
# Advancing Geotechnical Risk Management in Mining with Spatially Enabled and Process-Driven Information Systems

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Marnus Bester
Thandile Dlokweni
Tankiso Mabote
Tim Russell
Shane Athmaram

AngloAmerican

# Contents



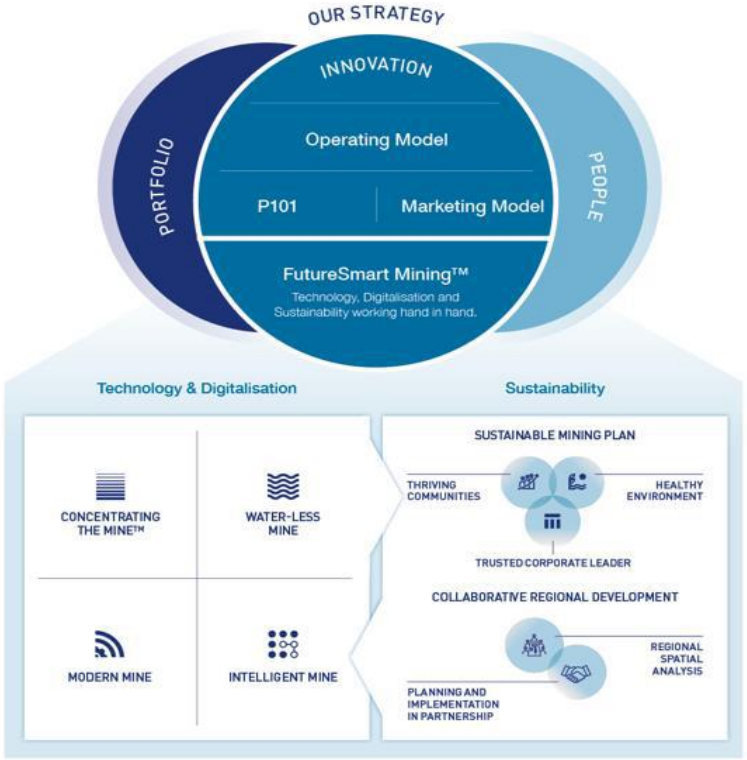
# Where we operate

## Global footprint*


* Number within dot denotes number of operations, shown by product.

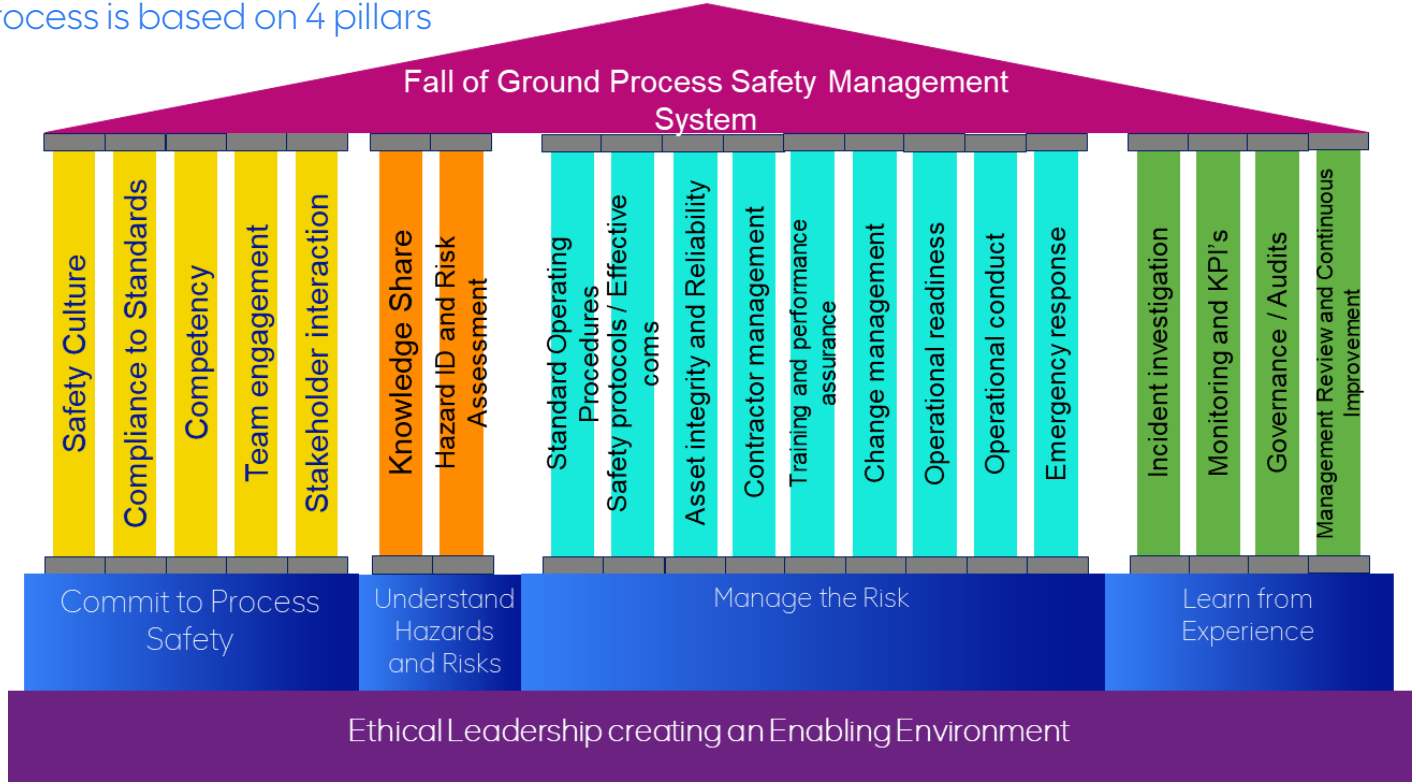
# Innovation is integral to the Anglo American strategy – aligning technology, digitalization and sustainability

- FutureSmart Mining™ is our innovation-led pathway to sustainable mining: technology, digitalisation and sustainability working hand in hand.
- Smart mining means re-imagining how we work at the mine and beyond – leveraging innovative and sustainable methods to drive safe, responsible production and high-performance teams.



# Risk Based Safety Management System

## The process is based on 4 pillars




A systematic approach to identify, assess, and mitigate risks associated with industrial processes. (Modified after CCPS (Centre for Chemical Process Safety), Guidelines for Risk Based Process Safety, 2007.)

# Context

## Key Objectives

### Supporting effective operational Geotechnical Risk Management

- Supports the Ground Control Management Plan with a risk-based approach to develop a mine plan with acceptable geotechnical risk to deliver safe production
- Aligned with Fall of Ground fatality elimination strategy

### Effective Hazard Identification - Inspections / Verification

- Early identification of deviations & anomalies to prevent uncontrolled falls of ground
- Detects noncompliance for timely mitigation
- Ensures regular verification of control effectiveness

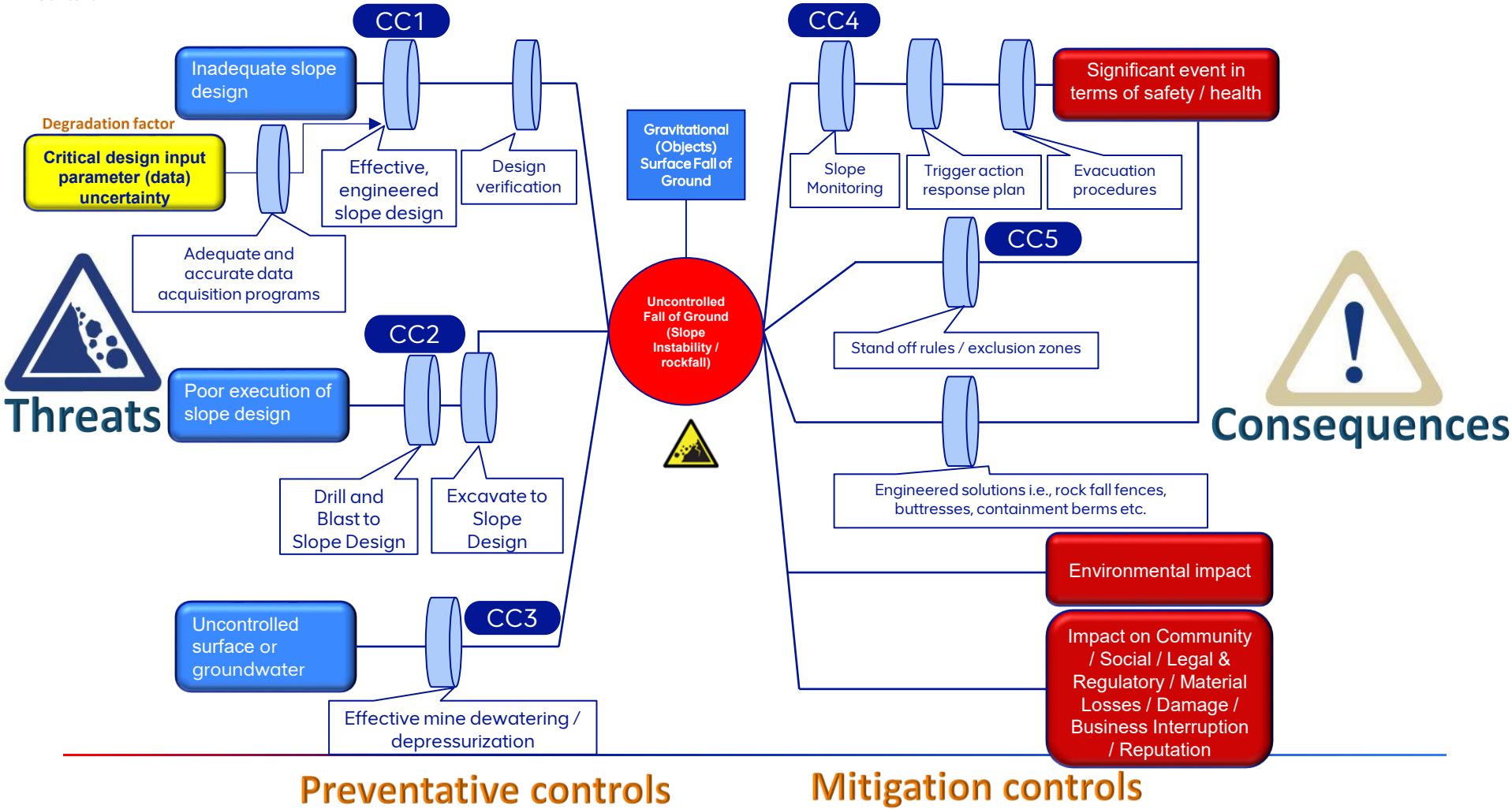
### Relevant Mandatory Clauses in the Anglo American Geotechnical Standard for Mining

•Competency-Based Training
    - Awareness training for personnel before mine access
    - Supervisors trained in hazard identification & mitigation

•Up-to-Date Mine Plans & Hazard Maps
    - Accessible to workforce, including waste dumps & stockpiles

•Defined Inspection Procedures that specifies frequency, responsibility & reporting on ground conditions

Context


CC1
Inadequate slope design
Degradation factor
Critical design input parameter (data) uncertainty
Effective, engineered slope design
Design verification
Adequate and accurate data acquisition programs
Threats
CC2
Poor execution of slope design
Drill and Blast to Slope Design
Excavate to Slope Design
Uncontrolled surface or groundwater
CC3
Effective mine dewatering / depressurization
Gravitational (Objects) Surface Fall of Ground
Uncontrolled Fall of Ground (Slope Instability / rockfall)
CC4
Slope Monitoring
Trigger action response plan
Evacuation procedures
Significant event in terms of safety / health
CC5
Stand off rules / exclusion zones
Engineered solutions i.e., rock fall fences, buttresses, containment berms etc.
Environmental impact
Impact on Community / Social / Legal & Regulatory / Material Losses / Damage / Business Interruption / Reputation
Consequences
Preventative controls
Mitigation controls

# Effective Operational Geotechnical Risk Management

## What are the physical deliverables to comply with legal and company requirements?

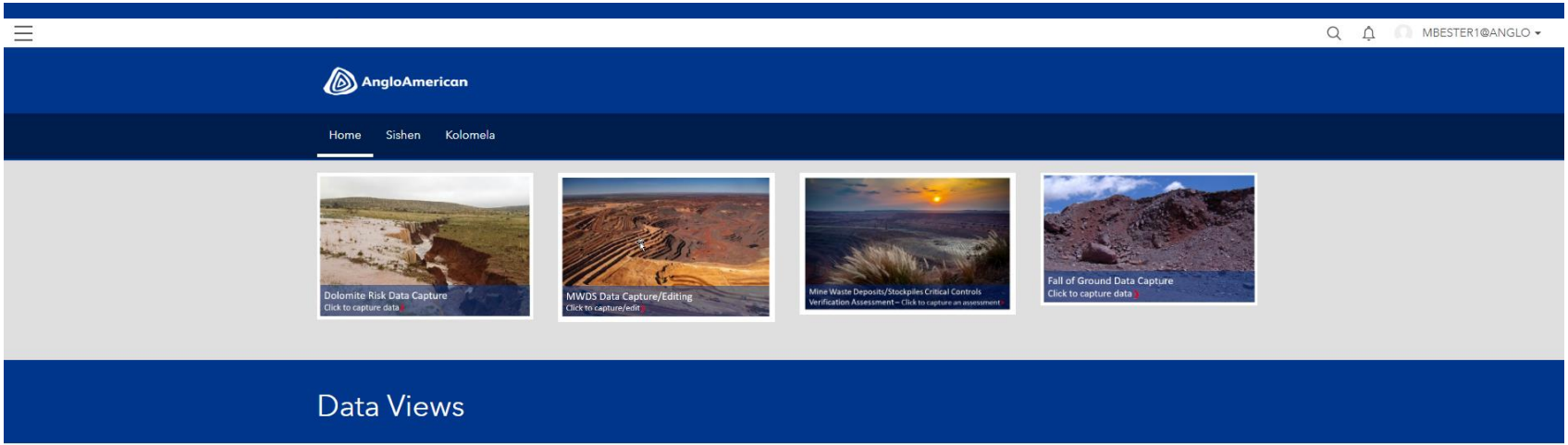
- Effective Hazard Identification / Inspections completed and documented as per risk-based frequency
- Effective Trigger action response plan in place
- Live Hazard Map in place and used for effective communication with production (What controls are required?)
- Standard Operating Procedures in place

| RANKING | PRIORITY | ACTION | DESCRIPTION |
|---|---|---|---|
| High | Stop & Fix | Controls are not in place and current control strategy will not function as intended | The situation must be rectified immediately. Stop work, implement interim controls, and implement controls to lower the risk |
| Medium | Fix within Shift | Control strategy is in place with gaps in other levels of controls such that the overall control strategy is unlikely to function as intended | The situation must be rectified urgently. Prioritise work required to execute identified controls |
| Low | Fix within Schedule | The overall control strategy is expected to function as intended with no immediate risk on the PUE, minor gaps exist on other levels of control. | Action to commence within a short-term schedule informed by mining plan, exposure |
| Mitigated | Normal operating conditions | Controls are in place; the control strategy is functioning as intended | No specific action is required, continue implementing the day-to-day standard operating procedures and controls |

# Supporting Effective Operational Geotechnical Risk Management with Information Management Systems

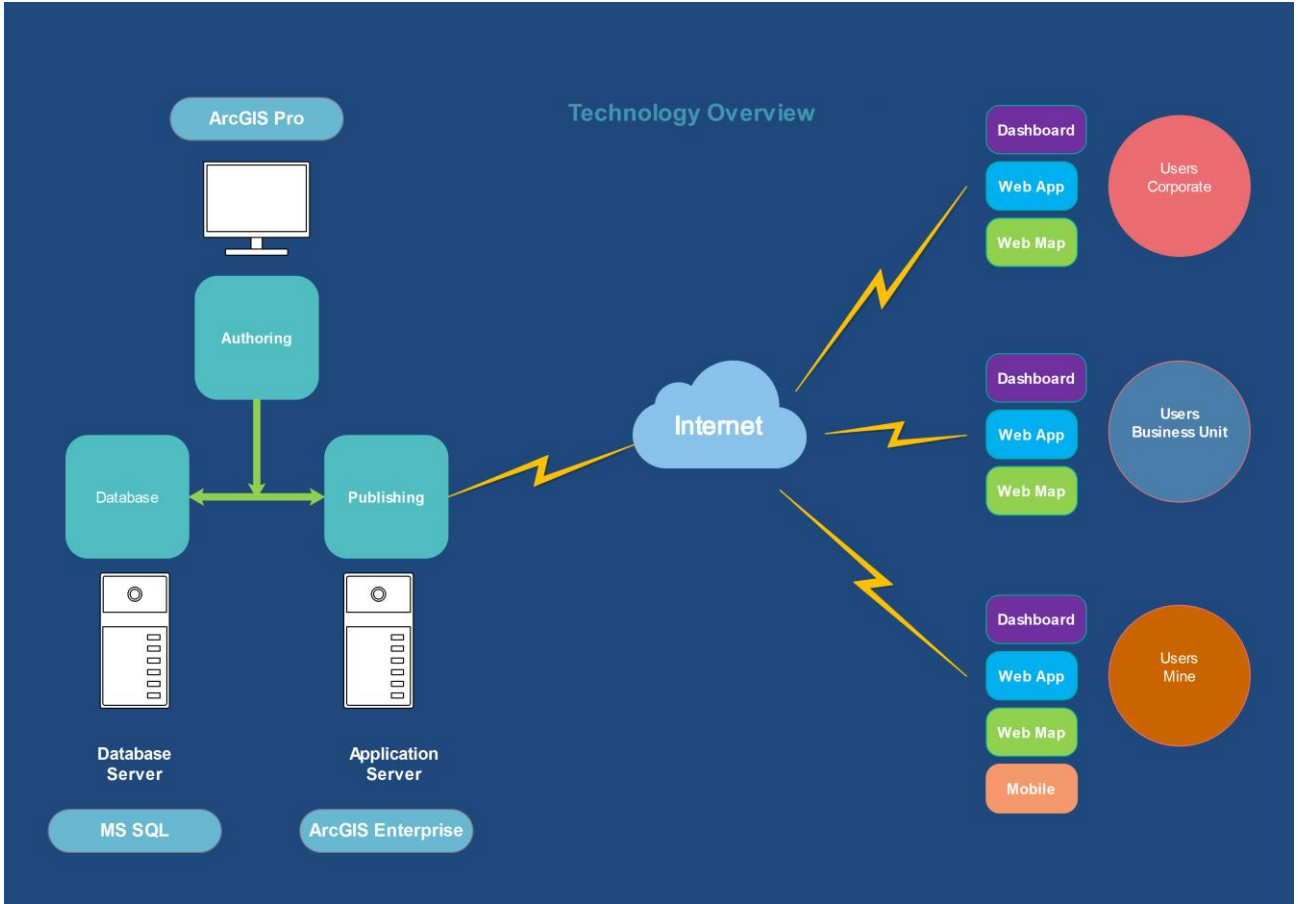

# Geotechnical Engineering Information Management System

All applications are accessible through a web-based portal, where access, editing and viewing functionalities are managed.



# Geotechnical Engineering Information Management System

## Technology Overview



# Overview of applications in the Geotechnical Engineering Information Management System

# Waste Dump and Stockpile Risk Management

## Application to capture and maintain all Waste dump and stockpile information in Anglo American

**Rating of Site** Location, Geology, Geometry, Mass, Stability Analysis, Construction and Performance

→

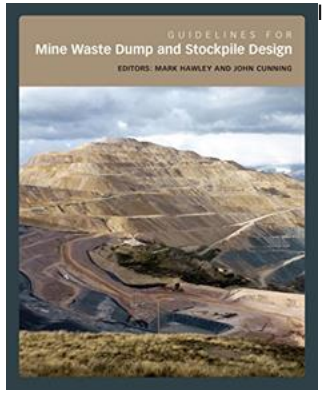
Aggregating of ratings to calculate Engineering Geology Index (**EGI**) and Design Performance Index (**DPI**)

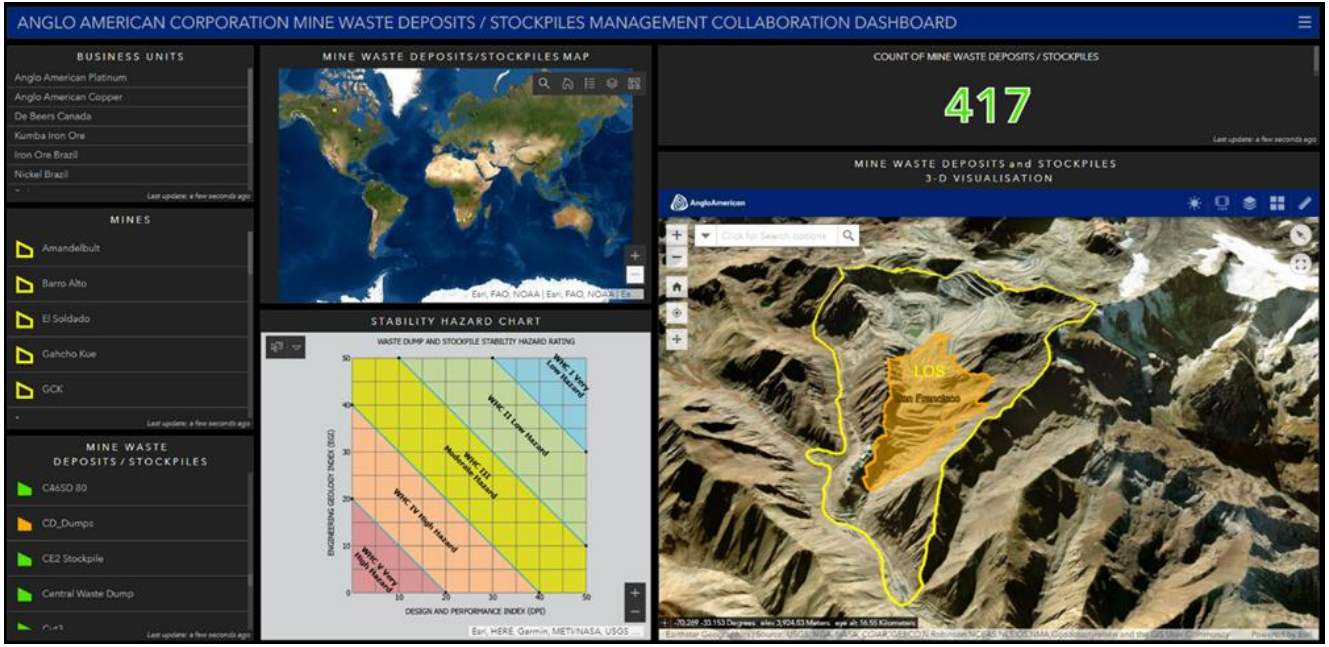
→

Waste Dump and Stockpile Stability Rating (**WSR**) and Hazard Class (**WHC**) based on indices EGI and DPI

→

**Required Level of Effort** for site investigation, analysis, design, construction and operation based on hazard class and risk assessment




# Live Hazard Map

## This app follows a consistent process for surface and underground mines that mirrors the workflow in reality

### Fall of Ground Hazard Life Cycle

Anomalies / Deviations identified during Routine Inspections or through conventional methods and technology applications

**Hazard Identification**

**Trigger the TARP**

**Risk Assessment**

**Assess Fall Out / Run Out Distance**

**Define Risk Controls and Develop Detailed Operational Instructions**

**Set TARP Level**

**Review or Update Hazard Status**

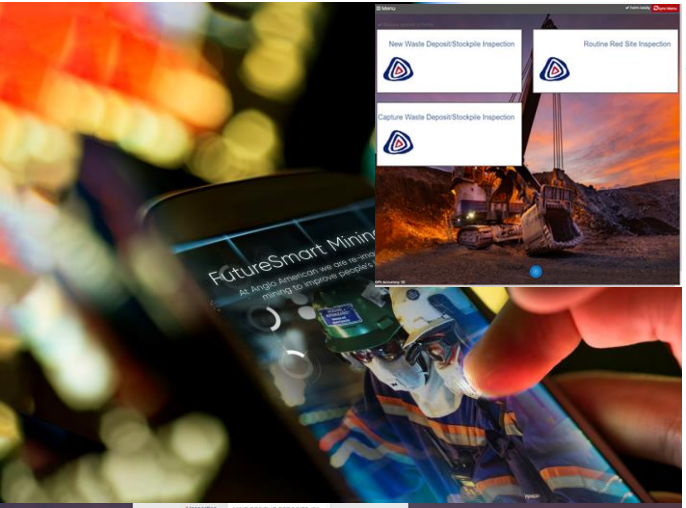
**Hazard eliminated**

Inspections to verify that all controls associated with FoG hazards remain adequate and effective

**Control Verification**

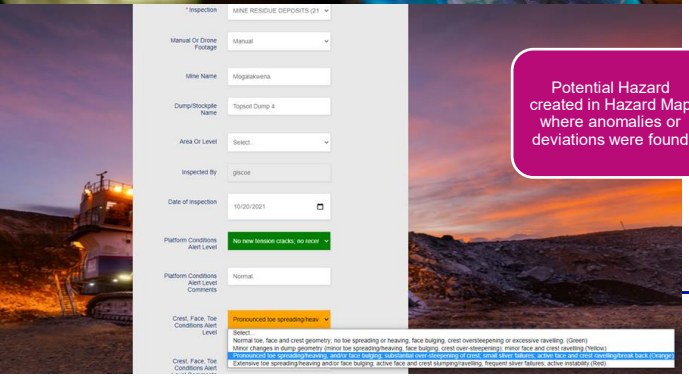
# Routine Inspections

## Routine inspections workflow designed for effective hazard identification (anomalies / deviations) and control verification










Schedule routine inspections and verification inspections on live hazard controls

Inspect as per inbox on mobile - physically or use drone footage on desktop.

Capture Observations using various inspection forms

Merge with parent database if device was offline

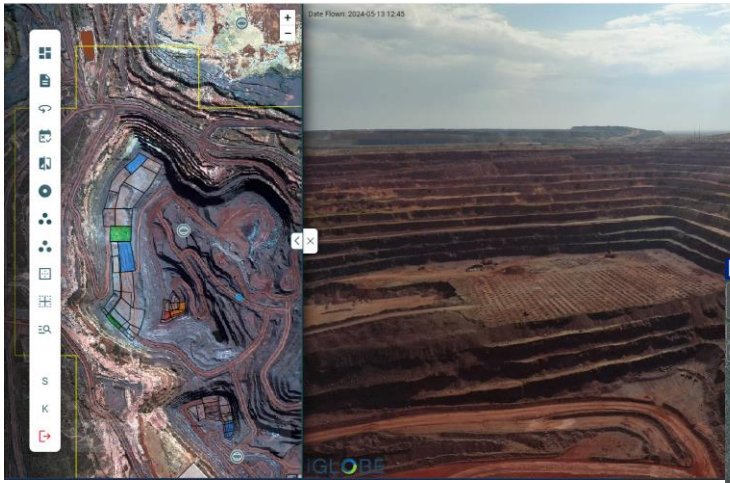
Web app updated with spatial inspection info

Potential Hazard created in Hazard Map where anomalies or deviations were found

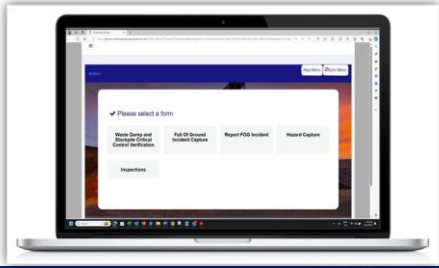
Reporting and Dashboard functions

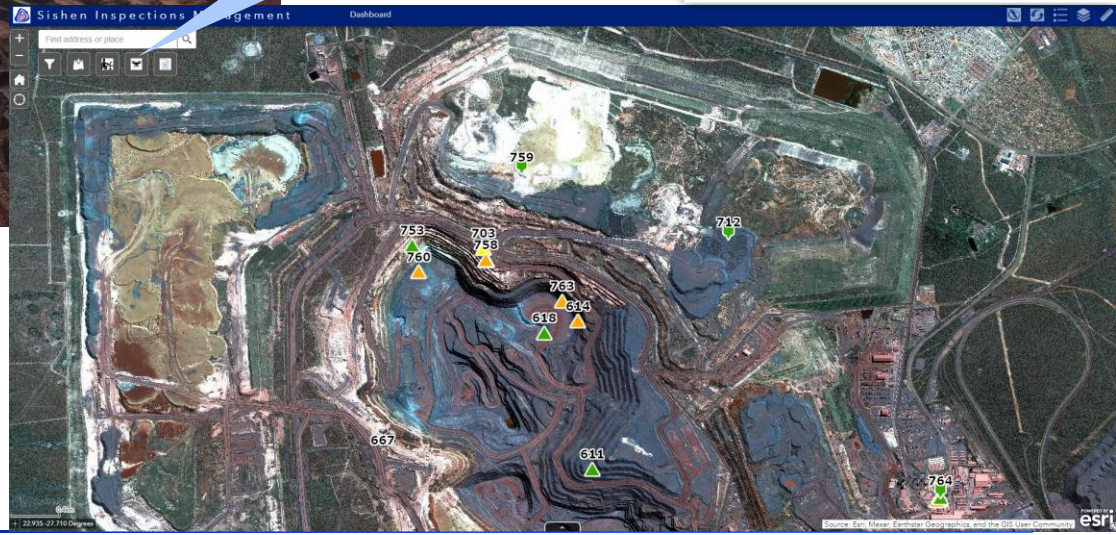
# Inspections application linked to Live Hazard Map

## Flexible system using desktop with drone portal or mobile to ensure effective hazard identification



Perform inspections using Desktop/Drone capture tool and any drone image platform






**Routine Inspections and Live Hazard Map**

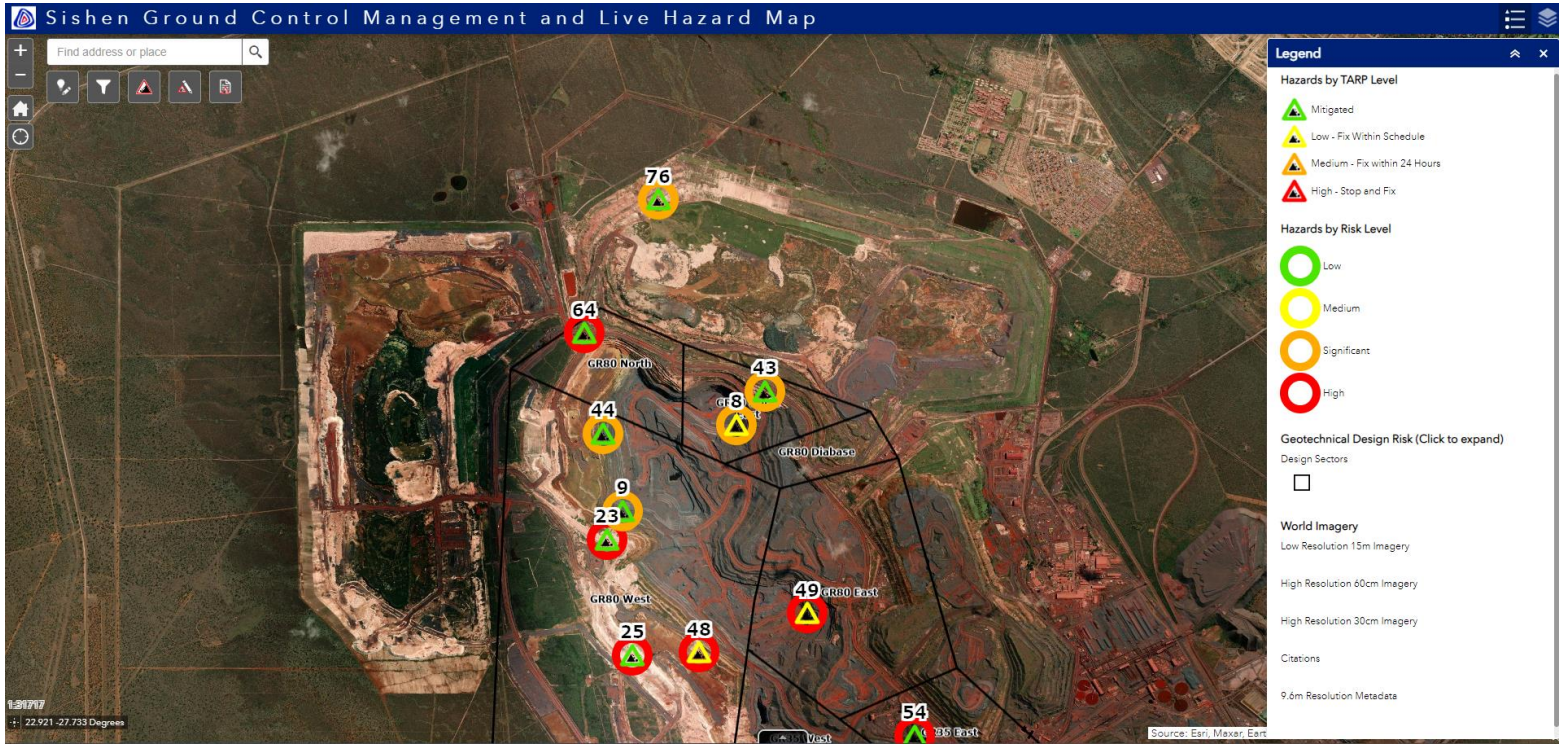
- Any deviations or anomalies identified automatically creates potential hazard on the Live Hazard Map for early mitigation
- All hazards classified and linked to threats in parent bow tie for ongoing analysis / verification of effectiveness of defined controls
- Set TARP level based on adequacy and effectiveness of controls
- Follow up inspections / verification in a dynamic mining environment

# Live Hazard Map

## Maintain all relevant information for active hazards in a dynamic mining environment

**Fall of Ground Hazards**

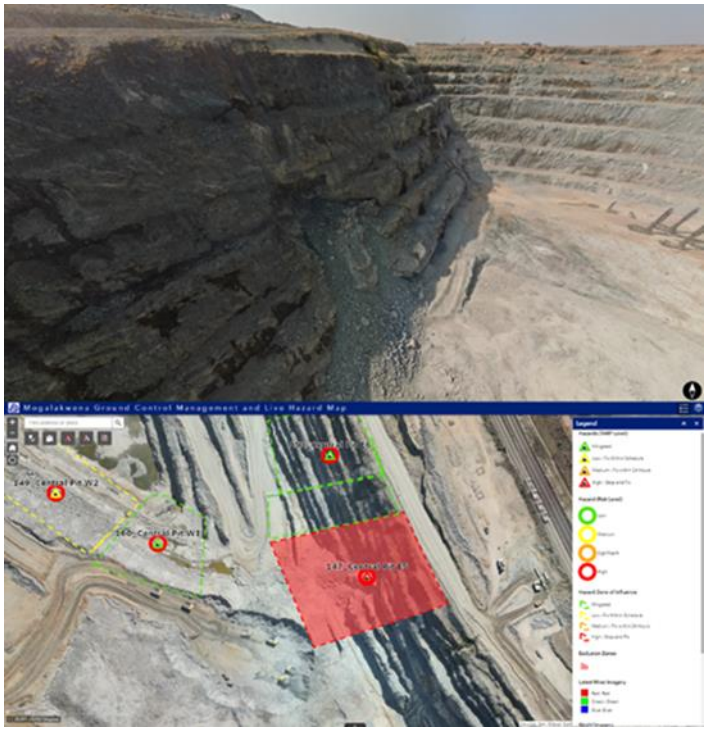
- Risk assessment based on likelihood and consequence - unmitigated
- TARP Level defined based on adequate and effective controls
- Photo record
- File uploads



# Live Hazard Map

## All active hazards zone of influence digitized based on fall out / run out distance assessment

- Zones of influence associated with every hazard are digitised in GIS over the latest imagery and can be easily edited/changed
- Shape polygons are automatically geo-referenced and can be exported to CAD programs
- Shape polygons are stored in a database with timestamps for future analysis, reference and tracking
- Zones of influence can be set to exclusion zones to indicate no go areas & integrated with other systems (Geo fencing capability)



# Live Hazard Map

## Any supplementary information can be added as layers to inform hazard identification and risk management

Geotechnical Design Risk information is readily available to facilitate effective communication.

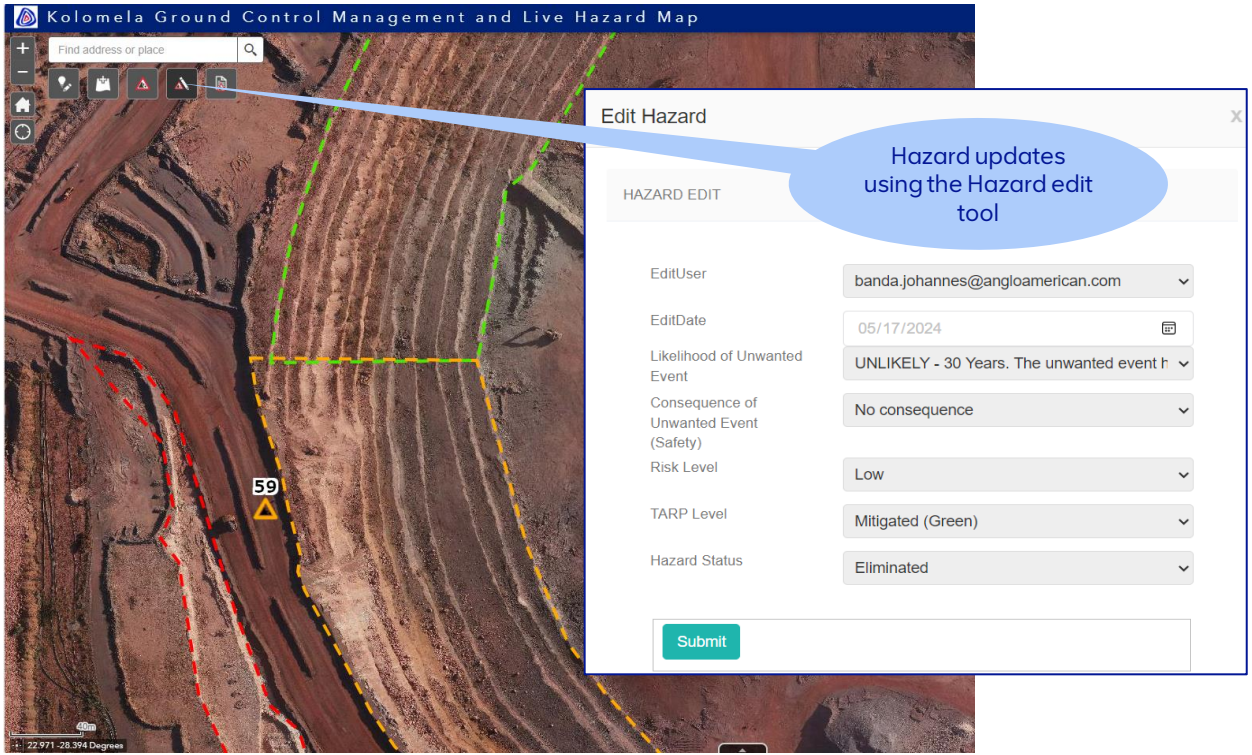
- Safety risk
- Financial risk
- Waste dump risk

Any other information required.

- Structural geological traces
- Surface water management and groundwater risk
- INSAR subsidence data layer
- Mine Planning information

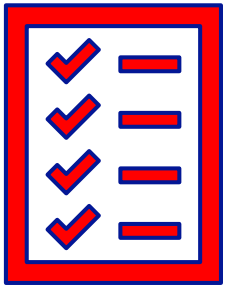
# Live Hazard Map

## Hazard control verification and editing – capture complete life cycle of each hazard




**Hazard edits**

- Person and date/time is captured to maintain transaction log / audit trail
- Update risk assessment (consequence) if exposure changes due to mine plan
- Update TARP level based on adequacy and effectiveness of controls
- Update Hazard status (active or eliminated)

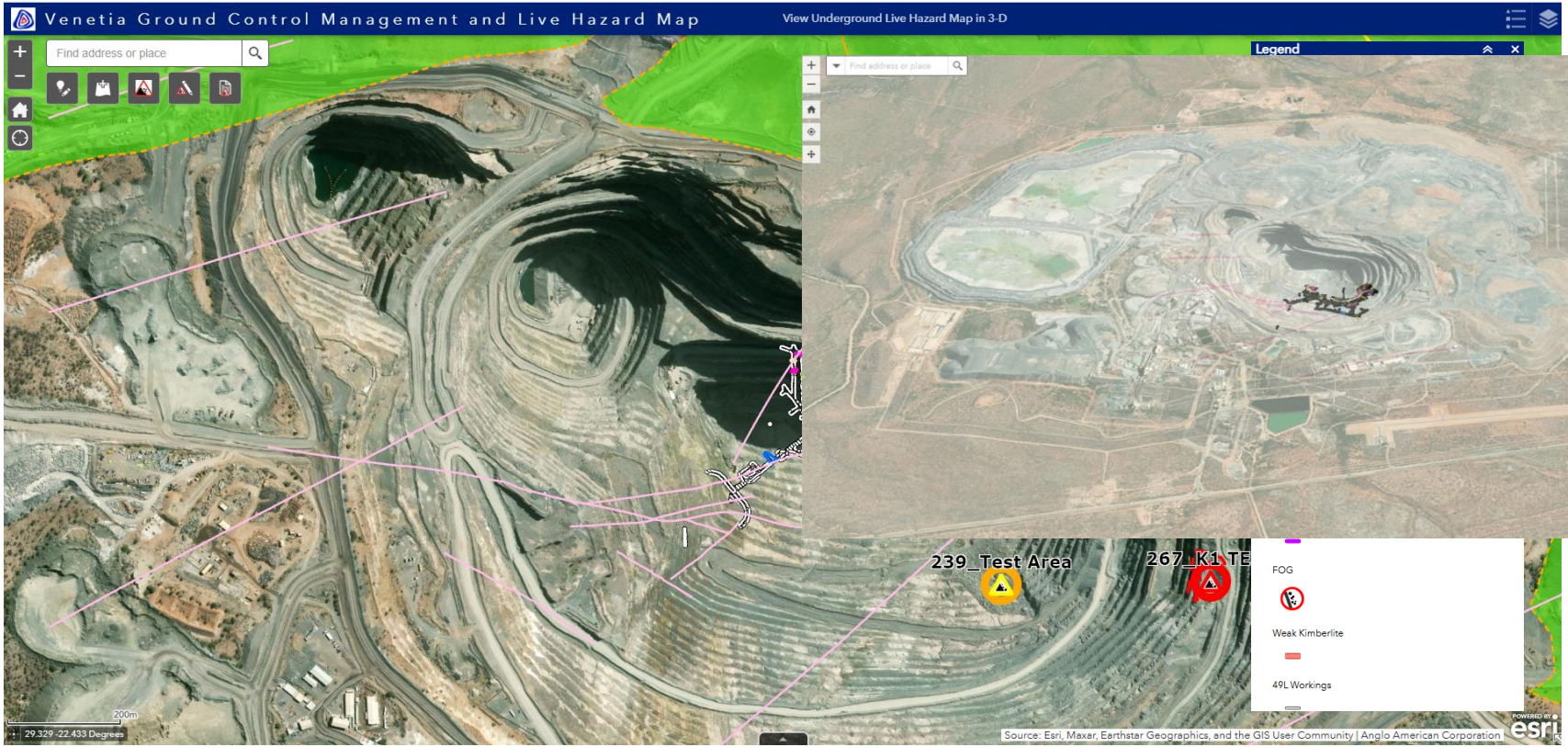


# Effective Operational Geotechnical Risk Management

## Ground Control Management and Live Hazard Map - examples

# Effective Operational Geotechnical Risk Management

## Ground Control Management and Live Hazard Map – underground example



# Effective Operational Geotechnical Risk Management

## The system supports effective communication - digital and conventional


**Hazard Map**

- Hazard ID
- Risk level
- Hazard Type
- TARP level
- Instructions / controls
- Responsible Person
- Sign off

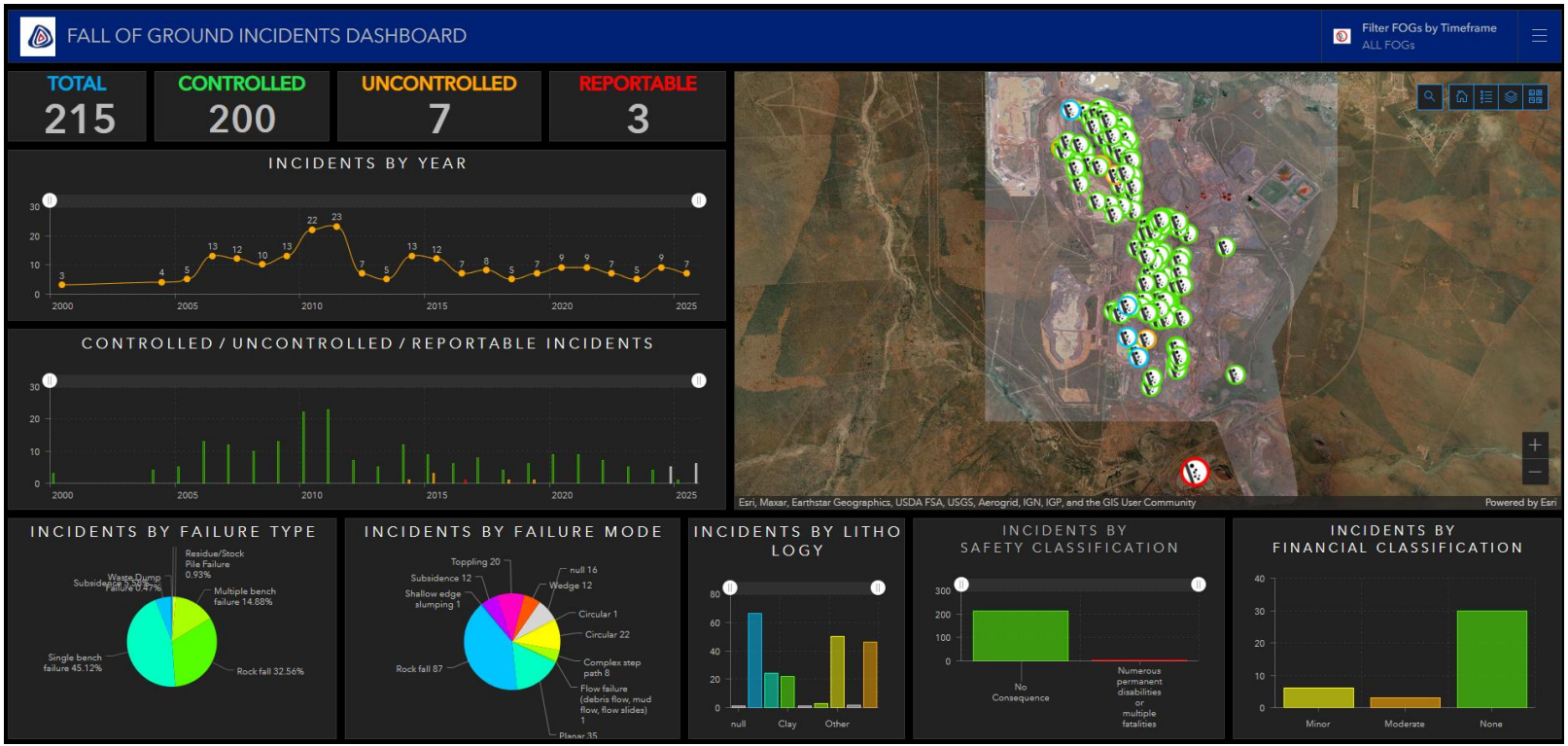
Export Hazard Map or detailed report per hazard to PDF


| Hazard ID | Risk Level | Hazard Type | Tarp Level | Instructions | Additional Instructions | Responsible Person |
|---|---|---|---|---|---|---|
| 8 | Significant | Rock fall | Low - Fix Within Schedule (Yellow) | Implement limit control,Implement effective dewatering / depressurisation,Implement effective slope monitoring | | |
| 9 | Significant | 4 | Medium - Fix Within Shift (Orange) | Implement limit control,Implement effective dewatering / depressurisation,Implement effective slope monitoring,Implement operational controls | | |
| 43 | Significant | Overall Slope Failure | Medium - Fix Within Shift (Orange) | Implement operational controls,Implement exclusion zones,Implement engineering barriers | | |
| 23 | Major | Multiple bench failure | Medium - Fix Within Shift (Orange) | Implement exclusion zones,Implement engineering barriers | | |
| 44 | Significant | Rock fall | Medium - Fix Within Shift (Orange) | Implement operational controls,Ensure accurate mine to design,Implement engineering barriers | | |
| 1 | Significant | Single bench failure | Medium - Fix Within Shift (Orange) | Implement engineering barriers | | |
| 64 | Major | 3 | Medium - Fix Within Shift (Orange) | Perform additional data acquisition required to improve confidence in geotechnical model,Perform more rigorous design work required to improve reliability of the geotechnical design,Implement limit control,Ensure accurate mine to design,Implement effective dewatering / depressurisation,Implement effective surface water control,Implement effective slope monitoring,Implement exclusion zones,Implement operational controls,Additional Instructions | Implement financial risk mitigation actions with mine planning to ensure mineral disruption of the mine schedule should instability occure. (Ensure adequate stockpile levels and or sufficient exposed ore.) | |

| Geotechnical Engineering | Technical Services Manager | Mining Operations | Survey | Safety |
|---|---|---|---|---|
| | | | | |

# Effective Operational Geotechnical Risk Management

## Learn from experience – Fall of Ground Incident Database and Dashboard



# Lessons learned

## Ensure Software Effectiveness

- Maintain simple, consistent processes that reflect reality.
- Avoid capturing incorrect workflows.
- Stick to fundamental risk/geotechnical/hydro management principles.

## Optimize Software Use

- The software should enhance the workflow, not disrupt it. Software must be on your way, not in your way or out of your way
- Don't assume a younger workforce will naturally adopt digital tools effortlessly. Effective change management is key for adoption and efficiency:
    - Focus on demonstrating how the tools make tasks easier and more efficient.  Additionally legal and governance aspects are addressed as history is maintained in the database.
    - Provide proper training and support to address varying levels of digital literacy.
    - Ensure tools align with practical workflows and are intuitive to prevent reverting to old, ineffective processes with known gaps.
- A phased approach is necessary—full digital transition takes time.
- Prioritize system integration for seamless functionality with other existing systems- prevent duplication.

# Conclusion

Establish robust, sustainable frameworks for risk management.

- Empower specialists with integrated, knowledge-driven systems.
- Align technology with practical mining and geotechnical needs.
- Balance cybersecurity compliance and operational efficiency in a large organization.
  - Strong security measures ensure data integrity and compliance - effective risk management solutions must be both secure and practical.
  - Streamlined approval and audit processes when developing systems enhance efficiency without compromising safety.
  - User training empowers teams to uphold cybersecurity while responding swiftly to on-the-ground challenges.
  - Balancing governance with operational needs ensures real-world impact on risk management.

# Thank you


QUESTIONS ?