



Offshore Salt Cavern Construction Risk Mitigation

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Sustainable Exploitation of the Subsurface

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Subsurface Gas Storage Innovations

“Sustainable Exploitation of the Subsurface”

Salt Cavern Gas Storage can contribute towards resolving the Energy Trilemma:

Decarbonisation
Security of supply
Affordability

To achieve these goals it is important to “encourage innovation” in:

Storage Services to an SNG market
Site Selection
Site Appraisal

Synthetic Natural Gas (SNG) Storage

The business development manager's key challenge is to prepare for an SNG economy.

What are the key drivers for an expanding SNG market?

Decarbonisation - SNG improves project economics for carbon neutral large combustion sites:

- Carbon Dioxide Utilisation (CDU) - captured CO₂ is used in production of SNG, and provides an additional source of revenue.

Security of Supply - SNG improves security by reducing reliance on gas imports:

- Annual production of SNG using CO₂ from the UK's large combustion plants, equates to the National Grid projected annual gas imports through to 2035.

Affordability - SNG minimises costs to consumers by minimising new infrastructure expenditure:

- SNG can utilise existing infrastructure, i.e. natural gas storage, and pipelines

“Affordability” of Subsurface Storage

The geoscientist’s key challenge is to help mitigate the risk of cavern construction budget overrun (expenditure & schedule)

1. **Site Selection:** what are the benefits from regional salt basin geological studies?
 - Structural history
 - Formation thicknesses
 - Lithofacies variation
2. **Site Appraisal:** what are the benefits from high resolution data?
 - Ultra high resolution seismic data
 - High resolution wire line logs

Site Selection -Salt Cavern Project

Basin vertical tectonic history:

- Formation thickness – greater salt formation thickness reduces number of caverns for a required working gas capacity

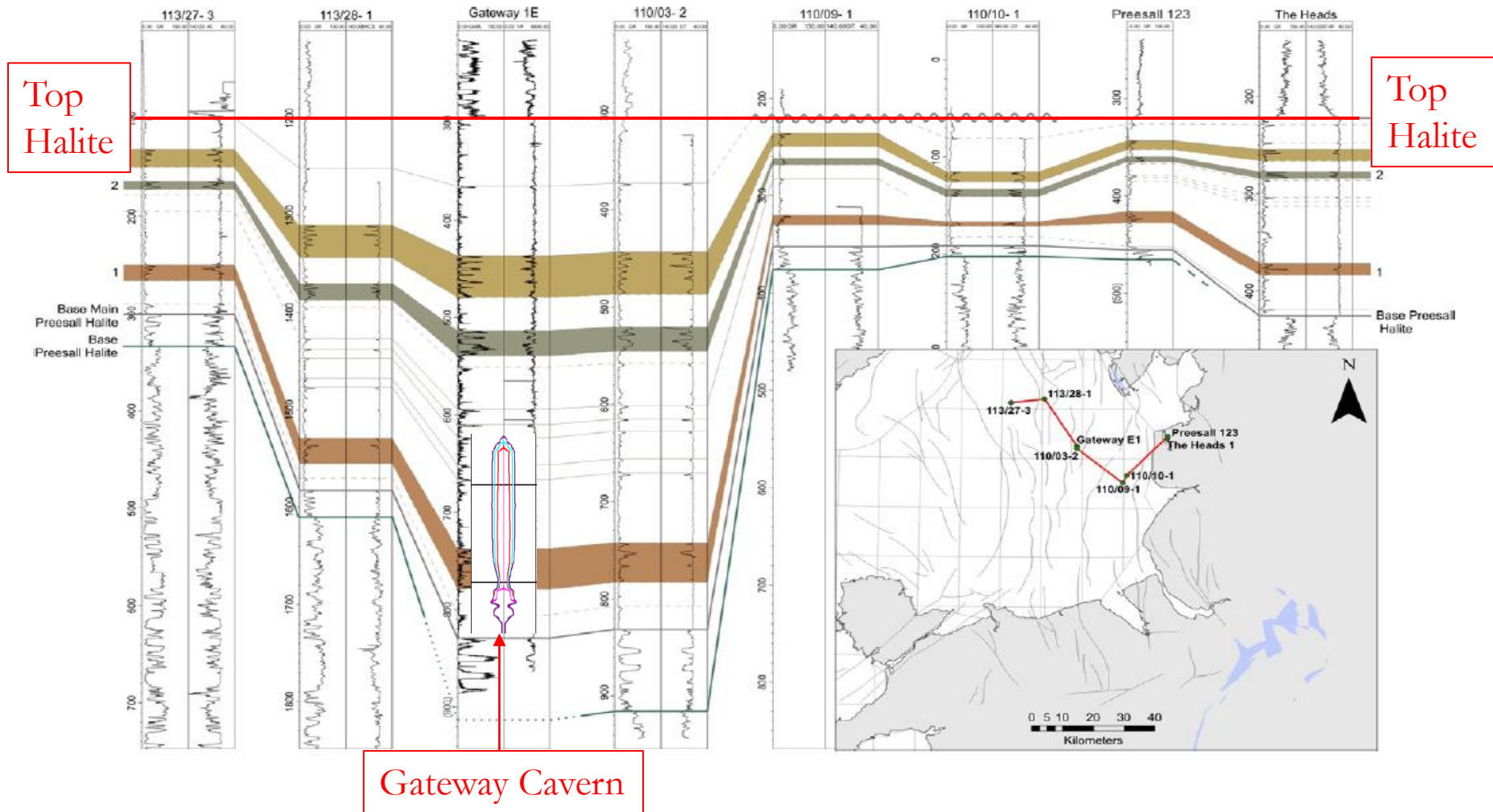
Basin horizontal tectonic history:

- Fault complexity – absence of faulting reduces risk of lower gas storage capacity due to irregular shaped caverns

Basin clastic deposition history:

- Lithofacies – absence of fluvial deposits reduces risk of smaller cavern spatial volume due to:
 - Smaller sump (lower insoluble content)
 - Regular shaped caverns (thinner mudstone formations)

Site Selection – Thick Salt



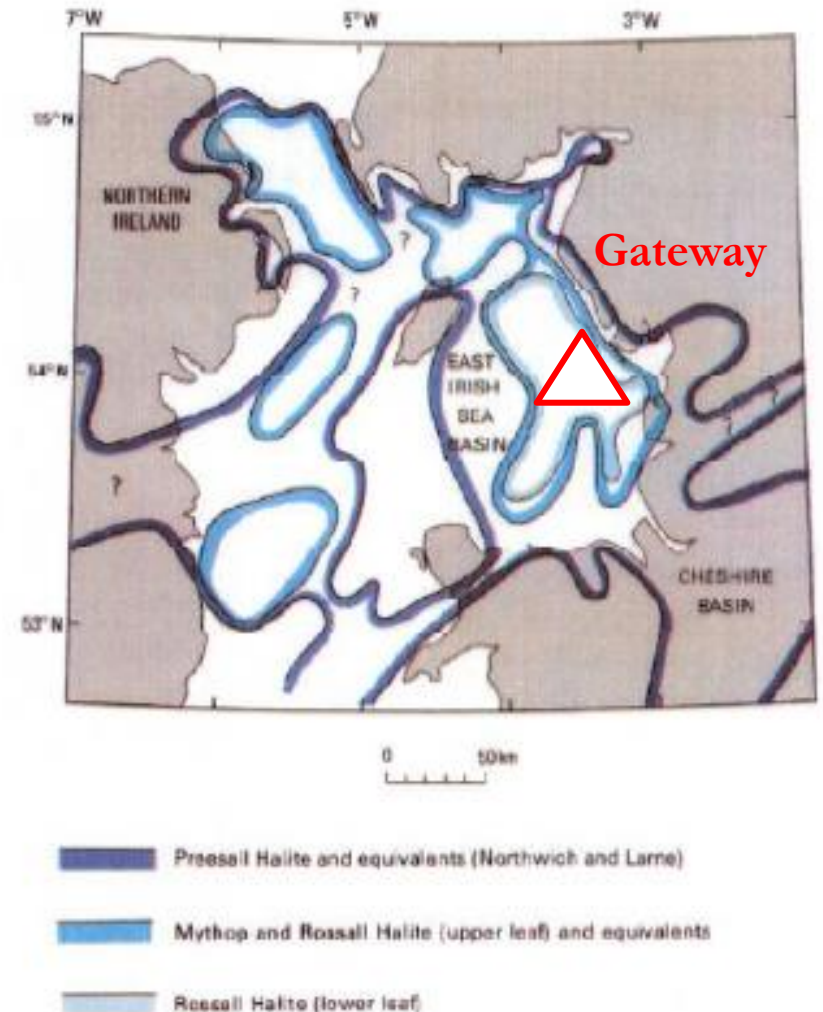
Site Selection – Regional Lithofacies

Flooded shelves suppress transport of siliciclastics into the basin (Hovorka, 2007)

Increased water depth in basin centre encourages increased halite precipitation

Gateway site located near basin depocentre.

Cheshire Basin located near basin margin.



Site Appraisal -Salt Cavern Geology

“Innovative Ideas” to Minimise Risk of Inaccurate Cavern Spatial Volume Estimates

1. Ultra High Resolution Seismic Data to improve Solution Mining Efficiency estimates:
 - Improves accuracy of “structural deformation mapping”
 - Improves accuracy of “clastic formation mapping”
2. High Resolution Wireline Logs to improve Sump Volume and Solution Mining Efficiency estimates:
 - Improves accuracy of “percentage insoluble content” estimates
 - Improves accuracy of “insoluble distribution” estimates

Site Appraisal – Offshore Seismic Survey

UHR Seismic Survey data acquisition:

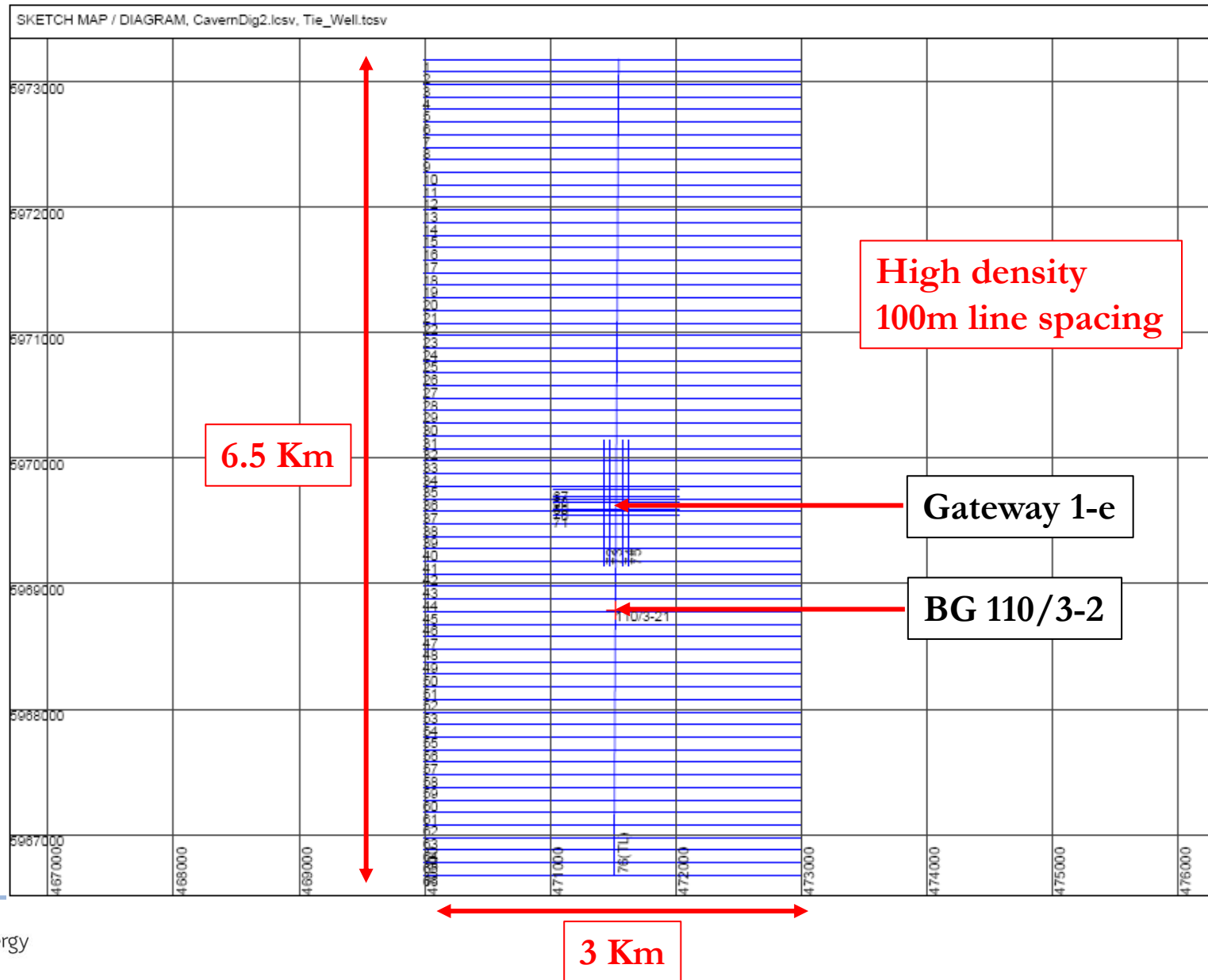
- Relatively “low cost” site survey vessel
- 2x40 cubic inch, and 2x20 cubic inch airguns
- 300m streamer



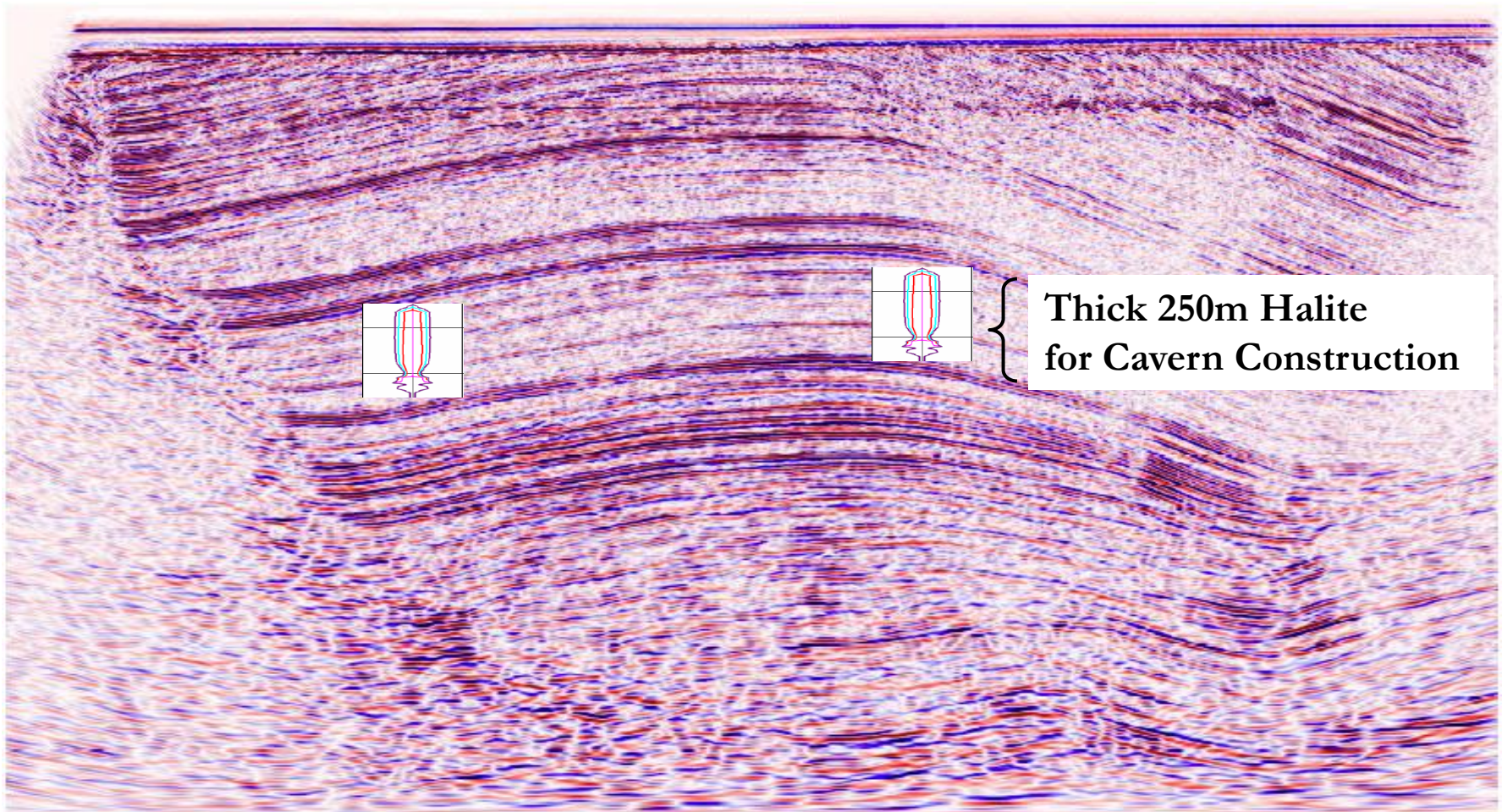
UHR Seismic Survey data for target depths of up to 1km:

- Vertical resolution 5-7m (Pre-existing data 30-40m)
- Centre frequency 130-150 Hz (Pre-existing data 30Hz)

Site Appraisal – Offshore Seismic Survey



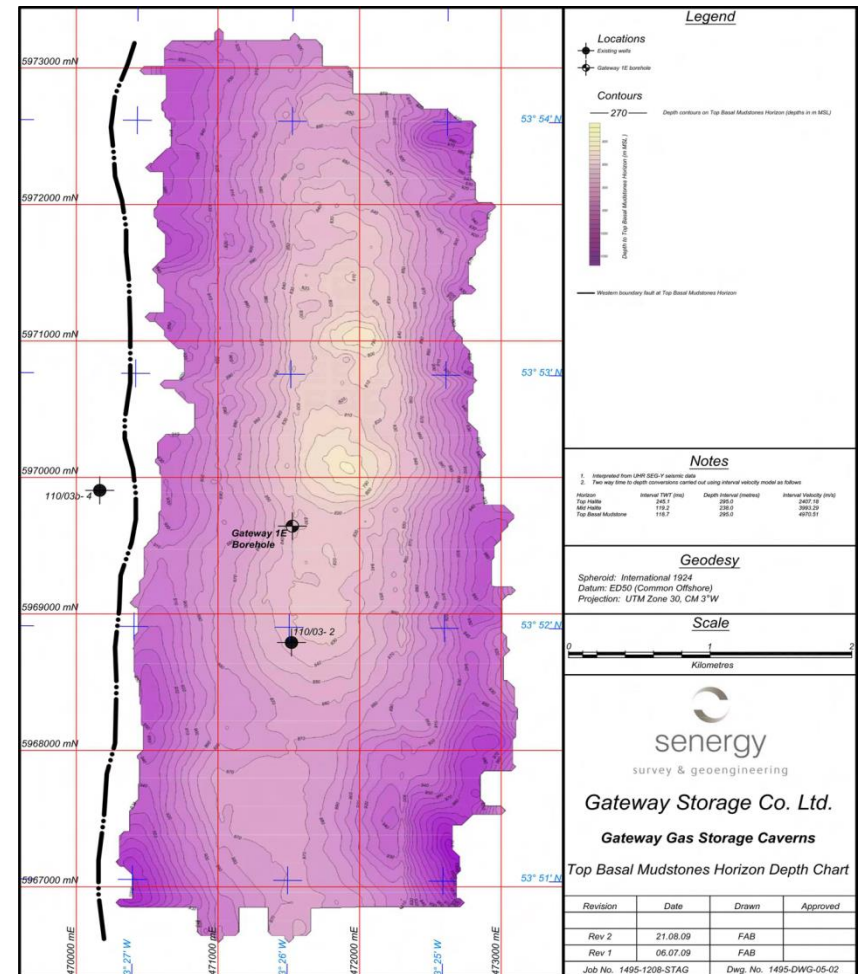
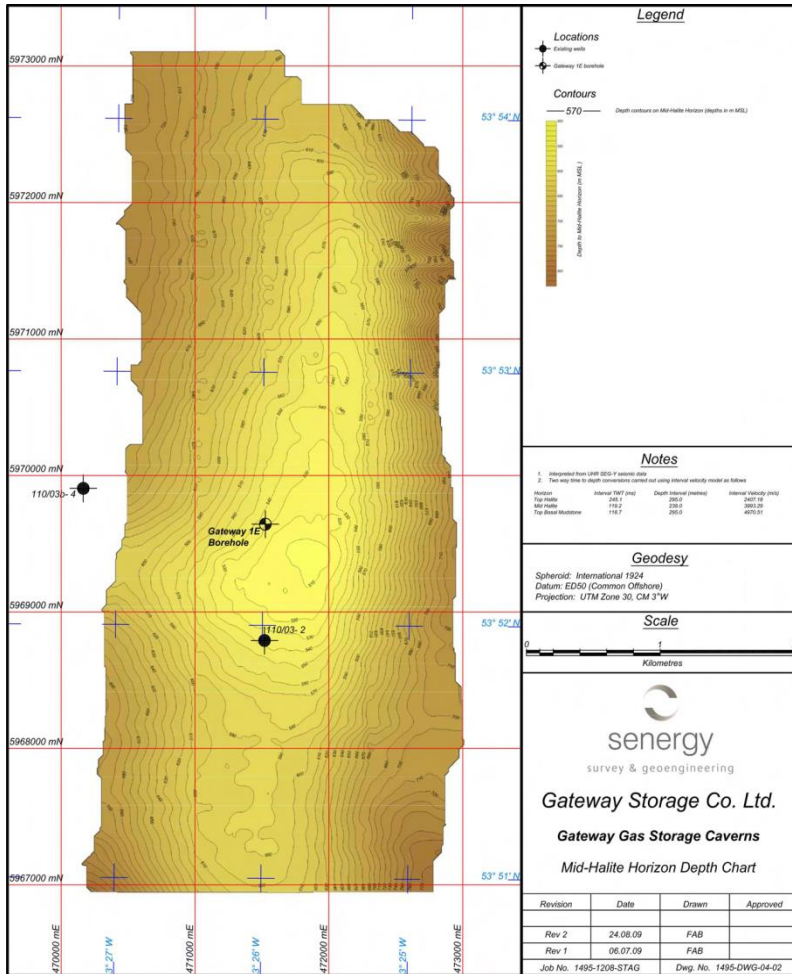
Site Appraisal – Thick Salt & Lithofacies



Example UHR seismic line:

Cavern interval depth accuracy; Mudstone lateral continuity accuracy

Site Appraisal – Seismic Interpretation



Top Cavern Interval – No Faults Identified

Base Cavern Interval – No Faults Identified

Site Appraisal – Drill Rig & HR Wireline Logs

Drill Rig:

Low cost modified Civil Engineering Rig:

- Lengthened legs
- Oil & gas safety standards



HR Wireline Logs:

Mining Industry Wireline Tools:

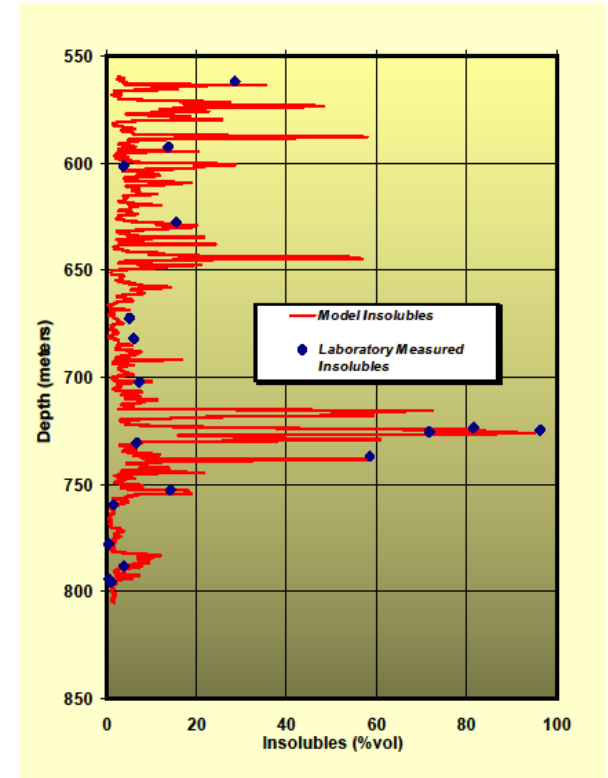
- Depth sampling interval is 2 cm.
- Typical oilfield sampling interval is either 10 or 20 cm in metric units.

Site Appraisal – Gateway Insoluble Content

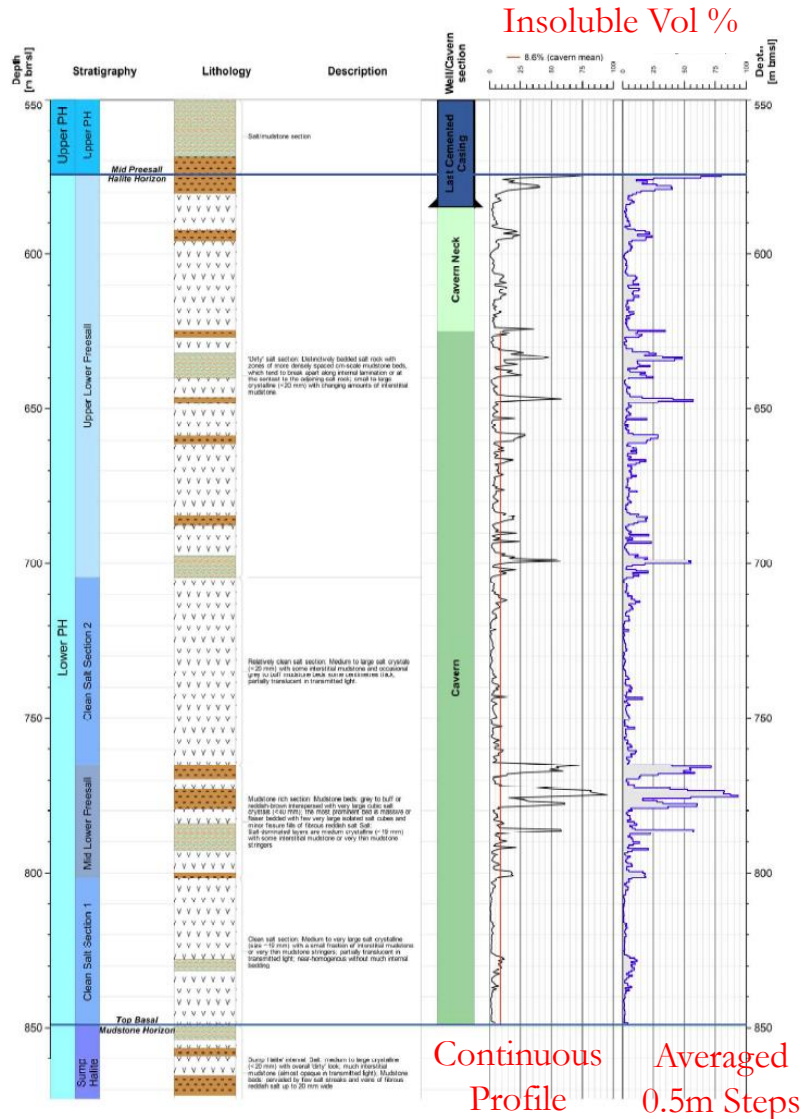
Correlation: Cores - Gamma Density Log

Estimated Insoluble Content: 8.6%

Cavern Development Interval
(560 Metres to 805 Metres)



Site Appraisal – Gateway Lithologies



Clean Salt Section: medium to very large salt crystals (>40mm); very thin mudstone stringers



“Dirty” Salt Section: Bedded salt rock with zones of cm scale mudstones



Mudstone Rich Section: mudstone beds interspersed with very large salt crystals (>40mm). Salt-dominated layers with very thin mudstone stringers

Anticipate high vertical solution mining efficiency

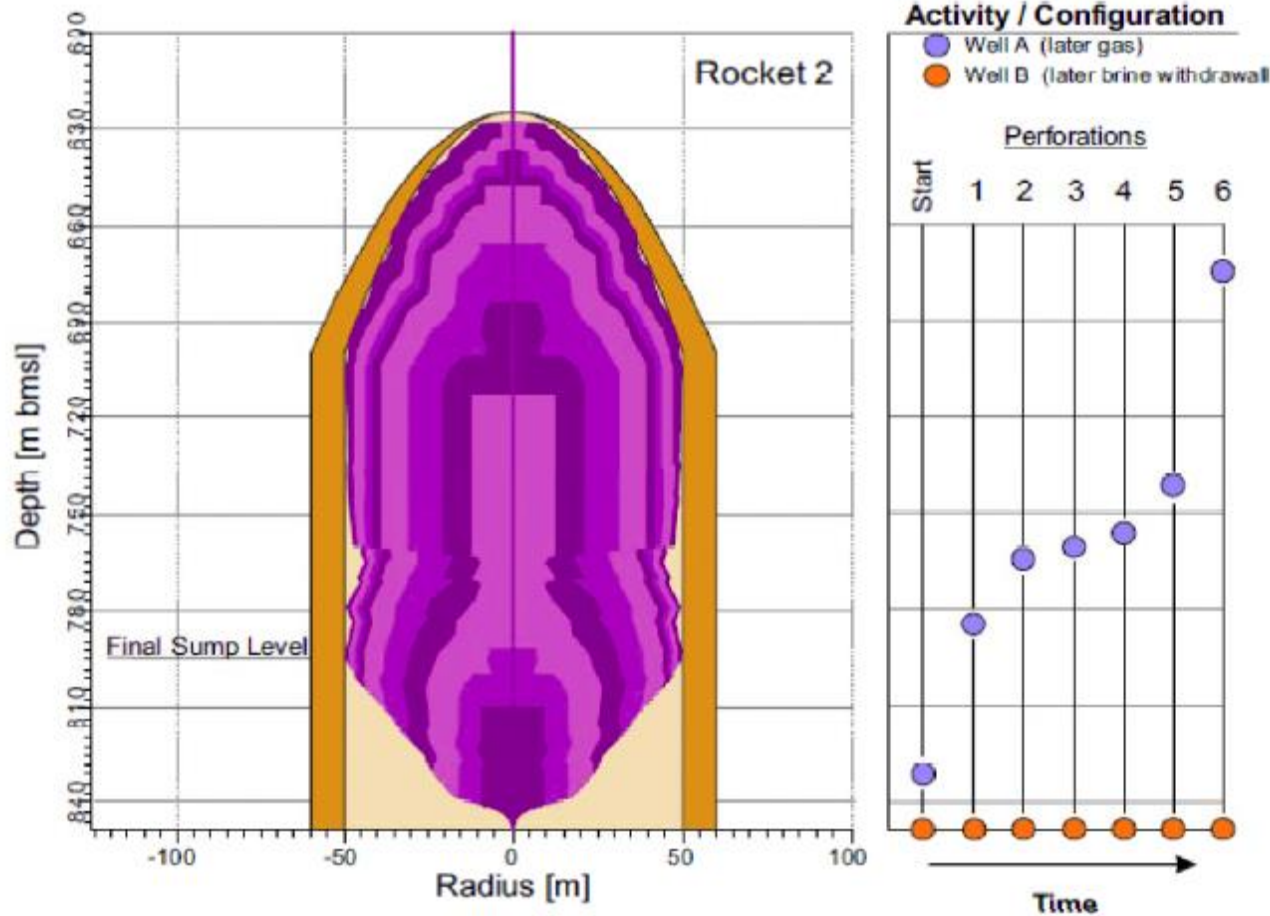
Site Appraisal – Solution Mining

Solution Mining Goals:

- Largest cavern volume within strict safety limits
- Shortest possible leaching duration
- Minimum number of interventions

Site Appraisal – Solution Mining

The coloured bands represent the stages of the leaching simulation process.



Dual Well Configuration:

Platform wireline perforations avoids need for costly drill rig.

Allows high solution mining flow rates to reduce cavern construction time

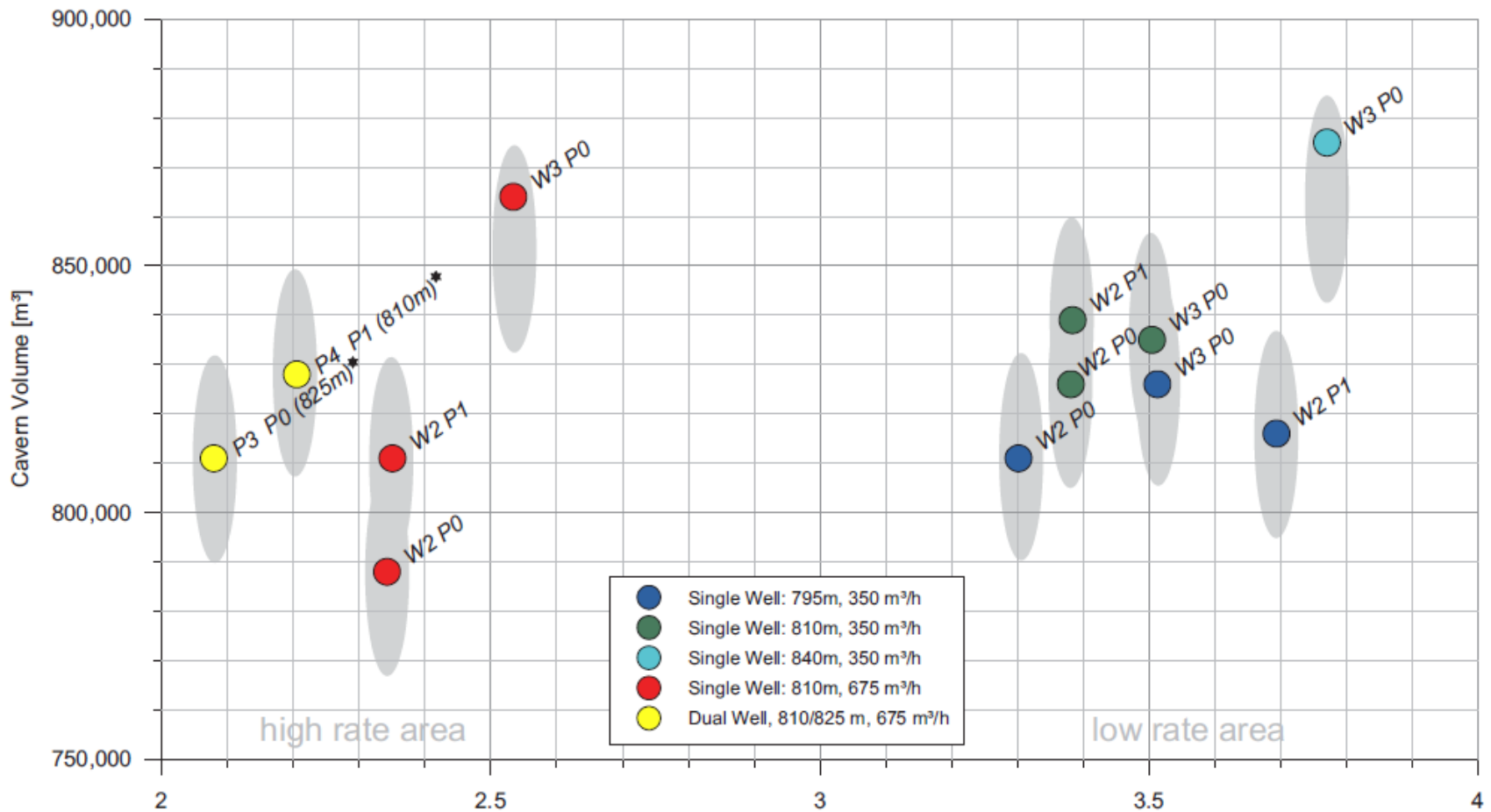
Rock Mechanical Envelope:

Allowable Diameter: 120m

Effective Diameter: 100m
(70%vol of the RME)

Normal Industry Practice – now being tested by BGS

Site Appraisal – Solution Mining



Cavern Volumes and Leaching Durations (years)

The most favourable ratio of cavern volume, leaching duration, intervention effort and maintenance flexibility was reached with the dual well configuration simulations.

Message

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- Site Appraisal