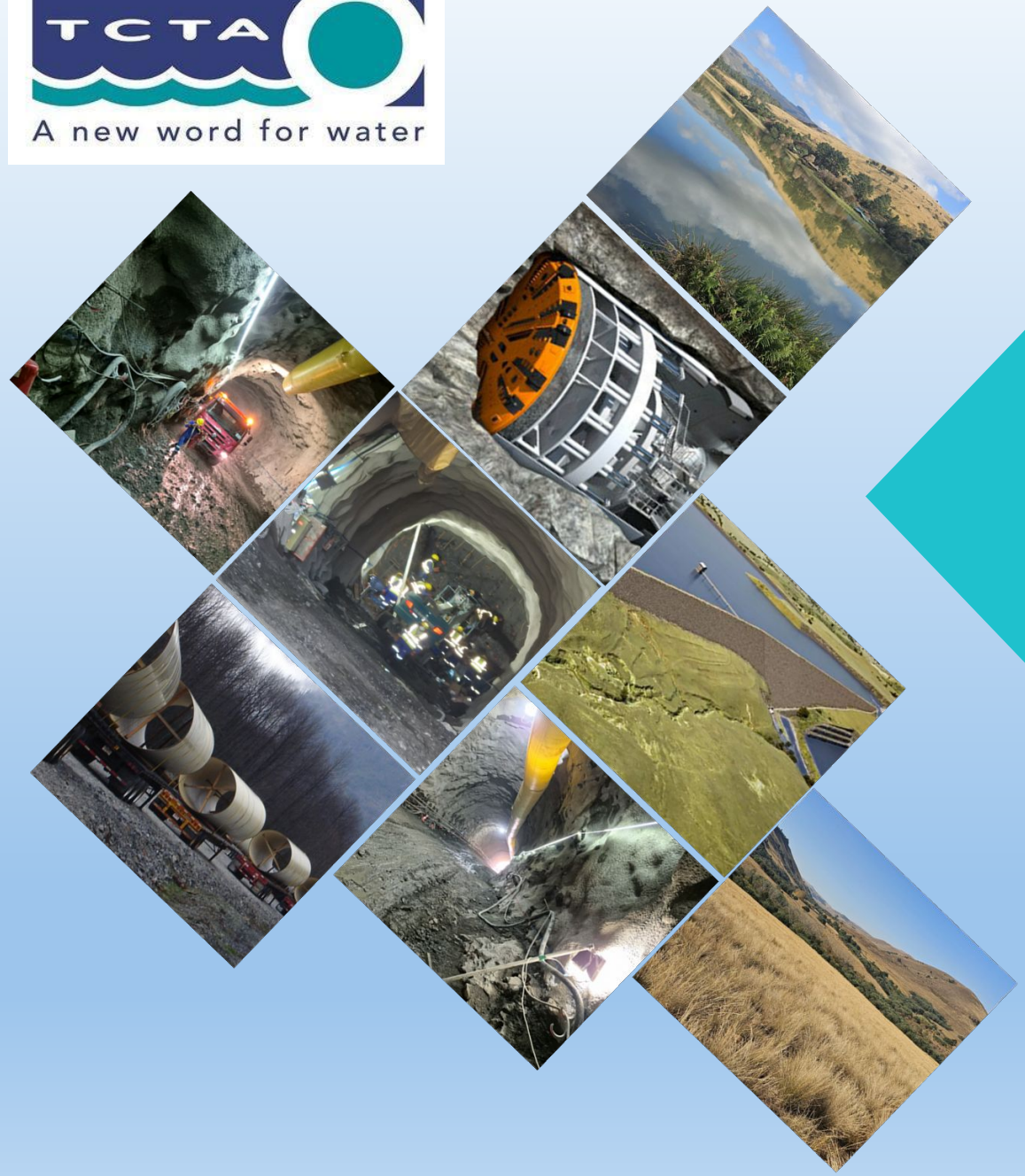


CONSULTING SERVICES FOR THE uMKHOMAZI WATER CONVEYANCE INFRASTRUCTURE (uMWP-1)

uMkhomazi Transfer Tunnel

Background, Geotechnical Conditions and Tunnel Design Considerations

Ryan Freese and Gerhard Keyter, GKP JV

Introduction

My Mom’s Aloe Garden

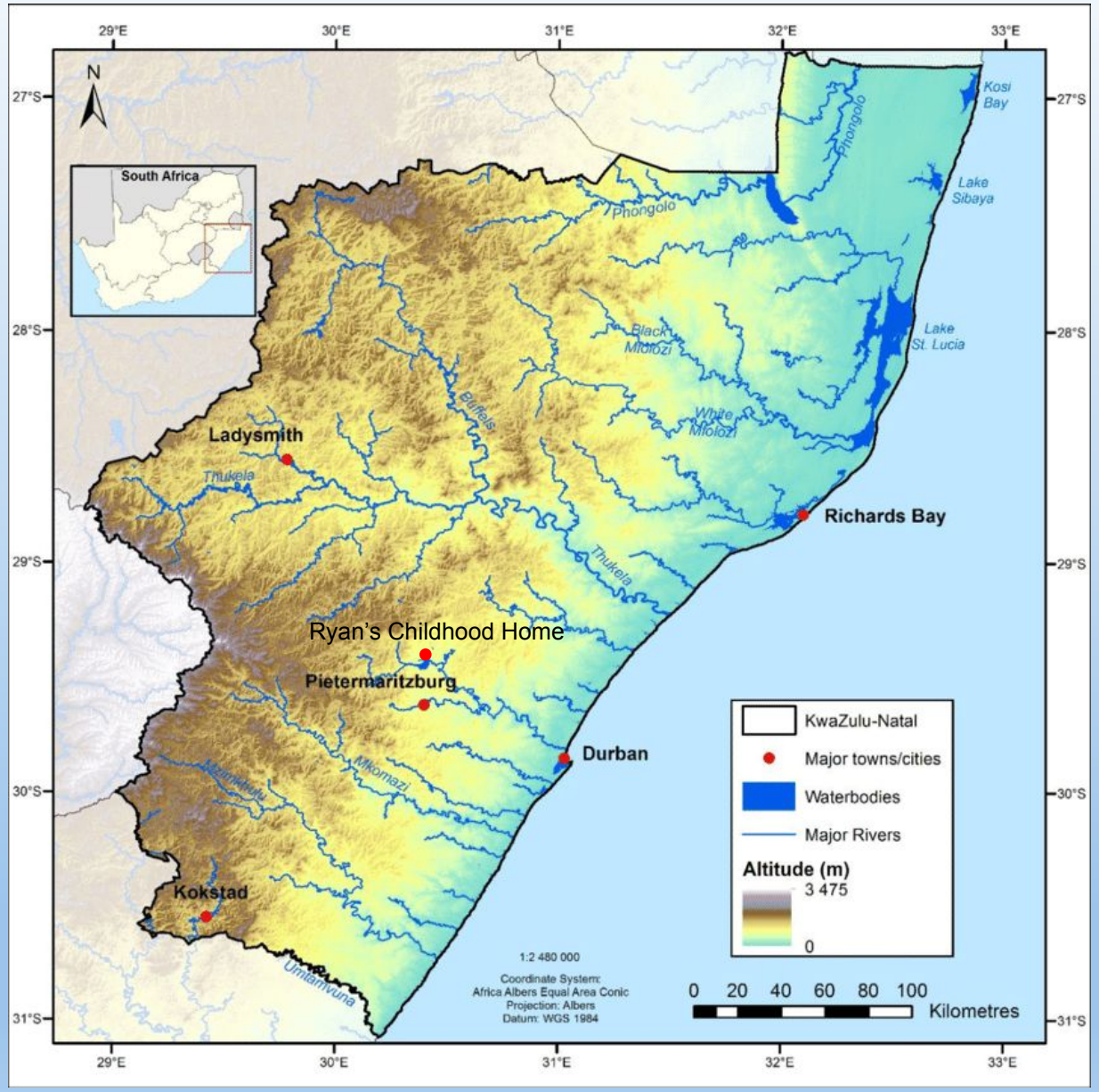
Introduction

My Mom's Aloe Garden

Introduction

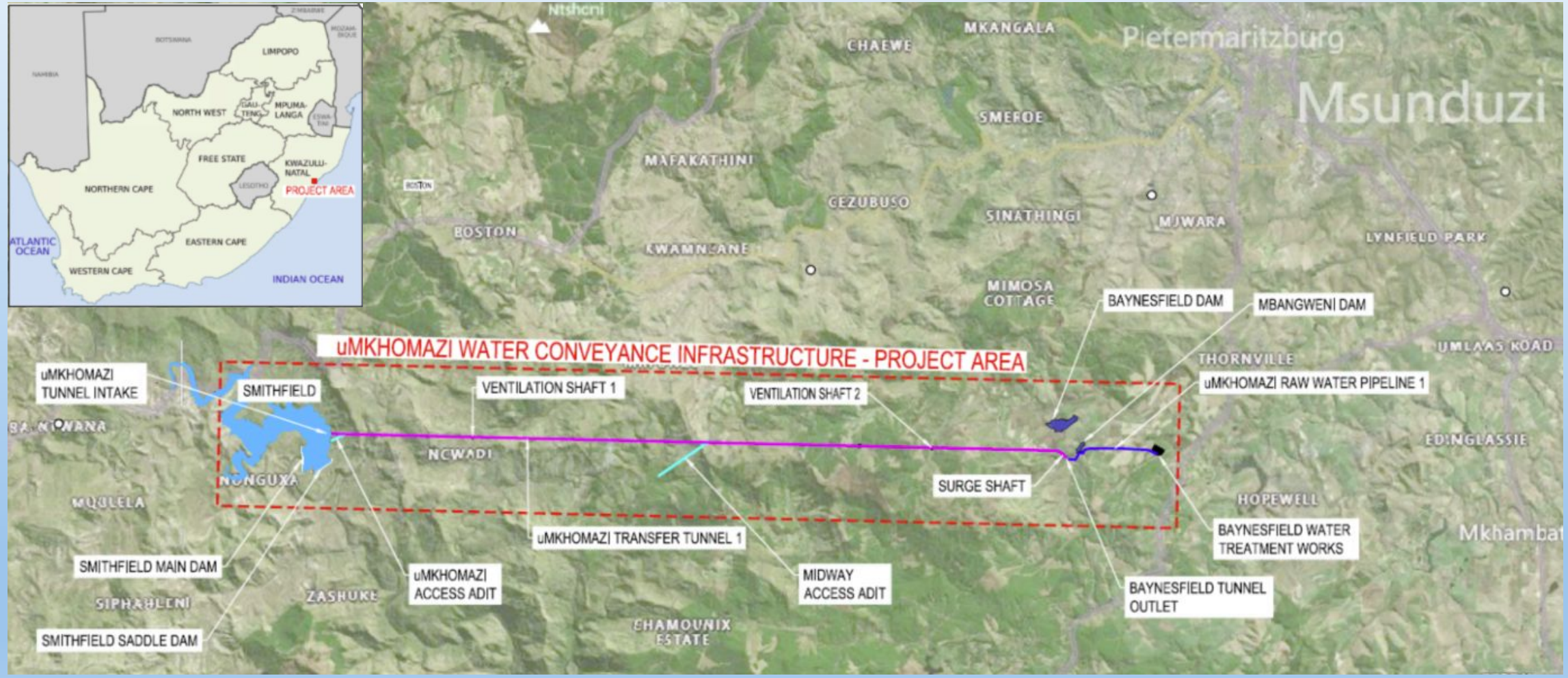
The Why

- KwaZuluNatal is out of water.
- The Umgeni System supplies PMB, DBN and surrounding settlements. In deficit since 2016.
- Where to next = the uMkhomazi River = place of cow whales (whales breed in estuary)



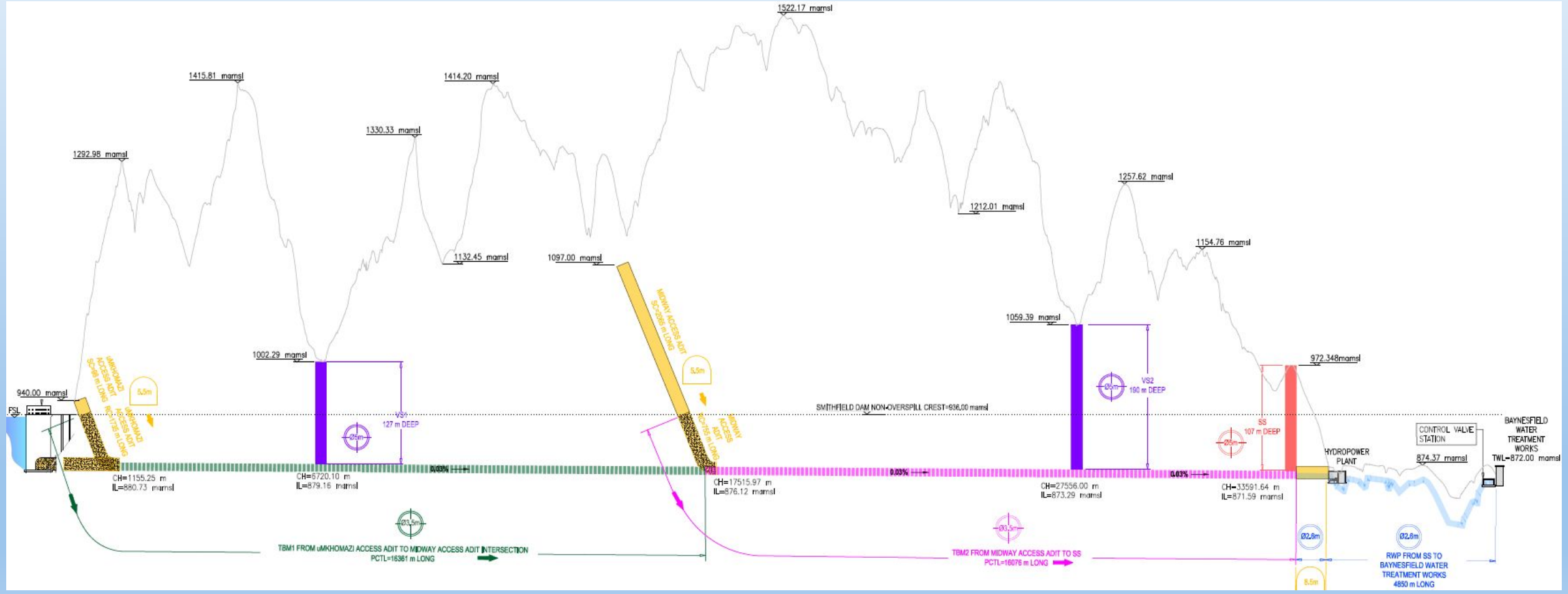
Introduction

uMkhomazi Tunnel Plan Layout



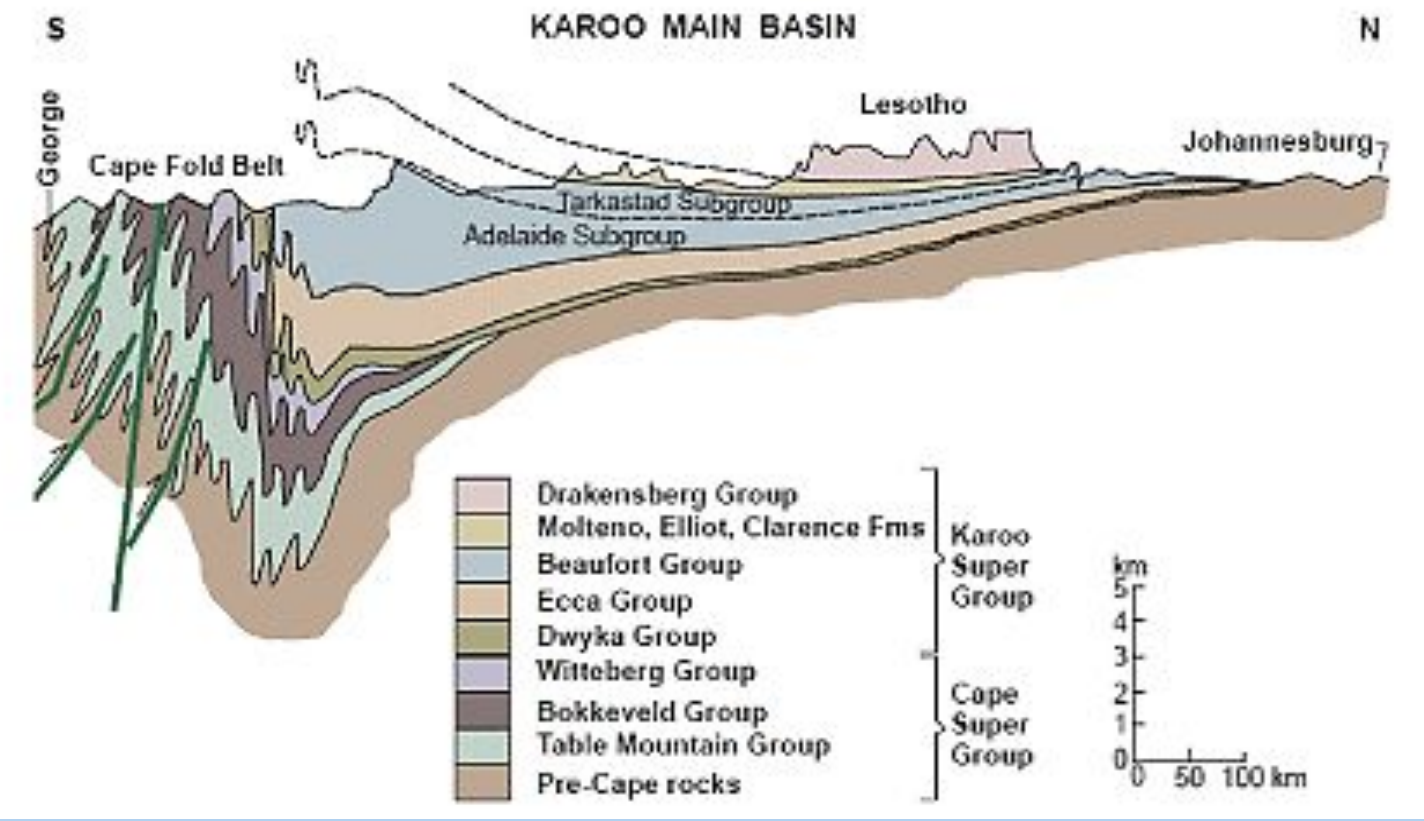
Introduction

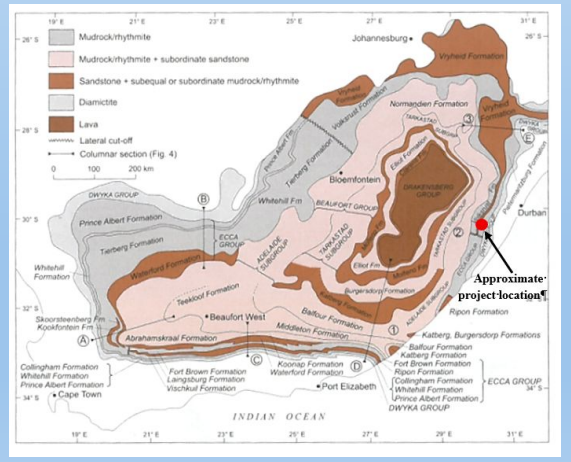
uMkhomazi Tunnel Section Layout



Geological Background

- Karoo Supergroup (300-183Ma).
- Subduction = Cape Fold Belt
- Retroarc foreland system = basin
- Basin filled:
  - Glacial-greenhouse-arid
  - Marine-lacustrine-fluvial-aeolian-igneous
- Breakup of Gondwana led to basalt cap and extensive sills/ dykes
- Shales, siltstones, sandstones, dolerite.





Geotechnical Investigations

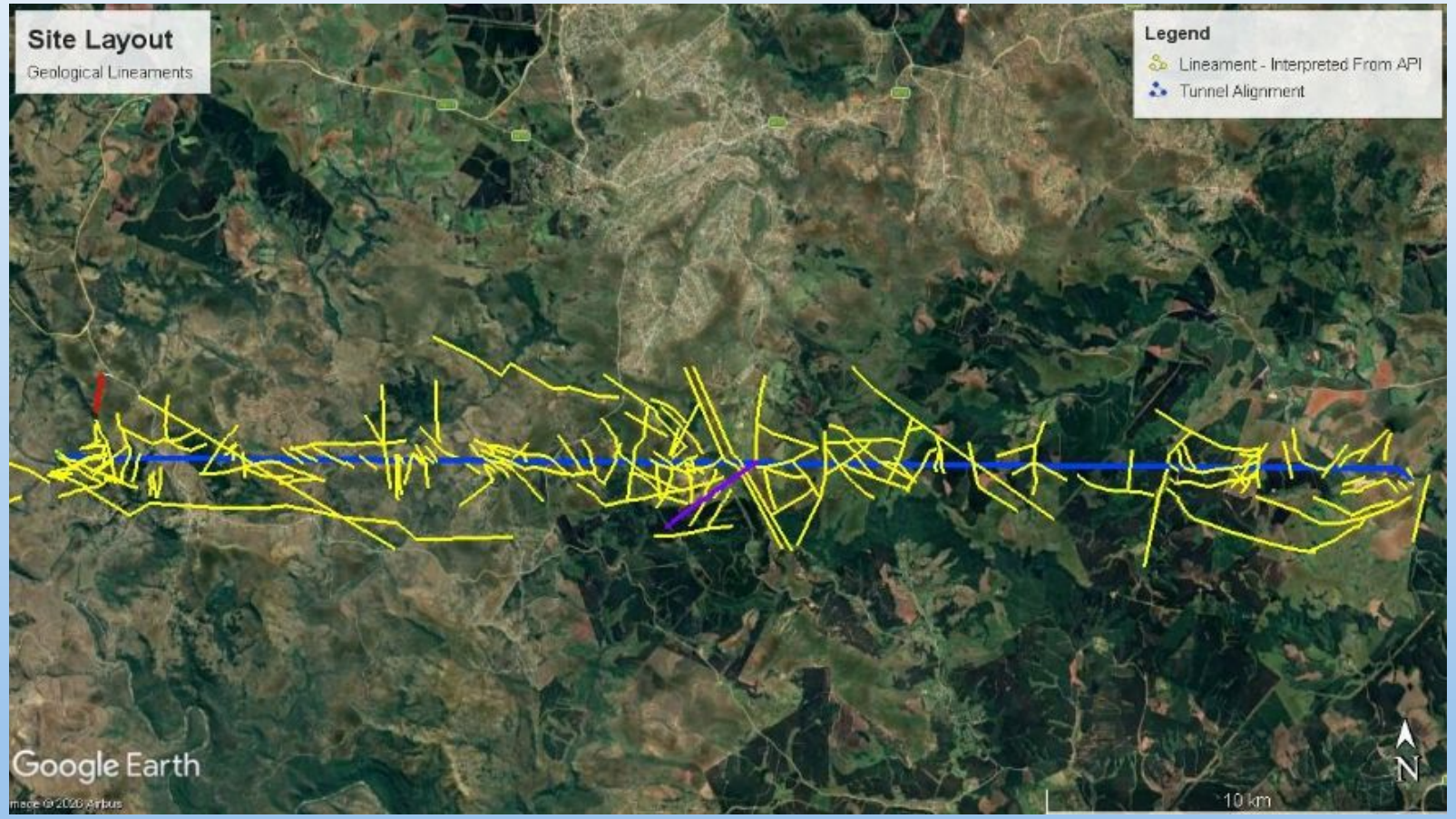
Tunnel Design Considerations

- Mixed Face Conditions
- Shale Durability/ Swelling
- Low TBM Advance Rates
- Water Inflows
- Abrasive Rock
- Squeezing Conditions
- Aggressive Groundwater
- Hazardous Gas
- Segment integrity
- Tunnel logistics

Geotechnical Investigations

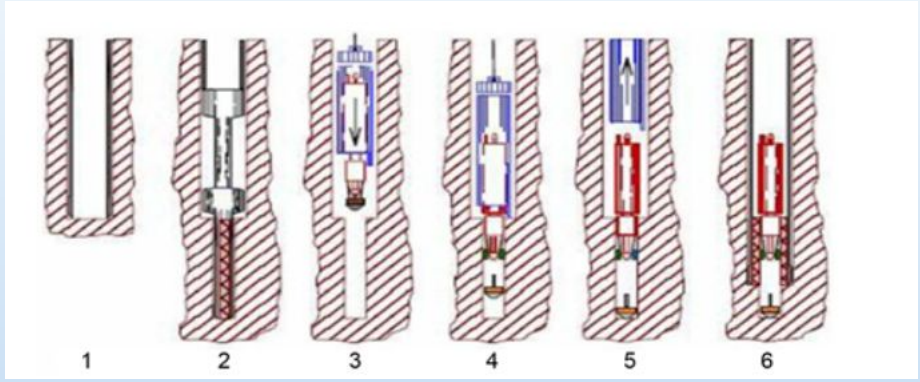
Investigations

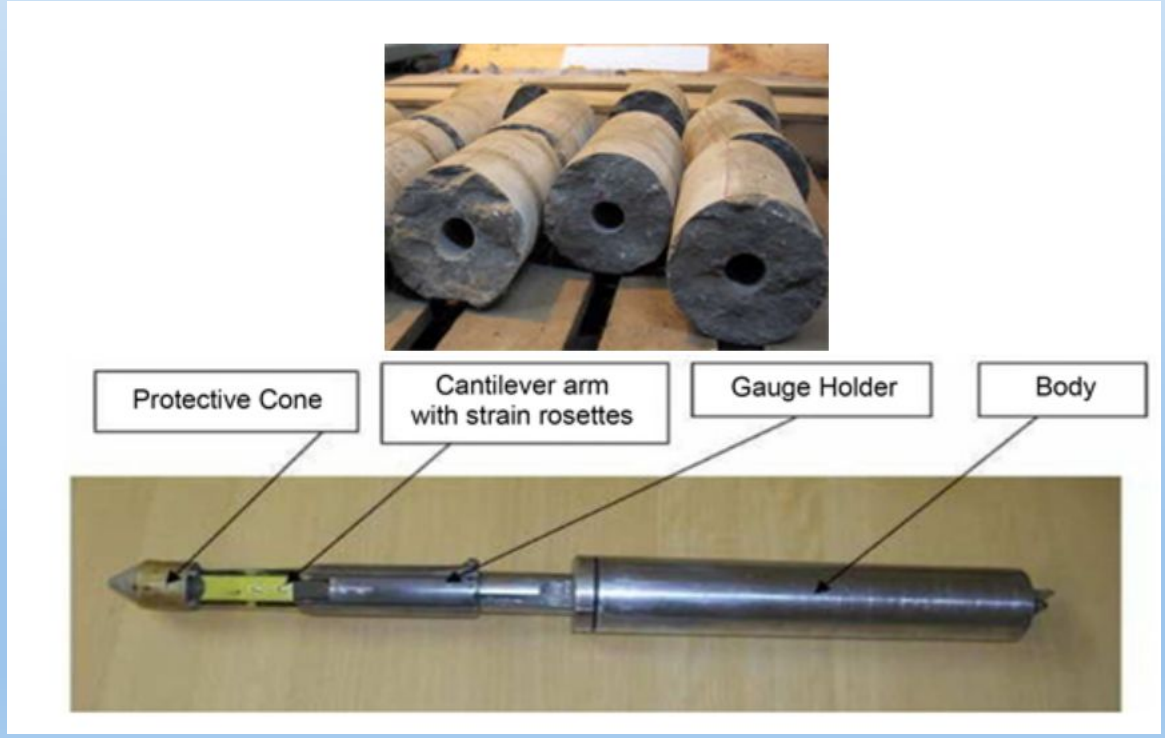
- Desk study
- Aerial Photographic Interpretation – Identify Lineaments
- Empirical experience in the area (e.g. Ingula PS Midmar Tunnel)



Geotechnical Investigations

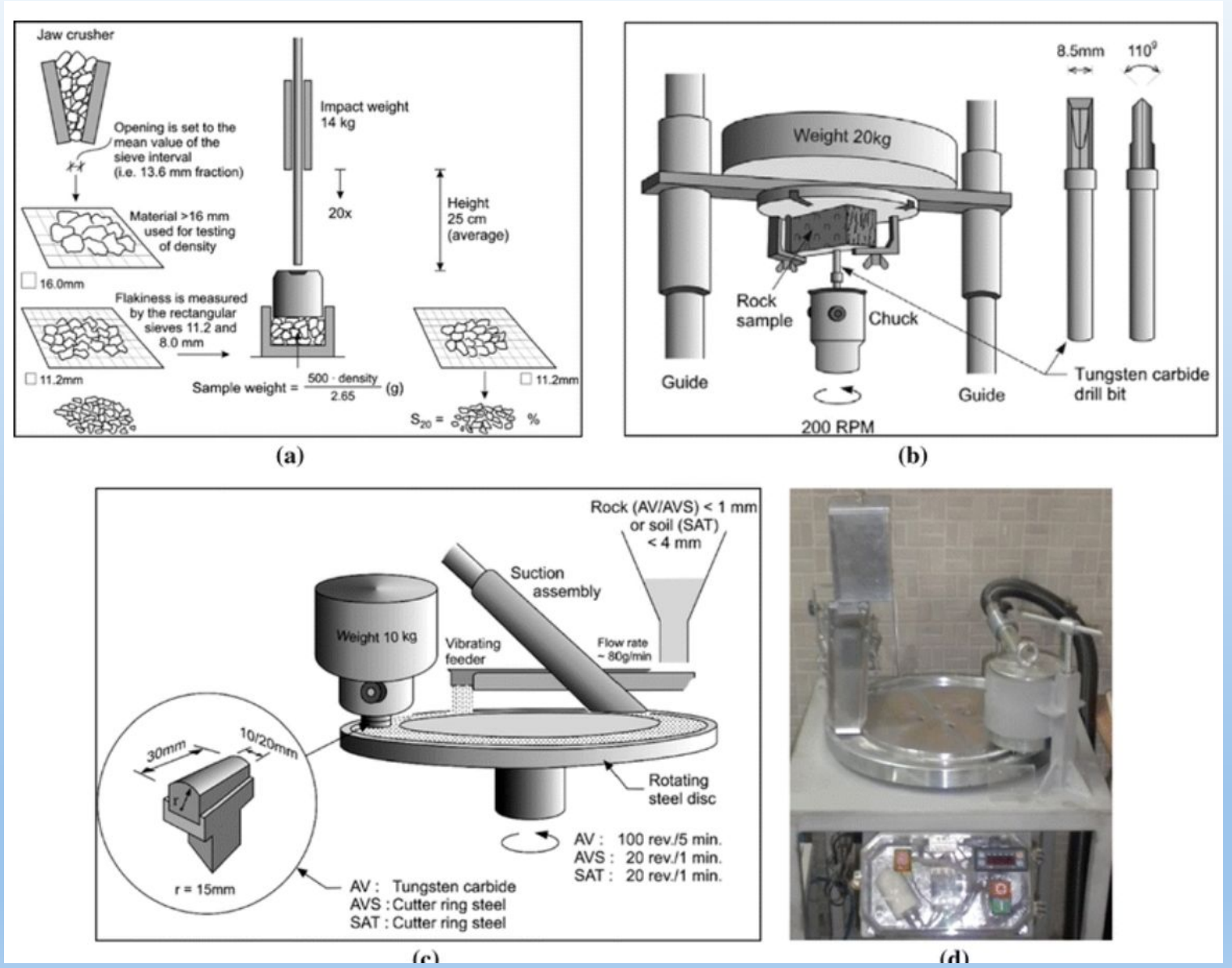
- Geophysics – ERT and Seismics (Airbourne)
- Borehole drilling: : 77 boreholes (7,940 m)
- Downhole geophysics: 47 surveys
- Packer testing: 470 Lugeon tests
- Stress testing: 5 Sigra overcoring
  - 7 Hydrofracture tests
- Test pits/trenches: 99 pits
- Sufficient Data in all:
  - Lithologies
  - Stratigraphies
  - Stress Conditions
  - Infrastructure Positions





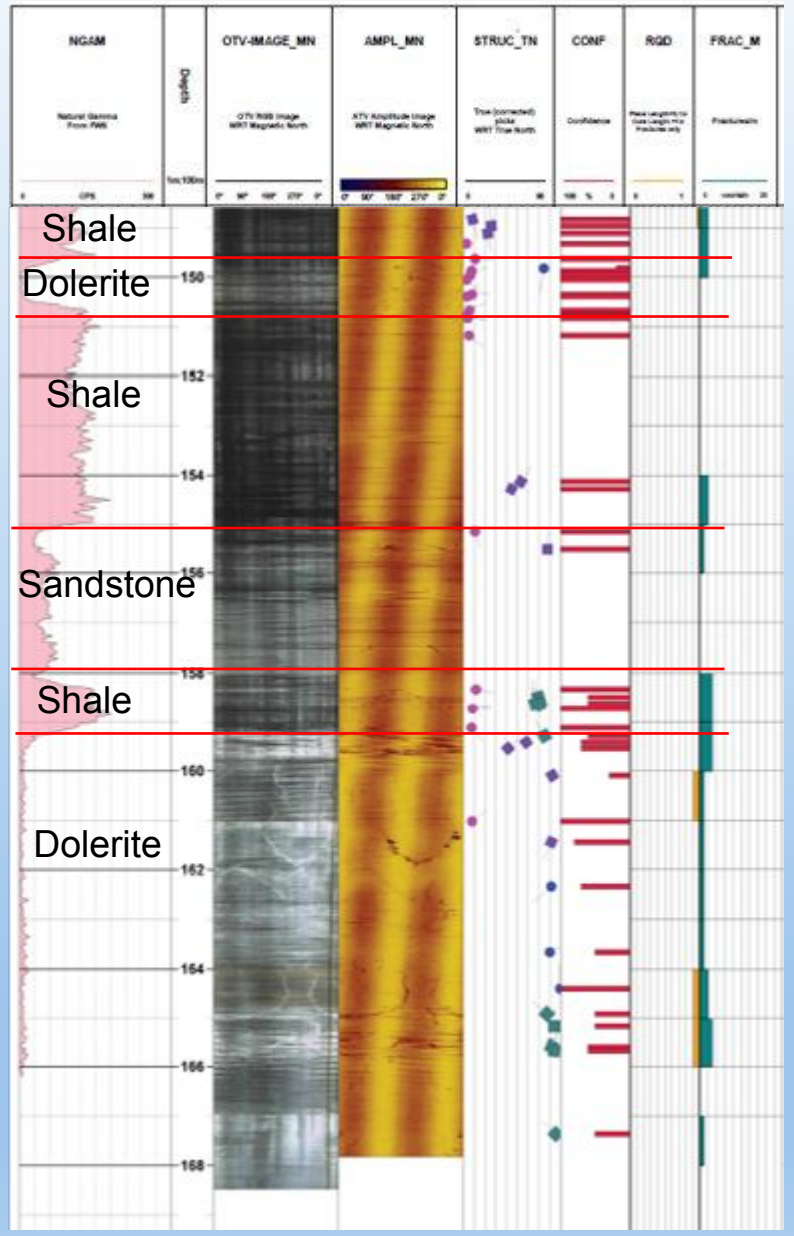
Geotechnical Investigations

- Laboratory Testing:
  - Strength/ Stiffness
  - Joint shear strength
  - Swelling
  - Durability
  - Mineralogy
  - TBM



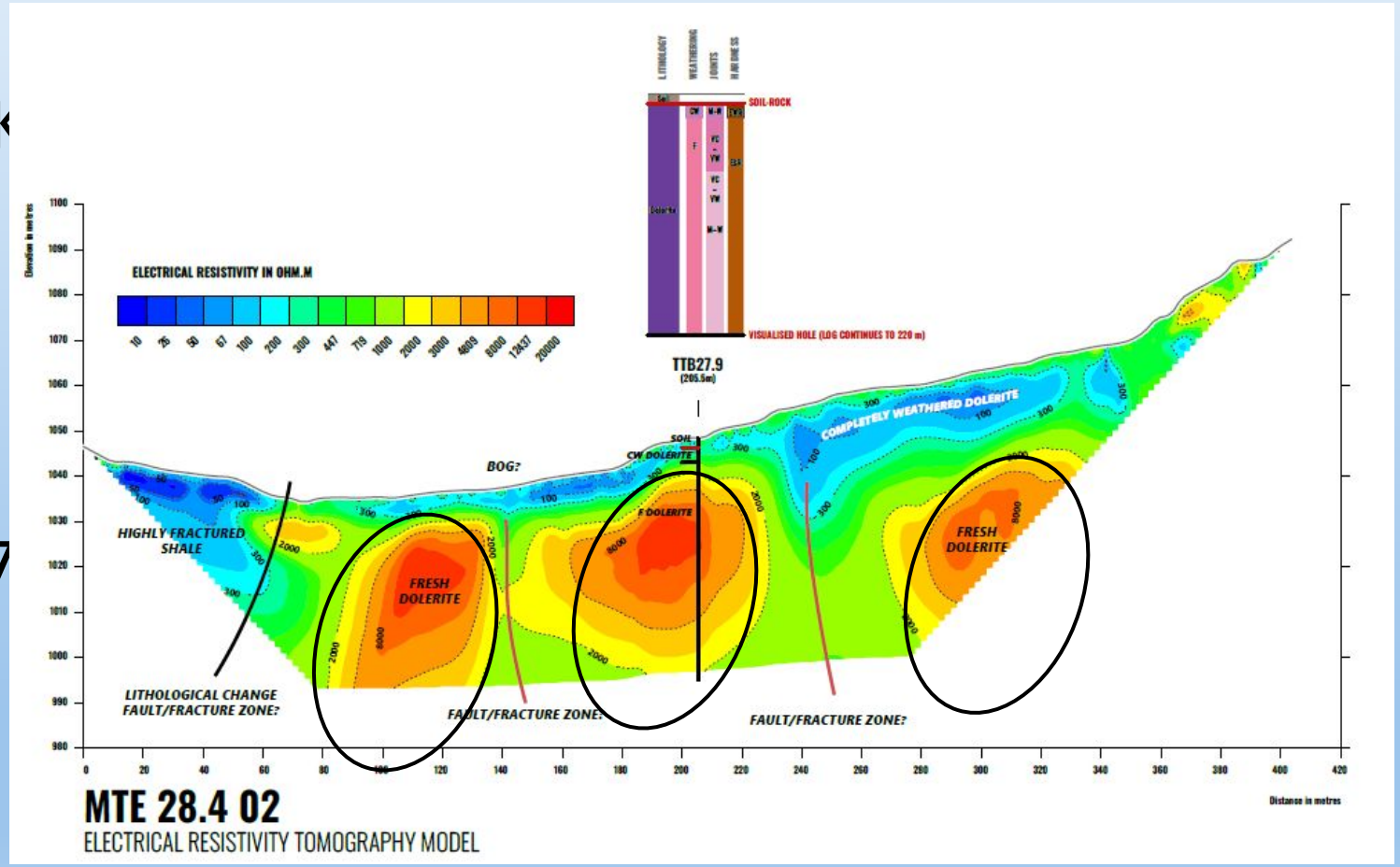
Geotechnical Investigations

- Downhole Geophysics
- Good correlation between sedimentary rocks, dolerite and Natural Gamma.
- Good check on logging.



Geotechnical Investigations

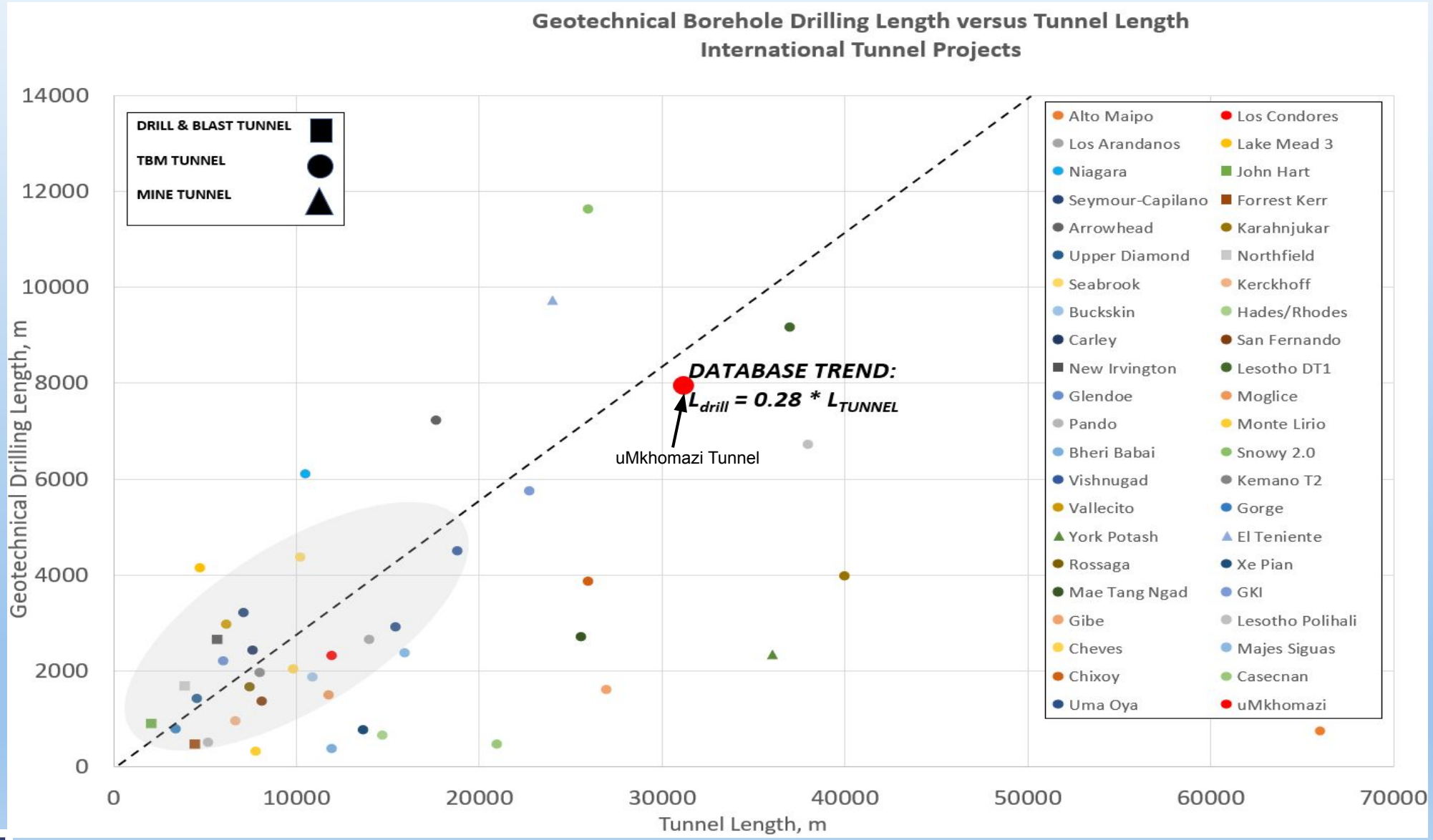
- ERT Geophysics
- Significant Lineament at K
- Dyke, multiple ‘Fingers’
- With multiple faults, weathered dolerite and sedimentary rock.
- Appears to be a approx. 7 dip to the West, normal fault???



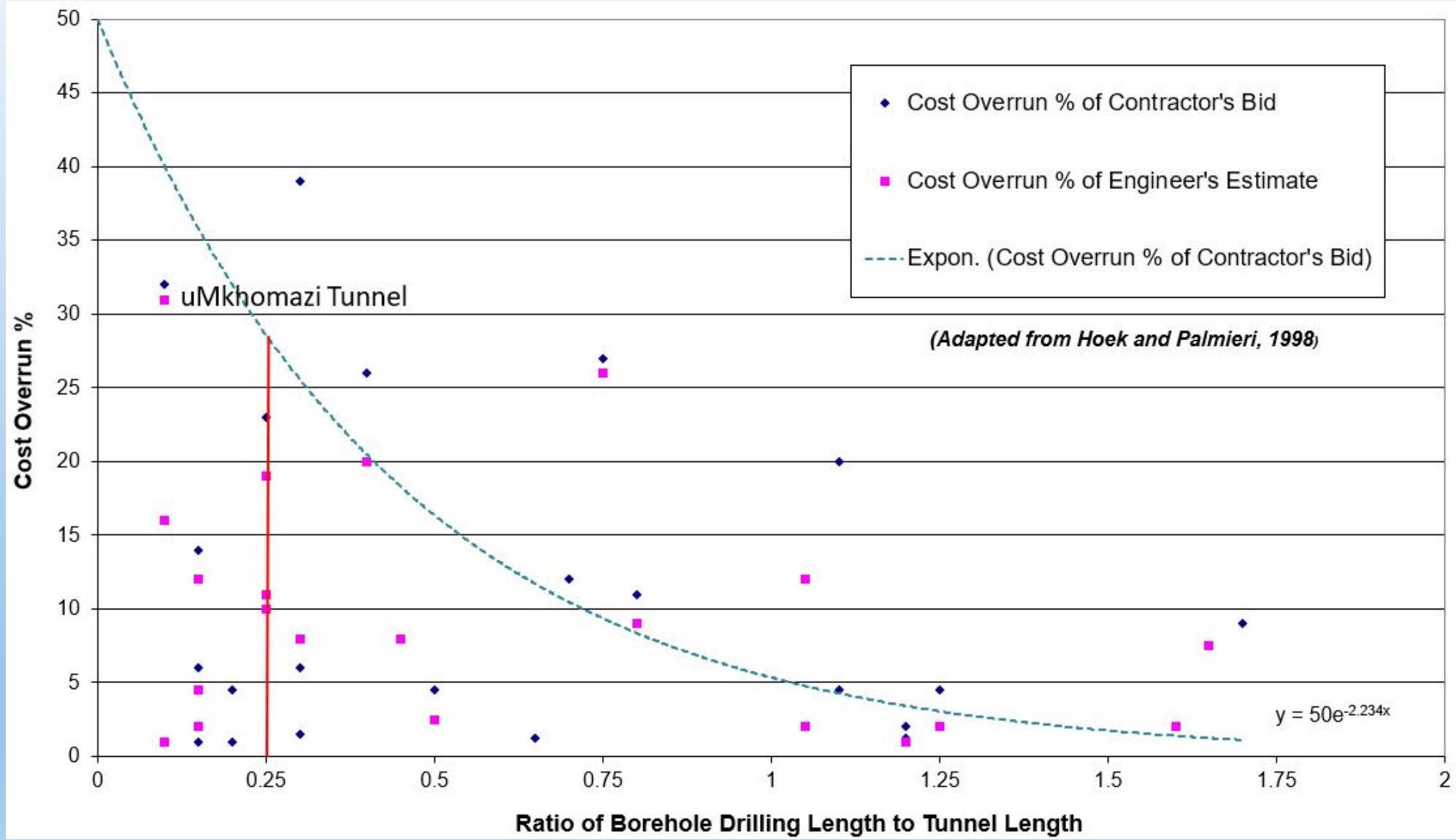
Geotechnical Investigations

- Openground Software used.
- All logging on tablets.
- Data management efficiencies.
- Direct import to modelling software.
- Reduce double handling.
- BUT teething issues.

Geotechnical Investigations

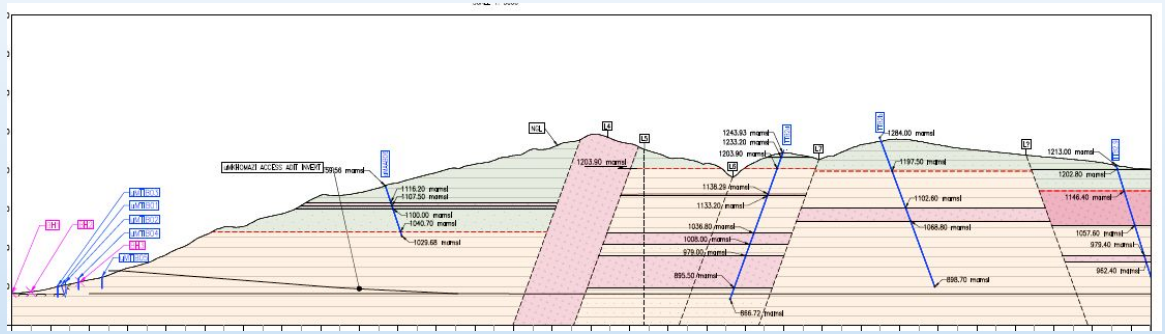


Geotechnical Investigations



Geotechnical Investigations

- **No minimum investigation specifications.**
- **Existing Benchmarks typically drill m vs tunnel m or % cost of project.**
- **Factors affecting extent of investigation:**
  - **Tunnel cover depth/ variability.**
  - **Tunnel length.**
  - **Tunnel type.**
  - **Critical associated infrastructure (i.e., large galleries, underground caverns, shafts, etc.)**
  - **Tunnelling method.**
  - **Geological, structural geological and hydrogeological complexity.**
  - **The occurrence of (i.e., density) of major geological structures and lineaments intersected by the proposed tunnelling route.**
  - **Proximity of the proposed underground works to existing tunnels, and the quality/transferability of legacy data.**
  - **Consequence class (design life, service criticality) and risk appetite.**
  - **Seismicity and in situ stress relevance.**



Recommendations

- **Risk-index based approach:**

Index Level	Project Characteristics	Borehole:Tunnel Length Ratio	Budget (%)	Investigation Requirements
Low	• Simple geology • Shallow cover depth • Existing tunnels & quality data • Low consequence • Drill & blast	0.1–0.3	0.3–0.7%	• Basic geophysics • Limited in-situ testing
Moderate	• Typical geology • Moderate cover depth • Nearby tunnels (poor/limited data) • Low-moderate consequence • Drill & blast	0.3–0.5	0.7–1.0%	• Moderate geophysics • Laboratory testing • In-situ testing
High	• Complex geology • High cover depth • Few regional tunnels • High consequence • TBM	0.5–0.8	1.0–1.5%	• Extensive geophysical, lab & in-situ testing • Stress measurements • TBM drillability suite (UCS, CERCHAR, DRI/BWI/CLI) • Systematic packer/pumping tests • Long-term groundwater monitoring
Very High	• Extreme/complex geology • High cover depth • No previous data • High consequence • TBM	≥0.8	≥1.5%	• Extensive geophysical, lab & in-situ testing • 2D/3D resistivity/tomography • Pilot adits/shafts (consider) • Contingency for additional investigations

Acknowledgements

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Q&A

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