December 2023

Ecological Assessment for Downstream Indus Impacts & Biodiversity Action Plan

Karachi Water & Sewerage Services Improvement Project

KWSSIP

KARACHI WATER AND SEWERAGE BOARD

REPORT ISSUE & REVISION RECORD

REVISION RECORD				
Description	**Issue**	**Revision**	**Date**	**Changes made**
Ecological Assessment for Downstream Indus Impacts & Keenjhar Lake Conservation Action Plan	01	00	19/07/2022	--
Ecological Assessment for Downstream Indus Impacts & Keenjhar Lake Conservation Action Plan	02	01	27/01/2023	WB comments addressed
Ecological Assessment for Downstream Indus Impacts & Keenjhar Lake Conservation Action Plan	03	02	31/08/2023	WB comments addressed
Ecological Assessment for Downstream Indus Impacts & Keenjhar Lake Conservation Action Plan	04	03	25/12/2023	WB comments addressed

Executive Summary

The Karachi Water and Sewerage Services Improvement Project (KWSSIP) is a joint development between the World Bank (WB) Group, the Asian Infrastructure Investment Bank (AIIB) and the Government of Sindh (in Pakistan), aimed at improving the access to safe water and sewerage services for the residents of Karachi, along with ameliorating the operational and financial performance of the Karachi Water & Sewerage Corporation (KWSC), all, over a spread of 12 years.

Currently, KWSC is withdrawing 650 MGD of water from Keenjhar Lake via Indus River. In addition, KWSC is planning to withdraw 260 MGD through the government financed associated bulk water scheme - K-IV Phase 1. [1]This assessment is undertaken to evaluate the potential impacts on aquatic and terrestrial ecosystems of Keenjar Lake, Kalri Baghar Feeder (KB) Canal Command Area and Indus River downstream Kotri (including coastal mangroves) due to the additional water supply supported under K-IV Phase 1 project.

A thorough desk review with updating of available database was undertaken which was followed by mapping with the development of potential impact zones, with its representative interpretation, field sampling visits undertaken for in situ understanding of habitat and followed by spot check for biodiversity. The scoping exercise is the most essential part of the assessment as it has provided the existing legal, regulatory requirements and obligations under international treaties, key issues as highlighted by the relevant stakeholders and impacts prevailing in the area of Interest (AoI) as well as occurred during project operations.

The Area of Interest (AoI), for this study, is taken as Keenjhar Lake's boundary itself, Kalri Baghar Feeder (KB) Canal Command Area and Indus Delta (covering an area of approx. 350,000 ha). Some of the environmental components like climate including precipitation, water and vegetation indices are studied at regional level.

The AoI is divided in three distinct zones, defined below:

- The boundaries of the Keenjhar lake - in red
- Kalri Baghar Feeder (KB) Canal Command Area - in light pink
- The Indus Delta covering 350,000 ha – in black

[2] Water Balance and Cumulative Impact Assessment of the Proposed Increase in Abstraction at Keenjhar Lake for the K-IV Mainstream Project (2023), NESPAK.

Figure ES1: Area of Interest (AoI)

A targeted stakeholder engagement approach was employed to determine the concerns and recommendations of all relevant stakeholders. The positive, negative or no impacts regarding various aspects of the bulk water supply option have been identified from the stakeholders' perspectives.

Following officials of Government Departments and NGOs were consulted and their feedback was noted which has described briefly in below points:

Table ES1: List of Stakeholders Consulted

S#	Name	Designation	Department / NGO
1.	Mr. Riaz Wagan	Chief Conservator of Forest, Sindh Mangroves and Rangelands	Sindh Forest Department, GOS
2.	Mr. Hyder Raza Khan	Project Director "Restoration of Riverine, Inland, Mangroves, Dry land & Urban Ecosystems of Sindh Province"	
3.	Mr. Mumtaz Soomro,	Deputy Conservator	Sindh Wildlife Department, GOS
4.	Mr. Habib Ur Rehman Narejo	Director Fisheries, Sindh Inland	Livestock & Fisheries Department, GOS
5.	Dr. Muhammad Hanif Chandio	Deputy Director Fisheries, Sindh Inland	
6.	Mr. Iqtedar Ahmed	Deputy Director Fisheries, Sindh Inland	
7.	Mr. Mr. Shakeel Qureshi	Deputy Project Director	KWSSIP
8.	Mr. Altaf Sheikh	Sr. Manger Conservation	WWF
9.	Mr. Danish Rashdi	Head of Karachi Office	IUCN
10.	Mr. Naveed Soomro	Coastal Habitats Expert	

The feedback from the stakeholders is summarized in below points:

Keenjhar Lake's Ecological Significance

- Keenjhar lake was not only designated the "wildlife sanctuary" for the migratory birds but also important refuge for the resident birds and terrestrial wildlife which is dependent on the wetland. Keenjhar lake also provides ecosystem services to the locals. Fishing is also practiced in the lake.
- The natural breeding grounds of fresh water fisheries are also depleting due to water scarcity.
- The Sindh Fisheries Department is primarily concentrating on fish breeding and aquaculture as a result of this concerning situation. The fish catch from the lake was reduced significantly, however, due to stoking activity, it is now been restored.
- The most significant feature of this region is fishing because it directly supports local subsistence.

Mangroves Ecosystem

- Within last 7-8 years, mangrove ecosystem is sustaining and even thriving from its previous degraded state, due to the joint interventions of Forest department, IUCN and Pakistan Navy as well as recent heavy precipitation events.
- All mangrove forests and all mangrove lands in the delta area **extending over more than 667,000 hectares (ha)** have been declared as "Protected Forests" by 2010 under Section 29 of the Pakistan Forest 1927
- By end of 2020, an area of some 75,000 hectares has been restored with mangrove plantations.
- The abstraction of water from Keenjhar Lake will have no impact on the mangroves and delta as the inflow of water from Indus River to Keenjhar lake is regulated through canals. The water allocated for Keenjhar is the irrigation water and has nothing to do with the e-flow.

E-Flow

- In 2005, the international panel of experts recommended that 5,000 cusecs of water per day as an e-flow should be maintained. However, this recommendation of maintaining the e-flow is not being fulfilled.
- The e-flow is already limited and is only available in significant quantities during the flooding season. The mangroves thrive on the precipitation as well as the negligible e-flow and regenerates post monsoon season.
- The water supply for Karachi is utmost important as the city is the industrial hub as well as biggest city of Pakistan, so the conservation of biodiversity which is already degraded in the AoI, should not be overruled over need of the water supply project, but sustainable measures to be adopted to protect, conserves, restore and offset the ecosystem.

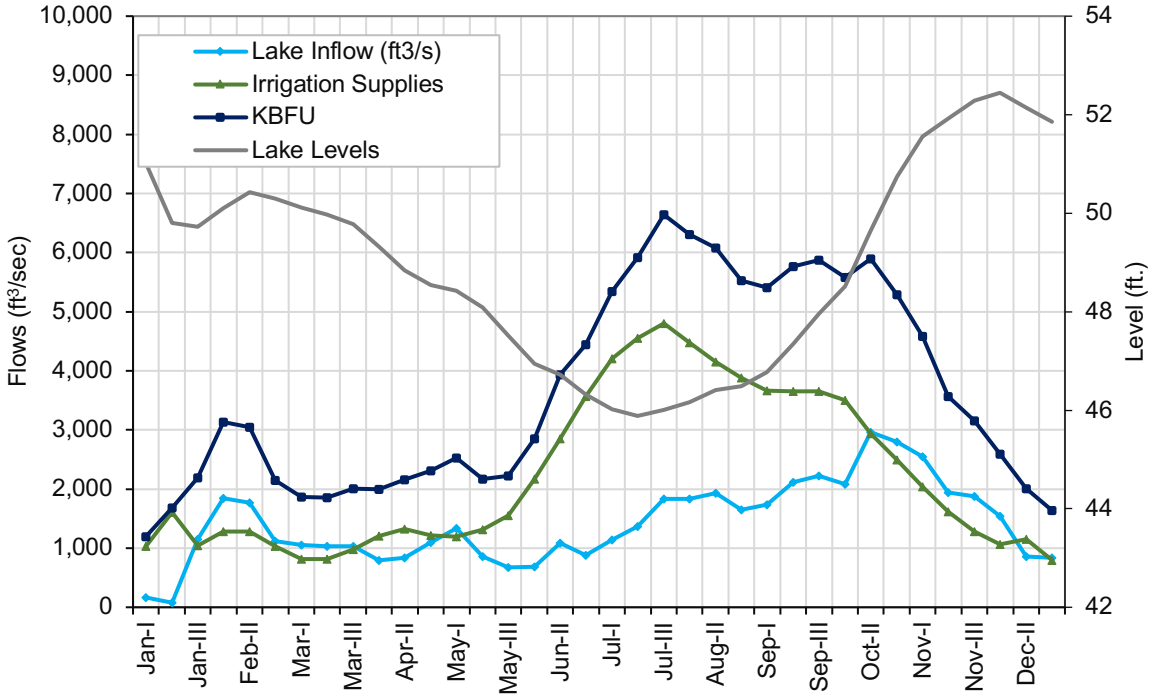
Cumulative Impact Assessment and Mitigation

Based on the above project description, four (04) project scenarios are developed to assess the ecological impacts on HCVs:

- Scenario 1 – Do Nothing or Baseline Scenario in which the water withdrawal is existing i.e., 650 MGD from Keenjhar Lake to Karachi.
- Scenario 2.1 – Implementation of K-IV phase 1 - Abstraction of additional 260 MGD (402 cusecs) of water for K-IV phase 1 from Keenjhar Lake so the cumulative abstraction = 650+260 = **910 MGD** (1,408 cusecs) by managing additional water supply from revamping Kalri Baghar Feeder Upper (KBFU) Project - to achieve its design capacity i.e., 9,100 cusecs.
- Scenario 2.2 – Implementation of K-IV phase 1 - by allocation of additional water from link canal through rotation of irrigation water if revamping of KBFU is not materialized.
- Scenario 2.3 – Implementation of K-IV phase 1 with no revamping of KBFU and no allocation of water from link canal.

Keenjhar Lake

Based on the recorded levels data (Year 2016-2022), it is evident that the lake has reached its maximum level at 54.0 feet and has never fallen below 43.3 feet. The lake's operation involves two main filling periods each year: one at the end of the flood season in September and the other at the end of January. Lake's operation exhibits significant fluctuations in water levels data across different years. However, the trends of lake levels also advocate the corrected inflows where level variations coincide with the incoming flows. The historic average flow series of KBFU, KBFL, Lake Regulator and Lake Levels are presented in Graph ES1.

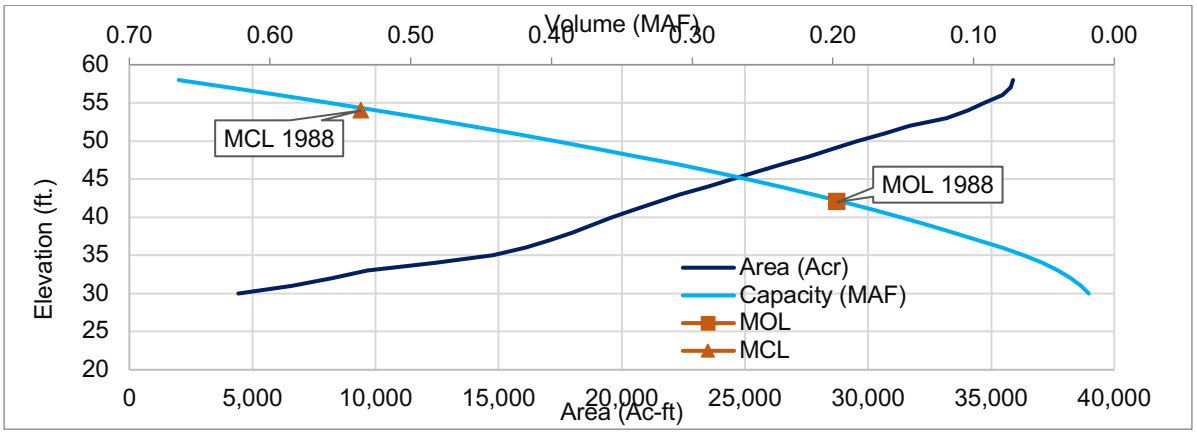


Graph ES1: Historic Flow Series of KBFU, KBFL and Lake Regulators

The gross storage capacity of the lake at maximum conservation level (MCL) i.e., RL 54.00ft is 0.52 MAF. Live storage capacity of the Lake between the maximum conservation level (MCL) and minimum operating level i.e., RL 42.00 is 0.33 MAF. It is observed that the lake has never been depleted below 43.3 ft. Levels data shows quite large variations in average daily levels (± 4 ft.) over the years.

This water balance at Lake's regulator RD concludes that out of 2.5 MAF flow volume received from KBFU, 1.49 MAF goes for irrigation whereas on average annual basis 1.01 MAF is fed into the lake or Karachi water supply.

The lake capacity has not been depleted appreciably over the years when compared for 1988 and 2017. The below graph shows that the capacity at MOL is 0.19 MAF.



Graph ES2: Elevation Area Capacity Curve (based on Survey 2017-18), source: NESPAK FS 2018

The consultant used the Landsat Imagery of the lake for those months when lake's maximum and minimum levels observed in the year 2018 and using NDWI technique of remote sensing, managed to delineate the lake area under water. Below figures and table shows the comparatively max. level observed on 29 November, 2018 (i.e., 52.6 ft.) and the min. level observed on 06 of June, 2018 (i.e., 46.3 ft.).

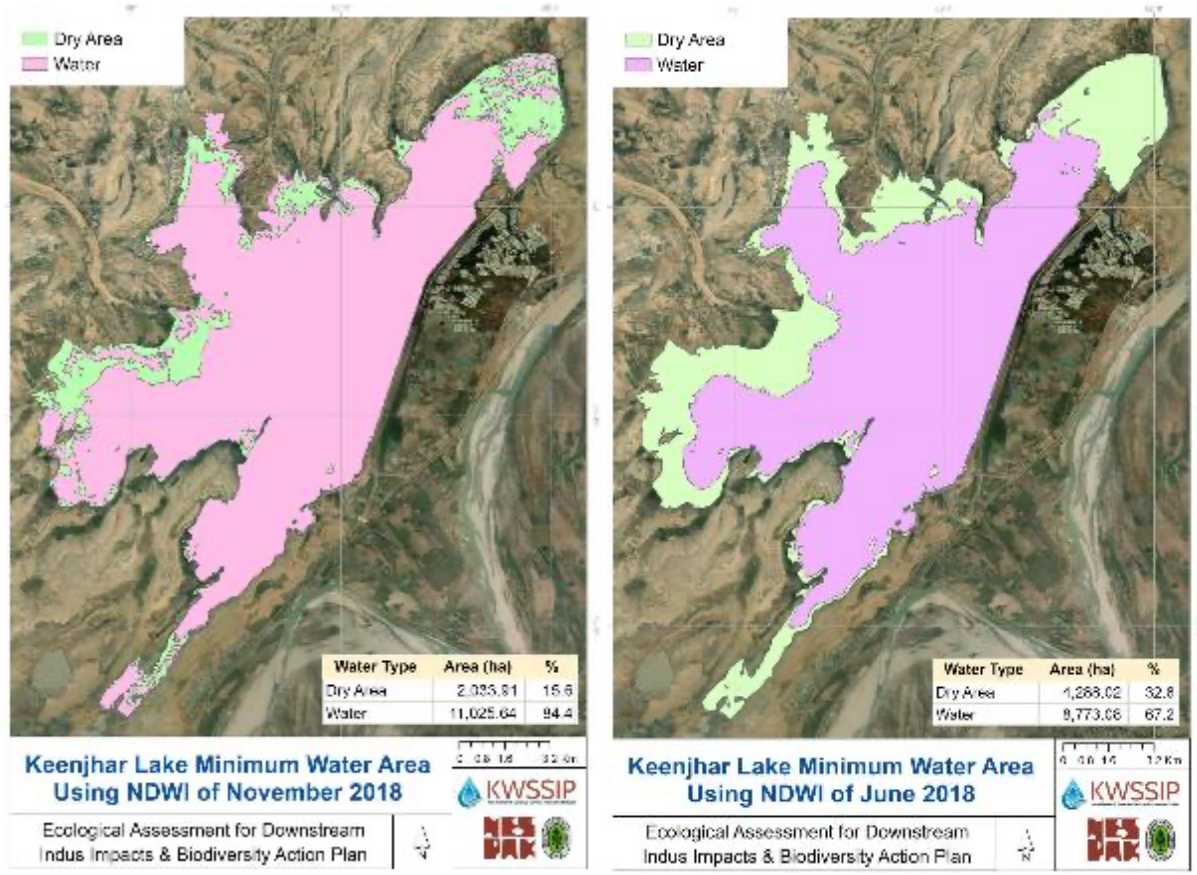


Figure ES2: Delineation of Keenjhar Lake water Area in (a) November 2018 and (b) June 2018, using NDWI

The difference of the area under water from maximum to minimum levels was **17.2%** and the area exposed at minimum levels was at the inlet and in the western boundaries, where the depth of the lake is lowest.

Table ES1: Estimation of dry and wet area of lake during max. and min water levels

November 2018		
Water Type	**Area (ha)**	**%**
Dry Area	2,033.91	15.6
Water	11,025.64	84.4
Total	**13059.55**	**100**
June 2018		
Water Type	**Area (ha)**	**%**
Dry Area	4,288.02	32.8
Water	8,773.08	67.2
Total	**13061.1**	

Over the period of time, Keenjhar lake is silted at the point of intake. Historically, the depth of the lake at the intake was 30-35 ft, which is now reduced to 7-8 ft due to siltation. Sindh Irrigation Department is working on the scheme to de-silt the lake and flushing of the silt. These types of interventions are needed for the lake replenishment. Deposition of silt per year, as per Fisheries Deptt. data is 4,335 acre-feet (14,650 m^3/day). If there is no desilting activity undertaken, taking the max. conservation level (MCL) of Lake i.e., 0.52 MAF at RL 54.0, the lake will be silted completely in 120 years.

The lake features an abundance of submerged, floating, and emergent aquatic plants, including *Potamogeton spp.*, *Phragmites spp.*, *Cyperus spp.*, *Nelumbo nucifera*, *Najas minor*, *Nymphaea spp.* and *Typha spp.* These offer fauna with both food and shelter. Numerous birds inhabit the dense Typha and Phragmites plants. The area surrounding the lake is teeming with semi-aquatic and terrestrial plant types.

Keenjhar Lake is an important breeding and wintering and staging area for a wide variety of terrestrial and migratory birds. About 65 species of waterfowl have been recorded. Since past many years, there is a decline in population of migratory birds. Urbanization and deforestation are major factor responsible for the decline of bird population both in abundance and diversity because most of the birds are sensitive to these changes (Mahboob et al., 2013).

Keenjhar Lake is rich in fish fauna. Current figures retrieved from Fisheries department show that the about 229 metric tons of fish has been caught in the 2021.

Several site surveys were undertaken at Keenjhar Lake. According to the findings of the surveys, the exposed areas are formed at the inlet and at the western boundaries of the lake. Regression of aquatic plants and succession of terrestrial invasive species were observed in those area. Also, human interference like cutting reeds and grazing cattle was also observed as the wetland is providing ecosystem services. The exposed areas or you can say the wet areas having shallow depth serve as breeding or overwintering habitats or migration stopover areas. This is also confirmed by the locals. These areas replenish their ecological character

when the lake filling starts in September / October months and will be ready for migration stopovers.

Command Area of KB Feeder

The cultivable command area of KB Feeder is 603,741 acres. The command area is comprising the whole district thatta including 4 talukas namely: - Ghorabari, Keti Bunder, Mirpur Sakro, and Thatta.

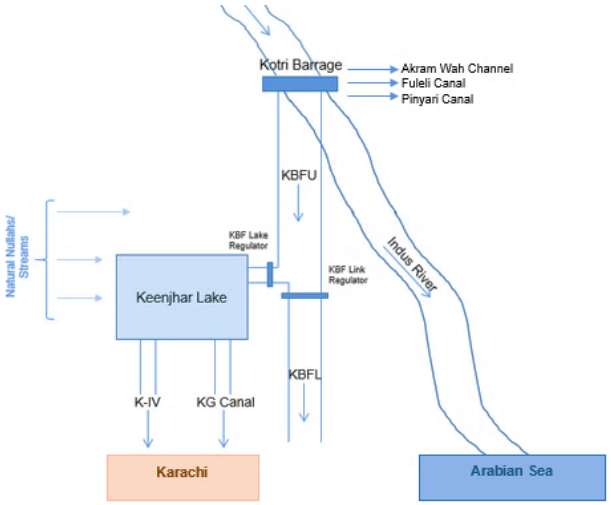
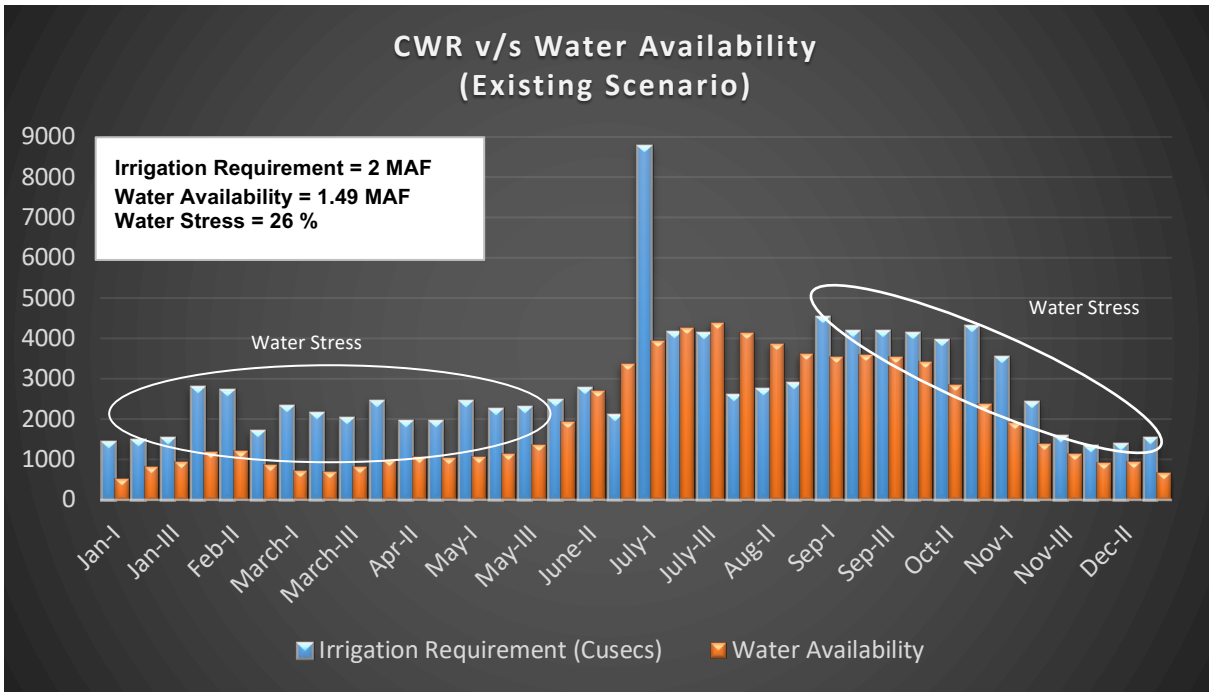


Figure ES3: Symbolic Line Diagram of KBFU and Keenjhar Lake System[2]

Kalri Baghar Feeder and its command area lies in Thatta districts, in addition to supplying water to Keenjhar lake for KW&SC and KB Feeder Lower (KBFL) command area. The canal command area lies on the right bank of the Indus River. At -2.4 RD the balance considered the flows coming from KBFU and its subsequent distribution to the flows going into the Lake and KBFL irrigation share. This water balance at -2.4 RD concludes that out of 2.5 MAF flow volume received from KBFU, 1.49 MAF goes for irrigation whereas on average annual basis 1.01 MAF is fed into the lake or Karachi water supply.

The cultivable command area of KB Feeder is 603,741 acres. The command area is comprising the whole district thatta including 4 talukas namely: - Ghorabari, Keti Bunder, Mirpur Sakro, and Thatta comprising 9 Talukas included 55 union councils. The historic operation of KBFU shows that it had never been operated at its design discharge during the last 20 year. Most of the lands of Project area are barren due to water logging, salinity and fish ponds. Some of the lands become waste land mainly due to non-availability of water because of mismanagement. The underground water in most of the area is highly brackish and unfit for cultivation. The rainfall is (200mm) insufficient, unpredictable and meager and it is not enough to meet the crop consumptive requirements. In Existing condition, there are already shortages and water stress in both rabi and kharif season and that's the reason beyond low yields in baseline or existing condition as shown in graph ES3.

[2] Water Balance and Cumulative Impact Assessment of the Proposed Increase in Abstraction at Keenjhar Lake for the K-IV Mainstream Project (2023), NESPAK.



Graph ES3: Crop water requirement v/s water availability for Exiting scenario

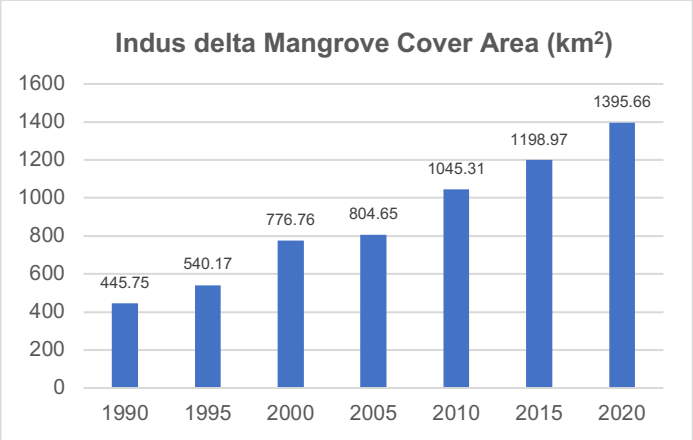
Due to hot weather and sporadic rainfall the flora cannot be expected to be very rich and diverse. Also, because of growing population and increasing agricultural activity, most of the natural vegetation in the district has been replaced by agricultural fields. Most of the plant species present in the site are cultivated. As a result of shift in land use from a previously uncultivated land to presently extensively cultivated area, the wildlife has noticeably absent. Due to human intervention, most of the endemic wildlife has either left or become locally extinct. The animals that are now found are common species that are highly adaptable and able to coexist with people. Cape hare, fox, Asiatic jackal and porcupine constitute the dominant wildlife species in the district. Cape hare is also sighted during the day which indicates that predators are not common in the area. The number and frequency of visits by other animals into the area is reported by the locals to have substantially reduced in recent period.

Indus Delta

This component of AoI encompasses an area of 667,209 ha of Indus Delta Region in the Thatta and Sujawal districts of Sindh Province in south-eastern Pakistan. The delta is a vast complex of tidal river channels and creeks, low-lying sandy islands, mangrove forests and inter-tidal areas[3].

[3] Project Document - Delta Blue Carbon – 1, March 2021 (https://deltabluecarbon.com/document/)

Indus delta is famous for its productivity, where mangroves have pivotal and contributory role in its making. Indus delta for its health continuity greatly depends on Indus downstream flow. A group of GIS experts were engaged in analyzing the growth trend of vegetation in Indus delta, their focus was more on temporal changes, and the results were quite surprising, 3.13 times increase during the last 30 years (Gillani, H. 2021).



Graph ES4: The quantitative increase in mangrove cover over the last 30 years

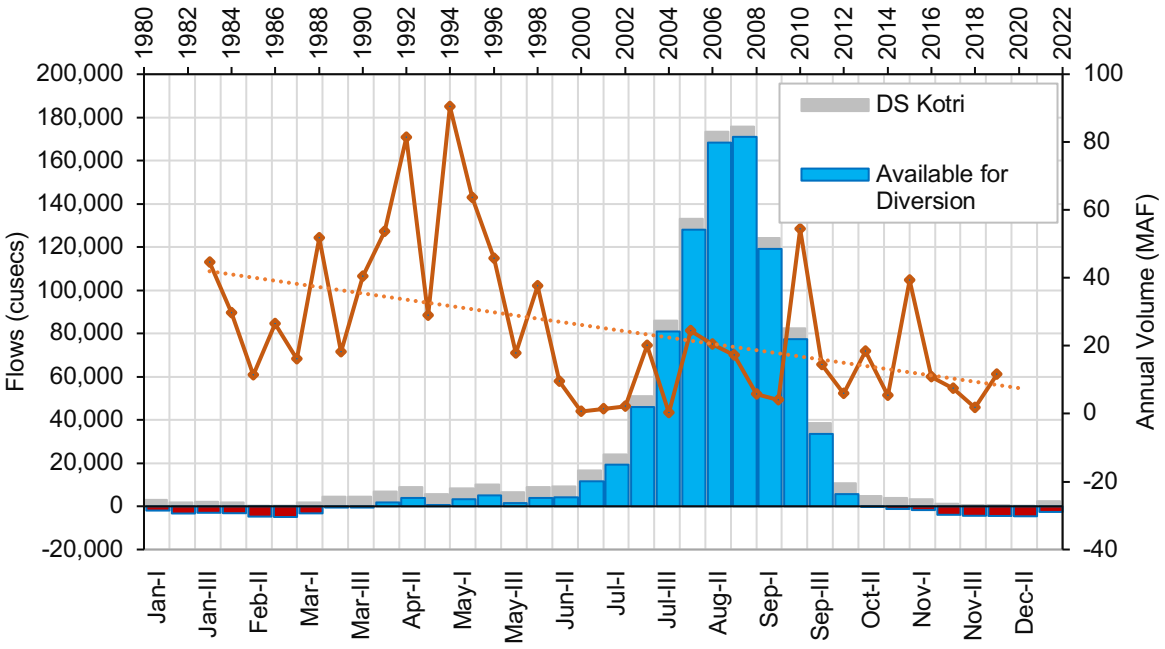
The growth of mangrove showed consistent incremental variation, whereas the downstream discharge represents a non-uniform pattern, the increase of one variable does necessarily correspond to the increase in another variable. It is a fact that fresh water flow has an influence in easing the growth conditions, however, adoption of smart forestry techniques, there were substantial improvement, comparing situation before 1980, the degradation process has controlled. This is a managing situation and could bring much better if the desired e-flow level could be maintained. Considering the quantum of flow, the value does not seem to be significant and apparently supports zero residual impact.

Water availability at Kotri d/s (in addition to environmental flows) has been studied in Water Balance Study by NESPAK (2023), and the analyses of flows at Kotri barrage (Graph ES5) suggest that the water has always been plentiful during the summer flood period starting from July to September, with flows reducing during the recession towards end of the year with expected occasional small rise near April.

Historic data at Kotri shows that that plentiful amount of water is available with average annual volume of around 25 MAF. Whereas, the actual water requirement downstream Kotri is far leaser. As per recommendations of International Experts (IPOE)[4] in 2004; water flow of 5,000 cusecs throughout the year should be ensured below Kotri Barrage to minimize the impact of seawater intrusion and meet the environmental flow needs flora and fauna. Also, a total volume of 25 MAF in five years (equivalent to 5 MAF annually) be released below Kotri barrage as flood flows (Kharif period).

The monthly distribution of flows DS Kotri suggests the availability of ample flows meeting e-flows requirements from April-I to October-III. Whereas, during the remaining time the DS riparian suffers shortages of e-flows. The grey lines in bars in the below chart shows the total availability at Kotri DS, blue bars present water that is available for diversion after meeting e-flows requirements and red bars show the deficit in the e-flows i.e., the magnitude and time where e-flows requirements have not been met with.

[4] Fernando J Gonzalez, Dr. Bart Schultz, Thinus Basson (2005), Final Report of IPOE For Review Of Studies On Water Escapages Below Kotri Barrage



Graph ES5: Flows Availability at Upstream and Downstream of Kotri Barrage

Table below shows overall summary of all scenarios and their ecological impacts with concrete solutions.

Table ES1: Comparison of Scenarios with impacts

Main Considerations for Comparison	Scenario 1	Scenario 2.1	Scenario 2.2	Scenario 2.3
	Do Nothing	*Implementation of K-IV Phase 1 - Abstraction of additional 260 MGD (402 cusecs) so the cumulative abstraction = 650+260 = 910 MGD (1,408 cusecs)*		
	Baseline Scenario in which the water withdrawal is 650 MGD from Keenjhar Lake	*By managing additional water supply WITH KBFU Revamping*	*By allocating water from link canal through rotation of irrigation water WITHOUT KBFU Revamping*	*WITHOUT KBFU lining and no allocation of water from link canal*
Source of additional water	-	Savings from KBFU lining and upgrading to original design capacity	Link Canal through rotation	There will be no additional supply from KBFU or from Kotri Barrage
Hydrology of Keenjhar Lake	The lake shrinks from max to min. levels in terms of area is 17.2% in May to August. Beyond 42 ft. RL., the shrinkage of the lake through water abstraction is not possible due to inability of drainage structure to extract water.	The results of the operational scenario suggest to have positive impact on overall water management where not only K-IV water needs are fulfilled but surplus flows are also available for irrigation. Also, the reservoir levels in this scenario follows more or less that of historic trend which means to have minimal impact of lake environment.	Impact will be same as in scenario 1. In this case, since the abstractions of 260 MGD are balanced with additional inflows to the lake therefore the system remains in equilibrium.	The lake will retain its minimum area often and the areas exposed will become permanent.
Siltation in Keenjhar Lake	Deposition of silt per year, as per Fisheries Deptt. data is 4,335 acre-feet (14,650 m3/day).	Due to the revamping of KBFU and due to 74.25% additional water (Existing flows and additional flows in case of revamping are 1.01 and 0.75 MAF/year, respectively) is flowing inside the lake, additional silt from River through KB feeder will	Siltation will not be an issue as compared with scenario 2.1, since lining of KBFU is not considered with this scenario.	Exposed areas subject to sunlight and wind, become prone to erosion and during flood season, when the lake is filled, these loose sediments tend to go into the water and add more sediment. The magnitude of

Main Considerations for Comparison	Scenario 1	Scenario 2.1	Scenario 2.2	Scenario 2.3
	Do Nothing	*Implementation of K-IV Phase 1 - Abstraction of additional 260 MGD (402 cusecs) so the cumulative abstraction = 650+260 = 910 MGD (1,408 cusecs)*		
	Baseline Scenario in which the water withdrawal is 650 MGD from Keenjhar Lake	*By managing additional water supply WITH KBFU Revamping*	*By allocating water from link canal through rotation of irrigation water WITHOUT KBFU Revamping*	*WITHOUT KBFU lining and no allocation of water from link canal*
		enter into the lake and deposited near the inlet of the lake. If the figure of silt accumulation provided by fisheries department are taken, the life of the lake will be reduced from 120 years to 69 years.		these added sediments is low, however, noticeable.
Flora and Fauna of Keenjhar lake	The ecology of the lake is degrading. *Hydrilla verticillata* (Water thyme) was observed at the southern periphery and outlet points where the lake's water is quite clear and where the sunlight reaches the bottom. change occurred during past years from many natural and human factors including precipitation patterns, siltation, eutrophication, pollution, hunting of birds, over-exploitation of fish etc. causes the biological decline and decrease in the	Due to additional silt accumulation near the inlet and shallow areas, potential succession vs regression of terrestrial and aquatic flora is anticipated.	Impact will be same as in scenario 2.1	There will be a succession of terrestrial flora into the exposed areas will happen as well as human influence like levelling and making thatched houses after cutting reed beds. Some habitats of migratory birds located in the shallow areas at the inlet and along the northern periphery of the lake will be lost due to terrestrial succession.

Main Considerations for Comparison	Scenario 1	Scenario 2.1	Scenario 2.2	Scenario 2.3
	Do Nothing	*Implementation of K-IV Phase 1 - Abstraction of additional 260 MGD (402 cusecs) so the cumulative abstraction = 650+260 = 910 MGD (1,408 cusecs)*		
	Baseline Scenario in which the water withdrawal is 650 MGD from Keenjhar Lake	*By managing additional water supply WITH KBFU Revamping*	*By allocating water from link canal through rotation of irrigation water WITHOUT KBFU Revamping*	*WITHOUT KBFU lining and no allocation of water from link canal*
	population and biodiversity of flora and fauna.			
Keenjhar lake Water Quality	Lake's water was being contaminated, however, SEPA took action against the polluters and regulated the effluent streams at their source in response to the Chief Minister (CM) Sindh directions.	No deterioration of lake's water quality is anticipated in Scenario 1 since the water balance will be achieved due to addition of 580 cusecs of water through lining of KBFU as compared with 402 cusecs of additional abstraction due to K-IV phase 1	Impact will be same as in scenario 2.1	Since there will be less water flow into the system due to existing supply and more demand and shortage periods, the lakes flushing mechanism will be disturbed and water quality parameters will be disturbed like DO, BOD, turbidity, TDS etc.
Impact on KB Feeder Canal Command Area	-	Due to additional and ensured supplies in case of revamping of KBFU, the yield of crops in scenario 2.1 will significantly increase as compare to existing situation. Resultantly, significant tangible and intangible benefits would be accrued. The farmers would be able to find opportunities to cultivate more lands that will ultimately improve their economic and livelihood conditions. Also,	Additional 260 MGD is being extracted and pose serious level of deficit and drought conditions in the command area. The shortages or deficit increases and became severe and pose serious level of yield compromises and crop failure and resultantly already deprived farming community may face economic crises and food insecurities as farming is the major source of livelihood in the command area of KBFL.	-

Main Considerations for Comparison	Scenario 1	Scenario 2.1	Scenario 2.2	Scenario 2.3
	Do Nothing	*Implementation of K-IV Phase 1 - Abstraction of additional 260 MGD (402 cusecs) so the cumulative abstraction = 650+260 = 910 MGD (1,408 cusecs)*		
	Baseline Scenario in which the water withdrawal is 650 MGD from Keenjhar Lake	*By managing additional water supply WITH KBFU Revamping*	*By allocating water from link canal through rotation of irrigation water WITHOUT KBFU Revamping*	*WITHOUT KBFU lining and no allocation of water from link canal*
		the cultivable flora and irrigated plantations will get more water and thrive.	The flora associated with the agriculture activities will be reduced. The saline conditions will be enhanced for water stress areas and the salt tolerant vegetation species like *Prosopis juliflora* which is an invasive species may succeed over other native plants. The fauna associated to this flora may get impacted, however, these are resident species and most of the wildlife species are absent due to extensive farming activities. It is envisaged that irrigated plantations will get less water compared with the existing situation, and therefore, will result in stunted growth or area reduction due to water scarcity.	
E-flows	The water has always been plentiful during the summer flood period starting from July to September, with flows reducing during the	The magnitude and volume of diverted flows from Kotri due to this scenario is very small as compared to overall water availability at Kotri DS and	Impact will be same as in scenario 1 – existing conditions will prevail, as there will be no additional diversions from Kotri are occurred.	Impact will be same as in scenario 1 – existing conditions will prevail

Main Considerations for Comparison	Scenario 1	Scenario 2.1	Scenario 2.2	Scenario 2.3
	Do Nothing	*Implementation of K-IV Phase 1 - Abstraction of additional 260 MGD (402 cusecs) so the cumulative abstraction = 650+260 = 910 MGD (1,408 cusecs)*		
	Baseline Scenario in which the water withdrawal is 650 MGD from Keenjhar Lake	*By managing additional water supply WITH KBFU Revamping*	*By allocating water from link canal through rotation of irrigation water WITHOUT KBFU Revamping*	*WITHOUT KBFU lining and no allocation of water from link canal*
	recession towards end of the year with expected occasional small rise near April. Irrigation water demand at Kotri Barrage is far greater than Karachi's requirements, so the total water requirement at Kotri is very seasonal. Historic data at Kotri shows that that plentiful amount of water is available with average annual volume of around 25 MAF. Whereas, the actual water requirement downstream Kotri is far leaser.	also the provision has been made to respect the e-flows, the DS Kotri regime is expected to have little impact of these diversions. On the contrary, the mangroves growth shows a consistent incremental pattern due to REDD+ projects. Current measures as of scenario1 will be applied.		
Impact on Indus Delta	A decline in freshwater flows due to upstream activities. This increases the salinity level in the wetlands areas and leads to sea intrusion into different terrestrial areas including fertile crop lands in the nearby vicinities.	The fish fauna is acclimatized with the existing situation and adapt the sea intrusion into the creeks. Since the DS Kotri regime is expected to have little impact due to diversions, while respecting e-flow, the impact on flora	Impact will be same as in scenario 2.1	Impact will be same as in scenario 1 – existing conditions will prevail

Main Considerations for Comparison	Scenario 1	Scenario 2.1	Scenario 2.2	Scenario 2.3
	Do Nothing	*Implementation of K-IV Phase 1 - Abstraction of additional 260 MGD (402 cusecs) so the cumulative abstraction = 650+260 = 910 MGD (1,408 cusecs)*		
	Baseline Scenario in which the water withdrawal is 650 MGD from Keenjhar Lake	*By managing additional water supply WITH KBFU Revamping*	*By allocating water from link canal through rotation of irrigation water WITHOUT KBFU Revamping*	*WITHOUT KBFU lining and no allocation of water from link canal*
		and fauna of Indus Delta will be insignificant.		
Impact on Mangroves in Indus Delta	No impact - growth of mangrove showed consistent incremental variation, whereas the downstream discharge represents a non-uniform pattern.	No impact.	Impact will be same as in scenario 2.1	Impact will be same as in scenario 1 – existing conditions will prevail
Mitigation measures / offsets	As long as the lakes water flow due to filling and discharge is maintained, its wetland character is maintained. Irrigation and fisheries department also undertaken deweeding activity. Keenjhar lake restoration programme to be initiated as done in the past in collaboration with WWF and IUCN. Existing ARR plantation	A study / modelling exercise to be conducted to ascertain the actual rate of silt entering into the lake and the area affected by it. Baseline water and ecological survey of Keenjhar Lake. Regular water and ecological survey on Keenjhar Lake. Survey of indicator species of flora and fauna including species of high conservation value and migratory birds.	A study / modelling exercise to be conducted to ascertain the actual rate of silt entering into the lake and the area affected by it for this scenario.	-

Main Considerations for Comparison	Scenario 1	Scenario 2.1	Scenario 2.2	Scenario 2.3
	Do Nothing	*Implementation of K-IV Phase 1 - Abstraction of additional 260 MGD (402 cusecs) so the cumulative abstraction = 650+260 = 910 MGD (1,408 cusecs)*		
	Baseline Scenario in which the water withdrawal is 650 MGD from Keenjhar Lake	*By managing additional water supply WITH KBFU Revamping*	*By allocating water from link canal through rotation of irrigation water WITHOUT KBFU Revamping*	*WITHOUT KBFU lining and no allocation of water from link canal*
		Community driven lake clean up and small-scale restoration activities De-silting and sediment flushing projects to be approved under ADP or Public Private Partnership (PPP) and implemented.		
Preference of scenarios	Not preferred in case of proposed project	Most preferred scenario	Not preferred, there will be impact on CCA of KB Feeder	Not preferred as there will be substantial impact on the ecology of the lake due to the lake's minimum level will attain over extended months in a year.

This Keenjhar Lake Conservation Action Plan (KLCAP) is developed which presents the management framework and action plan for the project scenarios and other projects related to the abstraction of water from Keenjhar Lake via Korti barrage.

The KLCAP actions as proposed in the list below are identified from the above impact assessment exercise. Each action will be transformed into a programme / project to be executed by relevant stakeholders.

- **Baseline water and ecological survey on Keenjhar Lake**: 1) Conduct ecological surveys of indicator species including plants, mammals, reptiles, amphibians, fish and birds (including migratory birds) of conservation value (HCVs) as identified in the baseline section for Keenjhar Lake especially Water Spinach *Ipomoea aquatica*, Phragmites spp. *P. australis*, Water Thyme *Hydrilla verticillate* (discourage growth), Mesquite (discourage growth), *Prosobranchia* (indicator of DO), Fishing Cat, Indian Pangolin, Pallas's Fishing Eagle, Greater Spotted Eagle, Common Pochard, River Tern, Black-bellied Tern, Ferruginous Duck, Southern Grey Shrike, Indian Flap-shell Turtle, Oxus Cobra/Brown Cobra, Russel's Sand Boa, Indian Monitor lizard, Indian Spiny-tailed Lizard, Fauji Khagga, Butter catfish, Freshwater catfish, Mozambique tilapia and Munglee (*Ailia coila*). 2) Develop detailed ecological baseline maps of habitats of indicator species based on the ecological survey. 3) Monitoring of lake water level, lake area (wet and dry), water quality and mapping through field survey and mapping as well as remote sensing and GIS analysis.
- **Regular water and ecological monitoring of Keenjhar Lake** 1) Conduct annual ecological survey to measure the trend of indicator species, 2) regular monitoring and mapping of lake level, area, water quality
- **Monitoring of siltation and de-silting** and sediment flushing projects in Keenjhar Lake to be approved.
- **Community driven lake clean up and small-scale restoration activities and awareness raising** for conservation and sustainable use of Keenjhar Lake for water supply, biodiversity, livelihood and tourism.
- **Creation of Keenjhar Lake Conservation Action Committee** by concerned government authorities including Sindh Irrigation Department, Sindh Forest and Wildlife Department, KWSC, SEPA, Sindh Fishery Department, WWF, IUCN, local community leaders to regularly review and oversight the implementation status of the lake conservation action plan, and inform the future actions.
- **Promotion of Agroforestry** by planting of native tree species that will provide not only provide alternative sources of timber, fuelwood, fodder and income to the local communities but also provides foraging and roosting places of birds and other fauna around the Lake's periphery. The project may will use local and native species such as Acacia nilotica, Azadirachta indica, Salvadora persica, Ficus religiosa, Ficus benghalensis etc. 5,000 trees at minimum to be planted around the Lake.

The strategy to be adopted for management of protection under the KLCAP is outlined below.

- Putting in place a protection system with financing through GOS and/or under PPP mode to fill the gaps in the existing system
- Monitoring on a long-term basis by an independent Monitoring and Evaluation (M&E) Consultant

It is recommended that KWSSIP/KWSC shall engage an M&E Consultant on the basis of clearly defined criteria including their experience and resources, to ensure monitoring of the project's compliance with the KLCAP, and to document the net gain in biodiversity through surveys and secondary data, at least once every year starting from the inception of the project. The M&E Consultant's terms of reference will define a clear work plan, including monitoring indicators, reporting structures and timelines. The firm engaged for independent monitoring will report its findings directly to the PIU KWSSIP and then to KLCAP Committee.

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List of Acronyms

AIIB	Asian Infrastructure Investment Bank
AoI	Area of Interest
ANR	Assisted Natural Regeneration
ARR	Afforestation, reforestation and re-vegetation
AUDD	Avoided unplanned forest degradation and deforestation
CIW	Conservation of intact or partially degraded wetlands
CSO	Community Social Organization
cusecs	Cubic Feet Per Second
GOS	Government of Sindh
HCV	High Conservation Value
ILO	International Labor Organization
IUCN	International Union for Conservation of Nature
KBFU	Kalri Baghar Feeder Upper
KLCAP	Keenjhar Lake Conservation Action Plan
KWSC	Karachi Water & Sewerage Corporation
KWSSIP	Karachi Water and Sewerage Services Improvement Project
MAF	Million Acre Feet
MGD	Million Gallons Per Day
NCCP	National Climate Change Policy
NCS	National Conservation Strategy
NEP	National Environmental Policy
NDWI	Normalized Difference Water Index
NDVI	Normalized Difference Vegetation Index
NGO	Non-Governmental Organization
PIU	Project Implementation Unit KWSSIP
PPP	Public Private Partnership
REDD+	Reducing emissions from deforestation, forests degradation, sustainable forest management and enhancement of forest carbon stocks
RS	Remote Sensing
RWE	Restoration of wetland ecosystems
SEPA	Sindh Environmental Protection Agency
SFD	Sindh Forest Department
SID	Sindh Irrigation Department
SSDWQ	Sindh Standards for Drinking Water Quality
SWD	Sindh Wildlife Department
WB	the World Bank
WAA	Water Apportionment Accord
WWF	World Wildlife Fund

Chapter 1 Introduction

The Karachi Water and Sewerage Services Improvement Project (KWSSIP) is a joint development between the World Bank (WB) Group, the Asian Infrastructure Investment Bank (AIIB) and the Government of Sindh (in Pakistan), aimed at improving the access to safe water and sewerage services for the residents of Karachi, along with ameliorating the operational and financial performance of the Karachi Water & Sewerage Corporation (KWSC), all, over a spread of 12 years.

The Project Development Objective is to improve access to safe water services in the project area and to increase KWSC's financial and operational performance.

This project is conceived as part of a long-term program comprised of four Series of Projects 1 to 4 (SOP 1-4). The second project (SOP-2) is expected to scale-up investments, most notably by financing the Malir Basin wastewater collection and treatment facilities and K4 Augmentation and downstream works.

1.1. Background and Rationale for Undertaking Ecological Assessment

The Karachi Water and Sewerage Services Improvement Project (KWSSIP) is a joint development between the World Bank (WB) Group, the Asian Infrastructure Investment Bank (AIIB) and the Government of Sindh (in Pakistan), aimed at improving the access to safe water and sewerage services for the residents of Karachi, along with ameliorating the operational and financial performance of the Karachi Water & Sewerage Corporation (KWSC), all, over a spread of 12 years.

Currently, KWSC is withdrawing 650 MGD of water from Keenjhar Lake via Indus River. In addition, KWSC is planning to withdraw 260 MGD through the government financed associated bulk water scheme - K-IV mainstream Project Phase 1. So, the cumulative abstraction will be 910 MGD (1,408 cusecs) from Keenjhar Lake.

Under Component 2 of KWSSIP project, K-IV Augmentation subcomponent will connect the government-financed K-IV treatment plants to the network. Since, the water for K-IV augmentation project is abstracted from K-IV main lines, an ecological assessment is required to evaluate the cumulative impacts of abstraction of water from the sources i.e., Keenjhar Lake which is fed by River Indus.

This assessment is undertaken to evaluate the potential cumulative impacts on aquatic and terrestrial ecosystems of Keenjhar Lake and Indus River downstream Kotri (including coastal mangroves) due to the additional water supply supported under K-IV Phase 1 project.

The ecological assessment is supported by a recent Water Balance and Irrigation Impact Assessment study undertaken by NESPAK in September, 2023. The aim of balance study is to assess the cumulative impacts of water use in K-IV Phase I on system water balance, agriculture and other users along with proposing mitigation measures while providing the necessary data for an input for this ecological assessment.

1.2. Methodology of the Study

As per the TORs of the study, following are the methodological steps designed for the ecological assessment:

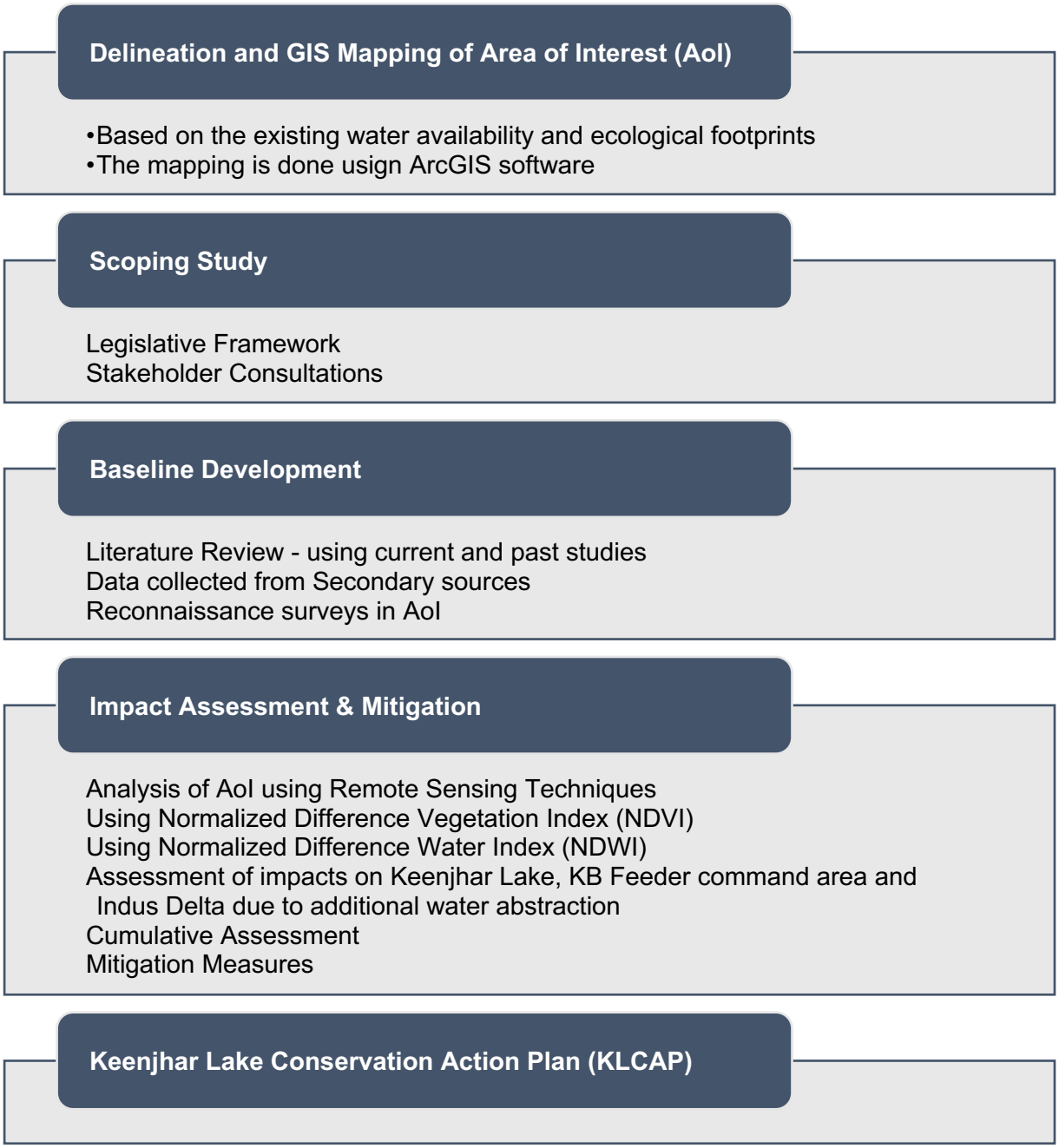


Figure 1-1: Methodological Steps of the Study

A thorough desk review with updating of available database was undertaken which was followed by mapping with the development of potential impact zones, with its representative interpretation, field sampling visits undertaken for in situ understanding of habitat and followed by spot check for biodiversity. The scoping exercise is the most essential part of the assessment as it has provided the existing legal, regulatory requirements and obligations

under international treaties, key issues as highlighted by the relevant stakeholders and impacts prevailing in the AoI as well as occurred during project operations.

1.2.1.1. Remote Sensing Techniques

Since the AoI is large enough to be assessed physically, remote sensing techniques are used in this study to compare the existing situation with the historic conditions. Especially, when the project is related to water and abstraction of water may cause water stress downstream of the water bodies under study, Normalized Difference Water Index (NDWI) has been used to ascertain the changes in the water pixel counts over certain time period. Also, the water is directly linked with the vegetation of the area of Interest (AoI), Normalized Difference Vegetation Index (NDWI) is also calculated.

Below is the detailed methodology of NDWI method:

Normalized Difference Water Index

The Normalized Difference Water Index (NDWI) is used to highlight open water features in a satellite image, allowing a water body to "stand out" against the soil and vegetation. The NDWI index was proposed by McFeeters in 1996. Its primary use today is to detect and monitor slight changes in water content of the water bodies. Taking advantage of the NIR (near-infrared) and GREEN (visible green) spectral bands, the NDWI is capable of enhancing the water bodies in a satellite image.

NDWI was calculated using the below formula:

$$NDWI = (Band\ 3 - Band\ 5) \div (Band\ 3 + Band\ 5)$$

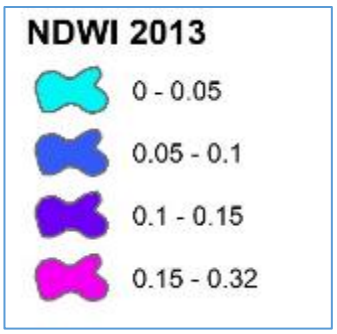
Note: The bands correspond to Landsat 8 imagery bands.

Interpretation of NDWI values:

- 0.2 – 1 – Water surface,
- 0.0 – 0.2 – Flooding, humidity,
- -0.3 – 0.0 – Moderate drought, non-aqueous surfaces,
- -1 – -0.3 – Drought, non-aqueous surfaces

Following were the classification of Water pixels based on the results and as shown below image:

- 0.0 – 0.05 – Humidity,
- 0.05 – 0.1 – Shallow water surface,
- 0.1 – 0.15 – Deep waters / stagnant waters
- 0.15 – max value – Turbid waters



The resultant imagery was reclassified to raster data and the pixels of water having values from 0 - +1, were counted to calculate the water pixel count. Since the resolution of each pixel of Ladsat 8 was 30x30 m, the area of each pixel was multiplied with the pixel area to get the total water area for each year.

1.2.2. Delineation of Area of Interest (AoI) and Influence Zones

The Area of Interest (AoI), for this study, is taken as Keenjhar Lake's boundary itself, Kalri Baghar Feeder (KB) Canal Command Area and Indus Delta (covering an area of approx. 350,000 ha). Some of the environmental components like climate including precipitation, water and vegetation indices are studied at regional level.

The AoI is divided in three distinct zones, defined below:

- The boundaries of the Keenjhar lake - in red.
- Kalri Baghar Feeder (KB) Canal Command Area - in light pink.
- The Indus Delta covering 350,000 ha – in black.

The assessment was done using primary data for Keenjhar Lake and Indus Delta through number of surveys, secondary data for KBF canal command area with the exception that the spot data using reconnaissance survey was collected for Mangroves plantation done for Sindh Forest Department (hereinafter referred to as "SFD").

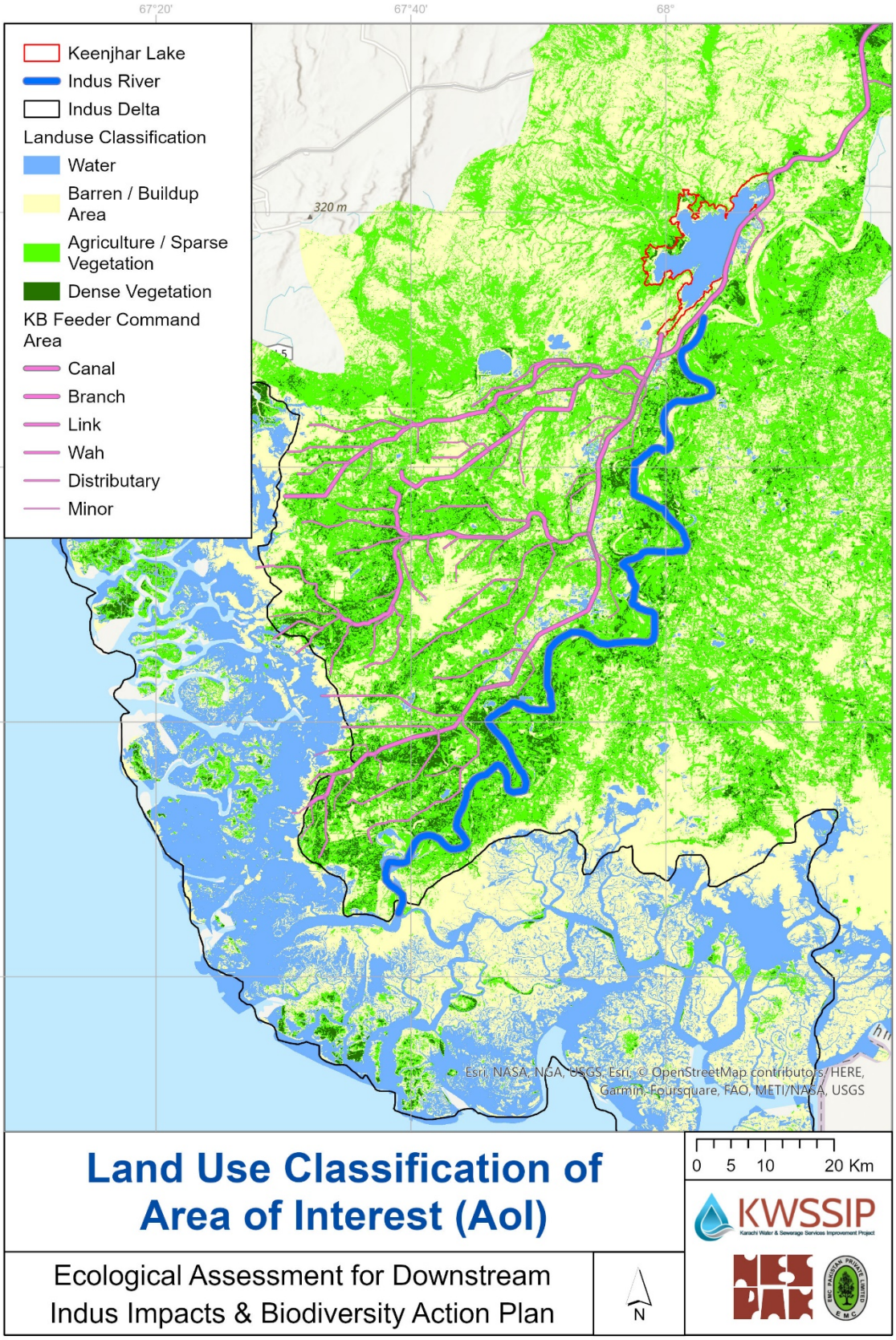


Figure 1-2: Area of Interest (AoI) with its land use classification

Chapter 2 Scoping Study

2.1. Legislative Framework

Pakistan has range of policies and laws related to the conservation of different components of biodiversity. In local context, Sindh Government has provided a legal cover for conservation of biodiversity in terms of provincial acts / ordinances which supersedes the national laws after 18th amendment. Pakistan is also ratified with some international treaties and conventions related to biodiversity. This section provides an overview of the policies, legislation, and international conventions requirements that have relevance to the ecological assessment of proposed project. All applicable regulatory requirements for the project are summarized in below table.

Table 2-1: Local applicable Policies and Legislations

Policy/Legislation	Summary	Relevance with the Study
Policy Requirements		
National Environmental Policy (NEP), 2005	The National Environmental Policy aims to protect, conserve and restore Pakistan's environment in order to improve the quality of life for the citizens through sustainable development.	The provisions of NEP are adhered in the study.
National Climate Change Policy (NCCP) 2021	NCCP broadly addresses all possible challenges of Climate Change adaptation and mitigation; and ensure to provide solid foundational framework for ensuing Climate Change Action Plans, Programs and Projects. NCCP identifies that the water security is one of the major survival concerns for Pakistan. Some of the policy measures suggested in the NCCP relevant to water security are: The need for additional water storage and distribution Infrastructure including dams and rehabilitation of existing irrigation infrastructure; Protect and preserve water catchment areas and reservoirs against degradation, silting and pollution through irrigation systems; Address sea water intrusion into the Indus Deltaic Region by allocating the essential water flow downstream Kotri.	NCCP suggests water security for population of Pakistan via development of additional water storage and distribution infrastructure, on the other hand, addresses the seawater intrusion impact by allocating adequate e-flow to downstream Kotri. **One of the** objectives of KWSSIP project is to improve and enhance the infrastructure of water conveyance system of Mega City Karachi. However, this study aims to assess the impacts of reduced flows on the ecosystem downstream Kotri due to additional water abstraction from Indus Rive from KWSSIP bulk water supply component and all phases of K-IV project.
Statutory Requirements		
The Sindh Wildlife Protection, Preservation,	This Act provides the protection, conservation, preservation, sustainable use of wildlife for establishment, management and	Keenjhar Lake was declared Wildlife Sanctuary in 1977

Policy/Legislation	Summary	Relevance with the Study
Conservation and Management Act, 2020 (Amended from Sindh Wildlife Protection Ordinance, 1972)	maintenance of protected areas in the Province of Sindh and to provide for matters connected therewith. The Act specifies classifications of the protected areas: national parks, wildlife sanctuaries and game reserves. Activities such as hunting, trapping wildlife, polluting / diverting resources, damaging infrastructure / cultural resources, cutting flora, cultivation, creating noise, quarrying / mining etc. is prohibited in protected areas.	under Sindh Wildlife Protection Ordinance, 1972. Some of the species declared as protected in the Act are reported in Keenjhar Lake microenvironment.
The Forest Act (Sindh Amendment) Act, 1994	The Act empowers the provincial forest departments to declare any forest area as reserved or protected. This Act prohibits the tree cutting in reserved and protected forest designated under the Act. Permission must be taken from the Sindh Forest department to execute the cutting of any tree. Section 1(1) of this Act mentions that illegal tree cutting is subjected to pose liability or punishment to the project owner.	A notification dated 15th February 2022 has been issued by Sindh Forest Department, under section 29 of the said Act, in which the 'intertidal land (Mangrove Areas) of Thatta and Sujawal is designated as protected. Indus deltaic plains and the trees itself are protected under the Act.
Sindh Fisheries Ordinance, 1980	This Act empowers the Government to lease or issue of licenses for fishing and fish trade. The Act empowers the fisheries departments to declare any waters to be a sanctuary for fish. This Act prohibits destruction of Fish habitat or aquatic life and discharge of factory waste or sewerage.	Since the assessment scope includes three water bodies i.e., Keenjhar Lake, Indus River downstream Kotri and Indus Deltaic plains, one of the ecological components which is strongly linked with local livelihood is Fishing. No such area located within AoI is declared as sanctuary for fish. Sindh Fisheries Department has issued licenses in public waters including Keenjhar Lake.
International Treaties and Conventions		
The Convention on Biological Diversity (CBD)	The convention has three main goals: the conservation of biological diversity (or biodiversity); the sustainable use of its components; and the fair and equitable sharing of benefits arising from genetic resources. The Government of Pakistan recognized the importance of these measures in the preparation of the National Conservation Strategy (1992) and in becoming a signatory	This document has been made in lines with the BAP Pakistan. For each component, the challenges pertinent to AoI are recognized, and a list of objectives and related measures to address the identified difficulties is proposed.

Policy/Legislation	Summary	Relevance with the Study
	to, and ratifying, the Convention on Biological Diversity (CBD) in 1994. A Keenjhar Lake Conservation Action Plan (KLCAP) was made which was the first attempt to meet the planning requirements of the Convention. This Keenjhar Lake Conservation Action Plan sets out a strategy for action under 13 main components which correspond to the Articles of the CBD	
Ramsar Convention on Wetlands, 1971	One of the obligations of signatories of the Ramsar Convention are, to designate wetlands for the List of Wetlands of International Importance; There are nineteen Ramsar sites in Pakistan.	Both Keenjhar Lake and Indus Delta are designated Ramsar Sites. The sites are of international importance and actions are undertaken and also proposed for conservation as well as sustainable use of their resources.
Convention on the Conservation of Migratory Species of Wild Animals	This convention aims to conserve migratory species within their migratory ranges. Indus Flyway is the famous International Migratory Bird Route Number 4, and in Sindh, it initiates from Guddu Barrage till Indus Delta. The migratory birds from Siberia followed this route till they reach the mudflats in the Indus Delta. The small Dhands (lakes) formed in the delta provide an excellent breeding and foraging grounds. In Keenjhar, the guest birds also visit each year in winter.	The study aims to provide a baseline for the migratory birds as well and provides the impact on the winter visitors due to project activities.
IUCN Red List of Threatened Species	Identification of threatened species as per the IUCN Red List defines the global conservation status of biological species. It uses a set of criteria to evaluate the extinction risk of thousands of species and subspecies.	Some of the species observed and reported in the AoI are listed in IUCN Red List.

2.2. Stakeholder Engagement

The perspective of stakeholders plays an important role in the ecological evaluation of the proposed project. A targeted stakeholder engagement approach was employed to determine the concerns and recommendations of all relevant stakeholders. The positive, negative or no impacts regarding various aspects of the bulk water supply option have been identified from the stakeholders' perspectives. Moreover, these findings have been analyzed in light of the environmental components of AoI as well as the objectives of the project. Based on the conclusions from the analysis of identified impacts, the consultation feedback concludes that stakeholders overwhelmingly support the water supply project; the positive aspects clearly outweigh the potential adverse impacts, however, also emphasize to reduce the degradation of important ecological areas including the Keenjhar Lake and Mangrove forests through mitigation measures.

Following officials of Government Departments and NGOs were consulted and their feedback was noted which has described briefly in below points:

Table 2-2: List of Stakeholders Consulted

S#	Name	Designation	Department / NGO
1.	Mr. Riaz Wagan	Chief Conservator of Forest, Sindh Mangroves and Rangelands	Sindh Forest Department, GOS
2.	Mr. Hyder Raza Khan	Project Director "Restoration of Riverine, Inland, Mangroves, Dry land & Urban Ecosystems of Sindh Province"	
3.	Mr. Mumtaz Soomro,	Deputy Conservator	Sindh Wildlife Department, GOS
4.	Mr. Habib Ur Rehman Narejo	Director Fisheries, Sindh Inland	Livestock & Fisheries Department, GOS
5.	Dr. Muhammad Hanif Chandio	Deputy Director Fisheries, Sindh Inland	
6.	Mr. Iqtedar Ahmed	Deputy Director Fisheries, Sindh Inland	
7.	Mr. Mr. Shakeel Qureshi	Deputy Project Director	KWSSIP
8.	Mr. Altaf Sheikh	Sr. Manger Conservation	WWF
9.	Mr. Danish Rashdi	Head of Karachi Office	IUCN
10.	Mr. Naveed Soomro	Coastal Habitats Expert	

2.2.1. Consultation with Sindh Forest Department

The bulk water supply option will abstract water from Keenjhar Lake and ultimately from Indus River. The Indus Delta comprises of Asia's largest arid mangrove forest which also enjoys the protected status by Sindh Forest Department (SFD). The Forest is dependent on the Indus fresh water as well as precipitation. Sindh Forest Department is the main custodian of the Riverine (Katcha) area and Indus Delta Mangrove Forests.

Figure 2-1: Consultation with SFD Officials

A targeted meeting with SFD official was undertaken on 16 June, 2022, in which the main features of the project were presented to the SFD officials and the concerns and recommendations of SFD on the proposed interventions of the project were noted.

The feedback from SFD is summarized in below points:

- In 2005, the international panel of experts recommended that 5,000 cusecs of water per day as an e-flow should be maintained.
- However, this recommendation of maintaining the e-flow is not being fulfilled.

- The mangroves in the delta are already under stress due to the reduced inflow of fresh water in the delta.
- Most of the e-flow is released by the Irrigation department during post monsoon flood season in which excessive water is available downstream. From that water, the mangroves regenerate and revive. For the rest of the months, the e-flow is almost negligible.
- There are 17 major creeks exist in the delta and only two creeks receive the fresh water from the river after reduction of flows due to construction of dams and barrages on Indus River since 1932. Rest of the creeks receive saline seawater due to tidal fluctuations. The delta has already lost its purpose.
- All mangrove forests and all mangrove lands in the delta area **extending over more than 667,000 hectares (ha)** have been declared as "Protected Forests" by 2010 under Section 29 of the Pakistan Forest 1927 and all trees there have been declared as reserved under Section 30.
- Due to the efforts of SFD, the mangrove forest cover has been increased from 600,000 ha to 667,000 ha. Mangroves cover has been increased due to Afforestation, reforestation and revegetation (ARR) activities done by SFD.
- By end of 2020, an area of some 75,000 hectares has been restored with mangrove plantations.
- All planting is done in partnership with local communities in the Project Zone, creating hundreds of jobs.
- The abstraction of water from Keenjhar Lake will have no impact on the mangroves and delta as the inflow of water from Indus River to Keenjhar lake is regulated through canals. The water allocated for Keenjhar is the irrigation water and has nothing to do with the e-flow.
- As stated earlier, the e-flow is already limited and is only available in significant quantities during the flooding season. The mangroves thrive on the precipitation as well as the negligible e-flow and regenerates post monsoon season.

2.2.2. Consultation with Sindh Wildlife Department

Keenjhar Lake was declared a wildlife sanctuary in 1977 as per Sindh Wildlife Protection Ordinance, 1972 (Currently revised to (Sindh Wildlife Protection, Preservation, Conservation and Management Act, 2020) by Sindh Wildlife Department (SWD) and a Ramsar Site in 1976. SWD is the main custodian of the wildlife sanctuary.

Figure 2-2: Consultation with SWD Official

A targeted meeting with SWD official was undertaken on 17 June, 2022, in which the main features of the project were presented to the Deputy Conservator and the concerns and recommendations on the proposed interventions of the project were noted.

The feedback from SWD is summarized in below points:

- Keenjhar lake should not be impacted due to abstraction of additional water. The outflow should be balanced with the inflow.
- Keenjhar lake was not only designated the “wildlife sanctuary” for the migratory birds but also important refuge for the resident birds and terrestrial wildlife which is dependent on the wetland.
- Keenjhar lake also provides ecosystem services to the locals. Fishing is also practiced in the lake.
- If siltation in the lake is increased due to additional water abstraction or inflow, it will impact the quality of the water and subsequently impact the ecology, flora and fauna.

2.2.3. Consultation with Proponent (PIU-KWSSIP)

A targeted meeting with Mr. Mr. Shakeel Qureshi, Deputy Project Director KWSSIP was undertaken on 17 June, 2022, to understand the water balance of Keenjhar lake before and during the operations of additional bulk water abstraction and all phases of K-IV.

Figure 2-3: Consultation with DPD KWSSIP

Mr. Shakeel said that the KB Feeder Canal is under capacity and currently not lined. The designed capacity of KB Feeder is 9,000 cusecs. However, the capacity is decreased over time due to

siltation. There is a project in the pipeline to be executed by the Government of Sindh for the lining of KB Feeder Canal.

2.2.4. Consultation with Directorate of Fisheries Sindh Inland Hyderabad, Livestock & Fisheries Department, Government of Sindh

The Lake provides several natural resources in which fishing is considerably important because most of the 50 villages nearby are either partially or fully dependent on the lake. Thus, around 35-40,000 people are dependent on the lake.

A targeted meeting with Director of Fisheries officials was undertaken on 20 June, 2022, in which the main features of the project were presented to the SFD officials and the concerns and recommendations of SFD on the proposed interventions of the project were noted.

Figure 2-4: Consultation with Directorate of Fisheries Sindh

The feedback from Directorate of Fisheries is summarized in below points:

- Due to the climate change impacts, drought is prevailing recently all over Sindh
- After 1999, there is no stability in the availability of fresh water for fishing grounds.
- In Badin Area (the lower riparian of Indus River), previously 2,000 fish farms were in operations and due to the shortage of fresh water, only 283 remain in operation.
- The natural breeding grounds of fresh water fisheries are also depleting due to water scarcity.
- Palla (*Tenualosa ilisha*) Fish, which is considered as one of the most delicious aquatic delights, found in Sindh province and usually caught in River Indus below Sukkur Barrage and Indus Delta. Indus Delta is the main breeding ground of Palla (*Tenualosa ilisha*) fish which is about to extinct due to the shrinkage of natural breeding grounds.
- The Sindh Fisheries Department is primarily concentrating on fish breeding and aquaculture as a result of this concerning situation. The fish catch from the lake was reduced significantly, however, due to stoking activity, it is now been restored.
- In Keenjhar Lake, the department has developed hatcheries to sustain the livelihood of local fishermen. Due to the increase in aqua-culture interventions, fish production has been increased from the declining conditions.
- There is no alternate source of income of fishermen community dwelling around the lake.
- World Bank funded project namely Accelerated Action Plan (AAP) is implemented and its objective is to stock the natural ponds and lakes through hatcheries.

- In Keenjhar and the downstream Indus, unsustainable fishing methods such the usage of illegal nets are used also, for which the department is taking action.
- Turbidity in the lake may have risen as a result of project activity and water withdrawal from Keenjhar Lake. Some fish species are harmed by this, whereas other fish species favor the conditions benefit as it provides a camouflage.
- As per the department, Rohu (*Labeo rohita*), Morakhi (*Cirrhinus mrigala*), Indian Carp (Local – Thela) (*Catla catla*), Dahi (*Labeo calbasu*), Tilapia, Gulfam, Catfishes (3-4 species) Sneakheads are usually found in the Lake.
- Nevertheless, the water supply for Karachi is utmost important as the city is the industrial hub as well as biggest city of Pakistan, so the conservation of biodiversity which is already degraded in the study area, should not be overruled over need of the water supply project, but sustainable measures to be adopted to protect, conserves, restore and offset the ecosystem.

2.2.5. Consultation with World Wildlife Fund (WWF)

WWF is extensively involved in conservation and rehabilitation of Keenjhar Lake under its wetland programme “Indus for All” and has a wetland center in the lake area. It also focuses on freshwater scarcity in the coastal areas of the Indus Delta. A targeted meeting with WWF was undertaken on 22 June, 2022, in which the main features of the project were presented and the concerns and recommendations of WWF on the proposed interventions of the project were noted.

Figure 2-5: Consultation with WWF

The feedback from WWF is summarized in below points:

- A small amount of industrial wastewater entering from Kotri Industrial Area has already degraded and contaminated Keenjhar Lake, a declared wildlife sanctuary. Abstraction will increase the concentration of contaminants, which will become considerable, if the quantity of water is lowered.
- Over the period of time, Keenjhar lake has been silted at the intake point. Historically, the depth of the lake at the intake was 30-35 ft, which is now reduced to 7-8 ft due to siltation. Sindh Irrigation Department is working on the scheme to de-silt the lake and flushing of the silt. These types of interventions are needed for the lake replenishment.
- The most significant feature of this region is fishing because it directly supports local subsistence. Due to abstraction of water from the Keenjhar, fishing resources downstream Kotri will be impacted. Therefore, water balance should be maintained.

- The same amount of water abstracted, should be discharged as e-flow downstream Kotri. The IRSA Water Accord 1991 should be revisited and followed in letter and spirit.
- To gather the most recent flow data downstream of Kotri, consulting with the Sindh Irrigation Department is crucial.

2.2.6. Consultation with International Union for Conservation of Nature (IUCN)

A targeted meeting with IUCN officials was undertaken on 24 June, 2022, in which the main features of the project were presented and the concerns and recommendations of IUCN on the proposed interventions of the project were noted.

Figure 2-6: Consultation with IUCN

Following officials of IUCN were present in the meeting:

- Mr. Danish Rashdi – Head of Karachi Office
- Mr. Naveed Soomro – Coastal Habitats Expert

The feedback from IUCN is summarized in below points:

- Seawater intrusion is prevalent in the Delta and will be pronounced if further reduction in the flow downstream delta;
- The downstream flow of the Indus results in the formation of small dhands (ponds), which serve as biodiversity hotspots for resident and migratory birds and are at risk of converting into saline wetlands due to seawater intrusion;
- Consistent e-flow is needed to ensure biodiversity in the area;
- Within last 7-8 years, mangrove ecosystem is sustaining and even thriving from its previous degraded state, due to the joint interventions of Forest department, IUCN and Pakistan Navy as well as due to recent heavy precipitation events;
- Costs should be associated with the e-flow losses and compensated to relevant authorities so that they may carry out redemptive measures in the Indus Delta to compensate for any biodiversity loss;
- Impact on fisheries and fish life in the area is greatly affected due to the reduction of fresh water flow in the downstream Indus, where the Fisherfolk community is forced to go into the deeper waters, depleting already diminishing fish populations;
- The *Avicenna marina* (one of the dominant mangrove specie) is thriving on precipitation and sustaining in the saline conditions; however, biodiversity should be maintained in the delta;

- Exotic species of plants and animals have been introduced in Keenjhar: e.g., Tilapia has been introduced in the lake, leading to an overall decline in the indigenous flora and fauna of the lake.
- The study should also focus on cost benefit analysis as the water supply to the Karachiites is very important and the basic need for the large population.

Chapter 3 Baseline Description

This section of the report covers the secondary as well as the data collected from the field for environmental and ecological baseline components of the AoI in detail.

As defined in section 1.3.2, the Area of Interest (AoI), for this study, is taken as Keenjhar Lake's boundary itself, KB Feeder command area and Indus Delta (covering an area of approx. 350,000 ha). The extent of cumulative effects of K-IV phase 1 is studies for AoI and environmental components like climate, hydrology, vegetation, water indices and their relationship with each other is studied regionally.

3.1. Climate

For the description of the meteorological and climatological profile of the AoI comprising two districts i.e., Thatta and Sujawal; the recent data, including the minimum and maximum temperature, precipitation, relative humidity wind speed and wind direction, is taken from the nearest Pakistan Meteorological Department's observatory located in Thatta City. Observations of climatological data are given in Table 3-1-6.

The maximum temperature remains high during May and June and annual maximum temperature ranges from 32.5°C to 33.5°C in Thatta. Minimum temperature usually fluctuates from 19.9°C to 21.4°C in Thatta.

Table 3-1: Mean Monthly Maximum Temperature (°C)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
MEAN MONTHLY MAXIMUM TEMPERATURE (MEAN DAILY MAXIMUM TEMPERATURE) (°C)													
2014	23.6	27.7	31.5	36.5	36.8	36.8	34.6	34.0	33.8	35.8	32.1	26.8	32.5
2015	24.9	28.7	31.7	36.1	36.9	37.8	34.2	32.6	34.5	35.7	31.2	27.0	32.6
2016	27.0	27.7	33.6	35.5	36.0	35.7	34.6	32.8	32.9	34.3	32.8	29.9	32.7
2017	23.7	29.3	33.2	36.6	36.9	37.1	33.4	33.8	33.9	36.9	31.6	26.4	32.7
2018	27.0	30.1	34.9	37.4	39.1	36.3	34.2	32.8	33.0	36.8	32.9	27.1	33.5
2019	25.4	26.1	31.4	36.5	36.9	37.7	35.3	32.8	35.5	35.4	30.1	25.0	32.3
2020	22.8	29.1	31.4	37.2	37.2	37.6	37.3	35.2	34.9	35.8	30.1	26.2	32.9
2021	24.8	30.7	34.7	37.9	37.7	36.6	34.8	32.8	35.5	34.3	32.2	25.8	33.1

Table 3-2: Mean Monthly Minimum Temperature (°C)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
MEAN MONTHLY MINIMUM TEMPERATURE (MEAN DAILY MINIMUM TEMPERATURE) (°C)													
2014	8.7	11.9	17.3	22.2	24.8	26.0	26.5	25.1	24.4	22.1	18.1	11.1	19.9
2015	10.4	14.6	16.7	22.9	25.4	26.8	26.1	24.8	23.7	22.7	16.8	10.5	20.1
2016	12.2	13.0	19.1	21.5	25.1	25.8	25.9	24.5	23.4	22.2	17.7	15.5	20.5
2017	11.5	14.2	19.1	22.9	26.5	28.0	26.2	25.7	24.9	23.6	17.0	11.9	21.0
2018	11.7	15.4	19.8	23.1	25.9	27.1	26.6	25.1	24.0	22.5	18.8	12.9	21.1
2019	11.9	13.4	18.5	23.4	26.0	27.8	27.5	25.9	27.0	24.2	18.4	12.5	21.4
2020	10.0	14.4	18.4	23.8	26.6	28.7	28.4	27.7	26.9	23.9	16.3	11.9	21.4
2021	8.6	14.9	20.5	23.9	27.1	27.9	27.3	25.8	26.0	23.0	17.8	12.1	21.2

Trend of annual precipitation in Thatta from 2014-2021 is shown below. 2014 and 2018 are considered as dry years in which low rainfall were recorded as compared to last 8 years. Mean annual precipitation is significantly declined from 2015 and only about 32.6mm of mean annual precipitation received by Thatta district in 2018. However, since last 3 years, significant rainfall is recorded in Thatta District with the highest of 539.0 mm - mean annual precipitation. July is characterized with highest mean monthly precipitation amount.

Table 3-3: Monthly Amount of Precipitation (mm)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
MONTHLY AMOUNT OF PRECIPITATION (mm)													
2014	0.0	0.0	0.0	0.0	0.0	0.0	7.0	13.9	8.8	0.0	10.1	0.0	39.8
2015	0.0	0.0	3.8	0.0	15.8	10.7	93.6	0.0	41.0	0.0	0.0	0.0	164.9
2016	0.0	0.0	0.0	0.0	0.0	6.3	1.2	123.8	0.0	0.0	0.0	0.0	131.3
2017	2.8	TRACE	0.0	0.0	0.0	48.4	79.8	85.3	15.0	0.0	0.0	0.0	231.3
2018	0.0	0.0	0.0	0.0	0.0	24.7	5.9	2.0	0.0	0.0	0.0	0.0	32.6
2019	8.0	1.3	7.0	0.0	0.0	0.0	192.2	267.8	40.7	0.0	18.0	4.0	539.0
2020	0.0	TRACE	0.0	0.0	0.0	0.0	47.1	261.8	25.0	0.0	0.0	0.0	333.9
2021	0.0	0.0	0.0	0.0	0.0	0.0	66.0	0.0	120.0	9.0	0.0	13.0	208.0

Relative humidity in Thatta normally ranges from 41.3% to 45.5% of relative humidity was observed during 2014-2021. Following are the monthly and annual observations of relative humidity in Thatta.

Table 3-4: Mean Monthly Relative Humidity at 1200 UTC (%)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
MEAN MONTHLY RELATIVE HUMIDITY (MEAN) AT 1200 UTC (%)													
2014	28.0	25.0	30.0	37.0	49.0	57.0	59.0	60.0	58.0	33.0	36.0	28.0	41.7
2015	37.0	38.0	31.0	41.0	53.0	51.0	66.0	65.0	53.0	41.0	30.0	26.0	44.3
2016	40.0	20.0	24.0	44.0	54.0	56.0	61.0	71.0	60.0	53.0	29.0	34.0	45.5
2017	36.0	25.0	29.0	35.0	50.0	55.0	68.0	65.0	60.0	38.0	28.0	26.0	42.9
2018	28.0	31.0	27.0	35.0	41.0	57.0	61.0	64.0	59.0	33.0	29.0	31.0	41.3
2019	34.1	32.1	29.5	37.3	45.4	51.0	60.5	70.9	63.1	41.1	41.2	33.9	45.0
2020	34.0	28.0	32.0	33.0	49.0	53.0	57.0	69.0	60.0	38.0	32.0	30.0	42.9
2021	29.8	30.4	33.4	34.6	45.4	54.5	63.8	62.4	66.2	43.9	27.5	34.1	43.8

Wind speed and direction in Thatta is listed below:

Table 3-5: Mean Monthly Wind Speed at 1200 UTC (Knots)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
MEAN MONTHLY WIND SPEED AT 1200 UTC (Knots)													
2014	0.3	3.3	3.4	0.5	0.7	0.8	0.7	0.6	0.7	3.1	2.5	2.0	1.6
2015	0.3	4.5	0.4	6.0	8.0	6.3	10.0	8.0	6.4	4.9	3.0	2.2	5.0
2016	3.1	3.1	5.0	7.5	10.5	8.9	9.8	7.5	10.0	5.0	2.4	2.5	6.3
2017	4.4	4.1	5.1	8.5	10.4	7.3	0.8	6.7	5.5	4.4	2.9	4.5	5.4
2018	0.3	0.3	4.9	0.6	0.8	7.9	8.1	7.3	7.3	3.3	2.7	2.9	3.9
2019	3.5	4.4	4.1	8.0	8.6	7.3	9.0	5.8	4.3	3.2	4.1	4.1	5.5
2020	3.9	2.6	4.8	6.4	7.7	6.6	5.5	5.0	4.4	2.7	2.8	2.6	4.6

2021	2.5	2.4	4.3	4.6	6.8	6.9	7.4	7.4	3.9	3.4	2.7	3.3	4.6

Table 3-6: Mean Monthly Wind Direction at 1200 UTC (Knots)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
MEAN MONTHLY WIND DIRECTION AT 1200 UTC													
2014	N45E	N27E	N45W	S32W	S46W	S45W	S65W	S42W	S60W	S27W	N11E	N60E	----
2015	N18E	N45W	S72W	S43W	S49W	S41W	S63W	S46W	S47W	S62W	N43E	N47E	----
2016	S45W	N60E	S41W	S60W	S34W	S45W	S70W	S76W	S68W	S56W	S45W	N3E	----
2017	N43E	N27E	S62W	S53W	S63W	S40W	S70W	S59W	S54W	S43W	N5E	N36E	----
2018	N53E	N55E	S76W	S56W	S65W	S40W	S52W	S54W	S56W	S41W	N21E	N51E	----
2019	N50E	N42E	S73W	S62W	S59W	S53W	S53W	S52W	S39W	S19E	N43E	N33E	----
2020	N30E	N34E	S70W	S56W	S65W	S57W	S67W	S63W	S47W	S45W	N37E	N45E	----
2021	N40E	S63W	S47W	S55W	S50W	S47W	S55W	S46W	S66W	S43W	N50E	N25E	----

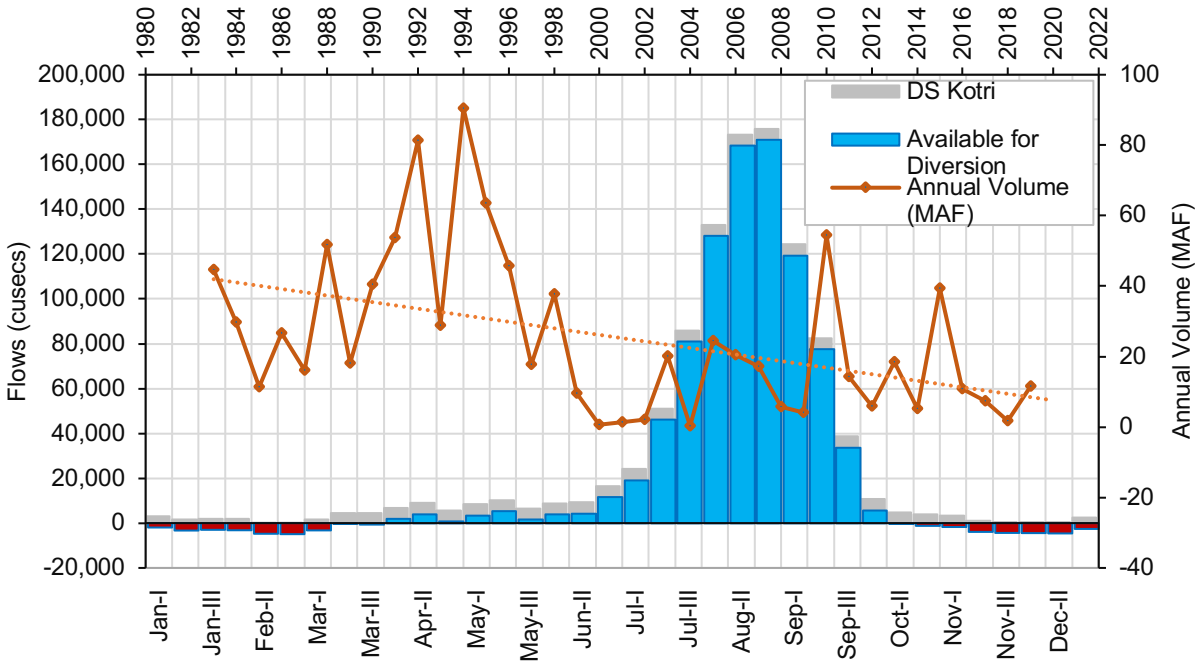
3.2. Hydrology of Indus River Downstream Kotri

The Kotri Barrage is the last control structure on the Indus, and the Indus empties into the Arabian Sea below Kotri. Water availability at Kotri d/s (in addition to environmental flows) has been studied in Water Balance Study by NESPAK (2023), and the analyses of flows at Kotri barrage (Graph 3-1) suggest that the water has always been plentiful during the summer flood period starting from July to September, with flows reducing during the recession towards end of the year with expected occasional small rise near April. Irrigation water demand at Kotri Barrage is far greater than Karachi's requirements, so the total water requirement at Kotri is very seasonal. Historic data at Kotri shows that that plentiful amount of water is available with average annual volume of around 25 MAF. Whereas, the actual water requirement downstream Kotri is far leaser. As per recommendations of International Experts (IPOE)[5] in 2004; water flow of 5,000 cusecs throughout the year should be ensured below Kotri Barrage to minimize the impact of seawater intrusion and meet the environmental flow needs flora and fauna. Also, a total volume of 25 MAF in five years (equivalent to 5 MAF annually) be released below Kotri barrage as flood flows (Kharif period).

IUCN (2004a) has recommended an essential release of 27 MAF per year for the continued well-being of the deltaic ecosystem. Another recommendation, although not scientifically robust, widely accepted or implemented, has suggested a continuous environmental flow below Kotri Barrage of 0.35 MAF per day (5,000 cubic meters per second)[6].

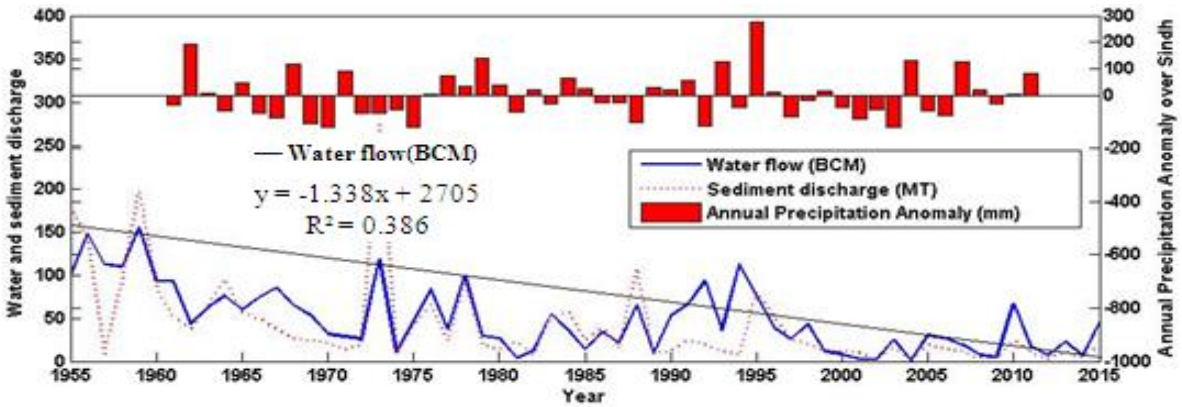
The monthly distribution of flows DS Kotri suggests the availability of ample flows meeting e-flows requirements from April-I to October-III. Whereas, during the remaining time the DS riparian suffers shortages of e-flows. The grey lines in bars in the below chart shows the total availability at Kotri DS, blue bars present water that is available for diversion after meeting e-flows requirements and red bars show the deficit in the e-flows i.e., the magnitude and time where e-flows requirements have not been met with.

[5] Fernando J Gonzalez, Dr. Bart Schultz, Thinus Basson (2005), Final Report of IPOE For Review Of Studies On Water Escapages Below Kotri Barrage
[6] Young, William J., Arif Anwar, Tousif Bhatti, Edoardo Borgomeo, Stephen Davies, William R. Garthwaite III, E. Michael Gilmont, Christina Leb, Lucy Lytton, Ian Makin, and Basharat Saeed. 2019. "Pakistan: Getting More from Water." Water Security Diagnostic. World Bank, Washington, DC.



Graph 3-1: Flows Availability at Upstream and Downstream of Kotri Barrage

The decline in river flow is evident from Graph 3-2, which illustrates the water decline trend in post-dam conditions. The sediment load in the delta has also decreased. The region has been classified as arid because annual precipitation is less than 250 mm per year, and this amount of precipitation has occurred only once in the past 60 years. Due to a lack of freshwater in the river system, agricultural land in the Indus Delta declined dramatically from 1998 to 2018 (Mahar and Zaigham, 2019), from 116,928 to 48,787 acres.



Graph 3-2: Yearly water and sediment discharge below the Kotri Barrage and annual precipitation anomalies over Sindh showing flood and drought

3.3. Baseline Data of Keenjhar Lake

Keenjhar Lake is situated at 113 km from Karachi and about 20 km North and North – East of Thatta town between the longitude of 68 and 69° NE and latitude 24 and 25° N (see Fig 3.4). It is a freshwater lake having an area of about 145 km^2 (Anon 1999). The lake's maximum depth is 8 m. The desert surrounding Keenjhar Lake is comprised of alternating layers of sandstone and limestone. (Keenjhar Ecological Assessment- IFAP 2008).

Keenjhar represents a perennial water body, numerous studies were conducted to enlist its physical and biological attributes, some the major findings as discussed here.

Historically it is formed by the union of two Lakes, Sonehri and Keenjhar through the construction of an embankment on their eastern side in 1950s. Originally these lakes came into being when River Indus changed its course, cutting-off these lakes. Before the construction of embankment, the lakes were fed by a dozen hill torrents on the western side. Now it gets most of its water from Indus River through canal. With this background, Keenjhar may be regarded as semi natural lake.

The lake is fed by the Kalri Baghar Feeder Upper (KBFU) canal originating from Kotri Barrage that enters at the northwest corners, and by many small seasonal streams entering on the western and northern shores. The only outlet is through the Jam branch canal at the southeast corner of the Lake (Anon, 2006). The lake is known as the largest freshwater lake of the country and its main source is from Indus River, however, some proportion of water is contributed from the run off from the adjacent hills and torrents. The local villagers residing around the lake are using water for their daily consumption (Anon, 2006). Keenjhar Lake is the main source of water supply to Karachi and parts of Thatta district.

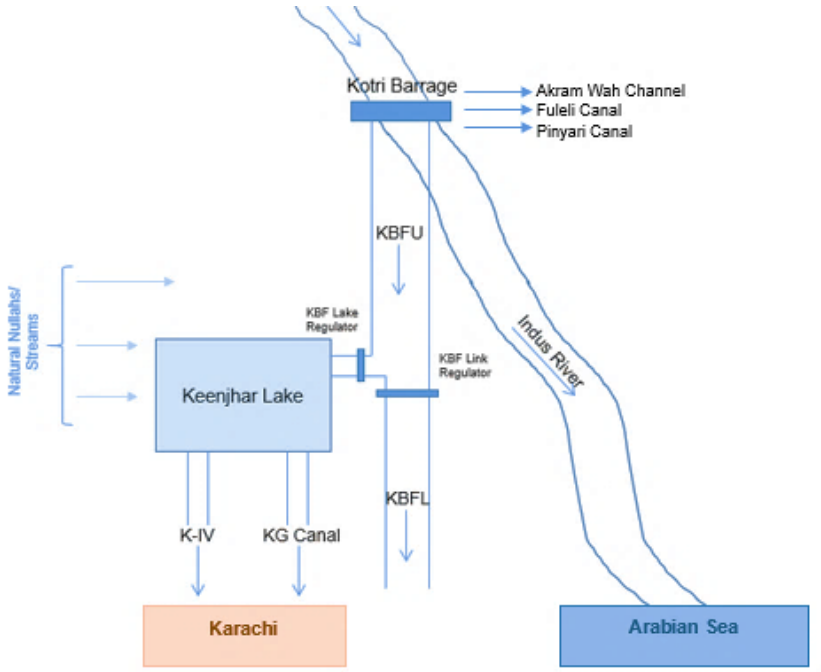


Figure 3-1: Symbolic Line Diagram of KBFU and Keenjhar Lake System[7]

Anon. (1999) reported that the lake's initial depth was around 18.5 m; however, subsequent siltation from Indus River has limited the lake's depth to 5-6.5 m.

[7] Water Balance and Cumulative Impact Assessment of the Proposed Increase in Abstraction at Keenjhar Lake for the K-IV Mainstream Project (2023), NESPAK.

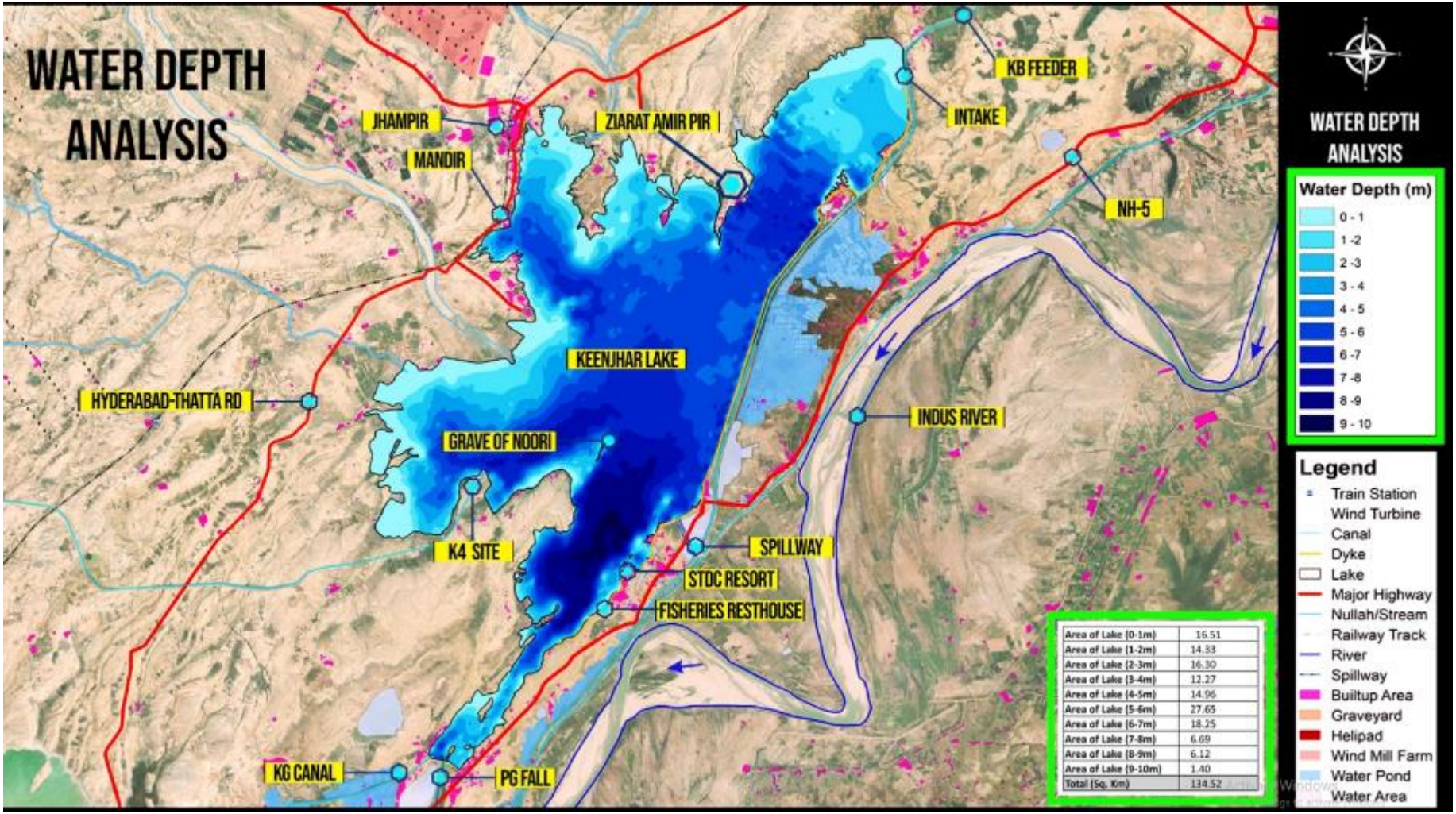


Figure 3-2: The bathymetric description of Keenjhar Lake and its surroundings (Source: Sindh Irrigation Department, GOS, study conducetd by NESPAK in 2015)

3.3.1. Current Hydrological Features of Keenjhar Lake

As per latest bathymetry by NESPAK 2015, the Lake is 32 km long, has surface area of 132 sq. km and live storage capacity of 0.339 MAF at present Maximum Conservation Level (MCL) of 16.45 m asl (54.00 ft)[8]. Presently, there are two outlet regulators on the lake; the PQ fall regulator (irrigation supplies to Thatta) and KG canal regulator (water supply to Karachi). The lake also receives runoff from catchment area of about 700 square miles. Salient hydrological data of the lake is presented below:

Table 3-7: Hydrological Data of Keenjhar Lake

Average Depth of water	**6.1 m**
Length of Embankments	19.3 km
Maximum Height of Embankments	9 m
Deposition of Silt per year	4335 Acre Feet
Original Design Life	132 years
Reduced Life after Silting	87 years
Life after Construction of Link Canal by passing Keenjhar Lake	192 years
Main water Supply Source	Kalri Baghar Feeder Upper
Outlet	Kalri Baghar Feeder Lower
Source: Directorate of Fisheries Sindh Inland Hyderabad, Livestock & Fisheries Department, GOS	

As mentioned in section 1.1, the aim of water balance study is to assess the cumulative impacts of water use in K-IV Phase I on system water balance, in addition, to calculate water balance of lake's operations for each scenario. Water balance has considered storage, inflows and outflows. KBFU is the only source of water to the Lake in addition to some occasional rainfall-runoff in summer season. Historic data indicates that spillway of the lake has never been operated. Outflows from the lake (KG canal and PQ fall) have been calculated from gauged data. Figure below shows the water balance of lake.

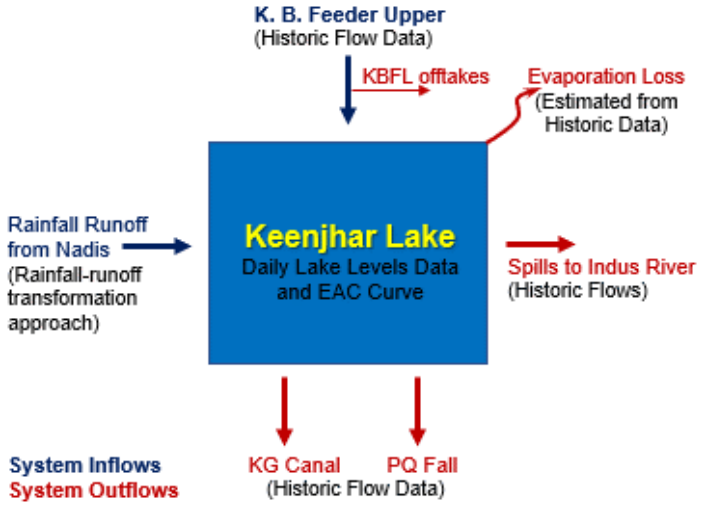


Figure 3-3: Water balance of Keenjhar Lake

[8] NESPAK (2015). "Feasibility Study of Present Network of Kalri Baghar Feeder and Keenjhar Lake and Suggesting Measures for Up-Gradation of the Same to Enhance Water Requirement from Keenjhar Lake to Karachi Water and Sewerage Board (KW&SB)"

Rainfall-Runoff into the Keenjhar Lake

The study area features arid climate where temperature is higher and rainfall is small. Mean annual rainfall magnitudes around 7 inches. There are some streams/ nullahs having drainage area of about 700 square miles and drain directly into the lake (Figure 3-4). The rainfall-runoff estimates suggest an average annual runoff contribution of 50,000 acre-ft. Major part of the runoff is received in the monsoon season whereas, the distribution over the years is quite erratic. Annual and monthly trends and flow duration analyses of rainfall-runoff potential are presented in Graphs 3-3 and 3-4. The trends suggest that the runoff potential across various years is highly unreliable as there will be no rainfall runoff in every 2 in 5 years.

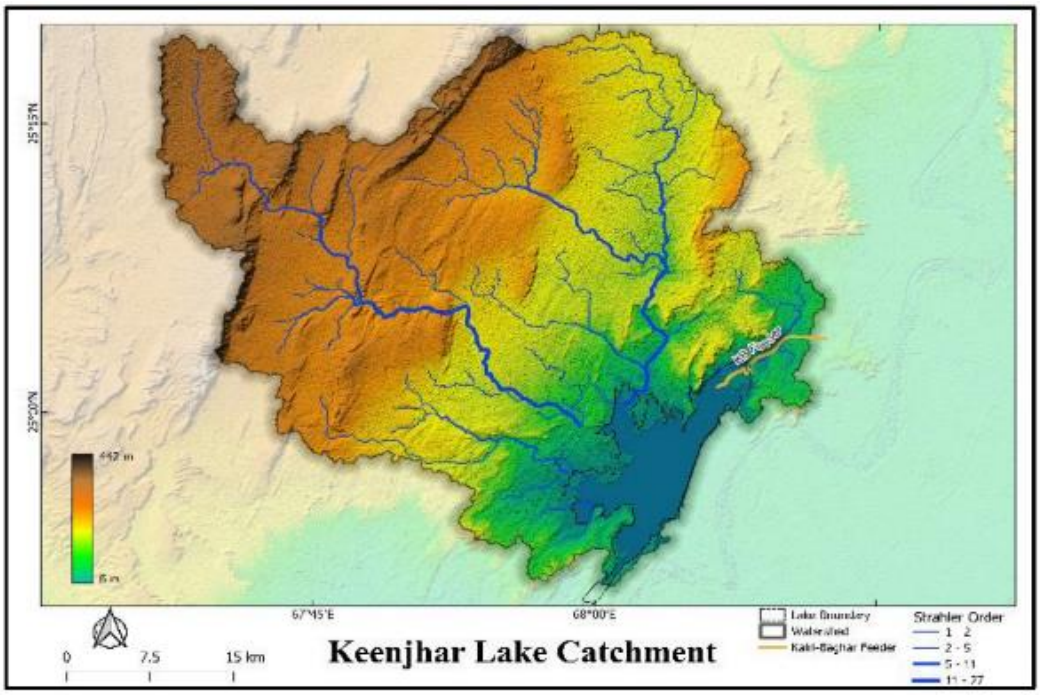
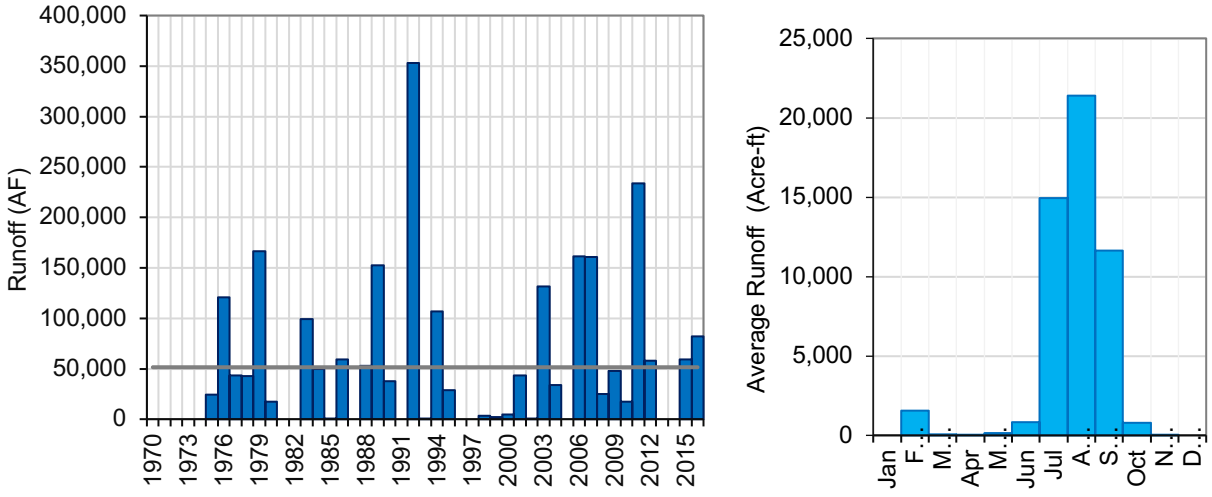
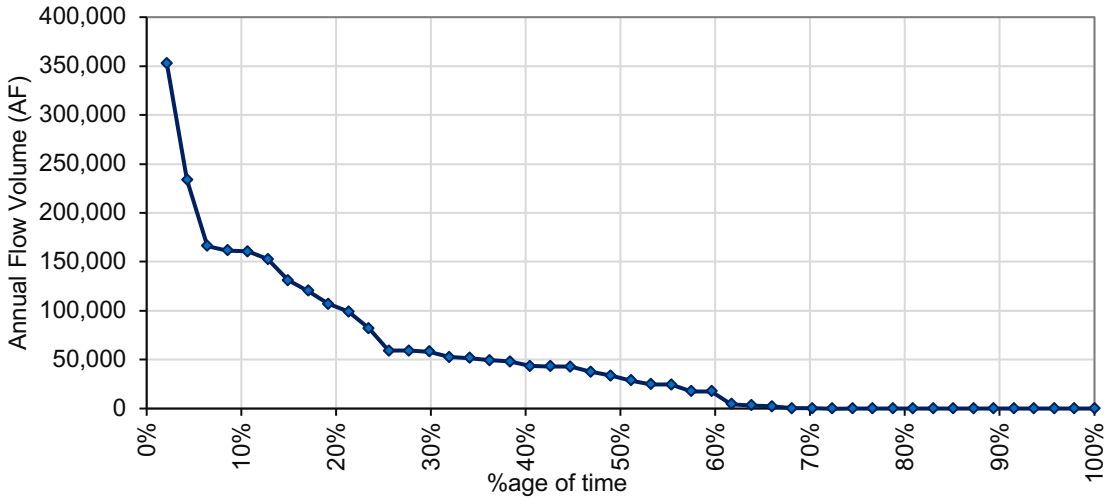


Figure 3-4: Catchment and Drainage Pattern of Water shed associated with the Lake



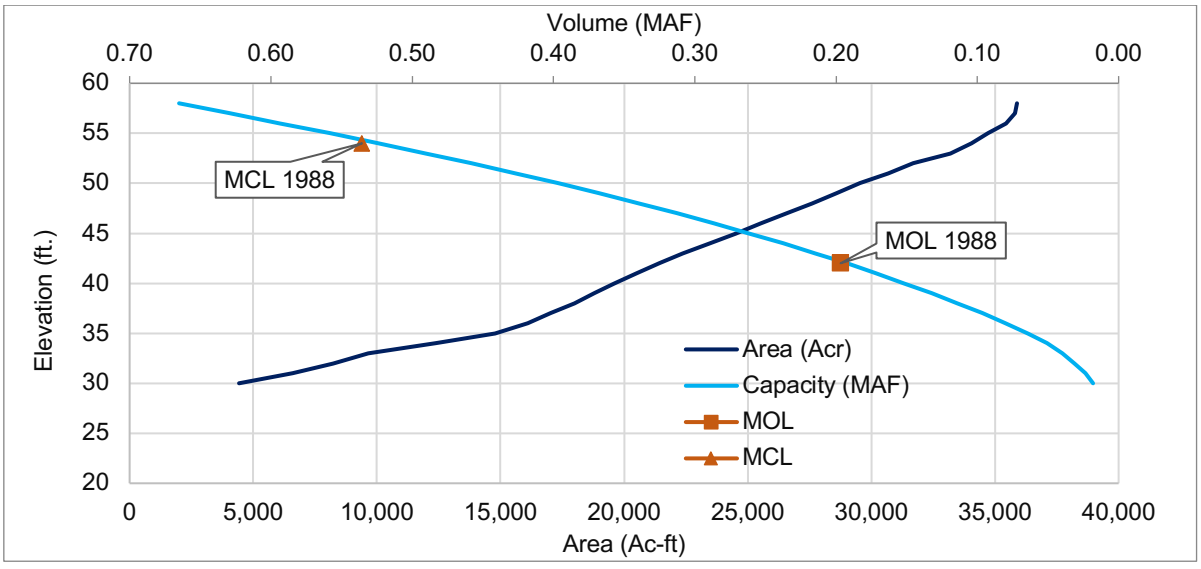
Graph 3-3: Annual and Monthly trends of rainfall-runoff



Graph 3-4: Flow duration analysis of rainfall runoff

Elevation Area Capacity Curve

- The gross storage capacity of the lake at maximum conservation level (MCL) i.e., RL 54.00ft is 0.52 MAF.
- Live storage capacity of the Lake between the maximum conservation level (MCL) and minimum operating level i.e., RL 42.00 is 0.33 MAF.
- It is observed that the lake has never been depleted below 43.3 ft. Levels data shows quite large variations in average daily levels (± 4 ft.) over the years.

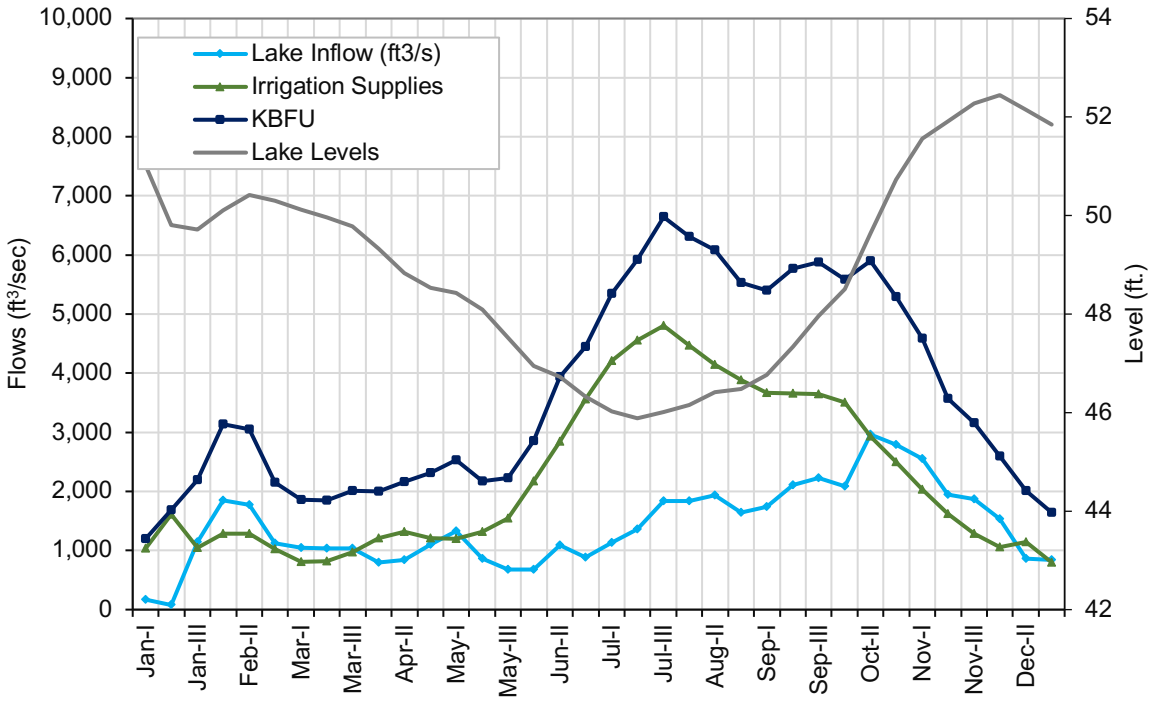


Graph 3-5: Elevation Area Capacity Curve (based on Survey 2017-18), source: NESPAK FS 2018

- The lake capacity has not been depleted appreciably over the years when compared for 1988 and 2017.
- The above graph shows that the capacity at MOL is 0.19 MAF.

Water Balance at Lake's Regulator

Based on the recorded levels data (Year 2016-2022), it is evident that the lake has reached its maximum level at 54.0 feet and has never fallen below 43.3 feet. The lake's operation involves two main filling periods each year: one at the end of the flood season in September and the other at the end of January. It's worth noting that the lake's operation exhibits significant fluctuations in water levels data across different years. However, the trends of lake levels also advocate the corrected inflows where level variations coincide with the incoming flows. The historic average flow series of KBFU, KBFL, Lake Regulator and Lake Levels are presented in Graph 3-8.



Graph 3-6: Historic Flow Series of KBFU, KBFL and Lake Regulators

This water balance at Lake's regulator RD concludes that out of 2.5 MAF flow volume received from KBFU, 1.49 MAF goes for irrigation whereas on average annual basis 1.01 MAF is fed into the lake or Karachi water supply.

The consultant used the Landsat Imagery of the lake for those months when lake's maximum and minimum levels observed in the year 2018 and using NDWI technique of remote sensing, managed to delineate the lake area under water. Below figures and table shows the comparatively max. level observed on 29 November, 2018 (i.e., 52.6 ft.) and the min. level observed on 06 of June, 2018 (i.e., 46.3 ft.).

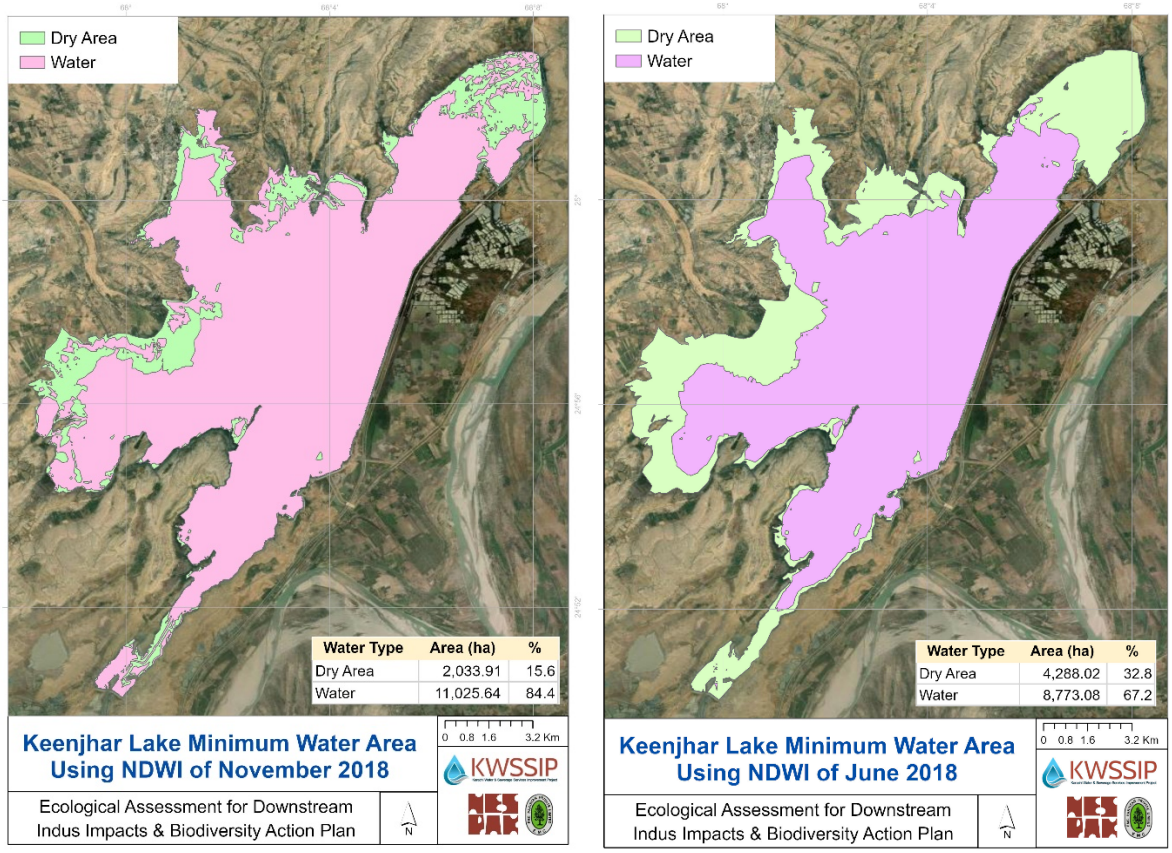


Figure 3-5: Delineation of Keenjhar Lake water Area in (a) November 2018 and (b) June 2018, using NDWI

The difference of the area under water from maximum to minimum levels was **17.2%** and the area exposed at minimum levels was at the inlet and in the western boundaries, where the depth of the lake is lowest.

Table 3-8: Estimation of dry and wet area of lake during max. and min water levels

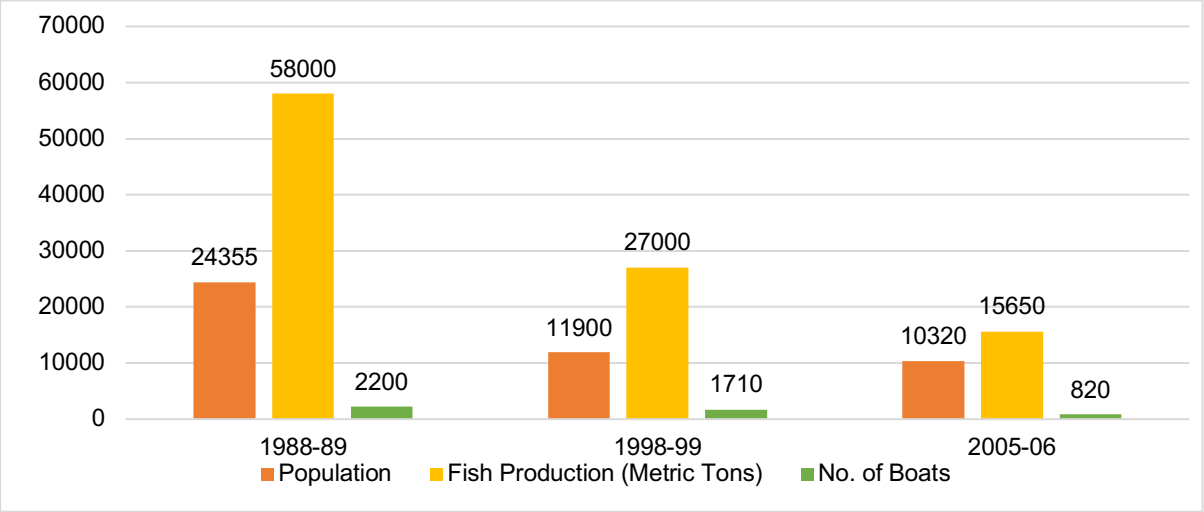
November 2018		
Water Type	**Area (ha)**	**%**
Dry Area	2,033.91	15.6
Water	11,025.64	84.4
Total	**13059.55**	**100**
June 2018		
Water Type	**Area (ha)**	**%**
Dry Area	4,288.02	32.8
Water	8,773.08	67.2
Total	**13061.1**	

A GIS based study had been conducted (Catherine, H. R. et al. 2021) to ascertain the vulnerability of the water body in terms of shrinkage in size. They also did classify the habitat using different algorithms and found hybrid one as more convenient and practical. The major outcome of this exercise was the resilient nature of this water body, that did not show any decline in the size of this wetlands even during the noticed drought period of 1998-2002.

3.3.2. Socioeconomic Parameters of Keenjhar Lake

The lake is surrounded by around 62 small and big villages that are under the jurisdiction of four Union Councils: Sonda, Oongar, Jhimpir, and Chatto Chan of Tehsil and District Thatta.

The important villages are Sonahri, Chill, Ghandri, Chakro, Moldi, Dolatpur, Chilliya, Khambo, and Hilllaya. Jhimpir town is likewise located on the lake's northwestern side. Prior to partition, it was bordered by around 40,000 fishermen residing in the aforementioned communities. Graph 3-4 demonstrates that with the building of the connection canal and the progressive depletion of water, the population of fishing settlements began to decline (Anon 2006).



Graph 3-7: Comparison of fishermen population and fish production (Source: Anon (2006))

The primary casts/tribes present are Shora, Palari, Gandara, Turk, Kapai, Hilaya, Katiyar, Khaskheli and Sarki etc. The primary occupations of the village are fishing and farming. Around the lake, members of the Palari, Shora, Hilaya, and Turk tribes are engaged in agriculture. On a large scale, pesticides are employed in agricultural areas. People graze their animals, including buffaloes, goats, cows, etc., in the buffer zone and surrounding the lake. Other fishing casts are usually referred to as Mirbahar. Permanent circular nets set in the lake called locally as "Gol Jaar" are also a sustainable fishing method.

Due to the reduction in fish catch, some individuals also mine stones from the neighboring rocky hills. Some villages also profit from local visitors from Karachi, Hyderabad, and Thatta who travel there for recreation. They have speedboats and charge between Rs. 1000 and Rs. 1500 a day, depending on the duration and distance. Due to the lack of safety equipment aboard these boats, several accidents have occurred in the past, resulting in numerous fatalities.

There, Sindh Tourism Development Corporation has established a Tourist Center with air-conditioned accommodations and a visitor facility. The facility has been constructed over a two-kilometer stretch on the lake's eastern shore, and cars and/or guests are charged an entrance fee. The Irrigation Department's facilities are modest and include a rest house. KWSC has its own system to regulate the lake's outlet on the south-western side. The Pakistan Army has also built a rest house on the lake's eastern shore. The Fisheries Department is also active in the region; it has a small facility on Keenjhar Lake and a major one in Chillya, which

is about 10 km away away. At Chillya, the Fisheries Department has training centre and a hostel along with fish hatchery.

Fish Landing Centers	**Chilya, Khambo, Hilya, Sonhari, Khudi, Jhimpir, Mouldi Doulatpur**
Boats In Keenjhar Lake	Wooden, Fibre Glass Boats, Row Boats and without Board Engine & Long Shaft Engine
Population	45,000 Souls Living around the Lake
Fishing Gears	1 Cast Net, 2 Dip Net, 3 Gill Net, 4 Drag Net, 5 Seine Net, 6 Trap Net (Pathra)
Main Commercial Fish Species: *Labeo rohita* (Rohu, Dumbhro, Kurriro), *Catla catla* (Thailhi), *Cirrihina mrigala* (Morakhi), *Cyprinus carpio* (Gulfam), *Notopterus chitala* (Gandan), *Cirrina reha* (Suhni), *Puntius chola* (Popri), *Mystus seenghala* (Seenghari), *Channa striatus* (Shakur), *Channa puntatus* (Mukkur), *Mastacembelus armatus* (Gouge), *Heteroneustus fossilis* (Luhar), *Ompok bimaculatus* (Fabino) *Wallago attu* (Mullee), *Tilapia mossambicus* (Dayo, Tilpo)	
Source: Directorate of Fisheries Sindh Inland Hyderabad, Livestock & Fisheries Department, GOS	

The Keenjhar (Kalri) Lake was declared as a Ramsar Site on July 23, 1976. It is located in the Thatta District of Sindh and covers 13,468 ha. According to local laws, it is also designated as a Wildlife Sanctuary. It is Pakistan's largest freshwater lake, with extensive reedbeds and abundant submerged and floating flora.

An internationally important area for breeding, staging and wintering waterbirds, supporting as many as 140,000 birds, including European Wigeon, Black Coot and Common Pochard. The lake is a major source of drinking water for Karachi and supports an important fishery[9].

3.3.3. Flora of Keenjhar Lake

The lake features an abundance of submerged, floating, and emergent aquatic plants, including *Potamogeton spp.*, *Phragmites spp.*, *Cyperus spp.*, *Nelumbo nucifera*, *Najas minor*, *Nymphaea spp.* and *Typha spp.* These offer fauna with both food and shelter. Numerous birds inhabit the dense Typha and Phragmites plants. The area surrounding the lake is teeming with semi-aquatic and terrestrial plant types.

Table 3-9: List of Flora of Keenjhar Lake[10]

S.#	Family	Plant species	Life form	Habit
1.	Acanthaceae	*Barleria acanthoides* Vahl	Phanerophyte	Shrub
2.	Acanthaceae	*Barleria hochstettri* Nees	Chamaephyte	Shrub
3.	Acanthaceae	*Barleria prionitis* L.	Phanerophyte	Shrub
4.	Acanthaceae	*Blepharis sindica* Stocks ex. T. Anders.	Therophyte	Herb
5.	Acanthaceae	*Ruellia patula* var. *alba* Saxton	Chamaephyte	Shrub
6.	Aizoaceae	*Trianthema portulacastrum* L.	Therophyte	Herb
7.	Aizoaceae	*Trianthema triquetra* Rottl. and Willd.	Therophyte	Herb
8.	Aizoaceae	*Zaleya pentandra* (L.) Jeffery.	Chamaephyte	Herb

[9] https://rsis.ramsar.org/ris/99
[10] Imran, Dr. Muhammad & G.Akbar, & Khatoon, Surayya & S.Islam, & Khan, Muhammad Zafar & N.Rizwan,. (2010). Floristic and phyto-sociological assessment of vegetation of Keenjhar Lake and Surrounding Area (Thatta, Sindh), Pakistan. International Journal of Biology and Biotechnology. 7. 147-158.

S.#	Family	Plant species	Life form	Habit
9.	Amaranthaceae	*Achyranthes aspera* L.	Chamaephyte	Subshrub
10.	Amaranthaceae	*Aerva javanica* (Burm.f.)Juss ex J.A. Schultes	Phanerophyte	Shrub
11.	Amaranthaceae	*Alternanthera sessilis* (L.) DC.	Chamaephyte	Herb
12.	Amaranthaceae	*Amaranthus graecizans* L.	Therophyte	Herb
13.	Amaranthaceae	*Amaranthus viridis* L.	Therophyte	Herb
14.	Amaranthaceae	*Digera muricata* (L.) Mart.	Therophyte	Herb
15.	Apocynaceae	*Rhazya stricta* Decne	Phanerophyte	Shrub
16.	Araceae	*Pistia stratioites* L.	Hydrophyte	Herb
17.	Arecaceae	*Nanorrhops ritcheana* (Griff.) Aitch.	Phanerophyte	Shrub
18.	Arecaceae	*Phoenix sylvestris* L.	Phanerophyte	Tree
19.	Aristolochiaceae	*Aristolochia bracteolata* Lamk.	Cryptophyte	Herb
20.	Asclepiadaceae	*Calotropis procera* (Ait.) Ait.f.	Phanerophyte	Shrub
21.	Asclepiadaceae	Caralluma edulis (Edgew.) Benth. & Hook.	Chamaephyte	Herb
22.	Asclepiadaceae	*Glossonema varians* (Stocks) Hook.f.	Chamaephyte	Herb
23.	Asclepiadaceae	*Leptadenia pyrotechnica* (Forsk.) Dcne.	Phanerophyte	Shrub
24.	Asclepiadaceae	*Oxystelma esculentum* (L.f) R.Br.	Cryptophyte	Climbing herb
25.	Asclepiadaceae	*Pentatropis nivalis* (J.F.Gmel.) Field & J.R.I.Wood	Chamaephyte	Climbing herb
26.	Asparagaceae	*Asparagus dumosus* Baker	Cryptophyte	Shrub
27.	Asteraceae	*Blumea obliqua* (L.) Druce	Chamaephyte	Herb
28.	Asteraceae	*Conyza aegyptiaca* Ait.	Camaephyte	Herb
29.	Asteraceae	*Echinops echinatus* Roxb.	Therophyte	Tall herb
30.	Asteraceae	*Eclipta prostrata* (L.) L.	Chamaephyte	Herb
31.	Asteraceae	*Grangea maderaspatana* (L.) Poir.	Therophyte	Herb
32.	Asteraceae	*Iphiona grantioides* Boiss	Chamaephyte	Subshrub
33.	Asteraceae	*Launaea procumbens* (Roxb.) Amin	Chamaephyte	Herb
34.	Asteraceae	*Launaea remotiflora (DC.) Stebbins*	Therophyte	Herb
35.	Asteraceae	*Pluchea arguta* Boiss.	Chamaephyte	Subshrub
36.	Asteraceae	*Pluchea wallichiana* DC	Phanerophyte	Shrub
37.	Asteraceae	*Pulicaria boissieri* Hook.f.	Chamaephyte	Herb
38.	Asteraceae	*Sonchus asper* Fig.	Therophyte	Herb
39.	Asteraceae	*Sonchus oleraceus* L.	Therophyte	Herb
40.	Asteraceae	*Vernonia cinerascens* Schultz. Bip.	Phanerophyte	Shrub
41.	Asteraceae	*Xanthium strumarium* L.	Phanerophyte	Shrub
42.	Avicenniaceae	*Avicennia marina* L.	Phanerophyte	Tree
43.	Boraginaceae	*Coldenia procumbens* L.	Chamaephyte	Herb
44.	Boraginaceae	*Cordia gharaf* (Forsk.) Ehren. ex Asch.	Phanerophyte	Tree
45.	Boraginaceae	*Heliotropium calcareum* Stocks	Chamaephyte	Subshrub
46.	Boraginaceae	*Heliotropium crispum* Desf.	Chamaephyte	Subshrub
47.	Boraginaceae	*Heliotropium curassavicum* L.	Chamaephyte	Herb
48.	Boraginaceae	*Heliotropium ophioglossum* Stocks ex Boiss.	Chamaephyte	Herb
49.	Boraginaceae	*Heliotropium ovalifolium* Forsk.	Chamaephyte	Herb
50.	Boraginaceae	*Heliotropium strigosum* Willd.	Chamaephyte	Herb
51.	Boraginaceae	*Sericostoma pauciflorum* Stocks ex Wight	Chamaephyte	Subshrub
52.	Boraginaceae	*Trichodesma indicum* (L.) R. Br.	Chamaephyte	Subshrub
53.	Brassicaceae	*Farsetia hamiltonii* Royle	Therophyte	Herb
S.#	Family	*Plant species*	Life form	Habit

S.#	Family	Plant species	Life form	Habit
54.	Burseraceae	*Commiphora stocksiana (Engler) Engler*	Phanerophyte	Large shrub – tree
55.	Burseraceae	*Commiphora wightii (Arn.) Bhandari*	Phanerophyte	Shrub – tree
56.	Caesalpiniaceae	*Senna holosericea (Fresen.) Greuter*	Chamaephyte	Subshrub
57.	Caesalpiniaceae	*Senna italica Mill.*	Chamaephyte	Subshrub
58.	Capparidaceae	*Cadaba fruticosa (L.) Druce*	Phanerophyte	Shrub
59.	Capparidaceae	*Capparis decidua (Forsk.) Edgew.*	Phanerophyte	Large Shrub
60.	Capparidaceae	*Capparis spinosa L.*	Phanerophyte	Subshrub
61.	Capparidaceae	*Cleome brachycarpa Vahl ex DC.*	Chamaephyte	Herb
62.	Capparidaceae	*Cleome scaposa DC.*	Therophyte	Herb
63.	Capparidaceae	*Cleome viscosa L.*	Therophyte	Herb
64.	Capparidaceae	*Gynandropsis gynandra (L.) Briq.*	Therophyte	Herb
65.	Capparidaceae	*Maerua arenaria (DC) Hook.f. & Thoms*	Phanerophyte	Shrub
66.	Caryophyllaceae	*Polycarpaea spicata Wight & Arn.*	Therophyte	Herb
67.	Caryophyllaceae	*Spergularia marina (L.) Griseb.*	Therophyte	Herb
68.	Chenopodiaceae	*Atriplex stocksii Boiss.*	Chamaephyte	Subshrub
69.	Chenopodiaceae	*Chenopodium album L.*	Therophyte	Herb
70.	Chenopodiaceae	*Chenopodium murale L.*	Therophyte	Herb
71.	Chenopodiaceae	*Haloxylon stocksii (Boiss.) Benth. & Hooker*	Phanerophyte	Shrub
72.	Chenopodiaceae	*Salsola imbricata Forsk.*	Phanerophyte	Shrub
73.	Chenopodiaceae	*Suaeda fruticosa Forsk. Ex J.F. Gmelin*	Phanerophyte	Shrub
74.	Convolvulaceae	*Convolvulus arvensis L.*	Chamaephyte	Twining herb
75.	Convolvulaceae	*Convolvulus glomeratus Choisy.*	Chamaephyte	Twining herb
76.	Convolvulaceae	*Convolvulus prostratus Forssk.*	Chamaephyte	Herb
77.	Convolvulaceae	*Convolvulus rhyniospermus Hochst. Ex Choisy*	Chamaephyte	Herb
78.	Convolvulaceae	*Convolvulus scindicus Boiss.*	Chamaephyte	Subshrub
79.	Convolvulaceae	*Cressa cretica L.*	Therophyte	Herb
80.	Convolvulaceae	*Ipomoea aquatica Forsk.*	Hydrophyte	Herb
81.	Convolvulaceae	*Ipomoea carnea Jacq.*	Phanerophyte	Large Shrub
82.	Convolvulaceae	*Ipomoea sindica Stapf*	Therophyte	Climber
83.	Convolvulaceae	*Merremia aegyptia (L.) Urban*	Therophyte	Climber
	Convolvulaceae	*Merremia hederacea (Burm.f.) Hall.f.*	Chamaephyte	Climber
84.	Convolvulaceae	*Seddera latifolia Hochst. & Steud.*	Chamaephyte	Subshrub
85.	Cucurbitaceae	*Citrullus colocynthis (L.) Schrad.*	Therophyte	Herb
86.	Cucurbitaceae	*Coccinia grandis (L.) Voigt*	Phanerophyte	Climber
87.	Cucurbitaceae	*Cucumis melo var. agrestis Naud.*	Therophyte	Climber
88.	Cucurbitaceae	*Cucumis prophetarum L.*	Chamaephyte	Climber
89.	Cucurbitaceae	*Luffa echinata Roxb.*	Chamaephyte	Climber
90.	Cucurbitaceae	*Mukia maderaspatana (L.) M.J.Roem.*	Chamaephyte	Climber
91.	Cyperaceae	*Bolboschoenus affinis (Roth.) Drobov*	Cryptophyte	Sedge
92.	Cyperaceae	*Bolboschoenus glaucus (L.) S.G. Smith*	Cryptophyte	Sedge
93.	Cyperaceae	*Cyperus alopecuroides Rottb.*	Cryphotphyte	Sedge
94.	Cyperaceae	*Cyperus articulatus L.*	Cryptophyte	Sedge

S.#	Family	Plant species	Life form	Habit
95.	Cyperaceae	*Cyperus exaltatus L.*	Cryptophyte	Sedge
96.	Cyperaceae	*Cyperus bulbosus Vahl.*	Cryptophyte	Sedge
97.	Cyperaceae	*Cyperus laevigatus L.*	Cryptophyte	Sedge
98.	Cyperaceae	*Cyperus longus L.*	Cryptophyte	Sedge
99.	Cyperaceae	*Cyperus pygmaeus Rottb.*	Hemicryptophyte	Sedge
100.	Cyperaceae	*Cyperus rotundus L.*	Cryptophyte	Sedge
101.	Cyperaceae	*Cyperus stoloniferus Retz.*	Cryptophyte	Sedge
102.	Cyperaceae	*Eleocharis geniculata (L.) Roem. & Schult.*	Hemicryptophyte	Sedge
103.	Cyperaceae	*Fimbristylis bisumbellata (Forssk.) Bubani*	Hemicryptophyte	Sedge
104.	Cyperaceae	*Pycreus dwarkensis (Sahni & Naithani) Hooper*	Hemicryptophyte	Sedge
105.	Cyperaceae	*Schoenoplectus litoralis subsp thermalis (Trabut) S.Hooper*	Crytophyte	Sedge
106.	Elatinaceae	*Bergia suffruticosa (Delile) Fenzl.*	Chaemaephyte	Subshrub
107.	Euphorbiaceae	*Euphorbia caducifolia Haines*	Phanerophyte	Large Shrub
108.	Euphorbiaceae	*Euphorbia clarkeana Hk.f.*	Therophyte	Herb
109.	Euphorbiaceae	*Euphorbia granulata Forsk.*	Therophyte	Herb
110.	Euphorbiaceae	*Euphorbia hirta L.*	Therophyte	Herb
111.	Euphorbiaceae	*Euphorbia serpens Kunth*	Therophyte	Herb
112.	Euphorbiaceae	*Phyllanthus maderaspatensis L.*	Therophyte	Herb
113.	Euphorbiaceae	*Phyllanthus reticulatus Poir.*	Phanerophyte	Shrub
114.	Fabaceae	*Alhagi maurorum Medic.*	Phanerophyte	Subshrub
115.	Fabaceae	*Alysicarpus ovalifolius (Schumach.) J. Leonard*	Therophyte	Herb
116.	Fabaceae	*Argyrolobium roseum (Camb.) Jaub. & Spach.*	Therophyte	Herb
117.	Fabaceae	*Crotalaria burhia Ham. Ex Bth.*	Phanerophyte	Subshrub
118.	Fabaceae	*Crotalaria medicaginea Lam.*	Therophyte	Herb
119.	Fabaceae	*Cyamopsis tetragonoloba (L.) Taub.*	Therophyte	Herb
120.	Fabaceae	*Indigofera argentea Burm.f.*	Chamaephyte	Herb
121.	Fabaceae	*Indigofera cordifolia Heyne ex Roth*	Therophyte	Herb
122.	Fabaceae	*Indigofera hochstetteri Baker*	Therophyte	Herb
123.	Fabaceae	*Indigofera linifolia (L.f.) Retz.*	Therophyte	Herb
124.	Fabaceae	*Indigofera oblongifolia Forsk.*	Phanerophyte	Shrub
125.	Fabaceae	*Rhynchosia minima (L.) DC.*	Chamaephyte	Climber
126.	Fabaceae	*Melilotus alba Desr.*	Therophyte	Herb
127.	Fabaceae	*Melilotus indica (L.) All.*	Therophyte	Herb
128.	Fabaceae	*Taverniera cuneifolia (Roth.) Arnott*	Phanerophyte	Subshrub
129.	Fabaceae	*Tephrosia purpurea (L.) Pers.*	Chamaephyte	Subshrub
130.	Fabaceae	*Tephrosia strigosa (Dalz.) Sant. & Mahcshw.*	Therophyte	Herb
131.	Fabaceae	*Trifolium alexandrianum L.*	Therophyte	Herb
132.	Fabaceae	*Trifolium fragiferum Linn*	Therophyte	Herb
133.	Fabaceae	*Vigna trilobata (L.) Verdc.*	Therophyte	Herb
S.#	Family	*Plant species*	Life form	Habit
134.	Gentianaeae	*Enicostemma hyssopifolium (Willd.) Verdoon*	Hemicryptophyte	Herb
135.	Hydrocharitaceae	*Hydrilla verticillata (L.f.) Royle*	Hydrophyte	Herb
136.	Illecebraceae	*Cometes surattensis L.*	Therophyte	Herb

S.#	Family	Plant species	Life form	Habit
137.	Lamiaceae	*Salvia santolinifolia Boiss.*	Chamaephyte	Subshrub
138.	Malvaceae	*Abutilon bidentatum A. Rich.*	Phanerophyte	Subshrub
139.	Malvaceae	*Abutilon fruticosum Guill.& Perr*	Phanerophyte	Subshrub
140.	Malvaceae	*Abutilon indicum (Linn.) Sweet*	Phanerophyte	Subshrub
141.	Malvaceae	*Abutilon muticum (Del.ex DC.) Sweet*	Phanerophyte	Subshrub
142.	Malvaceae	*Hibiscus micranthus L.f.*	Chamaephyte	Subshrub
143.	Malvaceae	*Hibiscus scindicus Stocks*	Chaemaephyte	Subshrub
144.	Malvaceae	*Pavonia Arabica Hochst. & Steud.*	Chamaephyte	Subshrub
145.	Malvaceae	*Senra incana Cav.*	Phanerophyte	Subshrub
146.	Malvaceae	*Sida ovata Forssk.*	Phanerophyte	Subshrub
147.	Mimosaceae	*Acacia nilotica (L.) Del. subsp. Indica (Benth.) Branan*	Phanerophyte	Tree
148.	Mimosaceae	*Acacia senegal (L.)Willd.*	Phanerophyte	Tree
149.	Mimosaceae	*Prosopis cineraria (Linn.) Druce.*	Phanerophyte	Tree
150.	Mimosaceae	*Prosopis glandulosa Torr.*	Phanerophyte	Large Shrub
151.	Mimosaceae	*Prosopis juliflora Swartz*	Phanerophyte	Large Shrub
152.	Molluginaceae	*Corbichonia decumbens (Forsk.) Exell*	Therophyte	Herb
153.	Molluginaceae	*Gisekia Pharnaceodies L.*	Therophyte	Herb
154.	Molluginaceae	*Glinus lotoides (L.) O.Kuntze.*	Chamaephyte	Herb
155.	Molluginaceae	*Limeum indicum Stocks ex. T. And.*	Chamaephyte	Herb
156.	Najadaceae	*Najas minor All.*	Hydrophyte	Herb
157.	Nelumbonaceae	*Nelumbo nucifera Gaertn.*	Hydorphyte	Herb
158.	Nyctaginaceae	*Boerhavia procumbens Banks ex Roxb.*	Cryptophyte	Herb
159.	Nyctaginaceae	*Commicarpus boissieri (Heimerl) Cufod.*	Phanerophyte	Herb
160.	Nymphaeaceae	*Nymphaea lotus Hook. f. & Thoms.*	Hydrophyte	Herb
161.	Plumbaginaceae	*Limonium stocksii (Boiss.) O.Kuntze*	Chamaephyte	Subshrub
162.	Poaceae	*Aeluropus lagopoides (L.) Trin. Ex Thw.*	Cryptophyte	Grass
163.	Poaceae	*Aristida adscensionis L.*	Therophyte	Grass
164.	Poaceae	*Aristida funiculata Trin. & Rupr.*	Therophyte	Grass
165.	Poaceae	*Aristida mutabilis Trin. & Rupr.*	Therophyte	Grass
166.	Poaceae	*Brachiaria ovalis (R. Br.) Stapf*	Therophyte	Grass
167.	Poaceae	*Brachiaria ramosa (L.) Stapf*	Therophyte	Grass
168.	Poaceae	*Brachiaria reptans (L.) Gardner & Hubbard*	Therophyte	Grass
169.	Poaceae	*Cenchrus ciliaris L.*	Hemicryptophyte	Grass
170.	Poaceae	*Cenchrus pennisetiformis Hochst. & Steud. ex Steud*	Hemicryptophyte	Grass
171.	Poaceae	*Cenchrus setigerus Vahl.*	Hemicryptophyte	Grass
172.	Poaceae	*Chloris barbata Sw.*	Haemicryptophyte	Grass
173.	Poaceae	*Chrysopogon aucheri (Boiss.) Stapf*	Hemicryptophyte	Grass
S.#	Family	*Plant species*	Life form	Habit
174.	Poaceae	*Cymbopogon jwarancusa (Jones) Schult.*	Hemicryptophyte	Grass
175.	Poaceae	*Cynodon dactylon (L.) Pers.*	Hemicryptophyte	Grass
176.	Poaceae	*Dactyloctenium aegyptium (L.) Willd*	Therophyte	Grass
177.	Poaceae	*Dactyloctenium aristatum Link*	Therophyte	Grass
178.	Poaceae	*Dactyloctenium scindicum Boiss.*	Hemi cryptophyte	Grass
179.	Poaceae	*Desmostachya bipinnata (L.) Stapf*	Cryptophyte	Grass

S.#	Family	Plant species	Life form	Habit
180.	Poaceae	*Dichanthium annulatum (Forsk.) Stapf*	Hemicryptophyte	Grass
181.	Poaceae	*Dichanthium foveolatum (Del.) Roberty*	Hemicryptophyte	Grass
182.	Poaceae	*Diplachne fusca (L.) P.Beauv. ex Roem & Schult.*	Cryptophyte	Grass
183.	Poaceae	*Echinochloa colonum (L.) Link*	Therophyte	Grass
184.	Poaceae	*Eleusine indica (Linn.) Gaertn.*	Therophyte	Grass
185.	Poaceae	*Elionurus royleanus Nees ex A.Rich.*	Therophyte	Grass
186.	Poaceae	*Eragrostis cilianensis (All.) Lut. Ex F.T. Hubbard*	Therophyte	Grass
187.	Poaceae	*Eragrostis ciliaris (L.) R. Br.*	Therophyte	Grass
188.	Poaceae	*Eragrostis japonica (Thunb.) Trin.*	Therophyte	Grass
189.	Poaceae	*Eragrostis minor Host*	Therophyte	Grass
190.	Poaceae	*Eragrostis pilosa (L.) Beauv.*	Therophyte	Grass
191.	Poaceae	*Eragrostis tenella (L.) P. Beauv. Ex Roem.*	Therophyte	Grass
192.	Poaceae	*Eriochloa procera (Retz.) C. E. Hubbard*	Hemicryptophyte	Grass
193.	Poaceae	*Lasiurus scindicus Henr.*	Hemicryptophte	Large Grass
194.	Poaceae	*Leptothrium senegalensis (Kunth) W.D. Clayton*	Hemicryptophyte	Grass
195.	Poaceae	*Ochthochloa compressa (Forsk.) Hilu*	Therophyte	Grass
196.	Poaceae	*Panicum antidotale Retz.*	Hemicryptophyte	Grass
197.	Poaceae	*Panicum turgidum Forsk.*	Hemicryptophyte	Grass
198.	Poaceae	*Paspalidium flavidum (Retz.) A. Camus*	Hemicryphophyte	Grass
199.	Poaceae	*Paspalidium geminatum (Forsk.) Stapf*	Hemicryptophyte	Grass
200.	Poaceae	*Paspalum vaginatum Swartz.*	Hemicryptophyte	Grass
201.	Poaceae	*Phragmites australis (Cav.) Trin.*	Cryptophyte	Large Grass
202.	Poaceae	*Phragmites karka (Retz.) Trin. Ex Steud.*	Cryptophyte	Large Grass
203.	Poaceae	*Saccharum benghalense Retz.*	Hemicryptophyte	Large Grass
204.	Poaceae	*Saccharum griffithii Munro ex Boiss.*	Hemicryptophyte	Large Grass
205.	Poaceae	*Saccharum spontaneum L.*	Hemicryptophyte	Large Grass
206.	Poaceae	*Sporobolus helvolus (Trin.) Dur. & Schinz*	Hemicryptophyte	Grass
207.	Poaceae	*Sporobolus kentrophyllus (K. Schum.) W.D. Clayton*	Hemicryptophyte	Grass
208.	Poaceae	*Sporobolus nervosus Hochst.*	Hemicryptophyte	Grass
209.	Poaceae	*Sporobolus sp. nov.*	Hemicryptophyte	Grass
210.	Poaceae	*Tetrapogon tenellus (Koen. Ex Roxb.) Chiov.*	Therophyte	Grass
211.	Poaceae	*Tragus roxburgii Panigrahi*	Therophyte	Grass
212.	Poaceae	*Urochondra setulosa (Trin.) C.E. Hubb.*	Hemicryptophte	Grass
213.	Polygalaceae	*Polygala erioptera DC.*	Therophyte	Herb
214.	Polygalaceae	*Polygala irregularis Boiss*	Chamaephyte	Herb

S.#	Family	Plant species	Life form	Habit
215.	Polygonaceae	*Persicaria glabra (Willd.) Gomes de la Maza*	Phanerophyte	Herb
216.	Polygonaceae	*Polygonum effusum Meisn*	Chamaephyte	Herb
217.	Polygonaceae	*Polygonum plebejum R. Br.*	Chamaephyte	Herb
218.	Polygonaceae	*Rumex dentatus L.*	Therophyte	Herb
219.	Pontederiaceae	*Eichhornia crassipes (Mart.) Solma*	Hydrophyte	Herb
220.	Portulacaceae	*Portulaca oleracea L.*	Therophyte	Herb
221.	Potamogetonaceae	*Potamogeton lucens L.*	Hydrophyte	Herb
222.	Potamogetonaceae	*Potamogeton natans L.*	Hydrophyte	Herb
223.	Potamogetonaceae	*Potamogeton perfoliatus L.*	Hydrophyte	Herb
224.	Rhamnaceae	*Ziziphus nummularia (Burm.f.) Wight & Arn.*	Phanerophyte	Shrub
225.	Rubiaceae	*Kohautia retrorsa (Boiss.) Bremek.*	Phanerophyte	Subshrub
226.	Salicaceae	*Populus euphratica Olivier*	Phanerophyte	Tree
227.	Salvadoraceae	*Salvadora oleoides Decne.*	Phanerophyte	Tree
228.	Salvadoraceae	*Salvadora persica L.*	Phanerophyte	Tree
229.	Salviniaceae	*Salvinia molesta Mitchelle*	Hydrophyte Fern	Herb
230.	Scrophulariaceae	*Anticharis linearis (Benth.) Hochst. Ex Aschers.*	Therophyte	Herb
231.	Scrophulariaceae	*Bacopa monnieri (L.) Wettstein*	Chamaephyte	Herb
232.	Scrophulariaceae	*Schweinfurthia papilionacea (L.) Merrill*	Chamaephyte	Herb
233.	Solanaceae	*Datura fastuosa L.*	Phanerophyte	Shrub
234.	Solanaceae	*Lycium edgeworthii Dunal*	Phanerophyte	Shrub
235.	Solanaceae	*Physalis divaricata D. Don*	Therophyte	Herb
236.	Solanaceae	*Physalis peruviana L.*	Therophyte	Herb
237.	Solanaceae	*Solanum cordatum Forssk.*	Phanerophyte	Straggling Shrub
238.	Solanaceae	*Solanum nigrum L.*	Therophyte	Herb
239.	Solanaceae	*Solanum surattense Burm.f.*	Chamaephyte	Herb
240.	Solanaceae	*Withania somnifera (L.) Dunal*	Phanerophyte	Subshrub
241.	Tamaricaceae	*Tamarix alii Qaiser*	Phanerophyte	Shrub
242.	Tamaricaceae	*Tamarix indica L.*	Phanerophyte	Shrub
243.	Tamaricaceae	*Tamarix pakistanica Qaiser*	Phanerophyte	Shrub
244.	Tamaricaceae	*Tamarix passernioides Del. ex Desv.*	Phanerophyte	Shrub
245.	Tamaricaceae	*Tamarix sarenensis Qaiser*	Phanerophyte	Shrub
246.	Tamaricaceae	*Tamarix sp. Nov.*	Phanerophyte	Shrub
247.	Tiliaceae	*Corchorus aestuans L.*	Therophyte	Subshrub
248.	Tiliaceae	*Corchorus depressus (L.) Stocks*	Chamaephyte	Herb
249.	Tiliaceae	*Corchorus tridens L.*	Therophyte	Herb
250.	Tiliaceae	*Corchorus trilocularis L.*	Therophyte	Herb
251.	Tiliaceae	*Grewia erythraea Schweinf*	Phanerophyte	Shrub
S.#	Family	*Plant species*	Life form	Habit
252.	Tiliaceae	*Grewia tenax (Forssk.) A. & S.*	Phanerophyte	Shrub
253.	Tiliaceae	*Grewia villosa Willd.*	Phanerophyte	Shrub
254.	Typhaceae	*Typha dominghensis Pers.*	Cryptophyte	Reed
255.	Verbenaceae	*Phyla nodiflora (L.) Greene*	Chamaephyte	Herb
256.	Violaceae	*Viola stocksii Boiss.*	Therophyte	Herb
257.	Zygophyllaceae	*Fagonia indica Burm.f.*	Chamaephyte	Herb

S.#	Family	Plant species	Life form	Habit
258.	Zygophyllaceae	*Tribulus longipetalus Viv.*	Therophyte	Herb
259.	Zygophyllaceae	*Tribulus ochroleucus (Maire) Ozenda & Quezel*	Therophyte	Herb
260.	Zygophyllaceae	*Tribulus terrestris L.*	Therophyte	Herb
261.	Zygophyllaceae	*Zygophyllum propinquum Decne.*	Chamaephyte	Subshrub
262.	Zygophyllaceae	*Zygophyllum simplex L.*	Therophyte	Herb

Table 3-10: Cultivated plant species recorded at Keenjhar Lake

S#	Family	Plant species	Common Name	Life form	Habit	IUCN Category
1	Boraginaceae	*Cordia myxa* L.	Assyrian plum	Phanerophyte	Small tree	LC
2	Caesalpiniaceae	*Cassia alata* Linn.	Ringworm bush	Phanerophyte	Shrub	LC
3	Caesalpiniaceae	*Parkinsonia aculeata* L.	Jerusalem thorn	Phanerophyte	Tree	LC
4	Fabaceae	*Sesbania bispinosa* (Jacq.) W.F. Wight	Prickly sesban	Phanerophyte	Subshrub	LC
5	Mimosaceae	*Leucaena leucocephala (Lam.) ed Wit.*	Ipil-ipil	Phanerophyte	Tree	LC
6	Moraceae	*Ficus benghalensis*	Banyan	Phanerophyte	Tree	-
7	Moraceae	*Ficus religiosa*	Peepul (sacred fig)	Phanerophyte	Tree	LC
8	Pedaliaceae	*Sesamum indicum* L.	Sesame	Phanerophyte	Shrub	-
9	Verbenaceae	*Clerodendrum inerme* Gaertn	Wild Jasmine	Phanerophyte	Shrub	-
Source: Phyto-Sociological Assessment of Vegetation of Keenjhar Lake Sindh, International Journal of Biology and Biotechnology 7 (3): 197-209, 2010						

In most climates there is a seasonal fluctuation of the water table. Habitats with standing water for most of the year may dry out completely in the summer whilst terrestrial soil may be flooded during a rainy season. At no time there is an abrupt change from land to water, but rather a gradual transition from dry through water logged to submerged soils. The reversion of vascular plants to aquatic life has involved colonization of all these transitional habitats as well as the water itself, and some of the marginal sites that are periodically flooded have come to possess their own distinctive plant association (Sculthorpe, 1967[11]).

This periodical phenomenon has been well observed at Keenjhar Lake. In winter, water level in the lake is high, that submerges most of the marginal soil up to the water and dykes. With the start of summer, the water gradually recedes, due to which in March-April, the soil along margins is exposed and it is water-saturated. Rich vegetation comprising species like C*oldenia procumbens*, *Glinus lotoides*, *Persicaria glabra*, *Ipomoea carnea*, *Ipomoea aquatica*. Ph*yla nodiflora*, *Amaranthus graecizans*, *Heliotropium ovalifolium*, etc. develops on this soil. Later in summer (June-July), this soil dries up and most of the plants die. Then again in the monsoon

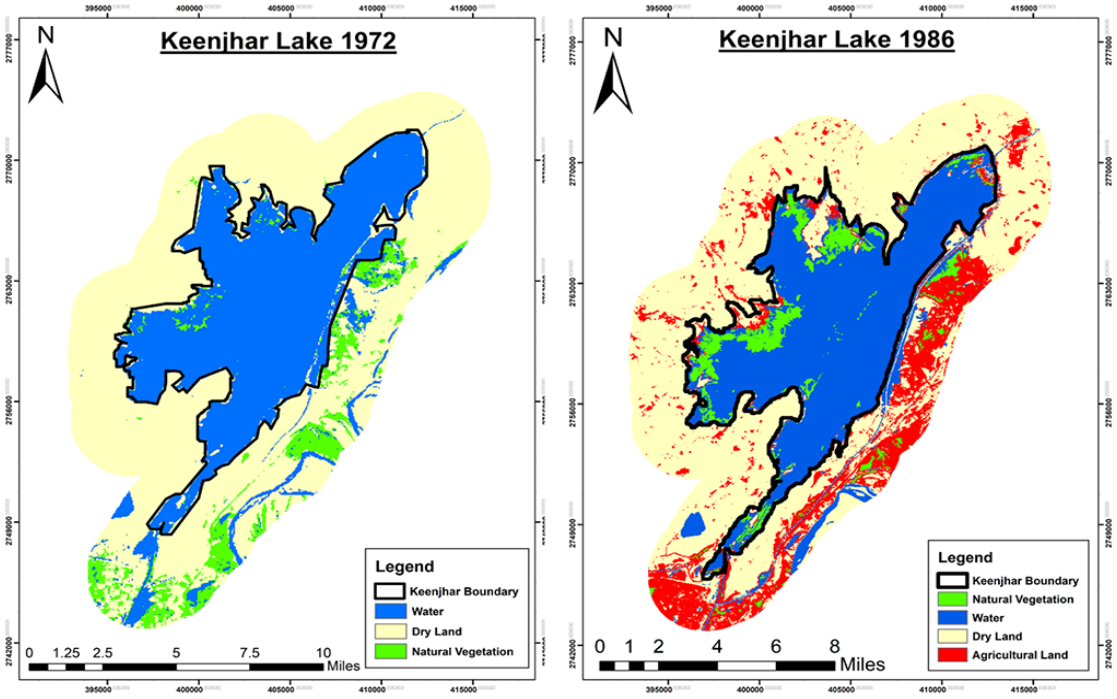
[11] Sculthrope, C.D. (1967). The Biology of Aquatic Vascular Plants. Edward Arnold (Publishers) Ltd. London. p.3

season (late July-Sept.) the vegetation along water margin develops[12]. It was also observed during recent site surveys.

3.3.3.1. Vegetation Trend

No such physical surveys have available which provides the changes in vegetation trends. The data above presents the record of plant species in 2010. However, one recent study based on remote sensing analysis has been conducted to evaluate the change in vegetation of Keenjhar Lake.

It has been observed that the natural vegetation cover had been depleted from 2751.48 to 2193.3 ha during 1972-2020[13]. The remote sensing analysis undertaken and presented below concludes that the vegetation has been reduced due to change of land use to agriculture at the periphery of the lake. The vegetation cover inside the lake's water body is altered with the lake's levels as well as with the change in exposed area. Figure below shows the trend of change in vegetation of Keenjhar Lake.



[12] M. Imran and S. Khatoon (2005). Floral Biodiversity Of The Wetlands Of Indus Delta Area, Southern Sindh, INT. J. BIOL. BIOTECH., 2 (1): 77-83, 2005

[13] Islam H, Abbasi H, Karam A, Chughtai AH, Ahmed Jiskani M. Geospatial analysis of wetlands based on land use/land cover dynamics using remote sensing and GIS in Sindh, Pakistan. *Science Progress*. 2021;104(2). doi:10.1177/00368504211026143

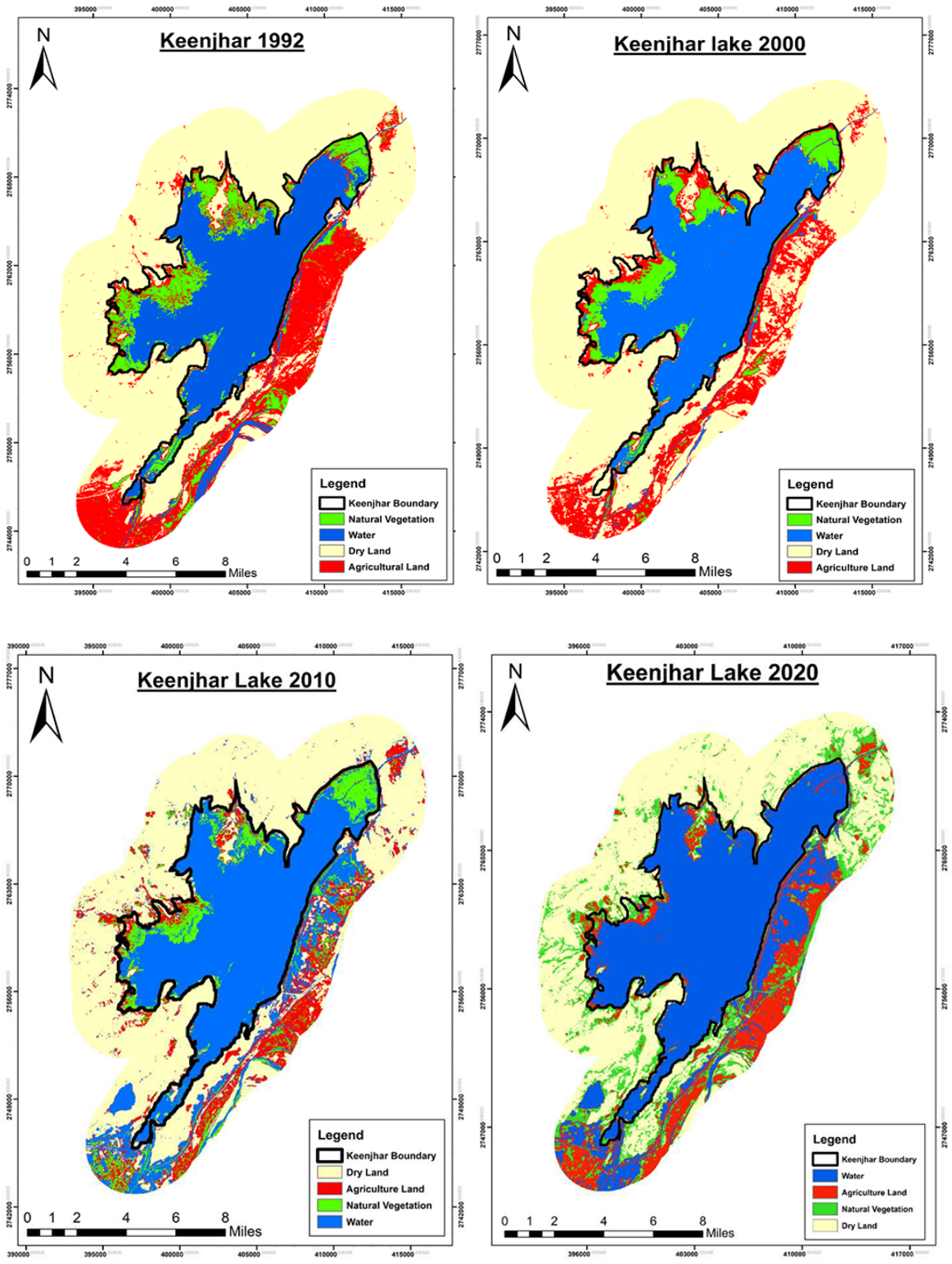
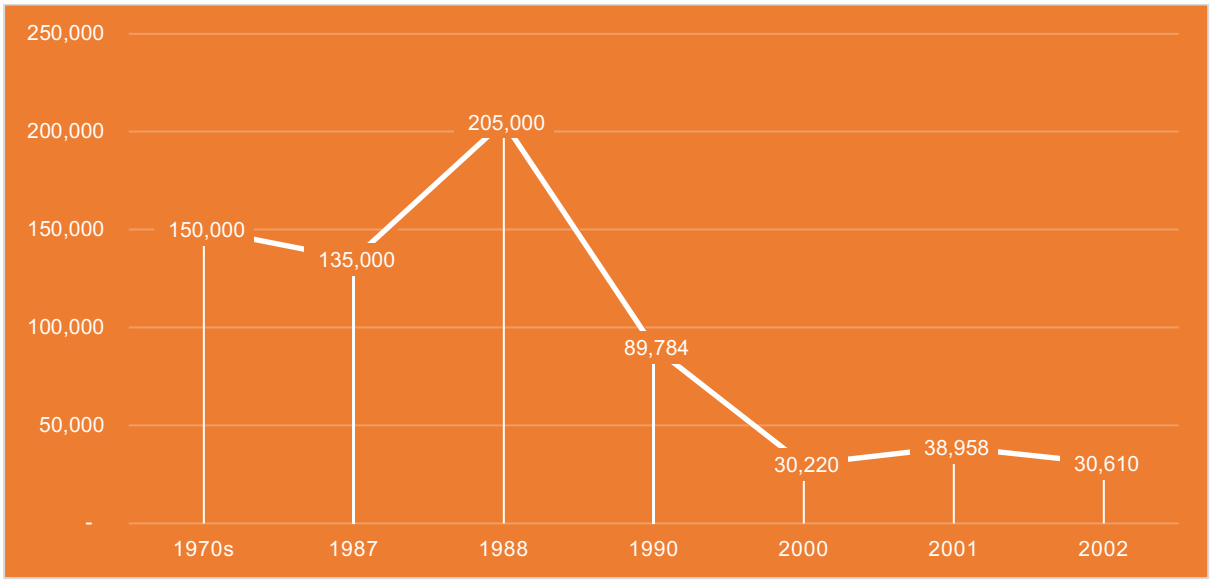


Figure 3-6: LULC maps of Keenjhar Lake from 1972 to 2020

3.3.4. Fauna of Keenjhar Lake

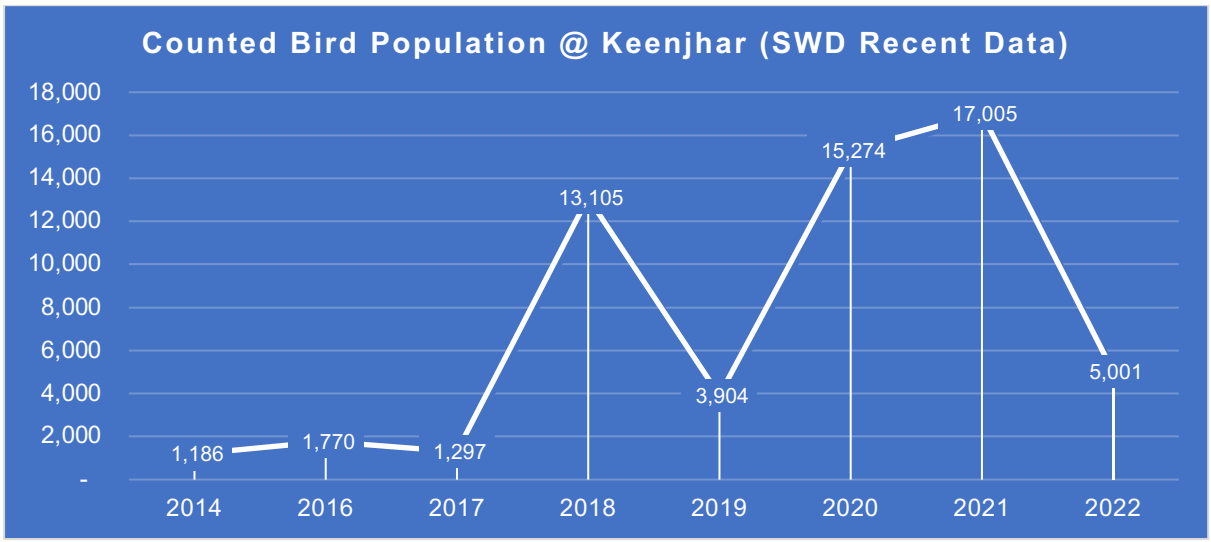
The area has a great importance as roosting, wintering and breeding site for several resident and migratory birds. Some of the significant breeding birds of this lake include the Night Heron (*Nycticorax nycticorax*), Cotton Teal (*Nettapus coromondelianus*), Pheasant-tailed Jacana (*Hydrophasianus chirurgus*), and Purple Moorhen (*Porphyrio porphyrio*), despite Cotton Teal's recent disappearance. Additionally, it is a crucial habitat for game birds including Chestnut-bellied Sandgrouse (*Pterocles exustus*) and Grey Partridge (*Francolinus pondicerianus*). The dominant species in the area are the Indian Monitor Lizard (Varanus bengalensis), Smooth-coated Otter (*Lutrogale perspicillata*) - vulnerable, Cotton Teal (*Nettapus coromandelianus*), Pallas's Fishing Eagle (*Haliaeetus leucoryphus*) - endangered, and Spiny-tailed Lizard (*Saara hardwickii*).

Keenjhar Lake is an important breeding and wintering and staging area for a wide variety of terrestrial and migratory birds. About 65 species of waterfowl have been recorded. Amjad and Kidwai (2002) gave following account of annual waterfowl census at Keenjhar Lake.



Graph 3-8: Population of migratory birds over different years (Amjad & Kidwai (2002))

The Consultant has managed to get an updated data set of bird census from SWD (**Annex II**), it deviates from consistency, however, this could be due to the influence of climate change. As the parameters indicating any temporal or spatial change was not noticed, so one cannot say that reduction in calling birds is due to any habitat degradation.



Graph 3-9: Population of migratory birds (recent patterns) – Source: Sindh Wildlife Department Census Data

3.3.4.1. General Reasons for the Decline of Migratory Birds Visits

According to the experts, there are several reasons for the decline of the migratory birds in Pakistan, specifically Sindh, and both natural and human interventions are to blame. An expert hunter, requesting anonymity, said that innumerable migratory birds used to fly to Sindh during 1984, the time since he has been into hunting. Now, only 30% of them come to the province[14].

Painted stork is local winter tourist of Pakistan facing marked decline in population size due to over hunting (Grimmett et al., 2008; BirdLife, 2016). Illegal hunting is another main threat to many migratory birds like geese, coot and ducks. The bar-headed geese are hunted brutally. The population of these birds has declined by the destruction and degradation of vegetated wetland habitats (Grimmett et al., 2008). Urbanization and deforestation are major factor responsible for the decline of bird population both in abundance and diversity because most of the birds are sensitive to these changes (Mahboob et al., 2013). Further ecological concerns of migratory birds are eutrophication, heavy metals and ago-chemical contamination due to which the population of migratory birds is decline and on threats. As the excessive use of pesticides severely affects the population of gulls, eagles, terns, geese, ducks and cormorants[15].

3.3.5. Fishing in Keenjhar Lake

Keenjhar Lake is rich in fish fauna. It includes *Ambassis nana*, *Badis spp*. *Puntius sarana*, *Puntiusticto*, *Catla catla*, *Channa spp. Cirrhinus mrigala Ctenopharyngodon idellus, Gadusia chapra, Glossogobius spp. Labeo rohita, Labeo gonius, Notopterus notopterus* and, *Rasbora rasbora*, etc. The livelihood of the local communities mainly depends on these resources. Anon (1999) mentioned an annual production of about 700 metric tonnes of fish. There has been reduction in the fish stock due to overexploitation. Current figures retrieved from Fisheries department show that the about 229 metric tons of fish has been caught in the last year as show in table below.

[14] Syed Ashraf Ali, The Express Tribune, February, 2019.
[15] : Umar, M., Hussain, M., Murtaza, G., Shaheen, F.A.and Zafar, F., 2018. Ecological concerns of migratory birds in Pakistan: A review. *Punjab Univ. J. Zool.*, 33(1): 69-76. http:dx.doi.org/10.17582/pujz/2018.33.1.69.76

Consultant has managed to collect the recent data of 2020-21 from Fisheries Department on the status of fish catch and the dependent fishermen. About 2,265 fishermen are dependent on the lake with 1,350 boats. There are four fish-landing centers at the Lake Viz., Khumbo, Chilya, Sonheri and Jhimpir. A total 321 fishing licenses have been issued recently.

The reported lists of floral and faunal species of found in or near the Keenjhar Lake is attached in **Annex I**.

3.3.6. Species of High Conservation Value (HCV) in Keenjhar Lake

The Lake is the home to at least 24 species on the IUCN Red List. Eleven birds, two mammals, five reptile species and seven fish species were reported in the microenvironment of the Lake.

Table 3-11: High Priority IUCN Red Listed species reported within the microenvironment Keenjhar Lake[16]

S#	Scientific name	Common name	IUCN Red Listing
1.	*Prionailurus viverrine*	Fishing Cat	VU
2.	*Manis crassicaudata*	Indian Pangolin	EN
3.	*Haliaeetus leucoryphus*	Pallas's Fishing Eagle	EN
4.	*Aquila clanga*	Greater Spotted Eagle	VU
5.	*Aythya ferina*	Common Pochard	VU
6.	*Sterna aurantia*	River Tern	VU
7.	*Sterna acuticauda*	Black-bellied Tern	EN
8.	*Aythya nyroca*	Ferruginous Duck	NT
9.	*Lanius merodionalis*	Southern Grey Shrike	VU
10.	*Lissemys punctata*	Indian Flap-shell Turtle	VU
11.	*Naja oxiana*	Oxus Cobra/Brown Cobra	NT
12.	*Eryx conicus*	Russel's Sand Boa	NT
13.	*Varanus bengalensis*	Indian Monitor lizard	NT
14.	*Saara hardwickii*	Indian Spiny-tailed Lizard	VU
15.	*Bagarius bagarius*	Fauji Khagga	*NT*
16.	*Ompok bimaculatus*	Butter catfish	*NT*
17.	*Wallago attu*	Freshwater catfish	*VU*
18.	*Ailia coila*		*NT*
19.	*Oreochromis mossambicus*	Mozambique tilapia	*VU*

The above listed HCV species are reported in different studies undertaken in the past. Detailed surveys are needed to ascertain the current existence and number of those species. For example, Smooth-coated Otter (*Lutrogale perspicillata*) which is a vulnerable specie according to IUNC red listing, is reported in the lake, however, experts have an opinion that it is not being observed since last few years.

[16] Khan, M. Z., Abbas, D., Ghalib, S. A., Yasmeen, R., Siddiqui, S., Mehmood, N., ... & Latif, T. A. (2012). Effects of environmental pollution on aquatic vertebrates and inventories of Haleji and Keenjhar Lakes: Ramsar Sites. Canadian Journal of Pure and Applied Sciences, 6(1), 1759-1783.

Table 3-12: District Wise Fisheries Statistics for The Year 2021-22 up to May-2022

S#	Name Of District	Fish Production (M. Tons)	Value In Rs.	No. Of Fishermen			No. Of Boats			
				Full Time	Part Time	Total	Row	Sail	Motor Boats	Total Boats
1	Keenjhar Lake	228.7	34,144,300	1,230	1,035	2,265	195	900	255	1,350
2	Sujawal	68	8,165,000	2,190	3,715	5,905	1,680	762	1,200	3,642
3	Thatta	324	63,360,714	5,655	4,240	9,695	1,420	835	805	3,060
	Total	**620.7**	**105,670,014**	**9,075**	**8,990**	**17,865**	**3,295**	**2,497**	**2,260**	**8,052**
Source: Director Fisheries Sindh Inland Hyderabad										

Table 3-13: Number of Fish Licenses issued (Public Waters Recent Data)

S#	Name of District	Fishing Licenses	Angling /Sport Licenses	Fish Dealer Licenses	Total Licenses Issued
1	Keenjhar Lake	287	10	24	321
2	Sujawal	183	0	32	215
3	Thatta	361	0	21	382
	Total	**1194**	**60**	**260**	**1514**
Source: Director Fisheries Sindh Inland Hyderabad					

3.3.7. Reconnaissance Visit 1 of Keenjhar Lake - 27 February, 2022

A reconnaissance visit of Keenjhar Lake was undertaken by the Consultant on 27 February, 2022. Below are some of the site pictures with description in the caption.

This is the head regulator of Keenjhar Lake at the end of KB Feeder Upper (KBFU) where the water is diverted and controlled to feed Keenjhar Lake, which is built in 1976. The design discharge of the regulator is 8154 cusecs (0.016 MAF per day).

An extensive growth of reedbeds (mainly *Phragmites spp.*) at the inlet of the lake is observed due to the shallowness and siltation over the time.

Beds of *Ipomoea aquatica* are also observed at the banks of lake.

A flock of resident birds floating over the water can be seen from a distance

Phalacorcorax niger (Little cormorant) are observed settling over an inundated tree branch at the center of the lake

Goats are rearing by the lcoal population residing along the lake

Local boats for tourism (also one of the livelihhood of the locals)

Picknickers also visit the lake in large numbers in the weekends at the south portion of the lake

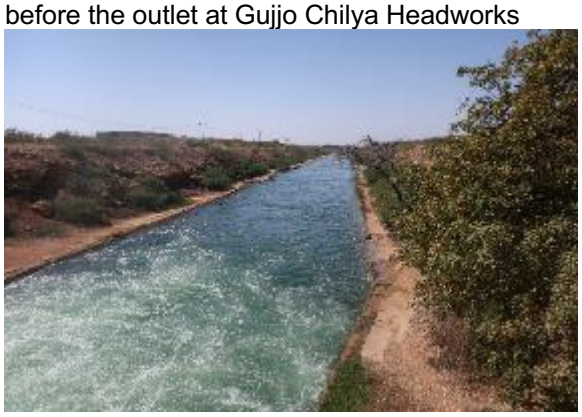
Reedbeds are located at the center of the lake which serves as beeding place for migratory as well as redients birds and hiding places of other faunal species

A floating hatchery system is installed by Fisheries Department for aqua culture, one of the WB funded.

Outlet of the lake into Keenjhar Gujjo (KG) Canal at Gujjo Chilya Headworks

Hydrilla verticillata (Water thyme) is observed before the outlet at Gujjo Chilya Headworks

Gujjo Chilya Headworks



Keenjhar Gujjo (KG) Canal

Prosopis juliflora (Mesquite) is found in dominant along the rocky banks of the Lake

Euphorbia caducifolia with Prosopis juliflora are also dominant in the microenvironment

A natural water pond called as Kuhi Dhand is formed due to water logging from the Lake which is also one of the site for birds roosting and breeding.

3.3.8. Reconnaissance Visit 2 of Keenjhar Lake – 11 June, 2023

Another reconnaissance visit of Keenjhar Lake was undertaken by the Consultant on 11 June, 2023, when the lake's level was 46.8 ft. RL. For this visit, special emphasis was on those areas which are usually dried in the condition of minimum lake's level, and then submerged when the lake is filled up. Therefore, 06 sampling sites were chose in the western boundaries and northern entrance of the lake. Below map shows the sampling sites locations. The sampling site were chosen to collect the baseline data of floral and faunal species observed.

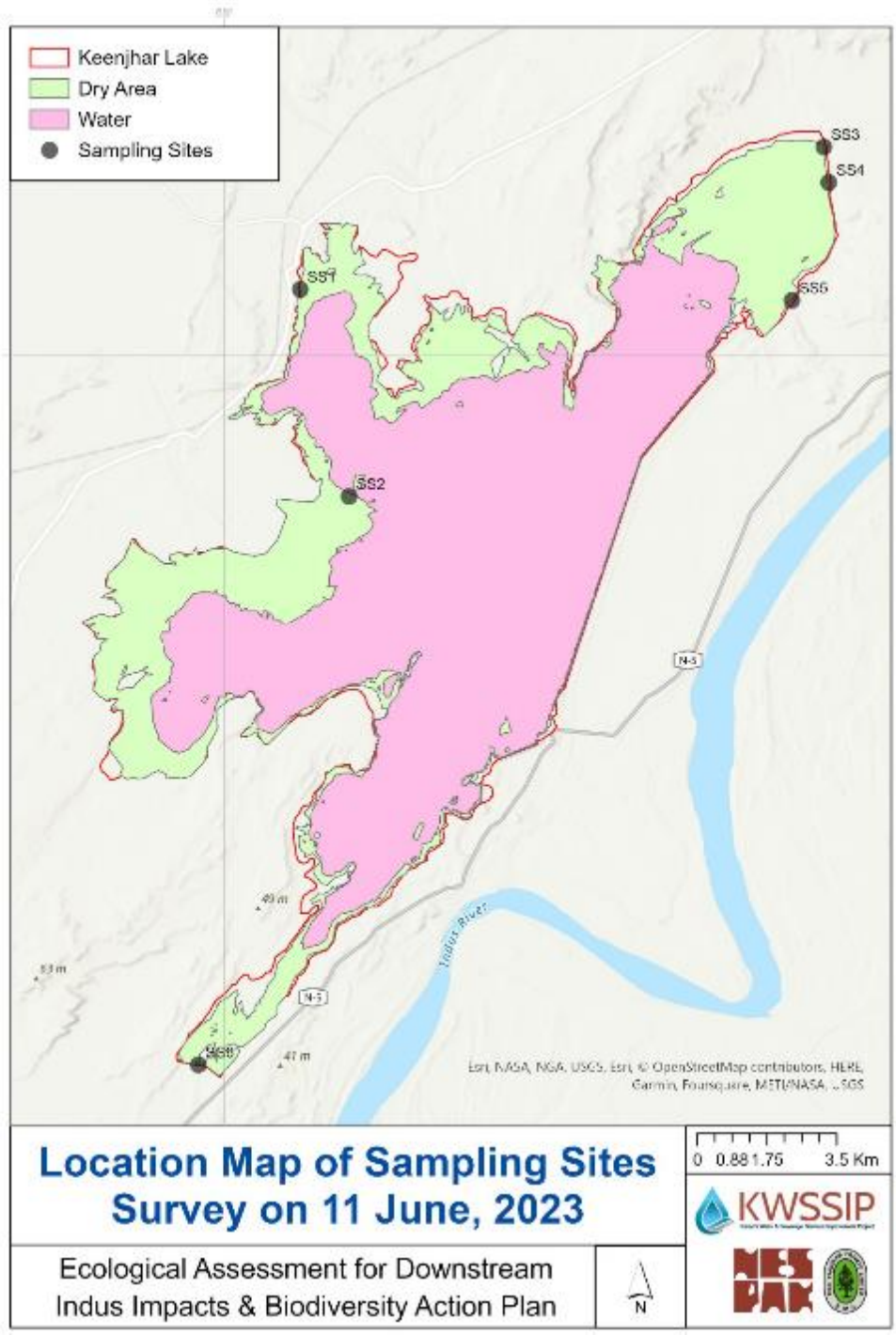


Figure 3-7: Sampling Site Location (Reconnaissance Survey 11 June, 2023)

Below are some of the site pictures as per sampling sites with description in the caption.

3.3.8.1. Sampling Site SS1

Description:

SS1 was chosen in the north-western periphery of the lake when the water receded back and SS1, due to its shallowness, became exposed. The sampling site is close to Jhimpir City.

Extensive growth of reedbeds (mainly *Phragmites spp.*) has been observed at SS1 with some ponding of water in potholes. This is the indication of area under water during raised levels. According to the locals, these reedbeds provide shelter to resident as well as migratory birds.

At further landward side in high lying area, the reedbeds are replaced by *Prosopis juliflora* (Mesquite) which is an indication of rocky, poor and saline soils. At further lake side, the reedbeds are followed with *Ipomoea aquatica* which was floating over the water surface and usually provides shelter to the fish. Below is the photo documentation of SS1.

An extensive growth of reedbeds (mainly *Phragmites spp.*) at SS1. As per consultation with locals, the area is inundated when the lake is filled with water.

Ponding of water oobserved due to percolation of water in potholes

A buffer zone between submerged area and land area


Prosopis juliflora (Mesquite) has been observed and indicator or land area.

3.3.8.2. Sampling Site SS2

Description:

SS2 was chosen as the area was exposed profoundly towards east direction due to shallowness. The sampling site is close to village named Chakro.

The site was quite flat with small grass observed over the exposed surface. No such shrubs or dried aquatic plants were observed at the site. According to the locals, the site is inundated almost 6-7 ft. when the lake reaches top level in November and December.


Exposed area along lake periphery


Exposed area shows no sign of major flora


Droppings of cattle showing it is subject to grazing


Few date plam trees observed, planted by locals

	
Hydrilla verticillata (Water thyme) was observed at the lake periphery	The site is also used for local fishing boats
	
Local village houses lcoated at quite a distance from lake's periphery, are inundated during max. water level of lake. The houses are made with the same reed / typha. Local cut the typa grass and made houses and other hand-made art work from the sticks.	

3.3.8.3. Sampling Site SS3

Description:

SS3 was chosen at the extended arm in the north direction at which the lake receives water (before the head regulator). Due to deposition of sediments, the area is quite shallow and becomes completely dry during June and July when the water level is lowest, as shown in figure 3-6. The sampling site is close to area named as Chul. The invasive terrestrial *Prosopis juliflora* (Mesquite) has invaded the site and the inlet arm of the lake, since some of the proportion of this site remains dry throughout the year.

Water ponding was also observed in low lying areas as the water receded back to the main water body. Dried patches of Phragmite were observed but extensively cut down by the locals to make the stick mattress and houses. Cattle grazing activity was also observed at the site. Dead gastropod mollusks shells in large quantity were observed. One of the reasons of their presence in that site, is the receival of fresh water at the inlet point and the availability of dissolve oxygen (DO) in high concentrations due to shallowness of the site. The amount of dissolved oxygen in the water is an important indicator of the abundance of some species, particularly *Prosobranchia* (Ertan et al., 1996; Yıldırım, 1999[17]).

[17] Ertan, O.Ö., Yıldırım, M.Z. and Morkoyunlu, A. 1996. The mollusca species and their feeding models that distributes in Konne Spring (Eğirdir-Turkey). Second İnternational Symposium on Aquatic Products in İstanbul; September 21-23 1996.


Exposed area at the inlet point of the lake

Prosopis juliflora (Mesquite) has been observed invading more towards the exposed area

Exposed area with dried and disturbed Phragmites habitat. Locals have extensively disturbed the area.

The line of dried plants with aquatic debri indicates the water line.

Cow dung and hooves prints show the extensive cattle grazing activity


Dead sheels of mollusks


The dried Phragmites

According to the locals, this is the main site for landing migratory birds due to its shallowness, beds of reeds and other flora for shelter and foraging.

3.3.8.4. Sampling Site SS4

Description:

SS4 was chosen as the head regulator sites of Keenjhar lake and link canal. No such exposed area was observed. The usual aquatic plants were observed in the water. The filling of the lake was continued during the survey.


Head regulator of Keenjhar Lake

Inlet of lake - the area on the left is exposed due to sediment deposition

3.3.8.5. Sampling Site SS5

Description:

SS5 was chosen in the same extended arm in the north direction where the lake received water, however, the site was chosen at the embankment in the eastern side. According to figure 3-6, this area is exposed, however, during the survey, shallow water was observed at the middle of the portions, which concluding that the lakes filling starts. The usual distributed patches of *Phragmites spp.* were observed in the water body with exposed areas located mainly alongside of the embankment. It means that the water, at its lowest water level, recedes beyond the embankments. At the embankment, growth of *Prosopis juliflora* (Mesquite) was observed.

Outlook of SS5

patches of ***Phragmites spp.*** were observed in the water body

Ipomoea aquatica is observed at the foot of enbankments indicatin the water reach.

Prosopis juliflora (Mesquite) growth at the enbankment

3.3.8.6. Sampling Site SS6

Description:

SS6 was chosen as the exist point of Lake in the southern arm, near Chillya village. Head regulators of KB Feeder Lower (KBFL) and KG Canal are located which regulates the outflow. Figure 3-6 shows the area is dried up and exposed, however, water was present at the outlet but not flowing out from KBFL regulator at the time of survey. Few dry patches along the outlet were observed. The usual aquatic plants were observed in the water and at the exposed area.

	
Outlet of lake at KBFL	
	
KBFL description	Water was not flowing from the regulaor
	
Usual flora as reported in the above sections were observed	However, water is flowing from KG Canal regulator for Karachi

3.3.9. Reconnaissance Visit 3 of Keenjhar Lake – 05 July, 2023

Another reconnaissance visit of Keenjhar Lake was undertaken by the Consultant on 05 July, 2023, when the lake's level was 47.3 ft. RL. The visit was follow-up of visit 2 and check the conditions during the start of filling of the lake.

Below are some of the site pictures with description in the caption.

View of the lake from Fisheries Department Resthouse

Water line see on the enbankment showing the highest level of the lake

Hydrilla verticillata (Water thyme) was observed at the edge of Fisheries Department Resthouse

Ecologists meeting with local representative of the area at Fisheries Department Resthouse

	
A staff guage is installed near the rest hhouse	A concrete tank was also establised comprising a gauge for measuring the higest levels of the lake. At the time of obsrevation, it was empty.
	
Cattle grazing activity was observed near the inlet of	The area near the inlet was still dry

3.3.10. Discussion on site surveys

- Boundaries of the lake are very dynamic and follows the water levels and bathymetry of the lake. Figure 3-6 shows the exposed areas during lowest water level conditions and they formed usually at the inlet and at the western boundaries of the lake. Regression of aquatic plants and succession of terrestrial invasive species were observed in those area. Also, human interference like cutting reeds and grazing cattle was also observed as the wetland is providing ecosystem services.
- Cattle grazes fresh grasses that germinate and flourishes after receding of lake water. Some people also grow Rabi season (winter) crops on exposed area at the fringes. When lake is again filled to its upper level in September, the same ecosystem revives.
- The exposed areas or you can say the wet areas having shallow depth serve as breeding or overwintering habitats or migration stopover areas. This is also confirmed by the locals. These areas replenish their ecological character when the lake filling starts in September / October months and will be ready for migration stopovers. According to the

historic lake levels, max. levels achieved when the wintering season starts from November / December.

- *Phargmites spp. (P. australis)* provides food and habitat for some organisms and serves to stabilize soils against erosion. Secondly, many biological features of this species predispose it to be used as a biological pollution filter[18]. It is typically found in ditches, disturbed sites, and can tolerate saline habitats. Due to its vigorous growth and effective vegetative spreading, P. australis forms dense stands providing sheltered and nutrient-rich habitats suiting various birds and invertebrates. They serve as breeding or overwintering habitats or migration stopover areas for numerous bird species including rare and endangered ones[19]. Reedbeds are also extensively used as night roosts by passerines and provide foraging and nesting sites to ducks and coots, the abundance of which is correlated with the reedbed area[20].
- Wetlands dominated by *P. australis* have for long provided local human communities with food (waterfowl, venison, fish), fodder and otherwise useful plant materials. Owever, if left unmanaged, moist areas overgrown with *P. australis* tend to change into terrestrial habitats (woodlands or grasslands depending on the regional climate) in a natural hydroseral succession process of wetland terrestrialization (landfilling). The terrestrialization of reed-dominated wetlands is primarily caused by their high net primary production.
- Direct use of reed stalks in the area is roof thatching or the use of the reed-dominated habitats for waterfowl hunting, cattle grazing or fishing. Reed harvesting is a specific, sustainable and socially valued economic use of reedbeds. However, cutting all dry stalks in summer deprives wintering animal species of their habitat, as well as many migratory bird species of a sufficient reed cover for breeding[21].
- Locals tend to harvest reeds. Reed harvesting is a specific, sustainable and socially valued economic use of reedbeds. However, cutting all dry stalks in summer deprives wintering animal species of their habitat, as well as many migratory bird species of a sufficient reed cover for breeding.
- *Ipomoea aquatica* also known as water spinach is a herbaceous trailing vine that grows perennially and is widely distributed. It is economically important and mostly cultivated by both rural and urban dwellers in Nigeria due to its nutritional composition and benefits. It has the ability to accumulate pollutants[22]. Currently used as fodder for cattle around the lake and found usually at the inlet site and in shallow waters usually found with *Phargmites spp.*
- *Hydrilla verticillata* (Water thyme) is a weed naturalized and invasive, has become the most serious aquatic weed problem for in the United States. Few studies have proved

[18] Meadows, R.E.; Saltonstall, K. Distribution of native and introduced Phragmites australis in freshwater and oligohaline tidal marshes of the Delmarva Peninsula and southern New Jersey. J. Torrey Bot. Soc. 2007, 134, 99–107.
[19] BirdLife International. European Birds of Conservation Concern: Populations, Trends and National Responsibilities; BirdLife International: Cambridge, UK, 2017.
[20] Broyer, J.; Calenge, C. Influence of fish-farming management on duck breeding in French fish pond systems. Hydrobiologia 2010, 637, 173–185.
[21] Čížková, H., Kučera, T., Poulin, B., & Květ, J. (2023). Ecological Basis of Ecosystem Services and Management of Wetlands Dominated by Common Reed (Phragmites australis): European Perspective. Diversity, 15(5), 629. MDPI AG.
[22] Ogungbile, P.O., Ajibare, A.O., Ayeku, P.O. et al. Bio-tolerance potential and environmental risks assessment of *Oreochromis niloticus* and *Ipomoea aquatica* in Agodi Reservoir, Nigeria. Sci Rep 12, 1594 (2022).

that the *H. verticillata* has the ability to remove arsenic, cadmium and lead elements from contaminated water[23]. It is known for its rapid and dense growth reducing plant diversity to a single species. Dense growth of water thyme in the aquatic ecosystem causes increase in daily swings in dissolved oxygen and pH, which influences habitat quality. Underneath a dense growth of water thyme in an aquatic ecosystem, oxygen levels can drop so low during night that fish could not survive at a long time. Same effects on acidity and oxygen can lead to rise in the level of release of nutrients from sediments. This drastic increase can induce phytoplankton blooms, which is an indicative symptom of a polluted lake. It was observed mostly near clear waters at the outfall and near the embankments where water is deep[24]. *Hydrilla verticillata* was observed at the southern periphery and outlet points where the lake's water is quite clear and where the sunlight reaches the bottom.

3.4. Baseline Description of Command Area of KB Feeder Lower (KBFL)

3.4.1. Riverine Area Downstream Kotri

This zone extends from Jiraksite -TM Khan Bridge and ends near Janghiisur near Kharochaan, this zone had been subject to numerous studies under various initiatives namely "Indus For All". Mahar (2016) published data of aquatic biodiversity of Indus River on one of booklet report. Mahar and Solangi (2017) worked on the review of Sindh coastal development authority act 1992 and Plan and given valuable suggestions for protection and restoration of natural resources. Mahar (2018) worked on the razor clam fishery and socio-economic conditions of fishing communities at Sindh Coastal zone near Indus River commanding area. OXFAM, (2015) carried out work on the climate change risks and vulnerabilities of Badin. Rabbani et al., (2008) presented a picture of the impact of sea level rise on Pakistan's coastal zones, in a climate change scenario. Abro et al., (2020) described a recent checklist of fishes of lower Indus basin and reported freshwater and estuarine fish species.

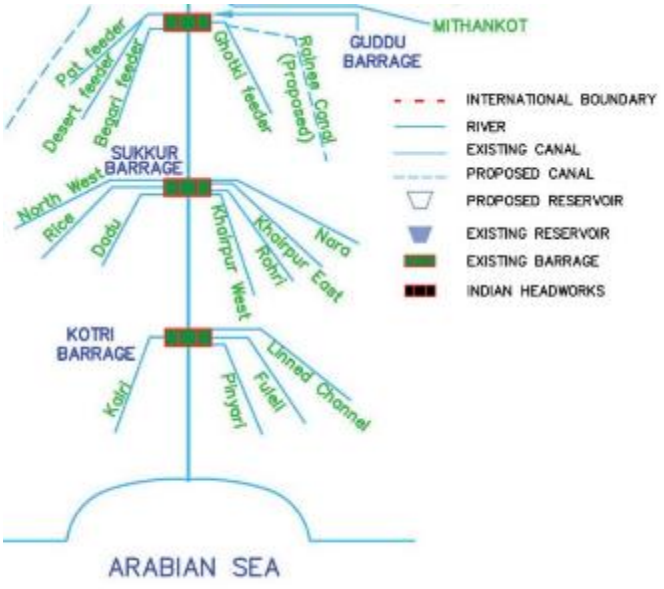


Figure 3-8: The Indus Basin water system downstream Kotri. Source: The World Bank (2010)

The riverine area downstream of Kotri Barrage is about 630,780 acres in size. The riverine lands (Katcha) have formed in a continuous strip along the flat plains of the meandering course

[23] Al-Tabatabai, H & alzurfi, Sadiq. (2020). AQUATIC PLANT (HYDRILLA VERTICILLATA) ROLES IN BIOACCUMULATION OF HEAVY METALS . The Iraqi Journal of Agricultural Sciences. 51. 574-584. 10.36103/ijas.v51i2.984.
[24] Eldrin DLR. Arguelles, 2019; Descriptive Study of Some Epiphytic Algae in Lake Laguna de Bay (Philippines), *Egyptian Journal of Aquatic Biology & Fisheries*, Vol. 23(2): 15 – 28 (2019)

of the river Indus, having widths ranging from 5 to 160 km and a flood-prone area on either side. Katcha lands are rich and productive as a result of nutrient-rich silt deposits during periods of river overflow and excellent soil. This entire riverine region is reliant on water flows downstream of the Kotri Barrage. Fisheries and agriculture are significant sources of income in the riverine region.

In reality, the riverine forests represent the region's primary forest resource. They supply lumber, firewood, pit supports for mines, feed and browse for cattle, biodiversity, and game animals, as well as various non-timber forest products such as tannin from bark, gum, honey, and even fish from dhands and dhoras (old river beds). The area of riverine forest is 88,182 acres. From Kotri Barrage to Indus Delta, an area of 88,092 acres is covered with scrub plants. In the past, these forests were exceedingly dense and widespread, and they supplied Middle Eastern countries and certain Indian cities with charcoal. In addition, it has supplied the local inhabitants with wood, fire wood, etc.

Agriculture is the primary industry in the riverine region located downstream of Kotri Barrage. Irrigated by the Indus River's floods, the region remained a rich source of agricultural crops and orchards. Even now, there is a farming area of 95,038 acres in the Katcha region from Kotri Barrage to Indus Delta. Similarly, the river downstream of Kotri Barrage is renowned for its abundance of fish. It has been the habitat not just of fresh inland/river fish, but also of species of fish that require both saline ocean water and fresh Indus water for survival and growth. Out of the total river reach of 174 miles from Kotri to the sea, the fisheries ground in the mainstream is about 100 miles from Kotri to Keti Bunder, with a 10- to 15-mile strip of Delta. Fishing communities have traditionally lived in riverine areas in permanent or semipermanent settlements (Mians) together with their boats and fishing gear. The major catch of these fishermen had been the traditional palla fish, which migrated upstream from the sea[25].

Figure 3-9: Diversity in composition and physiography of Indus River downstream

A floristic list had been compiled at different sites from downstream Kotri Barrage to Janghisur (**Annex I**). The vegetation samples were identified with the support of different Floras (Ali &

[25] Indus Flow Downstream Kotri Barrage - Need or Wastage? By Sikander Brohi, SZABIST 2003

Qaiser, 1992-1998, 2000-2007; Ali & Nasir 1989-1991; Jafri, 1966; Batanouny, 1981; Matthew, 1981-83; Nasir & Ali 1970-1989; Qureshi, 2004; Stewart 1972; Shetty & Singh, 1987 & 1991; Bhandari, 1978; Boulos, 1991).

3.4.2. KB Feeder Command Area

Kalri Baghar Feeder and its command area lies in Thatta districts, in addition to supplying water to Keenjhar lake for KW&SC and KB Feeder Lower (KBFL) command area. The canal command area lies on the right bank of the Indus River. At -2.4 RD the balance considered the flows coming from KBFU and its subsequent distribution to the flows going into the Lake and KBFL irrigation share. This water balance at -2.4 RD concludes that out of 2.5 MAF flow volume received from KBFU, 1.49 MAF goes for irrigation whereas on average annual basis 1.01 MAF is fed into the lake or Karachi water supply.

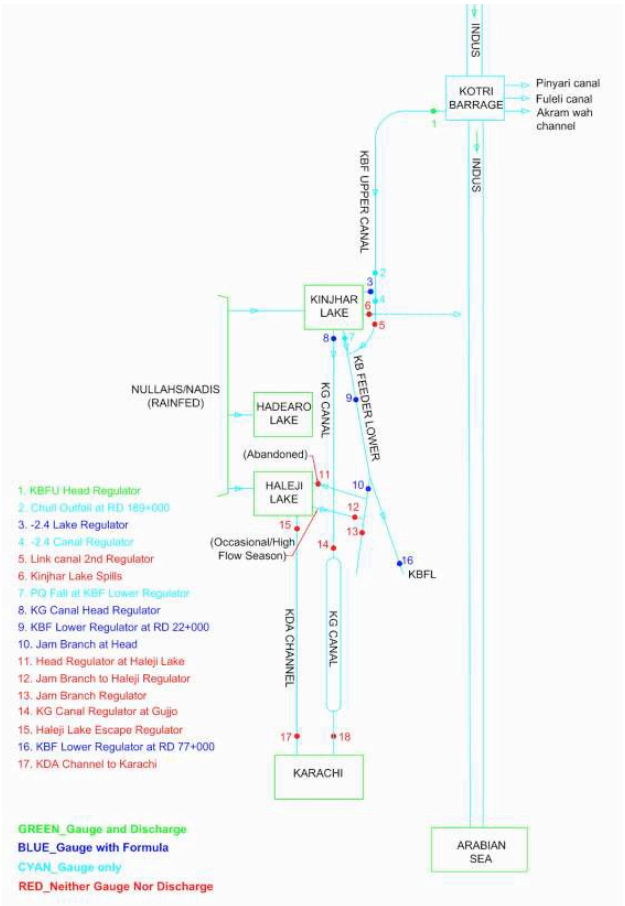


Figure 3-10: Schematic Layout of KBFU Conveyance System[26]

Major Canal Network of Kalri Baghar Feeder Network comprises the following irrigation channels below:

1. Kalri Baghar Feeder Upper – Irrigation Canal
2. Kalri Baghar Feeder Lower – Irrigation Canal
3. Link Canal – Irrigation Canal
4. Karachi-Gujju Canal – Water Supply to Karachi
5. Distributaries, minors and sub-minors

Below table and figure shows the canals and branches of KB feeder which feeds the command area.

[26] Feasibility Studies for Present Network of Kalri Baghar Feeder and Keenjhar Lake, NESPAK 2018

Table 3-14: Canals and Branches of KB Feeder (Right Bank of Kotri Barrage)

Name	**K.B.Feeder Upper**	**Link Canal**	**K.B.Feeder Lower**	**Jam Branch**	**Sakro Branch**	**Raj Wah Ex Sakro Branch**	**Nari Chach Lower**	**Odero Lal Branch**
Parent Channel	Kotri Barrage	K.B. Feeder U	Kinjher Lake	K.B.Feeder L.	K.B. Feeder L.	Sakro Br.	Jam Br.	K.B. Feeder L.
Offtake RD	0	189	0	22	103	97	17	103
Length (km)	60.8	34.4	24.6	60.6	52.5	9.2	38.9	61.3
Discharge Design (cusecs)	9000	8154	7456.81	2894.89	2500.69	326.46	504.3	873.06
GCA (acres)	NA	1577	2441	25721	42589	5383	15089	153416
CCA (acres)	603741	1577	2441	25485	42287	5213	15039	147848
Outlets	241	3	6	118	74	25	77	NA
Outlets Design Disch (cusecs)	104.44	7	11	2321.87	2375.54	265.06	403.44	NA
Zones	Kotri Barrage	Kotri Barrage	Kotri Barrage	Kotri Barrage	Kotri Barrage	Kotri Barrage	Kotri Barrage	Kotri Barrage
Circle		Baghar Circle	Baghar Circle	Baghar Circle	Baghar Circle	Baghar Circle	Baghar Circle	Baghar Circle
Division		Kalri Baghar	Kalri Baghar	Sakro	Sakro	Sakro	Sakro	Sakro
Main Canal	KB Feeder	KB Feeder	KB Feeder	KB Feeder	KB Feeder	KB Feeder	KB Feeder	KB Feeder
Barrage	Kotri	Kotri	Kotri	Kotri	Kotri	Kotri	Kotri	Kotri

GCA: Gross Command Area
CCA: Cultivable Command Area
NA: Not available
Source: https://irrigation.sindh.gov.pk/pub_gismaps.aspx

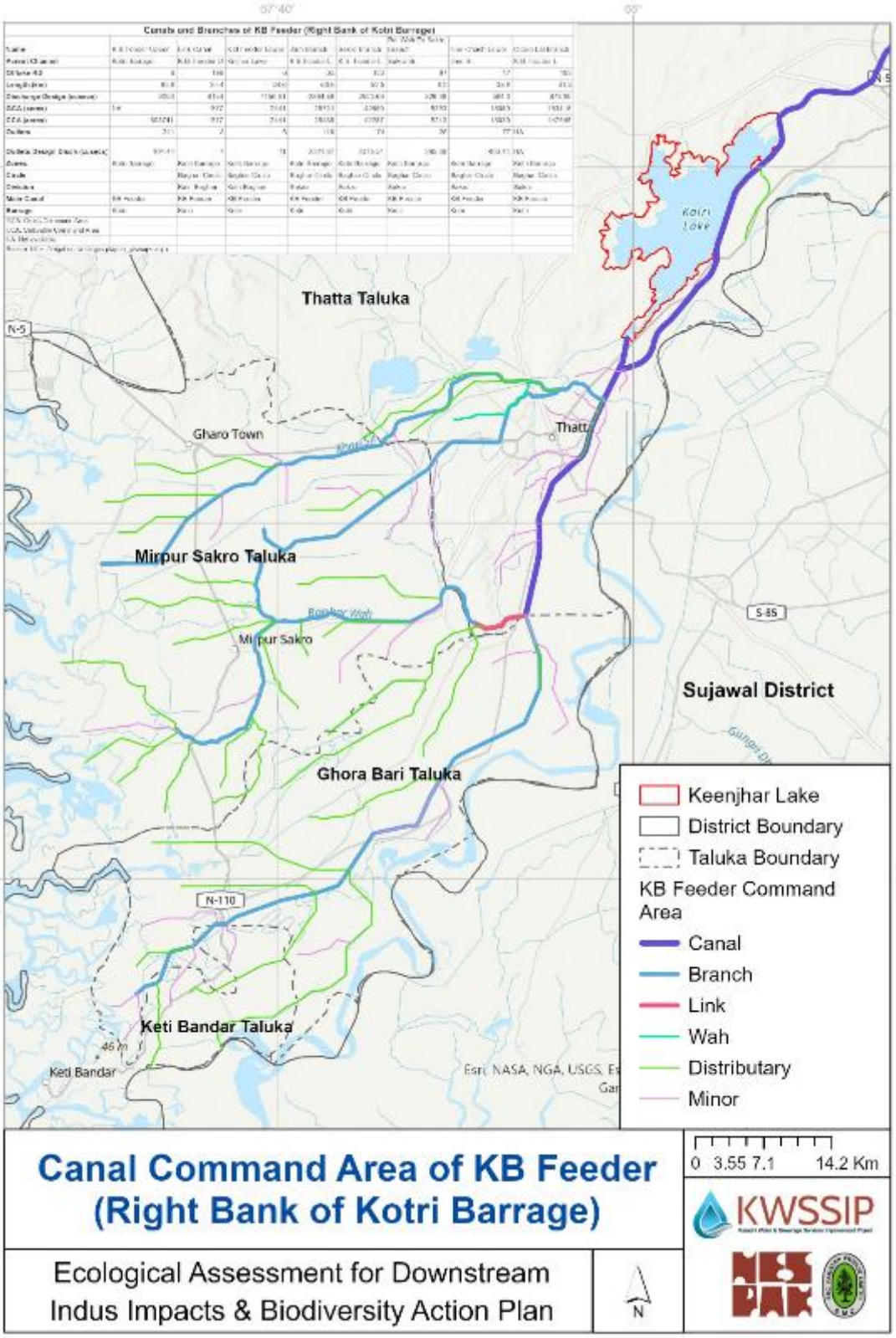
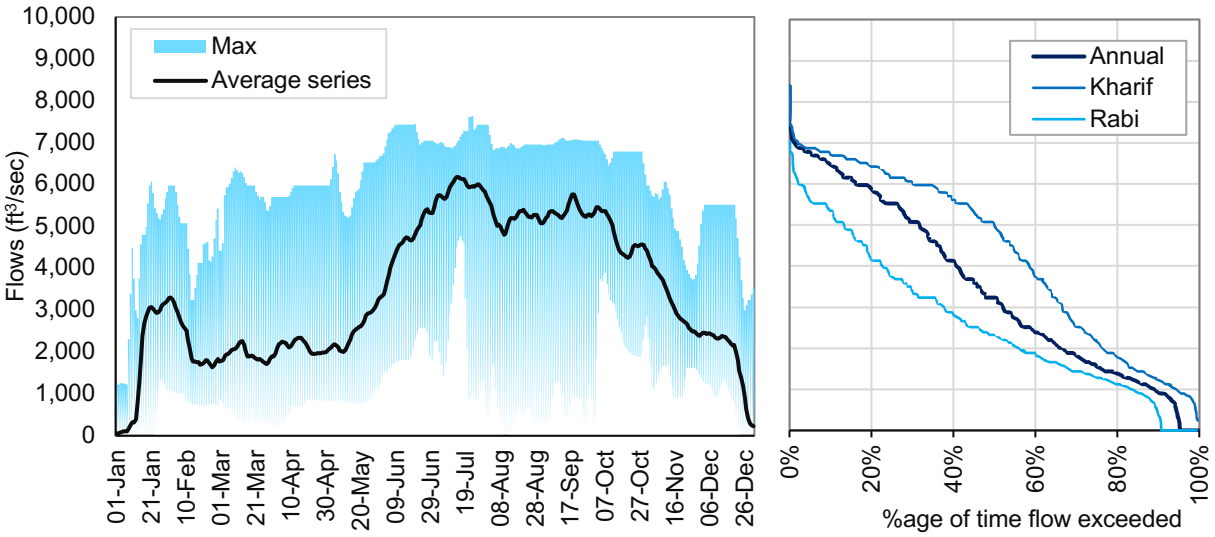


Figure 3-11: KB Feeder canal command area showing canals, branches, links, wahs, distributaries and minors

The historic operation of KBFU presented in Graph 3-20 shows that it had never been operated at its design discharge during the last 20 year. Below is the graph representing the most recent discharge values over a year in KB Feeder.



Graph 3-10: Historic operation and flow duration analyses of KBFU canal

The cultivable command area of KB Feeder is 603,741 acres. The command area is comprising the whole district thatta including 4 talukas namely: - Ghorabari, Keti Bunder, Mirpur Sakro, and Thatta comprising 9 Talukas included 55 union councils. Most of the lands of Project area are barren due to water logging, salinity and fish ponds. Some of the lands become waste land mainly due to non-availability of water because of mismanagement. The underground water in most of the area is highly brackish and unfit for cultivation. The rainfall is (200mm) insufficient, unpredictable and meager and it is not enough to meet the crop consumptive requirements. Below is the description of social environment of Thatta district.

3.4.3. Description of Ecology of KB Feeder Command Area

The central part of the district is dominated by agricultural fields and human habitations and it is the command area of KB Feeder. The North-North western part is hilly known as Kohistan which is dry arid region of district with sparse vegetation which is not part of the study area. The South-South western part of the district is deltaic region where Mangrove Forest is situated which is discussed in other section.

3.4.3.1. Flora

Due to hot weather and sporadic rainfall the flora cannot be expected to be very rich and diverse. Also, because of growing population and increasing agricultural activity, most of the natural vegetation in the district has been replaced by agricultural fields. Most of the plant species present in the site are cultivated.

Table 3-15: List of Key Plant Species found in district Thatta

Flora type	Scientific Name	Common Name
Trees	*Acacia nilotica*	babul

Flora type	Scientific Name	Common Name
	Acacia senegal	khor, babur
	Albizzia lebbeck(L) Benth	Sirus
	Calotropis procera	
	Salvadora oleoides	khabar
	Acacia arabica	kikar
	Commiphora wrighti Bhandari	Guggul/ Mukul
	Commiphora stocksiana	
	Datura metel L.	Dhaturo
	Tamarix gallica	lai
	Tamarix aphylla	lai
	Euphorbia cauducifolia	
	Lasiurus sindicus	
	populus euphratica	*willo* or bahan
	Capparis aphyila	karir, kirur
	Salvadora oleoides Dcne	Khabbar
	Eleusine flagelliforia	
	Salsola foetidia	
	Baleria acanthoides	
	Aristida sp.	
	Ziziphus nummularia	
	Cordia gharaf	Lyar
	Grewia villosa	
	Leptodenia pyrotecneca	
	Lyssium depressum	
	Pterophyllum oliveri	
	Tecomella undulata	Roxb.
	Seeman	Lohiro
Grass	Arisdita adscensionis	
	A. utabilis	
	Cenchrus ciliaris	
	Cenchrus biflorus	
	Cenchrus pennisetformis	
	Cynodon dacdylan	
	Cymbopogon jawarancusa	
	Digitaria sp	
	Eleucine flagellifera	
	Phyla nodiflora (L.)	
	Greene	
	Saccharum spontaneum	
	Sporobolus marginantus	
	Desmostachya bipinnata (L.)	
	Stapf (Dabh)	
Forbs	Aerva tomentosa	
	Cassia holoserica	
	Convolvulus glomeratus	
	Crotolaria bifolia	
	Fagonia cratica	
	Helotropium ophioglossum	
	Rynccosia minima	
Bush	Devi	
	Chali	
	Damral	

Flora type	Scientific Name	Common Name
	Darathi	
	Rhazya stricta	
	Fagonia indica	Damaho/drummahu
	Cordia gharaf	Levar
	Seena holosericea	dadwal/dadool
	Peganum harmala L.	
	Indegofera oblongifolia	jhal

Source: Ecological Survey conducted by EMC (2012)

Among trees Lohiro (*Tecoma undulate*), Khunbhat (*Acacia Senegal*), Babul (*Acacia nilotica*), Kandi (*Prosopis cineraria*), Devi (*Prosopis juliflora*) are common.

Commonly found shrubs include Khabar (*Salvadora oleoides*), *Calotropis procera*, Kirir (*Caparis aphyla*), Lai (*Tamarix aphylla*), Lawa (*Tamarix dioca*), Ber (*Ziziphus numularia*), Kaanhn (*Saccharum spontaneum*).

3.4.3.2. Fauna

Wildlife

As a result of shift in land use from a previously uncultivated land to presently extensively cultivated area, the wildlife has noticeably educed. Due to human intervention, most of the endemic wildlife has either left or become locally extinct. The animals that are now found are common species that are highly adaptable and able to coexist with people. Cape hare, fox, Asiatic jackal and porcupine constitute the dominant wildlife species in the district. Cape hare is also sighted during the day which indicates that predators are not common in the area. The number and frequency of visits by other animals into the area is reported by the locals to have substantially reduced in recent period.

Birds

The most common birds found in the district are sparrows, robins and doves. Characteristic bird species that have adapted to the environment and are still found in the area include the Indian grey partridge (*Francolinus pondicertanis*), chest-nut-bellied sand grouse (Pterocles exustus), rock dove (Columbia livia), Indian little button quail (*Turnix sylvatica*) and Eurasian roller (*coracias garrulous*). Other birds reported in the area include Grey Parttridge (*Francolinus pondiceranus*); Indian Sand grouse (*Pterocles exustes*); Painted Sand grouse (Pterocles indicus); Partridge (*Ammoperdix griseogularis*) Teetar/Sissi Tittar; Common Quail (*Coturnix coturnix*) Butair/Bhuntrio; Eurasian Wryneck (*Jynx torquilla*) Gandam Muroor/Nando Kath-Kulho; Sindh Woodpecker (*Dendrocopos assimilis*) Sindhi Khat-Khat/Kath Kutho; Common Hoopoe (*Upupa epops*) Hud Hud; Indian Roller (*Coracias benghalensis*) Neel Kanth/Sat Rango; Asian Koel (*Eudynamys scolopacea*) Koel/Koel; Rose-ringed Parakeet (*Psittacula krameri*) Tota, Gulabi Kanth Tota/Mitthu; Spotted Owlet (*Athene brama*) Chittidar Ullu/Nandho Chibhro; Rock Pigeon (*Columba livia*) Jhungi Kabutar; Indian Collared Dove (*Streptopelia decaocto*) Bari Fakhta; Common Crane (*Grus grus*) Koonj; Tawny Eagle (*Aquila rapax*) Gandoori Okab, Common Myna (*Acridotheres tristis*) Myna; Pale Crag-martin (*Hirundo obsoleta*) Ababeel; House Sparrow (*Passer domesticus*).

Reptiles

The spiny-tailed lizard (*Uromastyx hardwickii*) Sandho/Sandha is highly abundant in this area. Most of the sand mounds in the district were found to have its burrows. The species are included in Appendix III of the CITES. The abundance of this lizard gives an indication about the absence of birds of prey in the area.

Other reptiles reported in the area includeYellow-headed Agama (*Stellio Agama nupta fusca*) Sar Pahari Girgit, Indian Garden Lizard (*Calotes versicolor*) Wann Kirro/Rang badal Girgit, Long-tailed Desert Lacerta (*Eremias guttulata watsonana*) Wadhi Puch Kirri/Taweel dum Sandhi, Sindh Sand Gecko (*Crossobamon orientalis*) Thari Kirri/Regi Chhupkali.

Mammals

Indian Pangolin (*Manis crassicaudata*) Safna Shikam is included in the IUCN Red List as low risk, near threatened; Jackal (*Canis aureus*) /Geedarr; Ratel (Honey Badger) (*Mellivora capensis*) Gorrpat/Qabar Ka Bijju; Small Indian Mongoose (*Herpestes javanicus*) Chhota-Neula; Black-naped Hare (*Lepus nigricollis dayanus*) Saho/Khargosh; Grey Spiny Mouse (*Mus saxicola*) Chooha are reported in the area.

Livestock

Locals rear herds of livestock for source of food and additional income. Sheep (*Ovis aries*), Goat (*Capra aegagrus hircus*), Camel (*Camelus*), Horse (*Equus caballus*), Ass (*Equus asinus*) and mule are the main livestock of the district. People prefer keeping cattle rather than goats or sheep. However, during drought condition Livestock in the district suffers in particular from shortage of high-quality feed and fodder crops as a result of the overall shortage of water[27].

3.4.3.3. Irrigated Plantations

The concept of irrigated forestry was introduced during the British Rule with an objective of supplying firewood to railways, steam boats and ships and fuel wood for military cantonments in the territory of Sindh then part of Bombay Presidency Species such as *Acacia nilotica* (Babul), *Dalbergia sissoo* (Shisham), *Eucalyptus camaldulensis* and *Salmalia malabaricum* (Simal) were planted in these plantations in varying proportions during different times under different conditions. Kotri Barrage command area has 0.03 million ha of irrigated plantations.

3.4.4. Description of Social Environment of KB Feeder Command Area

3.4.4.1. Administration Background

District of Thatta population is about 0.98 million which is almost 2.0% of Sindh's population of about 47.9 million. With 184,868 households, the average household size in the district of Thatta is 5.3 as per the Census of 2017 compared to average household size of 5.5 in Sindh. According to MICS 2018-19, mean household size of Thatta is 7.7 as compared to mean household size of 6.5 in Sindh. 82% of Thatta population resides in rural areas and 18% resides in the urban areas.

[27] Pakistan Emergency Situational Analysis, District Thatta, 2014

Thatta population comprises of 510,279 males and 469,504 females with 52% and 48% of the district's population respectively. District of Thatta spans over an area of 7,705 sq. km which is 5.5% of Sindh's total area of 140,914 sq. km. The population density of the district is 127/sq. km.

District Thatta comprises of 4 talukas, namely: - Ghorabari, Keti Bunder, Mirpur Sakro, and Thatta. District Thatta has 4 Urban Centers, 55 Union Councils and 655 Revenue Villages.

Table 3-16: Population Distribution by gender and urban/Rural Census-2017

Population	Households
979,817	184,868
Rural	**Rural**
803,759	152,881
82.00%	83.00%
Urban	**Urban**
176,058	31,987
18.00%	17.00%

Population by Gender

	Total	Rural	Urban
Male	510,279	418,992	91,287
Female	469,504	384,754	84,750
Transgender	34	13	21

Source: PBS- Final Census Results 2017

Table 3-17: Ownership of Housing of district Thatta

Location	Own %	Rent %	Others/Missing %
Sindh	77.7	14.9	7.3
Thatta	88.4	4.4	7.3

Source: Sindh District Profile-2021

3.4.4.2. Utilities

Access to basic facilities like clean drinking water, toilets and sanitation services provide a holistic supply-side service provision coverage in a district.

In District Thatta, 82.0% of households have improved sources of drinking water compared to 96.0% households in Sindh having improved sources of drinking water. In terms of access to sanitation services, 24.4% of households in Thatta have access to improved sanitation

services compared to 65.9% of households in Sindh with access to improved sanitation services. The prevalence of open defecation in Thatta is 58.4% compared to 24.0% in Sindh.

Table 3-18: Source of Drinking Water of district Thatta

Location	Basic Service %	Limited Service %	Unimproved %	Surface water %
Sindh	90.3	5.7	2.1	1.9
Thatta	72.8	9.1	2.4	15.8

Source: Sindh District Profile-2021

Table 3-19: Access to Sanitation district Thatta

Location	Basic Service %	Limited Service %	Unimproved %	Surface water %
Sindh	58.8	7.1	11.1	24
Thatta	20.6	3.8	17.1	58.4

Source: Sindh District Profile-2021

3.4.4.3. Health

District Thatta has a total of 8 Government, Departmental, Private and Local Bodies Hospitals with a capacity of 300 beds compared to 648 Hospitals in Sindh with a capacity of 30,126 beds. Thatta has a total of 22 Basic Health Units (BHUs) with a capacity of 44 beds compared to 800 BHUs in Sindh with a capacity of 1615 beds. Thatta has a total of 6 Rural Health Centers (RHCs) with a capacity of 80 beds compared to 133 RHCs in Sindh with a capacity of 1703 beds in Sindh.

Thatta has a total of 91 Dispensaries with a capacity of 10 beds compared to 2,996 Dispensaries with a capacity of 715 beds in Sindh. District Thatta has a total of 8 TB Clinics with no beds compared to 228 TB Clinics with total capacity of 42 beds in Sindh. Thatta has 6 Mother & Child Health Centers (MCHCs) with a total of 4 beds compared to 227 MCHCs with a total of 181 beds. Similarly, Thatta has 1 Maternity Home out of 42 Maternity Homes in the province.

Table 3-20: Health care facilities in Thatta

Health facility name	Medical Centers	Beds
Basic Health Units (BHUs)	22	44
Rural Health Centers (RHCs)	6	80
Dispensaries	91	10
Government	10	0
Semi Government	3	0
Local Bodies	50	0
Private	28	10
TB Clinics	8	0
Government	8	0
Private	0	0
Mother and Child Health Centers (MCHC)	6	4
Government	0	0
Semi Government	1	4

Local Bodies	0	0
Private	5	0
Maternity Homes (Government)	1	NA

Source: Sindh District Profile-2021

3.4.4.4. Housing

Housing characteristics including household size, ownership status, roofing, walls and assets provide a holistic description of the overall well-being of the household. Description of household characteristics provide a snapshot for the government to improve target housing conditions as per district-wise deprivations.

In District Thatta, 88.4% of population owns houses while 11.7% don't own their houses (4.4% rented) compared to 77.7% of the population in Sindh province who own their houses. According to MICS 2018-19, the average number of persons per room in Thatta is 4.9 compared 4.1 persons per room in Sindh. Similarly, the mean household size of District Thatta is 7.7 compared to mean household size of 6.5 in Sindh.

Only 39.8% of households in Thatta have Pacca roofing compared to 70.7% households in province that have Pacca roofing. Similarly, only 38.1% households in Thatta have Pacca walls compared to 70.7% households in the province that have Pacca walls.

3.4.4.5. Education

District of Thatta has a total of 1,607 schools out of a total of 49,103 schools in the province of Sindh. Out of 1,607 schools, there are 552 schools for boys,182 schools for girls, and 873 mixed schools.

Table 3-21: Numbers of Government Schools in district Thatta

Location	Total	Boys	Girls	Mixed
Sindh	49,103	8,617	6,685	33,801
Thatta	1,607	552	182	873

Source: Sindh District Profile-2021

1,607 schools in District Thatta have a total enrollment of 78,434 with 50,854 boys (64.8%) and 27,580 girls (35.2%). There are 1,727 male teachers and 663 female teachers in the schools in Thatta. Total number of rooms in 1,607 school s in Thatta amount to 3,476 out of which 2,501 are classrooms. There are 908 functional schools in Thatta while 699 schools are dysfunctional, non-functional, non-viable or closed.

Table 3-22: Enrollments of Students in district Thatta

Location	Boys	Girls
Sindh	2,812,000	1,749,140
Thatta	50,854	27,580

Source: Sindh District Profile-2021

Male literacy rate (15-49 years) in Thatta is 26.5% compared to 59.0% in Sindh while the female literacy rate is 14.3% compared to 40.9% in Sindh.

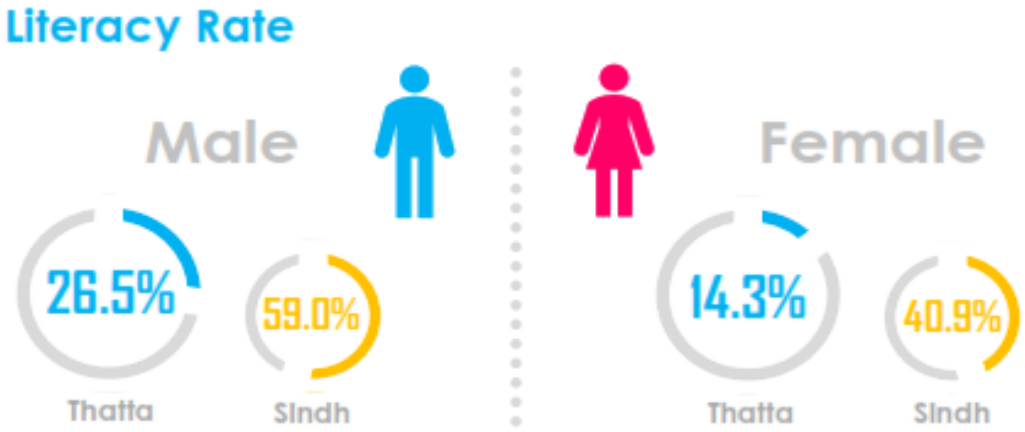


Figure 3-12: Male and Female literacy rate of district Thatta

3.4.4.6. MPI (Multi-Dimensional Poverty Index)

Multi-Dimensional Poverty Index measures the number of people/households that are 'multidimensionally' poor. Essentially, it means the number of people (or HHs) deprived in at least one third of the weighted indicators (H) along with the weighted average number of deprivations poor people experience at the same time (A). The weighted indicators are along three broad dimensions: -Education, -Health, and -Living Standards.

In District Thatta, the MPI value is 0.60 which is higher than the average MPI Value of 0.25 in Sindh.

Table 3-23: MPI Head Count of district Thatta

Location	M-Poverty Headcount 2018 (H)	MPI 2018	% Vulnerable to Poverty	% In Severe Poverty
Sindh	0.47	0.25	12.5	28.3
Thatta	0.86	0.60	4.00	69.00

Source: Sindh District Profile-2021

3.4.4.7. Economic Profile

Agriculture

Majority of the area lies barren due to land degradation (water logging, salinity and fish ponds). The major crops grown in Thatta during Rabi season are Wheat, oilseeds, vegetables and fodder. The Kharif season crops include rice, cotton, maize, chilies and Kharif fodder. Sugarcane and banana were grown as perennial crops. The computed existing cropping pattern and intensities are given in Table 3-24. The existing annual cropping intensity of the project area has been worked out as 52 percent only (i.e., 27.60 percent during Kharif, 13.4 percent during Rabi season and 11 percent in perennial). The cropping pattern constitutes specifically Rice (23 %) Cotton (1.4 %) Maize (0.4 %) K. Fodder (0.8 %) K. Vegetable (2 %)

Wheat (5.40 %) Oilseeds (3.30 %) R. Vegetable (3.7 %) R. Fodders (1 %) Sugarcane (8 %) and Banana (3 %)[28].

Table 3-24: Existing Cropping Pattern and Intensities (% of CCA)

		CCA = 676000 acres
Crops	**Intensity (%)**	**Cropped Area (acres)**
Rice	23.00	155480
Cotton	1.40	9464
Maize	0.40	2704
Vegetable (Chilies)	2.00	13520
Kh. Fodder-(Maize)	0.80	5408
Kh. Total:	**27.60**	**186576**
Wheat	5.40	36504
Oilseed	3.30	22308
Tomato	3.00	20280
Onion	0.70	4732
R. Fodder (Barseem)	1.00	6760
Ra. Total:	**13.40**	**90584**
Orchards II (Banana)	**3**	**20280**
Sugarcane	8	54080
Perennials Total:	**11**	**74360**
Grand Total:	**52**	**351520**

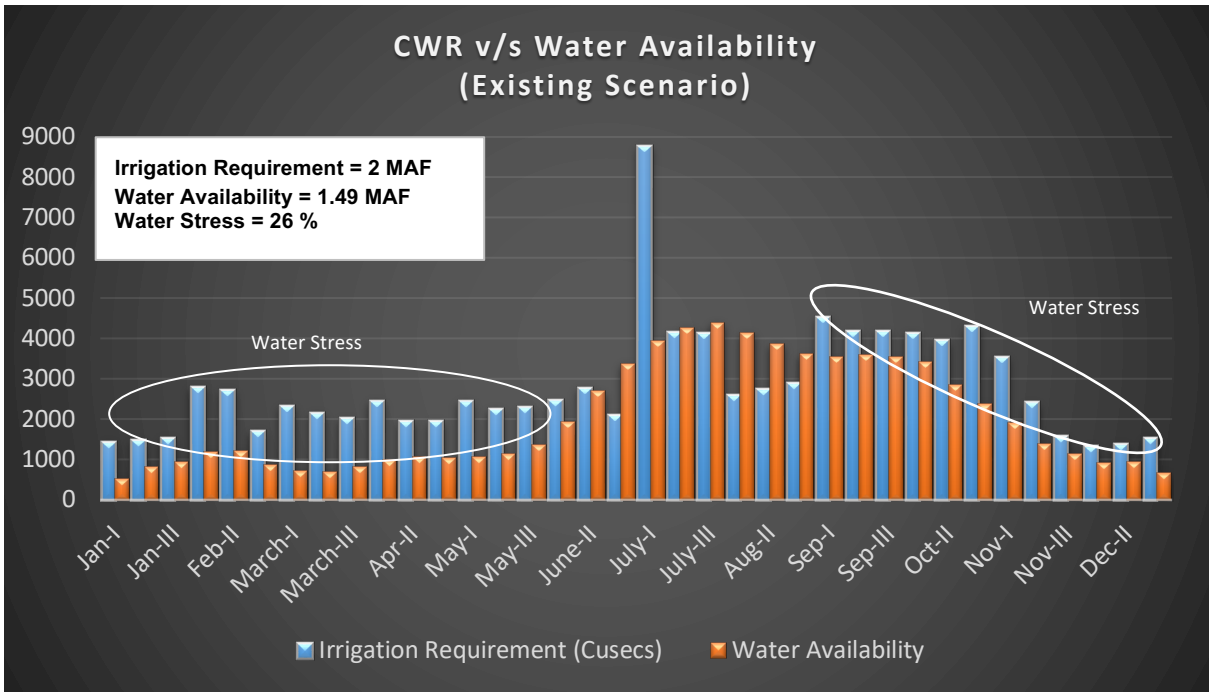
Source: Water Balance and Cumulative Impact Assessment of the Proposed Increase in Abstraction at Keenjhar Lake for the K-IV Mainstream Project (2023), NESPAK.

The exiting yields for Rabi crops i.e. wheat, oilseed, tomato, onion and R. fodder are estimated as 830, 3005, 360, 3005, 3950, and 13786 kg/acre, respectively. The exiting yields for Kharif crops i.e. rice, cotton, maize, K. vegetable and K. fodder are estimated as 1314, 1088, 450, 1213 and 4100 kg/acre, respectively. While for perennial crops like banana and sugarcane yields are estimated as 1980 and 20970 kg/acre, respectively. Human labor is an important input used at all stages of crop production from preparatory tillage to harvesting. Mostly family labor is used in project area for crop production whereas temporary hired labor is used particularly in peak demand period especially at the time of wheat harvesting. Female labor is playing a vital role in the project area for agricultural field activities, especially during the peak labor requirement.

Crop Water Requirement

In Existing condition as shown in graph 3-11 there are already shortages and water stress in both rabi and kharif season and that's the reason beyond low yields in baseline or existing condition. During rauni, pre germination, germination, development and maturity stages deficit has been observed.

[28] Water Balance and Cumulative Impact Assessment of the Proposed Increase in Abstraction at Keenjhar Lake for the K-IV Mainstream Project (2023), NESPAK.



Graph 3-11: Crop water requirement v/s water availability for Exiting scenario

Livestock & Fisheries

The livestock head-count in District Thatta is 2,297,937 out of the total livestock count of 46,279,313 in Sindh (4.9%). District Thatta has 410,614 cattle, 367,117 buffaloes, 162,131 sheep, 351,366 goats, and 973,268 poultry. Fish production in Thatta is 8,670 M. Tons out of 133,150 M. Tons in Sindh (6.5%). Thatta has a total of 6,922 fishermen out of 45,013 in Sindh (15.4%). Similarly, Thatta has 1,031 boats out of 7,215 boats in Sindh.

Table 3-25: Livestock Count of Thatta

Livestock	Sindh	Thatta	Share of Thatta (%)
Cattle	6,925,022	410,614	5.9
Buffaloes	7,341,162	367,117	5.0
Sheep	3,958,508	162,131	4.0
Goats	12,572,221	351,366	2.7
Camels	278,424	10,702	3.8
Horses	44,999	3,036	6.7
Mules	19,512	566	2.9
Asses	1,004,925	19,137	1.9
Poultry	14,135,540	973,268	6.8

Source: Sindh District Profile-2021

3.5. Baseline Description of Indus Delta - A relatively mixed zone with compromised agriculture and ultimately, making an interface with mangroves

This component of AoI encompasses an area of 667,209 ha of Indus Delta Region in the Thatta and Sujawal districts of Sindh Province in south-eastern Pakistan. The delta is a vast complex of tidal river channels and creeks, low-lying sandy islands, mangrove forests and inter-tidal areas. The delta's mangrove forests are unique in being the largest area of arid climate mangroves in the world[29].

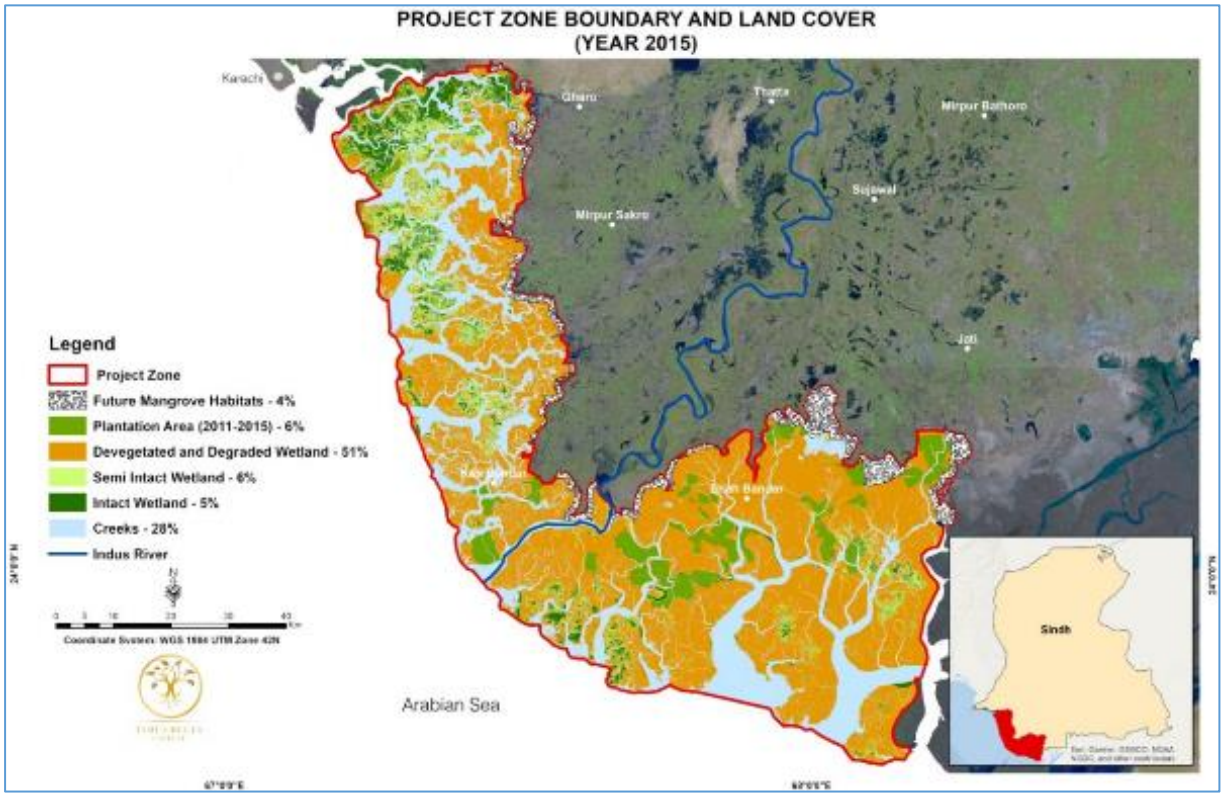


Figure 3-13: Map showing Indus Delta Boundaries and land cover (Source: Project Document - Delta Blue Carbon – 1, March 2021)

The Indus Delta contains the world's largest area of arid climate mangroves. The Indus Delta is comprised of 17 major creeks, numerous minor creeks and extensive areas of mangrove forests and tidal wetlands. The dense mangrove forests are mainly located in the pockets created by the creeks. The dense mangrove forests are primarily found in creek-formed pockets. About 667,209 ha in size, the delta is a significant ecosystem in this region. It relies almost entirely on freshwater discharges from the Indus River and a small amount of freshwater from Karachi's domestic and industrial effluents.

3.5.1. Climate

Tropical climate prevails in the Indus Delta region. While the monsoon regime dominates the eastern portion of the country, coastal regions receive minimal precipitation. The average annual rainfall along the coast of Sindh is approximately 200 mm. April and October are

[29] Project Document - Delta Blue Carbon – 1, March 2021 (https://deltabluecarbon.com/document/)

transitional months between the southwest and northeast monsoon seasons, which last from May to September and November to March, respectively. Wind speeds during SW monsoons are approximately 25-30 Knots and during NE monsoons they are 5-10 Knots. Therefore, atmospheric and oceanic circulation is more vigorous during the SW monsoon than during the NE monsoon. The circulation of the southwest monsoon appears to penetrate deeper, influencing the movement of water masses below the thermocline, whereas the drift during the northeast monsoon is relatively shallow. The tides are of the mixed semidiurnal type, with two high tides and two low tides each day, with the highest tide reaching a height of 2.60 m.

3.5.2. Historical freshwater and sediment supply into the Indus Delta area

The fertile high-lying deltaic areas, mainly at the interface of the Indus River and away from the coast, were cultivated on fresh water from the river, or a mixture of saline and fresh water having very low salinity levels. During that era, the communities of Kharo Chan, Keti Bundar and Shah Bundar had very good agrarian economy and these areas would produce red rice in abundance on fresh water, as reported in gazetteers and revenue records (Hague, 1894).

The increase in salinity due to depleting freshwater has reduced the suitability of the delta for the cultivation of agricultural and horticultural crops, and raising of livestock due to loss of grazing lands. The mangrove ecosystem has also been degraded due to a combination of water flow reductions and direct human destruction and overuse (Inam et al., 2006)[30].

The Project Zone is located in the Indus Ecoregion, a biodiversity hotspot identified by the WWF's Global 200[31]. The Ecoregion consists of riverine forests along the Indus River, mangrove forests and tidal wetlands in the coastal areas, and desert ecosystems on the periphery. The area, which covers around 65% of the Sindh Province, is regarded as the 40 most biologically rich in the Asia-Pacific region.

The fan-shaped Indus Delta is the fifth largest delta in the world and is located south of the Indus Ecoregion. It is a vast complex of multiple tidal river channels and 17 major creeks, low-lying sandy islands, mangrove forests, and intertidal lands extending from Korangi Creek in the west to Sir Creek near the Indian border in the east. **In November 2002, the Indus Delta was designated a Ramsar Site**.

3.5.3. Communities Livelihood

The livelihoods of Indus Delta communities revolve around three areas: fishing, agriculture, and raising livestock. Other than the farming community, a large number of the landless own and manage livestock and work in non-farm employment. Most of the other workers are engaged in casual labor. Agro-based industries are also operational in the area and a source of employment for some, particularly the sugar and rice industries. The majority of the population in the Indus Delta rely on fishing as their main livelihood source.

[30] Inam, Asif, Peter D. Clift, Liviu Giosan, Ali Rashid Tabrez, Muhammad Tahir, Muhammad Moazam Rabbani and Muhammad Danish, 2007. The Geographic, Geological and Oceanographic Setting of the Indus River. *In Large Rivers: Geomorphology and Management, Edited by A. Gupta © 2007 John Wiley & Sons, Ltd.*

[31] Olsen, D.M. and E. Dinerstein. 2002. The Global 200: Priority Ecoregions for global conservation. Annals of the Missouri Botanical Garden 199-224

Figure 3-14: Fishing is the main occupation (Photo Credit: Project Document - Delta Blue Carbon – 1, March 2021)

3.5.4. Biodiversity

The dominating flora of this section is mainly dominated by mangroves in the intertidal zone. The adjacent area, though defined as riverine, is mainly occupied by *Salvadora persica* and *Salvadora oiliedes*, species of Tamarix may also be found making interphase. The following floristic list represents a few of the dominant life forms in the area.

Algal blooms can also be seen in the post-monsoon and early winter seasons. They often restrict mangrove growth by entangling them with their thallus.

Table 3-26: Floral diversity of Janghi Sur downstream Indus River to Arabian sea.

Mangroves				
1	*Avicennia marina*	Timer	Least Concern	The mangroves of provide the habitat for fish, birds, reptiles, mammals, amphibians and crustaceans.
2	*Rhizophora mucronata*	Kumri	Least Concern	
3	*Aegiceras corniculatum*	Chaunr	Least Concern	
4	*Ceriops tagal*	Kiriri	Least Concern	
Algae				
5	*Cyanophyta*	Not Available	Common	• Food chain • Fish culture • Sewage treatment
6	*Chlorophyta*	Not Available	Common	
7	*Bacillariophyta*	Not Available	Common	
8	*Euglenophyta*	Not Available	Common	

Note*: The conservation status vegetation has been assessed through IUCN red list of species.

Coastal Biodiversity

The main vegetation type in the Indus Delta is the mangrove forest. Eight species of mangroves have been reported historically along the Sindh Coast i.e., *Avicennia marina, Rhizophora mucronata*, *Ceriops tagal, Aegiceras corniculatum, Ceriops roxburgiana, Burguiera conguga, Rhizophora apiculate and Sonneratia caseoiaris*. At present, only four survive. *Avicennia marina* is the most common mangrove species found in the area. Avicennia marina can attain heights up to 9 m and girth of 50 cm^2. The other species found are *Rhizophora mucronata*, *Ceriops tagal* and *Aegiceras corniculatum*.

Figure 3-15: Mature Mangrove Plantation Observed in the AOI

Within the Delta, there are two distinct types of mangrove forest, as depicted in Figure 3-14. In addition, planting activities are planned for a land cover type classified as highly degraded mangrove areas in order to increase and improve forest cover through reforestation and assisted natural regeneration.

Figure 3-16: Dense Mangrove Forest type in the Project Zone on the left and Sparse Mangrove on the right

Dense mangroves are typically found in narrow stretches along creeks and are dominated by *Avicennia marina*, *Rhizophora mucronata*, and *Ceriops tagal*, among others. *Avicennia marina* can grow as tall as 9 m and as wide as 50 cm^2. There has been some growth of *Tamarix spp*, *Acacia nilotica*, and *Prosopis juliflora*. Undergrowth may include small bushes of *Calotropis procera*, *Atriplex griffithii*, *Aerva javanica*, and *Polycarpaea corymbosa*. The forest class of Sparse Mangroves is most prevalent in sandy, dry areas, such as coastal dunes. *Suaeda*

fruticosa, *Salsola barysoma*, *Abutilon indicum*, *Sericostoma pauciflorum*, *Cressa cretica*, *Heliotropium undulatum*, *H. curassavicum*, *Solanum surattense*, *Cyperus conglomeratus*, and various grasses make up the majority of the vegetation.

A salient feature of arid mangroves in the Delta is that there is no understorey of shrubs, herbs and grasses mainly due to high saline conditions and lack of fresh water. However, the natural regeneration of *Avicennia marina* does occupy the gaps found in between other species like *Rhizophora mucronata* and *Ceriops tagal*. Vertically, the three major strata observed along the tidal creeks are: supratidal, intertidal, and subtidal. In each of these three vertical strata, there is a distinct community of species connected with mangrove vegetative structures.

The arboreal sections of mangrove forests comprise the supratidal or uppermost layer. Birds, reptiles, crabs, snails, insects, and spiders inhabit this layer. The intermediate or intertidal layer ranges from high to low water tidal heights and contains the mangroves' aerial root systems. The tides periodically submerge the major inhabitants of this zone (algae, barnacles, isopods, snails, crabs, amphipods and oysters). The lower or subtidal layer exists under the mean low water mark, where mangrove roots provide as a substrate for creatures accustomed to persistent submersion (anemones, tunicates, octocorals, nudibranchs, polychaetes, algae, sponges, brittlestars, shrimp and jellyfish).

Terrestrial and supratidal biodiversity

WWF 2007-08 have reported that 75 bird species including 28 resident and 47 migratory species, 21 species of reptiles, two species of amphibians, 63 species of fish and 24 species of shellfish in the region.

The Indus River, which runs through the heart of the Delta is the main migration route called Indus Flyway is the famous International Migratory Bird Route Number 4. The migratory birds from Siberia followed this route till they reach the mudflats in the Indus Delta. The small Dhands (lakes) formed in the delta provide an excellent breeding and foraging grounds.

Termites and ants (Formicidae) are pervasive and are clearly the most abundant terrestrial animals in these mangroves. It is estimated that may species of ants live in direct association with the mangroves, utilizing hollow twigs and branches as nest sites[32].

Among mammals, wild boar, the Indian jackal, the Bengal fox, the fishing cat, cetaceans (humpback dolphin and bottle-nosed dolphin) and the endangered Indian Pangolin were recorded. Sea snakes are the most common reptiles in the creeks and deltaic plains.

Intertidal and subtidal biodiversity

In addition to the mangrove trees, other primary producers in mangrove communities and adjacent areas include microscopic and macroscopic algae. Microscopic algae are found in the plankton (phytoplankton), on mangrove roots (periphyton) and other substrates (epibenthic), and within the tissues of sea anemones, ascidians, sponges, and other animals (endobionts).

[32] Feller, I.C. and M. Sitnik, 1996. Mangrove Ecology Workshop Manual. Smithsonian Institution, Washington, D.C

A total of 38 finfish species, 21 shellfish (shrimps, gastropods and bivalves) were identified at different locations in the Delta. *Liza subviridis* of the family Mugilidae, was found to be the dominant species making 14.36% of the total, whereas two other species of the family Sciaenidae, *Johnius carouna* and *Otolithes ruber*, were at 9.41% and 9.94%, respectively[33].

3.5.5. Species of High Conservation Value (HCV) of Indus Delta

The Delta is the home to at least 11 species on the IUCN Red List. Seventy-five birds, ten mammals, and eight reptile species were recorded from sampling locations of Keti Bander, Kharochaan, Shah Bander and the Korangi Creek[34].

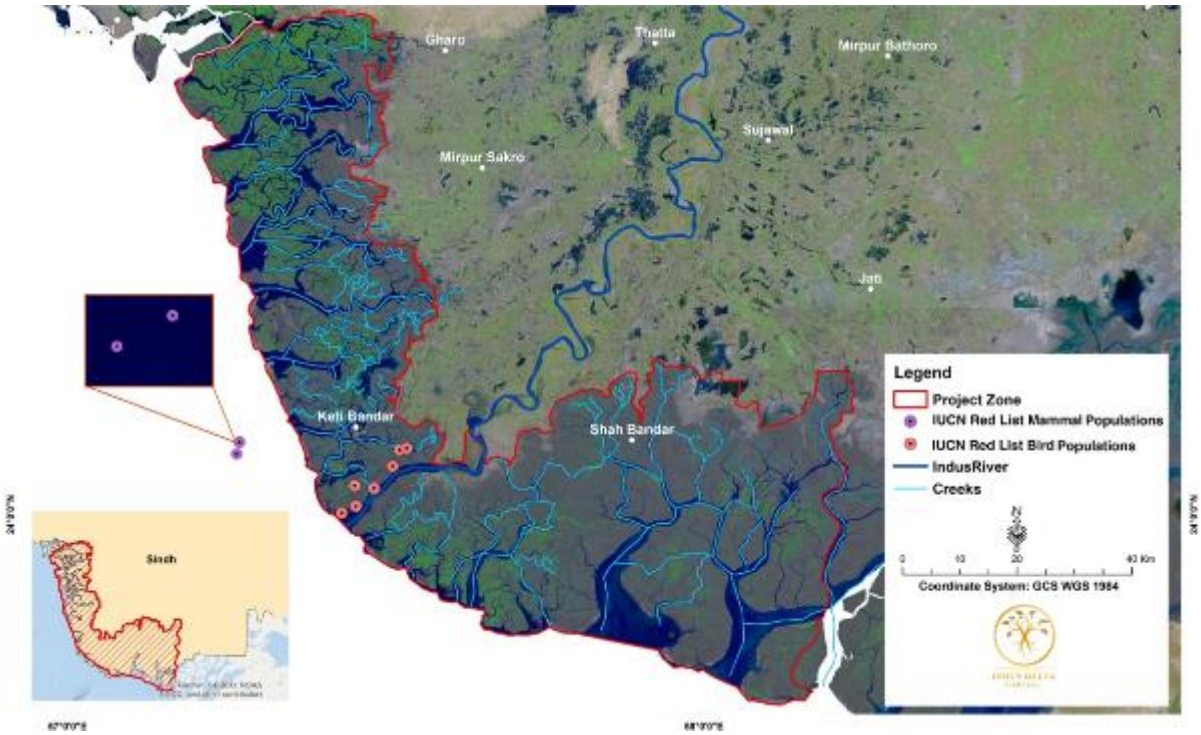


Figure 3-17: Map delineating Biodiversity HCV areas within the Project Zone (Source: Indus Delta Capital - Karachi)

Below table listed the reported species having High Conservation Value.

Table 3-27: High Priority IUCN Red Listed species found within the Indus Delta

Species Name	IUCN Red Listing	CITES Appendix
Fishing cat (*Prionailurus viverrinus*)	VU	II
Indian pangolin (*Manis crassicaudata*)	EN	II
The Indian humpback dolphin (*Sousa plumbea*)	EN	I
Painted stork (*Mycteria leucocephala*)	NT	
Dalmatian pelican (*Pelecanus oncrotalus*)	NT	
Egyptian vulture (*Neophron percnopterus*)	EN	I
Cinerous vulture (*Aegypius monachus*)	NT	II
Black- tailed godwit (*Limosa limosa*)	NT	II
Bar-tailed godwit (*Limosa lapponica*)	NT	II
Eurasian curlew (*Numenius arquata*)	NT	I

[33] Project Document - Delta Blue Carbon – 1, March 2021
[34] Project Document - Delta Blue Carbon – 1, March 2021

3.5.6. Reconnaissance Survey of Indus Delta

Consultant team visited the different ARR plots managed by SFD in Indus Delta inside the REDD+ project boundary to observe the planted mangrove as well as natural growth especially in Dabbo, Hajamro, Khobar, Turshan and Khar Creeks.

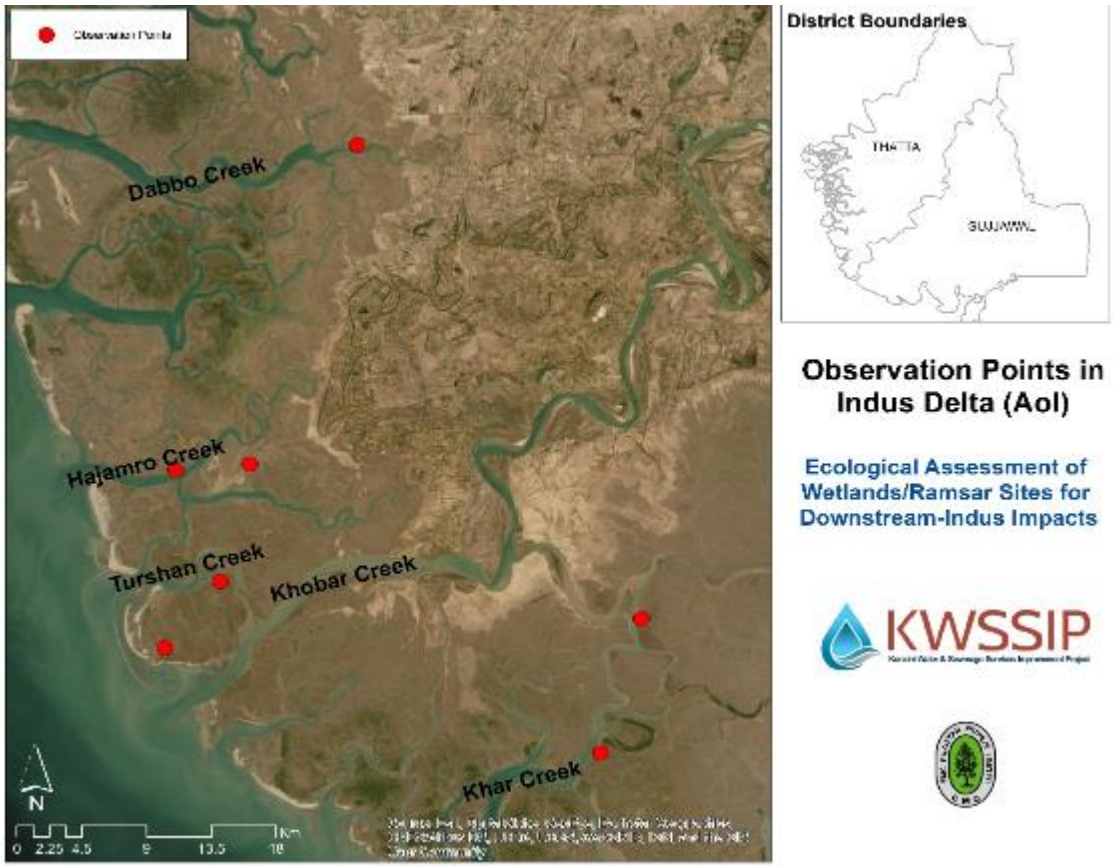


Table 3-28: Locations of Reconnaissance Survey Observation Points in Indus Delta Creek System

Figure 3-18: Pictures taken during Reconnaissance Survey

Observation Point 1, Khobar Creek

Northing (m) 2657273, Easting (m) 339036

Planted growth was shown in the observed location. Plantation of about 4 ft. tall *Avicennia marina* was observed. The plantation was done in 2015 as per SFD staff.

Observation 2, Khobar Creek

Northing (m) 2662051, Easting (m) 342888

Good plants of about 2-3 ft. in height of *Avicennia marina* are observed in patches with natural plantation. Crab holes are also observed in the area. The observation was taken at low-tide conditions and the point is submerged in water during high tide.




Observation Point 3, Hajamro Creek

Northing (m) 2670052, Easting (m) 339779

Healthy plantation of about 3 ft. in height *Avicennia marina* was observed which is as per SFD, planted in 2018. The *Rhizophora mucronata* was also planted in restocking recently by SFD. The Rhizophora plants were about 1-1.5 ft tall. The observation was taken at high-tide conditions and the point is submerged in water during survey.


Observation Point 4, Hajamro Creek

Northing (m) 2670470, Easting (m) 344939

Small plantation of *Rhizophora mucronata* was observed about 1 ft. tall with small natural plants of *Avicennia marina*. Due to low-lying area, the mortality rate of plants is high as per SFD officials. The area is mostly barren due to high salinity, high-lying profile of the area and no reach of fresh water from the river.


Observation Point 5: (SP16), Khar Creek

Northing (m) 2649727, Easting (m) 369322

Good healthy plants of about 2 ft. in height of *Avicennia marina* are observed in pattern. Very few plants of *Rhizophora mucronata* were also observed.


Observation Point 6: (SP27), Khar Creek

Northing (m) 2659360, Easting (m) 372126

Best plantation of about 6-7 ft. tall Rhizophora mucronata was observed. The plantation was done in 2015 as per SFD staff.




Observation Point 4, Dabbo Creek

Northing (m) 2693432, Easting (m) 352399

Sparse plantation of *Avicennia marina* was observed with a shrub *Tamarix aphylla*. The area is high-lying, however, *Avicennia* was restocked very well.


Other Specie Observations


A mudskipper prevalent in the area


Indian Pond Heron


Slug shells also prevalent in low-lying areas


Leptocephalus spp. often observed in low-lying mudflats where marine water reaches


Camel grazing is also prevalent in the area


Some parts of the mudflats are degraded due to unavailability of fresh water, usually they are high-lying areas

It is also observed during site visits of ARR plots of that plantation has been done by SFD but due to below environmental factors, mortality occurred and plants did not survive. To mitigate this, SFD restocks each year.

- **High-lying areas** - The water as well as nutrients could not reach in those areas and plants are either not grown or are very stunted. These areas located along fringes or near villages which are traditionally located on the elevated areas.
- **Soil** –The soil quality significantly affects the growth of the plants. In a same year planting plot, the growth of the plants varies or due to unfavorable soil, mortality occurs. So, in some plots, growth can be seen in patches. Soils found in the Indus Delta are not

peatlands but instead mineral lands. Depth varies and is subject to deposition and erosion. The soils tend to be well drained and low lying. The morphological development of the Indus Delta is primarily the result of interaction of fluvial and marine processes. The delta and its soils have historically been formed in an arid climate and under conditions of high river discharge, moderate tide range (2.6 m), extremely high wave energy (14 x 10' erg/sec), and strong monsoon winds from the southwest in summer and from the northeast in winter (Wells and Coleman, 1985)[35]. Indus Delta is a wave-dominated delta, characterized as a transgressive sand body, capped by extensive aeolian dune deposits[36].

- **Inundated areas / tidal influx** - These areas are completely submerged in water during high or low tide. So, the wave action plays their role and washes away the seeds or affects the saplings.
- **Grazing** – Grazing is also a factor which was not observed during field visit but reported in areas, albeit, significantly controlled by SFD officials. (Camel browsing used to be extremely harmful to the growth and natural regeneration areas).

Assisted Natural Regeneration (ANR)

In some of the plots, the plantation is undertaken without any pattern. During plantation drive, seeds spread or saplings sown in random manner in empty spaces among the natural mangrove plants.

Conclusion of the Survey

The extensive experience of SFD in restoring mangroves provides valuable lessons for other Asian nations to adopt and use. Since 2015, they have performed admirably in mangrove plantation throughout the Indus Delta. During the site visit, it was observed that SFD's personnel is safeguarding the planted areas from grazing and preserving them by restocking. Sindh's management of mangrove forests has seen a shift from neglect to active protection and from a top-down approach to a bottom-up, participatory approach reflecting recognition of many local, national and regional values of mangroves. These shifts have resulted in the evolution of numerous approaches for mangrove restoration that have been utilized effectively to rehabilitate degraded areas and maintain mangrove populations, notably in the Indus Delta, which is home to the majority of Pakistan's mangroves.

[35] Technical report no. 424 deltaic morphology and sedimentology with special reference to the Indus River Delta J T Wells and J M Coleman 1985.
[36] Project Document - Delta Blue Carbon – 1, March 2021.

Chapter 4 Impact Assessment and Mitigation Measures

4.1. Project Scenarios

Based on the above project description, four (04) project scenarios are developed to assess the ecological impacts on HCVs:

- Scenario 1 – Do Nothing or Baseline Scenario in which the water withdrawal is 650 MGD from Keenjhar Lake.
- Scenario 2.1 – Implementation of K-IV phase 1 - Abstraction of additional 260 MGD (402 cusecs) so the cumulative abstraction = 650+260 = **910 MGD** (1,408 cusecs) from Keenjhar Lake by managing additional water supply from revamping Kalri Baghar Feeder Upper (KBFU) to 9,100 cusecs.
- Scenario 2.2 – Implementation of K-IV phase 1 - by allocation of additional water supply from link canal through rotation of irrigation water if the lining of KBFU is not materialized / feasible.
- Scenario 2.3 – Implementation of K-IV phase 1 with no revamping of KBFU and no allocation of water from link canal.

Scenario 1 describes the baseline conditions and existing impacts occur on the ecosystems of HCVs. According to the review of baseline conditions of HCVs, the ecosystems are already degraded and in the declining state. Only one environmental component which is required to replenish and sustain the ecosystems present for HCVs is the water from Indus River which is the lifeline for Keenjhar Lake as well as downstream Kotri.

Scenario 2 describes the implementation of K-IV phase I and it is further bifurcated w.r.to the source of additional water supply or no additional water supply.

High Conservation Values (HCVs)

High Conservation Values (HCVs) are the critical biological, ecological, social, economic and cultural values in ecosystems and landscapes that are the key values which need to be conserved in the management of natural systems.

Keenjhar Lake is ecologically and socioeconomically important while command area of KBFU is socioeconomically important since it do not contain the key ecologically values and the area is highly modified by agriculture through irrigation. Most of the riverine forest existed along the banks of the Indus River has now been converted into agriculture lands.

4.2. Assessment of Impacts of Scenario 1

Scenario 1 describes the baseline conditions and existing impacts occur on the ecosystems of AoI. According to the review of baseline conditions of AoI, the ecosystems are already degraded and in the declining state. Water from Indus River and monsoon rains are the two

components which are essential to replenish and sustain the ecosystems present in AoI and the lifeline for Keenjhar Lake as well as Indus Delta.

The water is abstracted from Kotri Barrage through irrigation canals as well as water supply canal to Keenjhar Lake. Adequate environmental flows are required to sustain the ecosystems downstream Kotri. Scenarios as defined in Section 4.1 are assessed in below sections for AoI.

4.2.1. Current Issues and Threats for Keenjhar Lake (Scenario 1)

4.2.1.1. Hydrology of Keenjhar Lake

Remote sensing and delineation of Lake's water area from 2013-2022 (the last 10 years) was used using NDWI method as it was used for the study for AoI. The water pixels were separated from the other land use pixels and visualized on a map to compare the changes from the last year. The NDWI maps are presented in **Annex III**. From the NDWI results, it is concluded that the Lake's surface area has not changed substantially in the last 10 years.

The existing conditions are depicted from below figures. The lake shrinks from max to min. levels in terms of area is **17.2%**. The areas exposed after the shrinkage of lake are located at the inlet and along the western periphery of the lake, where the depth of the lake is lowest. The variation in the area submerged in water is the key factor affects the ecology and wetland character of the lake. The shrinking of the lake's area is not significant as perceived.

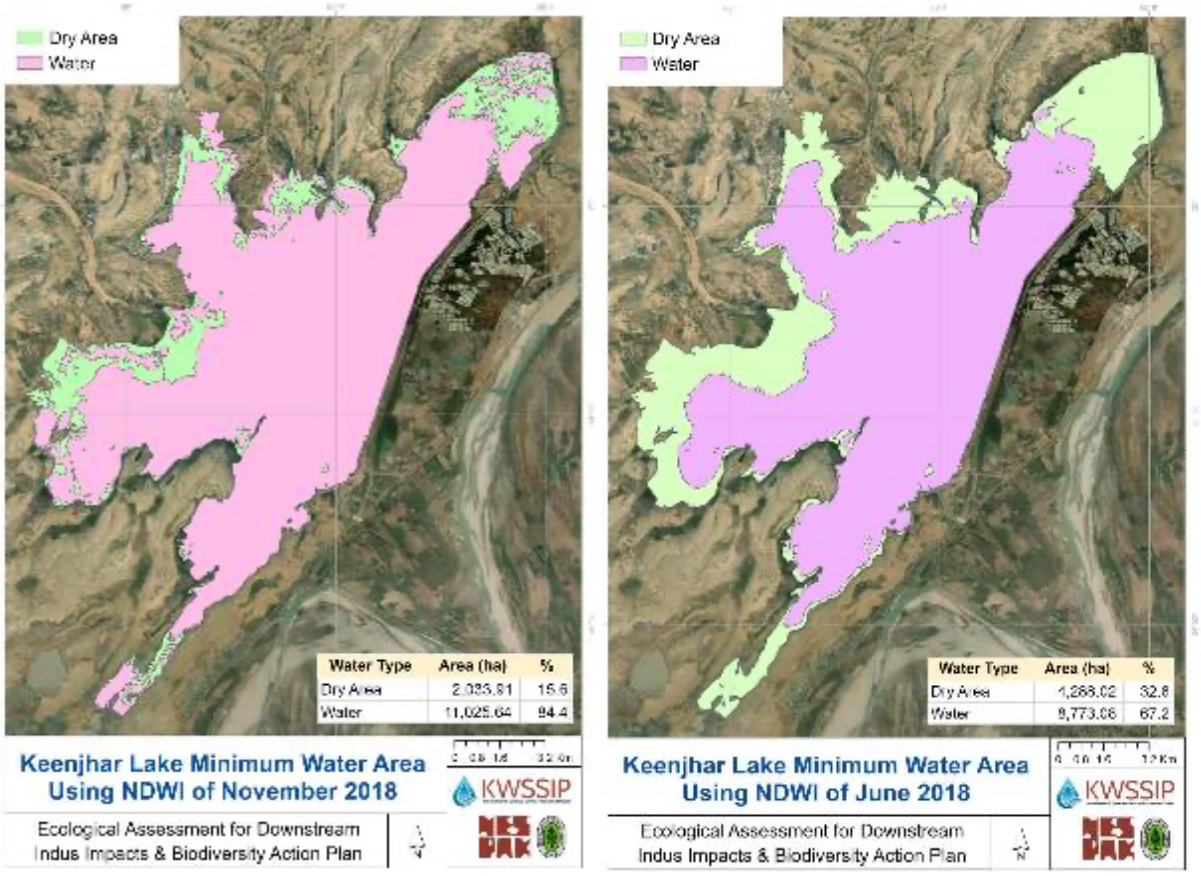


Figure 4-1: Delineation of Keenjhar Lake water Area in (a) November 2018 and (b) June 2018, using NDWI

Based on the above conclusions and the remote sensing analysis, it is concluded that there are hydrological changes in the lake reservoir but to some extent and limited to minimum water levels of 42 feet RL. The comparison of lake capacity data of latest bathymetry conducted by NEPSAK in 2019 with that of given in a study conducted in 1988[37] shows no substantial loss in the reservoir capacity. This is due to the fact thar relatively clearer water reaches the lake from the barrage though KBFU.

4.2.1.2. Lake's Water Quality

The qualitative analysis of water has been done (Adnan, K. et al. 2017) and reported as "all parameters in lake water are in compliance with the guideline values of WHO set for drinking water. The lake water is suitable for the survival and sustenance of aquatic life". It is reported and also pointed out by some of the stakeholders that small degree of untreated wastewater was entered into the Lake through KB Feeder when the combined effluent treatment plant of Kotri Industrial Area was out of order. The Sindh Environmental Protection Agency (SEPA) took action against the polluters and regulated the effluent streams at their source in response to the Chief Minister (CM) Sindh directions.

Nizamani, M.A. et al. 2020 reported that KB feeder is the main point where pollution accumulates due to wastewater discharge of anthropogenic pollution sources. The sources are WAPDA colony, villages domestic wastewater and Kotri industrial area[38]. Since this is an enforcement issue and has been resolved by the agency.

4.2.1.3. Siltation

The fertility of agricultural lands of Indus Basin is maintained by regular silt deposition by Indus River waters. The river water carries silt and clay in it and this load is deposited with the reduction of water velocity. In Keenjhar lake, silt is deposited surrounding intake point with water spread and reduction of water velocity, but clay which remains in suspension is deposited in main lake in still water.

The main silt load is received during monsoon season rainfall i.e., from July to October. Therefore, Keenjhar lake also receives its share of most silt during this period as, afterwards, river water has minimum silt. The upper water level of lake is maintained until December and maximum silt is received during this period. From January until July-August (start of rainy season), lower lake level will be maintained with river water carrying minimum silt load. Hence, looking to the present capacity and upper water level of Lake (54') and main silting period from July to October when lake remains at its full supply level, the addition withdrawal of water, additional siltation will be insignificant as from November to June, almost filtered water flows in to the lake.

Over the period of time, Keenjhar lake is silted at the point of intake. Historically, the depth of the lake at the intake was 30-35 ft, which is now reduced to 7-8 ft due to siltation at the inlet. Sindh Irrigation Department is working on the scheme to de-silt the lake and flushing of the silt.

[37] Study of Kalri Baghar Feeder System", (1988), by Sir M. MacDonald & Partners MMP in association with Associated Consulting Engineers ACE (Pvt) Ltd

[38] Nizamani, M.A. Water Quality Assessment of Keenjhar Lake, Thatta. Preprints 2020, 2020070722 (doi: 10.20944/preprints202007.0722.v1)

Deposition of silt per year, as per Fisheries Deptt. data is 4,335 acre-feet (14,650 m^3/day). If there is no desilting activity undertaken, taking the max. conservation level (MCL) of Lake i.e., 0.52 MAF at RL 54.0, the lake will be silted completely in 120 years.

As per NESPAK report, lake's capacity has not been depleted appreciably over the years when compared for 1988 and 2017 and it receives inflows through an irrigation network wherein most of sediments deposited at the intake point prior to enter in main water body.

Nevertheless, some amount of silt is still coming into the system as it is evident in **Annexure III** in which the changes in turbidity of the lake is represented using the NDWI maps (NDWI values from 0.15-0.3 as shown in pink color). The significant accumulation of sediments is shown at the inlet i.e., head regulator (pink color).

No silt excluders or silt ejectors are installed at the Keenjhar regulator, however, the angle makes a difference, since the regulator angle is 90° while the angle of Link Canal is 180° which directs most of the silt towards link canal. Below imagery represents the angles of regulators.

Figure 4-2: Layout of Regulators at -2.4 RD of KBFU

4.2.1.4. Impact on Flora and Fauna

The baseline defined in section 3.3 presents the threats and issues associated with flora and fauna in case of Scenario 1. The ecology of the lake is degrading. The reconnaissance in section 3.3 also presents the similar conclusion as below:

Boundaries of the lake are very dynamic and follows the water levels and bathymetry of the lake. Figure 4-2(b) shows the exposed areas during lowest water level conditions and it formed usually at the inlet and along the western periphery of the lake. Regression of aquatic plants and succession of terrestrial invasive species were observed in those areas. Also, human interference like cutting reeds and grazing cattle was also observed as the wetland is providing ecosystem services.

Cattle grazes fresh grasses that germinate and flourishes after receding of lake water. Some people also grow Rabi season (winter) crops on exposed area at the fringes. When lake is again filled to its upper level in September, the same ecosystem revives. However, due to excessive siltation at the inlet, the revival of aquatic ecosystem is not being achieved.

Hydrilla verticillata (Water thyme) is a weed naturalized and invasive species. It is known for its rapid and dense growth reducing plant diversity to a single species. Dense growth of water thyme in the aquatic ecosystem causes increase in daily swings in dissolved oxygen and pH, which influences habitat quality. Underneath a dense growth of water thyme in an aquatic ecosystem, oxygen levels can drop so low during night that fish could not survive at a long time. Same effects on acidity and oxygen can lead to rise in the level of release of nutrients from sediments. This drastic increase can induce phytoplankton blooms, which is an indicative symptom of a polluted lake. It was observed mostly near clear waters at the outfall and near the embankments where water is deep[39]. *Hydrilla verticillata* was observed at the southern periphery and outlet points where the lake's water is quite clear and where the sunlight reaches the bottom.

On the other hand, the introduction of carnivorous Tilapia species into the lake disrupts the food chain of fish. It is a predator species and has dominated over the native herbivorous species present in the lake such as Thaila, Rohu and Murakhi. Although the introduction of exotic fish species would benefit the fishermen, on the other hand, it has dominated over the native herbivorous species as per some studies and also highlighted during stakeholder consultations.

In contrast, exotic plant species have dominated the whole open region of the lake. These invasive species consist of *Salvania molesta* (Water Fern) and *Eichhornia crassipes* (Water Hyacinth). This eutrophication causes habitat damage and degradation, the shortening of fishing sites, and alterations to the lake's fisheries infrastructure. These plants also serve as breeding grounds for mosquitoes, posing grave threats to the human populations in the vicinity (Safi, Amtyaz. et al. 2017).

Nevertheless, the change occurred during past years from many natural and human factors including precipitation patterns, siltation, eutrophication, pollution, hunting of birds, over-exploitation of fish etc. causes the biological decline and decrease in the population and biodiversity of flora and fauna.

Nevertheless, as long as the lakes water flow due to filling and discharge is maintained, its wetland character is maintained. Irrigation and fisheries department also undertaken deweeding activity.

4.2.2. Current Mitigation / Offset Measures and Efforts to restore the Ecology of Keenjhar Lake

Under the World Bank funded Indus Eco Region Community Livelihood Project (IECLP) (P146252), Fisher sustainability schools were established in Keenjhar Lake area in order to demonstrate Better Management Practices (BMPs) such as pen culture, cage culture, stock management, habitat management, improved landing, fish handling and processing. The objective of the project is to pilot alternative livelihood opportunities and improve capacity of

[39] Eldrin DLR. Arguelles, 2019; Descriptive Study of Some Epiphytic Algae in Lake Laguna de Bay (Philippines), *Egyptian Journal of Aquatic Biology & Fisheries*, Vol. 23(2): 15 – 28 (2019)

households of fisher communities in four priority sites of the Indus Eco-region name – Keenjhar Lake; Manchar Lake; Chotiari and Nara Canal[40].

The Sindh Fisheries and Livestock Department is primarily concentrating on fish breeding and aquaculture as a result of this concerning situation. The fish catch from the lake was reduced significantly, however, due to stoking activity, it is now been restored.

According to Fisheries and Livestock Department, recently, fish hatcheries were being established around Keenjhar Lake and about five million seedlings of various fish species were being released into the lake to promote fishing sector in the province[41].

In Keenjhar Lake, the department has developed hatcheries to sustain the livelihood of local fishermen. Due to the increase in aqua-culture interventions, fish production has been increased from the declining conditions. World Bank funded project namely Accelerated Action Plan (AAP) is implemented and its objective is to stock the natural ponds and lakes through hatcheries.

More scientific detailed studies of Keenjhar Lake should be taken via academia and Sindh Wildlife Department with respect to habitat modifications due to environmental hazards present in the lake.

4.2.3. Climate Change Impacts

The general findings from a wide variety of GCM outputs (and emissions scenarios) indicate that models are in agreement regarding future temperature increases. Increases are estimated to be at worst close to 3°C by the 2050s. Northern Pakistan experiences greater summer and winter temperature increases than southern Pakistan. Moreover, winter temperature increases are typically greater than summer temperature increases. Due to large standard errors, the models do not agree on changes in precipitation; however, there is some evidence of a general trend toward an increase in summer precipitation and a decrease in winter precipitation. Changes appear to be more pronounced in the southern regions of the country. These models are probably more accurate for the irrigated plains than the mountainous upper basin[42].

4.2.4. Current Threats to Biodiversity for Indus Delta (Scenario 1)

The main threat to the biodiversity in Indus Delta is habitat reduction through mangrove degradation and deforestation. Besides loss of forest which leads to habitat loss and fragmentation for some water-dependent species, other factors causing loss of habitat and wetland degradation include:

- A decline in freshwater flows due to upstream activities. This increases the salinity level in the wetlands areas and leads to sea intrusion into different terrestrial areas including fertile crop lands in the nearby vicinities;

[40] Implementation, completion and results report, Department of Agriculture, Sindh, Indus Eco Region Community Livelihood Project (IECLP), 2019
[41] Dawn News, May 17th, 2022
[42] Yu, Winston, Yi-Chen Yang, Andre Savitsky, Donald Alford, Casey Brown, James Wescoat, Dario Debowicz, and Sherman Robinson. 2013. The Indus Basin of Pakistan: The Impacts of Climate Risks on Water and Agriculture. Washington, DC: World Bank. doi: 10.1596/978-0-8213-9874-6

- Excessive and indiscriminate harvesting of fisheries and other coastal resources beyond their regenerative capacities;
- Inadequate engagement of key stakeholder groups to participate in resources conservation and development;
- A general lack of awareness and capacity amongst stakeholders to sustainably manage wetlands, their ecosystems, resources and their ecosystem services;
- Poor law enforcement due to lack of investment into mangrove forests protection, conservation, regeneration, and coastal areas conservation and rehabilitation;
- Human-wildlife conflict;
- Sea level rise;
- Inadequate supply of sediments into the wetlands causing the delta front to be eroded.

Over a number of decades, mangrove forests in the Indus Delta have experienced massive-scale deforestation and degradation due to a number of contributing factors. These include their use by the local communities as a source of fuelwood, fodder and open range grazing by livestock. The situation has been exacerbated by the reduced supply of fresh water and sediments into the deltaic area due to upstream activity[43].

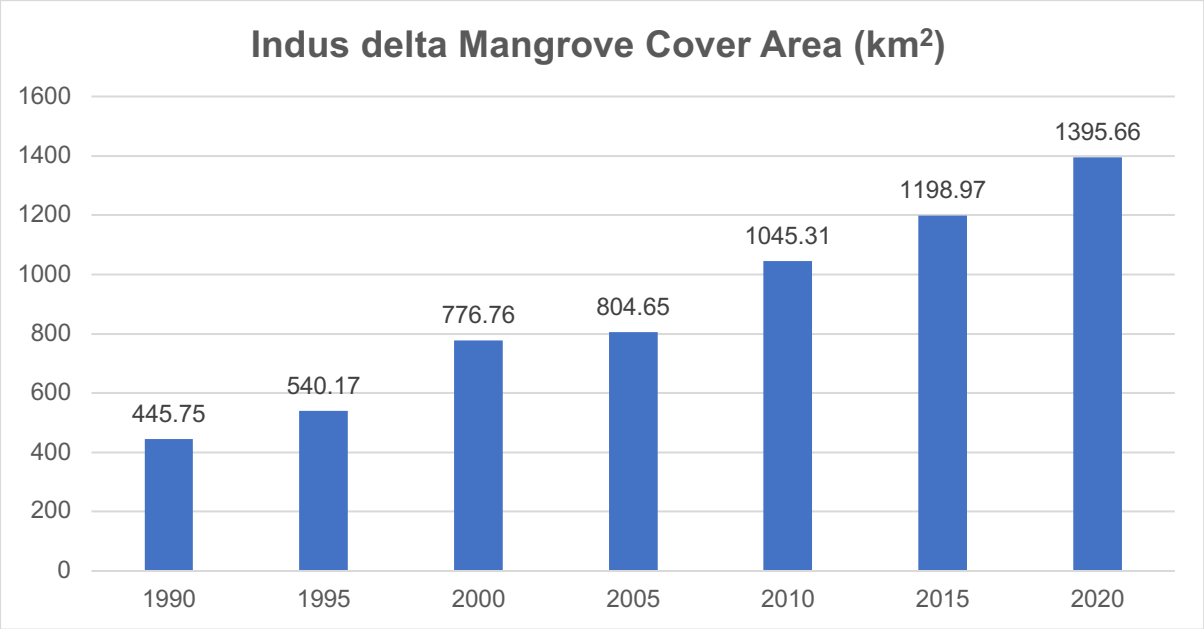
4.2.4.1. Mangroves vs Downstream Flow

Indus delta is famous for its productivity, where mangroves have pivotal and contributory role in its making. Indus delta for its health continuity greatly depends on Indus downstream flow. It's a dilemma that besides knowing this importance, downstream flow had been diverted erratically under numerous influences to transform rainfed agriculture to irrigated one. This happened during the last couple of decades, resulting the transformation of flow from perennial to seasonal, greatly impacting the e-flow, i.e., respecting the minimum amount of water to retain the integrity of ecosystem.

The distance from Keenjhar lake to the end of delta is around more than 100 Kms, however, considering the sensitivity and likelihoods of influence. This study tried to find out a relation between the downstream flow and the growth of vegetation.

A group of GIS experts were engaged in analyzing the growth trend of vegetation in Indus delta, their focus was more on temporal changes, and the results were quite surprising, 3.13 times increase during the last 30 years (Gillani, H. 2021).

[43] Project Document - Delta Blue Carbon – 1, March 2021.



Graph 4-1: The quantitative increase in mangrove cover over the last 30 years.

To find out any relationship between the downstream Kotri discharge, and its possible influence on growth of mangroves. Though the set of available information are not precisely matching, nevertheless represents some common overlap. The pattern of discharge does not represent a uniform pattern but somewhat an erratic one.

Comparing the pattern of two variables, there appears no direct relation between the growth of mangroves and downstream discharge (See graph 4-6). The growth of mangrove showed consistent incremental variation, whereas the downstream discharge represents a non-uniform pattern, the increase of one variable does necessarily correspond to the increase in another variable. As per SFD, most of the e-flow is released by the Irrigation department during post monsoon flood season in which excessive water is available downstream. From that water, the mangroves regenerate and revive. For the rest of the months, the e-flow is almost negligible.

Eight species of mangroves have historically been reported in the delta, but only four remain today due to construction of dams over Indus and degradation of delta over time before 1980. These are, *Avicennia marina*, *Rhizophora mucronata*, *Ceriops tagal*, and *Aegiceras corniculate*. The percentage proportion of the four species at the start of ARR project was: *Avicenna marina* (90%), *Rhizophora mucronata* (8%), *Aegiceras corniculatum* (1.5%) and *Ceriops tagal* (0.5%) (Sindh Forest Department, 2014). *Avicennia marina* occurs as an almost monotypic stand throughout the delta. Both *Rhizophora mucronata* and *Ceriops tagal* are mainly present because of the afforestation and re-forestation efforts of Sindh Forest Department and the Delta Blue Carbon (DBC) project.

The efforts to establish any direct relationship between the forest and the downstream flow was not supported by numerical data, the mangrove growth shows a consistent incremental pattern. Contrary to the downstream flow which seems erratic and not consistent.

The data collected, supported by independent verification, any direct or indirect relationship between growth of mangrove and discharge of water downstream was not established. It is a fact that fresh water flow has an influence in easing the growth conditions, however, adoption of smart forestry techniques, there were substantial improvement, comparing situation before 1980, the degradation process has controlled. This is a managing situation and could bring much better if the desired e-flow level could be maintained. Considering the quantum of flow, the value does not seem to be significant and apparently supports zero residual impact.

4.2.4.2. Sea Level Rise (SLR) and Erosion

Significant effects of SLR on the Pakistan coast are anticipated to be distinct in the Indus Deltaic plains. Indus Delta, forms due to drainage of mighty Indus River into the Arabian Sea, comprises of tidal mudflats, in which erosion and accretion both occur frequently due to tidal fluctuations. A 2.0 m SLR in the delta can engulf an area of about 7,500 km^2 under the sea.

Tidal action of above 4 meters, happen in the Indus delta, have the potential to erode banks of the creeks. Such high tide events were recorded in 1986, 1990, 1993 and 1999 in which devastated damages were occurred on the social infrastructure of coastal area especially in Badin, Sindh (M. M. Rabbani & Tabrez, 2008[44]).

The degree of erosion throughout the Sindh coast is predicted to accelerate due to SLR. The creeks within the Delta, including Kahhar, Ghoro, Hajamaro and Kaanhir are active erosion hotspots, with erosion rates ranging from 31-176 meters per year. From 2006 to 2009, the south bank of Ghoro Creek's mouth had the highest erosion frequency of 176 meters per year, with a retreat rate of 425 meters (WWF, 2012[45]).

Figure 4.6 delineates the areas within the Delta that – by year 2114 – are expected to be eroded, that remain intertidal, i.e., are persistent, and that have become intertidal and thus form new mangrove habitats.

[44] M. M. Rabbani, A. I., & Tabrez, S. M. (2008). The Impact of Sea Level Rise on Pakistan's Coastal Zones– In A Climate Change Scenario. National Institute of Oceanography.
[45] WWF. (2012). Delta-Wide Hazard Mapping - A Case Study of Keti Bundar, Kharo Chann, and Jiwani. Karachi. WWF Pakistan

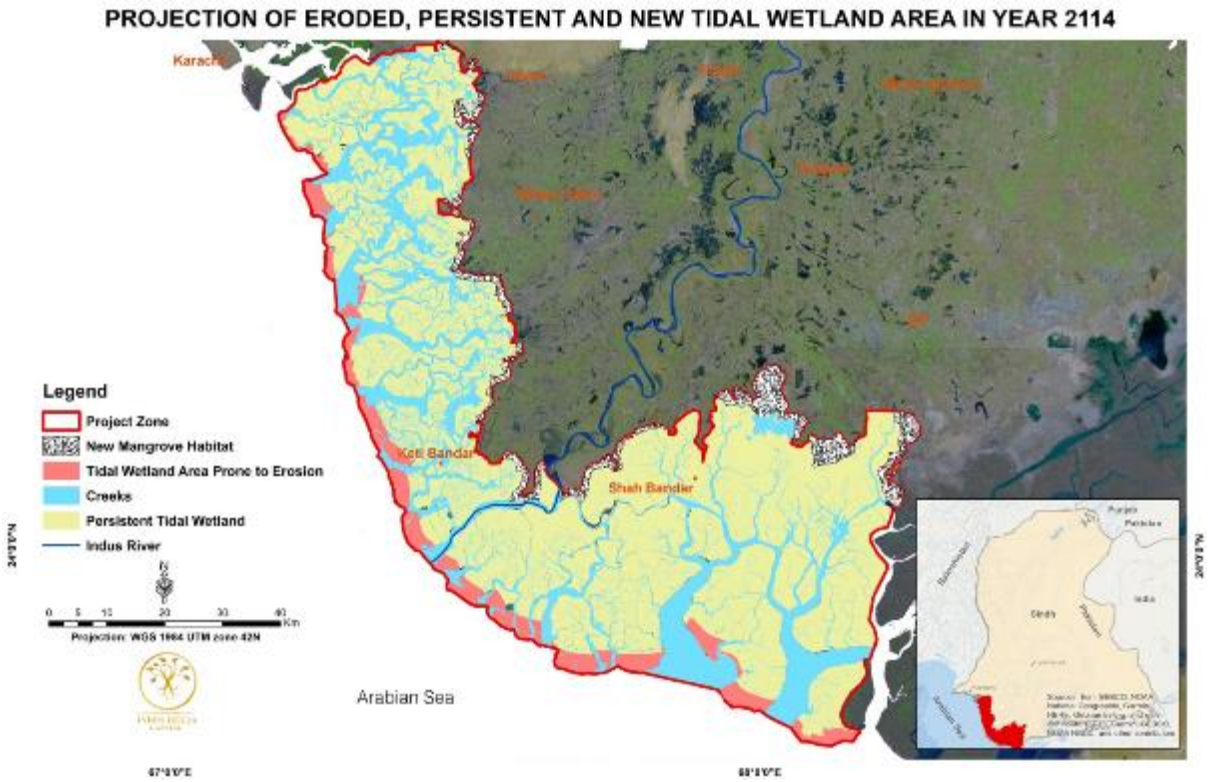


Figure 4-3: Projection of eroded, persistent and new tidal wetland area over 100 years of expected sea level rise (Source: Indus Delta Capital - Karachi)

4.2.5. Current Mitigation / Offset Measures and Efforts to restore the Ecology in Indus Delta

4.2.5.1. Afforestation, Reforestation and Regeneration (ARR) Plantation by SFD

In the coastal region, SFD has planted approximately 75,000 hectares of mangroves between 2015 and 2020 under REDD+ project. The project was originally conceived as a REDD+ project activity including both AUDD/CIW and ARR/RWE on tidal wetlands (Figure 4.7).

In that project, all of the ecological barriers were duly taken care of when propagules are taken to sites where they otherwise do not reach, their flushing with tide water is stopped when pits are made for planting, and grazing and fodder collection are controlled in newly planted areas (Figure 4.7) by the Forest Department. Once plantations were established, then through root zone development natural regeneration begin to occur. The protection of the deltaic plains against drivers of forest degradation was also taken care of.

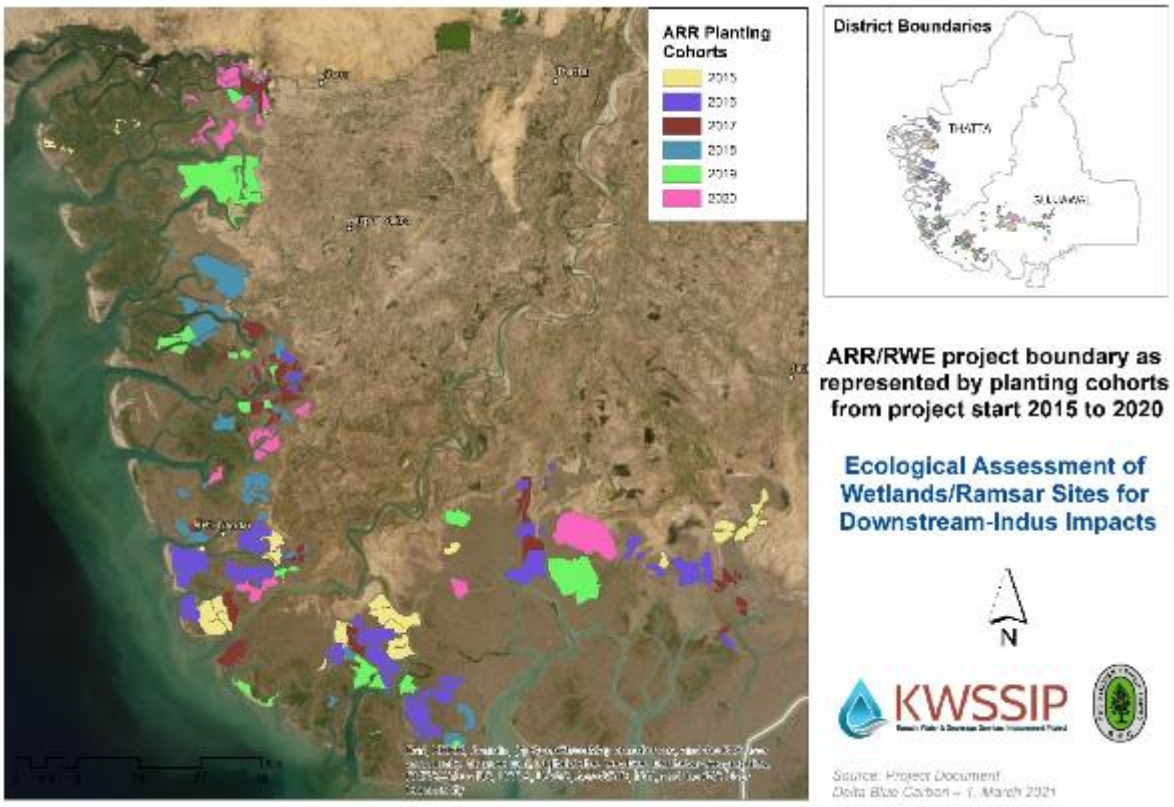


Figure 4-4: ARR/RWE project boundary as represented by planting cohorts from project start 2015 to 2020

SFD has done tremendous job undertaking mangrove plantation throughout the Indus Delta since 2015. As observed during the site visit (Figure 4.8 & 4.9), they are maintaining the planted areas through their staff by protecting it from grazing and maintaining it by restocking technique.

Figure 4-5: Plantation is taking place by SFD at one of the plots (vertical lines showing rows of sapling or propagule sowing)

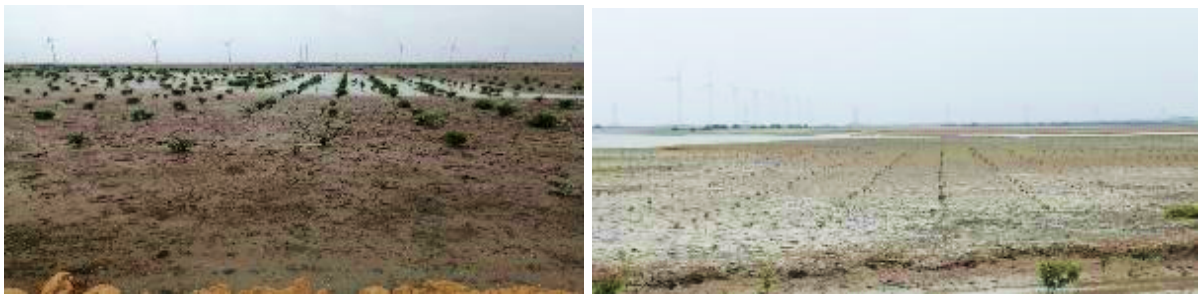


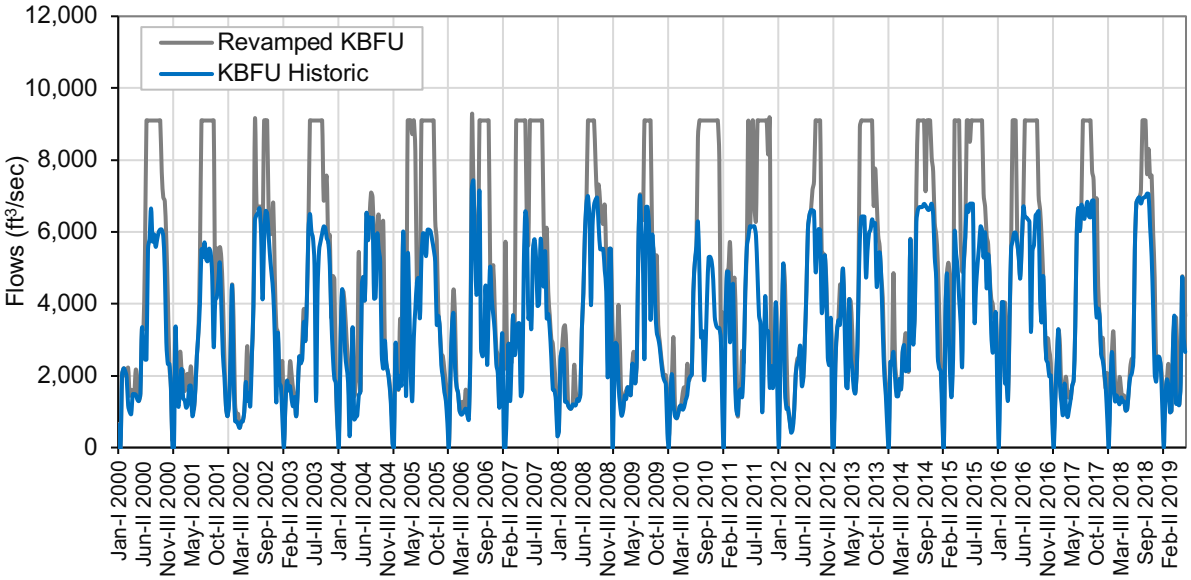
Figure 4-6: Some recent plantation undertaken by SFD

4.3. Assessment of Impacts of Scenario 2.1

Scenario 2.1 describes the implementation of K-IV phase I i.e., abstraction of 260 MGD (402 cusecs) additional water from Keenjhar Lake, hence the cumulative abstraction will be 910 MGD (1,408 cusecs) from Keenjhar Lake by lining and managing additional water supply from revamping KBFU to 9,100 cusecs, and allocating all the additional diversions from Kotri to Karachi. The scenarios of KBFU lining and revamping suggest that additional flows that can be made available for the lake are 0.12 and 0.75 MAF, respectively. Ecological impacts within AoI have been assessed for this scenario.

Water Balance of Revamping KBFU

Operating the canal on design discharge at least during the flood season is the main objective and theme of this scenario. The flow duration analyses of the historic and proposed operation of KBFU suggests that the canal can be operated to design for about 3 months of Kharif flood while making no damage to the e-flows. In addition, the rising and receding floods there exists substantial potential to operate the canal at higher flows. Beyond these 3 months of operation at design discharge, the canal can be operated at higher than historic flows for up to 8 months.

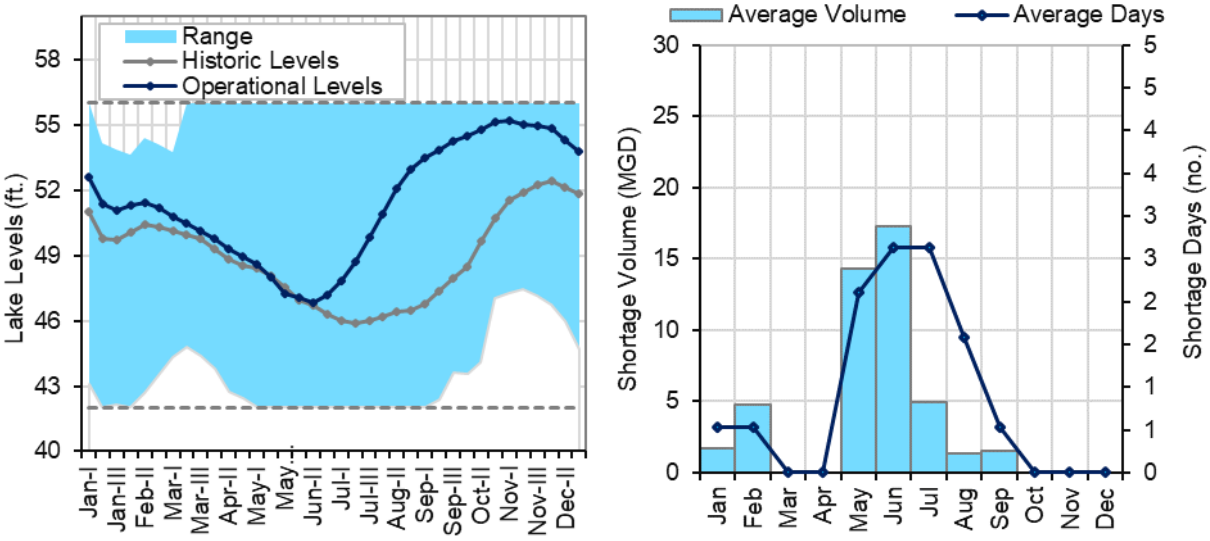


Graph 4-2: Proposed revamped operation of KBFU based on historic water availability

4.3.1. Anticipated Impacts of Scenario 2.1 on Keenjhar Lake

4.3.1.1. Hydrology of Keenjhar Lake

The lake's operations for scenario 2.1 (with revamped KBFU) were modelled in latest water balance study. Lake operation has been carried out with revamped KBFU and the additional flows are allocated to the Keenjhar Lake share. The results of the operational scenario suggest to have positive impact on overall water management where not only K-IV water needs are fulfilled but surplus flows are also available for irrigation. Also, the reservoir levels in this scenario follows more or less that of historic trend which means to have minimal impact of lake environment. There are occasional system shortages of very small magnitude which are due to historic dry years. The average shortage volume is of the magnitude of 10 MGD and annually there will be shortage of about one 10-daily. Graph 4-3 presents operational lake levels and resultant shortage days/ volume under KBFU revamped scenario.



Graph 4-3: Lake Levels and Resultant Shortage Days/ Volume under KBFU Revamped Scenario

4.3.1.2. Lake's Water Quality

No deterioration of lake's water quality is anticipated in Scenario 1 since the water balance will be achieved.

- ☐ Current mitigation measures as applied to maintain Lake's water quality will be continued.
- ☐ SEPA's role in controlling contamination of the lake is important.

4.3.1.3. Siltation

Due to the revamping of KBFU and due to 74.25% additional water (Existing flows and additional flows in case of revamping are 1.01 and 0.75 MAF/year, respectively) is flowing inside the lake, additional silt from River through KB feeder will enter into the lake and deposited near the inlet of the lake. If the figure of silt accumulation provided by fisheries department are taken, the life of the lake will be reduced from 120 years to 69 years.

The shallow areas of the lake will be silted first as they are also close to the intake point and will be exposed / dried over extended periods. The Regression of aquatic plants and succession of terrestrial invasive species will be pronounced in this area. There will be negative as well as positive impact on fishes as some of them prefer turbid waters. The turbidity does not favor *Hydrilla verticillata* (Water thyme) – a weed which requires clear waters.

- ☐ A study / modelling exercise to be conducted to ascertain the actual rate of silt entering into the lake and the area affected by it.
- ☐ De-silting and sediment flushing projects to be approved under ADP or Public Private Partnership (PPP) and implemented.

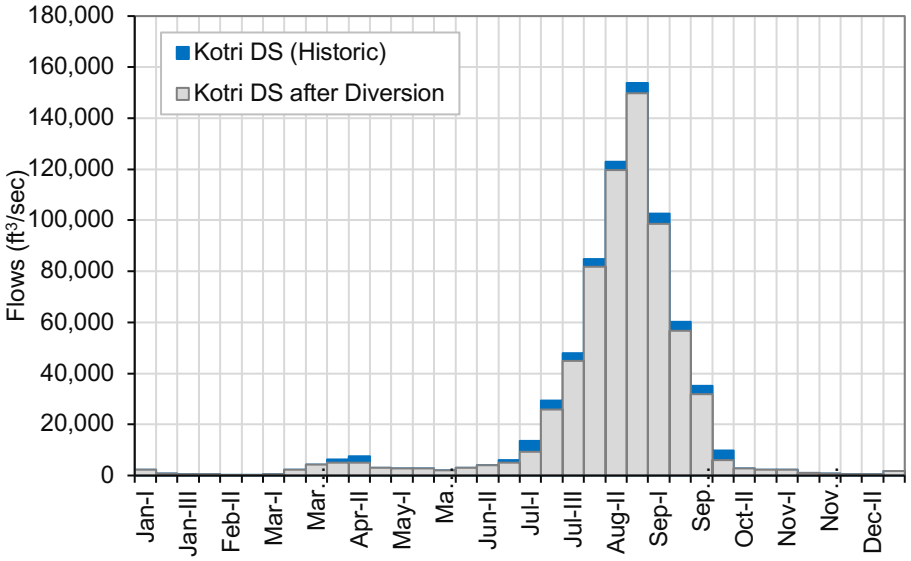
4.3.1.4. Impact on Flora and Fauna

No impact, since the water balance will be achieved in the lake.

4.3.2. Anticipated Impacts of Scenario 2.1 on The Indus Delta

4.3.2.1. Mangroves vs Downstream Flow

Since revamped KBFU shall divert the necessary additional flows from Kotri DS to run the canal at its design discharge. Since the magnitude and volume of diverted flows is very small as compared to overall water availability at Kotri DS and also the provision has been made to respect the e-flows, the DS Kotri regime is expected to have little impact of these diversions. A comparison of Kotri DS flows before and after diversion scenario is provided in Graph 4-4 where an idea about potential impact of diversions on DS Kotri water availability can be made.



Graph 4-4: Kotri DS flows before and after diversions for KBFU

On the contrary, the mangroves growth shows a consistent incremental pattern due to REDD+ projects. Current measures as of scenario1 will be applied.

4.3.2.2. *Change in Fish Abundance*

No significant change of fish abundance from scenario 1 is anticipated due to additional diverted flows. The additional diversion of water is limited as shown in Graph 4-4 and the e-flow is erratic. The fish fauna is acclimatized with the existing situation and adapt the sea intrusion into the creeks.

4.3.2.3. *Sea Level Rise (SLR) and Erosion*

The additional water diversion quantum is insignificant compared with the water currently been released into the delta. No incremental change in erosion of creeks and mudflats is envisaged due to Scenario 2.1.

4.4. Assessment of Cumulative Impacts of Scenario 2.2

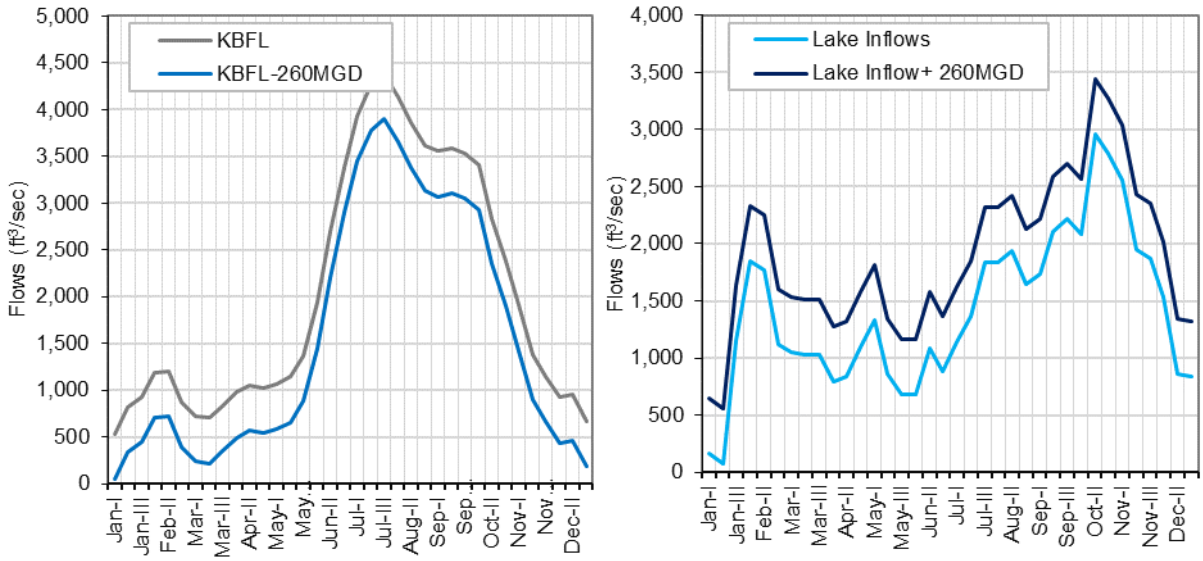
Scenario 2.2 describes the implementation of K-IV phase 1 – by allocation of additional water supply from link canal through rotation of irrigation water if the lining of KBFU is not materialized / feasible.

4.4.1. Anticipated Cumulative Impacts of Scenario 2.2 on Keenjhar Lake

4.4.1.1. *Hydrology of Keenjhar Lake*

A 260 MGD of water from KBFL share is diverted to the lake to be supplied to Karachi. This scenario is an important consideration in case the K-IV goes into implementation with no considerable structural and/ or non-structural water resources management intervention.

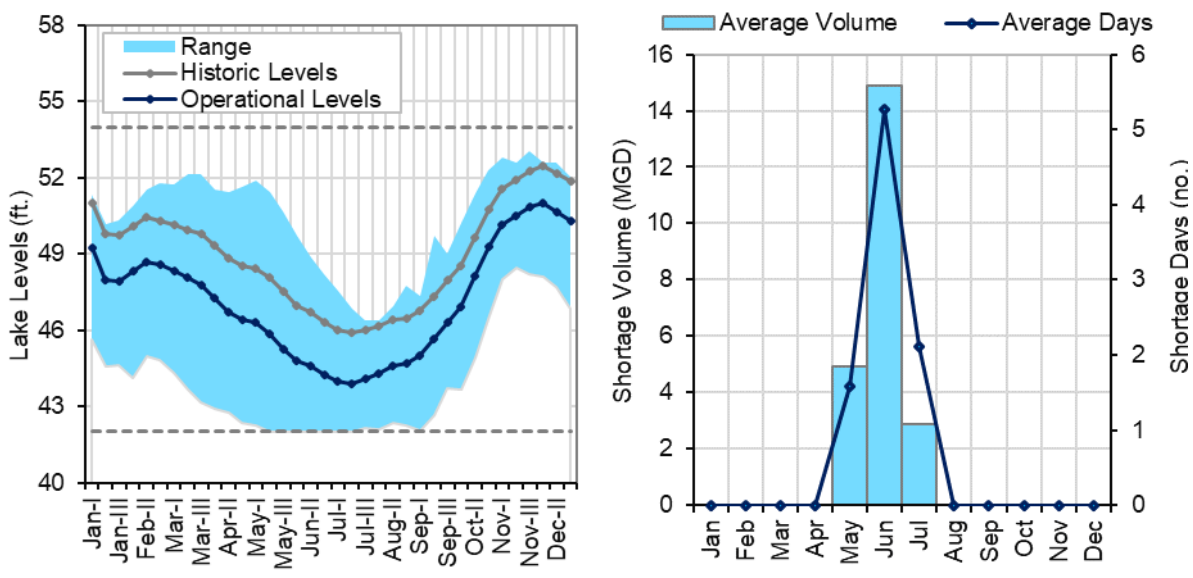
Graph 4-5 presents flow patterns at KBFL and Lake regulators as a result of scenario 2.2 where a constant abstraction from KBFL and addition to Lake regulator shares are made.



Graph 4-5: Flow patterns at KBFL and Lake regulators as a result of scenario 2.2

The results indicate that due to enhanced inflows to the lake, the average levels remain constantly higher than that of historic as shown in Graph 4-6. In this case, since the

abstractions of 260 MGD are balanced with additional inflows to the lake therefore the system remains in equilibrium. The system shortages are of the magnitude of around 20 MGD on average annual basis with average number of shortage days being around 9 days.



Graph 4-6: Lake Levels Variation and Distribution of Shortages for Scenario-3

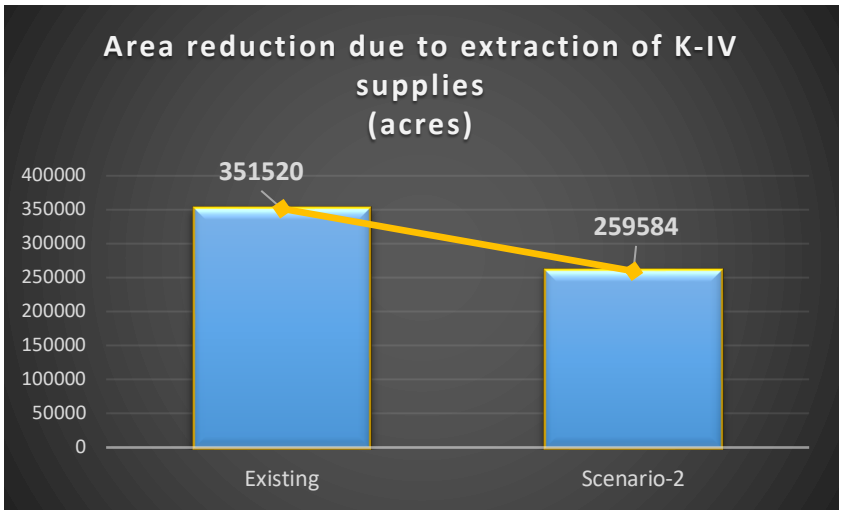
Equilibrium has been achieved, in addition to it, the water retention is decreased as compared to as compared with the baseline situation (scenario 1). Therefore, significance of adverse impacts related to hydrology, water quality and flora and fauna for Keenjhar Lake will be reduced slightly.

Siltation will not be an issue as compared with scenario 2.1, since revamping of KBFU is not considered in this scenario. Since additional water is flowing into the system, siltation issue will be persistent, but not significant as in case of revamping of KBFU which can bring extra silt. The ecological impact will also be not as significant as in scenario 1.

4.4.2. Anticipated Cumulative Impacts of Scenario 2.2 on Command Area of KB Feeder

It has been assessed that in command area of KBFL existing yields are already low as there are shortages in rabi and kharif seasons of existing scenario and in scenario 2.2, additional 260 MGD is being extracted and pose serious level of deficit and drought conditions in the command area. The severity of the impact of deficit on crop yield depends on various factors, including the duration and intensity of the drought, the type of crops being grown, crop development stage etc. in scenario 2.2 the deficit prevails throughout the growing period of crops (rabi & kharif).

It has also been assessed that there was substantial decrease in the agriculture area of 91,936 acres (3,51,520 to 2,59,246) due to reduction in supplies (Graph 4-7).

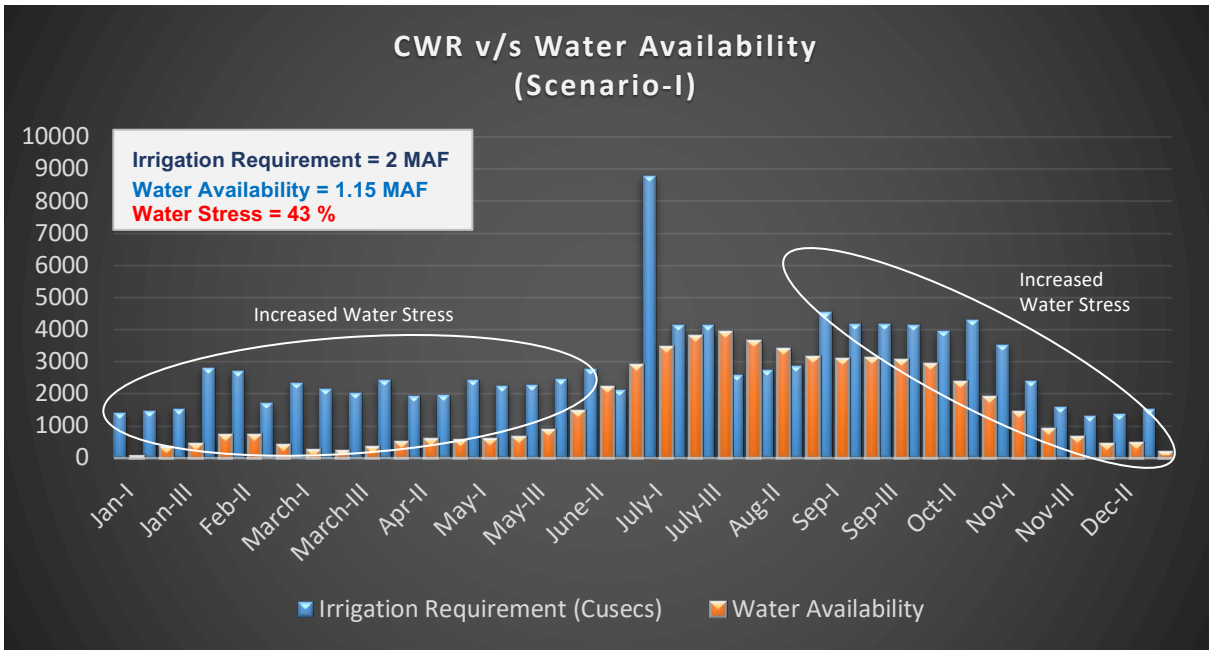


Graph 4-7: Agriculture area reduction due to extraction of K-IV supplies (acres)

The annual cropping intensity of the project area has been worked out as 38.35 percent only (i.e., 30 percent during Kharif, 6.4 percent during Rabi season and 1.95 percent in perennial). The cropping pattern constitutes specifically Rice (12 %) Cotton (5 %) Maize (5 %), K. Vegetable (2 %) and K. Fodder (6 %). During rabi season Wheat (4 %) Oilseeds (0.5 %) R. Vegetable (1.4 %) R. Fodders (0.5 %) Sugarcane (1.45 %) and Banana (0.5 %).

Crop Water Requirement (CWR)

In scenario 2.2 as shown in graph 4-8 below, the shortages or deficit increases and became severe and pose serious level of yield compromises and crop failure and resultantly already deprived farming community may face economic crises and food insecurities as farming is the major source of livelihood in the command area of KBFL.



Graph 4-8: Crop water requirement v/s water availability for Scenario 2.2

This diversion of 260 MGD for Scenario 2.2, will inevitably subject the crops in the region to will increase the crop stress. Consequently, the annual cropping intensity within the project area is expected to decrease significantly, from 52% to 38.35 percent. This revised distribution will allocate 30 percent of the land for Kharif crops, 6.4 percent for Rabi season crops, and 1.95 percent for perennial crops, highlighting the adjustment required to accommodate the essential demand for water supply in the K-IV project.

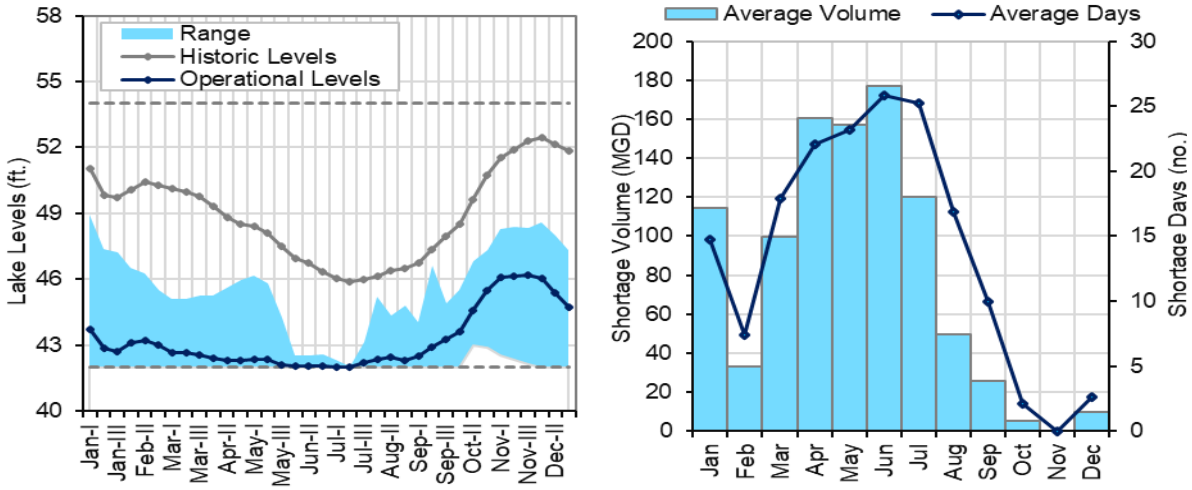
Due to the less water availability as compared with the water requirements and reduction of agriculture area, severe ecological impacts anticipated for scenario 2.2. The flora associated with the agriculture activities will be reduced. The saline conditions will be enhanced for water stress areas and the salt tolerant vegetation species like *Prosopis juliflora* which is an invasive specie may succeed over other native plants. The fauna associated to this flora may get impacted, however, these are resident species and most of the wildlife species are absent due to extensive farming activities. It is envisaged that irrigated plantations will get less water compared with the existing situation, and therefore, will result in stunted growth or area reduction due to water scarcity.

4.4.3. Anticipated Cumulative Impacts of Scenario 2.2 on The Indus Delta

Impacts related to hydrology, water quality and flora and fauna for Indus Delta will be the same as of scenario 2.1.

4.5. Assessment of Cumulative Impacts of Scenario 2.3

Scenario 2.3 describes the implementation of K-IV phase 1 with no revamping of KBFU and no allocation of water from link canal. In this particular scenario, the lake tends to deplete very quickly as the system can only meet the needs of KG canal, extracting 260 MGD additional means a very rapid drawdown and disruption off all the supplies to Karachi (KG canal and K-IV). The system suffers annual shortage days of around 170 and average shortage volume of 170 days. Variation lake levels with respects to historic operation and distribution of shortages for do nothing scenario are presented in Graph 4-9. The time-series of 10-daily operations carried out shows that the system constantly remains in stress for the 21-years and bears year-around shortages.



Graph 4-9: Lake levels variation and distribution of shortages for do nothing scenario

The ecological impacts anticipated are discussed below:

- The lake will retain its minimum area as shown in the figure 4-1(b) and the areas exposed will become permanent.
- There will be a succession of terrestrial flora into the exposed areas will happen as well as human influence like levelling and making thatched houses after cutting reed beds.
- Some habitats of migratory birds located in the shallow areas at the inlet and along the northern periphery of the lake will be lost due to terrestrial succession.
- Exposed areas subject to sunlight and wind, become prone to erosion and during flood season, when the lake is filled, these loose sediments tend to go into the water and add more sediment. The magnitude of these added sediments is low, however, noticeable.
- Since there will be less water flow into the system due to existing supply and more demand and shortage periods, the lakes flushing mechanism will be disturbed and water quality parameters will be disturbed like DO, BOD, turbidity, TDS etc.

Present system is unable to meet any additional water demands of KW&SC and shall result in complete disruption of supplies to Karachi.

Below is the impact analysis of each specie included in IUCN Red List and having High Conservation Value:

- Black-bellied Tern which is endangered as per IUCN Red List, usually breeds on sandspits and islands) and marshes, occasionally on smaller pools and ditches. The smaller pools made in the shallow areas of Keenjhar Lake become the habitat of Black-bellied Tern, and if levelled or destroyed by human interventions, will not be available for this specie.
- Fishing Cat which is vulnerable as per IUCN Red List, lives foremost in the vicinity of wetlands, streams, oxbow lakes, reedbeds. Fishing cat populations are threatened by destruction of wetlands and have declined severely over the last decade[46]. Due to the destruction of reedbeds in exposed areas, the specie may get impacted, however, the Cat was not reported along the Lake recently.
- Indian Pangolin which is endangered as per IUCN Red List, is well adapted to dry areas and desert regions, but prefers more barren, hilly regions and prefers soft and semi-sandy soil conditions suitable for digging burrows. The succession of terrestrial flora and exposed area favors the specie in terms of habitat; however, human intervention would threaten its population.
- Pallas's Fishing Eagle which is endangered as per IUCN Red List, is closely associated with wetlands, principally large lakes and rivers. It generally nests in trees near water. Breeding takes place from September-February. The felling of large trees near wetlands has reduced the availability of nest and roost sites. The spread of water hyacinth

[46] Mukherjee, S.; Appel, A.; Duckworth, J.W.; Sanderson, J.; Dahal, S.; Willcox, D.H.A.; Herranz Muñoz, V.; Malla, G.; Ratnayaka, A.; Kantimahanti, M.; Thudugala, A.; Thaung, R. & Rahman, H. (2022) [errata version of 2016 assessment]. "Prionailurus viverrinus". IUCN Red List of Threatened Species. 2016

Eichhornia crassipes is a problem, as is the siltation of lakes due to catchment deforestation.

- Greater Spotted Eagle which is vulnerable as per IUCN Red List, occurs in lowland forests near wetlands, nesting in different types of (generally tall) trees, depending on local conditions. It is a migratory species, with birds leaving their breeding grounds in October and November to winter in southern Europe, southern Asia and north-east Africa (del Hoyo et al. 1994). Habitat destruction poses a significant threat, as suitable habitat mosaics of woodland and wetland have been lost as a result of deforestation and wetland drainage.
- Common Pochard which is vulnerable as per IUCN Red List, requires well-vegetated eutrophic to neutral swamps, marshes, lakes. This is a migratory bird and during the winter the species frequents similar habitats to those it breeds in, including large lakes, slow-flowing rivers, reservoirs, brackish waters, marshes, and flooded gravel pits (Brown et al. 1982, Madge and Burn 1988, del Hoyo et al. 1992, Fox et al. 1994, Scott and Rose 1996). The species may be threatened by disturbance from hunting. Invasive carp Cyprinus carpio may also provide competition for resources with this species, and have been shown to negatively impact the Pochard (Maceda-Veiga et al. 2017).
- River Tern which is vulnerable as per IUCN Red List, is known to be breed in high concentrations in large reservoirs and rivers. It feeds predominantly on fish, small crustaceans, insects, and frogs (Mundkur 1991). Breeding occurs mainly in February-May, although the season may extent from November to May (del Hoyo et al. 1996, Mundkur 1991). Nesting areas are vulnerable to flooding, predation and disturbance (del Hoyo et al. 1996). Human disturbance, encroachment of wetlands by settlements, disturbance by birdwatchers, egg and chick trampling by domestic animals are common threats to this specie.
- Black-bellied Tern which is endangered as per IUCN Red List, is found on large rivers (usually breeding on sandspits and islands) and marshes, occasionally on smaller pools and ditches. Increased disturbance and over-harvesting of wetland products are blamed for the recent complete disappearance of the breeding population within Chitwan National Park (Nepal) (F. Cuthbert in litt. 2002). In India, the species is facing major threats due to low water levels and reduced flow rates, connecting the nesting sandbars to the bank and resulting in predation by free-ranging dogs and trampling by cattle.
- Ferruginous Duck which is near-threatened as per IUCN Red List, is a migratory bird shows a strong preference for fresh standing water. It requires shallow water 30-100 cm deep close to littoral vegetation for feeding and generally avoids large open areas (del Hoyo et al. 1992, Scott and Rose 1996, Kear 2005). Breeding Shallow eutrophic freshwater pools and marshes with dense abundant submergent, floating, emergent and shoreline vegetation (e.g. reedbeds) are the major breeding habitats (del Hoyo et al. 1992, Kear 2005, N. Petkov in litt. 2008). The species is threatened by the degradation and destruction of well-vegetated shallow pools and other wetland habitats (e.g. changes to the vegetation community, disruption of water regimes, siltation, and increased water turbidity) as a result of excessive drainage and water abstraction.

- Southern Grey Shrike which is vulnerable as per IUCN Red List, their habitat includes cereal-growing land with groves, hedgerows, bushes, meadows. The main threats are likely to be agricultural intensification, with increased use of pesticides and herbicides reducing prey availability, and the removal of hedges and trees reducing the number of available hunting perches and nest sites and reducing food availability.
- Indian Flap-shell Turtle which is vulnerable as per IUCN Red List, lives in the shallow, quiet, often stagnant waters of rivers, streams, marshes, ponds, lakes. Waters with sand or mud bottoms are preferred because of the turtle's tendency to burrow. Swampy areas with soil and exposure to sunlight are common nesting sites.
- Oxus Cobra/Brown Cobra which is near-threatened as per IUCN Red List, is often found in arid and semiarid, rocky or stony, shrub- or scrub-covered foothills. The Caspian Cobra feeds mostly on small mammals, amphibians, occasionally fish, birds and their eggs. It also reportedly feeds on other snakes. Wetland territorialization will favor its habitat.
- Russel's Sand Boa which is near-threatened as per IUCN Red List, prefers sandy tracts. Feeds on Rodents, geckos and small birds. Wetland territorialization will favor its habitat.
- Indian Monitor lizard which is near-threatened as per IUCN Red List, found in dry semiarid desert habitats to floodplains, scrubland, and moist forest. The wild population is decreasing as it is hunted for both consumption and medicinal purposes as well as for the skin.
- Indian Spiny-tailed Lizard which is vulnerable as per IUCN Red List, generally found in firm ground rather than pure sand dunes, Hardwicke's spiny-tailed lizard is often found living in colonies, sometimes on the outskirts of villages. Hardwicke's spiny-tailed lizard is largely herbivorous and feeds on terrestrial plant fruits. Hardwicke's spiny-tailed lizard is on the verge of extinction in western Rajasthan due to rampant poaching by nomads, who value this reptile both for its meat and as a medicine. Wetland territorialization will favor its habitat.
- Fauji Khagga (fish) which is near-threatened as per IUCN Red List, are inhabitants of both fresh and brackish water environments and occupy the benthopelagic zone of water bodies. As a benthic insectivore and a simple lithophilous spawner, *B. bagarius* is highly sensitive to siltation. They can tolerate the temperature range between 18–25 °C as a tropical fish and a pH range of 6.5–7.8. Outside this range, make the wetlands unsuitable for *B. bagarius*.
- Butter catfish which is near-threatened as per IUCN Red List, is usually found in shallow waters, in both lacustrine and fluviatile conditions. it often shows shoaling habits and seems to prefer large rivers and lakes and seemingly hardly enters small rivers or small affluents. The species is important in regulating small fish populations in the fresh water ecosystem.
- Freshwater catfish which is vulnerable as per IUCN Red List, found in large rivers, lakes and tanks. A large, voracious and predatory catfish which thrives in heels with grassy margin. Associated with deep, still or slow-flowing water with a mud or silt substrate. Siltation and overfishing are major threats.

- Ailia coila which is near-threatened as per IUCN Red List, habitat of *A. coila* is sharply decreasing due to natural and anthropogenic causes.
- Mozambique tilapia which is vulnerable as per IUCN Red List, generally prefer slow moving water bodies such as lagoons, rivers and impoundments. Mozambique tilapia are often the most abundant species in disturbed habitats like urban drainages, since they can tolerate a broad range of conditions. Mozambique tilapia are thought to be one of the most salt-tolerant of all the tilapia species, tolerating salt concentrations of 0–120 parts per thousand (ppt; seawater is 35 ppt). The optimal temperature range needed by Mozambique tilapia for growth and reproduction is 22–30°C. The species can, however, survive at temperatures between 16 and 39°C.

4.5.1. Anticipated Cumulative Impacts of Scenario 2.3 The Indus Delta

Impacts related to hydrology, water quality and flora and fauna for Indus Delta will be the same as of scenario 1.

4.5.2. Proposed Mitigation Measures

4.5.2.1. Baseline water and ecological survey on Keenjhar Lake

1) Conduct ecological surveys of indicator species including plants, mammals, reptiles, amphibians, fish and birds (including migratory birds) of conservation value (HCVs) as identified in the baseline section for Keenjhar Lake especially Water Spinach *Ipomoea aquatica*, Phragmites spp. *P. australis*, Water Thyme *Hydrilla verticillate* (discourage growth), Mesquite (discourage growth), *Prosobranchia* (indicator of DO), Fishing Cat, Indian Pangolin, Pallas's Fishing Eagle, Greater Spotted Eagle, Common Pochard, River Tern, Black-bellied Tern, Ferruginous Duck, Southern Grey Shrike, Indian Flap-shell Turtle, Oxus Cobra/Brown Cobra, Russel's Sand Boa, Indian Monitor lizard, Indian Spiny-tailed Lizard, Fauji Khagga, Butter catfish, Freshwater catfish, Mozambique tilapia and Munglee (*Ailia coila*). 2) Develop detailed ecological baseline maps of habitats of indicator species based on the ecological survey. 3) Monitoring of lake water level, lake area (wet and dry), water quality and mapping through field survey and mapping as well as remote sensing and GIS analysis.

4.5.2.2. Community Driven Lake Clean up

Community will be involved by local NGOs i.e., WWF and IUCN to start a lake's cleaning Drive. Before the clean-up drive, awareness session will be needed to aware the local community about the importance of lake's ecosystem and services it provides. The methodology and mechanism of the drive will also be discussed. The engagement of communities will be responsibility of NGOs. Other stakeholders like SID and SWD will actively participate in the drive. The drive will be implemented by KWSC/KWSSIP.

4.5.2.3. Promotion of Agroforestry

Planting of native tree species that will provide not only provide alternative sources of timber, fuelwood, fodder and income to the local communities but also provides foraging and roosting places of birds and other fauna around the Lake's periphery. The project may will use local

and native species such as *Acacia nilotica, Azadirachta indica, Salvadora persica, Ficus religiosa, Ficus benghalensis etc*. 5,000 trees at minimum to be planted around the Lake.

4.5.2.4. Awareness raising

An essential project aim is to raise awareness among various stakeholder groups about mangroves and coastal ecosystems. Towards this objective, it is carrying out a variety of initiatives. These include awareness raising about the different ecosystem services of Keenjhar Lake and mangroves ecosystems (provisioning services such as spawning sites and nursery habitats for different types of fishes and shrimps, regulating services such as role in climate change mitigation and adaptation, production of various non-wood products, etc.; regulation of the harmful impacts of tsunamis, etc.; supporting services such as habitat provision for different types of wildlife; and information, cultural and recreational services), best practices in the conservation, development and sustainable management of wetlands and mangroves, and mobilization of financial resources for their conservation and sustainable development.

4.5.2.5. Trainings and capacity building

Training and capacity building of stakeholder groups relevant to the project area e.g., Irrigation department, fisheries department, forest department and wildlife department is vital crucial for Keenjhar wetland and mangrove conservation, development and sustainable management. Training activities among others will include:

- training in different lake's rehabilitation and development activities (rehabilitation of Phragmites Spp. during dry season, rehabilitation of and monitoring of dry / exposed areas, de-weeding of lake, planting trees and after-care, etc.),
- participatory planning, implementation, monitoring and evaluation of lake's conservation and development interventions,
- rapid rural appraisal and community development measures, etc.

Table below shows overall summary of all scenarios and their ecological impacts with concrete solutions.

Table 4-1: Comparison of Scenarios with impacts

Main Considerations for Comparison	**Scenario 1**	**Scenario 2.1**	**Scenario 2.2**	**Scenario 2.3**
	Do Nothing	*Implementation of K-IV Phase 1 - Abstraction of additional 2 60 MGD (402 cusecs) so the cumulative abstraction = 650+260 = 910 MGD (1,408 cusecs)*		
	Baseline Scenario in which the water withdrawal is 650 MGD from Keenjhar Lake	*By managing additional water supply WITH KBFU lining*	*By allocating water from link canal through rotation of irrigation water WITHOUT KBFU lining*	*WITHOUT KBFU lining and no allocation of water from link canal*
Source of additional water	-	Savings from KBFU lining and upgrading (revamping) to original design capacity	Link Canal through rotation	There will be no additional supply from KBFU or from Kotri Barrage
Hydrology of Keenjhar Lake	The lake shrinks from max to min. levels in terms of area is 17.2% in May to August. Beyond 42 ft. RL., the shrinkage of the lake through water abstraction is not possible due to inability of drainage structure to extract water.	The results of the operational scenario suggest to have positive impact on overall water management where not only K-IV water needs are fulfilled but surplus flows are also available for irrigation. Also, the reservoir levels in this scenario follows more or less that of historic trend which means to have minimal impact of lake environment.	Impact will be same as in scenario 1. In this case, since the abstractions of 260 MGD are balanced with additional inflows to the lake therefore the system remains in equilibrium.	The lake will retain its minimum area often and the areas exposed will become permanent.
Siltation in Keenjhar Lake	Deposition of silt per year, as per Fisheries Deptt. data is 4,335 acre-feet (14,650 m3/day).	Due to the revamping of KBFU and due to 74.25% additional water (Existing flows and additional flows in case of revamping are 1.01 and 0.75 MAF/year, respectively) is flowing inside the lake, additional silt from River through KB feeder will enter into the lake and	Siltation will not be an issue as compared with scenario 2.1, since lining of KBFU is not considered with this scenario.	Exposed areas subject to sunlight and wind, become prone to erosion and during flood season, when the lake is filled, these loose sediments tend to go into the water and add more sediment. The magnitude of these added sediments is low, however, noticeable.

Main Considerations for Comparison	Scenario 1	Scenario 2.1	Scenario 2.2	Scenario 2.3
	Do Nothing	*Implementation of K-IV Phase 1 - Abstraction of additional 2 60 MGD (402 cusecs) so the cumulative abstraction = 650+260 = 910 MGD (1,408 cusecs)*		
	Baseline Scenario in which the water withdrawal is 650 MGD from Keenjhar Lake	*By managing additional water supply WITH KBFU lining*	*By allocating water from link canal through rotation of irrigation water WITHOUT KBFU lining*	*WITHOUT KBFU lining and no allocation of water from link canal*
		deposited near the inlet of the lake. If the figure of silt accumulation provided by fisheries department are taken, the life of the lake will be reduced from 120 years to 69 years.		
Flora and Fauna of Keenjhar lake	The ecology of the lake is degrading. *Hydrilla verticillata* (Water thyme) was observed at the southern periphery and outlet points where the lake's water is quite clear and where the sunlight reaches the bottom. change occurred during past years from many natural and human factors including precipitation patterns, siltation, eutrophication, pollution, hunting of birds, over-exploitation of fish etc. causes the biological decline and decrease in the	Due to additional silt accumulation near the inlet and shallow areas, potential succession vs regression of terrestrial and aquatic flora is anticipated.	Impact will be same as in scenario 2.1	There will be a succession of terrestrial flora into the exposed areas will happen as well as human influence like levelling and making thatched houses after cutting reed beds. Some habitats of migratory birds located in the shallow areas at the inlet and along the northern periphery of the lake will be lost due to terrestrial succession.

Main Considerations for Comparison	Scenario 1	Scenario 2.1	Scenario 2.2	Scenario 2.3
	Do Nothing	*Implementation of K-IV Phase 1 - Abstraction of additional 2 60 MGD (402 cusecs) so the cumulative abstraction = 650+260 = 910 MGD (1,408 cusecs)*		
	Baseline Scenario in which the water withdrawal is 650 MGD from Keenjhar Lake	*By managing additional water supply WITH KBFU lining*	*By allocating water from link canal through rotation of irrigation water WITHOUT KBFU lining*	*WITHOUT KBFU lining and no allocation of water from link canal*
	population and biodiversity of flora and fauna.			
Keenjhar lake Water Quality	Lake's water was being contaminated, however, SEPA took action against the polluters and regulated the effluent streams at their source in response to the Chief Minister (CM) Sindh directions.	No deterioration of lake's water quality is anticipated in Scenario 1 since the water balance will be achieved due to addition of 580 cusecs of water through lining of KBFU as compared with 402 cusecs of additional abstraction due to K-IV phase 1	Impact will be same as in scenario 2.1	Since there will be less water flow into the system due to existing supply and more demand and shortage periods, the lakes flushing mechanism will be disturbed and water quality parameters will be disturbed like DO, BOD, turbidity, TDS etc.
Impact on KB Feeder Canal Command Area	-	Due to additional and ensured supplies in case of revamping of KBFU, the yield of crops in scenario 2.1 will significantly increase as compare to existing situation. Resultantly, significant tangible and intangible benefits would be accrued. The farmers would be able to find opportunities to cultivate more lands that will ultimately improve their economic and livelihood conditions. Also,	Additional 260 MGD is being extracted and pose serious level of deficit and drought conditions in the command area. The shortages or deficit increases and became severe and pose serious level of yield compromises and crop failure and resultantly already deprived farming community may face economic crises and food insecurities as farming is the major source of livelihood in the command area of KBFL.	-

Main Considerations for Comparison	Scenario 1	Scenario 2.1	Scenario 2.2	Scenario 2.3
	Do Nothing	*Implementation of K-IV Phase 1 - Abstraction of additional 2 60 MGD (402 cusecs) so the cumulative abstraction = 650+260 = 910 MGD (1,408 cusecs)*		
	Baseline Scenario in which the water withdrawal is 650 MGD from Keenjhar Lake	*By managing additional water supply WITH KBFU lining*	*By allocating water from link canal through rotation of irrigation water WITHOUT KBFU lining*	*WITHOUT KBFU lining and no allocation of water from link canal*
		the cultivable flora and irrigated plantations will get more water and thrive.	The flora associated with the agriculture activities will be reduced. The saline conditions will be enhanced for water stress areas and the salt tolerant vegetation species like *Prosopis juliflora* which is an invasive species may succeed over other native plants. The fauna associated to this flora may get impacted, however, these are resident species and most of the wildlife species are absent due to extensive farming activities. It is envisaged that irrigated plantations will get less water compared with the existing situation, and therefore, will result in stunted growth or area reduction due to water scarcity.	
E-flows	The water has always been plentiful during the summer flood period starting from July to September, with flows reducing during the	The magnitude and volume of diverted flows from Kotri due to this scenario is very small as compared to overall water availability at Kotri DS and	Impact will be same as in scenario 1 – existing conditions will prevail, as there will be no additional diversions from Kotri are occurred.	Impact will be same as in scenario 1 – existing conditions will prevail

Main Considerations for Comparison	Scenario 1	Scenario 2.1	Scenario 2.2	Scenario 2.3
	Do Nothing	*Implementation of K-IV Phase 1 - Abstraction of additional 2 60 MGD (402 cusecs) so the cumulative abstraction = 650+260 = 910 MGD (1,408 cusecs)*		
	Baseline Scenario in which the water withdrawal is 650 MGD from Keenjhar Lake	*By managing additional water supply WITH KBFU lining*	*By allocating water from link canal through rotation of irrigation water WITHOUT KBFU lining*	*WITHOUT KBFU lining and no allocation of water from link canal*
	recession towards end of the year with expected occasional small rise near April. Irrigation water demand at Kotri Barrage is far greater than Karachi's requirements, so the total water requirement at Kotri is very seasonal. Historic data at Kotri shows that that plentiful amount of water is available with average annual volume of around 25 MAF. Whereas, the actual water requirement downstream Kotri is far leaser.	also the provision has been made to respect the e-flows, the DS Kotri regime is expected to have little impact of these diversions. On the contrary, the mangroves growth shows a consistent incremental pattern due to REDD+ projects. Current measures as of scenario1 will be applied.		
Impact on Indus Delta	A decline in freshwater flows due to upstream activities. This increases the salinity level in the wetlands areas and leads to sea intrusion into different terrestrial areas including fertile crop lands in the nearby vicinities.	The fish fauna is acclimatized with the existing situation and adapt the sea intrusion into the creeks. Since the DS Kotri regime is expected to have little impact due to diversions, while respecting e-flow, the impact on flora	Impact will be same as in scenario 2.1	Impact will be same as in scenario 1 – existing conditions will prevail

Main Considerations for Comparison	Scenario 1	Scenario 2.1	Scenario 2.2	Scenario 2.3
	Do Nothing	*Implementation of K-IV Phase 1 - Abstraction of additional 2 60 MGD (402 cusecs) so the cumulative abstraction = 650+260 = 910 MGD (1,408 cusecs)*		
	Baseline Scenario in which the water withdrawal is 650 MGD from Keenjhar Lake	*By managing additional water supply WITH KBFU lining*	*By allocating water from link canal through rotation of irrigation water WITHOUT KBFU lining*	*WITHOUT KBFU lining and no allocation of water from link canal*
		and fauna of Indus Delta will be insignificant.		
Impact on Mangroves in Indus Delta	No impact - growth of mangrove showed consistent incremental variation, whereas the downstream discharge represents a non-uniform pattern.	No impact.	Impact will be same as in scenario 2.1	Impact will be same as in scenario 1 – existing conditions will prevail
Mitigation measures / offsets	As long as the lakes water flow due to filling and discharge is maintained, its wetland character is maintained. Irrigation and fisheries department also undertaken deweeding activity. Keenjhar lake restoration programme to be initiated as done in the past in collaboration with WWF and IUCN.	A study / modelling exercise to be conducted to ascertain the actual rate of silt entering into the lake and the area affected by it. Baseline water and ecological survey of Keenjhar Lake. Regular water and ecological survey on Keenjhar Lake. Survey of indicator species of flora and fauna including species of high conservation value and migratory birds.	A study / modelling exercise to be conducted to ascertain the actual rate of silt entering into the lake and the area affected by it for this scenario.	-

Main Considerations for Comparison	Scenario 1	Scenario 2.1	Scenario 2.2	Scenario 2.3
	Do Nothing	*Implementation of K-IV Phase 1 - Abstraction of additional 2 60 MGD (402 cusecs) so the cumulative abstraction = 650+260 = 910 MGD (1,408 cusecs)*		
	Baseline Scenario in which the water withdrawal is 650 MGD from Keenjhar Lake	*By managing additional water supply WITH KBFU lining*	*By allocating water from link canal through rotation of irrigation water WITHOUT KBFU lining*	*WITHOUT KBFU lining and no allocation of water from link canal*
		Community driven lake clean up and small-scale restoration activities De-silting and sediment flushing projects to be approved under ADP or Public Private Partnership (PPP) and implemented.		
Preference of scenarios	Not preferred in case of proposed project	Most preferred scenario	Not preferred, there will be impact on CCA of KB Feeder	Not preferred as there will be substantial impact on the ecology of the lake due to the lake's minimum level will attain over extended months in a year.

Chapter 5 Keenjhar Lake Conservation Action Plan

This Keenjhar Lake Conservation Action Plan (KLCAP) will serve as a principal execution module that would not only guide in mitigating the adverse ecological impacts during K-IV project implementation, but also help to ensure that the area under study (AoI) is restored from its present highly degraded state. Continuous monitoring and evaluation of interventions proposed under the KLCAP will be exercised to ensure that mitigation measures are effectively implemented to maintain the ecological integrity.

This section presents the management framework and action plan for the project scenarios and other projects related to the abstraction of water from Keenjhar Lake via Korti barrage.

5.1. KLCAP Actions

This Keenjhar Lake Conservation Action Plan (KLCAP) is developed which presents the management framework and action plan for the project scenarios and other projects related to the abstraction of water from Keenjhar Lake via Korti barrage. The KLCAP actions as proposed in the list below are identified from the above impact assessment exercise. Each action will be transformed into a programme / project to be executed by relevant stakeholders.

- **Baseline water and ecological survey on Keenjhar Lake**: 1) Conduct ecological surveys of indicator species including plants, mammals, reptiles, amphibians, fish and birds (including migratory birds) of conservation value (HCVs) as identified in the baseline section for Keenjhar Lake especially Water Spinach *Ipomoea aquatica*, Phragmites spp. *P. australis*, Water Thyme *Hydrilla verticillate* (discourage growth), Mesquite (discourage growth), *Prosobranchia* (indicator of DO), Fishing Cat, Indian Pangolin, Pallas's Fishing Eagle, Greater Spotted Eagle, Common Pochard, River Tern, Black-bellied Tern, Ferruginous Duck, Southern Grey Shrike, Indian Flap-shell Turtle, Oxus Cobra/Brown Cobra, Russel's Sand Boa, Indian Monitor lizard, Indian Spiny-tailed Lizard, Fauji Khagga, Butter catfish, Freshwater catfish, Mozambique tilapia and Munglee (*Ailia coila*). 2) Develop detailed ecological baseline maps of habitats of indicator species based on the ecological survey. 3) Monitoring of lake water level, lake area (wet and dry), water quality and mapping through field survey and mapping as well as remote sensing and GIS analysis.
- **Regular water and ecological monitoring of Keenjhar Lake** 1) Conduct annual ecological survey to measure the trend of indicator species, 2) regular monitoring and mapping of lake level, area, water quality
- **Monitoring of siltation and de-silting** and sediment flushing projects in Keenjhar Lake to be approved.
- **Community driven lake clean up and small-scale restoration activities and awareness raising** for conservation and sustainable use of Keenjhar Lake for water supply, biodiversity, livelihood and tourism.

- **Creation of Keenjhar Lake Conservation Action Committee** by concerned government authorities including Sindh Irrigation Department, Sindh Forest and Wildlife Department, KWSC, SEPA, Sindh Fishery Department, WWF, IUCN, local community leaders to regularly review and oversight the implementation status of the lake conservation action plan, and inform the future actions.

Table 5-1 below present each KLCAP action and its implementation responsibility and timing for implementation.

Table 5-1: KLCAP Actions Implementation Framework

KLCAP Action	Implementation Responsibility	Timings	Tentative Budget (USD)
Creation of Keenjhar Lake Conservation Action Committee by concerned government authorities including Sindh Irrigation Department, Sindh Forest and Wildlife Department, KWSC, SEPA, Sindh Fishery Department, WWF, IUCN, local community leaders to regularly review and oversight the implementation status of the lake conservation action plan, and inform the future actions.	KWSC / KWSSIP	Before the start of K-IV project	-
Conduct critical habitat assessment in Keenjhar Lake and Indus Delta for all phases of K-IV including further biodiversity surveys for plants, mammals, reptiles, amphibians and birds of conservation value (HCVs) as identified in the baseline section for Keenjhar Lake especially Water Spinach *Ipomoea aquatica*, Phragmites spp. *P. australis*, Water Thyme *Hydrilla verticillate* (discourage growth), Mesquite (discourage growth), *Prosobranchia* (indicator of DO), **Fishing Cat, Indian Pangolin, Pallas's Fishing Eagle, Greater Spotted Eagle, Common Pochard, River Tern, Black-bellied Tern, Ferruginous Duck, Southern Grey Shrike, Indian Flap-shell Turtle, Oxus Cobra/Brown Cobra, Russel's Sand Boa, Indian Monitor lizard, Indian Spiny-tailed Lizard, Fauji Khagga, Butter catfish, Freshwater catfish, Mozambique tilapia and Munglee (*Ailia coila*).**	Independent Consultant hired by KWSC in association with SWD, IUCN and WWF	Before the start of K-IV project	110,000
Prepare a detailed map of habitats of conservation value			
Conduct bird study in both Ramsar sites as well as to ascertain the reason for the decrease in counts of migratory birds.			
Use of environmental flow models such as DRIFT or HEC-RAS to assess cumulative impacts of all water supply projects.			28,000
De-silting and sediment flushing projects to be approved under ADP or Public Private Partnership (PPP) and implemented.	SID	Continuous	To be estimated in PC-I documents
Prepare a long-term monitoring plan for the habitats and species of conservation value.	Independent Consultant in association with SWD, IUCN and WWF	Continuous	See monitoring budget below

KLCAP Action	Implementation Responsibility	Timings	Tentative Budget (USD)
Community driven lake clean up and small-scale restoration activities and awareness raising for conservation and sustainable use of Keenjhar Lake for water supply, biodiversity, livelihood and tourism.	SID	Biannually	10,000
Planting of native tree species that will provide not only provide alternative sources of timber, fuelwood, fodder and income to the local communities but also provides foraging and roosting places of birds and other fauna around the Lake's periphery. The project may will use local and native species such as *Acacia nilotica*, *Azadirachta indica*, *Salvadora persica*, *Ficus religiosa*, *Ficus benghalensis* etc. 5,000 trees at minimum to be planted around the Lake.	SFD	At the inception of K-IV project till the plantation drive is complete	95,000

1 USD = 270 PKR

5.2. Institutional Arrangement for Implementation of KLCAP

Formal institutional arrangements are necessary to be designated in order to implement the mitigation measures and actions proposed in KLCAP are implemented effectively. At present, there is no separate channel to look after the affairs related to ecology in AoI. Many stakeholders are involved in the AoI and looked almost the relevant issues but with zero coordination among them. Current local legislation, systems and operating procedures of ecological management in Government departments, although exist, but implemented inadequately. The capacity building of Government departments is required to strictly implement the law as well as precautionary measures.

The responsibility of flow regulations of water to Keenjhar and downstream Kotri lies with Sindh Irrigation Department (SID). The responsibility for watch and ward of the terrestrial and aquatic ecological resources lies with SWD, while the Fisheries Department regulates inland fishing. SFD is also the key player in planting, managing and protecting mangrove forests. Main key player for implementing the K-IV project is KWSC which do not have a jurisdiction at downstream Kotri rather it lies with SID, revenue department and SFD.

Key players for implementation of KLCAP recommendations:

1. Karachi Water & Sewerage Corporation (KWSC)
2. Sindh Irrigation Department (SID)
3. Sindh Wildlife Department
4. Sindh Forest Department
5. Sindh Environmental Protection Agency
6. WWF
7. IUCN

All the key players are important to implement the recommendation of KLCAP. The strategy to be adopted for management of protection under the KLCAP is outlined below.

- ☐ A KLCAP Management Committee to be formulated including the representative of all above stakeholders
- ☐ Regular oversight and monitoring by the Management Committee
- ☐ Putting in place a protection system with financing through GOS and/or under PPP mode to fill the gaps in the existing system
- ☐ Monitoring on a long-term basis by an independent Monitoring and Evaluation (M&E) Consultant

Figure below illustrates the institutional arrangements for implementation of KLCAP.

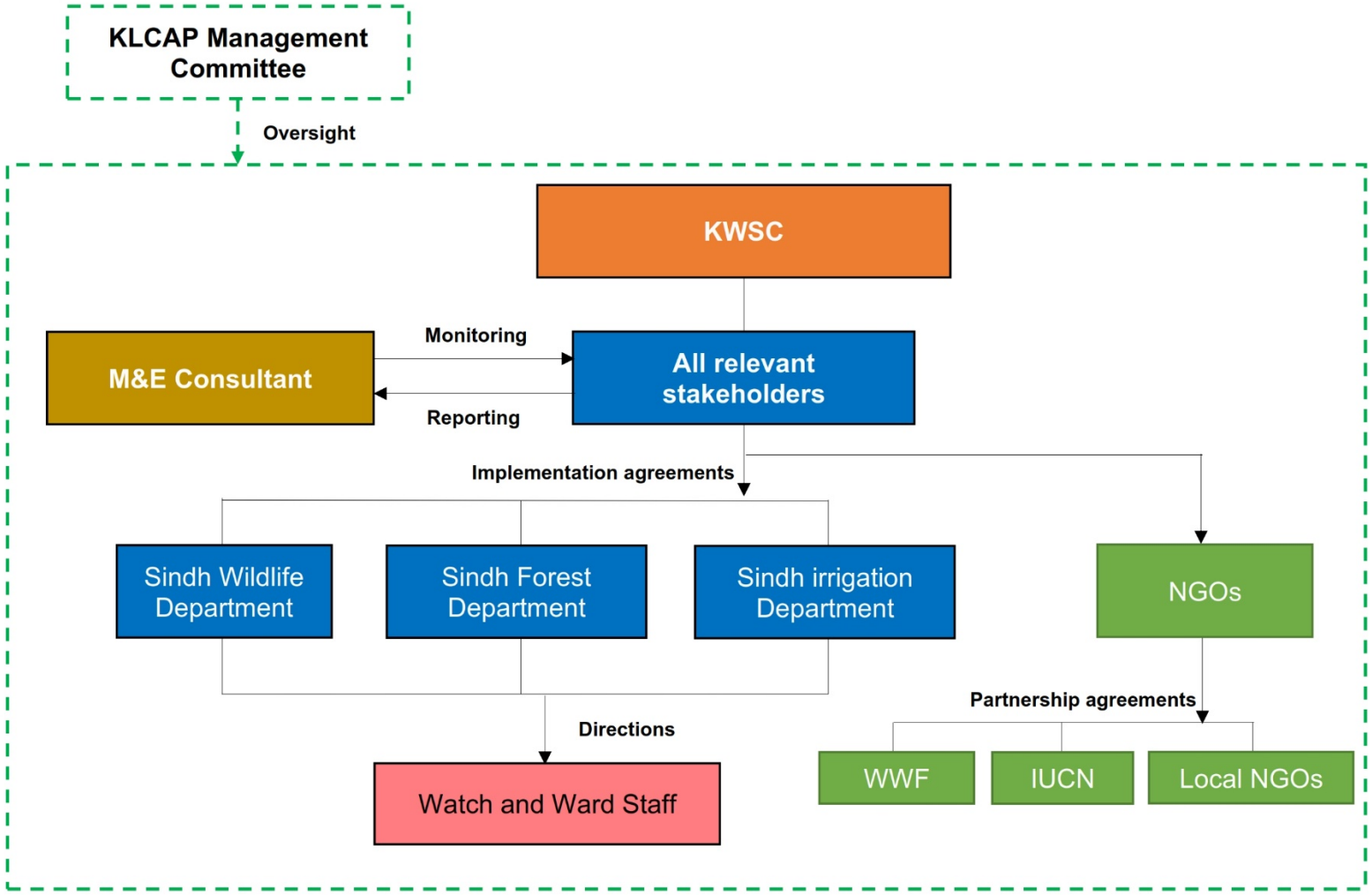


Figure 5-1: Institutional arrangements for the implementation of KLCAP

5.2.1. KLCAP Management Committee

The KLCAP Management Committee will be established by the GOS. The Committee will have the following constitution:

- Managing Director KWSC
- Representative of Wildlife Department – Member
- Representative of Irrigation Department - Member
- Representative of Forest Department – Member
- Representative of WWF – Member
- Representative of IUCN – Member
- Recognized Expert in Zoology – Member
- Recognized Expert in Botany – Member

The progress review meetings of the Committee will be undertaken on monthly basis.

5.3. Monitoring & Evaluation (M&E)

The terms of reference of M&E are as follows:

- To liaison with all the stakeholders to get the updated information on the implementation of mitigation measures / actions proposed in the KLCAP;
- To screen out any deterioration or improvement in the ecosystems that may have taken place after each as well as all project scenarios, and when the project impacts actually begin to occur;
- To assess whether or not Net Gain in biodiversity has been achieved, comparisons will be made with the Pre-Project conditions;
- To assess the adequacy of mitigation measures.

Monitoring Indicators Information on the following indicators will be collected and reported.

• Hydrology for Keenjhar Lake and Downstream Indus	• Siltation of Keenjhar Lake
• Flora and fauna especially HCVs (Biodiversity) in Keenjhar lake and Indus Delta	• Water quality of Keenjhar Lake
• **Area of Keenjhar Lake through RS**	•

5.3.1. Monitoring & Evaluation (M&E) Consultant

It is recommended that KWSC KLCAP Committee shall engage an M&E Consultant on the basis of clearly defined criteria including their experience and resources, to ensure monitoring of the project's compliance with the KLCAP, and to document the net gain in biodiversity through surveys and secondary data, at least once every year starting from the inception of the project. The M&E Consultant's terms of reference will define a clear work plan, including

monitoring indicators, reporting structures and timelines. The firm engaged for independent monitoring will report its findings directly to the PIU KWSSIP and then to KLCAP Committee.

5.3.2. Framework for Monitoring of Indicators

The following table presents the monitoring of indicators mentioning environmental parameters, frequency, locations and applicable standards.

Table 5-2: Framework for Monitoring of Indicators

Indicator	Info required	Relevant Stakeholder	Method	Frequency	Monitoring Responsibility	Budget (USD)
Hydrology	Average monthly discharges at regulators of: • KB Feeder, • Kotri Barrage and • Chilya (Keenjhar)	SID	• Gauging station / head regulators	Monthly	SID operators	-
Keenjhar Lake water level	Daily water level from existing gauges	SID	• Gauges installed at the lake	Daily	SID operators	-
Keenjhar Lake Area	Satellite imageries of that month	SID	• Remote sensing analysis using NDWI	Monthly	GIS specialist hired by M&E Consultant	Remuneration 12,800 per year
Water quality of Keenjhar Lake	All parameters as defined in Sindh Standards for Drinking Water Quality (SSDWQ[47])	SEPA	• Sampling at different locations in the lake (atleast 4 samples) and • testing grab samples in a certified lab	Quarterly	M&E Consultant	4,000/- per year
Siltation of Keenjhar Lake	• Sediment distribution within the lake, adequacy and • implementation of control measures for siltation	SID	• Analysis using ArcGIS, • sampling of water for turbidity at sample locations in the lake (atleast 10 samples) using a boat. • Turbidity will be checked in nephelometric turbidity units (NTU) and the results will be compared with SSDWQ.	Quarterly	M&E Consultant	20,000/- per year
Flora and fauna including HCVs / Habitat enhancement	• Indicator species include especially Water Spinach Ipomoea aquatica, Phragmites spp. *P.*	SWD	• Sampling sites along Keenjhar Lake for ecological monitoring of HCVs through experts • liaison with stakeholders,	Biannually	M&E Consultant	18,000/- per year

[47] Although there are no standards to surface water quality in Sindh, however, since the water of Keenjhar will be used for drinking water after treatment, SSDWQ will be used as reference.

Indicator	Info required	Relevant Stakeholder	Method	Frequency	Monitoring Responsibility	Budget (USD)
	australis, Water Thyme *Hydrilla verticillate* (discourage growth), Mesquite (discourage growth), *Prosobranchia* (indicator of DO), Fishing Cat, Indian Pangolin, Pallas's Fishing Eagle, Greater Spotted Eagle, Common Pochard, River Tern, Black-bellied Tern, Ferruginous Duck, Southern Grey Shrike, Indian Flap-shell Turtle, Oxus Cobra/Brown Cobra, Russel's Sand Boa, Indian Monitor lizard, Indian Spiny-tailed Lizard, Fauji Khagga, Butter catfish, Freshwater catfish, Mozambique tilapia and Munglee (Ailia coila). • current health and conservation status of HCVs, • protection measures applied • status of invasive species		• consultation with communities			
Fishing	• Fish biodiversity, • status of invasive species, • fish catch statistics, • fishing practices		• Sampling of major wetlands for monitoring of fish fauna and fishing through experts, • liaison with stakeholders,	Biannually	M&E Consultant	18,000/- per year

Indicator	Info required	Relevant Stakeholder	Method	Frequency	Monitoring Responsibility	Budget (USD)
			• consultation with fishing communities			

1 USD = 270 PKR

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Annexures

Annex I: List of Floral & Faunal Species

Reported lists of floral and faunal species of found in or near the Keenjhar Lake

List of Mammals

S#	Scientific name	Common name	IUCN Red Listing
20.	*Hemiechinus collaris*	Long-eared Desert Hedgehog	LC
21.	*Hystrix cristatus*	Indian Crested Porcupine	LC
22.	*Funambulus pennanti*	Palm Squirrel	LC
23.	*Rattus rattus*	Roof Rat	LC
24.	*Mus musculus*	House Mouse	LC
25.	*Mus saxicola*	Grey Spiny Mouse	LC
26.	*Nesokia indica*	Short-tailed Mole Rat	LC
27.	*Meriones hurrianae*	Indian Desert Jird	LC
28.	*Tatera indica*	Indian Gerbil	LC
29.	*Gerbillus nanus*	Balochistan Gerbil	LC
30.	*Hipposideros fulvus*	Leaf-nosed Bat	LC
31.	*Pipistrellus Kuhlii*	Kuhl's Bat	LC
32.	*Rhinopoma microphyllum*	Large Mouse-tailed Bat	LC
33.	*Canis aureas*	Asiatic Jackal	LC
34.	*Vulpes bengalensis*	Bengal Fox	LC
35.	*Vulpes vulpes*	Desert Fox	LC
36.	*Herpestes edwardsi*	Grey Mongoose	LC
37.	*Herpestes javanicus*	Small Indian Mongoose	LC
38.	*Felis chaus*	Jungle Cat	LC
39.	*Prionailurus viverrina*	Fishing Cat	VU
40.	*Sus scrofa*	Indian Wild Boar	LC
41.	*Manis crassicaudata*	Indian Pangolin	EN
42.	*Lepus nigricollis*	Desert Hare	LC

List of Birds

S#	Scientific name	Common name	IUCN Red Listing
1.	*Tachybaptus ruficollis*	Little Grebe	LC
2.	*Phalacorcorax niger*	Little Cormorant	LC
3.	*Nycticorax nycticorax*	Night Heron	LC
4.	*Ardeola grayii*	Pond Heron	LC
5.	*Bubulcus ibis*	Cattle Egret	LC
6.	*Egretta garzetta*	Little Egret	LC
7.	*Egretta intermedia*	Intermediate Egret	LC
8.	*Ardea alba*	Great White Egret	LC
9.	*Ardea purpurea*	Purple Heron	LC
10.	*Elanus caeruleus*	Black-winged Kite	LC
11.	*Milvus migrans*	Black Kite	LC
12.	*Haliastur indus*	Brahminy Kite	LC
13.	*Haliaeetus albicilla*	White-tailed Sea Eagle	LC
14.	*Haliaeetus leucoryphus*	Pallas's Fishing Eagle	EN
15.	*Gyps fulvus*	Griffon Vulture	LC
16.	*Circaetus gallicus*	Short-toed Eagle	LC
17.	*Circus aeruginosus*	Marsh Harrier	LC
18.	*Aquila clanga*	Greater Spotted Eagle	VU
19.	*Pandion haliaetus*	Osprey	LC
20.	*Falco tinnunculus*	Kestrel	LC

S#	Scientific name	Common name	IUCN Red Listing
21.	*Falco chiquera*	Red-headed Merlin	LC
22.	*Anas acuta*	Pintail	LC
23.	*Anas crecca*	Common Teal	LC
24.	*Anas strepera*	Gadwall	LC
25.	*Anas poecilorhyncha*	Spotbill Duck	LC
26.	*Anas clypeata*	Shovellller	LC
27.	*Aythya ferina*	Common Pochard	VU
28.	*Aythya fuligula*	Tufted Duck	LC
29.	*Nattapus coromandelianus*	Pygmy Cotton Teal	LC
30.	*Francolinus pondicerianus*	Grey Partridge	LC
31.	*Amaurornis phoenicurus*	White-breasted Waterhen	LC
32.	*Gallinula chloropus*	Indian Moorhen	LC
33.	*Fulica atra*	Coot	LC
34.	*Hydrophasianus chirurgus*	Pheasant-tailed Jacana	LC
35.	*Himantopus himantopus*	Black-winged Stilt	LC
36.	*Charadrius leucurus*	White-tailed Lapwing	LC
37.	*Vanellus indicus*	Red-wattled Lapwing	LC
38.	*Charadrius dubius*	Little Ringed Plover	LC
39.	*Charadrius alexandrinus*	Kentish Plover	LC
40.	*Calidris minuta*	Little Stint	LC
41.	*Calidris temminckii*	Temminck's Stint	LC
42.	*Gallinago gallinago*	Common Snipe	LC
43.	*Tringa stagnatilis*	Marsh Sandpiper	LC
44.	*Tringa nebularia*	Greenshank	LC
45.	*Tringa ochropus*	Green Sandpiper	LC
46.	*Tringa glareola*	Wood Sandpiper	LC
47.	*Tringa hypoleucos*	Common Sandpiper	LC
48.	*Larus argentatus*	Herring Gull	LC
49.	*Larus ichthyaetus*	Great Black-headed Gull	LC
50.	*Larus ridibundus*	Black-headed Gull	LC
51.	*Chlidonias hybridus*	Whiskered Tern	LC
52.	*Gelochelidon nilotica*	Gull-billed Tern	LC
53.	*Sterna **aurantia***	River Tern	VU
54.	*Sterna albifrons*	Little Tern	LC
55.	*Sterna acuticauda*	Black-bellied Tern	EN
56.	*Pterocles exustus*	Chestnut-bellied Sandgrouse	LC
57.	*Columba livia*	Blue Rock Pigeon	LC
58.	*Streptopelia decaocto*	Collared Turtle Dove	LC
59.	*Streptopelia senegalensis*	Little Brown Dove	LC
60.	*Psittacula krameri*	Rose-Ringed Parakeet	LC
61.	*Eudynamus scolopacea*	Koel	LC
62.	*Centropus sinensis*	Greater Coucal or Crow Pheasant	LC
63.	*Caprimulgus mahrattensis*	Syke's Nightjar	LC
64.	*Apus affinis*	House Swift	LC
65.	*Ceryle rudis*	Lesser Pied Kingfisher	LC
66.	*Alcedo atthis*	Common Kingfisher	LC
67.	*Halcyon smyrnensis*	White-breasted Kingfisher	LC
68.	*Merops orientalis*	Green Bee-eater	LC
69.	*Coracias bengalensis*	Indian Roller	LC
70.	*Upupa epops*	Hoopoe	LC
71.	*Dinopium bengalensis*	Lesser Golden-backed Woodpecker	LC

S#	Scientific name	Common name	IUCN Red Listing
72.	*Eremopterix grisea*	Ashy-crowned Finch Lark	LC
73.	*Eremopterix nigriceps*	Black-crowned Finch Lark	LC
74.	*Ammomanes deserti*	Desert Finch Lark	LC
75.	*Galerida cristata*	Crested Lark	LC
76.	*Alauda gulgula*	Oriental Sky Lark	LC
77.	*Riparia paludicola*	Plain Martin	LC
78.	*Hirundo rustica*	Barn Swallow	LC
79.	*Hirundo smithii*	Wire-tailed Swallow	LC
80.	*Anthus rufulus*	Paddyfield Pipit	LC
81.	*Anthus campestris*	Tawny Pipit	LC
82.	*Motacilla flava*	Yellow Wagtail	LC
83.	*Motacilla alba*	Pied Wagtail	LC
84.	*Motacilla maderaspatensis*	White-browed Pied Wagtail	LC
85.	*Pycnonotus leucogenys*	White-cheeked Bulbul	LC
86.	*Pycnonotus cafer*	Red-vented Bulbul	LC
87.	*Luscinia svecica*	Bluethroat	LC
88.	*Phoenicurus ochruros*	Black Redstart	LC
89.	*Oenanthe alboniger*	Hume's Wheatear	LC
90.	*Oenanthe deserti*	Desert Wheatear	LC
91.	*Oenanthe picata*	Pied Chat	LC
92.	*Saxicoloides fulicata*	Indian Robin	LC
93.	*Sylvia curruca*	Lesser Whitethroat	LC
94.	*Cettia cetti*	Cetti's Warbler	LC
95.	*Prinia inornata*	Plain Prinia	LC
96.	*Prinia flaviventris*	Yellow Bellied Long- tailed Warbler	LC
97.	*Orthotomus sutorius*	Tailor Bird	LC
98.	*Acrocephalus stentoreus*	Clamorous Great Reed Warbler	LC
99.	*Acrocephalus agricola*	Paddy-field Warbler	LC
100.	*Phylloscopus neglectus*	Plain Leaf Warbler	LC
101.	*Rhipidura rhipidura*	White-browed Fantail Flycatcher	LC
102.	*Turdoides caudatus*	Common Babbler	LC
103.	*Turdoides earlei*	Striated Babbler	LC
104.	*Turdoides striatus*	Jungle Babbler	LC
105.	*Nectarinia asiatica*	Purple Sunbird	LC
106.	*Dicrurus macrocercus*	Black Drongo/King Crow	LC
107.	*Lanius merodionalis*	Southern Grey Shrike	VU
108.	*Lanius isabellinus*	Isabelline Shrike	LC
109.	*Lanius vittatus*	Bay-backed Shrike	LC
110.	*Dendrocitta vagabunda*	Tree Pie	LC
111.	*Corvus splendens*	House Crow	LC
112.	*Sturnus vulgaris*	Common Starling	LC
113.	*Acridotheres tristis*	Indian Myna	LC
114.	*Acridotheres ginginianus*	Bank Myna	LC
115.	*Passer domesticus*	House Sparrow	LC
116.	*Petronia xanthocollis*	Yellow-throated Sparrow	LC
117.	*Ploceus manyar*	Streaked Weaver	LC
118.	*Lonchura malabarica*	White-throated Munia/Indian Silver Bill	LC
119.	*Emberiza striolata*	Striolated Bunting/House	LC

S#	Scientific name	Common name	IUCN Red Listing
		Bunting	

List of Reptiles

S#	Scientific name	Common name	IUCN Red Listing
1.	*Lissemys punctata*	Indian Flap-shell Turtle	VU
2.	*Bungarus caeruleus*	Indian Krait	LC
3.	*Naja naja*	Indian Cobra	LC
4.	*Naja oxiana*	Oxus Cobra/Brown Cobra	NT
5.	*Coluber fasciolatus*	Banded Racer	LC
6.	*Lycodon striatus*	Spotted Wolf Snake	LC
7.	*Platyceps ventromaculatus*	Glossy-bellied Racer	LC
8.	*Platyceps rhodorachis*	Streaked Kukri Snake	LC
9.	*Oligodon taeniolatus*	Cliff Racer	LC
10.	*Psammophis condanarus*	Indian Sand Snake	LC
11.	*Ptyas mucosus*	Dhaman	LC
12.	*Eryx conicus*	Russel's Sand Boa	NT
13.	*Echis carinatus*	Saw-scaled Viper	LC
14.	*Daboia russelii*	Russel's Viper	LC
15.	*Acanthodactylus cantoris*	Indian Fringe-toed Lizard	LC
16.	*Ophisops jerdonii*	Punjab Snake-eyed Lacerta	LC
17.	*Varanus bengalensis*	Indian Monitor lizard	NT
18.	*Saara hardwickii*	Indian Spiny-tailed Lizard	VU
19.	*Trapelus megalonyx*	Afghan Ground Agama	LC
20.	*Trapelus agilis*	Brilliant Agama	LC
21.	*Calotes versicolor*	Indian Garden Lizard	LC
22.	*Eublepharis macularius*	Fat-tailed Gecko	LC
23.	*Cyrtopodian kachhensis*	Warty Rock Gecko	LC
24.	*Cyrtopodian scaber*	Keeled Rock Gecko	LC
25.	*Hemidactylus flavivirdis*	Yellow-bellied House Gecko	LC
26.	*Hemidactylus brookii*	Spotted Indian House Gecko	LC
27.	*Hemidactylus leschenaultia*	Bark Gecko	LC

List of Amphibians of Keenjhar Lake

S#	Scientific name	Common name	IUCN Red Listing
1.	*Euphlyctis cyanophylictis*	Skittering Frog	**LC**
2.	*Duttaphrynus stomaticus*	Indus or Marbled Toad	**LC**

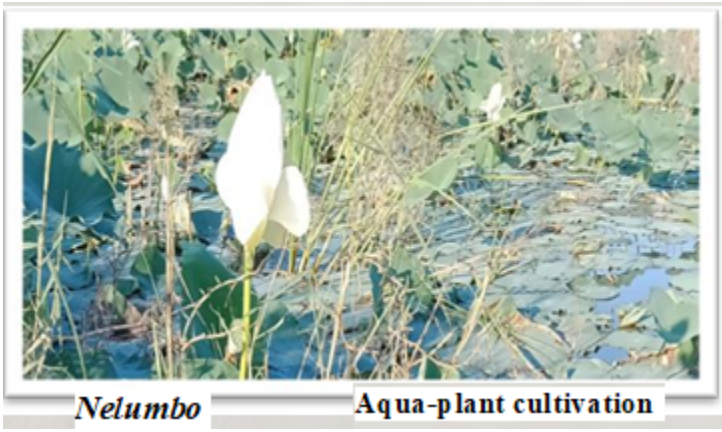
List of Fishes of Keenjhar Lake

S#	Scientific name	IUCN Red Listing
1.	*Gadusia chapra*	***LC***
2.	*Notopterus chitala*	***NT***
3.	*Notopterus notopterus*	***LC***
4.	*Chela cachius*	***LC***
5.	*Salmostoma bacaila*	***LC***
6.	*Securicula gora*	***LC***

7.	*Amblypharyngodon mola*	***LC***
8.	*Aspidoparia morar*	***LC***
9.	*Barilius vagra*	***LC***
10.	*Esomus danricus*	***LC***
11.	*Rasbora daniconius*	***LC***
12.	*Barbodes sarana*	***LC***
13.	*Catla catla*	***LC***
14.	*Cirrhinus mrigala*	***LC***
15.	*Cirrhinus reba*	***LC***
16.	*Labeo calbasu*	***LC***
17.	*Labeo dero*	***LC***
18.	*Labeo dyocheilus*	***LC***
19.	*Labeo gonius*	***LC***
20.	*Labeo rohita*	***LC***
21.	*Osteobrama cotio*	***LC***
22.	*Puntius chola*	***LC***
23.	*Puntius sophore*	***LC***
24.	*Puntius ticto*	***LC***
25.	*Cyprinus carpio*	***EN***
26.	*Ctenpharyngodon idella*	***LC***
27.	*Aristchthys nobilis*	***DD***
28.	*Hypophthalmichthys molitrix*	***LC***
29.	*Mystus bleekeri*	***LC***
30.	*Mystus cavasius*	***LC***
31.	*Mystus vittatus*	***LC***
32.	*Rita rita*	***LC***
33.	*Bagarius bagarius*	***NT***
34.	*Gagata cenia*	***LC***
35.	*Nangra nangra*	***LC***
36.	*Ompok bimaculatus*	***NT***
37.	*Wallago attu*	***VU***
38.	*Heteropneutes fossilis*	***LC***
39.	*Ailia coila*	***NT***
40.	*Clpisoma garua*	***LC***
41.	*Clpisoma naziri*	***LC***
42.	*Eutropiichthys vacha*	***LC***
43.	*Xenentodon cancila*	***LC***
44.	*Channa marulia*	***LC***
45.	*Channa punctata*	***LC***
46.	*Chanda nama*	***LC***
47.	*Parambassis baculis*	***LC***
48.	*Parambassis ranga*	***LC***
49.	*Sicamugil cascasia*	***LC***
50.	*Colisa fasciata*	***LC***
51.	*Colisa lalia*	***LC***
52.	*Oreochromis mossambicus*	***VU***
53.	*Mastacembelus armatus*	***LC***

Source: M. Z. Khan, D. Abbas, S. A. Ghalib, R. Yasmeen, S. Siddiqui, M. Nazia, A. V. Latif, "Effects of environmental pollution on aquatic vertebrates and inventories of Haleji and Keenjhar Lakes: Ramsar Sites", Canadian Journal of Pure and Applied Scieces, Vol. 6, No. 1, pp. 1759-1783, 2012

Aquatic plants cultivated as fruit and vegetables at and surroundings of Keenjhar lake

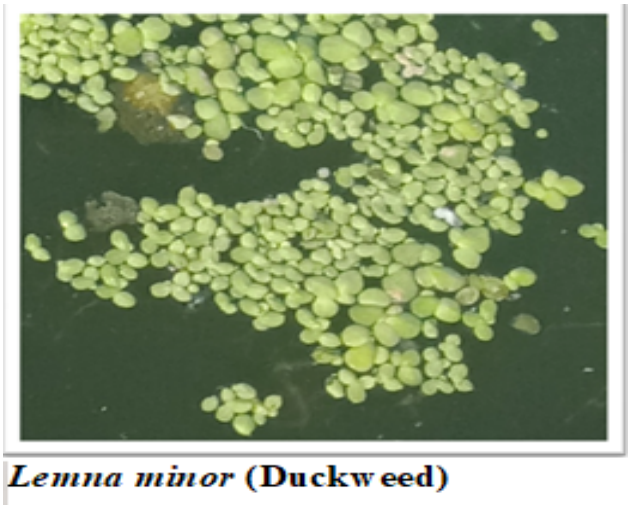


Nelumbo Aqua-plant cultivation

Nymphia

Aqua-plant Cultivated Fruits and Vegetables

Hydrilla verticillata (Water thyme)



Lemna minor (Duckweed)

Eichhornia crassipes (water hyacinth)

Floral diversity of Kotri downstream Indus River to Janghi Sur

#	Botanical Name	Local Name	Status	Economic importance
Hydrophytes				
1	*Cyperus difformis*	Kal	Common	Brooms
2	*Eichhornia crassipes*	Gul bakauli	Common	Weed
3	*Nelumbo nucifera*	Kanwal	Common	Weed
4	*Nymphia nouchalli*	Nilofar	Common	Weed
5	*Hydrilla verticillata*	Jhanji	Common	Weed
6	*Najaz marina*	Khanodo	Common	Aquatic weed
7	*Typha domigensis*	Pun	Common	Used for roofing thatched houses
8	*Phragmites vallatoria*	Aquatic Reed	Common	
9	*Ipomoea aquatica*	Naaro	Common	Fodder
Herbs				
10	*Leptadenia pyrotechnica*	Kheep	Common	Medicinal value
11	*Senna italica*	Ghorawal	Common	Fodder
12	*Suaeda fruiticosa*	Laani	Common	
13	*Cyprus rotundus*	Kal	Common	Fodder
14	*Desmostachya bipinnata*	Drabh Gaah	Common	Fodder
15	*Ricinus communis*	Castor Bean	Common	Oil Yield
16	*Calotropis procera*	Akk	Common	Milk latex
17	*Abutilon muticum*	Kapohi	Common	Ornamental
18	*Abutilon indicum*	Jhangli – panir	Common	Medicinal value
19	*Momordica balsamina*	Jhangli Karela	Common	Medicinal value
20	*Indigofera argentea*	Neer	Common	Used as Dye
21	*Indigofera linifolia*	Punjabi Torki	Common	Used as Dye
Trees				
22	*Ziziphus nummularia*	Ber	Common	
23	Delbergi sisssoo	Taari	Endangered	Furniture wood
24	*Azadirachta indica*	Neem	Common	Medicinal value
25	*Tamarix aphylla*	Laee	Common	Wind breaker
26	*Prosopis cineraria*	Kandi	Endangered	Shade tree
27	*Cordia myxa*	Lasura	Threatened	Shade tree
28	*Ficus religiosa*	Peepal	Threatened	Shade tree
29	*Sesbania grandiflora*	Manghandri	Common	Timber

Note*: The conservation status vegetation has been locally assessed.

Diversity of crops of Indus River downstream

#	Crop name	Local Name	Season	Yield per Acre
Cash Crops				
1	Wheat	Wheat	Autumn- winter	2170 kg/ha
2	Millet	Jowar	Summer	9-14 tons/ha
3	Maize	Makai	Winter	1300 kglha
4	Chickpea	Matar	Winter	5595 kg/ha
5	Mung Bean	Mung	Winter	6-8 kg/ha
6	Lentil	Mash	Winter	6- 8 quintals
7	Fenugreek	Methi	Winter	10 to 11 quintals/ha
8	Rapeseed	Sirah	Winter	4500 kg/ha
9	Mustard	Jambho	Winter	5 – 6 quintals/acre
10	Alfalfa	Loosan	Round the Year	20-35 tons/ha
11	Banana	Banana	Spring	40 – 50 tons/ha

12	Sugarcane	Sugarcane	Winter	36.5 to 43.4 tonnes/ha
13	Betel leaf	Paan	Round the Year	6 to 7 million leaves/ha
14	Tobacco	Tobacco	Winter	792kg/ha
15	Rice	Rice	Summer	1609 kg/ha
Vegetables				
1	Potato	Potato	Summer	145604 kg/ha
2	Tomato	Tomato	Round the Year	180,000 kg/ha
3	Onion	Onion	Summer	62.5 tonnes/ha
4	Red Chilli	Chile	Summer	80 to 100 qt/ha
5	Sweet Potato	Gajar	Summer	25 tons/ha
6	Reddish	Moori	Summer	20 tons/ha
7	Sugar beet	Shalgam	Summer	50 – 60 tons/ha
8	Cabbage	Gobi	Summer	20 tons per ha
9	Spinach	Palak	Winter	20- 30 tons/ha
10	Bottle Gourd	Toori	Winter	48 tons/ha
Fruits				
1	Melon	Kharboza	Summer	25 – 30 tons/ha
2	Watermelon	Tarbooz	Summer	25 – 30 tons/ha
3	Oil Palm	Palm tree	Winter	4 tons oil palm/ha

*Sources:
- Economic Survey of Pakistan 2019 – 20 www.finance.gov.pk
- Pakistan Agriculture Research Council (parc.gov.pk)
- National Agriculture Research Centre (parc.gov.pk)
- Pakistan Bureau of Statistics (pbs.gov.pk)

Agriculture sector at Indus River Kotri downstream to Khober creek

Wetland and dry land terrestrial grasses and herbs in Indus River Kotri downstream

Cyperus difformis (Rice Sedge)

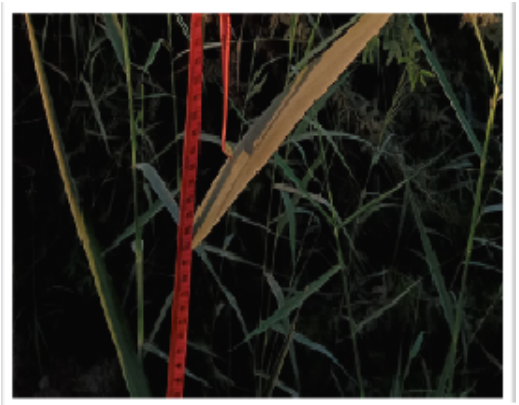
Cyperus rotundus (Coco Grass)

Desmostachya bipinnata (Deep root grass)

Desmostachya bipinnata (Deep root grass)

Wetland and terrestrial herbs in Indus River Kotri downstream

Typha domigensis (Southern cattail)

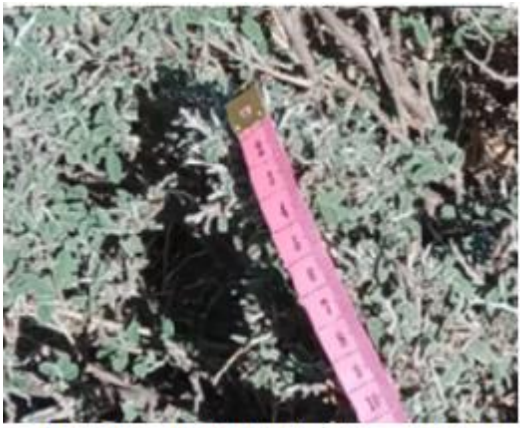


Phragmites vallatoria (Reed grass)

Senna italica (Italian Senna)

Indigofera argentea (Wild indigo)

Indigofera argentea (Egyptian Indigo)



Indigofera linifolia (Arabian indigo)

Terrestrial herbs in Indus River Kotri downstream command area

Abutilon muticum (Room maple)

Abutilon indicum (County mellow)

Momordica balsamina (Balsam apple)

Leptadenia pyrotechnica (Desert Herb)

Calotropis procera (Milk Weed)

Ricinus communis (Castor oil plant)

Terrestrial trees in Indus River Kotri downstream to Khober creek area

Prosopis glandulosa

Prosopis juliflora

Prosopis cineraria

Sesbania gradiflora

Ziziphus nummularia

Delbergisisssoo

Azadirachta indica (Neem)

Cordia myxa (Bambar)

Albizia lebbeck (Siris Tree)

Acacia nilotica (Sindhi Babul)

Salvadora oleoides (Khabar)

Salvadora persica (Khabar – Peroon)

Flora of intertidal zone in creek area

Tamarix aphylla (Desert Palm)

Suaeda fruticosa (Seablite)

Avicennia marina (Mangrove)

Dominant Avifauna of Indus delta

Tachybaputus ruficollis (Little Grebe or Dabchick) *Tadorna tadorana* (Common Sheld Duck) *Anas acuta* (Northern Pintail)

Fulica atra (Black or Eurasian Coot) *Egretta garzetta* (Little Egret) *Mesophoyx intermedia* (Median Egret)

Ardeola grayii (Pond-Heron) *Himantopus himantopus* (Black-winged Stilt) *Sula dactylatra* Masked booby

Ceryle rudis Pied kingfisher

Annex II: Mid-Winter Waterfowl Census of Keenjhar Lake Wildlife Sanctuary

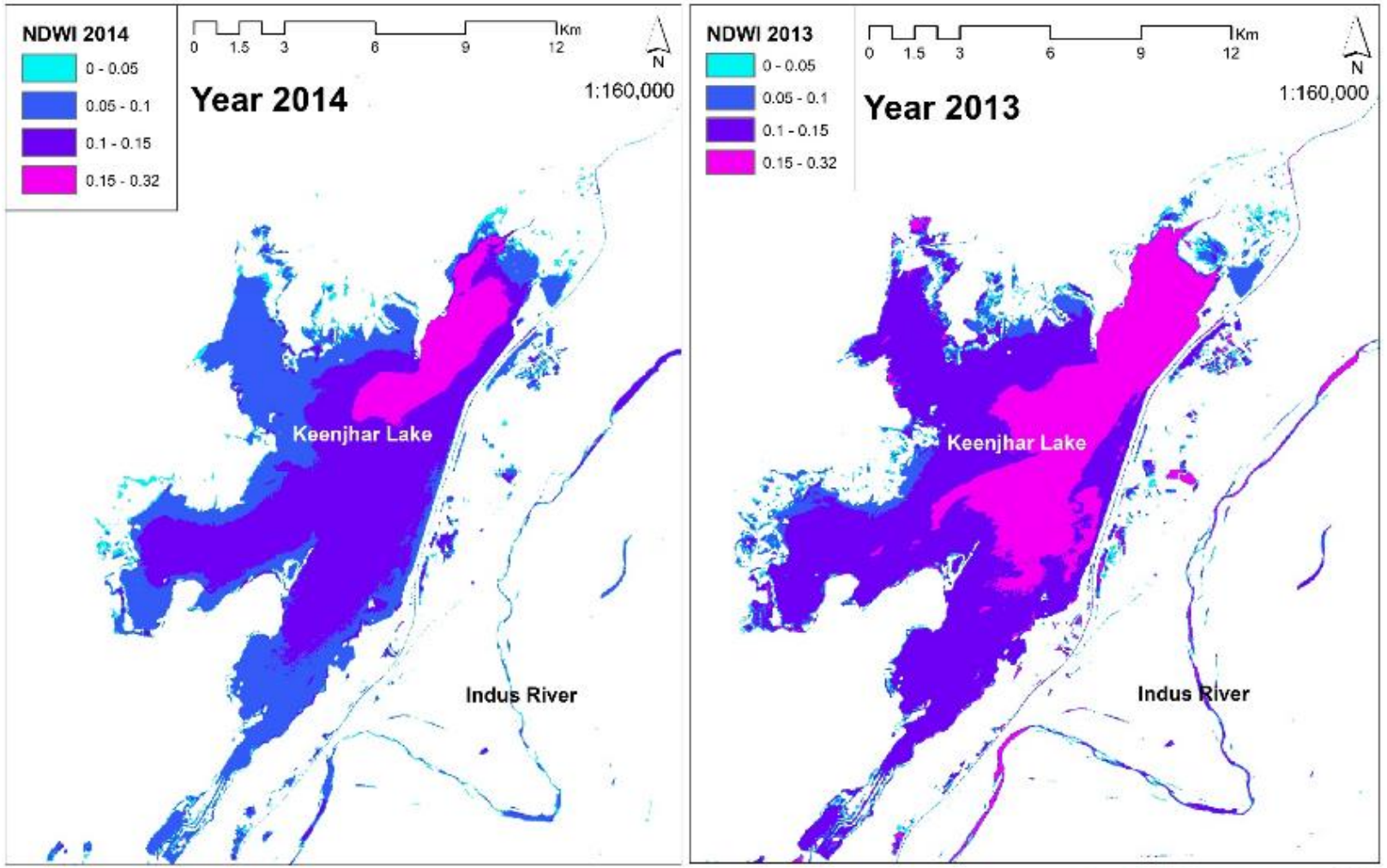
SINDH WILDLIFE DEPARTMENT

MID-WINTER WATERFOWL CENSUS OF KEENJHAR WILDLIFE SANCTUARY

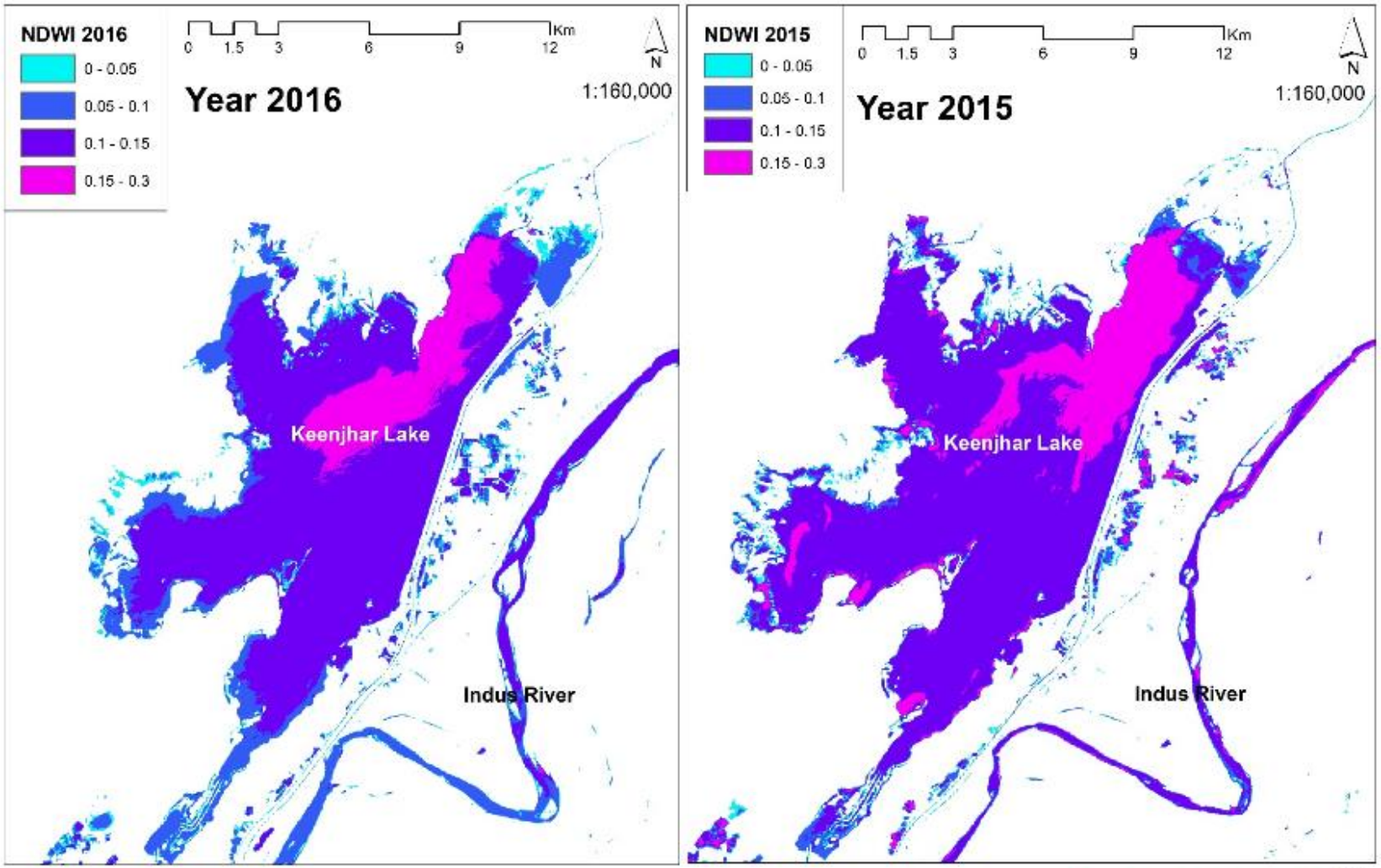
YEAR	TOTAL POPULATION
2014	1186
2016	1770
2017	1297
2018	13105
2019	3904
2020	15274
2021	17005
2022	5001

RASHEED AHMED KHAN
Deputy Sanctuary Warden
Sindh Wildlife Department

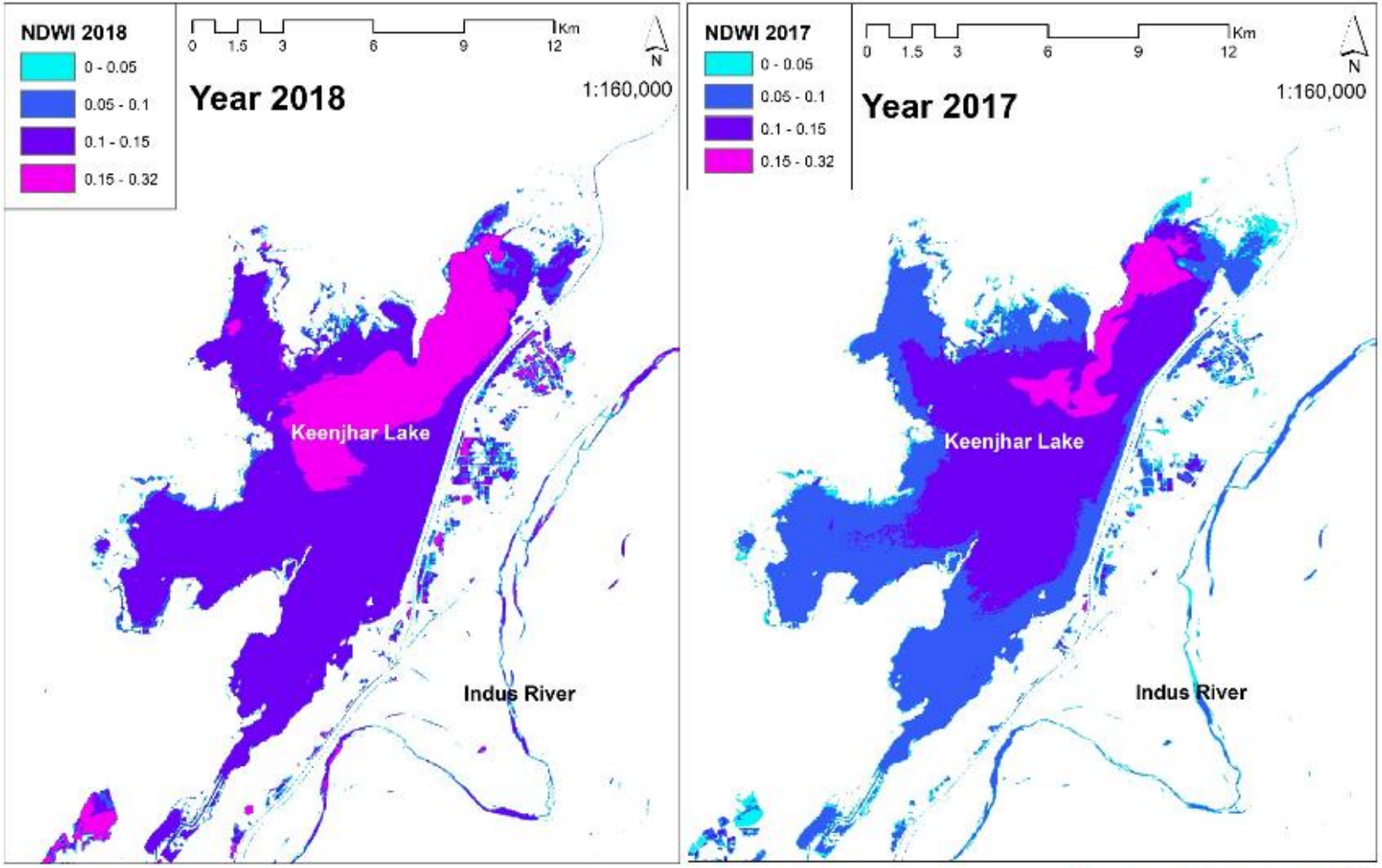
Annex III: Remote Sensing and Delineation of Keenjhar Lake's Surface Area using NDWI Method



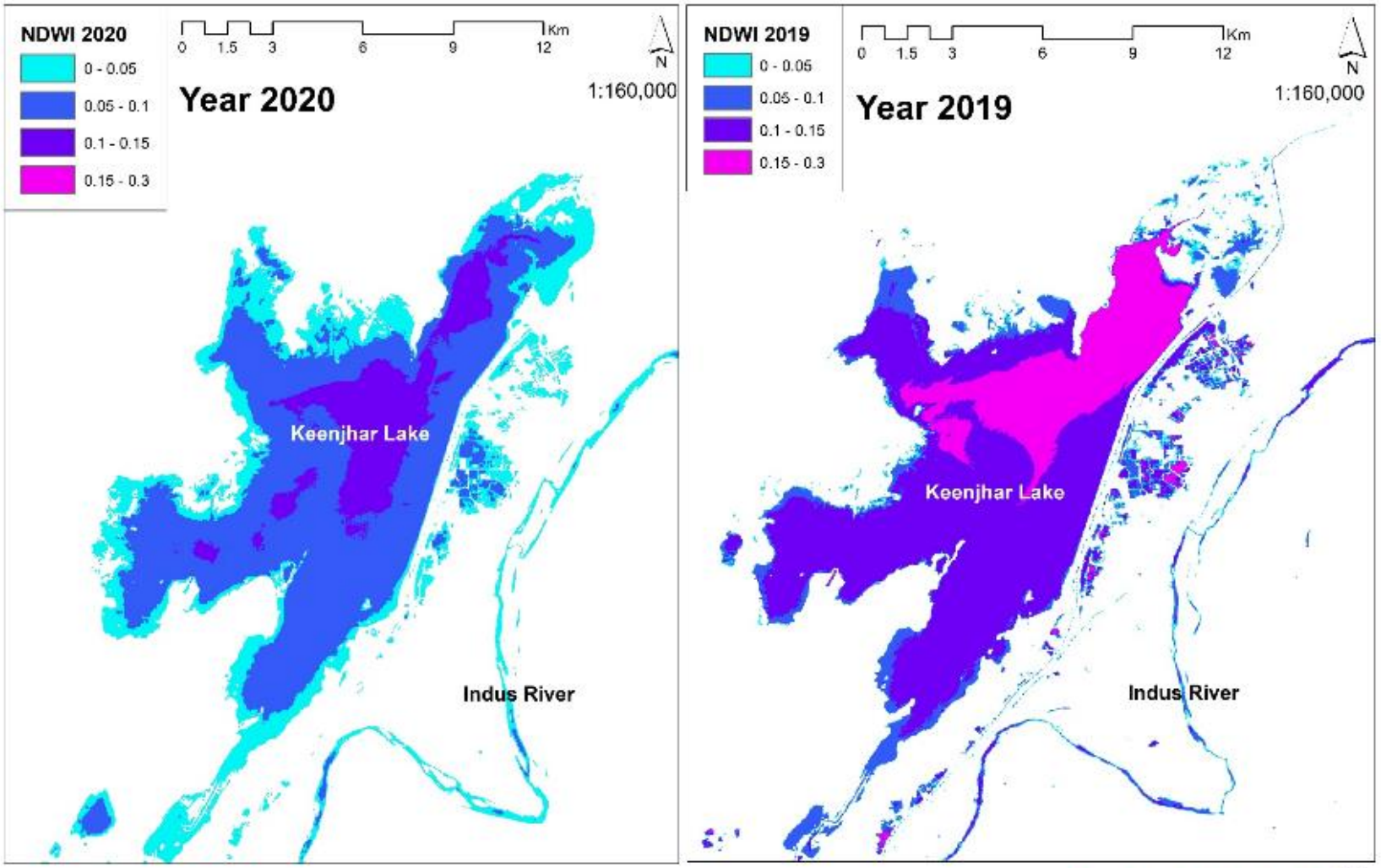
Visualization of Changes in Keenjhar Reservior on Annual Basis Using Normalized Difference Water Index (NDWI)



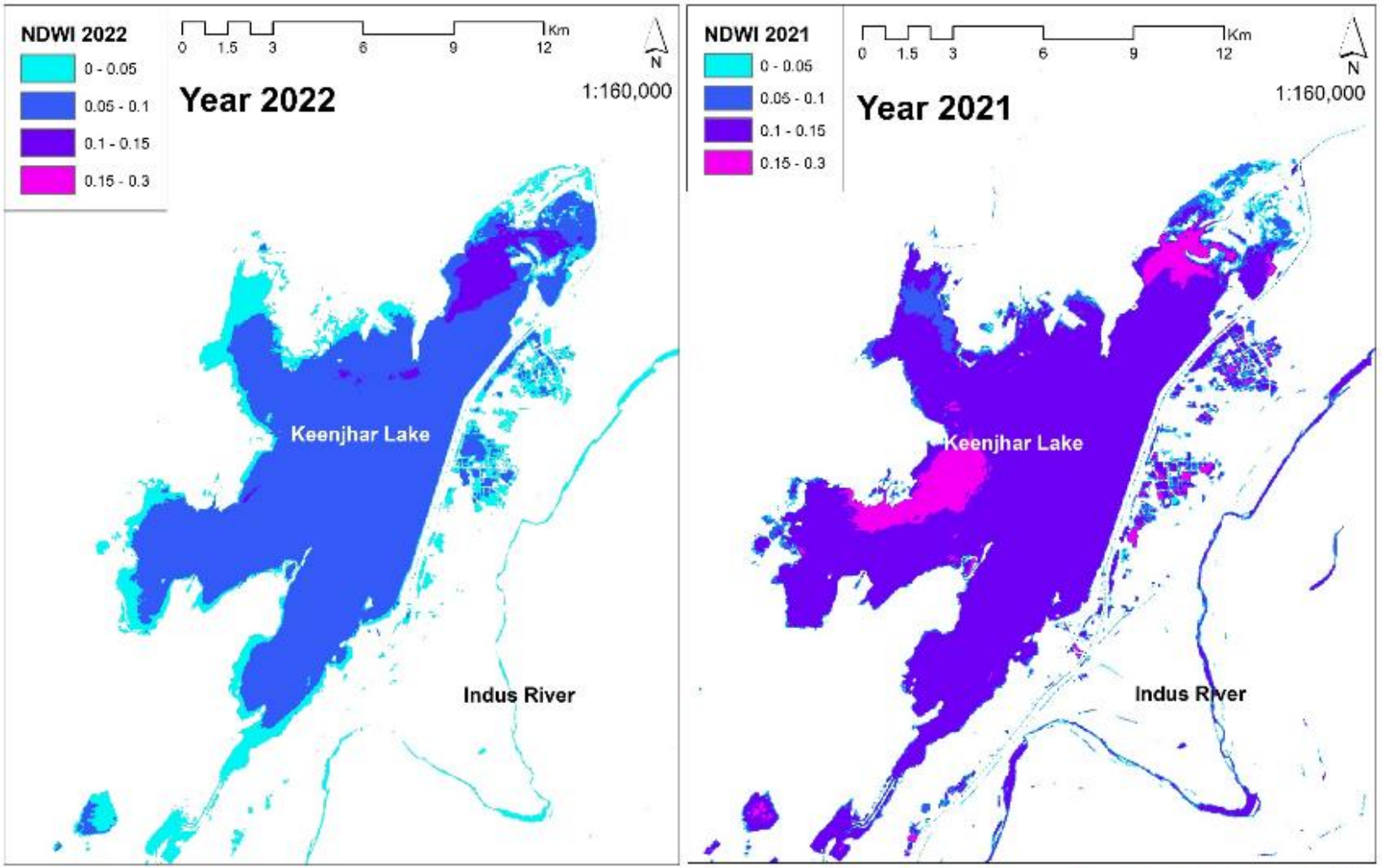
Visualization of Changes in Keenjhar Reservior on Annual Basis Using Normalized Difference Water Index (NDWI)



Visualization of Changes in Keenjhar Reservior on Annual Basis Using Normalized Difference Water Index (NDWI)



Visualization of Changes in Keenjhar Reservior on Annual Basis Using Normalized Difference Water Index (NDWI)



Visualization of Changes in Keenjhar Reservior on Annual Basis Using Normalized Difference Water Index (NDWI)