

**MANGROVE MANAGEMENT PLAN  
FOR SETTING UP 100 MLD DESALINATION PLANT  
FOR JWDL AT JODIYA VILLAGE, JAMNAGAR DISTRICT, GUJARAT**



**FOR  
JODIYA WATER DESALINATION LIMITED,  
NOIDA, UTTAR PRADESH**

**EIA CONSULTANT**



QS ISO 9001 Certified

QCI - NABET Accredited

NABL Accredited

DSIR - MoST Accredited

**INDOMER COASTAL HYDRAULICS (P) LTD.**  
**(ISO 9001: 2015 CERTIFIED, NABET- QCI, CDC - MoST & NABL ACCREDITED)**  
**63, GANDHI ROAD, ALWAR THIRUNAGAR, CHENNAI 600 087.**

---

**CONTENTS**

	Page No.
List of Figures	2
1 PROJECT OVERVIEW	3
2 PURPOSE OF THE REPORT	6
3 FIELD STUDY ON MANGROVES	7
4 PIPELINE CORRIDOR	11
5 QUANTIFICATION OF MANGROVES ALONG PIPELINE CORRIDOR	12
6 MANGROVE PLANTATION	13
7 DEVELOPMENT OF NEW MANGROVE HABITATS	18
8 POTENTIAL AREAS FOR MANGROVE PLANTATION	19
9 MANGROVE NURSERY	20
10 MONITORING OF MANGROVE	30
11 CONCLUSION	31

---

## LIST OF FIGURES

### Figure

- 1 Location map of the project site
- 2 Distribution of Mangroves around project region
- 3 Mangrove areas to be affected

## 1. PROJECT OVERVIEW

Gujarat Water Infrastructure Limited (GWIL) is the Government of Gujarat undertaking company which takes up various bulk water infrastructure projects across the Gujarat State. In order to meet the acute drinking water shortage in Jodiya, it has planned to set up 100 MLD Sea Water Reverse Osmosis Desalination plant at Jodiya village, Jamnagar District, Gujarat.

Proposed development includes the following:

- Seawater Reverse Osmosis (SWRO) Desalination plant of 100 MLD Capacity.
- Intake Channel of 10 m width and Raw water (Intake) pond of 396.7 m x 257 m.
- Brine reject outfall pipeline of 4600 m from Land Fall Point.
- Product water pipeline.
- Approach road of about 4000 m connecting desalination plant and Jodiya village.

The project site is located at Jodiya village, Jamnagar District, Gujarat. Project site is located close to decommissioned Jodiya Port bordering Und creek, Gulf of Kachchh (Fig. 1). The project site is an under developed area with presence of Marine National Park, Marine Sanctuary and Forest area under section 4 in the 10 km buffer zone. On either side of the banks of Und creek upto open sea, dense patches of mangroves are present.

### Seawater intake

Intake description: The seawater intake is planned through a channel connecting Und creek to storage pond, which will be active during the high tidal hours.

The coagulation-flocculation processes will be carried out in the intake channel and the decantation will begin. From the lagoon, the water will be boosted with the use of a total of (3 + 1) motor-pump groups equipped with floating sockets that will drive the water to the plant.

Intake volume: The seawater requirement for the plant will be 250 MLD.

---

**Outfall location**

Outfall location: Discharge point will be located at 4600 m away from Land Fall Point. The desalination plant will discharge the brine reject into the Open Gulf through designed outfall system. The RO concentrate will go directly to the outfall collector. The outfall chamber will also collect the effluent from other stages of the desalination plant.

Outfall Volume: The 150 MLD of brine reject will be discharged into the open Gulf. The salinity of the return water released into the sea will be about 76 ppt, which will have the salinity difference of 36 ppt higher than ambient salinity of 40 ppt.

The proposed construction of desalination plant in the marine environment includes laying of intake and outfall pipeline. Laying of outfall pipeline will affect the mangroves present in the banks of Und river along the proposed pipeline corridor. Mangrove map of project site is shown in Fig. 2.

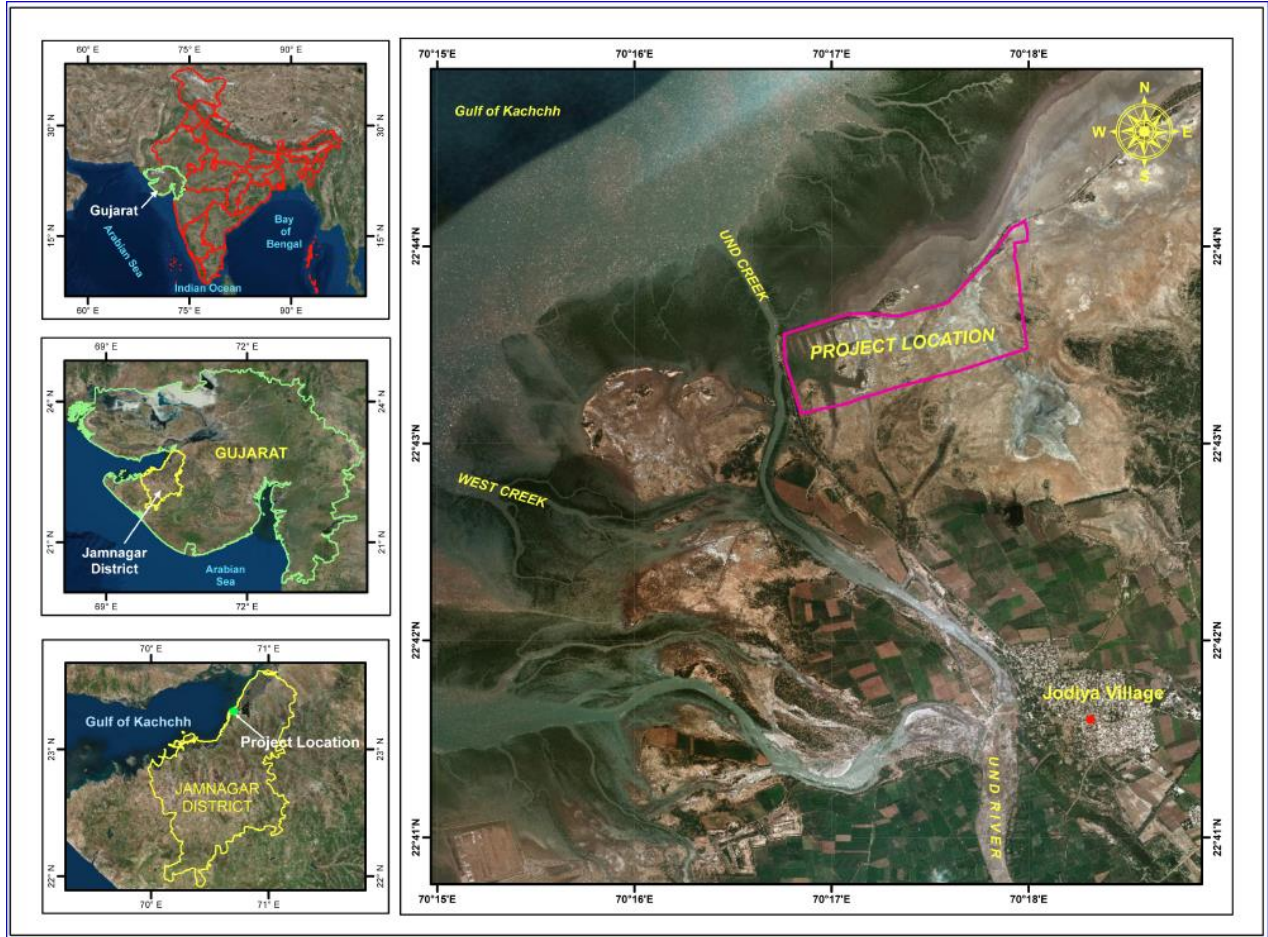


Fig. 1. Location map of the project site

---

## 2. PURPOSE OF THE REPORT

Proposed outfall pipeline corridor will be passing through the mangrove patches present in the intertidal region. Mangrove management plan has been developed to mitigate the impacts on mangroves during laying of pipelines and to suggest suitable afforestation program. Purpose of mangrove management plan developed includes the following:

- To suggest suitable mitigation measures to minimize the destruction of mangroves in the vicinity of pipeline corridor.
- To suggest suitable afforestation program to compensate the mangroves affected,
- To outline the mangrove monitoring program.

### 3. FIELD STUDY ON MANGROVES

As a part of Marine Ecology and Biodiversity study, the presence of Mangroves and their distribution were carried out in May- June 2018. Dense mangroves having height of about 2 to 3 m are seen along the banks of the creek and in the intertidal region along the Gulf of Kachchh. The distribution of mangrove patches is shown in Fig. 2. Mangroves remain as dwarf type within the fringing creeks while they are grown tall in the intertidal zone. Nine species of mangroves are observed which are indicated below.

- *Avicennia marina*,
- *Rhizophora mucronata*,
- *Bruguiera gymnorrhiza*,
- *Sonneratia apetala*,
- *Acanthus ilicifolius*,
- *Sesuvium portulacastrum*,
- *Salvadora persica* and
- *Suaeda* sp.

Among all, the *Avicennia marina* is seen to be most dominant species in the region. The following are the mangroves that were observed in the 10 km buffer zone.

Family	Species Name	Common/Vernacular name
True Mangroves		
Avicenniaceae	<i>Avicennia marina</i> var. <i>acutissima</i>	Tivar, Tavarian
Rhizophoraceae	<i>Rhizophora mucronata</i>	Tavar Loop-root or red mangrove
	<i>Bruguiera gymnorrhiza</i>	Ham Motitavar
Lythraceae	<i>Sonneratia apetala</i>	Kantaliyo, Holy mangrove
Acanthaceae	<i>Acanthus ilicifolius</i>	Tavar Loop-root or red mangrove
Mangrove Associates		
Aizoaceae	<i>Sesuvium portulacastrum</i>	-
Salvadoraceae	<i>Salvadora persica</i>	
Amaranthaceae	<i>Suaeda</i> sp.	
	<i>Salicornia</i> sp.	

### Mangroves and Mangrove Associates



Mangrove patches in the creek upstream  
(*Avicennia* sp.)



Mangrove patches in the creek mouth  
(*Avicennia* sp.)



*Sesuvium portulacastrum*



*Rhizophora mucronata*



*Salicornia* sp.



*Salvadora persica*





Mangroves in the Und creek



*Banks of Und creek is occupied with dense mangroves. Total of 9 species of mangroves and associates were observed near the project site. Avicennia marina is the most dominant, most common species of Und creek. This dense mangrove patches are observed 1.5 km away from desalination plant site and are notified under Marine Sanctuary.*

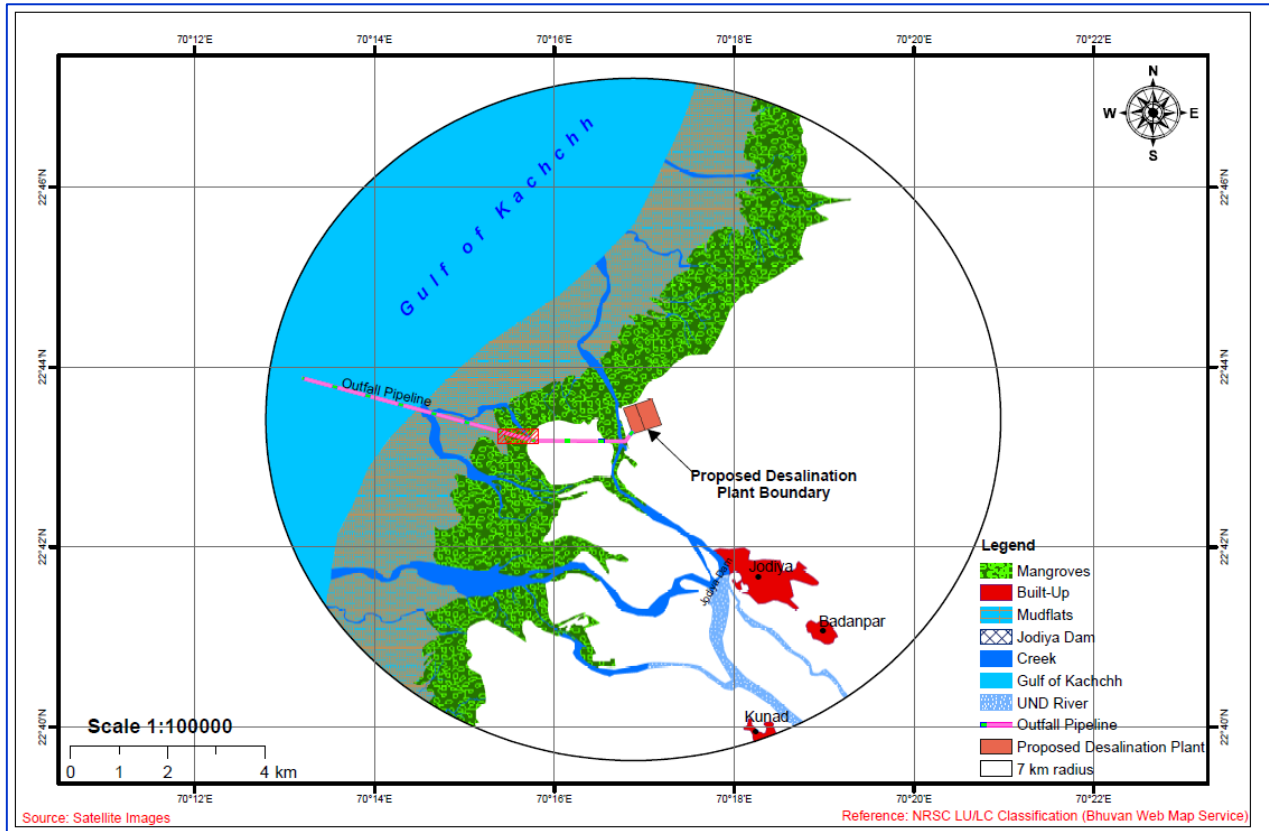


Fig. 2. Distribution of mangroves around project region

#### 4. PIPELINE CORRIDOR

The brine reject outfall is proposed at open Gulf at 4.6 km from the land all point. The outfall pipeline will pass through the existing mangrove covering a stretch of 500 m long and 10 m wide. Google earth view of outfall pipeline with mangrove area likely to be affected is shown in Fig. 3.

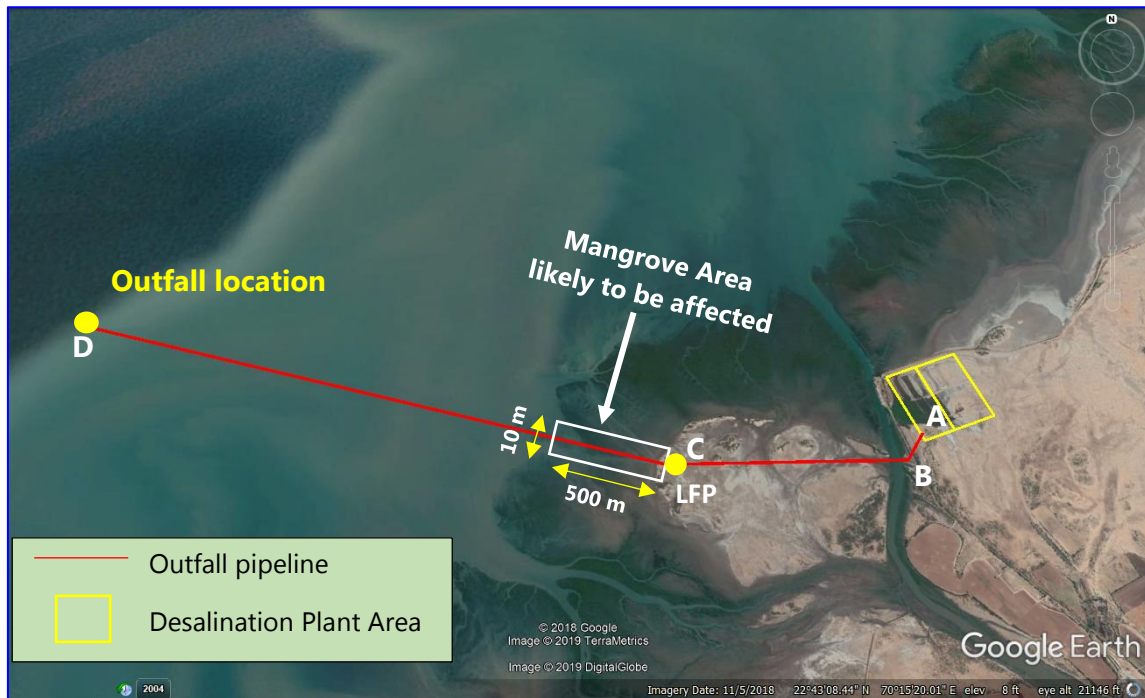


Fig. 3. Mangrove Area likely to be affected

The point A-B is having a pipeline length of 260 m, B-C is having 1740 m and C-D is having 4600 m. Careful planning of pipeline corridor has been taken care during the planning stage to avoid dense patches present on the Und creek. This has been ensured by routing the pipeline through intertidal area devoid of mangrove vegetation for about 2.1 km (inland). From Land Fall Point (LFP) to discharge point, pipeline of about 500 m length will pass through existing sparse mangrove patches towards the discharge point. Careful planning and field observation have been made to minimize the foot print on mangroves by selecting appropriate corridor of sparse mangroves.

## 5. QUANTIFICATION OF MANGROVES ALONG PIPELINE CORRIDOR

Calculation has been made to arrive amount of clearance required and to suggest suitable afforestation measures.

Length of pipeline crossing through Mangrove Area	:	500 m
Operational width including buffer zone during construction	:	10 m
Total Area likely to be affected	:	5000 m <sup>2</sup>

This pipeline corridor is dominated by *Avicennia marina* of 2 to 3 m height. It is estimated that the proposed outfall pipeline will directly affect mangrove patches present in the 5000 m<sup>2</sup>. The density distribution of the mangroves = 1 plant / 4 m<sup>2</sup>. Accordingly, about 1250 number of mangroves will be affected.

Clearing of vegetation in the proposed corridor will be done either using hand and land-based equipment in consultation with Gujarat Ecological Commission and District Forest Officer, Jamnagar.

Marking of working boundaries and education to workers about the importance of mangroves to avoid unwanted disturbance to mangroves existing outside operational corridor shall be done to avoid movement of workers and impact due to laying of pipeline.

## 6. MANGROVE PLANTATION

### ***Relevant Notification***

As per the MOEFCC OM J.11011/97/2003-IA dated 11.03.2010, the project proponent shall plant a minimum of 10 trees for every tree cut along the pipeline route in consultation with local District Forest Officer (DFO). However, Ministry has observed that there is a practical difficulty in implementation of the same due to non-availability of land along the pipeline route or in non-forest area land for compensatory afforestation. *It has been decided by Ministry that pipeline project will be subject to the condition that there is a provision for compensatory plantation of adequate width along the pipeline route or in non-forest area in lieu of the trees to be cut.*

### ***Afforestation Program***

As per Notification, adequate width along the pipeline is recommended. To compensate the loss of 5000 m<sup>2</sup> mangrove area where in about 1250 nos. mangroves will be affected, it is proposed to plant 4 times amounting to 5000 nos. of *Avicennia marina*, the most dominant and common species and *Rhizophora mucronata* in an area covering 20000 m<sup>2</sup>.

15 mangrove species have been reported from Gujarat state. They are *Avicennia marina*, *Avicennia officinalis*, *Avicennia alba*, *Acanthus ilicifolius*, *Aegiceras corniculatum*, *Bruguiera cylindrica*, *Bruguiera gymnorrhiza*, *Ceriops tagal*, *Ceriops decandra*, *Excoecaria agallocha*, *Kandelia candel*, *Lumnitzera racemosa*, *Rhizophora mucronata*, *Rhizophora apiculata* and *Sonneratia apetala*. *A. marina* is the most dominant species and accounts for about 97% of the mangrove cover of the State. *R. mucronata*, *C. tagal*, *A. corniculatum*, *A. ilicifolius* and *S. apetala* have localized abundance. (<https://forests.gujarat.gov.in>).

**Site selection:** The plantation can be made close to the proposed site where sparse mangrove patches are present. These species can be planted in areas where mangroves are likely to grow, will restore and enhance the diversity and ecosystem in the project area. At other places like north of bund, sparse mangroves are present. These areas and other nearby areas can also be explored for the suitability of afforestation. Young *A. marina* plants growing near the bund, offer more confidence for the proposed afforestation. However, it is recommended that mangrove

plantation shall be done at appropriate location at appropriate period, in consultation with District Forest Officer and Gujarat Ecology Commission.



Sites near the bund - potential areas for afforestation



Sites near the bund – New *Avicennia marina* young plants

### Stake holders in the Afforestation Program

- JWDL,
- Villagers of Jodiya Taluka,
- Forest and Environment Department, Govt. of Gujarat

- MNPCS, Jamnagar, Govt. of Gujarat,
- Department of Fisheries, Govt. of Gujarat, and
- Gujarat Ecology Commission

## Afforestation Methods

Gujarat Forest Department has developed three models of mangrove plantations, of which suitable methods shall be adopted for afforestation measures for the present program.

### i. Direct seed sowing

Direct seed sowing technique is used at the sheltered intertidal areas. This is because the strong tidal currents may wash off the seeds. The matured seeds and propagules are planted in such areas. Before plantations, the land is cleared from algal deposition and other unwanted materials. Subsequently, seeds and propagules are sown. The plantation is not irrigated as they receive tidal inundations through creeks. However, regular weeding should be conducted to remove algal deposition.



Mangrove reforestation in Gujarat: Direct seed sowing (Source: ISME)



Nursery development

### ii. Raised bed plantations

This model is unique and is used only in Gujarat due to high tidal amplitude of 2-10 meters with an average of 4-6 meters. As this plant location also comes under this tidal area, this method can be comfortably used for afforestation. This technique is used in the non-sheltered intertidal areas. Under this model, soil mounds of about one meter diameter and 15-30 cm height are prepared. Subsequently about 80-100 seeds or propagules are sown at each mound. The cluster of seeds/

propagule is able to withstand strong tidal currents. Although only few of the sown seeds/propagules eventually survive, the objective of creating mangrove habitat is fulfilled.



Raised bed plantations

### iii. Fishbone channel plantations

This technique is used in such intertidal area which are elevated and, therefore, do not receive regular tidal inundation. However, by improving inundation conditions, these areas become suitable for mangrove development. Thus, channels are dug similar to fish bone structure. The canal which opens in sea waters is called main canal and the subsidiary canals, aligned at 45 degree to main canal, are called distribution or feeder canals. The main canal is about 3 meter wide at top while two meter wide at bottom with height of 1.25 meter. However, the feeder canals are 1 meter wide at top and 0.80 meter wide at bottom having a height of 1 meter. The plantations are being raised at upper 1/3rd slope of feeder canal and the area between two feeder canals.



Fish Bone Channels at Pichavaram mangrove, Tamilnadu



Afforestation

In the low tidal amplitude area, 'canal bank planting' technique with 'fish bone' design is preferable for restoration; and, in the high tidal amplitude area, restoration will be made by direct seed sowing and seedling planting in the mud flats. In this regard, understanding of the planting site is necessary, especially, in respect of tidal amplitude, ground level height, salinity, soil texture and topography.

## 7. DEVELOPMENT OF NEW MANGROVE HABITATS

For the development of new mangrove habitats, Govt. of Gujarat carried out detailed survey of entire Gujarat coast and identified potential areas for mangrove afforestation. The potential areas have been categorized into three zones A, B and C.

Zone A Represents potential area which receives regular tidal inundations and where mangrove habitats can be developed without any treatment of land.

Zone B is a potential area which receives inadequate tidal inundation and is presently not suitable for mangrove habitat, however, it can support mangrove habitat after land treatment to increase the tidal inundation.

Zone C is a potential area which receives very occasional tidal inundation and cannot support mangrove species, however, mangrove associates can be raised in such areas.

The present project site will come under Zone A as the area experiences high tidal amplitude and continuous inundation. Both *Avicennia marina* and *Rhizophora mucronata* are the most suitable species for afforestation in these areas.

---

## 8. POTENTIAL AREAS FOR MANGROVE PLANTATION

Sparse mangrove patches along the proposed pipeline corridor (south) and near to desalination plant in Und creek, identified during baseline survey, can be considered for compensatory mangrove afforestation including development of nursey.

However, the mangrove plantation will be made in consultation with District Forest Officer and Gujarat Ecology Commission.

## 9. MANGROVE NURSERY

**Types of nursery:** Nurseries can be classified based on tidal location. A '**floating mangrove nursery**' is one established in upland areas (above the highest tidal range). This nursery is used to provide a longer-term supply of seedlings. A '**flooded mangrove nursery**' is established in low intertidal areas, which are regularly flooded by tidal waters. This kind of nursery provides seedlings for one or two-year planting projects and requires less effort in terms of setup and maintenance. (Source: *Mangrove Nursery Manual, GTZ, October 2010*)



A 'floating mangrove nursery' in upland locations requires frequent watering.  
(Source: *Mangrove Nursery Manual, GTZ, October 2010*)



A 'flooded mangrove nursery' on lowlying tidal lands is flooded regularly.

### **Selection of nursery site**

The selection of a site for mangrove nursery is the first important step in the nursery establishment. The location of the nursery influences the survival rate of saplings. Some important criteria to be considered are as below:

- Relatively flat land,
- Closeness to fresh water sources,
- Easy transportation access,
- Good drainage (not waterlogged),
- Proximity to the planting site,
- Mechanisms to allow periodic inundation,
- Access to good quality salt and fresh water,
- Shade regulation, and
- Good quality propagation.

The size of a nursery site can vary from 1-10 ha depending on the species to be planted, the planting area, and seedling requirements.

Determining the number of seedlings to grow in the nursery can be estimated by following the following guidelines.

- To plant 1 ha of *Rhizophora apiculata* with a density of 10,000 seedlings per ha (an additional 20% of seedling requirement is also included), the seedbed will require 350 m<sup>2</sup>. An area of 150 m<sup>2</sup> is needed for an office and storage (total area requirement is around 500 m<sup>2</sup>).
- To produce 100,000 seedlings of *Avicennia marina*, an area of 2000 m<sup>2</sup> is needed, with about 65% designated as seedbeds.
- To produce 1,000,000 bare-root seedlings of *Sonneratia caseolaris*, an area of 5000 m<sup>2</sup> is needed, with seedbeds occupying around 70% of the total area.

### **Collection of fruits and propagules**

The availability and type of planting materials vary depending on the species of mangrove. For example, there are long propagules for *Rhizophora* species, rounded propagules for *Avicennia* and small seeds for *Sonneratia*. Flowering and fruiting seasons need to be ascertained for different species.



Collection of *Rhizophora* propagules  
(Source: Mangrove Nursery Manual, GTZ, October 2010)



Collection of *Avicennia* propagules

The maturity of fruits and propagules can be assessed according to the criteria listed below.

Species	Colour	
	Immature	Mature
<i>Avicennia marina</i>	Green	Yellowish fruit skin
<i>Rhizophora apiculata</i>	Dark green	Pale to red brown
<i>Rhizophora mucronata</i>	Dark green	Pale
<i>Ceriops tagal</i>	Green	Pale to red brown
<i>Sonneratia caseolaris</i>	Pale green	Dark green
<i>Lumnitzera racemosa</i>	Green	Red brown

Maturity of fruits and propagules



*Avicennia marina* - Yellowish fruit skin matured



*Rhizophora apiculata* - Pale to red brown



*Rhizophora mucronata* - Pale



*Ceriops tagal* - Pale to red brown



*Sonneratia caseolaris* - Dark green

## **Selection of mangrove species for afforestation**

Species selection must be based on the tolerance to salinity, preference of substratum, inundation duration, etc. *Avicennia marina* (in areas where alluvium deposits are high), *Rhizophora apiculata*, *R. mucronata* and *Ceriops tagal* may be selected for the present afforestation. Suitable soils are muddy to soft clay with an inundation frequency of 6-8 hours per day. If in places where inundation occurs only during spring tides, the land height may be lowered by digging and removing some hard-clay layers so as to receive regular tides. *Lumnitzera racemosa* is grown in coastal areas where soil is mainly solid mud or clay. The wide tolerance of this species helps it grow well in both normal tidal condition and more waterlogged areas. The species can tolerate sustained freshwater inundation and salinity levels of upto 78psu. *Ceriops tagal* is similar to *Rhizophora apiculata*. *Ceriops tagal* can be grown behind *Avicennia* forests. Favourable soils are semi-solid or solid mud, fertile or sand-mixed soils. Tidal inundation frequency should last no more than 4 hours per day. In places where inundation occurs only at certain times in the day, the land level can be lowered by digging and removing hard-clay layers in order to receive regular tides. (Source: Mangrove Nursery Manual, GTZ, October 2010)

## **Soil preparation, Seedbed preparation**

Soil is collected from nearby canals, dried and ground into small particles (<3 mm diameter) and then mixed with ashes of rice husks or humus from plants at a 5:1 soil-ash ratio. This soil mixture should be supplemented with a small amount of fertiliser such as 0.5% of NPK (16:16:8) and cow dung at time of mixing and crushing of the soil. Use loam soil and avoid clay soil.

High seedbeds are about 1.2 m x 20–25 m (width and length). A pathway of 0.3-0.4 m between seedbeds is designed for watering and supervision of seedlings. Low seedbeds are similar to high seedbeds and are about 1.2 m x 20–25 m, except that the seedbeds are 15-20 cm below ground level. Mixed plastic containers are placed inside the seedbeds. The seedbeds are flooded to a depth of about 10 cm. A pathway of 0.3-0.4 m between seedbeds is maintained for watering and caring for the seedlings.

### **Filling plastic containers**

The size of the plastic containers is 10 cm x 18 cm. Small perforations should be made at the bottom of each bag to drain excess water. After mixing the soil and fertilisers, a 5 mm x 5 mm steel mesh is used to remove weeds and other plant residue before filling bags. Organic matter for mixing with the soil shall be available on the beach. The filled containers should be kept in the shade to harden the substrate.

After filling, containers should be arranged onto seedbeds, 7 to 10 days before planting seedlings. The seedbeds are then submerged in water for some time. The water will be completely drained afterwards. Water submersion should be done once a week to maintain moisture levels.

### **Seed stock for sowing**

Soil-mixed containers should be watered before sowing or planting the seedlings.

- For *Avicennia marina*, propagules are placed directly into the plastic container. Once the fruit is germinated, the containers will be arranged onto seedbeds for easy management.
- Propagules of *Rhizophora apiculata*, *R. mucronata* and *Ceriops tagal* are planted upright in the centre of a plastic container up to one third of the propagule length. They should be planted in the early morning or late afternoon.
- For *Sonneratia caseolaris* and *Lumnitzera racemosa*, seeds are sown directly into containers with 2-3 seeds per container. An alternate way of planting is to directly sow the seed into seedbeds. Seedlings with a height of 5-7 cm are then uprooted and transplanted into plastic containers.

### **Management of Nursery**

For successful maintenance of nursery, the important parameters, such as shade, watering, weeding, application of fertilisers, insecticides, etc., need to be adequately taken care of.

Shade: Shade should be provided for young seedlings for first two weeks after planting. Shade levels of 60-70% can be provided by a black mesh or *Nypa* leaves. The shaded area can be reduced to 30-50% after one month depending on the condition of the seedlings and weather. After two months, the shade levels can be further reduced to 20-30% and can be completely removed after three months.

Watering: During initial stages, watering should be carried out twice a day – once in morning and again in late afternoon using a rose-water container. When seedlings are strongly established and developed, a higher volume of water will be required. This water should be provided by tidal waters through canals.

Application of fertilisers: Fertiliser should be applied as 3-4 g of N:P:K (16:16:8) dissolved in 1 litre of water to irrigate seedlings. Some pesticides or fungicides should also be added to control diseases and insect pests. After applying fertiliser, wash the seedlings with water to remove fertiliser residue on leaves which may cause burning. In the final application, potassium is added to strengthen seedlings. Fertilisation should be stopped 20 days before preparing the seedlings for field planting.

Weeding: Weeding should be carried out regularly to keep seedlings free from competition. Breaking a film layer on the soil surface is needed to provide oxygen and air incorporation into the soil after each rainy period. A pointed stick can be used to break the film layer by gently digging a 2-3 cm depth of soil far away from root zone. Supervision of mangrove saplings is critical as crabs tend to eat the seedlings.

Re-arrangement of sapling bags: The sapling bags are rearranged once every three months to prevent roots from penetrating deeply into the soil layer.

### **Nursery techniques for different species**

For each species, the nursery techniques such as harvesting, preservation, processing of seeds, etc., differ moderately. Here we will see the techniques for the two important and potential species existing in the project site, viz., *Avicennia* sp., and *Rhizophora* sp. to understand some generalised features.

## 1. *Avicennia* sp.

### Harvesting, preservation and processing of seeds

Propagules (incorrectly called fruit) turn yellow at the time of ripening and can be collected from the ground or from the tree. Propagules must be healthy and intact without any infections, disease or insect pests. 300 propagules weigh approximately 1 kg. Sowing freshly collected propagules gives the best results. In situations where immediate sowing is not possible, propagules can be preserved in a moist state in a 20 cm layer and kept in the shade. Preservation should not exceed 5-10 days.

### Planting in plastic containers

Immediately after collection, propagules should be planted upright in the centre of a plastic bag containing soil. It is best to do the planting during the early morning or late in the evening. Planting bags are placed on seedbeds for management convenience.

### Management of nursery

*Irrigation:* After planting, water is provided by flooding the seedbed once a week. Once the seedlings reach a height of 20-25 cm, a higher volume of water is required. These should be flooded with tidal waters.

*Application of fertiliser:* Dissolve 3-4 g of NPK (16:16:8) + DAP in 1 litre of water and spray this on the seedbed. Thereafter, clean water should be sprayed to wash off residues on the leaves and prevent them from getting burnt. The application of fertiliser should be combined with the application of pesticides. In the final fertiliser application, only potassium should be used in order to enhance the seedlings' vigour. Fertiliser application must be stopped at least 20 days before planting. Regular inspection of the nursery should be conducted to detect incidence of insect pests and diseases.

### Criteria for the readiness of seedlings for field planting

- Age: 6-8 months old;
- Height: 35-40 cm and bearing 8-10 leaves (Figure 20);
- Stem: upright with profuse root system, and,
- Healthy with no symptoms of disease or insect pests.

## **2. *Rhizophora apiculata***

### Harvest, preservation and processing of seeds

To obtain propagules of the best quality with the highest survival rates, propagules should be intact without symptoms of infectious disease or insect pests. Length of propagules should be at least 23 cm with >1 cm diameter and more than 20 g fresh weight. It should have no roots or leaves.

Fruit preservation: Immediately planting freshly collected propagules will yield the best results. If preservation is needed, the following procedure should be followed:

- Place propagules in a shady place, arranged in 20 cm layers.
- Make sure sufficient water is provided.
- Preservation should not exceed 10 days.

There is a routine method used by farmers to preserve propagules. After collection, propagules are kept in a jute-bag and placed in a shadow canal where tidal waters keep them wet. This method of preservation can prolong their survival for 15 days. When *Rhizophora* propagules are transported over long distances, it is important to ensure that moist conditions are maintained in order to reduce losses during seedling establishment.

Planting of fruits into soil mixed containers: Plant one third of the fruits into the centre of a soil mixed container in an upright position. The planting is best done in the early morning or late afternoon.

## Management of nursery

Prepare shade mesh: Over the first 1-2 weeks of planting, seedlings should be shaded with a black mesh. The percentage of shade varies from 30-50% depending on actual weather conditions. A lesser degree of shade is applied when seedlings produce new roots and are stronger.

Irrigation: In the first two weeks, water is provided by flooding the seedbeds once a week. As seedlings develop, watering can be done using water from the regular flood tide.

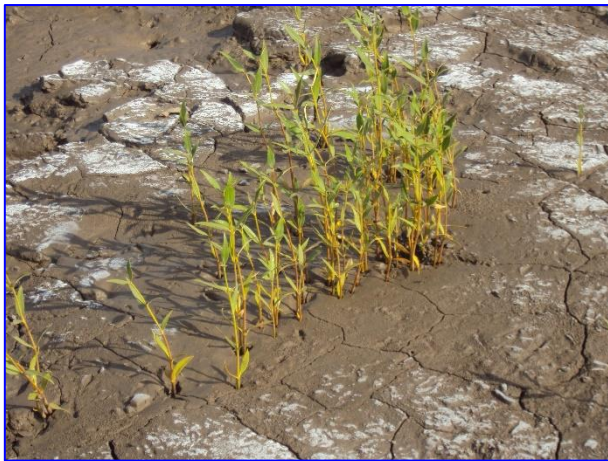
Fertilisation: Dissolve 3-4 g NPK (16:16:8)+DAP into 1 litre of water and then spray it onto the seedbed. It is important to subsequently spray clean water to wash fertiliser residues off of leaves in order to avoid leaf burn. Fertiliser application should be combined with pesticides and fungicides to control leaf eaters and pathogens. The final application of fertiliser should use Phosphorus and Potassium in order to promote robust saplings, but should be discontinued at least 20 days before delivering seedlings for field planting.

Weeding and turning over the top layer of soil is important to provide oxygen for root development, particularly after rain or irrigation. This should be done at a depth of about 2-3 cm and 10-15 cm away from the root zone.

## Criteria for the readiness of seedlings for field transplanting

- Age: 4-5 months old.
- Seedling height: 40-50 cm, with 8-10 leaves
- Upright stem and profuse root with no symptoms of disease or insect attack.

Thus, minor differences will exist on nursery management techniques among different species. Those can be referred to from literature and necessary precautions and planning be designed for successful maintenance of nurseries and planting in the field. Field planting of *Avicennia* sp. at Bhavnagar, Gujarat is given below.



Afforestation of *Avicennia* sp. saplings near Bhavnagar coast, Gujarat.

## 10. MONITORING OF MANGROVE

Monitoring of mangroves will ensure effective management of mangrove vegetation present in the project site.

- Mangrove survey - Mangrove health status
- Mangrove mapping

**Monitoring of Mangroves:** Half yearly monitoring program shall be conducted to ensure effectiveness of environmental management plan and afforestation programs carried out.

Monitoring should include the following for both existing and areas where afforestation will be carried out.

- Number of plants per unit area
- Number of dead limbs
- Number of species
- Average height of trees

**Mangrove mapping:** Mangrove mapping shall be conducted using field survey within 10 km buffer zone of project site to visually understand the variation of existing and future status of mangrove area after establishment of project. Google imagery and Arc GIS tools can be used as supporting tools.

**Institutes For Mangrove Plantation And Restoration:** Project proponent shall seek the help of following departments/institutes to take up the mangrove replantation. Gujarat State Forest Department have carried out a number of scientific studies on the suitability of various sites for mangrove afforestation / restoration and have implemented many projects in past decades. The other two institutes also have rich expertise. Thus, interaction with these and other departments/Institutes will enable the project proponents to design and implement the program successfully.

- Gujarat State Forest Department,
- MNPCS - Jamnagar, Govt. of Gujarat,
- Gujarat Institute of Desert Ecology (GUIDE), and
- Gujarat Ecology Commission (GEC)

## 11. CONCLUSION

Rehabilitation of degraded mangrove areas is one of the most important components in all the Mangrove Management Plans. Whereas low and moderately degraded areas can be restored in most of the cases by promoting natural regeneration in the area, a severely degraded mangrove area calls for artificial regeneration for its quick restoration.

Information on characteristics of flowering, fruiting, planting material and germination in various species of mangroves is necessary so as to plan timely collection of seeds/ fruits/ propagules for raising successful nurseries and plantations.

Once planted, mangroves tend to expand on their own as the trees drop seedlings as they grow, which then constitute new forests. The seedlings that float away also become the source of forests in suitable areas.



Avicennia sp. in Bhavnagar, Gujarat



*Avicennia* sp., *Rhizophora* sp. in Jodiya, LFP, Gujarat