



**FRIEDA RIVER**

Frieda River Limited

## **Sepik Development Project**

Environmental Impact Statement

Chapter 11 – Extreme Natural Hazards and  
Incidental Events

SDP-6-G-00-01-T-084-012





## **11. EXTREME NATURAL HAZARDS AND INCIDENTAL EVENTS**

### **11.1 Background**

Environmentally hazardous discharges resulting from low probability, high consequence extreme natural hazards and incidental events, such as landslides, severe flooding, earthquakes and tsunamis, or aircraft accidents, are fundamentally different from the predicted normal operational discharges of wastes and wastewaters described in the Physical and Biological Impact Assessment (see Chapter 8) and social impacts described in the Socio-economic Impact Assessment (see Chapter 9). The Project design incorporates the requirements of relevant technical codes and operating and control measures with the specific aim of preventing such incidents and/or their consequences. Natural events of sufficient (i.e., extreme) magnitude to cause significant damage to Project facilities and infrastructure have a very low probability of occurrence over the life of the Project.

FRL and third-party operators of Project components will adopt the following general safeguards in preparedness for potential extreme natural hazards and incidental events during the life and closure of the Project:

- Adopt conservative designs and incorporate a suitable factor of safety or contingency to manage reasonably foreseeable events.
- Develop and implement corporate and operational risk management plans.
- Continuously develop and implement the ISF stewardship program. This will include the provision of world class experts in the various critical disciplines, including geotechnical engineering, tailings management, seismicity and dynamic design analyses, hydrology, hydraulic design and embankment and tunnel construction to review the design, construction and operation of the ISF.
- Develop and implement emergency response plans and procedures (including spill response) for extreme natural hazards and incidental events as part of the Significant Incident Management Plan for the Project.
- Conduct induction training and periodic refresher training for employees and contractors on safety, and site-specific regulations concerning safety, including emergency response training (relative to roles).
- Attend to government statutory compliance, notification and liaison requirements and procedures.

Nevertheless, extreme natural hazards and incidental events can occur. Consequently, the main risks have been assessed and management measures identified as described in this chapter. This includes risks related to:

- Failure of the ISF embankment and overtopping wave.
- ISF overturn.
- Failure of the open-pit wall and consequent overtopping wave (post-mining).
- Failure of the tailings pipeline.
- Failure of the concentrate pipeline.
- Hazardous materials spillage or leakage.

- Inundation of Vanimo Ocean Port facilities.
- Fire and explosion.
- Vessel collision.
- Aircraft or vehicle incident.
- Epidemic or pandemic and communicable diseases.
- Civil unrest, demonstrations or riots.

As part of the detailed design process, further hazard and risk identification, and hazard and risk mitigation workshops will be conducted to refine the assessment and if necessary incorporate further controls into final Project design. The Project's stakeholder engagement plan (Chapter 4) describes FRL's mechanisms for ongoing communication, including consultation with relevant agencies and other stakeholders regarding these potential risks and FRL's emergency response and contingency plans.

This chapter also outlines relevant legislation and guidelines applicable to environmental risks, hazards and harm (Section 11.2), and provides an initial assessment of specific risks and their associated causes, management measures, and emergency control procedures (Sections 11.3 to 11.16). The focus is on material hazards and incidents resulting from the Project that may cause high or extreme consequences such as adverse off-site impacts in terms of acute or chronic human health issues, injuries or fatalities, or impacts on the natural environment. These are defined as per the PanAust Enterprise Risk Management Procedure.

## **11.2 Legislative Framework and Guidelines**

### **11.2.1 PNG Legislation**

PNG legislation does not contain specific requirements for extreme natural hazard identification or risk assessment for a mining project. However:

- Section 7(1) of the *Environment Act 2000* imposes a general environmental duty on persons not to carry out an activity that causes or is likely to cause environmental harm unless that person takes all reasonable and practicable measures to prevent or minimise that harm.
- Section 43(1) of the *Mining Act 1992* requires that proposals submitted for mining leases (and special mining leases) provide adequately for environmental protection.
- The Environmental Code of Practice for the Mining Industry (OEC, 2000) requires the development of contingency plans to manage the risks of unexpected incidents, such as natural phenomena or equipment failures.

The risks and management measures to address them described in this chapter address these requirements.

### **11.2.2 Other Guidelines**

#### **Corporate Policy and Standards**

The Project will be managed by FRL under the governance of the PanAust Risk Management Policy and procedures and PanAust Group Sustainability Policy and Sustainability Management Standards. These are described in Chapter 3. The Sustainability Management Standards provide a basis from which to drive continuous improvement towards leading industry practice in sustainability and to establish performance requirements and auditable criteria which can be measured. As part of this approach, FRL will adopt PanAust's Enterprise Risk Management Procedure for the assessment and management of risks.

FRL will implement processes and promote the necessary culture and competencies to identify, assess, prioritise, document and manage health, safety and environmental hazards throughout the life cycle of the Project. Hazards associated with facilities, structures, activities or situations will be identified and assessed using systematic processes that are implemented in a consistent manner by suitably competent and experienced persons. Methods of risk assessment to determine individual hazards or combinations of hazards that could give rise to a sudden material hazard event will follow the same basic steps and have the same components to meet AS/NZS ISO 31000 Risk Management Standard.

### **International Environmental, Health and Safety Standards**

The IFC, a member of the World Bank Group, has developed a set of environmental, health, and safety guidelines that serve as a technical reference to support the implementation of the IFC performance standards. These documents provide general and industry-specific examples of 'good' international industry practice. IFC guidelines and performance standards are described in Section 3.5.1.

Recommended practices described in the IFC guidelines, including those concerned with natural hazards and incidental events, will be considered throughout the detailed design process for the Project, and were considered during preparation of the Project's EMMPs (Attachment 2).

### **Guidelines Relevant to the Integrated Storage Facility**

A range of guidelines have been adopted to address the inherent risk associated with extreme natural hazards that may impact the construction and operation of the ISF. These include:

- Australian National Committee on Large Dams (ANCOLD) guidelines for:
  - Design of Dams for Earthquakes (ANCOLD, 1998).
  - Tailings Dams - Planning, Design, Construction, Operation and Closure (ANCOLD, 2012b).
  - Selection of Acceptable Flood Capacity for Dams (ANCOLD, 2000).
  - Consequence Categories for Dams (ANCOLD, 2012a).
  - Environmental Management of Dams (ANCOLD, 2001).
  - Dam Safety Management (ANCOLD, 2003a).
  - Risk Assessment (ANCOLD, 2003b).
- Canadian Dam Association guidelines:
  - Dam Safety Guidelines (CDA, 2013).
  - Application of Dam Safety Guidelines to Mining Dams (CDA, 2014).
- International Commission on Large Dams (ICOLD) guidelines, including bulletins for improving tailings dam safety, risk assessment in dam safety management, tailings dam risks of dangerous occurrences and dam break flood analysis. These guidelines include:
  - Bulletin 059-1987: Dam Safety Guidelines (ICOLD, 1987).
  - Bulletin 139-2011: Improving Tailings Dam Safety – Critical Aspects of Management, Design, Operations and Closure (ICOLD, 2011).
  - Bulletin 154-2015: Dam Safety Management: Operational Phases of the Dam Life Cycle (ICOLD, 2015a).
  - Bulletin 158-2015: Dam Surveillance Guide (ICOLD, 2015b).
- IFC guideline – Environment, Health and Safety Guidelines for Mining (IFC, 2007d).

## 11.3 Failure of ISF Embankment and Overtopping Wave

### 11.3.1 Cause and Consequence

As described in Section 5.6, the partial or complete failure of the ISF embankment presents a catastrophic environmental and social risk to the Project. The extent of downstream impacts will depend on the size of failure, the location of the failure or distance from the embankment and the depth of the failure. Potentially catastrophic impacts of embankment failure and dam break would potentially affect more than 30 villages located downstream along the river systems including the Frieda and Sepik rivers (and, potentially, future communities as a consequence of in-migration towards the mine area) and impacts to the environment. As such, an ISF embankment failure is classified as “extreme” under ANCOLD and ICOLD guidelines. Section 5.6 provides details of the ISF design that address this consequence and the stewardship program FRL will implement through construction, operations and closure to prevent partial or complete failure of the ISF embankment.

Overtopping of the ISF due to higher than expected rainfall, or a significant volume of rock and materials sliding into the reservoir causing a landslide which generates a substantial wave, may lead to the release of contaminated water. This water may impact the downstream natural environment, the aquatic environment and subsequently human health.

Failure of the ISF embankment may be caused by:

- Fault movement beneath the facility embankment triggered by a major seismic event reducing the integrity of embankment foundations and core.
- Slope instability near the embankment. In particular, liquefaction of foundation soil (alluvium) during filling of the ISF due to a seismic or major landslide event.
- Persistent high-intensity rainfall, leading to landslips particularly in the Frieda River valley. Blockage of the Frieda River valley by landslide debris could impede dam and river discharge flows downstream. The accumulated water could pool behind landslide material and adversely impact the dam foundations/structure, potentially reducing embankment stability.
- Aerial landslides generating mass movements of material from the slopes surrounding the ISF. This could generate a wave that could impact or overtop the embankment.
- Seismic or landslide event causing movement of the downstream crest, reducing embankment integrity.
- Crest deformation (i.e., the embankment crest reduced from RL 238 m) during a seismic event potentially damaging the embankment core.
- Spillway blockage causing dam overtopping and reduced embankment stability.
- Instability caused by undetected local geological structures beneath the embankment wall.
- Poor water management leading to overtopping of the ISF and breach or rupture of the embankment.
- Lack of, or inappropriate maintenance of, the embankment and the ISF reservoir causing reduced embankment integrity.
- Differential settlement leading to cracking of the plinth and increased seepage causing reduced embankment stability.

With appropriate controls in place, primarily relating to the application of conservative design standards and criteria and a specific ISF stewardship program incorporating a dam safety program, management oversight and an independent external review by the TRIP (see Chapter 5), the probability of a failure is very unlikely. However, the extreme consequences of complete failure leading to the uncontrolled release of large quantities of water and solids (from waste rock and tailings placement) would likely result in extreme downstream environmental and social impacts. These would include:

- Flooding of downstream environments with consequential environmental impacts.
- Loss of life in the vicinity of the ISF, and loss of livelihood in communities located downstream of the ISF on the Frieda, Sepik, Wario and Wogamush rivers, Kaugumi and lower Saniap creeks and Lake Warangai.
- Long-term environmental contamination through the release and widespread distribution of waste rock and tailings and potentially acid-forming material, with subsequent downstream impacts on water quality, soils and biota.
- Physical damage to downstream aquatic and terrestrial environments, including loss of flora and fauna due to habitat inundation and destruction, extensive erosion and altered water quality.
- Exposure of potentially acid-forming material that is still retained within the ISF due to the reduced water levels, leading to the formation of AMD and subsequent impacts, primarily in terms of water chemistry, i.e., reduced pH and elevated metal concentrations in downstream waters.

### **11.3.2 Management Measures**

As described in Section 5.6, the likelihood of partial or complete failure of the ISF will be limited by:

- Incorporating geotechnical earthquake and slope stability studies and analysis, including drilling and the seismic hazard assessment, into the ISF design.
- Acquiring geotechnical information to inform and categorise the embankment foundations of the ISF. This includes embankment design controls such as asphalt concrete core, concrete plinth, plastic concrete cut-off wall, transition/filter zones and grout curtain for embankment seepage control.
- Considering seismicity and landslip in design parameters and modelling. This includes establishing a Storm Buffer Volume to protect the dam from overtopping, diversion tunnels and bypass valves.
- Adopting conservative design features relating to the structural capacity of the ISF embankment and spillway to ensure the dam is constructed to endure a maximum credible earthquake, provide an acceptable factor of safety (FOS) against instability (1.5 FOS for long-term drained conditions and 1.2 FOS for post-seismic conditions) and accommodate rainfall events that have a low probability of occurring, e.g., allow storage of water from a probable maximum precipitation 72-hour rainfall event, which at Frieda River is 1,350 mm.
- Subjecting all aspects of the ISF design, construction, operation and closure to expert peer review by the TIRP.

- Engaging and involving potentially affected parties downstream of the ISF embankment to identify community risks and develop appropriate management strategies.

FRL will develop emergency response plans and procedures in the very unlikely event of partial or complete failure of the ISF embankment. These plans will include the following key elements.

### **Early Warning Surveillance Monitoring of ISF Embankment**

FRL will prepare an operation, maintenance and surveillance manual prior to commissioning of the ISF as part of its stewardship program and consistent with the ANCOLD guidelines.

Surveillance monitoring will be undertaken to provide early warning of threats to the integrity of the ISF embankment. This will follow the *Mining Association of Canada: Developing an Operation, Maintenance and Surveillance Manual for Tailings and Water Management Facilities (2011)* document as this is considered the industry standard (Appendix 2a). The surveillance monitoring will be the responsibility of the FRHEP Manager, the Engineer of Record (EOR) and the Dam Safety Inspector who will be independent of the EOR and ISF Design Team.

Surveillance monitoring will cover the integrity and performance of the ISF embankment and spillway, as well as the hydroelectric intakes, integrity of the gate operation, surge chamber, tunnel drainage systems, embankment seepage outlet and the integrity of the turbine inlet valve operation.

Surveillance monitoring will be undertaken by trained personnel in accordance with ANCOLD (2012b) guidelines as detailed in Table 11.1.

**Table 11.1 Dam safety inspection levels and frequency for ‘extreme’ dam failure consequence category**

<b>Type of Inspection</b>	<b>Personnel</b>	<b>Purpose</b>	<b>Frequency of Inspection</b>
Comprehensive	Dams Engineer and Specialist (where relevant)	The identification of deficiencies by a thorough onsite inspection, by evaluating data, and by applying current criteria and prevailing knowledge. Equipment should be test operated to identify deficiencies.	After first year of operation then once every two years.
Intermediate	Dams Engineer	The identification of deficiencies by visual examination of the dam and review of surveillance data against prevailing knowledge. Equipment is not necessarily operated.	Annual.
Routine	Operations personnel/inspector	The identification and reporting of deficiencies by field and operating personnel as part of their duties at the dam.	Daily to three times per week.
Special	Dams Engineer and Specialist	The examination of a particular feature of a dam for some special reason (e.g., after earthquakes, heavy floods, rapid draw down).	As required.

**Table 11.1 Dam safety inspection levels and frequency for ‘extreme’ dam failure consequence category (cont’d)**

Type of Inspection	Personnel	Purpose	Frequency of Inspection
Emergency	Dams Engineer	The examination of a particular feature of a dam which has been identified as having a possible deficiency or which has been subject to abnormal conditions.	As required.

The instrumentation to be used to monitor the performance of the embankment and associated structures during construction, first filling of the reservoir, operations and closure is detailed in Table 13-1 of Appendix 2a.

### **Alert and Communication System and Procedures for Potentially Affected Communities**

The emergency response plan will detail alert and communications systems and procedures that will provide early notification of potential emergency situations. This may include the use of:

- Radio networks.
- Mobile phone networks.
- Audible alerts in villages and other community meeting places.

FRL will conduct awareness training about these systems and procedures in potentially affected communities to ensure that communities understand the alert and communications system that will be used in the very unlikely event of an ISF emergency.

### **Evacuation Plan for the Site and Potentially Affected Communities**

The emergency response plan will include details regarding:

- Triggers for the escalation of emergency response procedures based on defined levels of threat for employees and potentially affected communities. The highest escalation will be for the evacuation of the ISF site and potentially affected communities.
- Evacuation of the ISF embankment and downstream infrastructure locations such as the hydroelectric power station.
- Evacuation of potentially affected communities to safe higher ground.

### **Emergency Support Plan for Essential Services to Affected Communities**

The emergency response plan will include details regarding the supply of food, water, accommodation and essential services such as medical support and water for ablutions in the very unlikely event of catastrophic failure of the ISF embankment. This will specify the means, frequency and duration of the supply.

## **11.4 ISF Overturn**

### **11.4.1 Cause and Consequence**

While conditions to induce regular (i.e., seasonal or cyclical) complete or partial mixing (also known as overturn) of the ISF reservoir were absent from the available meteorological data record, complete or partial mixing of tropical reservoirs may occur in response to one, or a combination of up to three processes, including:

- Surface wind stress that mixes the water from the surface toward the bottom of the reservoir.
- Convective mixing due to cooling of the upper layers of the reservoir as a result of reduced atmospheric temperatures.
- Mixing as a result of upstream water inflows to the reservoir.

Modelling has shown that the ISF reservoir will typically behave as a thermally stratified waterbody, with warmer layers persisting towards the surface above cooler more dense layers towards the bottom of the reservoir (Appendix 2b). The storage of waste rock and tailings at the bottom of the reservoir has the potential to result in poor water quality (i.e., low dissolved oxygen, sulphides, nutrients and elevated concentrations of metals) due to anoxic reduction of waste rock, tailings and natural sediments in the bottom layers of the reservoir. While not predicted from the current modelling, if meteorological conditions that lead to an overturn eventuated, partial or complete mixing of the reservoir has the potential to result in poor water quality reaching watercourses downstream of the embankment. The downstream water quality would vary depending on whether there is partial or complete mixing in the reservoir, as well as the chemical processes leading to poor water quality in the bottom layers of the reservoir. The volume of water in the upper layers would provide some level of dilution to reduce concentrations of sulphides and metals and increase temperature and dissolved oxygen levels.

Following an overturn event, should it occur, the stratification within the lake would re-establish relatively quickly (in the order of months) and the release of poor water quality, as a result of the mixing, to the upper Frieda River would consequently improve.

#### **11.4.2 Management Measures**

Sensitivity tests in the Limnology Study (Appendix 2b) using high flows were performed using a 1:1,000 year ARI 6-hour duration hydrograph and a synthesised extreme one-day storm event with sustained cool temperature of 15°C, prevailing wind speed of 10 m/s from the west and no direct solar radiation. While these sensitivity tests did not induce overturn, the processes that have the potential to result in poor quality water reaching the upper Frieda River as a result of an overturn, are highly complex.

The limnological modelling outcomes will be verified by monitoring of the ISF characteristics once the facility is constructed. This will include water quality monitoring at depth in the reservoir. Measures to manage an overturn may involve review of the ISF operation as well as waste deposition strategy.

### **11.5 Failure of Open-pit Wall and Consequent Overtopping Wave (Post-Mining)**

#### **11.5.1 Cause and Consequence**

Post-mining failure of the open-pit wall, resulting in bulk movement of rock into the open-pit lake, has the potential to generate a wave of water that would move as a pulse through downstream environments. Such an event may come about from:

- The HIT open-pit is located near partially lithified colluvium from major historic landslides along the Fiak Fault. A seismic event may remobilise the weak composition of these deposits making the area prone to landslips, reducing the integrity of open-pit walls.
- Collapse of the open-pit wall during a seismic event.

- Persistent high-intensity rainfall leading to landslips.
- Unstable slope angles and unknown local geological structures.

The potential consequences of this wave could include:

- Temporary or partial flooding of the downstream environment with subsequent loss of life or injury to people who may be in its path, habitat inundation and destruction, and restricted community access.
- Environmental contamination through the release of the acidic open-pit lake water with subsequent impacts on downstream water quality.

Physical damage to Project infrastructure or equipment remaining during closure (i.e., access road and water treatment plant) may also occur.

### **11.5.2 Management Measures**

The likelihood of post-mining, open-pit wall failure will be limited by engineering and design controls such as:

- Slope designs which incorporate the results of slope-stability modelling and testing based on ongoing geotechnical and hydrological data collection throughout the life of mine.
- Quality control and peer review of the open-pit mine design and post-mining open-pit lake.
- Designing and installing an open-pit lake spillway, passive release points, or containment bank(s) to adequately control open-pit lake levels, and confine releases post mining.

In addition, FRL will complete regular assessments of open-pit wall slope angles and stability during geotechnical reviews of the open-pit throughout Project operation.

If an overtopping event were to occur, noting that management measures above would reduce the likelihood of this occurring, the ISF spillway has been designed to accommodate the Probable Maximum Flood (PMF) event so that it has both freeboard and flow capacity to attenuate such an event.

## **11.6 Failure of Tailings Pipeline**

### **11.6.1 Cause and Consequence**

Failure of the 16-km-long floating pipeline transporting tailings from the process plant into the ISF could result in impacts that vary in severity, associated with a partial (leak) to a total loss of containment, and may arise from system malfunction, corrosion or vessel collision. Pipeline failure may also result from extreme natural events, such as landslips within the upstream catchment of the ISF or seismic activity, that have the potential to generate a wave of water within the ISF.

As indicated above, the consequences of potential impacts arising from the tailings pipeline failure will vary depending on the nature of the event and the location of the failure. Pipeline leakage or rupture will result in the release of tailings in the ISF and, if this occurs at or near the surface, water quality within this surface layer (the 'epilimnion' zone) will be affected. The maximum volume of tailings discharged into the ISF would be approximately 18,000 m<sup>3</sup> (based on a 16-km-long, 1.2-m-diameter pipeline) assuming a worst-case scenario where the entire pipeline volume is discharged into the surface layer of the ISF.

Geochemical testwork (Appendix 1) has indicated that the tailings will be net acid generating if not disposed of subaqueously and the lag time for oxidation of the tailings if exposed to atmospheric conditions is predicted to be in the order of 12 weeks. If exposed, the material is expected to oxidise, producing acidic conditions and mobilisation of metals.

Should a pipeline rupture occur within the reservoir, contaminants in the tailings liquor will be diluted within the reservoir and, with the exception of the finest fractions, the solids will settle before reaching the embankment. The solids are not expected to oxidise within the reservoir, and based on the concentrations of contaminants in the tailings liquor, its circumneutral pH, and the subsequent dilution provided by the reservoir, it is unlikely that the release of tailings will cause short-term toxicity to aquatic biota within the ISF.

The finest fractions of suspended tailings may be transported through the ISF and discharged to the Frieda River, and subsequently the Sepik River as suspended load, with the potential for adverse impacts on water quality and aquatic biota downstream.

If the leak occurs near the edge of the reservoir, there is the potential for tailings to be deposited along the shoreline, which may subsequently become oxidised causing localised impacts on water and sediment quality within the ISF, and potentially result in short-term toxic effects to aquatic biota in the vicinity of the rupture. Given that the ISF will be used as a repository for the storage of waste rock and tailings, the aquatic system within the ISF will be highly modified regardless of a leak or spill.

### **11.6.2 Management Measures**

The likelihood of partial failure of the tailings pipeline will be limited by:

- Appropriate pipeline design and quality control, including peer review.
- Tailings testwork prior to pipeline installation.
- Hydrostatic testing prior to commissioning.
- Establishing a preventative maintenance regime.
- Conservative operating procedures.
- Selection of pipeline route to minimise interaction with the barge trafficking routes.
- Submerging the pipeline below the surface to enable barges to safely pass over the pipeline.
- Establishing an emergency tailings pipeline to be used during maintenance or in the event of pipeline failure.
- Additional downstream monitoring in the event of a pipeline rupture.

FRL will monitor the tailings pipeline for leaks, ruptures or failures and, in the event of such failures, implement shutdown procedures. Pump pressure and flow monitoring will assist with detecting leaks or blockages within the tailings pipeline. Visual inspections of the pipeline will also be undertaken regularly during operations.

Should such a significant failure occur, FRL will implement an emergency response plan to ensure that transport of tailings to the shoreline and embankment is limited. Tailings deposited on the shoreline will be, where possible, removed and disposed within the ISF.

## 11.7 Failure of Concentrate Pipeline

### 11.7.1 Cause and Consequence

The most extreme (but credible) potential concentrate spill scenario involves rupture of the concentrate pipeline along the pipeline route. The pipeline will be buried for most of the route, apart from watercourse crossings where the pipeline will be reinforced and suspended under bridges for major creeks and rivers and installed using open trenching for smaller watercourses. The pipeline will have pressure monitoring to detect leaks and main line valves will be installed either side of:

- The May River.
- The Sepik River.
- Seren Creek (located approximately 36 km south of Vanimo).
- Booster pump station 1 (located 4 km east of Green River).
- Booster pump station 2 (located 53 km north-east of Green River).

Although efforts would be made by FRL to restrict and recover lost concentrate, it is feasible that up to 1,900 m<sup>3</sup> of concentrate contained within the pipeline could be lost to the environment if a severe break was to occur. This has the potential to impact aquatic environments should the rupture occur at or near a river crossing. Other concentrate spill scenarios have the potential to occur during transfer and storage due to a range of factors, including equipment malfunction or operator error. Such events may occur through concentrate handling during:

- Storage of filtered concentrate at the Vanimo Ocean Port (filtered concentrate will have a moisture content of approximately 9.5%).
- Transfer of bulk concentrate from the concentrate export facility to export vessels at Vanimo.

The potential impacts from concentrate spills will vary depending on a number of factors, including the amount of material released and the location of the spill (i.e., terrestrial, aquatic or marine). The release of concentrate during transport or transfer may cause acute short-term toxicity in the receiving environment or longer-term adverse environmental and social issues. Potential impacts resulting from large-scale concentrate spills potentially include:

- Degradation of land or soil, with consequential impacts on productivity.
- Contamination of surface water, with subsequent impacts on drinking water and human health.
- Loss of terrestrial, aquatic and marine biota due to short-term toxicity or via bioaccumulation.

The bioavailability and hence toxicity of copper and other residual metals and metalloids in the environment is influenced by a number of biophysical factors, including the complexing capacity of natural organic matter, pH, water hardness and salinity.

The expected ranges for elemental composition of concentrate produced by the Project is approximately 25 to 33% copper, 10 to 29% iron, 10 to 29% sulphur and 10 to 29% silica (Toxikos, 2011). Concentrate water quality assay results indicate that concentrate water will contain less than 100 µg/L copper if maintained above pH 9; the expected pH range for concentrate delivered to the Vanimo Ocean Port filtration plant is between pH 9 and 10.

Studies investigating copper toxicity on biota have demonstrated both lethal and sublethal effects at a range of copper concentrations, particularly on marine biota, as indicated by the data provided in Table 11.2. Sublethal effects on biota include reduced growth and hatchling rates in molluscs, crustaceans and fish (Koehnken, 1997).

**Table 11.2 Results of copper toxicity tests on various organisms**

Organism	Species	Duration of Experiment (hours)	EC <sub>50</sub> /LC <sub>50</sub> <sup>*</sup> (µg/L)
Algae	<i>Nitzschia closterium</i>	N/A	10
	<i>Phaedactylum triconutum</i>	N/A	100
	<i>Nitzschia palea</i>	N/A	10
Copepod	<i>Scutellidium sp.</i>	24	180
	<i>Paracalanus parvus</i>	24	190
	<i>Acartia simplex</i>	24	200
Crab larvae	<i>Paragrapsus quadridentatus</i>	96	170
Amphipod	<i>Allorchestes compressa</i> (Adult)	96	500
	<i>Allorchestes compressa</i> (Juvenile)	96	110
Shrimp	<i>Callinassa australiensis</i>	96	1,030
		168	340
		240	220
		336	190
Gastropod	<i>Polinices incei</i>	96	1,170
	<i>Polinices sordidus</i>	96	770
Mussel	<i>Mytilus edulis</i>	96	480
Fish (marine)	<i>Fundulus heteroclitus</i>	96	170
	<i>Rivulus marmoratus</i>	96	140
Fish larvae (marine)	<i>Lagodon rhomoides</i>	96	150
	<i>Leiostomus xanthurus</i>	96	160
	<i>Micropogon undulatus</i>	96	210
	<i>Brvoortia tyrannus</i>	96	610

\* EC<sub>50</sub> applies to algal tests and LC<sub>50</sub> applies to all other organisms. The LC<sub>50</sub> (lethal concentration 50%) is the concentration required to kill half the members of a tested population over a specified test duration. The EC<sub>50</sub> (effective concentration 50%) is the effective concentration that reduces the rate of cell division by 50% (UNECE, 2009). Source: Koehnken (1997).

In the instance where there was a concentrate spill from pipeline rupture into a watercourse (e.g., the Sepik or May rivers), or the marine environment from handling during concentrate loading, the rapid dilution of concentrate and mixing with the receiving waters will mitigate many of the lethal and sublethal impacts to biota. Dissolution tests and particle size assessments, conducted in 2012, evaluated the aquatic toxicity of the Project's copper concentrate in freshwater and marine environments. Results are summarised in Table 11.3<sup>1</sup>. To provide context for these results, ANZECC/ARMCANZ water quality guidelines specify concentration trigger values of 1.4 µg/L and 1.3 µg/L of copper in freshwater and marine environments respectively (ANZECC/ARMCANZ, 2000). The PNG Water Quality standards specify 1 mg/L (i.e., 1,000 µg/L) and 0.03 mg/L (i.e., 30 µg/L) of copper in freshwater and marine environments respectively.

Dissolution tests indicate that the concentrate is not classifiable as a Miscellaneous Dangerous Good (Class 9) Environmentally Hazardous Substance for the purpose of inland transport (Toxikos, 2011). However, comparative tests to evaluate marine toxicity indicate that the

<sup>1</sup> Freshwater experiments were conducted at a pH of 6.3 to 6.5 while marine water experiments were conducted at a pH of 8.3 to 8.5.

concentrate is classifiable as a Miscellaneous Dangerous Good (Class 9) Environmentally Hazardous Substance for the purpose of marine transport (Toxikos, 2011). The discrepancy in this classification is largely due to the increased dissolution potential of copper in the marine environment (Toxikos, 2011).

**Table 11.3 Dissolved copper concentrations from Project concentrate in seven-day freshwater and marine dissolution tests**

Concentration of Cu Concentrate (mg/L)	Time (hr)	Average* Cu Concentration Freshwater† (µg/L)	Average* Cu Concentration Marine Water§ (µg/L)
1	2	<1	<10
	6	<1	<10
	24	<1	<10
	96	<1	<10
	168	<1	<10
10	2	1	10
	6	1	20
	24	1	30
	96	2	50
	168	4.2	70
100	2	7	70
	6	8.7	90
	24	13.5	140
	96	24.3	260
	168	38.7	300

\* Six measurements (n=3 triplicate samples, n=2 duplicate aliquots) at each time point and loading were used to calculate the average concentrations of dissolved metals. If a concentration was reported as below practical quantification limit (PQL), this was assumed to be a zero for the calculation of an average.

† Approximately 27% of the copper samples were below the laboratory PQL (1 µg/L) for freshwater testing.

§ Approximately 33% of the copper samples were below the laboratory PQL (10 µg/L or 20 µg/L) for marine water testing. Source: Toxikos (2011).

### 11.7.2 Management Measures

Short-term acute impacts on water quality and biota resulting from concentrate spillage due to a potential catastrophic rupture will be mitigated primarily by rapid spill response and recovery of the spilt concentrate where practical.

For any spillage into watercourses due to a pipeline rupture, there will be dilution of the concentrate if/as it enters nearby watercourses. Likewise, spills during storage and transfer of concentrate at the Vanimo Ocean Port will be diluted in the marine environment. Longer-term impacts on terrestrial, aquatic or marine biota, such as bioaccumulation, will be mitigated via rapid spill response and concentrate recovery to limit dissolution to the environment.

The likelihood of concentrate spills from ruptures occurring along the pipeline will be limited by:

- Appropriate pipeline design materials (steel) and pipeline alignment selection based on public safety, pipeline integrity and the consequence of leakage.
- Installing cathodic protected systems along the pipeline with potential test posts installed 5 km apart to monitor potential corrosion and therefore integrity of the pipeline.

- Internal inspection of the pipeline via pig launching and receivers.
- Installation of remote security cameras to monitor all pump stations and aboveground facilities in case of vandalism.
- Implementation of real-time leak detection systems along the pipeline to enable early detection of pressure drops or imbalance from tampering or leaks. Pressure leaks detected via these systems will automatically close valves. A maintenance team will be sent to the location of the leak to assess and repair damaged sections of pipeline. Mainline valves will be installed where the pipeline is above the surface to control the flow of concentrate slurry and restrict if needed. Most of the pipeline will be buried to restrict spread of slurry in the unlikely event of rupture.
- Routine visual inspections along the pipeline route.
- The installation of additional protective measures will be integrated into the pipeline design at major river crossings including the Sepik River. Crossings will be designed to AS 2885.1:2012 and API RP 1102.

The likelihood of concentrate spills occurring at the Vanimo Ocean Port and the extent of the spill, should they occur, will be limited by:

- Monitoring concentrate transfer points to enable early detection of spills or leaks.
- The design of concentrate storage facilities at the processing plant and concentrate export facility. This includes using enclosed concentrate sheds.
- Implementing containment facilities at the concentrate handling system to minimise spillage of concentrate. This may include enclosed transfer points, conveyor belts and loading boom and telescopic loading to limit spillage.

In addition, detailed operator training with respect to concentrate handling, transport and transfer procedures (with reference to the storage and handling of Class 9 (Miscellaneous) dangerous goods and articles (AS/NZS 4681-2000)), and emergency response measures for spills at the Vanimo Ocean Port and along the pipeline will be implemented.

## **11.8 Hazardous Materials Spillage or Leakage**

### **11.8.1 Cause and Consequence**

The Project will transport hazardous materials such as diesel, reagents, lime and lubricants between the mine facilities, Vanimo Infrastructure Area and Vanimo Ocean Port. Similar to concentrate handling, hazardous materials spillage or leakage has the potential to occur during transport, transfer and storage due to vehicle incident, equipment malfunction, vandalism or operator error.

The potential impacts of hazardous materials spillage or leakage will vary depending on a number of factors, including the type and amount of material released and the location of the spill or leak (i.e., terrestrial, aquatic or marine). Large-scale hazardous materials spills or leaks may result in adverse environmental and social effects on the receiving environment, with potential impacts including:

- Contamination of surface water or groundwater, with potential impacts on drinking water.
- Sterilisation of land or soil, with consequential impacts on productivity and resource use.
- Loss of terrestrial and aquatic biota.

### **11.8.2 Management Measures**

Procedures for hazardous materials transport, storage and handling are described in Section 5.9. Additional relevant measures include:

- Designing hazardous materials transfer and storage facilities according to relevant standards and guidelines.
- Implementing a hazardous materials management plan detailing specific requirements for the handling, transport, storage, appropriate spill response kit and disposal of hazardous materials as per the Project EMMPs.
- Implementing a dangerous goods marine transport procedure in accordance with International Maritime Dangerous Goods Code.
- Detailed operator training with respect to hazardous material transfer procedures and emergency response measures for spills and leaks.
- Vehicle and vessel refuelling at designated sites and approved locations.
- Regularly inspecting and replenishing task-appropriate spill response kits and equipment to ensure that appropriate supply quantities are available at all times.
- Monitoring pipe and hose pressure during fuel transfers to enable early detection of spills or leaks.
- Undertaking regular integrity testing and maintenance of hazardous materials transfer hoses and couplings.
- Installing bunding and secondary containment measures around hazardous material storage tanks and containers in accordance with PNG and Australian standards, such as AS 1940:2017 for the storage and handling of flammable and combustible goods.

## **11.9 Inundation of Vanimo Ocean Port Facilities**

### **11.9.1 Cause and Consequence**

The Project will store hazardous materials and concentrate at the Vanimo Ocean Port. Inundation may occur due to storm surges, earthquakes or tsunamis events.

Potential consequences of inundation of the Vanimo Ocean Port include:

- Loss of life and livelihoods due to surging tsunami wave and inundation of Vanimo Ocean Port facilities, e.g., hazardous materials storage and handling areas, concentrate filter plant and ship loader and water treatment plant. There is also the potential for facilities at the Vanimo Infrastructure Area to be affected, including warehouse facilities, workshop, carpark, laydown areas, accommodation and administration buildings. This event would also significantly impact the populace and businesses of Vanimo.
- Environmental contamination through the uncontrolled release of hazardous materials, caused by failure or inundation of storage tanks and containers located at the bulk liquids storage and handling areas. Subsequent impacts of hazardous materials release (spillage or leakage) on water quality and biota are discussed in Section 11.7.

## 11.9.2 Management Measures

The likelihood of inundation of Vanimo Ocean Port facilities and Vanimo Infrastructure Area will be limited by engineering and design controls such as:

- Locating the export facilities area and Vanimo Infrastructure Area above storm surge levels, with consideration for potential exposure to tsunamis.
- Providing for emergency containment of the concentrate facilities at Vanimo Ocean Port in accordance with the *Marine Pollution (Preparedness and Response) Act 2013*.
- Using appropriate containment structures in accordance with Australian standards, such as AS 1940:2017 for the storage and handling of flammable and combustible goods.

## 11.10 Fire and Explosion

### 11.10.1 Cause and Consequence

Mining and ore processing operations require the storage and handling of flammable and combustible substances, which can lead to the release of potentially explosive or flammable emissions. Potential causes of unplanned fire or explosion include equipment malfunction, hazardous materials leakage or spillage, operator error and deliberate acts of vandalism.

The environmental impacts associated with uncontrolled fire or explosion may include breakout fire into surrounding vegetation, and release of large quantities of air emissions and contaminated runoff from firewater, with subsequent impacts on water quality, biota and human health.

### 11.10.2 Management Measures

The likelihood of uncontrolled fire and explosion will be limited by the following measures:

- Storing explosives and blasting accessories in a secured magazine compound, located at least 500 m away from other infrastructure.
- Complying with appropriate statutory standards and requirements for the construction of explosives magazines.
- Storing and handling flammable and combustible substances, including waste, under conditions that limit the risk of fire and toxic emissions, such as AS 1940:2017 for the storage and handling of flammable and combustible goods.
- Specifying plant and facility design criteria for fire prevention, detection, control and personnel safety requirements.
- Ensuring that 'hotworks' do not take place in the vicinity of flammable or combustible materials.
- If fire hazard exists (e.g., during infrequent, extended periods of drought), stockpiling cleared vegetation in an open area (i.e., surrounded by a firebreak) instead of burning cleared vegetation.
- Identifying firefighting equipment suitable for the level of risk at hand and performing regular maintenance and testing to ensure that equipment remains in good working order.
- Implementing a hazardous materials management plan, detailing specific requirements for the handling, transport, storage, appropriate spill response kit and disposal of hazardous materials.

## **11.11 Vessel Collision**

### **11.11.1 Cause and Consequence**

During construction, freight will be transported from Wewak, Lae and Madang ports, via barge along the Sepik River to the Frieda or May river ports until the access road has been completed. Riverine vessels may also be used to transport personnel from points of hire along the Sepik River. The Sepik, May and Frieda rivers are also commonly used by other non-Project vessels for activities such as fishing, transport of people and materials, commercial activity such as logging, and domestic uses such as bathing. Consequently, the potential exists for collisions between Project vessels and other vessels, individuals or environmental obstructions (such as floating natural debris) due to operator error, equipment malfunction (e.g., mooring failure) or obstruction in the waters. The socio-economic impacts associated with the vessel movements on these rivers during construction are described in Chapter 9.

The damage from a vessel collision with other vessels, individuals or floating debris may lead to the release of fuel and other contaminants to the freshwater or marine environments and, in some instances, depending on the severity of the collision, may lead to vessels sinking and/or the loss of life. Subsequent impacts of uncontrolled hazardous materials release to the environment are discussed in Section 11.7.

### **11.11.2 Management Measures**

The likelihood of vessel collisions or sinking, or collision with an individual will be limited by the following measures:

- Ensuring all operators have adequate skills and experience and conduct periodic refresher training.
- Frequent monitoring and assessment of weather conditions and seismic activity to advise operation and vessel movements.
- Regular servicing and inspection of vessels to ensure that they are operating in good working order.
- Implementing a vessel traffic control system including enforcing speed limits applicable to the size of the vessel.
- Fitting vessels with adequate navigational and communications equipment and installing searchlights and night-vision equipment to assist with the identification of small craft, floating obstacles and river banks, during night operation.
- Ensuring that operators maintain a safe distance between vessels and individuals at all times.
- Developing and implementing a community river safety management plan including vessel crew education, community risk awareness (inclusive of discussion with other users of river systems and ocean ports), operational vessel management protocols and appropriate physical safety measures (such as visual and audible warnings) where required during construction and operations.
- Suspending vessel transport operation should extreme weather conditions make operations unsafe. During such conditions, vessels will be moored in the nearest safe location until conditions are deemed safe enough to recommence operation.

In addition, adequate safety equipment and appropriate spill response kits will be stored on all vessels.

## **11.12 Aircraft or Vehicle Incident**

### **11.12.1 Cause and Consequence**

The Project requires the transport of personnel, equipment and materials to site using aeroplanes, helicopters and road vehicles. The Project will include upgrades to the existing Frieda River airstrip and upgrade of the airport at Green River to accommodate increased passenger movements associated with the development and the operation of the Project (Section 5.7.3).

The transport of personnel, equipment and materials via aeroplanes, helicopters and road vehicles (including buses) gives rise to the potential for an incident to occur, such as collision with another vehicle or an individual. Aircraft or vehicle incidents may occur due to factors such as operator error, equipment malfunction, poor maintenance or extreme weather.

Potential consequences from an aircraft or vehicle incident include:

- Loss of life, severe injury or injury.
- Damage to infrastructure and property (Project and non-Project owned).
- Social tension, particularly if local communities are involved.
- Environmental contamination via the release of hazardous materials and potential fire (depending on the vehicles and cargo involved in the incident, e.g., a major incident involving a diesel tanker).

### **11.12.2 Management Measures**

The likelihood of aircraft and vehicle incidents will be limited by the following measures:

- Designing and operating airports to comply with the Civil Aviation Safety Authority of PNG requirements with respect to navigation equipment, security, maintenance and refuelling.
- Designing and constructing airstrips to take topographic constraints and weather conditions into consideration, such as areas prone to flooding and low-lying fog.
- Servicing and inspecting aircraft regularly, in accordance with PanAust's aviation protocols, and vehicles to ensure that they remain in good working order.
- Ensuring that only appropriately licensed personnel operate aircraft and light or heavy vehicles.
- Providing inductions for passengers travelling in aircraft, detailing specific response procedures to emergency situations and potential incidents.
- Designing road alignments to Australian codes and Standards and PNG Department of Works standards.
- Defining engineering and terrain constraints as part of road design criteria to enhance road surface protection, taking design control measures such as camber, visibility, bunds and alignment into consideration.

- Conducting vehicle route risk assessments factoring in the type of vehicle used on the roads and watercourse crossings and installing speed limits and signage to advise road users of safe operating speeds and conditions.
- Inspecting vehicles and road surfaces regularly to ensure they remain of a suitable and safe standard.
- Providing fatigue management training to drivers.
- Developing and implementing a community road safety management plan including driver education, community risk awareness, operational road traffic management protocols, and appropriate physical safety measures, including vehicle-pedestrian separation where required.

## **11.13 Epidemic or Pandemic and Communicable Diseases**

### **11.13.1 Cause and Consequence**

Potential health impacts and management measures associated with the Project are detailed in Chapter 9. Epidemic or pandemics, communicable disease outbreaks (e.g., tuberculosis, hepatitis, HIV/AIDS) and vector-borne diseases have the potential to occur throughout the duration of the Project due to:

- In-migration and transfer of vector-borne diseases and pathogens.
- The large national and international workforce that will travel to and from site.
- Poor hygiene practices on site, and low hygiene awareness of Project workforce.
- Interaction of the Project workforce with the local community, particularly isolated communities with limited access to medication or health facilities.

Potential consequences of epidemics or pandemics and communicable disease outbreaks include:

- Loss of life or severe illness.
- Illness leading to loss of livelihood and income, due to the inability to source food, water, resources or work.
- Community unrest.

### **11.13.2 Management Measures**

The likelihood of epidemics or pandemics and communicable disease outbreaks will be limited by the following measures:

- Providing pre-employment and periodical medicals for employees.
- Implementing strategies to manage the impact of diseases through assessment, surveillance, action plans and monitoring.
- Developing a workplace program to educate the workforce about limiting new HIV infections and providing care and support for infected and affected employees.
- Implementing outreach activities among the Project workforce, local community and the broader society to raise awareness and educate people about prevention of vector-borne and communicable diseases and encouraging improved hygiene practices.

- Establishing a regular pattern of village medical patrols, the priorities of which may include immunisations, tuberculosis screening, maternal and HIV/AIDS education and nutrition.
- Implementing provisional support for the improvement of clean water supplies and effective sewage disposal facilities in communities affected by the Project.
- Providing camp and worksite amenities and medical facilities to promote good hygiene practices and healthy lifestyles amongst the Project workforce.
- Specifying the minimum standards for all contractor facilities and implementing an audit program to ensure these are met and maintained.

## **11.14 Civil Unrest, Demonstrations or Riots**

### **11.14.1 Cause and Consequence**

Civil unrest, demonstrations and riots have the potential to occur during the development of the Project due to a number of factors such as:

- Changes in social structure and distribution of wealth.
- Real or perceived unequal distribution of employment and benefits creating conflict, particularly between social or clan groups.
- Population increase and in-migration to local communities neighbouring the Project area. Newcomers may conflict with local communities.
- Increased access to, and affordability of, contraband, leading to increased law-and-order issues.
- Project-related investment resulting in increased police and security personnel presence in the area and the potential for disproportionate use of force.

Potential consequences and impacts resulting from civil unrest, demonstrations and riots include:

- Loss of life or severe injury.
- Damage to infrastructure and property (Project and non-Project owned).

### **11.14.2 Management Measures**

The likelihood of civil unrest, demonstrations and riots throughout the duration of the Project will be limited by the following measures:

- Identifying landowners prior to Project commencement to manage compensation and royalty benefits to local communities affected.
- Establishing buffer zones and site access control strategies along the infrastructure corridor to control access to the mine site.
- Implementing the in-migration and human resources and localisation plans to minimise opportunistic migration into local areas. These will outline:
  - A clear employment strategy with preferential use of local labour where possible. This includes preferential employment opportunities to Zone 1 communities commuting via bus transportation along the infrastructure corridor.

- The use of a Fly-in Fly-out commute employment model (i.e., no “employment at the gate”) for communities outside Zone 1 when practicable.
- Ensuring that all security personnel are provided with appropriate training including the controlled use of force, human rights and code of conduct awareness.
- Implementing the business development, supply and procurement plan that will outline the process for establishing contracts with service providers.
- Supporting a community leadership development program that will aim to increase communities’ understanding of the distribution of compensation and royalties associated with the Project.
- Developing and implementing a Project security plan.
- Establishing a Project grievance mechanism through which affected people or communities can register their complaints.
- Working in conjunction with the Sandaun and East Sepik provincial governments to limit in-migration, increase police presence in the mine area, and support law-and-order services.

## 11.15 General Management Measures

In addition to the preceding management measures for each scenario, general measures have been designed to limit the escalation of a series of minor events such as spills or leaks, none of which is, by itself, a major hazard. Therefore, the facilities associated with the Project will be designed to detect conditions that could lead to hazardous situations that need rapid (and automatic where necessary) application of corrective measures.

Personnel will be trained to manage operational activities with a high regard for safe work procedures and to react appropriately in the event of emergencies. The safety of the facilities requires that plant is inspected and maintained, and that safe procedures are used and improved, based on experience, to limit the probability of occurrence of hazardous conditions.

These design measures and planning will contribute to reducing the potential for hazardous events to occur.

Management measures that will help prevent or limit the level of impact from extreme natural hazards and incidental events are summarised in Table 11.4.

**Table 11.4 Management measures for extreme natural hazards and incidental events**

No.	Management Measure
MM143	Engage and involve parties potentially affected by ISF embankment failure to identify community view points and develop appropriate response and management strategies.
MM144	Conduct awareness training of the alert and communications system procedures to all potentially affected communities, FRHEP employees and contractors in the unlikely event of an ISF emergency.
MM145	Undertake surveillance monitoring by trained personnel to inspect the tailings pipeline for signs of leaks, ruptures and failures during operation. Shut down procedures will be implemented if such a failure occurs.
MM050	Store, handle and transport hazardous substances in accordance with Australian Standards AS1940:2017 and AS3780:2008, and the PNG Environmental Code of Practice for Vehicle/Machinery Workshops and Petroleum Storage/Resale/Usage Sites.
MM052	Provide appropriate spill response equipment for Project facilities, vehicles and vessels.

**Table 11.4 Management measures for extreme natural hazards and incidental events (cont'd)**

No.	Management Measure
MM054	Develop and implement oil spill prevention and response plans.
MM141	<p>An emergency response plan (as part of the Sepik Infrastructure Project (Vanimo Ocean Port) EMMP) will be developed and implemented that will:</p> <ul style="list-style-type: none"> <li>• Include a spill response plan for concentrate, oil and other hazardous substances.</li> <li>• Provide for training of staff during the induction process to facilitate awareness of their responsibilities, ensure that they are able to identify all risks or sources of potential chemical and fuel spills, and can apply appropriate control measures.</li> </ul>
MM146	<p>Engineering and design controls at Vanimo Ocean Port facilities and Vanimo Infrastructure Area include:</p> <ul style="list-style-type: none"> <li>• Locate the export facilities area and Vanimo Infrastructure Area above storm surge levels, with consideration for potential exposure to tsunamis.</li> <li>• Emergency containment of the concentrate facilities at Vanimo Ocean Port in accordance with the <i>Marine Pollution (Preparedness and Response) Act 2013</i>.</li> <li>• Use appropriate containment structures in accordance with Australian standards, such as AS1940 for the storage and handling of flammable and combustible goods.</li> </ul>
MM147	Suspend vessel transport operation should extreme weather conditions make operations unsafe. During such conditions, vessels will be moored in the nearest safe location until conditions are deemed safe enough to recommence operation.
MM148	Design and operate airports to comply with the Civil Aviation Safety Authority of PNG requirements with respect to navigation equipment, security, maintenance and refuelling.
MM149	Design and construct airstrips to take topographic constraints and weather conditions into consideration (such as areas prone to flooding and low-lying fog).
MM150	Define engineering and terrain constraints as part of road design criteria to enhance road surface protection, taking design control measures such as camber, visibility, bunds and alignment into consideration.
MM151	Conduct vehicle route risk assessments factoring in the type of vehicle used on the roads and watercourse crossings and install speed limits and signage to advise road users of safe operating speeds and conditions.
SEM044	Develop and implement measures which include vessel crew education, community risk awareness, operational vessel management protocols, and appropriate physical safety measures (such as visual and audible warnings) where required for construction and operations.
MM152	Provide fatigue management training to drivers and vessel operators.
SEM048	Educate workers on disease prevention and health promotion, and encourage workers to share their learnings with the community.
SEM051	Implement infectious disease management programs for workers, incorporating worker education, to reduce potential for disease occurrence.
SEM047	Construct and operate workforce accommodation and messing facilities in accordance with recognised standards for hygiene and safety.
SEM049	Implement a Project-wide induction process that covers, as a minimum: ethics; health; environment; safety; alcohol and drug use; workforce diversity; harassment; and cultural and social sensitivities of workers and communities.
MM153	Implement In-Migration Plan and Human Resources and Localisation Plan to minimise opportunistic migration into local areas.
MM154	Develop and implement a Project security plan.
SEM050	Conduct background checks on security personnel and train them in the Voluntary Principles on Security and Human Rights.

## **11.16 Emergency Response**

Emergency response procedures will be developed by FRL to address the scenarios described above as well as other emergency scenarios that will have on-site impacts and, hence, are not addressed herein. These procedures will include appropriate procedures for notifying potentially affected parties. Additionally, there will be appropriate measures related to the storage and disposal of clean up materials used in response to the discharge of a hazardous substance to the environment. The Project will also include medical and emergency facilities, including ambulance and emergency response buildings and equipment.

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