Surface and Groundwater Scenarios of Balochistan; Present, Past, and Future

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Abstract

Over half a century ago, Balochistan was a rosy land of peace, love, passion, traditions, and adventures. There was a system, harmony, and order in all fields of life. Diverse climatic conditions with a gorgeous coastal line, distinct deserts, plains, valleys, unique ecology, ecosystems, high mountain ranges, forested topographic landscapes, and vast physiography with a mesmerizing beauty that fascinates everyone. The water table was a few meters below the ground surface; valleys had springs, hand-to-motorized pumps, and artesian-to-dug wells were common for potable and domestic supply. The rural population depended on karezes and flood waters for traditional irrigation, which comprise rainwater harvesting, and spate irrigation. The surface and groundwater scenarios were promising for the traditional way of water utilization, and there were no concerns over water quality and contamination. The rural electrification and systematic groundwater investigations started in 1970. Thereafter, farmers swiftly switched to groundwater irrigation for the reliability of food production. The suction pumps were converted into deep submersible pumps powered by electricity, resulting in a competitive race for more groundwater-extraction. Subsequently, there was a boom in population, urbanization, agriculture, industry, and mining. The natural resources were devastated, aquifers were exhausted, the continuous decline of the groundwater table became a threat to the sustainable irrigation and public water supply systems, and numerous springs and karezes ran dry. The impact of climate change is quite apparent, causing extreme heat waves, instant rain showers, flash floods, and prolonged droughts. Balochistan became the least water-secure and completely failed to manage its water-associated developmental challenges. The groundwater, the Indus River share, and the flood water constitute 4%, 39%, and 57%, respectively, of all the water resources. Around 40% of the floodwater is utilized while the remaining would hopefully make changes to the landscape of Balochistan one day. The 'Integrated Watershed Management Strategy' is the ultimate resolve to manage, conserve, and utilize precious water resources.

Keywords: Aquifer, surface water scenario, groundwater scenario, Balochistan

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1. Introduction

Today's Balochistan, a southwestern province of Pakistan, is known for its harsh climatic conditions with vast deserted valleys, mountain ranges, and bare topographic landscapes due to lack of utilization of flood water resources. climate change, variability in temperature, and precipitation caused extreme weather events and mega floods. The historical and future forecasts of climatological drought over Quetta, represent the continuation of climatic severity that put an economic burden on its residents (Durrani et al., 2018). The management, developmental, socioeconomic, environmental, and water utilization concerns precisely indicate that Balochistan is not water secure (Bank, 2018). Desertification has been driven by human-induced factors well advanced over the past few decades (Gils and Baig, 1992).

Excessive groundwater (GW) withdrawals are the main cause of the widespread GW decline and contamination of water resources (Imad, 2018). Quetta Valley aquifers are declining by 1-4 meters/year, resulting in deterioration of GW quality, land subsidence, and drying up of all springs and karezes. Common waterborne diseases are the result of contaminated water supply and poor sanitation facilities. Environmental disasters cause intense rain and flash floods that alter water-dependent ecosystems, biodiversity, watersheds, forests, and range lands (Bank, 2018). Water governance poses the biggest challenge in the province, which includes the downfall of the Quetta Water Supply, the irrigation system along poor legal and policy frameworks (Gils and Baig, 1992). Balochistan's coastline stretches over 800 km from the SE of the Indus Delta to the Pakistan-Iran border and has great potential for development through the China-Pakistan Economic Corridor and modernized Gwadar Port (Farooqui and Aftab, 2018).

2. Climate change and droughts

Balochistan plateau has diverse climatic zones that comprise upper and lower highlands, deserts, and plains. The mountain ranges constitute 53%, alluvial fans 22%, piedmont plains 12%, and sand plains 7% of the province's land mass (Pakistan, 2011). Ecologically, the northern highlands are characterized by cold winters, frosts, and moderate summers, with a yearly precipitation of 120-260 mm. In the southwestern deserts, summer temperatures reach 51°C, but winters are mild, and rainfall is from 123 to 219 mm (Consultants, 2017). The coastal areas have mild summers and winters, with annual rainfall ranging from 70 to 140 mm (Table 1).

The significant weather and climatological parameters are precipitation, air temperature, humidity, potential evapotranspiration (PET), wind speed and direction, cloud cover, and daily sunshine hours. Changes in climate parameters may alter regional and local hydrologic cycles that impact the quantity of surface water and recharge of GW resources. Fig. 1 shows the meteorological parameters data of the Quetta station for a period of 45 years from 1975 to 2020 representing long-term changes in environmental trends. The statistical trend of average temperature represents an increase from 24.2°C in 1975 to 25.8°C in 2020, with an overall increase of 1.6ºC. The precipitation represents a considerable decreasing trend. The escalating trend in temperature with a declining trend of precipitation auto-correlated each other in the long term.

Table 1. River basins show the number of rain and river gauges, cumulative yearly precipitation, climatic zones, drainage area, and population.

	Basins	Rivers	Rain / River Gauges (Nos.)	Precipitation (mm)	Climatic Zones	Area (000) Km^2	Population (000) (2020)
1	**Indus River**	Gaj	1 / -	200	Semi-Arid Semi-Humid Zone	6	177
2		Kachhi-Plain	7 / 3	122		32	1,877
3		Kadai	1 / -	185		4	212
4		Kaha	1 / -	217		12	227
5		Kand	-	224		2	27
6		Kunder	-	208		6	50
7		Mulla	1 / 1	173		16	200
8		Nari	8 /3	258		22	569
9		Zhob	5 /3	228		17	166
Total			**24 / 10**	**202**	**-**	**116**	**3,503**
10	**Closed River**	Hamun-e-Lora	1 / 1	124	Arid Zone	8	161
11		Hamun-e-Mashkel	4 / -	133		85	944
12		Pishin	8 / 3	219		18	4,361
13		Rakshan	1 / -	123		13	401
Total			**14 / 4**	**150**	**-**	**124**	**5,866**
14	**Makran Coastal**	Dasht	4 / 1	86	Hyper-Arid Zone	28	1,596
15		Gwadar-Ormara	4 / -	71		17	472
16		Hingol	5 / 1	102		35	973
17		Hub	1 / -	137		9	260
18		Porali	5 / 3	140		18	327
Total			**19 / 5**	**107**	**-**	**107**	**3,627**
GRAND TOTAL			**57 / 19**	**153**	**-**	**347**	**12,996**

There are four kinds of droughts, i.e., meteorological, hydrological, agricultural, and socioeconomic. Due to meager precipitation, drought has become a permanent climatic phenomenon in Balochistan. The drought hazard map of Balochistan shows the Vulnerability Index along with hazard classes presented in Fig. 2, (Adnan and Ullah, 2020). The historical data in Table 2 shows that from 1878 to 2020 there were 34 droughts of mild, moderate, and severe categories, which means a drought every 4 years or so (GOB, 2021).

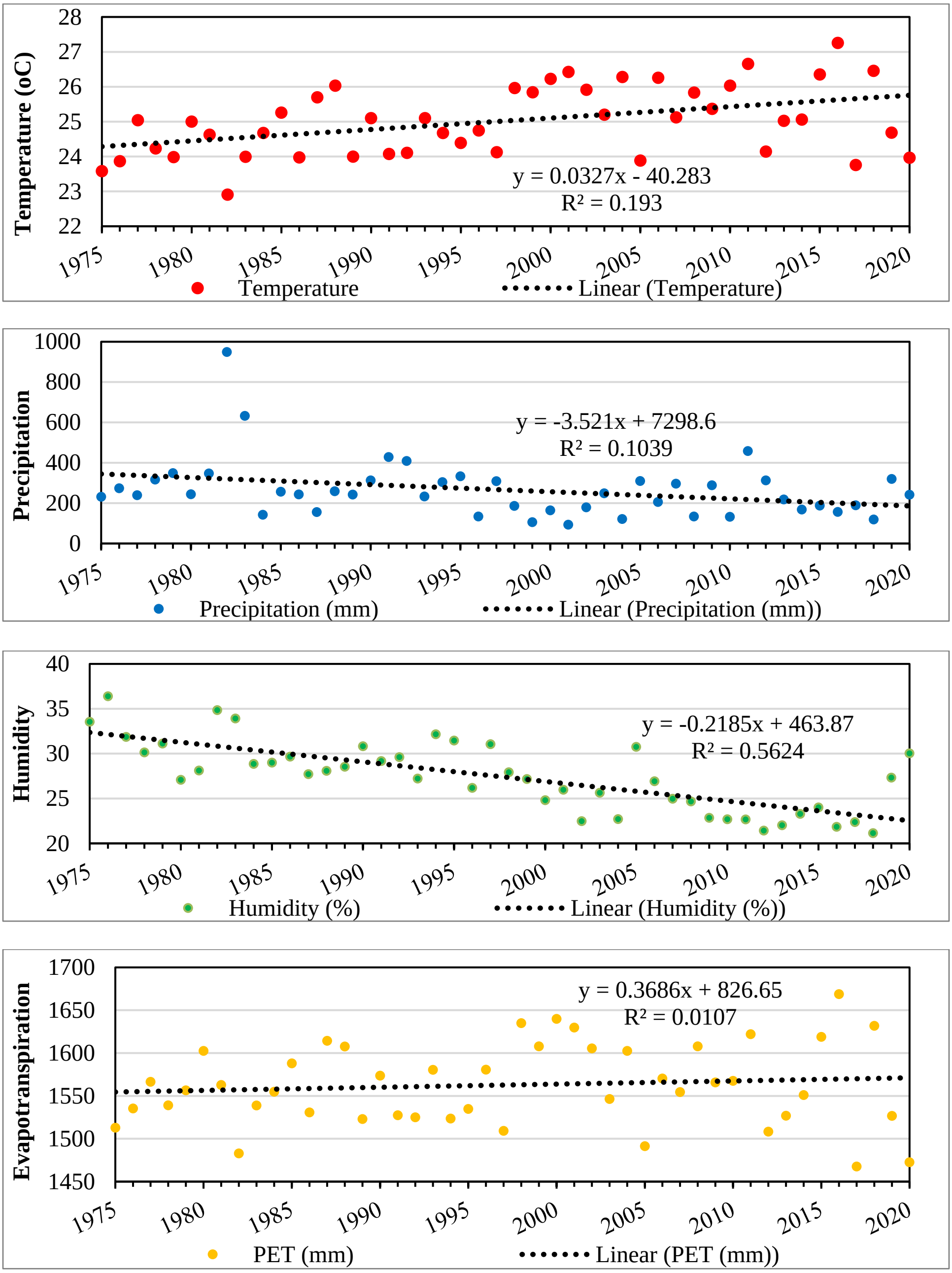

Figure 1. Linear regression trends and correlation between cumulative yearly average temperature, precipitation, humidity, and PET data of Quetta for 1975-2020.

3. River Systems

Pakistan has three types of river systems: the Indus River System, Closed River Systems that form Playa lakes, and Makran Coastal Rivers that drain directly into the Arabian Sea (Fig. 3). The mighty Indus River is 3,180 km long, with a catchment area of 1.165 million km^2, of which 0.693 million km^2 lies within Pakistan (Young et al., 2019). Besides Pakistan, the Indus catchment area covers parts of India, China, and Afghanistan. The catchment area of the Indus River spans the entire Kashmir, Khyber Pakhtunkhwa, Punjab, Sindh provinces, and the northeastern part of Baluchistan.

Baluchistan is dominated by the surface drainage of 18 ephemeral rivers which are divided into 73 sub-basins based on major streams. The watersheds are destroyed by over-exploiting their natural resources and have lost their capacity to retain surface and GW to produce base flow to the streams. It releases the entire quantity of precipitation as flash floods to the streams. The 18 rivers are classified into three groups; among them, nine rivers are part of the Indus River System, four are Closed River System, and five rivers are of the Makran Coastal Basin. The three river groups are presented in green, yellow, and blue colors in Fig. 4, and the data about these 3 groups are also presented in the same colors in different tables. The nine rivers are part of the Indus River, with an area of 116,000 km^2 contributing surface flow to the Indus River. The four closed river basins formed playa or temporary lakes called Hamuns in the Balochi language. The five rivers of the Makran Coastal Basin drain directly into the Arabian Sea. The Hingol River, with a length of 565 km, is the longest river in the province, where in some sections water flows around the year. The catchment areas of all individual rivers are given in Table 1.

Table 2. Drought occurrences in Balochistan during 1878-2020, (Irrigation & Power Dept. GOB, 2021).

Drought Category	Precipitation Deficiency (%)	Total Occurrences	Recurrence Interval
Mild	20 - 29	13	9
Moderate	30 - 39	12	11
Severe	40 and above	9	13

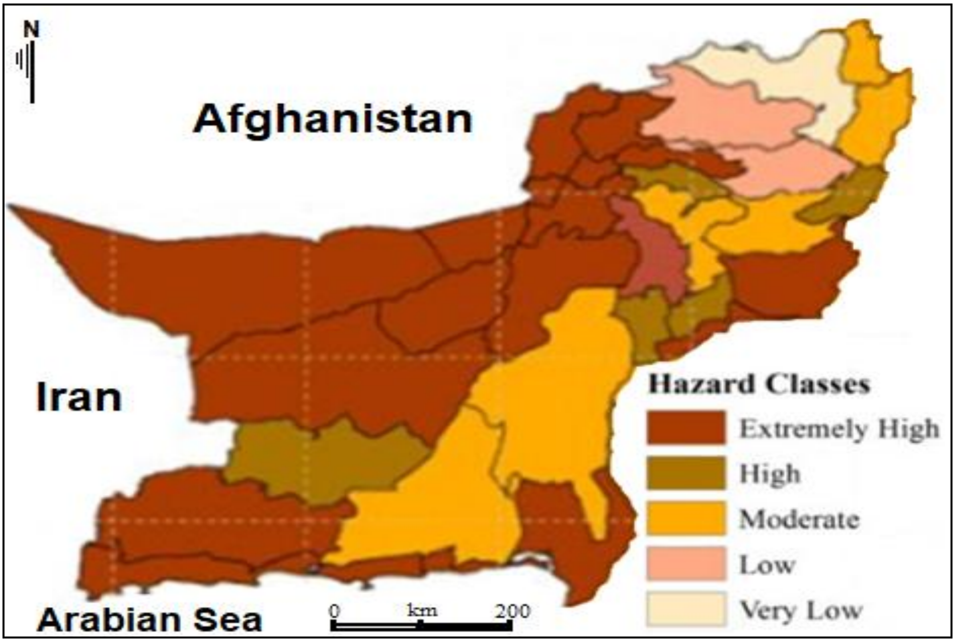

Figure 2. Drought hazard map of Balochistan, showing vulnerability Index, modified after (Adnan and Ullah, 2020).

Figure 3. Indus River Basin and river basins of Balochistan, modified after Young et al. (2019).

Figure 4. Map of Balochistan showing 18 river basins, and enlarged map of the Pishin River Basin.

4. Irrigation Schemes and Dams

The rural population depends on karezes and flood waters for traditional irrigation which comprises rainwater harvesting (Khushkaba), and spate irrigation (Sailaba). The economy of the province depends on agriculture because 75% of the rural population and 60% labor force are engaged in agriculture (Benmessaoud, 2013). The population of Balochistan as per the 1972 census was 2.43 million, which reached 12.344 million by 2017, 14.984 million in 2023, and is expected to become 20.4 million by 2050

Water is the only factor reducing agricultural efficiency and the income of farming. The major water sources containing GW is 4%, the Indus Basin share is 39%, and the flood flow is 57%. Agriculture consumes 93% of the total water used in Balochistan (Bank, 2008). The provincial Irrigation and Power Department (I&P Dep.) has built 300 small perennial irrigation schemes, with a total water utilization capacity of 14 Mm^3/yr, to irrigate 2,500 km^2 of land annually (Table 3).

Pakistan Water Apportionment Accord was signed in 1991 between all provinces to allocate the Indus water share out of 145 Bm^3 (Billion cubic meters). Balochistan got a share of 5 Bm^3. Hence a few canals carry Indus water to the Kachhi Plain of Baluchistan. The Kachhi Canal originates from the Taunsa Barrage in Punjab, Pat

Feeder Canal emerges from Guddu Barrage, and Kirther Canal from the Sukkur Barrage in Sindh. It is the only gravity-fed canal system in the province, with a total water-carrying capacity of 4 Bm^3 to irrigate 3,000 km^2 of land.

There are 19 stream gauges located out of 73 streams, that physically cover 30% drainage area of the province. Several dams in each river basin are present including small, medium, and large, (Consultants, 2017). Small dams, called delay action dams, were constructed for GW recharge (Table 3). There are about 300 plus delay action dams in the province with a water storage capacity of less than 1 Mm^3 each, medium-size storage dams have a capacity of more than 1 Mm^3 and only 6 large storage dams.

5. Declining of Groundwater Table

The GW level in Kachhi Plain is declining at the rate of 5-25 cm/yr. There is no GW monitoring system for the rest of the 17 river basins of Balochistan. The provincial Irrigation Department is conducting GW monitoring in 4 subbasins, including Quetta, out of 73 subbasins of the province since 1984. The GW level is depleting equally at a high rate in four subbasins of the Pishin River Basin. The GW monitoring record of Quetta Valley from 2003 to 2015 represents that the water table is declining from 1-4 m/year, the total decline differs from 12 to 41m. The demand and supply of aquifer waters are at risk due to continuous GW depletion.

Tehsil Karezat of Pishin District is famed for its centuries-old Karez system which is progressively drying and ultimately would die forever. The 106 karezes of the tehsil were constructed in different eras; the oldest one is 600 years old, whereas Marghakai Karez is 450 years old and 2 km long. Every Karez has a history, identity, construction tales, and dignity of the community. Out of 106 karezes, 37 are partially active, and 69 dried out in the last 3-20 years (Table 4). The drying of karezes is due to droughts and the mining of GW through mechanical means.

6. Surface and groundwater balance

The major rivers and streams in Baluchistan are given in Fig. 5. The surface and GW are extracted and utilized with different means and quantities for different capacities like domestic supply, livestock, agriculture, and nature (Table 5). Water supply schemes are considered human consumption and livestock is about 10% of human consumption. Agricultural share of water is the biggest quantities in all river basins, thereafter, sharing for the nature. The share of water supply schemes and livestock comes in the last (Consultants, 2017).

Table 6 represents the surface and GW balance or water budget of all the rivers individually and collectively. Collectively, all river discharges to the Indus River Basin are 4 Bm^3, out of which 1 Bm^3 is utilized by various needs, and 3 Bm^3 is contributed from Balochistan to the Indus River. The GW recharges from precipitation and surface runoff reaches 1.1 Bm^3, and withdrawal is 1.3 Bm^3 (Pakistan Engineering Services and Cameos Consultants, 2017). The annual withdrawal of GW is an excess quantity of 0.24 Bm^3 of GW in the four most populated river basins

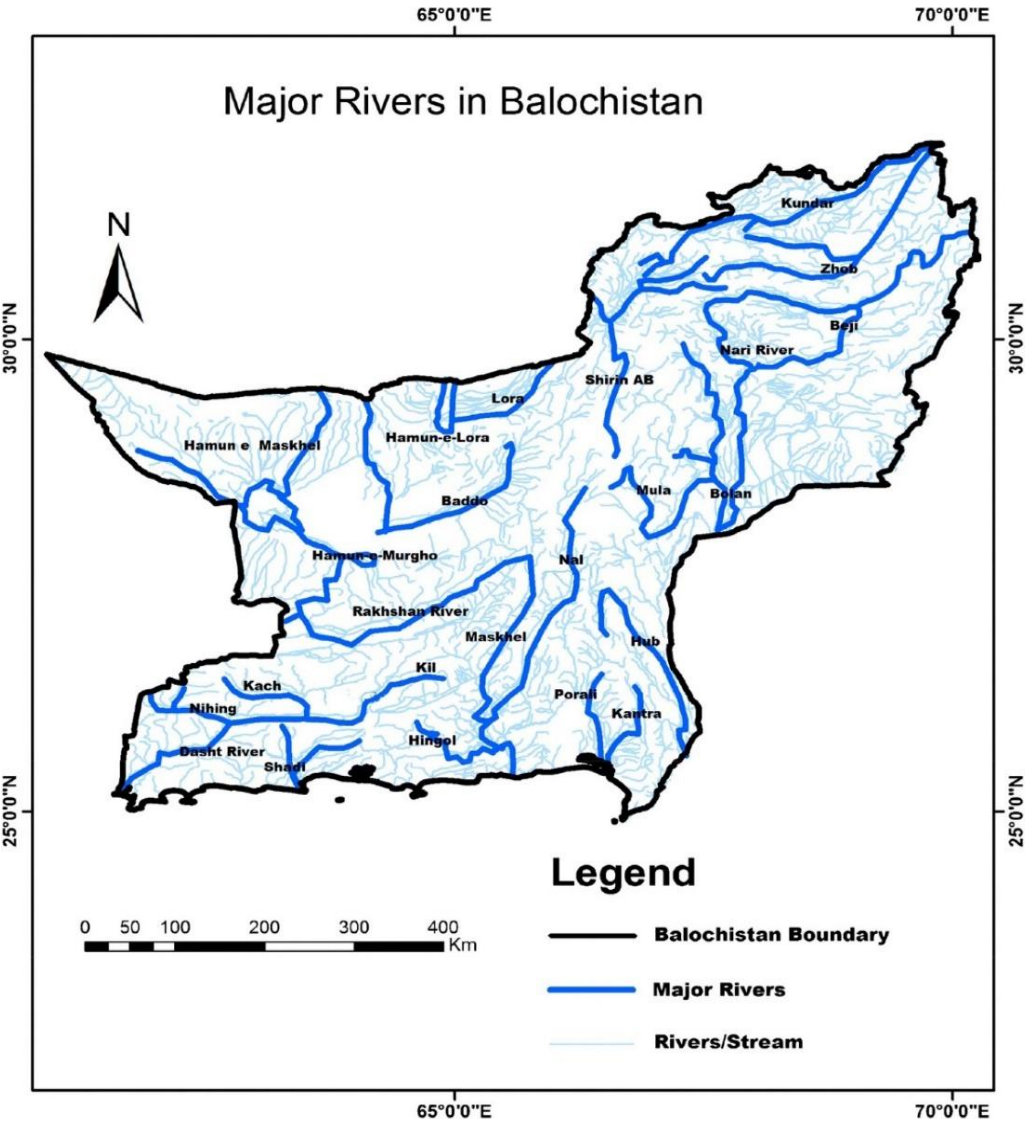

Figure 5. Drainage network in Baluchistan.

Table 3. Basin-wise existing water infrastructure of storage dams and irrigation schemes.

#	Basins	Rivers	Storage Dams (Nos.)	Storage Capacity (Mm^3)	Irrigation Schemes (Nos.)	Usage Capacity (Mm^3)
1	Indus River Basin	Gaj	10	7	17	1.6
2		Kachhi-Plain	17	6	42	4.2
3		Kadnai	22	9	-	-
4		Kaha	19	8	3	0.1
5		Kand	3	2	-	-
6		Kunder	6	3	-	-
7		Mulla	17	12	3	0.4
8		Nari	79	46	56	2.2
9		<u>Zhob</u>	43	63	50	2.4
Total / Av.			**216**	**156**	**171**	**10.9**
10	Closed River Basins	Hamun-e-Lora	3	2	-	-
11		Hamun-e-Mashkel	13	22	3	0.2
12		<u>Pishin</u>	167	57	63	1.4
13		Rakshan	5	0	27	0.5
Total			**188**	**91**	**93**	**2.1**
14	Makran Coastal Basins	<u>Dasht</u>	17	249	19	0.4
15		<u>Gwadar-Ormara</u>	17	101	-	-
16		Hingol	23	12	3	0.1
17		<u>Hub</u>	11	279	-	-
18		Porali	13	16	3	0.3
Total			**81**	**657**	**25**	**0.8**
Grand Total			**485**	**904**	**289**	**13.8**

Table 4. Karez system at Tehsil Karezat, District Pishin, Balochistan as of 2020.

Union Councils	Karez Status (Nos.)					Age (years)		Dried (years)	
	Total	Active	%	Dried	%	Min.	Max.	Min.	Max.
Bolazai	15	2	13	13	87	25	500	5	20
Dilsora	15	9	60	6	40	100	500	4	10
G-Khanai	12	6	50	6	50	120	450	5	16
Gharshina	9	1	11	8	89	120	350	6	17
Khanozai	6	4	67	2	33	80	400	3	16
M-Zakaryazai	19	14	74	5	26	50	300	5	15
R-Malazai	30	1	3	29	97	80	600	5	20
TOTAL	**106**	**37**	**35**	**69**	**65**	**25**	**600**	**3**	**20**

Table 5. River basin-wise water usage in an average year (Mm^3).

#	Basins	Rivers	People	Livestock	Agriculture	Nature	Total
1	**Indus River Basin**	Gaj	2.6	0.3	86	20	108
2		Kachhi-Plain	75.9	3.1	1,202	65	1,346
3		Kadanai	9.8	0.5	124	13	147
4		Kaha	3.2	2.9	35	58	99
5		Kand	2.1	0.1	22	4	29
6		Kunder	12.2	0.2	47	15	74
7		Mula	18.4	1.1	188	23	231
8		Nari	22.5	2.0	295	197	517
9		Zhob	11.1	1.6	234	52	298
		Total	**157.8**	**11.8**	**2,233**	**447**	**2,849**
10	**Closed River Basins**	Hamun-e-Lora	1.1	0.1	261	15	277
11		Hamun-e-Mashkel	14.0	1.3	76	220	311
12		Pishin	32.6	1.2	658	26	718
13		Rakshan	3.9	0.1	86	36	126
		Total	**51.6**	**2.7**	**1,081**	**296**	**1,432**
14	**Makran Coastal Basins**	Dasht	13.9	0.2	94	75	183
15		Gwadar-Ormara	5.8	0.2	61	49	116
16		Hingol	7.8	0.9	225	114	347
17		Hub	4.8	0.5	119	38	163
18		Porali	8.8	1.2	136	130	276
		Total	**41.1**	**3.0**	**635**	**406**	**1085**
		Grand Total	**250.5**	**17.5**	**3,949**	**1,149**	**5,366**

7. Water Governance

To manage the surface and GW along with natural resources, the provincial government took several actions during the last five decades. The year-wise details of all substantial actions, orders, acts, accords, ordinances, and subsidies are presented in Table 7. After rural electrification and systematic GW investigation by WAPDA during the 1970s, a substantial increase in the number of tubewells is observed, (Imad, 2018).

During the last few decades, the governments of Pakistan (GOP) and Balochistan (GOB) devised different national and provincial policies and strategies to manage and protect depleted natural resources (Aftab et al. 2018). The protection of surface and GW resources is the central point of almost all policies. The policies were stipulated with the help of national and international consultants, donors, UN agencies, NGOs, etc. Some of the national and provincial policies and strategies designed for Balochistan are presented in Table 8.

Table 6. River basin wise surface and groundwater balance of Balochistan.

#	Basins	Rivers	Surface Water (Bm^3)			Groundwater (Bm^3)		
			Discharge	Usage	Balance	Recharge	Withdrawal	Balance
1	**Indus River Basin**	Gaj	0.23	0.03	0.21	0.07	0.07	0.00
2		Kachhi-P	1.90	0.63	1.27	0.18	0.17	0.01
3		Kadnai	0.08	0.01	0.07	0.03	0.12	-0.09
4		Kaha	0.52	0.10	0.41	0.19	0.32	-0.13
5		Kand	0.02	0.00	0.02	0.01	0.02	-0.01
6		Kunder	0.10	0.03	0.08	0.05	0.05	0.00
7		Mulla	0.34	0.04	0.30	0.12	0.13	0.01
8		Nari	0.82	0.13	0.69	0.27	0.18	0.09
9		Zhob	0.27	0.11	0.16	0.16	0.27	-0.11
Total			**4.27**	**1.08**	**3.19**	**1.08**	**1.32**	**-0.24**
10	**Closed River Basins**	H-e-Lora	0.19	0.03	0.16	0.04	0.14	-0.10
11		H-e-Mashkel	2.08	0.31	1.77	0.30	0.03	0.27
12		Pishin	0.30	0.17	0.13	0.17	0.57	-0.40
13		Rakshan	0.32	0.03	0.29	0.05	0.08	-0.03
Total			**2.89**	**0.54**	**2.35**	**0.56**	**0.82**	**-0.26**
14	**Makran Coastal Basins**	Dasht	0.66	0.08	0.58	0.10	0.09	0.01
15		Gwadar-O	0.55	0.06	0.48	0.04	0.03	0.02
16		Hingol	0.94	0.14	0.81	0.20	0.17	0.03
17		Hub	0.38	0.08	0.30	0.08	0.09	-0.01
18		Porali	1.11	0.24	0.87	0.14	0.15	-0.01
Total			**3.63**	**0.60**	**3.03**	**0.56**	**0.52**	**0.04**
Grand Total			**10.79**	**2.22**	**8.57**	**2.20**	**2.66**	**-0.44**

Table 7. Governance issues and actions taken by the provincial government, modified after Imad (2018).

#	Governance Issues	Years
1	18 Water Supply Schemes	1970
2	Rural Electrification	1971
3	Systematic GW Investigation started	1972
4	Subsidized Power	1973
5	Interest-free pumping loans	1974
6	Groundwater Ordinance	1980
7	Canal and Drainage Ordinance	1980
8	Water User Association Ordinance	1981
9	Flat rate on electric bills	1981
10	WASA Quetta Act	1984
11	Subsidized Tubewells	1988
12	Pakistan Water Apportionment Accord	1991
13	Private drilling intensified	1992
14	Ban on tubewells in Quetta Subbasin	1995
15	Irrigation and Drainage Authority Act	1997
16	90% subsidy on electricity bills	1997
17	1,407 PHED, Water Supply Schemes	1997
18	Drought Rehabilitation Programs	2000
19	Electric supply reduced by 50%	2004
20	Drought Rehabilitation Programs	2006
21	Local Government Act	2010
22	Balochistan Environmental Protection Act	2012
23	171 WSS Effected by Devastating Floods	2012
24	3,550 PHED Water Supply Schemes	2022

8. Integrated Watershed Management Strategy

The Integrated Watershed Management Strategy (IWMS) is a means to deal with anthropogenic activities and natural resources in watersheds (Aftab et al., 2018). The governance of water resources is the key factor of IWMS. This strategy addresses socioeconomic and environmental concerns, with community empowerment and interest in managing sustainable water resources at the watershed levels. The IWMS is formulated with the consideration of all federal and provincial governments' strategies and policies to conserve natural resources (Aftab et al., 2018).

Table 8. National and provincial strategies and policies related to protecting natural resources.

#	Year	Strategies and Policies	Organizations
National Strategies and Policies (GOP)			
1	2015	National Biodiversity Strategy	IUCN
2	2015	National Forest Policy	MO* Climate Change
3	2014	Millennium Development Goals	Global Water Partnership
4	2012	National Sustainable Development Strategy	UNDP
5	2012	National Climate Change Policy	MO Climate Change
6	2010	National Rangeland Policy	MO Environment
7	2005	National Environmental Policy	MO Environment
8	2004	Agricultural Perspective and Policy	MO FA* & Livestock
9	2002	Pakistan Water Sector Strategy	MO Water & Power
10	1992	National Conservation Strategy	IUCN
Provincial Strategies and Policies (GOB)			
11	2014	Provincial Water Policy	Irrigation & Power Dept.
12	2013	Poverty Alleviation Strategy	PPA* FUND
13	2011	Sustainable Development Policy	IUCN
14	2010	Participatory GW Management Strategy	Techno Consult Int.
15	2010	Ground Water Management Action Plan	Techno Consult Int.
16	2006	Integrated Water Resources Management Policy	I&P Department
17	2000	Balochistan Conservation Strategy	IUCN
18	2000	Strategy to Improve Governance	GKW Consult
19	2000	Water Sector Strategy	Taraqee Foundation
20	1992	Environmental Policy	Soil Survey of Pakistan

MO* = Ministry of; FA* = Food, Agriculture; PPA* = Pakistan Poverty Alleviation

9. Conclusions

1. For a better future, the frequent intense rain showers and mega-floods may be converted into an opportunity with improved governance.
2. Modernized surface and groundwater monitoring systems for data collection are essential for future planning.
3. At least 73 large dams are required to construct one on each major stream to regulate flood flows, and control the release of water for agriculture, water supply, and groundwater recharges.
4. It is imperative to implement the Integrated Watershed Management Strategy in letter and spirit.

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