UNDERTAKING RESPONSE

EA No: 0809-001 **Undertaking No: 11**

Date Received

Transcript: Day 4, pg. 178

Undertaking:

The Giant Mine Project Team to resubmit section 2.1.2 of the Failure Modes report (attachment to Review Board Information Request #12) clarifying definition of "long term".

Response:

Revision on page 11 – removed sentence at the end of paragraph 3 under risk evaluation heading.

Please see attached IR Response, *Information Request No: MVEIRB 12 (Qu 1, 2, 3, 4 & 5),* June, 2011.

INFORMATION REQUEST RESPONSE

EA No: 0809-001 **Information Request No: MVEIRB 12 (Qu 1, 2, 3, 4 & 5)**

Date Received: February 21, 2011

Linkage to Other IRs: MVEIRB IR 8, 13, 14, 15 and YKDFN IR 5, 10

Date of this Draft: June 17, 2011 *** Draft No: 2**

Preamble

The DAR section on accidents and malfunctions only examines failures of individual elements of the project in isolation. It describes what would happen assuming all design features, mitigation measures and emergency response plans are functioning ideally. It does not address likelihoods and severity of each risk. It provides no scenarios of larger events that could cause compound failures of several elements, or consequences of domino effects within overall systems. This includes the larger events described in section 9.

The risk assessment defines “credible” events as those that have a reasonable probability of occurring within the first 25 years, based on the temporal scope of the EA. However, the temporal scope defines the activities assessed, not the duration of effects of the project to be considered. The Board assesses what happens because of development activities occurring within that time, not only the effects that happen during that time. The developer’s definition of “credible” appears to exclude all long-term risks and low probability events.

Question 1: Please identify risks for the life of the project, beyond those occurring during initial development activities.

Question 2: Please identify scenarios for events in short and long-term which could cause multiple failures of components of the project

Question 3: Please evaluate probabilities and severities and consequences (including costs) resulting from those scenarios

Question 4: Please describe how failures of individual components would affect the larger systems they are a part of

Question 5: Please describe probabilities, severities and consequences (including costs) for the events discussed in section 19 plus any additional long-term risks identified (see point 1, above).

Reference to DAR (relevant DAR Sections): DAR s. 9, DAR s. 10

Reference to the EA Terms of Reference: ToR 2.3, ToR 3.2.5

*** Is Issue within the scope of Terms of Reference? Yes**

Question 1: Please identify risks for the life of the project, beyond those occurring during initial development activities

Question 1 Response:
Three risk workshops were arranged and at the first session, Failure Scenario Analysis (FSA) Trees were developed which summarizes failure scenarios relevant to this project. These failure trees identify the initiating events for the overall project, as well as the impact a component failure has on an overall system. Appendix A of the attached report, "Failure Mode Effects Criticality Analysis (FMECA) - Giant Mine Remediation - Giant Mine Remediation – Mackenzie Valley Environmental Impact Review Board – Information Request 12 Response," presents these failure trees for the various systems and evaluates risk in both the short and long term.

Question 2: Please identify scenarios for events in short and long-term which could cause multiple failures of components of the project

Question 2 Response:
Cascading Event Scenarios and Multiple Cause Scenarios were developed to assess how multiple failures of components would affect the Giant Mine project in both the short and long term. A cascading event scenario refers to a series of accidents and malfunctions occurring because of one initiating event; which may cause another malfunction to lead to a series of other multiple malfunctions. The cascading event scenarios developed for both the short and long term of the project are presented in Appendix B of the attached report. Multiple cause scenarios were also examined in preparing the response for question 2. A multiple cause scenario is a specific fault scenario which includes two or more initiating events occurring simultaneously. These types of scenarios generally have a lower likelihood as they require two unrelated causes to happen simultaneously. In the evaluation of multiple cause scenarios, focus was placed on evaluating multiple cause scenarios for the freeze and water management systems. The multiple cause scenarios developed for both the short and long term are presented in Appendix C.

Question 3: Please evaluate probabilities and severities and consequences (including costs) resulting from those scenarios

To evaluate the probabilities, severities and consequences, experienced workshop participants reviewed the hazards and risks from the FSA Trees and further examined consequences, probabilities and severities through Failure Modes Effects Criticality Analysis (FMECA). The risks were broken down into detail and were given a rating for the likelihood of occurring, and a risk rating for public safety, environment and cost consequences. If the scenario posed risks at a level of moderate to high, mitigating measures / design elements were applied and the risk rating was re-evaluated. The FMECA tables for the major systems are presented in Appendix D of the attached report.

Question 4: Please describe how failures of individual components would affect the larger systems they are a part of

The first of three risk workshops arranged developed Component FSA Trees which summarizes how a component failure can affect an overall system of the Giant Mine project. Appendix A of the attached report presents these component FSA trees for the various systems and looks at risk in both the short and long term.

Question 5: Please describe probabilities, severities and consequences (including costs) for the events discussed in section 10 plus any additional long-term risks identified (see point 1, above).

To evaluate the probabilities, severities and consequences discussed in section 10, the workshop participants reviewed the risks from the FSA Trees and further examined consequences, probabilities and severities through FMECA. The risks were broken down into detail and were given a rating for the likelihood of occurrence, and a risk rating for public safety, environment and cost consequences. If the scenario posed risks at a level of moderate to high, mitigating measures / design elements were applied and the risk rating was re-evaluated. The FMECA tables for the major systems are presented in Appendix D of the attached report.

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Agency or Organization

Public Works and Government Services Canada

Failure Mode Effects Criticality Analysis (FMECA) - Giant Mine Remediation – Mackenzie Valley Environmental Impact Review Board – Information Request 12 Response

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Revision Log

Revision #	Revised By	Date	Issue / Revision Description
0	-	June 8, 2011	DRAFT Report
1	Jennifer Singbeil	June 16, 2011	FINAL DRAFT Report
2	Larissa Wall	June 17, 2011	FINAL Report
3	Michelle Wainwright	November 8, 2011	FINAL Report

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Appendices

1. Introduction

Giant Mine is an abandoned gold mine which is currently under the care and maintenance of Indian and Northern Affairs Canada (INAC) while preparations are made to implement the long term remediation plan for the site. The Giant Mine Remediation project Developer's Assessment Report (DAR) (SRK, 2010) is currently under review by the Mackenzie Valley Environmental Impact Review Board (MVEIRB). The DAR outlines the overall remediation plan for all aspects of the site. In addition, the preliminary design is currently being developed to expand on the overall plan outlined in the DAR. The DAR includes Section 10 which assesses risks associated with the remedial plan outlined in the DAR for the first 25 years of implementation.

1.1 Scope

The scope of this report is to address requests for information which were raised during the MVEIRB review of the Giant Mine Remediation plan outlined in the DAR. The purpose of this report is to address the Information Requests (IR) on the subject of risk by expanding on the risk assessment completed as part of the DAR development and completing a Failure Mode Effects Criticality Analysis (FMECA). AECOM Canada Ltd. (AECOM) and Golder Associates Ltd. (Golder) developed this report, which is a summary and compilation of risks identified and assessed in workshops by a number of participants.

1.2 Information Request (IR)

Information Request #12 was developed by the MVEIRB Review Board and includes 5 questions which are listed below.

1. Please identify risks for the life of the project, beyond those occurring during initial development activities.
2. Please identify scenarios for events in short and long-term which could cause multiple failures of components of the project.
3. Please evaluate probabilities and severities and consequences (including costs) resulting from those scenarios.
4. Please describe how failures of individual components would affect the larger system they are part of.
5. Please describe probabilities, severities and consequences (including costs) for the events discussed in section 10 *(of the DAR)* plus any additional long term risks identified (see point 1 above).

This report supports responses to the above questions.

1.3 Workshops

Three workshops were held for the purpose of identifying and assessing risks. The following was the overall purpose of the workshops.

Develop sequences of events over the short and long term that may lead to component failures and consequential losses. Identify the causes of key component failure. Describe or develop mitigation measures or safeguards included in the remedial design and management system to manage, mitigate or prevent these failures.

There were three workshops held to achieve the overall purpose. The workshop details are listed below including a list of participating agencies. A detailed list of those that attended on behalf of each agency is attached in Appendix E.

Workshop 1:

- March 22 to 24, 2011 in Vancouver
- Participants: INAC, PWGSC, Department of Justice (DOJ), Golder, and AECOM.

Workshop 2:

- April 4 to 6, 2011 in Vancouver
- Participants: INAC, PWGSC, DOJ, Golder, AECOM, and SRK Consulting (SRK).

Workshop 3:

- May 30 and 31, 2011 in Edmonton
- Participants: INAC (including technical advisor, Brodie Consulting), PWGSC, Golder, and AECOM

The first workshop included a brainstorming session to identify events and major component failures. Participants expanded on the consequences of each of the events identified and developed the first draft of the Failure Scenario Analysis (FSA). Components which could result in major system failure were also identified in the FSA format. Failure scenarios were developed through trees indentifying the sequence of events in the scenario. These failure scenarios were used in the second workshop to analyze the risk associated with these scenarios. The third workshop reviewed these risks as it applied to the short term and long term scope of the Giant Mine Project. Risk mitigating measures were included in the risk estimates, and where appropriate, additional measures were recommended and the risk was re-assessed.

2. Risk Assessment Framework

2.1 Risk Timeline

2.1.1 Short Term

Short term risks, as defined for the purpose of this risk assessment, are risks which occur during the implementation of the Giant Mine Remediation project. This timeline begins on day one of the remediation contract for that specific system or component and ends when steady state has been achieved, for an approximate duration of 25 years. The Giant Mine Remediation project will involve a series of remediation contracts which may not occur simultaneously, therefore the short term risk timeline may vary from one system or component to another.

For example, the short term timeline for the existing structure demolition would begin on day one of the demolition contract and would be complete once all the existing structures are decontaminated, demolished and the waste sorted, transported and disposed of. The short term timeline for structural demolition may be less than the general 25 year timeline, depending on the sequencing of demolition.

2.1.2 Long Term

The risk of events which could occur after steady state is achieved is defined as long term for the purpose of this assessment. This timeline begins after steady state is achieved and continues in perpetuity. However, the identification and assessment of these risks is limited to what the assessment team can envision for the next 100 years based on the current remediation plan. This 100 year period is the time in which the remedial components are expected to function within specified parameters with ongoing maintenance. This time frame does include low probability events, such as a 1 in 500 year rainfall event. If the remediation plan is changed, or at some future point a new remediation technology is implemented, the long term risks would require reassessment.

2.2 Assumptions

Risks were identified and assessed within the scope of this report in the context of the following general assumptions. Any specific assumptions for a particular failure mode or scenario are included in Section 3.4 of this report.

2.2.1 Permits

All required permits or other approvals are assumed to have been attained prior to the start of project implementation. Delays as a result of permit or approval application have not been included into the short term timeline for the risks identified and assessed. Risks associated with permits and approvals have not been included in the scope of this assessment.

2.2.2 Funding

Funding for the remediation is assumed to be in place prior to project implementation. Delays in the project and the risks to the project as a result of funding delays have not been assessed, except as a total project failure scenario in the assessment of institutional failures.

2.2.3 Care and Maintenance

The scope of this risk assessment does not include the care and maintenance period and the risks which could occur before the start of the short term risk timeline. It is assumed that care and maintenance will continue until project implementation and that the remediation contracts will overlap with the care and maintenance contract and all systems would be maintained as per current standards until the implementation starts.

2.2.4 Worker Health and Safety

Worker health and safety is not included in this assessment. Worker health and safety will change based on the methods for completing the work, which the remediation contractor will decide. The assumption is that worker health and safety will be assessed once the detailed remediation design is completed and all tasks would be performed with appropriate health and safety plans by staff with appropriate training, in compliance with the applicable regulations (eg. NWT Mine Health & Safety Act).

2.3 Definitions

The following terms are defined to closely align with the Developer's Assessment Report (DAR) (SRK, 2010) and to remain consistent with language used in the IR. These definitions will be used to describe the possible risks to maintain consistency throughout this assessment.

2.3.1 Initializing Event / Cause

An initializing event or cause is the root of all failure scenarios and is the cause of system or component failure. An initiating event can lead to either an accident or malfunction and includes natural events, technological causes, or human error. A list of major initiating events or causes assessed for the Giant Mine Remediation project is included in Section 2.4 of this report.

2.3.2 Accident

An accident is an unplanned event which leads to system or component failure. An accident could be a result of a specific initiating event or cause. Examples of accidents include extreme weather, human error and traffic accidents. Prevention measures could be implemented to decrease the likelihood of an accident and mitigating measures could be implemented to reduce the effects of an accident.

2.3.3 Malfunction

A malfunction is the failure of a system, component or sub-component (eg. equipment) to function in a manner for which it was intended. A malfunction can result from an initiating event or cause as defined above.

2.3.4 Credible Event

A reasonable probability of occurrence based on professional judgement in the context of project-specific conditions.

2.3.5 Failure Scenario

A failure scenario is a specific sequence of events starting with an initiating event or cause which leads to system or component failure and corresponding impacts from that failure.

2.3.6 Cascading Events Scenario

A cascading events scenario starts with one initiating event or cause which causes the failure of multiple systems or components.

2.3.7 Multiple Cause Scenario

A multiple cause scenario starts with two or more unrelated initiating events or causes which occur simultaneously and cause the failure of systems or components.

2.3.8 System Failure

A system failure within the Giant Mine Remediation project is a major design or operating system that can no longer perform its function as required. System failures have the largest impact on the integrity of the project and are major remediation design elements. Each system has the potential to fail through a variety of initiating events or causes. A list of systems assessed for the Giant Mine Project is included in Section 2.5 of this report.

2.3.9 Component Failure

A component failure within the Giant Mine Remediation project occurs when one or more parts or components of a system can no longer perform its function as required. A list of all components assessed for the Giant Mine Project is included in Section 2.5 of this report.

2.3.10 Mine Water Treatment Plant (Mine WTP) and Effluent Treatment Plant (ETP)

The Effluent Treatment Plant (ETP) is the current treatment plant at the Giant Mine Site. This treatment plant is operational only seasonally. In the short term the ETP will be operational while the new Mine Water Treatment Plant (Mine WTP) is being constructed. The Mine WTP will be operational on a full time basis in the long term as part of the Water Management System.

2.4 Initiating Events at Giant Mine

The following have been identified as the major initiating events (accidents) or causes of failure scenarios at the Giant Mine Remediation project. These initiating events may cause other accidents or malfunctions, which in turn impact systems and components of the project. .

1. Environment (Extreme Weather)
2. Flood
3. Forest Fire
4. Power Failure
5. Seismic
6. Climate Change

2.5 Systems and Components at Giant Mine

The following have been identified as the seven major systems and associated components/subcomponents of the Giant Mine Remediation project.

1. Water Management System
   - A. Water Storage
   - B. Piping
   - C. Existing Effluent Treatment Plant (ETP)
     - i. Settling/Polishing Pond
   - D. Mine Water Treatment Plant (eg. Chemical supply for operation)

   E. Diffuser
   F. Pumps
   G. Bay Assimilation Capacity (eg. Loss of capacity in receiving environment)

2. Underground System
   A. Arsenic Chambers/Stopes
   B. Non-arsenic Chambers/Stopes
   C. Crown Pillars/Sills
   D. Backfill

3. Baker Creek System
   A. Banks
   B. Creek Beds (Stability)
   C. Stream Channel
      i. Ice damming
      ii. Blockages (Beaver Dams)

4. Freeze System
   A. Freeze Implementation
      i. Freeze Plant
      ii. Passive Cooling Infrastructure Component
   B. Drill Holes
   C. Frozen Shell
   D. Frozen Block
      i. Passive Freezing (Monitoring System)
   E. Intentional Thaw

5. Surface System
   A. Tailings
      i. Cover
      ii. Dam
      iii. Spillways
   B. Open Pits/ Surface Openings
      i. Site Security
   C. Highway

6. Buildings (Short Term Only)
   A. Roaster
   B. Mill
   C. Stack

7. Institutional System (Management of the Project)

2.6 Risk Assessment Methods

The following sections describe the methods used to assess risk over the short and long term that have the potential to lead to system failure, component failures and consequential losses. These methods identify key initiating events or causes and identify the potential impacts of system or component failures. Failure scenarios for each system are then assessed for likelihood and severity of impact to public health, the environment and cost. A combination of the likelihood and severity of impact is used to categorize the risk associated with that particular failure scenario. Where appropriate, a description of possible mitigation measures is included and a reassessment of the risk is completed.

2.6.1 Failure Scenario Analysis (FSA)

2.6.1.1 Description of FSA

As described in Canadian Standards Association's Risk Analysis Requirements and Guidelines (CSA, 1991), Failure Scenario Analysis (FSA) is a method of identifying and organizing conditions and/or factors that can contribute to a specific undesired event. In this method, there is one initiating event (the root) with connecting accidents or malfunctions that lead to system or component failures that are caused by the root event. Failure Scenario Analysis (FSA) allows for a systematic analysis of how a variety of factors relate directly to the initiating event.

2.6.1.2 Process

The following steps outline the process of the FSA method.

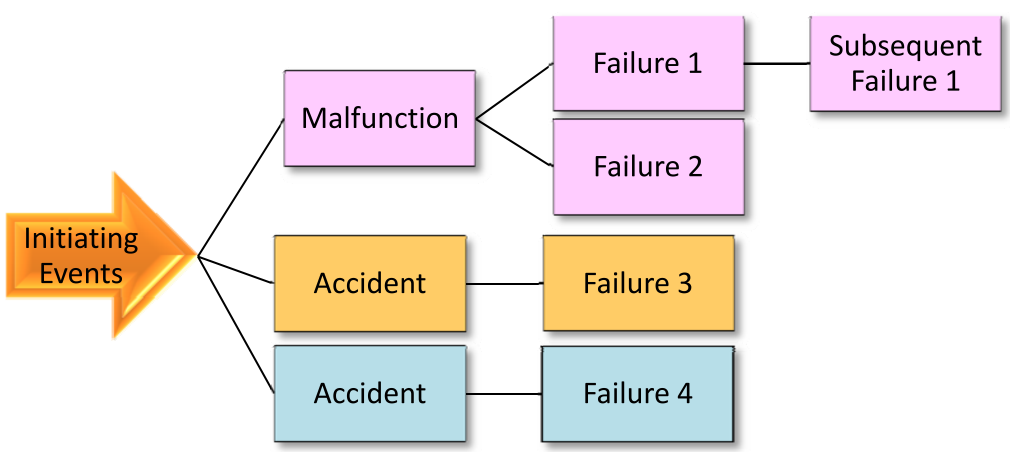
1. Defining the undesired event to study;
2. Obtaining an understanding of the system;
3. Constructing a tree linking the scenario events;
4. Evaluating the tree; and
5. Identifying failure scenario controls (prevention and/or mitigating controls)...

The FSA process was completed at the first risk workshop, as described in Section 1.3. Participants of this workshop identified the initiating events as well as the major systems and components failures of the Giant Mine Remediation project.

2.6.1.3 Failure Scenario Tree

One of the advantages of using an FSA approach is the ability to clearly illustrate the sequence of events that can take place or are required to take place for a failure to occur. This method effectively illustrates how resistant a system is to single or multiple initiating events. Figure 1 displays an example of the layout of an initiating event failure tree.

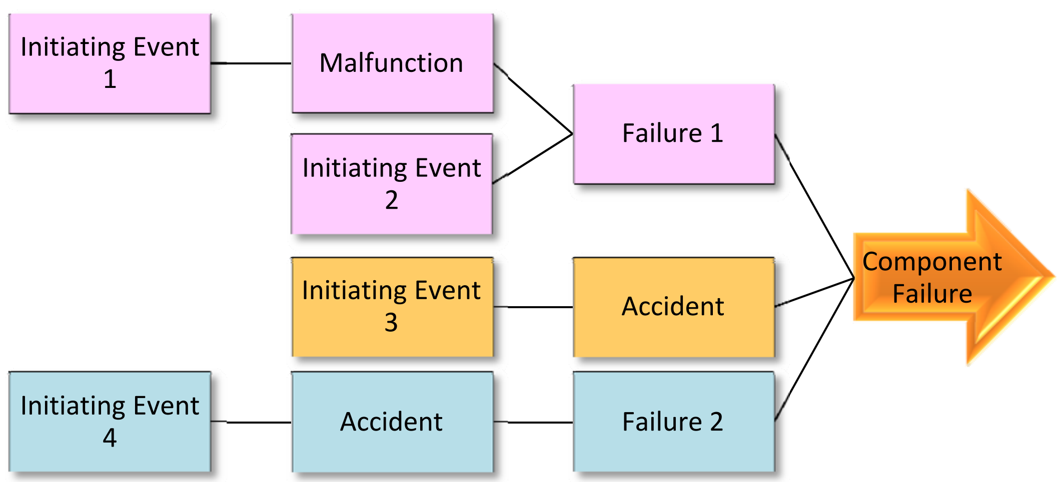
Figure 1: Initiating Event Failure Tree



This method distinguishes time frames of the malfunction/accident being analyzed. The same malfunction can have different results depending on whether it has occurred in the short term period of the project or the long term. To decipher between these, pink events occur in the short term, blue events occur in the long term, and orange events occur in both short and long term.

This method of analysis was also used to identify various credible initiating events and malfunctions/accidents that can lead to one of the components of the Giant Mine to fail. Figure 2 illustrates this layout of a component failure tree. The advantage to using this layout is it provides insight to all the different ways the major components can fail.

Figure 2: Component Failure Tree



2.6.2 Failure Mode Effects Criticality Analysis (FMECA)

This section is an adaptation of Golder Associates, Introduction to the Systems FMECA Method for Risk Assessment. (Golder, 2011)

2.6.2.1 Description of FMECA

<u>*Overview*</u>

The Systems Failure Modes and Effects Criticality Analysis (FMECA) method is an adaptation of the FMEA method originally developed to assess the detailed risk associated with parts and components of equipment. This adaptation includes studying large systems, rather than small components, identifying risk mitigation measures, estimating and ranking the risk using the risk matrix and documenting the results in the FMECA tables. The Systems FMECA method covers all of the standard risk assessment steps.

The Systems FMECA method allows teams of experienced personnel to evaluate large systems by identifying analysis objectives, analysis processes, and failure modes. Credible failure modes and their associated consequences were first identified using an assessment protocol and the knowledge base of the risk assessment team. Controls and/or design elements to mitigate risk were also identified. Public safety, environment, and cost risk (as defined in the objectives) was estimated for each failure mode and associated consequence using a risk matrix approach.

Team Workshop

The Systems FMECA method was based on a team of experienced personnel assessing risks in a systematic workshop process. The team for Giant Mine included AECOM, Golder, SRK, PWGSC, INAC, and DOJ representatives as detailed in Section 1.3 of this report. The experience of team members, along with key documents, provided the knowledge base and the workshop format provided a method to build synergies given the wide range of experience and knowledge.

Analysis

The first step in risk analysis involved defining the objectives and context for the assessment. Objectives focused on the assessment of specific impacts that may include any number of risks to the public, the environment, or cost. The scope of the analysis defined the system and how it can be divided into principal units to be analyzed separately (and then as a complete system).

A Systems FMECA is a comprehensive process designed to identify potential significant and credible “failure modes” associated with the system being assessed (e.g., an operating facility assessed unit by unit). The “failure mode” describes how a system may fail and includes all possible causes ranging from natural events, such as earthquakes to equipment failures, operator errors, and management system deficiencies. Potential public safety, environment, or cost “effects”, as defined in the study objectives, are also identified for each failure mode. For example, environmental “effects” may be measured in terms of environmental clean-up costs following a release from a facility. A series of events usually needs to occur before a “failure mode” results in an “effect,” and therefore the complete series of events or failure scenario is assessed. Following the identification of this series of events, the risk or “criticality” is estimated using a Risk Matrix approach described in Section 2.6.2.2.

2.6.2.2 Risk Matrix

For each of the significant failure modes and corresponding consequences (failure scenarios) identified in the Systems FMECA, a measure of the associated risk was estimated using risk matrix methodology. A risk matrix is comprised of one index representing the measure of frequency and another index representing the measure of consequence severity. When a failure mode and consequence scenario was identified, the associated risk was estimated by locating it within the risk matrix.

A number of attributes of the risk matrix are illustrated in Figure 3.

Figure 3: Risk Matrix Format

	CATEGORY	CONSEQUENCE SEVERITY				
		A) Low	**B) Minor**	**C) Moderate**	**D) Major**	**E) Critical**
	I) Public Safety	Low-level short-term subjective symptoms/ No measurable physical effect/ No medical treatment	Objective but reversible disability/impairment and/or medical treatment injuries requiring hospitalization	Moderate irreversible disability or impairment to one or more people	Single fatality and /or severe irreversible disability or impairment to one or more people	Multiple fatalities
	II) Environment	No impact	Minor localized or short-term impacts	Impact on valued ecosystem component	Impact on valued ecosystem component and medium-term impairment of ecosystem function	Serious long term impairment of ecosystem function
	III) Cost ($)	<100,000	100,000-1M	1.0M-10M	10M-50M	>50M
LIKELIHOOD						
Index	**Event/Years**					
1	**More than once every 5 years**					
2	**Once every 15 years**					
3	**Once every 30 years**					
4	**Once every 100 years**					
5	**Once every 1000 years**					

Increasing Risk

Likelihood Index

As shown in Figure 3, the likelihood or frequency index on the left of the matrix ranges from a “1” (Frequent) to a “5” (Infrequent) event and is more formally defined in terms of frequency with an events/year value. The index is divided into orders of magnitude with the expectation that the knowledge base of the team and the historical industry performance record will be sufficient to estimate the level of risk to this accuracy.

Consequence Categories

In this matrix, 3 categories of consequences have been assessed for the Giant Mine Remediation project; public safety, environment, and cost.

The severity of effects for each category of consequence is defined by an index ranging from “Low” to “Critical.” These indices are detailed with the definitions used for this risk assessment workshop. In total, there are three separate risk matrices shown in Figure 3 (one for each consequence category), and each failure scenario would be located in one or more of these three matrices as appropriate.

Risk Evaluation

Risk evaluations were completed following the identification of risk scenarios and measurement of consequences. The evaluation of risk requires determining the acceptability of risk as defined through the different locations (or risk values) within the risk matrix developed for the risk assessment.

The criteria for evaluating risks were developed for the risk management program and were useful for comparing risks, such as those among different operations, or for prioritizing risks. The risk matrix shown in Figure 3 was divided into five groups representing the criteria for managing risks. These groups were color-coded from Green (lowest risk) to Yellow to Orange to Red to Dark Red (highest risk).

The high priority risk level (color-coded dark red and red) may be associated with a management action to “Reduce Risk.” Action steps may involve more detailed study to improve the risk estimate and determine if it is actually lower than estimated.

The intermediate risk levels (color-coded orange and yellow) may be associated with various management actions to “Reduce Risk as Appropriate” and involve balancing the cost of mitigating risk with the benefits received. Action steps may again involve further study to improve the risk estimate. They may also include prioritizing the application of resources according to the identified risks and implementing measures to decrease risk either by decreasing frequency, consequences, or a combination of the two. The risk matrix illustrates this concept of reducing risk. Different cost implications are often associated with the choice of decreasing frequency, consequences, or a combination of the two.

The lowest risk level (color-coded green) may be associated with the management action to “Monitor and Control Risk” and involve accepting the risk as long as it is both monitored and controlled to ensure it does not creep up to the next level.

2.6.2.3 FMECA Table

Results from the Systems FMECA are documented in an FMECA Table that includes the following information:

- System, unit description
- Component / Subcomponent
- Risk Issue / Failure
- Event / Causes
- Potential Consequences (one or more for each failure mode)
- Risk Estimate
- Planned Mitigation / Controls / Management Measures
- Evaluation
- Residual Risk Estimate according to frequency and consequence location in each risk matrix

A schematic of the FMECA Table format used, with an example for one failure scenario, is presented in Figure 4 below.

Figure 4: FMECA Table Format

ID	COMPONENT	SUBCOMPONENT	RISK ISSUE / FAILURE	EVENT/CAUSES	POTENTIAL CONSEQUENCES	LIKELIHOOD	CONSEQUENCE SEVERITY			PLANNED MITIGATION/CONTROLS/ MANAGEMENT MEASURES	EVALUATION	LIKELIHOOD	CONSEQUENCE SEVERITY			Confidence Estimate
							Public Safety	Environment	Cost				Public Safety	Environment	Cost	
Short Term																
SS-4	Ditches		Accident: Flooding	Extreme rainfall	Sediment discharge, erosion and sediment release to Baker Creek.	3	A	C	B	Ditches will be upgraded to final design standard including rip-rap cover treatment on erodible fine material.	Erosion and sediment control during construction will reduce the risk of sediment releases.	4	A	C	B	High

As shown, the above table documents a description of the failure scenario including existing safeguards, an estimate of the residual risk for all relevant categories, and any further comments or background on uncertainty associated with the assessment. Where appropriate, a follow up risk rating classification was completed after mitigating measures were assessed. Uncertainty in the assessment (or risk rating) as a result of knowledge base, random process, etc., are described qualitatively through the confidence index column (high, medium, or low).

3. Risk Assessment Results

3.1 Identified Risks for the Giant Mine Remediation Project

3.1.1 Short and Long Term FSA

The Failure Scenario Trees developed in the first workshop are included in Appendix A. These trees summarize credible failure scenarios relevant to the Giant Mine Remediation project. They identify both the effects of initiating events on the overall project as well as the impact component failure has on overall systems of Giant Mine.

These Failure Scenario Trees address Question 1 of IR 12, as they identify the risk events for this project in both the short and long term. The component failure trees address Question 4 of IR 12, as they identify how a component failure can affect an overall system of the Giant Mine project.

These trees were used as a basis to develop the failure scenarios, cascading event scenarios, and multiple cause scenarios assessed in the FMECA tables.

3.2 Cascading Events Scenarios

Cascading events refer to the series of accidents and malfunctions that may occur because of one initiating event. One malfunction may cause another series of malfunctions which in turn can cause other undesirable results. The time period of occurrence (during the short or long term) also has an influence on end results.

These cascading events scenarios for both the short and long term time frames are summarized in the tables included in Appendix C.

The information in the tables addresses Question 2 of IR 12, as they identify multiple failure scenarios for both system and components at Giant Mine in both the short and long term.

3.3 Multiple Cause Scenarios

Multiple cause scenarios are specific fault scenarios which include two or more initiating events occurring simultaneously. These fault scenarios have a low likelihood of occurring because the likelihood of two unrelated causes happening simultaneously is lower than that of the causes happening separately.

The identified multiple cause scenarios, included in Appendix D, focus on the freeze system and the water management system. These are generally the systems which are associated with higher ratings for risk and will continue to operate in the long term.

The information in these tables addresses Question 2 of IR 12, as they identify additional multiple failure scenarios in the short and long term for both system and components.

The cascading events and multiple cause scenarios include a link in the tables to the appropriate FMECA risk assessment for that scenario.

3.4 Likelihood and Consequence Severity of Identified Failure Scenarios

3.4.1 Short and Long Term FMECA

The information in the FMECA tables addresses Questions 3 and 5 of IR 12. This assessment was completed for the failure scenarios identified by the following methods:

1. The FSA;
2. The cascading event scenarios; and
3. The multiple cause scenarios.

The FMECA tables are included in Appendix B of this report. These tables are organized by major project system and the short and long term risks for that system are included in the same table.

In failure scenarios where risks were moderate to high, additional mitigating measures were recommended and the risk estimate was re-evaluated. If the risk estimate for a fault scenario was low to moderate mitigating measures may have been recommended but a re-evaluation of the risk rating was not completed.

3.5 Summary

The assessment of risk for the Giant Mine Remediation project was completed by utilizing a Failure Scenario Analysis (FSA) and a Failure Modes and Effects Criticality Analysis (FMECA) which follow the reference Canadian Standards Association Risk Analysis Requirements and Guidelines (CSA, 1991). Workshops were held to carry out this risk assessment be identifying the major systems and components for the Giant Mine Remediation project, developing associated failure scenarios and assessing the associated risks.

The FSA method identified failure scenarios for specific initiating events and failure scenarios for specific components, which effectively identifies risks in the short and long term for the Giant Mine Remediation Project. The FSA method was used to develop failure scenarios, cascading event scenarios, and multiple cause scenarios. These scenarios were then assessed using the FMECA method. The FMECA tables are organized according to the major project systems identified in this assessment, listed below.

- Underground System
- Freeze System
- Baker Creek System
- Surface System
- Water Management System
- Institutional System (Management of the project)
- Buildings (Short Term Only)

If the FMECA tables assigned risk levels as moderate to high, additional mitigating measures were recommended and the risk estimate was re-evaluated. As a result of applying the mitigation, the re-evaluated risk generally decreased, either through a decrease in the likelihood of the failure or a decrease in impacts to the public, environment and/or cost.

The purpose of this assessment was to identify risks which impact the overall objective of the Giant Mine Remediation Project, which include:

- Manage the underground arsenic trioxide in a manner that will minimize the release of arsenic to the surrounding environment, minimize public and worker health and safety risks during implementation, and be cost effective and robust over the long term;
- Remediate the surface of the site to the industrial use guidelines under the NWT *Environmental Protection Act*, recognizing that portions of the site will be suitable for other land uses with appropriate restrictions;
- Minimize public and worker health and safety risks associated with buildings, mine openings, and other physical hazards at the site; and
- Restore Baker Creek to a condition that is productive as possible, given the constraints of hydrology and climate.

4. References

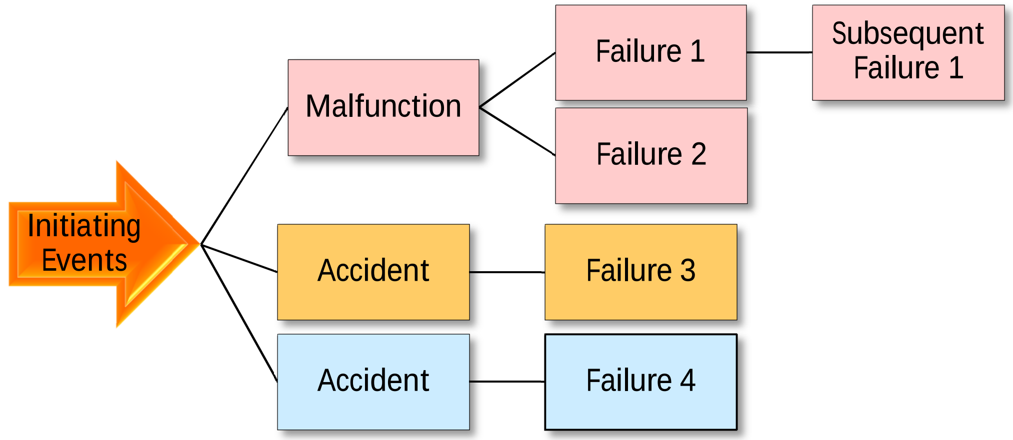
SRK Consulting (SRK), 2010. Giant Mine Remediation Project Developer’s Assessment Report, EA0809-001, October 2010.

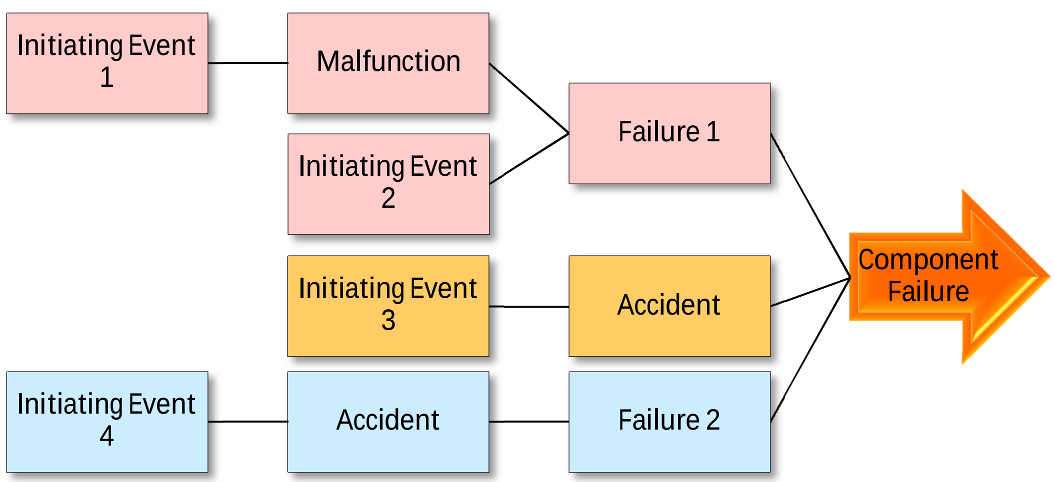
Canadian Standards Association (CSA), 1991. Risk Analysis Requirements and Guidelines. CAN/CSA-Q634-91. November 1991.

Golder Associates Ltd. (Golder), 2011. Introduction to the Systems FMECA Method for Risk Assessment.

Appendix A

Failure Scenario Analysis (FSA)

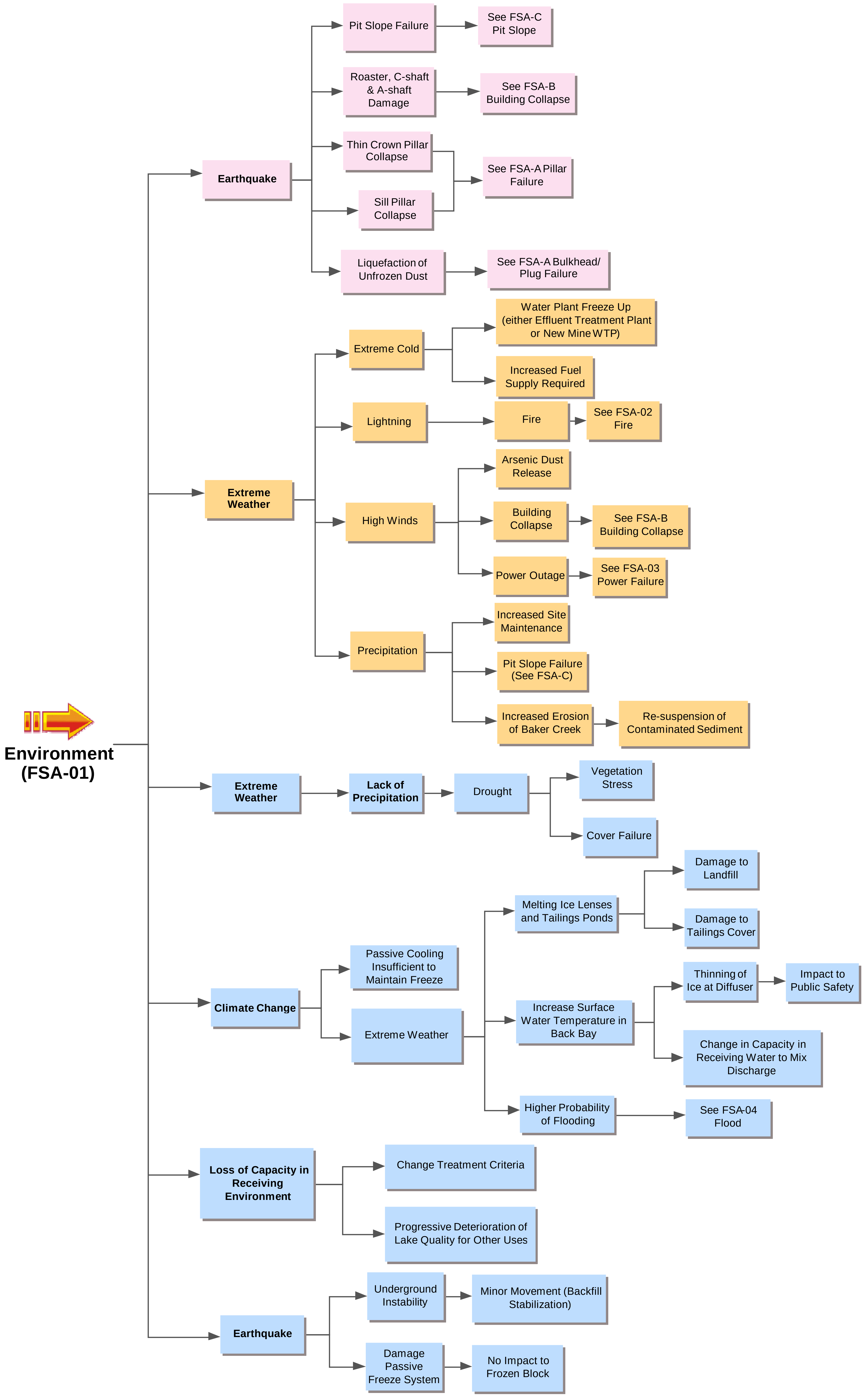




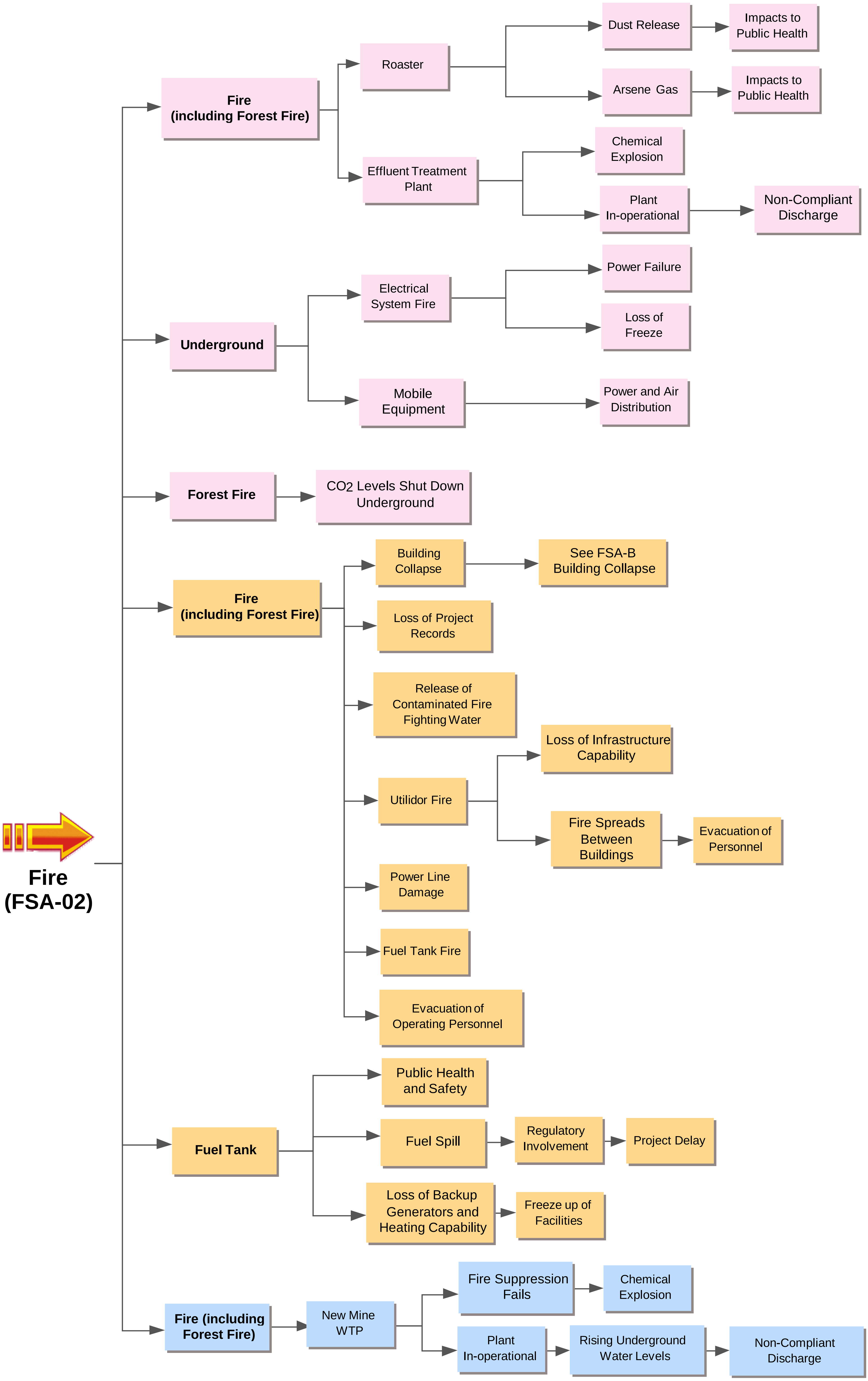
Pink events are relevant in the short term

Orange events are relevant in short and long term

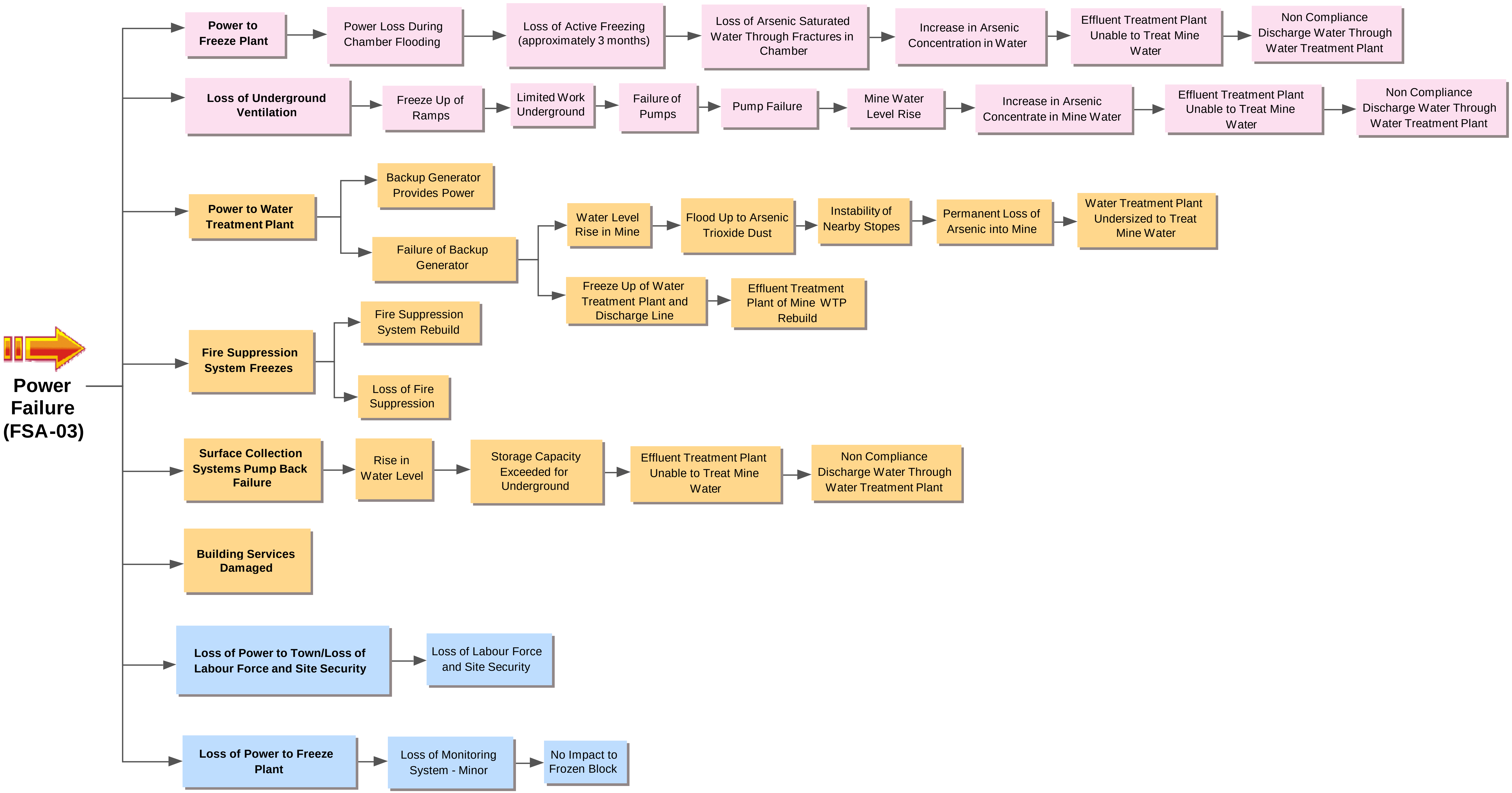
Blue events are relevant in the long term

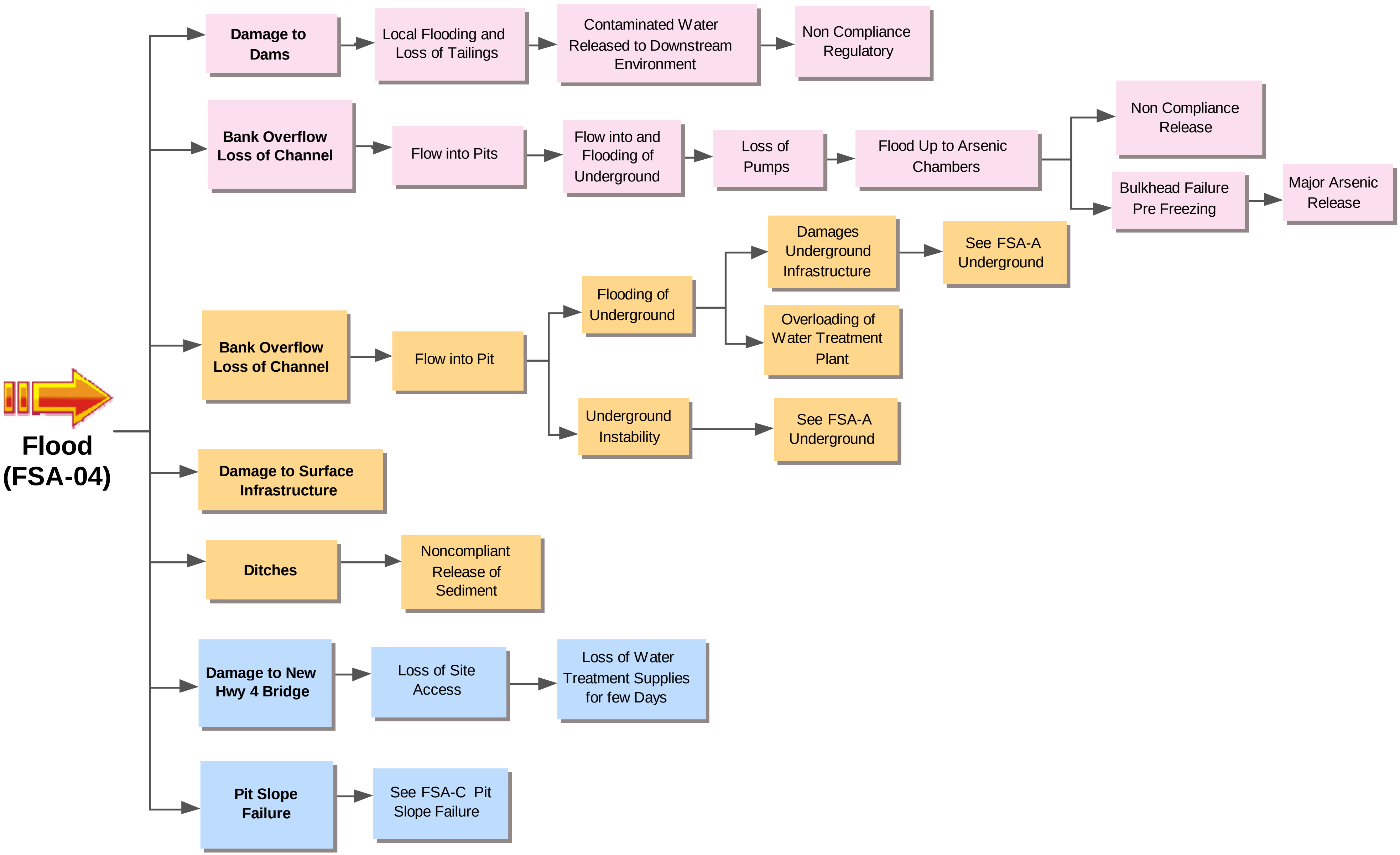


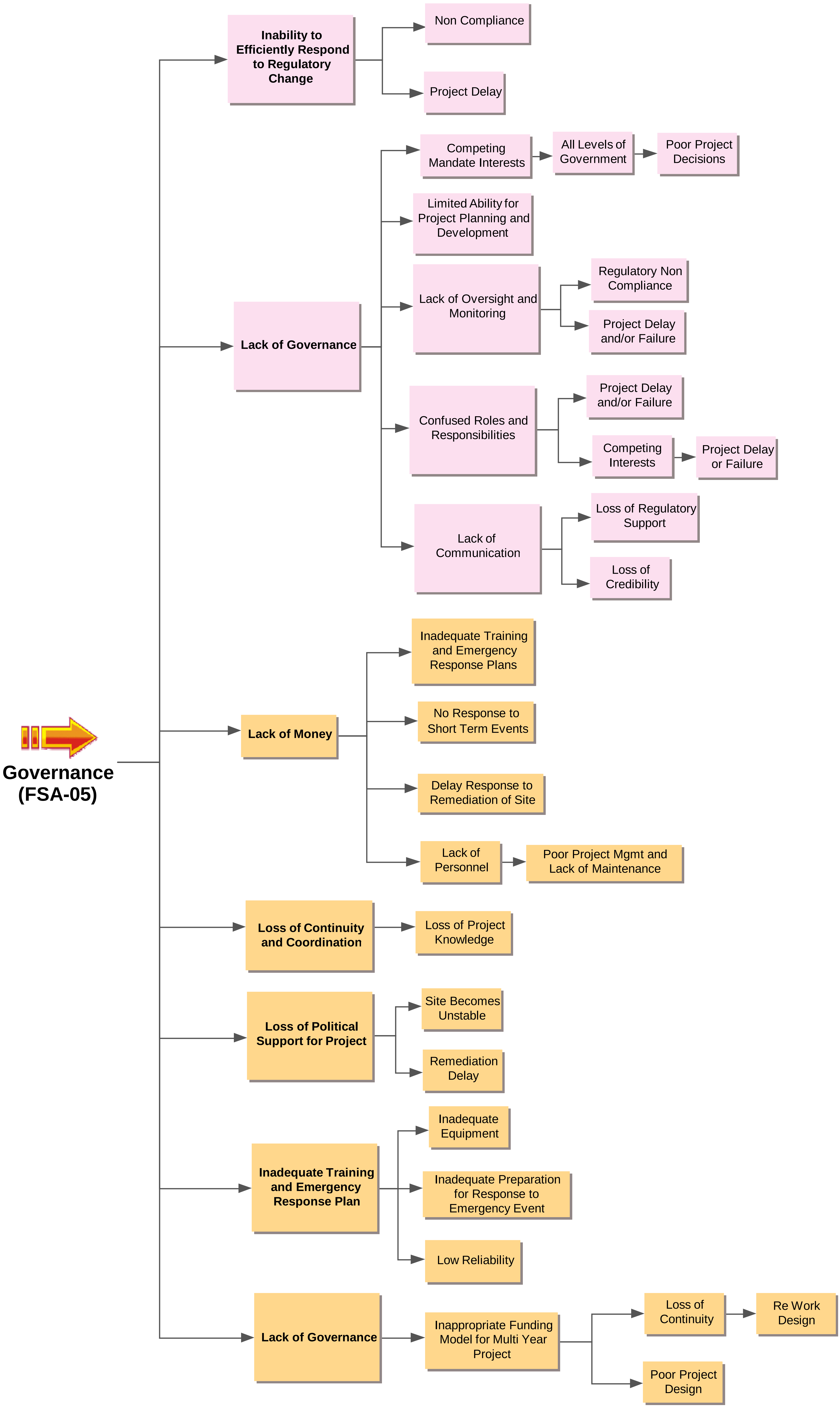
Environment (FSA-01)
Earthquake
Pit Slope Failure
See FSA-C Pit Slope
Roaster, C-shaft & A-shaft Damage
See FSA-B Building Collapse
Thin Crown Pillar Collapse
Sill Pillar Collapse
See FSA-A Pillar Failure
Liquefaction of Unfrozen Dust
See FSA-A Bulkhead/ Plug Failure
Extreme Weather
Extreme Cold
Water Plant Freeze Up (either Effluent Treatment Plant or New Mine WTP)
Increased Fuel Supply Required
Lightning
Fire
See FSA-02 Fire
High Winds
Arsenic Dust Release
Building Collapse
See FSA-B Building Collapse
Power Outage
See FSA-03 Power Failure
Precipitation
Increased Site Maintenance
Pit Slope Failure (See FSA-C)
Increased Erosion of Baker Creek
Re-suspension of Contaminated Sediment
Extreme Weather
Lack of Precipitation
Drought
Vegetation Stress
Cover Failure
Climate Change
Passive Cooling Insufficient to Maintain Freeze
Extreme Weather
Melting Ice Lenses and Tailings Ponds
Damage to Landfill
Damage to Tailings Cover
Increase Surface Water Temperature in Back Bay
Thinning of Ice at Diffuser
Impact to Public Safety
Change in Capacity in Receiving Water to Mix Discharge
Higher Probability of Flooding
See FSA-04 Flood
Loss of Capacity in Receiving Environment
Change Treatment Criteria
Progressive Deterioration of Lake Quality for Other Uses
Earthquake
Underground Instability
Minor Movement (Backfill Stabilization)
Damage Passive Freeze System
No Impact to Frozen Block

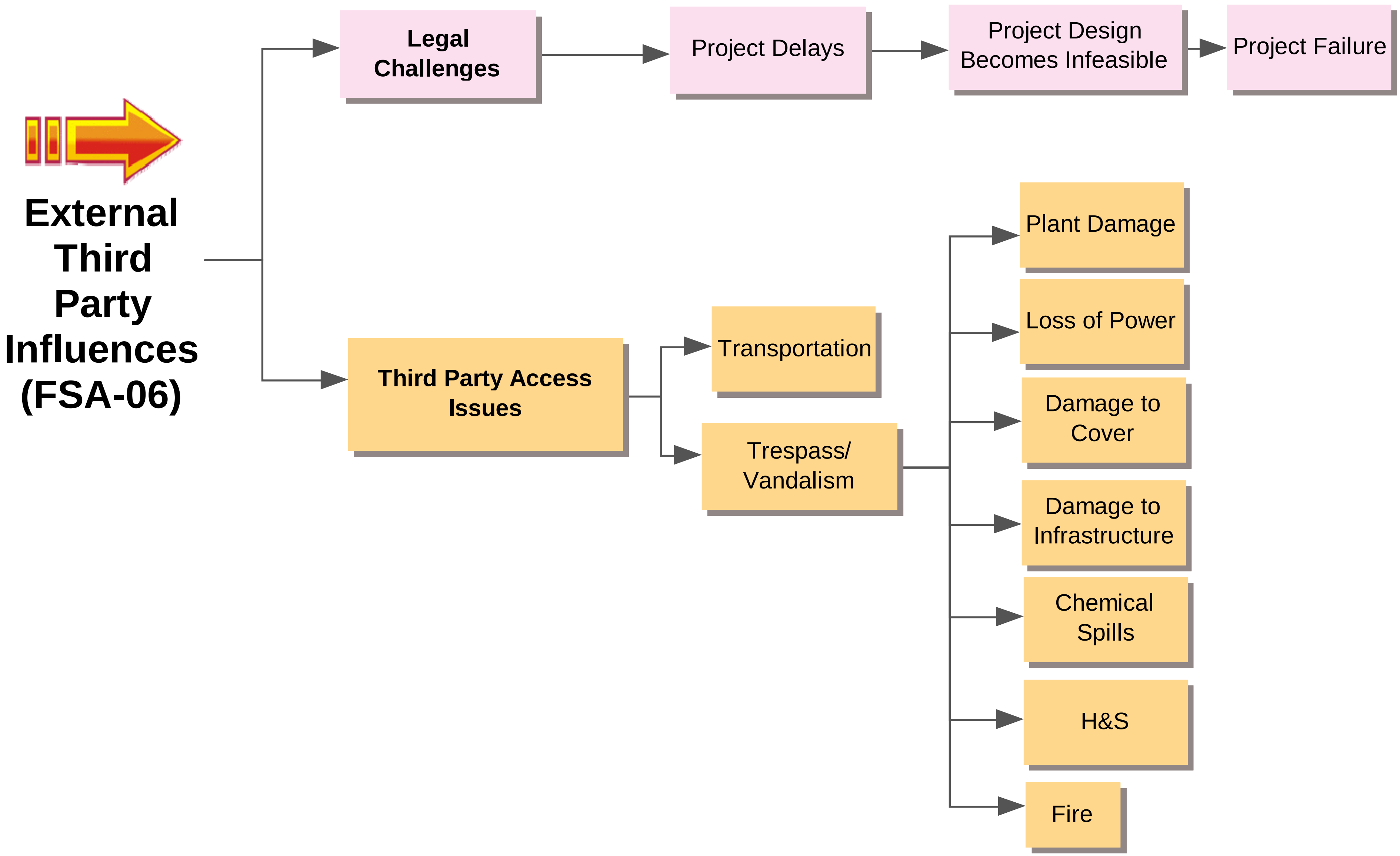


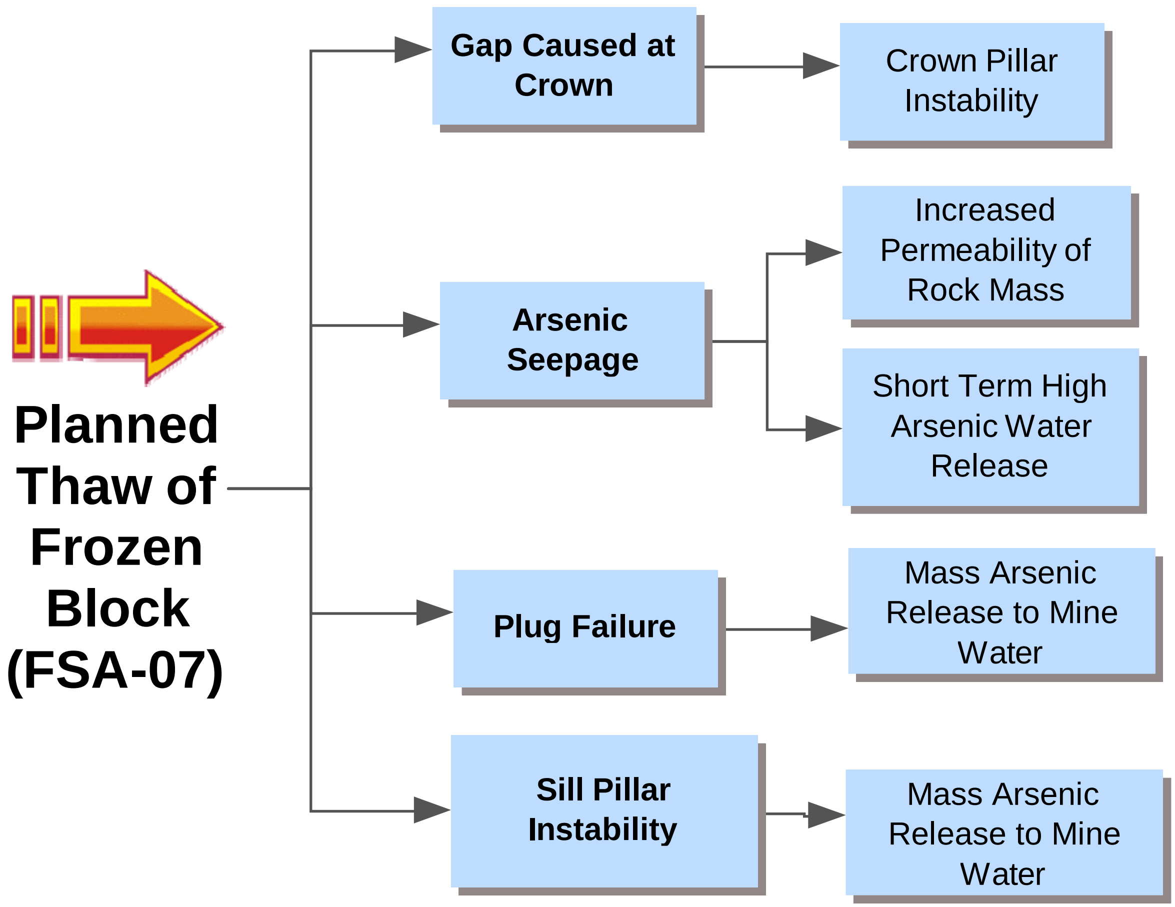
Fire (FSA-02)
Fire (including Forest Fire)
Roaster
Dust Release
Impacts to Public Health
Arsene Gas
Impacts to Public Health
Effluent Treatment Plant
Chemical Explosion
Plant In-operational
Non-Compliant Discharge
Underground
Electrical System Fire
Power Failure
Loss of Freeze
Mobile Equipment
Power and Air Distribution
Forest Fire
CO2 Levels Shut Down Underground
Fire (including Forest Fire)
Building Collapse
See FSA-B Building Collapse
Loss of Project Records
Release of Contaminated Fire Fighting Water
Utilidor Fire
Loss of Infrastructure Capability
Fire Spreads Between Buildings
Evacuation of Personnel
Power Line Damage
Fuel Tank Fire
Evacuation of Operating Personnel
Fuel Tank
Public Health and Safety
Fuel Spill
Regulatory Involvement
Project Delay
Loss of Backup Generators and Heating Capability
Freeze up of Facilities
Fire (including Forest Fire)
New Mine WTP
Fire Suppression Fails
Chemical Explosion
Plant In-operational
Rising Underground Water Levels
Non-Compliant Discharge

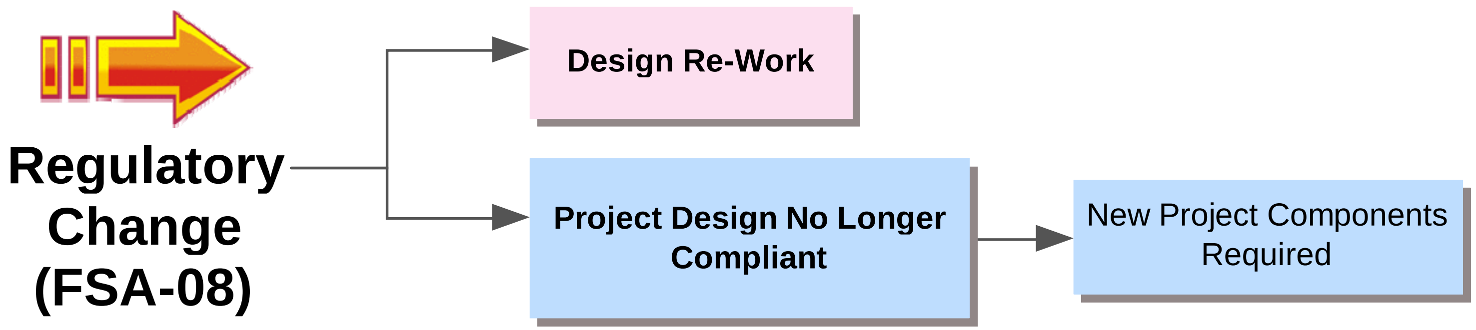

Power Failure (FSA-03)
Power to Freeze Plant
Power Loss During Chamber Flooding
Loss of Active Freezing (approximately 3 months)
Loss of Arsenic Saturated Water Through Fractures in Chamber
Increase in Arsenic Concentration in Water
Effluent Treatment Plant Unable to Treat Mine Water
Non Compliance Discharge Water Through Water Treatment Plant
Loss of Underground Ventilation
Freeze Up of Ramps
Limited Work Underground
Failure of Pumps
Pump Failure
Mine Water Level Rise
Increase in Arsenic Concentrate in Mine Water
Effluent Treatment Plant Unable to Treat Mine Water
Non Compliance Discharge Water Through Water Treatment Plant
Power to Water Treatment Plant
Backup Generator Provides Power
Failure of Backup Generator
Water Level Rise in Mine
Flood Up to Arsenic Trioxide Dust
Instability of Nearby Stopes
Permanent Loss of Arsenic into Mine
Water Treatment Plant Undersized to Treat Mine Water
Freeze Up of Water Treatment Plant and Discharge Line
Effluent Treatment Plant of Mine WTP Rebuild
Fire Suppression System Freezes
Fire Suppression System Rebuild
Loss of Fire Suppression
Surface Collection Systems Pump Back Failure
Rise in Water Level
Storage Capacity Exceeded for Underground
Effluent Treatment Plant Unable to Treat Mine Water
Non Compliance Discharge Water Through Water Treatment Plant
Building Services Damaged
Loss of Power to Town/Loss of Labour Force and Site Security
Loss of Labour Force and Site Security
Loss of Power to Freeze Plant
Loss of Monitoring System - Minor
No Impact to Frozen Block

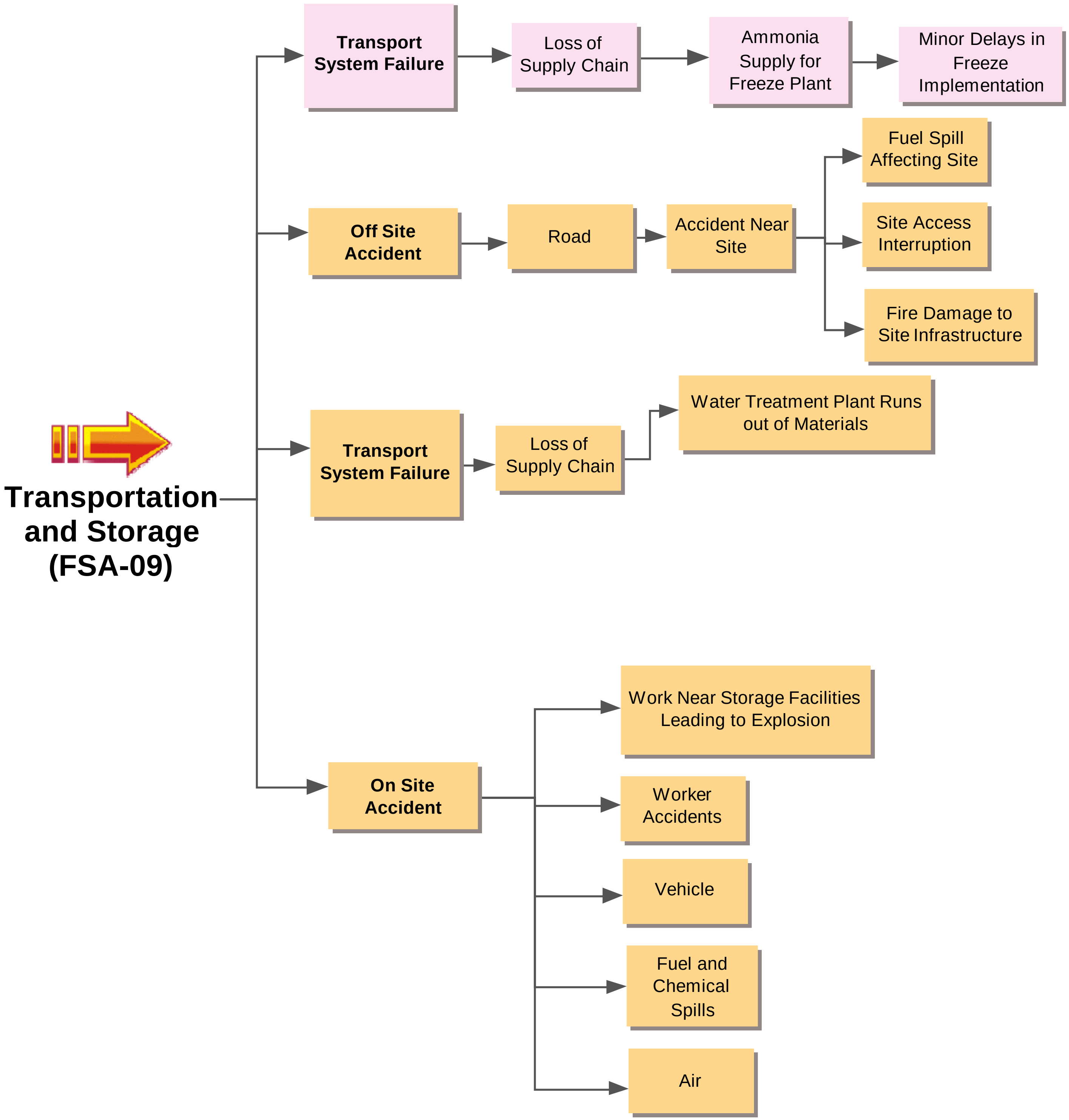

Flood (FSA-04)
Damage to Dams
Local Flooding and Loss of Tailings
Contaminated Water Released to Downstream Environment
Non Compliance Regulatory
Bank Overflow Loss of Channel
Flow into Pits
Flow into and Flooding of Underground
Loss of Pumps
Flood Up to Arsenic Chambers
Non Compliance Release
Bulkhead Failure Pre Freezing
Major Arsenic Release
Bank Overflow Loss of Channel
Flow into Pit
Flooding of Underground
Damages Underground Infrastructure
See FSA-A Underground
Overloading of Water Treatment Plant
Underground Instability
See FSA-A Underground
Damage to Surface Infrastructure
Ditches
Noncompliant Release of Sediment
Damage to New Hwy 4 Bridge
Loss of Site Access
Loss of Water Treatment Supplies for few Days
Pit Slope Failure
See FSA-C Pit Slope Failure

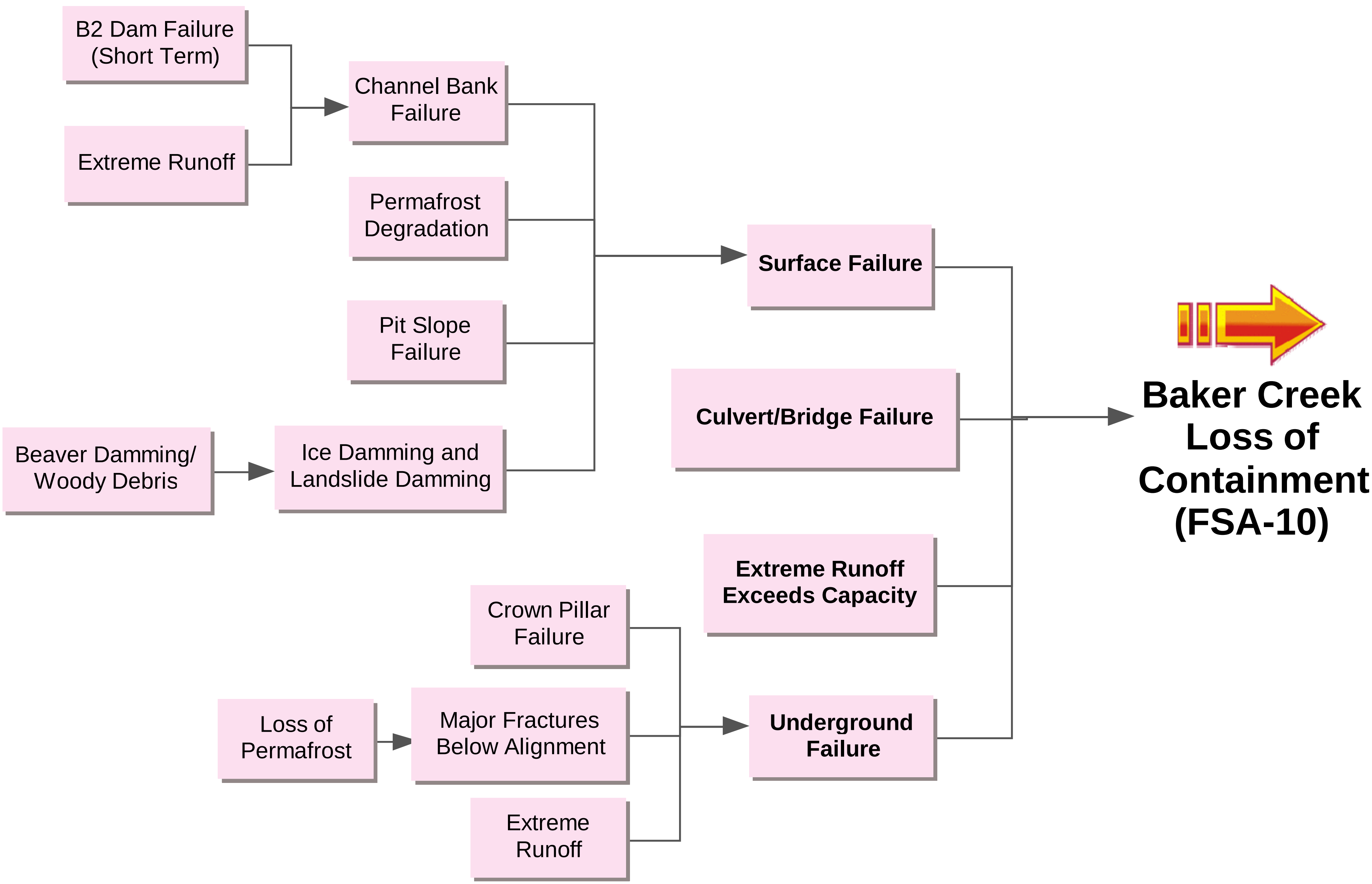

Governance (FSA-05)
Inability to Efficiently Respond to Regulatory Change
Non Compliance
Project Delay
Lack of Governance
Competing Mandate Interests
All Levels of Government
Poor Project Decisions
Limited Ability for Project Planning and Development
Lack of Oversight and Monitoring
Regulatory Non Compliance
Project Delay and/or Failure
Confused Roles and Responsibilities
Project Delay and/or Failure
Competing Interests
Project Delay or Failure
Lack of Communication
Loss of Regulatory Support
Loss of Credibility
Lack of Money
Inadequate Training and Emergency Response Plans
No Response to Short Term Events
Delay Response to Remediation of Site
Lack of Personnel
Poor Project Mgmt and Lack of Maintenance
Loss of Continuity and Coordination
Loss of Project Knowledge
Loss of Political Support for Project
Site Becomes Unstable
Remediation Delay
Inadequate Training and Emergency Response Plan
Inadequate Equipment
Inadequate Preparation for Response to Emergency Event
Low Reliability
Lack of Governance
Inappropriate Funding Model for Multi Year Project
Loss of Continuity
Re Work Design
Poor Project Design


External Third Party Influences (FSA-06)
Legal Challenges
Project Delays
Project Design Becomes Infeasible
Project Failure
Third Party Access Issues
Transportation
Trespass/ Vandalism
Plant Damage
Loss of Power
Damage to Cover
Damage to Infrastructure
Chemical Spills
H&S
Fire

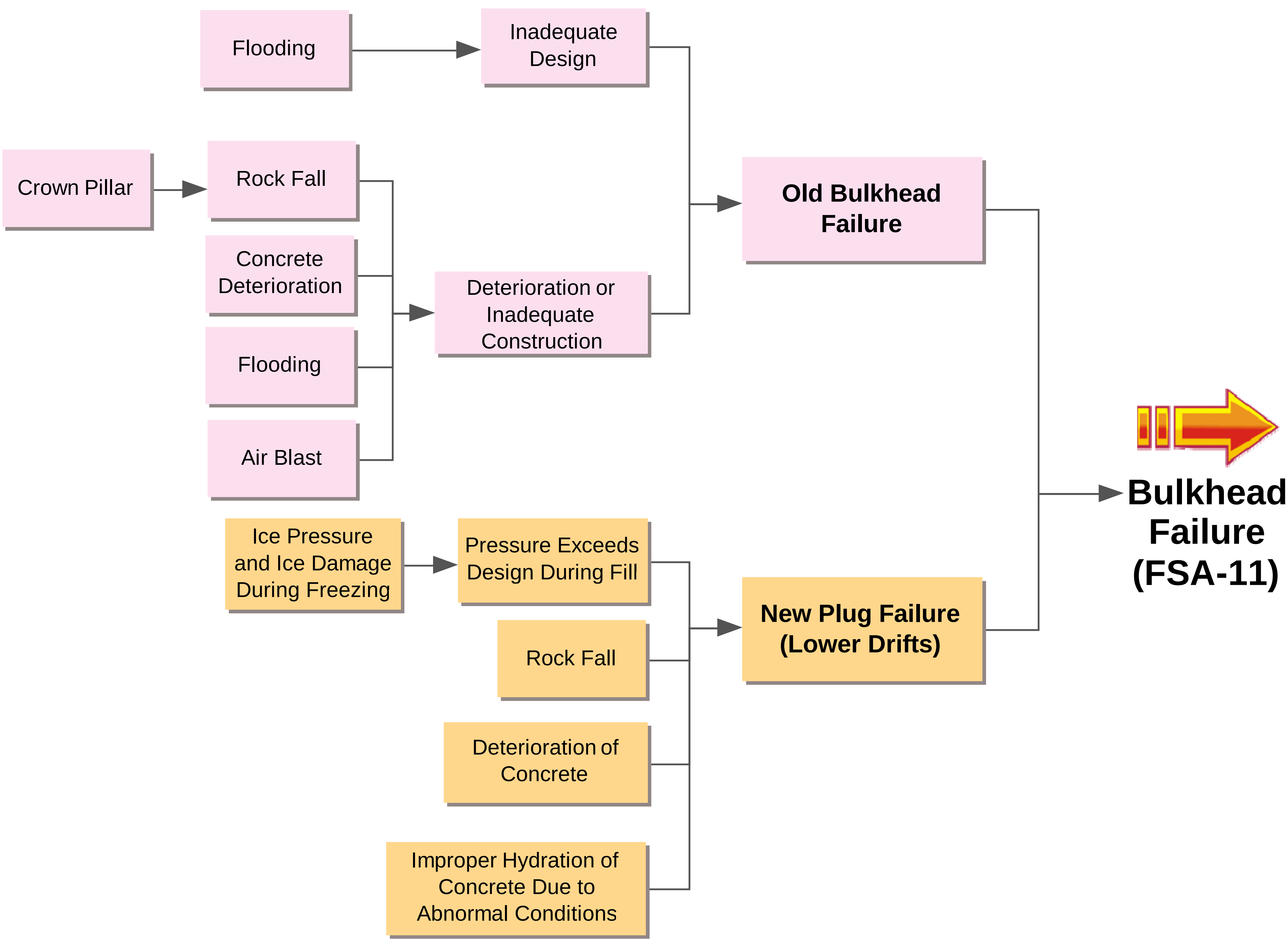

Planned Thaw of Frozen Block (FSA-07)
Gap Caused at Crown
Crown Pillar Instability
Arsenic Seepage
Increased Permeability of Rock Mass
Short Term High Arsenic Water Release
Plug Failure
Mass Arsenic Release to Mine Water
Sill Pillar Instability
Mass Arsenic Release to Mine Water

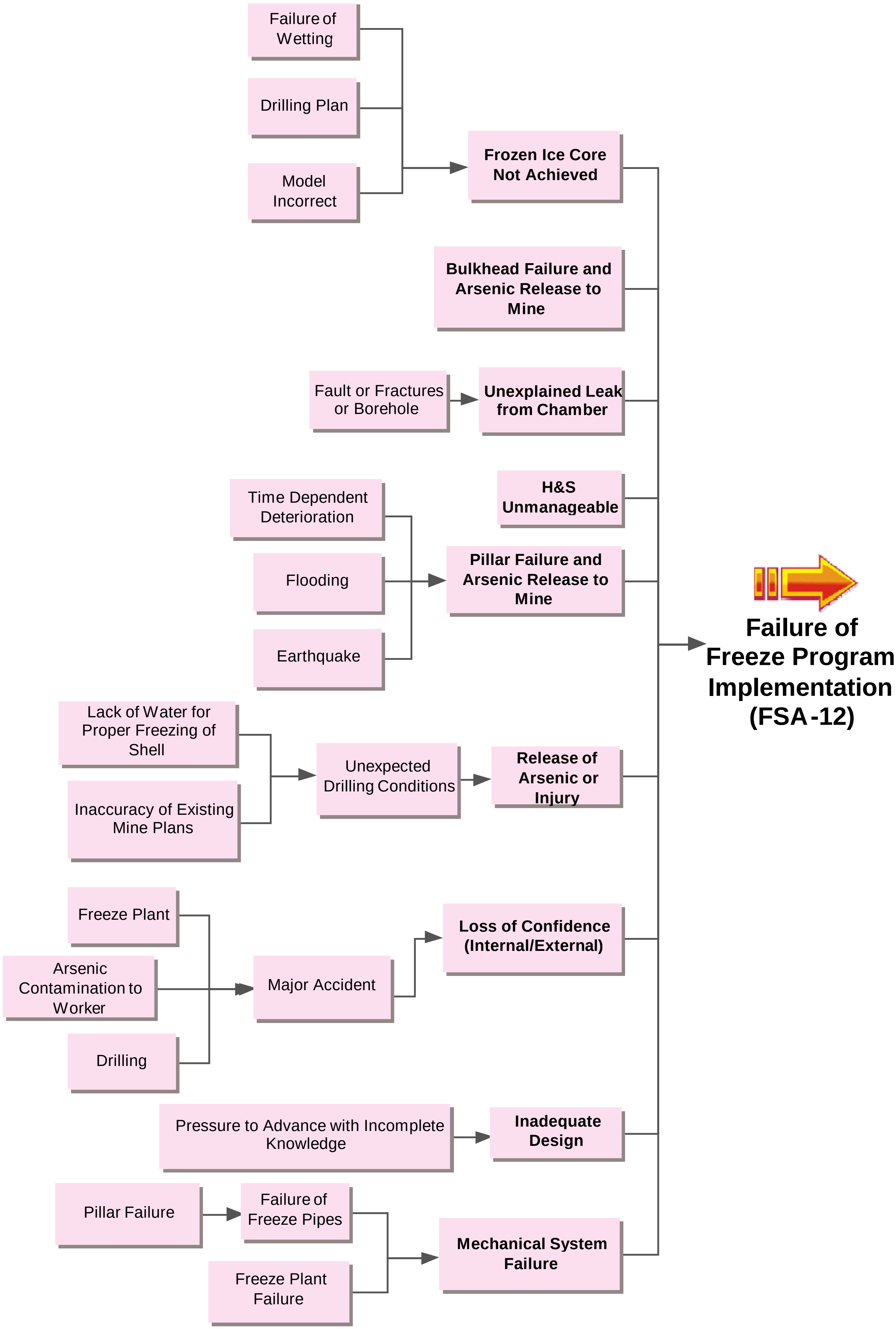

Regulatory
Change
(FSA-08)
Design Re-Work
Project Design No Longer Compliant
New Project Components Required


Transportation and Storage (FSA-09)
Transport System Failure
Loss of Supply Chain
Ammonia Supply for Freeze Plant
Minor Delays in Freeze Implementation
Off Site Accident
Road
Accident Near Site
Fuel Spill Affecting Site
Site Access Interruption
Fire Damage to Site Infrastructure
Transport System Failure
Loss of Supply Chain
Water Treatment Plant Runs out of Materials
On Site Accident
Work Near Storage Facilities Leading to Explosion
Worker Accidents
Vehicle
Fuel and Chemical Spills
Air

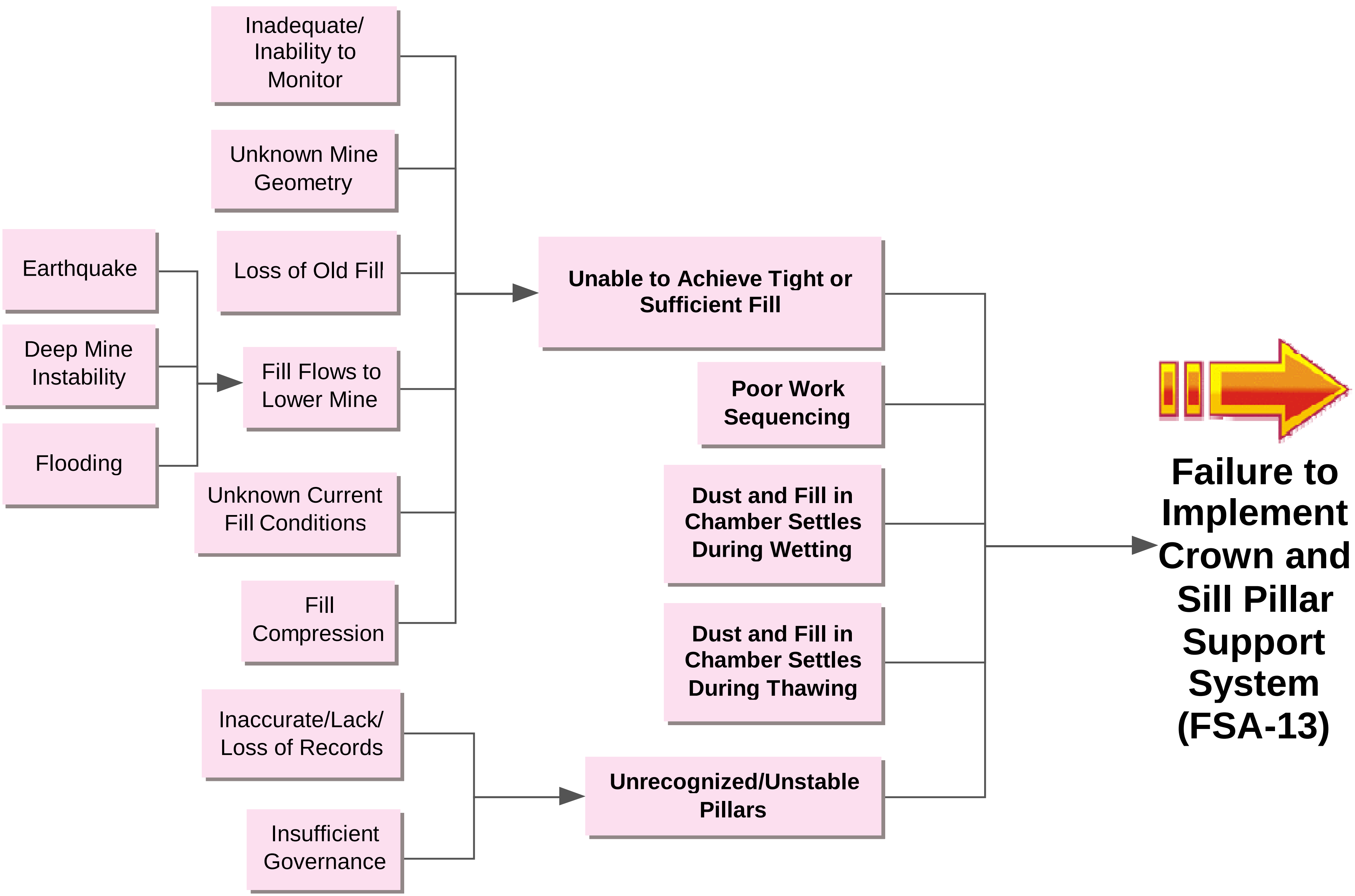


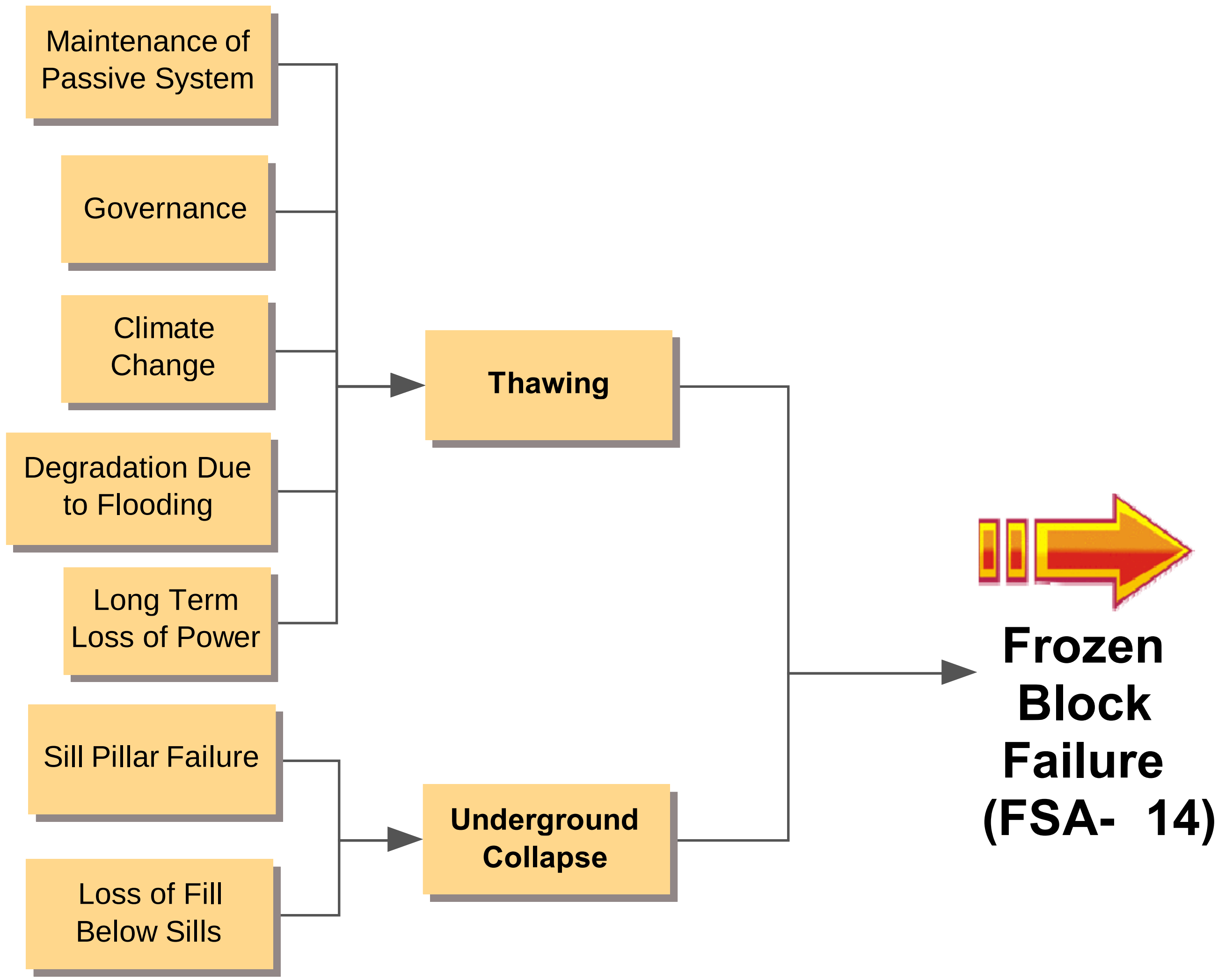
B2 Dam Failure (Short Term)
Extreme Runoff
Channel Bank Failure
Permafrost Degradation
Pit Slope Failure
Beaver Damming/ Woody Debris
Ice Damming and Landslide Damming
Surface Failure
Culvert/Bridge Failure
Extreme Runoff Exceeds Capacity
Crown Pillar Failure
Loss of Permafrost
Major Fractures Below Alignment
Extreme Runoff
Underground Failure
Baker Creek Loss of Containment (FSA-10)


Flooding
Inadequate Design
Crown Pillar
Rock Fall
Old Bulkhead Failure
Concrete Deterioration
Deterioration or Inadequate Construction
Flooding
Air Blast
Bulkhead Failure (FSA-11)
Ice Pressure and Ice Damage During Freezing
Pressure Exceeds Design During Fill
New Plug Failure (Lower Drifts)
Rock Fall
Deterioration of Concrete
Improper Hydration of Concrete Due to Abnormal Conditions

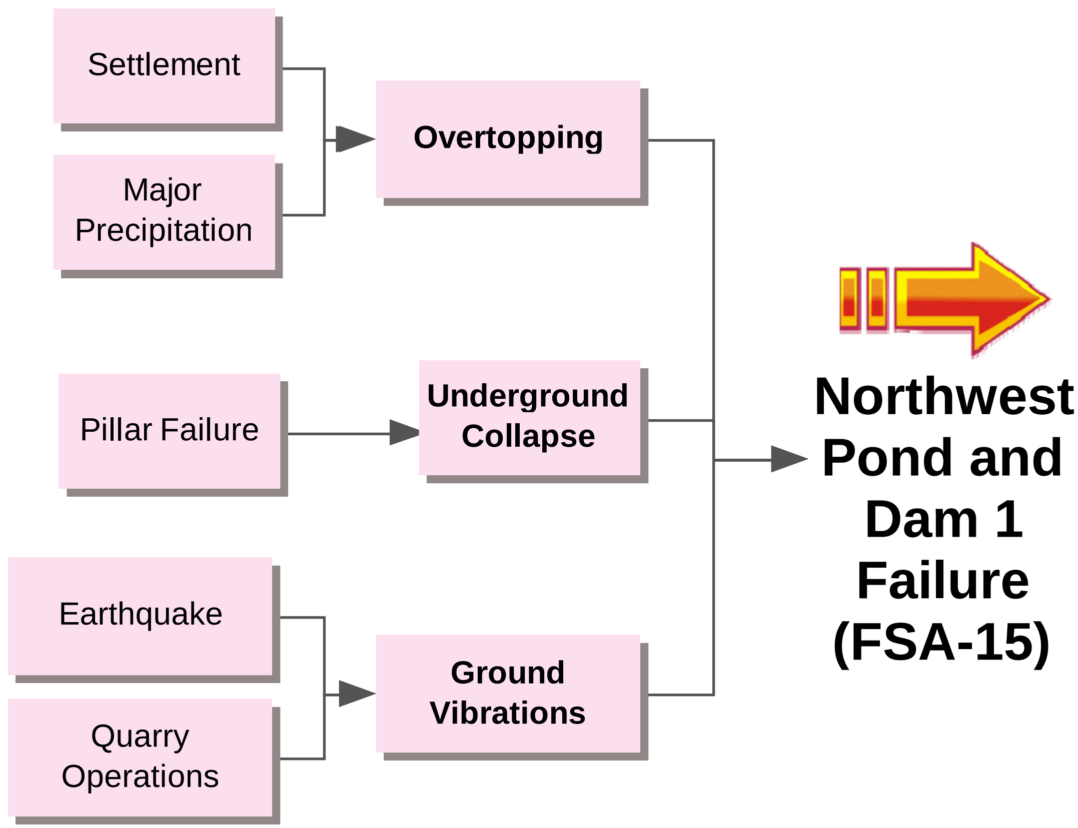


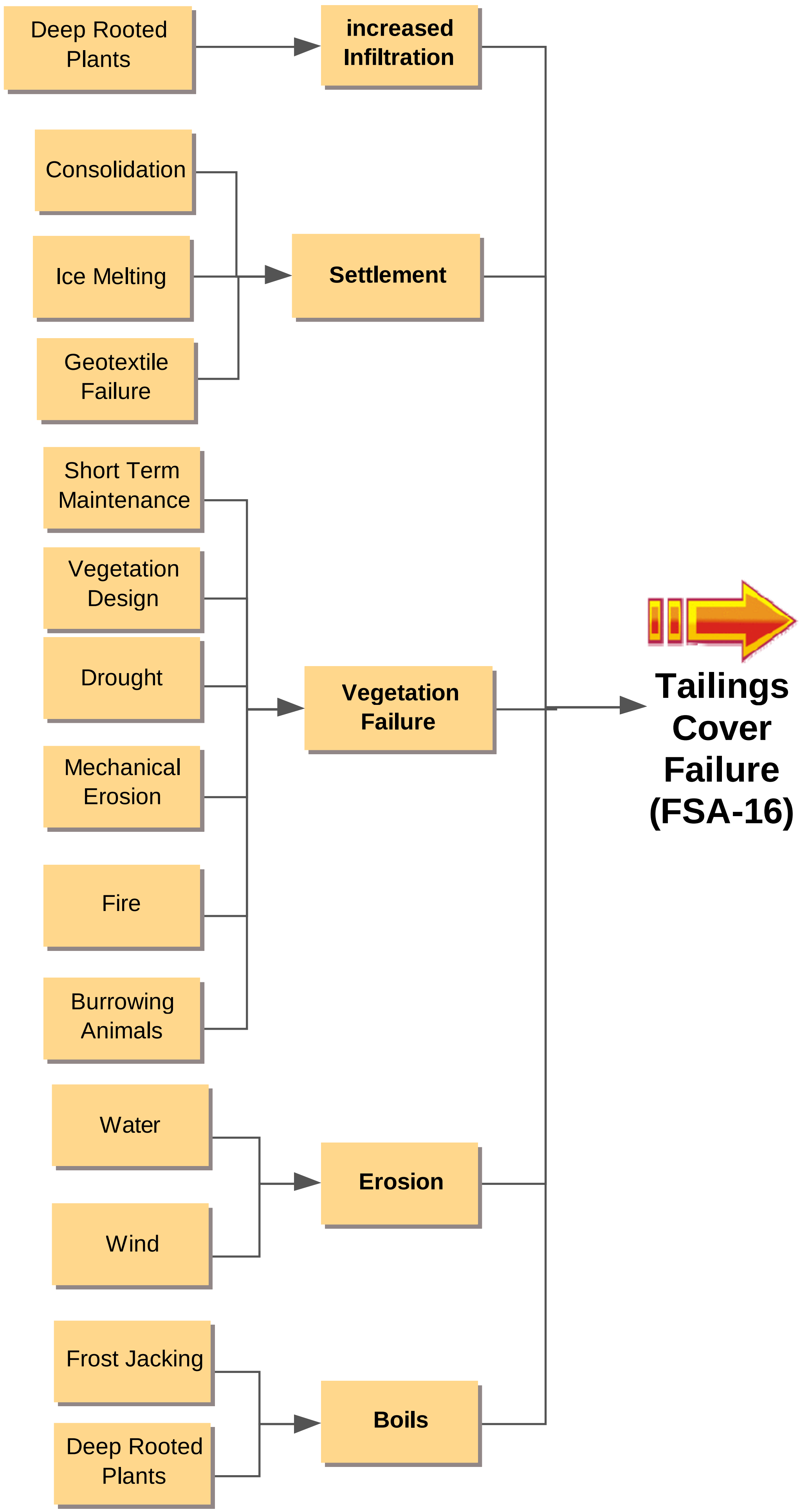
Failure of Wetting
Drilling Plan
Model Incorrect
Frozen Ice Core Not Achieved
Bulkhead Failure and Arsenic Release to Mine
Fault or Fractures or Borehole
Unexplained Leak from Chamber
H&S Unmanageable
Time Dependent Deterioration
Flooding
Earthquake
Pillar Failure and Arsenic Release to Mine
Failure of Freeze Program Implementation (FSA-12)
Lack of Water for Proper Freezing of Shell
Inaccuracy of Existing Mine Plans
Unexpected Drilling Conditions
Release of Arsenic or Injury
Freeze Plant
Arsenic Contamination to Worker
Drilling
Major Accident
Loss of Confidence (Internal/External)
Pressure to Advance with Incomplete Knowledge
Inadequate Design
Pillar Failure
Failure of Freeze Pipes
Freeze Plant Failure
Mechanical System Failure

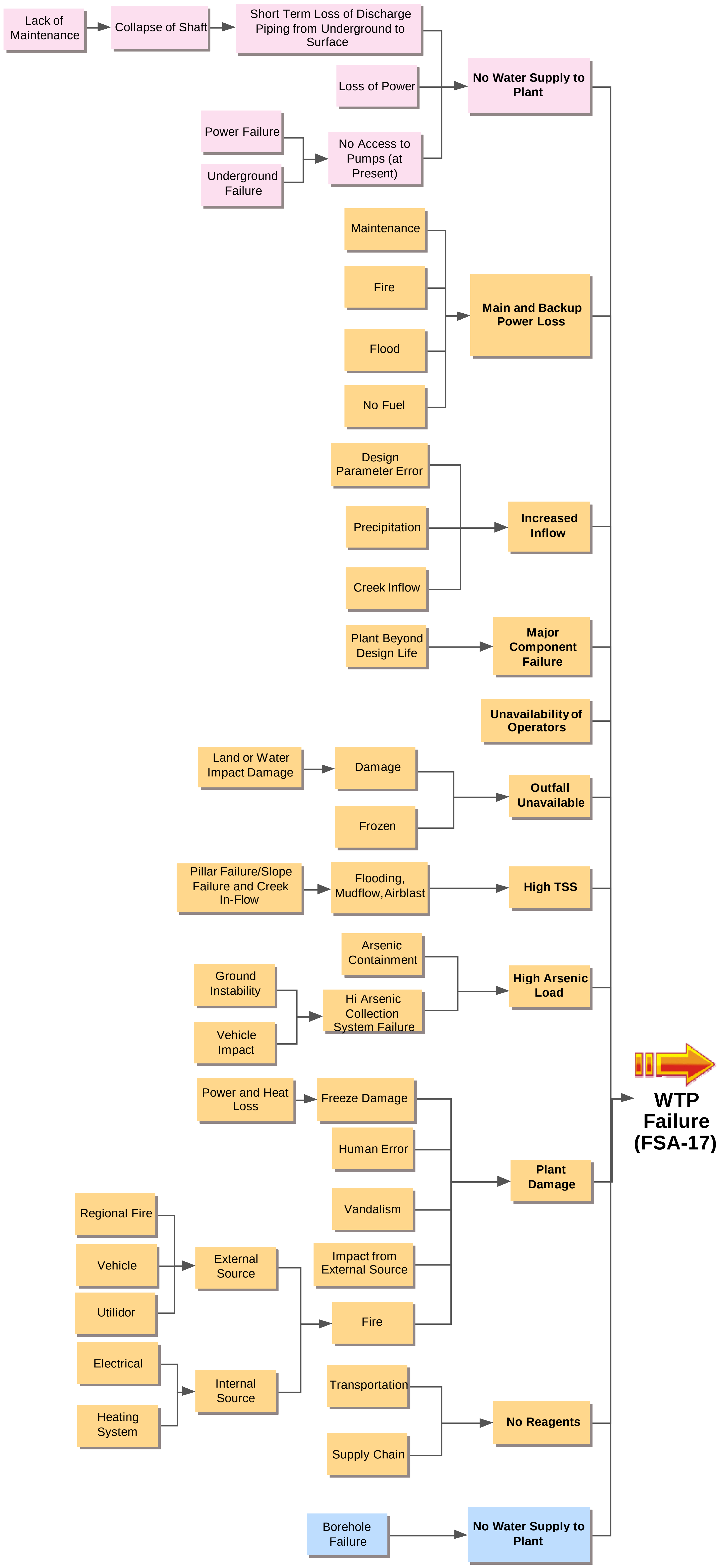

Inadequate/ Inability to Monitor
Unknown Mine Geometry
Earthquake
Loss of Old Fill
Deep Mine Instability
Fill Flows to Lower Mine
Flooding
Unknown Current Fill Conditions
Fill Compression
Unable to Achieve Tight or Sufficient Fill
Poor Work Sequencing
Dust and Fill in Chamber Settles During Wetting
Dust and Fill in Chamber Settles During Thawing
Inaccurate/Lack/ Loss of Records
Insufficient Governance
Unrecognized/Unstable Pillars
Failure to Implement Crown and Sill Pillar Support System (FSA-13)

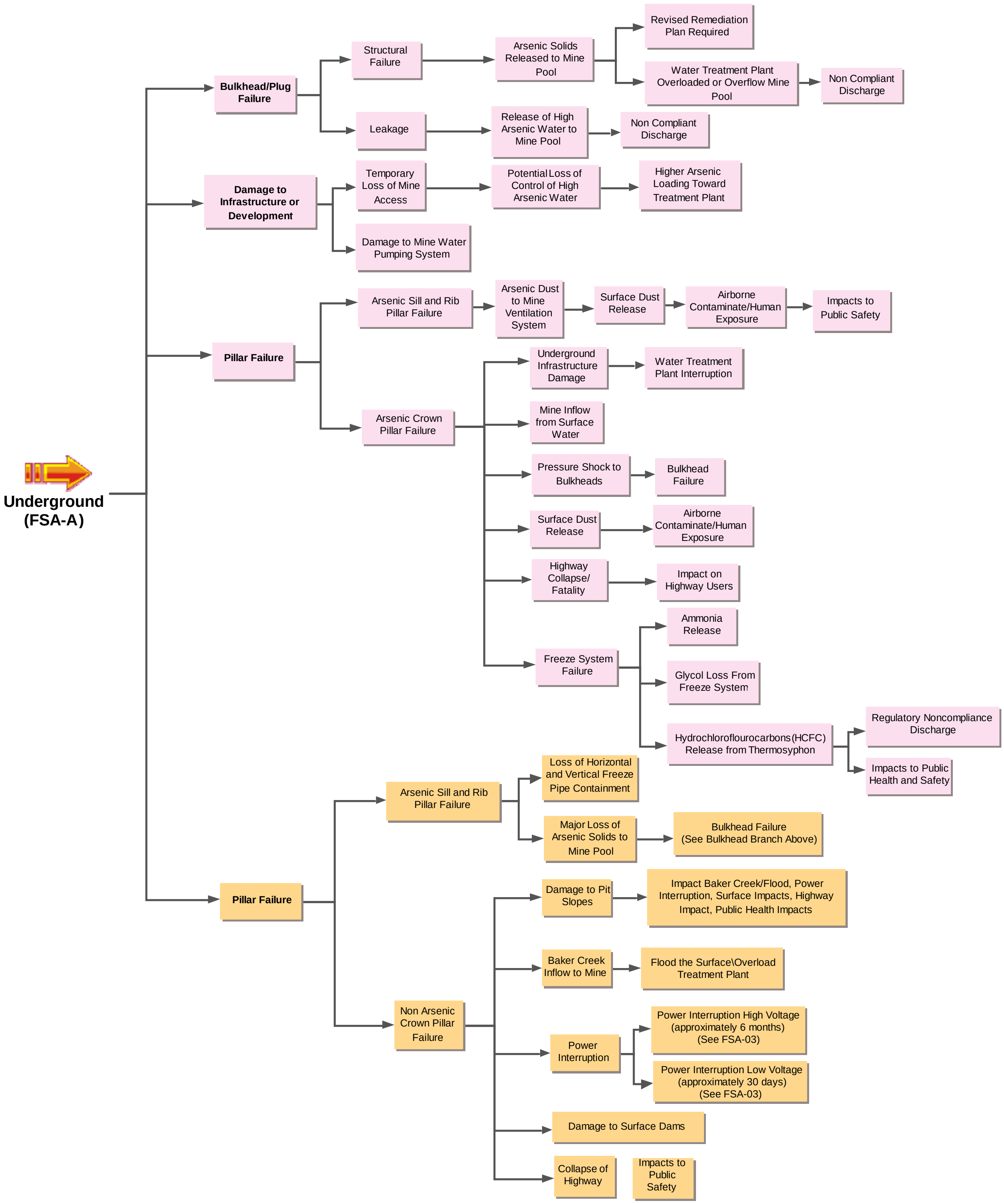


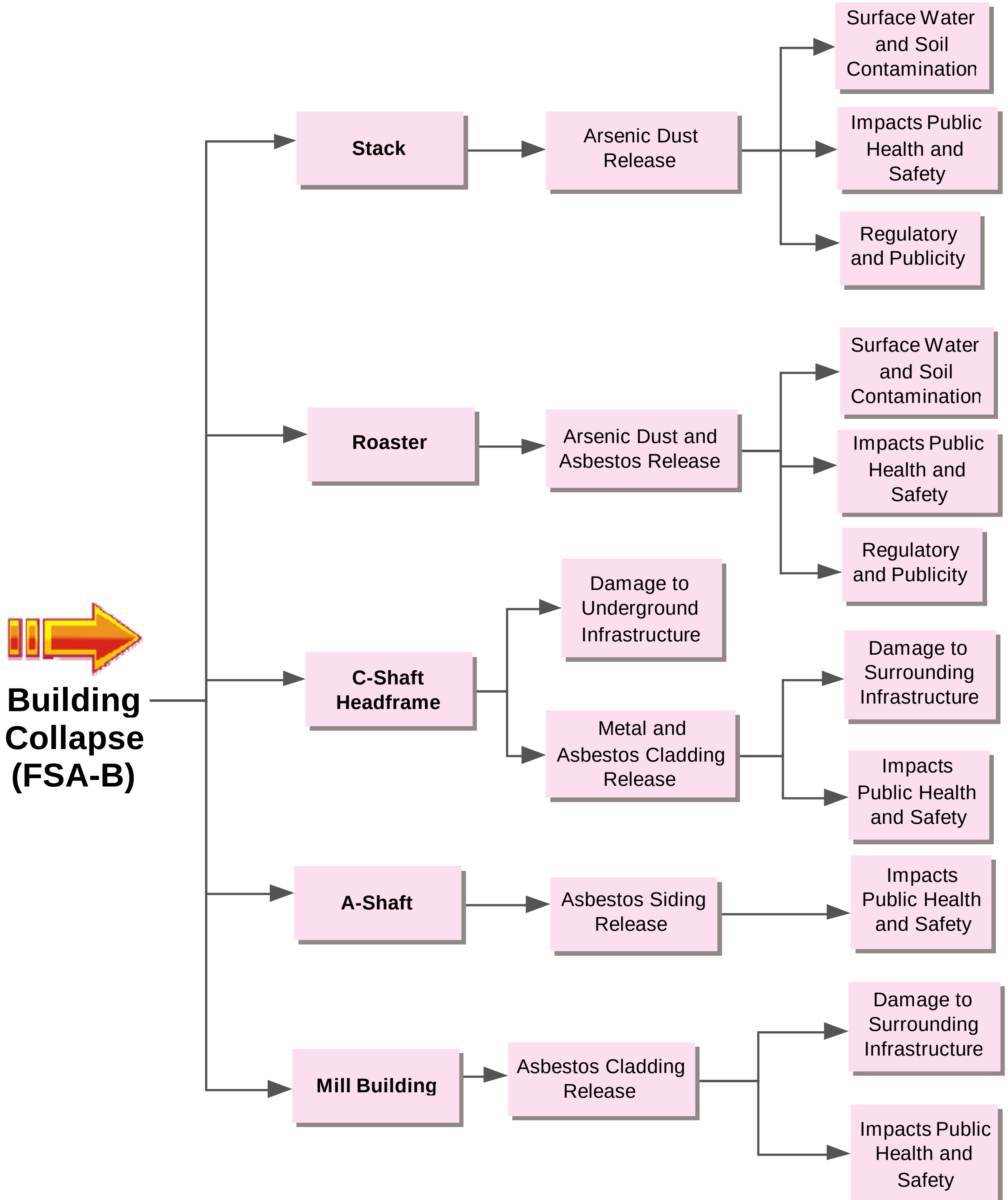
Maintenance of Passive System
Governance
Climate Change
Degradation Due to Flooding
Long Term Loss of Power
Thawing
Sill Pillar Failure
Loss of Fill Below Sills
Underground Collapse
Frozen Block Failure (FSA- 14)

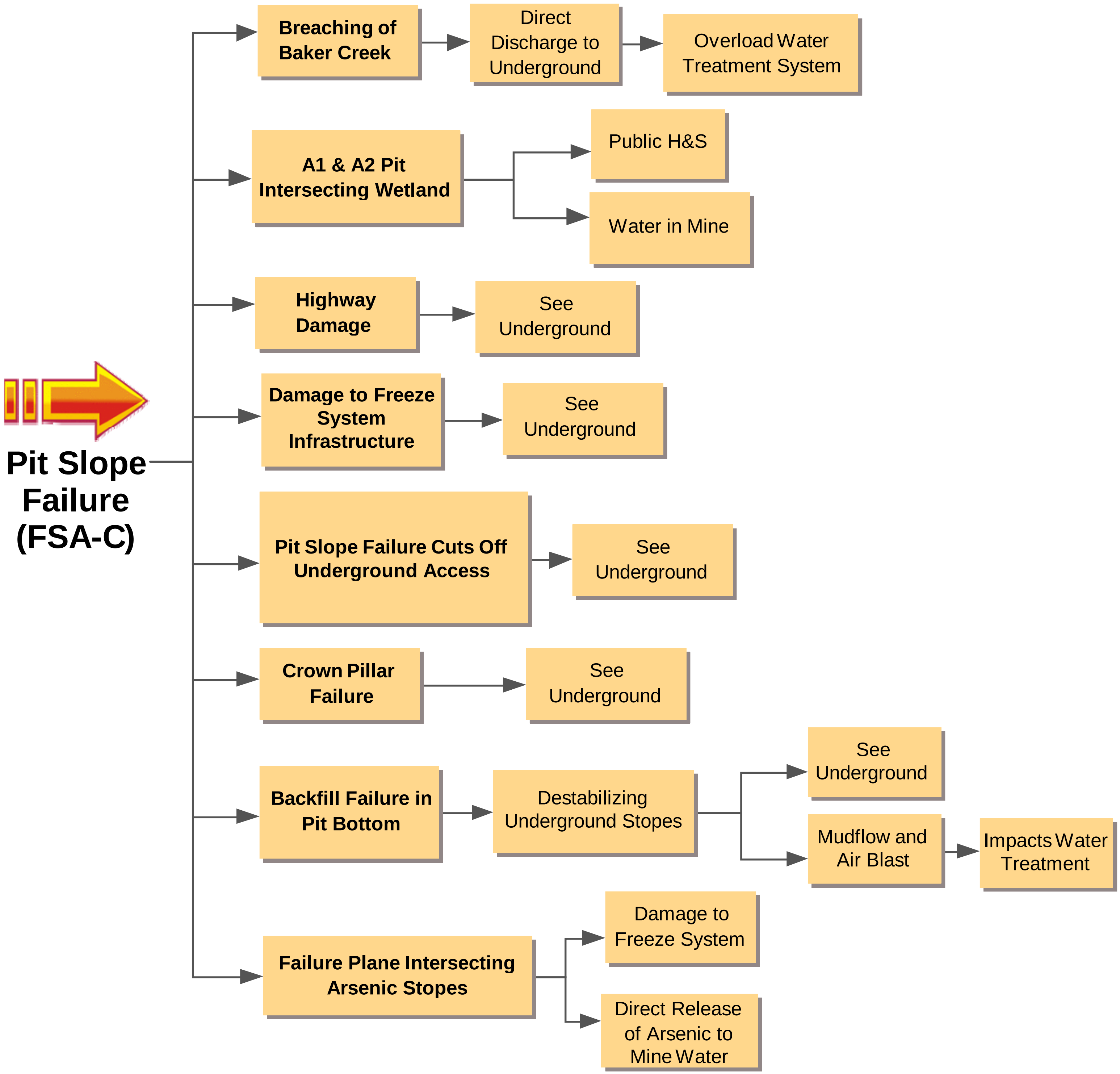

Settlement
Major Precipitation
Overtopping
Pillar Failure
Underground Collapse
Earthquake
Quarry Operations
Ground Vibrations
Northwest Pond and Dam 1 Failure (FSA-15)


Deep Rooted Plants
increased Infiltration
Consolidation
Ice Melting
Geotextile Failure
Settlement
Short Term Maintenance
Vegetation Design
Drought
Mechanical Erosion
Fire
Burrowing Animals
Vegetation Failure
Water
Wind
Erosion
Frost Jacking
Deep Rooted Plants
Boils
Tailings Cover Failure (FSA-16)


Lack of Maintenance
Collapse of Shaft
Short Term Loss of Discharge Piping from Underground to Surface
Loss of Power
No Water Supply to Plant
Power Failure
Underground Failure
No Access to Pumps (at Present)
Maintenance
Fire
Flood
No Fuel
Main and Backup Power Loss
Design Parameter Error
Precipitation
Creek Inflow
Increased Inflow
Plant Beyond Design Life
Major Component Failure
Unavailability of Operators
Land or Water Impact Damage
Damage
Frozen
Outfall Unavailable
Pillar Failure/Slope Failure and Creek In-Flow
Flooding, Mudflow, Airblast
High TSS
Arsenic Containment
Ground Instability
Vehicle Impact
Hi Arsenic Collection System Failure
High Arsenic Load
Power and Heat Loss
Freeze Damage
Human Error
Vandalism
Impact from External Source
Fire
Plant Damage
Regional Fire
Vehicle
Utilidor
External Source
Electrical
Heating System
Internal Source
Transportation
Supply Chain
No Reagents
Borehole Failure
No Water Supply to Plant
WTP Failure (FSA-17)


Underground (FSA-A)
Bulkhead/Plug Failure
Structural Failure
Arsenic Solids Released to Mine Pool
Revised Remediation Plan Required
Water Treatment Plant Overloaded or Overflow Mine Pool
Non Compliant Discharge
Leakage
Release of High Arsenic Water to Mine Pool
Non Compliant Discharge
Damage to Infrastructure or Development
Temporary Loss of Mine Access
Potential Loss of Control of High Arsenic Water
Higher Arsenic Loading Toward Treatment Plant
Damage to Mine Water Pumping System
Pillar Failure
Arsenic Sill and Rib Pillar Failure
Arsenic Dust to Mine Ventilation System
Surface Dust Release
Airborne Contaminate/Human Exposure
Impacts to Public Safety
Arsenic Crown Pillar Failure
Underground Infrastructure Damage
Water Treatment Plant Interruption
Mine Inflow from Surface Water
Pressure Shock to Bulkheads
Bulkhead Failure
Surface Dust Release
Airborne Contaminate/Human Exposure
Highway Collapse/ Fatality
Impact on Highway Users
Freeze System Failure
Ammonia Release
Glycol Loss From Freeze System
Hydrochloroflourocarbons(HCFC) Release from Thermosyphon
Regulatory Noncompliance Discharge
Impacts to Public Health and Safety
Pillar Failure
Arsenic Sill and Rib Pillar Failure
Loss of Horizontal and Vertical Freeze Pipe Containment
Major Loss of Arsenic Solids to Mine Pool
Bulkhead Failure (See Bulkhead Branch Above)
Non Arsenic Crown Pillar Failure
Damage to Pit Slopes
Impact Baker Creek/Flood, Power Interruption, Surface Impacts, Highway Impact, Public Health Impacts
Baker Creek Inflow to Mine
Flood the Surface\Overload Treatment Plant
Power Interruption
Power Interruption High Voltage (approximately 6 months) (See FSA-03)
Power Interruption Low Voltage (approximately 30 days) (See FSA-03)
Damage to Surface Dams
Collapse of Highway
Impacts to Public Safety


Building Collapse (FSA-B)
Stack
Arsenic Dust Release
Surface Water and Soil Contamination
Impacts Public Health and Safety
Regulatory and Publicity
Roaster
Arsenic Dust and Asbestos Release
Surface Water and Soil Contamination
Impacts Public Health and Safety
Regulatory and Publicity
C-Shaft Headframe
Damage to Underground Infrastructure
Metal and Asbestos Cladding Release
Damage to Surrounding Infrastructure
Impacts Public Health and Safety
A-Shaft
Asbestos Siding Release
Impacts Public Health and Safety
Mill Building
Asbestos Cladding Release
Damage to Surrounding Infrastructure
Impacts Public Health and Safety


Pit Slope Failure (FSA-C)
Breaching of Baker Creek
Direct Discharge to Underground
Overload Water Treatment System
A1 & A2 Pit Intersecting Wetland
Public H&S
Water in Mine
Highway Damage
See Underground
Damage to Freeze System Infrastructure
See Underground
Pit Slope Failure Cuts Off Underground Access
See Underground
Crown Pillar Failure
See Underground
Backfill Failure in Pit Bottom
Destabilizing Underground Stopes
See Underground
Mudflow and Air Blast
Impacts Water Treatment
Failure Plane Intersecting Arsenic Stopes
Damage to Freeze System
Direct Release of Arsenic to Mine Water

Appendix B

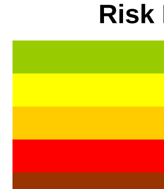
Failure Mode Effects Criticality Analysis (FMECA)

Risk Matrix

CATEGORY	CONSEQUENCE SEVERITY				
	A) Low	**B) Minor**	**C) Moderate**	**D) Major**	**E) Critical**
I) Public Safety	Low-level short-term subjective symptoms/ No measurable physical effect/ No medical treatment	Objective but reversible disability/impairment and/or medical treatment injuries requiring hospitalization	Moderate irreversible disability or impairment to one or more people	Single fatality and /or severe irreversible disability or impairment to one or more people	Multiple fatalities
II) Environment	No impact	Minor localized or short-term impacts	Impact on valued ecosystem component	Impact on valued ecosystem component and medium-term impairment of ecosystem function	Serious longterm impairment of ecosystem function
III) Cost	$<100,000	$100,000- 1 Million	$1.0-10 Million	$10-50Million	$ >50Million

LIKELIHOOD	
Index	**Event/Years**
1)	**More than once every 5 years**
2)	**Once every 15 years**
3)	**Once every 30 years**
4)	**Once every 100 years**
5)	**Once every 1000 years**

Risk Rating



Low
Moderate
Moderately High
High
Very High

Source: INAC NCSP Project Risk Management Guidance Document

FMECA - Giant Mine Remediation Program

Risk Scenario Event Sequences Chart: Underground System

ID	COMPONENT	SUBCOMPONENT	RISK ISSUE / FAILURE	EVENT/CAUSES	POTENTIAL CONSEQUENCES	LIKELIHOOD	CONSEQUENCE SEVERITY Public Safety	CONSEQUENCE SEVERITY Environment	CONSEQUENCE SEVERITY Cost	PLANNED MITIGATION/CONTROLS/ MANAGEMENT MEASURES	EVALUATION	LIKELIHOOD	CONSEQUENCE SEVERITY Public Safety	CONSEQUENCE SEVERITY Environment	CONSEQUENCE SEVERITY Cost	Confidence Estimate
Short Term																
UGS-1	Bulkheads		Bulkhead and horizontal bulkhead failure during construction prior to freezing.	Accident and/or Malfunction: Accelerated deterioration or damage to bulkheads.	Damage or deterioration of bulkheads may allow arsenic to be released to main mine area. Potential exists for arsenic dust to be released into the mine pool with an increase in the amount of arsenic laden water that will require treatment.	4	A	A	C	The care and maintenance of the bulkheads and underground water management occurring prior to the start of the project will continue until all identified bulkheads are stabilised through priority sequencing. Bulkhead surveillance program will continue in the short term and emergency action will be taken where necessary to stabilise bulkheads. Construction activities will be coordinated to minimize risk to arsenic containment. Pressure relief will be installed as necessary during the construction phase. Should bulkhead failure or plug leakage occur the Water Treatment Plant is sized and operated to accommodate the additional arsenic concentration to prevent release of arsenic to the environment.	This risk is present with the current dry conditions of the arsenic dust contained behind bulkheads. Pressure relief is anticipated to be effective during construction phase. Measures will reduce risk, but likelihood is not materially changed before frozen conditions in the stopes/chambers are established. Plugs serve to reduce the risk of a failure scenario with water inflow from Baker Creek. (See Baker Creek System and Water Management System). It is anticipated that a new plug failure will only be a partial failure. Where exterior plugs are installed to contain arsenic dust, these will be designed to withstand not only dry conditions but for the fully saturated head of wetted, but not yet frozen dust.					High
UGS-2	Plugs		New plug failure during construction.	Malfunction: Improper hydration of concrete due to abnormal conditions, deterioration of concrete, rock fall, pressure exceeds design during stope/chamber wetting, ice pressure and ice damage during freezing resulting in partial plug failure.	Partial failure may allow arsenic to be released to unfrozen mine areas. Potential exists for thousands of tonnes of arsenic dust released into the mine pool with a substantial increase in the amount of arsenic laden water that will require treatment.	5	A	A	C	The care and maintenance of the bulkheads and underground water management occurring prior to the start of the project will continue until all identified bulkheads are stabilised through priority sequencing. Bulkhead surveillance program will continue and emergency action will be taken where necessary to stabilise bulkheads. Construction activities will be coordinated to minimize risk to arsenic containment. Pressure relief will be installed as necessary during the construction phase. Should bulkhead failure or plug leakage occur the Water Treatment Plant is sized and operated to accommodate the additional arsenic concentration to prevent release of arsenic to the environment.	This risk is present with the current dry conditions of the arsenic dust contained behind bulkheads. Pressure relief is anticipated to be effective during construction phase. Measures will reduce risk, but likelihood is not materially changed before frozen conditions in stopes/chambers are established. Plugs serve to reduce the risk of a failure scenario with water inflow from Baker Creek. (See Baker Creek System and Water Management System). It is anticipated that a new plug failure will only be a partial failure. Where exterior plugs are installed to contain arsenic dust these will be designed to withstand not only dry conditions but for the fully saturated head of wetted, but not yet frozen dust.					High
UGS-3	Crown Pillar		Crown pillar failure at arsenic chambers during construction.	Accident: Collapse through to ground surface.	Release of arsenic dust to atmosphere.	3	B	C	C	Backfilling the void under the crown pillar. Maintenance of site accident controls. In the event of a substantial dust release, a community notification protocol will be followed.	Tight backfilling of voids is planned.	5	B	C	C	High
UGS-4			Non-arsenic crown pillar failure during construction	Accident: Collapse through to ground surface.	Potential for impact to highway, public areas and parking lot over unsupported voids, as well as damage to pit slopes and Baker Creek.	4	D	A	C	Void under crown pillars will be filled. Further site characterization will continue to identify all voids requiring backfilling. Where subsidence may occur, backfilling will be completed.	Backfilled voids will not present a risk of serious collapse.	5	B	A	C	Moderate

UGS-5	Sill Pillar		Sill pillar failure at arsenic chambers during construction	Accident: Collapse due to rock or ground support degradation	Loss of arsenic dust to mine pool and to the ventilation system. Potential exists for thousands of tonnes of arsenic dust released into the mine pool with a substantial increase in the amount of arsenic laden water that will require treatment.	3	B	B	D	Voids under sill pillars will be backfilled. This will include cementatious backfill in critical areas, and additional support for sill pillars where required. In the event of a sill pillar collapse that results in an increase in arsenic concentration in the mine water pool the Water Treatment Plant is sized and operated to accommodate the additional arsenic concentration to prevent release of arsenic to the environment. To minimize the release of arsenic dust to the atmosphere the mine ventilation system will be shut down following a sill pillar collapse. In the event of a substantial dust release a community notification protocol will be followed.	All sill pillars are currently subject to long-term monitoring. This will continue during the remediation phase. Despite the loss of a sill pillar an attempt will be made to freeze the affected chamber. Stress increase to the sill pillars from wetting would not occur until after backfilling and frozen shell thus minimising the risk of a failure event.	5	A	A	C	Moderate
Long Term																
UGS-6	Sill Pillar		Sill pillar failure at arsenic chambers	Accident / Malfunction: Collapse due to rock or ground support degradation and water movement causing instability.	Loss of immediate support to backfill under arsenic chambers.	4	A	A	C	More backfill will be added.	Long-term monitoring will continue. All chambers will be frozen and voids backfilled minimizing the risk of occurrence and consequences.	5	A	A	C	Moderate
UGS-7			Movement of non-arsenic related backfill due to large fluctuations in minewater level.	Accident: Upset condition associated with Baker Creek (See Baker Creek System for Scenarios)	Such an event has the potential to affect both water storage and treatment. A flood event will increase the amount of water stored underground and subsequently treated.	5	A	A	C	The volume of water treated through the Water Treatment Plant may temporarily increase to draw down the mine pool water to the target level. Discharged water will remain compliant.	The length of time to reach mine storage capacity is uncertain.					Low
UGS-8	Crown Pillar		Non-arsenic Crown Pillar Failure.	Accident: Collapse through to ground surface.	Potential for impact to highway, public areas and parking lot through loss of immedate support to backfill under stopes.	5	C	A	C	More backfill will be added. Where subsidence may occur post-backfilling will be completed.	Backfilled voids will not present a risk of serious collapse.					Moderate

FMECA - Giant Mine Remediation Program

Risk Scenario Event Sequences Chart: Freeze System

ID	COMPONENT	SUBCOMPONENT	RISK ISSUE / FAILURE	EVENT/CAUSES	POTENTIAL CONSEQUENCES	LIKELIHOOD	CONSEQUENCE SEVERITY			PLANNED MITIGATION/CONTROLS/ MANAGEMENT MEASURES	EVALUATION	LIKELIHOOD	CONSEQUENCE SEVERITY			Confidence Estimate
							Public Safety	Environment	Cost				Public Safety	Environment	Cost	
Short Term																
FS-1	Drill Holes		Drilling Failure (Single Drill Hole)	Malfunction: Inaccuracy of existing mine plans may mean that some holes are initially drilled too close or too far from chambers. Unexpected drilling conditions such as discontinuities in the rock or intersecting an existing drill hole or shear zone may be encountered.	Drilling circulation may be lost. Arsenic dust may be released to surface, if there is drilling into a chamber or stope.	1	A	A	B	Where a drill hole intersects the freeze hole, layout will be refined and the hole redrilled. Where a drill hole enters a chamber, shut-down and control procedures will be followed to minimise the release of dust. In the event of a dust release, a community notification protocol will be followed.	Failures will be single events and will not substantially affect the timing or ability to establish a frozen block.	4	A	A	B	Moderate
FS-2			Drilling Failure (Entire Freeze Program)	Malfunction: Inaccuracy of existing mine plans, unexpected drilling conditions, find existing drill hole or shear zone.	Failure of a substantial number of drill holes has the potential to delay the establishment of the frozen blocks. Multiple failures present the same risks as single hole failures.	1	A	A	C	The drilling results would be used to refine freeze hole layout. Holes would be redrilled and the project schedule amended accordingly. Where a drill hole enters a chamber, shut-down and control procedures will be followed to minimise the release of dust. In the event of a dust release, a community notification protocol will be followed.	Failures will be single events. While timing will be affected, drill failures will not impact the ability to establish frozen block. Up to 5% of holes are anticipated to be redrilled to account for unexpected conditions.	3	A	A	C	Moderate
FS-3	Active Freeze System		Extended time to establish a frozen shell	Malfunction and/or Accident: Vibration from quarrying operation or earthquake leading to damage of the active freeze system.	Delay in establishing frozen block and increase in cost.	5	A	A	C	Time to freeze the shell will be recalculated and the project schedule amended accordingly. Grouting of rock fractures will be completed.	While timing will be affected, only the length of time and potentially an increase in the energy required to freeze the shell will be required. No resulting consequences.					High
FS-4	Frozen Shell		Extended time to establish a frozen shell	Accident: Water in the rock higher than predicted.	The latent heat and flow of this water causes an extension in the freeze time.	4	A	A	B	Time to freeze the shell will be recalculated and the project schedule amended accordingly. Grouting of high groundwater flow will be completed.	While timing will be affected, only the length of time and potentially an increase in the energy required to freeze the shell will be required. No resulting consequences.					Moderate
Long Term																
FS-5	Frozen Block		Planned Thaw Causes Failure (Engineered)	Natural thaw, the application of heat by reversing the cooling system or other unknown method.	Degraded rock quality, crown pillar and sill pillar failure fractured during freezing causes increased permeability of rock mass increasing groundwater capture, allowing high concentration arsenic contaminated water to reach mine pool. Additional water from thawing puts stress on plugs.	5	A	A	C	Water Treatment Plant is sized and operated to accommodate the additional arsenic concentration to prevent release of arsenic to the environment. Until additional plant components are constructed that can process contaminated water to achieve compliant discharge water will be stored underground.	As this would be a planned, engineered event, it is anticipated that the risks of such an undertaking would undergo a separate full review and assessment. A thaw would be very slow, taking decades.					High
FS-6			Unplanned Thaw Causes Failure	Accident: Climate Warming	Degraded rock quality, crown pillar and sill pillar failure fractured during freezing causes increased permeability of rock mass increasing groundwater capture, allowing high concentration arsenic contaminated water to reach mine pool.	5	A	A	C	The current freeze system is designed to exceed the prediction for climate change. In the event that local climate warming far exceeds modeled predictions the passive freeze system would be expanded with the option of supplementing the passive cooling with active cooling.	Ground and air temperature and mine water monitoring would detect early signs of change to the frozen block, before actual melting would start to occur. Remedial action could be taken for one or all of the blocks before any thaw. A thaw would be very slow, taking decades.					High
FS-7			Unplanned Thaw Causes Failure	Malfunction: Failure of freeze system	Degraded rock quality, crown pillar and sill pillar failure fractured during freezing causes increased permeability of rock mass increasing groundwater capture, allowing high concentration arsenic contaminated water to reach mine pool.	5	A	A	C	The freeze system will be repaired or upgraded as necessary and re-established. The Water Treatment Plant is sized and operated to accommodate the additional arsenic concentration to prevent release of arsenic to the environment.	Ground and air temperature and mine water monitoring would detect early signs of change to the frozen block, before actual melting would start to occur. Remedial action could be taken for one or all of the blocks before any thaw. A thaw would be very slow, taking decades.					High
FS-8			Unplanned Thaw Causes Failure	Malfunction: Long-term loss of power **and** passive cooling ineffective	Degraded rock quality, crown pillar and sill pillar failure, fracturing due to freezing, increased permeability of rock mass, increased arsenic load to water, increase in groundwater capture, release of arsenic contaminated water to mine pool.	5	A	A	D	The freeze system will be repaired or upgraded as necessary to maintain effective cooling and re-established. The Water Treatment Plant is sized and operated to accommodate the additional arsenic concentration to prevent release of arsenic to the environment.	Ground and air temperature and mine water monitoring would detect early signs of change to the frozen block, before actual melting would start to occur. Remedial action could be taken for one or all of the blocks before any melting would start to occur. A thaw would be very slow, taking decades and would not impact restoration of power or the frozen block.					High
FS-9	Passive Cooling Infrastructure		Wildfire damages the passive cooling system	Accident: Wildfire	Repairs to the cooling and monitoring systems are required.	5	A	A	C	Vegetation will be controlled around the passive cooling piping.	Repairs would easily be made before any frozen block thaw. Thaw would be very slow, taking decades. No resulting consequences.					High
FS-10			Warming from climate change exceeds cooling capacity of existing passive cooling infrastructure	Accident: Global warming vastly greater than maximum predictions. Reduced efficiency of passive freezing system.	Upgrade to current freeze infrastructure.	5	A	A	D	The freeze infrastructure will upgraded as necessary to maintain effective cooling and re-established.	Ground and air temperature and mine water monitoring would detect early signs of change to the frozen block, before actual melting would start to occur. Remedial action could be taken for one or all of the blocks before any melting. Thaw would be very slow, taking decades and would not impact restoration of the frozen block.					High

FMECA - Giant Mine - Risk Assessment of Remediation Program

Risk Scenario Event Sequences Chart: Baker Creek System

ID	COMPONENT	SUBCOMPONENT	RISK ISSUE / FAILURE	EVENT/CAUSES	POTENTIAL CONSEQUENCES	LIKELIHOOD	CONSEQUENCE SEVERITY: Public Safety	CONSEQUENCE SEVERITY: Environment	CONSEQUENCE SEVERITY: Cost	PLANNED MITIGATION/CONTROLS/ MANAGEMENT MEASURES	EVALUATION	LIKELIHOOD	CONSEQUENCE SEVERITY: Public Safety	CONSEQUENCE SEVERITY: Environment	CONSEQUENCE SEVERITY: Cost	Confidence Estimate
Short Term																
BCS-1	Baker Creek Channel Integrity		Baker Creek overflows during construction.	Accident: Channel partially or completely blocked with ice, rock and / or beaver dams.	Water would overflow into pits, spill into the underground and flood the underground workings. Mine water arsenic concentration would potentially reach levels 100 times current values. Erosion off tailings in Baker Pond impacts water quality in the creek.	4	A	D	C	Ice build-up in the channel will continue to be monitored and cleared as possible. Damage to dykes will be repaired. Supplies of emergency response materials will continue to be maintained on-site, such as aquadams, liners, and equipment. See Water Management System table for measures related to mine inundation.	Channel wall failure occurs during freshet; Impractical to mediate during flow; Pumping system is overwhelmed; Current channel capacity is a 1:200 year event with no ice dam or other blockage. Adding 1m of fill over 100m length at C1, capacity moves close to 1:500 year storm. Good information base.	5	A	D	C	High
BCS-2			Bank damage during construction	Accident and/or Malfunction: Machine damage or other mechanism resulting in sediment being released into environment.	Impact to fish or fish habitat.	1	A	C	B	Construction will be scheduled to occur outside of restricted periods. Erosion control measures will be in place for all works in and around the creek. Construction monitoring will address deficiencies. An emergency response plan will be in place.	It is typically difficult to prevent all sediment release during proposed local re-alignment. All construction impacts around Baker Creek are anticipated to be short-term.	3	A	B	B	High
BCS-3	Creek Bed		Ground vibration from quarrying operation or earthquake leading to the collapse of a crown pillar compromising pit wall stability leading to a compromise of pillars under creek which results in the loss of containment of Baker Creek which now flows into the underground mine during construction.	Malfunction and/or Accident: Vibration from quarrying operation or earthquake.	Water would overflow into pits, spill into the underground and flood underground workings. Mine water arsenic concentration would potentially reach levels 100 times current values.	5	A	D	C	Should mine inundation occur the new Water Treatment Plant will be sized and operated to accommodate the additional arsenic concentration to prevent the continued long-term release of arsenic to the environment. Emergency pumping capacity would be sourced and installed.	There is a short period of exposure to this risk: 2 years for the construction for Baker Creek local re-alignment. Risk rating does not change with mitigation as they are responses not preventions.					High
BCS-4			Baker Creek loses channel containment during Freshet resulting in large inflows to the mine underground workings.	Accident: Loss of ground support at C1 Pit and A2 Pit Raise	Water would spill into the underground and flood underground workings. Mine water arsenic concentration would potentially reach levels 100 times current values and flood to surface in open pits with potential release to the environment. Loss of current mine dewatering system. Initiation of backfill instability.	3	B	D	E	Conduct additional investigations to confirm stability assessments (previous and current) and implement monitoring program. Consider alternative creek alignment options to those in remedial plan that minimizes risk, balances restoration and fisheries objectives with site and project cost restraints. Emergency upstream flow diversion to prevent from continuous inflow.	Based on delayed care and maintenance cost and increased water treatment cost. Potential significant underground instability issues that require mitigation. Likely suspended sediment discharge into watercourse with emergency stream diversion. This assumes that underground backfilling has not taken place yet at A2 Pit Raise.	3	B	C	D	Low
BCS-5			Seepage from Baker Creek floods Stope C212 and/or Chamber 14 during construction.	Accident: A new seepage pathway develops, through a mechanism such as an existing drill hole or subsidence near pit crest that is connected to the underground.	Bulkhead failure (plug construction in progress) with arsenic dust lost into lower portion of mine. Water from Baker Creek flows into the mine resulting in major addition of water to the mine. Arsenic concentration could potentially be 1000 times higher than current levels. However, water is contained within the mine and does not overflow to the environment. Chamber cannot be frozen as planned. Major cost consequence as chamber cannot be frozen and therefore there is a significant increase in water treatment costs. Water stored underground until water treatment capacity is increased, consequently there is no release to the environment.	4	A	A	D	Ongoing seepage monitoring at bulkheads. Where monitoring results indicate pressure build up, relief valves could be installed. Plugs will be installed in C212, B208 and Chamber 14 with pressure release valves.	This scenario results in less water entering the mine due to the limited flow from seepage vs. a freshet flooding event. There is a short period of exposure to this risk: 2 years for construction of plugs in C212, B208 and Chamber 14 drifts. No malfunction scenario anticipated as the result of Baker Creek local re-alignment.	5	A	A	D	High
Long Term																
BCS-6	Bank		Bank Overflow	Accident: Stable channel overflows during large flow greater than the design flows.	No inflow to the mine up to nominal 1:500 year flood event. Accumulation of additional water in mine pool. No release to the environment.	4	A	A	B	Long-term maintenance of Baker Creek to maintain flood design capacity. Surplus volume above the 1:500 flood can be stored in the mine and can be treated in the water treatment system. No impact to frozen stopes/chambers.						High

ID	COMPONENT	SUBCOMPONENT	RISK ISSUE / FAILURE	EVENT/CAUSES	POTENTIAL CONSEQUENCES	LIKELIHOOD	CONSEQUENCE SEVERITY			PLANNED MITIGATION/CONTROLS/ MANAGEMENT MEASURES	EVALUATION	LIKELIHOOD	CONSEQUENCE SEVERITY			Confidence Estimate
							Public Safety	Environment	Cost				Public Safety	Environment	Cost	
BCS-7			Bank Overflow	Accident: Glaciation of channel through mine site area.	Overflow into mine at various points. Accumulation of additional water is contained in mine pool. No release to the environment.	3	A	A	B	Long-term maintenance of Baker Creek to maintain channel integrity during winter months. Tailings covered in Baker Pond.	Likelihood reflects observation of recent events.					High
BCS-8	Creek Bed		Ground Collapse Breaks Through to Surface Under Baker Creek	Accident: Earthquake.	No mechanism leading to collapse as backfilling of critical mine openings completed.	5	A	A	A	All critical mine openings are backfilled and / or stabilized; Backfill designed against liquifaction; Consider alternative creek alignment options to those in remedial plan that minimizes risk, balances restoration and fisheries objectives with site and project cost restraints; Long-term maintenance as necessary.	All critical mine openings are identified through historical search and review of current data and/or investigation.					High
BCS-9			Channel Deterioration	Accident: Permafrost thawing and erosion.	Sediment release, loss of rip-rap, channel configuration (loss of flood plain and risk of overflow into mine).	4	A	A	B	Long-term maintenance of Baker Creek to maintain channel integrity.	Ground ice to be addressed during construction if encountered.					High
BCS-10			Baker Creek loses channel containment during Freshet resulting in large inflows to the mine underground workings.	Accident: Loss of ground support at C1 Pit and B2 Pit	Water would spill into the underground and flood underground workings. Loss of mine dewatering system. Water floods frozen stopes, chambers and workings and to surface via pits. Non-compliant discharge from Water Treatment Plant and potential release to the environment via pits.	3	B	C	C	Consider alternative creek alignment options to those in remedial plan that minimizes risk, balances restoration and fisheries objectives with site and project cost restraints.		5	B	C	C	Moderate

FMECA - Giant Mine - Risk Assessment of Remediation Program

Risk Scenario Event Sequences Chart: Surface System

ID	COMPONENT	SUBCOMPONENT	RISK ISSUE / FAILURE	EVENT/CAUSES	POTENTIAL CONSEQUENCES	LIKELIHOOD	CONSEQUENCE SEVERITY Public Safety	CONSEQUENCE SEVERITY Environment	CONSEQUENCE SEVERITY Cost	PLANNED MITIGATION/CONTROLS/ MANAGEMENT MEASURES	EVALUATION	LIKELIHOOD	CONSEQUENCE SEVERITY Public Safety	CONSEQUENCE SEVERITY Environment	CONSEQUENCE SEVERITY Cost	Confidence Estimate
Short Term																
SS-1	Dams	Dam 1, Dam 21 and 22	Accident / Malfunction: Release of ponded water by overtopping.	Major precipitation.	Release of untreated water from tailings ponds. Short term water treatment failure and reduced capacity to store water underground.	5	A	C	C	Ponds maintained with a 1 meter free board that allows for major storm events.	The 1 meter freeboard allows for substantial storage for a major rainfall event. In the event of the freeboard being exceeded, water will be discharged into the underground. Implications to underground water storage and water treatment addressed on the Water Management System sheet. No resulting consequences.					High
SS-2			Accident / Malfunction: Ground vibrations.	Earthquake or quarrying operations.	Accelerated settlement and potential overtopping.	5	A	C	C	Monitored blasts at quarry as part of quarry operations.	The dams are stable structures. In the event of overtopping, water will be discharged into the underground. Implications to underground water storage and water treatment addressed on the Water Management System sheet. No resulting consequences.					High
SS-3		Dam 21B and Dam 1	Accident: Flooding	Major storm causing flood.	Damage to Dam 21B and Dam 1, local flooding and minor loss of tailings downstream and into surrounding environment.	5	A	C	C	Ponds maintained with 1 meter free board that allows for major storm events. In the event of serious damage, water retained by Dam 1 would be discharged to underground.	Unlikely event for rainfall not exceeding the 24-hour, 100 year storm event. No resulting consequences.					High
SS-4	Ditches		Accident: Flooding	Extreme rainfall	Sediment discharge, erosion and sediment release to Baker Creek.	3	A	C	B	Ditches will be upgraded to final design standard including rip-rap cover treatment on erodible fine material.	Erosion and sediment control during construction will reduce the risk of sediment releases.	4	A	C	B	High
SS-5	Tailings Covers (including spillway)		Accident: Consolidation / Settlement	Permafrost melting, consolidation, or geotextile failure.	Potential for localized disruption of surface water drainage, minor exposed tailings, localized increased infiltration.	3	A	A	C	Monitoring during construction and reconstruction as necessary. Construction sequencing.	No off-site sediment or tailings transport. No resulting consequences.	4	A	A	C	High
SS-6			Accident: Development of Boils	Frost jacking.	Potential for localized failure and minor tailings exposure.	2	A	A	C	Monitoring during construction and reconstruction as necessary. Construction sequencing.	No off-site sediment or tailings transport. No resulting consequences.	4	A	A	C	High
SS-7			Accident: Erosion	Extreme rainfall on recently completed cover or on cover during construction.	Potential for erosion creating run-off channels, sediment release and tailings exposure.	2	A	A	B	Monitoring during construction and reconstruction as necessary. Construction sequencing.	Impacts will be limited by the selection of tailings cover material and revegetation plan.					High
Long Term																
SS-8	Dams	Dam 1, Dam 21 and 22 Failure	No Long Term Ponds so risk eliminated. Ponds are covered.							Risk eliminated	No resulting consequences.					High
SS-9	Ditches		Accident: Flooding	Extreme rainfall	Sediment discharge, erosion and sediment release to Baker Creek.	4	A	C	B	Long term configuration constructed. Long term erosion maintenance as necessary.	Final erosion protection measures will reduce the risk of sediment releases. No resulting consequences.					High
SS-10	Public Safety	Public Access	Accident: Injury or fatality	Unauthorized public access to site hazards such as open pits.	Injury or fatality.	5	D	B	B	Site security and additional physical measures such as fencing, capping and berms will be maintained around hazards such as steep slopes and open pits.	Measures will limit the risk of an incident.	5	B	A	A	Moderate
SS-11	Tailings Covers		Accident: Consolidation / Settlement	Permafrost melting, consolidation, geotextile failure	Surface water drainage, exposed tailings, localized increased infiltration.	4	A	A	C	Long term maintenance as necessary.	No off-site sediment or tailings transport. No resulting consequences.					High
SS-12			Accident: Development of Boils	Frost jacking, deep rooted plants	Localized failure and minor tailings exposure.	4	A	A	C	Long term maintenance as necessary.	No off-site sediment or tailings transport.					High
SS-13			Accident: Erosion	Water and wind	Erosion of run-off channels and sediment release.	4	A	A	B	Long term maintenance as necessary.	Impacts will be limited by tailings cover material and revegetation plan.					High
SS-14			Accident and/or Malfunction: Limited vegetation success	No maintenance / poor vegetation design (local plants and vegetation), drought, mechanical erosion, fire, burrowing animals.	Erosion creating run-off channels, sediment release and tailings exposure.	3	A	A	B	Long term maintenance as necessary.	No resulting consequences.					High

FMECA - Giant Mine - Risk Assessment of Remediation Program																	
Risk Scenario Event Sequences Chart: Surface System																	
ID	COMPONENT	SUBCOMPONENT	RISK ISSUE / FAILURE	EVENT/CAUSES	POTENTIAL CONSEQUENCES	LIKELIHOOD	CONSEQUENCE SEVERITY			PLANNED MITIGATION/CONTROLS/ MANAGEMENT MEASURES	EVALUATION	LIKELIHOOD	CONSEQUENCE SEVERITY			Confidence Estimate
							Public Safety	Environment	Cost				Public Safety	Environment	Cost	
SS-15			Malfunction: Incompatible land-use	Change in land-use damages cover.	Exposure of tailings.	3	A	A	B	Restrict land use to compatible uses. Where an incompatible use is proposed undertake necessary site measures to protect the tailings cover.	Preventing the development of incompatible land uses depends on continued governance of the site. No resulting consequences.					High
SS-16			Accident and/or Malfunction: Cover penetration	Deep-rooted invasive species.	Increased water infiltration and metal uptake in plants.	4	A	A	B	Removal of deep rooted plants as necessary.	Monitoring and maintenance is anticipated to minimise invasive deep rooted plants in damaging tailings covers. No resulting consequences.					High

FMECA - Giant Mine - Risk Assessment of Remediation Program

Risk Scenario Event Sequences Chart: Water Management System

ID	COMPONENT	SUBCOMPONENT	RISK ISSUE / FAILURE	EVENT/CAUSES	POTENTIAL CONSEQUENCES	LIKELIHOOD	CONSEQUENCE SEVERITY			PLANNED MITIGATION/CONTROLS/ MANAGEMENT MEASURES	EVALUATION	LIKELIHOOD	CONSEQUENCE SEVERITY			Confidence Estimate
							Public Safety	Environment	Cost				Public Safety	Environment	Cost	
Short Term																
WMS-1	Existing Plant	Treatment Capacity	Inability to treat water	Accident: Existing plant is substantially destroyed by fire, either by forest fire or other causes.	No water treatment in the year of the fire; Contaminated water remains in the underground water pool.	4	A	A	C	The construction of the planned news water treatment plant would be accelerated. Temporary water treatment system established as required. Contaminated water would remain in the mine pool until a new plant is constructed.	A short-term replacement plant will likely be unnecessary given that water can be stored underground for this time period.	5	A	A	C	High
WMS-2				Malfunction: Mechanical failure	No water treatment for two months.	3	A	A	B	Ongoing maintenance of the existing plant will continue until the new plant is operational.	Past maintenance has been effective in maintaining plant operations.					High
WMS-3				Malfunction: Plant deterioration		3	A	A	B	Mechanical systems will be repaired or replaced as necessary to maintain treatment functions.	This is consistent with current practice and will continue.					High
WMS-4				Accident: Freeze up		3	A	A	B	In the event of loss of heating at the plant, systems would be drained to prevent damage. In the event of a freeze event damaging plant components these would be rebuilt to restore plant function. Contaminated water would remain in the mine pool until the plant is operational.	Specific procedures will be developed as part of the Water Treatment Plant operating system, including emergency response and recovery actions.					High
WMS-5				Malfunction: Current re-agent supplier unable to meet demand.		3	A	A	B	Reagents would be sourced from several suppliers. Reagents inventory held onsite. Contaminated water would remain in the mine pool until the plant is again operational.	More than one supplier of the reagent is available. Cost to change is unknown, but is conservatively estimated.					High
WMS-6	Existing Plant	Power Supply	Loss of power supply to the plant	Accident and/or Malfunction: Loss of the power line to the plant causing a disruption in the power supply to the plant for one month.	No water treatment for one month requiring storage of untreated water underground in the mine.	3	A	A	B	Contaminated water would remain in the mine pool until power is restored.	A short-term replacement plant will likely be unnecessary given that water can be stored underground for this time period.					High
WMS-7	Settling/ Polishing	Polishing Pond	Suspended solids are not effectively removed in the settling and polishing ponds	Malfunction: Upset in settling system	Discharge to the environment would not be possible. Possible to re-suspend sediment in Spring.	3	A	A	B	Monitoring of suspended solids will be maintained to ensure flocculent levels are adequate. Equipment will be maintained to limit risk of an upset. If TSS in exceedance of discharge standards are encountered the water in the ponds will be recirculated for treatment before discharge.	Regular monitoring is a built-in mitigation to limit the likelihood of discharging poor quality water.					High
WMS-8	Underground storage	Concentration of arsenic in mine water pool.	Bulkhead Failure and/or leaking from plug failure during construction prior to freezing.	Accident and/or Malfunction: Accelerated deterioration or damage to bulkheads or partial plug failure.	Partial failure may allow arsenic to be released to main mine area. Potential exists for thousands of tonnes of arsenic dust released into the mine pool with a substantial increase in the amount of arsenic laden water that will required treatment through the Water Treatment Plant.	4	A	A	C	The care and maintenance of the bulkheads and underground water management occurring prior to the start of the project will continue until all identified bulkheads are stabilized or plugs constructed through priority sequencing. Bulkhead surveillance program will remain ongoing and emergency action will be taken where necessary to stabilize bulkheads. Construction activities will coordinated to minimize risk to arsenic containment. Pressure relief will be installed as necessary during the construction phase. Should bulkhead failure or plug leakage occur the Water Treatment Plant will be sized and operated to accommodate the additional arsenic concentration to prevent release of arsenic to the environment.	This risk is present with the current dry conditions of the arsenic dust contained behind bulkheads. Where exterior plugs are installed to contain arsenic dust these will be designed to withstand not only dry conditions but for the fully saturated head of wetted, but not yet frozen dust. In the short-term risk is reduced but likelihood is not materially changed because frozen conditions have not been established. Scenarios involving mechanisms of water inflow are covered in the Baker Creek System.					High
WMS-9			New Plug Failure During Construction	Malfunction: Improper hydration of concrete due to abnormal conditions, deterioration of concrete, rock fall, pressure exceeds design during fill, ice pressure and ice damage during freezing resulting in partial plug failure.		5	A	A	C	Plug design will take into account hydration factors, ice pressure impact and deterioration factors. Design of plugs will be such that they will not be able to completely fail. Should plug leakage occur the Water Treatment Plant will be sized and operated to accommodate the additional arsenic concentration to prevent release of arsenic to the environment.	Where exterior plugs are installed to contain arsenic dust these will be designed to withstand not only dry conditions but for the fully saturated head of wetted, but not yet frozen dust.					High
WMS-10			Sill Pillar Failure at Arsenic Chambers/Stopes During Construction	Accident: Collapse due to rock or ground support degradation.	Loss of arsenic dust to mine pool and to the ventilation system. Potential exists for thousands of tonnes of arsenic dust released into the mine pool with a substantial increase in the amount of arsenic laden water that will required treatment through the Water Treatment Plant.	3	B	B	D	Voids under sill pillars will be backfilled. This will include cementatious backfill in critical areas, and additional support for sill pillars where required. In the event of a sill pillar collapse that results in an increase in arsenic concentration in the mine water pool the Water Treatment Plant will be sized and operated to accommodate the additional arsenic concentration to prevent release of arsenic to the environment. To minimize the release of arsenic dust to the atmosphere the mine ventilation system will be shut down following a sill pillar collapse. In the event of a substantial dust release, a community notification protocol will be followed.	All sill pillars are currently subject to long-term monitoring. This will continue during the remediation phase. Despite the loss of a sill pillar an attempt will be made to freeze the affected chamber. Stress increase to the sill pillars from wetting would not occur until after backfilling and frozen shell have been completed, thus minimizing the risk of a failure event. A visible dust release may result in a perception that impacts are higher than actual.	5	A	A	C	Moderate

FMECA - Giant Mine - Risk Assessment of Remediation Program

Risk Scenario Event Sequences Chart: Water Management System

ID	COMPONENT	SUBCOMPONENT	RISK ISSUE / FAILURE	EVENT/CAUSES	POTENTIAL CONSEQUENCES	LIKELIHOOD	CONSEQUENCE SEVERITY			PLANNED MITIGATION/CONTROLS/ MANAGEMENT MEASURES	EVALUATION	LIKELIHOOD	CONSEQUENCE SEVERITY			Confidence Estimate
							Public Safety	Environment	Cost				Public Safety	Environment	Cost	
WMS-11	Underground storage	Concentration of arsenic in mine water pool.	Significant increase in mine water arsenic concentration from the failure of an arsenic chamber/stope.	Accident: Seepage from Baker Creek floods C212 and/or B208 and/or Chamber 14 during construction	Hydrostatic pressure in a flooded chamber causes a bulkhead failure before or during plug construction resulting in the loss of arsenic dust as a slurry into the lower portion of mine. Arsenic concentrations in the mine water pool have the potential to reach 1000 times higher than current concentration. Chamber cannot be frozen. Major cost consequence as chamber cannot be frozen and therefore there is a significant increase in water treatment costs. Water stored underground until water treatment capacity is increased, consequently there is no release to the environment.	4	A	A	D	Water Treatment Plant is sized and operated to accommodate the additional arsenic concentration to prevent release of arsenic to the environment. Until a plant is constructed that can process contaminated water to achieve compliant discharge, water will be stored underground.	Accelerated construction of a new plant will take six months. Water can be stored underground for this time period.	5	A	A	D	High
WMS-12			Vibration from quarrying operation or earthquake.	Malfunction and/or Accident: Collapse of a crown pillar compromising pit wall stability or pit slope stability leading to a compromise of pillars under creek which results in the loss of containment of Baker Creek which now flows into the underground mine during construction.	Potential release to the environment. Mine water arsenic concentration potentially reaching levels 100 times current values.	5	A	D	C	Should mine flooding occur the new Water Treatment Plant will be sized and operated to accommodate the additional arsenic concentration to prevent the release of arsenic to the environment. Emergency pumping capacity would be sourced and installed while new permanent pumping capacity is built.	There is a short period of exposure to this hazard as the re-alignment of Baker Creek is anticipated to be complete within two years of the start of the project.					High
WMS-13	Pumps		Overflow of pump back at 22B	Accident: Local power failure, site power failure	Overflow into environment affecting Trapper Lake.	5	A	B	A	Local diesel backup generators will be used.	Seep will dry up in the long-term after tailings are covered.					Moderate
Long Term																
WMS-14	New WTP		Inability to produce compliant effluent water and maintain water level in the mine	Malfunction: Plant under designed for the treatment volumes and arsenic concentrations.	Underground storage in the mine will be used up over time as the plant will not have the capacity to process all of the contaminated water for release as compliant effluent.	4	A	A	C	Robustness will be built into the system, limitations will be relevant around capacity. The plant will be designed for flow and concentration at the beginning of the remediation phase, when inflow is the highest. If the plant is found to be undersized additional treatment capability will be added to the plant. The plant will be modified as necessary during the periodic recapitalization of the facility (every 25 years).	With the creation of the frozen block flows will be further reduced. Additional studies are planned to improve on current mine storage calculations.					Low
WMS-15		Power Supply	Main and Backup Power Loss	Accident: Forest fire	No water treatment for 3 months.	5	A	A	B	Fuel management will occur around the plant and power line to minimize the change of impact from a forest fire.	Fuel management and a fire suppression plan will maintain the risk as low over the very long term.					High
WMS-16				Malfunction: Maintenance failure		5	A	A	B	A maintenance management program and a recapitalization plan will be established for the plant. Mechanical systems will be repaired or replaced as necessary to maintain treatment functions.	Recapitalization is expected to occur every 25 years.					High
WMS-17				Malfunction: No generator fuel		5	A	A	B	Back-up generation capacity will be standard for all key components of the project.	In the event of a prolonged power outage water will remain underground. With the creation of the frozen block contact water will be eliminated.					Moderate
WMS-18				Malfunction: Lack of grid power		5	A	A	B	Back-up generation capacity will be standard for all key components of the project.	In the event of a prolonged power outage water will remain underground. With the creation of the frozen block contact water will be eliminated.					Moderate
WMS-19			Major Water Treatment Outage	Malfunction: Failure of mechanical systems	No water treatment for 3 months	4	A	A	C	A maintenance management program and a recapitalization plan will be established for the plant. Mechanical systems will be repaired or replaced as necessary to maintain treatment functions.	Recapitalization is expected to occur every 25 years.					High
WMS-20				Malfunction: Plant freeze up		4	A	A	C	In the event of loss of heating to the plant, systems would be drained to prevent damage. In the event of a freeze event damaging plant components these would be rebuilt to restore plant function. Contaminated water would remain in the mine pool until the plant is again operational.	The operating plan for the plant will include an emergency and recovery component to limit the down time of the plant in the event of an accident. In the event of a prolonged plant outage water will remain underground. With the creation of the frozen block contact water will be eliminated.					High
WMS-21				Malfunction: Reagent supplier unable to meet demand		4	A	A	C	Reagents would be sourced from a new supplier. Contaminated water would remain in the mine pool until the plant is again operational.	More than one supplier of the reagent is available. Cost to change is unknown, but is conservatively estimated					High
WMS-22				Malfunction: Lack of maintenance.		4	A	A	C	A maintenance management program and a recapitalization plan will be established for the plant. Mechanical systems will be repaired or replaced as necessary to maintain treatment functions.	Recapitalization is expected to occur every 25 years.					High
WMS-23	Underground Storage	Concentration of arsenic in mine water pool.	Movement of non-arsenic related backfill due to large fluctuations in minewater level	Accident: Upset condition associated with flooding from Baker Creek.	Such an event has the potential to affect both water storage and treatment. A flood event will increase the amount of water stored underground.	5	A	A	C	The volume of water treated through the water treatment plan may temporarily increase to draw down the mine pool water to the target level. Discharged water will remain compliant. Surface subsidence where it presents a hazard will be filled.	With the creation of the frozen block, contact water will be eliminated.					High

FMECA - Giant Mine - Risk Assessment of Remediation Program

Risk Scenario Event Sequences Chart: Water Management System

ID	COMPONENT	SUBCOMPONENT	RISK ISSUE / FAILURE	EVENT/CAUSES	POTENTIAL CONSEQUENCES	LIKELIHOOD	CONSEQUENCE SEVERITY			PLANNED MITIGATION/CONTROLS/ MANAGEMENT MEASURES	EVALUATION	LIKELIHOOD	CONSEQUENCE SEVERITY			Confidence Estimate
							Public Safety	Environment	Cost				Public Safety	Environment	Cost	
WMS-24			Frozen Block Thawing -- climate change	Accident: Degraded rock quality, crown pillar and sill pillar failure fractured during freezing causes increased permeability of rock mass increasing ground water capture, allowing high concentration arsenic contaminated water to reach mine pool. Additional water from thawing puts stress on plugs.	Release of arsenic contaminated water to mine pool and ultimately to Water Treatment Plant.	5	A	A	C	Expansion of freeze system to overcome the warming. This work would be completed well in advance of chambers thawing out.	Natural thawing would affect all chambers. Freeze system is designed for consequences of climate change. Passive cooling does not rely on long term power for continued function.					High
WMS-25			Frozen Block Thawing -- Malfunction: Failure of freeze system	Malfunction: Degraded rock quality, crown pillar and sill pillar failure fractured during freezing causes increased permeability of rock mass increasing ground water capture, allowing high concentration arsenic contaminated water to reach mine pool. Additional water from thawing puts stress on plugs.	Release of arsenic contaminated water to mine pool and ultimately to water treatment plant	5	A	A	C	The freeze system will be repaired and re-established. In the event that this is not selected or is not possible, the Water Treatment Plant will be re-sized and operated to accommodate the additional arsenic concentration to prevent release of arsenic to the environment. Until additional plant components are constructed that can process contaminated water to achieve compliant discharge water will be stored underground.	A malfunction of the freeze system is likely only to affect a single block. Monitoring of the frozen block temperatures and mine water quality will allow for early detection and pinpointing of failure. It is assumed that thawing in such an event would be the result of natural thawing, not from the intentional application of heat to the frozen blocks.					High
WMS-26	Underground storage	Storage Volume	Mine inundation	Accident: Flood from Baker Creek	Accumulation of additional water in mine pool. No release to the environment	4	A	A	B	The volume of water treated through the water treatment plant may temporarily increase to draw down the mine pool water. Discharged water will remain compliant.	With the creation of the frozen block contact water will be eliminated.					High
WMS-27	Diffuser		Thinner ice cover around diffuser	Malfunction: Diffuser operation in a warmer winter. Modelling does not accurately predict the effect of discharge on ice cover	Safety issue for people utilizing area because ice is thinner than expected.	3	D	A	A	Ice thickness around the diffuser location will be monitored. The location of the diffuser will be marked to alert travelers of its location. If monitoring indicates that thinning of ice to unsafe levels is occurring from the diffuser discharge effluent will be cooled prior to discharge through longer retention in the settling and polishing system.	Modelling taking into account the depth of the diffuser and the anticipated temperature of the discharge water predicts that there will be no affect on ice thickness.	4	A	A	A	High
WMS-28	Receiving Environment	Assimilation Capacity	Detectable increase in arsenic the in receiving environment (Back Bay)	Malfunction: Long term changes in lake conditions and/or modeling inaccuracy.	Small incremental increase in arsenic concentration in Back Bay	5	A	B	A	No change in detectable arsenic levels in Back Bay area expected due to the large assimilation capacity, however, ongoing monitoring will allow early detection of any changes. Changes, if any would not show up for decades and action to address such would likely require a detailed level of assessment at that time to determine options.	The execution of the remediation plan will reduce the amount of arsenic entering the environment from current levels.					High
WM-29		Discharge Regulations	Water Remediation Criteria become more stringent	Malfunction: Regulatory changes, design criteria become more stringent	Re-design and construct new Water Treatment Plant.	3	A	A	C	In the event of more stringent discharge criteria, expand/redesign the Water Treatment Plant to meet the new criteria.	Design and operation of the plant will conform to changes in regulations to maintain compliant discharge as part of recapitalization.	4	A	A	B	High

FMECA - Giant Mine - Risk Assessment of Remediation Program

Risk Scenario Event Sequences Chart: Institutional System

ID	COMPONENT	SUBCOMPONENT	RISK ISSUE / FAILURE	EVENT/CAUSES	POTENTIAL CONSEQUENCES	LIKELIHOOD	CONSEQUENCE SEVERITY			PLANNED MITIGATION/CONTROLS/ MANAGEMENT MEASURES	EVALUATION	LIKELIHOOD	CONSEQUENCE SEVERITY			Confidence Estimate
							Public Safety	Environment	Cost				Public Safety	Environment	Cost	
Short Term																
IS-1	Governance		Governance Failures	Malfunction: Competing mandates within INAC (regulatory and funding), between departments in GoC, territorial government (funding and regulatory)	Slow reaction time to situations consequence is a project delay (3 months)	3	A	B	C	Project management systems, contingency funding, risk management program, project structure, cooperation agreement b/w government, appropriate ERP, appropriate contracting, different contracting rules	Assumed that in the event of a significant risk to humans or the environment, rapid action by the government would take place. Also assumes contractor delay cost. The perceived impacts may be higher.	4	A	B	C	High
IS-2	Governance		Governance Failure	Malfunction: Lack of external communication	Loss of regulatory support; Loss of credibility	2	A	A	A	Additional activities and consultation would be conducted						Moderate
IS-3	Governance		Governance Failure	Malfunction: Lack of oversight and monitoring	Confused roles and responsibilities within the Remediation Team leads to the temporary discharge of inadequately treated water	4	A	B	B	INAC's project management quality control / quality assurance is in place; Independent engineer engaged	The scenario assumed is as worst case; The perceived impacts may be higher.					Moderate
IS-4	Governance		Governance Failure	Malfunction: Loss of political support for frozen block option	Lack of funding for freeze component requiring stabilization and pump and treat	3	A	A	A		Leads to substantial cost savings. The perceived impacts may be higher.					Moderate
IS-5	Governance		Governance Failure	Malfunction: Inadequate training and emergency response	Primary consequence is discharge of inadequately treated water into Back Bay	3	A	A	A	Ensure quality assurance program is in place (i.e. check training of staff and monitoring program)	Assumed short term perceived impacts on the recreational use of Back Bay was identified; No drinking water impacts. A Surveillance Network Program would be in place.					Moderate
IS-6	Governance		Governance Failure	Malfunction: Loss of continuity and coordination	Loss of project knowledge	2	A	A	B	Data control and mentoring of personnel. Governance structure firmly in place and is embedded in project delivery.		3	A	A	B	Moderate
IS-7	Regulatory		Water Remediation Criteria become more stringent	Malfunction: Regulatory changes	Plant expansion/redesign, additional parameters to treat	4	A	A	C	Ensure plant design is expandable and plant re-capitalization every 25 years (treatment technology improvements incorporated into future plants)	Assumed that an existing plant is in place, plant expansion / re-design required to meet new standards.					Moderate
Long Term																
IS-8	Governance		Governance Failure	Malfunction: Lack of external communication	Loss of regulatory support; Loss of credibility	2	A	A	A	Regular consultation and ongoing investment in communications						Moderate
IS-9	Governance		Governance Failure	Malfunction: Lack of oversight and monitoring	Confused roles and responsibilities within the lead agencies lead to the temporary discharge of inadequately treated water	4	A	B	B	Governance structure firmly in place; Ongoing monitoring and QA as per the Water License; Planned redundancy within the water treatment process; Year-round water treatment reduces concentration and flow rate						Moderate
IS-10	Governance		Governance Failure	Malfunction: Inappropriate funding model for multi-year project	Funding cycle leads to inability to develop long term contracts and high turnover of staff which results in upsets of treatment of non-compliant water	3	A	A	A	Governance structure firmly in place; Ongoing monitoring and QA as per the Water License; Planned redundancy within the water treatment process; Year-round water treatment reduces concentration and flow rate	Short term, localized impacts that are readily mitigated.					Moderate
IS-11	Governance			Malfunction: Loss of continuity and coordination by management	Operation and Maintenance and monitoring commitments can no longer be fulfilled; Leads to non-compliant discharge of a period of approximately 2 months	4	A	B	B	Governance structure firmly in place; Ongoing monitoring and QA as per the Water License; Planned redundancy within the water treatment process; Year-round water treatment reduces concentration and flow rate	Assumed discharge into Back Bay not caught due to monitoring no longer occurring; Reporting to authorities on a monthly basis is a requirement.					Moderate
IS-12	Governance		Remediated Mine Components	Malfunction: End land use changes	Additional remediation required	4	A	B	D	Governance structure firmly in place; Ongoing monitoring and QA as per the Water License	Assumed end change of land use requiring remediation causing localized site disturbance to establish ecosystem.	5	A	B	D	Moderate
IS-13	Regulatory		Water Remediation Criteria become more stringent	Malfunction: Regulatory changes	Plant expansion/redesign, additional parameters to treat	3	A	A	C	Ensure plant design is expandable and plant re-capitalization every 25 years (treatment technology improvements incorporated into future plants)	Assumed existing plant in place, plant expansion / re-design required to meet new standards.	4	A	A	C	Moderate

FMECA - Giant Mine - Risk Assessment of Remediation Program

Risk Scenario Event Sequences Chart: Infrastructure System

ID	COMPONENT	SUBCOMPONENT	RISK ISSUE / FAILURE	EVENT/CAUSES	POTENTIAL CONSEQUENCES	LIKELIHOOD	CONSEQUENCE SEVERITY			PLANNED MITIGATION/CONTROLS/ MANAGEMENT MEASURES	EVALUATION	LIKELIHOOD	CONSEQUENCE SEVERITY			Confidence Estimate
							Public Safety	Environment	Cost				Public Safety	Environment	Cost	
Short Term																
INF-1	Buildings	Roaster	Weather damage	Accident: Extreme weather/high winds	Strong wind exposes arsenic and friable asbestos	3	A	A	A	Care and maintenance will continue for this structure until demolition. During demolition work areas will be contained or isolated.	Long term - all buildings will be demolished which will eliminate the risks associated with this structure. Impacts may be perceived as higher.					Moderate
INF-2			Weather damage	Accident: Extreme weather/high winds	Strong wind results in building debris blown towards highway with the potential to injure.	4	C	A	A	Care and maintenance will continue for this structure until demolition. Impacts may be perceived as high.	Long term - all buildings will be demolished which will eliminate the risks associated with this structure. Impacts may be perceived as higher.					High
INF-3			Earthquake	Accident: Earthquake (max. 6.0 magnitude for the region)	Building damage that exposes contaminants and complicates demolition.	5	A	A	B	During demolition work areas will be contained or isolated.	Long term - all buildings will be demolished which will eliminate the risks associated with this structure. Impacts may be perceived as higher.					High
INF-4			Complcations encountered during demolition	Malfunction: Building removal failure	Building damage	3	A	A	B	This structure will be decontamininated prior to demolition. Care and maintenance will continue for this structure until demolition. During demolition work areas will be contained or isolated.	Long term - all buildings will be demolished which will eliminate the risks associated with this structure.					High
INF-5		Stack	Earthquake	Accident: Earthquake (max. 6.0 magnitude for the region)	Collapses on Roaster	5	A	A	B	During demolition work areas will be contained or isolated.	Long term - all buildings will be demolished which will eliminate the risks associated with this structure.					High
INF-6			Complcations encountered during demolition	Malfunction: Building removal failure	Building damage	3	A	A	B	During demolition work areas will be contained or isolated.	Long term - all buildings will be demolished which will eliminate the risks associated with this structure.					High
INF-7		C-Shaft Headframe	Weather damage	Accident: Extreme weather/high winds	Strong wind results in building debris blown towards highway with the potential to injure.	4	C	A	A	This structure will be decontamininated prior to demolition. Care and maintenance will continue for this structure until demolition. During demolition work areas will be contained or isolated. Cladding to be removed in 2011.	Long term - all buildings will be demolished which will eliminate the risks associated with this structure.					High
INF-8			Weather damage	Accident: Extreme weather/high winds	Asbestos cladding is disturbed and asbestos released into the air.	3	B	B	A	During demolition work areas will be contained or isolated.	Long term - all buildings will be demolished which will eliminate the risks associated with this structure.					High
INF-9			Complcations encountered during demolition	Malfunction: Building removal failure	Building damage	3	A	A	A	During demolition work areas will be contained or isolated.	Long term - all buildings will be demolished which will eliminate the risks associated with this structure.					High
INF-10		A-Shaft Headframe	Weather damage	Accident: Extreme weather/high winds	Strong wind exposes friable Asbestos	3	A	A	A	This structure will be decontamininated prior to demolition. Care and maintenance will continue for this structure until demolition. During demolition work areas will be contained or isolated.	Long term - all buildings will be demolished which will eliminate the risks associated with this structure.					High
INF-11			Complcations encountered during demolition	Malfunction: Building removal failure	Building damage	3	A	A	A	Care and maintenance will continue for this structure until demolition. During demolition work areas will be contained or isolated.	Long term - all buildings will be demolished which will eliminate the risks associated with this structure.					High
INF-12		Mill	Weather damage	Accident: Extreme weather/high winds	Strong wind results in building debris blown towards highway and injures a person	4	C	A	A	This structure will be decontamininated prior to demolition. Care and maintenance will continue for this structure until demolition. During demolition work areas will be contained or isolated.	Long term - all buildings will be demolished which will eliminate the risks associated with this structure.					High
INF-13			Weather damage	Accident: Extreme weather/high winds	Asbestos cladding is disturbed and asbestos released into the air	3	B	B	A	Care and maintenance will continue for this structure until demolition. During demolition work areas will be contained or isolated.	Long term - all buildings will be demolished which will eliminate the risks associated with this structure.					High

FMECA - Giant Mine - Risk Assessment of Remediation Program

Risk Scenario Event Sequences Chart: Infrastructure System

ID	COMPONENT	SUBCOMPONENT	RISK ISSUE / FAILURE	EVENT/CAUSES	POTENTIAL CONSEQUENCES	LIKELIHOOD	CONSEQUENCE SEVERITY			PLANNED MITIGATION/CONTROLS/ MANAGEMENT MEASURES	EVALUATION	LIKELIHOOD	CONSEQUENCE SEVERITY			Confidence Estimate
							Public Safety	Environment	Cost				Public Safety	Environment	Cost	
INF-14			Earthquake	Accident: Earthquake (max. 6.0 magnitude for the region)	Minor building damage	5	A	A	B	During demolition work areas will be contained or isolated.	Long term - all buildings will be demolished which will eliminate the risks associated with this structure.					High
INF-15			Complcations encountered during demolition	Malfunction: Building removal failure	Building damage	3	A	A	B	Care and maintenance will continue for this structure until demolition. During demolition work areas will be contained or isolated.	Long term - all buildings will be demolished which will eliminate the risks associated with this structure.					High
INF-16		General Buildings	Forest fire, large grass fire or other large scale fire on site.	Accident: Lightning, human error	Loss of C dry, WTP, freeze system and other structures	5	B	B	C	Fire response plan for the site will be maintained. The loss of the WTP and freeze system are covered under failures on the Water Management and Freeze System Sheets.	Heat value of forest fire is low for area, reasonable fire breaks between structures currently existing except WTP. Arsene gas requires high temperatures to ignite and therefore presents little risk.					High
INF-17	Underground Equipment	Scoop Tram	Underground Fire	Accident: Accident leads to fire	Loss of scoop tram or electrical systems underground	4	A	A	B	Fire response plan for the site will be maintained. In the event of damage, critical components will be repaired/replaced.	Any impact to the freeze program will be short term.					High
INF-18	Fuel Storage	Tanks	Fuel tank rupture and fire	Malfunction and/or Accident: Collision	Accident leads to release and combustion of fuel	5	A	B	B	Fire response plan for the site will be maintained. Site controls such as speed limits and barriers to prevent vehicle accidents will be in place. Spills will be remediated.	Site controls and emergency planning are anticipated to minimise the occurrence and consequence of accidents.					High
INF-19		Transportation	Fuel spill on-site	Malfunction: On-site accident involving the transportation of fuel.	Contaminated soil and contaminated water, potentially affecting Baker Creek	4	A	C	C	Site controls such as speed limits and barriers to prevent vehicle accidents will be in place. Spills will be remediated. A spill response emergency plan will be maintained and spill response supplies will be stored on site.	Site controls and emergency planning are anticipated to minimise the occurrence and consequence of accidents.					High
Long Term																
INF-20	Mine Water Treatment Plant	Reagent Storage	On-site ferric sulphate spill	Malfunction: On-site accident	Contaminated soil and contaminated water, potentially affecting Baker Creek	4	A	C	C	Site controls such as speed limits and barriers to prevent vehicle accidents will be in place. Spills will be remediated. A spill response emergency plan will be maintained and spill response supplies will be stored on site.	Site controls and emergency planning are anticipated to minimise the occurrence and consequence of accidents.					High
INF-21	Buildings		Freeze up of infrastructure, which may include Water Treatment Plant, and office complex and interruption in freeze operations	Accident: Site power failure	Freeze up of infrastructure, which may include Water Treatment Plant, and Office Complex; Interruption in freeze operations. Details of consequences are addressed under the Water Management System Sheet and Freeze System.	3	A	A	B	Emergency response and recovery planning for key systems, including the installation of emergency generation capacity and protocols for Water Treatment Plant shut down and restart. Details of measures are addressed in the Water Management System and Freeze System .	Emergency response and recovery plans and the addition of emergency generation capacity for key systems will minimise the impacts of site power failure.					High

Appendix C

Cascading Event Scenarios

Giant Mine - Risk Assessment of Remediation Program
Cascading Event Scenario - Short Term (Implementation) - Table 1

Initiating Event	Failure Sequence ----------->									Result	FMECA Reference
Earthquake	Component Failure: Arsenic Crown Pillar Failure	Pressure shock to bulkheads	Component Failure: Bulkhead Failure	Arsenic solids released to mine pool	Increase in arsenic concentration in minewater	ETP and Mine WTP not design to high test water	Component Failure: ETP and Mine WTP Failure			Increase in cost. Release to the environment.	UGS-3 followed by UGS-1
Earthquake	Component Failure: Crown Pillar Failure	Crown pillar failure leads to pit slope or pit wall instability	Collapse under Baker Creek	Component Failure: Baker Creek Failure	Baker Creek flows into mine	Increase in arsenic concentration in minewater	ETP and Mine WTP not design to high test water	Component Failure: ETP and Mine WTP Failure		Release to the environment	WMS-12
Earthquake	Component Failure: Baker Creek Failure (base of creek collapses)	Baker Creek flows into mine	Increase in arsenic concentration in minewater	Minewater flood damages underground infrastructure	Component Failure: Mine dewatering pumps fail	Mine floods to surface				Release to the environment. Baker Creek Canal re-alignment required. Underground pumping system replacement required.	BCS-4
Flood	Component Failure: Baker Creek Bank Overflow	Flow into mine	Rise in minewater	Increase in arsenic concentration in minewater	Component Failure: Underground instability (wet conditions)	Release of arsenic to mine pool	ETP under designed to handle concentration levels	New Mine WTP not operational yet	Component Failure: ETP treatment not effective	Impact to environment.	BSC-1 followed by UGS-5

Giant Mine - Risk Assessment of Remediation Program
Cascading Event Scenario - Long Term (Post-Construction) Table 2

Initiating Event	Failure Sequence -------------->								Result	FMECA Reference
Extreme Weather (Global Warming above anticipated levels)	Component Failure: Passive Freeze System Failure	Thaw of frozen block	Underground Instability	Component Failure: Sill Pillar Failure	Release of arsenic contaminated water to mine pool	Minewater requires more treatment.	Mine WTP throughput decreases	Component Failure: Mine WTP requires upgrades	Increase cost	WMS-24
Earthquake	Component Failure: Baker Creek Failure (base of creek collapses)	Baker Creek flows into mine	Increase in arsenic concentration in minewater	Minewater flood damages underground infrastructure	Component Failure: Mine dewatering pumps fail	Mine floods to surface			Non-compliant discharge to the environment. Baker Creek Canal re-alignment required. Underground pumping system replacement required.	BCS-10

Appendix D

Multiple Cause Scenarios

Giant Mine - Risk Assessment of Remediation Program
Multiple Cause Scenario - Short Term (Implementation) - Table 3

Multiple Cause Scenario Number	Initiating Events	Failure Sequence -------------->						Result	FMECA Reference
MCS-1	Effluent Treatment Plant (ETP) Supply of Chemicals Interrupted (2 months)	Component Failure: Baker Creek Base Collapse	Flood into mine	Flood up to underground pumping system	Component Failure: Underground Pump Failure	Replace pumping system		Increase in cost Release to environment.	BCS-4
	Failure of Baker Creek base during freshet			Mine floods to surface	New Mine WTP not operational yet	Loss of arsenic into mine pool	Component Failure: ETP Treatment not Effective		
MCS-2	Wetting Plan for Freeze System Not Effective. Saturated Unfrozen in Chambers	Component Failure: Underground Stability Failure	Major loss of arsenic slurry into mine	Component Failure: ETP would require upgrades or additional temporary treatment would be required to treat the elevated arsenic in minewater.	Component Failure: Re-design of Underground Stability Program			Increase in cost	UGS-5
	Sill Pillar Failure				Component Failure: Loss of arsenic into other portions of the mine (previously non-arsenic containing) would require a re-design of a portion of the freeze system				

Giant Mine - Risk Assessment of Remediation Program
Multiple Cause Scenario - Long Term (Post-Construction) - Table 4

Multiple Cause Scenario Number	Initiating Events	Failure Sequence ------------>					Result	FMECA Reference
MCS-3	New Mine Water Treatment Plant (Mine WTP) is down for annual general maintenance (1 week)	Component Failure: Baker Creek Bank Overflow	Flood into mine	Flood up to underground pumping system	Component Failure: Underground Pump Failure	Replace pumping system	Increase in cost No impact to Mine WTP	BCS-6, WMS-23
	Extreme weather causes a flood event over the designed capacity of Baker Creek and a power outage			Flood up to frozen arsenic chambers	Arsenic residue lost into minewater	Nominal increase concentration of arsenic in minewater		
MCS-4	Snow and ice of tailings cover melts creating higher then normal run-off	Component Failure: Tailings Cover (Geotextile) Fails	Run-off does not migrate off-site				No impact	SS-11
	Greater than anticipated consolidation occurs on tailings cover							
MCS-5	Loss of Long Term Power	Component Failure: Passive Freeze System	Degraded rock quality	Crown and sill pillar failure	Increase arsenic loading to minewater	Mine WTP (on back-up power) increases treatment rate	Increase in cost	FS-8
	Passive Freeze System Failure							

Appendix E

List of Participants for Workshops

Workshop 1:

i. March 22 to 24, 2011 in Vancouver
ii. Participants:

INAC

- INAC -Ben Nordahn
- Department of Justice – Carla Conkin

PWGSC

- PWGSC – Henry Westermann, P.Eng.
- PWGSC - Corrine Stokowski
- PWGSC - Norm Quail
- PWGSC - David Abernathy
- PWGSC - Desmond O'Connor
- PWGSC - Doug Townson, NWTAA, B.Arch.
- PWGSC - Lisa Dyer, P.Eng.
- PWGSC - Mark Cronk, P.Eng.

DXB Projects

- DXB Projects - Dave Bynski, P.Eng, PMP

AECOM

- AECOM - Robert Boon, P.Eng.
- AECOM - David Knapik, P.Eng.
- AECOM - Rudy Schmidtke, M.Sc, P.Eng.
- AECOM - Jennifer Singbeil, P.Eng.

Golder

- Golder - John Hull, P.Eng.
- Golder - Cameron Clayton, M.Eng, P.Geo.
- Golder - Darren Kennard, P.Eng.(BC)
- Golder - David Caughill, P.Eng.
- Golder - Katharine Harrison
- Golder - Randa Salameh
- Golder - Richard Beddoes, P.Eng.
- Golder - Nathan Schmidt, Ph.D., P.Eng.

Workshop 2:

i. April 4 to 6, 2011 in Vancouver
ii. Participants:

INAC

- INAC –Michael Nahir, M.Eng., P.Eng.
- INAC - Martin Gavin, P.Eng.
- INAC - Adrian Paradis
- Department of Justice – Carla Conkin
- Government of the Northwest Territories (GNWT) – Ken Hall
- Brodie Consultants Ltd. – John Brodie, P.Eng.
- SRK Consulting (SRK) – Daryl Hockley, P.Eng.; Peter Mikes, P.Eng.
- SENES – Bruce Halbert

PWGSC

- PWGSC - Henry Westermann, P.Eng.
- PWGSC - Corrine Stokowski
- PWGSC - Norm Quail
- PWGSC - David Abernathy
- PWGSC - Desmond O'Connor
- PWGSC - Lisa Dyer, P.Eng.
- PWGSC - Mark Cronk, P.Eng.
- PWGSC - Chris Doupe
- PWGSC - Sharon Nelson

DXB Projects

- DXB Project - Dave Bynski, P.Eng., PMP

AECOM

- AECOM - David Knapik, P.Eng.
- AECOM - Rudy Schmidtke, M.Sc, P.Eng.
- AECOM - Gordon Woollett, P.Eng.
- AECOM - Barry Williamson, P.Eng.

Golder

- Golder –.John Hull, P.Eng.
- Golder - Ross Hammet, P.Eng.
- Golder - Richard Beddoes, P.Eng.
- Golder - David Caughill, P.Eng.
- Golder - Katharine Harrison
- Golder - Brian Griffin, B.A.Sc
- Golder - Nathan Schmidt, Ph.D., P.Eng.

Workshop 3:

i. May 30 and 31, 2011 in Edmonton
ii. Participants:

INAC

- INAC –Michael Nahir, M.Eng., P.Eng.
- Brodie Consultants Ltd. – John Brodie, P.Eng.

PWGSC

- Norm Quail
- Mark Cronk, P.Eng.

DXB Projects

- DXB Projects - Dave Bynski, P.Eng., PMP

Golder

- Golder - John Hull, P.Eng.
- Golder - Darren Kennard, P.Eng. (BC)

AECOM

- AECOM - Rudy Schmidtke, M.Sc, P.Eng.
- AECOM - David Knapik, P.Eng.
- AECOM - Jennifer Singbeil, P.Eng.
- AECOM - Jillian Roth, EIT
- AECOM - Larissa Wall