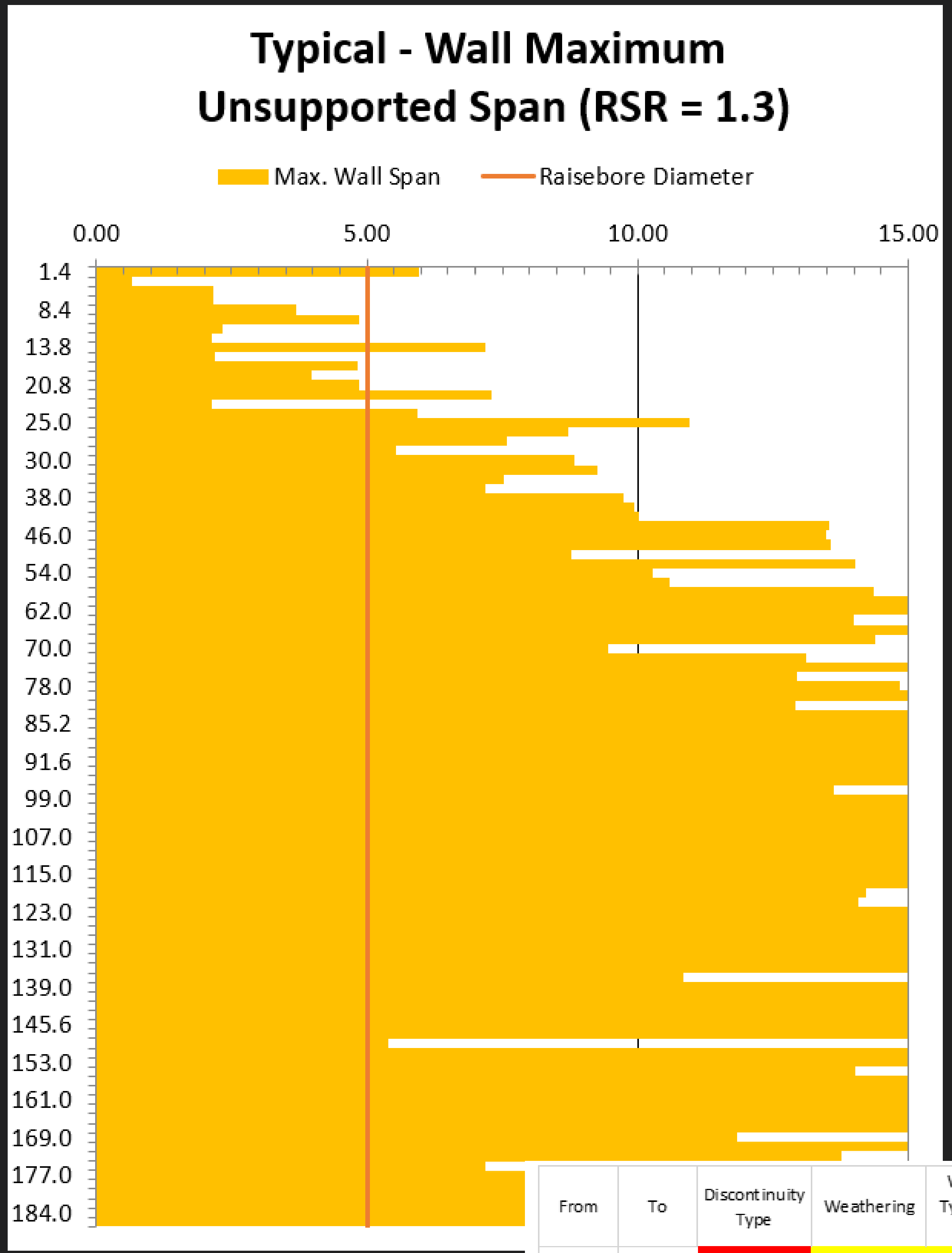
RAISEBORE DESIGN AND BACK ANALYSIS
THE MGT WAY
EAGCG WORKSHOP 2 MARCH 2023
JOHN PLAYER AND PETER EVANS

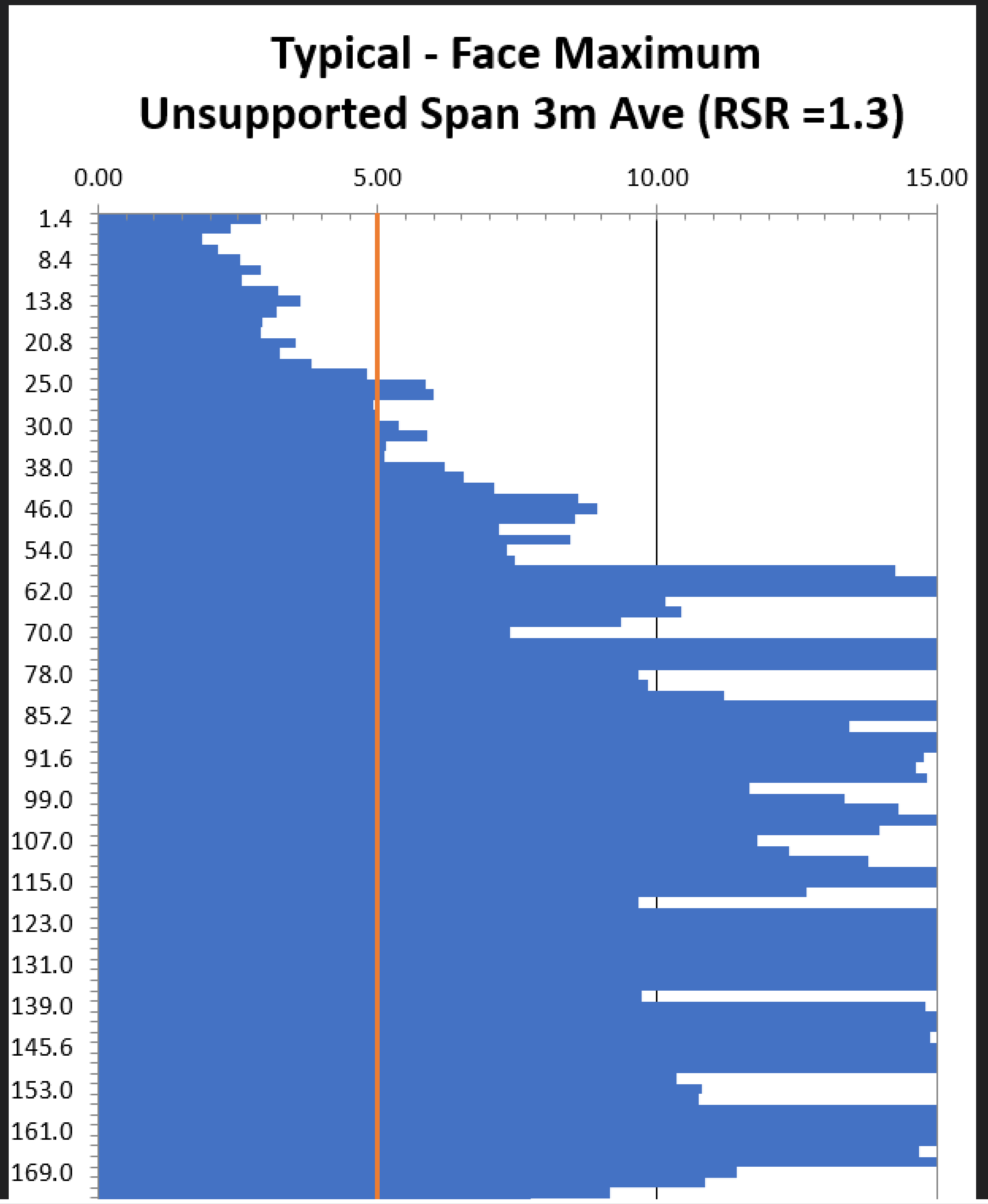
MINEGEOTECH
MAXIMISING VALUE THROUGH INNOVATION

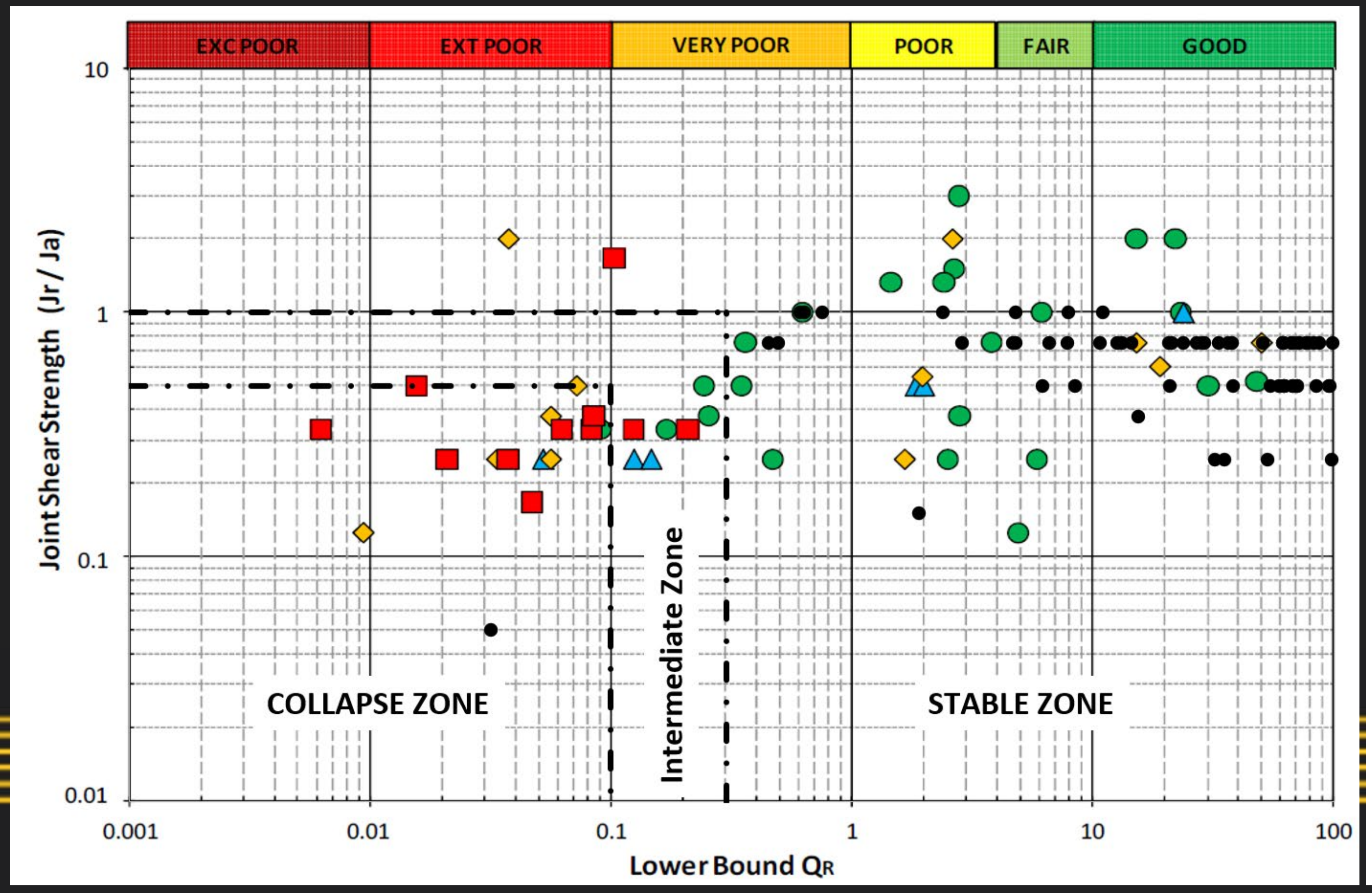
MINELiDAR

MCCRACKEN AND STACEY

- Contractors and Engineers are used to the results
- Q-system based rock mass classification from a geotechnical investigation hole or generalized from rockmass logging
  - Worse and typical conditions per domain
- Generalised kinematic setting using other data sources due to challenges in core orientation in vertical holes
- Smoothing an important part of the input
- Material Properties
  - UCS testing
  - Contractor testing - RBi
- “Stable” is not no overbreak, but a stable final shape
- Output
  - stable dimensions
  - Empirical comparisons

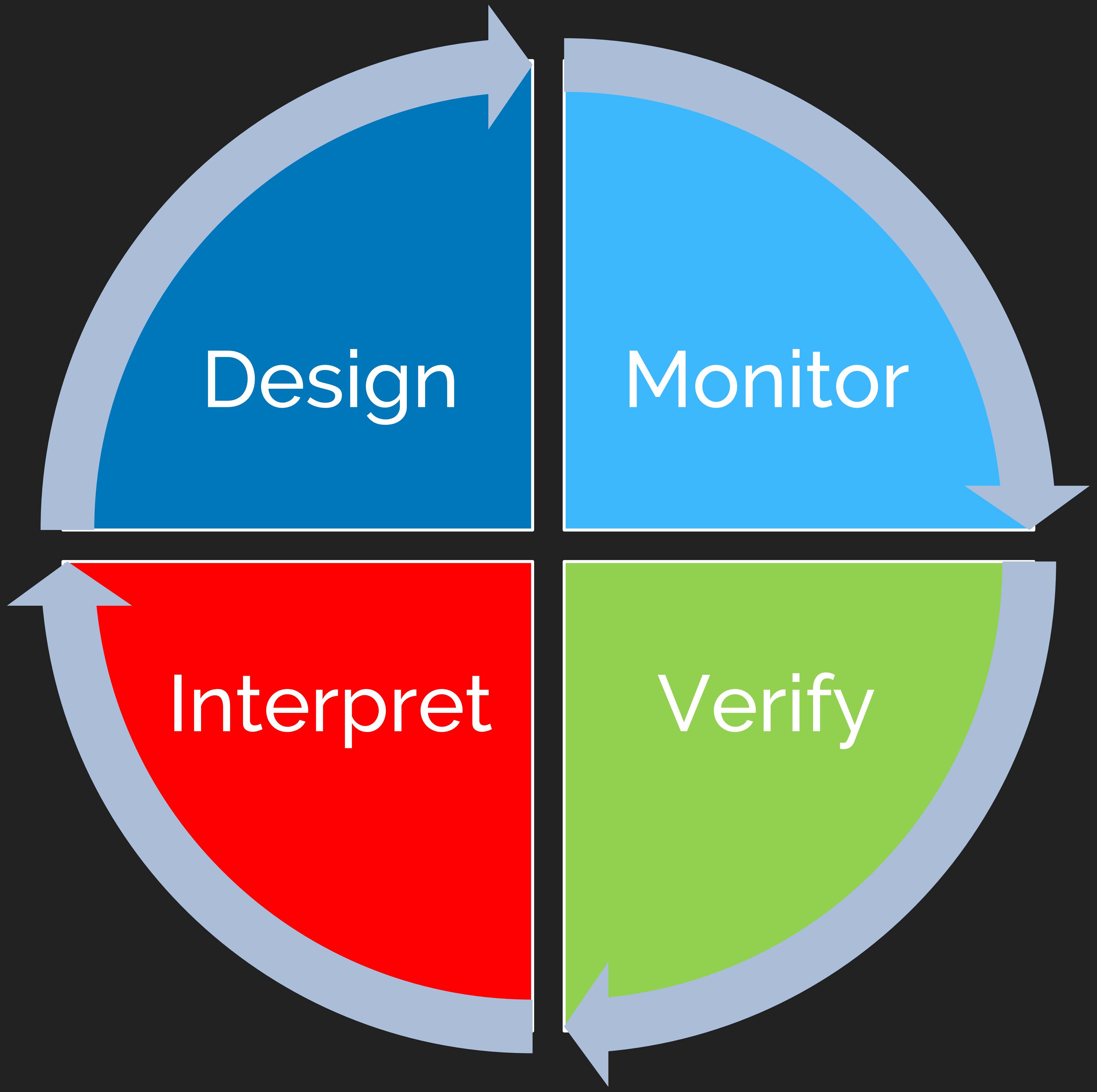






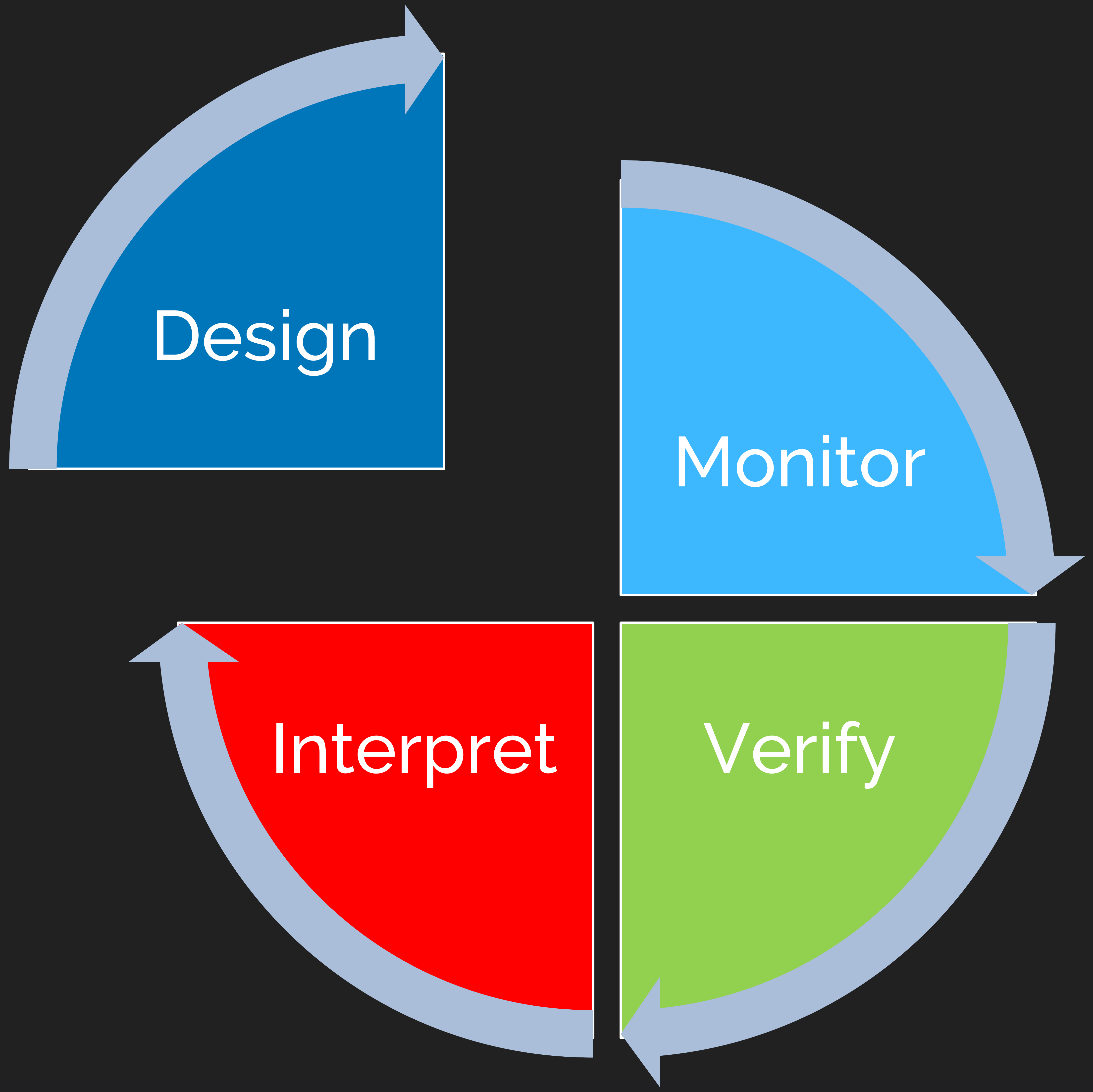
From	To	Discontinuity Type	Weathering	Wall - Qr Typical 3m Ave	Wall - Qr Worse 3m Ave	Face - Qr Typical 3m Ave	Face - Qr Worse 3m Ave	Wall - Max Span Typical 3m Ave	Wall - Max Span Worse 3m Ave	Face - Max Span Typical 3m Ave	Face - Max Span Worse 3m Ave	RQD/Jn vs Qr	Jr/Ja vs Qr
0	1.4	SAP	MW	3.7	3.7	3.7	1.3	4.4	4.4	2.9	2.9	STABLE	STABLE
1.4	3	SAP	MW	2.0	2.0	2.0	0.8	3.4	3.4	2.4	2.4	UNSTABLE	UNSTABLE
3	4.5	SAP	MW	0.5	0.5	0.5	0.4	1.9	1.9	1.9	1.9	STABLE	STABLE
4.5	6.4	SAP	MW	1.0	1.0	1.0	0.6	2.6	2.6	2.1	2.1	STABLE	STABLE
6.4	8.4	SAP	MW	2.5	2.5	2.5	0.9	3.7	3.7	2.5	2.5	STABLE	STABLE
8.4	10.2	JOI	SW	3.5	3.5	3.5	1.3	4.3	4.3	2.9	2.9	STABLE	STABLE
10.2	11.2	JOI	SW	2.0	2.0	2.0	1.0	3.5	3.5	2.6	2.6	STABLE	STABLE
11.2	12.5	JOI	SW	4.1	1.0	4.1	0.6	4.6	2.6	3.2	2.1	STABLE	STABLE
12.5	13.8	JOI	SW	5.9	1.1	5.9	0.6	5.3	2.7	3.6	2.1	STABLE	STABLE
13.8	15.5	JOI	SW	4.2	1.7	4.2	0.8	4.6	3.2	3.2	2.3	STABLE	STABLE
15.5	17.4	JOI	SW	3.6	3.6	3.6	1.3	4.3	4.3	2.9	2.9	STABLE	STABLE
17.4	19	JOI	SW	3.7	3.7	3.7	1.3	4.4	4.4	2.9	2.9	STABLE	STABLE
19	20.8	JOI	SW	6.1	6.1	6.1	2.1	5.4	5.4	3.5	3.5	STABLE	STABLE
20.8	21.35	JOI	SW	4.6	4.6	4.6	1.7	4.8	4.8	3.3	3.2	STABLE	STABLE
21.35	22.4	JOI	SW	7.1	7.0	7.1	2.6	5.7	5.7	3.8	3.8	STABLE	STABLE
22.4	24	JOI	SW	12.9	12.8	12.9	4.6	7.2	7.2	4.8	4.8	STABLE	STABLE
24	25	JOI	FR	21.7	21.7	21.7	7.7	8.9	8.9	5.9	5.9	STABLE	STABLE
25	26.6	JOI	FR	22.9	22.9	22.9	8.1	9.1	9.1	6.0	6.0	STABLE	STABLE
26.6	28	JOI	FR	14.1	14.1	14.1	5.0	7.5	7.5	4.9	4.9	STABLE	STABLE
28	28.9	JOI	FR	14.5	14.5	14.5	5.1	7.6	7.6	5.0	5.0	STABLE	STABLE
28.9	30	JOI	FR	17.4	17.4	17.4	6.2	8.2	8.2	5.4	5.4	STABLE	STABLE
30	32	JOI	FR	21.8	21.2	21.8	7.5	8.9	8.8	5.9	5.8	STABLE	STABLE
32	34	JOI	FR	15.6	13.2	15.6	4.7	7.8	7.3	5.1	4.8	STABLE	STABLE
34	36	JOI	FR	15.4	14.8	15.4	5.2	7.8	7.6	5.1	5.0	STABLE	STABLE
36	38	JOI	FR	25.0	25.0	25.0	8.8	9.4	9.4	6.2	6.2	STABLE	STABLE
38	40	JOI	FR	28.5	28.5	28.5	10.1	9.9	9.9	6.5	6.5	STABLE	STABLE
40	42	JOI	FR	34.6	34.6	34.6	12.2	10.7	10.7	7.1	7.1	STABLE	STABLE
42	44	JOI	FR	56.3	56.3	56.3	19.9	13.0	13.0	8.6	8.6	STABLE	STABLE
44	46	JOI	FR	61.6	61.6	61.6	21.7	13.5	13.5	8.9	8.9	STABLE	STABLE
46	48	JOI	FR	55.2	55.2	55.2	19.5	12.9	12.9	8.5	8.5	STABLE	STABLE
48	50	JOI	FR	35.6	35.6	35.6	12.6	10.9	10.9	7.2	7.2	STABLE	STABLE
50	52	JOI	FR	53.7	51.1	53.7	18.0	12.8	12.5	8.4	8.3	STABLE	STABLE
52	54	JOI	FR	37.5	27.2	37.5	9.6	11.1	9.7	7.3	6.4	STABLE	STABLE
54	56	JOI	FR	39.4	36.8	39.4	13.0	11.3	11.0	7.4	7.2	STABLE	STABLE
56	58	JOI	FR	199.2	89.8	199.2	31.7	21.6	15.7	14.2	10.4	STABLE	STABLE
58	60	JOI	FR	618.9	181.3	618.9	64.0	34.0	20.8	22.4	13.7	STABLE	STABLE
60	62	JOI	FR	251.1	141.7	251.1	50.0	23.7	18.9	15.6	12.4	STABLE	STABLE

RAISEBORE DESIGN AND BACK ANALYSIS, THE MGT WAY



- Design
  - Empirical (M&S) or
  - Appropriate Failure criterion with discrete structures in 3D inelastic models
- Monitor
  - Water loss
  - Seismicity generated
  - Rig data (often hard to get due to contractor protection)
  - Oversize reporting to bottom of the raise
- Verify
  - Video
  - Lidar scan for “as built”
    - Water ingress on structure, stress breakout, blocky fall out

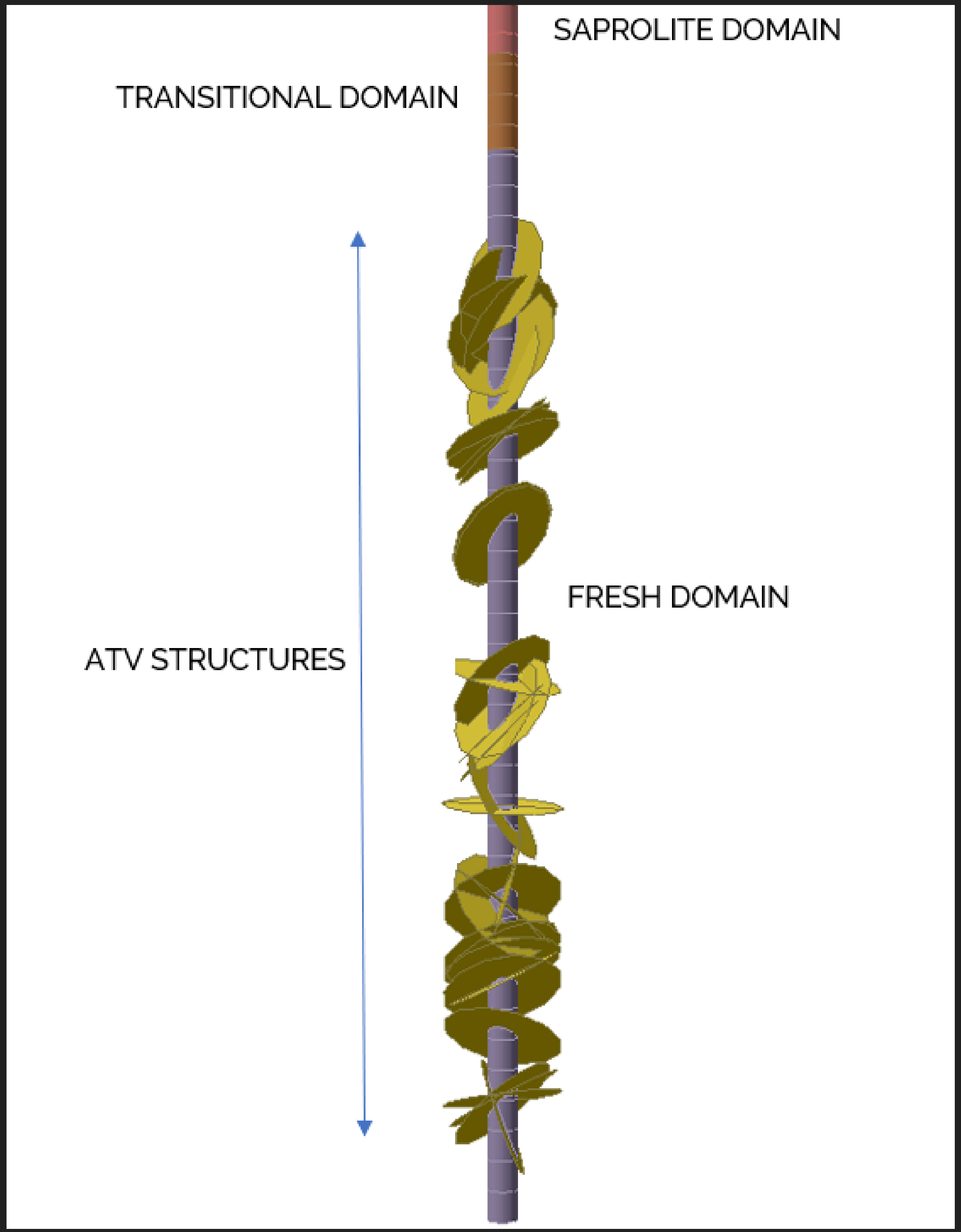
DESIGN



DESIGN – ROCK MASS FAILURE CRITERION 3D INELASTIC MODELLING 2020'S

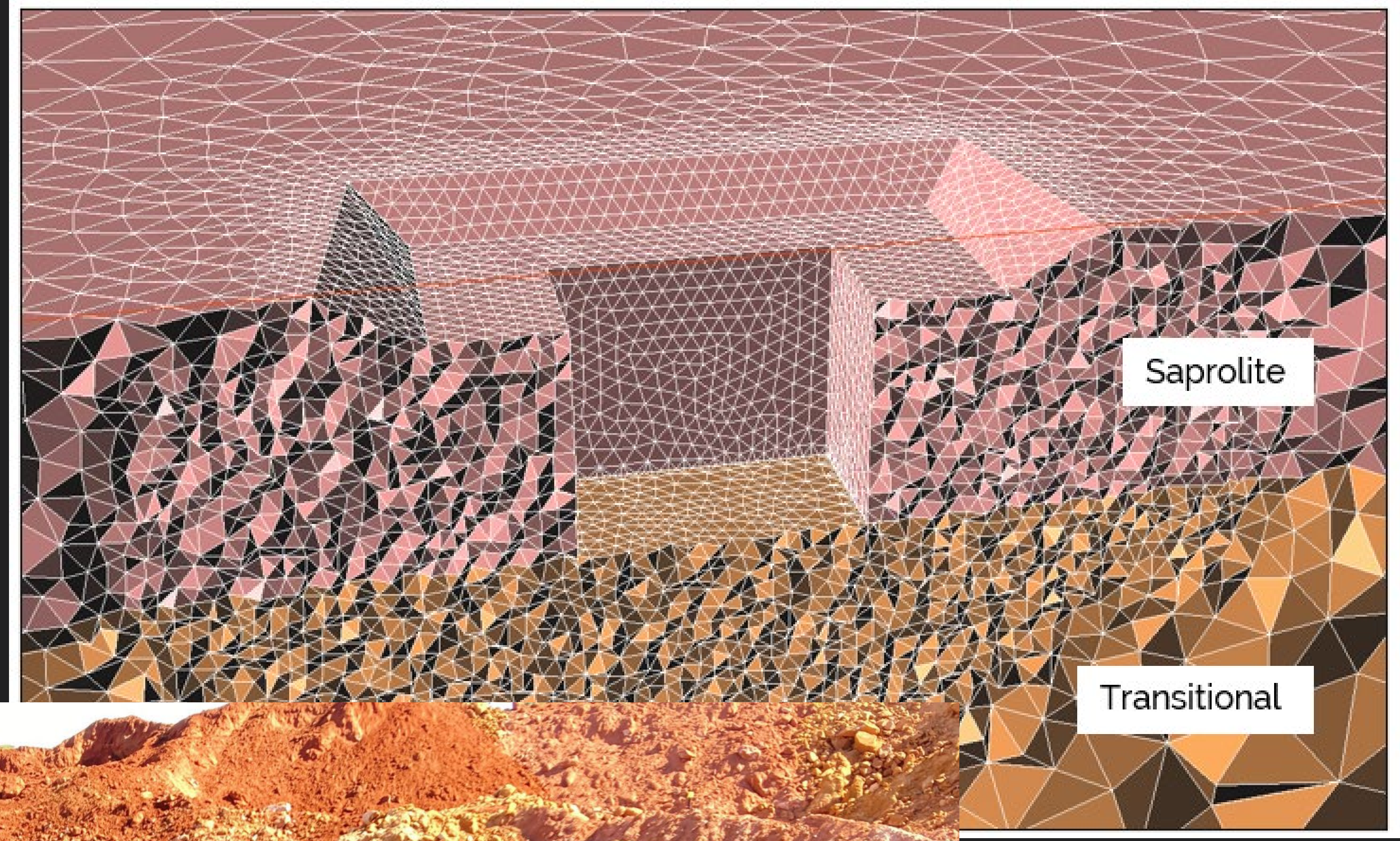
- What is the geological, hydrogeological and mine setting / purpose of the raise
- What are the infrastructure / collar requirements of the raise ?

- Geotechnical investigation hole along axis of raise
  - ATV-OTV down the drill hole
    - Discrete structural orientations from ATV-OTV
    - Properties from logging
  - Geotechnical logging of core establishing domains
  - Consolidated drained triaxial testing in "soils"
  - Hoek Cell single stage triaxial and BDT testing in rock (trans and fresh)
  - Appropriate Failure Criterion in 3D inelastic models



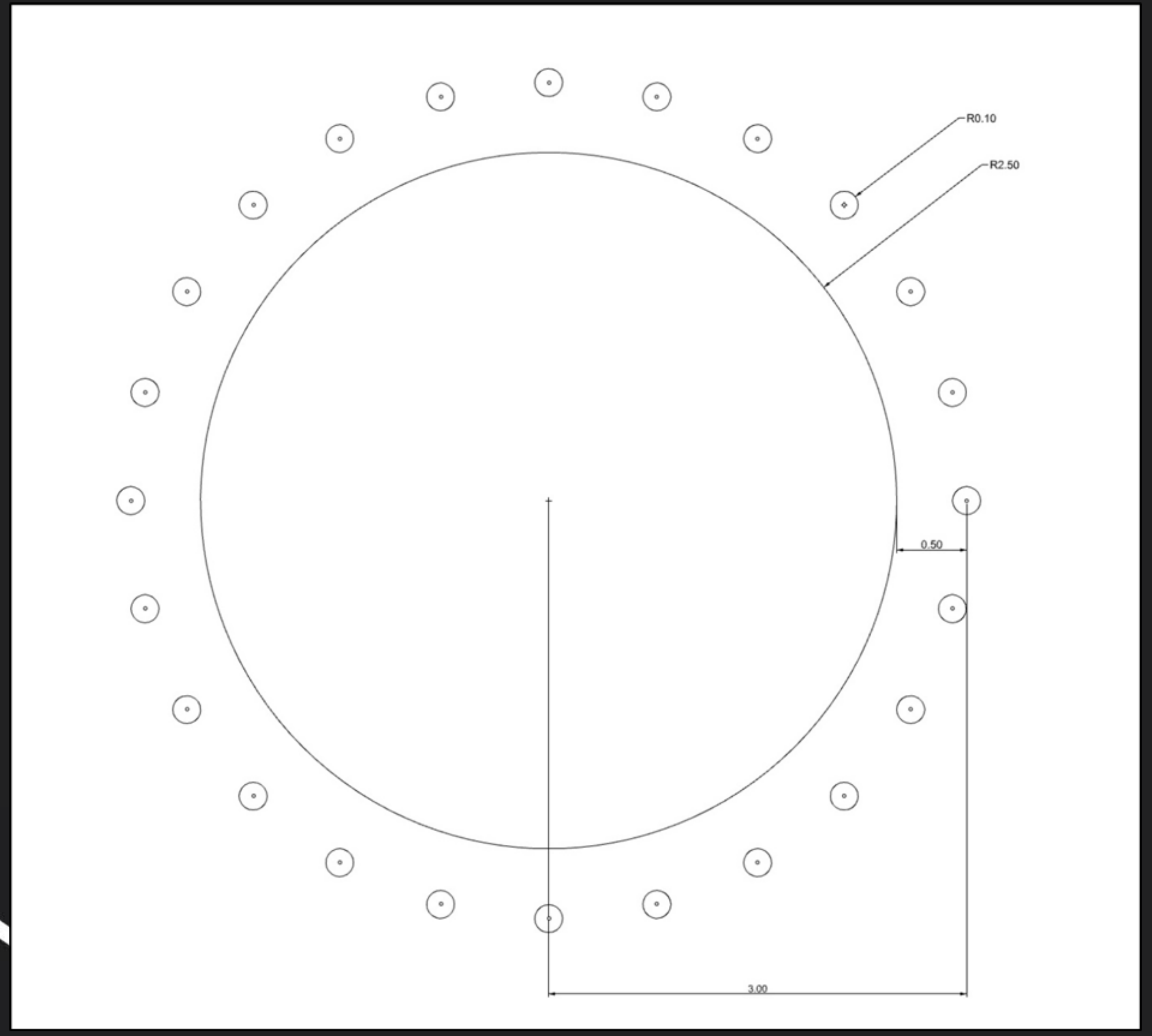
DESIGN – ROCK MASS FAILURE CRITERION 3D INELASTIC MODELLING 2020'S

- Mohr-Coulomb for "soils"
  - Consolidated drained testing for material properties
    - Use variance as applicable
  - Establish water table
  - Socket Design for excavation (Stress reduction factor approach) when weak saprolite not stable to raisebore
  - Mass concrete pour



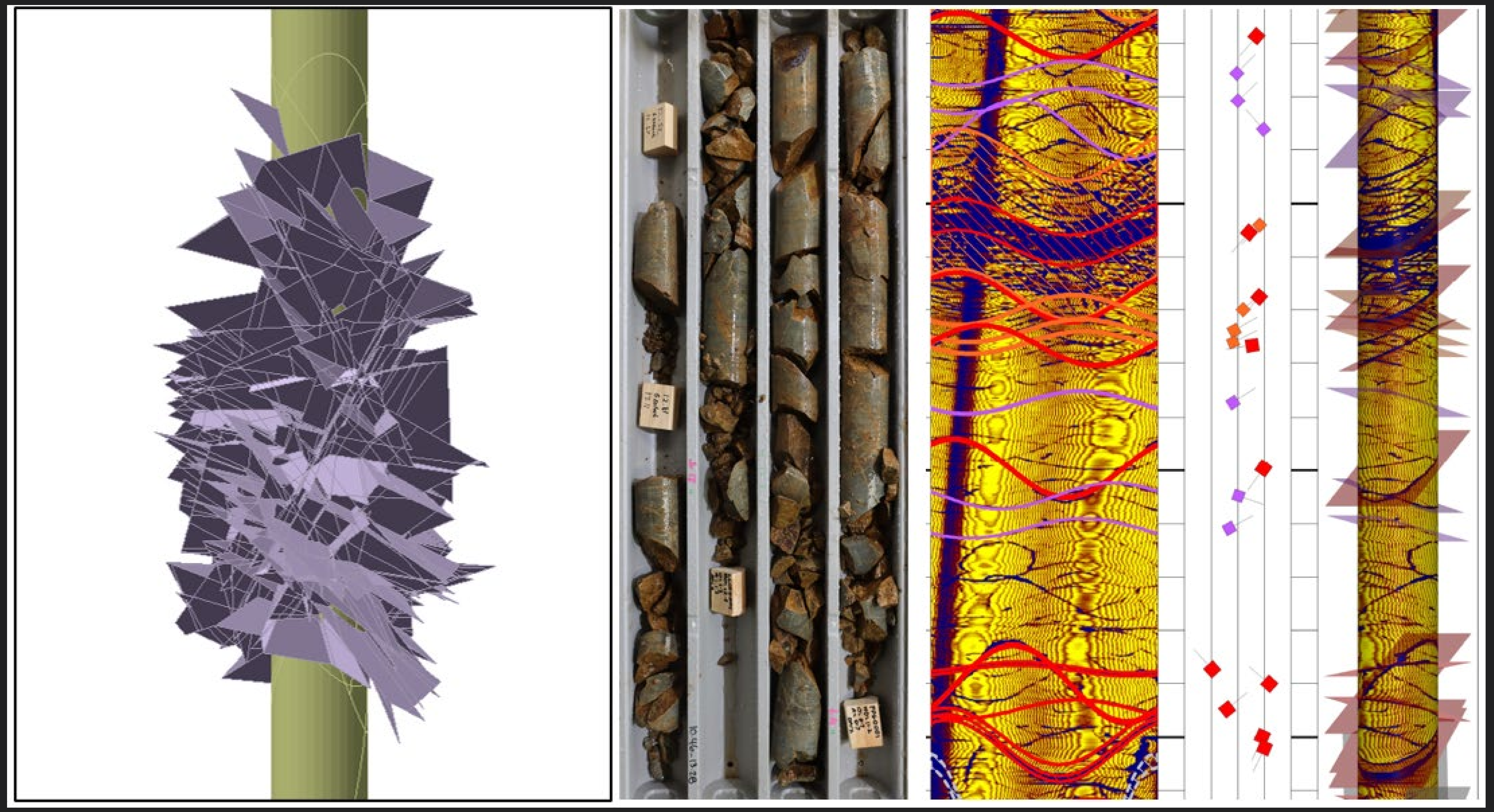
DESIGN – ROCK MASS FAILURE CRITERION 3D INELASTIC MODELLING 2020'S

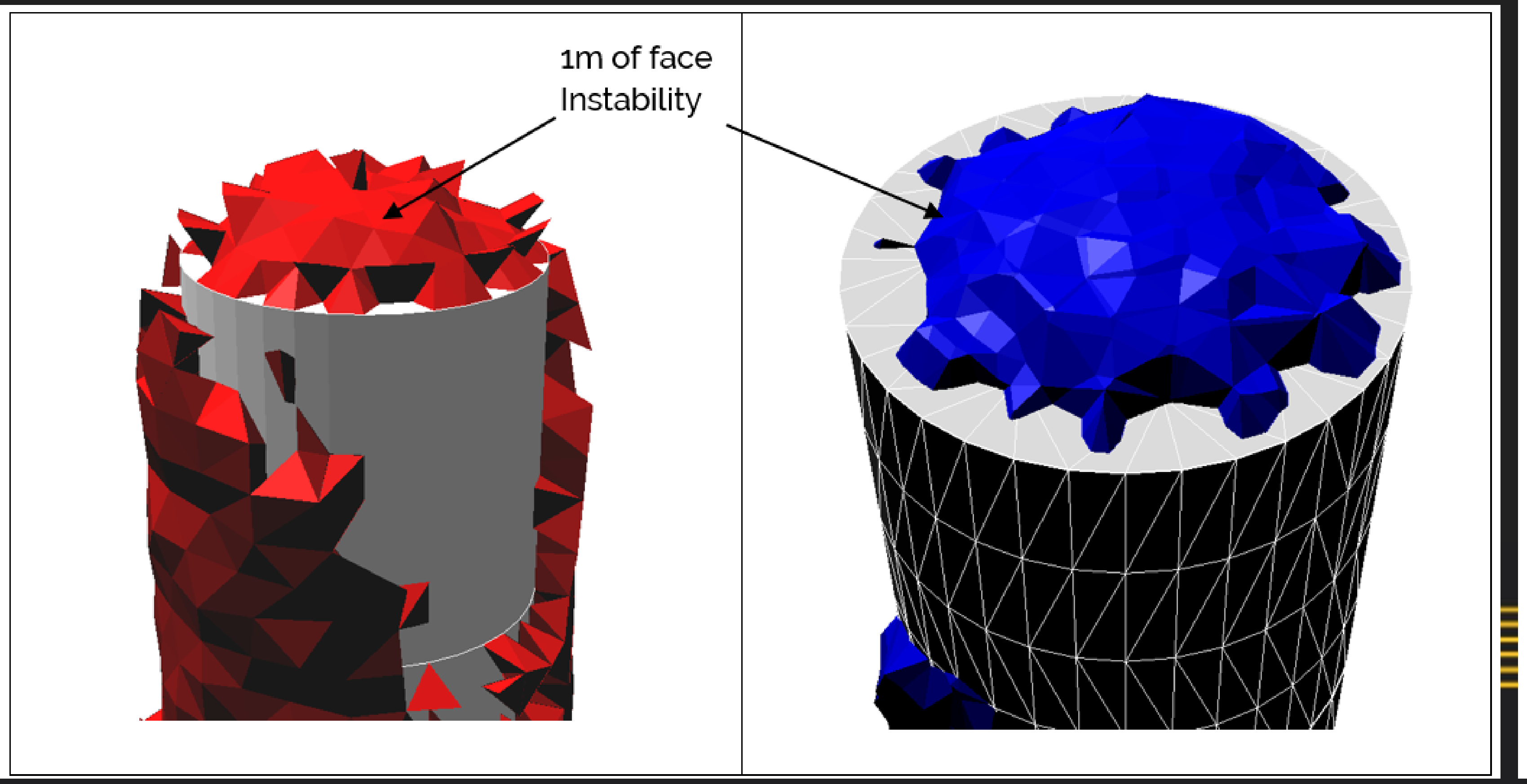
- Mohr-Coulomb for "soils"
  - Pile design - connection from mass concrete into transitional
    - Spacing related to structural spacing from ATV
    - Every second hole drilled and then installed, grouted, then repeat
    - Temporary prior to shotcrete spray

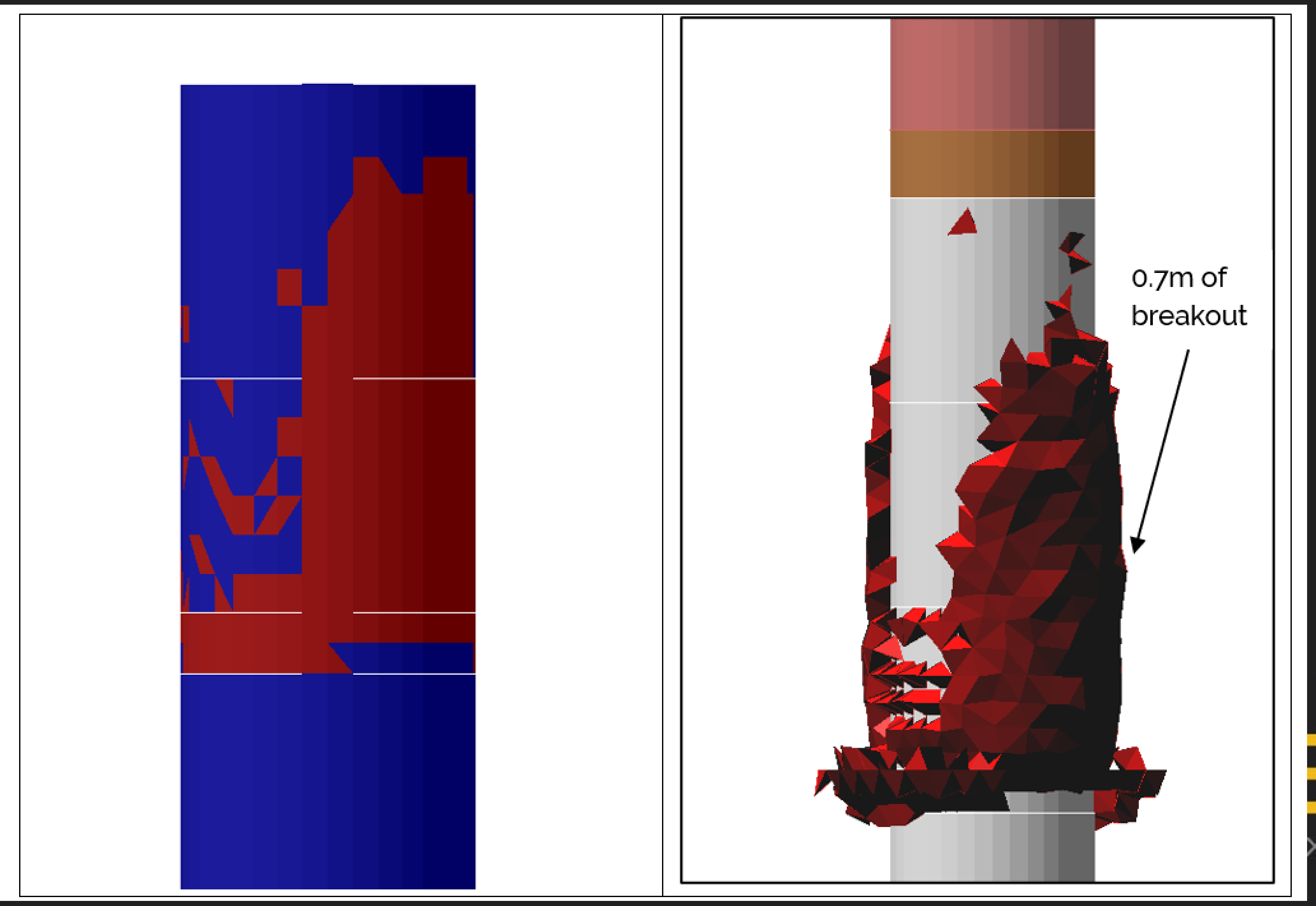


DESIGN – ROCK MASS FAILURE CRITERION 3D INELASTIC MODELLING 2020'S

- Transitional rock mass
  - Structure from ATV-OTV
  - Cannot generate mesh in the model
  - Take a rock mass approach with GSI from logging (Hoek et al 2013)
- Unstable in model from element yield and volumetric strain
- Breakout modelled without piles
- Face stability also tested by staging the model and establishes a zone for not lowering the head

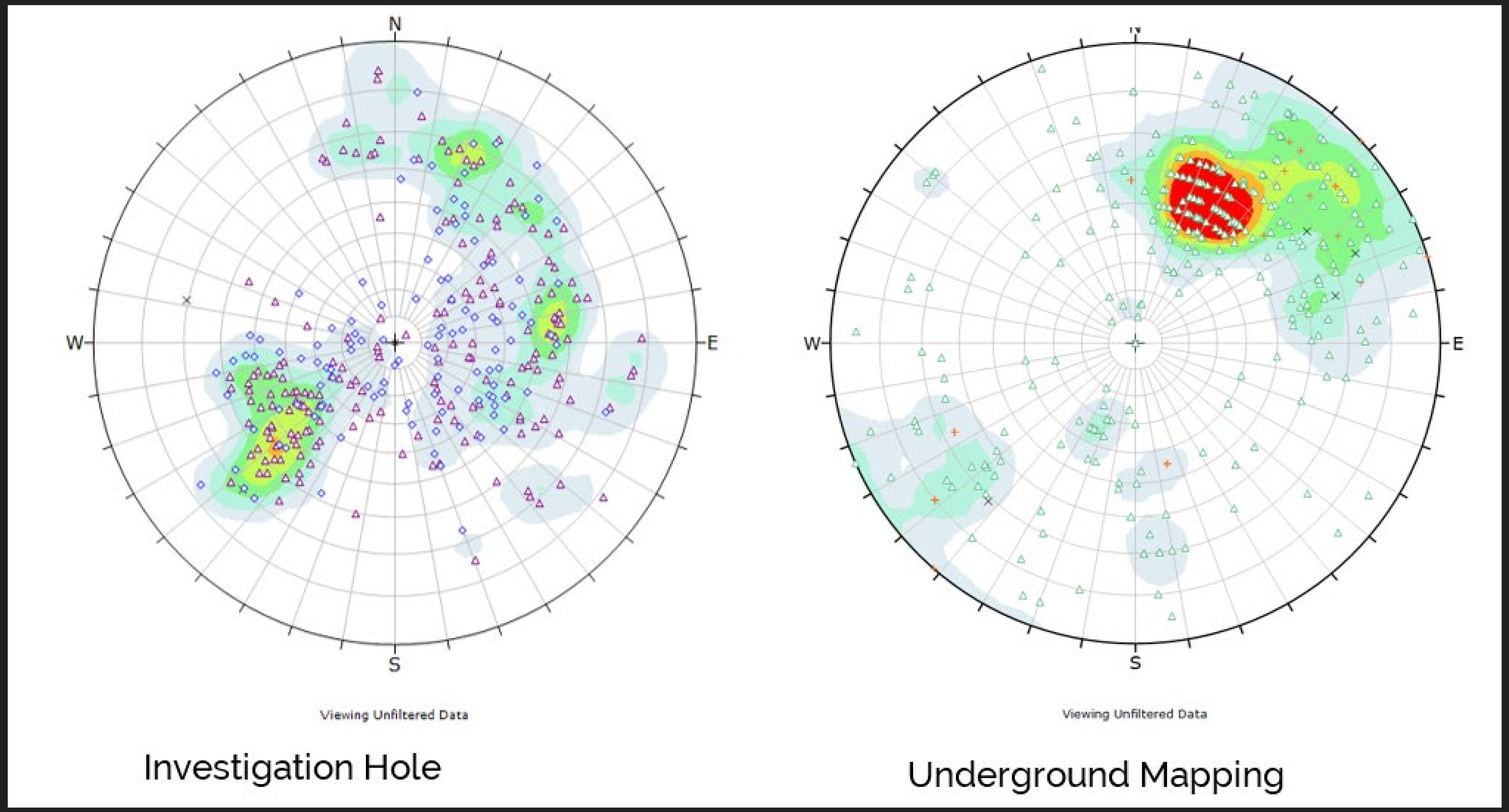


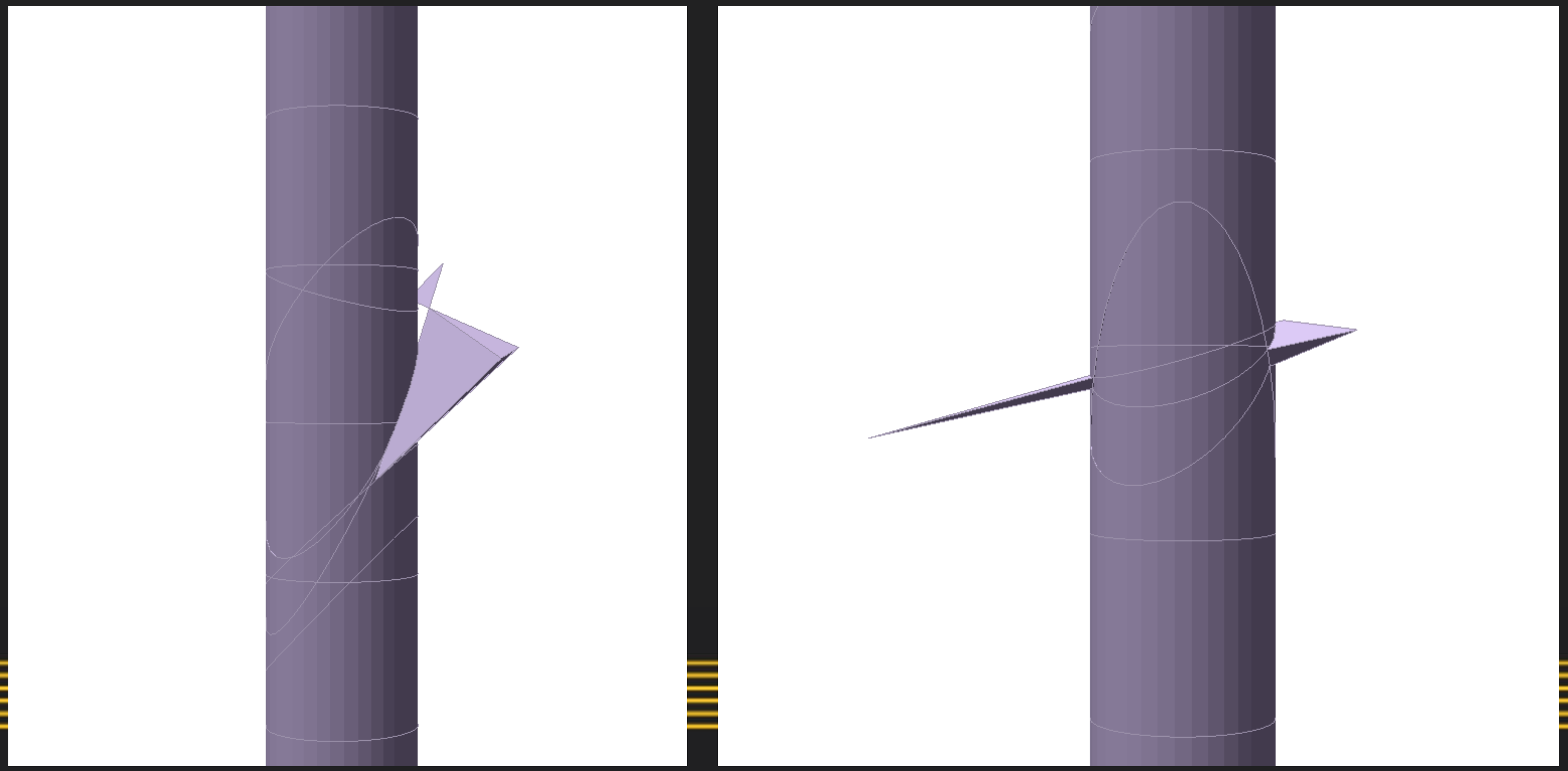


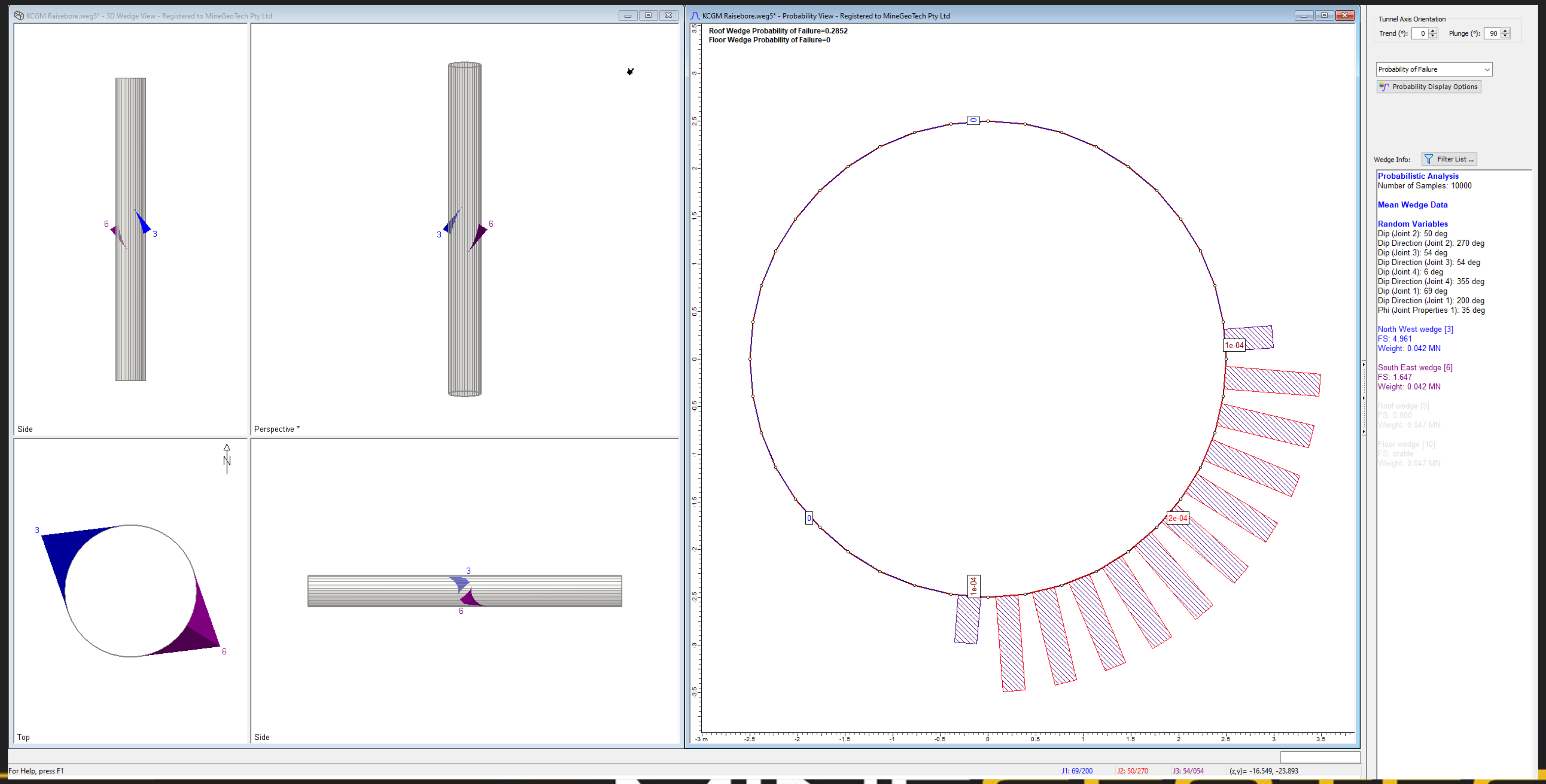


DESIGN – ROCK MASS FAILURE CRITERION 3D INELASTIC MODELLING 2020'S

- Fresh rock
  - Discrete structures built within the model allows testing for kinematically unstable blocks
  - Compare the investigation hole with other data sources
  - Resolved blocks that are present but unable or can enter the raise for walls and face
    - Consider probabilistic and discrete approaches
  - Remaining raise is tested for yielded elements considering structure properties and factor of safety

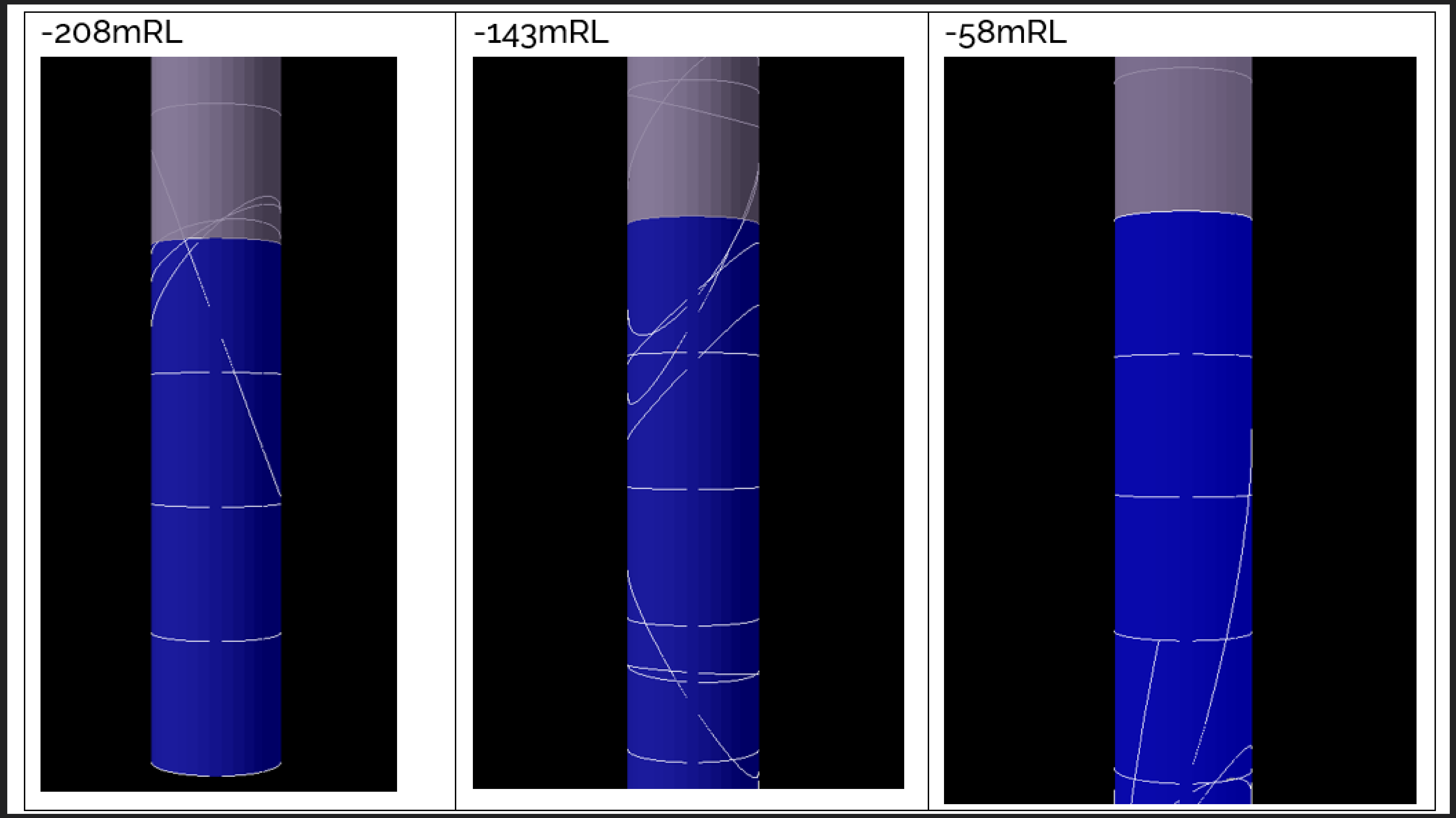


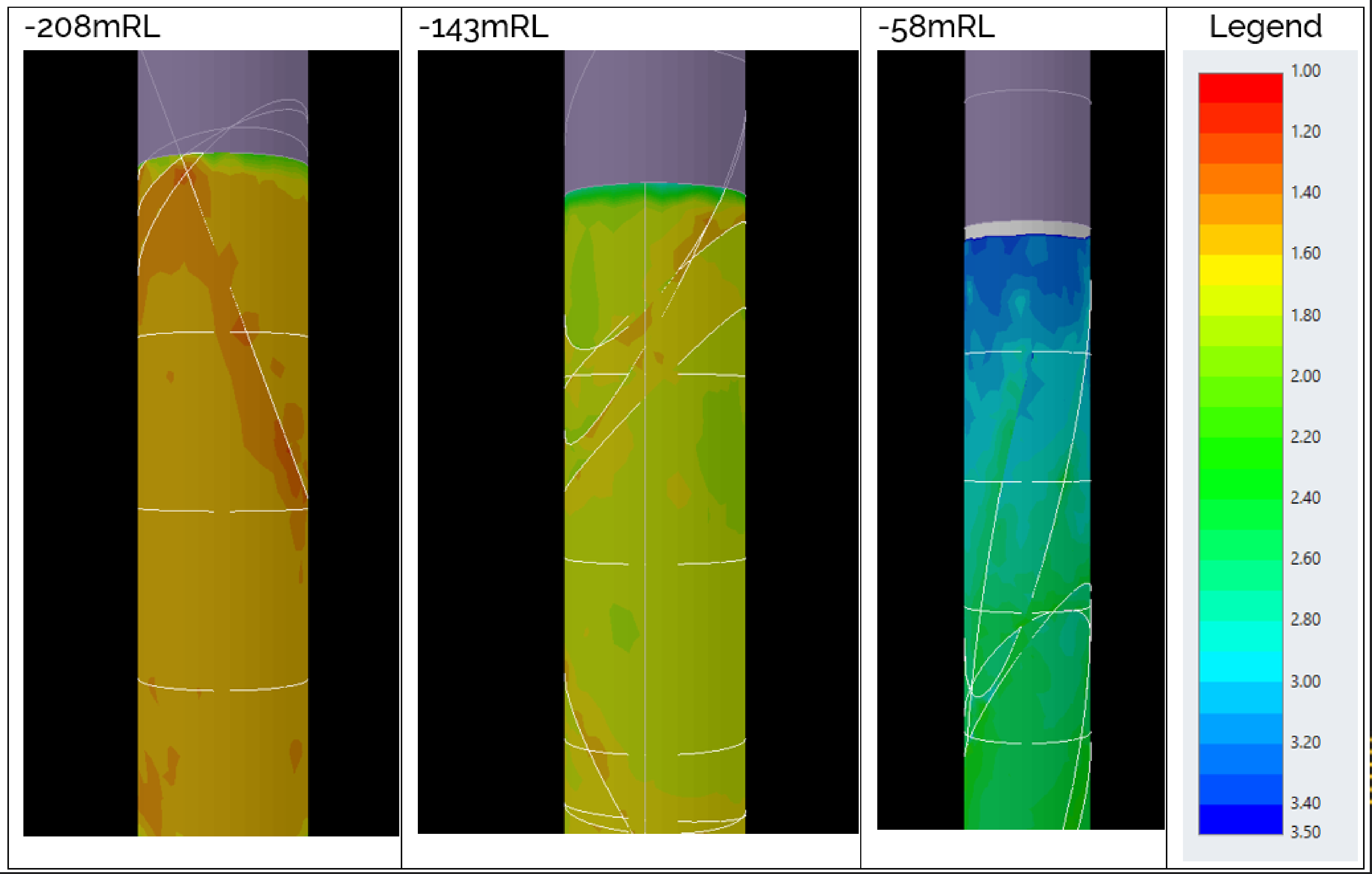




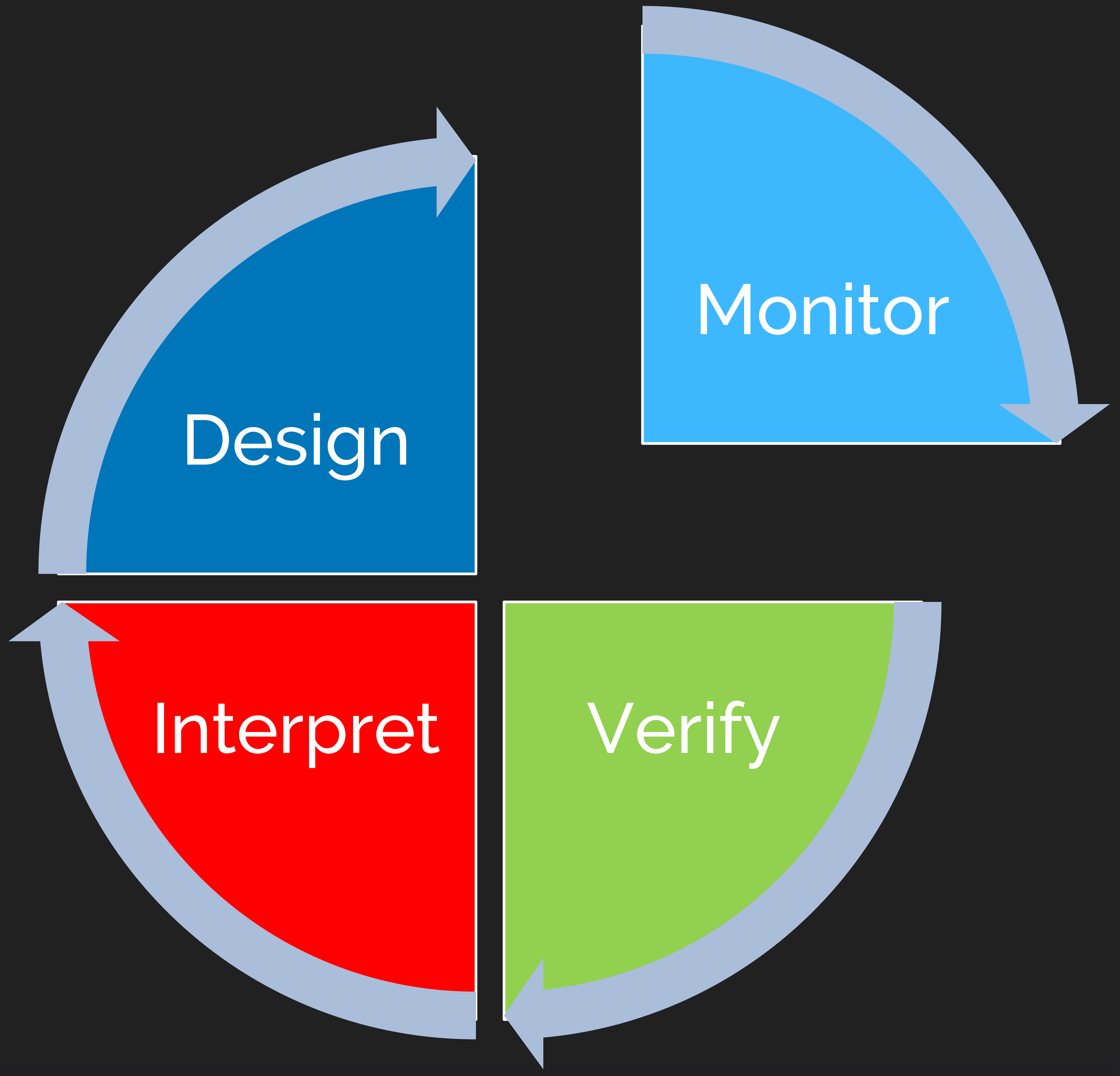
DESIGN – ROCK MASS FAILURE CRITERION 3D INELASTIC MODELLING 2020'S

- Fresh rock
  - Review intact failure modes on triaxial samples and establish variance or upper and lower bounds
  - Establish stress settings to test the model over
  - Raise is tested for yielded elements considering structures properties and factor of safety (then consider volumetric or shear strain as required and appropriate (massive – anisotropic rockmass)
  - In this case – no damage is forecasted in the fresh rock





MONITOR



MONITORING

- Drillers records
  - Shift advance
  - Rig details
  - Drillers ground conditions
- Seismic activity when reaming
- Water loss when drilling (how much grout is added to control water loss)
  - investigation hole
  - Pilot hole
- Water ingress
  - investigation hole, piloting, reaming

Water loss on fault

MONITORING – DRILLERS PLOD

DAILY DRILLING SUMMARY

RIG No. RB07

DATE: 16-01-20 SITE:

HOLE DESCRIPTION: Length 163.23 (8M COP) Diameter 4.5M

OPERATORS: D/S.... N/S

RB 74390

	Drilling Time	Pilot Advance	Reaming Advance	Manhours	No. of Men	Rod Handling	RUC Delays	Machine Servic	Mine Delay	Rig Up	Rig Down
DAY SHIFT	8.10		2.59M	24	2	·20	1.00	·30	2.00		
NIGHT SHIFT	6·10		3.02	~~84~~ 12	~~8~~ 1	·20	·50	·30	4·10		
TOTAL	14.20		5.61	36	3	·40	1.50	1.00	6.10		
PROGRESSIVE	397.00		108.82			77.50	298.50	60.40	332.10		

Rig Information	Min	Max
Pen Rate	39	45
Thrust	50	250
Torque - MPa	50	140
~~Hour Meter~~ RPM	0.5	3

Pre-starts	D	N
Rig	✓	
LV	✓	
Kubota / IT	✓	
Area Inspect	✓	

Float Box %	
D	90%
N	90%

Day Shift Serial No.	Rod Length	Serial No.	Rod Length
TE-013	1.07		
RUC-1219	1.52		

Night Shift Serial No.	Rod Length	Serial No.	Rod Length
RUC-1315	1.52		
RUC-1104	1.50		
RUCC-018	N/C		

TIME FROM	TIME TO	RUC DELAY REASON D/S	RUC DELAY REASON N/S	TIME FROM	TIME TO	MINE DELAY REASON D/S	MINE DELAY REASON N/S
		08:00-08:30 = travel	19:30 - 20:00 Travel check B/T			06:30-07:30 = Meeting	18:30-1900 · Meeting
		17:30-18:00 = travel	03:00 - 03:20 check B/T Travel			07:50-08:00 = Re-entry	19:00-1930 · Re-entries
						13:00-18:30 = E.O.S	0320 - 0630 - Wait on bogger

REMARKS: D/S - Continue Back Ream
N/S - Continue Back Ream - check B/T Top LHS Wall Fail at Breakthrough, called shiftboss, wait on bog out

SITE FOREMAN MINE MANAGER

Raisebore Penetration Rate

DATE: 16-01-20 SITE: SHIFT: Day RIG: R07 OPERATOR:

ROD No	ROD Length	Depth	Start time	Finish time	Drill time	Torque	Weight	rpm	Pen/r	Breakout / Ground conditions
TE-013	1.07	104.28	09:00	11:20	2.20	50-140	200-250	2-3	45	Blocky / Good
RUC-1219	1.52	105.80	11:30	14:50	3.20	50-130	200-250	2-3	45	Blocky / Good
RUC-1315	1.52	N/C	15:00	17:30	2.30	40-130	200-250	2·3	—	non complete
										Blocky / Good

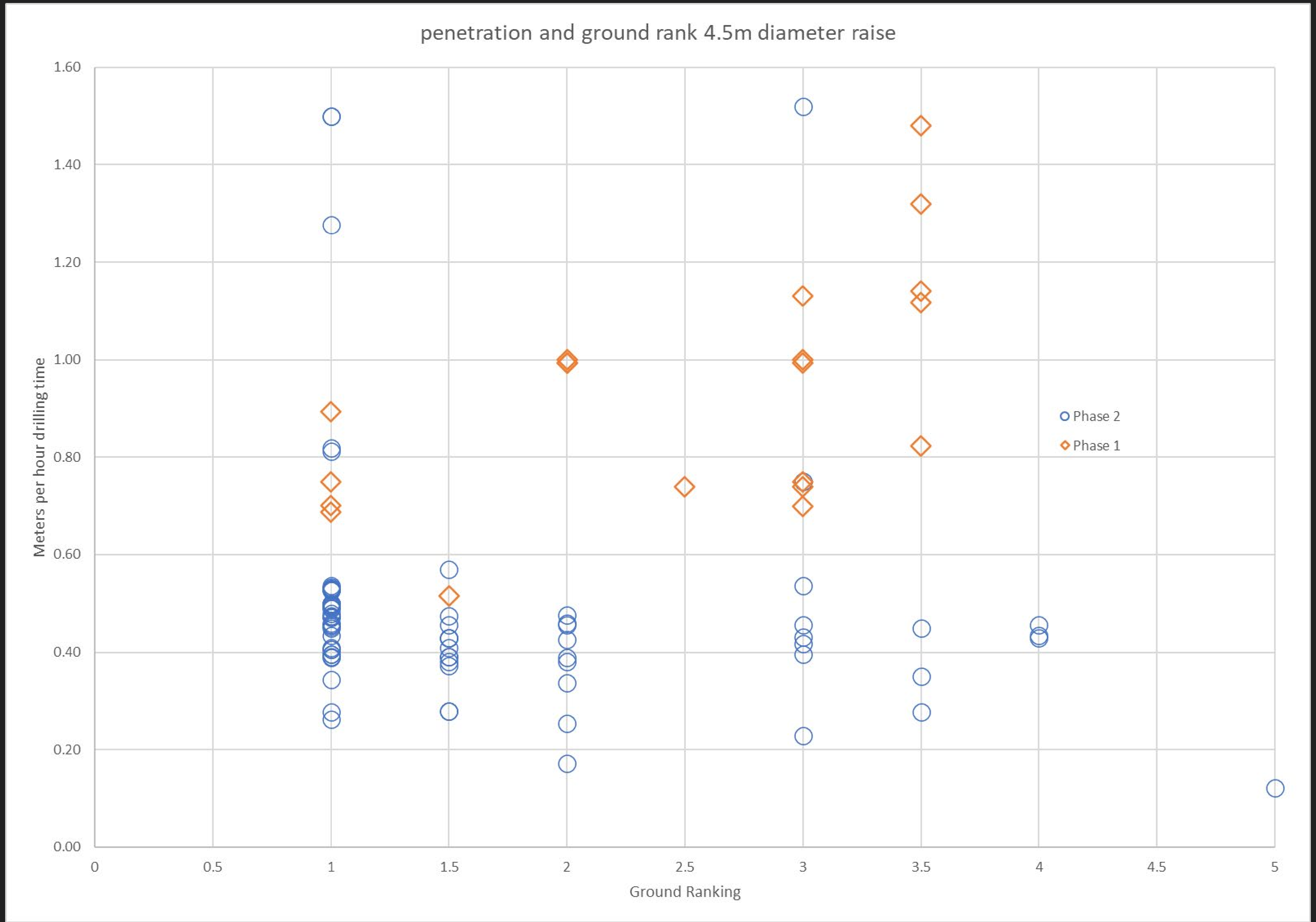
SIGN:

SHIFT: Night OPERATOR:

ROD No	ROD Length	Depth	Start time	Finish time	Drill time	Torque	Weight	rpm	Pen/r	Breakout / Ground conditions
RUC-1315	1.52	107.32	0830	1030	2.00	50-100	50-70	0.5-1	N/C	Blocky Ground
RUC-1104	1.50	108.82	1040	0230	3.50	50-130	70-250	0.5-3	39	Blocky at the start / Good Ground
RUCC-018	1.51	N/C	0240	0300	·20	60-110	70-100	0.5-1	N/C	Blocky Ground
										Non-complete

SIGN:

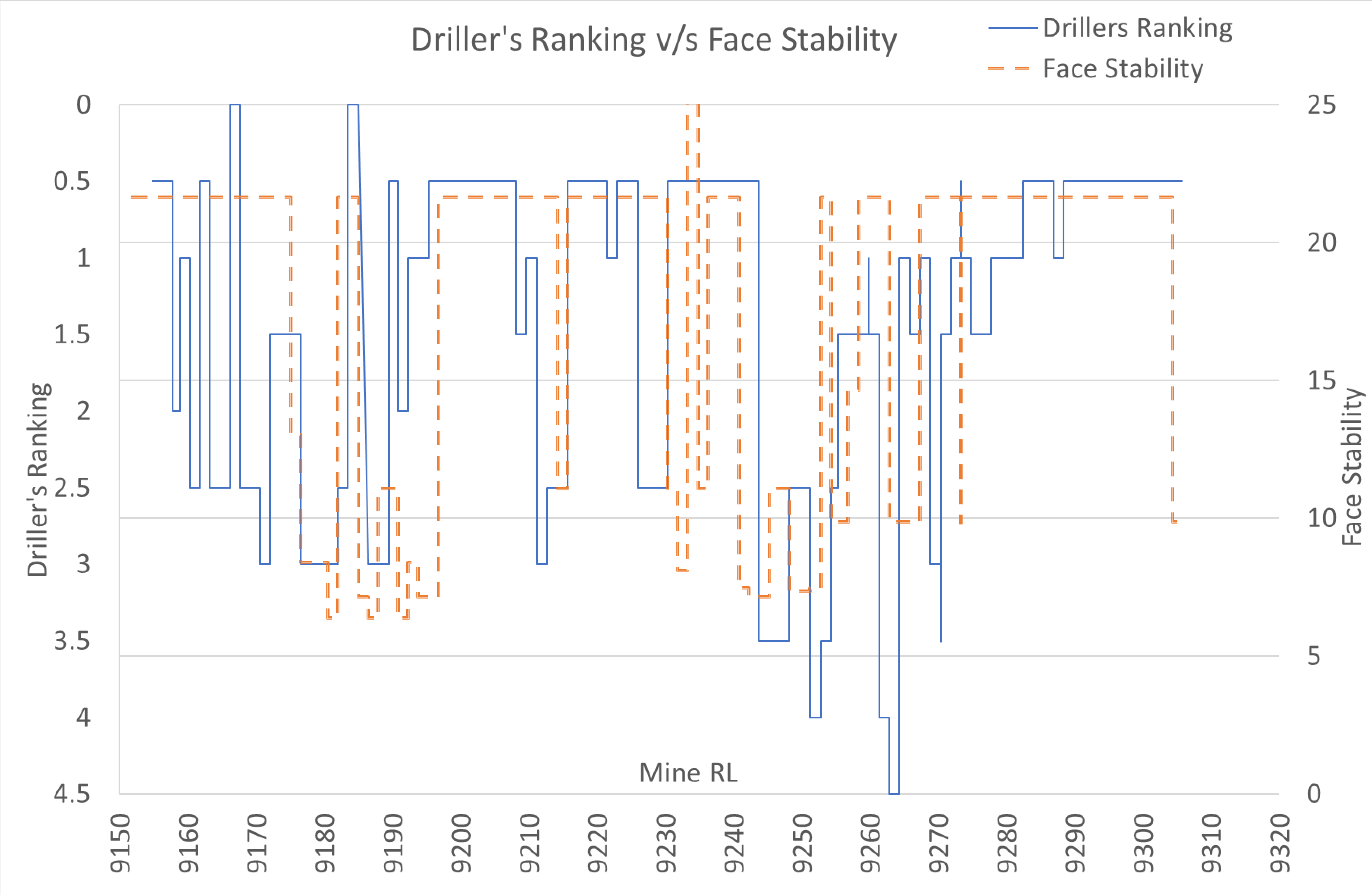
MONITORING – DRILLERS PLOD



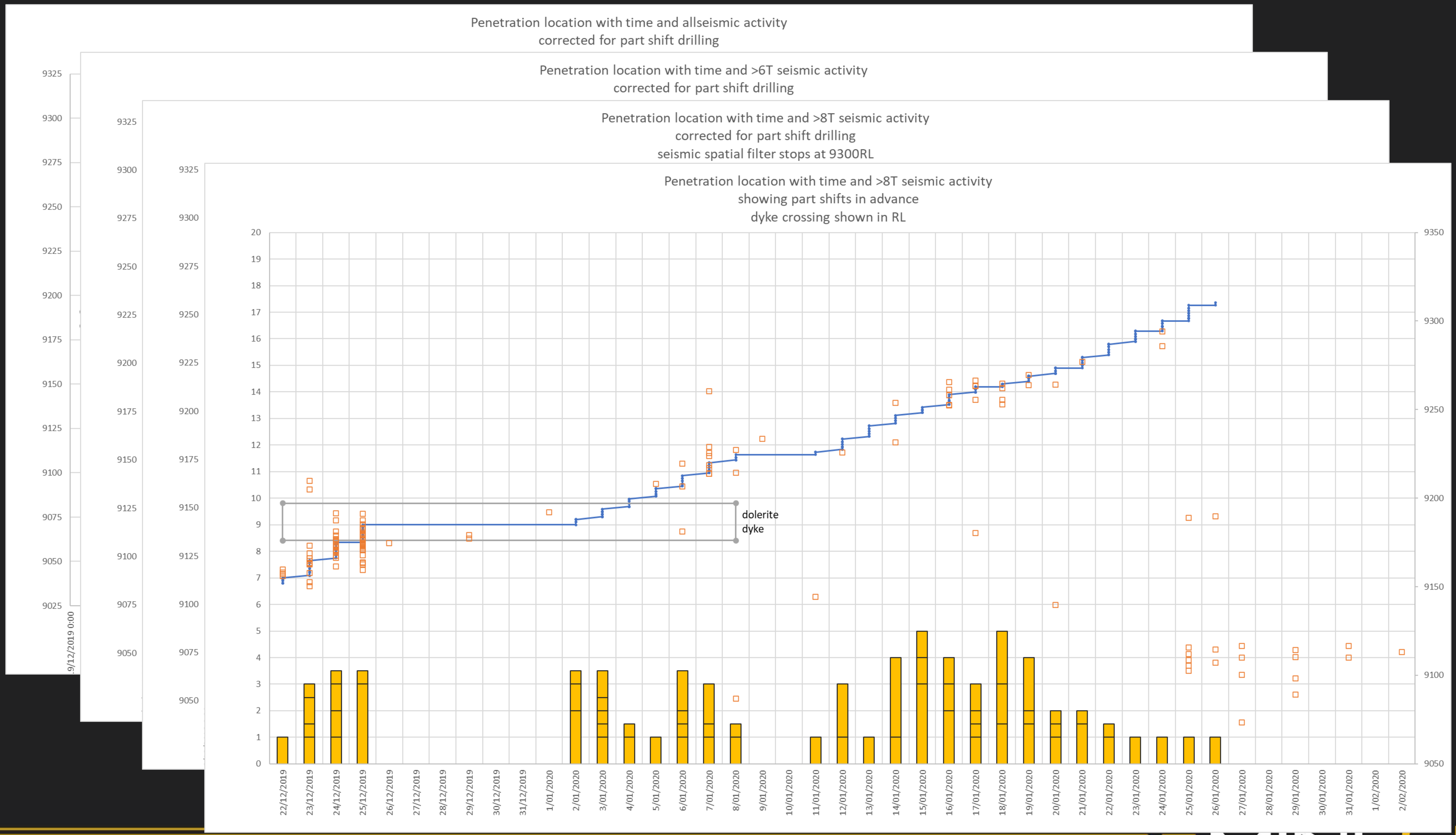
Drillers Comment	Ground Ranking
Good Ground / competent ground	1
Good / blocky ground Blocky patches / good	1.5
Blocky ground	2
Blocky broken ground Very blocky ground	3
Blocky broken ground rock stuck on reamer Broken soft	3.5
Lost face Broken Ground 3 & 4 stalls	4
Very broken blocky ground multiple stalls Spud in / face kept falling away, very blocky big slabs	5

Penetration rate is not necessarily related to the ground conditions at the face

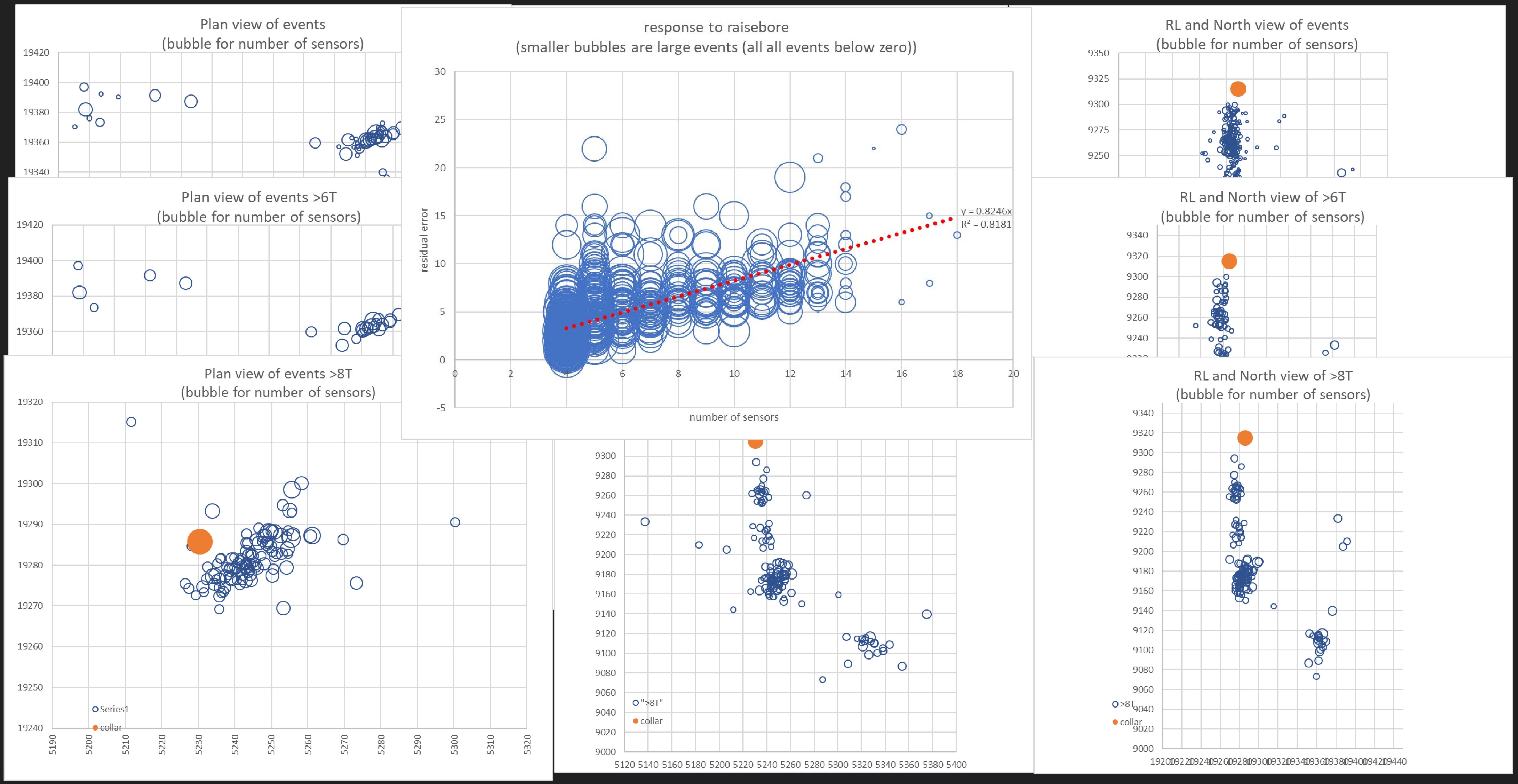
MONITOR – DRILLERS PLODS AND M&S FACE STABILITY SPAN



MONITORING - SEISMIC RECORDS – FILTER THE AREA – NUMBER OF TRIGGERS



MONITORING - SEISMIC RECORDS – FILTER THE AREA – NUMBER OF TRIGGERS



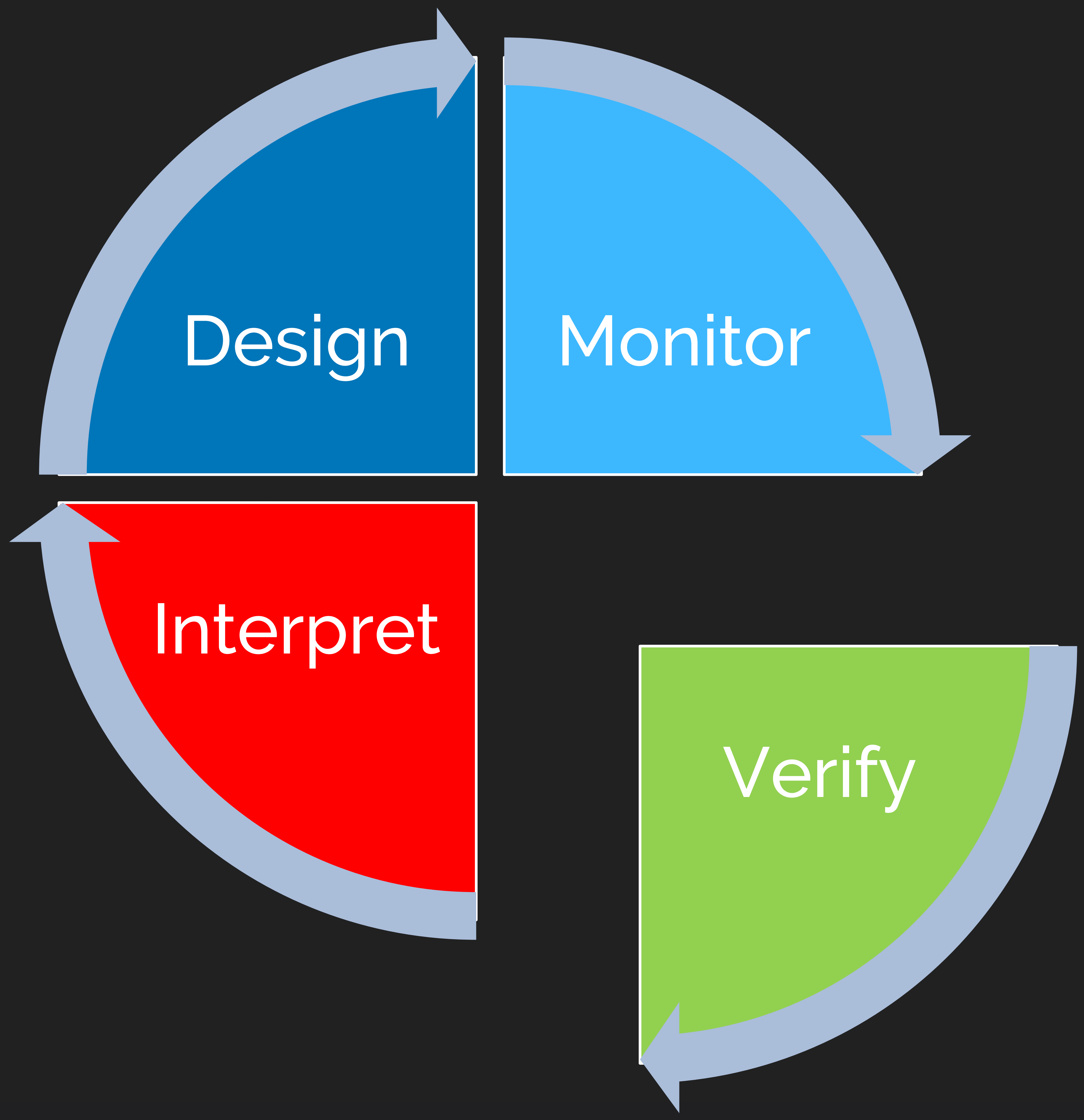
MINELiDAR

VERIFY

Safe access

High resolution spatial data can be delivered with support analysis and interpretation

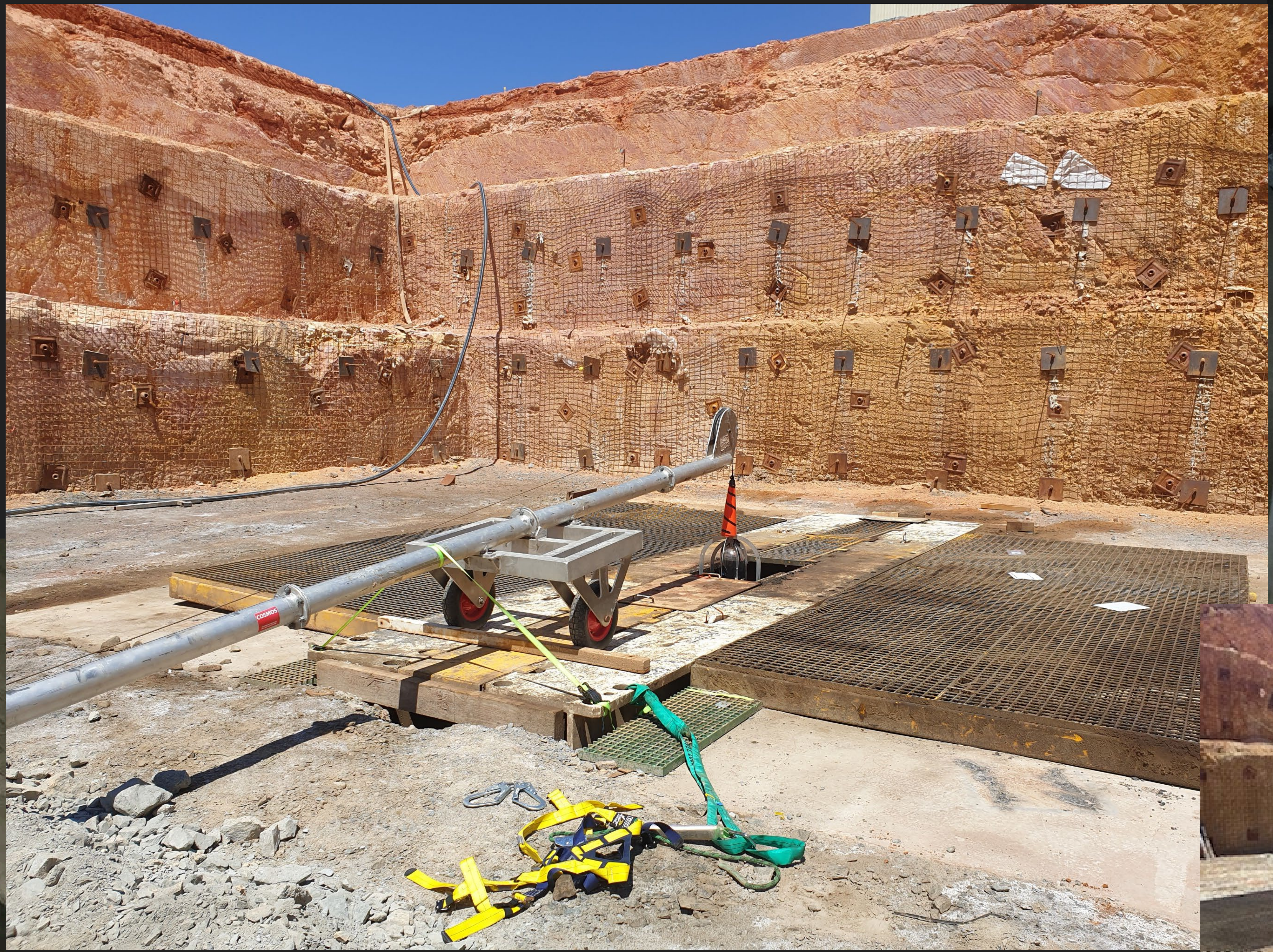
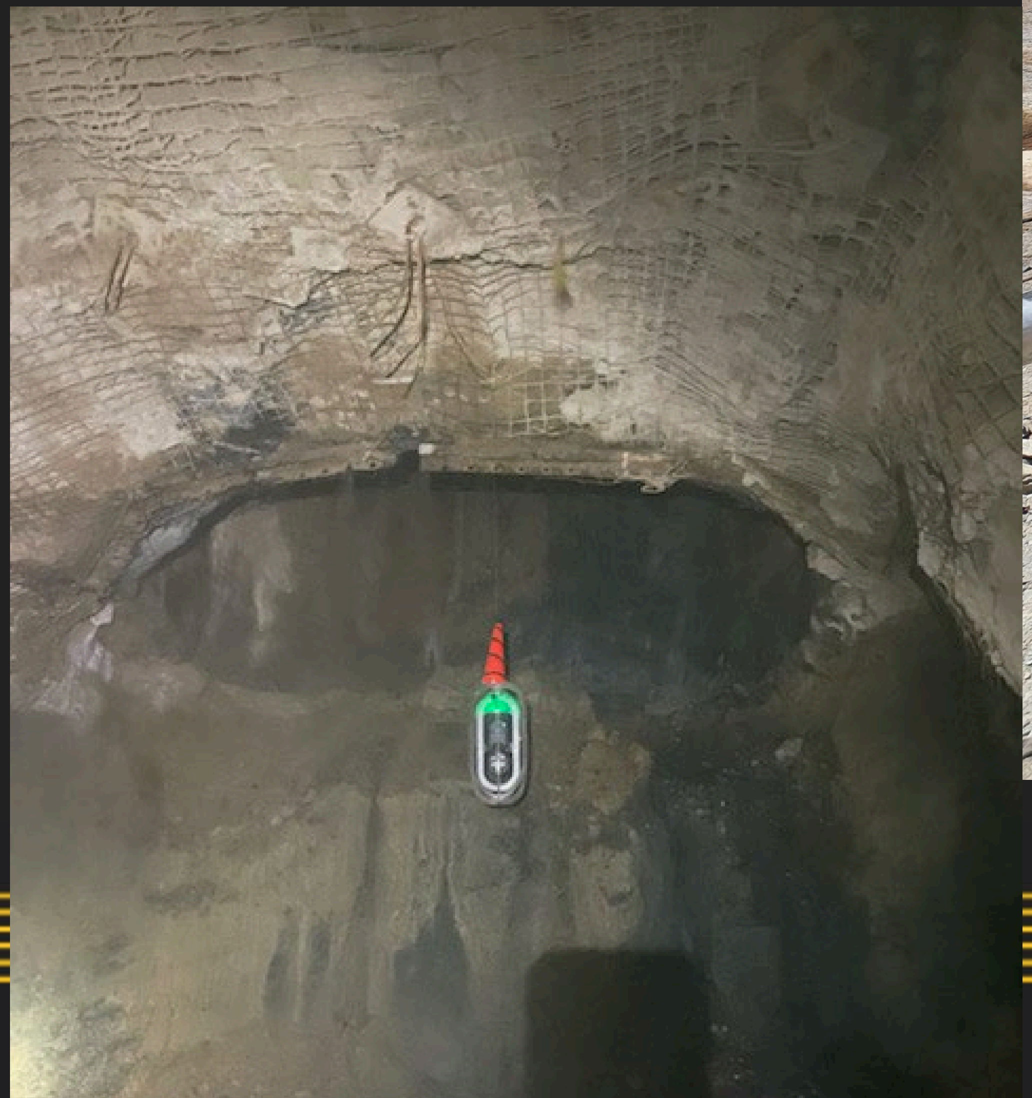
High value critical capital infrastructure that our mines are dependent upon



MINEGEOTECH
MAXIMISING VALUE THROUGH INNOVATION

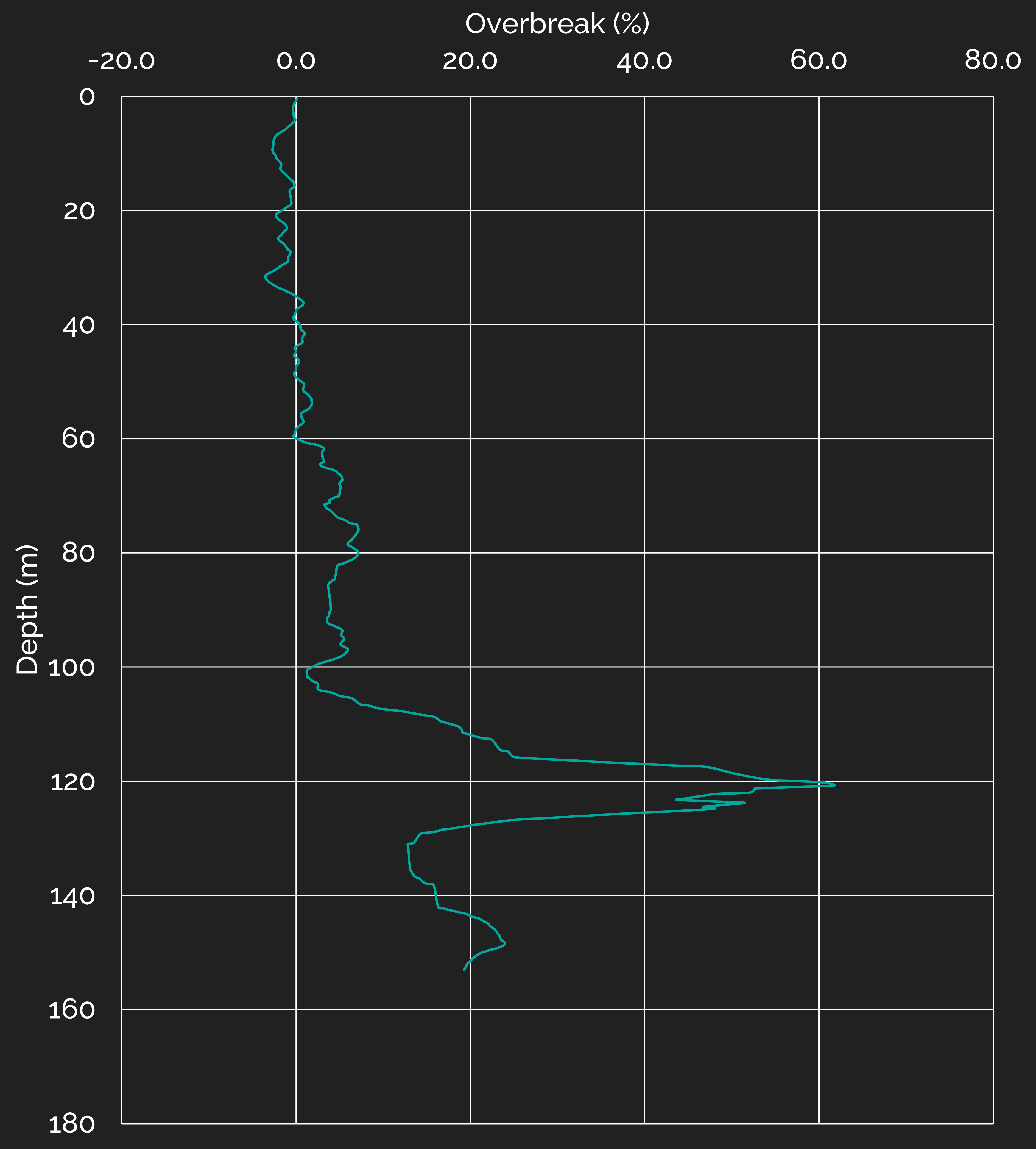
VERIFY

- Safe Access to the top of the raise on surface or underground
- Video and Lidar
- Rock mass damage
  - Location
  - Extent
  - Mechanism
  - Degradation with time

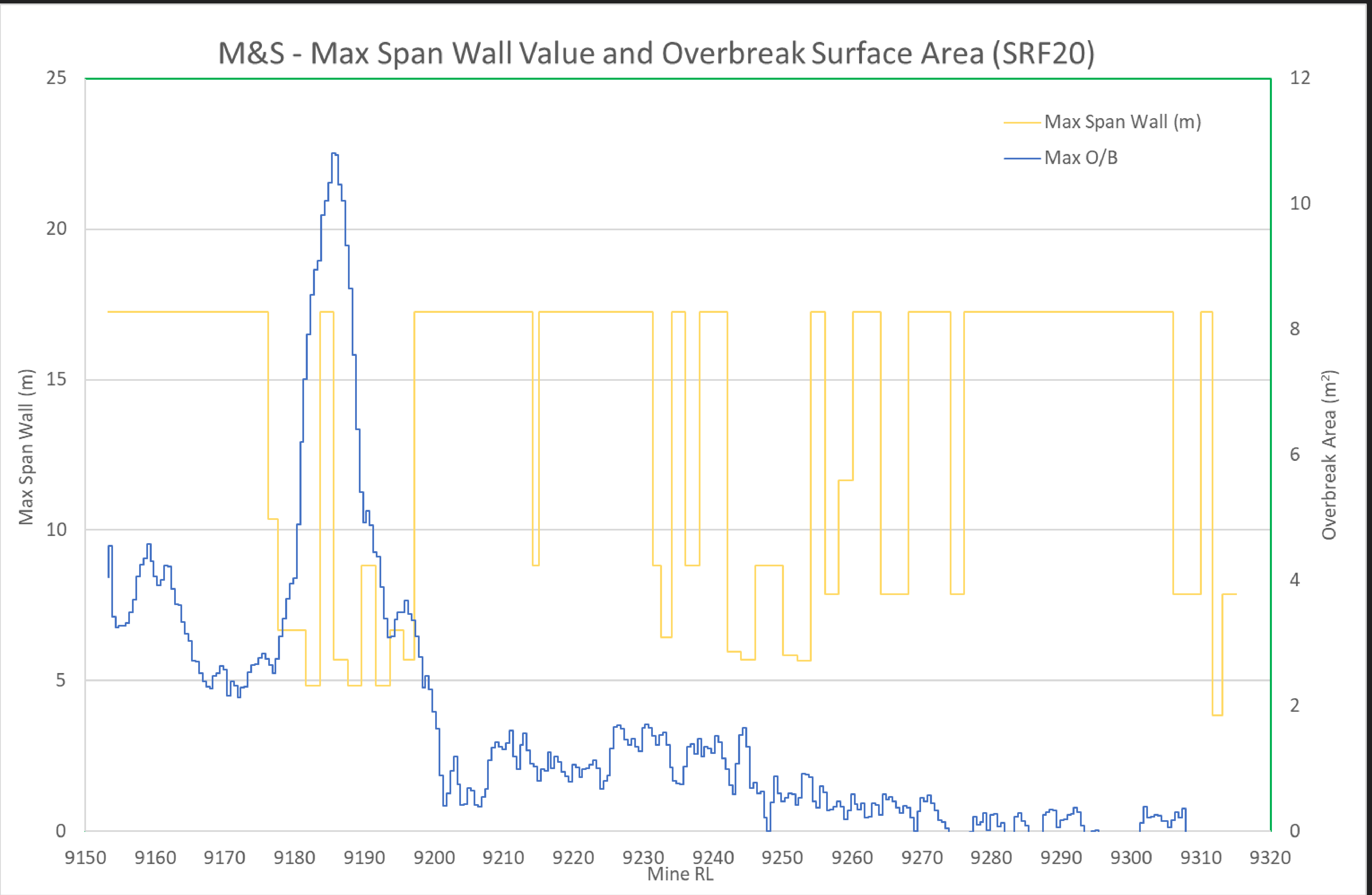

VERIFY THE OVERBREAK ALONG THE RAISEBORE AGAINST FORECAST PERFORMANCE – CASE 1

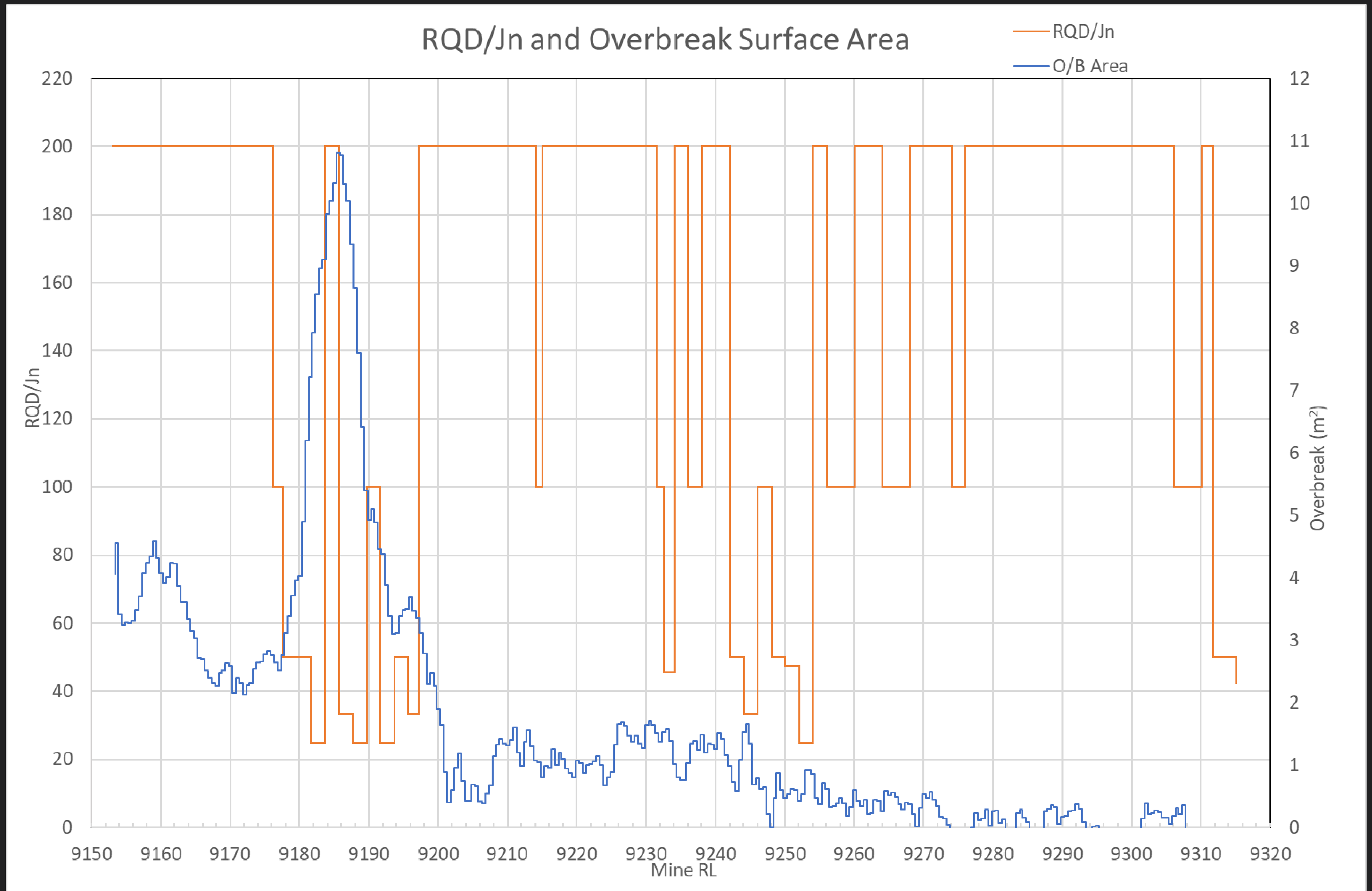
- Raisebore overbreak case review
- Overbreak analysed every 0.25m
- Entire raise approximately 180m^3 of overbreak
  - Total overbreak in this raise is approximately 7%
- 95% of that material from the lower 45m of the raise
  - Overbreak in the lower 45m is around 23%



VERIFY THE OVERBREAK ALONG THE RAISEBORE AGAINST FORECAST PERFORMANCE – CASE 1

MINELiDAR

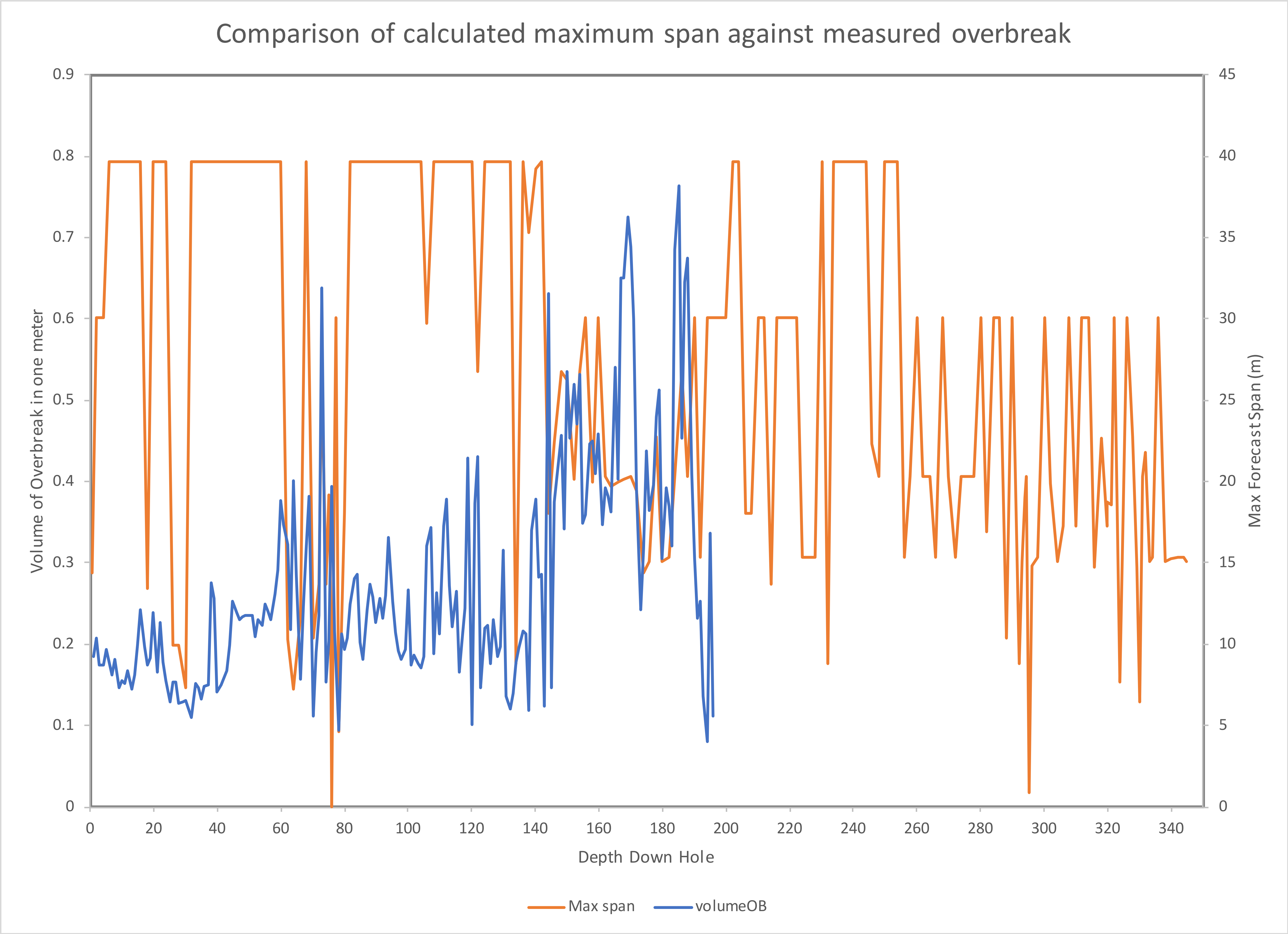




Planned as 4.5m raise

VERIFY THE OVERBREAK ALONG THE RAISEBORE AGAINST FORECAST PERFORMANCE – CASE 2

- 60m³ calculated from the LiDAR scan
  - Overbreak in this raise was less than 3%
- Primarily attributed to stress spalling the length of the raise
- Overbreak results correlated well with areas of lower maximum stable span values
  - A key observation is that whilst the raise is stable it doesn't mean no overbreak

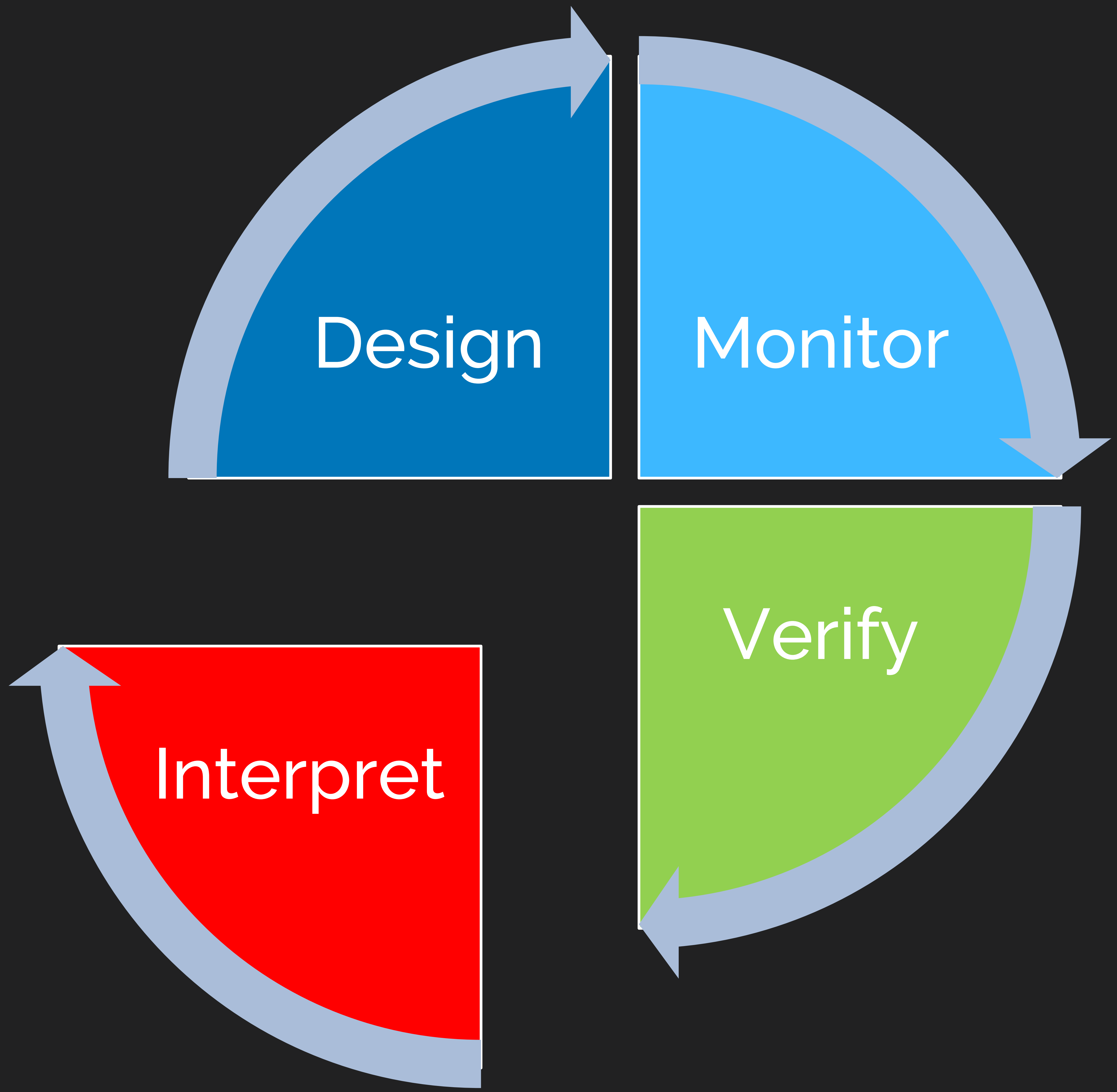


INTERPRET

Structural controls

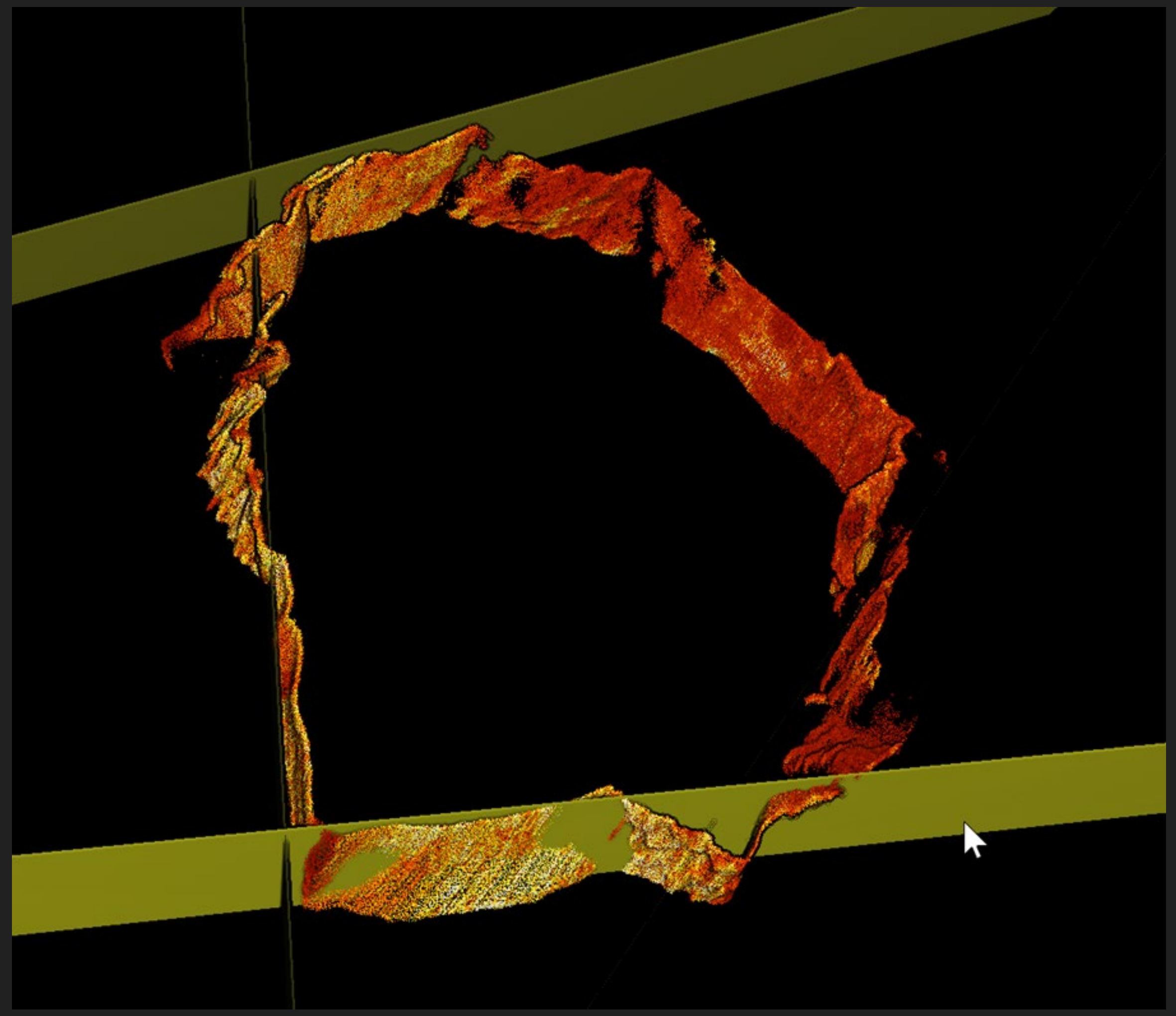
Stress orientation

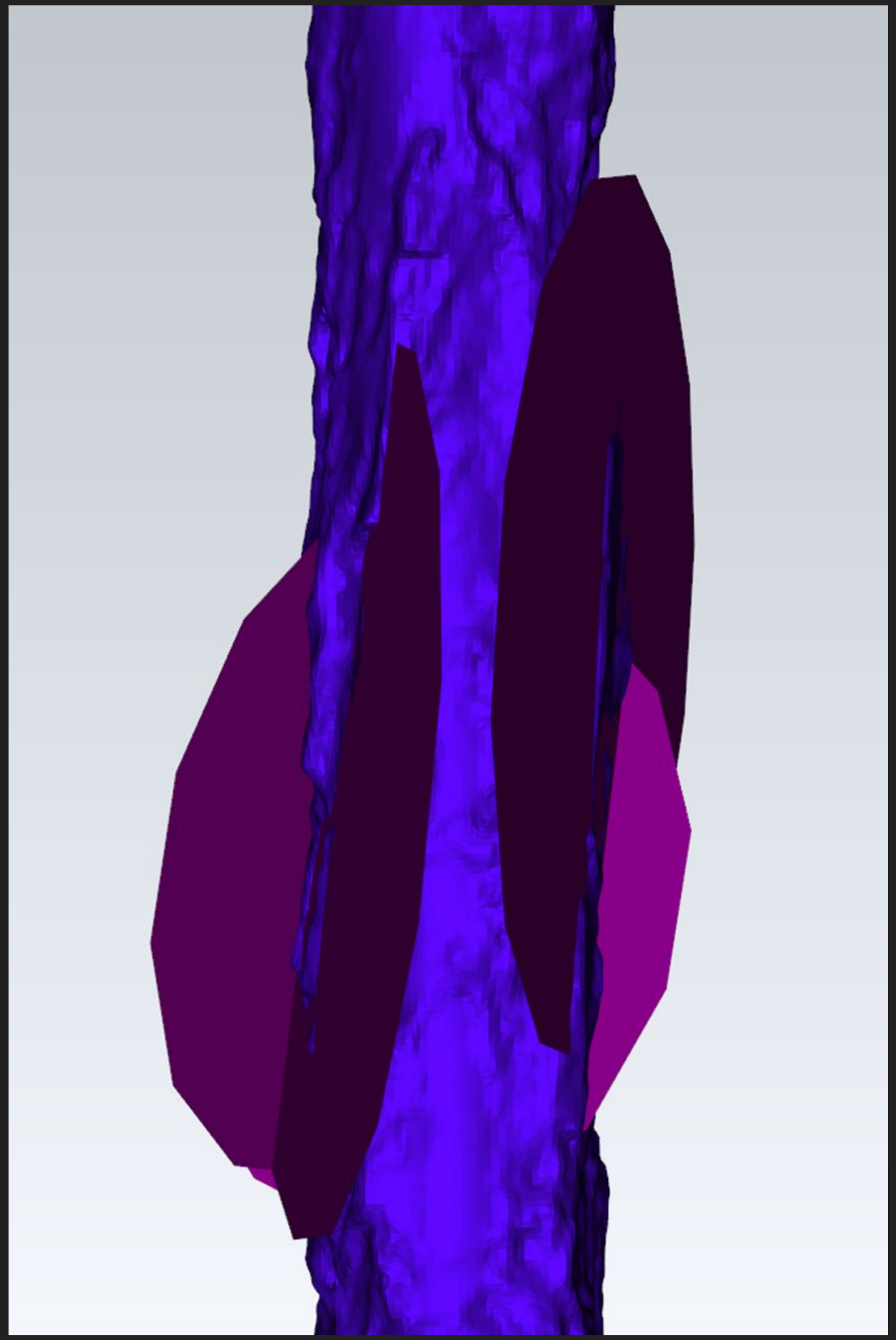
Rock mass yield criterion

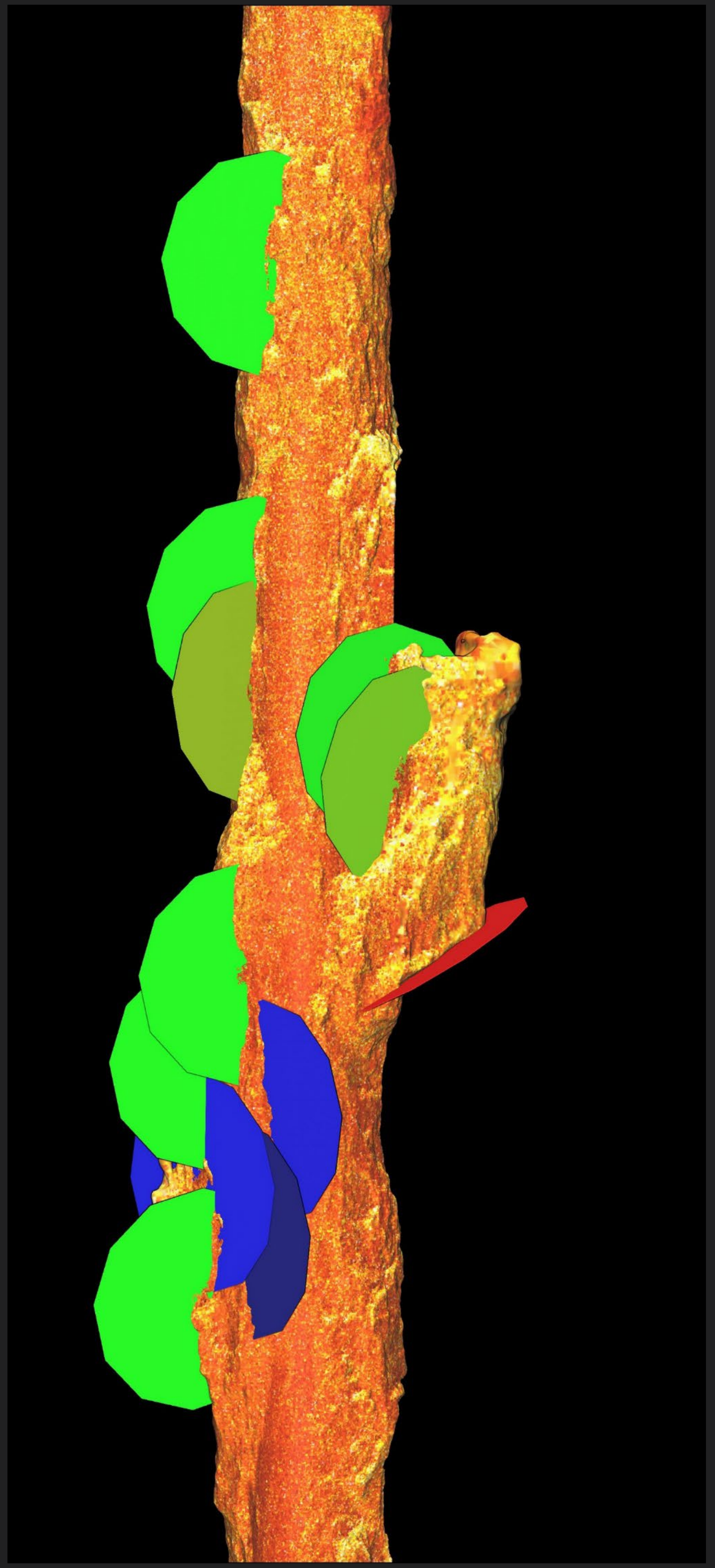


INTERPRET – STRUCTURAL CONTROL

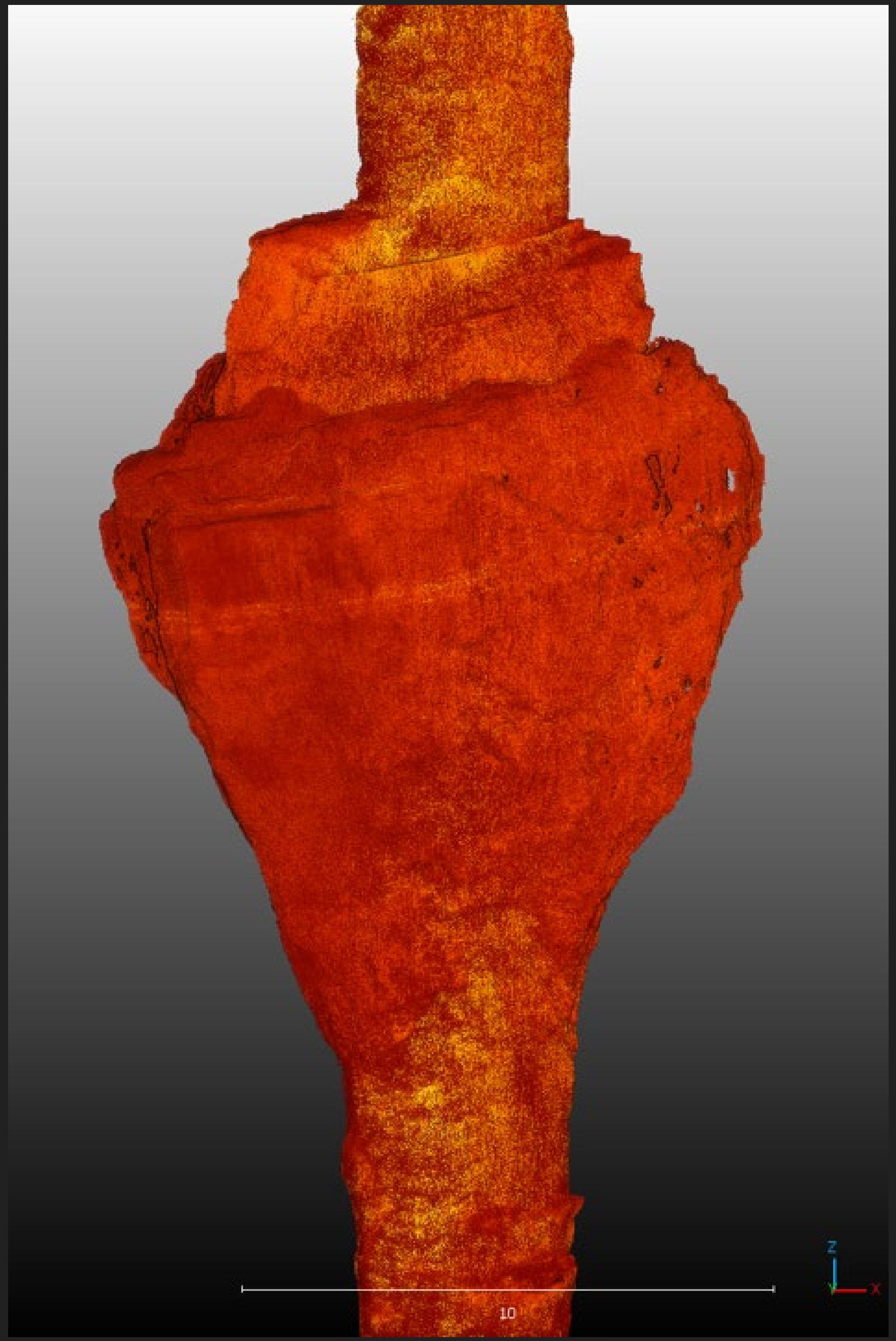
- Best seen by spinning around the point clouds
- Failure mechanisms can be a combination of factors

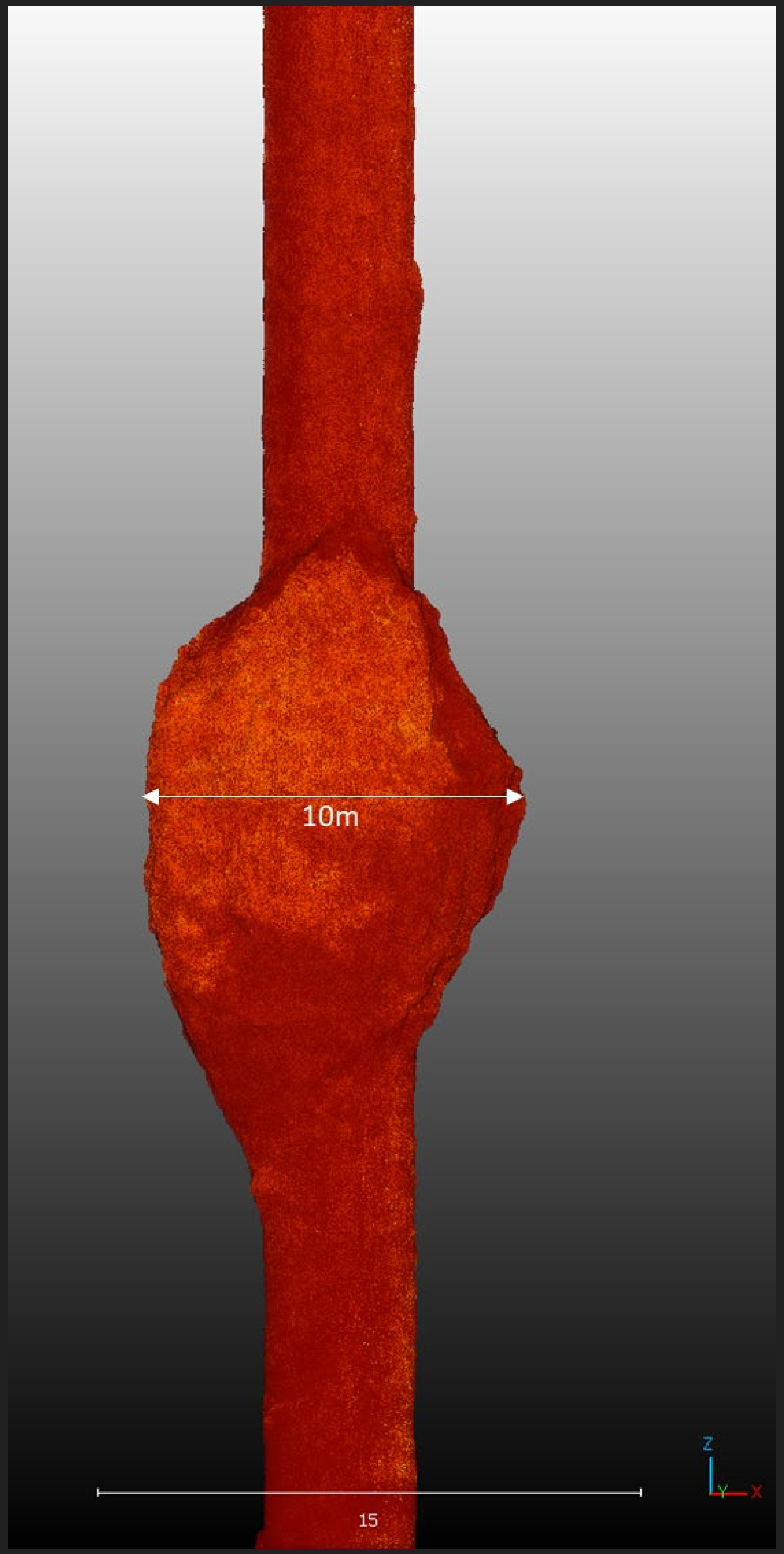


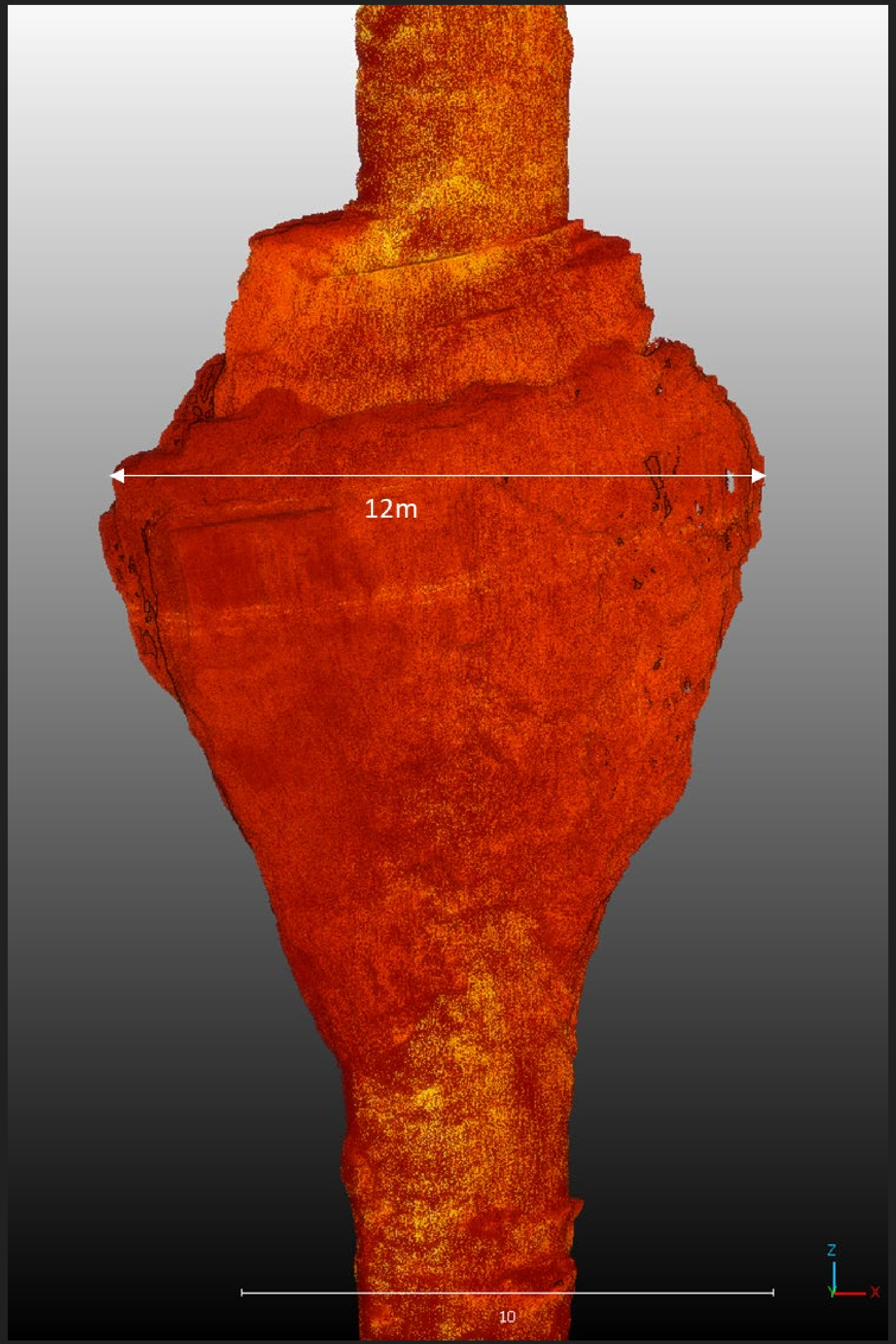




INTERPRET – STRUCTURAL CONTROL



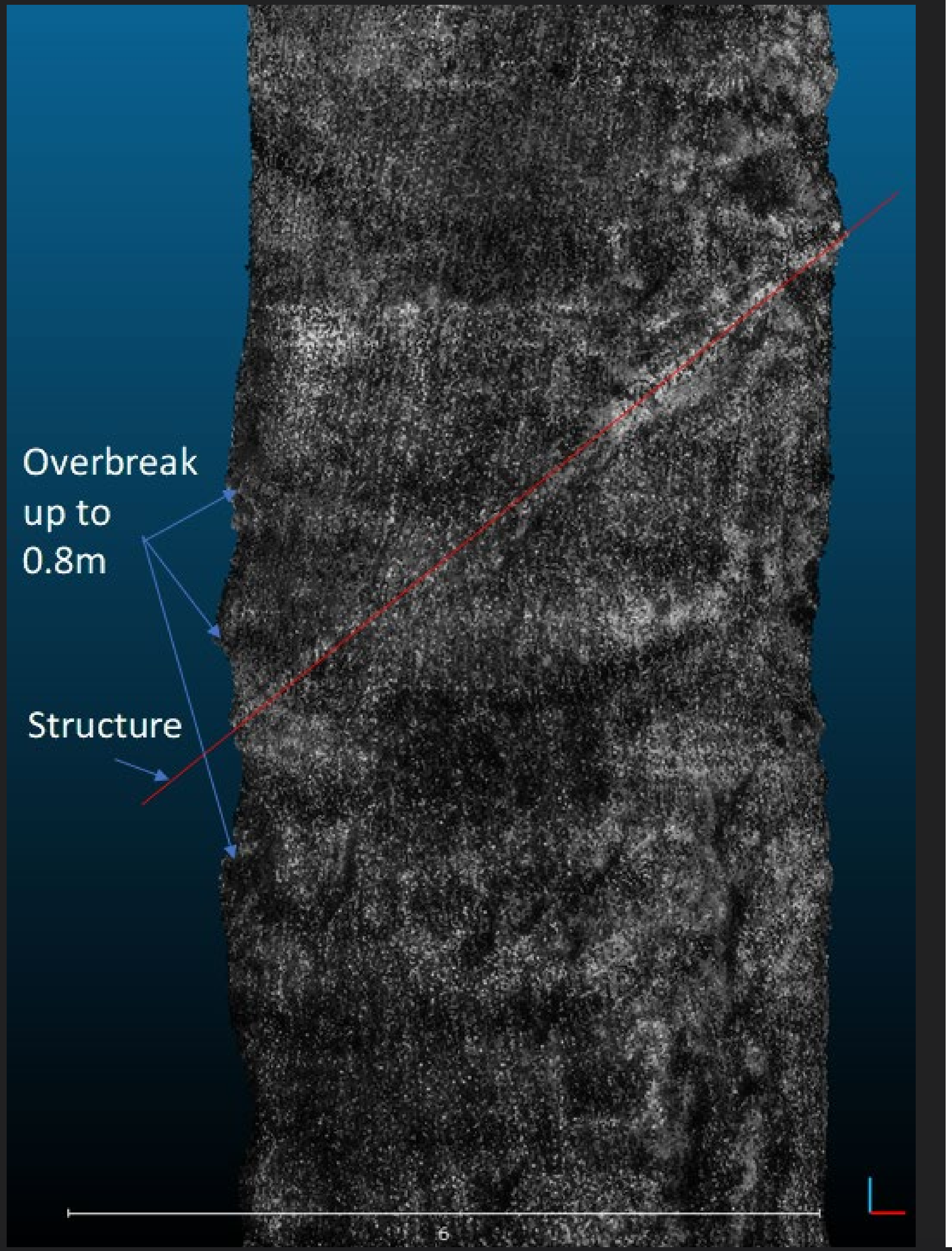


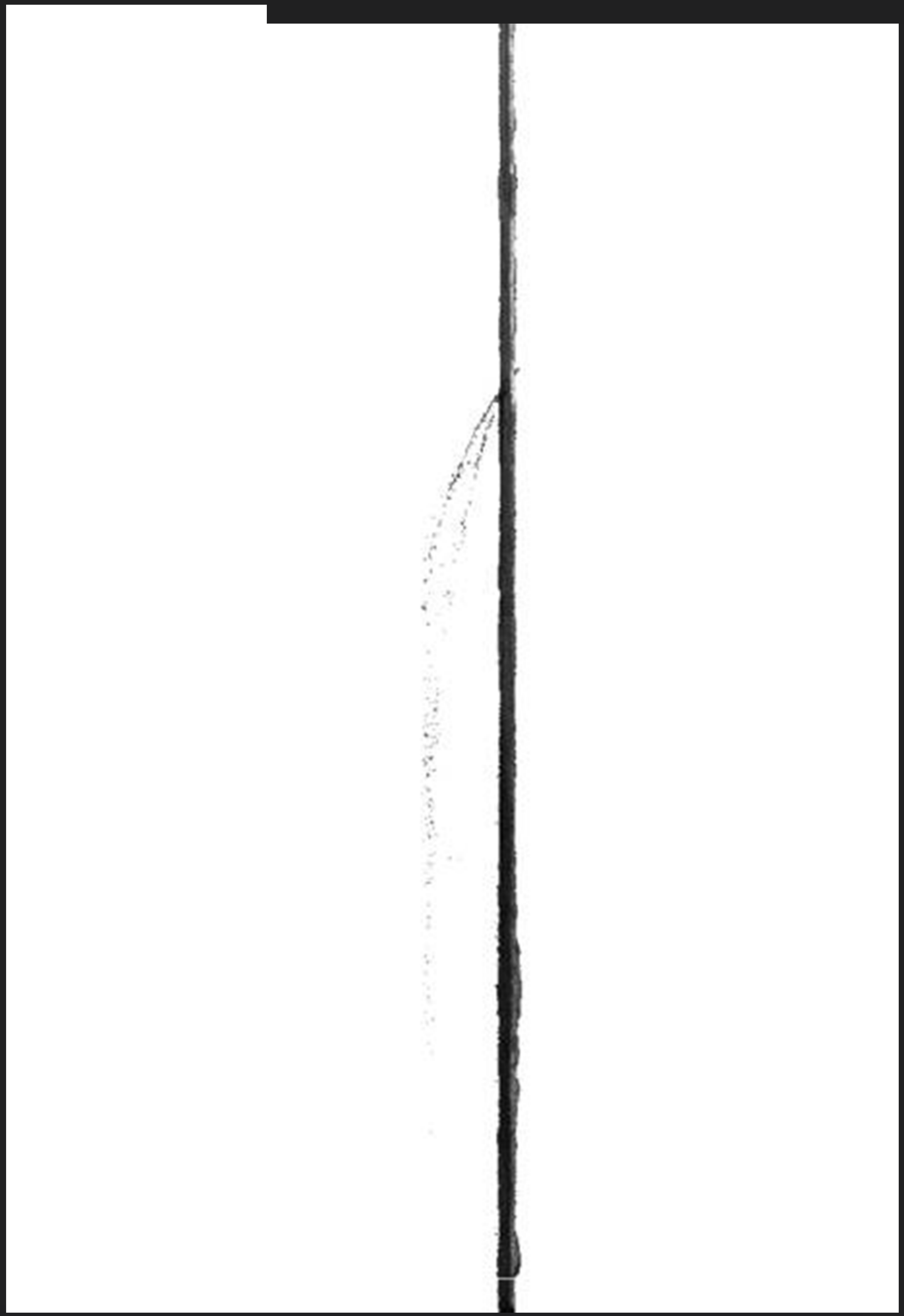


INTERPRET - STRUCTURAL CONTROL

INTERPRET – STRUCTURE CONTROL

- Moderate increase of overbreak around structure
- Raise was wet
  - But not associated with overbreak in the raise.

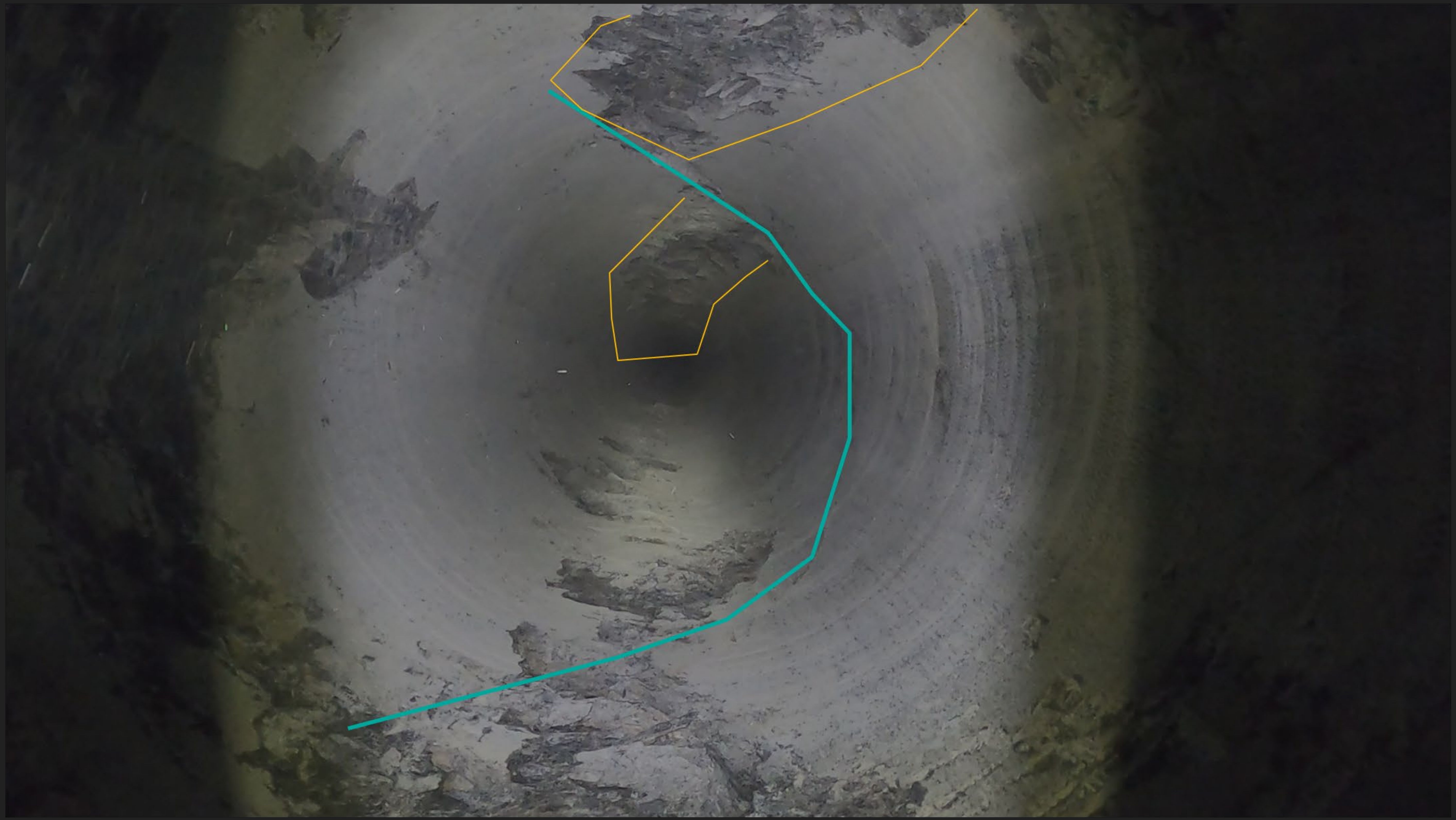




INTERPRET – YIELDING MECHANISM
STRESS SPALLING AND DOG EARING – STRESS ORIENTATION

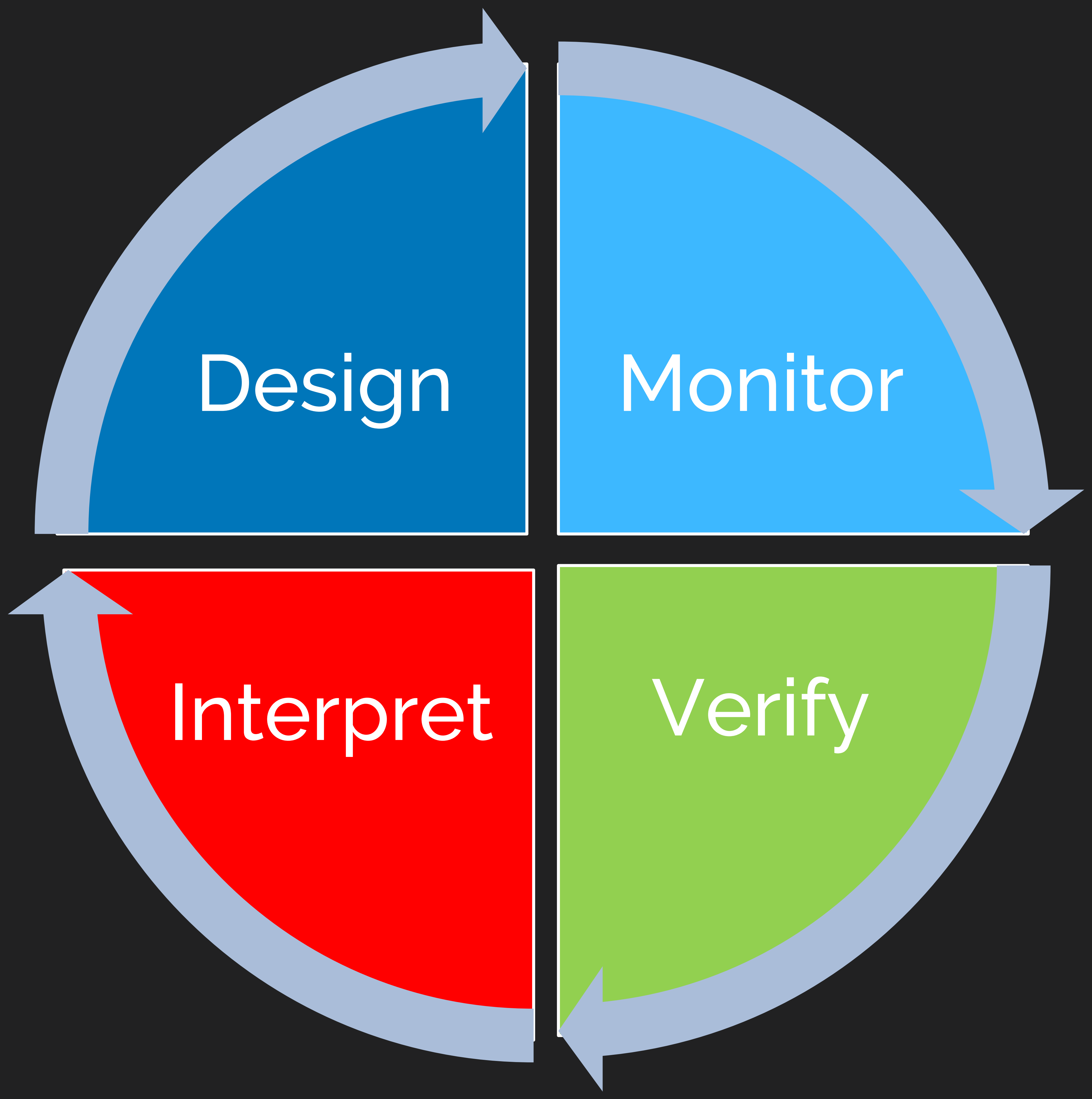
INTERPRET - STRESS SPALLING

INTERPRET - STRESS ORIENTATION - ROTATION



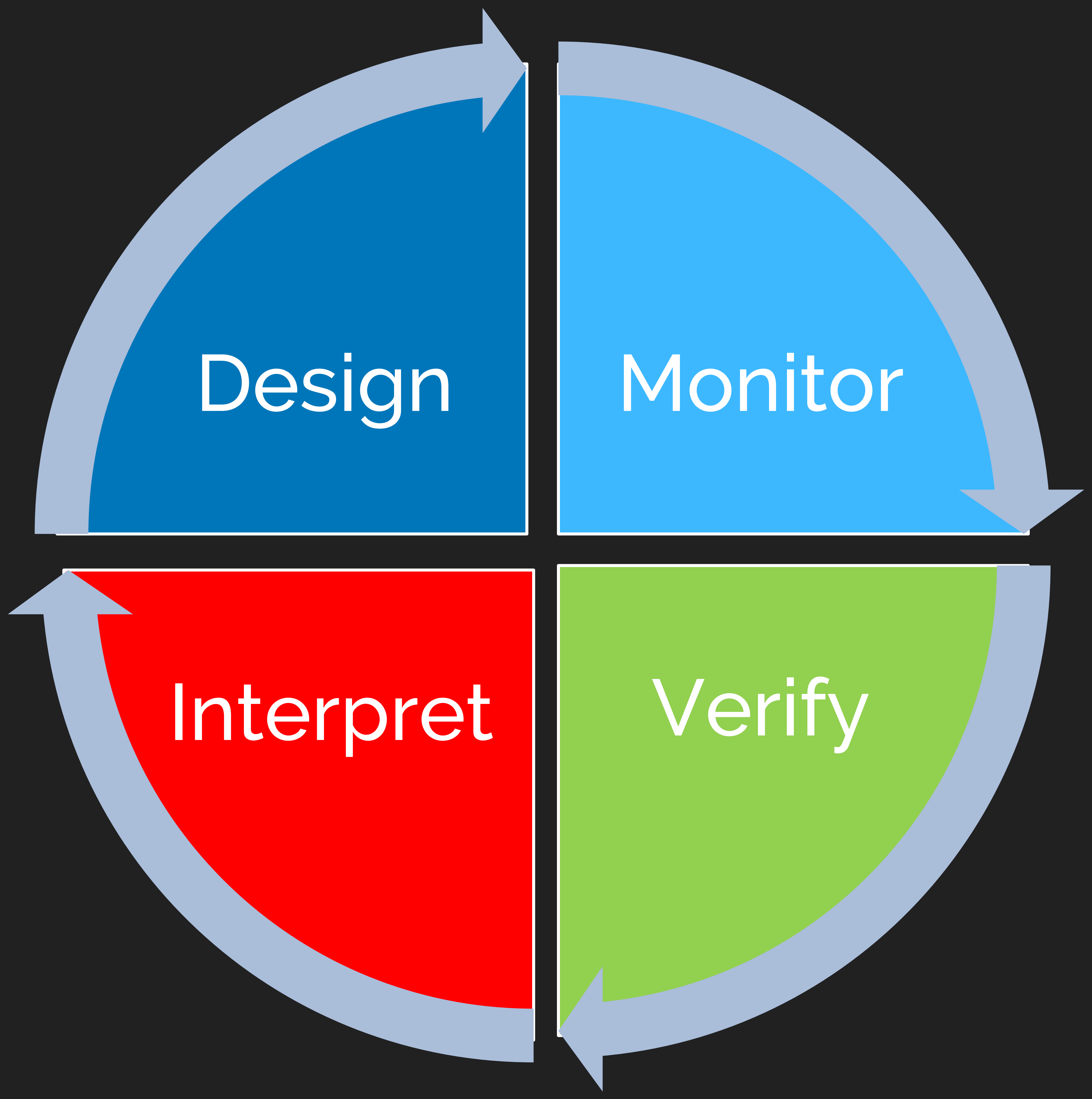
MINELiDAR

CONCLUSION



- Raisebore are high capital expense and LOM infrastructure that should be assessed, the loss of these infrastructure has critical impact on mine production
- The Design process for Raisebores can and should be done better
  - Diamond investigation hole
  - Intact rock properties to obtain Hoek-Brown criteria
  - Rock mass logging
  - Structure from ATV
  - 3D Non-linear finite element modelling in conjunction with discrete structural analysis using relevant voids.
- Note M&S stable - is not no overbreak or no face issues, its not collapsed

CONCLUSION



- Raisebore are high capital expense and LOM infrastructure that should be assessed
- The Design process for Raisebores can and should be done using non-linear finite element modelling in conjunction with discrete structural analysis. M&S stable - is not no overbreak or no face issues
- Use all available data sources to Monitor reaming
- Verify the performance of the raise by undertaking a video and lidar scan. Compare performance to the forecast - not just empirical but from numerical models.
- Interpret the rock mass strength and damage, structural controls, understand the in-situ stress and requirements for ground support

DESIGN, MONITOR, VERIFY, INTERPRET

ACKNOWLEDGEMENTS

- Thank you to our clients that have supported The MGT Way by engaging us to work on your projects and provide these outcomes.

Meet the Team

Dr John Player,
Director and Principal Engineer

Peter Evans,
Principal Geotechnical Engineer – Shafts

MineLidar

Emma Jones,
Principal Study Manager – Geotechnical

WANT TO EXPLORE MORE?

Get in touch with our team at MineGeoTech to find out how we can help you maximise value through innovation

MINEGEOTECH

www.minegeotech.com.au

contact@minegeotech.com.au

+61 8 9381 3215

MINELiDAR