2016 WG ReSAGPAPR Soil and Groundwater Professions Technical Training Workshop

Integrated Thinking and Technical Tools on Groundwater Investigation

Chih Huang, Ph.D., P.E., P.M.P.
General Manager
InnoFusion Environmental Management (iFEM)

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Outline

- Why Integrated Site Investigation
- Key Factors to the Success
- Tools Available
- Case Study

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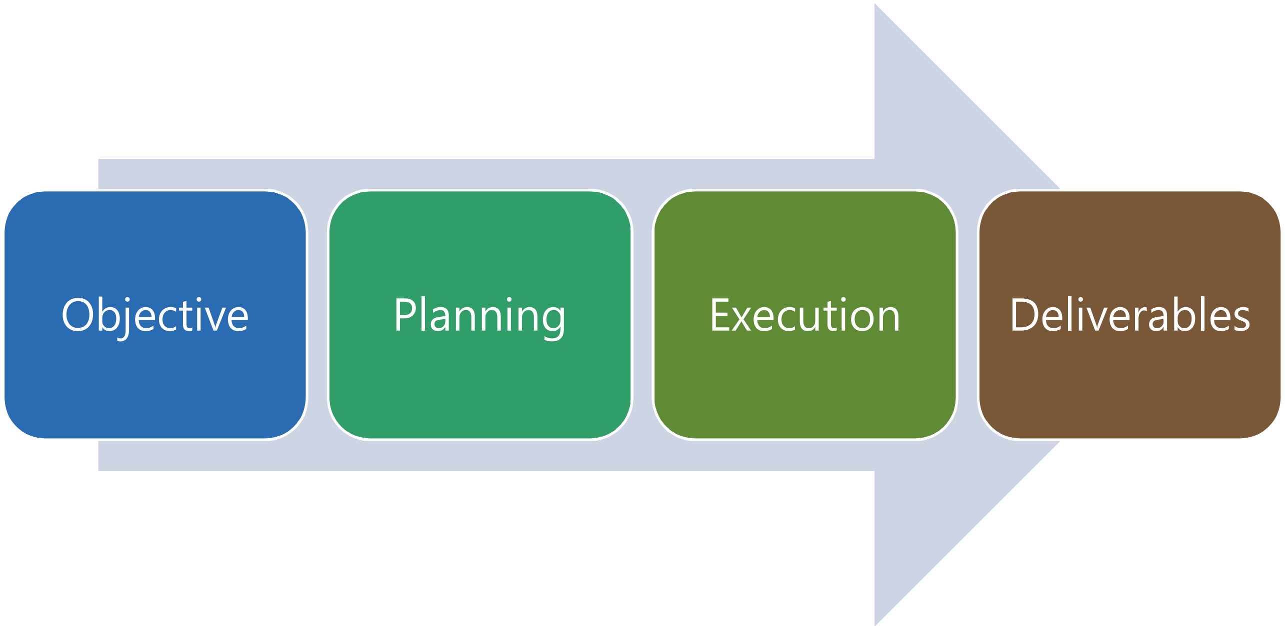
Why Integrated Site Investigation

- Site investigation is the basis of any remedy design
- Fit for the objectives
- Mindset
- Uncertainty management



Why Integrated Site Investigation

- Site investigation is critical to the success of remediation

Why Remediation Fail or over-budget (USEPA)

Reason	Percentage
mistaking or incomplete Site Conceptual Model (SCM)	80%
Incorrect selection of remediation technology	10%
Wrong Implementation or operation	10%

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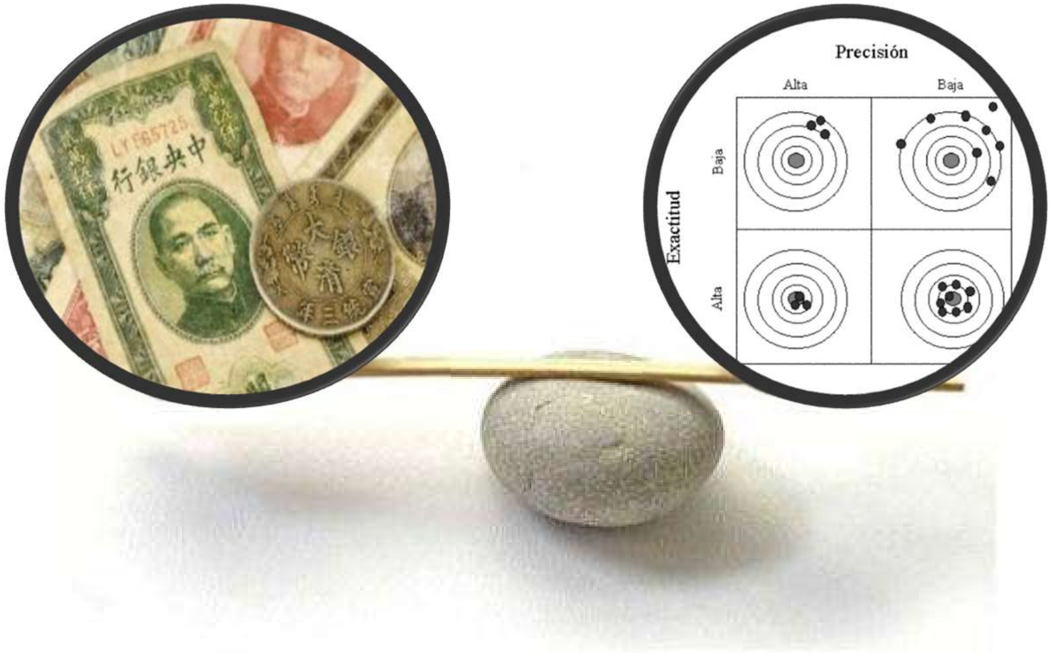
Why Integrated Site Investigation

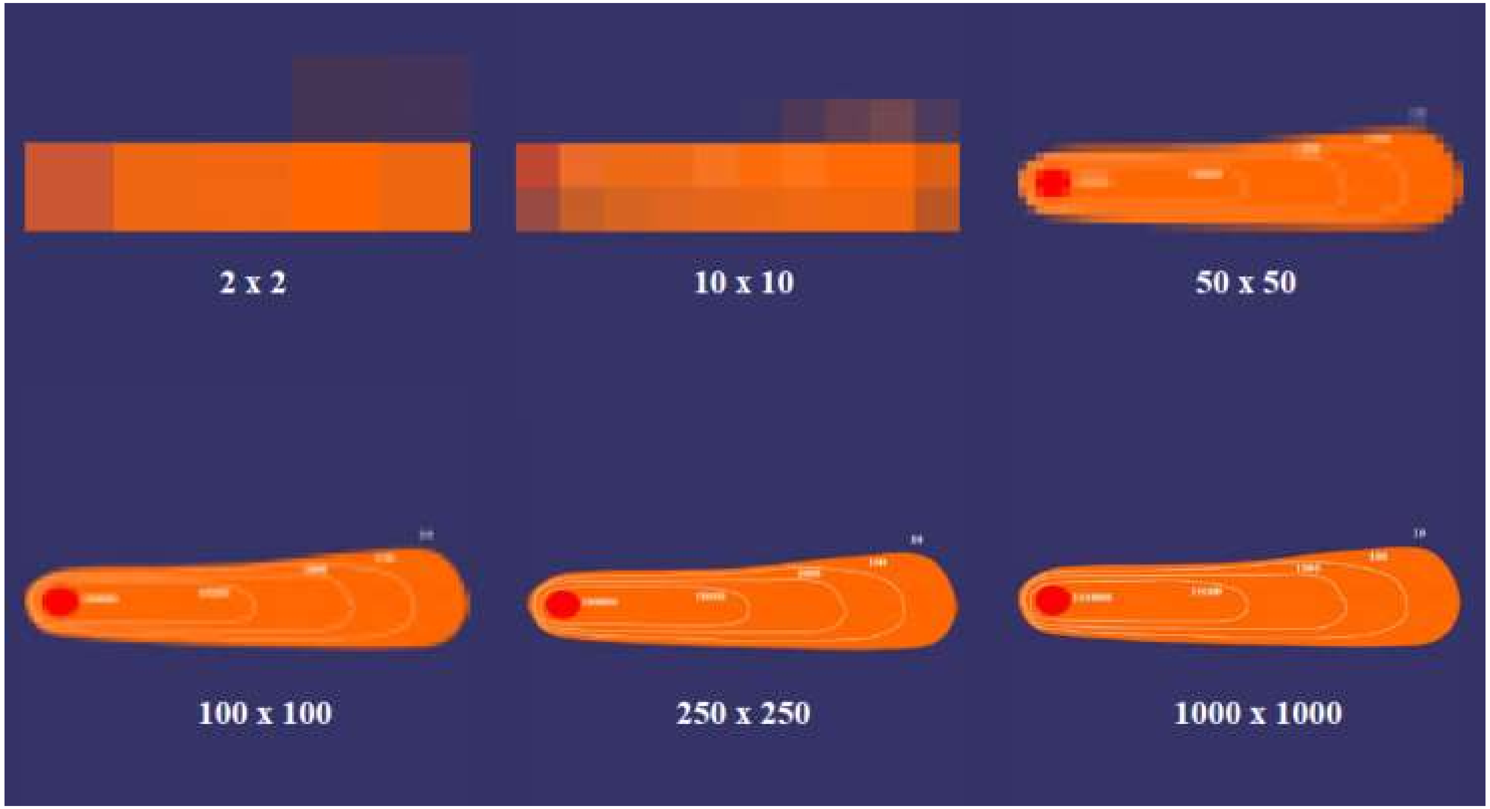
Why Integrated Site Investigation

- Balancing



Why Integrated Site Investigation

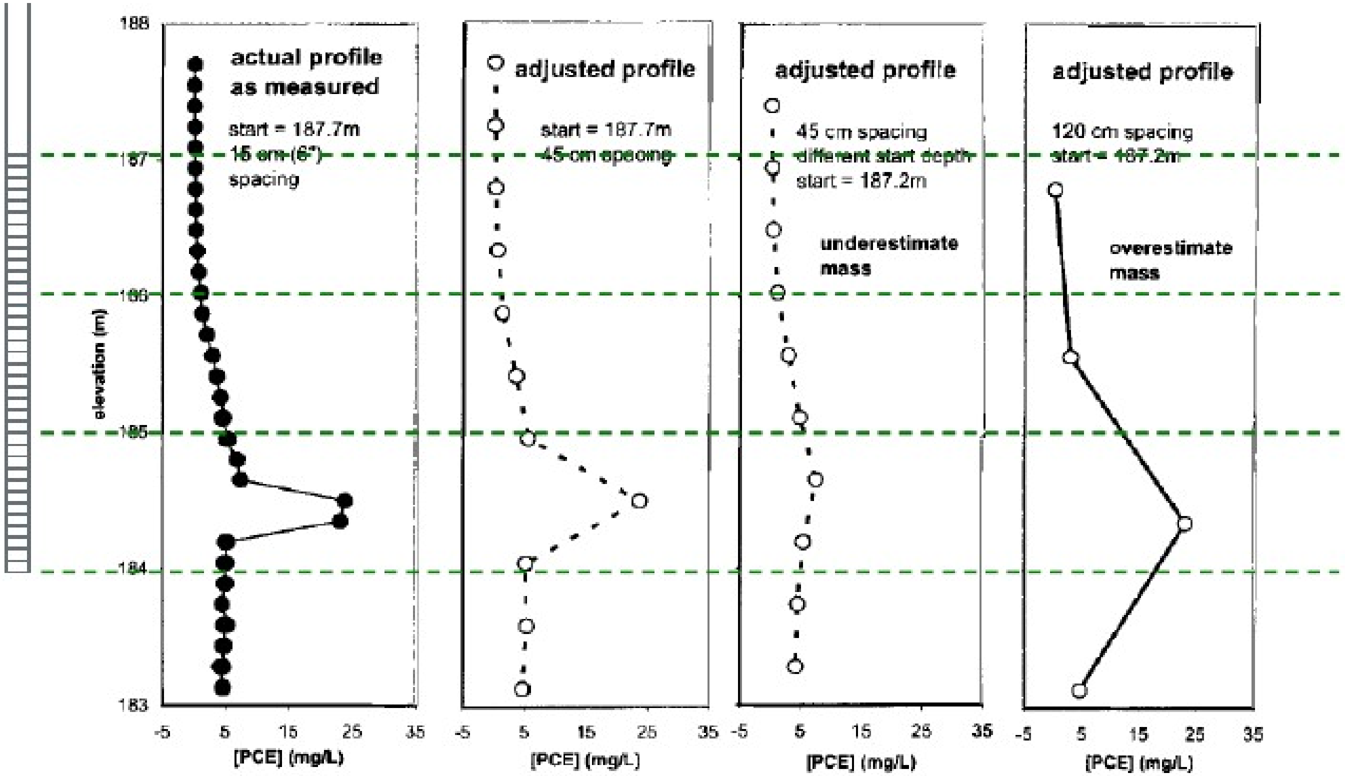
- Resolution matters



Quantity vs. Quality

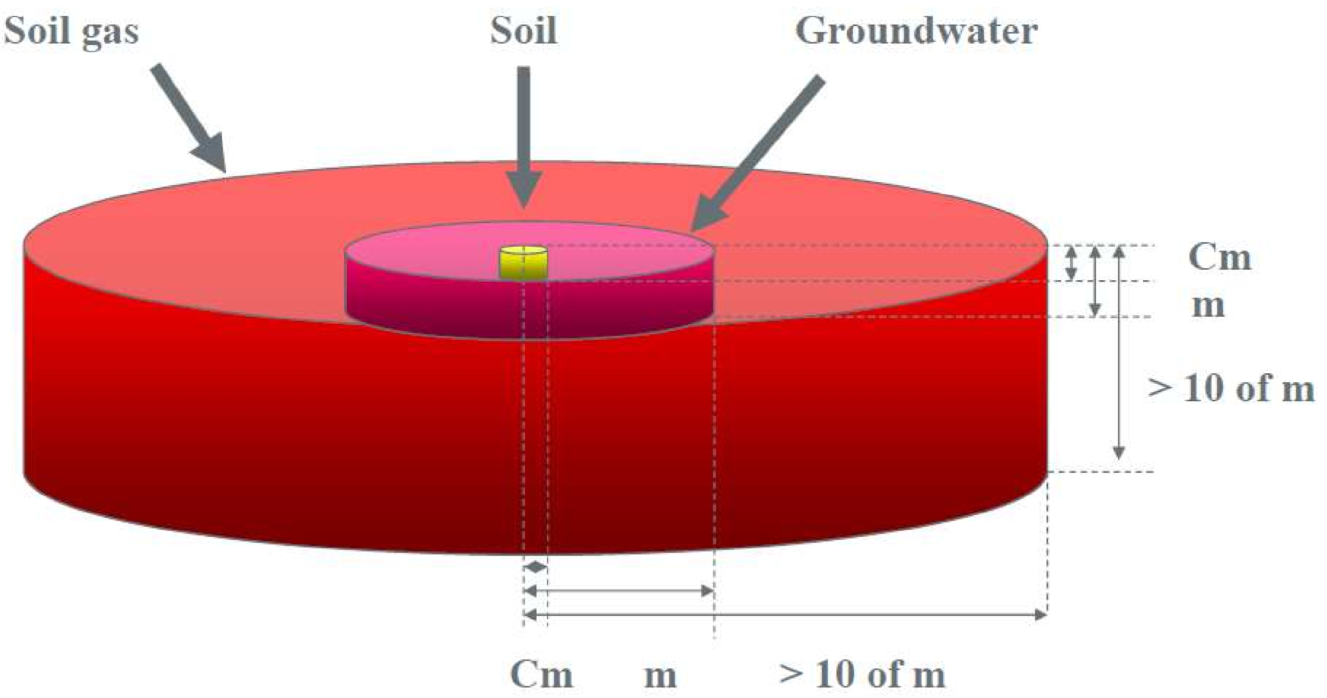
Why Integrated Site Investigation

- Resolution matters



Why Integrated Site Investigation

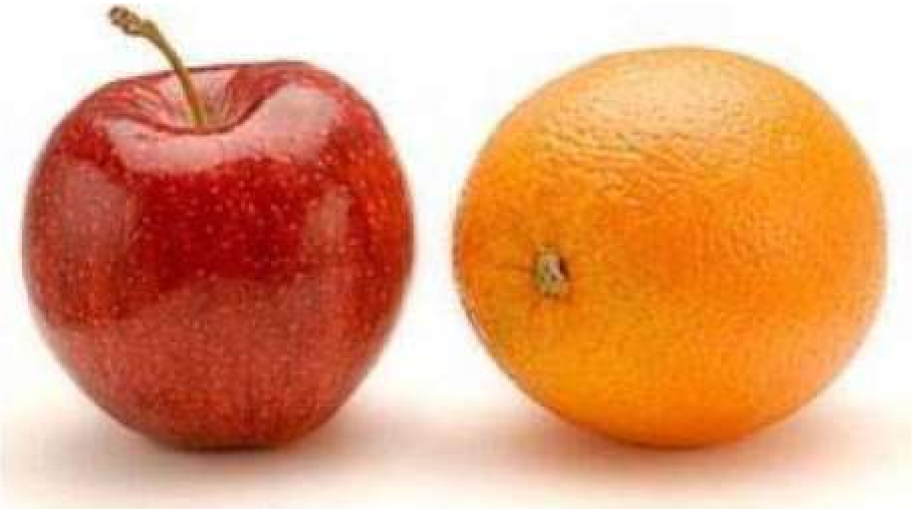
- Mindset and tool selection



What do the data tell us?

Why Integrated Site Investigation

- Investigation=Understanding the site condition
- Monitoring=temporal variation of one place
- Frequently, monitoring tools are used for investigation



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Why Integrated Site Investigation

- Integrated thinking

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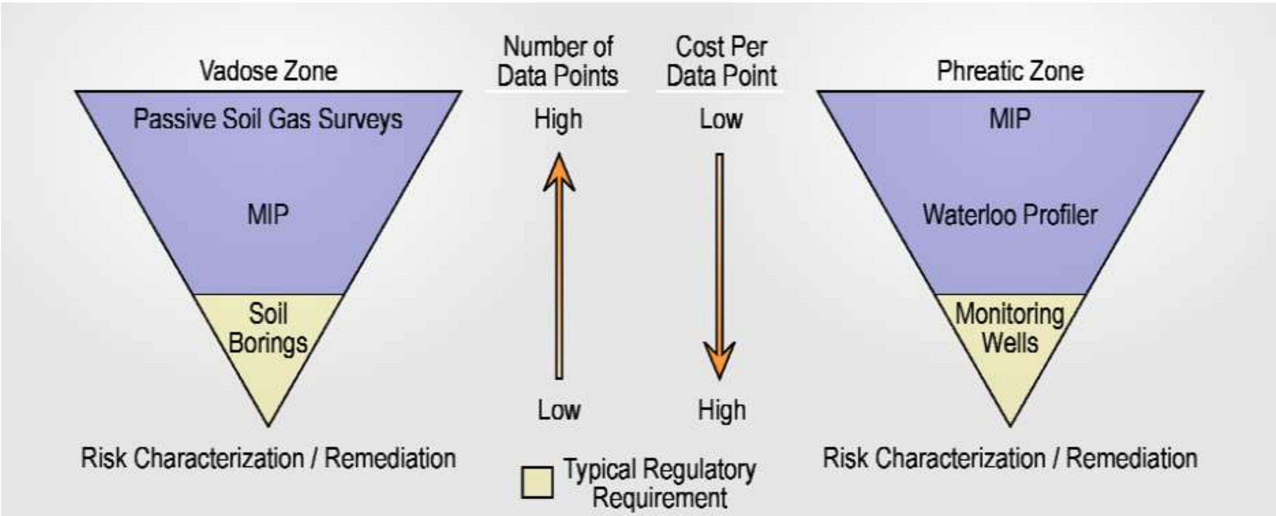
Key Factors to Success

- Conceptual Approach
  - Initially, a high number of lower cost data are generated to minimize sampling uncertainty
  - These data are used collaboratively with fewer, moderate cost data to define the horizontal and vertical extents of contamination
  - A small number of high quality, quantitative data are generated to satisfy regulatory requirements and to minimize analytical uncertainty.



Key Factors to Success

- Key factors to be considered
  - A multi-disciplinary team that has expertise in geology, hydrogeology, and geochemistry, and apply a "toolbox" approach
  - Design an investigation program that focuses on understanding and managing uncertainty in decision-making
  - Sampling uncertainty arises from the heterogeneity inherent in natural hydrogeological systems. Examples include
    - the spatial structure of hydraulic conductivity controlling groundwater flow
    - capillary pressure controlling DNAPL movement
    - soil-water partitioning coefficients controlling retardation of volatile organic compounds (VOCs)

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High Resolution Site Characterization

- Why consider High Resolution Site Characterization (HRSC)
  - Increasing pressure on environmental professionals and contractors to provide rapid, cost-effective site investigations and remediation
  - Site investigation programs are known for seemingly endless phases of assessment and high degrees of uncertainty, due to the use of traditional investigation tools and approaches
  - an efficient, cost-effective approach for the environmental professionals to rapidly investigate sites
  - Lack of certainty affects one's ability to make sound decisions with respect to a host of health, environmental, financial, and reputational risks

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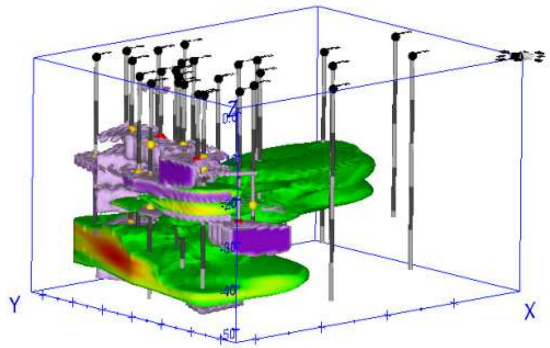
High Resolution Site Characterization

- What is HRSC
  - High resolution site characterization (HRSC) is an alternative approach to site investigation that significantly reduces uncertainty and enables development of cost effective solutions to address those risks identified.
  - By applying proven scientific principles, investigation approaches, and characterization tools, we generate detailed two- or three-dimensional conceptual site models (CSMs) to support effective decision making



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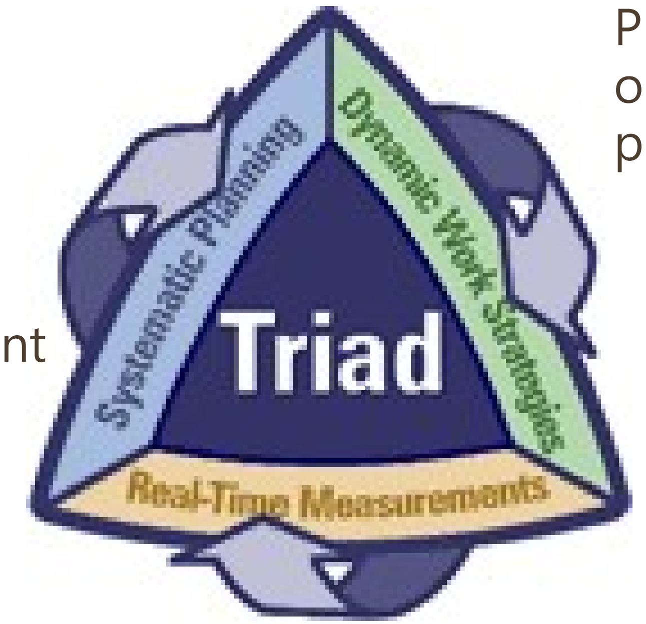
High Resolution Site Characterization

Sampling plan prior to execution:

1. Define objectives

2. Interpretation of data

3. Data quality requirement (uncertainty)



Predefined logical process for on-site change of sampling plan

real-time measurement tools for on-site decision and facilitate the sampling decision

Tools Available

- Direct-Push Sampling
  - Geoprobe SP16/SP21
  - Waterloo Profiler
  - BAT Sampler
  - Cone Sipper

- Hydrogeological Measurement
  - Electrical Conductivity (EC)
  - Cone penetrometer (CPT)
  - Hydraulic Profiling Tool (HPT)

Direct Sensing and Analysis

- MIP (w/FID, PID, ECD, XSD)
- Laser-Induced Fluorescence (LIF)
- Immunoassay
- Colorimetric

Quantitative Analysis

- Mobile laboratory
- Fixed laboratory

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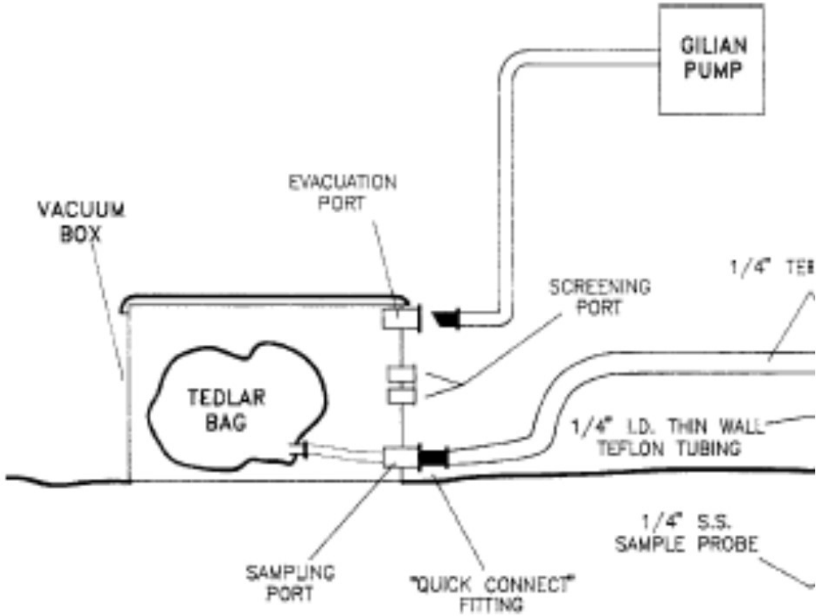
Tools Available

- Soil Gas
  - Measuring the contaminant concentrations existing in the gas phase (void) in the unsaturated zone (soil)



Tools Available

- Soil Gas
  - General applicability

Contaminant Property	Condition
Vapor Pressure	> 0.5 mm-Hg
Henry's Constant	> 0.1
Soil Moisture	< 80%
Sampling Point	No Clay

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Tools Available

■ Soil Gas

- Some examples

Petroleum	Vapor Pressure
Unleaded Gasoline	258 – 774 mm-Hg
Diesel	2 mm-Hg @ 20℃
Fuel Oil	0.2 mm-Hg @ 20℃

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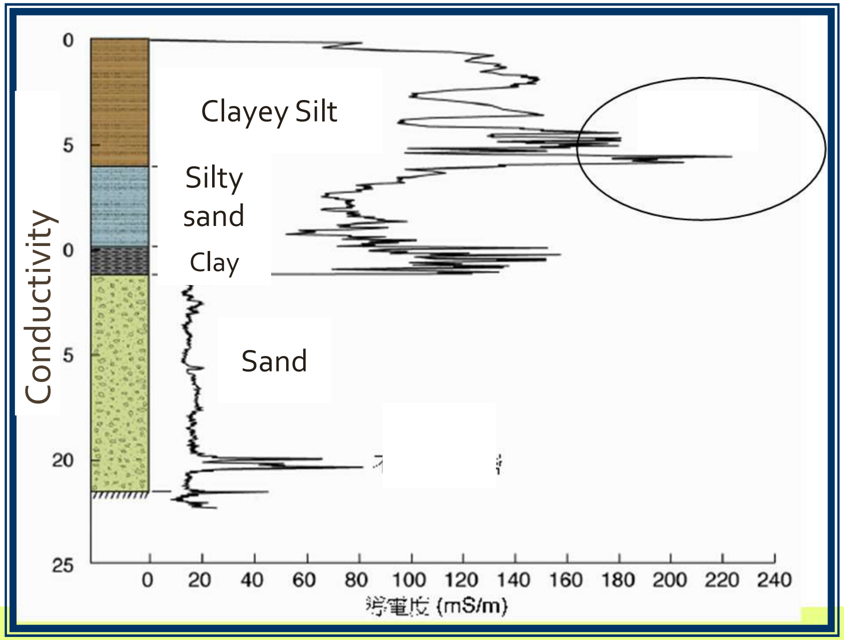
Tools Available

■Direct Sensing

☐ Conductivity

- ➢ Measuring the conductivity or resistivity of the soil
- ➢ Clay exhibits higher conductivity compared to sand
- ➢ Groundwater table can be distinguished by the sudden change in conductivity

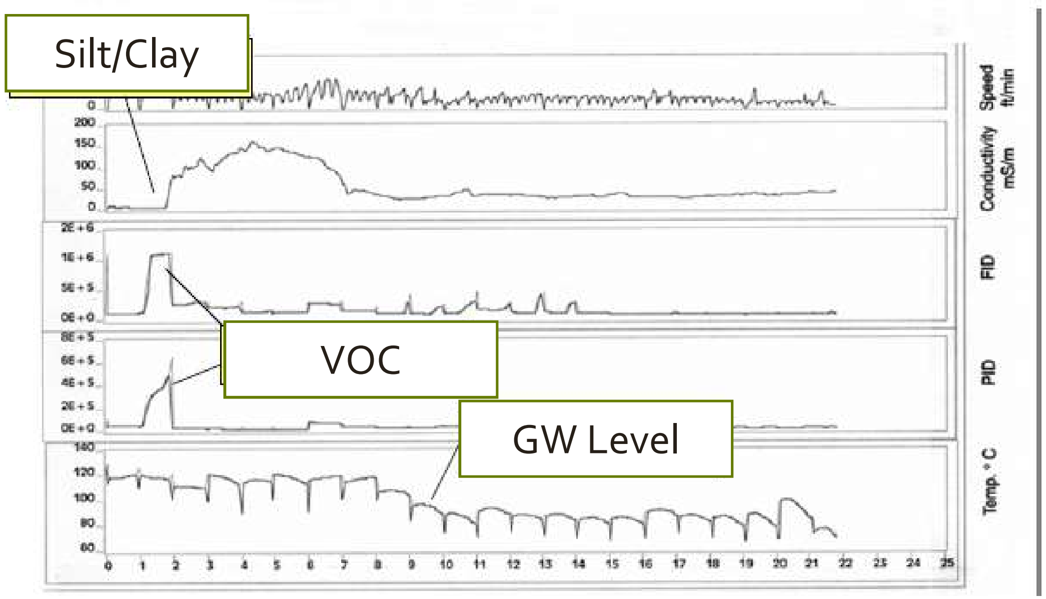


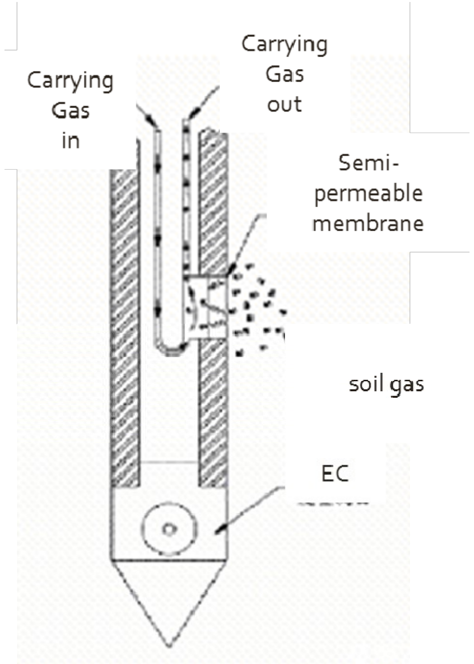
Tools Available

■Direct Sensing

☐Membrane Interface Probe (MIP)

➢ Measuring the soil gas continuously by carrying the soil gas with carrying gas to the detector





Tools Available

- Direct Sensing
- ■ Laser Induced Fluorescence Technology
  - Detects free phase & residual LNAPL
  - Utilizes DPT Technology
  - Real-Time Data
  - Fast Production Rates of 100 + Meters per Day
  - High Resolution of 2 to 3 cm per Data Pt.

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Tools Available

Direct Sensing

- Laser Induced Fluorescence Technology

- Computer with real-time log
- UV laser light
- Fiber optic cable in rods
- SPOC: Shock-Protected Optical Compartment
- Sapphire window

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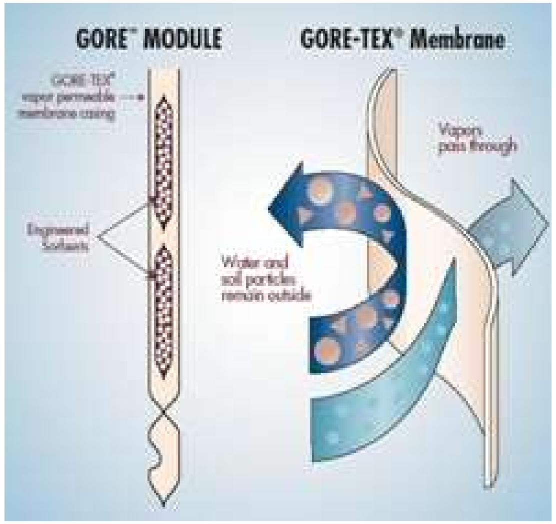
Tools Available

- Passive Vapor Sampling Using Gore Sorber Modules
  - Utilizes tubes containing an absorbent material, which is placed in a sampling matrix near the surface. As contaminants in the soil and groundwater volatilize, gases are adsorbed onto the material
  - Application include soil and groundwater quality characterization at:
    - Refineries and Fuel storage terminals
    - Fire training areas
    - Manufactured gas plants and Retail petroleum facilities
    - Solvent manufacturing/distribution facilities
    - Dry cleaners and Airports
    - Landfills and Military sites
    - Brownfield sites



Tools Available

- Passive Vapor Sampling Using Gore Sorber Modules
  - Limitations and Concerns
    - Contaminant type, contaminant depth and the possible presence of subsurface barriers (e.g., dense clay layers) determine the method's effectiveness.
    - Samplers detect the presence of certain compounds, but the results are reported in ion flux, rather than concentration. So, flux counts are related to concentrations, they cannot be directly extrapolated.
    - The porosity of the membrane material has been found to be inconsistent. The membrane material also is prone to tearing during installation.
    - Use of passive soil sampling techniques requires rigorous quality assurance program to be followed.

Used for:

- VOCs
- SVOCs
- Halogenated compounds
- Petroleum hydrocarbons
- Polynuclear aromatic hydrocarbons

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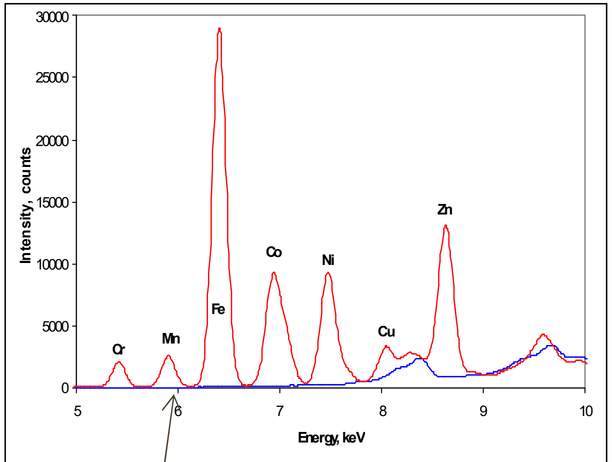
Tools Available

- X-Ray Fluorescence (XRF)
  - Significance
    - Map the contaminated site for "hotspots" and helps in decision making.
    - Rapid and simple on-site analysis: Measure directly on the ground or prepared samples
    - Results are immediately available: Instant decision making
    - Quick and reliable pass/fail messages for go/no-go decisions
    - Preliminary screening of contaminated soil reduces the amount of laboratory analyses needed

Number of X-rays indicates how much of the element is present



The energy of the X-rays indicates which elements are present

Tools Available

- X-Ray Fluorescence (XRF)
  - Limitations and Concerns
    - The screening data can be comparable to the laboratory analysis only if the sample preparation is very similar to the laboratory methods. If element in question is not homogenously distributed in the sample, it affects the efficiency of the instrument
    - While using the instrument directly in field, the position of the instrument, Relative humidity and/ or temperature affect both the analyzer and the substrate and may influence the reported values
    - The instrument reports concentrations in the first 30mm surface only. So while measuring small, thin or low density samples Interferences caused by elements/materials other than the metal of interest (by absorption, scattering, or enhancing the fluorescence) affect the efficiency of the instrument
    - The instrument may be used to screen liquid samples, but has a very limited repeatability of the data

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Tools Available

- PetroFlag Analyzer
  - Field portable method for the determination of total petroleum hydrocarbons (TPH) in soil
  - Safe and easy to use
  - PetroFlag meter is a light-weight, rugged, handheld unit powered by a 9-volt battery and 4,000 tests can be run on a single alkaline battery

Petroflag can be for a broad range of hydrocarbons:

- Diesel fuel
- Kerosene
- Crude oil
- Motor oil
- Hydraulic fluid
- Grease
- Transformer oil
- #2,#4, and #6 fuel oils

Tools Available

- PetroFlag Analyzer
  - Limitations and Concerns
    - If the hydrocarbon type is unknown, the instrument can be used as a general screen so that no false negative results are generated.
    - The detection range is from 10 to 20000 parts per million. No chlorinated solvents are used in any part of the procedure. Moisture does not affect test results up to saturation (20-25% water). Usable temperature range is from 5°C to 45°C.
    - Light hydrocarbons such as fresh gasoline can be detected by PetroFlag but only at high concentrations (>1000 ppm). It is generally recommended not to use PetroFlag for gasoline except as a general screen for high levels.
    - PetroFlag is unaffected by the presence of salt or surfactants.
    - The presence of naturally occurring hydrocarbons in soil, eg, vegetable oils, may cause high readings with PetroFlag. This high bias can be compensated for by calibrating the instrument with a blank soil that contains an equivalent concentration of the naturally occurring material.

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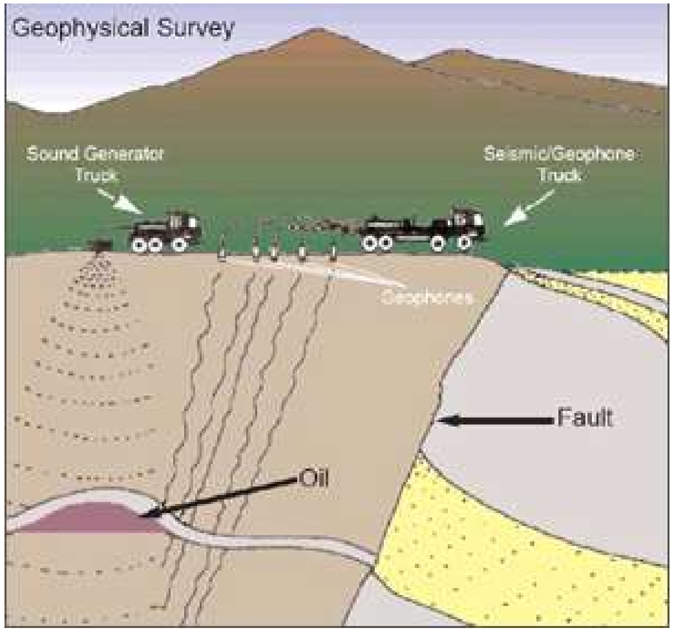
Tools Available

- Subsurface Physics
  - Systematic collection of geophysical data for spatial studies.
  - In archaeology, it refers to ground-based subsurface mapping using a number of different sensing technologies. Data collected from the surface can be used for mapping subsurface archaeological features without excavation
  - Different Techniques used in Subsurface Physics are:
    - Electromagnetic Methods
    - Ground Penetrating Radar Methods
    - Magnetic Methods
    - Seismic Methods
    - Very Low Frequency EM
    - Gravity Methods
    - Groundwater Motion Monitoring



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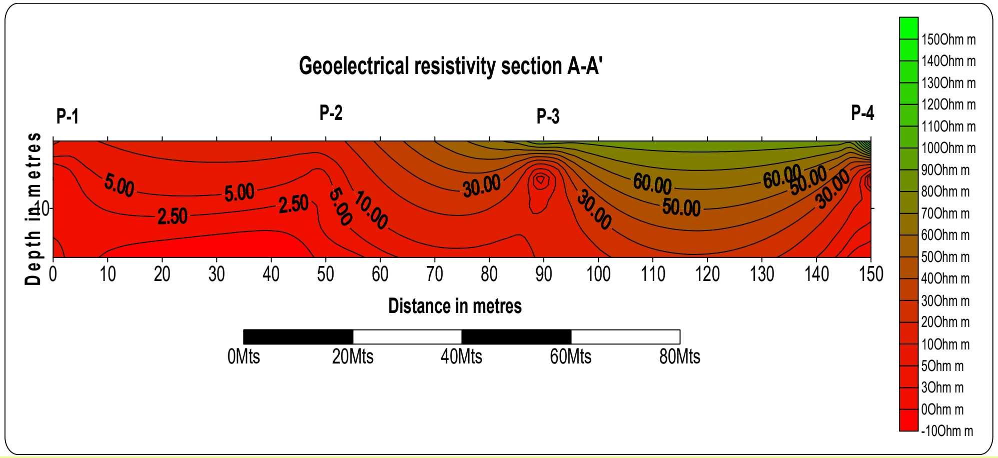
Tools Available

- Geosurface Physics
  - Geophysical Survey is used to evaluate sub-surface geologic and hydrogeologic conditions
  - This was done to identify potential preferential groundwater migration pathways for e.g. transmissive bedrock fracture / joint-sets and / or weathered zones that may be preferential contaminant pathway
  - The Geophysical data, historical sub-surface geology and contaminant distribution data were used to refine the Conceptual Site Model to identify the effective management of identified hexavalent chromium impacts to groundwater



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Case Study

Traditional Investigation Methodology		High Resolution Investigation (LIF)	
Establishment		***Establishment***	
Mobilisation	$350	Mobilisation	$750
Operational Costs		***Operational Costs***	
Drill Rig (1000 ft) One-Inch Temp. Well Install	$1,200/day $5/ft	Drill Rig (1000 feet) LIF and UVOST Tooling	$1,200/day $2,600/day
Scope of Works	***Est. Cost***	***Scope of Works***	***Est. Cost***
4 Days – 28 Soil Cores 28 Temporary Wells	**$10k**	3 Days -28 LIF Borings, Rpt. 2 Temp. Monitoring Wells	**$13k**

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Case Study

- Agile determination of excavation
  - TPH analyzer as a field based analytical methodology at a project site located in Navi Mumbaiwas
  - It was used to detect TPH in soil and aided in identifying hot-spots , validation of the excavation pits and assessment of residual soil to detect if any contamination was left behind.
  - Excavated soil was also screened using PetroFlag to ensure that clean soils were not sent to the local Treatment, Storage and Disposal Facility. Petroflag helped in reducing significant costs of laboratory analysis and aided in quick decision making.

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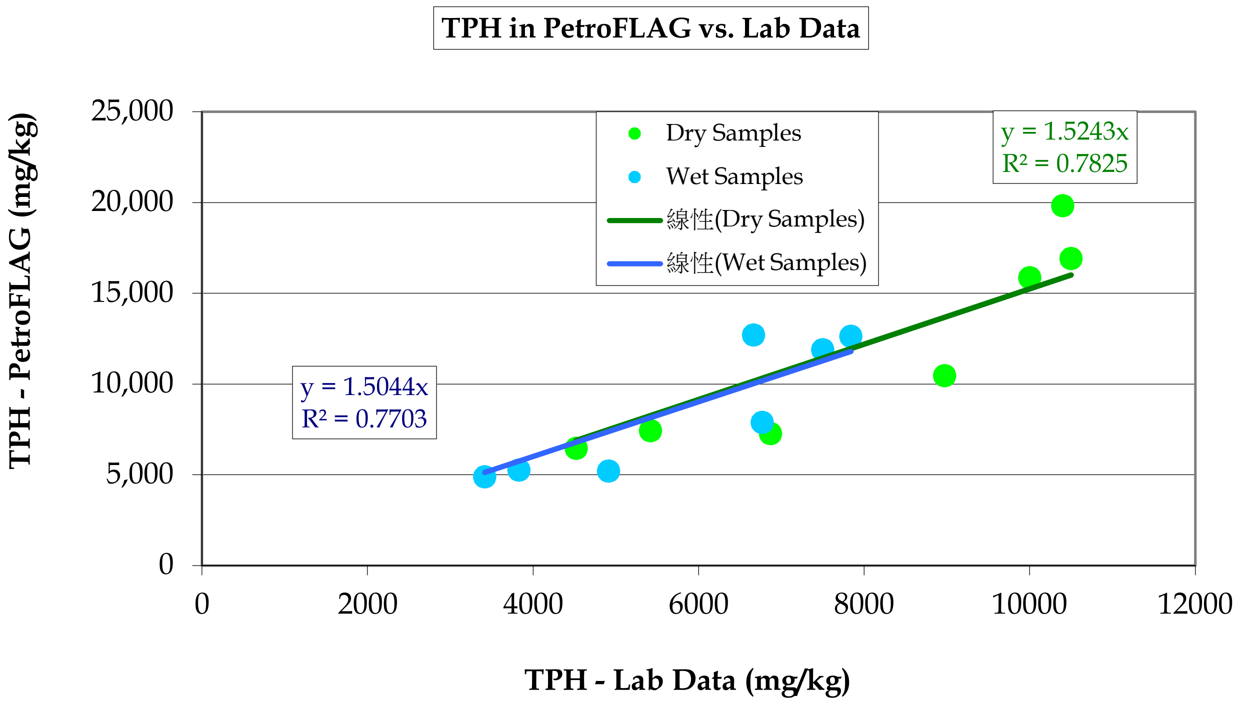
Case Study

- Agile determination of excavation
  - To analyze the accuracy of PetroFlag, some of the counter samples were sent to the laboratory and it was found that there was not much variation in the results.



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Thank you for your attention

Chih Huang

TEL: +886-2-2766-6808

chih.huang@ifem.com.tw

Apollo Technology Co., Ltd.

Issues and Countermeasures for the Investigation of Soil and Groundwater Contaminated with Chlorinated Hydrocarbon

Speaker: Hsin-Chang Liu, Ph. D.

DISATER PREVENTION
RESEARCH
WATER ENVIRONMENT
國立交通大學
防災與水環境研究中心
DISATER PREVENTION & WATER ENVIRONMENT RESEARCH CENTER, NCTU

Outline

- ❖ **Introduction**
  - What's Environmental Geophysics
  - The purpose and requirements for Geophysics Surveys
- ❖ **Method**
  - **E**lectro-**M**agnetic Method (**EM**)
  - **R**esistivity **I**mage **P**rofiling (**RIP**)
  - **E**lectrical **R**esistivity **T**omography (**ERT**)
  - **G**round **P**enetrating **R**adar (**GPR**)
- ❖ **Case Study**
- ❖ **Conclusion**

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Introduction

- What's Environmental Geophysics
- The Purpose and Requirements for Geophysics Surveys

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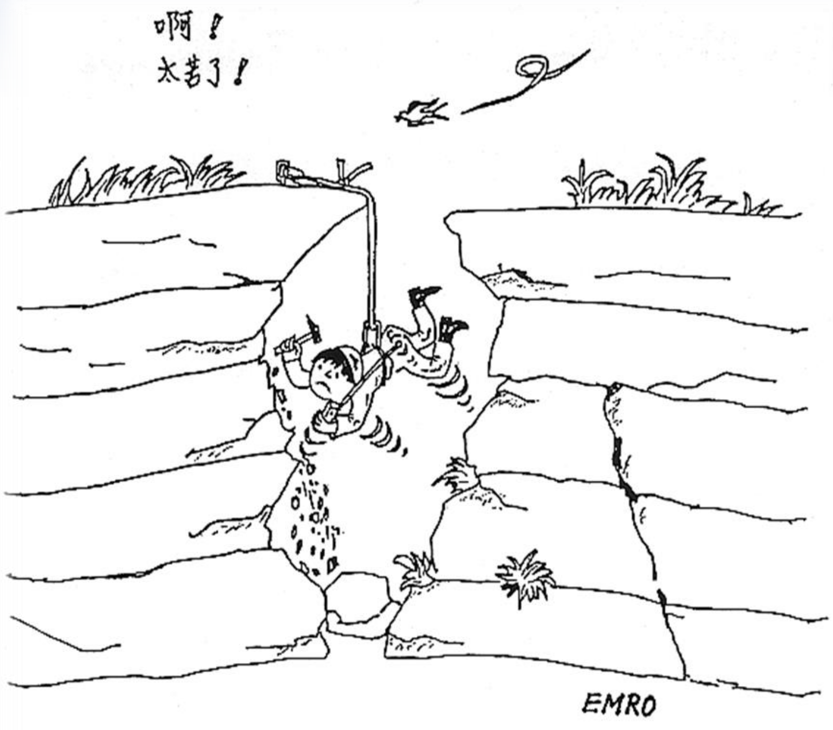
Men will triumph over nature?

- Want to understand underground environment is a very, very difficult challenge!



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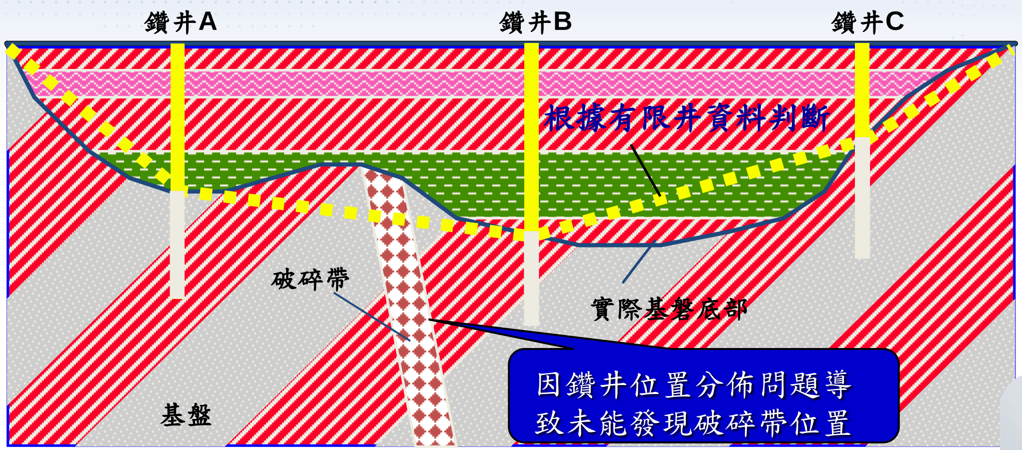
Drilling or Excavation is Difficult to Solve the Underground Problems



- Many types and depth varied with underground wastes
- We can't see the underground wastes
- Traditional way of drilling is expensive and have to spend much time

How to imagine the depth of underground garbage wastes, before excavation ?

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Environmental Geophysics

- Geophysics is the physics of the Earth and its environment in space; also the study of the Earth using quantitative physical methods. The term geophysics sometimes refers only to the geological applications.
- Geophysics is applied to societal needs, such as mineral resources, mitigation of natural hazards and environmental protection. Geophysical survey data are used to analyze potential petroleum reservoirs and mineral deposits, locate groundwater, find archaeological relics, determine the thickness of glaciers and soils, and assess sites for environmental remediation.

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Typical Environment Problems

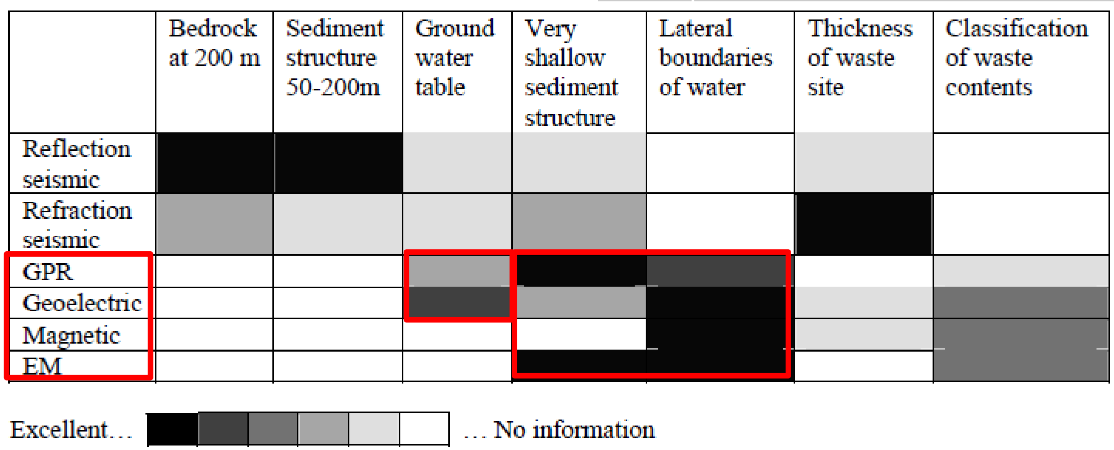
- Mapping the preferential air channels during sparing in sandy soil
- Detection of physical objects (cables, UXO)
- Monitoring of processes in a contaminant plume near a landfill
- Detection of hot spots DNAPL in the subsoil
- Detection of oil contamination in industrial area

Typical Environment Problems

- For these five problems a check was done on the performance of the geophysical techniques
- The result is summarized below

Area	Geophysical Applications
1	**GPR** can image heterogeneity at 10cm scale, application from surface or borehole multi electrode geoelectric (preferably from borehole or push away system) cheaper but less detailed aspect "monitoring" (changes from the time zero situation) is helpful
2	GPR: in sand adequate, in clayey soils of limited use, "all" type objects (also synthetics). EM for conductive objects (metal) magnetometer (for iron/steel objects)
3	extent of plume (if conductive) by **GPR**, EM, geoelectric processes in the plume: little options available
4	GPR: detection of first non-permeable layer and irregularities therein. If within depth range: perhaps direct detection of DNAPLs **reflection seismics**: "deep" (20m+) heterogeneity
5	GPR: some claims that direct detection is possible.

Source: 2002 US. EPA



Comparison of information content of different geophysical data sets (taken from Green, 1999).

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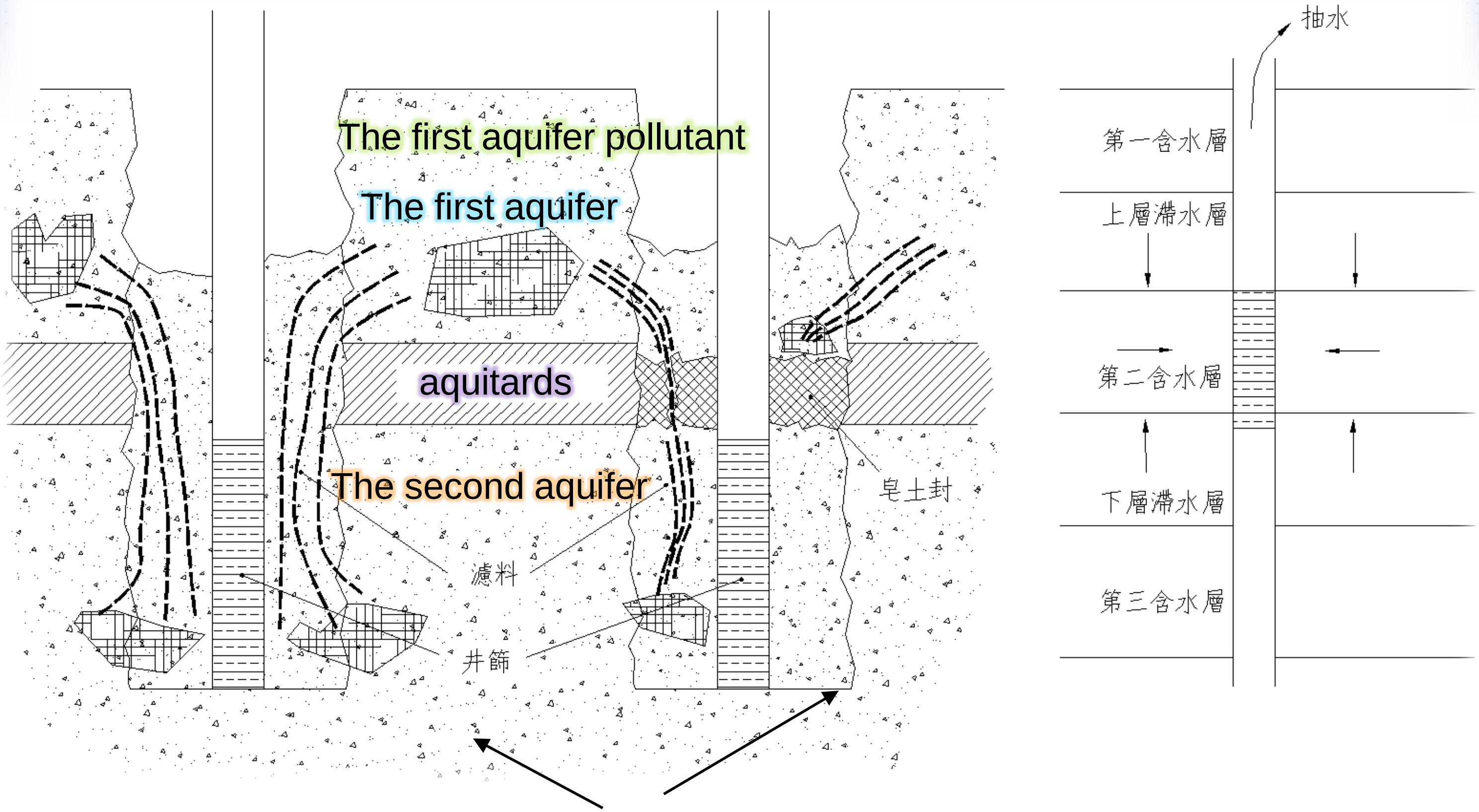
The Bottleneck of the Deep Pollution Investigation



Leakage of contaminants to the second aquifer

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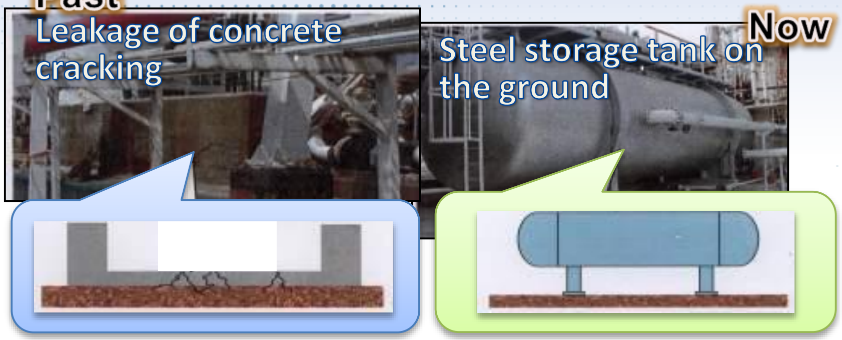
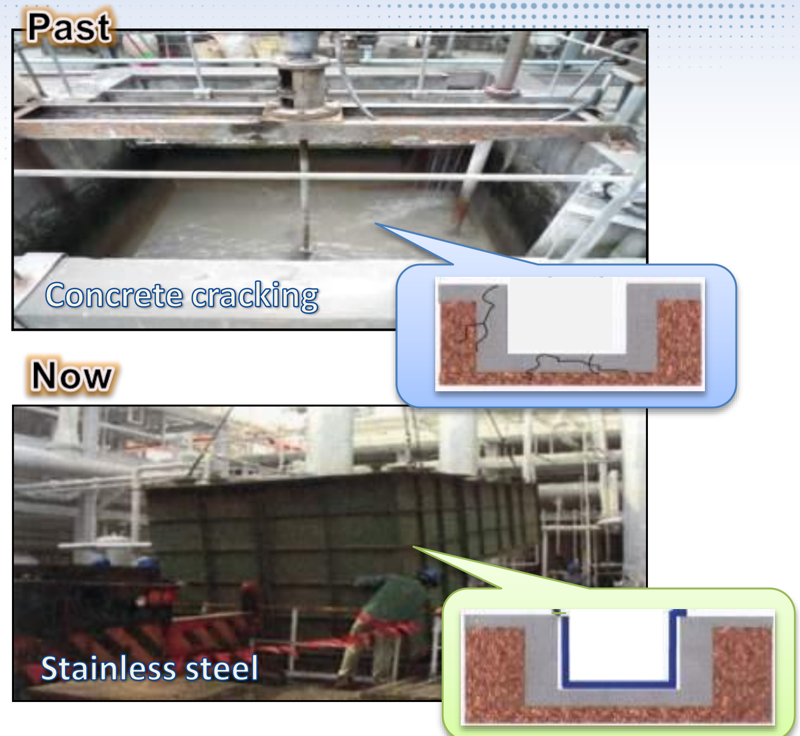
Countermeasures for the Investigation of Contaminant Potential Area

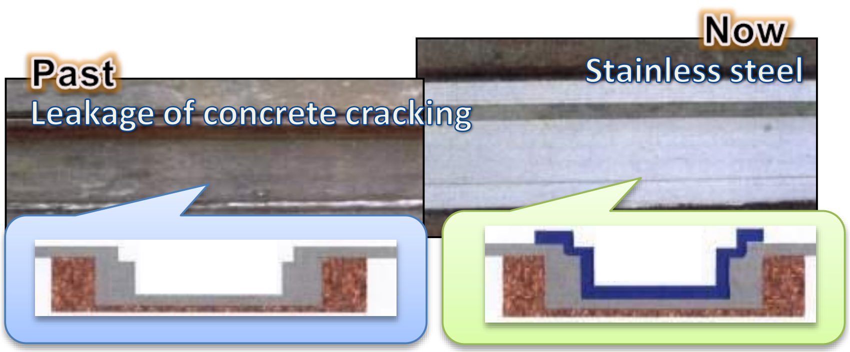
Investigation of Soil and Groundwater Chlorinated Solvents Pollution Potential in Operating Factories



Wastewater collection tank



Water collecting basin



Formosa Plastics Corporation / Jen-Wu Plant

- Modernization and refurbishment cause that contaminant areas are not easy to detect

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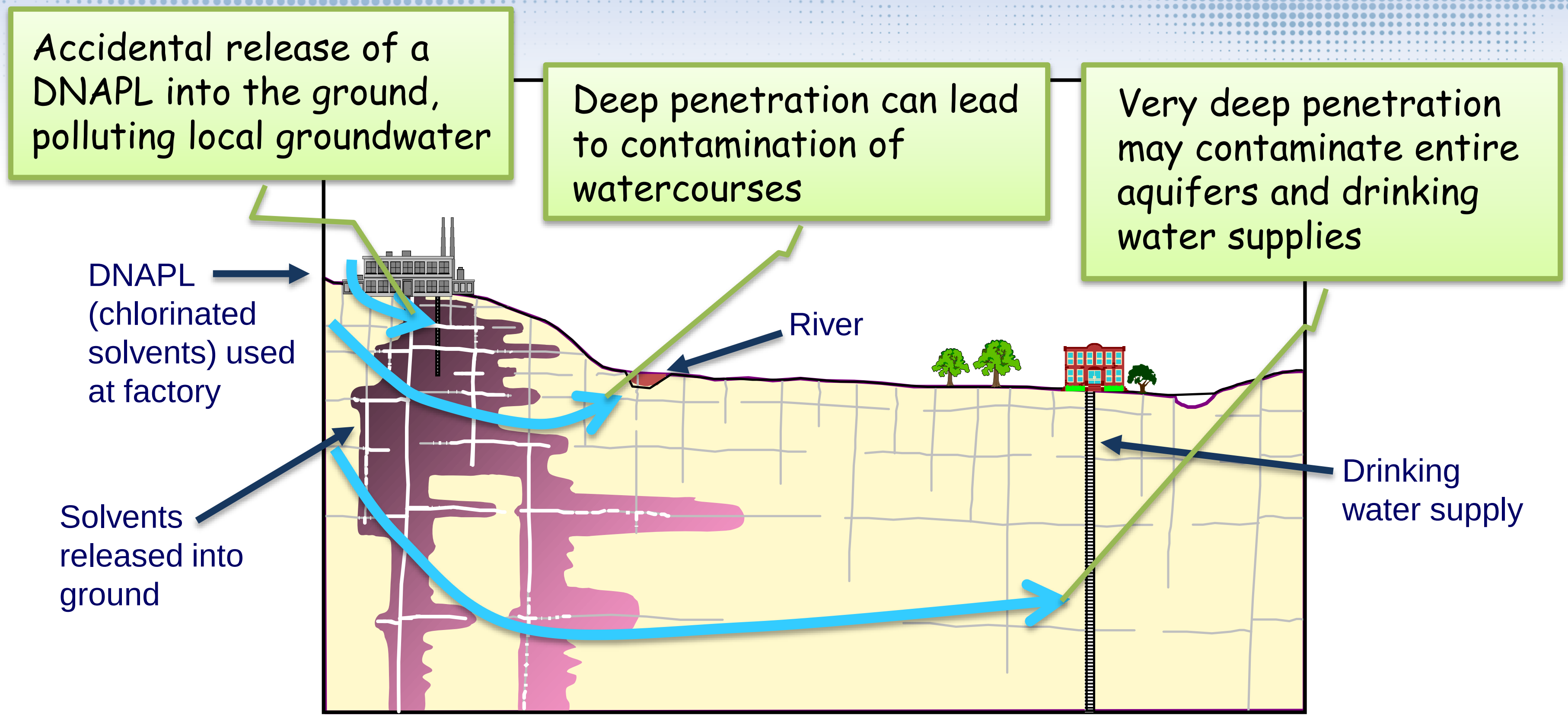
The Problem



❖ The release of DNAPLs into the subsurface as a result of practices that are unacceptable today has caused widespread contamination of aquifers.

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Environmental Pollution Detection Equipments

Ground - Penetrating Radar
SSI EKKO PRO & GSSI SIR-3000
Depth 0-10m

Electromagnetic Conductivity Survey
GF Instruments CMD-31
Depth 0-6m

Seismic Surface-wave
OYO McSEIS-SXW
Depth 0-20m

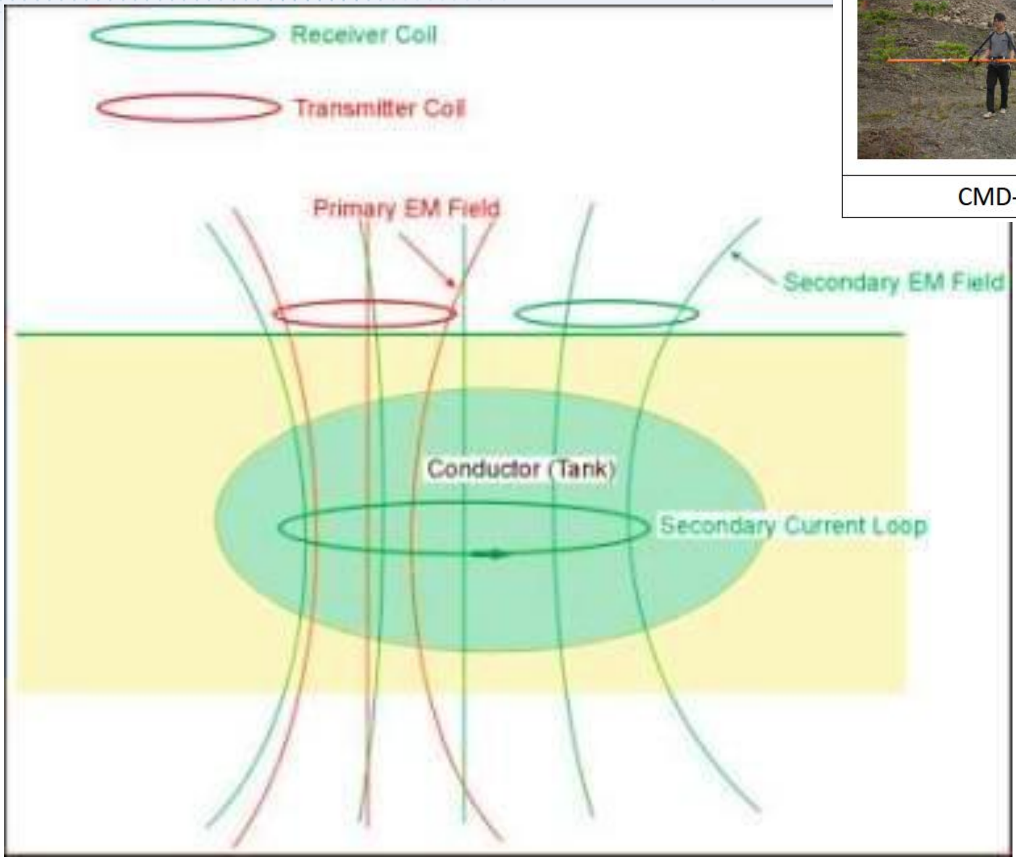
Electrical Resistivity
AGI Super Sting R8/IP
Depth 0-100m

Magnetics Survey
Geometrics G858
Depth 0-30m

Method

- Electro-Magnetic Method (EM)
- Resistivity Image Profiling (RIP)
- Electrical Resistivity Imaging / Tomography (ERI / ERT)
- Ground Penetrating Radar (GPR)

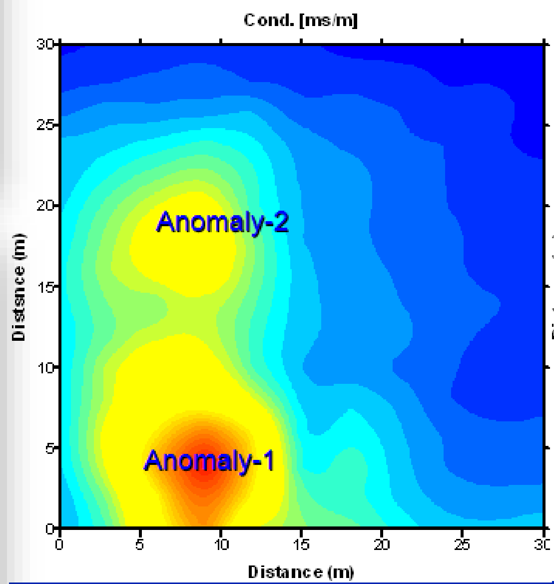
EM Method

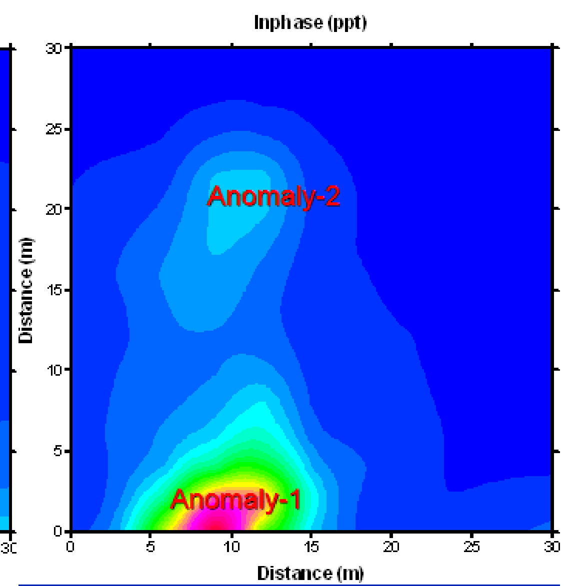


		
CMD-4	CMD-1	CMD-Tiny

Shiao Lin Village

- Shaio Lin Village, Taiwan, drastic changes after typhoon Morakot





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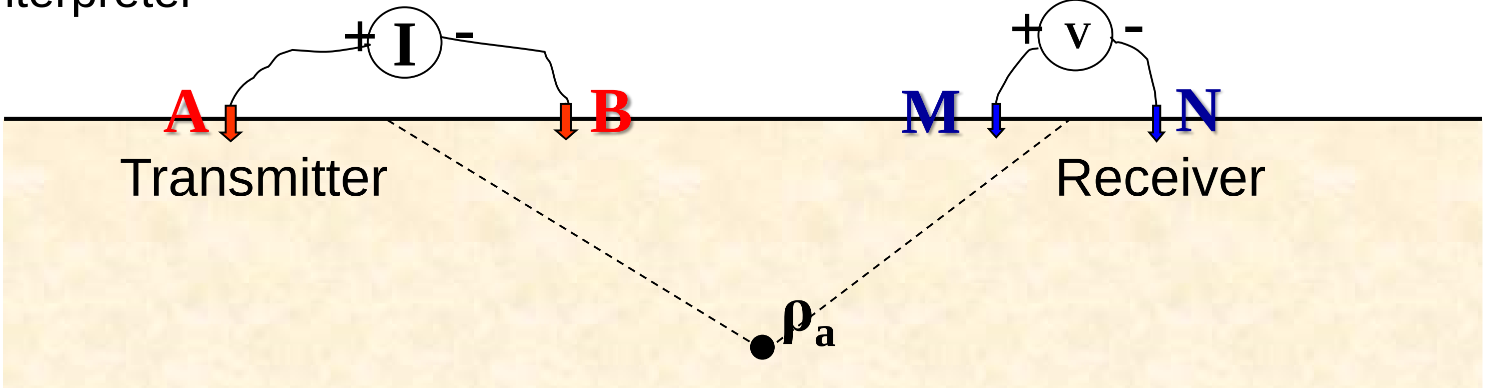
Method

- Electro-Magnetic Method (EM)
- **Resistivity Image Profiling (RIP)**
- **Electrical Resistivity Imaging / Tomography (ERI / ERT)**
- Ground Penetrating Radar (GPR)

Resistivity Method

- For **each measurement**, a DC electric current is injected into the ground through two electrodes (A and B)
- The resulting electric potential is measured between another two electrodes (M and N)
- An apparent resistivity value (ρa) is derived from injected current, measured voltage and geometric factor
- Measured data are inverted to produce true subsurface resistivity distribution
- Resistivity distribution is correlated to subsurface geology by a data interpreter



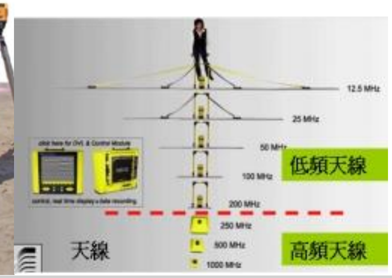
Method

- Electro-Magnetic Method (EM)
- Resistivity Image Profiling (RIP)
- Electrical Resistivity Imaging / Tomography (ERI / ERT)
- **Ground Penetrating Radar (GPR)**

Ground Penetrating Radar

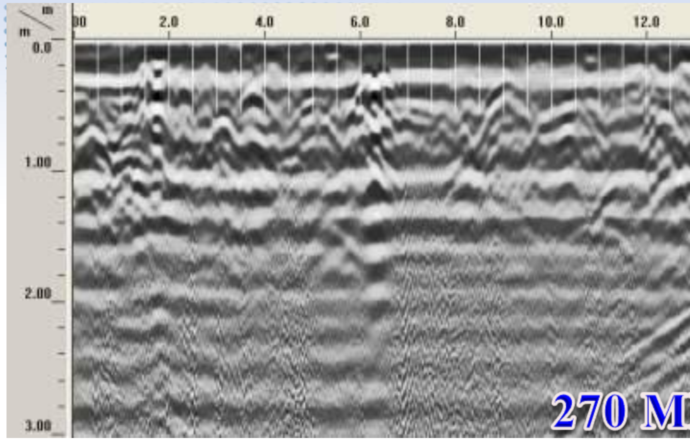
- **Antenna Frequency (12.5、25、50、100、200、270、400、450、900、1,200、1,600 MHz)**

GSSI System

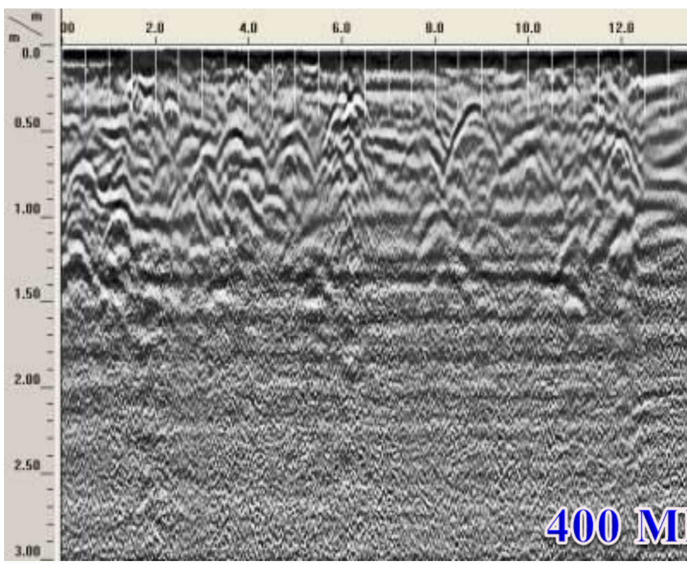


Sensor & Software

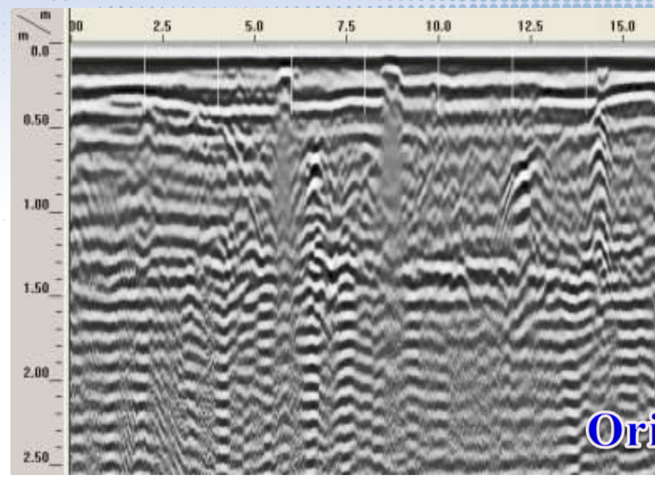
Frequency Problem



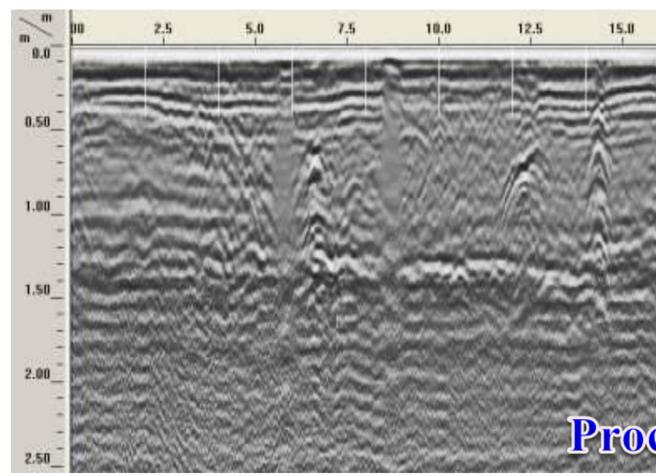
270 MHZ



400 MHZ



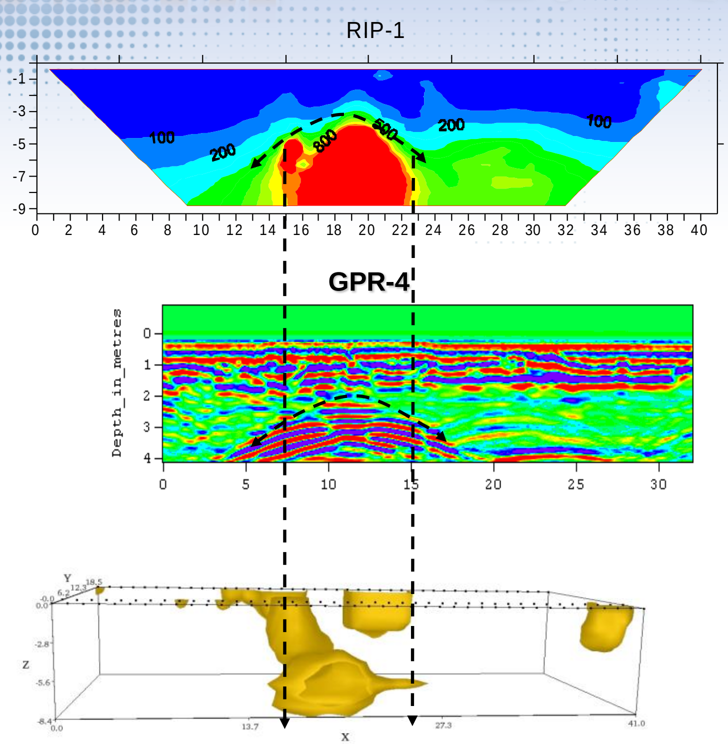
Original

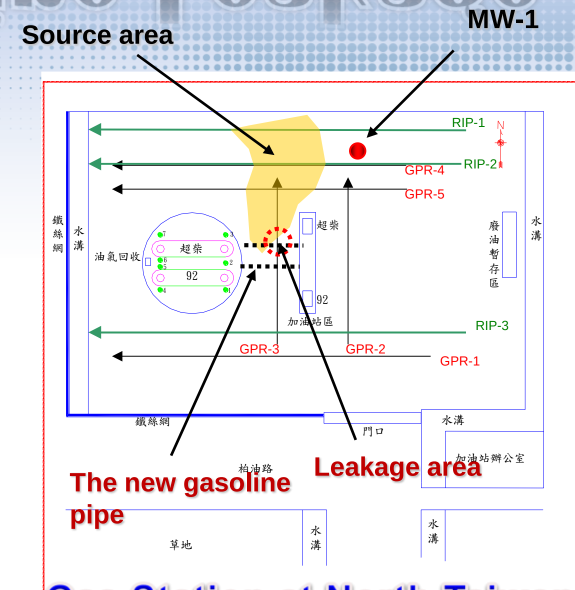


Process

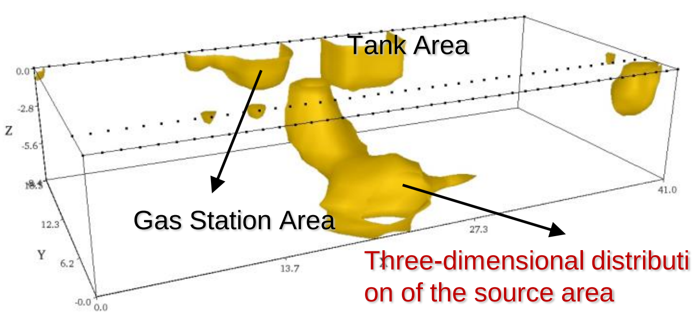
LNAPL – Pipeline Leakage

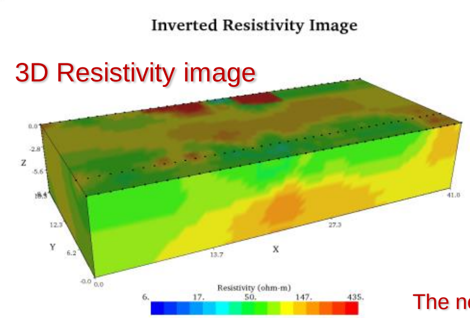
- Combine the GPR & ERT methods to detect the gas leakage areas

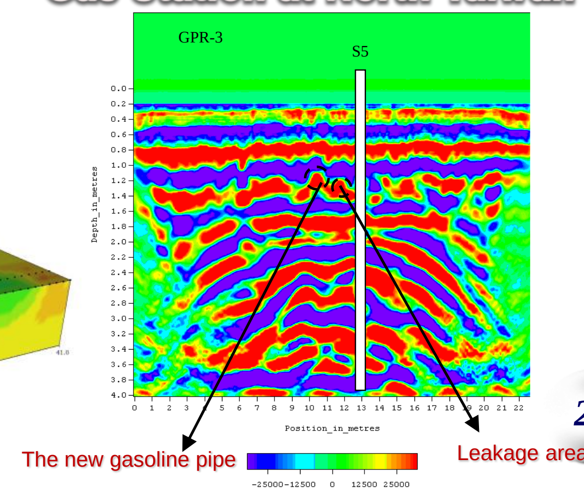




Gas Station at North Taiwan



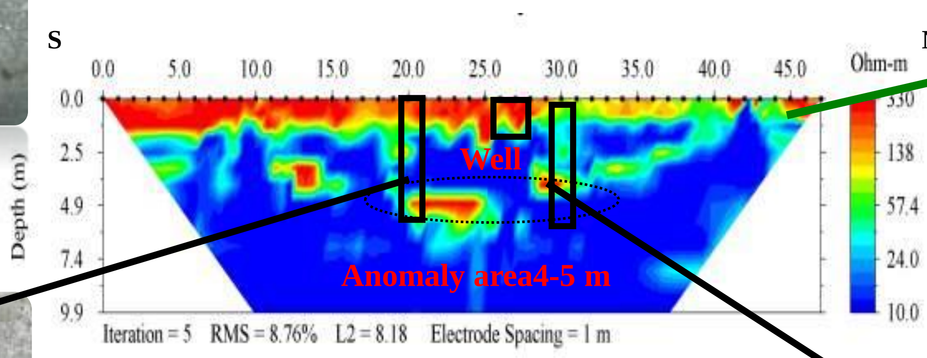




LNAPL - Contaminated Sites

- Field samplings can be visually confirmed 20m and 30m were found the contaminations
- Contaminated depth about 2.0~4.8 m: depth range 4.0~4.8 m contaminated obviously，the clay layer below the 5 m without contaminations

1.5~3.4 m clay or silt (slightly)



Wenner-Schlumberger Array

EWH3 Sample (mg/Kg)

5.8-6.0m
Naphthalene ：**2250**
TPH(C6-C9)：127
TPH(C10-C40)：8,810

EWH3 MW (mg/L)

Benzene ：**5.34**
Naphthalene ：**39.4**

3.4~4.8 m silt_sand (Obviously)

4.0~4.8 m silt_sand (Obviously)

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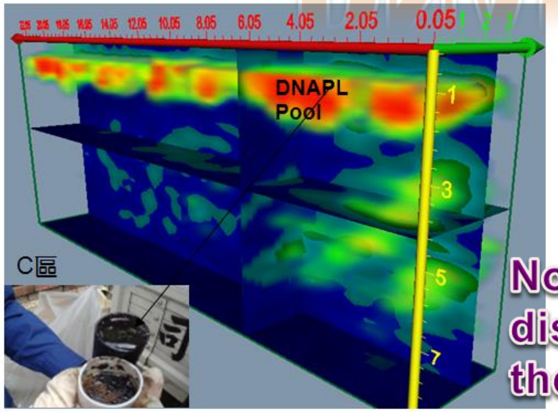
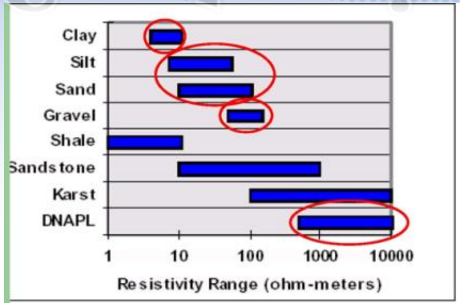
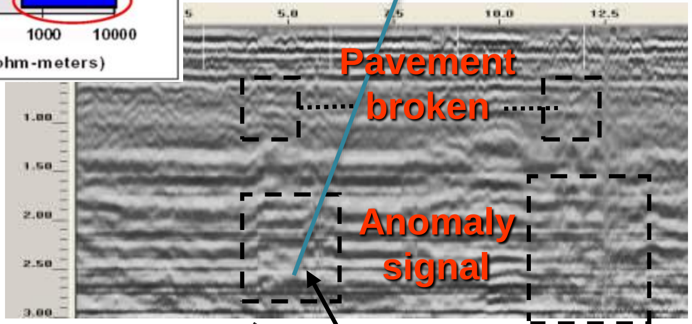
DNAPL - Contaminated Sites



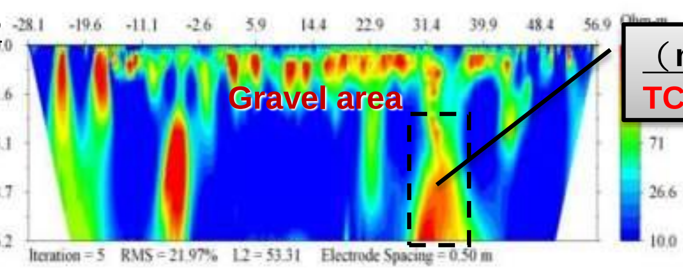
Not easy to distinguish the signal



(mg/L)
TCE：5.12

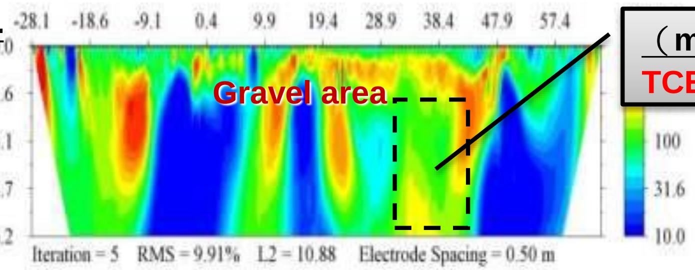


L03

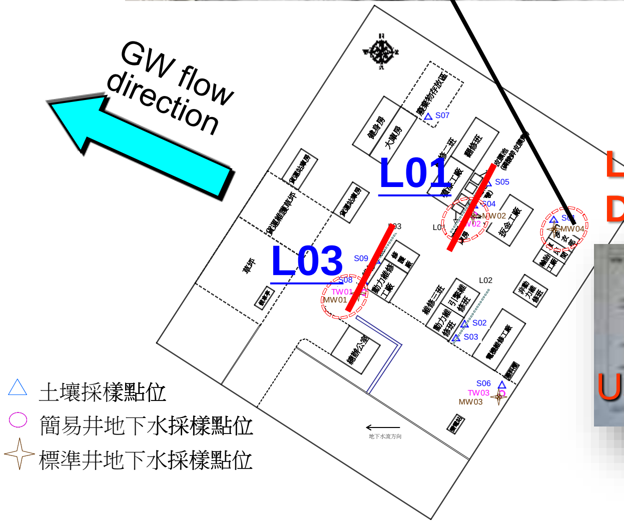


(mg/L)
TCE：0.213

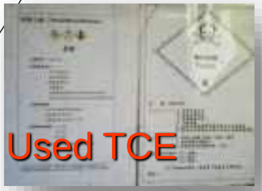
L01



(mg/L)
TCE：0.18



Laundry Department



Combine the OhmMapper & GPR method detect the Dnapl Site

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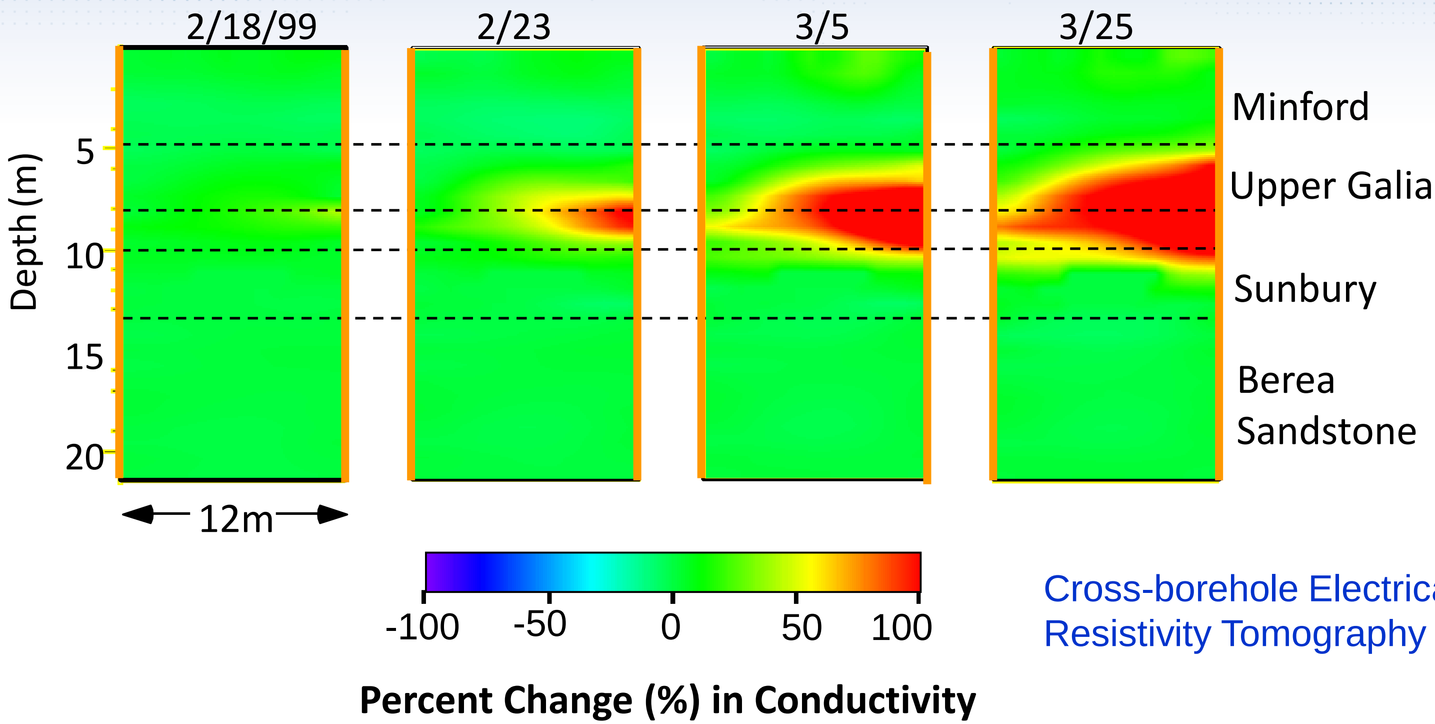
Case Study

Monitoring of Steam Injection

- Rising temperature caused soil electrical conductivity to increase



Cross-borehole Electrical Resistivity Tomography (ERT)

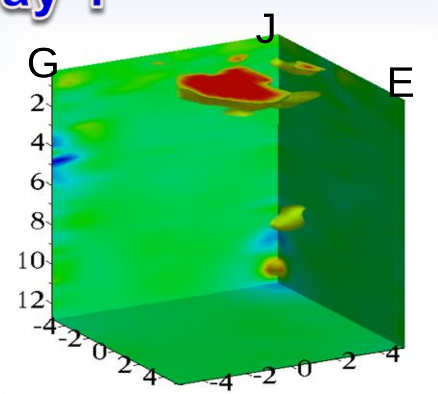
Steam enhanced remediation at Portsmouth Gaseous Diffusion Plant was funded by US DOE and conducted by SteamTech Environmental Services under subcontract to Bechtel Jacobs Co LLC.

LaBrecque, D.J., and Yang, X., 2001, Difference Inversion of ERT Data: a Fast Inversion Method for 3-D in Situ Monitoring, Journal of Environmental and Engineering Geophysics (JEEG), Vol 6, Issue 2, pp. 83-89.

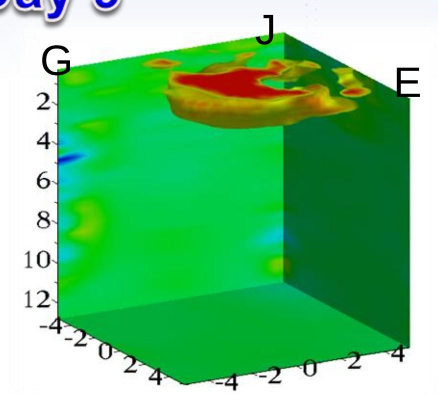
Water Infiltration Monitoring

❖ **Tracking wetting fronts which show increasing electrical conductivity values**

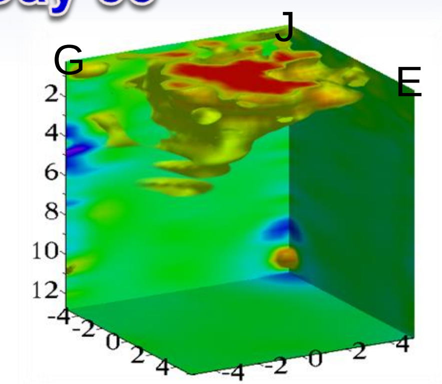
Day 1



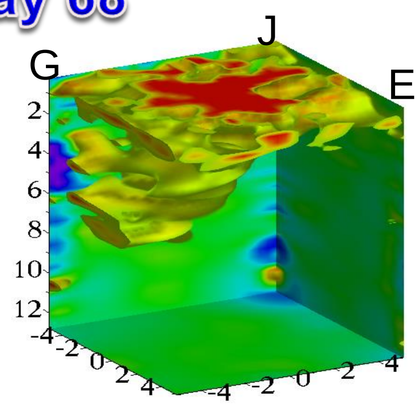
Day 9



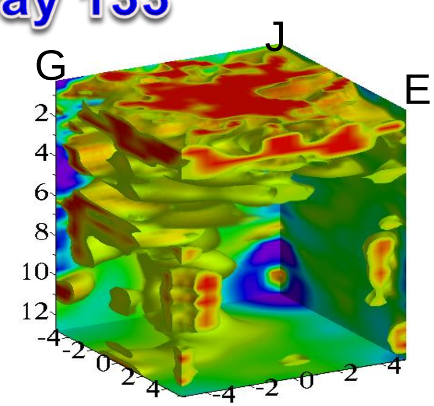
Day 33



Day 68



Day 133



-80 -40 0 40 80

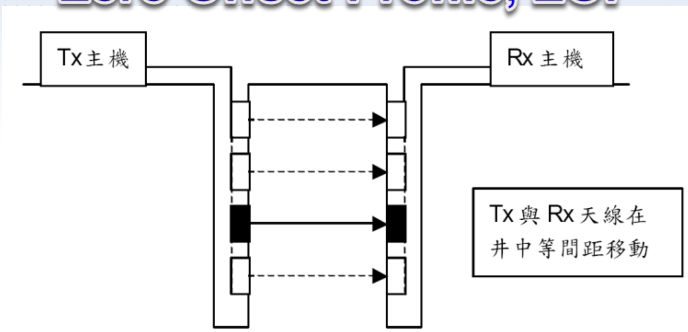
Percent Difference of Conductivity,

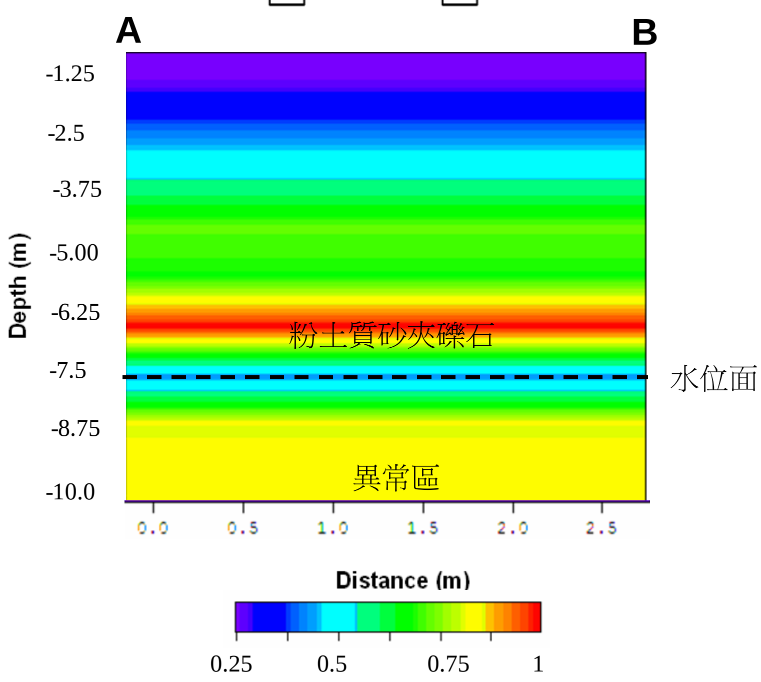
Infiltration started on 3/11/1999 (Day 0)

Xianjin Yang, 1999, Stochastic Inversion of 3D ERT Data, PhD thesis, the University of Arizona

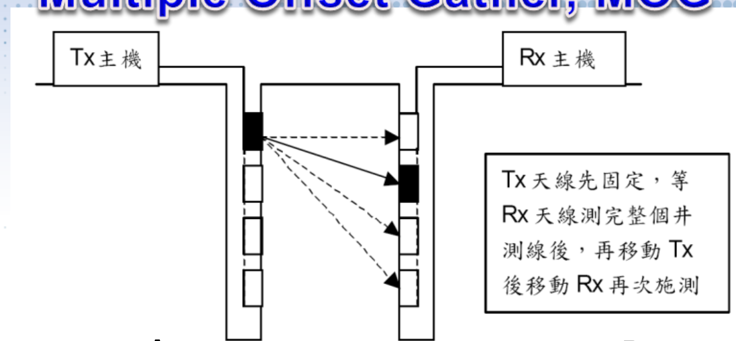
Borehole GPR

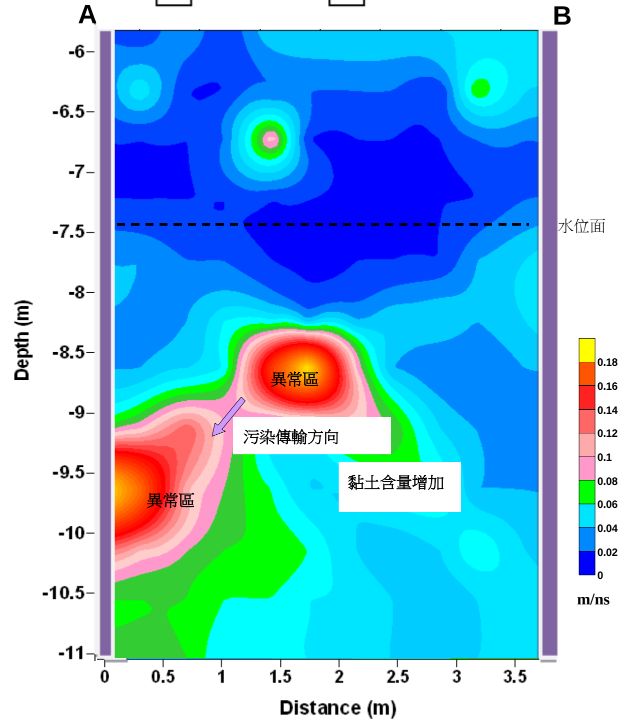
Zero Offset Profile, ZOP





Multiple Offset Gather, MOG





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Conclusion

Conclusion

- Environmental geophysics survey has the advantages of survey rapidly, high resolution result and less affected by the surface topography and objects
- It is suitable to either a wide range of general survey or a small-scale precise survey
- The methods of EM, ERT and GR etc. can be applied to unknown waste and nap plume
- The effective survey technical depends on the features of the suite. In addition, a successful interpretation can be obtained with some aids of log data



Thank you for your attention

APOLLO TECH Apollo Technology Co., Ltd.

15F-1, 421, Songshan Road, Xinyi District,
Taipei City 11083, Taiwan, R.O.C.

Tel: +886-2-2726-2099 Fax:+886-2-2726-2037

E-mail: apollo@apollotech.com.tw

Website: www.apollotech.com.tw