Environmental Impact Assessment of the Tidal Link Failure and Sea Intrusion on Ramsar Site No. 1069

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Abstract—**This paper presents the impact on the RAMSAR site No. 1069 that receives fresh water by the Kotri drainage system. At present, the complex faces threats by effluents from the Left Bank Outfall Drain (LBOD) system and from saline seawater intrusion during high tides. These threats have destroyed the ecosystem of the lakes Cholari, Mehro, Pateji and Sanhro belonging to the complex. The total present lake area, maintained at the Cholari weir crest level, is about 170km^2. The lakes are expanding, available data shows that there is an increase up to 700% in the original lakes' area, from 6058 to 41220 acres from 1954 to 1977. This is mainly caused by the operation of Kotri Barrage surface drainage system and has positive impact on lakes' ecology because the drainage effluent is of marginal salinity. The rapid increase in the lakes' area, of about 40% within 2 years after the functioning of the Tidal Link with saline effluents from LBOD and sea intruded water have changed the ecology of the area. This posed significant impact on the ecosystem. Conversely, a similar rise in water level due to sea intrusion has nearly doubled the surface area and reposed a negative impact on the system. These lakes were giving shelter to a wide variety of local and migratory birds and had aquatic biodiversity. Hence, parts of Sanhro and Mehro dhands have been recognized by the RAMSAR Convention.**

Keywords-Tidal Link; Sanhro and Mehro dhands; LBOD; ecosystem; sea intrusion

I. INTRODUCTION

Tidal Link is the component which makes the LBOD unique among drainage projects in Pakistan and probably in the world. The saline water must be disposed of in such a way that it could not damage other areas or fresh water bodies. With the ever-growing awareness of the need to protect the natural environment, disposal to lakes, rivers or natural depressions has become unacceptable. The Tidal Link allows strongly saline effluents to flow directly to the sea. It extends from the end of the Kadhan Pateji Outfall Drain (KPOD) to the Sir Tidal Creek [1]. Prior to the construction of the Tidal link the water of Pateji/Cholri Dhand area was maintained at a level of approximately 5 feet above mean sea level by a natural land bar separating it from the Rann of Kutch. Since the construction of the Kotri surface drainage system in the 1960s, the Dhands have become an environmentally important wildlife sanctuary, and also support a thriving fishing industry [2].The spinal drain was constructed to dispose drainage water into sea via the Tidal Link [3]. The southerly section of the LBOD system was constructed in 1995 having length of 25 miles. It has a point of junction from KPOD to its outfall in Sir Creek [4].

Disasters that commonly occur in fast succession are cyclones, heavy rainfall, floods and droughts. Manmade disasters have affected the coastal population badly as well [5]. However, in several parts of Badin district, saline water has brought land degradation and submergence of the area due to failure of the system to meet the desired results. Coastal wetlands are of pivotal importance to human activities and natural systems [6, 7]. However, it is challenging to determine quantitative measure values for the wetlands due to several factors such as complicated hydro-biological functions,

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socioeconomic context and diversity [8]. Policy suggests that both market and non-market values of the wetlands can be considered into account during decision making. Globally, 50% reduction has been seen in the wetlands [9]. One third of the species are dependent on wetlands [10]. The urbanization and climate change are bringing about the wetlands at the brink of degradation [11, 12]. Sinatry and Shakoor Dhands lie at the Pakistan-India border and are fed by Dhoro Puran. The area is swampy at the location of Tidal Link and is covered with large interconnected water bodies such as Cholri, Pateji Sanhro-Mehro, and Khadi Dhands [13]. After the construction of the LBOD, the natural flow of the water was altered and the waters from the 3 dhands flow into the Cholri and Cholri Weir via Shah Samando creek and Runn of Kutch into the open sea [14]. It is worth mentioning that more than two dozen breaches have taken place in the Tidal Link Drain after the Cyclone 2A. The Cholri Weir controlling the water level in dhands was damaged and completely washed out during the cyclone. This altered water flows and water exchange and affected the water emancipations from the LBOD in the area [14]. A sharp incline angle of the bank of the Tidal Link Drain near RD–93 was observed due to the impact of the Cyclone 2A at various locations. The water from the Arabian Sea and from the Indian Territory now directly enters into the Tidal Link Drain. The movement of the water is unrestricted from the Tidal Link Drain to adjacent dhands and vice versa [15]. When the water salinity was tested at different RDs, high values were recorded at RD–114, RD–124, RD–93 and RD–74, indicating sea water presence. There has been a free exchange of water between Dhands due to the washing away of Tidal Link Drain at different places [15]. The high amount of salinity of the Rann of Kutch affects the salinity of Tidal Link Canal left bank as it flows through its breaches. At least up to 1997, the salinity conditions stayed favorable in Dhands. Presently, the range of salinity conditions goes from those typical for sea water to the hyper saline Pateji Dhand.

II. STUDY AREA

The drainage water across Pateji Dhand and Cholri into the Arabian Sea via Shah Samando Creek is delivered by the man made Tidal Link drain. The research study area is located at latitude of 24°29'7162"N and longitude 68°60'5430"E. The length of Tidal Link is 41km starting from its juncture point with KPOD in the Northeast upto the Shah Samando Creek in the Southwest. The Tidal Link is built in such a way that it can transport about 3,118 cusecs of drainage water. The alignment of the tidal Link passes across Pateji and Cholri Dhands which are linked with Mehro and Sanhro Dhands. These Dhands have drained the excess water into the Rann of Kutch. Tidal Link now blocks this drainage.

III. MATERIALS AND METHODS

The pH and salinity values of Tidal Link and Dandhs were measured on site.

A. pH Meter

The HI 8014 measures pH with temperature compensation. It measures QRP as well. Different modes of measurements can be switched by the user.

B. Refrectometer

The salinity and specific gravity of sea water can be measured using this device.

C. Failure of Constructed Cholri Weir

The design of the weir was in such a way that it could flow in either direction to the tidal cycle having a cresl level of 4.5ft and length of 18000ft. The water level in the Dhands must not exceed the limit of 6ft. As a comparison, the designed water levels in the incoming Karo Ghungro and FuleliGuni outfall drains are 10 and 11ft [16].

D. Cyclone 2A, 19th May 1999

In this area, rainfalls and cyclones are common phenomena, responsible for causing damage to the Tidal Link and infrastructures. Before Cyclone 2A, the creeks were connected to the sea 50m away from the main city of Badin [17].

IV. RESULTS AND DISCUSSION

There is a 700% increase in original Dhands area from 6058 to 41220 acres from 1954 to 1977 due to the operation of Kotri Barrage surface scheme. This has positive impact on Dhands ecology because the drainage effluents are of marginal saline. But the rapid increase in the Dhands area of about 40% within 2 years after the functioning of the Tidal Link with saline effluents from LBOD and sea intruded water have been changing the ecology of the area.

TABLE I. DHANDS AREA BEFORE TIDAL LINK CONSTRUCTION

Dhand name	Area acres			Extended area acres (1997)
	1954	1977	1991	
Cholri	300	5715	5560	60,000
Mehro	620	9575	9730	
Sanhro	975	16525	15908	
Bakradi	234	620	In Mehro	
Bakar	1575	600	In Pateji	
Pateji	2354	5714	6332	
Mandhar	Not exist	2471	4300	
Narahi	Not exist	Dry	Dry	
	6058	41220	41800	60,000

A. Sources of Dhands Water Supply

The sources of water supply of the area are mainly from the tail end channels of Fuleli and Pinyari canal of Kotri Barrage. The area is also supplemented by outfall drains. Kadhan-Pateji, Karo Gunghro and Fulleli Guni discharge into the Dhands area. These drains carry effluents from agricultural lands and storm water during monsoon rains from a total catchment area of more than 2000 sq. miles. Karo-Gunghro outfall drain and Ahmed Rajo branch drain discharge into Sanhro Dhand. Fuleli-Gunni outfall drain discharges into Mehro Dhand. Some sub drains and branch drains of Kadhan-Pateji outfall system discharge via KPOD into the Pateji Dhand (Table II).

TABLE II. DISCHARGES OF KOTRI SURFACE DRAINS IN TIDAL AREA

Drain name	Out fall	Discharge (cusecs)
Fulleli Guni Outfalls Drain	Mehro Dhand	2550
Ahmed Rajo Branch Drain	Mehro Dhand	80
Karo Gunghro Outfalls Drain	Sanhro Dhand	1768
KPOD	Tidal Link	3626

B. Impact of Tidal Link on the Dhand Complex

In 1995, the Tidal Link was built so that it could withdraw 3 million tons of salt and 0.7 million acre feet of sewage into the sea per year. Issues were brought up concerning the operation of the Tidal Link Drain such as saline water flow rates, water movements and their influence upon the Dhands and coastal wetlands. In order to sustain the area ecology, a long (1800ft) weir was constructed on the Norther Bank of Tidal Link and the south limb of Cholri Dhand. The drain of the Tidal Link does not flow through any agricultural lands. The Cholri weir contributes in maintaining the water balance and quality in Dhands. The water samples were collected from different areas (Figures 1-4) which were affected by the high tide of Sea (before the construction of the Tidal Link) and were sent to the Sindh University for analysis in 1997. The pH values of all samples have been found within permissible limits except the sample from Sanhro. The electric conductivity was higher at Cholri, Fuleli Tidal-129RD. The other samples were within permissible limits. The measured chloride content was in the range of 1000 to 40000ppm, and the salinity was relatively low in most of the samples.

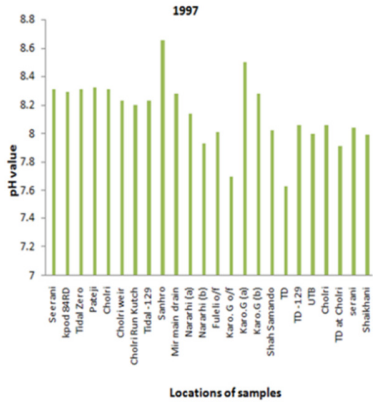

Fig. 1. pH values before the construction of the Tidal Link

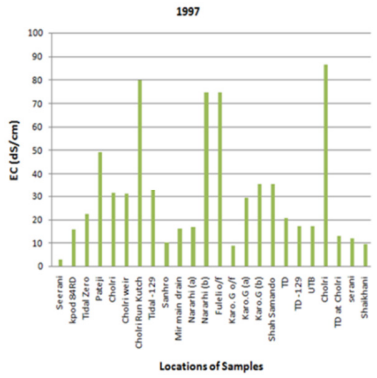

Fig. 2. Electric conductivity before the construction of the Tidal Link

C. Cyclone 2A and Tidal Link Damages

The monsoons dominate the coastal zone of Indus Delta from July to September. Most of the damages to infrastructures are caused by cyclones and heavy rainfalls in this area. The cyclone 2A damaged the Tidal Link severely. This calamity left the banks of 56 locations with partial breaches. The system could not sustain the storm water due to its failure. The sweet to saline water Dhands like Mehro, Kadan - Pateji, Sanhro and Cholri were turned saline due to seawater intrusion.

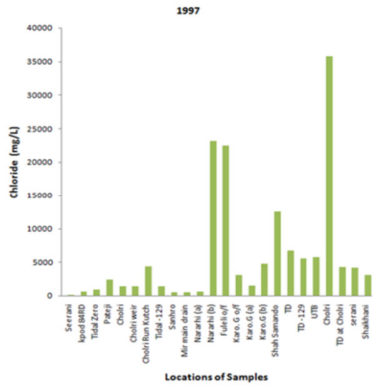

Fig. 3. Cloride values before the construction of the Tidal Link

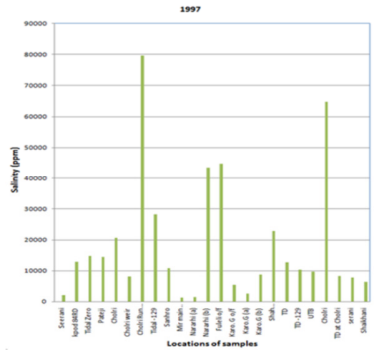

Fig. 4. Salinity values before the construction of the Tidal Link

Before cyclone 2A the creeks were connected to the sea water 50km away from the main Badin city. The sea water approached many villages at a distance of 35km from the main city. Water samples were collected in 2001 from different locations/areas (Figures 5-8) affected by high sea tides before the construction of the Tidal Link and were sent to Sindh University for analysis. The results showed that pH values of all samples were within permissible limits except the sample from Sanhro. The electric conductivity was higher in the samples from Cholri, Fuleli Tidal-129RD, while the other samples were within permissible limits. The measured chloride content was in the range of 2000 to 16000mg/L. Salinity refers to the total amount of soluble salts in the water. It is expressed in dS/m at 25^{o}C. Excess soluble salts present in water can change its chemical and physical characteristics. Salinity has been used here as a main indicator for sea water intrusion. The salinity recorded during 2001 shows that Cholri and Pateji dhands were generally as saline as sea water (34000ppm), and that Sanhro and Mehro Dhands were of low salinity (6000ppm) although still well above the salinity of canal water (450ppm). KPOD water had also low salinity (5000ppm) in winter. There is no dilution source for the dhands and adjoining agricultural fields resulting to salt accumulation on the Dhands bed, intrusion on land and spreading on the area through winds.

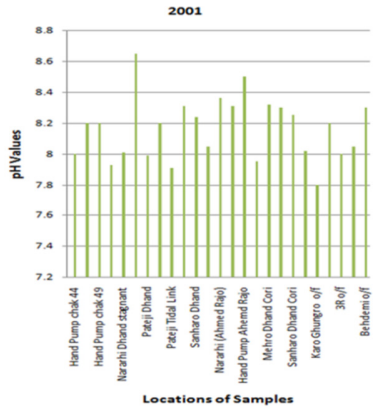

Fig. 5. pH values after the construction of the Tidal Link

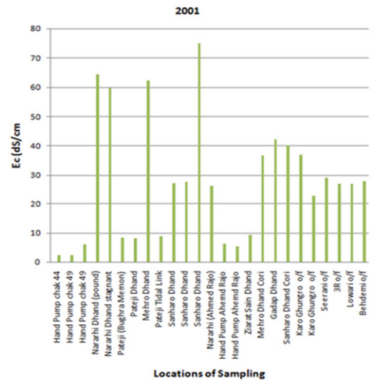

Fig. 6. Electric conductivity after the construction of the Tidal Link

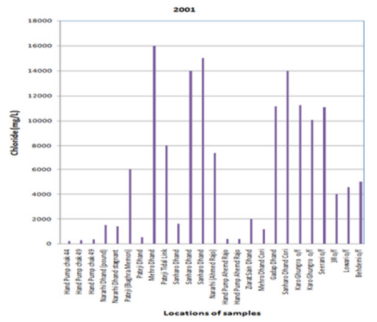

Fig. 7. Cloride values after the construction of the Tidal Link

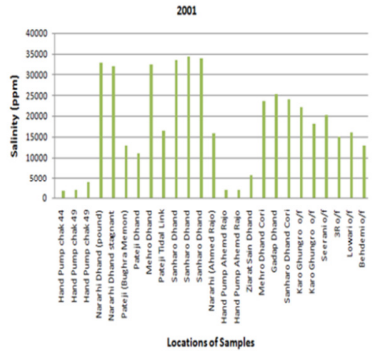

Fig. 8. Salinity values after the construction of the Tidal Link

D. Seawater Intrusion Tidal Link

Probably, the main cause of the excess amount of salinity in the tidal link drain is the water exchange between Dhands and the high salinity adjoining creeks. The seawater from Shah Samando Creek has now extended up to RD-55 and beyond. According to the visible topographic changes, the outfall of the tidal link has shifted from RD-155 to an area between RD-93 and RD-125. The water salinity in Tidal Link Drain at various RDs ranged from 30 to 45ppt, the water salinity at RD-93 varied between 30 and 44ppt, but mostly remained between 30 and 35ppt. Lower water salinity indicates the influence of KPOD water in the tidal link drain. No brackish water/fresh water was observed to enter Dhands or the tidal link drain.

E. Seawater Intrusion in Dhands

The area between the high tidal zone and the agricultural lands contains a few but huge Dhands. The water in these Dhands varies from sweat to saline. High amount of salinity in the Dhands is probably the result of seawater mixing with the Tidal Link and the decreased flows in a few of the Kotri drains (Fuleli and Karo). The flow from Kotri drains consequently ends up in the Tidal Link via Narri Sanhro and Mehro Dhands. Evaporation may be an effective factor for balancing the water level in Dhands. The polluted streams from sugar factories and others may pose a serious threat to them. Figures 9-13 show the values of surface water salinity per year. Water quality has been improved by the recent rainfall flood in 2011. Due to the inter-connection of sea water with Cholri weir, the Narri and associated dhands aren't suitable for accumulating fresh or rainfall water.

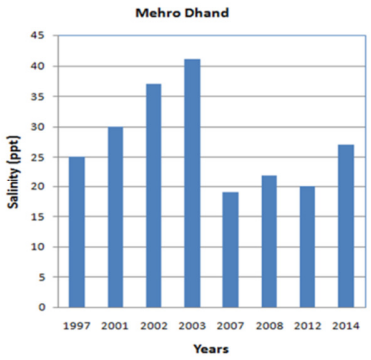

Fig. 9. Salinity of Mehro Dhand

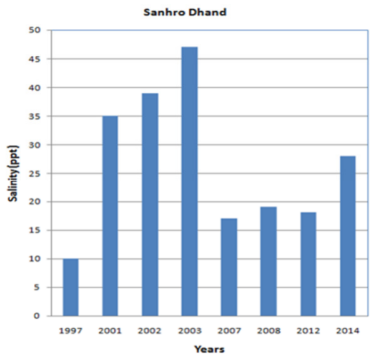

Fig. 10. Salinity of Sahro Dhand

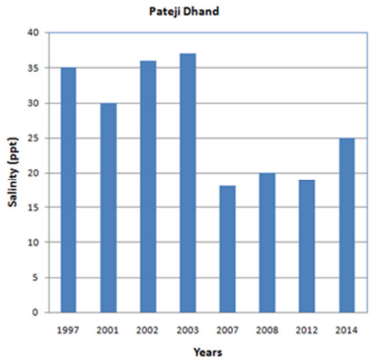

Fig. 11. Salinity of Pateji Dhand

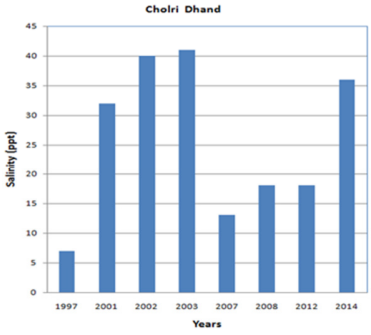

Fig. 12. Salinity of Cholri Dhand

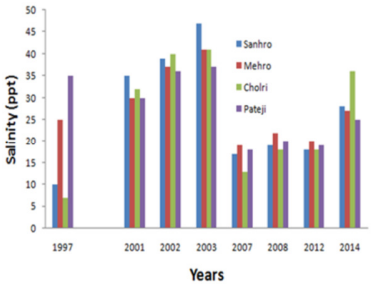

Fig. 13. Salinity of Sahro, Mehro, Cholri and Pateji Dhands

F. Satellite Images of the Dhand Area

The total area covered by the Dhands (Cholri, Pateji, Sanhro, and Mehro) is about 153 sq. miles. These dhands are interconnected naturally via open narrow channels. Various species of migrating birds from Siberia to North Pole, aquatic life of fish and plants rely on these Dhands for their survival.

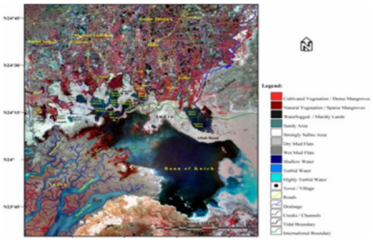

Fig. 14. Satellite image of the Tidal Link area, 21 Oct. 1989

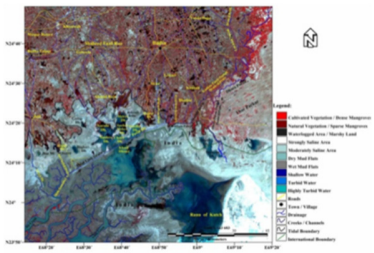

Fig. 15. Satellite image of the Tidal Link area, 3 Feb. 1999

Compared to the 1989 image (Figure 14) of the Tidal Link, the natural vegetation/swamps have vanished in 1999 (Figure 15). When compared to 1999, a massive water body appears to have shrunk in the southern part of Kadhan, Cholri and Pateji Dhands. Tidal Link Drain appears to have stopped water inflow from irrigation canals draining to Cholri and Patrji to Kadhan and thus converted them to wet mud flats.

G. Environmental and Socioeconomic Impact

Dhand water attracts thousands of migratory birds from Siberia and Europe from November until the end of March. Dhands serve as feeding grounds, only few of the migratory birds species breed there. The Dhands are rich in aquatic life, they produce large numbers of shrimps and fish, which depend on fresh and sea water during their life cycle. Crops cultivated in the years 1993 to 1998 in the affected area in Rabi (November to May) are: wheat, barely, vegetables, mustard seed, sunflower, hurbo and maize fodder. In Kharif (May to October) are: maize fodder, rice, sugar cane and vegetables. Fish farming is active and growing in this area, with the majority of the workforce belonging to the fisher community. The main stakeholders of the area are small landowners, harees (tenants) and laborers. They are involved in agriculture, small business, livestock, fishing, and various manual labor occupations. Information collected shows that the numbers of small and medium landowners are the majority. The majority of farmers holds lands below 12.5 acres.

V. CONCLUSIONS

The Dhands are an environmental concern, they possess estuary ecology and maintain a biodiversity of flora and fauna. The concept of the Cholri Weir was to maintain 5ft water depth in the Dhands and give way overflow water to the Tidal Link, in order to maintain the ecology of the area. The effect of the natural disaster of the 1999 Cyclone, high tides during the 2000 quake, the 26 May 2001 storm and the 2003, 2006 and 2011 heavy storms further damaged Tidal Link. They have completely shattered the system from Shah Samando creek to Seerani drain. The satellite images show the completely wash away picture of the Tidal Link. There is a free way of sea flooding during high tides and rough weather particularly in monsoon season from Shah Samando creek. These conditions along with drought triggered seawater intrusion in the area severely demaged the area's ecology. Agricultural fields, fresh water reserves and fishing activities have been reduced. Dhand water attraction of migratory birds declined. Inhabitants have to travel far away from their homes in search of basic commodities such as food, water, firewood, fodder, etc. something that directly impacts human life in this area. Wild

life pattern has changed, the seasonal migrating has not been seen in this area since long, particularly after the failure of the Tidal Link. Sweet water fish have been replaced by saline water species whose majority is carnivore, their colonies are continuously increasing and eventually they will lead the remaining native species to extinction. Generally, the ground water is saline and the residents are depended on the occasionally available canal water or are forced to purchase water from venders. The contaminated water causes various diseases like diarrhea, jaundice, abdominal and skin diseases, which are common in the area. Concluding, the failure of the Tidal Link had a serious impact in the life of common people.

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