Draft Guidelines on tools and techniques for hazard identification and risk assessments

Developed by the Legal and Technical Commission

DRAFT FOR STAKEHOLDER CONSULTATION
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Background

1. During the continuation of its twenty-sixth session, the Commission considered draft guidelines on tools and techniques for hazard identification and risk assessments associated with the draft regulations on exploitation of mineral resources in the Area (ISBA/25/C/WP.1). The draft guidelines were prepared by a working group of the Commission.

2. The purpose of these guidelines are to provide information to applicants and contractors on approaches and tools to address hazard identification and conduct risk assessment. The intent of these activities is to reduce the risk of incidents as much as reasonably practicable.

3. The draft regulations on exploitation of mineral resources in the Area contains several instances where a contractor must take measures to prevent, reduce and control hazards to the Marine Environment and recommends an applicant or contractor conducts hazard identification and risk assessment in the preparation of Environmental Plans.

4. To give effect to the requirements and recommendations contained in the draft regulations on exploitation of mineral resources in the Area, the Commission considered that it was necessary to prepare: (i) Guidelines (Appendix I) on tools and techniques for hazard identification and risk assessments

Appendix I

Draft Guidelines on tools and techniques for hazard identification and risk assessments

CONTENTS

I. INTRODUCTION

1. This guideline has been developed to provide practical and technical guidance on the tools and methodologies for hazard identification and risk assessment associated with exploitation of mineral resources in the Area, which is generally applicable to numerous parts of the Exploitation Regulations.

2. Given the inherent uncertainties in the context of mineral exploitation in the Area, a rigorous risk management strategy is necessary at every phase of the project. Therefore, the risk management process is to be incorporated into various components of the Contractor's application for a Plan of Work for exploitation, including the Health and Safety Plan (HSP), Closure Plan, Environmental Impact Assessment (EIA), Environmental Management and Monitoring Plan (EMMP), and Emergency Response and Contingency Plan (ERCP), and also incorporated into day-to-day exploitation operation activities, including the management and operation of mining support vessels.

A. Purpose of this Guideline

3. The purpose of this guideline is to provide information on approaches and tools to address hazard identification and risk assessment. The intent of these activities is to "reduce the risk of incidents as much as reasonably practicable, to the point where the cost of further risk reduction would be grossly disproportionate to the benefits of such reduction."

4. The guidance below is not intended to be prescriptive; the aim is to provide sufficient direction to enable Contractors to formulate an approach for the implementation of risk management strategies through the use of hazard identification and risk assessment tools. The intention is that the guidance contained below is a reasonably comprehensive starting point, from which a practical and appropriate hazard identification and risk assessment can be developed within a process that involves rigorous stakeholder engagement. The guideline is also intended to be useful to users and reviewers (including a wide range of stakeholders) of the following Plan of Work components: HSP, Closure Plan, EIA, EMMP, and ERCP.

5. Hazard identification and risk assessment activities should reduce the risk of Incidents and impacts of exploitation on the marine environment as much as reasonably practicable and should:

a) Establish the necessary risk assessment and risk management systems to effectively implement the proposed Plan of Work in accordance with Good Industry Practice, Best Available Techniques and Best Environmental Practices and these regulations, including the technology and procedures to meet health, safety and environmental requirements for the activities proposed in the Plan of Work;
b) Provide a basis for the environmental impact assessment and the Environmental Impact Statement; and
c) Provide for the protection of human life and safety.

B. Format of this Guideline

6. This guideline is structured into five sections:

Section 1: Details the purpose and scope of the guideline and provides the Contractor with information on the organization of the guideline, and how it links to the regulations and other guidelines.

Section 2: Details the key principles of hazard identification and risk assessment, triggers/timing the risk management process, and a discussion of pertinent Stakeholders.

Section 3: Details the risk assessment process, specifically establishing the context, hazard identification, risk analysis, risk evaluation, risk treatment, monitoring, review, and communication. In addition, a summary of potential risk assessment tools and techniques is provided.

Section 4: Provides a summary of the best practices associated with the risk assessment and risk management process.

Section 5: Provides references and links to additional sources of information useful for hazard identification and risk assessment.

C. Use of this Guideline

7. This guideline should be read in conjunction with the Exploitation Regulations, the relevant Exploration Regulations as well as other International Seabed Authority Standards and Guidelines.

8. The appropriate Regional Environmental Management Plan (REMP) should also be considered by the Contractor in that it may affect more regional hazards and risk elements.

9. Additional resources can be found in Section 5 of this guideline. Overarching guidance documents for all industries include International Organization for Standardization (ISO) 31000:2018 Risk management – Guidelines and International Electrotechnical Commission (IEC) 31010:2019 Risk management - Risk assessment techniques. There are numerous guidance documents from national jurisdictions and related industries that can provide valuable and relevant approaches to performing hazard identification and risk assessment.

II. GENERAL PRINCIPLES FOR HAZARD IDENTIFICATION AND RISK ASSESSMENT

A. Key Principles

10. Two of the fundamental policies and principles of the Exploitation Regulations are to provide for "the effective protection of the marine environment from the harmful effects which may arise from exploitation" and to provide for "the protection of human life and safety".

11. All activities associated with the exploitation of minerals in the Area inherently involve some level of potential risk to the environment and/or the health and safety of the personnel engaged to perform such activities. Hazard identification and risk assessment are critical elements used in the preparation of key risk management documents (e.g., EIA [documented in the EIS], EMMP, ERCP, HSP, etc.) which establish appropriate controls used by the Contractor under the Authority to reduce the potential for harm to both the environment and humans. The principles of risk management are well-established across a wide-range of industries, and there is a wealth of valuable guidance on the methodologies and tools associated with transparent, systematic processes to review and control risks, including an International Standards Organization (ISO) standard on risk management (ISO 31000), which can apply to Exploitation, in addition to many others.

B. Approaches to Risk Assessment

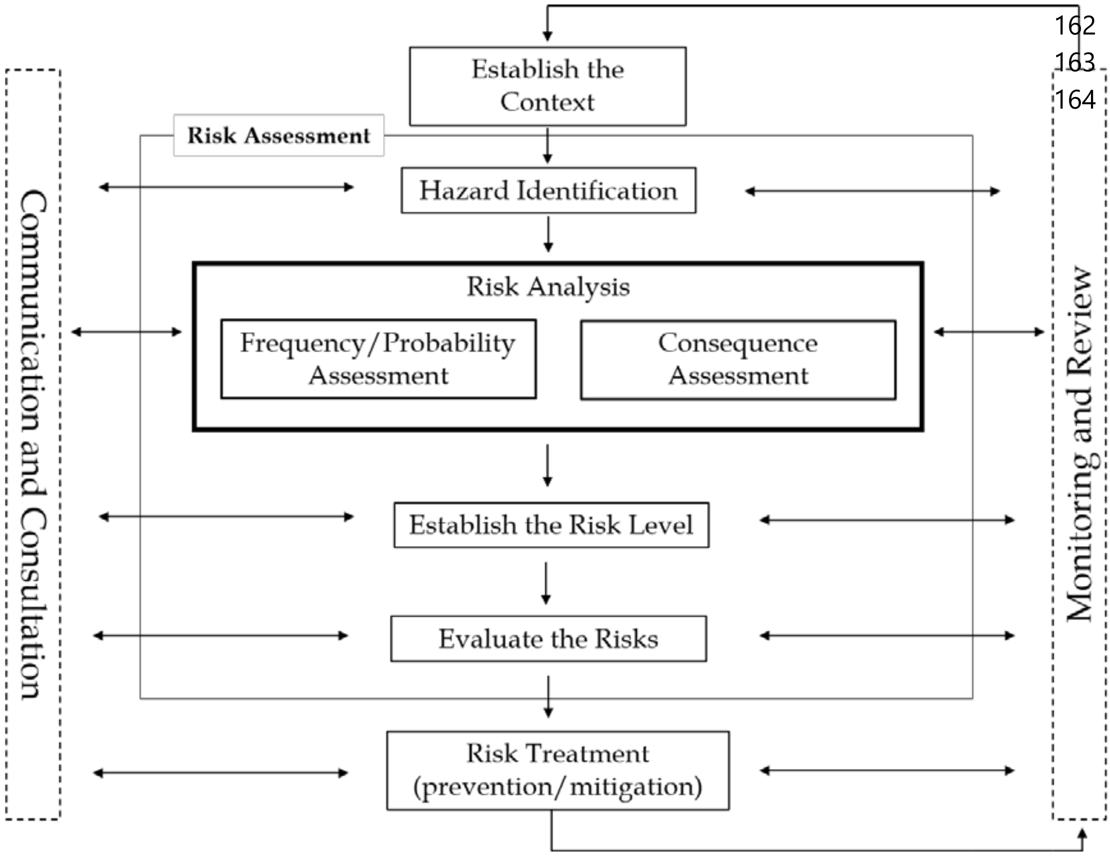
12. Risk assessment is part of risk management which provides a structured process that identifies how objectives may be affected and analyzes the risk in term of consequences and their probabilities before deciding on whether further treatment is required. Risk assessment attempts to answer the following fundamental questions:

- What can go wrong?
- How likely is it?
- What are the impacts?
- Is the level of risk acceptable or does it require mitigation?

13. As shown in Figure 1 below, the following elements represent the pillars of risk assessment (i.e., identifying, analyzing, assessing and communicating risks):

- Establishing Context;
- Hazard Identification;
- Risk Analysis (frequency and consequence assessment);
- Risk Evaluation (risk representation);
- Risk Treatment;
- Monitoring and reviews; and
- Communication and consultation.

Figure 1: Overview of the risk assessment process within the context of the risk management process (Source: adapted from IEC/ISO31010)



C. The importance of stakeholder consultation

14. Successful risk assessment is dependent on effective communication and consultation with stakeholders. A robust and transparent process of performing hazard identification and risk assessment activities will be critical to the review and acceptance of management documents generated as a result. These stakeholders include, but are not limited to:

- Organs of the Authority (Secretariat, Legal and Technical Commission, Council, Assembly)
- Member States;
- Sponsoring State(s);
- Other relevant ISA Contractors;
- ISA Observers;
- Scientific community;
- Environmental (non-governmental organization (NGO)) community;
- Industry stakeholders (e.g. suppliers, sub-contractors, potential customers); and
- Other entities as appropriate.

III. RISK ASSESSMENT PROCESS

15. Hazard identification and risk assessment fits within a larger process that ensures the Plan of Work meets the objectives outlined in Section 2.1 above throughout the entire life-cycle of the project. The other Standard/Guidelines listed in section 1.3 are intrinsically linked with the risk assessment and risk management process, and the Contractor should review the applicable guidelines regarding these plans when performing the hazard identification and risk assessment.

16. The following table presents a brief summary of the risk assessment components involved in each phase of the project life-cycle, as well as the associated reporting requirements to the Authority:

Project Phase	Phase-Specific Risk Assessment Characteristics	Submission to the Authority
Pre-feasibility study and/or Feasibility Study	- Broad review of potential hazards and risks associated with the mineral deposit and proposed Exploitation, in which all geological, engineering, legal, operating, economic, social, environmental and other relevant factors are considered.	- Results incorporated into the mining workplan included in the Application for approval of a Plan of Work submitted to the authority under regulation 7 of the Exploitation Regulations.
Detailed Plan of Work Design	- Establishment of hazard identification and risk assessment process; - Identification of hazards and evaluation of risks specifically associated with environmental impacts, health and safety, security risks, management and operation of mining support vessels, and closure associated with the proposed Exploitation.	- Results incorporated into the following components of the Application for approval of a Plan of Work submitted to the authority under regulation 7 of the Exploitation Regulations, including HSP and Closure Plan (guideline 1), EIA (guideline 2), EMMP (guideline 3), and ERCP (guideline 9).
Operations	- On-going risk assessment and new hazard identification based on the environmental and safety monitoring results and the adaptive management process; and - Modifications as needed to the HSP, EMMP, and ERCP to ensure that mitigation and safety results are acceptable.	- Annual reporting to the Authority under regulation 38 (1) of the Exploitation Regulations throughout the duration of the contract.

Project Phase	Phase-Specific Risk Assessment Characteristics	Submission to the Authority
Closure	- Risks relating to Environmental Effects are to be quantified, assessed and managed, which includes the gathering of information relevant to closure or suspension of Exploitation; and - Evaluation of post-closure hazards and risks and associated proposed post-closure monitoring and mitigation measures.	- Closure Plan submitted to the Authority under regulations 59 and 60 of the Exploitation Regulations at least 12 months prior to the planned end of production.
Post-Closure Monitoring	- On-going risk assessment and new hazard identification based on the post-closure environmental monitoring results and adaptive management process.	- Final performance assessment report submitted at the cessation of post-closure monitoring activities to the Authority under regulation 61 of the Exploitation Regulations.

A. Establishing Context

17. Establishing the context informs the rest of the risk assessment process including the definition of risk assessment objectives, risk criteria, and identification of appropriate risk assessment tools and techniques. For a specific risk assessment, [e.g., the environmental risk assessment (ERA) in the case of an EIS/EMMP/ERCP, or health and safety risk assessment in the case of the HSP/ERCP], establishing the context should include:

a) Establishing the external context with respect to the environment in which the system, (i.e., the Exploitation) operates, including:

- cultural, political, legal, regulatory, and economic factors, whether international, national, regional or local; and
- perceptions and values of external stakeholders.

b) Establishing the internal context with respect to:

- capabilities of the Contractor organization in terms of resources and knowledge;
- internal stakeholders and policies; and
- internal structures (e.g. governance, roles, and accountabilities).

c) Establishing the context of the risk management process.

d) Defining risk criteria involves deciding

- the nature and types of consequences to be included and how they will be measured;
- the way in which probabilities are to be expressed;
- how a level of risk will be determined;
- the criteria by which it will be decided when a risk needs treatment;
- the criteria for deciding when a risk is acceptable and/or tolerable; and

- whether and how combinations of risks will be taken into account.

18. One particular aspect of deep seabed Exploitation that complicates the assessment of environmental impacts is that there is a lack of scientific certainty associated with deep sea species and ecosystems This requires application of a precautionary approach, as indicated by the regulation 2 (e) (ii) of the Exploitation Regulations. There are fewer uncertainties associated with the evaluation of health and safety risks associated with surface vessels on the open ocean and operational machinery, as there are a number of existing and well-established industries (e.g., offshore oil/gas drilling, land-based mining; dredging, deep-sea fishing) that can be drawn upon to inform the hazard identification and risk assessment processes necessary to protect human health and safety with the aim to adhere to reducing risks to a level considered consistent with the ALARP principle.

B. Hazard Identification

19. Hazards, which are sources of potential harm, should be identified as the first step of the risk analysis process. The hazards associated with all aspects of the project should be identified and understood before moving to the second step of identifying the risks for analysis. The hazard identification process should be dynamic and ongoing to ensure that any new hazards are identified following changes in the Plan of Work and throughout different phases of the project. This phase is critical in the context of the risk management since an overlooked hazard (hence, risk) cannot be further assessed and controlled.

20. The hazard identification process should include a review of all potential hazards that could result in consequences to personnel, the surface vessel(s), and the environment during all project phases. There are a number of general categories of potential hazards that should be reviewed with respect to the proposed Plan of Work activities and Mining Area. Hazard categories and example aspects to evaluate include, but are not limited to:

- Natural environment/ecosystem issues (i.e. Exploitation causing changes in water composition, clarity, or noise affecting the food chain and availability of prey; potential oxygen depletion; sediment plume effects in the water column; bioaccumulation of toxic metals and other contaminants, etc.);
- Pollution and hazardous substance issues (i.e. potential pollution from vessels or equipment to the Marine environment, potential for fire/explosions, biological hazards, etc.);
- Occupational issues (e.g. hazards present in the work environment, potential for personnel issues, ergonomic problems, etc.);
- Climatic and natural events (e.g. impacts of hurricanes, lightning, wind, etc.); and
- Socioeconomic issues (e.g. potential identification of human remains of an archaeological or historical nature, impacts of marine traffic, fisheries, and other user of the Area).

21. Commonly used techniques to aid in hazard identification include, but are not limited to, the following:

- Hazard Identification Technique (HAZID);
- Hazard Review;
- What-If Analysis;
- Checklist Analysis;

- Hazard and Operability (HAZOP) Analysis; and
- Failure Modes and Effects Analysis (FMEA).

22. These techniques are described in further detail in ISO/ICE 31010. Links to resources to assist with hazard identification are provided in Section 6.2.

23. For existing and well-established technologies and industries, hazard identification can heavily rely on previous experience and studies and may only require a simple identification technique to enumerate the hazards. For example, as noted in Section 3.1, evaluation of health and safety hazards associated with surface vessels on the open ocean and operational machinery can use the well-established risks from similar industries (offshore oil/gas drilling, land-based mining; dredging, deep sea fishing) as a guide. However, for use of new technologies or work in ecosystems where there is a lack of full scientific certainty (i.e. deep seabed exploitation, deep sea species and ecosystems), a more thorough analysis should be employed (such as HAZOP) to confer sufficient confidence that all the hazards have been identified.

C. Risk Analysis

24. Risk analysis consists of determining the consequences and their probabilities for each identified hazard, or risk event. The consequences and probabilities for each hazard are then combined to determine a level of risk (see Section 3.4). This process involves an assessment of (1) the frequency/probability of the hazard occurring and (2) the consequence severity of the hazard. This can be accomplished using both quantitative and qualitative methods.

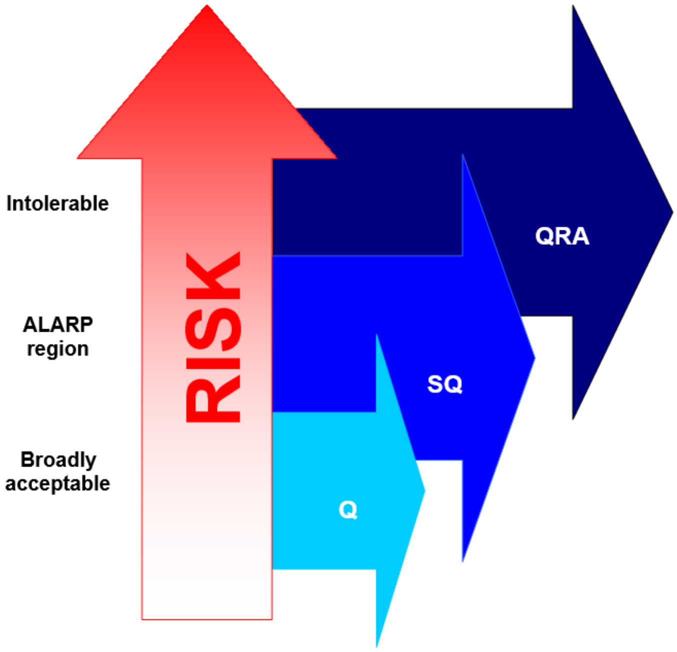
25. The risk assessment methodology applied should be efficient (cost-effective) and of sufficient detail to enable the ranking of risks in order, for subsequent consideration of risk reduction. The rigour of assessment should be proportionate to the complexity of the problem and the magnitude of risk. It is expected that assessment would progress through the following stages (see Figure 2):

- **Qualitative (Q),** in which frequency and severity are determined purely qualitatively.
- **Semi-quantitative (SQ),** in which frequency and severity are approximately quantified within ranges.
- **Quantified risk assessment (QRA),** in which full quantification occurs.

26. These approaches to risk assessment reflect a range of detail of assessment from Q (lowest) to full QRA (highest). The choice of approach should take into account the following dimensions:

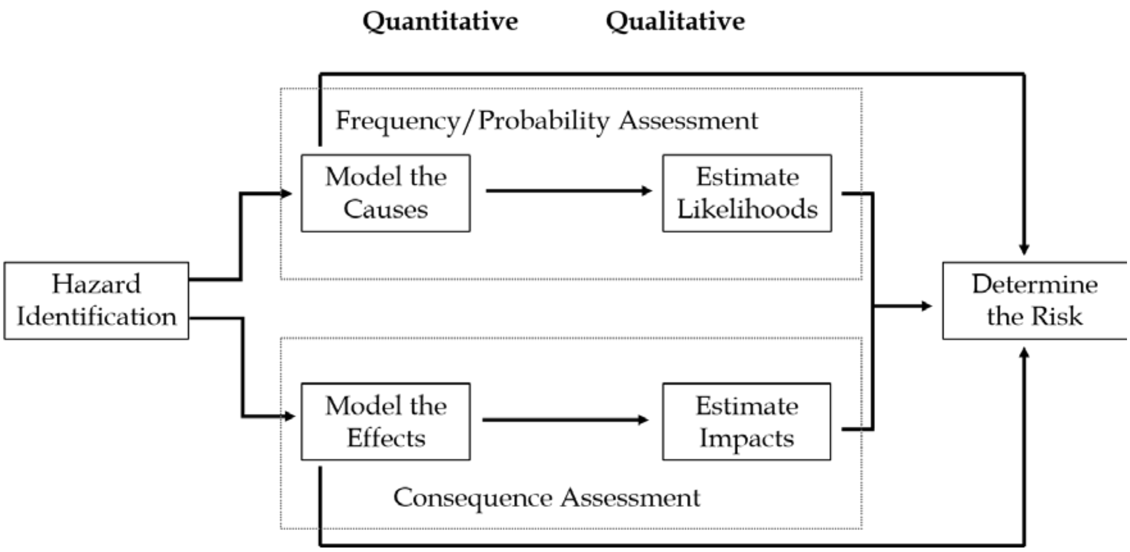
- The level of estimated risk (and its proximity to the limits of tolerability).
- The complexity of the problem and/or difficulty in answering the question of whether more needs to be done to reduce the risk.

Figure 2: Proportionate risk assessment



The overall process from hazard identification to determination of the risk is graphically represented in Figure 3.

Figure 3: Overview of the risk analysis process (Source: adapted from Vamanu et al., 2016)



27. Choosing the appropriate risk assessment approach or combination of approaches is a key step in supporting the risk management process. Qualitative risk assessment is commonly based on experience or expertise and results in categorical estimates of risk. Quantitative risk assessment involves the assignment of data-supported numeric values in the assessment of probability and consequence. It commonly follows an initial qualitative

assessment, focusing on the highest-priority risks identified. Quantitative risk assessment is more likely to be used to account for the compounding of effects between multiple scenarios or events.

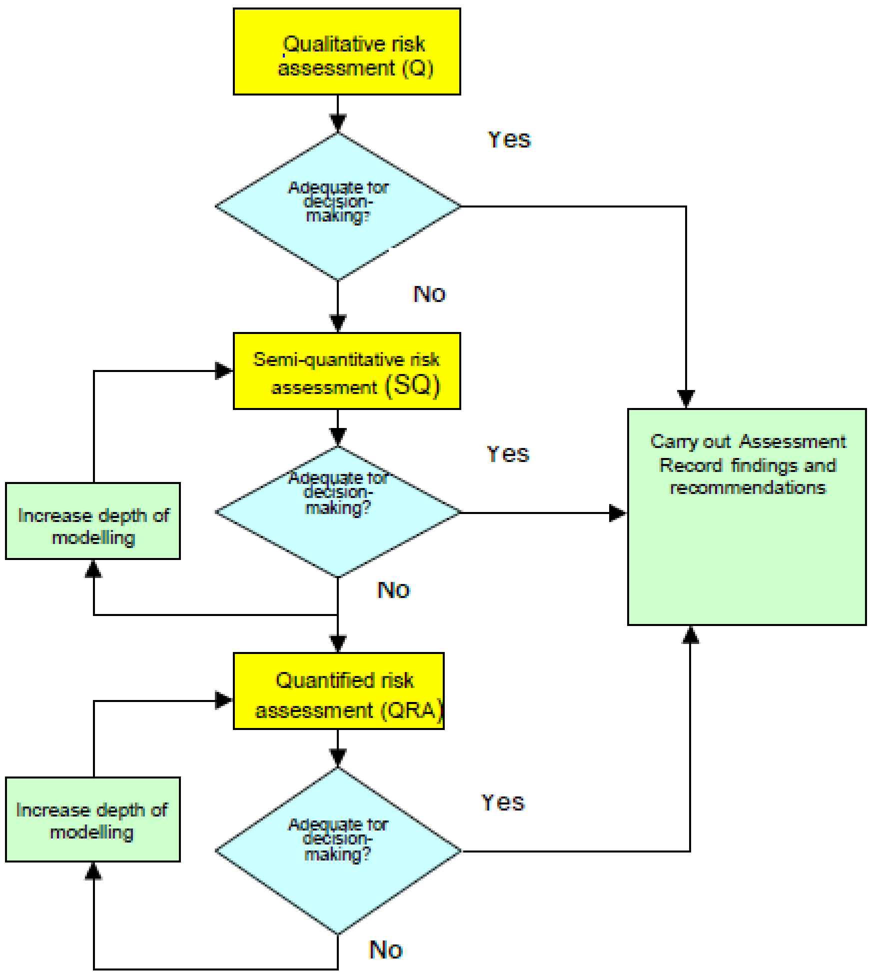
28. Importantly, risk assessment should be used to provide an input into the decision-making process and those responsible for such decision making should be suitably qualified, experienced and of sufficient seniority to be competent and accountable for their actions.

29. The lower levels of assessment (Q and SQ) are considered most appropriate for screening for hazards and events that need to be analysed in greater detail, e.g. to assist in determining the events to be included in the representative set for more detailed assessment. One approach to deciding the appropriate level of detail would be to start with a qualitative approach and to elect for more detail whenever it becomes apparent that the current level is unable to offer:

- The required understanding of the risks;
- Discrimination between the risks of different events; or
- Assistance in deciding whether more needs to be done (making compliance judgements).

Figure 4 below indicates a screening process to determine appropriate risk assessment level.

Figure 4: Screening to determine appropriate risk assessment level



30. Both qualitative and quantitative risk assessments provide Contractors with the knowledge required to properly control and communicate the risk. Qualitative assessments, involving expert judgment, may be sufficient for many operations, such as simple operations where the level of risk is dependent on fewer variables and where uncertainties are relatively low. Quantitative assessments, however, can offer additional insight when the operation or technology is more complex; decisions regarding the effectiveness of risk controls and potential consequences are dependent on many variables; multiple paths to failure exist; the magnitude of risk is greater; or uncertainties are higher. Ultimately, choosing the appropriate risk assessment method is also for proper communication of risk between the Contractor, the Authority, and other stakeholders.

31. Risk estimation entails assessing both the severity (consequence) and frequency (likelihood) of hazardous events. The amount of detail and effort required increases from qualitative (Q) to semi-quantitative (SQ) to quantified risk assessment (QRA). For the Q or SQ approaches, a risk matrix is a convenient method of ranking and presenting the results. It is important that the risk matrix used should be capable of discriminating between the risks of the different hazardous events for the installation

32. Examples of quantitative and qualitative assessment methods are provided in Section 3.9.

33. Frequency/probability assessment and consequence assessment procedures are discussed in the following subsections.

1. Frequency/Probability Assessment

34. The objective of the frequency/probability assessment is to provide a characterization of risk hazards by likelihood of occurrence, by estimating how likely a hazardous event is to occur, the range of outcome(s) from that event, and the frequency of those outcome(s). Three general approaches are commonly employed to estimate probability; they may be used individually or jointly:

1. Use of relevant historical data;
2. Probability forecasts using predictive techniques; and
3. Expert opinion used in a systematic and structured process.

35. During a frequency assessment, inductive or deductive analysis can be used to determine the range of outcomes from an event. Inductive hazard analysis uses a bottom up technique that discusses a hazard event and its possible effects on the entire operation. Deductive hazard analysis uses a top down technique that suggests that the operation is failing in a certain way and attempts to determine the possible causes or behaviors that have contributed to the failure of the operation.

36. The level of detail resulting from a frequency assessment is dependent upon what stage of the project is being evaluated; the further along the project is, the more detail and data can potentially be included in the assessment. If a quantitative approach to frequency assessment is not possible through use of available data from the specific project, the frequency assessment should consider the use of statistical data on the historical frequency of events.

37. The results of the probability assessment can be used to assign each risk a specific probability category, which can then be used in the risk evaluation (see Section 3.4). An example probability scale for environmental and health and safety impacts is presented below:

Likely	> 50% probability of one incident during the project period
Reasonably	10-50% probability of one incident during the project period
Unlikely	1-10% probability of one incident during the project period
Remote	0.1-1% probability of one incident during the project period
Extremely	< 0.1% probability of one incident during the project period

38. Examples of frequency assessment methods are provided in Section 3.9. Links to resources to assist with hazard identification are provided in Section 5.2.

2. Consequence Assessment

39. Consequence assessment evaluates the level of impact that could occur. Consequence assessment evaluates the level of impact from a hazardous event on personnel, the surface vessel(s), and the environment. For example, consequences can include the accidental release of material, a release of energy, or loss of onboard resources. An event may have a range of impacts of different magnitudes and affect a range of different objectives and different stakeholders. The types of consequence to be analyzed and the stakeholders affected will have been decided when the context was established (Section 3.1).

40. Consequence analysis can involve:

- Taking into consideration existing controls to treat the consequences, together with all relevant contributory factors that affect consequences;
- Relating the consequences of the risk to the original objectives;
- Considering both immediate consequences and those that may arise after a certain time has elapsed, if this is consistent with the scope of the assessment;
- Considering secondary consequences, such as those impacting upon associated systems, activities, equipment or organizations.

41. The activities employed in the consequence assessment phase may include:

1. Characterizing the material or energy associated with the hazard being analyzed;
2. Estimating (using models and correlations) the transport of the material and/or the propagation of the energy in the environment to the target of interest (people, structure, etc.);
3. Identifying the effects of the propagation of energy or material on the target of interest; and
4. Quantifying the health, safety, environmental, or economic impacts (depending on the target of interest).

Consequence modelling usually involves sophisticated computer programs designed for specific tasks, most of which are intended for safety or environmental purposes (for example, fire, explosion overpressure, smoke and gas dispersion modelling). Such models can predict range, intensity, and mortality and morbidity rates.

42. The results of the probability assessment can be used to assign each risk a specific consequence category, which can then be used in the risk evaluation (see Section 3.4). An example consequence scale for environmental impacts based on water quality is presented below:

No	The hazard is not expected to cause any negative effects on water or sediment quality. There are no expected negative effects on the ecosystem (no chronic effects). This means that the water concentration and/or sediment concentration is not expected to exceed limit values for chronic effects on biota.
Low	The risk of causing negative effects on water or sediment quality is low. The risk of negative effects on the ecosystem is low (chronic effects). This means that the water concentration and/or sediment concentration is not expected to exceed limit values for chronic effects on biota. Recovery is possible.
Conside rable	The hazard causes considerable negative effects on water or sediment quality. The hazard causes considerable negative effects on the ecosystem (chronic effects). This means that the water concentration and/or sediment concentration is expected to exceed limit values for chronic effects on biota. Only partial recovery is possible, but in a long-term perspective (>1,000 years).
Large	The hazard causes large negative effects on water or sediment quality. The hazard causes large negative effects on the ecosystem (chronic or acute effects). This means that the water concentration and/or sediment concentration is expected to exceed limit values for chronic effects on biota. Only partial recovery is possible, but in a long-term perspective (>1,000 years).
Severe	The hazard causes severe negative effects on water or sediment quality. The hazard causes severe negative effects on the ecosystem (chronic or acute effects). This means that the water concentration and/or sediment concentration is expected to exceed limit values for chronic effects on biota.

43. Examples of consequence assessment methods are provided in Section 3.9. Links to resources to assist with hazard identification are provided in Section 5.2.

3. Accounting for Uncertainties

44. The risk management process is intended to aid decision making by taking account of uncertainty and the possibility of future events or circumstances (intended or unintended) and their effects on agreed objectives. There are often considerable uncertainties associated with the analysis of risk. An understanding of uncertainties is necessary to interpret and communicate risk analysis results effectively. The analysis of uncertainties associated with data, methods, and models used to identify and analyze risk plays an important part in their application. Uncertainty analysis involves the determination of the variation or imprecision

in the results, resulting from the collective variation in the parameters and assumptions used to define the results. An area closely related to uncertainty analysis is sensitivity analysis. When making decisions as part of managing risk, it is important to remember that this is not an absolute science; it is about managing uncertainty to achieve the objectives of protecting human health and the marine environment.

45. Within the context of deep seabed Exploitation, there are gaps in information for risk assessment and a lack of full scientific certainty. Because of these uncertainties, it is important that principles of precautionary approach are applied to environmental risk assessment. The precautionary approach requires addressing and preventing environmental risks at early stages, even if uncertainties remain.

D. Risk Evaluation

46. Evaluating risk is a complex area in which, in the purist sense, the risk level is compared to predetermined acceptance criteria to facilitate decisions on treatment. There are some instances in which this is applicable and the assessment results are more absolute, allowing an understanding of risk levels with acceptable/unacceptable criteria and clarity on decisions about the extent and nature of treatment and priorities. The Exploitation Regulations do not list thresholds for environmental impacts, (refer to guideline 2: EIA/EIS).

47. Until such time as sufficient data on the Area exists that the Authority establishes EIA thresholds and other standards, Contactors could use project-specific and area-specific impact thresholds based on data and analyses commensurate in quality with the importance of the impact.

48. After the Contractor evaluates the risk level, risks should be ranked/categorized according to their significance (low, moderate, or high risk), which will inform the level of risk treatment required to achieve ALARP.

1. Risk Representation

49. Risk representation is the term used to describe the act of combining the results obtained though the hazard identification and risk assessment (frequency and consequences) activities in an easy format to be communicated to stakeholders and used to inform the decision-making process. There are multiple methods of risk representation (e.g., risk matrix, F-N curves, risk profile, risk isopleth, risk index), but the risk matrix is the most frequently used risk representation tool.

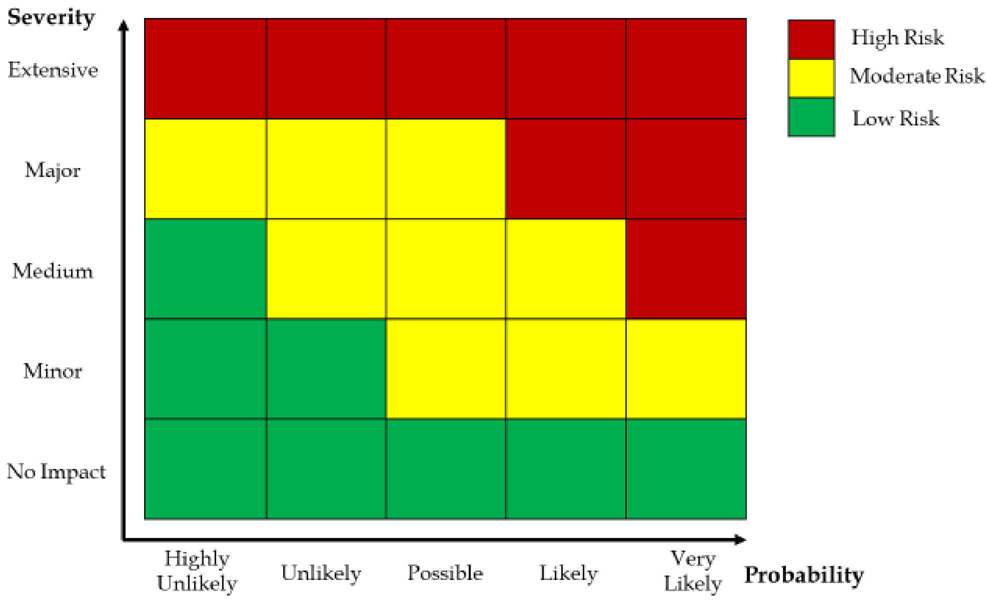
51. The Contractor should consider the following criteria when identifying risk representation methods. The method should be:

- easy to apply;
- easy to understand;
- widely accepted (and thus, a useful risk communication tool for multi-disciplinary teams);
- allows risks to people, environment, assets to be treated consistently; and,
- allows prioritization of the hazards.

52. The risk matrix is a way of graphically representing risk. A risk matrix has two dimensions: consequence (also known as severity) and frequency (also known as likelihood or probability). Within the space defined by these dimensions, three areas are delimited (Figure 5), namely:

- A green area, corresponding to the low-probability, low-consequence;
- A yellow area, corresponding to the medium-probability, medium-consequences; and
- A red area, corresponding to the high-probability, high-consequences.

Figure 5: Example Risk Matrix Structure (Source: adapted from Offshore Risk Assessment, 2016)



53. Risk matrices provide a consistent, concise way to communicate the level of risk a hazard (whether environmental or health and safety) presents. Hence, a risk matrix allows multi-disciplinary teams to rank the risks in order of significance, screen out the insignificant ones and evaluate the need of further risk reduction/preventions measures, (i.e., risk treatment) to be taken in case of various hazards.

54. Figure 5 above provides a very simple example of a risk matrix, but in practice there is a wide range of forms for the layout, labelling, definition of severity and probability terms. A number of examples have been provided in Section 5.2 for reference.

2. Cumulative Risk

55. One issue that isn’t addressed through the risk matrix tool is cumulative risk because the risk matrix is used to evaluate one hazard at a time. The Contractor will want to determine if the potential accumulation of smaller risks results in an unacceptable risk if not addressed.

56. Cumulative risk can be due to the aggregate effects of multiple exploitation operations in a region or the combination of different impacts from a single activity.

Cumulative risk is likely to be less obvious, as it is often subtle and spread over time. The Exploitation Regulations require cumulative risks to be considered for environmental impacts in the EIS (and by extension, the EMMP). From a health and safety perspective, cumulative impacts may result from personnel exposure to multiple stressors, (inhalation, repetitive motion, etc.). The Exploitation Regulations include a duty to cooperate with the scientific community, other Contractors, and the Authority in identifying gaps in scientific knowledge regarding the Area and developing best practices that will improve existing standards and protocols. This will necessitate an iterative process as knowledge of the affected ecosystems, (and to a lesser extent, operational personnel) evolves.

E. Risk Treatment

57. After the Contractor has evaluated the risk level of each hazard, risk treatment (also referred to as risk mitigation or control) options should be evaluated. This involves selecting one or more relevant options for changing the probability of occurrence, the effect of risks (i.e. severity), or both, and implementing these options.

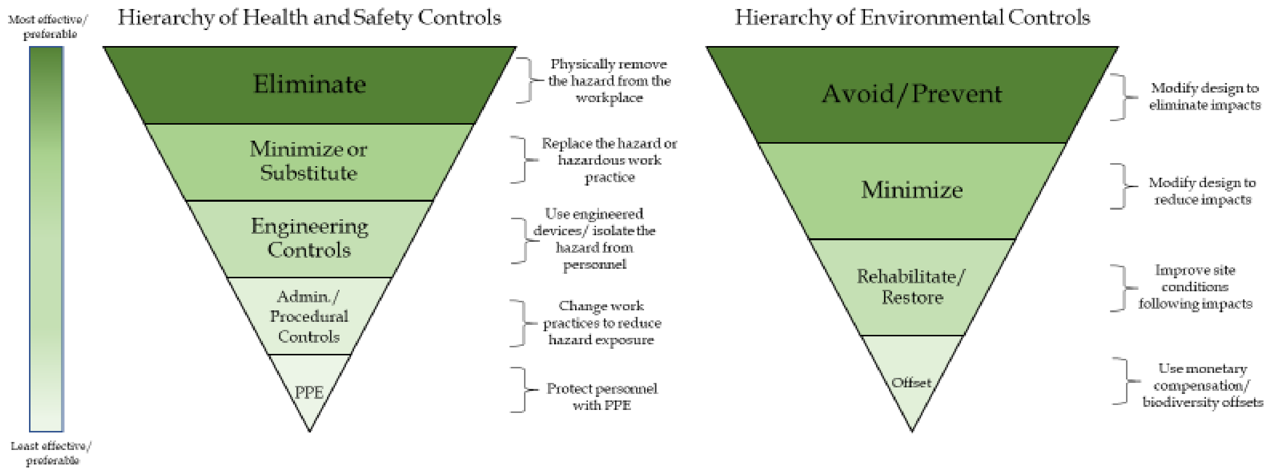
58. Results from the risk assessment process serve as inputs to the risk treatment process. While it is typically accepted that moderate risks (in the yellow category of the risk matrix) or high risks (in the red category of the risk matrix) require risk treatment, it does not necessarily mean that risks that are classified as low (green category of the risk matrix) are controlled to an ALARP level. In the context of exploitation of minerals in the deep seabed environment, there may be low risks that still require risk treatment/risk management, (e.g., manage via routine procedures or monitoring).

59. Inherent in most approaches to risk treatment is the need to appropriately design and effectively execute risk controls. A risk control is a system, process, procedure, equipment or other organizational capacity that prevents the consequences of the threat from occurring. Controls can be:

- Preventive - aimed at preventing the unwanted events from occurring;
- Detective – designed to detect the unwanted event as it is occurring;
- Protective - designed to reduce the immediate impacts; or,
- Mitigating - designed to reduce the long-term impacts of the unplanned event through eventual recovery to an acceptable state.

60. Figure 6 shows the basic hierarchy of controls for health and safety and environmental risks. The key objective of risk management is avoidance of impacts (to the environment or humans) caused by planned or unplanned activities associated with Exploitation in the Area.

Figure 6: Hierarchy of health and safety and environmental controls



61. Once the Contractor identifies a preferred risk treatment option, the modified scenario can be re-assessed to determine the new level of risk (i.e., re-assessing the consequence severity and likelihood), with the objective to determine whether further treatment is required and/or if secondary risks are introduced. If present, secondary risks should be incorporated into the same treatment plan as the original risk and the link between the two risks should be identified. An example of this might be the application of an engineering control to reduce the chance of a release to the environment (e.g., a redundant valve), but the change poses additional health and safety risks (e.g., without pressure relief, the trapped pressure between the valves creates an increased risk of injury).

62. The identified risk controls will form the foundation of environmental and health and safety management plans (and associated component management plans). Obligations for reporting the effectiveness of the risk treatment methods is discussed in Section 3.6.

F. Monitoring and Review

63. The Contractor should conduct ongoing monitoring and periodic review of the risk management process and its outcomes throughout the life-cycle of the project. This review may be conducted concurrent with audit and review of the EMMP. The purpose of monitoring and review is to assure and improve the quality and effectiveness of the risk assessment process, implementation and outcomes. In particular, risk controls implemented by the Contractor should be monitored for effectiveness (i.e., re-evaluated) over time and adapted to changing conditions.

64. A risk management review will:

1. Evaluate the effectiveness of the existing risk treatment actions and risk levels by reviewing environmental and health and safety monitoring records, corrective actions, and the results of any prior audits; and,
2. Identify any new hazards and associated risks resulting from changes in the Plan of Work or implementation of new phases of the project.

65. Review or audit of a risk management plan could be undertaken at the following times and may corresponded with a review or audit of the EMMP or HSP:

1. Following environmental and health and safety incidents (e.g., 'Notifiable Events' as laid out in appendix I of the Exploitation Regulations) such as a significant leak of hazardous substance, unauthorized mining discharge, adverse environmental conditions with likely significant environmental consequences, impairment/damage to environmentally critical equipment, occupational lost time illness or injury, medical evacuation, or fatality;
2. When there is a substantive adjustment to the relevant Regional Environmental Management Plan (REMP); and
3. Periodically, for deep seabed exploitation and/or monitoring activities undertaken over extended timeframes, (e.g., every two years for operations/closure period lasting five years or less, and every five years for operations/closure period lasting more than five years).

66. A procedure should be developed by the project management team for conducting risk management audits and include the following key components:

- Establish audit procedures;
- Determine the frequency of audits;
- Develop processes for scheduling, reporting, and maintaining records, (e.g., maintenance of a formal risk register);
- Ensure that the auditors are competent, in that they should be able to undertake the audit objectively and competently. Audits may be undertaken by internal parties or external competent persons; and
- Address personnel responsible for conducting the review and required resources.

67. The Contractor should include information about risk management in the annual report to be submitted in accordance with regulation 38 of the Exploitation Regulations. Refer to Section 3.8 for further detail regarding reporting requirements.

G. Risk Communication Process

68. Communication and consultation are important considerations at each step of the risk management process and may include the following key components:

- Cooperation and dialogue with stakeholders, with a focus on consultation and engagement;

- Developing a communication plan for both internal and external stakeholders at the earliest phase of the project;

- Identifying, recording, and integrating, if necessary, stakeholder perceptions of risk into the decision-making process; and

- Establishing a team approach to define the context, ensure that all risks are identified, and ensure that different views are considered.

69. As discussed in the context of adaptive management in guideline 3, consultation and cooperation among users of the Area and relevant stakeholders will aid in the advancement

of scientific understanding of sites where mineral exploitation will occur, mining technologies, impacts and the environment's response, thereby providing critical feedback to inform future decision-making. Consultation involves a dialogue with people who may be interested in or affected by a proposed activity. It is an opportunity to inform people about the proposed project and an invitation to contribute to the project design/issue identification and resolution process. Specifically, with regard to risk assessment, communication is a key part of building trust, improving understanding within the stakeholder community about exploitation of the Area and the related risks, and helping industry to better understand the views of stakeholders who may be affected by those activities. It is recommended that Contractors take the following seven principles of risk communication into account throughout the life-cycle of the project:

1. Accept and involve the public as a partner.
2. Plan carefully and evaluate your efforts.
3. Listen to the stakeholder's specific concerns.
4. Be honest, frank, and open.
5. Work with other credible sources.
6. Meet the needs of the media.
7. Speak clearly and with compassion.

70. Therefore, in accordance with regulation 3 of the Exploitation Regulations, a plan for on-going consultation with parties identified to have existing interests in the proposed project area, as well as relevant stakeholders (refer to Section 2.2) should be provided. The Contractor should describe the proposed consultation methods and timelines and relevant stakeholders and interested parties to be contacted.

H. Recording and Reporting

71. The risk management process and its outcomes should be documented and reported through appropriate mechanisms, such as within the application for the Plan of Work (see Section 3.0) and the annual report (discussed below). Recording and reporting aims to:

- Communicate all risks considered and risk management activities conducted;
- Provide information for decision-making and identify key intervention points;
- Serve as a reference when reviewing risks after some time has elapsed to consider changed circumstances due to strategy implementation or changed business, environment, regulatory, social conditions; and
- Assist with interactions with stakeholders, including those with responsibility and accountability for risk management activities.

72. The extent of the report will depend on the objectives and scope of the assessment, except for very simple assessments, the documentation can include:

- Objectives and scope;
- Description of relevant parts of the system and their functions;
- A summary of the external and internal context of the organization and how it relates to the situation, system or circumstances being assessed;
- Risk criteria applied and their justification;
- Limitations, assumptions and justification of hypotheses;
- Assessment methodology;

- Risk identification results;
- Data, assumptions and their sources and validation;
- Risk analysis results and their evaluation;
- Sensitivity and uncertainty analysis;
- Critical assumptions and other factors which need to be monitored;
- Discussion of results;
- Conclusions and recommendations; and
- References.

73. Risk registers are commonly used to present risk information, to document the outputs from the risk identification process and to present the results of risk analysis and strategy development. Typical contents of risk registers include:

- A tabulation of the risk events considered;
- Events excluded, the reasons for excluding them, and their likelihoods and consequences;
- The results of risk analysis and evaluation; and
- Existing control measures, planned management actions, allocations of responsibility, and timings of actions.

74. Links to resources to assist with developing risk registers are provided in Section 5.2.

75. Risk analysis results will be incorporated into the following components of the Application for approval of a Plan of Work submitted to the authority under regulation 7 of the Exploitation Regulations, including HSP and Closure Plan, EIA as documented within the EIS, EMMP, and ERCP.

I. Risk Assessment Tools and Techniques

76. Various risk assessment tools and techniques for hazard identification and risk analysis are discussed in ISO/IEC 31010. Links to resources to assist with hazard identification and risk analysis are provided in Section VI, B.

IV. RISK MANAGEMENT BEST PRACTICE

77. Below is a summary of some best practices to consider during risk assessment and risk management activities undertaken in an effort to conform with the Exploitation Regulations:

1. Establish risk management systems that are based on Good Industry Practice, Best Available Techniques, and Best Environmental Practices including the technology and procedures to meet health, safety and environmental requirements for the activities proposed in the Plan of Work [regulation 13 (3) (c)];

2. Design the risk management program to reduce the risk of Incidents as much as reasonably practicable, to the point where the cost of further risk reduction would be grossly disproportionate to the benefits of such reduction, taking into account the relevant guidelines. The reasonable practicability of risk reduction measures should be kept under review in the light of new knowledge and technology developments

and Good Industry Practice, Best Available Techniques and Best Environmental Practices. In assessing whether the time, cost and effort would be grossly disproportionate to the benefits of further reducing the risk, consideration should be given to best practice risk levels compatible with the operations being conducted (regulation 32);

3. Apply the precautionary approach, as reflected in principle 15 of the Rio Declaration on Environment and Development, to the assessment and management of risk of harm to the marine environment from exploitation in the Area (regulation 44 (a)); and

4. Openly consult and cooperate with users of the Area and relevant stakeholders on the risks and impacts of exploitation on the marine environment (regulation 3).

V. ABBREVIATIONS, ACRONYMS AND DEFINITIONS

ALARP	As Low as Reasonably Practicable
CCFA	Common Cause Failure Analysis
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EMMP	Environmental Management and Monitoring Plan
EMS	Environmental Management Systems
ERA	Environmental Risk Assessment
ERCP	Emergency Response and Contingency Plan
ETA	Event Tree Analysis
FMEA	Failure Modes and Effects Analysis
FMECA	Failure Mode & Effect Criticality Analysis
FSA	Formal Safety Assessment
FTA	Fault Tree Analysis
HAZID	Hazard Identification Technique
HAZOP	Hazard and Operability
HRA	Human Reliability Analysis
HSP	Health and Safety Plan
IEC	International Electrotechnical Commission
ISBA	International Seabed Authority
ISO	International Organization for Standardization
JHA	Job Hazard Analysis
LOPA	Layers of Protection Analysis
NGO	Non-governmental organization
PRA	Probabilistic Risk Assessment
QRA	Quantitative Risk Assessment
REMP	Regional Environmental Management Plan
SICA	Scale-Intensity-Consequence Analysis
SMS	Safety Management System
SOOB	Summary of Operation Boundaries
SWIFT	Structured What-If Technique
UNCLOS	United Nations Convention on the Law of the Sea
WOAD	World Offshore Accident Database

78. Precautionary Approach is an approach to environmental risk assessment where environmental risks are addressed and prevented at early stages, even if uncertainties remain, recognized in Principle 15 of the Rio Declaration, which states that: “In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.” The precautionary approach does not necessarily mean proposed projects with unknown effects or impacts should not proceed;

however, these projects should proceed with appropriate checks and risk reduction measures in place.

79. The concept of As Low As Reasonably Practicable (ALARP) is a principle in risk management of reducing “the risk of incidents as much as reasonably practicable, to the point where the cost of further risk reduction would be grossly disproportionate to the benefits of such reduction.” As stated in the Exploitation Regulations “the reasonable practicability of risk reduction measures shall be kept under review in the light of new knowledge and technology developments and Good Industry Practice, Best Available Techniques and Best Environmental Practices

VI. INFORMATION SOURCES

A. References

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B. Useful Links

Topic	URL
Standards and Guidelines	
International Organization for Standardization (ISO) 31000:2018 Risk management – Guidelines	https://www.iso.org/iso-31000-risk-management.html
International Electrotechnical Commission (IEC) 31010:2019 Risk management - Risk assessment techniques	https://www.iso.org/standard/72140.html
Pacific-ACP States Regional Guidance Documents and Reports (multiple resources)	http://dsm.gsd.spc.int/index.php/publications-and-reports
Risk Assessment Tools and Techniques	
Risk assessment and management: Leading Practice Sustainable Development Program for the Mining Industry (Commonwealth of Australia, 2016)	https://www.industry.gov.au/data-and-publications/leading-practice-handbook-risk-management
Offshore Risk Assessment: An overview of methods and tools (Vamanu, 2016)	https://euoag.jrc.ec.europa.eu/vicos/uploads/2018/10/03/Offshore%20Risk%20Assessment.Methods%20and%20tools.pdf
DNVGL-RP-O601 Recommended Practice: Managing environmental aspects and impacts of seabed mining (2016)	https://www.dnvgl.com/oilgas/download/dnv-gl-rp-O601-managing-environmental-aspects-and-impacts-of-seabed-mining.html
Probabilistic Risk Assessment: Applications for the Oil & Gas Industry (National Aeronautics and Space Administration, 2017)	https://www.bsee.gov/sites/bsee.gov/files/pra-05012017-whitepaper.pdf

Topic	URL
Hazard Identification and Risk Assessment (National Offshore Petroleum Safety and Environmental Management Authority, 2017)	https://www.nopsema.gov.au/assets/Guidance-notes/A122420.pdf
Guidance Notes on Risk Assessment Applications for the Marine and Offshore Oil and Gas Industries (American Bureau of Shipping, 2000)	https://ww2.eagle.org/content/dam/eagle/rules-and-guides/current/other/97_riskassessapplmarineandoffshoreoandg/pub97_riskassesment.pdf
Offshore Risk Assessment Vol 1. Principles, Modelling and Applications of QRA Studies (Vinnem, 2020)	https://www.springer.com/gp/book/9781447174431
Ecological risk assessment for deep-sea mining (Washburn, 2019)	https://www.researchgate.net/publication/333538553_Ecological_risk_assessment_for_deep-sea_mining
Section 4.6.3 Summary of Operation Boundaries (SOOB) Combined Operations – Health, Safety and Environmental Case Guidelines for Mobile Offshore Drilling Units (International Association of Drilling Contractors, 2015)	https://www.iadc.org/forms/access-hse-case-guidelines-modu/
Guidelines for Ecological Risk Assessment (US EPA, 1998)	https://www.epa.gov/risk/guidelines-ecological-risk-assessment
Climate Change effects and impacts assessment: A guidance manual for local government in New Zealand [publication ME 870, Chapter 6-Risk Assessment] (NZ Ministry for the Environment, 2008)	https://www.mfe.govt.nz/publications/climate-change/climate-change-effects-and-impacts-assessment-guidance-manual-local-6
Guidance on Risk Assessment for Offshore Installations (UK Health and Safety Executive, 2006)	https://www.hse.gov.uk/offshore/sheet32006.pdf
Revised Guidelines for Formal Safety Assessment (FSA) for Use in the IMO Rule-Making Process, (IMO, 2018)	http://www.imo.org/en/OurWork/Safety/SafetyTopics/Documents/MSC-MEPC%202-Circ%2012-Rev%202.pdf
Risk Management Framework for Mining in BC [Governance Example] (Ministry of Energy, Mines and Petroleum Resources, Ministry of Environment and Climate Change Strategy, The Environmental Assessment Office, 2018)	https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/mineral-exploration-mining/documents/compliance-and-enforcement/miningbc_risk_management_framework_july2018.pdf

Topic	URL
Risk Assessment Examples	
Expert risk assessment of activities in the New Zealand Exclusive Economic Zone and Extended Continental Shelf (National Institute of Water and Atmospheric Research Ltd, 2012)	https://www.mfe.govt.nz/publications/marine/expert-risk-assessment-activities-new-zealand-exclusive-economic-zone-and
Chapter 19 Environmental Management Plan - Port of Gladstone Western Dredging Project Environmental Impact Statement (GHD, 2009)	http://eisdocs.dsdip.qld.gov.au/Port%20of%20Gladstone%20Western%20Basin%20Dredging/EIS/19-environmental-management-plan.pdf
Navigational Risk Assessment for The New Zealand King Salmon Co. Ltd. (Enhanced Operating Systems Limited, 2012)	https://www.epa.govt.nz/assets/FileAPI/proposal/NSP000002/Evidence/4bd456a77f/Navigational-Risk-Assessment.pdf
Environmental Impact Statement for South of Embley Project – Section 19 Hazard and Risk, (Rio Tinto Alcan, n.d.)	https://www.yumpu.com/en/document/read/52661607/embley
Risk Management Framework for Mining in BC [Governance Example] (Ministry of Energy, Mines and Petroleum Resources, Ministry of Environment and Climate Change Strategy, The Environmental Assessment Office, 2018)	https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/mineral-exploration-mining/documents/compliance-and-enforcement/miningbc_risk_management_framework_july2018.pdf
Risk Representation – Risk Matrix Examples	
Basic Risk Assessment Matrix (Western Australia Department of Environment and Conservation)	https://ww2.health.wa.gov.au/~/media/Files/Corporate/general%20documents/Clandestine%20drug%20labs/PDF/Risk-Assessment-Matrix-Provided-by-the-Department-of-Environment-Regulation.pdf
Final Guidelines for Port & Harbour Risk Assessment and Safety Management Systems in New Zealand (Maritime Safety Authority of New Zealand, 2004)	https://www.maritimenz.govt.nz/commercial/ports-and-harbours/documents/Port-harbour-risk-assessment.pdf