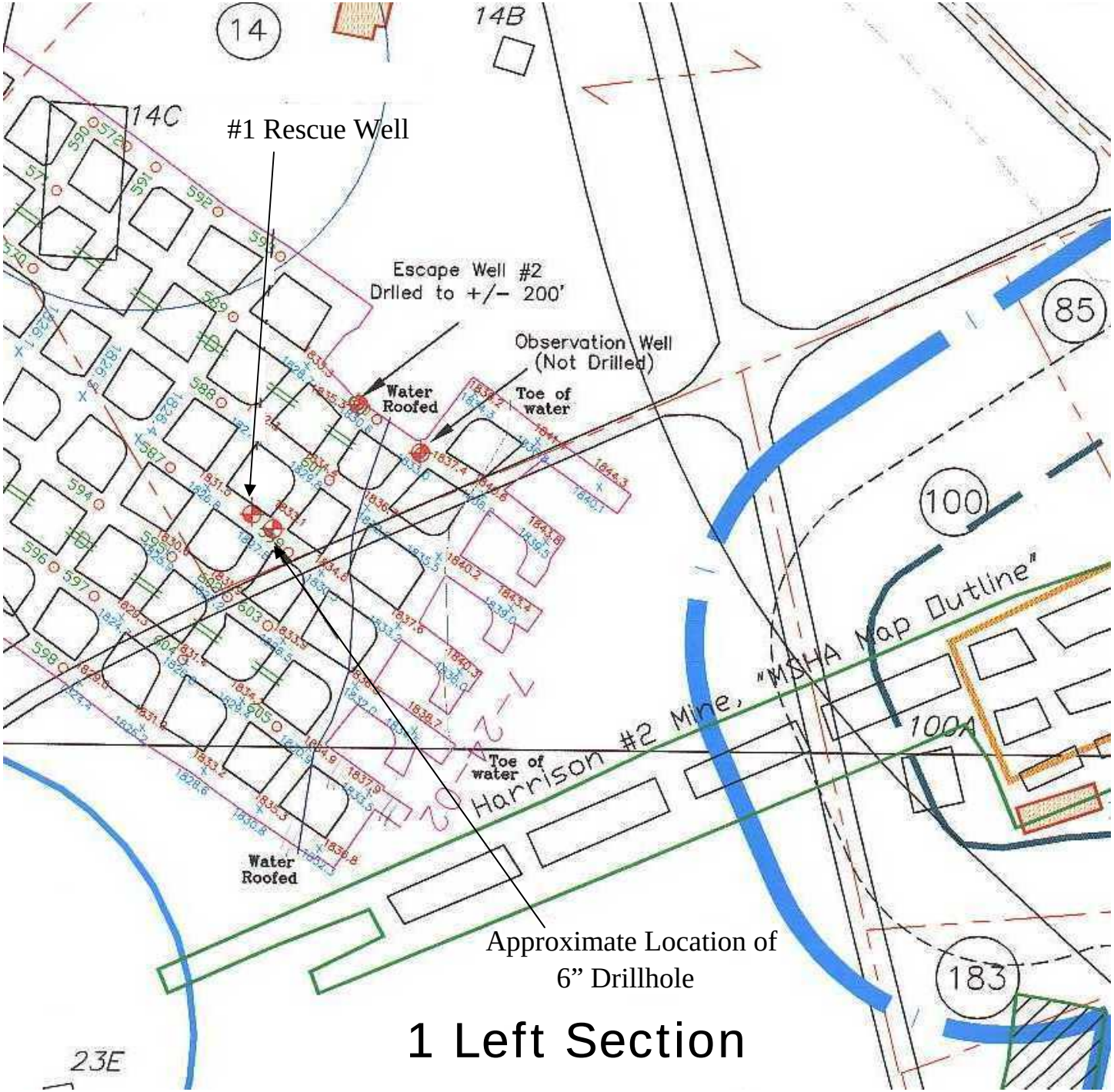
Congressional Study

- National Research Council , Committee on Coal Waste Impoundments
- $2,000,000
- Developed report, “Coal Waste Impoundments: Risks, Responses, Alternatives, 2002

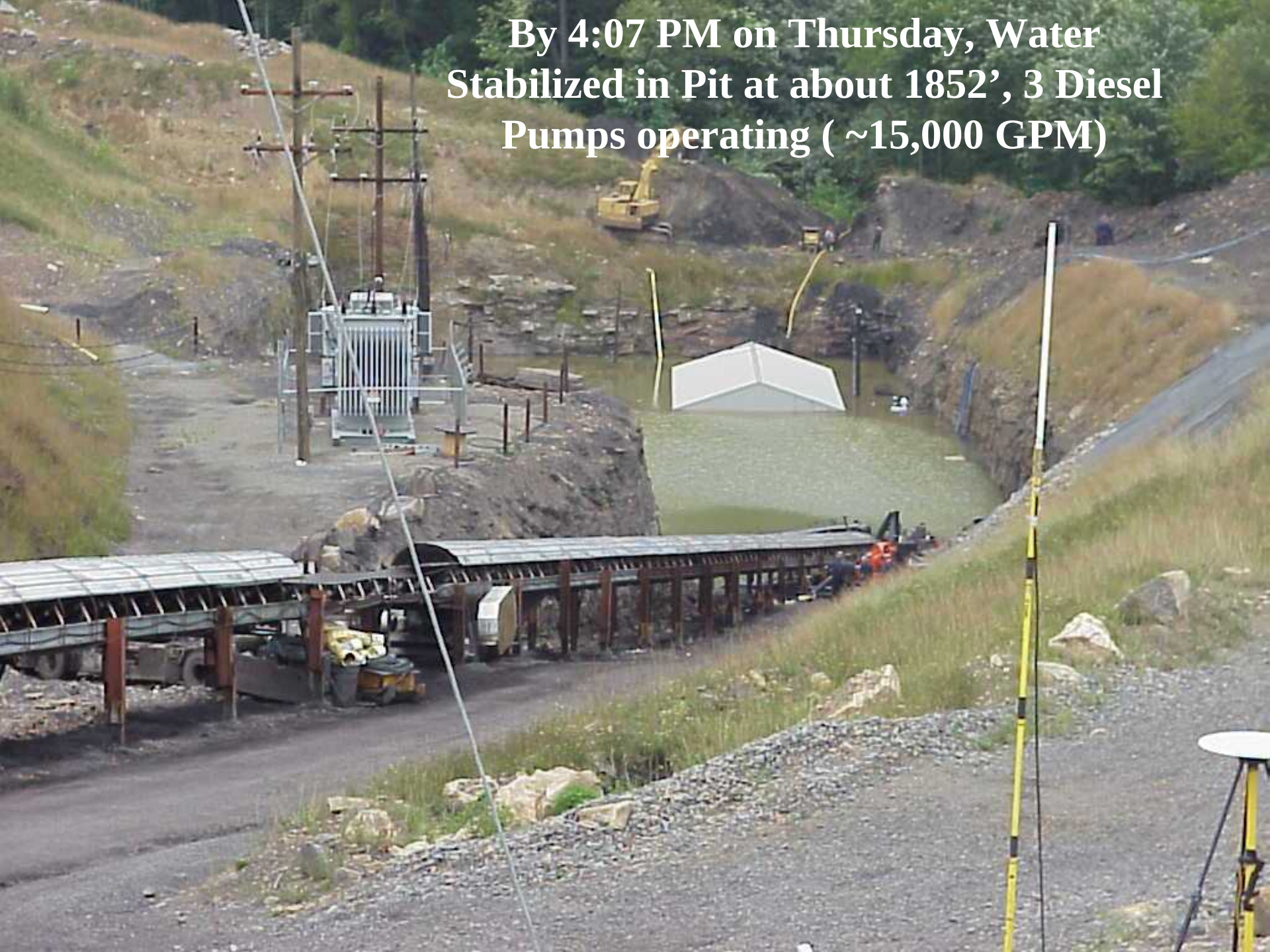
NRC Recommendation

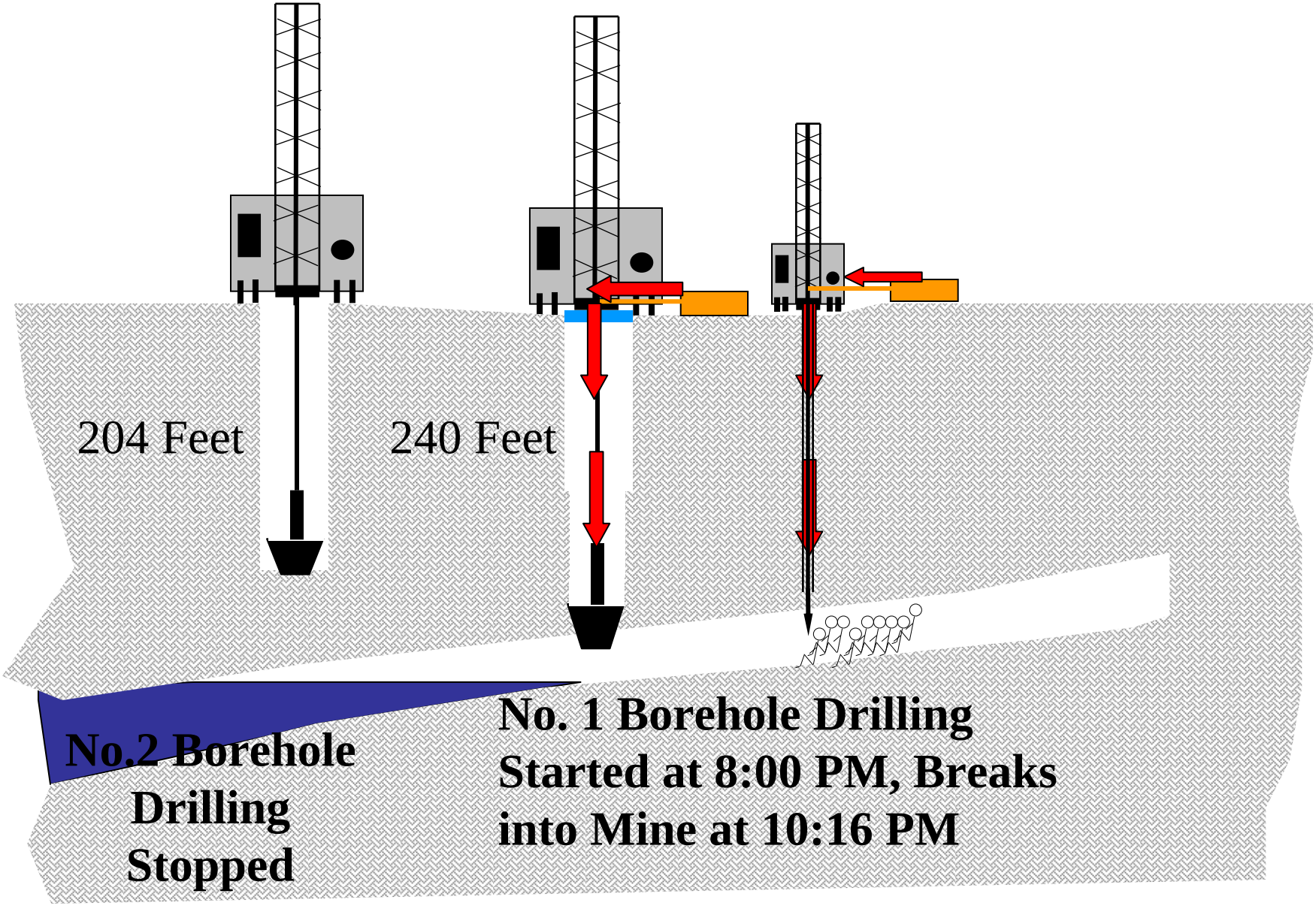
- *The council recommends that demonstration projects using modern geophysical techniques be funded, and that results be widely conveyed to the mining industry and to government regulatory personnel through workshops and continuing education.*

Quecreek No. 1 Mine Inundation and Rescue, July 24-28,2002



1 Left Section


By 4:07 PM on Thursday, Water Stabilized in Pit at about 1852’, 3 Diesel Pumps operating (~15,000 GPM)


204 Feet
240 Feet
No.2 Borehole Drilling Stopped
No. 1 Borehole Drilling Started at 8:00 PM, Breaks into Mine at 10:16 PM

FIRE
54

Active Mines: Inundation Accidents Magnitude of the Problem

- From 1995 through June 2002, mine operators reported 181 mine inundations.
- Of these, at least 107 were unplanned cut-throughs that resulted in water inundations.

House/Senate Conference Agreement

- "$10,000,000 for digitizing mine maps and developing technologies to detect mine voids, through contracts, grants, or other arrangements, to remain available until expended.“
  - MSHA Allocation:
    - $3.9M to Mine Mapping – Disbursements to States
    - $6.1M to Void Detection – Funded Projects to Demonstrate available technologies for void detection.

Request for Proposals (RFP)

- *Purpose: "The U.S. Department of Labor, Mine Safety and Health Administration is seeking sources to conduct demonstration projects for advancing the current state of technology in detecting underground mine voids."*

Progress of Demonstration Projects

- Pre-solicitation Notice
- Request For Proposals
- Objective Scoring System Developed
- MSHA Contracted with outside technical reviewers
- Review Teams Formed
  - MSHA Representative
  - Other Government (generally USACE) Representative
  - University Professor of Geophysics
- Down-selection process (5/26/2004)
  - 11 Respondents to receive further consideration
- Oral Presentations (7/27-30/2004)
- Negotiations 8/2004 - Present
- Final Selections 8/2004 – 4/2005

Response to RFP

- 58 Proposals
- 23 Sources
- Methods Covered
  - Surface Seismic Reflection
  - Inseam Seismic Reflection
  - DC Resistivity
  - Seismic Land Streamer
  - Synthetic Aperture Radar
  - Underground Electomagnetics
  - Microgravity
  - SASW
  - Ground-penetrating Radar
  - Look-Ahead Radar
  - Forward-Looking Seismic
  - Mobile Field Robotics (dry voids)
  - Mine Fish (wet voids)
  - Gravity Gradiometer
  - Time Domain Electromagnetics
  - Airborne Electromagnetic Conductivity
  - Drillstring Radar
  - MASW
  - 3-D Sonar
  - Cross-hole Seismic Tomography
  - Radio Imaging
  - 3-D Downhole Laser
  - Residual Potential Mapping

14 Selected Projects Now Underway

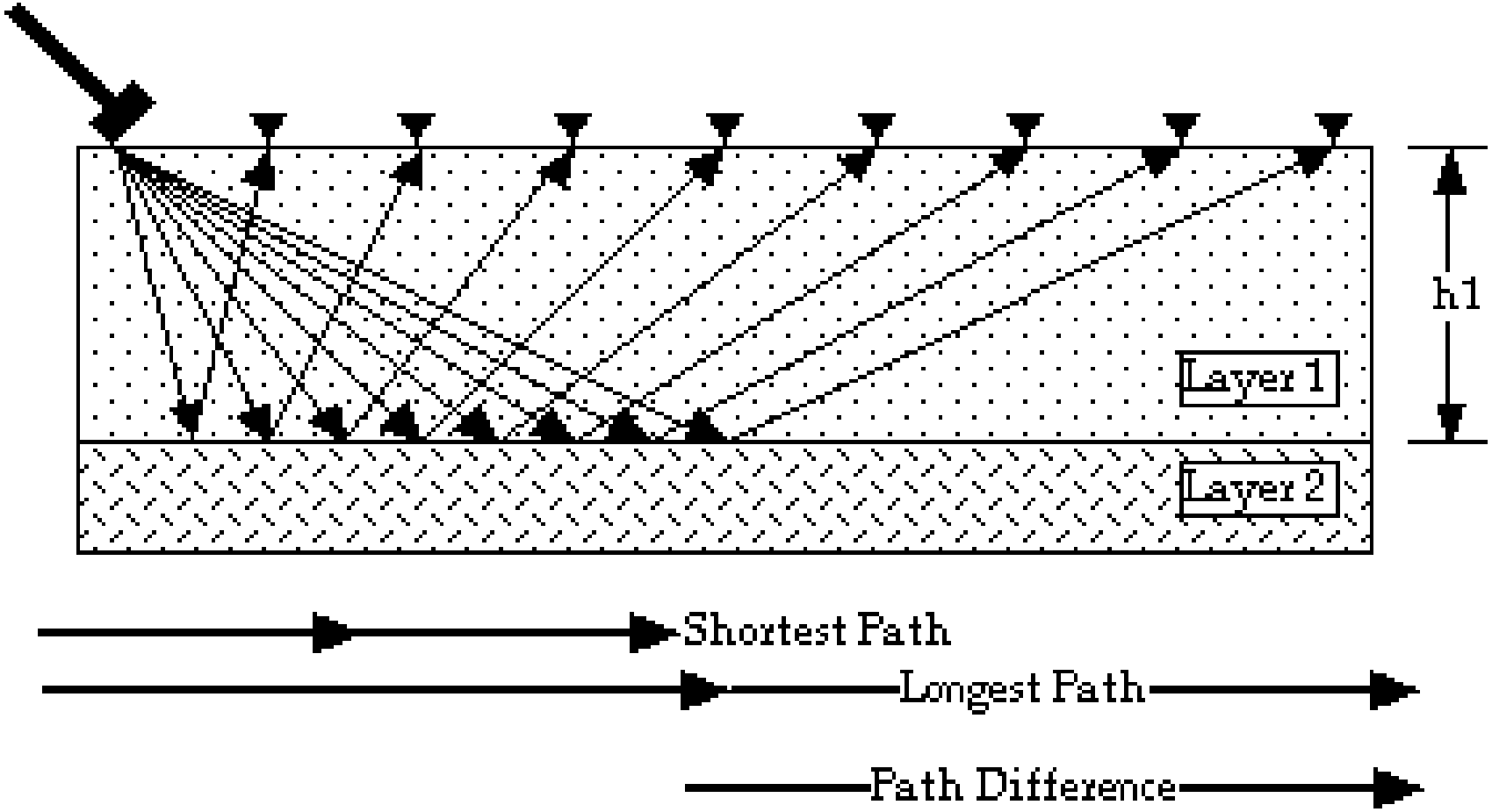
- Surface Seismic Reflection (2)
- Borehole Seismic Tomography (2)
- Vertical Seismic Profiling (1)
- In-seam Seismic (ISS) (various sources) (4)
- Electrical Resistivity (1)
- Time Domain Electromagnetics (1)
- Look Ahead Radar (1)
- Borehole Radar Tomography (1)
- Delta EM Gradiometry (1)

Surface Seismic Reflection Projects

- Blackhawk GeoServices
  - Black Beauty Coal Co., Riola Mine Complex

- LM Gochioco Associates
  - Sterling Coal Corp., Carroll Hollow Mine

Surface Seismic Reflection



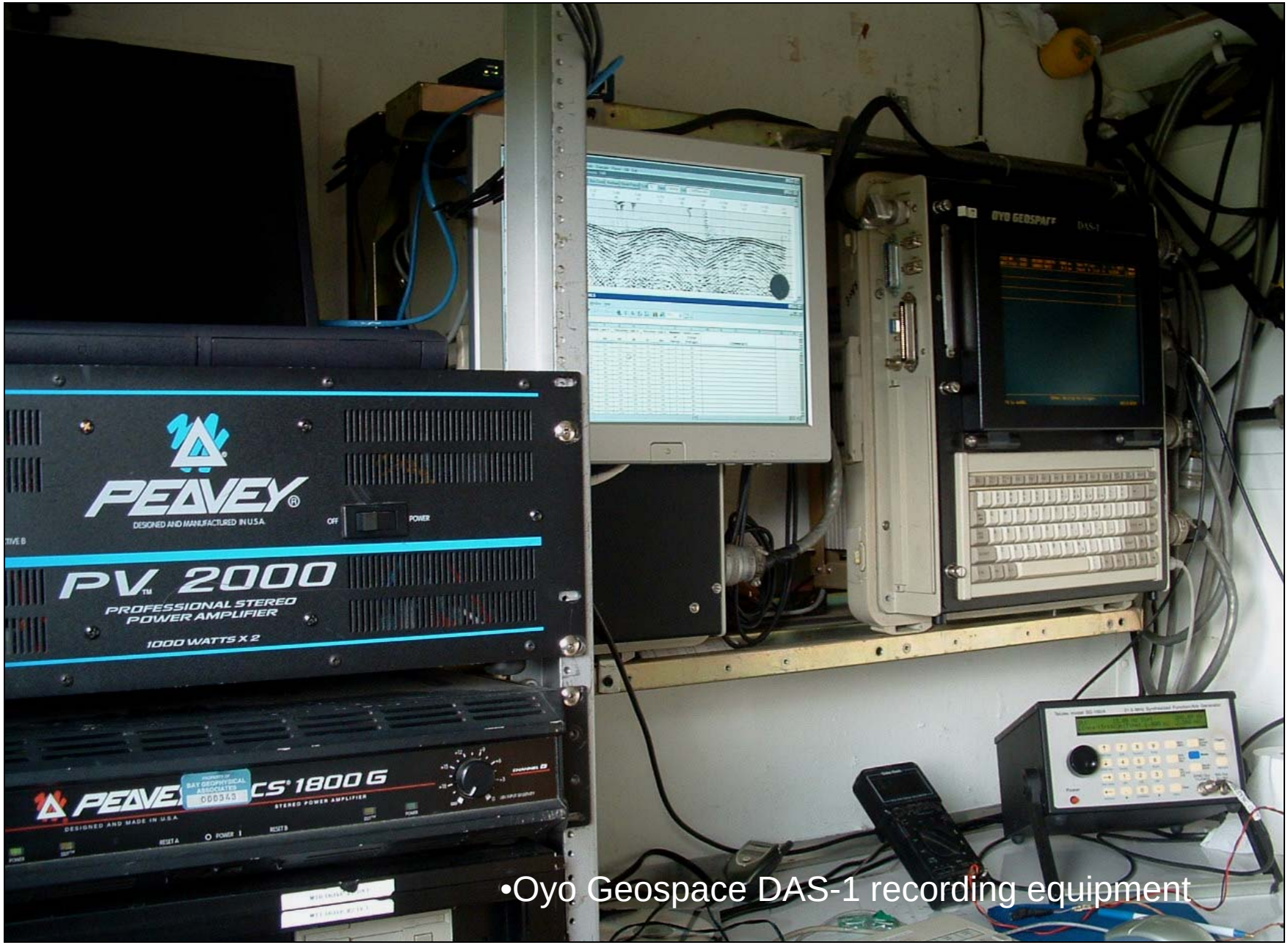
•6 receiver (geophones) lines, 1050’ long, 10’ geophone spacing along each line (105 geophones per line/630 total geophones), marked by Pink flags

•15 source lines, 1050’ long, 10’ source location spacing along each line (105 source locations per line/1575 total source locations), marked by Blue flags

•Close-up of Oyo Geospace 40 Hertz geophone, positioned vertically

- MicroVibrator source units setup along designated source location capable of generating shear (S) waves or primary (P) waves independent of one another
- Two source units were required to provide a stronger signal during shear (S) wave data acquisition

Jeep
TEXAS
C09-VXJ



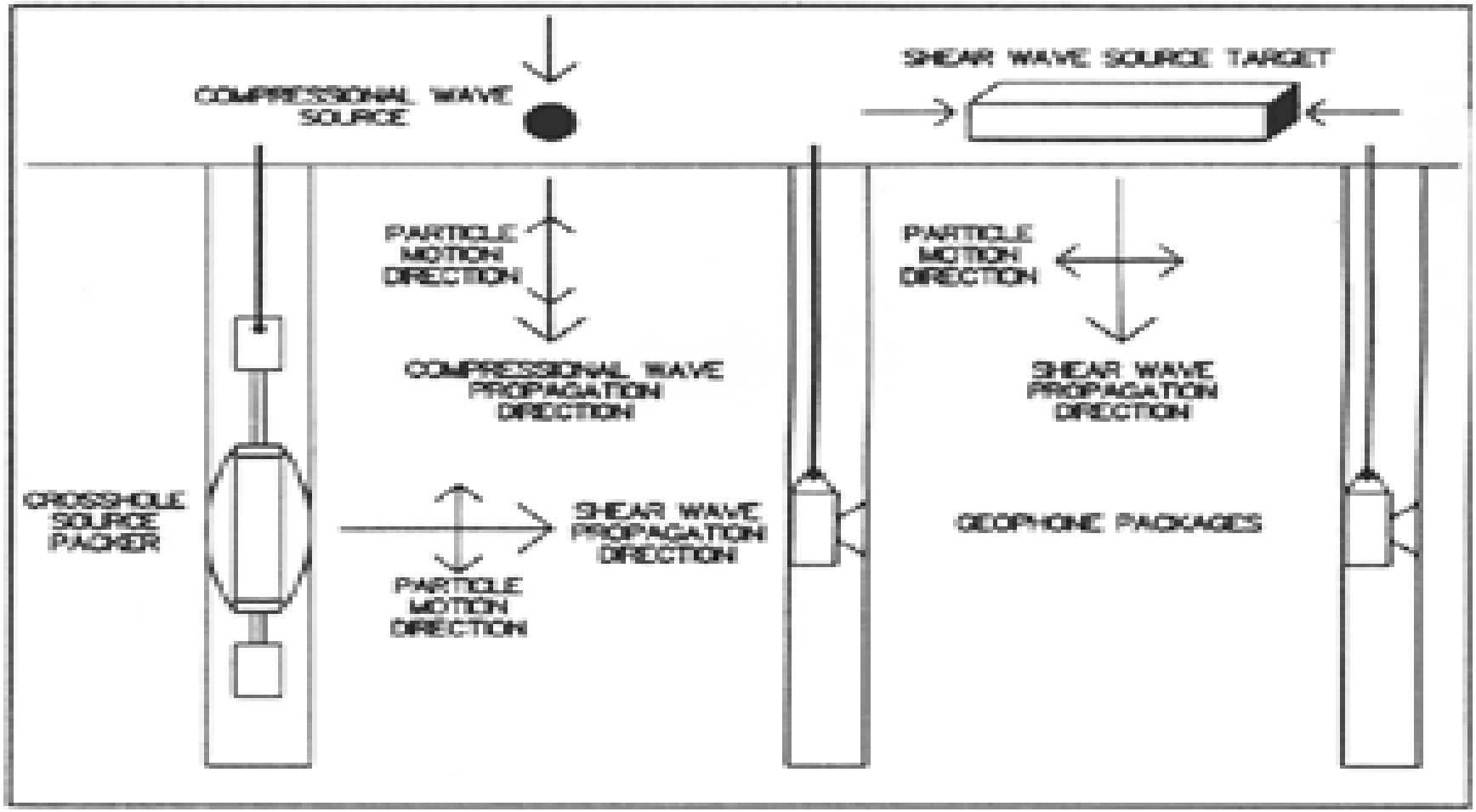
•Oyo Geospace DAS-1 recording equipment

Borehole Seismic Tomography Projects

- Blackhawk GeoServices
  - Black Beauty Coal Co., Riola Mine Complex

- Colorado School of Mines
  - Edgar Experimental Mine, Army Tunnel

Borehole Seismic Tomography

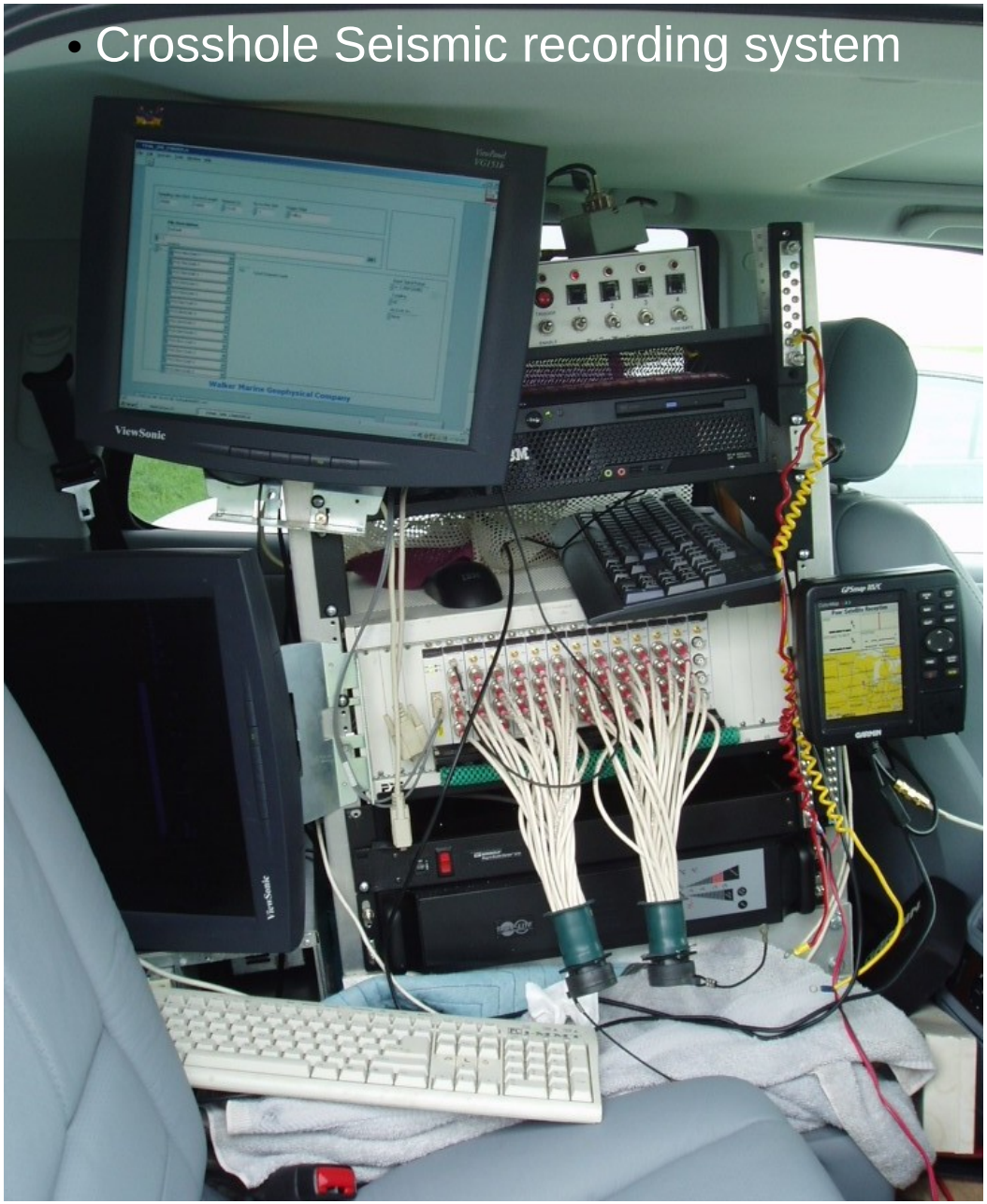


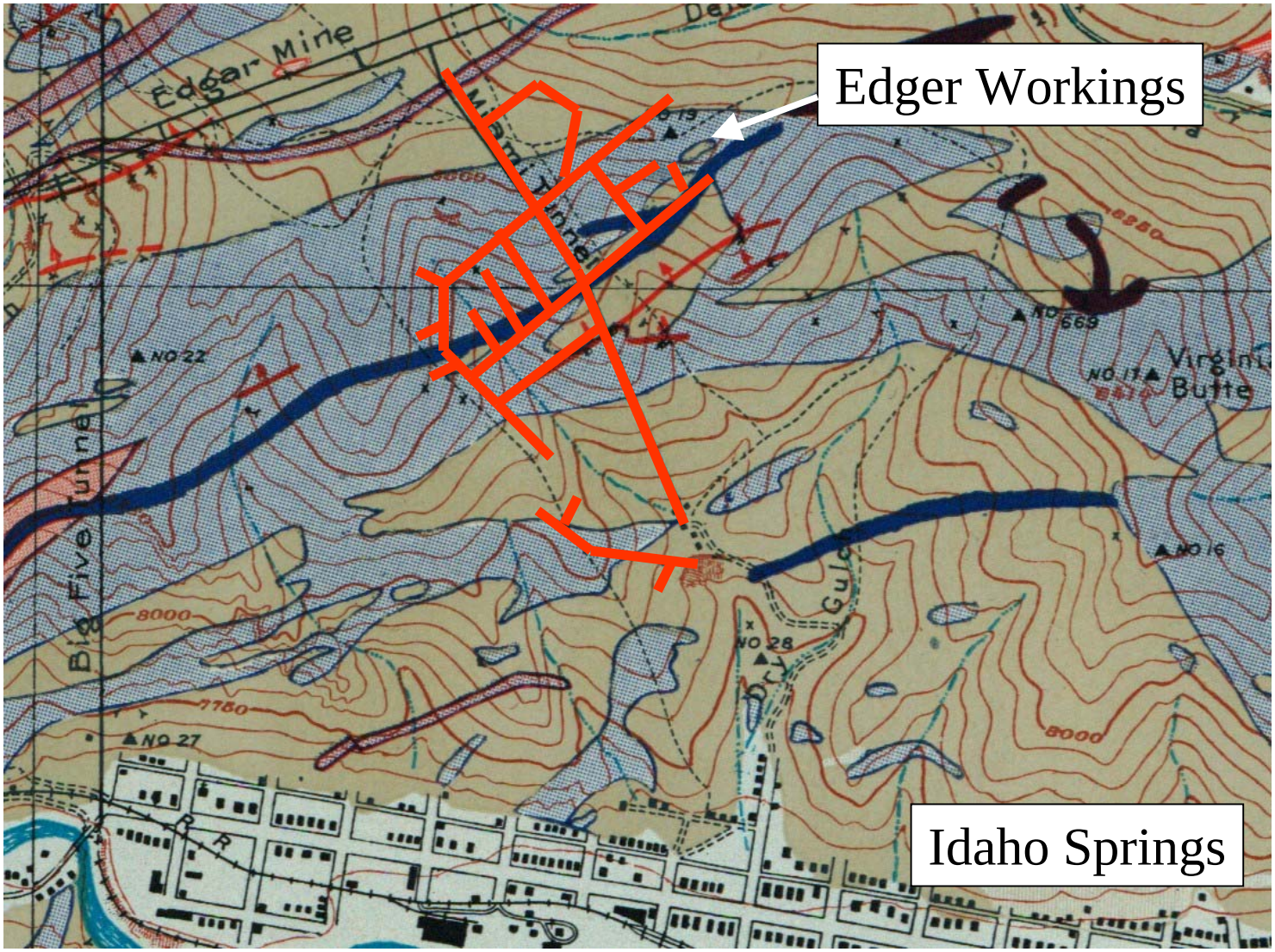
• Borehole XHT-NS#3
• 6-inch-diameter steel casing

Downhole source is a DHSS-5500 air gun, 2000 psi

- Full-waveform Sonic probe – measures velocity within rock strata

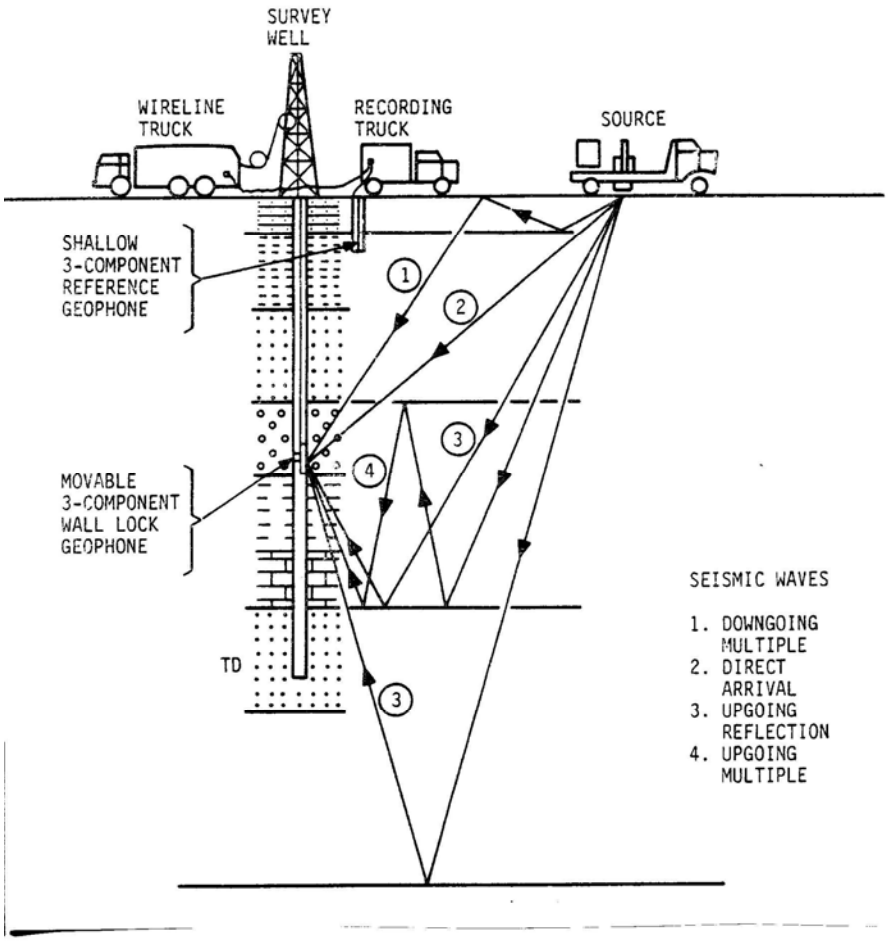
- Crosshole Seismic recording system





Edgar Mine is located in Idaho Springs, CO, about 30 miles west of Denver

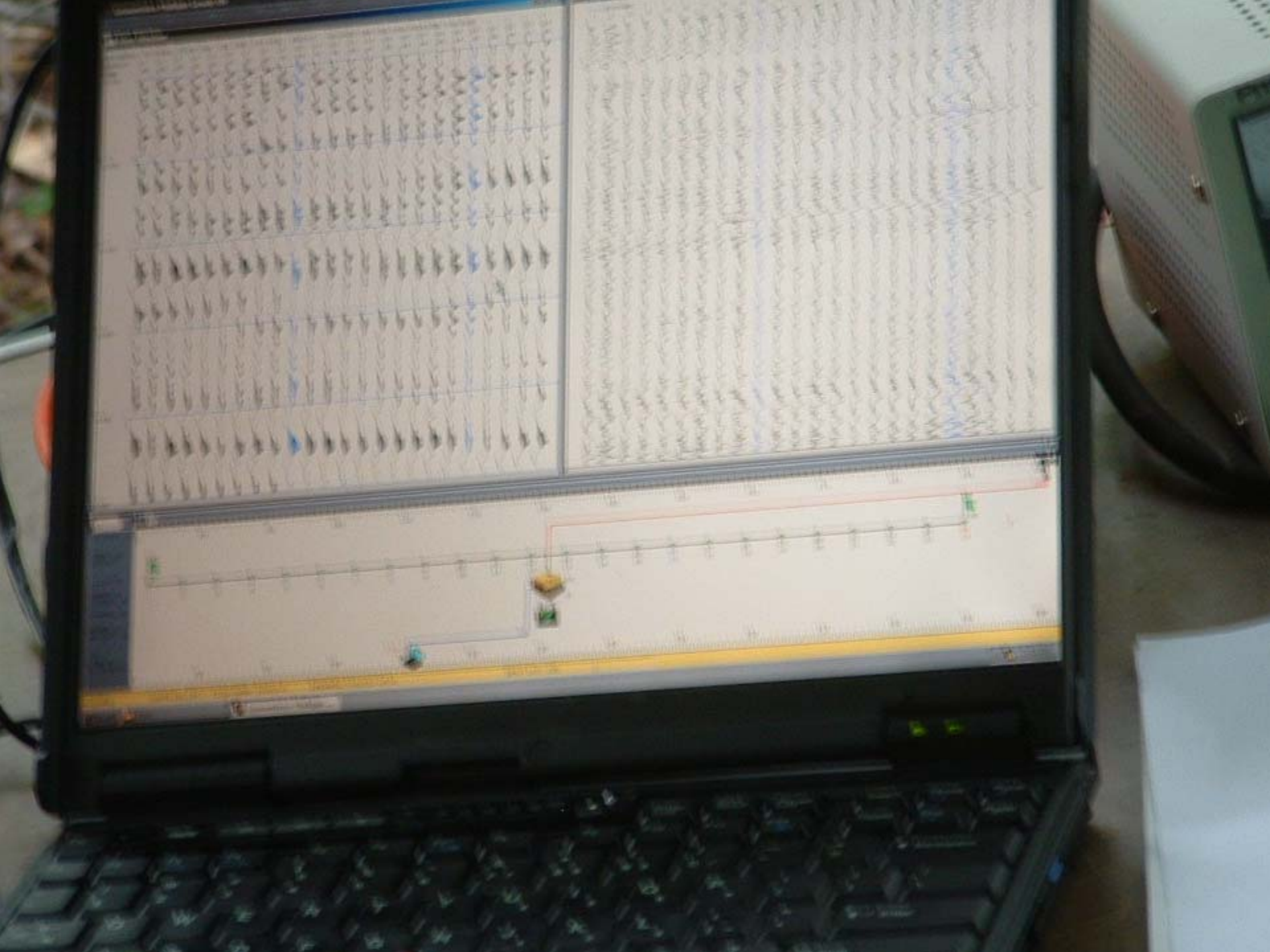
Vertical Seismic Profiling (VSP)



Vertical Seismic Profiling (VSP) Project

- L.M. Gochioco & Associates Inc.
  - Sterling Coal Corp., Carroll Hollow Mine

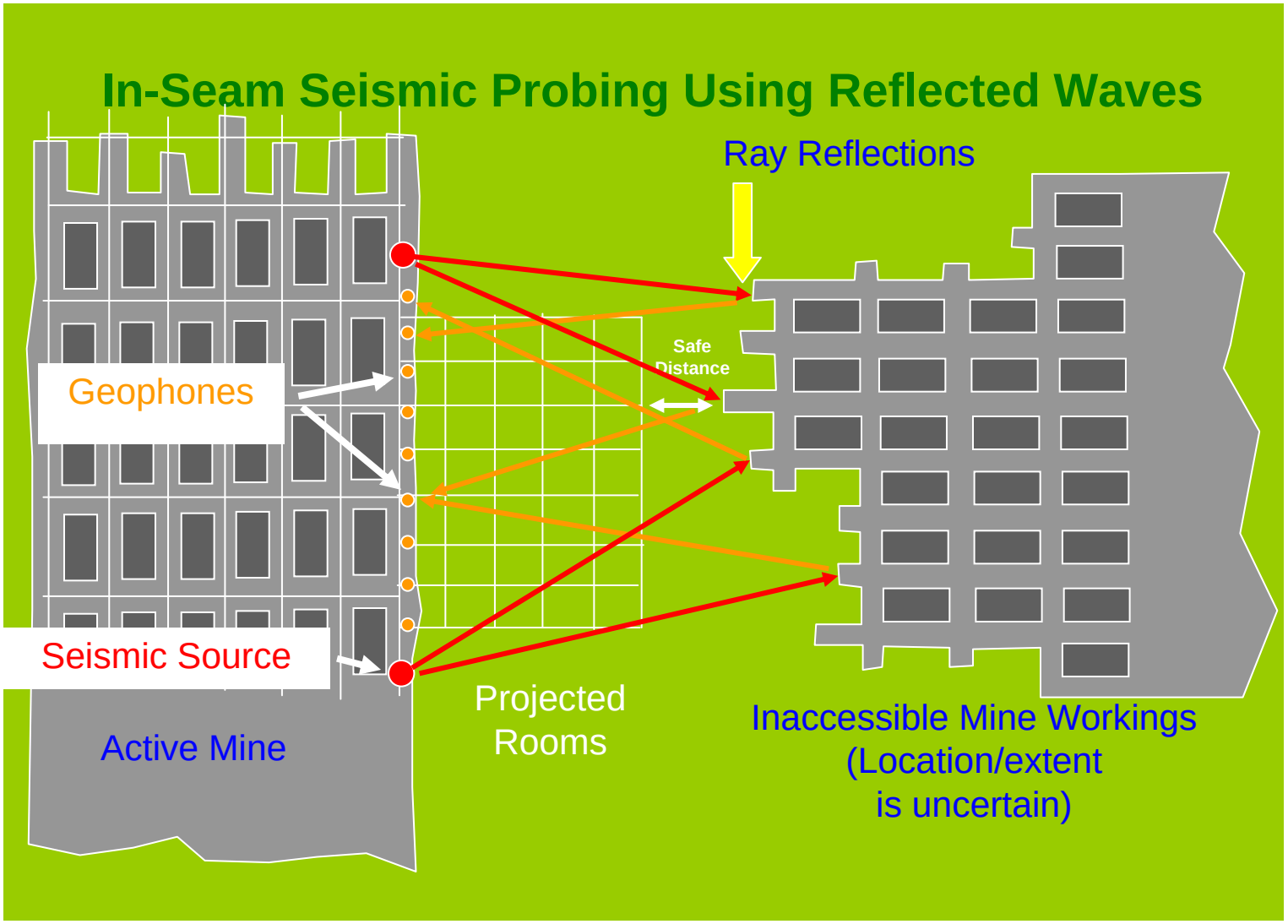
4×4



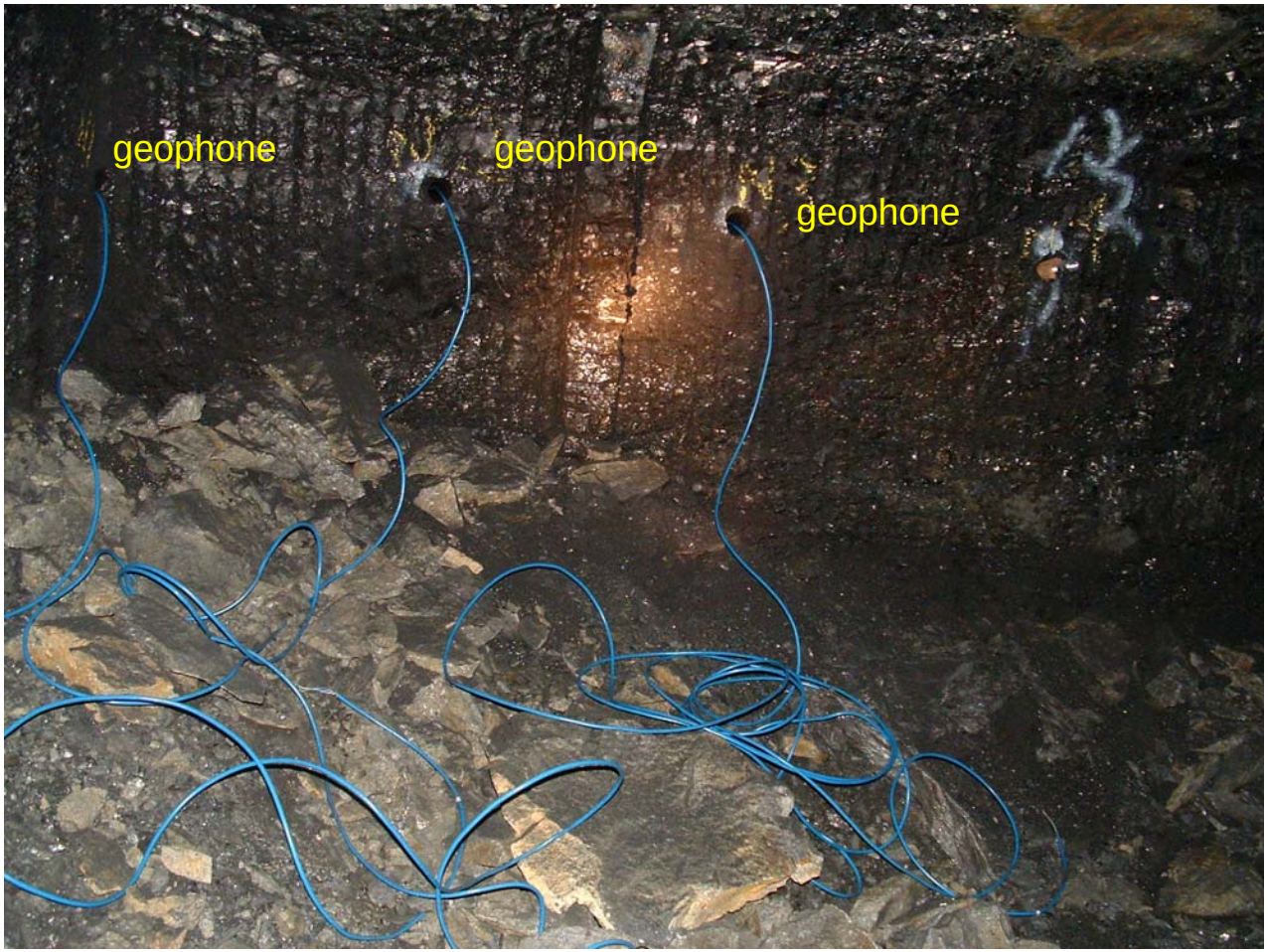
Inseam Seismic Reflection Projects

- Pennsylvania State University
  - Anthracite Coal Mine
  - Bituminous Coal Mine
  - Trona (Soda Ash) Mine
- L.M. Gochioco & Associates Inc.
  - Sterling Coal Corp., Carroll Hollow Mine
  - Paramount Coal Corp., Mine No. 4
- Mashall Miller Associates, Inc.
  - Sources and Receiver at Outcrop
- Wright State University
  - Continuous Miner vibration source, receivers on Surface

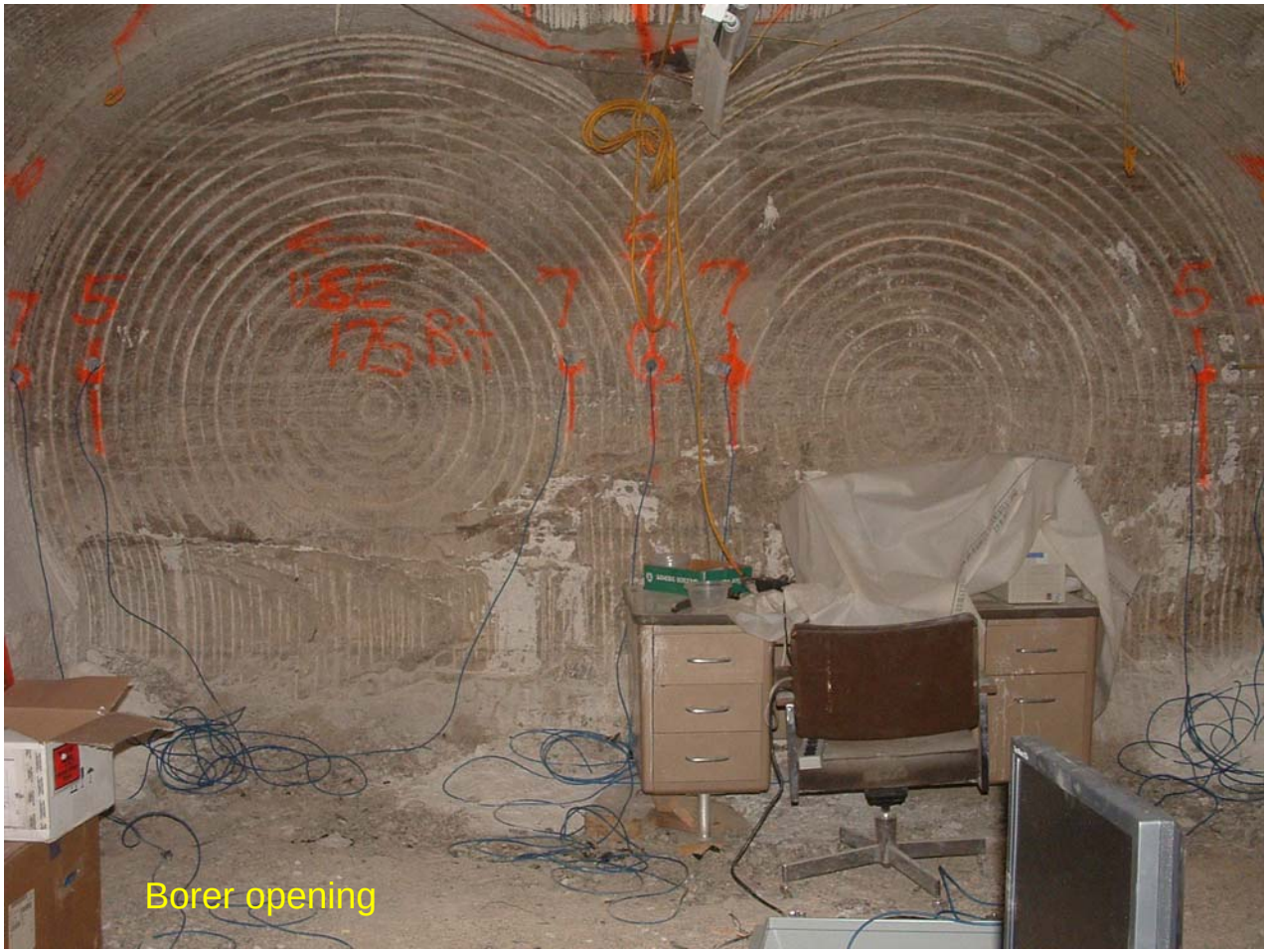
Inseam Seismic (ISS)



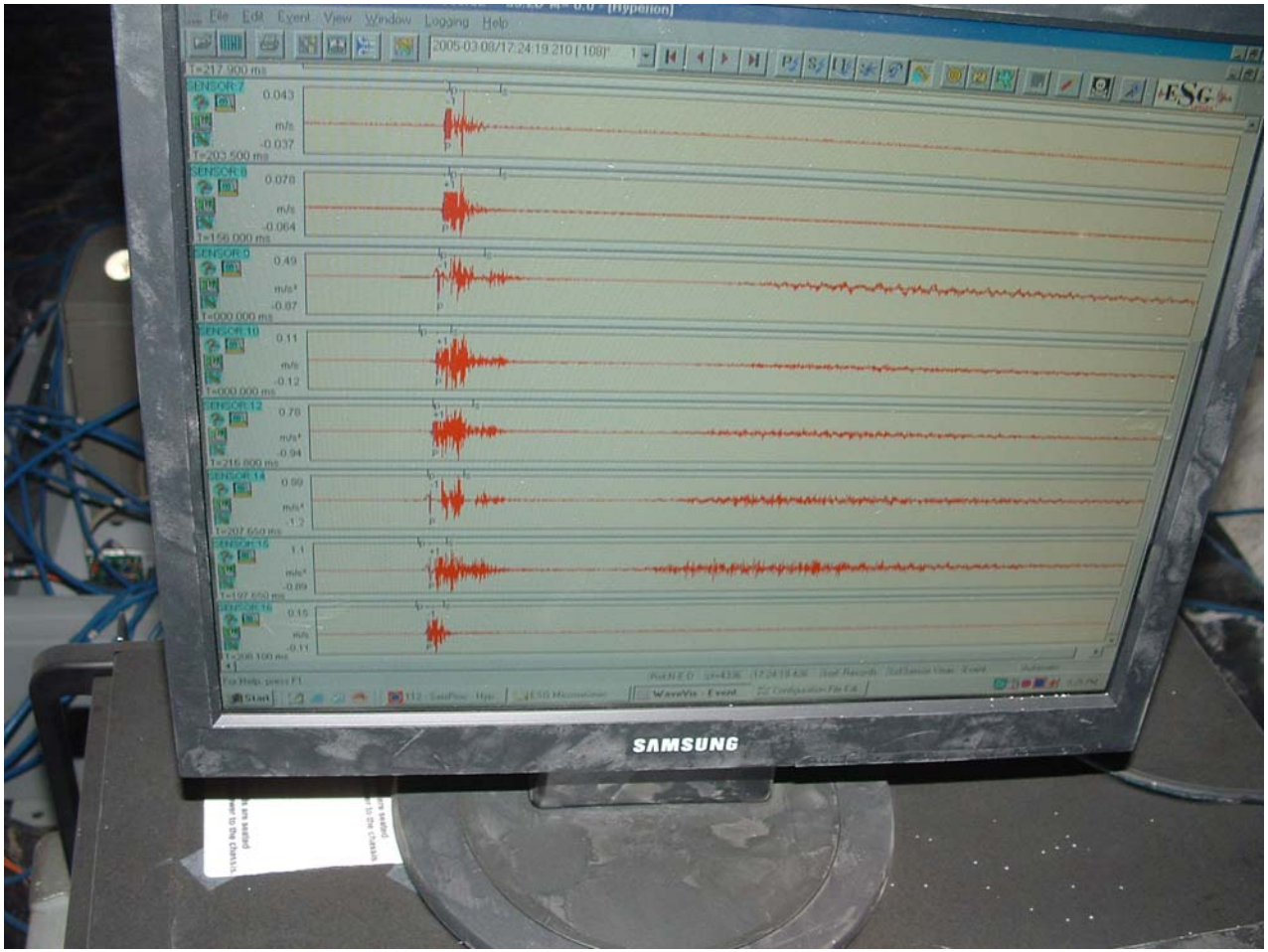
Installed Sensors in a Barrier



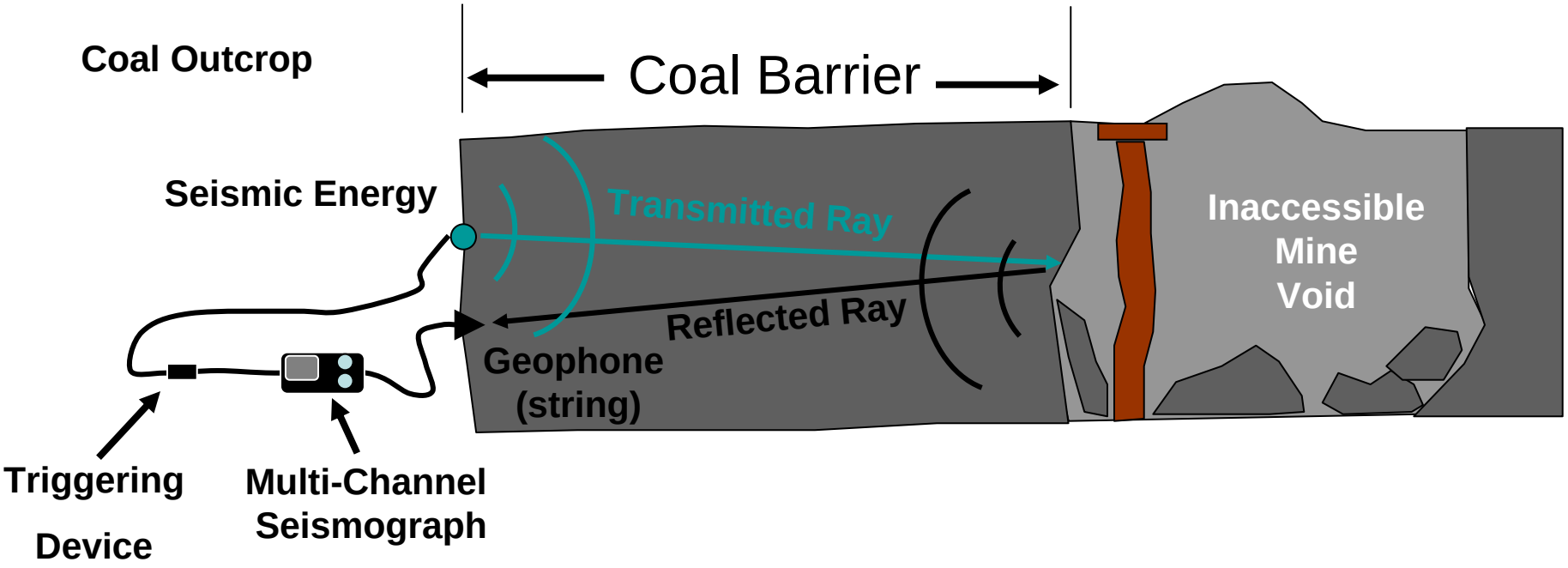
Trona Mine Sensors at Shop Area



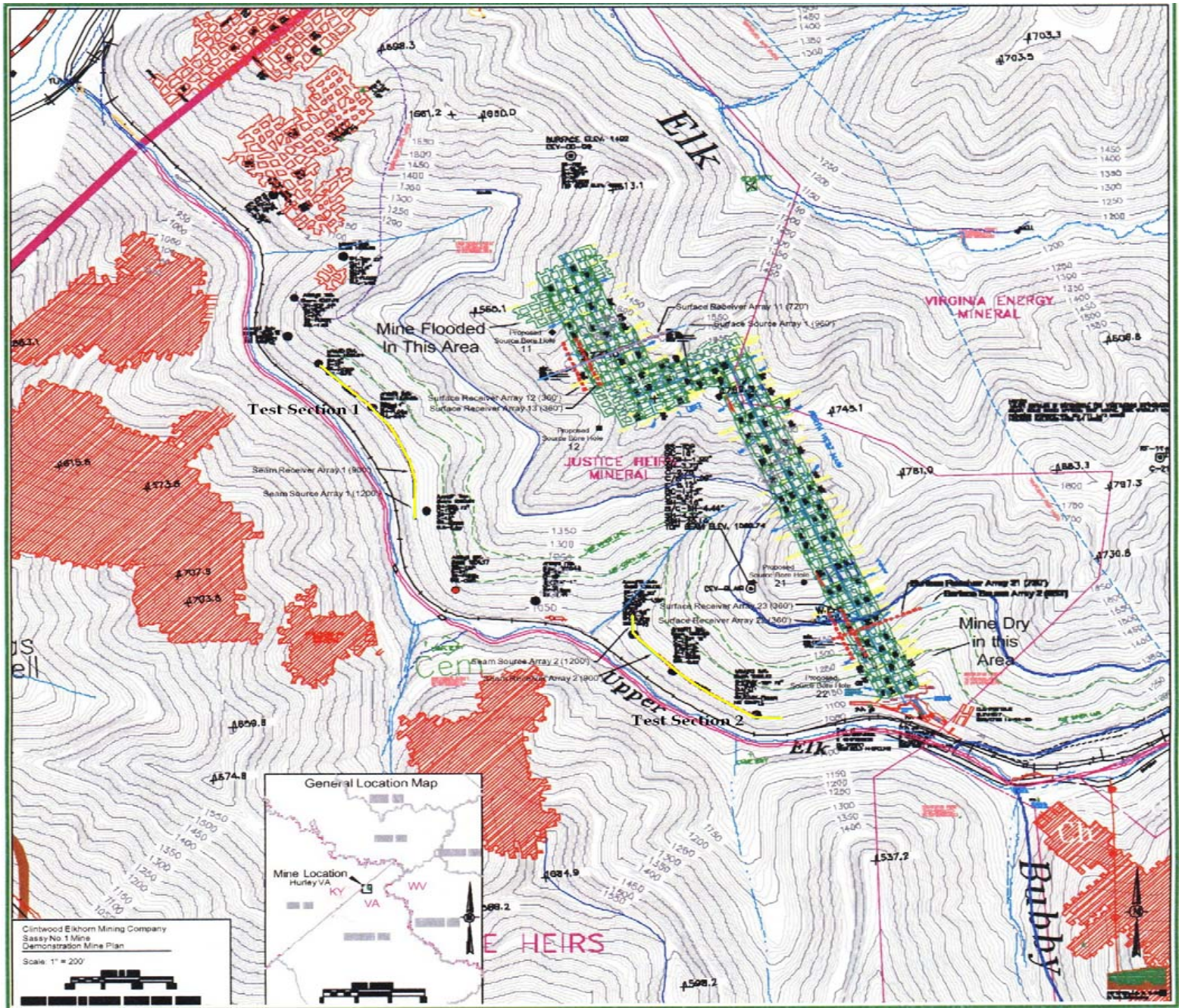
Reflection Test Wave Forms



In-seam Seismic Reflected Wave Principles



Plan View of Test Site



1) Pink line represents the data acquisition points for preliminary readings.

2) 60 vertically mounted geophones were placed along the end of the current production panel and the 160 feet to lower left.

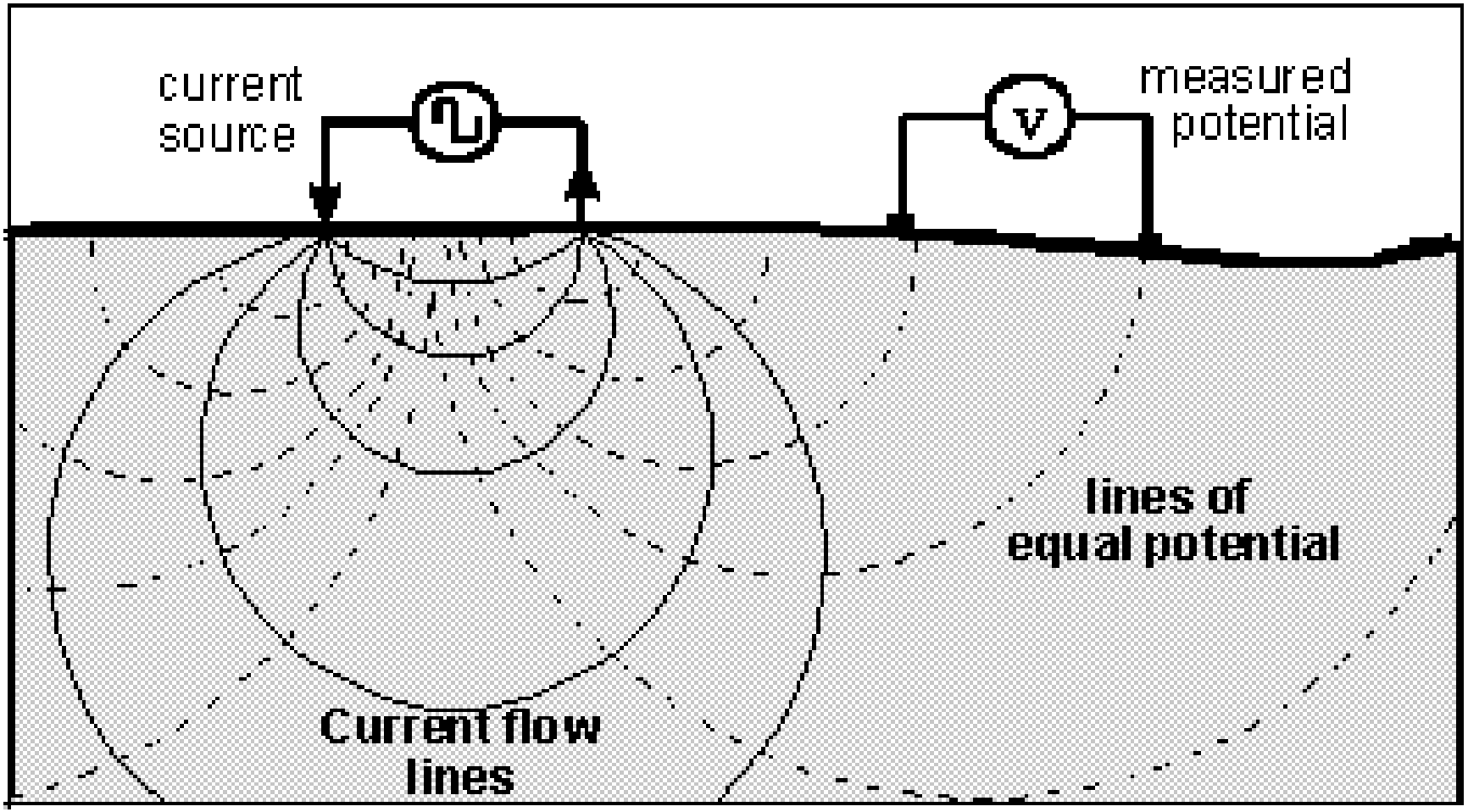
3) 120 phones, in 2 parallel lines 60 phones per line were placed perpendicular to panel. Crossing barrier pillar to abandoned Bunsen mine. (60 vertical, 42 horizontal, 6 individual 3 component settings)

These are the geophones placed perpendicular to current mining. Crossing the anticipated barrier to the abandoned Bunsen mine. Flags represent the location of 60 vertically mounted geophones. Just to the right of the flags (you can see the cables and the first 3-component set-up) are the horizontally mounted and the 3-component geophones.
(Nov 23, 2004)

Close-up view of the 3 component system.
Notice the orientation of the orange spring housings.
(Nov 23, 2004)

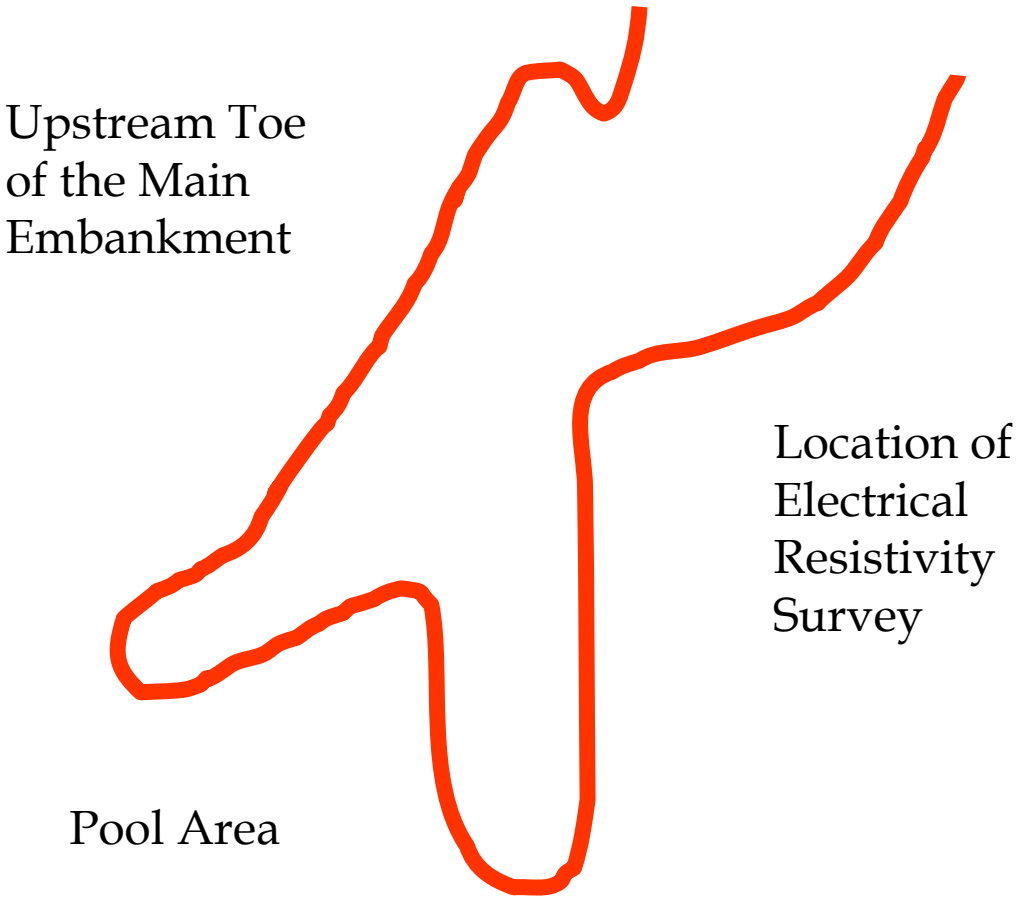
Dr. Hauser during data acquisition. (Nov 23, 2004)

Electrical Resistivity



Electrical Resistivity Project

- D’Appolonia Engineering Division of Ground Technology Incorporated
  - Pine Ridge Coal Company, Lot’s Branch Impoundment


Upstream Toe
of the Main
Embankment
Location of
Electrical
Resistivity
Survey
Pool Area

How Electrical Resistivity Exploration Works

- An electrical current is injected into the ground through two current electrodes and the resulting voltage measured at two potential electrodes.
- The difference between the current and voltage values provide the resistivity of the subsurface material.
- Since resistivity is an intrinsic physical property, the subsurface material is identified by comparing its resistivity to that of know materials.
- The process is repeated along survey lines laid out in parallel or in series to obtain a subsurface profile.
- This technique is generally effective to depths of 50 to 100 feet.

Electromagnetic and Radar Methods

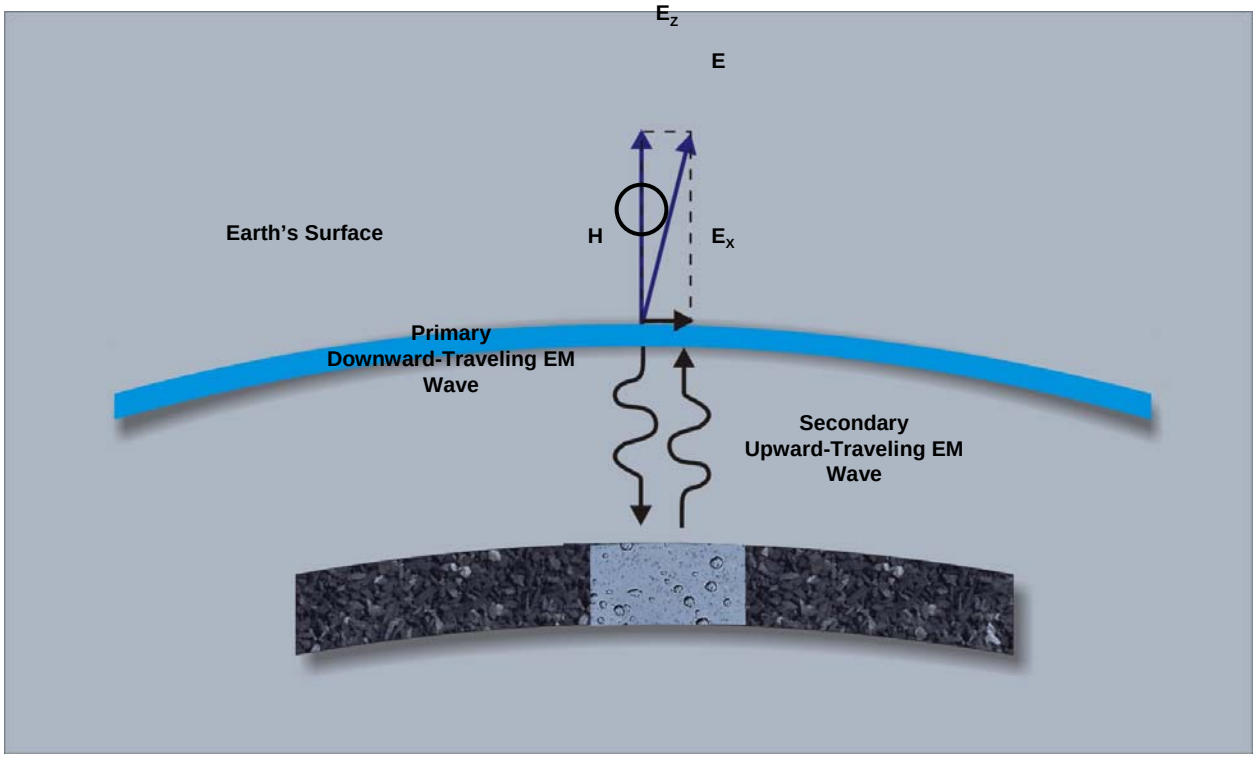


Figure 6-3. *Traveling electric field components illustrate the tilt in the vertical electric field component*

When the downward-traveling

Electromagnetic and Radar Projects

- D’Appolonia Engineering Division of Ground Technology Incorporated
  - Pine Ridge Coal Company, Lot’s Branch Impoundment
- Stolar Research Corporation – EM Gradiometer
  - Consolidation Coal Company, Emery Mine
- Colorado School of Mines – Borehole Radar Tomography
  - Edgar Experimental Mine

Upstream Toe
of the Main
Embankment

Location of
First Trial
Run of EM
exploration

Pool Area

How Time Domain Electromagnetic (TDEM) Exploration Works

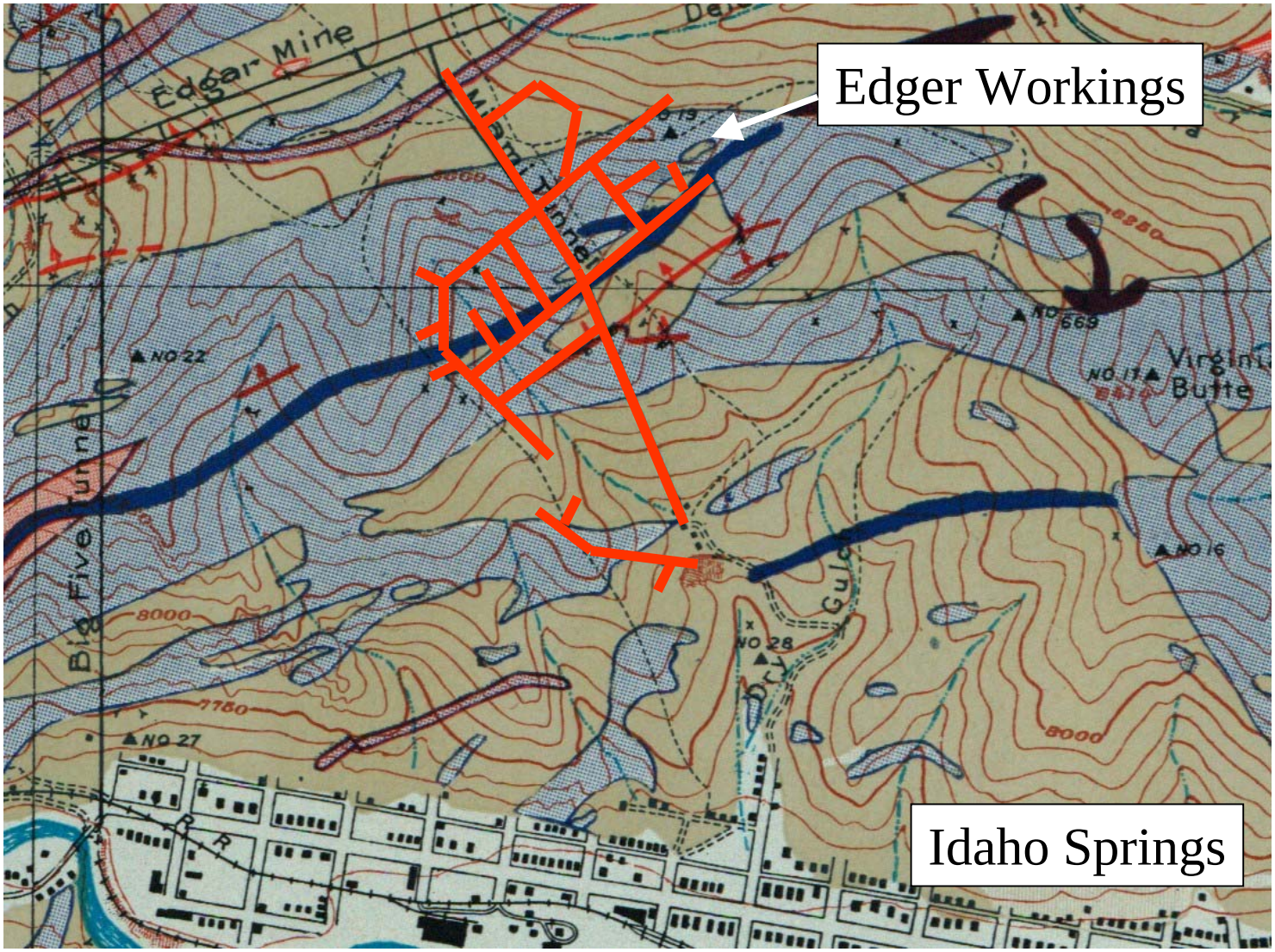
- A transmitter induces an alternating current into the ground at equal time intervals.
- Secondary EM fields are created in the ground when the transmitter is switched off.
- Measurements of the secondary EM fields are used to map variations in the subsurface electrical resistivities.
- D'Appolonia indicates that TDEM may be preferable over Frequency Domain Electromagnetics (FDEM) where overburden thickness exceeds 50 meters.

Pulling the mobile transmitter parallel to the receiver survey line.

Gradiometer receiver at first survey area. Depth of cover over the entries is approximately 80 to 100 Feet.

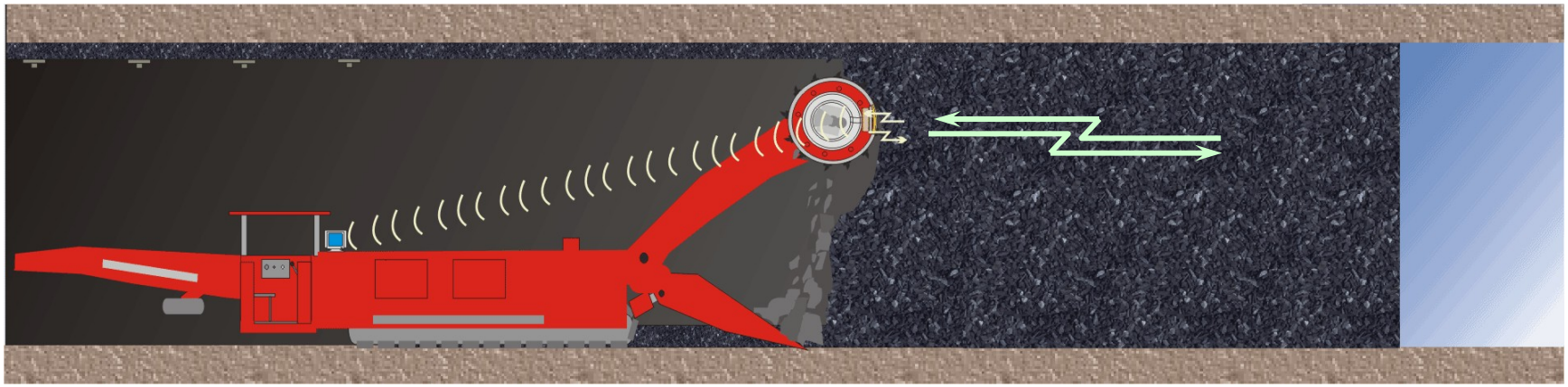
Colorado School of Mines - Borehole Radar

- Measures electromagnetic wave propagation through various ray paths and relates attenuation and phase shift to geologic anomalies
- Can be used as a tomographic method



Edgar Mine is located in Idaho Springs, CO, about 30 miles west of Denver

Look-Ahead Radar



Look-Ahead Radar Project

- Stolar Research Corporation – Handheld Device
  - Consolidation Coal Company

U.S. Department of Labor

MSHA

Mine Safety & Health Administration