Linking a Business Intelligence geotechnical platform to a responsive Risk Evaluation platform

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1. Abstract

Two case histories will be presented where MissionOS, a highly configurable, cloud based (geotechnical & civil eng.) data management system is linked to Optimum Risk Estimates (ORE). One deals with a large slow creeping landslide, the other with tailings systems risk assessment. In both cases integrated monitoring and risk assessment analyses have to be performed “continuously”.

MissionOS is a Business Intelligence type of software platform specialised for managing geotechnical instrumentation and monitoring data; ORE is a dynamic, convergent Risk Assessment/ Management software platform.

MissionOS allows real time or discrete (if telemetry is not available) automatic or “by hand” data transfers, easy reports, alert management and aggregated views of any number of monitoring instruments among which, for example: inclinometers, piezometers, extensometers, strain gauges, vibrating wire pressure and load cells, vibration monitoring, flowmeters, rain-gauges, meteorological stations, topographic points, PSInsar, etc.

Preliminary off-line studies performed with ORE using extant data deliver preliminary estimates of: probability of failure of various modes, consequences of failure modes, risk analysis based on extant data, preliminary alert thresholds, concepts related to emergency procedures.

As soon as Mission OS data start to flow toward ORE, it is possible to compare measured values vs. preliminary estimate and operate meaningful calibrations, check of alert thresholds, emerging crises scanning, updates of data (variability) and, if necessary, update probabilities and all the other significant parameters.

The case histories will show examples of dashboards, graphic reports the linked platforms bring to mining end-users, whether they are mining managers, stewards or other key corporate stakeholders.

2. Introduction

This paper presents two case histories where MissionOS, a highly configurable, cloud based (geotechnical & civil eng.) data management system is linked to ORE a Risk Assessment/ management software platform (Oboni, Oboni, 2016a, 2016b).

The case histories bear on a large slow creeping landslide impinging on linear facilities and logistic corridor, the other with tailings systems risk assessment. In both cases integrated monitoring and risk assessment analyses have to be performed "continuously" and/or at discrete intervals.

In a paper at this conference ORE is also linked to a high performance drone imagery/analysis system (Frasca & Al., 2016). It is foreseen that in the near future a "full circle" (Fig. 1) will be established between MissionOS which is a Business Intelligence type of software platform specialized for managing geotechnical instrumentation and monitoring data; Monitoring devices suppliers, satellites imagery, and drones/low altitude sensors carrier and finally ORE which is a Risk Assessment/ management software platform capable of receiving those data streams and update as frequently as desired probabilities, possibly consequences, hence the risk landscape of an operation.

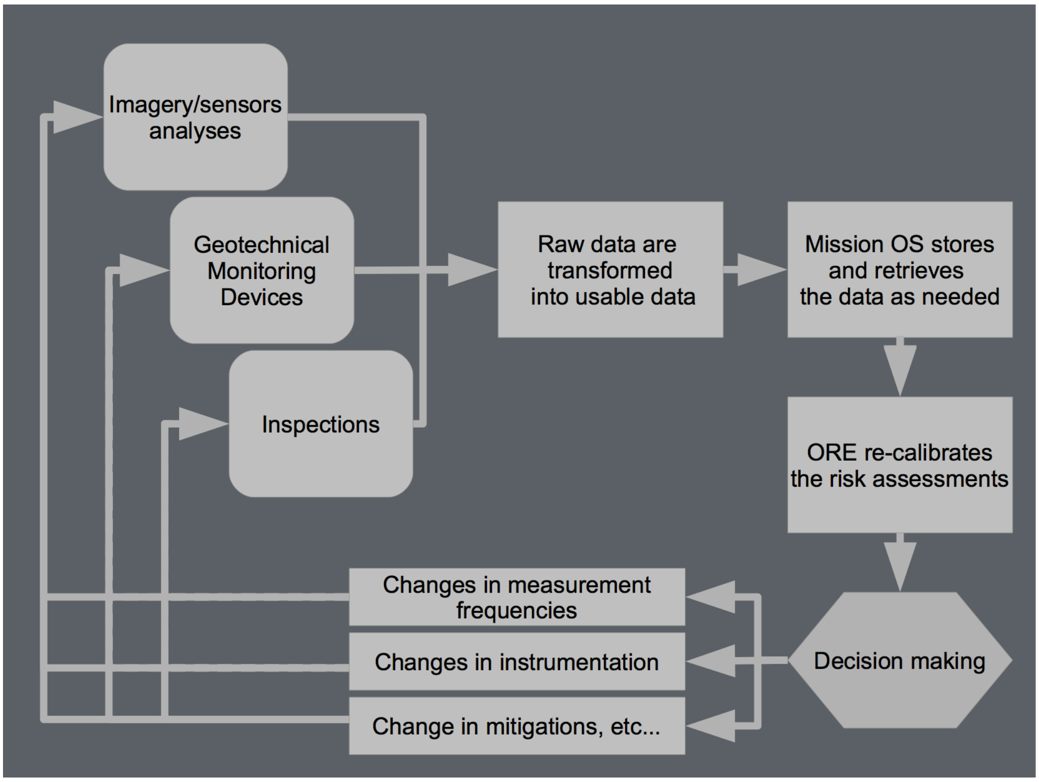

Fig. 1 Scheme of the MissionOS-ORE continuous process. Scalable and drillable from cradle to grave for any project, alternative, operation.

The full circle described above is the weapon of choice of any Tailings Stewardship program, with all data, risk assessment and mitigation decisions at hand and updated.

3. Summary of MissionOS capabilities

MissionOS is a highly configurable, cloud based data management system with a front end, web based (available anywhere), interactive portal used to review and analyze project data and information. The key benefits of MissionOS are its ability to:

- capture data from many sources (manual, automatic),
- create a common database for all – no disagreements about whose data to use,
- present the data in an intelligible form via the web based portal,
- prepare reports, with up to date data and analysis, virtually automatically,
- generate efficient meetings and strongly reduce ‘emergency’ clarification meetings,
- spare time spent chasing for factual information – decision can be made more rapidly with agreed data,
- allow management at all levels to hold paperless meetings with current data viewed and analyzed on the system,
- give access to Project's Historical Data to all designers from one unified data library,
- make data available across all phases of the project and across all contracts and all (authorized) parties,
- manage alert/alarm/action levels sending email and/or SMS to controlled users groups.

This allows all parties using the system, including senior managers, to easily and rapidly review the current status of the project and start management procedures at overcoming alarm thresholds defined by ORE. It allows management and engineers to focus on risk management. There are tangible and intangible benefits deriving from MissionOS use. Intangible benefits are considered to be potentially as valuable as the tangible (directly quantifiable) benefits and include a focus on hazard identification and dynamic risk evaluation rather than (uninformed) risk taking, as well as the use of one data set visible to all parties.

The major economies of using MissionOS across all project participants is that reporting is consistent and largely automatic, and that preparation and meeting time is spent discussing the issues rather than preparing and reviewing the data and reports. MissionOS' characteristics and capabilities yield numerous benefits to its users. Below is a summary:

- cloud based System as a Service (SaaS) (can be installed on Client’s Servers),
- modules available to manage all monitoring, progress, financial data and reporting, mapping,
- interactive progress reporting and monitoring across actual and predicted data sets,
- configurable environment, interactive and standardized written and graphical reporting,
- manage and send alarms when the instruments exceed predetermined thresholds (defined by ORE).

Other benefits of MissionOS are:

- efficiency of data capture and data management. Availability on a need to know basis,
- transparent, easy to communicate, audit-able data on customized dashboards,
- “Blogs” to capture commentaries on events as they evolve, leading to better management,
- data created is available for later use, as appropriate; enabling knowledge acquired in project data to be available for the future (e.g. actual metrics used for tender estimates, data used for risk assessments, etc.),
- data structured for analytics and can therefore be used for active rather than passive or delayed risk management as projects progress.

4. ORE methodology capabilities

In this section the Optimum Risk Estimates (ORE) methodology is summarized (Oboni, Oboni, 2016a, 2016b). A systematic approach to risk considerations in decision-making and project management support is paramount especially when various layers of uncertainties surround alternatives, projects, operations, because decision-makers need to understand the:

- assumptions made, so that evaluations can be discussed, audited),
- uncertainties surrounding the decision,
- probabilistic future behavior (evolution),
- benefits of updating risk information during the life cycle of the system,
- benefits of a scalable (from “high level” to detailed operational, no information wasted) risk analysis system.

The approach needs to cover in a convergent system:

- physical losses (human and assets),
- business interruption (BI),
- environmental damages ,
- reputational damages and crisis potential.

Over the last two decades Riskope has developed and field tested a Step by Step Quantitative Risk Assessment Framework (QRAF) approach named ORE (Optimum Risk Estimates ©Oboni Riskope Associates Inc.) (Fig. 2) ORE delivers its results with a series of graphic representation (dashboards) and other communication means agreed upon with the client. ORE delivers the multi-hazard risk landscapes for the studied system.

Data from extant reports, monitoring devices, expert opinion and quantitative data generated by monitoring and contractors, owners are merged, after taking the necessary precautions, to distil new probability-magnitude estimates for the hazards and their consequences, thus allowing Bayesian updates of the risks. At each new measurement risks are displayed in ORE dashboards to give managers and decision makers the best possible understanding of the risk landscape evolution.

Through the process uncertainties are re-evaluated in the risk register. ORE foresees the formulation of a blended consequence metric to be agreed in advance of any specific Risk Assessment with the Client.

“Total risk” is defined for each record. Deliverable is a General Risk Register, sorted by decreasing “total risk” or other selected filters. ORE foresees an optional treatment of the prior results based on proprietary methodologies encompassing the definition of the client's risk Tolerability (Tolerance) Threshold. A ranking based on the intolerable part of risks is then developed to highlight critical areas of the operation and to guide recommendations on possible mitigations. This leads to efficiently discarding non critical risks, hence to more efficient decisions (Oboni, Oboni, 2014).

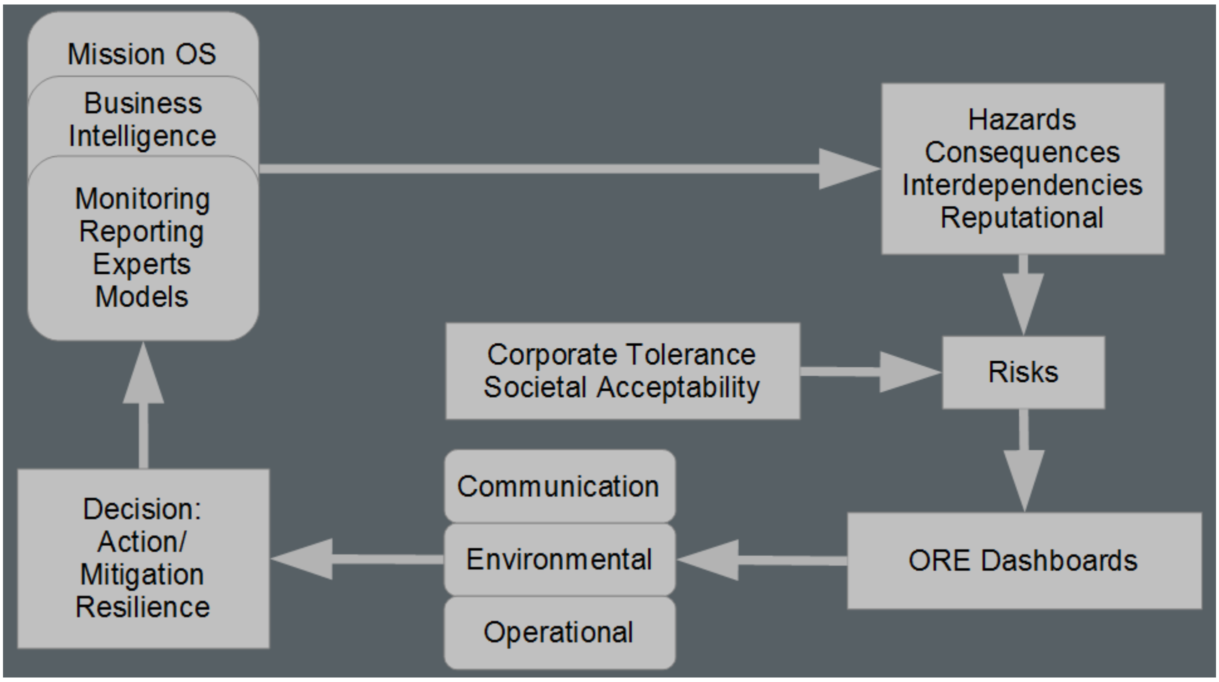

Fig. 2 Scheme of the ORE (Optimum Risk Estimates) continuous process. Scalable and drillable from cradle to grave for any project, alternative, operation. The top left box is where the link between MissionOS quantitative data and ORE takes place.

As an option ORE foresees the probabilistic alternatives' life-cycle economic evaluation of various phases of construction and service life with CDA/ESM (Comparative Decision Analysis/Economic Safety Margin ©Oboni Riskope Associates Inc.) (Oboni, Oboni, 2010).

5. How to use repeated quantitative updates within the ORE platform and Mission OS

Frequencies

In this section we will focus the attention on the discrete or continuous (dynamic) probabilistic updating of various types of data which may include, for example: deformation velocity (cm/year, for example), number of events of a certain magnitude (number of events exceeding a certain magnitude per year, for example), etc. The updating allows then to re-frame probabilities present in the ORE risk register and to dynamically re-evaluate the risks (discretely or continuously). As a reminder, the annual observed rate of occurrence R (frequency) of an event of magnitude M (could be a rockfall, a mud slide, a water surge) can be expressed (Crovelli, 2000, Ang, Tang, 1975) as:

$R=n_{i(M)}/N$

$n_{i(M)}$ number of observed events of magnitude >=M occurred historically.

N total number of observed events (of any magnitude) occurred historically.

For example: 15 rockfalls >=1m^3 have been observed over a total number of 100 rockfalls of any magnitude. R=15/100=0.15 The return period Tr of the event (average # of years between two events equally or exceeding magnitude M), provided the frequency is independent of time is:

Tr = 1/R

For example with R=0.15, T_r = 1/0.15= 6.67 years.

Bayesian analysis and updating

Using the Poisson distribution it is possible to link the number of occurrences of an event over a selected time t to the mean occurrence rate (frequency) (Frasca et Al, 2016). As the monitoring system and MissionOS deliver new occurrences of events, frequency and related probabilities can be updated, leading to updated risks yielded by ORE.

Bayesian analyses allow to update frequencies and probabilities as new data are generated (Ang, Tang, 1975, Straub, Grêt-Regamey, 2006). Consider for example the case where the available information is a set of observed n settlements points, which are described by their entity and the time during which they occurred. Note that the Bayesian update will be valid only insofar the observations are free of error and complete, reason why regular monitoring is a necessity.

In order to allow later Bayesian update ORE has to include the a priori estimate of frequencies or probabilities. If no data are available beyond a Min-Max range defined by models or expert opinions, the simplest and oldest rule to minimise errors is to assume a uniform distribution (Fig .3).

However, if sufficient data were available, ORE could also be set-up with a more refined “PRIOR” distribution and then use Bayes to obtain the first “POSTERIOR” distribution, followed by the second posterior etc. The application of Bayes shows that one single event provokes a shift of the distribution as shown in Fig. 4.

Exceedance Probabilities

The exceedance probability is the probability of an event being greater than or equal to a given value, i.e. to exceed, for example a given Magnitude M. It is important to forecast the future exceedance of previously observed extremes. Similar analysis to the previous one can be performed. Based on repeated monitoring campaigns and MissionOS gathered data it is possible to re frame the probabilities of exceedance and thus to rationally update the risk register.

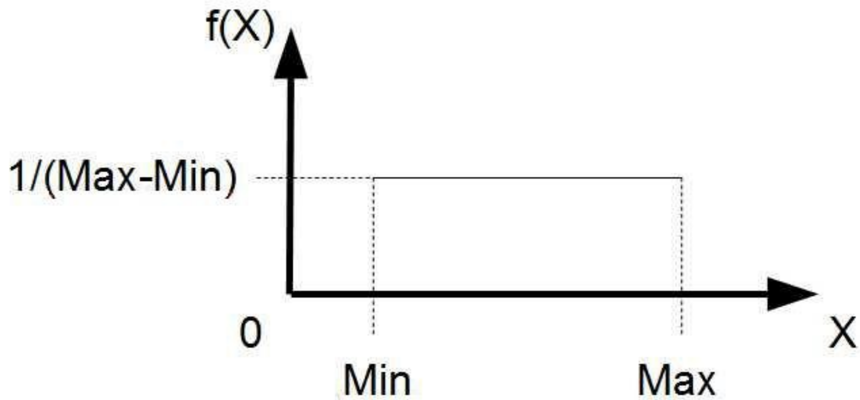

Fig 3. Uniform distribution f parameter x between its estimated extreme values Min, Max.

Fig 4. A priori and a posteriori distribution of a parameter x between its estimated extreme values 0.2, 1.

6. Joint capabilities

Obviously the link between MissionOS and ORE is synergetic, insofar it allows delivering on a regular basis updated risk assessments, as monitoring evolves, with an economy of means.

The Table below explains how the synergy may be created, step by step.

Table 1: Large dump instability (landslide) integrated monitoring and risk assessment analyses

Instrumentation type (Mission OS setup) Possible to upload extant data...	Inclinometers, extensometers, piezometers, flowmeters (on drainages, ditches), rain-gauges, meteorological stations, topographic points measured either discreetly or via telemetry.
Off-line preliminary studies (ORE with extant data)	Rain-velocity correlation/relationship Probability of failure of various modes base on extant variability Consequences of failure modes Risk analysis based on extant data Preliminary alert thresholds Emergency procedures
Data acquisition (Mission OS)	Comparison with extant variability Check of alert thresholds Emerging crises scanning Updates of data (variability): if necessary updated probabilities; new alert thresholds; updated emergency procedures.
Benefits of Mission OS + ORE	Always updated Emergent criticalities are spotted Acute crisis profiling Risk profile is updated Alert thresholds and emergency procedures updated as necessary.

NB: this would apply to an open pit wall, or a slide impinging on a critical mining infrastructure as well.

Table 2: Tailings Systems

Instrumentation type (Mission OS setup) Possible to upload extant data...	Piezometers, flowmeters (on drainages, ditches), rain-gauges/precipitations, weather parameters, topographic points (water level, dam crest), pumping, wells, discharge measured either discretely or via telemetry.
Off-line preliminary studies (ORE with extant data)	Probability of exceedance/failure of balance of various modes base on extant variability Consequences of failure modes Risk analysis based on extant data Preliminary alert thresholds Emergency procedures

Data acquisition (Mission OS)	Comparison with extant variability Check of alert thresholds Emerging crises scanning Updates of data (variability): if necessary updated probabilities; new alert thresholds; updated emergency procedures.
Benefits of Mission OS + ORE	Always updated Emergent criticalities are spotted Acute crisis profiling Risk profile is updated Alert thresholds and emergency procedures updated as necessary. Data availability 27/7 from anywhere on a need to know basis.

7. Large instability case history

In order to decide appropriate mitigations, a risk assessment of a large slow creeping landslide (10Mm3) impinging on linear facilities and infrastructure, was prepared.

At the time of the initial risk assessment monitoring with traditional techniques and devices was already being performed and those data (mostly topographic, inclinometers and piezometers readings) were used for the initial risk assessment. Piezometers, inclinometers, topographical targets and extensometers were indeed present (Fig. 5) and regularly measured at the site, some of the instruments being read at discrete intervals, some being read continuously via wireless data transmission.

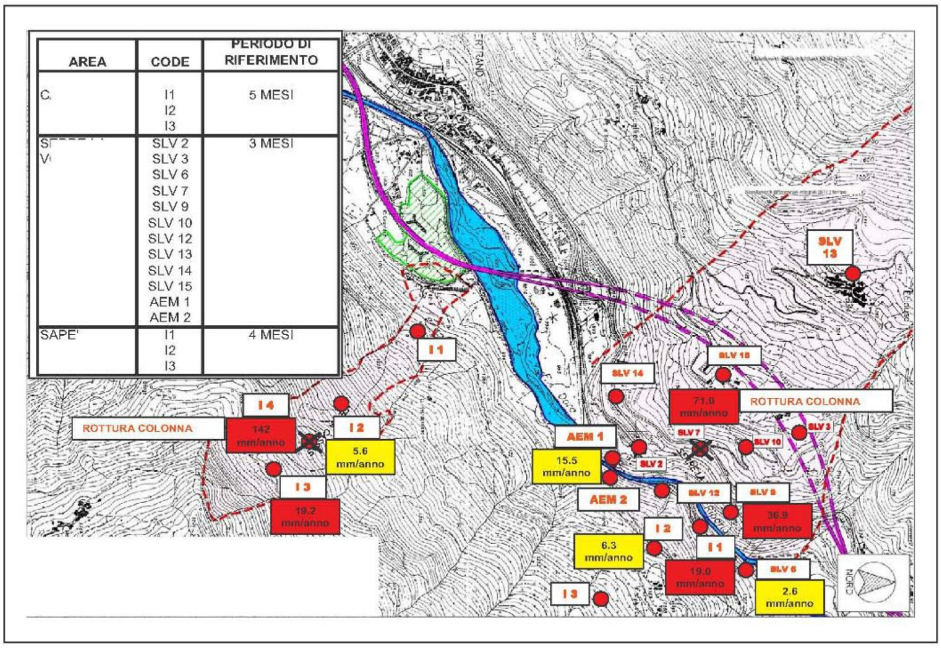

Fig 5. Geotechnical instruments present on the slope during the "static" phase, i.e. the preliminary risk assessment.

The risk assessment used the Oboni-Bourdeau (Oboni, Bourdeau, 1983, Oboni et Al. 1984, Oboni, Egger, 1985) probabilistic slope stability method, showed which failure modes were most critical in terms of probability of sudden accelerations (paroxysms) (Fig. 6) and consequences to the transportation corridor and the watercourse lying at the toe (Fig. 7).

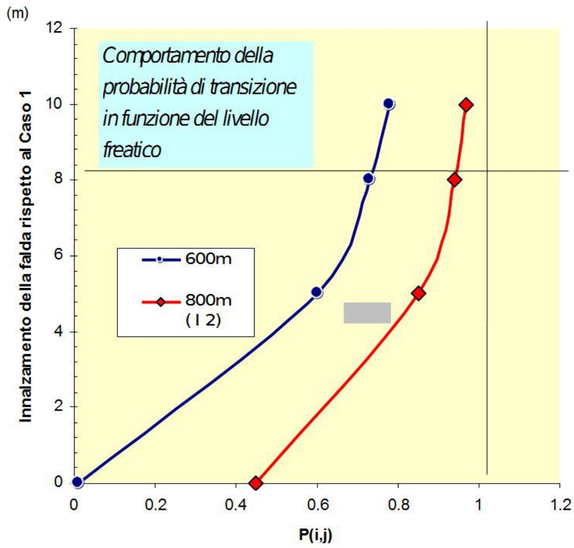

Fig 6. Graph displaying the asymptotic increase of the probability of catastrophic acceleration of the 10Mm3 mass as a function of the water table raise due to unfavourable meteorology cycle.

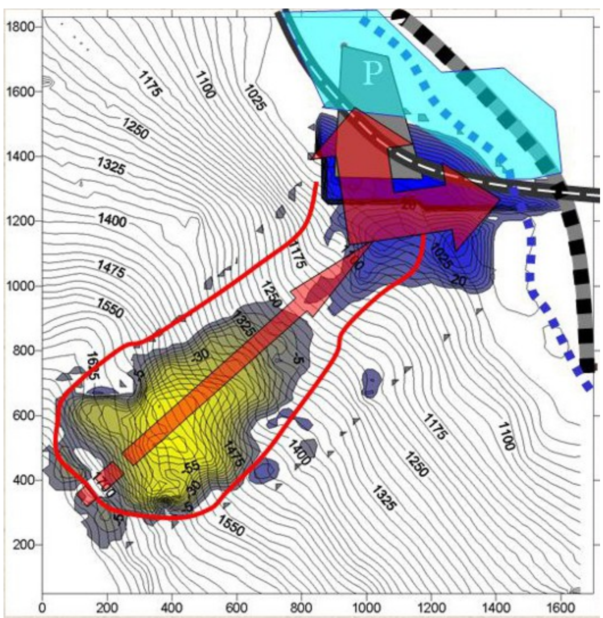

Fig 7. Catastrophic runout of the 10Mm^3 slow creeping landslide.

Failure modes varied from relatively shallow slides (less than 500,000m^3 in volume and less than 10m deep) possibly occurring on top of the massive historic slow-creeping mass (10Mm^3, up to 100m deep).

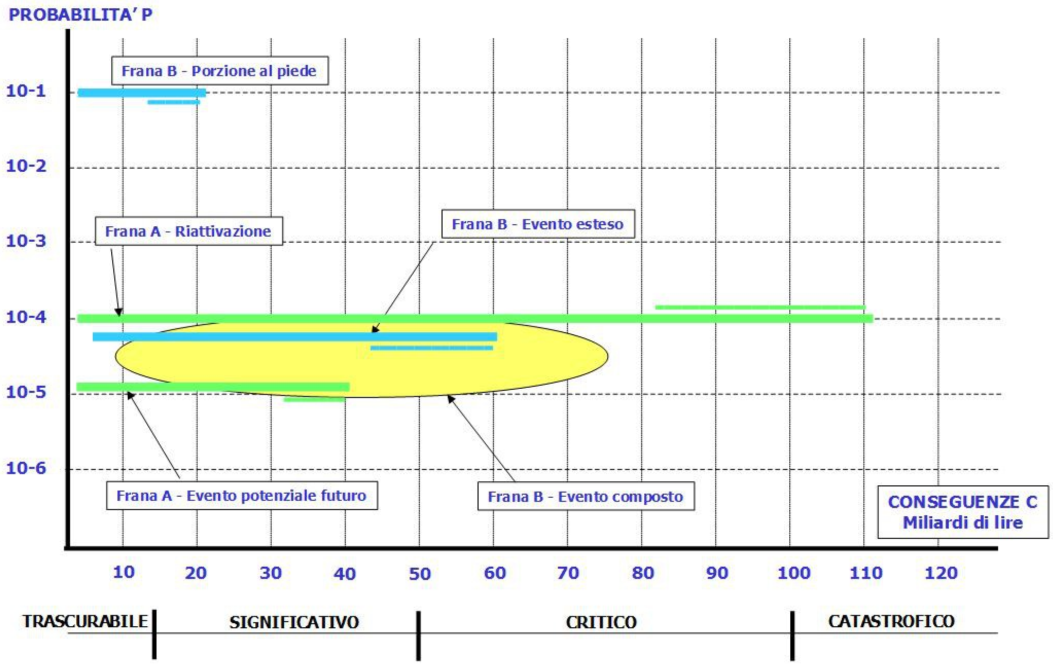

Fig 8. First round "static" risk assessment results.

Figure 8 displays the results of the first round "static" risk assessment for a series of scenarios involving various volumes of potentially unstable slope. The horizontal axis shows various levels of potential consequences which are only known with strong uncertainties (hence the long ranges of consequences for each scenario. One scenario in particular had a strong uncertainty on the annual probability of occurrence (vertical axis), thus depicted with the shaded ellipse.

MissionOS web based data system was then deployed to record data, manage AAA (Alarm, Alert, Action) notifications in case of reaching the alarm/ alert/ action predefined levels and managing notifications to the teams.

Due to numerous instrumental failures over time, winter conditions and other problems it became extremely valuable to enable the MissionOS system to manage satellite data (settlements) over surfaces that were not yet monitored (Fig. 9).

The idea was to pair the aerial photo base with the distribution of the vertical movements of a much wider area than those that can be covered with individual instruments. The Permanent Scatterers Synthetic Aperture Radar Interferometry (PSInSAR™) introduces a quality/quantity based element fostering a clearer understanding of the movements' field in a given area or slope otherwise impossible or too costly to monitor.

It became possible to prepare a sophisticated set of alert thresholds encompassing past precipitations (the mobile average precipitation at 300 days turned out to be the best indicator), deformation velocities field, as depicted in Table 3.

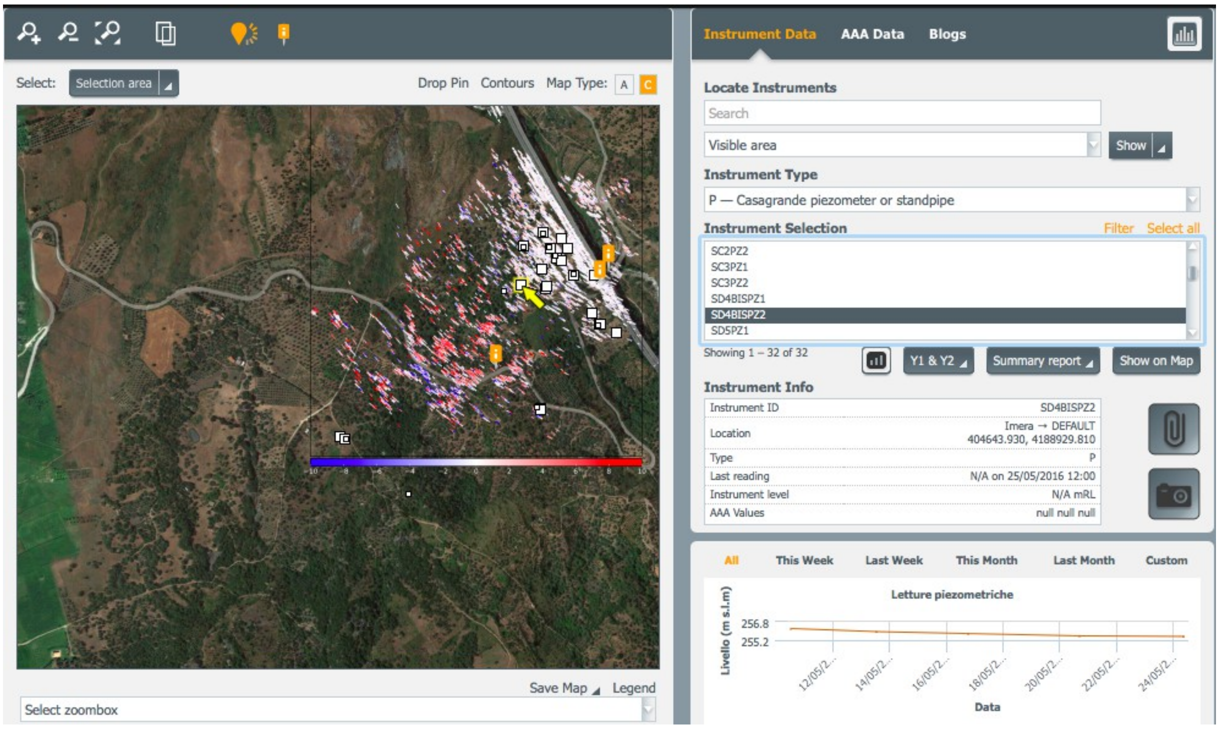

Fig. 9. PSInsar data plotted on the aerial map and the existing instruments. The distribution area is wider than the area covered by the instruments, allowing a deeper understanding of the phenomena and the possibility to further investigate areas not yet covered by instrumental measurements

Table 3: Tailings Systems

Velocity cm/d	Velocity m/yr	Measurements per month	Status	Level 3	Level 4
0.01	0.05		Normal		
0.03	0.1		Attention		
0.05	0.2	1	Pre-alert 1		
0.11	0.4	3	Pre-alert 1		
0.14	0.5	30	Pre-alert 2		
0.27	1	30	Pre-alert 2	Plan 1	Plan 2
0.82	3	30	Alert	Plan 1	Plan 2
1.37	5	30	Alert	Plan 2	Plan 3
1.92	7	30	Alert	Plan 2	Plan 3
2.74	10	30	Alert	Plan 3	Plan 3

By linking MissionOS and ORE, the probability of occurrence of the various failure modes, their consequences are automatically re-calculated and updated on a regular basis to help engineers calibrating yearly monitoring and mitigations expenses (thus performing rational risk based decision making) when time is of the essence and public, workers, infrastructure safety have to be ensured. As shown in Figure 10 MissionOS interface screen displaying aerial images and summary data constitute the basic gate.

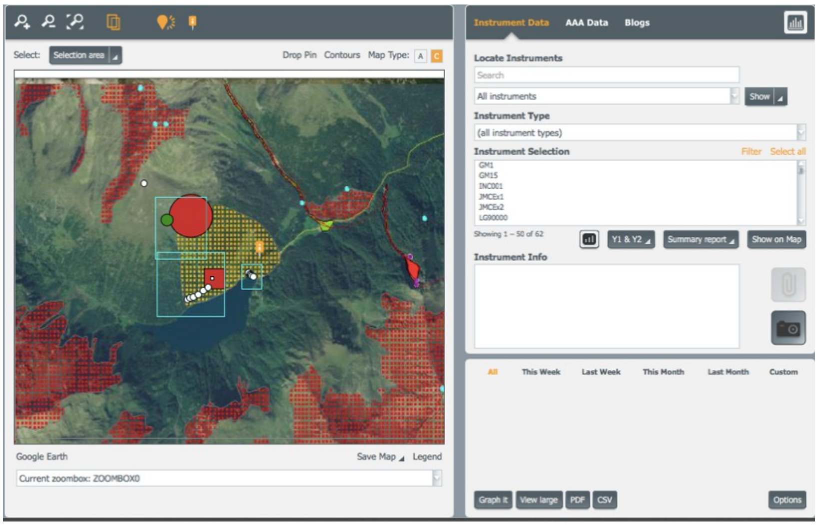

Fig 10. MissionOS interface screen: topographic map with phenomena and monitoring devices. On the right the data manager panel.

With MissionOS it is easy to show the instruments' graphs and elaborate contour maps for ground settlements, groundwater, etc. data used in the risk analysis (Fig. 11, 12).

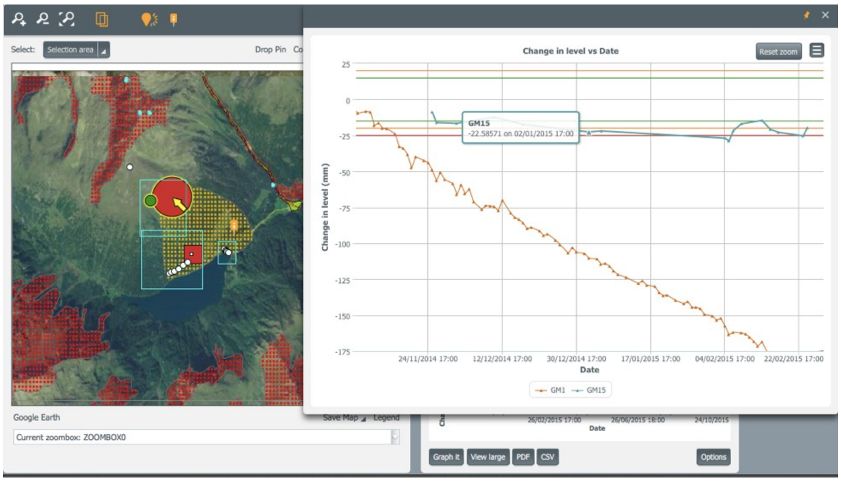

Fig 11. All MissionOS graphs are interactive to investigate single points and/or zoom in to see more details. When clicking the graph a yellow arrow shows immediately the pertinent instrument location. The graphs are related to the alert levels to swiftly show the relations between current reading and notification levels.

“Continuous” monitoring revealed that the slide responded as foreseen by the probabilistic analyses in case of a particular cycle of adverse meteorological events. All stakeholders were shown the evidence of the instrumental and probabilistic analyses together with expected landslide evolution. Thanks to clear risk communication and understanding they agreed on the appropriate level of mitigation in the form of a drainage tunnel, which gained strong “social” support.

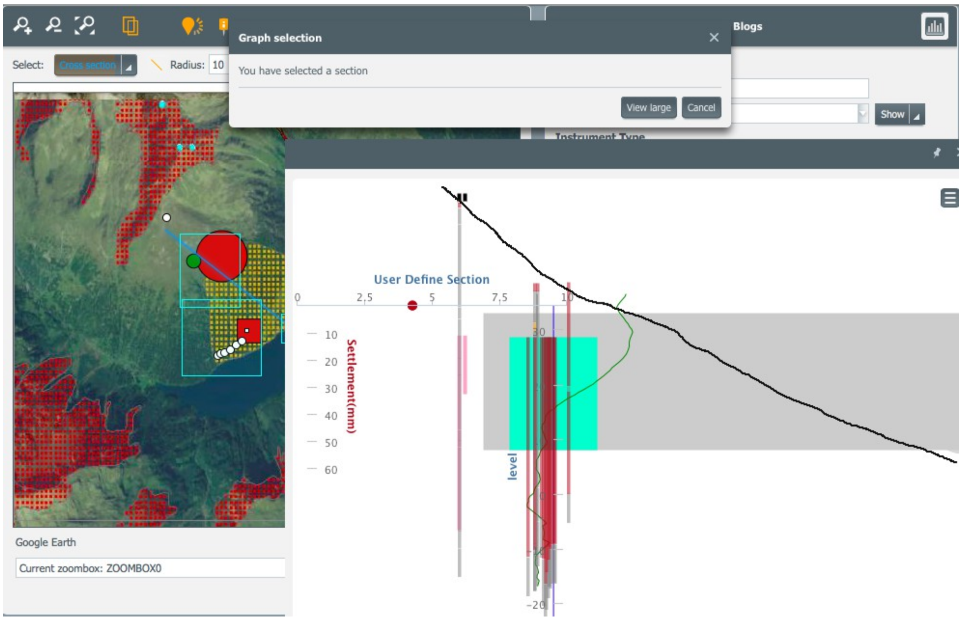

Fig 12. MissionOS powerful data cross sections tools. These data are vital for quantitative evaluation of the probability of failure or of acceleration of the unstable masses

MissionOS allowed to maintain an updated data base and, through the AAA notifications, a high level of awareness to all landslide, climatological (a station was built on site) and drainage tunnel parameters (drainage flows). The platform has been used to manage and monitor the mitigative project realisation and the stabilisation phase after the work completion allowing some optimisation and improvement on the data basis.

8. Tailings Systems

Tailings systems (for a single operations or for the entire portfolio of a mining company, within the frame of a Stewardship Program) are complex systems where a Business Intelligence platform should be used to integrate all data related to climatology, water balance, contaminants, phreatic levels, topographical movements, etc. Figure 13 depicts such a system in schematic way, Figs 14 and 15 display two examples of Mission OS information screens.

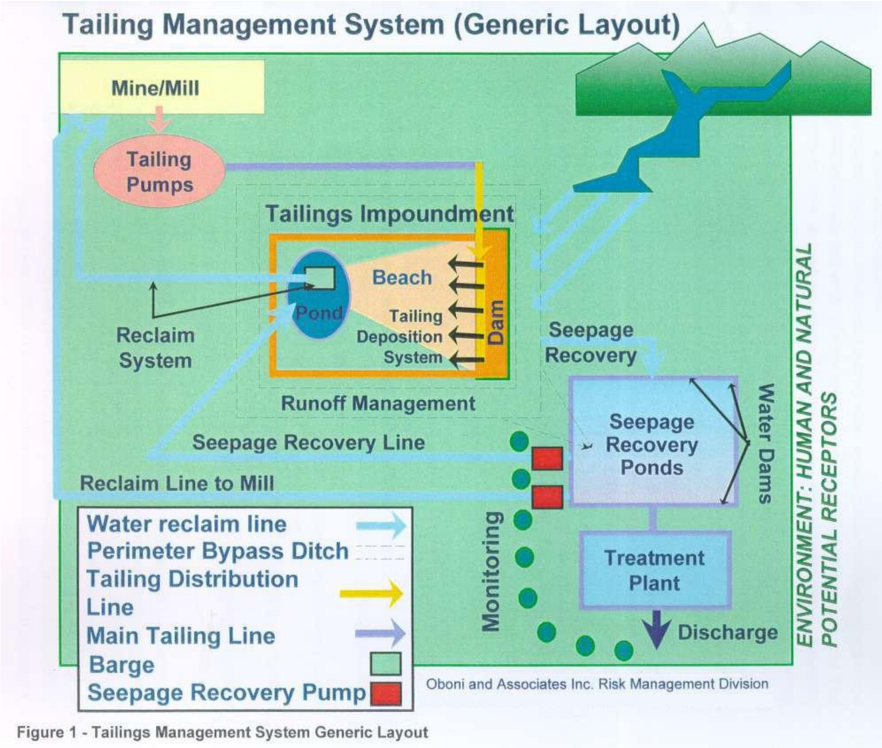

Fig 13. A schematic representation of a Tailings Management System at a mine operation.

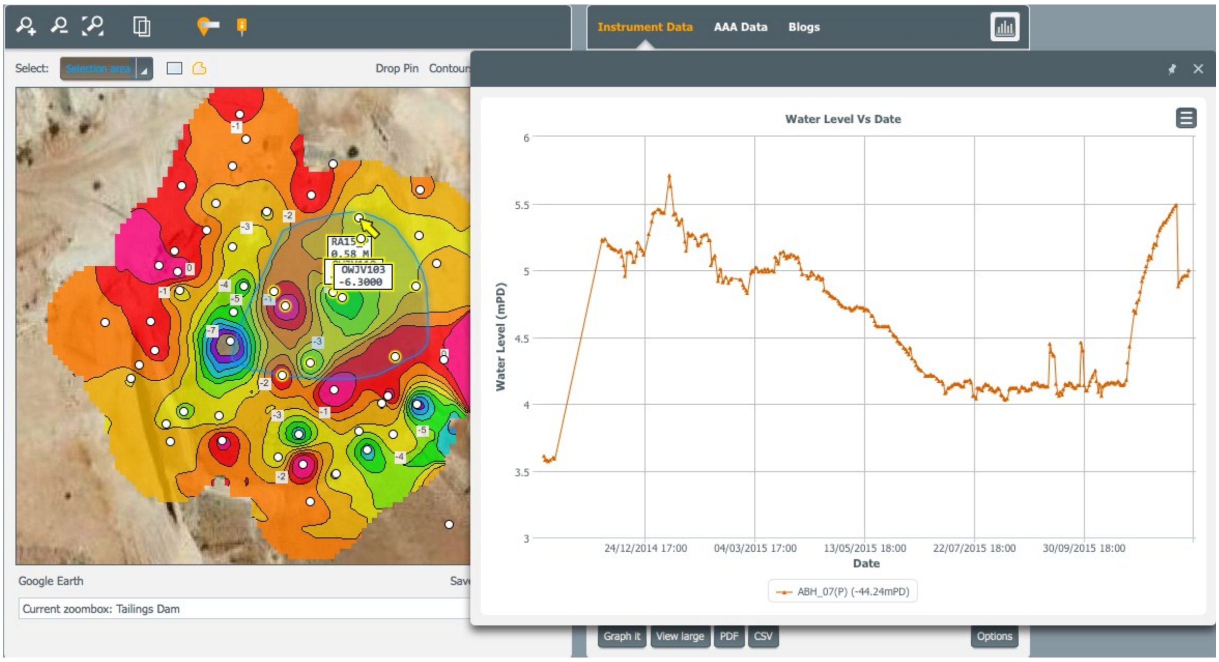

Fig 14. Monitoring a tailing dam . The graph displays the water level within the piezometer showed by the arrow

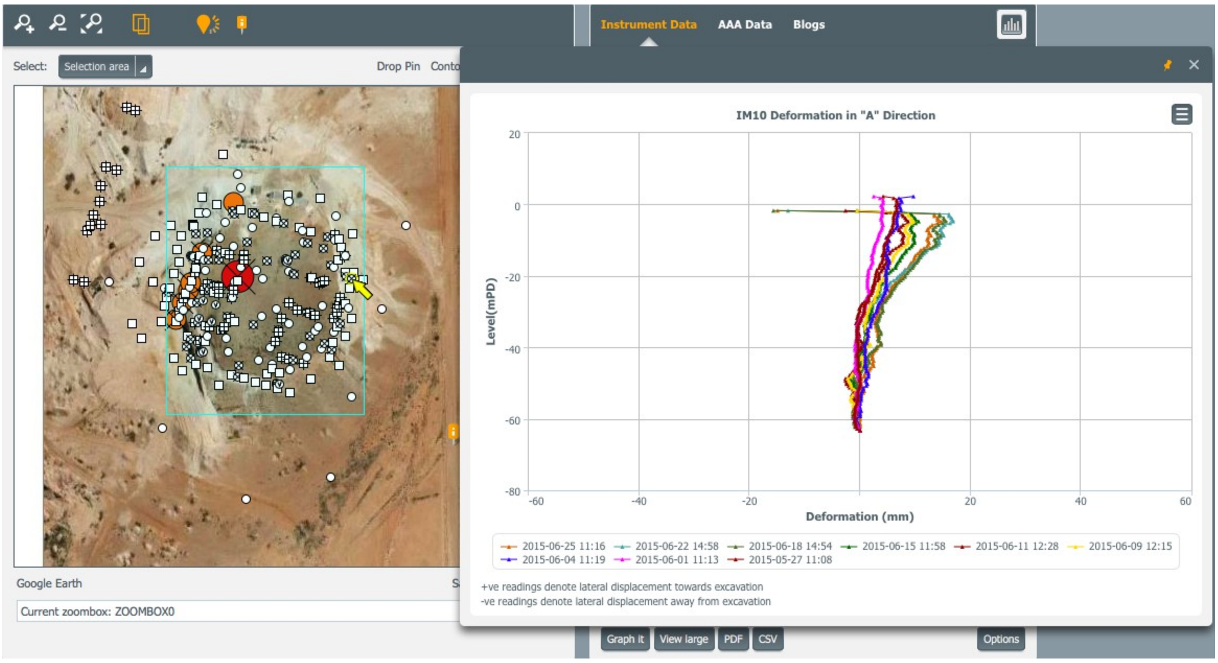

Fig 15. Inclinometers were installed on the tailing dam. The graph on the right shows the readings vs. time for the instrument showed by the yellow arrow

Of course, a tailings system can be made of several ponds, each one with more than one dam as depicted in Figure 16.

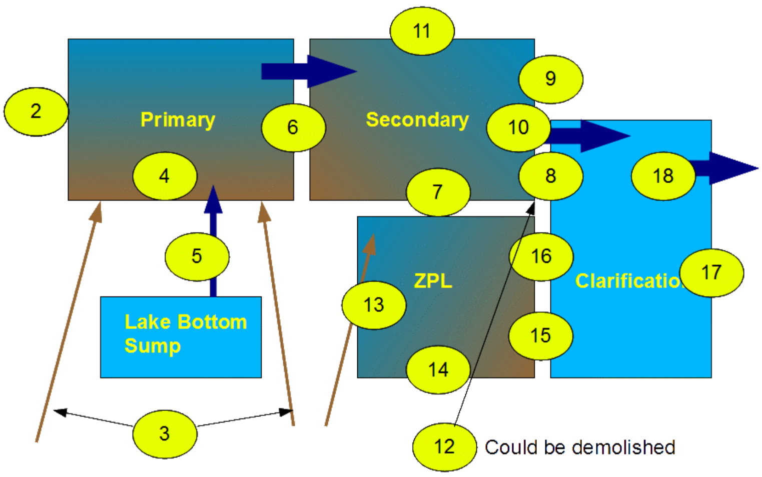

Fig 16. A water treatment pond system project with 18 macro elements including pipelines, dams, and weirs. Dams were split into subsections for the analysis. The cascading ponds suggest a high level of system's interdependency which will have to be accounted for in the risk assessment.

The risk assessment of such a system can be updated and discussed on a regular basis thanks to the "full circle" described in the introduction (Fig. 1, 2).

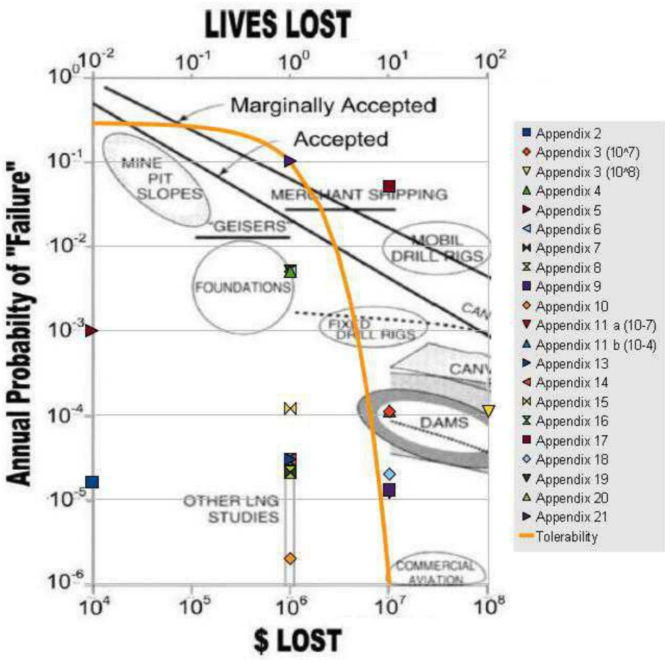

Fig. 17 Example of Tailings Management System graphic results.

Figure 17 displays the results for 21 macro-elements (dams sectors) named “Appendix 1-21” to preserve client's confidentiality, of a system similar to the one displayed in Figure 16. Historic social risk tolerance and corporate risk tolerance thresholds (Oboni, Oboni, 2007 Oboni, Oboni, 2014) are displayed. Risks below and to the left of the orange curve are within corporate tolerance. Risks below societal tolerance, but to the right of the orange curve would be societally tolerable, but corporately intolerable.

Scenarios above societal tolerability would lead to major societal disapproval.

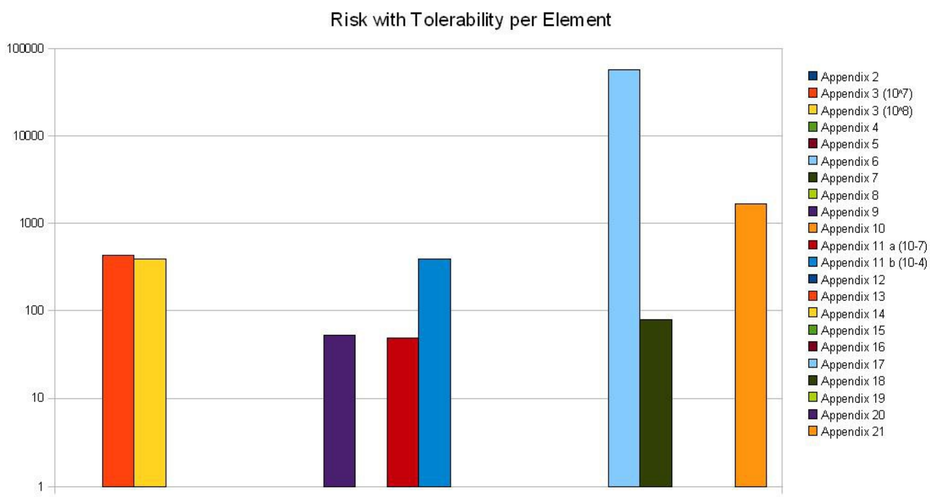

Fig 18. Intolerable risk per element of the 21 macro element system

Figure 18 shows another set of results for a system with 21 macro-elements. The 21 macro elements intolerable risks are shown in an unsorted way. Each coloured column corresponds to one element, the vertical axis shows the intolerable total risk in a monetary metric selected for that study.

Prioritizing using the intolerable portion of risks filters critical risks removing from the decision-making the zero-risk bias, which is the preference for reducing a small risk to zero over a greater reduction in a larger risks.

9. Conclusions

The link between MissionOS and ORE, or even better, the full circle encompassing quantitative imagery treatment either by sophisticated drones with adequate embarked sensors or PSInsar is of immense benefit for those in charge of one or more mining operations, a portfolio of Tailings Management systems.

Tailings Stewardship programs who by definition should create a repository of data, stimulate communication and generate lesson learned information are perfect candidates for a MissionOS-ORE deployment. At the end of the day there will be:

- Less personnel on the ground (also means less mistakes)
- Faster interpretation of instrumental and risk assessment results
- Immediate updates
- AAA notifications sent by email and/or SMS to the stakeholders
- Swift reporting to stakeholders
- Better decision making
- Scale economy.

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