Introduction to Near Surface Environmental Geophysics Webinar

Region 5
Superfund
Chicago, Illinois

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Field Services
Section

A Practical Guide for Commonly Used Methods & Applications

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Presentation Goals:

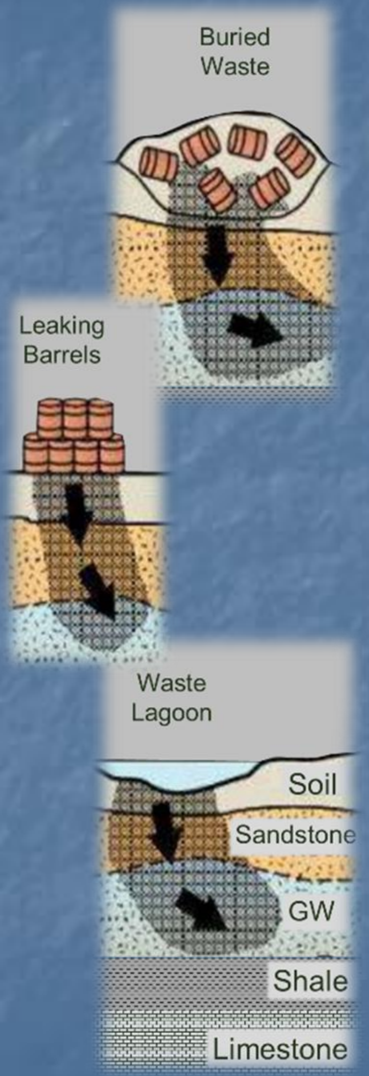
- Reveal options for several geophysical methods to characterize subsurface at hazardous waste sites
- Basic background how methods work
- How to plan/request subsurface surveys
- Avoiding interpretation pitfalls

What is "Near Surface" Geophysics

- A class of geophysical instruments, generally portable, capable of collecting data quickly within tens of feet below the ground surface
- Investigation ranges vary dependent on type of tool used & site conditions
- Deeper surveys require bulkier, more powerful equipment, some requiring acres of space

Types of Near Surface Targets

- Buried metal (ferrous & non-ferrous)
  - Clues to burial depths, if known: type of backhoe, bulldozer, etc. used for burial
- Contaminant plumes
  - Plume conductivities greater or less than in situ background matrix most likely detectable
  - Generally several inches or more in thickness
- Characterization of geology
  - Soils, clay, sand, bedrock, major voids
- Characterization of hydrogeology



Physical Properties Measured

- Velocity (acoustic & EM)
  - Seismic (acoustic)
  - Radar (EM)
- Electrical Impedance
  - Electromagnetics
  - Resistivity

- Magnetic
  - Magnetics
    - Passive method

Credit: Red Leaf

- Density
  - Gravity
    - Passive
- Radioactive decay
  - Natural gamma
    - Passive method

Geophysical Property Functions

Associated Tools

- Passive methods
  - Magnetics — Magnetometer
  - Gravity — Gravimeter

- Electric* & Electromagnetic (EM)
  - Electrical resistivity* — Resistivity meters
  - EM Induction (EMI)
    - Frequency Domain — Fixed & mixed EM freq's
    - Time Domain — Time Domain EM tools
  - EM Radiation (EMR) — Ground penetrating radar

- Acoustic
  - Seismic — Seismic system tools
    - Refraction
    - Reflection

Common Geophysical Tools/Targets
Rapid Near Surface Data Collection

- Magnetometer
  - Detects Ferrous metals
- Tanks, Drums, Wells, Foundations, Landfills

- Electromagnetics
  - Measures Ground Conductivity
  - Metal Detection (Ferrous & Non Ferrous)
- Stratigraphy changes, Soil moisture changes, Contaminate plumes, Distinguish metal types, shapes

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- Ground Penetrating Radar
  - EM microwave pulses to image subsurface
  - Measures changes in material properties
- Stratigraphy changes, Contaminate plumes, Burial pits, tanks, drums Approximate depths to anomalies

Common Geophysical Tools
Deeper - More Expansive – Time Intensive Data Collection

- Seismic
  - Stratigraphy changes due to reflecting/refracting sound waves
- Stratigraphy

- Electrical Resistivity
  - Stratigraphy changes due to ground conductivity changes
- Stratigraphy, contaminant plumes

- Gravity
  - Measures gravitational acceleration
- Void detection

Detection Limits* for Geophysical Tools

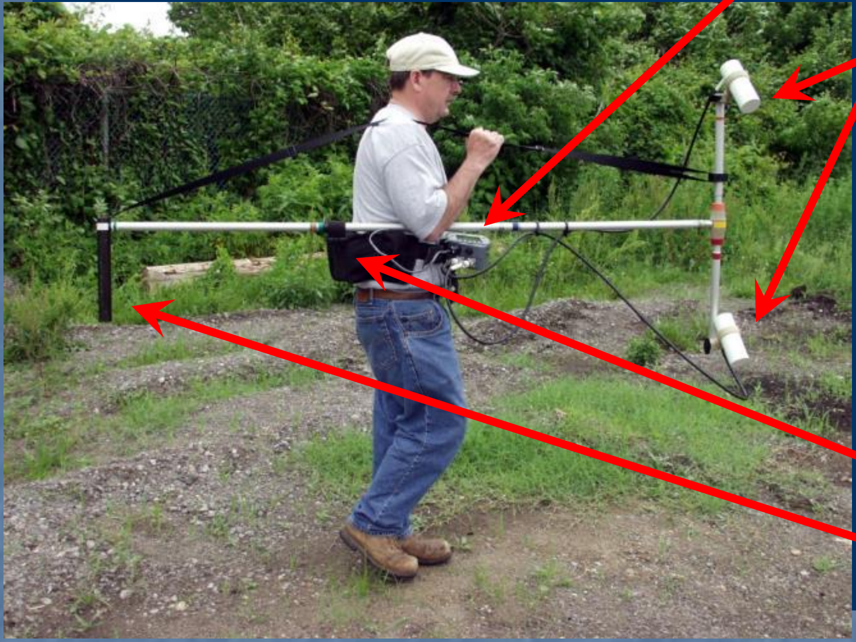
METHOD	DETECTION LIMIT*
Magnetometer	Based on ferrous mass 40’
Gravimeter	Based on size of void 40’
Electrical Resistivity	Line length, power source 100’+
Electromagnetic (EM)	
Fixed Freq. Domain	EM 31 15’
Variable Freq. Domain	GEM 2 surface to 30’
Time Domain	EM 61 15’
GPR	Freq. & soil dependent 0 - 40’
Seismic	
Refraction	Line length, power source 50’+
Reflection	Line length, power source 50’+

* Variable limits dependent on site conditions & equipment capabilities

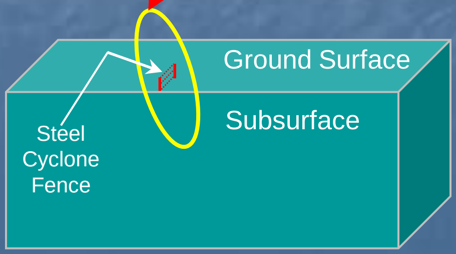
Common Environmental Geophysical Survey Tools

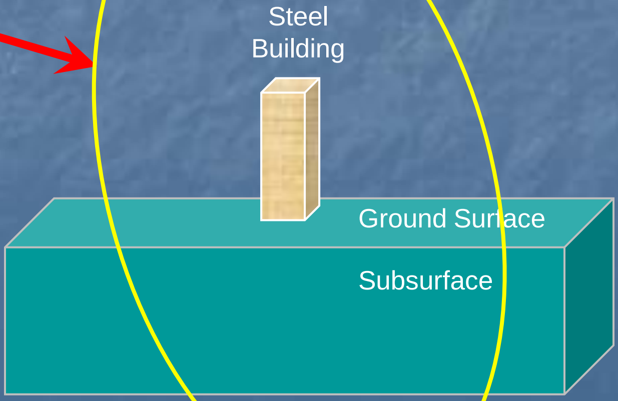
Gradient Magnetometer

Detects Ferrous Metal
(minor response from some fired clays)



- Data logger stores data
- Real time on-screen output
- GPS (optional)
- 2 sensors define gradient mag
- Hand carried / vehicle mount
- 0-40′ BGS dependent on mass
- Passive sensors no Tx /Rx
- Report out: contour, quasi 3D
- Fanny-pack batteries
- Brass counter-weight
- Above ground area / influence





Metal Detector ≠ Magnetic Method

photo credit: Wikipedia

METAL DETECTORS use internal power to create a electromagnetic field to locate metal

MAGNETOMETERS are passive instruments and only sense ambient magnetic fields

Typical GPR: Cart Platform

Images of Subsurface

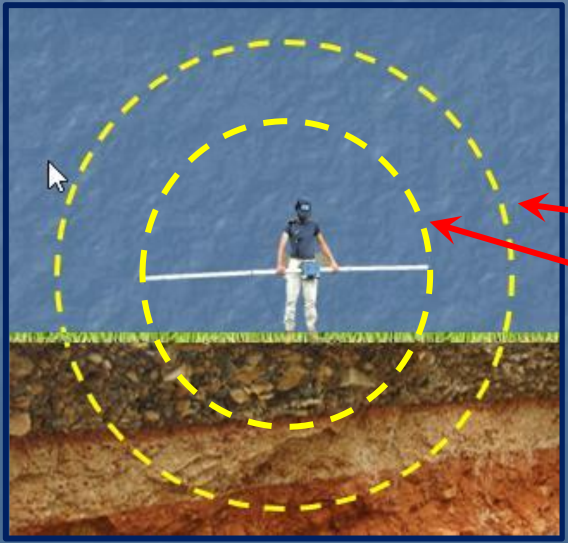
Estimates Depth to Targets

Confirm Buried Tanks - Shapes

- Must have contact w/ ground
- Hand pushed / vehicle towed
- GPS (optional)
- Data logger stores data
- Real time on-screen output
- Uses EM energy, batt. power
- Antenna contains Rx & Tx
- Antenna size shows frequency
- Freq's: high/shallow, low/deep
- Cart adjusts to antenna size
- Above ground area / influence
- 0-30' BGS depends on freq's
- Report out: single x-sec or 3D

EM31
Fixed Freq. Domain

Conductivity & Metal Detection
(Ferrous & Non Ferrous Metal)



Walk Boom Pointed Forward Not as Shown

Detection Limit Range

- Hand carried / vehicle towed
- GPS (optional)
- Uses EM energy, batt. power
- Rx & Tx antenna at each end
- Two readings taken @ once
- Gnd. cond. = Quad. phase
- Metal detection = In-phase
- Fixed frequency = fixed depth
- Data logger stores data
- Real time on-screen output
- Coil angle sets depth limit
- Vertical angle ≈ 12′ depth
- Horizontal angle ≈ 8′ depth
- Report out: contour maps

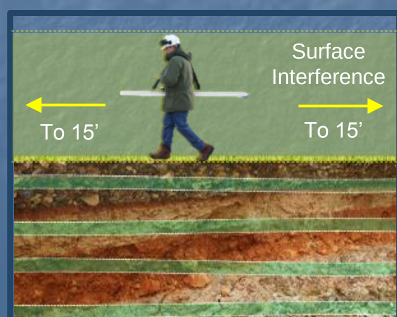
GEM2 – Multi Frequency Domain

Conductivity & Metal Detection

(Ferrous & Non Ferrous Metal)

Detection Limit Range

Multiple EM Pulsed Frequencies

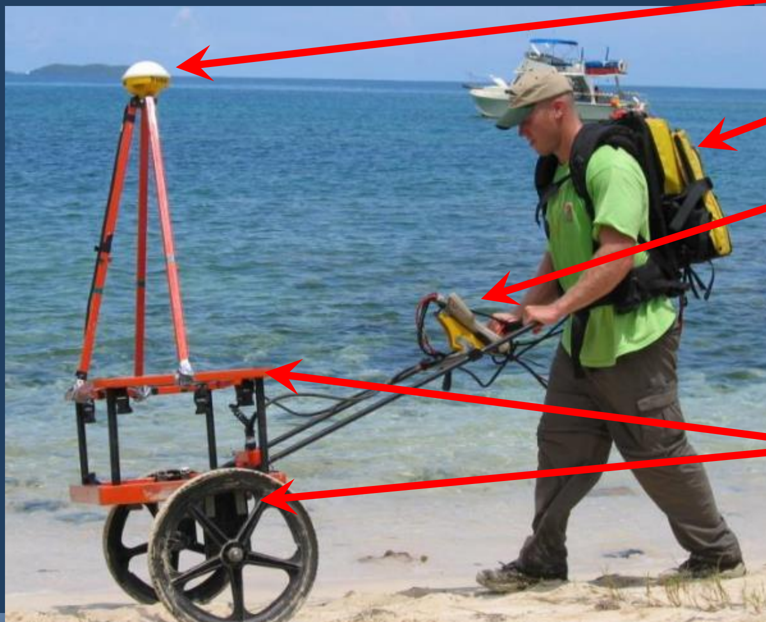


Targeted Intervals Displayed

- Hand carried / vehicle towed
- Data logger stores data
- Multiple simultaneous readings
- Multi frequency / multi depths
- GPS (optional)
- Gnd. cond. = Quad. phase
- Metal detection = In-phase
- No horizontal angle like EM31
- On-screen data view allowed - not practical (older units only)
- Antenna: Tx & Rx at each end
- Antenna: bucking amid Tx-Rx
- Uses EM energy, batt. power
- Typically 5-6 frequencies used
- Report out: contour maps, 3D
- Surface area interference 15’

EM 61 High Sensitivity Metal Detector

Detects Any Metal



- Hand push/pull - vehicle tow
- GPS (optional)
- Backpack: batt. & controller
- Data logger stores data
- Real time on-screen output
- Uses EM energy
- 3 antennas (coils): 2 Tx & Rx
- Coils allow shallow/deep data
- Detection depths 0-15’ BGS
- Report out: contour map
- Above ground area / influence

Above Ground Detection Limit to 15’ AGL

Direct Current Resistivity

Detects Changes in Subsurface Conductivities by measuring voltages from currents applied

- Resistivity array batt. powered
- Programmed internal switching
- Often duplicated for more detail
- 100’ bgs pending cable length, DC power, opposing transmission materials
- Elevation tool for electrodes
- Tape measures
- Electrodes
- Sting* controller / processor
- Cabling for electrodes
- Not optimal congested areas
- Report out: pseudo-sections

*Sting is a trademark of AGI

Seismic Refraction

Commonly Used Environmental Surveys
Records 1st Arrivals of P-Wave



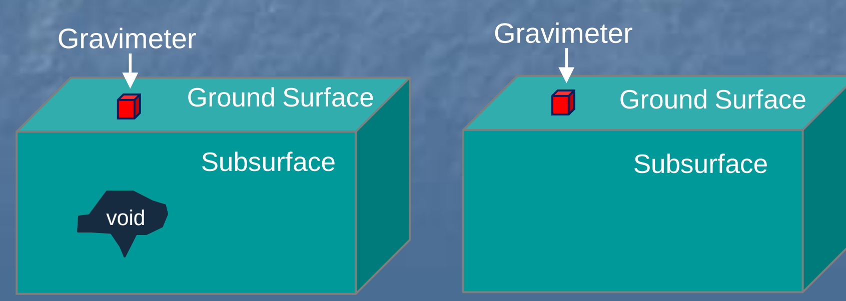

- P-wave: pressure or primary wave, rest of wave ignored
- Records first refracted energy
- Finds depth to GW, bedrock, weathering zone
- Close-up of geophone
- Sound source: plate & hammer
- Geophones and cabling
- Sensitive to external noise
- Geophones in ground
- Seismograph linked to laptop
- Not optimal congested areas
- Report out: seismic record

Micro Gravimeter

Measures Material Density

Maps Voids and Intrusions

- Must have contact w/ ground
- Time intensive data collection
- Susceptible to vibration / wind
- Unit stores data, batt pwr'ed
- Real time on-screen output
- Passive sensor - no Rx & Tx
- Report out: contour map
- Corrects tides by unit location
- DoI* depends on mass
- Non unique measurements



DoI* = Depth of Investigation

Borehole Geophysical Methods for Existing 2" Monitoring Wells

- When are existing 2" wells a focus for borehole geophysics?
  - Legacy wells prior to federal intervention
  - Five year reviews
- Common available options
  - Optical camera (sidewall/downhole views)
  - Natural gamma
  - Ground conductivity (non-metal casing)

Modeling for Interpretation

- Two kinds of simple models
  - Forward
  - Inverse
- Models depend on input conditions and data
- Models can be very helpful in visualizing the site
- Models are not reality

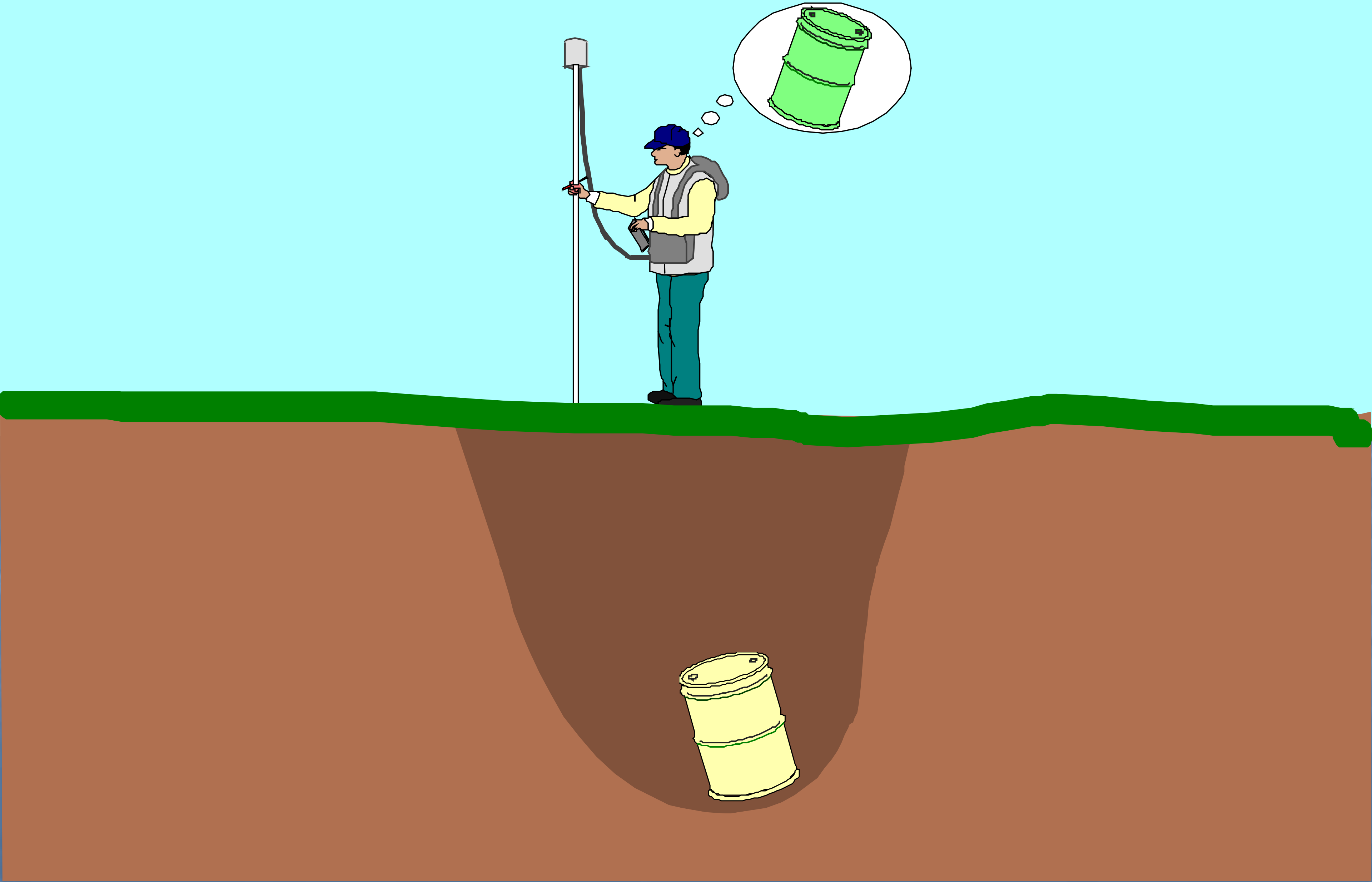
Geophysical Methods Advantages

- Non-intrusive
- Rapid data collection
- Detects a variety of targets
- Screens large areas
- Fills in data gaps

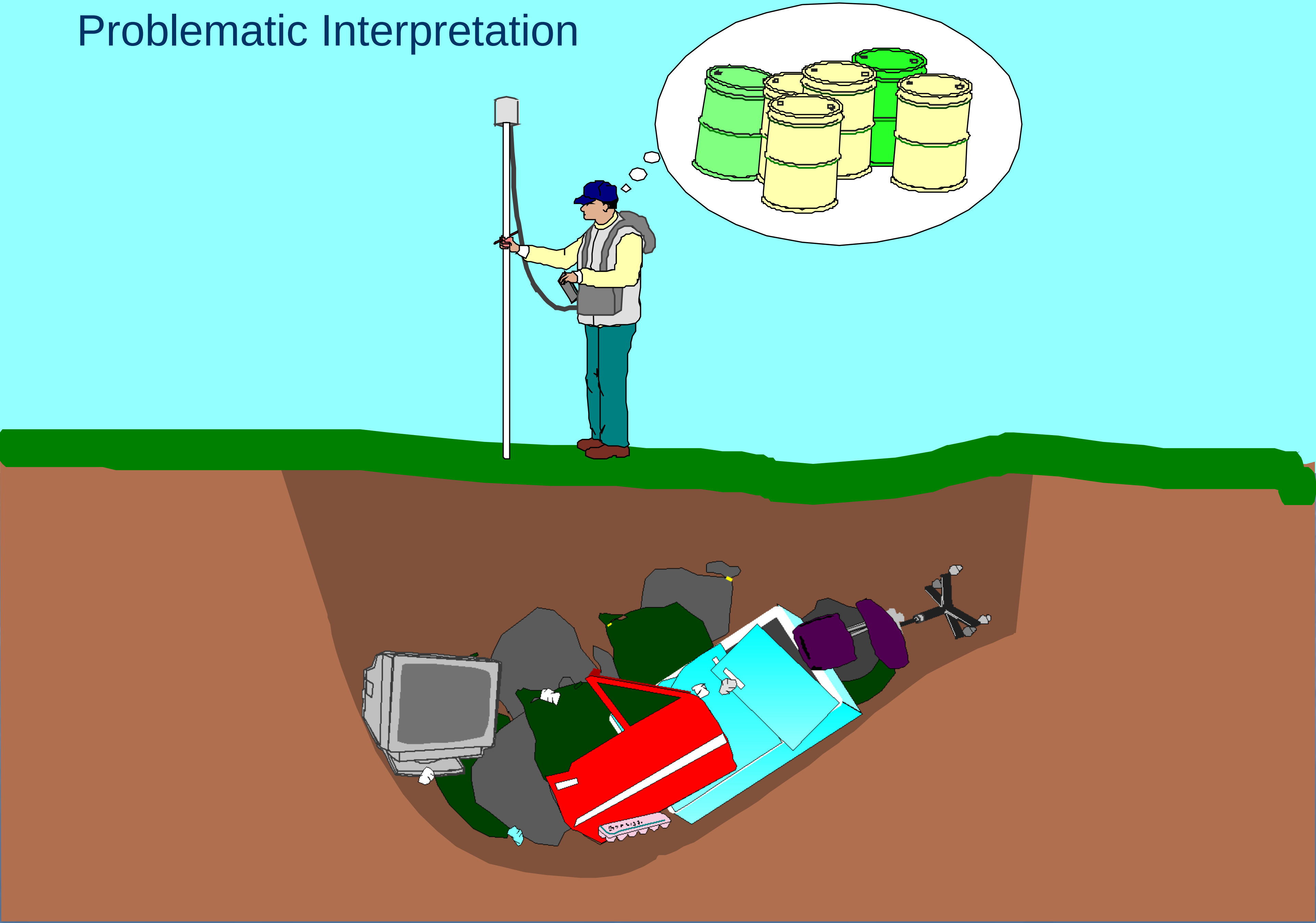
Geophysical Methods Limitations

- Methods require a specialist
- Physical contrasts must exist
- Resolution varies by method & depth of target
- May be expensive
- Interpretations are non-unique

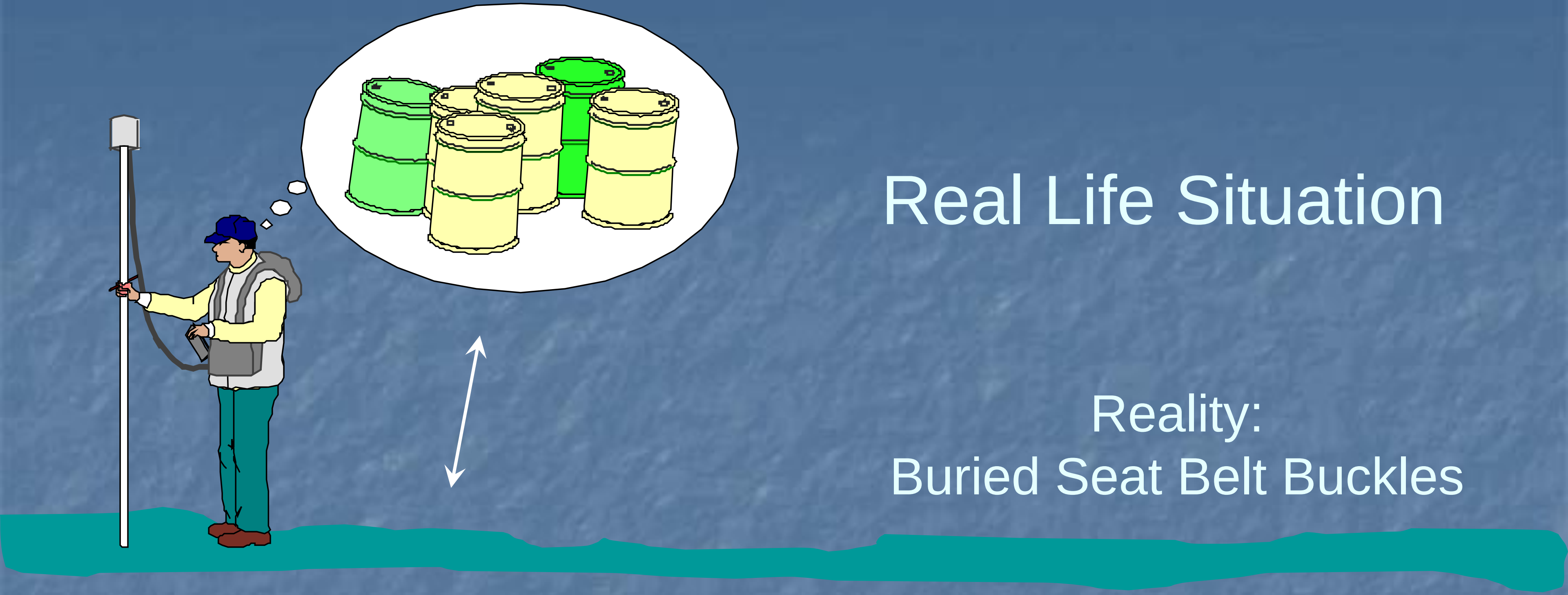
Correct Interpretation



Problematic Interpretation



Real Life Situation



Reality:
Buried Seat Belt Buckles

GEOPHYSICAL SURVEY DESIGN

JIM URSIC - U.S. ENVIRONMENTAL PROTECTION AGENCY - CHICAGO, ILLINOIS

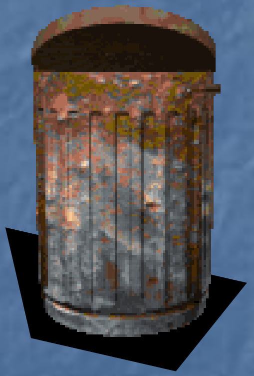
Planning – Reviewing Geophysical Surveys

Survey Design Rationale

- Establishes a plan
- Find potential pitfalls
- Maximize benefit
- Minimize surprises
  - Property line issues
  - Archeological sites
  - Utility lines
- Customize requests

Pre-survey Planning: Garbage IN – Garbage OUT

- Inadequate background information & planning dooms a survey before it starts:
  - Requires more time in the field
  - Increases costs
  - Missed targets
  - Questionable data

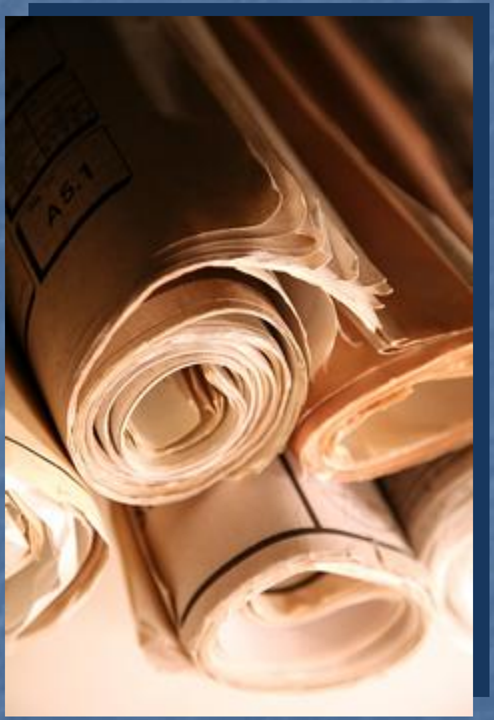


Define Problem

- List issues of concern
- Can geophysics help?
- Data confirmable?
- How will results benefit your plan?

Background Paperwork Review

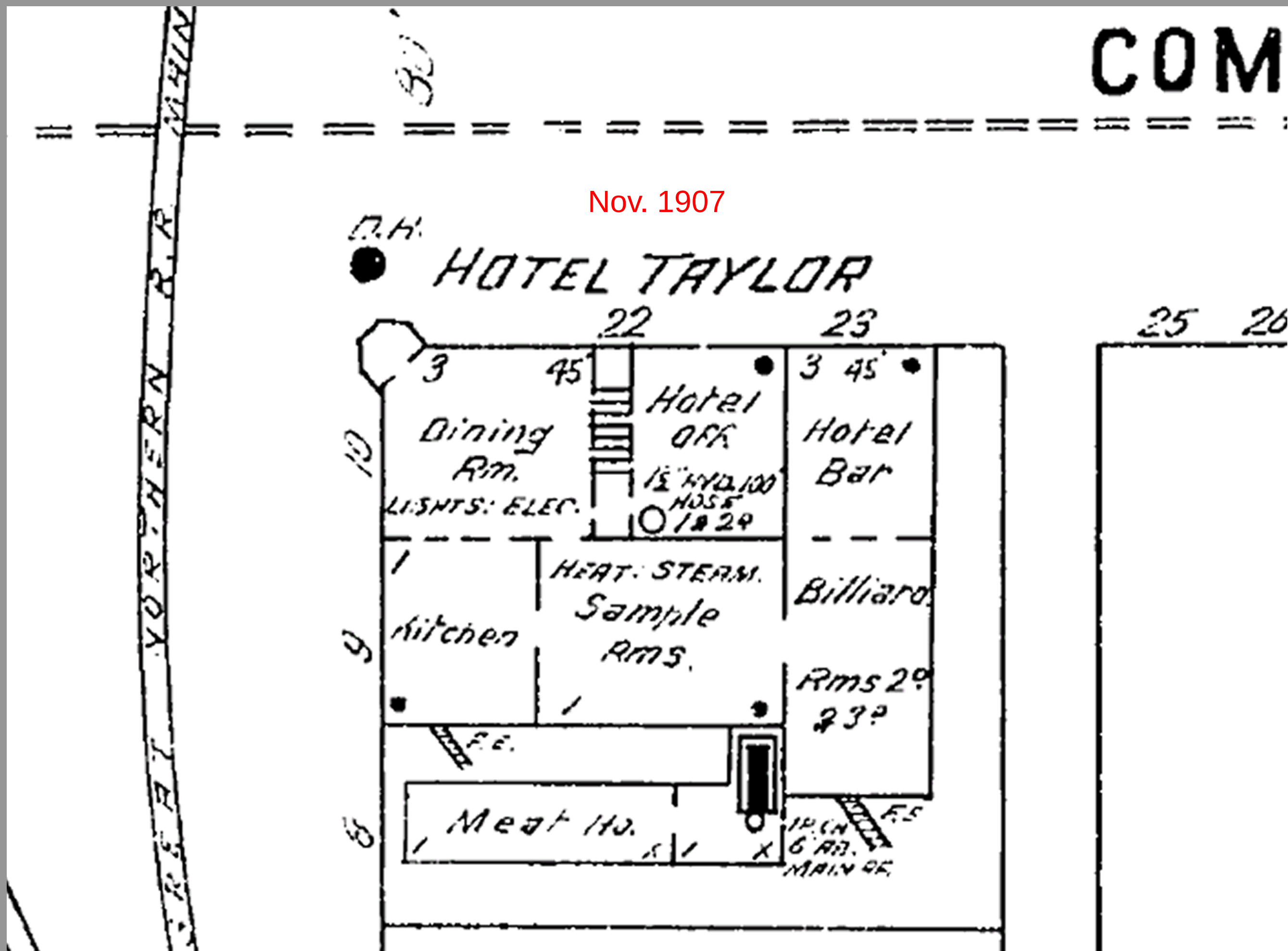
- Site history
- Previous studies
- Geology
- Geohydrology
- Geographic issues
- Health, safety & QAPP issues



Background Maps/Image Review

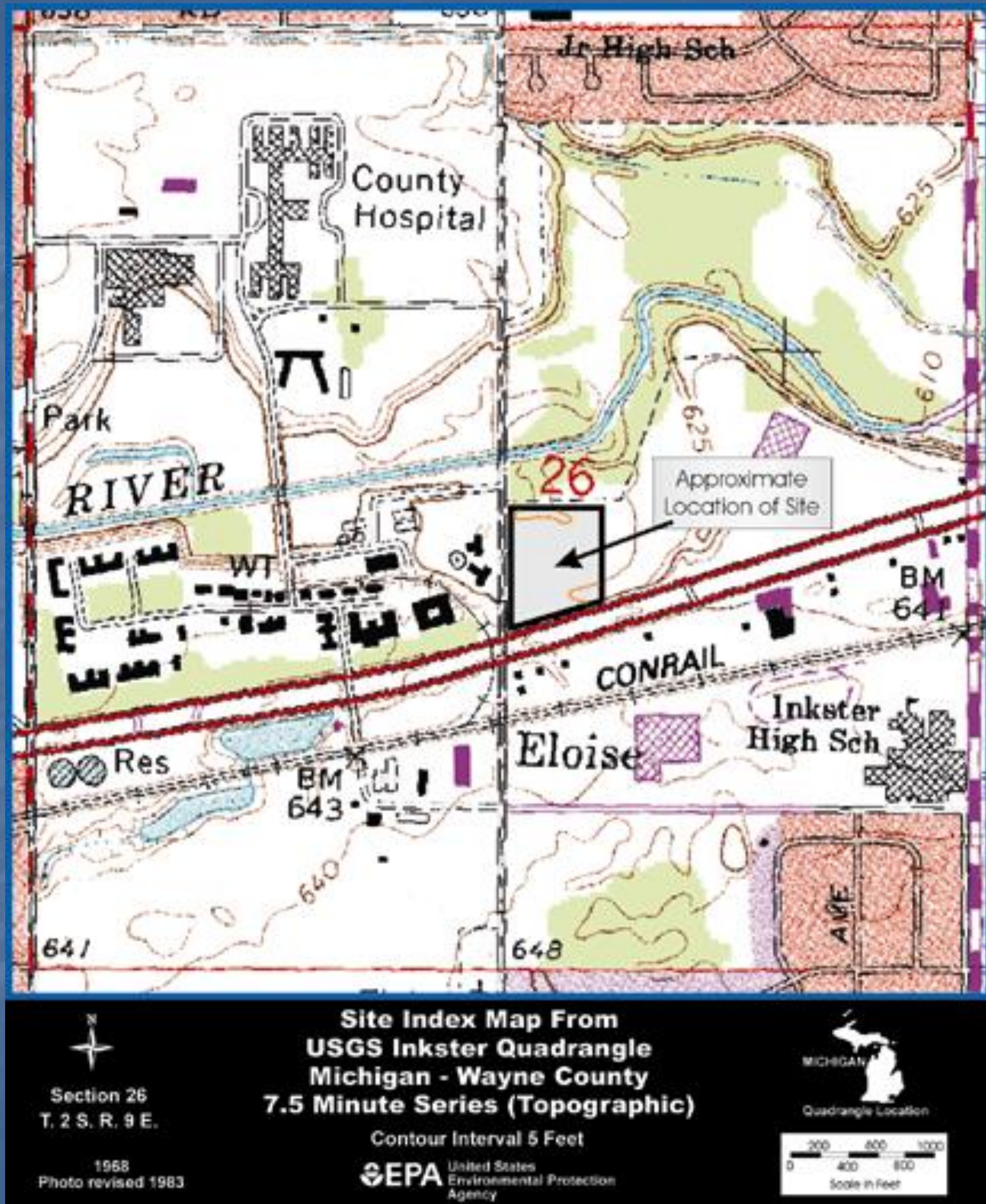
- Sanborn or other Public Maps
  - Historical site records & buildings
- Topographic Maps
  - Terrain conditions
- Geologic Maps
  - Indirect conditions
- Aerial Images - internet
  - Indirect conditions

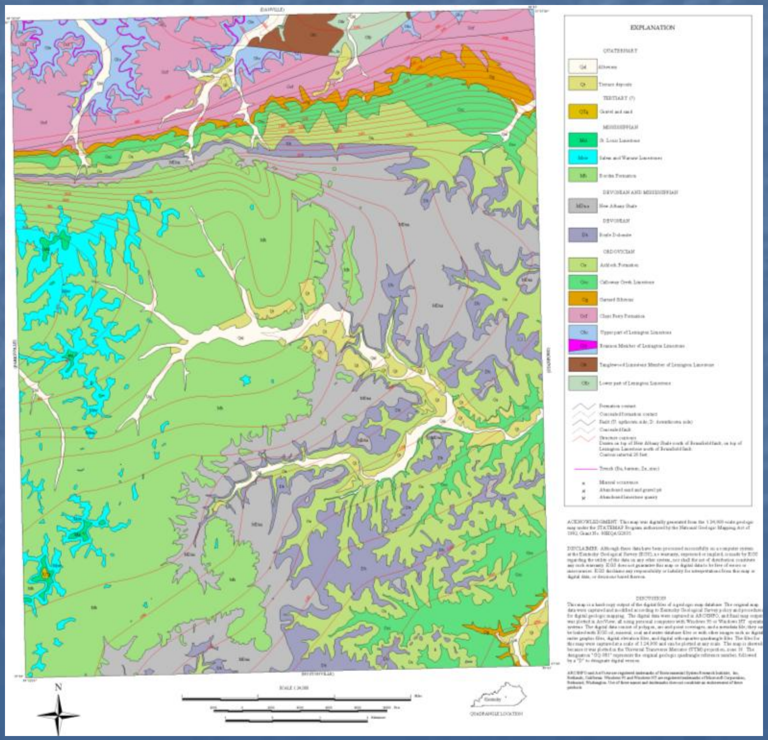
Sanborn Map Example: Anacortes, Washington State



Sanborn UMI

Topographic & Geologic Maps





Example of Aerial Photo Details

Following up from previous slide's topographic map

Background Photo Review

Same
Building

Recent Site Photo

Historical Site Photo

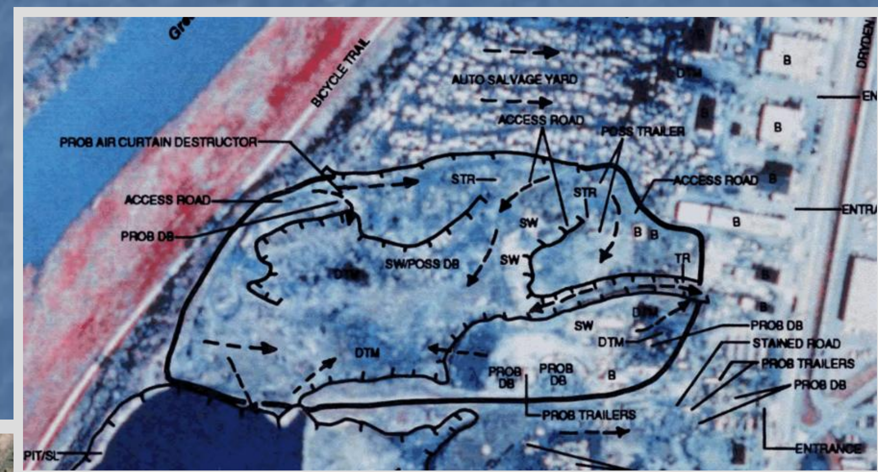
Circa 1990 Aerial Photo

Circa 1960 Aerial Photo

Photo Interpretation

May 7, 1981: Color Infrared

Sept 25, 1936: B & W



Remote Sensing
& Imagery Analysis
Services (RSIAS)
Office of Environmental
Information (OEI),
RTP North Carolina

Lammers Barrel
Beavercreek, Ohio

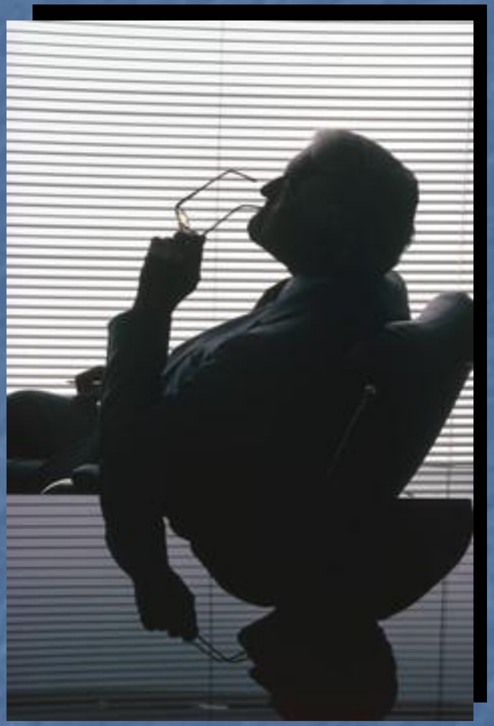
April 5, 1988: Color

http://intranet.epa.gov/gis/remotesensing.html

Formerly Environmental
Photographic
Interpretation Center

Other Issues To Consider

- Property boundaries
- Consent for access
- Traffic & pedestrians
- Vegetation status
- "Noise" issues
- Utility location
- Archeological sites



National Historic Preservation Act

- Why should we care?
  - It's the law
  - It's EPA's policy
  - It's a good idea

Public Law 89-665; 16 U.S.C 470 & Subsequent Amendments

Code of Federal Regulations (CFR)

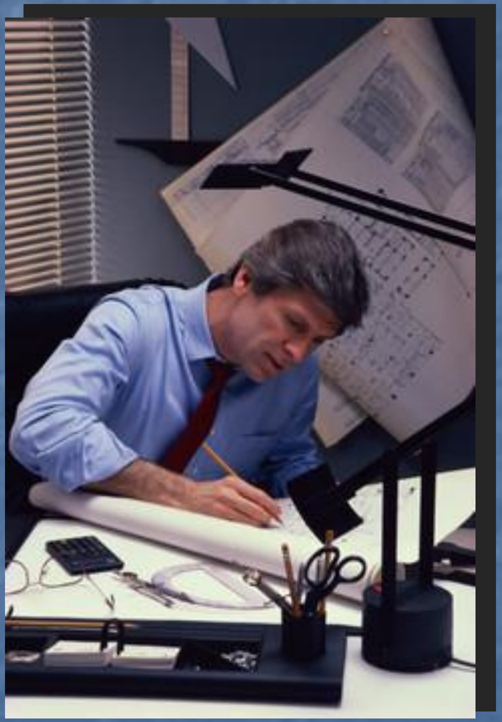
(for Hazardous Waste Sites)

"Handling Drums & Containers"

- 1910.120 (j) (1) (x) "A ground-penetrating system or other type of detection system or device shall be used to estimate the location and depth of buried drums or containers"

Analyze Background Information to Determine..

- Area to be surveyed
- Size - number of suspect targets
- Potential problems
- Site reconnaissance needed?



Match Most Favorable Geophysical Techniques to Problem

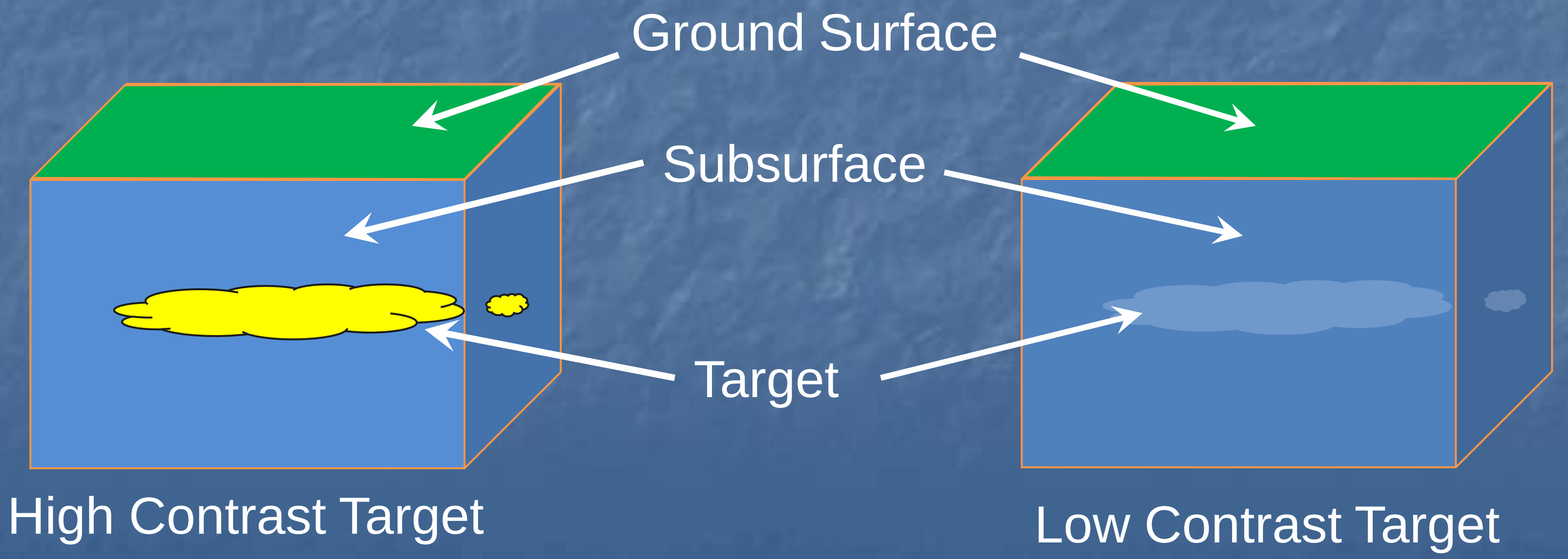
- What method(s) contrast most from background?
- Can instrument operate over site terrain?
- Know depth confines
- “Noise” issues

Dealing With Noise Issues

- Accounting for un-wanted Interferences
  - Power lines, fences, cars
- Apply a “walk-away” test
  - Start at source
  - Walk-away until readings normalize – note distance

Target Contrasts & Background

- What physical properties are associated with:
  - Target elements
  - Natural background elements surrounding target
  - Is their enough physical contrast between both?
- What is the extent of problem
  - lateral limits & vertical depths

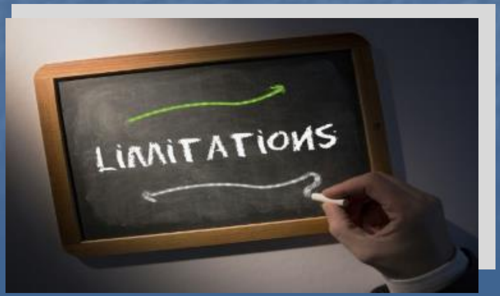


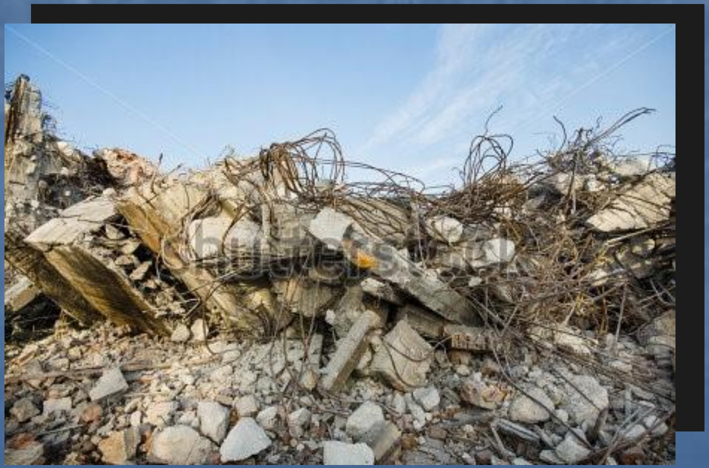
Matching Methods to Target Elements

- Determine what physical property is associated with target element
- Is metal part of target element?
  - Metal ferrous or non-ferrous
- Is geologic structure critical to target element?
  - Location of bedrock, clays, permeable formations
- Contaminate plume present?
  - Low or high plume conductivity
- Groundwater location
- Landfill boundaries
- Voids

Further Defining Methods

- Once physical method is selected:
  - What are the limitations of the selected method
  - Is method easily operated in the site environment
  - Are there nearby objects that cause interference
  - How to document results for replicating survey, if necessary






Optimize Data Collection Routine

- Establish how data will be collected
  - Traverse pattern
  - Grid spacing
  - Axis labeling
  - Data Location ID (ft/M)

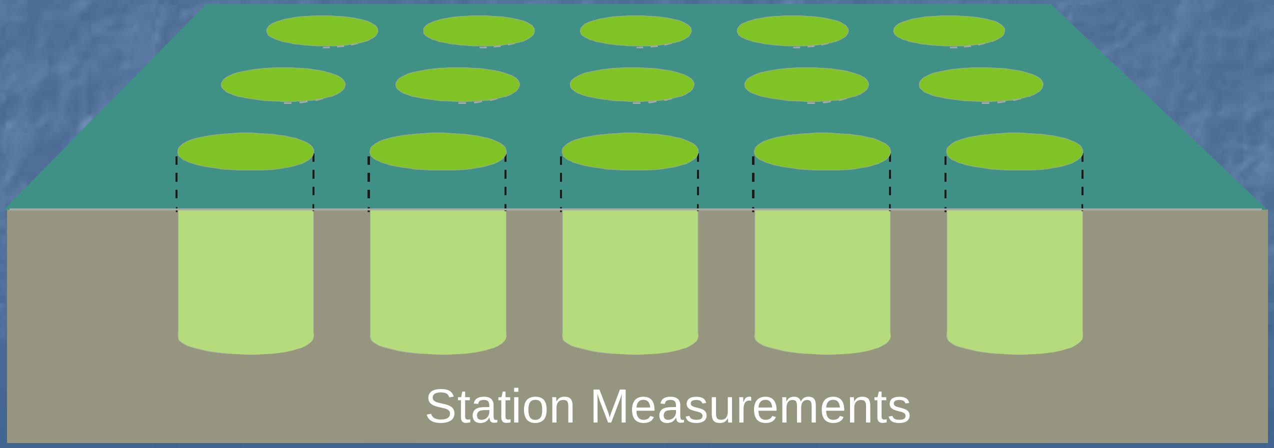
Key Issues For Collecting Data

- Systematic collection (grid or lines)
- Spacing dependent on target size
- Accurate grid or line establishment
- Method to ensure location accuracy
- Maintain good field notes
- Take plenty of photographs!

Data Collection Grids

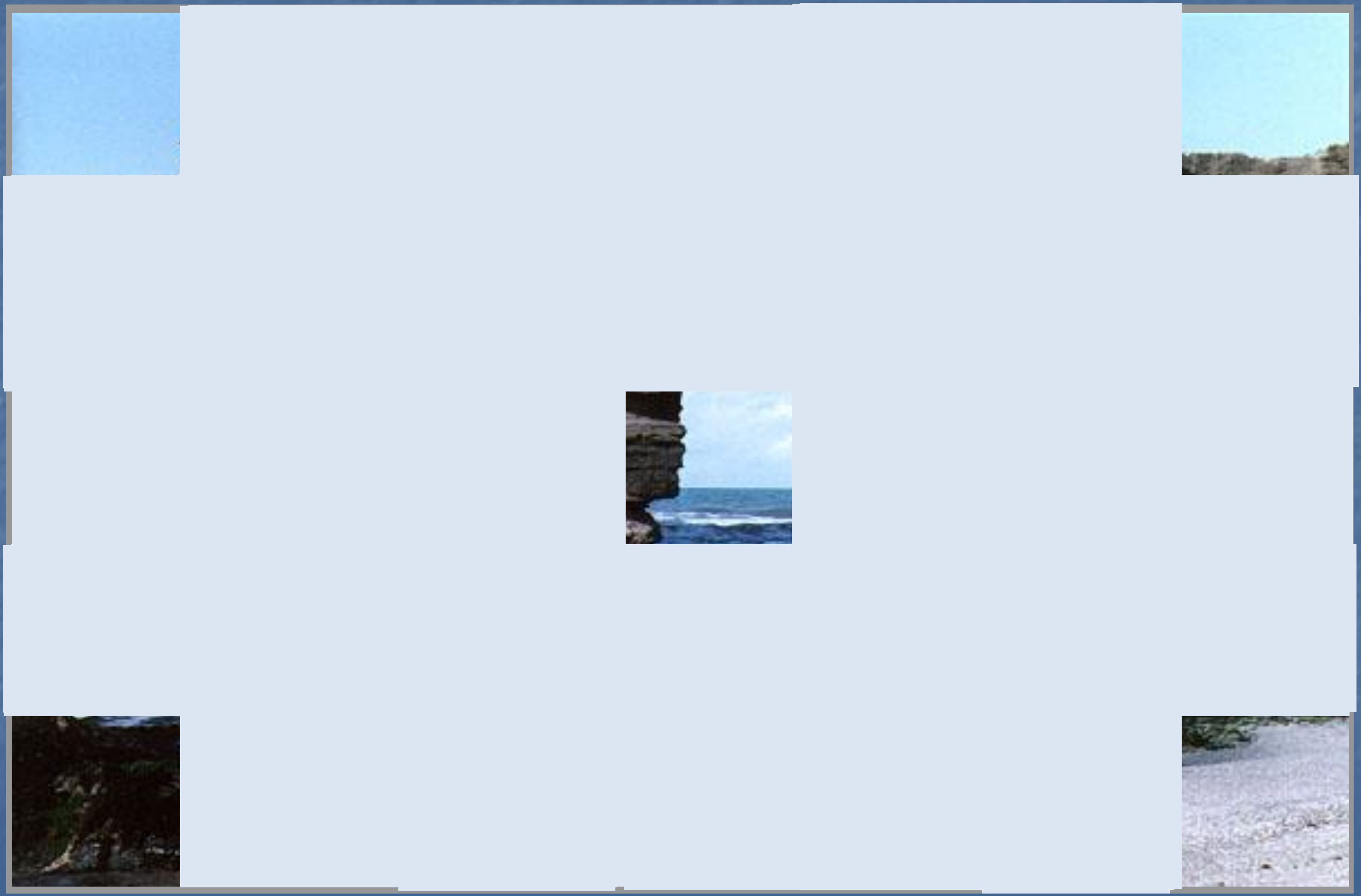
"Data Grid"
Recent
Instrument
Technology

Data Grid for
1970's 80's
Instrument
Technology



(modified from Benson et al., 1988)

Consider Analogy Between Data Density & Photographic Pixels



Detection Probability

(Using Individual Station Measurements)

At = Area ft^2 of Target (Circle)

As = Site Area ft^2 is 1 Acre

○ At = Area of Target
43

As = Area of Site
43,560

Probability of Detection	As/At = 10	As/At = 100	As/At = 1000
100	16	160	1600
98	13	130	1300
90	10	100	1000
75	8	80	800
50	5	50	500

Number of data points required

(modified from Benson et al., 1988)

Determining Grid Spacing

$$\frac{\text{Area of Site in ft}^2}{\text{Area of Target in ft}^2} = \text{a in ft}^2$$

a x Probability Factor = Sampling Points (Approx.)

$$\frac{\text{Area of Site in ft}^2}{\text{Sampling Points}} = \text{b}$$

$$\sqrt{\text{b}} = \text{Grid Spacing in Feet}$$

Probability Factors

100% = 1.625	75% = 0.8
98% = 1.3	50% = 0.5
90% = 1.0	

Typical Acquisition Traverses

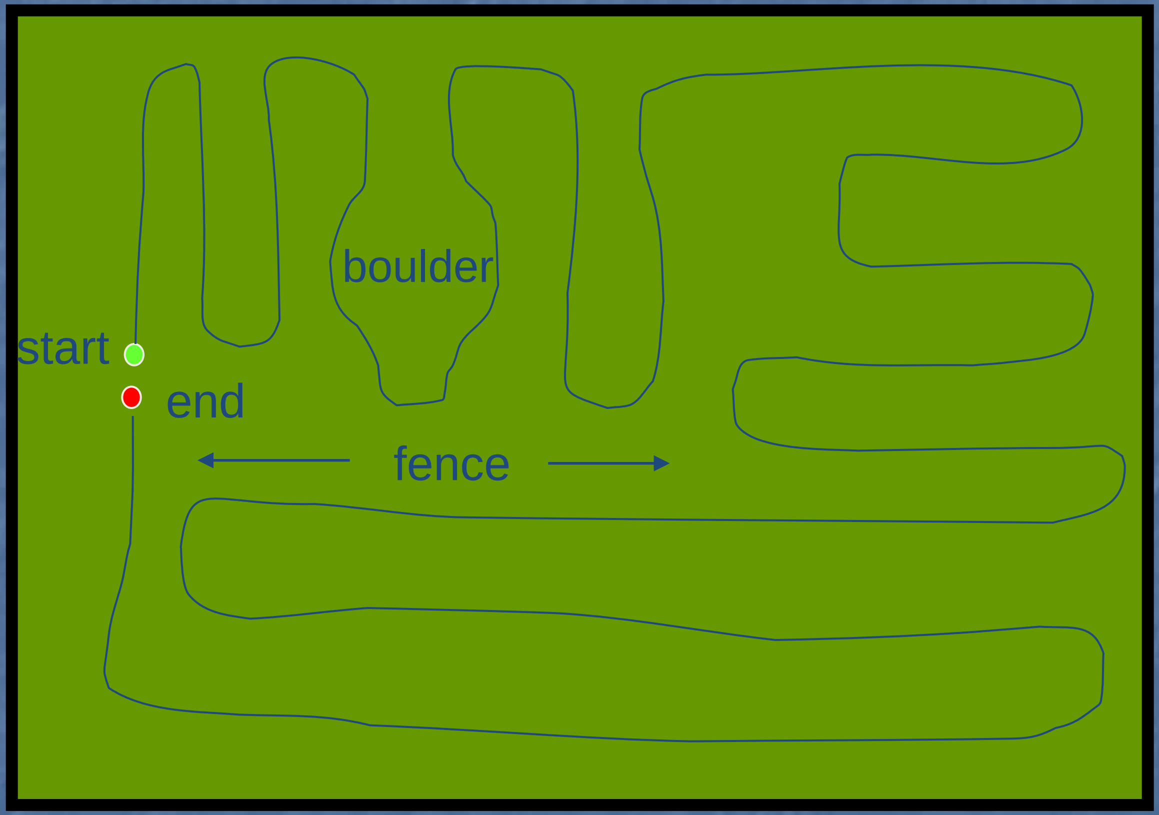
Modes

- Alternating mode
  - Most often used
- Random mode
  - Used for small or large areas
- Parallel mode
  - Irregular shaped sites
  - Work from one base line

Details

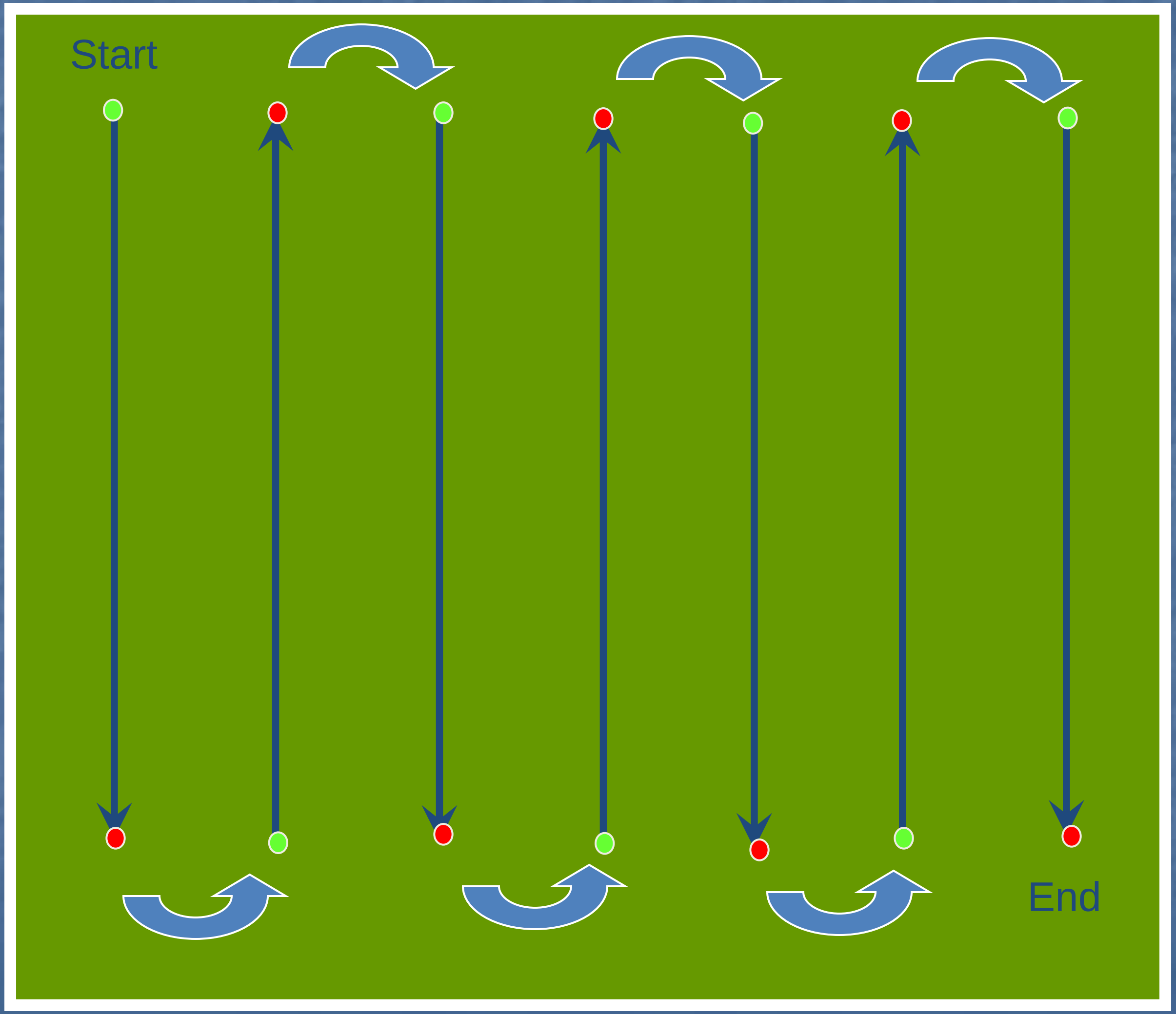
- Areas broken into rectangular shapes
- Irregular boundaries
  - Use multiple base lines
- Positioning methods
  - Station to Station
  - Timed – collection
  - Wheel encoder
  - GPS

Random Survey Pattern



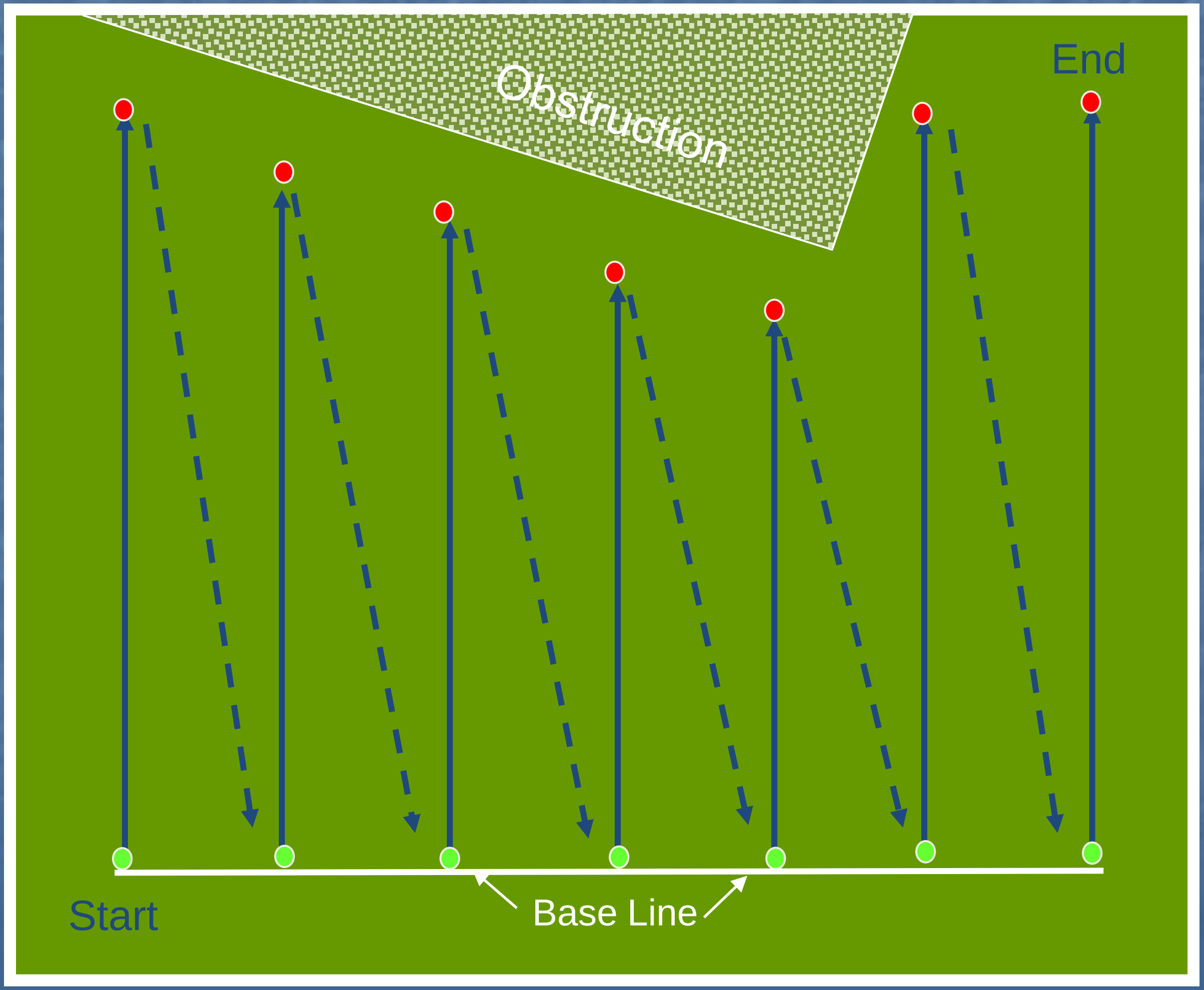
Small Back Yard Example

Alternating Traverses



Parallel Traverse – No GPS

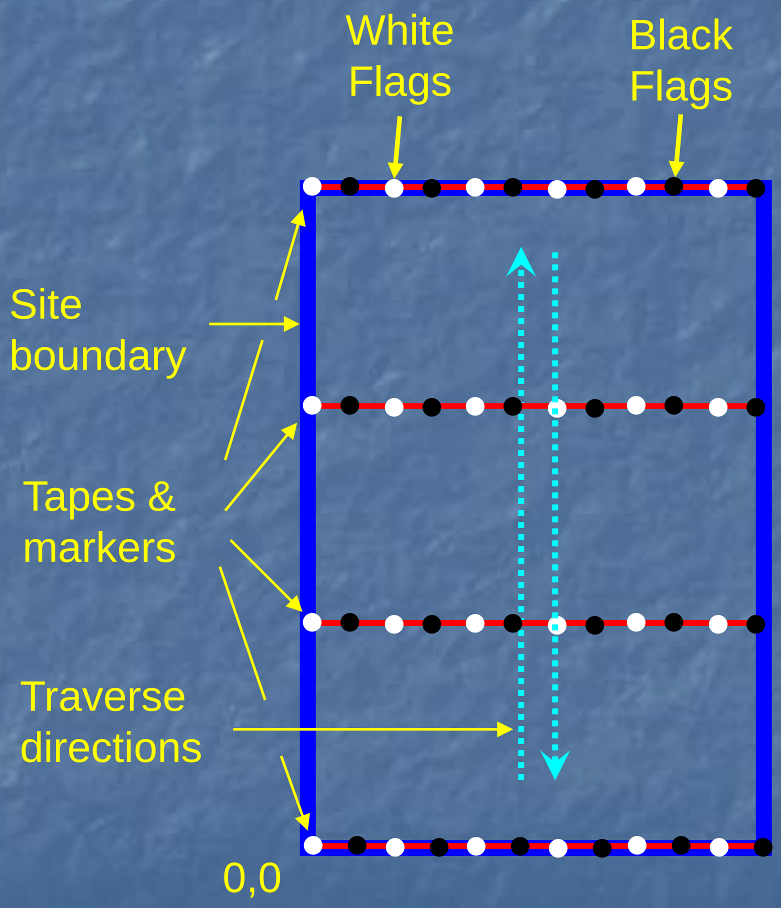
Solid Line: Recording



Dash: Not Recording

Alternating Traverse Grid Setup No GPS Guidance

- Layout grid markers at desired spacing
  - Flagging (plastic)
  - Spray chalk or paint
  - Ropes
  - Wooden stakes
- Large sites require multiple marker lines



Data Recorder Types/Methods

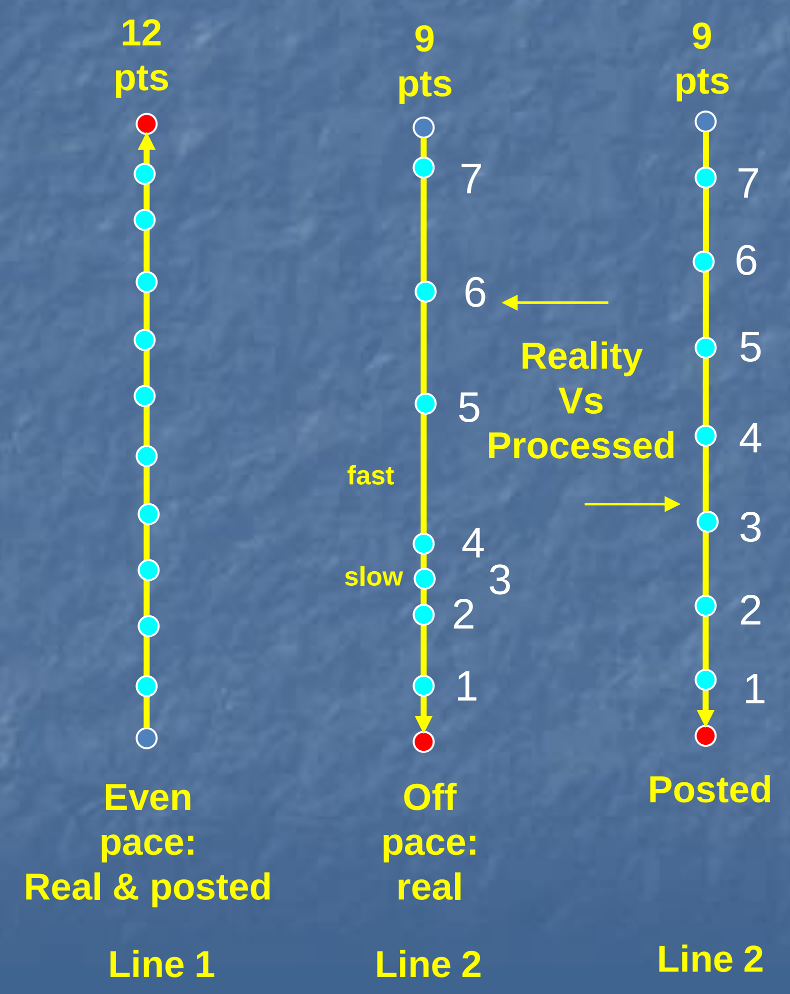
- Station distance position
  - X, Y, set by distance
- Time
  - X, Y, distance set by a time unit
- Encoder wheel
  - X, Y, distance - a unit of wheel revolution
- GPS
  - X, Y set by longitude and latitude

Data Recorders: Correction Issues for Positioning

- Timed devices: - spacing issues
  - Corrections for pace (use pause key)
- GPS devices
  - Use proper datum, projections, units
  - Correct for errors
- Wheel encoder devices
  - Resolve distance errors (calibrate)

Time - Continuous Data Acquisition Issues for Y Axis Example

- Operator inputs start & end points per line
- Unit auto "fits" data to input distance
  - Assumes same pace
- Obstacles usually slows pace
- Use data pause features as needed



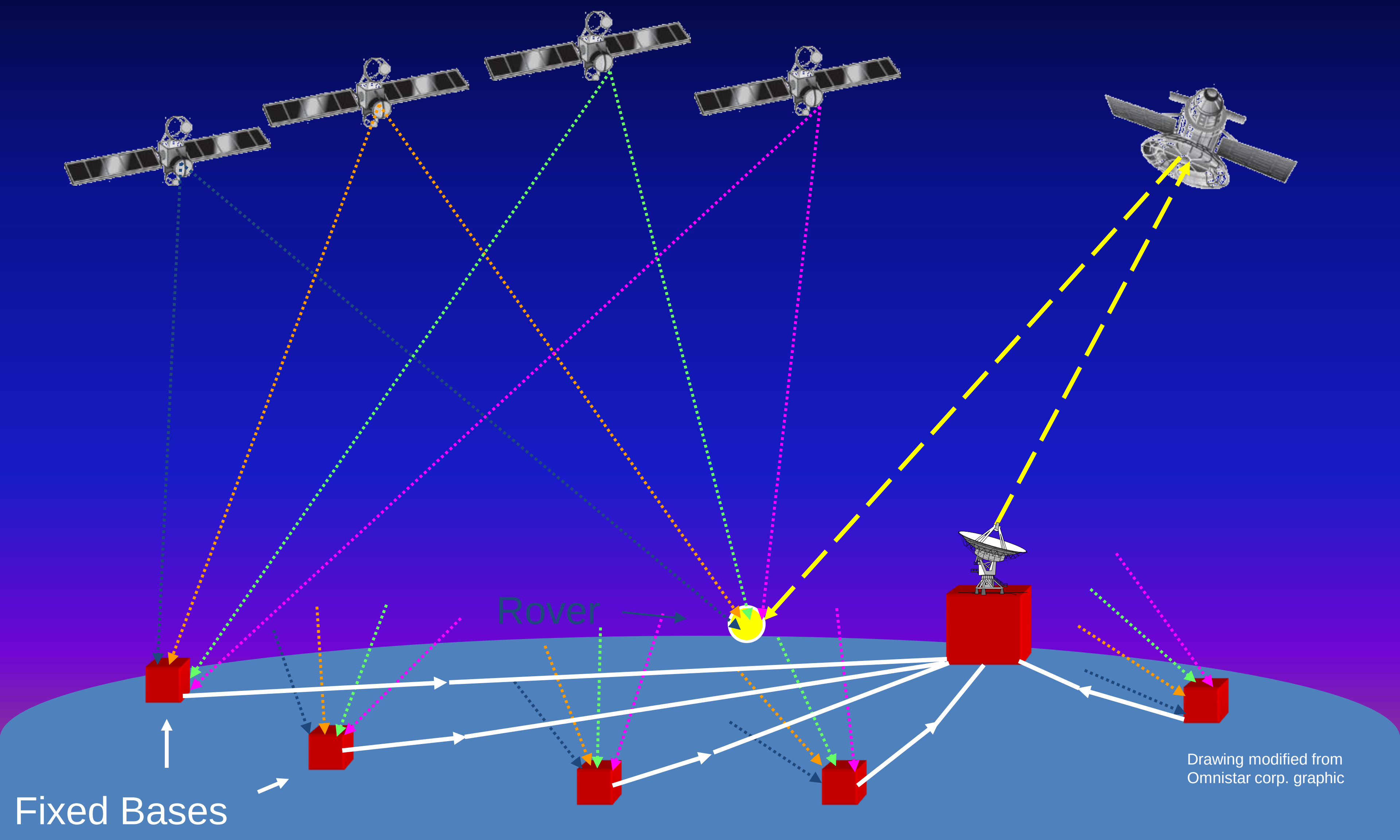
Global Positioning Systems

- Accuracies vary by method & equip. used
- Here are 2 analogous examples:
- Some on a scale to be within 120′ of an airport threshold, as an example
- Others on a scale to be within centimeters from the center of runway
- Use proper datums, projections & units

Several GPS Methods

- Stand alone GPS receiver
- Differential correction (DGPS)
  - Real time using beacons, base stations
- Post processing GPS values
- RTK Survey Grade
  - Tx base station, Rx at rover, satellites
- 3 Grades of GPS accuracy & cell phone
  - Recreational, mapping, survey, Cell Phone,
  - 25′ 3′ cm 80′

How a Differential GPS Service Works



Integrating GPS to Other Systems

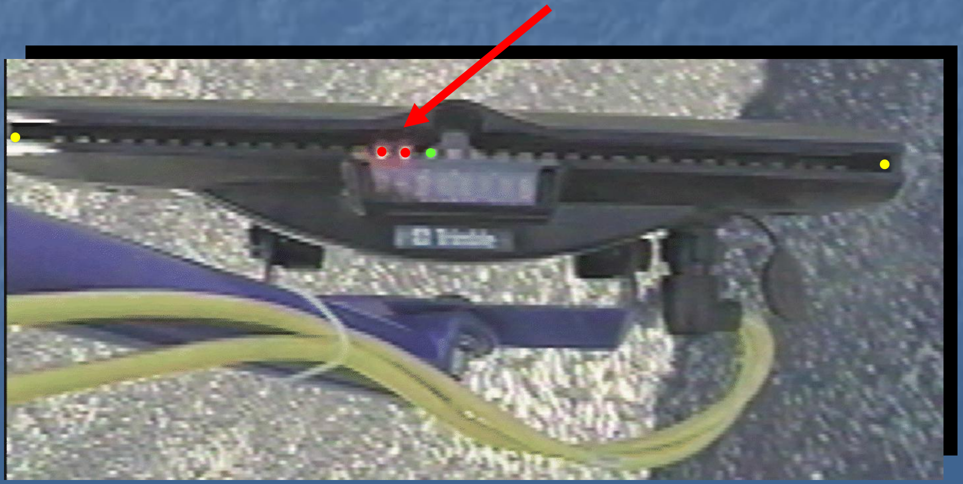
- Most geophysical instruments will connect and integrate GPS systems
  - Will record & tie all data to lat-long
- What if you want to traverse specific routes? Two possible options:
  - Trimble AgGPS 132 parallel swathing
  - Field Analysis & Sampling Tool (FAST)

FAST
Field Analysis & Sampling Tool

- System integrates a field laptop to GPS and instrumentation
- Free downloadable program for EPA staff
- OS limited to Windows XP
- Requires non-EPA imaged field laptop
- Operator traces their traverses over pre-loaded grid using laptop screen
- System can be programmed for XRF, various radiation tools and other tools

Trimble Parallel Swathing Lightbar Guidance

- Center: on line
- Left: move left
- Right: move right
- Outer edges yellow: nearing line end
- Outer edges red: at line end
- Advances to next spacing



Geophysical Tool Options
Which Method is Applied First?

- Dependent on site goals
- Generally........First
  - Methods having larger sensing areas
  - Rapid data collection times
- Generally........Second
  - Methods with more definitive sensing capabilities

Check List For Considering Geophysical Survey

- Define problem
- Research history
- Find area of concern
- Note site conditions
- Describe target(s)
- Estimate depth
- Will geophysics help?
- List methods that will show most contrast
- How will you use this information?

A Note About Contracting Geophysical Jobs

- Use source that is knowledgeable about all geophysical methods
- Write contract to assume several “what if” scenarios to deal with special issues
- Obtain copies of raw data & notebooks
- Be aware that interpretation & reports may be optional

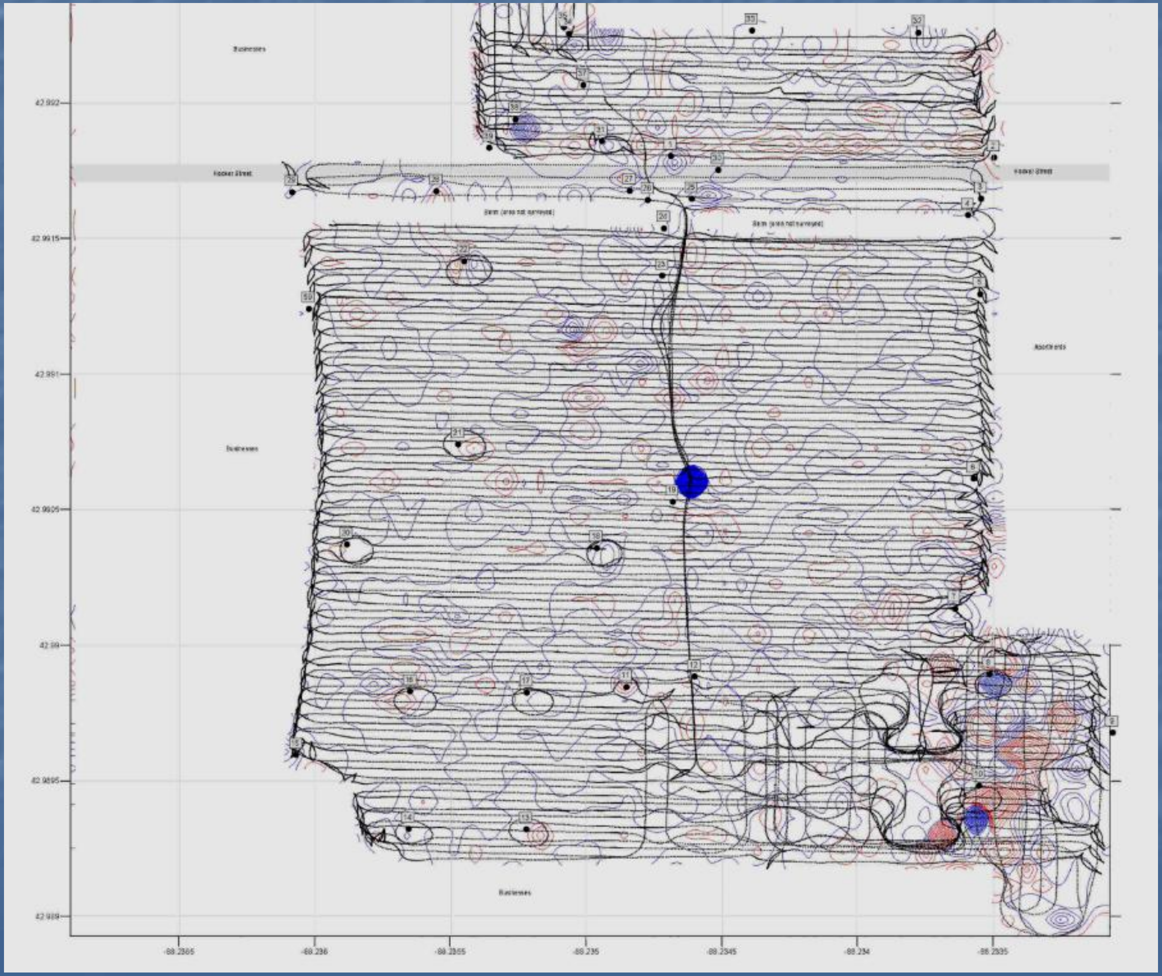
Geophysical Data Examples

Mag Data
Example of Rubble Landfill

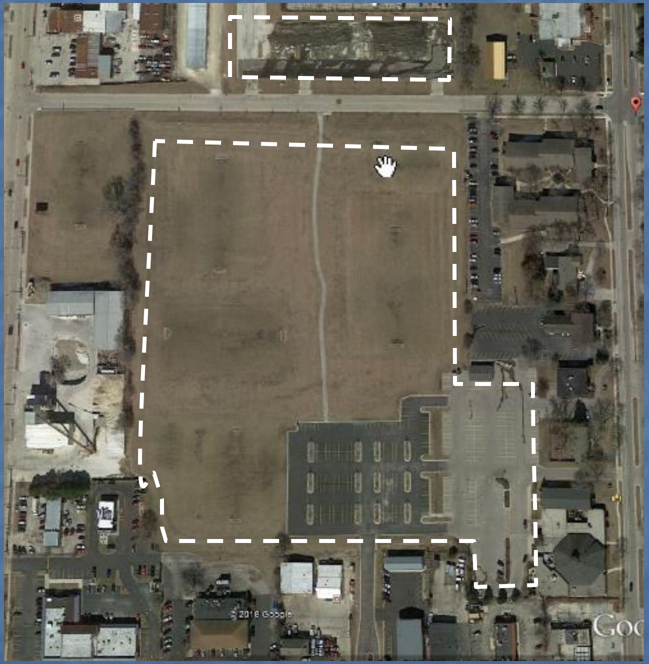
Waukesha, WI

Aerial View

Example of Rubble Landfill Mag Data



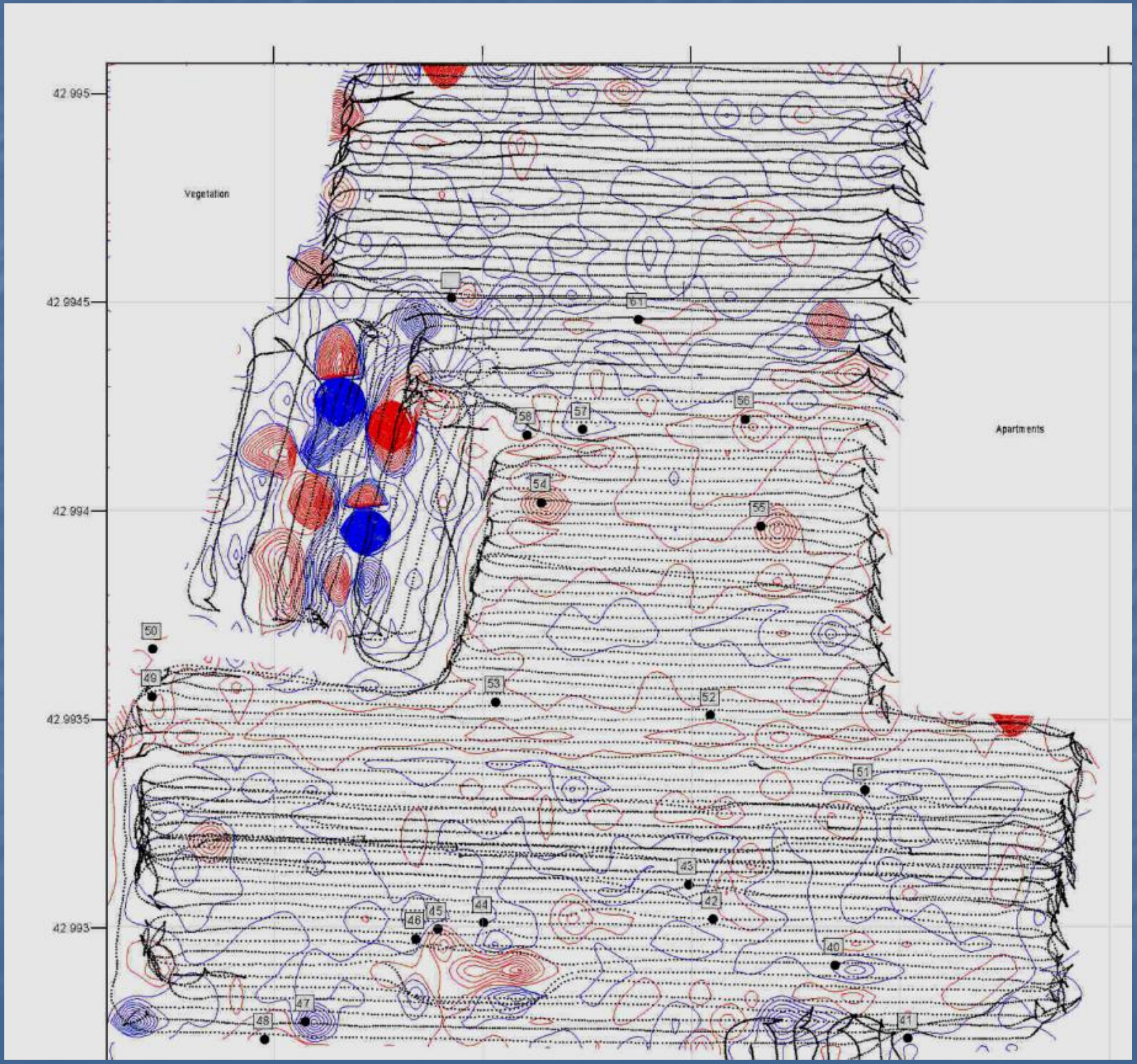
Waukesha, WI



Aerial View

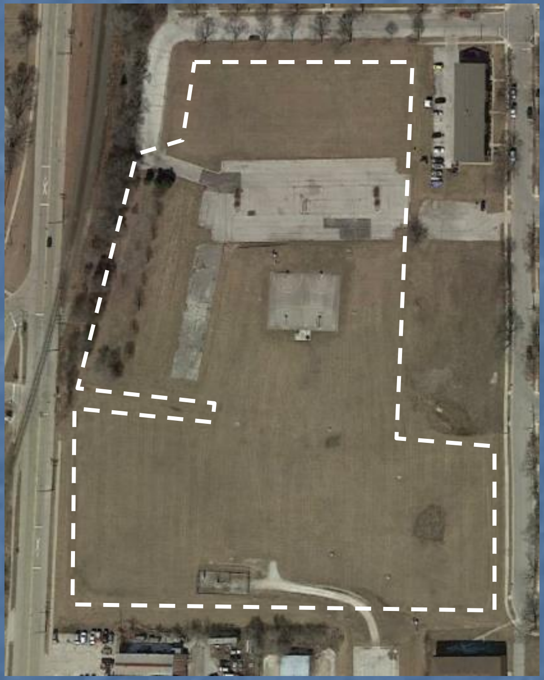
Black=traverse lines; Red=neg. contours; Blue=pos. contours

More Rubble Landfill Mag Data



Black=traverse lines; Red=neg. contours; Blue=pos. contours

Waukesha, WI

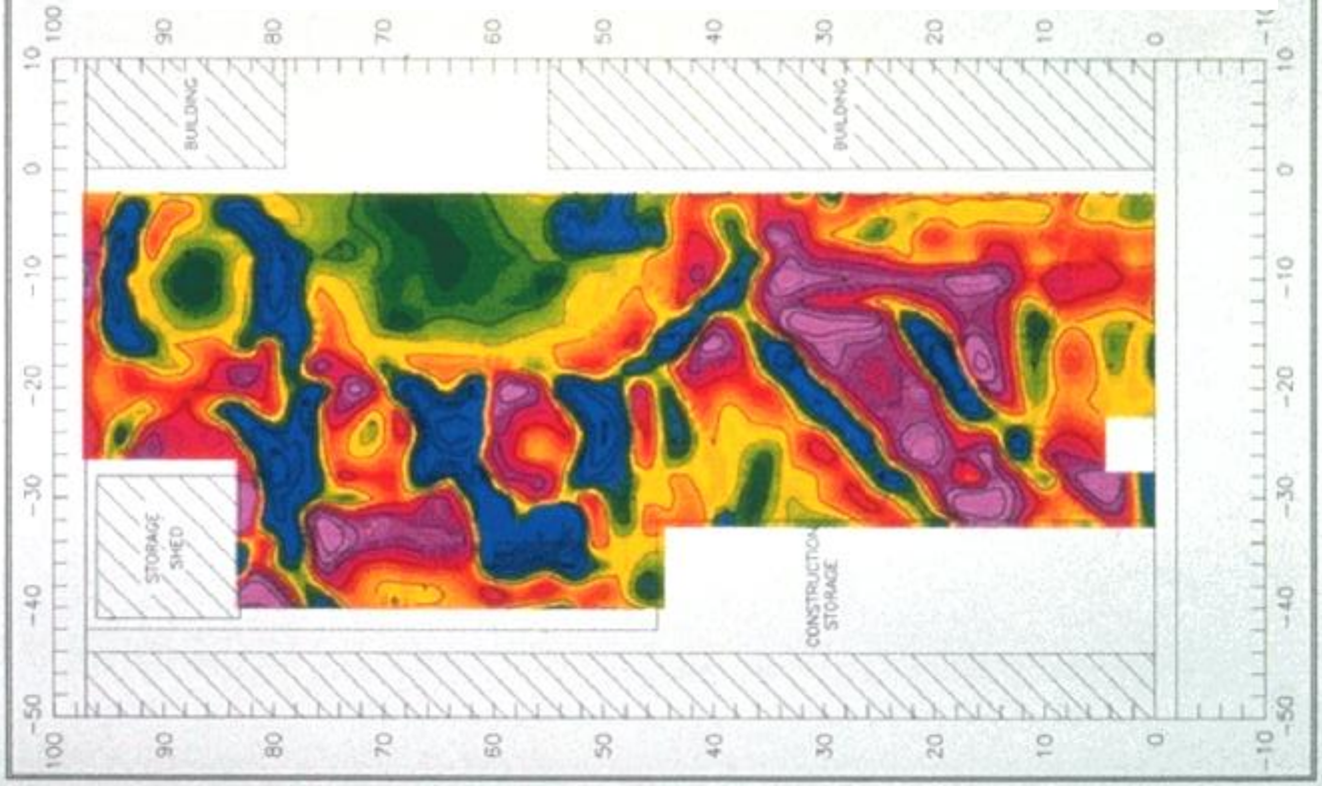


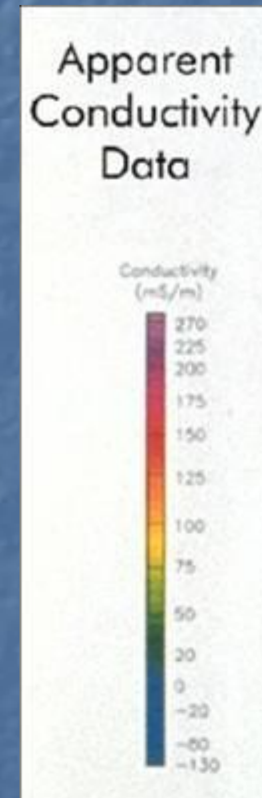
Aerial View

EM 31 Data - Example

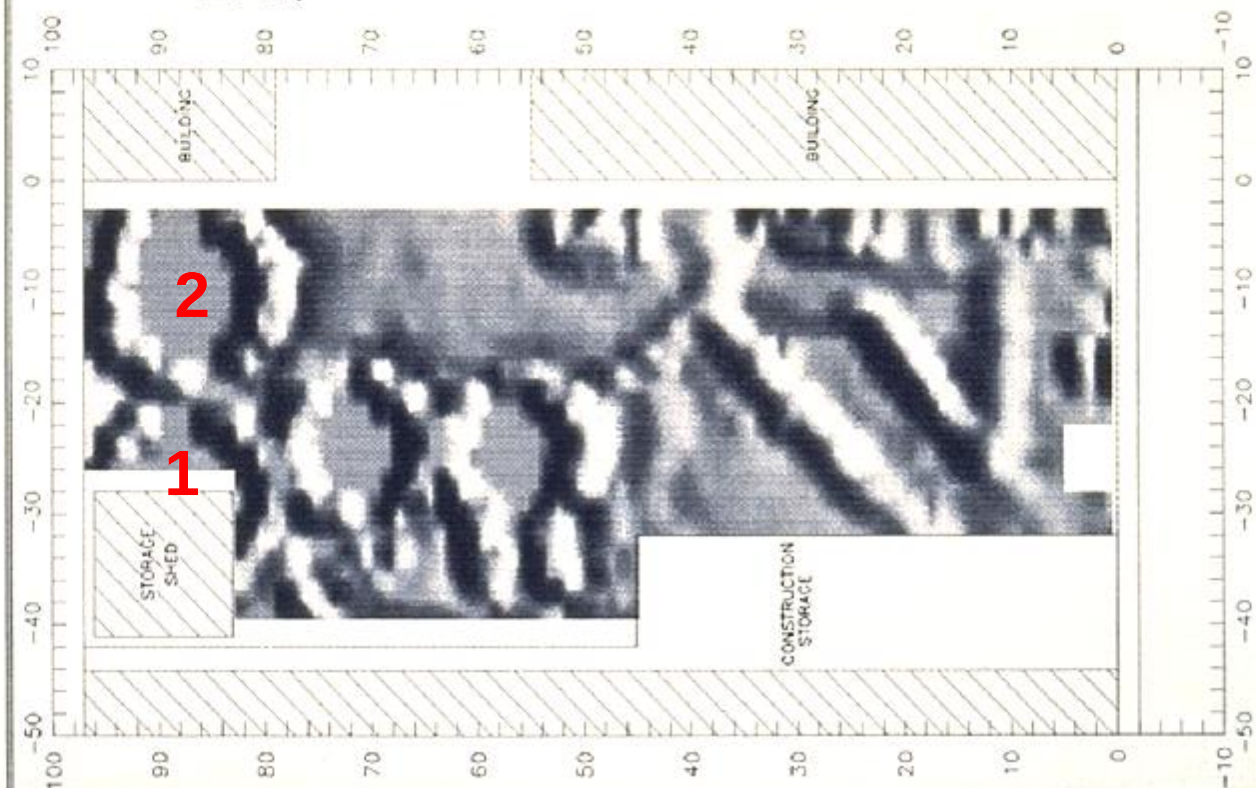
Vacant lot in Toronto
Ontario, Canada

Apparent Conductivity Data – Quad Phase





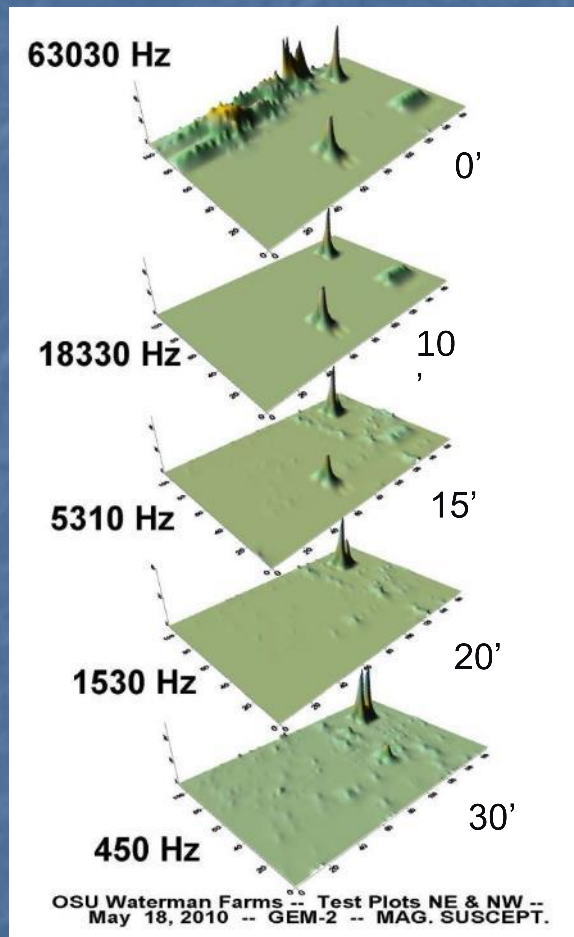
Shaded Relief Map – In Phase



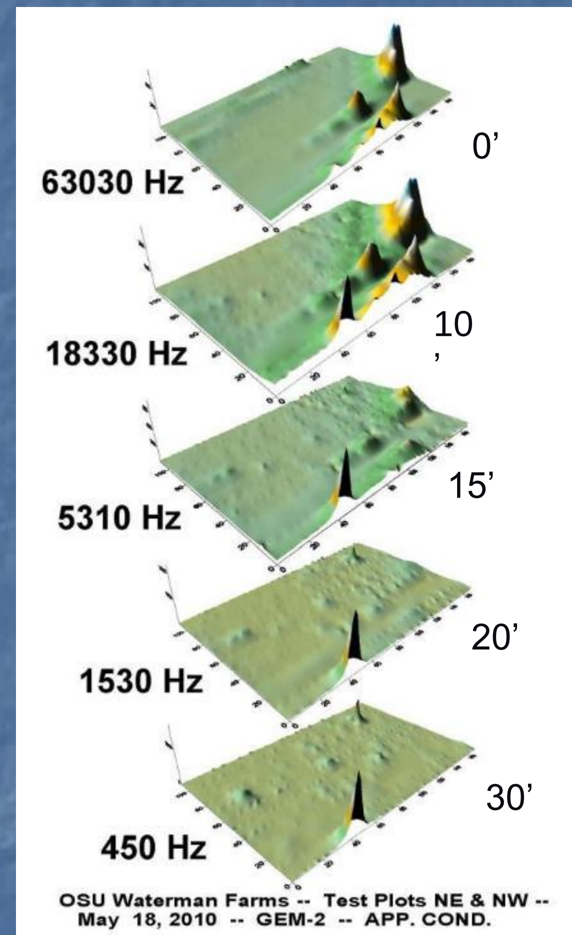
Lot During Excavation

Photo Reference Points

GEM 2 EPA/OSU Test Site
Waterman Farm, Columbus, Ohio

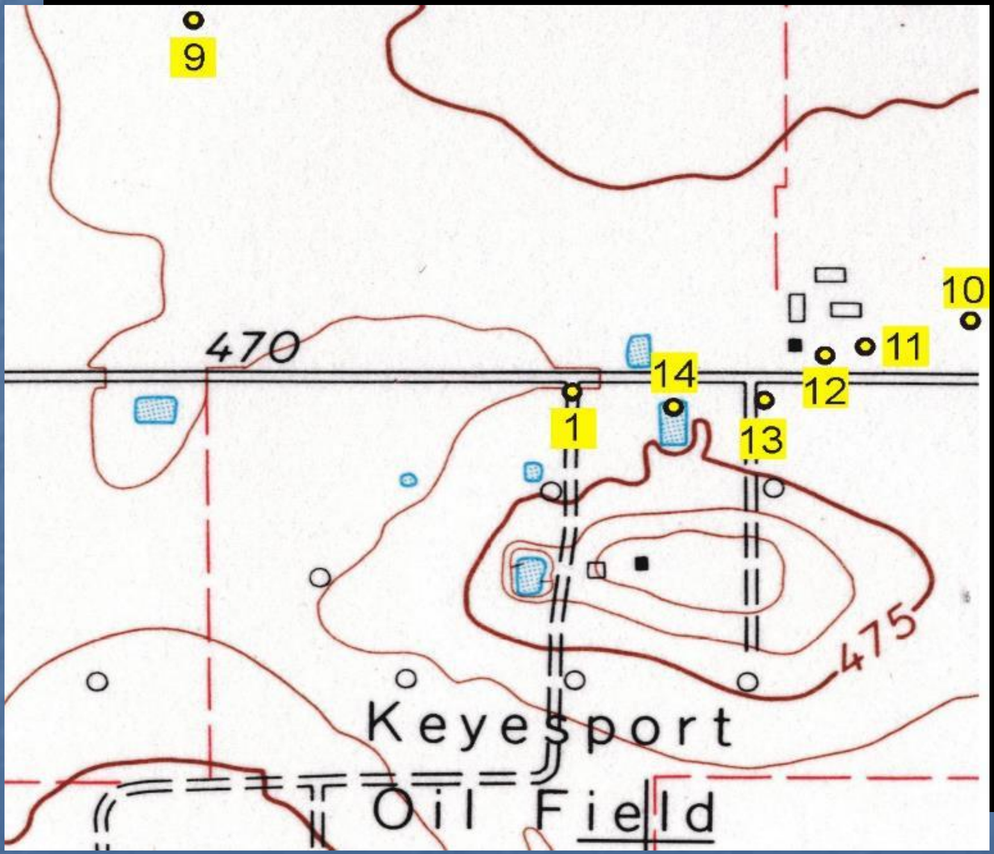


Magnetic Susceptibility
(In-Phase)



Apparent Conductivity
(Quadrature Phase)

Direct Push Soil Conductivity



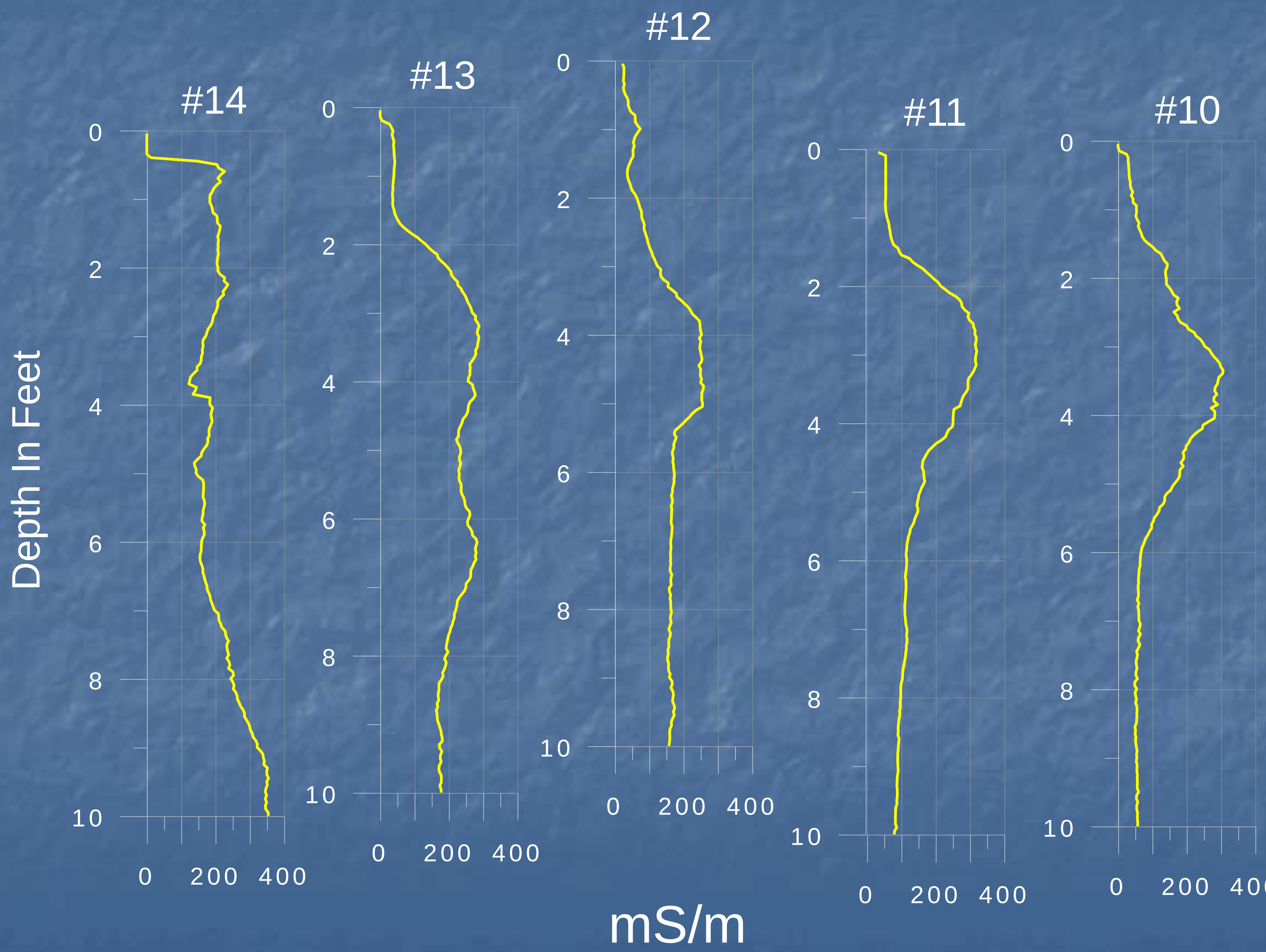
Source: USGS Keyesport, Illinois 7.5 Minute Topographic Map
Contour Interval = 5 feet

Wenner Array Sensor

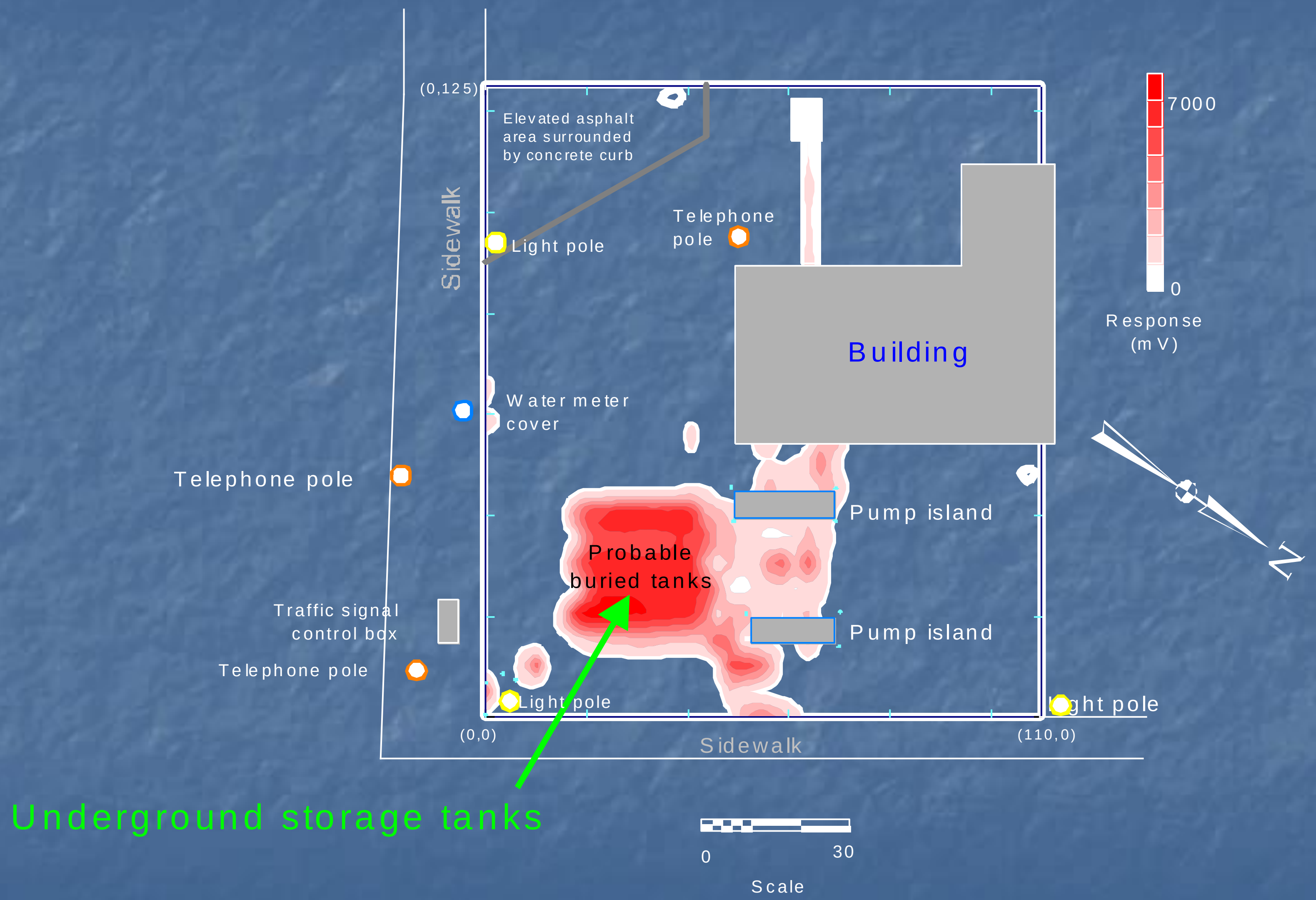
GeoProbe® Electrical Conductivity Direct Push

Direct Push Unit Powered by Skid Steer

Direct Push Conductivity Data

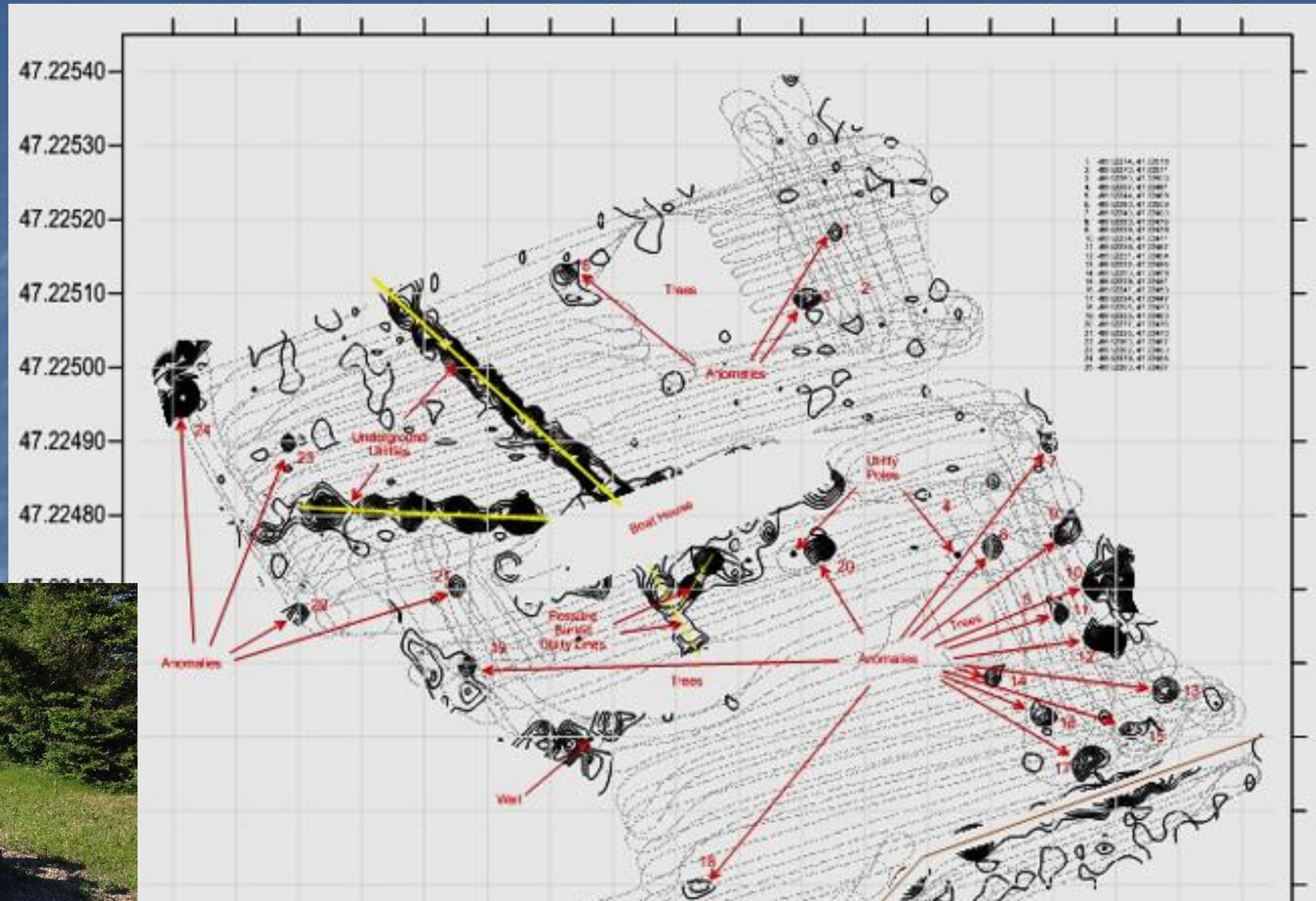


EM61 Metal Detection - Data



Abandoned Gas Station, East St. Louis, Illinois

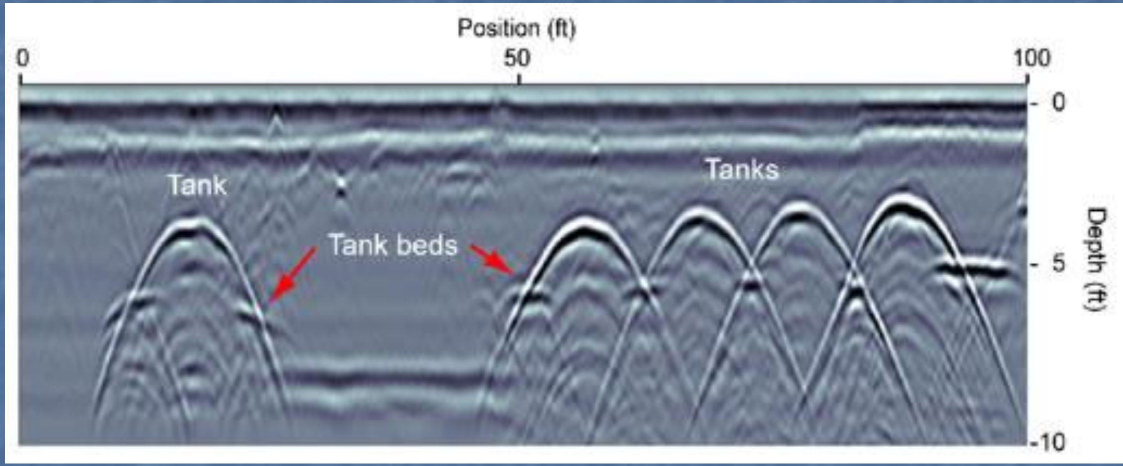
EM-61 Data Closed USCG Station



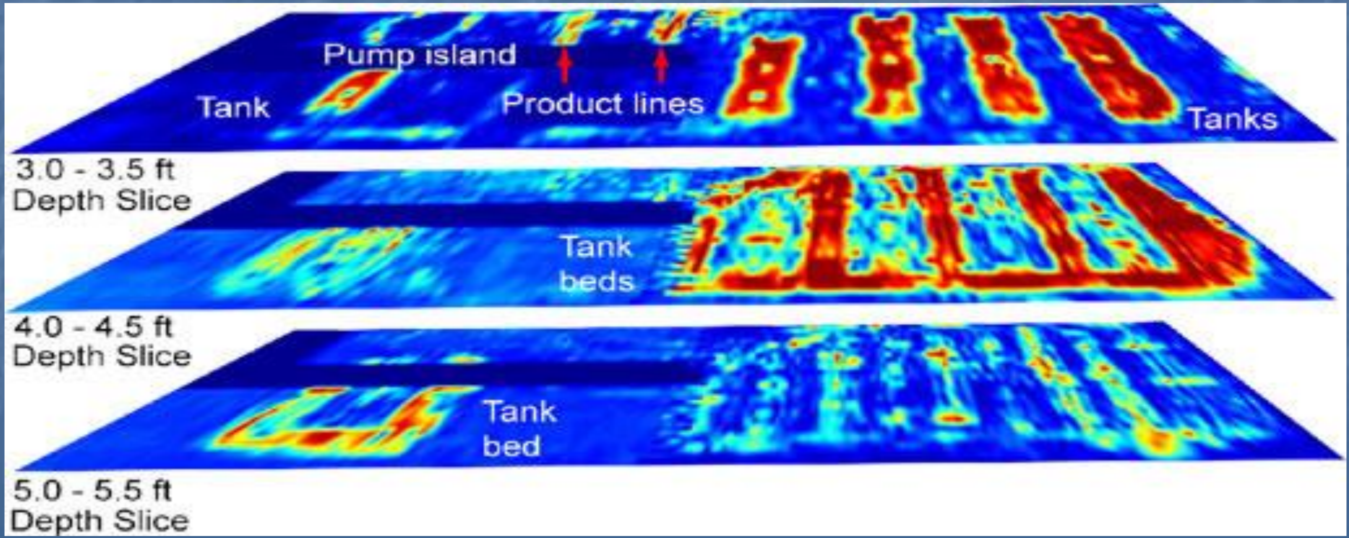
N. of Hancock, MI

GPR Data - Buried Storage Tanks

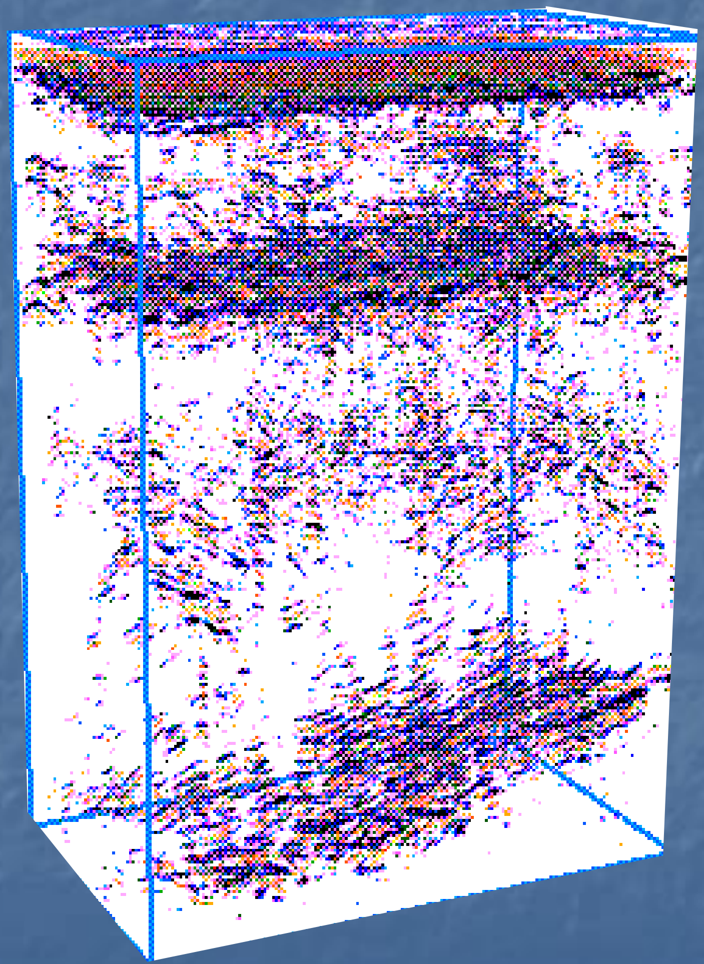
1 Cross-Section Slice

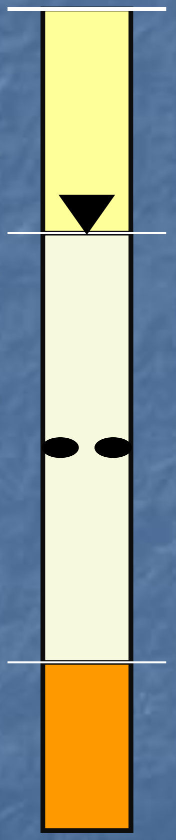


Post Processed
Plan View
Time Slices



3-D GPR

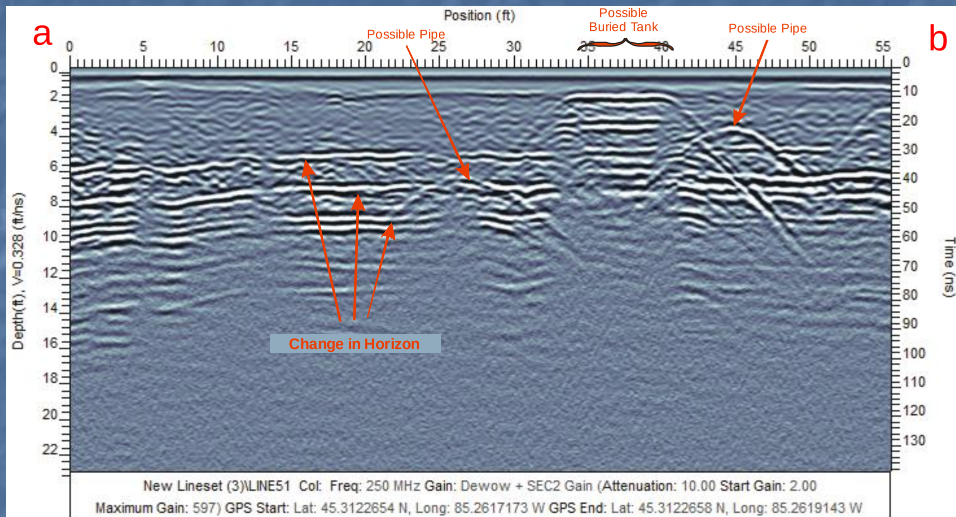


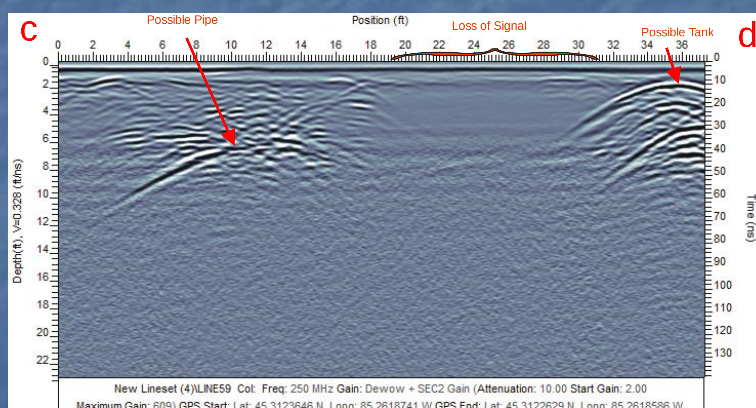


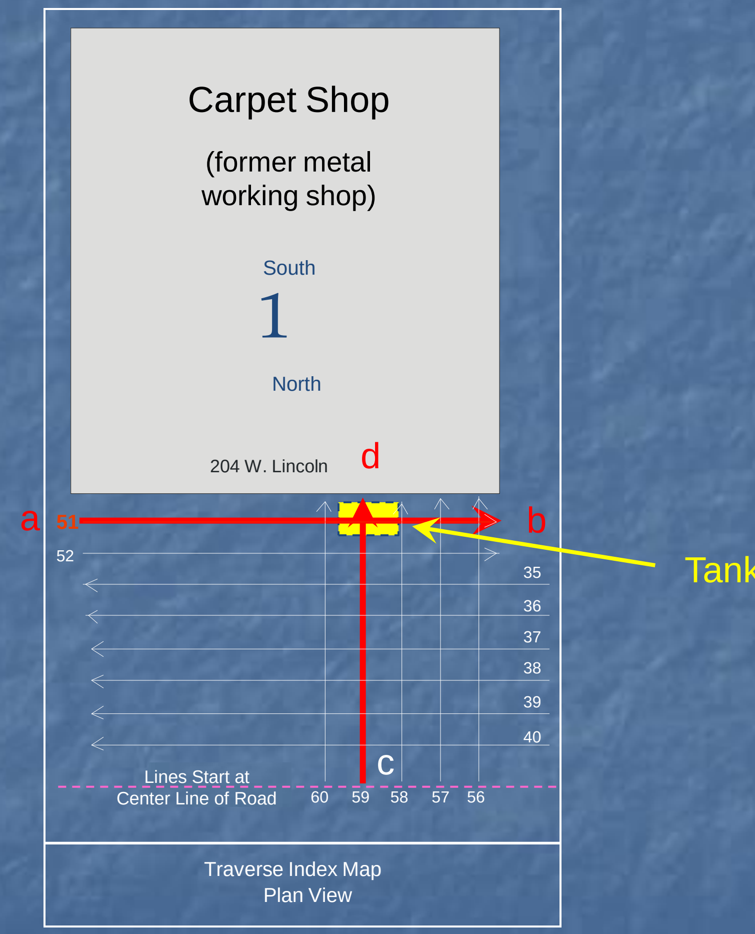
Marquette, MI
30 m by 6 m area
6 - 8 m depth

Source: Grumman Exploration

GPR Leaking Tank - Upper Michigan

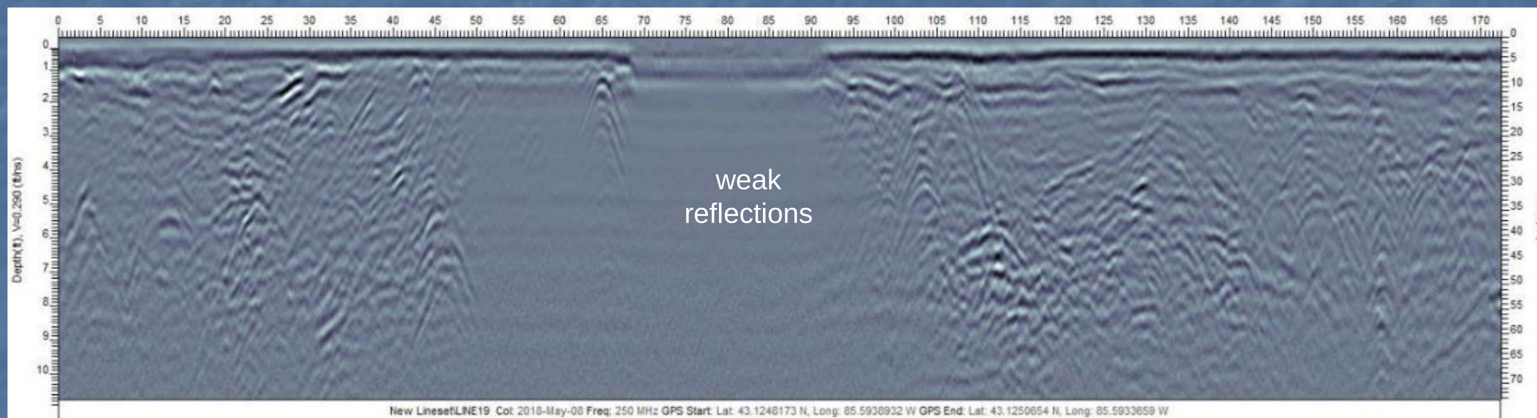




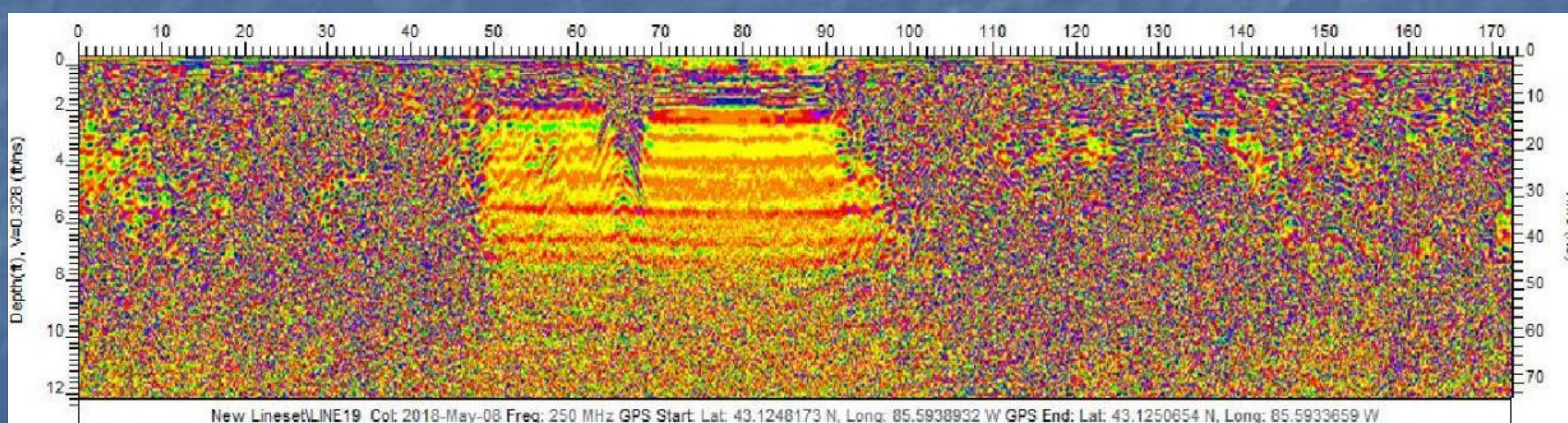


Backyard in Michigan – Stressed Vegetation Area

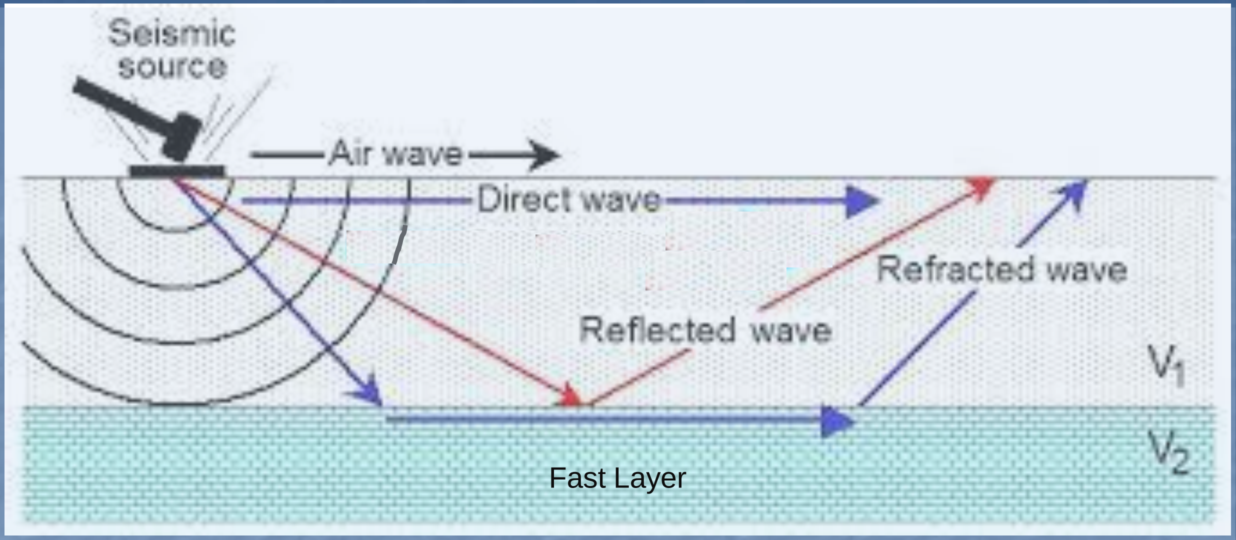
Default “Bone” GPR Image

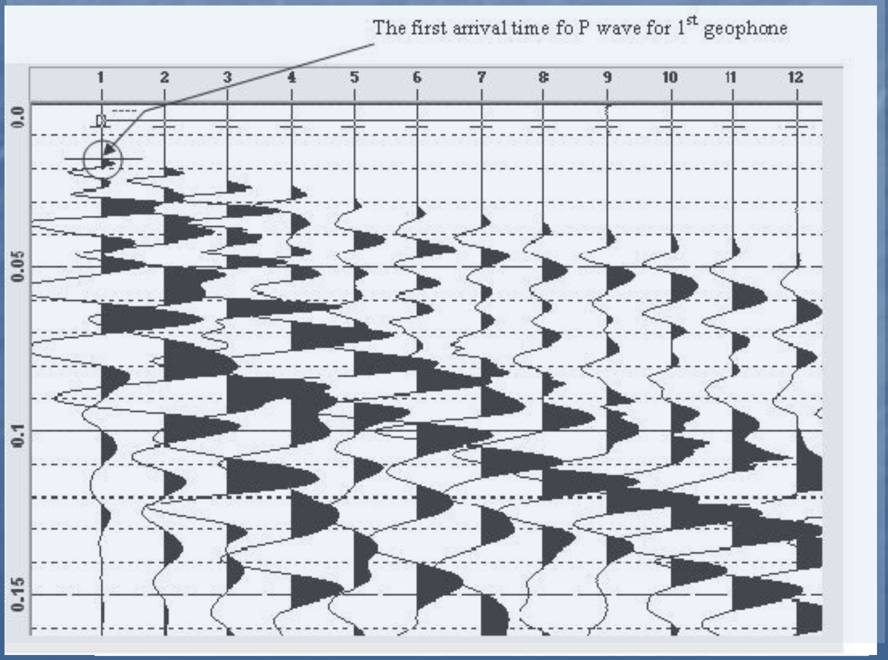


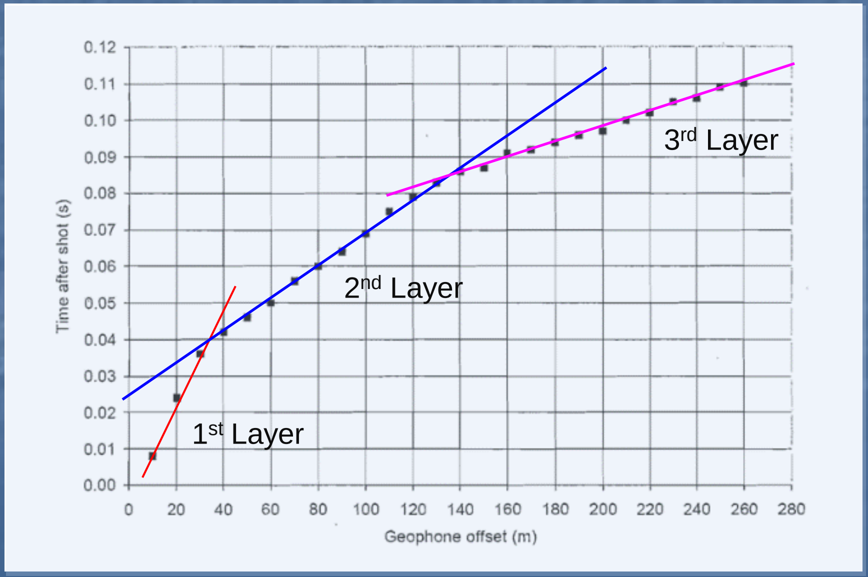
“Prism” Option GPR Image



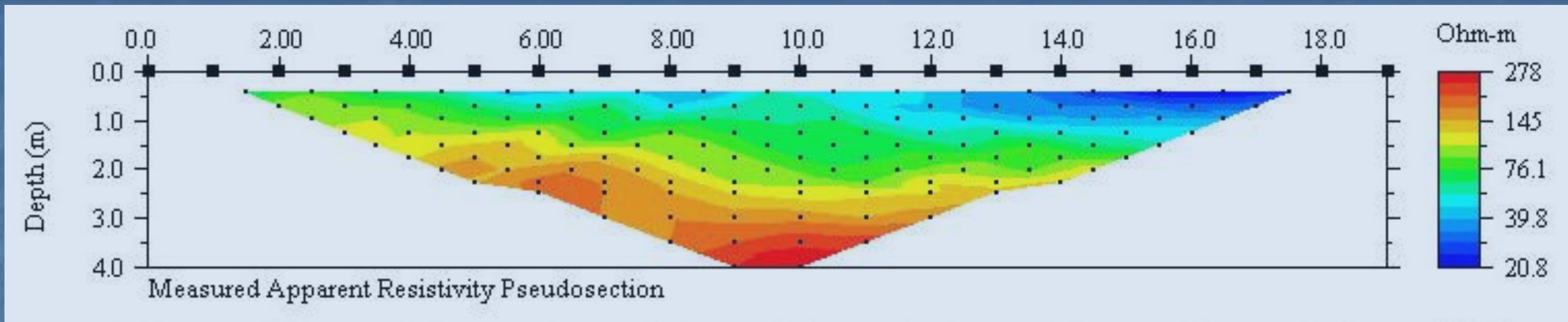
Seismic Refraction Example



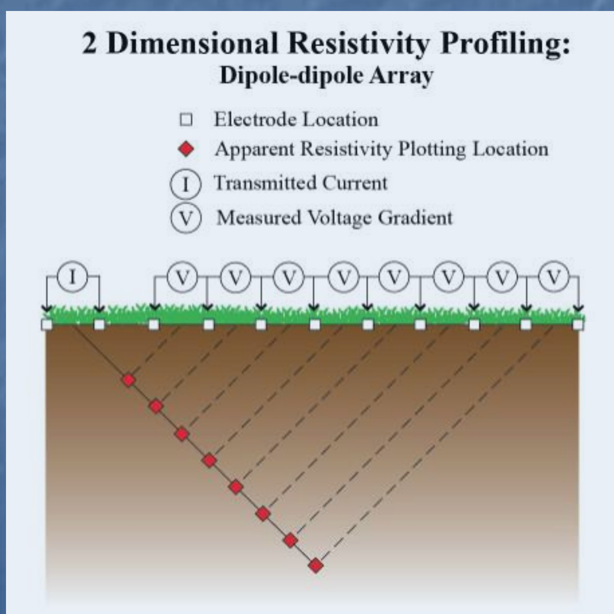




Distance (m)



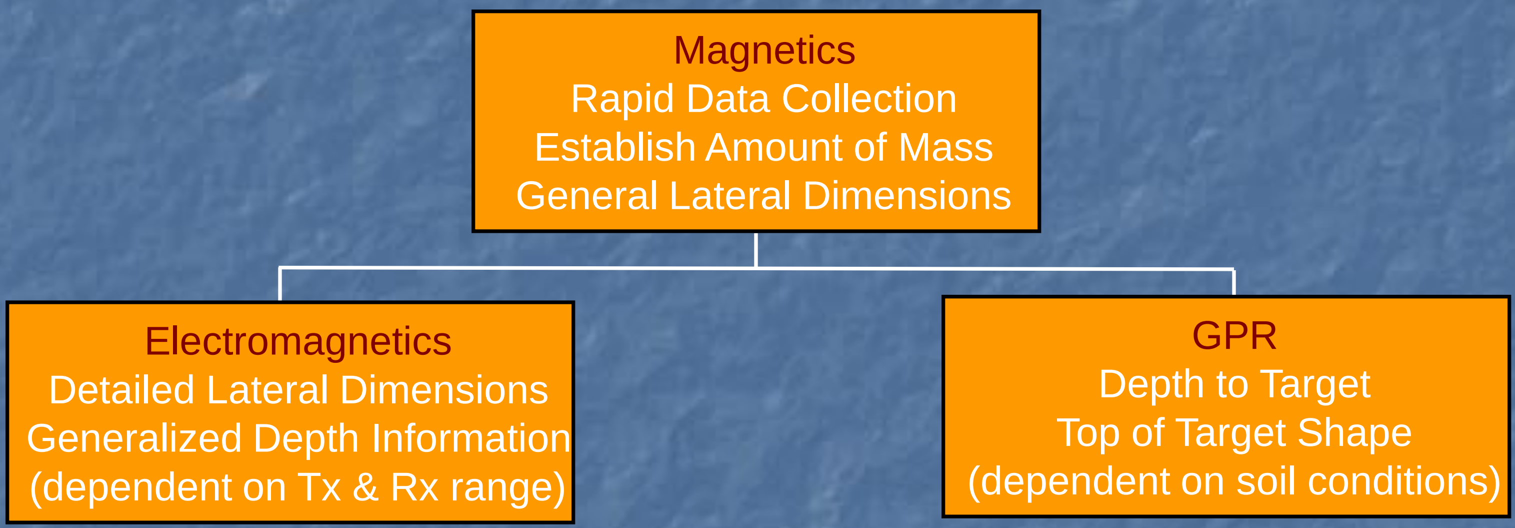
2 dimensional measurement configuration for a resistivity profile



Earth Resistivity Example

Source: AGIUSA, agiusa.com

One Example for Confirmatory Methods



Requesting A Survey
(Questions Provider Should Ask You)

- How big is the site?
- Composition of targets?
- Orientation & size of targets, if known
- Depth or burial method of targets, if known
- Describe terrain & site conditions
- Explain special circumstances

Provider Submits Plan *(Questions You Should Ask)*

- Why are selected method(s) appropriate?
- What tool & configurations will be used?
- Method to ensure data location accuracy?
- What deliverables will be provided?
- Will data be presented for the layperson?
- How can I relocate area at a later date?

Limitations

- Subject to cultural noise
- Detection of small objects reduced with depth
- Depth estimates most difficult for non-homogenous masses
- Masses cannot be uniquely characterized

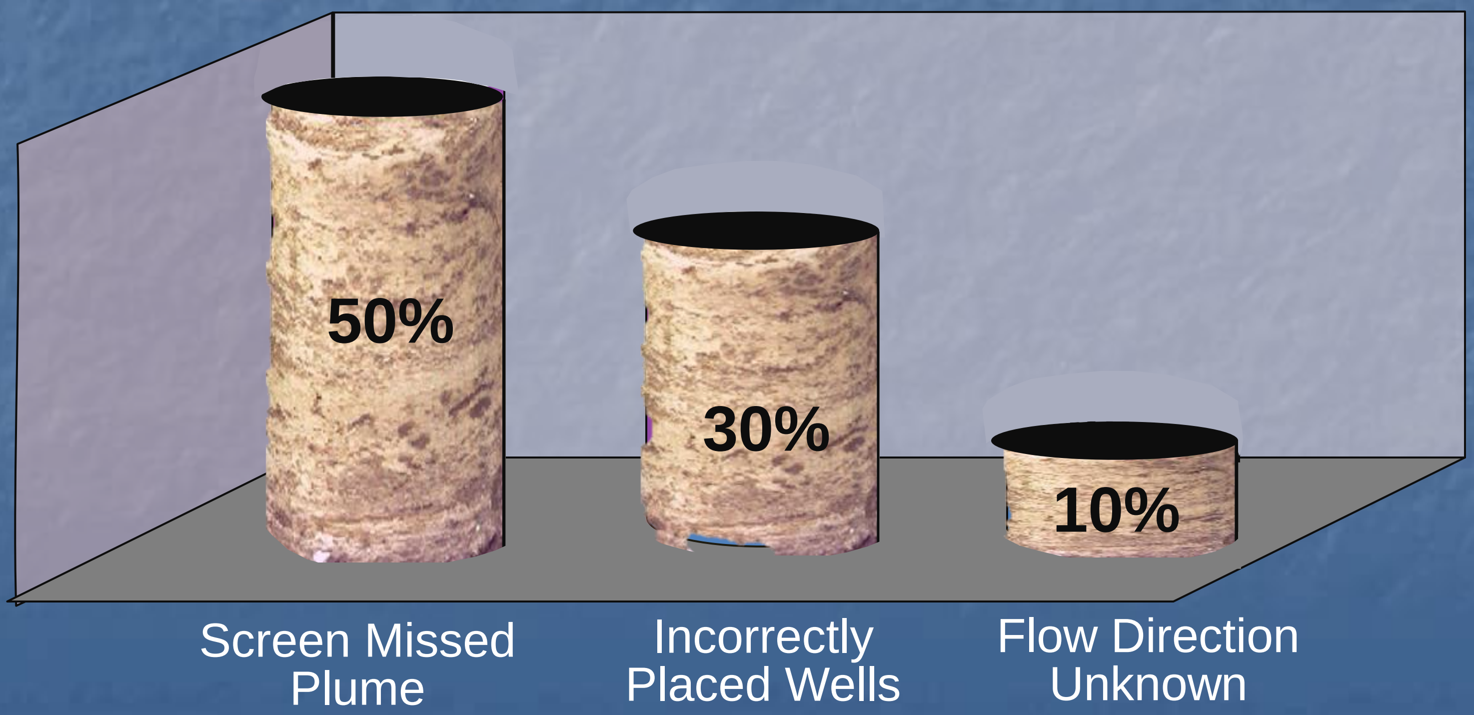
Brief Comments Concerning 2” Monitoring Wells

Monitoring Wells - Need for Doing the Job Efficiently

EPA Studied Wells At 22 Sites & Concluded:

Borehole Sensing Methods for Ground-Water Investigations at Hazardous Waste Sites

S. W. Wheatcraft, K. C. Taylor, J. W. Hess, T. M. Morris - Environmental Monitoring System Laboratory - U.S. EPA Las Vegas, NV
EPA/600/2-86/111 December 1986

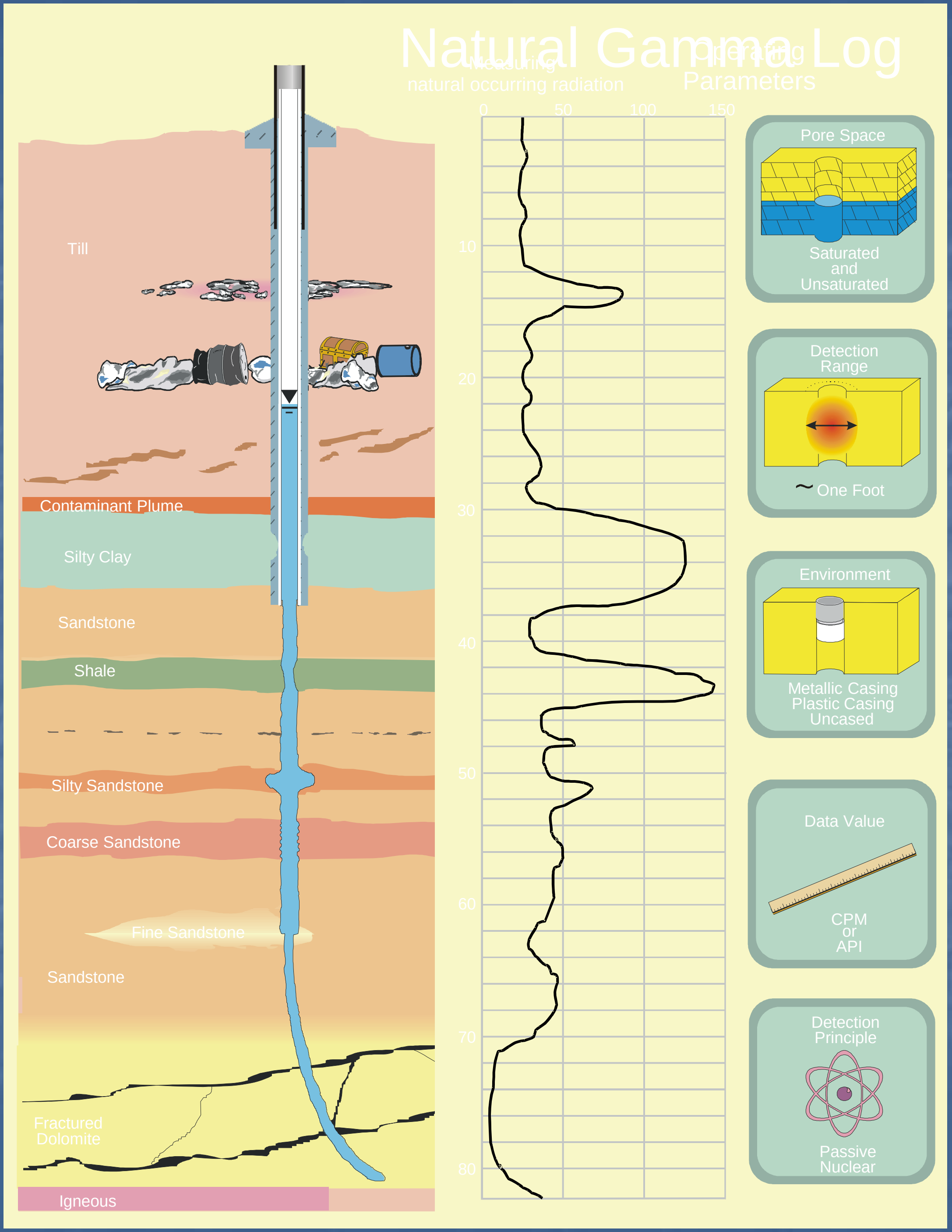


Summary Common Borehole Geophysical Topics

- Requires access by a pre-existing hole
- Tools capable of detecting
  - Stratigraphy changes
  - Porosity
  - Fluid flow
  - Casing/annulus integrity/hole diameter
- Limited by well construction method & presence - absence of fluids
  - Open hole, plastic or metal casing
  - Diameter of well may limit some tool use
  - Presence of fluids will limit what tools can be used

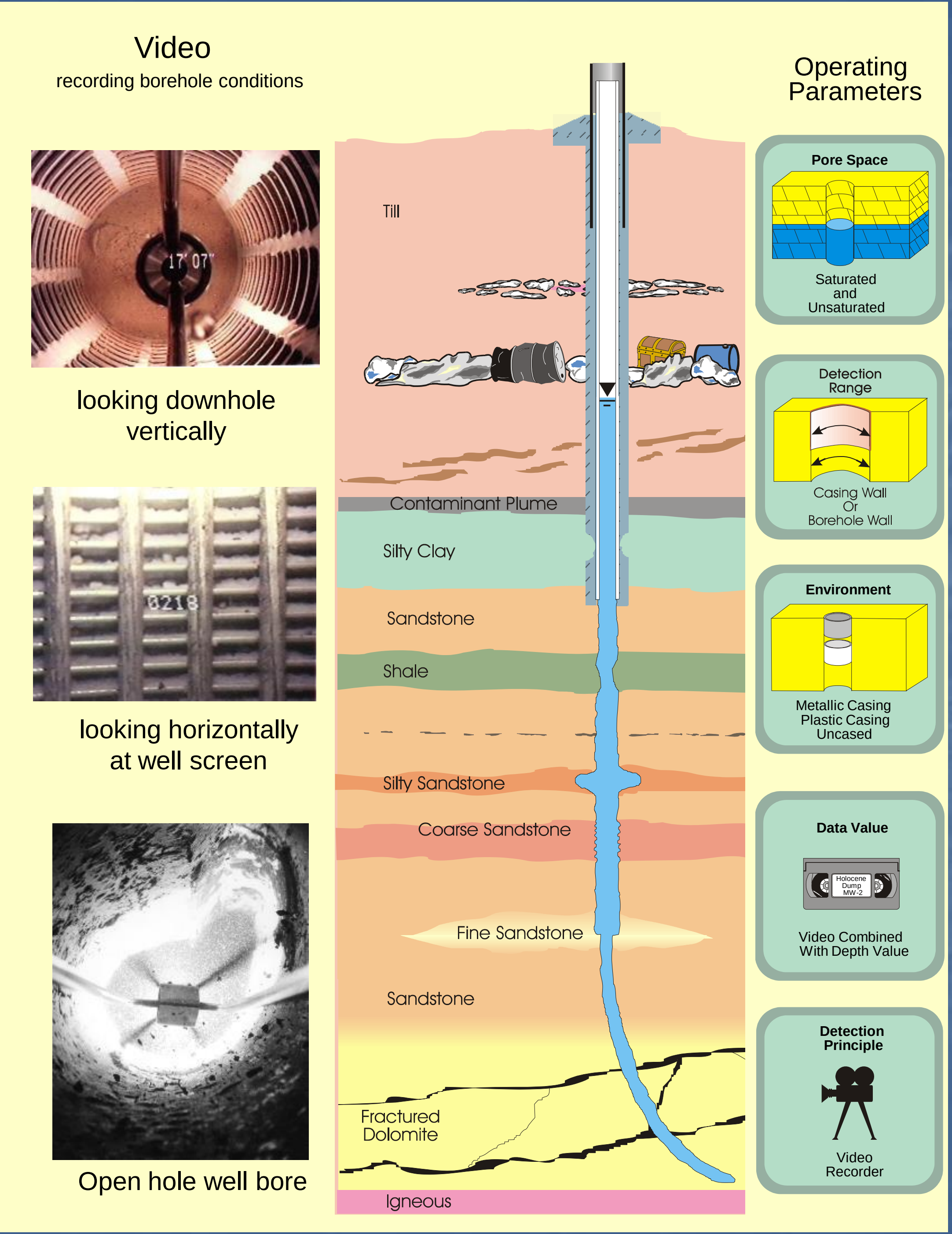
Natural Gamma

- Lithology
- Shale intervals
- Correlation



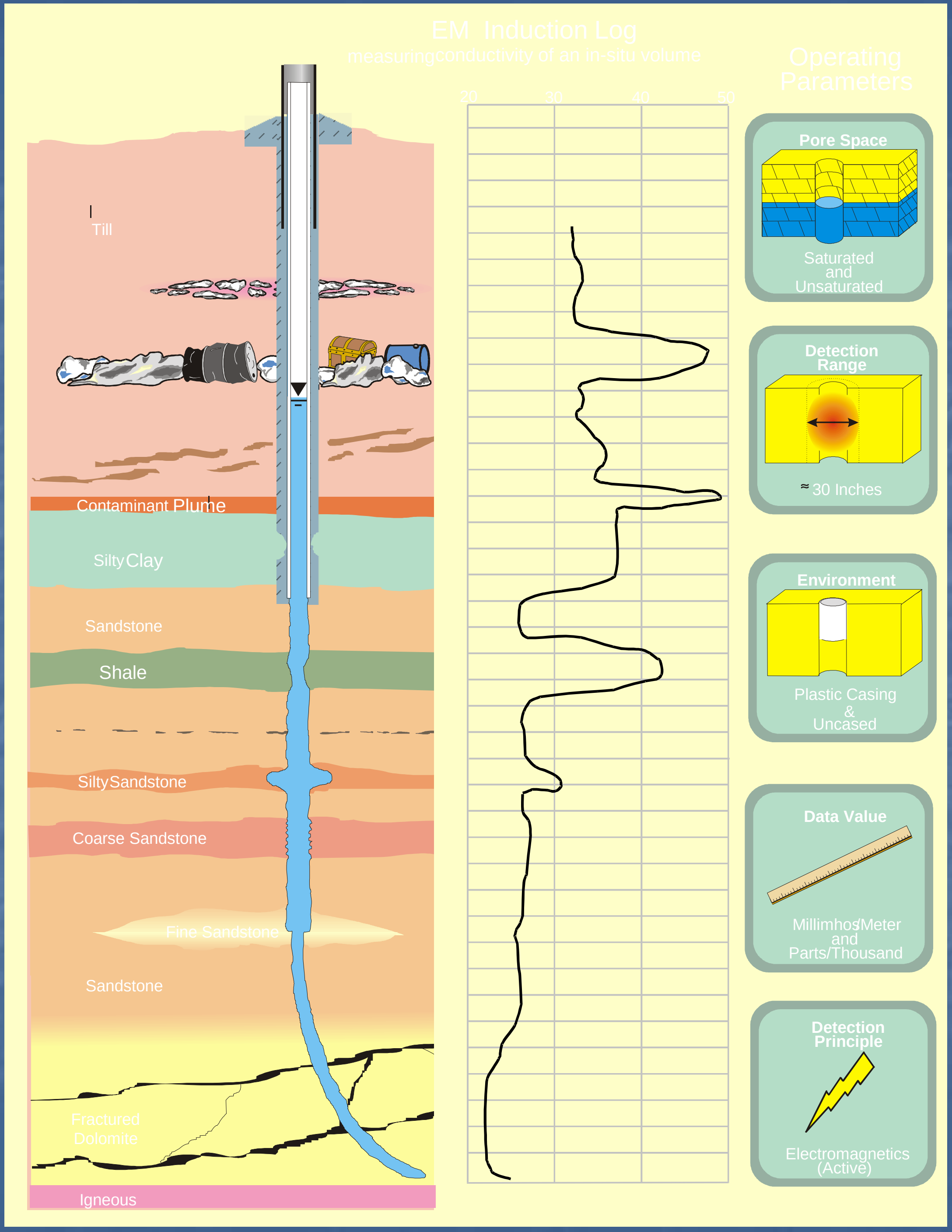
Video

- Wellbore/casing condition
- Investigate foreign objects in borehole
- Record stratigraphy

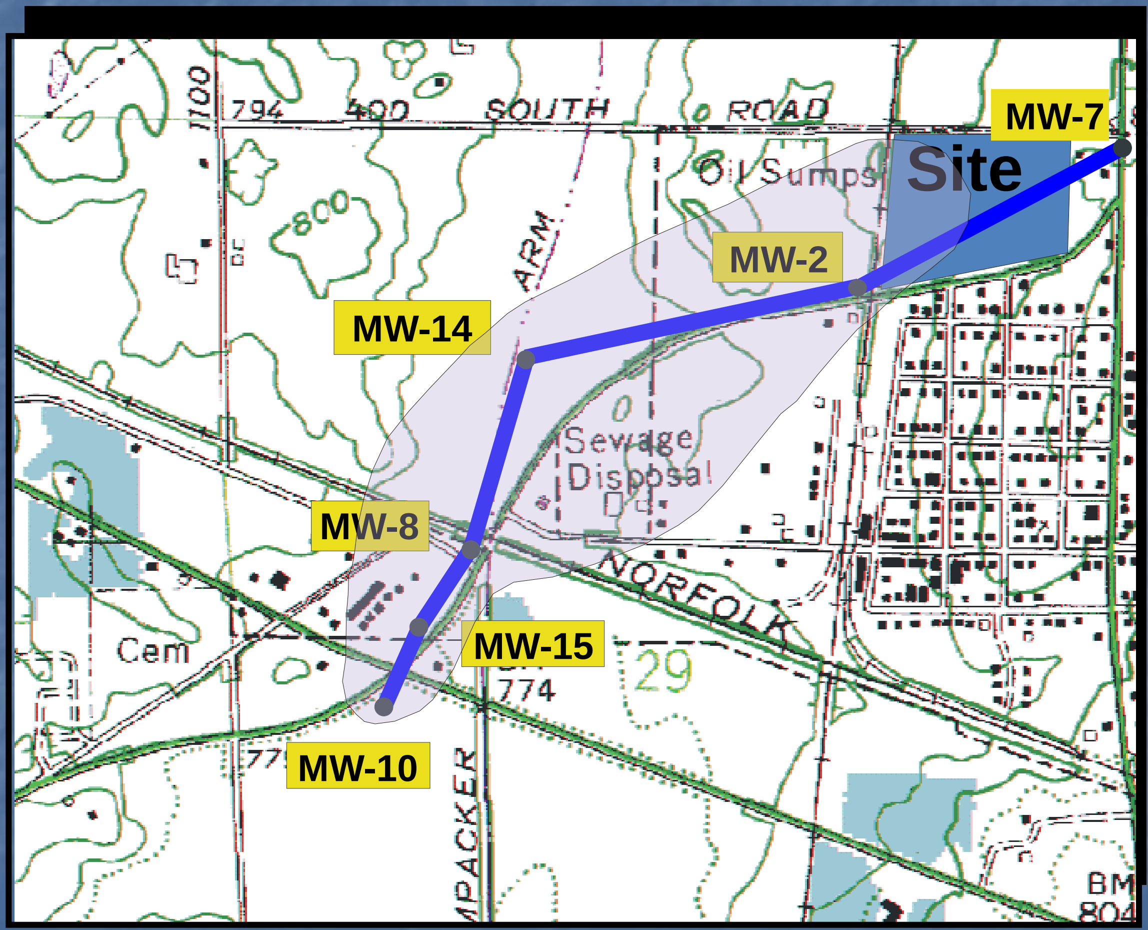


Electro-Magnetic Induction

- Locate certain contaminant plumes
- Stratigraphy
- Ferrous/non-ferrous cultural objects
- Quality of borehole fluid

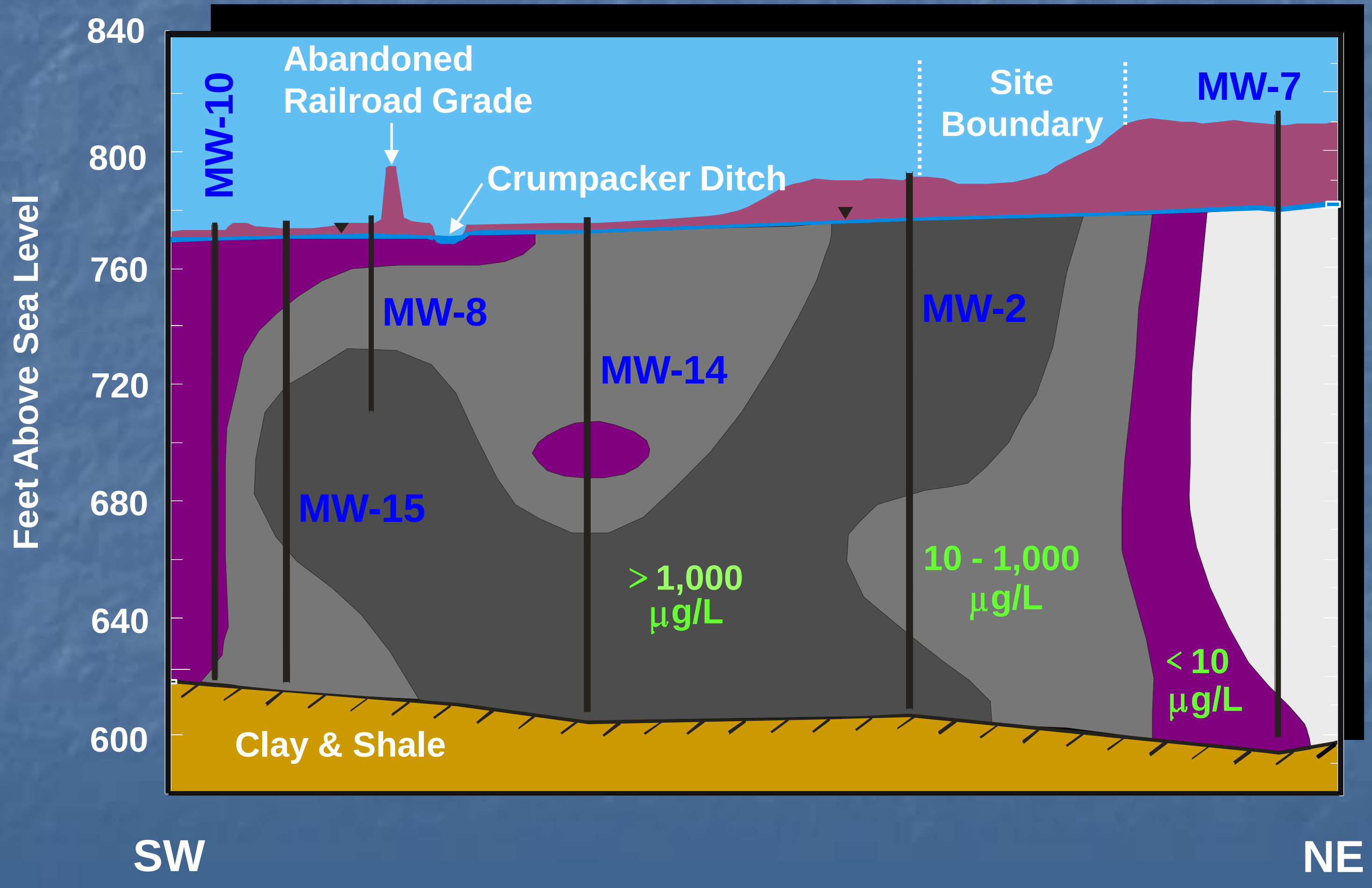


Electromagnetic Induction Tool
Plan View



1,4-Dioxane Plume Tracking

Plume X-Section



Well Examples from the Field

Broken Inner Casing

Stable apron

Failed apron

Well Examples from the Field

Still locked
outer casing broken hinge

Nested wells
one missing cap
others not secured

Well Examples from the Field

Missing lock
bent from nearby traffic

Outer casing subsided
no cover, cap, faded ID

Well Examples from the Field

Lock missing, faded ID

Inner casing heaved

Well Examples from the Field

Inner casing heaved
can't open

Outer/Inner casing sawed off,
no well ID, original reference
point removed

Well Examples from the Field

Well in grade school playground red circle shows items removed from inner casing, no lock, well cap

Missing locks, fading IDs

Well Examples from the Field

6” well, no external ID
or stick-up marker

No lock, ID fading

Well Examples from the Field

Six inch well, bent

Missing inner well cap

Well Examples from the Field

Broken lock

Broken lock

Well Examples from the Field

Wide photo shot
snow plow damage

Close up of snow plow damage

Well Examples from the Field

Lock missing, attempt made to secure cap with wire

Outer casing found lose enough to be lifted out of ground

Well Examples from the Field

No lock or inner cap.
Damage before or after guard posts?

No lock or inner well cap, wasp nest, subsiding of grouting materials

Well Examples from the Field

Annulus plug weathered & cracked

Security wire mesh fence pilfered

Common Problems from the Field

Locate well: GPS, metal detector, chisel, heat, hammer, socket & wrench

Where is that well?

Questions?