

Inception Report

Ecological, Hydrological and Socio-economic Impact Studies for the Kalpasar Dam Project, Gulf of Khambhat, Gujarat



Submitted to:



NCCR

National Centre for Coastal Research (NCCR)
Ministry of Earth Science, Government of India
NIOT Campus, Velacherry-Tambaram Main Road,
Pallikaranai, Chennai - 600100, India

Submitted by:



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1. Introduction

Biodiversity is the basic entity and foundation for human survival and sustainability. It consists of animals, plants, and microorganisms on Earth, including different types of ecosystems, and they occupy and influence human life and maintain the quality of living. As per the Convention on Biological Diversity (CBD), "Biodiversity is the variability of living organism from all sources including, inter alia, terrestrial, marine and other aquatic systems and the ecological complex of which they are part; this includes diversity within species, between the species and the ecosystem". India is the seventh-largest country in the world harboring 10 bio-geographic zones and 27 bio-geographic provinces, which is the home for 7-8% of recorded species and is regarded as the 17th mega diversity country. The biodiversity of India contains 91,212 faunal and 45,500 floral species. As per species richness, India ranks 7th position in mammals, 9th in birds, and 5th in reptiles around the globe. According to Red List threatened species (2008) of the International Union for Conservation of Nature (IUCN), India is having 413 globally threatened faunal species endowed with vast inland and marine bio resource.

Biodiversity is being increasingly threatened globally, nationally, and regionally due to various natural and anthropogenic sources. Besides this, anthropogenic activities create several pressures on biological resources that lead to destruction, alteration, and degradation of habitats, which subsequently leads to loss of biodiversity. India has played a pivotal role in the conservation and sustainable use of natural resources from time immemorial. Some legislation has been enforced by the Government of India which directly or indirectly helps in the conservation and management of biodiversity of the country. These include the Forest Act, 1972, Forest (Conservation) Act, 1980, Wildlife (Protection) Act 1972, the Air (Prevention and Control Pollution) Act 1974, the Water Cess Act 1977, and the Umbrella provision of Environment (Protection) Act 1986. The Biological Diversity Act 2002 and the Biological Diversity Rules, 2004 are aimed at safeguarding the floral and faunal biodiversity of the country for research and commercial purposes.

As far as Gujarat state is concerned, four bio-geographic zones i.e desert, semi-arid, the Western Ghats, and coastal habitat strengthen the biodiversity pattern of the State associating five biotic provinces namely forest, desert, wetlands, coastal, and grassland ecosystems. The coastline of Gujarat is 1,650 km encompassing two Gulfs and associated coastal ecosystems such as mangroves, coral reefs, estuaries and mudflats.

The Gulf of Khambhat is a tidal regime in the Arabian sea bordering the state of Gujarat, formed at the mouth of major rivers such as; Tapti, Narmada, Mahi, Sabarmati, and Dhadhar that form estuaries along the western coast. The Gulf of Khambhat is about 200 km long, 20 km wide along the north, and up to 70 km wide in the southern part of the project area. The coastal area of the Gulf of Khambhat is

sharing its area with four districts of the Gujarat state namely; Bhavnagar, Ahmedabad, Anand, and Bharuch. Similarly, The Gulf of Kachchh flourishes in marine wealth and is considered as one of the biologically rich marine habitats along the west coast of India. The coastal and marine flora of both the Gulfs is highly diverse and includes sand dune vegetation, mangroves, seagrasses, macrophytes, and phytoplankton.

Background about the KALPASAR Dam Project

The proposed dam is located on the Gulf of Khambat just below the confluence of the important rivers such as Narmada, Viswamithri and Sabarmathi. The project aims primarily to store the fresh water discharges from the rivers for multiple uses where the climatic changes have been felt severely in recent times. To satisfy the demand from the public for drinking water and agriculture, the projects have given importance even though there are several consequences to the rear end users and the coastal environment. Even though land-based reservoirs like dams have various advantages, they have their own disadvantages like land acquisition, clearing of forest area, loss of bio-diversity, submergence of land and forests, diversion works during construction, etc. Per capita water storage in India for domestic purposes is too small compared with developed countries. The major benefits of the upcoming Kalapasar Project as detailed in many available documents on the Project- could be summarized as under, *Water Supply for domestic use, Irrigation from the fresh water reservoir, Water supply for industrial purposes, Reclamation of land, Road communication facilities through a long four lane bridge road across the Gulf of Khambhat, Development of water transport systems, Fisheries development in a major fresh water reservoir.*

The coastal reservoir is a unique structure constructed at an estuary, gulf, or bay or in the sea (at the point where a river meets a sea) to store the portion of excess water at flood times. This seawall or dike structure may run for kilometres together in the coastline. These coastal reservoirs and coastal wetlands to ensure water quality plays a critical role for the rural coastal population Even inlet and outlets are controlled such that only good quality water enters the reservoir with very little stagnation of water. One can adopt very innovative designs with an intelligent sensor network to operate the coastal reservoirs efficiently.

These coastal reservoirs provide freshwater for agriculture, livestock and domestic consumption, water for industry, and recharge the groundwater levels, which are under the immense strain of over-exploitation. Earlier studies have highlighted the fact that there is enough water available, but the deficiency is in storage. A large portion of fresh water from river systems, groundwater and wetlands drain into the sea due to insufficient storage facilities. Coastal reservoirs enable the storage of excess river floodwaters near the coast for future use (Sitharam 2016).The coastal area of the Gulf of Khambhat shares its area with four districts of the Gujarat state, namely, Bhavnagar, Ahmedabad, Annad and Bharuch

2. Rationale of the Study

Development of any reservoirs, ports and harbors as well as dams involves an effective management plan towards environmental wellbeing that guarantees both sustainable growth and a healthy ecosystem functioning around its vicinity. There is a need for innovative solutions for any developmental activity which are in harmony with the ecosystem and are robust or adaptable under change. Over the temporal scale, habitat and ecosystem change with the influence of natural phenomena viz. climatic shift as well as change in landscape features, etc. as well as of anthropogenic pressure. Insights from the above concept, the ambitious project delineates conversion of a marine water ecosystem into a freshwater ecosystem, projected over a few decades in the Gulf of Khambhat region. In the context of the present condition, the aquatic system of the Gulf of Khambhat has three major ecosystems include; marine, brackish water/estuarine, and freshwater ecosystem based on the inherent salinity of the aquatic system existing in the area. Along with these major ecosystems, multiple macro and micro-ecosystem and habitats are present in the areas which are classified under coastal ecosystem (intertidal mudflats, swamp forests, salt marsh, creeks, etc.) and terrestrial ecosystem (coastal sandy beaches, sand dune, grassland, scrubland, small islands, riverbank, etc.). These admixtures of ecosystem and habitats support thousands of species adapted and distributed to each of the ecosystem and habitats with different diversity and compositions in space and temporal gradients. Hence, understanding the status of biodiversity in each ecosystem is a pre-requisite to generate baseline status of the ecology and biodiversity of the project area and its influence area, and also helpful in projecting the probable shift in species composition and diversity in due course of time with the change in an aquatic ecosystem, landscape features, and other changes arise due to anthropogenic activities. Thus, the study was proposed to generate baseline status of biodiversity in the project area, assessing the probable shift in species diversity due to ecosystem changes, socio-economic impact assessment with respect to change in biodiversity and fisheries, and assessment of the groundwater regime of the area in view of the change in the aquatic ecosystem of the project influence areas.

The baseline primary data for the environmental conditions in the Project Influenced Area (PIA)/ (Kalapasar Dam project) are established based on reconnaissance survey and field survey investigation. And largely this to understanding the ecological setup, identification of various ecosystems and habitats, and fixing sample size and location for each group of biodiversity. The scope of the present investigation includes analysis of different biological components of the proposed Kalapasar project environment, such as marine, estuarine and freshwater environmental biodiversity monitoring strategies was considered. The detailed marine bio diversity and fisheries survey has been initiated on mid- December 2021.

3. Scope of Works

Following are the objectives of the study:

1. Species diversity in the Gulf of Khambhat especially around the project area.
2. Probable Shift in species diversity as the environment changes from saline, brackish and fresh water.
3. Socio-economic Impacts due to change in Biodiversity especially with respect to Fisheries.
4. Ground water status and Technology for Ground water quick recharge as the environment changes from saline, brackish and fresh water



4. Project Inception, Approach and Design, and Preliminary Information

4.1. Objective 1: Species diversity in the Gulf of Khambhat especially around the project area.

Objective 2: Probable Shift in species diversity as the environment changes from saline, brackish and fresh water

4.1.1. Terrestrial Biodiversity

A reconnaissance survey was conducted from 16th-19th November 2021 and preliminary survey was conducted between 20th -24th December 2021, to understand the biological attributes and different habitat types within terrestrial ecosystem and to make plan for systematic sampling to generate baseline data on terrestrial biodiversity within the 10 km periphery of the coastline of Gulf of Khambhat region. The entire study area from Dahej to Bhavnagar has been visited covering all river estuary areas such as Narmada, Vishwamitry, Mahi, Dhadhar, Bhogavo, etc. During preliminary field visit, various coastal habitats such as coastal forests, scrub forests, grassland, coastal wetland, inland wetland, small islands, sandy beaches, ravine, settlements, agricultural landscape, etc., which are the part of terrestrial ecosystem were observed. Based on survey, a map of the study area has been prepared for systematic survey and sampling of various components of terrestrial biodiversity. The sampling approach and techniques to be adopted to assess the terrestrial biodiversity was also determined which are described in below sections. Additionally, some secondary data and information available on the terrestrial biodiversity of the study area has also been collected from various sources including published paper, technical reports, books and supporting documents from different stakeholders like research organization, NGOs, Govt. Departments, Project proponents, etc. to prepare the checklist of the terrestrial biodiversity of the study area.

A brief account of different terrestrial biodiversity components (birds, amphibian, reptiles and mammals), the sampling location map and, the methodology adopted to understand the baseline status of the biodiversity and to assess the shift in species diversity and composition of different groups of terrestrial biodiversity in view of the project cycle are mentioned in separate sub-section below:

4.1.1.1. Sample Size and Sampling Technique:

Fixing of the sampling location: First of all, demarcation of the area to carry out intensive survey of the terrestrial biodiversity (Flora and higher vertebrate fauna) in the coastal region covering 5 km periphery from the coastal line of the Gulf of Khambhat (above the proposed project) and river mouth (falling to the Gulf of Khambhat above the proposed project) was done using QGIS software. The polygons of 5 km² size for conducting a systematic sampling was also created using fishnet tool in QGIS. Further, the polygons file was then overlaid on google earth image of the

study area to prepare the sampling location map that can be used in the field while placing the transect in each grid (figure 1). The map shows that due to irregular dimension, the whole study area could not be equally divided into 5 km² size grids. It is depicted that the study area contains 55-60 grids having more than 70% percentage of the area. Hence, these grids can be used as the sampling sites. However, the placement of transects (1-2 km length) in grids will be done from land to seaward or vice versa.

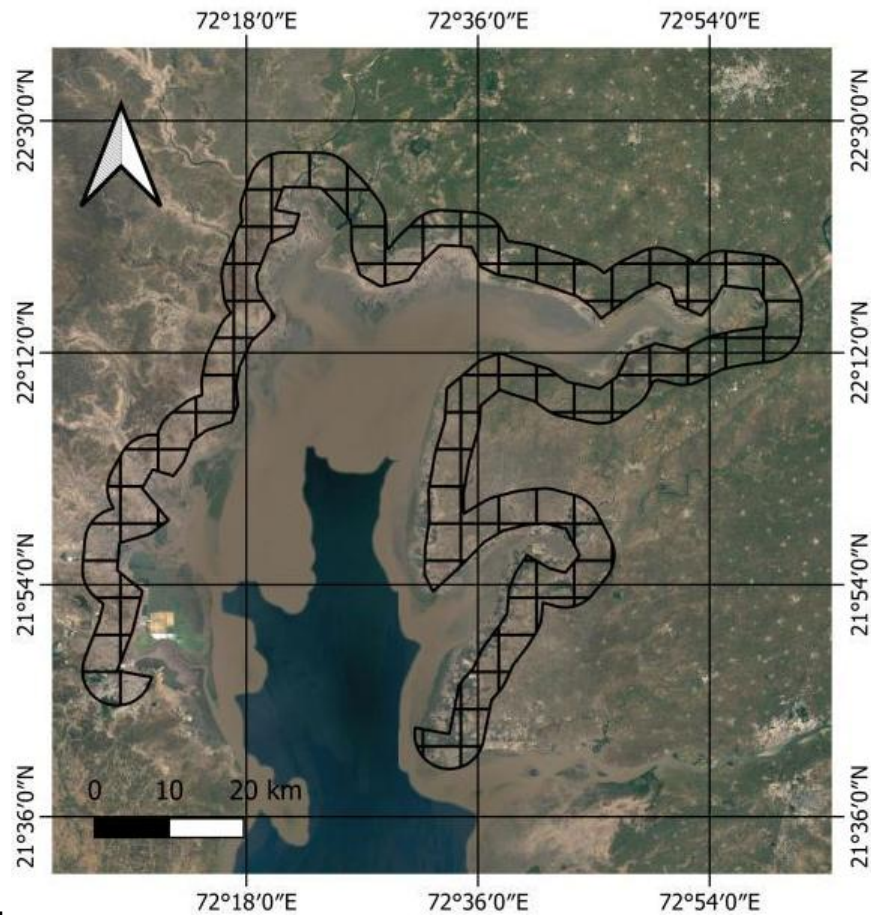


Figure 1: Proposed Grid Map of the Terrestrial Biodiversity Study



Figure 2: Field visit carried out by teammembers

4.1.1.2. Survey methodology for flora and major groups of fauna

4.1.1.2.1. Floral Biodiversity Status: Status of floral species will be assessed in the representative habitats covering forest, grassland, scrubland and wastelands around project site. Quantitative data will be collected using Standard Quadrature Sampling Methods followed by Mueller-Dombois and Ellenberg (1967), Kershaw and Wright (1980). Status of tree, shrub, grass, creepers and herbs will be quantified using square shaped plot of size 10m, 5m and 1m respectively.

4.1.1.2.2. Faunal Biodiversity Status: The various groups of faunal species including mammal, bird, reptile, amphibian and fishes will be assessed in the representative locations and habitat including wetland, forest, scrubland, open land, wasteland, cropland, etc.

Insects: Intensive survey will be made to assess insect species of the study area. Insects observed during the field survey will be recorded and photographed for further identification and documentation. The photographs of all insect captured in the field will be identified using handbook and monographs of various groups of insects.

Fishes: List of fish fauna found in the coastal area, ponds and lakes will be prepared by field survey, surveying local fish market (if fish market available nearby the study area), and conducting interviews with the local fisherman (if fishing activity takes place) and fish catch and landing centres around the project area.

Herpeto-fauna (Amphibian and Reptile): Intensive search will be made along the hedges of water bodies including pond, lake and river and streams to quantify the amphibian species. Status of other herpetofauna will be monitored and assessed by intensive survey by using standard methods (Campbell and Christman, 1982; Welsh, 1987; Corn and Bury, 1990 and Heyer *et al.*, 1994).

Birds: Avifaunal status will be assessed both in terrestrial and aquatic habitats (freshwater bodies, brackish water, mangrove, marine, etc.). Total count or flock count method (Sridharan, 1989; Bhupathy, 1991; Thompson, 2002; Steinkamp *et al.*, 2003) will be adopted to monitor and assess the aquatic birds in all wetlands and waterlogged areas. Point centre count method/perambulation techniques (Hutto *et al.*, 1986; Bibly *et al.*, 1992; Rosenstock *et al.*, 2002) will be applied to monitor and assess the status of terrestrial bird species. Additional efforts will be made to locate/identify the presence of breeding/nesting sites of avi-faunal species.

Mammals: Status and distribution of different mammal species will be monitored and quantified by direct count while walking along the Line transect in various type of habitats (Burnham *et al.*, 1980; Sale and Berkmuller, 1988; Rodger, 1991).

In addition, indirect evidences for the presence of mammalian species will be collected through opportunistic survey for estimation of the relative density and abundance of mammalian fauna in the area. The indirect survey of the mammalian

fauna will be conducted using standard methods (Thompson *et al.*, 1989; Daniel, 1992; Henke and Knowlton, 1995; Allen *et al.*, 1996).

4.1.1.3. Data Documentation, Analysis and Interpretation

Data collected through the intensive survey and available secondary information, the comprehensive checklist of species in each ecosystem will be prepared. Further, the primary data collected through the survey will be analysed to estimate the species diversity in the project area using statistical software.

4.1.1.4. Identification of Threatened Habitat and Ecological Important Areas

Initially, the protected areas (PAs) boundary will be procured from the competent authority. Thereafter, the ecologically sensitive areas like Biosphere Reserve, National Parks, Wildlife Sanctuaries, Archaeological sites and/or Heritage site will be identified by overlaying the protected areas boundary shape file on the study area. In case if the project area falls under or overlap with any of the PA categories or the eco-sensitive zone then based on intensive survey, the threatened habitat and ecologically important areas will be assessed for developing measures for conservation and management plan of the identified habitat.

4.1.1.5. Identification and Preparation of Checklist for Endemic and Threatened Species

Based on the Primary survey on different components of biodiversity and collation of secondary information on biodiversity of the project coverage area, an intensive checklist of various floral and faunal biodiversity under major ecosystem types viz. terrestrial, marine, coastal/brackish, freshwater ecosystem, etc. will be prepared.

As per the intensive checklist, the endemic species of the Gulf of Khambhat, endemic to Gujarat coast and Endemic to India will be identified based on available species distribution map and various literatures.

Further, the checklist of the threatened species of the area will be prepared based on the Red List of Threatened species of IUCN and various Schedules of Wildlife (Protection) Act, 1972.

4.1.1.6. Work done So Far

- Reconnaissance survey completed
- Sampling location and sample size fixed, and planning for intensive survey has been made
- Secondary information on biodiversity of the project area has been collected
- Preliminary surveys for some sample location were completed.

4.1.1.7. An Account of the Terrestrial Biodiversity

The baseline information on the terrestrial biodiversity (flora and fauna) component is given based on the EIA (2011) report carried out for the study area. It is observed that the area supports 57 different species of plants including 17 trees, 21 shrubs, 5 nos. of twiners/ climbers and 7 spp. of grass whereas in fauna, the area harbours 12 spp. of Arthropoda, 1 amphibian, 6 reptiles, 41 spp. of birds and 22 of mammals. As per Gujarat Ecology Society, 2018, a total of 114 different bird species belonging to 42 families reported from the Mahi Estuary whereas 187 species from the Sabarmati Basin. Further, 14 mangrove plant spp. and 19 of their associated plant species are also reported by GES, 2018.

The coastal area of the Gulf of Khambhat lies in the study area having varied terrestrial and aquatic habitat such as grassland, scrubland, salt marsh, estuaries, creeks, mudflats, mangrove, river, artificial ponds, salt pans, aquaculture ponds, etc. which are enriched with migratory and resident birds. Among the total recorded bird species of Gujarat, total of 178 (i.e., 33.8%) species were recorded from the Dholera region in which 102 species were resident while 76 species (i.e., 30.8%) were migratory birds (Bandopadhyay and Dutta, 2013). A total of 317 bird species including 154 species of resident bird and 163 species of winter, summer, or passage migrants were reported from the Bhal area (Pandya *et al.*, 2018). The Environment Impact Assessment (EIA) study of the Solar Power Project of DSIR, recorded 70 bird species from the study area comprised of 63 residents and 7 migratory species (Pandya *et al.*, 2018).

Secondary information available on terrestrial biodiversity of the study area have been collected from various sources including published paper, technical reports, books and supporting documents from different stakeholders like research organization, NGOs, Govt. Departments, Universities, Project proponents, etc.

Intensive survey has been conducted during 20th to 24th December 2021 to facilitate to determine the sampling locations, numbers and techniques to be adopted to assess the terrestrial biodiversity.

4.1.1.7.1. Terrestrial Floral Diversity Status

A total of 14 transect and 70 quadrates have been laid down for floral data collection covering all river estuary area from Gogha to Jambusar. Data on phytosociology such as diversity, density, frequency etc. have been collected. Status of floral species has been assessed in the representative habitats covering forest, grassland, scrubland and wastelands around project site. Quantitative data have been collected using Standard Quadrature Sampling Methods followed by Mueller-Dombois and Ellenberg (1967), Kershaw and Wright (1980). Status of tree, shrub, grass, creepers and herbs has been quantified using square shaped plot of size 10m, 5m and 1m respectively.

Various habitats such as forest, grassland, scrubland, wastelands and coastal etc. have been surveyed during the visit. The herbaceous species of coastal vegetation is mainly

composed of *Aleuropus lagopoides*, *Seuda nudiflora*, *Cressa cretica*, *Sessuvium portulacastrum*, *Salsola baryosma* whereas tree species such as *Avicennia marina*, *Salvadora persica* have been observed. Scrub vegetation is mainly dominated by tree species such as *Prosopis juliflora*, *Accacia nilotica*, *Prosopis cenararia*, *Accacia leucophloa*, etc. Shrub species such as *Euphorbia cauducifolia*, *Cassia auriculata*, *Cassia occidentalis*, *Calotropis procera* etc. have been recorded. The herbaceous species such as *Alternanthera sessilis*, *Parthenium hysterophorus*, *Peristrophe bicalyculata*, *Blumea oblique*, *Digera muricata*, *Solanum surrettense*, *Vernonia cenararia*, *Corchorus capsularis* etc. Wetland habitat have been mainly represented by tree species such as *Prosopis juliflora*, *Tamarix aphylla*, *Salvadora persica*, *Ficus benghalensis*, *Parkinsonia aculeate* while the shrub species such as *Calotropis procera*, *Capparis decidua*, *Cassia auriculata*, *Abutilon indicum*, *Zizyphus numularia* etc. have been recorded. The herbaceous flora is mainly composed of *Hygrophilla auriculata*, *Xatnium strumarium*, *Echinops echinatus*, *Indigofera cordifolia*, *Occimum canum* etc. The grasses such as *Cynadon dactylon*, *Chloris barbata*, *Sporoboulus helvovlus*, *Dichanthium annulatum*, *Cyperus rotundus*, *Fimbrystilis dichotoma*, *Scirpus litterolis* etc. have been observed. Around 60 floral species have been recorded during the survey.

4.1.1.7.2. Terrestrial Faunal Diversity Status

The preliminary report on faunal diversity was based on the sampling was carried out at eleven different village sites such as Ghogha, Nava Bandar, Juna Bandar, Kala Talav-1 (Bhavnagar), Kheta Khatli, Ganeshgad, Kotda and Jaswantpura which fall under Bhavnagar districts and, Khambat, Kala Talav-II, Vadgam and Kamboi of Bharuch District. A total of 851 minutes (~14 hours) of time-effort was made in the survey. Of this, the survey was conducted for the highest time-period ~195 minutes each at Nava Bandar and Ghogha sites whereas the least at Kala Talav-II (15 minutes) and Juna Bandar (22 minutes) sites. A total of 73 species of birds were recorded during the preliminary survey in which, 42 were terrestrial and 31 aquatic species. The taxonomic composition of the birds indicates that these bird species belong to 32 families of 14 different orders. By looking at bird composition at order level, the highest no. of species (18) belong to Passeriformes and 13 each to Pelecaniformes and Charadriiformes. Out of 73 birds, a no. of 14 species including Common Pochard, Great White (Rosy) Pelican, Common Crane, etc., were found to be migratory whereas others were either residents or residential migrants. ICUN status-wise analysis showed 64 birds under least concern (LC) category, 5 near threatened (NT) and 4 vulnerable (VUL). However, different migratory birds' status showed that out of 14 species, twelve were under least concerned (LC) while 1 each under near threatened (NT) and vulnerable (VUL) category. The WPA status of the recorded birds indicated total 67 species under schedule IV, 5 (Schedule I) and one (schedule III). In terms of diversity indices, the site-wise comparison analysis shows that the highest number of species was observed at Khambat (37) and Nava Bandar (29) may be due to the maximum time devoted to the sites during survey. Also, the results showed the highest diversity and evenness each for Khambat (~3 and 0.92), Kotda (2.2 and 0.85)

and Ghogha (2.02 and 0.78) whereas the richness for Kahmbat (7.5), Kala Talav (3.5) and Nava Bandar (3.9) sites.

From the survey, it is concluded that the area supports a good number of aquatic and terrestrial bird species and, migratory birds in particular (Figure 1-3). And still, there is a scope of increase in the numbers of birds as the study progresses. Similarly, apart from birds, species of other major fauna groups (mammal and reptile) were also observed during the survey. In mammals, species such as Squirrel, Mongoose, Common Langur, Blackbuck, Nilgai and Jackal whereas among reptiles, common garden lizard, monitor lizard, rat snake, green sea turtle were recorded.



Greater Flamingos



Great White (Rosy) Pelican



Black/ Brown Headed Gull



Common Crane



Sarus Crane



Painted Stork

Figure 3: Avifauna diversity recorded in the Kalpasar region

4.1.1.2. Marine and Coastal Biodiversity

Biodiversity is being increasingly threatened globally, nationally, and regionally due to various natural and anthropogenic sources. Besides this, anthropogenic activities create several pressures on biological resources that lead to destruction, alteration, and degradation of habitats, which subsequently leads to loss of biodiversity.

The coastline of Gujarat is 1,650 km encompassing two Gulfs and associated coastal ecosystems such as mangroves, coral reefs, estuaries and mudflats. Mangroves possess several unique characteristics that make them structurally and functionally different from other halophytes. Mangroves comprise several salt-tolerant plant species that grow along the inter-tidal zones of river and sea, or estuarine habitat and river-delta. Mangrove forests are considered to be the most productive and diverse ecosystem, the species can survive in a hostile environment and exhibit a variety of adaptations like high salinity, extreme tides, strong winds, high temperatures, low oxygen, and muddy soil (Kathiresan 2010). The highest mangrove cover in Gujarat is found in the Kachchh district, followed by Jamnagar and Bharuch. Gujarat, situated on the west coast of India has the largest coastal area of around 28,000 km² and longest coastline (1650 km) which supports a variety of marine flora and fauna. In Gujarat, mangrove cover is 1103 km², which includes 175 km² moderately dense mangroves (15.86%) and 928 km² open mangroves (84.13%). Intertidal mudflats are transitional areas between land and sea. Tidal mudflats form at the edges of many tidal estuaries and creek systems and are found in three broad climatic regions viz., i) low-latitude tidal mudflats in arid and wet tropical or subtropical regions, where they may be colonized by mangroves, ii) mid-latitude tidal mudflats of temperate regions; and iii) high-latitude tidal mudflats influenced by ice. In general, mudflats augment mangrove structures due to their existence between sea/creek and mangroves.

Macrobenthic invertebrates are abundant and diverse in intertidal environments, owing to the high concentration of organic matter and nutrients retained in the soil substratum and the overlying water (Atrill 2002; Fujii 2007). The species composition, density, and biomass of benthic macrofaunal group on intertidal flats vary significantly, and this variability has been linked to environmental variables such as salinity, sediment types, and tidal depth (Ysebaert and Herman 2002; Fujii 2007; Pandya 2011). Among these, sediment substrate formations and characteristics such as particle size are some of the important features of habitat selection by different benthic animals (Snelgrove and Butman 1994). Numerous studies were undertaken in the intertidal mudflats where an assortment of organisms is differentially distributed both horizontally and vertically. In general, physical environmental perturbations (e.g. desiccation and thermal stress) determine the upper limit of organisms in an intertidal belt, while biotic interactions (e.g. competition and predation) determine the lower limit (Vachhrajani and Pandya 2011).

Intertidal organisms represent a major biotic component in the marine environment. They have an important role to play in the food chain at different trophic levels in a coastal environment. Hence, the abundance and distribution of intertidal fauna in any marine habitat can be an indicator of ecosystem health and the impact of human interference. Likewise, many environmental impacts can be identified by changes in assemblages of intertidal fauna. Rapid coastal industrialization in recent years has underlined the importance of complete understanding and continuous monitoring of marine environments especially coastal stretches where human activity is intense and evaluating the stability and functioning of this ecosystem and the impacts due to developmental activities. In a port environment, dredging together with continuous movement of vessels and anthropogenic activities might create perturbations that result in major impacts. Assessment of these effects has usually targeted bottom substrata and the associated benthic fauna. Hence benthic communities are logical targets whose density, diversity, community structure, and seasonal variation will be a powerful tool to understand their dynamic habitats.

In the present study, intertidal fauna was studied from 20 locations in the periphery of the Gulf of Khambhat starting jurisdiction from Ghogha to Dahej. Additionally, 15 locations were surveyed for mangrove sites of the Gulf of Khambhat.

4.1.1.2.1. Approach and Methodology

Reconnaissance Survey: A reconnaissance survey was made in the second week of November and Last week of December for all the project influence areas for understanding the ecological setup, identification of various ecosystems and habitats, and fixing of sample size and locations for each group of biodiversity. The scope of the present investigation includes analysis of different biological components of the proposed Kalpsar project environment such as marine, estuarine, and freshwater environmental biodiversity monitoring strategies was considered.

Intensive Survey: Intertidal faunal assemblages were studied for their density and distribution at 17 locations along the Narmada estuary and 12 locations at the mangrove sites in the intertidal belts of Dahej. Sampling and assessment of intertidal communities were done at the intertidal zone during low tide to get a holistic representation of intertidal fauna. Total buffer area of the proposed project site is made into 5 km² grid. The total area will be 3284.23 km², out of which 10% of the area will be surveyed, which comes to approximately 328 km². Similarly, the inner core area is approximately 2063.4 km² in which the total area covered for sampling will be 206 km². A total of 30 grids of 5 x 5 km size will be carried out for intertidal habitat with a sample size of 1x1m. Three to six replicate quadrature samples will be assessed for the variability in macro-faunal population structure and the density will be averaged for the entire intertidal belt. At each site quadrates of 1 m x 1 m were randomly laid in triplicates and all visible macrofaunal organisms encountered inside the quadrature were identified, counted, and recorded. Besides, the sediment sample was collected within the quadrature for macrobenthic organisms and was sieved

through 0.5 mm mesh. The organisms retained in the sieve were fixed in 5-7% formalin and stained further with Rose Bengal solution for ease of spotting at the time of sorting. All the fauna were sorted, enumerated, and identified to the advanced taxonomic level possible after referring to the available literature.

As per satellite imagery and availability of mangroves, the entire 30 grids will be covered with a sample size of 5x5 km in triplicates of 90 samples. Within the inner core area of Khambhat, randomly 20 quadrates will be covered, in which 3 parameters such as phytoplankton, Zooplankton and benthos with a total sample size of 60 in number. Mangrove vegetation characteristics in the selected locations spread over Kalpasar project location following quadrature method (Kershaw 1973). For the study, the whole mangrove formation within the Kalpasar project limit was divided into six major blocks such as Ghogha, Bhavnagar, Zankhi, Dholera, Vadgam, and Dahej. At each sampling locations, quadrates of various sizes were laid. For trees, quadrates of 10 x 10 m were laid. Within each 10 x 10 m quadrate, four quadrates of 1 m x 1 m and another four quadrates of 2 m x 2 m were laid randomly to enumerate regeneration and recruitment classes, respectively. Thus, a total of 40 quadrates for trees and 120 quadrates each for regeneration and recruitment classes to assess the mangrove diversity in the study area. In each quadrate, the total number of trees was counted, tree height, Girth at Breast Height (GBH), and canopy cover (length and width) were measured using ranging rods and measuring tapes. The GBH of all individuals above >1 m was measured. In the case of a branching stem at a specific height, all the branches were added together. Seedlings with a height of 50 cm. To quantify and document the halophytes as Kalpasar project stratified random quadrature method was followed. The mangrove locations were grided into 2 x 2 km. In each grid presence and absence of halophytes and other mangrove-associated species were recorded. In each 10 m x 10 m mangrove quadrate, 04 quadrates each of 1 m x 1 m were laid for assessing halophytes. To enrich the species inventory, areas falling outside the quadrates were also explored. Specimens of species were collected to gather more information on habitat. The species were identified using standard keys.

The other faunal species, including mammals, reptiles, amphibians, and fishes, will be recorded from the mangroves and mudflat areas. The status of mammalian species will be recorded and quantified by direct count (Rodger, 1991) & indirect survey (Henke and Knowlton, 1995; Allen *et al.*, 1996). Herpetofauna and amphibians will be recorded and assessed during an intensive survey following Corn and Bury (1990) and Heyer *et al.* (1994). Identification of fish (Jayaram 2010; Chhapgar 2008), Porifera (Hooper *et al.* 2002); Scyphozoa (Jarms and Morandini 2019), Mollusca (Apte 2012; 2014; 2017; Subba Rao 2003; 2017; Bosch *et al.*, 1996; Oliver 1996), Crustaceans (Naderloo 2018), Echinoderms (James and Pearse 1971), and Polychaeta (Rouse and Pleijel 2001) will be carried out by following the standard literature and revised papers. Macrofauna such as sea dolphin, dugong, shark, Schedule-1 species, and corals will be observed visually.



Figure 4: Map representing Kalpasar Dam Project study area

Table 1: Station Location

GRID NO	CODE	PLACE NAME
1	GJ	Ghogha Jetty
2	GJT	Behind Jain temple
3	LG	GMV Port
4	NDP	Nirma Disposal point
5	ADL	Adhelai
5	ZAN	Zankhi
6	BH	Bhangadh
7	GG	Ganeshgada
8	YP	Yashbantapura
9	DR-1	Dholera Rahtalav -1
10	DR-2	Dholera Rahtalav -2
11	DB	Dholera- Bhatho
12	TD	Tadatalav
13	VD	Khambhat
14	KV	Vadgawn
15	KH	Kavi
16	VE	Vishmitra estuary
17	GMV-1	GMV Port Dahej-1
18	GMV-2	GMV Port Dahej-2
19	LNG	LNG petronet
20	DLH	Dahej light house

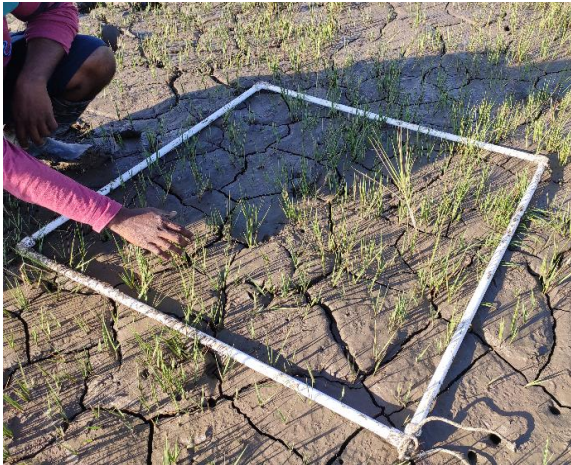


Figure 5: 1 x 1 m Quadrant



Boleophthalmus dussumieri



Uca



Uca annulipes



Grapsus albolineatus



Cardisoma carnifera



Littorina intermedia



Bartschicoma gaimardi

Figure 6: Intertidal fauna recorded during the study at Kalpasar Project location and its periphery

4.1.1.2.3. Preliminary Observations on Coastal and Marine Biodiversity

Ghogha

The Mangrove along the Ghogha coast near the intertidal area was of Recruitment and Regeneration classes. The regeneration and recruitment classes were comparatively high. Total 66,000 plant for Recruitment class and 2,30,000 regeneration class were recorded during the survey. The dominant mangrove species in the study area was the *Avicennia marina*.

Bhavnagar (GMV PORT)

The dominated species of mangrove was *Avicennia marina* with an average height of 145 cm of the average canopy covering 0.4m². Besides this few plants of *Cerops tagal* of less than 100 cm were also encountered during survey.

Vadagam (Jambusar)

The dominated species of mangrove was the *Avicennia marina* which are planted in a total area of 21,042 ha. A nursery of *A. marina* was made followed by planting of trees by ota method of the average height of 106 cm of average canopy cover 1.4m².

Dahej

The mangrove density in Vishwamitri estuarine area was 3872 individuals/Ha with an average height of 1.4 m with tree grith of 12.1 cm. The mangrove canopy cover in the Vishwamitri River estuary ranged between 0.2 m and 7.0 m which indicates that high-density mangrove plants could influence the development of canopy growth. The average ratio of absolute tree density to regeneration class was 1.7 and that of regeneration to recruitment class was 1.5 in Vishwamitri River estuary mangroves. Thus, the establishment of luxuriant mangrove stand in the Vishwamitri River estuary revealed that the mangroves are well sheltered with no major disturbances. The ratio of regeneration to recruitment class indicates the existence of typical habitat that supports seed distribution, establishment, and survival of mangroves. Similarly, a higher ratio of regeneration to recruitment class is an indication of site suitability for further mangrove development.

Mudflats, Halophytes and Associated Flora

The mudflats were observed as either covered with or without vegetation. The mudflats without vegetation cover were those observed on the sub-tidal, inter-tidal, and high-tidal zones of the shore. These types of mudflats were mostly observed along Ghogha, GMV Port, Zankhi, Dholera Rahtalav, Vishmitra estuary, and Dahej. The mudflats with vegetation were usually those covered with mangroves, halophytes, or algae. Since halophytes and other associated vegetation were not encountered from a majority of quadrates, only a few floral species listing is given for the present study. The halophyte tree species i.e. *Salvadora persica* was found in some pockets of mangroves. In addition to this, halophytes like *Salicornia brachiata*, *Sesuvium portulacastrum*, *Suaeda sp.*, and *Porterasia coarctata*, as well as saline grasses like

Aeluropus lagopoides were observed in location Ghogha, Ganeshgada, Yashbantapura, Khambhat, Vadgawn, and Dahej locations.

Additionally, during the present study, four groups of benthic organisms namely Bivalves, Gastropods and Fishes (mudskipper), and crabs were noted. Mollusca is dominant in the intertidal area and mangrove associated area of Gulf of Khambhat.



Figure 7: Glimpses of field survey

4.3: Objective 3: Socio-economic Impacts due to change in Biodiversity especially with respect to Fisheries

Fisheries are important biological resources and livelihood for the mankind over a long period. In the project area, a sizable population of fishing communities are involved in fishing along the entire Gulf of Khambhat and also a large number of people involved in fish culture. The proposed project will generate considerable changes in the ecosystem which may impact on the fishery resources, its diversity, composition and productivity. This will subsequently leads to impact on the socio-economics of the fishing communities and other people involved in the fish culture and related trade/industry. Collection of secondary data on various socio-economic parameters for the project are collected from viz. Department of Fisheries, Research institutes working on fishery and allied resources along with online and offline resources.

4.3.1. Baseline/ Intensive Survey

Intensive survey has been made from 20th to 24th December 2021 covering study area from Gogha to Jambusar particularly the coastal areas. Further, secondary information and data have been collected from various online and offline resources to design the survey and study.

Intensive survey of the study area, specific to the fisherman villages, fish market, fish landing centre and fisheries culture sites have been conducted. This survey is made for planning of study location, sample size estimation for further intensive field survey and collection of baseline information about demographic structure and socio-economic condition of the communities dependent on fish resources for livelihood and fishery business. The survey has been helpful in identifying parameters and indicators for the socio-economic study.

Further, survey and sampling have been made in the entire coastal stretch of the project influence area using questionnaire survey; Focus Group Discussion (FGD), stakeholder's discussion and consultation have been made with the fisheries department and organization working on different aspects of fisheries.

The intensive surveys are made to whole project coverage area and its influence areas around the Gulf of Khambhat coast and river courses meeting with the Gulf of Khambhat have been surveyed covering all parameters and indicators to assess the socio-economic impact of the proposed project on livelihood of the communities and people involved in fishing resources. The above data have been collected based on Interviews and questionnaire survey using designed and open-ended questionnaire datasheet. In addition, focus group discussions have been also be made to gather information on the socio-economic status and identifying impact due to the direct and indirect intervention of the proposed project.

The baseline information is collected to define the socio-economic profile/status of the fishing community and people residing in coastal villages, includes:

- i. Demographic structure: Population, Caste and Community, Agriculture & Livestock
- ii. Infrastructure base in the study area: Road, Railway, Electricity, Water supply, Energy, School, etc
- iii. Economic attributes: Employment, Income, etc
- iv. Health status: Disease, Medical facility, etc
- v. Culture and Aesthetic attributes
- vi. Socio economic status with reference to Quality of Life
- vii. Awareness and opinion of the people about the project: Collection of data on probable Positive impact and Negative impact.



4.3.2. Data Analysis & Interpretation

The secondary data and primary data collected through baseline survey have been scientifically documented and further analysis is under progress made for assessment of socio-economic profile/status, impact assessment on livelihood of communities and people in view of the proposed project. The secondary and primary data have been compiled together to generate cumulative results and further analysis will be made with the help of standard statistical software include; Microsoft Excel and SPSS Inc.

4.3.3. Work done So Far

- Preliminary survey has been made to major fishing area and fish landing centre in and around the project areas
- Fishing villages within the coastal areas of Gulf of Khambhat has been identified
- Sample size and sampling villages for questionnaire survey, FGDs and stakeholders consultation has been made for collecting data regarding the socio-economic impact on fishing communities
- Some secondary data related to the fisheries of the area and fish catch and productivity has been collected

4.3.4. Summary of Information Collected through the preliminary survey

There are five peripheral districts of the study area of Kalpsar project viz. Bharuch, Vadodara, Anand, Ahmedabad and Bhavnagar. There are around 221 fishing centres operating in these five districts. The marine fisher population of these five districts is around 14,624. Out of the total five peripheral districts, the marine fishing population distributed in four districts i.e. Bharuch, Anand, Ahmadabad and Bhavnagar. The marine fish production is around 9225 tonnes from three districts (Bharuch, Anand & Bhavnagar). The fishing centres in Dhandhunka taluka is around 13 and active fisherman are around 494 where as in Khambhat taluka 3 fishing centres and around 663 active fishermen. Similarly, there are about 14 fishing centres and 1908 active fishermen in Jambusar taluka of Bharuch District. There are about 11 fishing centres and 1399 active fishermen in Amod and Vagra taluka. There are only 2 fishing centres and 25 active fishermen in Bhavnagar and Vallabhipur taluka of Bhavanagar District.



4.3.5. Fisherman village and Fish Landing Centre:

During the preliminary survey, team visited three major fish landing centres (Ghogha, Khambhat and Kavi) of the Gulf of Khambhat and discussed with various stakeholders to collect baseline information (table 1) to fix sample location and size for the intensive survey to collect baseline data to understand the dependency of coastal communities on biodiversity-specific to fisheries.

Table 9: List of Fishermen villages and Fish landing centres around Gulf of Khambhat

Sr. No.	Village name	Number of fisherman	District
1	Ghogha*	250	Bhavnagar
2	Juna and navu Bandar	25	
3	Kalatalav	15	
4	Khetakhatli	20	
5	Ganeshgadh	12	
6	Narbad	18	
7	Nava Madhiya	15	
8	Jashvantpura	18	
9	Madhiya	08	
10	Anadpur	11	Ahmadabad
11	Khambhat*	100	Anand
12	Junakotada	150	Ahmedabad
13	Jamadi	15	Bharuch
14	Kavi*	300	
15	Dehgam	20	

*: Fish landing centre

4.4.: Objective 4: Ground water status and Technology for Ground water quick recharge as the environment changes from saline, brackish and fresh water

4.4.1 Background Information

A multipurpose dyke has been proposed in Gulf of Khambhat as Kalpsar project (Fig.8) for the future development of the area.

The proposed benefits from this project are as follows.

- Highest importance and priority to irrigation and drinking water for Saurashtra and Central Gujarat regions.
- The Reservoir will have the storage more than double the Sardar Sarovar (Narmada Reservoir) capacity.
- More than 10.54 lakhs hector land in 39 talukas of 6 districts of Saurashtra region will get irrigation benefit facility including rejuvenation of rivers. More than 60 existing dams will get permanently filled up with water.
- The Wind and solar energy will be generated which can also be used for lifting fresh water from the reservoir to the canal.
- Bhavnagar port will get revived which will result in the speedy development of the region Because of the Kalpasar Project
- There will be a large saving in travel time and fuel due to the reduction in the distance by about 200 km between Bhavnagar to Surat-Mumbai.
- The saline groundwater of the coastal area of Saurashtra & Central Gujarat will get converted into fresh water with a reduction in soil salinity.
- Substantial improvement in groundwater quality as well as soil salinity of the coastal area of Saurashtra & Central Gujarat.
- About 2 lakh ha land along the periphery of the reservoir will be opened up for development towards value-based land utilization.
- The enhanced benefit of world-class industrial estates like Dahej and Dholera will be available to Bhavnagar/Saurashtra region.

In a view to understand the impact and relent to mitigation plan in the form of Detailed Project Report various aspects including hydro-geology of project area as well as its surrounding area has been set as one of the objectives. (Fig. 2) As an inception of hydro-geological studies a reconnaissance visit and review of secondary literature have been initiated and broader hydrogeological aspects have been attempted to incorporated in the present summary report.

4.4.2 Aim & Objectives

The main aim to carry out geo-hydrological assessment is to prepare detailed project report on feasible solutions for any possible impact of Kalpsar Dam in the area on groundwater in term of quality and or quantity along with its application in various usages. To achieve aim following main objectives have been set for developing DPR.

- To understand current groundwater scenario in term of aquifer type, spread, water level fluctuation and water quality based on assessment of available literature on similar type of study and data
- To understand water use practices in project area and their seasonal occurrence and availability
- To assess water quality and its impact on land resources
- To identify current trend on water level and quality fluctuation and projection of changes during post implementation of Kalpsar and estimate rate at which gradual transaction of saline water into brackish to fresh water
- To understand socio economic analysis in project area and to assess possible change in livelihood due to implementation of Kalpsar
- To understand current practices for managing water / groundwater during lean period by community
- To understand community perception on Kalpsar impact and how it can be managed with decentralized solution
- To carry out assessment of positive / negative impact on land and water resources in influencing area of Kalpsar
- To carry out feasibility studies of various techniques for impact mitigation and map out feasible areas for respective technical solutions
- To estimate investment for mitigation

4.4.3 Approach and Methodology

To conduct the study integrated watershed basin management approach as depicted in fig 9, will be adopted where qualitative and quantitative assessments of existing land and water resources will be carried out. The proposed watershed basin analysis will be held in all water basins mentioned in table 2.

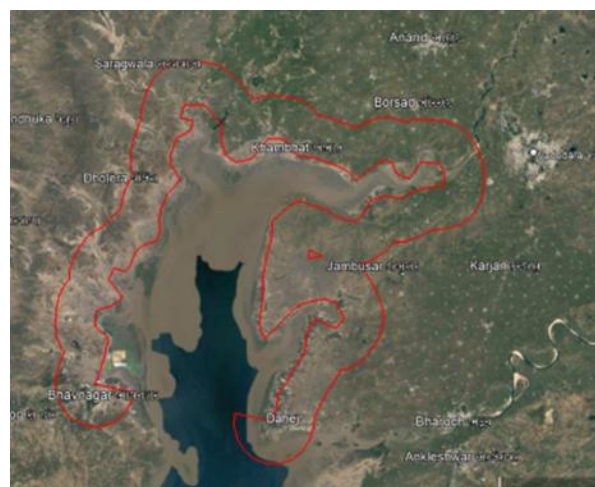


Figure 8. Location of Kalpsar Dam

Table: 2 Zone wise List of Rivers Contributing Surface Water Inflows to the Study Area.

Sr. No.	Zone	Name of Rivers
1	Western part - from Bhavnagar to Dholera	Shukh-bhadar, Kalubhar, Keri, Ghelo, Bhogawo, Sabarmati, Khari
2	Northern part - from Dholera to Jambusar	Vatrak, Dhadhar, Mahi, Vishvamitri
3	Eastern part – from Jambusra to Dahej	Narmada

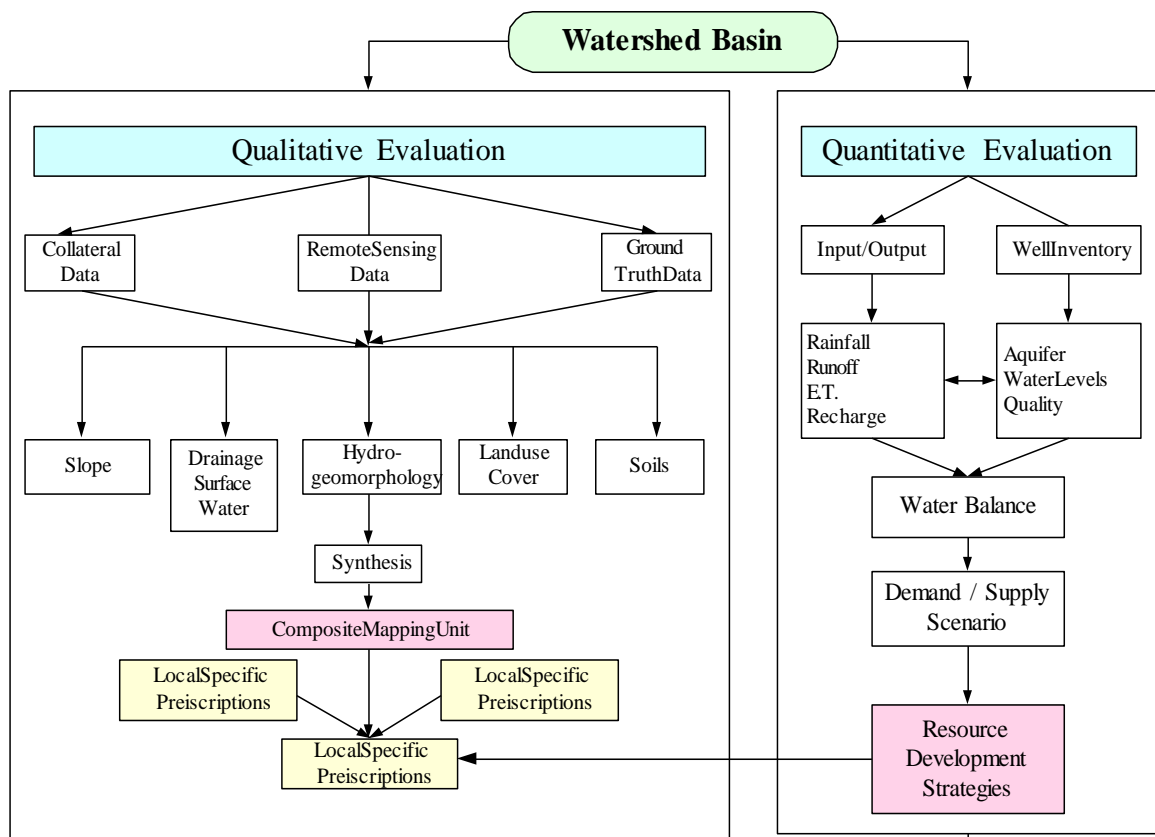


Figure 9: Approach Methodology for Study

4.4.4 Data Collection

Secondary literature and studies will be reviewed to understand and further refining the primary data procurement procedures. The reviewed literature’s authenticity and accuracy will be cross checked by holding field visits and ground checked before its citation as well as for drawing on conclusions. Outputs of this review will be used as base for detailing of primary data collection and studies to bring more granularities and objective specific methodology and samplings. In addition to this climate related and historical groundwater data will be obtained through reliable and authentic sources. This step will be followed by primary data collects by various approaches

and surveys be designing comprehensive Performa and questioners. Primary data will be collected to understand existing water potential, land use practices, etc.

Following primary data will be collected with respective method.

- Inventory of few existing wells in various typologies of landforms in study areas.
- Water Sample collection for each invented well and TDS, pH analysis will be done for all wells while one forth well sample will be used for detail chemical analysis.

4.4.5 Thematic Mapping

To characterize terrain thematic mapping for geology, aquifer, landuse, landform, drainage, slope etc. will be prepare to classify area according to recharge / runoff potential, probable mine impacted zone, sea water intrusion zones and watershed characteristics.

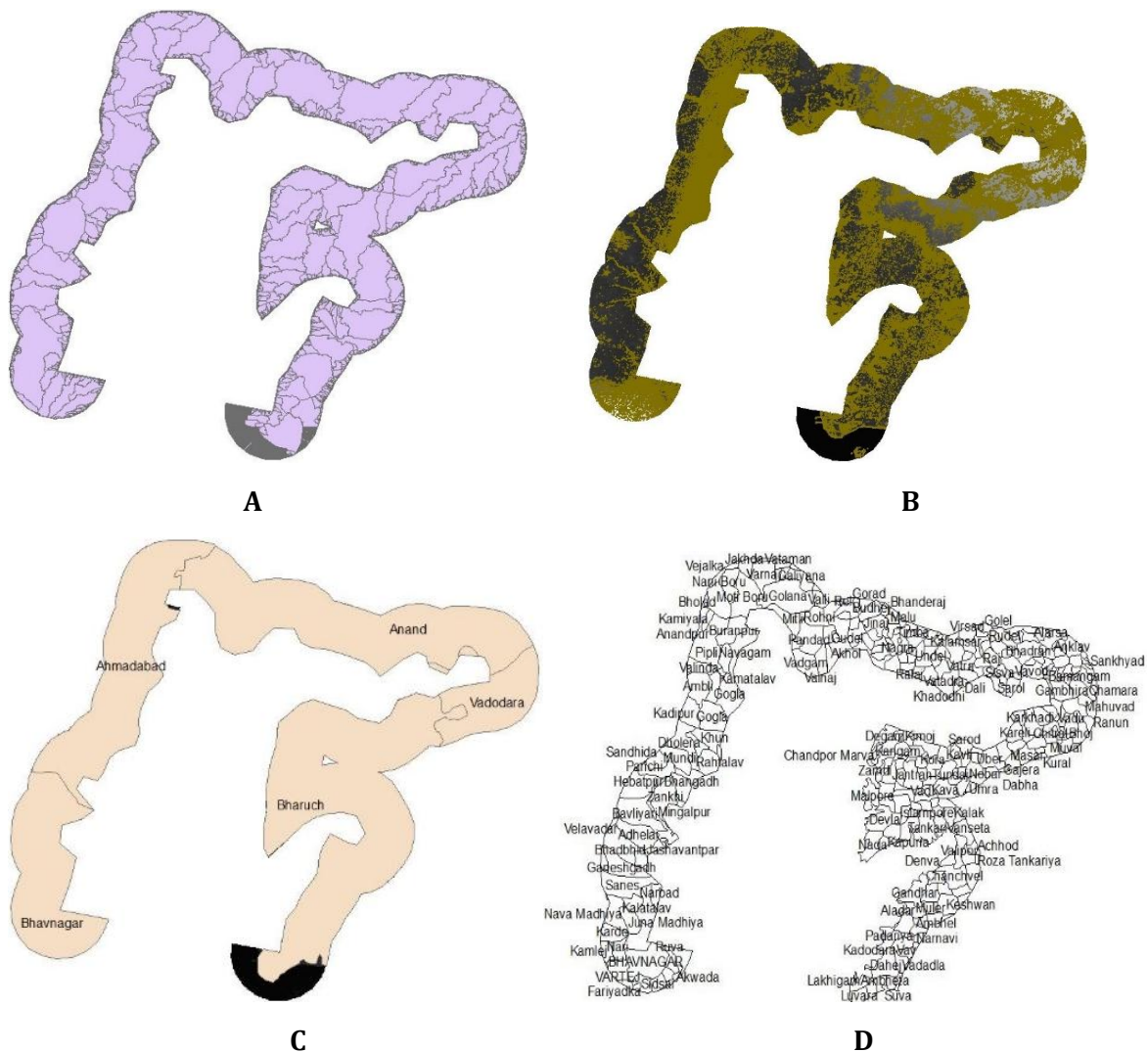


Figure 10: Example of Thematic Map for creating base line information A. Micro watersheds; (B) DEM based countour model; (C) Districts Covered under Study and (E) Village Distributions

This will help to quantify impact of mining as well as to develop area specific mediatization measures to cop up with land use changes. Satellite image of the area will be used to efficiently carry out mapping exercise. And ground check of analyzed satellite data will be held to produce accurate information of the area. Examples of thematic maps have been illustrated in fig. 4, where the study area will be divided into various thematic zones considering basins, contour, and village boundary. The data collection for following thematic maps will be collected considering these basic sub areas of project areas. In up stream of Kalpsar dam the study will be carried out in total five district namely Bhavnagar, Ahmedabad, Anand, Vadodara and Bharuch while in downstream area it will be in Amreli in west and Surat district in east of Gulf of Khambhat. However, the basic mapping exercise will be carried out based on area delineated as 10 km strip around submergence of Kalpsar dam, that will be modified based on geo-hydrological reviews of the area considering following parameters

- Aquifer recharge areas extension
- Exposure of aquifer on surface those are opening in Gulf of Cambay
- The area under influence of spring tide
- Regional physiographical divisions

4.4.6 Groundwater mapping

Groundwater mapping will be done to understand groundwater flow directions and status of water level. Besides this water quality maps will be prepared based on occupied secondary data. All the maps will be prepared with respect to AMSL and FSL of Kalpsar. The projection will be made by using modelling approach with the help of GIS software. To define groundwater scenario following secondary data will be obtained from government departments, universities and will be verified based on primary data collection by holding well inventory in the project areas withing 5 km by 5 km grid. The well inventory will be carried out in defined performa as shown in annexure 1.

Table 3: Proposed Data Set and Information for Geo-hydrology Analysis

Data	Information	Analysis
Subsurface Geological Data	Well, litholog from GWRDC, CGWB of all coastal areas	Cross section across the Gulf and along the Gulf
Water Level Fluctuation	Groundwater department Pre and post monsoon water levels data of last five years	ISO Water level maps Secular changes in water level and trend analysis
Water quality Fluctuation	Groundwater department Pre and post monsoon water levels data of last five years	ISO TDS maps Secular changes in water quality and trend analysis

Data	Information	Analysis
	Water quality parameter TDS, Chloride, pH	Quality indices Drinking water and irrigation
Rainfall data	Rainfall analysis of catchment area and study area	Trend in overland flow
Land use data	Remote sensing analysis	Geomorphological categorization for developing mitigation strategies.
Landform	GIS analysis based on Satellite images and Google images	

4.4.7 Mitigation Planning

Based on thematic mapping and hydrogeological evaluation of area strategies for different geohydrological typologies will be prepared and set of recommendations will be made for incremental development and management of land and water resources of the area. Various recharge techniques, water harvesting techniques, soil moisture conservation activities based on hydrogeological characteristics of the area will be listed out. The customized design and estimation will be prepared to estimate investments. To carry out community centric planning various consultations at regional level will be plan where the strategies and activities will be shared with stakeholders to check its feasibility.

4.4.8 Reconnaissance Visit Observations

A reconnaissance visit has been planned during 15-19 November 2021 to define the strategy and activity for study. However, the primarily upstream zones have been prioritized for planning and therefore, secondary literature and field observations-based attempt have made to build understanding on broad hydro-geological characteristics of an area. Following are broad descriptions about the hydro-geology of upstream zones of project area.

4.4.9 Hydro-geological Characteristics:

To understand hydrology the study area has been divided into two broad classes as upstream of Kalpsar Dam and downstream of Kalpsar dam. As inception of study has begun with upstream side, again the area categories into three categories based on location with respect to Gulf of Khambhat viz. (01) Western part - from Bhavnagar to Dholera (02) Northern part - from Dholera to Jambusar and (03) Eastern part – from Jambusar to Dahej. So far hydrology of the study area is concerned; it receives surface water inflows from various rivers Table 4. Shows zone wise list of rivers contributing water inflows to the study area.

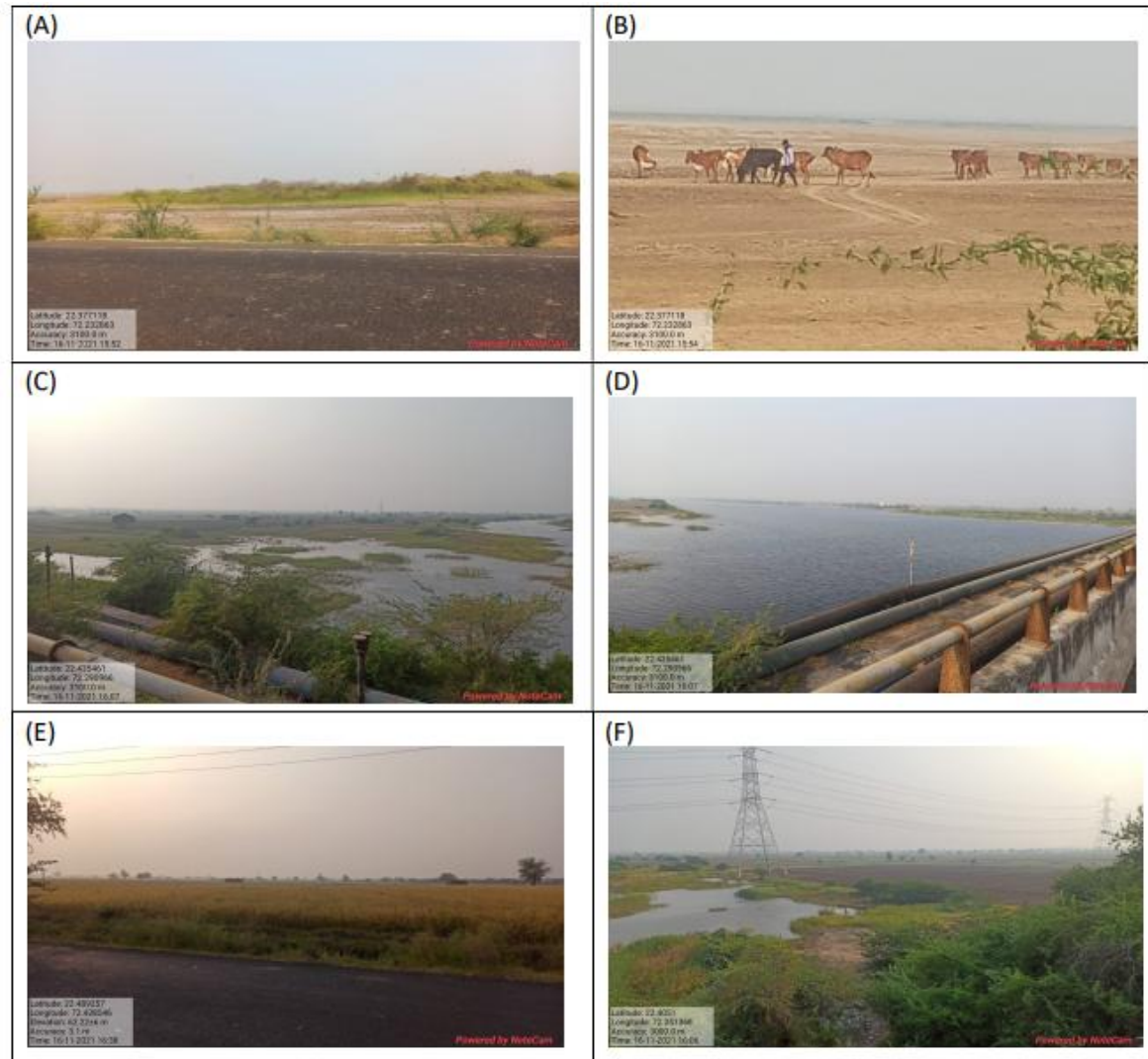


Figure 12: Field Photograph showing various landforms and terrain use around Dholera SIR area (A) Salt encrustation; (B) Non agriculture land; (C) Bhogavo River-1; (D) Bhogavo river -2 and (E) Rainfed and Canal based irrigation.

Table: 4 Zone wise List of Rivers Contributing Surface Water Inflows to the Study Area.

Sr. No.	Zone	Name of Rivers
1	Western part - from Bhavnagar to Dholera	Shukh-bhadar, Kalubhar, Keri, Ghelo, Bhogawo, Sabarmati, Khari
2	Northern part - from Dholera to Jambusar	Vatrak, Dhadhar, Mahi, Vishvamitri
3	Eastern part – from Jambusra to Dahej	Narmada

Occurrence of groundwater is a function of several variables related to hydro-meteorological and hydro-geological set up of a region. The hydro-meteorological parameters that are appreciated regionally and contributes, water input while the hydro-geological parameters create an environment for groundwater movement, storage and quality. Further to develop a framework for detailed understand, preliminary field visits and secondary literature have been reviewed and general framework has been prepares as shown in table 3. From the analysis of the geomorphological map,

([https://sci-](https://sci-hub.st/https://doi.org/10.1080/01431169308954012)

[hub.st/https://doi.org/10.1080/01431169308954012](https://doi.org/10.1080/01431169308954012))

the following observations can be made; (i) Flood plains, valley fills and sandy plains adjacent to river but away from the coast were identified as either free of salinity or negligible saline areas. (ii) Alluvial plains away from the coast were either non-saline or moderately saline. However, the locations where black soils exist are slightly saline (away from the coast) and saline to highly saline (close to the coast) as observed during the field checks. (iii) The areas under mud flats are saline. Old mud flats are either moderately saline or highly saline according to their drainage conditions and proximity to coast and, have been classified accordingly.(iv) Saline flats and salt-encrusted areas were classed as salt-encrusted. The surface water spread map was used to identify salinity in: (i) Areas close to the creeks, covered by mud flats as highly saline, (ii) Areas inundated by spring tides as highly saline, (iii) Areas adjacent to big water tanks near the coast, whose water is used for irrigation, were categorized as non-saline or moderately saline depending upon the tonal variation/vegetation or crop density. However, this is applicable to areas close to the coast in flat regions only. The vegetation/crop density of good, moderate and low categories were identified in combination with geomorphological units, water spread, terrain slope and soils and considered as indicative of non-saline, low saline to medium saline, and medium saline to highly saline soil, indicated by S1, S2 and S3, respectively, in this area. (Fig. 13).



Figure 13: Coastal Salinity Map of the Area Along Bhavnagar-Valsad Coast Based on Landsat-2 MSS Data (1977081)

4.4.10 Water Quality: So far water quality in project area is concerned many departments such as GPCB, CGWB and academic institutions like M.S Universities have conducted various studies in different zones of project area. However, due to different methodology and objectives of respective studies hold in different area need some more attempt to compile, organize and drawing any conclusions for water quality status in study area. As an example, some compilations have been mentioned in table and some details of chemical properties of groundwater has been mentioned in table 6 for upstream northern zone of upstream side of study area.

Table 5: Hydrogeological Characteristics of the Project Area

Soil	Physio-graphic unit	Topography	Surface-water spread/drainage	Salinity	Region	Geology	
<i>Par to Kim river (district Valsad, part of Surat)</i>							
1	Heavy/shallow	Mud flat	Very flat	Gulf water/moisture	Highly saline	Coastal patches/marshy land	Deccan trap
2	Brown to dark brown in colour	AP	Flat to very flat < 2 percent	Mostly close to creeks & wet areas, tidal effect	Highly saline	Coastal plains	Deccan trap with dendritic drainage
3	Brown to dark brown in colour	AP	Flat	Away from creeks	Medium to slight	Coastal but away from creeks	Deccan trap
4	Brown to dark brown in colour	AP	Flat	Near rivers & rivulets	Negligible	Close to Railway (Surat to Bombay)	Deccan trap
5	Dark	OMF	Flat	Tanks	Medium Salinity		Deccan trap
<i>Kim to Mahi river (district Surat, Bharuch and Vadodara)</i>							
1	Heavy clayey	Mud flats	Very flats	Gulf water	High	Along coast & river mouth, creeks	Deccan trap
2	Top surface black	AP	Very flats	Creeks or close to coast	High	Close to coast	Deccan trap
3	Medium to deep towards coast	AP	Flat	Away from coast	Medium to slight	Mostly away from coast	Deccan trap
4	Medium to black	AP/FP	Flat	Rivers or rivulets	Negligible salinity	Close to railway (Surat to Vadodara)	Deccan trap
5	Dark Black	OMF	Flat	Tanks	Medium salinity		Deccan trap
<i>Mahi to Sabarmati river (district Kheda & Ahmedabad)</i>							
1	Medium clay profile	Mud flats	Very flats	Gulf water	High	South of Khambhat along Gulf E-W extent	Deccan trap
2	Medium to deep	AP	Flat	Canals & tanks	Negligible	Anand-Nadiad area up to N-W	Deccan trap

Soil	Physio-graphic unit	Topography	Surface-water spread/drainage	Salinity	Region	Geology
					and W of Khambhat	
3	Dark	OMF	Flat	Tanks	Medium salinity	N-W and W of Khambhat Deccan trap
Sabarmati to Ghogha river (district Ahmedabad, Surendranagr and Bhavnagar)						
1	Medium to deep	Mud flat	Very flat	Gulf water	High	Mud flats on the coastal area Deccan trap
2	Loamy soil	OMF	Very flat	Rivulets and canals	High	E of Sabarmati towards coast Deccan trap
3	Loamy soil	SF	Very flat	Rivulets	High	N of Bhavnagar Deccan trap
4	Medium	VF	Flat	Rivulets	Medium/slight	NW of Bhavnagar Deccan trap

Ref: <https://sci-hub.st/https://doi.org/10.1080/01431169308954012>

Table 6 Zone Wise Groundwater Quality in Project Area Based on Previous Assessments

Zone	U/S Western		U/S Northern	U/S Eastern
Basin	Sabarmati	Bhadar	Kavi river	
Parameter	Average Values			
pH	8.42			
Ec (pS/cm)	2352	7156		
TDS (mg/l)	1518	7500	8472	
Na (mg/l)	337.55			
Mg (mg/l)	105.34			
F (mg/l)	1.27			
NO ₃ (mg/l)				
CL (mg/l)	415.44		7747.9	
SO ₄ (mg/l)	283.54			

Source: <https://www.jstor.org/stable/24089634>

Dholera Project Area (DPA) is located 110 km South on Ahmedabad, on way to Bhavnagar, in northeast fringe of Saurashtra part of Gujarat State. It is typical coastal

plain having elevation in range from 3 to 9 m amsl. Geo-morphologically, area is occupied by old mudflats, patches of flood plains, recent mudflats and salt pans. General slope of the area is from west to east. The area is drained by small ephemeral Bhadar river and its tributaries. The eastern part is at the lowest level occupied by salt encrusted soils, mud flats and creeks and it get inundated by tidal front from Gulf of Kambhat. DPA is underlain by quaternary alluvium, consisting cyclic alternate units of silt, gravels, sand and clay - shale etc of variable thickness and lateral continuation at depth. These quaternary sediments having aggregate thickness of more than 100 m are followed by another 500 - 600 m of tertiary age sediments. All these marines to fluvio-marine type sediments of quaternary and tertiary age underlying DPA were deposited in subsiding Cambay Graben and rest on very thin horizon of laterite of Paleocene age, a by-product of weathering process undergone on basement Deccan Trap (Basalt rock) of Upper Cretaceous to lower Eocene age at depth.

DPA is underlain by fluvio marine sediments which have intrinsic constraints for the availability of fresh groundwater at sustainable measures. Various natural attributes such as a low relief coastal plain, proximity to sea front towards eastern side and connate brackish / saline water in its subsurface system etc have resulted into brackish and saline groundwater stagnation in shallow aquifer system of DPA since geological past. As per CGWB groundwater monitoring data base, this area has shallow brackish to saline groundwater condition. The groundwater exploration at depth more than 300 m, carried out by CGWB near Dholera (22°14'30" N Lat; 72°13'30" E Lon) has revealed saline groundwater having EC 7156 $\mu\text{S}/\text{cm}$ at 25°C in confined aquifer system at depth (258-310 m bgl). In another study taken up for geothermal project, the hot spring water near Dholera found to have meteoric origin. Due to the regional tectonic structure and up-welled mantle condition, high temperature gradients have heated this water during their downward movement along deep channel ways of tectonic origin. The water has risen back to the surface after reaching the boiling point. All such points indicate that, at present there is not any scope to divert or recharge stagnated storm water of DPA into its subsurface system. The data available with CGWB, on basis of regional hydrogeological survey, groundwater exploration and periodic groundwater monitoring, etc., indicate that general groundwater levels in DPA and surrounding area varies from 2 to 10 m bgl and quality varies from marginal brackish to saline. At shallow depth aquifer, groundwater quality is from moderate to brackish (TDS in range 3000 to 12000 ppm). Deep confined aquifer has brackish to saline groundwater with piezometric level near artesian to 20-30 m bgl. This area gets monsoon runoff and flood water from its drainage system having large catchment in the western highland. There is a scope to harness such fresh runoff in DPA. Khambhat is situated near the bay of Khambhat. So, water quality of this area is found degraded due to influence of sea water intrusion during tidal and non-tidal periods

4.4.11 Groundwater Quality Assessment in U/S Northern Region in Kavi River – A Tributary of Mahi River

The Mahi river is one of the major west's flowing perennial rivers and flowing through Central Gujarat into the Gulf of Cambay near Kavi village. The area between Wanakbori to Gulf of Cambay is gently sloping to almost flat near the Gulf and is a fully developed and fertile alluvial tract. The type of soil is deep black coastal alluvium in Bharuch district and medium black in Vadodara and Anand districts. The geology is recent to sub-recent alluvium. (Fig. 6)

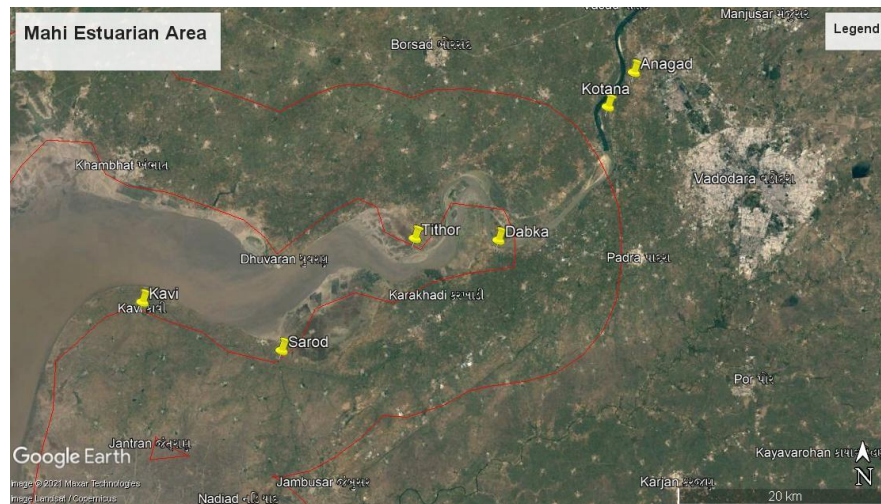


Fig. 13 Locations Showing Water Sample Collection in Kavi River Basin

For pre-monsoon and post-monsoon results of T. D. S., it is observed that as the distance from Kavi town increases, the T.D.S. values decrease of ground water samples. The high pre-monsoon values of the T.D.S. get normalized after the post-monsoon period because of the rain water recharge and dilution with the high T.D.S. water. It was also seen that the pre-monsoon T.D.S. values of groundwater samples of Sarod, Kareli and Dabka at 15, 24.8 and 32.9 km. Distances from Kavi are 8472 p.p.m., 13036 p.p.m. and 8076 p.p.m. The high T.D.S. values of Sarod and Kareli ground water samples may be due to their location near Kavi and they are in Jambusar taluka, which is nearer to the bay of Khambhat. All the tube wells in Jambusar taluka are affected by sea water intrusion. Kareli is at more distance from Kavi as compared to Sarod but the high T.D.S. is observed at Kareli. The probable reason may be due to over withdrawal of ground water or may be due to local geological formation. At Dabka, value of T.D.S. decreased compared to Sarod as Dabka is 17.90 km. away on u/s from Sarod. The post-monsoon T.D.S. values decreased more at Kareli as compared to Sarod. This may be due to the effect of rainfall recharge dilution and their location from Kavi. The decrease in T.D.S. value at Dabka is less compared to Sarod and Kareli.

From table and graphs for pre-monsoon and post-monsoon results of Cl, it is observed that as the distance from Kavi town increases the Cl values decreases of ground water. The high pre-monsoon values of the Cl get decreased after the post-

monsoon period because of the rainwater recharge. 2. High values of Cl for pre-monsoon of ground water samples of Kotana and Angadh are observed. The higher Cl value observed at Kotana compared to Angadh similar to T.D.S. values. The post-monsoon values of Cl decreased more at Kotana as compared to Angadh. This may be for same reasons as mentioned in I (2). 3. It was also seen that the pre-monsoon Cl values of ground water samples of Tithor and Dabka at 25.05 and 32.90 km distances from Kavi are 7747.59 mg/lit. and 7197.76 mg/lit. The Cl value is decreases at Dabka as compared to Tithor as the Dabka is far away from Tithor by 7.85 km u/s. Another possible reason may be Tithor is located on the bank of river where effect of river meandering to prove high amount of Cl in ground water. The post-monsoon values of Cl decreased. The decrease in Cl value at Dabka is less compared to Tithor. This may be due to local geological formations.

Ref:

http://www.rangeland.ir/article_512811_105efd5f1de82366fa26bb0686abbb42.pdf

For pre-monsoon and post-monsoon results of TH, it is observed that. As the distance from Kavi town increases the TH values varying of ground water samples and so no clear relation can be predicted. The high pre-monsoon values of the TH decreased after the post-monsoon. The high pre-monsoon values of the TH decreased after the post-monsoon period because of the rain water recharge. High values of TH for pre-monsoon of ground water samples of Kotana and Angadh are observed. The high value of pre-monsoon TH at Kotana compared to Angadh is observed. The post-monsoon TH values decreased much more at Kotana as compared to Angadh. This is similar to variation of T.D.S. and Cl at above stations. The values of pre-monsoon and post-monsoon T.D.S. of ground water samples of villages located on right bank of river are observed less compared to the villages on left bank of river. This may be due to irrigation by MRBC from Wanakbori weir on right bank of Mahi River (Table 7).

Table 7: Groundwater Quality in Villages of Kavi River

Village	Hardness mg/lit			Ca ⁺² mg/lit	Mg ⁺² mg/lit	Cl ⁻² mg/lit	SO ⁻⁴ mg/lit	Zn ⁺² mg/lit	pH
	Total	Permanent	Temporary						
Dhuvaran	510	240	270	251	265	232	268	3.5	7.38
Pandad	512	232	280	248	260	234	270	3.8	7.53
Vadgam	524	268	256	259	266	229	251	4.1	7.24
Mitli	536	243	293	249	264	231	254	4.4	7.38
Kalamsar	519	212	307	239	251	242	256	3.7	7.52
Lunej	498	210	288	233	252	249	250	3.9	6.66
Sokhda	484	214	270	221	241	223	229	4.2	6.86
Tamsa	491	218	273	232	249	228	234	4.8	6.98
Ralej	468	231	237	219	239	235	238	4.4	6.94
Vasna	451	229	222	224	238	236	241	4.9	6.92

Ref: <http://www.ijaema.com/gallery/50-october-2562.pdf>

Annexure 1

Well No.		Date		Sample No.	
Village		Taluka			
Location	Longitude	Latitude			
Name of the Owner				Survey No.	
Local Name of the Well/Farm/Area					
Use	Drinking Water		Irrigation		Drinking For Cattle
					Abused
Lifting Device	Oil Engine			Electric motor	Hp
Measurement of "Y" for Discharge in m					
Well / Tube Well Information					
Type of Well	Open /Dug Well	Dug cum Bore Well	Step Well	Bore Well	Virda
Well Detail			Geological Information		
Measurement Point (MP) level	Ground Level	Parapet Level	Rock Type		Thickness m
Height of MP from GL		m			
Total Depth		m			
Diameter		m			
Water level		m			
Casing/Curbing Depth		m			
In Case of DCB Please give following information					
Type of Bore Hole	Horizontal	Inclined	Vertical		
Number of Bore Hole					
Depth/Length of Bore Hole					
Year of Bore Hole					
Casing Size inch					
Casing Type	PVC		Cement Pipe		
Geological Information					
Rock Type	Thickness	Status of Water			
	m	Quality (Fresh, brackish, saline)	Water Zone (Dry/Saturated/Moist)		
Terrain Characteristic of the Surround area					
Geology					
Geomorphology					
Tectonic Aspects					
Landuse Pattern					

Water Utilization Pattern from Well			
<i>Purpose</i>	<i>User Human and/or cattle</i>	<i>Unit</i>	
Domestic			Population
			Population
Agriculture	Crop Type	Acre	Season and Duration

Well Behavior or Changes in Water in Different Seasons		
<i>Season</i>	<i>Change in water level m</i>	<i>Change in water quality Taste wise</i>
Pre Monsoon Season		
Post Monsoon Season		
During Drought Season		
During period from its Construction to today		
Note: Expression of Taste as sweet, brackish, saline		

Well/Bore Well History

Surveyed By: _____ Sign : _____ Date: _____

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