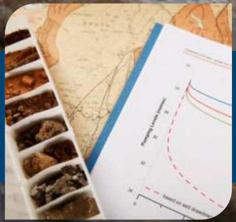
Recent developments in Groundwater technology and best practices.

Dr Jürgen Schaeffer
General Manager, AGT

11th ASIA-PACIFIC MINERAL RESOURCE EXHIBITION & CONFERENCE 2016 -Kuala Lumpur, Malaysia



Australian Groundwater Technologies AGT

Social, Cultural and Financial Future Lies with Best WATER MANAGERS

"making water work"

Recent developments in Groundwater technology and best practices

- Regional Investigations and Data Collection
- Drilling Practices
- Pumping Systems
- Water Resource Management

“making water work”

Australian Groundwater Technologies AGT

Social, Cultural and Financial Future Lies with Best WATER MANAGERS

Regional Investigations & Data Collection

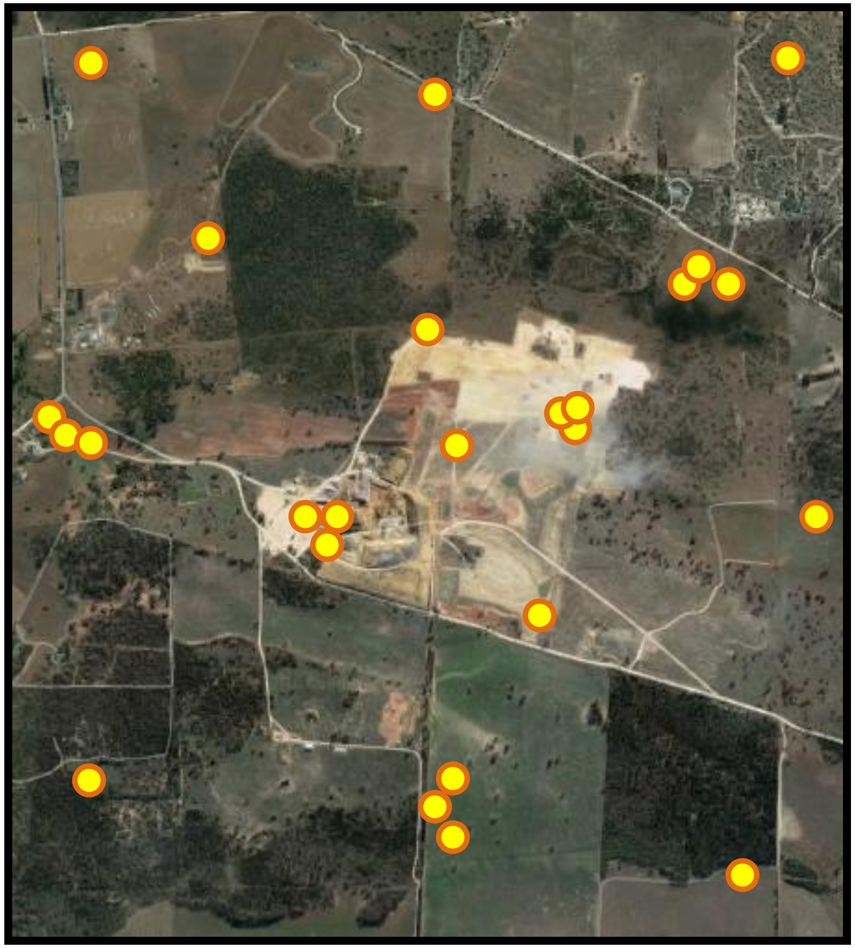
- Collect hydrogeological data in early stages
  - Groundwater data
  - Geotechnical information
  - Relevant Base Environmental Data
- Early indication of engineering design, environmental compliance and ease of development
- Incremental cost to exploration program **BUT**
  - Significantly reduces future environmental and feasibility study investigations
    - Early identification of issues
- Reduces time related to project approval

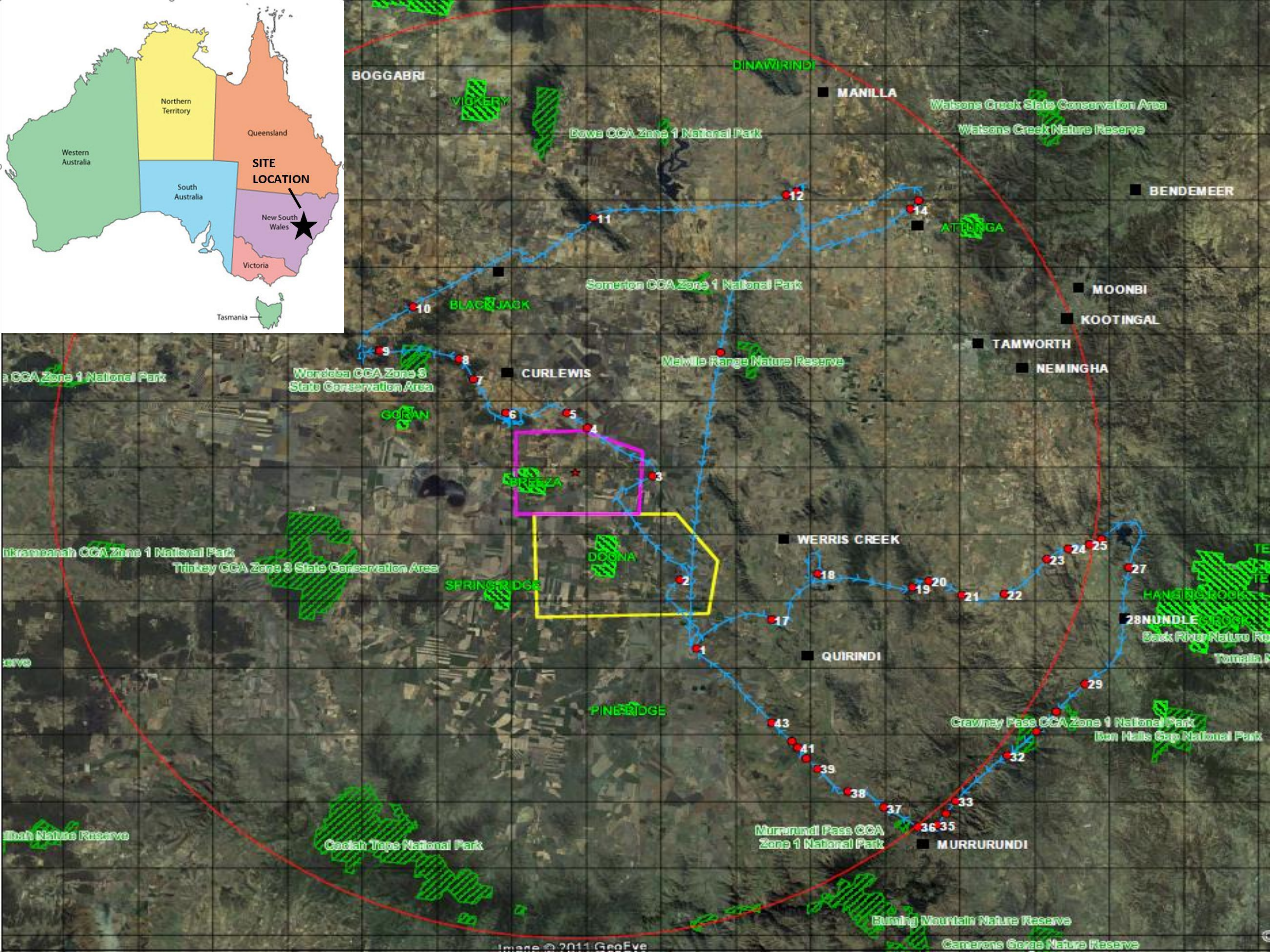


Data Collection Planning/Efficiency

15 holes

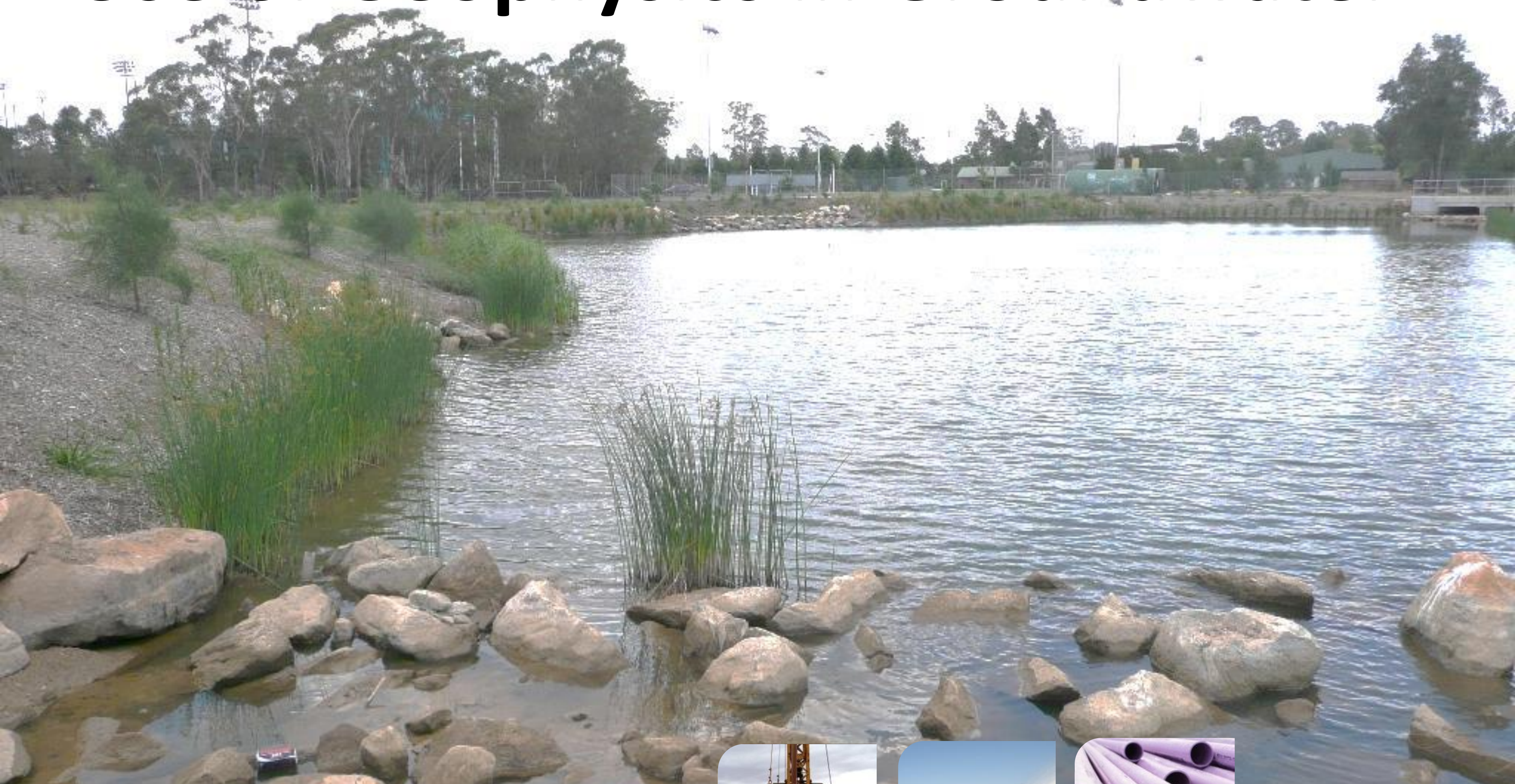
25 holes





Western Australia
Northern Territory
Queensland
South Australia
New South Wales
Victoria
Tasmania
SITE LOCATION
BOGGABRI
MANILLA
BENDEMEER
MOONBI
KOOTINGAL
TAMWORTH
NEMINGHA
CURLEWIS
WERRIS CREEK
QUIRINDI
NUNDLE
MURRURUNDI
DINAWIRINDI
VICKERY
Dowe CCA Zone 1 National Park
Watsons Creek State Conservation Area
Watsons Creek Nature Reserve
ATTUNGA
Somerton CCA Zone 1 National Park
BLACK JACK
Melville Range Nature Reserve
Wondoba CCA Zone 3 State Conservation Area
GORAN
BREEZA
DOONA
SPRING RIDGE
Trinkey CCA Zone 3 State Conservation Area
PINE RIDGE
Crawney Pass CCA Zone 1 National Park
Ben Halls Gap National Park
Murrurundi Pass CCA Zone 1 National Park
Coolah Tops National Park
Burning Mountain Nature Reserve
Cameron Gorge Nature Reserve
Image © 2011 GeoEye

Use of Geophysics in Groundwater



"making water work"

Social, Cultural and Financial Future Lies with Best WATER MANAGERS

Applications

- Mapping geologic landforms
- Determining regional geologic structures
- Mapping unconsolidated rocks and soils
- Mapping and classifying certain rock types
- Investigating depth to groundwater
- Mapping groundwater contamination and quality



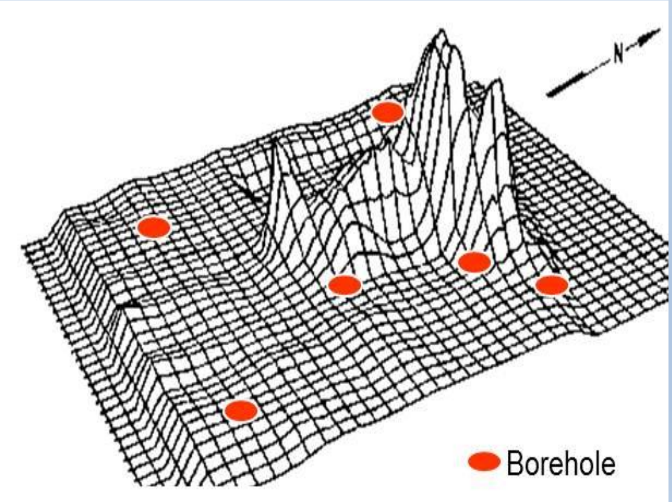
Why Use Technology

- Cost effective compared to traditional SI methods. Costs vary depending on survey type and design

• Airborne Surveys	$500/km	$0.5/m	Least Costly
• Ground Surveys	$5,000/km	$5/m	↓
• Seismic	$15,000/km	$15/m	
• Drilling	$250,000/km	$250/m	Most Costly

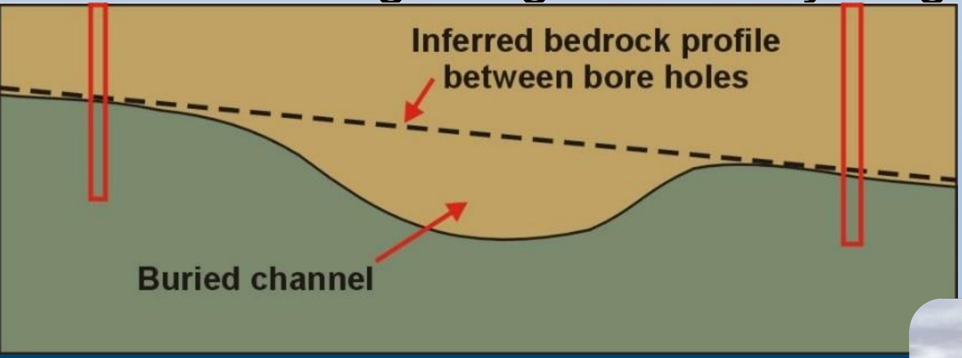
These costs are based on experience in Australia and do not include mobilisation costs and are very dependent upon depth of investigation and survey parameters

- Rapid and total coverage of large areas
  - Satellite and airborne systems allow large areas to be quickly surveyed and imaged
  - Can identify regional geological features that are critical in groundwater systems
  - If rely on boreholes only may not fully understand geologic setting and therefore miss the aquifers



Why Use Technology

- Overcomes interpolation errors
- Compliments traditional site investigation methods
- Overcome many site access issues (e.g. jungle, rivers, lakes)
- Low environmental impact – generally non-invasive and non-destructive
  - Interpretation of geophysics best done in conjunction with other geological and hydrogeological data

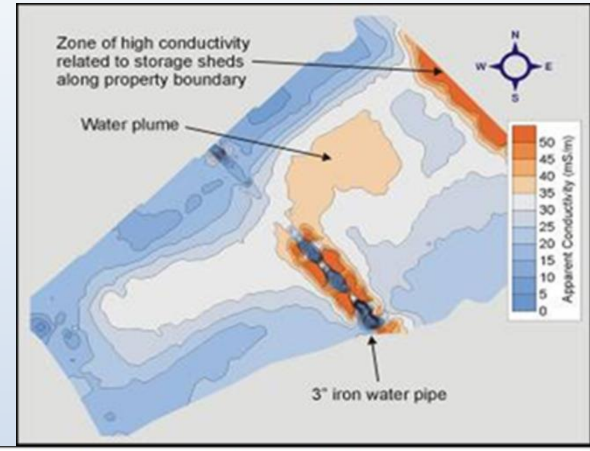


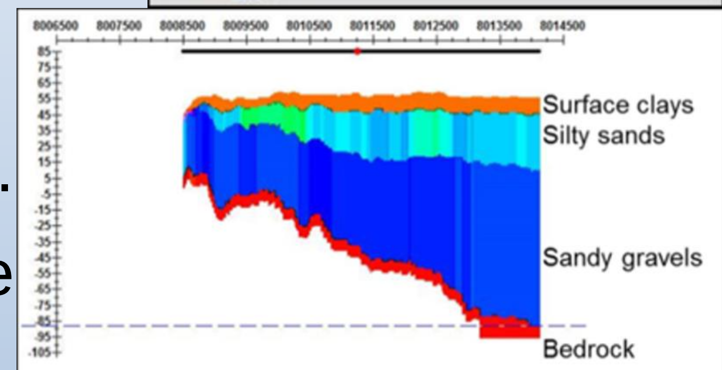


Regional Groundwater Investigations

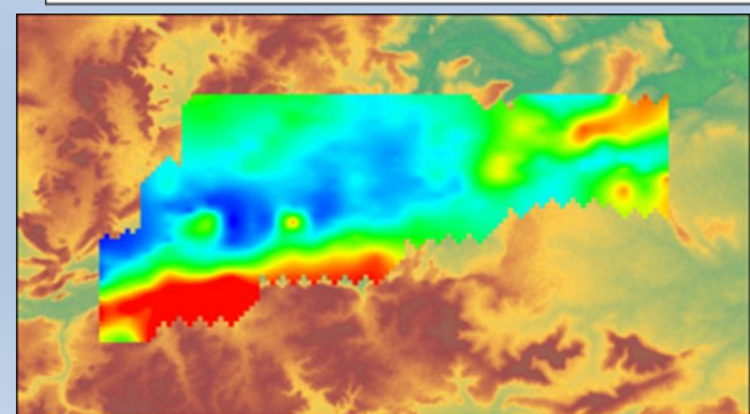
Airborne –<u>Electromagnetics</u>

- Most widely used
- Effective for mapping and identifying
  - Different geological units
  - Faults and fracture zones
  - Water quality and contamination
- Measures conductivity of the Ground.
- Airborne provides rapid site coverage and least cost/km





Example Airborne EM Inversion Section

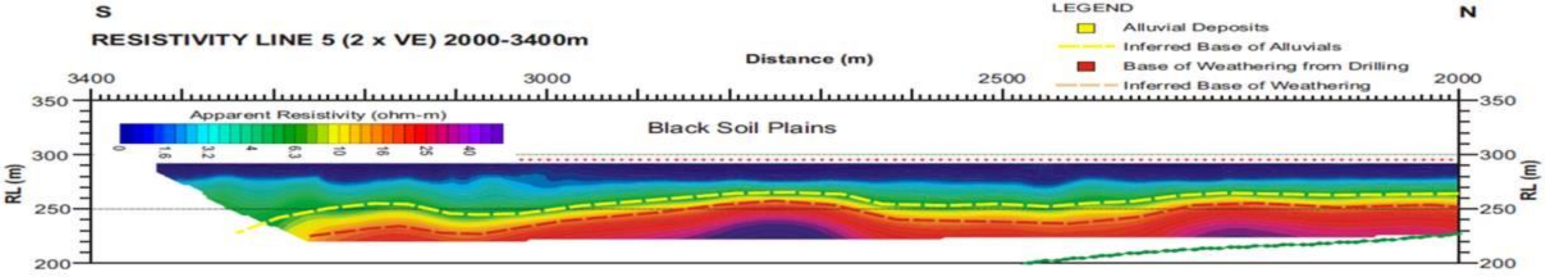

Conductivity draped over DTM


Local Groundwater Investigations

Landbased – Electrical resistivity

– Widely used for groundwater investigation.

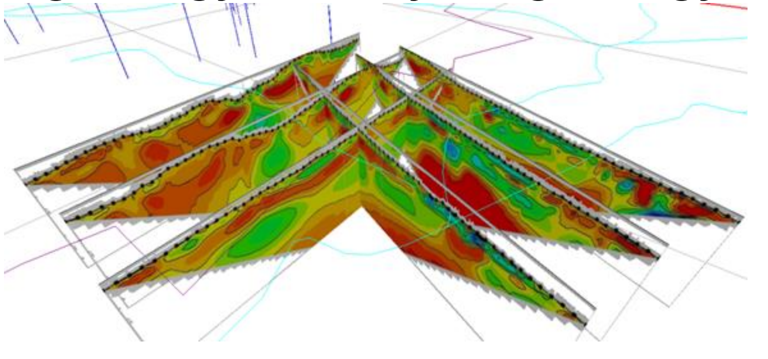
– Provides high resolution images of the subsurface that can be used to target drilling locations



Groundwater Imaging

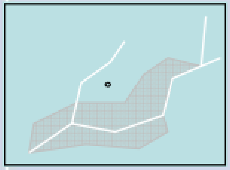
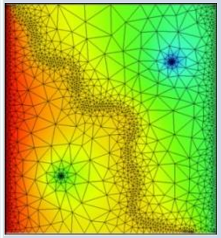
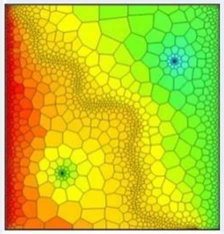
– 3D Soil Moisture and Groundwater Mapping

– Visualization of variation in subsurface geology and hydrogeology.

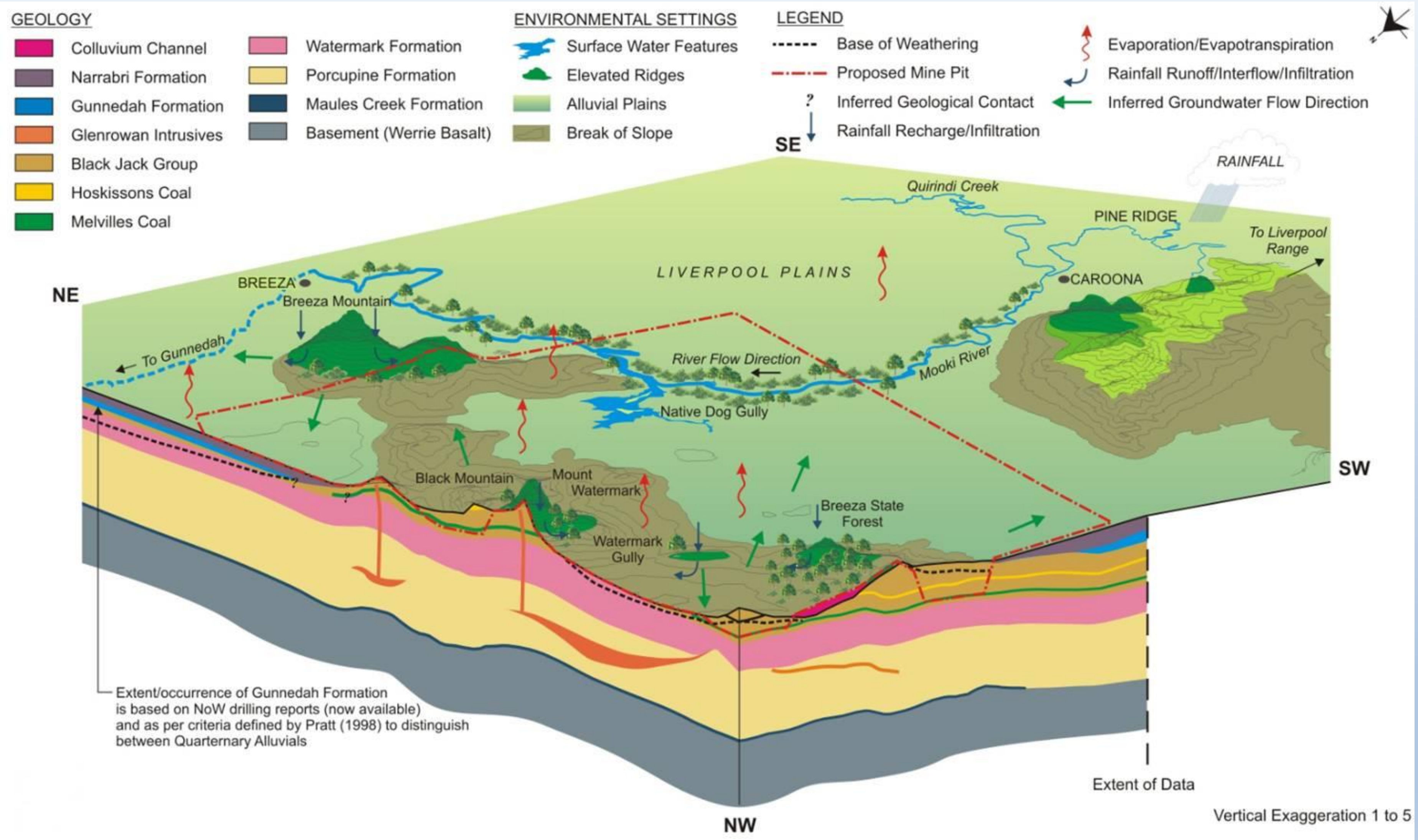


GROUNDWATER MODELLING

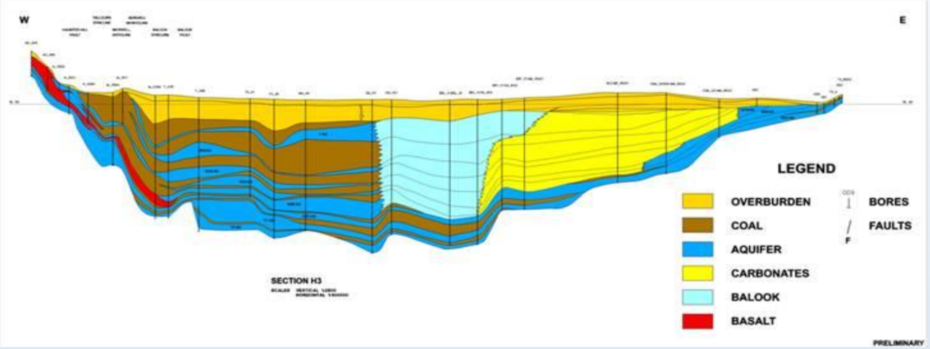
Groundwater Modelling Methods Summary

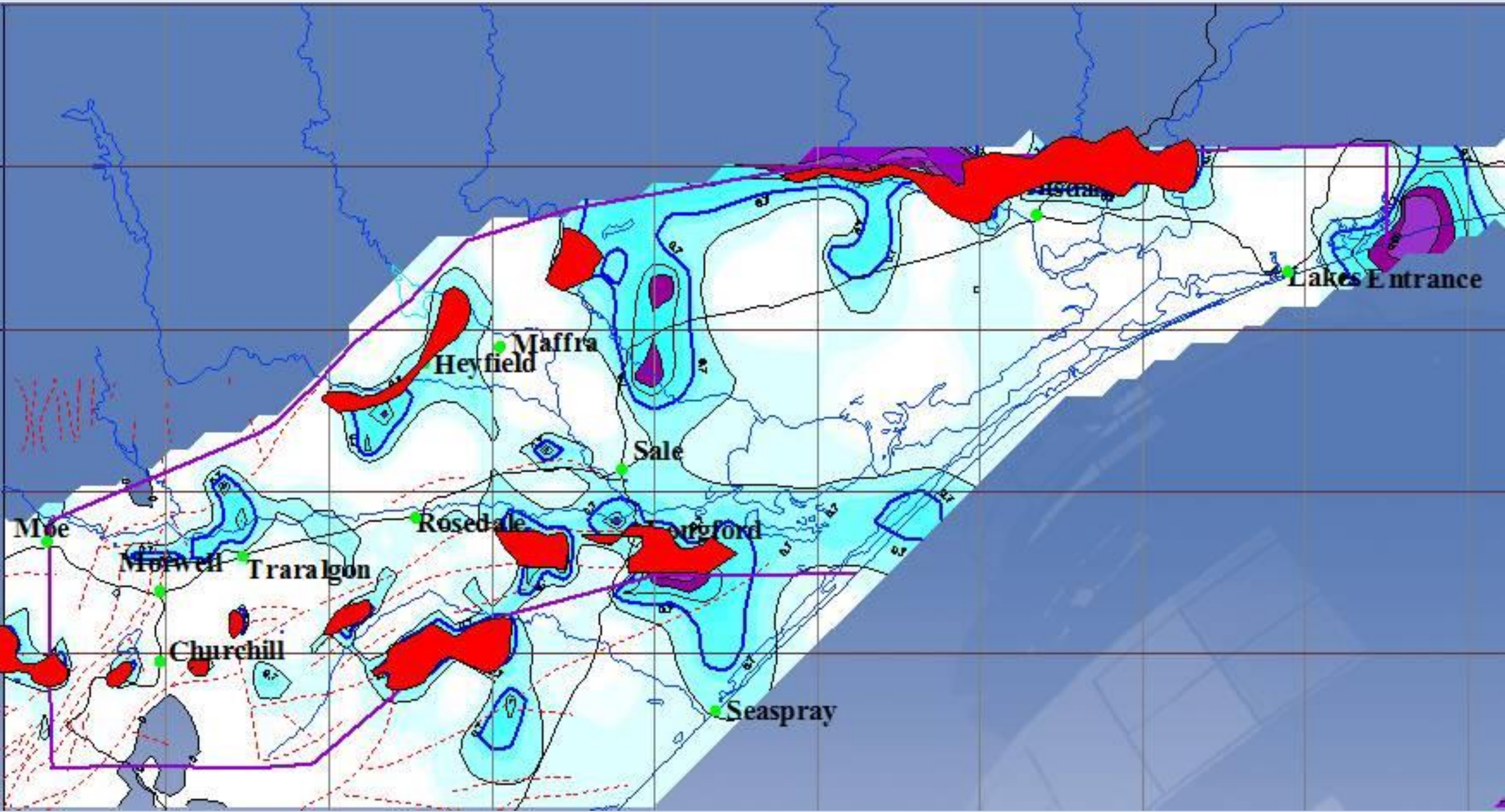
Method	Grid Type	Advantages	Disadvantages	Common Applications	Key Available Codes	
Analytic element	Grid-independent	Simple and easy to use; minimal computational cost	Limited complexity	Quick analyses, screening models, regional 2-D steady-state modelling	GFLOW	
Finite difference	Structured, rectangular grid	Relatively simple mathematics; structured, user-friendly input/output	Difficulties representing complex system geometry, inefficient grid refinement (must extend to model domain boundaries), requires continuous model layers	Widely considered current industry standard (MODFLOW) for regional groundwater flow modelling	MODFLOW; MIKE-SHE; MODHMS; HYDRUS-1D	
Finite element	Unstructured, triangular grid	Can represent complex geometry; efficient refinement (e.g., around wells)	Still requires continuous model layers; mass conservation not guaranteed	Highly complex transient, variable-density groundwater flow and solute transport modelling	FEFLOW	
Finite volume	Unstructured grid (any geometry)	Allows discontinuous layers; efficient refinement	Less commonly used at present: potential learning curve and compatibility issues	Few at present: potential to replace finite-difference as standard if widely adopted by modelling community	MODFLOW-USG; HydroGeoSphere	

Geological Conceptualisation

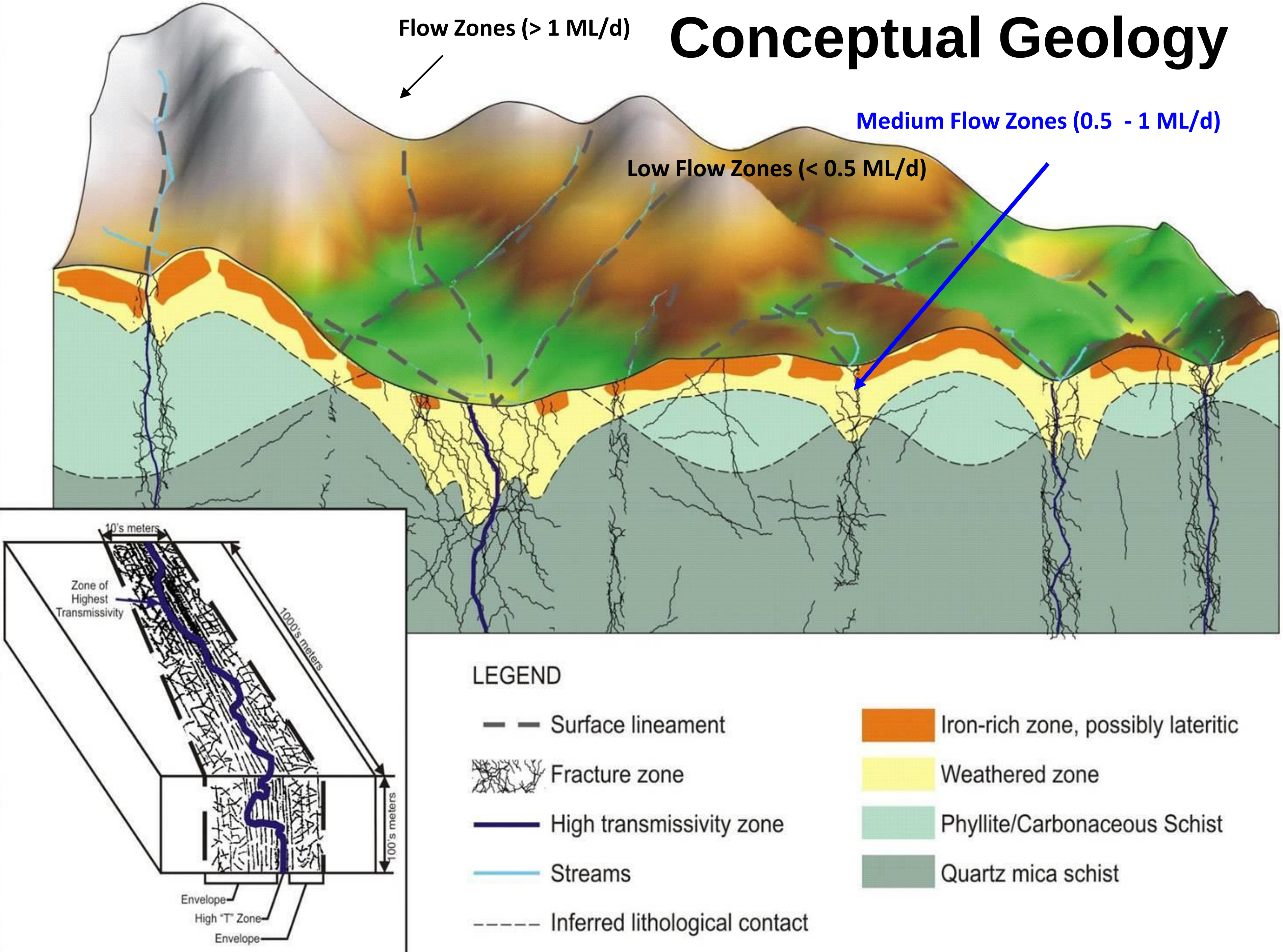


Conceptualisation





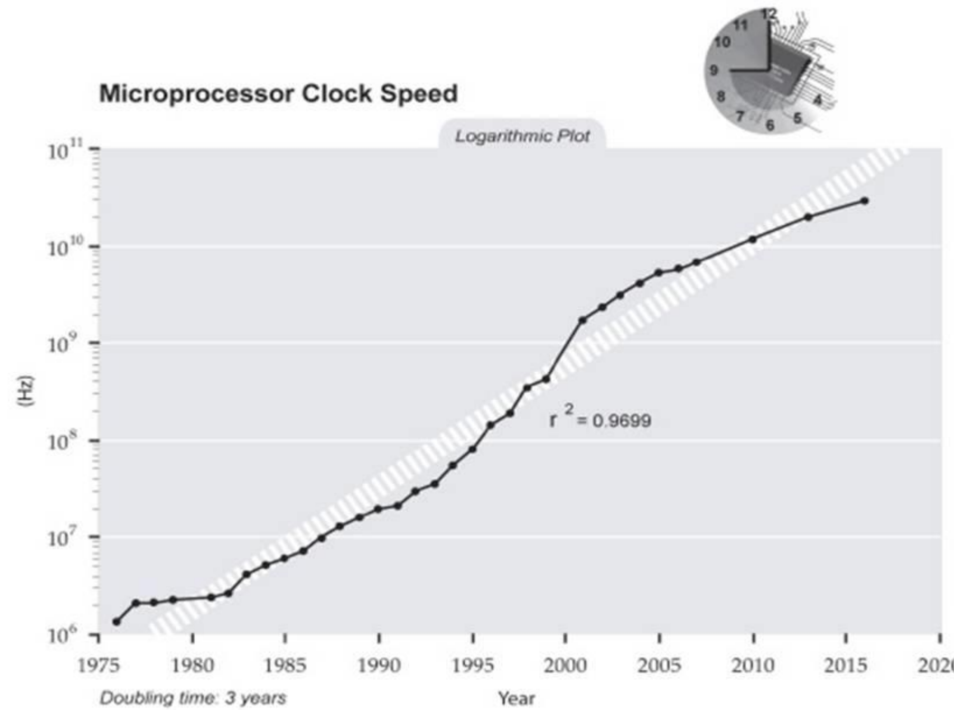
Conceptual Geology



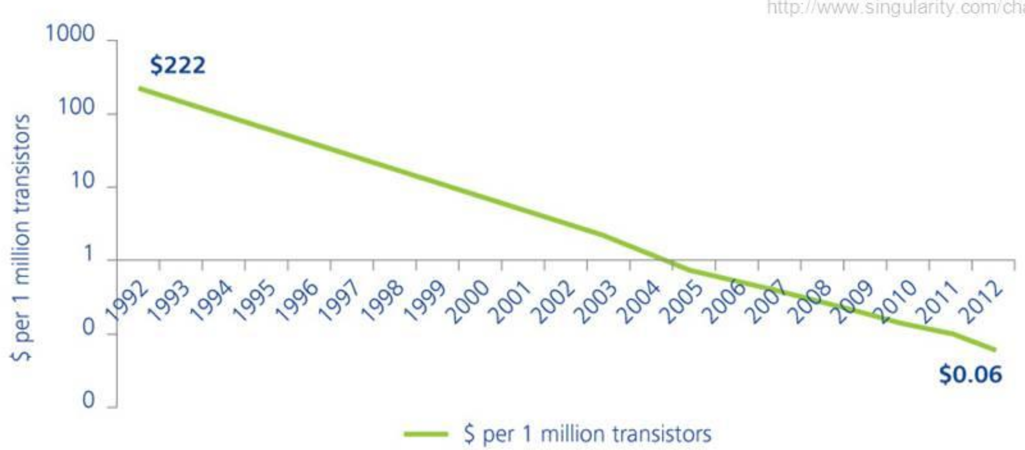
Computing Capability

Computer processors:

- ***>10,000** times faster in 2015 compared with 1975*
- ***>1,000** times cheaper in 2012 compared with 1992*



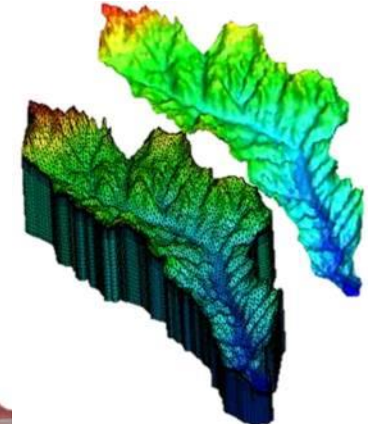
http://www.singularity.com/charts/page61.html

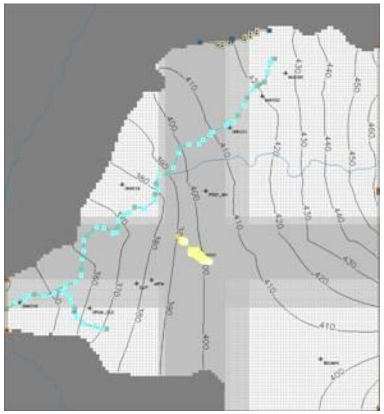


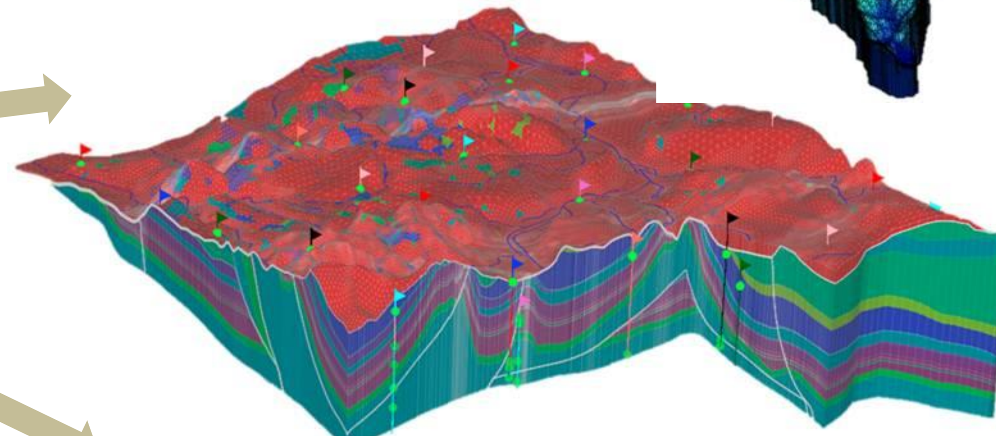
Graphic: Deloitte University Press | DUPress.com

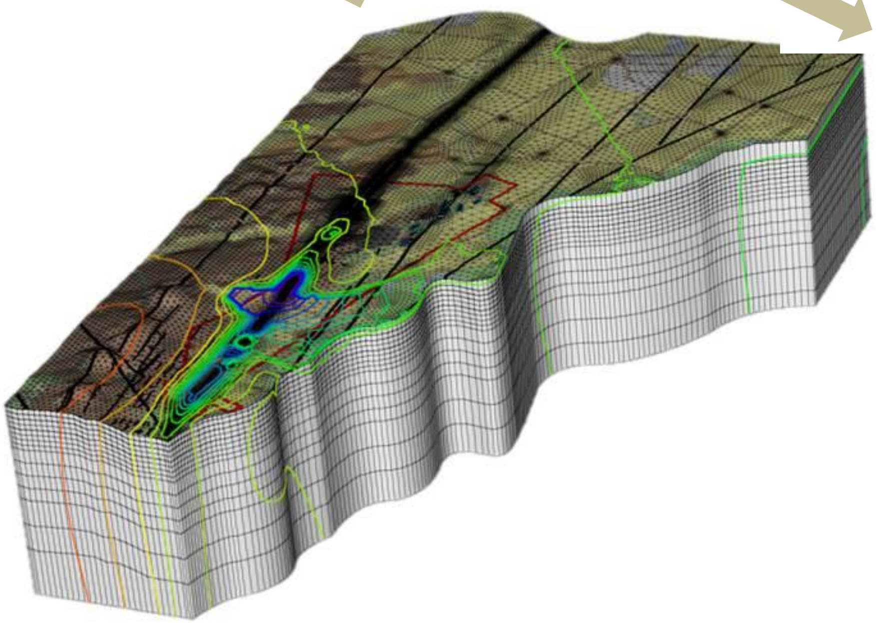
Source: Leading technology research vendor

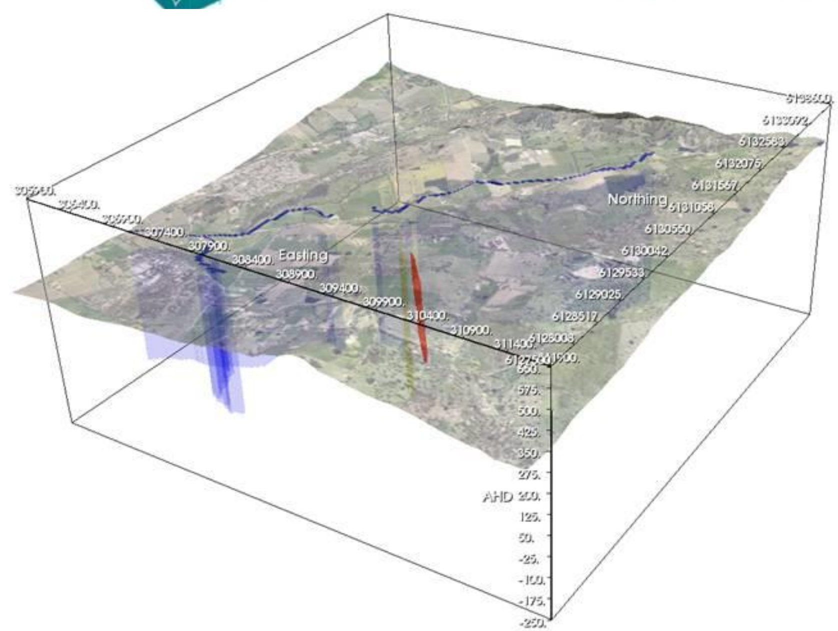
Improved Visualization Tools



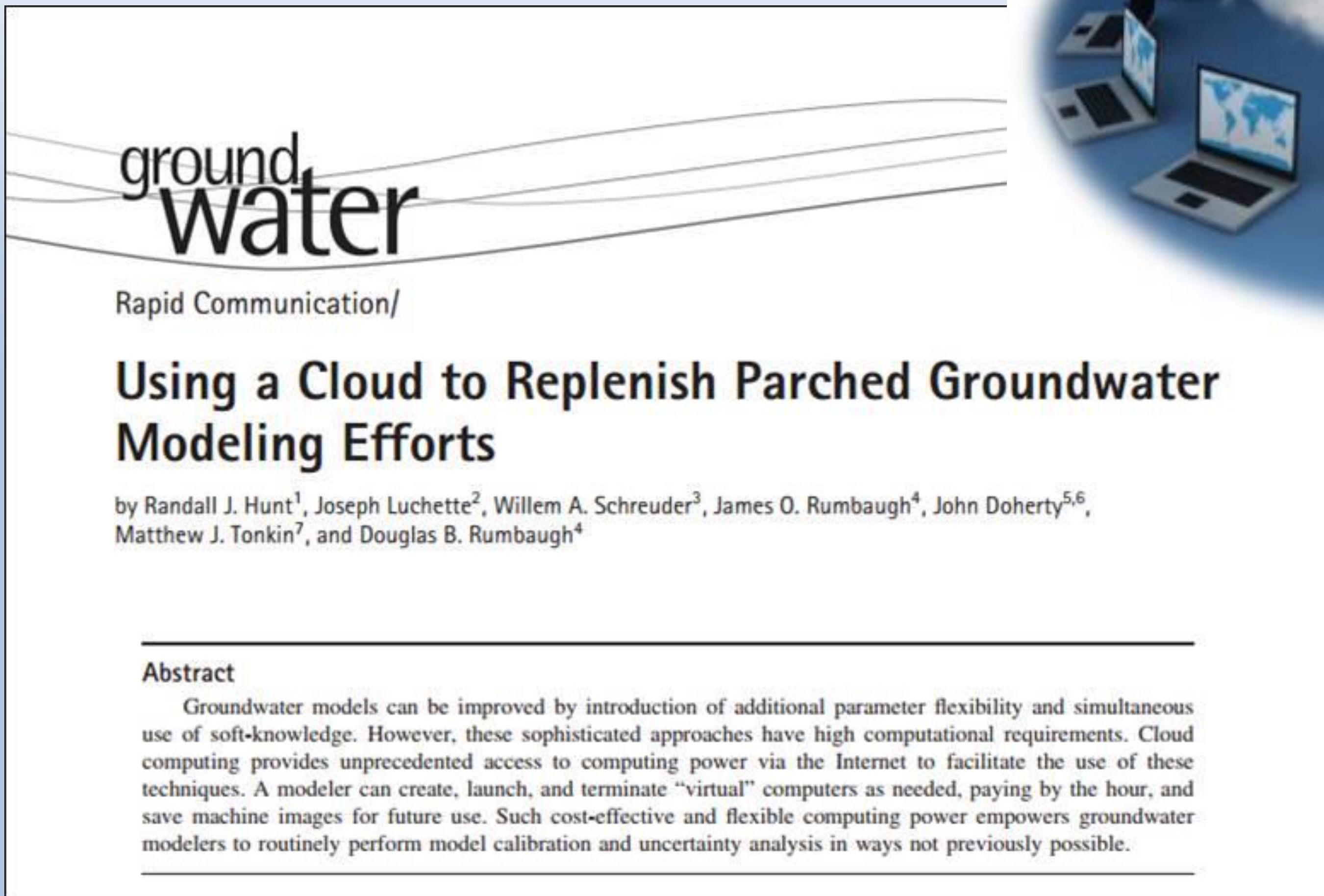








The Cloud


groundwater

Rapid Communication/

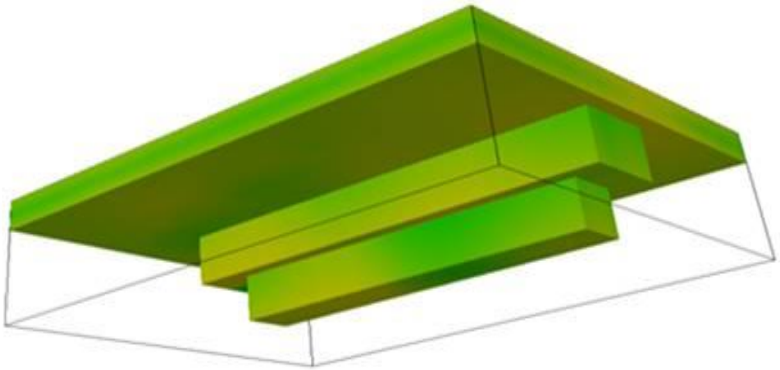
Using a Cloud to Replenish Parched Groundwater Modeling Efforts

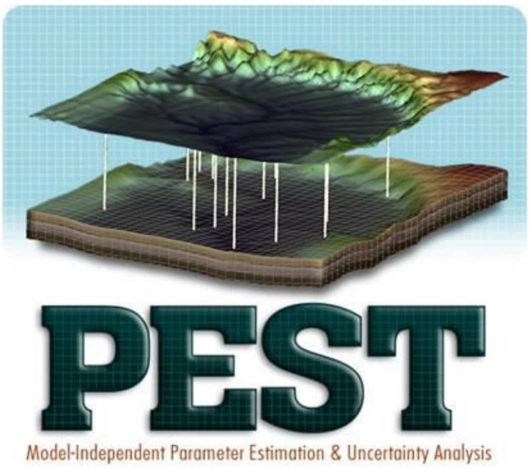
by Randall J. Hunt[1], Joseph Luchette[2], Willem A. Schreuder[3], James O. Rumbaugh[4], John Doherty[5,6], Matthew J. Tonkin[7], and Douglas B. Rumbaugh[4]

Abstract

Groundwater models can be improved by introduction of additional parameter flexibility and simultaneous use of soft-knowledge. However, these sophisticated approaches have high computational requirements. Cloud computing provides unprecedented access to computing power via the Internet to facilitate the use of these techniques. A modeler can create, launch, and terminate "virtual" computers as needed, paying by the hour, and save machine images for future use. Such cost-effective and flexible computing power empowers groundwater modelers to routinely perform model calibration and uncertainty analysis in ways not previously possible.

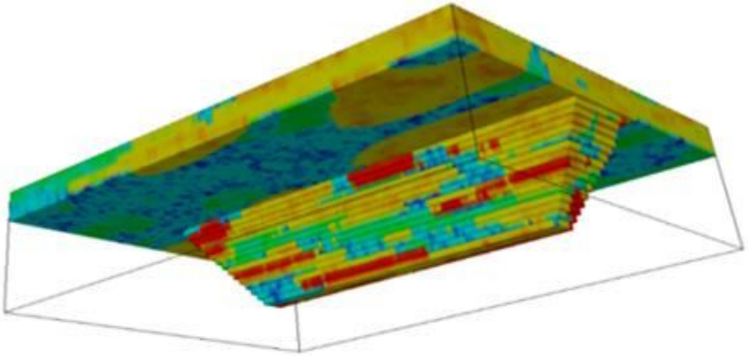
Uncertainty





"Everything should be made as simple as possible, but not simpler"

- Albert Einstein



Drilling Practices

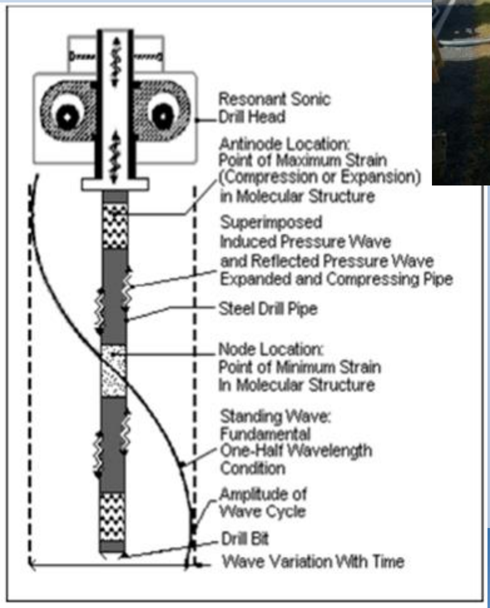
- Sonic
- S Wireline

Sonic Drilling

- Soil penetration technique
- Quality continuous Soil Sampling

Applications

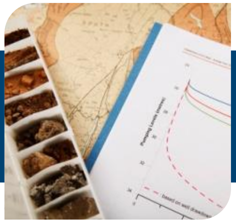
- Environmental / hydrogeological
- Geotechnical/Geo -construction
- Embankment Drilling
- Tunnel Projects
- Earth Retention/Anchor Installation
- Mini/Micro pile Installation
- Pier Installation/Foundation exploration
- Grouting



Advantages

- Continuous core samples
- No refusal.
- Speed and Efficiency.

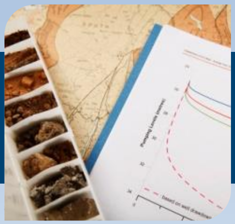
Sonic Drilling



Sonic vs RC Composite Assays

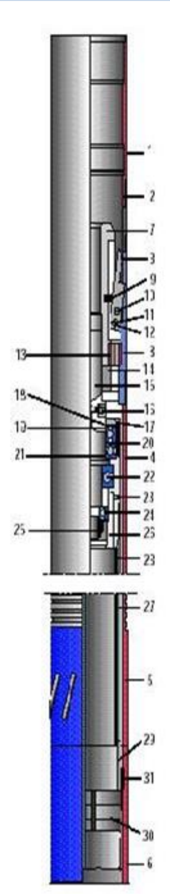
Zone	RC EHM (%)	Sonic EHM (%)	Sonic - RC Diff %
Free-Digging	2.42	2.77	14%
Hard	2.87	3.12	9%
Medium-Grade	6.94	7.73	11%
High-Grade	11.54	17.53	52%
Barren Footwall	5.43	1.77	-67%

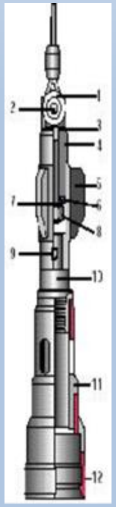
- Sonic grades 9-14% higher in the upper, aeolian units
- Sonic grades 52% higher in high-grade basal unit
- Note the misleading RC grade of the footwall mudstones



“S”-Wireline

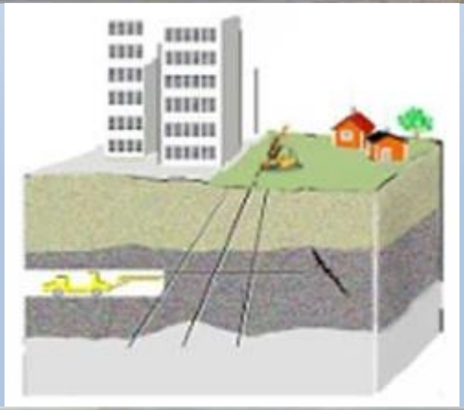
- Improved core recovery drilling method.
- Flexible core barrel system
  - Hole Size 146 mm
  - Core Size 102 mm (4“)
- Triple tube core barrel
- Alternative to 4C coring
- Alternative to Sonic





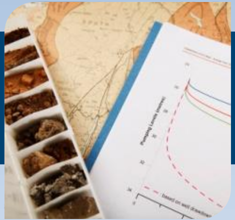
When should you utilise…..

- **For undisturbed core sampling in shallow depth from 0-350m**



Applications:

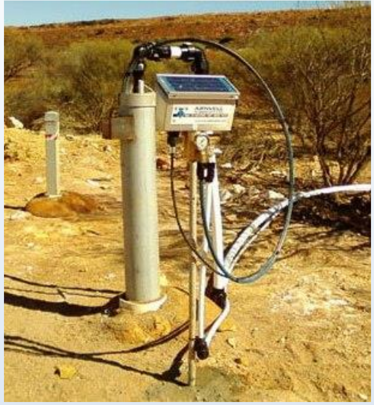
- **Core sampling in difficult formation**
- **Bulk sampling (100mm)**
- **Site Investigations for infrastructure works**
- **Mining and Tunneling**
- **Grouting projects**
- **Environmental and Geotechnical investigations**

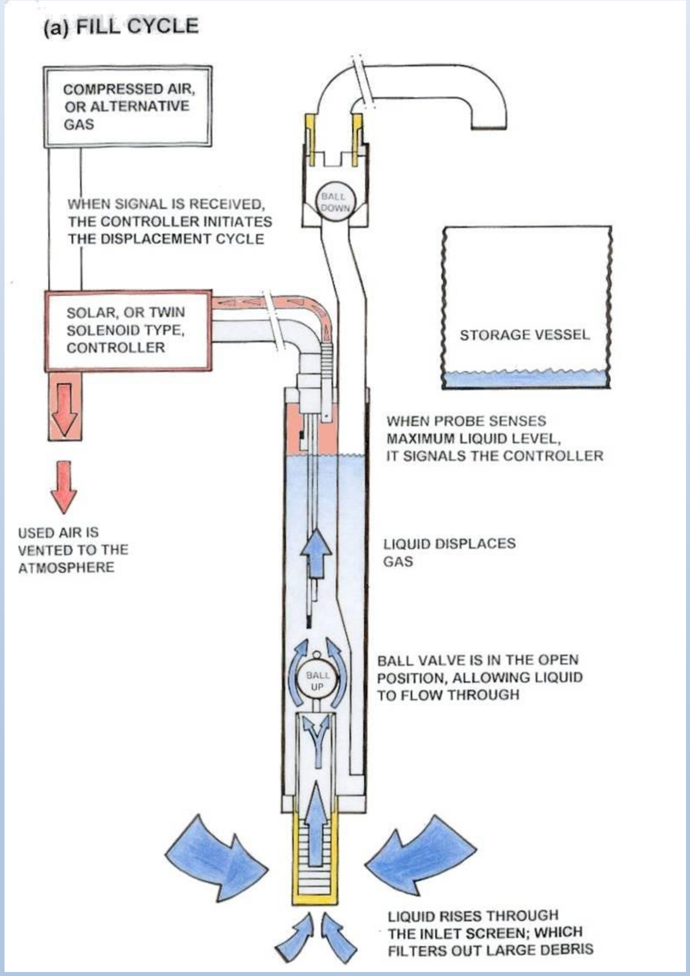


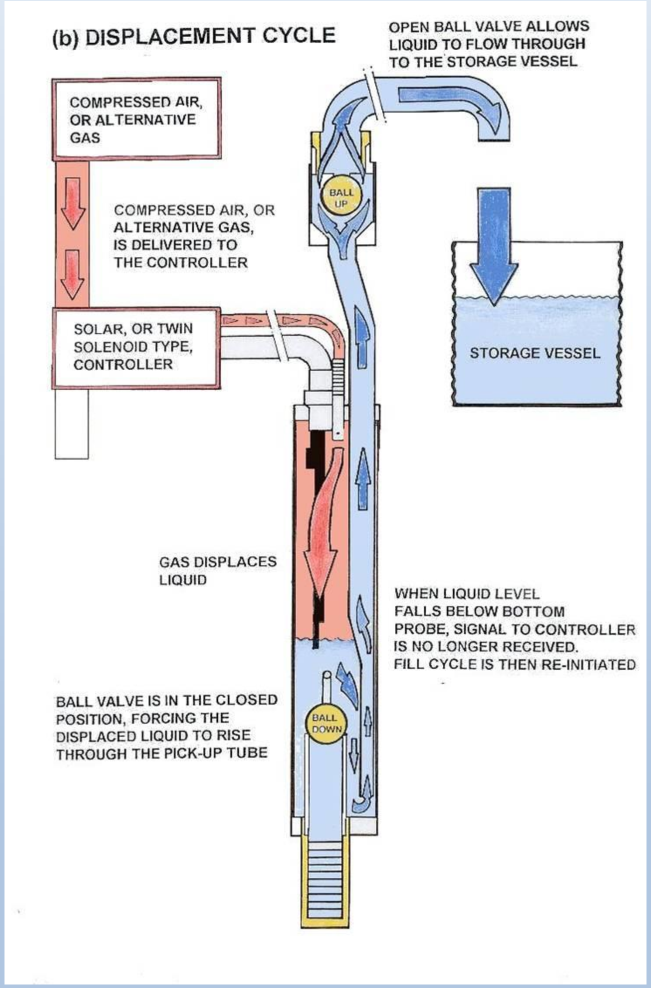
GROUNDWATER PUMPING SYSTEMS

Pumping systems – Airwell Pumps

- Air Displacement Method





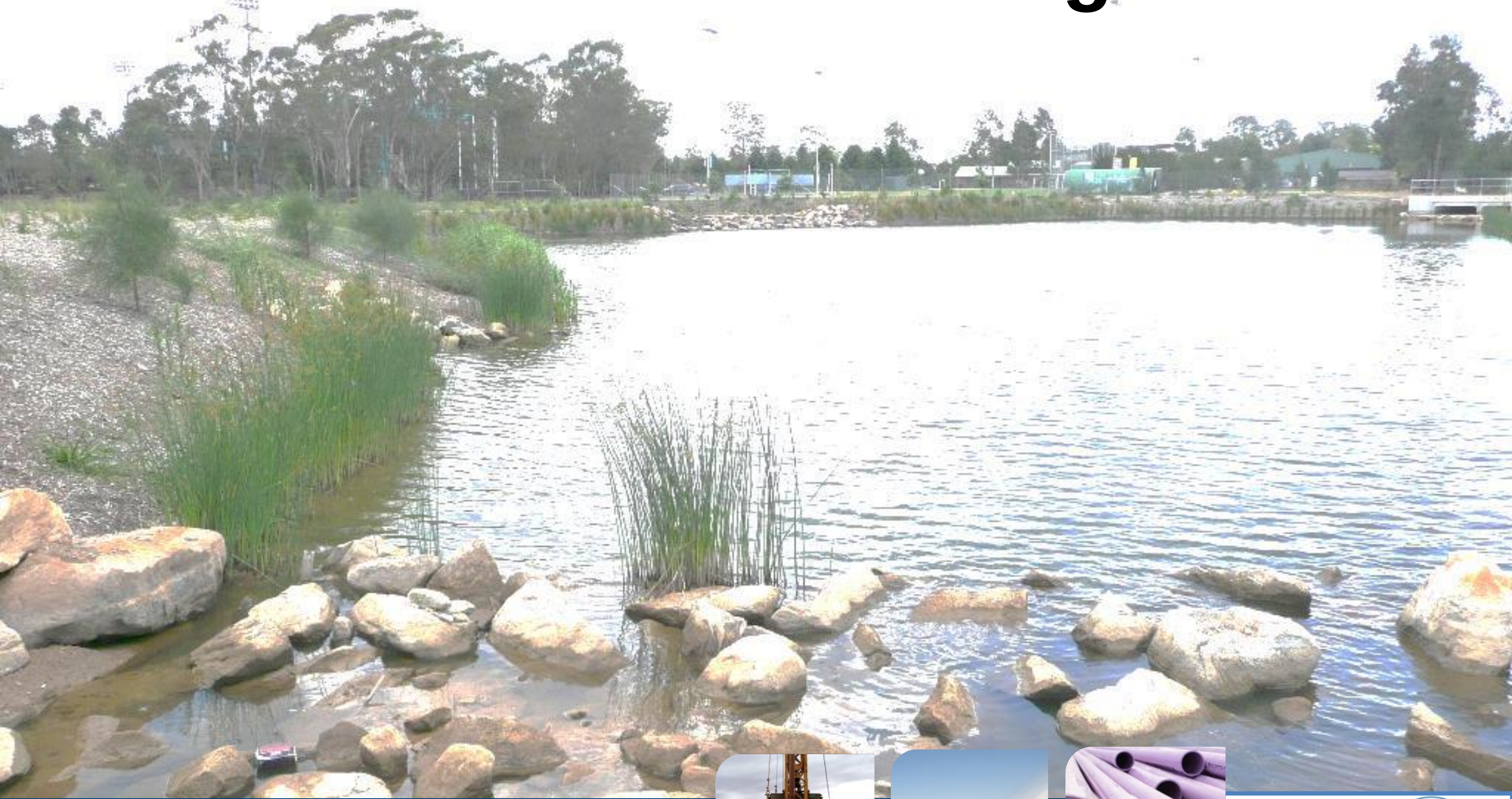


Applications

- **Salinity Management/Interception**
- **Leachate Recovery of Tailings Dams and Landfill Sites**
- **Pollution and Hydrocarbon Recovery**
- **Water/Bore Sampling**
- **Bore Flow Testing**
- **Contaminated Site Remediation**
- **Mine Site Dewatering**
- **Water Transfer and Harvesting**
- **Potable, Process and Remote Water Supply**
- **Low Yielding Aquifers**



Water Resource Management



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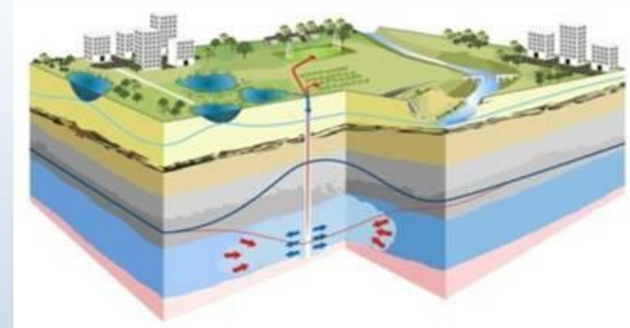
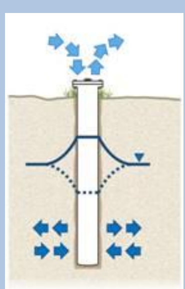
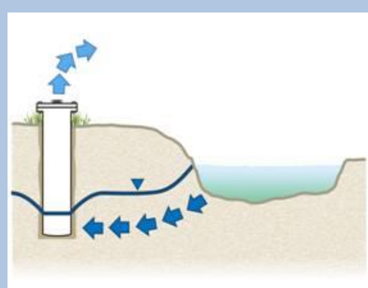
MAR

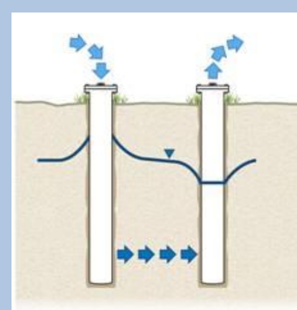


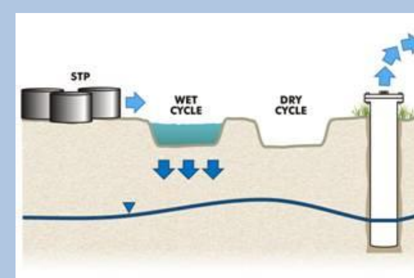
Managed Aquifer Recharge

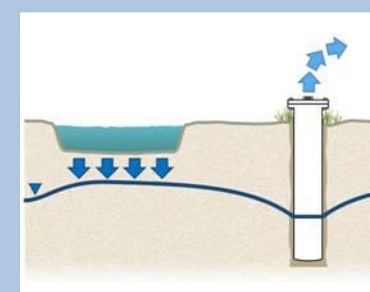
- Purposeful recharge of an aquifer to store water for later abstraction
  - Stormwater (excess or redirected),
  - Treated wastewater
  - Co-produced (associated water) from mining or petroleum activities
- Water can be added to the aquifer by various methods e.g.
  - Infiltration (via structures such as ponds, basins, galleries and trenches)
  - Injection and recovery via purposely constructed wells (ASR)











ASR **Bank Infiltration** **ASTR** **SAR** **Infiltration Basin**

- Collectively the various methods of enhanced aquifer recharge are referred to as Managed Aquifer Recharge (MAR).

Applications

- **Mining**
- **Petroleum**
- **Water Supply**
- **Agriculture**
- **Sporting Complexes**
- **Construction**

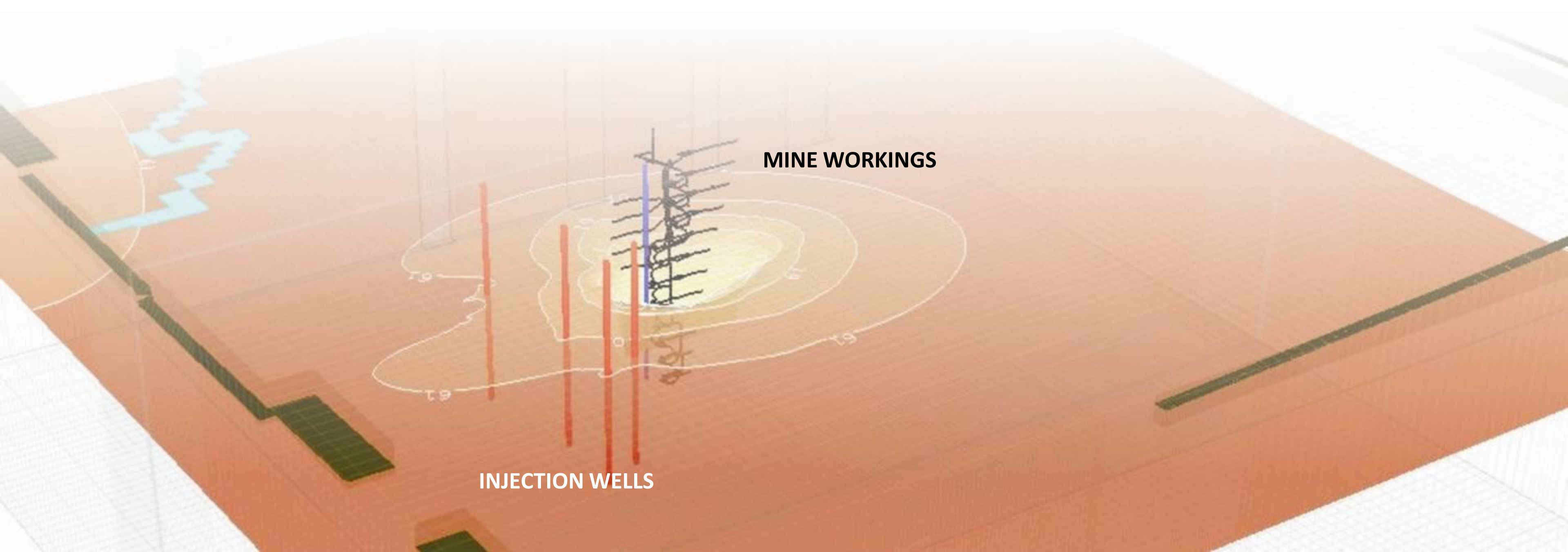


MAR in Mining

- **Effectively manage water that may otherwise be wasted**
- **Augment traditional water supplies and**
- **Address a variety of legacy issues associated with overuse**

MAR for Conventional Underground Zinc Mine

- Mine inflows were higher than expected (16 L/s)
- Requirement to manage excess water via Managed Aquifer Recharge
- Fractured rock aquifer of limited beneficial use (highly saline)
- Injection borefield developed @ 4L/s/bore



MAR/ASR in Golf course (2 Case study)

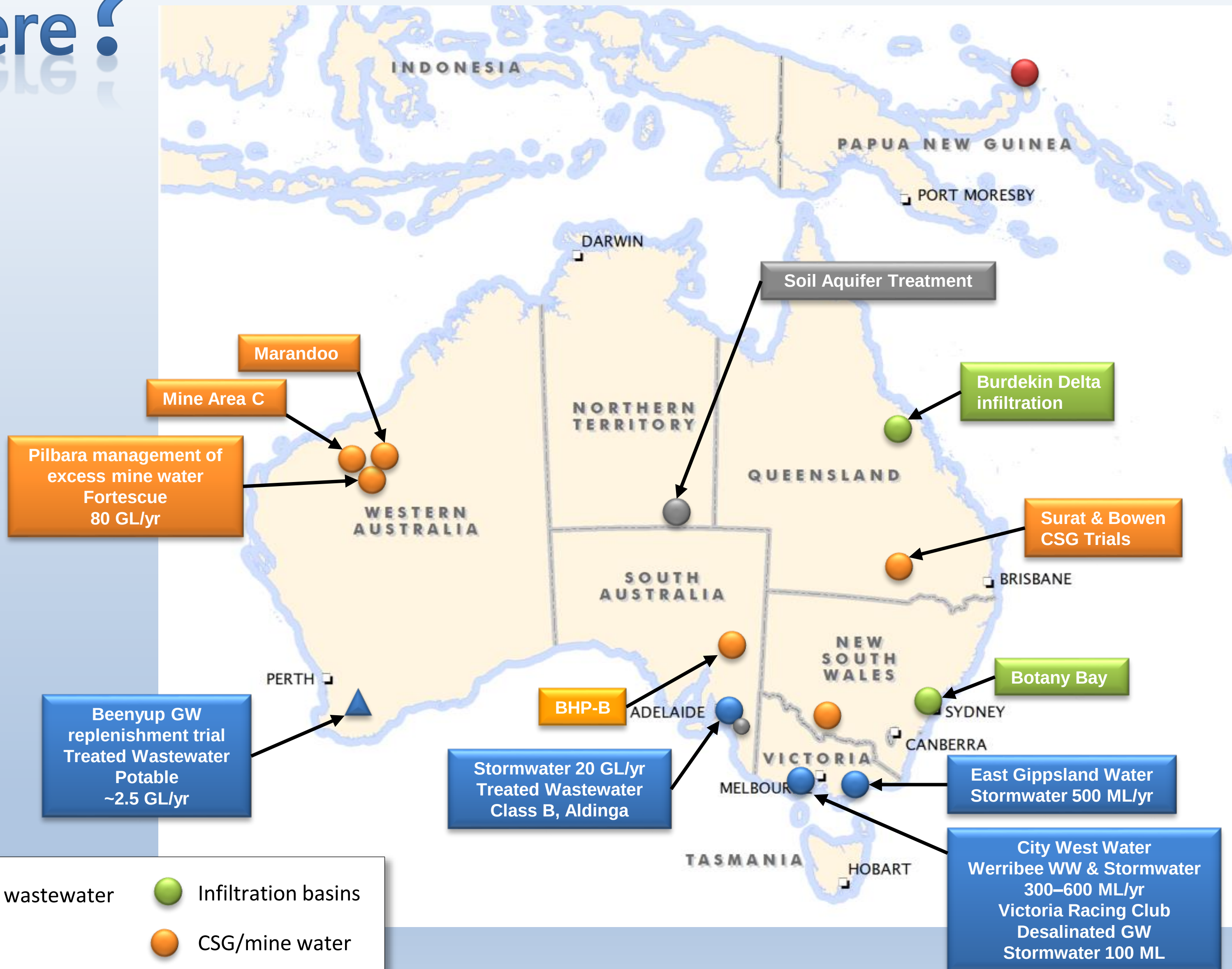
Glenelg Golf Course - Water Harvesting

- 300 ML/yr of stormwater
- Stored in aquifer during winter
- Recovered in summer for course watering

Grange Golf Course –GW Replishment

- 250 ML/yr of groundwater from the Tertiary limestone aquifer for irrigation of the golf course.
- Declining groundwater levels and increasing salinity
- Harvests and stores low salinity wetland treated stormwater
- Injection into the aquifer for subsequent reuse
  - **Recovery of groundwater levels**
  - **Improvement in water quality**

Where?



- Potable treated wastewater
- Infiltration basins
- Stormwater
- CSG/mine water
- SAT Treated wastewater

Thank you for your attention