ENVIRONMENTAL IMPACT ASSESSMENT STUDY FOR CRZ CLEARANCE FOR CONSTRUCTION OF PASSENGER JETTY AND ASSOCIATED LANDSIDE FACILITIES ON THE EASTERN SIDE OF THE KADMATH ISLAND, LAKSHADWEEP

PROJECT CODE: 892062425

For

सत्यमेव जयते

U.T. ADMINISTRATION OF LAKSHADWEEP

Through

COCHIN PORT
कोचिन पत्तन प्राधिकरण
Cochin Port Authority

COCHIN PORT AUTHORITY (CoPA)
KOCHI

March 2025

INDOMER COASTAL HYDRAULICS (P) LTD.

(ISO 9001: 2015 CERTIFIED, QCI – NABET & NABL ACCREDITATED)
63, GANDHI ROAD, ALWAR THIRUNAGAR, CHENNAI 600 087.
Tel: + 91 44 2486 2482 to 84; (M) (+91) 96000 56652/ 99629 37397
Web site: www.indomer.com, E-mail: ocean@indomer.com

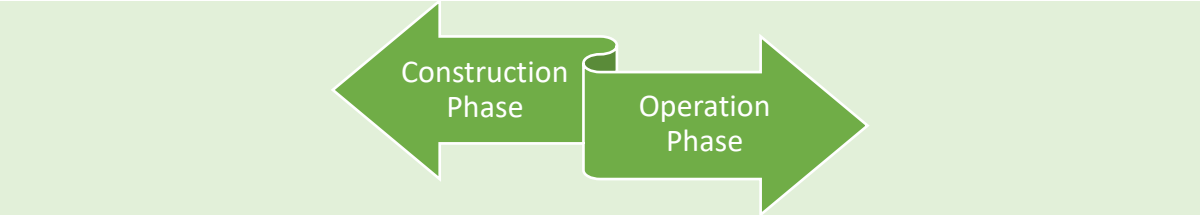
4. IMPACT ASSESSMENT AND MITIGATION MEASURES

As mentioned in Chapter 2, Kadmath Island currently has a western jetty inside lagoon, which is used to handle small passenger boats and cargo vessels. In addition to the western jetty, there are a southern jetty and a small eastern jetty. However, the existing facilities on Kadmath Island are not sufficient to accommodate larger vessels, as the western jetty is old and was originally designed for small passenger boats and cargo vessels. The southern and eastern jetties are also limited to landing activities. To address navigational concerns and meet berthing requirements, a development plan for Kadmath Island has been proposed.

In this particular project, the sizable impact will primarily occur during the construction of the berthing jetty and approach trestle and the construction of the landside facilities will have only have a minimal environmental impact. The development covers: construction of 360 m long berthing Jetty, 310 m long approach trestle on the marine environment and a passenger facilitation center development of warehouse, security cabin and road connectivity on the land of eastern side of Kadmath Island. The anticipated impacts and the corresponding mitigation measure due to the proposed activities are discussed. In reference to **Fig. 1.3.**

4.1. Identification of Impacts

Impacts are identified with respect to two stages of the project viz., i) Construction phase and ii) Operation phase.



a. Construction Phase

Construction phase in the present project involves activities like excavation, raw material transportation, stacking piling, foundation work, deck construction, building construction, installation of fenders & lighting buoys etc.

Due to the sensitive ecosystem, which are mainly made up of coral reefs and lagoons, building a jetty on a Kadmath Island during the construction phase is likely to have a significant negative impact on the marine environment. These effects could include coral reef damage, increased turbidity, sediment disturbance, noise pollution, possible oil spills and disruption of local marine life. During construction period the impact on environment will be of short term, temporary and localized. However, to limit the impact on valued environmental components, mitigation measures are suggested.

b. Operation Phase

During the operational phase of a jetty, key activities include vessel berthing and departure, cargo loading and unloading, passenger boarding, mooring operations, pilotage, security checks, waste management etc.

Operations near jetty can have impact on the coral reef with vessel anchors and movement. The pollution due to leakage of wastes may affect the marine life close to jetty corridor.

4.2. Anticipated Environmental Impacts

Based on the proposed development, the impacts due to the following activities are discussed.

Impact on terrestrial environment	Impact on marine environment
Impact on Air Environment Impact on Noise Environment Impact on Water Environment Impact on Land and Soil Environment Impact on Socio Economic Environment	Impact due to construction of Jetty and approach trestle Impact due to handling of cargoes Impact due to movement of vessels Impact on planktons Impact on benthos Impact on fish Impact on corals

4.3. Terrestrial Environment

4.3.1. Air Environment

a. Construction phase

Possible Impacts:

The construction activities for the proposed passenger jetty, approach trestle and associated structure including site preparation, excavation, construction of piles, operation of construction equipment, handling and transportation of construction materials, operation of DG sets and pumps, etc. could contribute to air pollution. On the other hand, the order of impact on terrestrial environment is limited to only during construction phase. The identified impacts are due to the following.

- **Construction dust** – Arisen from handling construction materials/debris in open area influenced by coastal wind during the construction activities.
- **$PM_{2.5}$** – Emission from exhausts of generator sets, vehicles and heavy equipment.
- **Noxious vapours** – Oils, glues, thinners, paints, treated woods, plastics, cleaners, other hazardous chemicals, generator sets, vehicles and heavy equipment.
- **Volatile Organic Compounds (VOCs)** – Depending on the construction materials used, emissions of VOCs from paints, adhesives, and other chemicals.

Mitigation:

- *Construction materials at site and carried on the vehicle/ vessel have to be properly covered.*
- *Sprinkling of water every day at periodic intervals on the ground on piled up construction materials are to be done.*
- *Dust barriers such as poly screens around the site boundaries have to be provided to create buffer against propagation of dust.*
- *The equipment used at the site have to be properly maintained.*
- *Construction work should be stopped during high wind time.*

b. Operation phase

Possible Impacts:

During the operation of jetty, the air environment can slightly get affected due to release of pollutants, but it will be restricted to the hours of vessel arrival time. The particulate matter (PM),

sulphur oxides (Sox) and carbon monoxide (CO) from vessel engine emissions are anticipated during loading and unloading activities.

Mitigation:

- *Implementing stricter emission standards for vessels*
- *Providing shore power to docked vessels to reduce engine idling emissions.*
- *Improving cargo handling practices to minimize the dust generation and spills.*
- *Regular monitoring of air quality around jetties to identify emission hotspots and implement necessary mitigation measures.*

Impact on the air environment is limited for a period during construction phase. Mitigation measures will be followed during both construction and operation phase to reduce the possible impact on air environment.

4.3.2. Noise Environment

a. Construction phase

Possible Impacts:

There can be an increase in noise from various machinery like pile drivers, excavators, barges, and other construction equipment, which can disturb nearby residential areas and marine life, particularly during the active construction phases.

Mitigation:

- *Personal protective gear has to be provided to workers while involving in high noise generating works.*
- *Highly efficient and regularly maintained equipment has to be used.*
- *Choice of generators and construction machinery/equipment will be restricted as per usage requirements.*
- *Special attention has to be given to the preservation of biodiversity around the jetty location.*

b. Operation phase

Possible Impacts:

Noise generation from movement of vessel and during handling of passenger cargoes in the jetty area are the only anticipated noise generation during the operation phase.

Mitigation:

- *Installing sound barriers or acoustic enclosures around the walk way region.*
- *Encouraging the use of quieter vessels and operating procedures.*
- *All machines must be lubricated and maintained regularly and located inside acoustic enclosures only.*

The construction and operation of Jetty may emit noise from machinery. However, the noise emitted due to the operation will be confined within the jetty premises.

4.3.3. Water Environment

a. Construction phase

Possible Impacts:

- Construction materials like paints, oils, cement mortar, sand etc. may fall inside the sea or may be carried into sea with runoff water leading to contamination.

Mitigation:

- *Construction material has to be stored in a closed place.*
- *Domestic wastewater has to be discharged into a septic tank soak pit arrangement.*
- *There should not be any dumping into the waterfront areas.*

b. Operation phase

- Drinking Water requirement during the operational phase will be met from the LTTD plant.
- Care to be taken that *sewage from facilitation centre, do not mix with Ground water or surface water.*
- *Domestic wastewater generated during operation phase has to be treated with STP.*

There is no significant impact anticipated on the water environment due to the construction and operation of Jetty.

4.3.4. Land and Soil Environment

a. Construction phase

Possible Impacts:

- Soil contamination can occur by deposition of uncovered construction materials exposed to wind and suspended load-laden runoff water.
- Improper drainage systems leading to leakage or overflow of wastewater and littering at the site by workers can result in land soil contamination.
- Alteration in the topsoil for site preparation and foundation can cause a change in the soil profile.

Mitigation:

- *Proper management of construction materials and activities have to be ensured. Loose materials such as cement and sand have to be stored in a closed place and adequately covered.*
- *Any construction material remained after completion of the construction activities for the proposed project must be removed from the site.*
- *Bins have to be provided separately for recyclable and non-recyclable wastes at strategic places which will be periodically emptied, and the waste disposed of adequately.*
- *Workers have to be made aware of the need for proper waste disposal.*
- *Excess excavated material will be properly stored and subsequently used for site levelling, approach road construction, landscaping, as required.*

b. Operation phase

Possible Impacts:

Operation of proposed facilities will not have major impact on land environment. Any other solid waste generated from the jetty has to be disposed of as per the Solid Waste Management Rules, 2016.

The impact of the proposed project on the land environment is expected to be low. Municipal solid waste produced during construction and operation phase have to be properly disposed.

4.3.5. Socio–Economic Environment

Development of Lakshadweep islands are essential for the regional and national economic development by way of safe movement of passengers, transportation of goods, developing new infrastructure etc. The development of Kadmath island will attract international tourists which is one of the major economic engines for the country and gain considerable amount of foreign exchange. Sustainable port operations should aim at inclusive development along with the local community.

Negative Impact

No specific negative impacts are foreseen on social aspects.

Positive Impact

- The issues pertaining to resettlement and rehabilitation are not envisaged in this project, as there is no land acquisition involved, as the proposed development is within the existing boundary of Kadmath Island.
- There are no cultural and heritage site which could be affected due to the proposed construction along on close proximity to the study area.
- Community development with the successful passenger jetty operation may lead to the development of supporting infrastructure such as housing, schools, roads and healthcare facilities which can benefit the local community.
- The proposed project could attract more tourists, boosting local tourism industries.
- The construction of a jetty and associated facilities can improve access to essential services like healthcare and education for coastal communities.

The proposed construction will have more positive impact on the socio-economic aspects of the Kadmath island by upgrading the safety and economy of Islanders.

4.4. Marine Environment

The marine component of the proposed project includes construction of passenger and cargo handling jetty, approach trestle and driving of piles. Evidently, the project would have impacts on the marine environment during its construction as well as operations. The impacts can potentially influence the local ecology given in **Table 4.1.** in the short- as well as long-term if appropriate mitigations are not in place as illustrated below. But the impact will be confined within the corridor outlined in **Fig. 4.1.**

Table 4.1. Different ecology sensitive area affected due to the project

Area	Approach Trestle Area (m^2)	Jetty Area (m^2)
Sanded Reef flat	3.82	-
Reef crest	2.54	70.33
Reef slope	-	226.92
	6.36	297.25
Total	303.61	

Fig. 4.1. Buffer corridor of the proposed development

4.4.1. Impact due to construction of Jetty and approach trestle

Construction of jetty and approach trestles will have more effect on marine environment compared to land environment.

4.4.1.1. Construction phase

The construction activity of jetty and approach trestle will consist of RCC deck (precast and in-situ) supported on bored cast in-situ reinforced concrete piles. The cross section of the jetty and approach trestle is given in Chapter 2.

Possible Impacts:

Disturbance to the marine habitation

(i) **Pile driving:** Piling will be required for the construction of jetty and approach trestle. Piles will be initially erected into the sea floor up to depth where hard stratum is available. The soil inside the pile will be dredged off and the same portion will be refilled with R.C.C concrete. Concrete mixing and construction debris in the marine environment are envisaged during the construction activity. Due to the pile driving activity the impact on following environmental parameters are anticipated:

Marine/coastal ecology: Disturbance from construction activities may cause displacement of fishery resources and other mobile bottom biota. Piling removes bottom biota and material covers bottom habitat, both of which may reduce fishery resources. Settlement of re-suspended sediments on fragile marine fauna and flora damages the ecosystem particularly coral reefs, which are formed by the extracellular product of symbiotic plants. The organisms attached to submerged structures need dissolved oxygen for respiration and the plants need sunlight for photosynthesis. Piles, concrete surfaces, rubble mounds and other similar structures in water could form new habitats, which may introduce undesirable species.

Construction materials, such as ship hulls, ballast water, and the structure of the jetty itself, can serve as vectors for the introduction of invasive species, which may outcompete or prey on native species.

Impact on Seawater and Seabed sediments: Resuspension of sediments in water leads to an increase in the level of suspended solids and concentration of organic matter, possibly toxic or harmful levels. This will cause temporary impact to seawater quality near proposed berthing jetty location. Contaminated bottom sediments (contained with heavy metal concentration) may lead to significant impact to seawater quality during piling. However, baseline data suggests that there is no heavy metal concentration build up in the seabed sediments.

Impact on benthos: Piling and other water side construction will cause loss/displacement to bottom habitat and its associated animal and plant life. Footprint on bottom habitat and associated life will be limited to area of piling. The turbidity induced during driving of piles will also have impact on the community structure and distribution of other marine life. However, the bottom will readily be recolonized by replacement of benthic organisms within few seasons.

Fishes: One of the major impacts of pile driving operations on the marine organisms especially on fishes is the underwater sound pressure waves generated during hammering of the piles. Pile driving may result in 'agitation' of fish indicated by a change in swimming behaviour.

The various factors which are known to influence the impact on fish are: (i) size and force of hammer strike; (ii) distance from the pile; (iii) depth of the water around the pile; (iv) depth at which fish swim in water column; (v) entrapped air in the water; (vi) oscillation of water level, (vii) geological composition of seabed, (viii) size of the fish; (ix) species of the fish; (x) presence of swim bladder; (xi) physical condition of the fish and (xii) effectiveness of sound/pressure attenuation technology used to minimize the impacts.

Plankton: The proposed project activity like piling may not have any direct bearing on plankton. It is expected that the plankton will drift away from the disturbed area leading to minimal loss to plankton. Further, compared to the abundance of the plankton in the site, the loss will be moderate and temporary.

Since the sediment texture is mainly comprised of fine sand, the noise due to piling is expected to be low. As the baseline data suggests there are varieties of fish species and green turtles are observed within the project area, the impact of piling is expected to be limited to benthos. However, these animals will usually return to the area once the disturbance ceases.

Corals: Construction activity near coral reefs can damage coral ecosystems by causing physical harm, increasing turbidity (cloudiness) from sediment plumes, and disrupting water flow, which in turn reduces the amount of food available to corals and ultimately affects their growth and survival. **Quantification of impacts on coral is given in Chapter 9.**

Mitigation measures

- *Existing roads in the Kadmath island shall be used for transportation of construction materials.*
- *Trucks transporting the materials will be covered to avoid susceptible for fugitive suspension.*
- *Vehicles having Pollution Under Control (PUC) certificates will be used. All vehicles used for transportation shall comply with CPCB emission norms.*
- *All workers, technicians and supervisors should make use of all safety equipment such as masks, goggles, helmets, safety belts, earmuffs safety shoes, lifesaving jackets, etc., as required, during the construction phase. Proper security arrangements will be made during nights to avoid any accidents due to unauthorized entry of workers, or civilians.*
- *The hazardous materials anticipated to be stored at the site during construction include gas for welding, fuel for operating construction equipment, paint, etc. All these and other materials of a dangerous or hazardous nature will be stored as per the norms.*
- *Clean and efficient construction techniques should be adopted.*
- *Piling should not be carried out during fish breeding season.*
- *Screening must be provided during piling activity.*
- *The construction schedule should be strictly followed, and no over runs should be ensured. Reducing the construction time with efficient techniques will rescue the period of impact.*
- *The scrap and waste construction materials should not be disposed into the seawater.*
- *Proper lubrication of pile driving machinery will ensure less noise.*
- *After pile driving and construction, continued monitoring of the affected area will be carried out.*
- *Continuous monitoring of coral reefs before, during, and after construction will be carried out.*

4.4.1.2. Operation phase

Possible Impacts:

During operation of jetty, major impact on marine environment is only due to the increase in vessel movement for handling Passenger and domestic cargo handling. Which will only have minimal impact to the marine environment. However, appropriate mitigation measures will be followed in order to reduce the impact on marine environment during operational phase.

Mitigation measures

- *Vessels coming near the Berthing jetty should not discharge anything into the sea.*
- *Waste in the jetty premises should be handled as per PCB norms.*
- *Tourists and Operators must be continuously educated for preservation of the Island ecosystem.*
- *Use low-impact, quieter equipment during operations and limit activities during critical times for marine species (e.g., during breeding or migration seasons).*

4.4.2. Impact on marine environment due to handling of various cargoes

4.4.2.1. Construction phase

During construction phase of jetty, approach trestle, passenger facilitation center -waiting hall warehouse, security building, road and associated facilities all the construction materials such as cement, steel, boulders, sand and other construction related materials will be transported from the mainland using vessels and it will be handled in the existing jetty area and then it will be transported to the storage place away from CRZ zones through existing roads of Kadmath Island. This handling of construction materials cargo will create minor impact on the marine water quality and marine habitat due to spillage while handling of construction materials. The various impacts are listed below:

- Accidental spill of powdered construction materials such as cement and sand on the marine environment will pollute the water quality, increase the sediment concentration, affecting the marine habitat. The release of cement particles during mixing and placement can contribute to turbidity and potential chemical contamination.
- Accidental release of plastic debris during construction can contribute to marine plastic pollution.
- Machinery used to transport and handle materials at the jetty may leak oils or fuels, which can spread on the water surface and create oil slicks and harming marine life.
- Materials like sand, gravel, or concrete are handled, there can be runoff into the water, causing increased turbidity.
- Handling dry construction materials, such as cement or sand, can create airborne dust that can affect air quality in nearby areas. This dust can be harmful to marine ecosystems.

Mitigation measures

- *Selecting appropriate vessel type to handle construction materials based on its weight and material type.*
- *Make sure that construction equipment is not overloaded or operated in a manner that could result in unnecessary sediment disturbance.*

- *Proper packing, sealing and labelling of construction material to avoid spillage of construction materials.*
- *Using proper handling equipment (closed handling) to avoid accidental spillage*
- *Using non-toxic, eco-friendly materials and coatings to reduce the risk of water contamination.*
- *Regularly monitoring water quality and marine life populations to assess the impact of construction.*
- *choose for construction materials that have a lower environmental impact, such as recycled aggregates, sustainable timber, or other green alternatives to reduce waste and minimize the environmental footprint.*

4.4.2.2. Operation Phase

After the construction the jetty will also be used to handle domestic cargo (food grains, fruits and vegetables, cereals, provisions, etc.) which comes from the mainland. Since the proposed berth is a multipurpose one and the nature of cargo will vary, it is proposed to provide one hydraulic lifting crane of 25T lifting capacity at the eastern jetty.

- Accidental spillage of cargoes due to improper handling.
- Improper packing of bulk grain cargo can injure workers.
- Packaging materials, such as plastic, cardboard, and crates, may be discarded improperly, contributing to marine litter and pollution.

Mitigation measures

The impact due to the handling of cargo will be minimal and will not have much impact on the marine environment.

4.4.3. Impact on plankton

a. Construction phase

Construction of Berthing Jetty will affect the plankton community as they are weak against the turbidity generated in the water due to construction activities. The impacts on these communities are directly linked to the extent up to which turbidity persist. It is anticipated that area of construction will be induced with turbidity may have localized effect on plankton.

b. Operation phase

There will be no impact on plankton community during operation phase.

4.4.4. Impact on benthos

a. Construction phase

Major impact to benthos is anticipated during the construction stage as well as during operational stage. During operational stage, impact to benthos is anticipated only due to movement of vessels. Other likely impact to benthos includes unwanted disturbance in the intertidal area of project site. Strict guidelines to workers should be given to avoid unwanted disturbance to tidal flats. The impact will be localized, and benthos will start recolonizing after the construction period.

b. Operation phase

There will be negligible impact on benthos community during operation phase.

4.4.5. Impact on fish

a. Construction phase

Due to construction of Berthing jetty, impact on fishes are also anticipated. However, since fishes are mobile, they tend to move away from under water disturbances. Thus, no significant impact on fishes is anticipated. The fishes will usually return to the original area once the construction activity is stopped.

Mitigation Measures

b. Operation phase

There will not be any significant impact on fishes during operation phase.

Impact on fishing activity

The development of berthing jetty will not disrupt fishing activity in the vicinity.

Mitigation Measures

Regular monitoring of the turbidity, sediment concentration and the heavy metals in the water column shall be carried out to observe the rise in concentration.

4.4.6. Impact on corals

Kadmath Islands is well known for its corals because of the coral reefs that surround the islands and the unique way they were formed. The construction of a jetty and approach trestle can significantly impact coral reefs throughout its construction and operation phase.

However, the impact on corals will be confined within the corridor mentioned in **Fig. 4.1.** and the total length of the approach trestle is 310 m from shore and length of the jetty 360 m. The piled foundation would take up only a small footprint of about 0.9 m dia. in trestle area and 1.3 m dia. in the jetty area.

4.4.6.1. Construction Phase

- Heavy machinery and construction equipment may crush or fragment coral formations.
- Prolonged exposure to sediment can hinder coral metabolism and calcification processes.
- Stress from construction activities can make corals more vulnerable to thermal stress and bleaching.
- Damage to reefs impacts fish populations that depend on coral habitats, affecting local fisheries.

4.4.6.2. Operation Phase

- Increased Turbidity due to movement of vessels will increase the sediment resuspension which will affect corals ecosystem.
- Anchors, propellers, and hulls of vessels can break or crush coral structures.

- Coral damage affects species dependent on reefs for shelter, feeding, and breeding, leading to a decline in biodiversity.
- Excessive lighting from the jetty at night can disrupt the behaviour of reef organisms, including corals, fish, and invertebrates.

Mitigation Measures

- Detailed coral Assessments study was carried out to identify and avoid ecologically critical coral reef zones during site selection.
- Ensure proper collection and disposal of construction debris to prevent contamination.
- Relocate affected coral colonies to nearby healthy reefs or artificial structures before construction begins.
- Construct artificial reefs to provide alternative habitats for displaced marine organisms.
- Prohibit the disposal of hazardous materials and regulate the use of antifouling paints on vessels to prevent leaching of toxins.
- Impose speed limits for vessels in proximity to coral reefs to reduce wake and sediment disruption.
- Establish a monitoring program to track coral health, water quality, and biodiversity around operational areas.

A detailed conservation plan on coral management is given in Chapter 9.

4.4.7. Impact on Seagrass bed

During the study, no seagrass bed were observed in the proposed project location, they are likely to occur further northern and southern areas.Therefore, the project site is devoid of seagrass. Hence, no impact.

4.4.8. Impact on Coastal Vegetation

Project site and surroundings are devoid of coastal vegetation.

4.4.9. Impacts on mangroves

Project site and surroundings are devoid of mangroves. Hence, no impact.

4.4.10. Impact on turtles

The coastline in this region is nearly straight and is oriented in North-South direction. The coastal region predominantly consists of sandy beaches. However, the width of the beach is small at eastern side compared to the north and south of the island so that the project location is not suitable for turtle nesting. Hence, no impact.

7. ADDITIONAL STUDIES

7.1. RISK ASSESSMENT AND DISASTER MANAGEMENT PLAN

7.1.1. Introduction

Emergency/ disaster is an undesirable occurrence of events of such magnitude and nature that adversely affect operations, cause loss of human lives and property as well as damage to the environment. Coastal infrastructure is vulnerable to various kinds of natural and manmade disasters. Examples of natural disaster are flood, cyclone, tsunami, earthquake, lightning, etc., and manmade disasters are like major fire, explosion, sudden heavy leakage of toxic/ poisonous gases, civil war, nuclear attacks, terrorist activities, sabotage, etc. It is impossible to forecast the time and nature of disaster, which might strike a common user infrastructure. An effective disaster management plan helps to minimize the losses in terms of human lives, assets and environmental damage and resumes working condition as soon as possible.

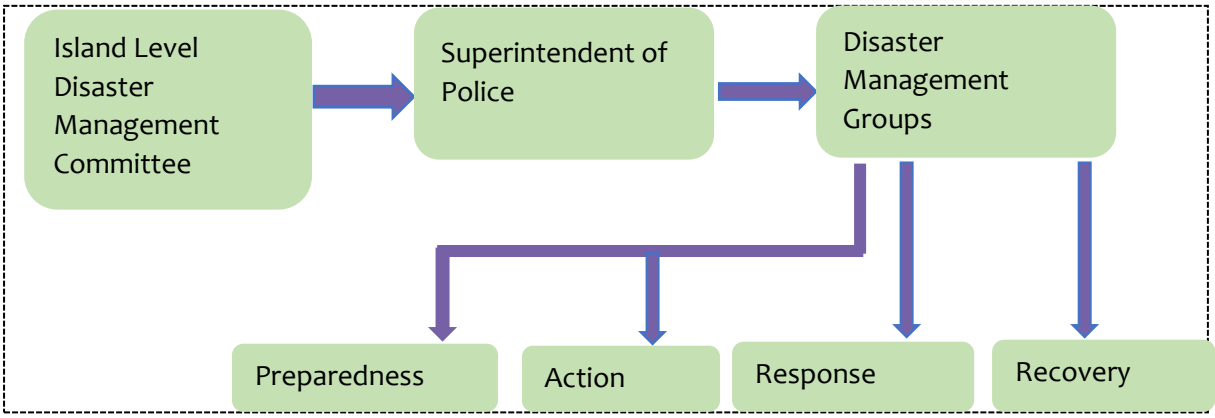
7.1.2. Risk Assessment

Risk is the probability that injury to life or damage to property and the environment will occur. The extent to which risk is either increased or diminished is the result of the interaction of a multitude of causation chains of events. The man-made disasters like fire and accidents also can occur during construction as well as operation phases which would cause the burns, injuries and even loss of human life and property, disrupt services like overhead power and communication lines. Potential impacts due to accidents include injuries and burns which demand surgical interventions, poisoning or exposure to toxic material, trauma and even loss of human life, property damage includes damage/loss of fishing vessels/crafts and other surface vehicles, mechanical devices and equipment used during construction and operational phases. Vessel collision, sinking of boats due to unattended leaks and damages are potential risks. Probability of any hazardous incident and the consequent damage also depend on:

- Wind speed,
- Wind direction,
- Atmospheric stability,
- Source of ignition

7.1.3. Disaster Management Plan

Emergency/disaster is an undesirable occurrence of events of such magnitude and nature that adversely affect operations, cause loss of human lives and property as well as damage to the environment. Coastal infrastructure is vulnerable to various kinds of natural and manmade disasters. Examples of natural disaster are Flood, Cyclone, Tsunami, Earthquake etc., and manmade disasters like major fire, explosion, sudden heavy leakage of toxic/poisonous gases, etc. An effective disaster management plan helps to minimize the losses in terms of human lives, assets and environmental damage.



Overall Disaster Management Hierarchy

Objective of Risk Assessment and Disaster Management Plan

DMP should be developed to make best possible use of the resources available in the operational area as well as outside available resources like Fire Services, Police, Civil Defence, Hospitals, Civil Administration, neighbouring institution and industries.

The objectives of Disaster Management Plan are:

- To contain and control the incident.
- To rescue the victim and treat them suitably in quickest possible time.
- To safeguard other personnel and evacuate them to safer places.
- To identify personnel affected/dead.
- To give immediate warning signal to the people in the surrounding areas in case such situation arising.
- To inform relatives of the casualties.
- To safeguard important records & information about the organization.
- To preserve damaged records & equipment needed as evidence for any subsequent enquiry.
- To rehabilitate the affected areas.
- To restore the facilities to normal working condition at the earliest.

7.1.4. Disaster Identification

a) Natural disaster

A disaster occurs when a hazard such as Earthquake, Flood or Cyclone coincides with a vulnerable situation. Based on project details, geography, environmental setting of the study area and available information following hazards have been identified which may possibly lead to disaster. The probability/seasonality of hazard is listed below **Table 7.1.**

Table 7.1. Probability/seasonality of hazard

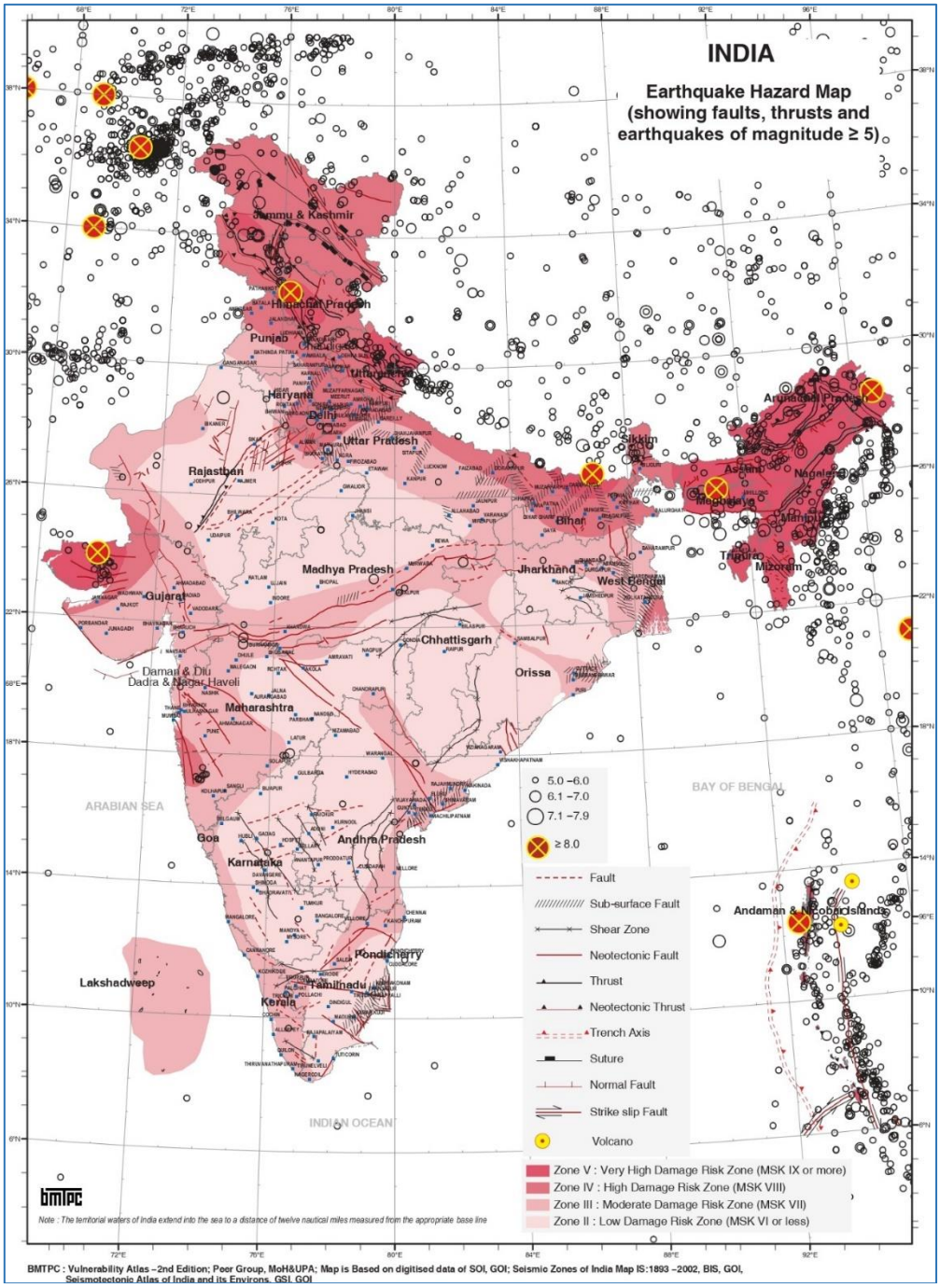
Identified natural hazards in the study area			
Sl. No.	Hazard	Project area	Findings
1	Earthquake	✓	Zone III (moderate risk zone)
2	Cyclone	✓	Wind speed of 2.5 m/sec.
3	Tsunami	✓	Moderate Damage Risk Zone B
4	Flood	x	Low (may occur due to very heavy rainfall, sea surge or tsunami)
5	Drought	x	Moderate Drought

(Source: NDMA - 2016 & 2019)

Disaster identification suggests that the project site is vulnerable to natural hazards. According to District Disaster Management Plan, probability of flood in the island is low and it may occur only in the event of very heavy rainfall, sea surge or tsunami. Among the identified impacts, Cyclone, Sea surge and Earthquake are most probable to occur in the vicinity of project area.

(i) Earthquake

As per Indian Seismic Zone Map, the Kadmath Island lies in Moderate Damage Risk Zone III where earthquakes of moderate intensity can be expected. Earthquake map is given below.



Earthquake zone map

Action Plan

During Earthquake:

- Evacuate to safest place by following emergency exist route.
- Hold onto a firm object.
- If outside, stay outside.
- If there is no place to take cover, then move to and brace against an inside wall.

After Earthquake:

- Collect report of damages from every division immediately after the event of earthquake.
- Inspection of affected area by Disaster Management Team.
- Procurement of emergency power in case of power failure.
- Inform Island authorities about the damage.
- Take necessary actions for the speedy recovery of operations.

(ii) Cyclones

Based on tracks of cyclones passed in Indian coastal region, the tracks of cyclones which have crossed the coast near Lakshadweep during 1924 to 2023 as documented by the Indian Meteorological Department (IMD) are presented in **Table 7.2.** and the track of cyclones is shown below. It indicates that totally 10 storms had occurred in the vicinity of the project region in the last 100 years. The occurrence of storms in this region are more frequent in December (04) followed by May (03) and November (03). More details are given in Chapter 3.

Table 7.2. Number of cyclones crossed over project area (1924 – 2023)

Month	Cyclones crossed over project area
January	-
February	-
March	-
April	-
May	03
June	-
July	-
August	-
September	-
October	-
November	03
December	04
Total	10

Source: cyclone e-atlas published by IMD – 2023

Action plan

In case of warning received from India Metrological Department, following action shall be taken immediately:

Before Cyclone

- Control room shall monitor low pressure formation, cyclone and IMD published details and warnings regularly.
- In case of any warnings, the same shall be reported to onsite disaster management head, HSE and group heads etc.
- Onsite Disaster Management team shall conduct a meeting, if possible, immediately after the warning to recollect the facilities and action to be taken.
- All preparations before the onset of cyclone, actions during cyclone shall be reviewed.

During Cyclone:

- Sound Emergency alarm/siren.
- Inform all staffs about the occurrence of event.
- Adequate manpower with tools, welding sets, ropes etc. shall be maintained during cyclone for rescue operation.

After Cyclone: Immediate attending of work area and report damage if any to higher authority. Immediate attending of damages and record should be kept for quick recovery as soon as possible.

(iii) Tsunami

Tsunami is a series of wave train generated in the ocean by a hydraulic impulsive force that vertically displaces the water column. Earthquakes, landslides, volcanic eruptions, explosions and even the impact of cosmic bodies taking place in the ocean can generate Tsunami waves with long periods (≈ 30 min), long wavelength (≈ 100 km) with a high velocity of propagation (≈ 700 km/hr).

Tsunamis are shallow water waves which propagate with phase velocity equal to the square root of the product of the acceleration due to gravity and the water depth. For example, in the Pacific Ocean, where the typical water depth is about 4000 m, the Tsunami wave travels at about 700 km/hr. Because the rate at which the wave loses its energy is inversely related to its wavelength, Tsunami not only propagates at high speed, but it can also travel great transoceanic distances with limited energy losses and reach different continents in shorter time i.e., the energy propagating with Tsunami waves remain nearly constant.

Among the various factors causing the occurrence of Tsunami, the large vertical movements of the earth's crust is more predominant and it can occur at tectonic plate boundaries. The plates that interact along these boundaries are called faults. Around the margins of the faults, the denser oceanic plates slip under the continental plates in a process known as subduction. Such subduction earthquakes are particularly very effective in generating the devastating Tsunamis.

The energy flux due to Tsunami is proportional to its velocity of propagation and height and it remains nearly constant till reaching the coast. Consequently, the velocity of propagation gets retarded when it enters shallower water and its height gets amplified. Because of this shoaling effect, the Tsunami that is imperceptible at Deep Ocean close to centimetre height may rise up to several metres near the coast called run up.

When Tsunami finally reaches the coast, the crest of the wave appears as rapidly risen water mass gushing into the coastline as a bore with a crashing velocity of 700 km/hr for more than 10 - 30 min. The trough of the wave will appear as the withdrawal of water mass with same speed back into the ocean swallowing everything on the land and dragging back into the ocean.

In worst case, if a Tsunami occurs then there will be surging of Tsunami waves with a speed of > 60 kmph into the shore and the run-up will be > 4 m. The gushing of water will sweep and flood the areas having elevation < 3 m MSL.

Disaster Management Plan for Tsunami and Storm Surge

Cyclone, Tsunami and Storm surge are the most destructive force among the natural devastations. It causes instant disaster and burial of lives and destruction to entire coastal properties. The damage and loss can be minimized if appropriate preparedness plan is formulated. The following statutory guidelines are recommended by National Disaster Management Authority (NDMA) to minimize the impact due to Cyclone, Tsunami and storm.

- Developing sand dunes along the coast with shrubs or Casuarina trees for stabilization of the sand dunes (Tsunami Mound).
- Raising the ground level (above the design water level) with natural beach sand so as to rehabilitate the coastal region.
- Development of coastal forest (green belt) by planting casuarinas and coconut trees along the coastline to cover minimum of about 500 m width of the beach.
- Adopting natural beach nourishment to create steep beach face.
- Creation of sandy ramps at close intervals along the coast.

In addition to the guidelines by NDMA, it is also necessary to adopt various preventive actions in the coastal region of the project site.

Preparedness Plan

The preparedness plan shall contain details about: i) warning that should be given ii) Protective measures to contain the effect of surging water level and iii) Other precautionary measures to be taken. The following measures are the key aspects in the preparedness plan.

i) Coordination with International and National Agencies
ii) Vigilant online monitoring
iii) Emergency Evacuation

Coordination with National Agencies

After the 2004 Tsunami affected the Indian sub-continent, the following organizations are involved on watch and cautioning the government and public in the event of possibility of occurrence of Tsunami. As a part of Tsunami hazard mitigation, warning systems have been established in India by the coordination of the following organizations.

i) Indian National Centre for Ocean Information Services (INCOIS), Hyderabad.
ii) National Disaster Management Authority (NDMA), New Delhi.
iii) Indian Meteorological Department (IMD), New Delhi.
iv) National Institute of Ocean Technology (NIOT), Chennai.

The contact details of National agencies are given below:

Organization	Address	Email ID	Contact Number
Lakshadweep Collectorate	Kavaratti	lk-coll@nic.in	04896 - 262256
Suptd.of Police	Kavaratti	lak-sop@nic.in	04896 - 262750

Vigilant online monitoring and emergency alarm

INCOIS in collaboration with NIOT has deployed DART buoys at 3 locations in the deep ocean along the fault plane of Andaman plate and Indonesian plate.

The online monitoring is capable of raising alarm in case of instantaneous change in surface elevation exceeding centimetre which can be caused by the generation of Tsunami. IMD interacts with the above institutions and takes the responsibility of broadcasting the disaster through various Medias. In case of a Tsunami, the warning is usually broadcast based on the earthquake occurred in the nearby ocean. Irrespective of definite occurrence of Tsunami, the possibility to occur is also considered as equally vulnerable and accordingly the warning news is instantly flashed through Radios and TVs. The notification is followed by orders from the local Government Authorities on reinforcing evacuation, prohibition to enter the demarcated risky zone and mobilizing facilities for easier evacuation and augmenting medical facilities.

There are a variety of evacuation notification systems in case of Cyclone, Tsunami and Storm surge. They include sirens, weather radio, Emergency Alert System, Telephones, Emergency Weather Information Network etc. In each system, it should be noted that the application and message is consistent as well as continuous with repetition of messages with periodicity at short time interval. It should be ensured that the warning reaches immediately to all people prone to the devastation. The time at which the cyclone, storm surge or Tsunami may reach the coast can be predicted with sufficient lead time. The destruction can be minimized if the coastal populations are warned and evacuated to elevated place and inland in time. Therefore, keeping vigil on the warning is the very important aspect in protecting the lives.

A vigilant team must be created. An Emergency Alarm should be in place in all the islands. If warning is given instantly activate the emergency alarm and give caution to the vigilant team so that they can immediately start the rescue operation.

The vigilant team should have proper knowledge about the warning systems and should have attended the training programs conducted by the Tsunami warning centres. The training should be given periodically to update the system and methods of warning. The team should take the responsibility of giving immediate warning to the people in and around the power plant in case of Tsunami and they have to undertake the Emergency Preparedness Action. Safety drills should be conducted periodically.

Operational and emergency preparedness procedures should be planned meticulously in order to act on the warning and to disseminate it rapidly and effectively to the public.

Emergency Evacuation

Evacuation of people from risk areas is the first priority when early warning is received or the natural warning sign indicates the immediate arrival of cyclone, Tsunami wave or rise of storm surge.

Evacuation plan describes the time span available before and during the Tsunami or storm surge event. When facing local threat, evacuation procedures most possibly will have the character of a 'runaway effort' and people should not expect to receive much institutional support. The primary objective should be bringing as many people as possible out of the reach of the wave's impact to safe or 'relatively safe' areas. Therefore, necessary steps have to be taken in advance to enable and support the community at risk to protect themselves at any time

(iv) Flood

In general, Lakshadweep Island is not prone to flood.

MASS RESCUE OPERATIONS

The Union Territory of Lakshadweep has formulated a Mass Rescue Operation (MRO) Contingency Plan to ensure a coordinated response during large-scale maritime disasters. The MRO plan is designed to utilize all available local resources and enhance inter-agency coordination within the maritime jurisdiction of the UT. The region is also highly vulnerable to natural disasters such as cyclones, thunderstorms, erosion, and occasional earthquakes, which have historically caused substantial loss of life and property, as seen in major storms recorded in 1847, 1891, 1922, 1963, 1977, 2004, and 2017. Due to the geographical isolation of the islands and their dependence on shipping for connectivity, efficient disaster preparedness, rapid response, and seamless cooperation among various resource agencies are crucial in mitigating risks and ensuring effective mass rescue operations at sea.

A Mass Rescue Operation (MRO) is a large-scale emergency response that occurs when the number of people in distress exceeds the normal Search and Rescue (SAR) capabilities. While MROs are rare compared to regular SAR operations, they can arise from flooding, earthquakes, ship or aircraft accidents, hazardous material incidents, or terrorist attacks, requiring immediate and coordinated action. The primary objective in any MRO is lifesaving, followed by environmental protection and property safety, driven by moral, legal, and public expectations. These operations demand rapid, large-scale mobilization of resources, involving multiple agencies working under a clear command structure to ensure seamless coordination. Effective communication systems, trained personnel, and extensive logistical support are crucial to sustaining rescue efforts, sometimes for weeks. MROs require intensive pre-planning, collaboration, and real-time execution.

The Mass Rescue Operation (MRO) Contingency Plan for Lakshadweep is designed to provide a structured and coordinated response to large-scale maritime emergencies. Its primary objective is to ensure an efficient and flexible rescue strategy in the Search and Rescue Region (SRR) of Lakshadweep, covering rescue procedures, training, documentation, and media coordination.

The Indian Coast Guard (ICG) is designated as the lead agency, with distress reports relayed to the Coast Guard District No.12 at Kavaratti, the District Collector, and other stakeholders for immediate action. Aerial and sea-based search operations are crucial for assessing incidents and launching timely rescue efforts.

The Mass Rescue Operation (MRO) Contingency Plan outlines a structured approach to managing large-scale rescue efforts at sea. On-scene responsibilities are shared between the On Scene Commander (OSC) and the ship's master or aircraft pilot, who oversee safety, medical care, and evacuation procedures. In most cases, passengers and crew should remain on board unless the vessel is in immediate danger. The Search and Rescue Mission Coordinator (SMC) designates the OSC, ensuring effective communication, resource mobilization, and coordination with all agencies involved.

The plan prioritizes tracking and accounting for all people, utilizing lifeboats, helicopters, and naval vessels for rescue operations. Ship companies are encouraged to have helicopter landing areas and hoist-winch systems for more efficient evacuations. Depending on circumstances, towing survival craft to shore may be safer than removing passengers at sea. The MRO is coordinated by

Rescue Coordination Centers (RCCs) but may escalate to higher authorities if international support is needed.

Key considerations in MRO planning include incident command structures, resource mobilization, immediate activation protocols, personnel deployment, survivor care, media management, and security control. The plan also emphasizes preparedness through regular training, communication systems, and logistical support to ensure an effective response. Practical recommendations include quick mobilization, use of larger vessels for evacuation, controlling airspace, securing debris for investigation, and integrating support services like the Red Cross and crisis management teams. Pre-planning and collaboration among government, military, and private agencies are essential to maximizing efficiency and saving lives in a mass rescue scenario.

9. ENVIRONMENTAL MANAGEMENT PLAN

9.1. Introduction

Development of any infrastructure in the coastal environment includes both social and environmental impacts. To address the anticipated impacts and to implement the mitigation measures, Environment Management Plan (EMP) needs to be formulated. EMP identifies the approach, procedures and methods that will be used to control and minimize the environmental and social impacts of construction and operational activities associated with project development. It is intended to reduce the negative impact and to enhance the positive benefits from the project.

The main objectives of Environmental Management are to:

- Identify key environmental issues anticipated to be encountered during construction and operation phases of the project
- Provide guidelines for appropriate mitigation measures
- Ensure the mitigation measures are implemented
- Establish systems and procedures for implementing mitigation measures
- Monitor the effectiveness of mitigation measures
- Take necessary prompt action when unforeseen impacts occur

The proposed project involves construction of jetty with approach trestle, passenger facilitation centre modern amenities, navigational aids, development of warehouse and road connectivity to existing road and development of auxiliary infrastructures. The impacts due to construction and operation of the proposed development were described in **Chapter 4**.

9.2. Environmental Management Plan

The various impacts in any project development can be categorized as mitigable and non-mitigable and it is essential to list the impacts accordingly. The key activities or aspects of the proposal that may potentially affect habitat of flora and fauna and require application of management controls include,

- Construction of the approach trestle: Site preparation, construction of piling/foundation, storing of construction materials, construction of sheet piles, construction of service utilities, construction of footpath.
- Construction of berth: Site preparation, construction of bollard, construction of wharf, constructions of deck slab, fixing of precast deck slab fixing of tyre fender construction of long beams, construction of piling/foundation, storing of construction materials, construction of sheet piles.
- Construction facilitation centre: Site preparation, construction of waiting hall including foundation, flooring etc., construction of security cabin, construction of warehouse.

Labour Management Plan

The total number of workers to be employed during construction phase will be around 18000 nos. Almost all the labours will be recruited as locals islanders and some from mainland and hence temporary labour camp/ residential colony has not been proposed for this project. The basic facilities required for the labours at the workplace as per the Contract Labour (Regulation & Abolition) Act, 1970 will be made available.

Sanitation Facility

There should be one latrine for every 25 males or females. Every latrine shall be under cover and so partitioned off as to secure privacy and shall have a proper door and fastenings. "For Men only" and "For Women only" must be displayed in the local language in the door of the latrines. The notice shall also bear the figure of a man or of a woman, as the case may be. Sanitation facility should be provided to the workers during construction.

Solid Waste Management

Construction waste consisting of bricks, stones, pipes, concrete waste, steel waste, etc. will be generated during the construction phase. The waste will be properly disposed or recycled.

Transportation and heavy machineries

- All vehicles used will have a valid Pollution Under Control Certificate.
- Regular servicing and maintenance of machineries as well as vehicles to control unwanted air pollutant emission.

Marine Environment

- Periodic monitoring on the seawater, seabed sediment and marine ecology will be carried out in the coastal region and the report will be submitted to the statutory bodies as required.

9.3. Coral Management Plan

Coral reefs are one of the most diverse and highly productive ecosystems in the coastal zone and contribute to the sustenance of the country through fisheries, tourism, etc., and also protect the shore from erosion and natural calamities by buffering of waves and currents. Coral reefs play a major role in climate change, by fixing atmospheric nitrogen, regulating CO_2 and Ca levels. Reefs also offer shelter to various organisms, including ornamental fishes, crabs, shrimps, sea cucumbers, sea urchins, octopuses, eels, etc.

Besides hard stony coral reefs, soft corals also exist in coral reef ecosystems, in clear, warm tropical seas. Hard corals produce a rigid skeleton made of calcium carbonate ($CaCO_3$). The calcium carbonate of corals provides a hard outer structure that protects the soft parts of the coral. Colonial hard corals are made up of hundreds to hundreds of thousands of individual coral polyps that cement themselves together by the calcium carbonate they secrete.

Soft corals do not produce rigid calcium carbonate skeletons and do not form reefs, though they are found in reef ecosystems. Like hard corals, most soft corals are also colonial; what appears to be a single large organism is actually a colony of individual polyps that form a larger structure. Visually, soft coral colonies tend to resemble trees, bushes, fans, whips, and grasses.

In India, a total number of 585 species (108 genera, 23 families) of Scleractinian fauna has been reported (De *et al*, 2020). Highest number of species (523 species belonging to 95 genera and 23 families), was reported from Andaman and Nicobar Islands, followed by Gulf of Mannar (169 species of 46 genera and 16 families), Lakshadweep Islands (165 species of 54 genera and 17 families) and Gulf of Kachchh (76 species of 30 genera and 11 families).

Among the Indian reefs, 298 species (52.6 %) occur only in Andaman and Nicobar Islands, and are not found in other reefs. Likewise, 28 scleractinian species (5 %) are unique to Gulf of Mannar,

followed by 7 unique species (1.2 %) in Lakshadweep Islands. In Gulf of Kachchh, only one unique species (0.2 %), namely *Acanthastrea simplex* occurs.

Among the total number of 585 species, 36 scleractinian species (6.4 %) are common and present in all the four major reef regions.

Lakshadweep Islands

In the south-western part of India, Lakshadweep reef archipelago is located 200-400 km away from the Indian mainland and is formed by a series of coral atolls. This Lakshadweep Chagos ridge supports the longest chain of true atolls and supports divergent ecosystems characterized by a rich diversity of corals and associated marine organisms. The submarine ridge that supports the islands, rises from a depth ranging from 1500 to 4000 m. There are 6 tiny islands, 12 atolls, 3 reefs and 5 submerged banks, covering an area of 32 km^2 with lagoons occupying about 4200 km^2. Only 11 of the 36 islands are inhabited (Venkatraman, 2006).

In the Lakshadweep Islands, among the 17 families, Acroporidae (51 species, 5 genera), Merulinidae (34 species, 14 genera), and Poritidae (17 species, 2 genera) form the major species assemblage. At the genera level, *Acropora* contributes 36 species, followed by *Porites* (14 species) and *Montipora* (9 species).

Department of Environment and Forest, Lakshadweep (2023), has recently compiled the database on hard corals and has listed 80 species of corals, belonging to 34 genera. They are *Acropora (21 species), Porites (6), Favites (5), Favia (3), Fungia (3), Pocillopora (3), Turbinaria (3), Astreopora (2), Galaxea (2), Montipora (2), Cyphastrea (2), Montastrea (2), Platygyra (2), Goniastrea (2), Goniopora (2), Lobophyllia (2), Isopora (1), Echinopora (1), Diploastrea (1), Leptoria (1), Plesiastrea (1), Merulina (1), Hydnophora (1), Mycedium (1), Pectinia (1), Pavona (1), Gardineroseris (1), Herpolitha (1), Polyphyllia (1), Symphyllia (1), Stylophora (1), Psammocora (1), Tubastrea (1)* and *Heliopora (1).*

Kadmath Island

Kadmath island has three types of habitats namely coral reef, seagrass and nesting ground for marine turtles. Such habitats are found in about one third of all shallow coastal waters in the tropics. All three ecosystems are of major importance and are closely interconnected through hydrodynamic circulation patterns and trophic system.

Coral Reef

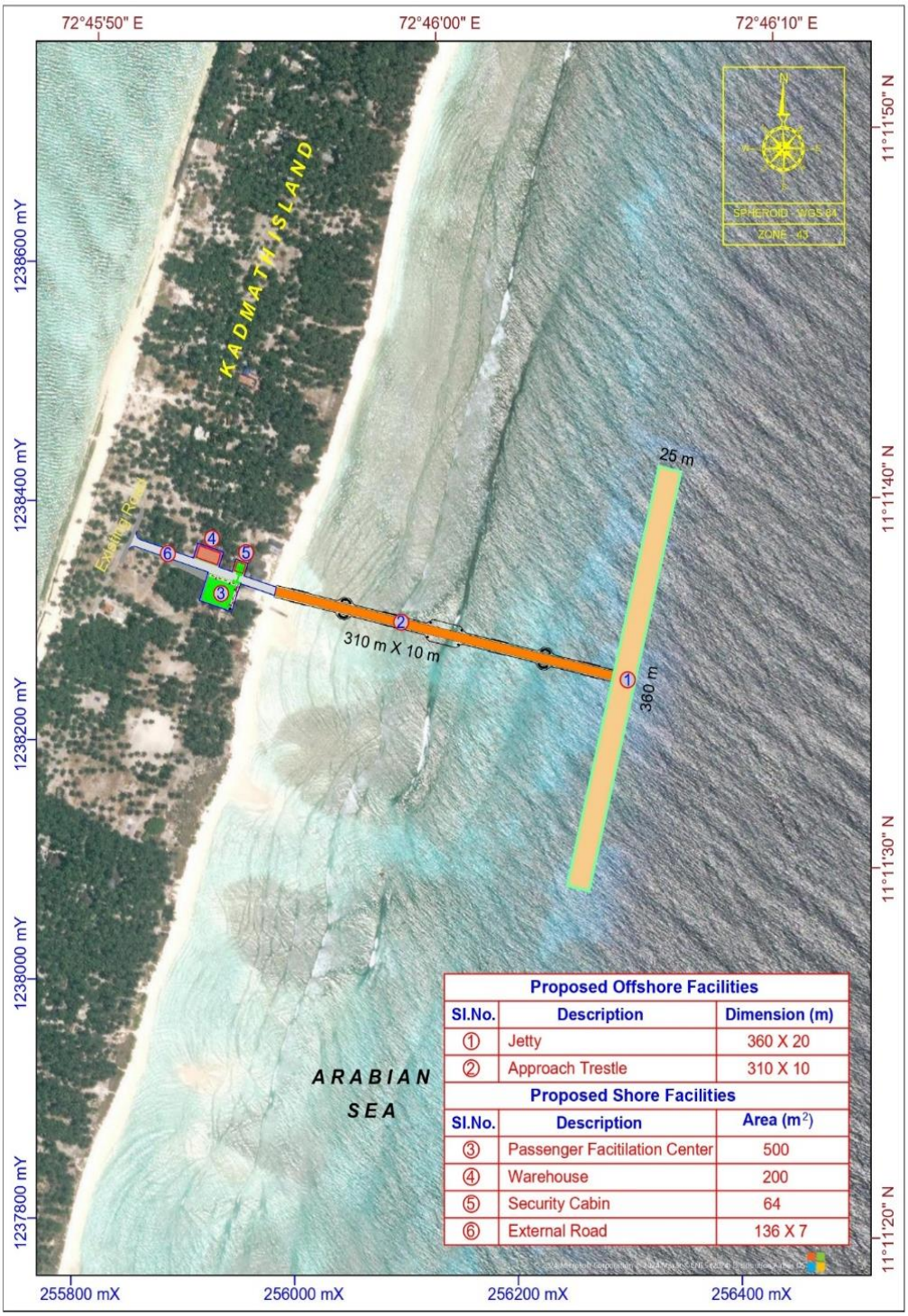
The reef zonation of the Kadmath island has reef flat, reef slope and lagoon. Fringing reefs are adjacent to the shorelines and act as spawning and nursery grounds for a large number of fin and shell fishes.

Fringing reefs are found mostly within and bordering the lagoon, at a distance of 300- 400 m from the shore and mostly within 5 m depth. Patch reefs are found scattered in the northwestern part of the lagoon.

Earlier, in the lagoon as well as reef slope area, 9 species of live corals were reported. The reported species were *Acropora formosa, Acropora robusta, Acropora* sp., *Acropora subglabra, Acropora tortuosa, Acropora vanghani, Favites* sp., *Pocillopora verrucosa* and *Lobophytum* sp. (ICMAM, 2001).

Project Region

The project site is located on the eastern side of Kadmath, near the existing low-lying jetty. In the project site, both the offshore and onshore facilities have been proposed. The offshore facilities include the jetty and approach trestle. The onshore (land) facilities include passenger waiting hall, security cabin and warehouse.



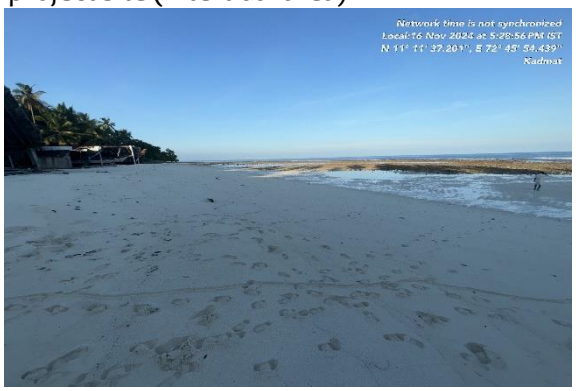
Proposed facilities in Kadmath Island - Easten side

Description:

The upper intertidal area is sandy of about 30 m width both on the northern and southern sides of the proposed jetty area. The mid intertidal area is characterized mostly by dead coral rocks, rubbles, etc., along with a few sparse live coral colonies. Live coral species include *Platygyra daedalea, Platygyra* sp., *Goniastrea* sp., *Porites* sp., *Cyphastrea* sp., *Stylophora* sp., etc. In the lower intertidal area, massive corals *Porites* sp., was observed as more common than other species.

Coral observation in proposed project site (intertidal area)

Sandy beach in upper intertidal area - north



Sandy beach in upper intertidal area - south

Dead corals next to sandy area

Sandy area in intertidal area

Dead coral in mid-tide area

Dead coral in mid-tide area

Platygyra sp.

Platygyra daedalea

Goniastrea sp.

Porites sp.

Cyphastrea sp.

Stylophora sp.

Dead coral in mid tide area

Dead coral in mid tide area

Experts involved in the coral study

Coral management plan has been prepared by the subject experts of Indomer. In order to meet specific requirements of this plan, the following subject experts are involved in the study. Dr. Deepak Apte, (Marine Ecology, Former Director of Bombay Natural History Society (BNHS), Dr. T. Balasubramanian, (Marine Biology, Former Dean and Director, C.A.S. in Marine Biology, Annamalai University), Dr. S. Sundaramoorthy, (Former Scientist F, ICMAM-PD, MoES, Chennai), Dr. P. Chandramohan, (Ocean Engineering, Former Scientist, CSIR-NIO, Goa), Dr. P. Venkadeswaran, (Plant Taxonomy and Ecology & Biodiversity) and Dr. G. Idayachandiran, (Marine Biology).

Habitat Analysis based on video transects

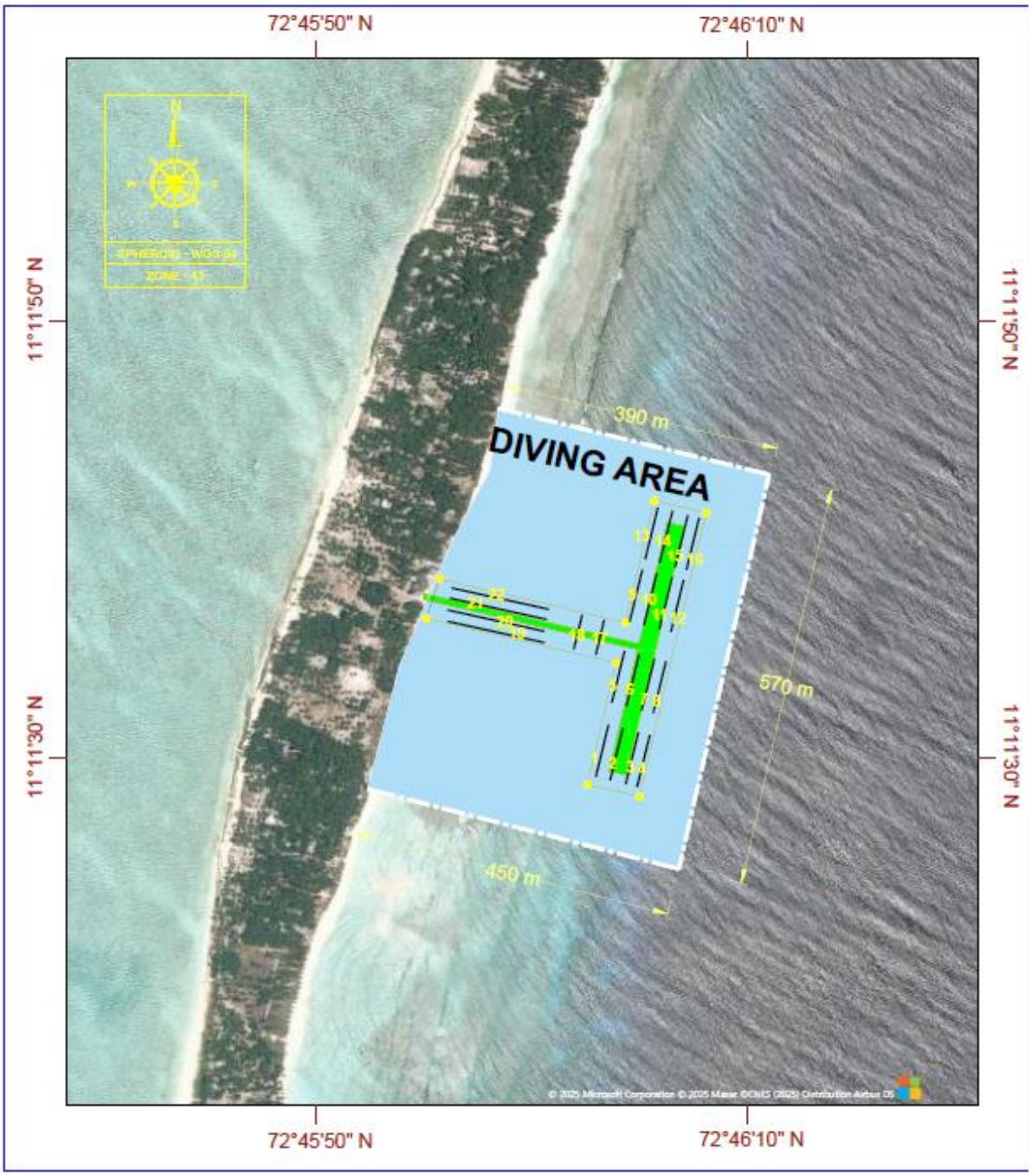
Methodology

This study utilized underwater video footage to assess benthic habitat composition along transects.

Transect Establishment: Transects were established with a defined length of 100 meters.

Video Acquisition: Underwater video footage was collected along each transect with help of SCUBA Diving/ Snorkelling.

Proposed project region of Kadmath eastern side of coral study (SCUBA diving) in 21 transects are given below.



Coral study at proposed eastern jetty of Kadmath island

Data Collection:

100 frames were randomly selected from each video (in case of multiple videos appropriate number of frames based on duration of video were extracted).

For each frame:

- The dominant benthic habitat within the frame was identified.
- Due to the inherent variability in camera angle and distance from the substrate, the largest habitat observed within the frame was assumed to represent the dominant habitat at that specific point along the transect.

- The percentage composition of each benthic class was determined based on the frequency of occurrence of each class within the 100 frames.

Majority habitat is **Algae** followed by **DCA**

Majority habitat is **Sand**

Majority habitat is **DCA** followed by CM

Kadmath E (T7) majority habitat is **Sand**

Habitat Classes used for analysis (Depends on location)

Higher class	Class Name (Code)	Class Information
Algae	ALG	Algae - turf
Algae	CA	Coralline algae (Pink)
Algae	HA	*Halimeda*
Dead Coral – Acropora with algae	DC_ACB	Dead Coral *Acropora* with algae
Dead Coral – with algae	DCA	Dead Coral with algae
Live Coral	AC_B	*Acropora* - Branching
Live Coral	AC_D	*Acropora* - Digitate
Live Coral	AC_SM	*Acropora* – Sub massive
Live Coral	AC_T	*Acropora* - Tabular
Live Coral	CB	Coral Branching
Live Coral	CB_POI	Coral Branching - Pocilloporid
Live Coral	CB_POR	Coral Branching - *Porites*
Live Coral	CB_STY	Coral Branching – *Stylophora* and allied
Live Coral	CE	Coral Encrusting
Live Coral	CF	Coral Foliose
Live Coral	CM	Coral Massive
Live Coral	SC	Soft Corals
Other	GC	Giant Clams
Other	SC	Sea Cucumber
Rubble	R	Rubble
Sand	S	Sand

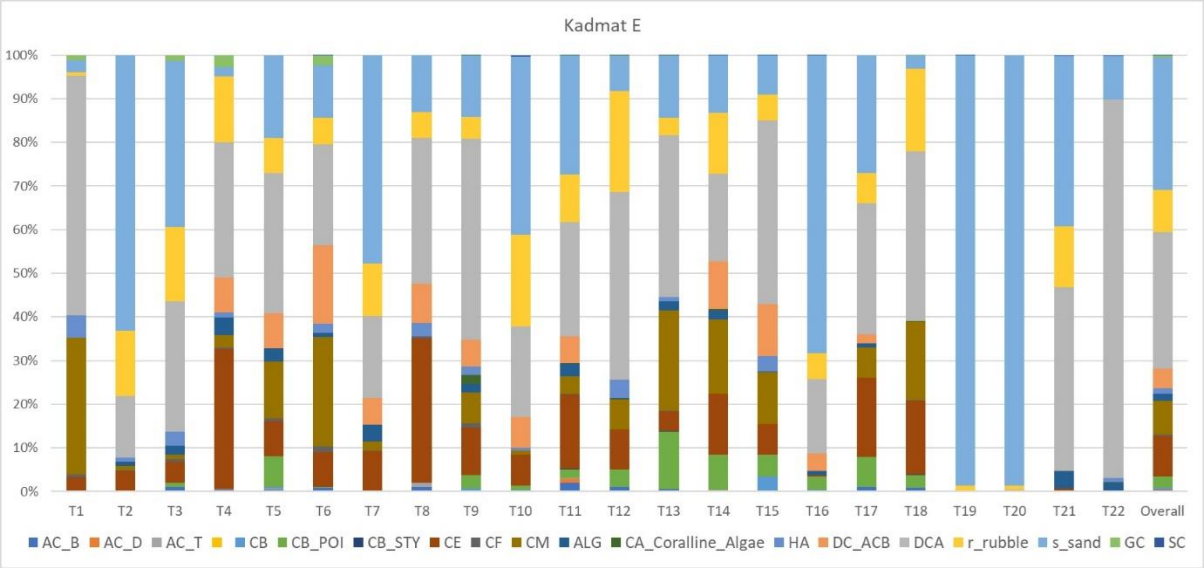
Assumptions and Limitations

Dominant Habitat Assumption:

The methodology relies on the assumption that the largest habitat observed in a frame accurately represents the dominant habitat at that point. This assumption may introduce bias, especially in areas with complex or heterogeneous benthic communities.

Camera Angle and Distance: Variations in camera angle and distance from the substrate can significantly influence the apparent size and visibility of different habitats. These factors were not explicitly accounted for in the analysis.

Random Frame Selection: The method assumes that the 100 frames selected are representative of the entire transect. However, the randomness of frame selection may introduce some degree of variability in the results.



T2, T19 and T20 are dominated with Sand and rubble

Dominant Habitat Components

Dead Coral with Algae (DCA): This component is also prevalent in several locations, indicating that there has been some coral mortality, which is now covered by algae.

Coral Massive (CM): This appears to be the dominant habitat component across many of the locations. It suggests a substantial presence of large, solid coral formations.

Other Significant Components

- **Live Corals:** Various types of live corals are present, including Acropora (AC_B, AC_D, AC_T), branching corals (CB), and encrusting corals (CE). These contribute to the overall coral cover and biodiversity.
- **Algae:** Algae are also a significant part of the habitat, with different types present such as turf algae (ALG) and coralline algae (CA -Coralline_Algae).
- **Rubble and Sand:** These components are present in varying amounts across the locations, suggesting areas with sediment accumulation or disturbance.

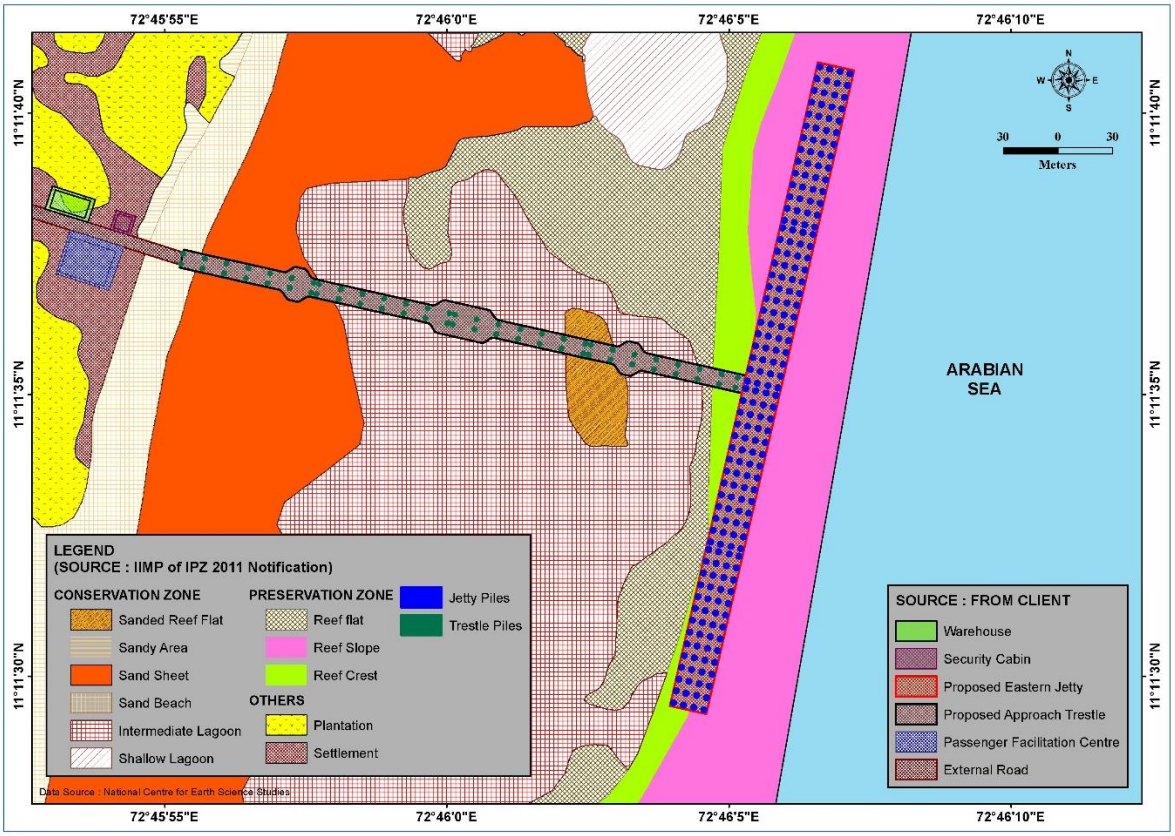
Overall Habitat Characteristics

The habitat appears to be a coral-dominated ecosystem with a mix of live and dead corals, algae, and sediment. The presence of CM suggests a relatively stable and mature habitat that provides important ecological functions. However, the presence of DCA indicates potential disturbances or stressors that have led to coral mortality.

CORAL MANAGEMENT PLAN

Eastern side

Corals are few compared to the western side (Lagoon side) of Kadmath island. According to the CRZ map, sanded reef flat and reef crest are present in the approach trestle region, and jetty area will occur within the reef crest and reef slope area. The proposed piles (both approach trestle and jetty) over the coral subzone are shown in the figure below.



Proposed piles (both approach trestle and jetty) over the coral subzones

Impact on reef during pile foundation

Total length of the approach trestle is 310 m from shore and length of the jetty 360 m. The pile foundation would take up only a small footprint of about 0.9 m dia. in trestle area and 1.3 m dia. in the jetty area. There will be 6 piles in sanded reef flat and 4 piles in the reef crest area in approach trestle and 53 piles in reef crest and 171 piles in the reef slope area at proposed jetty area. Totally 303.61 m^2 of coral subzone will be impacted during the pile foundation. The details of respective coral reef subzone areas that will be impacted are given in below table.

Details of coral reef subzone areas likely to be impacted

Area	Approach Trestle Area (m^2)	Jetty Area (m^2)
Sanded Reef flat	3.82	-
Reef crest	2.54	70.33
Reef slope	-	226.92
	6.36	297.25
Total	303.61	

Impact on corals

Pile construction activities may cause physical damage to the reef, either through direct contact or sediment movement.

Water turbidity will be increased by the suspended sediments produced by piling operations. Because symbiotic algae (zooxanthellae) are necessary for coral life, their ability to photosynthesis is restricted by high turbidity, which decreases light penetration.

The coral ecosystem may get contaminated if fuels, lubricants, or other chemicals used in piling operations flow into the nearby coral environment. Corals may be impacted from improperly handled cement and other building materials that change the nearby water environment.

Mitigation measures

Before the piling operation, any live corals observed in the proposed piling activity area, shall be relocated to a neighbouring environment using the techniques described in the coral conservation methods mentioned below.

Appropriate silt curtains shall be used during piling operations, in order to minimize/ contain the turbidity / suspended sediment levels, of the ambient water environment.

Closed grab excavator shall be used for all piling constructions, and double casings with Y-shaped funnels installed will keep any muddy water spills contained within the casing, and additional protection from the Y-shaped funnel to prevent affecting the reef environment outside the work area.

The proposed pile foundation has sufficient spacing, limiting hydrodynamic changes in the flow regime and preventing negative impact on water quality while operation.

Threats to corals

Coral reefs are subjected to various natural and anthropogenic stressors, including climate change, (such as rising seawater temperatures), diseases, cyclonic disturbance, declining water quality (turbidity, pollution, pathogens, etc.,), sedimentation, destructive fishing methods, over-exploitation of reef fauna, tourism, physical damage due to anchor drop, etc. In addition to climatic causes, primarily high seawater temperatures, the uncontrolled and growing dumping of untreated residential sewage into the reef habitat are also major threats to the corals (Thinesh *et al.,* 2009).

Climate change

Climate change, especially sea surface temperature, is one of the main factors influencing the health of coral ecosystem. Corals have a low capacity for adaptation and are susceptible to thermal

stress. Unless there is thermal adaptation or adaptation by corals, increases in sea surface temperature of around 1-3°C are predicted to cause more frequent coral bleaching events and widespread death (Eakin *et al.,* 2008).

Coral disease

Diseases are major secondary stressors causing coral mortality in the reefs. Diseases may cause irreversible damage to the corals structure and functioning. Diseases affecting hard corals have become the most important factor in the decline of coral reefs in some regions (Weil, 2004). Reproduction, growth, community structure, species diversity, and many other animals linked with reefs can all be significantly altered by coral disease.

In an earlier study of coral diseases in Gulf of Mannar and Lakshadweep Islands (Kavaratti, Agatti) during 2011, nine coral diseases (white band, white pox, white plague, pink line syndrome, pink spot, yellow band, fungal blotch, black band and necrotic patches) were observed. Coral disease prevalence was higher in coral reefs of Gulf of Mannar than in the Lakshadweep islands (Kavaratti and Agatti) (Thangaradjou *et al*., 2016).

In a recent study (Jan. 2016 - Nov. 2018), on coral diseases in Chetlat island, six coral diseases were observed and reported to cause mortalities in hard corals. The six coral diseases observed were Black Band Disease (BBD), White Syndrome (WS), Pink Line Syndrome (PLS), Porites Ulcerative White Spot (PUWS), White Band Disease (WBD) and Porites Peeling Tissue Loss (PorPTL) disease, affecting different genera of reef building corals. Among the affected genera, *Porites* hosted the highest number with six coral diseases, followed by *Pavona* with two diseases and the remaining genera were affected by one disease each (Thaha and Rathod, 2019).

Coral Management

Coral reef conservation aims to preserve biological productivity and diversity, provide traditional and sustainable uses (such as fisheries and tourism), and shield the reefs' aesthetic, historical, biological, and geological value from human interference. Protecting coral reefs by reducing or eliminating the stressors causing degradation should be important for their conservation. Development of coral nursery and transplantation are the ideal techniques for increasing the coral cover in the islands.

Pollution control

Maintaining the health and richness of coral reef ecosystem depends on preventing pollution in these reef ecosystems. Sewage waste should be treated before it is released into the sea, to prevent harmful chemicals, nutrients, and pathogens causing damage to coral reefs. By limiting the use of single-use plastics and encouraging recycling initiatives, plastics can be kept out of the ocean, where they can damage marine life and destroy coral reefs.

Shipboard pollution

Coral reefs are affected by shipboard pollution, which is mostly caused by harmful materials that ships release into the ocean. Marine pollution can be caused by ships improperly disposing of their waste material, particularly plastics. Plastics can introduce harmful compounds, block sunlight, and physically damage corals. Ballast water from ships frequently contains contaminants, disease causing pathogens, and invasive species that can damage coral reefs and other marine life by disturbing the local marine ecosystem.
The proposed project on jetty construction is for increasing the passenger and cargo traffic to the islands. The passengers in ships need to be cautioned about prevention of pollution by disposal of

solid / liquid wastes to the marine environment. The vessel crew by default shall adhere to the standard norms.

Prevention of oil spill

Coral reefs are impacted by oil spills both directly and indirectly, which can degrade ecosystems, reduce biodiversity, and make recovery difficult in the long term. Corals obtain their energy from symbiotic interactions with algae (zooxanthellae). These algae can be damaged by oil pollution, which causes coral bleaching, a condition in which the corals expel the algae, losing their colour and vitality.

Oils, especially diesel, petrol, aviation fuel, kerosene, etc., are likely to be transported in significant quantities to the islands. Standard safety precautions shall be taken for loading, transporting and unloading the above items. Standard oil spill contingency plans shall be prepared according to the passenger / cargo ships quantum, and shall be implemented accordingly, in case of any oil spill, or leakage, etc.

Invasive species management

Certain invasive species, such as predatory starfish (like the crown-of-thorns starfish), cause direct impact to coral colonies and degrade reefs by feeding on coral polyps. Because they modify nutrient cycling, reduce the amount of food available to the marine organisms, or alter the physical structure of the reef, invasive species are able to alter the way ecosystem's function. In order to preserve coral reefs and their biodiversity, it is essential to stop the spread of invasive species through improved ballast water management and appropriate fishing methods.

Conservation methods

In Lakshadweep archipelago, the corals have been degraded / threatened by a range of natural and anthropogenic stressors, like cyclones, climate change, and anthropogenic interventions (Riyas *et al*. 2020). These threats necessitate the development and implementation of active coral restoration programs.

Transplantation of corals can serve as an ideal management strategy for development of coral colonies in the reef. Coral restoration can be achieved by transplanting fast-growing and healthy coral fragments. Massive corals have also been recommended for transplantation due to their lower susceptibility to damage and mortality. Therefore, both branching and non-branching corals shall be used for coral restoration.

Coral rescue program

The live coral colonies, both branching and massive corals, likely to be damaged at the proposed project area, shall be collected and relocated in a suitable nearby location, for survival at natural conditions. The live coral colonies along with the substrate (e.g., dead coral rock, on which the live coral colony has developed), can also be removed as such and translocated. Suitable sites may be identified prior, in and around the island for such coral rescue programs. Further, these also should be monitored for their survival percentage.

Coral translocation

Coral translocation is the technique of relocating corals, usually to improve coral populations in places under stress from the environment or rehabilitate damaged reefs. The main objective is to

relocate coral colonies to more favourable conditions where they have a better chance of survival. Coral fragments or entire colonies are carefully removed and then moved to restoration areas.

Coral transplantation

Obtaining coral larvae or fragments from healthy populations, raising them in controlled conditions (like coral nurseries), and then relocating them to damaged reefs is a method of transplantation.

In Lakshadweep islands, large extents of dead coral reefs and rocky intertidal areas are observed. In these islands, transplantation of corals can serve as an ideal management strategy for conservation and development of new coral colonies.

A recent study was conducted by Department of Science and Technology, Lakshadweep Administration, with an aim to develop an effective transplantation method by establishing a coral nursery in the Kavaratti lagoon, focusing on the use of fast-growing coral species to facilitate the rapid restoration of degraded reefs.

Coral nursery development

Coral fragments were collected from different locations of the lagoon, including the intertidal zone, inner reef lagoon, reef crest of the atoll, etc., to obtain different fragments grown in different conditions and locations in the lagoon. Coral fragments of both acroporid and non-acroporid corals that naturally grew in the lagoon and other areas were collected and placed in artificial substrates (concrete blocks) and monitored for their survival and growth rates for 2-year period during Jan.2016 – Jan.2018 (Riyas *et al*., 2024). Growth rate of acroporid corals was higher than non-acroporid corals. It was reported that establishment of a coral nursery also led to increased habitat for marine life and fish aggregation, contributing to enhanced biodiversity and ecosystem resilience.

Coral nursery can be developed in the lagoon area using both acroporid and non-acroporid coral species. Coral transplantation can be taken up in suitable locations around the island and in lagoon areas, for coral restoration of the island (Ramesh *et al*. 2020).

Transplanted coral fragments deployed in the lagoon bed at Kavaratti (2016 to 2018)

Well-developed coral colonies in the transplantation site after two years (2016 to 2018)

Source: *Riyas et al. (2024) Successful establishment of a coral nursery for active reef restoration in Kavaratti Island.*

Creating awareness

Knowledge and awareness of economic / ecological importance of coral reefs is crucial to their preservation and long-term management. Such awareness should be created to the stakeholders, including general public, students, fishermen, tourist operators, government and non-government organisations, etc.

In order to educate the community on the importance of coral reefs, including their role in biodiversity, coastal protection, and livelihoods (such as fishing and tourism), workshops, seminars, and school programs should be organized. Also, locals should be involved in coral conservation initiatives, such as restoration projects, reef monitoring, and sustainable fishing methods, in order to cultivate a sense of responsibility and involvement.

Recommendations

- Establishment of a coral nursery has been demonstrated successfully in Kavaratti Island lagoon. It is recommended that coral nursery may be developed in the lagoon of Kadmath Island.
- Coral restoration / transplantation program shall be implemented in suitable sites, in order to improve coral reef coverage.
- Restoration / increase of coral cover will improve fish aggregation, increasing ecological stability and biodiversity.
- Restored coral reefs will also result in increase of fish populations, benefiting local fishing communities and promoting eco-tourism and livelihood opportunities.
- The expertise of Zoological Survey of India also can be used to implement coral conservation plan.

Budget Estimate for Coral Transplantation

The piling operation will impact of about 303.61 m^2 of coral reef subzone area. However, for conservation purposes, the area affected by the piling operation will be considered as triple of actual area (910.83 m^2).

Budget required for coral transplantation of 910.83 m^2 for three years management was worked out to be Rs. 40,00,000/- and the details are given below.

S. No.	Budget for corals Transplantation	In Rupees
	Boat rent charges	
1	Boat rent collecting site (Rs. 5000 per day X 20 days)	1,00,000
2	Boat rent recipient site (Rs. 5000 per day X 20 days)	1,00,000
3	Boat rent for three years monitoring (Rs. 5000 per day X 120 days)	6,00,000
	Total	**8,00,000**
	Labour charges	
1	Labour charge for collections and packing (20 days)	2,50,000
2	Labour charge for recipient site (20 days)	2,50,000
	Total	**5,00,000**
	Staff charges	
1	Scientists (1 X 50000 X 24)	12,00,000
2	Assistant (1 X 20000 X 24)	4,80,000
	Total	**16,80,000**
	Major equipment	
1	SCUBA gears (4 nos.)	6,00,000
2	Air Compressor (1 no)	1,40,000
3	Underwater camera with housing (2 nos.)	2,00,000
4	Maintenance / Service of Equipments / accessories	80,000
	Total	**10,20,000**
	Grand Total	**40,00,000**

*In total, a sum of **Rs. 40 lakhs** is allocated for 5 years for the coral conservation plan.*

Conclusion

The present study reveals that around the study area dead coral with algae and coral massive habitats were observed. According to the CRZ map, the proposed approach trestle and jetty area piles will pass over coral reef subzones (sanded reef flat, reef crest, and reef slope). The piling operation will impact of about 303.61 m^2 of coral reef subzone area. However, for conservation purposes, the area affected by the piling operation will be considered as triple of actual area (910.83 m^2).

In order to increase coral cover, coral transplantation of coral fragments at suitable sites are recommended. For this purpose, Rs. 40,00,000 shall be allotted for coral transplantation of 910.83 m^2 for three years.

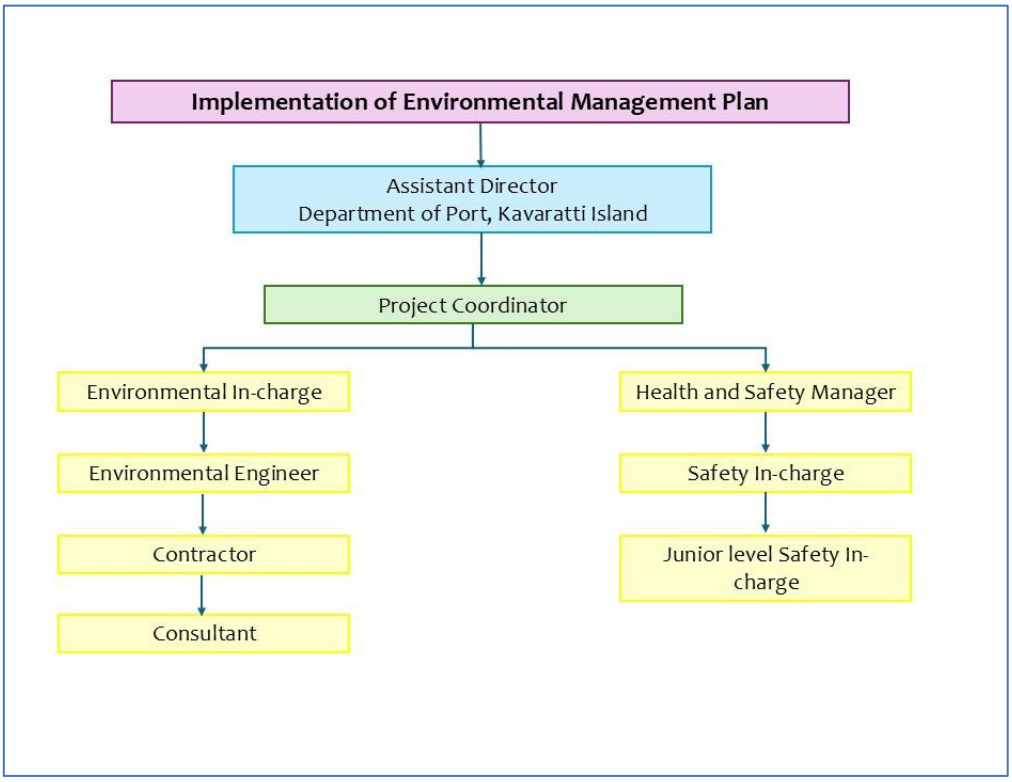
9.4. Environment Management Cell

EMC will be headed by the person who have qualification and reported to the MoEF&CC committee.

- Preparation and implementation of Environmental Supervision Plan during construction.
- Ensuring adequate training and education to all staff involved in environmental supervision.
- Implement Environmental Monitoring Plan during construction and operation.
- Ensure effective communication and explanation of the content and requirements of the EMP to contractors and subcontractors.
- Provide appropriate and adequate resources allocated for the effective implementation and maintenance of the EMP.
- Review of EMP performance and implementation of corrective actions, or stop work procedures, in the event of breaches of EMP conditions, that may lead to serious impacts on local communities or affect the reputation of the project.
- Report any major environmental incidents that may have a significant impact on the surrounding environment.
- Evaluating the efficacy of the EIA, mitigation measures as stipulated in the EMP.
- Coordination with Lakshadweep Pollution control boards for prevention and control of environmental pollution.
- Carryout half yearly monitoring program and preparation of compliance report.
- To implement Environmental Clearance condition stipulated by MOEFCC.
- Maintain environmental monitoring records.

9.5. Implementation of EMP

Overall implementation of EMP will be the responsibility of EMC. Various implementation items, description, and appropriate time to implement EMP are listed below.



EMP Implementation flow diagram

9.6. Communication and reporting

Training: Training shall be given to the workers during the construction and operation phase for identification of various hazards, methods to combat and responsiveness to emergency preparedness etc.

Communication: Information with respect to any untoward incidences during the construction and operation of the project shall be communicated to local Gram Panchayat, local village workers, and other project-related individuals. Environmental issues should be communicated to the concerned Govt. agencies such as LCZMA, Lakshadweep Pollution Control Board (LPCB), Forest and Environment Department, District Collector etc.

Reporting: The EMC will be responsible for conducting environment monitoring, compilation, and review of monitoring data, filling up the statutory forms/returns, maintenance of records regarding hazardous waste, environment awareness activities, submission of compliances six months EC compliance to State Pollution Control Board and MoEFCC regional office.

9.7. Environmental Monitoring and review

The EMC will continually review the EMP, and implementation of the mitigation measures described in Chapter 4 to assess the effectiveness of the proposed measures. The management will conduct periodic review to ascertain effectiveness of the EMP as follows:

- Take routine annual review of the EMP.
- Review of EMP after an accident or significant non-compliance is reported.
- Examine report and findings of the post project monitoring results and evaluation submitted by the EMC from time to time.
- Assess feedback from workers/stake holders and take action where necessary.

9.8. EMP Budget

The adequate budget allocation to operate EMP is necessary to make resource available for its effective implementation.

Based on the EMP for the proposed project discussed in above, the budget allocation required is estimated to be about ₹. 1.25 Crore The break-up of the proposed budget is given below.

Sl. No.	Environment Management Plan	Cost/year (₹.)
1	Environmental Monitoring Programme	25,00,000
2	Environment Management Cell	25,00,000
3	Labour, Safety and Cleanliness Management	25,00,000
4	Solid waste management	25,00,000
5	Post project monitoring	25,00,000
Total		1.25 Crore

ENVIRONMENTAL IMPACT ASSESSMENT STUDY FOR CRZ CLEARANCE FOR CONSTRUCTION OF PASSENGER JETTY AND ASSOCIATED LANDSIDE FACILITIES ON THE WESTERN SIDE OF THE KADMATH ISLAND, LAKSHADWEEP

PROJECT CODE: 892062425

For

सत्यमेव जयते

U.T. ADMINISTRATION OF LAKSHADWEEP

Through

COCHIN PORT
कोचिन पत्तन प्राधिकरण
Cochin Port Authority

COCHIN PORT AUTHORITY (CoPA)
KOCHI

March 2025

INDOMER COASTAL HYDRAULICS (P) LTD.

(ISO 9001: 2015 CERTIFIED, QCI – NABET & NABL ACCREDITATED)
63, GANDHI ROAD, ALWAR THIRUNAGAR, CHENNAI 600 087.
Tel: + 91 44 2486 2482 to 84; (M) (+91) 96000 56652/ 99629 37397
Web site: www.indomer.com, E-mail: ocean@indomer.com

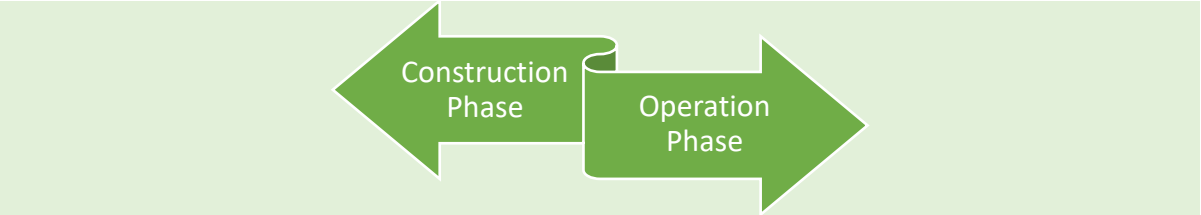
4. IMPACT ASSESSMENT AND MITIGATION MEASURES

As mentioned in Chapter 2, Kadmath Island currently has a western jetty inside lagoon, which is used to handle small passenger boats and cargo vessels. In addition to the western jetty, there are a southern jetty and a small eastern jetty. However, the existing facilities on Kadmath Island are not sufficient to accommodate larger vessels, as the western jetty is old and was originally designed for small passenger boats and cargo vessels. The southern and eastern jetties are also limited to landing activities. To address navigational concerns and meet berthing requirements, a development plan for Kadmath Island has been proposed.

In this particular project, the sizable impact will primarily occur during the construction of the berthing jetty and approach trestle and the construction of the landside facilities will have only have a minimal environmental impact. The development covers: construction of 70 m long berthing Jetty, 75 m long approach trestle on the marine environment and a passenger facilitation centre, development of boat landing centre, finger jetty, boat Repair shed, Ice plant, and Fuel station on western side of Kadmath Island. The anticipated impacts and the corresponding mitigation measure due to the proposed activities are discussed. In reference to **Fig. 1.3.**

4.1. Identification of Impacts

Impacts are identified with respect to two stages of the project viz., i) Construction phase and ii) Operation phase.



a. Construction Phase

Construction phase in the present project involves activities like excavation, raw material transportation, stacking piling, foundation work, deck construction, building construction, installation of fenders & lighting buoys etc.

Due to the sensitive ecosystem, which are mainly made up of coral reefs and lagoons, building a jetty on a Kadmath Island during the construction phase is likely to have a significant negative impact on the marine environment. These effects could include coral reef damage, increased turbidity, sediment disturbance, noise pollution, possible oil spills and disruption of local marine life. During construction period the impact on environment will be of short term, temporary and localized. However, to limit the impact on valued environmental components, mitigation measures are suggested.

b. Operation Phase

During the operational phase of a jetty, key activities include vessel berthing and departure, cargo loading and unloading, passenger boarding, mooring operations, pilotage, security checks, waste management etc.

Operations near jetty can have impact on the coral reef with vessel anchors and movement. The pollution due to leakage of wastes may affect the marine life close to jetty corridor.

4.2. Anticipated Environmental Impacts

Based on the proposed development, the impacts due to the following activities are discussed.

Impact on terrestrial environment	Impact on marine environment
Impact on Air Environment Impact on Noise Environment Impact on Water Environment Impact on Land and Soil Environment Impact on Socio Economic Environment	Impact due to construction of Jetty and approach trestle Impact due to handling of cargoes Impact due to movement of vessels Impact on planktons Impact on benthos Impact on fish Impact on corals

4.3. Terrestrial Environment

4.3.1. Air Environment

a. Construction phase

Possible Impacts:

The construction activities for the proposed passenger jetty, approach trestle and associated structure including site preparation, excavation, construction of piles, operation of construction equipment, handling and transportation of construction materials, operation of DG sets and pumps, etc. could contribute to air pollution. On the other hand, the order of impact on terrestrial environment is limited to only during construction phase. The identified impacts are due to the following.

- **Construction dust** – Arisen from handling construction materials/debris in open area influenced by coastal wind during the construction activities.
- **$PM_{2.5}$** – Emission from exhausts of generator sets, vehicles and heavy equipment.
- **Noxious vapours** – Oils, glues, thinners, paints, treated woods, plastics, cleaners, other hazardous chemicals, generator sets, vehicles and heavy equipment.
- **Volatile Organic Compounds (VOCs)** – Depending on the construction materials used, emissions of VOCs from paints, adhesives, and other chemicals.

Mitigation:

- *Construction materials at site and carried on the vehicle/ vessel have to be properly covered.*
- *Sprinkling of water every day at periodic intervals on the ground on piled up construction materials are to be done.*
- *Dust barriers such as poly screens around the site boundaries have to be provided to create buffer against propagation of dust.*
- *The equipment used at the site have to be properly maintained.*
- *Construction work should be stopped during high wind time.*

b. Operation phase

Possible Impacts:

During the operation of jetty, the air environment can slightly get affected due to release of pollutants, but it will be restricted to the hours of vessel arrival time. The particulate matter (PM), sulphur oxides (Sox) and carbon monoxide (CO) from vessel engine emissions are anticipated during loading and unloading activities.

Mitigation:

- *Implementing stricter emission standards for vessels*
- *Providing shore power to docked vessels to reduce engine idling emissions.*
- *Improving cargo handling practices to minimize the dust generation and spills.*
- *Regular monitoring of air quality around jetties to identify emission hotspots and implement necessary mitigation measures.*

Impact on the air environment is limited for a period during construction phase. Mitigation measures will be followed during both construction and operation phase to reduce the possible impact on air environment.

4.3.2. Noise Environment

a. Construction phase

Possible Impacts:

There can be an increase in noise from various machinery like pile drivers, excavators, barges, and other construction equipment, which can disturb nearby residential areas and marine life, particularly during the active construction phases.

Mitigation:

- *Personal protective gear has to be provided to workers while involving in high noise generating works.*
- *Highly efficient and regularly maintained equipment has to be used.*
- *Choice of generators and construction machinery/equipment will be restricted as per usage requirements.*
- *Special attention has to be given to the preservation of biodiversity around the jetty location.*

b. Operation phase

Possible Impacts:

Noise generation from movement of vessel and during handling of passenger cargoes in the jetty area are the only anticipated noise generation during the operation phase.

Mitigation:

- *Installing sound barriers or acoustic enclosures around the walk way region.*
- *Encouraging the use of quieter vessels and operating procedures.*

- *All machines must be lubricated and maintained regularly and located inside acoustic enclosures only.*

The construction and operation of Jetty may emit noise from machinery. However, the noise emitted due to the operation will be confined within the jetty premises.

4.3.3. Water Environment

a. Construction phase

Possible Impacts:

- Construction materials like paints, oils, cement mortar, sand etc. may fall inside the sea or may be carried into sea with runoff water leading to contamination.

Mitigation:

- *Construction material has to be stored in a closed place.*
- *Domestic wastewater has to be discharged into a septic tank soak pit arrangement.*
- *There should not be any dumping into the waterfront areas.*

b. Operation phase

- Drinking Water requirement during the operational phase will be met from the LTTD plant.
- Care to be taken that *sewage from facilitation centre, do not mix with Ground water or surface water.*
- *Domestic wastewater generated during operation phase has to be treated with STP.*

There is no significant impact anticipated on the water environment due to the construction and operation of Jetty.

4.3.4. Land and Soil Environment

a. Construction phase

Possible Impacts:

- Soil contamination can occur by deposition of uncovered construction materials exposed to wind and suspended load-laden runoff water.
- Improper drainage systems leading to leakage or overflow of wastewater and littering at the site by workers can result in land soil contamination.
- Alteration in the topsoil for site preparation and foundation can cause a change in the soil profile.

Mitigation:

- *Proper management of construction materials and activities have to be ensured. Loose materials such as cement and sand have to be stored in a closed place and adequately covered.*

- *Any construction material remained after completion of the construction activities for the proposed project must be removed from the site.*
- *Bins have to be provided separately for recyclable and non-recyclable wastes at strategic places which will be periodically emptied, and the waste disposed of adequately.*
- *Workers have to be made aware of the need for proper waste disposal.*
- *Excess excavated material will be properly stored and subsequently used for site levelling, approach road construction, landscaping, as required.*

b. Operation phase

Possible Impacts:

Operation of proposed facilities will not have major impact on land environment. Any other solid waste generated from the jetty has to be disposed of as per the Solid Waste Management Rules, 2016.

The impact of the proposed project on the land environment is expected to be low. Municipal solid waste produced during construction and operation phase have to be properly disposed.

4.3.5. Socio–Economic Environment

Development of Lakshadweep islands are essential for the regional and national economic development by way of safe movement of passengers, transportation of goods, developing new infrastructure etc. The development of Kadmath island will attract international tourists which is one of the major economic engines for the country and gain considerable amount of foreign exchange. Sustainable port operations should aim at inclusive development along with the local community.

Negative Impact

No specific negative impacts are foreseen on social aspects.

Positive Impact

- The issues pertaining to resettlement and rehabilitation are not envisaged in this project, as there is no land acquisition involved, as the proposed development is within the existing boundary of Kadmath Island.
- There are no cultural and heritage site which could be affected due to the proposed construction along on close proximity to the study area.
- Community development with the successful passenger jetty operation may lead to the development of supporting infrastructure such as housing, schools, roads and healthcare facilities which can benefit the local community.
- The proposed project could attract more tourists, boosting local tourism industries.
- The construction of a jetty and associated facilities can improve access to essential services like healthcare and education for coastal communities.

The proposed construction will have more positive impact on the socio-economic aspects of the Kadmath island by upgrading the safety and economy of Islanders.

4.4. Marine Environment

The marine component of the proposed project includes construction of passenger and cargo handling jetty, approach trestle and driving of piles. Evidently, the project would have impacts on the marine environment during its construction as well as operations. The impacts can potentially influence the local ecology given in **Table 4.1.**in the short- as well as long-term if appropriate mitigations are not in place as illustrated below. But the impact will be confined within the corridor outlined in **Fig. 4.1.**

Table 4.1. Different ecology sensitive area affected due to the project

Area	Trestle Area (m^2)	Jetty Area (m^2)	Finger jetty (m^2)
Sandy Beach	2.54	-	1.27
Shallow lagoon	12.72	25.91	5.09
Total Area (m^2)	15.26	25.91	6.36
Total area of coral sub zone	**47.53**		

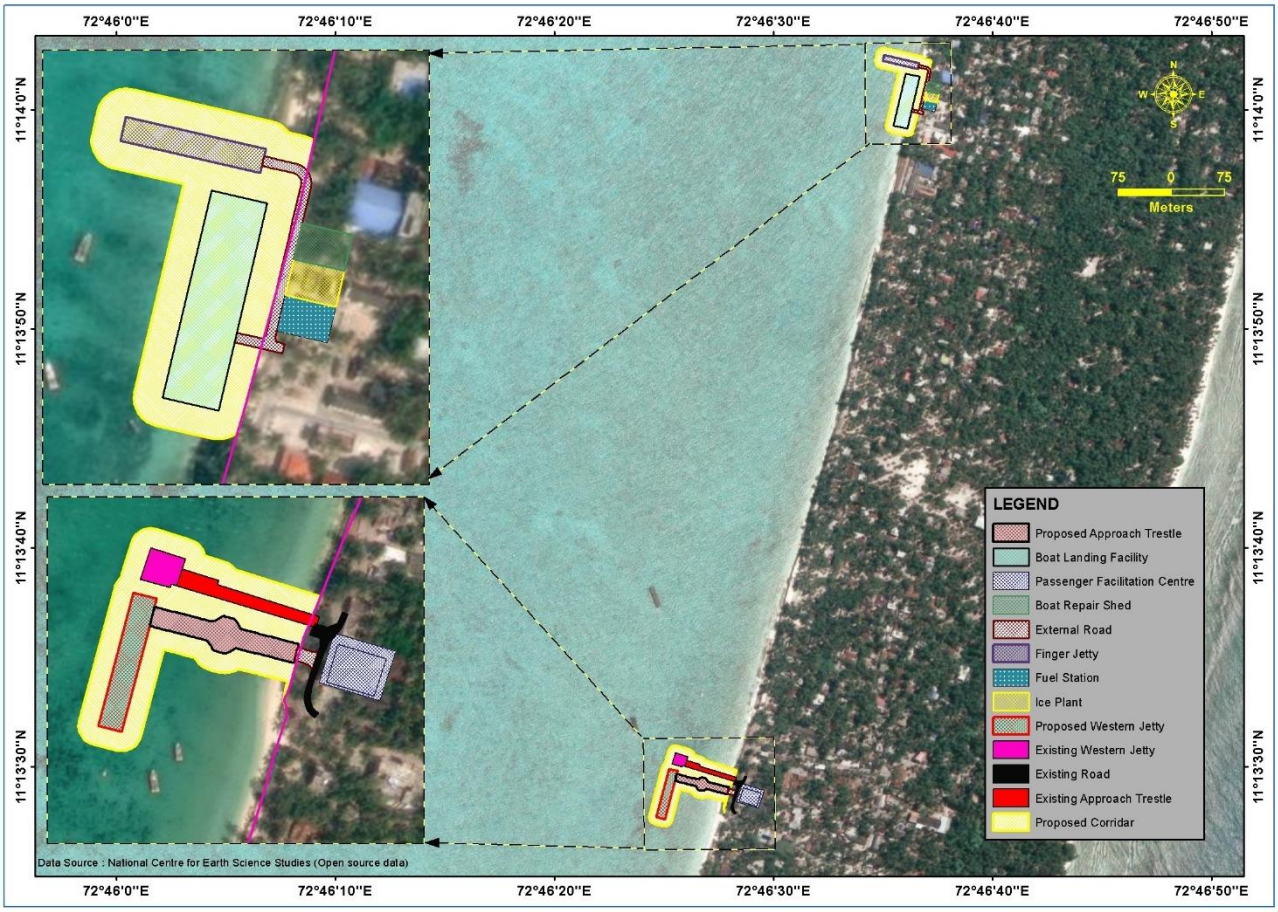


Fig. 4.1. Buffer corridor of the proposed development

4.4.1. Impact due to construction of Jetty, approach trestle and finger jetty

Construction of jetty, approach trestles and finger jetty will have more effect on marine environment compared to land environment.

4.4.1.1. Construction phase

The construction activity of jetty, approach trestle and finger jetty will consist of RCC deck (precast and in-situ) supported on bored cast in-situ reinforced concrete piles. The cross section of the jetty and approach trestle is given in Chapter 2.

Possible Impacts:

Disturbance to the marine habitation

(i) **Pile driving:** Piling will be required for the construction of jetty and approach trestle. Piles will be initially erected into the sea floor up to depth where hard stratum is available. The soil inside the pile will be dredged off and the same portion will be refilled with R.C.C concrete. Concrete mixing and construction debris in the marine environment are envisaged during the construction activity. Due to the pile driving activity the impact on following environmental parameters are anticipated:

Marine/coastal ecology: Disturbance from construction activities may cause displacement of fishery resources and other mobile bottom biota. Piling removes bottom biota and material covers bottom habitat, both of which may reduce fishery resources. Settlement of re-suspended sediments on fragile marine fauna and flora damages the ecosystem particularly coral reefs, which are formed by the extracellular product of symbiotic plants. The organisms attached to submerged structures need dissolved oxygen for respiration and the plants need sunlight for photosynthesis. Piles, concrete surfaces, rubble mounds and other similar structures in water could form new habitats, which may introduce undesirable species.

Construction materials, such as ship hulls, ballast water, and the structure of the jetty itself, can serve as vectors for the introduction of invasive species, which may outcompete or prey on native species.

Impact on Seawater and Seabed sediments: Resuspension of sediments in water leads to an increase in the level of suspended solids and concentration of organic matter, possibly toxic or harmful levels. This will cause temporary impact to seawater quality near proposed berthing jetty location. Contaminated bottom sediments (contained with heavy metal concentration) may lead to significant impact to seawater quality during piling. However, baseline data suggests that there is no heavy metal concentration build up in the seabed sediments.

Impact on benthos: Piling and other water side construction will cause loss/displacement to bottom habitat and its associated animal and plant life. Footprint on bottom habitat and associated life will be limited to area of piling. The turbidity induced during driving of piles will also have impact on the community structure and distribution of other marine life. However, the bottom will readily be recolonized by replacement of benthic organisms within few seasons.

Fishes: One of the major impacts of pile driving operations on the marine organisms especially on fishes is the underwater sound pressure waves generated during hammering of the piles. Pile driving may result in 'agitation' of fish indicated by a change in swimming behaviour.

The various factors which are known to influence the impact on fish are: (i) size and force of hammer strike; (ii) distance from the pile; (iii) depth of the water around the pile; (iv) depth at which fish swim in water column; (v) entrapped air in the water; (vi) oscillation of water level, (vii) geological composition of seabed, (viii) size of the fish; (ix) species of the fish; (x) presence of swim bladder; (xi) physical condition of the fish and (xii) effectiveness of sound/pressure attenuation technology used to minimize the impacts.

Plankton: The proposed project activity like piling may not have any direct bearing on plankton. It is expected that the plankton will drift away from the disturbed area leading to minimal loss to plankton. Further, compared to the abundance of the plankton in the site, the loss will be moderate and temporary.

Since the sediment texture is mainly comprised of fine sand, the noise due to piling is expected to be low. As the baseline data suggests there are varieties of fish species and green turtles are observed within the project area, the impact of piling is expected to be limited to benthos. However, these animals will usually return to the area once the disturbance ceases.

Corals: Construction activity near coral reefs can damage coral ecosystems by causing physical harm, increasing turbidity (cloudiness) from sediment plumes, and disrupting water flow, which in turn reduces the amount of food available to corals and ultimately affects their growth and survival.**Quantification of impacts on corals is given in Chapter 9.**

Mitigation measures

- *Existing roads in the Kadmat island shall be used for transportation of construction materials.*
- *Trucks transporting the materials will be covered to avoid susceptible for fugitive suspension.*
- *Vehicles having Pollution Under Control (PUC) certificates will be used. All vehicles used for transportation shall comply with CPCB emission norms.*
- *All workers, technicians and supervisors should make use of all safety equipment such as masks, goggles, helmets, safety belts, earmuffs safety shoes, lifesaving jackets, etc., as required, during the construction phase. Proper security arrangements will be made during nights to avoid any accidents due to unauthorized entry of workers, or civilians.*
- *The hazardous materials anticipated to be stored at the site during construction include gas for welding, fuel for operating construction equipment, paint, etc. All these and other materials of a dangerous or hazardous nature will be stored as per the norms.*
- *Clean and efficient construction techniques should be adopted.*
- *Piling should not be carried out during fish breeding season.*
- *Screening must be provided during piling activity.*
- *The construction schedule should be strictly followed, and no over runs should be ensured. Reducing the construction time with efficient techniques will rescue the period of impact.*
- *The scrap and waste construction materials should not be disposed into the seawater.*
- *Proper lubrication of pile driving machinery will ensure less noise.*
- *After pile driving and construction, continued monitoring of the affected area will be carried out.*
- *Continuous monitoring of coral reefs before, during, and after construction will be carried out.*

4.4.1.2. Operation phase

Possible Impacts:

During operation of jetty, major impact on marine environment is only due to the increase in vessel movement for handling Passenger and domestic cargo handling. Which will only have minimal impact to the marine environment. However,appropriate mitigation measures will be followed in order to reduce the impact on marine environment during operational phase.

Mitigation measures

- *Vessels coming near the Berthing jetty should not discharge anything into the sea.*
- *Waste in the jetty premises should be handled as per PCB norms.*
- *Tourists and Operators must be continuously educated for preservation of the Island ecosystem.*
- *Use low-impact, quieter equipment during operations and limit activities during critical times for marine species (e.g., during breeding or migration seasons).*

4.4.2. Impact on marine environment due to handling of various cargoes

4.4.2.1. Construction phase

During construction phase of jetty, approach trestle, passenger facilitation center, road and associated facilities all the construction materials such as cement, steel, boulders, sand and other construction related materials will be transported from the mainland using vessels and it will be handled in the existing jetty area and then it will be transported to the storage place away from CRZ zones through existing roads of Kadmath Island. This handling of construction materials cargo will create minor impact on the marine water quality and marine habitat due to spillage while handling of construction materials. The various impacts are listed below:

- Accidental spill of powdered construction materials such as cement and sand on the marine environment will pollute the water quality, increase the sediment concentration, affecting the marine habitat. The release of cement particles during mixing and placement can contribute to turbidity and potential chemical contamination.
- Accidental release of plastic debris during construction can contribute to marine plastic pollution.
- Machinery used to transport and handle materials at the jetty may leak oils or fuels, which can spread on the water surface and create oil slicks and harming marine life.
- Materials like sand, gravel, or concrete are handled, there can be runoff into the water, causing increased turbidity.
- Handling dry construction materials, such as cement or sand, can create airborne dust that can affect air quality in nearby areas. This dust can be harmful to marine ecosystems.

Mitigation measures

- *Selecting appropriate vessel type to handle construction materials based on its weight and material type.*
- *Make sure that construction equipment is not overloaded or operated in a manner that could result in unnecessary sediment disturbance.*

- *Proper packing, sealing and labelling of construction material to avoid spillage of construction materials.*
- *Using proper handling equipment (closed handling) to avoid accidental spillage*
- *Using non-toxic, eco-friendly materials and coatings to reduce the risk of water contamination.*
- *Regularly monitoring water quality and marine life populations to assess the impact of construction.*
- *choose for construction materials that have a lower environmental impact, such as recycled aggregates, sustainable timber, or other green alternatives to reduce waste and minimize the environmental footprint.*

4.4.2.2. Operation Phase

After the construction the jetty will also be used to handle domestic cargo (food grains, fruit sand vegetables, cereals, provisions, etc.) which comes from the mainland. Since the proposed berth is a multipurpose one and the nature of cargo will vary, it is proposed to provide one hydraulic lifting crane of 10T lifting capacity.

- Accidental spillage of cargoes due to improper handling.
- Improper packing of bulk grain cargo can injure workers.
- Packaging materials, such as plastic, cardboard, and crates, may be discarded improperly, contributing to marine litter and pollution.

Mitigation measures

The impact due to the handling of cargo will be minimal and will not have much impact on the marine environment.

4.4.3. Impact on plankton

a. Construction phase

Construction of Berthing Jetty will affect the plankton community as they are weak against the turbidity generated in the water due to construction activities. The impacts on these communities are directly linked to the extent up to which turbidity persist. It is anticipated that area of construction will be induced with turbidity may have localized effect on plankton.

b. Operation phase

There will be no impact on plankton community during operation phase.

4.4.4. Impact on benthos

a. Construction phase

Major impact to benthos is anticipated during the construction stage as well as during operational stage. During operational stage, impact to benthos is anticipated only due to movement of vessels. Other likely impact to benthos includes unwanted disturbance in the intertidal area of project site. Strict guidelines to workers should be given to avoid unwanted disturbance to tidal flats. The impact will be localized, and benthos will start recolonizing after the construction period.

b. Operation phase

There will be negligible impact on benthos community during operation phase.

4.4.5. Impact on fish

a. Construction phase

Due to construction of Berthing jetty, impact on fishes are also anticipated. However, since fishes are mobile, they tend to move away from under water disturbances. Thus, no significant impact on fishes is anticipated. The fishes will usually return to the original area once the construction activity is stopped.

Mitigation Measures

b. Operation phase

There will not be any significant impact on fishes during operation phase.

Impact on fishing activity

The development of berthing jetty will not disrupt fishing activity in the vicinity.

Mitigation Measures

Regular monitoring of the turbidity, sediment concentration and the heavy metals in the water column shall be carried out to observe the rise in concentration.

4.4.6. Impact on corals

Kadmath Islands is well known for its corals because of the coral reefs that surround the islands and the unique way they were formed. The construction of a approach trestle, jetty and finger jetty can significantly impact coral reefs throughout its construction and operation phase.

However, the impact on corals will be confined within the corridor mentioned in **Fig. 4.1.** and the total length of the approach trestle is 75 m from shore, length of the jetty 70 m and finger jetty is 50 m. The piled foundation would take up only a small footprint of about 0.9 m dia. each in trestle area & finger jetty and 1 m each in jetty area.

4.4.6.1. Construction Phase

- Heavy machinery and construction equipment may crush or fragment coral formations.
- Prolonged exposure to sediment can hinder coral metabolism and calcification processes.
- Stress from construction activities can make corals more vulnerable to thermal stress and bleaching.
- Damage to reefs impacts fish populations that depend on coral habitats, affecting local fisheries.

4.4.6.2. Operation Phase

- Increased Turbidity due to movement of vessels will increase the sediment resuspension which will affect corals ecosystem.
- Anchors, propellers, and hulls of vessels can break or crush coral structures.
- Coral damage affects species dependent on reefs for shelter, feeding, and breeding, leading to a decline in biodiversity.
- Excessive lighting from the jetty at night can disrupt the behaviour of reef organisms, including corals, fish, and invertebrates.

Mitigation Measures

- Detailed coral Assessments study was carried out to identify and avoid ecologically critical coral reef zones during site selection.
- Ensure proper collection and disposal of construction debris to prevent contamination.
- Relocate affected coral colonies to nearby healthy reefs or artificial structures before construction begins.
- Construct artificial reefs to provide alternative habitats for displaced marine organisms.
- Prohibit the disposal of hazardous materials and regulate the use of antifouling paints on vessels to prevent leaching of toxins.
- Impose speed limits for vessels in proximity to coral reefs to reduce wake and sediment disruption.
- Establish a monitoring program to track coral health, water quality, and biodiversity around operational areas.

A detailed conservation plan on coral management is given in Chapter 9.

4.4.7. Impact on Seagrass bed

In the present study, seagrass species of *Thalassia hemprichii* and *Cymodocea rotundata* were observed in the project region. Seagrass cover is more and in healthy condition in Kadmath islands of the Lakshadweep. There will only be less impact on seagrass bed due to the proposed development during the construction phase.

4.4.8. Impact on Coastal Vegetation

Project site and surroundings are devoid of coastal vegetation.

4.4.9. Impacts on mangroves

Project site and surroundings are devoid of mangroves. Hence, no impact.

4.4.10. Impact on turtles

The west coastal region is protected by groynes and sandy beaches (wider in south). The width of the proposed project location beach is very small so that the western side of lagoon side is not feasible for turtle nesting. Hence, no impact.

7. ADDITIONAL STUDIES

7.1. RISK ASSESSMENT AND DISASTER MANAGEMENT PLAN

7.1.1. Introduction

Emergency/ disaster is an undesirable occurrence of events of such magnitude and nature that adversely affect operations, cause loss of human lives and property as well as damage to the environment. Coastal infrastructure is vulnerable to various kinds of natural and manmade disasters. Examples of natural disaster are flood, cyclone, tsunami, earthquake, lightning, etc., and manmade disasters are like major fire, explosion, sudden heavy leakage of toxic/ poisonous gases, civil war, nuclear attacks, terrorist activities, sabotage, etc. It is impossible to forecast the time and nature of disaster, which might strike a common user infrastructure. An effective disaster management plan helps to minimize the losses in terms of human lives, assets and environmental damage and resumes working condition as soon as possible.

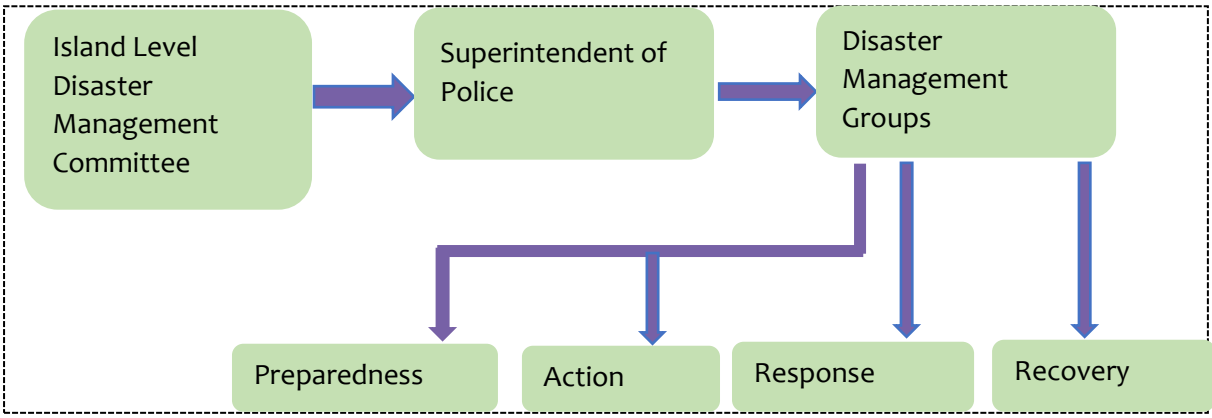
7.1.2. Risk Assessment

Risk is the probability that injury to life or damage to property and the environment will occur. The extent to which risk is either increased or diminished is the result of the interaction of a multitude of causation chains of events. The man-made disasters like fire and accidents also can occur during construction as well as operation phases which would cause the burns, injuries and even loss of human life and property, disrupt services like overhead power and communication lines. Potential impacts due to accidents include injuries and burns which demand surgical interventions, poisoning or exposure to toxic material, trauma and even loss of human life, property damage includes damage/loss of fishing vessels/crafts and other surface vehicles, mechanical devices and equipment used during construction and operational phases. Vessel collision, sinking of boats due to unattended leaks and damages are potential risks. Probability of any hazardous incident and the consequent damage also depend on:

- Wind speed,
- Wind direction,
- Atmospheric stability,
- Source of ignition

7.1.3. Disaster Management Plan

Emergency/disaster is an undesirable occurrence of events of such magnitude and nature that adversely affect operations, cause loss of human lives and property as well as damage to the environment. Coastal infrastructure is vulnerable to various kinds of natural and manmade disasters. Examples of natural disaster are Flood, Cyclone, Tsunami, Earthquake etc., and manmade disasters like major fire, explosion, sudden heavy leakage of toxic/poisonous gases, etc. An effective disaster management plan helps to minimize the losses in terms of human lives, assets and environmental damage.



Overall Disaster Management Hierarchy

Objective of Risk Assessment and Disaster Management Plan

DMP should be developed to make best possible use of the resources available in the operational area as well as outside available resources like Fire Services, Police, Civil Defence, Hospitals, Civil Administration, neighbouring institution and industries.

The objectives of Disaster Management Plan are:

- To contain and control the incident.
- To rescue the victim and treat them suitably in quickest possible time.
- To safeguard other personnel and evacuate them to safer places.
- To identify personnel affected/dead.
- To give immediate warning signal to the people in the surrounding areas in case such situation arising.
- To inform relatives of the casualties.
- To safeguard important records & information about the organization.
- To preserve damaged records & equipment needed as evidence for any subsequent enquiry.
- To rehabilitate the affected areas.
- To restore the facilities to normal working condition at the earliest.

7.1.4. Disaster Identification

a) Natural disaster

A disaster occurs when a hazard such as Earthquake, Flood or Cyclone coincides with a vulnerable situation. Based on project details, geography, environmental setting of the study area and available information following hazards have been identified which may possibly lead to disaster. The probability/seasonality of hazard is listed below **Table 7.1.**

Table 7.1. Probability/seasonality of hazard

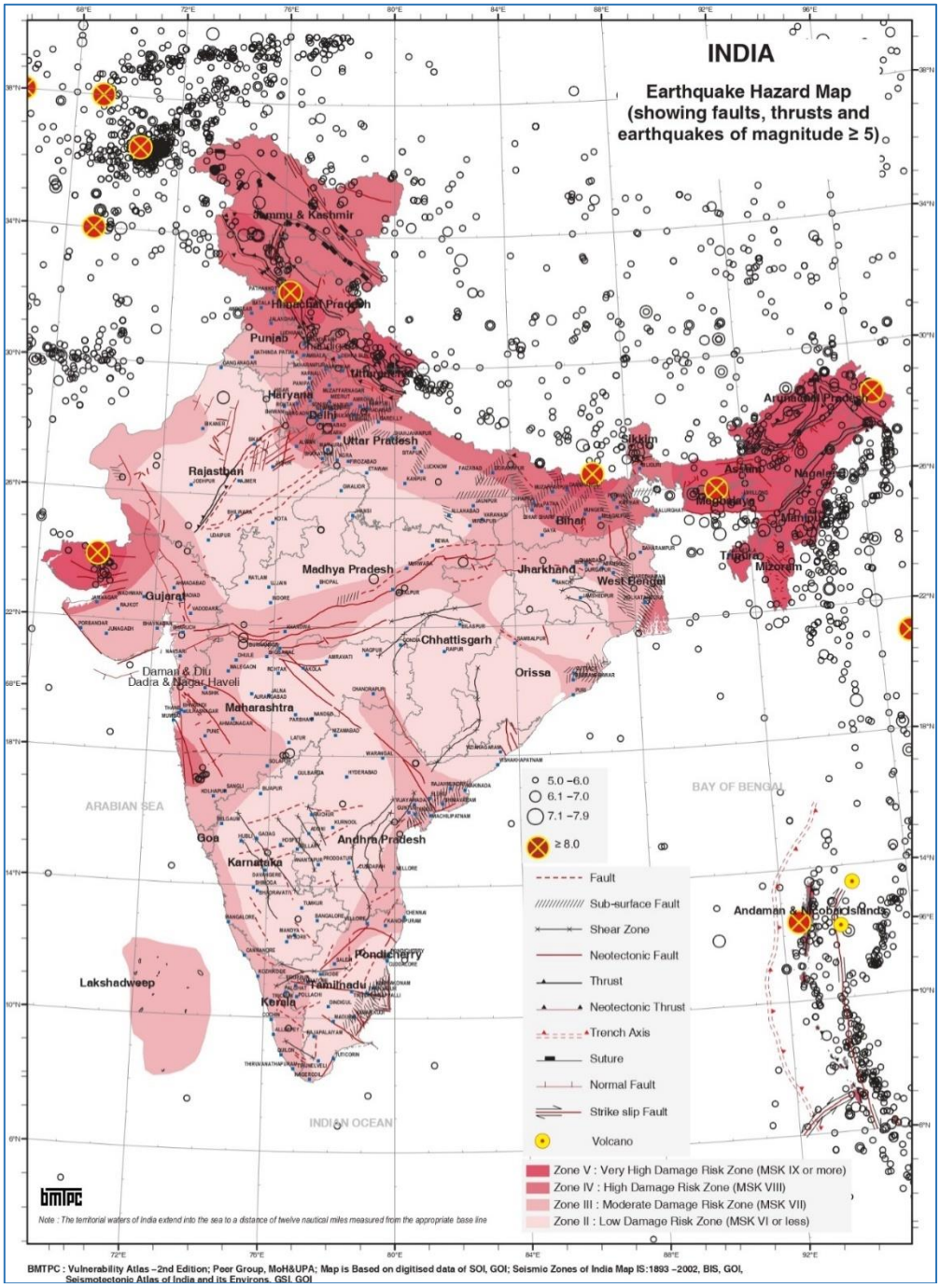
Identified natural hazards in the study area			
Sl. No.	Hazard	Project area	Findings
1	Earthquake	✓	Zone III (moderate risk zone)
2	Cyclone	✓	Wind speed of 2.5 m/sec.
3	Tsunami	✓	Moderate Damage Risk Zone B
4	Flood	x	Low (may occur due to very heavy rainfall, sea surge or tsunami)
5	Drought	x	Moderate Drought

(Source: NDMA - 2016 & 2019)

Disaster identification suggests that the project site is vulnerable to natural hazards. According to District Disaster Management Plan, probability of flood in the island is low and it may occur only in the event of very heavy rainfall, sea surge or tsunami. Among the identified impacts, Cyclone, Sea surge and Earthquake are most probable to occur in the vicinity of project area.

(i) Earthquake

As per Indian Seismic Zone Map, the Kadmath Island lies in Moderate Damage Risk Zone III where earthquakes of moderate intensity can be expected. Earthquake map is given below.



Earthquake zone map

Action Plan

During Earthquake:

- Evacuate to safest place by following emergency exist route.
- Hold onto a firm object.
- If outside, stay outside.
- If there is no place to take cover, then move to and brace against an inside wall.

After Earthquake:

- Collect report of damages from every division immediately after the event of earthquake.
- Inspection of affected area by Disaster Management Team.
- Procurement of emergency power in case of power failure.
- Inform Island authorities about the damage.
- Take necessary actions for the speedy recovery of operations.

(ii) Cyclones

Based on tracks of cyclones passed in Indian coastal region, the tracks of cyclones which have crossed the coast near Lakshadweep during 1924 to 2023 as documented by the Indian Meteorological Department (IMD) are presented in **Table 7.2.** and the track of cyclones is shown below. It indicates that totally 10 storms had occurred in the vicinity of the project region in the last 100 years. The occurrence of storms in this region are more frequent in December (04) followed by May (03) and November (03). More details are given in Chapter 3.

Table 7.2. Number of cyclones crossed over project area (1924 – 2023)

Month	Cyclones crossed over project area
January	-
February	-
March	-
April	-
May	03
June	-
July	-
August	-
September	-
October	-
November	03
December	04
Total	10

Source: cyclone e-atlas published by IMD – 2023

Action plan

In case of warning received from India Metrological Department, following action shall be taken immediately:

Before Cyclone

- Control room shall monitor low pressure formation, cyclone and IMD published details and warnings regularly.

- In case of any warnings, the same shall be reported to onsite disaster management head, HSE and group heads etc.
- Onsite Disaster Management team shall conduct a meeting, if possible, immediately after the warning to recollect the facilities and action to be taken.
- All preparations before the onset of cyclone, actions during cyclone shall be reviewed.

During Cyclone:

- Sound Emergency alarm/siren.
- Inform all staffs about the occurrence of event.
- Adequate manpower with tools, welding sets, ropes etc. shall be maintained during cyclone for rescue operation.

After Cyclone: Immediate attending of work area and report damage if any to higher authority. Immediate attending of damages and record should be kept for quick recovery as soon as possible.

(iii) Tsunami

Tsunami is a series of wave train generated in the ocean by a hydraulic impulsive force that vertically displaces the water column. Earthquakes, landslides, volcanic eruptions, explosions and even the impact of cosmic bodies taking place in the ocean can generate Tsunami waves with long periods (≈ 30 min), long wavelength (≈ 100 km) with a high velocity of propagation (≈ 700 km/hr).

Tsunamis are shallow water waves which propagate with phase velocity equal to the square root of the product of the acceleration due to gravity and the water depth. For example, in the Pacific Ocean, where the typical water depth is about 4000 m, the Tsunami wave travels at about 700 km/hr. Because the rate at which the wave loses its energy is inversely related to its wavelength, Tsunami not only propagates at high speed, but it can also travel great transoceanic distances with limited energy losses and reach different continents in shorter time i.e., the energy propagating with Tsunami waves remain nearly constant.

Among the various factors causing the occurrence of Tsunami, the large vertical movements of the earth's crust is more predominant and it can occur at tectonic plate boundaries. The plates that interact along these boundaries are called faults. Around the margins of the faults, the denser oceanic plates slip under the continental plates in a process known as subduction. Such subduction earthquakes are particularly very effective in generating the devastating Tsunamis.

The energy flux due to Tsunami is proportional to its velocity of propagation and height and it remains nearly constant till reaching the coast. Consequently, the velocity of propagation gets retarded when it enters shallower water and its height gets amplified. Because of this shoaling effect, the Tsunami that is imperceptible at Deep Ocean close to centimetre height may rise up to several metres near the coast called run up.

When Tsunami finally reaches the coast, the crest of the wave appears as rapidly risen water mass gushing into the coastline as a bore with a crashing velocity of 700 km/hr for more than 10 - 30 min. The trough of the wave will appear as the withdrawal of water mass with same speed back into the ocean swallowing everything on the land and dragging back into the ocean.

In worst case, if a Tsunami occurs then there will be surging of Tsunami waves with a speed of > 60 kmph into the shore and the run-up will be > 4 m. The gushing of water will sweep and flood the areas having elevation < 3 m MSL.

Disaster Management Plan for Tsunami and Storm Surge

Cyclone, Tsunami and Storm surge are the most destructive force among the natural devastations. It causes instant disaster and burial of lives and destruction to entire coastal properties. The damage and loss can be minimized if appropriate preparedness plan is formulated. The following statutory guidelines are recommended by National Disaster Management Authority (NDMA) to minimize the impact due to Cyclone, Tsunami and storm.

- Developing sand dunes along the coast with shrubs or Casuarina trees for stabilization of the sand dunes (Tsunami Mound).
- Raising the ground level (above the design water level) with natural beach sand so as to rehabilitate the coastal region.
- Development of coastal forest (green belt) by planting casuarinas and coconut trees along the coastline to cover minimum of about 500 m width of the beach.
- Adopting natural beach nourishment to create steep beach face.
- Creation of sandy ramps at close intervals along the coast.

In addition to the guidelines by NDMA, it is also necessary to adopt various preventive actions in the coastal region of the project site.

Preparedness Plan

The preparedness plan shall contain details about: i) warning that should be given ii) Protective measures to contain the effect of surging water level and iii) Other precautionary measures to be taken. The following measures are the key aspects in the preparedness plan.

i) Coordination with International and National Agencies
ii) Vigilant online monitoring
iii) Emergency Evacuation

Coordination with National Agencies

After the 2004 Tsunami affected the Indian sub-continent, the following organizations are involved on watch and cautioning the government and public in the event of possibility of occurrence of Tsunami. As a part of Tsunami hazard mitigation, warning systems have been established in India by the coordination of the following organizations.

i) Indian National Centre for Ocean Information Services (INCOIS), Hyderabad.
ii) National Disaster Management Authority (NDMA), New Delhi.
iii) Indian Meteorological Department (IMD), New Delhi.
iv) National Institute of Ocean Technology (NIOT), Chennai.

The contact details of National agencies are given below:

Organization	Address	Email ID	Contact Number
Lakshadweep Collectorate	Kavaratti	lk-coll@nic.in	04896 - 262256
Suptd.of Police	Kavaratti	lak-sop@nic.in	04896 - 262750

Vigilant online monitoring and emergency alarm

INCOIS in collaboration with NIOT has deployed DART buoys at 3 locations in the deep ocean along the fault plane of Andaman plate and Indonesian plate.

The online monitoring is capable of raising alarm in case of instantaneous change in surface elevation exceeding centimetre which can be caused by the generation of Tsunami. IMD interacts with the above institutions and takes the responsibility of broadcasting the disaster through various Medias. In case of a Tsunami, the warning is usually broadcast based on the earthquake occurred in the nearby ocean. Irrespective of definite occurrence of Tsunami, the possibility to occur is also considered as equally vulnerable and accordingly the warning news is instantly flashed through Radios and TVs. The notification is followed by orders from the local Government Authorities on reinforcing evacuation, prohibition to enter the demarcated risky zone and mobilizing facilities for easier evacuation and augmenting medical facilities.

There are a variety of evacuation notification systems in case of Cyclone, Tsunami and Storm surge. They include sirens, weather radio, Emergency Alert System, Telephones, Emergency Weather Information Network etc. In each system, it should be noted that the application and message is consistent as well as continuous with repetition of messages with periodicity at short time interval. It should be ensured that the warning reaches immediately to all people prone to the devastation.

The time at which the cyclone, storm surge or Tsunami may reach the coast can be predicted with sufficient lead time. The destruction can be minimized if the coastal populations are warned and evacuated to elevated place and inland in time. Therefore, keeping vigil on the warning is the very important aspect in protecting the lives.

A vigilant team must be created. An Emergency Alarm should be in place in all the islands. If warning is given instantly activate the emergency alarm and give caution to the vigilant team so that they can immediately start the rescue operation.

The vigilant team should have proper knowledge about the warning systems and should have attended the training programs conducted by the Tsunami warning centres. The training should be given periodically to update the system and methods of warning. The team should take the responsibility of giving immediate warning to the people in and around the power plant in case of Tsunami and they have to undertake the Emergency Preparedness Action. Safety drills should be conducted periodically. Operational and emergency preparedness procedures should be planned meticulously in order to act on the warning and to disseminate it rapidly and effectively to the public.

Emergency Evacuation

Evacuation of people from risk areas is the first priority when early warning is received or the natural warning sign indicates the immediate arrival of cyclone, Tsunami wave or rise of storm surge.

Evacuation plan describes the time span available before and during the Tsunami or storm surge event. When facing local threat, evacuation procedures most possibly will have the character of a 'runaway effort' and people should not expect to receive much institutional support. The primary objective should be bringing as many people as possible out of the reach of the wave's impact to safe or 'relatively safe' areas. Therefore, necessary steps have to be taken in advance to enable and support the community at risk to protect themselves at any time

(iv) Flood

In general, Lakshadweep Island is not prone to flood.

MASS RESCUE OPERATIONS

The Union Territory of Lakshadweep has formulated a Mass Rescue Operation (MRO) Contingency Plan to ensure a coordinated response during large-scale maritime disasters. The MRO plan is designed to utilize all available local resources and enhance inter-agency coordination within the maritime jurisdiction of the UT. The region is also highly vulnerable to natural disasters such as cyclones, thunderstorms, erosion, and occasional earthquakes, which have historically caused substantial loss of life and property, as seen in major storms recorded in 1847, 1891, 1922, 1963, 1977, 2004, and 2017. Due to the geographical isolation of the islands and their dependence on shipping for connectivity, efficient disaster preparedness, rapid response, and seamless cooperation among various resource agencies are crucial in mitigating risks and ensuring effective mass rescue operations at sea.

A Mass Rescue Operation (MRO) is a large-scale emergency response that occurs when the number of people in distress exceeds the normal Search and Rescue (SAR) capabilities. While MROs are rare compared to regular SAR operations, they can arise from flooding, earthquakes, ship or aircraft accidents, hazardous material incidents, or terrorist attacks, requiring immediate and coordinated action. The primary objective in any MRO is lifesaving, followed by environmental protection and property safety, driven by moral, legal, and public expectations. These operations demand rapid, large-scale mobilization of resources, involving multiple agencies working under a clear command structure to ensure seamless coordination. Effective communication systems, trained personnel, and extensive logistical support are crucial to sustaining rescue efforts, sometimes for weeks. MROs require intensive pre-planning, collaboration, and real-time execution.

The Mass Rescue Operation (MRO) Contingency Plan for Lakshadweep is designed to provide a structured and coordinated response to large-scale maritime emergencies. Its primary objective is to ensure an efficient and flexible rescue strategy in the Search and Rescue Region (SRR) of Lakshadweep, covering rescue procedures, training, documentation, and media coordination.

The Indian Coast Guard (ICG) is designated as the lead agency, with distress reports relayed to the Coast Guard District No.12 at Kavaratti, the District Collector, and other stakeholders for immediate action. Aerial and sea-based search operations are crucial for assessing incidents and launching timely rescue efforts.

The Mass Rescue Operation (MRO) Contingency Plan outlines a structured approach to managing large-scale rescue efforts at sea. On-scene responsibilities are shared between the On Scene Commander (OSC) and the ship's master or aircraft pilot, who oversee safety, medical care, and evacuation procedures. In most cases, passengers and crew should remain on board unless the vessel is in immediate danger. The Search and Rescue Mission Coordinator (SMC) designates the OSC, ensuring effective communication, resource mobilization, and coordination with all agencies involved.

The plan prioritizes tracking and accounting for all people, utilizing lifeboats, helicopters, and naval vessels for rescue operations. Ship companies are encouraged to have helicopter landing areas and hoist-winch systems for more efficient evacuations. Depending on circumstances, towing survival craft to shore may be safer than removing passengers at sea. The MRO is coordinated by Rescue Coordination Centers (RCCs) but may escalate to higher authorities if international support is needed.

Key considerations in MRO planning include incident command structures, resource mobilization, immediate activation protocols, personnel deployment, survivor care, media management, and

security control. The plan also emphasizes preparedness through regular training, communication systems, and logistical support to ensure an effective response. Practical recommendations include quick mobilization, use of larger vessels for evacuation, controlling airspace, securing debris for investigation, and integrating support services like the Red Cross and crisis management teams. Pre-planning and collaboration among government, military, and private agencies are essential to maximizing efficiency and saving lives in a mass rescue scenario.

7.2. Modelling Study

National Technology Centre for Ports, Waterways and Coasts, Department of Ocean Engineering, Indian Institute of Technology Madras, Chennai has done the detailed modelling study on currents and wave transmission which are attached as a separate report Measurements &*conducting Mathematical Model Studies for the Development of Jetties and Breakwaters in Lakshadweep Islands* in **Annexure II.**

9. ENVIRONMENTAL MANAGEMENT PLAN

9.1. Introduction

Development of any infrastructure in the coastal environment includes both social and environmental impacts. To address the anticipated impacts and to implement the mitigation measures, Environment Management Plan (EMP) needs to be formulated. EMP identifies the approach, procedures and methods that will be used to control and minimize the environmental and social impacts of construction and operational activities associated with project development. It is intended to reduce the negative impact and to enhance the positive benefits from the project.

The main objectives of Environmental Management are to:

- Identify key environmental issues anticipated to be encountered during construction and operation phases of the project
- Provide guidelines for appropriate mitigation measures
- Ensure the mitigation measures are implemented
- Establish systems and procedures for implementing mitigation measures
- Monitor the effectiveness of mitigation measures
- Take necessary prompt action when unforeseen impacts occur

The proposed project involves construction of jetty with approach trestle, passenger facilitation centre with modern amenities, development of boat landing centre with finger jetty, boat Repair shed, Ice plant, and Fuel station and road connectivity to existing road and development of auxiliary infrastructures. The impacts due to construction and operation of the proposed development were described in **Chapter 4**.

9.2. Environmental Management Plan

The various impacts in any project development can be categorized as mitigable and non-mitigable and it is essential to list the impacts accordingly. The key activities or aspects of the proposal that may potentially affect habitat of flora and fauna and require application of management controls include,

- Construction of the approach trestle: Site preparation, construction of piling/foundation, storing of construction materials, construction of service utilities, construction of footpath.
- Construction of berth: Site preparation, constructions of deck slab, fixing of pre cast deck slab fixing of tyre fender construction of long beams, construction of piling/foundation, storing of construction materials.
- Construction facilitation centre: Site preparation, construction of waiting hall including foundation, flooring etc.

Labour Management Plan

The total number of workers to be employed during construction phase will be around 18000 nos. The labours will be recruited as locals islanders and most of the labours are recruited from mainland. The basic facilities required for the labours at the workplace as per the Contract Labour (Regulation & Abolition) Act, 1970 will be made available.

Sanitation Facility

There should be one latrine for every 25 males or females. Every latrine shall be under cover and so partitioned off as to secure privacy and shall have a proper door and fastenings. "For Men only" and "For Women only" must be displayed in the local language in the door of the latrines. The notice shall also bear the figure of a man or of a woman, as the case may be. Sanitation facility should be provided to the workers during construction.

Solid Waste Management

Construction waste consisting of bricks, stones, pipes, concrete waste, steel waste, etc. will be generated during the construction phase. The waste will be properly disposed or recycled.

Transportation and heavy machineries

- All vehicles used will have a valid Pollution Under Control Certificate.
- Regular servicing and maintenance of machineries as well as vehicles to control unwanted air pollutant emission.

Marine Environment

- Periodic monitoring on the seawater, seabed sediment and marine ecology will be carried out in the coastal region and the report will be submitted to the statutory bodies as required.

9.3. Coral Management Plan

Coral reefs are one of the most diverse and highly productive ecosystems in the coastal zone and contribute to the sustenance of the country through fisheries, tourism, etc., and also protect the shore from erosion and natural calamities by buffering of waves and currents. Coral reefs play a major role in climate change, by fixing atmospheric nitrogen, regulating CO_2 and Ca levels. Reefs also offer shelter to various organisms, including ornamental fishes, crabs, shrimps, sea cucumbers, sea urchins, octopuses, eels, etc.

Besides hard stony coral reefs, soft corals also exist in coral reef ecosystems, in clear, warm tropical seas. Hard corals produce a rigid skeleton made of calcium carbonate ($CaCO_3$). The calcium carbonate of corals provides a hard outer structure that protects the soft parts of the coral. Colonial hard corals are made up of hundreds to hundreds of thousands of individual coral polyps that cement themselves together by the calcium carbonate they secrete.

Soft corals do not produce rigid calcium carbonate skeletons and do not form reefs, though they are found in reef ecosystems. Like hard corals, most soft corals are also colonial; what appears to be a single large organism is actually a colony of individual polyps that form a larger structure. Visually, soft coral colonies tend to resemble trees, bushes, fans, whips, and grasses.

In India, a total number of 585 species (108 genera, 23 families) of Scleractinian fauna has been reported (De *et al*, 2020). Highest number of species (523 species belonging to 95 genera and 23 families), was reported from Andaman and Nicobar Islands, followed by Gulf of Mannar (169 species of 46 genera and 16 families), Lakshadweep Islands (165 species of 54 genera and 17 families) and Gulf of Kachchh (76 species of 30 genera and 11 families).

Among the Indian reefs, 298 species (52.6 %) occur only in Andaman and Nicobar Islands, and are not found in other reefs. Likewise, 28 scleractinian species (5 %) are unique to Gulf of Mannar,

followed by 7 unique species (1.2 %) in Lakshadweep Islands. In Gulf of Kachchh, only one unique species (0.2 %), namely *Acanthastrea simplex* occurs.

Among the total number of 585 species, 36 scleractinian species (6.4 %) are common and present in all the four major reef regions.

Lakshadweep Islands

In the south-western part of India, Lakshadweep reef archipelago is located 200-400 km away from the Indian mainland and is formed by a series of coral atolls. This Lakshadweep Chagos ridge supports the longest chain of true atolls and supports divergent ecosystems characterized by a rich diversity of corals and associated marine organisms. The submarine ridge that supports the islands, rises from a depth ranging from 1500 to 4000 m. There are 6 tiny islands, 12 atolls, 3 reefs and 5 submerged banks, covering an area of 32 km^2 with lagoons occupying about 4200 km^2. Only 11 of the 36 islands are inhabited (Venkatraman, 2006).

In the Lakshadweep Islands, among the 17 families, Acroporidae (51 species, 5 genera), Merulinidae (34 species, 14 genera), and Poritidae (17 species, 2 genera) form the major species assemblage. At the genera level, *Acropora* contributes 36 species, followed by *Porites* (14 species) and *Montipora* (9 species).

Department of Environment and Forest, Lakshadweep (2023), has recently compiled the database on hard corals and has listed 80 species of corals, belonging to 34 genera. They are *Acropora (21 species), Porites (6), Favites (5), Favia (3), Fungia (3), Pocillopora (3), Turbinaria (3), Astreopora (2), Galaxea (2), Montipora (2), Cyphastrea (2), Montastrea (2), Platygyra (2), Goniastrea (2), Goniopora (2), Lobophyllia (2), Isopora (1), Echinopora (1), Diploastrea (1), Leptoria (1), Plesiastrea (1), Merulina (1), Hydnopora (1), Mycedium (1), Pectinia (1), Pavaona (1), Gardineroseris (1), Herpolitha (1), Polyphyllia (1), Symphyllia (1), Stylophora (1), Psammocora (1), Tubastrea (1)* and *Heliopora (1)*.

Kadmath Island

Kadmat island has three types of habitats namely coral reef, seagrass and nesting ground for marine turtles. Such habitats are found in about one third of all shallow coastal waters in the tropics. All three ecosystems are of major importance and are closely interconnected through hydrodynamic circulation patterns and trophic system.

Coral Reef

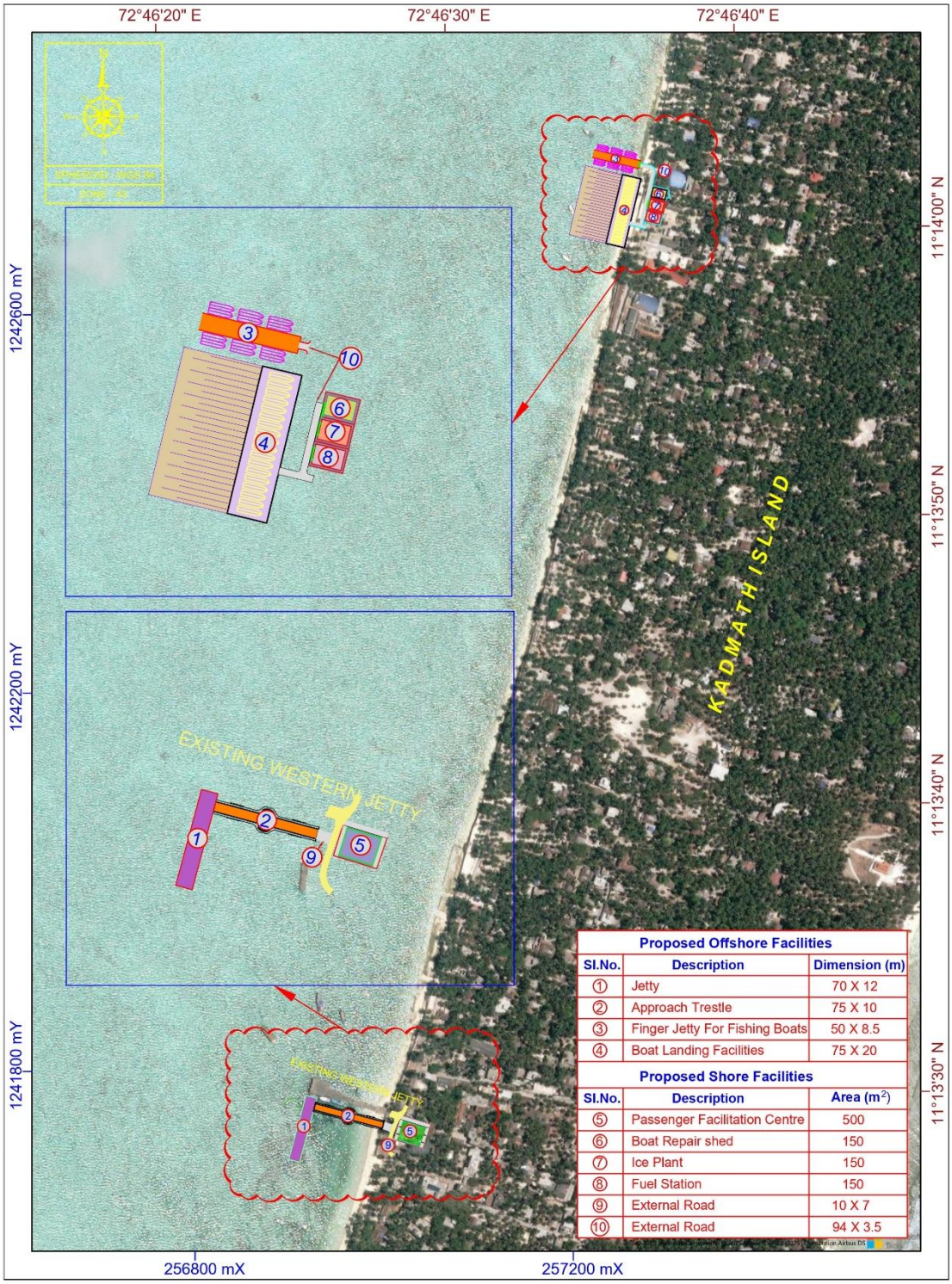
The reef zonation of the Kadmath island has reef flat, reef slope and lagoon. Fringing reefs are adjacent to the shorelines and act as spawning and nursery grounds for a large number of fin and shell fishes.

Fringing reefs are found mostly within and bordering the lagoon, at a distance of 300- 400 m from the shore and mostly within 5 m depth. Patch reefs are found scattered in the northwestern part of the lagoon.

Earlier, in the lagoon as well as reef slope area, 9 species of live corals were reported. The reported species were *Acropora formosa, Acropora robusta, Acropora* sp., *Acropora subglabra, Acropora tortuosa, Acropora vanghani, Favites* sp., *Pocillopora verrucosa* and *Lobophytum* sp. (ICMAM, 2001).

Project Region

The project site is located on the western side of Kadmath. The proposed offshore and shore facilities have been given in the figure below.



Proposed facilities in Kadmath Island - Western side

Description:

In the project area, on either side of the proposed jetty, very narrow sandy patches were observed. However, these areas are inundated during high tide and also protected by shore protection structures. No corals were observed in the proposed project site.

Live coral colonies were observed on northwest and other areas of the island. The live corals observed include *Acropora lamarcki, Acropora digitifera*, *Acropora* sp., *Porites lobata*, *Porites* sp., *Favites flexosa*, *Psammocora contigua*, *Platygyra sinensis* and *Platygyra* sp.

Coral observation in proposed project site (intertidal area)

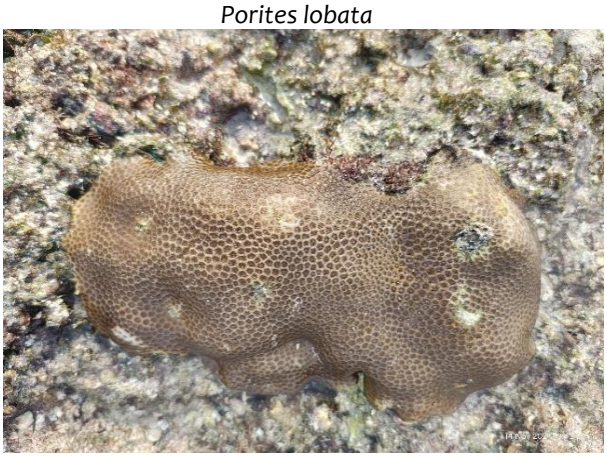
Acropora lamarcki

Acropora digitifera

Acropora sp.

Porites lobata

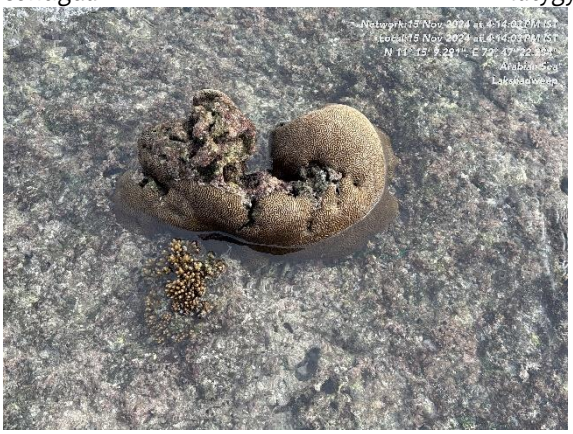
Porites sp.



Favites flexosa

Psammocora contigua

Platygyra sinensis



Platygyra sp.

Experts involved in the coral study

Coral management plan has been prepared by the subject experts of Indomer. In order to meet specific requirements of this plan, the following subject experts are involved in the study. Dr. Deepak Apte, (Marine Ecology, Former Director of Bombay Natural History Society (BNHS), Dr. T. Balasubramanian, (Marine Biology, Former Dean and Director, C.A.S. in Marine Biology, Annamalai University), Dr. S. Sundaramoorthy, (Former Scientist F, ICMAM-PD, MoES, Chennai), Dr. P. Chandramohan, (Ocean Engineering, Former Scientist, CSIR-NIO, Goa), Dr. P. Venkadeswaran, (Plant Taxonomy and Ecology & Biodiversity) and Dr. G. Idayachandiran, (Marine Biology).

Habitat Analysis based on video transects

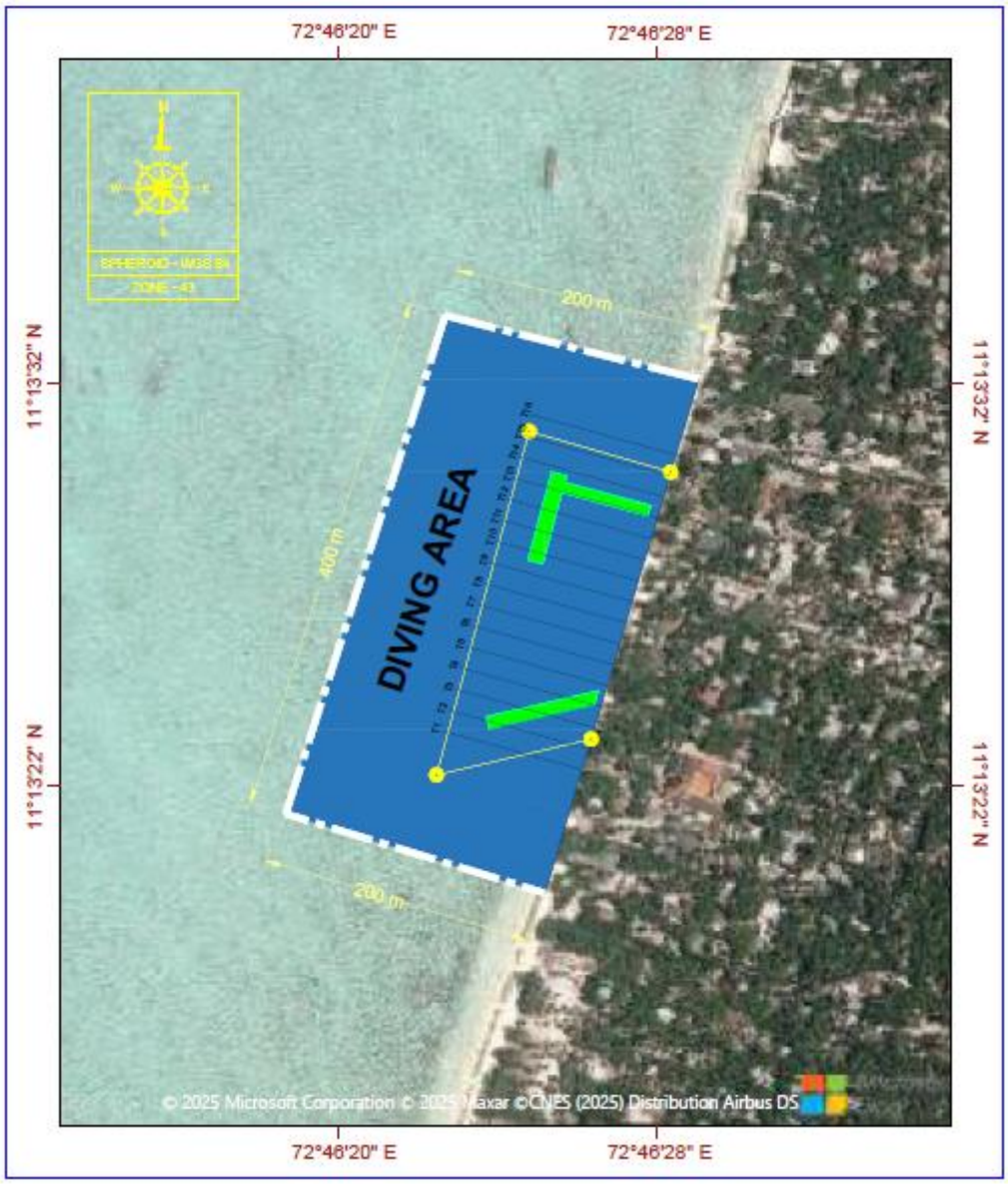
Methodology

This study utilized underwater video footage to assess benthic habitat composition along transects.

Transect Establishment: Transects were established with a defined length of 100 m.

Video Acquisition: Underwater video footage was collected along each transect with help of SCUBA Diving/ Snorkelling.

Proposed project region of Kadmath western side of coral study (SCUBA diving) in 16 transects are given below.



Coral study at proposed western jetty of Kadmath island

SCUBA diving at western side of Kadmath island

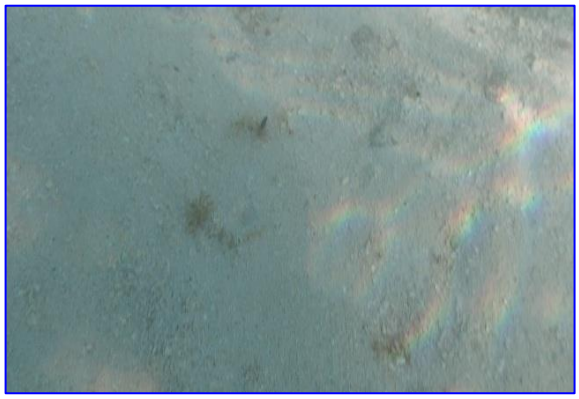
Data Collection:

100 frames were randomly selected from each video (in case of multiple videos appropriate number of frames based on duration of video were extracted).

For each frame:

- The dominant benthic habitat within the frame was identified.
- Due to the inherent variability in camera angle and distance from the substrate, the largest habitat observed within the frame was assumed to represent the dominant habitat at that specific point along the transect.
- The percentage composition of each benthic class was determined based on the frequency of occurrence of each class within the 100 frames.

Majority habitat is **Algae** followed by **DCA**



Majority habitat is **Sand**

Majority habitat is **DCA** followed by CM

Kadmat E (T7) majority habitat is **Sand**

Habitat Classes used for analysis (Depends on location)

Higher class	Class Name (Code)	Class Information
Algae	ALG	Algae - turf
Algae	CA	Coralline algae (Pink)
Algae	HA	*Halimeda*
Dead Coral – Acropora with algae	DC_ACB	Dead Coral *Acropora* with algae
Dead Coral – with algae	DCA	Dead Coral with algae
Live Coral	AC_B	*Acropora* - Branching
Live Coral	AC_D	*Acropora* - Digitate
Live Coral	AC_SM	*Acropora* – Sub massive
Live Coral	AC_T	*Acropora* - Tabular
Live Coral	CB	Coral Branching
Live Coral	CB_POI	Coral Branching - Pocilloporid
Live Coral	CB_POR	Coral Branching - *Porites*
Live Coral	CB_STY	Coral Branching – *Stylophora* and allied
Live Coral	CE	Coral Encrusting
Live Coral	CF	Coral Foliose

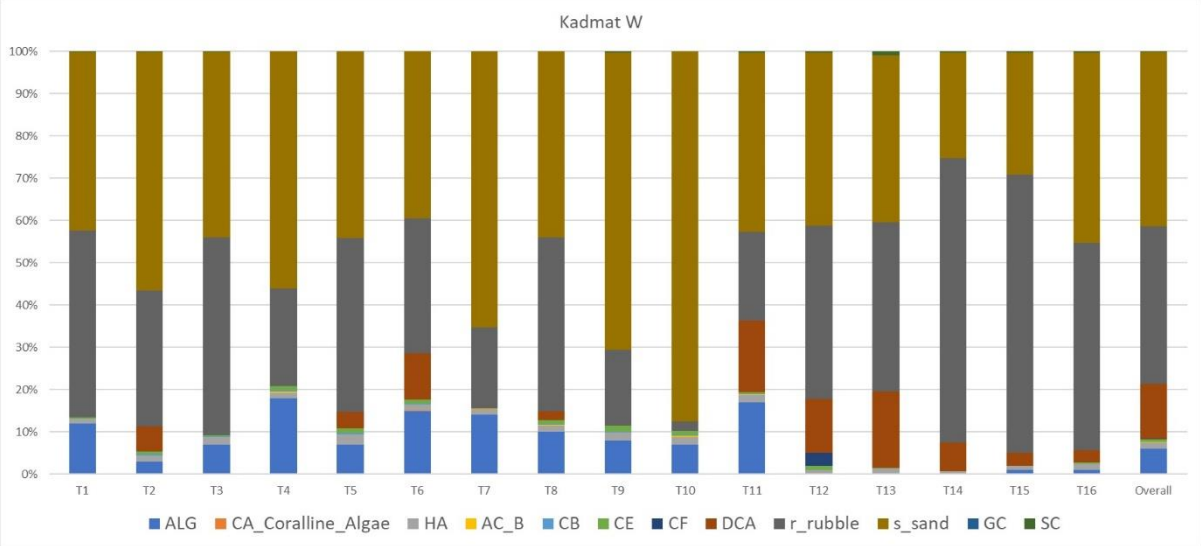
Live Coral	CM	Coral Massive
Live Coral	SC	Soft Corals
Other	GC	Giant Clams
Other	SC	Sea Cucumber
Rubble	R	Rubble
Sand	S	Sand

Assumptions and Limitations

Dominant Habitat Assumption: The methodology relies on the assumption that the largest habitat observed in a frame accurately represents the dominant habitat at that point. This assumption may introduce bias, especially in areas with complex or heterogeneous benthic communities.

Camera Angle and Distance: Variations in camera angle and distance from the substrate can significantly influence the apparent size and visibility of different habitats. These factors were not explicitly accounted for in the analysis.

Random Frame Selection: The method assumes that the 100 frames selected are representative of the entire transect. However, the randomness of frame selection may introduce some degree of variability in the results.



Dominant Habitat Components

- **Sand (s-sand):** This appears to be the most dominant habitat component across many of the locations. It suggests a significant presence of sand substrate.

- **Rubble (r-rubble):** Along with sand dead remains of corals as a small parts broken since many years are present in large proportions.

  Both these makes on average 70% of total habitat components.

Other Significant Components

- **Dead Coral with Algae (DCA):** This component is also prevalent in several locations, indicating that there has been some coral mortality, which is now covered by algae.

- **Live Corals:** Various types of live corals are present, including Acropora (AC_B, AC_D, AC_T), branching corals (CB), and encrusting corals (CE). These contribute to the overall coral cover and biodiversity.

  T2, T5, T6, T8, T10, T11 has only 1% cover of live corals where as T4, T9 has 2% and only T12 has 4% coral cover which is largest of all the sampled transects.

- **Algae:** Algae are also a significant part of the habitat, with different types present such as turf algae (ALG) and coralline algae (CA_Coralline_Algae).

- **Rubble:** This component is present in varying amounts across the locations, suggesting areas with sediment accumulation or disturbance.

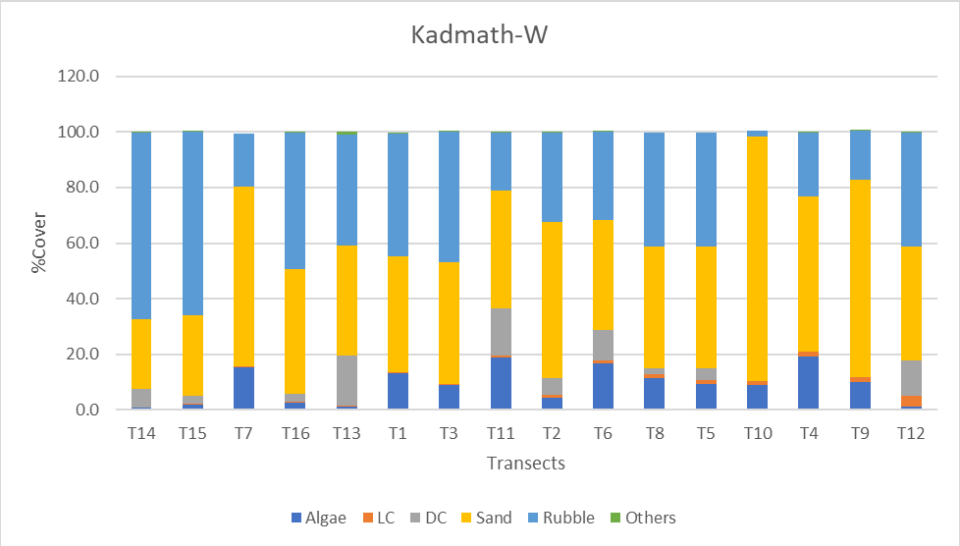


Figure 1 % Coverage of major benthic habitats at Kadmath- W (Arranged as per Coral coverage [LC-Orange color])

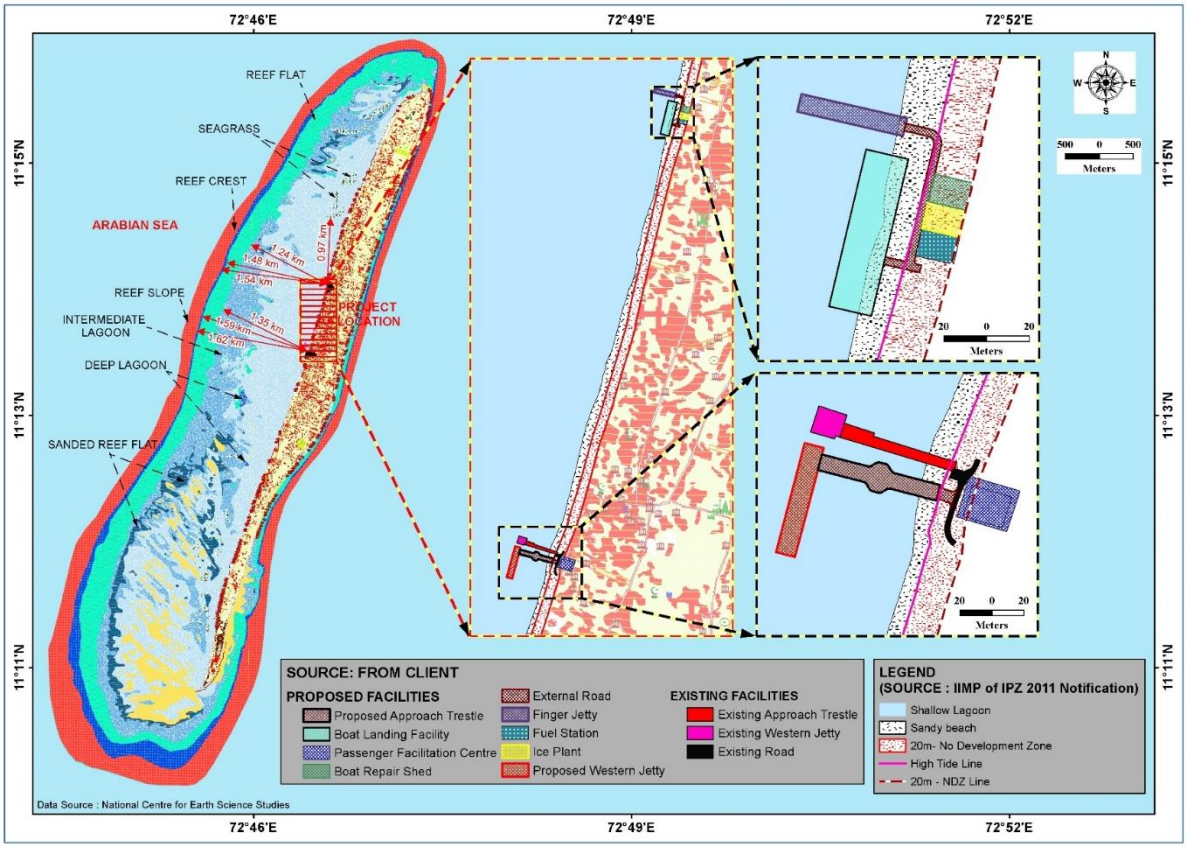
Overall Habitat Characteristics

The habitat appears to be a sand-dominated ecosystem with a mix of live and dead corals, algae, and rubble. The presence of DCA indicates potential disturbances or stressors that have led to coral mortality. The dominance of sand might suggest a habitat that is more exposed to wave action or currents, leading to sediment accumulation.

CORAL MANAGEMENT PLAN

Western side

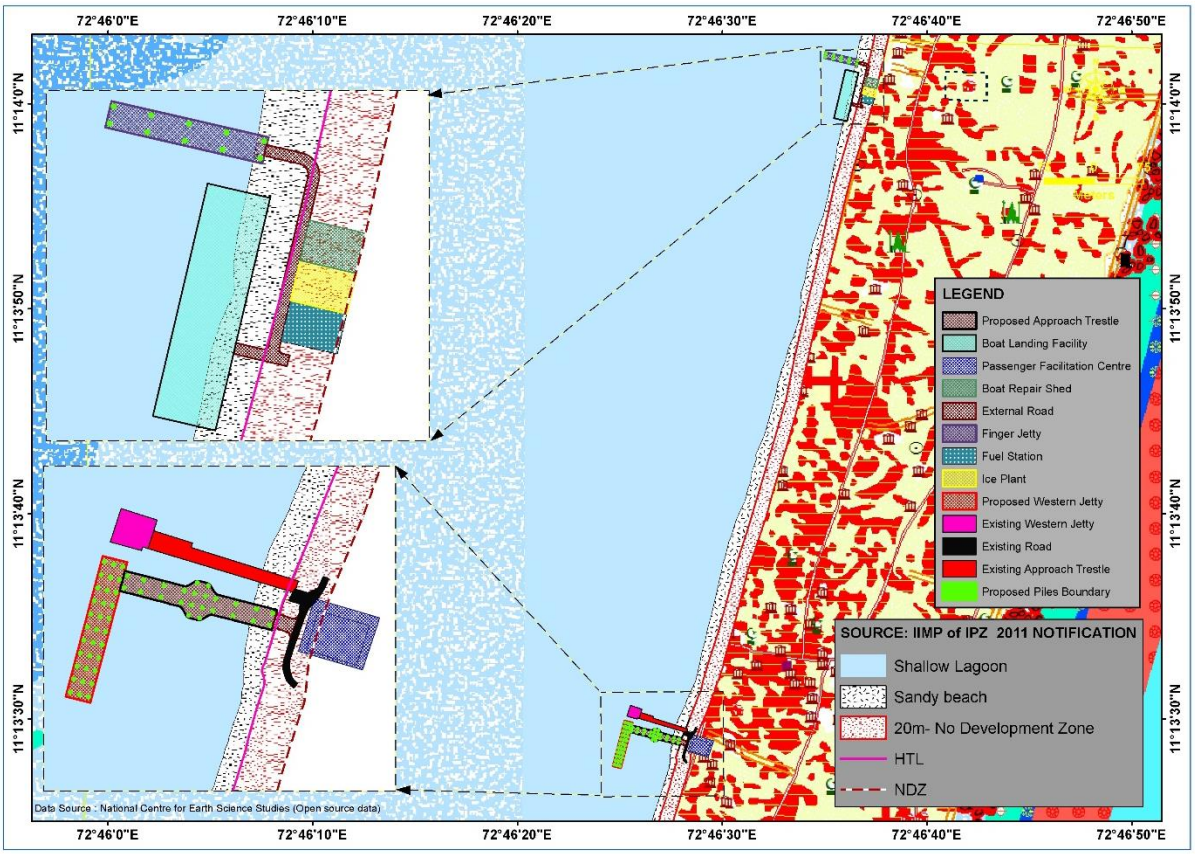
Corals are healthy and abundant compared to the eastern side of Kadmath island. Still the live corals are present in 700 m away from the proposed jetty. According to the CRZ map, the proposed project region comes under the sanded beach and shallow lagoon area. Distance of corals from proposed facilities as per IIMP map given in below figure.



Distance of corals from proposed facilities as per IIMP map

Impact on reef during pile foundation

The lengths of the approach trestle, jetty and finger jetty are 75 m, 70 m and 50 m respectively. The pile foundation would take up only a small footprint of about 0.9 m dia. in approach trestle & finger jetty and 1 m dia. in jetty area. In approach trestle totally 24 piles pass over sandy (4) and shallow lagoon (20); in jetty area totally 33 piles pass over shallow lagoon and in finger jetty 10 piles pass over sandy (2) and shallow lagoon (8). Totally 47.53 m^2 of area will be impacted during the pile foundation in sandy and shallow lagoon area. The impacted areas due to pile foundation are given in table below. The proposed piles (approach trestle, jetty and finger jetty) over the zones are shown in the figure below.



Proposed piles (approach trestle, jetty and finger jetty)

Impacted areas due to pile foundation

Area	Approach Trestle Area (m^2)	Jetty Area (m^2)	Finger jetty (m^2)
Sandy Beach	2.54	-	1.27
Shallow lagoon	12.72	25.91	5.09
Total Area (m^2)	15.26	25.91	6.36
Total area of coral sub zone	**47.53**		

Impact on corals

Pile construction activities may cause physical damage to the reef, either through direct contact or sediment movement.

Water turbidity will be increased by the suspended sediments produced by piling operations. Because symbiotic algae (zooxanthellae) are necessary for coral life, their ability to photosynthesis is restricted by high turbidity, which decreases light penetration.

The coral ecosystem may get contaminated if fuels, lubricants, or other chemicals used in piling operations flow into the nearby coral environment. Corals may be impacted from improperly handled cement and other building materials that change the nearby water environment.

The positioning of piles may disrupt the normal flow patterns of water, which could impact the rates of sedimentation and nutrient transport surrounding coral reefs.

Mitigation measures

Before the piling operation, any live corals observed in the proposed piling activity area, shall be relocated to a neighbouring environment using the techniques described in the coral conservation methods mentioned below.

Appropriate silt curtains shall be used during piling operations, in order to minimize/ contain the turbidity / suspended sediment levels, of the ambient water environment.

Closed grab excavator shall be used for all piling constructions, and double casings with Y-shaped funnels installed will keep any muddy water spills contained within the casing, and additional protection from the Y-shaped funnel to prevent affecting the reef environment outside the work area.

The proposed pile foundation has sufficient spacing, limiting hydrodynamic changes in the flow regime and preventing negative impact on water quality while operation.

Threats to corals

Coral reefs are subjected to various natural and anthropogenic stressors, including climate change, (such as rising seawater temperatures), diseases, cyclonic disturbance, declining water quality (turbidity, pollution, pathogens, etc.,), sedimentation, destructive fishing methods, over-exploitation of reef fauna, tourism, physical damage due to anchor drop, etc. In addition to climatic causes, primarily high seawater temperatures, the uncontrolled and growing dumping of untreated residential sewage into the reef habitat are also major threats to the corals (Thinesh *et al.,* 2009).

Climate change

Climate change, especially sea surface temperature, is one of the main factors influencing the health of coral ecosystem. Corals have a low capacity for adaptation and are susceptible to thermal stress. Unless there is thermal adaptation or adaptation by corals, increases in sea surface temperature of around 1-3°C are predicted to cause more frequent coral bleaching events and widespread death (Eakin *et al.,* 2008).

Coral disease

Diseases are major secondary stressors causing coral mortality in the reefs. Diseases may cause irreversible damage to the corals structure and functioning. Diseases affecting hard corals have become the most important factor in the decline of coral reefs in some regions (Weil, 2004). Reproduction, growth, community structure, species diversity, and many other animals linked with reefs can all be significantly altered by coral disease.

In an earlier study of coral diseases in Gulf of Mannar and Lakshadweep Islands (Kavaratti, Agatti) during 2011, nine coral diseases (white band, white pox, white plague, pink line syndrome, pink spot, yellow band, fungal blotch, black band and necrotic patches) were observed. Coral disease prevalence was higher in coral reefs of Gulf of Mannar than in the Lakshadweep islands (Kavaratti and Agatti) (Thangaradjou *et al*., 2016).

In a recent study (Jan. 2016 - Nov. 2018), on coral diseases in Chetlat island, six coral diseases were observed and reported to cause mortalities in hard corals. The six coral diseases observed were Black Band Disease (BBD), White Syndrome (WS), Pink Line Syndrome (PLS), Porites Ulcerative White Spot (PUWS), White Band Disease (WBD) and Porites Peeling Tissue Loss

(PorPTL) disease, affecting different genera of reef building corals. Among the affected genera, *Porites* hosted the highest number with six coral diseases, followed by *Pavona* with two diseases and the remaining genera were affected by one disease each (Thaha and Rathod, 2019).

Coral Management

Coral reef conservation aims to preserve biological productivity and diversity, provide traditional and sustainable uses (such as fisheries and tourism), and shield the reefs' aesthetic, historical, biological, and geological value from human interference. Protecting coral reefs by reducing or eliminating the stressors causing degradation should be important for their conservation. Development of coral nursery and transplantation are the ideal techniques for increasing the coral cover in the islands.

Pollution control

Maintaining the health and richness of coral reef ecosystem depends on preventing pollution in these reef ecosystems. Sewage waste should be treated before it is released into the sea, to prevent harmful chemicals, nutrients, and pathogens causing damage to coral reefs. By limiting the use of single-use plastics and encouraging recycling initiatives, plastics can be kept out of the ocean, where they can damage marine life and destroy coral reefs.

Shipboard pollution

Coral reefs are affected by shipboard pollution, which is mostly caused by harmful materials that ships release into the ocean. Marine pollution can be caused by ships improperly disposing of their waste material, particularly plastics. Plastics can introduce harmful compounds, block sunlight, and physically damage corals. Ballast water from ships frequently contains contaminants, disease causing pathogens, and invasive species that can damage coral reefs and other marine life by disturbing the local marine ecosystem.

The proposed project on jetty construction is for increasing the passenger and cargo traffic to the islands. The passengers in ships need to be cautioned about prevention of pollution by disposal of solid / liquid wastes to the marine environment. The vessel crew by default shall adhere to the standard norms.

Prevention of oil spill

Coral reefs are impacted by oil spills both directly and indirectly, which can degrade ecosystems, reduce biodiversity, and make recovery difficult in the long term. Corals obtain their energy from symbiotic interactions with algae (zooxanthellae). These algae can be damaged by oil pollution, which causes coral bleaching, a condition in which the corals expel the algae, losing their colour and vitality.

Oils, especially diesel, petrol, aviation fuel, kerosene, etc., are likely to be transported in significant quantities to the islands. Standard safety precautions shall be taken for loading, transporting and unloading the above items. Standard oil spill contingency plans shall be prepared according to the passenger / cargo ships quantum, and shall be implemented accordingly, in case of any oil spill, or leakage, etc.

Invasive species management

Certain invasive species, such as predatory starfish (like the crown-of-thorns starfish), cause direct impact to coral colonies and degrade reefs by feeding on coral polyps. Because they modify nutrient cycling, reduce the amount of food available to the marine organisms, or alter the physical structure of the reef, invasive species are able to alter the way ecosystem's function. In order to preserve coral reefs and their biodiversity, it is essential to stop the spread of invasive species through improved ballast water management and appropriate fishing methods.

Conservation methods

In Lakshadweep archipelago, the corals have been degraded / threatened by a range of natural and anthropogenic stressors, like cyclones, climate change, and anthropogenic interventions (Riyas *et al*. 2020). These threats necessitate the development and implementation of active coral restoration programs.

Transplantation of corals can serve as an ideal management strategy for development of coral colonies in the reef. Coral restoration can be achieved by transplanting fast-growing and healthy coral fragments. Massive corals have also been recommended for transplantation due to their lower susceptibility to damage and mortality. Therefore, both branching and non-branching corals shall be used for coral restoration.

Coral rescue program

The live coral colonies, both branching and massive corals, likely to be damaged at the proposed project area, shall be collected and relocated in a suitable nearby location, for survival at natural conditions. The live coral colonies along with the substrate (e.g., dead coral rock, on which the live coral colony has developed), can also be removed as such and translocated. Suitable sites may be identified prior, in and around the island for such coral rescue programs. Further, these also should be monitored for their survival percentage.

Coral translocation

Coral translocation is the technique of relocating corals, usually to improve coral populations in places under stress from the environment or rehabilitate damaged reefs. The main objective is to relocate coral colonies to more favourable conditions where they have a better chance of survival. Coral fragments or entire colonies are carefully removed and then moved to restoration areas.

Coral transplantation

Obtaining coral larvae or fragments from healthy populations, raising them in controlled conditions (like coral nurseries), and then relocating them to damaged reefs is a method of transplantation.

In Lakshadweep islands, large extents of dead coral reefs and rocky intertidal areas are observed. In these islands, transplantation of corals can serve as an ideal management strategy for conservation and development of new coral colonies.

A recent study was conducted by Department of Science and Technology, Lakshadweep Administration, with an aim to develop an effective transplantation method by establishing a coral nursery in the Kavaratti lagoon, focusing on the use of fast-growing coral species to facilitate the rapid restoration of degraded reefs.

Coral nursery development

Coral fragments were collected from different locations of the lagoon, including the intertidal zone, inner reef lagoon, reef crest of the atoll, etc., to obtain different fragments grown in different conditions and locations in the lagoon. Coral fragments of both acroporid and non-acroporid corals that naturally grew in the lagoon and other areas were collected and placed in artificial substrates (concrete blocks) and monitored for their survival and growth rates for 2-year period during Jan.2016 – Jan.2018 (Riyas *et al*., 2024). Growth rate of acroporid corals was higher than non-acroporid corals. It was reported that establishment of a coral nursery also led to increased habitat for marine life and fish aggregation, contributing to enhanced biodiversity and ecosystem resilience.

Coral nursery can be developed in the lagoon area using both acroporid and non-acroporid coral species. Coral transplantation can be taken up in suitable locations around the island and in lagoon areas, for coral restoration of the island (Ramesh *et al*. 2020).

Transplanted coral fragments deployed in the lagoon bed at Kavaratti (2016 to 2018)

Well-developed coral colonies in the transplantation site after two years (2016 to 2018)

Source: *Riyas et al. (2024) Successful establishment of a coral nursery for active reef restoration in Kavaratti Island*

Creating awareness

Knowledge and awareness of economic / ecological importance of coral reefs is crucial to their preservation and long-term management. Such awareness should be created to the stakeholders, including general public, students, fishermen, tourist operators, government and non-government organisations, etc.

In order to educate the community on the importance of coral reefs, including their role in biodiversity, coastal protection, and livelihoods (such as fishing and tourism), workshops, seminars, and school programs should be organized. Also, locals should be involved in coral conservation initiatives, such as restoration projects, reef monitoring, and sustainable fishing methods, in order to cultivate a sense of responsibility and involvement.

Recommendations

- Establishment of a coral nursery has been demonstrated successfully in Kavaratti Island lagoon. It is recommended that coral nursery may be developed in the lagoon of Kadmath Island.
- Coral restoration / transplantation program shall be implemented in suitable sites, in order to improve coral reef coverage.
- Restoration / increase of coral cover will improve fish aggregation, increasing ecological stability and biodiversity.
- Restored coral reefs will also result in increase of fish populations, benefiting local fishing communities and promoting eco-tourism and livelihood opportunities.
- The expertise of Zoological Survey of India also can be used to implement coral conservation plan.

Budget Estimate for Coral nursery and Transplantation

Budget required for coral nursery and transplantation for three years management was worked out to be Rs. 50,00,000/- and the details are given below.

S. No.	Budget for Coral nursery / Transplantation	In Rupees
1	**Coral Nursery development**	**10,00,000**
	Boat rent charges	
1	Boat rent collecting site (Rs. 5000 per day X 20 days)	1,00,000
2	Boat rent recipient site (Rs. 5000 per day X 20 days)	1,00,000
3	Boat rent for three years monitoring (Rs. 5000 per day X 120 days)	6,00,000
	Total	**8,00,000**
	Labour charges	
1	Labour charge for collections and packing (20 days)	2,50,000
2	Labour charge for recipient site (20 days)	2,50,000
	Total	**5,00,000**
	Staff charges	
1	Scientists (1 X 50000 X 24)	12,00,000
2	Assistant (1 X 20000 X 24)	4,80,000

S. No.	Budget for Coral nursery / Transplantation	In Rupees
	Total	**16,80,000**
	Major equipment	
1	SCUBA gears (4 nos.)	6,00,000
2	Air Compressor (1 no)	1,40,000
3	Underwater camera with housing (2 nos.)	2,00,000
4	Maintenance / Service of Equipments / accessories	80,000
	Total	**10,20,000**
	Grand Total	**50,00,000**

*In total, a sum of **Rs. 50 lakhs** is allocated for 5 years for the coral conservation plan.*

Conclusion

According to the CRZ map, no coral sub zones were demarcated in the approach trestle, jetty and finger jetty areas. However, the present underwater coral transect study indicated live corals in 9 transects (T2, T5, T6, T8, T10, T11, T4, T9 and T12) out of total 16 transects. The presence of mix of live and dead corals, algae, and rubble indicates some level of biological activity and habitat complexity. In order to increase coral cover, coral transplantation of coral fragments at suitable sites are recommended. For this purpose, Rs. 50,00,000 shall be allotted for three years.

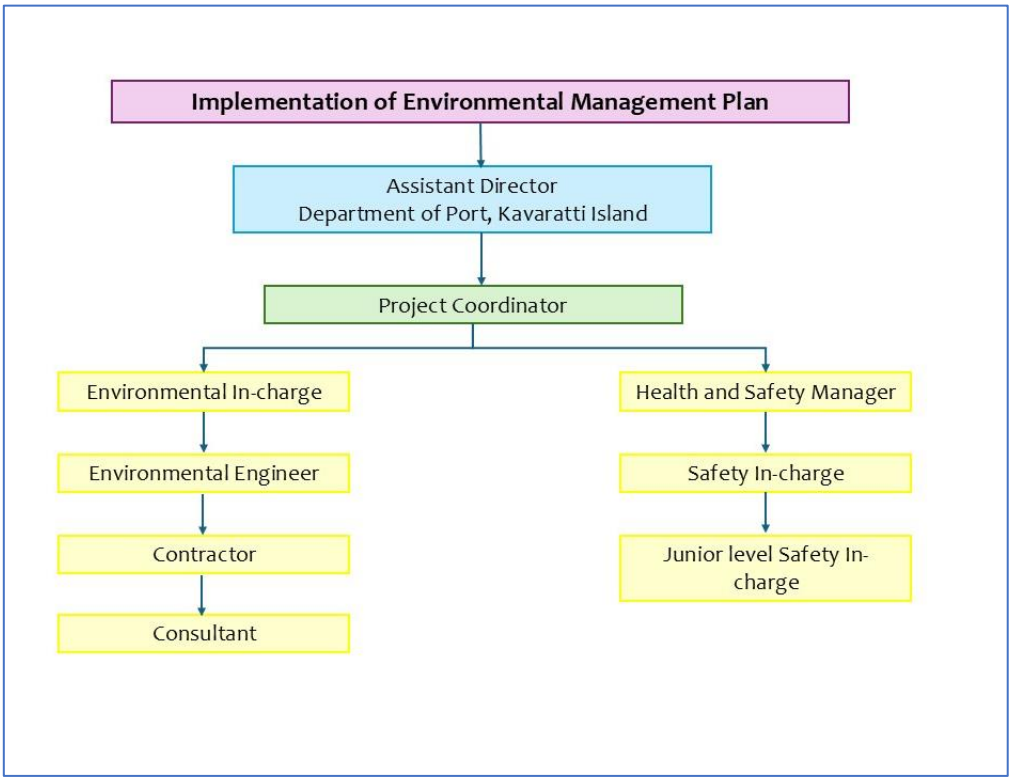
9.4. Environment Management Cell

EMC will be headed by the person who have qualification and reported to the MoEF&CC committee.

- Preparation and implementation of Environmental Supervision Plan during construction.
- Ensuring adequate training and education to all staff involved in environmental supervision.
- Implement Environmental Monitoring Plan during construction and operation.
- Ensure effective communication and explanation of the content and requirements of the EMP to contractors and subcontractors.
- Provide appropriate and adequate resources allocated for the effective implementation and maintenance of the EMP.
- Review of EMP performance and implementation of corrective actions, or stop work procedures, in the event of breaches of EMP conditions, that may lead to serious impacts on local communities or affect the reputation of the project.
- Report any major environmental incidents that may have a significant impact on the surrounding environment.
- Evaluating the efficacy of the EIA, mitigation measures as stipulated in the EMP.
- Coordination with Lakshadweep Pollution control boards for prevention and control of environmental pollution.
- Carryout half yearly monitoring program and preparation of compliance report.
- To implement Environmental Clearance condition stipulated by MOEFCC.
- Maintain environmental monitoring records.

9.5. Implementation of EMP

Overall implementation of EMP will be the responsibility of EMC. Various implementation items, description, and appropriate time to implement EMP are listed below.



EMP Implementation flow diagram

9.6. Communication and reporting

Training: Training shall be given to the workers during the construction and operation phase for identification of various hazards, methods to combat and responsiveness to emergency preparedness etc.

Communication: Information with respect to any untoward incidences during the construction and operation of the project shall be communicated to local Gram Panchayat, local village workers, and other project-related individuals. Environmental issues should be communicated to the concerned Govt. agencies such as LCZMA, Lakshadweep Pollution Control Board (LPCB), Forest and Environment Department, District Collector etc.

Reporting: The EMC will be responsible for conducting environment monitoring, compilation, and review of monitoring data, filling up the statutory forms/returns, maintenance of records regarding hazardous waste, environment awareness activities, submission of compliances six months EC compliance to State Pollution Control Board and MoEFCC regional office.

9.7. Environmental Monitoring and review

The EMC will continually review the EMP, and implementation of the mitigation measures described in Chapter 4 to assess the effectiveness of the proposed measures. The management will conduct periodic review to ascertain effectiveness of the EMP as follows:

- Take routine annual review of the EMP.
- Review of EMP after an accident or significant non-compliance is reported.
- Examine report and findings of the post project monitoring results and evaluation submitted by the EMC from time to time.
- Assess feedback from workers/stake holders and take action where necessary.

9.8. EMP Budget

The adequate budget allocation to operate EMP is necessary to make resource available for its effective implementation.

Based on the EMP for the proposed project discussed in above, the budget allocation required is estimated to be about ₹.1.25 Crore. The break-up of the proposed budget is given below.

Sl. No.	Environment Management Plan	Cost/year (₹.)
1	Environmental Monitoring Programme	25,00,000
2	Environment Management Cell	25,00,000
3	Labour, Safety and Cleanliness Management	25,00,000
4	Solid waste management	25,00,000
5	Post project monitoring	25,00,000
Total		1.25 Crore

Appendix - N

1.1.1.5 HANDLING EQUIPMENT AND GANGWAY

(i) **Details of 25T Crane**

Since the proposed berth is a multipurpose one and the nature of cargo will be varying, it is proposed to provide one hydraulic lifting cranes of 25T lifting capacity at the eastern jetty. As part of the scope, Contractor is required to provide one hydraulic lifting cranes of 25T lifting capacity at the eastern jetty.

a) Crane Type:

Pick-n-Carry Crane with minimum 25 tons lifting capacity.

b) Engine:

Fuel Type: High Speed Diesel

Power: 70kW and 300NM

c) Speed:

Min 25kmph

d) Drive

4 Wheel Drive

e) TELESCOPIC BOOM

Three part telescopic zoom with hydraulically operated extension

f) Reach and Height

Reach of atleast 14m from front axel

Lift Height of 15m from ground

g) Weights(@ Operating Site):

- Front Axle Load : 8,500 kgs
- Rear Axle Load : 13,000 kgs
- Total Load : 21,500 kgs

h) Dimensions:

- Overall Length : 12,750 mm
- Overall Width : 2,670 mm
- Overall Height : 3,100 mm
- Wheel Base : 4,800 mm

(ii) Gangway

Also to facilitate embarkation and disembarkation of passengers to and from the vessels, it is proposed to provide a gangway of length of about 12m and minimum width 1m at the eastern jetty as per specification provided in tender drawing.