Pre-Feasibility Report

Development of Kalpasar Project across Gulf of Khambhat, Gujarat, INDIA

KALPASAR

NCCR

Submitted to

Narmada, Water Resources, Water Supply and Kalpasar Department

Government of Gujarat

Prepared by

National Centre for Coastal Research

Ministry of Earth Sciences Government of India

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1 Executive Summary

The Kalpasar Project or the Gulf **of Khambhat Development Project** envisages building a 60 km dyke across the Gulf of Khambhat for establishing a huge fresh water coastal reservoir for irrigation, drinking and industrial purposes essentially to meet the water demands of the drought prone Saurashtra region of Gujarat. The Kalpasar Project was seeded by primordial ideas and suggestions by numerous renowned personalities.

The idea was initiated way back in 1955 when the Netherlands Engineering Consultants (NEDECO), a Dutch company, undertook land reclamation of the Bhal area in Saurashtra region (1955-68) and envisaged construction of a 25 mile long earthen bund and 10,000 feet long weir to prevent tidal flooding by sea water, preserve rain water and improve soil-water regime for crop production. However, the project proposal, with respect to its present form and features, has evolved through interplay of ideas and concepts which have been concretized through many studies conducted by Government of Gujarat (GoG).

The ambitious Kalpasar project is envisaged as a multi-purpose project to cater to the irrigation, drinking water, transport and energy demands of the Saurashtra region and involves construction of 60.13 km dyke across the Gulf, a flood regulator to discharge the excess water, a 16-lane roadway and a 4-lane permanent way connecting the eastern and western districts of Gujarat.

The project is of high societal importance and primary to irrigation and drinking water demands of the Saurashtra and central Gujarat region. About 10.54 Lakh hectares land in 37 taluks of nine districts of Saurashtra will get irrigation benefits in addition to rejuvenation of rivers and ground water in this region.

The proposed dyke will form a fresh water reservoir of 7800 million cubic meters and would receives water from four major river systems namely i.e., Sabarmati, Mahi and Dhadhar and Narmada. A 16-lane roadway and a 4-lane permanent way for rail transport are proposed to be built over the dyke which will significantly reduce the travel distance from 240 km around the Gulf to 60.13 km across the Gulf. With the construction of the Project dyke, the tidal water inflow into the peripheral land areas around Gulf will be considerably reduced thereby opening up an opportunity for recovery of tide affected land area.

The Dyke length of 26.7 km will be in the Gulf (sea portion) and 13.6 km will be towards east in Bharuch district and would cover an area of 152 ha (67 % of Government land and 33% of private land) and 19.83 km will be towards west in Bhavnagar district and would cover an area of 398 ha of land (90% of Government land of 10% private land). The area under the proposed flood regulator would be 1345 ha (100% owned by the Government). There would be no major resettlement of habitations due to project development, however, rehabilitation due to loss of land and livelihood will be assessed in detail and presented in the EIA report.

Kalpasar Project is expected to create a sustainable region in the heart of Gujarat with enhanced development potential which includes: (1) Water management and irrigation for the water deficient areas of Saurashtra. (2) Renewable Energy generation (3) Land creation in the Gulf, due to the stabilization of the tidal variations which are common in

Khambhat region, (4) Improved Connectivity between Bharuch and Bhavnagar thereby forming the "Golden Triangle" with Ahmedabad, the reduction in travel distance from 240 km to 60.13 km will also directly contribute towards the reduction in fuel consumption and emission of green house gases.

2 Project Introduction

2.1 Background Information

The concept of the Gulf of Khambhat Development Project, popularly known as Kalpasar Project, to create freshwater reservoir by constructing a dyke, was seeded by primordial ideas and suggestions by numerous renowned personalities. Netherlands Engineering Consultants (NEDECO), a Dutch company, which undertook land reclamation of the Bhal area in Saurashtra region during 1955-68, envisaged construction of a 25 mile long earthen bund and 10,000 feet long weir to prevent tidal flooding by sea water and preserve rain water and improve the soil-water regime for crop production.

Shri Bhogilal Shah, Member of Rajya Sabha (1952-56), mooted the idea of constructing a dyke across the Gulf for creating a big freshwater pond to be named as "Gandhisar" at the Bhavnagar session (1962). Shri Shah's idea was carried forward by Dr.Viththubhai Patel, an eminent earthen dyke engineer of international repute and progressive farmer of Bhavnagar, who provided an engineering format to the idea of Shri Bhogilal Shah in the year 1964. These incipient ideas and suggestions appear to have seeded the concept of the Gulf of Khambhat Development Project.

Professor E. M. Wilson, UNO Tidal Power Expert, proposed construction of a barrage across the Gulf between Ghogha and Dahej to develop tidal power along with the fresh water reservoir in the year 1975. Government of Gujarat made a proposal to develop fresh water reservoir as well as road/rail transport in the year 1986. Taking cognizance of these, the Government of Gujarat, on recommendation of the Expert Advisory Group of Gujarat (EAG), finally approved vide office order dated 22nd January, 2003 to carry out feasibility studies. Since then many studies have been conducted by GoG right from conceptualisation to detailed project report preparation for Kalpasar Project.

2.2 Studies Undertaken

The project proposal, with respect to its form and features, has evolved through interplay of ideas and concepts which have been concretized through the Reconnaissance Study (1988), Pre-feasibility Study (1996-98), Six Specific Studies (1999) and many other studies/investigations/expert consultations.

2.2.1 Reconnaissance Study (1988)

The reconnaissance study was carried out by M/s Haskoning (Netherlands) & Associates. The study stipulated 65 Km long rock fill dyke across the Gulf between Ghogha (west bank) and Hansot (east bank) for the development scenario of tidal power generation and freshwater storage, having tidal power basin integrated with fresh water reservoir. The reconnaissance study report concluded that the project is potentially viable and recommended to carry out pre-feasibility study to firm up the project features.

2.2.2 Pre-feasibility Study (1996-98)

The pre-feasibility study, carried out by M/s Haskoning & Associates, was a step forward to make an in-depth investigation. The study proceeded with the consideration of alternatives of dyke alignment and development potential and finally came out with the project features.

The pre-feasibility study demonstrated the technical viability of the project and recommended to proceed with feasibility studies after carrying out intermediate studies (specific studies) on some selected aspects such as tidal power production, pollution control, morphology of estuaries, drainage conditions, salt balance in the reservoir, and integration of benefits of Kalpasar Project with that of other projects.

2.2.3 Six Specific Studies (1999)

The Six Specific Studies included the following aspects:

- Techno-economic appraisal of tidal power generation
- Water quality and pollution control
- Hydraulic and morphological impact
- Drainage, land reclamation and salt balance modelling in fresh water reservoir and surrounding areas
- Integration of Kalpasar Project benefits with that of other projects of Gujarat State
- Economic and financial evaluation

The six specific studies confirmed that the project is technically feasible and economically viable. Several groups of experts as well as institutes were involved in examination of the reports of six specific studies.

2.2.4 List of Feasibility Studies

In the pursuit of establishing technical feasibility of the Kalpasar Project, various feasibility studies have been carried out. These studies including engineering investigations for data base development by NCCR are as follows,

Table 1: List of Feasibility studies

S.No	Feasibility Study	Organization	Year
1	Topographical survey 0 to 10 m contour along peripheral area of reservoir.	SOI	2006
2	Ground water conditions in Kalpasar Command area in Saurashtra	S.C.Sharma	2008
3	Fisheries Development	K R Narayanan	2008
4	A study on positive impact of Kalpasar reservoir project in Saurashtra region	Shri V. A. Patel & Dr. D. G. Faldu,	2008

S.No	Feasibility Study	Organization	Year
5	Scope of Work for EIA & SIA Studies for Kalpasar Project	NEERI	2008
6	Water availability study for Kalpasar project main report	CDO	2009
7	Taluka-wise Irrigation planning and Agro-economic impact of Kalpasar Project in coastal areas of Saurashtra region	Shri V. A. Patel & Dr. D. G. Faldu	2009
8	Pre-feasibility report on survey carried out for Development of 1470MW Wind power project at Gulf of Khambhat Development Project	SUZLON	2010
9	Techno Economic Feasibility report	Kalpasar	2011
10	Studies on sea-level rise along the Gujarat coast and changes in regional climate over Gujarat	NIO Goa	2011
11	A study of agronomical constraints in agriculture in the command area of semi-arid and arid regions of Saurashtra	Dr. D. G. Faldu,	2011
12	Irrigation Facilities	Shri. P. D. Trivedi National consultant	2011
13	Assessment of Baseline Environmental quality and social status of Kalpasar Project	CSIR-CSMCRI	2011
14	Present Status of Salt Pans and Assessment of Social, Economical and Environmental Impact of the Kalpasar Reservoir Project	CSIR-CSMCRI	2011
15	Concept and Structure Plan and Preparation of Base Map of the Kalpasar Project Area	CEPT	2013
16	Geo physical survey for revised dyke corridor	NIOT	2010&2014
17	Traffic Assessment Study for GoK Development Project	L&T Ramboll & GERI	2013
18	Bathymetry Survey in Southern portion of Gulf of Khambhat	NIOT	2014
19	Water Sampling and Water Quality Monitoring Program	GPCB	2014
20	Vetting of Water Availability Studies for Gulf of Khambhat Development Project	NIH	2014
21	Primary and alternate locations of Flood Regulator 2 DT	Kalpasar	2014

S.No	Feasibility Study	Organization	Year
22	Primary Dyke cross sections	Kalpasar	2015
23	Impact of Kalpasar Project on the existing and Proposed Ports	NIO Goa & NEERI	2016
24	Bathymetry Survey in Northern portion of Gulf of Khambhat	NIOT	2017
25	Estimation of Probable Maximum Flood (PMF), Design flood including determining spillway capacities	Department of Hydrology, IIT Roorkee	2018
26	Design of spillway report	Kalpasar	2018
27	Study of Tsunami waves impact on structures and Tsunami Inundation Modeling for the Kalpasar Project	CSIR-NGRI	2016
28	Impact of Storm surges, Wind waves and Seiches	IIT Delhi	2017
29	Hydrodynamic and Sediment model studies and related measurements	NIOT	2018
30	Impact on mangroves consequential to creation of Kalpasar reservoir and mitigation strategy	CSIR-CSMCRI	2016
31	Synopsis of the environmental and socio-economic aspects of the various studies related to Kalpasar project	Gujarat Ecology Society	2018
32	Reclaimable land plan GIS data base	CEPT	2019
33	Geotechnical Investigations along the Dyke Alignment	M/s Gujarat State Petroleum Corporation (GSPC)	2021
34	GAP Analysis and Preparation of Design Basis Report for Kalpasar Project	ARUP	2022
35	Seismic Hazard Assessment for Kalpasar Project	NGRI	2022
36	Studies related to reservoir sieches, Impact of Dyke on regional scale, design water levels and waves.	IIT Madras (OED)	On Going
37	Geotechnical Aspects, Design of Dyke and Flood Regulator for Kalpasar Project	IIT Madras (CED)	On Going
38	Numerical and Physical Model Studies for Dyke and Flood Regulator.	CWPRS	On Going
39	DPR for the development of Wind Solar Hybrid System	NIWE	On Going

S.No	Feasibility Study	Organization	Year
40	CRZ Maps for obtaining CRZ clearance for the Kalpasar Project	NCSCM	On Going
41	Environment Impact Assessment (EIA) for Kalpasar Project	NEERI	On Going
42	Social Impact Assessment for Kalpasar Project	NIAS	On Going
43	Ecological, Hydrological and Socio-Economic Impact Studies	GUIDE	On Going
44	Assessment of Sea Level Rise due to Climate Change, Inundation in Gulf- Post Construction of Dyke and Updating studies on Impact of Tsunami.	INCOIS, IITM Pune	On Going
45	Studies Related to Traffic Assessment, Design of road, Rail and Bridge Components for Kalpasar Project	L&T	On Going
46	Dyke Closure Studies and Design of Gates for Flood Regulator	Royal Haskoning	On Going
47	Security Studies for Kalpasar Project	RRU	On Going
48	Morphological Impact Studies	L&T and NIOT	On Going
49	Financial Model Studies for Kalpasar Project	IIM Bangalore	On Going

* **SOI:** Survey of India, **NEERI:** National Environmental Engineering Research Institute, **CDO:** Central Design Organization, **NIO:** National Institute of Oceanography, **CSIR:** Council of Scientific & Industrial Research, **CSMCRI:** Central Salt and Marine Chemicals Research Institute, **CEPT:** Centre for Environmental Planning and Technology, **NIOT:** National Institute of Ocean Technology, **L&T:** Larsen & Toubro, **GERI:** Gujarat Engineering Research Institute, **GPCB:** Gujarat Pollution Central Board, **NIH:** National Institute of Hydrology, **IIT:** Indian Institute of Technology, **GNLU:** Gujarat National Law University, **NGRI:** National Geographical Research Institute, **COMACOE:** Coastal Marine Construction & Engineering Ltd, **CWPRS:** Central Water and Power Research Station, **NIWE:** National Institute of Wind Energy, **NCSCM:** National Centre for Sustainable Coastal Management, **NIAS:** National Institute of Advanced Studies, **GUIDE:** Gujarat Institute Of Desert Ecology, **INCOIS:** Indian National Centre for Ocean Information Services, **IITM:** Indian Institute of Tropical Meteorology, **RRU:** Rashtriya Raksha University, **IIM:** Indian Institute of Management

Ongoing studies are likely to be completed by September except design related by September 2022.

2.3 Introduction

The Gulf of Khambhat extends from north to south of about 250 km and the width varies from 25 km at the inner end to 250 km at the outer mouth, covering an area of 25000 sq.km, of which only 1600 sq. km will be enclosed by constructing a dyke across the Gulf between Bhavnagar and Dahej. The project location is influenced by higher tidal range of 9m and currents velocities of around 3 m/s at the head of the Gulf.

To meet the freshwater demand for drinking, agriculture and improvement in groundwater resources, the Government of Gujarat proposed an ambitious project called Kalpasar Project which involves construction of dyke with a length of about 60.13 km out of which about 26.7 km length will be in the Gulf and 33.43 km length is extended on both flanks upto nearest road across the Gulf of Khambhat. The proposed dyke forms fresh water reservoir which receives water from four major sources (Sabarmati, Mahi, Dhadhar and Narmada) and seven minor rivers in Saurashtra region (Wadhwan Bhogavo, Limbdi Bhogavo, Sukhbhadar, Utavli, Keri, Ghelo, and Kalubhar). A 16-lane roadway along with 4-lane permanent way for rail transport is proposed to be built over the Dyke which will significantly reduce the travel distance from 240 km around the Gulf to 60.13 km across the Gulf. With the construction of the Kalpasar project, the tidal water inflows into the peripheral land areas around Gulf area reduced opening up opportunities for recovery of tide affected lands.

2.4 Project Developer

The contact details of authorized person are as follows:

Name: Shri D. C. Thacker **Designation:** Chief Engineer(K-1) & Additional Secretary	**Address for Communication:** Narmada And Water Resources, Water Supply and Kalpasar Department, Government Of Gujarat Block No. 8, 7th Floor Sardar Bhavan, New Schivalaya Gandhinagar 382 010, India

2.5 Project Site Location

The Kalpasar dyke with a length of about 60.13 km out of which about 26.7 km length will be in the Gulf i.e., sea and 33.43 km length is extended on both flanks upto nearest road across the Gulf of Khambhat falls in Kardej village, Bhavnagar district towards west and other end falls in Paniyadra village, Bharuch district towards east. The location map of Kalpasar Project is shown in **Figure 1**.

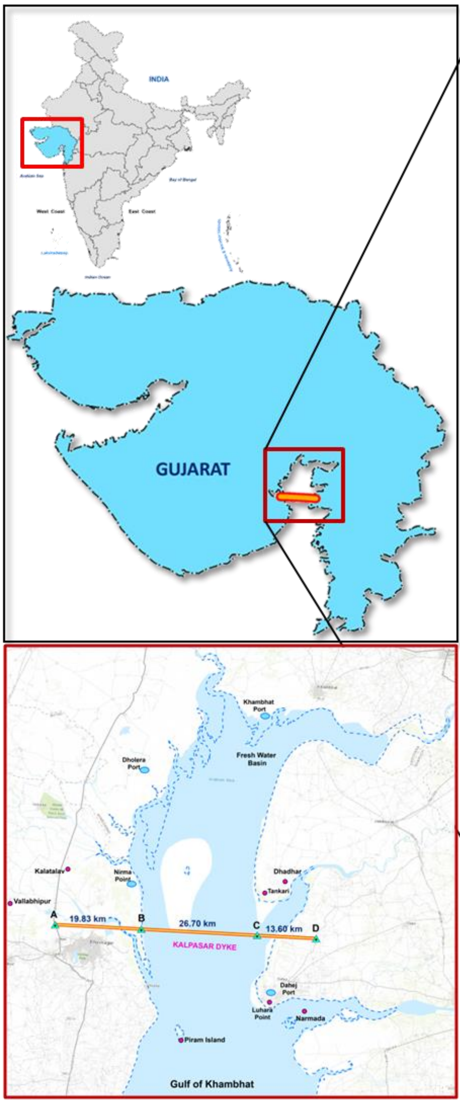
2.6 Brief Description of Nature of Project

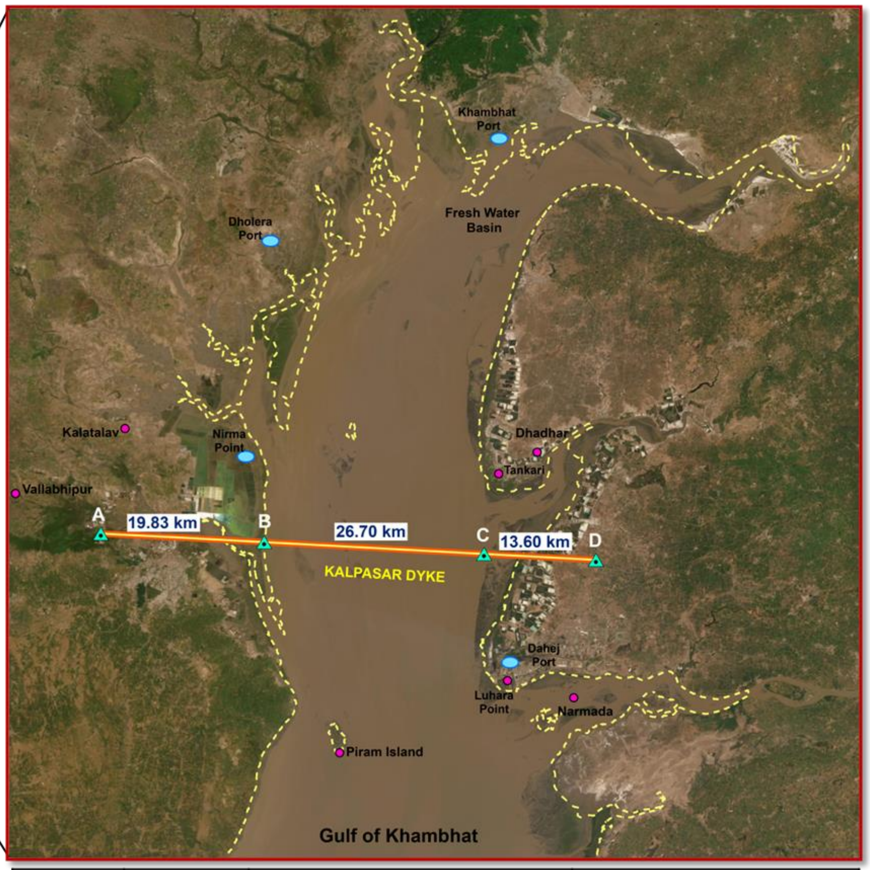
The Saurashtra region of Gujarat has been experiencing severe droughts for few decades due to reduction in ground water table and scarcity of fresh water. To meet the freshwater demand for drinking, agriculture and improvement in groundwater resources, the Government of Gujarat (GoG) proposed an ambitious project called Kalpasar Project which involves construction of dyke with a length of about 60.13 km out of which about 26.7 km length will be in the Gulf (sea portion) and 33.43 km length is extended on both flanks upto nearest road across the Gulf of Khambhat.

Following are the project components would be taken by Kalpasar department under this proposal for development are as follows:

1. Construction of 60.13 km of dyke i.e., 26.7km length will be in the Gulf (sea portion) and 13.6 km length towards east i.e., Bharuch district and 19.83 km towards west i.e., Bhavnagar district

2. Fresh water reservoir will be created in upstream of dyke with capacity of 7800 million cubic meters.
3. A 150m wide road/rail corridor i.e., 16 lane roadways along with 4-lane permanent way for rail transport is proposed to be built over the Dyke
4. Flood regulator to discharge flood water.





Survey Line ID	Survey Points	Description	Coordinates	
			Longitude	Latitude
L3	A.	Intersection of L-3 on Bhavnagar-Pipali Highway	72° 3' 58.978"E	21° 48' 23.527"N
	B.	Intersection of L-3 on gulf side Bhavnagar.	72° 15' 28.908"E	21° 48' 25.596"N
	C.	Intersection of L-3 on gulf side Dahej.	72° 30' 58.032"E	21° 48' 25.992"N
	D.	Intersection of L-3 on intertidal Dahej side paniyadra, End Point	72° 38' 51.180"E	21° 48' 25.704"N

Figure 1: Location of Kalpasar Project

2.7 Need for the Project

The project is of highest importance and priority to meet the irrigation and drinking water demands of the Saurashtra and Central Gujarat regions specially in view of meeting water demand and adaptability to climate change. Approx. 10.54-lakh hectare land in 37 talukas of nine districts of Saurashtra region will benefit from this project aprt from rejuvenation of rivers and groundwater. More than 60 existing dams will be permanently filled with fresh water.

By constructing road over the dyke alignment, there will be large saving in travel time and fuel consumption due to reduction in distance by about 136 km between Bhavnagar to Surat/Mumbai. With the construction of the Kalpasar dyke, the tidal water inflows into the peripheral land areas around the Gulf area will be reduced thereby opening up opportunity for recovery and reclamation of tide affected lands. The project also involves development of renewable energy by setting up of wind and solar farms in reclaimed land to meet the power requirement of the lift irrigation system for pumping the water from proposed fresh water reservoir.

The saline ground water in the coastal area of Saurashtra & Central Gujarat will get converted into fresh water with reduction in soil salinity. Substantial improvement in ground water quality as well as soil salinity of coastal area of Saurashtra & Central Gujarat is envisaged.

About 1.2 lakh hectare land along the periphery of the reservoir will be created for development towards value-based land utilization and ecosystem based developments. Moreover enhanced benefit of world class growth centres like Dahej and Dholera will be available to Bhavnagar/Saurashtra region.

2.7.1 Similar Projects

2.7.1.1 Saemangeum Project

Following the world food crisis in the 1970s and the poor harvest of the 1980s the Korean Government developed planned for large scale tideland reclamation and this project.

The west coast of the Korean peninsula has a indented shoreline with a gently sloping sea bottom. The tidal range reaches approximately 6 m in spring tide in the Saemangeum site. These favourable geographic and hydraulic conditions permitted the Korean Government to initiate several tideland reclamation projects along the coastline. The Korean Agricultural and Rural Infrastructure Corporation (KARICO) and the Ministry of Agriculture and Forestry (MAF) of the Republic of Korea launched a large-scale tideland reclamation project, the Saemangeum Project, in 1991.

The Project site is located at the mid-west coast of Korean peninsula, approximately 200 km south from Seoul. The Project covers a total area of 401 km^2 which, after the completion of the internal structures, included 283 km^2 of reclaimed tidal flats and a desalinated reservoir of area 118 km^2. The major sea dikes required to enclose this huge area of the Saemangeum estuary also included two drainage sluices and navigation locks.

The watersheds of the Saemangeum reservoir covers 3,319 km^2 and includes the basins of two major rivers, that flow into the reservoir, meandering through the plains. Water depths along the sea dikes vary from 4 m to 27 m below MSL (Mean Sea Level). Deep tidal channels were developed at three regions with a thickness of fine sand deposits on the sea bed reaching to 20 to 30 m. Some of the major engineering works that formed part of the project includes the following:

a. Sea dikes, total length: 33.0 km, crest elevation: 8.5 to 11.0 m above MSL, typical height: 22.0 m, typical bottom width: 290.0 m at typical section
b. Reservoir, storage capacity: 535.million m^3, available storage: 355 million m^3, water surface area at normal water level: 96.7 km^2
c. Drainage sluices, 2 sets (one set of 10 and one of 8) of 30m x 15m radial gate type sluices, combined total maximum discharge ~16,000 m^3 /s
d. Navigation locks
e. Fishway

Figure 2: Location and Aerial View of Saemangeum dyke

2.7.1.2 Afsluitdijk

In the second half of the 19th century, the Dutch population was exploding, and there was an increasing need for land for agriculture and animal husbandry. Moreover, the region around the former Zuiderzee was vulnerable to flooding.

The Zuiderzee had been a large bay south of the North Sea which gave maritime access to five provinces of the Netherlands, and particularly during the Dutch Golden Age provided a protected entrance and exit for the harbour of Amsterdam and several other important Dutch sea harbours. Furthermore, the Zuiderzee provided relatively shallow and calm fishing grounds for the many towns bordering the bay. However, the opening of the North Sea Canal in 1876 gave a much shorter direct entrance to the Amsterdam harbour, and overfishing had depleted the shallow bay. In 1916, a combination of a storm at sea and an enormous surge of water from the IJssel caused flooding in large parts of the area around the Zuiderzee. Therefore, the Dutch government planned for the large project called Afsluitdijk by shutting off the Zuiderzee from the North Sea.

Afsluitdijk was constructed between 1927 and 1932 and runs from Den Oever in North Holland province to the village of Zurich in Friesland province. Some of the key features of the project includes the following:

a. Total length of Afsluitdijk is 32 km, width of 90 metres and an elevation of 7.25 metres above sea level.
b. Road connection between North and West of the Netherlands, through which 15,000 vehicles drive every day.
c. Fishway
d. Afsluitdijk has 25 Discharge Sluices, which are large holes in the dyke covered with a slide; and
e. Upper and Lower navigation locks

Figure 3: Afsluitdijk across the North Sea

2.8 Economic Impacts/benefits of the Project

2.8.1 Improvement in water regime

Due to creation of freshwater reservoir, surface water input into the soil of the project region will improve considerably. More importantly, the water input, being largely stored underground, will be amenable to more effective and efficient utilization by adopting better methods and mode of irrigation. The total water input will be sufficient for optimally irrigating two crops (kharif and rabi season crops).

Notwithstanding the limitation of inadequate and uncertain rainfall, lower level of surface water availability, steadily depleting and degrading ground water resource base and salinity infestation of land resource base, the farmers of the Saurashtra region have been aiming for the efficient use of available agricultural production resources viz. land, irrigation water (surface/ground water) and other inputs by adopting crops which are less water requiring and more economically rewarding. The main crops have been groundnut and cotton.

With the substantial level of additional supply of Kalpasar project water, the rabi season crop area will expand and the farmers will be inclined to adopt crops such as wheat, mustard, onion and garlic, spices and condiments (cumin, fenugreek) and other high value-crops. Adoption of modern irrigation systems (Drip/Sprinkler) may be a great possibility, particularly in shallow soil areas, in order to produce more using less water.

2.8.2 Improvement in Soil Productivity

The soils are usually salt affected, which hamper the soil productivity. With the massive water input, the soil salinity level will gradually reduce, and the soil condition will improve and bring in improvement of soil productivity.

2.8.3 Change in Cropping Pattern

With the introduction of irrigation, there will be a shift from the existing system of mainly unirrigated agriculture to irrigated agriculture. The farmers will respond very favourably to the water made available to them for higher return. The main crops in the region are groundnut and cotton. With the substantial level of additional supply of Kalpasar project water, the rabi season crop area will expand and the farmers will be inclined to adopt crops such as wheat, mustard, onion and garlic, spices and condiments (cumin, fenugreek) and other high value-crops. The cropping pattern of the command area of Kalpasar Project may be assessed considering factors viz. agro-climatic conditions, productivity of the land including limitations, availability of other production resources, market demand and other related aspects inclusive of farmers' responsiveness.

2.8.4 Transportation

Construction of dyke road across the Gulf of Khambhat will connect the Saurashtra region with South Gujarat, transport distance will be reduced significantly, reducing thereby reducing the transportation costs. At present travelling from Bhavnagar to Surat involves going through Vataman- Vadodara-Bharuch-Surat road network. However, after the Gulf of Khambhat dyke is constructed, Bhavnagar will be directly connected to Dahej. The distance between Saurashtra to South Gujarat would be reduced by about 150 km and the saving in time will range from 6 hours to 1.5 hour. Travel distance and time reduction is given in **Table 2**.

Table 2: Distance and Time Saving due to dyke transportation system

Place	Bharuch		Dahej		Surat	
	Without Kalpasar Project	With Kalpasar Project	Without Kalpasar Project	With Kalpasar Project	Without Kalpasar Project	With Kalpasar Project
Bhavnagar	262 km	125 km	279 km	106 km	343 km	207 km
	08:12	02:16	08:50	02:02	10:11	04:50
Saving (km/time	137 km (06:04)		173 km (06:45)		136 km (05:20)	

Place	Bharuch		Dahej		Surat	
	Without Kalpasar Project	With Kalpasar Project	Without Kalpasar Project	With Kalpasar Project	Without Kalpasar Project	With Kalpasar Project
)						
Amreli	369 km	228 km	382 km	209 km	449 km	303 km
	09:00	04:22	09:27	04:04	10:01	06:55
Saving (km/time)	141 km (04:30)		173 km (5:40)		146 km (03:06)	
Porbandar	518 km	414 km	531 km	395 km	599 km	496 km
	09:52	06:57	10:10	08:16	11:50	09:31
Saving (km/time)	104 km (02:55)		136 km (02:06)		103 km (02:19)	
Rajkot	344 km	285 km	360 km	266 km	428 km	367 km
	08:34	04:49	08:50	05:34	10:32	07:22
Saving (km/time)	59 km (03:45)		94 km (03:15)		62 km (03:10)	
Jamnagar	450 km	374 km	463 km	355 km	531 km	456 km
	11:28	07:29	12:01	07:26	12:45	10:03
Saving (km/time)	76 km (04:01)		108 km (04:35)		75 km (02:43)	
Junagadh	438 km	334 km	451 km	315 km	519 km	416 km
	10:40	05:46	11:10	06:36	11:08	08:20
Saving (km/time)	104 km (04:50)		136 km (04:37)		103 km (02:48)	

Place	Hajira		Navsari		Valsad		Mumbai	
	Without Kalpasar Project	With Kalpasar Project	Without Kalpasar Project	With Kalpasar Project	Without Kalpasar Project	With Kalpasar Project	Without Kalpasar Project	With Kalpasar Project
Bhavnagar	370 km	214 km	365 km	230 km	415 km	279 km	610 km	475 km
	10:20	04:29	11:29	06:30	12:20	07:34	13:14	08:42
Saving (km/time)	156 km (05:50)		135 km (05:00)		136 km (04:46)		135 km (04:31)	
Amreli	473 km	317 km	472 km	333 km	521 km	382 km	716 km	571 km
	10:42	06:38	11:20	08:35	12:10	09:39	13:04	10:48
Saving (km/time)	156 km (04:00)		139 km (02:44)		139 km (02:31)		145 km (02:16)	
Porbandar	622 km	503 km	621 km	519 km	670 km	568 km	866 km	764 km
	12:10	10:32	13:09	11:11	14:00	12:15	14:53	13:23
Saving (km/time)	119 km (01:40)		102 km (01:58)		102 km (01:44)		102 km (01:30)	
Rajkot	451 km	374 km	453 km	390 km	507 km	439 km	695 km	635 km

	11:10	07:50	11:51	09:02	12:41	10:06	13:35	11:15
Saving (km/time)	77 km (03:20)		63 km (02:49)		68 km (02:35)		60 km (02:20)	
Jamnagar	554 km	463 km	555 km	479 km	602 km	528 km	798 km	724 km
	13:15	09:42	14:04	11:43	14:54	12:47	15:48	22:15
Saving (km/time)	91 km (03:30)		76 km (02:21)		74 km (02:08)		74 km (01:53)	
Junagadh	542 km	423 km	541 km	439 km	600 km	488 km	786 km	684 km
	11:45	08:52	12:26	10:59	13:17	11:04	14:10	12:12
Saving (km/time)	119 km (02:50)		102 km (02:26)		112 km (02:13)		102 km (01:58)	

Most of the heavy vehicles (goods movement) heading Saurashtra and Kutch from South Gujarat will be able to utilize this route once the road is provided over the proposed dyke. Also, there is going to be significant development activities in the study area in view of the corridor, Dholera SIR Projects, Federa International Airport, Port activities, Tourism Development, Agriculture activities, and other related activities.

Technically, it is envisaged to extend Bhavnagar railway line onto the Kalpasar dyke, while on the east side, the Dahej-Bharuch broad gauge line is in operation. Hence, on top of dyke, the railway connectivity will be useful for goods as well as passenger traffic between Saurashtra and Surat/Mumbai. There will be a great reduction in distance between Saurashtra and Mumbai.

2.8.5 Renewable Energy

Kalpasar Project has a huge renewable energy potential through wind and solar power development. As per pre-feasibility report on development of wind power, there is a potential capacity of about 1500 MW to generate about 2500 million units. The potential capacity for solar power is calculated to be around 1000 MW. It will be possible to meet the energy needs of the project through these wind and solar power sources that are proposed to be created under the Kalpasar Project. Wind and solar power projects will produce renewable energy that will be utilized for lifting fresh water from the reservoir to the canal as well as for meeting the energy requirement of the sundry socio-economic activities.

2.8.6 Tourism

The Gulf of Khambhat Development Project will boost the development in Saurashtra significantly. Significant development activities in the study area is envisaged in view of DMIC corridor, Dholera SIR Projects, Fedra International Airport, Port activities, Tourism Development, Agriculture activities, etc. There are also strong tourism opportunities in the form of Nalsarovar, Velavadar, Vadodara. With the Kalpasar dyke stabilizing the Gulf, the tourism potential of the fair can be further harnessed with waterfront development adjoining newly created land, similar to that of Kerala.

2.8.7 Fisheries

The transformation of marine water lake into a freshwater lake will lead to replacement of less potential marine fisheries by freshwater fisheries. Considering the inland freshwater fish production in the interior parts of the peripheral districts, the 1600 sq. km Kalpasar freshwater reservoir would at least produce 2000 tons (valued at Rs.150 million) at the initial stages and 20,000 tons (Valued at Rs.1500 million) at full development stage. This will push up inland fish production of the state which is presently at very low level (0.91 lac ton) contributing only 1.72 % to the country level.

Seed stocking of economic fish varieties, training of local fishermen in fishery operations, provision of capture implement and creation of infrastructure for fish landing, handling, storage and marketing are some of the fishery development programmes contemplated under Kalpasar project.

2.8.8 Availability of Land Area

With the construction of the Kalpasar dyke, the tidal water inflows into the peripheral land areas around the Gulf will be reduced thereby opening up opportunity for recovery of tide affected land area. In the wake of the construction of the Kalpasar dyke and the creation of the Kalpasar freshwater reservoir, the tidal affected lands in the periphery of the reservoir will open up areas for eco development. Among the various development avenues, the development of the land for value-based utilization holds the highest economic promise considering the factual situations of Kalpasar Project based development features such as transport, energy, ports and others coupled with the upcoming development in the neighbouring areas.

The Gulf of Khambhat Development Project will naturally reclaim the tidal affected lands in the periphery of the dyke enclosure. These lands mainly fall in (+) 5 m MSL and (+) 8 m MSL contours. BISAG based on computer stimulation model have estimated that about 2 lakh ha would be created. This land will have huge positive economic implications, discussed in the section of Socioeconomic Impact. This area can be developed towards value-based land utilization like energy (solar and wind), port, urban and industrial infrastructures, tourism resorts. Overall the land created will help to improve the economic status of the state and people at large.

2.8.9 Improvement in Groundwater

Due to availability of fresh water from canal system around 10 Lakh ha of area would be under irrigation. With the availability of 4500 MCM/year for irrigation, pressure on groundwater will reduce. Considering infiltration rate of 30 to 35% there would be additional ground water recharge between 1400-1600 MCM/year. This will improve the ground water condition both in terms of increase in water table and reduction in salinity. There are plans to promote drip and sprinkler irrigation to reduce overuse of water in the region, with arid conditions and prevent sodicity of soils.

The GKDP canals will also firm up existing reservoir in the command area and in turn benefit in prevention of salinity ingress along the sea coast of Saurashtra region. Amreli, Jamnagar, Junagadh, Bhavnagar and Porbandar districts would benefit from the salinity projects already in operation from the Kalpasar canals. This in turn would benefit the ground water resources of the region.

2.9 Employment Generation

The Kalpasar project is likely to generate employment of 20,000 during construction phase, employment of 300 during operation phase in addition to huge opportunities of employment in agriculture, tourism, fishing and economic development.

3 Project Description

3.1 Site Location

The Kalpasar dyke with a length of about 60.13 km out of which about 26.7 km length will be in the Gulf i.e., sea and 33.43 km length is extended on both flanks upto nearest road across the Gulf of Khambhat falls in Kardej village, Bhavnagar district towards west and other end falls in Paniyadra village, Bharuch district towards east. The location map of Kalpasar project is shown in **Figure 1**.

3.2 Project Alternatives

During project evolution, many alternatives were studied. Out of which, three specific alternatives were considered and studied further as given below:

- Alternative I: Dyke with freshwater storage including Narmada discharge
- Alternative II: Dyke with tidal basin and freshwater storage including Narmada discharge.
- Alternative III: Dyke with only Fresh water storage without Narmada discharge

3.2.1 Alternative I: Dyke with freshwater storage including Narmada discharge

This alternative was proposed during the study by Royal Haskoning. The dyke alignment and development potential along with the project features comprised of following and is shown in **Figure 4**.

1. Construction of 62.9 km (28.9-km Gulf closure and 34.0-km Narmada closure) long dyke between Ghogha and Hansot.
2. Creation of tidal basin of 500 km^2 integrated with freshwater reservoir of 1600 km^2 area.
3. Estimated 5,ooo MW Capacity of tidal power.
4. Flood Regulator at the Narmada mouth with 65 discharge openings, each of 17 m width.
5. The development potential of the project included availability of 12,552 MCM water; Reclamation of 1,19,000 ha land area; Reduction of travel distance between Saurashtra and South Gujarat by about 200 km.
6. +13m MSL as the crest level of the dyke proposed.
7. The total cost was estimated at Rs. 19,253 crores.

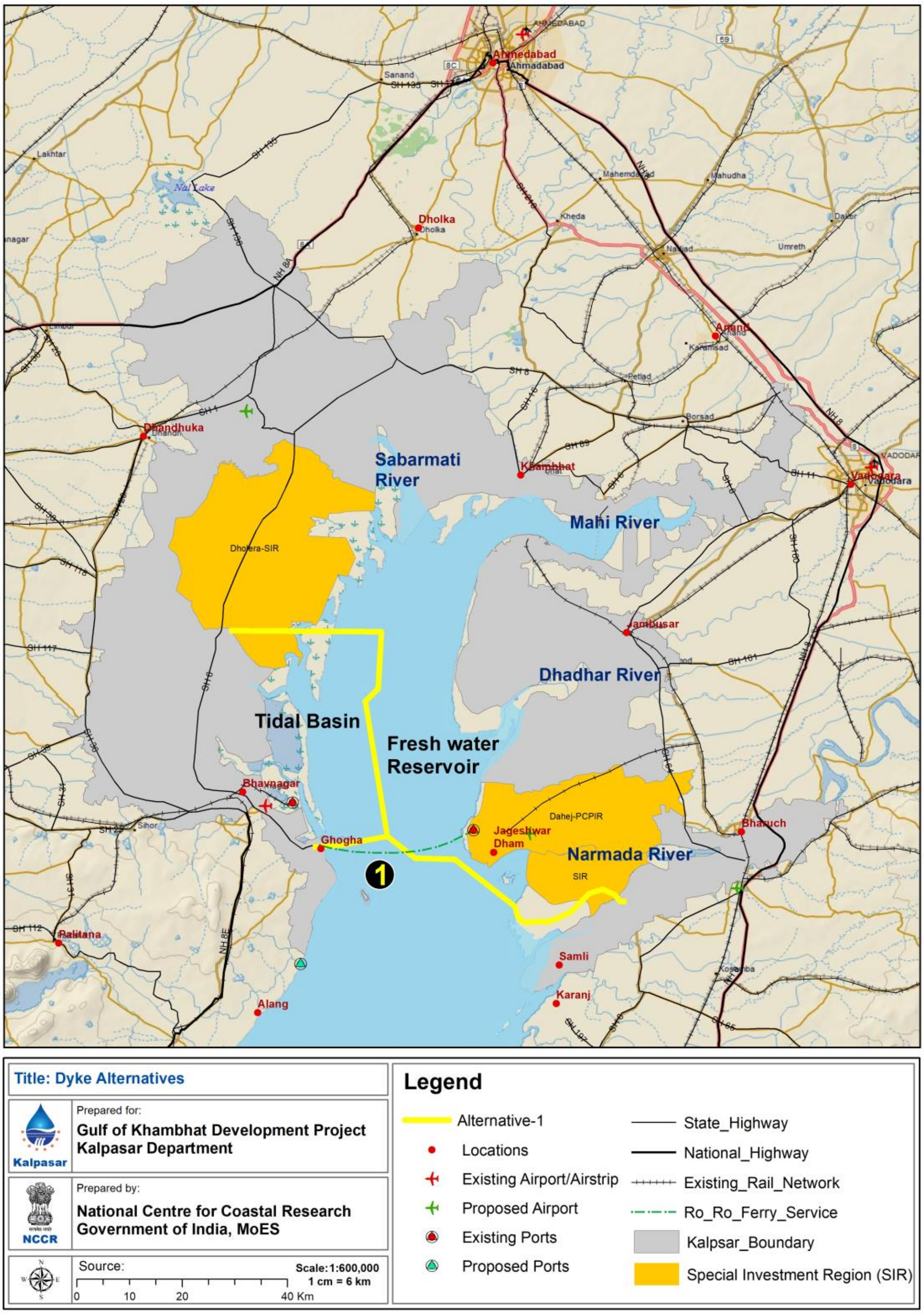


Figure 4: Alternative I: Dyke with freshwater storage including Narmada discharge

3.2.2 Alternative II: Dyke with tidal basin and freshwater storage including Narmada discharge

The Alternative I was further modified during six specific studies by Kalpasar Department. As part of this study several changes were made in Alternative I particularly with respect to the tidal basin, configuration of dyke alignment, dyke design criteria and safety features, dyke construction technique, and project cost estimation. The alternative II is shown in **Figure 5**.

1. The Gulf closure was decreased from 28.90 km to 20.46 km, to provide space for tidal power block in the deep section. To accommodate flood flows and silt loads the main dyke was moved 5km away from Dahej bank. Accordingly, the total length had increased to 64.16 km (20.46 km Gulf Closure and 43.70 km Narmada closure)
2. The tidal basin was extended to 700 km^2 and an option of double-basin system was also studied for enhancing tidal power generation.
3. The new estimate of tidal power was 5,88o MW capacity.
4. The Narmada flood regulator located was shifted to existing main flow channel of the river.
5. The development potential of the Project included availability of 12,248 Mm^3 water; 1,19,000 ha of land area; Reduction of travel distance between Saurashtra and South Gujarat by about 200 km.
6. The crest level of the dyke was increased to (+) 14.5 m MSL.
7. The total project cost was estimated at Rs. 44,301 crores.

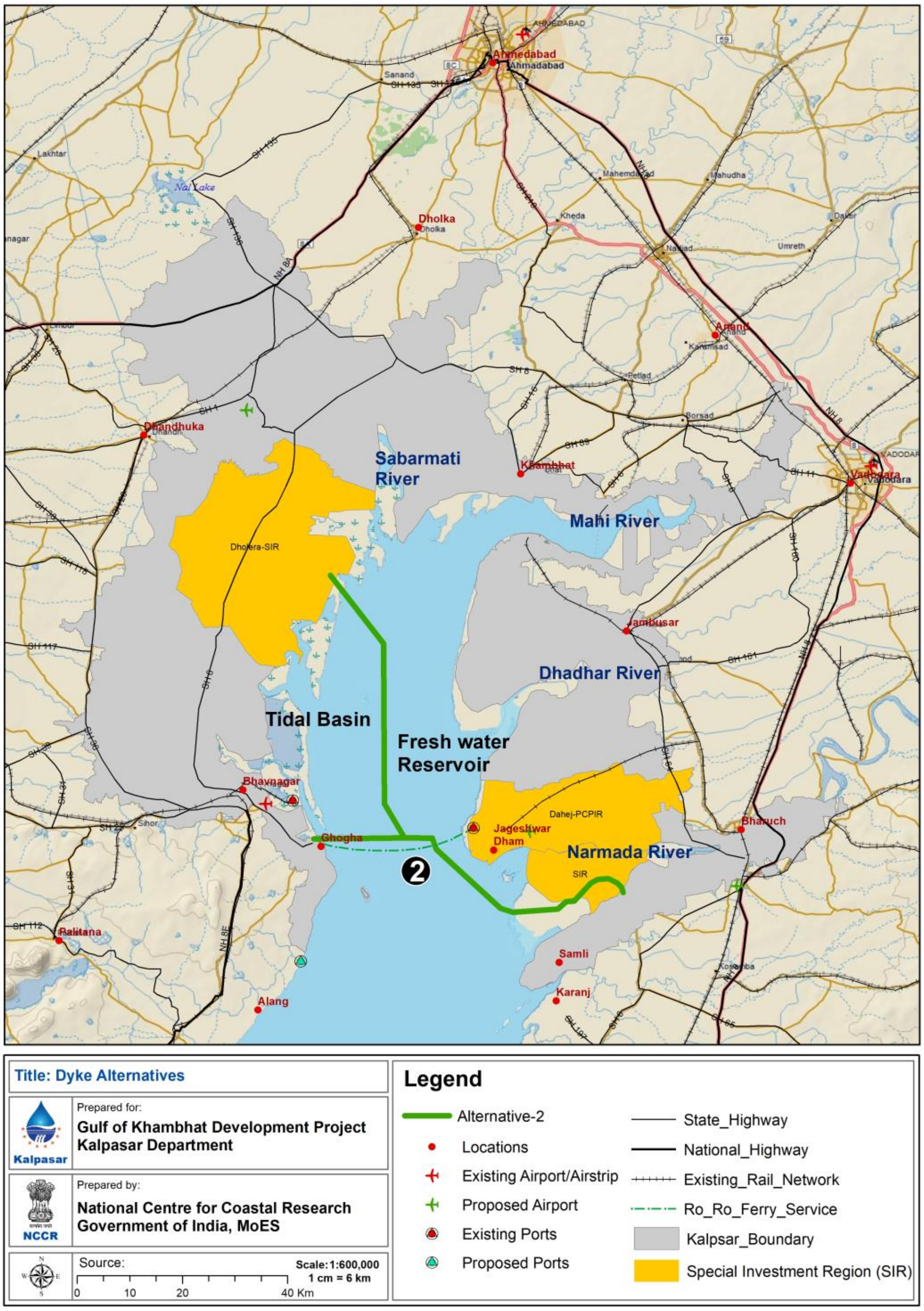


Figure 5: Alternative II: Dyke with tidal basin and freshwater storage including Narmada discharge

3.2.3 Alternative III: Dyke with only Fresh water storage without Narmada discharge

A detailed review of study reports on Reconnaissance Study, Prefeasibility Study, Six Specific Studies were taken up and the option of tidal power was dropped owing to following reasons:

- Combining a saline tidal basin with a freshwater reservoir would threaten freshwater sustainability in case of high salt leakage from the tidal basin.
- The concrete structure of tidal power block is not a suitable option as it may lead to liquefaction of the foundation material and could induce earthquakes given the seismic nature of the Gulf.
- It may be difficult to construct a tidal power block of sufficiently reliable design, given the complexity required, involving caissons weighing 60,000-1,00,000 tonnes.
- The production cost of tidal energy is high, and the cyclical tidal energy produced in large quantities will be difficult to absorb into the regional power system since peak and off-peak demands, which vary, do not fit easily with tidal energy production.
- The project cost gets greatly heightened with the inclusion of a tidal power component which is around 64 percent of the total project cost; financial support will be difficult to obtain from public/private sources for this project.
- The creation of a saline tidal basin on the Saurashtra side would aggravate salinity ingress onto land and ground water.

Concurrently, the alignment of the dyke was shifted 15 km North due to environmental and marine geo hazards.

1. Review of past Geotechnical and Seismic Studies revealed presence of 500 m thick silty fine sands of very low bearing capacity. In particular, at the mouth of the Narmada River the soil conditions are very poor.
2. Several faults, along junctions through the Ghogha- Hansot dyke alignment zone, makes the seabed stability highly prone to up–throw and down–throw along the fault lines.
3. Deep channels were also observed across the Ghogha–Hansot alignment.
4. In the proposed dyke alignment, the water from Narmada is diverted through a barrage-cum-canal. So, the sediment load will greatly reduce in the reservoir, as the Narmada inflows carrying the heavy sediment load will be off-loaded through the barrage into the sea.
5. Due to shift in dyke alignment, there will be shorter closure length (29 km) as compared to the earlier alignments.
6. Most significantly, with the avoidance of the closure of the Narmada’s mouth breeding habitat of the marine fish in the Narmada estuary will remain unaffected, thereby eliminating negative environmental repercussions.
7. In addition, the existing ports of Dahej and Bhavnagar, being left out of the dyke enclosure, will not face any hindrance in their functioning and development.

Further, to finalize the actual dyke alignment 21 sections were studied in a stretch of 3 km along the dyke corridor based on following surveys:

1. Seismic Magnitude survey,
2. Sub bottom profiling,
3. Corridor Bathymetry Contour with Sub-bottom Profiling (SBP) Coverage,
4. Single beam bathymetry
5. Seabed Sonic image from Multi-beam backscatter

6. Grab Sampling,
7. Particle size distribution Curve, and
8. Electro-vibro core tests and cone penetration tests

The final Alignment as shown in **Figure 6** was finalized based on observed fault lines/lineaments for all the deep-water channel areas with various geophysical and geotechnical data.

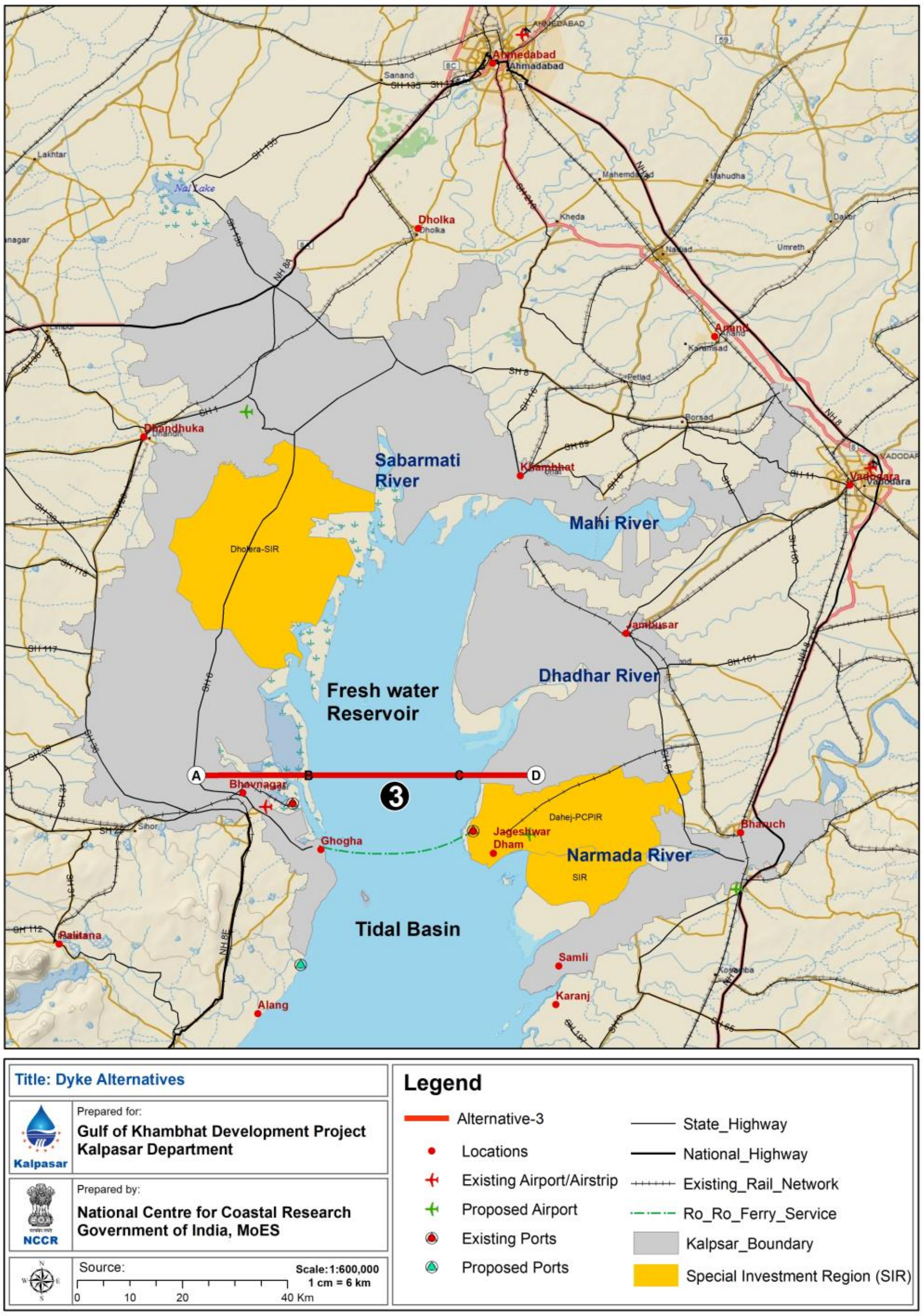


Figure 6: Alternative III: Dyke with only Fresh water storage without Narmada discharge

3.2.4 Project Alternative Evaluation

The evaluation of project alternatives is carried out and given in

Table 3.

Table 3: Analysis of Alternatives

S.No	Parameter	Alternative I	Alternative II	Alternative III
1.	Alignment	**(Ghogha-Dahej-Hansot)**	**(Ghogha-Dahej-Hansot)**	**(Bhavnagar – Paniyadra)**
2.	Length of Dyke	62.9 km length in Gulf (28.9-km Gulf closure and 34.0-km Narmada river closure)	64.16 km length in Gulf (20.46 km Gulf Closure and the 43.70 km Narmada river closure)	26.7 km length in Gulf (additional 33.43 km in intertidal / land on west side and east coast respectively)
3.	Tidal basin and freshwater reservoir area	Tidal basin of 500 km^2 integrated with freshwater reservoir of 2000 km^2	Tidal basin area of 700 km^2 integrated with freshwater reservoir of 2000 km^2	Tidal Basin Not envisaged, Fresh Water basin of 1600 km^2.
4.	Key Difference	Narmada river Mouth is inside Reservoir	Narmada river Mouth is inside Reservoir	Narmada river Mouth is out Reservoir
5.	Tidal Power production with installed capacity	5000 MW	5880 MW	Not envisaged
6.	Travel distance reduction	200 km	200 km	180 km
7.	Saline intrusion	Moderate	Moderate	No
8.	Improvement in ground water quality	Moderate	Low	High
9.	Increase in productive land area	Moderate	Moderate	High

S.No	Parameter	Alternative I	Alternative II	Alternative III
10.	Fresh Water contamination due to seepage of salt water	High	High	Low
11.	Soil Conditions	Very Loose	Very Loose	Loose to Medium
12.	Project Cost	Rs. 19,253 crore (in 1997)	Rs. 44,301 crore (in 1999)	Rs. 1,00,000 crores (in 2022)
13.	Environmental Benefits	Moderate	Low	Beneficial
14.	Wildlife sanctuary	Nil in 10 km radius Black buck national park- 11.16 km	Nil in 10 km radius Black buck national park- 45.57 km	Nil in 10 km radius Black buck national park- 37.7 km
15.	Forest area	Nil	Nil	Nil

Based on the analysis and taking various expert opinions, ***alternative III*** is selected as best alternative for development considering various benefits.

3.3 Site Information

Table 4: Site Information Summary

S.No	Item	Description
1	Location	Gulf of Khambhat, Gujrat-India
2	District	Bhavnagar & Bharuch
3	State	Gujarat
4	Topography	Gulf & Intertidal Area
5	Temperature	Summer average temperature is around 40°C, Winter is cold with December recording the coolest temperatures averaging around 15°C.
6	Wind Speed	Maximum sustained winds of magnitude 144-158 kmph (≈ 40-43 m/s) class of winds during the cyclone in the western part of the GoK. High wind speeds of up to 21 m/s are likely to occur during the SW monsoon. Annual average of daily max windspeed in GoK is nearly 14-15 m/s.
7	Rainfall	Of the basins that run into the GoK, the Narmada basin

		receives the highest rainfall with an interannual variability of 700 mm to 1250 mm (1901 to 2020) while the Saurashtra catchment area receives lowest rainfall ranging from 420 mm to 640 mm. The rest of the basins receive rainfall in the range 650 mm to 1115 mm.
8	Relative Humidity	Relatively humid conditions prevail during monsoon months JJAS with relative humidity ranging from 75 to 80%, while the other months it ranges between 30 to 50%.
9	Seismicity	Seismic zone III (IS: 1893:2016)
10	Nearest Road Connectivity	Bhavnagar Pipali NH 751, Gujarat SH 6
11	Nearest Rail Connectivity	Bhavnagar Railway station (9.96 Km from point A), Dahej Railway station (13.3 Km from point D)
12	Nearest Seaport	Bhavnagar (20 Km from point A), GMB Dahej Port (17.6 km from point D)
13	Nearest Airport	Bhavnagar airport (16 Km from point A), Vadodara Airport (102 Km from point D),
14	Nearest Town/ Village	Bhavnagar (from point A), Paniadara (from point D)
15	National Parks/Wildlife Sanctuaries	Nil in 10 km radius, Black buck national park is at 37.7 km

3.3.1 Climate

The Gulf experiences dry tropical monsoon climate with an average annual rainfall of about 800 mm. The monsoon begins on June or July and ends in September. The rainfall is erratic in occurrence, duration, and intensity. The winters are generally cool and dry.

3.3.1.1 Rainfall

Winter Season (January-February): Rainfall is minimum in winter season with the amounts of 2.7 and 1.7 mm for Bhavnagar and Veraval respectively. The winter rainfall hardly contributes to the annual rainfall of both the stations.

Hot Weather (March - May): During this period, both stations show contrasting rainfall activity with the Veraval station having no rainy days and Bhavnagar stations have very little rainfall. The rainfall amounts are slightly more than the winter season with the seasonal rainfall amounts of 7.4 mm and 1.9 mm for Bhavnagar and Veraval respectively.

Southwest Monsoon (June - September): This is the main rainy season for both the stations. The monsoon sets in the state by end of June or first week of July. The season contributes to about 92% and 95% of the mean annual rainfall for Bhavnagar . The monsoon rainfall amounts being 566 and 731 mm for the above stations. The maximum rainfall is received in the peak monsoon month of July.

Northeast Monsoon (October-December): This period contributes to about 6% and 5% of the mean annual rainfall for the stations Bhavnagar. The mean rainfall during this season is 37.9 mm and 34.7 mm respectively for the above mentioned stations.

3.3.1.2 Temperature

Month	Maximum Temp (deg C)	Minimum Temp(deg. C)	Average Max Temp (deg. C)	Average Min Temp (deg. C)
	2018			
January	32.6	12.4	28.6	15.4
February	36.1	14.4	31.8	18.1
March	39.8	18.6	35.9	21.8
April	40.3	21.5	38.5	25.3
May	44.1	24.1	40.5	27.2
June	42	25.6	38.7	28.5
July	38	24.5	32.8	25.9
August	36.1	23.7	33.0	25.3
September	38.2	22.3	33.8	23.9
October	38.4	19.8	36.9	23.8
November	36.1	16.1	33.5	19.7
December	30.7	10.2	28.1	14.5
	2019			
January	32.4	8.6	27.7	13.1
February	35.6	9.6	29.9	15.4
March	39.4	14.6	33.9	21.1
April	43.7	20.4	39.0	25.6
May	41.9	23.9	38.8	26.7
June	42.5	23.6	37.1	27.9
July	38.2	23.8	35.2	27.2
August	33.9	24.5	31.7	25.4
September	34.4	24.6	32.1	25.7
October	35.4	22.7	32.9	24.9
November	33.4	18.6	31.4	21.8
December	30	12	27.7	17.3

3.3.1.3 Wind Speed

Month	Minimum wind speed(Kmph)	Maximum wind speed(Kmph)	Average wind speed (Kmph)
2018			
January	2	14	5.4
February	4	16	6.4
March	2	22	7.7

Month	Minimum wind speed(Kmph)	Maximum wind speed(Kmph)	Average wind speed (Kmph)
April	4	30	11.9
May	10	36	20.5
June	6	46	25.9
July	6	42	19.3
August	12	34	18.5
September	4	28	15.2
October	4	20	10.1
November	0	18	8.4
December	2	22	11.3
2019			
January	6	26	15.0
February	8	28	15.8
March	4	28	14.8
April	6	30	18.2
May	14	38	28.4
June	8	42	26.7
July	10	40	21.3
August	4	24	15.0
September	2	28	12.8
October	4	18	11.6
November	0	14	7.9
December	4	20	12.5

3.3.1.4 Relative Humidity

Month	Minimum Humidity(%)	Maximum Humidity(%)	Average Humidity(%)
2018			
January	38	71	53
February	29	65	42
March	21	65	38
April	20	52	32
May	29	55	38
June	48	94	63
July	56	89	68
August	63	97	79
September	54	86	69
October	34	86	53
November	35	61	45
December	37	94	55

3.3.2 Bathymetry

The bathymetric survey in the northern Gulf of Khambhat is essential for estimating reservoir volume assessment and for numerical model studies on shallow water processes. Due to the presence of vast intertidal area and strong currents resulting from macro –tidal regime, there were difficulties in the physical collection of data. So, indirect method using satellite imageries, different kind of instrumented systems were made to fill the gaps of the data for the study especially. The intertidal region with large tidal variations and heavy currents are difficult to survey and also the work site is too shallow for normal vessels to operate with endurance and too far for small crafts to operate.

The intertidal areas are surveyed using satellite imageries and the Bathymetry with low draft boat was carried out using conventional survey systems like single beam echo sounder for depth measurement with position and navigation control.

27 ground control points have been used for georeferencing the satellite imageries. Simultaneously the data from the network of tide gauges to record tidal elevation variation over a period of year has been used to delineate intertidal boundary. Then, the contours of different elevation over inter tidal region has been prepared to make a digital terrain model that would cover the required area. Survey extended with portions of Mahi, Sabarmati, Narmada and Tapti Rivers up to tidal influenced area. The survey plan lines below corridor (Nirma to Gopnath) are east-west line (64 lines), from Gopnath to Diu, lines are aligned to SW-NE direction (130 lines). The southern portion covers totally 21,109 line km surveys. The data was collected on parallel lines from south to north. The bathymetry and Topography Coverage of Gulf of Khambhat is shown in **Figure 7**.

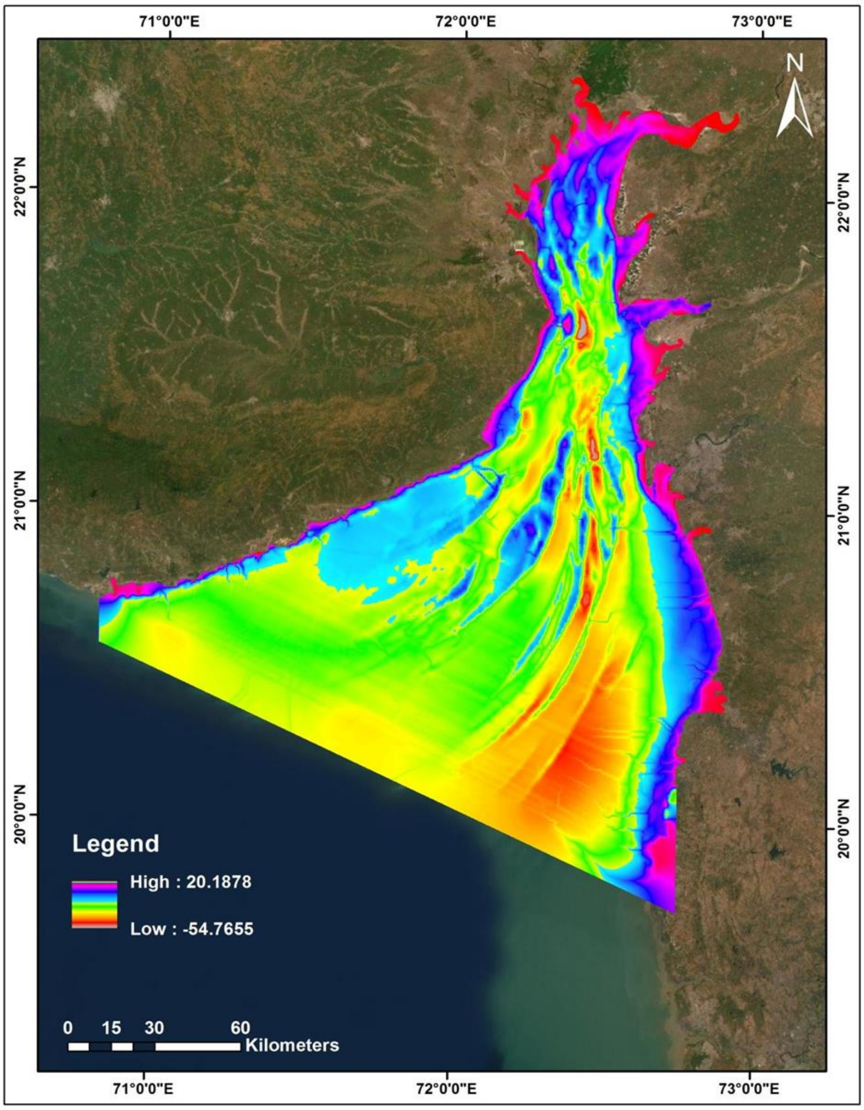


Figure 7: Bathymetry of Gulf of Khambhat

Bathymetry with maximum water depth of 30 m with respect to MSL around the dyke alignment has been observed. The **Figure 7** is a shade relief of this bathymetry with clear indication deep water. Numbers of tidal stations were established along Gulf Khambhat to produce a co-tidal model to aid bathymetric reduction of sounding data. An examination of the overall features as observed from Figure indicates the presence of four main channels separated by ridges on either side with some of them discontinuous or at places merging with the other channels.

3.3.3 Ocean Parameters

3.3.3.1 Tide

The GoK with its unique shape and orientation has a very high tidal range (~12 m) and tidal flow (~4 m/s). With a wide mouth of about 180 km in the south, which narrows down to about 5 km at the northern end, the Gulf channels a large amount of water from the ocean into the system due to the tidal influx, which makes any operation in the Gulf tedious.

The currents in the GoK are mainly influenced by the tides. Tides also play an important role in the movement of the suspended sediments and results in the formation of several mud banks and found to cause severe changes in the coastal profile and bottom topography in the entire region of the Gulf.

Tide gauges were chosen based on the site location, installation possibility and availability of structure in the region. The reconnaissance survey was carried out along the eastern and western side of the Gulf to identify the availability of fixed structures. Mixed tide was observed at Diu at the mouth of Gulf of Khambhat.

The west coast of India are influenced by mixed semi-diurnal type (M2 – type), with a large diurnal inequality and varying amplitude – which decreases from north to south along both the coasts. Because of its unique position – nearness to the Tropic of Cancer, funnel shape of the Gulfs Coast. There is a gradual decrease in the tidal form factor from Gulf mouth to head in the eastern and western Gulf of Khambhat. The minimum magnitude is obtained at Bhavnagar (0.22), which gradually increased at Pipavav with a maximum at Diu on the western coast. The tidal form factor is found to increase from north to south, unlike the major tidal constituents, which increase from south to north. The minimum magnitude of 0.15 is obtained in the case of Khambhat (northern GoK). The maximum magnitude of the tidal form factor of 0.85 is noticed at Nawabandar, which situates at the south-western GoK in the Saurashtra coast.

24 met ocean observatories were installed to measure tide, current, barometric pressure, wind and direction in Diu, Jaffrabad, Pipavav, Mahuva, Gopnath, Haathab, Bhavnagar, Nirma, Adelai, Dholera (S), Dholera (N), Dhuvaran, Mahi River, Kavi Bandar, Devla, Dadar, Dahej , Badbhut, Olpad, Hazira, Bilimora, Dhaman, Wadhavan, MC Diu, MC Billmora, Off Narmada, Mal Bank, Dyke Corridor as shown in the map (**Figure 9)** .

Fabricated towers / floating catamaran have been used to base the sensors of met-ocean observatories.

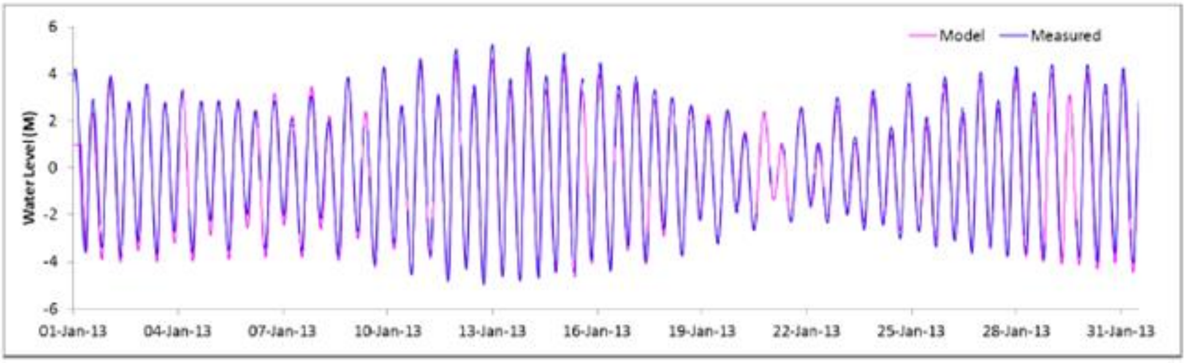


Figure 8: Water level Observation in Gulf of Khambhat

In the Gulf of Khambhat, the MHWS of 4.7 m at Manhuva Bander rises to 6.5m at Gopnath point to 10.2m at Bhavnagar. The maximum spring tide recorded at Bhavnagar is 12.5m, which is second only to that of the highest tide recorded anywhere in the world.

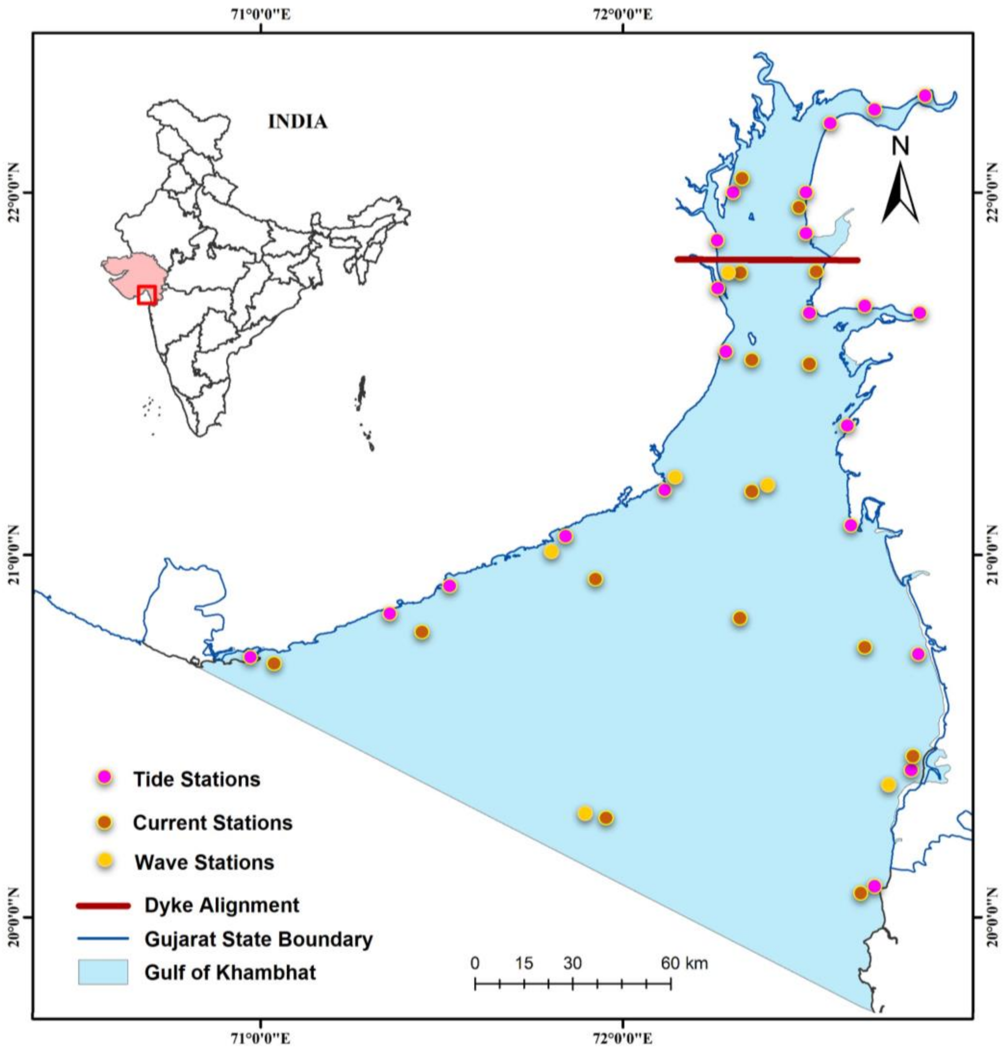


Figure 9: Details of tide, current and wave station locations along Gulf of Khambhat

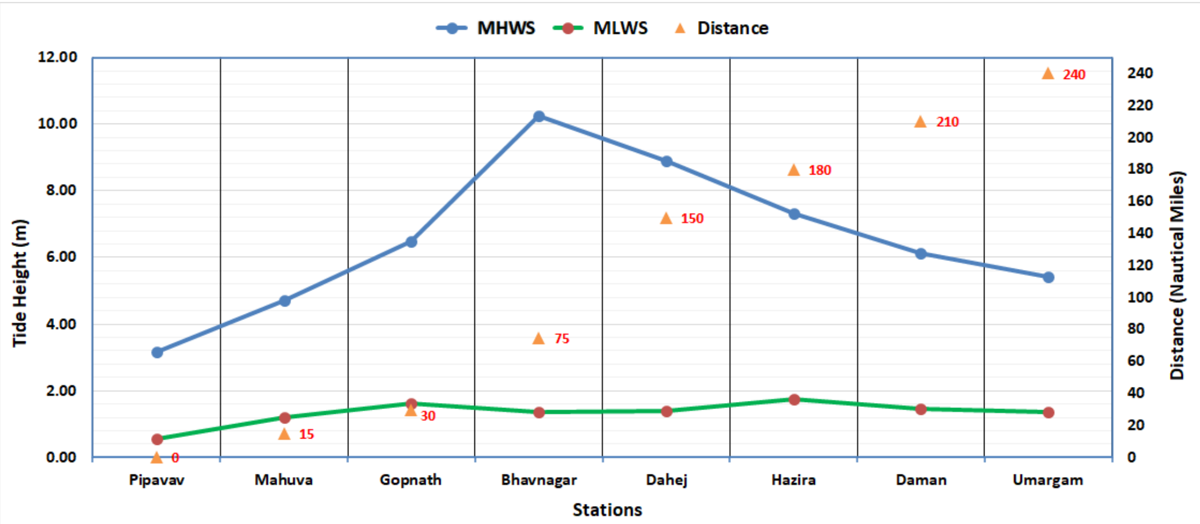


Figure 10: Propagation of Tides

3.3.3.2 Waves

The waves in the northern Arabian Sea largely depend on the winds blowing over the Indian Ocean and Arabian Sea. Wind generation of waves involves a transfer of energy from moving air to water surface. The amount of energy exchanged depends mainly on velocity, duration, and fetch (the distance over which the wind blows, which has an important influence on wave height and period) of the wind. Waves along the west coast of India are high during the summer monsoon. Waves also are generated by low atmospheric pressure (storm surges) and displacement of the ocean floor, in particular by earthquakes (tsunami)

Wave measurements were carried out in 6 locations in and around the Gulf of Khambhat at different water depths. The instruments used for data collection are data well wave rider buoy (GPS make), Weather buoy (integrated at NIOT), and Valeport non-directional tide gauge.

From the measured data, the occurrence, frequency distribution, directional distribution of wave height and period and percentage of exceedance were given both in tabular and graphical format for different wave parameters like significant, maximum, average wave height, period and wave direction. Maximum and significant wave heights of Mid Channel Diu were 4.3 m and 2.7 m respectively on 18 June 2012. The significant wave heights off Daman and Mahuva are 1.96m and 1.8m respectively during the observation period April to November 2012. In 2013 (January to May), the maximum significant wave height off Dam corridor is 1.3 m recorded. In 2013 (March to October observation period) the maximum significant wave height recorded off Bhavnagar, Narmada and Umargoan are 0.8m 2.98 m and 5.2m respectively. There is no predominant mean wave direction recorded, however most of the waves were from SW and NE from the wave data recorded off Mid channel Diu. There is no predomiant wave direction off dam corridor recorded. Non directional tide gauges are deployed at other locations and hence there are no wave direction recorded there.

Table 5: Wave characteristics of Gulf of Khambhat

Wave characteristics	Dyke corridor (Off Bhavnagar)	Central location (Off Narmada)	Outer channel (Mid channel Diu)
Wave height	The maximum significant wave height off Dyke corridor is 1.3 m during January to April, 2013 observation. About 88.5% wave are less than 0.25 m	The maximum significant wave height off Narmada was 2.98 m	Maximum and significant wave height of Mid channel Diu was 4.3 m and 2.7 m respectively during April to June, 2012. However, during March to October, 2013 period the maximum Hs were 5.2m.

Wave period	The dominant wave period were ranged between 0-4s (74%) followed by 7.8 sec (23.6%)	The dominant wave period were ranged between 4-8 sec (85.6%) followed by 8-12 sec (14.4%)	The dominant wave period were ranged between 4-8 sec (97.6%) followed by 8-12 sec (2.4%).
Wave direction	There is no pre-dominant wave direction.	There is no pre-dominant wave direction	There is no pre-dominant wave direction.

3.3.3.3 Tides and Currents

The GoK with its unique shape and orientation has a very high tidal range of about 13m and strong tidal currents of more than 3m/s and is a non-linear shallow-water system. With a wide mouth of about 180 km in the south, which narrows down to about 5 km at the northern end, the Gulf channels a large amount of water from the Arabian Sea into the system due to the tidal influx, which makes any operation in the Gulf tedious. The Gulf is primarily driven by tidal currents with a total tidal variance of 90%. Coastal current prevents the gulf-water to be flushed out into the open sea directly. The tidal range at Gulf of Khambhat is the largest along the Indian coastline with an average tidal range of 10 m near Bhavnagar. The tides of GoK are mixed and predominantly semi-diurnal in nature. M2 (semi-diurnal) and K1 (diurnal) constituents influence the hydrodynamics of the gulf of Khmabhat significantly, compared to the other constituents. The tides in GoK have large diurnal inequality and varying amplitudes. Tidal range gradually increases from the southern gulf to northern gulf with a maximum at the inner Gulf and had a slight decrease at the northern most location. Tide gets amplified significantly inside the Gulf due to its shape and varying bottom friction coefficients as well as the large width of the continental shelf of the central west coast of India. Observations indicate that, the semi-diurnal tides in the GoK, amplify about three to four fold from mouth (~ 0.4m at Pipavav) to head (~1.50 m -Bhavnagar and then reduce to ~ 0.70 Khambhat) which mainly contribute to the tidal amplification; in contrast, the amplification of diurnal tides is much smaller although a similar trend is followed by the other major constituents (S2, K1 and O1). At Pipavav, neap and spring tide elevations are 4 and 4.8 m, respectively. At Bhavnagar, in the western part of the Gulf, the maximum spring tidal height is found to be 11.6 m and the maximum neap tidal height is 10 m. The average maximum amplitude is observed during July, which is due to the influence of peak south-west monsoon. The tidal amplitude is greater during the flood flow rather than the ebb.

The tidal currents at the mouth are dominated by the M2 constituent with amplitude with amplitude of about 4-5 times higher than that of K1. The quarter diurnal compound tides include the major constituent MS4, derived from the interaction of M2 and S2, which lag the forcing tides (M2 + S2). Among the shallow water constituents, M4 dominates the entire Gulf with significant amplitudes (~10 cm s^{-1}) and gets amplified towards the head of the Gulf (~30 cm s^{-1}), followed by MS4. At the head, the M4 component contributes significantly up to 40%. The M2 amplitudes are comparable to M4 near the head. High M4/M2 ratio characterize the Gulf as flood asymmetric. The M2/S2/MS4 combination also contributes towards the asymmetry. Between, Jaffrabad to Nirma semi-diurnal tides are predominant while diurnal tide dominates from Kavi onwards. Two tidal combinations (M2/M4 overtide and M2/S2/MS4 compound tide) are the major contributors to the flow velocity skewness in the GoK with mixed, mainly semi-diurnal tidal regime. The principal over-tide and compound tides are M4 and MU2, respectively. The amplitude of the major tidal constituents (M2, S2, O1 and K1) at Bhavnagar is 3.33, 1.06, 0.69 and 0.28 m and at Diu is 0.48, 0.21, 0.42 and 0.19 m respectively which infers the dominance of the semi-diurnal component in the tidal amplification. In the western part of the Gulf diurnal tides dominate while in the eastern part semi- diurnal tides dominate. The summer amplitudes of the major tidal constituents are much higher than that of the winter amplitudes and the seasonal variability of the tidal constituents is comparatively higher in the inner stations than that of the offshore stations.

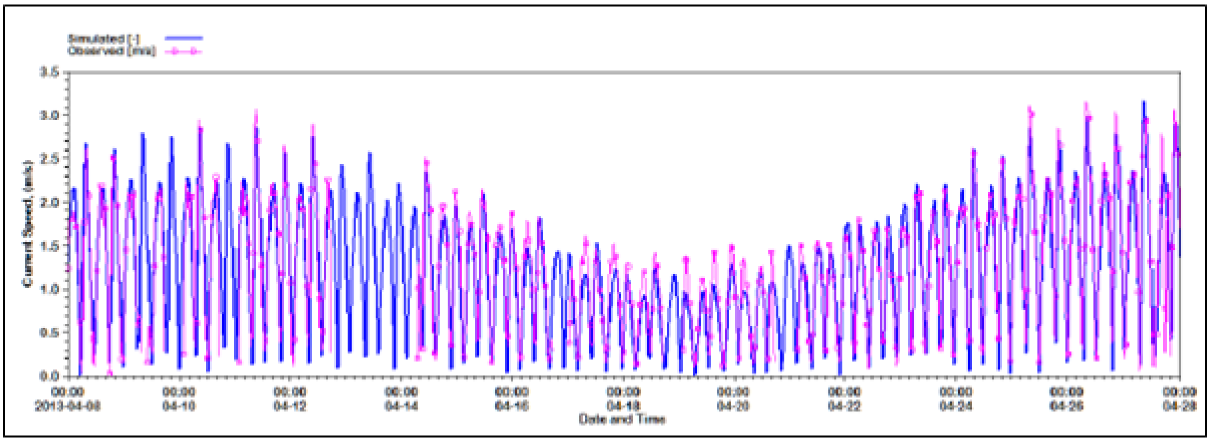


Figure 11: Current Speed

3.3.4 Geology

The Western Continental Margin of India (WCMI) has a different evolutionary history with five major offshore sedimentary basins such as the Kutch, Saurashtra, Mumbai, Konkan and Kerala. The northern part of the west coast is geologically prominent due to the presence of extensive Deccan flood basalt province which masks the pre-existing Precambrian geology of the region. It is very well known that the dominant structural and tectonic trends along the west coast are the Dharwar trend (NW–SE to NNW–SSE), the Aravalli trend (NE–SW), and the Satpura trend (ENE–WSW to E–W). The WCMI is characterized by wider continental shelf which increases from around 50 km off Cochin in south to more than 300 km off Saurashtra-Mumbai coast in north. While major rivers Sabarmati, Narmada, and Tapti discharge the sediments into the Gulf of Khambhat, the Luni River joins the Arabian Sea at the Gulf of Kutch. The northern most part of the west coast was the first to be subjected to continental rifting since the late Triassic giving rise to the three pericontinental Mesozoic marginal rift basins in the onshore such as the Kutch, Narmada, and Cambay basins at the northwest coast. All the three basins had evolved in different periods in the Mesozoic and contain varying thickness of Mesozoic sediments. The Cambay basin is an intracratonic graben bordered by Radhanpur–Barmer arch in the west and the Aravalli orogenic belt on the east. The basin is bounded by enechelon faults paralleling the Dharwar trend and lies across the Aravalli and

Narmada trends. Several transverse faults divide the Cambay basin into six tectonic blocks. Geophysical studies in the basin indicate that at least 1200 m of Mesozoic sediments could be lying below the basaltic traps which form the floor of nearly 5000 m thick sedimentary sequence. The Narmada basin which formed as a rift basin in the late Cretaceous is the southern most of the three marginal basins. It embayed into a narrow graben along the Narmada–Son lineament. Among these three basins, marine sediments of late Cretaceous occur only in this basin, whereas in the other two basins, this is a period of non-deposition and volcanic activity.

The most part of the onshore Saurashtra basin is covered by the Deccan traps except in the periphery; the tertiary sediments are present along the coastal strip with sediments of lower Cretaceous exposed in the northern part. In the western and the southeastern part of Saurashtra, the exposed Deccan traps consist of several volcanic plugs of alkaline complexes which are pipe-like igneous intrusions having limited horizontal dimensions from few hundred meters to a few kilometres. The region is also characterized by the presence of E–W and NE–SW oriented dyke swarms of Deccan volcanic activity and coincides with the dominant structural trends of the region.

The generalized stratigraphy of onshore Saurashtra basin consists of Precambrian basement overlain by Mesozoic sediments, Deccan traps, and thin cover of Neogene as well as Quaternary sediments with exposures of Mesozoic and Cenozoic sedimentary rocks and Deccan traps in the basin **Figure** .

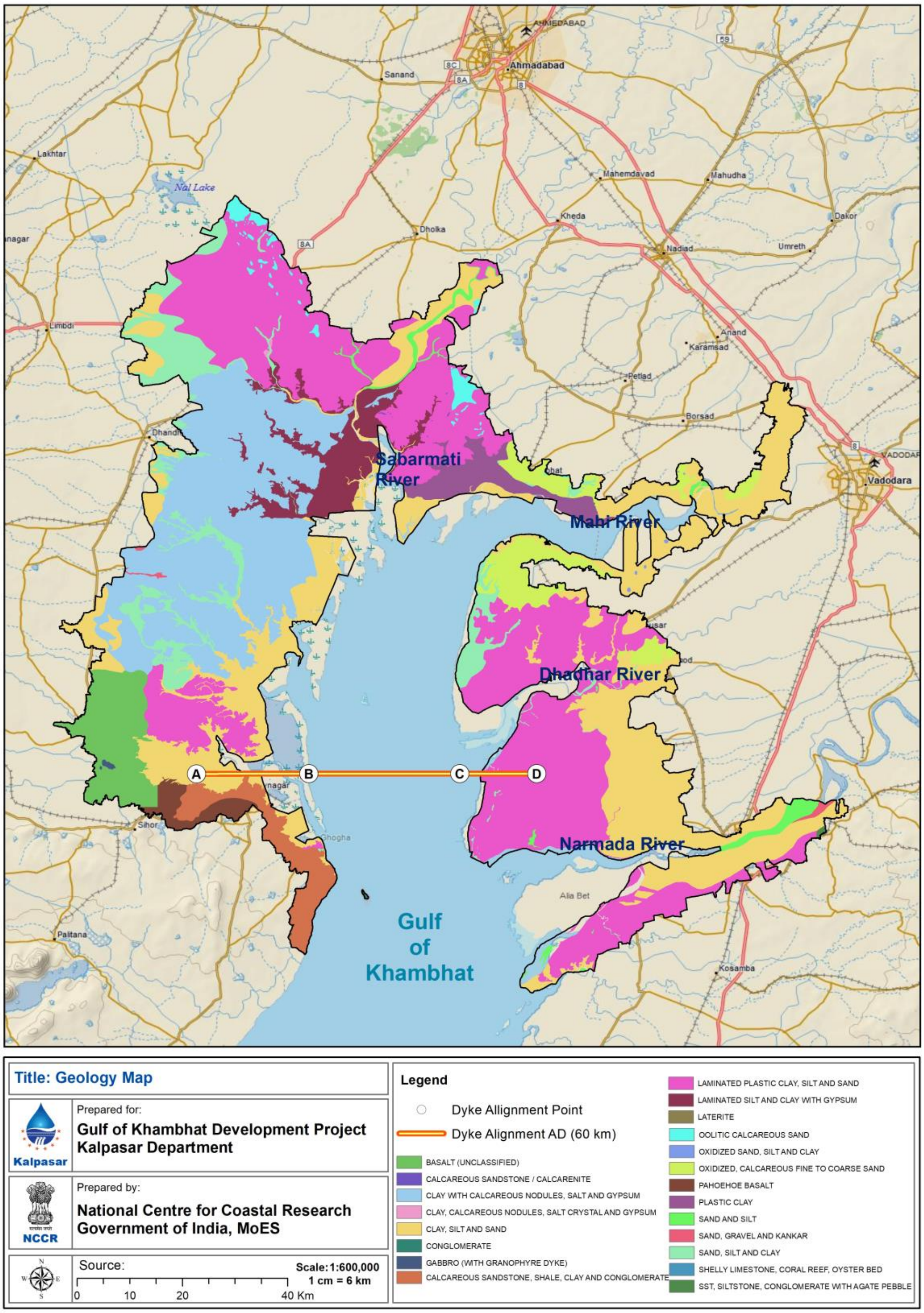


Figure 9: Geological Map of Project Region

3.3.5 Soil Classification

The Narmada, Sabarmati, Mahi and Tapti rivers empty into the Gulf. The Gulf is shallow and abounds in shoals and sandbanks including the Mal Bank at the river mouths and the Malacca Banks at the Gulf's entrance to the Arabian Sea. The Gulf is known for its extreme tides, which vary greatly in height and speed. At low tide the bottom is left nearly dry for some distance below the town of Khambhat including the investigation site. Seabed soil types and a combination of current, tidal and wave forces combine to create an environment which leads to seabed sediment being lifted and transported. The result is the natural depletion of soil in one area and its aggradation in another.

Boreholes were carried at 41 locations and CPT was carried out at 8 locations for the design of the Kalpasar dyke. The depth of investigation varied from 15 m to 200 m. Standard Penetration Test (SPT), Cone Penetration Tests (CPTu) with pore pressure measurement, In-Situ Vane Shear Test, In-Situ P-S Suspension Logging and In-Situ Permeability were carried out to provide data on the in-situ soil conditions.

Tests were performed both on-board and onshore for testing the soil sample collected during the field investigation. Visual Description, Natural Moisture Content, Unit Weight, Torvane, Pocket Penetrometer, Specific gravity, Grain Size Distribution, Atterberg's Limits, Shrinkage Limit, Free Swell Index were carried out to determine the physical properties of the soil. Corrosive tests on soils to determine the effects of Chloride, Sulphate, pH, Electrical Resistivity, Organic matter and Carbonate content were also carried out along with determination of dissolved matter. Strength tests like Unconsolidated Undrained Triaxial Test (Clayey Soils), Consolidation Test, Consolidated Undrained Triaxial Test with pore pressure measurement, Consolidated Drained Triaxial Test, Cyclic Triaxial Test, Direct Shear Test (Sand), Standard and Modified Proctor Density Tests, Laboratory Constant head and Falling Head Permeability tests, Resonant Column Test were carried to determine the strength characteristics of the soil. Tests like cyclic triaxial and resonant column indicates whether the sample is susceptible to liquefaction.

Based on the results and the soil profile in the region, the entire geotechnical profile can be split into three sectors. The type of soil identified is almost similar in the classified sectors i.e., clayey soil with intermediate pockets of silt and sand in Bhavnagar intertidal region, silty sand of varying density with few pockets of silty clay, clayey silt, shell fragments, sandy silt and a few gravels in the gulf region. Dahej intertidal region consists of stiff to hard clay in the top few layers followed by dense sand with few pockets of clay, silt as intermediate layers.

3.3.6 Seismicity

Based on the geology and tectonics of the region around the Kalpasar dyke, 6 zones were identified, namely: (i) Saurashtra; (ii) Kutch failed rift region; (iii) ADFB and Vindhyan region; (iv) Narmada Son failed rift region; (v) Deccan volcanic province; and (vi) Arabian Sea.

(1) The seismicity in the Kutch region is most intense. This region has experienced at least two major earthquakes in historical past, the recent one in 2001 (M 7.6). The entire crust appears to be seismogenic, as seen from the focal depth of the earthquakes.

(2) The Narmada Son failed rift region appears to be moderately active and has produced moderate to strong magnitude earthquakes. Even in this region, entire crust seems to be seismogenically active.

(3) The Saurashtra, Deccan and ADFB & Vindhyan are less active and the seismicity appears to be confined in the upper crust (<15 km). The Arabian sea region appears to be least active; and

(4) Cambay rift has also been highlighted in the geological maps of India. However, it does not seem to be active, as seen from the seismicity map. Hence it is not considered here as a potential seismic source. Seismic map with the project alignment is shown as **Figure** .

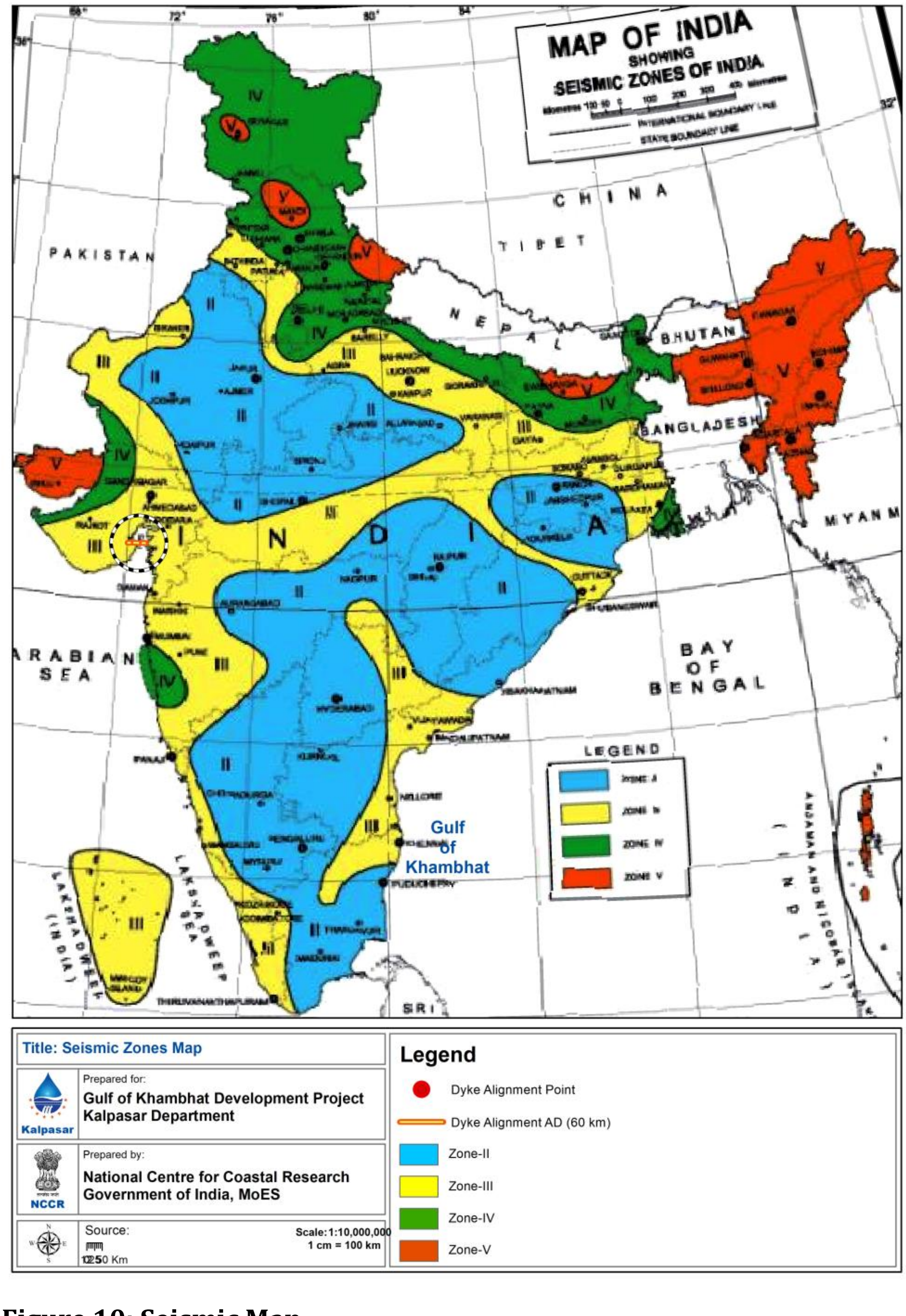


Figure 10: Seismic Map

3.3.7 Topography

The project area upto +10m has a systematic slope with low gradients tapering towards the Gulf. The tidal mud flats are the dominant and continuously present lands forms. They are grossly flat interspersed with raised mud flats, bets, mangrove swamps, island bars and offshore bars. The low-level tidal mud flats are diurnally submerged, while the higher level tidal mudflats are periodically submerged when the tide levels are high. The areas around the Narmada River have variant topography. The right bank areas are at higher elevations with 8.5 m level near the Bhadbhut barrage project site rising to 10.0 m level at Bhadbhut to 12.5 m level at Bharuch. These areas are protected from floods. The left bank areas are at lower elevations with 5.0 m near the project site rising gradually to 10.00 m level near Ankleshwar. The Aliabet area downstream of the project site is having contour levels of 4.0 to 4.5 m. The low laying left bank areas are affected by floods.

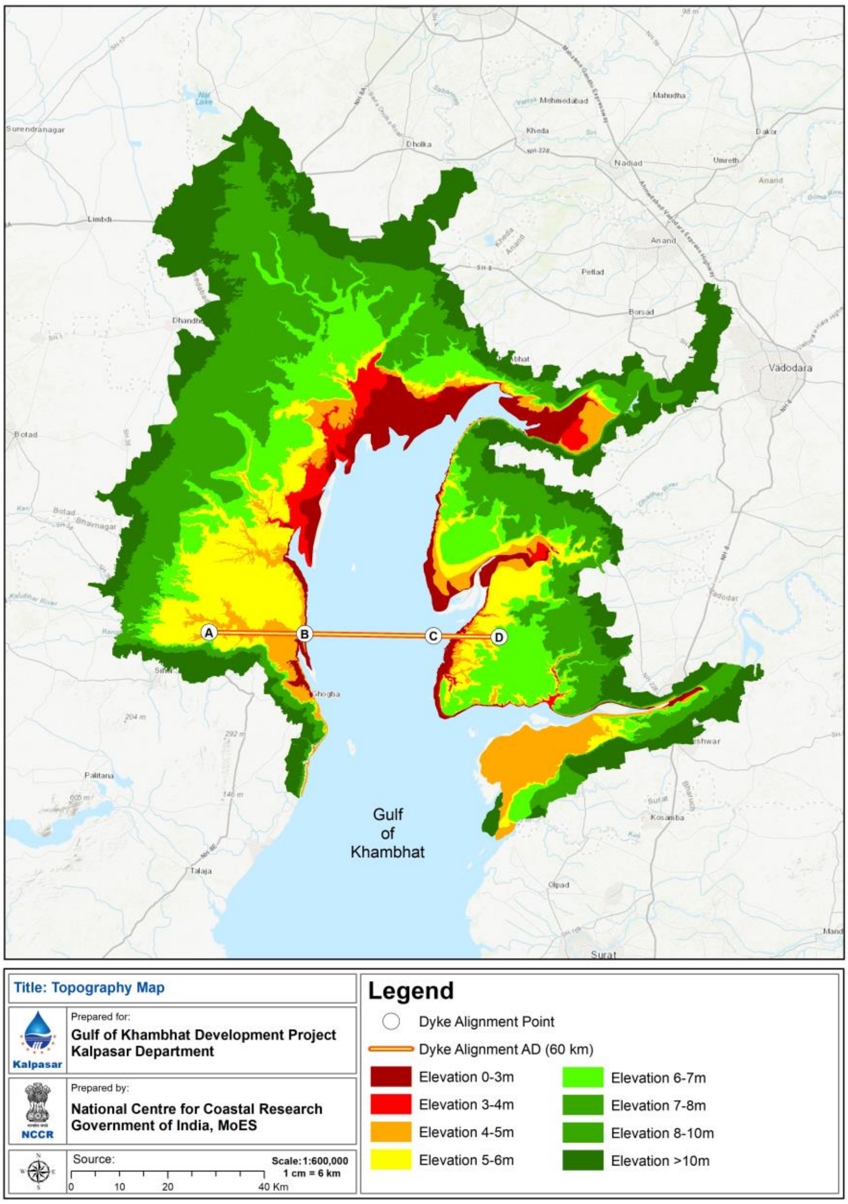


Figure 11: Topography of Project Region

3.3.8 Eco Sensitive Areas

The eco sensitive map covering 15km radius around the dyke alignment is shown as **Figure** . There are no wildlife sanctuaries or national parks in 15 km radius as listed in wildlife protection act (WPA) of India. Blackbuck National Park is located at 37.7 km from the dyke alignment.

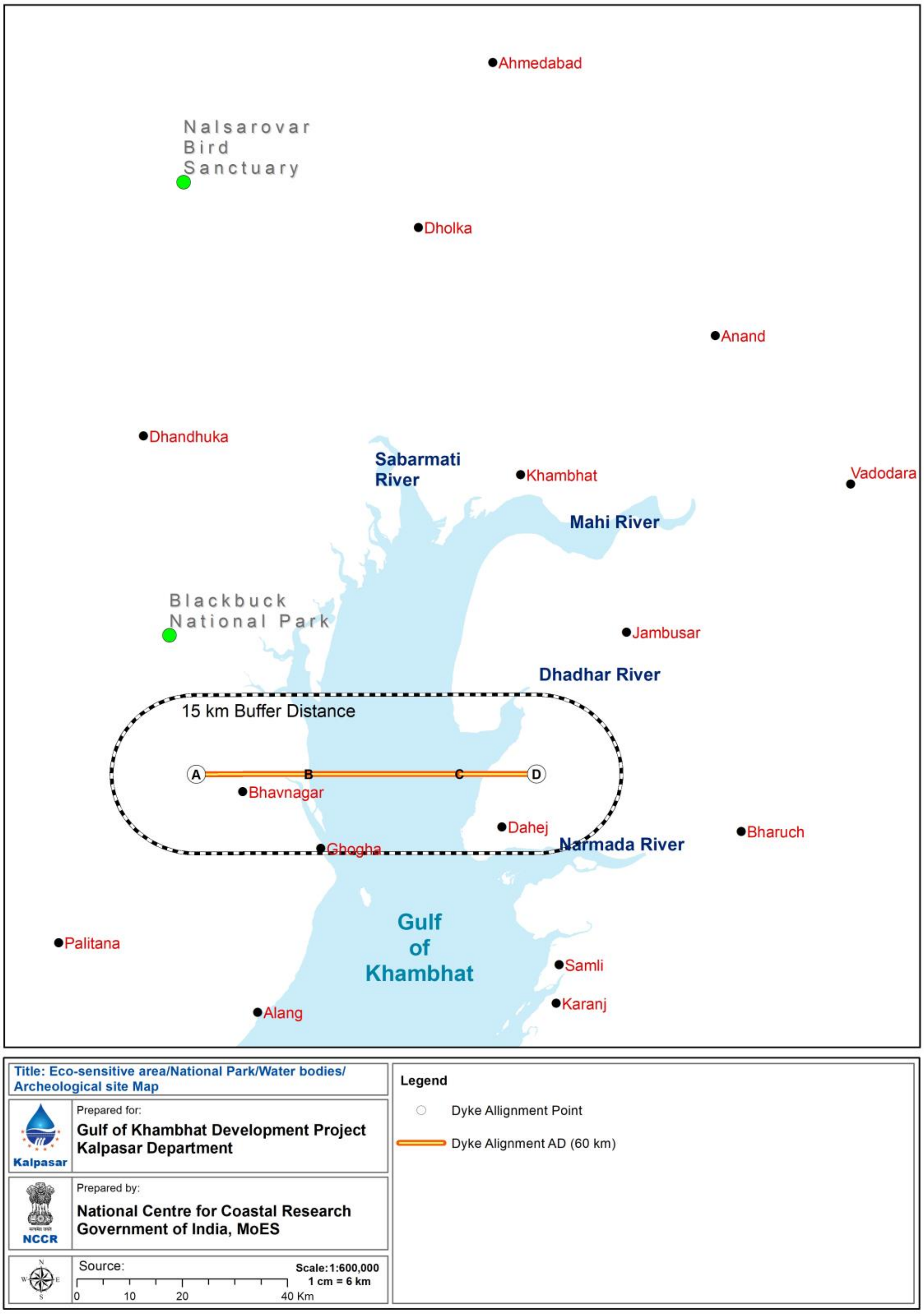


Figure 12: Eco sensitivity Map

3.3.9 Existing Connectivity

The Kalpasar is a multipurpose project comprising the construction of a dyke for a length about 60.13 km out of about 27 km length in Gulf and 33 km length is extended on both flanks up to nearest road crossing between Bhavnagar-pipali highway at Kardej Village on Bhavnagar side on western coast and Gujarat State Highway-6 at Paniyadra village on Dahej side, on eastern coast of Gulf of Khambhat respectively.

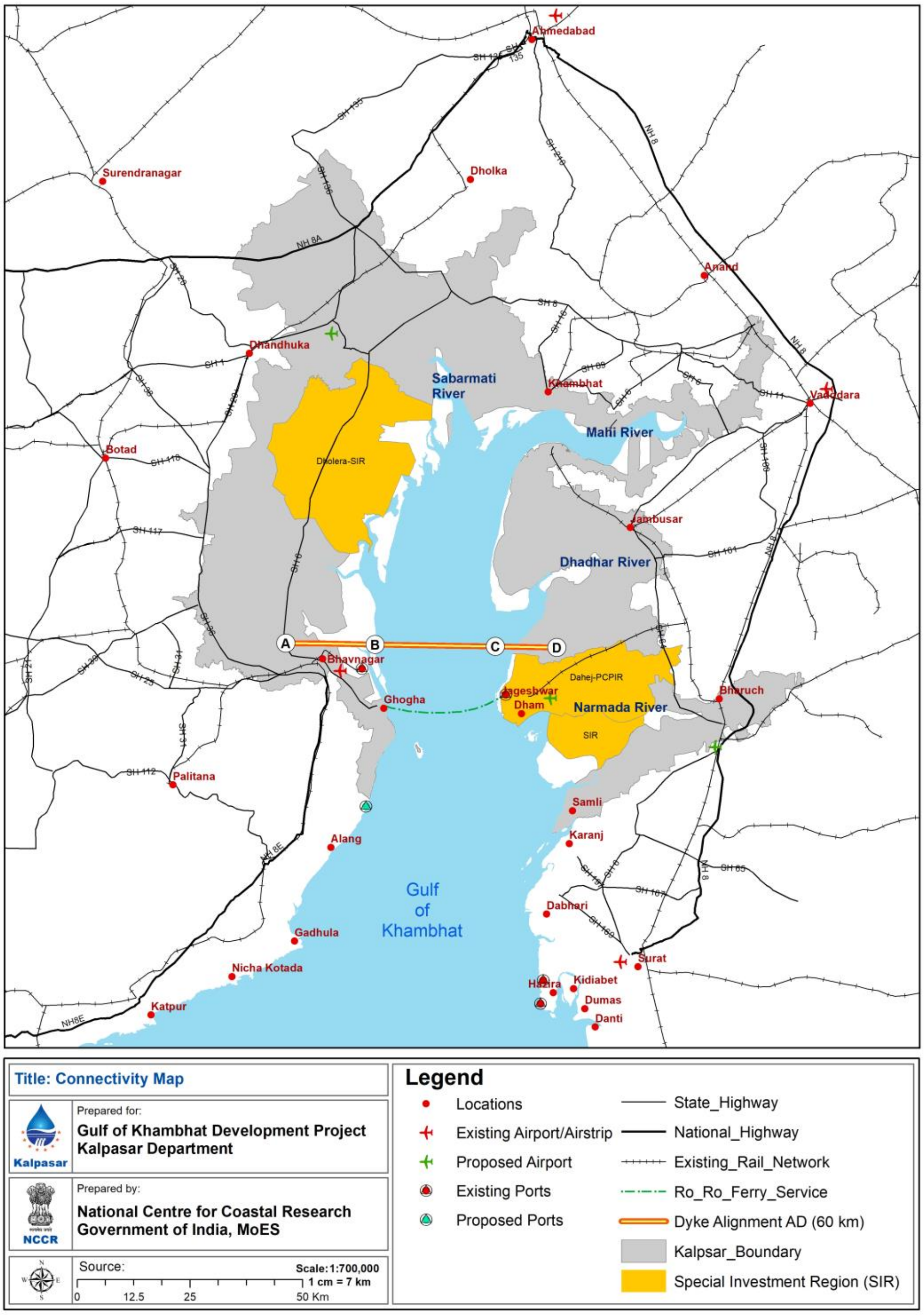


Figure 13: Site Connectivity map

Bhavnagar Airport, which is few kilometres from the town, is the nearest landing strip runway. Bhavnagar is well-connected to other cities of Gujarat such as Ahmedabad, Surat and Vadodara by road, with bus services operated by the state-owned transport corporation. Bhavnagar Terminus under the Bhavnagar railway division, connect it to Ahmedabad, Mumbai, Surat, Vadodara, Mangalore, Kochi, Trivandrum, Kolkata, Chennai, Bangalore, Kakinada and other major cities of India by rail and road.

3.3.10 Land ownership

Dyke length of 26.7km will be in the Gulf (sea portion) and 13.6 km will be towards east i.e., Bharuch district covers an area of 152 ha (government land of 67 % and private land of 33 %) and 19.83 km will be towards west i.e., Bhavnagar district which cover an area of 398 ha of land (government land of 90 % and private land of 10 %). Area under development flood regulator is 1345 ha (100% government land).

4 Planning Brief

Following are the project components that would be taken by Kalpasar department under this proposal for development are as follows:

1. Construction of dyke i.e., 26.7km length will be in the Gulf (sea portion) and 13.6 km length towards east i.e., Bharuch district and 19.83 km towards west i.e., Bhavnagar district
2. Fresh water reservoir on upstream of dyke with capacity of 7800 million cubic meters.
3. A 150m wide road/rail corridor i.e., 16 lane roadway along with 4-lane permanent way for rail transport is proposed to be built over the Dyke
4. Flood regulator to release of flood water

The Kalpasar project alignment is shown in **Figure** .

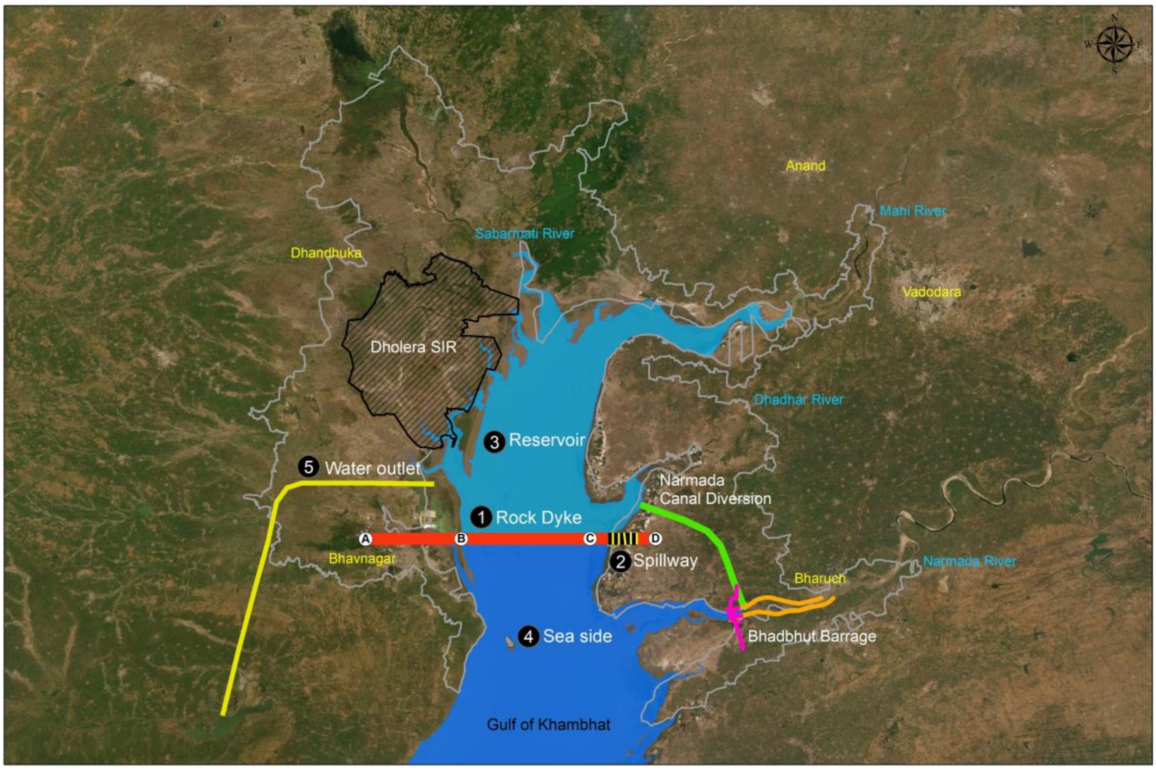


Figure 14: Kalpasar Project Alignment

4.1 Fresh Water Reservoir

Gulf of Khambhat is bordered by the Saurashtra peninsula and Central and South Gujarat. The proposed dyke forms a reservoir which receives water from three major rivers (Sabarmati, Mahi and Dhadhar) and seven minor rivers in Saurashtra region (Wadhwan Bhogavo, Limbdi Bhogavo, Sukhbhadar, Utavli, Keri, Ghelo, and Kalubharalso). A diversion canal is also proposed at Bhadbhut barrage on Narmada river to divert additional water into the reservoir. Apart from this, direct rainfall on the Kalpasar reservoir will also contribute to fresh water in reservoir. A schematic map of various River basins contributing to the proposed Kalpasar project is shown in **Figure** . To estimate water availability from the aforesaid rivers, flow series was analysed from 1901 to 2018 by central design office, Gujarat and the same was vetted by NIH (National Institute of Hydrology) Roorkee. Based on this study, water availability for the proposed reservoir for 50% dependability criteria is about 7800 million cubic meters.

The proposed reservoir has a water spread area of about 1600 sq. km. The area-capacity curve for reservoir is developed based on the topography and bathymetry for the reservoir as shown in **Figure** . For the operation of the reservoir, it is imperative that water levels namely, Full Reservoir Level (FRL), Maximum Water Level (MWL), Maximum Drawdown Level (MDDL), should be determined.

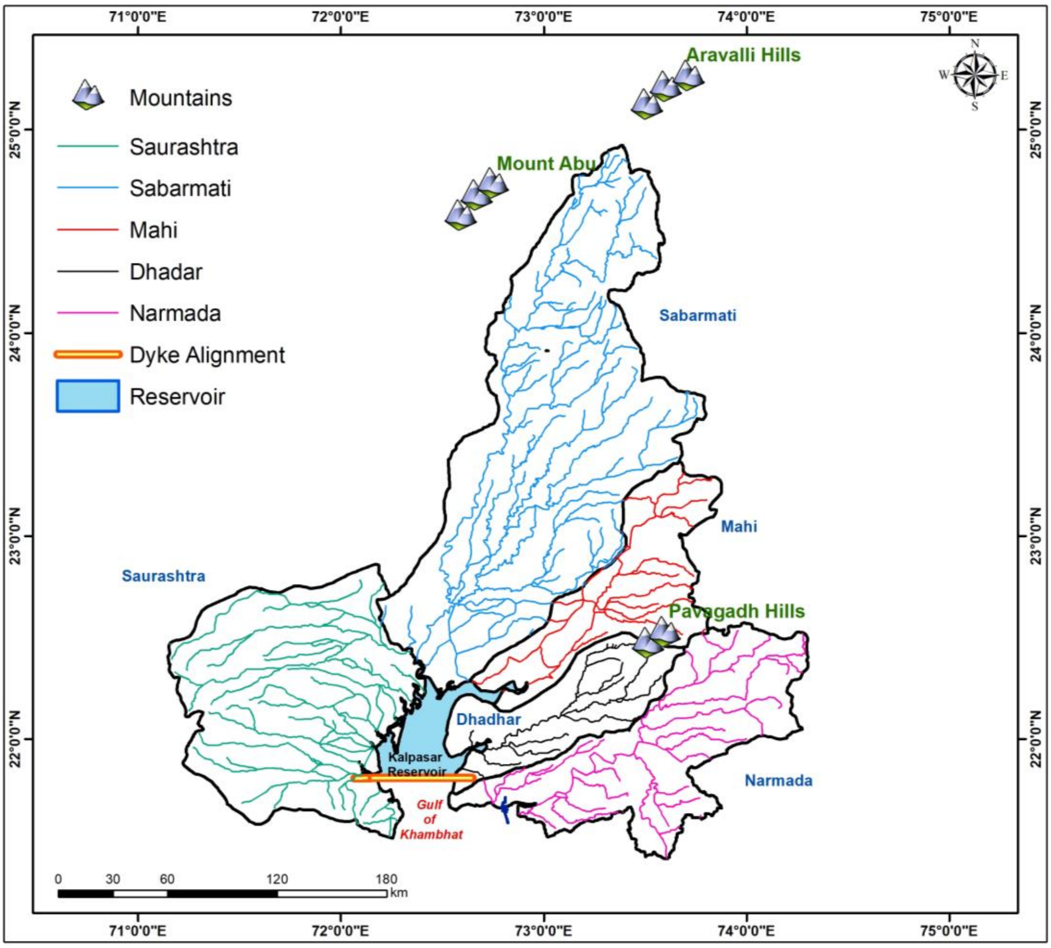


Figure 15: River Basins contributing to the Kalpasar Reservoir

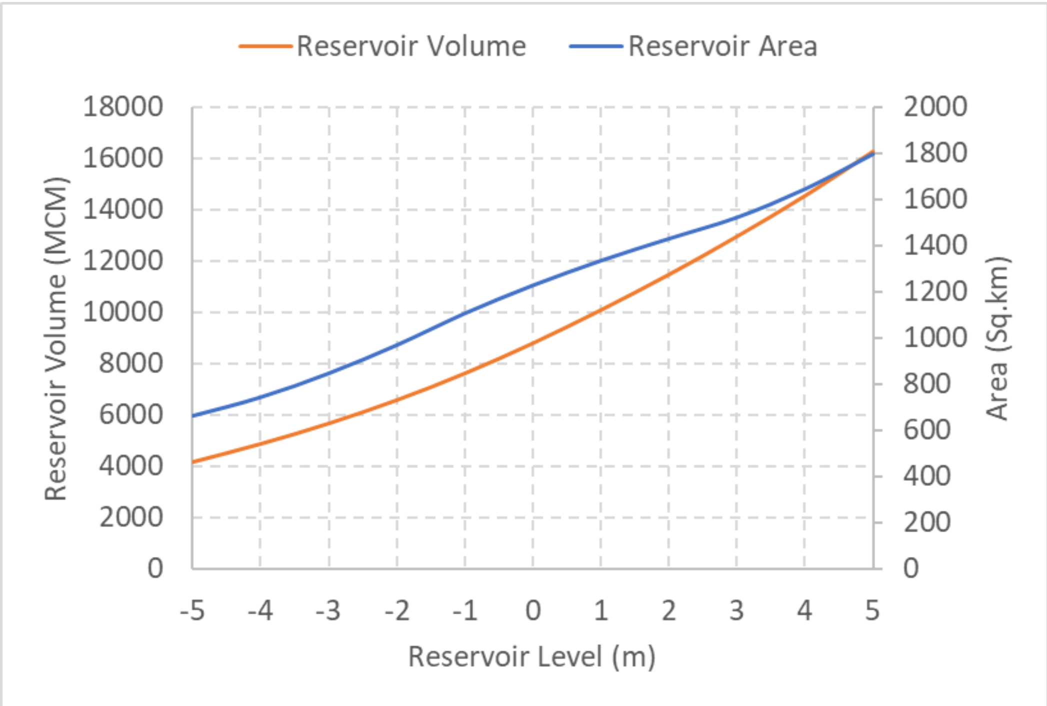


Figure 16: Area Capacity Curve for the Reservoir

The MDDL is an important level of the reservoir water since it governs the useful life of the reservoir in terms of dead storage capacity and sedimentation. It also influences the scale of density stratification of the reservoir water which is critical for freshwater utilization in the transitional phase of transformation from saline sea water to freshwater reservoir. Larger the dead storage capacity, greater is the advantage in respect of the useful life of the reservoir and the utilization of fresh water during the transitional phase of the reservoir. Considering the downstream condition with respect to the tide levels, as the occurrence of the low tide level below (–) 3 m MSL to (–) 4 m MSL are large, good opportunity exists for flushing out of the deeper layer more saline water. The rate of sedimentation in the Gulf region is estimated to be around 14 Mm^3/year. It will need storage of about 4886 Mm^3 for a design life of 400 years, for storage. Taking all the above into consideration, area below (-) 4 m is assumed to be dead storage i.e. (-) 4 m MSL is the MDDL of the reservoir. The area-capacity curve for reservoir with respect to MDDL is shown in **Figure** .

Full Reservoir Level is to store to meet the planned water demand for various uses like irrigation, domestic and industry. Based on 50% dependability, the estimated amount of water discharged by all rivers is 7807 Mm^3. From Figure 6.3, the volume available between levels (–) 4.0 m MSL and (+) 3.0 m MSL is just sufficient to store the fresh water for the intended use. The Full Reservoir level is, therefore, set to (+) 3m MSL.

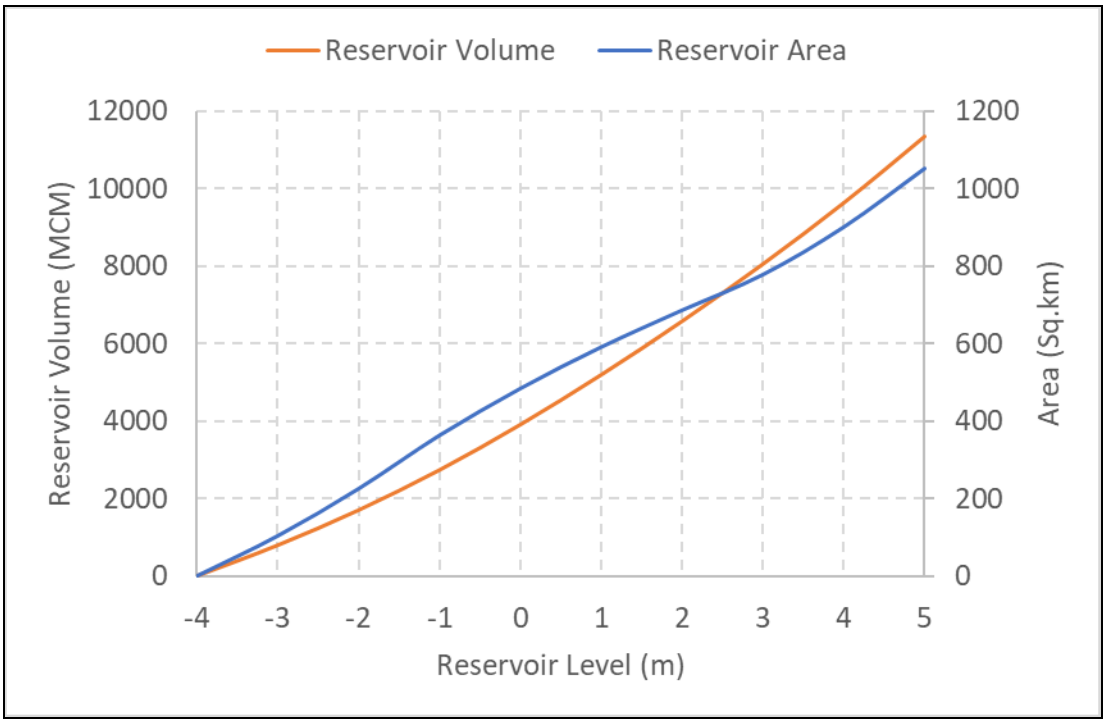


Figure 17: Area Capacity Curve for the Reservoir with respect to MDDL

The Maximum Water Level (MWL) is the highest level to which the reservoir water will rise while temporarily absorbing the flood water before its passage through the regulator as it comes in full operation. The present water level reaches a maximum of (+) 5.5 m during the Highest Astronomical Tide (HAT) at proposed dyke location.

Therefore, any increase in MWL above (+) 5.5m will cause inundation in the nearby villages. . Flood routing study indicates that storage between (+) 3m and (+) 5m MSL will have substantial volume to absorb water level rise due to flooding. The other developments such as Dholera Special Investment Region (DSIR) are planned to be implemented above (+) 5.5m. Therefore, the MWL is determined to be (+) 5m MSL. Any additional volume of water has to be released by means of a flood regulator and the capacity of the flood regulator is to be designed for sufficient discharge.

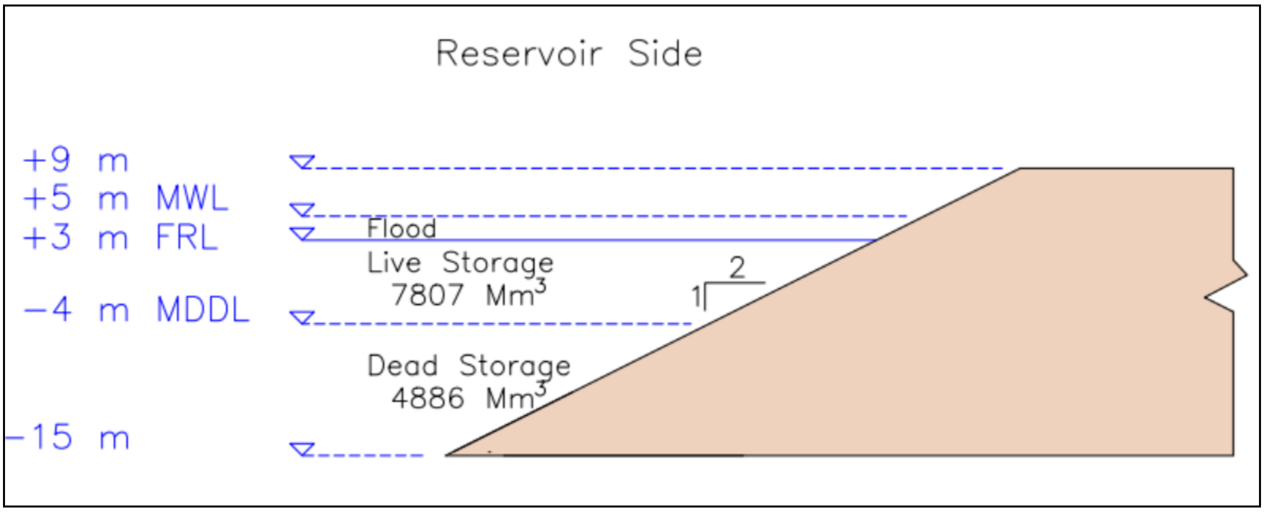


Figure 18: Various Water Levels on Reservoir Side

4.2 Dyke

The total length of the dyke including the embankments is about 60.13 kms. The total length of dyke is divided into three zones based on the bathymetry and soil profile in the project area. The three zones are (i) Intertidal zone at Bhavnagar, (ii) Gulf region and (iii) Intertidal zone at Dahej. The length of the intertidal zone at Bhavnagar is 19.83 km and the seabed level in this zone is around (+) 4.0 m to 4.5 m MSL with claying soil. The Gulf region is about 26.7 km and extending till (-) 28 m below MSL with predominantly silty sand. The length of Intertidal zone at Dahej is 13.60 kms and the sea bed level in this region is (+) 3.0 to 5.0 m MSL with claying soil. The water level in intertidal zone varies from 0.5 to 2.0m during high tides. The sea bathymetry profile along with its elevation is shown in Figure 21.

The dyke section on sea side is designed with breakwater using the Hudson Formula and model studies conducted at CWPRS. The breakwater consists of Armor layer (primary layer), secondary, core and toe berm as shown in **Figure** . The armour layer of rubble mound consists of concrete ACCROPODE II / X-bloc + units to protect the structure from waves/ storm surge on seaside. The under layer and core layer consist of stones. A toe berm is provided on the seaside, to protect structure from scouring due to interaction of tide and wave with structure. The reservoir side is filled with dredged sand to support 130m transporation corridor with side slope of 1:2. The sand fill embankment on the reservoir side is protected by providing the rock toe protection. The typical cross section of the dyke is given **Figure** .

The crest level of the breakwater is designed based on the for safety and structural design as per the Euro top manual for environmental condition such as tide, waves, storm surge and Tsunami. The crest level of breakwater is designed based on the wave overtopping criteria.

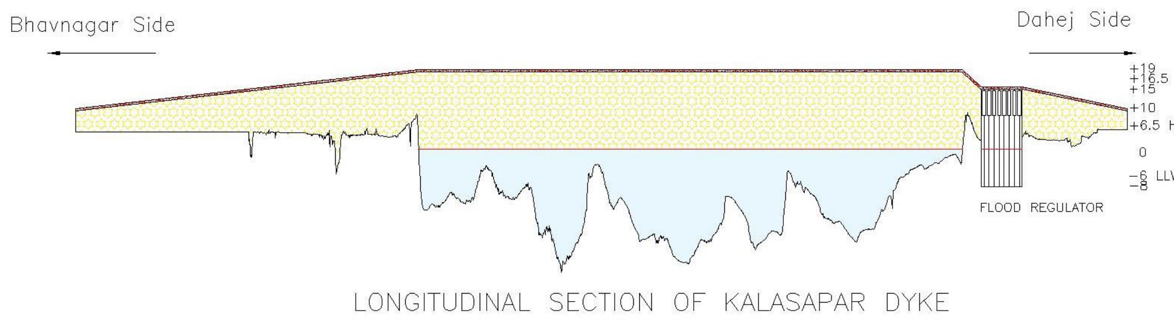


Figure 22: Bathymetry profile in longitudinal direction and elevation of the dyke

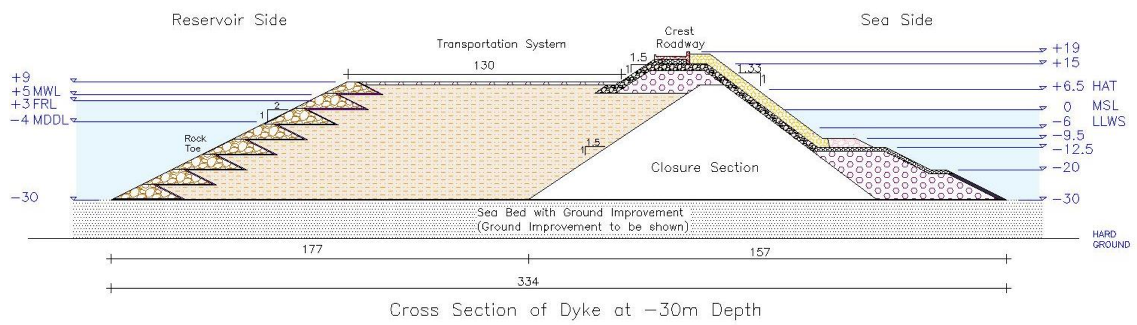


Figure 19: Cross section of the dyke/Breakwater

4.3 Flood Regulator

Flood regulator is a structure constructed in dyke to discharge surplus water from the reservoir to sea, in order to avoid inundation on the reservoir inflow river banks. It also protects the intrusion of sea water into reservoir side, especially during high tides and storm surges, thus preventing increase in salinity of the reservoir and inundation of coast upstream of reservoir. It is proposed to place the flood regulator in Dahej side of the dyke. The location of flood regulator was explored based on the following factors. (i) lengths of approach channel and tail channel, and (ii) wave action on gates and therefore additional protection structures to be adopted. Based on this a detailed study was taken up and the alignment as shown in **Figure** was chosen with approach channel of 10 km (approx.) and tail channel of 11 km (approx.).

With 50% dependability, based on the amount of water discharged by all rivers and by removing the dead storage volume, the volume available between levels – 4.0 m MSL and + 3.0 m MSL is just sufficient to store the fresh water for the intended uses. The Full Reservoir level is, therefore, set to +3m MSL. The MWL is the highest level to which the reservoir water will rise while temporarily absorbing the flood water before its passage through the spillway as it comes in full operation. The present water level reaches a maximum of +5.5 m during the Highest Astronomical Tide (HAT). Therefore, any increase in MWL above +5.5m will cause inundation in the nearby villages and development projects. Flood routing study carried out by Kalpasar Department indicates that storage between +3m and +5m MSL will have substantial volume to absorb water level rise due to flooding. The other developments such as Dholera Special Investment Region (DSIR) are planned to be implemented at +5.5m. Therefore, the MWL is determined to be +5m MSL.

The Probable Maximum Flood for the basin needs to be estimated for determining the capacity of the regulator. The following steps were carried out in estimation of Probable Maximum Flood (PMF) for Kalpasar Reservoir, (i) Estimation of Maximum Rainfall in Catchment Area, (ii) Flood generated by each River Basin, and (iii)PMF at Reservoir by combining Flood from various Basins. Indian Institute of Technology, Roorkee has taken up a detailed study and estimated peak discharge of 86,000 cumecs. The tidal variations on the seaside are estimated to be (+) 6.5 m and (-) 6m MSL post-implementation of dyke. However, as the MWL on the reservoir side is fixed to (+) 5m MSL, the flood regulator can be operational only for about 15 hrs/day, when the water level on the seaside is below (+) 5m MSL. Accordingly, the capacity of the flood regulator is designed to have a larger discharge to compensate the deficiency in operation time. The capacity of flood regulator is designed to be 1,10,000 Cumecs, with a gross width is 2,200 meters and net width is 1,800 meters having 100 spans of 18 meters width and 99 no. of 4 m thick piers.

The control structure is major component in flood regulator, which regulates and controls the outflow from the reservoir. It prevents outflow from a reservoir below a fixed level and allows the flow when the water surface in the reservoir rises above the level. In most of the cases, the control section consists of a weir, which may be sharp crested, ogee or broad crested. For the Kalpasar reservoir Ogee profile is proposed. The shape of the crest or the upper curve of the ogee profile of this flood regulator is made to conform closely to the profile of the lower surface of the nappe (or lower nappe). Alternative crest elevations of the ogee for -3.5m, -2m, 0.0m and +3m were examined from above considerations. Study of the above reveals that it would be impractical to have the crest of the spillway higher than El-3.5m as it will result in very long flood regulator. Gates are provided on the crest of the control structure to regulate the flow of water from the reservoir. The crest gates will be vertical lift type, of the size 18m wide x 10m high and will be provided with double seals to resist water levels from both sides. The breast wall of the size 18m wide x 12.5 m height x 0.35 mm Thick will be provided on top of the Vertical lift gates. The configuration of flood regulator is shown in **Figure 25**.

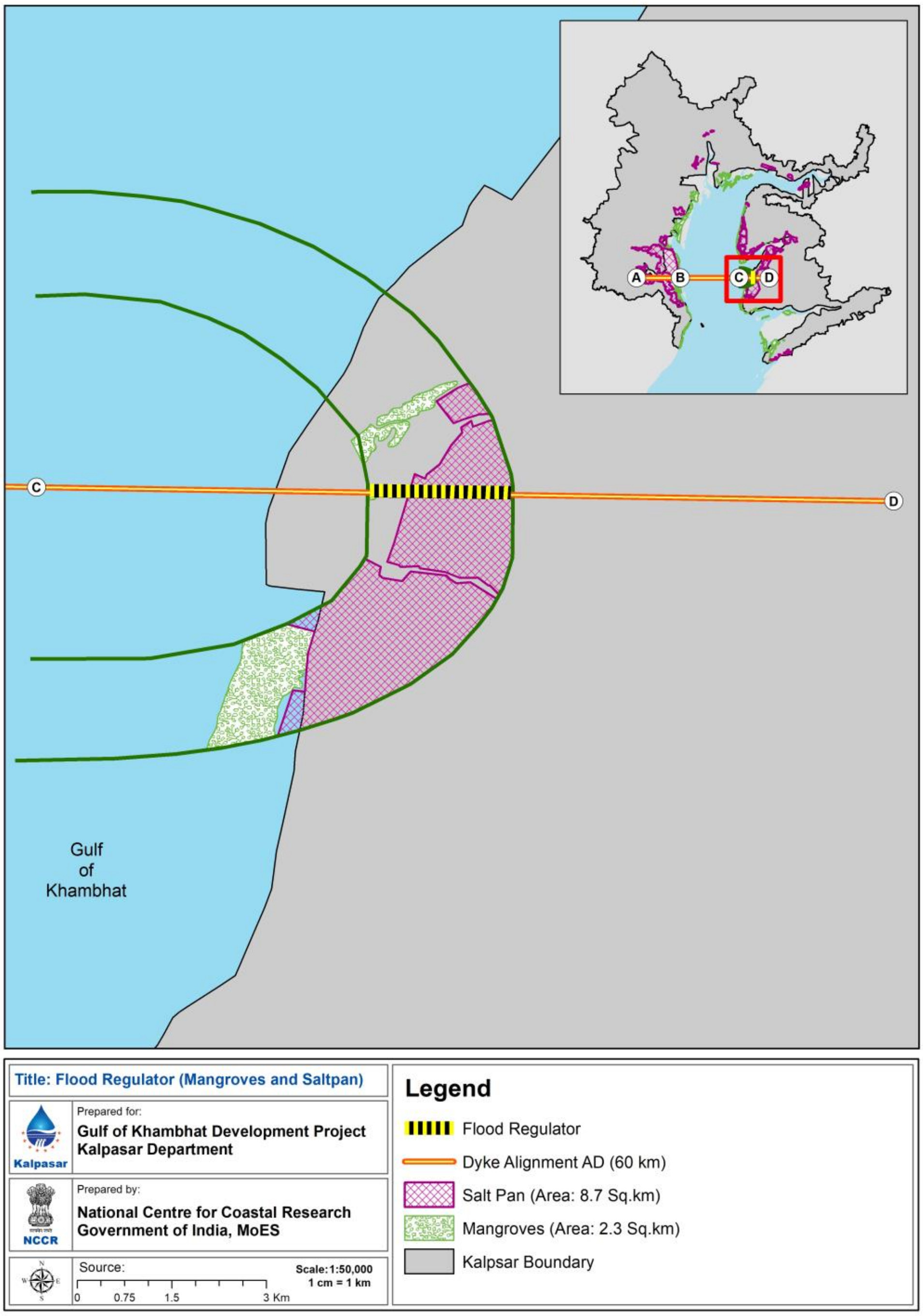


Figure 20: Alignment of proposed Flood Regulator and Channels

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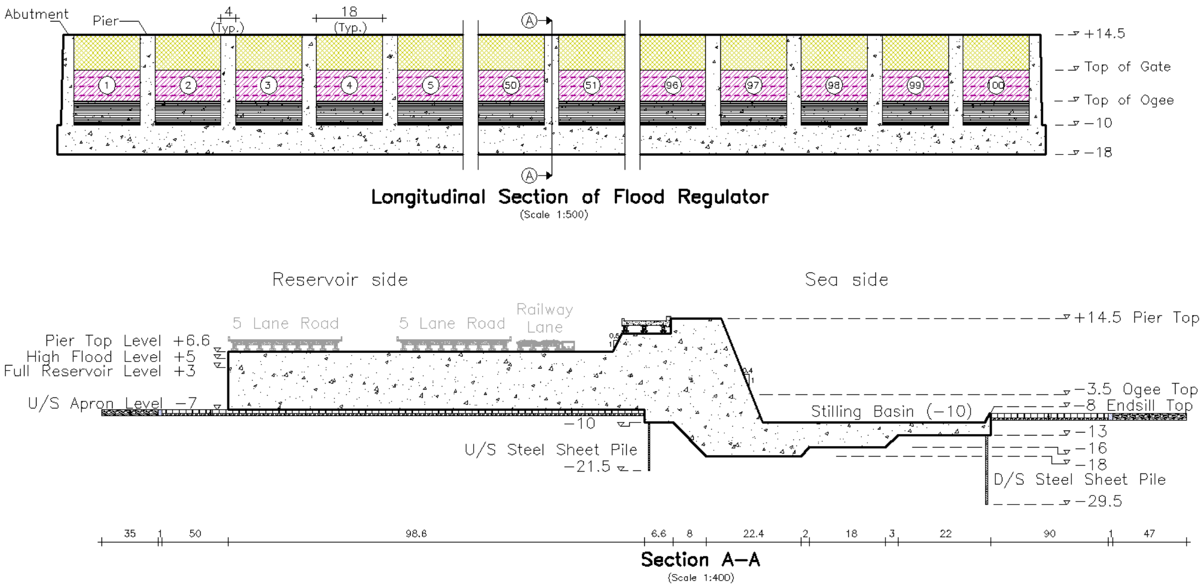

Figure 21: Configuration of Flood Regulator

4.4 Roadway and Rail

The crest of the dyke is proposed to be used as transportation corridor as this will significantly reduce transportation distance and also the carbon footprint from districts in East Gujarat to Saurashtra region. 16-lane road for vehicles and a 4-lane railways is proposed as part of transportation system based on detailed transportation study by L&T. The proposed road connects the Bhavnagar-Pipali Highway at Kardej on Bhavnagar side and Gujarat State Highway - 6 at Paniyadra on Dahej side. This will reduce distance from 240 km to 60.13 km as shown in **Figure** .

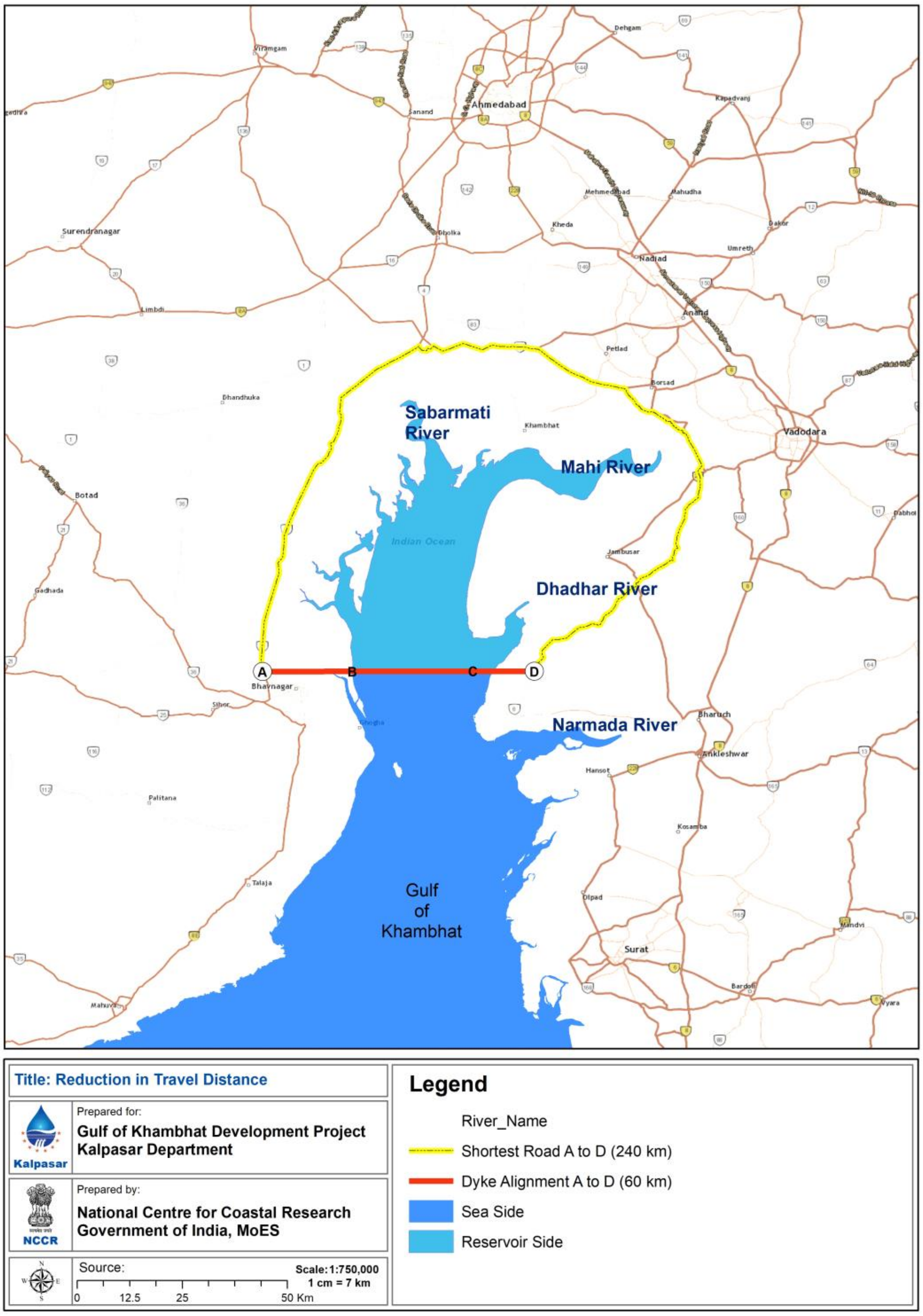

Figure 22: Existing and Proposed Road Network along the Dyke

The storm surge and seiches study by Indian Institute of Delhi indicate an increase in water level of 2.5m in the reservoir during hypothetical cyclone track. So, the transportation corridor is located on the crest of sand fill embankment on the reservoir side at an elevation of (+) 9.0 m MSL elevation (4m above MWL).

4.4.1 Roadways

The roadways are designed for a design speed of 100kmph using standards as adopted for National Highways. Eight-lane roadways are provided for each direction. The width of the eight-lane road is 28m in each direction. Median of 6 m is considered. Head light glare is cut-off by planting shrubs of 1.5 m height (flowering plants) in the median. Paved shoulder of 1.5 m and Earthen shoulder of 1 m is considered. Multi—Utility Lane (MUL) of 4 m width which will take care of Utilities, Kiosks, Instrumentation, Emergency Parking, Truck Laybys, Patrol vehicles, Tow away vehicles, first aid, Emergency Telephone, landscaping etc. is proposed. Pedestrian zone of 2.5 to 3 m is considered. On the reservoir side, Tree Zone/ Landscaping (5 m) is proposed so that night light will not disturb the marine life. 3 m clearance is provided between rail or road corridor. Drainage system is provided along the roadway on the reservoir side. A 2.4 km long bridge will be provided at flood regulator location, where the road and railway lines will pass over the flood regulator. In addition, a 10 m width access road is constructed on crest of breakwater on seaside for accessing the flood regulator for operation and maintenance.

The electric poles are installed on the roadway to provide adequate lighting along the road, and it enables the road users to see more accurately and easily the carriageway and its surrounding areas at night. Toll plaza booths will be set on the roadway for toll collection. Typical cross section of roadway is shown in **Figure** .

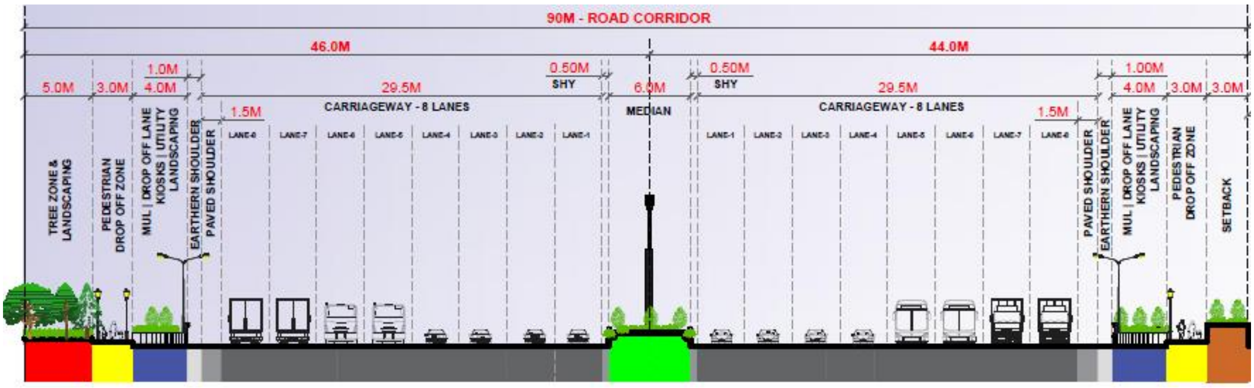

Figure 23: Configuration of Proposed Roadway

4.4.2 Railway

Two sets of railway lines are proposed on the dyke that connects the railway lines to Bhavnagar and Dahej railway stations. The electrically powered trains are proposed for the transport of passengers as well as cargo. One corridor is dedicated to cargo while the other is dedicated towards passenger movement. Two 20 m railway corridor is proposed as shown in **Figure** .

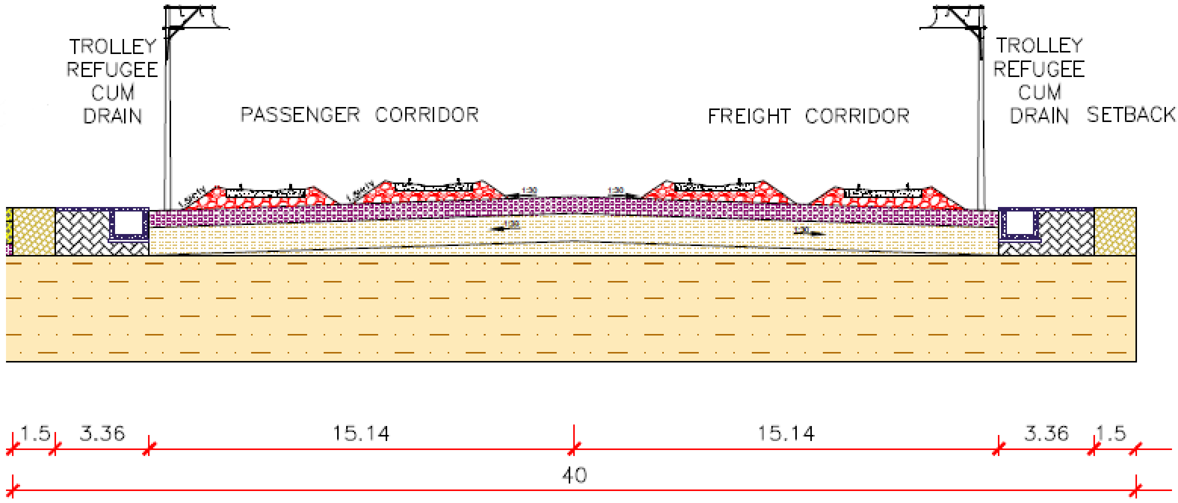

Figure 24: Configuration of Proposed Railways

4.5 Renewable Energy

It is proposed to have wind and solar hybrid system in the restored lands and between MWL and FRL around the reservoir. Preliminary study by National Institute of Wind energy indicate that about 1,500 MW capacity wind turbine generators and 1,000 MW capacity of solar power is feasible. The proposed hybrid system can generate about 2500 million units of power annually. The tentative layout of proposed farms is given in **Figure** .

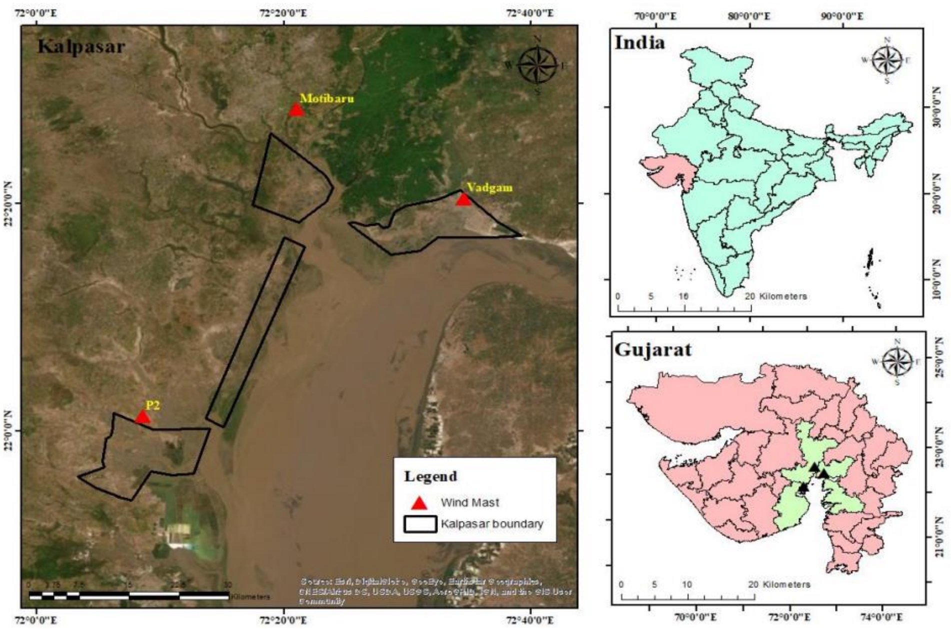

Figure 25: Tentative location of the Wind and Solar Farms

4.6 Construction Methodology and Source of material

4.6.1 Dyke

A conceptual methodology has been arrived at based on the available geotechnical data and hydrodynamic conditions. Dyke closure study and bed protection study were carried out to determine the construction sequence. Necessary ground improvement is also studied in regions where the available soil will not be able to sustain the dyke. Ground improvement on the intertidal regions include chemical stabilization of top layers followed by PVDs to consolidate the soil. The ground improvement in the Gulf region comprises of vibro-compaction. The construction in intertidal region, Gulf region and regulator will happen independently.

Bed protection study based on scour development indicates the length of bed protection ranges between 200 - 1300 m on either side of the dyke. The thickness of the bed protection is also to be varied from 0.5 – 1.5 m based on the velocity of flow. The bottom protection will be placed all along the dyke using hopper barges along alignment to prevent scour from occurring.

The bathymetry along the dyke has three shallow submerged Islands. It is proposed to have larger cross-section for dyke at these locations which will be constructed initially. These sections will used for storage of construction materials and will make construction easier. The dyke closure study indicates that the currents increase as high as 6 m/s for final 7 km and requires stones of 8-10 tons. Therefore, the final 7 km section will use sudden closure by means of caisson. These caissons will be constructed on the coast, launched into the sea, towed to required location and then ballasted. These caissons are provided with gates which will be used for sudden closure. The caissons are to be first installed before start of dyke closure.

The width of the dyke foundation varies from 200 to 300 m. It is proposed to first construct the closure section upto a height of (+) 8 m using rocks to create a barrier over which the remaining construction activity will progress. The dyke closure section is proposed to be constructed either side towards the center using end on method and rocks are dumped using trucks.

Once the dyke closure is completed the secondary layer, armour layer and toe protection works are completed. On the reservoir side, the sand fill embankment is provided using dredged material from reservoir side. This will also increase the capacity of reservoir. The sand fill embankment on reservoir side is protected by providing the rock toe protection. A filter layer is provided between the rock section and sandfill embankment section. After completion of sand embankment layer, 1 m of rock section is provided over which road and railways are built.

4.6.2 Flood Regulator

The flood regulator required dredging till (-) 18 m below MSL for establishing the foundation. The dredging is done using excavators and during entire process the dewatering of seepage water and stability of slope will be maintained. As the location of flood regulator is on land the construction will be simpler. The foundation for the flood regulator includes raft and pile, these are constructed initially, which is followed by construction of regulating devices. The piers and super structure are then constructed. The gates with hydromechanical and electric systems will then be installed. The approach channels are parallelly dredged to the required depth ((-) 7 m in approach and (-) 8 m in tail end) and retaining structures are constructed to maintain the channel slopes.

4.6.3 Material Quantities

The details of material and Manpower required during construction stage of project are given in **Table** .

Table 6: Material/resource requirements

S.No	Material	Quantity	Remarks
1.	Stones and Aggregate	160 Mm^3	
2.	Cement for Construction	2.5 MMT	
3.	Steel for Construction	1 MMT	
4.	Sand for Construction	4 Mm^3	
5.	Dredging for channel and Regulator	250 Mm^3	About 250 Mm^3 of soil will be dredged which will be used for preparation of dyke and embankments for channels
6.	Maintenance dredging	5 Mm^3	
7.	Water Requirement	5 MLD	
8.	Manpower Requirement-construction/operation phase	20,000/300	
9.	Power Requirement	25 MW	
10.	Diesel Requirement	20 ML/Year	
11.	STP	10.8 KLD	STP will be developed in the working areas. Treated wastewater will be utilized in green areas within the building area

5 CRZ Area

The proposed Kalpasar alignment is superimposed on Gujarat Coastal Zone Management Authority Plan (CZMP) and is shown in **Figure to Figure** .

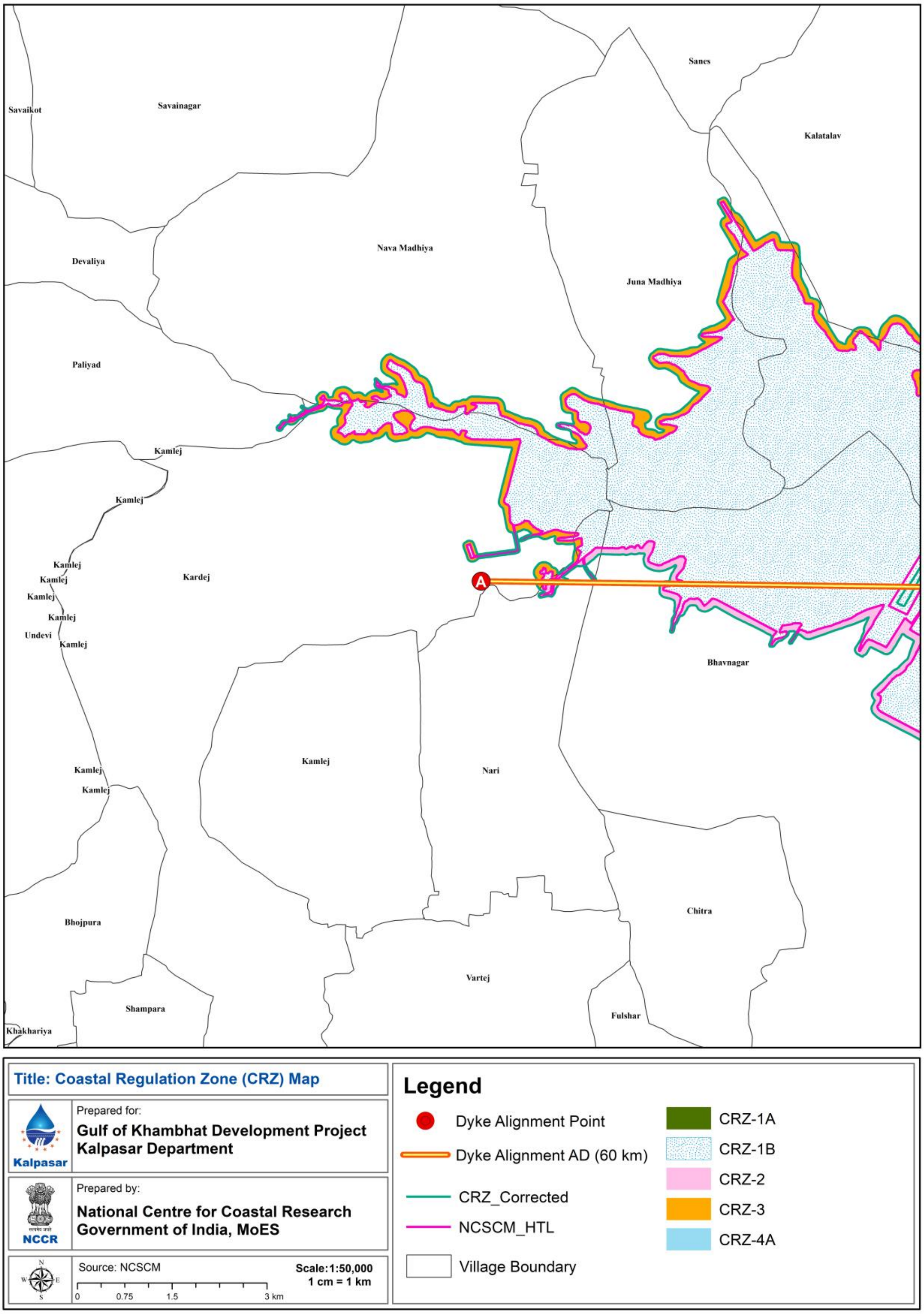

Figure 26: Alignment on CZMP – Part 1

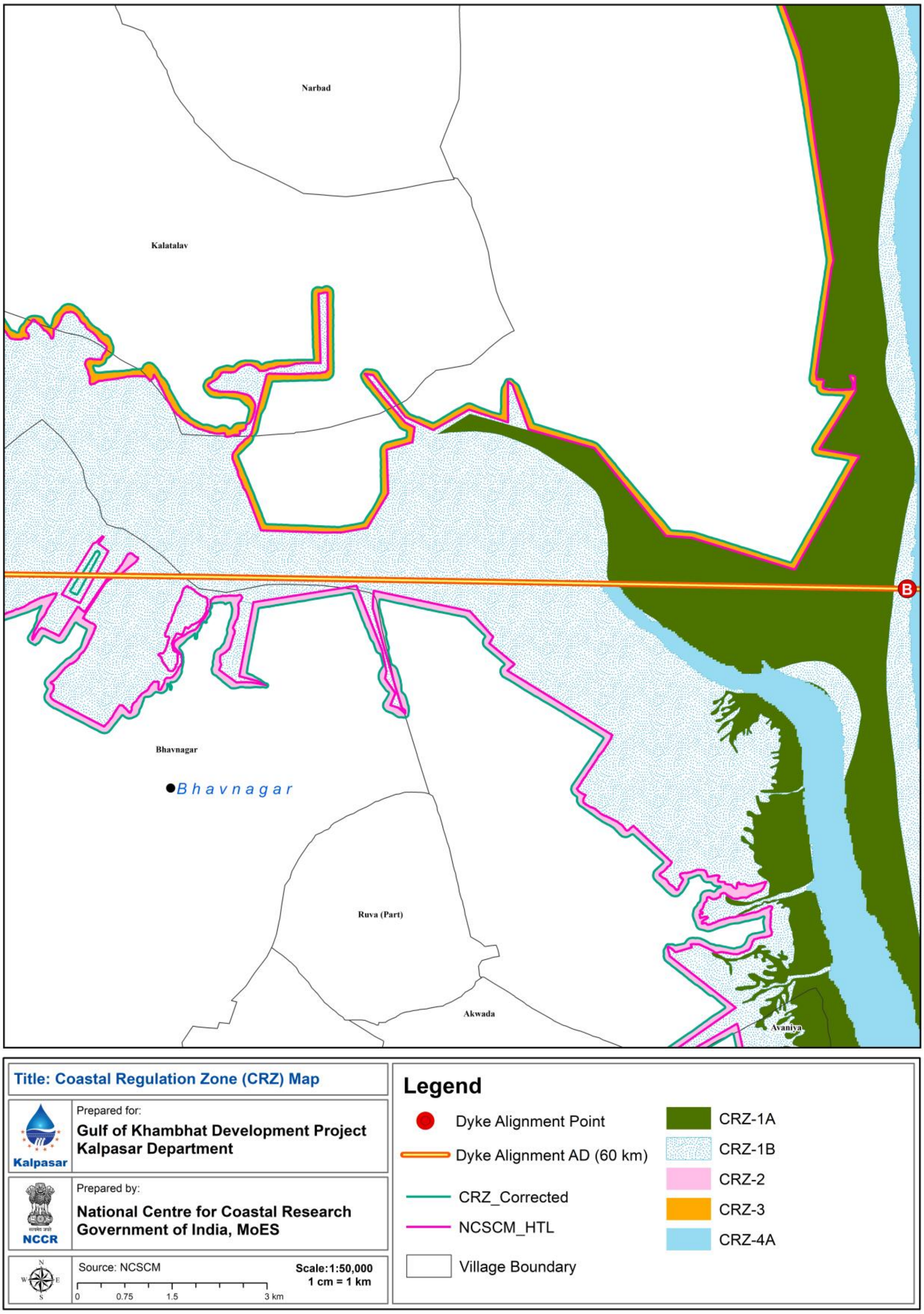

Figure 27: Alignment on CZMP - Part 2

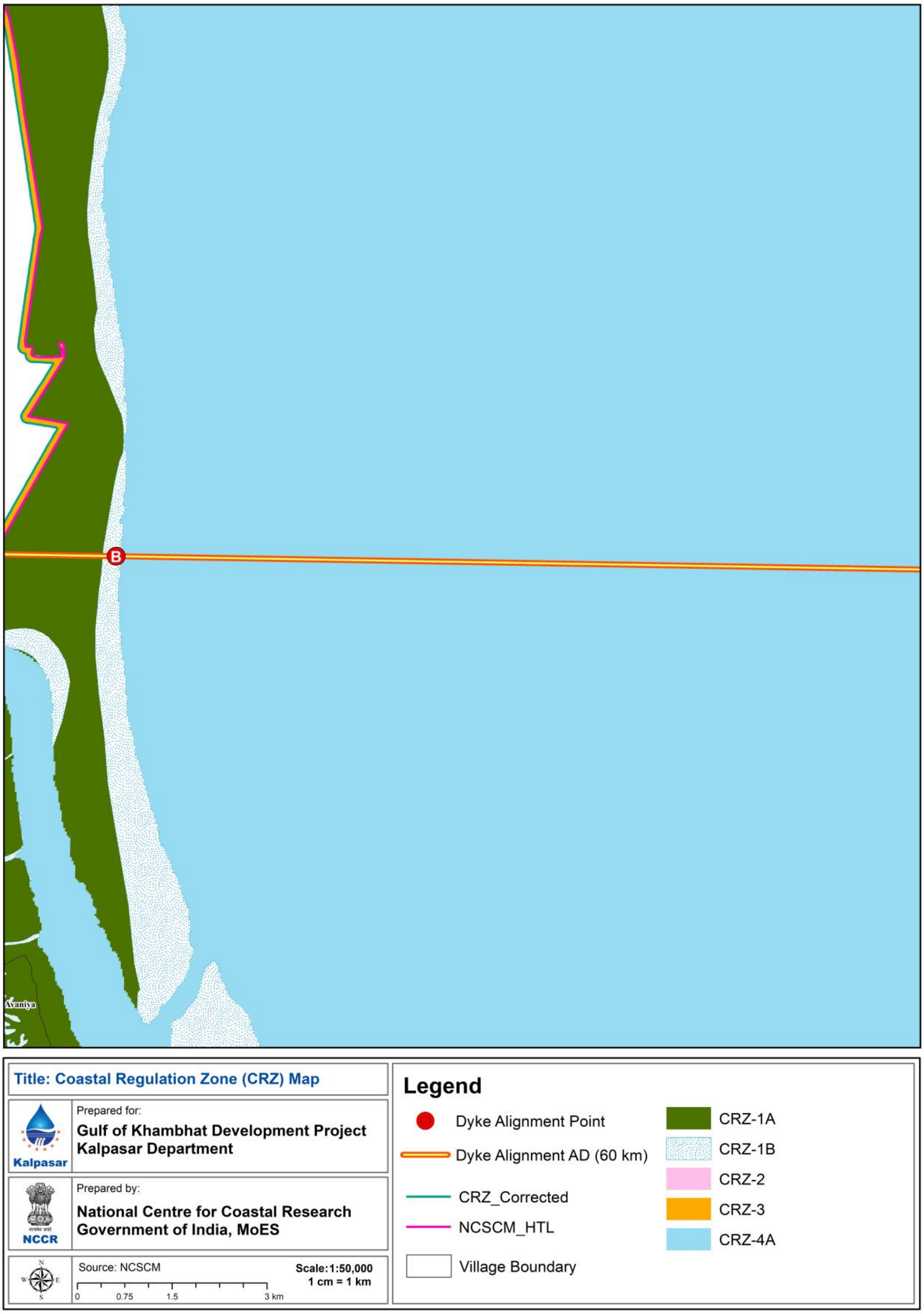

Figure 28: Alignment on CZMP - Part 3

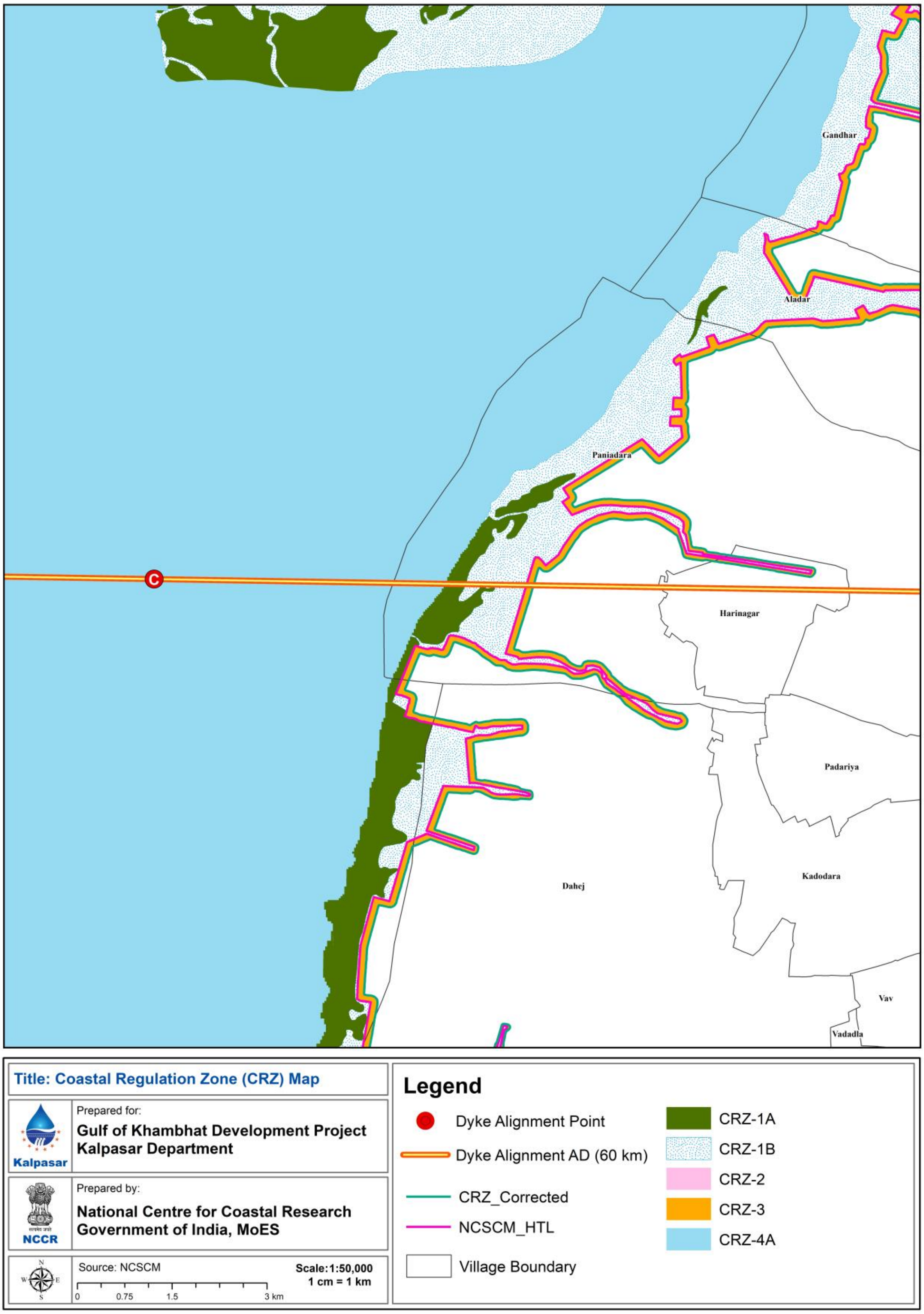

Figure 29: Alignment on CZMP - Part 4

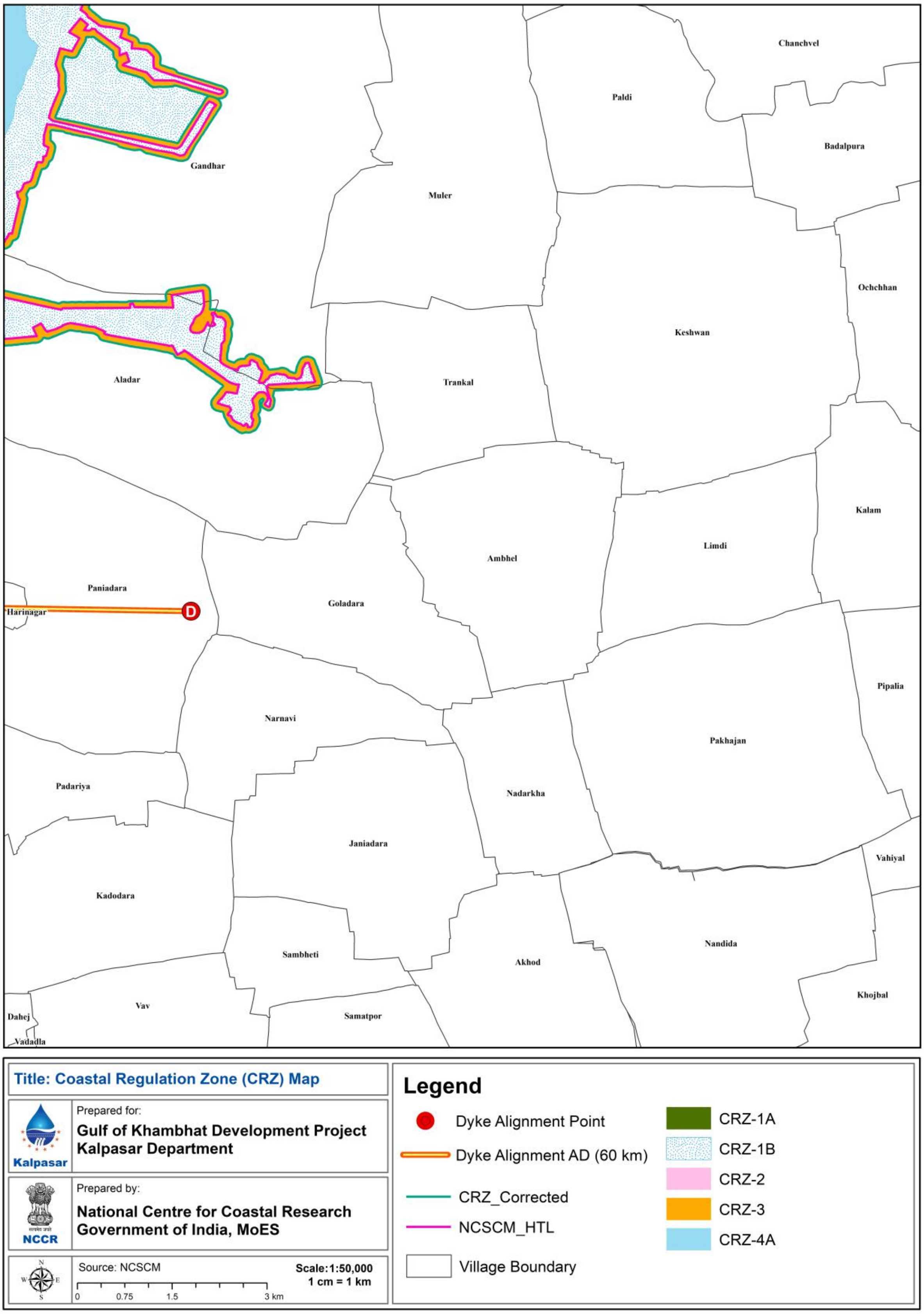

Figure 30: Alignment on CZMP - Part 5

The alignment falls in CRZ IA, IB, II, III, IVA and IVB as per CZMP and details are given in **Table** .

Table 7: CRZ Area of project alignment falling as per CZMP

CRZ Area	Area (sqkm)
CRZ IA- Mangrove and its buffer	69
CRZ IB- Intertidal area of Gulf and backwaters	1017
CRZ II- CRZ area of backwaters flowing towards east and west flanks falling in urban area	1
CRZ III- CRZ area of backwaters flowing towards east and west flanks falling in rural area	101
CRZ IVA- sea area of Gulf of Khambhat	1496
CRZ IVB- CRZ influenced backwaters flowing towards east and west flanks	

The project is of strategic importance and is public utility as a part of infrastructure development. Thus the proposed project is a permissible activity as per CRZ notification, 2011 and 2019.

6 Rehabilitation and Resettlement Plan

The Dyke length of 26.7 km will be in the Gulf (sea portion) and 13.6 km will be towards east in Bharuch district and would cover an area of 152 ha (76 % of Government land and 33% of private land) and 19.83 km will be towards west in Bhavnagar district and would cover an area of 398 ha of land (90% of Government land of 10% private land). The area under the proposed flood regulator would be 1345 ha (100% owned by the Government) . There would be no major resettlement of habitations due to project development, however, rehabilitation due to loss of land and livelihood will be assessed in detail and presented in the EIA report.

7 Project Schedule and Cost Estimates

7.1 Project Schedule

The proposed project including four major components (i) Dyke, (ii) Transportation System, (iii) Flood Regulator and (iv)Other Minor Infrastructure is proposed to be completed in duration of 6 years. The details are as given below:

S.No	Timeline in Years	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6
1.1	Bed Protection for Dyke												
1.2	Dyke Closure Sequence												
1.3	Construction of Remaining Dyke												
2.0	Transportation System												
3.1	Flood Regulator												
3.2	Approach and Tail end Channels												
4.0	Other minor Infrastructure like Admin Building and Control Room												

7.2 Estimated Project Cost

The total project cost is estimate as Rs.1,00,200 Crores. The detail breakup is as given below:

S.No	Item	Cost (INR Crores)
1	Construction of Dyke including Transportation system above it	65,000
2	Construction of Flood Regulator including Bridge for Transportation system and channels	20,000
3	Renewable Energy	15,000
4	Other Minor Infrastructure	200
	Total	**1,00,200**

8 Analysis of Proposal

Gujarat, despite many rivers is a water deficit state, since it is able to utilise only 54% of its available surface water resource for want of suitable inland site to store the remaining 46% of surface water which simply empties into the sea. The Gulf of Khambhat Project, or KALPASAR Project, aims at the creation of a fresh water reservoir in the Gulf of Khambhat by the construction of a dyke connecting the east and west bank of the Gulf.

The ambitious Kalpasar project is envisaged as a multi-purpose project to cater to the irrigation, drinking water, transport and energy demands of the Saurathra region and involves construction of 60.13 km dyke across the Gulf, a flood regulator to discharge the excess water, a 16-lane roadway and a 4-lane permanent way connecting the eastern and western districts of Gujarat and the proposed transportation system will reduce the travel distance from 240 km to 60.13 km.

Fresh water reservoir of 7800 million cubic meters created by constructing the dyke across the Gulf of Khambhat will be one of 10 largest manmade lake/reservoir in the world.

The Kalpasar Project development is completely state strategic policy with an aim to provide fresh water for drinking, irrigation and industrial purpose along with improvement and creation of world class transportation infrastructure to improve the socio-economic conditions of the Saurashtra region and the State of Gujarat.