7 PHYSICOCHEMICAL ENVIRONMENTAL IMPACTS

7.1 Overview

This section identifies and assesses the direct and indirect impacts of the Collector Test to the physicochemical components of the receiving environment. Impacts of various stages of the Collector Test are considered for the following zones: atmospheric (above surface), euphotic (0 to 200 m), mesopelagic (200 to 1,000 m), bathypelagic (1,000 to 4,000 m) and abyssal (4,000 to 6,000 m) including the benthic component. A summary of relevant environmental effects considered (that is, project related activities that interact with the physicochemical receiving environment) is provided in Table 7 1.

The Collector Test EIA is a sub-component of the commercial ESIA that is currently in progress. At the time of writing all baseline campaigns have been completed and analysis of the samples and data is ongoing. The baseline information presented in Section 5 represents a subset of the baseline being developed for the commercial ESIA that is sufficient to inform the Collector Test EIA. Where uncertainty exists, it has been acknowledged, and a precautionary approach applied. It is a key objective of the Collector Test to inform the commercial ESIA process which in turn reduces the level of inherent uncertainty of the commercial project.

Table 7-1. Summary of environmental effects for the physicochemical environment

ACTIVITY	VULNERABLE VECS	ENVIRONMENTAL EFFECTS
Return transit of vessel from San Diego to the CCZ	Air Quality / GHG	Vessel's diesel engines will emit fumes into the atmosphere.
	Light / Noise / Vibration	Vessel will be illuminated at night and the and diesel engines will generate noise and vibration.
	Water Quality	Intentional or accidental release of pollutants from the vessel.
Offshore Inspection and Preparation	Water Quality	Leakage of hydraulic fluids, oil, or other substances from the ROV.
PCV Deployment	Water Quality	Leakage of hydraulic fluids, oil, or other substances from the PCV.
Riser Commissioning	Water Quality	Leakage of hydraulic fluids, oil, or other substances from the ROV.
	Noise / Vibration	Surface and/or subsea noise or vibrations caused by pressure testing of the riser pipe.
Subsea Connection of Jumper on PCV	Water Quality	Leakage of hydraulic fluids, oil, or other substances from the ROV.

ACTIVITY	VULNERABLE VECS	ENVIRONMENTAL EFFECTS
System Testing	Water Quality	Manoeuvring the PCV on the seabed, pick-up test runs, and system test runs will physically disturb the sediments and nodules creating a sediment plume.
	Light / Noise / Vibration	The PCV will be equipped with lights and cameras to monitor operations during system testing. Manoeuvring the PCV on the seabed and pick-up test runs will create noise and vibration. Riser installation and commissioning tests, system integration testing, and system test runs all have the potential to create noise and vibration at the surface and throughout the water column from use of the air lift and through pressure testing of the system.
	Sediment Geochemistry and micro-topography	Manoeuvring the PCV on the seabed, pick-up test runs, and system test runs will mix the surface layers of the sediment.
	Water Quality	Mid water plume will be released into the bathypelagic zone at 1,200 m.
Riser and PCV Recovery	Water Quality	Leakage of hydraulic fluids, oil, or other substances from the ROV.

7.2 Environmental Effects

The environmental effects of the Collector Test have the potential to impact a number of physicochemical VECs including air quality and greenhouse gases, acoustics and vibration, ambient light, water quality, sediment biogeochemistry and micro-topography.

Relevant environmental effects have been categorised as:

- Those associated with surface vessel operations, such as atmospheric emissions, acoustics, light, and routine vessel discharges which will primarily affect the surface and ambient environment.
- Those specific to the Collector Test operations such as changes to water quality, plume generation, sediment biogeochemistry, and the generation of noise and vibration within the water column.

Impact assessment focusses primarily on the second category as many of the impacts associated with routine shipping operations are mitigated through adherence to international conventions and guidelines or through the shipping companies standard operating procedures.

7.2.1 Surface Vessel Operations

7.2.1.1 Air Quality & GHG Emissions

Two potential impact pathways have been identified whereby project related activities could result in the release of carbon to the atmosphere: i) through the release of GHGs from the burning of fossil fuels due to transportation and operation of equipment; and ii) disruption of ocean sediments resulting in the release of inorganic carbon to the atmosphere. The release of GHGs from the burning of fossil fuels is discussed below.

The main sources of GHG emissions during the Collector Test will come from the fuel used by 3 vessels (hidden gem, support vessel and science vessel), followed by the Collector Test equipment, passenger air travel, and shipping by sea of equipment. We are assuming a total of 100 people will be traveling roundtrip to San Diego from central Europe as an overestimate, and that ten full 40ft shipping containers will arrive to San Diego from Rotterdam. The Collector Test will have a duration of 60 days. Using these conservative metrics, the EPA GHG Equivalencies Calculator was used to estimate the emissions from the Collector Test[8]. The estimated total GHG emissions expected to be generated by the Collector Test are 20,466 tonnes of CO2e in the ratios described in the Collector Test GHG emissions estimate (see Appendix 3 for calculation details)

Table 7-2. Collector Test GHG emissions estimate

	Air Travel CO_2e (tonnes)	Vessel CO_2e (tonnes)	Collector Equipment CO_2e (tonnes)	Total equipment shipping emissions CO2e (tonnes)	Total Collector Test emissions CO2e (tonnes)
Estimated Total GHG Emissions Collector Test	334.84	17,159.67	2,969.60	1.81	**20,465.93**

Process optimization to mitigate fuel usage is an ongoing process. Meanwhile, NORI will offset Collector Test emissions via carbon credits in the next 5 years while looking for carbon projects that support ocean conservation and health. Technology development will include fuel optimization of the riser pipe system, monitoring and evaluating advances in alternative fuels for ships vessels that that might be viable candidates for use. NORI is in full support of the Paris climate agreement and a 1.5°C path. To that end, the company is implementing the recommendations of the Task Force on Climate-Related Financial Disclosures (TCFD) this year and will be developing Science Based Targets (SBTi) and climate scenario analysis to further embed climate change into TMC's strategy.

7.2.1.2 Noise & Vibration

Commercial shipping vessels operate in almost all parts of the ocean and are the major source of anthropogenic noise (McKenna *et al.* 2013). The predominant noise from shipping is low frequency (<500 Hz) (OSPAR[9], 2009). Underwater sound is made up of both particle motion and acoustic pressure. While

[8] https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

[9] OSPAR: Convention for the Protection of the Marine Environment of the North-East Atlantic

sound pressure in the marine environment naturally acts in all directions, vibration is particle oscillation back and forward in a particular direction (ISO/DIS, 2016). Species exposed to ocean noise can experience damage from either component of sound-pressure or vibration.

The main components of underwater noise are generated from the ship design (that is, hull form, propeller, the interaction of the hull and propeller, and machinery configuration), which are fixed dependent on the design of the ship used. However, operational modifications and maintenance measures can be implemented as ways of reducing noise for both new and existing ships. In 2014, the International Maritime Organisation (IMO) developed non-mandatory technical guidelines to minimize the introduction of incidental noise from commercial shipping operations into the marine environment to reduce potential adverse impacts on marine life. These guidelines provide shipping operators with recommend design and operational measures to reduce radiated noise[10], that will be implemented during the project as practicable.

In addition, the IMO has designated "Particularly Sensitive Sea Areas" (PSSAs) that deserve special protection due to their recognized ecological, socio-economic, or scientific significance, and which may be vulnerable to damage by ships. Ship routeing measures are proposed for adoption in connection with a PSSA to protect marine life. The CCZ is not designated as a PSSA.

Most noise and vibration generation by the ship's propeller and hull will occur during transit to and from the CCZ. Whilst on station, ship movements will be minimised although there will still be some noise and vibration generated by the dynamic positioning thrusters.

Sources of underwater noise generation in addition to that generated by the SSV are discussed in Section 7.2.2.2.

7.2.1.3 Light

As operations will be continuous surface vessels will emit light during the hours of darkness. Known and potential impacts to biota from changes to ambient light regimes include: (i) hindrances to navigation, migration, and communication; (ii) localised suppression of zooplankton diel vertical migration by artificial skyglow; (iii) aggregating fish under lighting leading to intensified predation; (iv) night-time bird strikes on illuminated vessels; (v) altered recruitment and site selection of invertebrate larvae (Merkel *et al.*, 2011; Davies *et al.*, 2014; 2015; 2016; Black 2005; Hu *et al.*, 2018).

Lighting of the back deck of the vessel will be unavoidable during night-time operations. High intensity lighting (e.g., spotlights) will only be used as necessary (e.g., during equipment deployment) and night-time ambient light levels will be maintained at levels appropriate for the activities being undertaken. As NORI-D is not located in an area of high marine traffic it is unlikely that cumulative light impacts will be of concern.

7.2.1.4 Water Quality

Water quality within NORI-D is considered near pristine (Section 5.11) and is important for sustaining a diverse ecosystem from the surface to the seafloor. Due to the distance of the site from the nearest source anthropogenic pollutants from the land, these pristine conditions are widely distributed and abundant throughout the offshore deep-sea environments in this part of the Pacific Ocean.

All vessels used to execute the project will be registered in a country that has ratified the Protocol of 1978 relating to the International Convention for the Prevention of Pollution from Ships (MARPOL). MARPOL

[10] https://www.imo.org/en/MediaCentre/HotTopics/Pages/Noise.aspx

is the main international convention aimed at the prevention of pollution from ships by operational or accidental causes (see Section 10).

Adherence to MARPOL requirements will minimise the risk of pollution to the marine environment and atmosphere in accordance with established international practices.

7.2.2 Collector System Testing

7.2.2.1 GHG Emissions

In some portions of the ocean, global warming is projected to raise abyssal (3000–6000 m) ocean temperatures by up to 1°C by 2100, causing water column oxygen concentration to drop by up to 3.7% or more in the eastern North Pacific Ocean; pH to decrease by 0.29 to 0.37; and flux of particulate organic matter (POM) to the seafloor to decrease significantly (Levin *et al.* 2020). Jones *et al.* (2013) projected a 5.51% reduction in particulate organic carbon (POC) flux by century's end, leading to a decrease of 3.63% in benthic metazoan biomass. Range changes of abyssal midwater and benthic organisms are among many other impacts that rising temperature will cause (Levin *et al.* 2020). More specific projections for the deep water and seafloor in the CCZ's southeast sector (SE), which includes NORI-D, are that by 2100 global warming will cause the following changes (expressed as percentages of current values): ΔT 0.01%; Δ O_2 -2.73%; Δ pH -0.07%; Δ POC -2.99% (Washburn *et al.* 2021).

Concern has been expressed about deep-sea mining's potential impacts on the carbon cycle and hence on climate change. Specifically, benthic disturbance caused by deep-sea mining could release carbon dioxide (CO_2), methane, or particulate organic carbon (POC); and deep-seas mining might affect future sequestration of carbon by microbial populations (e.g., Chin & Hari 2020, Greenpeace International 2019). The extent to which the deep sea contributes to carbon cycling or climate change mitigation is currently not completely understood, nor are the extent of climate change exacerbation that might result from deep-sea mining (Danovaro *et al.* 2014, Chin & Hari 2020) or the ongoing impacts of climate change on abyssal processes. The primary mechanisms through which deep-sea mining, and specifically the Collector Test, could contribute to climate change are discussed below; and the anticipated impacts for of the Collector Test are quantified.

Broadly, four mechanisms might affect the deep ocean's climate system functions as a result of deep-sea mining. These are:

1. CO_2 equivalent (CO2e) emissions from ship & equipment operation and other transport
2. Disruption of sediment leading to release of stored carbon into the water or atmosphere
3. Release of dissolved CO_2 when abyssal seawater is brought to the surface
4. Disruption of future carbon sequestration caused by deep-sea ecosystem disturbance

Each potential path of carbon cycle interference is discussed below, followed by quantification of expected impacts for the Collector Test. Since required analysis focuses on impacts of the Collector Test, per se, further treatment of the collected nodules (e.g., processing, storage, refining) is not included. Also, because we expect minimal carbon-cycle impact arising from autonomous or remotely operated underwater vehicles, midwater instruments to sample water chemistry or plankton, and mooring or servicing of instruments to measure sound, sedimentation, or other parameters, we have not quantified these items.

Finally, carbon emissions associated with tests conducted by Deep Green Metals (now TMC) prior to the Collector Test, have also been addressed.

(a) CO2e emissions from ship & equipment operation and other transport

Carrying out the Collector Test requires operation of ships and equipment; air transportation of scientists, staff, and crew; and sea freight transport of equipment. All of these have associated greenhouse gas (CO2e) emissions. These emissions have been calculated as **20,466 metric tons** (see Section 7.2.1.1)

(b) Disruption of sediment leading to release of stored carbon into the water or atmosphere

Disrupted sediment will form benthic plumes near the seafloor. A small portion of sediment will also be entrained into the riser pipe, transported to the surface processing vessel, separated from nodules, filtered, and discharged at 1200 m, forming midwater plumes there. Some carbon in both plumes could eventually reach the surface leading to atmospheric carbon dioxide release; however, analyses suggest that remineralization of POC by abyssal disturbance is unlikely to influence atmospheric CO_2 concentrations in the near future due to (1) the low concentration and refractory nature of carbon in abyssal sediments (Orcutt *et al.* 2020) and the centuries to millennial time scales of carbon cycling at those depths (Atwood *et al.* 2020); and (2) the very slow circulation of deep water to the surface. In contrast to surface waters which are connected globally to each other over decadal timescales (Jönsson & Watson 2016), deep water only reaches the surface via thermohaline circulation, with circulation ages estimated at ~ 600 years for the whole ocean (Toggweiler & Key 2003) and ~900 years for the Pacific Ocean (Matsumoto 2007). On the other hand, any CO_2 added to the water column would contribute to the acidification (pH reduction) already underway from ocean uptake of rising levels of CO_2, which has already begun dissolving sedimentary $CaCO_3$—which normally neutralizes excess CO_2 and prevents runaway acidification—in sediments of the deep Atlantic Ocean (Sulpis *et al.* 2018).

Given that the PCV will travel 82 linear km during the Collector Test, and the collector width is 6 m, the potential disturbed area is 4.9×10^5 m^2. We calculate total sediment movement based on sediment disturbance depths of 5 cm (expected), 2.5 cm (low end), and 10 cm (high end) (Paulikas *et al.* 2022); the results of the Collector Test will help refine this number. NORI-D sediment wet weight is 1.17 grams/cm^3 and dry weight is 0.31 grams/cm^3 (TMC data, included in Paulikas *et al.* 2020). Total organic content (TOC) of surface sediment is approximately 0.5% by weight in eastern CCZ sediments (0.5% in GSR and IOM contract areas [Mewes *et al.* 2014]; 0.49% in NORI-D [TMC data included in Paulikas *et al.* 2020]; 0.6% in BGR contract area [Volz *et al.* 2018]). TOC declines sharply in the first few cm of sediment, but we use its surface value, ~0.5%, as a conservative estimate of displaced carbon. Flocculation will occur in the benthic sediment plume owing to the high concentration of particles and presence of organic material, thereby hastening settling, whereas it is not expected in the midwater plume due to its more dilute particle content, high discharge velocity, and low availability of organic matter in receiving water. Consequently, experiments indicate that 99% of benthic plume sediment may resettle within 1-2 months and within 1-100 km, with plumes rising not more than 100-200 m (Jones *et al.* 2017) (modelling conducted as part of this EIA suggests that most of the benthic plume remains below 20m above the seafloor; see Section (j)); meanwhile midwater plumes should remain aloft much longer owing to their greater distance from the bottom, smaller particle size, and lack of flocculation (Muñoz-Royo *et al.* 2021). During the year or more it takes for very small particles to sink to the bottom, the smallest sediment could be transported 1,000 km or more depending on currents and turbulence (Muñoz-Royo *et al.* 2021). If the residual non-settled carbon remains afloat indefinitely, it may reach the surface and potentially the atmosphere, only after centuries of thermohaline circulation. Based on these parameters, allowing a +/- 25% variation in total disturbed area, and assuming 1% of carbon in displaced sediment from the Collector Test eventually rises to the surface, the expected emissions from the Collector Test would be 1.4 metric tons of CO_2, with a likely range of 0.5-3.5 metric tons depending on disturbance depth and area.

By comparison, Orcutt *et al.* (2020, Supplement Information) estimated the carbon suspended in plumes by disturbance of 3,000 km^2 (~6,000 times larger than the Collector Test area) to a depth of 10 cm (our high-end estimate) to be 5.2×10^5 metric tons. If 1% of this reaches the atmosphere and becomes atmospheric CO_2, this is equivalent to **3.1 metric tons of CO_2** that would be released from a 4.9 x 10^5 m^2 Collector Test-sized area, consistent with our calculated range.

(c) Release of dissolved CO2 when abyssal seawater is brought to the surface

Colder, higher-pressure abyssal seawater containing higher levels of dissolved CO_2 will be entrained as nodules are lifted to the surface. This water will be naturally depressurized and slightly warmed as it is filtered out at the surface and eventually discharged back into the ocean. The time spent at the surface's lower pressures and higher temperatures allows some equilibration with atmospheric CO_2, resulting in the release of some dissolved inorganic carbon (DIC) into the atmosphere. Additionally, the porous structure of nodules contains abyssal seawater whose CO_2 content will enter the atmosphere by equilibration with nodule-hold water during collection, or eventually by evaporation during onshore processing of collected nodules.

CO2SYS (Lewis & Wallace 1998; see also Robbins *et al.* 2010) was used to calculate ocean carbon chemistries, specifically the changes in DIC and CO_2 partial pressures between NORI-D abyssal conditions and the different temperatures to which abyssal water could be exposed at surface pressure. To express a maximal boundary, we assume full equilibration, and that the entire difference in DIC would be emitted to the atmosphere. Bottom water which is entrained as nodules are lifted into the riser could release some CO_2 to the atmosphere while exposed to air bubbles for 545 s or less during the final 2500 m of ascent, and then to ambient air for another estimated 300 s in the hold of the surface-production vessel. These times are much lower than the time required to equilibrate, but the time spent at the surface can affect the extent of temperature rise. Calculations use an estimated average hold temperature for the Collector Test of 6.13°C, with a stress test at 8.13°C. Volume and weight of abyssal seawater pumped during 259 hours at 0.097 m^3/s sum to an expected total of 90,443 m^3 or 92,613 kg of seawater. The calculation of CO_2 flux is very sensitive to input parameters, such that slight differences in temperature, pH, alkalinity or other input parameters can produce different results. Therefore, a range of in-situ values was used representing areas in and surrounding the CCZ, including NORI-D, with parameters 'total alkalinity' ranging from 2380 to 2482 umol / kg water and 'total DIC' ranging from 2172.5 to 2340 umol / kg water; initial depth 4300 m, temperature 1.5°C, salinity 34.67, total phosphate 2.25, and total silicate 148.37, was specified. An upper bound of CO_2 release was calculated by noting the change in DIC when fully equilibrating to surface CO_2 partial pressure of 415 uatm at a specified temperature. Under the above ranges of values, the maximal noted change in DIC was 12,593 moles, for a CO_2 release of 554 kg.

Nodules also contain seawater within their pores. In tests conducted on NORI-D nodules dried at 120°C for 12 hours lost an average of 28.65% of their weight (AMC 2019), while Kuhn and Rühlemann (2021), using nodules from the BGR contract area in eastern CCZ near NORI-D, determined average salt-corrected water content to be 32% for nodules dried at 105°C for 48 hr. The mean of those two results, 30%, was used as an upper limit of the water content of the Collector Test's 3,600 metric tons of harvested nodules that might eventually equilibrate at the surface—or 1,080 metric tons of abyssal seawater. This water initially enters the nodule hold with the nodules, and some of it will mix with seawater in the hold and/or be exposed to surface air and will begin to equilibrate. If all 1,080 metric tons fully equilibrated with hold water, conservatively assumed at a warm 30°C, the maximal release is 15.1 kg of CO_2. Eventually, any pore water that does not equilibrate in the hold during the Collector Test will be released during onshore processing; one could consider the total DIC content of nodule pore water as eventually released to the atmosphere, even though this happens onshore after the Collector Test. Given a DIC of ~2215 umol / kg for NORI-D, 1,080 kg of abyssal water contains ~2392 mol DIC, equivalent to ~105 kg of CO_2.

Finally, contingency flows were modelled, in which backup flow paths may be triggered if an operational event requires halting the pump and diverting abyssal water flow. As an absolute worst case, the maximal CO_2 flux was calculated if 200 such events were to occur over the course of testing. We conservatively modelled each contingency event as sustaining maximal flow rates for 18 minutes (approximately double the riser pipe travel time from 2500 m to the surface) with full equilibration at 30°C. Under this stress test, maximal total release of CO_2 was calculated to be 299.6 kg for 200 contingency events. We hence take the total CO_2 flux from riser water for the Collector Test to be bounded by the sum of the above three calculations, 959 kg, or **<1 metric ton of CO_2.**

(d) Disruption of future carbon sequestration caused by deep-sea ecosystem disturbance

Carbon in particles that sinks into deep water may be respired by microbes or others to CO_2 (remineralized) or buried in sediments. If respired, resulting CO_2 is dissolved in deep waters and will return to the atmosphere on average about 1000 years later (Jiao *et al.* 2014); but if incorporated in sediments and undisturbed it will only reappear in the atmosphere over geological time (on the order of 125 million years) through volcanism or exposure as continental rocks and subsequent weathering (Jiao *et al.* 2014, Jiao *et al.* 2010). Microbes also play a role in sequestering methane (Armstrong *et al.* 2012), but that is not significant in the CCZ's aerobic surface sediments. Nodule collection will cause disruption of microbial colonies through sediment stirring, dispersal, and compaction, and through nodule removal. This could temporarily reduce carbon sequestration abilities by heterotrophic and chemoautotrophic bacterial populations until they regrow and regain full function, though note that Orcutt *et al.* (2020) considered this impact on carbon sequestration potential to be minimal.

POC flux plus microbial assimilation of DIC by chemoautotrophic microbes (Sweetman 2018) produces a total organic carbon content (TOC) of approximately 0.5% by weight in eastern CCZ sediments, as described above. POC flux to the bottom in the eastern CCZ is 1.5–1.8 mg C_{org} m^{-2} dy^{-1} between 10° and 15°N, declining to 1.3 mg C_{org} m^{-2} dy^{-1} north of 15°N (Volz *et al.* 2018). Experiments conducted in the eastern EEZ (Sweetman *et al.* 2019) yielded values of 0.97±0.18 mg C m^{-2} dy^{-1} and 0.59±0.10 mg C m^{-2} dy^{-1} for bacterial sequestration of phytodetritus and 1.2 mg C m^{-2} dy^{-1} for bacterial sequestration of DIC by chemoautotrophic processes. The average of the two phytodetritus results, 0.78 mg C m^{-2} dy^{-1}, plus the DIC result, 1.2 mg C m^{-2} dy^{-1}, yields 1.98 mg C m^{-2} dy^{-1}, or 723 mg C m^{-2} yr^{-1}. Microbial communities begin recovering from disturbance within years, but full recovery could take decades or longer (Sweetman *et al.* 2018) and possibly much longer owing to geochemical changes in the sediment (Vonnahme 2020). Assuming zero microbial carbon sequestration for 100 years, Collector Test disturbance of 4.9 x 10^5 m^2 would foreclose the opportunity to sequester **35.4 metric tons of carbon**. This is a maximal estimate for that time frame, considering (1) that microbial populations begin recolonizing sooner than 100 years; and (2) the POC originating as phytodetritus settling from the photic zone will continue at a rate of 1.5–1.8 mg C_{org} m^{-2} dy^{-1} and will remain on the bottom even in the absence of microbial processing.

(e) Carbon emissions from pre-Collector Test investigations

Previous investigations by the company in NORI-D during the period 2012-2020 conducted 249 box cores (each 0.75 m^2) and towed a 1.1 m wide epibenthic sled an unspecified distance while collecting 5,050 kg of nodules (4,500, 280, 190, 80 in NORI areas D, C, A and B, respectively.) Assuming the sled to have an effective collecting width of 1 m, the distance towed to collect 5,050 kg of nodules would have been 337 m, 505 m, or 1010 m at nodule densities of 15, 10 and 5 kg m^{-2}, respectively, with associated direct sediment disturbance of 337 m^2 to 1010 m^2. Assuming disturbance depth of 10 cm (the high end of our range given the use of a mechanical sled) and carbon content numbers from above, the released carbon likely ranged from 52.2 kg to 158.6 kg. The small area disturbed by box cores, 186.75 m^2, would have additionally removed 27.7 kg C (without plume formation). Total released carbon thus ranged from 79.9 kgC to 186.3 kgC. The total area impacted by the sled and box cores, 379.5 m^2 to 1,017 m^2, may have prevented the future sequestration of between 27.7 kgC and 73.7 kgC over a 100-year period. Maximal total carbon impact of pre-Collector Test investigations is thus estimated to be **108 kg to 260 kg of CO_2.**

(f) Total Emissions Estimate

Orcutt *et al.* (2020) state that proposed mining of nodule-bearing sediments and resulting resuspension of particles and organic matter will likely have a minimal impact on the ecosystem service of carbon sequestration. This is because: (i) sediments contain extremely low quantities of organic matter, most of which has already been processed by bacteria and is not particularly bioavailable; (ii) only a small proportion will be suspended into the water column; and (iii) most organic material in suspended particles will be remineralized by microbes in the water column. Our modelling is consistent with this conclusion, and we have additionally shown that the amount of CO_2 in riser water at risk of release to the atmosphere during the Collector Test is small, as is a century's loss of carbon sequestration potential.

The Collector Test's largest source of carbon emissions, 20,466 metric tons, will come from ship and equipment operations and transport, followed by at most 35 metric tons from possible future sequestration loss, up to 3.5 metric tons from sediment disruption, and < 1 metric ton from riser water. This overall climate impact, 2.05 x 10^4 metric tons, is 5 orders of magnitude less than annual ocean uptake of atmospheric CO_2, currently 2.5 ± 0.4 Pg C / year (2.5 ± 0.4 x 10^9 mt C / year) (Watson *et al.* 2020); and six orders of magnitude less than global emissions of CO_2 in 2021 (36.4 x 10^9 mt) (Statista).

7.2.2.2 Underwater Noise & Vibration

(a) Noise & vibration audit

A preliminary desktop noise and vibration audit has been conducted to characterise the potential sources of underwater noise and vibrations generated by the Collector Test and to assess likely consequential impacts to marine fauna (Appendix 4). The key objectives of the audit are to:

- Identify the key sources of underwater noise and vibration sources, assess their source levels based on literature reviews and using relevant information from comparative analogues.
- Assess the extent to which Project-generated sound fields propagate and/or attenuate to levels within the range of ambient background noise, using simple geometric spreading laws.
- Calculate distances from Project-generated noise sources to isopleths (lines of equal sound levels) at which acoustic threshold criteria for selected noise-sensitive marine fauna occur, using Project-generated noise source levels.
- Identify and assess potential Project underwater noise and vibration impacts on marine fauna, propose appropriate mitigation and management measures to reduce potential adverse impacts, and assess the residual impacts after implementation of the mitigation and management measures.
- Provide information and data from this underwater noise and vibration assessment to assist in preparation of the Environmental Management and Monitoring Plan (EMMP).

(b) Sources of underwater noise

Potential sources of Project-generated underwater noise and vibrations are:

- Underwater noise and vibrations at the sea surface due to the presence and operation of the Surface Support Vessel (SSV) and occasional presence of an Offshore Supply Vessel (OSV).
- Mid-water underwater noise and vibration generated by the Vertical Transport System (VTS in the water column occupied by VTS such as the flexible jumper hose from the Prototype Collector Vehicle (PCV) to the base of a rigid steel pipe (riser) and thence to the moon pool of the SSV. The depth of the water column affected by the VTS is about 4,300 m, including the epipelagic (0-200 m), mesopelagic (200–1,000 m) and bathypelagic (1,000–4,300 m).
- Near surface and mid-water underwater noise and vibration generated by the flow of process wastewaters (returned seawater, fine sediments, fine nodule fragments) through return pipe from the SSV to its outlet at 1,200 m below biological more productive zones. The depth of the water column affected directly by acoustic noise and vibration from the wastewater return pipe includes the epipelagic zone (0–200 m), mesopelagic zone (200–1,00 m) and a 200-m-long sections of the upper bathypelagic zone (i.e., 1,000–1,200 m).
- Underwater noise and vibrations generated at the ocean floor and benthic environment by the PCV undertaking nodule collection, and by PCV-onboard noise sources such as water jet pumps, suction pumps, nodule separation units, electric-driven tracks, etc.

- High-frequency underwater noise produced by navigation and positioning systems or geophysical instruments such as Multibeam Echosounders (MBES), Acoustic Doppler Current Profilers (ADCP), Ultra-short Baseline (USBL), Long Baseline (LBL), etc.

(c) Key Collector Test components

The Collector Test system has three main components, which follow the general mining sequence from seafloor nodule harvesting through nodule lifting via the vertical transport system (i.e., the riser) to the surface support vessel:

- Seafloor: Nodule harvesting using a Prototype Collector Vehicle (PSV).
- Water column: Vertical Transfer System (VTS) - riser and airlift system
- Surface: Surface Support Vessel (SSV) and offshore supply vessel (OSV).

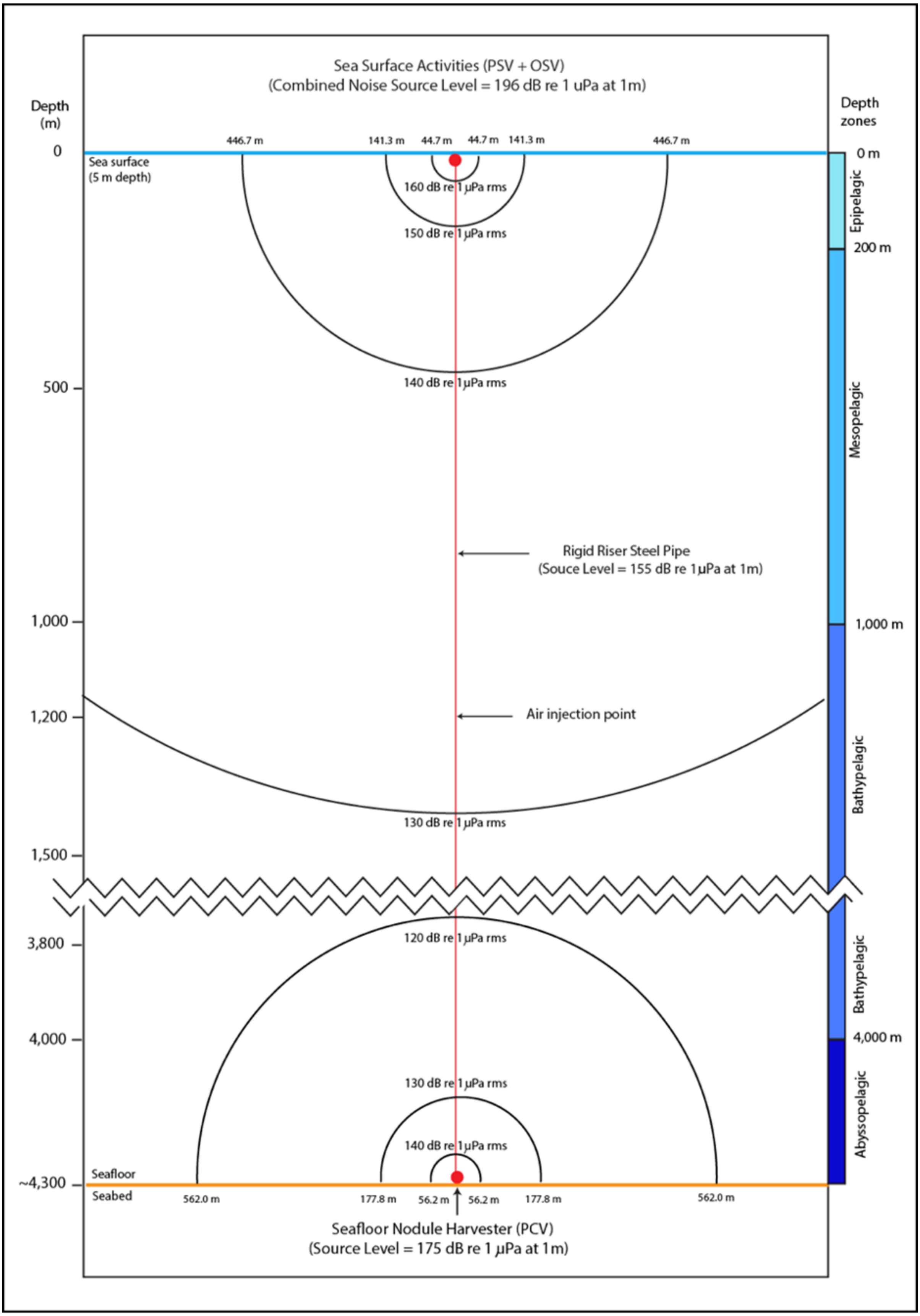
(d) Key sound fields

Underwater noise source levels for each key component of the Collector Test have been calculated in the noise audit report (Appendix 4). A visualisation of Project-generated underwater sound fields is shown in Figure 7-1, which presents a diagram of the extent of the sound fields generated by the louder noise sources resulting from Project related activities.

In Figure 7-1, both the horizontal and vertical distances to isopleths of interest including isopleths that represent acoustic threshold criteria for selected marine fauna. For example, distances to the 140 dB re 1 µPa rms above which disruptive behavioural effects on baleen whales may be expected encompasses an area of 0.62 km^2 of the ocean around the Project's surface vessels (i.e., SSV and OSV in DP mode). Similarly, the 130 and 120 dB re 1 µPa rms isopleths, encompass areas of 19.5 km2 and 62.7 km2, respectively. The apparent large area of 62.7 km^2 encompassing the 120 dB re 1 µPa rms isopleth is similar to that produced by a large Panamax tanker at cruising speed with a source level of about 190 dB re 1 µPa at 1m. The 140 and 150 dB re 1 µPa rms isopleths are not shown around the riser, as they are close to the rise and are masked by in its upper and lower sections by the non-impulsive continuous broadband noise fields emanating downwards and upwards from the Project's surface vessels in DP mode and the nodule collector (PCV), respectively.

The predicted sound fields for the collector test are described in Figure 7-1 and will be verified and refined during the Collector Test and a comprehensive noise model developed for full-scale production. The main concerns with noise related impacts are the effects on the physiology and behaviour of marine biota, this is discussed in Section 8.2.2.1.

Figure 7-1. Predicted sound fields from key Collector Test components



The use of simple geometric propagation and transmission loss equations to calculate distances to isopleths of acoustic threshold criteria for selected noise-sensitive marine fauna is a simplification. However, conservative values have been used so that a reasonable idea of potential impact zones of Project-generated underwater noise could be determined and allow impacts on marine fauna to be assessed.

This summary above presents the results and findings of a desktop study (Appendix 4). Underwater noise and vibration measurements and detailed acoustic modelling were not undertaken.

7.2.2.3 Light

The camera systems on the PCV and ROV will be equipped with high intensity lights to illuminate the surroundings so that operations can be monitored and recorded. Recent studies have identified light pollution from vessels and ROVs as a potential environmental impact associated with mining activities (e.g., Christiansen *et al.*, 2020). However, risk assessments indicate that the scale of impact from artificially generated light from exploration activities will be localised and any risks are generally assessed as 'low' in terms of ecosystem-level effects (e.g., SPC, 2013; Verichev *et al.*, 2014; Washburn *et al.*, 2019). Howard *et al.* (2020) found that artificial lights from ROVs during exploration activities present a low level of risk and any effects will be temporary, however the effects of light for a commercial-scale system requires further analysis.

It is unlikely that artificial light will lead to direct mortality in fishes and invertebrates, and only for certain species will it induce subtle behaviour changes including attraction, avoidance, and in rare cases stress from vision impairment (Kochener *et al.*, 1998; Gordon *et al.*, 2002; Widder *et al.*, 2005; Ryer *et al.*, 2009; Weaver and Billet, 2019).

Still, there is some evidence to suggest that shrimp associated with hydrothermal vents are sensitive to light from ROVs which provides a potential proxy to understand the effects of artificial light in abyssal ecosystems. The shrimp were shown to be well adapted for the detection of low light (Van Dover *et al.*, 1989; Collin *et al.*, 2000), however considering that light effects are intermittent, these effects did not significantly influence shrimp populations (Copley *et al.*, 2007; Gollner *et al.*, 2017). These findings highlight that adaptation to low light in certain species does not imply high vulnerability to artificial light, or the potential for ecosystem-scale changes.

We are unaware of any evidence to suggest that artificial light would lead to significant changes in ecosystem functioning within or beyond the area designated for Collector Test activities. Considering the small scale and short duration of Collector Test activities, it is reasonable to characterise the impacts from artificial light as negligible.

A more comprehensive assessment of the impacts of artificial light will be provided within the commercial EIA for the full-scale mining system.

7.2.2.4 Water Quality

(a) Leakage of fluids from underwater equipment

In the unlikely event of a leak, all chemicals used in submersible equipment (that is, ROV and PCV), will be compliant with OSPAR (2009) standards, ensuring compliance with established international standards for acceptable levels of environmental performance of chemicals in terms of toxicity, persistence, and bioaccumulation.

(b) Return Water Temperature

The temperature of return water is influenced by thermodynamic processes during vertical transport of seawater within the riser system (Allseas, 2020). Strong crossflows will result in convective cooling of the pipe, bringing the temperature of return water to within a few degrees of ambient seawater temperature (Rzeznik *et al.*, 2019). It is estimated that return water discharge temperature will be approximately 3°C greater than ambient seawater temperature at a depth of 1200 m (Figure 3-16). Thermal pollution has been raised as a potential pressure on deep-sea ecosystems (e.g., Miller *et al.*, 2018).

Muñoz-Royo *et al.* (2021) found return water plumes to be highly turbulent at the point of midwater discharge and rapid mixing to occur with the ambient seawater. It is expected that any localised temperature changes will return to ambient levels (±1°C) within hours (see Muñoz-Royo *et al.*, 2021). It is unlikely that slightly warmer seawater around the point of discharge would lead to direct mortality, however, it may induce subtle behavioural responses such as avoidance.

As there are no known studies on the ecological effects of temperature changes from midwater discharge activities associated with deep sea mining, proxies have been used to characterise potential impacts. Hypersaline discharge water from desalination plants has been extensively studied in scientific literature and is used as a proxy to identify the possible extent of thermal pollution. Discharge temperatures from desalination plants can be several degrees above the ambient seawater and it generally has been shown that rapid mixing occurs with receiving waters and temperatures return to background levels (< 1°C difference) within tens of metres of outfalls (Winters *et al.*, 1979; Bath *et al.*, 2004; RPS, 2009; Roberts *et al.*, 2010).

Any heat stress resulting from the midwater plume during Collector Test activities is expected to be negligible, due to the small temperature differential; temporary, due to periodic relocation of the discharge location; and localised, due to high turbulence, mixing and dilution of discharge water with ambient seawater.

A more comprehensive assessment of the impacts of thermal pollution will be provided within the commercial ESIA for the full-scale mining system.

(c) Return Water Oxygen Concentration

Dissolved oxygen increases have been identified as a potential impact of midwater discharge activities. The oxygen saturation of the water within the riser pipe will increase due to the interaction with compressed air injected to lift the nodule-sediment slurry. Consequently, a localised increase in oxygen saturation will occur near the return water outlet, located at a water depth of 1200 m. Muñoz-Royo *et al.* (2021) show that the return water will be highly turbulent, and it is expected that oxygenated seawater will mix rapidly with the surrounding seawater and dilute close to ambient levels within tens of metres of the outlet. However, the oxygen saturation level at the outlet during discharge activities is currently unknown and will be measured and compared with ambient oxygen profiles during the testing of the riser system.

Many midwater species are well-adapted to low oxygen levels (e.g., Childress *et al.,* 1998; Wishner *et al.*, 2008; Maas *et al.*, 2014; Seibel *et al.*, 2016; Wishner *et al.*, 2018). Oxygen minimum zones support complex zooplankton communities (e.g., Wishner *et al.*, 201°; Wishner *et al.*, 2020), which underpin ecosystem functioning. This has led to the assumption that oxygen increases from midwater discharge activities during the Collector Test could influence ecosystem functioning. This assumption must be considered together with broader climate effects including global ocean deoxygenation (Levin *et al.*, 2020).

In recent decades it has become increasingly clear that climate-induced global ocean deoxygenation and expansion of oxygen minimum zones threatens marine food web stability and ecosystem functioning (Levin *et al.*, 2018). Midwater discharge will take place approximately 200 m below the oxygen minimum zone that was identified from in situ oxygen profiles. Although oxygen levels could increase within the immediate vicinity of the discharge pipe, we are unaware of any evidence to suggest that this would lead to direct mortality in zooplankton species and alter ecological functioning within or immediately below the oxygen minimum zone. It is reasonable to assume that subtle behaviour changes could result during the

12 days required for the testing of the riser system for zooplankton that pass within metres of the outlet pipe.

Any localised increases in oxygen would be negligible compared with climate-induced global ocean deoxygenation (oxygen loss). Oxygen is essential for marine ecosystem functioning and oxygen loss in an already oxygen-poor environment is an increasing problem (Breitburg *et al.*, 2018; Sweetman *et al.*, 2017; Wishner *et al.*, 2018; Wishner *et al.*, 2020). We expect localised increases in oxygen from the testing of the riser system to have a negligible effect when considered as a cumulative effect together with global ocean deoxygenation, or potentially as a slightly positive effect on midwater ecosystem functioning when considered as an individual effect. However, further research is required to characterise the positive or negative effects of oxygen change in midwater environments for the commercial ESIA. In situ measurements gathered during the testing of the riser system will provide valuable insight into the oxygen levels associated with discharge water.

7.2.2.5 Sediment Plumes

Collector test activities will result in the generation of two plumes, a benthic plume in abyssal zone at >-4,000 m and mid-water plume in the bathypelagic zone at -1,200 m. The benthic plume will be generated as the PCV moves across the seabed collecting nodules disturbing bottom sediments up to a depth of 10 cm. The mid-water plume will be generated by the return of surface processing water from the SSV to the water column.

(a) Plume Composition

As the plumes originate from the same source material, both will consist of fine clay and silt material with elevated concentrations of authigenic manganese oxides. The proportion and size of broken nodule fragments in the benthic and mid-water plumes will differ as agitation in the riser pipe and surface processing will cause nodules to breakdown resulting in a higher proportion of small nodule fragments in the mid-water plume. This will be quantified during the Collector Test.

Studies have shown that the upper 10-15 cm of the sediments of the eastern CCZ are characterized by solid-phase Mn enrichments (Mewes *et al.*, 2014) and a broad upper oxic zone expanding over > 0.5 m (e.g., Halbach *et al.*, 1988; Mewes *et al.*, 2014; 2016; Wegorzewski and Kuhn, 2014; Kuhn *et al.*, 2017; Volz *et al.*, 2018; Heller *et al.*, 2018). In such oxic environments, reduction of oxides leading to the release of associated bound metals, is unlikely to occur (BGR, 2019). The mobilisation of particle-bound trace metals will instead be determined by the solubility of the particular minerals present, particle concentration and size (BGR, 2019). Conversely, adsorption of dissolved metals on to suspended particles will depend on pH, the type of minerals present, and their concentrations. Manganese and iron oxides, which are relatively abundant in CCZ sediments, are strong scavengers (BGR, 2019), which readily bind to dissolved metals.

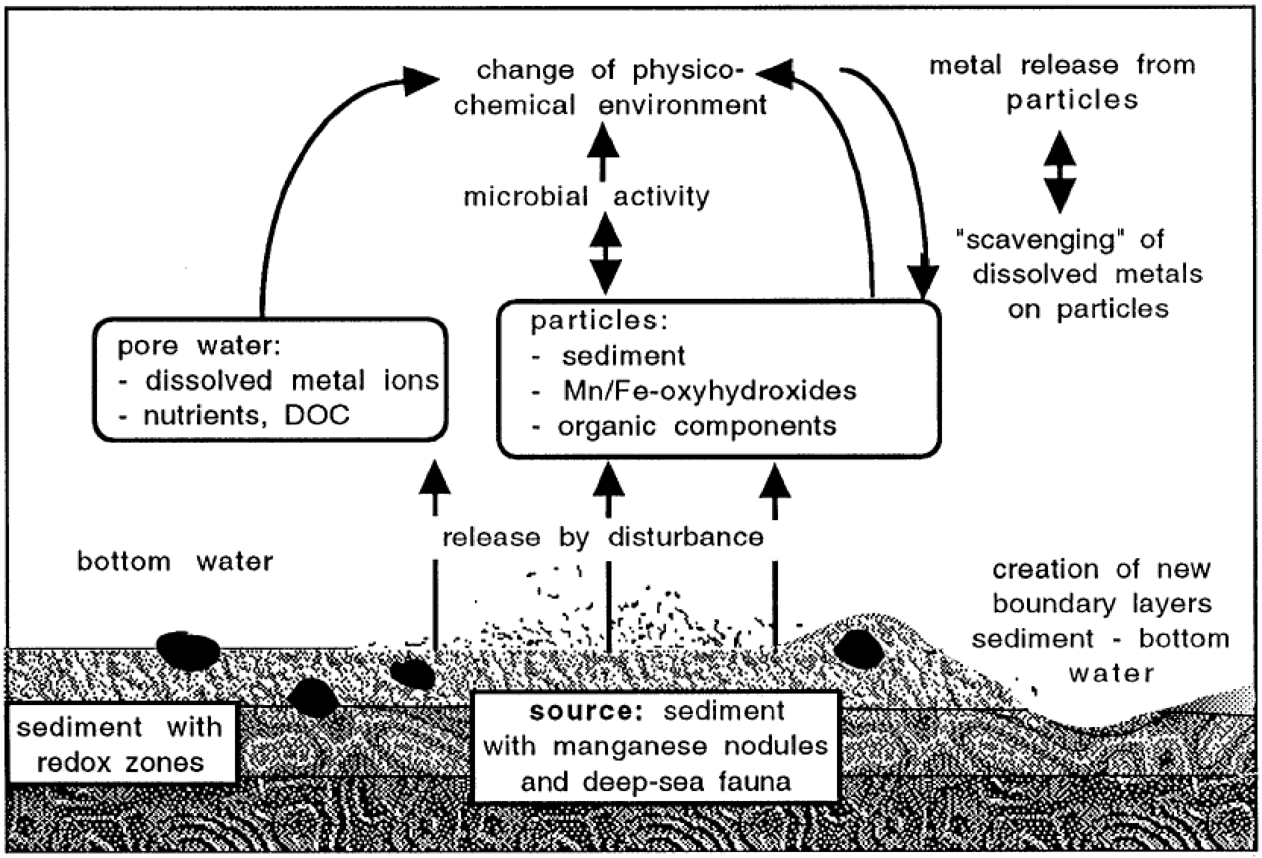
Movement of the PCV across the seabed will disturb the top ~10 cm of sediment which has mostly oxic porewater. Laboratory experiments investigating the impacts of deep-sea mining on water quality have shown an increase in particulate loads (and therefore an increase in available surface area of oxide particles) leads to increased sorption of particle-reactive elements from the water column (Koschinsky *et al.*, 2003). Koschinsky *et al.* (2001) also reported the following findings:

- Nutrients and heavy metals were released to bottom waters as the pH decreased slightly after sediment disturbance. Following this mobilisation, fast re-adsorption of heavy metals onto suspended particles occurred.
- The time required and degree of metal adsorption were strongly dependent on the type of particle available, with manganese oxides having a stronger sorption capacity for most heavy metals than the sediment particles.

- If the environment becomes more reducing, or if strongly complexing organic compounds are present, heavy metals are released rather than adsorbed which could occur where there is an increased availability of degradable organic matter or chemically reactive waste is deposited.
- The metals manganese (Mn), cobalt (Co), nickel (Ni), zinc (Zn), copper (Cu), cadmium (Cd), lead (Pb) and iron (Fe) were generally found in higher concentrations in sediment porewater than water of the overlying water column and show fast reabsorption to suspended particles after release and are strongly complexing organic agents (that is, a substance capable of forming a complex compound with other materials in solution).

These findings (summarised in Figure 7-2) indicate that if high concentrations of dissolved metals are released from pore waters during sediment disturbance, they would likely be immobilised by scavenging mineral oxides and suspended particulates found in oxic bottom waters. This hypothesis will be tested as part of the commercial ESIA baseline studies and informed by the Collector Test.

Figure 7-2. Potential impacts from the disturbance of seafloor sediment



Source: Koschinsky *et al.* (2001).

(b) Plume Model

DHI Water & Environment, Inc. (DHI) was commissioned to carry out hydrodynamic and plume modelling studies for the Collector Test assuming that the activities would be conducted in the TF (Area 6; Section 3.3.2). Models have been developed for dispersal of both the benthic plume and the mid-water plume (DHI, 2021; Appendix 5).

While the modelling approach adopted allows a differentiation between the near field (where momentum and density are controlling) and the far field (passive dispersion), sediment discharge volumes for the Collector Test are relatively small, such that only the far field processes are considered in the assessment (that is, the effects of momentum and buoyancy are assumed to effect less than one model computational cell ca. 50 m).

(c) Software

The numerical modelling involved a range of 'MIKE by DHI' models that captured, reproduced, and evaluated the deep ocean hydrodynamic processes, mid-water column and near seabed sediment spill within the TF. This necessitated coupling with a hydrodynamic sediment transport model. The model modules applied in this study are briefly described below.

- MIKE 3 FM HD is a three-dimensional hydrodynamic model is based on a flexible mesh approach and it has been developed for applications within oceanographic, coastal, and estuarine environments. The spatial discretization of the equations is performed using a cell cantered finite volume method. The horizontal discretization can combine triangles and quadrilateral elements, while the vertical is based on a combined sigma-z discretization. MIKE 3 FM HD is used to simulate the water levels, current, salinity and temperature in the area of interest over a typical January production period.
- MIKE 3 FM MT is a three-dimensional model for multi-fraction cohesive sediment transport that describes the processes of settling, erosion, transport and deposition of sediment under the influence of currents and waves. This model was directly coupled with the hydrodynamic model to include sediment plume density effects etc. in the hydrodynamics. The model includes routines for flocculation, hindered settling and fluid mud and can incorporate both cohesive and non-cohesive material in the same simulation. The MIKE 3 FM MT model calculates the resulting transport, dispersion, deposition, and re-suspension of fine sediments brought into suspension by the Collector Test works.

(d) Model Setup

Details of the hydrodynamic model developed by DHI for the Collector Test can be found in Appendix 4 an overview of salient characteristics is provided below.

Bathymetry - The model bathymetry within NORI-D has been established from the survey point cloud of depth soundings (Multibeam Survey Data, 50m resolution). Outside the survey area bathymetry data is taken from the General Bathymetric Chart of the Oceans (GEBCO_2020) grid. The GEBCO_2020 Grid is the latest global bathymetric product released and developed through the Nippon Foundation-GEBCO Seabed 2030 Project. Agreement between the multibeam survey data and the GEBCO data at the boundary of the concession area is found to be good.

Mesh - For the assessment of the short-term Collector Test, the developed mesh for the HD model of the NORI-D area has been cropped in size to focus on the TF. For the Collector Test model design, a nominal 50m mesh resolution covering the TF has been found to provide a reasonable balance between resolution of bed features and the sediment plume against computational time. This resolution is decreased progressively towards the model boundaries, with a nominal mesh resolution of 2000m at the model boundary (approximately 30km from the TF).

The resulting mesh, after completion of the various development sensitivity tests, is shown in Figure 7-3. The full model domain bathymetry is shown in Figure 7-4A, with detail of the area, where the sediment plume is anticipated, shown in Figure 7-4B.

Figure 7-3. Collector Test model mesh

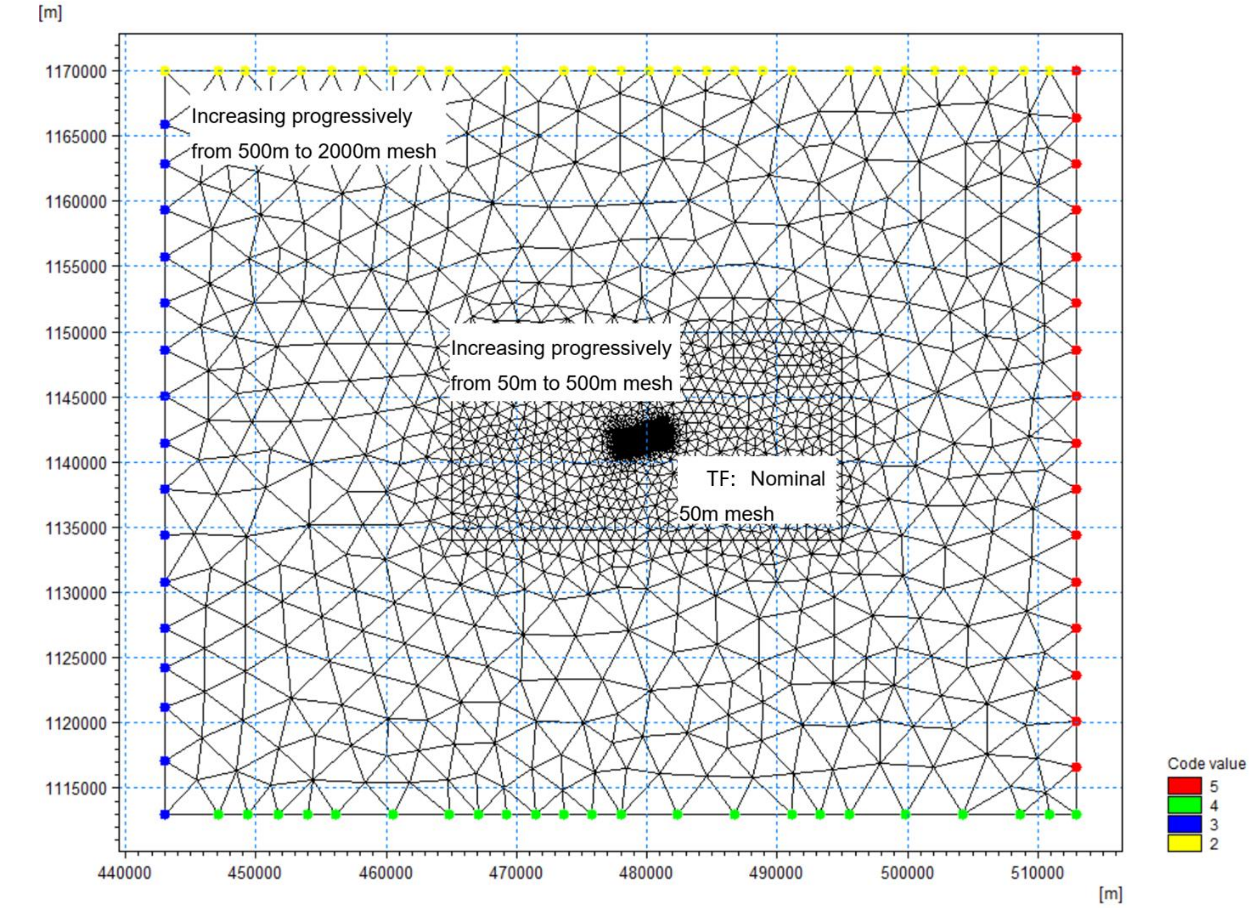
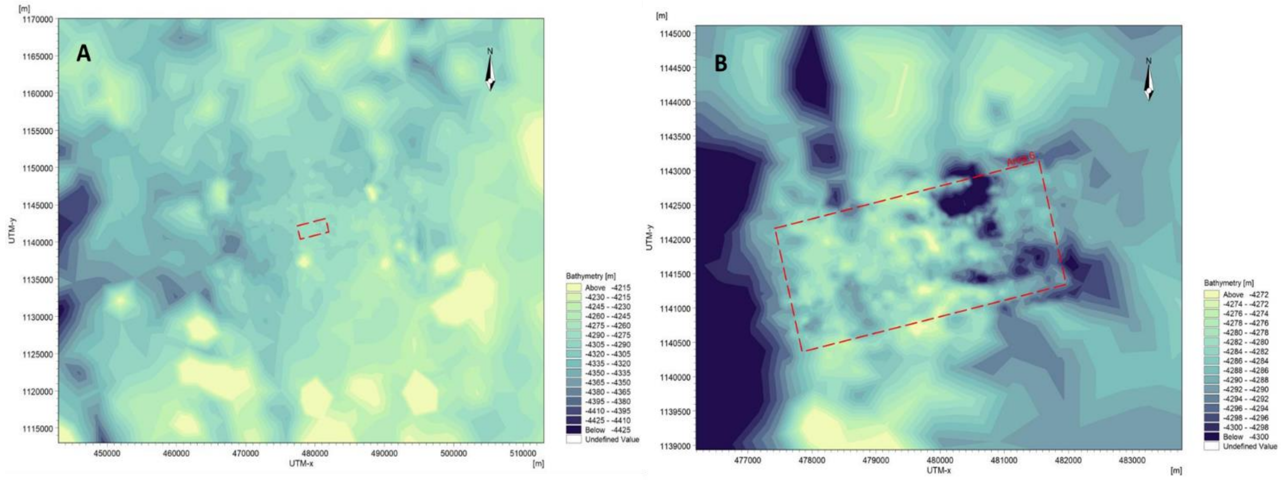
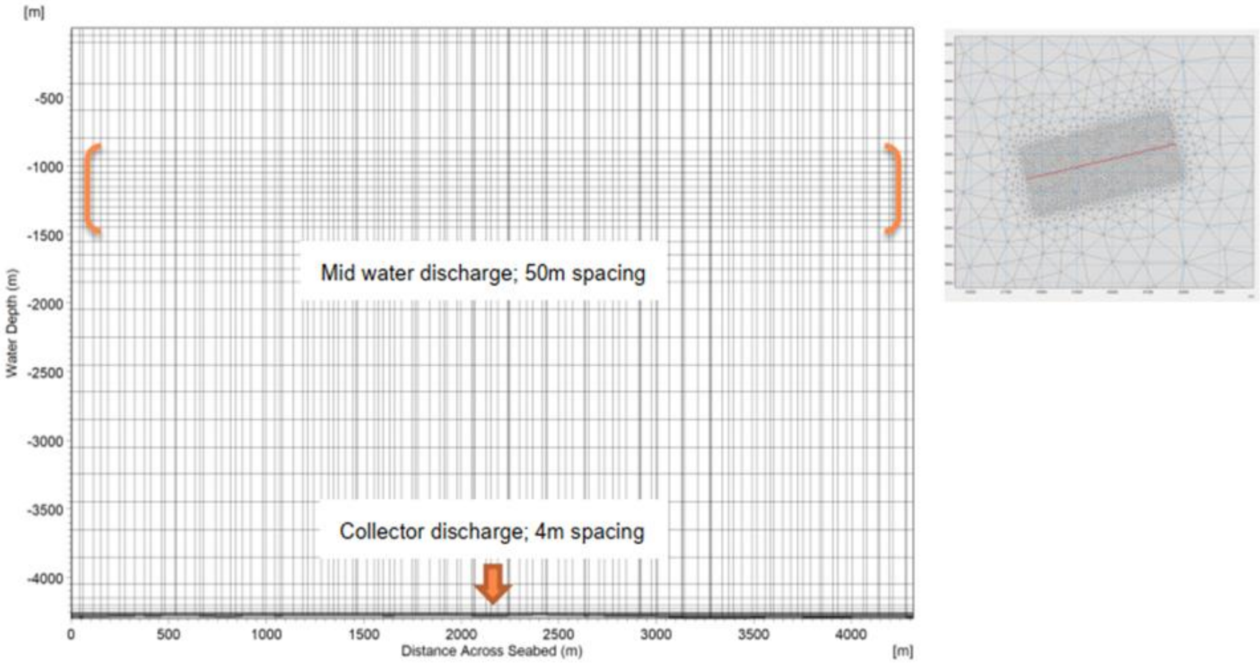


Figure 7-4. NORI-D Test Field sediment plume model bathymetry with the pilot Collector Test (A); detail of Test Field (B)



Layers - The vertical layer thickness in MIKE 3 FM can be defined either as a fraction of the water depth (adaptive layering, termed σ layers) and/or at fixed water depths (z layer). For computational efficiency, a σ layer arrangement appears appealing. However, due to the deep ocean depths of NORI-D and the relatively large local variations in depth in the TF, a combined σ-z grid was found to provide superior performance in terms of salinity, temperature and near-bottom currents. Consequently, as the ultimate purpose of the modelling is to resolve the sediment plume transport and dispersion near the seabed and near the mid-water column discharge, a combination of an adaptive layering scheme and fixed water depths has been adopted for the pilot collector model as defined. Using a mixed σ-z distribution, the model includes 51 layers over the water depth (Figure 7-5).

Figure 7-5. Longitudinal slice through test field site*



* Vertical resolution increases around the mid water column discharge (-1000m) and near the seabed.

(e) Model Validation

Since 2019, DHI has progressively developed the hydrodynamic (HD) model for NORI-D. At the time of writing, model validation has been performed against 8 months of current measurements from the NORI-D area (CSA 2020).

Validation of modelled vs. measured current speed through the water column shows generally good model performance. The hydrodynamic model will continue to be progressively improved as more data becomes available (from subsequent field campaigns). However, based on the validation results presented in DHI (2022) the hydrodynamic model is considered fit for purpose for the assessment of the relatively small scale (from a sediment spill perspective) Collector Test.

(f) Sediment Settling Characteristics

The sediment settling characteristics of the seabed material, that will be introduced into the water column as a result of the Collector Test operations, have been determined based on detailed laboratory tests of seabed sediment from the NORI-D concession area undertaken by iSeaMC (iSeaMC 2020; Appendix 6). From a modelling perspective, the results of these laboratory experiments can be summarised by a set of sediment settling velocities as a function of sediment concentration.

The sediment settling velocity formulation in MIKE 3 FM MT divides the concentration regime into three zones (Figure 7-6). For the purpose of the Collector Test the assumption is made that the concentration in the passive plume will not exceed the passive plume hindered settling limit, which is expected to be in the order of 10g/l.

Based on the iSeaMC laboratory data, flocculation is assumed not to occur at concentrations below 0.03g/l (30mg/l). Between 0.03g/l and 10g/l flocculation is assumed to occur as a function of the total concentration of floc generating material. This is consistent with the iSeaMC laboratory results for NORI-D bottom sediments at shear rates representative of the boundary of the active plume (iSeaMC 2020).

Discussion relating to the validity of this assumption against other published data is provided in DHI (2022; Appendix 4).

A comparison between modelled and measured settling velocity for three sediment fractions is shown in Figure 7-7. Overall, it should be stressed that this is a very high level of agreement between measured and modelled settling velocity. This is only possible due to the high-quality settling velocity measurements provided by iSeaMC (i.e., Average absolute % error between measured and modelled = 15% Figure 7-7).

Figure 7-6. Sediment settling velocity formulation in MIKE 3 MT (outside the hinder settling regime)

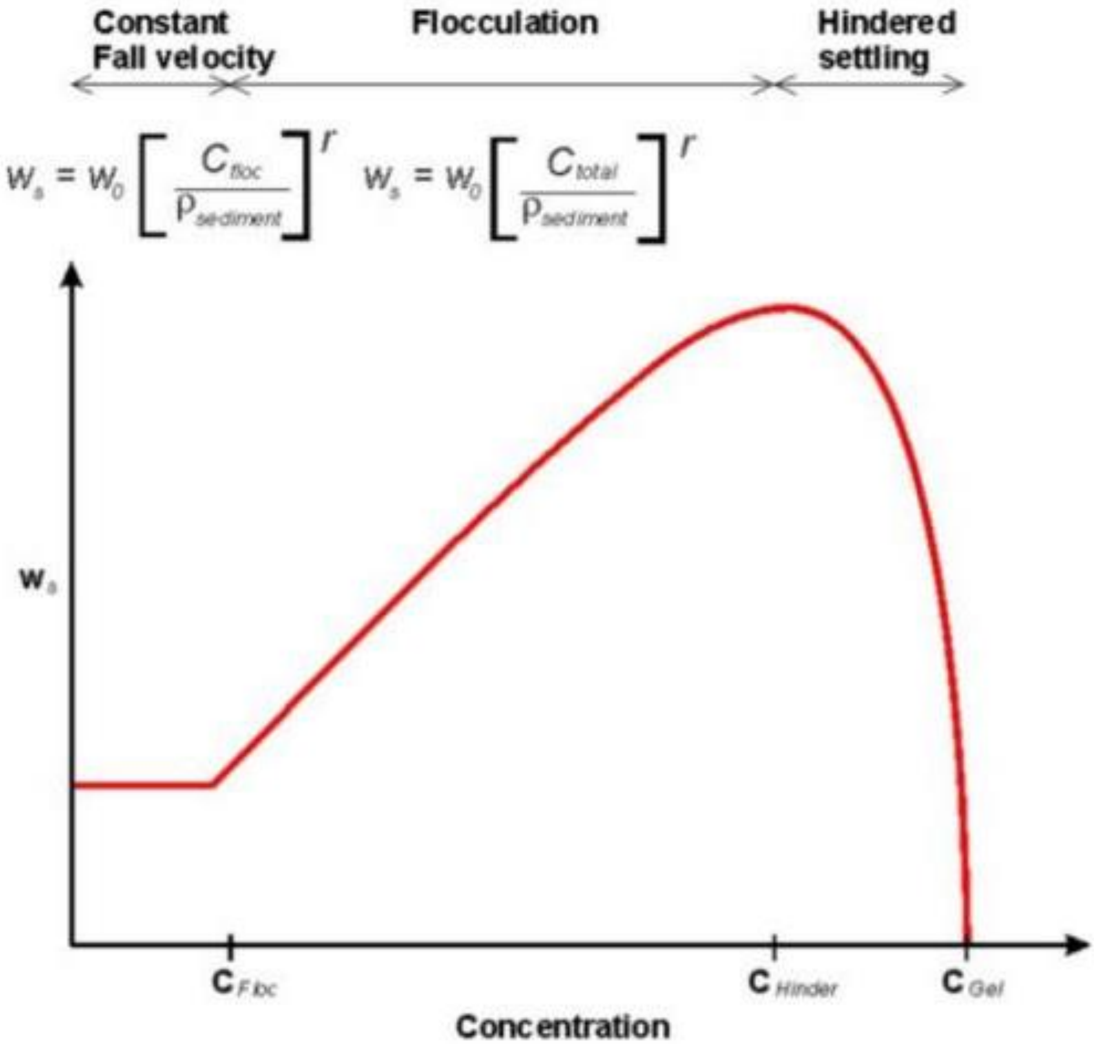
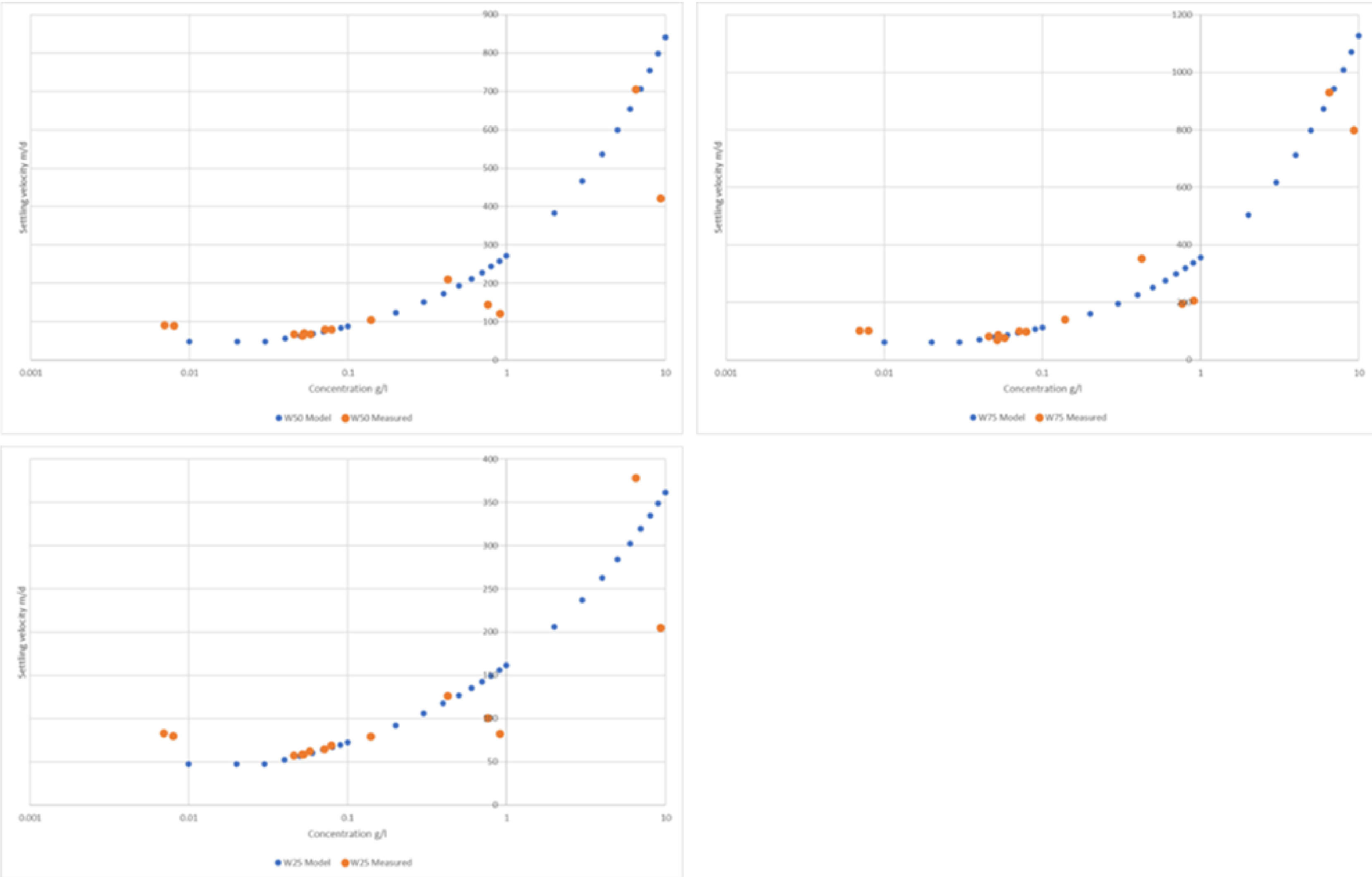


Figure 7-7. MIKE 3 MT sediment settling velocity for NORI-D bottom sediment as a function of concentration compared to iSeaMC measurements (iSeaMC 2020) for the 3 sediment fractions identified by the laboratory experiments [Average absolute % error between measured and modelled = 15%]



(g) Sediment Deposition and Resuspension Characteristics

Short term measurements of blanketing (iSeaMC 2020) indicate an initial deposition density in the order of 100kg/m^3 to 160kg/m^3. This is typical for freshly deposited fine material (DHI, 2017). However, this will tend to consolidate with time and a longer-term deposition density in the order of 180kg/m^3, which is considered more appropriate (DHI 2017) for quantification of the net sedimentation at the end of the Collector Test program. This difference between initial and longer-term deposition density should be taken into account in the interpretation of the sedimentation results, in that, initial deposition thicknesses may be up to a factor of 2 higher than those presented, dropping to the presented figures over a period of weeks after the completion of the pilot Collector Test program as a result of consolidation. Further, it is noted that data from iSeaMC indicates considerable micro scale variability in sedimentation thickness as a result of the presence of the nodules. This is expected to (at the micro scale) increase sedimentation thickness by between 30% and 100% in the depressions between nodules compared to the area average and decrease deposition over the nodules by a corresponding amount, at least until an average blanketing deposition depth of 11mm is achieved (iSeaMC 2020), after which deposition would become more uniform. The critical shear stress for re-suspension is based on the results of re-suspension laboratory experiments carried out by iSeaMC in the presence of nodules (iSeaMC 2020), converted from limiting current speed to bottom shear stress.

(h) Discharge Characteristics

At the time of simulation, the Collector Test was scheduled for January 2022. Hydrodynamic forcing for the sediment plume model simulation is thus selected from a typical January period, with January 2017 being selected as typical.

The mid-water column return flow discharge is modelled at 1000m below surface. Table 7-3 provides a summary of the key mid-water column discharge characteristics for the base Collector Test operation. These data are scaled by the production for each scenario.

Table 7-3. Mid-water column discharge characteristics

PARAMETER	VALUE
Residual nodule sediment load	1.17 kg/s (0.0006 m^3/s)
Residual seabed sediment load	1.17 kg/s (0.0005 m^3/s)
Water discharge	0.097 m^3/s (99/51kg/s)
Total Discharge including sediment	0.0981 m^3/s
Discharge temperature	7.5°C
Discharge salinity	34.67 PSU
Discharge configuration	Single 0.2m ø
Discharge velocity	3.12 m/s
Discharge orientation	Vertically down
Discharge depth	1,000 m
Mid water column discharge offset	330 m in advance of PCV.
Riser movement	Same speed as PCV

The benthic plume discharge characteristics for the base Collector Test operation are summarised in Table 7-4. These data are scaled by the production for each scenario.

Table 7-4. Benthic plume discharge characteristics

PARAMETER	VALUE
Discharge port vertical orientation	0°
Number of nozzles	4
Height above seabed	4m
Discharge port velocity	0.7 m/s
Discharge port area	1 m^2
Residual nodule sediment Load	Base 0.38 kg/s (0.0002m^3/s)
Residual seabed sediment load	Base 16.72 kg/s (0.007m^3/s)
Water discharge	Base 2.186 m3/s (2241kg/s)
Total discharge including sediment	Base 2.1932 m^3/s
Discharge temperature	Ambient at bed
Discharge Salinity	Ambient at bed
PCV speed	Varies depending on scenario
PCV track	Varies depending on scenario
Spill from tracks and track cleaning system	Not included for Collector Test sediment plume assessment as no data on spill rates, but expected to be small
Spill from collector head	Disturbance allowance of 2% of fine sediment flux = 0.02 * 17.10 kg/s = 0.342 kg/s released at seabed with no discharge velocity. This is in line with data from hydraulic suction dredging techniques.

(i) Collector Test Operations

System Test Runs (STR) (see Figure 3-26) are the only portion of the Collector Test that will generate any significant volume of sediment spill, with five (5) cases identified (Figure 7-8). Table 7-5 summarizes the key data relevant from the sediment plume modelling for the 5 sediment plume generating cases. The total Collector Test operations generating spill of will last 61.5hrs over an expected operational period of 259hrs. The total sediment spill over this operational period is approximately 259T from the mid water discharge and 4015T from the PCV on the seabed.

Figure 7-8. Spill generating runs - Configuration

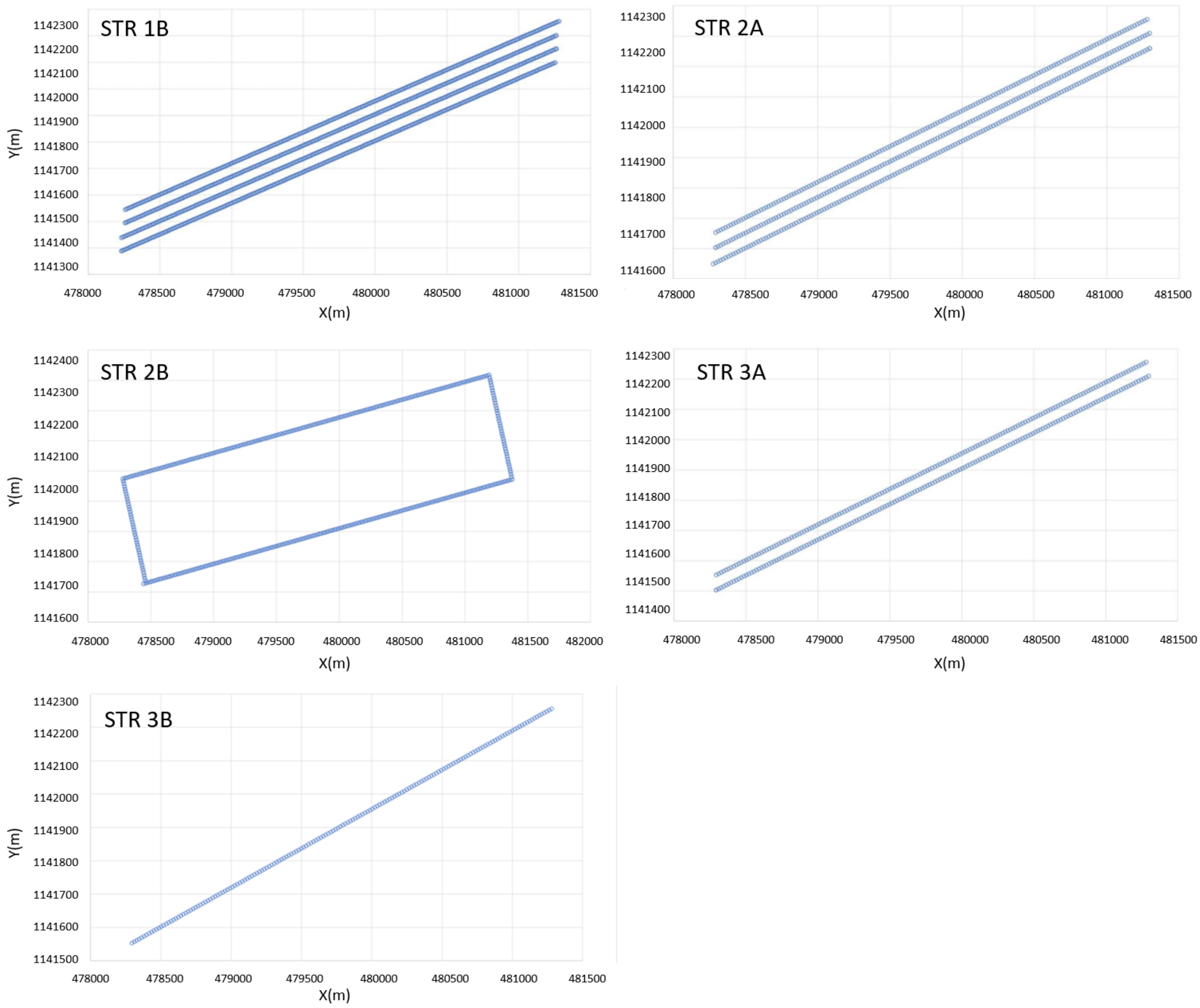


Table 7-5. Spill generating runs - Parameters

PARAMETER	VALUE				
	STR1B	STR2A	STR2B	STR3A	STR3B
Duration on seabed	26hrs	9hrs	21hrs	4.5hrs	8hrs
Run length	12.4km (4x3.1km run lines)	9.3km (3x3.1km run lines)	22.32km (Contours)	6.2km (2x3.1km run lines)	6.2km (2x3.1km run lines) but only mining on lane 2
Average harvester speed	0.14m/s	0.3m/s	0.3m/s	0.4m/s (Average of 2 lanes)	0.25m/s (Average of 2 lanes)
Turn Distance	377m (4 turns)	377m (2 turns)?	Radius 20-200m (Production does not stop)	188m (1 turn)	188m (1 turn)
Lane spacing	50m	38m	N/A	10m	50m
Run duration (at 0.14m/s)	Production 24.6hrs	Production 8.6hrs	Production 20.6hrs	Production 4.3hrs	Production 3.4hrs
Turning time	Turning 0.75hrs	Turning 0.35hrs	Turning N/A (Production does not stop)	Turning 0.1hrs	Turning. N/A (as only one production pass)

PARAMETER	VALUE				
	STR1B	STR2A	STR2B	STR3A	STR3B
Delays	26 - 24.6-0.75 = 0.65hrs insert at turning	9.0-8.6-0.35= 0.05hrs insert at turning	N/A (ignoring the 0.4hr discrepancy)	4.5 - 4.3-0.1 = 0.1hrs insert at turning	Not relevant (as only one production pass)
Net turning and delay time per turn (no production)	0.35hrs/turn	0.2hours	N/A	0.2hrs/turn	Not relevant (as only one production pass)
Production rate	686.9T in 12.4km = 55.3T/km	750T in 9.3km = 80.6T/km	1780T in 22.3km = 79.75T/km	515T in 6.2km = 83.0T/km	283.3T in 3.1km = 91.4T/km
Mid-Water discharge	Present	Present	Present	Present	Present

(j) Plume Model Results

Results are presented in terms of incremental (above background) sedimentation and incremental (above background) Total Suspended Sediment (TSS) concentration, rather than absolute sedimentation and suspended sediment concentration. This is considered normal practice for sediment plume modelling (e.g. PIANC 2010, Marnane *et al.* 2017) for cases where:

- The background sedimentation and suspended sediment concentration varies weakly in space and time. In these cases it can be assumed that the environmental receptors are adapted to this weakly varying background and will thus respond to incremental stress above this background.
- Background concentrations are sufficiently low as to not influence the settling properties of the incremental material brought into suspension by the activities.

Although the field program is ongoing at the time of writing, adequate field data is now available to confirm that it is a reasonable assumption, due to the slowly varying current conditions in the area and deep oceanic nature of the environment, that these two fundamental assumptions supporting the use of an incremental rather than absolute approach to the sediment plume modelling, are valid. Further, the available field data allows a preliminary definition of background suspended sediment concentrations and sedimentation rates for the NORI-D area to be made at least at a level of reliability suitable for assessment of the collector system sediment plume results (DHI, 2022). These estimates will be updated as additional field data is recovered and used to refine the model prior to the completion of the commercial ESIA.

Figure 7-9 to Figure 7-23 present the sedimentation and incremental TSS concentration for the individual 5 sediment producing STR scenarios for reference purposes. Results for the cumulative operations (i.e., the integral of the 5 STR scenarios) are presented in Figure 7-24 and Figure 7-25.

The incremental sedimentation is expressed in mm based upon an assumed medium term deposition density of 180kg/m^3 (see Section 5.11.1.6).

To take into account both the magnitude and duration of the incremental TSS, the incremental TSS is expressed as the percentage exceedance of 0.1mg/l, 1mg/l, 5mg/l and 10mg/l above background concentration. With the lower threshold of 0.1mg/l being representative of 10% of the calculated background concentration (see Section 5.11.2.7).

It is noted that the presentation of sediment plume results as exceedance of threshold limits is the standard and most informative approach for providing information on the characteristics of a dynamic sediment plume and its potential impacts on biological receptors. This is because biological receptors tend to respond to a function of both magnitude and duration of exposure, not just the magnitude of exposure. Unfortunately, much of the academic literature on deep sea mining plumes presents the characteristics of a plume by a dilution factor, instantaneous concentration or a statistical descriptor of the concentration which are poor descriptors for impact assessment purposes. Unfortunately, this difference in results presentation method makes direct comparison with the present results to literature difficult. To address this a comparison of the present Collector Test sediment plume results and literature values is provided in Appendix D of DHI (2022). Compensating for, amongst other factors, results presentation method, the comparison demonstrates that there is a good correlation between the plume characteristics documented in the present report for the Collector Test and plume extent found in literature.

It is relevant to describe how Exceedance of a threshold is calculated by considering the following examples:

- A concentration of 2mg/l present at a specific location for 2hrs over a 10hr analysis period would result in an exceedance of 0.1mg/l of 20%, 1mg/l of 20% and an exceedance of 5mg/l of 0%
- A concentration of 6mg/l present for 2hrs over the same 10hr analysis period would result in the same exceedance of 0.1mg/l and 1mg/l of 20%, but also an exceedance of 5mg/l of 20%

As exceedance is influenced by the duration over which the statistics are calculated, results are presented for a statistical period starting from when production commences, finishing 24hrs and 48hrs after production stops for all concentration thresholds, plus 96hrs after production stops for the lower threshold limit of 0.1mg/l. The suitability of these statistical analysis periods is discussed in Appendix A of DHI (2022). In assessing the TSS exceedance results as a function of time, it is beneficial to consider exceedance probability as a measure of the exposure of a specific location to a specific concertation threshold (e.g. 0.1mg/l). When the concentration falls below that threshold (either by the plume moving away from that location or due to dispersion and settling) the exceedance probability at that specific location will start to decline. i.e., a 2hr exposure in the first 10 hours is 20%, but a 2hr exposure in the first 10 hours over a 20hr assessment period is only 10%. Providing exposure information over different assessment periods is critical to the assessment of potential consequence of the plume as it allows a short- term concentrated exposure to be differentiated from a long-term low level persistent exposure. These situations would otherwise not be captured by basic statistical descriptors such as max concentration.

It is also relevant to highlight that, once the loading has been removed (i.e., at the end of a specific operation) and once the plume concentration has fallen below the threshold being assessed, the extent of the plume expressed as exceedance probability will not change in location or size. Only the exceedance probability will change as the assessment duration increases. This may seem counter intuitive, but by adopting in the case of the Collector Test a statistical analysis period ending 24hours (or longer) after the end of the operation the exceedance probability is presenting exposure information for the maximum plume extent at the specific threshold concentration being assessed. As the statistical analysis period extends, the percentage of the total time that a specific exposure event represents will reduce as there are no new exposure events once that initial 24hour period post operation is passed.

In Figure 7-9 to Figure 7-23 the boundary of the TF is shown, with Universal Transverse Mactator (UTM) co-ordinates overlaid, to provide scale. Incremental TSS results are presented at fixed heights above the seabed (5m and 20m) for the collector and at a fixed water depth (1050m) for the mid-water column discharge (i.e., 50m below the discharge port), as well as the sedimentation footprint generated by the benthic plume. Higher quality images can be found in the source document (DHI, 2022).

Figure 7-9. Scenario STR1B: Exceedance percentage of 0.1mg/l, from the start of production to 24 (A), 48 (B), and 96 (C) hours post-production; exceedance percentage of 1.0mg/l, from the start of production to 24 (D) and 48 (E) hours post-production; exceedance percentage of 5.0mg/l, from the start of production to 24 (F) and 48 (G) hours post-production; exceedance percentage of 10.0mg/l, from the start of production to 24 (H) and 48 (I) hours post-production at 5m above the seabed.

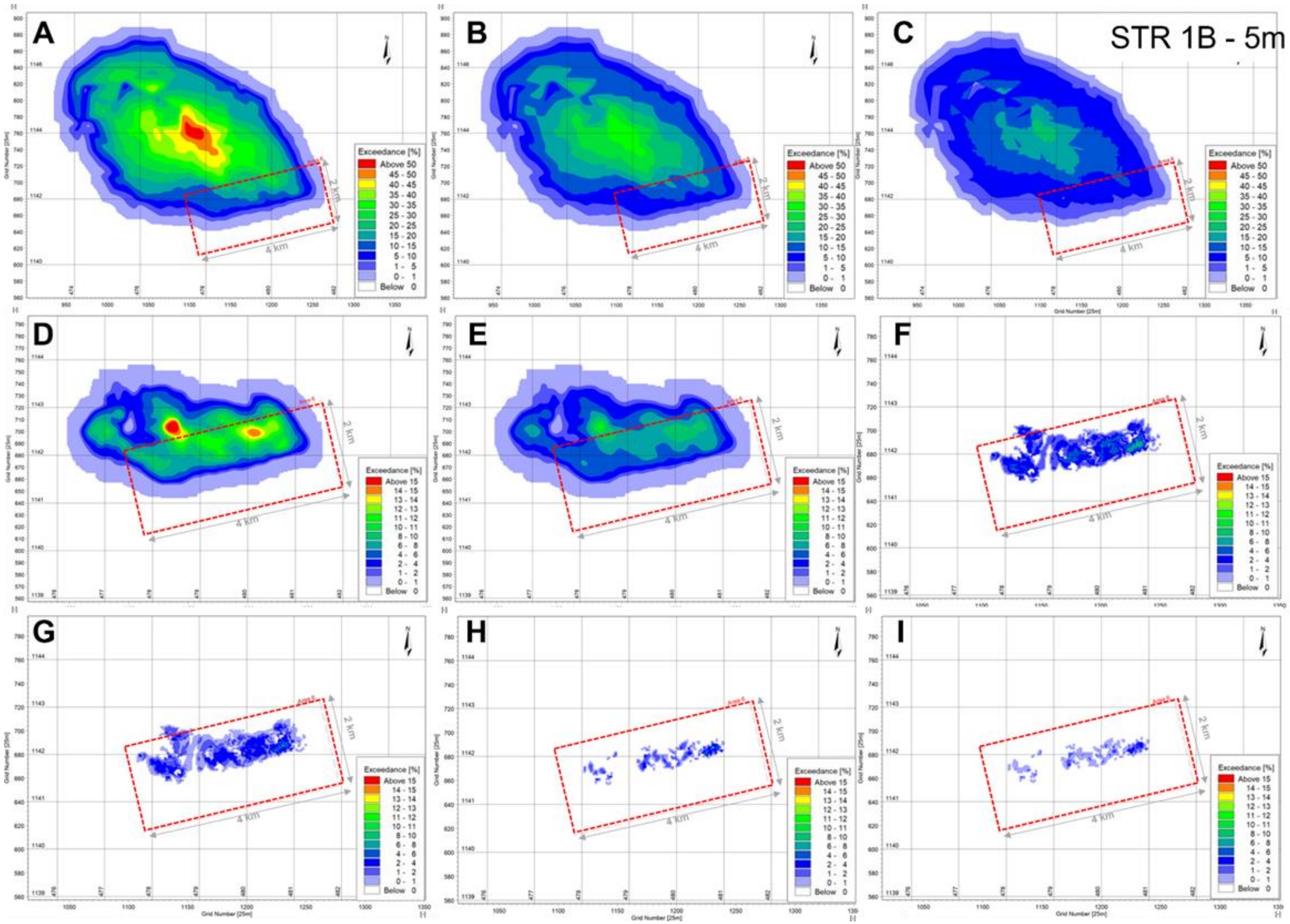


Figure 7-10. Scenario STR1B: Exceedance percentage of 0.1mg/l, from the start of production to 24 (A), 48 (B), and 96 (C) hours post-production; exceedance percentage of 1.0mg/l, from the start of production to 24 (D) and 48 (E) hours post-production; exceedance percentage of 5.0mg/l, from the start of production to 24 (F) and 48 (G) hours post-production; exceedance percentage of 10.0mg/l, from the start of production to 24 (H) and 48 (I) hours post-production at 20m above the seabed.

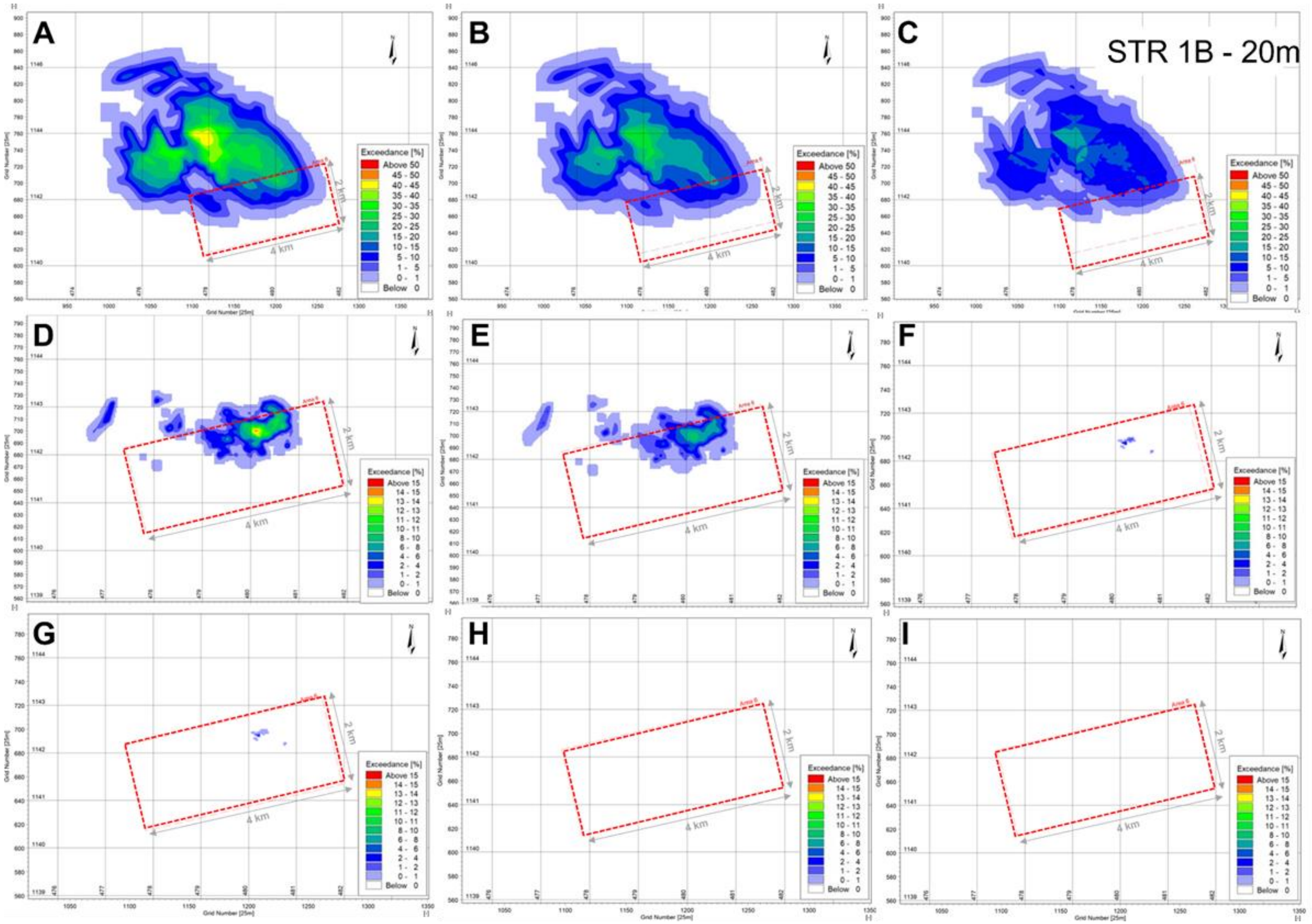


Figure 7-11. Scenario STR1B: Exceedance percentage of 0.1mg/l, from the start of production to 24 (A), 48 (B) and 96 (C) hours post-production at 50m below the mid-water column discharge location (or 1050m below the surface). Benthic sedimentation (mm) ca. 10 days after completion of operation.

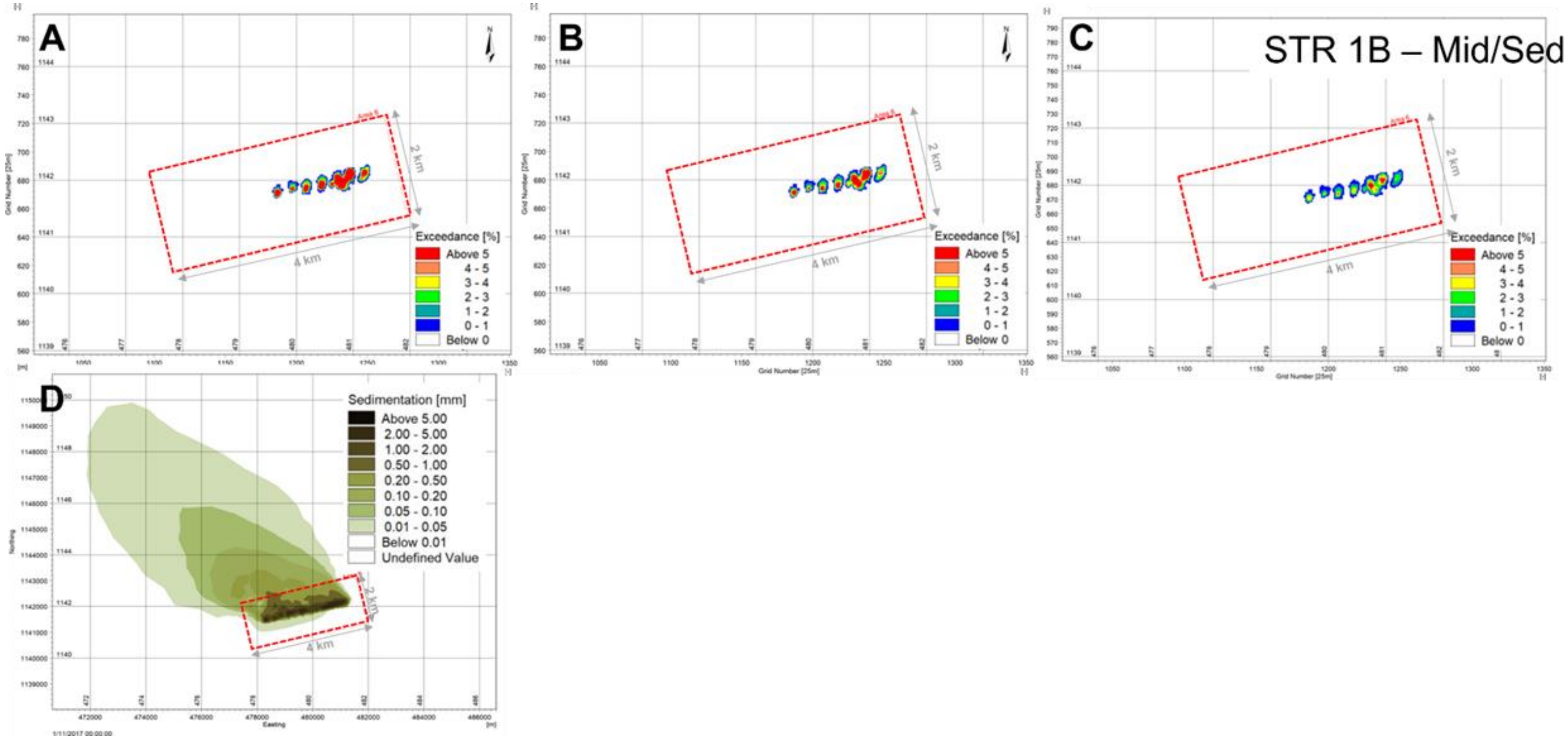


Figure 7-12. Scenario STR 2A: Exceedance percentage of 0.1mg/l, from the start of production to 24 (A), 48 (B), and 96 (C) hours post-production; exceedance percentage of 1.0mg/l, from the start of production to 24 (D) and 48 (E) hours post-production; exceedance percentage of 5.0mg/l, from the start of production to 24 (F) and 48 (G) hours post-production; exceedance percentage of 10.0mg/l, from the start of production to 24 (H) and 48 (I) hours post-production at 5m above the seabed.

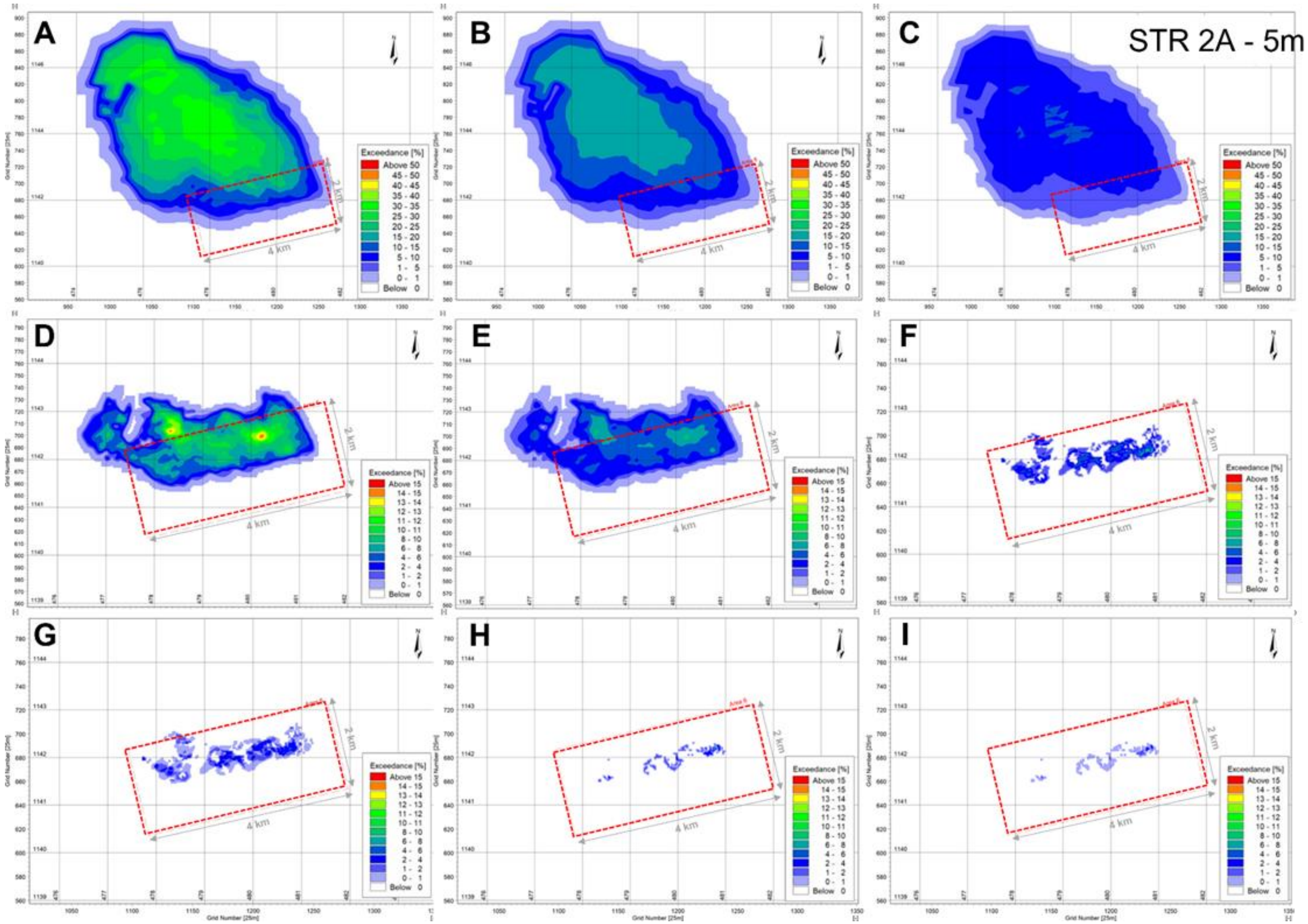


Figure 7-13. Scenario STR 2A: Exceedance percentage of 0.1mg/l, from the start of production to 24 (A), 48 (B), and 96 (C) hours post-production; exceedance percentage of 1.0mg/l, from the start of production to 24 (D) and 48 (E) hours post-production; exceedance percentage of 5.0mg/l, from the start of production to 24 (F) and 48 (G) hours post-production; exceedance percentage of 10.0mg/l, from the start of production to 24 (H) and 48 (I) hours post-production at 20m above the seabed.

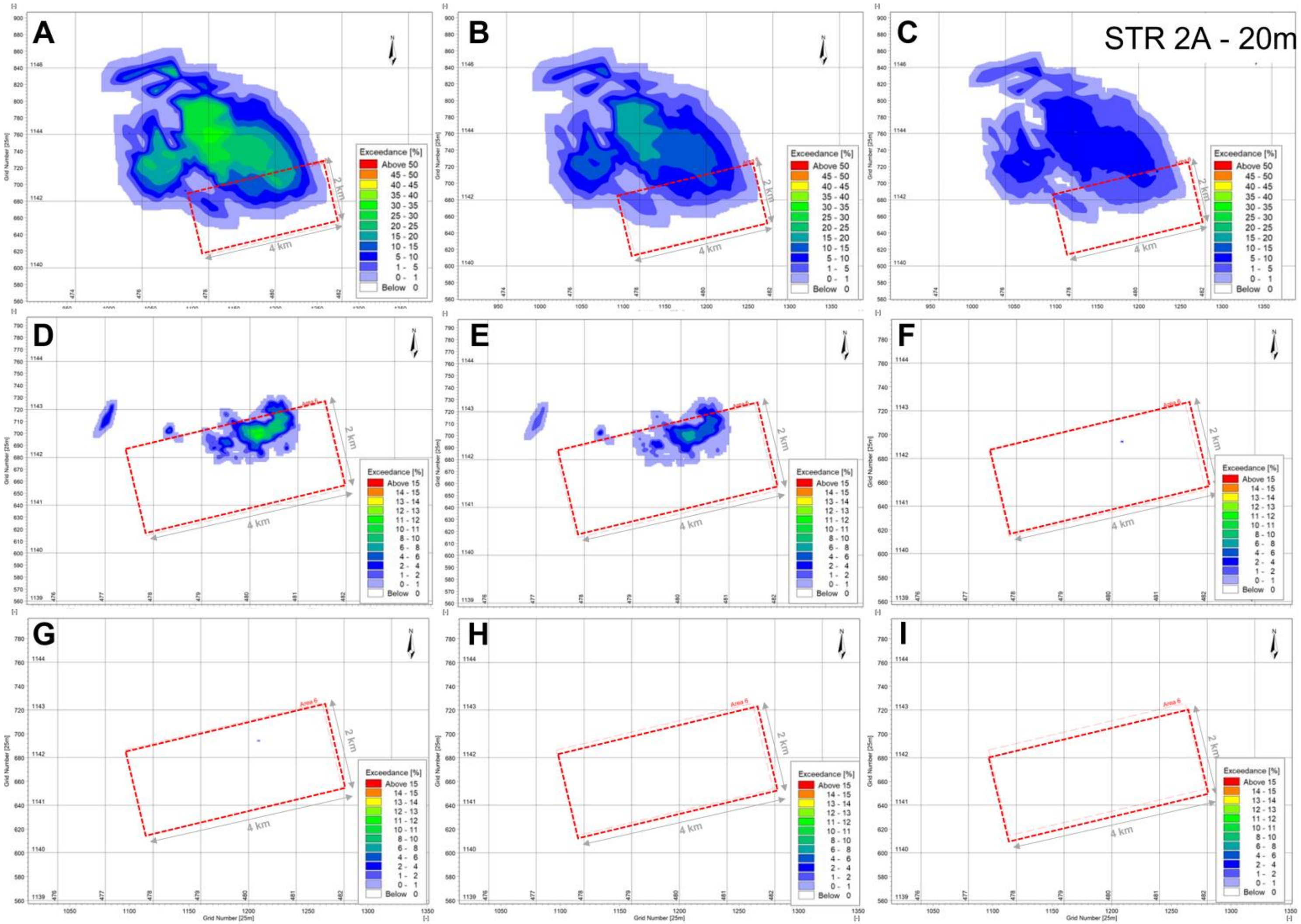


Figure 7-14. Scenario STR2A: Exceedance percentage of 0.1mg/l, from the start of production to 24 (A), 48 (B) and 96 (C) hours post-production at 50m below the mid-water column discharge location (or 1050m below the surface). Benthic sedimentation (mm) 10 days after completion of operation

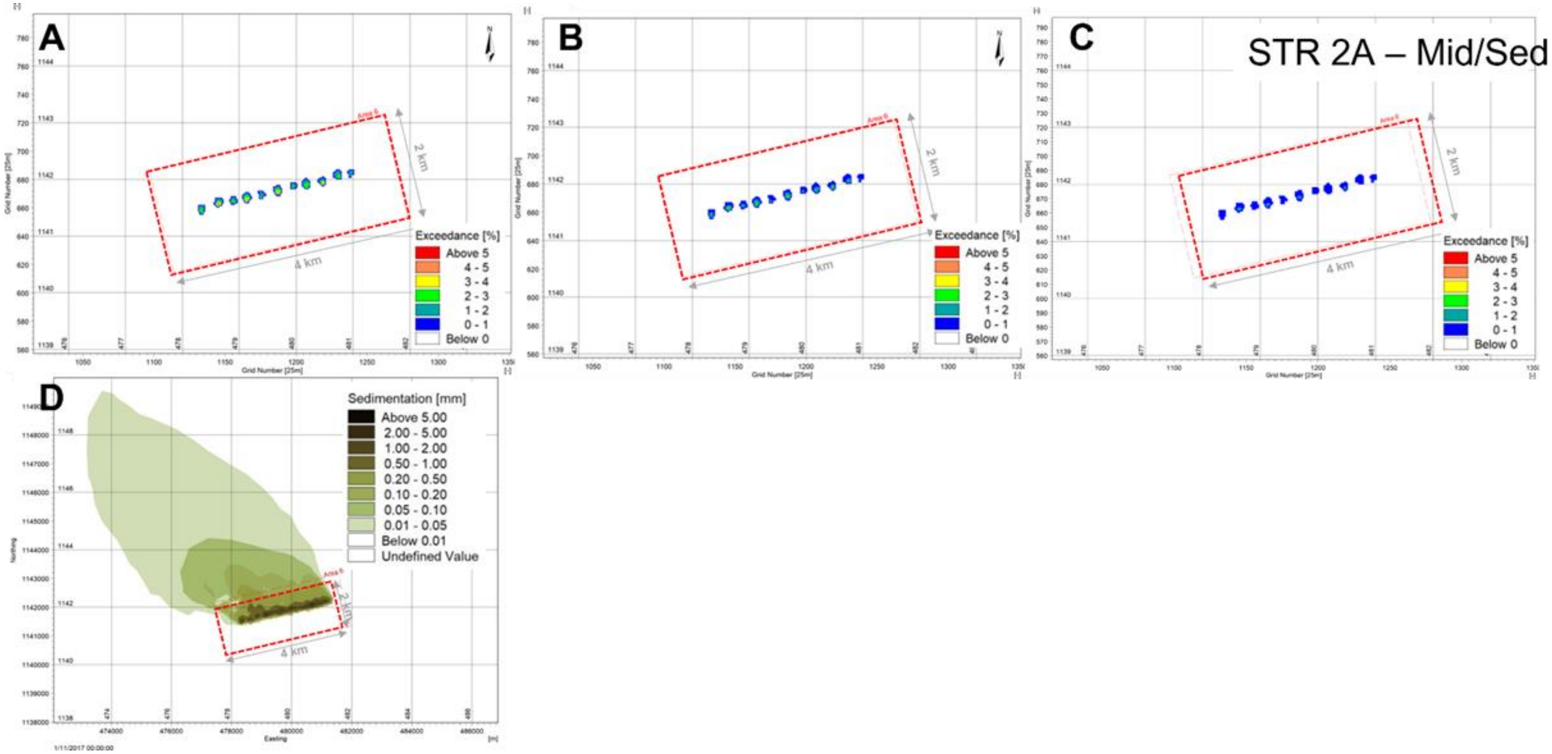


Figure 7-15. Scenario STR2B: Exceedance percentage of 0.1mg/l, from the start of production to 24 (A), 48 (B), and 96 (C) hours post-production; exceedance percentage of 1.0mg/l, from the start of production to 24 (D) and 48 (E) hours post-production; exceedance percentage of 5.0mg/l, from the start of production to 24 (F) and 48 (G) hours post-production; exceedance percentage of 10.0mg/l, from the start of production to 24 (H) and 48 (I) hours post-production at 5m above the seabed.

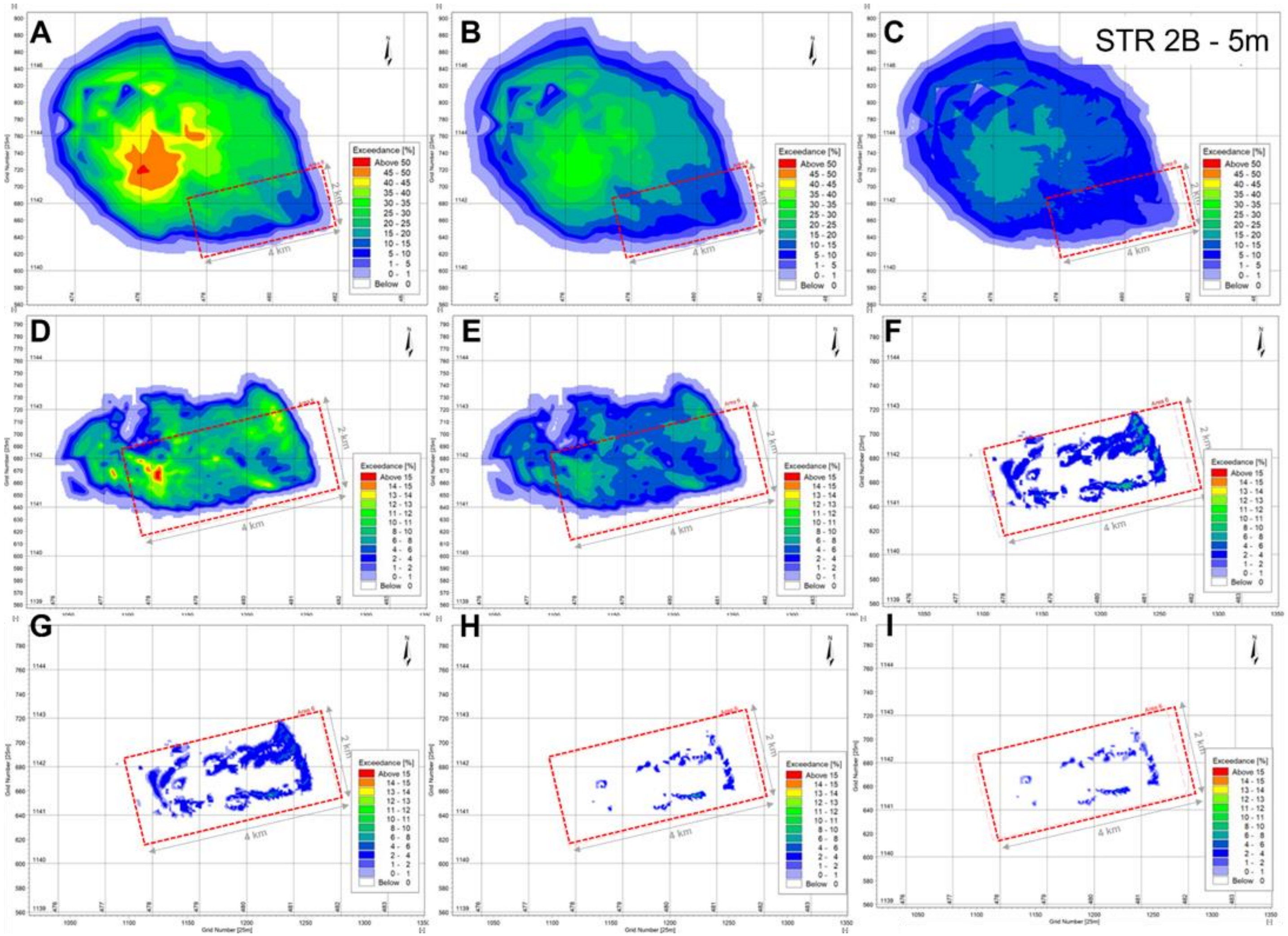


Figure 7-16. Scenario STR2B: Exceedance percentage of 0.1mg/l, from the start of production to 24 (A), 48 (B), and 96 (C) hours post-production; exceedance percentage of 1.0mg/l, from the start of production to 24 (D) and 48 (E) hours post-production; hours post-production; exceedance percentage of 5.0mg/l, from the start of production to 24 (F) and 48 (G) hours post-production; exceedance percentage of 10.0mg/l, from the start of production to 24 (H) and 48 (I) hours post-production at 20m above the seabed.

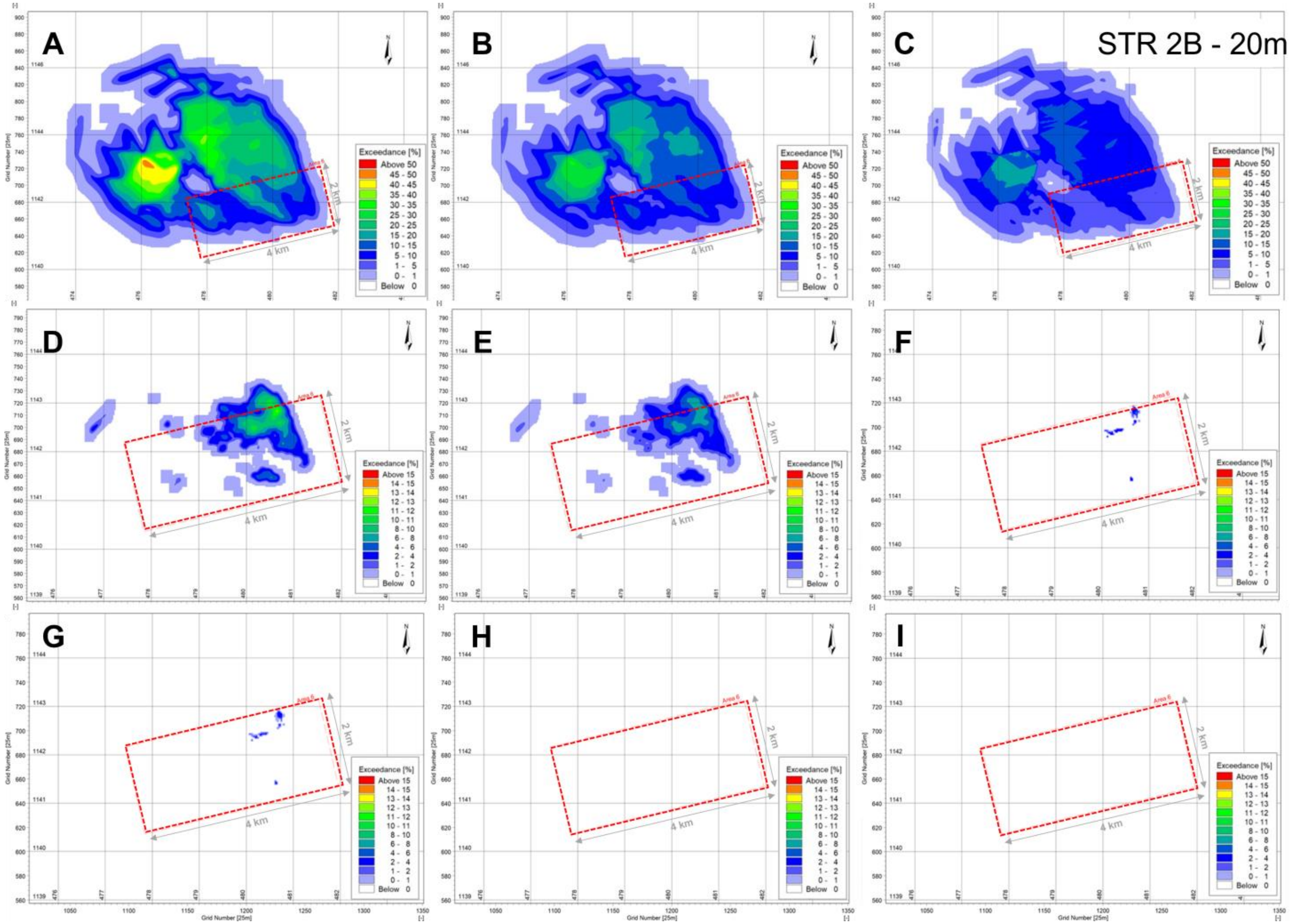


Figure 7-17. Scenario STR2B: Exceedance percentage of 0.1mg/l, from the start of production to 24 (A), 48 (B) and 96 (C) hours post-production at 50m below the mid-water column discharge location (or 1050m below the surface). Benthic sedimentation (mm) ca. 10 days after completion of operation.

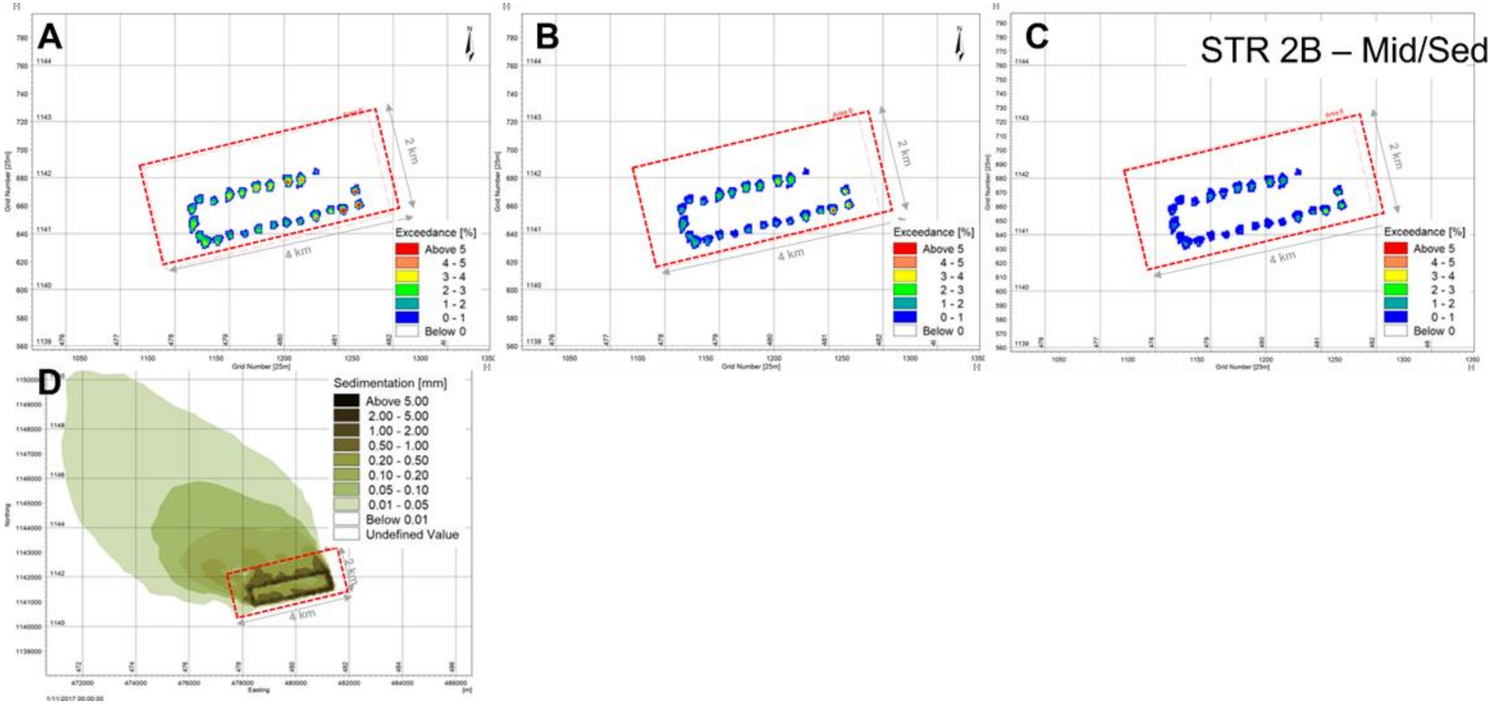


Figure 7-18. Scenario STR3A: Exceedance percentage of 0.1mg/l, from the start of production to 24 (A), 48 (B), and 96 (C) hours post-production; exceedance percentage of 1.0mg/l, from the start of production to 24 (D) and 48 (E) hours post-production; exceedance percentage of 5.0mg/l, from the start of production to 24 (F) and 48 (G) hours post-production; exceedance percentage of 10.0mg/l, from the start of production to 24 (H) and 48 (I) hours post-production at 5m above the seabed.

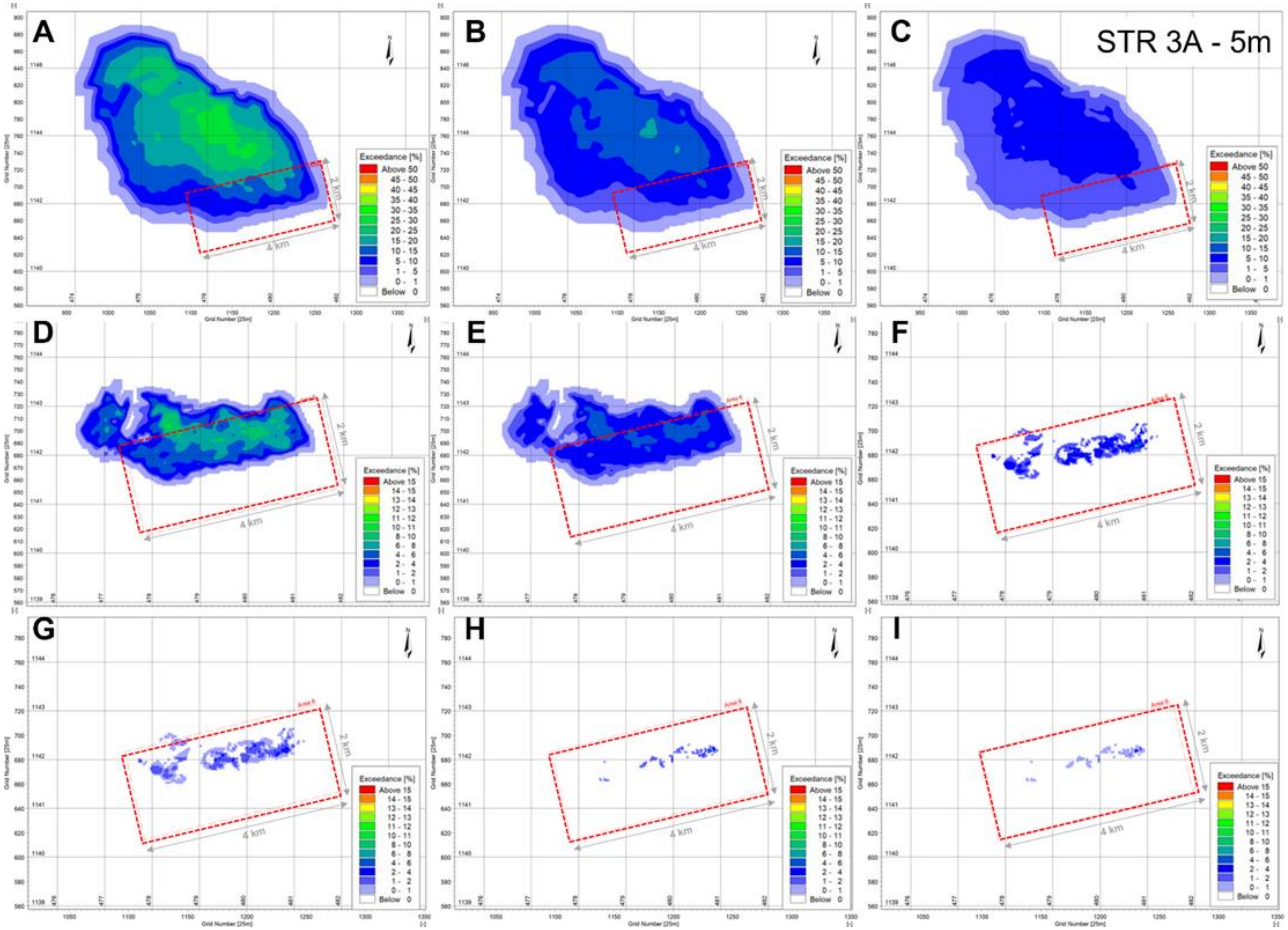


Figure 7-19. Scenario STR3A: Exceedance percentage of 0.1mg/l, from the start of production to 24 (A), 48 (B), and 96 (C) hours post-production; exceedance percentage of 1.0mg/l, from the start of production to 24 (D) and 48 (E) hours post-production; exceedance percentage of 5.0mg/l, from the start of production to 24 (F) and 48 (G) hours post-production; exceedance percentage of 10.0mg/l, from the start of production to 24 (H) and 48 (I) hours post-production at 20m above the seabed.

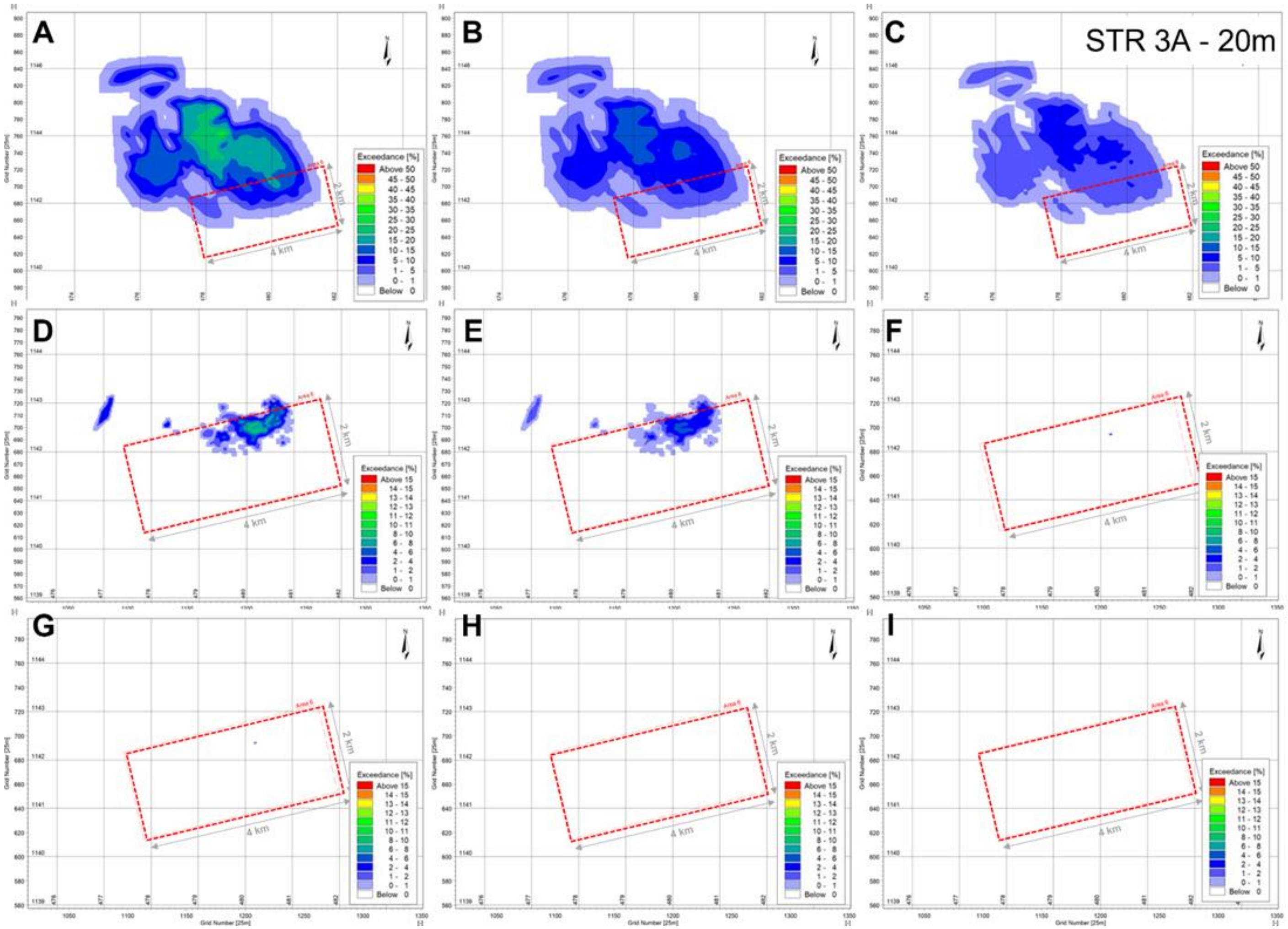


Figure 7-20. Scenario STR3A: Exceedance percentage of 0.1mg/l, from the start of production to 24 (A), 48 (B) and 96 (C) hours post-production at 50m below the mid-water column discharge location (or 1050m below the surface). Benthic sedimentation (mm) 10 days after completion of operation.

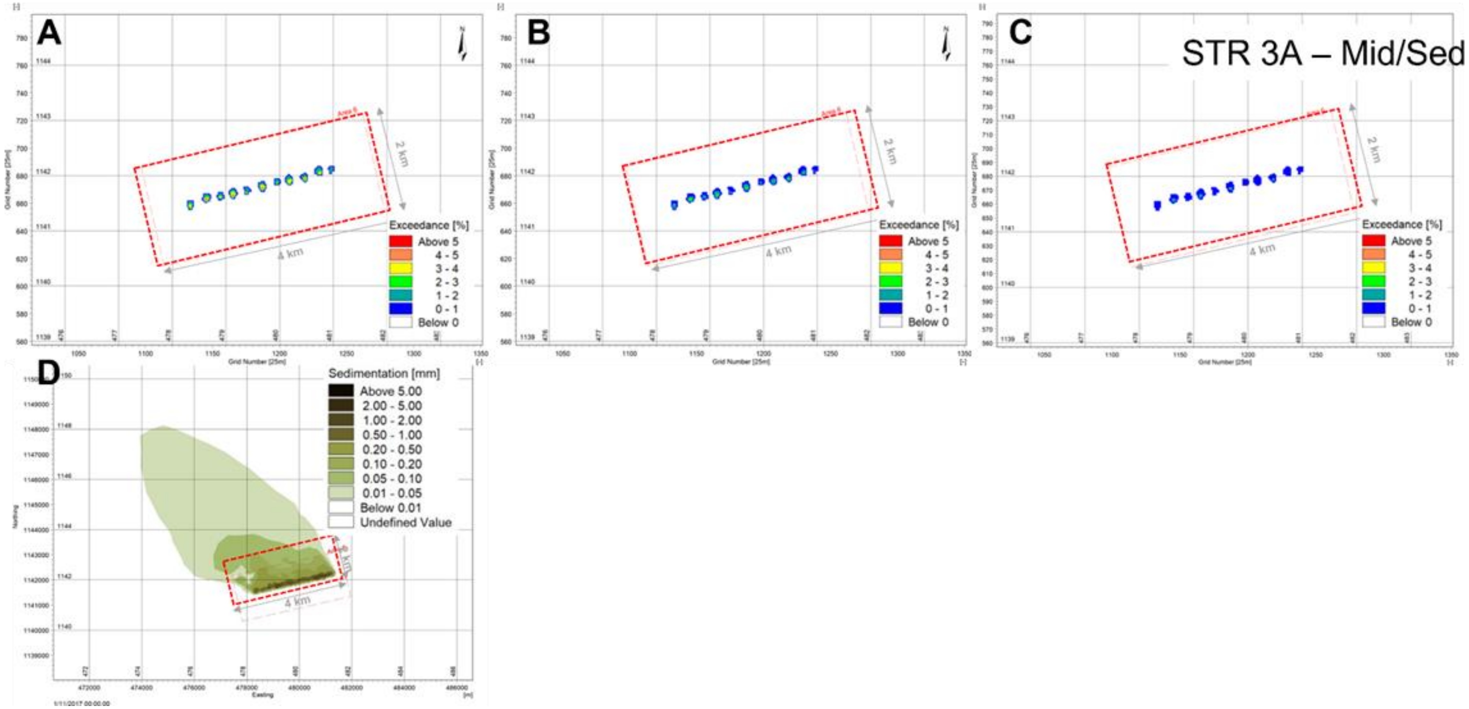


Figure 7-21. Scenario STR3B: Exceedance percentage of 0.1mg/l, from the start of production to 24 (A), 48 (B), and 96 (C) hours post-production; exceedance percentage of 1.0mg/l, from the start of production to 24 (D) and 48 (E) hours post-production; exceedance percentage of 5.0mg/l, from the start of production to 24 (F) and 48 (G) hours post-production; exceedance percentage of 10.0mg/l, from the start of production to 24 (H) and 48 (I) hours post-production at 5m above the seabed.

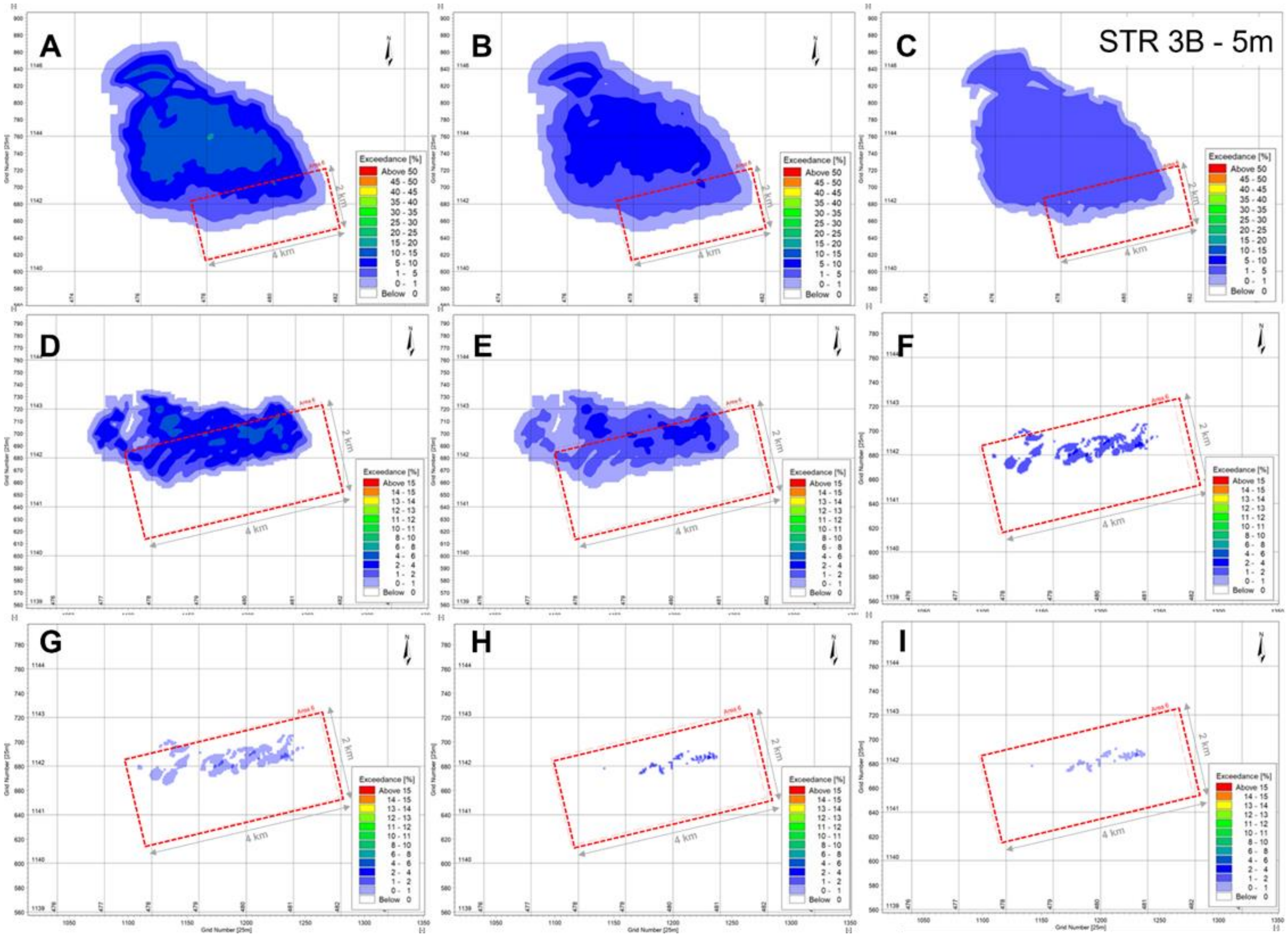


Figure 7-22. Scenario STR3B: Exceedance percentage of 0.1mg/l, from the start of production to 24 (A), 48 (B), and 96 (C) hours post-production; exceedance percentage of 1.0mg/l, from the start of production to 24 (D) and 48 (E) hours post-production; exceedance percentage of 5.0mg/l, from the start of production to 24 (F) and 48 (G) hours post-production; exceedance percentage of 10.0mg/l, from the start of production to 24 (H) and 48 (I) hours post-production at 20m above the seabed.

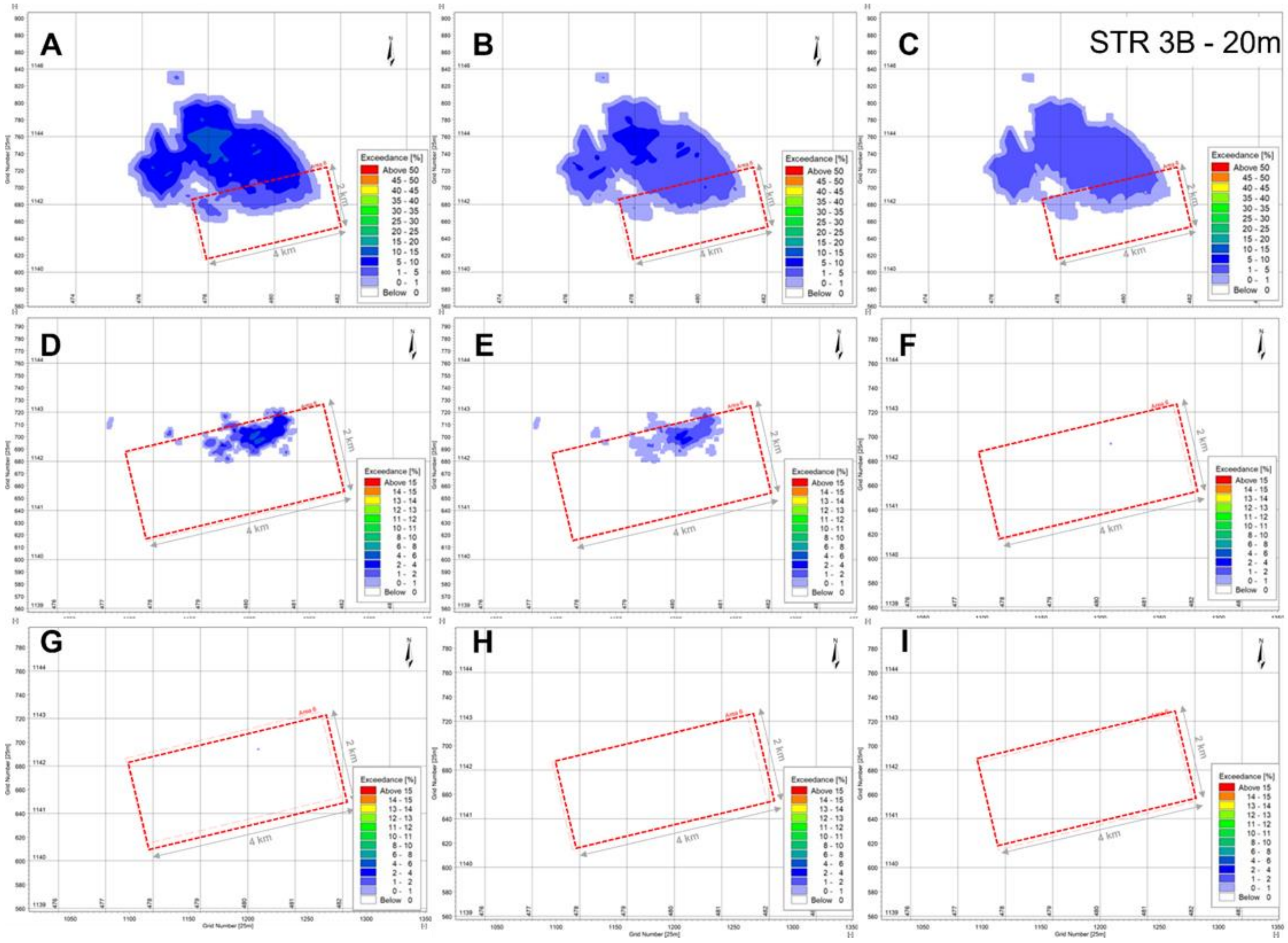
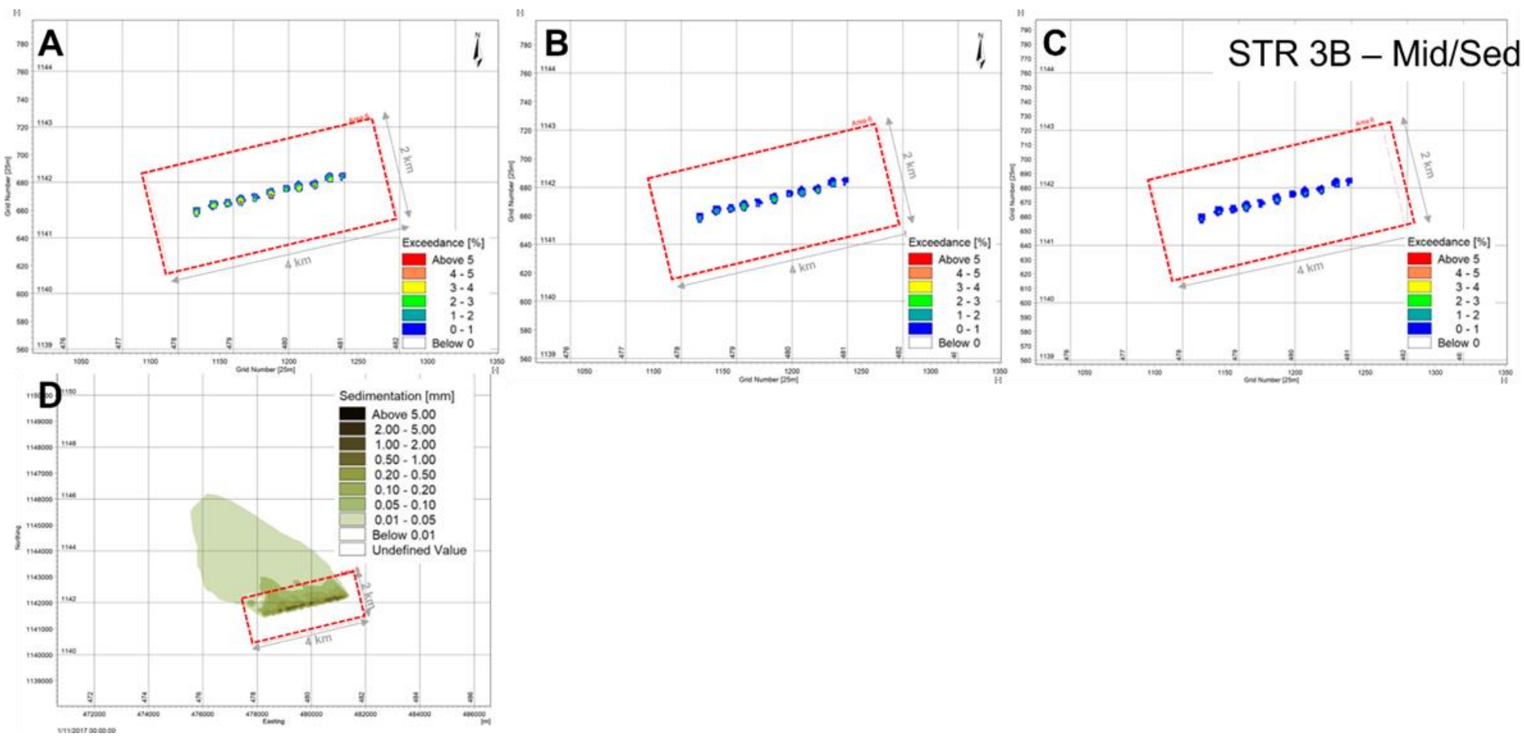


Figure 7-23 Scenario STR3B: Exceedance percentage of 0.1mg/l, from the start of production to 24 (A), 48 (B) and 96 (C) hours post-production at 50m below the mid-water column discharge location (or 1050m below the surface). Benthic sedimentation (mm) 10 days after completion of operation.

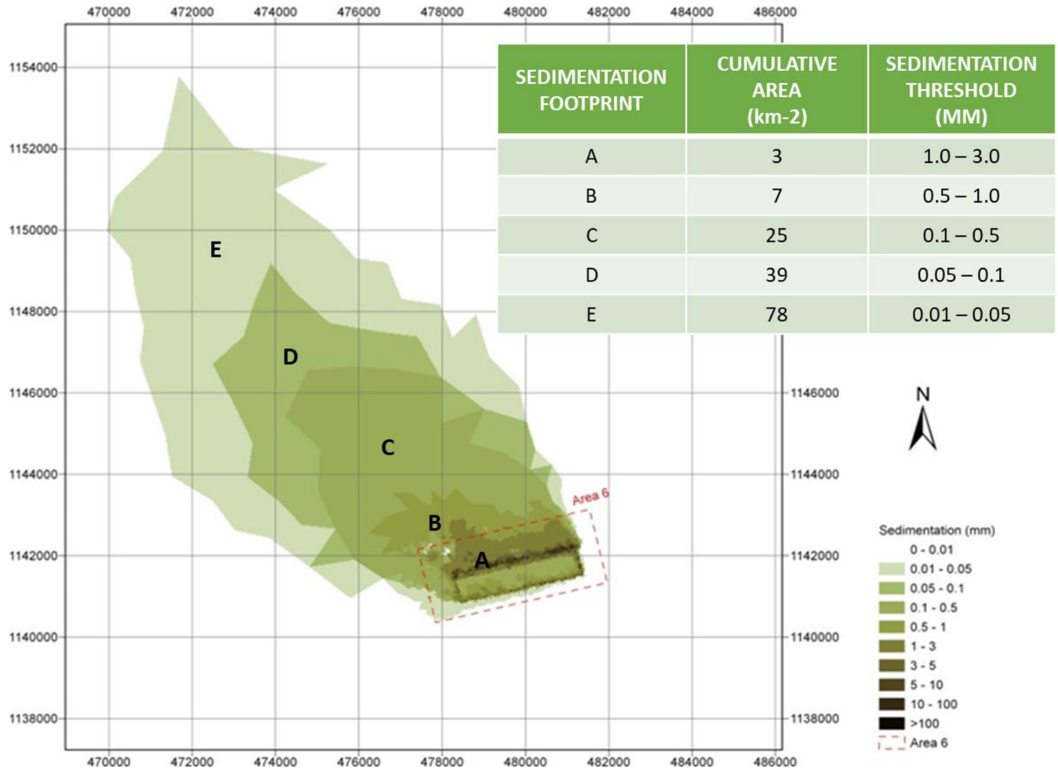


(k) Cumulative Results

(i) Benthic sedimentation

Cumulative sedimentation results are presented to a threshold of 0.01mm results in the capture of 97% of the deposited material (i.e., only 3% of deposited material is found in areas with sedimentation thickness <0.01mm; Figure 7-24). Based on the NORI-D sediment trap measurements (CSA, 2022), a plotting limit of 0.01mm has been adopted (i.e., 10% of the sediment trap short-term sedimentation background or equivalent order to the longer-term consolidated sedimentation rate based upon radioisotope analysis). However, given the level of variability in the sedimentation rate above the mean a potentially biologically relevant threshold of >0.1mm (i.e., 1 standard deviation rounded up) has been adopted as the limit above which a habitat is likely to experience sedimentation rates outside the normal levels of background variation. This assumption is valid as it has been demonstrated that the benthic habitat in NORI-D is subjected to sedimentation rates several times background on an intermittent basis (see Section 5.11.1.6).

Figure 7-24. Benthic sedimentation footprints at various deposition depths



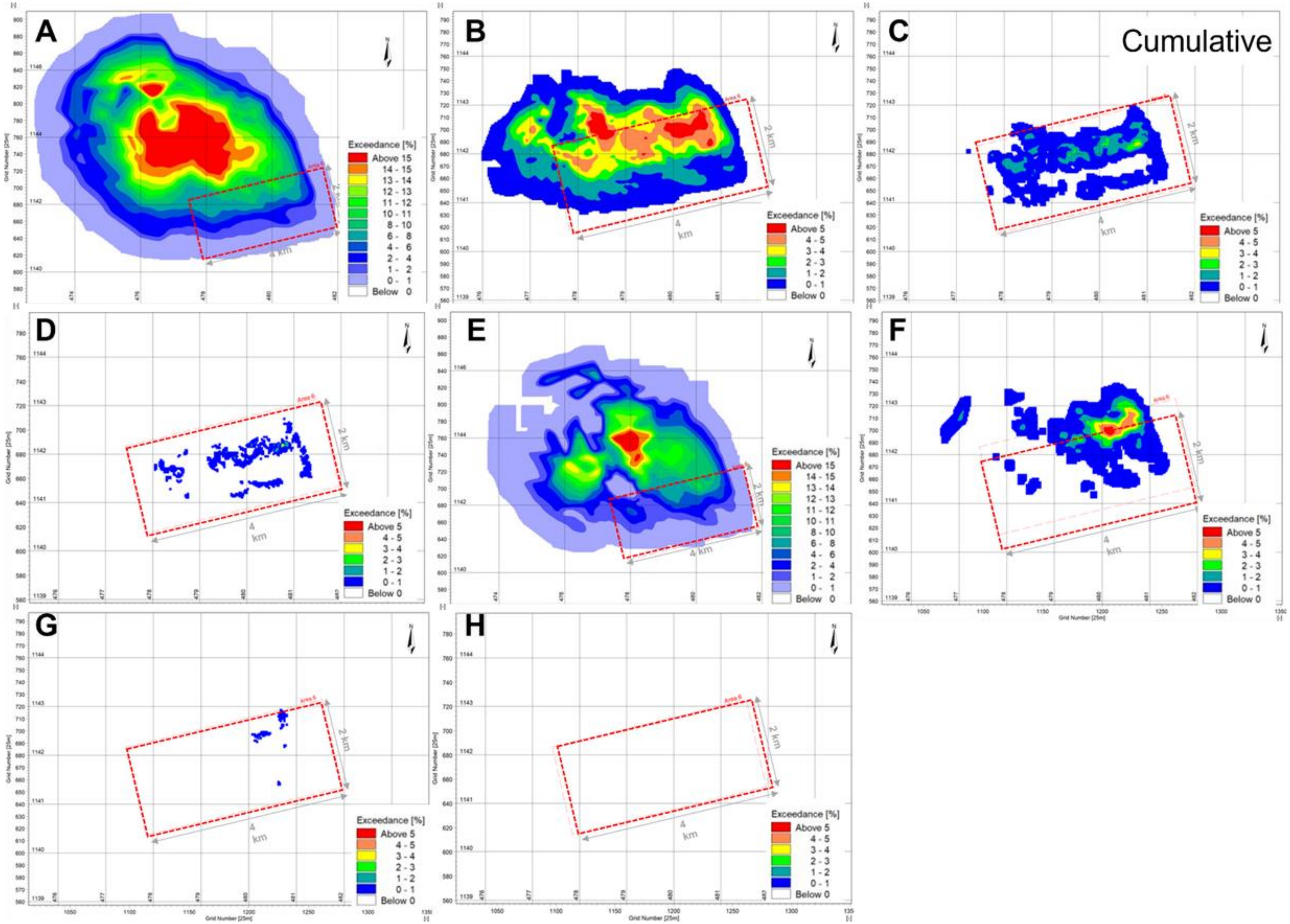
(ii) Benthic Plume

For the cumulative total suspended sediment concentrations, the specific timing of the individual test runs generating spill is important. An estimate of the sequence and likely timing of the five test runs generating sediment spill is documented in Table 7-6. It is noted that the operations generating spill constitute only 61.5hours out of the total 259 hours STR operation.

Table 7-6. STR sequence and start time offset for cumulative suspended sediment assessment

STR ORDER	TOTAL TIME PER STR	STR START TIME SHIFT FROM PREVIOUS STR START
1b	95hrs	0
2a	41hrs	95hrs
2b	61hrs	41hrs
3a	29hrs	61hrs
3b	33hrs	29hrs

Figure 7-25. Net exceedance percentage of 0.1mg/l (A), 1.0mg/l (B), 5.0mg/l (C), 10mg/l (D) at 5m above the seabed; and 0.1mg/l (E), 1.0mg/l (F), 5.0mg/l (G), 10mg/l (H) at 20m above the seabed, from start of STR1b to 24hrs after completion of STR3b (i.e., termination of productive trials).



(iii) Mid-water Plume

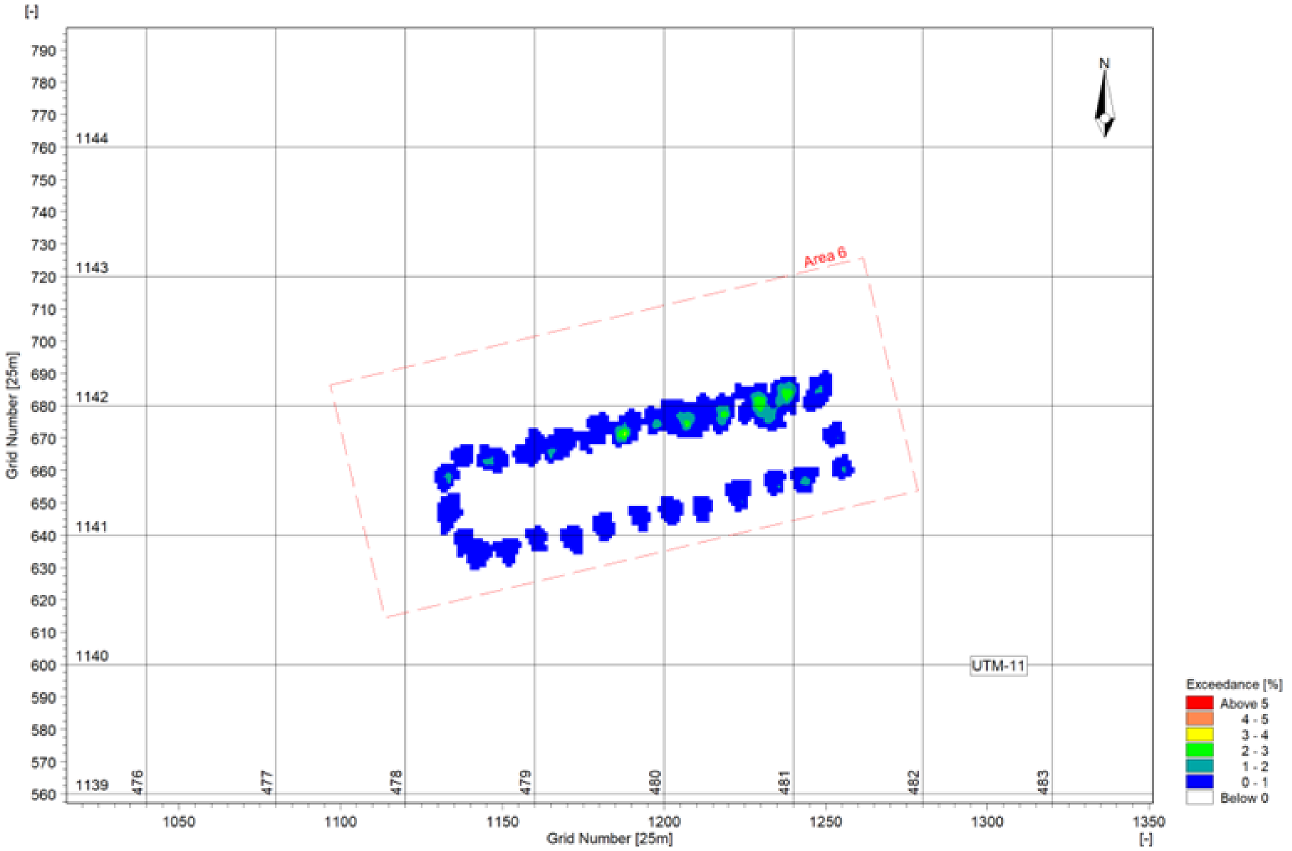
It is anticipated that approximately 8,500 m^3 of process water will be discharged per day during testing of the riser system, with a total of approximately 22,000 m^3 over the course of the Collector Test.

The mid-water discharge point has been modelled at 1,000 m below the surface and follows the tracks of the PCV for all scenarios.

Cumulative net exceedances of 0.1 mg/l at 50m below the modelled mid-water column discharge location (or 1050m below the surface) from start of STR2a to 24hrs after completion of STR3b are shown in Figure 7-26.

The modelled dynamics of the mid-water discharge as it is released from the return pipe is summarised in Figure 7-27. As discharge exits the pipe the heavier fraction (e.g., nodule fragments, cold water and larger sediment particles) falls towards the seabed and contributes to the benthic plume generated by the PCV (Figure 7-27A-C). Eventually, all the heavier components of the discharge will fall to the seabed creating two plumes: a mid-water plume of the lighter faction below the point of discharge and a benthic plume of the heavier faction at the seabed (Figure 7-27D-E). As the surface vessel and riser pipe move away from the benthic plume it dissipates, as does the remaining mid-water plume (Figure 7-27G-I).

Figure 7-26. Net exceedance percentage of 0.1mg/l at 50m below the mid-water column discharge location (or 1050m below the surface) from start of STR2a to 24hrs after completion of STR3b



Summary statistics for the cumulative Collector Test mid-water plume are provided in Figure 7-28. Results show total hours where 1mg/l is exceeded over the entire 259-hour operation and where 0.1 mg/l is exceeded at 50 m below the mid-water column discharge location (or -1,050 m below the surface).

Figure 7-27. Modelled dynamics of mid-water plume

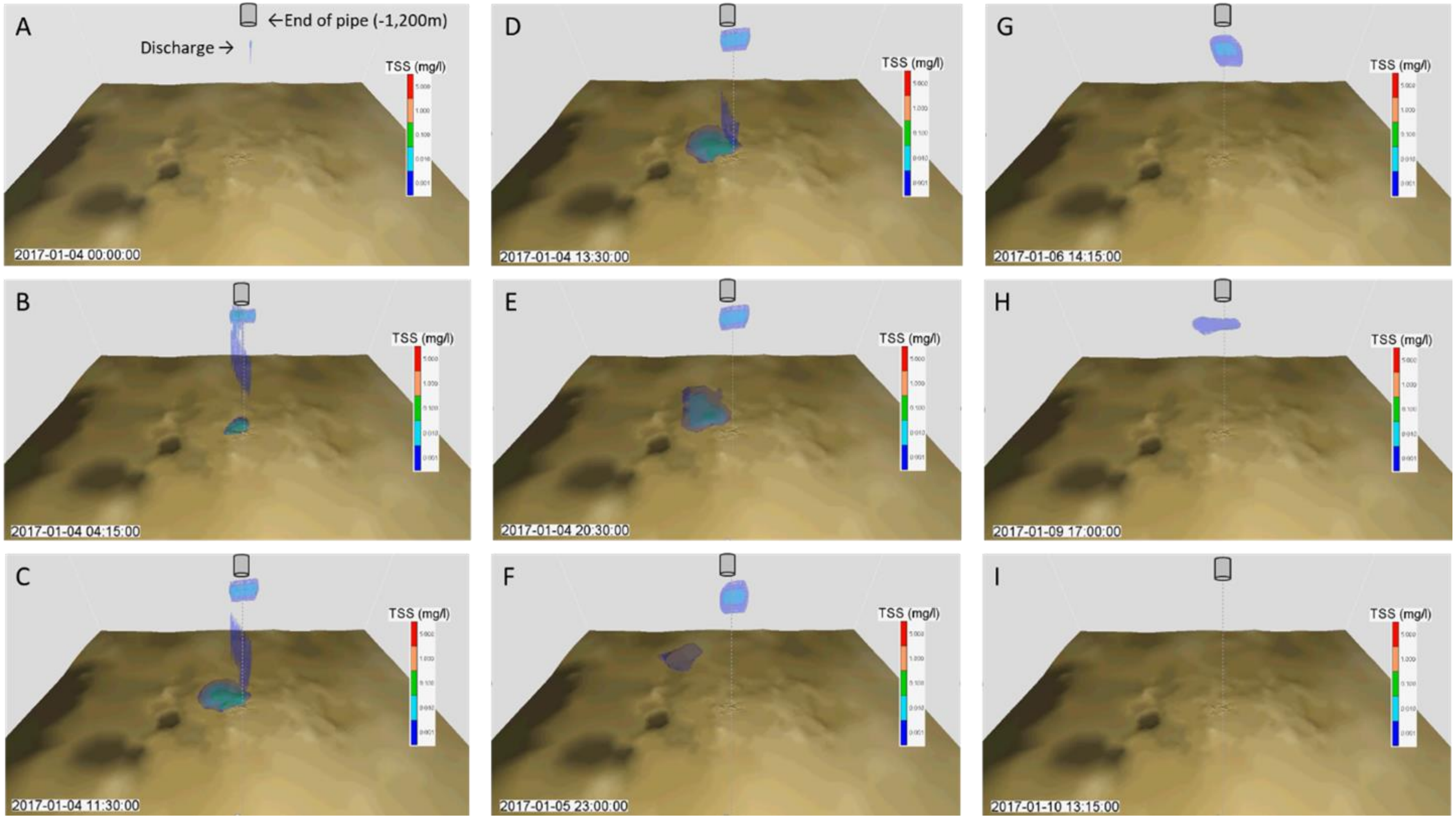
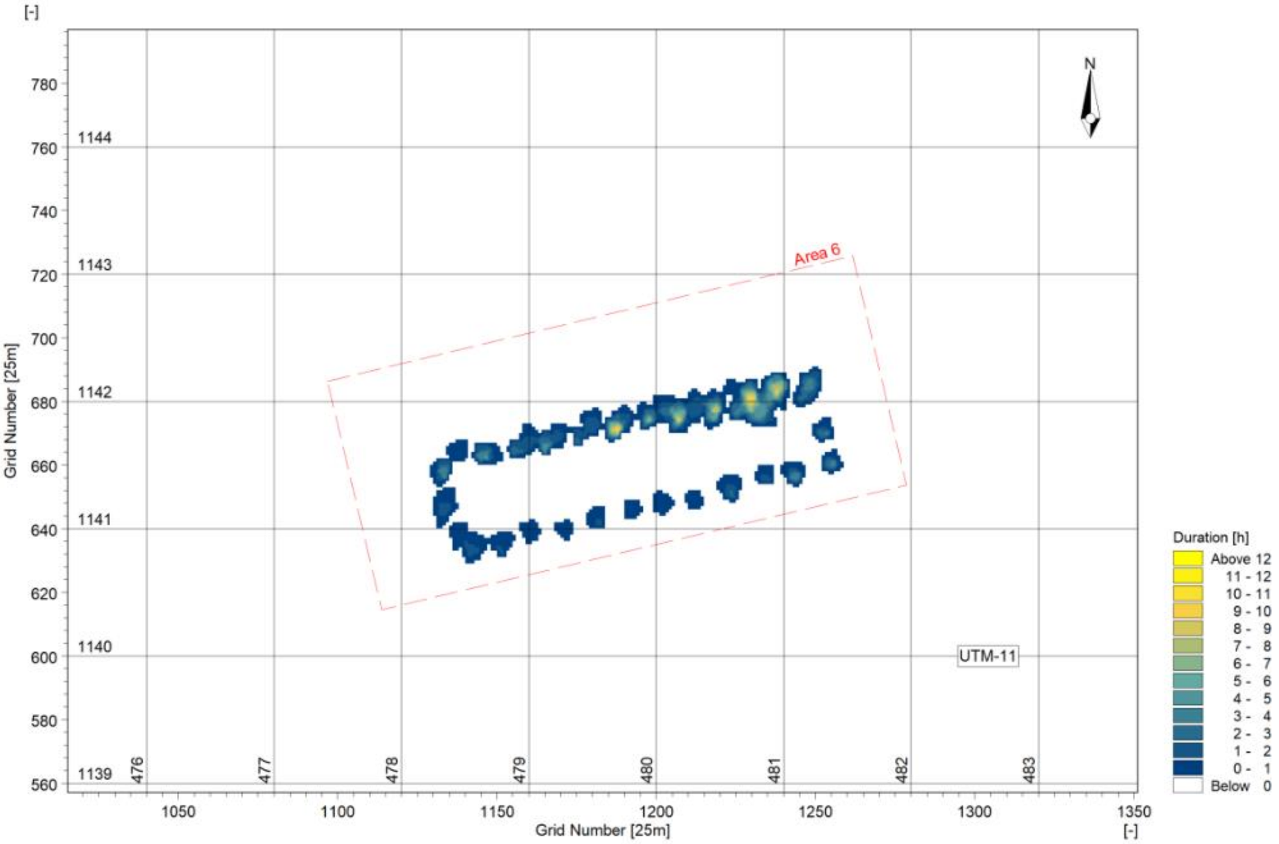


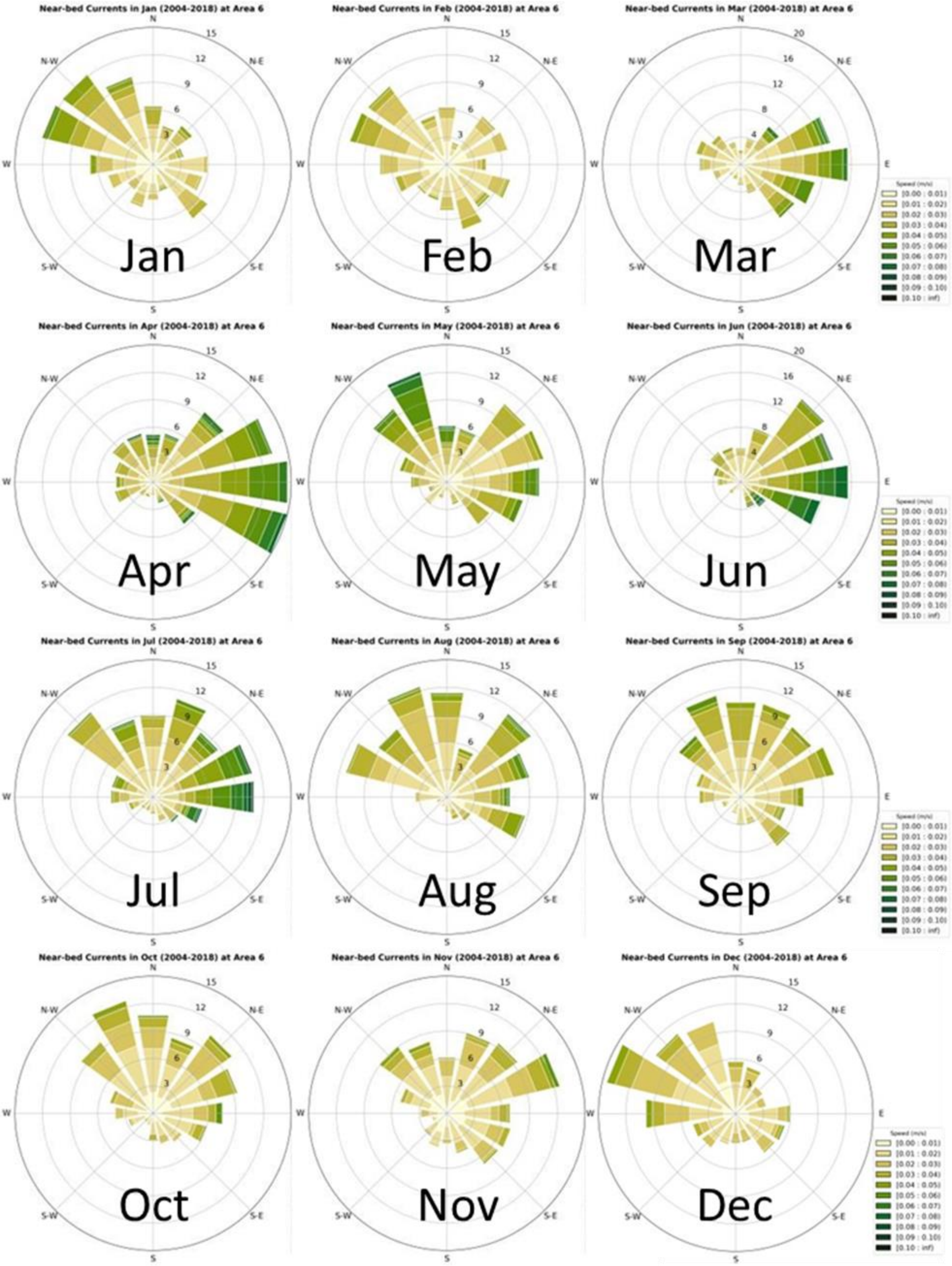
Figure 7-28. Total duration (hours) where 0.1mg/l is exceeded at 50 m below the mid water column discharge point.



(l) Seasonality

Sediment plume modelling has been based on a Collector Test program occurring in January 2022. This was the best information available at the time of simulation. Ultimately it is recognized that the schedule for the Collector Test may vary. Due to variability in the prevailing current conditions at the site (both seasonal and inter-annual variability due to the presence / absence of macro eddies, strength of oceanic processes etc.) some variability in the net migration of the sediment plume, depending on the ultimate schedule of the pilot test program, is to be expected. Figure 7-29 shows the average monthly near-bed current roses for 2004 to 2018 based upon the Hybrid Coordinate Ocean Model (HYCOM; www.hycom.org) that are used as boundary conditions for the sediment plume model (DHI, 2021). Based upon these current roses and consistent with the sediment plume results, a Collector Test campaign undertaken during typical (that is, average) January conditions is likely to see a north-westerly drift of the plume. Conversely, the same program occurring during June/July would likely see a net easterly plume drift, with a similar overall magnitude, but slightly higher spatial extent (in terms of area) (DHI, 2021).

Figure 7-29. Seasonal variability in near bed current conditions (current flowing to) at the location of the long mooring in the NORI-D area based on HYCOM data 2004 to 2018 (HYCOM 2021)



Source: (CSA, 2020)

(m) Plume Characteristics

Based on the results of the plume modelling it is expected that the plumes generated by the Collector Test will have the following characteristics:

(i) Benthic Plume

TSS exceedances of 0.1 mg/l are within one standard deviation of the mean TSS concentrations recorded at depths between 4000 and 4150 m from 4 sites within NORI-D sampled during Campaign 4E (see Table 5-3) (CSA, 2022).

At TSS concentrations >0.1 mg/l, the benthic plume will mostly be contained vertically 20m from the sea floor and horizontally to within 4-6 km radius from the point of origin. Beyond these limits modelling predicts that the plume concentration will rapidly fall below 0.1 mg/l.

The period of benthic plume dilution to background levels will be monitored during the Collector Test and the plume model updated accordingly.

(ii) Sedimentation Footprint

Following completion of all 5 sediment spill producing test runs (i.e., STR1B to STR 3B) a sediment footprint with a depth >0.1mm may be generated over an area of 25 km^2 (see Figure 7-24). The extent of the sediment footprint and the sediment depth gradient with distance from the point of plume generation will be monitored during the Collector Test and the plume model updated accordingly.

(iii) Mid-water Plume

TSS exceedances of 0.1 mg/l are within one standard deviation of the mean TSS concentrations recorded at depths between 950 m and 1,250 m from 4 sites within NORI-D sampled during Campaign 4E (see Table 5-3) (CSA, 2022).

Exceedances of 0.1 mg/l are laterally constrained to approximately 100 - 150 m from the point of discharge. The modelling does not show a strong lateral trajectory of the plume in any particular direction. For all scenarios, the 0.1 mg/l exceedances of the lateral dispersal plume do not extend outside the TF.

Dilution of the mid-water plume with distance from the point of discharge will be monitored during the Collector Test and the plume model updated accordingly.

7.2.2.6 Sediment Geochemistry & Micro-topography

The sediment properties of the seafloor throughout the CTA and wider NORI-D are not unique to this area and are comparable to other areas in the eastern tropical Pacific. Nodules are also abundant and widespread throughout the CCZ (van Wijk and de Hoog, 2020; Wedding *et al.*, 2013). Also, the CTA does not include any major seafloor features, such as seamounts. and has been selected as it is relatively flat with a slope grade of less than 4°.

The seafloor properties represented in the CTA are not unique to this area and are well represented throughout NORI-D and the wider eastern CCZ.

(a) Sediment Geochemistry

Across almost all geochemical parameters analysed to date no notable differences have been observed between the CTA and PRZ study sites or between regions with different nodule types or geoforms (UOL, 2022) (see Section 5.13.1). The only parameter that showed notable variability between sites was inorganic carbon and this may be related to differences in the abundance of calcifying benthic forams (UOL. 2022).

Given the apparent uniformity in sediment geochemistry across the parts of NORI-D sampled to date it is reasonable to assume that due to the small scale of sediment disturbing activities associated with the Collector Test (i.e., 0.5km^2 direct disturbance; 25km^2 biologically relevant sedimentation footprint) impacts to this VEC will not be significant.

(b) Sediment Micro-topography

As the PCV moves across the seafloor the tracks of the propulsion system and the removal/burial of nodules will modify the micro-topography of the disturbed sediments. In addition, the PCV will create a benthic plume of suspended sediment which will be deposited across the broader seafloor outside of the area directly disturbed by the PCV.

The mid-water discharge will also contribute to sediment being dispersed, settling on the seafloor and modifying topography.

Small-scale alterations to seafloor topography may be short-lived or long lasting and could affect hydrodynamic currents close to the seafloor as well as sediment transport processes (BGR, 2019). Experiments conducted at Jacobs University Bremen in Germany found that the presence of nodules may influence seafloor hydrodynamics by creating vortexes, erosion and accumulation zones (iSeaMC, 2020).

During the Collector Test the PCV will traverse a distance of about 82 km in completing the system test runs. Approximately 3,600 wet tonnes of nodules will be collected, and although nodules >80 mm in diameter will not be collected, they will likely be buried as the PCV passes over them or be covered by sedimentation. The area of the TF from which nodules will be removed or buried is estimated to be about 0.5 km^2. The removal and burial of nodules will create a change in seafloor micro-topography (that is, changes in seafloor topography of tens of centimetres) over the disturbed area. In addition, the micro-topography of an area of approximately 25km^2 will be modified due to sediment deposition to a depth >0.1 mm.

This level of seafloor disturbance is considered to be the minimal necessary to understand the impacts of direct and indirect sediment disturbance by the collector system and represents 0.1% of NORI-D.

7.3 Impact Mitigation

The primary mitigation methods employed for the Collector Test involve optimal design of the collector system equipment and the testing operations to minimise environmental impacts.

7.3.1 Equipment Design

The following features have been incorporated into the design of the collector system to minimise impact to the physicochemical components of the receiving environment:

1. The Collector Test System is 20% the scale of a full-size commercial system and is considered sufficient to meet the testing objectives while minimizing the environmental disturbance footprint.

2. The Prototype Collector Vehicle is 50% scale of a full-size commercial vehicle and is considered sufficient to meet the testing objectives while minimizing the environmental disturbance footprint.
3. The nozzles of the PCV have been designed to exploit the Coandă effect, (the tendency of a fluid jet to stay attached to a convex surface) to minimize sediment disturbance during nodule pick-up.
4. Nozzle head height adjustment allows for fine tuning of the Coandă effect by changing the relative force of the water jet and suction combination on the seabed. The ability to fine tune in this manner will optimize the efficiency of nodule pick-up whilst minimizing sediment disturbance.
5. The first stage of the nodule processing system is designed to separate nodules from sediment inside the PCV. Special pump equipment is used for separating fines from the nodule flow stream, keeping as much sediment as possible at the seafloor.
6. The PCV tracks will be fitted with water jets, powered by a dedicated pump which will clean sediment from the outer track surface and inner sprocket path prior to ascending to the surface, reducing the amount of benthic sediment transported to the surface.
7. Where possible, all chemicals used in submersible equipment (i.e., ROV and PCV), will be biodegradable and compliant with OSPAR (2009) standards for the protection of the marine environment.
8. The nodule surface separator and storage system has been fitted with a 2-way diverter valve that can send the slurry stream directly to the buffer tank. This provides a protection from sudden unexpected over-load and spill.
9. The depth of the return water outlet has been set at 1,200 m, 200 m below the measured oxygen minimum zone. Due to the particle momentum of the outfall the effective discharge depth may be as deep as 1,280 m.
10. All vessels used during the Collector Test will adhere to MARPOL regulations aimed at preventing both accidental pollution and pollution from routine vessel operations.
11. Use of modern ships and offshore supply vessels that comply with IMO (2014) guidelines, will minimize noise generation.
12. Use of modern and efficient thruster systems and dynamic positioning systems (e.g., DP II in preference to DP I, or DP III in preference to DP II). will minimize noise generation.
13. The of Vertical Transport System (VTS) using airlift riser technology rather than noisier technologies such as risers with multiple slurry pumps or risers fitted with a Subsea Slurry Lift Pump (SSLP) fitted with individual positive displacement pump module displacement pump at its base.
14. The outlet of the return process wastewater pipe will be located at 1,200 m depth, which is below the biologically productive epipelagic zone 90–200 m depth and upper mesopelagic zone (200–1,000 m depth), as well as minimising activities in the sound-fixing-and-ranging (SOFAR) channel (typically at a depth of ~1000 m in the CCZ) within which low-frequency sound is transmitted over very long distances (hundreds to thousands of kilometres).

7.3.2 Test Planning

15. The GHG emissions for the Collector Test have been calculated and will be offset.
16. All Collector Test operations will be confined to an 8 km^2 TF.

7.3.3 Test Operations

17. The duration of the entire Collector Test is limited to 860 hours, and the duration of system testing (period of maximum plume generation) is limited to 259 hours. Most impacting activities associated with the Collector Test will be temporary, short in duration, and spatially contained.
18. The ROV and all associated equipment will be maintained and inspected for leaks prior to deployment.

7.4 Risk Assessment

Risk assessment is an analysis of the probability of occurrence of an event and the impact on the receiving environment if it occurs. The EIA study team conducted a risk assessment for physicochemical VECs (Table 7-7 Column 7 “Residual Risk”), based on the current understanding of the project, using the criteria described in Table 4-14 and Table 4-15.

The results of the risk assessment indicate that with the implementation of the proposed mitigation measures and any prescribed additional project specific controls (Table 7-7, Columns 4 and 8 respectively) no residual significant impacts to the physicochemical component of the receiving environment are anticipated at a regional scale.

Table 7-7. Impact significance and risk assessment - physicochemical VECs

ACTIVITY	VULNERABLE VECS	IMPACTS	MITIGATION MEASURES	CONSEQUENCE[‡]			LIKELIHOOD	RESIDUAL RISK	ADDITIONAL PROJECT SPECIFIC CONTROLS	SIGNIFICANT IMPACT
				M	S	RATING				
Return transit of the vessel from San Diego to the CCZ	Air Quality / GHG	Vessel's diesel engines will emit fumes into the atmosphere reducing local air quality and contributing to GHG emissions.	MARPOL requirements will be adhered to on all vessels used during the project, minimising the risk of pollution to the marine environment and atmosphere in accordance with established international standards. The GHG emissions for the Collector Test have been calculated and will be offset.	2	1	Negligible	Almost Certain	Low	Not required	NO
	Noise / Vibration	Vessel's diesel engines will generate noise and vibrations which could disturb birds, cetacean, and turtles.	Vessels will not pass through any "Particularly Sensitive Sea Areas" (PSSAs) as designated by the IMO. While on station ship movements will be minimised to reduce propeller generated noise.	2	1	Negligible	Almost Certain	Low	Not required	NO
	Water Quality	Intentional or accidental release of pollutants from the vessels could negatively impact water quality negatively impact water quality throughout the water column.	MARPOL requirements will be adhered to on all vessels used during the project, minimising the risk of pollution to the marine environment and atmosphere in accordance with established international standards.	1	1	Negligible	Rare	Negligible	Not required	NO
Offshore Inspection and Preparation	Water Quality	Leakage of hydraulic fluids, oil, or other substances from the ROV could negatively impact water quality throughout the water column during its descent to the seabed.	The ROV and all associated equipment will be maintained and inspected for leaks prior to deployment. Where possible, chemicals used in underwater equipment, such as the ROV and PCV, will be biodegradable and compliant with the OSPAR standards, ensuring compliance with established international standards for acceptable levels of environmental performance of chemicals in terms of toxicity, persistence, and bioaccumulation.	1	1	Negligible	Rare	Negligible	Not required	NO
PCV Deployment	Water Quality	Leakage of hydraulic fluids, oil, or other substances from the PCV could negatively impact water quality throughout the water column during subsea lowering.	The PCV and all associated equipment will be maintained and inspected for leaks prior to deployment. Where possible, chemicals used in underwater equipment, such as the ROV and PCV, will be biodegradable and compliant with the OSPAR standards, ensuring compliance with established international standards for acceptable levels of environmental performance of chemicals in terms of toxicity, persistence, and bioaccumulation.	1	1	Negligible	Rare	Negligible	Not required	NO

ACTIVITY	VULNERABLE VECS	IMPACTS	MITIGATION MEASURES	CONSEQUENCE‡			LIKELIHOOD	RESIDUAL RISK	ADDITIONAL PROJECT SPECIFIC CONTROLS	SIGNIFICANT IMPACT
				M	S	RATING				
Jumper and Riser Deployment	Water Quality	Leakage of hydraulic fluids, oil, or other substances from the ROV during manipulation of the jumper or riser could	The PCV and all associated equipment will be maintained and inspected for leaks prior to deployment. Where possible, chemicals used in underwater equipment, such as the ROV and PCV, will be biodegradable and compliant with the OSPAR standards, ensuring compliance with established international standards for acceptable levels of environmental performance of chemicals in terms of toxicity, persistence, and bioaccumulation	1	1	Negligible	Rare	Negligible	Not required	NO
Riser Commissioning	Noise / Vibration	Surface and/or subsea noise or vibrations caused by pressure testing of the airlift in the riser pipe could disturb birds, fish, cetaceans, and turtles.	The air lift will only be in continuous operation during the system integration test and productive system test runs, limiting the time of underwater noise and vibration generation from this source to approximately 283 hours. This impact is temporary and will be removed once the Collector Test has ended without any residual impacts. The riser pipe will use Vertical Transport System (VTS) airlift technology rather than noisier technologies such as risers with multiple slurry pumps or risers fitted with a Subsea Slurry Lift Pump (SSLP) fitted with individual positive displacement pump module displacement pump at its base. The outlet of the return process wastewater pipe will be located at 1,200 m depth, which is below the biologically productive epipelagic zone 90–200 m depth and upper mesopelagic zone (200–1,000 m depth), as well as minimising activities in the sound-fixing-and-ranging (SOFAR) channel (typically at a depth of ~1000 m in the CCZ) within which low-frequency sound is transmitted over very long distances (hundreds to thousands of kilometres).	2	2	Low	Almost Certain	Low	Not required	NO
Subsea Connection of Jumper on PCV	Water Quality	Leakage of hydraulic fluids, oil, or other substances from the ROV during connection of the jumper on the PCV could negatively impact water quality throughout the water column.	The ROV, Jumper and Riser hoses and all associated equipment will be maintained and inspected for leaks prior to deployment. Where possible chemicals used in underwater equipment, such as the ROV and PCV, will be biodegradable and compliant with the OSPAR standards, ensuring compliance with established international standards for acceptable levels of environmental performance of chemicals in terms of toxicity, persistence, and bioaccumulation.	1	1	Negligible	Rare	Negligible	Not required	NO
System Testing	Water Quality	Manoeuvring the PCV on the seabed, pick-up test runs, and system test runs will physically disturb the sediments and nodules creating a sediment plume and potentially mobilizing particle-bound nutrients and trace metals.	The area of direct physical disturbance of the sea floor will be restricted to $0.5 km^2$ within the 8 km^2 TF. Under the current Collector Test design, plume modelling indicates that at TSS concentrations >0.1 mg/l, the benthic plume will be mostly contained vertically 20m from the sea floor and horizontally to within 4-6 km radius from the point of origin. Beyond these limits	2	1	Negligible	Almost Certain	Low	Not required	NO

ACTIVITY	VULNERABLE VECS	IMPACTS	MITIGATION MEASURES	CONSEQUENCE‡			LIKELIHOOD	RESIDUAL RISK	ADDITIONAL PROJECT SPECIFIC CONTROLS	SIGNIFICANT IMPACT
				M	S	RATING				
		Water quality in the bathypelagic zone and below could be impacted by increased turbidity caused by suspended sediments and mobilized chemicals released from the return water pipe outlet at 1,200m.	modelling predicts that the plume concentration will rapidly fall below 0.1 mg/l. Statistical analysis of TSS concentration modelling results of the mid-water plume at -1050m depth indicate that the cumulative duration of exceedances of 0.1mg/l are expected to be less than 8 hrs over the 259 hours of operation (i.e., <5%), and show very little lateral migration. This suggests that in terms of TSS, impacts to mid-water water quality will be temporary, of short duration, and confined to the water column above the TF.							
	Light / Noise / Vibration	Manoeuvring the PCV on the seabed and pick-up test runs will create light, noise, and vibration. Riser installation and commissioning tests, system integration testing, and system test runs all have the potential to create noise and vibration disturbances at the surface and throughout the water column from use of the air lift and through pressure testing of the system.	The air lift will only be in continuous operation during the system integration test and productive system test runs, limiting the time of underwater noise and vibration generation from this source to approximately 283 hours. This impact is temporary and will be removed once the Collector Test has ended without any residual impacts. Exposure to underwater light, noise and vibration generated by the PCV will be limited to 566 hours over the span of the system testing. The PCV and ROV lights will be used sparingly and turned off when not required for visual inspection (e.g., during assent and descent). The riser pipe will use Vertical Transport System (VTS) airlift technology rather than noisier technologies such as risers with multiple slurry pumps or risers fitted with a Subsea Slurry Lift Pump (SSLP) fitted with individual positive displacement pump module displacement pump at its base. The outlet of the return process wastewater pipe will be located at 1,200 m depth, which is below the biologically productive epipelagic zone 90–200 m depth and upper mesopelagic zone (200–1,000 m depth), as well as minimising activities in the sound-fixing-and-ranging (SOFAR) channel (typically at a depth of ~1000 m in the CCZ) within which low-frequency sound is transmitted over very long distances (hundreds to thousands of kilometres).	2	2	Low	Almost Certain	Low	Not required	NO
	Sediment Geochemistry and micro-topography	Manoeuvring the PCV on the seabed, pick-up test runs, and system test runs will mix the surface layers of the sediment, disrupting oxygen concentration gradients in the surface layers and potentially mobilizing particle-bound nutrients and trace metals. Sedimentation from the operational and mid-water plumes may also alter micro-topography of benthic sediments.	The area of direct physical disturbance of the sea floor will be restricted to 0.5 km^2 within the 8 km^2 TF. Sediment geochemistry uniformity has been demonstrated across the parts of NORI-D sampled to date. The Collector Test has been designed to minimise the total area of sea floor disturbance to just 25.5 km^2. This is considered to be the minimal level of disturbance necessary to understand the impacts of direct and indirect sediment modification and represents just 0.1% of the area of NORI-D.	2	2	Negligible	Almost Certain	Low	Not required	NO

ACTIVITY	VULNERABLE VECS	IMPACTS	MITIGATION MEASURES	CONSEQUENCE‡			LIKELIHOOD	RESIDUAL RISK	ADDITIONAL PROJECT SPECIFIC CONTROLS	SIGNIFICANT IMPACT
				M	S	RATING				
Riser and PCV Recovery	Water Quality	A ROV will be used for recovery, leakage of hydraulic fluids, oil, or other substances from the ROV could negatively impact water quality throughout the water column.	The ROV, Jumper and Riser hoses and all associated equipment will be maintained and inspected for leaks prior to deployment. All chemicals used in underwater equipment, such as the ROV and PCV, will be compliant with the OSPAR standards, ensuring compliance with established international standards for acceptable levels of environmental performance of chemicals in terms of toxicity, persistence, and bioaccumulation.	1	1	Negligible	Rare	Negligible	Not required	NO

8 BIOLOGICAL ENVIRONMENTAL IMPACTS

8.1 Overview

This section identifies and assesses the impacts of the Collector Test on biological VECs. Impacts at various stages of the Collector Test are considered for the following zones: atmospheric (above the water), euphotic (0 to 200 m), mesopelagic (200 m to 1,000 m), bathypelagic (1,000 m to 4,000 m) and abyssal (4,000 m to 6,000 m) including the benthic component. A summary of relevant environmental effects (that is, project related activities that interact with biological components of the receiving environment) considered is provided in Table 8-1.

The Collector Test EIA is a sub-component of a comprehensive commercial ESIA that is currently being conducted. It is anticipated that all the planned ESIA baseline studies will be completed by the end of 2022, until then gaps may remain in our understanding of the sensitivity of key VECs represented within NORI-D. Where such uncertainty exists, it has been acknowledged, and the precautionary approach applied to the analysis. It is a key objective of the Collector Test to collect information which reduces the level of inherent uncertainty in the operational phase of the project.

Table 8-1. Summary of environmental effects for biological VECs

ACTIVITY	VULNERABLE VECS	ENVIRONMENTAL EFFECTS
Return transit of vessel from San Diego to the CCZ	Cetaceans/Turtles	Vessel strike Vessel noise and light
Offshore Inspection and Preparation	Benthic Biota (sediment, nodule, free swimming)	Deployment of the ROV and other equipment (inc. LBL network) to the seabed will physically disturb animals living on the nodules and in sediments.
	Benthic Habitat Quality	Deployment of other equipment (inc. LBL network) to the seabed will physically disturb benthic habitat by creating contours in the sediment.
PCV Deployment	Cetaceans/Turtles	Lowering the PCV through the splash zone could disturb or physically strike cetaceans or turtles that are in close proximity to the vessel.
	Benthic Biota (sediment, nodule, free swimming)	Touchdown of the PCV on the seabed will disturb animals living on the nodules and in sediments.

ACTIVITY	VULNERABLE VECS	ENVIRONMENTAL EFFECTS
	Benthic Habitat Quality	Touchdown of the PCV on the seabed will disturb the benthic habitat by creating contours in the sediment and/or moving or crushing nodules.
Jumper and Riser Deployment	Cetaceans/Turtles	Lowering the jumper and riser tubes through the splash zone has the potential to disturb or strike cetaceans or turtles that are in close proximity to the vessel.
System Testing	Cetaceans	Riser installation and commissioning tests, system integration testing, and system test runs all have the potential to create noise and vibration disturbances at the surface and throughout the water column from use of the air lift and through pressure testing of the system which could disturb diving and foraging behaviour.
	Microbes	Manoeuvring the PCV on the seabed, pick-up test runs, and system test runs will physically disturb the sediments and nodules potentially disrupting the microbial community structure in the surface layers of the sediment, and seafloor metabolic activity,
	Benthic Biota (sediment, nodule, free swimming)	Manoeuvring the PCV on the seabed and pick-up test runs will create noise and vibration which could disturb or displace motile large macrofauna. Riser installation and commissioning tests, system integration testing, and system test runs all have the potential to create noise and vibration disturbances at the surface and throughout the water column from use of the air lift and through pressure testing of the system. PCV will emit light. Manoeuvring the PCV on the seabed and pick-up test runs will physically disturb or remove sediment and nodule dwelling animals. System test runs will create a benthic plume, as entrained sediment is ejected from the rear of the PCV; this plume will be denser than that formed during the manoeuvrability and pick-up test runs and will blanket and smother surrounding sessile biota.
	Benthic Habitat Quality	Manoeuvring the PCV on the seabed and pick-up test runs will physically disturb the benthic habitat by creating contours in the sediment, disrupting surface layers of sediment, and/or moving or crushing nodules. System test runs will create a benthic plume, as entrained sediment is ejected from the rear of the PCV; this plume will be

ACTIVITY	VULNERABLE VECS	ENVIRONMENTAL EFFECTS
		denser than that formed during the manoeuvrability and pick-up test runs and will blanket surrounding benthic habitat.
	Nekton	Nekton in the euphotic, pelagic and bathypelagic zones could be impacted by noise and vibration from the air lift system and by suspended sediment and mobilized chemicals released from the return water pipe outlet at 1,200 m.
	Zooplankton	Zooplankton in the euphotic, pelagic and bathypelagic zones could be impacted by noise and vibration from the air lift system and by suspended sediment and mobilized chemicals released from the return water pipe outlet at 1,200 m.
Riser and PCV Recovery	Cetaceans/Turtles	Rising the jumper hose, riser pipe, and PCV through the splash zone could disturb or physically strike cetaceans or turtles that are in close proximity to the vessel.

8.2 Environmental Effects

The environmental effects of the Collector Test have the potential to impact a number of biological VECs, including: cetaceans/turtles; benthic biota (sediment, nodule, free swimming); benthic habitat quality; microbes; nekton; zooplankton.

Relevant environmental effects have been categorised as:

- Those associated with surface support vessel operations, such as vessel strike; and
- Those specific to the Collector Test operations such as physical disturbance to biota and habitats.

8.2.1 Surface Vessel Operations

8.2.1.1 Birds, Cetaceans & Turtles

(a) Impacts to birds

Airborne noise generated by the SSV could potentially disturb marine birds by masking communication render seabirds unable to locate mates or share foraging information (Dooling & Therrien, 2012). Given that the CCZ is located several thousand kilometres from the nearest major land mass it is unlikely that project related activities will significantly disturb nesting, mating or foraging behaviours.

(b) Impacts to Cetaceans & Turtles

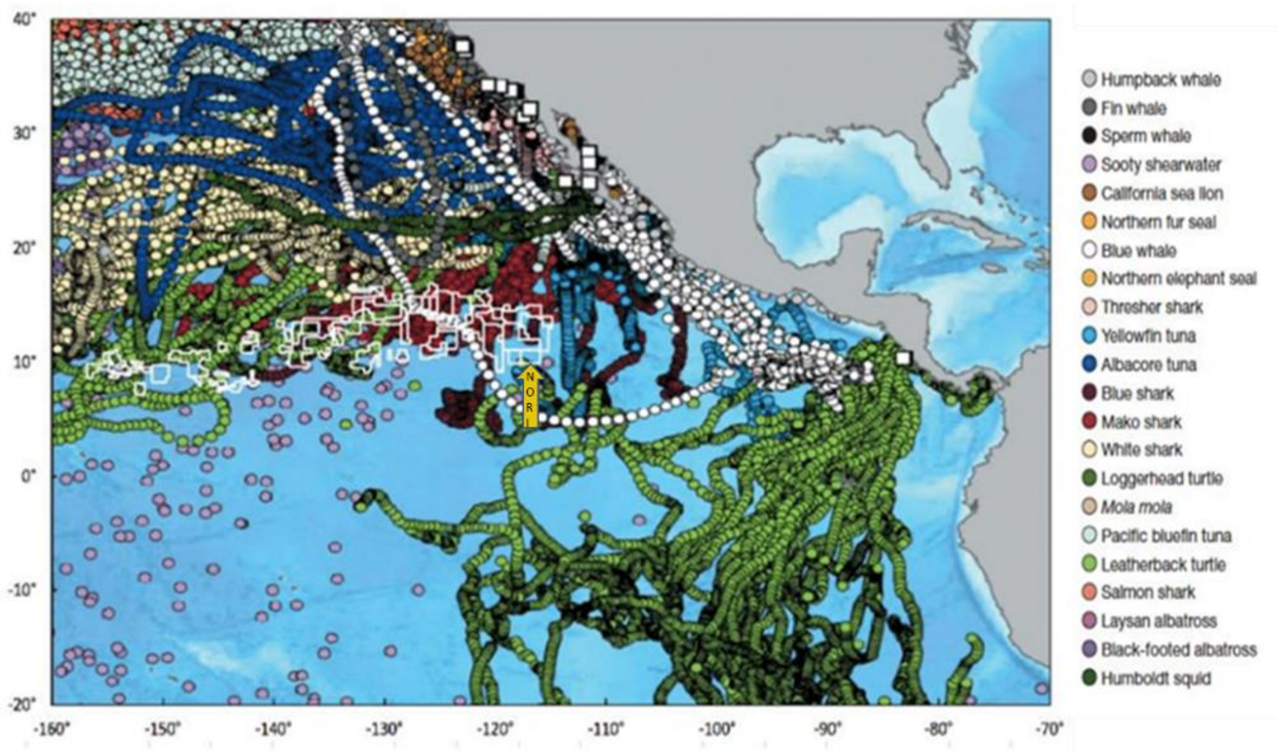
Lighting of the back deck of the vessel will be unavoidable during night-time operations, which will be minimised by limiting the use of high intensity lighting (e.g., spotlights) to an ‘as needed’ basis (e.g., during equipment deployment) and maintaining night-time ambient light at levels appropriate for the activities being undertaken. A marine mammal observer (MMO) will be present during all offshore operations and to act immediately to protect species of concern should they enter the vessel’s exclusion zone prior to and sometimes during operations. The MMO will advise personnel onboard to delay or shutdown operations until the animals are at a safe distance and also to record behaviour and sightings at other times.

As NORI-D is not located in an area of high marine traffic it is unlikely that cumulative light impacts will be of concern.

Direct vessel strike of cetaceans and turtles is an impact pathway that is relevant to all shipping. Tracking data for key migratory species in the eastern Pacific is available which shows that NORI-D is located outside of many of the known migratory routes (Figure 8 1). In addition, all vessels will keep watch from the bridge 24/7 as is best practice, and NORI will continue to research the frequency of cetacean and turtle sightings in NORI-D as part of the ongoing PelagOS observation efforts.

The International Maritime Organisation has developed a guidance document for minimising the risk of collisions between ships and whales (IMO, 2013) and recommends that the most effective mitigation measures include good route planning, keeping watch and continued scientific research.

Figure 8-1 Tracking data for migratory species in the eastern tropical Pacific



Source: Fathom Pacific (2020b) adapted from Block *et al* (2011)

8.2.2 Collector System Testing

8.2.2.1 Cetaceans & Turtles

(a) Underwater Noise & Vibration

A summary of the preliminary noise model for activities associated with the Collector Test has been described in Section 7.2.2.2; with further detail provided in Appendix 4. The potential impacts from noise and vibration arising from activities associated with the Collector Test are summarised below.

(i) Acoustic Impacts to Marine Fauna

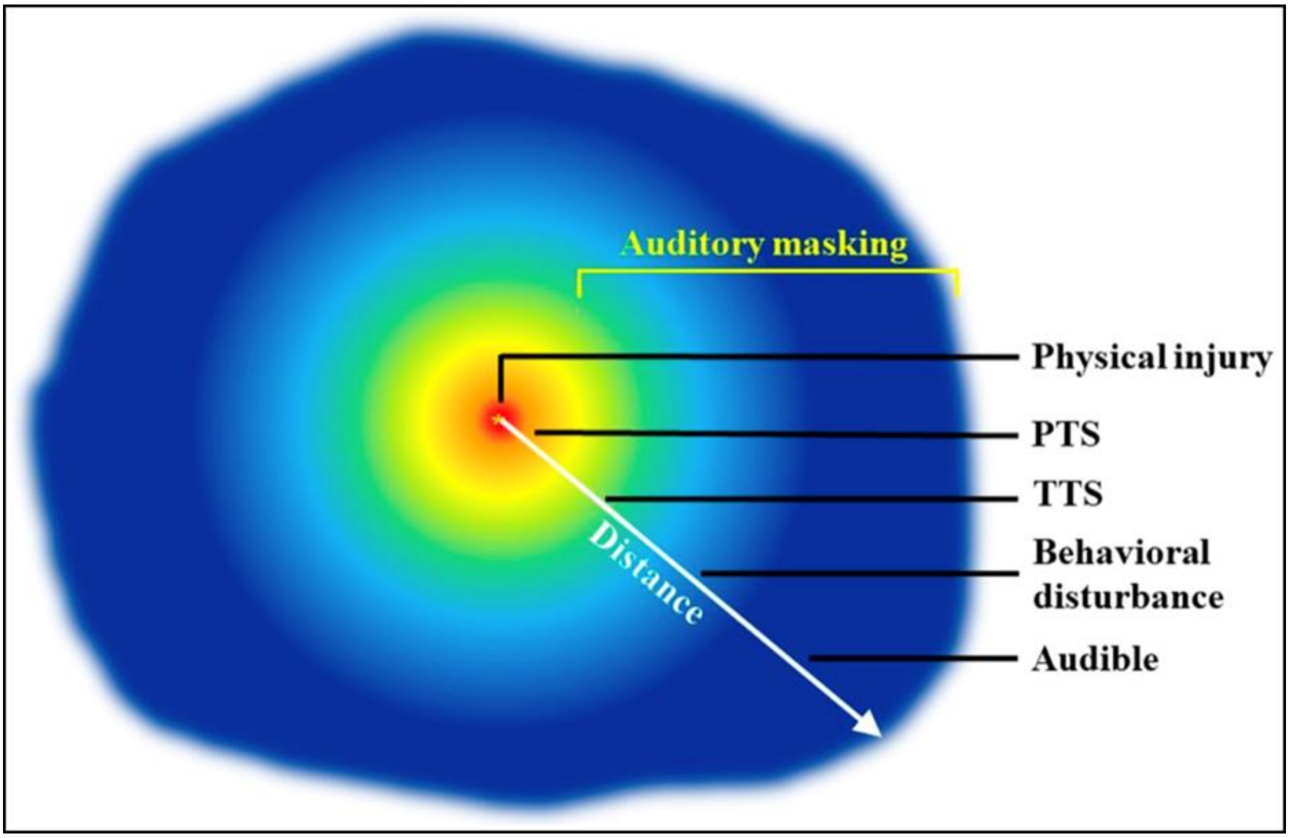
The following residual impact assessment of the proposed Collector Test runs and system tests to selected noise-sensitive marine fauna representative of the in the following three key ISQ-recognised depth zones (ISA, 2020):

- Surface and epipelagic zone – combined noise of the SSV and OSV.
- Midwater (epipelagic, mesopelagic and bathypelagic) zone – Riser noise.
- Benthic and deepwater bathypelagic and abyssopelagic zone – seabed nodule harvester (PCV) noise.

(ii) Acoustic Zones of Influence

One approach of attempting to assess the effects of noise on marine pelagic fauna is the concept of acoustic zones of influence (Richardson & Malme, 1995). Figure 8-2 shows a simple acoustic impact model based on the distance of the noise source from the receiver (receptor) such as a whale.

Figure 8-2. Conceptual acoustic zones of influence



Source: Guan and Brookens (2021) based on the original concept by Richardson and Malme (1995). PTS is Permanent Threshold Shift. TTS is Temporary Threshold Shift.

In Figure 8-2, the physical injury and permanent hearing loss (onset of Permanent Threshold Shift or PTS) zones represent acoustic damage impacts to marine fauna whereas the zones of temporary hearing loss (on set of Temporary Threshold Shift or TTS) and behavioural changes represent acoustic disturbance impacts. The zone of audibility is taken as the maximum potential radius of influence and is limited either by the hearing threshold of the marine animal under consideration or by the intensity of the sound related to ambient noise in that frequency range.

Acoustic masking may occur when Project-generated underwater noise impedes the ability of a marine animal to perceive a biologically relevant signal (Erbe *et al*., 2016). For this to occur the noise must be loud enough and have similar frequency content to the signal, as well as occurring at the same time.

The audibility or detectability (i.e., above background ambient levels) of Project-generated noise by a receptor (marine animal) is generally not considered an adverse impact, as long as acoustic damage or acoustic disturbance effects are not evident. It is also evident that the ambient noise varies over a wide range of levels (as much as 27 dB as measured at NORI-D; see Section 5.5) as conditions vary. Such variation is frequent and common. This has significant effects since the range (distance) of audibility of a source will depend on the noise level.

The following assessments of acoustic impacts relate principally to known noise sensitive marine fauna or groups. Oceanic birds such as albatrosses, petrels and storm-petrels, shearwaters are assessed not to be vulnerable to the Project-generated underwater noise as those species capable of diving are only transiently exposed to underwater noise resulting in insufficient cumulative exposure for acoustic impacts to occur.

(iii) Acoustic Threshold Criteria for Cetaceans

A review of the literature revealed the following threshold levels of non-impulsive broadband noise at which acoustic damage and behavioural effects have been observed.

Many studies have defined a received sound level of 180 dB re 1 µPa rms as “harassment” and that a 160 dB re 1 µPa rms is the level likely to cause “behavioral response” (e.g., avoidance) (NMFS, 2013). Based on a literature search, the following acoustic threshold criteria have been adopted as a starting point to estimate the size of the area affected by Project-generated underwater noise, which is dominated by non-impulsive, continuous broad band noise. Therefore, the acoustic threshold of 180 dB re 1 µPa rms has been adopted as threshold above which acoustic damage to a cetacean may be expected.

Acoustic Disturbance Threshold Criteria:

- Upper acoustic disruptive behavioural threshold of **160 dB re 1 µParms**:
  - Threshold for onset of disruptive behavioural responses and significant avoidance of non-impulsive noise source, (NMFS, 2014)
- Lower acoustic behavioural threshold of **120 dB re 1 µParms**:
  - Threshold for onset of more subtle behavioural responses such as increased presence at the surface and less frequent diving, but avoidance not expected.

The application of the 120 dB re 1 µParms threshold can sometimes be problematic because this threshold level can be either at or below the ambient noise level at certain locations (Bess et al. (2018).

Permanent and Temporary Hearing Loss Threshold Criteria:

Table 8-2 presents non-impulsive sound PTS and TTS threshold criteria for cetacean functional hearing groups based on NOAA (2016) and Finneran (2016).

Table 8-2. Non-impulsive noise PTS and TTS threshold criteria for cetaceans

Cetacean functional hearing group (Southall et al., 2007)	Hearing range	Non-impulsive Sound Exposure Level ($SEL_{24\text{-}h}$) (dB re 1 $\mu Pa^2 \cdot s$)	
		PTS threshold	TTS threshold
Low-frequency (LF) cetaceans	7 Hz to 35 kHz	199	179
Mid-frequency (MF) cetaceans	150 Hz to 160 kHz	198	178
High-frequency (HF) cetaceans	227 Hz to 160 kHz	173	153

Source: NOAA (2016) and Finneran (2016). The SEL assumes that a cetacean would remain in the area for 24 hours, which is an unlikely scenario; therefore, threshold levels would need to larger for shorter duration periods.

Table 8-3 presents impulsive noise PTS and TSS threshold criteria for cetacean functional hearing groups.

Table 8-3. Impulsive noise PTS and TSS threshold criteria for cetaceans

Hearing Group	NMFS (2014)	NMFS (2018)			
	Behaviour	PTS onset Thresholds*		TTS onset Thresholds*	
	SPL_{rms}	SEL_{24h}	SPL_{pk}	SEL	SPL_{pk}
	dB re 1µPa	dB re 1µPa2·s	dB re 1µPa	dB re 1µPa2·s	dB re 1µPa
LF	-	183	219	168	213
MF	160	185	230	170	224
HF	-	155	202	140	196

Source: NMFS (2014, 2018). * Dual metric acoustic thresholds for impulsive sounds; whichever threshold results in the largest isopleth for calculating PTS onset is to be used. The threshold criteria are unweighted. LF, MF, and HF denotes low-frequency, mid-frequency and high-frequency cetacean functional hearing groups, respectively.

(iv) Impacts to Baleen Whales (Mysticeti)

Six species of baleen whales may be expected to occur in the CCZ including humpback, minke, Bryde's, sei, fin and blue whales. The humpback whale (Megaptera novaeangliae) has been selected as a representative for baleen whales as this species has been the most heavily researched in relation to its reactions and behaviour to both impulsive underwater noise (e.g, marine seismic surveying using airgun arrays) and non-impulsive underwater noise (e.g., shipping traffic, drilling and dredging).

As most of the underwater noise generated by the Collector Test components and activities are non-impulsive, continuous broadband noise, received levels in SPL rms have been selected to assess impacts on humpback whales as a surrogate for all baleen whales. Since baleen whales are associated primarily with the sea surface and epipelagic zone, the principal Project-generated noise is associated with the Project's surface vessels (SSV and OSV) in DP mode over the Collector Test Area.

Acoustic damage

Acoustic damage impacts to baleen relate to potential injury, tissue damage or permanent hearing loss (as measured by Permanent Threshold Shift (PTS) onset). The findings of the present study are as follows:

- The adopted published threshold criterion for acoustic damage to cetaceans (180 dB re 1 µPa rms) is limited to a zone within 4.5 m of the combined SSV and OSVs, which represents an extremely small area and volume of water unlikely to be approached by a humpback or other baleen whale.
- In the case of diving baleen whales, the acoustic damage isopleth of 180 dB re 1 µPa rms is not exceeded in epipelagic or mesopelagic waters in the vicinity upper half of the rigid riser, which has a line source level of 155 dB re 1 µPa a 1m.
- The non-impulsive cumulative Sound Exposure Level (SEL24 hr) PTS threshold criterion of 199 dB re 1 µPa2·s (Table 8-2) and impulsive cumulative SEL threshold of 183 dB re 1 µPa2·s (Table 8-3) are not predicted to be exceeded given that a baleen whale is most unlikely to remain in direct proximity of the SSV/OSV thrusters for a period of 24 hours. Therefore, no tissue damage or permanent hearing loss (PTS onset) to baleen whales is predicted.
- The non-impulsive cumulative Sound Exposure Level (SEL24 hr) TTS threshold criterion of 179 dB re 1 µPa2·s (Table 8-2) and impulsive cumulative SEL of 168 of dB re 1 µPa2·s are not predicted to be exceeded given that a baleen whale is most unlikely to remain in direct proximity of the SSV/OSV thrusters for a period of 24 hours. Therefore, no temporary hearing loss (TTS onset) to baleen whales is predicted.

- No acoustic injuries or auditory damage (e.g., PTS and TTS) to baleen whales are predicted from the operation of high-frequency transducers used in acoustic navigation or positioning systems or multibeam echosounders (MBES), as they would have to pass transducers at close range and remain there to be subjected to sound levels that can cause these effects. Most baleen whales have hearing sensitivities below that of the high-frequency instruments, for example the humpback whale (range 20 Hz to 8 kHz).

Overall, no acoustic damage impacts to baleen whales at the surface or diving are predicted from underwater noise generated by Project's surface vessel activities or riser.

Acoustic disturbance

Two acoustic behavioural disturbance threshold criteria for baleen whales are considered: a) 160 dB re 1 µPa rms that elicits disruptive behaviour (e.g., deviating around a noise source or vacating an area to avoid of a noise source), and b) 120 dB re 1 µPa rms above which baleen whales show more subtle behavioural responses or reactions may occur (e.g., brief orientation responses or minor changes in locomotion speed, direction, or diving). The findings of the present study are as follows:

- The acoustic threshold criterion of 160 dB re 1 µParms for disruptive behavioural impacts (e.g., whales deviating or vacating an area) is only exceeded within 45 m of the Project's surface vessels in DP mode, which represents a small area or volume of seawater within which a baleen whale is unlikely to approach or remain within in such close proximity to the vessels.
- The acoustic threshold criterion of 120 dB re 1 µParms for low level or subtle behavioural impacts to cetaceans is exceeded within 4.4 km radius of the Project's surface vessels in DP mode. Baleen whales within this zone will be exposed to non-impulsive continuous broadband noise above 120 dB re 1 µPa rms, which will readily be audible as it will be above ambient background noise (range 97 to 118 dB re 1 µParms). The radius of the 120 dB re 1 µParms sound field will reduce during periods of rainfall or higher sea states, which increase ambient levels near the ocean surface.
- Given that free-ranging, approaching baleen whales should be able to sense the Project-generated noise gradient and may initiate a range of responses, such as moving towards or away from the Surface vessel sin DP mode, or not reacting at all. In addition, the Project's Test Area and its predicted ensonified zone is not within the known migratory routes of baleen whales.

This assessment concludes that Project activities are not expected to cause any adverse impacts on baleen whales. The equivalent underwater noise field out the 120 dB re 1 µParms isopleth would be a Panamax tanker at its normal cruising speed (~13 knots) with a noise source level of 190 dB re 1 µPa at 1 m. Since the Project's surface vessel activities are highly localised to a specific offshore site (i.e., the Test Area within the NORI-D lease area), the noise source may be considered as a relatively 'fixed' or stationary location, and to which some cetaceans show less aversion or avoidance behaviour. For example, Richardson *et al*. (1995) state that "stationary industrial activities producing continuous noise result in less dramatic reactions by cetaceans than do moving sound sources, particularly ships".

Overall, acoustic disturbance impacts to baleen whales from Project activities are assessed to be negligible and not significant given the small area of ocean affected compared to the surrounding large expanse of ocean.

Auditory Masking

There are no peer-reviewed threshold criteria for assessing masking effects on baleen whales when exposed intermittently or continuously to low sound pressure levels within the range of ambient background levels. Notwithstanding, the findings of this assessment are:

- Potential masking impacts to cetacean vocalisation or communications are predicted to be low, given the low source sound pressure levels generated by the Project's surface vessels in DP mode, which reduce rapidly with distance from the source.
- Potential masking may be countered by baleen whales such as humpback and northern right whales, by increasing the intensity or altering the frequencies of their calls when present in an area where noise is above ambient levels.
- Communications between baleen whale mother and calf pairs (should they be present on the CCZ) are least likely to be affected by masking, given their natural protective and close proximity to each other.

(v) Impacts to Toothed Whales (Odontoceti)

The impacts to toothed whales are predicted to less than those predicted for baleen whales above and, as mid-frequency cetaceans, they are sensitive to higher sound frequencies ranging from 150 Hz to 160 kHz which, although there is some overlap at the lower frequencies, are generally above those generated by the Project (20 Hz to 2 kHz).

Acoustic Damage

- The adopted published threshold criterion for acoustic damage to cetaceans (180 dB re 1 µPa rms) is limited to a zone within 4.5 m of the combined SSV and OSVs, which represents an extremely small area and volume of water unlikely to be approached by a humpback or other baleen whale.
- In the case of diving toothed whales (which dive deeper than baleen whales), the acoustic damage isopleth of 180 dB re 1 µPa rms is not exceeded in epipelagic or mesopelagic waters in the vicinity upper half of the rigid riser, which has a line source level of 155 dB re 1 µPa a 1m.
- The non-impulsive cumulative Sound Exposure Level (SEL24 hr) PTS threshold criterion of 198 dB re 1 µPa2·s (Table 8-2) and impulsive sound SEL of 185 dB re 1 µPa2·s (Table 8-3) are not predicted to be exceeded given that a toothed or dolphin whale is most unlikely to remain in direct proximity of the SSV/OSV thrusters for a period of 24 hours. Therefore, no tissue damage or permanent hearing loss (PTS onset) to toothed whales is predicted.
- The non-impulsive cumulative Sound Exposure Level (SEL24 hr) TTS threshold criterion of 178 dB re 1 µPa2·s (see Table 8-2) and impulsive sound SEL of 170 dB re 1 µPa2·s (Table 8-3) are not predicted to be exceeded given that a toothed whale or dolphin is most unlikely to remain in direct proximity of the SSV/OSV thrusters for a period of 24 hours. Therefore, no temporary hearing loss (TTS onset) to toothed whales or dolphins is predicted.
- No acoustic injuries or auditory damage (e.g., PTS and TTS) to toothed whales or dolphins are predicted from the operation of high-frequency transducers used in acoustic navigation or positioning systems or multibeam echosounders (MBES), as they would have to pass transducers at close range and remain there to be subjected to sound levels that can cause these effects.
- While most toothed whales and dolphins have hearing sensitivities that overlap that of the high-frequency instruments, they will readily detect the Project's high frequency signals. However, toothed whales or dolphins approaching the Test Area will detect the sound gradients of the high-frequency instruments sound signals may be attracted to sound beams, avoid them or show little interaction

No acoustic damage impacts to toothed whales are predicted from the low-frequency noise (20 Hz to 2 kHz) generated by the Project's surface vessels (SSV and OSV) in DP mode, which will generate non-impulsive, continuous broadband noise with frequency between 20 Hz and 2 kHz. In addition, no acoustic damage impacts from the Projects' high-frequency transponders or geophysical instrument sources to toothed whales or dolphins are predicted. In some cases, dolphin species may be attracted to the Project's high-frequency signals as is commonly observed for some dolphin species (e.g., bottlenose dolphins) that are inquisitive and regularly approach vessels that are actively using side scan sonars or multibeam echosounders (NSR, 2001).

Acoustic Disturbance

- The acoustic threshold criterion of 160 dB re 1 µParms for disruptive behavioural impacts (e.g., whales deviating or vacating an area) is only exceeded within 45 m of the Project's surface vessels in DP mode, which represents a small area or volume of seawater within which a toothed whale or dolphin is unlikely to approach or remain within in such close proximity to the vessels.
- The acoustic threshold criterion of 120 dB re 1 µParms for low level or subtle behavioural impacts to cetaceans is exceeded within 4.4 km radius of the Project's surface vessels in DP mode. Toothed whales and dolphins within this zone will be exposed to non-impulsive continuous broadband noise above 120 dB re 1 µPa rms, which will readily be audible as it will be above ambient background noise (range 97 to 118 dB re 1 µParms). The radius of the 120 dB re 1 µParms sound field will reduce during periods of rainfall or higher sea states, which increase ambient levels near the ocean surface. However, unlike baleen whales, toothed whales and dolphins are unlikely to be deterred by such low levels of continuous broadband noise containing low frequencies.

Overall, acoustic disturbance impacts to toothed whales and dolphins are predicted to be negligible.

Acoustic Masking

The sound emissions from underwater acoustic positioning systems and geophysical instruments comprise brief, high frequency pulses (in the order of a few milliseconds), occurring several seconds apart. Masking effects in toothed whales caused by the high-frequency emissions from underwater acoustic positioning systems and geophysical instruments would be temporary and negligible because the bandwidths are limited to various narrow beam frequencies (e.g., 12 kHz for MBES) compared to the broader spectrum of toothed whale communication calls and echolocation. In addition, sound levels drop very rapidly within a short distance outside the beams.

(vi) Impacts to Sea Turtles

Acoustic Threshold Criteria

Sea turtle hearing sensitivity is not well studied and there are no published noise level criteria unconstrained, free-ranging sea turtles at sea. Avoidance reactions to seismic sources have been documented in caged turtles at levels between 166 and 179 dB re 1 µPa rms (McCauley *et al*., 2000; Moein-Bartol *et al*., 1995). The lower threshold level of 166 dB re 1 µPa rms is based on research by McCauley *et al*. (2000) who exposed caged turtles to the impulsive noise of a single airgun (Bolt 600B, 20-cubic inch chamber), increased swimming speed was noted above 166 dB re 1 µPa rms and more erratic behaviour above 175 dB re 1µPa rms. Therefore, for the purposes of the present report, a conservative acoustic behavioural disturbance threshold of 175 dB re 1 µPa rms has been adopted in this report as applicable to free-ranging sea turtles that may be exposed to non-impulsive, continuous broadband noise typical of the proposed Collector Test activities at the ocean surface (e.g., the SSV).

Popper *et al*. (2014) proposed that dual injury threshold levels of a cumulative SEL of 210 dB re 1 µPa2·s and a peak SPL of 207 dB re 1 µPapk applicable to fish should apply to sea turtles. However, Table 8-4 lists more recent physiological threshold criteria that have been proposed by Hulton *et al*. (2020) for TTS onset, PTS onset and gastrointestinal tract injury onset in sea turtles.

Table 8-4. Recent acoustic threshold criteria for sea turtles

Behavioural criteria	Physiological criteria		
	TTS onset	PTS onset	GI onset injury *
175 dB re 1 µPa rms	189 dB re 1 µPa^2·s *	204 dB re 1 µPa^2·s *	243 dB re 1 µPa$_{pk}$
	226 dB re 1 µPa$_{rms}$	232 dB re 1 µPa$_{rms}$	-

Notes: * Units are for Sound Exposure Level (SEL) all other values are in units for Sound Pressure Level (SPL).
GI onset injury denotes a gastrointestinal tract injury SPL of 50% (Hutton, 2020).

Acoustic Damage

The range hearing sensitivities (25 to 1,600 Hz) overlaps the frequency range of Project-generated noise (20 Hz to 2 kHz). The following summarises acoustic damage impacts to sea turtles from Project-generated noise sources:

- The 232 dB re 1 µParms for TTS onset is not exceeded by any Project-generated noise source; therefore, permanent hearing loss in sea turtles is not predicted.
- The 226 dB re 1 µParms for PTS onset is not exceeded by any Project-generated noise source; therefore, temporary hearing loss in sea turtles is not predicted.

Overall, acoustic damage impacts to sea turtles are assessed to be negligible given the absence of loud Project noise sources.

Acoustic Disturbance

The following summarises acoustic damage impacts to sea turtles from Project-generated noise sources:

- The disruptive behavioural threshold criterion of 175 dB re 1 µPa rms is exceeded within 7.5 m of the point source (vessel draft of 5 m below the sea surface) of surface vessels in DP mode. This represents a minor impact zone for sea turtles, which are unlikely to approach the surface vessels at lower levels within the sound gradient.
- The disruptive behavioural threshold criterion of 175 dB re 1 µPa rms is not exceeded by riser noise, which has a source level of 155 dB re µPa at 1 m. Therefore, acoustic disruptive disturbance of diving sea turtles from low-level riser noise is not predicted.
- Seabed noise from the nodule harvester (PCV) will have no impact on sea turtle behaviour, given that diving turtles do not dive to the deep ocean environment (i.e., abyssopelagic zone).

Overall, no acoustic disturbance impacts to free-ranging sea turtles in the Nori-D Test Area are predicted.

Auditory Masking

Adult sea turtles do not vocalise underwater, therefore, there is no capacity for masking impacts.

8.2.2.2 Benthic Biota

Benthic biota may be impacted in a number of ways by activities associated with the Collector Test. Sessile fauna attached to nodules (e.g., corals, bryozoans, xenophyophores, sponges etc.), sediment infauna (e.g., polychaetes, nematodes etc.) and motile deposit feeders (e.g., holothurians, echinoids etc.) may be compressed within the sediments if caught under the tracks of the PCV. These organisms will also be extracted with nodules or entrained into the onboard nodule processing system. Sessile obligates may also be smothered by mobilized sediment or have respiratory or feeding functionality compromised due to exposure to sediment loads outside natural range of variation.

The Collector Test will directly impact approximately 0.5 km^2 of the seabed by mechanical disturbance of the sediments by the nozzles and PCV tracks (Section 3.5.2.7). It will also cause indirect impacts to approximately 25 km^2 of seabed through deposition of sediments at levels outside the natural range of variation (Section (j)).

The CTA has been strategically located in the 'Flatter area' geoform which represents the largest Level 2/3 geoform by area in NORI-D (8,553.70 km^2). This avoids disturbance to other Level 2 geoforms such as abyssal hills and seamounts that have been shown to be higher in species richness and standing stock biomass compared to adjacent areas devoid of topographic variability (Clark et al., 2009; Cuvelier et al., 2020; Durden et al., 2015, 2020; McClain, 2007; Ramirez-Llodra et al., 2005; Rowden et al., 2010). Placing the CTA in the 'Flatter area' as a program design measure to minimise the potential impacts to biodiversity, as this geoform type is assumed to be less species rich than the abyssal hills.

Baseline data analysed to date has identified no notable variations in metazoan density between sites, with metazoan megafauna density being relatively homogenous across NORI-D, ranging between 0.93 – 1.08 specimens per meter square of seabed (Section 6.3.1.4).

Macrofauna baseline data suggests that all sites within the CTA, including the TF, appear very similar in terms of abundance and community composition which is a promising result for properly monitoring future changes (Section 6.3.3.4).

Within the CTA, meiofauna communities differed between sites, with significant differences between the TF and NF/FF (p=0.001), whereas no significant differences were observed between NF and FF (p=0.163). However, data did show that most taxa are shared across the entire NORI-D Area (17 occur in all three NORI-D Zones sampled (Section 6.3.4.4).

In terms of benthic foraminifera, the nodule sites in the PRZ, had comparable assemblages to the CTA region making these specific sites a good control (Section 6.3.5.5.).

In combination, these data indicate that the benthic biota represented in the TF are found in other areas of the CTA, the PRZ and the wider NORI-D. Therefore, it is unlikely that the small-scale impacts to the TF and parts of the CTA from mechanical disturbance of the sediments and sedimentation will have a significant impact to benthic biota that could result in 'serious harm' to the receiving environment at a regional level.

8.2.2.3 Benthic Habitat Quality

(a) Changes in micro-topography

This has been addressed d in Section (b). For the same reasons discussed in Section 8.2.2.1 it is unlikely that the small-scale impacts to the TF and parts of the CTA from mechanical disturbance of the sediments and sedimentation will have a significant impact to benthic habitat quality that could result in 'serious harm' to the receiving environment at a regional level.

Changes in micro-topography of the seabed are one of the impacts of the Collector Test that needs to be monitored to inform the design and operation of the commercial system. In this context, a non-significant level of impact that can be monitored and quantified is desirable.

(b) Sediment Plumes

The potential impacts of sediment plumes on benthic, benthopelagic and pelagic organisms are well documented (e.g., Glover *et al.*, 2003; Jones *et al.*, 2017; Oebius *et al.*, 2001; Ramirez-Llodra, 2011; Jumas 1981; Sharma, 2011; 2015; Smith, 1999) and Christiansen *et al.*, (2020) provide a summary of the potential impacts of benthic plumes on biota, including:

- Burying/smothering of sessile organisms.
- Impaired respiration and filter feeding efficiency through clogging of gills and filtration apparatus as a result of high loads of suspended inorganic particles.

- Competition of unpalatable particles with organic food particles resulting in less efficient suspension feeding.
- Interference with odour plumes released from food falls, resulting in lower detection rates and generally lower food availability for scavengers.
- Attenuation of chemosensory and bioluminescent capacity in some organisms leading to reduced probability of finding a mate and to lower reproduction rates.

It is anticipated that benthic, benthopelagic and pelagic organisms within the TF and other parts of the CTA will be exposed to some, if not all, of these impacts to varying degrees. To assess the potential significance of plume related impacts, the duration sediment loads exceed the natural limits of variation, the magnitude of exceedance, and the spatial extent of exceedance are all important factors.

Modelling of the cumulative exceedances of the benthic plume indicates that for the 24-hour period following the cessation of plume generating activities (i.e., the end of productive trials) at 5 m above the seabed, exceedances of > 0.1 mg/l are expected to persist for >15% of the time (i.e., > 3.6 hrs) over an area of approximately 5-6 km^2 (i.e., red area, Figure 7-25A). For the same 24-hour period at 20 m above the seabed, exceedances of > 0.1 mg/l are expected to persist for >15% of the time (i.e., > 3.6 hrs) over an area of approximately 1 km^2 (i.e., red area, Figure 7-25E). These results suggest that the vertical distribution of the benthic plume is largely contained below 20m from the seabed, a finding consistent with that reported by JPI Oceans (2022), which will be verified by plume monitoring conducted during the Collector Test.

Modelling of the cumulative exceedances of the mid-water plume indicates that for the 24-hour period following the cessation of plume generating activities (i.e., the end of productive trials) at 50 m below the point of discharge, exceedances of > 0.1 mg/l are expected to persist for <3% of the time (i.e., <1 hrs). And that the exceedances are confined to 200-250m from the point of discharge beyond which exceedance times fall below 0 (Figure 7-26).

Based on these model outputs it is reasonable to characterise benthic and mid-water plume generation and impacts as:

- Temporary – Plume generation will permanently cease at the end of productive trials (i.e., after completion of STR3b):
- Short in duration – With minor exceptions (STR1B (Figure 7-10) and STR2B (Figure 7-16)), modelling predicts that at 20 m above the seabed, exceedances of > 0.1 mg/l will fall to <10% (i.e., 9.6 hrs) 96 hrs after the cessation of productive trials:
- Vertically contained – Modelling indicated that most exceedances are at ≤ 5m above the seafloor, with exceedance times falling between 5 – 20 m elevation above the seafloor.

Monitoring of plume dynamics to verify the modelling is a primary objective of the Collector Test as this will inform the design and operation of the commercial system. In this context, a non-significant level of plume generation that can be monitored and quantified is desirable. During the Collector Test, the behaviour of both benthic and mid-water plumes will be monitored in real-time using a number of static and autonomous/robotic platforms integrated with a suite of sensors. The ultimate fate of the materials from the plumes will also be determined. This information will be used to verify and refine the plume modelling.

(c) Long-term Monitoring

Post-Collector Test, the TF site and impacted parts of the CTA will be designated as IRZs and used to conduct long-term environmental recovery studies (Chapter 12).

The aim of long-term studies will be to monitor recovery in areas subjected to disturbance. Results of monitoring will be benchmarked against the pre-test biological baseline of the CTA (Chapter 6) and the ongoing monitoring of VECs at the PRZ and control sites.

The IRZs will not be disturbed further following the Collector Test will be preserved and monitored for the duration of operations (i.e., up to 30 years).

8.2.2.4 Microbes

Removing nodules from the seafloor may alter the provision of ecosystem services, such as nutrient regeneration, C-transformation and burial through dissolved inorganic carbon fixation and bioturbation (Wenzhöfer *et al.* 2001; Smith *et al.* 2008; Thurber *et al.* 2014; Sweetman *et al.* 2017; 2019).

Recent in-situ studies in the contract areas in the eastern CCZ have shown that microbes dominate benthic biomass in upper sediment (0-5cm) layers and are the most important organism group cycling organic material (Sweetman *et al.* 2019)

Microbes are also capable of absorbing significant amounts of dissolved inorganic C into their biomass thereby removing CO_2 from the water column, indicating that microbes and macrofauna play important ecosystem roles in abyssal environments, and may be sensitive to disturbance (Mevenkamp *et al.* 2017; Stratmann, Mevenkamp, *et al.* 2018)

Previous studies have shown that benthic ecosystem functioning is exponentially related to benthic biodiversity (Danovaro *et al.* 2008), any modifications to benthic biodiversity caused by disturbance may have significant impacts on microbial activities, seafloor respiration rates and bioturbation activities. Analyses of data from the DISCOL experiments shows that microbially mediated biogeochemical function may need over 50 years to return to undisturbed levels (Vonnahme *et al.*, 2020).

Studies on microbial procaryotes to date suggest regional similarity in taxonomic diversity and community composition across sampled areas of the CCZ, but clear differences per habitat type (i.e., sediment and nodule versus seawater samples) and cruises (likely due to differences in high- throughput sequencing library preparation) (ISBA 2020) (Section 6.3.7).

Although preliminary, these data indicate a level of similarity in taxonomic diversity and community composition across sampled areas. Although it is acknowledged that additional analysis is required in this area, these similarities do support the assumption that it is unlikely that the small-scale impacts to the TF and parts of the CTA from mechanical disturbance of the sediments and sedimentation will cause significant impacts to the microbial biota that could reasonably be considered as 'serious harm' to the receiving environment at a regional level.

Post-Collector Test, the TF and impacted parts of the CTA will be designated as IRZs used to conduct long-term environmental recovery studies (Chapter 9).

The aim of long-term studies will be to assess how microbial activities, C-cycling and seafloor respiration rates have altered following the disturbance, and how they recover. Results of monitoring will be benchmarked against the pre-test baseline of the CTA (Chapter 6) and the ongoing monitoring of VECs at the PRZ.

The IRZs will not be disturbed further following the Collector Test will be preserved and monitored for the duration of operations (i.e., up to 30 years).

8.2.2.5 Nekton & Zooplankton

(a) Underwater Noise & Vibration - Fish

Acoustic Thresholds

Table 8-5 presents acoustic damage (injury and PTS onset) and acoustic disturbance threshold criteria for fishes exposed to impulsive and non-impulsive noise.

Table 8-5. Acoustic threshold criteria for fish functional hearing groups

Fish Functional Hearing Group	Acoustic injury and PTS onset	Impairment/Acoustic Disturbance	
		Recoverable Injury	TTS onset
Thresholds for impulsive noise:			
Group 1 fish: No swim bladder (particle motion detection)	219 dB SEL or 213 dB SPL_{pk}	216 dB SEL or 213 dB SPL_{pk}	>219 dB SEL
Group 2 fish: Swim bladder not involved in hearing (particle motion detection)	210 dB SEL24h or 207 dB SPL_{pk}	203 dB SEL or 207 dB SPL_{pk}	>186 dB SEL
Group 3 fish: Swim bladder involved in hearing (primarily sound pressure detection or 'hearing')	207 dB SEL or 207 dB SPL_{pk}	203 dB SEL or 207 dB SPL_{pk}	186 dB SEL
Thresholds for non-impulsive continuous noise:			
Group 3 fish: Swim bladder involved in hearing (primarily sound pressure detection or 'hearing')	–	170 dB SPL_{rms}	158 dB SPL_{rms}

Source: Based on Xodus (2016) and Popper et al. (2014); Peak sound pressure level (SPL) in units of dB re 1 µPa; sound exposure level (SEL) in units of dB re 1 µPa2·s.

In Table 8-5 there are no acoustic injury and PTS onset for non-impulsive, continuous broadband noise.

Acoustic Damage

No acoustic damage impacts to fishes are predicted, given the absence threshold criteria for permanent acoustic injury or PTS onset to non-impulsive, continuous broadband noise (see Table 8-5). This agrees with Popper et al. (2014) who state there is no direct evidence of mortality or potential mortal injury to fishes from ship noise which, in the case of the current Project, would also apply to non-impulsive, continuous broadband noise associated with the riser and seabed PCV activities.

Acoustic Disturbance

The following summarises acoustic disturbance impacts to fishes from Project-generated noise sources:

- The behavioural threshold criterion of 150 dB re 1 µParms is exceeded within 141.3 m of the point source (vessel draft of 5 m below the sea surface) of surface vessels in DP mode. This represents a minor impact zone for fishes, which are unlikely to approach the vessels at lower levels within the sound gradient.
- The behavioural threshold criterion of 150 dB re 1 µParms is exceeded within 3.2 m of the riser, which has a line source level 155 dB re 1µPa at 1m. Fish behavioural disturbance and avoidance within this very small impact zone is assessed as negligible.
- The TTS onset threshold of 158 dB re 1 µParms is exceeded within 56.2 m of the point source (vessel draft of 5 m below the sea surface) of surface vessels in DP mode. This represents a small impact zone for fishes to experience temporary hearing loss. Fishes are unlikely to remain in proximity of the surface vessels owing to underwater noise and turbulent flows generated by the thrusters and, therefore unlikely to be exposed to TTS onset.

- The acoustic recoverable injury threshold of 170 dB re 1 µParms is exceeded within 14.1 m of the point source (vessel draft of 5 m below the sea surface) of surface vessels in DP mode. This represents a small impact zone for fishes, which are also unlikely to remain in proximity of the surface vessels owing to underwater noise and turbulent flows generated by the thrusters and, therefore unlikely to succumb to recoverable injuries.
- The acoustic recoverable injury threshold of 170 dB re 1 µParms is not exceeded in the vicinity of the riser and only within 1.8 m of the seabed PCV (with production). Overall, no recoverable injuries to midwater or deepwater fishes are predicted for the riser and PCV operation.
- The TTS onset threshold of 158 dB re 1 µParms is exceeded within 56.2 m of the point source (vessel draft of 5 m below the sea surface) of surface vessels in DP mode. This represents a small impact zone for fishes to experience temporary hearing loss. Fishes are unlikely to remain in proximity of the surface vessels owing to underwater noise and turbulent flows generated by the thrusters and, therefore unlikely to be exposed to TTS onset.
- The TTS onset threshold of 158 dB re 1 µParms is not exceeded in the midwater environment surrounding the riser, which has a line source level of 155 dB re 1 µPa at 1 m, which is of similar in magnitude to the TSS onset threshold. Therefore, temporary hearing loss in midwater fishes is not predicted.
- The TTS onset threshold of 158 dB re 1 µParms is exceeded within 7.1 m the seabed PCV (with production), which as has source level of dB re 1 µPa at 1 m. This represents a very small impact zone for deepwater and abyssopelagic fishes and, therefore, temporary hearing loss is not predicted.

Overall, acoustic disturbance impacts to shallow water, midwater environment and deepwater fishes are assessed to be negligible, given the relatively low to moderate source levels of non-impulsive continuous broadband noise and the fact that the sound fields attenuate rapidly with distance. In addition, fishes are expected to acclimate (‘habituate’) or at least desensitise to the sound fields emanating from the Project’s point or line noise sources to some degree.

Auditory Masking

Since the vocalisation and communication frequency ranges of some fish species overlaps the frequency range of the Project’s proposed activities (20 Hz–2 kHz), there is a potential for the masking of fish vocalisations and communication calls, especially benthic soniferous species.

At the seabed, the source level of the Collector Test of the PCV (with production) is predicted to be 175 dB re 1 µPa at 1m, which 140, 130 and 120 dB re 1 µPa rms isopleths at distances of 56.2, 177.8 and 562 m, respectively. These zones within which potential masking of fish vocalisation and communications are assessed to be small, thus masking impacts to seabed fish vocalisations and other communication calls would be highly localised and not significant in the wider population of benthic soniferous fish in adjoining seabed areas.

A limitation for assessing masking impacts is the absence of a species list of deep-water, epibenthic and benthic fish species for the NORI-D Test Area or adjoining CCZ areas. This is currently under development and will be available for the commercial ESIA.

(b) Underwater Noise & Vibration - Invertebrates

Acoustic Thresholds

In the absence of any peer reviewed acoustic threshold criteria for marine invertebrates, the accepted practice is to use the acoustic threshold criteria for the Group 2 fish functional hearing group (i.e., fishes without a mechanically coupled gas bladder to the inner ear). However, in Table 8-5, there are only threshold criteria for the Group 3 fish functional hearing group fishes (i.e., swim bladder involved in hearing); therefore, the threshold criteria for non-impulsive noise for the Group 3 fish functional hearing group have been conservatively adopted for those marine invertebrates capable of sensing sound pressure.

While it is generally accepted that most marine invertebrates have sensory organs or systems that sense particle motion (e.g., vibrations), there are no peer-reviewed marine invertebrates threshold criteria for particle motion. In the absence of vibration threshold criteria, particle motion has been considered qualitatively in the present report and especially those cases where a Project Collector Test component is likely to generate vibrations in the ocean floor.

Acoustic Damage

Most marine invertebrates in the water column (e.g., squid and jellyfishes) and benthic environment (e.g., decapod crustaceans and molluscs) do not have any gas-filled chambers (Lovell *et al*., 2005), there is no possibility for amplification of sound pressure waves from Project-generated noise sources.

Given that the Collector Test components and activities generate non-impulsive continuous broadband noise, acoustic damage impacts are not expected in those marine invertebrates of the upper ocean, midwater environment and deepwater and benthic environment.

Acoustic Disturbance

Most macroinvertebrate species within the NORI-D contact area are benthic sedentary forms, which are unable to evade PCV-generated underwater noise and vibration. Vibration impacts at the seabed from operation of the PCV are predicted to be highly localised to the immediate area of nodule harvesting, therefore behavioural disturbance of benthic macroinvertebrates is assessed to be negligible. Many benthic macroinvertebrates will be physically disturbed by nodule harvest test runs, which is addressed separately in the Draft Collector Test EIS.

In terms of acoustic disturbance to cephalopods in the water column, which are a major prey item for deep diving whales, Kaifu *et al*. (2007) have shown that the common squid (*Loligo vulgaris*) responds by jetting and moving away from a noise source. This behavioural response may be expected to occur in those cephalopod species within the Collector Test Area. area.

- The adopted acoustic threshold criterion of 150 dB re 1 µPa rms for water column cephalopods above which behaviour effects may be expected is exceeded at 141.3 m from the underwater noise generated by the Project's surface vessels (SSV and OSV in DP mode). This potential behavioural impact zone represents a very small area or volume of seawater within which cephalopods may occur. This Project-generated noise is not predicted to adversely disturb water column cephalopods, owing to their high mobility and behavioural avoidance of the Project's louder noise sources

Overall, the Project's acoustic noise and/or vibration sources within the water column or near the seabed are not predicted to result in significant behavioural disturbance of marine invertebrates, owing to the relatively small areas or volumes of seawater within which the acoustic behavioural threshold criterion of 150 dB re 1 µParms is exceeded or the highly located area of vibrations within the seabed and immediate overlying water.

(c) Underwater Noise & Vibration – Summary of Impacts

The underwater noise generated in the shallow-water environment (surface support vessels in DP mode), midwater environment (riser tests), and deep ocean environment (seabed nodule harvesting test runs) are unlikely to trigger any long-term, persistent, deleterious impacts upon marine fauna within these three environmental compartments recognised by the ISA (2020).

The apparent low levels of acoustic impacts to marine fauna assessed are partly due to the following:

- The Collector Test program is a scaled down version camped to a full commercial operation. For example, PCV will be 50% of the dimensions (size) of the commercial PCV and the commercial collector system will comprise five of the larger PCVs operating simultaneously feeding via flexible jumper hoses into a single rigid riser steel pipe.
- The vertical transport system rigid steel riser will be of a larger diameter.
- Collector Test runs and system tests are of short duration.
- The main type of underwater noise generated by the Collector Test components is non-impulsive, continuous broadband or intermitted broadband or narrowband noise.
- The generally low to moderate sound pressure levels of the modelled three loudest noise sources:
    - surface vessels in DP mode– 193 dB re 1 µPa at 1m.
    - vertical transport system (riser) – 150 – 155 dB re 1 µPa at 1m.
    - seabed nodule harvesting (with production) – 175 dB re 1 µPa at 1m.
- The general absence of loud impulsive noise sources, only occasional impulse noise from thruster cavitation during surface vessels maintaining station by dynamic positioning (DP).

These findings will be confirmed as part of the Collector Test by conducting pre-test modelling of the sound sources and sound fields generated by the main Collector System and verifying the acoustic model in the field.

The findings presented with regard to the extent of Project-generated sound fields is in general agreement with one other acoustic study of a similar collector test system that has been published by van der Schaar *et al*. (2020) for the Blue Nodules Global Sea Mineral Resources (GSR) contract area in the CCZ. Figure 8-3 shows a sound pressure level map of the mining scenario based on propagation loss computed with Bellhop acoustic software and source levels estimated from field measurements and literature.

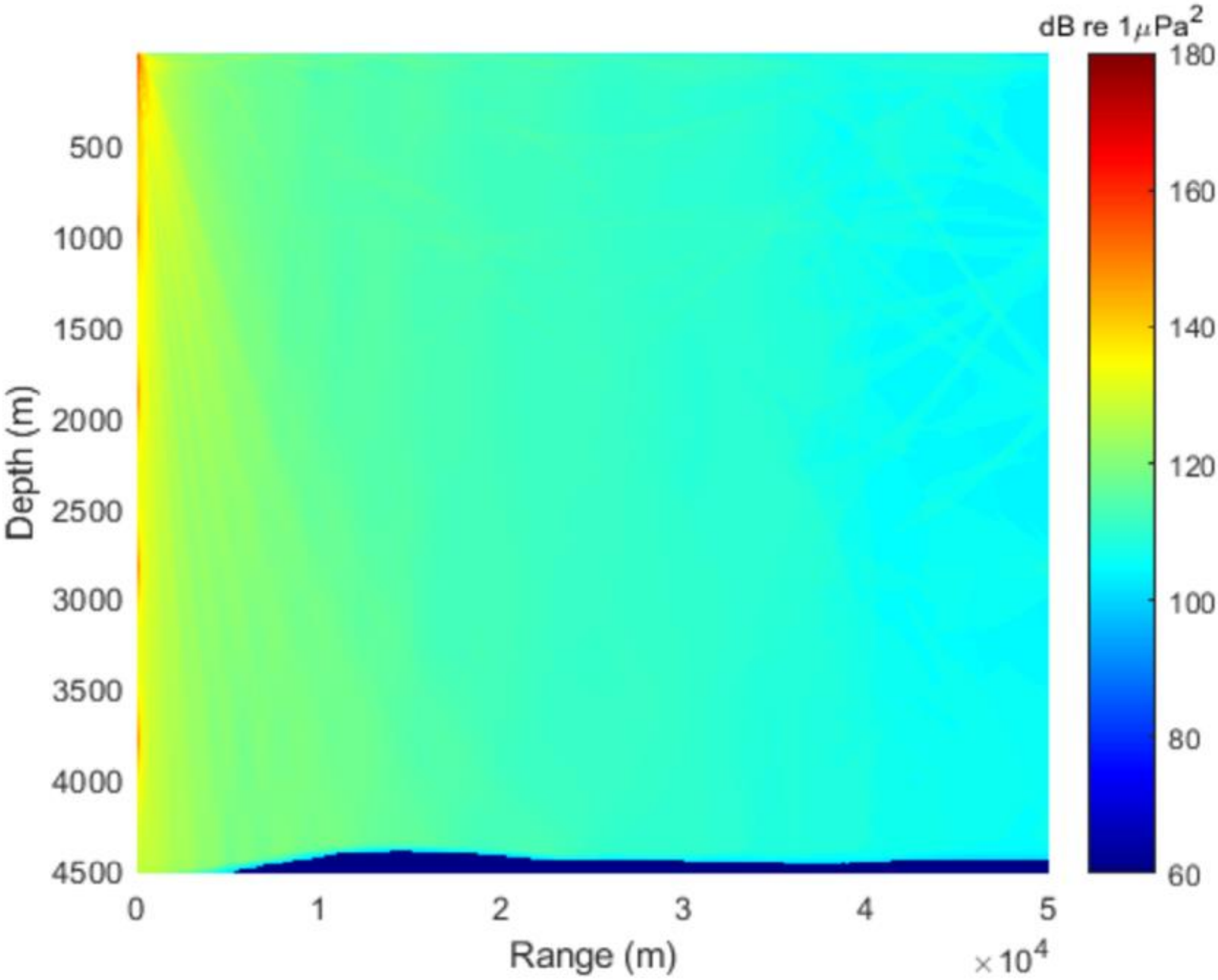
In Figure 8-3, at the surface and epipelagic zone, the surface support vessels source is visible in the vertical water column as are the slurry lift pumps at 944 m, 1,889 m, 2,883 m and 3,778 m depths. However, the sound source of the GSR nodule collector vehicle is not visible, as the sound emitted by the vehicle on the sea floor is dominated by the sound contributions of the other sources (van der Schaar *et al*., 2020). In the case of the Collector Test, the vertical transport system (riser) will not have multiple and noisy vertical slurry pumps but have a single airlift system with air injection around 2,500 m depth.

(d) Plumes

Impacts to nekton and zooplankton communities from nodule collection are most likely to originate from the effects of the mid-water plume as a result of surface processing water being returned to the ocean (Drazen *et al.*, 2020).

Abundant suspension feeders, including protists, crustaceans, polychaetes, salps, and appendicularians, filter small particles from the water and form an important part of the pelagic food web (Conley *et al*, 2018) and mid-water plumes have the potential to cause distress by clogging respiratory and olfactory surfaces (Wilber & Clarke 2001). Suspension feeders may also suffer from dilution of food materials by inorganic sediments and clogging of fragile mucous filter nets (Hu 1981). Fine sediment may adhere to gelatinous plankton, reducing their buoyancy (Robison 2009).

Figure 8-3. Sound pressure map for the Blue Nodule Project (van der Schaar *et al.* 2020)



The impact of resuspending metals from sediment and nodules transported from the seafloor and released from the mid-water plume has been highlighted (Hauton *et al.* 2017). Many metals (e.g., copper, lead, cadmium, chromium, mercury, zinc, arsenic, nickel, iron, lanthanum, yttrium) have been shown to exert toxic effects across trophic levels: from phytoplankton and zooplankton (Hauton *et al.* 2017; Mestre *et al.* 2017) and although extensive data quantify the toxicity of metals in solution in shallow-water organisms, these may not be representative of the toxicity in deep-sea organisms, which may differ biochemically and physiologically and which will experience those toxicants under conditions of low temperature and high hydrostatic pressure, (Hauton *et al.* 2017).

Sediment plumes will also absorb light and change backscatter properties, reducing visual communication and bioluminescent signalling that are essential for prey capture and reproduction in mid-water animals (Haddock *et al.*, 2010). Noise from mining activities could cause physiological stress or interfere with larval settlement, (Lin *et al.* 2019) foraging, and communication in fish (Popper *et al.* 2003).

Modelling of the mid-water plume predicts that TSS exceedances of 0.1 mg/l are within one standard deviation of the mean TSS concentrations recorded at depths between 950 m and 1,250 m from 4 sites within NORI-D sampled during Campaign 4E (see Table 5-3) (CSA, 2022).

Exceedances of 0.1 mg/l, (and hence the impact zone where pelagic biota may be temporarily exposed to sediment levels outside the observed natural range of variation), are laterally contained 200 - 250 m from the point of discharge. The modelling does not show a strong lateral trajectory of the plume in any direction. For all scenarios, the 0.1 mg/l exceedances of the lateral dispersal plume do not extend outside the TF.

In comparing mid-water plume dimensions from literature values presented as max concentrations or dilution factors to the % exceedance used for impact assessment purposes in Section 7.2.1.4 it is thus essential to compensate for the results presentation method. It is also essential to take into account differences in the amount of sediment released into the water column.

For example, the mid water plume presented by Muñoz Royo *et al*. 2021 generates in 11 days a plume size of approximately 200km^2 at a 400,000 dilution level. However, the mass released over that 11 days is approximately 15 times higher than will be released by the Collector Test operations planned at NORI-D. While it is recognized that a linear relationship between amount of sediment released and plume size is an over-simplification, it is apparent that the plume from the Collector Test demonstrates a similar scale of effect when differences in sediment release and results presentation method are considered (i.e., 200km^2/15 = 13.3 km^2 to compensate for spill volume is similar to the 16km^2 Collector Test results for the same 400,000 dilution limit).

With exceedances of ≥0.1 mg/l laterally contained 200 - 250 m from the point of discharge and an overall plume dispersal footprint of just 16km^2 (compared with 200km^2 Muñoz Royo *et al*. 2021). It is reasonable to assume that plume related impacts to pelagic biota will be tightly spatially contained and unlikely to cause significant impacts to the pelagic biota that could reasonably be considered as 'serious harm' to the receiving environment at a regional level.

As part of the Collector Test monitoring program, nekton and zooplankton communities will continue to be tracked post-disturbance. Baseline metal concentrations in pelagic fish will also be established and tracked (see Section 6.4.8).

Dispersal of the mid-water plume is one of the impacts of the Collector Test that needs to be monitored to inform the design and operation of the commercial system. In this context a non-significant level of impact that can be monitored and quantified is desirable.

8.3 Impact Mitigation

The primary method for minimisation of impacts to biological VECs is by considered planning and design of the collector system and test program. In addition to measures to minimise impacts to physicochemical VECs described in Section 7.3, the following additional design features have been incorporated into the Collector Test to minimise impacts to biological VECs:

8.3.1 Equipment Design

1. A specially designed Launch and Recovery System (LARS) for the PCV has been fitted to the side of the Hidden Gem. The LARS affords a very high degree of control for raising and lowering the PCV through the splash zone, allowing the operation to be paused or slowed at any time and minimizing the likelihood of any significant interactions with marine fauna.

8.3.2 Test Planning

2. The area of seabed that will be directly disturbed by the PCV has been contained to just 0.5km^2; considered to be the minimum level of disturbance required to credibly assess the functionality of the system and potential environmental impacts. This represents just under a quarter (23%) of the 2.2 km^2 that was disturbed within the 10.8 km^2 DISCOL experiment in the Peru basin[11].
3. CTA has been located in the Level 2/3 'Flatter area' which is the largest geoform by area (8,553.70 km^2) in NORI-D, rather than in the Level 2 'Abyssal hills' geoform. This placement is

[11] https://www.discol.de/discol-/-atesepp;jsessionid=6AC61B752493647E6439C9CF1B2FD023

intentional as Abyssal hills and seamounts have been shown to be higher in species richness and standing stock biomass compared to adjacent areas devoid of topographic.

4. The area of seabed experiencing sedimentation rates above the demonstrated natural range of variation (i.e., ≥0.1 mm) is limited to 25km^2. This is considered the minimum level of disturbance required to credibly assess the functionality of the system and potential environmental impacts.
5. Measures recommended by the International Maritime Organisation for minimising the risk of collisions between ships and whales will be implemented during the Collector Test campaign, including: good route planning for transit to the site, keeping watch, continued scientific research into the migratory species that utilize NORI-D.
6. The wet weight of nodules collected during the Collector Test will be restricted to approximately 3,600 tonnes, limiting the impacts of the test due to loss of nodule habitat and direct impacts to benthic biota.
7. Nodules >80 mm in diameter will not be collected. Larger nodules will be left in the TF where they may continue to provide habitat value for nodule obligate biota, if not buried by sediment.
8. Modelling predicts that mid-water exceedances of ≥0.1 mg/l will be laterally contained to 200 - 250 m from the point of discharge and an overall plume dispersal footprint of will be just 16km^2; this is 8% of the 200 km^2 plume footprint generated by the Muñoz Royo et al. (2021) study.

8.3.3 Test Operations

9. A marine mammal observer (MMO) will be present during all offshore operations and to act immediately to protect species of concern should they enter the vessel's exclusion zone prior to and sometimes during operations. The MMO will advise personnel onboard to delay or shutdown operations until the animals are at a safe distance and also to record behaviour and sightings at other times.
10. The air lift will be in operation during the Riser installation and commissioning, System Integration Test and System Test Runs. This is considered to be the minimum operating time required to meet the objectives of the Collector Test and limits exposure to potentially impactful underwater noise to approximately 529 hours.

8.4 Risk Assessment

The results of the risk assessment indicate that with the implementation of the proposed mitigation measures and any prescribed additional project specific controls (Table 8-6, Columns 4 and 8 respectively) no residual significant impacts to the biological component of the receiving environment are anticipated at a regional scale.

Table 8-6 Impact significance & risk assessment - Biological VECs

ACTIVITY	VULNERABLE VECS	IMPACTS	MITIGATION MEASURES	CONSEQUENCE M	CONSEQUENCE S	CONSEQUENCE RATING	LIKELIHOOD	RESIDUAL RISK	ADDITIONAL PROJECT SPECIFIC CONTROLS	SIGNIFICANT
Return transit of the vessel from San Diego to the CCZ	Cetaceans/Turtles	Vessel strike	Measures recommended by the International Maritime Organisation (IMO, 2013) for minimising the risk of collisions between ships and whales will be implemented during the Collector Test campaign, including: good route planning for transit to the site, keeping watch, continued scientific research into the migratory species that utilize NORI-D.	1	1	Negligible	Possible	Negligible	A marine mammal observer (MMO) will be present during all offshore operations and to act immediately to protect species of concern should they enter the vessel's exclusion zone. The MMO will be empowered to advise personnel onboard to delay or shutdown operations until the animals are at a safe distance and to record behaviour and sightings at other times.	NO
Offshore Inspection and Preparation	Benthic Biota (sediment, nodule, free swimming)	Deployment of the ROV and other equipment (inc. LBL network) to the seabed has the potential to physically disturb sediment and nodule dwelling animals.	The CTA and TF have been strategically positioned to avoid geoforms that potentially support higher levels of biodiversity (i.e., Abyssal hills). Data is presented indicating that the benthic biota represented in the TF are found in other areas of the CTA, the PRZ and the wider NORI-D. The Collector Test has been designed to limit the area of seabed directly disturbed by the PCV to just 0.5km^2. This is considered the minimum level of disturbance required to credibly assess the functionality of the system and potential environmental impacts. The area of seabed experiencing sedimentation rates above the demonstrated natural range of variation (i.e., ≥0.1 mm) is limited to 25km^2. This is considered the minimum level of disturbance required to credibly assess the functionality of the system and potential environmental impacts.	1	1	Negligible	Almost Certain	Low	Not required	NO
	Benthic Habitat Quality	Deployment of other equipment (inc. LBL network) to the seabed will physically disturb benthic habitat by creating contours in the sediment.	The area of the seabed that will be disturbed with each touchdown of an LBL beacon will be negligible.	1	1	Negligible	Almost Certain	Low	Not required	NO
PCV Deployment	Cetaceans/Turtles	Lowering the PCV through the splash zone could disturb or physically strike cetaceans or turtles that are in close proximity to the vessel.	A specially designed Launch and Recovery System (LARS) for the PCV has been fitted to the side of the Hidden Gem. The LARS affords a very high degree of control for raising and lowering the PCV through the splash zone, allowing the operation to be paused or slowed at any time and minimizing the likelihood of any significant interactions with marine fauna.	1	1	Negligible	Possible	Negligible	A marine mammal observer (MMO) will be present during all offshore operations and to act immediately to protect species of concern should they enter the vessel's exclusion zone. The MMO will be empowered to advise personnel onboard to delay or shutdown operations until the animals are at a safe distance and to record behaviour and sightings at other times.	NO
	Benthic Biota (sediment, nodule, free swimming)	Touchdown of the PCV on the seabed will physically disturb or displace sediment and nodule dwelling animals.	The footprint of the PCV measures 6x6 m the area that will be disturbed with each touchdown of the PCV (i.e., non-propelled) will be negligible.	1	2	Negligible	Almost Certain	Low	Not required	NO

ACTIVITY	VULNERABLE VECS	IMPACTS	MITIGATION MEASURES	CONSEQUENCE			LIKELIHOOD	RESIDUAL RISK	ADDITIONAL PROJECT SPECIFIC CONTROLS	SIGNIFICANT
				M	S	RATING				
	Benthic Habitat Quality	Touchdown of the PCV on the seabed will physically disturb the benthic habitat by creating contours in the sediment and/or moving or crushing nodules.	The footprint of the PCV measures 6x6 m the area that will be disturbed with each touchdown of the PCV (i.e., non-propelled) will be negligible.	1	2	Negligible	Almost Certain	Low	Not required	NO
Jumper and Riser Deployment	Cetaceans/Turtles	Lowering the jumper and riser tubes through the splash zone has the potential to disturb or physically strike cetaceans or turtles that are in close proximity to the vessel.	None	1	1	Negligible	Possible	Negligible	A marine mammal observer (MMO) will be present during all offshore operations and to act immediately to protect species of concern should they enter the vessel's exclusion zone. The MMO will be empowered to advise personnel onboard to delay or shutdown operations until the animals are at a safe distance and to record behaviour and sightings at other times.	NO
System Testing	Cetaceans/Turtles	Riser installation and commissioning tests, system integration testing, and system test runs all have the potential to create noise and vibration disturbances at the surface and throughout the water column from use of the air lift and through pressure testing of the system which could disturb diving and foraging behaviour.	The air lift will only be in continuous operation during the system integration test and productive system test runs, limiting the time of underwater noise and vibration generation from this source to approximately 283 hours. This impact is temporary and will be removed once the Collector Test has ended without any residual impacts. This impact is temporary and will be removed once the Collector Test has ended without any residual impacts. The of Vertical Transport System (VTS) using airlift riser technology rather than noisier technologies such as risers with multiple slurry pumps or risers fitted with a Subsea Slurry Lift Pump (SSLP) fitted with individual positive displacement pump module displacement pump at its base.	2	4	Low	Almost Certain	Medium	A marine mammal observer (MMO) will be present during all offshore operations and to act immediately to protect species of concern should they enter the vessel's exclusion zone. The MMO will be empowered to advise personnel onboard to delay or shutdown operations until the animals are at a safe distance and to record behaviour and sightings at other times.	NO
	Microbes	Manoeuvring the PCV on the seabed, pick-up test runs, and system test runs will physically disturb the sediments and nodules potentially disrupting the microbial community structure in the surface layers of the sediment, and seafloor metabolic activity	The Collector Test has been designed to limit the area of seabed directly disturbed by the PCV to 0.5km^2. This is considered the minimum level of disturbance required to credibly assess the functionality of the system and potential environmental impacts. The area of seabed experiencing sedimentation rates above the demonstrated natural range of variation (i.e., ≥0.1 mm) is limited to 25km^2. This is considered the minimum level of disturbance required to credibly assess the functionality of the system and potential environmental impacts.	2	1	Negligible	Almost Certain	Low	Not required	NO
	Benthic Biota (sediment, nodule, free swimming)	Manoeuvring the PCV on the seabed and pick-up test runs will create noise	The CTA and TF have been strategically positioned to avoid geoforms that potentially support high levels of biodiversity (i.e., Abyssal hills). Data is presented indicating	2	1	Negligible	Almost Certain	Low	Not required	NO

ACTIVITY	VULNERABLE VECS	IMPACTS	MITIGATION MEASURES	CONSEQUENCE			LIKELIHOOD	RESIDUAL RISK	ADDITIONAL PROJECT SPECIFIC CONTROLS	SIGNIFICANT
				M	S	RATING				
		and vibration which could disturb or displace motile large macrofauna. Riser installation and commissioning tests, system integration testing, and system test runs all have the potential to create noise and vibration disturbances at the surface and throughout the water column from use of the air lift and through pressure testing of the system. PCV will emit light. Manoeuvring the PCV on the seabed and pick-up test runs will physically disturb or remove sediment and nodule dwelling animals. System test runs will create a benthic plume, as entrained sediment is ejected from the rear of the PCV; this plume will be denser than that formed during the manoeuvrability and pick-up test runs and will blanket and smother surrounding sessile biota.	that the benthic biota represented in the TF are found in other areas of the CTA, the PRZ and the wider NORI-D. The Collector Test has been designed to limit the area of seabed directly disturbed by the PCV to just 0.5km2. This is considered the minimum level of disturbance required to credibly assess the functionality of the system and potential environmental impacts. The area of seabed experiencing sedimentation rates above the demonstrated natural range of variation (i.e., ≥0.1 mm) is limited to 25km^2. This is considered the minimum level of disturbance required to credibly assess the functionality of the system and potential environmental impacts. Nodules >80 mm in diameter will not be collected. Larger nodules will be left in the TF where they may continue to provide habitat value for nodule obligate biota, if not buried by sediment. The wet weight of nodules collected during the Collector Test will be restricted to approximately 3,600 tonnes, limiting the impacts of the test due to loss of nodule habitat and direct impacts to benthic biota.							
	Benthic Habitat Quality	Manoeuvring the PCV on the seabed and pick-up test runs will physically disturb the benthic habitat by creating contours in the sediment, disrupting surface layers of sediment, and/or moving or crushing nodules. System test runs will create a benthic plume, as entrained sediment is ejected from the rear of the PCV; this plume will be denser than that formed during the manoeuvrability and pick-up test runs and will blanket and smother surrounding sessile biota.	The Collector Test has been designed to limit the area of seabed directly disturbed by the PCV to just 0.5km^2. This is considered the minimum level of disturbance required to credibly assess the functionality of the system and potential environmental impacts. The area of seabed experiencing sedimentation rates above the demonstrated natural range of variation (i.e., ≥0.1 mm) is limited to 25km^2. This is considered the minimum level of disturbance required to credibly assess the functionality of the system and potential environmental impacts. Nodules >80 mm in diameter will not be collected. Larger nodules will be left in the TF where they may continue to provide habitat value for nodule obligate biota, if not buried by sediment. The wet weight of nodules collected during the Collector Test will be restricted to approximately 3,600 tonnes, limiting the	2	1	Negligible	Almost Certain	Low	Not required	NO

ACTIVITY	VULNERABLE VECS	IMPACTS	MITIGATION MEASURES	CONSEQUENCE			LIKELIHOOD	RESIDUAL RISK	ADDITIONAL PROJECT SPECIFIC CONTROLS	SIGNIFICANT
				M	S	RATING				
			impacts of the test due to loss of nodule habitat and direct impacts to benthic biota.							
	Nekton	Nekton in the euphotic, pelagic and bathypelagic zones could be impacted by noise and vibration from the air lift system and by suspended sediment and mobilized chemicals released from the return water pipe outlet at 1,200 m.	The air lift will only be in continuous operation during the system integration test and productive system test runs, limiting the time of underwater noise and vibration generation from this source to approximately 283 hours. This impact is temporary and will be removed once the Collector Test has ended without any residual impacts. The of Vertical Transport System (VTS) using airlift riser technology rather than noisier technologies such as risers with multiple slurry pumps or risers fitted with a Subsea Slurry Lift Pump (SSLP) fitted with individual positive displacement pump module displacement pump at its base. Modelling predicts that mid-water exceedances of ≥0.1 mg/l will be laterally contained to 200 - 250 m from the point of discharge and an overall plume dispersal footprint of will be limited to $16km^2$. The return water will be discharged outside the bounds of the measured oxygen minimum zone at 1,200m. The effective discharge depth is likely to be extended up to 1,280m providing additional distance between the point of discharge and the productive mesopelagic zone.	2	2	Low	Almost Certain	Low	Not required	NO
	Zooplankton	Zooplankton in the euphotic, pelagic and bathypelagic zones could be impacted by noise and vibration from the air lift system and by suspended sediment and mobilized chemicals released from the return water pipe outlet at 1,200 m.	The air lift will only be in continuous operation during the system integration test and productive system test runs, limiting the time of underwater noise and vibration generation from this source to approximately 283 hours. This impact is temporary and will be removed once the Collector Test has ended without any residual impacts. The of Vertical Transport System (VTS) using airlift riser technology rather than noisier technologies such as risers with multiple slurry pumps or risers fitted with a Subsea Slurry Lift Pump (SSLP) fitted with individual positive displacement pump module displacement pump at its base. Modelling predicts that mid-water exceedances of ≥0.1 mg/l will be laterally contained to 200 - 250 m from the point of	2	2	Low	Almost Certain	Low	Not required	NO

ACTIVITY	VULNERABLE VECS	IMPACTS	MITIGATION MEASURES	CONSEQUENCE			LIKELIHOOD	RESIDUAL RISK	ADDITIONAL PROJECT SPECIFIC CONTROLS	SIGNIFICANT
				M	S	RATING				
			discharge and an overall plume dispersal footprint of will be limited to 16km2. The return water will be discharged outside the bounds of the measured oxygen minimum zone at 1,200m. The effective discharge depth is likely to be extended up to 1,280m providing additional distance between the point of discharge and the productive mesopelagic zone							
Riser and PCV Recovery	Cetaceans / Turtles	Rising the jumper hose, riser pipe, and PCV through the splash zone could disturb or physically strike cetaceans or turtles that are in close proximity to the vessel.	A marine mammal observer (MMO) will be present during all offshore operations and to act immediately to protect species of concern should they enter the vessel's exclusion zone. The MMO will be empowered to advise personnel onboard to delay or shutdown operations until the animals are at a safe distance and to record behaviour and sightings at other times.	1	1	Negligible	Possible	Negligible	Not required	NO

9 CUMULATIVE & TRANSBOUNDARY IMPACTS

9.1 Cumulative Impacts

Cumulative impacts may include (Type 1) the aggregate of different stressors that have, do or likely will act on an ecosystem; (Type 2) repetition of the same type of stressor acting on it over time; or (Type 3) impacts on migratory species that may encounter stressors of the same or different types during other portions of their migratory path. In general, cumulative effects of stressors may be additive, synergistic or antagonistic, and may differ by response level (e.g., community, population, trophic level), and synergistic interactions may be quite comment (Crain, Kroeker, Halpern 2008).

Existing cumulative anthropogenic impacts in the CCZ are relatively low (Figure 9-1A) and increased only slowly from 2003-2013 (Figure 9-1B), but those assessments may be conservative because (i) some human activities with known stressors, e.g., deep-sea mining, plastic pollution, sound pollution and others) could not be included owing to limited or non-existent data, (ii) more recent data for 2014-2019 could not be included because datasets were not yet complete, and (iii) non-linear (synergistic) effects may be more common than modelled (Halpern *et al.* 2019).

Existing stressors include occasional sound (shipping, fishing, geological exploration), commercial fishing and gradual anthropogenic rises in temperature and pH associated with climate change. It is assumed that all will continue at their current rate during the Collector Test, but that no new activities (e.g., CO_2 disposal, hazardous waste disposal etc.) will be added.

Previous investigations in NORI-D during the period 2012-2020 have collected 4,770 kg of nodules; completed 259 box cores (each 0.25 m^2); and towed a 1.1 m wide epibenthic sled resulting in aggregate seafloor disturbance of less than 10,000 m^2. Autonomous or remotely operated underwater vehicles, midwater instruments to sample water chemistry or plankton, and mooring or servicing of instruments to measure sound, sedimentation or other parameters are assumed to have had minimal impact.

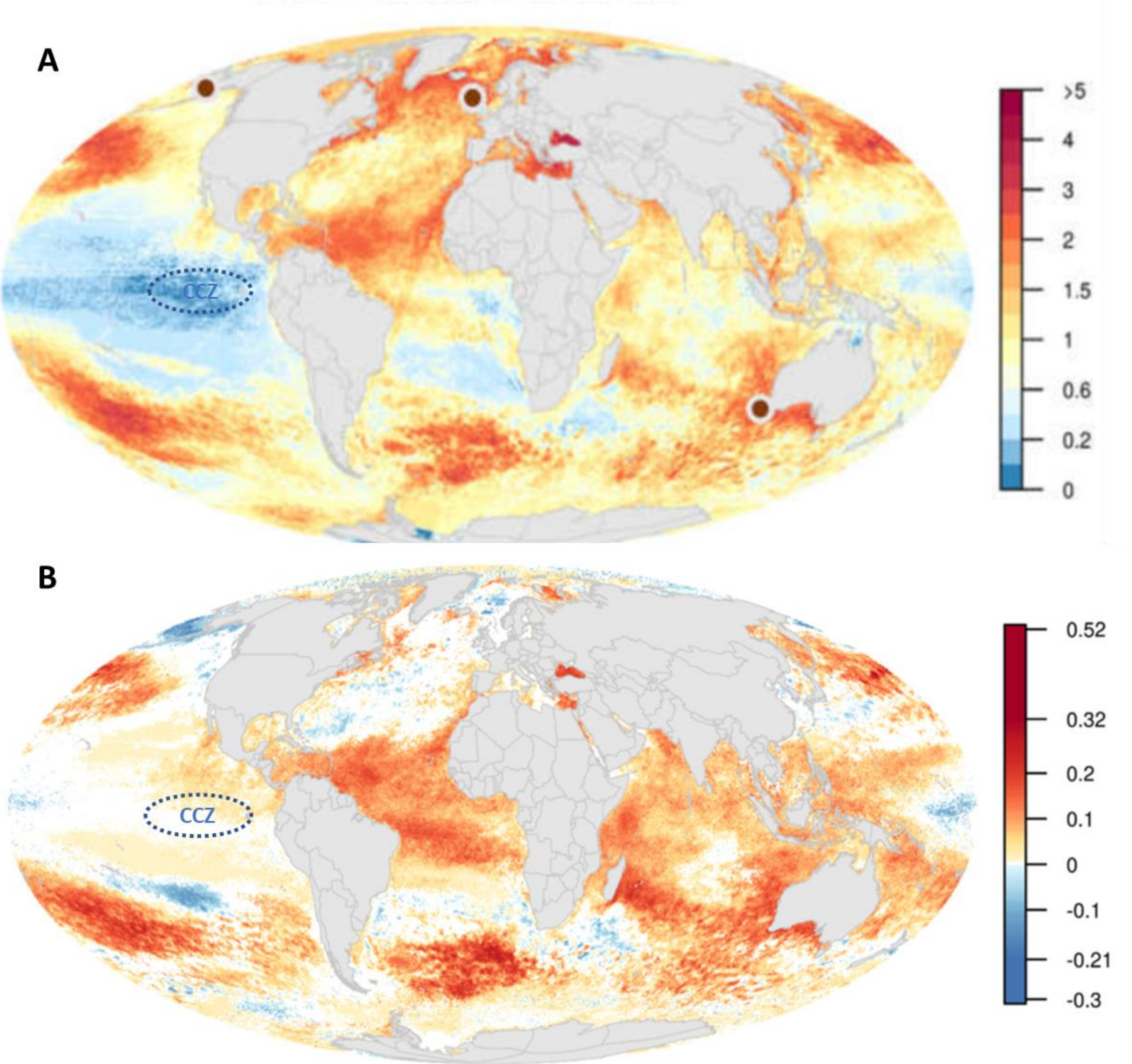
Within the 150 km^2 CTA, new stressors will be introduced in a directly disturbed 0.5 km^2 portion of the 8 km^2 (2 km x 4 km) TF during 860 hours (35.8 days) of tests that will include driving the PCV 82 km, with 259 hours (10.8 days) at full test operation. The area of seabed experiencing sedimentation rates above the demonstrated natural range of variation (i.e., ≥0.1 mm) is limited to 25.5km^2 and entrained sediment to the surface, and discharging "waste" water, sediments and fines at 1,200 m depth.

Stressors produced during Collector Testing will include sound (ship, robot and riser pipe operations), light (ship and robot operations), sediment disturbance (movement, compaction), sedimentation, increased total suspended solids (TSS), turbidity (benthic plumes, midwater discharge of entrained sediments and fines), extraction of nodules, mobilization of toxins (if any) from sediments, sediment pore water and nodule fines, and local changes in temperature, oxygenation or other physiochemical parameters.

Different combinations of stressors could affect different types and size classes of organisms, and in different ways, but such cumulative effects are still poorly understood. Beyond obviously injurious impacts, non-injurious effects could accumulate to have population-level effects mediated through physiological impacts and probably other mechanisms (Williams *et al.* 2015).

Stressors expected during the Collector Test period are discussed below. Owing to the limited time and extent of the Collector Test it is reasonable to assume that risk from cumulative impacts to ecological function and the environmental services they support would be low.

Figure 9-1. A - Static map of cumulative human impact score (CHI - a unitless metric) for 2013; B- Estimated annual change in CHI 2003-2013 (adapted from Halpern 2015).



9.1.1 Sound

Sound (or vibrations) can act as Type 2 cumulative impacts on nearly all organisms but may also produce Type 3 impacts on marine mammals and others that experience other stressors during their long-distance migrations. Impact severity is dependent on sound frequency, intensity, duration and repetition.

9.1.2 Light

At the surface, light can be an indirect stressor for marine birds, interfering with navigation or causing collision with ships, but could also have positive impacts by guiding them to resting places or improved fishing via attraction of vertically migrating organisms and their predators. In the water column or on the seafloor light could produce Type 1 or 2 cumulative impacts.

9.1.3 Total Suspended Solids (TSS), turbidity, oxygen, temperature rise and local heavy metals

These stressors may have Type 1 and 2 cumulative impacts on abyssopelagic fishes and invertebrates, though active swimmers may be able to escape many stressors at Test Collector Scale. Trophic stressors will likely be undetectable over the short Collector Test time period. There is currently no evidence that dissolved metals would be released along with the sediments and fines (Muñoz-Royo *et al.*, 2021). Paul *et al.* (2021) evaluated the risk of toxicity from dissolved copper released from pore water by deep-sea mining as negligible, but also called for further research on different size fractions of copper, co-release of several metals, and variations of pH.

9.1.4 Extraction of nodules

Nodule associated fauna will be the most severely impacted group of organisms. Those on nodules that are collected, crushed or buried by sediments will be killed, but survivors on uncollected nodules will face loss of substrate for reproduction as well as increased TSS, sedimentation and light. Cumulative impacts will be Type 1 and 2. Nodule removal is predicted to cause loss of 17.9% of taxa and 30.6% of trophic network links in the CCZ owing mainly to removal of stalked glass sponges living attached to the nodules as key structural species that support a high diversity of associated fauna (Straatmann *et al.* 2021).

9.1.5 Cumulative benthic stressors

Compaction, TSS, sedimentation and light will be Type 1 and 2 cumulative stressors, affecting sessile, filter-feeders most severely, motile deposit feeders to a lesser extent except for those killed outright by collection and rejection, compression by collector tracks or burial. Megafauna may be most susceptible to harm, followed by macrofauna, meiofauna and microfauna, with recovery rates likely to occur in reverse order.

9.1.6 Physical & chemical stressors

At the small scale and short duration of the Collector Test, changes in physical (temperature, pH) or chemical (e.g., oxygen concentration, toxic metals or other dissolved substances will rapidly dilute to ambient conditions owing to the huge volume of surrounding water and continuous movement of the test apparatus. TSS and turbidity will decline with time and distance from the point of benthic disturbance or midwater discharge but take longer to reach ambient conditions. The finest particles (2-10µ) will drift for long times (~1 yr or more) and distances (up to ~1,000 km or more) but reaching sufficiently low concentration and accumulated deposition that impacts would be difficult to discern.

The area of the CCZ directly-disturbed area of Collector Test, 0.5 km^2 section is compared to surrounding areas and areas encountering other types of disturbance in Table 9-1.

Table 9-1. Size comparison of directly-disturbed area of Collector Test, 0.5 km^2, compared to surrounding areas and areas encountering other types of disturbance.

Site	Area (km^2)	Size Comparison (Multiple)	Reference
Collector Test directly disturbed area	0.5	-	-
DISCOL directly disturbed area	2.16	4.3	www.discol.de
NORI-D	25,160	50,320	ISA
CCZ Contract area	1,200,000.0	2,400,000	ISA
CCZ area	4,500,000.0	9,000,000	ISA
N. Pacific abyssal seabed	24,906,630.0	49,813,260	www.bluehabitats.org
Submarine cables	12,000.0	24,000	Jouffray *et al.* 2019, OSPAR 2009
Seabed annually trawled by fisheries	4,900,000.0	9,800,000	Sala *et al.* 2021
Global agricultural land	47,953,427.0	95,906,854	World Bank 2020

9.2 Transboundary Impacts

There is potential for some of the stressors from the Collector Test to impact across contract zones, water column depth zones, and possibly political boundaries. Many such demarcations are independent of species distributions, hence the need for assessments of transboundary governance arrangements (Fanning *et al.* 2015). We mention the most likely transboundary impacts in order of depth.

9.2.1 Stressors from surface activities

9.2.1.1 Noise

Noise is a stressor produced by Collector Test surface activities that has the potential to cross contract zones or political boundaries. In deep water, sound transmission directionality is strongly downward and may easily couple into the Sound Fixing And Ranging (SOFAR) channel (Erbe *et al.* 2019) which is at about 750 m in the vicinity of Hawaii. Rapidly intensifying soundscapes during the Anthropocene (Duarte *et al.* 2021) have been of concern with respect to marine mammals (Erbe *et al.* 2019), but harm or effects on behaviour, vocalization, stress, feeding, reproduction or survival have also been reported for invertebrates, fish and others (Weilgart 2018, Duarte *et al.* 2021). Long-term biological significance is not always known but very high-energy sounds (airguns, naval sonar) can produce anatomical damage, escape responses leading to embolism and is linked to mass strandings of whales and dolphins (Weilgart 2018, Erbe *et al.* 2019, Duarte *et al.* 2021). Anthropogenic sound in the CCZ area is currently relatively low, approximately 85 to 90 dB re 1 µPa2 (Duarte *et al.* 2021, Fig. 3A). Hydrocarbon pollution from a significant fuel or oil loss could also cross contract zones, though likelihood is small. No surface-generated stressor will affect the seabed in any significant way except for breakup of a ship, (extremely unlikely) or loss of equipment and subsequent recovery.

9.2.1.2 Sediment Mobilization

(a) Water column or seabed to other contract zones

Horizontal transport of sediment, TSS, turbidity, carbon or toxic chemicals (if any) will occur at current-driven rates likely averaging up to 3 cm/s (calm conditions), 5 or 6 cm/s (intermediate), 8 cm/s (active) (EIS). Mesoscale eddies averaging 8.8 cm/s and 12.5 cm/s for cyclonic and anticyclonic eddies, respectively, may persist for long periods (weeks or months) and travel thousands of km influencing deep water and bottom currents, and influencing cumulative stress by stirring up some bottom sediments (Purkiani *et al.* 2020), but also speeding dispersal of suspended sediment and turbidity (Aleynik *et al.*, 2017). Blanketing thickness beyond ~400 m from a disturbance is likely to be less than 1 mm (Gausepohl, *et al.* 2020). Distribution of settled particles by currents or eddies may continue for years. Sound produced in midwater could also cross into other contract zones or political jurisdictions, particularly if it enters the SOFAR channel (Erbe *et al.* 2019), though air injection into the riser pipe (2,500 m) and discharge of riser water (1,200 m) will both be below SOFAR channel depth.

(b) Water column or seabed to photic zone or atmosphere

Upward transport into the photic zone or atmosphere of sediment, turbidity, carbon, nutrients, toxic chemicals or other from depths exceeding 1,000 meters can only occur via hydrothermal circulation on a centuries to millennial timescale.

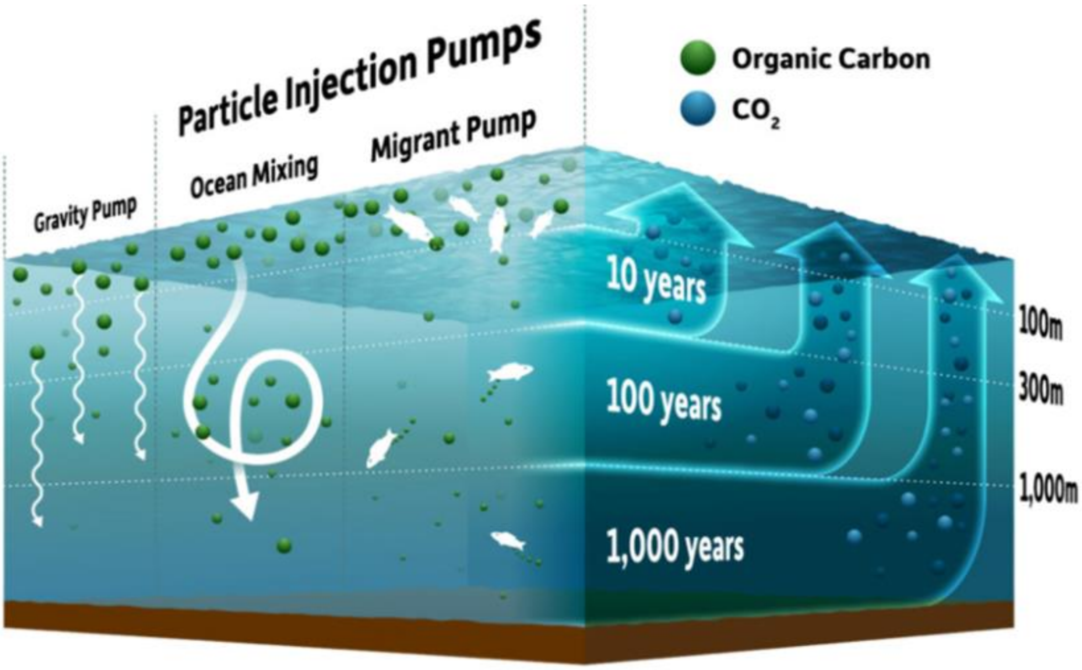
(c) Seabed to water column

Sediment in benthic plumes is expected to rise no more than about 200 m, but it will impact the Benthic Bottom Layer that can at times contain large numbers of larvae (meroplankton) of sessile benthic invertebrates as well as benthic fish.

(d) Seabed or water column to other oceanic or global areas

Any sound entering the SOFAR channel could potentially reach other Pacific Ocean areas or cross political boundaries. Drift of some very small particles could also reach areas beyond the CCZ with concentration exponentially decreasing depending on current speed, turbulence and other mixing parameters. The nearest political boundaries are hundreds of kilometres distant, but particles less than 10µ can remain suspended for a year or more and travel 1,000 km or more, perhaps crossing some political boundaries and depositing over an area comparable to the entire CCZ at rates equal to about one percent of ambient rates of sediment deposition (~1 mm/yr) (Muñoz-Royo *et al.* 2021). Dissolved substances would dilute more quickly than suspended particles, making them unlikely to reach distant areas in significant quantities.

Figure 9-2. Oceanic Pumps[12]



Earth's oceans naturally pull carbon from the atmosphere and store it deep within the ocean waters. The deeper a particle sinks, the better, because the carbon will take a longer time to return to the surface and into the atmosphere. Researchers previously believed the transfer of particles from the surface to the deep ocean occurred simply due to gravity (the gravity pump). Weber and his colleagues found that other processes are important in transferring carbon to the deep ocean, including ocean mixing and transport via animals such as small fish (the migrant pump). The researchers refer to these processes collectively as "particle injection pumps" because they can "inject" particles at much deeper depths before the carbon is released. (University of Rochester illustration / Michael Osadciw)

9.2.1.3 Transboundary social or economic impacts

Transboundary social or economic impacts are extremely unlikely to occur. The number of nodules collected (3,600 tons) is too small to impact any existing metal producers. Based on information provided by van der Grient and Drazen (2021) linking the potential for intersection between deep-sea mining and high-seas fisheries to the spatial scale of mining impacts, material impacts on fisheries is highly unlikely given the very limited scale and short duration of the testing.

[12] (Illustration source: New view of how ocean 'pumps' impact climate change. University of Rochester News Centre. https://www.rochester.edu/newscenter/ocean-pumps-carbon-cycle-climate-change-377692/April 25, 2019)

10 HAZARDS, MITIGATION & EMERGENCY RESPONSE PLAN

10.1 Introduction

This section provides a high-level overview of NORI's approach to management of unpredicted hazards and emergency planning. All project related activities will be conducted from the Allseas vessel '*Hidden Gem*' and a yet to be identified scientific support vessel. It is a requirement that shipping companies supplying the vessels will have established procedures for health and safety, emergency response, international maritime and navigational certification and compliance audits, crew qualifications and certifications, organisational charts of responsibilities, oil spill prevention and response plans, training, drills, inductions, audits, standard operating procedures etc.

The safety, hazard management systems and emergency response plans developed by the vessel suppliers will be reviewed and approved by NORI during contractual negotiations.

Once vessel selection has been finalised, NORI will develop task-specific procedures to cover hazards, environmental risks, and mitigations specific to the activities of contracted staff and points of integration with the vessel's safety and emergency response procedures. This section describes the overarching principles that NORI will apply as part of this integration.

10.2 Potential Hazards

Hazards associated with the Collector Test and vessel operations with potentially severe consequences have been identified and are discussed below. Offshore, such events are usually associated with accidents leading to fuel or chemical spills, fires, explosions, or hazardous emissions.

Environmentally hazardous discharges resulting from accidental and extreme natural events are fundamentally different from normal operational discharges and emissions. These are essentially unplanned events, to be anticipated as possibilities, for which preventative action, reactive responses, or both, are required.

The probability of accidental events is low, given that the design of Project components and the selection of contractors are subject to the requirements of relevant technical codes, operating procedures, and control measures designed to minimise the likelihood of accidents. Similarly, natural events of sufficient magnitude to cause severe consequences have a low probability of occurrence and specific operational procedures will be developed and implemented under such circumstances.

While rare, accidents and extreme events can occur and there is potential for loss of life, environmental harm, asset loss and reputational damage. The focus of this assessment is to evaluate the potential consequences associated with major hazards, in terms of the criteria provided in Section 4.

Should accidents occur, NORI will mobilise resources according to established emergency response plans. Hazard and risk assessment of such events is integral to the Project and will be undertaken from Project design through to execution. This process includes:

- Hazard Identification Risk Assessment (HIRA).
- Assessment of identified risks against screening criteria, taking into consideration the likelihood of occurrence and the severity of consequences.
- Implementation of mitigation measures to reduce risks to 'As Low As Reasonably Practicable' (ALARP).

- Systematic examination of process and engineering safety during operations, through the conduct of a hazard and operability (HAZOP) study.
- Induction training, drills and regular refresher courses that address site safety and emergency procedures in the event of an accident or natural hazard.
- Planning for recovery in the event of an incident.

Risks have been mitigated through a combination of design features, material selection, monitoring equipment, standard operating procedures, personnel competence and training.

A preliminary HIRA was conducted using the risk assessment approach described in Section 4. Project activities were assessed in terms of the likelihood and consequence should a hazard be realised. The risk assessment assumes the effective implementation of proposed mitigation measures and examines the residual risks resulting from accidental or extreme natural events. A precautionary approach to risk has been adopted with rankings assigned considering a worst-case credible scenario.

A summary of the HIRA is provided in Table 10-1. All residual risk ratings were assessed as ***Low*** or ***Medium.*** Further discussion of risks rated as ***Medium*** is provided below.

10.2.1 Chemical Leakage or Spillage

Spills of chemicals or fuel may potentially occur as a result of leaks or failure of equipment or extreme incident such as a vessel collision (Section 10.2.3) or loss of containment. A spill may have detrimental impacts on water quality and adversely affect the marine ecosystem.

A spill risk assessment will be undertaken following the completion of the final project design. This will identify specific activities where there is potential for spills and describe mitigation measures to minimise the risk.

Mitigations measures and operating procedures will be reviewed and revised as needed considering the outcomes of the spill risk assessment. Proactive and reactive measures will be used to minimise the risk of fuel and other hazardous materials and their potential impacts. Proactive measures may include:

- Appropriate material selection and corrosion control in hoses, equipment and storage tanks.
- Pipe/hose pressures to be monitored to enable early detection of any leakages or spillage.
- Maintenance and monitoring programs to ensure the integrity of equipment and detect loss of containment.
- Emergency shutdown and containment systems.
- Provision and maintenance of spill response and containment equipment appropriate to the level and type of risk and located at all areas of possible spills.
- Ensure sufficient containment or bunding of chemical storage areas to prevent rain/drainage water being contaminated.
- Implementation of personnel training and field exercises in spill prevention, containment, and response.
- Reporting of all spills and near misses followed by a root cause analysis and corrective actions plan to prevent recurrence.
- Implementation of waste (solid and liquid) management plans.
- Implementation of a vessel water management plan that separates clean runoff from potentially contaminated water to minimise the potential for the release of contaminated water.

Reactive measures in the event of an incident will be dependent on the level of the spill, consistent with international government and industry approaches to spill response management.

All activities associated with the implementation of the project will be subject to the requirements of the International Convention for the Prevention of Pollution from Ships (MARPOL) which includes regulations aimed at preventing both accidental pollution and pollution from routine vessel operations.

MARPOL includes six technical annexes the requirements of which will be adhered to throughout the Project.

10.2.2 Fire & Explosion

The Collector Test will involve the storage and handling of flammable and combustible substances that can lead to the generation of potentially explosive and/or flammable gas emissions resulting in a fire or explosion. While the Project does not require the use of explosives, potential environmental impacts associated with the use of other flammable and combustible substances, such as fuel, may result in fire, release of significant quantities of hazardous smoke to the air and contaminated runoff, for example, from water used for firefighting.

Preliminary mitigation measures include:

- Induction to include all areas of risks of fire and types of fire, reporting fire events, response actions, locations/usage of fire-fighting equipment.
- Restricted access to high fire-risk areas.
- Storage and handling of all flammable and combustible substances, including waste, under conditions which minimise the risk of fire or toxic emissions, for example, provide adequate separation distances between potential ignition sources and flammable materials and classify hazard areas.
- Specific design criteria for fire prevention, detection, control and personnel safety requirements.
- Ensuring that ‘hot works’ do not take place near flammable materials.
- Implementation of passive and active fire prevention and fire-fighting techniques for each hazard area.
- Identification and regular maintenance and testing of fire equipment adequate for the level of risk to ensure good working order.

10.2.3 Vessel Collisions

The transit route will intersect a number of international shipping routes, some utilised more than others. International maritime practices will be observed and the vessel equipped with communication and navigation aids.

Vessel collisions may occur during extreme weather conditions or due to human error, for example, due to poor coordination and communication with third-party vessels, mechanical faults, poor visibility and rough sea conditions. Resulting impacts includes injuries to people, the release of ballast water and spills of fuels and other hazardous materials that have the potential to impact water and sediment quality and ecological receptors.

A number of mitigation measures will be implemented to minimise the potential for impacts associated with vessel collisions:

Relevant maritime authorities notified of the planned Collector Test activities as required.

Third parties potentially operating in the vicinity of the Collector Test location notified of the timing of the Collector Test and any safety exclusion zones.

Vessel positioning equipment used, including marine radar and a global navigation satellite system (that is, the United States Government NAVSTAR Global Positioning System).

10.2.4 Detachment of PCV from Umbilical

The detachment of the PCV from its umbilical while in the water column or on seabed, for whatever reason, will represent a serious operational incident. The umbilical supplies power and telemetry, and serves as the lift line. Therefore, in this situation the PCV will be a “dead vehicle” and will have to be recovered using independent means.

This situation, while not expected and relatively serious, does nevertheless occur on occasion and therefore shall be covered by a contingency procedure. This “emergency recovery procedure” is currently under development and final details are not available. However, the procedure shall be reviewed and approved by both Allseas and TMC management, and the Joint Technical Steering Committee, prior to mobilisation.

It is tentatively expected that the emergency recovery procedure will involve deployment of a separate back-up lift line from either the Hidden Gem vessel or another support vessel. The lift line will be certified for a suitable SWL and terminated with a suitable ROV-shackle. During PCV recovery it will be connected to the PCV’s emergency recovery points using the work-class ROV which will be on the Hidden Gem. The vehicle will be recovered through the water column and handed over at a pre-determined depth to the LARS on the Hidden Gem which will then lift the dead vehicle through the transition zone and to deck. It LARS has already been designed with an actively rotatable “snubber” which is specifically configured for aligning the dead PCV through the recovery cursor, as may be necessary should it be lifted in an adverse orientation.

10.2.5 Detachment of Riser Pipe from PCV

The detachment of the riser pipe from the surface support vessel while in the water column, for whatever reason, will represent a serious operational incident. However, as a hazard it is considered a very low probability because the entire riser system has been designed in accord with prevailing reliability-based design codes for deepwater marine risers for which a very significant and known track record of successful operations exists. In fact, as a former oilfield drill ship, the Hidden Gem surface support vessel itself already has an extensive individual track record of ultra-deepwater riser deployment and recovery in harsh environment conditions.

In accord with the design codes, the engineering process of the collector system riser has addressed the integrity and safety requirements through extensive design checking, validation, simulation, FMECA and FAT testing as described in earlier sections. Industry leading riser engineers and vendors have supplied the riser system.

The detachment situation, while of very low probability, does require to be covered by a contingency procedure. This emergency recovery procedure is currently under development and final details are not available. However, the procedure shall be reviewed and approved by both Allseas and TMC management, and the Joint Technical Steering Committee, prior to mobilisation.

It is tentatively expected that the procedure will involve an immediate survey of the detached riser and its contents in the water column or on the seabed to establish its condition and integrity. Based on an assessment of this information a decision on proceeding with the most suitable abandonment/recovery technique will be made. Available techniques will include the mobilisation of emergency pipe lifting tools which can be deployed using either from anchor handler type vessels and/or crane vessels with deepwater winching equipment.

10.3 Emergency Response Planning

A high level of emergency preparedness will be established and maintained to ensure that responses to emergencies and incidents are effective and without delay.

A pre-established emergency response team will be on-call and capable of mobilising and responding to emergencies. It will be staffed with competent individuals and organised into teams with allocated and clearly defined roles.

The crew and science teams will be trained to respond to emergencies, rescue injured persons and perform emergency actions in coordination with other agencies and organisations that may be involved in emergency response.

An emergency response plan (ERP) shall be developed with a systematic approach in managing incidents and emergencies. This will be based on potential emergency scenarios identified by risk assessment processes.

The ERP will contain as a minimum:

- Description of the emergency response team organisation (structure, roles, responsibilities and decision makers).
- Process flow chart for managing various emergency response scenarios, with contact details for relevant personnel.
- Description of response procedures (details of response equipment and location, procedures, training requirements, duties) for the following:
  - Hazardous materials spills.
  - Fire and explosions.
  - Vessel collisions.
  - Man overboard.
  - Emergency medical evacuation (MEDEVAC) procedures for injured or ill personnel.
  - Extreme weather.
  - Attack by third parties.
- Descriptions and procedures for alarm and communications systems.
- Description of on-site first aid supplies and available backup medical support.
- Description of other available emergency facilities and response times.
- Description of survival equipment.

All personnel will be provided with and trained in the use of suitable emergency response equipment, including medical emergency equipment and lifeboats. These will be appropriately managed and located for effective use.

Exercises in emergency preparedness shall be practiced regularly.

10.4 Hazard Identification Risk Assessment (HIRA)

Prior to the commencement of each campaign associated with the Collector Test a HIRA will be complected to identify and assess the hazards associated with the activities that will be conducted and thereby controlling the risk by implementing mitigation measures before the start of the work to avoid the incident. HIRA is intended to develop a proactive rather than reactive approach to risk management.

The HIRA process that will be implemented is summarised in Figure 10-1.

10.4.1 Summary of Residual Risk

Table 10-1 provides a summary of the residual risk assessment.

Assuming the successful implementation of mitigation measures and emergency control procedures described, all residual risks associated with potential major hazards have been assessed as ***Low*** to ***Medium*** and are considered to be ALARP.

Figure 10-1. HIRA process

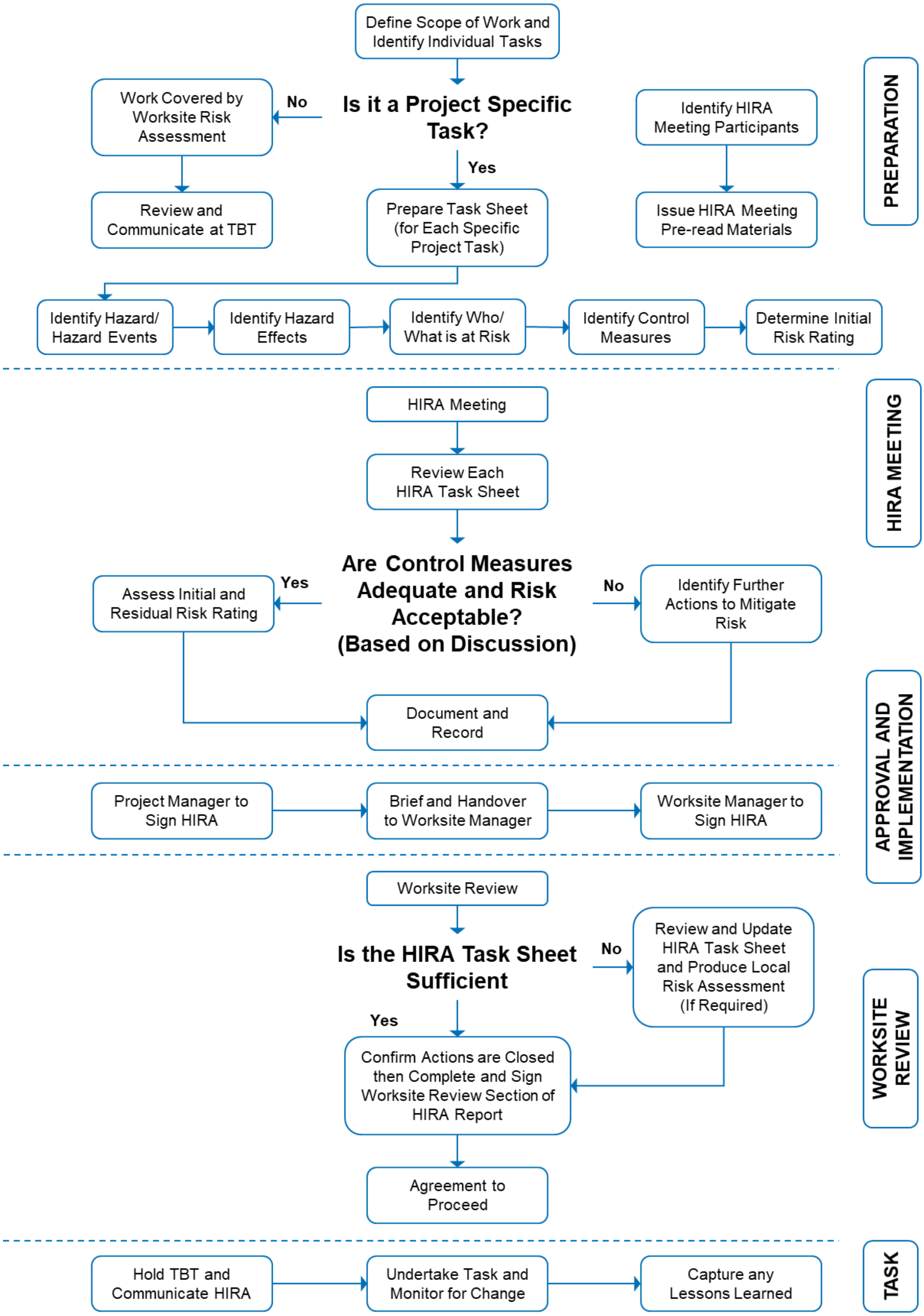


Table 10-1. Major hazards residual risk assessment (L – Likelihood; C – Consequence)

HAZARD/EVENT	IMPACT	MITIGATIONS	RISK		
			L	C	RATING
Extreme weather Tropical cyclones, (storms and hurricanes), lightning)	Vessel damage resulting in loss of containment/ unplanned release and environmental contamination	• Monitor routine weather forecasting and alert systems. • Provisions for detachment and buoying of the riser to allow the vessel to move away from danger areas, returning and re-coupling after the storm (Confirm if this applies to the PCV test if it is necessary). • Develop procedures: ○ Wave shielding. ○ 'Survival mode' procedure for when the sea state exceeds the design sea state. ○ Damage assessment and clean up. • Provide supplies to protect personnel and equipment during a severe weather event. • Develop standard operating procedures for lightning storms.	C	2	Low
Seismic event	Seafloor instability Subsidence	• Real-time monitoring for seismic activity during Collector Test.	A	3	Low
Hazardous material leakage or spillage	Potential contamination having a detrimental impact on water and sediment quality and potentially adversely affecting the marine ecosystem.	• Undertake spill risk assessment. ○ Develop / familiarise with procedures that consider: ○ Induction and training (e.g., chains of command and procedures/reporting in event of a spill) ○ Locations of potential spill areas, types of spill, safety equipment, clean up equipment, contamination separation systems. ○ Emergency shutdown and response systems. ○ Maintenance and monitoring programs of equipment and discharges. ○ Personnel training and field exercises in oil spill prevention, containment, and response (e.g., absorbent mop-up and recovery). ○ Reporting of all spills and near misses followed by a root cause analysis and corrective actions plan to prevent recurrence. • Implement waste and water management plans.	B	3	Low

HAZARD/EVENT	IMPACT	MITIGATIONS	RISK		
			L	C	RATING
Fire and explosion	Environmental harm Fatality	• Provide adequate separation distances between potential ignition sources and flammable materials. • Classify hazard areas and implement passive and active fire prevention and fire-fighting techniques for each hazard area. • Ensure adequate fire-fighting equipment is available and routinely maintained.	A	5	Medium
Vessel collisions	Potential loss of containment of hazardous materials having a detrimental impact on water and sediment quality and potentially adversely affecting the marine ecosystem. Fatality	• Implement standard operating procedures consistent with international maritime practices. • Maintain contact with relevant maritime authorities. • Communication and navigation aids. • Define and implement a safety exclusion zone.	A	5	Medium
Detachment of PCV from Umbilical	Loss of communications and control of PCV, 'dead vehicle' on seabed. Potential for leakage of fluids from the PCV if damaged or not recovered.	• The PCV and all associated equipment will be maintained and inspected for leaks prior to deployment. • All chemicals used in underwater equipment, such as the ROV and PCV, will be compliant with the OSPAR standards, ensuring compliance with established international standards for acceptable levels of environmental performance of chemicals in terms of toxicity, persistence, and bioaccumulation. • An emergency recovery procedure will be developed and included in the Collector Test environmental management plan, prior to the start of operations. • ROV will be on standby at all times to assist with emergency recovery procedures.	C	2	Low
Detachment of Riser Pipe from PCV	If the riser detaches from the PCV and there is nodule slurry present within the riser and or jumper then some release of nodules and slurry is possible.	• The Riser Pipe and all associated equipment will be maintained and inspected prior to deployment. • An emergency recovery procedure will be developed and included in the Collector Test Environmental Management Plan, prior to the start of operations. • ROV will be on standby at all times to assist with emergency recovery procedures.	C	3	Medium

11 RISK PRIORITISATION

The risks posed by predictable impacts associated with the Collector Test on physicochemical and biological VECs have been assessed in Table 7-7 and Table 8-6 respectively. Similarly, the risks posed by unpredictable events (hazards) have been assessed in Table 10-1.

Risks have been characterised as ‘low’ ‘medium’ or ‘high’ based on the following descriptions:

- Low risk outcomes are considered to have been reduced to low as reasonably practicable (ALARP) by the implementation of the prescribed management measures;
- Medium risk outcomes are also considered to have been reduced to ALARP by the implementation of the prescribed management measures, however, a degree of unresolved uncertainty may exist or the consequences of a realised risk are high. Monitoring of these operations will be a priority and they may be modified or suspended if unanticipated outcomes are observed;
- High risk outcomes, activity should not proceed without the development of additional focused mitigation measures.

Based on the EIA team’s understanding of the activities associated with the Collector Test and receiving environment, no activities have been assessed as being ‘’significant’ due to the routine nature of many of the activities (e.g., operation of surface vessels) and the small scale of the Collector Test. Therefore, it is not considered necessary to develop additional mitigation measures to supplement the mitigation measures and any specified additional project specific controls described in Sections 7-4, 8.3 and Chapter 10 to further reduce residual risks.

12 ENVIRONMENTAL MONITORING, MANAGEMENT & REPORTING

12.1 Introduction

The Collector Test and testing of mining components are part of baseline studies required by the ISA as primary inputs to the ESIA for a commercial mining contract (ISBA/25/LTC/6/Rev.1(s. VI(B)(33)). The test provides an opportunity to challenge assumptions about how the mining system will function and how VECs will respond to disturbance from project related activities. This information will be used to optimize the design of the full-scale mining system and the operational environmental monitoring and management plan (EMMP). This section describes the scope of requirements for the Collector Test monitoring programme.

In Q1 of 2020, NORI contracted scientists and commercial consultants to conduct a programme of environmental baseline studies at NORI-D. Key to this work is a comprehensive characterization and comparison of the baseline conditions at the CTA and the PRZ.

Monitoring at the CTA and the subsequent IRZ will be conducted in the following phases:

1. Collector System Performance
    a. Pre-test baseline characterisation
    b. Test monitoring
    c. Post-test monitoring

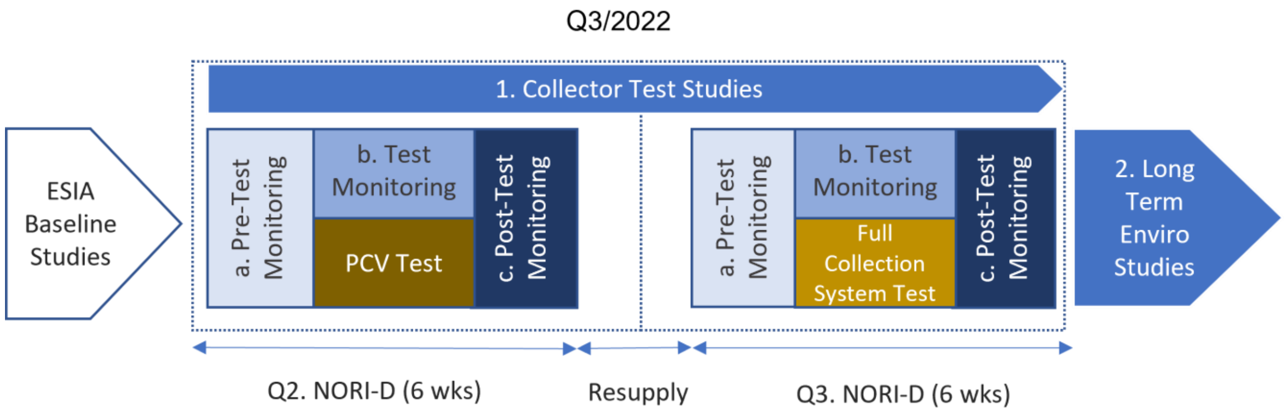
The collection of environmental baseline data from NORI-D has been ongoing since 2012. The offshore studies currently in progress are part of the commercial ESIA focussing on the surface, pelagic and benthic components of the receiving environment. The anticipated completion date for the baseline studies is Q2/2022. The pre-test baseline data for both the CTA and the PRZ will serve as a benchmark against which post-test changes in the status of VECs, and long-term recovery, can be compared. Full details of the ongoing monitoring program to be implemented during commercial operations will be detailed in the EMMP developed for the commercial ESIA.

Monitoring of the Collector Test will be conducted over two sequential campaigns currently scheduled for Q3/2022. The first campaign will focus on testing the PCV, and the second campaign will focus on the performance of the full collection system (Figure 12-1).

Monitoring will comprise of pre-test, test, and post-test phases conducted over short temporal scales (hours, days, weeks), predominantly focusing on the technical performance of the collection system and immediate environmental impacts. The Collector Test also provides an opportunity to challenge assumptions made during collector system design and verify plume models.

Post-test studies will be conducted in the hours, days, weeks or months immediately following the completion of testing activities. The purpose of this monitoring program will be to quantify the immediate impacts of mining to the receiving environment, the findings will inform the commercial ESIA.

Figure 12-1. Collector Test monitoring framework



2. Long-term Environmental Studies

Long-term environmental recovery studies will be conducted over a timeframe of years to decades post-test, and details will be included in the commercial EMMP. The aim of long-term studies will be to monitor how benthic and pelagic communities recover following disturbance. Results of monitoring will be benchmarked against the pre-test baseline of the CTA and the ongoing monitoring of VECs at the PRZ. Parts of the CTA will be designated as an impact reference zones (IRZ) following the test. The IRZs will not be mined following the Collector Test will be preserved and monitored for the duration of mining operations.

12.2 Environmental Monitoring

12.2.1 Collector System Performance

During the Collector Test the technical and environmental performance of the PCV and the collector system will be monitored over two campaigns scheduled for Q3/2022. The PCV and collector system will be deployed and controlled by Allseas from the mining vessel *Hidden Gem,* and the monitoring activities will be conducted from a yet to be identified support vessel.

The performance of the PCV and collector system will be monitored in real-time in the near-field (that is, <200 m from the collector system) and far-field (≥200 m to the limit of measurable change in an environmental parameter). It is acknowledged that this is a broad definition and that far-field limits will vary depending on the metrics being measured. However, real time measurements of turbidity and total suspended sediment (TSS) will provide indications of the likely extent of other ecological changes.

For the purpose of monitoring collector system performance, the receiving environment has been divided into the following impact zones based on the nature of the impacts expected to occur and the monitoring methods that will be applied:

- Impact Zone 1 – Atmosphere, Surface Waters and Euphotic (0 m - 200 m) zone
- Impact Zone 2 – Mesopelagic (200-1,000 m) and Bathypelagic (1,000 m - 4,000 m) zones
- Impact Zone 3 – Abyssal (4,000 m - 6,000 m) and Benthic (seabed) zones

12.2.1.1 Impact Zone 1

Twenty-four-hour operations aboard the mining vessel and support vessel will introduce new sources of air, light, noise and vibration pollution into the atmosphere, surface waters and euphotic zone. This has the potential disturb feeding and migration behaviours of charismatic megafauna (for example, dolphins, turtles, fishes, birds) inhabiting or transiting through the area. Increased night-time light levels from the vessels could also interfere with diurnal feeding patterns of some organisms, as may noise and vibration from the riser pipe and air lift system.

Monitoring of the environmental performance of the collector system in Impact Zone 1 will address the following questions:

- What are the potential sources of impact to VECs in Impact Zone 1 from the vessel and shallow water components of the collection system?
- What are the baseline levels for the following environmental effects during the operation of the collector system and surface vessels?
    - Air pollutants
    - Noise and vibration generation from vessels and collector system components
    - Light emissions both above and below water
    - Sources of surface and shallow water pollutants from the support vessels and collection system

Table 12-1 summarises the objectives for monitoring in Impact Zone 1, rational for monitoring, available monitoring methods, proximity of monitoring to the collector system (near or far field), and the phase of the monitoring program during which the activities will be conducted (that is, (1) Pre-Collector Test baseline characterisation; (2) Collector Test monitoring; (3) Post-Collector Test monitoring).

Table 12-1. Monitoring parameters for Impact Zone 1

OBJECTIVE / MEASUREMENT	RATIONALE	POTENTIAL MONITORING METHODS	FIELD†		MONITORING PHASE‡		
			NEAR	FAR	1	2	3
Physicochemical							
Monitor vessel air pollutant emissions	Long-term occupation of the area can alter local air quality and be detrimental to the health of workers and crew	Onboard air quality sensors (NO_x, SO_x, CO_x, VOCs, PAH, particulates); stack and vessel emission models.	•	-	-	•	-
Measure baseline light emissions to the atmosphere and shallow waters from the surface vessels and associated shallow water assets.	Increased night-time light levels from the vessel may interfere with diurnal feeding patterns and migratory behaviours in some organisms	Photosynthetically active radiation (PAR) sensor aboard the vessel Diurnal CTD casts using rosette with PAR sensor affixed.	•	-	-	•	-
Measure noise generation levels from the vessel and associated shallow water assets (e.g., air lift and riser pipe)	Increased noise levels from the vessel and associated assets may interfere with feeding and migratory patterns in some organisms	Sound meters aboard the vessel Surface mixed layer drifting hydrophone arrays	•	•	-	•	-
Particle sizes and load of return water	Size spectra and total particle load of return water must be	Laser Diffraction Particle Size Analyzer (LISST)	•	-	-	•	-

OBJECTIVE / MEASUREMENT	RATIONALE	POTENTIAL MONITORING METHODS	FIELD†		MONITORING PHASE‡		
			NEAR	FAR	1	2	3
	characterised prior to its return to ocean to inform plume modelling and impacts on biological VECs	Discrete water sample for TSS					
Monitor quality of surface processing water on the vessel.	The quality of the water that is entrained into the riser needs to be measured onboard the surface vessel and thresholds for potential pollutant levels in the return water developed.	Onboard sampling of riser water quality for Nutrients (NO_3, NO_2, NH_4, PO_4, SiO_4, TOC, Alkalinity): discrete water samples. Metals (Al, Cd, Co, Cu, Fe, Pb, Mn, Hg, Ni, Zn): discrete, trace metal clean water samples. Oxygen inline optode and Winkler titrations Temperature, Salinity: pH	•	-	-	•	-
Biological							
Presence of cetaceans, turtles and birds	Changes in behaviour or exposures to risk	On-board observation program,	•	•	•	•	-

†Near field is defined as within 200 m of the collector system, far-field as >200 m from the collector system to the limit of measurable changes in environmental parameters.‡ (1) Pre-Collector Test baseline characterisation; (2) Collector Test monitoring; (3) Post-Collector Test monitoring.

12.2.1.2 Impact Zone 2

During system test runs (STRs) water and sediment from a depth of ≥4,000 m will be entrained into the riser pipe and transported to the surface processing vessel where it will be separated from nodules, filtered, and returned to the ocean at a mid-water depth of 1,200 m. When returned to the ocean discharged bottom waters will be warmer, more oxygenated, and contain higher concentrations of fine particles (sediments and nanoparticles) and dissolved metals than mesopelagic water. Thus, it is essential to understand the dynamics and fate of the mid-water discharge plume. Impacts from the discharge could affect the mesopelagic (200 m - 1,000 m) and bathypelagic (1,000 m – 4,000 m) zones.

DHI has developed a hydrodynamic (HD) model of NORI-D, which has been partially validated against measured metocean observations from the moorings that have been deployed across the site for the past two years (see Section 7.2.2.4). Monitoring of plume dispersal during the STRs represents an opportunity to further validate, refine, and update the HD model. The information gathered during real-time monitoring of the mid-water plume is considered essential to scaling up the HD model to be representative of conditions during commercial mining operations.

Monitoring of the environmental performance of the collector system in Impact Zone 2 will address the following questions:

- What is the lateral and vertical expanse of the mid-water discharge plume?
- What is the TSS concentration gradient with distance from the return water outlet?
- What is the optimum depth for the return water outlet?

- What are the effects of the plume on the chemical properties of the mesopelagic and bathypelagic?
- What are the effects of the plume on physical properties of the mesopelagic and bathypelagic?
- What are the effects of the plume on biota of the mesopelagic and bathypelagic?
- What are the effects of riser noise and vibration on the biota of the mesopelagic and bathypelagic?

Table 12-2 summarises the objectives for monitoring in Impact Zone 2, rational for monitoring, monitoring methods, proximity of monitoring to the collector system (near or far field), and the phase of the monitoring program during which the monitoring activities will be conducted.

Table 12-2. Monitoring parameters for Impact Zone 2

OBJECTIVE/ MEASUREMENT	RATIONALE	POTENTIAL MONITORING METHODS	FIELD†		MONITORING PHASE‡		
			NEAR	FAR	1	2	3
Physicochemical							
Particle sizes and load of plume at outfall	Measurement of discharge at the surface and plume TSS at discrete distances from the outfall to limits of lateral/vertical detection. This information will be used to validate the mid-water plume modelling	Laser Diffraction Particle Size Analyzer (LISST) Discrete water sample for TSS Discrete filter samples for particle-based metal concentrations	•	•	-	•	-
Measurement of plume properties gradients from the point of discharge	ISA Recommendations III.B.14; III.B.15.(a).(i)–(ii) Monitoring of the particle sizes / concentrations and the physical and chemical properties of mid-waters along vertical and lateral transects from the discharge location is required to determine the extent of potential impacts to pelagic water quality and biota from the point of discharge.	Robotic or autonomous vehicle(s) equipped with Acoustic Doppler Current Profiler(s) (ADCP(s)), and sensors/sampling capabilities for NO_3, NO_2, NH_4, PO_4, SiO_4, TOC, Alkalinity. Trace metal CTD-rosette with sensors / sampling capabilities for Al, Cd, Co, Cu, Fe, Pb, Mn, Hg, Ni, Zn. Static moorings or landers with upward and downward facing ADCPs (where appropriate) for profiling, CTD, LISST, redox, optode, transmissometer. Onboard determination of select tracer	•	•	-	•	-

OBJECTIVE/ MEASUREMENT	RATIONALE	POTENTIAL MONITORING METHODS	FIELD†		MONITORING PHASE‡		
			NEAR	FAR	1	2	3
		concentrations. (e.g., Al, Mn) Oxygen: Winkler titrations w/ discrete samples (due to low O_2 discharge zone)					
Monitor riser and discharge-based noise / vibration pollution	ISA Recommendations III.A.13; III.B.15.(b)(iv) Noise from mining activities may alter the behaviours of marine mammals and other animals.	Autonomous vehicles and static moorings equipped with hydrophones	•	•	-	•	-
Biological							
Evaluate plume related impacts on pelagic filter feeders	ISA Recommendations III.A.13; III.B.14; III.B.15.(d).(iii) Increased TSS in the mid-water could cause abrasion or overloading of filtering or respiratory apparatus of pelagic suspension feeders.	1 m MOCNESS net tows. In situ pumping inside and outside of plume Compound Specific Stable Isotope Analysis of Mesozooplankton (0.2-0.5 mm) amino acids Transects with shadowgraph camera equipped ROV.	-	•	•	•	•
Evaluate effects of mid-water return system and plume on total biomass	Discharge and noise associated with mining could lead to death or alteration of lifestyle / feeding behaviours in mid-water communities.	Saildrone transects through the discharge areas to evaluate changes to water column biomass vertical structure (volume backscatter) and diel vertical migration patterns	-	•	-	•	•

†Near field is defined as within 200 m of the collector system, far-field as >200 m from the collector system to the limit of measurable changes in environmental parameters‡ (1) Pre-Collector Test baseline characterisation; (2) Collector Test monitoring; (3) Post-Collector Test monitoring.

12.2.1.3 Impact Zone 3

The prototype collector vehicle (PCV) will disturb sediments as it collects nodules from the surface of the seabed. Nodule obligate organisms permanently attached to nodules will be entrained in to the PCV and may suffer trauma as they pass through the onboard nodule processing system or they may be transported to the surface vessel. The majority of the hard substrate habitat that nodules provide may be removed in mined areas.

Sediments resuspended by the PCV will increase turbidity in bathypelagic boundary water layer to a height of up to 20 m above the seabed (Section 7.2.2). Displaced sediments will form a plume behind the PCV which will eventually settle potentially covering nodule habitat, smothering benthic organisms, and affecting pelagic filter feeders. The behaviour of sediment plumes in terms of TSS concentrations and lateral and vertical dispersal is important to understand when predicting the magnitude of potential impacts of the benthic plume to benthic biota and habitats.

As for the mid-water plume, DHI has developed a hydrodynamic (HD) model for the benthic plume from the Collector Test. Monitoring the benthic plume dispersal during PCV operations represents an opportunity to further validate, refine, and update the HD model to predict full operational scale conditions.

Realtime monitoring of plume dispersal and concentrations will be conducted with the aid of sensors placed on the seabed, and PCV, AUV and ROV assets, which will track the PCV as it conducts field trials.

Monitoring of the environmental performance of the collector system in Impact Zone 3 will address the following questions:

- How much light and noise will be generated by the PCV during operations?
- How will the hydrodynamic conditions created by the PCV movement and onboard processes impact sediment behaviour?
- How does the PCV impact the physical structure (micro-topography) and geochemistry of the sediments?
- Does sediment flocculation occur as predicted by models developed from laboratory-based experimentation (that is, iSeaMC, 2020)?
- How efficient is the PCV at collecting nodules?
- What is the habitat value of the nodules left behind by the PCV?
- What is the lateral and vertical dispersal footprint of the benthic plume?
- What is the sedimentation area and deposition thickness?
- What are the sedimentation gradients with distance from the source?
- What is the fate of biota entrained into the collector system?

Table 12-3 summarises the objectives for monitoring in Impact Zone 3, rational for monitoring, monitoring methods, proximity of monitoring to the collector system (near or far field), and the phase of the monitoring program during which the monitoring activities will be conducted.

Table 12-3. Monitoring parameters for Impact Zone 3

OBJECTIVE/ MEASUREMENT	RATIONALE	POTENTIAL MONITORING METHODS	FIELD†		MONITORING PHASE‡		
			NEAR	FAR	1	2	3
Physicochemical							
Depth of penetration of the PCV tracks into the sediment	ISA Recommendations III.C.38(b)	Robotic or autonomous vehicle multibeam echo sounder surveys	•	-	-	•	-
Lateral disturbance to sediment micro-topography caused by the PCV	ISA Recommendations III.C.38(c)	Robotic or autonomous vehicle multibeam echo sounder surveys	•	-	-	•	-
Width, length and pattern of collector tracks on seafloor	ISA Recommendations III.C.38(c)	Robotic or autonomous vehicle	•	-	-	•	-

OBJECTIVE/ MEASUREMENT	RATIONALE	POTENTIAL MONITORING METHODS	FIELD†		MONITORING PHASE‡		
			NEAR	FAR	1	2	3
		multibeam echo sounder surveys					
Ratio of sediment separated from the mineral source by the PCV	ISA Recommendations III.C.38(d)	PCV mounted sensors	•	-	-	•	-
Volume and size spectra of material rejected by the PCV	ISA Recommendations III.C.38(f)	PCV mounted sensors	•	-	-	•	-
Measure plume particle load and size distributions	ISA Recommendations III.C.38(k)	In-situ pumps for particle collection Robotic or autonomous vehicle mounted transmissometer. ROV-mounted niskin bottles	•	•	-	•	-
Lateral and vertical dispersal profile of plume	ISA Recommendations III.C.38(k)	Benthic lander equipped with optical backscatter sensors (OBS) and an upward looking ADCP. Robotic or autonomous vehicle equipped with transmissometer Trace metal CTD (w/LADCP) casts along transects from the plume (metals, TSS, etc.)	•	•	-	•	-
Thickness of sediment redeposition layer	ISA Recommendations III.C.38(k)	Benthic lander equipped with sediment traps. Robotic or autonomous vehicle multibeam echo sounder and image surveys	•	•	-	•	-
Monitor PCV generated noise pollution	Noise from mining activities may alter the behaviour of marine animals.	Hydrophones deployed near riser system and remote monitoring via moored and static instruments and autonomous vehicles.	•	•	-	•	-
Monitor collector generated light pollution	Light from mining activities may alter the behaviour of marine animals.	Light output estimate for collector Light sensor on rosette	•	•	-	•	-
Biological							
Changes in seabed respiration and redox structure	Understanding change and recovery of ecosystem function	Benthic respirometer chamber landers	•	•	•	-	•

OBJECTIVE/ MEASUREMENT	RATIONALE	POTENTIAL MONITORING METHODS	FIELD†		MONITORING PHASE‡		
			NEAR	FAR	1	2	3
		Benthic microelectrode landers Multicore pore water samples (Pb210, redox chemistry)					
Changes in seabed microbial communities	Understanding change and recovery of ecosystem function	eDNA samples with multicore	•	•	•	-	•
Changes in seabed meiofauna communities	Understanding change and recovery of ecosystem function	eDNA samples with multicore Multicore or ROV pushcore samples for sieving, taxonomy and quantification	•	•	•	-	•
Changes in seabed macrofauna communities	Understanding change and recovery of ecosystem function	eDNA samples with multicore Box-core or ROV pushcore samples for sieving, taxonomy and quantification	•	•	•	-	•
Changes in seabed megafauna communities	Understanding change and recovery of ecosystem function	ROV mounted cameras	-	•	•	-	•
Changes to demersal scavenger communities	Understanding change and recovery of ecosystem function	Baited lander traps and cameras	-	•	•	-	•
Characterise concentrations of trace toxic metals in dominant animals	Introduction of sediment and porewaters into the boundary layer can alter community structure, animal abundance and food web function.	ROV target sampling of benthic organisms along transect vertical and lateral transects from PCV/impact area. Representative pelagic samples from the zooplankton in the epi-, meso- and bathypelagic collected from MOCNESS samples.	•	•	•	•	•
Evaluate plume-related effects to the food web	A likely effect of sediment discharge or resuspension into the bottom waters is the alteration of feeding for suspension feeders.	In situ pumping inside and outside of plume ROV with D-samplers and suction samplers Baited traps and camera traps for demersal scavengers Box or multi cores for infauna and nodule-attached fauna Stable isotope analysis of tissues	•	•	•	•	•
Evaluate plume effects on microbes	High tissue turnover rate organisms are most likely to show	Discrete CTD samples in and out of the plume, ideally as	•	•	•	•	•

OBJECTIVE/ MEASUREMENT	RATIONALE	POTENTIAL MONITORING METHODS	FIELD†		MONITORING PHASE‡		
			NEAR	FAR	1	2	3
	changes / toxicity from metals and other compounds in bottom water	close to discharge as possible In situ pumping					
Evaluate changes in bioluminescent communities in bottom waters	Suspended particles can alter ranges for bioluminescent signalling	CTD rosette with transmissometer deployed from surface vessel ROV with transmissometer	•	•	-	•	-
Evaluate effects of plume (blanketing) on sessile & pelagic filter feeders	Discharges and noise associated with mining could lead to death or alteration of lifestyle / feeding behaviours in benthic communities	ROV transects with 4K camera	•	•	•	•	•
Evaluate effects of plume (blanketing) on demersal scavenger communities	Discharges and noise associated with mining could lead to death or alteration of lifestyle / feeding behaviours in benthic communities	ROV transects with 4K camera Baited camera landers	•	•	•	•	•
Survivability of benthic organisms entrained into the collector system	Physical trauma to benthic organisms as they pass through the collector system	Install cages on the collector to trap entrained biota	•	•	-	•	-

†Near field defined as within 200 m of the collector system, far-field as >200 m from the collector system to the limit of measurable changes in environmental parameters‡ (1) Pre-Collector Test baseline characterisation; (2) Collector Test monitoring; (3) Post-Collector Test monitoring.

12.3 Long-Term Environmental Studies

12.3.1 Experimental Design

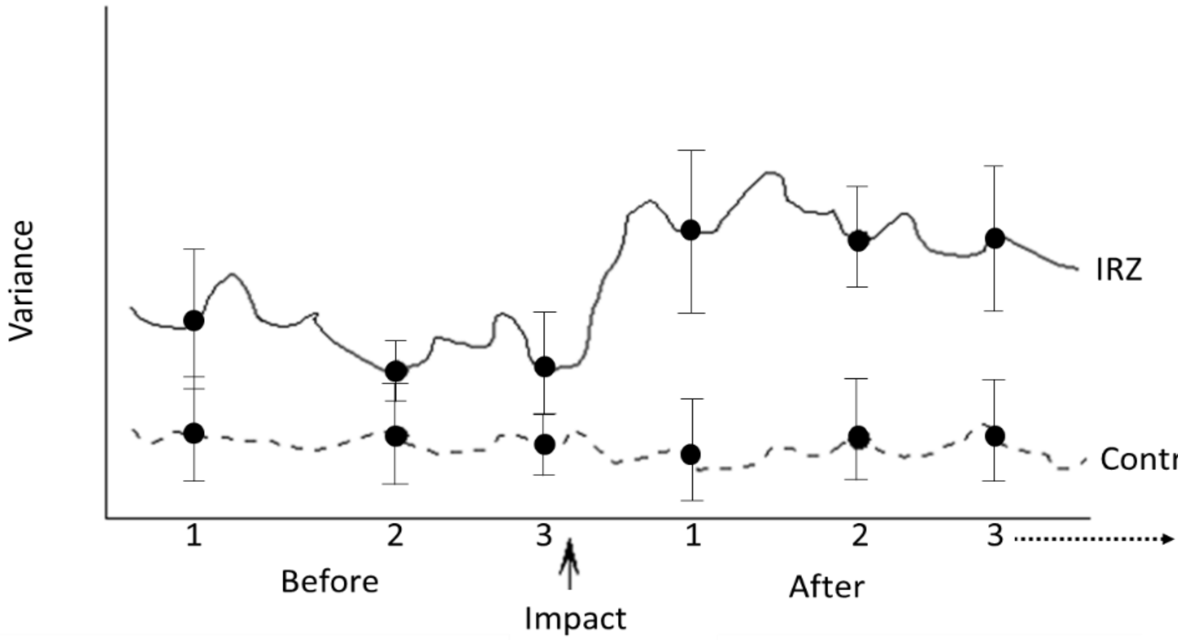
Long-term environmental studies will be conducted over a timeframe of years to decades post Collector Test. The objective of these studies will be to monitor how benthic and pelagic communities and habitats recover following disturbance. Results of monitoring will be benchmarked against the pre-test baseline of the CTA (which will become the IRZ after the Collector Test) and the ongoing monitoring of VECs at the PRZ.

Studies on the long-term effects of the disturbance will be structured as a before-after-control-impact (BACI) design for key variables employing a stratified random sampling design. Environmental change (impact) will be detected by measuring variables sampled from the two separate sites (that is, IRZ and PRZ), before and after the disturbance.

Impacts from disturbance to the IRZ will be apparent as a significant interaction term in an analysis of variance (ANOVA), where the factors in the analysis would be ‘time’ with two levels (‘before’ and ‘after’) and ‘site’ with two levels (‘control’ and ‘impact’). The behaviour of variables in the IRZ would change relative to the behaviour of the PRZ after the disturbance (Figure 12-2). The values of the measurement variable would not have to be identical in the two sites before the disturbance because the inference would be based on the interaction term in the analysis.

After disturbance, if the variable's pattern of behaviour in the IRZ areas differs significantly from its pattern of behaviour in the control site, the differences are unlikely to be due to chance.

Figure 12-2. Proposed BACI design with three sampling events (solid dots) before and multiple after system testing (arrow) from the IRZ and Control site; modified from Underwood (1996)



Data informing the 'before' component of the BACI design has been collected as part of the baseline studies described in Chapters 5 and 6; with additional data to be collected during the pre-disturbance phase of the Collector Test studies.

The first post-test data informing the 'After' component of the BACI design will be collected as part of the post-disturbance phase of the Collector Test scheduled for Q3/2022 (Figure 12-1). Detailed experimental designs for the Collector Test studies, including sampling plans, sampling effort, replicate numbers, laboratory analysis requirements etc. will be included in a Collector Test specific EMMP that will be developed in consultation with the science partners that conducted the baseline studies. Long-term temporal data will be collected as part of the commercial monitoring program and detailed in the commercial EMMP.

At the time of writing Requests for Proposals (RFPs) have been issued for key components of the Collector Test studies and monitoring, and proposals have been received and are under consideration. A planning meeting with the science partners is scheduled for early Q2 2022, to finalise the Collector Test study plan. Representatives from the ISA/LTC will be invited to attend this planning meeting. A detailed EMMP will be submitted to the ISA no later than 2-months prior to the planned start date of activities in the CCZ.

12.3.2 Data Management

12.3.2.1 qCore Database

All monitoring data will be entered into the qCore database that has been designed by NORI specifically as a repository for data collected during the ESIA studies. The qCore database provides:

- A repository for field events, sample data, platform details and various metadata associated with scientific operations and monitoring activities.

- A register for specimens and sampling products such as specimens, images and electronic datafiles.
- An efficient sample barcode labelling and tracking system, including for validation, inventory, and chain of custody purposes.
- Record and dashboard program progress.
- A facility for OHS, environmental and QA/QC management of projects.
- A facility for data checking and rapid data exploration.
- A facility for efficient output of regular data and reporting product.
- Centralised storage of any type of ecological and environmental data.

During the Collector Test monitoring the qCore database system will be utilised to achieve the following:

- Registration of sample collecting platforms and processes.
- Registration of sampling events (deployments and recoveries of sampling platforms).
- Registration of data and sample objects generated by sampling events, such as imagery, physical samples, data files, sensor readings, observations, mapping files (for example rasters, spatial data) etc.
- Printing sample object labels for sample receptacles.
- Tracking completeness of sample objects and completeness of trace-back information
- Tracking chain-of-custody of samples off the ship to destination laboratory.
- Registration and querying of analysed data submitted post-voyage.

To achieve these requirements, the data management system will have access to:

- A dedicated offshore data officer supported by on-land data manager.
- Necessary hardware and software components.
- Internet connection to central database computer.
- Intranet connection to a positioning system to track locations of the vessel, transponders and other positioning feeds associated with a shipboard survey system.

12.3.2.2 Data Dissemination

The qCore data management system is designed to fulfil the obligations of reporting to ISA and delivery of data to the ISA DeepData database. These obligations set the requirements for science team collaboration. The core requirements are:

- Spatial and temporal allocation of data.
- Responsible person allocation to data.
- Unique sample IDs nested in voyage information, locations, gear types.
- Layers and measurement parameters nested in sample IDs and linked to methods.
- Photos linked directed to samples.
- All attributes in a standardised list of “valid values”, required fields, units of measurements etc.
- Compliance with ISA upload data structures (melted or long-format data).

In addition, contracted scientific organisations will publish data in open access publications to encourage scientific advances and transparency.

12.4 Environmental Management

Measures to manage potential environmental impacts to non-significant levels are described in Sections 7.3 and 8.3. In addition, design features of the collector system developed to further minimise environmental impacts have been discussed in Section 3. Details of specific management measures will be documented in an Environmental Monitoring and Management Plan (EMMP) that will be developed for the Collector Test and submitted to the ISA prior to the commencement of operations. This plan will outline commitments and procedures on how management measures will be implemented, how the effectiveness of such measures will be monitored, what the management responses will be to the monitoring results and what reporting systems will be adopted and followed.

12.5 Reporting

12.5.1 Internal Reporting

Results from monitoring activities will be recorded and reports prepared that contain data used to assess performance of the Collector Test equipment and the effectiveness of the design and management measures. Findings will assist in validating the plume model and impact predictions in this EIS and inform the EIS and EMMP for commercial scale mining. The general structure of the monitoring reports will be:

- Introduction.
- Legislative framework and standards.
- Monitoring criteria.
- Monitoring methods.
- Monitoring results.
- Auditing.
- Recommendations and corrective action.

12.5.2 External Reporting

Monitoring reports will be submitted to the International Seabed Authority (ISA) on an annual basis as per ISBA/19/C/17 Regulation 32 which states:

> The contractor shall report annually in writing to the Secretary-General on the implementation and results of the monitoring programme and shall submit data and information, taking into account any recommendations issued by the (Legal and Technical) Commission.

Compliance with the EMMP will be described in these reports, plus recommendations made for any corrective actions.

NORI will also disclose the results of additional assessments and monitoring activities to the ISA annually.

NORI plans to host a public stakeholder event to present the results of the collector test.

12.5.3 Incident Reporting

Any spills, incident or uncontrolled release which enters the marine environment is a recordable incident which will be notified to the ISA within required reporting timeframes of the incident occurring as per ISBA/19/C/17 Regulation 33 which states:

> A contractor shall promptly report to the Secretary-General in writing, using the most effective means, any incident arising from activities which have caused, are causing or pose a threat of serious harm to the marine environment.

The notification to the ISA will include the following:

- The incident and all material facts and circumstances concerning the incident that is known at the time.
- Any actions taken to avoid or mitigate any adverse environmental impacts.
- Any corrective actions that have been taken, or may be taken, to prevent a repeat of similar incidents occurring.

Following MARPOL OPRC-HNS 2000 Protocol any relevant third-party authorities will also be notified as required.

12.5.4 Corrective Actions

The monitoring and inspection process incorporates both formal and informal corrective actions. Any environmental incident investigations or non-conformance identify the factor(s) that led to the hazard, injury/illness, incident, or other system failure and recommend appropriate corrective actions to be taken including the re-evaluation of work practices. Revised work practices are communicated through the relevant manager to employees, contractors, and the ISA.

12.5.5 Observers and Monitoring

NORI recognizes the importance of having observers from the ISA and Nauru onboard the surface support vessel to monitor test activities. The placement of observers will allow for supervision of the activity and reporting to both Nauru and the ISA through physical examination and inspection of the testing activity. Berths have been reserved for both the ISA and Nauru.

NORI is also developing a public dashboard which will provide stakeholders with the ability to track and monitor aspects of the collector test.

12.6 Limitations

- This EIA is only applicable to the Collector Test which will consist of the equipment and activities described in Section 3 of this EIS.
- The plume modelling results presented in Section 7 are only applicable to the Collector Test activities described in Section 3 of this EIS.
- The findings of this EIA are applicable to the Collector Test activities only and not the operational phase.

12.7 Assumptions

The findings of this EIA assume the following (letters A-G refer to Figure 12-3):

A. All activities associated with the Collector Test are confined to the CTA (150 km^2) and the over lying water column.

B. All direct disturbance of the seabed by the PCV is confined to the TF (8 km^2).

C. The overall area of seabed that will be directly disturbed by the tracks of the PCV is limited to 0.5 km^2.

D. Collector Test activities will be conducted in accordance with the test plan. All onsite activities associated with the Collector Test will be completed within a 3-month period. The duration of the entire Collector Test is limited to approximately 36 days, and the duration of system testing (period of maximum plume generation) is limited to approximately 12 days. Most impacts associated with the Collector Test will be temporary, of short duration, and spatially constrained.

E. The benthic and mid-water plume exceedance models in Section 7.2.2.4 are an accurate representation of plume dynamics.

F. Seasonal variations in physical oceanography (e.g., current direction; water temperature etc.) will not cause a material change in the magnitude of TSS exceedances described by the plume models in Section 7.2.2.4. And that any seasonal change in direction of plume drift is inconsequential to the findings of this EIA.

G. The biota impacted by activities associated with the Collector Test are well represented in similar abyssal plain and pelagic habitat abundant throughout NORI-D and the wider CCZ.

12.8 Uncertainty

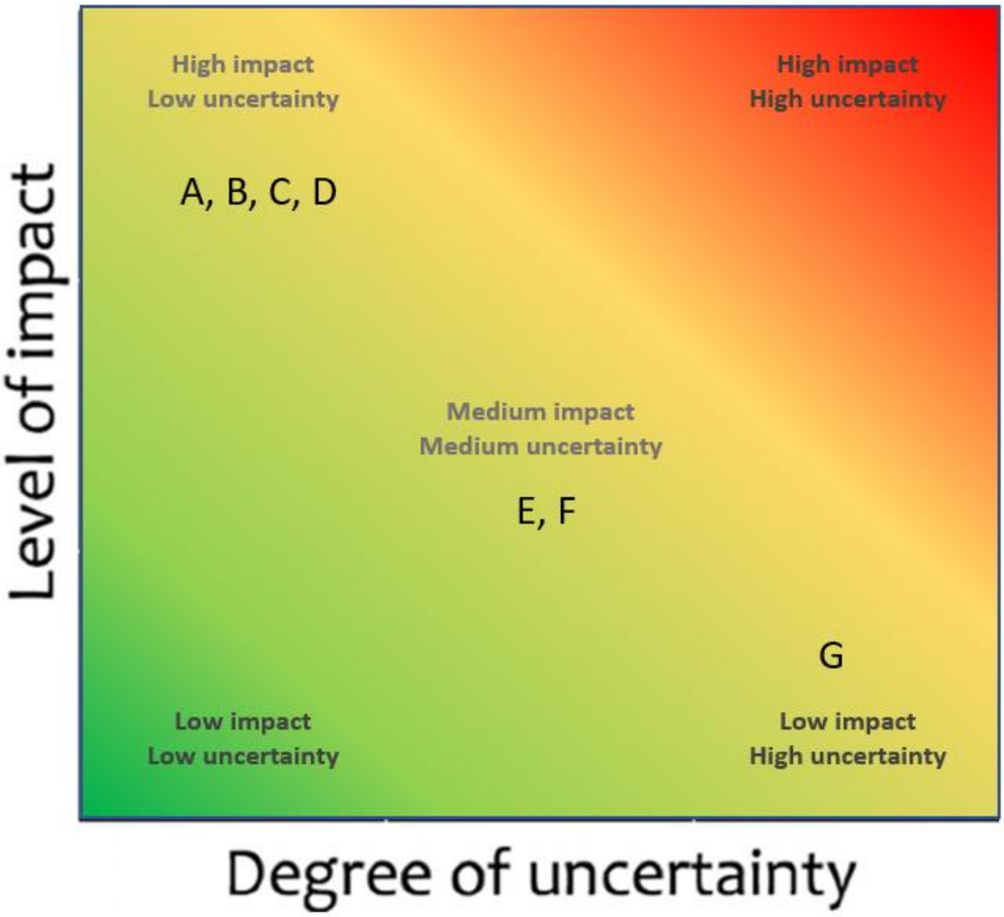
Uncertainty is almost unavoidable in EIAs (Tennøy *et al.*, 2006) as they typically involve situations in which the full range of possible options and their impacts cannot be known (Ozdemir & Saaty, 2006). Assumptions then have to be made to address knowledge gaps, which introduce uncertainty into the EIA process. It is important for informed decision making that the sources of uncertainty are identified, and treatments proposed.

Some forms of uncertainty are easily managed, for example the uncertainties introduced by assumptions A-E in Section 12.7 are readily treated by ensuring that the specifications for the Collector Test described in the EIS are implemented as described. Thus, although an activity may have the potential to cause a high impact, there is a low level of uncertainty (i.e., high confidence) in the measures put in place to ensure this does not occur. These assumptions occupy the top left-hand corner of the impact/uncertainty matrix (i.e., high impact/low uncertainty; Figure 12-3).

Uncertainty around plume dynamics (assumptions E and F in Section 12.7) has been treated by the development of TSS exceedance models (Section 7.2.2.4). The models predict that benthic and mid-water plumes will be mostly constrained to the TF and associated water column, and that TSS will rapidly fall to background levels. However, the models are in the early stages of development and need to be verified by field observations that will be conducted during the Collector Test and any observed excursions outside predicted plume boundaries will provide empirical data as an ongoing process for improvement of the model's predictive reliability. As such, there is still some degree (medium) of uncertainty around the accuracy of the models. Due to the temporary nature and limited size of plumes that will be generated by the small-scale activities of the Collector Test (as described in Section 7.4.3) the potential impact is conservatively described as medium. These assumptions occupy the central part of the impact vs uncertainty matrix (i.e., medium impact/medium uncertainty; Figure 12-3).

At the time of writing, the physical and biological baselines are well progressed. The current work program will collect additional baseline data which will improve statistical robustness moving forward. Notwithstanding, any residual uncertainty in the Collector Test EIA has been treated by minimising the magnitude of impacts to the biological component of the receiving environment (i.e., activities are temporary; the area of seabed and volume of the water column impacted by the PCV and plumes has been minimised). This treatment positions assumption G in the bottom right-hand corner of the impact/uncertainty matrix (i.e., low impact/high uncertainty; Figure 12-3).

Figure 12-3. Impact vs uncertainty matrix (modified from Speziale & Geneletti 2014)



Note: Letters refer to Assumptions in Section 12.7

Figure 12-3 depicts the uncertainty profile for the Collector Test and shows that the 'high risk' top right-hand corner of the matrix (i.e., high impact/high uncertainty) has been avoided.

13 CONSULTATION & REVIEW

13.1 Introduction

NORI conducted a global stakeholder consultation workshop in Q1 2020 to inform both the collector test EIA and operational ESIA processes. Following the workshop, a Scoping Report was developed and submitted to the ISA in June 2020. ISA Recommendations (ISBA/25/LTC/6/Rev.1/E41(d)) encourage sponsoring states to also conduct stakeholder consultations as part of the collector test EIA process. NORI's sponsoring state, Nauru has developed and is implementing a stakeholder consultation process. The EIS has also been subjected to expert review prior to submission. Details of the stakeholder consultation conducted to date, planned consultation by the sponsoring state and the peer review process is provided below.

13.2 NORI Global Stakeholder Workshop

NORI conducted a Global Stakeholders Workshop was in San Diego, USA, on 5 and 6 February 2020. The objective of the event was to elicit stakeholder input into the strategy and philosophy proposed by NORI for the Collector Test EIA and commercial ESIA processes.

Over 55 stakeholders attended the two-day event in person and a further 20 attended via webinar. Workshop participants came from over 20 countries, including: Australia, Belgium, Canada, Chile, Cook Islands, Fiji, Germany, Ghana, India, Jamaica, Kiribati, Nauru, Norway, Poland, Portugal, Switzerland, The Netherlands, Trinidad and Tobago, United Kingdom, and United States of America.

Invitations were sent to over 250 people and a detailed participant list can be found in Appendix 7. Independent facilitators led the workshop and a number of external and internal speakers made presentations on different aspects of the mining process, environmental considerations, and NORI's ESIA program.

Presenters included:

- Brian Balcom, CSA Ocean Sciences
- Gerard Barron, Chairman and CEO of The Metals Company
- Dr. Michael Clarke, NORI/The Metals Company
- Dr. Thomas Dahlgren, University of Gothenburg
- Dr. Jennifer Durden, National Oceanography Centre
- Margo Deiye, Permanent Representative to the ISA
- Matt Edmunds, Fathom Pacific Ltd
- Dr. Jeff Drazen, University of Hawaii
- Dr. Adrian Flynn, Fathom Pacific Ltd
- Dr. Daniel Jones, National Oceanography Centre
- Larry Madin, Woods Hole Oceanographic Institution
- Alex Laugharne, CRU International Consulting
- Tony O'Sullivan, NORI/The Metals Company
- Daina Paulikas, The Metals Company
- Wanfei Qiu, Programme Manager (Marine Environment), ISA
- Dr. Gregory Stone, Chief Ocean Scientist, NORI/The Metals Company
- Professor Andrew Sweetman, Heriot Watt University
- Scott Wilson, Maersk
- Dr. Clare Woulds, University of Leeds
- Dr. Chris Kelly, CSA Ocean sciences

- Dr. Steven Katona, College of the Atlantic

5th February 2020

Day 1 of the workshop provided participants with an overview of the workshop format and insight into metal supply and demand in the 21st century. Other topics included thoughts about where metals for the green transition should come from. The ISA Secretariat's environmental programme manager gave an overview of the ISA's regulatory processes. Nauru's Permanent Representative to the ISA presented shared why their nation has chosen to be involved in the industry and a facilitated discussion was undertaken with all participants to discuss concerns about nodule collection.

Figure 13-1. Participants at the NORI global stakeholders workshop, San Diego, USA, 5 and 6 February 2020

6th February 2020

Day 2 presentations included discussion on the deep-sea environment in the CCZ, details on how the deep-sea nodule collection system works, and the EIA process (including the TOR and scoping report), objectives, and details of NORI's proposed program for both the Collector Test EIA and commercial ESIA. The key environmental baseline and monitoring studies were also presented and an overview of each study package was presented by the scientific and research organizations who were conducting the work packages. The issue of serious harm was also discussed. A detailed agenda from the workshop has been supplied as Appendix 7.

Learnings and feedback from this workshop have been incorporated into the Collector Test EIA process and the proposed environmental monitoring plans.

Following the workshop, NORI developed a Scoping Report and submitted the report to the ISA in June 2020.

13.3 Sponsoring State Stakeholder Consultation

(13) ISA Recommendations (ISBA/25/LTC/6/Rev.1/E41(d)) state: *In the event that a stakeholder consultation has not yet been conducted by the sponsoring State, the Commission, through the Secretary-General, may encourage the sponsoring State(s) to conduct such consultation. The Commission, through the Secretary-General, may request the sponsoring State, in the event it conducts the stakeholder consultation, to forward to the Secretary-General the comments submitted by stakeholders with a view to passing this information to the contractor. Any available information concerning such stakeholder consultation will be made available on the website of the International Seabed Authority;*

After reviewing previous EIA Collector Test stakeholder consultation processes and considering international best practice, Nauru has developed the following consultation process. This process was shared with the ISA Secretariat prior to finalization.

30 July 21

- Submission of NORI EIA to ISA
  - Within 30 days the Secretary General will acknowledge the receipt of the EIS and check for completeness
  - The LTC will initiate the review of the EIA at its next meeting for completeness, accuracy and statistical reliability in conformity of the Recommendations

30 August 21

- Secretary General to provide feedback on EIA completeness.

1 September 2021

- If the Secretary General determines that the EIA is complete and requires to no additional information
  - Nauru will provide formal notification to ISA Members of the submission of the NORI EIA and share the stakeholder consultation process
  - Nauru to post EIA for comment on Nauru government website (45-day comment period)
  - NORI to post EIA on TMC website for comment (45-day comment period)

6 -10 September 2021

13 Nauru will host a preliminary stakeholder workshop. NORI will present an overview of the EIA to facilitate the start of the stakeholder consultation phase October 2021

- Stakeholder comment period closes
- Nauru to share stakeholder comments with NORI for review and comment

1 March 2022

- Nauru to submit summary of stakeholder comments and NORI's response to Secretary General
- Nauru may provide direction or feedback to NORI based on its review and stakeholder comments

- NORI to submit any revisions or updates to the to the EIA based on stakeholder comments to the ISA

7 March 2022

- Nauru to host stakeholder workshop to provide NORI with the opportunity to respond to stakeholder comments

On or before 30 July 2022

At the conclusion of its review, the LTC will provide recommendations to the Secretary General as to whether the EIA should be incorporated into the programme of activities under the contract.

(*note: dates are indicative and subject to change)

13.4 Expert Review

Expert review will be included at several points in the commercial ESIA process. The Collector Test EIS is considered an appropriate milestone in the process at which to elicit expert opinion as this will augment the overall quality of the commercial ESIA. Experts from a range of disciplines have provided comment on the Collector Test EIS, including oceanographers, marine biologists, and environmental impact specialists.

The expert review panel members listed in Table 13-1 have provided comment and input in to this EIS.

Table 13-1. Expert panel review members

NAME	AFFILIATION	AREA OF EXPERTISE
Dr Larry Madin	Independent Consultant	Pelagic Biology
Dr Dan Jones	National Oceanographic Centre (UK)	Benthic megafauna
Lochlan Gibson	Certified Impact Assessor	Environmental Impact Assessment
Conn Nugent	Independent Consultant	Communications specialist on conservation and sustainable economies.

14 CONCLUSION & RECOMMENDATION

14.1 Conclusion

The Collector Test is an essential component of the commercial ESIA. It is necessary to demonstrate the technical, economic, and environmental feasibility of operations proposed for the commercial phase of the project. The Collector Test is an opportunity to demonstrate the feasibility of the nodule collector system and test any assumptions made during its design.

The information presented in this EIS supports the finding that the proposed mitigation measures, additional project specific controls and small scale of the test program sufficiently minimise all physicochemical, biological, and cumulative impacts to non-significant levels. In the absence of significant residual impacts, the risk of the Collector Test resulting in 'serious harm' to the marine environment at a regional scale, is 'Low'.

14.2 Recommendation

The Collector Test should proceed under the conditions described in this EIS which will be operationalised in the Environmental Monitoring and Management Plan (EMMP) to be submitted to the ISA prior to mobilization. The learnings from the information gathered during testing should be reflected in the findings of the commercial EIS and applied to the design and operations of the full-scale system to reduce uncertainty and minimise environmental impacts during commercial operations.