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Role of Dams in the Economic Growth of Pakistan

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Abstract

Pakistan is located in a semiarid to arid region where rainfall is highly deficient and does not match the crop requirements. In most plain areas of the country it is less than 500 mm and is unevenly distributed over the year. As Pakistan is not an oil rich country, its economy depends on agriculture sector which accounts for about 23 % of the GDP and 42% of total employed labour force. It is also the largest source of foreign exchange earnings. Agriculture of country is mostly dependent on Indus River System (IRS). IRS maintains World's largest integrated irrigation network called Indus Basin Irrigation System (IBIS).

Historically IBIS had been fed through run of river supplies derived from Indus and its five major tributaries. As a result of Indus Water Treaty with India in 1960, Indus Basin Project (IBP) works were constructed during the sixties and the seventies. Two mega multipurpose projects (Mangla and Tarbela dams), five barrages one gated siphon and eight interriver link canals were constructed to regulate and convey water of western rivers to irrigation canals taking off from eastern rivers. Pakistan Water and Power Development Authority (WAPDA) completed the construction of all sixteen IBP components within a decade. Two multipurpose dams, Mangla (Live Storage 6.6 billion cubic meter (BCM), Installed Capacity 1000 MW) and Tarbela (Live Storage 11.9 BCM, Installed Capacity 3478 MW) were built on Jhelum and Indus rivers respectively. These multipurpose mega dams provide about 70% of total existing storage capacity and hydropower infrastructure (producing one fifth of the country's electricity during 2007-08). These dams were constructed to regulate and supplement flows in irrigation network to sustain Pakistan's agriculture. These dams are primarily operated according to irrigation requirements of the country while inexpensive hydroelectricity is produced as a byproduct. This paper highlights the role of the two large multi purpose dams i.e. Mangla and Tarbela commissioned in 1967 and 1976 respectively, in the economic development of Pakistan. Careful analysis of four decades historic data (from 1967 to 2006) after the construction of these dams on the canal head diversions of IBIS, when compared with the historic run of river supplies, reveals that about 20% additional flows are available for irrigation during low flow season. The paper also analyzes these dams role in providing hydroelectricity that sustains the energy sector of Pakistan. Moreover impact on the economic growth of the country due to failure to construct the mega multipurpose dam since 1976 to date is explored. The results reveal that sustainability in the economy of country is only possible by building large multi purpose dams for storage to regulate flows for irrigation and hydropower.

Keywords: Indus River System, Indus Basin Irrigation System, Mangla and Tarbela Dams

Introduction

1 Country Over View

Pakistan has an area of 796095 km^2 and a population of 160 million. Population wise Pakistan is the ninth largest country in the World population wise. Pakistan has one of the largest networks of surface irrigation systems in the World irrigating about 18 million hectares (MH) of land.

Politically the country is divided into four provinces, Punjab, Sindh, North West Frontier Province (NWFP) and Balochistan. Moreover some areas have special status, which include Federally Administrated Tribal Area (FATA), Federally Administrated Northern Area (FANA) and disputed State of Azad Jammu and Kashmir with India (Fig -1).

2 Indus River System (IRS)

Agriculture of country is mostly dependent on Indus River System (IRS), which comprises of the rivers Indus, Jhelum, Chenab, Ravi, Bias and Sutlej and the northern and western tributaries (Fig 1). It maintains World’s largest integrated irrigation network called Indus Basin Irrigation System (IBIS).

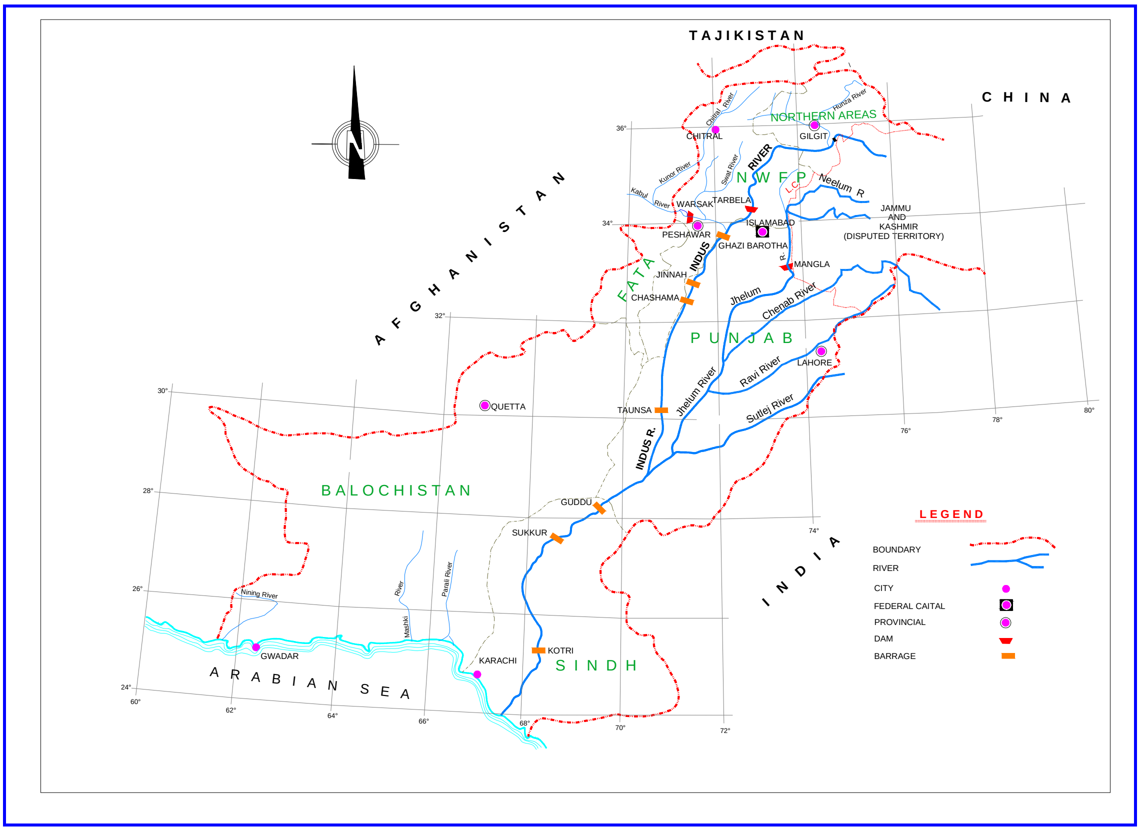

Figure 1: Map of Pakistan showing River System of Pakistan.

The impact of the Indus on Pakistan is considerable because of its size and capacity. It has the 7th largest delta and the 12th largest drainage area in the world. Its annual water runoff places it the10th, and annual sediment discharge places it the 6th in the world. Hence, by any yardstick, Indus River and its basin is a very large geographical and natural phenomenon (Majeed Zahid , 2008) .

Indus River and its tributaries on average carry about 180 BCM of water annually. This includes about 169 BCM contribution from the three western rivers of Indus, Jhelum and Chenab and their tributaries Chitral, Swat, Kabul, Haro and Soan rivers. The remaining 11 BCM of water is contributed by the eastern rivers[1] of Ravi, Sutlej and Bias. Most of the inflow, about 131 BCM is diverted for irrigation while the remainder flows to the sea phenomenon (Majeed Zahid, 2008).

3 Historical Background Of Indus Basin Irrigation System

Historically IBIS had been fed through run of river supplies derived from Indus and its five major tributaries. Pakistan after its independence in 1947 had a water dispute with India when on April 1, 1948 India cut off the flows of the eastern rivers, on which most of the Pakistan's agriculture is dependent. The dispute was resolved through Indus Basin Treaty signed between Pakistan and

[1] Waters of these three rivers have been now completely utilized by India according to the Indus Basin Treaty signed in 1960.

India in September 1960 under aegis of the World Bank after lengthy negotiations.

The Indus Basin Treaty provided waters of three eastern rivers Sutlej, Beas and Ravi to India and three western Rivers Chenab, Jhelum and Indus to Pakistan. For supplying water to Pakistan's irrigation network (the largest man made canal system in the world) the IBP was designed and constructed to replace the waters of eastern rivers.

Under IBP works, two mega multipurpose projects (Mangla and Tarbela dams), five barrages one gated siphon and eight inter river link canals were constructed to regulate and convey water of western rivers to irrigation canals taking off from eastern rivers. WAPDA completed the construction of sixteen IBP components within a decade (WAPDA, 2006-07).

Tarbela and Mangla multi purpose mega projects sustain Pakistan's agriculture economy by supplementing and regulating irrigation supplies and providing inexpensive electricity to the country. Bulk of flows in IRS, about 88% of total mean annual are experienced in the 70 to 90 days) from June to August of summer cropping period of Kharif (April to September). The remaining 12% flows are available for winter cropping period of Rabi (October to March), (Ch : 2005). Flows in Rabi season are low because of the frozen glaciers and low rainfall during the winter season. It is reverse to the irrigation requirement, which is 60% for Rabi and 40% for Kharif. Therefore high flow variation and deficient rainfall dictates that mega storage dams be constructed to optimally use the water throughout the year according to crop requirements (Ch: 2005).

Neglecting addition of mega multi purpose dam during last three decades for storage and hydel power generation after construction of Mangla and Tarbela dams has resulted in less availability of water for irrigation and high electricity tariff which has negative impact on the economic growth of Pakistan.

Mangla Dam

It is an earth fill dam built across river Jhelum (12th biggest of its type in the World) completed in 1967. Its height above the riverbed is 116 m with a crest length of 3.15 km. It has a lake area of 256 km^2 having a total gross storage of 6.52 BCM (presently reduced to 5.52 BCM) for supplementing and regulating irrigation supplies. Moreover it has hydropower generation capacity of 1000 MW (10 x 100 MW), which produces mean annual electricity of 5 billion KWh. Main spillways has a capacity of 28612 m^3/sec and emergency spillway has a capacity of 6500 m^3/sec.

Figure 2: View of dam and Reservoir from Mangla Fort

Tarbela Dam

It is an earth and rock fill dam built across river Indus. It was the largest in the World at the time of its completion in 1977. Its height above the riverbed is 148 m and its crest length is 2.75 km. It has a lake area of 256 km^2 having a gross storage of 14.3 BCM (presently reduced to 10.3 BCM) for supplementing and regulating irrigation supplies. Moreover it has hydropower generation capacity of 3478 MW consisting of 14 units. First 4 units of 700 MW were installed in 1977, next 4 units of 700 MW in 1982 then 2 units of 350 MW in 1985 and finally 4 units of 1782 MW capacity were installed in 1992-93. It generates mean annual electricity of 15 billion KWh. Main spillway has a capacity of 18413 m^3/sec and auxiliary spillway has a capacity of 23796 m^3/sec.

Figure 3: Tarbela Dam and its Lake

Figure 4: Tarbela Power House

The agricultural benefits of the Tarbela project are evident from the fact that canal-irrigated areas in the country increased by about 45 % from 10 million ha to 15 million ha as a result of increased canal supplies because of Tarbela Dam. The total cultivated area in the country increased by about 13% from 19.5 million ha before Tarbela to 22 million ha presently. It also resulted in an improved cropping pattern for areas in the country receiving irrigated water from Tarbela. The increases in the cultivated areas are, for wheat (37%), for cotton (45 %), for rice (40%) and for sugar cane (52 %) (Majeed Zahid: - 2006).

Impact Of Dams Operation On Water Regulation And Power Sector

1 Impact Of Dams Regulation On Canal Withdrawals

These mega dams optimally regulate the flows for IBIS throughout the year by storing water in Monsoon season from June to August for Rabi crops and for early Kharif i-e April and May and late Kharif i-e September. Further more since commissioning of these dams sensitivity to canal with drawls in Rabi and early Kharif has decreased.

1.1 Estimated Financial Water Storage Benefits

The total water storage benefits corresponding to releases for irrigation between 1966-67 to 2005-06 from both the dams is 547 BCM stands at 2.60 billion US$ [2](Calculated at a rate of Rs. 200/acre foot[3] from 1966-67 upto 1991-92 and from 1992-93 to 1996-97 at the rate of Rs.300/acre-ft and thereafter at the rate of Rs.900/acre-ft upto 2005-06 at present exchange rate of Rs with US $) given in Table 1 and shown in Figure 5.

[2] 1 US $ = Rs. 72 (July 2008)

[3] 1 acre-foot = 1232 m^3

Table 1 : Total irrigation flows benefits of both dams from their commissioning upto 2005-06.

Year (from June to July)	Mangla Release (BCM)	Tarbela Release (BCM)	Total Releases (BCM)	Million US $
1967-68 to 1980-81	76.96	-	76.96	173.5
1975-76 to 1980-81	-	63.63	63.63	143.5
1981-82 to 1985-86	31.32	59.91	91.23	205.7
1986-87 to 1990-91	28.93	51.90	80.83	182.3
1991-92 to 1995-96	27.50	43.38	70.88	239.7
1996-97 to 2000-01	28.06	54.43	82.49	837.0
2001-02 to 2005-06	28.58	52.27	80.86	820.4
TOTAL	221.35	325.53	546.88	2602.0

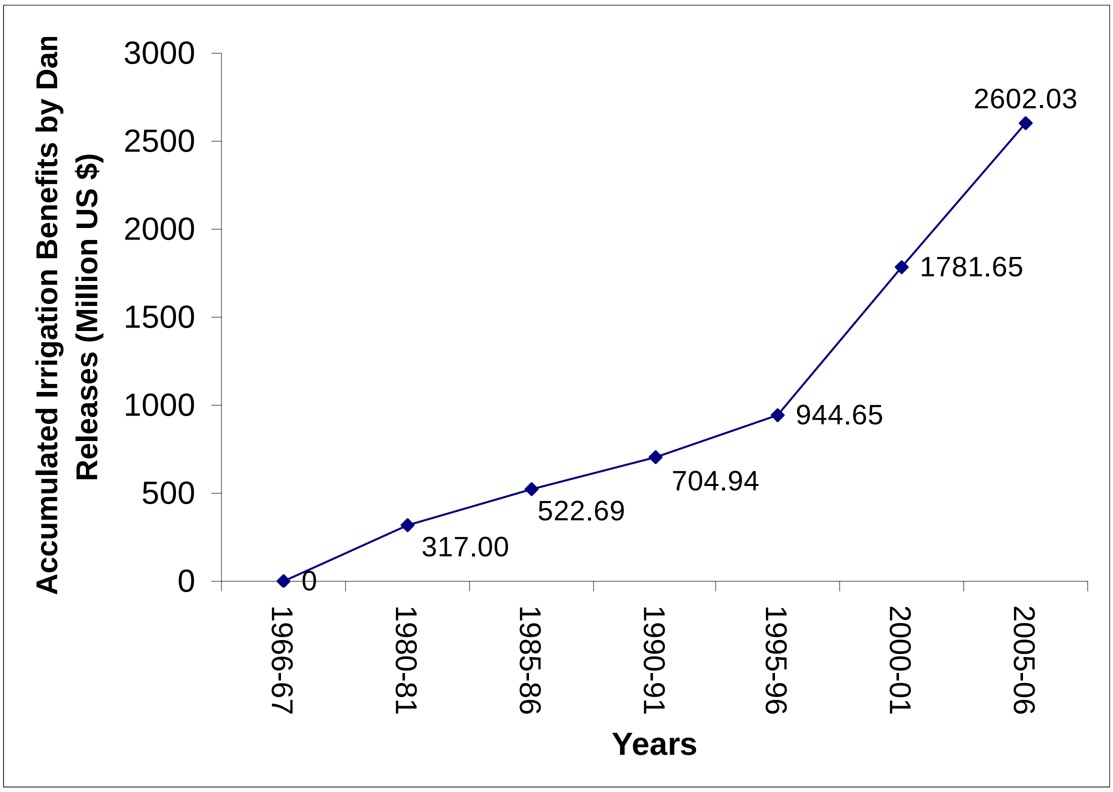

Figure 5: Total accumulated benefits to date due to flow releases from dams from 1966-67 to 2005-06 (ref : Wapda Annual Report (2006-07))

1. 2 Water Additionality Assessment Due To Dams Operation

Impact of Mangla and Tarbela Dam's reservoir operation on the canal head diversion of IBIS has been analyzed for the post-dam period of 1967-2006 and compared with the pre-reservoirs period of 1960-67 by using historic discharge data. Flow measurements are taken at the rim-stations of Indus Basin Rivers at points where these enter the plains or at key locations such as storage sites. The record at rim-stations does not account for the run-off generated from local tributaries below these stations. Additionally Chashma Barrage cum Reservoir having a live storage of about 0.6 BCM on Indus which was commissioned in 1971 is included for calculation at rim stations but not described because its storage is about 30 times and releases impact is about 15 times less than the releases gained by Mangla and Tarbela dams together.

Historic stream flow data is collected from WAPDA and Indus River System Authority (IRSA). Designated rim-stations of western rivers are at Kalabagh, Nowshera, Mangla and Marala on Indus, Kabul, Jhelum and Chenab, while those on Eastern Rivers are at Balloki and Suleimanki on Ravi and Chenab Rivers, respectively.

Further the assessment of impact has been sub-divided into low flows of late Kharif (September); Rabi (October to March); and early Kharif 2006; comparison of canal head withdrawals during different periods (Figure 6); and percentage increase of canal head withdrawals in the period 1976-2006 against the base period 1960-1967 (Figure 7).

The impact assessment on canal head withdrawals of IBIS has been calculated on the evaluation of canal head withdrawals in IBIS over 1960-2006 (Table 2); and storage The above information has been utilized to derive the relevant results pertaining to: historic uses and available surface water to IBIS during low flow seasons from 1960- (April-June) and high flow period (July-August). Release from the dams during low flow seasons from 1967-2006 (Table 3).

Above evaluation reveals that the increase in canal head withdrawals from 1960-67 (base period) to 1976-2006 for the low flow period of early Kharif, late Kharif and Rabi was around 20 % (refer Figure 7). In quantitative terms the corresponding increase in canal head withdrawals was about 15.32 BCM as given in table 2 column 9. This clearly indicates these dams brought about increase in canal head withdrawals.

Table 2: Canal Head Withdrawals in the Indus Basin Irrigation System 1960-2006

Sr. #.	Period	Early Kharif (Apr-Jun)	High Flow Kharif (Jul-Aug)	Late Kharif (Sep)	Kharif Total (Apr-Sep) (3+4+5)	Rabi (Oct-Mar)	Annual (6+7)	Low Flow Apr-Jun-Sep and Oct-March (8-4)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1.	Pre-Mangla (1960-67)	29.92	31.02	13.44	74.39	34.08	108.47	77.45
2.	Pre-Chashma (1967-71)	32.64	32.24	14.27	79.15	37.61	116.76	84.52
3.	Pre-Tarbela (1971-76)	31.31	33.15	14.01	78.46	37.18	115.64	82.49
4.	Post-Tarbela (1976-2006)	34.42	32.50	14.87	81.79	43.54	125.33	92.82
5.	Increase in 1976-2006 with respect to 1960-67 periods.	15 %	4.8 %	10.65 %	9.95 %	27.73 %	15.54 %	20 %

All releases are given in Billion Cubic Meter s(BCM)

Table 3: Storage Release from the On-Line Reservoirs During Low Flow Seasons from 1967-2006

Sr. #	Period / Reservoir	Early Kharif (Apr-Jun)	Late Kharif (Sep)	Rabi (Oct-Mar)	Total
1.	Pre-Chashma (1967-71) (Mangla)	0.29	0.48	5.34	6.11
2.	Pre-Tarbela (1971-76) (Mangla +Chashma)	0.11	0.27	6.51	6.89
3.	Post-Tarbela (1976-2006) (Mangla+Chashma+Tarbela)	1.25	1.74	13.82	16.81

All releases are given in Billion Cubic Meters (BCM)

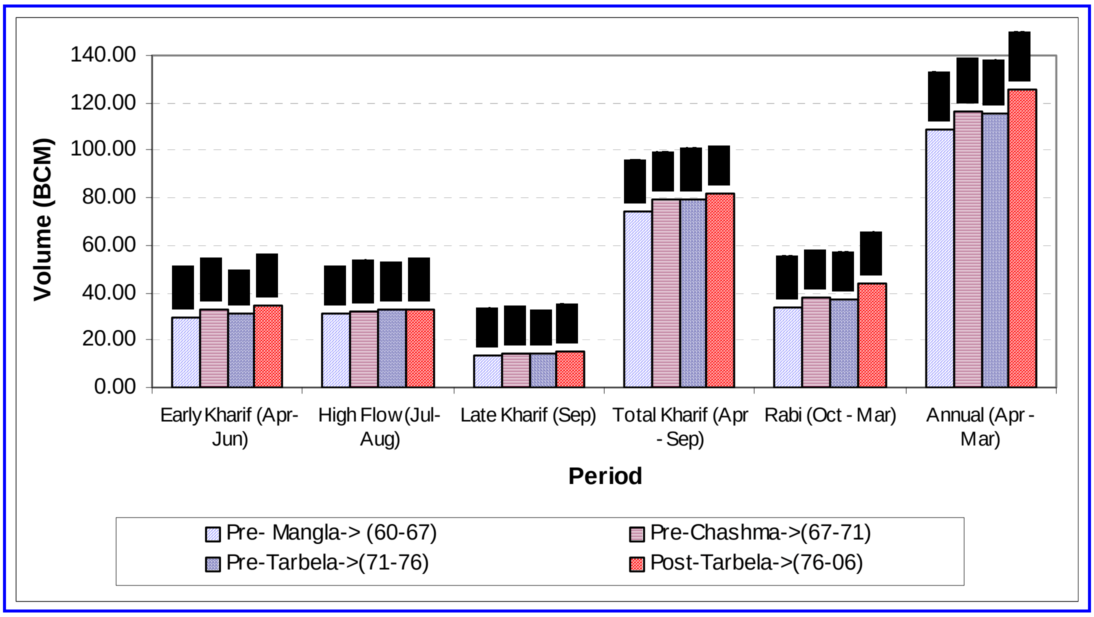

Figure 6: Comparison of Canal Head Withdrawals of Different Periods

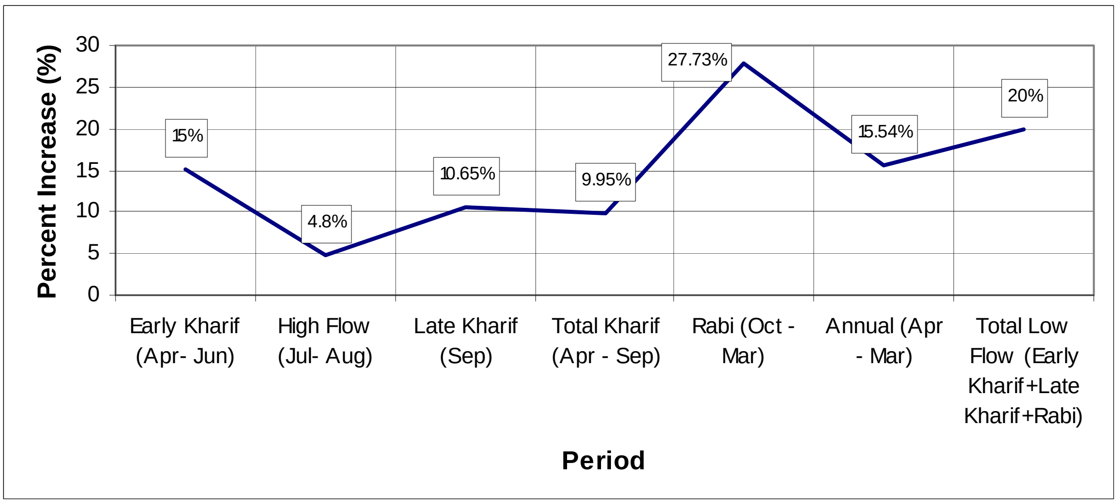

Figure7: Percentage Increase of canal withdrawals in period 1976-2006 against 1960-1967

International Panel of Experts (IPOE) Review Studies on Water Escapages Below Kotri Barrage in November recommended that an escapage of 142 m^3/s (5,000 ft^3/s) at Kotri Barrage throughout the year is required to: check seawater intrusion; accommodate the need for fisheries and environmental sustainability; and to maintain and preserve the river channel morphology. Based on the post-Tarbela flow data, the above recommendations would result in a required additional release downstream of Kotri Barrage during low flow months of 1.55 BCM (1.26 MAF) in an average year and 2.71 BCM (2.20 MAF) in a typical dry year. This is also ensured due to presence of the storage dams to maintain minimum flows as and when required Government of Pakistan, (2005).

2 Impact on Power Sector

These dams made a substantial contribution to the interconnected national power system. The total electricity generation of Mangla and Tarbela hydropower plants was 478 billion KWh with total direct benefits of 6.2 billion US$ upto year 2005-06 (Calculated at various exchange rates over the years of Rupees with US $ price/unit is 0.3 Rs/KWh) accumulated benefits are shown in Figure 8 in the Table 4.

Accumulative generation of Mangla and Tarbela dams aggregated to 478 billion KWh from their commission up to year 2005-06 which is equivalent saving of about 119 million tons of furnace oil, which saves foreign exchange of 13.8 billion US$ (at various exchange rates of Rs with US $ and oil prices over the years) and greenhouse gas emissions (details are given in Table 5). Total share of electricity due to these dams was about 50% of total power system up to 1995-96, which subsidize the whole electricity system of the country with generation cost of less than half a cent. Because of failure in constructing new dams the hydel generation of the country reduced to about 30% of the total in 2006-07, which is responsible for steep hike in electricity tariffs.

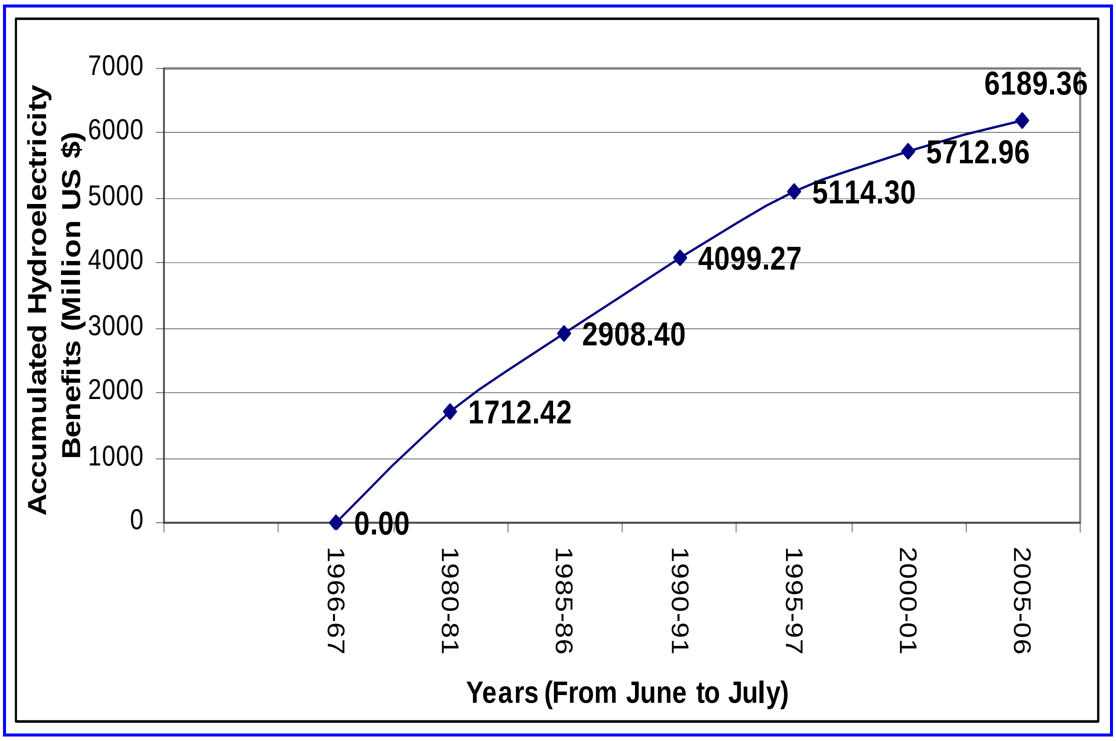

Figure 8: Total accumulated benefits to date due to hydroelectricity generation from dams from 1966-67 to 2005-06 (ref : Wapda Annual Report (2006-07))

Table 4: Hydel Electricity Generation Benefits of both dams from their commissioning to 2005-06

Year (from June to July)	Mangla (GWh)	Tarbela (GWh)	Total (GWh)	Benefits (Million US $)
1967-68 1980-81	41028	-	41028	1243
1975-76 to 1980-81	-	15482	15482	469
1981-82 to 1985-86	21692	32127	53819	1196
1986-87 to 1990-91	28643	49240	77883	1191
1991-92 to 1995-96	30533	68264	98797	1015
1996-97 to 2000-01	22533	73252	95784	599
2000-01 to 2005-06	23482	71322	94805	476
Total	167911	309687	477598	6189

Table 5: Saving in million tons of oil equivalent due hydel electricity generation both dams from their commissioning to 2005-06.

Year (from June to July)	Mangla (GWh)	Tarbela (GWh)	Total (GWh)	Savings in Furnace Oil Mill. Tons	Savings (Mill US$)
1967-68 1980-81	41028	-	41028	10	611
1975-76 to 1980-81	-	15482	15482	4	231
1981-82 to 1985-86	21692	32127	53819	13	1722
1986-87 to 1990-91	28643	49240	77883	19	2036
1991-92 to 1995-96	30533	68264	98797	25	2250
1996-97 to 2000-01	22533	73252	95784	24	3006
2000-01 to 2005-06	23482	71322	94805	24	3908
Total	167911	309687	477598	119	13765

Impact on the Energy and Agriculture Sector Due to Inability to Construct a Large Multipurpose Dam

Unfortunately mega multipurpose large dams were not constructed after Tarbela due to political dispute between the provinces impacting the economy of Pakistan appreciably. It was planned that a mega dam project would be necessary to be constructed after every decade.

A clear indication of need for building new dams for the economy of country was felt in 1994-1996 in the form of power shortages and scarcity in water for irrigation has been experienced. At that time the government had to opt an expensive option of installing Independent Power Projects (IPPs). The operating cost structure was transformed by increasing purchases of power from IPPs.

The share of hydropower generation (with its low operating cost) declined from 47% to 29%; between 1997 to 2001 (Figure 8) in the absence of the proposed dam (M.Fraser, 2005) construction.

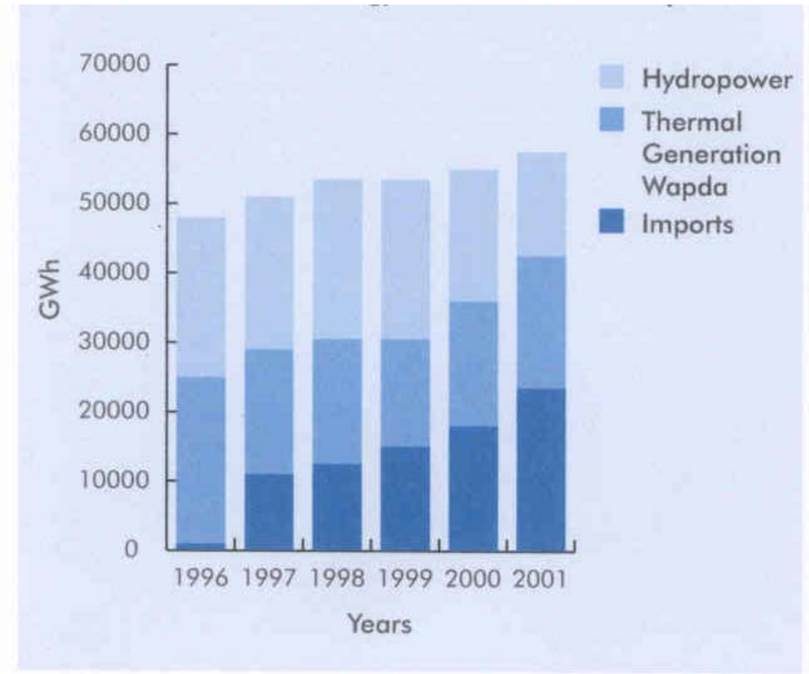

Figure 9: Energy generation by WAPDA and Imports (IPPs) (M.Fraser : 2005)

If the large multipurpose dams were built as per planned schedule or if only one dam of the capacity of Tarbela was added to the system the hydel share instead of decreasing from 47% to 29% from 1997 to 2001 would have been maintained about half the share of total generating capacity. It would have resulted in stabilizing in electricity tariffs due to less operating costs of hydel power generation. Moreover dependence on IPP,s would have been more than 50% (2000 MW instead of present figure of more than 5000 MW).

Storage capacity of existing dams in Pakistan depleting at the rate of 0.18 BCM per year (Haq : 2005) leading to storage loss of 5 BCM to date which accounts for about 20% storage loss for irrigation. Furthermore with average annual increase in population of about 3 million, additional water resources of 0.62 BCM are required to sustain and extend irrigation network of remaining area to meet the food requirements of the country. Unfortunately instead of an increase in the irrigation network a deficiency of irrigation water for the existing system especially in late and early Kharif and Rabi (October to March) has been experienced in the absence of mega multipurpose dam.

Conclusions

The operation of Mangla and Tarbela dams from their commissioning to 2006, as compared to pre-reservoirs period of 1960-67, reveals:

i. Cumulative incremental irrigation water benefits over the period of 1967-2006 were 2.6 billion US $ due to regulation of these big storage dams.
ii. Withdrawals of IBIS increased by about 20 percent in the low-flow periods of early Kharif i-e April and May in Rabi from October to March and late Kharif i-e September, which ensuring regular water supply throughout the year in this semi arid, agriculture based economy.
iii. Hydropower contribution from these dams from 1967 to 2006 aggregated to 478 billion KWh. Correspondingly estimated benefits were 6.8 billion US$ which saved 119 million tons of furnace oil resulting in saving of foreign exchange of 13.5 billion US$.
iv. Electricity benefit, which is by product of dam operations, is 3 times the direct irrigation benefits and in present era plays a vital role when the furnace oil prices are at their peak i-e 120 US$ a barrel.
v. Combined impact of above two factors was a substantial contribution to sustainable economic growth of Pakistan.
vi. These dams regulation ensures minimum flows as and when required necessary to avoid saltwater intrusion from the sea in low line areas during low flow season.

Recommendations

The benefits gained from existing mega multipurpose dams and the adverse impact on power and irrigation sector of Pakistan due to failure of constructing a mega multipurpose dam in the last 4 decades, clearly demonstrates that dams ensure essential irrigation water supplies for food security and provide energy security by providing affordable electric energy for agriculture, industrial and domestic sectors necessary for sustainable economic growth of the country. The development of dams for proper management of river waters can only improve economic viability, preserve ecosystem and enhance social justice of the country in the coming years. Availability of inexpensive electricity and required irrigation waters are the key factors for improvement in living standard of common man. Therefore immediate construction of mega multipurpose dams is imperative. The benefits gained from existing Tarbela and Mangla Dam Projects reinforce this finding.

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References

1- Ahmad Zia, Ahmad Tahir (2003) "Hydropower Development and Poverty Alleviation in Pakistan" Hydropower and Dams, Issue five.

2- Ch. Muhammad Mushtaq , Bhatti S. Ali (April, 2005) "Water storage and its role in the National economy" Lahore proceedings of Seminar on Water Storage by large dams. The Institute of Engineers, Pakistan.

3- Federal Bureau of Statistics, "Various Publications for Consumers Price Indices, Pakistan Economic Survey, Government of Pakistan" Islamabad – Pakistan.

4- Government of Pakistan (2005), "Study I: Water Escapages Below Kotri Barrage to Check Sea Water Intrusion". Islamabad – Pakistan.

5- Government of Pakistan, (2005), "Study II: Water Escapages Downstream of the Kotri Barrage to Address Environmental Concerns", Islamabad – Pakistan.

6- Government of Pakistan, Finance Division, (June, 2007), "Economic Survey of Pakistan" Islamabad, Pakistan.

7- Haq Izhar ul , Bhatti S. Ali, (April, 2005) "Water security and role of large dams", Lahore proceedings of Seminar on Water Storage by large dams. The Institute of Engineers, Pakistan

8- "Indus Waters Treaty" signed between Pakistan and India in September 1960.

9- M.Fraser Julia (May, 2005), "Lessons from the Independent Private Power Experience in Pakistan" World Bank Energy and Mining Sector Board Discussion paper.

10- Majeed Zahid , Zia-ul Hasan and Awais Latif (13-15, March 2008) "Water Resource Development ion Pakistan – Issues and Challenges" International Symposium Asia-2008, Danang, VietNam.

11- Majeed Zahid -Zia-ul Hasan (June 18, 2006) Proceeding of International Symposium on Dams in the Societies of 21st Century. Barcelona, Spain.

12. Water Resources Management Directorate (WRMD)-"Various Publications on Rim-Station Inflows, Canal Head Withdrawals and other Statistics", WAPDA, Lahore – Pakistan.

13. WAPDA (January, 2008) , Power System Statistics – 32nd Issue, Planning Department Power Wing, Wapda,Wapda House, Lahore, Pakistan.

14-WAPDA, (2006-07), “Wapda Annual Report 2006-07” Public Relations Division, Wapda House Lahore, Pakistan.