International Seabed Authority ISBA/27/C/8

Council

Distr.: General
31 January 2022

Original: English

Twenty-seventh session
Council session, part I
Kingston, 21 March–1 April 2022
Item 11 of the provisional agenda*
Draft regulations on exploitation of mineral resources in the Area

Draft guidelines on the tools and techniques for hazard identification and risk assessments

Prepared by the Legal and Technical Commission

Contents

* ISBA/27/C/L.1.

21-17333 (E) 280122

I. Introduction

1. The present Guidelines have been developed to provide practical and technical guidance on the tools and methodologies for identifying Hazards and assessing Risks associated with the Exploitation of Mineral Resources in the Area and are generally applicable to numerous parts of the Exploitation Regulations.

2. Given the uncertainties inherent in 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 a Contractor's application for a Plan of Work for Exploitation, including the HSP, the Closure Plan, the EIA, the EMMP and the ERCP. It is also to be incorporated into day-to-day Exploitation activities, including the management and operation of mining support vessels and Installations.

A. Purpose of the present Guidelines

3. The purpose of the present Guidelines is to provide information on approaches and tools for Hazard identification and Risk assessment. The intent 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 to the implementation of Risk Management strategies through the use of Hazard identification and Risk assessment tools. The guidance contained below is intended as 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 present Guidelines are also intended for 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 inform methods to reduce the Risk of Incidents and impacts of Exploitation on the Marine Environment as much as reasonably practicable and should:

(a) Serve to 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, Best Environmental Practices and the 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 EIA and EIS;

(c) Provide for the protection of human life and safety.

B. Format of the present Guidelines

6. The present Guidelines consist of the following sections:

- Section I contains details concerning the purpose and scope of the Guidelines and provides the Contractor with information on the organization of the Guidelines and the ways in which they are linked to the regulations and other Guidelines.

- Section II contains details concerning the key principles of Hazard identification and Risk assessment, triggers for and timing of the Risk Management process, and a discussion of pertinent Stakeholders.
- Section III contains details concerning the Risk assessment process, specifically establishing the context, Hazard identification, Risk analysis, Risk evaluation, and Risk treatment, monitoring, review and communication. In addition, a summary of potential Risk assessment tools and techniques is provided.
- Section IV contains a summary of the best practices associated with the Risk assessment and Risk Management process.
- Section V contains a list of abbreviations and definitions of terms used throughout the present Guidelines.
- Section VI contains references and links to additional sources of information useful in Hazard identification and Risk assessment.

C. Use of the present Guidelines

7. The present Guidelines should be read in conjunction with the Exploitation Regulations, the relevant Exploration Regulations and other Standards and Guidelines of the Authority.

8. The appropriate 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 VI of the present Guidelines. Overarching guidance documents for all industries include ISO standard 31000:2018 (Risk management: guidelines), IEC standard 31010:2019 (Risk management: risk assessment techniques) and ISO standard 9000:2015 (Quality management: fundamentals and vocabulary). There are numerous guidance documents issued by national jurisdictions and related industries that can provide valuable and relevant approaches to performing Hazard identification and Risk assessment.

II. General principles of 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., the EIA as documented in the EIS, the EMMP, the ERCP, the HSP and others). In them, appropriate controls used by the Contractor are established 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 ISO

standard on risk management (ISO 31000:2018), which can be applied to Exploitation, in addition to many others.

B. Approaches to Risk assessment

12. Risk assessment is a part of Risk Management; it is a structured process to identify how objectives may be affected and analyse the Risk in terms of consequences and their probability before a decision is made on whether further treatment is required. Risk assessment is an attempt to answer the following fundamental questions:

(a) What can go wrong?

(b) How likely is it to go wrong ?

(c) What are the impacts?

(d) Is the level of Risk acceptable or does it require Mitigation?

13. As shown in figure 1 below, the following elements form the pillars of Risk assessment (i.e. identifying, analysing, assessing and communicating Risks):

(a) Establishing context;

(b) Hazard identification;

(c) Risk analysis (frequency and consequence assessment);

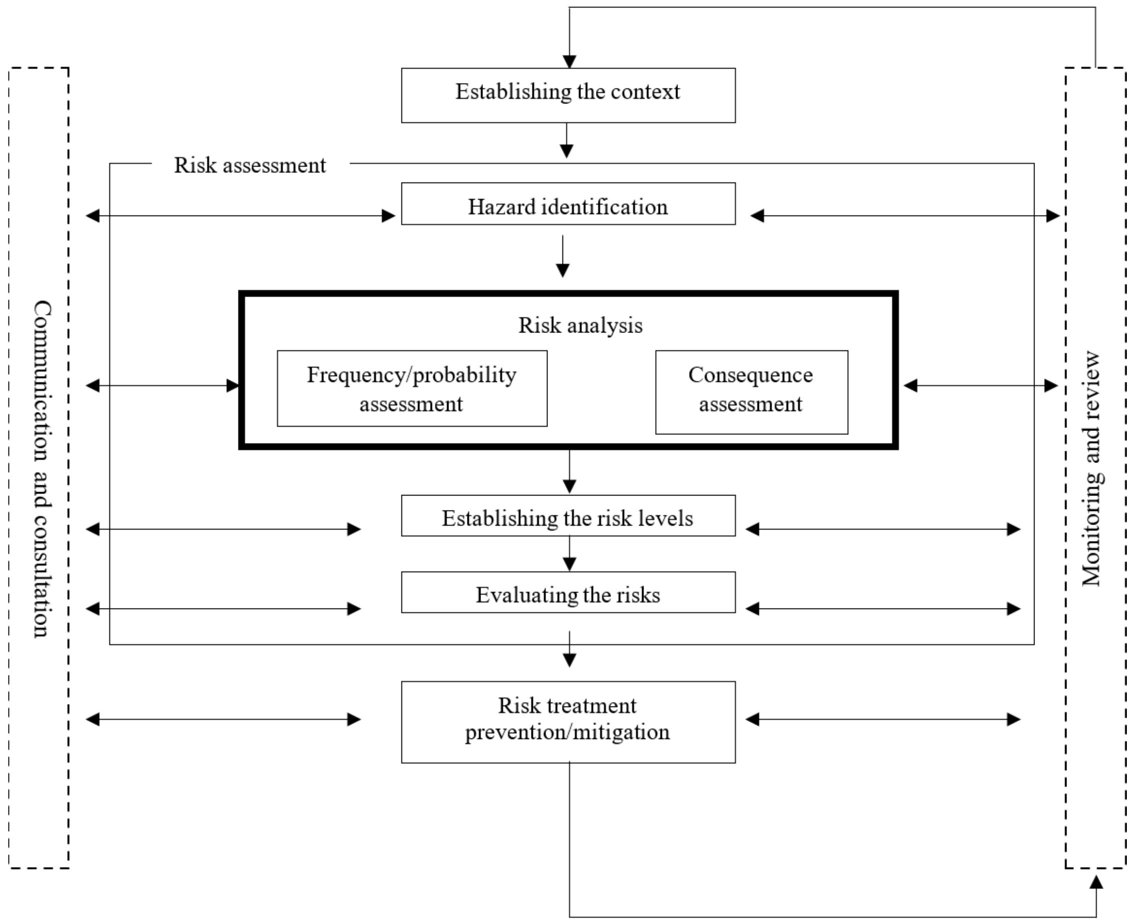
(d) Risk evaluation (risk representation);

(e) Risk treatment;

(f) Monitoring and reviews;

(g) Communication and consultation.

Figure 1
Overview of the Risk assessment process within the context of the Risk Management process



Source: Adapted from ISO/IEC standard 31010:2019.

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:

(a) Member States;

(b) Sponsoring State(s);

(c) Other relevant Authority Contractors;

(d) Authority observers;

(e) Scientific community;

(f) Environmental (non-governmental organization) community;

(g) Industry Stakeholders (e.g. suppliers, subcontractors, potential customers);

(h) Other entities, as appropriate.

III. Risk assessment process

15. Hazard identification and Risk assessment fits within a larger process that ensures that the Plan of Work meets the objectives outlined above in section II.A, throughout the entire life cycle of the project. The other Standards and Guidelines listed in section I.C, are intrinsically linked with the Risk assessment and Risk Management process, and the Contractor should review the applicable Guidelines regarding those plans when performing the Hazard identification and Risk assessment.

16. Table 1 contains a brief summary of the Risk assessment components accompanying each phase of the project life cycle, as well as the associated reporting requirements to the Authority.

Table 1
Risk assessment components

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
Design of a detailed Plan of Work	– 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 Installations, 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, Closure Plan, EIA, EMMP and ERCP
Operations	– Ongoing Risk assessment and new Hazard identification based on the environmental and safety monitoring results and the adaptive management process – 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 the Exploitation – 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	Ongoing 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 and Risk criteria, and the identification of appropriate Risk assessment tools and techniques. For a specific Risk assessment, (e.g. the 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 the following:

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

(i) Physicochemical, biological, social, cultural, political, legal, regulatory and economic factors, whether international, national, regional or local;

(ii) Perceptions and values of external Stakeholders;

(b) Establishing the internal context with respect to:

(i) Capabilities of the Contractor organization in terms of resources and knowledge;

(ii) Internal Stakeholders and policies;

(iii) Internal structures (e.g. governance, roles and accountability);

(c) Establishing the context of the Risk Management process;

(d) Defining Risk criteria involves deciding on the following:

(i) The nature and types of consequences to be included and how those will be measured;

(ii) The way in which probabilities are to be expressed;

(iii) The way in which a level of Risk will be determined;

(iv) The criteria by which it will be decided when a Risk needs treatment;

(v) The criteria for deciding when a Risk is acceptable and/or tolerable;

(vi) 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. A Precautionary Approach is therefore required, as indicated by regulation 2 (e) (ii) of the Exploitation Regulations. There are fewer uncertainties with regard to the evaluation of health and safety Risks associated with surface vessels and Installations on the open ocean and with operational machinery, as there are a number of existing and well-established industries (e.g. offshore oil and 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 to adhere to reduce Risks to a level considered consistent with the ALARP principle.

B. Hazard identification

19. Hazards are sources of potential harm; identifying them should be the first step in 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 for personnel, surface vessels and the environment during all phases of the project. There are a number of general categories of potential Hazards associated with the activities proposed in the Plan of Work and Mining Area that should be reviewed. Hazard categories and examples of aspects to evaluate include, but are not limited to:

(a) Natural environment and ecosystem issues (i.e. Exploitation causing changes in water composition or clarity, or noise affecting the food chain and availability of prey; potential oxygen depletion; sediment plume effects on the seafloor and water column; bioaccumulation of toxic metals and other contaminants, among others);

(b) Pollution and hazardous substance issues (i.e. potential pollution from vessels or equipment to the Marine Environment, potential for fire, explosions and biological Hazards, among others);

(c) Occupational issues (e.g. Hazards present in the work environment, potential for personnel issues and ergonomic problems, among others);

(d) Climatic and natural events (e.g. impacts of hurricanes, lightning and wind, among others);

(e) Socioeconomic issues (e.g. potential identification of human remains of an archaeological or historical nature, impacts on marine traffic, fisheries, and traditional and other users of the Area).

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

(a) HAZID technique;

(b) Hazard review;

(c) What-if analysis;

(d) Checklist analysis;

(e) HAZOP analysis;

(f) Failure modes and effects analysis.

22. Those techniques are described in further detail in ISO/IEC standard 31010:2019. Links to resources to assist with Hazard identification are provided in section VI.B.

23. For existing and well-established technologies and industries, Hazard identification can rely heavily on previous experience and studies and may require no more than a simple identification technique to enumerate the Hazards. For example, as noted in section III.A, for the evaluation of health and safety Hazards associated with surface vessels and Installations on the open ocean and operational machinery, use can be made of the well-established Risks in similar industries (offshore oil and gas drilling, land-based mining, dredging and 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, and deep-sea species and ecosystems), a more thorough analysis should be employed (such as the HAZOP analysis) to gain sufficient confidence that all the Hazards have been identified.

C. Risk analysis

24. Risk analysis is the process 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 sect. III.D). This process involves an assessment of (a) the frequency and probability of the Hazard occurring and (b) the severity of the consequences associated with the Hazard. This can be accomplished using both quantitative and qualitative methods.

25. The Risk assessment methodology applied should be efficient (cost-effective) and sufficiently detailed to enable the ranking of the Risks for the subsequent consideration of Risk reduction. The rigour of the assessment should be proportionate to the complexity of the problem and the magnitude of the Risks. It is expected that assessments would progress through the following stages (see figure 2):

(a) Qualitative, in which frequency and severity are determined purely qualitatively;

(b) Semi-quantitative, in which frequency and severity are quantified approximately, within ranges;

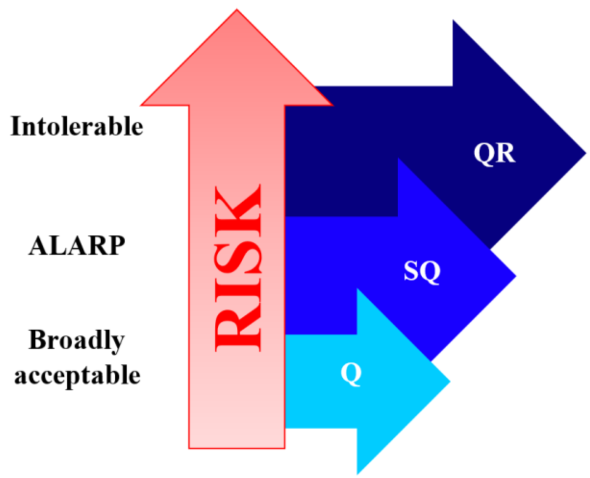
(c) Quantified Risk assessment, in which full quantification occurs.

26. These approaches to Risk assessment reflect a range of detail of assessment from qualitative (lowest) to fully quantified (highest). The approach should be chosen taking into account:

(a) The level of estimated Risk (and its proximity to the limits of tolerability);

(b) The complexity of the problem and/or the difficulty encountered in answering the question whether more needs to be done to reduce the Risk.

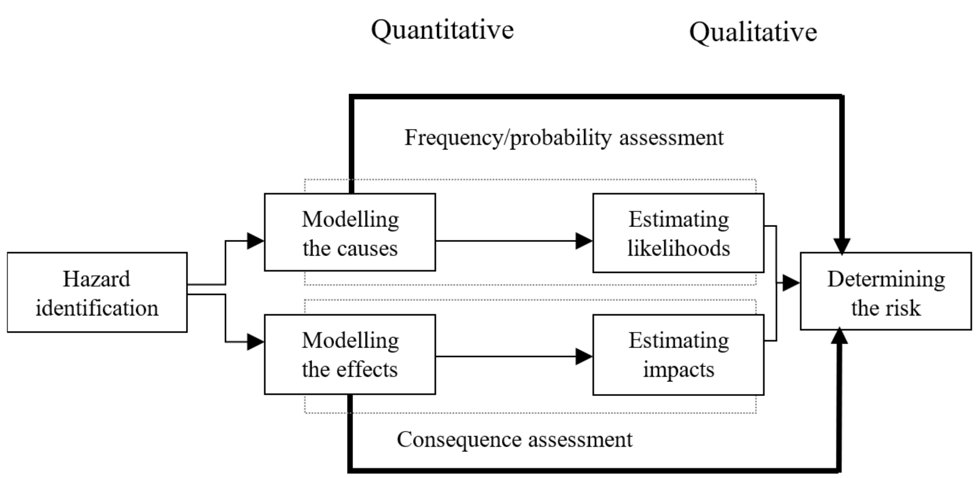
Figure 2
Proportionate Risk assessment



Abbreviations: Q, qualitative Risk assessment; SQ, semi-quantitative Risk assessment; QRA, quantified Risk assessment.

27. 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 and others.

28. Choosing the appropriate Risk assessment approach or combination of approaches is a key step in supporting the Risk Management process. Qualitative Risk assessments are commonly based on experience or expertise and result in categorical estimates of Risk. Quantitative Risk assessments involve the assignment of data-supported numeric values in the assessment of probability and consequence. They commonly follow an initial qualitative assessment focused on the highest-priority Risks identified. Quantitative Risk assessments are more likely to be used to account for the compounding of effects from multiple scenarios or events.

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

30. The lower levels of assessment (qualitative and semi-quantitative) are considered most appropriate for screening for Hazards and events that need to be analysed in greater detail, for example to assist in determining the events to be included in the representative set for a more detailed assessment. One approach to deciding the appropriate level of detail would be to start with a qualitative approach and to opt for more detail whenever it becomes apparent that the current level is unable to offer the following:

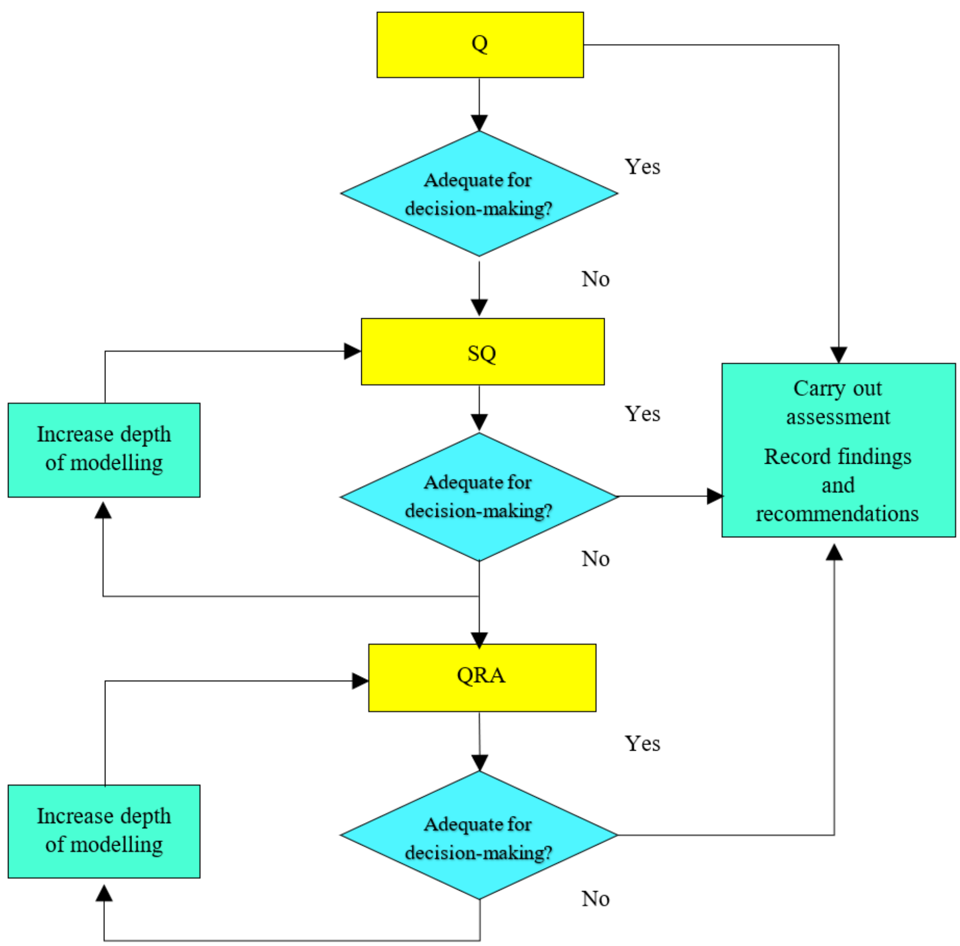
(a) The required understanding of the Risks;

(b) Discrimination between the Risks of different events;

(c) Assistance in deciding whether more needs to be done (making compliance judgements).

31. Figure 4 below depicts a screening process to determine the appropriate Risk assessment level.

Figure 4
Screening to determine appropriate Risk assessment level



Abbreviations: Q, qualitative Risk assessment; SQ, semi-quantitative Risk assessment; QRA, quantified Risk assessment.

32. Both qualitative and quantitative Risk assessments provide Contractors with the knowledge required to properly control and communicate the Risk. Qualitative assessments, which involve expert judgment, may be sufficient for many operations, such as simple operations in which the level of Risk is dependent on fewer variables and where uncertainties are relatively low. Quantitative assessments, however, can offer additional insight if 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 Risk is greater, or uncertainties are greater. Ultimately, choosing the appropriate Risk assessment method is also useful for the proper communication of Risk between the Contractor, the Authority and other Stakeholders.

33. Risk estimation entails assessing both the severity (consequence) and frequency (likelihood) of hazardous events. The amount of detail and effort required is progressively greater for qualitative, semi-quantitative and quantified Risk assessments. For the qualitative or semi-quantitative approaches, drawing up a Risk matrix is a convenient method for 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.

34. Examples of quantitative and qualitative assessment methods are provided below.

Procedures

35. Frequency/probability assessment procedures and consequence assessment procedures are discussed below.

Frequency/probability assessment

36. The objective of a frequency/probability assessment is to provide a characterization of Risk Hazards by likelihood of their occurrence by estimating how likely a hazardous event is to occur, the range of outcomes from such an event and the frequency of such outcomes. The three following general approaches are commonly employed to estimate probability; they may be used individually or jointly:

(a) Use of relevant historical data;

(b) Probability forecasts using predictive techniques;

(c) Expert opinion used in a systematic and structured process.

37. During a frequency assessment, inductive or deductive analysis can be used to determine the range of outcomes of an event. In inductive Hazard analysis, a bottom-up technique is used to consider a Hazard event and its possible effects on the operation in its entirety. Deductive Hazard analysis is a top-down technique used to consider hypothetical situations in which an operation is failing in a certain way and an attempt is made to determine the possible causes or contributing behaviours.

38. The level of detail resulting from a frequency assessment is dependent on the stage of the project at which it 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 by using available data on the project in question, the use of statistical data on the historical frequency of events should be considered for the frequency assessment.

39. The results of the probability assessment can be used to assign a specific probability category to each Risk, which can then be used in the Risk evaluation (see sect. III.D). An example of a probability scale for environmental impacts and health and safety impacts is presented in table 2.

Table 2
Probability scale for environmental impacts and health and safety impacts

Category	*Probability of an Incident occurring during the project period*
Likely	> 50%
Reasonably likely	10%–50%
Unlikely	1%–10%
Remote	0.1%–1%
Extremely remote	< 0.1%

40. Examples of frequency assessment methods are provided below. Links to resources to assist with Hazard identification are provided in section VI.B.

Consequence assessment

41. In consequence assessment, the level of the impact that could occur is evaluated, as is the level of the impact of a hazardous event on personnel, surface vessels and the environment. For example, consequences can include the accidental release of material, a release of energy or the loss of onboard resources. An event may have a range of impacts of different magnitudes and affect a range of objectives and Stakeholders. The types of consequences to be analysed and the Stakeholders affected are decided earlier, when the context is established (see sect. III.A).

42. Consequence analysis may involve the following:

(a) Taking into consideration existing controls to treat the consequences, together with all relevant contributory factors that affect the consequences;

(b) Relating the consequences of the Risk to the original objectives;

(c) Considering both immediate consequences and those that may arise after a certain time has elapsed, if consistent with the scope of the assessment;

(d) Considering secondary consequences, such as those having an impact on associated systems, activities, equipment or organizations.

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

(a) Characterizing the material or energy associated with the Hazard being analysed;

(b) Estimating (by means of models and correlations) the transport of the material and/or the propagation of the energy in the environment to the target of interest (people, structures and others);

(c) Identifying the effects of the propagation of energy or material on the target of interest;

(d) Quantifying the health, safety, environmental or economic impacts (depending on the target of interest).

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

45. The results of the probability assessment can be used to assign a specific consequence category to each Risk, which can then be used in the Risk evaluation (see sect. III.D). An example of a consequence scale for environmental impacts based on water quality is presented in table 3.

Table 3
Consequence scale for environmental impacts based on water quality

Negative effects	*Description*
No	The Hazard is not expected to have 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 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.
Considerable	The Hazard has considerable negative effects on water or sediment quality. The Hazard has 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 in the long term (more than 1,000 years) is possible.
Large	The Hazard has large negative effects on water or sediment quality. The Hazard has 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 from a long-term perspective (more than 1,000 years) is possible.
Severe	The Hazard has severe negative effects on water or sediment quality. The Hazard has 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. Recovery is not possible.

46. Examples of consequence assessment methods are provided in section III.C. Links to resources to assist with Hazard identification are provided in section VI.B.

Accounting for uncertainties

47. The Risk Management process is intended to support decision-making by taking account of uncertainty and the possibility of future events or circumstances (intended or unintended) and their effects on agreed objectives. The uncertainties associated with the analysis of Risk are often considerable. An understanding of those uncertainties is necessary to interpret and communicate Risk analysis results effectively. Risk is identified and analysed using data, methods and models, and the analysis of uncertainties associated with those plays an important part in their application. Uncertainty analysis involves determining the variation or imprecision in the results brought about by 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 revolves around managing uncertainty to achieve the objectives of protecting human health and the Marine Environment.

48. By considering the uncertainty in data, analyses and interpretation, an assessment can be made of where there are major gaps in understanding the impacts of the proposed activities, which can help to direct further work to improve knowledge and confidence.

49. Because deep seabed mining is a new industry associated with uncertainties, it is important that the Precautionary Approach is applied to the management of environmental Risk. The Precautionary Approach requires addressing and preventing environmental Risks at early stages, even if uncertainties remain.

D. Risk evaluation

50. Evaluating Risk is a complex area in which, in the purest 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, showing which Risks are acceptable and which are not, so that clear decisions can be made concerning the extent and nature of treatment and priorities. The Exploitation Regulations do not list thresholds for environmental impacts (EIA/EIS).

51. Until sufficient data on the Area exist and 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 extent of the impact.

52. Once the Contractor has evaluated the Risk level, Risks should be ranked and categorized according to their significance (low, moderate, or high Risk), which will inform the level of Risk treatment required to achieve a level of Risk that is As Low As Reasonably Practicable.

1. Risk representation

53. 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.

54. When considering Risk representation, the Contractor should choose a method that meets the following criteria:

(a) Easy to apply;

(b) Easy to understand;

(c) Widely accepted (and thus, a useful Risk communication tool for multidisciplinary teams);

(d) Allows Risks to people, environment, assets to be treated consistently;

(e) Allows prioritization of the Hazards.

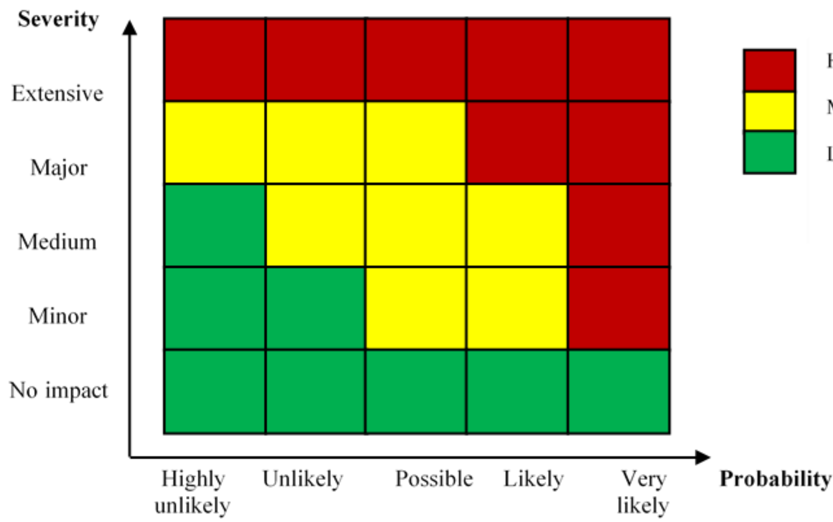
55. The Risk matrix is a way of graphically representing Risk. A Risk matrix has two dimensions: consequence (also known as severity) and frequency (also known as likelihood or probability). Within the space defined by these dimensions, the following three areas are delimited (see also figure 5):

(a) A green area, corresponding to low probability and limited consequences;

(b) A yellow area, corresponding to medium probability and moderate consequences;

(c) A red area, corresponding to high probability and extensive consequences.

Figure 5
Example of a Risk matrix structure



Source: Adapted from Vamanu and others.

56. Risk matrices are a consistent, concise way to communicate the level of Risk that a Hazard presents, whether it relates to the environment or to health and safety. 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 for further Risk reduction/prevention measures (i.e. Risk treatment) to be taken with regard to various Hazards.

57. Figure 5 above is a very simple example of a Risk matrix; in practice there is a wide range of forms for the layout, labelling, definition of severity and probability terms. There are many methods in addition to the matrix format (see Standard and Guidelines for the Environmental Impact Assessments Process and ISO standard 31000:2018), although the key to a successful Risk assessment involves evaluating similar components, even if those are analysed using different methods and presented in different ways. A number of examples have been provided for reference in section III.C.

2. Cumulative Risk

58. One issue that is not addressed through the Risk matrix tool is cumulative Risk, because the Risk matrix is used to evaluate one Hazard at a time. It is in the interest of the Contractor to determine whether smaller Risks, if not addressed, can accumulate and, together, become an unacceptable Risk.

59. Cumulative Risk can be due to the aggregate effects of multiple Exploitation operations in a region or the combination of different impacts resulting from a single activity. Cumulative Risk is likely to be less obvious, as it is often subtle and spread over time. The Exploitation Regulations contain a recommendation to consider cumulative Risks in the EIS (and by extension, the EMMP) for their environmental impacts. From a health and safety perspective, cumulative impacts may result from personnel exposure to multiple stressors, (inhalation, repetitive motion and others). 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

60. 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 an occurrence, the effect of Risks (i.e. severity), or both, and implementing those options.

61. Results from the Risk assessment process serve as inputs into 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 a level that is As Low As Reasonably Practicable. 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).

62. 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:

(a) Preventive – aimed at preventing the unwanted events from occurring;

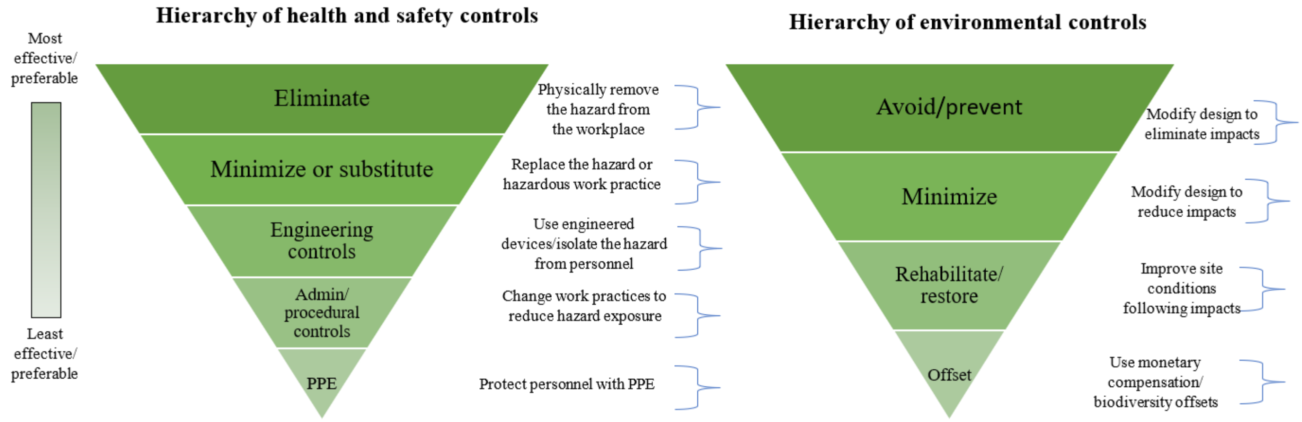
(b) Detective – designed to detect the unwanted event as it is occurring;

(c) Protective – designed to reduce the immediate impacts;

(d) Mitigating – designed to reduce the long-term impacts of the unplanned event through eventual recovery to an acceptable state.

63. 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 (on 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



Abbreviation: PPE, personal protective equipment.

64. Once the Contractor identifies a preferred Risk treatment option, the modified scenario can be reassessed to determine the new level of Risk (i.e. reassessing the severity and likelihood of the consequences), with the objective of determining 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 chances of a release into 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).

65. The identified Risk controls will form the foundation of the EMS and HSP. Obligations for reporting the effectiveness of the Risk treatment methods is discussed in section III.E.

F. Monitoring and review

66. The Contractor should conduct ongoing monitoring and periodic reviews of the Risk Management process and its outcomes throughout the life cycle of the project. Such a 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.

67. A Risk Management review serves to:

(a) 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;

(b) Identify any new Hazards and associated Risks resulting from changes in the Plan of Work or implementation of new phases of the project.

68. A review or audit of a Risk Management plan could be undertaken at the following times. It may coincide with a review or audit of the EMMP or HSP.

(a) Following environmental and health and safety events (e.g. Notifiable Events as set out in appendix I to the Exploitation Regulations), such as a significant leak of hazardous substance, an unauthorized Mining Discharge, adverse environmental conditions with likely significant environmental consequences, impairment of and/or damage to environmentally critical equipment, occupational time lost to illness or injury, medical evacuation, or a fatality;

(b) When there is a substantive adjustment to the relevant REMP;

(c) 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).

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

(a) Establish audit procedures;

(b) Determine the frequency of audits;

(c) Develop processes for scheduling, reporting and maintaining records (e.g. maintenance of a formal Risk register);

(d) 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;

(e) Address personnel responsible for conducting the review and required resources.

70. The Contractor should include information concerning Risk Management in the annual report to be submitted in accordance with regulation 38 of the Exploitation Regulations. Reference is made to section III.H, for further details regarding reporting requirements.

G. Risk communication process

71. Communication and consultation are important considerations at each step of the Risk Management process and may include the following key components:

(a) Cooperation and dialogue with Stakeholders, with a focus on consultation and engagement;

(b) Developing a communication plan for both internal and external Stakeholders at the earliest phase of the project;

(c) Identifying, recording and integrating, if necessary, Stakeholder perceptions of Risk into the decision-making process;

(d) Establishing a team-based approach to define the context, ensure that all Risks are identified and ensure that different views are considered.

72. Consultation and cooperation among users of the Area and relevant Stakeholders will aid in the advancement of the scientific understanding of the sites where mineral Exploitation will occur, the mining technologies involved, the impacts and the environment's response, which results in 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 of 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:

(a) Accept and involve the public as a partner;

(b) Plan carefully and evaluate efforts made;

(c) Listen to the Stakeholders' specific concerns;

(d) Be honest, frank, and open;

(e) Work with other credible sources;

(f) Meet the needs of the media;

(g) Speak clearly and with compassion.

73. Therefore, in accordance with regulation 3 of the Exploitation Regulations, a plan for ongoing consultation with parties identified as having existing interests in the proposed project area, as well as relevant Stakeholders (see sect. II.C) should be provided. The Contractor should describe the proposed consultation methods and timelines, as well as the relevant Stakeholders and interested parties to be contacted.

H. Recording and reporting

74. 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 sect. III) and the annual report (discussed below). The aim of recording and reporting is to:

(a) Communicate all Risks considered and Risk Management activities conducted;

(b) Provide information for decision-making and identify key intervention points;

(c) Serve as a reference when reviewing Risks after some time has elapsed to consider circumstances that have changed owing to strategy implementation or changed business, environmental, regulatory or social conditions;

(d) Assist in interactions with Stakeholders, including those who bear responsibility and are accountable for Risk Management activities.

75. The extent of the report will depend on the objectives and scope of the assessment, and the documentation can include:

(a) Objectives and scope;

(b) Description of relevant parts of the system and their functions;

(c) Summary of the external and internal context of the organization and how it relates to the situation, system or circumstances being assessed;

(d) Risk criteria applied and their justification;

(e) Limitations, assumptions and justification of hypotheses;

(f) Assessment methodology;

(g) Risk identification results;

(h) Data, assumptions and their sources and validation;

(i) Gaps in uncertainties regarding data, analyses or interpretation;

(j) Risk analysis results and their evaluation;

(k) Sensitivity and uncertainty analysis;

(l) Critical assumptions and other factors that need to be monitored;

(m) Discussion of results;

(n) Conclusions and recommendations;

(o) References.

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

(a) A tabulation of the Risk events considered;

(b) Events excluded, the reasons for excluding them and their likelihood and consequences;

(c) The results of Risk analysis and evaluation;

(d) Existing control measures, planned management actions, allocations of responsibility and timing of actions.

77. Links to resources to assist with developing Risk registers are provided in section VI.B.

78. 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 the HSP, the Closure Plan, the EIA as documented within the EIS, the EMMP and the ERCP.

I. Risk assessment tools and techniques

79. Various Risk assessment tools and techniques for Hazard identification and Risk analysis are discussed in ISO/IEC standard 31010:2019. Links to resources that can be useful in Hazard identification and Risk analysis are provided in section VI.B.

IV. Best practice in Risk Management

80. Below is a summary of some of the best practices to consider when undertaking Risk assessment and Risk Management activities in an effort to conform with the Exploitation Regulations:

(a) Establish Risk Management systems based on Good Industry Practice, Best Available Techniques and Best Environmental Practices, including the technology and procedures to meet health and safety and environmental requirements for the activities proposed in the Plan of Work (regulation 13 (3) (c)). In that regard, the Contractor could consider having its Risk Management systems assessed by an accredited certification body;

(b) Design the Risk Management programme 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);

(c) 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));

(d) 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
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EMMP	Environmental Management and Monitoring Plan
EMS	Environmental Management System
ERA	Environmental Risk Assessment
ERCP	Emergency Response and Contingency Plan
HAZID technique	Hazard identification technique
HAZOP analysis	Hazard and operability analysis
HSP	Health and Safety Plan
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
REMP	Regional Environmental Management Plan

"Hazard" means any object, situation, or behaviour that has the potential to cause injury, ill health or damage to property or the environment.

"Risk" means the probability, high or low, that any Hazard will actually cause harm.

"Risk Management" means the coordinated activities to direct and control an organization with regard to Risk.

"Precautionary Approach" means an approach to environmental Risk Management in which environmental Risks are addressed and prevented at early stages, even if uncertainties remain, recognized in principle 15 of the Rio Declaration, which reads as follows: "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 that proposed projects with unknown effects or impacts should not proceed; however, such projects should proceed with appropriate checks and Risk reduction measures in place.

"As Low As Reasonably Practicable" ("ALARP") means the 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 laid down 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

Topic	*URL*
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
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
Risk Assessment Examples	
Expert risk assessment of activities in the New Zealand Exclusive Economic Zone	https://www.mfe.govt.nz/publications/marine/expert-risk-assessment-activities-new-zealand-exclusive-economic-zone-and

Topic	*URL*
and Extended Continental Shelf (National Institute of Water and Atmospheric Research Ltd, 2012)	
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