Prevention

Root-Cause Analysis Report

MINING: WATER MANAGEMENT

November 2019

Ontario

Table of Contents

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Root-Cause Analysis Workshop: Summary

- The Water Management Root-Cause analysis took place on April 16th, April 17th and June 7th
- The analysis rendered over 300 solutions/controls (or activities that may support development of a control) that could be relied upon to mitigate the risk in question
- A validation meeting took place on September 4th to review and endorse the findings from the analysis

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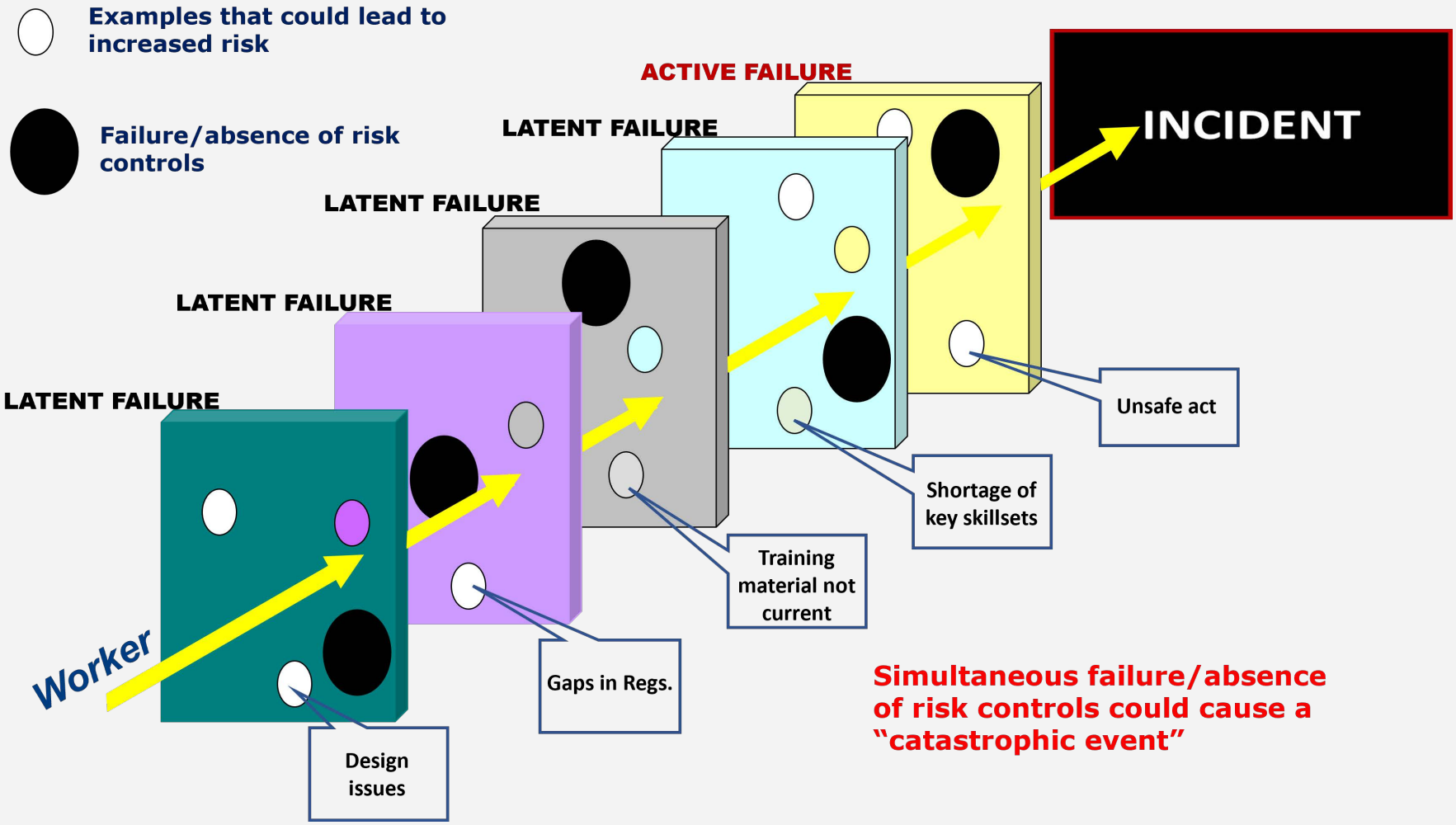
Risk Assessment Project: The Subject Of Inquiry



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Revisiting 2014 Risk Assessment Results: Top 10 Risk Categories

#	Category	Situation or Condition or Factor that could result in Injury or Illness OR What could keep you up at night?
1	Ground control	Rock bursts underground
2	Mobile Equipment	Large vehicle and pedestrian or small vehicle interaction is common and lethal
3	Occupational Disease	Exposure to hazardous substances(dusts, materials, metals), gases/ fumes, biological materials or forms, physical Hazards (vibration, noise, heat/cold stress, light.)
4	Fatigue	Working Shiftwork resulting in disrupted sleeping patterns
5	Training	Supervisors in some mines in Ontario lack the proper experience and Training. Inexperienced and improperly trained supervisors pose a threat to themselves and their direct-report workers.
6	Ventilation	Little in the way of controls on diesel equipment operating in certain areas. No way for workers to know how much equipment is working in any given area. Diesel emissions now a recognized cause of cancer
7	Lockout/ Guarding	Failure to isolate energy as a result of inappropriate lockout/tagging
8	Mine Services	Working from a scoop-tramp bucket (i.e.. For fan installation and the provision of other services)
9	Water Management	Run of muck due to water in an ore pass
10	Hoisting	Lack of proper signals when hoisting

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Root-Cause Analysis: Risk Statement

Based on the results of the Mining Review, the following risk statement was selected by the subject matter expert participants for Root-Cause Analysis using the **“Fishbone”** approach.

“ Worker exposed to run of material due to presence of water”

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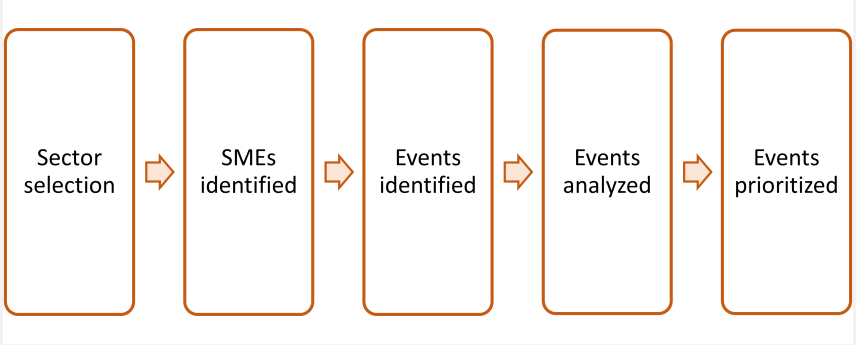
Workshop: A Bipartite and Collective Process

- Workshop participants were peer-recognized subject matter experts
- Workshop process was open, transparent and collaborative
- Workshop was face-to-face. No teleconferencing
- Any ranking/prioritization of causal factors was done using Employer and Worker input only (Ministry does not vote)
- Validation included presentation of results to individuals in the mining sector who were not part of the workshop group



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Water Management: Root-Cause Analysis Workshop Participants

#	Name	Company/Representation
1	**Craig Allair***	United Steelworkers
2	**Eric Lachance***	United Steelworkers
3	**Fern Houle***	K.G.H.M Limited
4	**Rick Ladoucer***	Goldcorp Limited
5	**Andre Timony***	Glencore Limited
6	**Glenn Staskus**	MOL (Operations)
7	**Christine Bibby**	MOL (Corporate Management) – Workshop Technical Support
8	**Robert Barclay**	MOL (Operations) - Facilitator
9	**Sujoy Dey**	MOL (Prevention) - Facilitator

***Voting participants**

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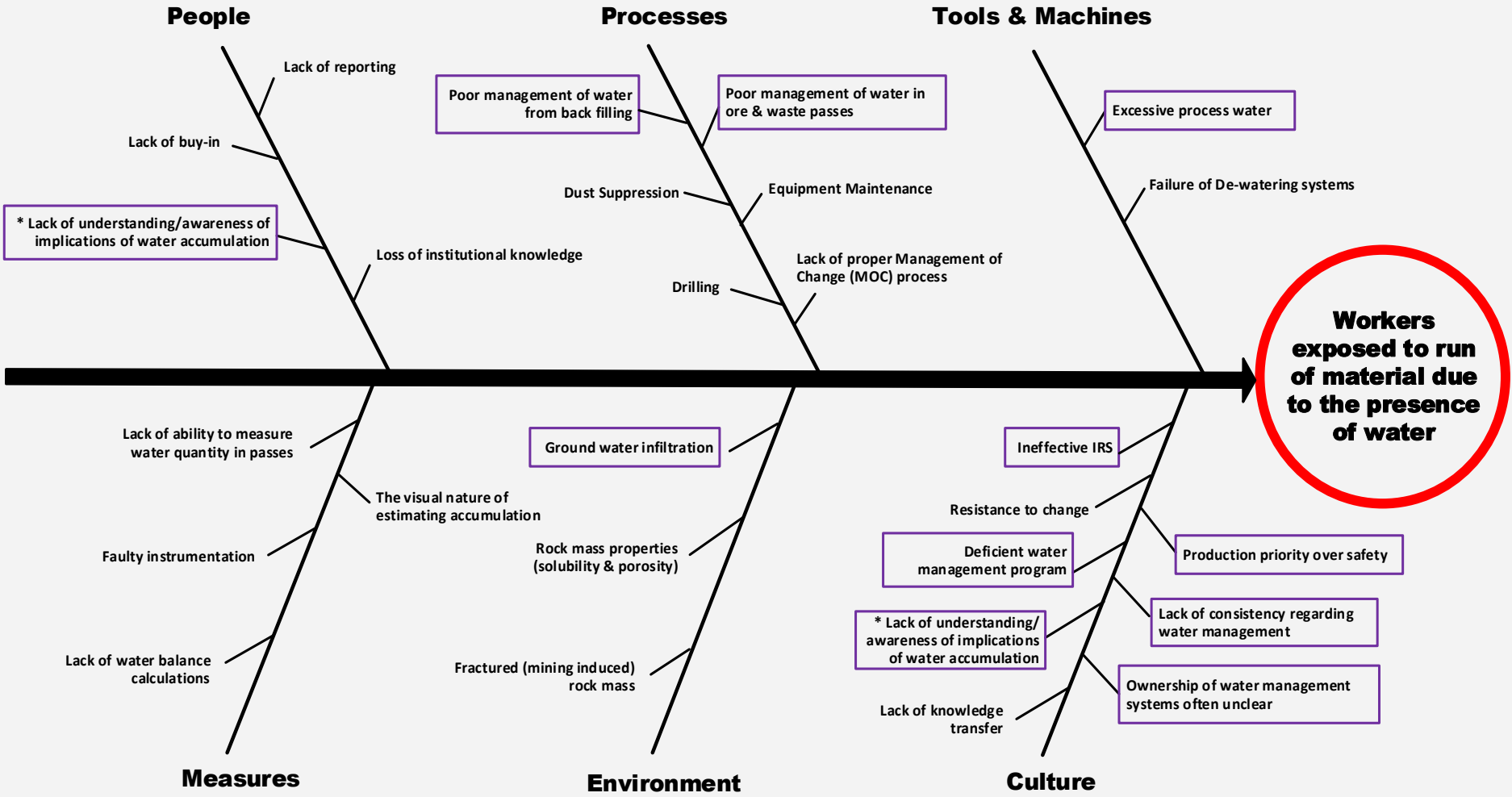
"Fishbone" Analysis: Primary Causal Factors

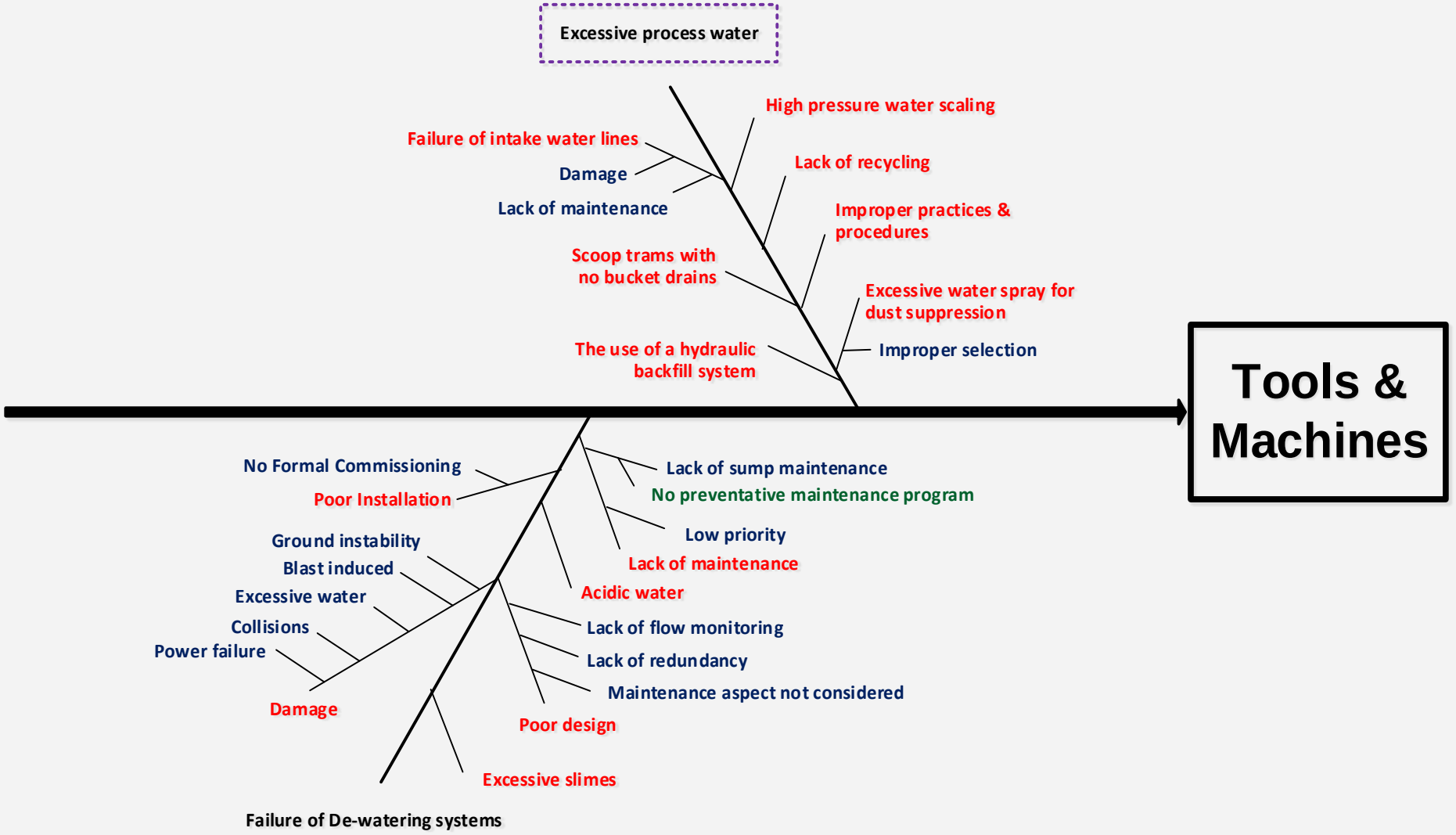


June 7, 2019
Created by: Christine Bibby, Risk Assessment Team, Ministry of Labour

Top 10 primary causal factor

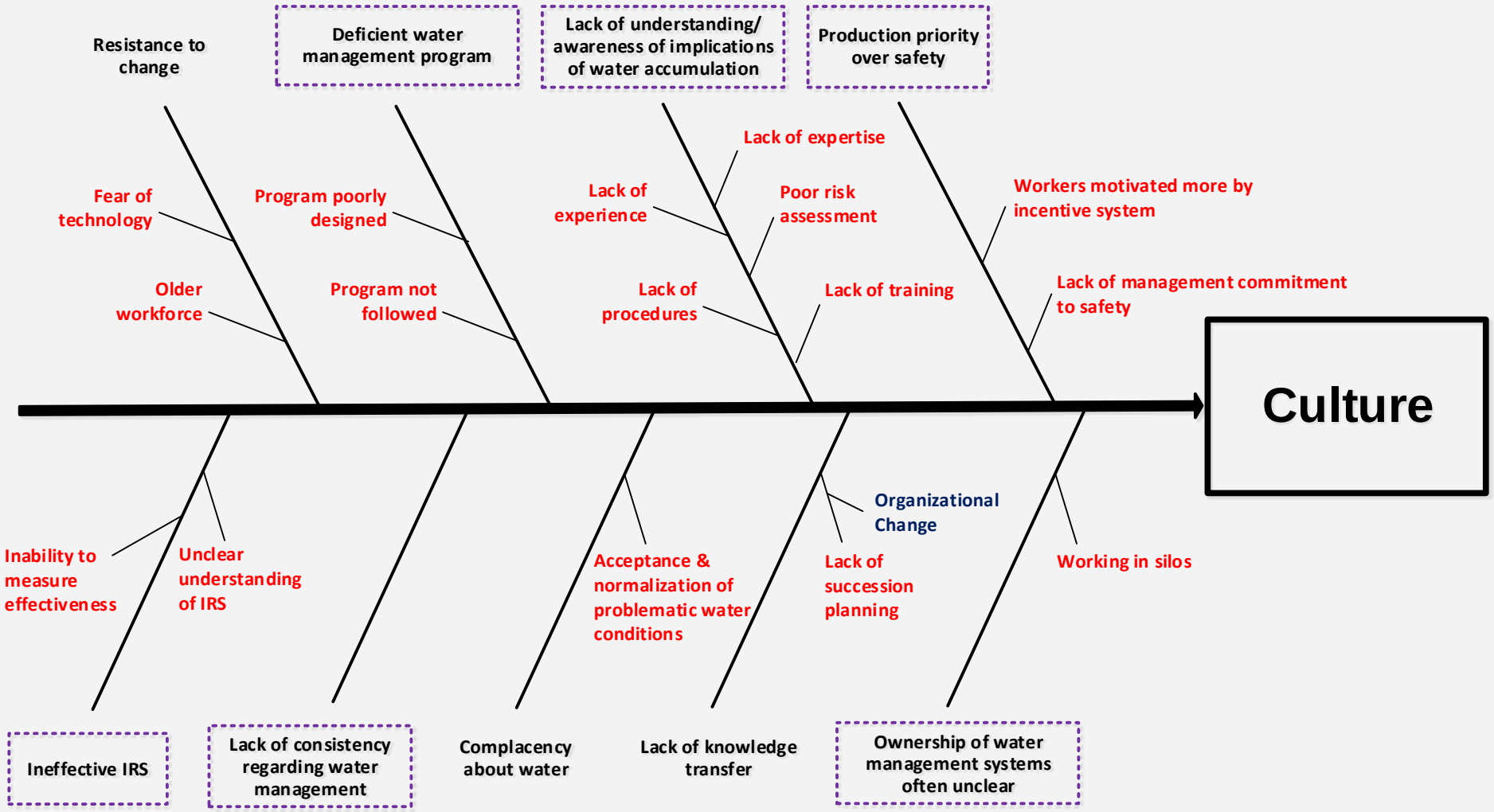
* Primary causal factor in multiple categories

Fishbone Analysis: Tools & Machines



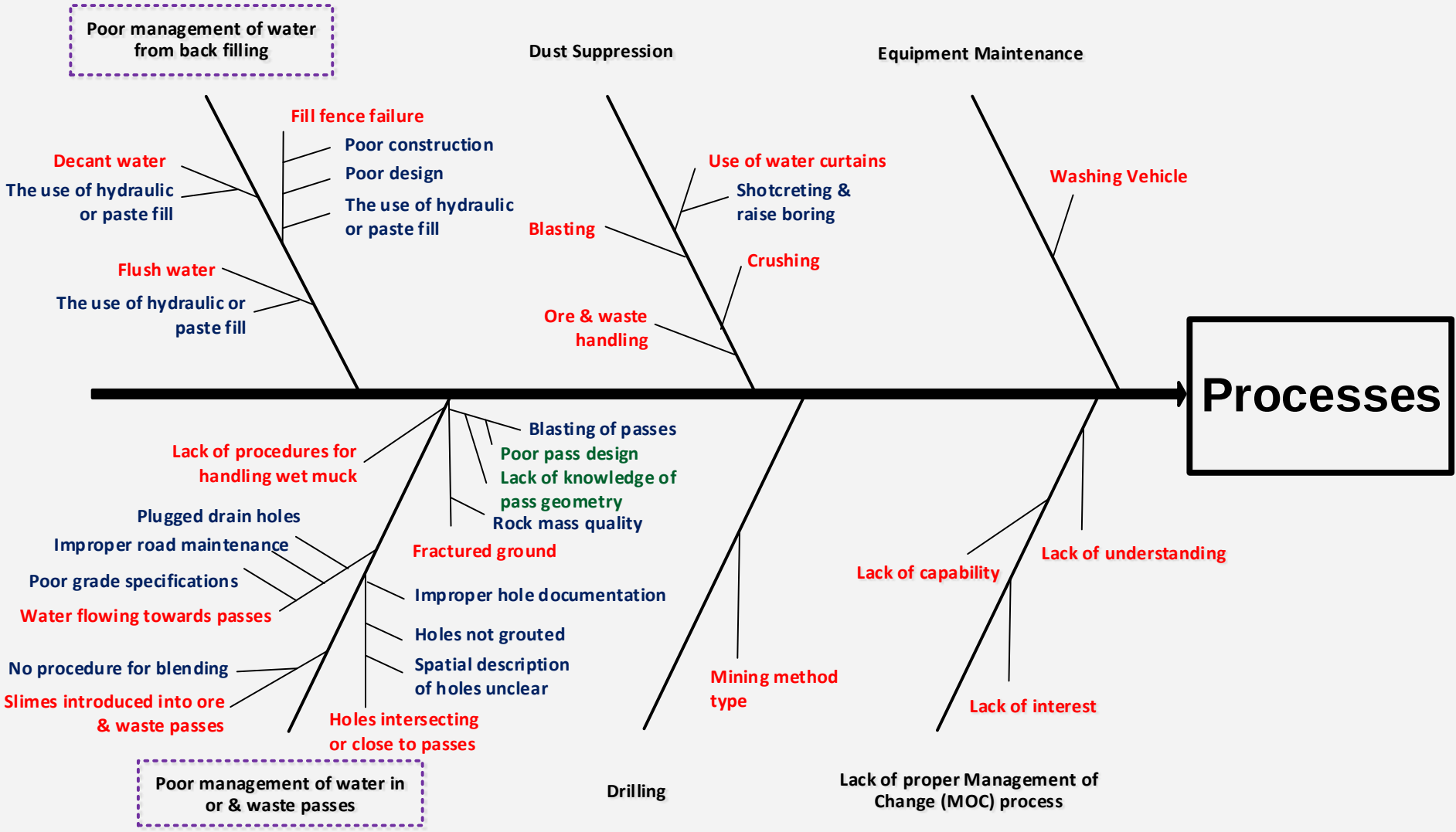
Top 10 Primary Root-Cause
Primary Root-Cause
Secondary Root-Cause
Tertiary Root-Cause
Quaternary Root-Cause

Fishbone Analysis: Culture



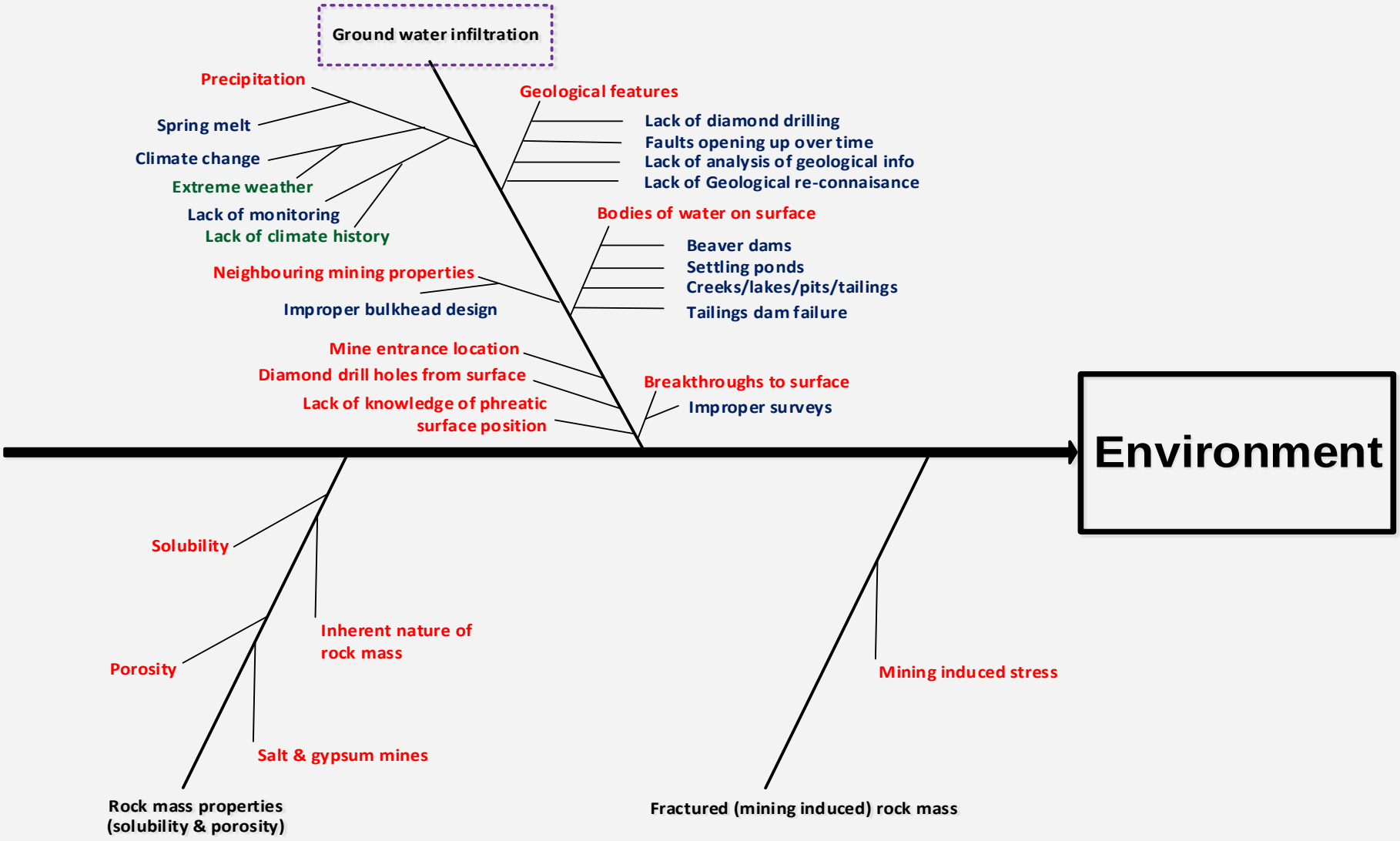
Top 10 Primary Root-Cause
Primary Root-Cause
Secondary Root-Cause
Tertiary Root-Cause

Fishbone Analysis: Processes

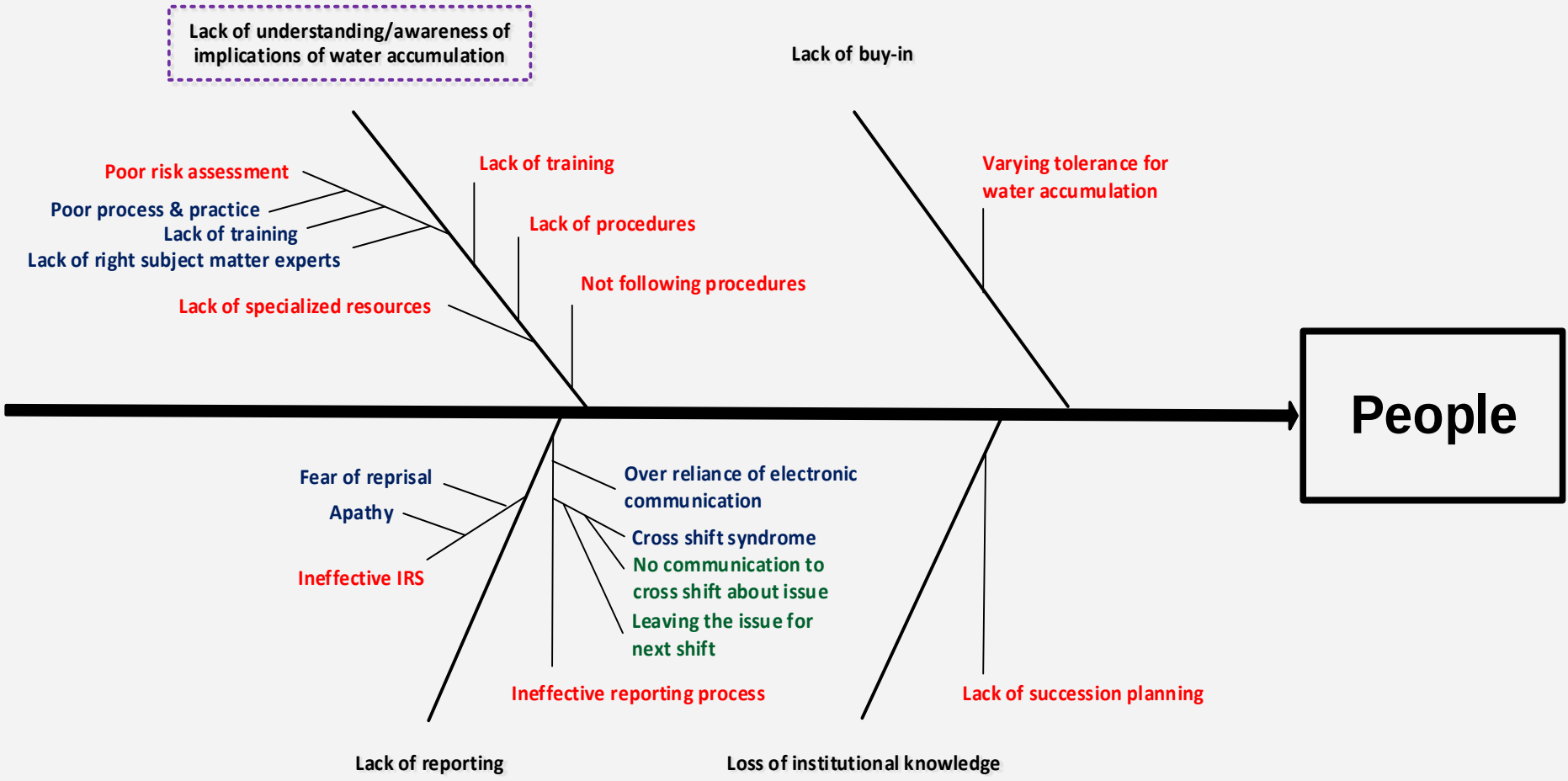


Top 10 Primary Root-Cause
Primary Root-Cause
Secondary Root-Cause
Tertiary Root-Cause
Quaternary Root-Cause

Fishbone Analysis: Environment



Fishbone Analysis: People



Top 10 Primary Root-Cause
Primary Root-Cause
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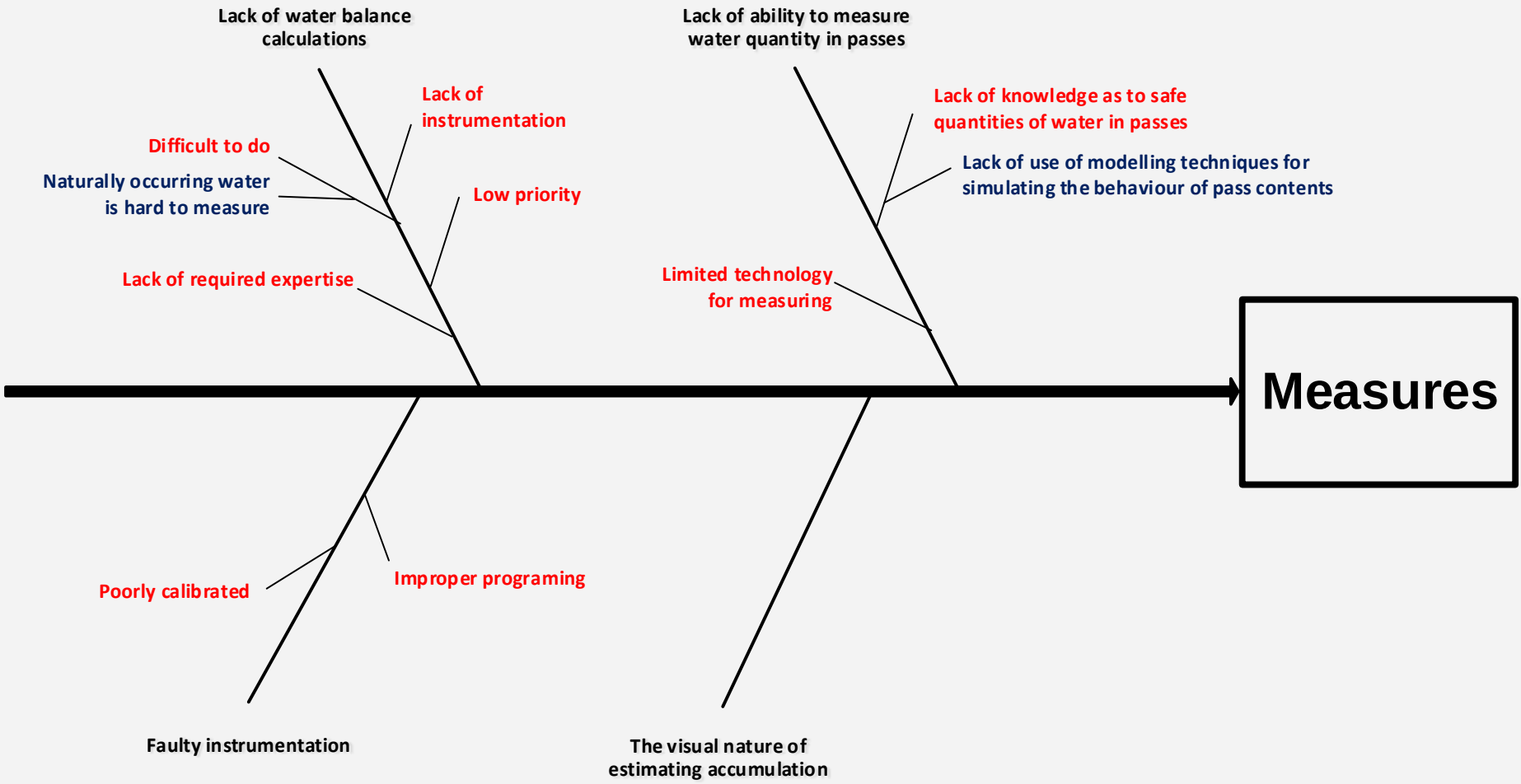
Tertiary Root-Cause
Quaternary Root-Cause

Fishbone Analysis: Measures



Top 10 Primary Root-Cause
Primary Root-Cause
Secondary Root-Cause
Tertiary Root-Cause

Root-Cause Analysis: Top 10 Primary Causal Factors

1. **Poor management of water in ore and waste passes -** Processes
2. **Lack of understanding/awareness of implications of water presence or accumulation –** People, Culture
3. **Production priority over safety -** Culture
4. **Excessive process water –** Tools & Machines
5. **Deficient water management program -** Culture
6. **Ownership of water management systems often unclear -** Culture
7. **Poor management of water from back filling -** Processes
8. **Ineffective IRS -** Culture
9. **Lack of consistency regarding water management -** Culture
10. **Ground water infiltration -** Environment

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List of solutions: Controls/activities that may support development of a control for the Top 10 primary causal factors

Note:

- ✓ Scope of this exercise does not include assessment of listed solutions/controls
- ✓ Any Control performance should be specified, observable, measurable and auditable

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1. Poor management of water in ore and waste passes

a.	Having drainage holes in a load haul dump unit bucket
b.	Automated ore and waste handling system (so no workers are present)
c.	Procedures and ratios for blending slimes in ore passes
d.	No slimes in passes
e.	Consistent documentation and effective surveying all diamond drill holes (record keeping)
f.	Having a water management system/program with clearly defined objectives and outcomes
g.	Policy of having no water in passes
h.	Grouting of drilled holes intersecting passes
i.	Proper grade design and road maintenance
j.	Proper ore pass design to avoid infiltration/accumulation of water and life expectancy (compensate for any deviations of design)
k.	Ore pass maintenance and cavity survey
l.	Having sufficient factor of safety for chutes associated with passes
m.	Preventative maintenance program for pass chutes
n.	Positioning of the ore pass (proximity of the pass relative to mining zones)

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1. Poor management of water in ore and waste passes- Contd.

o.	Ore pass hang-up procedure
p.	Monitoring levels of water or saturation measurements
q.	Adequate quality control program for hydraulic backfill
r.	Stope/panel fill dilution monitoring
s.	Modified blasting process and sequencing/secondary stope sequencing when up against fill to reduce dilution from backfill
t.	Process for managing water lines (to protect and repair damaged water lines)
u.	Procedure for pulling wet muck when encountered
v.	Control flush water from backfill process
w.	Grouting wet fractured ground in the vicinity of passes
x.	Lining of passes (shotcrete, concrete, steel plates, etc.)
y.	Monitoring the placement of hydraulic backfill for failures (e.g. fill fence failure)
z.	Engineered designed backfill fence with commissioning process
aa.	Monitoring maintenance programs for drain holes and sumps
bb.	Monitoring key areas for the presence of moisture for upset conditions
cc.	Procedure/process for decanting wet material before introducing to pass

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Note: This list is not in any order of priority

2. Lack of understanding/awareness of implications of water presence or accumulation

a.	General understanding (E.g. Risks of the hazards) of the water management program in place at the mine (Training, orientation, safety meetings)
b.	Understanding and awareness of (E.g. Risks of the hazards) relevant water management program in place specific to “your” work (E.g. Chutes, material handling systems, etc.)
c.	Heightened awareness of water accumulation sources (and risks) to workers at the site
d.	Communication of risk assessment results to workers
e.	Risk assessment process having proper quorum and specialized resources
f.	Ensuring that risk assessment reflects the nature of the work (E.g. situations/conditions that may result in an unwanted event)
g.	An unbiased risk assessment conducted by a trained facilitator
h.	Worker/supervisor understanding their rights, roles and responsibilities under Section 87. (8)
i.	Having access to the right technical expertise when required (E.g. process water vs. naturally occurring water)
j.	Ensuring compliance to relevant modular training program
k.	Advance the maturity of mining sector risk capability culture (E.g. Stages of risk maturity culture: Vulnerable, Reactive, Compliant, Proactive, Resilient): See Appendix A
l.	Having a good sense of company culture (E.g. age, etc.) and measuring it (E.g. WSN CAAT tool) to establish systems that are compatible to the culture

Note: This list is not in any order of priority

3. Production priority over safety

a.	Reassess/rethink the incentive system
b.	Corporate culture: “Safety starts at the top”
c.	Consistent application of safety culture across all levels
d.	Consistently apply expectations and accountability across all levels
e.	Having the proper KPIs and leading indicators focused on safety and not just production
f.	Best-in-class industry benchmarking during variable production cycles
g.	Supervisors aligned with safety culture
h.	Supervisors understanding the risks, hazards, and controls for the work they are supervising
i.	Having the right criteria for supervisor selection
j.	Worker inclusion & engagement in risk assessments, JHSC
k.	Having a good sense of company culture (E.g. age, etc.) and measuring it (E.g. WSN CAAT tool) to establish systems that are compatible to the culture

Note: This list is not in any order of priority

4. Excessive process water

a.	Having drainage holes in a load haul dump unit bucket
b.	Having a water management system/program with clearly defined objectives and outcomes
c.	Grouting to control how process water migrates through the system
d.	Set metrics for process water intake and monitor for compliance
e.	Monitoring levels of water
f.	Having the amounts of water specified in water permitting applications well rationalized
g.	Adequate quality control program for hydraulic backfill
h.	Investigate opportunities to look for alternatives for hydraulic backfill
i.	Hydraulic backfill technology to identify ways of minimizing water requirements
j.	Process for managing water lines (to protect and repair damaged water lines)
k.	Control flush water from backfill process

Note: This list is not in any order of priority

4. Excessive process water – Contd.

l.	Monitoring key areas for the presence of moisture for upset conditions
m.	Identify process where you can recycle water
n.	Preventative maintenance process for process water system
o.	Water intake system subject to asset integrity program
p.	Alternative dust suppression methods
q.	Best-in-class industry benchmarking for water utilization

Note: This list is not in any order of priority

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5. Deficient water management program

a.	Making it a priority
b.	Set higher standards as a basis for development (minimum standards not good enough)
c.	Ensure program based on good engineering/industry practices and aligned with future guidelines
d.	Ensure accountability through performance plan requirements and compliance verification against the management program
e.	Setting water management performance metrics (E.g. near-miss report, incident report) & reaction criteria
f.	External review/audit of the program
g.	Worker inclusion & engagement (E.g. JHSC) in the development of the water management program
h.	Effective I.R.S
i.	Advance the maturity of mining sector risk capability culture (E.g. Stages of risk maturity culture: Vulnerable, Reactive, Compliant, Proactive, Resilient): See Appendix A
j.	Having a good sense of company culture (E.g. age, etc.) and measuring it (E.g. WSN CAAT tool) to establish systems that are compatible to the culture
k.	General understanding (E.g. Risks of the hazards) of the water management program in place at the mine (Training, orientation, safety meetings)
l.	Understanding and awareness of (E.g. Risks of the hazards) relevant water management program in place specific to “your” work (E.g. Chutes, material handling systems, etc.)

Note: This list is not in any order of priority

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5. Deficient water management program – Contd.

m.	Heightened awareness of water accumulation sources (and risks) to workers at the site
n.	Communication of risk assessment results to workers
o.	Risk assessment process having proper quorum and specialized resources
p.	Ensuring that risk assessment reflects the nature of the work (E.g. situations/conditions that may result in an unwanted event)
q.	An unbiased risk assessment conducted by a trained facilitator
r.	Worker/supervisor understanding their rights, roles and responsibilities under Section 87. (8)
s.	Having access to the right technical expertise when required (E.g. process water vs. naturally occurring water)
t.	Ensuring compliance to relevant modular training program

Note: This list is not in any order of priority

6. Ownership of water management systems often unclear

a.	Clear, defined roles and responsibilities and accountabilities
b.	Clear response plans for upset conditions (E.g. Triggered Action Response Plan (TARP))
c.	Awareness of response plans for upset conditions (E.g. Awareness of the Triggered Action Response Plan (TARP))
d.	Understanding the holistic view of the water management system (E.g. Process map of the system, systems thinking)
e.	Water management plan should include a process map of the system (E.g. Showing the interfaces between different departments involved) with defined responsibilities
f.	Succession planning and knowledge transfer

Note: This list is not in any order of priority

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7. Poor management of water from back filling

a.	Consistent documentation and effective surveying all diamond drill holes (record keeping)
b.	Having a water management system/program with clearly defined objectives and outcomes
c.	Proper grade design and road maintenance
d.	Grouting of holes intersecting stopes to be filled
e.	Cavity survey of stope to be filled
f.	Having sufficient factor of safety for backfill systems
g.	Preventative maintenance program for backfill systems
h.	Adequate quality control program for hydraulic/paste backfill
i.	Stope/panel fill dilution monitoring
j.	Process for managing fill lines (to protect and repair damaged water lines)
k.	Control flush water from backfill process
l.	Monitoring the placement of hydraulic/paste backfill for failures (e.g. fill fence failure)

Note: This list is not in any order of priority

7. Poor management of water from back filling – Contd.

m.	Engineered designed backfill fence with commissioning process
n.	Monitoring maintenance programs for drain holes and sumps
o.	Monitoring key areas for the presence of moisture for upset conditions
p.	Procedure/process for decanting backfill material
q.	Proper fill design and Quality Assurance/Quality Control
r.	Understanding where the critical/vulnerable points are in the backfill delivery system and responding accordingly
s.	Training: Compliance to fill placement module (U0076 perform fill placement)
t.	Having up-to-date drawings showing fill delivery systems
u.	Having the right signage identifying backfill lines (direction, destination)

Note: This list is not in any order of priority

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8. Ineffective IRS

a.	Clear understanding of IRS
b.	Management and worker commitment to IRS
c.	Identify indicators to monitor IRS (E.g. KPIs on closure of worker concerns)
d.	External support (E.g. HSA Climate assessment and audit tool)
e.	Health and safety training for worker and supervisor including ongoing training and training for new workers
f.	JHSC and worker health and safety representative “health and safety training
g.	Senior leadership action should drive safety culture through employee engagement and buy-in
h.	Supervisor getting core skills to support building healthy workplace relationships (e.g. mentoring, coaching, inclusion into common core)
i.	Continuous improvement of the system

Note: This list is not in any order of priority

9. Lack of consistency regarding water management

a.	Ensure program based on good engineering/industry practices and aligned with future guidelines
b.	Understanding the consequences of being inconsistent
c.	Specified tolerance for water management program KPIs
d.	Sharing of practices and information between organizations & contractors
e.	Importance of reporting water problems/issues at the workforce level
f.	Routine and rigorous auditing against the water management program

Note: This list is not in any order of priority

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10. Ground water infiltration

a.	Having topographical information showing water bodies on surface in close proximities to mines. Also, showing depth of those water bodies
b.	Topographical information should be integrated into the water management program
c.	Knowledgeable local mining history (E.g. Historical workings: depth, lateral extent, to what extent they are flooded)
d.	Looking at available information on flood plains, seasonal run-offs, provincial and regional agencies
e.	Proper geological interpretation and mapping
f.	Historical and current geological mapping
g.	Hydro and geological investigations
h.	Understanding regional geological features that could affect the mine (that could serve as conduits for water transmission)
i.	Records of diamond drill holes
j.	Effective diamond drill coverage for the deposits
k.	Establish tentative mining limits, from the ore body delineation
l.	Survey control to known reference points

Note: This list is not in any order of priority

10. Ground water infiltration – Contd.

m.	Grouting of diamond drill holes on surface
n.	Identification and characterization of overburden
o.	Proper selection of mine entrance
p.	Factor climate considerations into the water management programs (spring run-off, flooding information)
q.	Periodic engineering assessments of tailings dams
r.	Identifying the thickness of rock mass quality of the surface crown pillar
s.	Crown pillar assessments of abandoned mines in close proximity
t.	Monitoring bulkheads of abandoned mines in close proximity
u.	Settling pond monitoring and maintenance program
v.	Record keeping for precipitation history
w.	Integrating precipitation information into water balance calculation

Note: This list is not in any order of priority

Appendix A: Stages of Risk Maturity

#	Risk Maturity Attribute	VULNERABLE	REACTIVE	COMPLIANT	PROACTIVE	RESILIENT
		No formal approach for risk management	Scattered silo based approach to risk management	Strategies policies in place and communicated	Integrated approach to risk management developed and communicated	Risk Management and controls fully embedded into the operations
1	**Organizational Risk Culture**	No care culture • Apathy • Near misses not considered • No/little training • Poor/no communication	Ad-hoc culture • Accept need to care • Some near miss reporting • Min/inconsistent training • Need to know basis	Compliance culture • Some participation • Near miss discussions • Acceptable training • Regular people involvement and focus	Ownership culture • Involvement at all levels • Near miss involvement • High level of training • Communication at high level, hiding nothing	Way of doing business culture • Comes naturally to all • Personnel involvement by all • Complete understanding (training) • Always informed/integrated communications
2	**Management Perspective**	No risk awareness or upper management involvement. Resistant/reluctance to change. Tendency to continue with existing processes even in the face of project failures	Risk process may be viewed as additional overhead with variable benefits. Upper management encourages, but does not require, use of RM. RM used only on selected projects	Accepted policy for RM. Upper Management requires risk reporting. Dedicated resources for RM. Bad news risk information is accepted	Top-down commitment to risk management, with leadership leading by example. Upper management uses risk information in decision-making	All the features of previous level plus: Proactive risk management encouraged and rewarded. Organizational philosophy accepts idea that people make mistakes
3	**Risk Management process (Stages of a Risk Management model)**	No structured application. No dedicated resources. No RM tools in use. No risk analysis performed.	Inconsistent application of resources. Qualitative risk analysis methodology used exclusively	Routine and consistent application to all projects. Dedicated project resources. Integrated set of tools and methods. Both qualitative and quantitative risk analysis methodologies used	Risk applied strategically & systematically to all activities. Risk-based reporting & decision making. Both qualitative and quantitative risk analysis methodologies used on having valid and reliable data sources	Culture of information on all stages with measurable indicators linked to organizational objectives. State-of-the-art tools and methods. Dedicated organizational resources for Risk Management
4	**Experience/ Competency**	No understanding of risk principles or language. No understanding or experience in accomplishing risk procedures	Limited to individuals who may have had little or no formal training	In-house core expertise, formally trained in RM skills. Development and use of specific processes and tools	All staff risk aware and capable of using basic risk skills. Learning from experience as part of the process	Regular training for personnel to enhance skills. Documentation, knowledge management and learning from experience is indispensable

Note: (a) RM = Risk Management; **(b)** Compliant **DOES NOT** refer to legal compliance

References:

1. Luciel Henrique de Oliveira, Luiz Carlos Di Serio, A new tool for assessing the Organizational Risk Maturity: a diagnose matrix, September 2014.
2. Dr. Patrick Foster, The Risk Management Journey, Safety Risk Management Process, 2016
3. Michael Herrington, How Mature is your Risk Management, Harvard Business Review, June 2012
3. The Risk Maturity Model: http://riskmaturitymodel.org/rims-risk-maturity-model-rmm-for-erm/
4. Assessing the 0rganization's risk maturity: https://www.iia.org.uk/media/269137/appendix_a.pdf
5. Enterprise Risk Management, A 'risk-intelligent' approach: Deloitte Risk Advisory – Deloitte, August 2015

Appendix B: Risk Assessment Methods/Standards*

1. Bayesian Analysis
2. Bow tie analysis
3. Brainstorming (e.g. what-if)
4. Business impact analysis
5. Cause and effect analysis
6. Checklists
7. Computer Hazard and Operability Studies (CHAZOP)
8. Consequence Analysis (also called Cause-Consequence Analysis)
9. Likelihood/Consequence matrix
10. Construction Hazard Assessment and Implication Review (CHAIR)
11. Decision tree
12. Delphi technique
13. Energy Barrier Analysis (or Energy Trace Barrier Analysis)
14. Environmental risk assessment
15. Event tree analysis
16. Failure Mode and Effect Analysis (FMEA)
17. Failure mode, effect and criticality analysis
18. Fault Tree Analysis
19. Fishbone (Ishikawa) Analysis
20. Hazard analysis and critical control points
21. Hazard and Operability studies (HAZOP)
22. Human Error Analysis (HEA)
23. Human reliability analysis
24. Job Safety Analysis (JSA)
25. Level of Protection Analysis (LOPA)
26. Markov analysis
27. Monte Carlo Analysis
28. Preliminary Hazard Analysis (PHA)
29. Reliability centered maintenance
30. Scenario analysis
31. Sneak circuit analysis
32. Structured/semi-structured interviews
33. SWIFT (i.e. structured what-if)
34. Systemic Cause Analysis Technique (SCAT)
35. Workplace Risk Assessment and Control (WRAC)

Risk Management Standards:

1. Risk Management Principles and Guidelines (ISO 31000:2009)
2. Risk Assessment Techniques (ISO/IEC 31010:2009)
3. OH&S Hazard Identification and Elimination and Risk Assessment and Control (CSA Z1002)
4. Process Safety Management (CSA Z767-17)
5. Enterprise Risk Management (COSO 2004)
6. Global Minerals Industry Risk Management (GMIRM)
7. International Council on Mining & Metals (ICMM)

*** Not an exhaustive list**

Appendix C: Ministry Contacts

- For additional information or questions, please contact:

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