STUDY ON SAND DUNES AND THEIR MANAGEMENT PLAN AT ANDHRA PRADESH

PROJECT: DEVELOPMENT OF GREENFIELD NON-MAJOR PORT AT RAMAYAPATNAM IN PRAKASAM DISTRICT OF ANDHRA PRADESH

Reply to MoEF&CC:
Plan should also detail out sand dune protection and restoration

For

ANDHRA PRADESH MARITIME BOARD
GOVERNMENT OF ANDHRA PRADESH

Through

THE INFRASTRUCTURE PEOPLE
RITES LIMITED, GURGAON

December 2021

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1. INTRODUCTION

Andhra Pradesh Maritime Board, Government of Andhra Pradesh has proposed to develop a Greenfield Non-major port at Ramayapatnam in Andhra Pradesh to meet the ever-increasing cargo demand in the State and Hinterland. The location of proposed Ramayapatnam port spreads centering around Latitude: 15°01’09” N and Longitude: 80°03’09” E. It is located at southeast corner of Prakasam District in Gudluru Mandal and east of Tettu Village. The location map of the proposed Ramayapatnam port and the port layout are shown in **Figs. 1** and **2**.

Need for the report

The Andhra Pradesh Coastal Zone Management Authority (APCZMA) has given permission for the development of the Port vide the letter no. 327/CRZ/Port/2021 on 18 September, 2021.

Environmental and CRZ clearance for the proposed development of port was sought during the 278th meeting of the MoEF&CC Expert Appraisal Committee Expert Appraisal Committee (EAC) of Infra 1 on 27.10.2021.

The EAC has asked to prepare and submit a detailed plan on sand dune protection and restoration measures under item no. 3.1.30 (iii) in the Minutes of Meeting.

Accordingly, the Sand Dune Management Plan has been prepared by Indomer Coastal Hydraulics (P) Ltd., Chennai, which is an ISO 9001:2015 organization and QCI - NABET accredited organization vide NABET/EIA/2023/RA 0207 dt. 29.07.2021.

<u>The report complies the requirement of MoEF&CC on the requirement of the Sand Dune Management Plan.</u>

2. CLASSIFICATION UNDER ECOLOGICALLY SENSITIVE AREAS

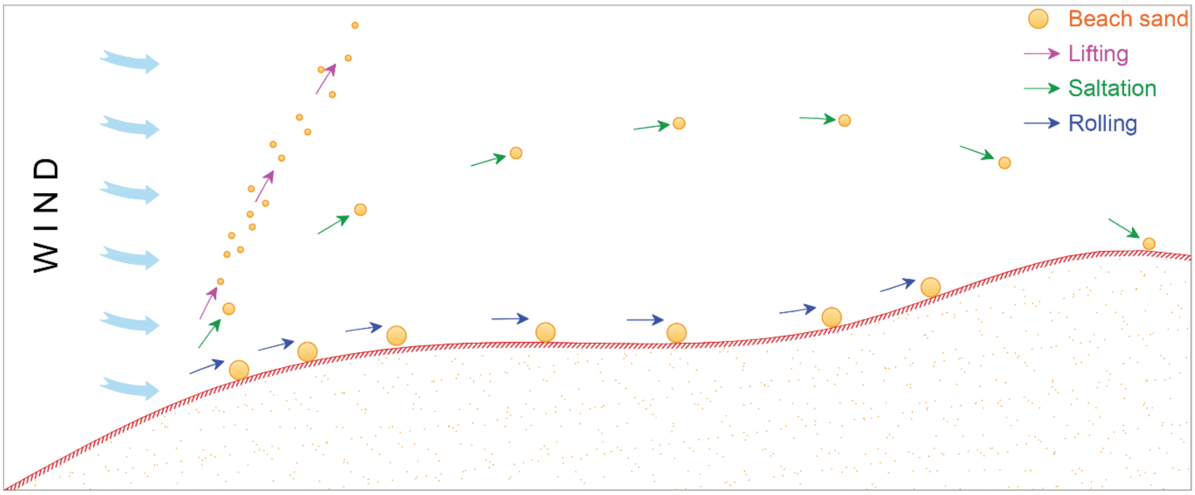
The proposed port will be spread over an area of 3437.10 acres, i.e. 802.70 acres in Phase I and 2634.40 acres in Phase II. In CRZ notification 2011, Para 7, item (i) CRZ I, the areas classified under Ecologically Sensitive Areas (ESA) are listed. The details of such areas are:

(a) Mangroves,
(b) Corals and coral reefs,
(c) Sand Dunes,
(d) Mudflats which are biologically active,
(e) Protected areas under the provisions of various acts,
(f) Salt Marshes,
(g) Turtle nesting grounds,
(h) Horse shoe crab habitats,
(i) Sea grass beds,
(j) Nesting grounds of birds and
(k) Areas or structures of archaeological importance and heritage sites.

Referring to CRZ map prepared by Institute of Remote Sensing (IRS), Anna University, there are four small patches of sand dunes in the project site which is shown in **Fig. 3**. This feature is demarcated as CRZ IA in the CRZ map.

3. DESCRIPTION OF SAND DUNES

Coastal sand dunes are formed by the littoral drift washed to shore by waves, beach building up, subsequent landward drift by wind. The beach sand is transported by component of shoreward wind and get drifted inland. The drifting of the sand particles takes the form of lifting, saltation and rolling or traction leading to the formation of series of dunes. Movement of beach sand is shown below.

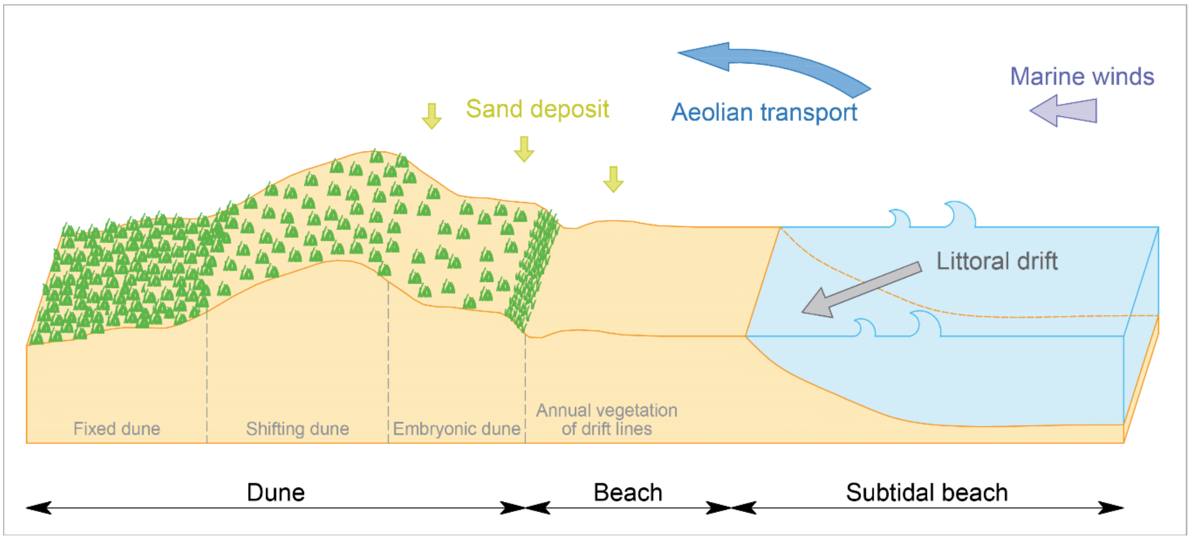


Movement of beach sand

The dunes at first form like ripples then migrate with wind transporting the dune form into the land by simultaneously increasing its height and width. Obstacles such as vegetation, fences, rocks and other geographic features trap and arrest the moving sand grains. As the sand grains get trapped, they start to accumulate and this is the start of dune formation. The typical formation of sand dunes is shown below.

These coastal sand dunes form as spatial transition between marine and terrestrial environments. It is a vital and essential formation of morphology by nature to act as the protection of the land against the vagary action of the sea from strong waves, coastal flooding, cyclones and tsunami. The size and width of the accumulation of beach dunes are proportional to the quantity of supply of the sand to the shore and intensity/duration of wind. Mostly the littoral materials are brought by the eroded sediments brought through the river discharge particularly during flood season.

Originally the sediment brought by littoral drift are supplied by eroded sediments inland brought by the flood water from rivers and the upgradation due to wave action on rocky headlands.



Typical formation of sand dunes

Classification of sand dunes

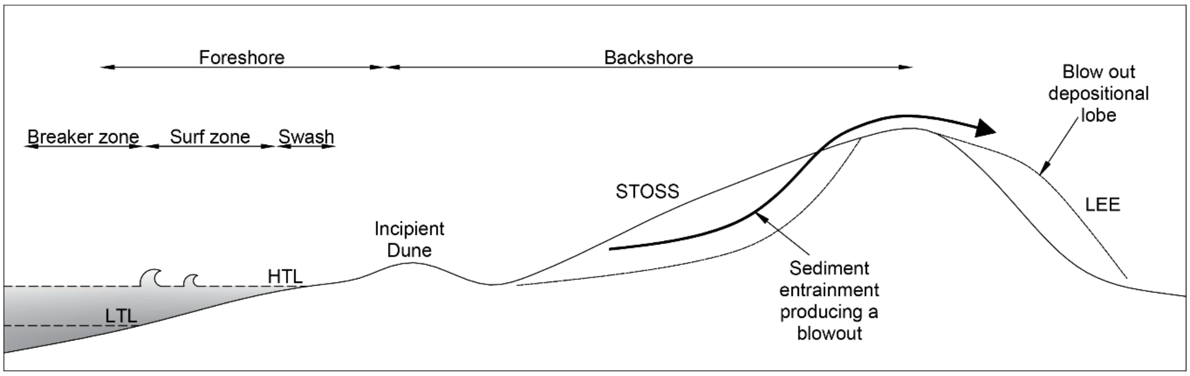
The stretch, rows and width of dunes take the shape depending upon the incoming wave characteristics, quantity of littoral drift, volume of sediment supply from rivers, wind velocity and direction, wind duration, vegetation on the shore and geomorphology of the shore. The pattern of sand deposition, accretion and erosion within the coastal environment result in the development of a variety of dune morphologies. The dune formation can be classified into two types as: i) Primary dunes and ii) Secondary dunes. The primary dunes are composed of sand blown directly from the beach face called active beach, whereas the secondary dunes develop following the subsequent modification of primary dunes.

3.1. Primary dunes

Primary dunes are formed with the supply of sand derived primarily from the beach face. The grown up vegetations play major role by arresting downwind drift in the development of the dune. They are seen closer to the shoreline, dynamically linked to beach processes, and significantly influenced by wave action.

Foredunes

Foredunes develop at the rear of the backshore environments (landward of the active beach) and generally comprise shore-parallel, convex, symmetrical to asymmetrical dune ridges. The morphology of foredunes is varied but they can be classified into three main types: incipient foredunes, established foredunes, and relict foredunes. Formation of foredunes is shown below.



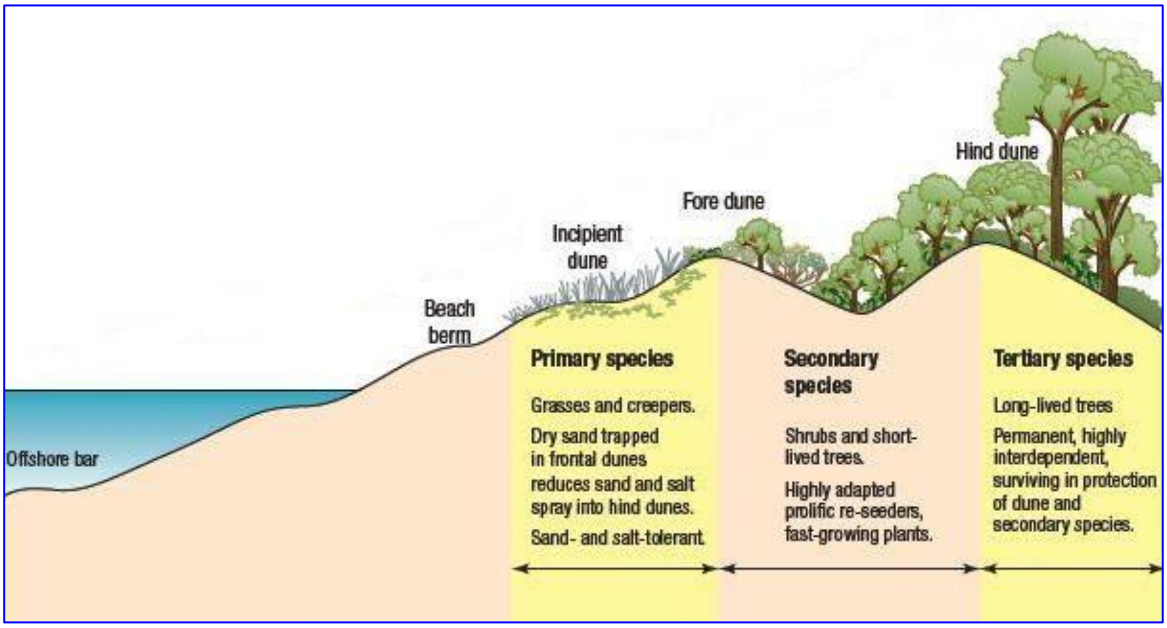
Foredune formation

Foredunes are the initial dunes which accumulate above the high spring tide mark and form due to the presence of some roughness element at the rear of the beach that rapidly reduces wind flow velocities, resulting in sediment accumulation. Driftwood sometimes forms the focus for the initial accumulation of dune sand, but vegetation is the most common roughness element that contributes to the formation of incipient dunes. Incipient foredunes are sometimes ephemeral features, tending to be eroded or completely removed by severe storm events at irregular intervals varying from a few months to several years, but they may survive and grow to become a larger established foredune, or become relict and stable as a new incipient foredune develops to seaward.

Established foredunes (also termed as frontal dune) also originate at the landward edge of the beach parallel to the shoreline. They develop from an incipient foredune and have a greater height, width, age, and/or morphological complexity. As an incipient foredune builds up, sand inundation and salt spray level decreases, while nutrient level and vegetation cover increases resulting in more stable dunes. The lee slope (i.e., the landward slope) is gradually often (but not always, depending on the latitude and coastal climate) colonised by a range of woody or shrub plant species that prefer more stable conditions. Sand is gradually deposited on the seaward slope, and sometimes the crest of the dune, which slowly becomes larger, forming an established foredune.

Foredunes tend to be largest at the rear of dissipative beaches because of higher sand transport rates, but other factors may also influence foredune height. Particularly important is the length of time a foredune remains adjacent to the beach receiving windblown sand. If not eroded away or replaced seaward by a new foredune, elevations of 20 m or more may be reached, but the higher the dune the greater the wind shear and the greater the likelihood of blowouts (erosional saucer and trough-shaped hollows). Foredunes are lower where a coast has prograde (built seawards) rapidly. This is because the rapid growth of each new foredune to seaward cuts off the supply of windblown sand to the previous foredune before it can accrete (build upwards) to a significant height.

If the sediment supply is adequate, a new incipient dune may form seaward of the established foredune, resulting in the established foredune being relatively isolated from the sediment supply. The isolation of the dune, coupled with coastal progradation, can result in the development of successive foredunes that may eventually form a wide foredune plain. This may consist of dozens of relict foredune ridges, which are usually parallel with the coast and mark former shoreline positions as shown below. The best examples, with relatively unmodified ridges, are of Holocene age, while older Pleistocene dunes generally have a more subdued topography, with greater soil development and often indurated horizons.

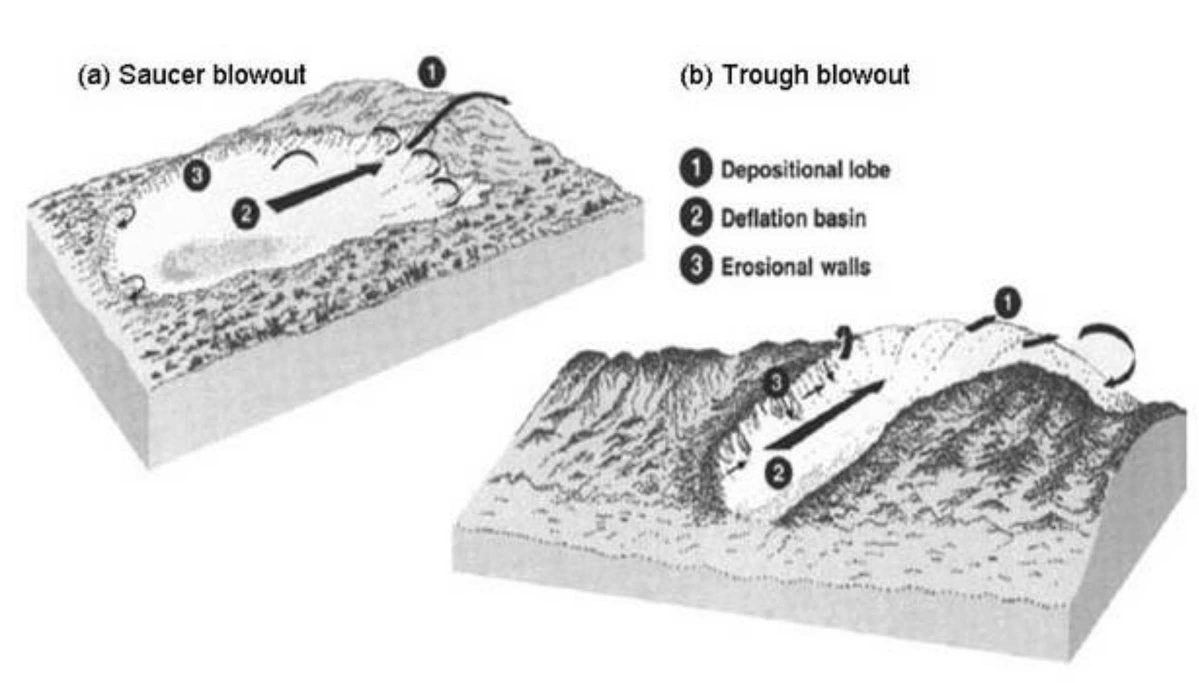


3.2. Secondary dunes

Secondary dunes are the result of the subsequent modification of the primary dune by continued aeolian processes, and are generally located further inland, separated from nearshore processes. The main secondary dunes include blowouts, parabolic dunes and transgressive dune fields. However, that parabolic and transgressive dune field dune types may also occur directly from the beach and are therefore also primary dunes when this occurs.

Blowouts

Blowouts commonly occur in the foredune or within and on older vegetated dunes. Blowouts are erosional dune landforms that are typically trough bowl or saucer-shaped depressions or hollows formed by wind erosion of a pre-existing sandy substrate or dune as shown in below figure. The breaching may occur naturally after erosion of the foredune by storm waves or by funnelling of winds through saddles (lows) in the crest of a high foredune or wherever there is a reduction in the vegetation cover, thus decreasing the local roughness and increasing the potential for sediment entrainment.

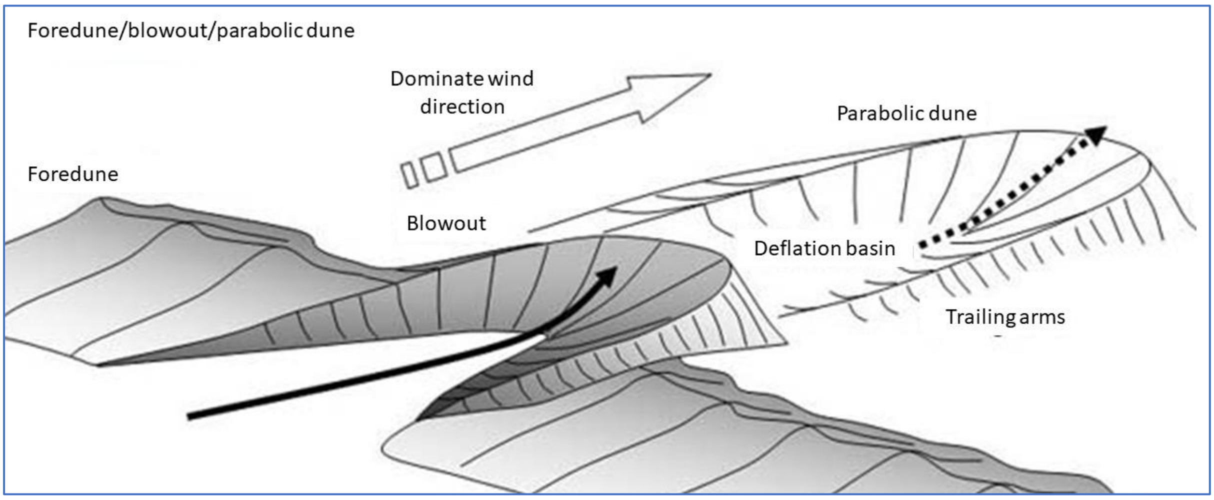


Types of blowouts secondary dune formation

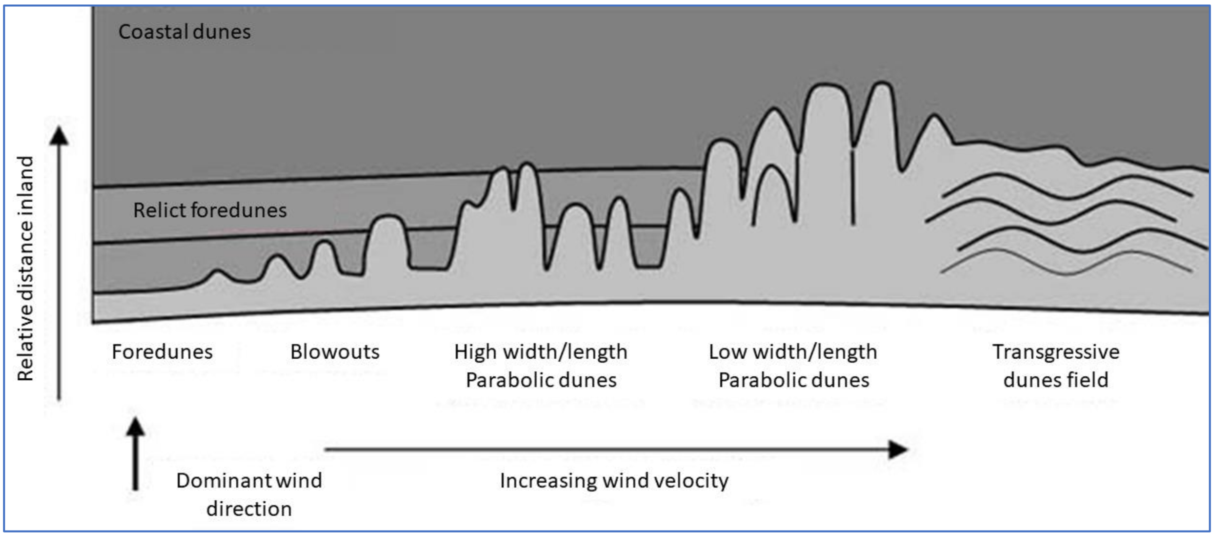
Although blowouts may be highly variable in their morphology, they can be classified into three main types:

- Saucer blowouts are shallow, semi-circular, ovoid or dish-shaped hollows, that often develop on relatively flat dune terrains. They are characterised by having steep marginal rims and flat to convex downwind depositional lobes.
- Bowl blowouts are deep, semi-circular to circular basins, characterised by long steep inner slopes, and more developed depositional lobes.
- Trough blowouts are generally narrow, and elongate with deeper deflation floors and basins, steeper and longer erosional lateral walls or slopes, and more pronounced deposition lobes.

The wind flow structure in a blowout may be very complex and highly turbulent. Generally, the wind flow is locally accelerated through the blowout and a high-speed jet is formed. Thus, wind speeds in the blowout are significantly greater than outside the blowout and this leads to high rates of sand erosion and transport. Winds remove sand from the deflation basin and the lateral walls and transport it downwind. The erosional walls are then over-steepened, and slumping occurs. This causes the erosional walls to retreat, widening the blowout and supplying sediment to the deflation basin, which is then subsequently transported to the depositional lobe. The wind flow is maximised up the axis of the blowout (middle of the deflation basin) towards the depositional lobe. It experiences rapid flow deceleration over the lobe crest, depositing sediment in a radial fashion over the depositional lobe. Deflation basins tend to continue to erode until a base level such as water table level or a more consolidated surface is reached (e.g., old soil profiles, an indurated sediment layer), or a lag surface where coarser materials such as pebbles, shell, or pumice may have been concentrated. Many blowouts become larger over time and may evolve into parabolic dunes.



Geomorphological expressions and characteristics of foredune, blowouts, and parabolic dunes



Geomorphological expressions and characteristics of main coastal dunes in relation to relative wind velocity and landward progradation

Parabolic dunes

Continued transport of sand through blowouts often results in the development of parabolic dunes. These consist of an actively advancing nose and depositional lobe with two trailing arms that enclose a deflation basin. This produces a characteristic U-shape (i.e., parabolic) or V-shaped dune. As they develop over a period of time their long axis orientation is closely aligned with that of the dominant wind direction. Shorter and wider parabolic dunes form where there is a wider range of wind directions

There are two principal sub-types of parabolic dunes:

- Long walled parabolic dunes display long trailing ridges and extensive deflation basins. The trailing ridges may range from hundreds of metres to several kilometres in length. They are particularly well developed on relatively flat terrain, in regions of low heath or shrubland, high sand supply, and strong winds.

- Elliptical dunes: Some parabolic dunes display a shorter form, often with more semi-circular or elliptical deflation basins. Multiple phases of dune development results in the elliptical dunes overlapping each other in an imbricate fashion (stacked like roof tiles). They develop in a range of situations including wetter areas or on flat terrain where deflation depths are limited, locations where wind speeds are relatively low and sediment supply remains relatively high, on hummocky or relatively steeper terrain where significant downwind migration is impeded, where there are multi-directional winds, and/or in dense, tall vegetation where the rate of advance is low and migration is impeded.

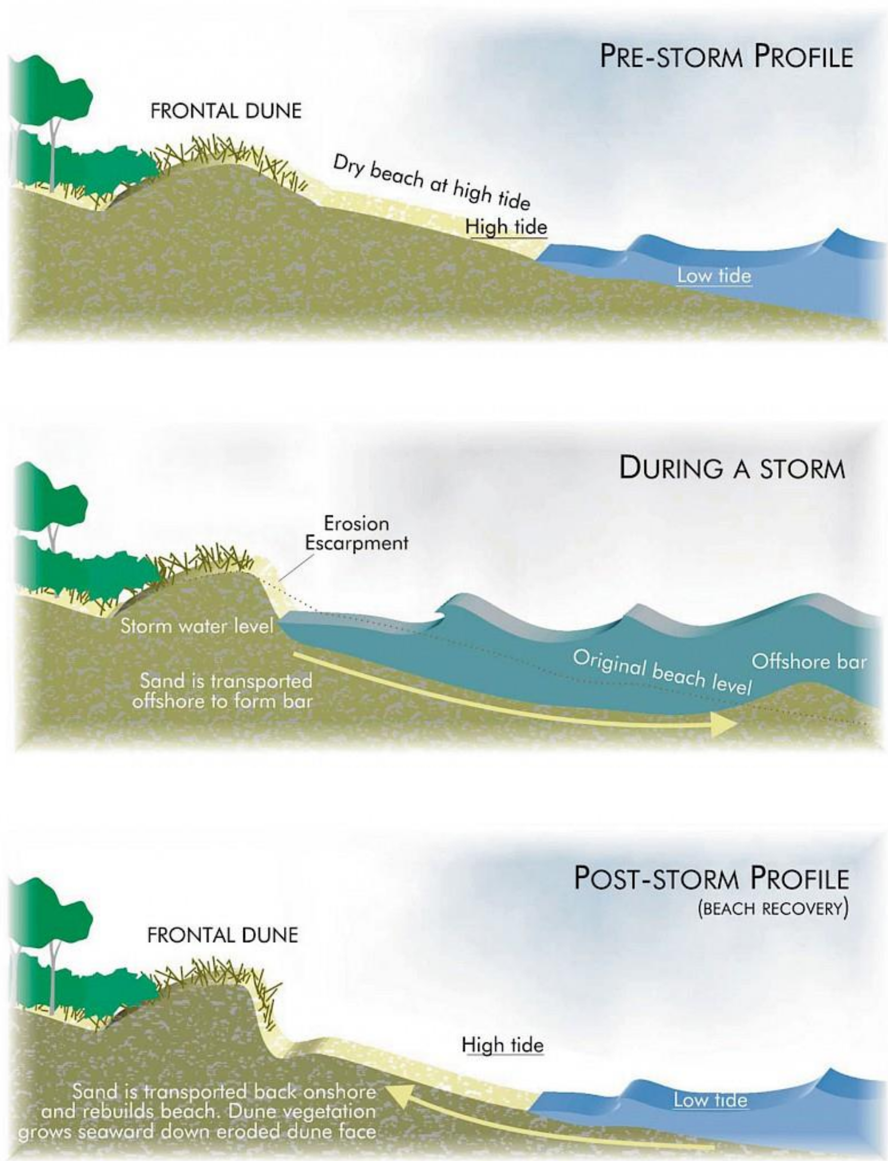
Transgressive sand sheets and dune fields

Transgressive sand sheets and dune fields are relatively large-scale aeolian sand deposits formed by the downwind and/or alongshore movement of sand over vegetated to semi-vegetated terrain. Transgressive sheets are relatively flat to undulating, largely dune-less sheets, whereas transgressive dune fields comprise various types of dunes on the surface. Transgressive dune fields have also been termed mobile dunes, sand drifts, and migratory dunes. Such dune fields may range from quite small to very large. They may be largely unvegetated, partially vegetated, or completely vegetated. They may be relatively featureless sand sheets or comprise a variety of dune types ranging from simple barchans, transverse dunes (dunes formed at right angles to the wind), barchanoidal transverse dunes to parabolic dunes.

4. IMPORTANCE OF SAND DUNES

4.1. Protection of coastal areas

Sand dunes serve a significant role on ecological stability of the Shore. The dunes are occupied by an extremely adapted cluster of plants and animals especially suited to life in such harsh conditions. Coastal sand dunes are very important in maintaining the geological formation of coastal areas that is important in sustaining the flora and fauna. Beach dunes are also a rich habitat for specific vegetation and wildlife. Natural sand dunes play a vital role in protecting our beaches, coastline and coastal developments from coastal hazards such as wave attack, storm surge, seasonal erosion, coastal flooding and Tsunami. Sand dunes also provide a supply of sand to maintain the stability of beach. The wider the band of dunes, the larger the reservoir of sand. Sand dunes acting as a natural barrier against extreme events like tsunami, storm surge and cyclone is illustrated below.



Natural Dune Dynamics – Extreme Events

4.2. Ecological and ethnobotanical significance

Before sugar was introduced into markets in south India, palmyra was a major plantation in southern Tamil Nadu from which jaggery was extracted. Jaggery was not only a major substitute for sugar. Jaggery extraction is still a source of livelihood for coastal communities in some parts of southern Tamil Nadu. The palmyra also yielded other useful products mats and baskets were woven from its fronds, and the tree trunks were used as poles and roof beams for houses. Further, the leaf fronds were and are used for thatching roofs.

The dunes are occupied by a highly adapted group of plants and animals especially suited to life in such harsh conditions. A few dune plant species are used for fish aggregation in traditional fishing. Sand dune legumes as cover crops in coconut (*Cocos nucifera*) basins serve as nitrogen fixers and provide green manure and mulch. They also serve as nutritious fodder for the livestock. Latex from *Launaea sarmentosa* is commonly used by fishermen to heal skin injury caused by fish spines while fishing.

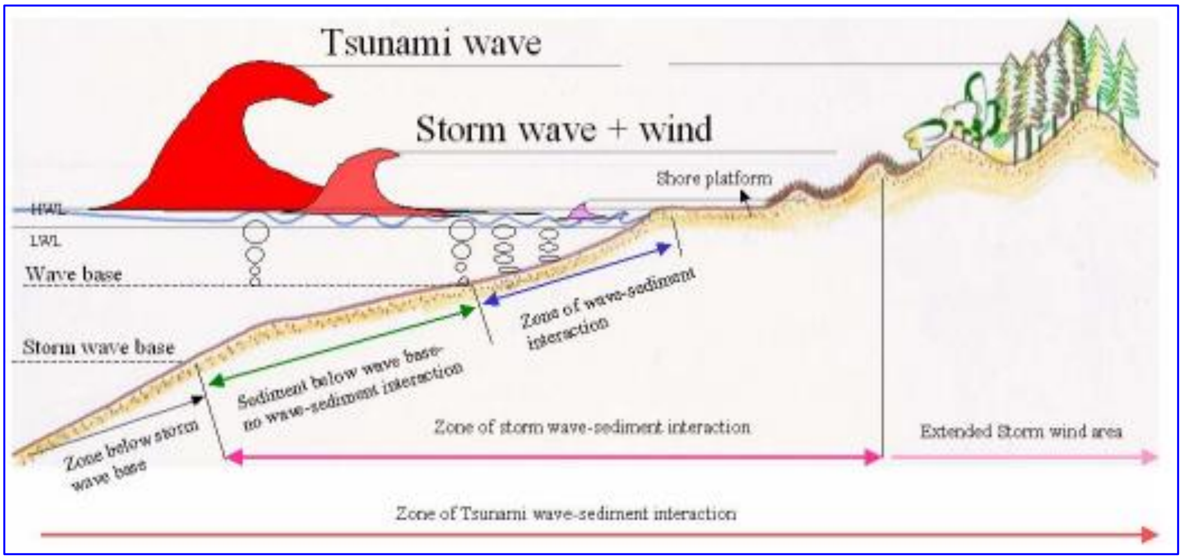
The dune plants let nesting turtles know they have reached a protected area of the beach to lay their eggs. Dunes provide an area for sea turtles to make their nests while the sea turtle nests help make the dunes healthier. Not many plants can grow in the sand at the beach because sand does not hold nutrients very well. All the sea turtle eggs laid will not hatch and not all of the hatchlings will make it out of the nest. This is an important natural cycle and the unhatched nest materials provide excellent nutrients for the dune plants use to grow bigger and stronger dunes.

4.3. Relation with fisherfolk

The beach space which includes the beach and the nearby sand dunes also are an important part of the social and day-to-day activities of fisherfolk. Foredunes and beaches are used for various purposes such as for landing boats, mending nets, auctioning of fish, sorting catch, drying fish and even for settlement. Further, fisherfolk prefer elevated regions of the coast (mainly on dunes) to build their houses, as this not only offers security from storms and waves, but it also affords them a direct view of the sea, which is vital for them to determine the direction of winds and the weather conditions prior to a fishing trip. Sand dunes are also closely integrated to the socioeconomic life of the coastal population living adjacent to them.

4.4. Protection from tsunami

Evidence of sand dunes as a defence against tsunami inundation is persuasive. Dunes act as windbreaks, protect against storm surges and tsunami inundation. During extreme events such as storms and tsunamis, this type of coast can act as a barrier for the area behind the dunes. Sand dunes and their vegetation cover are the best natural protective measures against coastal flooding and tsunami inundation.



4.5. Prevention of saltwater intrusion

Coastal sand dunes are vital in maintaining the groundwater level of coastal areas, which is vital in sustaining not only the flora and fauna, but also form an important source of freshwater for coastal populations. Dunes are known to prevent intrusion of saltwater into the fresh aquifers of coastal areas. Very often, extensive sand dune systems may have inter-dunal swales (freshwater bodies), which are low elevation areas located between dunes. Swales are otherwise known as dune slacks or inter-dunal wetlands. These water bodies are formed in areas where the water table is high. They act as sinks for the rainwater and help in recharging the aquifers. Swales typically support densely populated wetland plant communities that form a striking contrast with the surrounding dry vegetation.

The dunes provide water quality services through water filtration, nutrient cycling, nutrient uptake and water storage.

Waves wash over intertidal beaches and large volumes of water sink into the sand. This process filters particulate and dissolved organic material from the water. The organic matter is delivered to the interstitial animals (those living in the spaces between the sand grains). Beaches with sand particles of varying sizes, including small fractions, retain the greatest amount of organic matter. As such beaches with varying sized sands are most effective at removing organic matter from ambient waters.

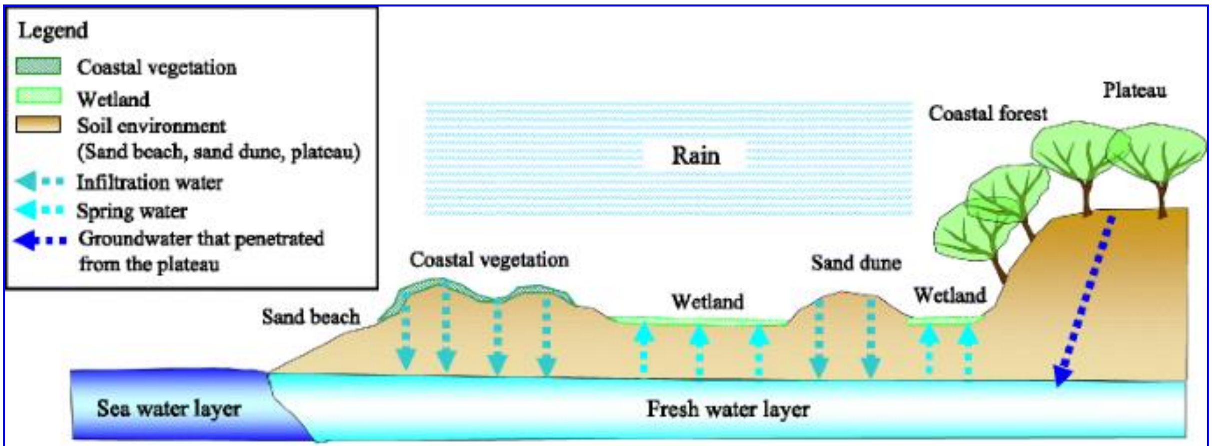
While ambient waters may be a source of organic matter, beaches have little primary production and are generally nutrient poor. Nutrients deposited on the beach are quickly processed. Nitrogen is cycled through the beach by the following processes:

- It is returned to the waterway from tidal and groundwater flushing.
- It is trapped in the beach and used by microbes or in-fauna.
- It is transferred to the groundwater.

- It is removed from the system by bacteria that convert organic nitrogen to dinitrogen gas. This process is called denitrification.

On the vegetated portions of the sandy shoreline, plants remove nutrients through the production of plant material. Some of this plant material is directly consumed by insects which are eaten by other animals forming part of the coastal food-web. Primary production not directly consumed provides detritus to the waterway and organic matter for the interstitial fauna on the beach.

The low areas between dunes, known as swales, are often areas of ground water discharge. Sufficient amounts of water in the swales can support the presence of a wetland community that can act to remove nutrient and other pollutants from the groundwater. The groundwater may discharge on the beach or in the nearshore.

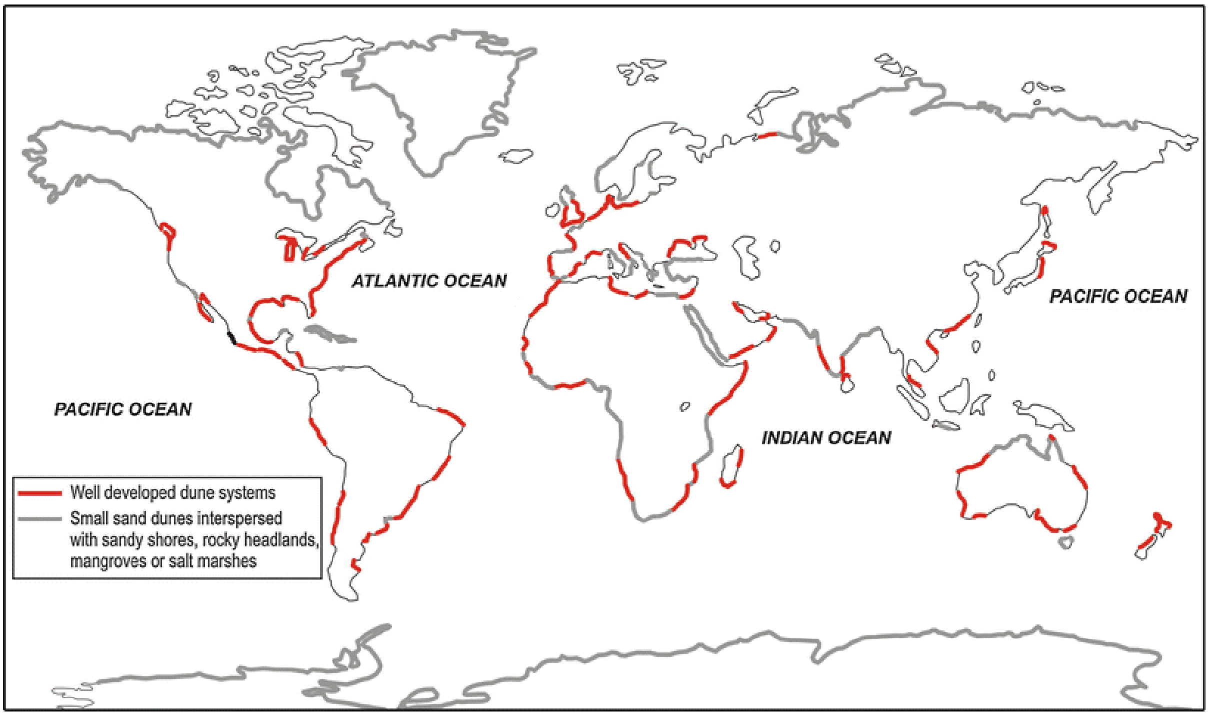


A coastal dune system is a buffer zone between the sea and land that forms a unique ecosystem.
The fresh water layer, which derives from the rainfall that infiltrates sands to a depth of approximately 10 m, is used as a domestic supply of drinking water etc, and the function of coastal area plays a roll as ecosystem service.

5. DISTRIBUTION OF SAND DUNES

5.1. Global distribution of sand dunes

Coastal sand dunes are found above the high-water mark of sandy beaches and occur on ocean, lake and estuary shorelines, as well as river mouths. They are most common along coasts exposed to strong winds and with abundant sediment supply. They occur in any climatic zone, from the Arctic to the Equator, meaning they are distributed almost worldwide as shown below.



Some examples of well-developed dune systems in the world are found along the Great Lakes, the Pacific and Atlantic coasts of USA and Mexico, the Gulf of Mexico, central America, Brazil, Europe (Great Britain, Ireland, western France, southern Spain, Denmark, The Netherlands and Poland), the Mediterranean, Southeaster Australia, South Africa, Indian east coast and Sri Lanka. In some places extensive coastal dune systems are lacking, but much of these coasts are comprised of long stretches of sandy shores interspersed with estuaries and rocky headlands.

5.2. Sand dunes in India

India being a peninsular country, with a coastline length of 8725 km having a breakup of 6631 km on main land; 1962 km on Andaman & Nicobar Islands; and 132 km on Lakshadweep islands. Among various forms of coastal morphology that define Indian coastline, the major form is the sandy beaches with dunes covering almost 60% of the system. The east coast of India is a classical one, covering almost 90% of coastline with sandy beach with dunes. The major rivers like Cauvery, Krishna, Godavari, Mahanadi and Brahmaputra bring huge amount of sediment to the littoral system and hence the formation of dunes is quite common along the east coast of India. Further the formation over geological years has created a very wide marine sand formation stretching inland reaching even 50 km wide particularly along the belts of Tuticorin, Nagapattinam, Pondicherry, Mahabalipuram, Krishnapatnam, Nizampatnam, Machilipatnam, Narsapur, Kakinada, Bhimunipatanam, Bhavanapadu, Gopalpur, Chilika, Konark, Puri, Paradip, Dhamra and Chandipur.

State wise Distribution of Sand dunes in India

Districts	Sand Dune distribution (acres)
Gujarat	16432.90
Maharashtra	1016.54
Goa	725.48
Karnataka	115.82
Diu & Daman	944.02
Tamil Nadu	7643.44
Andhra Pradesh	28650.42
Odisha	23924.55
West Bengal	652.28
Pondicherry	68.74
Total	80174.19

Source: *Assessment of Coastal and Marine Ecosystem Goods and Services - Linking Coastal Zone Management to Ecosystem Services in India - Sand Dunes, NCSCM, 2018-19.*

5.3. Sand dunes in Andhra Pradesh

The coastline of Andhra Pradesh is partly bounded by the Coromandel Coast (shared by Tamil Nadu and Andhra Pradesh) in the south and North Circars coast (shared by Andhra Pradesh and Odisha) in the north.

In general, the coastline of Andhra Pradesh is characterized by open beaches, sand bars, sand spits and river mouths. Coastal Andhra Pradesh forms between the Eastern Ghats and the Bay of Bengal, from the northern border with Odisha to Pulicat lake in the South. The length of Andhra Pradesh coast extends for about 975 km. The general characteristics of this coastal is comprised of spits, wide beaches, mangroves, mudflats, bars, barriers, lagoons, sand dunes, salt pans, etc. Coastal geomorphic features like deltas, dune system, red sediments beach rock etc. are prominent along Andhra Pradesh coast.

Sand dune distribution is high in Andhra Pradesh with an area of about 28,650 acres in 223 patches of various coastal districts. The distribution of sand dunes along coastal districts of Andhra Pradesh is given below.

District wise Distribution of Sand dunes in Andhra Pradesh

Districts	No. of sand dune patches	Sand Dune distribution (acres)
Nellore	120	18650.82
Prakasam	44	2587.96
Krishna	1	51.94
Visakhapatnam	18	770.79
Vizianagaram	4	65.06
Srikakulam	36	6523.85
Total	223	28650.42

Source: *Assessment of Coastal and Marine Ecosystem Goods and Services - Linking Coastal Zone Management to Ecosystem Services in India - Sand Dunes, NCSCM, 2018-19.*

5.4. Sand dunes in project site

An area of about 124.74 acres inside the project boundary is identified as sand dunes. There are four continuous patches of sand dunes found in the project region as shown in **Fig. 4**. The maximum width of each sand dune patch is given below.

Patch No.	Width (m)	Area (acres)
1	73	5.12
2	396	50.62
3	462	45.07
4	348	23.93
Total area		124.74

These sand dunes are elevated up to 1 to 1.5 m approximately. The sand dunes in the project region are found to be sparsely vegetated. Some of the common species found over the sand dunes in the project region are *Spinifex littoreus*, *Ipomea pes-caprae, Opuntia stricta*, *Calotropis gigantea, Casuarina equisetifolia*, *Borassus flabellifera* and *Vachellia nilotica*.

Sand dune at project region

Sand dune at project region

6. THREATS TO SAND DUNES

Sand dunes are a continuously evolving system and will respond to the change occurring in their local environment. Storm events and heavy recreational use can cause a significant detrimental impact on this fragile habitat. Some of the major threats that lead to degradation of the coastal sand dune ecosystems are detailed below.

6.1. Sand Mining

Coastal sand is rich in valuable minerals and metals and this has led to large scale mining of beach sand by large industries. Large scale extraction of sand from beaches impoverishes the supply of sand to the adjacent sand dunes altering coastal topography considerably. Sand is also extracted in large amounts for construction activities.

Impacts of sand mining are:

- Coastal sand mining affects the coastal terrain and leads to coastal erosion. For example, In Karnataka, rampant sand mining is leading to coastal erosion. The government is now forced to spend crores of rupees to form a barrier against coastal erosion.

- Depletion of sand from coastal areas results in deepening of rivers and estuaries, and the enlargement of river mouths and coastal inlets.

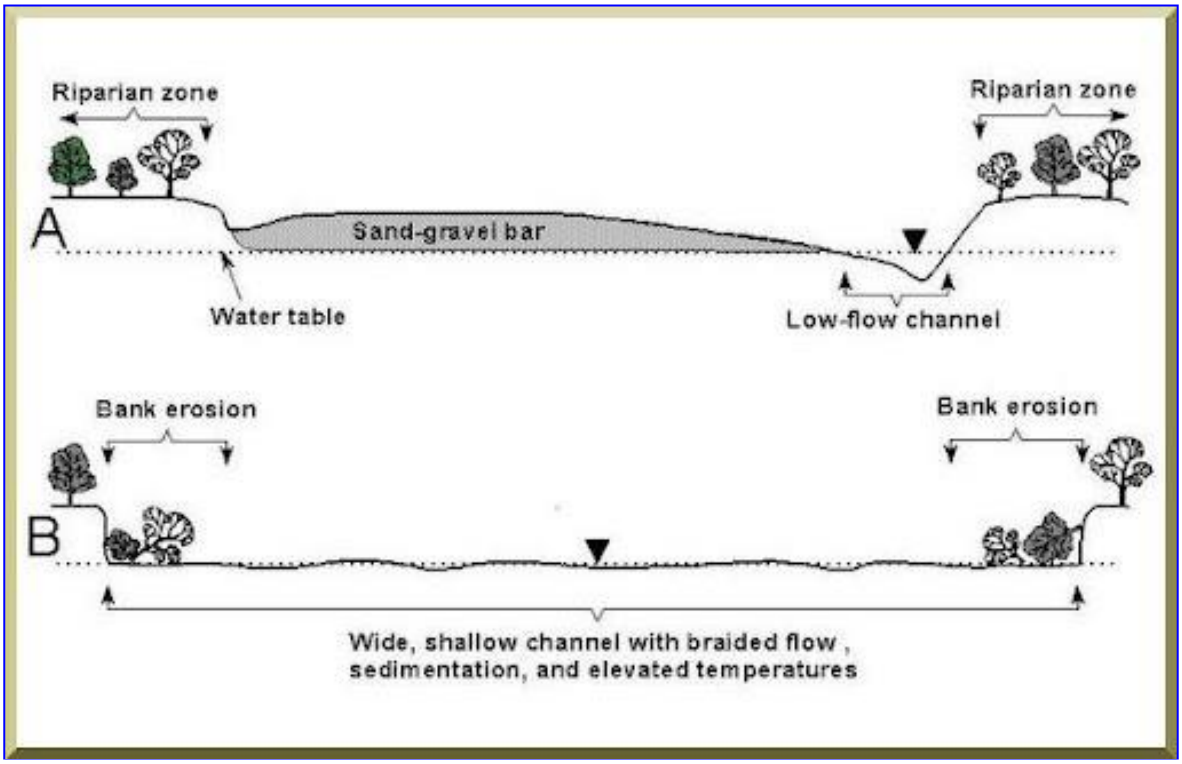
- Coastal sand mining may also lead to saline-water intrusion from the nearby sea and the effect of mining is compounded by the effect of sea-level rise.

- Coastal Mining disturbs the wildlife living in the beach ecosystem. For example, turtles such as the Olive Ridley Sea turtles arrive at beaches to dig nests in the sand and lay their eggs. After laying their eggs, the turtles cover them with sand to protect the nests from predators. When the hatchlings emerge, they move across the beach and enter the sea. However, when sand mining occurs in turtle nesting habitats, it leads to the loss of nesting sites.

- Coastal Sand mining may create turbidity in the water. The turbidity can create a barrier that prevents sunlight from entering the water, which is harmful to corals that need sunlight. Fish may also die-off due to a lack of food and oxygen in the turbid waters. Thus, the entire aquatic system may fail due to sand mining.

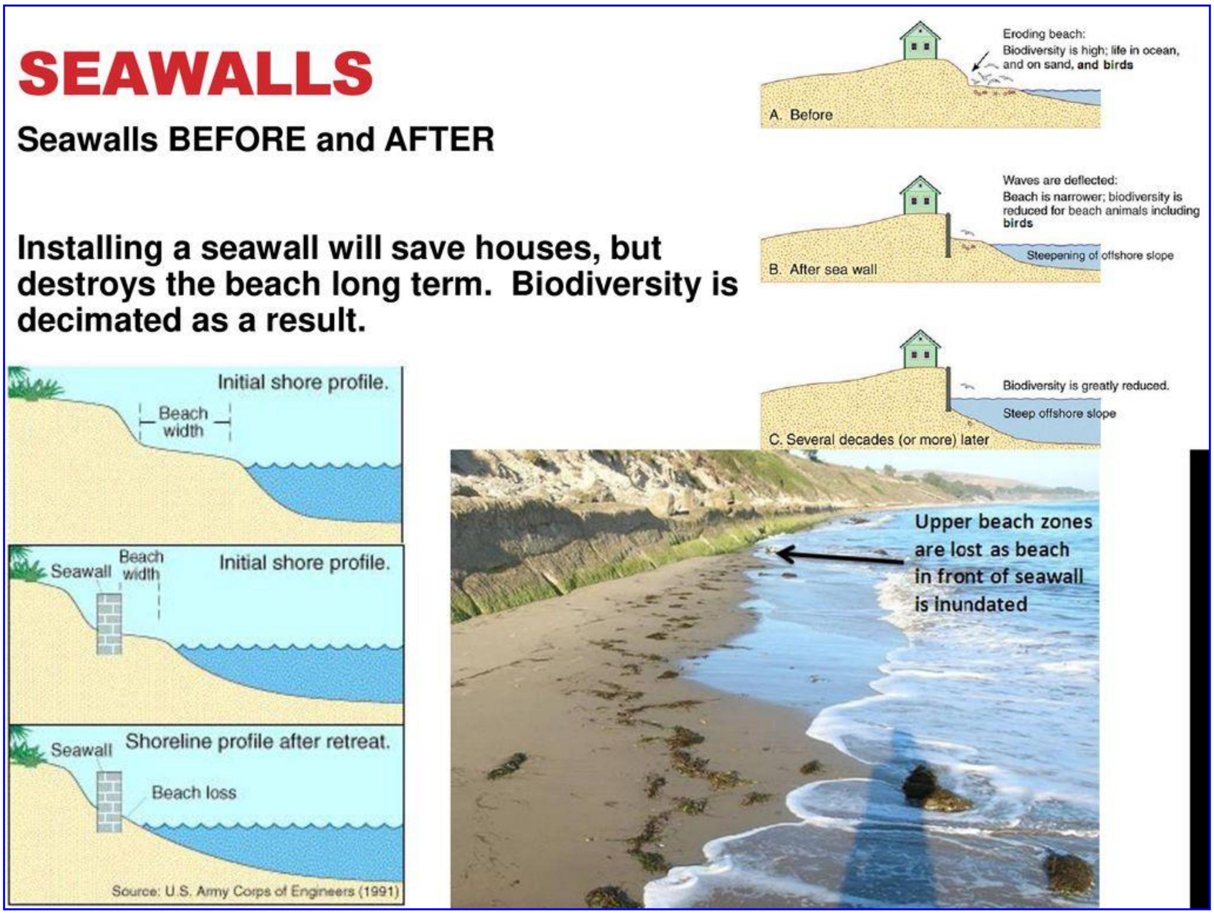
- Beaches, dunes, and sandbanks act as barriers to flooding. The sand mining removes such barriers. As a result, areas near the sea or river become more prone to flooding.

It is necessary that the state governments must ensure mining volumes does not exceed the predetermined sustainable mining quantity proposed. Strict measures must be put in place to ensure that the mining volumes don’t exceed that.



6.2. Construction of seawalls

The extent of coastline using seawalls for coastal protection erected for the most part to protect areas of housing and industrial development is increasing every year. Coastal sand dunes depend on the adjacent sandy beaches for their supply of sand. Building seawalls along the shores not only changes the sediment dynamics of the coast, leading to drastic changes in the natural balance between erosion and accretion, it also starves the sand supply on the adjacent sand dunes, leading to more erosion of dunes and making the coastline more vulnerable.



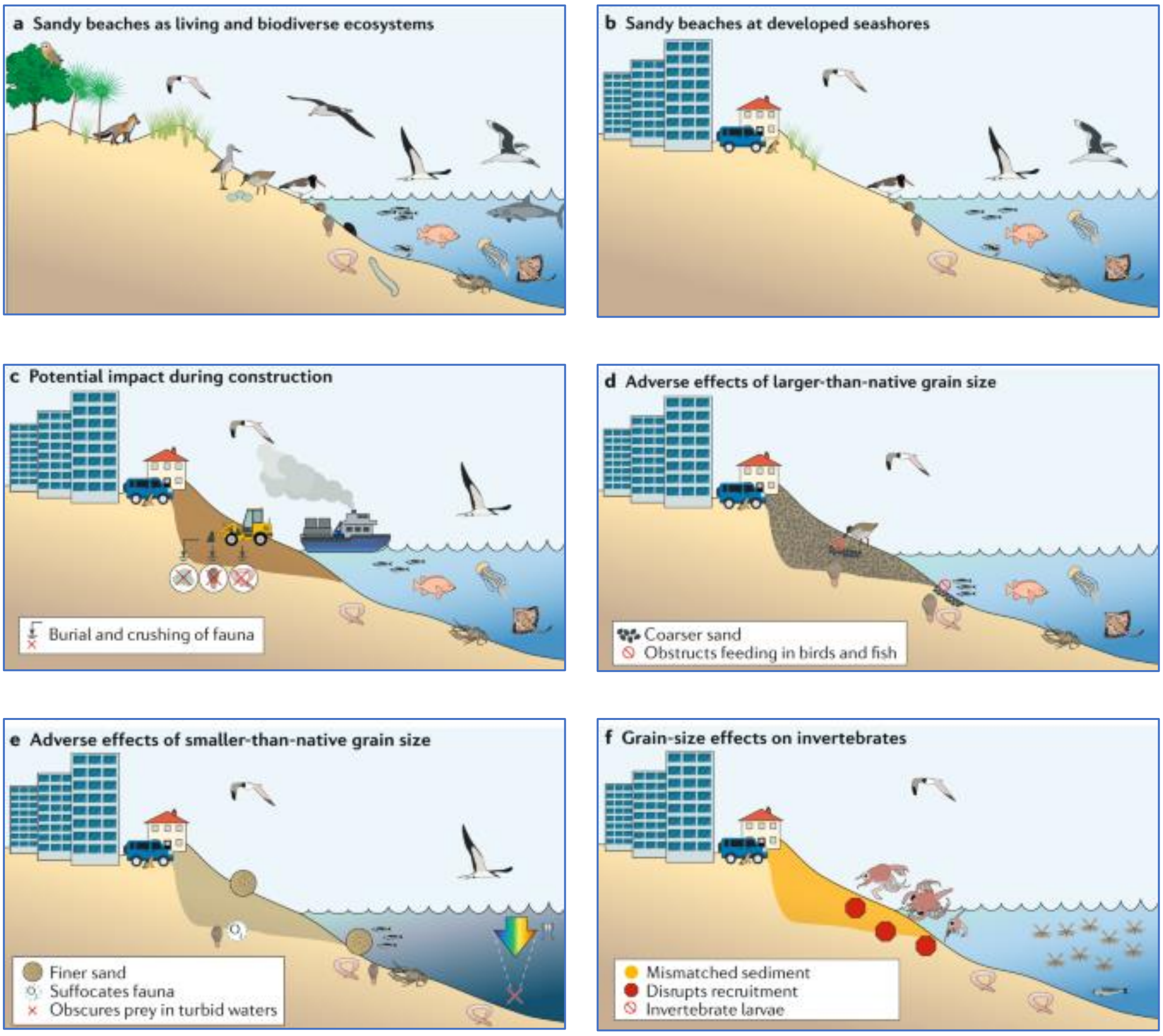
6.3. Infrastructural development

This includes housing estates and tourism related activities along the coastal areas that have degraded sand dunes considerably. Such developments increase recreational pressure and disturb natural, interdependent systems like topography, vegetation and water table levels, amplifying the need to undertake artificial coastal defence. They also prevent the natural retreat of the dunes. Future developments need to facilitate natural ecological processes, particularly along sections of the coast with natural sea defence.

Two major risks exist due to development of building in sand dune region

- Stability risk – is a result of the mobile nature of sand which makes up the sand dune. The removal of vegetation coupled with exposure to the wind can lead to the erosion of the sand dune and undermining of the foundations under buildings. Once this action commences, immediate engineering works are required to stabilise the situation to prevent possible collapse of a building. Vegetation plays a vital role in keeping sand dunes stable by holding the sand together and shielding it from the wind.

- Locational risk – the close proximity of sand dunes to the sea creates immediate risks in storm situations. Whether or not a sand dune is stable, it is possible on some exposed beaches for storm waves to attack the dunes and transport the sand out to sea. These situations are mostly beyond human control and houses nearest the frontal dunes are most at risk.



6.4. Pollution

Pollution, both on and offshore, can have detrimental effects on coastal flora and fauna. Beach pollution, especially from oil, can shift public pressure to the more sensitive foredunes resulting in greater erosion. Plastic flotsam and other non-biodegradable material on the coast lead to major changes in the sand budget of coastal areas. It also chokes the flora and fauna. Most common pollutants found in dunes and their main effects in dune community systems is given below.

Air:

- Chlorofluorocarbons (CFCs)
- Chlorocarbons (CCs)
- Methyl Chloroform (MCF)
- Organ bromides (OBs)
- Dioxins (NO_x)

From inland:

- Plastics and glass
- Organic matter

- Wastewater effluent
- Antibiotic resistant bacteria
- Agriculture - fertilizer & pesticides
- Municipal - Pathogenic bacteria, Filamentous fungus, Organic enrichment, Phosphorus & Nitrogen
- Mineral salts

From sea:

- Plastic
- Oil spills
- Ballast waters
- Heavy metals
- Radionuclides

Effects:

- Biodiversity (decrease)
- Abundance (decrease)
- Richness (decrease)
- Opportunists (increase)
- Tolerant species (increase)
- Sensitive species (decrease)

6.5. Grazing

Sand dunes are traditionally grazed by agricultural livestock. This has now mostly ceased and can lead to scrub encroachment.

6.6. Recreational pressure

This is one of the very serious threat to sand dunes and shingle habitats. Unlimited public access to coastal sand dunes leads to its deterioration and can accelerate erosion and blow-out formation.

Recreation activities severely impact dune systems and are often responsible for the damage and even destruction of habitats. Sandy beaches are the most popular areas of the seashore. In fact, more people use sandy beaches than any other type of marine or coastal habitat. As a consequence, recreation activities are tremendously concentrated which implies a high density of occupation. Recreation activities produce various impacts on the natural environment with extreme negative effects, one of the most important being trampling by animals and humans and crushing by vehicles. Dune vegetation is adapted to the stressful natural conditions and highly dynamic environment of sandy seashores however, it is very vulnerable to man-made disturbances such as those connected to trampling.

Off-road vehicles are usually used on beaches and dunes all over the world for recreation. Due to weight and type of motion, the damage caused by these vehicles is more widespread than that caused by human. The negative impacts they cause include damage of the physical properties and stability of the substrate, destruction of vegetation and disturbing, injuring or killing fauna. Direct mortality affects not only vertebrates like turtles and birds (destruction of eggs and young) but also invertebrates such as isopods, amphipods, crabs and certain echinoderms. The passage of motorised vehicles causes severe damage, the dune system taking years to recover.

6.7. Casuarina plantations

When trees like *Casuarina equisetifolia* are planted on fore dunes instead of hind dunes they do not serve as wind breakers but are uprooted and have detrimental impacts on the fore dunes instead of protecting them. Sand dune vegetation throughout the world has been recognized for its ecological significance. Natural disturbances have always been a part of beach and dune building processes. Ongoing abrasions, heavy load of salt spray, sand accretion and wave action are some of the natural processes that affect the coast. Dune plants act as an obstruction, increase surface roughness and cause reduction in the surface speed of sand carrying wind. The reduction in speed results in the deposition of sand around the plants. These cycles of sand deposition and growth result in dune formation. Spinifex littoreus and Ipomoea pes-caprae are two of the most successful sand trapping plants. They are known as psammophytes. Pioneer plants trap and hold the sand and create conditions which encourage development of taller plants.

Such plantations on dunes have been taking place on a large scale along the entire east and west coasts of India and this has had a major effect on large areas of dune landscape. Some sites hold large casuarina plantations which have the effect of suppressing the dune vegetation communities and lowering the water table. They also outcompete most of the local varieties of plants, causing considerable local reduction of biodiversity.

7. SAND DUNE VEGETATION - NATURAL PROTECTION

Sand dune vegetations or psammophytes comprise vital components of coastal sand dune habitats owing to their bioengineering role in sediment accumulation, sand binding and land building processes. Beach ecosystems in India have been studied for their physical, geological and restoration aspects. Although coastal sand dune ecosystems are categorized as ecologically sensitive, their floral and faunal composition is poorly understood. As such, a gap exists in the understanding of diversity, ecology and functioning of dune vegetation from the Indian coasts.

Coastal dune constitutes a variety of habitats essential for the maintenance of food webs and productivity. Sand dune vegetation comprises important components of coastal sand dune habitats owing to their role in sediment accumulation, sand binding and land building processes. Dune vegetation harbours many economically important species of plants like, *Casuarina equisetifolia, Borassus flabellifer, Eucalyptus* sp. in the coastal regions of India.

7.1. Threats for sand dune vegetation

The dune flora from India is subjected to various natural and anthropogenic pressures leading to a loss of habitat. The east coast is more vulnerable to natural hazards such as cyclones, storms and occasional tsunamis. The likely effect of an eventual sea level rise is also predicted. In comparison, most of the rich coastal sand dune habitats are located along the central west coast of India. The major threats arise from anthropogenic pressures, particularly tourism related activities and sand mining.

7.2. Dune vegetation in Andhra Pradesh

Sand dunes in Andhra Pradesh are low elevated having dominant vegetation of *Spinifex littoreus* and *Ipomoea pes-caprae*. There are 48 species of dune vegetation are found of which, *Abutilon indicum*, *Acalypha indica*, *Acanthospermum hispidum*, *Aeschynomene indica*, *Borassus flabellifer*, *Calotropis gigantea*, *Passiflora foetida*, *Prosopis juliflora*, *Senna tora*, *Spinifex littoreus* and *Tephrosia purpurea* are very common.

List of sand dune and associate flora in Andhra Pradesh

Sl. No.	Botanical Name	Family	Abundance	IUCN Status
1	Abutilon indicum	Malvaceae	Common	NE
2	Acalypha indica	Euphorbiaceae	Common	NE
3	Acanthospermum hispidum	Asteraceae	Common	NE
4	Acrachne henrardiana	Poaceae	Moderate	NE
5	Aerva lanata	Amaranthaceae	Least	NE
6	Aeschynomene indica	Fabaceae	Common	LC
7	Aloe vera	Liliaceae	Common	NE
8	Alysicarpus monilifer	Fabaceae	Moderate	NE
9	Anacardium occidentale	Anacardiaceae	Moderate	NE
10	Argemone maxicana	Papaveraceae	Least	NE

Sl. No.	Botanical Name	Family	Abundance	IUCN Status
11	Barleria noctiflora	Acanthaceae	Moderate	NE
12	Boerhavia diffusa	Nyctaginaceae	Moderate	NE
13	Borassus flabellifer	Arecaceae	Moderate	NE
14	Brachiaria ramosa	Poaceae	Moderate	LC
15	Brachiaria reptans	Poaceae	Least	LC
16	Bulbostylis barbata	Cyperaceae	Moderate	NE
17	Calotropis gigantea	Asclepiadaceae	Moderate	NE
18	Casuarina equisetifolia	Casureneiaceae	Moderate	LC
19	Catharanthus roseus	Apocyanaceae	Moderate	NE
20	Chloris barbata	Poaceae	Moderate	NE
21	Citrullus colocynthes	Cucurbitaceae	Moderate	NE
22	Cyperus arenarius	Cyperaceae	Common	LC
23	Cyprus rotundus	Cyperaceae	Moderate	NE
24	Dactyloctenium aegyptium	Poaceae	Moderate	NE
25	Enicostema axillare	Gentianaceae	Least	NE
26	Eragrostis amabilis	Poaceae	Least	NE
27	Gisekia pharnaceoides	Molluginaceae	Moderate	NE
28	Glinus oppositifolius	Molluginaceae	Moderate	LC
29	Ipomoea pes-caprae	Convolvulaceae	Common	NE
30	Kyllinga bulbosa	Cyperaceae	Least	LC
31	Kyllinga hyalina	Cyperaceae	Least	NE
32	Launaea sarmentosa	Asteraceae	Least	NE
33	Mollugo cerviana	Molluginaceae	Moderate	NE
34	Ocimum tenuiflorum	Lamiaceae	Common	NE
35	Opuntia stricta	Cactaceae	Moderate	LC
36	Passiflora foetida	Possifloraceae	Common	NE
37	Pedalium murax	Pedaliaceae	Least	NE
38	Percularia daemia	Asclepiadaceae	Least	NE
39	Prosopis juliflora	Fabaceae	Common	NE
40	Ricinus communis	Euphorbiaceae	Least	NE
41	Saccharum spontaneum	Poaceae	Least	LC
42	Senna auriculata	Caesalpiniaceae	Moderate	NE
43	Senna tora	Caesalpiniaceae	Common	NE
44	Sesuvium portulacastrum	Aizoaceae	Common	NE
45	Spinifex littoreus	Poaceae	Common	NE
46	Tephrosia purpurea	Fabaceae	Common	NE
47	Trachys muricata	Poaceae	Least	NE
48	Tribulus terrestris	Zygophyllaceae	Common	NE

NE - Not evaluated, LC - Least concern

7.3. Order of formation of vegetation on sand dune

Zone 1 (up to 100 m from shoreline)

Zone 1 would comprise of pioneer shallow rooted herb like, *Sesuvium portulacastrum*, creeper like, *Ipomoea pes-caprae* and Grasses like *Cyperus arenarius* and *Spinifex littoreus* on the frontal dune (**Fig. 5**). These species can withstand burial by sand and salt stress, as the foredune areas receive maximum salt spray owing to their proximity to the sea. *Ipomoea pes-caprae* would be ideal in the foreshore due to its occurrence and rapid vegetative propagation. The plant is estimated to generate about 446,000 plants per annum, through tissue culture, from a single nodal segment of *Ipomoea pes-caprae*.

Zone 2 (100 m to 200 from shoreline)

Zone 2 would consist of a mid-shore zone of herbs, medium-rooted shrubs and small tress. *Pedalium murax*, *Cyperus arenarius*, and *Borassus flabellifer* are some of the species which could be occupy this zone. Species from Zone 1 could also be used along with the shrubs so that a natural succession of vegetation is achieved. Within the 200 m *Casuarina equisetifolia* cultivations begins.

Zone 3 (200 m to 300 m)

Zone 3 could be represented by deep rooted coastal sand dune species of taller shrubs and trees such as *Acacia auriculiformis*, *Anacardium occidentale*, *Ziziphus* sp. and *Cocos nucifera* (**Fig. 5**). Although some of the plants (*Anacardium occidentale* and *Cocos nucifera*) proposed in Zone 3 are not native to the India, these species have been introduced centuries ago and have got naturalized in the area. Also, these trees provide socioeconomic benefits to the local inhabitants and, their influence on the native flora is insignificant.

7.4. Dune vegetation in project region

The survey conducted in the project region indicate presence of some vegetation with plants comprising *Prosopis juliflora*, *Calotropis gigantean*, *Borassus flabellifera*, *Spinifex littoreus*, *Ipomoea pes-caprae* and *Sesuvium* sp. *Spinifex littoreus* and *Ipomea pesr-carpae* is the most common creeper found in the study area occasionally forming open mats.

Prosopis juliflora

Calotropis gigantia

Borassus flabellifera

Spinifex littoreus

Ipomea pes-caprae

Sesuvium sp.

7.5. Sand dune faunae

Coastal sand dune fauna is limited and are generally neglected, especially in the Indian context. However, these species contain unique faunal elements. The harsh conditions on dunes have led to an impoverished faunal and floral diversity. But most of the existing organisms are highly adapted and specialised to overcome harsh environmental conditions. Vertebrates include reptiles like fan- throated lizard (*Sitana ponticeriana*), birds like sky larks (*Alauda arvensis*) and Indian roller (*Coracias benghalensis*), a few small raptors and mammals, especially rodents like common rat and mice and small carnivores like mongoose (*Herpestes edwardsi*).

8. SAND DUNE MANAGEMENT PLAN

8.1. General

Having understood the positive role played by sand dunes in protecting human life and property behind them, it is necessary to ensure that the dunes are protected from human encroachment, conversion of dune areas to accommodate the developmental needs by razing the dunes, mining of sand from dunes for construction etc. Protection of dunes through legislation is one of the most ideal way to ensure that no adverse effect of any sort occurs either to disturb the dunes or removing them for human needs. In India, the Coastal Regulation Zone (1991, 2011) declared the dunes as CRZ I areas meaning that they are environmentally and ecologically sensitive. This has ensured over the years, a restriction of developmental activities along the coastal areas including the dune areas. The major issue in the management of the dunes, is identification of the problem i.e., cause of destruction or dwarfing of dunes. Besides prevention of destruction through legislation, the management aspects include actions to stabilize the existing dunes and their reconstruction through defined methods. It may not be worthwhile to undertake these measures for the dunes that were destroyed by natural forces, as such dunes are likely to reappear in the following fair-weather seasons. This also applies to the shifting and unstable dunes which mostly belong to the foredunes. Therefore, management practices proposed for conservation, stabilization and reconstruction can alone by justified for the dunes affected by the human activities.

The management plan should essentially have following components:

- Identification and clear definition of the problem
- Establishment of achievable objectives
- Development of strategies to achieve objectives with involvement of all stakeholders
- Preparation of plan incorporating these components with implementation mechanisms
- Compatibility with other plans and policies

8.2. Proposed activities

The presence of continuous sand dune patches is identified across the coast of Prakasam District. Prior to the finalization of the port layout and facilities, the Coastal Zone was surveyed and the ecologically sensitive sand dune area (CRZ IA), has been demarcated and the project proponent has been advised to plan the developmental activities by avoiding the area to the maximum extent possible.

The layout is planned in such a way that the proposed project facilities are away from the sand dunes. The sand dunes will not be disturbed during both construction and operation phase.

8.3. Anticipated impact to sand dunes

- Cutting and destroying of dunes will result in beach erosion particularly during storm weather. However, the project doesn't envisage any such destruction over the stretch of sand dunes.

- Usage of dune area for storage/transportation of construction materials.

- Utilizing the sand from sand dunes for construction activities.

- Destruction of dune vegetation due to the foot print of port workers over the sand dunes.

8.4. Mitigation measures

The proposed development of port involves sand dune area within its project boundary. Dunes will not be cut or removed during the construction. In fact, the development will further strengthen the sand dunes to act against the action of waves, currents, tides and other natural disasters. These above features which will restrict the wind drift of the sand from the seaside into the land and it will help for building up of the dunes further. In case, the dune plantations are marginally affected by the proposed activities, it can be mitigated. The following effective strategies for management of the sand dunes should be developed for efficient dune management system.

- Suitable area with minimum disturbance to sand dunes must be selected for construction activities like stacking, storing, welding, etc.

- Possible plantation of dune vegetations with native coastal species must be examined in consultation with the forest department and to be implemented as a protective measure to manage the sand dunes. It will also help to improve the dunes further.

- No waste/sewage from port to be disposed on dunes at nearshore.

- Reduce human trampling in protected dune area.

- Take up local level education for village people on importance of sand dunes.

- Taking up back shore growth of sand trapping local vegetation belt in conjunction with forest department.

- Warning and awareness boards must be put up to avoid dune disturbance in the coast by the public. The sign boards must also be in regional language - Telugu.

Warning board

Awareness board

Sample boards

- Separate garbage management facilities for nearby villages to prevent dumping in the beach side.

- Plastic free zone establishment in dune area in conjunction with local level village heads to save the dune areas.

- Dune grass may be planted on the dunes to trap the sand at the eroding windward faces of dunes and to maintain their actual positions. This may also help to reduce the scouring effect of wind in blowouts and traps sand to fill them in secure areas of loose sand including blowout deposited areas.

- Dune Fencing: Construction of fences shall be adopted all along the seaward face of the dunes to decrease the speed of wind on the surface which also promotes the foredune deposition of transferred sediment. Fencing is also used to accumulate sand and to extend the width and height of existing dunes. It is also used to enclose stock, and to exclude people, to reduce grazing and trampling damage to vegetation.

- Development and campaign of planning policies and practices will endeavour to prevent or minimize the additional losses of sand dune habitat.

- Reviving of traditional sand dune restoration and management practices must be taken into account.

- Engagement and support (monetary and technical) to local communities for the restoration and protection of sand dunes and associated ecosystems.

- Dune thatching with brushwood is a low wind barrier which helps to entrap sand and protect the newly sowed vegetation. It must be worked from the top of a slope downwards. The top branches should not be protruded above the top of the slope since there is a possibility of the wind to grab them

8.5. Sand dune restoration

In cases where destruction of the dune system has passed a stage where simple methods such as removal of stress factors and protection may not reverse the damage, restoration efforts may be necessary. Dune restoration efforts not only help in dune formation, but also help in bringing back floral and faunal diversity, which previously existed in the healthy system.

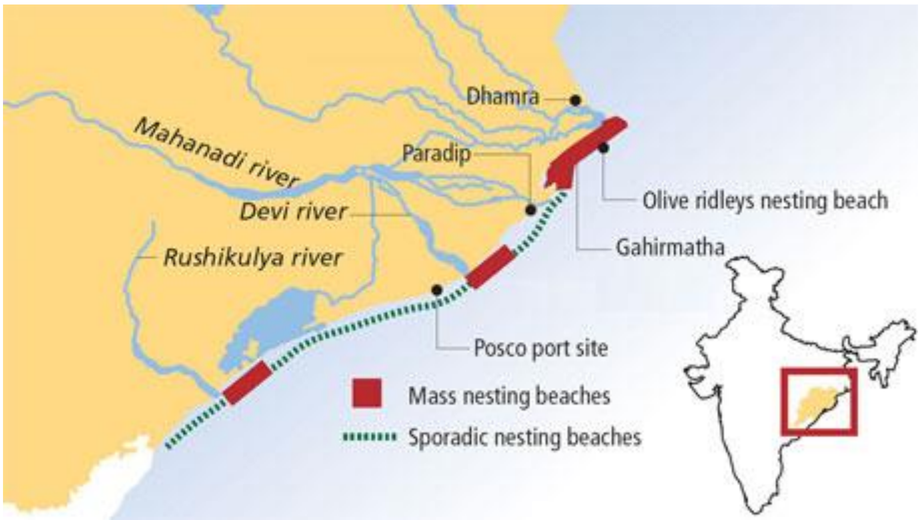
Sand dunes stabilization and restoration is being carried out in many parts of the world, but Faroda, 1998 did long-term study in the semi-arid regions of northwest India is the best suited approach to sand dune restoration in India. According to this literature, most sand dune stabilization programmes include:

- protection of the area from human and livestock encroachment
- creation of micro-wind breaks on the dune slopes, using locally available shrubs or materials either in a checkerboard pattern or in parallel strips
- direct seeding or transplantation of indigenous and exotic species
- plantation of grass slips or direct sowing of grass seeds on leeward side of micro-wind breaks
- management of re-vegetated sites

It is important to use locally available runners and shrubs for the stabilization of the sand dune slope. It has been reported that small shrubs and grasses are better sand binders than trees, and hence should be used for the binding of sand on the slopes. In consultation with the local and state forest department, the adaptive native species must be identified and appropriately considered for dune restoration or management.

9. COMPARISON WITH OTHER SAND DUNES IN INDIA

Sand dunes provide ideal location for turtle nesting. Odisha is well known for its turtle nesting site. Mass hatching of Olive Ridley turtles began at Odisha's Rushikulya rookery, a major nesting site of these marine turtles. However, sporadic turtle nesting sites are found through entire coast of Odisha.



Turtle nesting ground in Odisha

Gopalpur port is a deep sea port of Gopalpur in Ganjam District, Odisha. The port has been developed on the banks of the Bay of Bengal. The seaport increases the sea trade of Odisha, as well as industry and employment.

The turtle nesting sites and sand dunes are also located in the vicinity of Gopalpur port. The port has been in operation 1986. Through effective management of port, the sand dunes in the region are protected and the nature has been preserved ever since. As a result, turtle nesting sites are identified near the port.

Similarly, through effective management on development of proposed Ramayapatnam port the nature of the sand dunes will be preserved.

10. BUDGET ALLOCATION

For conservation of sand dunes, the project proponent is to form a separate sand dune conservation cell in consultation with Forest Department of Andhra Pradesh. This cell should consist of Environmental Coordinator, Environmental Engineer, Biologist, NGO (if needed), Environmental Consultant and Additional staffs from local. The cost for monitoring and the conservation actions for sand dunes for every year from commencement of project is given in the table below.

Budget allocation for Sand Dune Conservation Plan

S. No.	Particulars		Cost in lakhs per year (₹)
1	Monitoring of sand dunes		
	Beach cleaning		1.5
	Dune vegetation monitoring		2.5
2	Education and awareness program		
	Installation of awareness board in English & regional languages		1.5
	Educate port workers and other locals in the vicinity		2.0
	Create short awareness films to publish in social media		1.5
4	Implementation of Environmental cell		
	Environmental Coordinator	(12 x 50000)	6.0
	Environmental Engineer	(12 x 25000)	3.0
	Biologist	(12 x 25000)	3.0
	Additional staffs from local of 5 nos.	(12 x 15000)	9.0
5	Involvement of NGO		5.0
6	Involvement of Environmental Consultant		5.0
Total			40

Total cost for Sand Dune Management Plan per year = ₹ 40 lakhs

11. CONCLUSION

The proposed port operation at Ramayapatnam does not have any direct nor indirect impact over the sand dune environment. Thus, the nature of the sand dunes will be preserved even during the proposed port development. If in case any impacts are observed over the sand dunes in future, the Environmental Management Cell of APMB in coordination with Andhra Pradesh Forest Department will carry out mitigation or restoration plans for the affected sand dunes.

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