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INTEGRATED WATER RESOURCE MANAGEMENT IN PAKISTAN

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ABSTRACT

Today emphasis on the integrated water resource management and proper utilization of available water is more than ever before. Pakistan is suffering from drought conditions since year 2000 till June 2010, due to which reduction in river discharges and lesser rains occurred. The reliance on ground water increased remarkably and extensive pumping was observed during the period. The average annual flow across the rivers is 138 MAF. The average escapage below Kotri is 31.31 MAF (1976-2010). If downstream Kotri requirement is taken as 8.6 MAF, then considering the raising of Mangla Dam and future usage by India, there is still 17.81 MAF water available for future development. It is emphasized that construction of first additional mega reservoir will be replacement of lost storage capacity due to sedimentation and second additional large dam will add to storage capacity. To integrate the available water in the system management of water resources and its utilization, a series of dams are needed, in a way that river flows are tamed in steps and reservoirs are managed as a cascade. The integrated water resource management includes harvesting the rain water by developing small and medium dams on hill torrents and by adopting techniques of ground water recharging so as to mitigate effects of extensive pumpage. The integrated water resources management at all levels and its use is earnestly needed. The integrated water resource potential on western rivers is to be exploited, and there are number of projects, which are at different stages of planning and execution by WAPDA to harness the western river flows to meet the irrigation and power requirements of the nation.

1. Introduction

Water is the essential component both for the existence of mankind and for the sustainable country's economic growth. Today emphasis on proper and balanced utilization of available water resources is more than ever before. Pakistan is suffering from drought conditions since year 2000 till June 2010, due to which reduction in river discharges and lesser rains occurred. The reliance on ground water increased remarkably and extensive pumping was observed during the period. However during year 2010 from July to September, there were severe floods

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and below Kotri flows were over 53 MAF. The situation necessitates conservation and integration of water resources to meet the water and energy requirements of the country.

Pakistan is situated in the western part of the Indo-Pak sub-continent. It is bounded on the west by Iran, on the northwest by Afghanistan, on the northeast by China and the disputed territory of Jammu and Kashmir, on the east by India and on the south by the Arabian Sea. The Indus Basin of the country which constitutes the mountain valley of the Indus river and its tributaries, the Indus plains, the Kachhi plain, desert areas of Sindh and the Rann of Kach. On the north, it is surrounded by Hindu Kush, on the northeast by Karakoram and Harmosh ranges, on the western side by Suleman and Kirthar ranges while Arabian Sea forms its southern boundary. The Himalayan mountains have highest peaks in the world with vast deposits of snow and ice having the capacity to block and capture the monsoon winds and their moisture. Hindu Kush and Karakoram mountains form the great water, which separates the Indus Basin waters from that of the Central Asia.

The Indus Basin is irrigated by the River Indus and its major tributaries which flow in longitudinal valley in structural troughs parallel to the mountains and after cutting through the mountains flowing steep and confined channels emerge into the alluvial plains which stretch over a distance of some 1520 Km to the tidal delta near the Arabian Sea. The Indus river system consists of; Western Rivers, River Indus, River Kabul, River Jhelum, River Chenab and Eastern Rivers, River Ravi, River Setluj and River Beas.

2. Average Annual Flows of Rivers of Indus Basin

The catchment area of the Indus river system is 364,700 square miles whereas, the average annual flows across the rivers are as given in Table-1.

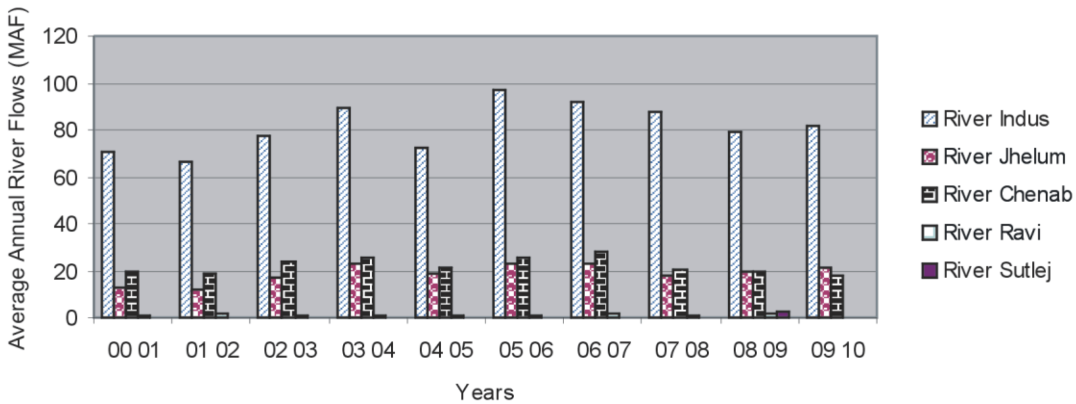
Table-1: Average Annual Flows of Rivers of Indus Basin

(MAF)

River	Average Annual Flow (1922-61)	Average Annual Flow (1985-95)	Average Annual Flow (2000-09)	Average Annual Flow (2009-10)
Indus	93	62.7	81.28	81.31
Jhelum	23	26.6	18.52	21.05
Chenab	26	27.5	22.52	17.90
Ravi	7	5	1.1	0.28
Sutlej	14	3.6	0.39	0.01
Kabul	26	23.4	18.9	17.4
Beas	0	0	0	0
Total	**189.0**	**148.8**	**142.71**	**138.00**

Source: WRM Directorate, WAPDA, Average Annual River Flows.

The Indus River System average annual inflows are measured at Rim Stations as indicated in Fig. 1.



Source: WRM Directorate, WAPDA

Fig 1: Average Annual River Flows of Indus Basin

Pakistan has three major reservoirs, which have original storage capacity of 15.74 MAF, but with the passage of time, they have lost almost 28% till 2010, of their storage capacity due to sedimentation as shown in Table - 2.

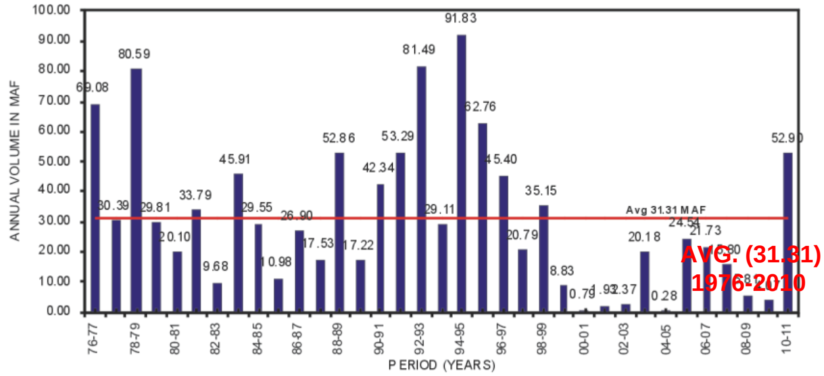
Table-2: Reservoir Sedimentation

Reservoir	Storage Capacity		Storage Loss		
	Original	Year 2009	Year 2009	Year 2012	Year 2025
	MAF	MAF	MAF	MAF	MAF
Tarbela	9.68 (1974)	6.78 (70%)	2.90 (30%)	3.18 (33%)	4.30 (44%)
Mangla	5.34 (1967)	4.46 (83%)	0.88 (17%)	0.90 (17%)	1.14 (21%)
Chasma	0.72 (1971)	0.37 (51%)	0.35 (49%)	0.29 (40%)	0.38 (52%)
Total	15.74	11.61 (74%)	4.13 (26%)	4.37 (28%)	5.82 (37%)

Source: WRM Directorate, WAPDA.

3. Average Escapages Below Kotri

Over the past thirty five years, up to September 2010, 1094.88 MAF of water had gone into the sea unutilized, equivalent to 10 years of canal withdrawal. Excluding the water required for protecting the ecosystem below Kotri, rest represents a direct economic loss. In monetary terms, after deducting 300 MAF required for environmental purposes, the value of unutilized water is US$ 149 billion. For better water management, storage capacity should be equivalent to at least 40% of annual water availability but Pakistan's live storage capacity of 11 MAF is just about 7 % of average annual river flows.



Source: WRM Directorate based on data provided by Govt. of Sindh

Fig 2: Escapage downstream Kotri (MAF)

The average escapage below Kotri is 31.31 MAF (1976-2010) and Fig. 2 represents the downstream Kotri escapage, while downstream Kotri requirements are approximately 8.6 MAF considering the raising of Mangla dam and future usage by India (Treaty 1960), there is still 18 MAF water available for future development as depicted in Table-3.

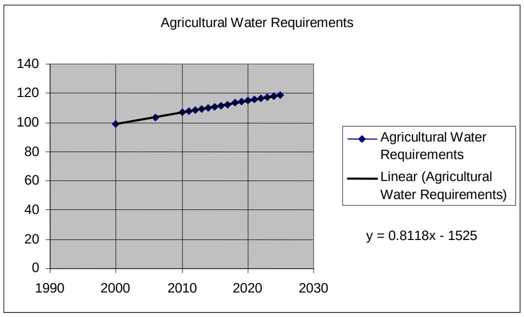
Table-3: River Flows and Storage Potential

(MAF)

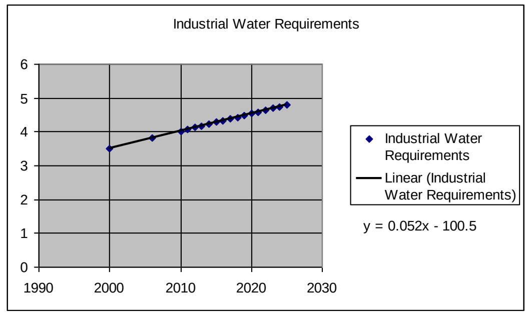
Down Stream Kotri Average Annual Flows (1976 – 2009)	31.31
Anticipated Uses	
Down Stream Kotri Requirement @ 5000 Cusecs round the year	8.6
Mangla Dam Raising Project	2.9
Indian Future Uses on Western Rivers (As per Indus Water Treaty)	2.0
Net Water Available	17.81
Diamer – Bhasha Dam Project	6.4
After Diamer – Bhasha Dam Project	11.41

4. Water Availability and Demand Gap

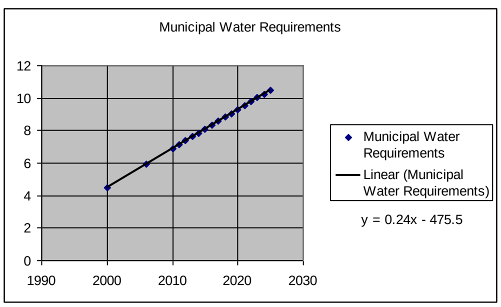
The average annual river flows is approximately 138 MAF, out of which almost 82% (113.16 MAF) occurs during summer seasons and 18 % (24.84 MAF) in winter, out of which 104 MAF is available at the canal heads for irrigation purposes, whereas, only 58.3 MAF reaches at the farm gate and 45.7 MAF is lost in conveyance system. The projected demand for agricultural usage is 119.0 MAF by the year 2025. The current industrial demand is about 3.9 MAF, which will increase to 4.8 MAF by the year 2025. The anticipated use for municipal and environmental use is 6.90 MAF and 1.46 MAF respectively which will be increased to 10.50 MAF and 1.70 MAF respectively by year 2025 as depicted in Figure-3 & Table-4.



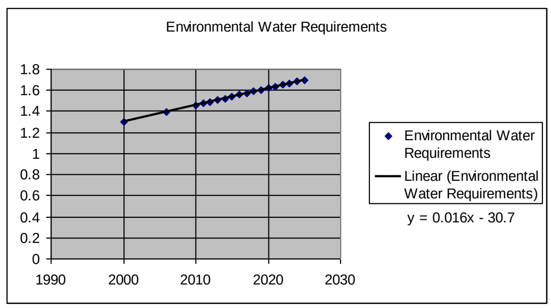
a) Agricultural Water Requirements



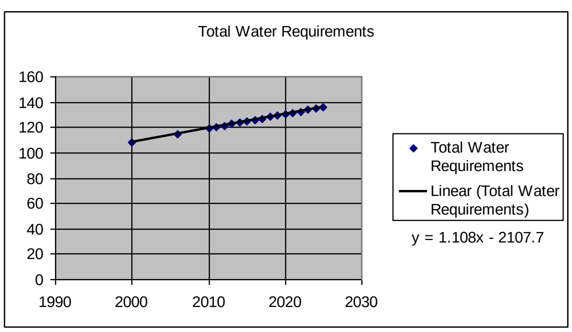
b) Industrial Water Requirements



c) Municipal Water Requirements



d) Environmental Water Requirements



e) Total Water Requirements

Fig 3: Current & Future Water Requirements (2000 – 2025)

Table-4: Current & Future Water Requirements of Pakistan (2000 – 2025)

(MAF)

Sr.No.	Usage	Present & Future Water Requirements				Additional Requirements in 2025
		2010	**2015**	**2020**	**2025**	
1	Agricultural	107	111	115	119	12
2	Industrial	4.02	4.28	4.54	4.8	0.78
3	Municipal	6.90	8.10	9.30	10.50	3.60
4	Environmental	1.46	1.54	1.62	1.70	0.24
	Total	**119.38**	**124.92**	**130.46**	**136**	**16.62**

Source: National Water Policy 2003 (Draft)

Moreover, as per global standards, 1000 m^3 per capita is the threshold value for water scarcity. Pakistan at present is striving with water scarcity and only 1038 m^3 of water is available per capita (projected figure of 2010), which will further be reduced to 751 m^3 per capita till year 2030.

The Table – 5 & Figure 4 show the anticipated growth in the population and the decline in per capita water availability.

Table-5: Water Availability Per Capita/Year (m^3)

Year	**Population (million)**	**Water Availability (Cubic Meter)**	**Global Criteria**
1951	34	5260	1000 m^3 per capita is the threshold value (Falkenmark & Wedstrand 1992)
2010	172	1038	
2020	204	877	
2025	221	809	

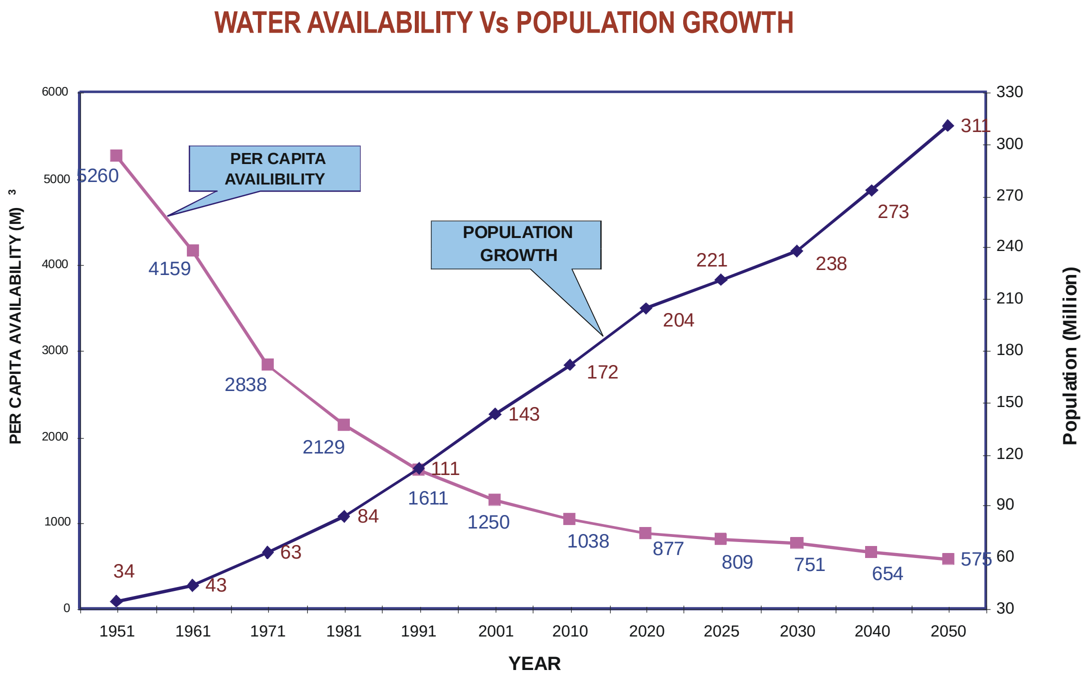


Fig 4: Per Capita Water Availability per year (m^3)

5. Integrated Water Resources Management

Integrated water resources management is the practice of making decisions and taking actions while considering multiple viewpoints - how water should be managed? These decisions and actions relate to situations such as river basin planning, organization of task forces, planning of new capital facilities, controlling reservoir releases, regulating floodplains, and developing new laws and regulations. The need for multiple viewpoints is caused by competition for water and by complex institutional constraints. The decision-making process is often lengthy and involves many participants. In Pakistan future water needs are substantially greater than the total potential supply there is a need to reduce the water losses from the water supply systems improvement of overall irrigation efficiency, construction of water reservoirs on potential sites along with adoption of artificial ground water recharge techniques to integrate the rain and excess flood water to supplement the depleting water aquifers. The Figure 5 shows the schematic diagram of integrated water resources use and its management.

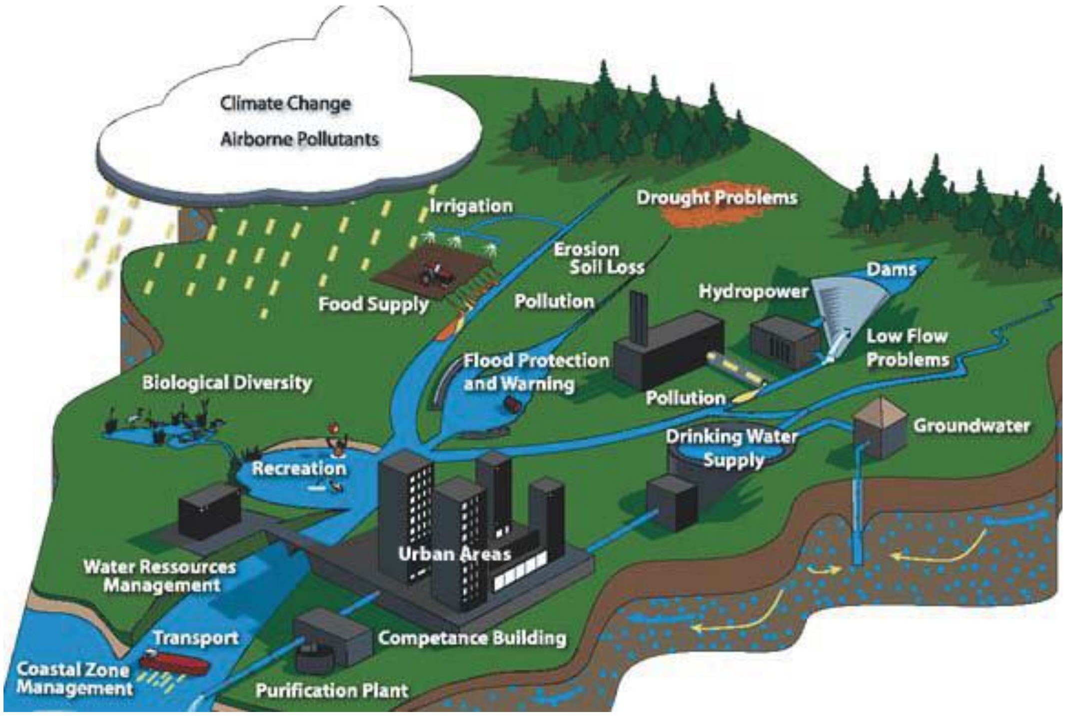


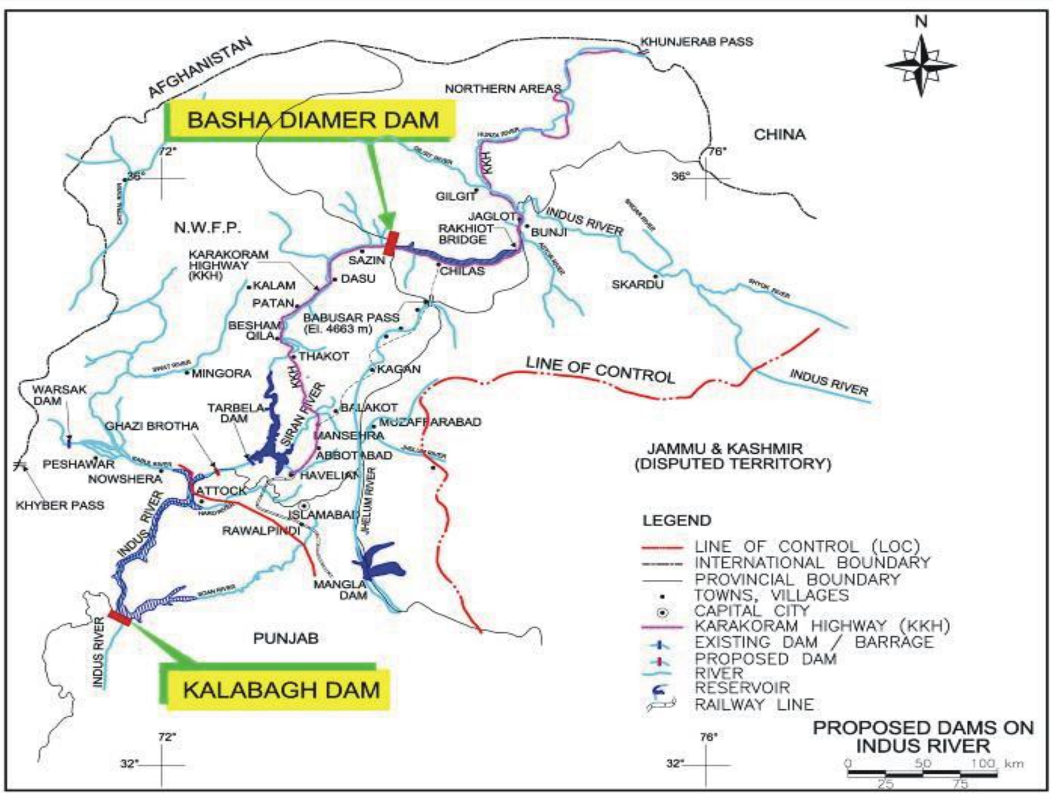
Fig-5: Schematic diagram of Integrated Water Resources

5.1 Integrated Water Resource Management Through Reservoir Construction

Integrated water resource management by reservoir construction, means to fulfill purposes of water management such as to manage water supply and wastewater within a system of units to manage the flood waters. It is a multi stage phenomenon, i.e. one project supplements the requirements of the other, in other words by operation one upstream project, downstream storage can be maintained. Considering the precipitation pattern of the region, the concept is ideal for Pakistan, especially for the western rivers, where we have a number of potential locations for construction of multipurpose projects. Since the average annual flow (1976-2010), down stream Kotri is 31.31 MAF, whereas, considering the post Mangla raising, Diamer-Basha dam and future uses by India, still there would be 11.41 MAF of water available for development of projects. WAPDA has conducted a comprehensive study on western rivers and identified different locations on River Indus and River Jhelum along with their tributaries for the development of multipurpose projects. The Table 6 shows the potential storage of different projects whereas, Figure 6 represents location of these potential sites.

Table-6: Storage potential of River Indus

Proposed Project	Storage (MAF)	Status
Bunji	0.06	Feasibility study completed Detailed design and Tender documents in progress.
Diamer Bhasha	6.4	Ready for Implementation
Dasu	0.69	Feasibility study completed Detailed design and Tender documents in progress.
Thakot HPP	0.16	PC-II submitted for approval
Pattan	0.06	PC-II approved
Yulbo	0.12	Desk study and field reconnaissance done
Tungus	0.05	Desk study initiated
Skardu	5.5	Desk study initiated
Shyok/Yugo	5.0	Desk study initiated
Total	18.5	



Source: Hydro Planning Organization, WAPDA

Fig 6: Location of Proposed and Existing Water Resource Projects in Pakistan

5.2 Integrated Water Resource Management by Adopting Techniques of Ground Water Recharging.

The optimum utilization of water resources is of utmost importance because the world as a whole is suffering from vast water shortage. Human societies exploit this water source to maintain life. Flood water is usually exploited through two main ways:

- Pumping the local alluvial aquifers that are occasionally and infrequently replenished by flood water percolation and
- Damaging the stream channel to store large volume of flood water for direct use or to enhance percolation into the local alluvial aquifers. Artificial recharge is a way to store water underground in times of water surplus to meet demand in times of shortage. The process is called 'Aquifer Storage and Recovery' (ASR).

Floods, both large and small, have been taking a heavy toll of life and property. It is generally recognized that complete prevention of floods is almost impossible. However, flood protection to the extent it is technically and economically feasible, is a socio-economic necessity. By proper planning, means can be developed not only to minimize flood losses but also to conserve the surplus flows for augmenting availability of water for productive use and to promote welfare of the community.

5.2.1 Underground Water Recharging from Hill Torrents.

Lands under torrent salaba are cropped using residual moisture from hill torrent flooding. Many techniques have been developed over time for conservation and utilization in Sindh, KPK and Balochistan. The flood flow of rivers and hill torrents of Balochistan has been assessed as 12.33 BCM (10 MAF) which almost go waste rather causing damage to land and population. The hill torrents in Pakistan constitute a secondary network of natural surface drainage system.

In Pakistan great potential exists for conservation of flood flows of hill torrents and large areas exist in the vicinity of hill torrents where this flow can be used for development of irrigation systems. Table-7, gives the culturable waste land and water conservation potential of various hill torrent areas of Pakistan.

Table-7: Culturable waste land water conservation potential of various hill torrent areas of Pakistan.

Province	Area	Culturable Waste land		Average Annual Water Conservation Potential	
		(Hectares)	(Acres)	(MAF)	(MCM)
Federal	Northern Area	60,700	149,929	0.940	1,159
	A J Kashmir	33,600	82.992	0.400	493
	FATA	178,700	441,389	1.500	1,850
	Sub-Total Federal	273,000	674,310	2.840	3,502
NWFP	D.I. Khan	419,000	1,034,930	0.800	986
	FATA	178,700	441,389	1.500	1,850
	Hazara, Kabul & Banu	442,300	1,092,481	3.760	4,636
	Sub-Total NWFP	1,040,000	2,568,800	6.060	7,472
Punjab	D.G Khan	349,700	863,759	0.854	1,053
	Pothowar	220,800	545,376	1.860	2,293
	Rachna & Chaj Doab	-	-	-	-
	Sub-Total Punjab	570,500	1,409,135	2.714	3,346
Sindh	Khirthar Range	279,300	689,871	0.296	365
	Karachi	64,560	159,463	0.094	116
	Sehwan & Petaro	207,000	511,290	0.330	407
	Sub-Total Sindh	550,860	1,360,624	0.720	888
Balochistan	Indus Basin Component	837,900	2,069,613	4.067	5,015
	Kharan	1,060,500	2,619,435	0.789	973
	Makran	2,781,500	6,870,305	3.000	3,690
	Sub-Total Balochistan	4,679,900	11,559,353	7.856	9,678
	Grand Total	**6,935,560**	**17,130,833**	**18.690**	**23,036**

5.2.2 Method of Aquifer Recharge for Underground Storage

There are two major methods of aquifer storage. These include:

a) Direct recharge method and indirect recharge methods:

  i) Spreading Basin,

  ii) Recharge Pits,

  iii) Ditches and

  iv) Recharge Wells.

b) Conjunctive wells.

Recharge wells are used to directly recharge water into deep water–bearing zones. Recharge wells could be used through the material overlying the aquifer and if the earth materials are unconsolidated, a screen can be placed in the well in the zone of injection. Recharge wells are suitable only in the areas where a thick impervious layer exists between the surface of soil and the aquifer to be replenished. A relatively high rate of recharge can be attained by this method. Clogging of the well screen or aquifer may lead to excessive buildup of water levels in the recharge well. In ideal conditions, a well accepts recharge water at least as readily as it will yield water by pumping.

To achieve artificial recharging on a much larger scale, construction of percolation tanks is a widely practiced technique in semi-basaltic terrain. Due to the high evaporation rates of surface water in the summer months, storage in ground water reservoir is a preferred method. In order to augment ground water storage, runoff water in several seasonal streams in a large watershed is impounded by constructing earthen bunds across the streams. Percolation Tanks are formed during the Monsoon season, behind such bunds. Collecting runoff water from catchments ranging from 10 to 50 sq. kms. This water percolates during the four months of the winter season (October-February) and by the beginning of summer the tanks become dry. Once the runoff water collected in the tank percolates to join the water table. It is, therefore, important to collect runoff whenever available, allow it to percolate and recharge the ground water reservoir, so that in the dry season, people, crops and cattle may depend upon ground water available dug wells and bored wells. The quality of groundwater can be improved due to the percolation of good quality runoff water from the tank. The silt accumulating in the tank bed, year after year, hampers the efficiency of a percolation tank, the beneficiary farmers have to de-silt the tank bed when the tank dries in the summer season.

6. Conclusions & Recommendations

- As Pakistan is facing acute water shortages, WAPDA's vision 2025 projects are being implemented on fast track to combat increasing shortage of water and improve regulation.
- The country needs more water storages to properly regulate the river flows during the crop seasons. The Integrated Water Resources Management (IWRM) is required at all levels in water competing sectors while, improving use efficiencies and adoption of other water conservation techniques.
- Canal water supply management needs improvement to avoid wastage of water and for equitable distribution of available water for the entire canal command.
- The high efficiency irrigation system like, bed, furrow, drip and sprinkler need to be adopted.
- Improve drought forecasting and management are necessary to prepare plans to reduce the damages due to such severe situation.
- Sustainable groundwater management under proper regulations should be adopted to safeguard aquifer deterioration underground water mining conditions.

7. References

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