Rank	Primary Root-Cause	**Solutions** (Controls/Activities that may support development of a Control)
1	**Poor management of water in ore & waste passes - Process**	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)
		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)

Rank	Primary Root-Cause	**Solutions** (Controls/Activities that may support development of a Control)
		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
		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

Rank	Primary Root-Cause	**Solutions** (Controls/Activities that may support development of a Control)
2	**Lack of understanding/awareness of implications of water accumulation - People & Culture**	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
		a. Advance the maturity of mining sector risk capability culture (E.g. Stages of risk maturity culture: Vulnerable, Reactive, Compliant, Proactive, Resilient)
		b. 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
		c. General understanding (E.g. Risks of the hazards) of the water management program in place at the mine (Training, orientation, safety meetings)
		d. 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.)
		e. Heightened awareness of water accumulation sources (and risks) to workers at the site
		f. Communication of risk assessment results to workers
		g. Risk assessment process having proper quorum and specialized resources
		h. Ensuring that risk assessment reflects the nature of the work (E.g. situations/conditions that may result in an unwanted event)
		i. An unbiased risk assessment conducted by a trained facilitator
		j. Worker/supervisor understanding their rights, roles and responsibilities under Section 87. (8)
		k. Having access to the right technical expertise when required (E.g. process water vs. naturally occurring water)
		l. Ensuring compliance to relevant modular training program

Rank	Primary Root-Cause	**Solutions** (Controls/Activities that may support development of a Control)
3	**Production priority over safety - Culture**	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
4	**Excessive process water - Tools & Machines**	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)

Rank	Primary Root-Cause	**Solutions** (Controls/Activities that may support development of a Control)
		k. Control flush water from backfill process
		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
5	**Deficient water management program - Culture**	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) and 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)
		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.)
		m. Heightened awareness of water accumulation sources (and risks) to workers at the site
		n. Communication of risk assessment results to workers

Rank	Primary Root-Cause	**Solutions** (Controls/Activities that may support development of a Control)
		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
6	**Ownership of water management systems often unclear – Culture**	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
		Succession planning and knowledge transfer
		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

Rank	Primary Root-Cause	**Solutions** (Controls/Activities that may support development of a Control)
7	**Poor management of water from back filling – Process**	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)
		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)
8	**Ineffective IRS – Culture**	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

Rank	Primary Root-Cause	**Solutions** (Controls/Activities that may support development of a Control)
9	**Lack of consistency regarding water management – Culture**	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
10	**Ground water infiltration – Environment**	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
		m. Grouting of diamond drill holes on surface
		n. Identification and characterization of overburden
		o. Proper selection of mine entrance

Rank	Primary Root-Cause	**Solutions** (Controls/Activities that may support development of a Control)
		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
		a. Proper de-watering system design
		b. Preventative maintenance program for de-watering system
		c. Having a water management system/program with clearly defined objectives and outcomes
		d. Having sufficient factor of safety for de-watering systems
		e. Process for managing de-watering lines (to protect and repair damaged de-watering lines)
		f. Monitoring maintenance programs for drain holes and sumps
		g. Monitoring key areas for upset conditions
		h. Proper fill containment design
		i. Understanding where the critical/vulnerable points are in the de-watering system and responding accordingly

Rank	Primary Root-Cause	**Solutions** (Controls/Activities that may support development of a Control)
11	**Failure of De-watering systems - Tools & Machines**	j. Having up-to-date drawings showing de-watering system infrastructure
		k. Having the right signage identifying drain holes, lines (direction, destination), sump location
		l. Proper pump selection and design
		m. Scheduling for pump maintenance
		n. Pressure/volume monitoring systems for water containment
		o. Water analysis to understand content (E.g. pH)
		p. Commissioning process for system components
		q. Management of Change (MOC) for system changes
		r. Periodic checks on design validity of de-watering system
		s. Protection of key assets from damage (E.g. Pump station)
		t. Incident reporting and back-reporting of system failures
		u. Short-term intervention strategy in the event of a system failure/breakdown (risk assessment)
12	**Lack of buy-in - People**	a. Advance the maturity of mining sector risk capability culture (E.g. Stages of risk maturity culture: Vulnerable, Reactive, Compliant, Proactive, Resilient)
		b. 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
		c. General understanding (E.g. Risks of the hazards) of the water management program in place at the mine (Training, orientation, safety meetings)
		d. 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.)
		e. Heightened awareness of water accumulation sources (and risks) to workers at the site
		f. Communication of risk assessment results to workers
		g. Risk assessment process having proper quorum and specialized resources
		h. Ensuring that risk assessment reflects the nature of the work (E.g. situations/conditions that may result in an unwanted event)
		i. An unbiased risk assessment conducted by a trained facilitator

Rank	Primary Root-Cause	**Solutions** (Controls/Activities that may support development of a Control)
		j. Worker/supervisor understanding their rights, roles and responsibilities under Section 87. (8) to ensure that drill holes are filled or grouted to prevent water entering a chute or raise
		k. Having access to the right technical expertise when required (E.g. process water vs. naturally occurring water)
		l. Ensuring compliance to relevant modular training program
		m. Effective IRS
		n. Proper on-boarding of employees
13	**Lack of ability to measure water quantity in passes – Measures**	a. Benchmark best practices in industry
		b. Leverage learnings from traditional practices from civil engineering with respect to soil/rock composition
		c. Reliance on the most accurate and up-to-date cavity monitoring information in order to determine quantity of water
		d. Seeking continuous improvement as new technology is introduced
		e. Consider new technology (E.g. sensor technology) for the ability to monitor water quantity or content
		f. On-going liaison with groups dealing with safety innovation
14	**Faulty instrumentation – Measures**	a. Preventative maintenance program
		b. Management of change process (e.g. proper procurement)
		c. Educating procurement staff on rationale for selection (e.g. cheaper is not always better)
		d. Ensuring technical support (internal or external) including engagement with suppliers
		e. Warning systems to identify when it is faulty
		f. Self-diagnosis capability
		g. Sufficient design considerations
		h. Training for staff on technology
		i. Having a proper installation plan (e.g. location, not where it is wet)
		j. Proper commissioning and calibration

Rank	Primary Root-Cause	**Solutions** (Controls/Activities that may support development of a Control)
		k. Ensuring robustness for the underground environment
		l. Best practices on selected instrumentation (e.g. benchmarking, sharing information)
		m. Continuous improvement/awareness on instrumentation technologies
15	**Dust suppression - Process**	a. Identify alternatives to water for dust suppression
		b. Optimizing water sprays through controls (as-needed basis)
		c. Explore broader application of foggers vs sprays
		d. Use dust collectors where possible
		e. Reassess fragmentation objectives (e.g. blast design)
		f. Reassess selected mine design processes (e.g. relocating crushing systems on surface)
		g. Underground roadway construction that does not contributing to dust creation (mine design)
		h. Controlling water away from key infrastructure (e.g. chutes, passes)
		i. Avoid rehandling of muck as much as possible
		j. Use wet as opposed to dry shotcreting
		k. Focus on dust removal rather than dust recycling (e.g. street sweepers)
		l. Optimizing ventilation flows (velocity) to reduce airborne dust
		Road maintenance program
		a. Effective IRS
		b. General understanding (E.g. Risks of the hazards) of the water management program in place at the mine (Training, orientation, safety meetings)
		c. 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.)

Rank	Primary Root-Cause	**Solutions** (Controls/Activities that may support development of a Control)
16	**Lack of reporting – People**	d. Heightened awareness of water accumulation sources (and risks) to workers at the site
		e. Communication of risk assessment results to workers (communication to cross-shift about issue, not leaving the issue for the next shift)
		f. Worker/supervisor understanding their rights, roles and responsibilities under Section 87. (8)
		g. Having access to the right technical expertise when required (E.g. process water vs. naturally occurring water)
17	**The visual nature of estimating accumulation – Measures**	a. More reliance on quantifiable measurement
		b. Training workers to understand optimal levels of saturation consistencies (e.g. ore and waste)
		c. Muck handling procedures and training
		d. Benchmarking/networking against other industries to estimate ore content (e.g. road construction for estimating water content in swampy areas)
		e. Better reliance on soil mechanics technology
		f. Be selective about where you can and cannot rely on visual estimation (e.g. substantiating visual estimation with quantifiable measurement for critical issues)
		g. Review of ore and waste processes for decanting water to ensure they do not create a hazard
18	**Fractured (mining induced) rock mass – Environment**	a. Selective grouting
		b. Cement lining
		c. Shotcreting with weepers
		d. Identify where the fractured areas are and will be, and design mine accordingly
		e. Mine life design and sequencing
		f. Controlling intensity of blast
		g. Designing infrastructure isolated from fractured rock mass (e.g. don't want a vertical sump near the ore body)
		a. Have a succession plan
		b. Have a knowledge transfer plan (e.g. all "knowledge eggs" are not in one basket)
		c. Knowledge transfer plan immune to organizational change

Rank	Primary Root-Cause	**Solutions** (Controls/Activities that may support development of a Control)
19	**Lack of knowledge transfer – Culture**	d. Better communication so that knowledge is not lost (e.g. when people are still around and not wait till their departure)
		e. Prioritize knowledge transfer based on risk
		f. Allow for overlap, cross-training, shadowing
		g. Better record retention and organization
		h. Eliminate the dependency on undocumented information (e.g. "it's all in his/her head")
		i. Management of change should involve personnel change
		j. Central drive for key information (e.g. document management system)
		k. Resource management so that there are no "gaps" (e.g. holidays, sick days, leaves, transfers, retirements)
20	**Rock mass properties (solubility & porosity) – Environment**	a. Understand characteristics of different strata (e.g. which are water transmitting and design mine accordingly)
		b. Understanding structural geology (e.g. where the faults are, water-transmitting capability, reactivating faults)
		c. Understanding secondary structures to faults
		d. Better understanding of hydro geology
		e. Understanding of the water table
		f. Understanding rock-type porosity
		g. Understanding interaction of geological structures with water sources (surface or underground)
		h. Understanding of the local geology (e.g. contacts, different lithologies)
		a. Have a succession plan
		b. Have a knowledge transfer plan (e.g. all "knowledge eggs" are not in one basket)
		c. Knowledge transfer plan immune to organizational change
		d. Better communication so that knowledge is not lost (e.g. when people are still around and not wait till their departure)
		e. Prioritize knowledge transfer based on risk

Rank	Primary Root-Cause	**Solutions** (Controls/Activities that may support development of a Control)
21	**Loss of institutional knowledge – People**	f. Allow for overlap, cross-training, shadowing
		g. Better record retention and organization
		h. Eliminate the dependency on undocumented information (e.g. "it's all in his/her head")
		i. Management of change should involve personnel change
		j. Central drive for key information (e.g. document management system)
		k. Resource management so that there are no "gaps" (e.g. holidays, sick days, leaves, transfers, retirements)
22	**Resistance to change – Culture**	a. Proper management of change training
		b. Proper change management training
		c. Introduce change so it is not overwhelming (e.g. high frequency of change)
		d. Effective communication of the change
		e. Understanding your workforce when planning change
		f. Proper education and training on the significance of water hazards
		g. Education and training on the water management program
		h. Selling the positive effects/rationale of the change (e.g. change is not a bad thing or "flavour of the month")
		i. Keeping hiring criteria up-to-date
		j. Building "resilience" to change
		a. Define how the threshold is established (risk assessment) that triggers an MOC
		b. Established assessment measures for controls emanating from a MOC
		c. Having a clearly defined baseline for water management design parameters
		d. Education and training on MOC
		e. Validate and approve MOC to get to an unbiased outcome

Rank	Primary Root-Cause	**Solutions** (Controls/Activities that may support development of a Control)
23	**Lack of proper Management of Change (MOC) process – Process**	f. Transparency on who owns the MOC process with respect to the water management program
		g. Clarity as to where water management resides in the overall mining process
		h. Resources to manage the MOC
		i. Water management program should have an MOC component to it
		j. Best practices on MOC
		k. Stay committed to the process
24	**Drilling – Processes**	a. Identify alternatives to water for drilling
		b. Reassess fragmentation objectives (e.g. blast design)
		c. Reassess selected mine design processes (e.g. reassessing drilling equipment)
		d. Ensure that water allocated for drilling does not exceed manufacturers' specifications/parameters
		e. Controlling water away from key infrastructure (e.g. chutes, passes)
		f. Optimizing ventilation flows (velocity) to reduce airborne dust
		g. Preventative maintenance for drilling equipment
		h. Optimal drilling bit selection and maintenance
		i. Investigate other technologies that are best-in-class
		j. Holistic view and understanding of drilling area
		k. Drill hole plan review process
		l. Estimate the percentage/proportion of drilling water with respect to total process water (enabling prioritization and elimination strategies)
		m. Select mining method to minimize drilling water
		n. Evaluate recycling water for drilling purposes
		a. Ability to obtain, interpret and analyze data (instrumentation)

Rank	Primary Root-Cause	**Solutions** (Controls/Activities that may support development of a Control)
25	**Lack of water balance calculations – Measures**	b. Need to define what actions are triggered when water balance exercise does not show a balance
		c. Capability to do a water balance calculation
		d. Comparison of water balance calculation findings to design specifications
		e. Specify the frequency of water balance calculations
		f. Factoring in effects from adjacent mines when calculating
26	**Equipment Maintenance – Processes**	a. Alternative methods/technology to washing equipment
		b. Estimate the percentage/proportion of washing water with respect to total process water (enabling prioritization and elimination strategies)
		c. Controlling the water from the process by directing it to its own sump