Queensland Tailings Group
Digitizing Tailings Facility Storage Monitoring

Introduction

- Chris Marcellus
  - Bentley for 3 + years – Solution Architect
  - 7 + years in IoT industry, designing and implementing monitoring solutions across the globe
  - Cirque du Soleil for 7+ years as Entertainment Rigger and Rope Access Technician

iTwin IoT in Mining

Bentley's iTwin IoT can be utilized to combine traditional IoT monitoring with the technology of a Digital Twin.

Tailings Management Solution

Seequent and Bentley's leading practice Tailings Management solution has, **at its core**, **a multi-stakeholder knowledge base** that enables a monitored digital twin and geotechnical analysis workflow that **turns static data into actionable intelligence** to create new operational efficiencies and reduce risk across the asset.

In an industry striving for best practice in Tailings Storage Facility management, OceanaGold's digital response to their Waihi operations offers a gold mine of information. With Bentley and Seequent's innovative software, the team created a data-driven digital twin, to better understand the physical asset and help manage safety.

Agenda

- Pilot Project Objective
- Why?
- Project Approach
- Workflow
- iTwin IoT Real-time Monitoring

 |

Bentley

Pilot Project Objective

- Enabling an easy to use, robust solution that can help a TSF owner better manage their tailings facilities and align with industry standards

The Standard

Global Industry Standard on Tailings Management (GISTM)

The independent Audit

Global Tailings Management Institute (GTMI)

New!

GTMI to oversee implementation and conformance of GISTM in core areas of:

- Assurance
- Awareness
- Knowledge sharing
- Disclosures

Bentley

Why?

- Structural integrity of tailings storage facilities are critical to community safety and environmental protection.

ICMM International Council on Mining & Metals

"Zero harm to humans"
Global Industry Standard on Tailings Management

… and the challenge!

- How to move from retrospective understanding of historical to proactively managing and predicting performance in the future.
- Tailings properties change spatially over time and require constant review against targets to ensure meaningful metrics are linked to preventable controls.
- Access to reliable information when its needed.

What Mining Companies Could Further be Doing

- Understand better the performance of existing tailings facilities; e.g.:
  - The volume of water locked-up in the tailings (typically 50 to 85%!)
  - The post-seismic and post-closure strengths of the tailings

…Professor David Williams

Bentley

Project Approach

3 Control Sections Instrumented

Control Sections not included

Phase 1

Collaboration & Knowledge Management

Seequent Central

Phase 2

Surveillance

Sensemetrics Telemetry

Phase 3

Digital Twin Generation

Leapfrog

Phase 4

Geotechnical Analysis

GeoStudio

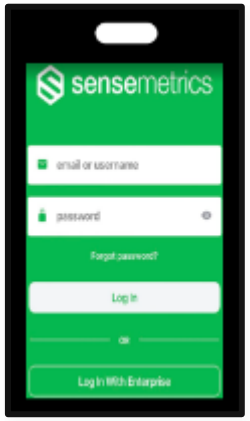
Excluded

- InSAR
- Drone (Lidar)
- Earthquake data
- Geophysics
  - Seismic Refraction
  - Electrical Restivity

3 Threads

14 Strands

(38 vibrating wire-line piezometers)

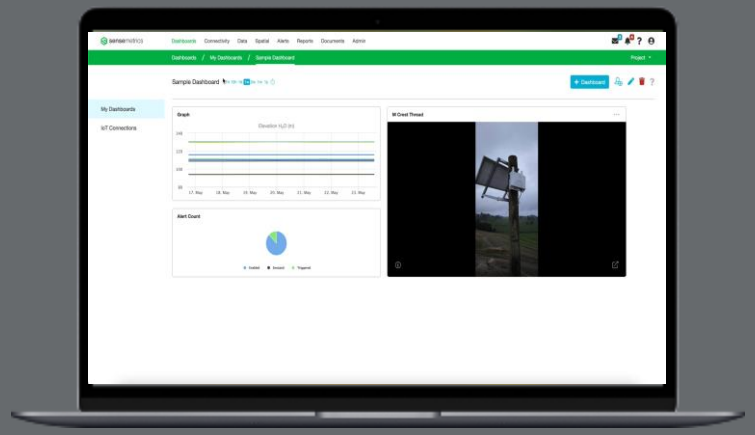


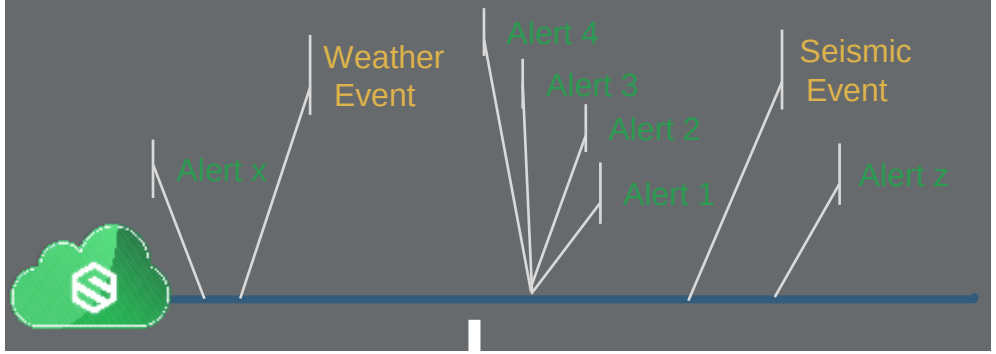
Mobile App

Bentley

Workflow

MONITORING

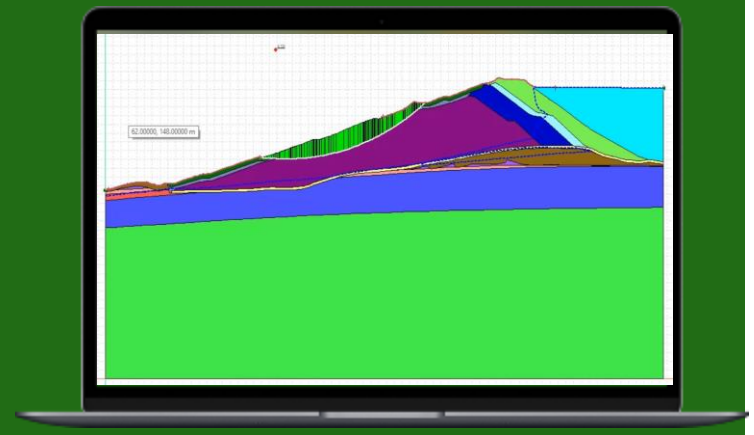




MODELLING

leapfrog | GEO

GEOTECHNICAL ANALYSIS



GeoStudio

CENTRAL

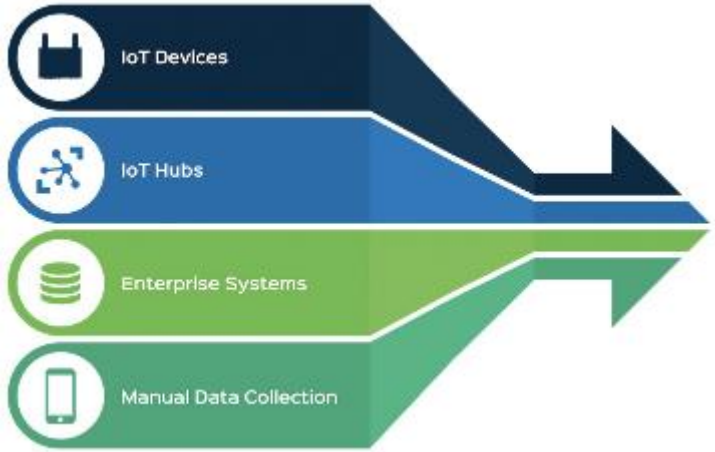
FOS

Knowledge Base

Bentley

Queensland Tailings Group
iTwin IoT Real-time Monitoring

IoT Asset Condition Monitoring



Sensor Data Acquisition

Connect to any sensor, read any data type, monitor, calibrate, and validate incoming raw data for immediate analysis.

Visualization & Analysis

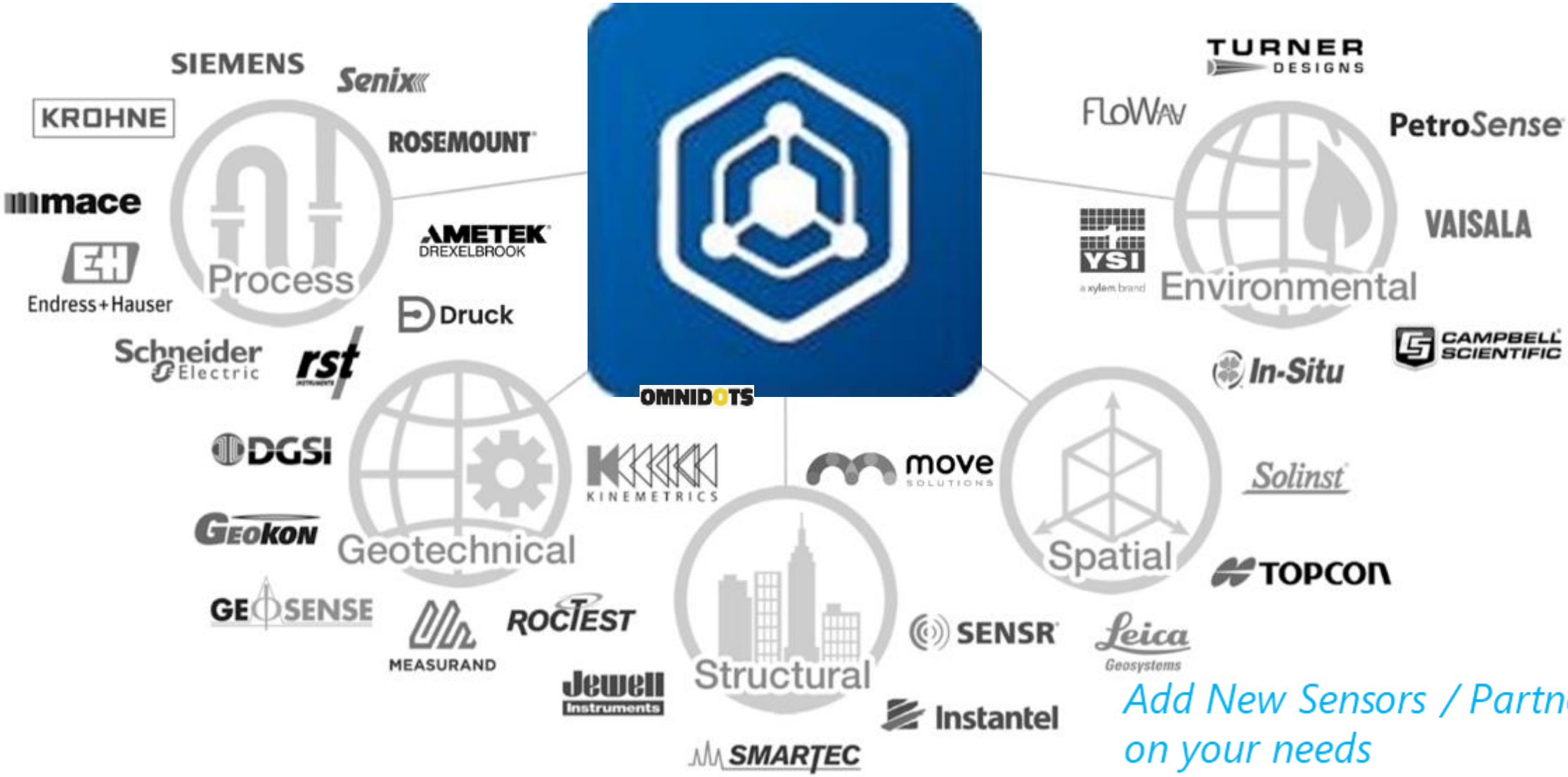
Browser-based tools and workflow-enhancing features provide valuable sensor data insight, helping you make sense of complex data.

Collaboration, Reporting, Alarms

Collaborate seamlessly with organizational permission controls. Create and share custom reports and tailor alerts to user-defined parameters with flexible notification distribution.

Bentley

iTwin IoT Vendor Agnostic Approach | Partner Ecosystem



Add New Sensors / Partners based on your needs

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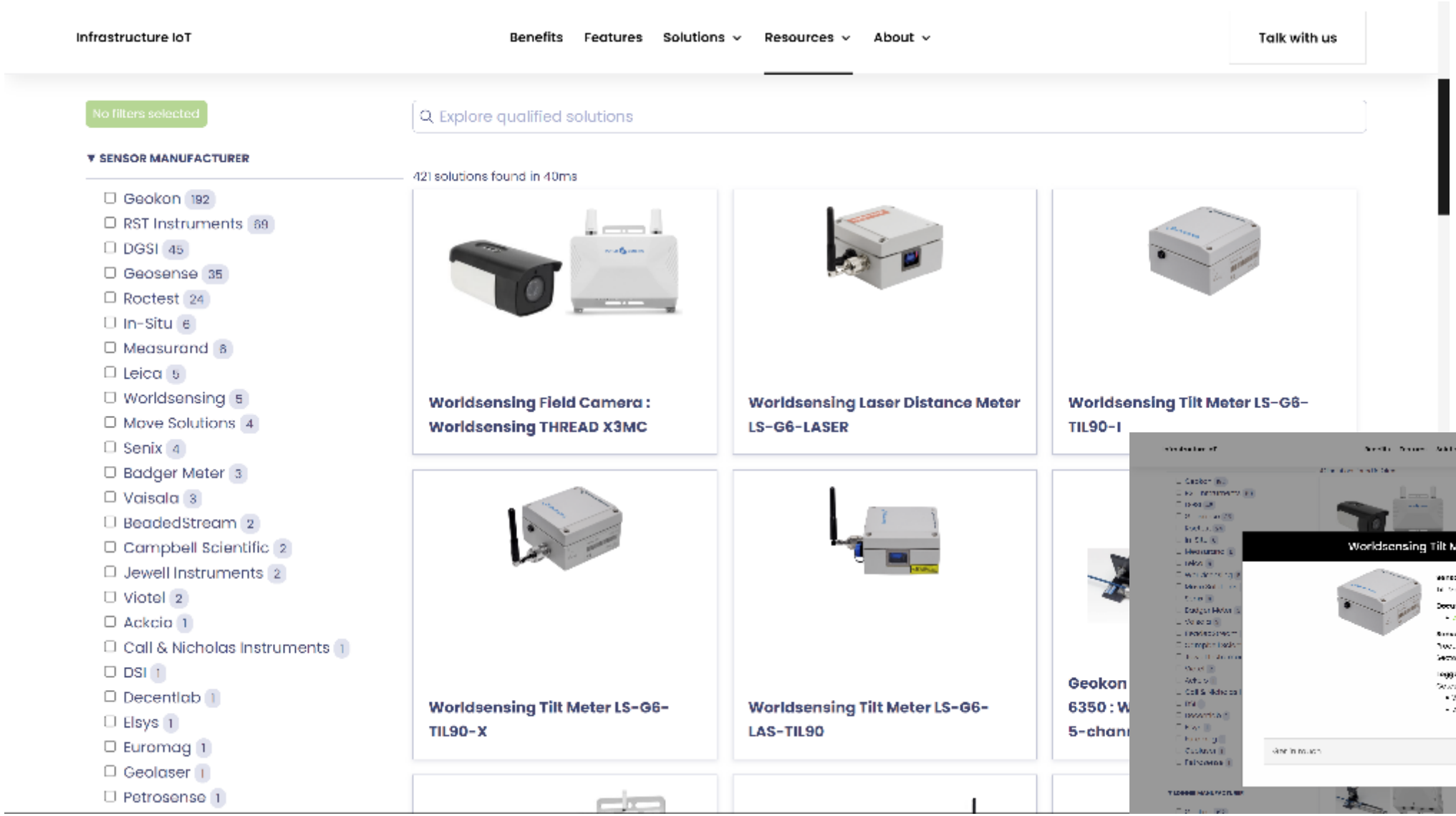
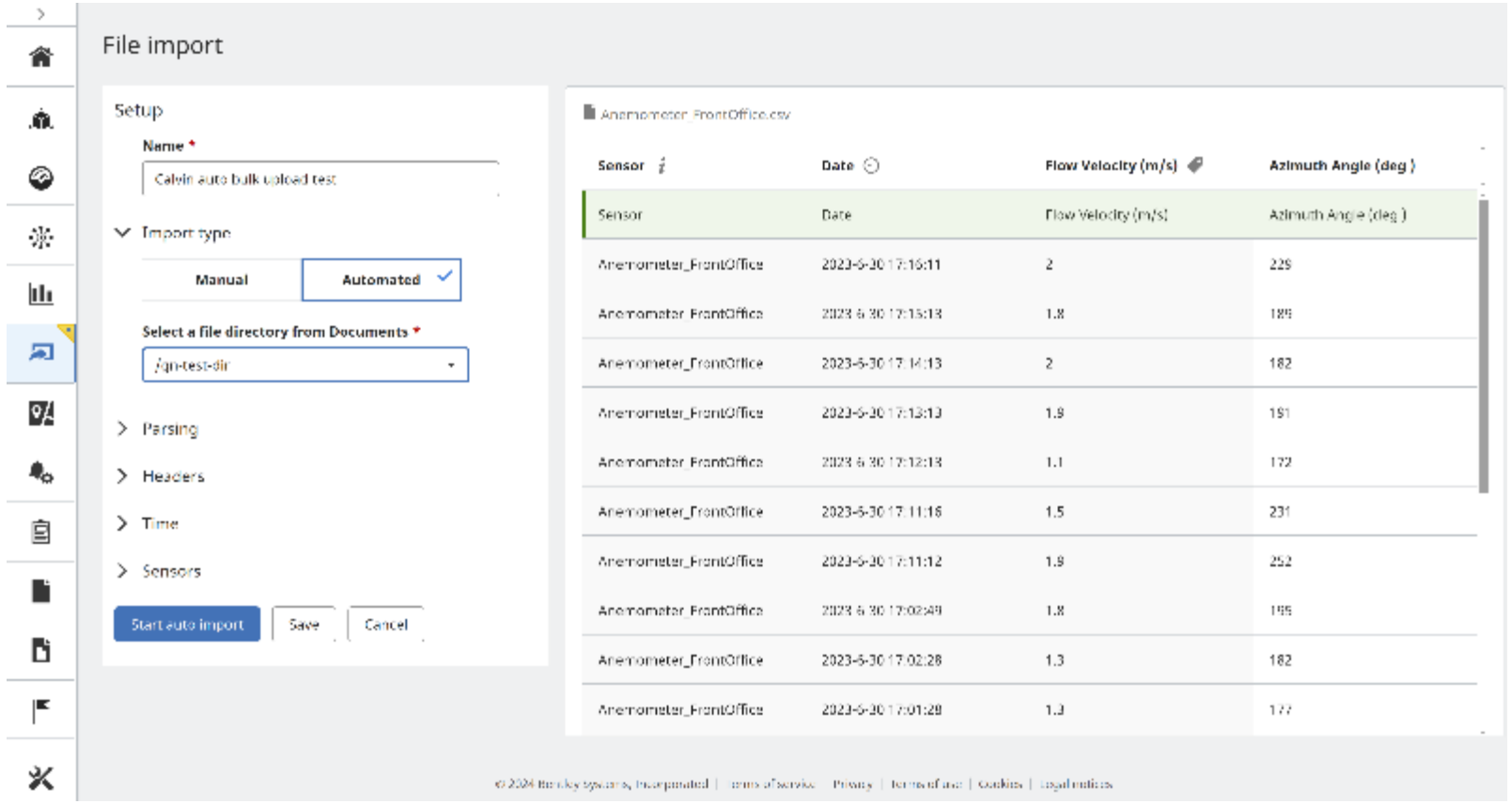
Partner Device Registry

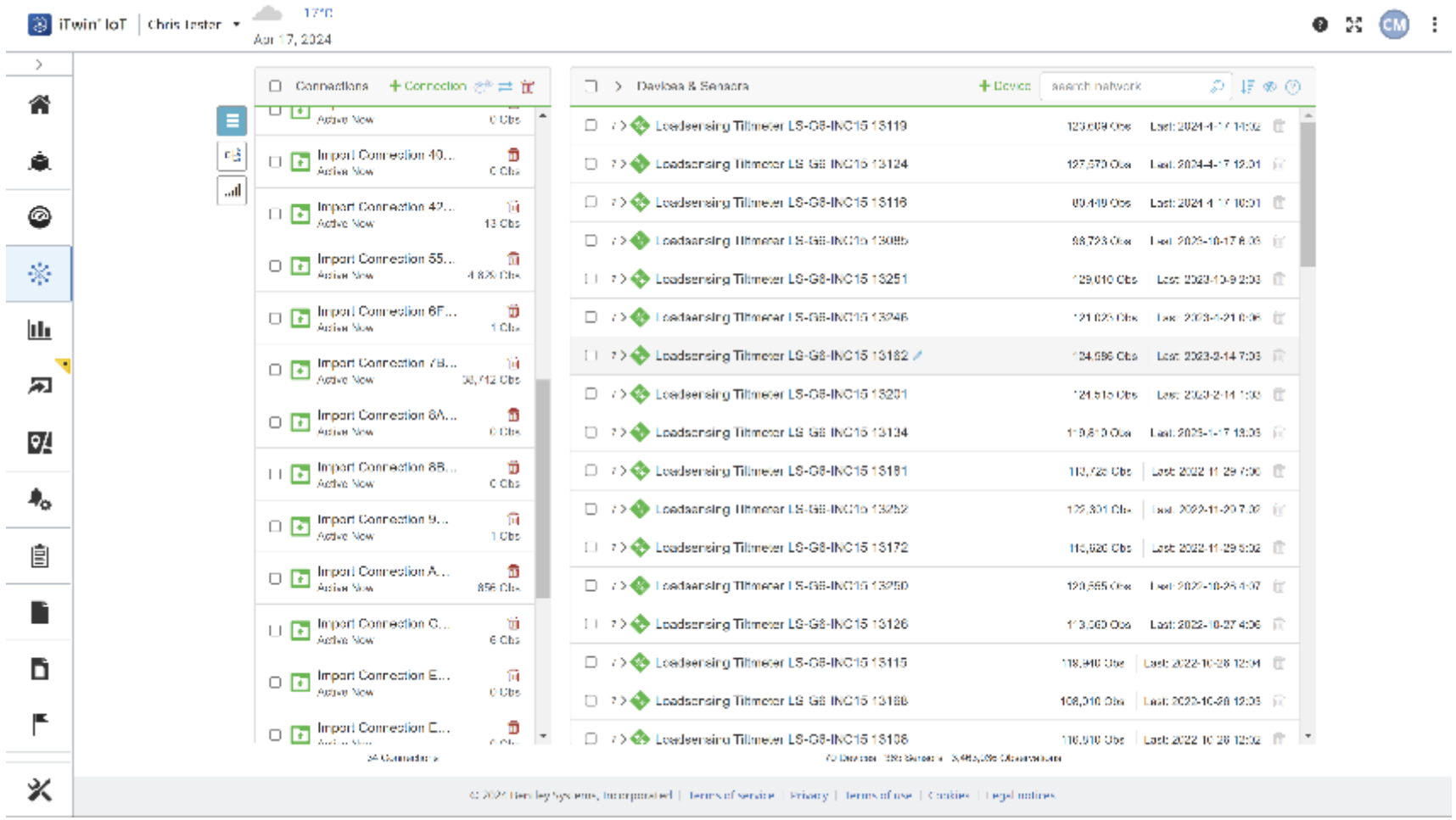


File Import



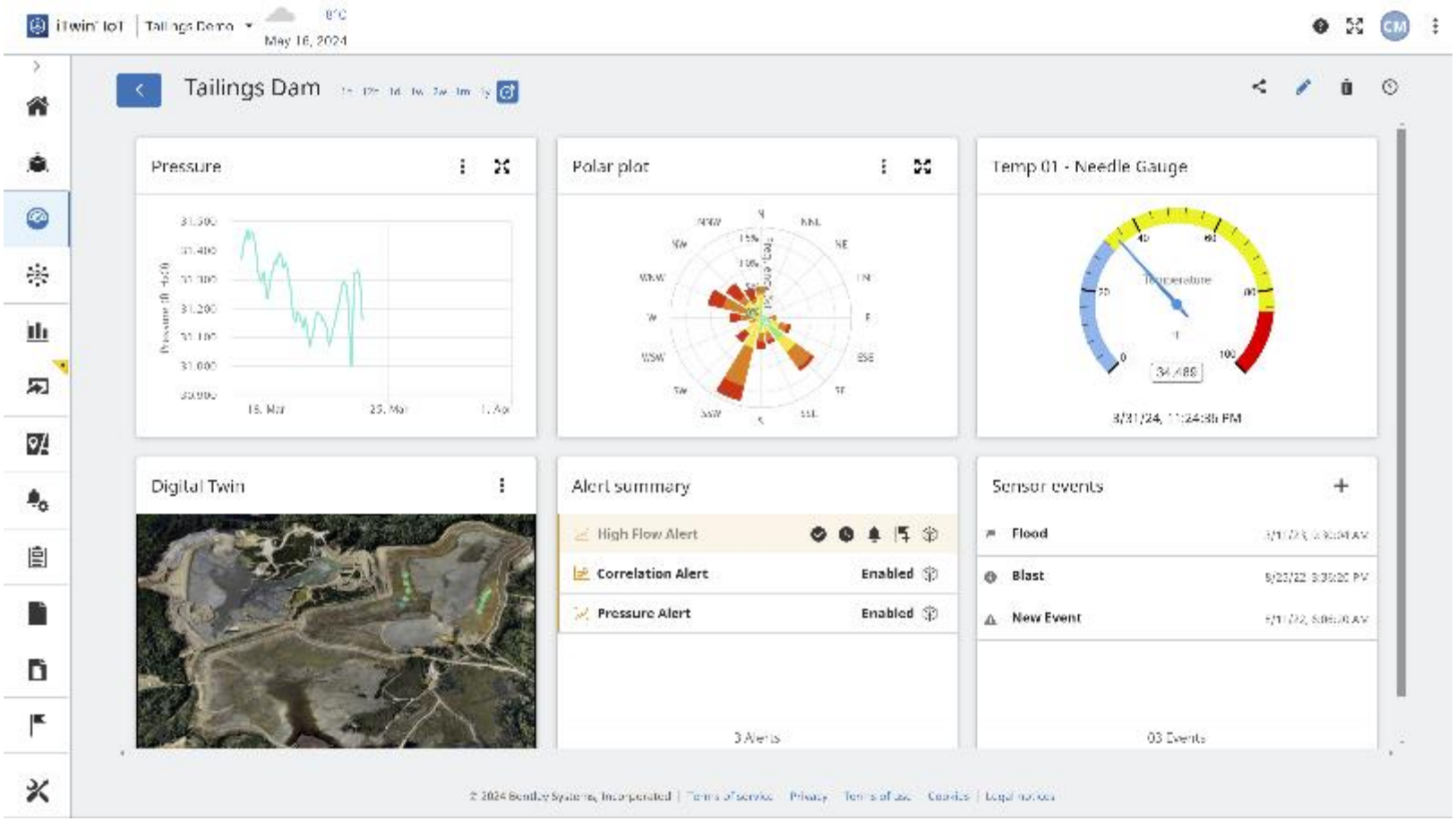
- File Import can be used if you're not using a directly supported hardware
  - Manual Data upload or Automated Data pushed to the platform over FTP
  - Create your own sensors and metrics or utilize any sensor configurations within the iTwin IoT library

Connectivity



- Connect and store your sensor data
- Configure sensor details as needed
- Integrations with partner connections from:
  - Worldsensing
  - Move Solutions
  - Leica
  - Topcon
  - Geokon
  - And more
- Additional connections include:
  - Manual Data Import
  - Automated Data Import
  - Sensor Data Service

Dashboards



- Customize your project view by creating a Dashboard with your data. There are several different card types that can be put onto one dashboard including:
  - Graphs
  - Camera Photos
  - Correlation Plots
  - Clustering Plots
  - Sensor Data Tables
  - And more

Tailings Demo

Thursday 29 Aug
10°C
5° - 10°

Rain Shower
Wind: 16km, W
Humidity: 83%

FRI	SAT	SUN	MON	TUE
4°-9°	6°-10°	3°-9°	4°-7°	6°-11°
Rain	Rain/Wind	Rain	Light Rain	Cloudy

Alert Summary

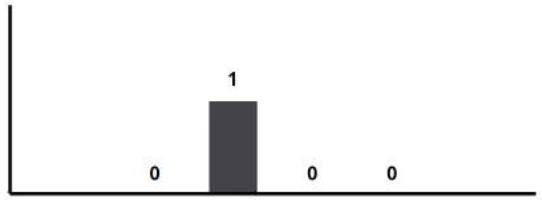
High Flow Alert	
Correlation Alert	Enabled
Pressure Alert	Enabled

3 Alerts

Sensor Count

Online
Offline
Low Power
Archived
Redirected

Alert Count



Idle
Triggered
Disabled
Snoozed

Notifications

You don't have any notification

Offline Sensors

13

1 Day

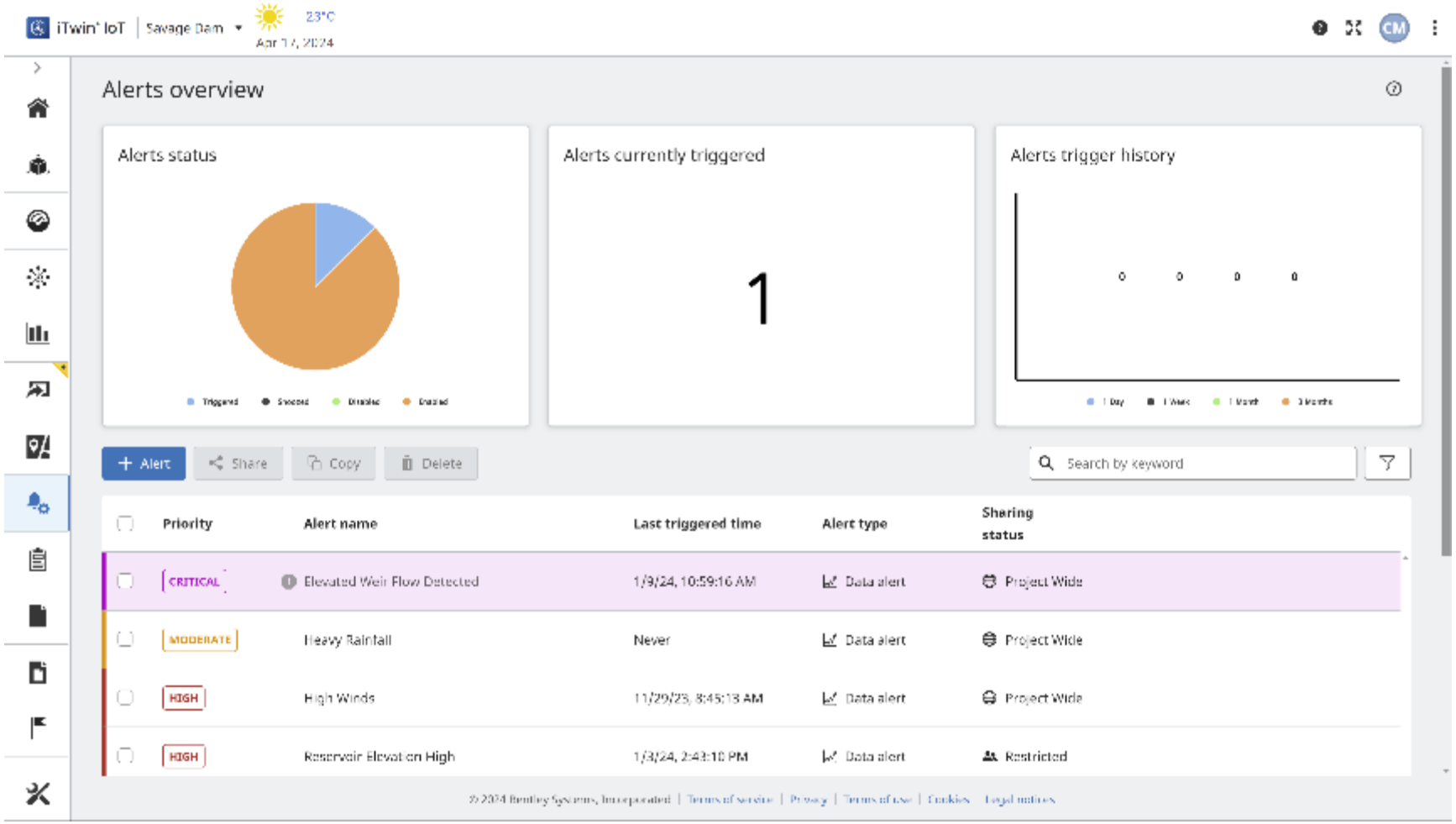
Average Communication Quality

0.0%

Current Monthly Data Usage

0 Bytes

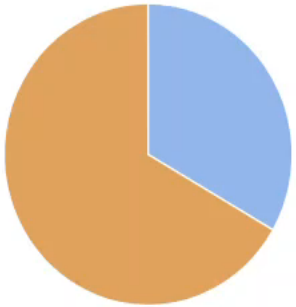
Alerts



- Create customized alerts and reactions based off your project's needs. 3 types of Alerts:
  - Data – Threshold alerts to track sensor metrics
  - Status – Outage alerts to track your system's last reported data
  - Correlation – Select any 2 sensors your project and apply a quadratic or linear formula and see how they correlate

Alerts overview

Alerts status

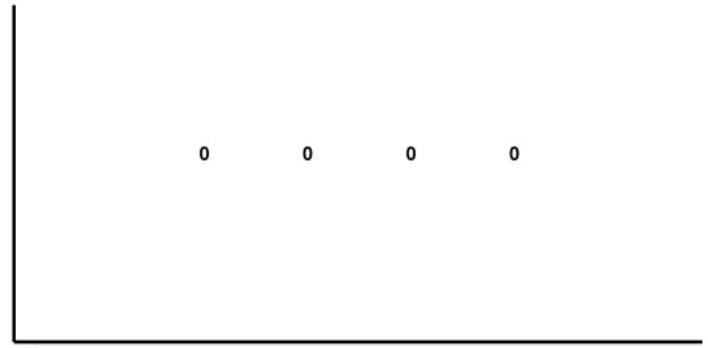


Triggered Snoozed Disabled Enabled

Alerts currently triggered

1

Alerts trigger history



1 Day 1 Week 1 Month 3 Months

+ Alert | Share | Copy | Delete

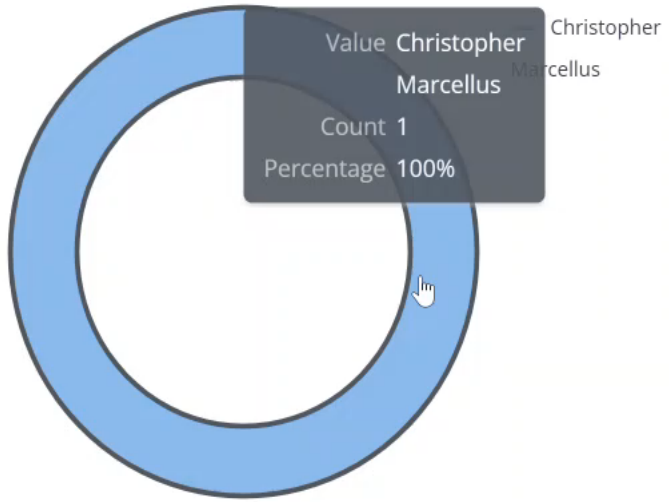
Search by keyword

Priority	Alert name	Last triggered time	Alert type	Sharing status
MODERATE	High Flow Alert	4/24/24, 5:33:25 AM	Data alert	Private
MODERATE	Correlation Alert	Never	Correlation alert	Private
MODERATE	Pressure Alert	Never	Data alert	Private

Type: Issue

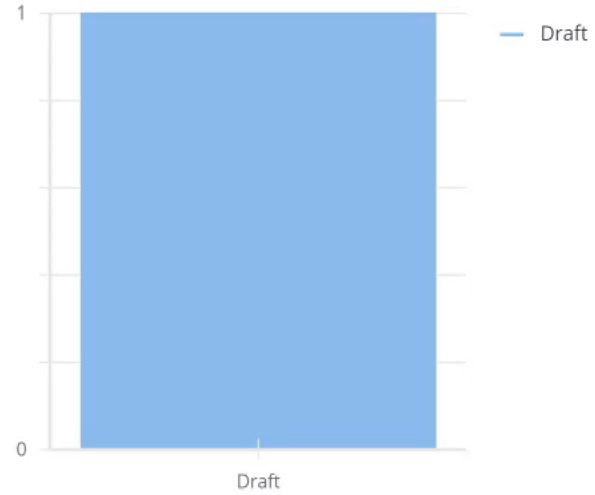
Last 60 Days

Radial Chart



Property: Assigned To

Bar Graph



Property: Status Select a Property

Quick Stats

Assigned to ...	Filled out Iss...	% Open
1	1	100%

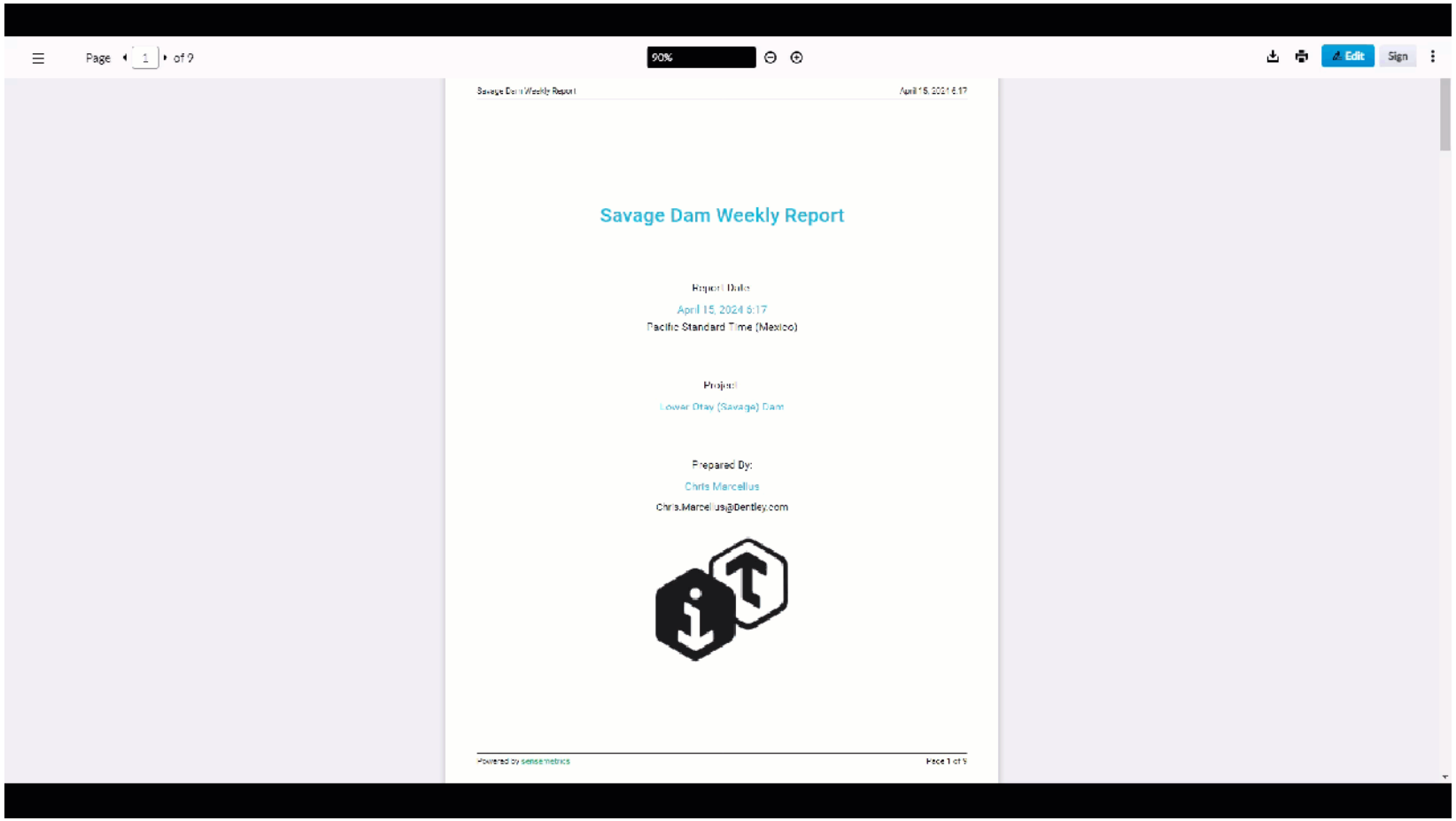
Open	Avg. Open	Longest Open
1	3 secs	3 secs

Closed	Avg. Close	Longest Close
0	N/A	N/A

Filled out Forms

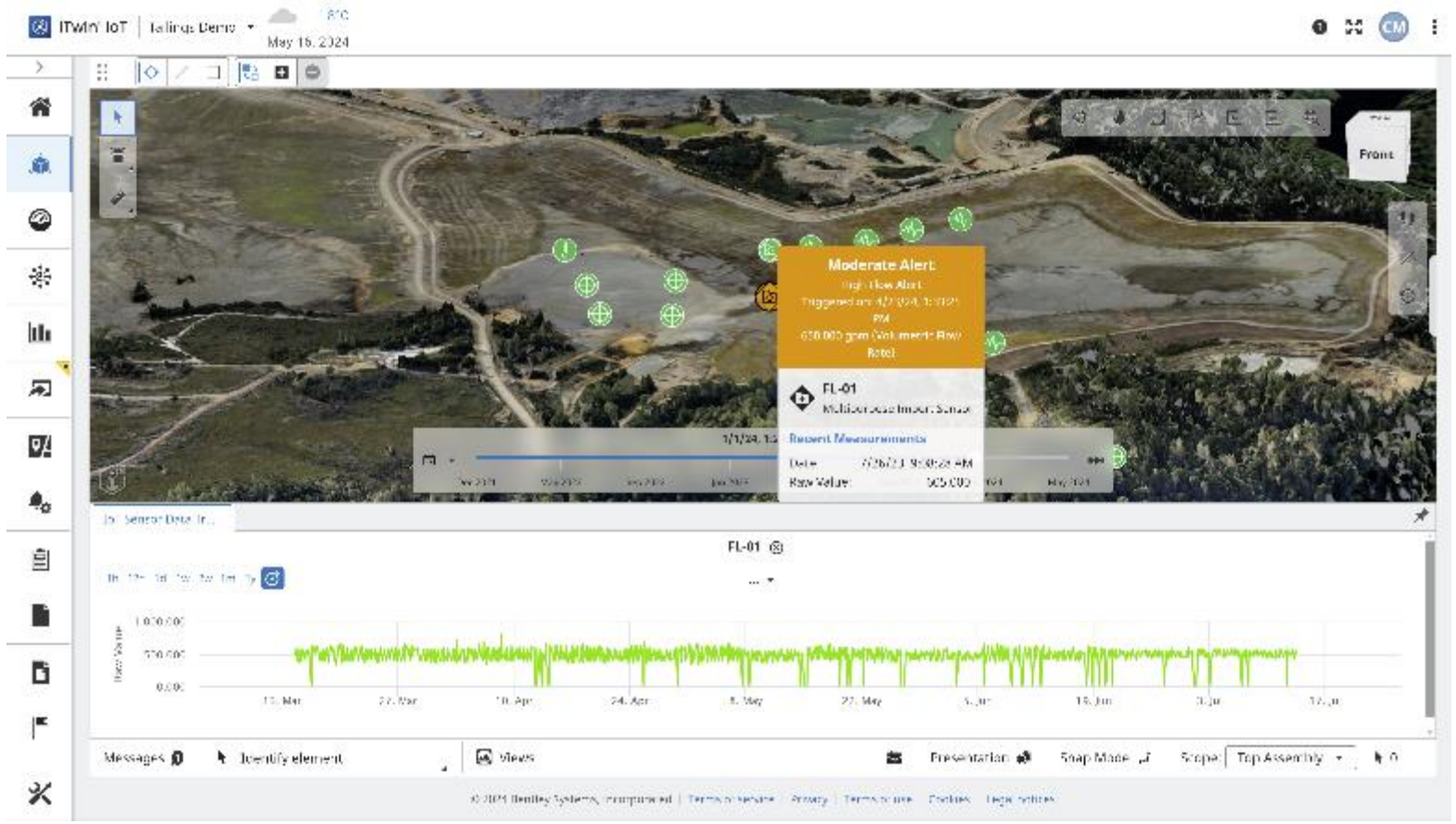
Display Name	Subject	State	Assigned To	Status	Created By	Created Date	Modified Date	Modified By	Linked Items
	Alert 'High Flow Alert' triggered by								

Reports

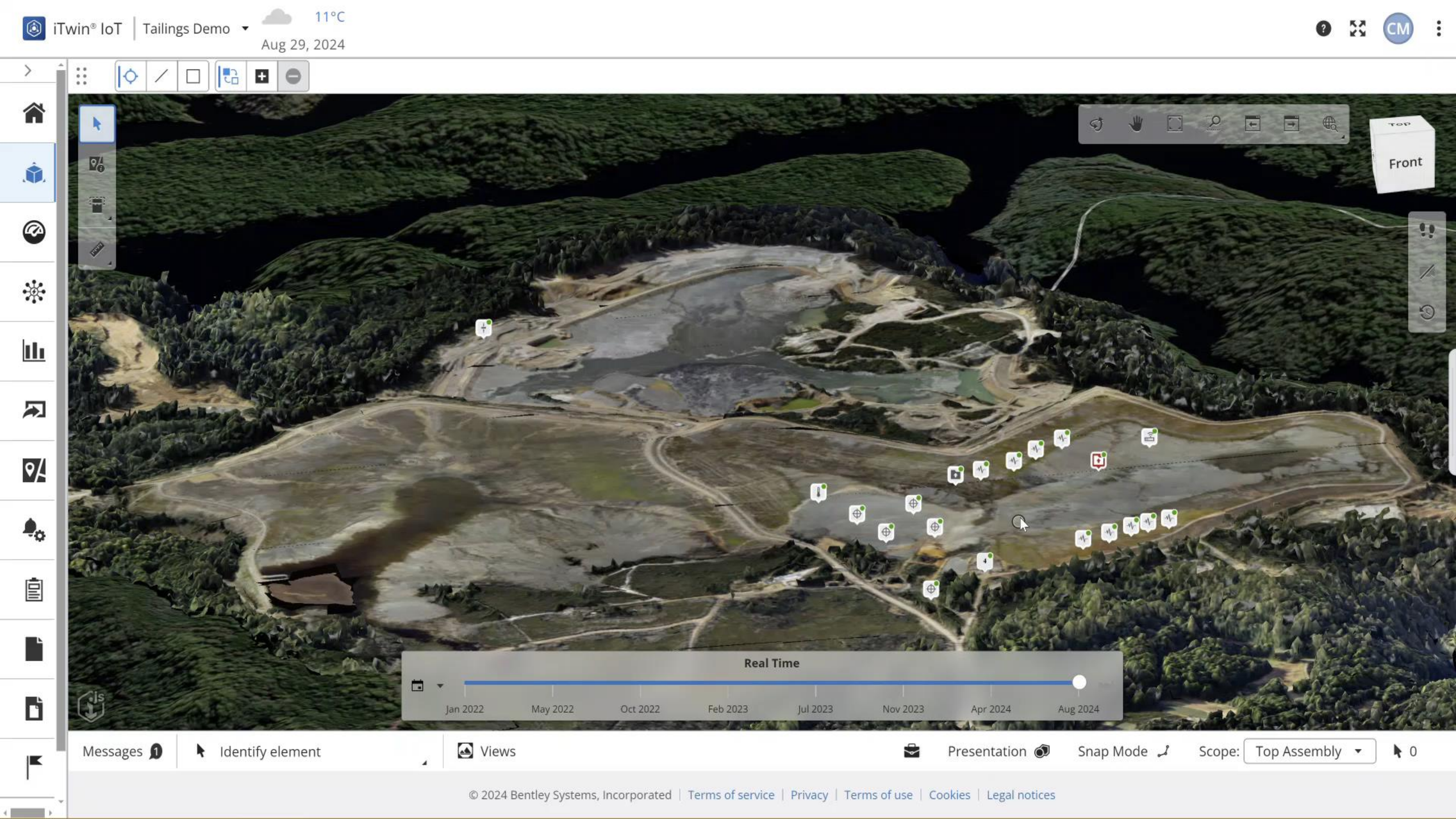


- Reports allows users to create and autogenerate customizable reports based on their project data. Sections include:
  - Cover Page
  - Table of Contents
  - Graphs
  - X/Y Graphs
  - Camera Photos
  - Alert Trigger History
  - Images
  - Notes
- Reports can be scheduled to generate daily, weekly, or monthly

Digital Twin



- The Digital Twin Module allows you to view your IoT data overlaid upon 3D imagery. This can be both BIM and Reality Mesh.


iTwin® IoT
Tailings Demo
11°C
Aug 29, 2024
CM
Front
Real Time
Jan 2022
May 2022
Oct 2022
Feb 2023
Jul 2023
Nov 2023
Apr 2024
Aug 2024
Messages
Identify element
Views
Presentation
Snap Mode
Scope:
Top Assembly
0
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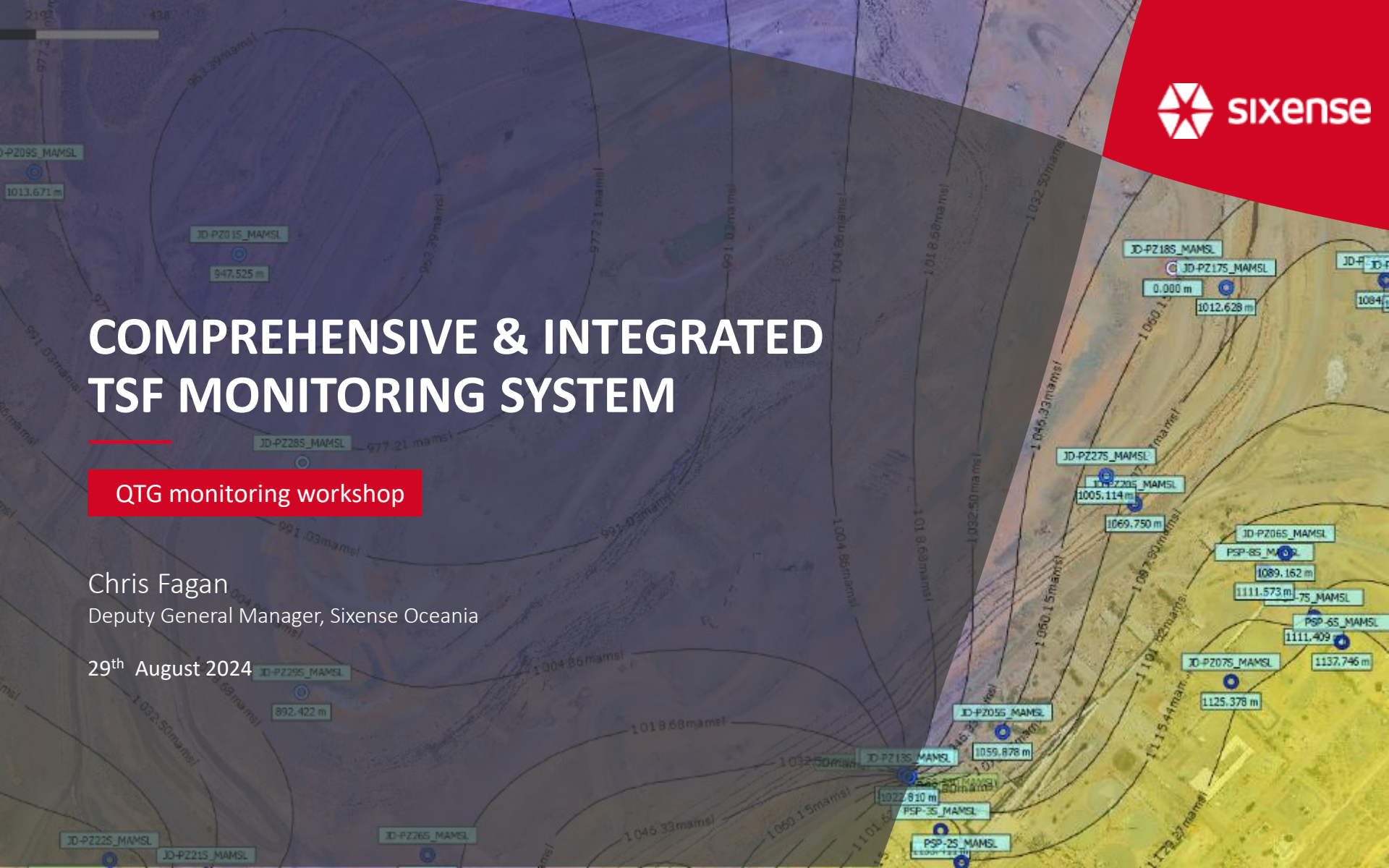
COMPREHENSIVE & INTEGRATED TSF MONITORING SYSTEM

QTG monitoring workshop

Chris Fagan
Deputy General Manager, Sixense Oceania

29th August 2024



AGENDA

01 ABOUT SIXENSE

02 OUR INSTRUMENTATION & MONITORING SOLUTION

03 USE CASES

04 CONCLUSION & RECOMMENDATIONS

01

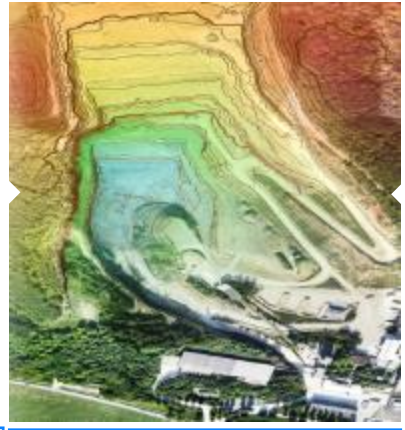
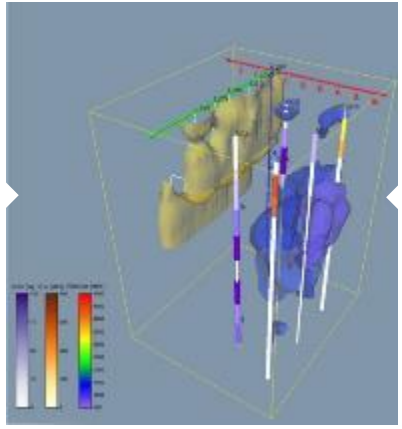
ABOUT SIXENSE GROUP

Quick introduction

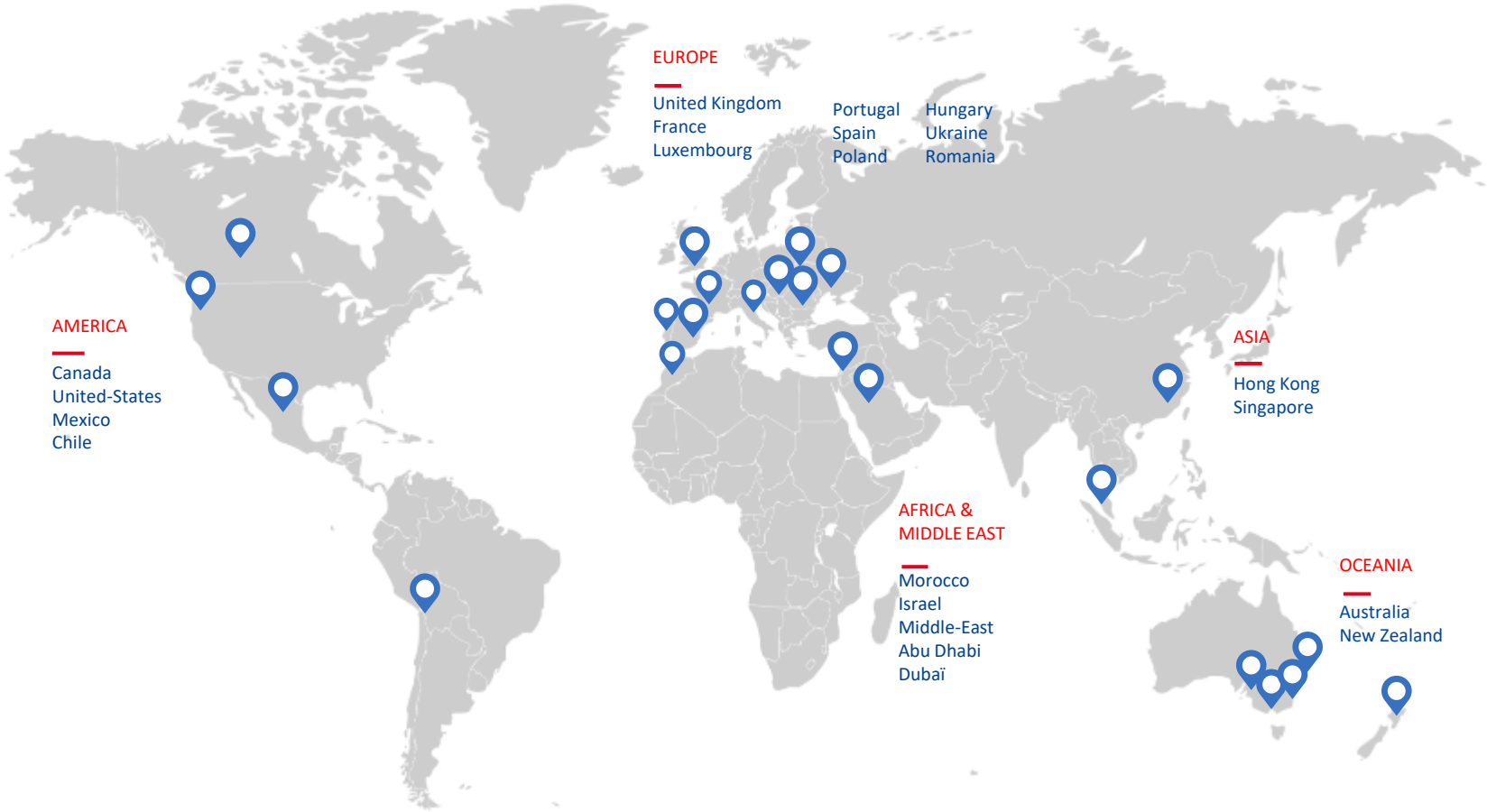
ABOUT SIXENSE

Mission

Offer advanced Technologies & Services to Designers, Builders, Operators and Managers to optimise their assets through their life cycles.

INSTRUMENTATION & MONITORING	DIGITISATION & INSPECTIONS	GEOPHYSICS & ENGINEERING	DIGITAL SOLUTIONS / SOFTWARE
			

SIXENSE GLOBALLY



SIXENSE LOCALLY

AUSTRALIA
Melbourne (HQ)
Sydney
Adelaide
Brisbane (*)

NEW ZEALAND
Auckland

+ SERVICES

- ✓ Monitoring Design
- ✓ Procurement
- ✓ Installation & Commissioning
- ✓ Automatic / Manual Monitoring
- ✓ Data management & QA/QC
- ✓ Data Reporting
- ✓ Consulting & Expertise
- ✓ Maintenance & Trouble shooting

02

INSTRUMENTATION & MONITORING OF TSF

Integrated solutions for
real-time monitoring

sixense

WHY USE A MONITORING SYSTEM?

- Manage the residual risk associated with uncertainty in design and modelling
- Early detection of developing instability
- Communication of alarm exceedance
- Confirming geotechnical characteristics are within expected/require performance range
- Ease communication & support decision

Develop a

⇒ Common (& Efficient) Situational Awareness

SAM2 | SITUATIONAL AWARENESS MATURITY MODEL

Objective of the GISTM

Common & Efficient situational awareness	• All parties have a common understanding of site(s) status. • Resources are spent on solving issues & taking right decisions.
Costly situational awareness	• Data gathered in one place ensuring common situational awareness. • Timely input process but non optimum tools and procedures
Diverse situational awareness	• Data stored different places. • Each individual has control of his/her area of responsibility.
Low situational awareness	• Site(s) data is inconsistent and do not cover all details needed. • Low communication between parties.

INTEGRATED MONITORING | ALL DATA IN ONE PLACE

a good start

DEFORMATION monitoring

- Cyclops ® (Total Station)
- ATLAS Satellite InSAR
- Laser scanning
- Load, strain, crack, etc.
- …

GEOTECHNICAL monitoring

- Inclinometers
- Extensometers
- Piezometers
- Pressure cells
- …

ENVIRONMENTAL monitoring

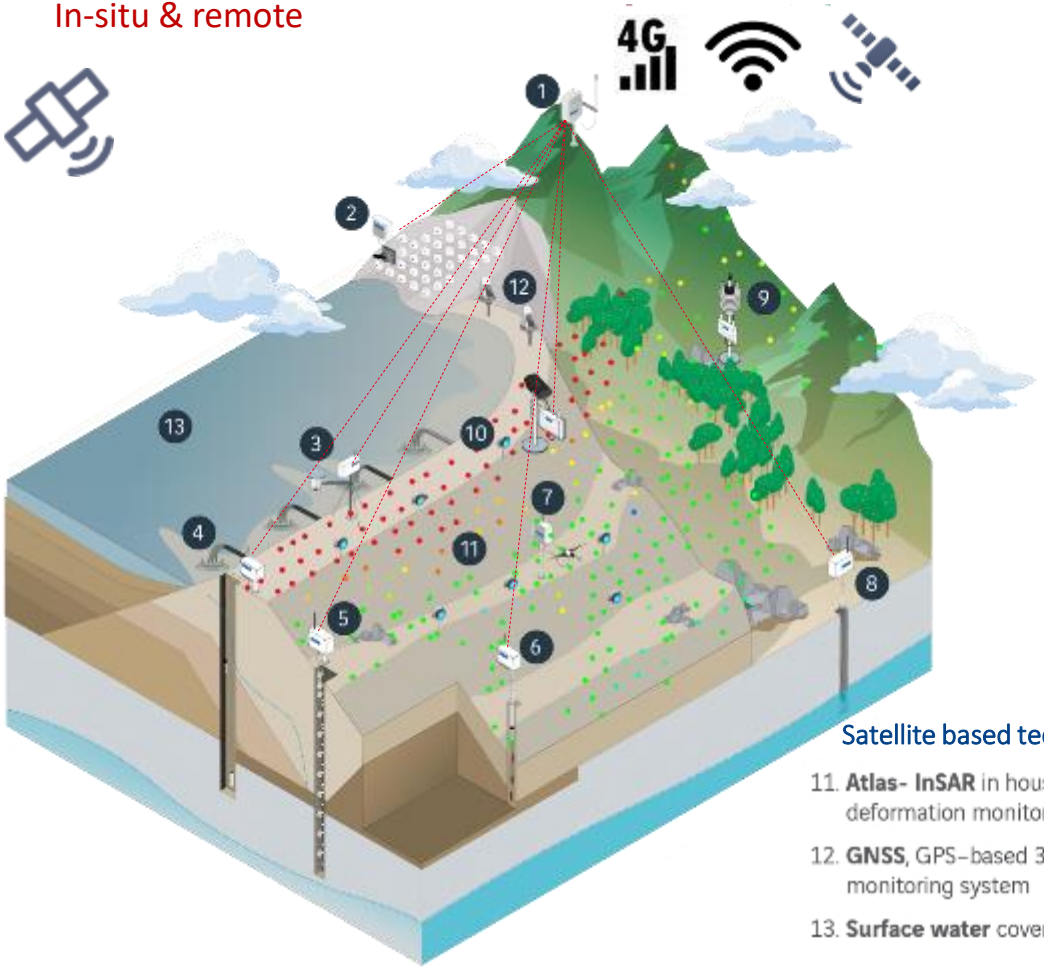
- Dust and weather stations
- Air and water pollution
- Noise and vibration
- …

Beyond Monitoring™

Monitoring Information & Management System (MIMS)

REAL TIME DATA COLLECTION | IMPROVE EFFICIENCY

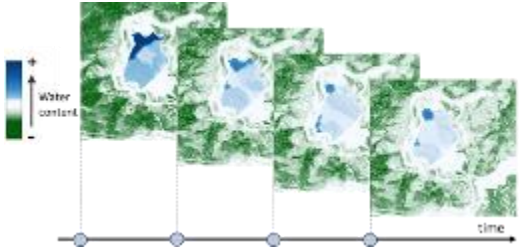
In-situ & remote



1. **Gateway** that wirelessly collects data from all sensors and sends it to the cloud
2. **Load cells** on retaining wall anchors
3. Wireless **Water level meter**
4. **Vibrating Wire Piezometer** (VWP) for ground water monitoring
5. **In Place Inclinometer** (IPI) or **Shape Array** (SAA) for vertical deformation profile
6. **Multi-Point Borehole Extensometers** (MPBX) for settlement / heave
7. **Crackmeter** to follow the evolution of existing cracks
8. **Water quality** monitoring
9. Multi-parameter **Weather station**
10. **Prisms & Total Station** (Cyclops) for 3D millimetric deformation monitoring

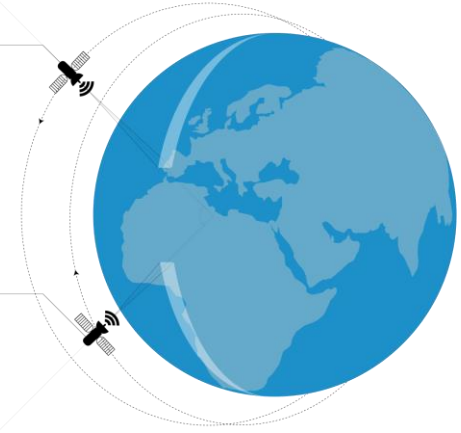
Satellite based technologies

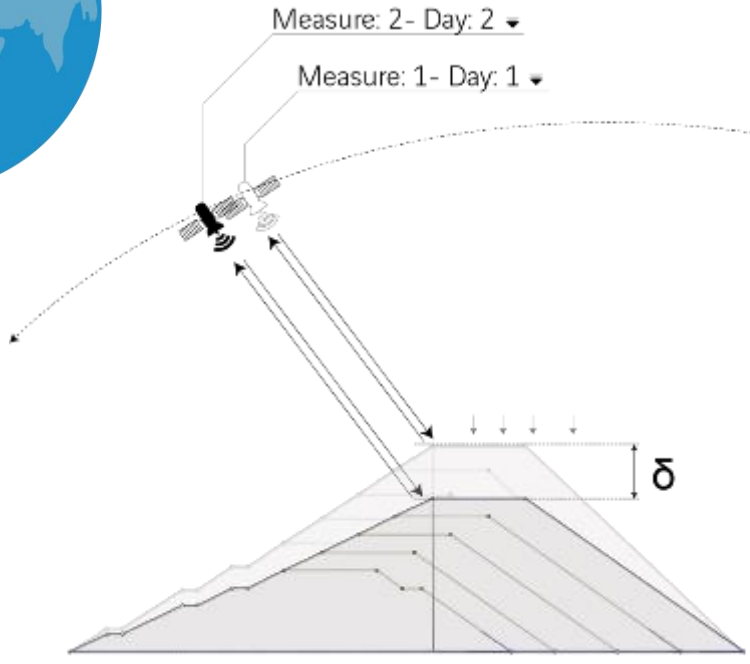
11. **Atlas- InSAR** in house satellite-based ground deformation monitoring over large areas
12. **GNSS**, GPS-based 3D deformation monitoring system
13. **Surface water** coverage time lapse

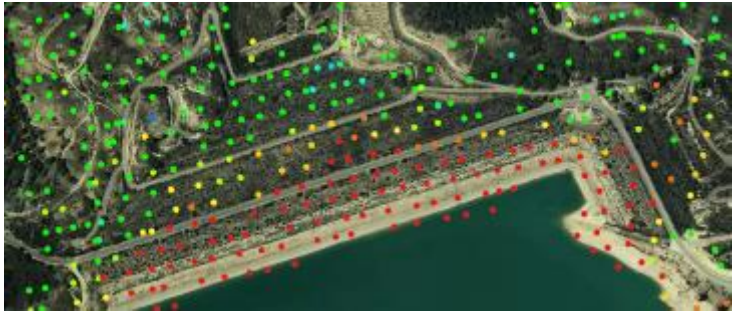


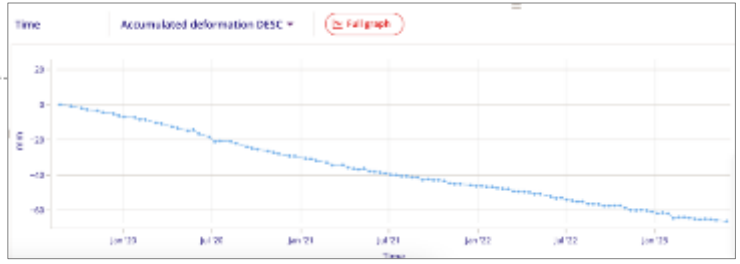
INTRODUCTION TO INSAR | Technology overview

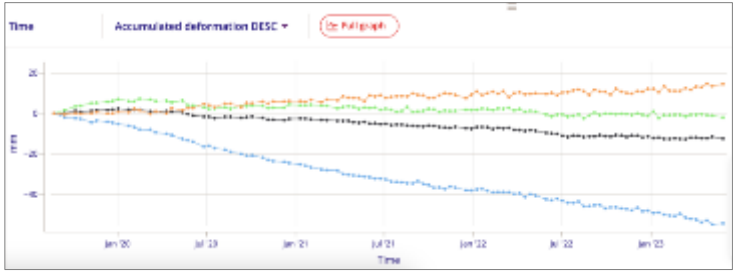
INterferometric **S**ynthetic **A**perture **R**adar



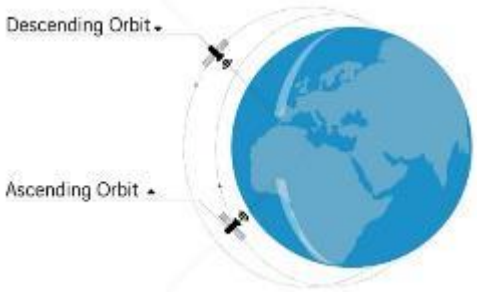


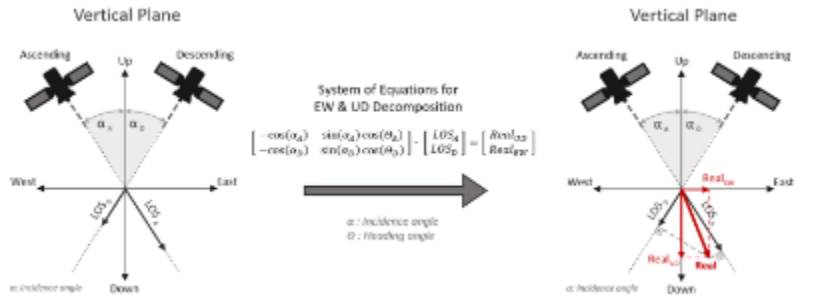




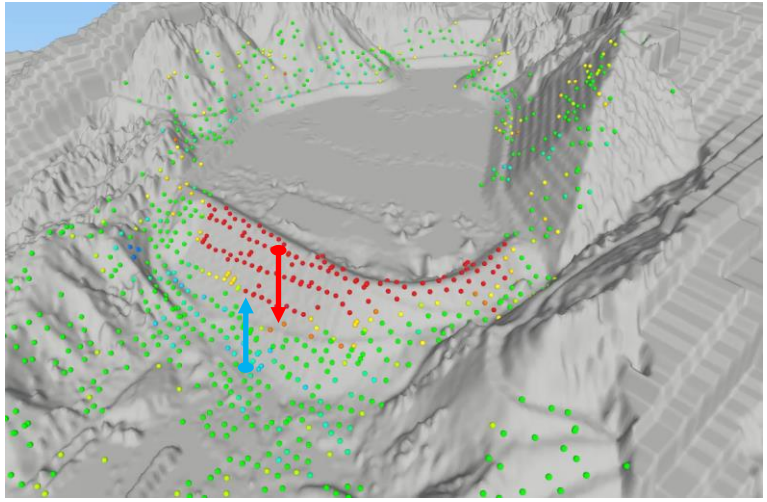


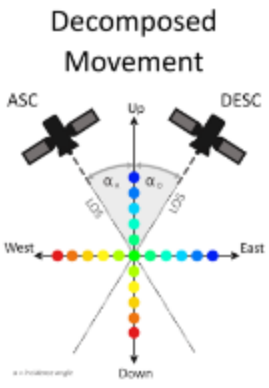
use case on TSF with dual orbits



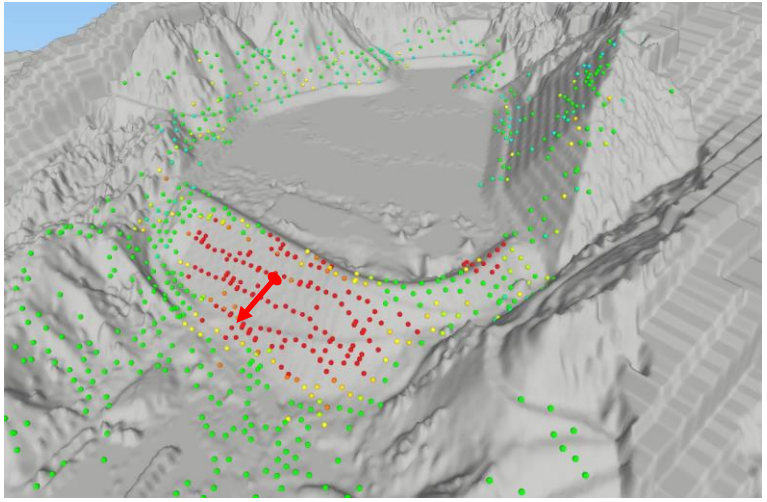


Up-Down





West - East



BEYOND MONITORING™ | KEY FEATURES

for Common & Efficient situational awareness

DATA INTEGRATION
All data in one place (including “big data”)

CORRELATION & DATA REDUCTION
Data insights

GIS PLATFORM
Layers based system

ALARM MANAGEMENT
Generation & real-time notifications

INTEGRATED REPORTING
Customized and automatic

JOURNAL
Time-stamped events for data interpretation

VISUAL INPECTIONS MANAGEMENT
Tour/campaigns of visual inspections

DATA INTEGRITY & SECURITY
ISO 27001 certification

03

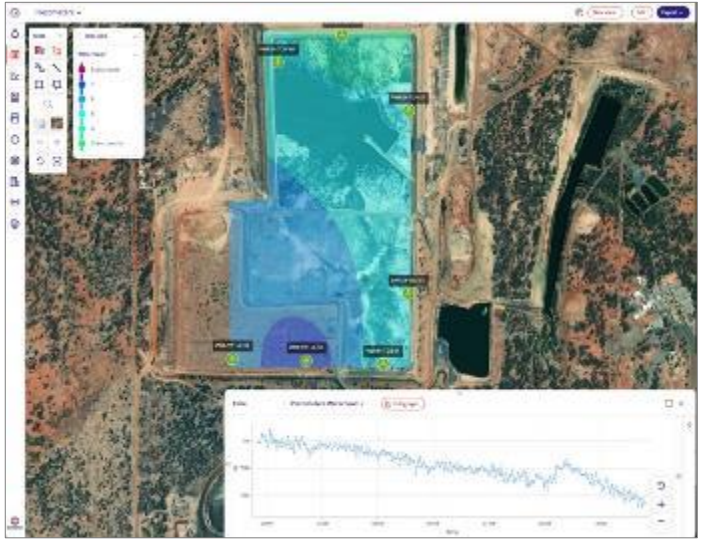
USE CASES

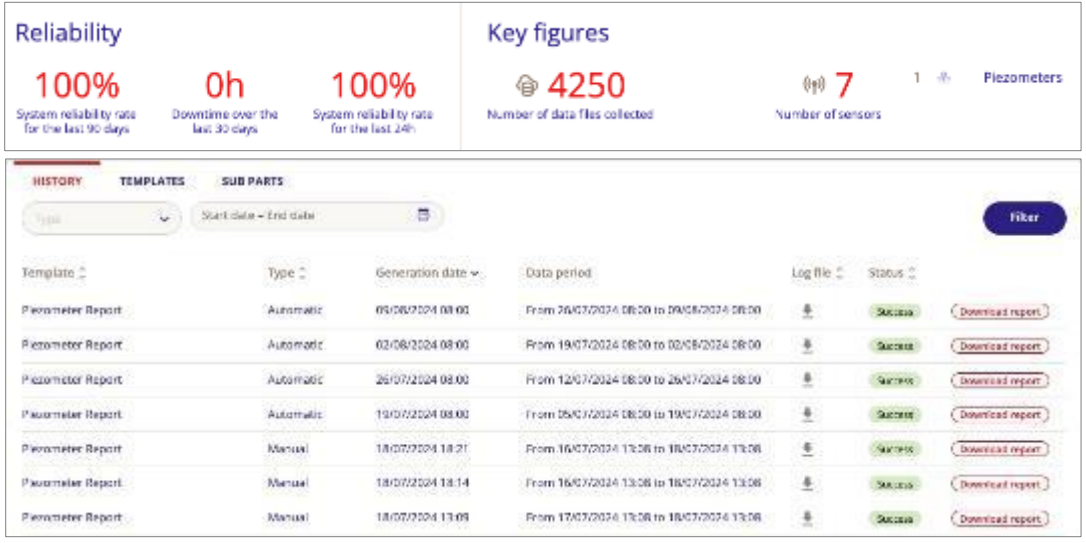
1 - Small
2 - Large
3 – Complex
4 – Multi-sites

sixense

TSF MONITORING | SMALL SITE

but state-of-the-art





TSF MONITORING | LARGE SITE

integrated with mines

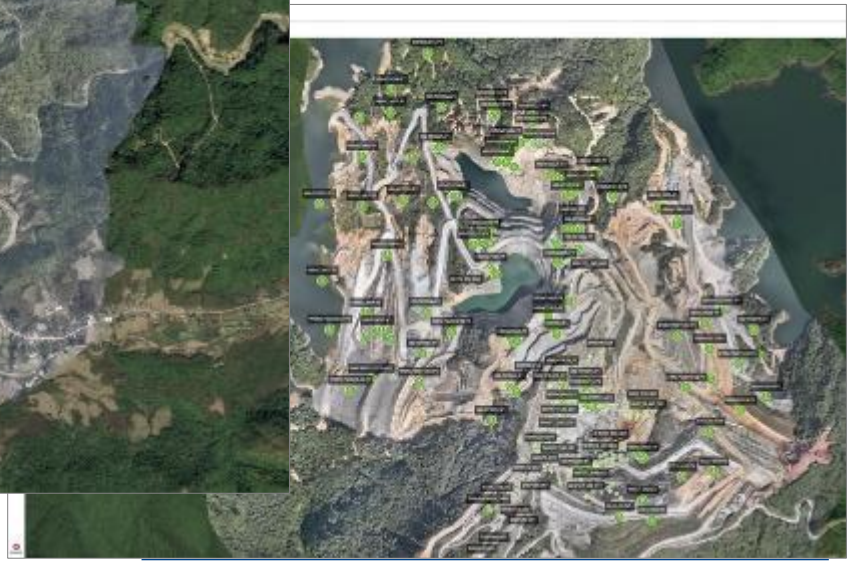
Reliability

100%	0h	100%
System reliability rate for the last 90 days	Downtime over the last 30 days	System reliability rate for the last 24h

Key figures

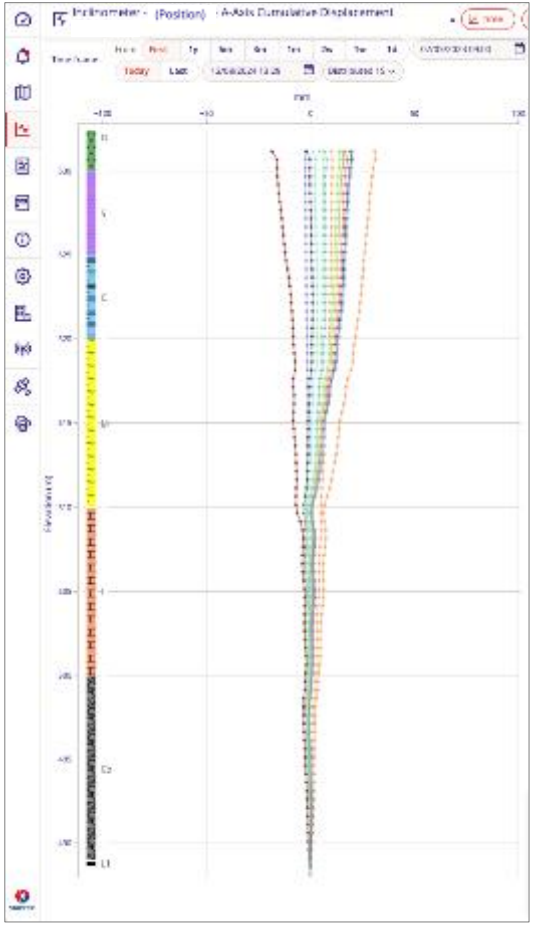
23721	2535
Number of data files collected	Number of sensors

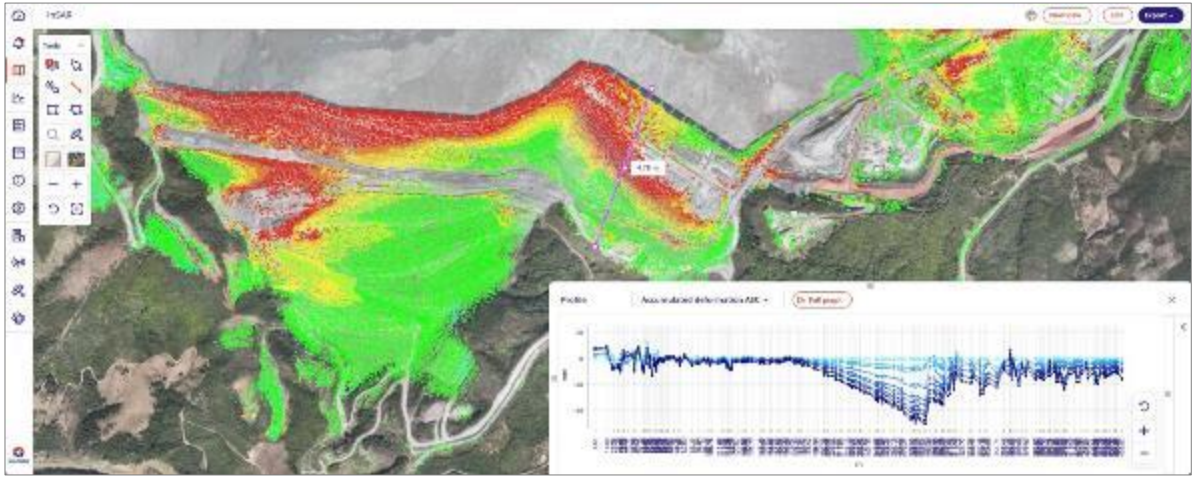
1	Targets	1285	5	Robotic total stations	11
2	Piezometers	1121	6	Weather stations	3
3	Water levels	100	7	Other sensors	1
4	Manual inclinometers	12			



TSF MONITORING | LARGE SITE

multiple technologies & big data





TSF MONITORING | COMPLEX SITE

with wide-ranging instrumentation

Reliability

100%	0h	100%
System reliability rate for the last 90 days	Downtime over the last 30 days	System reliability rate for the last 24h

Key figures

1884201 Number of data files collected

397 Number of sensors

1	Piezometers	248	6	Vibrations	4
2	Targets	83	7	Manual inclinometers	4
3	In place inclinometers (IPI)	25	8	Other sensors	3
4	Liquid levels	19	9	Station groups	3
5	Robotic total stations	4	10	Data loggers	2

TSF MONITORING | COMPLEX SITE

comprehensive piezometer network

BH-09-02

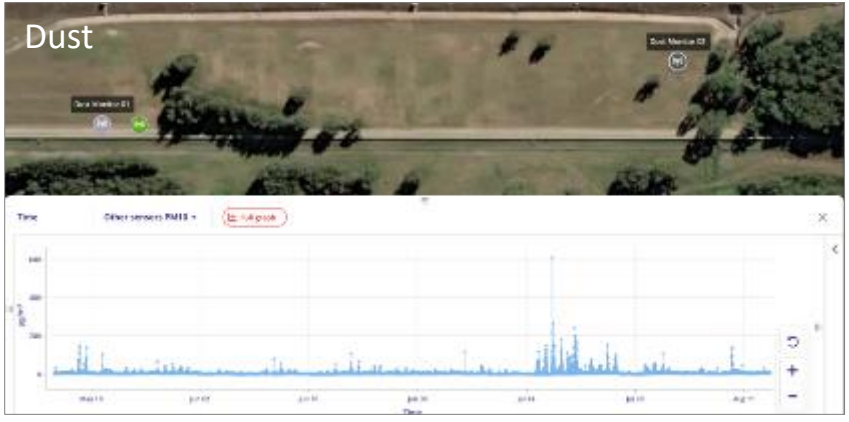
GENERAL	CHARACTERISTICS	LOCATION
Alternative asset identifier		
Alternative sensor identifier		
Calibration date	25/02/2024	
Calibration end date		
Depth of the piezometer in relation to the top of the tube	25	
Installation company	Sixense	
Installation date	06/08/2024	
Maker	HMA	
Model	350 kpa	
Serial number	S 15116	
Vertical datum	AHD	
Z from the top of the tube	290	

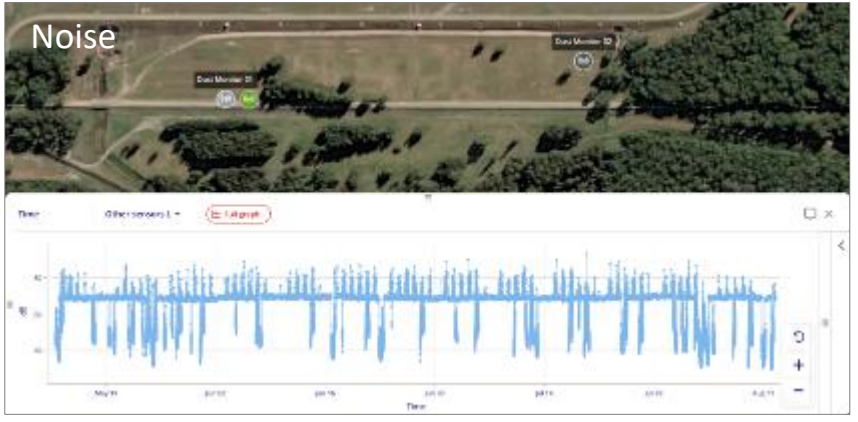
TSF MONITORING | COMPLEX SITE

Automated Total Station & Prisms (NO USE OF VENDOR SOFTWARE)

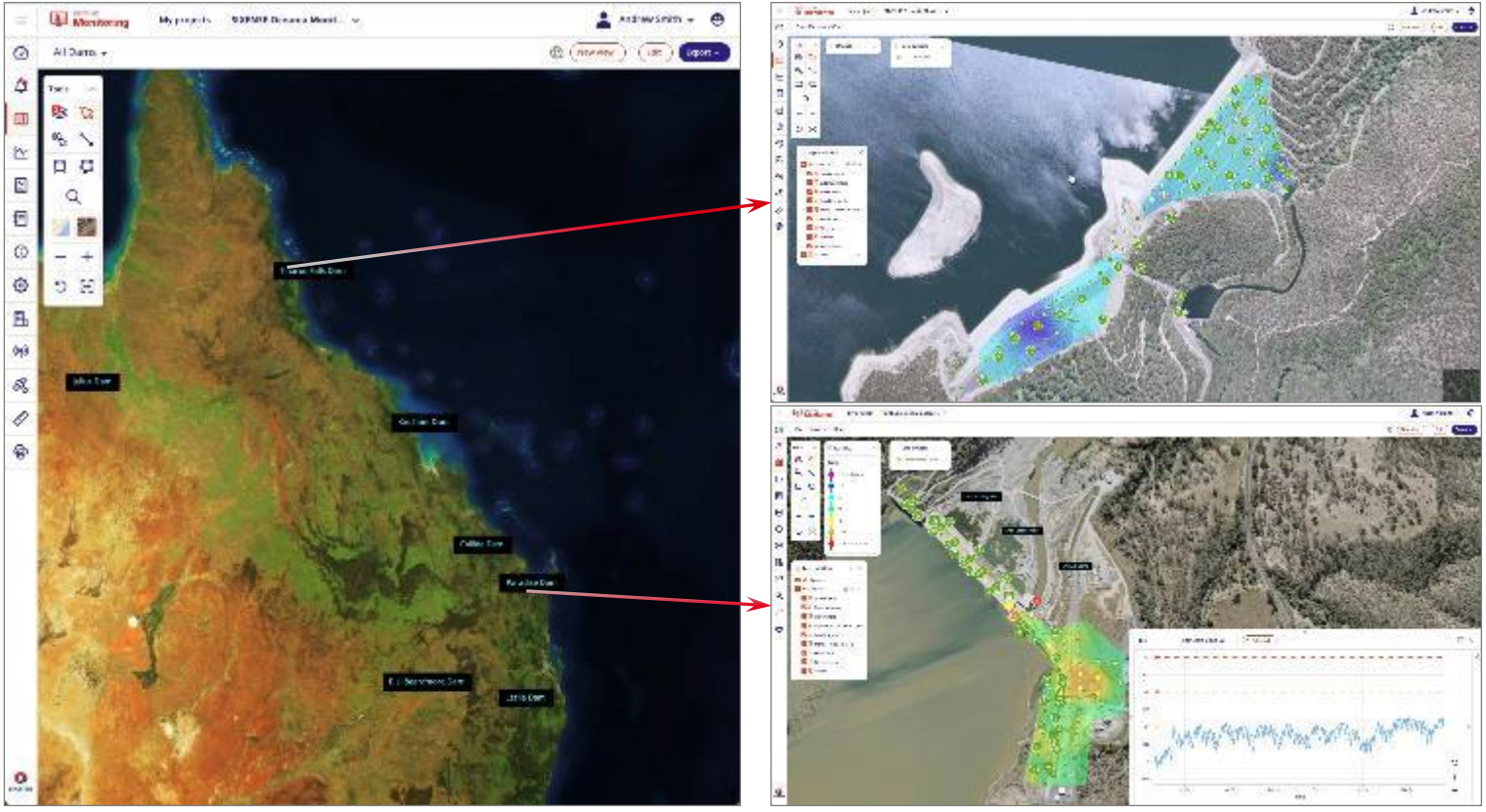
TSF MONITORING | COMPLEX SITE

Noise, vibration, dust, flowmeter….



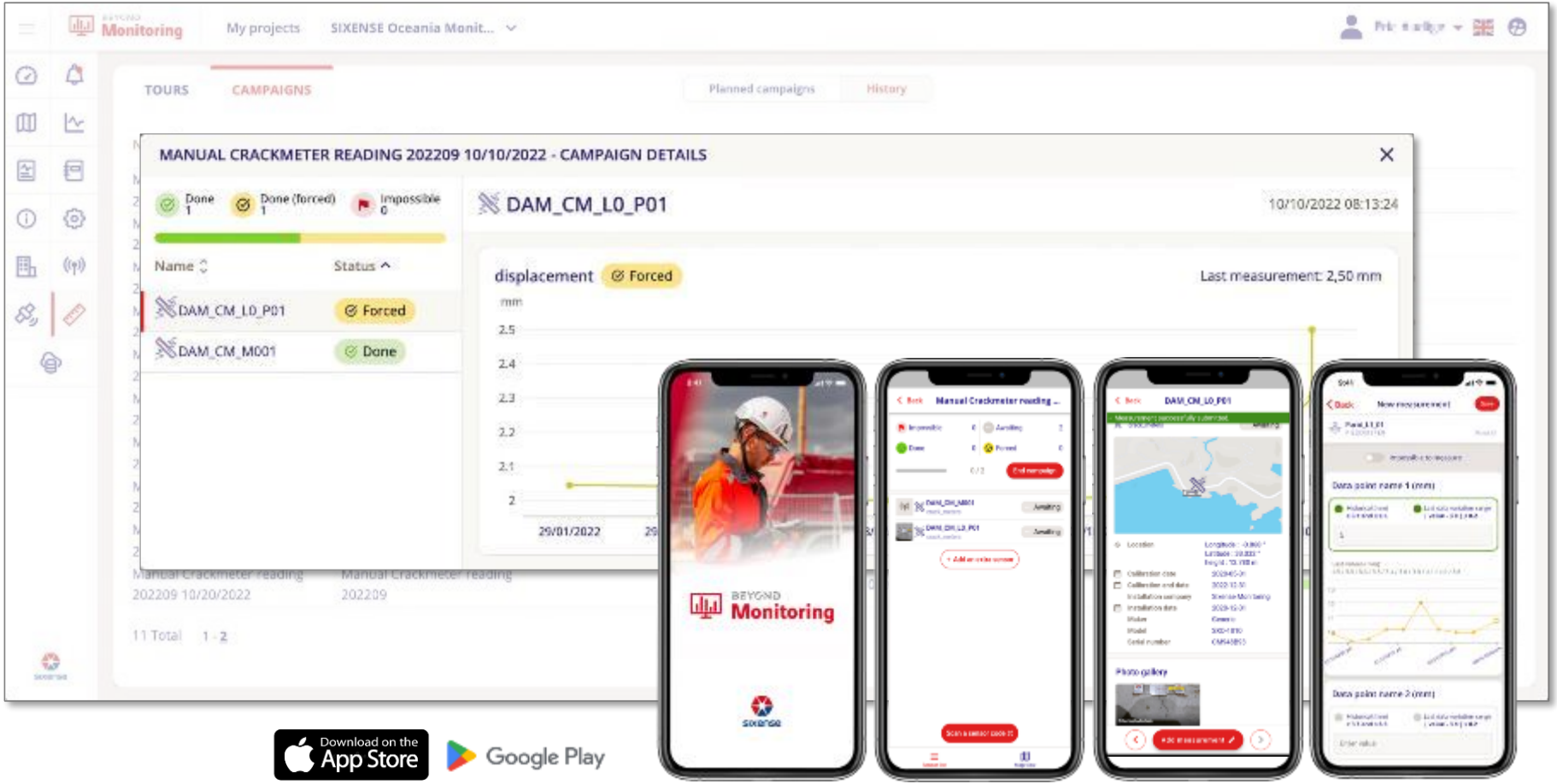


Multi sites



TSF MONITORING | ANY SITE

Tours & Campaigns for reliable manual data collection

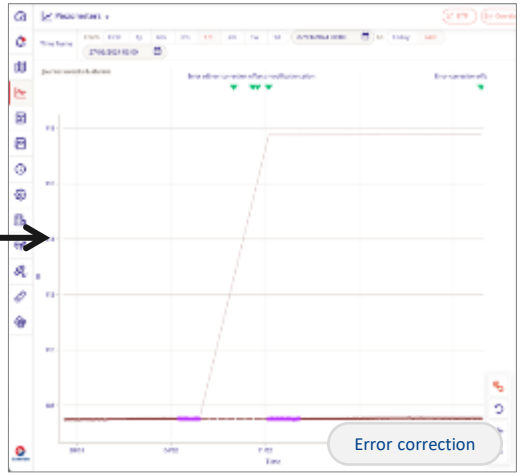


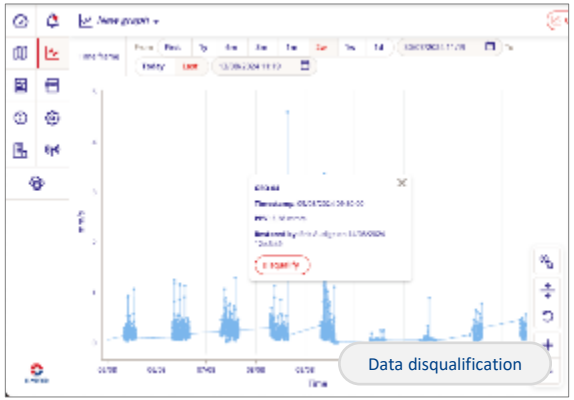
Download on the App Store

Google Play

TSF MONITORING | ANY SITE

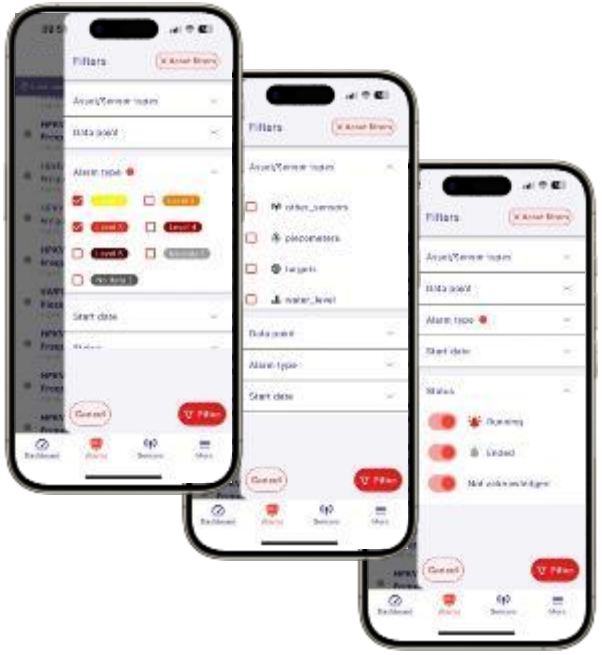
Beyond Monitoring Toolbox



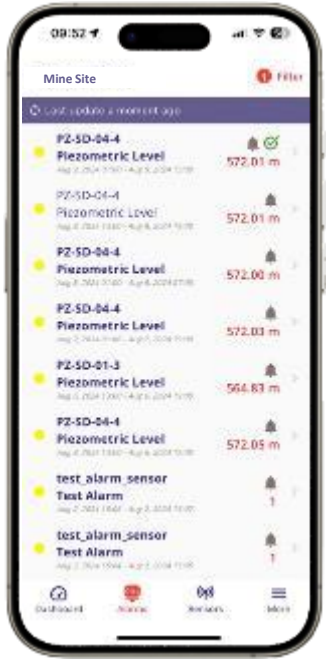


TSF MONITORING | ANY SITE

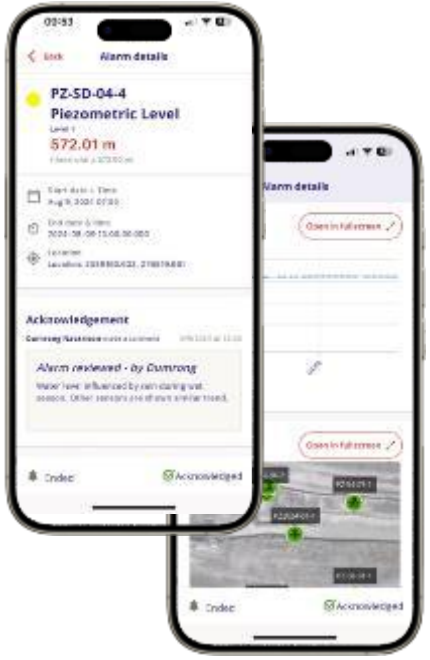
Alarm management via mobile app



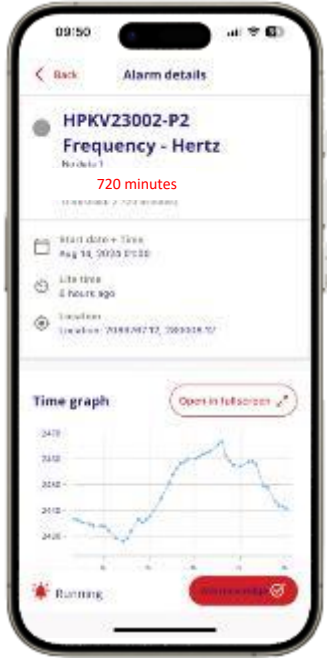
1 - Filter the alarms
with multiple parameters



2 – Get the list



3 – Visualize, analyse
& acknowledge



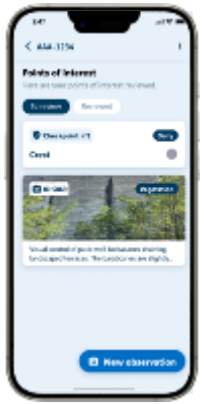
System alarm
(no data threshold here)

TSF MONITORING | ANY SITE

Visual Surveillance Inspections

CREATE

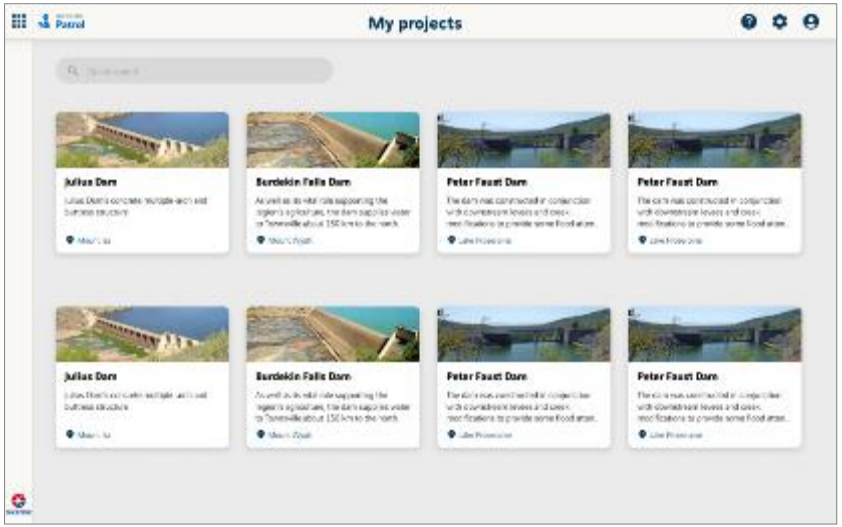
PLAN



INSPECT

ASSESS

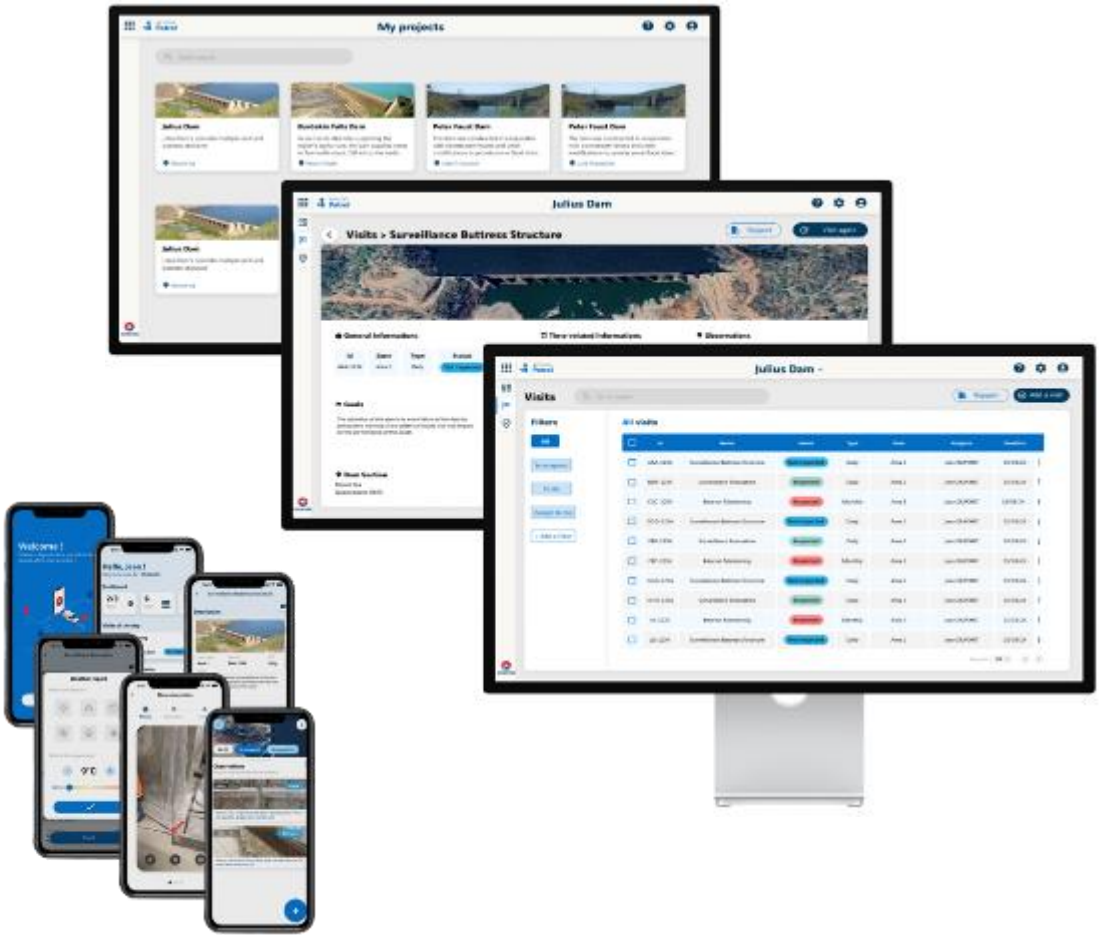
REPORT



MANAGE

TSF MONITORING | ANY SITE

Visual Surveillance Inspections



Features :

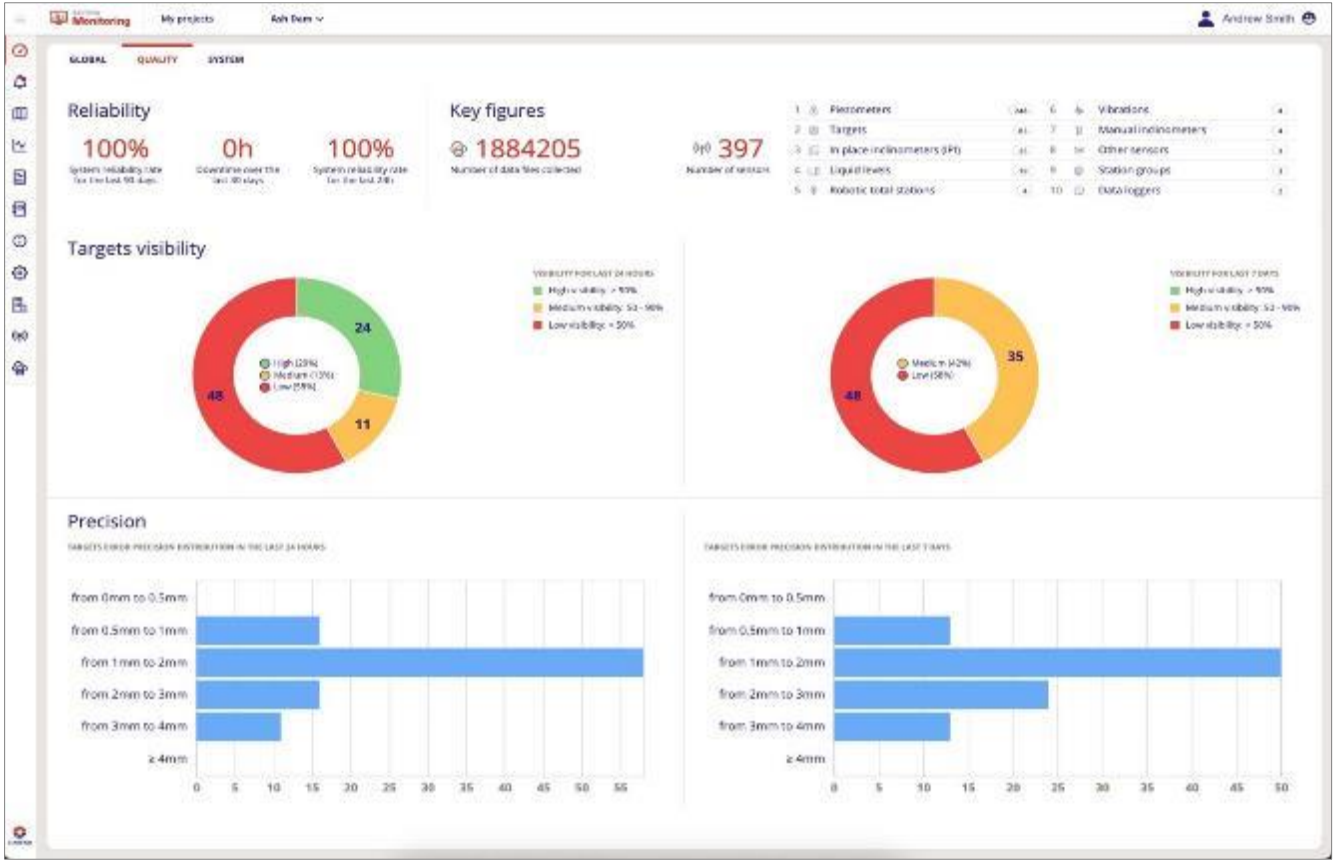
- Definition of a survey tours
- Surveys scheduling and assignment to teams
- Reporting of field observations
- Monitoring the evolution of the structure
- Alarm triggering
- Information sharing

Benefits :

- Cooperation between the various stakeholders
- Monitoring the progress of observations
- Data security
- Standardisation of inspections
- Productivity improvement
- Easy and intuitive to use

TSF MONITORING | COMPLEX SITE

Quality dashboard



04

CONCLUSION

& recommendations

sixense

CONCLUSIONS & RECOMMENDATIONS

To create **Common & Efficient** situational awareness

1. One size doesn't fit all
   - Carefully write the monitoring specifications.
   - Consider the wide range of instrumentation available for the purpose (all have benefits & limitations)

2. Carefully select the monitoring platform (MIMS)
   - It shall be **holistic** (sensors, data, features, observations, communication…)
   - Cloud services are powerful but Cyber **Security** shall be central
   - It's a critical component for **Quality**
   - It's a key element of **Productivity**

3. Don't underestimate data management
   - This is the key to consistent data quality

4. And don't forget that at the end of the day….

data Availability & data Quality are everything.

THANK YOU FOR YOUR ATTENTION

www.sixense-group.com.au
contact.oceania@sixense-group.com

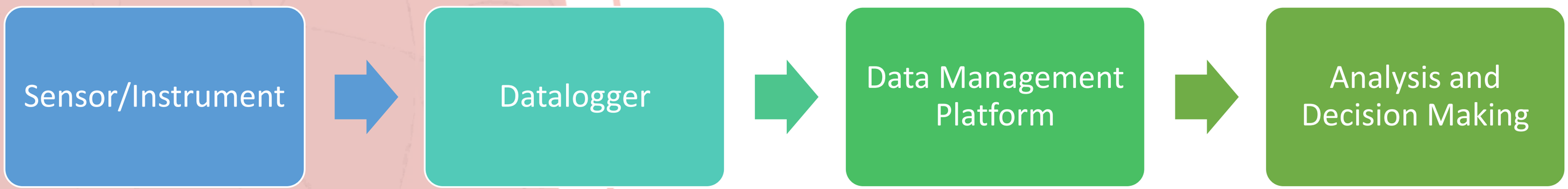
Geomotion
AUSTRALIA

The Human Aspect of a TSF Monitoring System

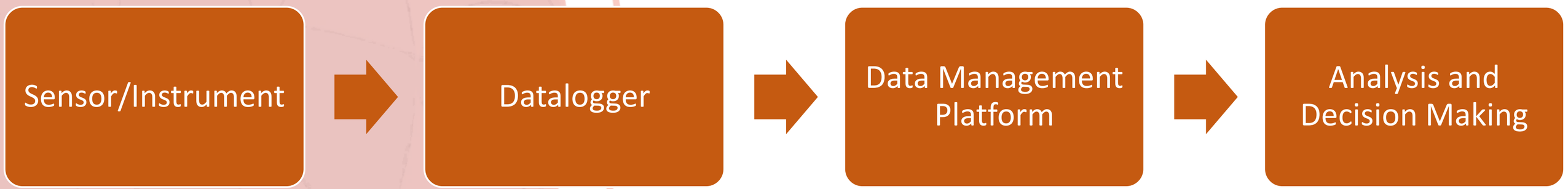
THE HUMAN ASPECT OF A TSF MONITORING SYSTEM

- Monitoring systems are powerful these days but far from all-powerful
- As technology rapidly advances and more tools are available to us, so also increases the complexity of the tools and software
- It takes years to fully familiarise with different systems, instruments and sensors and how they interact with the earth all while striking a balance with the expectation to mine faster, safer and more sustainably
- AI or ML are generating a lot of buzz recently across the world and in multiple industries
- Will large data sets collected by mines ever be available to train the models?
- The human aspect of a monitoring system is, and will be for a long time, the most crucial

FLOW OF DATA AND INFORMATION



FLOW OF DATA AND INFORMATION



HUMAN ASPECT - SENSORS

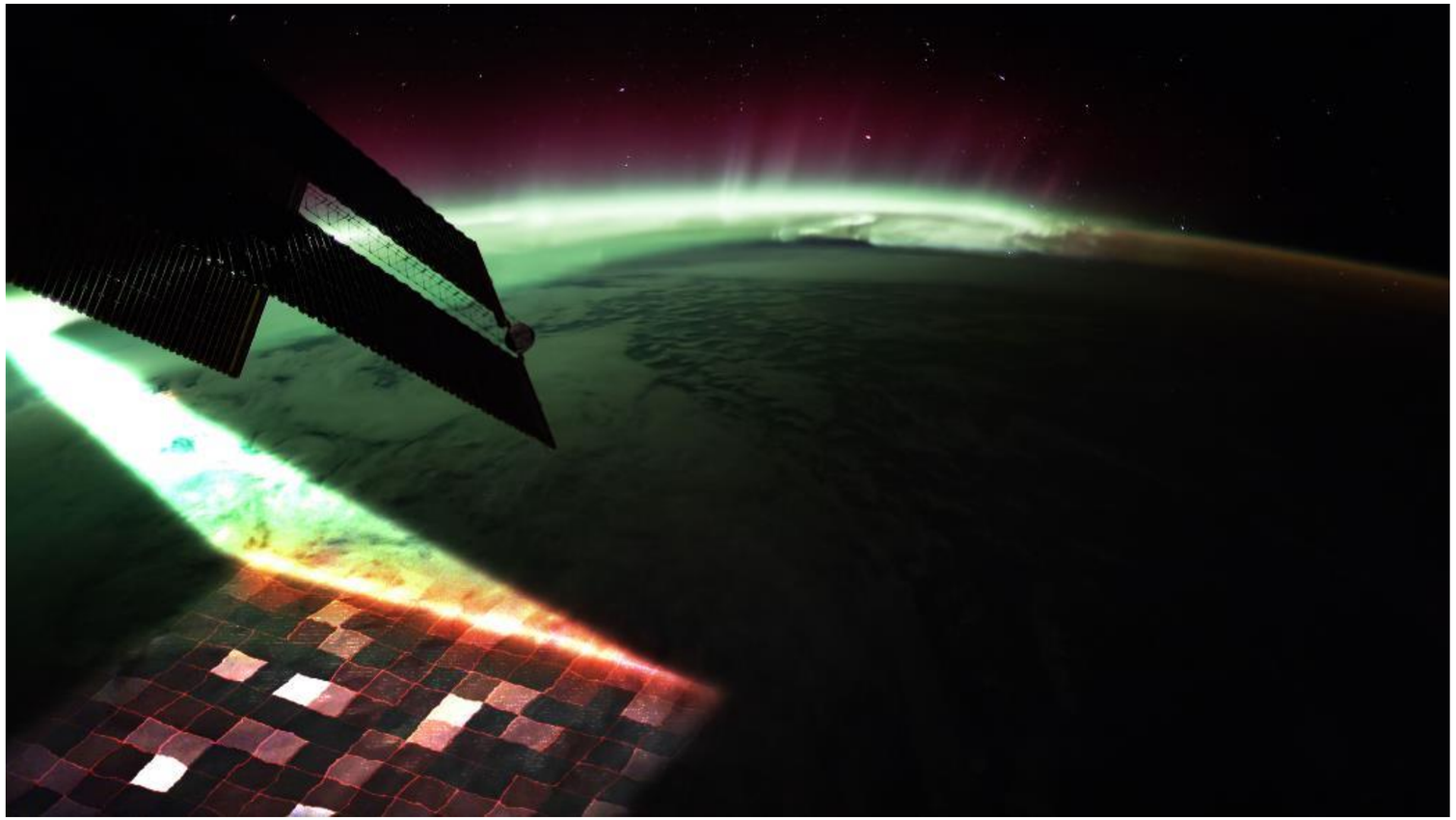
- Are they being installed to manufacturer instruction? (Grout properties, methodology followed, installation records detailed and accurate, install verification, installed safely, etc.)
- Post-installation support available?
- Innovative solutions able to be built to solve issues on site?
- Commission is focused on data quality
  - Sanity checks such as common-sense calculations on a piezometer are essential

HUMAN ASPECT - LOGGERS

- Set up correctly
- Installation protected and able to withstand site conditions?
- Adequate allowance for maintenance if needed?
- Radio system optimised and reviewed?
  - Even on easy-to-use platform like Loadsensing this is still a consideration

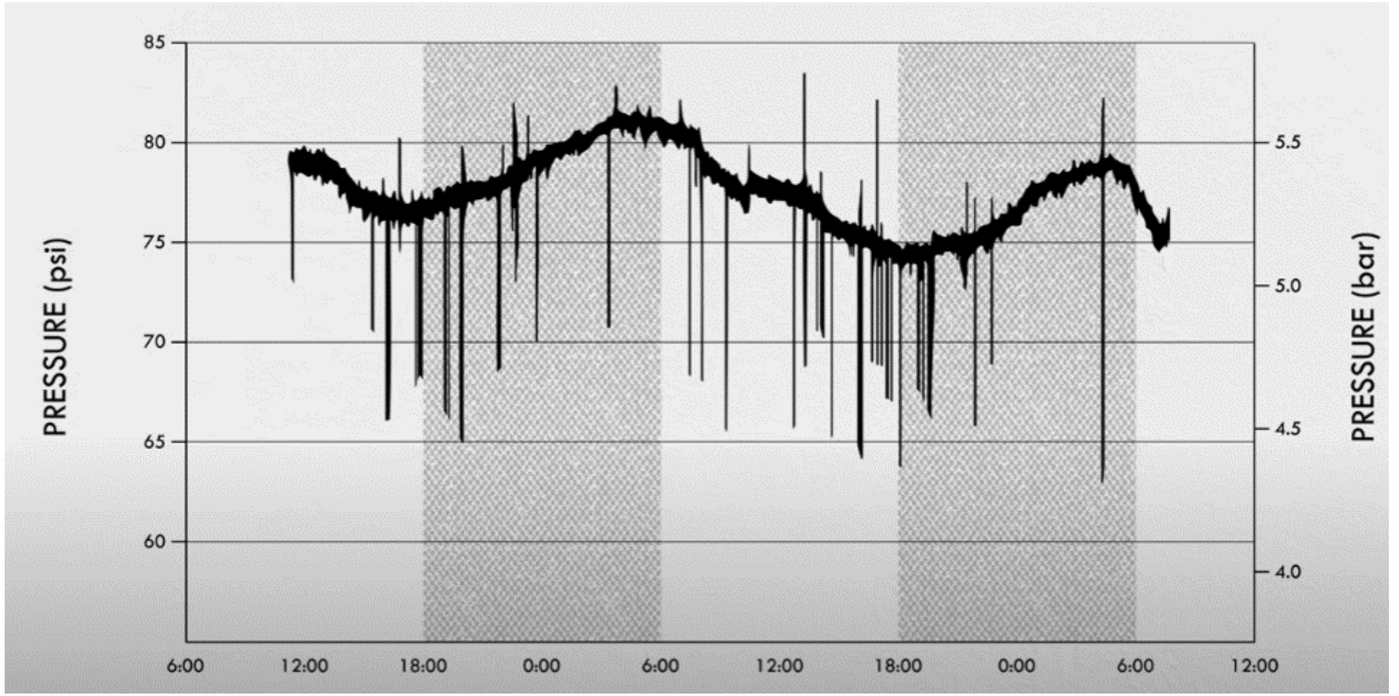
HUMAN ASPECT – DATA HOSTING

- Cloud service
  - Uptime needs to be high
  - Performance needs to be monitored
  - Set up properly and securely
- MIMS Platform
  - Consistent approach to calibration
  - Ensure quality control on the measurements, and actively maintain the monitoring systems – data management services are a blessing!



HUMAN ASPECT – ANALYSIS AND DECISION MAKING

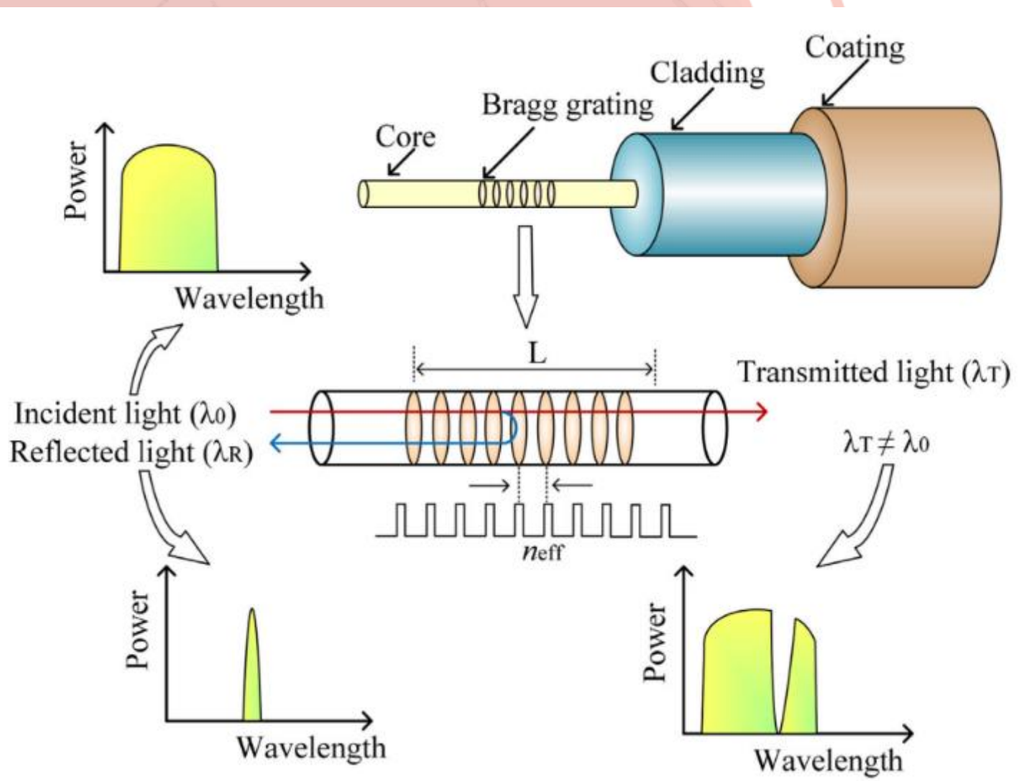
- Arguably the most important stage is the analysis and decision making based on the data
- Deriving actionable insights from monitoring data
- Applying expertise and critical thinking to raw data
- Inform teams for safety, progression of works, design changes, etc.
- Ultimately where the value of a monitoring system lies



AVOIDING DATA DEBT

- Monitoring systems are often launched and promptly forgotten but still expected to function effectively
- Near continuous construction on many tailings dams means the environment is ever-changing
- Data builds up over time – generated by sensors, satellites, radar
- Data needs to be cleansed and filtered on a regular basis
- Newer technologies will produce more and more data

FIBRE OPTICS



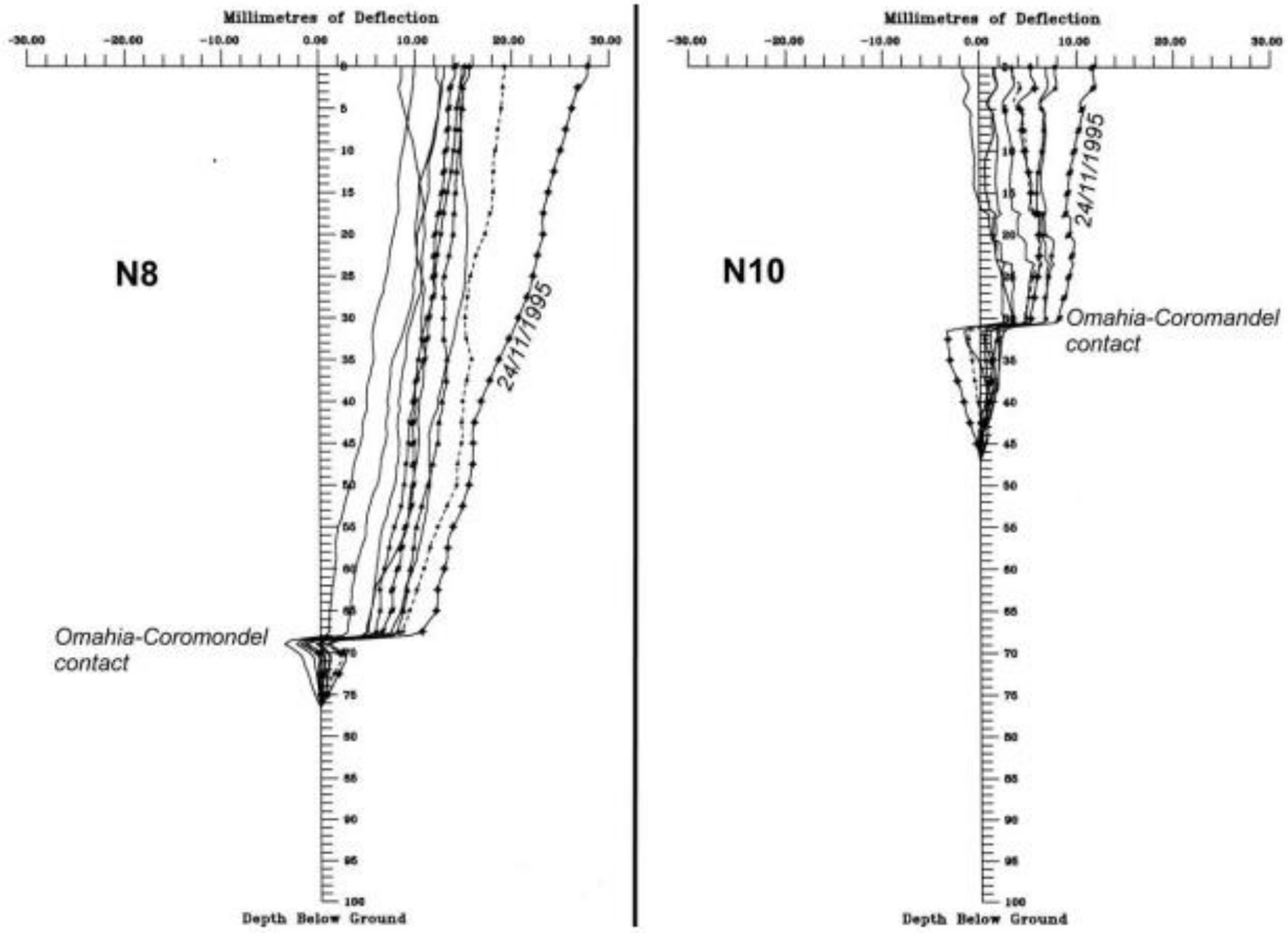
- The ability for distributed, dynamic, accurate and high spatial resolution data is incredibly powerful
- Some caution needs to be applied, systems are already complex, monitoring complex ground conditions and interactions
- Generates significant quantity of data, systems need to be in place to filter, process and make useable
- Hardware, software, commissioning, maintenance, technical support, training, data management, all need to be considered
- However, if these are mastered the technology offers great benefits for TSF monitoring systems

THE CHAMPION

- Quite often when a monitoring program drops in efficacy, it's because it's forgotten about, fallen behind, etc.
- Almost all monitoring projects need a 'system champion' to tie it all together, TSF monitoring is no exception
- Pushes for quality monitoring, do or delegate
  - Asking the question 'what problem is this instrument solving? What question is this sensor answering?', not necessarily just more monitoring
  - Enforces equipment specifications
  - Provide solutions to technical difficulties
  - Quality control on measurements, actively maintaining monitoring systems
  - Enacts an action plan when things go wrong
- Carries the not-so-easy burden of distilling this information, applying context and communicating that to other stakeholders

THE CHALLENGE OF COMMUNICATING DATA

- Vast amounts of data produced
- Complex interaction with geology, weather, works progress, site conditions
- Labour shortages in geotechnical engineering
- In some cases, data is difficult to effectively visualise – complex subsurface movements that would be imperceptible to naked eye
- ISO still being developed, no technical reference for analysing/interpreting data or recognising errors



TSF FAILURES

- TSF failures are unfortunately common, and Australia is no exception with a mine TSF failing recently
- InSAR data showed very clear movement in the lead up to collapse
- For 2 months beforehand, the structure was moving. Something on this dam wall was changing
- Fortunately, it wasn’t as catastrophic as other recent TSF failures, but lessons still need to be learnt
- Could this have been prevented or mitigated if monitoring data was being actively reviewed? If there was a champion actively reviewing this data with site activities?
- Seemingly inevitable that more cases such as this will eventuate with tailings dam failure rates increasing

MAKING IT AS EASY AS POSSIBLE TO GET RIGHT

- Lean on manufacturers and instrumentation specialists
- Keep on top of system maintenance
  - QA/QC on instrument readings essential, especially when working on multiple projects
  - Data management services
- Reduce human error as much as possible
  - Retrofitting manual monitoring with automated dataloggers
  - Environmental effects and different processes make repeatable readings difficult with manual surveys or readings
  - Online web platform allows multiple people to review data on multiple projects
  - User friendly and intuitive interfaces simply data interpretation

CONCLUSIONS

- Modern monitoring technology is impressive, but is effectively useless without people at the wheel
- Try not to get bogged down in purely having modern and complex systems without the adequate experience and processes to analyse it. They do, however, hold a lot of potential if used correctly
- Need more champions in the industry who have experience with monitoring data and push for better monitoring programs
- The goal at the end of the day is to prevent harm to people and the environment, monitoring is an important tool in the arsenal for this purpose if used correctly. It has and will continue to save lives.

THANKS FOR LISTENING!

FROM DATA TO DECISIONS:

REAL-TIME DEFORMATION MONITORING SYSTEM, NANORADAR

AUGUST 2024

GEOBOTICA

LET ME

TELL YOU A STORY


“THE STOPES LOOK LIKE
THIS… JUST NOT AS CLEAN”

“THIS IS HOW YOU GET UNDERGROUND”


“IT’S REAL MINING.”

THIS IS WHAT YOU NEED TO MAKE

A SLOPE STABILITY RADAR…

(With no moving parts)
(That fits in your pocket)
(That weighs less than a self-rescuer)
(It's got to run on batteries for at least a week)
(Oh it's got to be water-proof, dust-proof… all the proofs)
(Filter out all the machinery and equipment)

(oh and it has to cost $20k because I need a lot of them)

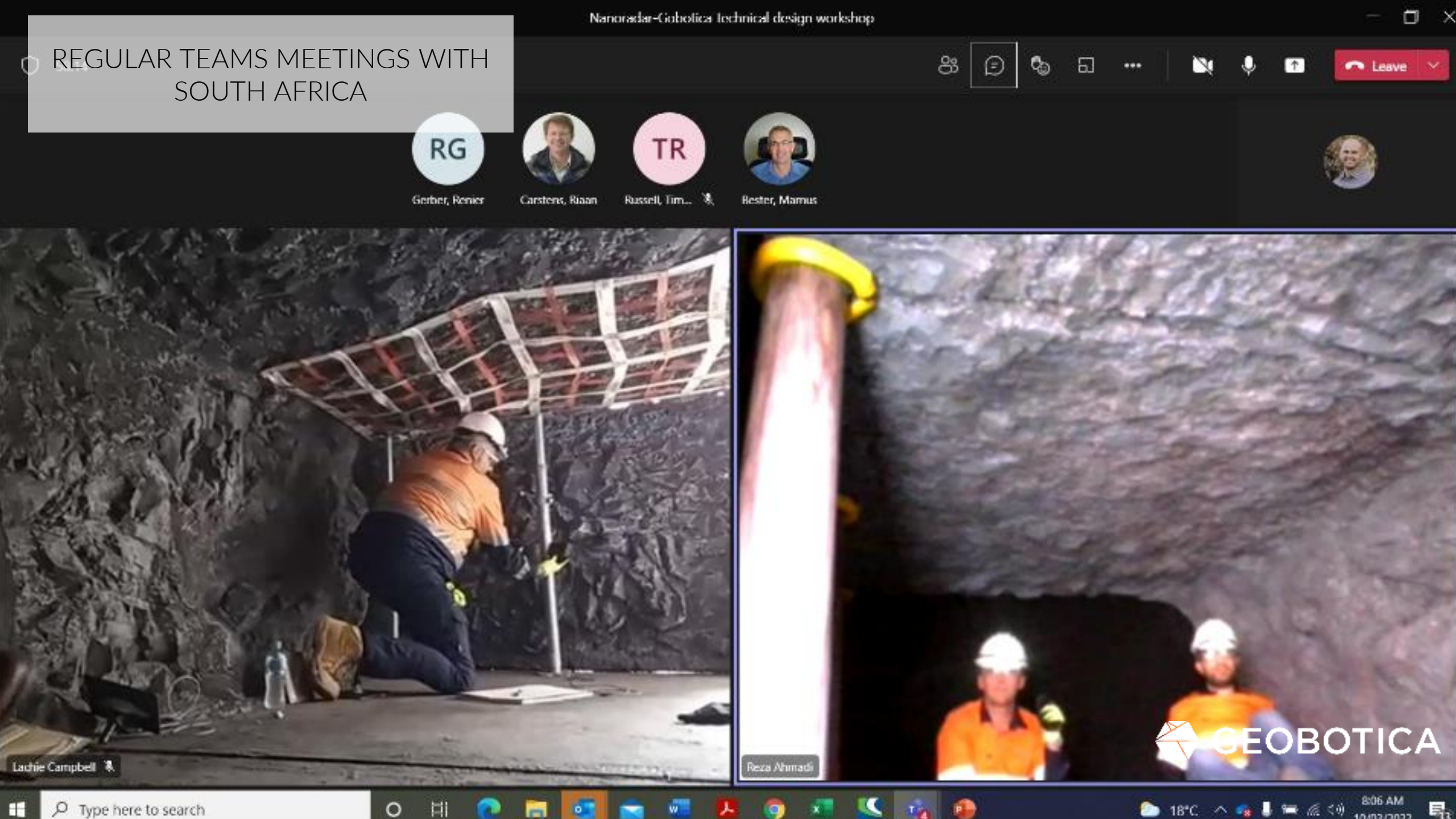
BUT IT WAS COVID, & WE COULDN'T GET TO SOUTH AFRICA.

SO WE BUILT A REPLICA 1:1 SCALE PLATINUM STOPE IN BRISBANE

1:1 SCALE PLATINUM STOPE


GEOBOTICA

REGULAR TEAMS MEETINGS WITH SOUTH AFRICA



The final product today

GEOBOTICA

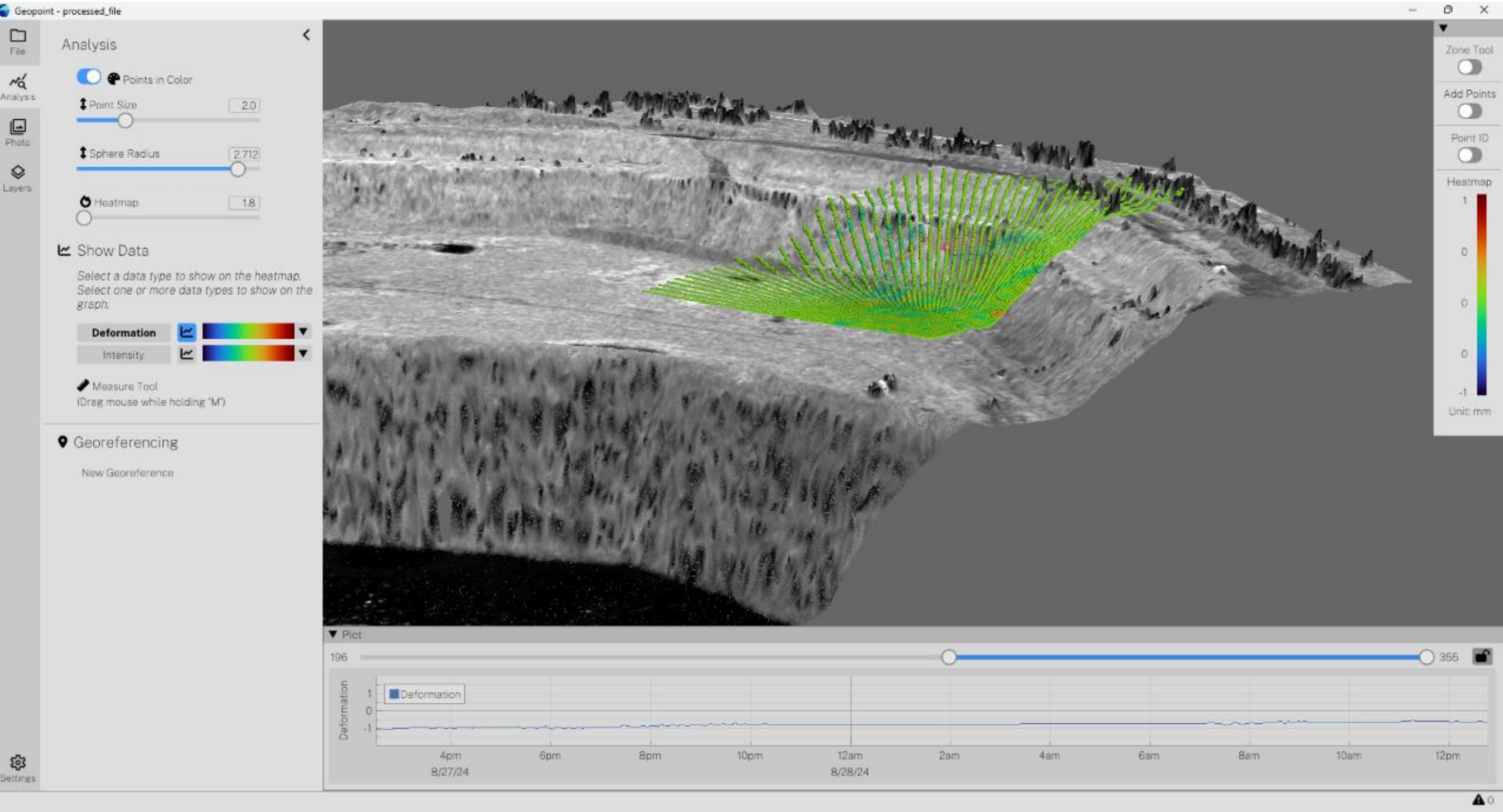
NANORADAR HARDWARE

- Developed with AngloAmerican
- Monitor sub-mm slope stability at a distance of up to 80m
- Near real-time 2 minute scans
- Useful in underground mining, tailings facilities or ultra-short range in pits
- 120 degrees in Azimuth by 40 degrees in Elevation
- Long battery life, or endless solar powered
- WiFi embedded
- E-paper screen
- Siren and lights
- Fully waterproof

GEOBOTICA

BUT

COULD WE USE IT FOR OPEN CUT?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Heatmap
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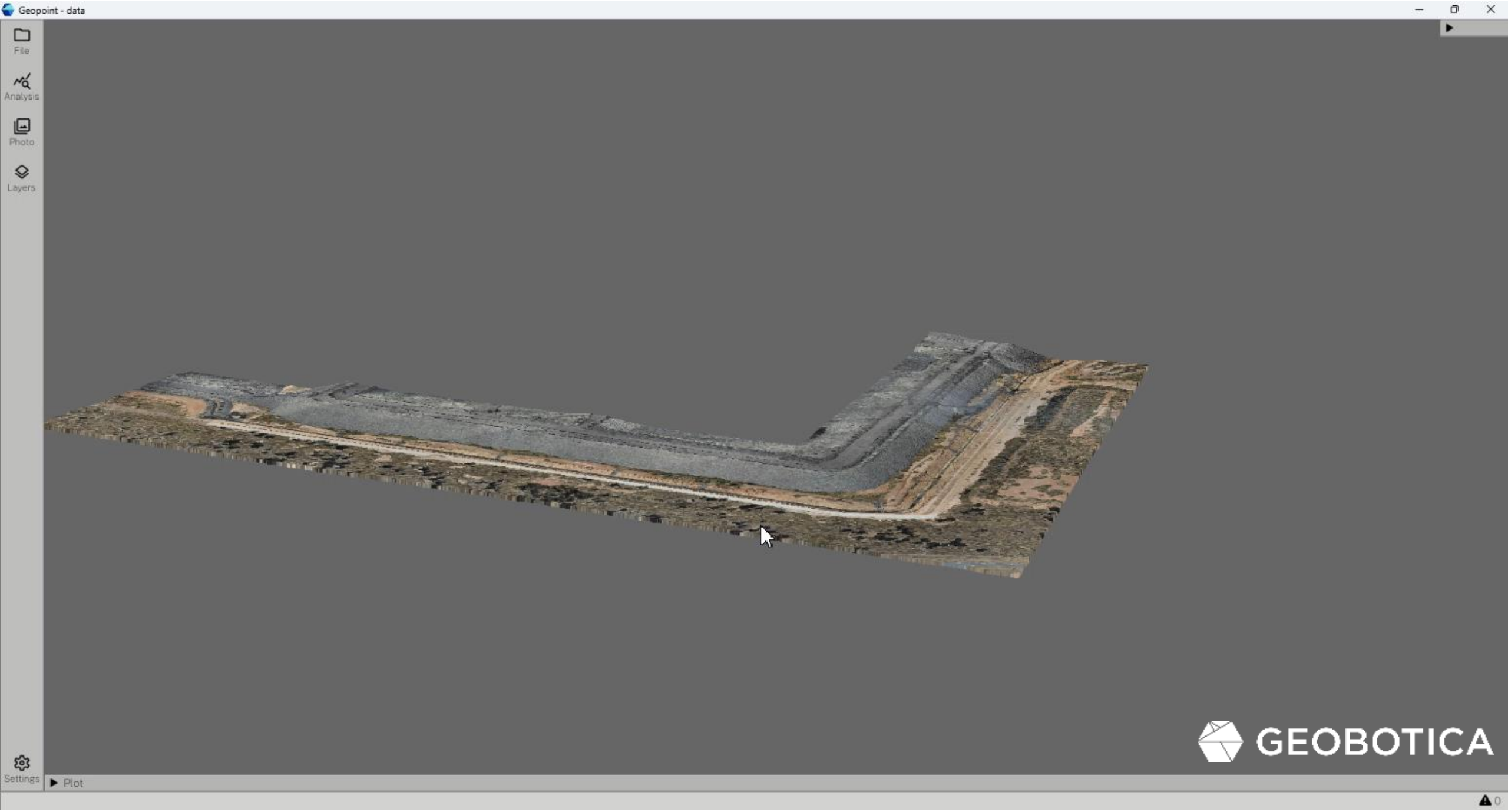
Show Data
Select a data type to show on the heatmap.
Select one or more data types to show on the graph.
Deformation
Intensity
Measure Tool
(Drag mouse while holding 'M')
Georeferencing
New Georeference
Zone Tool
Add Points
Point ID
Heatmap
1
0
0
0
-1
Unit: mm
Plot
196
355
Deformation
1
0
-1
4pm
8/27/24
6pm
8pm
10pm
12am
8/28/24
2am
4am
6am
8am
10am
12pm

OR

WHAT ABOUT TAILINGS EMBANKMENTS?

CAN WE USE IT FOR TAILINGS EMBANKMENTS?

GEOBOTICA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GEOBOTICA
0

NANORADAR DEPLOYMENT

All-in-one box:

- Mast for NanoRadar deployment in any direction
- Solar and batteries
- Enough power for NanoRadar + excess power and storage for communications (eg, wifi repeater, or 4G modem) + camera + weather station
- 21kg, single-person lift
- Fully waterproof
- Lockable, powdercoated box
- Ideal for open-cut mine deployments

GEOBOTICA

STARLINK & WIFI NETWORK

13 NANORADARS

TARP FOR DEFORMATION

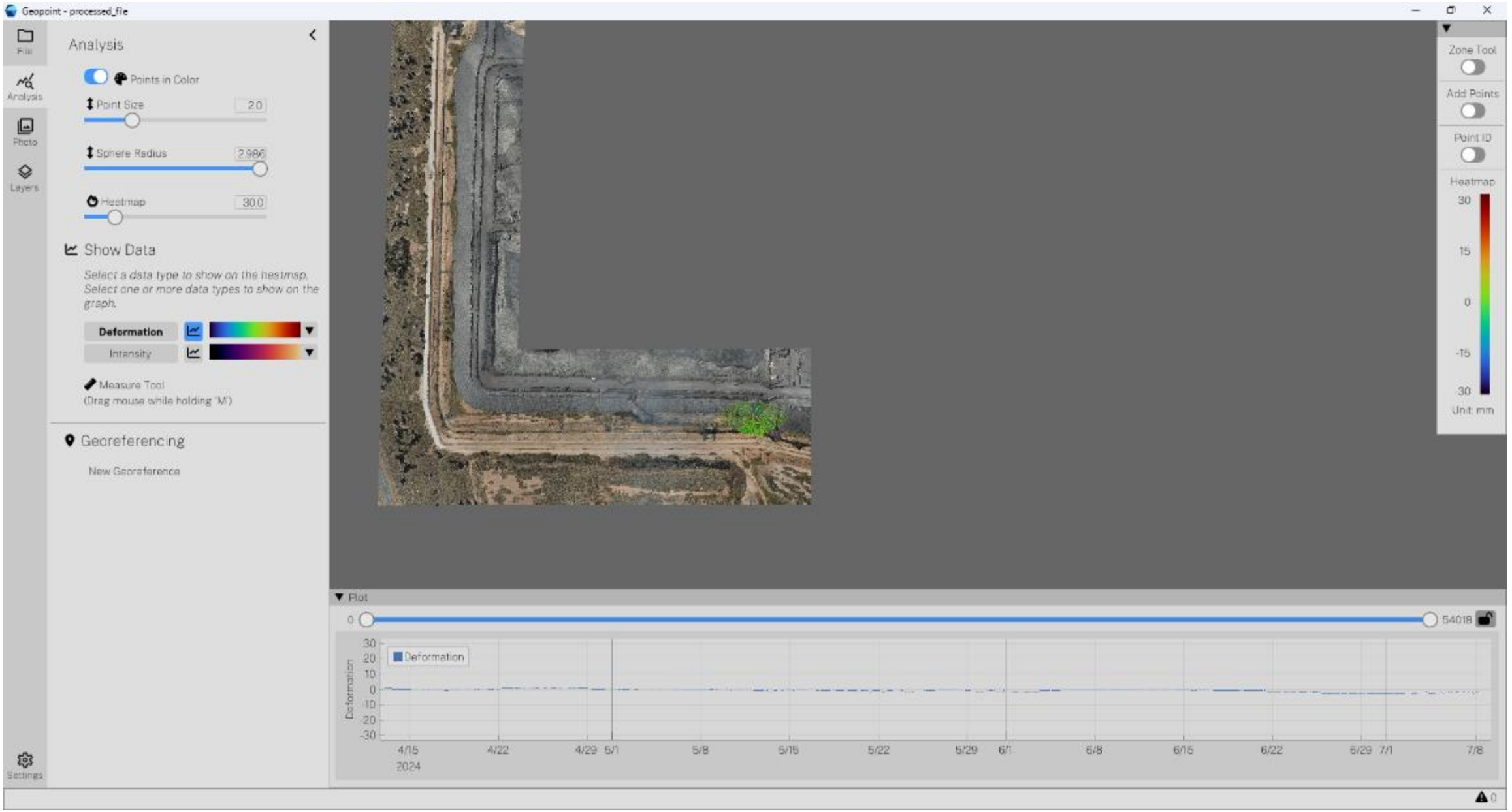
First trigger:

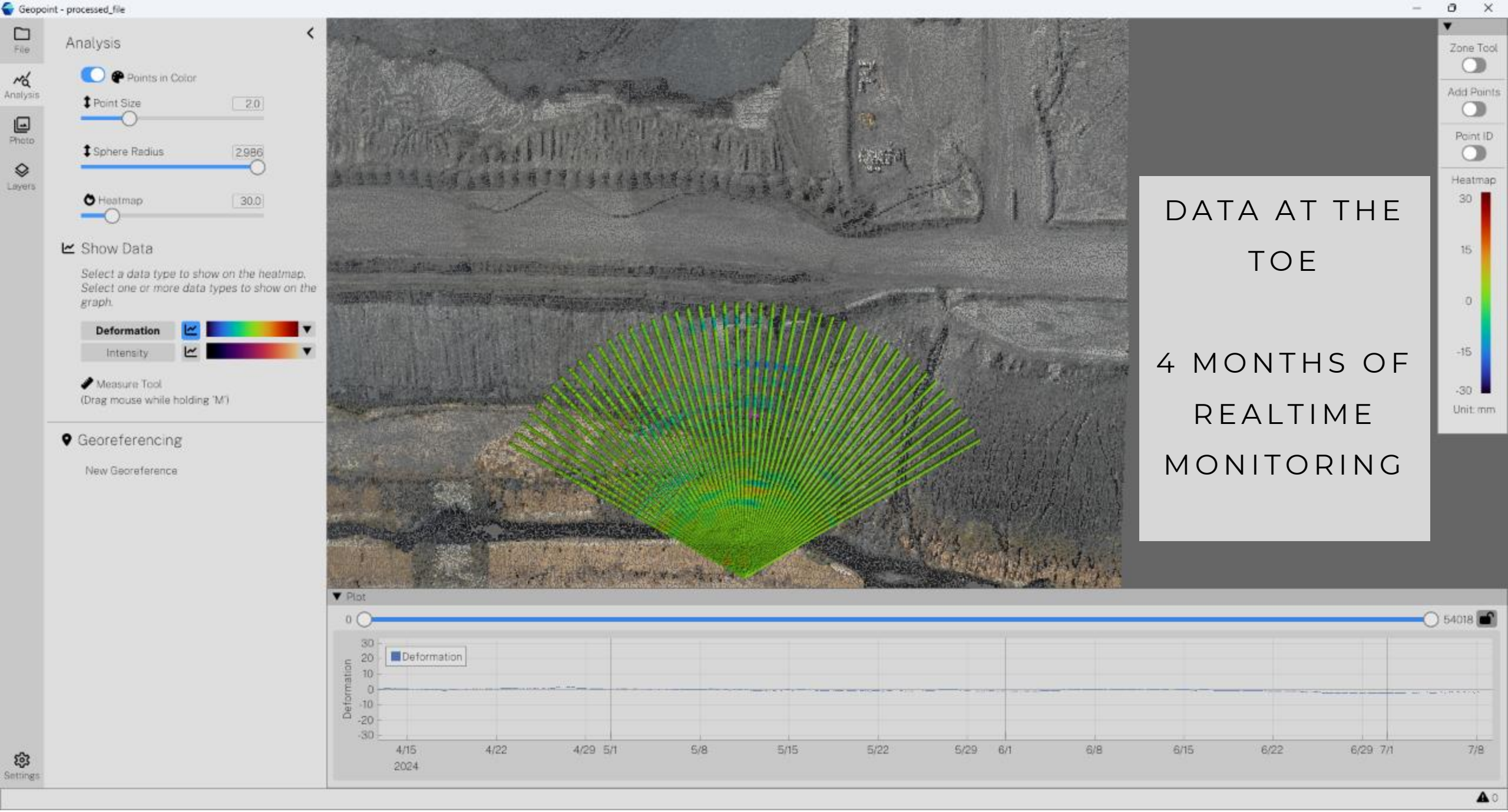
- Velocity of 25mm a day

  Or

- Total displacement of 250mm

LET'S LOOK AT THE DATA

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Point Size
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Sphere Radius
2.986
Heatmap
30.0
Show Data
Select a data type to show on the heatmap. Select one or more data types to show on the graph.
Deformation
Intensity
Measure Tool
(Drag mouse while holding 'M')
Georeferencing
New Georeference
Zone Tool
Add Points
Point ID
Heatmap
30
15
0
-15
-30
Unit: mm
DATA AT THE TOE
4 MONTHS OF REALTIME MONITORING
Plot
0
54018
Deformation
30
20
10
0
-10
-20
-30
4/15
2024
4/22
4/29
5/1
5/8
5/15
5/22
5/29
6/1
6/8
6/15
6/22
6/29
7/1
7/8
0

Geopoint - processed_file

File
Analysis
Photo
Layers
Settings

Analysis

Points in Color

Point Size 24

Sphere Radius 3.000

Heatmap 30.0

Show Data

Select a data type to show on the heatmap. Select one or more data types to show on the graph.

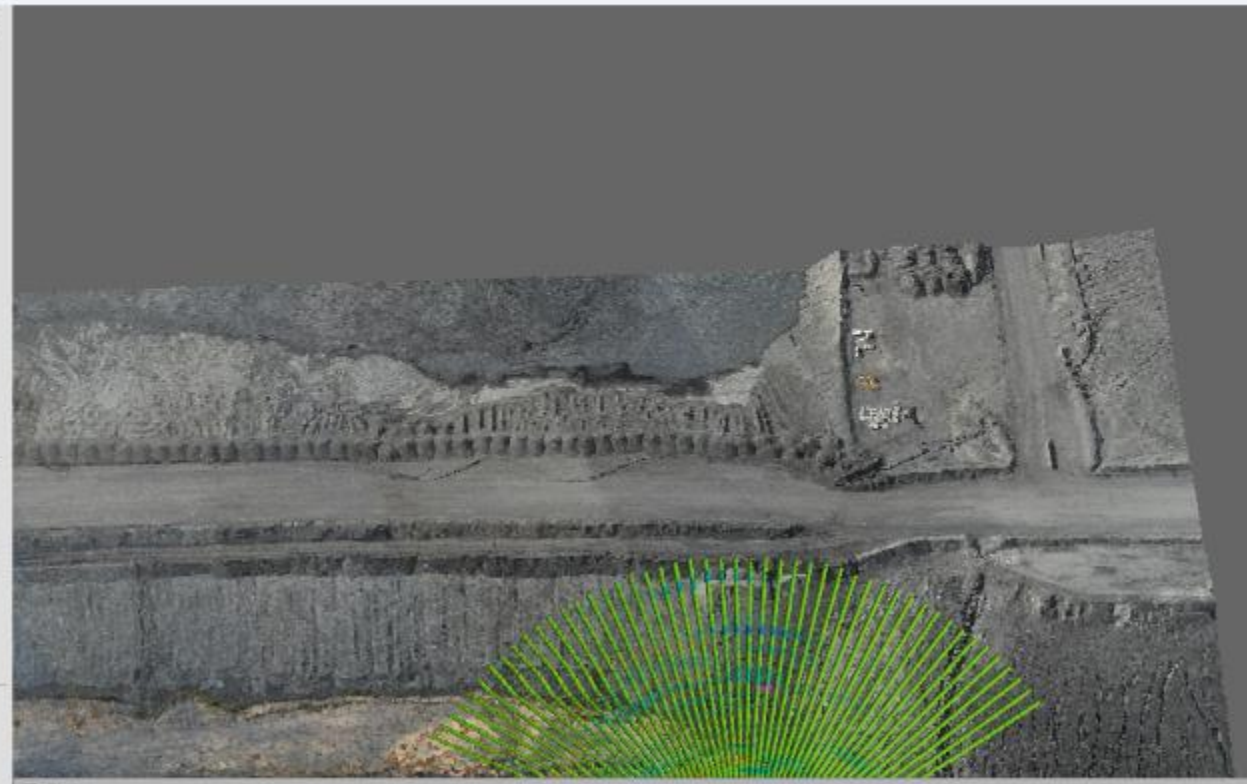
Deformation

Intensity

Measure Tool
(Drag mouse while holding 'M')

Georeferencing

New Georeference



EXPAND THE CHART FOR AN IDEA OF PRECISION

Zone Tool

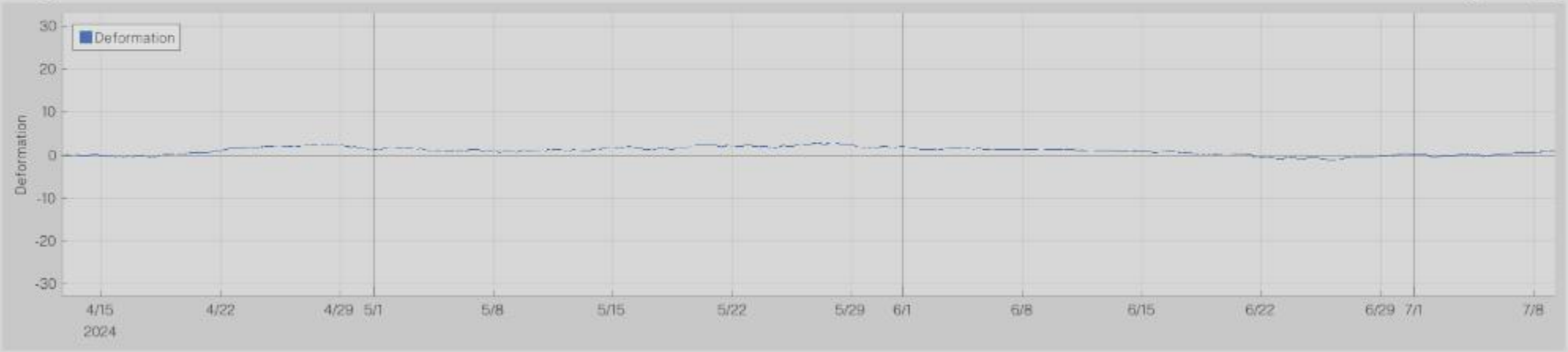
Add Points

Point ID

Heatmap
30
15
0
-15
-30
Unit: mm

Plot

0 54018



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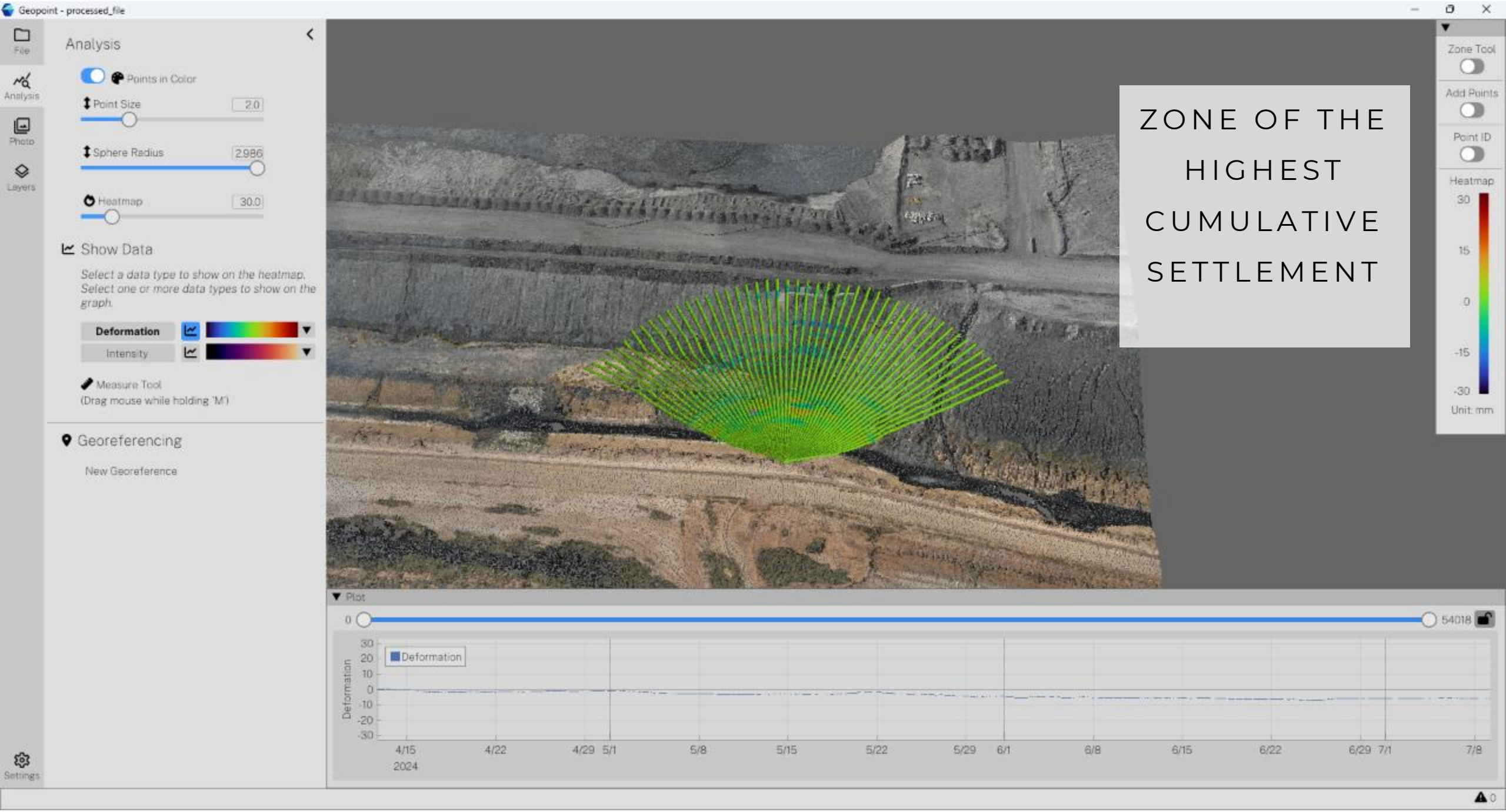
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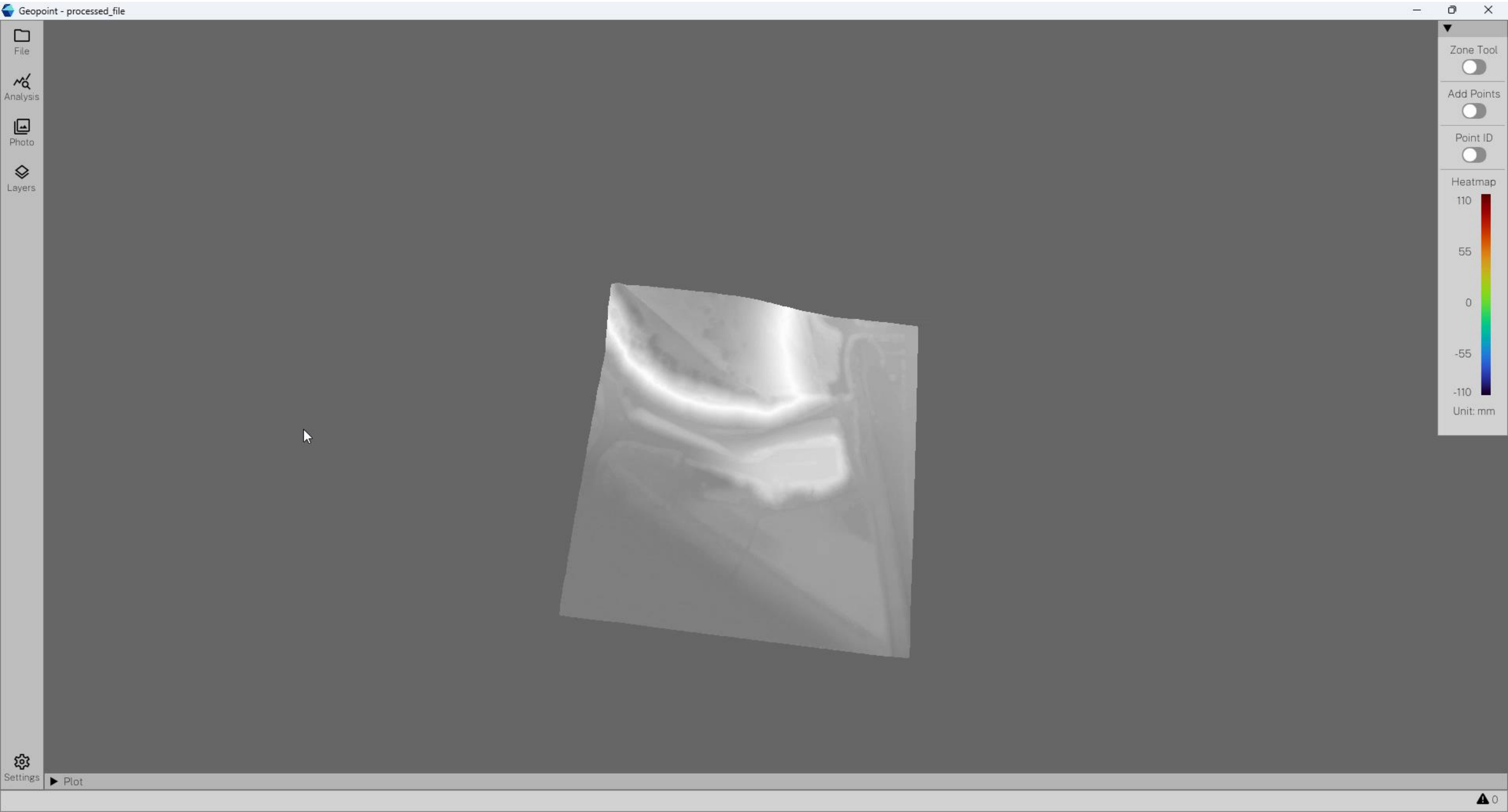
Analysis
Points in Color
Point Size
2.0
Sphere Radius
2.986
Heatmap
30.0
Show Data
Select a data type to show on the heatmap. Select one or more data types to show on the graph.
Deformation
Intensity
Measure Tool
(Drag mouse while holding 'M')
Georeferencing
New Georeference
ZONE OF THE HIGHEST CUMULATIVE SETTLEMENT
Zone Tool
Add Points
Point ID
Heatmap
30
15
0
-15
-30
Unit: mm
Plot
0
54018
Deformation
30
20
10
0
-10
-20
-30
4/15
2024
4/22
4/29
5/1
5/8
5/15
5/22
5/29
6/1
6/8
6/15
6/22
6/29
7/1
7/8
0

26

STABILITY HAS BEEN ESTABLISHED.

REAL-TIME MONITORING CONTINUES.

… BUT THERE'S A SPOT ON THE BUNKER THAT NEEDS MONITORING.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Settings
Zone Tool
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Point ID
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Unit: mm
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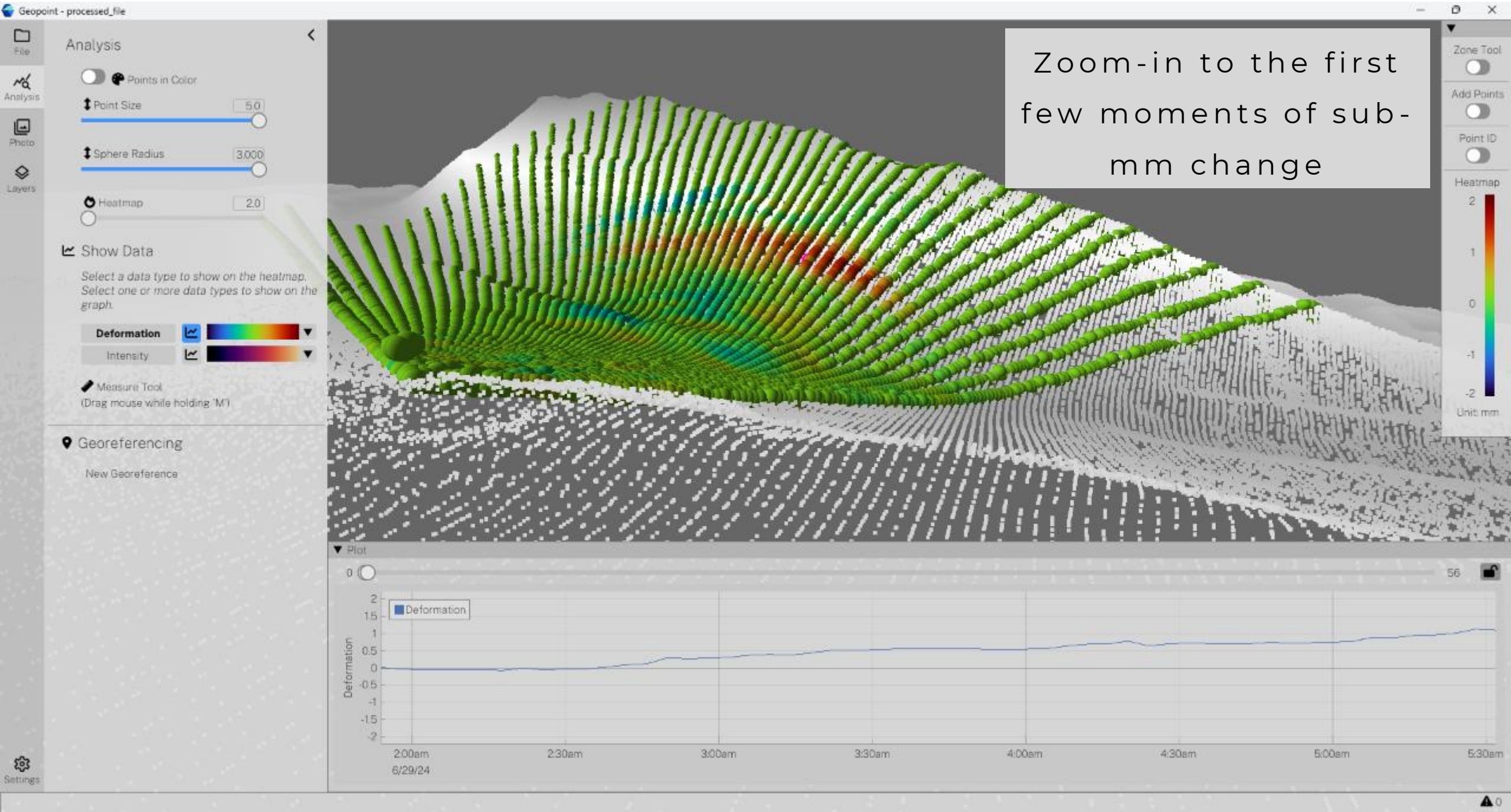
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Analysis
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Points in Color
Point Size
5.0
Sphere Radius
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Heatmap
2.0
Show Data
Select a data type to show on the heatmap.
Select one or more data types to show on the graph.
Deformation
Intensity
Measure Tool
(Drag mouse while holding 'M')
Georeferencing
New Georeference
Zoom-in to the first few moments of sub-mm change
Zone Tool
Add Points
Point ID
Heatmap
2
1
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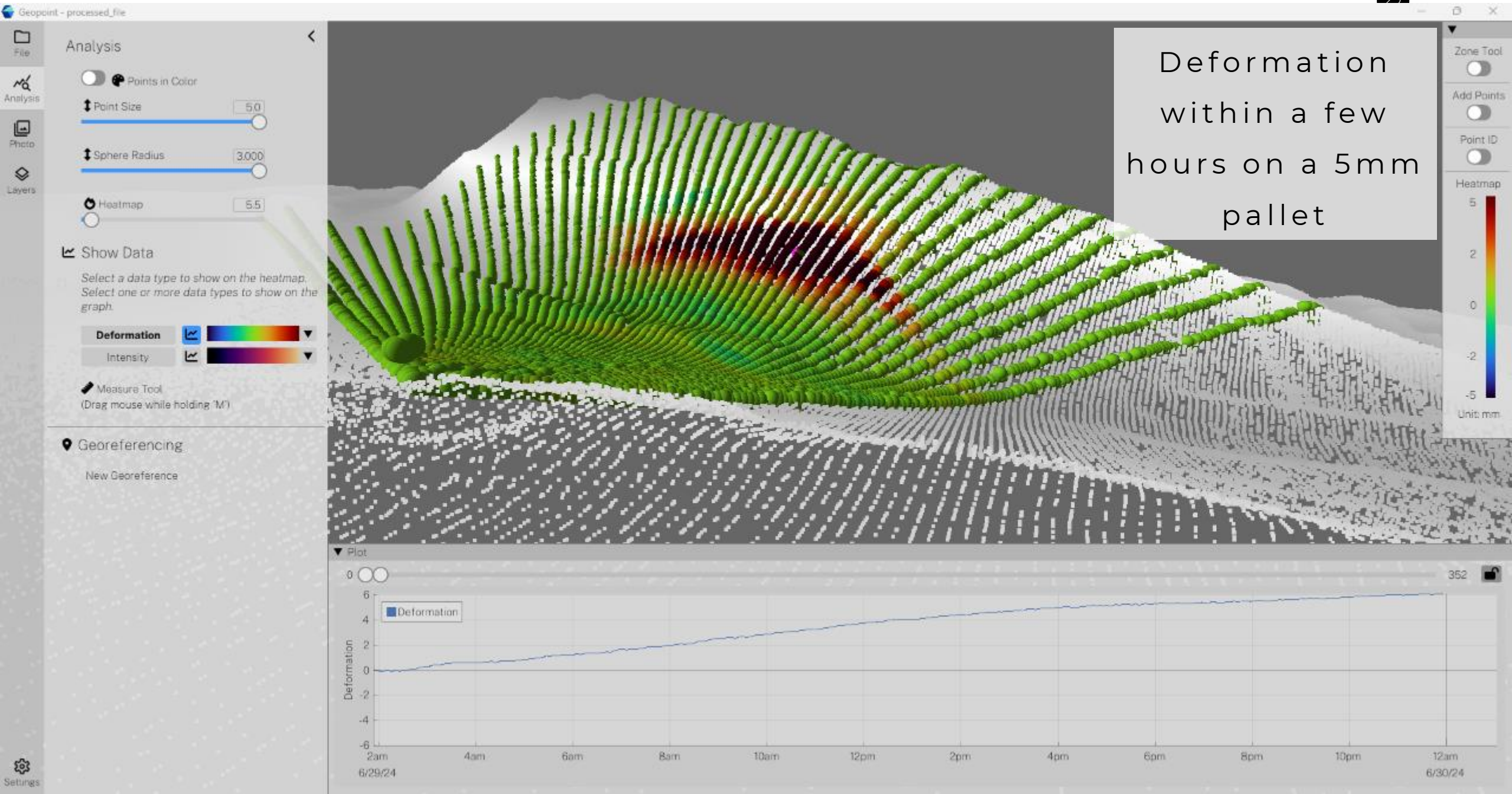
-2
Unit: mm
Plot
0
56
Deformation
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
2:00am
6/29/24
2:30am
3:00am
3:30am
4:00am
4:30am
5:00am
5:30am
0

29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Heatmap
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Show Data
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Select one or more data types to show on the graph.
Deformation
Intensity
Measure Tool
(Drag mouse while holding 'M')
Georeferencing
New Georeference
Deformation within a few hours on a 5mm pallet
Zone Tool
Add Points
Point ID
Heatmap
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-2
-5
Unit: mm
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Deformation
6
4
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-4
-6
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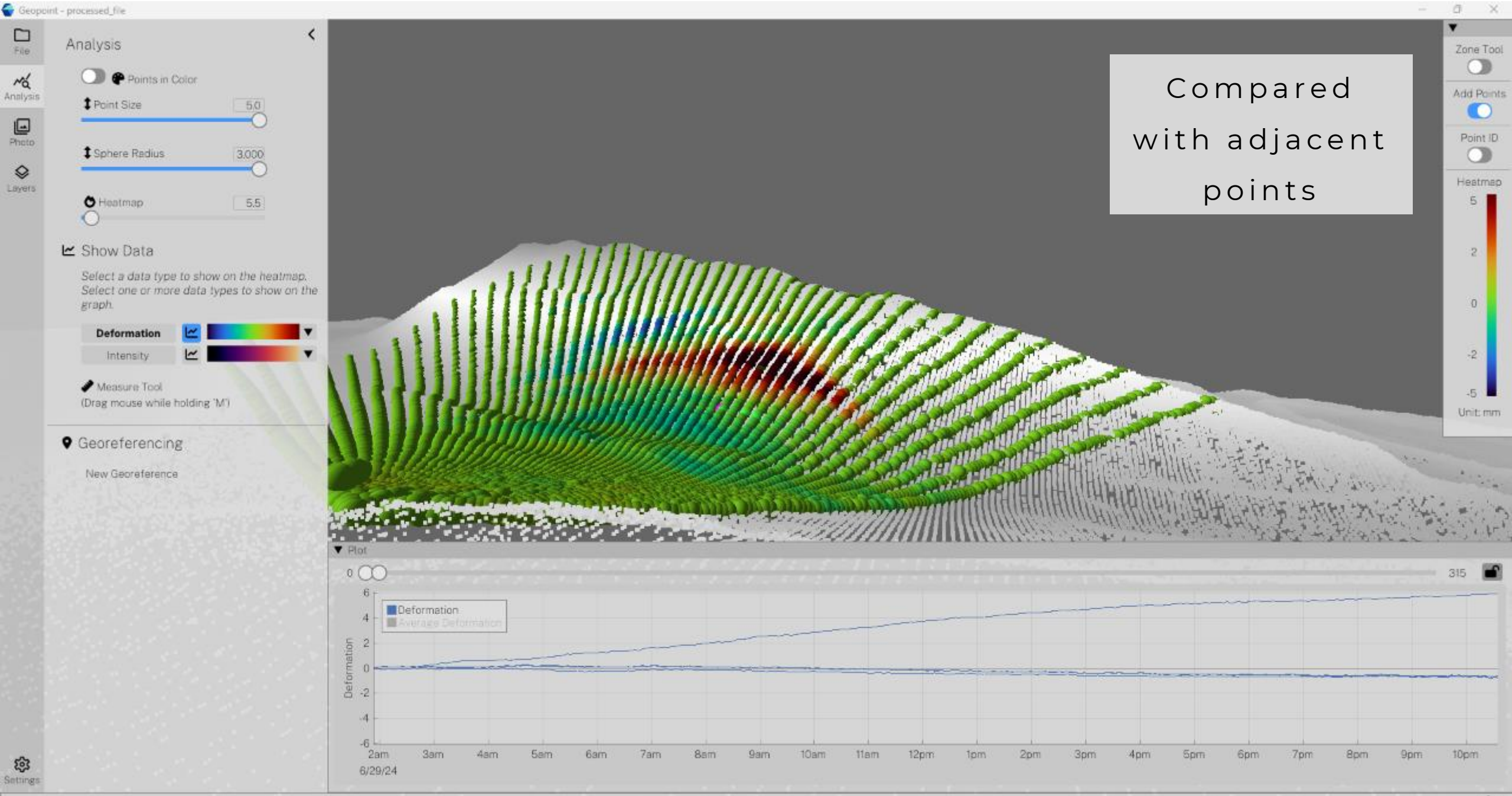
12am
6/29/24
6/30/24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Layers
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Point Size
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Sphere Radius
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Heatmap
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Show Data
Select a data type to show on the heatmap.
Select one or more data types to show on the graph.
Deformation
Intensity
Measure Tool
(Drag mouse while holding 'M')
Georeferencing
New Georeference
Compared with adjacent points
Zone Tool
Add Points
Point ID
Heatmap
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Unit: mm
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Deformation
Average Deformation
6
4
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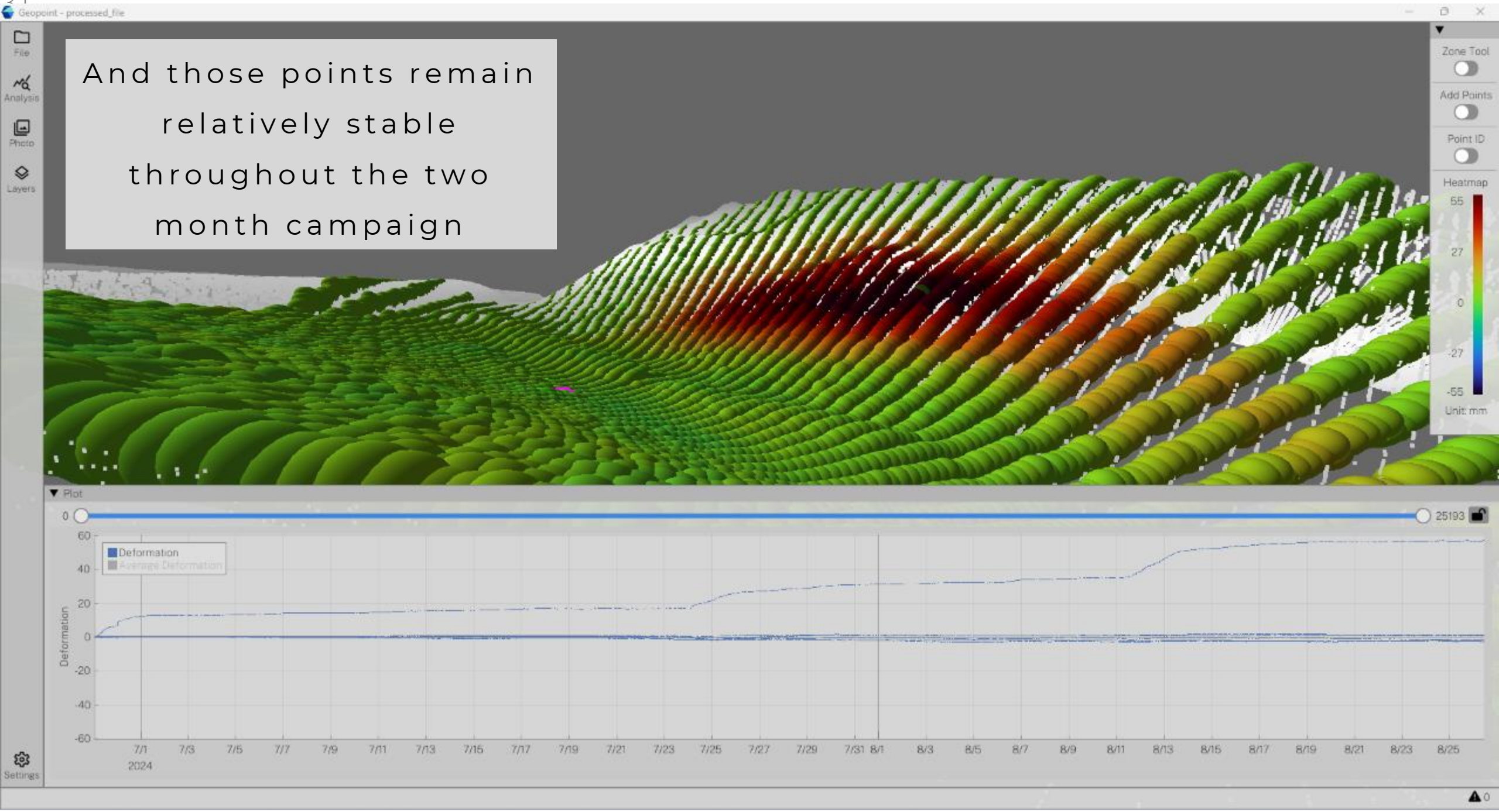
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File
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And those points remain relatively stable throughout the two month campaign
Zone Tool
Add Points
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Heatmap
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0
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Unit: mm
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25193
Deformation
Average Deformation
60
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20
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Deformation
7/1
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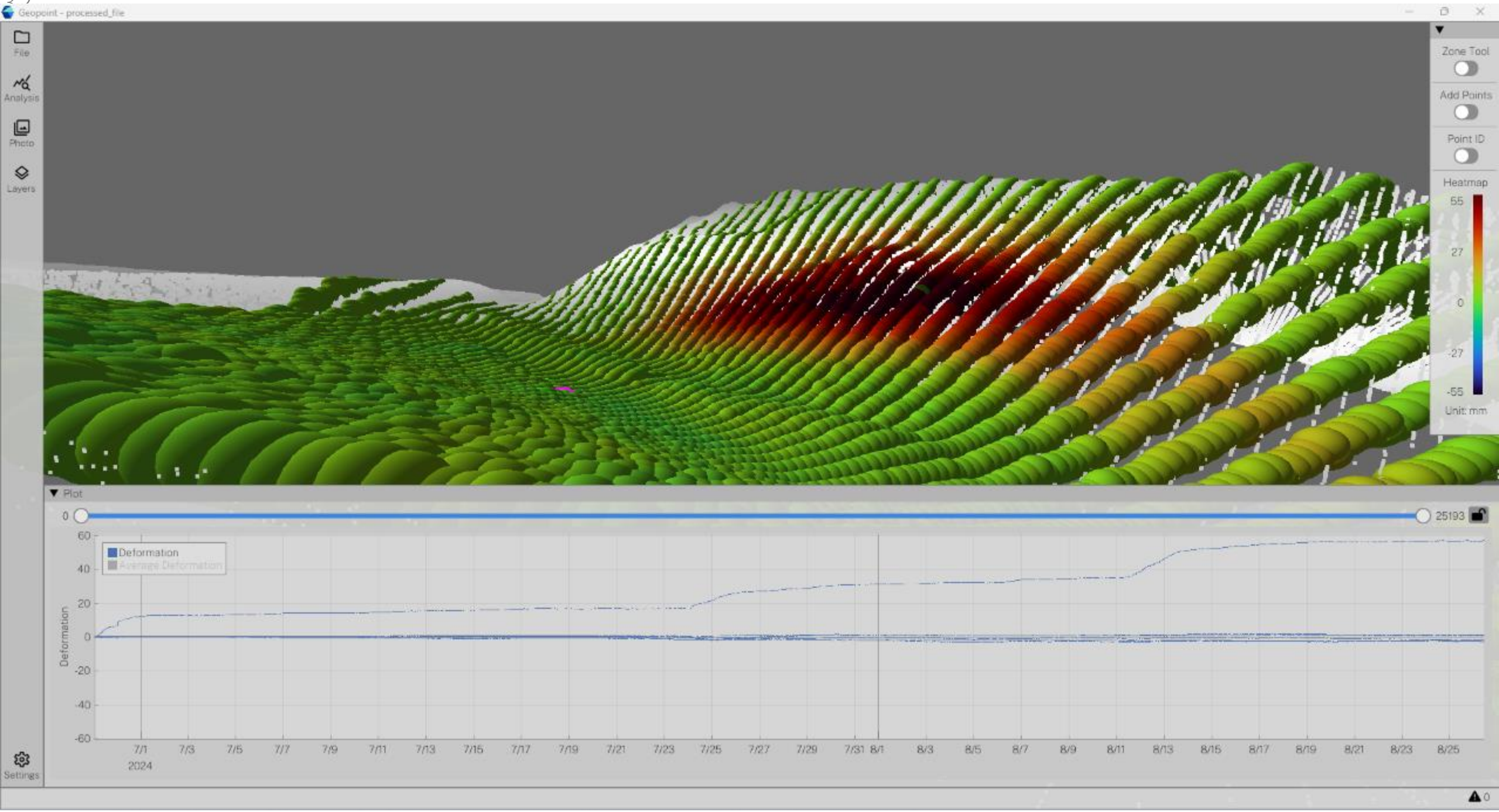
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Deformation
Average Deformation
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Deformation
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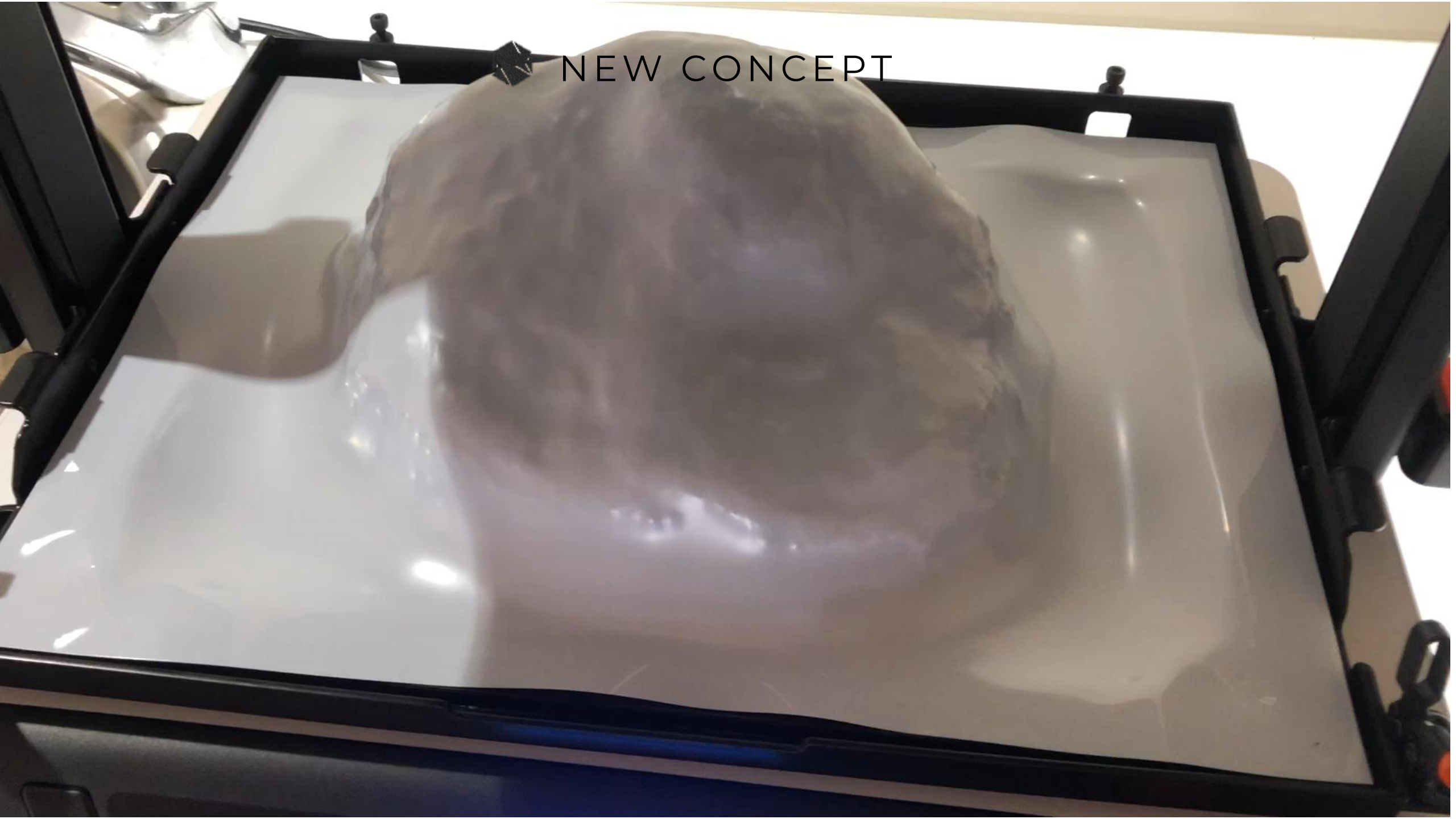
0

END WITH SOMETHING FUN:

CAN WE MAKE A ROCK-RADAR?

NEW CONCEPT

NEW CONCEPT



UNIQUE SYNTHETIC ROCK MATERIAL, MADE FROM ACRYLIC AND PARTICULATE. POURABLE INTO A MOULD AND SETS AS ROCK

RESULT OF EXPERIMENT:

THERE ARE TWO ROCKS HERE, ARE THEY BOTH FAKE? BOTH REAL? OR ONE OF EACH?

(Answer, the lower one is fake, the upper one is real)

We are a tiny start-up based here in Brisbane. We are a small team who are trying to make a difference.

We need your support and help if we are going to make a big difference in the industry.

If you think you can help, or if you want to try out a radar, please drop us a line.

info@geobotica.com

GEOBOTICA

HxGN MineMonitoring

HEXAGON | IDS GeoRadar

TSF Monitoring:

Best practices, Data correlation and modelling

Agenda

- TSF Monitoring Best practices
  - SM/SMV SMA
- Data correlation Case Study
- Modelling

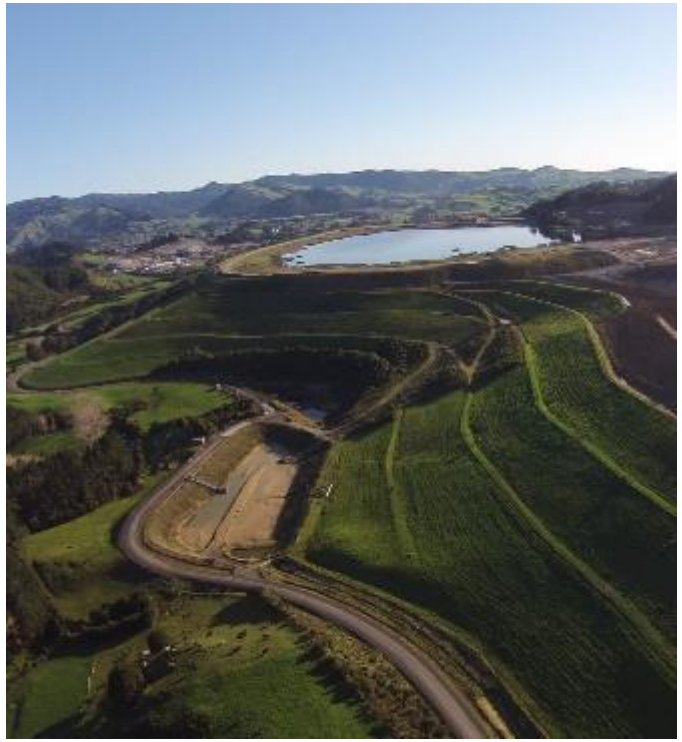
TSF - Dynamic and active structures

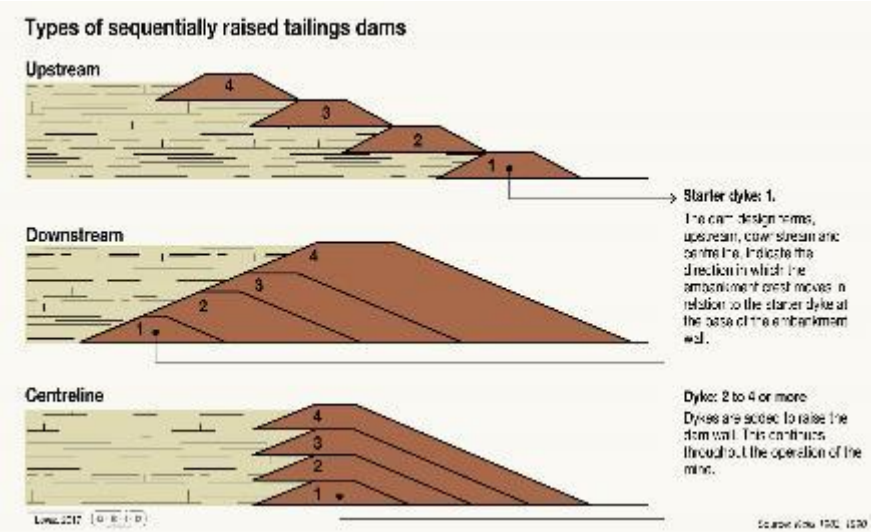
Complex dynamic structures such as TSF require a diversification of instruments and monitoring technologies to proactively monitor the stability both below and on the surface.

Storage of the largest bulk industrial mining by-products produced by mining

The use of more than one instrument will usually be required to take into account all the variables.

Often vegetated and thus requiring special techniques to get clean data





TSF - Dynamic and active structures

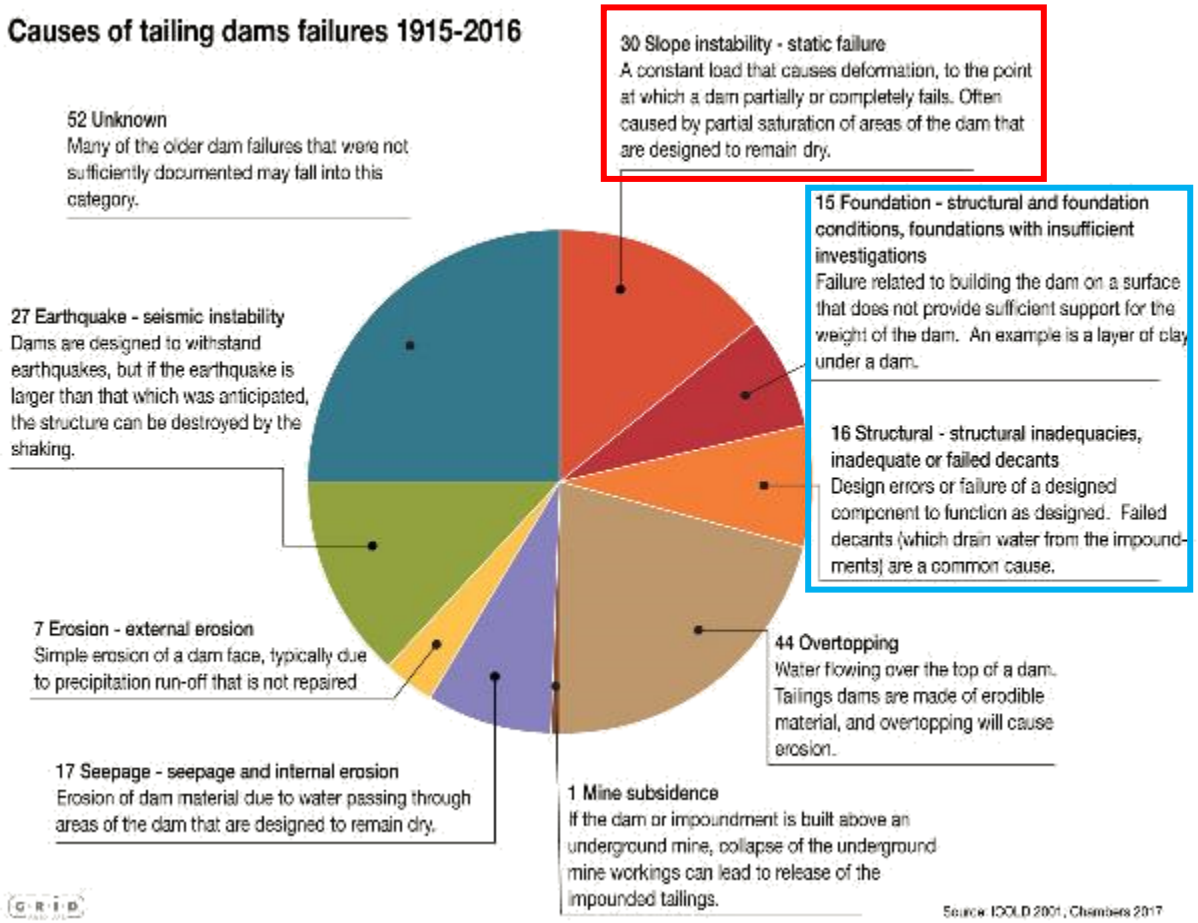
Small or no deformation before collapse
(quicker evolution from critical to collapse)

TSF – fundamental risks

- *Foundation failures*
- *Internal erosion/piping*
- *Overtopping*
- *Seepage*
- *Seismicity*
- *Slope instability*

Variable nature of tailings material also introduces variables

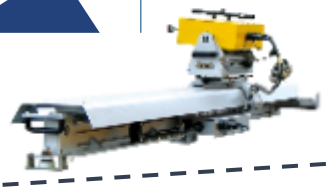
- *Strength profiles of material itself*
- *Water content*
- *compressibility*

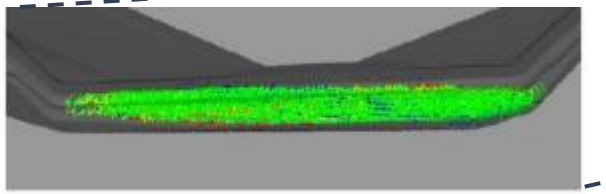


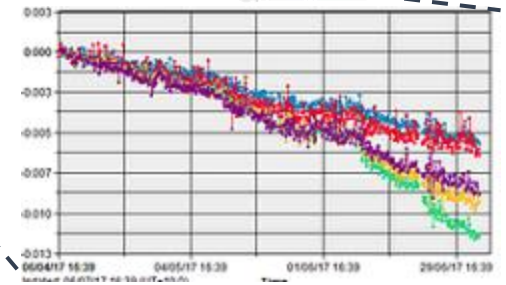
Deformation before collapse (slower evolution from critical to collapse)

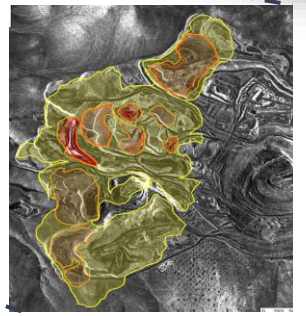
Monitoring Strategies - Connected ecosystem of monitoring sensors

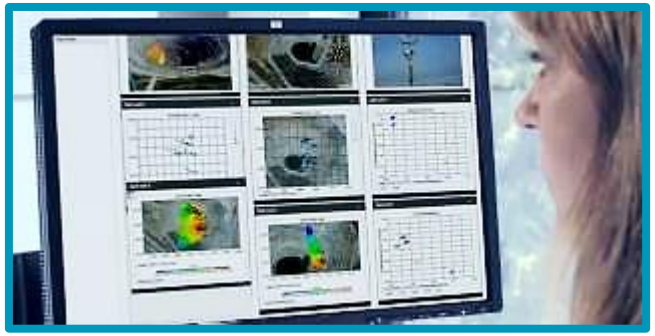
IDS GeoRadar











PART OF HEXAGON

Monitoring Strategies – Risk Assessment/Monitoring Priorities

RISK

	Very Low Risk		*Medium Risk*		*Critical Risk*
EXAMPLE	Old TSF, Dry Environment, No exposure risk	Downstream Ideal conditions	Design problems identified	New Raise	Large community exposure risk downstream TSF slope failure
MONITORING	Review as Required	Less frequent Episodic • Visual • Survey • Satellite InSAR • Drones	More frequent Episodic • Visual • Survey • Satellite InSAR • Drones	Automated Tech • Piezos • Prisms • GNSS • Radar	Real time Multiple tech Alarming

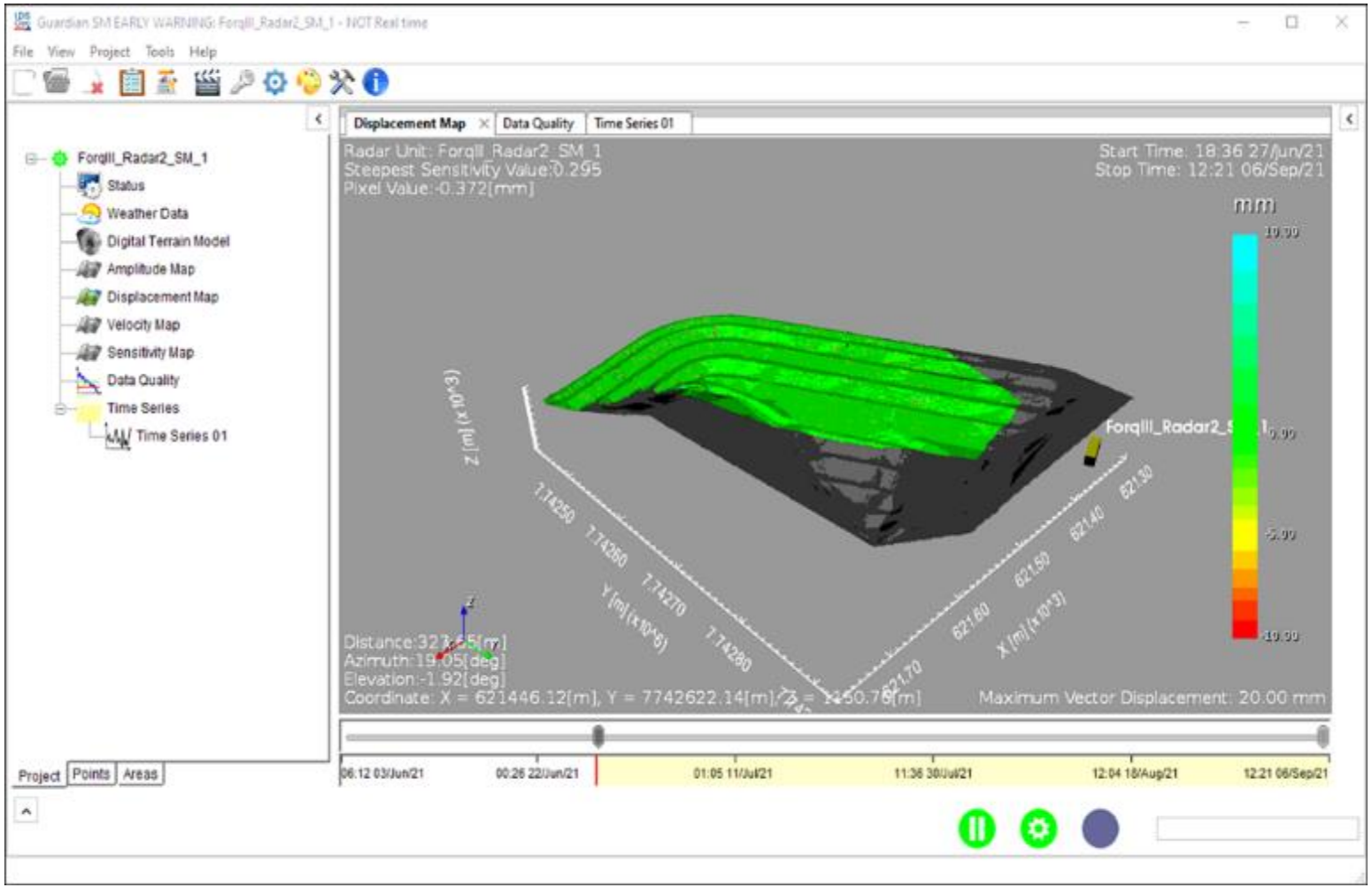
Guardian Slow Movement Analysis for *High* Risk TSF Monitoring

2 embedded processing algorithms are available – SM and SMV (vegetated)

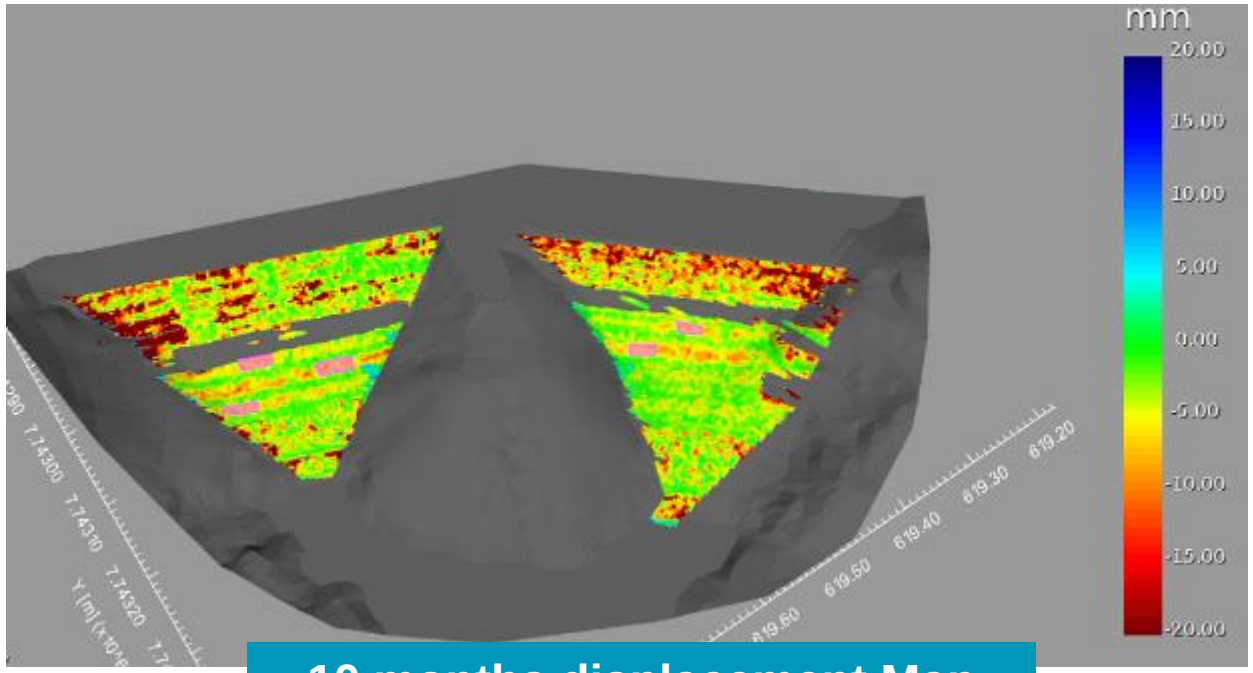
Guardian Slow Movement is a specific Guardian version focused on detection of slow movement measurement. The latest SM/SMV algorithms have been specifically developed for TSF monitoring.

SM and SMV can be selected during monitoring session creation

Guardian Slow Movement uses a live dataset from a Guardian real-time project and then re-processes that dataset in order to detect and visualize slow movement data (millimeter movements over extended time periods).

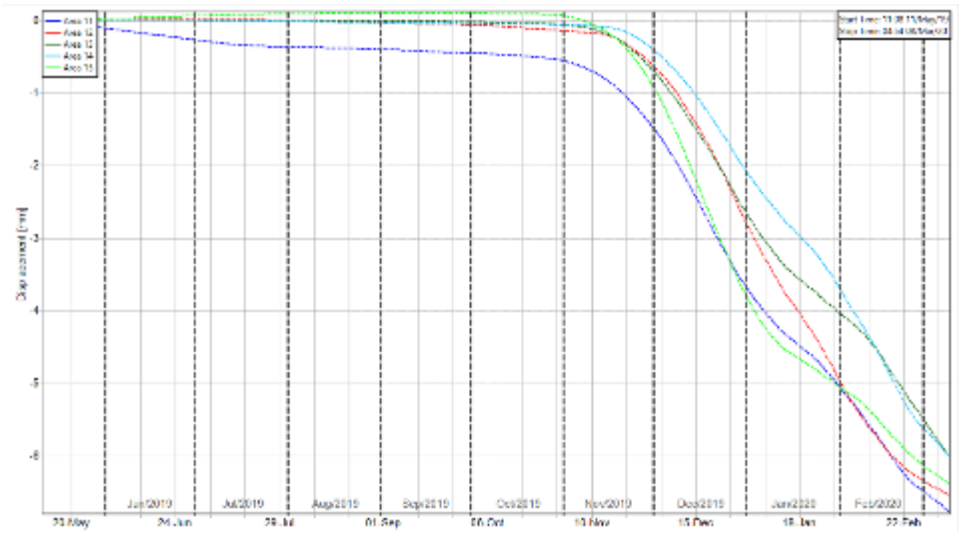


WHY use GBSAR & SMA/SMV for slow moving TSF



10 months displacement Map

1 mm/month sensitivity



10 months of data
~0.6mm/month

In ideal circumstances it should be instigated from the start of monitoring to detect areas that can then be focused on with additional monitoring - i.e areas of possible concern moving forward can be identified

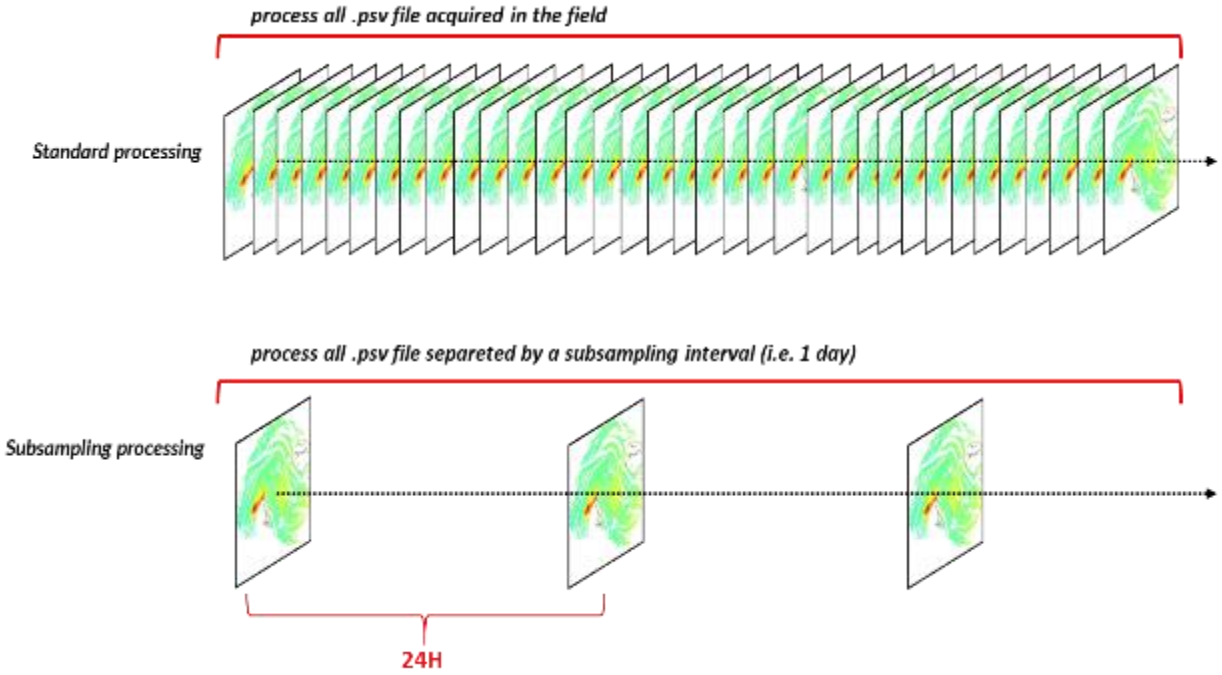
SMA (subsampling) for very slow moving TSF – SM/SMV

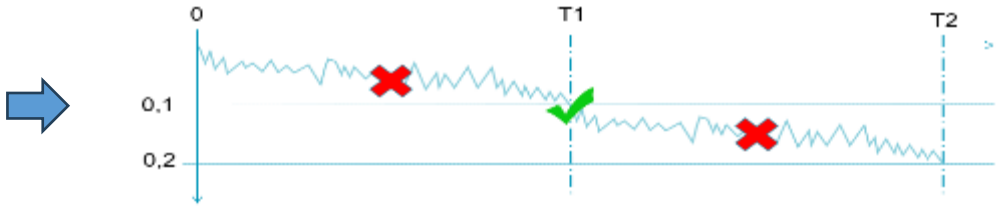
To allow visualization of slow movements, and so execute a Slow Movement Analysis, Guardian offers a dedicated processing feature.

Instead of processing all data acquired by the radar, this alternative processing considers a set of acquisitions separated by a time interval defined by the user, basically a subsampling interval.

WHY? The standard processing and adaptive thresholds used in real time processing (PSI interferometry) make use of statistical analysis for pixel classification (correlation in space & time) and can mean that very slow-moving pixels (mm/month) may be classified as “non-moving".

We overcome this by using a larger sampling time window (e.g. 24hours) for the accurate classification of very slow-moving pixels as required for successful TSF monitoring.



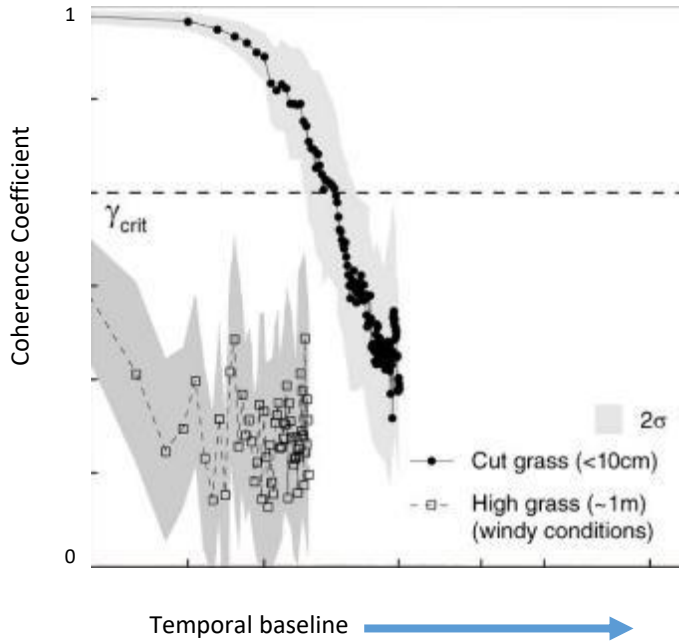


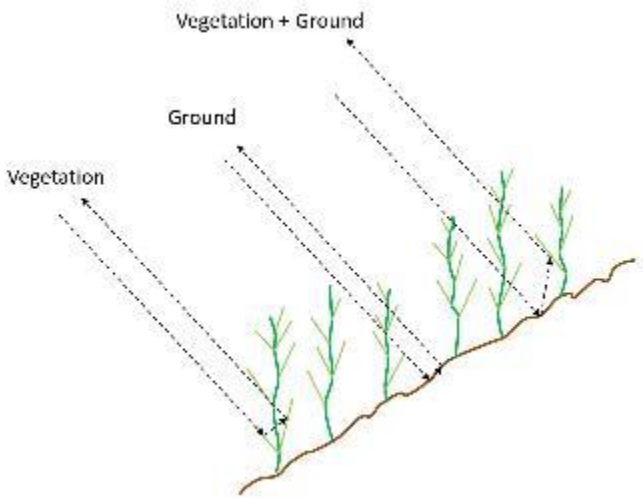
Processing Algorithm	Interval of PSV	The Slowest Detectable Movement		
		(mm/hour)	(mm/day)	(mm/month)
Real Time Processing (Including Multiscale Processing)	1.5 Minutes	0.028	0.67	20
Slow Movement Analysis (Subsampling)*	12 hours	0.008	0.20	6
	1 Day	0.004	0.10	3
	3 Days	0.001	0.03	1

SMV Basics for TSF monitoring

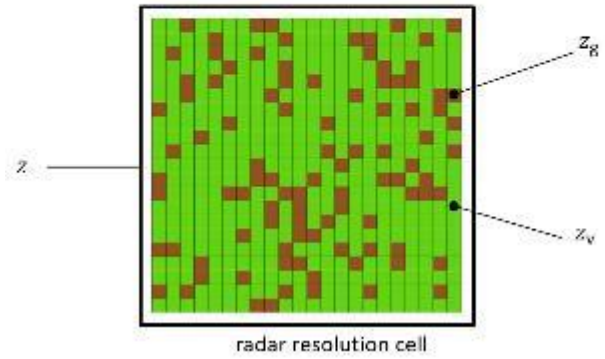
Very similar subsampling process but with the additional requirement to remove the effects of the random motion (de-correlation of radar data) of the vegetation

Derived Coherence evolution over time - *Caduff (2014)*





$$z = \sum_{g \in G} z_g + \sum_{v \in V} z_v$$



Random motion of the vegetation results in a de-correlation time in relation to the acquisition time interval (velocity)

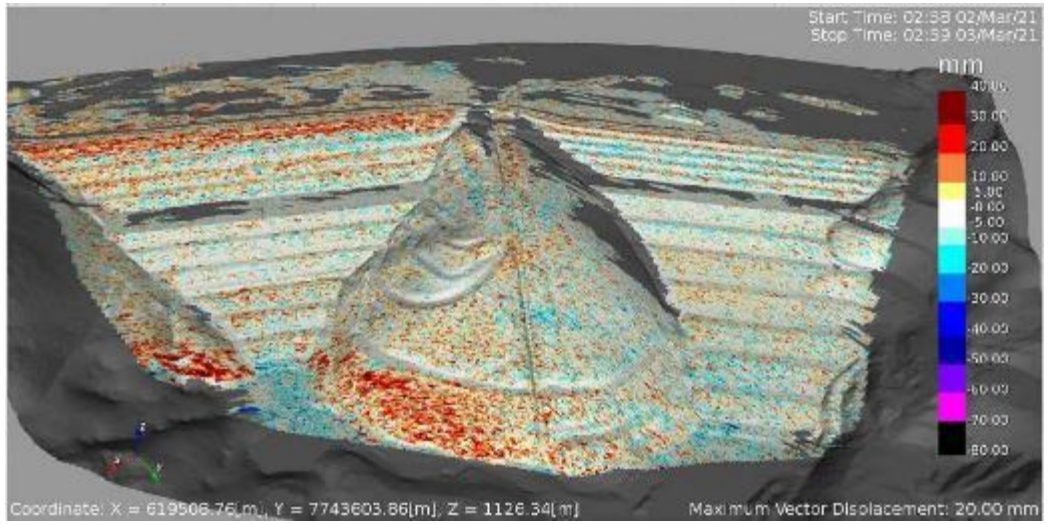
Compared to the uniform ground motion which has a uniform LoS velocity

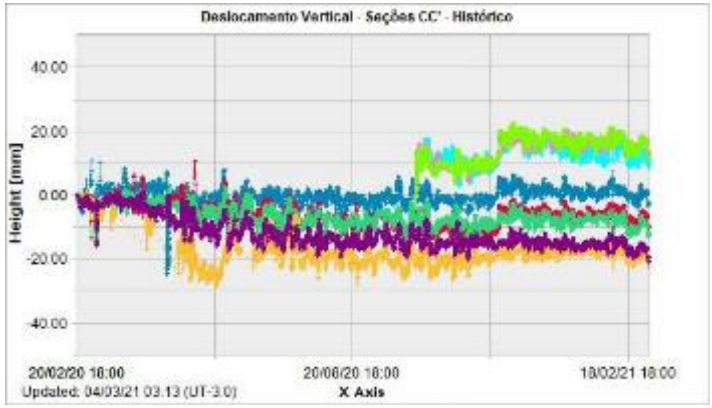
Based on these velocities specific averages are then used to ensure reliable slow movement detection in (low) vegetated environments.

WORK in PROGRESS…..

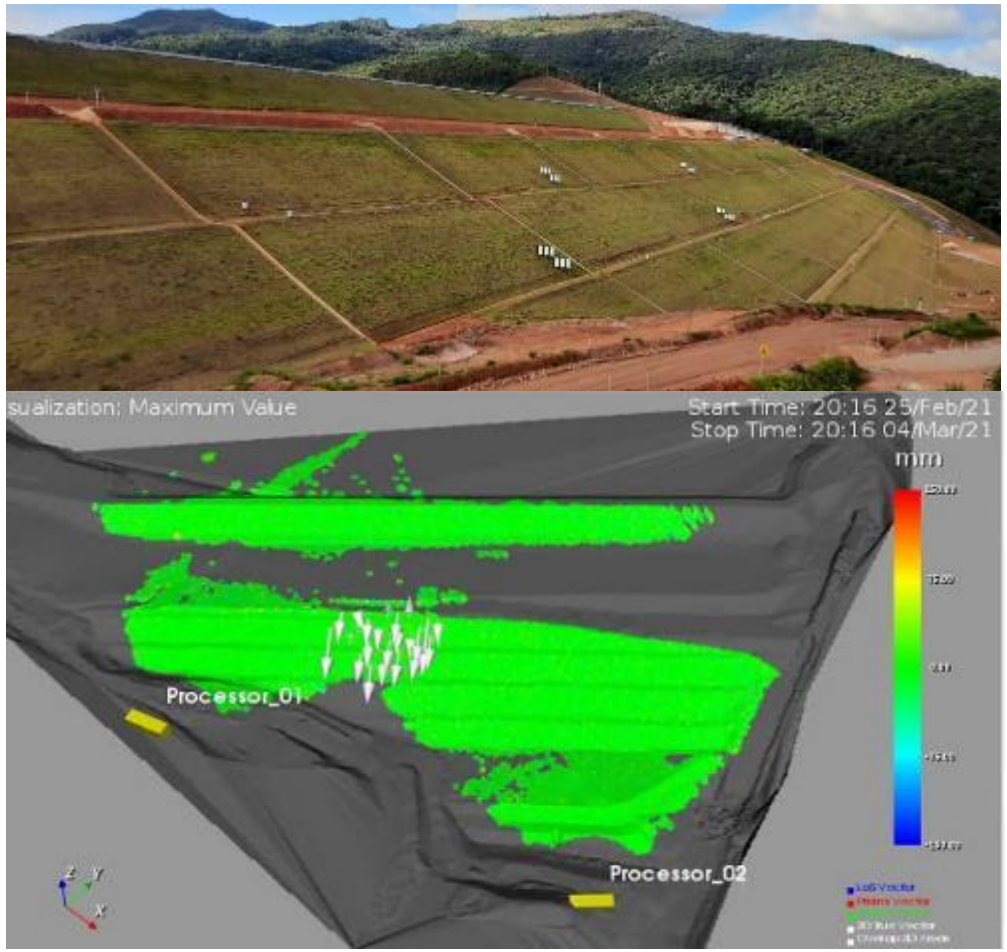
IBIS-FM EVO monitoring in SAMARCO (Brazil)

TSF monitoring with IBIS - FM EVO and TM60 in Brazil





Vegetated TSF monitoring with IBIS – FM EVO and TM60 in Brazil



Data Correlation – Connected eco system of monitoring sensors TPS, GNSS and GBSAR using SMA

Rio TINTO – Corta Atalaya Open Pit (Andalusia, SPAIN) – Largest open pit in Europe.

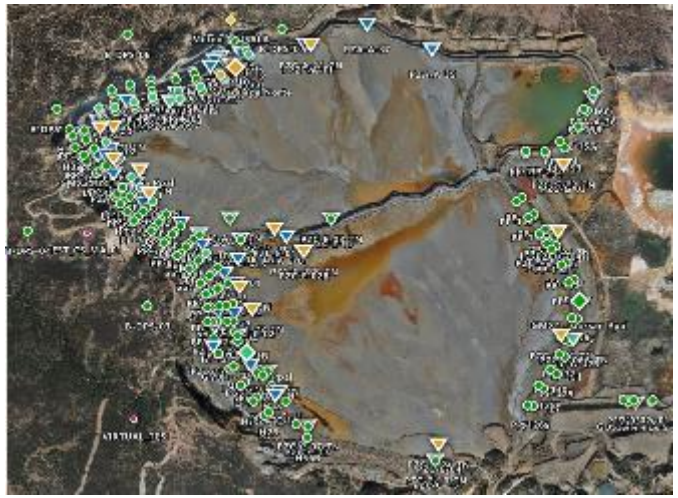
Instruments from different vendors for the TSF monitoring regime

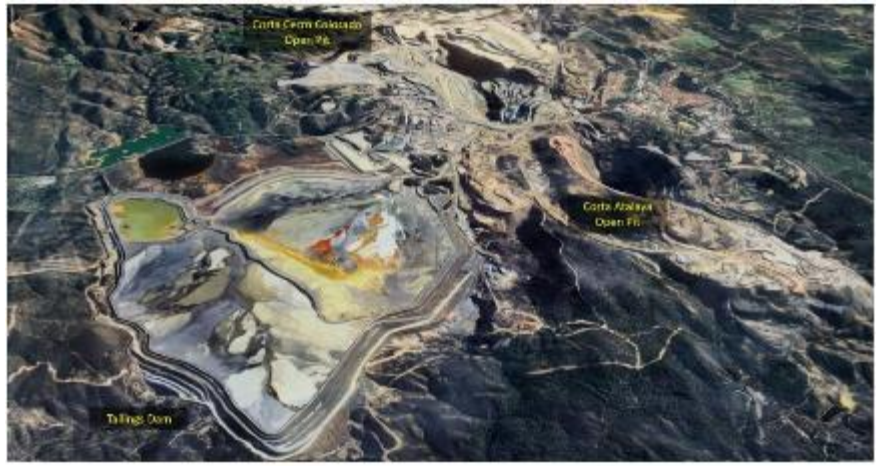
Integration and digitization of data from different devices

Multi-disciplinary approach to TSF monitoring

Technology	Units
TPS / Prisms	150
GMX GNSS	4
GBSAR	1
OWP (Open Well Piezometers)	46
CSP (Closed Standpipe Piezometers)	30
Markers GCP	9
Weather Station	1
Inclinometers	21

Table. Sensors number installed

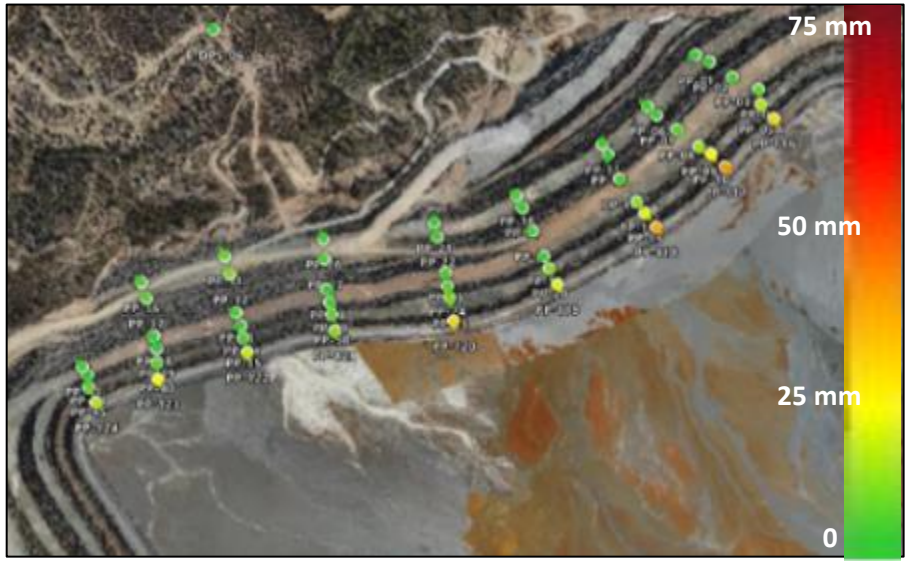




As a "living" project, both Geodetic and Geotechnical instrumentation will be reviewed and implemented as needed.

Data Correlation – TPS and GNSS Results

3-month time interval – June -> September 2023



Prisms Location on the TSF (Vaguada Norte)

GNSS Location on the TSF (Vaguada Norte)

Lower Part prisms: from 1 to 10 mm
Upper Part Prisms: 11 to 47 mm

The average measured 3D movement is about 42 mm in 3 months

Data Correlation – TPS and GBSAR Results

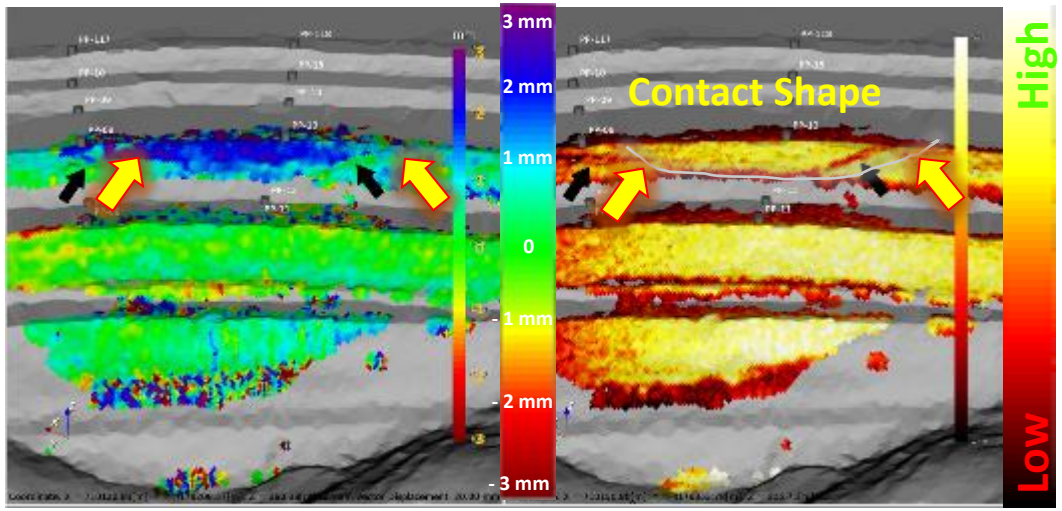
3-month time interval – June -> September 2023

Goal was to validate the GBSAR measurement of 1mm/month with TPS data.

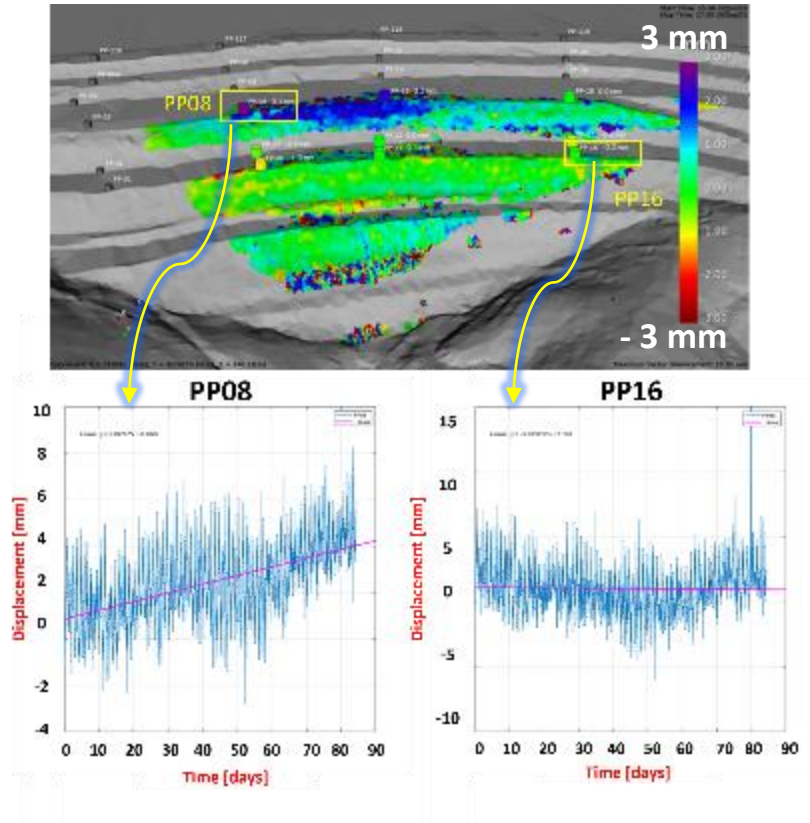
TPS displacement data (vertical/horizontal) projected along radar LoS to make it comparable

Display both datasets on the same radar displacement map with the same colour bar settings.

High correlation between the two datasets and validation of GBSAR measurements

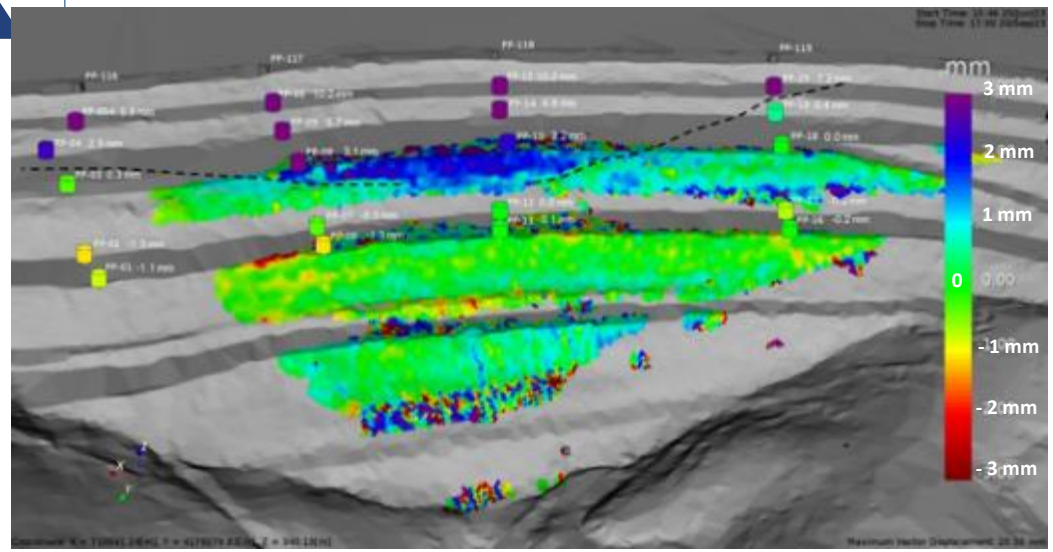


Displacement Map VS Amplitude Map (Vaguada Norte)

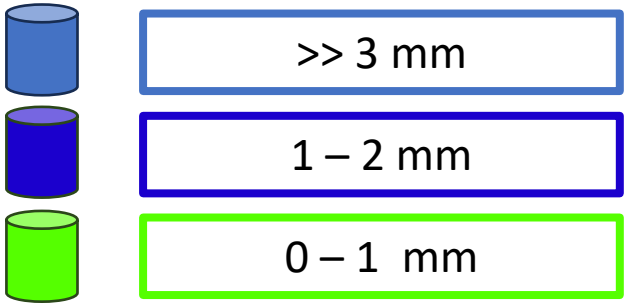


Radar Displacement Map VS TPS/Prisms measurements

Data Correlation – TPS and GBSAR Results



GBSAR Displacement Map and TPS / Prisms outside the radar coverage (Vaguada Norte)



TPS measurements are comparable and consistent with the GBSAR radar displacement map

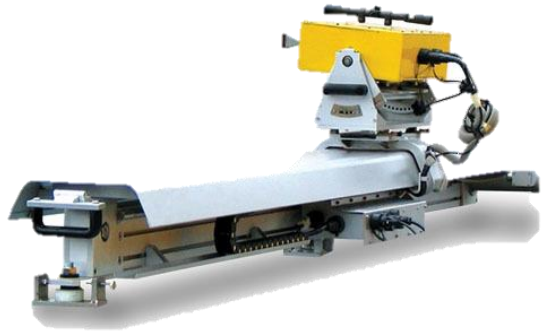
Vaguada Norte TSF is a Dynamic structure with a discontinuity at the top which is continuously growing with new material deposition being pumped and discharged from different points around the TSF. The compaction and normal movement of material internally within the dam creates the expected structural discontinuities that we see above.

- i.e. slow movement of approximately 1mm/month with greater displacement trends being indicated at the top than the bottom

Data confirmed with GBSAR and TPS

Downstream tailings Dam – VALE - Brazil

Sensor	Time interval	Number of points
RTS Prisms	6 months	38 available 21 for comparison
IBIS-FM	1 year (6 months for comparison)	~ 80k

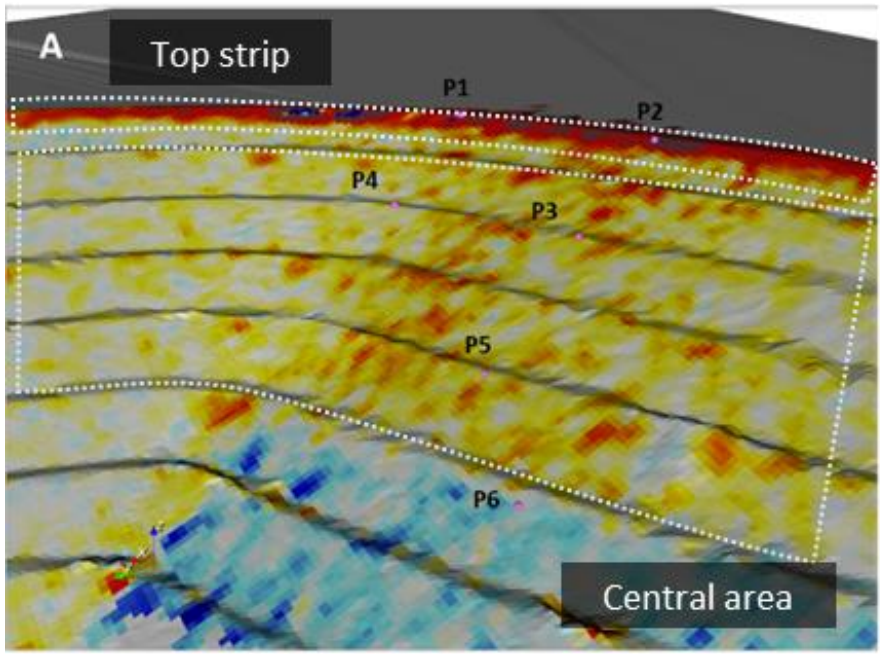


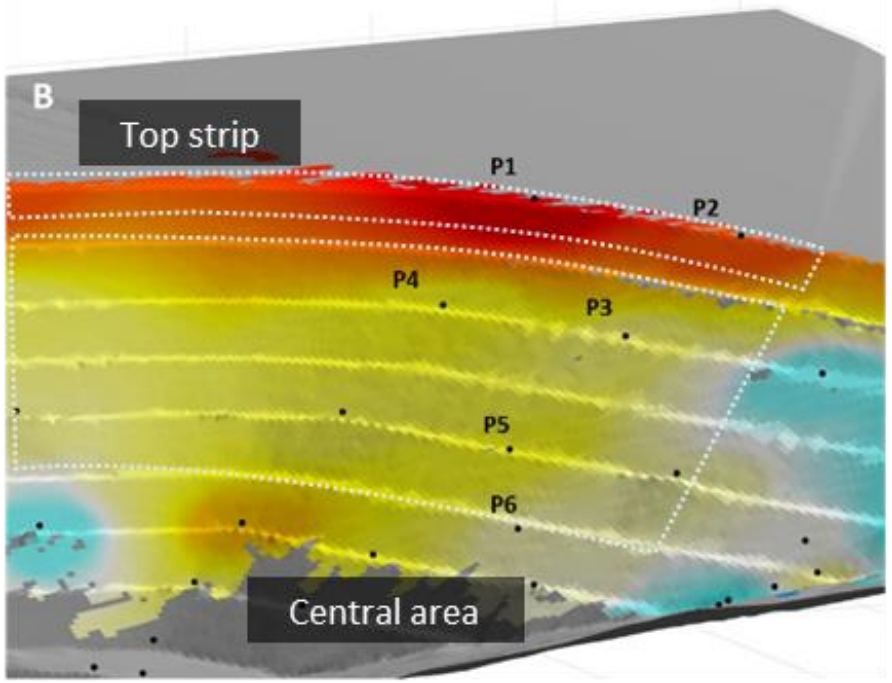
Downstream tailings Dam - Data Correlation – Velocity Maps

LoS Velocity Maps comparison

IBIS-FM Radar Map
(Guardian-SMV)

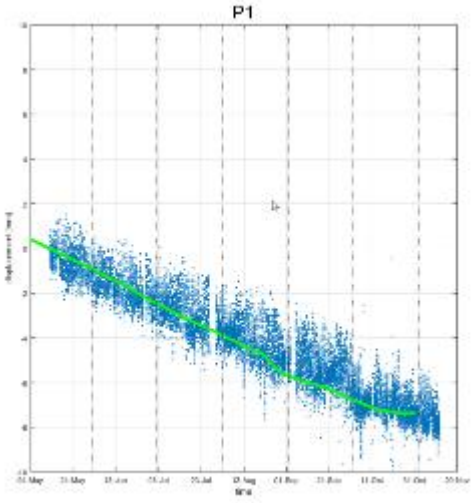
Prism Map
(Interpolation)





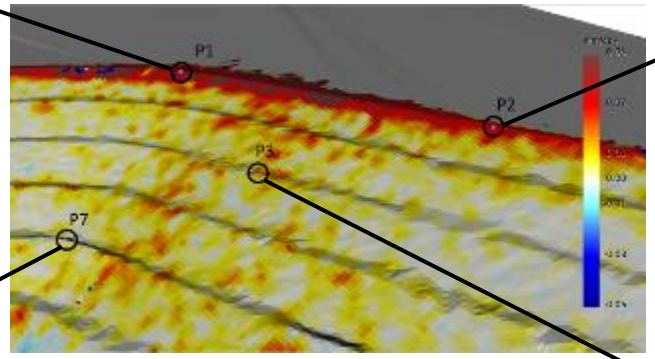
Downstream Tailings Dam Data Correlation – Time Series Comparison

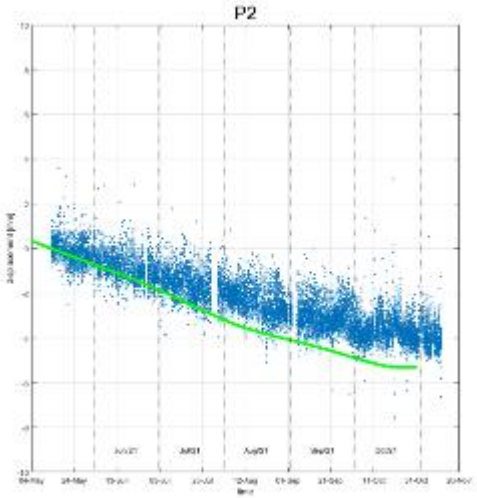
IDS GeoRadar

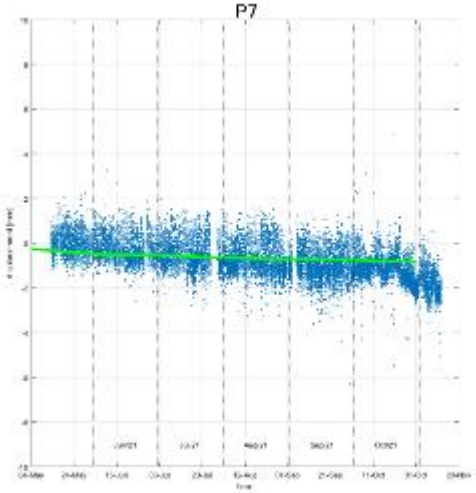


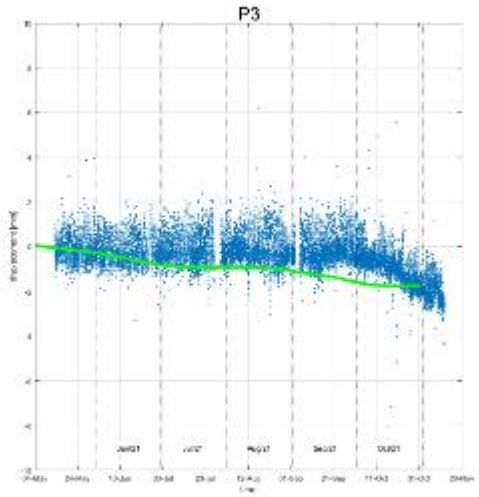
IBIS-FM Radar

Prisms









Mapping and Modelling verification using radar data and 3rd party software rocscience

Spatial Validation

Figure 2 – Cumba slope failure with mapped and modelled faults (Bar et al. 2022)

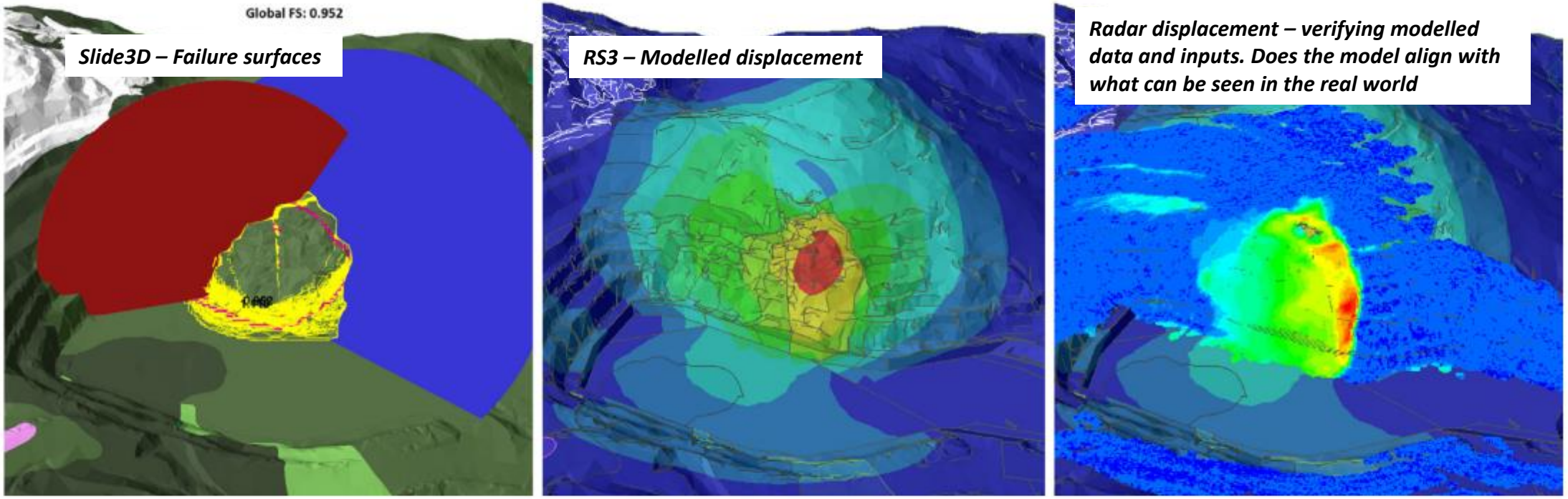
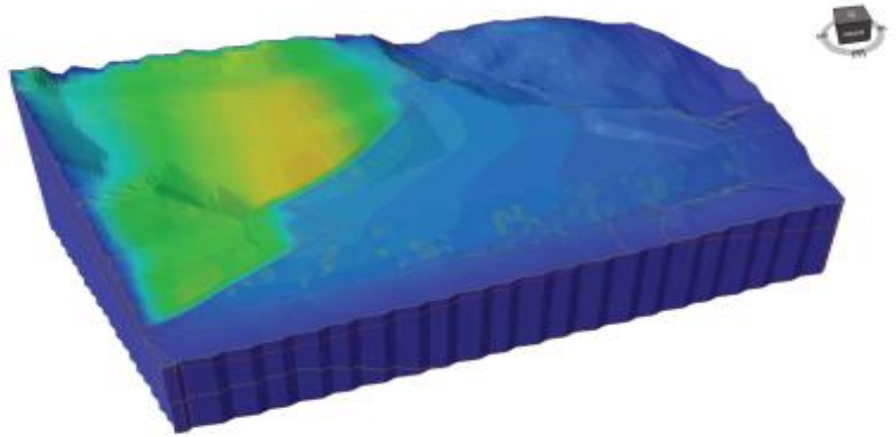
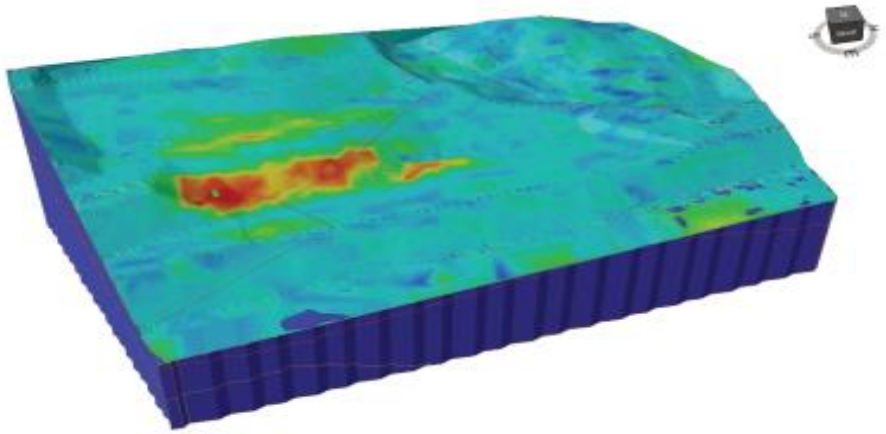


Figure 3 – Cumba slope failure back-analysis results for partly daylighting wedge. (a) 3D limit equilibrium method (FoS_{3D} = 0.95); (b) 3D finite element method; (c) Model spatial validation using radar displacement data (Bar et al. 2022)

(a)



(b)



(c)

Figure 5 (a) Back-analysed 3D finite element analysis results showing maximum strain concentration along the fault; (b) Back-analysed 3D finite element analysis results showing maximum total displacement; (c) IBIS-FM radar monitoring data overlain on excavated slope surface showing good correlation between maximum measured deformation and maximum modelled displacement

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