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21 – ACCIDENTS AND MALFUNCTIONS

21.1 INTRODUCTION

In accordance with Section 42 of YESAA, the assessment of a project must include determination of the significance of any environmental or socio-economic effects resulting from accidents or malfunctions. Additional federal and territorial legislation pertaining to accidents and malfunctions are discussed in Appendix 21-A. Environmental risk assessment is a systematic review of the potential for failure of engineered systems and their effects, and incorporates design and contingency planning (Pelletier and Dushnisky 1993). The primary purpose of a risk assessment is to identify hazards associated with a project, assess the associated risks, and bring the risks to tolerable level on a continuous basis (Paithankar 2011). The general approach to risk assessment involves the identification and analysis of information in terms of risk to environmental and socio-economic values; the outcome of the risk assessment is used to identify risk reduction strategies (Ministry of Environment, Lands and Parks 2000).

Credible hazard scenarios with potentially moderate to major impacts or consequences are assessed in this section of the Casino Project Proposal; the analysis of risk includes the evaluation of the likelihood of occurrence of an incident, and the consequences of an incident should one occur. A qualitative risk assessment was used: qualitative approaches to risk assessment are the most commonly applied and use descriptive terms to identify broad likelihoods and consequences of events (Paithankar 2011). Qualitative methods often illustrate the ranking of risks using a risk matrix (Paithankar 2011). Section 21.3 provides the methodology used to assess the risks associated with accidents and malfunctions.

The assessment was completed by examining Project components or activities to develop an understanding of accidents and malfunctions that could occur for all phases of the Project, and all potential hazard scenarios associated with the accident or malfunction. Accidents and malfunctions are unplanned events that may be caused by design failure, equipment malfunction, or human error. The accidents and malfunctions assessment includes discussion of hazard scenarios; their potential causes; design measures implemented to reduce the likelihood and consequence of any incident; the potential effects of any incident on Valued Components (VCs); and mitigation and management measures that will be implemented to further reduce the risk of occurrence. The effect of natural events, such as earthquakes or floods, that could affect the Project are discussed elsewhere in this Proposal.

The scope of the risk assessment considers accidents and malfunctions associated with the following Project components:

- Site preparation;
- Mining;
- HLF and processing;
- Mine waste management (tailings and waste rock);
- Water supply and management;
- Liquefied Natural Gas (LNG) and diesel use;
- Transport of equipment, personnel, materials, and product to and from site utilizing trucks and aircraft;
- Hazardous material storage and use; and

- Waste disposal.

Potential accidents or malfunctions associated with the Project components were assessed for all Project phases. The effects of accidents and malfunctions on employee health and safety or on the economics of the Project will be addressed as part of the Project health and safety program and in the operations management manual, respectively, and are not addressed in this section of the Proposal. A set of credible incident scenarios was selected for assessment, based on the Project design. Typical risks associated with mining developments include transportation accidents resulting in fuel or chemical spills; tailings line rupture or release; and tailings impoundment or spillway failure (Pelletier and Dushnisky 1993). The credible hazard scenarios assessed for the Casino Project were:

- Embankment failures;
- Slope failures;
- Spills or leaks;
- Transportation accidents;
- Water conveyance and storage systems failure;
- Fires and explosions; and
- Failure of erosion and sediment control measures.

Interactions between the hazard scenarios associated with the accidents and malfunctions and the Project VCs are discussed. The hazard scenarios, design measures, potential effects of any incident on VCs; and mitigation and management measures to address each high level risk are recorded in a Risk Register. The completed Risk Register for the Casino Project can be found in Appendix 21B.

21.2 METHODOLOGY

The method used to assess the significance of potential accidents and malfunctions follows the general approach and framework of a Failure Modes and Effects Analysis (FMEA). The purpose of a FMEA is to assess the risk of failure in a process and identify the most important areas for improvement; it is a step-by-step process to identify the ways in which a component or process may fail (the “failure modes”) and assess the consequences of those failures (“effects analysis”). For this assessment, the “failure modes” are the accidents and malfunctions. The “effects analysis” is the determination of risk.

Risk assessment involves risk identification (what could happen, how, when, and why) followed by risk analysis (Purdy 2010). Risk analysis involves developing an understanding of the risk in terms of consequences and likelihood, and making a decision about an acceptable level of risk and the need for additional treatment (Purdy 2010). Options to “treat” the level of risk include avoiding the risk by not initiating the activity; removing the source of risk; or implementing measures to alter the likelihood or consequences (Purdy 2010). Risk assessments can follow quantitative, semi-quantitative, or qualitative approaches. Quantitative analyses use numerical measurements to describe conditions, while qualitative analyses are based on existing research, professional experience, and judgement (Ministry of Environment, Lands and Parks 2000). Most risk assessments are neither purely quantitative nor qualitative, since qualitative analyses rely to some extent on numerical background information, and quantitative analyses are based on assumptions and expert opinion; both require professional judgement when dealing with uncertainty (Ministry of Environment, Lands and Parks 2000).

A qualitative risk assessment was conducted for the Casino Project in order to identify all components or activities and potential hazard scenarios that could pose a risk to the Project VCs. Qualitative approaches use descriptive terms to identify likelihoods and consequences of events (Paithankar 2011). The ranking of risks for each hazard scenario are illustrated on a risk matrix. The general approach followed in the assessment is presented Figure 21.2-1 and discussed in the following paragraphs.

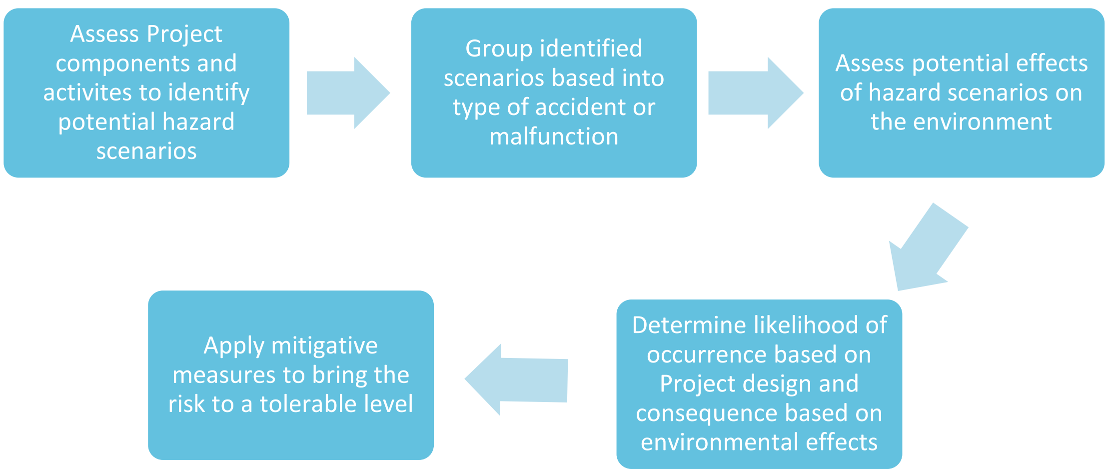

Figure 21.2-1 Accidents and Malfunctions Risk Assessment Methodology

21.2.1 Risk Identification and Analysis

Professional judgment was used to identify potential accidents and malfunctions associated with each of the major Project components and activities and resulting hazards that were determined to be credible. For this assessment, the Project description provided in Section 4 of this Proposal was reviewed to identify the major components of the Project, which comprise:

- Site preparation activities (borrow pits, clearing and grubbing, mass excavation and fill, topsoil and overburden stockpiles);
- Mining (open pit drilling and blasting, crushing and conveying of ore and waste);
- Heap leach facility (heap leach pad, events pond, operation and cyanide destruction plant, constructed wetland at closure);
- Processing (gold extraction plant, sulphide ore processing, concentrate handling);
- Tailings Management Facility (TMF) (embankment, cyclone plant, tailings distribution pipelines, potentially reactive waste rock and overburden);
- Water supply and management (riverbank caisson and radial well system, temporary and permanent storage ponds, collection and diversion ditches);
- LNG and diesel facility;

- Transport of equipment, materials, personnel to/from site (including the Freegold Road construction and use);
- Hazardous materials storage and use; and
- Waste disposal.

A Risk Register was developed to document the major components or activities and potential accidents or malfunctions associated with each. A Risk Register is a tool used to record details of all risks identified for a component or activity. The Risk Register includes a description of each risk; when it could occur; factors that could affect the likelihood or consequence of a risk; the likelihood and consequence of a failure; actions and controls that would be implemented to mitigate the risks; and an assessed risk grade.

Each "risk" was assigned an alphanumeric code to reflect the Project component and the hazard scenario and carried forward in the assessment.

Risk is typically defined as the product of the likelihood and the consequence of an event. Likelihood is assigned based on the level of design information available for the Project, review of historic or current mining accidents and malfunctions, and professional judgement. Consequence is assigned based on the spatial and temporal context of the Project. Qualitative descriptors for the four likelihood categories are provided in Table 21.2-1. Qualitative descriptors for the four consequence categories are provided in Table 21.2-2.

Table 21.2-1 Likelihood Rating Criteria

Unlikely	Event is not expected to occur during the life of the Project
Rare	Low probability of occurrence during the life of the Project
Possible	Event may occur during the life of the Project
Likely	Event is expected to happen at least once during the life of the Project

Table 21.2-2 Consequence Rating

Very Low	Effects occur near the source, are contained, and are immediately reversible
Low	Effects extend beyond event site but are confined, and persist over the short-term but are reversible through mitigation
Moderate	Effects extend beyond event site, have medium-term recovery but are reversible through mitigation, with no residual impacts
High	Effect is widespread, requires long-term recovery with mitigation, leaves a residual impact

Confidence in the likelihood and consequence ratings is provided in the Risk Register; low confidence in the ratings would be a result of insufficient information regarding details of the Project component or activity, or incomplete knowledge of the site-specific setting (or a combination of the two); high confidence would be assigned where information is available on design and failure modes for similar components or activities.

21.2.2 Risk Evaluation and Ranking

The primary objective of a risk assessment is to provide context in making decisions, ideally decisions that result in acceptable levels of risk to environmental, social and economic values (Ministry of Environment, Lands and Parks 2000). The likelihood and consequence of the hazard scenarios identified in the previous steps was therefore discussed subsequently in terms of the Project VCs. The assessment of potential effects to VCs from the accident and malfunction hazard scenarios is based on an initial screening of interactions. A three-point scale was used to rank potential interactions, ranging from ‘0’ where no interaction is anticipated to ‘2’, denoting a higher risk interaction; the criteria for each rank are defined in Table 21.2-3.

Table 21.2-3 VC Interaction Code

Code	Anticipated level of interaction
0	No interaction
1	Interaction is not anticipated to result in an environmental or socio-economic effect with implementation of mitigation and management measures.
2	Interaction could result in an environmental or socio-economic effect of concern, even with implementation of mitigation measures.

Interactions between potential accidents and malfunctions and the Project VCs are provided on Figure 21.2-2; all VCs potentially affected by each hazard scenario are indicated in the Risk Register (Appendix 21B).

	Valued Components													
Accidents and Malfunctions	**Surficial Geology, Terrain, and Soils**	**Water and Sediment Quality**	**Air Quality**	**Noise**	**Fish and Fish Habitat**	**Rare Plants and Vegetation Health**	**Wildlife**	**Community Vitality**	**Community Infrastructure and Services**	**Sustainable Livelihood**	**Employability**	**Economic Development and Business Sector**	**Cultural Continuity**	**Land Use and Tenure**
Embankment Failure	2	2	0	0	2	2	2	0	0	0	0	0	0	0
Slope Failure	2	2	0	0	2	2	2	0	0	1	0	0	0	1
Spills/Leaks	2	2	0	0	2	0	2	0	1	2	0	0	0	0
Water Management Failure	2	2	0	0	2	2	1	0	0	0	0	0	0	0
Fire/Explosion	0	0	2	2	0	2	1	0	1	1	0	0	0	2
Transportation Accident	0	0	0	0	0	0	1	0	2	0	0	0	0	0
Erosion and Sediment Control Measures Failure	1	2	0	0	2	1	1	0	0	0	0	0	0	0

Figure 21.2-2 Accidents and Malfunctions VC Interaction

The next step in the risk assessment is to identify additional management or monitoring strategies for all hazard scenarios. Management measures could include additional mitigation for moderate or higher risk scenarios, and monitoring and adaptive management for lower risk activities.

Using the likelihood and consequence ratings for each hazard scenario, a risk grade is assigned based on a risk matrix, as illustrated on Figure 21.2-3.

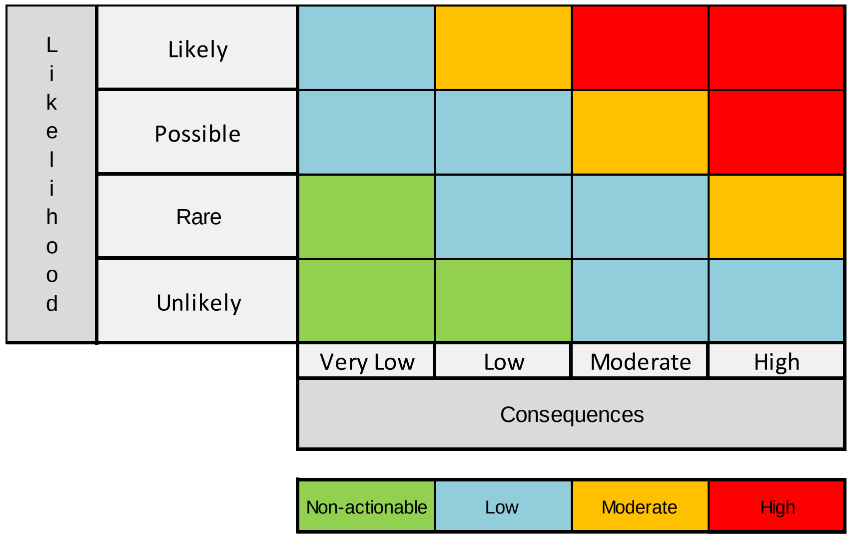

Figure 21.2-3 Risk Matrix Template

Risk grades range from Non-actionable (negligible risk; no additional mitigation or re-design required) to High (serious risk; re-design or operational changes required). Hazard scenarios ranked as 'Non-actionable' risk to 'Moderate' risk are considered Not Significant; those rated as 'High' are considered to constitute a potentially significant impact on Project VCs. Risk grades are used to assist management and decision making in determining where focus will be needed at the design detail stage or during operations to minimize the risk of failure of a component or activity.

21.3 RISK IDENTIFICATION

The Casino Project is primarily a copper and gold mine that is anticipated to process approximately 120,000 t/d or 43.8 million t/y of material over 22 years of full production. The Casino Project will produce gold and silver doré and copper and molybdenum concentrates from both heap leach and conventional flotation recovery processes. A detailed description of the Project is provided in Section 4.

21.3.1 Site Preparation and Construction

Site preparation activities for the Casino Project include:

- Clearing and grubbing of vegetation;
- Topsoil salvage for future use in reclamation
- Construction of sediment and erosion control structures;
- Development of site staging and laydown areas;
- Large mass excavations and fills;
- Excavation of borrow sites for aggregates; and
- Foundation preparation for infrastructure.

Potential accidents and malfunctions and hazards assessed with site preparation activities were identified as:

- Slope or wall failure in borrow sites, resulting in slope failure or instability in surrounding terrain;

- Failure of sediment and erosion control structures during clearing and grubbing, development of site staging and laydown areas, or foundation preparation, resulting in discharge of deleterious substances (sediment) to the environment;
- Failure of sediment and erosion control structures during topsoil salvage and stockpiling;
- Spills or leaks from heavy equipment and machinery used for site preparation, resulting in release of deleterious substances (fuels, lubricants, etc.);
- Vehicle collisions (trucks, track and wheel dozers, graders, water trucks, etc.) resulting in spills or leaks of deleterious substances (fuels, lubricants, etc.); and
- Accident or equipment failure relating to the Concrete Batch Plant, resulting in the discharge of deleterious substances (uncured concrete or concrete leachate) to the environment.

Site preparation activities will be conducted primarily in the construction phase, but will extend into the Operation Phase for components such as the TMF, HLF, and waste rock and topsoil stockpiles, which will be developed over the life of the mine as the Open Pit expands.

21.3.2 Mining

21.3.2.1 Open Pit

The Casino Project Open Pit, located between the headwaters of Casino Creek and Canadian Creek, will occupy an area of approximately 300 ha at its greatest extent. The Open Pit will be developed using standard drill and blast techniques. Activities associated with Open Pit operation include:

- Drilling and Blasting:
  - Blast holes will be drilled and explosives (ammonium nitrate and fuel oil (ANFO)) dispensed into the blast holes; and
  - Blasting trials are implemented when there are observed changes in the characteristics of the rock during excavation.
- Open Pit development:
  - Overburden will be cleared at the Open Pit edge at a 2H:1V slope;
  - Benches 8 m wide and 15 m tall with a face angle of 65º will be used for the majority of the Open Pit;
  - Inter-ramp angles of 45º will be used for the majority of the Open Pit, angles of 42º will be used to minimize wedge failures as necessary.
- Water management:
  - Diversion ditches will be constructed to collect surface runoff, snowmelt and seepage along the pit crest and the base of the weathered bedrock materials and divert it away from the pit;
  - Horizontal drains will be drilled in pit walls to drain groundwater;
  - Vertical wells will be drilled to reduce water pressure in the pit walls; and
  - Pumps and collection systems will transfer water from the pit excavation to a surface sump.

At closure the Open Pit will be partially backfilled with low grade ore and lime will be added to increase the pH. Water from the tailings pond will be pumped and stored in the Open Pit until the TMF wetlands are active, and diversion ditches will be removed to allow the Open Pit to passively fill with water; once the Open Pit fills to the point of overflow (estimated to occur within 50 to 100 years), pit drainage will enter the TSF wetland via decant control valve.

Potential accidents and malfunctions and hazards assessed for Open Pit activities are:

- Fuel spill in Open Pit during refueling or resulting from vehicle collisions;
- Pit wall failure resulting in adjacent slope instability;
- Fly rock and air overpressure wildlife injury or mortality and damage to public infrastructure from blasting accidents; and
- Open pit flooding and overtopping during operations.

21.3.2.2 Ore Crushing, Conveying, Hauling, Stockpiling

Ore materials from the Open Pit will be hauled to the ore stockpiles or the crusher system for crushing to reduce ore size to required specifications. The following stockpiles will be used during the course of construction and operations:

- Gold ore intended for the heap leach will be stockpiled starting in Year -3 and continuing up to Year 15;
- Low-grade ore will be stored in several temporary stockpiles adjacent to the plant site and crusher up to Year 17 and milled during the last four years of mine operations;
- Supergene oxide (SO_X) ore will be stockpiled during the construction phase and in Year 1 of operations for processing during Years 4 to 12; and
- Sulphide coarse ore reclaim: primary crushed sulphide ore will be stockpiled on the ground in a covered coarse ore reclaim stockpile until it will be fed to the semi-autogenous (SAG) mill circuit.

Potential accidents and malfunctions and hazards assessed for ore handling activities are:

- Ore stockpiles slope failure resulting in deposit of material into surrounding terrain (sediment); and
- Blockage of water collection or diversion ditches at toe of stockpiles, resulting in discharge of deleterious substances to environment (contact water).

21.3.3 Processing

The sulphide ore processing facility produces mineral concentrates of copper and molybdenum using conventional flotation technology. The oxide ore processing facility produces gold and silver doré bars via heap leaching and carbon adsorption technology.

21.3.3.1 Sulphide Ore Processing Facility

Sulphide ore processing will be comprised of primary crushing, a conventional single-line SAG mill circuit, and conventional copper-molybdenum flotation to produce concentrates of molybdenum and copper. Copper concentrates will flow by gravity from the flotation circuit to a copper concentrate thickener. Thickened copper concentrate will be filtered in three tower-type copper concentrate pressure filters into filter cakes. The filter cakes will be discharged on to a conveyor belt that transfers them to a covered copper concentrate stockpile until shipment. Copper concentrate from the concentrate stockpile will be moved by front-end loaders onto highway haul trucks.

Molybdenum concentrates from the flotation circuit flow by gravity to an agitated filter feed tank. Molybdenum concentrate slurries will be filtered to create filter cakes, which will travel through dryer before discharging to the molybdenum concentrate storage bin. Molybdenum concentrate will be bagged in super-sacks for shipment by highway haul trucks.

The sulphide ore processing facility also includes:

- Tailings thickener;
- Potential Acid Generating (PAG) Tailings distribution pipeline to the TMF;
- Tailings distribution launder (for bulk Non-PAG tailings) to the Cyclone Plant; and
- Tailings distribution pipeline (for bulk, underflow, and overflow Non-PAG tailings) from the Cyclone Plant.

Potential accidents and malfunctions and hazards assessed as part of the sulphide ore processing facility are:

- Failure of containment vessels, mechanical equipment or control system resulting in on-site reagent spill to or in sulphide ore processing facility;
- Failure of mechanical equipment or control system resulting in on-site concentrate spill;
- Failure of the thickeners, pipes, and pumps from sulphide ore processing facility to the TMF and release of PAG tailings; and
- Reagent fire or spill in sulphide ore plant site.

21.3.3.2 Oxide Ore Processing Facility

The oxide ore processing facility produces gold and silver doré bars via heap leaching and carbon adsorption technology. Copper contained in the oxide ore will be recovered as a copper sulphide precipitate using the Sulphidization, Acidification, Recycling and Thickening (SART) process. Crushed oxide ore will be placed on the heap leach in stages over a period of approximately 18 years. The oxide ore processing facility includes:

- Heap leach facility:
  - Heap leach pad
  - Earthen embankment
  - Composite liner system
  - Leak detection and recovery system (LDRS)
  - Insulated drip-type irrigation system
  - Leachate collection system (solution collection pipes and pumps to facilitate recovery of enriched (pregnant) leach solution.
- Events pond and embankments; constructed to full size prior to commencing operations of the HLF
- Pipeline from the in-heap collection area of the heap leach facility discharges the pregnant solution to the gold recovery building; and
- Gold recovery building housing the carbon adsorption facility (ADR plant) and SART facilities.

Preliminary closure plans for the oxide ore processing facility include:

- Rinsing and drain-down of the ore and cyanide destruction;
- Removal of the geosynthetic liners from the overflow spill way and the events pond;
- Decommissioning of the pregnant solution recovery system; and

- Removal of pregnant solution, events pond pumps and pipeworks.

Potential accidents and malfunctions and hazards assessed for the oxide ore processing facility are:

- Failure of tanks, pipes, pumps between HLF and gold recovery building, resulting in release of pregnant solution;
- Heap leach pad embankment or slope failure or Events Pond overflow or embankment failure resulting in discharge of deleterious substances to environment (sediment, barren solution, pregnant solution); and
- Fire or spill involving processing reagents.

21.3.4 Mine Waste Management

All waste rock, tailings and water from the mine and process operations will be stored in the Casino Project TMF, located southeast of the Open Pit within the Casino Creek headwater valley. The TMF is designed to retain tailings, potentially reactive waste rock and overburden materials, and acidic supergene waste.

21.3.4.1 Tailings Management Facility

The TMF will be comprised of:

- Two earth-rockfill-cyclone sand, zoned embankments constructed by a centerline raise construction method, with upstream and downstream shells constructed from dozer compacted cyclone sand and other suitable borrow materials;
- Cyclone plant to generate clean sand from the bulk Non-PAG (Non-Potentially Acid Generating) tailings for embankment construction and tailings distribution pipelines (bulk non-PAG tailings, PAG tailings, cyclone sand, cyclone overflow);
- Mill and cyclone plant reclaim water systems;
- Waste storage area in the upstream portion of the TMF impoundment for potentially reactive waste rock and overburden;
- Supernatant (surface water) pond;
- Water management system (seepage collection ditches and pond, and seepage recycle system); drainage piping added to embankments in Years 1, 4, 10, and 22;
- A closure spillway and downstream channel near the right abutment of the West Saddle Embankment terminating at an erosion protected plunge pool at the confluence of Brynelson Creek; spillway will pass a 24-hr probable maximum flood event; and
- Wetland treatment for the removal of copper at closure.

The TMF will be developed starting in the construction phase in Year -4 and will be utilized throughout the mine life. Potential accidents and malfunctions and hazards assessed for the TMF are:

- TMF embankment failure or overtopping;
- Tailings distribution pipelines failure (bulk non-PAG tailings, PAG tailings, cyclone sand, cyclone overflow); and
- Reclaim water line rupture resulting in release of contact water and causing erosion and sedimentation.

21.3.4.2 Topsoil, Overburden and Non-PAG Waste Rock Management

Non-PAG waste rock will be produced as part of the Open Pit pre-stripping activities during the construction phase and will be used in construction of the TMF starter embankment. The Non-PAG waste rock that is either unsuitable for use as construction material or in excess of construction material requirements will be placed in the waste storage area of TMF or an adjacent surface dump. During general site preparation, overburden will be salvaged and placed in temporary stockpiles located around the mine site for use in reclamation activities.

Potential accidents and malfunctions and hazards assessed for waste rock and overburden management are:

- Stockpile erosion and sedimentation; and
- Slope failure in stockpiles or waste rock dumps.

21.3.5 Water Supply and Management

21.3.5.1 Water Supply and Distribution

During construction (Year -3 to Year -1) a Temporary Freshwater Supply Pond located within the TMF catchment area will be developed by retaining flows in an upper Casino Creek headwater tributary behind a cofferdam. During operations, freshwater will be sourced from the Yukon River by a riverbank caisson and radial well system. Freshwater will be piped to site via the Yukon River Fresh Water Pipeline, which will be an aboveground insulated pipeline with four booster stations. Water will be stored on site in a Freshwater Pond located northeast of the Open Pit and adjacent to the Yukon River Access Road. The Yukon River Fresh Water Pipeline will follow an existing road that leads northward from the Casino mine site to the Yukon River along Britannia Creek.

The hazard scenario assessed for the water supply and distribution system was equipment or design failure (cofferdam failure, pipeline rupture, etc.) resulting in discharge of water with the potential to cause erosion and sedimentation.

21.3.5.2 Site Wide Water Management

The objectives of water management at the Casino Project are to keep contact water and non-contact water separate, to minimize erosion in disturbed areas, and to mitigate the release of sediment laden waters to the receiving environment. This will be achieved through sediment control ponds, cofferdams, pumping systems, runoff collection ditches, diversion channels, and stabilizing disturbed land surfaces to minimize erosion. During operations the following measures will be used to meet the water management objectives:

- Diversion ditches will divert runoff around TMF embankments, ore stockpiles, and Open Pit during operations;
- Sediment control fencing placed around the down-gradient perimeter of mine components;
- Water management ponds to collect and store surface runoff and seepage;
- Open Pit horizontal drains to drain groundwater and vertical wells to reduce water pressure; and
- Upslope catchment runoff diverted to the TMF during Closure and Post Closure;
- During Closure water management structures not required for monitoring in Post-Closure will be decommissioned and reclaimed and water will be directed to the Open Pit for filling.

The hazard scenario assessed for the water management component is equipment or design failure (cofferdam failure, pipeline rupture, pump failure, etc.) resulting in discharge of contact or non-contact water, resulting in erosion and sedimentation or discharge of other deleterious substances to the environment.

21.3.6 Fuel Storage and Distribution

The Project will utilize an on-site power plant to generate its own electrical power using LNG to fuel generator drivers. Power will be supplied throughout the site by two power plants: the Supplementary Power Plant will be established near the accommodations camp during the construction phase and the Main Power Plant will be located at the plant site for operations.

During Year -4 diesel fuel will be used at the Supplementary Power Plant; diesel will be transported to the Casino mine site using a fleet of tanker trucks capable of self-loading and discharging. Diesel fuel will be stored in a diesel fuel storage tank installed next to the plant.

Beginning in Year -3, the LNG receiving, storage, and distribution facility will be constructed at the plant site. The LNG will be transported to the Casino mine site from Fort Nelson, British Columbia via double wall vacuum tanker trucks for and transferred to site-fabricated storage tank(s) tanks at -162°C and 1+ atmospheric pressure. A vaporization facility will convert the LNG into natural gas form at an appropriate pressure for use at the power plants.

Potential accidents and malfunctions and hazards assessed for the bulk delivery and fuel storage of the LNG are (Drube et al 2012):

- Tank or piping failure due to collision, impact or overpressure;
- Tank failure due to loss of strength from fire exposure;
- Material failure due to corrosion or brittle fracture;
- Piping failure due to vibration and/or thermal fatigue;
- Operator error (e.g., leaving a valve open);
- Accident, operator error, or equipment malfunction during fuel delivery and unloading; and
- Mechanical failure in tank, tanker offloading pumps, or refueling equipment leading to vapor leak or LNG spill.

Drube et al (2012) note that “Refueling stations perform a similar function regardless of fuel. Variations relate to the location, nature and volume of fuel stored and the risks around fuel dispensing. LNG is viewed as more hazardous due to the large volumes stored above ground and the relative volatility of the fuel itself compared to … diesel.” Therefore, the hazards for storage and transfer of diesel are similar to those of LNG.

21.3.7 Transport of Equipment, Materials and Personnel

Throughout the both the Construction and Operation phases of the Casino Project trucking will be the primary inbound and outbound transport from the Casino mine site. Aircraft will be used for transporting personnel.

21.3.7.1 Trucking

Material will be transported to site by truck along the Freegold Road from Carmacks. The Freegold Road Extension will be a two-lane, all-weather gravel road designed to accommodate double-trailer and Tridem trucks, and will have 18 major bridge crossings and 71 major culvert or short span bridge crossings. The Freegold Road

Extension has been designed to meet the BC Ministry of Forests and Range Forest Road Engineering Guidebook (2nd Edition, 2002) for a 70 km/h design speed with some 50 km/h sections where road geometry is limited by the terrain.

Predicted traffic volume during construction will vary from 870 vehicles in Year -4 to 9,512 vehicles in Year-2; these numbers include transport trucks supplying mining equipment, camp, fuel and supplies, as well as light vehicles. During the Operation Phase transport traffic is anticipated for shipping of copper and molybdenum concentrate and copper sulphide precipitate; LNG and diesel tanker trucks; ancillary supplies and equipment; and waste removal.

During closure and decommissioning it is anticipated that diesel will be delivered to the site.

Traffic accidents or traffic-related incidents could result due to one or more of the following reasons:

- Operator error (including driver impairment);
- Equipment failure;
- Road conditions;
- Weather conditions;
- Improper road maintenance (grading, snow removal); and
- Wildlife crossings.

As noted by Drube et al (2012), transport of fuel using public roads raises a number of safety concerns because of the large volumes involved; the primary concern is either a high-impact crash or mechanical failure leading to the release of fuel into the environment. In the case of LNG, a cryogenic LNG spill could lead to injuries, property damage, or fire. Potential causes of loss of containment for LNG noted by Drube et al (2012) are:

- Tank or piping failure due to impact or overpressure;
- Material failure due to corrosion or brittle fracture;
- Piping failure due to vibration and/or thermal fatigue; and
- Operator error.

The following hazard scenarios associated with traffic accidents or incidents are assessed:

- Hazardous materials spill;
- Injury, mortality to wildlife;
- Fire/explosion causing injury, mortality, use of essential services RCMP, fire department, ambulance service; and
- Motor vehicle collision resulting in damage to public facilities.

21.3.7.2 Aircraft

Aircraft will be used for employee transport to and from the Casino mine site. The airstrip design has been developed to conform to Transport Canada’s Aerodrome Standards and Recommendations Practices (TP312) and is designated a Code 3C Non-instrument runway. The projected average number of flights per year in the construction and Operations Phase for personnel rotations is 359 and 152, respectively.

Aircraft accidents could result due to one or more of the following reasons:

- Operator error (including pilot impairment);
- Equipment failure;
- Airstrip conditions; and
- Weather conditions.

The following hazard scenarios associated with aircraft accidents or incidents on landing or takeoff at the Casino airstrip are assessed:

- Injury, mortality to wildlife;
- Hazardous materials spill; and
- Fire/explosion.

21.3.8 Hazardous Material Storage and Use

Hazardous materials (other than LNG and diesel previously discussed) that will be required for mine operation include explosives, lubricants, and processing reagents. This section discusses the potential accidents and malfunctions that could be associated with the handling, storage and use of explosives materials and processing reagents.

21.3.8.1 Explosives Manufacture and Storage

The Casino Project requires the use of explosives during construction of the infrastructure site pads, construction of access roads, and production of the Open Pit. Blasting will be carried out using ANFO manufactured at the Casino mine site. Fixed emulsion and ammonium nitrate will be stored on site. Facilities associated with explosives manufacture and storage area consist of:

- Bulk ammonium nitrate outdoor storage area (silos);
- Bulk fuel area;
- Magazine for storage of detonators, detonating cord, boosters ;
- Emulsion manufacturing facility;
- Wash bay;
- Maintenance facility; and
- Trucks.

The explosives facility will be located at the north end of the Casino mine site, taking into consideration Natural Resources Canada (NRCan) requirements for siting. All materials will be stored in accordance with applicable regulations and standards and will be managed by a NRCan licensed explosives contractor.

The accidents and malfunctions assessed related to explosives storage are fires, explosions, and spills.

21.3.8.2 Processing Reagents

Reagent storage, mixing, and distribution will be conducted for the reagents used in the sulphide ore and oxide ore processing circuits. The reagent storage and mixing facilities for the flotation circuits will be located within a structurally independent building adjacent to the flotation building. An 8,000 t pebble lime silo will be located apart from the flotation building. Chemicals used in the sulphide ore (flotation) process and a brief description of their use are provided in Table 21.3-1. Chemicals used in the Heap Leaching Circuit process and a brief description of their use are provided in Table 21.3-2.

Table 21.3-1 Sulphide Ore Process Reagents

Chemical	Description/Typical Material Safety Data Sheet Information
Sodium-diisobutyl dithiophosphinate (Aerophine 3418A Promoter)	Colorless to light yellow, odorless, mobile liquid; slightly alkaline; auto-ignition temperature 437°C; completely soluble in water; LC50 Bluegill, 96-hour: 375 mg/l Daphnia, 48-hour: 149 mg/L
Sodium diethyl dithiophosphate/sodium di-secondary butyl dithiophosphate (Aerofloat 208 Promoter)	Slight fire hazard when exposed to heat or flame; acid may react with metals to produce hydrogen, a highly flammable and explosive gas; heating may cause expansion or decomposition leading to violent rupture of rigid containers; may emit acrid smoke and corrosive fumes.
Methyl Isobutyl Carbinol (MIBC, frother)	Clear liquid with a “sweet” odour; Flammable liquid and vapour. Vapours are heavier than air and may travel across the ground and reach remote ignition sources causing a flashback fire danger. Low toxicity: LD50 >2000 mg/kg for rat and rabbit
Pebble Lime (CaO, pH modifier)	White or gray, odorless lumps, granules, or powder. Not combustible or flammable but reacts with water to form calcium hydroxide while generating heat, which could ignite combustible materials. Not explosive but reaction with water or other incompatible materials causes material to swell and may rupture containers. High pH therefore toxic to aquatic organisms and aquatic systems.
Fuel Oil (#2 Diesel fuel, moly collector)	Colourless to straw or red oily liquid with kerosene like odour. Combustion may produce CO, CO_2 and reactive hydrocarbons.
Sodium Hydrosulfide (NaHS, copper mineral depressant)	High pH therefore toxic to aquatic organisms and aquatic systems (pH 11). Auto-ignition temperature 120°C; releases highly toxic and highly flammable hydrogen sulfide gas if mixed with an acid or if exposed to excessive heat. Toxic to terrestrial vertebrates.
Flomin D-910 (Sodium dithiophosphate)	Prepared by the reaction of phosphorus pentasulfide with sodium hydroxide; commonly called “Nokes reagent”
Flocculant	Typical flocculant like Anionic Polyacrylamide is a colourless of white granular powder with a pH of 6.0. Flammable, dust explosions may occur if material is dispersed in air. Flammability may be enhanced by presence of strong oxidizers.
Potassium amyl xanthate (PAX – pyrite flotation)	May spontaneously ignite on exposure to moist air; flammable gas (carbon disulfide) when wet; highly toxic gases (carbon disulfide,

Chemical	Description/Typical Material Safety Data Sheet Information
	hydrogen sulfide) if heated to decomposition. If discharged to waterways, xanthates may persist for several days; highly toxic to aquatic life - may form complexes with heavy metals.

Table 21.3-2 Oxide Ore Process

Chemical	Description/Typical Material Safety Data Sheet Information
Sodium Cyanide (NaCN)	Solid white substance with a faint "bitter almond" odour; soluble in water. Decomposes on heating, emitting toxic fumes, including those of hydrogen cyanide, and ammonia; toxic to animals in comparatively low concentrations. Known to cause bird kills in tailings dams.
Caustic Soda (sodium hydroxide, NaOH)	Odourless white solid; highly reactive with metals; reactive with oxidizing agents, reducing agents, acids, alkalis, moisture.
Pebble Lime (CaO)	White or gray, odorless lumps, granules, or powder. Not combustible or flammable but reacts with water to form calcium hydroxide while generating heat, which could ignite combustible materials. Not explosive but reaction with water or other incompatible materials causes material to swell and may rupture containers. High pH - toxic to aquatic organisms and aquatic systems.
Hydrochloric Acid (HCl)	Liquid with a pungent odour; colourless to light yellow. Reacts violently with water, especially when water is added to the product; absorption of gaseous hydrogen chloride on mercuric sulfate becomes violent at 125°C; sodium reacts very violently with gaseous hydrogen chloride; reacts with oxidizers releasing chlorine gas. Incompatible with, alkali metals, carbides, borides, metal oxides, vinyl acetate, acetylides, sulphides, phosphides, cyanides, carbonates; reacts with most metals to produce flammable hydrogen gas.
Sodium Hydrosulphide (NaHS)	High pH therefore toxic to aquatic organisms and aquatic systems (pH 11). Auto-ignition temperature 120°C; releases highly toxic and highly flammable hydrogen sulfide gas if mixed with an acid or if exposed to excessive heat. Toxic to terrestrial vertebrates.
Sulphuric acid (H_2SO_4)	Clear, colourless to dark brown, odourless; dense, oily liquid; hygroscopic. Will not burn but can decompose at high temperatures, forming toxic gases such as sulphur oxides. Contact with combustible materials may cause fire; highly reactive. Contact with many organic and inorganic chemicals may cause fire or explosion; contact with metals liberates flammable hydrogen gas; reacts violently with water; reacts with most metals, especially

Chemical	Description/Typical Material Safety Data Sheet Information
	when diluted with water; this reaction produces highly flammable hydrogen gas that may explode if ignited.
Activated Carbon	Black, odourless, pelletized powder; insoluble in water;
Antiscalant	Typical antiscalants such as -1,1 Diphosphonic Acid 1-hydroxyethane may produce Co_x, PO_x and phosphine on combustion.
Flocculant	Typical flocculant like Anionic Polyacrylamide is a colourless white granular powder with a pH of 6.0. Flammable, dust explosions may occur if material is dispersed in air. Flammability may be enhanced by presence of strong oxidizers.

The accidents and malfunctions assessed related to processing reagent storage are fires, explosions, and spills.

21.3.9 Solid and Hazardous Waste Management

21.3.9.1 Solid Waste

Non-Hazardous Solid Wastes produced as part of Casino mine construction, operations and closure will include woody debris, domestic camp wastes (food, plastics, paper), and inert bulk wastes (rubber belts, drywall, etc.). Woody debris from clearing and grubbing will be stockpiled for local use, mulched, or burned in slash piles. The waste will be sorted by material and depending on the material, hauled-offsite by truck to an approved disposal area, disposed of on site in a landfill, or incinerated on site before being disposed of in a landfill. Open air controlled burning of inert combustible materials will be conducted on an as-needed basis to eliminate large quantities of construction related wood waste and cardboard that would otherwise use up landfill capacity.

The main disposal method for combustible non-hazardous wastes will be incineration using a variable flow dual chamber incinerator. Incineration will divert putrescible waste from the landfill and prevent problems associated with odours, which may attract wildlife. Inert solid waste and ashes from the incinerator will be disposed of in landfills. Regular cover will be applied over the landfill sites and a cap of native overburden will be placed on top of the landfill before decommissioning.

The accidents and malfunctions assessed related to solid waste management are:

- Fire or explosion from incinerators, woody debris slash piles;
- Leaks from storage or disposal drums; and
- Leaching from landfill

21.3.9.2 Hazardous Waste

Hazardous wastes (used batteries, used paint, reagent containers, waste petroleum products and oils, etc.) will be temporarily stored in special containers and/or at designated locations on site and will be shipped to registered hazardous waste disposal facilities, burned on site, or returned to manufacturers or to recycling depots. Manifests will be prepared for all materials shipped off-site and the receivers will be required to maintain chain of custody records. Estimated volumes of hazardous and recyclable wastes will be developed during detailed engineering design.

The accidents and malfunctions assessed related to hazardous waste management are leaks and spills.

21.3.9.3 Sewage Management

A pre-engineered and pre-fabricated sewage treatment plant system accepts and treats all sanitary wastewater with an aerobic process that allows for bio-oxidation of the sanitary wastes to suitable levels for discharge into the environment. Wastewater will be either pumped from the mine buildings to the wastewater treatment plant, or collected in holding tanks and delivered via truck to the wastewater treatment plant. Treated effluent will be disposed of in a rock drain, designed to the standards of the Yukon Government.

The accidents and malfunctions assessed related to sewage management are leaks and spills.

21.3.10 Reclamation

Typical and proposed mine reclamation activities include:

- Grading, covering, and revegetation of final slopes (overburden stockpiles, waste management dumps, HLF) to provide adequate drainage and erosion protection from surface runoff;
- Placement of soil cover material containing adequate growth media (fines) to sustain re-vegetation and prescribing a vegetative cover that is capable of self-regeneration without continued dependence on fertilizer or re-seeding;
- Constructed wetlands within the TMF to treat any residual low levels of cyanide and trace metals resulting from precipitation infiltrating through the HLF closure cap.

Further details on the reclamation measures are provided in Section 4.

21.4 RISK ANALYSIS AND EVALUATION

A Risk Register was developed to document the major components or activities and potential accidents or malfunctions associated with each. A Risk Register is a tool used to record details of all risks identified for a component or activity. The Risk Register includes a description of each risk; the phase in which the component or activity would occur; the design or management measures to reduce the likelihood or magnitude of a failure; the likelihood and consequence ratings; mitigation measures; and the assessed risk grade. The following seven credible hazard scenarios associated with one or more of the Project components or activities were assessed, and are discussed in detail in the following paragraphs:

- Embankment failures;
- Slope failures;
- Spills or leaks;
- Transportation accidents;
- Water conveyance and storage systems failure;
- Fires and explosions; and
- Failure of erosion and sediment control measures.

The Risk Register is provided in Appendix 21B.

21.4.1 Embankment failure

Potential embankment failure associated with each of the following Project components is assessed in this section:

- TMF;
- Heap Leach Pad;
- Heap Leach Pad Events Pond;
- Freshwater Ponds;
- Process Water Pond; and
- Water Management Pond.

21.4.1.1 Tailings Management Facility Embankment Failure

Azam and Qi (2010) attempted to statistically analyze available data on tailings dam failures; failure modes were attributed to unusual weather events, seepage, poor management (inappropriate dam construction procedures, improper maintenance of drainage structures, and inadequate long-term monitoring programs), slope instability, structural defect, and overtopping. Overtopping can be attributed to inadequate spillway design, spillway debris blockage, or settlement of the dam crest, while seepage occurs around pipes and spillways, through animal burrows and through cracks in the dam or dam foundations (International Commission on Large Dams (ICOLD) 2013). Improved engineering practices, construction technology, and more stringent safety criteria have significantly reduced dam failures since the 1990s (Azam and Qi 2010). The decrease over the several decades in the failure rate of dams has been attributed to, among other things, improvements in investigation techniques and dissemination of knowledge on risks (ICOLD 2013).

The likelihood of a TMF embankment failure is difficult to predict. Azam and Qi (2010) note that the failure rate over the last 100 years, based on a world inventory of 18,401 mine sites, is estimated as 1.2%; however, Haile and Brouwer (2012) note that “it is incorrect to imply that any particular proposed or actual dam structure is more or less likely to fail based solely on the extrapolation of general dam failure statistics”, and that the assessment of the integrity and stability of any dam is more correctly based on site-specific conditions and facility details.

The TMF Main and West Saddle Embankments have been designed in accordance with the CDA Dam Safety Guidelines, and based on site geotechnical, hydrogeological, hydrometeorological, and seismic information (Knight Piésold 2012a). The embankments will be constructed as water-retaining zoned structures with a low permeability core zone and appropriate filter and transition zones to prevent downstream migration of fines. The core zone will include a seepage cut-off key into competent rock in the foundation. Foundation preparation for the TMF embankments will involve the stripping of topsoil and vegetation and excavation of underlying frozen soils to competent, stable bedrock or non-frost susceptible overburden foundation. The removed material will be replaced with core, filter or shell zone material. The design basis for the embankments includes a Hazard Classification Consequence Category of “High”, as defined by the CDA Dam Safety Guidelines. The Main Embankment will be constructed in several stages over the operating life of the mine using the centreline method of construction. Development of sufficient tailings beach area is required between the supernatant pond and the embankment to provide a stable upstream construction surface for the centreline embankment raises.

Two levels of design earthquake are considered in the design of the Casino Project’s TMF: the Operating Basis Earthquake (OBE) for normal operations, and the Maximum Design Earthquake (MDE) for extreme conditions, as described in Section 4.3. A design earthquake of magnitude 8.0 has been selected as the MDE, based on a review of regional tectonics and historical seismicity. Based on the CDA Guidelines classification for a “High” consequence dam, the Casino Project TMF is designed for a probabilistically derived event having an annual exceedance probability of 1/2,500.

The centerline raise construction method is a widely used construction technique that “affords superior seismic and static stability as compared to upstream construction methods and results in an inherently stable structure that does not rely on the strength of the deposited tailings solids … there are relatively few instances of catastrophic failure for tailings dams constructed using the centerline and downstream methods” (Haile and Brouwer 2012). The results of the stability analyses conducted for the Project indicate that the design satisfies the minimum requirements for factors of safety for short term (operational) and long term (post-closure) stability (1.3 and 1.5, respectively) (Knight Piésold 2012a). The seismic analysis for the TMF embankment indicates that any embankment deformations during OBE or MDE earthquake loading would be minor, and would not have any significant impact on embankment freeboard or result in any loss of embankment integrity (Knight Piésold 2012a).

Based on these design measures using the site specific geotechnical, hydrogeological, hydrometeorological, and seismic information, the likelihood of failure has been rated as Unlikely. In the event of a TMF embankment failure the consequences would be High if tailings and supernatant water were released into the environment, depending on the magnitude of the release.

Failure of the Main Embankment could result in release of tailings and supernatant into the Casino Creek valley, and potentially into the Dip Creek watershed. This section describes the potential effects of a TMF embankment failure on the following VCs:

- Surficial Geology, Terrain, and Soils;
- Water and Sediment Quality;
- Fish and Fish Habitat;
- Rare Plants and Vegetation Health; and
- Wildlife.

Release of tailings and supernatant water could result in an increase in metals concentration in soil, water, and sediment; alteration or loss of fish habitat; direct fish mortality; destruction of rare plants or loss of rare ecological land types; and loss of wildlife habitat downstream of the embankments.

The extent of any effect would depend on the type of embankment failure (partial to catastrophic) and on the amount of tailings released. Partial failure, or total embankment failure during the construction or early operations period would result in localized effects, due to the relatively smaller volume of tailings released, while a catastrophic failure of the embankment during the final years of operation or during closure could inundate the Casino Creek watershed. The Project Emergency Response Plan (Appendix 22B) will outline the containment and cleanup measures to be implemented in the unlikely event of any TMF embankment failure, methods for the disposal of contaminants and debris, and post-incident evaluations.

21.4.1.2 Heap Leach Pad Embankment and Events Pond Embankment Failure

The heap leach pad and events pond will be located upstream and within the same catchment area as the TMF thereby minimizing potential environmental impact (Knight Piésold 2012b). The heap leach pad embankment constructed at the toe of the proposed pad will provide stability to the heap leach pad and provide in-heap storage for solution. The heap leach pad is designed to be operated predominantly as a ‘dry’ pad with minimal solution storage occurring in the in-heap storage during normal operating conditions. The embankment will be constructed with an upstream slope of 3H:1V and downstream slope of 2H:1V to ensure embankment stability. Storage of leachate during operations is not expected to occur during the course of normal operations; however, during significant rainfall events or during a process shut-down, in-heap storage will be used. The heap leach pad liner system is designed to be operated as a dry operation, with pregnant leachate solution being pumped out as soon as it collects in the sump; this will reduce the hydraulic head on the liner system. If required however, solution storage in the ore-pore volume behind the confining embankment is possible up to elevation 1096 m (approximately two days irrigation volume) before discharging over the confining embankment spillway.

The Events Pond will be situated immediately down gradient of the HLF embankment and pond flows will be conveyed via the HLF spillway. The Events Pond is designed to meet the following design criteria:

- Storage capacity to contain the excess heap leach pad leachate and surface runoff from the 1 in 100 year 24-hour storm event without discharge to the TMF; and
- Spillway designed to discharge the 1 in 200 year 24-hour storm event with a minimum embankment crest freeboard of 0.3 metres.

Solution stored in the events pond will be pumped back to the heap leach pad using the events pond pump station, designed to empty the 1 in 10 year storm runoff volume over ten days, and the 1 in 100 year volume over 12.5 days (Knight Piésold 2012b). During storm events greater than the 1 in 200 year 24-hour, water volumes exceeding the events pond storage capacity will be conveyed to the TMF pond via the events pond spillway.

The heap leach pad and events pond feasibility design were based on site geotechnical investigations, hydrogeological conditions, and a probabilistic seismic hazard assessment. Construction of the embankment will involve stripping the topsoil and excavating the underlying frozen colluvial and residual soils down to competent, stable bedrock (Knight Piésold 2012b). Failure modes for the embankments will be similar to those for the TMF embankments (unusual weather events, seepage, poor management, slope instability, structural defect, and overtopping).

Based on the design measures using the site specific geotechnical, hydrogeological, and seismic information, the likelihood of heap leach embankment failure has been rated as Unlikely. In the event of a HLF embankment failure the consequences would be Very Low, since the Events Pond immediately downstream of the heap leach pad embankment is designed for sufficient storage capacity to contain the excess leachate and surface runoff from the 1 in 100 year 24-hour storm event without discharge to the environment.

The likelihood of an events pond embankment failure is rated as Unlikely, based on the design and construction methods. The consequences for an Events Pond embankment failure are rated as Very Low since water volumes exceeding the events pond storage capacity will be conveyed to the TMF pond via the events pond spillway and not be discharged to the environment.

Failure of the Events Pond embankment simultaneously or as a result of a heap leach pad embankment failure could result in release of barren and pregnant solution; however, this would be contained within the TMF and not be discharged into the environment. No effects on VCs are therefore predicted. The Project Emergency Response Plan (Appendix 22B) will outline the containment and cleanup measures to be implemented in the event of any heap leach pad or Events Pond embankment failure, methods for the disposal of contaminants and debris, and post-incident evaluations. Special handling methods for cyanide may be required; this will be outlined in the Emergency Response Plan.

21.4.1.3 Freshwater Pond Embankment Failure

The Temporary Freshwater Supply Pond required during construction will be located within the TMF footprint, while the permanent Freshwater Pond for operations will be located northeast of the Open Pit. Failure modes for the cofferdam and permanent Freshwater Pond embankment will again be similar to those for the TMF embankments (unusual weather events, seepage, poor management, slope instability, structural defect, and overtopping). The likelihood for both is rated as Rare. Consequence of a failure for the Temporary Freshwater Supply Pond cofferdam are rated as Very Low, since the pond will be located in the headwaters of Casino Creek and will be upstream of the TMF Main Started Embankment, which will capture any flows that result. Consequence of a failure for the operations Freshwater Pond embankment are rated as Moderate, since failure could result in discharge of sediment-laden water into Britannia Creek, and possibly into the Yukon River downstream. Catastrophic failure of the embankment could result in the release of the entire contents of the Freshwater Pond. Detail design of the embankments will consider CDA guidelines and site-specific geotechnical information.

Release of water from the Freshwater Pond could affect the following VCs:

- Water and Sediment Quality
- Fish and Fish Habitat

Discharge of sediment-laden water into Britannia Creek could alter water quality by increasing the turbidity. Effects of high suspended sediments on fish and fish habitat include changes in fish physiology, altered behaviour patterns, and in-filling of stream substrate, altering the quantity and quality of rearing, spawning and incubation habitat. The spatial extent of the effect would depend on the volume of water released and the flow within the receiving water body. If a breach were to occur during high stream flows, the sediment would remain in suspension and be transported a greater distance than if a breach occurred during low stream flows. In the event of an embankment failure of the operational Freshwater Pond, the Water Management Plan and an erosion and sediment control plan would be implemented to limit the extent of impact, and to remediate any impacted areas.

21.4.1.4 Process Water Pond and Water Management Pond Embankments Failure

Process water reclaimed from the tailings pond and from the plant will be collected in a 63,700 m^3 process water pond. Process water will be comprised of combined thickener overflow, reclaim water from the tailings pond, and fresh water. Overflow solution from the bulk concentrate, and copper concentrate thickeners will also be pumped to the process water pond. The Water Management Pond will be located downstream of the TMF main embankment, in the Casino Creek valley. The Water Management Pond is designed to collect embankment seepage and runoff.

The likelihood of failure of the Process Water Pond is rated as Rare and consequence is rated as Very Low, since any material released would be ultimately captured within the TMF located down-gradient of the site. The likelihood of failure of the Water Management Pond is rated as Rare and consequence is rated as Moderate.

Embankment failure of Process Water Pond and Water Management Pond could affect the following VCs:

- Surficial Geology, Terrain, and Soils;
- Water and Sediment Quality;
- Fish and Fish Habitat;
- Rare Plants and Vegetation; and

- Wildlife.

Soil contamination could result in areas down-gradient of the Process Water Pond in the event of an embankment failure. It is expected that released process water could be fully contained upon implementation of measures outlined in the Emergency Response Plan, since the area will be adjacent to other Project components such as the Sulphide Ore Processing Facility and the Low Grade Ore Stockpile.

The Water Management Pond will have measureable concentrations of tailings, reagent residues, and potentially metals. Environmental effects of an embankment failure and release of process water into Casino Creek could include altered water quality; direct mortality of fish and other aquatic biota and wildlife; and disturbance of rare plants and vegetation. Effects could extend several kilometres downstream in Casino Creek and potentially into Dip Creek. The extent of any effect would depend on the type of embankment failure (partial to catastrophic) and on the amount of process water released. Partial failure, or total embankment failure during the construction or early operations period could result in localized effects, due to the relatively smaller volume of water released. A catastrophic failure of the embankment during the final years of operation or during closure could affect the Casino Creek watershed.

Water quality concerns include TMF seepage water quality. The PAG tailings from milled ore are assumed to require complete subaqueous disposal in the TMF in order to maintain a saturated state and inhibit oxidation and potential reactivity. The PAG tailings will be isolated in a centrally located region in the TMF to reduce potential mixing and contact with the embankments and to decrease overall seepage potential. Supergene material produced during construction and early operations will be placed in an upstream area of the TMF, where the predicted seepage rate is low.

The Project Emergency Response Plan (Appendix 22B) will outline the containment and cleanup measures to be implemented in the event of any TMF embankment failure, methods for the disposal of contaminants and debris, and post-incident evaluations.

21.4.2 Slope failure

Potential slope failure associated with each of the following Project components is assessed in this section:

- Pit wall;
- Ore stockpiles;
- Heap Leach Pad (during operation and closure); and
- Topsoil and Non-PAG Waste Rock and Overburden stockpiles.

21.4.2.1 Pit Wall Slope Failure

Pit wall slope failures can range from minor bench raveling to massive slope failures; failure modes include unknown geologic structures, abnormal weather patterns, or seismic shock (Girard 2001). Minor slope failures within the Open Pit are anticipated as part of the development process due to ongoing drill and blast activities and the potential to encounter areas of instability. The Open Pit slope design for the Casino Project is based on kinematic and rock mass stability analysis and site-specific geotechnical and hydrogeological information. Design factors considered in selecting the final Open Pit wall angle include slope height, rock mass strength, ground water pressure, blasting, and inter-ramp angles. Slope monitoring will be conducted during all stages of Open Pit development; monitoring will include geotechnical analysis of the pit walls including geotechnical mapping, tension crack mapping, surface prism monitoring, piezometer installation, and automated monitoring systems.

Open Pit perimeter well and horizontal bench wells, as well as pumping wells, will be used to extract groundwater and depressurize pit slopes to increase pit wall stability as required. Incorrect blasting activities may lead the progressive deterioration of the wall face and instability; therefore, blasting trials will be implemented when there are observed changes in the characteristics of the rock during excavation. Regular inspections will identify areas of potential instability and result in mitigative measures to decrease the likelihood of failure.

Despite the design and proposed monitoring measures, some level of instability can still be expected in any surface operation, and “even slopes with conservative slope designs may experience unexpected failure” (Girard 2001); therefore, the likelihood of an Open Pit wall failure at the Casino Project has been rated as Possible. In the event of an Open Pit slope failure the consequences would be Low, since the material will remain within the pit.

Slope failure near the northwest side of the Open Pit in Year 10 of operations, as the pit wall intersects Canadian Creek, could result in an adverse impact on Surface Water and Sediment Quality. With the implementation of erosion and sediment control measures, it is anticipated that any effects would be localized and easily remediated, with no residual impacts. Monitoring will be conducted to detect instability at an early, noncritical stage to allow for the implementation of mitigation measures, as noted by Girard (2001), and the Emergency Response Plan will outline measures for containment and remediation, if required.

21.4.2.2 Ore Stockpiles Slope Failure

During operations, mined ore to be processed at the HLF during Years -3 to 15 will be stored in a temporary stockpile near the crusher on the valley slope east of the Open Pit. The Supergene Oxide (SOX) ore and Low Grade ore will also be stored in temporary stockpiles (Knight Piésold 2012c). The SOX ore will be stockpiled between the Open Pit and main plant site during pre-production and in Year 1 of operations for milling during Years 4 to 12. Low Grade ore will be stockpiled east and south of the main plant site, on valley slopes above the TMF, as well as at the same locations used for the SOX ore south of the Open Pit after Year 12. Low Grade Ore will be milled during Years 19 to 22 of operation. Ore stockpiles will be generally situated on south to east facing slopes between the TMF and the Open Pit; the east facing slopes are generally better drained and have frost-susceptible soils (Knight Piésold 2012c).

Factors that affect slope failure include slope angle, the presence of water, and physical properties of the slope material. Slope failures can range in magnitude from small slumps to mass wasting events. Hazards associated with slope failure of the ore stockpiles were identified as deposit of ore onto surrounding terrain; and blockage of surface runoff or diversion ditches at the toe, resulting in discharge of sediment-laden water into nearby waterways. Slope erosion and slope failure likelihood and consequence were both assessed.

Design measures to minimize the risk of ore stockpile slope failures include (Knight Piésold 2012c):

- Geological information and geotechnical conditions for the ore stockpiles were derived from site investigations which have included test pitting, geotechnical drilling, laboratory testing of recovered rock core and bulk soil samples, in situ permeability testing and geophysical surveys;
- A probabilistic seismic hazard assessment has been carried out for the Casino project site to provide seismic parameters for design of project facilities; the Casino Project site will be situated in a region of low seismicity and moderate seismic hazard;
- All temporary stockpiles will be designed to remain stable under both static and seismic loading conditions; the minimum acceptable factor of safety for ore stockpiles under static conditions is 1.3 for short-term operating conditions and 1.5 after closure and reclamation;

- The design earthquake defined for seismic stability assessment of the stockpile slopes is the 1 in 500 year earthquake and earthquake magnitude of 8.0; and
- Sediment control fencing will be placed around the down-gradient perimeter sections of the ore stockpiles to prevent sediment discharge from the stockpiles.

Pre-production and operational activities that will ensure stockpile stability include clearing vegetated areas and removing the organic layer to initiate melting of permafrost; removal of unsuitable material in the foundation prior to loading; loading the stockpile in lifts, with each lift developed at the angle of repose (1.3H:1V); retaining 20 m benches along the toe of each lift to establish a maximum overall slope angle of 2H:1V; and loading and developing the lifts parallel to the slope (where possible) to avoid stress concentrations (Knight Piésold 2012c).

The surface and diversion ditching system along the upslope side of the ore stockpiles will divert surface flow around the stockpiles to minimize contact with the water; water will be discharged to the TMF. The diversion ditching system includes the following design criteria:

- Design storm conveyance 1 in 100 year 24-hour duration storm event;
- Maximum design storm flow depth of 0.5 m and minimum freeboard of 0.3 m; and
- Minimum channel side slope of 2H:1V

The likelihood and consequence of ore stockpile erosion were rated as Possible and Very Low, respectively. Any material from localized erosion would be captured on the 20 m wide benches at the toe of each lift.

Based on the ore stockpile design measures using the site specific geotechnical, hydrogeological, hydrometeorological, and seismic information, the likelihood of stockpile slope failure has been rated as Rare. In the event of a slope failure the consequence was rated as Very Low, since the stockpiles will be all located on valley slopes above the TMF. The seismic stability assessment of the ore stockpiles concluded that “the consequences of a stockpile slope failure due to earthquake shaking will be minimal and restricted to minor displacement of the surface of the stockpile slopes (ravelling). There would be a negligible impact on the integrity of the stockpile and little, if any, impact on other mine site facilities” (Knight Piésold 2012c).

Erosion or failure of the ore stockpile slope could result in release of small amounts of ore material onto the surrounding terrain or into the diversion or runoff ditches. This section discusses the potential effects of this scenario on the following VCs:

- Surficial Geology, Terrain, and Soils; and
- Water and Sediment Quality.

Soil and water contamination from metal leaching could result from deposition of ore if the site was not remediated in a timely manner. The stockpiles will be developed at the angle of repose of 1.3H:1V with 20 m benches along the toe of each lift to establish a maximum overall slope angle of 2H:1V. Contact water will report to the TMF and not be discharged to the environment. Material is not anticipated to travel far from the toe of the slope should a slope failure occur; in the event of a failure the Emergency Response Plan would be implemented. The Plan will outline containment and cleanup and site restoration and remediation measures.

21.4.2.3 Heap Leach Pad Slope Failure

The heap leach pad will consist of a confining embankment, pad liner system, irrigation system, and leachate collection system to collect and convey the leachate solution to the gold extraction plant (Knight Piésold 2012b). The pad will be located on a uniformly sloping sidehill with an approximate slope of 5H:1V. The heap leach pad will be constructed in five pad development stages with successive bench lift heights of approximately 8 m, commencing in Year -3. The benches will have repose bench face angles of 1.4H:1V; benches approximately 9 m wide will be left at the toe of each lift to establish a final overall slope angle of approximately 2.5H:1V to provide stability of the heap and allow for on-going reclamation during operations. The pad foundation preparation, liner installation, and leachate collection piping will be developed as the footprint of the leach pad expands upslope to accommodate additional ore lifts. The confining embankment, events pond, and perimeter diversion ditches will be developed prior to commencing ore stacking and leaching. The heap leach pad embankment constructed at the toe of the pad will provide stability and provide in-heap storage for solution. The leaching process will involve the irrigation of weak cyanide solution over successive lifts of heaped ore.

The critical aspects of heap leach design are the depth of the ore, presence of water and local terrain; Thiel and Smith (2003) have noted that "Heap leaching presents a combination of extreme base pressures and high moisture conditions not present in any other containment application". Key geotechnical concerns of heap leach facilities as summarized by Thiel and Smith (2003) include:

- Slope Stability: extreme heights and base pressures resulting in global failures; sliding block stability along geomembrane interfaces; elevated degrees of saturation; chemical and biological degradation of ore; first-lift stability affected by lift thickness and stacking direction;
- Liquefaction: earthquake induced failures; liquefaction flowslide;
- Water management: surplus water balances; high phreatic levels; and
- Liner Durability and Leakage: coarse rock overliner systems; extreme pressure caused by weight of heap and equipment; durability against chemical attack.

Ulrich, Andrade, and Gardner (2003), in a review of heap leach operations in Chile and Peru, also noted problems with failed risers used to deliver solution to the heap, resulting in erosion or localized sloughing failures on the face of the heap. The failures did not affect overall performance but did require remedial action (Ulrich, Andrade, and Gardner 2003).

During operation of the heap leach pad, slope failure could result in rupture of the irrigation or collection pipes or liner damage and subsequent discharge of barren process solution or pregnant solution, both containing cyanide, into the environment. During closure and decommissioning or post-closure, slope failure could result in damage to the heap cover or to destruction of the wetland downstream, or exposure of PAG materials. The spill or release of barren or pregnant solution will be discussed in Section 21.5.3.

Thiel and Smith (2003) found no documentation of static flowslide liquefaction in leach piles, although seismic-induced dynamic liquefaction has occurred. A review of the regional seismicity was carried out to enable selection of an appropriate design earthquake event for seismic stability assessment of the Casino Project HLF. Analyses were carried out to examine the stability of the heap leach pad under both static and seismic conditions and factors of safety were calculated; the minimum acceptable factor of safety for the heap leach pad under static conditions for short-term operating conditions long-term (post-closure) are 1.3 and 1.5, respectively; Results of the stability analyses indicate that the leach pad will be stable with a minimum static factor of safety of 1.6 (Knight Piésold 2012b). Estimation of seismically induced deformations of the pad from the design earthquake was included in the assessment; for a design earthquake magnitude of 8.0 negligible heap leach pad deformations were predicted. Knight Piésold (2012b) concluded that consequences of failure during an earthquake event are likely to be minimal and restricted to some displacement of the heap leach pad slopes; a conservative design earthquake corresponding to the 1 in 500 year return period event was adopted for the design.

To minimize saturation of the heap, rough grading and backfill will be used to grade the naturally undulating bedrock surface to provide a uniformly and positively drained surface (minimum pad grade of 2%) upon which to place the pad liner system and ensure leachate flow toward the leachate collection piping system and sump located at the centre of the embankment toe.

Linear low-density polyethylene (LLDPE) will be used for the geomembrane liner systems for the heap leach pad because it generally exhibits higher interface friction values compared to other geomembrane liners, shows good performance under high confining stresses, and higher allowable strain for projects where moderate settlement may become an issue (Knight Piésold 2012b). Since the stability of the heap leach pad is sensitive to the interface shear strengths associated with the liner system laboratory, shear strength tests for each of the liner interfaces within the composite liner systems will be tested for detailed design studies.

Closure measures for the heap leach pad will include grading, covering, and revegetation of final heap slopes to provide adequate drainage and erosion protection from surface runoff. Bench lift heights of 8 m will be constructed at repose bench face angles of 1.4H:1V. The 9 m wide benches left at the toe of each lift to establish a final overall slope angle of 2.5H:1V will provide stability of the heap and allow for on-going reclamation during operations.

The likelihood of slope failure of the heap leach facility during operations has been rated as Unlikely, based on the design parameters, and the consequence has been rated as Moderate. The 8 m high lifts proposed for the Casino Project are significantly less than the 50 m to 150 m high lifts discussed by Thiel and Smith (2003), for which factor of safety margins and reliability estimates are based on techniques and methods designed for much smaller heaps. Site investigations at the Casino site were used to determine geotechnical implications for the Feasibility design; additional subsurface investigations will be conducted to confirm foundation conditions for future design studies. The likelihood of slope failure of the heap leach facility post-closure has also been rated as Unlikely, based on closure design parameters; the consequence has been rated as Very Low.

The VCs potentially affected by slope failure of the heap leach pad are:

- Surficial Geology, Terrain, and Soils; and
- Water and Sediment Quality

Localized slumping of the heap leach during operations could result in deposit of ore adjacent to the pile; if not remediated in a timely manner the slope failure could cause localized soil contamination. Geotechnical instrumentation will be installed to monitor the performance of the HLF on an on-going basis to ensure the safe and effective operation of the HLF (Knight Piésold 2012b). Slope movement monuments and survey control points will be installed and monitored to ensure the integrity and stability of the ore heap.

Closure measurements of the heap leach pile will include rinsing and drain-down of the ore and cyanide destruction. A constructed wetland established downstream of the facility and upstream of the TMF will treat any residual low levels of cyanide and trace metals resulting from precipitation infiltrating through the closure cap. Water will not be discharged until it meets existing standards or site-specific water quality objectives.

21.4.2.4 Topsoil / Overburden and Waste Rock Storage

During operations potentially reactive waste rock and overburden, comprising PAG and Metal Leaching (ML) materials will be disposed of subaqueously in the waste storage area of the TMF (Knight Piésold 2012c). In addition, NAG waste rock will be produced during pre-production mining and used in the construction of the TMF overburden from the Open Pit will be stripped and if suitable for reclamation purposes, will be stored in stockpiles adjacent to the Open Pit The waste storage area will be fully contained within the final TMF at closure, therefore no closure activities will be required to ensure long-term geotechnical stability.

The Topsoil/Overburden Stockpiles will be located on hilltop areas, where permafrost is generally limited or absent, north of the HLF and south of the TMF (Knight Piésold 2012c). Overburden and topsoil materials will be stockpiled separately.

Factors that affect slope failure were previously mentioned (slope angle, the presence of water, and physical properties of the slope material). Hazards associated with slope failure of the stockpiles include deposition of material onto surrounding terrain, and discharge of contact water into Casino Creek.

The minimum acceptable factor of safety for waste stockpiles under static conditions is 1.3 for short-term operating conditions and 1.5 after closure and reclamation; the Topsoil/Overburden Stockpiles will be removed before or at closure of the mine for use in reclamation of the TMF and HLF (Knight Piésold 2012c). The design earthquake defined for seismic stability assessment of the stockpile slopes is the 1 in 500 year earthquake, with a corresponding magnitude of 8.0.

Waste rock deposition shall satisfy short and long term stability requirements. Design measures to minimize the risk of waste storage area slope failures include (Knight Piésold 2012c):

- An overall slope of 1.5H:1V has been assumed for design purposes;
- TMF will be operated to maintain a minimum distance of 1 km between the waste storage area and TMF embankments to allow development of a NAG tailings beach and provide a low permeability transition zone to function as a seepage limitation and control measure;
- Trial sections may be constructed in the field during the initial stages of development to monitor waste pile stability and foundation performance; and
- Waste rock shall be end dumped over the crest to allow for maximum segregation of the coarser material at the base of each bench.

Design measures to minimize the risk of Topsoil/Overburden Stockpile slope failures include (Knight Piésold 2012c):

- Wet conditions will be avoided when possible during soil salvage operations;
- Topsoil/Overburden Stockpiles will be limited to a maximum height of about 20 m, with consideration of site-specific ground conditions, and constructed as wrap around dumps in an ascending sequence to improve overall stability, as each constructed lift will act as a buttress for the toe of the next lift;
- The overall slope angle will average 14 degrees (4H:1V) to minimize the risk of slope instability, reduce erosion potential and improve the amenability for vegetation growth;
- Toe berms to ensure stockpile stability may be required, depending on foundation conditions and the strength characteristics and condition of the stockpiled material;
- Excessive traffic will be avoided during the salvage process to minimize admixing, compaction and rutting;
- Erosion will be managed by limiting the height and slope of stockpiles. Erosion control measures will be implemented to reduce exposure of bare soil; and

- Where possible soil stockpiles will be oriented to reduce wind erosion and located to reduce wind exposure.

A stability assessment was carried out for the waste storage area Topsoil/Overburden Stockpiles. The slope of the waste material adjacent to the tailings deposit will be buttressed by the tailings, with only a few metres height of the waste pile above the surface of the tailings; therefore, stability was not deemed a concern (Knight Piésold 2012c). Slopes and benching of the waste rock will depend on the elevation difference between the waste rock, tailings and supernatant pond during operations, as well as the condition of the tailings (Knight Piésold 2012c).

The likelihood and consequence of waste rock stockpile slope failure were rated as Possible and Very Low, respectively. Any slope failure or sloughing and ravelling of waste material will be contained within the TMF; it is anticipated that the tailings beach will slope upward between the pond and embankments, and be approximately 200 m wide (Knight Piésold 2012c).

Based on the Topsoil/Overburden Stockpile design measures using the site specific geotechnical, and seismic information, the likelihood of stockpile slope failure has been rated as Possible. In the event of a slope failure the consequence was rated as Moderate.

Failure of the Topsoil/Overburden Stockpile slopes could result in release of small amounts of sediment onto the surrounding terrain. This section discusses the potential effects of this scenario on the following VCs:

- Surficial Geology, Terrain, and Soils

Topsoil and overburden material is not anticipated to travel far from the toe of the stockpile slopes should a slope failure occur, given the low gradient slopes. However, in the event of a failure the Emergency Response Plan would be implemented. The Plan will outline containment and cleanup and site restoration and remediation measures.

21.4.2.5 Freegold Road Extension Foundation

The Freegold Road extension will be located in valley bottoms where feasible to avoid unstable terrain. However sections of the road will necessarily cross relatively mountainous terrain with moderate to steep cross slopes. The hazard scenario assessed for slope failure associate with the Freegold Road extension is discharge of sediment and road fill material to the environment. Accidents associated with use of the road are discussed in Section 21.4.4.

Terrain stability mapping was conducted for the proposed road development. Terrain stability “refers to the likelihood of a landslide initiating in a terrain polygon following road construction activities and timber harvesting” (Knight Piésold 2012d). Terrain stability was evaluated based on slope angle, slope aspect, surficial geology, permafrost conditions and the presence of gullied terrain, the key attributes controlling landslide susceptibility (Knight Piésold 2012d). The terrain stability classification scheme focussed on the likelihood of slope detachments such as slides and flows as opposed to slope displacements such as soil creep, which could be expected to occur in gently sloping, ice-rich terrain that is classified as ‘stable’ in the terrain mapping (Knight Piésold 2012d). The terrain stability mapping indicated that approximately 9% of the proposed Freegold Road extension will be within ‘potentially unstable’ terrain and approximately 3% within ‘unstable’ terrain.

The proposed alignments traverse extensive areas of permafrost terrain, which presents a sensitive construction environment. The terrain assessment noted that “permafrost degradation can occur both during and after construction, resulting in the possibility of differential settlement of embankments and bridge foundations, slope instability and, erosion and sediment delivery to watercourses” (Knight Piésold 2012d). The key objective in such an environment is to maintain a stable permafrost regime. The road surface elevation will be constructed on rockfill embankment 2.0 m above the existing ground and the existing ground will not be disturbed. This stabilises the road against washouts and protects against permafrost degradation under the road. Where the road climbs out of the valley bottoms, the road construction method will include cut and fill. Where permafrost is encountered, cut slopes will require buttressing with a layer of angular rock fill on top of filter fabric to prevent permafrost degradation and act as a retaining structure to improve slope stability. Road drainage systems to control runoff and to provide a barrier and storage for snow and falling rocks have been considered in the road design. The Freegold Road Extension will be actively maintained year round to provide access to and from the Casino Project. Regular road maintenance will include snow clearing to ensure user safety and preserve the condition of the access road. Construction activities will follow best practices that will be outlined in an Environmental Health and Safety Management System. Casino Mining Corporation will engage in discussions with the Yukon Government to determine the closure and decommissioning objectives for the Freegold Road Extension; for the purpose of this risk assessment it is assumed that the will be decommissioned following closure of the Casino Project.

The likelihood of a slope failure along the Freegold Road extension during construction and operation has been rated as Rare. Consequence is rated Low.

Local effects to Surficial Geology, Terrain, and Soils could result from a slope failure of the Freegold Road extension foundation. Road slumping or sloughing would be contained and remediated to ensure continued operation of the Casino Project.

21.4.2.6 Borrow Sites

Local effects to Surficial Geology, Terrain, and Soils could result from a slope failure of borrow sites; the likelihood of such an event was rated as Possible and Consequence has been rated as Very Low, since effects would be restricted to the immediate area and remedied if necessary.

21.4.3 Spills/Leaks

Spills or leaks from Project equipment or machinery could be associated with each of the following components and activities:

- Spill of fuel from mobile and stationary equipment during refueling and maintenance in pit or on site;
- Failure of the HLF liner, tanks, pipes, and pumps and release of leach/pregnant solution;
- Failure of tanks, pipes, pumps between HLF and gold recovery building, resulting in release of pregnant solution;
- Failure of control system or operator error during handling or mixing resulting in on-site reagent spill;
- Failure of mechanical equipment or control system resulting in on-site concentrate spill;
- Failure of the thickeners, pipes, and pumps from sulphide ore processing facility to the TMF and release of PAG tailings;
- Tailings distribution pipelines failure (bulk non-PAG tailings, PAG tailings, cyclone sand, cyclone overflow);
- Vehicle collisions (trucks, track and wheel dozers, graders, water trucks, etc.);
- Hazardous materials spill resulting from aviation accident during takeoff or landing;
- Spill or release of liquid or solid chemicals during on-site transfer and handing;

- LNG storage tank rupture;
- LNG spill during transport;
- Leaks from storage or disposal containers;
- Leaching from landfill; and
- Release of uncured cement or concrete leachate to environment from a failure of the Concrete Batch Plant.

Accidental release of hazardous materials could result in contamination of soil, air or water; cause vegetation damage; and be toxic to wildlife or humans, either on site or along the transport route. Consequences of any spill depend on the magnitude and extent of the spill; the material, quantity, location, and duration of the spill; and environmental conditions at the time. Hazardous materials associated with the Project can be grouped into four categories:

- Petroleum products and lubricants (e.g., LNG, diesel, oils and degreasers);
- Sulfide and oxide ore processing reagents;
- Blasting compounds (e.g., ammonium nitrate, fuel oil); and
- Tailings.

Likelihood and consequences and hazard scenarios associated with each of these are discussed in this section.

21.4.3.1 Refueling Spills

During construction and operation, heavy equipment will be used for clearing and grubbing; stripping and removing overburden; mining and transporting ore and waste to stockpiles, crushers, or waste rock dumps; and maintaining disturbed and working areas. Heavy equipment will include drills, cable shovels, trucks, wheel and track dozers, graders, excavators, and loaders. The primary fuel sources are diesel and LNG.

A diesel bladder tank farm will be used in early construction; this will be replaced by a permanent steel diesel fuel storage tank with dispensing facilities at the supplementary power plant in Year -4. The LNG will be stored at the Casino plant site and re-gasified to natural gas as required. In addition to providing natural gas for the power plants, LNG will be used in the tanker trucks transporting the LNG, over-the-highway tractors hauling concentrates, lime, grinding media; and, if feasible, to power the mine fleet.

Diesel and LNG will be transferred from tanker trucks to storage tanks by enclosed lines, hoses, and pumps equipped with pressure transducers and volume counters to ensure tanks cannot be overfilled. All storage tanks will be constructed and managed in accordance with the National Fire Code and in conformity with the Environmental Code of Practice for Aboveground Storage Tank Systems Containing Petroleum Products. Stationary equipment will be located away from watercourses and bermed and lined with an impermeable barrier with a holding capacity equal to 110% of the largest tank within the berm. Two mobile re-fuelers and two portable fueling stations will supply LNG to required locations throughout the Casino mine site.

The hazard scenario assessed for refueling is the discharge of a hazardous material to the environment.

The likelihood of a spill during re-fueling of equipment with LNG or diesel in the Open Pit during mining activities throughout the mine life was rated as Likely. Because the spilled material would be within the Open Pit and not discharged to the environment the Consequence is rated as Very Low. No effects to VCs are therefore anticipated. The likelihood of a LNG spill during refueling of Project equipment outside of the Open Pit is rated as

Likely. Because of the potential for the spilled material to be discharged to land in the area surrounding the spill the Consequence is rated as Low. The likelihood of a diesel fuel spill during re-fueling of mine equipment is rated as Likely and the Consequence is rated as Very Low, since equipment will be re-fueled from a central location, and the diesel refueling facility will have secondary containment.

The VCs that could be affected by spills that occur during refueling of equipment with LNG or diesel are:

- Surficial Geology, Terrain, and Soils

Spills to land during re-fueling activities are expected to be localized and small to moderate volume. Small diesel spills will usually evaporate and disperse naturally within a day; naturally occurring soil microbes will readily degrade diesel oil within one to two months (National Oceanic and Atmospheric Administration 2013). However, spills to land can affect soil physical properties, soil chemistry, and biological organisms, affecting soil biodiversity (Hughes and Stallwood 2006). Following a spill, the low molecular weight volatile fractions quickly evaporate, leaving the high molecular weight poly-aromatic hydrocarbons which may sink below the ground surface and pool in depressions above the permafrost (Hughes and Stallwood 2006). The rate of naturally occurring biodegradation will depend on contaminant and substratum properties (Coulon and Delille 2006) as well as soil liquid water and temperature (Schafer et al 2009). Natural remediation by Antarctic soil microorganisms was found to be slow due to low availability of liquid water, lack of nutrients to support microbial growth, and low temperatures (Hughes and Stallwood 2006).

Unlike diesel spills, LNG spills completely evaporate, leaving no residue that could harm soil or groundwater (Drube et al 2012).

Should a spill occur, site staff will implement the Emergency and Spill Response Plan. Any contaminated materials will be handled in accordance with the Waste Management Plan. Any hydrocarbon contaminated material will be collected and deposited within land-farm treatment facilities for remediation at the Casino site. Soil remediation occurs through volatilization and natural biological processes and once hydrocarbon levels meet the applicable Yukon Government remediation standards, the soil will be transferred to the landfill, likely to be used as cover material. If treatment is not effective, the material will be disposed of off-site at a licensed disposal facility. Hydrocarbon contaminated water, snow and ice will be treated within the oily water treatment systems within the maintenance shops located at the Casino mine site. Excessive volumes of contaminated snow and ice will be stored within a dedicated cell of the land-farm until the material has melted and can be transported by pump truck to the oily water treatment system in the maintenance shop.

21.4.3.2 Vehicle Accidents

On-Site Vehicle Accidents

Heavy equipment required during the construction phase includes drills, cable shovels, trucks, wheel and track dozers, graders, excavators, and loaders for site clearing and grubbing, stripping and removing overburden; mining and transporting ore and waste to stockpiles, crushers, or waste rock dumps; and maintaining disturbed and working areas. The number of vehicles and equipment will range from 17 during Year -3 to 26 in Year -1.

During operations, shovels and front-end loaders will be used to load mine haul trucks. Backhoe excavators will be utilized for general earthworks, snow removal, and limited mining activity. Wheel and track bulldozers will be used for cleanup around mining activities and for control of rock on the benches. Graders and water trucks will be used for main haul road maintenance. All movement of vehicles within the Open Pit will be monitored by a central dispatching system to ensure worker health and safety and efficiency in operation.

For the purpose of this assessment, on-site vehicle accidents include aircraft accidents during takeoff or landing at the Casino airstrip. The existing airstrip will be replaced with a facility that permits safe and efficient all season operations for aircraft such as the Hawker-Sidley HS 748 turboprop aircraft and the Bombardier Dash 8-100 or 200 series turboprop. These aircraft may be better suited than larger aircraft to fly in the area as their slower speeds would be an asset in the challenging terrain. Aircraft will be used primarily for transport of personnel; therefore, hazardous materials are those associated with the running and maintenance of the aircraft itself.

The likelihood of vehicle collisions (trucks, track and wheel dozers, graders, water trucks, etc.) resulting in spills or leaks of deleterious substances outside of the Open Pit is rated as Possible. Consequence is rated as Low, since the volume of material spilled will be equal to, or less than, the volume of the fuel tank of each vehicle.

The likelihood and significance of vehicle collisions resulting in spills or leaks of deleterious substances within the Open Pit is rated as Rare, since vehicle movement will be monitored by a central dispatching system; Consequence is rated as Very Low because the spilled material would be contained within the Open Pit and not discharged to the environment.

The likelihood of an aircraft accident resulting in spills or leaks of deleterious substances is rated as Rare. Consequence is rated as Moderate, since the volume of material spilled will be equal to, or less than, the volume of the fuel tank of each aircraft. However, consequence will depend on the location and magnitude of the spill in relation to any watercourse; materials entering Dip Creek could result in effects beyond the event site that would not be readily remediated.

The VCs that could be affected by spills that occur as a result of on-site vehicle collisions are:

- Surficial Geology, Terrain, and Soils;
- Water and Sediment Quality; and
- Fish and Fish Habitat.

Spills would be expected to be localized and small to moderate in volume. Should a spill occur, site staff will implement the Emergency and Spill Response Plan. Any contaminated materials will be handled in accordance with the Waste Management Plan. Any hydrocarbon contaminated material will be collected and deposited within land-farm treatment facilities for remediation at the Casino site. Soil remediation occurs through volatilization and natural biological processes and once hydrocarbon levels meet the applicable Yukon Government remediation standards, the soil will be transferred to the landfill, likely to be used as cover material. If treatment is not effective, the material will be disposed of off-site at a licensed disposal facility. Hydrocarbon contaminated water, snow and ice will be treated within the oily water treatment systems within the maintenance shops located at the Casino mine site. Excessive volumes of contaminated snow and ice will be stored within a dedicated cell of the land-farm until the material has melted and can be transported by pump truck to the oily water treatment system in the maintenance shop.

Off-Site Vehicle Accidents

The Freegold Road Extension, a new, 120 km long, two-lane, gravel, all-weather resource road will be used for year-round hauling of materials into and out of the Casino mine site during operations. There will be 18 major bridge crossings located along the route, which include crossings of Bow Creek, Big Creek, Hayes Creek, and Selwyn River, and 71 major culvert crossings. Of particular concern to the Proponent is the spill of any substance to water at any of the watercourse crossings along the transport route. During the last two years of construction, LNG will be transported from Fort Nelson to the Casino Project via tanker trucks at an average frequency of two trucks per day; during operations this number will increase to eleven. The volume, form and transportation logistics of the process reagents noted in Table 21.3-1 and Table 21.3-2 will be determined during detail design engineering of the Project.

The likelihood of a vehicle accident resulting in a spill is a combination of the likelihood of a vehicle accident times the likelihood of loss of cargo from the vehicle and a failure of the containment method. Transportation of goods and materials will be in accordance with all applicable regulations and legislation, as well as the Explosives and Hazardous Materials Transport Permit required for the Project. The likelihood of an off-site vehicle accident resulting in the release of reagents or concentrate to the environment is rated as Possible; Consequence is rated as Moderate. Copper concentrate will be dewatered and transported as a filtered cake; molybdenum concentrate will be dewatered and packaged in super sacks for transport.

The likelihood of an off-site vehicle accident resulting in the release of LNG to the environment is rated as Unlikely; Consequence is rated as Low given the characteristics of the material. The likelihood of an off-site vehicle accident resulting in the release of diesel to the environment is rated as Unlikely; Consequence is rated as High given the characteristics of the material. Spills to water could result in a significant impact on water and sediment quality and on fish and fish habitat, depending on the location of the spill; the volume and characteristics of material spilled; and the flow within the watercourse. Chinook and chum salmon have been documented in Big Creek. Chinook have also been reported in the Selwyn River and Dip Creek (Knight Piésold 2012d). Impacts could include direct mortality to aquatic biota, sediment contamination resulting in chronic adverse effects, and loss of habitat. Effects could be localized in slower flowing, low gradient streams, or extend for several kilometres in higher gradient or larger rivers. Fish mortality affecting the species population could have an indirect effect on the Sustainable Livelihood VC, if that species was part of a traditional fishery. The VCs that could be affected by spills that occur as a result of off-site vehicle collisions are:

- Surficial Geology, Terrain, and Soils;
- Water and Sediment Quality;
- Fish and Fish Habitat; and
- Sustainable Livelihood.

Soil contamination from diesel spills would be localized and remediated following measures outlined in the Emergency and Spill Response Plan, as described above. Any contaminated materials will be handled in accordance with the Waste Management Plan. Spills to land are expected to be localized and small to moderate in volume. Small diesel spills will usually evaporate and disperse naturally within a day; naturally occurring soil microbes will readily degrade diesel oil within one to two months (National Oceanic and Atmospheric Administration, 2013). However, spills to land can affect soil physical properties, soil chemistry, and biological organisms, affecting soil biodiversity (Hughes and Stallwood 2006). Following a spill, the low molecular weight volatile fractions quickly evaporate, leaving the high molecular weight poly-aromatic hydrocarbons which may sink below the ground surface and pool in depressions above the permafrost (Hughes and Stallwood 2006). The rate of naturally occurring biodegradation will depend on contaminant and substratum properties (Coulon and Delille 2006) as well as soil liquid water and temperature (Schafer et al 2009). Natural remediation by Antarctic soil microorganisms was found to be slow due to low availability of liquid water, lack of nutrients to support microbial growth, and low temperatures (Hughes and Stallwood 2006).

Diesel spills to water could result in direct mortality of fish and invertebrates, since diesel is considered to be one of the most acutely toxic oil types (National Oceanic and Atmospheric Administration, 2013). Because of its low viscosity it is readily dispersed in the water column; this oil could then adhere to fine-grained suspended sediments which would settle out and result in sediment contamination (National Oceanic and Atmospheric

Administration, 2013). Lytle and Peckarsky (2001) assessed the effects of a diesel fuel spill on stream macroinvertebrates over a 15 month period and found that the spill significantly reduced invertebrate density and taxonomic richness in the area immediately below the spill. Schein et al (2009) concluded that diesel toxicity could impair the health of fish populations, depending on the extent of chemical or mechanical dispersion (naturally caused by fast-flowing, turbulent rivers) and life stage of the fish. Dispersion of diesel increases the bioavailability and apparent toxicity to fish embryos - dispersion was reported to cause acute lethality to juvenile trout between 40 mg/L and 200 mg/L (Schein et al 2009). Best practices will be followed when siting and using the mobile re-fuelers and two portable fueling stations (e.g., ensuring that they are more than 30 m from any watercourse).

As previously noted, LNG spills completely evaporate, leaving no residue that could harm soil or groundwater (Drube et al 2012). Liquefied natural gas evaporates at -162°C (it's normal boiling point) at atmospheric pressure and forms a visible cloud which is initially heavier than air until the methane vapour warms to -108°C; at this point the natural gas becomes lighter than air and therefore dissipates (Drube et al 2012; ABS Consulting 2004). If spilled to water, LNG is lighter than water and boils on top until it evaporates (Drube et al 2012). As described by ABS Consulting (2004): "When spilled onto water, LNG will initially produce a negatively buoyant vapor cloud (i.e., the cold vapors are more dense than air and stay close to the water or ground). As this cloud mixes with air, it will warm up and disperse into the atmosphere." Natural gas is also non-toxic; therefore, no impacts to water or sediment quality or fish and fish habitat are expected.

In the event that a transport truck carrying reagents or concentrate is involved in a collision or accident, the effects of a reagent or concentrate spill will depend on the volume released, which will be primarily determined by the containment methods used. Environmental effects could range from negligible to moderate, depending on the location of the spill (to land or water) and the characteristics of the product. The following materials released to water could result in impacts to fish and fish habitat:

- Sodium-diisobutyl dithiophosphinate: at high concentrations acutely toxic to aquatic life
- Pebble Lime (CaO), because of the high pH, would be expected to be toxic to aquatic organisms and aquatic systems;
- Sodium Hydrosulfide (NaHS): strongly alkaline
- Potassium amyl xanthate: may persist for several days in water; highly toxic to aquatic life and may increase metal uptake in fish
- Sodium Cyanide (NaCN): highly toxic to fish, amphibians, aquatic insects and aquatic vegetation; cyanide is acutely toxic to most species of fish at concentrations greater than 200 µg/L.

Access and transportation management during the operation phase will include regular maintenance and inspections for safe operation of vehicles, snow clearing, and the application of dust suppressants as required. Ore handling and spills response is included in the Emergency and Spill Response Plan. The Project Road Use Plan will outline speed limits and their enforcement; right-of-way; truck traffic communications; and the community notification and update process for the village of Carmacks.

21.4.3.3 Heap Leach Facility Systems Failure

The hazard scenario assessed for the heap leach facility systems is failure of the liner, pipes, and sumps and release of leachate into the environment. Liner failure could include puncture of the geomembranes and pipe rupture could result from deformation of adjacent soil liner or overliner from sub-optimal compaction or from freezing and cracking. The following paragraphs discuss the design measures to be implemented to minimize the potential for release of leachate into the environment.

Operations will involve the irrigation of a weak cyanide solution over each ore lift and the recovery of pregnant solution in collection pipes and pumps. The solution will be pumped to the gold extraction plant for metal extraction and recycled for re-use in the leaching process. The irrigation lines will be buried to prevent freezing during winter conditions.

The heap leach pad liner system is designed to eliminate to the greatest extent possible leakage losses of pregnant solution through the bottom and sides of the leach heap pad. The composite liner consists of synthetic and natural materials to act as 'barrier' and 'drainage' layers (Knight Piésold 2012b). The heap leach pad is designed to operate as a dry pad (minimal solution storage during normal operating conditions); however, the liner system was designed to meet the required performance standards for fully saturated solution storage conditions. The liner on the upper sloped surfaces of the heap leach pad (above the in-heap leachate solution elevation) will be comprised of:

- 1 metre thick overliner (38 mm minus with less than 10% fines content);
- 80 mil (2 mm) linear low-density polyethylene (LLDPE) geomembrane; and
- 0.3 metre thick compacted low permeability soil liner.

The liner in the sections of the heap leach pad that will be below the leachate collection pipes, on the lower portions of the slopes, will be a double liner system comprised of the following components:

- 1 metre thick overliner (38 mm minus with less than 10% fines content);
- 80 mil (2 mm) LLDPE geomembrane;
- 0.3 metre thick compacted low permeability soil liner;
- Non-woven, needle punched geotextile layer;
- Leak Detection and Recovery System (LDRS); and
- 60 mil (1.5 mm) linear low-density polyethylene (LLDPE) geomembrane.

Geomembranes refer to synthetic lining materials typically consisting of any of a number of types of plastic polymer (Ulrich, Andrade, and Gardner, 2003). Issues to consider when selecting geomembranes relevant to the Casino Project site include resistance to puncture and the interface friction angle with materials above and below them (Ulrich, Andrade, and Gardner, 2003). The LLDPE geomembrane was selected based on its higher interface friction values, compared to other geomembrane materials; ease of installation in cold climates; good performance under high confining stresses; and higher allowable strains for moderate settlement (Knight Piésold 2012b). The layers of the liner system will be extended to the top of the embankment and perimeter berms to provide full containment, and anchored and backfilled in a trench along the perimeter to ensure that ore loading does not pull the liner into the pad. A perimeter berm will be constructed as part of the liner tie-in around the perimeter to ensure that heap solution is contained and prevent surface runoff from the adjacent slopes entering the pad collection system. A one metre layer thick of coarse crushed ore will be placed over the entire liner system footprint to protect the liner against damage during ore placement and act as a drainage layer for the piped leachate collection system, reducing head loading on the liner.

The leachate collection system will recover the pregnant solution and facilitate solution transport off the heap leach pad as quickly as possible to reduce the potential risk of leachate solution losses through liner system. The collection system consists of the following:

- Lateral collection pipes;

- Collection header pipes;
- Main header collection pipes; and
- Leachate collection sumps.

The piping system will be embedded within the one metre thick overliner layer. Ulrich, Andrade, and Gardner (2003) note that several researchers and pipe manufacturers have modelled in-heap conditions and found that small pipes, despite changing their shape, will maintain a flow path beneath the heap even under simulated loads of 100 metres or more of ore; the pipes did change shape but in almost all cases, maintained a similar opening size. The sumps will be located at the toe of the confining embankment and will be comprised of a 600 mm diameter steel vertical riser pipe. The lower collection zone will be embedded in a 3 m thick zone of clean screened gravel and the upper zone will be embedded in a 3 m thick zone of compacted crushed ore. The compacted crushed ore ensures that settlement around the vertical riser does not occur and damage the collection system. The collection system is designed to convey the leachate off the pad, thereby minimizing the potential for geochemical breakdown of the liner.

The LDRS will capture and convey any solution that leaks through the overlying geomembrane and low permeability soil layers. The heap leach pad leachate collection system will be sub-divided into 16 independently monitored cells separated by small berms; each cell will have a dedicated leakage detection collection system. Flow rates from the collection pipes will be continuously monitored and measured prior to discharging into a collection sump.

Based on the design criteria and monitoring proposed, the likelihood of failure of any of the heap leach pad liners or irrigation and collection pipes resulting in discharge of leachate solution to the environment is rated as Unlikely. The consequences of a release would be High if leachate were to enter Casino Creek.

Failure of any component of the heap leach facility systems could result in release of leachate, containing high concentrations of cyanide and metals, and potentially blasting residues and suspended solids, into Casino Creek. As noted by Canadian Council of Ministers of the Environment (1999) “Soils represent the major potential pathway for cyanide contamination of groundwater … high concentrations of cyanide in effluents present a hazard to both soil and groundwater, since microbial degradation of the compound may be inhibited”.

This section describes the potential effects of this hazard scenario on the following VCs:

- Surficial Geology, Terrain, and Soils;
- Water and Sediment Quality;
- Fish and Fish Habitat; and
- Wildlife.

Surficial Geology, Terrain, and Soils

The transport and distribution of cyanide in soils is affected by volatilization and biodegradation; cyanides may also be adsorbed by clays and biological solids in the soils (Canadian Council of Ministers of the Environment 1999). The rate of hydrogen cyanide and metal cyanide adsorption in soils is small in comparison to rates of volatilization and biodegradation; however, cyanide must be present as hydrogen cyanide in order to volatilize from soils (Canadian Council of Ministers of the Environment 1999). Cyanide ions may also complex with heavy metals, especially iron, and precipitate out of solution (Canadian Council of Ministers of the Environment 1999). Soil fungi or bacteria can convert cyanide to carbonate and ammonia; in aerobic conditions at low concentrations cyanide will decompose to ammonia, carbon dioxide, and nitrogen or nitrate. Under anaerobic conditions cyanide could decompose to ammonium ion, nitrogen, thiocyanate, and carbon dioxide (Canadian Council of Ministers of the Environment 1999).

The Canadian Council of Ministers of the Environment has derived soil quality guidelines for different land uses. In the unlikely event of a heap leach pad systems failure resulting in release of leachate to the soil, the Emergency and Spill Response Plan will be implemented. The results of soil quality monitoring will be compared to the soil quality guidelines and further remediation will be implemented if necessary.

Water and Sediment Quality

Potential effects to surface water and sediment quality directly from a release of leachate from the heap leach pad are considered to be minimal, since Casino Creek will be located more than 3 km from the southwest perimeter of the heap leach pad.

The potential for adverse effects on groundwater quality exists via soil contamination. In soils with pH greater than 4, cyanides dissolved in leachate tend to precipitate out; however, some could remain in solution and cause groundwater contamination, especially under anaerobic conditions (Canadian Council of Ministers of the Environment 1999). Surface water contamination could occur as a result of surface water interaction with groundwater. A surface and groundwater monitoring program would be implemented following remediation of any spill, and water sample results would be compared to Canadian Environmental Quality Guidelines for the end user (e.g., aquatic life).

Fish and Fish Habitat

Cyanide is acutely toxic to most fish species at high concentrations (greater than 200 µg/L). (Ministry of Environment, Lands and Parks 1998). Cyanide can combine with metals to form a variety of compounds, depending on pH, temperature, dissolved oxygen, salinity, and the presence of other ions (Ministry of Environment, Lands and Parks 1998). Free cyanide is the sum of hydrogen cyanide (HCN) and the cyanide ion (CN^-) – the distribution of free cyanide between hydrogen cyanide and the cyanide ion depends on pH and temperature; in water with pH less than 8, the predominant form is hydrogen cyanide, which is volatile (Gensemer et al. 2006). Free cyanide toxicity to aquatic life mainly results from HCN; according to Gensemer et al. (2006) "most metallocyanide complexes are not very toxic".

The U.S. Environmental Protection Agency current ambient water quality criteria for cyanide (developed in 1984) for freshwater aquatic life are 22 µg and 5.2 µg CN/L (free cyanide) for chronic and acute, respectively (Gensemer et al. 2006). The Canadian Environmental Quality Guideline for water quality the protection of aquatic life (derived in 1987) is set at 5 µg/L as free cyanide; no sediment quality guidelines currently exist.

Potential effects to aquatic life from a release of leachate to surface water from the heap leach pad is considered to be minimal, since Casino Creek will be located more than 3 km from the southwest perimeter of the heap leach pad. As previously discussed, there is potential for contamination of groundwater via soil contamination from a heap leach systems failure. Following cleanup and disposal of contaminated soil in accordance with the Emergency and Spill Response Plan, a surface and groundwater monitoring program would be implemented. Water sample results would be compared to Canadian Environmental Quality Guidelines for the protection of aquatic life.

Free cyanide is readily absorbed by terrestrial animals through inhalation, ingestion, and contact with skin and mucous membranes; ingestion of plants containing cyanide is the most frequent cause of poisoning (Canadian Council of Ministers of the Environment 1999). Most mammal and bird species are able to rapidly degrade low doses of cyanide to nontoxic products; however large doses result in death (Canadian Council of Ministers of the Environment 1999). The LD_{50}s (lethal dose, or amount of substance, required to kill 50% of a test population) for mammals and birds range from 1.43 mg CN/kg body weight to 11.15 mg CN/kgbody weight (Canadian Council of Ministers of the Environment 1999). It is anticipated that the perimeter berm around the heap leach pad will limit the amount of in-heap leachate released and thus the area of soil contaminated to areas immediately adjacent to the heap leach pad; therefore, the potential impacts to wildlife are not considered significant since animals are assumed to exhibit avoidance behaviour of the area due to noise and human presence.

21.4.3.4 Tailings Distribution Facilities Failure

Three tailings streams will discharge into the TMF: PAG tailings, bulk NAG tailings and the cyclone overflow (the fine fraction of bulk NAG tailings) (Knight Piésold 2012a). The TMF design includes separate tailings lines from the main plant site for the PAG tailings and NAG tailings. Thickened NAG tailings from the processing plant will have a solids concentration of 55% solids by weight; this will be directed to the cyclone feed tank where it will be diluted with pond reclaim water to an optimum solids concentration of 36%, and will then flow by gravity to the cyclones.

The cyclone feed tank will be comprised of four compartments: the NAG tailings and dilution water report to the first compartment before flowing over a baffle to a rubber lined 38” carbon steel pipe to the cyclone cluster. In the event that bypass of the cyclones is required, the 38” carbon steel pipe can be isolated with a knife gate valve. The slurry level would then increase in the overflow compartment before reaching an overflow weir; from the overflow weir the slurry flows to a bypass compartment piped through the cyclone plant and cyclone overflow distribution system, where it will be deposited on the upstream side of the tailing dam (Knight Piésold 2012a). The fourth compartment of the cyclone feed tank takes all tank overflows and spillage in emergency situations and feeds into a 42” emergency spillage line, which takes the spillage to the nearest location of the tailings pond .

The cyclone underflow (sand fraction) will be discharged from the sand plant as slurry at 65 – 74% solids (by weight) to construction cells along the upstream and downstream shells of the TMF embankment. The cyclone overflow material (fine fraction) will be discharged directly to the TMF impoundment as slurry at approximately 25% solids by weight. The cyclones will be in operation for approximately nine months of each year, since cyclone operations become more problematic as the temperature decreases during the winter months (Knight Piésold 2012a). The bulk NAG tailings will be deposited during the winter months and any other time the cyclone plant is not in operation. The bulk NAG tailings and cyclone overflow will be discharged to the TMF from valved off-takes located along the Main Embankment and from the West Saddle Embankment. The PAG tailings will be deposited within the TMF near the Waste Storage Area; the PAG tailings line will be laid heading east from the main plant, running between the low grade ore stockpiles. Upon mine closure the tailings and reclaim delivery systems, cyclone plant and all pipelines, structures and equipment not required beyond mine closure will be dismantled and removed from site.

The hazard scenario assessed for the tailings distribution lines is rupture, either due to freezing temperatures or to damage from heavy equipment, resulting in a release of tailings to the environment during the construction and operation phases. Three scenarios are discussed:

- PAG tailings line rupture between the main plant and TMF;
- NAG Bulk tailings line rupture between the main plant and the cyclone plant; and
- NAG Tailings underflow and overflow into the TMF.

Risks and mitigation plans accounted for in the cyclone and transport system include (Knight Piésold 2012a):

- Slack flow and associated high tailings slurry velocities, up to 11 m/s, creates very high wear in the piping: risk of high pipeline wear in sloped sections (slack flow) was resolved through the use of ceramic orifices to dissipate energy and reduce slack flow section lengths, and ceramic lined pipes on remaining slack flow pipe section;

- Risk of blockage of the cyclone underflow pipeline was mitigated through proper design and flush water availability along the whole pipe;
- Risk of freezing of pipeline addressed through design using heat tracing and insulation; during operations the slurry pipelines will be drained for shutdowns longer than two hours;
- Risk of valve malfunctions due to freezing will be mitigated through insulation and heat tracing; and
- Risk of pipeline failure addressed through drainage construction to ensure that spills are directed into the TMF through a 42" emergency spillage pipe.

The higher elevation of the main plant site relative to the TMF will enable gravity discharge for the tailings streams, therefore any PAG tailings released from a tailings line rupture between the main plant site and TMF would eventually report by gravity flow to the TMF, if not contained and cleaned up immediately. Similarly, release of material from a NAG tailings rupture between the main plant site and TMF embankments would flow by gravity to the TMF. Rupture of the cyclone sand piping system would result in release of cyclone underflow from the NAG tailings on the downstream side of the embankment; the underflow is approximately 74% solids by weight and is anticipated to be captured within the sand deposition cells. Rupture of the tailings fines from the cyclone overflow discharge lines would result in deposit of NAG tailings onto the beach of the TMF.

Based on the design measures the likelihood of a tailings line rupture is rated as Rare and the consequence is rated as Very Low.

Release of tailings into the environment could affect the following VCs:

- Water and Sediment Quality; and
- Fish and Fish Habitat.

Failure of the PAG tailings pipeline between the main plant and the TMF would result in release of material into the terrestrial environment; because the main plant site will be located at higher elevation than the TMF all material would be captured within the TMF. No impacts to VCs are anticipated.

Failure of the NAG tailings pipeline would result in release of tailings onto the downstream side of the embankment or onto the tailings beach within the TMF. Deposit of the cyclone underflow tailings on the downstream embankment could result in unplanned release of seepage water from the cyclone sand; this water would report to the surface ditch system, which discharges into the water management pond located downstream of the embankment or into Casino Creek between the embankment and the Water Management Pond. Seepage and runoff collected in the water management pond will be pumped back into the TMF. Tailings seepage water could have elevated concentrations of total suspended solids and some metals; the length of creek affected will be less than 500 metres; no fish have been documented in the upper reaches of Casino Creek in the area of the TMF.

21.4.3.5 Hazardous Materials Storage

Reagent spills occurring during storage, mixing and distribution could include:

- Spill of liquid chemicals during offloading of trucks;
- Release of solid chemicals during on-site transfer and handing;

- Overflow of storage tanks; and
- Failure of pumps, pipes, valves.

Facilities for storage and handling of reagents will be located on an area of relatively flat terrain approximately two kilometres south of the Open Pit. Spills would be expected to be localized and small to moderate in volume. Should a spill occur, site staff will implement the Emergency and Spill Response Plan; any contaminated materials will be handled in accordance with the Waste Management Plan. The likelihood of spills or leaks of reagents during storage, mixing and distribution is rated as Possible. Consequence is rated as Very Low, based on the location of the facility upslope of the TMF and away from any watercourse. Reagent storage and mixing facilities for flotation circuits located within a structurally independent building to ensure that any material released is fully captured on site.

The likelihood of spills from the LNG or diesel storage tank is rated as Rare, while consequence is rated as Very Low. All storage tanks will be constructed and managed in accordance with the National Fire Code and in conformity with the Environmental Code of Practice for Aboveground Storage Tank Systems Containing Petroleum Products. An LNG spill containment pond will be designed to capture any spill in the event of a storage tank rupture.

The VCs that could be affected by spills that occur as a result of on-site vehicle collisions are Surficial Geology, Terrain, and Soils. Soil contamination could result in areas down-gradient of the storage facilities. Soil contamination would be localized and remediated following measures outlined in the Emergency and Spill Response Plan, as previously described. Any contaminated materials will be handled in accordance with the Waste Management Plan.

21.4.3.6 Concentrate Loading

Thickened copper concentrate will be filtered in three tower-type copper concentrate pressure filters into filter cakes, which will be discharged on to a conveyor belt that transfers them to a covered copper concentrate stockpile until shipment. Copper concentrate will be moved by front-end loaders onto highway haul trucks.

Molybdenum concentrate slurries will be filtered in one tower type molybdenum concentrate pressure filter to create filter cakes, which then travel through a Holo-Flite type dryer and discharge to a molybdenum concentrate storage bin. Molybdenum concentrate will be withdrawn from the dried molybdenum concentrate storage bin by a packaging system and will be bagged in super-sacks for shipment by highway haul trucks.

The likelihood of a spill of small amounts of material is rated as Possible; consequence is rated as Very Low, since the material will be contained within the main plant and not released to the environment. No effects on VCs are therefore predicted.

21.4.3.7 Landfill Management

A permanent waste management facility established during the construction phase will consist of a building and adjacent laydown areas. The waste management facility serves as a central depot where wastes generated across the Casino mine site will be managed, properly processed, packaged, labelled, inventoried, secured (e.g., on pallets) and stored for transport, disposed of on site or reused on site. Landfill sites within the Casino mine site will be used to dispose of inert solid waste and ashes from the incinerator. Regular cover will be applied over the landfill sites and a cap of native overburden will be placed on top of the landfill before decommissioning, so that the content of the landfill will remain permanently isolated. Open air controlled burning of inert combustible materials will be conducted on an as needed basis to eliminate large quantities of construction related wood waste and cardboard that would otherwise use up landfill capacity.

The likelihood of a leak from storage or disposal containers was assessed as Possible and consequence was rated as Very Low, since all containers will be maintained within a central depot prior to being shipped off-site for disposal. The likelihood of leaching from the on-site landfill was rated as Rare and consequence was rated as Very Low, since the landfill will only be used for deposition of inert solid waste and ashes.

Water and Sediment Quality was the VC identified as being potentially affected by a leak from storage or disposal containers or seepage from the landfill. The footprint of the landfill will be minimized through planned waste minimization and recycling practices, and volume reduction from the incineration of a portion of the waste stream. The landfill will only be operated by trained personnel who will carry out regular inspection and monitoring of the facility.

21.4.3.8 Concrete Batch Plant

The hazard scenario assessed for the concrete batch plant during site construction is the release of uncured cement or concrete wash water to the environment. The likelihood was rated as Unlikely and consequence was rated as Very Low, since a low-volume batch or portable concrete mixer will be used. Procedures outlined in the environmental management plans will be followed to minimize the likelihood of release and measures to ensure containment.

Water and Sediment Quality and Fish and Fish Habitat are the VCs potentially affected in the event of a concrete release. However, most of the project infrastructure for which concrete will be required (the main plant and SART plant) will be in the Casino Creek valley upstream of the TMF; any material released in these areas would report to the TMF.

21.4.4 Transportation Accident

Access and transportation management during the construction and operation phases is described in Sections 4. Projected traffic volume during construction and operations are provided in Section 4. Traffic accidents could result from operator error, equipment failure, poor road conditions, improper road maintenance, inclement weather, or wildlife interactions. Accidents include collisions between mine vehicles and public vehicles or other mine vehicles, collision between mine vehicles and public infrastructure, plane crash on takeoff or landing, or mine vehicle collision with wildlife. Accidents could result in wildlife injury or fatality or damage to public infrastructure. The assessment is restricted to the potential for transportation accidents occurring along the Freegold Road and Freegold Road Extension between Carmacks and the mine site, and to aircraft incidents at the Casino Project airstrip on takeoff and landing.

The likelihood of collision between mine related vehicles, between a mine vehicle and a public vehicle, or a mine vehicle and public infrastructure such as a bridge crossing along the Freegold Road resulting in blocked access along the road is rated as Possible, given the estimated traffic volume over the life of the mine. Consequence is rated as Low. The Upgrade portion of the road has been diverted away from the village of Carmacks to minimize the potential for damage to public services. Effects would be restricted to the immediate site; drivers will be trained to immediately implement the Emergency Response Plan (if able) and the site of the incident will be communicated to mine management and the public as necessary (via radio).

The likelihood of a collision of a mine vehicle with wildlife is rated as Likely; consequence is rated as Low based on potential impacts to wildlife at the population level. Creation of a movement barrier to wildlife as a result of snow removal activities along the Freegold Road (Extension and Upgrade) is rated as Possible and Consequence is rated as low, since effects would be restricted to the immediate area.

The likelihood of an aviation accident is rated as Rare. In the event that one did occur, consequences of the accident itself (e.g., not related to any subsequent spill or fire) would be Low. The Emergency Response Plan would be implemented by Project personnel.

The VCs potentially affected by transportation accidents include:

- Wildlife;
- Sustainable Livelihood; and
- Land Use and Tenure.

The Project will not significantly affect wildlife populations as a result of transportation accidents. A Road Use Plan, as described in Section 23, will be developed and will specify rules for the use of the Freegold Road Extension to ensure safe access to the Casino mine site, including:

- Potential use of the access road by the public including hunters;
- Speed limits and enforcement;
- Yielding the right-of-way to wildlife and reporting wildlife observations;
- Travelling in convoys for safety;
- Emergency and spill response procedures;
- Radio control; and
- Community notification and update process for the village of Carmacks.

Speed limits and additional mitigation measures will be implemented at bridge crossings and during inclement weather to minimize the risk of damage to public infrastructure that could hinder the use of the publicly accessible portion of the road by other parties.

21.4.5 Water Management Failure

Water management procedures for the Casino Project are summarized in Section 4.4.1.4 and described in detail in the Water Management Plan. Water management features include the TMF, water supply, sediment control structures, cofferdams, pumping systems, runoff collection ditches, and diversion channels, as well as the engineered wetland at closure.

Accidents and malfunctions associated with water management at the mine site could include:

- TMF overflow;
- Events pond overflow;
- Diversion or collection ditches failure;
- Cofferdam failure or overtopping; and
- Water supply pipe or pump failure.

A preliminary dam classification for the TMF was carried out following the CDA Dam Safety Guidelines (2007) to select the appropriate flood event. The TMF was classified as a High consequence dam; in accordance with the

CDA guidelines the Inflow Design Flood (IDF) Annual Exceedance Probability for a High consequence dam is “One third between 1/1,000 and the Probable Maximum Flood”. The IDF is the most severe inflow flood for which a dam is designed. The IDF up to and including Year 1 of operations was designed for a 1,000 year event for 72 hour storm duration; during operations the IDF was selected as "one third between 1,000 years and the Probable Maximum Flood event for 72 hour storm duration". The IDF design for closure was the Probably Maximum Flood event for a 24 hour storm duration. The design includes sufficient freeboard to accommodate the IDF above maximum supernatant pond level at each stage plus 2 m allowance for wave run-up.

The 1 in 1000 year flood is a flood having a 0.1% probability of occurrence being exceeded in any year. The Probable Maximum Flood is the largest possible flood based on an analysis of the maximum possible precipitation in a given area. Based on the design criteria, the likelihood of the TMF overtopping was rated as Unlikely and consequence was rated as Moderate.

The Events Pond will be constructed to full size prior to commencing operations of the heap leach facility and will provide storage for excess leachate and runoff that could be generated as a result of rainfall events exceeding the in-heap storage capacity. The flood flow used in the design is the 1 in 100 year 24-hour storm event (98,600 m^3). The Events Pond spillway is designed to discharge the 1 in 200 year 24-hour storm event with a minimum embankment crest freeboard of 0.3 metres. The pond will be operated as a dry-facility, therefore will only receive and store runoff water during significant storm events. Based on the design criteria, the likelihood of the Events Pond overtopping was rated as Unlikely and consequence was rated as Very Low, since any material overtopping the Events Pond embankment or spillway would report to the TMF and be contained on site,

The diversion ditches for the ore stockpiles will meet the following design criteria:

- Design storm conveyance: 1 in 100 year 24-hour duration storm event;
- Minimum freeboard = 0.3 m;
- Maximum design storm flow depth = 0.5 m; and
- Minimum ditch grade = 0.01 m/m.

During the construction phase of the Casino Project, initial water requirements for the oxide ore processing facilities will be met by pumping water from the temporary fresh water pond located at within the TMF catchment area along Casino Creek. The temporary fresh water pond will be utilized from Year -3 to Year -1. A cofferdam to capture flows will be sized to ensure that it does not overtop. Likelihood of failure of the cofferdam was rated as Rare; Consequence was rated as Very Low.

The permanent fresh water supply for the Casino Project will be sourced from the Yukon River. The water will be collected in a riverbank caisson and radial well system and pumped through an aboveground, insulated 17.4 km long pipeline with four booster stations. The design capacity of the fresh water collection and transfer system will be approximately 3,400 m^3 per hour. The likelihood of a water supply mechanism failure was rated as Possible and consequence was rated as Low. Rupture of the freshwater supply pipeline could cause erosion and sedimentation into the adjacent Britannia Creek or downstream in the Yukon River; however, the fresh water pipeline will roughly follow an existing road that leads northward from the Casino mine site to the Yukon River along Britannia Creek; the existing road will act as a service road to facilitate access, inspection, and maintenance of the fresh water pipeline during construction and operation.

Failure of any of the water management structures could result in release of fresh or contact water into the Casino Creek or Britannia Creek watersheds. This section describes the potential effects of a failure on the following VCs:

- Water and Sediment Quality; and
- Fish and Fish Habitat.

Overflow of the TMF, Events Pond or collection ditches could result in the release of contact water to the environment. Contact water would contain elevated concentrations of deleterious substances such as tailings and supernatant (from the TMF), cyanide and metals (from the Events Pond) and suspended sediments (from the collection ditches). Failure of the water supply pipeline or related structures or overtopping of the diversion ditches would result in the release of fresh water high in suspended solids.

Release of tailings and supernatant could result in an increase in metals concentration in water and sediment; alteration or loss of fish habitat; and direct fish mortality. The spatial and temporal extent of any effect would depend on the magnitude of the flood. Any material released from the Events Pond would be contained within the TMF and not released into the environment. The TMF design includes sufficient freeboard to accommodate the IDF above maximum supernatant pond level at each stage, plus a 2 m allowance for wave run-up, therefore release to the environment and potential effects on Water and Sediment Quality and Fish and Fish Habitat are not anticipated.

The cofferdam and diversion ditches will manage fresh water; any overflow would contain elevated levels of suspended sediment but no other Project-related deleterious substances. Release of this non-contact water into the environment would occur only during high inflows; the volume released is anticipated to be a small proportion of the flood flows, therefore incremental effects of the high suspended sediment laden water would not have an impact on the VCs.

Water management procedures during construction, operations, and closure will include site hydrological and meteorological monitoring; additional mitigation or design measures will be implemented a necessary if high flood flows are forecast.

21.4.6 Fire/Explosion

A fuel source, heat, and oxygen all need to be present for a fire to ignite. An explosion is a sudden release of energy, either mechanical or chemical. Fires or explosions could be associated with each of the following Project components and activities:

- Blasting resulting in air overpressure or flyrock damage;
- Improper storage or handling of processing reagents;
- Vehicle collision;
- LNG or diesel spill;
- Waste management (waste oil burners, woody debris slash piles); and
- Plane crash.

As noted in Section 4.4.1.6, fuel, hazardous materials, and explosives will be stored in separate structures in accordance with applicable regulations and permitting requirements. Under the *Explosives Act* it is illegal to store any explosive in a magazine that is not a licensed magazine. All explosives will be transported, stored and handled in compliance with applicable federal and territorial legislation and guidelines, including the “Blasting Explosives and Initiation Systems Storage, Possession, Transportation, Destruction and Sale” publication of Natural Resources Canada (2008). Improper blasting techniques during construction and operation could result in fly rock or air overpressure injury to wildlife or the public. During operations, blasting will only occur during daylight hours at designated times in order to minimize risk to all mine personnel in the vicinity. Blasting times will be posted at the Casino mine site and response measures put in place in case of an emergency according to the Explosives Management Plan. The likelihood of a fire or explosion resulting from improper storage or handling of explosive agents is rated as Unlikely; consequence is rated as Moderate.

Some of the processing reagents are flammable when exposed to an ignition source or in combination with other chemicals and could emit acrid smoke and corrosive fumes. Sodium cyanide, for example, could be combustible at high temperature and produce toxic and flammable vapours. When in contact with acid or acid salts, flammable hydrogen cyanide gas could be formed. Project buildings will include a fire protection system comprised of a primary fire pump (and backups) and sprinkler systems. The likelihood of a fire or explosion involving processing reagents is rated as Rare; consequence is rated as Moderate based on industry standard storage and handling procedures and control measures.

Vehicle collisions on site or along the transport route could release fuel (LNG or diesel) or combustible processing reagents; if an ignition source is present a fire or explosion could result. As noted in Section 21.4.3.2, the likelihood of a vehicle accident resulting in a spill is a combination of the likelihood of a vehicle accident times the likelihood of loss of cargo from the vehicle and a failure of the containment method; an ignition source must also be present for a fire or explosion to subsequently occur. Transportation of goods and materials will be in accordance with all applicable regulations and legislation, as well as the Explosives and Hazardous Materials Transport Permit required for the Project. An LNG spill could result in formation of a vapour cloud which could ignite in the presence of an ignition source if the concentration of the vapour cloud was within a flammability range of 5-15% by volume (Drube et al 2012). In an unconfined space the methane vapour would quickly evaporate and disperse (e.g., the fuel would be too light to burn); in a confined space there would be a risk of explosion of the vapour in the presence of an ignition source (Drube et al 2012). A diesel spill would pool on the ground since diesel has a lower vaporization rate; this leads to a higher potential for a fire or explosion (in comparison to LNG) if not cleaned up immediately.

Explosions associated with release of LNG from a container include (Drube et al 2012):

- Rapid phase transformation: transition of LNG to a gaseous state due to rapid pressure release from a storage tank;
- Rapid phase transition: small to moderate explosions could result if large volumes of LNG contact water, leading to a burst of heat transfer; and
- Boiling liquid expanding vapour explosion: in storage tanks lacking appropriately designed fire insulation, an external heat or fire source could heat the contents of the tank, leading to boiling of the liquid and increasing vapour pressure, which consequently reduces the strength of the tank above the liquid due to the increased temperature. If the temperature of the tank exceeds a critical temperature the container could fail, causing high pressure vapour to be released; the failure of the storage tank then causes a “rapid pressure reduction and subsequent phase change and pressure surge”.

Rapid phase transformation explosions are not likely because LNG will be stored at low pressure and tanks are equipped with pressure release devices. According to Drube et al (2012) a rapid phase transition resulting in a significant energy release requires a leak rate exceeding 10,000 gallons per minute (equivalent to 37,854 litres or 37.854 cubic metres per minute). All LNG tanks built to US standards require insulation jackets that remain in place during a fire and keep the upper portion of an LNG tank from reaching critical temperature (Drube et al 2012).

For these reasons the likelihood of a fire or explosion related to a vehicle collision or the LNG storage facility are both rated as Unlikely; due to the potential for a fire to spread or release toxic fumes, or an ensuing explosion, the consequences are rated as High.

Burning of any waste in waste oil burners or woody debris slash piles will be done by qualified and trained personnel in accordance with applicable guidelines and standards, as well as site-specific operating permit conditions. The likelihood of a fire related to waste management is rated as Possible, with consequences rated as Moderate.

The risk of a plane crash resulting in a fire or explosion is a combination of the risk of a plane crash, followed by the release of a flammable substance in the presence of an ignition source. The likelihood of a plane crash was assessed in Section 21.4.4 as Rare; therefore, the likelihood of a plane crash resulting in a fire or explosion is also Rare. The consequence of a fire or explosion on the environment is rated as High, since there would be a potential for the fire to spread over a wide area of the crash site.

A fire or explosion related to any of the Project components or activities could affect the following VCs:

- Air Quality;
- Noise;
- Rare Plants and Vegetation Health;
- Wildlife;
- Community Infrastructure and Services;
- Sustainable Livelihood; and
- Land Use and Tenure.

Explosions related to blasting are not anticipated to affect any VCs: wildlife would not likely be present in the mine area due to avoidance of human activity and would therefore not be affected by fly rock or air overpressure.

A fire or explosion releasing toxic fumes into the environment could have an adverse impact on air quality. Site wide firefighting measures would be implemented to contain the fire and minimize the duration of the release; however, existing air quality guidelines could be exceeded in the immediate area and in surrounding areas, depending on wind direction and velocity.

Explosions would have an adverse impact on ambient sound levels but the impact would be short term and infrequent.

Potential impacts to the remaining VCs would depend on the location and size of the fire and the ability of mine personnel to contain the blaze. Effects to wildlife could include direct mortality and loss of habitat; loss of rare plants would be permanent, while native vegetation would be expected to regenerate naturally over the medium term. Sustainable livelihood and land use and tenure could be impacted in the short to medium term if dependant on wildlife or vegetation lost to a fire.

The site water requirement for firefighting will be 341 m^3/h for two hours; this will be provided by ensuring a reserve capacity of 682 m^3 in the lower portion of the freshwater pond. Project buildings will include a fire protection system comprised of a primary fire pump (and backups) and sprinkler systems. Portable fire extinguishers will be provided in all buildings and mobile equipment. A Fire Response Plan developed as part of the Emergency Response Plan will include details of standard fire prevention measures and procedures to be implemented for site activities, as well as standard equipment, training and emergency response measures to be used for the Project.

21.4.7 Erosion and Sediment Control Measures Failure

The following erosion and sediment control measures assessed and the potential for failure are discussed in this section:

- Ore, topsoil or overburden stockpile erosion causing blockage of collection or diversion ditches at the toe;
- Slumping or sloughing of the Freegold Road foundation; and
- Excess sediment generation from clearing and grubbing.

Material carried downslope on the ore, topsoil or overburden stockpiles has the potential to infill the collection or diversion ditches at the base, thereby decreasing the capacity of the channels and increasing the risk of discharge of a deleterious substance to the environment. The ore stockpiles will be developed with 20 m benches along the toe of each lift to capture sloughing or ravelling material.

Management practices to reduce potential for soil erosion during handling or storage are described in Section 4.4.7.5; the measures include limiting the height and slope of the piles, vegetation planting to reduce exposure time, and locating piles in areas to reduce wind exposure. Topsoil stockpiles will be constructed with an overall slope angle of 4H:1V to minimize slope instability, reduce erosion potential, and improve the amenability for vegetation growth.

Two areas along the Freegold Road route have potential terrain stability issues, indicating the likelihood of future slope erosion. Detailed design measures to address these concerns could include retaining walls.

Sediment generation during clearing and grubbing will be minimized. A site preparation plan will be implemented in conjunction with the Project Construction Environmental Management Plan to manage and minimise environmental effects during construction activities.

The likelihood of erosion and sediment control measures for each of these scenarios is considered Possible, with consequences ranging from Very Low to Moderate, depending on site specific locations. Consequence was rated as Very Low for the ore, topsoil or overburden stockpiles, since any material released from the piles would be contained on site; consequence was rated as Moderate for the Freegold Road, since terrain instability could extend beyond the immediate construction site, depending on construction methods and site conditions.

The VC that would be affected would be Surficial Geology, Terrain and Soils. Effects would be short-term and reversible with mitigation and remediation.

21.4.8 Reclamation Measures Failure

The malfunctions assessed related to reclamation activities include:

- Metals uptake in vegetation on reclaimed areas greater than predicted;
- Failure of vegetation to become self-regenerating; and
- Failure of constructed wetland passive treatment for water quality.

The likelihood for metals uptake in vegetation on reclaimed areas resulting in adverse effects on wildlife was rated as Possible and consequence was rated as Low. Progressive reclamation will occur during mine operations and reclaimed areas will be monitored for physical and geochemical stability. Monitoring programs will be designed to determine the affinity for selected plant species to uptake metals and determine if the metals are bioavailable. Should monitoring during operations indicate that uptake of metals is a concern, mitigation measures will be taken into consideration, including re-vegetating with indigenous plants not used by wildlife.

The likelihood for failure of re-vegetated areas to become self-sustainable was rated as Possible; consequence was rated as Moderate. Challenges in establishing vegetation at northern sites include a short growing season, amount and timing of precipitation, and average temperatures. Disturbed areas will be progressively reclaimed during construction and operations and these areas will be monitored to assess revegetation success. Various seed mixes and soil mixes will be tested to determine the most effective one. This work will start early in the Operation Phase of the mine and given the long operations life of the mine will allow ample time to refine the choices. The information derived from the monitoring program will be used to inform the site closure plan, including any requirements for mulches, fertilizers, or other amendments.

The likelihood for failure of the constructed wetland for passive treatment of effluent from the HLF was rated as Rare and consequence is rate as Very Low. The proponent proposes to construct and commission the wetland in advance of the decommissioning of the Cyanide Destruction Plant (CDP) to demonstrate the effectiveness of the wetland. Monitoring during operations will assess the effect of climate on passive wetland treatment and confirm the modelling results for water quality. The CDP will not be decommissioned until such time as the wetlands are demonstrated to be functioning reliably. A contingency option includes adapting the operational seepage collection system for supplemental treatment using sulphate reducing bacteria. Water will not be discharged to the environment unless it meets existing guidelines or established water quality objectives.

21.5 SUMMARY

A total of 61 potential accident or malfunction hazard scenarios were identified and described in the Risk Register for the Project (Appendix 21-B). Based on likelihood and consequence, 15 scenarios were categorized as Non-actionable Risk (Table 21.5-1); 35 scenarios were categorized as Low Risk (Table 21.5-2); and 35 scenarios were categorized as Moderate Risk (Table 21.5-3). No accidents or malfunctions were categorized as High Risk based on the feasibility level design provided in the Project Description, therefore no accidents or malfunctions are expected to result in significant impacts on environmental or social VCs.

Table 21.5-1 Non-Actionable Activities

Scenario	Hazard	Likelihood	Consequence
1.d	Air overpressure infrastructure damage	Unlikely	Very Low
1.f	Ore stockpile slope failure	Rare	Very Low
1.h	Fuel spill in open pit from collision	Rare	Very Low
2.a	HLF embankment failure	Unlikely	Very Low
2.c	Events pond overflow	Unlikely	Very Low
2.d	Events pond embankment failure	Unlikely	Very Low
4.b	NAG and PAG tailings distribution pipeline failure	Rare	Very Low
9.a	Temporary freshwater supply pond cofferdam failure	Rare	Very Low
9.c	Process water pond failure	Rare	Very Low
10.a	LNG or diesel storage tank rupture	Rare	Very Low
10.d	LNG or diesel spill during transport	Unlikely	Low
11.c	Leaching from landfill	Rare	Very Low
12.c	Concrete or washwater spill	Unlikely	Low
13.c	Failure of constructed wetland passive treatment resulting in release of effluent higher than permit levels	Rare	Very Low

Table 21.5-2 Low Risk Activities

Scenario	Hazard	Likelihood	Consequence
1.a	Fuel spill in open pit during refueling.	Likely	Very Low
1.b	Pit wall failure resulting in slumping or mass wasting within the pit	Possible	Low
1.c	Fly rock from blasting	Possible	Low
1.e	Open pit overtopping during operations	Rare	Moderate
1.g	Ore stockpile erosion	Possible	Very Low
2.b	HLF slope failure, deposit of ore in surrounding terrain	Unlikely	Moderate
2.e	HLF liner, tanks, pipes, and pumps failure releasing leachate solution	Unlikely	High
3.a	Release of pregnant solution between HLF and Gold Recovery Building	Rare	Low
3.b	Reagent spill during mixing and handling in main plant or SART plant	Possible	Very Low

Scenario	Hazard	Likelihood	Consequence
3.c	Concentrate spill in sulphide ore plant site	Possible	Very Low
3.d	Tailings release between sulphide ore plant site and TMF embankment	Rare	Moderate
3.e	Reagent fire in sulphide ore plant site	Rare	Moderate
4.a	TMF embankment failure	Unlikely	High
4.c	TMF overflow	Unlikely	Moderate
4.d	TMF seepage greater than design	Possible	Low
4.e	TMF reclaim water line rupture resulting in release of contact water and causing erosion and sedimentation	Possible	Very Low
5.a	Stockpiles and dump erosion and sedimentation	Possible	Very Low
5.b	Waste Rock Stockpiles and dump slope failure	Possible	Very Low
6.a	Collision of mine related-vehicles causing blocked access along road	Possible	Low
6.d	Collision resulting in fire or explosion	Unlikely	High
6.e	Plane crash at airstrip causing injuring or mortality	Rare	Low
6.f	Plane crash at airstrip causing fuel spill to land or water	Rare	Moderate
7.a	Ammonium nitrate fuel oil (ANFO) spill on site	Possible	Very Low
7.b	Processing reagent spill on site	Possible	Very Low
7.c	Fire/explosion at explosives factory	Unlikely	Moderate
7.d	Fire/explosion in reagent storage area/oxide ore processing facility	Unlikely	Moderate
8.a	Freegold Road blocked drainage	Possible	Low
8.b	Freegold Road slope failure	Rare	Low
8.d	Improper snow management creating wildlife barrier resulting in wildlife mortality	Possible	Low
9.b	Freshwater Pond embankment failure or overtopping	Rare	Moderate
9.d	Water Management Pond failure	Rare	Moderate
9.e	Water supply system failure	Rare	Moderate
9.f	Diversion or collection ditches failure	Possible	Low
10.c	Fire/explosion during LNG or diesel transport	Unlikely	High
11.b	Leaks from waste disposal containers	Possible	Very Low
12.a	Borrow site slope/wall failure	Possible	Very Low

Scenario	Hazard	Likelihood	Consequence
12.b	Erosion during site prep	Possible	Low
12.d	Vehicle collisions resulting in spills or leaks of fuels, lubricants	Possible	Low
13.a	Failure of constructed wetland passive treatment resulting in release of effluent higher than permit levels	Possible	Low

Table 21.5-3 Moderate Risk Activities

Scenario	Hazard	Likelihood	Consequence
2.f	Fire involving processing reagents	Rare	High
5.c	Topsoil/Overburden Stockpiles and dump slope failure	Possible	Moderate
6.b	Collision resulting in spill to land or water - reagent or concentrate	Possible	Moderate
6.c	Wildlife collision	Likely	Low
6.g	Plane crash at airstrip causing fire or explosion	Rare	High
8.c	Freegold Road erosion into waterway	Possible	Moderate
10.b	LNG facility fire/explosion	Rare	High
10.e	LNG or diesel spill during refueling of Project equipment outside of Open Pit	Likely	Low
11.a	Fire/explosion associated with waste management	Possible	Moderate
13.b	Failure of vegetation to become self-regenerating resulting in erosion and sedimentation	Possible	Moderate

The risk rankings are summarized on the risk matrix (Figure 21.5-1).

Likelihood					
	Likely	1.a	6.c 10.e		
	Possible	1.g 3.b 3.c 4.e 5.a 5.b 7.a 7.b 11.b 12.a	1.b 1.c 4.d 6.a 8.a 8.d 9.f 12.b 12.d	5.c 6.b 8.c 11.a 13.b	
	Rare	1.f 1.h 4.b 9.a 9.c 10.a 11.c 13.a 13.c	3.a 6.f 8.b	1.e 3.d 3.e 6.f 9.b 9.d 9.e	2.f 6.g 10.b
	Unlikely	1.d 2.a 2.c 2.d	10.d 12.c	2.b 4.c 7.c 7.d	2.e 4.a 6.d 10.c
		Very Low	Low	Moderate	High
		Consequences			

Non-actionable	Low	Moderate	High

Figure 21.5-1 Casino Project Risk Matrix

The Casino Project considered site-specific geotechnical, hydrogeological and hydrometeorological characteristics in developing the feasibility level design to minimize the likelihood of any potential accidents or malfunctions. In northern environments, colder temperatures, permafrost, and snowfall can present specific challenges that need to be taken into consideration in the design, construction, and operation of the Project. The heap leaching process proposed has been demonstrated to be viable in climates similar to those of the Casino Project area; examples include the Brewery Creek Mine, near Dawson City, and the Fort Knox Mine in Alaska. The TMF has been designed to ensure that it has the ability to remain operational under winter freezing conditions; the design has taken into consideration the possibility of freezing of the supernatant pond, freezing of the tailings discharge stream, and the potential for excess dust generation resulting from the 'freeze drying' process which destroys capillary tensions in partially saturated sand materials. The projected energy requirement of the Casino Project at its peak is estimated as 130 MW; electrical power will be generated and distributed by an on-site LNG generation facility. The use of LNG as a fuel source was selected based on the lower air emissions and fewer environmental and safety concerns relative to other fossil fuels. All construction, operation, closure and reclamation activities will be closely governed by environmental management and monitoring plans, including an Emergency Response Plan, to ensure that the consequences of any accidents or malfunctions, should they occur, are minimized and remediated. Based on the likelihood and consequence ratings, none of the accidents or malfunctions were considered to have a significant impact on any of the Project VCs.