| # | Primary Root-Cause | Controls |
|---|---|---|
| 1 | **Lack of burst-prone ground support** | a. Improve Cost effectiveness, efficiency |
| | | b. Excavation Design for potential installation of burst prone support |
| | | c. Understand lifecycle of excavation |
| | | d. Be proactive in your mining planning to accommodate future burst prone GS design |
| | | e. Anticipation process for installation of burst prone support |
| | | f. Improve installation equipment availability |
| | | g. Predetermine areas for burst prone support (pre-hab) |
| | | h. Operations acceptance of ground control recommendations for burst prone support |
| | | i. Incorporate burst prone support into the cycle (consider it single pass installation – not primary/secondary) |
| | | j. Prioritize secondary support. Link to mining plan schedule |
| | | k. Improve the ability to measure the residual capacity of the support |
| | | l. Equal importance to production bonus system for pre-hab and rehab |
| | | m. Quality control of surface support (need for continuous improvement) |
| | | n. Continuous improvement of the design of the composite burst prone support system |
| | | o. Better clarity on the specs of the various dynamic supports |
| | | p. Better understanding of the interaction between individual components of burst prone system (e.g. not always numerically driven) |
| 2 | **Lack of understanding of geology and stress conditions** | a. Optimize use of diamond drill information (analysis of borehole breakouts using Accoustic televiewer) |
| | | b. Increased use of cutting-edge technology, but due diligence required before use. Currently using mechanical engineering software (finite element software). |
| | | c. Need people at the mine site with the ability to use the technology |
| 3 | **Lack of management commitment to safety** | a. Define seismic risk management plan in corporate health and safety policy |
| | | b. Formal audits and reviews to ensure operational execution is aligned with corporate expectations |
| | | c. JHSC vigilance and participation |
| | | d. Effective IRS |
| 4 | **Ineffective risk management process** | a. Educate and involve all workplace parties in the power of risk assessment and management |
| | | b. Report near-miss data to incorporate into risk assessment analysis |
| | | c. Business analytics to feed into risk assessments |
| | | d. Better data and analysis to reduce subjectivity |
| | | e. Train people on risk assessment facilitation |
| | | f. Provide risk assessment guidelines |

| # | Primary Root-Cause | Controls |
|---|---|---|
| | | g. Better capability of HSAs to provide support on risk assessments |
| | | h. Tangible results on operations based on risk assessment (closing the loop on the risk management cycle) |
| | | i. Formalized risk assessment program to comply with sections 5.1, 5.2, 5.3 of the mining reg. |

| # | Primary Root-Cause | Controls |
|---|---|---|
| 5 | Improper mine plan | a. Pre-mine geomechanical/stability analysis |
| | | b. Deliberate effort to get strategic geotechnical information as early as possible |
| | | c. Flexibility in mine plan to accommodate changes in ore reserves |
| | | d. Capable planning personnel |
| | | e. Mindful of engineering fundamentals while meeting economic targets |
| 6 | Lack of understanding of seismic hazards | a. Educate on and keep workplace parties aware of seismic hazards |
| | | b. Ensure conversation at the face (muck-pile discussion) |
| | | c. Foster awareness of the triggers/causes of seismic hazards |
| | | d. Communicate any seismic concerns at crew lineup meetings and continue the discussion underground at the face |
| | | e. Basic level of training for supervisor on the seismic viewer |
| | | f. Formal ground control training and review |
| 7 | Dysfunctional IRS | a. Clear definition of IRS |
| | | b. Management commitment to IRS |
| | | c. Every supervisor having the same understanding of IRS |
| | | d. Implement improvement strategies based on IRS survey results |
| | | e. Continuous improvement of the system |
| | | f. KPIs on closure of workers' concerns |
| 8 | Installation of ground support by workers using handheld support | a. Proper blasting controls |
| | | b. Scaling before installing ground support |
| | | c. On-going scaling |
| | | d. Proper training for application (bolting off a muckpile vs platform: ground support type) |
| | | e. Consideration given to modified leading edge support (e.g. stiffer bolts or zero gauge screen straps) |
| | | f. Ensuring capability & capacity of the tools (e.g. sufficient air pressure for handheld tools, rebar pushers, drill bits) |
| | | g. Ensure proper housekeeping for retreat purposes |
| | | h. Adequate re-entry protocol & monitoring (for large blasts or seismic events) |
| | | i. Proper ground support selection & installation procedure (taking into consideration burst prone walls and face) |
| | | j. Proper ground support design (engineered) |
| | | k. Clear communication of ground support requirements for site specific conditions |
| | | l. Proper workplace inspections |
| | | a. Having processes to collect geotechnical information (geophysics: Acoustical Televiewer (ATV), Optical Televiewer (OTV), diamond drilling, mapping) |
| | | b. Better classification of structures/faults with regards to seismic risk |

| # | Primary Root-Cause | Controls |
|---|---|---|
| 9 | **Lack of understanding of structural geology** | c. Better use of pilot/reconnaissance holes |
| | | d. Having a robust design to capture uncertainties |
| | | e. Understanding local geology (utilizing diamond drill and previous cut mapping information) |
| | | f. Understanding of lithology, ore type and structure |
| | | g. Understanding of location and condition (ore contact, abutment, sill pillar, proximity to faults/structures) |
| | | h. Making good use of the data analysis |
| | | i. Better resources (structural geologists), skillsets to analyze the geotechnical information |
| | | j. Retraining program |
| 10 | **Lack of specialized resources (industry/consultants/regulators)** | a. Better collaboration with universities, colleges and industry towards providing programs that have better emphasis on geology and ground control |
| | | b. Setting up an environment for better collaboration between geology and mining programs |
| | | c. More organized, structured and formalized training program for new recruits |
| | | d. Refresher training |
| | | e. Define the desired requirements of a ground control engineer/specialist |
| | | f. Elevate the profile of a ground control engineer/specialist |
| | | g. Incentivize (E.g. Payscale) |
| | | h. Create opportunities for others who are interested to get into ground control |
| | | i. Regulation considerations for a ground control specialist (having a ground control specialist for every mine site) |
| | | j. Consult with HSA for the optimum qualification for a ground control specialist |
| 11 | **Deficiency/lack of microseismic equipment** | a. Micro-seismic monitoring needs based on risk assessment (Reg. 854: 5.1, 5.2, 5.3) |
| | | b. Define best practices for micro-seismic monitoring (E.g. through workshops) |
| | | c. Define best practices for data analysis |
| | | d. Proper maintenance & upgrading/coverage of the seismic/sensor array |
| | | e. Elevating the importance of maintaining the micro-seismic system in the mines |
| | | f. Dedicated resources for maintenance of sensors |
| | | g. Ensure training on operating the system |
| | | h. Elevate importance of the ground control program |
| 12 | **Lack of isolation process** | a. Define and disseminate best practices for re-entry protocols |
| | | b. Assessing the technical risk/criteria for setting application priorities for re-entry protocols |
| | | c. Perform continuous review of the re-entry protocol (back-analysis of applications of re-entry protocols) |
| | | d. Develop better business case for remote equipment based on risk |
| | | e. Improve benchmarking of response to similar risks with other jurisdictions |

| # | Primary Root-Cause | Controls |
|---|---|---|
| | | f. Collaborate with suppliers towards optimizing existing remote equipment (i.e. remote bolters and loaders). |
| | | g. Take advantage of the latest 3D scanning |
| 13 | **Inadequate geotechnical data information** | a. Having processes to collect geotechnical information (geophysics: Acoustical Televiewer (ATV), Optical Televiewer (OTV), diamond drilling, mapping) |
| | | b. Better classification of structures/faults with regards to seismic risk |
| | | c. Better use of pilot/reconnaissance holes |
| | | d. Having a robust design to capture uncertainties |
| | | e. Understanding local geology (utilizing diamond drill and previous cut mapping information) |
| | | f. Understanding of lithology, ore type and structure |
| | | g. Understanding of location and condition (ore contact, abutment, sill pillar, proximity to faults/structures) |
| | | h. Making good use of the data analysis |
| | | i. Better resources (structural geologists), skillsets to analyze the geotechnical information |
| | | j. Retraining program |
| | | k. Define best practices for collecting geotechnical data |
| | | l. Review and update what is relevant |
| | | m. Better coordination of operation priorities and engineering/geology data collection needs |
| | | n. Take advantage of the latest 3D scanning |
| | | o. Timely collection and interpretation of the data |
| | | p. Better communication between workplace parties (operations, geology, engineering, planning) |
| 14 | **Ineffective ground control communication system** | a. Compliance with Section 65 |
| | | b. Regular updates to crews |
| | | c. Discussion on ground control during new employee orientation |
| | | d. Ensure that supervisor & worker common core training is supplemented with local ground control considerations |
| | | e. Ensure that the site specific training requirements adequately reflect the intention of the common core |
| | | f. Customize communication to fit worker needs (i.e. trades people vs mine operators) |
| | | g. Having processes in place to cover cross-shift communication |
| | | a. Having processes to collect geotechnical information (geophysics: Acoustical Televiewer (ATV), Optical Televiewer (OTV), diamond drilling, mapping) |
| | | b. Better classification of structures/faults with regards to seismic risk |
| | | c. Better use of pilot/reconnaissance holes |
| | | d. Having a robust design to capture uncertainties |
| | | e. Understanding local geology (utilizing diamond drill and previous cut mapping information) |

| # | Primary Root-Cause | Controls |
|---|---|---|
| 15 | **Lack of identification of problematic geologic structure** | f. Understanding of lithology, ore type and structure |
| | | g. Understanding of location and condition (ore contact, abutment, sill pillar, proximity to faults/structures) |
| | | h. Making good use of the data analysis |
| | | i. Better resources (structural geologists), skillsets to analyze the geotechnical information |
| | | j. Retraining program |
| | | k. Define best practices for collecting geotechnical data |
| | | l. Review and update what is relevant |
| | | m. Better coordination of operation priorities and engineering/geology data collection needs |
| | | n. Take advantage of the latest 3D scanning |
| | | o. Timely collection and interpretation of the data |
| | | p. Better communication between workplace parties (operations, geology, engineering, planning) |
| | | q. Continue monitor rock mass (including seismic and displacement monitoring) as mine extraction progresses and sequencing changes |
| 16 | **Lack of reporting of near-miss events** | a. Clearly define what a “near miss” is |
| | | b. Establish a culture where “near miss” is not swept under the rug |
| | | c. Less finger-pointing and more of a learning issue (blameless) |
| | | d. Train supervisors & workers on the importance of reporting near miss incidents |
| | | e. Better communication between cross-shifts (allow for some overlap time to make sure that happens) |
| 17 | **Loss of capacity of ground support over time** | a. Compliance with Section 73 (quality control) |
| | | b. Regular risk assessment of ground support to assess integrity over time (E.g. expected life, changing ground conditions, residual capacity, re-conditioning needs, blasting, corrosion) |
| | | c. More research in measuring/evaluating residual capacity |
| | | d. Opportunity to evaluate dynamic 3D scanning technology |
| 18 | **Ineffective on-boarding for employees** | a. Compliance with Section 65 |
| | | b. Elevate the importance of the ground control program |
| | | c. Clear communication of seismic risk and risk mitigation measures |
| | | d. Regular updates to crews |
| | | e. Discussion on ground control during new employee orientation |
| | | f. Ensure that supervisor & worker common core training is supplemented with local ground control considerations |
| | | g. Ensure that the site specific training requirements adequately reflect the intention of the common core |
| | | h. Customize communication to fit worker needs (i.e. trades people vs mine operators) |
| | | i. Having processes in place to cover cross-shift communication |

| # | Primary Root-Cause | Controls |
|---|---|---|
| 19 | **Mechanized equipment for ground support installation not versatile enough to accommodate variety of ground support in burst prone areas** | a. Encourage development of new equipment for small openings (better collaboration with suppliers) |
| | | b. Encourage innovation in mining methods (e.g. boring methods, tunnel boring methods (tbms)) |
| | | c. Encourage innovation in shaft sinking methods (station excavation) |
| | | d. Refine existing technology for remote installation (E.g. type of bolt) |
| | | e. Ensure compatibility of ground support for automated installation methods |
| | | f. Adapt composite ground support systems (E.g. post groutable bolts) to automated installation methods |
| | | g. Engage in benchmarking to identify best practices for automating ground support installation |
| 20 | **Improper back analysis of past rockbursts** | a. Better records for rockbursts |
| | | b. Adopt risk analysis practices for back analysis (E.g. Root-cause analysis: understand cause and effect) |
| | | c. Better analysis of data collected under Section 72 for rockbursts |
| | | d. Allocate sufficient time and resources for back analysis |
| 21 | **Lack of understanding of material properties and seismic response** | a. Recognize variation of rock strength properties within lithological units |
| | | b. Identify location of contacts between rock types |
| | | c. Classify faults (in terms of gouge content, frictional properties, geometry) |
| | | d. Make better use of geophysical findings (to define the state of failure) |
| | | e. Understand the rock mass response to mining (rather than just the unit rock strength): Seismic monitoring, time-lapse monitoring, observation borehole |
| | | f. Complete the design loop (E.g. continuous calibration of numerical models) |
| 22 | **Insufficient micro-seismic monitoring capability** | a. Micro-seismic monitoring needs based on risk assessment (Reg. 854: 5.1, 5.2, 5.3) |
| | | b. Define best practices for micro-seismic monitoring (E.g. through workshops) |
| | | c. Define best practices for data analysis (E.g. including wave form analysis) |
| | | d. Define best practices for array design |
| | | e. Proper maintenance & upgrading/coverage of the seismic/sensor array |
| | | f. Elevating the importance of maintaining the micro-seismic system in the mines |
| | | g. Dedicated resources for maintenance of sensors |
| | | h. Dedicated resources for managing the system and daily data processing |
| | | i. Succession plan for the management of the system |
| | | j. Ensure training on operating the system |
| | | k. Elevate importance of the ground control program |
| | | l. Better utilize existing diamond drill holes for the purpose of putting in micro-seismic sensors/geophones |
| | | m. Ongoing expansion of arrays to ensure coverage of mining areas |
| | | a. Exercise deliberate measures to ensure reconciliation between initial projections and actual ground response |

| # | Primary Root-Cause | Controls |
|---|---|---|
| 23 | **Lack of closure of design loop** | b. React appropriately (revise and adjust) according to findings from your reconciliation |
| | | c. Well documented design package histories and procedures in place |
| | | d. Ensure proper document retention |
| | | e. Ensure proper capture in mine design package of external work (E.g. with consultants) |
| | | f. To foster continuity through standardization and succession planning |
| | | g. Apply lessons learned to future mining |
| 24 | **Lack of proper analysis of seismic monitoring data** | a. Micro-seismic monitoring needs based on risk assessment (Reg. 854: 5.1, 5.2, 5.3) |
| | | b. Define best practices for micro-seismic monitoring (E.g. through workshops) |
| | | c. Define best practices for data analysis (E.g. including wave form analysis) |
| | | d. Define best practices for array design |
| | | e. Proper maintenance & upgrading/coverage of the seismic/sensor array |
| | | f. Elevating the importance of maintaining the micro-seismic system in the mines |
| | | g. Dedicated resources for maintenance of sensors |
| | | h. Dedicated resources for managing the system and daily data analysis |
| | | i. Succession plan for the management of the system and analysis of the data |
| | | j. Ensure training on operating the system |
| | | k. Elevate importance of the ground control program |
| | | l. Better utilize existing diamond drill holes for the purpose of putting in micro-seismic sensors/geophones |
| | | m. Ongoing expansion of arrays to ensure coverage of mining areas |
| | | n. Better mining sector support for seismic data analysis (source parameter & mechanism) |
| 25 | **Lack of buy-in from workers on rules and procedures** | a. Ensure buy-in at all levels of the organization |
| | | b. Rely on evidence where burst prone support has been successful or unsuccessful |
| | | c. Training and "sell" the importance of the need |
| | | d. Sharing information/best practices/experiences/case studies between mining operations & sites |
| | | e. Better awareness of the mine plan (or updated plan) showing burst prone areas. |
| | | f. Follow/review geo-mechanical studies of mining plan for a specific area prior to execution |
| | | g. Involve the workers in developing the procedures |
| | | h. Clear communication of the importance of rules & procedures |
| | | a. Compliance with Section 65 |
| | | b. Ensure buy-in at all levels of the organization |
| | | c. A process for educating the workforce on what the procedures are |

| # | Primary Root-Cause | Controls |
|---|---|---|
| 26 | **Lack of compliance with site procedures for seismic hazards** | d. Regular review of seismic hazards and site procedures (to be addressed under Reg. 854: 5.1) |
| | | e. Identify those workplaces that have elevated seismic hazards and have a formal review of the procedures before working in those workplaces |
| | | f. Debriefing of incidents where procedure were not followed and to identify what the consequences were of not following those procedures |
| | | g. Demonstrate the value of these procedures through tangible examples (E.g. distressing, face bolting) |
| | | h. Provide clear explanations in situations where procedures may have to be modified because they may introduce new hazards (E.g. De-stress hole in a footwall shoulder in a narrow vein cut and fill) |
| | | i. Audit for compliance to the procedures |
| | | j. Amend Section 65 to require that the communication plan be updated annually |
| | | k. Review these procedures during orientation for new employees and regular updates of these procedures |
| | | l. Integrate these procedures into the training program |
| 27 | **Ground control role undervalued based on level of risk** | a. Regulation considerations for a ground control specialist (having a ground control specialist for every mine site) |
| | | b. Management to be more proactive commensurate to assessed ground control risk |
| | | c. Reiterate that ground instability is deemed to be the highest risk in underground mining |
| | | d. Education on ground control (and the associated risks) is critical for senior management |
| | | e. Budgetary allocations for ground control requirements should reflect the importance of ground control risks |
| | | f. Section 6 should have a risk assessment component |
| | | g. Better awareness and enforcement of Section 6 |
| | | h. HSA technical advisory committee (TAC) should define best practices for ground control function and resources required (including people, tools, etc.) |
| | | i. Elevate the profile of a ground control engineer/specialist |
| | | j. Recognition that dealing with basic ground control hazards is part of all underground workers responsibility |
| | | k. Create opportunities for others who are interested to get into ground control |
| | | l. Consult with HSA for the optimum qualification for a ground control specialist |
| 28 | **Loss of institutional knowledge** | a. Proper documentation of seismic hazards (saved as long as mine is in operation) |
| | | b. Updating Section 72 to say that records should be kept at long as mine is in operation |
| | | c. Succession planning and job shadowing |
| | | d. Exit strategy to allow for transfer of knowledge for departing employees |
| | | e. Establish site specific standards on documentation and data collection of underground observation |
| | | f. Clear definition of data organization structure, and the relevance of the data being collected |
| | | g. Improve mentoring to new/junior employees |
| | | h. Meet demand through new technology (e.g. ipad) |
| | | i. To foster continuity through standardization |

| # | Primary Root-Cause | Controls |
|---|---|---|
| | | j. Provide guidelines for documentation (Here is how to do it!) |
| 29 | **Loss of accuracy over time/geometry change (with respect to seismic monitoring)** | a. Keeping seismic arrays up-to-date |
| | | b. Encourage suppliers of the systems to work on 3D velocity models |
| | | c. Better funding for R&D of advanced systems/analysis (aligning decision with highest sector risk) |
| | | d. Daily in-house processing & training to check for accuracy |
| | | e. Planning to adapt micro-seismic monitoring systems to accommodate upcoming changes in mining methods |
| | | f. Better utilize existing diamond drill holes for the purpose of putting in micro-seismic sensors/geophones |
| | | g. Ongoing expansion of arrays to ensure coverage of mining areas |
| | | h. Dedicated resources for data processing and system maintenance |
| 30 | **Workers not adequately solicited on knowledge of seismic hazards** | a. Compliance with Section 64 & 65 |
| | | b. Provide timely feedback loop on workers' concerns regarding seismicity (E.g. formal crew discussions on site specific hazards) |
| | | c. Check for communication gaps at all interfaces (E.g. worker-supervision, supervision-engineering) |
| | | d. On-going review and updating the communication plan |
| | | e. A process for educating the workforce on what the procedures are |
| | | f. Regular review of seismic hazards and site procedures (to be addressed under Reg. 854: 5.1) |
| | | g. Identify those workplaces that have elevated seismic hazards and have a formal review of the procedures before working in those workplaces |
| | | h. Debriefing of incidents where procedure were not followed and to identify what the consequences were of not following those procedures |
| | | i. Demonstrate the value of these procedures through tangible examples (E.g. distressing, face bolting) |
| | | j. Provide clear explanations in situations where procedures may have to be modified because they may introduce new hazards (E.g. De-stress hole in a footwall shoulder in a narrow vein cut and fill) |
| | | k. Audit for compliance to the procedures |
| | | l. Amend Section 65 to require that the communication plan be updated annually |
| | | m. Review these procedures during orientation for new employees and regular updates of these procedures |
| | | n. Integrate these procedures into the training program |
| 31 | **Variability in risk tolerance** | a. Move towards better analytics for more objective decision making (reduce subjectivity of decision making) |
| | | b. Education (to include management) and constant feedback to lower variability |
| | | c. Compliance with Reg 854: 5.1, 5.2, 5.3 |
| | | d. Reducing the risk by engineering controls (E.g. remote loading of a development round, Alimak vs. Raise Bore) |
| | | e. Segregate economic risk vs health & safety risk (worker and manager of the mine) |
| | | a. Proper documentation of seismic hazards (saved as long as mine is in operation) |
| | | b. Succession planning and job shadowing |

| # | Primary Root-Cause | Controls |
|---|---|---|
| 32 | **Changing skill sets with new management** | c. Exit strategy to allow for transfer of knowledge for departing employees |
| | | d. Establish site specific standards on documentation and data collection of underground observation |
| | | e. Clear definition of data organization structure, and the relevance of the data being collected |
| | | f. To foster continuity through standardization. |
| | | g. Provide guidelines for documentation (Here is how to do it!) |
| | | h. Well documented histories and procedures in place |
| | | i. Encourage seamless transition through job/task overlap |
| | | j. JHSC involvement to enable management to execute on their commitment |
| | | k. Role description & expectations for a manager is up-to-date |
| | | l. Managers must have underground ground control common core and joint health & safety certification |
| | | m. Improve visualization and integration of the data sets from different models (2D and 3D) |
| | [illegible] | a. Encourage suppliers of the systems to work on 3D velocity models |
| | | b. Better funding for R&D of advanced systems/analysis (aligning decision with highest sector risk) |
| | | c. Push for better business case (compelling argument to health & safety) to the industry given the fact that this is the #1 risk |
| | | d. Planning to adapt micro-seismic monitoring systems to accommodate upcoming changes in mining methods |

| # | Primary Root-Cause | Controls |
|---|---|---|
| 33 | **Gaps in micro-seismic monitoring technology development** | e. Better utilize existing diamond drill holes for the purpose of putting in micro-seismic sensors/geophones |
| | | f. Ongoing expansion of arrays to ensure coverage of mining areas |
| | | g. Dedicated resources for data processing and system maintenance |
| | | h. Better communication and collaboration between different parties (suppliers, seismologists, and operations) |
| | | i. Better use of micro-seismic data towards defining gaps in technology development |
| | | j. MLRC should engage with Mirarco, CEMI, Norcat, etc. |
| 34 | **Lack of innovation** | a. Expedite remote loader technology for development blasting |
| | | b. Better funding for R&D of advanced systems/analysis (aligning decision with highest sector risk) |
| | | c. Push for better business case (compelling argument to health & safety) to the industry given the fact that this is the #1 risk |
| | | d. Encourage development of new equipment for small openings (better collaboration with suppliers) |
| | | e. Encourage innovation in mining methods (e.g. boring methods, tunnel boring methods (tbms)) |
| | | f. Encourage innovation in shaft sinking methods (station excavation) |
| | | g. Encourage companies that apply narrow vein techniques to explore innovation |
| 35 | **Lack of mine operator acceptance of technology for mitigating seismic risk** | a. Ensure buy-in at all levels of the organization |
| | | b. Rely on evidence where technology has been successful or unsuccessful |
| | | c. Training and “sell” the importance of the need |
| | | d. Sharing information/best practices/experiences/case studies between mining operations & sites |
| | | e. Involve the workers in developing the procedures for new technology |
| | | f. Clear communication of the importance of mitigating the seismic risk |
| | | g. Regular review of seismic hazards and site procedures (to be addressed under Reg. 854: 5.1) |
| | | h. Identify those workplaces that have elevated seismic hazards and have a formal review of the procedures before working in those workplaces |
| | | i. Debriefing of incidents where procedure were not followed and to identify what the consequences were of not following those procedures |
| | | j. Demonstrate the value of technology through tangible examples (E.g. distressing, face bolting, support for dynamic loading) |
| | | k. Provide clear explanations in situations where technology may have to be modified because they may introduce new hazards (E.g. De-stress hole in a footwall shoulder in a narrow vein cut and fill) |
| 36 | **Inadequate ground deformation monitoring** | a. Include ground deformation monitoring in the mine design plan (budget for it) |
| | | b. Validate numerical modelling results through deformation monitoring |
| | | c. Make monitoring equipment more operationally friendly (automation) |
| | | d. Use 3D scan technology |
| | | e. Close the design loop |

| # | Primary Root-Cause | Controls |
|---|---|---|
| | | f. External third party review of the monitoring system<br>g. Use ground deformation monitoring in conjunction with seismic monitoring<br>h. Identifying areas proactively as to where ground deformation monitoring is required |

| # | Primary Root-Cause | Controls |
|---|---|---|
| 37 | **Foreign ownership (may be out of province) different to local culture** | a. Education for the owners on local culture |
| | | b. Proper documentation of seismic hazards (saved as long as mine is in operation) |
| | | c. Establish site specific standards on documentation and data collection of underground observation |
| | | d. Clear definition of data organization structure, and the relevance of the data being collected |
| | | e. To foster continuity through standardization |
| | | f. Provide guidelines for documentation (Here is how to do it!) |
| | | g. Well documented histories and procedures in place |
| | | h. JHSC involvement to enable management to execute on their commitment |
| | | i. Role description & expectations for a manager is up-to-date |
| | | j. Managers must have underground ground control common core and joint health & safety certification |
| 38 | **Boom or bust cycle in the mining sector** | a. Bust: Retain technical resources to be able to address high risk hazards |
| | | b. Boom: Make sure that new employees are properly trained and appraised of the seismic risks |
| 39 | **Lack of reporting due to resulting (extra) work** | a. Streamline/simplify reporting processes |
| | | b. Highlight/educate the importance of reporting |
| | | c. Close the loop/communicating back (reporting, investigations, recommendations) with timelines |
| | | d. Ensure proper training for reporting seismic events/hazards |
| | | e. Put systems/processes in place to enable reporting |
| | | f. Supervisors must be trained in how to respond to reporting |
| 40 | **Poor management of re-conditioning requirements** | a. Risk-based prioritization with timelines |
| | | b. Involve the JHSC in the risk-based prioritization process |
| | | c. Tie-in reconditioning to production schedule |