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Real-time and Scheduled Monitoring of TSFs

Dam Performance Examples

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CANADA BEST MANAGED COMPANIES Platinum member

Introduction

What's important:

- High-tech and 'traditional' monitoring systems both useful
- Multiple monitoring technologies/methods
- Regular construction surveys
- Readily available data (downloadable)
- Data recorded at a high frequency
- Data record spanning several years

The Site

Alumina refinery, bauxite processed, waste product is residue (‘red mud’)

8 x upstream raised TSFs and 1 x filtered stack

Filtered Stack

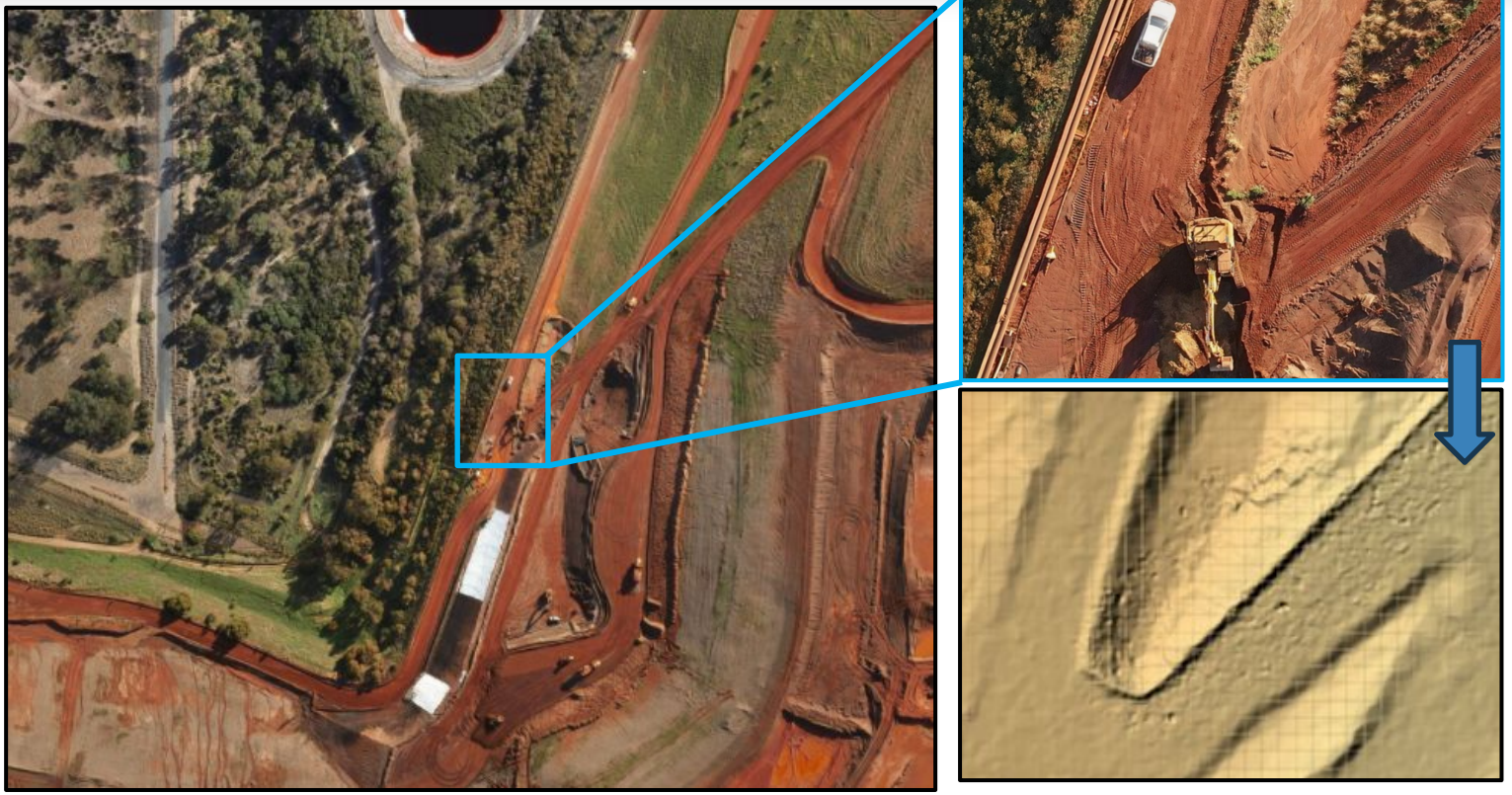
Wet TSF

Monitoring at the Site

Instrument Type	Real-time / Scheduled	Purpose	Number	Frequency
Vibrating Wire Piezometers (VWPs)	Real-time	Pore water pressure	415	30 minutes
Inclinometers	Scheduled	Deformation	42	Monthly
Shape Array Inclinometer	Real-time	Deformation and displacement	1	30 minutes
Prisms	Scheduled	Displacement	43	Monthly
GNSS Prisms	Real-time	Displacement	5	10 minutes
Underdrain sump levels using VWPs	Real-time	Liquor levels	28	30 minutes
Pond water levels	Scheduled	Liquor levels	15	Weekly
InSAR	Scheduled	Displacement	-	11-day satellite flyover
Photogrammetry survey	Scheduled	Deposition monitoring, construction progress	-	Fortnightly or as required
Drone photography	Scheduled	Visual assessment	-	Fortnightly
Extensometers	Scheduled	Displacement	30	Monthly
Slope monitoring radar	Real-time	Deformation	1	10 minutes
Standpipes	Scheduled	Pore pressure	10	As reqd

59 monitored transects

Aerial Photography



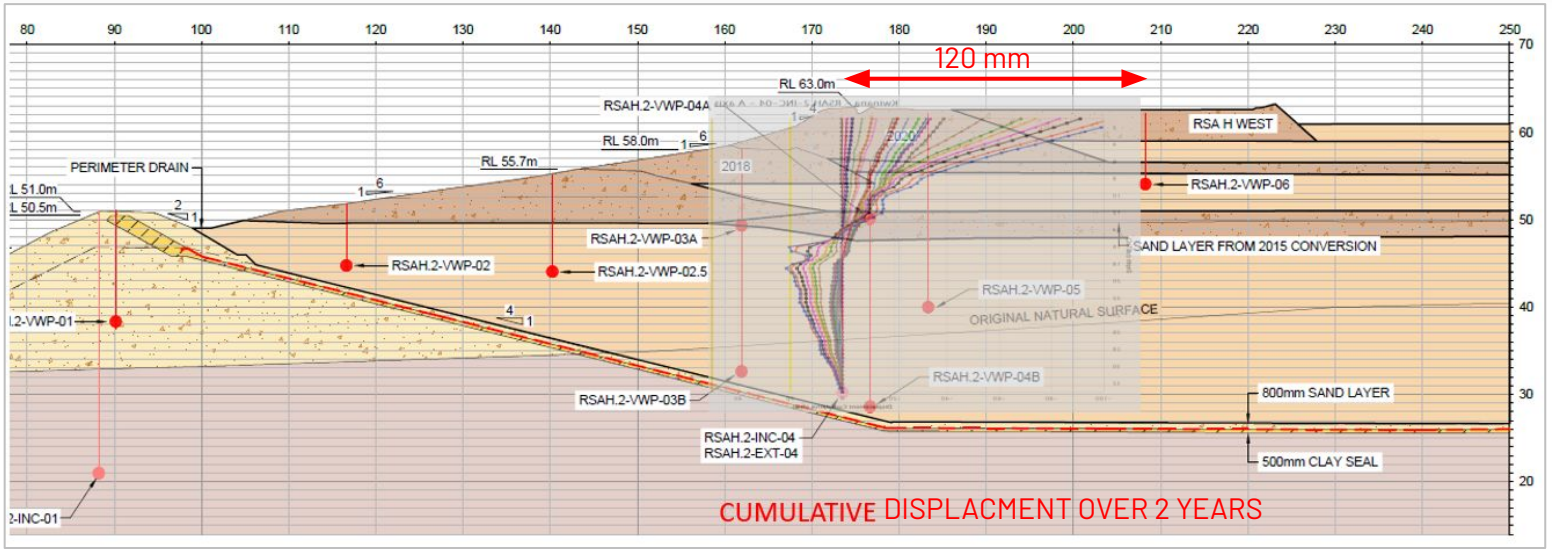
Photogrammetry Surveys

Feb 2025

Oct 2025

Jan 2026

Example 1 – Slope Deformation



Inclinometer cumulative displacement (exaggerated scale)

← Downstream

Upstream →

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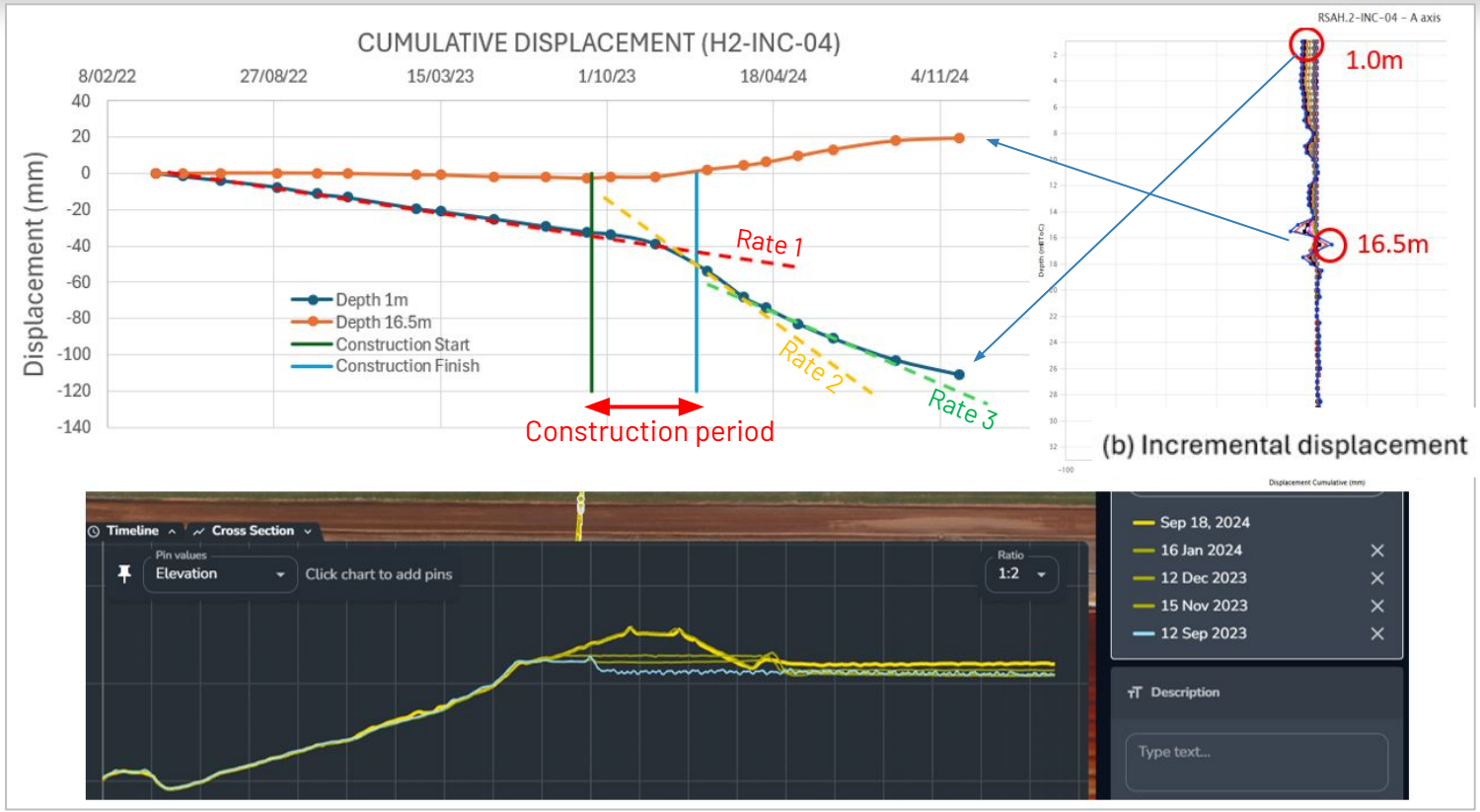
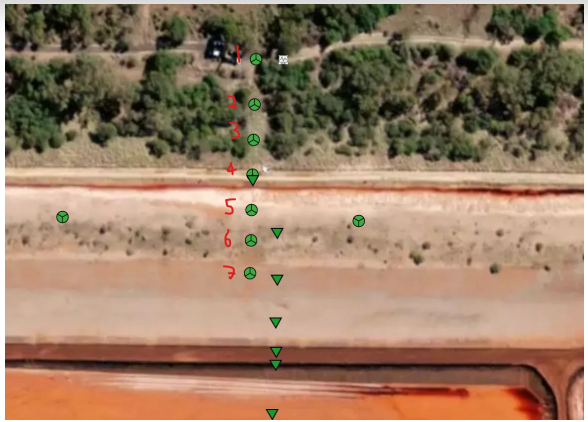
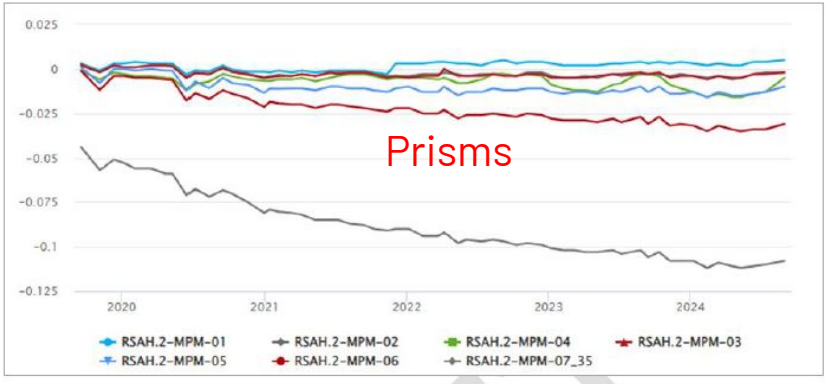
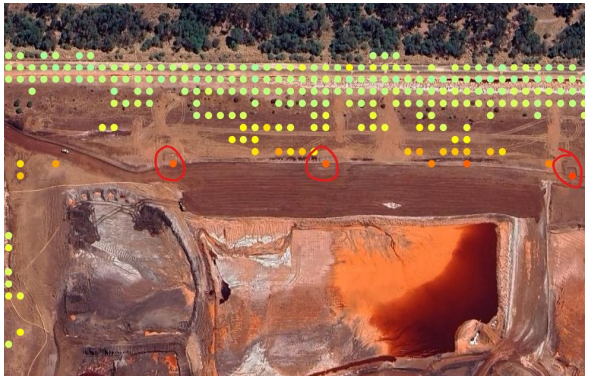


Example 1 – Slope Deformation







Example 1 – Slope Deformation

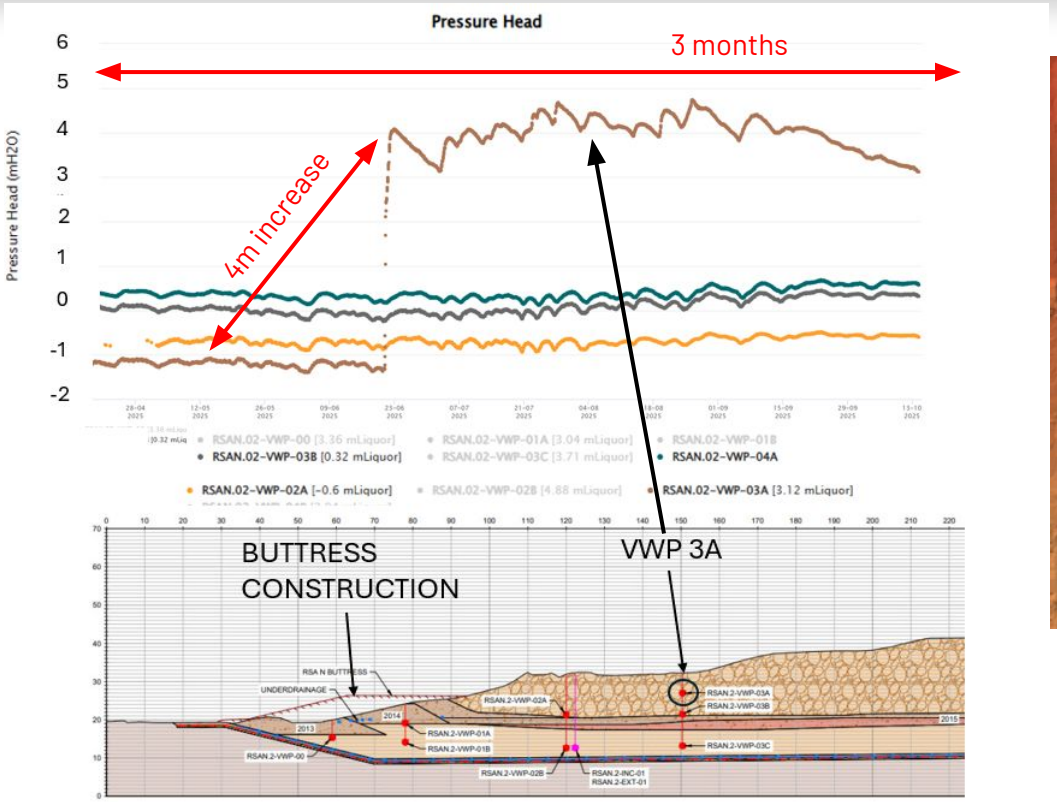
Conclusions

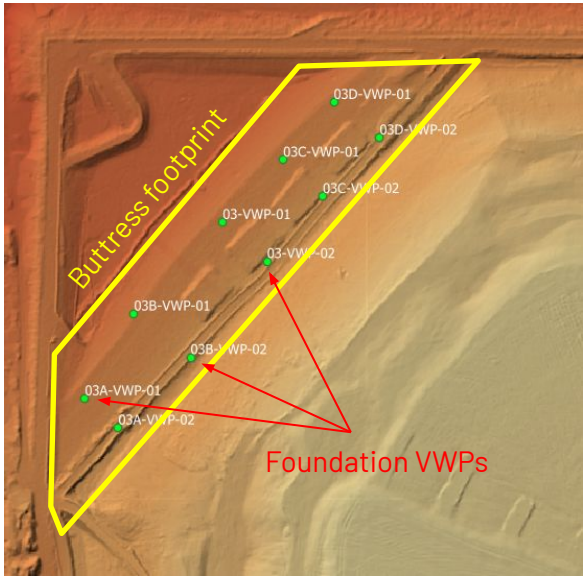
- Monitoring data indicate:
  - Displacement is mainly vertical (settlement)
  - The inclinometer is buckling at depth
  - No evidence of rotational or shear displacements
  - Displacement is slowing not indicative of a progressive failure or strain softening

Lessons

- The analysis was helped by:
  - Frequent inclinometer and photogrammetry surveys

Example 2 - Filtered Tailings Stack





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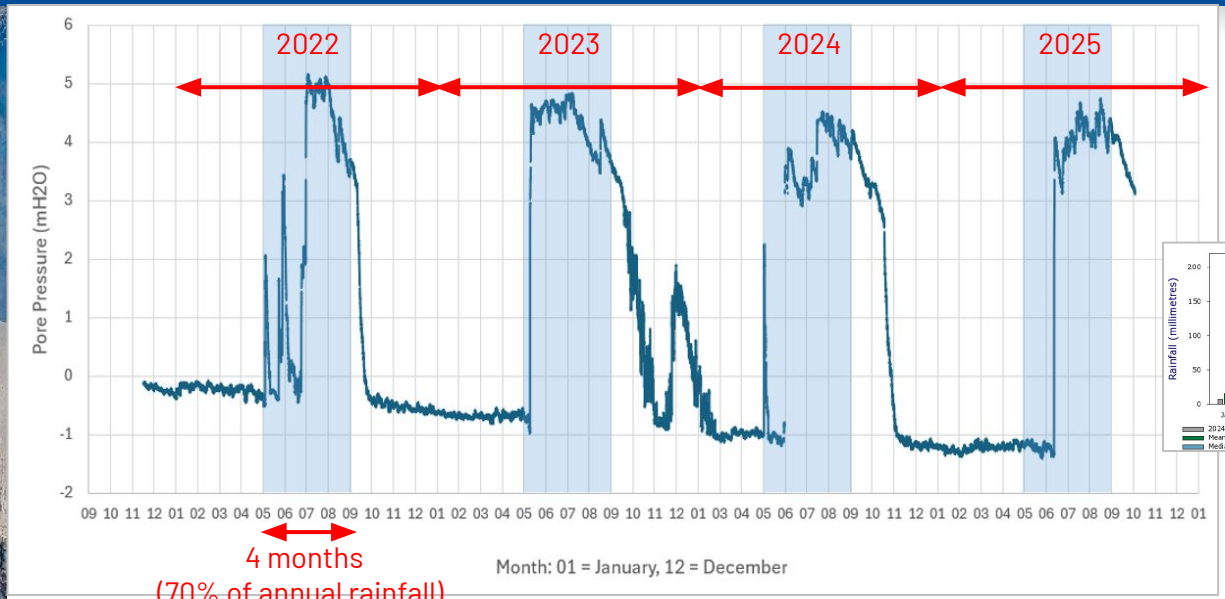
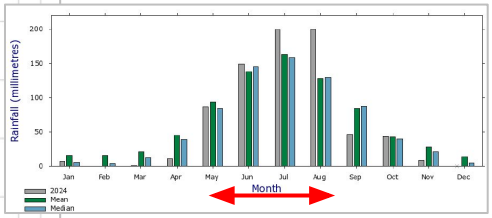




4 months
(70% of annual rainfall)

Pressure head of VWP 3A over a four-year period, indicating response to wet season rainfall, (shaded regions; May to September each year)

Example 2 - Filtered Tailings Stack

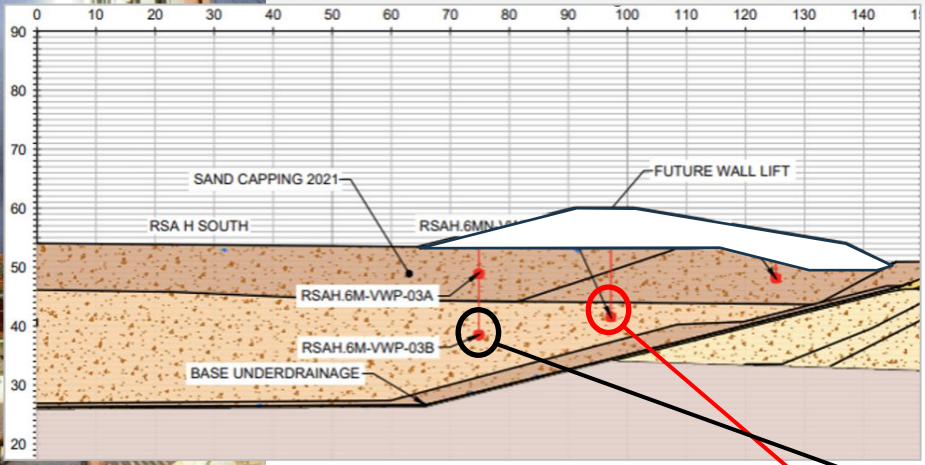
Conclusions

- Similar but higher pore pressures had occurred several times in the past
- The high pore pressures were unrelated to the buttress construction
- Decision to continue with construction

Lessons

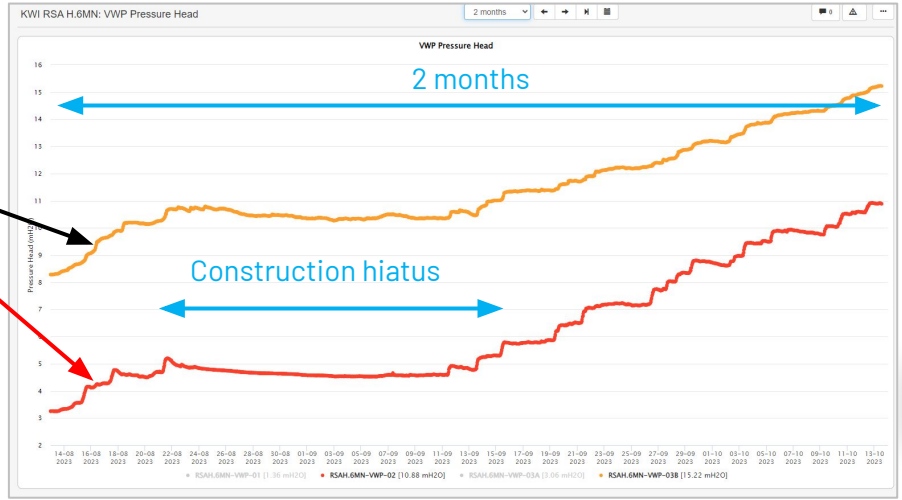
- Long data record proved to be valuable
- Dry stacks are not dry!

Example 3 - Construction Induced Pore Pressure



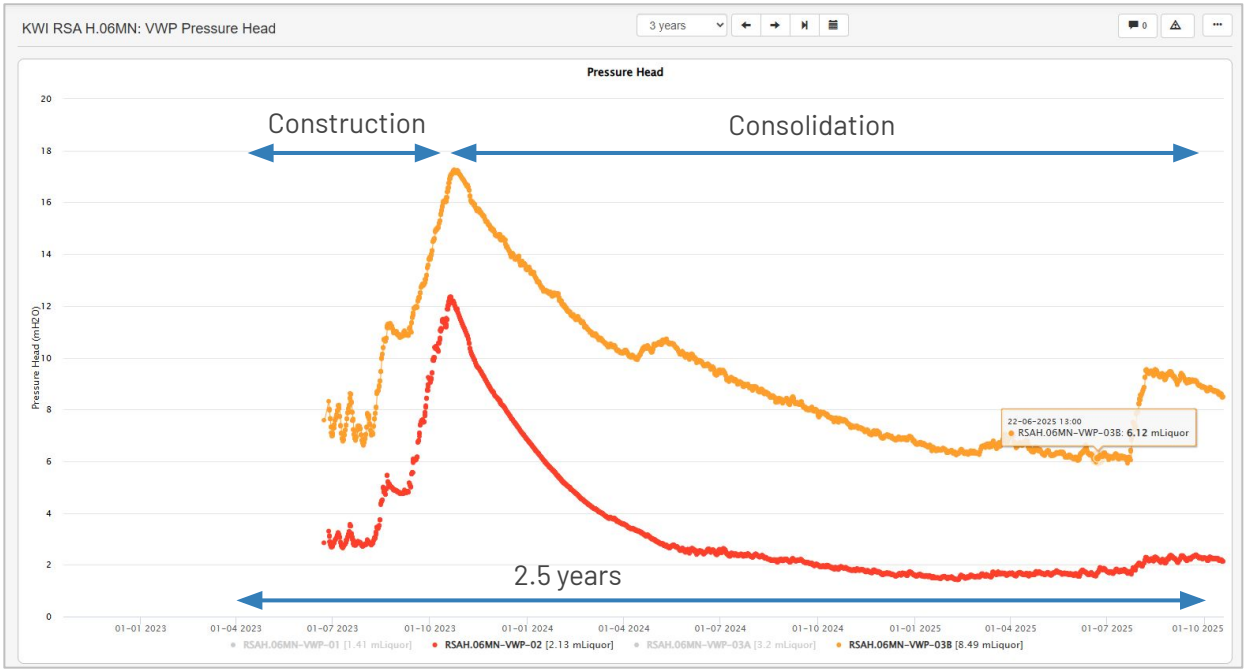
Arrangement of VWPs in the tailings below the raise embankment ("Future Wall Lift")

Pore pressure time series for VWP-02 and VWP-03B during construction of the upstream raise of the embankment



Example 3 – Construction Induced Pore Pressure

Consolidation Rate



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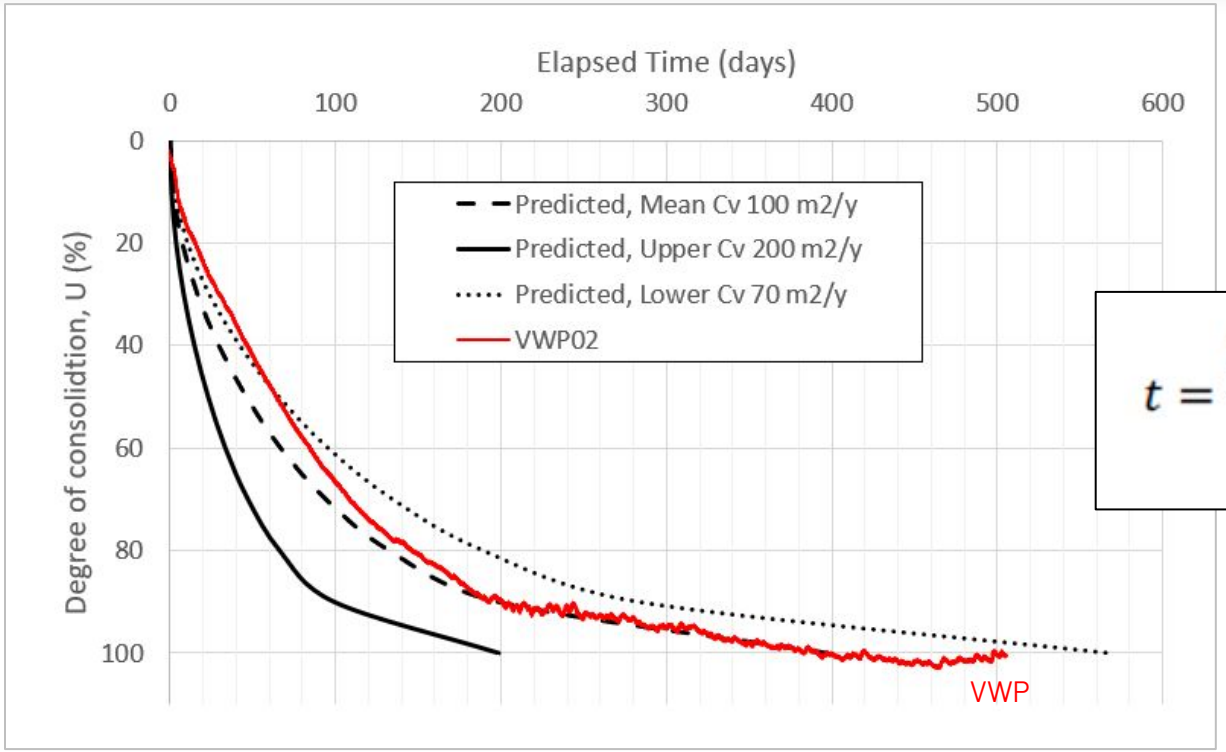
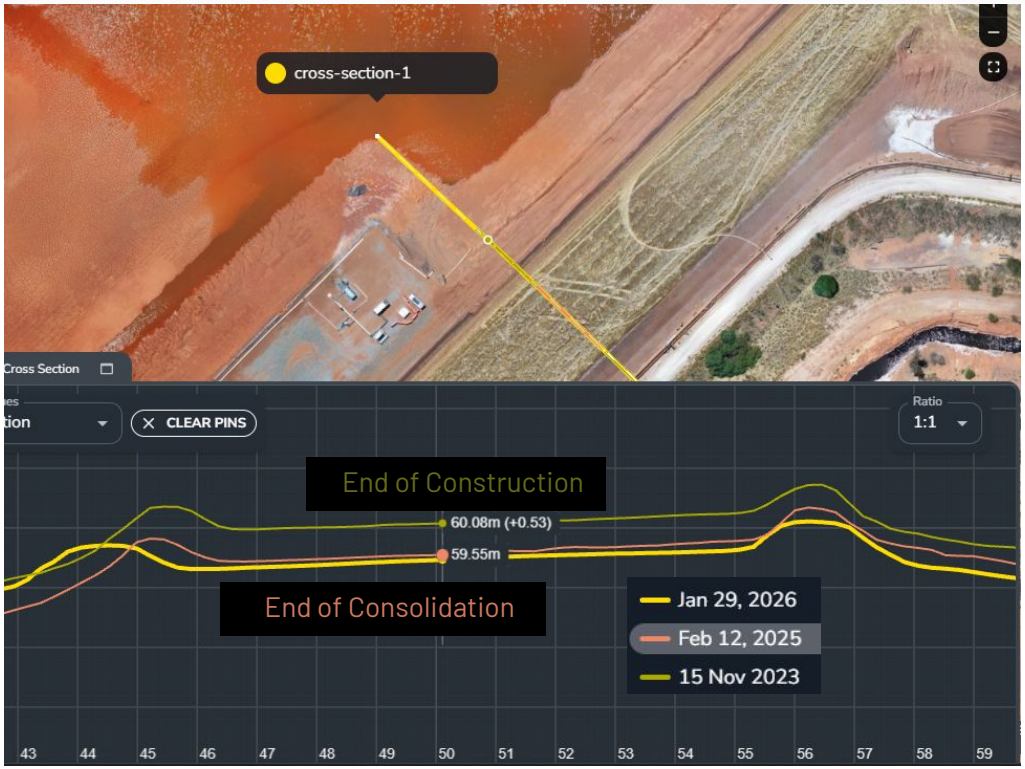
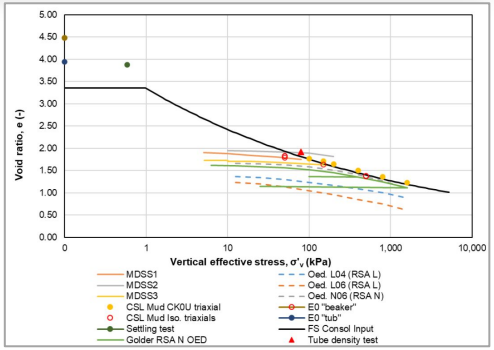


$$t = \frac{T_v H_{dr}^2}{c_v}$$

Example 3 – Settlement





$$S = \frac{C_c H_0}{1 + e_0} \log\left(\frac{\sigma'_0 + \Delta\sigma'}{\sigma'_0}\right)$$

Settlement

Actual = 530 mm

Predicted = 590 mm

Cc ~ 1.4

e_0 = 1.6, $\Delta\sigma'$ = 86 kPa

Example 3 – Construction Induced Pore Pressure

- Validate and estimate parameters:
  - B-bar ≈ 0.7 (over the period of interest)
  - $c_v \approx 100\ m^2/y$
  - Post-construction settlement

$$\bar{B} = \frac{\Delta u}{\Delta \sigma_1}$$

- Useful for subsequent analysis, design and construction monitoring

Lessons

- Helpful to have frequent data acquisition
- A long data record

CONCLUSION

What is important?

- Multiple monitoring technologies/methods
- A mix of high-tech and 'traditional'
- Frequent construction surveys
- Aerial imagery
- Readily available data (downloadable format)
- Frequent acquisition (30-minutes, daily etc.)
- Data record spanning several years

THANKS!

Any questions?

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