PAKISTAN ENGINEERING CONGRESS

74TH ANNUAL SESSION
JAN. 2016 – DEC. 2017

ANNUAL SYMPOSIUM

ON THE TOPIC OF

"IMPACT OF INFRASTRUCTURE DEVELOPMENT AND PAKISTAN ECONOMY"

Volume 38 **LAHORE**

ON BEHALF OF PAKISTAN ENGINEERING CONGRESS

Pakistan Engineering Congress as a body does not hold itself responsible for the opinions expressed by different authors in this Volume

Compiled and Edited

By:

Engr. Syed Mansoob Ali Zaidi

Member Executive Council / Convener Symposium Committee

Published By:

Engr. Nayyar Saeed

Secretary PEC

Price Rs. 500/-
Members Free

Can be had at:

PAKISTAN ENGINEERING CONGRESS

(4th Floor) Pakistan Engineering Congress Building,
97-A/D-1, Liberty Market Gulberg-III, Lahore 54660
(Near Liberty Roundabout)
Phone: (042) 35784238, (042) 35784235 Fax: (042) 35784236
Web-site: www.pecongress.org.pk
E-mail: info@pecongress.org.pk
ISBN: 978-969-603-035-5

PAKISTAN ENGINEERING CONGRESS
THE EXECUTIVE COUNCIL FOR THE 74th SESSION

PRESIDENT
Engr. Ch. Ghulam Hussain

Immediate Past President
Engr. Iftikhar Ahmad (President 73rd Session)

VICE-PRESIDENTS

1. Engr. Husnain Ahmad
2. Engr. R. K. Anver
3. Engr. Ijaz Ahmad Cheema
4. Engr. Dr. Izhar-ul-Haq
5. Engr. Tariq Rasheed Wattoo
6. Engr. Ch. Muhammad Arif
7. Engr. Akhtar Abbas Khawaja
8. Engr. Syed Shehzad Raza
9. Engr. Muhammad Amin

OFFICE BEARERS

1.	Engr. Nayyar Saeed	Secretary
2.	Engr. Ch. Muhammad Aamir Ali	Joint Secretary
3.	Engr. Najam Waheed	Treasurer
4.	Engr. Capt (R) M. Qadir Khan	Publicity Secretary
5.	Engr. Amjad Saeed	Business Manager

EXECUTIVE COUNCIL MEMBERS

1. Engr. Riaz Ahmad Khan
2. Engr. Syed Abdul Qadir Shah
3. Engr. Syed Mansoob Ali Zaidi
4. Engr. Iftikhar ul Haq
5. Engr. Abdul Khaliq Khan
6. Engr. Pervaiz Iftikhar
7. Engr. Sheikh Muhammad Saeed Tahir
8. Engr. Tahir Anjum Qureshi
9. Engr. Brig. Farooq Murawat
10. Engr. Latif Khan
11. Engr. M. Anwar Qaseem Qureshi
12. Engr. Capt. (R) M. Qadir Khan
13. Engr. Ali Arshad Hakeem
14. Engr. Dr. Muhammad Saeed
15. Engr. Syed Anwar ul Hassan
16. Engr. Amjad Saeed
17. Engr. Khalid Javed
18. Engr. Najam Waheed
19. Engr. Ahmad Nadeem
20. Engr. Anwar Ahmad
21. Engr. Muhammad Usman
22. Engr. Jamil Ahmad Basra
23. Engr. Muhammad Ibrahim Malik
24. Engr. Brig (R) Sohail Ahmad Qureshi
25. Engr. Mashhadi Hussain Zaidi
26. Engr. Liaquat Hussain
27. Engr. Syed Nafasat Raza
28. Engr. Muhammad Sharif Shah
29. Engr. Atiq ur Rehman
30. Engr. Jhangir Larik
31. Engr. Faisal Shehzad

PROFILE
OF
ENGR. CH. GHULAM HUSSAIN,

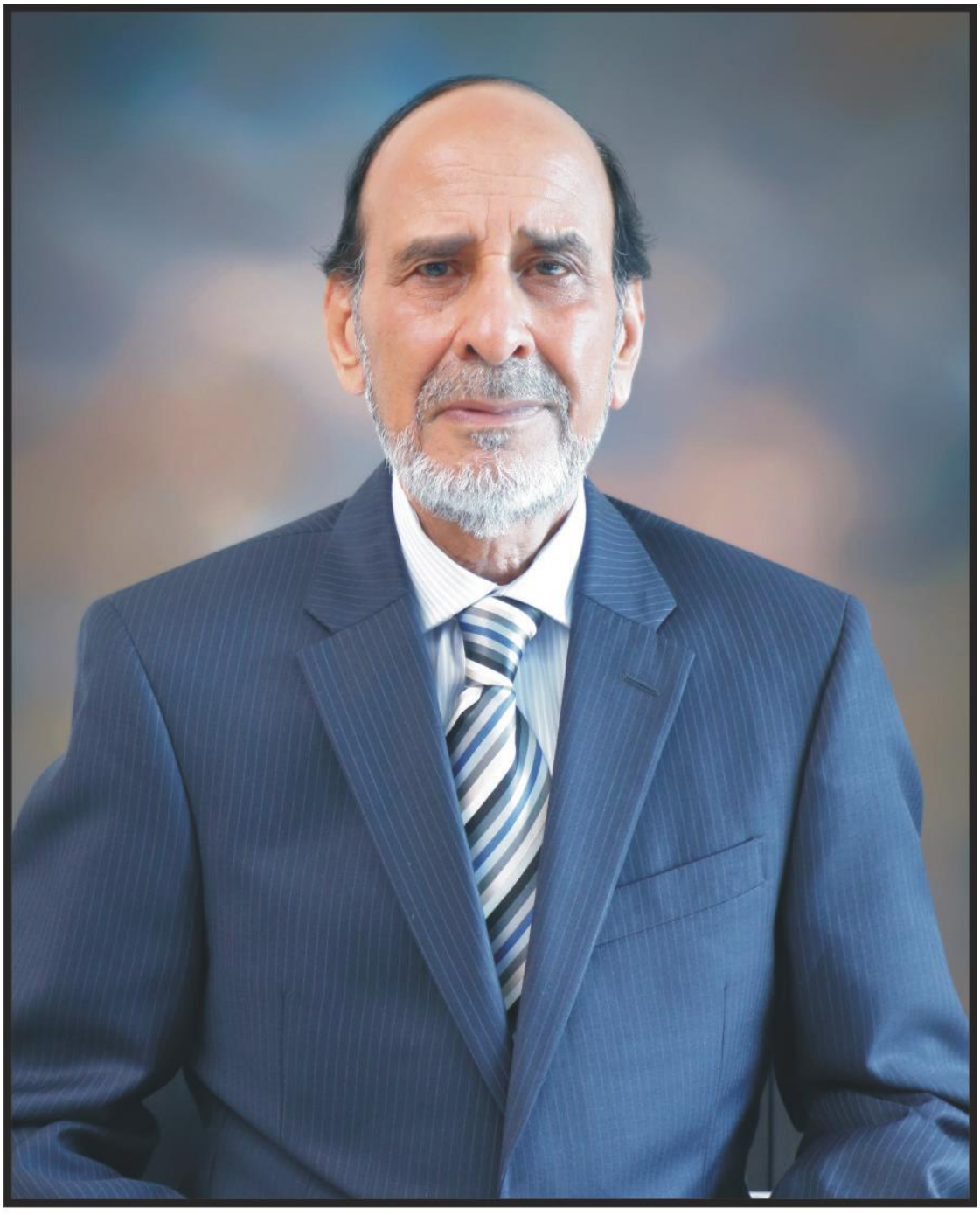
President, Pakistan Engineering Congress

Engr. Ch. Chulam Hussain is the Chief Executive of M/s National Development Consultants (Pvt) Limited, one of the leading Engineering Organizations of the Country. He was born on October 10, 1942 at Amritsar India. He passed B.Sc (Civil Engineering) in 1965 from the University of Engineering and Technology, Lahore. He joined "Water and Power Development Authority" and was involved in the execution of Indus-Basin replacement works. He did M.Sc. in Civil Engineering with specialization in Soil and Foundation in 1978. Engr. Ch. Ghulam Hussain has about Fifty two (52) years vast and varied experience of National and International Development Projects in Libya and Saudi Arabia where he supervised the construction of Makkah Jeddah Madina Expressway. In Pakistan he remained involved in the execution of mega projects such as: National Drainage Programme, Punjab, Sindh, NWFP and Balochistan Components; Chashma Right Bank Canal (CRBC); Pehur High Level Canal; Right Bank Outfall Drain – I & III; Fordwah Eastern Sadiqia Drainage Component; SWABI SCARP; Gomal Zam Dam Multipurpose Project; High Head Indus Tributaries (Alai Khwar-Duber Khwar-Khan Khwar) Hydropower Project; Diamer Basha Dam; Hingol Dam;

He is author of Nine (9) Technical Papers which were presented at National and International Forums and Published in renowned journals.

- Currently he holds the portfolio of the President of Pakistan Engineering Congress, which is the most prestigious and the oldest Engineering Organization of the Sub-continent established in 1912.
- He remained President of Association of Consulting Engineers Pakistan (ACEP) from April 2001 to April 2004 and April 2014 to April 2016.
- He was the Vice-President of Federation of Consultants from Islamic Countries (FICIC) Region-6 for 2 terms, i.e.: 2012-14 and 2014-16.
- Member, American Society of Civil Engineers.
- He worked as Secretary General, Pakistan Engineering Congress from January 2001 to December, 2003 and January, 2007 to July, 2011.
- He also worked as Vice-President, Pakistan Engineering Congress from January, 2004 to December, 2015.
- He remained member of the Central Council of IEP for three consecutive terms from 1992-2000.
- He is member of the Governing Body of Pakistan Engineering Council.

Engr. Ch. Ghulam Hussain has been elected un-opposed as President of Pakistan Engineering Congress, for term 2016-2017. With his extensive International administrative experience, he managed the Congress affairs in a very successful and befitting manner during his tenure.



Engr. Ch. Ghulam Hussain
President
Pakistan Engineering Congress
(74th Session)

PAKISTAN ENGINEERING CONGRESS
SYMPOSIUM COMMITTEE
(74TH SESSION)

1.	Engr. S.M.A. Zaidi	Convener
2.	Engr. Iftikhar ul Haq	Co-convener
3.	Engr. Husnain Ahmad	Member
4.	Engr. Dr. Izhar ul Haq	Member
5.	Engr. Riaz Ahmad Khan	Member
6.	Engr. Akhtar Abbas Khawaja	Member
7.	Engr. Abdul Khaliq Khan	Member
8.	Engr. Najam Waheed	Member
9.	Engr. Anwar Ahmad	Member
10.	Engr. Amjad Saeed	Member

TABLE OF CONTENTS

Sr. No.	Paper No.	Title of Paper	Author's Name	No. of Pages
01		KEY NOTE ADDRESS	Engr. Syed Mansoob Ali Zaidi	01
02.	329	IMPACT OF INFRASTRUCTURE DEVELOPMENT ON PAKISTAN ECONOMIC GROWTH	Engr. Riaz Rashid Engr. Khurram Amin	05
03.	330	IMPACT OF ENERGY DEVELOPMENT ON ECONOMY OF PAKISTAN-CHALLENGES AND CONSTRAINTS	Engr. Hafiz Muhammad Mukhtar, Engr. Muhammad Rafiq	17
04.	331	PRIORITY CONSTRUCTION OF CASCADE HYDROPOWER PROJECTS ON INDUS MAIN UNDER AMBIT OF CHINA-PAK ECONOMIC CORRIDOR (EPEC)	Engr. Riaz Nazir Tarar, Engr. Muhammad Jabbar	25
05.	332	BUNJI HYDROPOWER PROJECT OPPORTUNITIES AND CHALLENGES	Engr. Abdul Khaliq Khan	55
06.	333	OPTIMIZATION OF PATAN HYDROPOWER PROJECT ON RIVER INDUS	Engr. Dr. Izhar-ul-Haq Engr. Muhammad Abid Sheikh	71
07.	334	720MW KAROT HYDROPOWER PROJECT	Engr. Iftikhar ul Haq	83
08.	335	ASSESSING IMPACT OF INFRASTRUCTURE ON PAKISTAN ECONOMY	Muhammad Ali Waheed Anjum	95
09.		List of Previous Papers Presented at Proceedings		103

KEY NOTE

By

Engr. Syed Mansoob Ali Zaidi[1]

INFRASTRUCTURE DEVELOPMENT AND ITS IMPACT ON ECONOMY

Honorable Chief Guest, Mr. President, delegates, members and professional colleagues!

Welcome to the todays proceedings!

Today's symposium looks at the most important sector of infrastructure development in economic growth of the country.

Several global regions, particularly the developing countries face many challenges for the infrastructural development in the economic and social fields. Pakistan is going through the same set of problems as are being faced by others in this aspect. The problems are even worse in the case of Pakistan because of a faster rate of population growth and also migration to the cities. To ensure a proper access to the services the public infrastructural programmes are thus required to be implemented at a matching rate. However, in spite of serious efforts, there is still a backlog of infrastructural development virtually all over the country. In case the issues remain unattended or slow in implementation, the lack of infrastructural development is likely to result into a growing social and economic disorder in the near future. The unequal levels of development, present another dimension of a problem associated with the infrastructural development plans.

Broadly the infrastructural development could be divided into three main groups, i.e.:

1	Physical	Water Supply, Drainage, Roads, energy etc.
2	Social	Housing, Medical, Education, etc.
3	Economic	Business Districts, Industry, Transport, Communication, etc.

It is important to note that there is no use of spending on development projects, if we allow these to deteriorate or vandalized. All infrastructures have to be adequately protected, maintained and upgraded on a regular basis.

Provision of basic services (electricity, water, sanitation) to every citizen is the basic right. But this could be permitted with certain conditions, and a due level of moral diligence both from the receivers and the authorities.

Our population growth and changes in demography, such as people moving from rural to urban areas, demand that government should strive to provide the infrastructure for more and more people and should also take interest in developing the new areas with due consideration that our natural resource is not unlimited. Water is one such example being a dwindling

[1] Convener Symposium Committee / Associate, National Development Consultants (Pvt) Ltd.

resource. We must therefore provide and plan infrastructure development and look at alternatives in a manner that does not put our future generations on handicap.

All infrastructural programmes are important, but some are more urgent than others. For example, water and energy are the basic needs and more important for a community than road quality and some others.

Our economy is largely influenced by Agriculture, and Agriculture is dependent mainly on Irrigation and requirement of Irrigation water is supported by Multipurpose storage Dams which support both Irrigation network and production of Hydel Power.

The efficacy of Storage Dams is also acknowledged by the dam antagonistic report by the "World Commission on Dams." The following quote would clarify.

There can no longer be any justifiable doubt about that:

- Dams have made an important and significant contribution to human development, and the benefits derived from them have been considerable, and reflect a comprehensive approach to integrating social, environmental and economic dimensions of development;

There are no shortcuts to equitable and sustainable development between human needs and the requirements of a healthy environment.

Dams were built to provide water for irrigated agriculture, domestic or industrial use, to generate hydropower or help control floods. But dams also altered and diverted river flows, affecting existing rights and access to water, and resulting in significant impacts on livelihoods and the environment.

Dams are a means to an end, not an end in themselves.

The World Commission on Dams considers that the end of any dam project must be the sustainable improvement of human welfare. This means a significant advance of human development on the basis that is economically viable, socially equitable, and environmentally sustainable.

Normal development plans should effectively consider, water, electricity and other infrastructures. But we usually fail to realize that the poor communities which lack these services, feel deprived and became resentful.

Developing a vision based on strategic objectives and prioritized sector policies, would significantly be able to eliminate the deficits in infrastructural development.

Detailed analysis of the options for developments in energy, water and other sectors, based on a common vision, are likely to emanate from our consultative/validation sessions for a much-needed framework for engagement of development partners.

In today's session our professionals will be presenting the following seven papers, five relate to the most urgent, the energy sector and two to general fields.

1. "Impact of infrastructure development on Pakistan economic growth" by Engr. Riaz Rashid and Engr. Khurram Amin.
2. "Impact of energy development on economy of Pakistan challenges and constraints" by Engr. Hafiz Muhammad Mukhtar & Engr. Muhammad Rafique.
3. "Priority Construction of Cascade Hydropower Project on Indus Main" by Engr. Riaz Nazir Tarar & Muhammad Jabbar.

4. "Bunji Hydropower Project" by Engr. Abdul Khaliq Khan
5. "Optimization of Patan Hydropower Project on Indus River" by Engr. Dr. Izhar-ul-Haq and Engr. Muhammad Abid Sheikh.
6. "720 MW Karot Hydro Power Project in Pakistan" by Engr. Iftikhar ul Haq
7. "Assessing impact of infrastructure on Pakistan economy" by Mr. Muhammad Ali and Mr. Waheed Anjum.

The main features of these papers will be presented by the respective authors, and I will not venture upon them. However to give you the main thrust of each paper it can be said that:

1. Papers titled "Impact of infrastructure development on Pakistan economic growth" traces the policy and general infrastructural development and recommends more thrust in investment in infrastructure for water, energy and agriculture sectors.
2. The paper on "Impact of energy development on economy of Pakistan challenges and constraints" discusses the need for infrastructure development and its impact on economy and proposes more interest and efforts in hydropower development. The government should prefer the hydropower development as a long term solution for energy shortage management.
3. The paper entitled "Priority construction of cascade hydropower project on Indus main" explains the need for a cascade power project on the main stem of the Indus. The cascade could be long or short i.e. of 6 to 3 plants. I will leave further interaction to author's presentation.
4. The paper on "Bunji Hydropower Project" authored by Engr. Abdul Khaliq Khan is quite interesting. The project is anticipated to add 7100 MW to the national grid with a gestation period of about 10 years. The paper also recommends a seminar on "Turbine Runners" which has become the call of the day in view of the sediment movement conditions in various resources and other relevant issues.
5. The paper on "Optimization of Patan Hydropower Project on Indus River" authored by Engr. Dr. Izhar-ul-Haq and Engr. Muhammad Abid Sheikh introduces various aspects of the project, which is estimated to add 2400 MW of power to the national grid with 12500 GWH generation.
6. The paper on "720 MW Karot Hydro Power Project in Pakistan" describes the project in detail. The project envisages power generation only. It is likely to add 720 MW of power to the national grid and a mean annual generation of 3206 GWH. Trial run for the operation is planned at the end of the 5th year.
7. The paper titled "Assessing impact of infrastructure on Pakistan economy" basically presents the role of policy changes and infrastructure development. Preference of investment in power generation, water and agriculture sectors has been strongly advocated.

This symposium will thus deliberate on the importance of infrastructure; especially hydropower projects in the country. At the end of the symposium a panel discussion involving

notable experts will be held and recommendations to the Government will be formulated for appropriate and expeditious actions.

I have already encroached long enough upon your precious time and will no more stand between you and the speakers.

Thank you for your time!

Paper No. 329

IMPACT OF INFRASTRUCTURE DEVELOPMENT ON PAKISTAN ECONOMIC GROWTH

Engr. Riaz Rashid & Engr. Khurram Amin

IMPACT OF INFRASTRUCTURE DEVELOPMENT ON PAKISTAN ECONOMIC GROWTH

By

Engr. Riaz Rashid[1] and Engr. Khurram Amin[2]

ABSTRACT

Infrastructure development is vital for economic growth of developing countries. The economic growth of Japan and Korea in 60s and 70s indicates vital role of infrastructure development and public investment in transport, communication and energy sector for economic growth of the country. Lack of infrastructure in Pakistan in transport, energy and water sector proved to be major hindrance towards economic growth of the country. Lack of investment in water sector reduced country's agricultural output, increased unemployment in rural areas, decreased per capita income of more than 50% of population associated with agriculture, which in return put pressure on urban centers due to migration from rural areas. High population growth of the country demands huge investment in water infrastructure to improve economic growth of the country and rural population and to absorb massive rural population in agricultural sector, in direct benefits must be accounted for while planning and deciding infrastructure development in the water sector. Comprehensive development framework which includes all major sectors is necessary and development should be coordinated in such a way that growth of one sector complement the growth of other sector. Sequencing and prioritizing of infrastructure is important keeping in view existing and future demand, employment and socio-economic condition of the people and long term and short-term impact of development. Infrastructure development is the only way for Pakistan to achieve its Millennium Development Goals (MDGs).

INTRODUCTION

The lack of infrastructure is hindering the economic growth in many developing countries. Investment in infrastructure development results in increased productivity and contributes toward future economic growth in developing countries where infrastructure is still insufficient (Kim, 2006). Therefore, infrastructure development is one of the most integral parts of the public policies in developing countries. Many International donor organizations such as World Bank, Asian Development Bank etc actively promote infrastructure development by providing funding to support development activities. However, the precise relationship between infrastructure and economic growth is still frequently debated.

Infrastructure development plays vital role in economic development of community and country. Lack of basic infrastructure and inequalities in infrastructure conditions forced people to migrate towards cities to seek better opportunities (Ahmad, 2013). Infrastructure development is considered as public service, comprises of electricity, water, road, transport. Water supply, gas, sanitation and energy (Estache and Garsous 2012). It has significant impact on economic growth of the country (Aschauer, 1998), if complemented by policies of financing and use of infrastructure. Lall, (1996) suggests positive impact of expenditure on transportation and communication sector over regional growth. Whereas, (Devarajan, 2011) found negative impact of over expenditure on transportation and communication sector to economic growth. Scale of economy is also important factor in achieving positive impact of infrastructure development.

1 Chief Engineer, Lahore Zone, Irrigation Department

2 Executive Engineer, Lahore Drainage Division.

Over supplying infrastructure more than current demand results in negative impact on economic growth (Kim, 2006). Governance and political stability are variables of political economy are significant elements that can affect the economic growth related with infrastructure development. Efficiency, accountability and reforms in public sectors are considered as vital element for effective monitoring and evaluation of projects funded by government (Ahmad 2013).

Pakistan has highest rate of urbanization in South Asia which has put more pressure on already stressed infrastructure (Ahmad, 2013). World Bank, (2007) reported that Pakistan's key infrastructure shortages lie in the water, irrigation, power and transport sectors. The country is amongst the most water-stressed in the world and rehabilitating current wear and tear in the water sector will require more than $7 billion in maintenance over the next 5 years. Pakistan faces severe power shortages of approximately 5,000 MW with per capita energy consumption among the lowest in the world, slowing industrial growth. The inefficiencies of the rail, road, port and aviation sectors are now costing the economy over 4 % of GDP. The productivity of agriculture sector is declining due to poor condition of irrigation infrastructure (Ahmad, 2013).JBICI, (2007)report shows that access to irrigation infrastructure helps to keep the incidence of chronic poverty at lower levels.

Improved infrastructure provide safety against natural disasters such as earthquakes, drought and floods which could result in negative economic impact on the country. Economic loss to Pakistan due to 2010 flood is estimated to be around Rs. 855 billion (Ahmad, 2013). Efficient infrastructure in transport, electricity and communication creates enabling environment for private sector to play their role for economic growth. Though Pakistan has invested heavily in public infrastructure development but poor governance remains major plague to these assets. Pakistan is among lowest ranked countries in "global infrastructure ranking" as indicated in Table -1.

Table-1: Global infrastructure Ranking.

	Transport	Electricity and telephony	ICT	Education	Health	Security	Public institutions
Malaysia	14	48	57	91	52	48	32
China	29	69	74	93	71	68	46
India	35	116	117	109	109	89	72
Sri Lanka	52	79	100	89	61	59	49
Pakistan	80	126	111	126	111	137	111
Philippines	104	101	93	83	97	117	112
Benin	115	118	120	123	120	95	91
Bangladesh	117	137	132	118	107	103	112

Source: Global competitiveness report, 2011–2012

ICT = Information and Communication Technology

IMPORTANCE OF INFRASTRUCTURE DEVELOPMENT

Better quality and quantity of infrastructure can improve and raise the human capital and productivity. Better road infrastructure improves jobs, education, access to markets for farmers and cut their cost and facilitate private investment. Siddiqui, (2008) concluded that investment in transport infrastructure bring about long term economic benefits to the country and help reduce poverty.Infrastructure development should be prioritized and sequenced. Public sector projects nearing completion should be given priority. Key infrastructure projects for energy, water and transport production inputs will require participation of the private sector, so rules for public

private partnerships should be made as straightforward as possible. Finally, projects to remove regional disparities should be initiated, potentially enabling greater labour force participation, particularly in war torn areas.

IMPACT OF INFRASTRUCTURE DEVELOPMENT ON ECONOMIC GROWTH

Assessment of impact of infrastructure development of public capital on GDP growth is difficult. (Estache and Garsous 2012) found that increase in 1% of public capital would lead to 0.08% increase in GDP. It is argued and debated about which type of infrastructure matters and when.

Impact of infrastructure depends on various factors such as.

a. Stage of development of the country

b. Assessment time period

c. Type of infrastructure

It is found that rate of return/ payoff for infrastructure development are higher in developing countries than developed countries (Tanvir and Manan, 2016). Studies on development of Spain proved that payoff from infrastructure development are higher at early stage of development and payoff reduced when developed stage achieved. Energy and transport sector have vital impact on economic growth and have significant payoff at all stages of development.

Assessment period is an important factor in determining impact of infrastructure development. Short period assessment always yields negative results due to high initial capital investment. However, if assessed on long term basis the impact on economic growth and GDP are significant due to creation of jobs and cumulative benefits gained from development and improvement of different other sectors related with improved infrastructure.

Different type of infrastructure have different impact on GDP growth depending upon the situation of the country, its existing resource, human resource capital and social demands of public. Energy sector has direct benefit in GDP development as it relates to development of many other sectors. Telecommunication has best documented impact on GDP growth and has highest and most impressive payoffs than any other sector. Impact of transportation infrastructure is consistently correlated with economic growth, with rate of return as high as 63% (Kim, 2006). China spends 1% of its Gross National Product (GNP) on transport infrastructure and its GDP growth is constantly in the range of 9%. Impact of transportation infrastructure is low in case of developed countries but for developing countries scenario is totally opposite and improvement of transport infrastructure hold positive impact on GDP growth. Water and sanitation have no direct connection with GDP growth but it has indirect connection with other sub sectors. Water sector is least documented and neglected sector interms of its impact on GDP growth. Good quality water ensures health, which drives productivity and boost agricultural growth. Higher payoffs from infrastructure development can be achieved by.

- Strengthening the Institutions and Accountability, less corruption and higher skills.
- Creating Competitive environment
- Ensuring Balance in regulations

Study on Egypt indicates that 1% increase in expenditure over infrastructure development results in 0.5% increase in per capita GDP in first decade and 1% by the third decade. 3% increase in expenditure would result in 1.5% increase in per capita GDP in first decade and 3 %

by the third decade (Meeks, 2012) which indicates positive impact of infrastructure development on GDP growth.

Tanvir and Manan,(2016) have concluded that infrastructure have positive and significant impact on economic growth of Pakistan and recommended that government should take aggressive steps to improve quality of infrastructure to fulfil the requirement of economic growth at high rate. Moreover, effective planning to ensure usefulness and fully utilization of infrastructure is essential to optimize the benefits in terms of GDP growth.

EXPERIENCE OF IMPACT ON DEVELOPING COUNTIRES

Industrialized country like Japan and Korea's expenditure on transportation was about 50-60% of total expenditure during their development stage. Infrastructure development in transportation and energy sector in this region had positive impact on urbanization and industrialization (Kim, 2006) which resulted in high economic growth.Experience of South Korea indicates that government investment in infrastructure is very important in early stage of development (Kim, 2006) as clear from Table-2 below.

Table-2: Sector wise GDP investment and growth in South Korea (%).

Development phase	GDP per capita	Gross investment rate of GDP	Transportation	Electricity	Communication
1954-1961	1.2	11.2	7.6	11.5	23.5
1962-1971	6.0	19.9	14.5	22.4	17.9
1972-1989	6.5	29.7	6.1	13.3	17.8
1990-2001	5.1	33.6	7.6	9.5	4.9
Total	5.2	22.9	8.8	15.5	19.0

Construction of roads, power stations, and communication created jobs and stimulated the economy of the regions, and thereby increasing total regional production. Infrastructure investment could reduce the production costs indirectly and raise their productivity which resulted in overall production increase in the regions. Table-3shows the decrease in investment in agricultural infrastructure and increase in investment in transport and communication in South Korea over the time span of 50 years.

Table-3: Yearly GDP investment in different sectors in South Korea (%).

	1953	1958	1965	1970	1975	1980	1985	1990	1995	2000
Agricultural and non-mineral resources	38.6	37.6	32.1	27.1	15.3	36.0	38.2	35.7	29.4	17.1
Fuel and power	5.1	2.1	4.4	9.2	14.8	16.0	9.3	4.1	1.9	9.2
Mining, manufacturing, and constructions	47.0	27.0	18.7	15.7	6.3	3.0	6.1	2.0	0.6	0.0
Transportation and Communications	9.3	32.0	37.2	41.1	40.2	29.0	25.8	32.2	49.2	55.0
Other economic services	-	1.4	7.4	6.9	23.3	17.0	20.6	26.0	19.0	18.7

Table-4 below shows impact of reduction in agricultural infrastructure development and increase of investment in transport and communication on the per capita income of rural and urban population. Decrease in investment on agricultural infrastructure resulted in increase in per capita income of rural population at reduced rate. However, increase in investment in transportation resulted in increase in percapita income of urban population at higher rate. Resultantly urban household income increased twice the rate of rural household income.

Table-4: Difference in Rural and Urban income over the years (1000 won Current Price)

• •	Rural Income		Urban Income		Ratios (%)	
• •	(1) per household	(2) per capita	(3) per household	(4) per capita	(1)/(3)	(2)/(4)
1963	83	130	80	144	103.3	89.9
1965	107	210	113	156	94.7	134.6
1970	232	251	381	321	60.9	78.2
1975	859	384	723	501	84.1	76.9
1980	2494	488	4133	910	60.3	53.6
1985	5552	807	7440	1256	74.6	64.3
1988	8130	1273	12228	1912	66.5	66.6
1996	23298	2590	44364	4640	52.5	55.8

IMPACT OF WATER INFRASTRUCTURE ON ECONOMIC GROWTH OF PAKISTAN

Impact of water infrastructure are not truly measured so far. In developing countries billions of hours are daily spent in fetching water for drinking and domestic need. However, many researchers believe that major benefit of water infrastructure is saving in time to fetch water which lay groundwork for economic growth of community and country (Meeks, 2012). Musouwir, (2008) has concluded that there is positive impact of investment in water infrastructure on economic growth and per capita income. He recommended that developing countries should allocate more on water infrastructure in their annual budget. Water infrastructure creates high quality job, strengthens the economy and improvement in water sector efficiency and reliability benefit other sectors (Quinn et al, 2017). Deficiency in infrastructure are the main reason for constraints in agricultural development in Pakistan (Looney, 1994). Imran, (2012) has concluded that power generation, ensuring availability of water for agriculture and improvement in transport have significant impact on economic growth of Pakistan. It is important to ensure coordination between different government programs to alleviate conflicts between different individual projects for more productive outcome than direct sector oriented project

In Pakistan demand of infrastructure development in roads, transportation and electric generation increases with increase in GDP growth. Though studies in developing countries have not found any direct impact of water infrastructure on GDP growth due to industrialized nature of the country's economy but Pakistan is still an agricultural country and water has direct connection with GDP growth. Agriculture contributes 25% to GDP, employs 45% of labor force, sustains 70% of population and accounts for 25% of direct export in the shape of cotton and textile and 35% indirect export in the shape of agro based products (Loony, 1994). It saves foreign exchange from importing agricultural products. Investing in water infrastructure is vital for economic growth of the country as more than 45% people associated with agriculture. In

Pakistan, per capita income gap between rural and urban area is high and discouraged farmers are heading to urban centers to earn their livelihood. The investment in water and agriculture sector is the only solution to increase the per capita income of rural households. Table-5 below shows the year wise public investment from 1970-90. It indicates reduction in water sector investment and increased investment in energy sector over the years and due to rise in urbanization and movement of farmers toward cities. The era between 1960-mid 70s remains the most popular era in terms of GDP growth with highest employment rate when expenditure over water infrastructure was much higher than other sectors.

Table-5: Public investment in Pakistan(%).

Year	Rural Works	Indus Basin	Energy	Railway	Large-scale Manufacturing
1970	3.1	31.0	4.7	6.6	5.4
1971	1.1	28.0	16.4	6.6	1.9
1972	1.2	30.0	12.6	3.5	3.0
1973	2.1	18.3	9.8	2.7	2.8
1974	1.3	10.8	10.4	1.7	5.5
1975	1.3	9.5	21.8	5.4	9.6
1976	1.0	9.1	19.6	3.9	19.4
1977	0.5	3.1	13.5	4.2	24.1
1978	0.3	4.2	13.7	3.7	30.3
1979	0.6	1.9	13.8	3.5	30.4
1980	0.6	2.7	8.8	3.4	24.9
1981	2.0	3.4	13.0	4.2	18.5
1982	2.6	2.8	12.5	4.5	15.0
1983	3.8	2.8	17.7	3.9	14.6
1984	3.6	1.5	16.2	2.6	15.0
1985	3.4	0.6	18.9	3.2	9.1
1986	3.7	0.6	17.6	3.7	9.6
1987	3.3	0.6	21.9	3.1	5.7
1988	3.7	0.4	22.2	2.3	5.1
1989	2.6	0.2	32.5	0.3	3.7
1990	2.2	0.2	32.8	0.8	4.3

Reference: Looney, 1994

The government should invest in improving per acre production, ensuring water for irrigation and improving water efficiency rather than bringing more area under cultivation. Investment in irrigation infrastructure have proven to alleviate poverty and welfare enhancing effects on rural communities (JBIC,2007). Research carried out by IWMI in Srilanka proves that irrigation generates higher and stable employment throughout the year. Further, irrigation enables households to earn higher daily wages, and this difference in daily wages is sufficient to uplift one person out of poverty for every working member. Not only do households in irrigated settings have better housing quality (as measured using the housing index), access to electricity, and other infrastructure, they also exhibit better health and lower incidence of malnutrition. Lack of modern irrigation infrastructure is major setback for country's agricultural development. Improved irrigated infrastructure increases the economic activity in the area, produce more jobs, improve education and average household income in rural areas (JIBC,2007). Huge investment is required to modernize, upgrade and overhaul the irrigation system. Currently flood irrigation system which is obsolete in many parts of the world is being

practiced causes waste of water resource. It need replacement with modern systems such as sprinklers system and canal lining is desired to save the waste of water due to seepage. Lack of adaptation of latest management practices and incorporating latest technology resulted in poor agricultural growth (Shah, 2009). So far, there is no system to utilize drainage water. It is also necessary to devise comprehensive integrated water resource management to utilize every drop of water for agricultural and economic growth of the country.

In Pakistan, there is clear disparity among urban areas and rural areas. Though investment and improvement of urban infrastructure, road, transportation and communication are mandatory for economic growth of individual and country but it is necessary to look at the rural centers which are mainly dependent on agricultural activities. The rural community get indirect benefits from transport infrastructure in the form of easy access to markets, but directly affected by irrigation infrastructure and improvement in water delivery system for better economic output. Better, equitable and durable water delivery system improves the agricultural production which results in economic growth of individual and contributes towards GDP growth. Poor irrigated infrastructure leads people to move to already stressed cities. This migration puts burden over urban centers, reduces agricultural output, reduces exports, increase in imports, affect the economic growth and GDP and becomes reason for many other illicit activities demanding extra public expenditure. The indirect benefits of investment in irrigated infrastructure out weights the direct benefits of improvement in GDP.

Timely Up-gradation of infrastructure to match with economic growth is major issue in Pakistan. Pakistan has seen economic growth in patches and failed to achieve constant growth for long period of time. The short sightedness of planners resulted in poor growth pattern which resulted in sharp decline after enjoying few good years of economic growth mainly due to unavailability of suitable infrastructure to support economic growth. Shah, (2009) states that Pakistan saw massive GDP growth of around 8% during 2003-04 due to boost in infrastructure development and then sharply decline to reach 2.5 % in 2008 because there was not enough energy, transport and water infrastructure in place to support and sustain growth rate of 7-8% annually. This short sightedness affected the socio-economic development and target to achieve MDGs.

One aspect of the development which is often neglected in dependency of sectors on each other. Infrastructure development of water sector need good transport system to timely transport agricultural goods and raw material to industries. Similarly, development of industries requires electricity and transport to complement their growth. Interdependency of different sectors require balanced growth and infrastructure development in each sector to boost overall economic growth of the country by avoiding redundancy of development. Huge investment in road network without establishment of markets and growth in agricultural products would fail to reap the benefit of road infrastructure. Though infrastructure development is key to economic growth of individual and country but consistency in policies, capacity building of institutions, skill development in each sector, engagement of stakeholders in decision making and proper accountability system in development sectors are important elements to ensure coordinated and consistent development and attract foreign investment in each sub sector.

CONCLUSION AND RECOMMENDATIONS.

Under the current economic scenario infrastructure development is vital for socio-economic growth of Pakistan. Infrastructure development will improve the conditions for foreign investment in trade, industry and development sector. It will create more jobs and improve local skill to match with international standards. It will improve the demand for raw material and enhance the local business. Major hydraulic structures like construction of dams, irrigation network and barrages can attract foreign investment and proved to provide economic benefits for longer period at low maintenance cost. Energy, Transportation, agricultural and water are main sectors

requiring huge and constant public investment to improve per capita income and ensure constant economic growth. Based on the above discussion the following recommendations are made for sustainable economic growth of Pakistan.

- Planning of infrastructure development must be coordinated with economic growth to meet with its requirements. During planning infrastructure development large portion of population associated with agriculture must be taken into consideration.
- While investing in water infrastructure the indirect benefits must be considered before making decision.
- Comprehensive integrated water management approach must be adopted to reap the benefits of every drop of water with modernized irrigation system and irrigation techniques to meet with the future challenges of over population and climate change.
- Comprehensive development framework, which includes all major sectors should be adopted and development should be coordinated in such a way that growth of one sector complements the growth of other sector.
- Sequencing and prioritizing of infrastructure is important keeping in view existing and future demand, employment and socio-economic condition of the people and long term and short-term impact of development.
- System of accountability, consistency of policies at national level, capacity building, skill development, monitoring and Evaluation and involving all stakeholders in decision making should be the main priority for sustainable development of infrastructure

References:

AHMED, V., ABBAS, A. and AHMED, S. 2013. Public Infrastructure and Economic Growth in Pakistan: A Dynamic CGE-Microsimulation Analysis. *Infrastructure and Economic Growth in Asia, Economic Studies in Inequality, Social Exclusion and Well-Being.*

ESTACHE, A. and GARSOUS, G. 2012. The impact of infrastructure on growth in developing countries. *IFC Economics Notes.*

GREY, D. and SADOFF, C. W. 2006. Water for Growth and Development. *A Theme Document of the 4th World Water Forum.* Commission Nacional del Agua: Mexico City.

IMRAN, M. and NIAZI, J. 2012. Infrastructure and Growth. Institute of Public Policy, BNU.

JAN, S. A., CHANI, M. I., PERVAIZ, Z. and CHAUDHARY, A. R. 2012. Physical infrastructure and economic development in Pakistan. Lahore: National College of Business Administration and Economics.

JBIC 2007. Impact of Irrigation Infrastructure Development on Dynamics of Incomes and Poverty: Econometric Evidence Using Panel Data from Sri Lanka. Japan Bank of International Cooperation.

KIM, B. 2006. Infrastructure Development for the Economic Development in Developing Countries: Lessons from Korea and Japan. *GSICS Working Paper Series.* Graduate School of International Cooperation Studies, Kobe University.

LOAYZA, N. V. and ODAWARA, R. 2010. Infrastructure and Economic Growth in Egypt. *Policy Research Working Paper 5177.* The World Bank.

LOONY, R. E. 1994. The impact of infrastructure on Pakistan agriculture sector. *The journal of developing areas,* 28**,** 469-486.

MEEKS, R. 2012. Water Works: The Economic Impact of Water Infrastructure. *Discussion Paper 2012-35.* Cambridge, Mass: Harvard Environmental Economics Program.

MUSOUWIR, T. H. 2008. Water and Economic Development: Correlation Between Investment in The Water Sector and Economic Growth of Developing Countries. Jakarta, Indonesia.

QUINN, A., FEENEY, K. and CASTRO, H. 2017. The Economic Benefits of Investing in Water Infrastructure. Value of Water Campaign.

SBP 2007. THE PAKISTAN INFRASTRUCTURE REPORT. Islamabad, Pakistan: State bank of Pakistan.

SHAH, F. 2009. Infrastructure Development: Remedy for Pakistan's economic demise. *News*.

TANVEER, A. and MANAN, N. 2016. IMPACT OF INFRASTRUCTURE ON ECONOMIC GROWTH OF PAKISTAN. *Journal of Economic Research,* 2**,** 1-12.

Paper No. 330

IMPACT OF ENERGY DEVELOPMENT ON ECONOMY OF PAKISTAN-CHALLENGES AND CONSTRAINTS

Engr. Hafiz Muhammad Mukhtar, Engr. Muhammad Rafiq

IMPACT OF ENERGY DEVELOPMENT ON ECONOMY OF PAKISTAN-CHALLENGES AND CONSTRAINTS

By

Engr. Hafiz Muhammad Mukhtar, Engr. Muhammad Rafiq

Abstract:

In Pakistan Currently the share of hydropower is about one third in total electricity generation of the country. The need of the day is to create new reservoirs and to reverse the present Hydel: Thermal share from 1:2 to 2:1 for availability of cheap electricity, very essential for sustainable economic growth of Pakistan.

This short paper will highlight the impact of infrastructure development in terms of energy projects, constraints and impact on the economy of Pakistan.

1. INTRODUCTION:

Pakistan is located in an area blessed with sufficient water resources in the form of Indus River System (IRS). IRS is fed from high snow and ice clad mountain peaks, glaciers and Monsoon rain waters. IRS comprises the rivers Indus, Jhelum, Chenab, Ravi, Bias and Sutlej and the northern and western tributaries of the Chitral, Swat, Kabul, Haro and Soan. The average annual inflows are 170 billion cubic meter, out of which about 22 billion cubic meter of live storage capacity has been harnessed which is about 13% of total available inflows. The IRS is capable of producing over 100,000 MW of hydropower but only 6.9% have been harnessed. The live storage capacity of the reservoirs is only 13% of the average annual flow volume, mainly due to sedimentation.

Currently the share of hydropower is about 1/3rd in total electricity generation of the country. The need of the day is to create new reservoirs and to reverse the present Hydel : Thermal share from 1:2 to 2:1 for availability of cheap electricity, very essential for sustainable economic growth of Pakistan.

2. EXISTING HYDROPOWER POTENTIAL

Indus River System (IRS) is capable of producing over 100,000 MW hydropower potential out of which about 6,902 MW of hydel potential has been exploited which is nearly 11.5% of the total hydropower potential of 60,158 MW summarized below:

Sr. No.	River/ Tributary	Power (MW)
A	**Hydropower Projects above 50 MW**	
1	**Indus River**	**39558**
2	**Tributaries of Indus in Gilgit-Baltistan**	**1698**
3	**Tributaries of Indus in Khyber-Pakhtunkhwa**	**4028**
	Sub Total (1-3)	**45284**
4	**Jhelum River**	**4341**
5	**Kunhar River**	**1455**
6	**Neelum River & its Tributaries**	**1769**
7	**Poonch River**	**462**

	Sub Total (4-7)	**8027**
8	**Swat River & its Tributaries**	**2297**
9	**Chitral River & its Tributaries**	**2285**
	Sub Total (8-9)	**4582**
	Total A	**57,893**
B.	**Hydropower Projects below 50 MW**	
1	**On Tributaries**	**1591**
2	**On Canals**	**674**
	Total B	**2265**
	TOTAL (A+B)	**60,158**

The Pakistan Water and Power Development Authority (WAPDA), an entity given the responsibility to pursue the energy needs of the country is vigorously trying to exploit the available hydropower potential and develop the untapped hydropower energy. Nineteen Nos. Hydel Power Stations having 6,902 MW of Hydropower projects in operation.

Pakistan, despite having extensive indigenous hydropower potential, had to switch over to expensive thermal power due to delay in commencement of Kalabagh Dam and later on further delays in other projects in the pipeline. These circumstances forced to purchase power from the private sector developers (oil and gas based plants) at a higher rate. The energy mix ratio of 2:1 for Hydro:Thermal which is considered ideal for sustained economic growth of a developing country, was changed from 2:1 to 1:2 during the last two decades. At present, the average generation cost of thermal power is about US cent 14/kwh as compared to US cent 4-5/kwh for hydropower. The country has suffered a lot due to lack of effective long term planning and non-implementation of the hydropower projects. The need of the day is to create hydropower projects and to reverse the present Hydel thermal share from 1:2 to 2:1 for availability of cheap electricity and sustainable economic growth of Pakistan.

The present installed power generation capacity in Pakistan is about 24,906 MW of which around 30.8% by Thermal (furnace oil+ indigenous gas) and 36.5% by IPP's (Thermal), 28.6% by hydropower (WAPDA & IPP's), 3.2% by Nuclear and 1% by Wind as shown in Table-a and Fig-b respectively.

Table-a: Existing Power Generation Capacity in Pakistan
(Ref: Power System Statistics-40th Issue)

Type of Generation	Installed Capacity (MW)	Energy Generation (GWh)
Hydropower by WAPDA	6,902	31,525
Thermal GENCOs	7,663	22,621
IPP Hydro	213	1,038
IPPs (Thermal)	9,085	53,139
Nuclear	787	5,349
Wind	256	621
Total	**24,906**	**114,292**

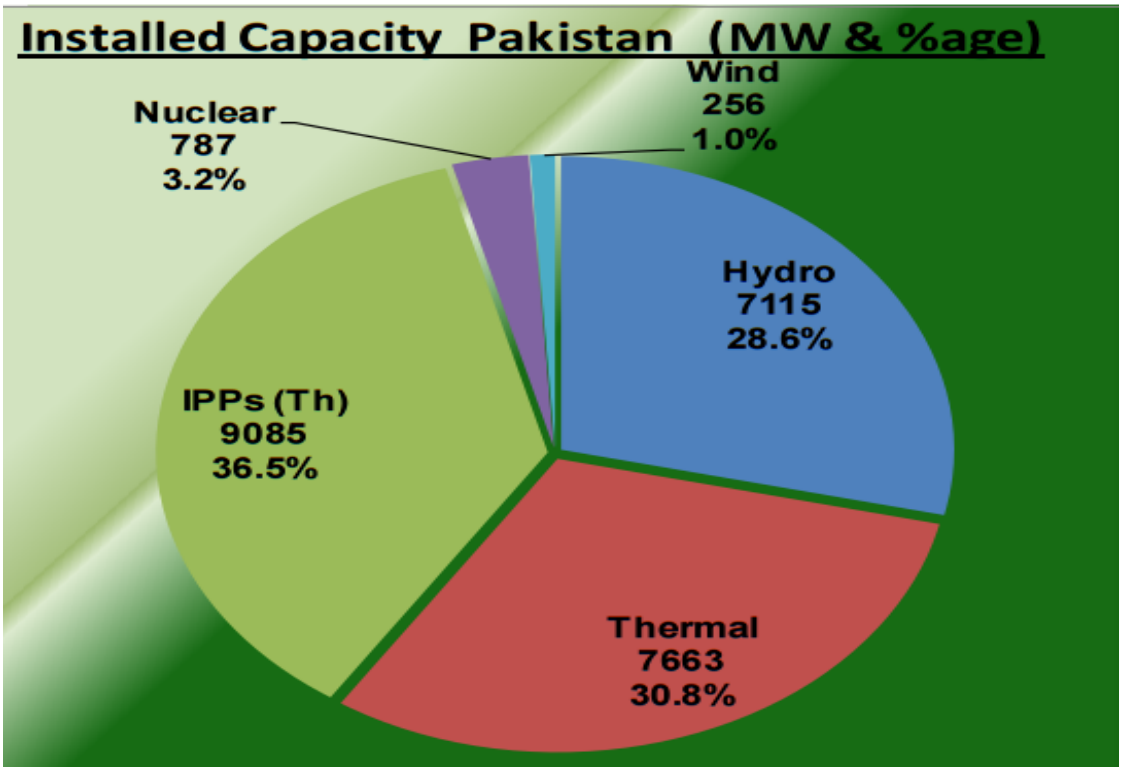


Fig-b: Electricity Generation by Fuel in Pakistan

The present power demand and supply gap extends up to over 5,000 MW at critical times for which we have to resort to extensive load shedding. Electricity is a stimulator for the socio-economic uplift of a country. However, today about 70% of the Pakistan's population has access to electricity. The high cost of power tariff and load shedding is playing havoc to the economic growth rate and purchase capacity of the poor consumers equally. The historic demand and future forecast at an average growth rate of 8% show that electricity requirement would rise to about 84,000 MW in the year 2030.

Hydropower development in Pakistan started in 1925 with the construction of 1.1 MW Renala Khurd hydropower station. At the time of independence, Pakistan inherited a very small power base of only 60 MW capacity for its 31.5 million people. Further, at the time of creation of WAPDA in 1958, the country's total hydropower capacity was enhanced to 119 MW. With the signing of Indus Basin Water Treaty in 1960, Pakistan was entitled to use 142 MAF (Indus 93, Jhelum 23 and Chenab 26) of surface water. Subsequently, 240 MW Warsak, 1000 MW Mangla and 3478 MW Tarbela Dam Projects were constructed.

The hydropower resources in Pakistan are mainly located in the mountainous areas in northern region of the Country lies in the Khyber-Pakhtunkhwa, Gilgit-Baltistan and Azad Jammu & Kashmir (AJ&K). The hydropower resources in the south being scarce mainly comprise from small to medium schemes on barrages and canal falls.

In Khyber Pakhtunkhwa, about 142 hydropower project sites, with a total capacity of 24,846 MW have been identified having high, medium and small heads. Out of these, 19 projects are in operation, 27 projects are under implementation in the public sector and 11 projects are under implementation in the private sector. The projects under implementation in the private sector are mainly run-of-river schemes with small daily pondage for peaking.

Azad Jammu & Kashmir is another important region having identified hydropower resource of about 6,489 MW. Hydropower development in AJ & K includes successful completion of 1,000 MW Mangla, and other small projects. Presently in AJ&K, 9 projects with a capacity of 1,039 MW are in operation and a number of hydropower projects with total capacities of 1,231 MW and 3,264 MW are under implementation in the public and private sectors respectively.

Numerous hydropower sites have been identified in the region of Gilgit-Baltistan. Due to low power demand in the region and absence of Extra High Voltage (EHV) transmission lines to transport power to load centre, these sites have not been developed so far. On account of difficult mountainous terrain and absence of EHV transmission line system, Gilgit-Baltistan is not connected to the National Grid, hence, sizeable projects have not been undertaken by private investors as yet. In Gilgit-Baltistan region total of 98 projects of 133 MW are in operation, 30 projects with a total capacity of 11,876 MW are under implementation by the Public Sector.

In Punjab, the main potential for power generation is on barrages and canal falls. About 296 potential sites with a total estimated capacity of 7,291 MW have been identified. Out of these, 8 projects including 1,450 MW Ghazi Barotha and 184 MW Chashma, are in operation, 7 projects are under implementation in the public sector and 31 projects in the private sector.

WAPDA, an entity given the responsibility to pursue the energy needs of the country is vigorously trying to exploit the available hydropower potential and develop the untapped hydropower energy. Currently hydropower projects with a total capacity of 4,856 MW are under construction which includes Golen Gol (106 MW), Neelum Jhelum (969 MW), Tarbela 4th Extension (1410 MW), Keyal Khwar (128 MW), Dasu Stage-I (2160 MW) and Kuram Tangi (Stage-I) (83.4 MW. The Diamer Basha Dam (4500 MW), Tarbela 5th Extension (1410 MW), Bunji HPP (7100 MW), Lower Spat Gah (496 MW) & Lower Palas Valley (665 MW) and Dasu HPP (Stage-II) (3240 MW) are ready for construction. Feasibility Studies/ Engineering Designs Studies for numerous hydropower projects with accumulative installed generation capacity of over 14000 MW are in hand which includes Mohmand Dam (800 MW), Harpo (34.5 MW), Phandar (80 MW), Patan (2400 MW), Thakot (4000 MW), Basho (40 MW), Shyok Dam (520 MW), Tungas (2200 MW), Yulbo (2800 MW), Middle Palas Valley (398 MW), Upper Palas Valley (157 MW), Middle Spat Gah (501 MW), Upper Spat Gah (277 MW). Most of these studies are at an advance stage of completion. Prospective plans for desk studies for other hydropower projects with a capacity of over 5000 MW have been completed and are ready for conducting feasibility studies to meet the future demands.

Power shortages as well as costly tariff due to higher reliance on thermal energy, are one of the biggest threats to our economy. Keeping in view the present energy crisis in Pakistan and the tariff which has become out of reach of the consumers, implementation of hydropower projects is the only viable solution. It is a dire need of time to initiate hydropower projects on top priority basis. Cheap and bulk energy production is required to be developed. For this, Major hydroelectric projects like Diamer-Basha (4500 MW), Bunji (7100 MW), Kalabagh (3600 MW) needs to be developed on priority basis. The major hydropower projects are essential to meet power shortfall and to reduce electric tariff. The above projects will give billions of units of cheap electricity, would cause reversing of present generation mix of thermal to hydel.

3. Challenges

Following are the main challenges being faced

- **Energy Crisis:** Only 6,902 MW has been developed so far out of 60,158 MW.

- **Water Scarcity:** Faulkener's index is around 970m^3/capita. Storage reservoirs are needed. Only 22 billion cubic meter of water has been tapped out of 170 billion cubic meter.
- **Finances for Development:**

  Studies of more than 22,000 MW are in hand in the form of Feasibility Studies and Detail Engineering Design. PSDP funding alone are not enough to facilitate WAPDA to develop this potential.

4. CRITICAL CONSTRAINTS AND MITIGATION OPTIONS

A number of projects have been studied to Feasibility Study and Detail Engineering Design Level. The project implementation takes a longer time than estimated in the studies. Based on experience gained in the last two decades, the following factors can be considered to be the barriers in the development of hydropower in Pakistan.

- Limited financial resources both for project studies and implementation
- Delay in release of PSDP funding from GoP.
- Lack of decision for implementation of mega projects
- Least priority for small to medium size projects
- Detailed investigations and long gestation period of hydropower projects
- Remote location of promising potential sites
- Lack of trained manpower for design and execution of hydropower projects
- Non availability of manufacturing facility for electro-mechanical equipments
- Lack of local construction companies to execute the medium to large size hydropower development.
- Less response from private investor in implementing hydropower projects
- Law and order & security issues in the country..

The above factors can be applied generally to a number of projects. The projects located in Northern Areas have some technical issues like seismic and sediments that needs to be resolved with extensive research on project to project basis. The project executing authorities needs to be strengthened to handle/ supervise project implementation and operation and maintenance of power stations.

Presently, the major issue restricting the hydropower development is the non availability of funds in foreign as well as in local currency. The donor agencies helped in financing to identify the potential of hydropower, but somehow remained reluctant to finance the projects for construction / implementation due to various reasons including security issues.

5. IMPACT OF ENERGY ON ECONOMY AND ENVIRONMENT

Energy is considered to be lifeline of any economy and most vital instrument of socio-economic development of a country. There has been an enormous increase in the demand of energy as a result of industrial development and population growth, in comparison to enhancement in energy production. Supply of energy is, therefore, far less than the actual demand. As a result, crisis has emerged. An energy crisis can be defined as any great bottleneck (or price rise) in the

supply of energy resources to an economy. Pakistan's energy infrastructure is not well developed, rather it is considered to be underdeveloped and poorly managed. Currently the country is facing severe energy crisis. During the past decade, no serious efforts have been made to increase power generation capacity. Moreover, rapid demand growth, transmission losses due to outdated infrastructure, power theft, and seasonal reductions in the availability of hydropower have worsened the situation. Consequently, the demand exceeds than the supply and hence load shedding or energy crisis is common.

Pakistan's energy crisis traces its roots to following obstacles. The shortage of electricity is mainly caused by the gap created between the demand and supply. There are various reason behind the less production of electricity in Pakistan which include lack of new power projects, high power tariff, rising burden of circular debt, power theft, and non-payment of timely electricity bills. Besides, people do not usually try to save electricity. We all talk about the corruption done by the government officials, but we never talk about corruption of the citizens who are perceived as innocent Pakistanis. At least 50% Pakistanis are either not pay the bills or give bribe to reduce their bill charges. All these problems should have to solved in order to overcome the energy crisis in Pakistan.

Pakistan is a country which is facing threatening and devastating shortage of electricity due to which all sectors of economy are being adversely affected too. For example, the economic progress is hampered by decline in agricultural productivity as well as by halt in operations of industries. Lower GDP growth and high inflation in recent years has also been attributed to shortfall in energy supply. As a result of decline in energy supply, new industrial units cannot be installed, rather the existing industrial units are gradually being closed.

Energy also impacts unemployment/employment. For instance, if industries are closed the workers will lose jobs. To generate jobs too, through setting up of new industries, energy is a prerequisite. So, employment and unemployment directly or indirectly related to the energy supply. Energy crisis can also contribute to social and psychological issues. These issues are directly related to the change of behavior of the citizen. Only because of the shortfall of the electricity, many people become victims of insomnia, which badly affects their lives and performance at work, if employed, ultimately indirectly effecting economical indicators.

Low economic growth due to energy crisis also results in increasing poverty. Currently, around forty percent of our population is living beyond poverty line and this ratio is increasing day by day. Ample control of energy crisis will surely yield in curbing the menace of poverty.

Energy crisis has, more or less, plagued all sectors of Pakistan's economy and therefore it is hampering national progress in a drastic manner. Nonetheless, menace of energy crisis can be overwhelmed by government through making effective policies and its proactive implementation. Simultaneously, it is the responsibility of all the citizens to utilize the available energy wisely for progress of the country.

6. CONCLUSION AND RECOMMENDATIONS

To meet the objectives of development, a tentative accelerated implementation programme for the reservoir/ run-of-river hydropower projects is the essential requirement of the day.

Rigorous efforts need to be made to arrange the financing from the foreign donor agencies and the project features and its economic viability may be made attractive for the potential investors. Strong and consistent efforts are required to improve the pace of hydropower development.

Government should prefer the hydropower development as a long term solution.

Paper No. 331

PRIORITY CONSTRUCTION OF CASCADE HYDROPOWER PROJECTS ON INDUS MAIN UNDER AMBIT OF CHINA-PAK ECONOMIC CORRIDOR (CPEC)

Engr. Riaz Nazir Tarar, Engr. Muhammad Jabbar

PRIORITY CONSTRUCTION OF CASCADE HYDROPOWER PROJECTS ON INDUS MAIN UNDER AMBIT OF CHINA-PAK ECONOMIC CORRIDOR (CPEC)

by

Engr. Riaz Nazir Tarar[1], Engr. Muhammad Jabbar[1]

Introduction

China Pak Economic Corridor (CPEC) is now under implementation through over US$50 billion massive investments till 2030. When implemented, it will be truly a game changer not only for China and Pakistan but also for other South Asian countries willing to join the Corridor.

CPEC is basically aimed at achieving all weather land connectivity between China and Pakistan through related infrastructural development. However, it will contribute significantly towards alleviating national energy shortages.

Electricity, although secondary source of energy, has become indispensable. Not only for households, but all other spheres like industry, transport, etc. Therefore, being the major source of energy, CPEC envisages a sizeable development of this sector also. A large component of this package will comprise thermal generation dependent on imported gas and coal including indigenous element (basically Thar), to the extent possible. This approach, though considered as short term panacea, will result in higher generation costs besides enhanced Pakistan's dependence on imported fossil fuels.

Current hydropower development component of CPEC to be implemented over the next few years term, is only limited to two run-of-river projects on tributaries of Indus River System. On the other hand, over 2/3rd of national hydropower potential sites are located on the Indus Main. Therefore, it seems necessary that development of hydropower on Indus Main, being sizeable as well as less costly, may be given priority. This can be best achieved by inclusion of relatively attractive Indus Main hydropower sites in CPEC.

NATIONAL ENERGY SCENARIO

Present and projected energy demand

It is assessed that realistic current (2017) the national peak energy demand is over 30,000 MW. Against this, the present total installed capacity is 23150 MW comprising: 15300 MW thermal; 7000 MW hydro; and 750 MW nuclear. In addition, a capacity of 440 MW is on line through renewable resources of wind, solar and biogas cogeneration. Corresponding dependable generation is about 80% in summer; and 65% in winter, thus casing perpetual load-shedding of around 5000 MW. This is due to a combination of constraints comprising: no dependable system spare capacity; de-rating of existing thermal units; non-availability of gas for thermal power stations; and seasonal reduction in hydropower capability due to drawdown of on-line reservoirs.

Prevailing thermal-hydro Mix and Generation Costs

Prevailing thermal-hydro installation ratio is about 70:30. Corresponding energy generation ratio is 67:33. Against this, the past (1990's) mix was 30:70. Due to reversal of thermal-hydro

[1] Respectively, Associate & Expert, National Development Consultants, Lahore.

contribution over the last 25 years the power tariffs have gone very high. Resultantly, GoP's present (2016) tariff at consumer end is averaging around Rs. 15 / kWh.

Main contributing factor to high power tariff is excessive IPP thermal generation costs varying between Rs. 10 / kWh for gas to Rs. 18 / kWh for furnace oil operated plants. On the other hand, overall generation cost of WAPDA's System is still around Rs. 5/kWh. It is average of: operative hydropower stations (Re. 1.6); Under Commissioning / Implementation Projects (Rs. 6.8); and Ready for Implementation Projects (Rs. 7.0).

MEDIUM TEM ELECTRICITY DEMAND

Projection upto 2030

Even on the basis of conservatively assumed annual compound growth rate of 7.5%, it is projected that over the period of 2016-30, peak electricity demand will increase from 29000 to 76000 MW. Projected yearly growth pattern of this medium term is shown in Table 1.

Table 1: Medium Term Power Demand Forecast

Year	Projected Peak Demand (MW)
2016	29,400
2017	31,500
2018	33,700
2019	36,400
2020	39,300
2021	42,300
2022	45,400
2023	48,800
2024	52,100
2025	55,900
2026	59,600
2027	63,400
2028	67,300
2029	71,400
2030	75,600

Source: *General Manager, Hydro Planning, WAPDA (2015)*

Coping Strategy

As reflected in 2013 National Power Policy to cope with the above Medium Term Electricity Demand, GoP is focusing on power development as per following priorities:-

i. Bringing the old de-rated thermal plants of WAPDA to design capacity including switch over from costly fossil fuels to coal.

ii. Adding coal based thermal generation on account of short term gestation and low running costs as compared to oil based stations.

iii. Preferring run-of-river hydropower facilities with somewhat shorter gestation period as compared to multi-purpose storage projects.

iv. Addition of 10400 MW generation under CPEC in the short run. However, it includes only 1590 MW of hydropower at: Suki Kinari on Kunhar (720 MW); and Karot on Jhelum River (720 MW)

v. Tapping of un-conventional sources of solar, wind and biomass through private sector.

Above strategy to cope with electricity demand notably ignores synergic multipurpose development of surface water not only for cheap renewable energy but direly needed storage water for sustenance of irrigated agriculture. This can be achieved through priority development of Diamer Basha Dam Project in conjunction with downstream cascade projects of Dasu, Pattan and Thakot in the Indus River reach upto Tarbela.

Pakistan Hydropower Potential

Fortunately, Pakistan is blessed with a conservatively estimated hydropower potential of over 55000 MW on Indus River System in the North. A break up is shown in Table 2.

Table 2: Identified Hydropower Potential of Upper Indus and Jhelum River Basins

Sr. No.	River / Tributary	Identified Capacity (MW)	Development Mode
1.	**Indus River and Tributaries**		
i.	Indus Main	39,100	A combination of storage and run-or-river (RoR) facilities particularly through Diamer Basha Dam Project and three cascade projects of Dasu, Pattan and Thakot
ii.	Tributaries	8,900	Mostly RoR
iii.	Sub-total (1)	48,000	
2.	**Jhelum and Tributaries**		
i.	Jhelum River	5,300	Mostly RoR except 1000 MW at Mangla Dam
ii.	Tributaries	1,900	Mostly RoR
iii.	Sub-total (2)	7,200	
3.	Total (1+2)	55,200	

For development of above hydropower potential, a number of sites have been already identified with locations shown in Annex-01.

Monenco's Hydro-Electric Inventory and Ranking Study

During early 1980's Montreal Engineering Company (MONENCO) of Canada conducted for WAPDA, a 'Hydroelectric Inventory and Ranking Study for Pakistan'. This study covered Indus River System in North including: Indus Main and its major tributaries; and Jhelum Main and its tributaries.

Regarding Indus, the study covered its stretch from the Line of Control (LoC) in Jammu and Kashmir to the proposed location of Kalabagh Dam Project. After first ranking of Basha Dam Project, it identified a number of sites for aggregate hydropower development of Indus Main as shown in Tarbela 3.

Table 3: Identified Hydropower Development on Indus Main According to MONENCO's Study

Sr. No.	Scheme		Identified Development Potential (MW)	Remarks
	River	Site		
1.	Indus	Basha	3,360	Since enhanced to 4500 MW based on subsequent studies / engineering design of Diamer Basha Dam Project
2.	Indus	Tungus	1,300	Feasibility studies yet to the taken up
3.	Indus	Yulbo	1,500	
4.	Indus	Bunji	2,900	Sine enhanced to 7100 MW based on Feasibility Study combining the two sites
5.	Indus	Rakhiot (Raikot)	2,700	
6.	Indus	Dasu	5,500	Already engineered for 4320 MW with stage-I of 2460 MW under implementation
7.	Indus	High Thakot	2,400	Since bifurcated into Pattan & Low Thakot; Feasibility for 2385 MW of Pattan already completed; and Feasibility Study of Thakot in hand through three sub-cascades to develop 3900 MW.
		Total	19,660	

INDUS CASCADE HYDROPOWER DEVELOPMENT

Current Engineering Status

It can be seen form Table 3 that originally identified capacity of 11260 MW for Diamer Basha Dam and its three cascades has since been enhanced to 15105 MW (about 34%) on the basis engineering studies. These projects are under different stages of implementation / engineering for an aggregate hydropower development of over 15000 MW (for locations refer to Annex-03). Out of these: -

i. Core implementation of Diamer Basha Dam Project (DBDP) is on the anvil through: Stage I for main dam and appurtenants; and Stage II for development of 4500 MW hydropower. Salient features of DBDP are shown in Annex-04.

ii. Run-or-river Dasu Hydropower Project (DHP), with total installed capacity of 4320 MW is going to be developed through two stages of 2160 MW each. Implementation of Stage I through sponsorship of World Bank is now in hand. Salient features DHP are shown in Annex-05.

iii. Pattan Hydropower Project (PHP) will be a run-of-river development with total installed capacity of 2385 MW. Its salient features as per Feasibility Study of 2015 are shown in Annex-06.

iv. Thakot Hydropower (THP) will be also a run-of-river development. Its Feasibility Study is in hand with scheduled completion by end 2017. According to conceptual planning, this project is now proposed for development through a main dam and three sub-cascades. Besides avoiding very long tunneling through treacherous geology, this option will have some incidental advantages. Firstly, it will minimize socio-environmental impacts including: land acquisition; relocation and resettlement. Secondly, it will avoid overwhelming the design tailwater levels of existing High Head Hydropower Projects of Khan and Allai Khwars without affecting their planned generation. Salient features of THP, based on the conceptual planning studies, are shown in Annex-07.

Cascading effect of Diamer Basha Dam Project

Hydropower Generation

It is estimated that cascading effect of Diamer Basha Dam Project (DBDP) on the downstream hydropower projects will be substantial. Project-wise details are shown in Table 4.

Table 4: Cascading Effect of Diamer Basha Dam Project on Downstream Hydropower Projects

Sr. #	Location	Installed Capacity (MW)	Status	Cascading Effect of Annual Additional Generation (GWh)	Remarks
I.	**Existing Projects**				
1.	Tarbela	3478	In operation	1300	
2.	Ghazi-Barotha	1450		1100	
3.	Jinnah	96		40	Estimated @ 10% of annual generation with 50% plant factor
4.	Chashma	184		80	
5.	Sub-Total I (1 to 4)	5208		2520	
II.	**Upcoming Projects**				
1.	Dasu	4320	Under Two Stage Implementation	5400	At about 25% of estimated total annual generation of 21500 GWh
2.	Pattan	2800	Feasibility Completed	1900	Based on 2015 Feasibility Study
3.	Thahkot	3800	Feasibility in hand	3200	15% of estimated total annual generation of 21,300 GWh
4.	**Sub-Total II (1 to 3)**	**10920**		**10500**	
III.	**Total Cascading Effect of Diamer Basha Dam Project (I + II)**	**16,128**		**13,020**	**Over 70% of annual at site generation of 18100 GWh**

Besides above annual power generation boost of 13,020 GWh (about 70% of at site generation), DBDP, along with downstream cascade projects upto Tarbela, will avoid annually CO^2 emission of about 14.2 million tonnes. At the prevailing rate of US$ 1.8 / tonne this will entitle Pakistan to an annual carbon credit of US$ 29.1 million as per break-up shown Table 5.

Table 5: Estimated Carbon Credit For Indus Cascade Hydropower Projects

Sr. No.	Project	Installed Capacity (MW)	Annual Average Generation (Gwh)	CO^2 Emission of Equivalent Thermal Generation (Kg/kWh)			Annual Co^2 Reduction (Million Tonnes)	Carbon Credit @ US$ 1.8 / Tonne (US$ Million)
				CCGT	FO	Average		
1.	Diamer Basha Dam	4500	18100	0.18	0.25	0.22	4.0	7.2
2.	Dasu Hydropower Project	4320	21500	0.18	0.25	0.22	4.7	8.5
3.	Pattan Hydropower Project	2385	12500	0.18	0.25	0.22	2.8	5.0
4.	Thakot	3800	21300	0.18	0.25	0.22	4.7	8.4
5.	Total	15,005	73,400				16.2	29.1

CCGT: Combined Cycle Gas Turbines

FO: Furnace Oil

Water Benefits

DBDP will provide the following sizeable water related benefits to national economy: -

i. Its live storage capacity of 6.4 MAF will alleviate the acute water shortages in Indus Basin Irrigation System.

ii. It will act as trap for heavy annual sediment load of about 200 million tonnes resulting in:-

   a. Enhancing useful life of Tarbela reservoir by 35 years.

   b. DHP, now being developed as stand above facility, will lose its re-regulatory storage capacity of 0.66 MAF (0.82 BCM) within 10-15 years. In the presence of DBDP, this will be extended to at least 50 years.

   c. Nominal 0.06 MAF (0.7 BCM) diurnal re-regulatory storage at Pattan Hydropower Project will get depleted in a very short time. On the other hand, due to trapping of sediment in DBDP, this facility will get perpetuated including the downstream cascade hydropower project of Pattan. This will be do away with the need of regular annual flushing with associated significant loss of energy.

   d. Similar will be the case for further downstream Thakot Hydropower Project.

iii. Through its sizeable live storage capacity of 6.4 MAF (7.9 BCM), DBDP will enable significant flood attenuation, particularly for super events like 2010.

ENERGY GENERATION COSTS OF VARIOUS OPTIONS

Indus Cascade Hydropower Development Projects

As already mentioned, core construction of DBDP is now proposed through two stage development of: main dam and appurtenants; and power generation facilities. Generation costs of DBDP have been worked on the basis of updated December 2016 investment cost under standalone and cascading scenarios. The supporting details are contained in Annex-08 which show per kWh generation costs of: 7.6 US cents for standalone scenario; and 4.4 US cents under cascading scenario.

Generation costs for the downstream RoR cascade projects are estimated between 1.6 US Cents (Dasu) and 5.2 US Cents (Pattan).

Thermal projects

Presently estimated generation costs of various thermal alternatives range between 9.6 and 16.7 US Cents / kWh (details in Annex-09).

Comparative costs

Comparative present generation costs for various modes are shown in Table 6.

Table 6: Comparative Generation Costs For Various Modes

Sr. No.	Generation Mode	Generation Cost (US Cents / kWh)	Remarks
1.	**Hydropower**		
	i. Multipurpose DBDP	7.6	Considering cascading effect on downstream Projects, it will reduce to 4.4 US Cents / kWh
	ii. Run-of-River	5.2	Pattan Hydropower Project of Indus Cascade
2.	**Thermal**		
	i. Natural Gas	7.7	According JICA Report, October 2015
	ii. Coal (Imported)	10.4	
	iii. Liquefied Natural Gas	11.8	
	iv. Furnace Oil	16.7	
3.	**Nuclear**	**13.0**	
4.	**Other Renewables:-**		
	i. Solar	14	Approximate upfront tariffs of NEPRA
	ii. Wind	12	
	iii. Biomass	10	

CONCLUSIONS & RECOMMENDATIONS

Conclusions

i. Medium term peak electricity demand is projected to increase from 29,400 MW (2016) to 75,600 MW (2030) showing an increase of over 250%.

ii. Coping strategy with this demand under National Power Policy 2013, envisages developments, both under public / private sectors, through the modes of: hydropower; thermal; nuclear; solar; wind; and bio-mass.

iii. Primary focus of development is on the thermal option with hydropower limited basically to run-of-river mode.

iv. Under CPEC, a capacity of 10400 MW is going to be added over the next 4 years or so. However, this includes only two run-of-river hydropower projects aggregating to 1590 MW.

v. Two stage implementation of DBDP with an installed capacity of 4500 MW is now contemplated over a period of 10 years.

vi. Fifty percent DHP capacity (2160 MW) is now being developed as run-of-river facility through Stage I spanning ever 6 years Balance capacity will be developed under Stage II during the next 7 years.

vii. Feasibility Study of Pattan Hydropower Project with installed capacity of 2385 MW has been completed in 2015.

viii. Feasibility Study of Thakot Hydropower Project with installed capacity of 3900 MW is now inhand.

ix. Conditions are now ripe for sizeable hydropower development through the cascade of DBDP and downstream Dasu, Pattan and Thakot projects.

x. This cascade development will enable harnessing over 15000 MW hydropower potential of Indus Main with aggregate annual generation of 73,400 GWh of energy. Out of this, about 13000 GWh will be due to cascading effect of DBDP comprising: 2520 GWh on existing projects; and 10500 GWh on the upcoming projects (refer Table 4).

xi. This cascade hydropower development will provide cheap energy at about 5 US cents / kWh against thermal and other renewal options varying between US Cents 8 to 17.

RECOMMENDATIONS

Now, when Diamer Basha Dam and Dasu Hydropower Projects are being taken up through staged development, it is recommended that to meet the medium term electricity demand through 2030, maximum effort be made to significantly enhance hydropower portfolio of CPEC. This should at least include: -

i. Second stage developments of both Diamer Basha Dam and Dasu Hydropower Projects

ii. Downstream cascade Pattan and Thakot Hydropower Projects.

REFERENCES

1. 'Hydroelectric Inventory and Ranking Studies For Pakistan: Phase A-Inventory and Ranking Study' by Montreal Engineering Company (MONENCO) of Canada; November 1984.

2. Review of Feasibility Report, Engineering Design, Tender Drawings / Documents of Diamer Basha Dam Project by Diamer Basha Consultants, June 2008.

3. Water and Energy – Synergetic Multi-purpose Development of Surface Waters, paper contributed by Riaz Nazir Tarar for World Water Day commemoration by Pakistan Engineering Congress in March 2014.

4. PC-I Proforma: Dasu Hydropower Project (Based on ECNEC approval of March 2014), WAPDA, Lahore.

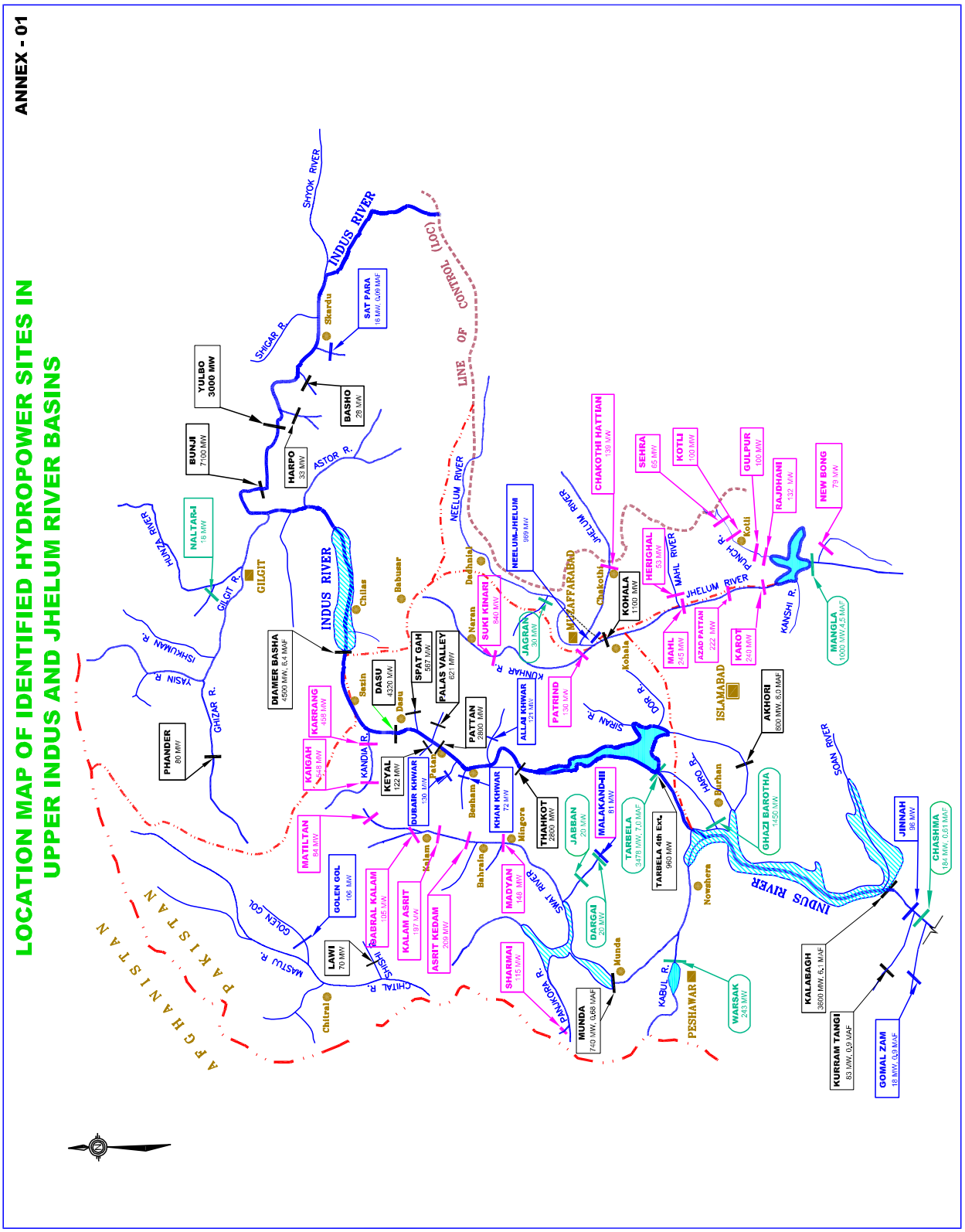
5. Feasibility Study of Pattan Hydropower Project by Pattan Hydropower Consultants, November 2015.

6. Thakot Hydropower Project Feasibility Study: Technical Memorandum 07 – Further Studies on Cascade Layouts by Thakot Hydropower Consultants, June 2016.

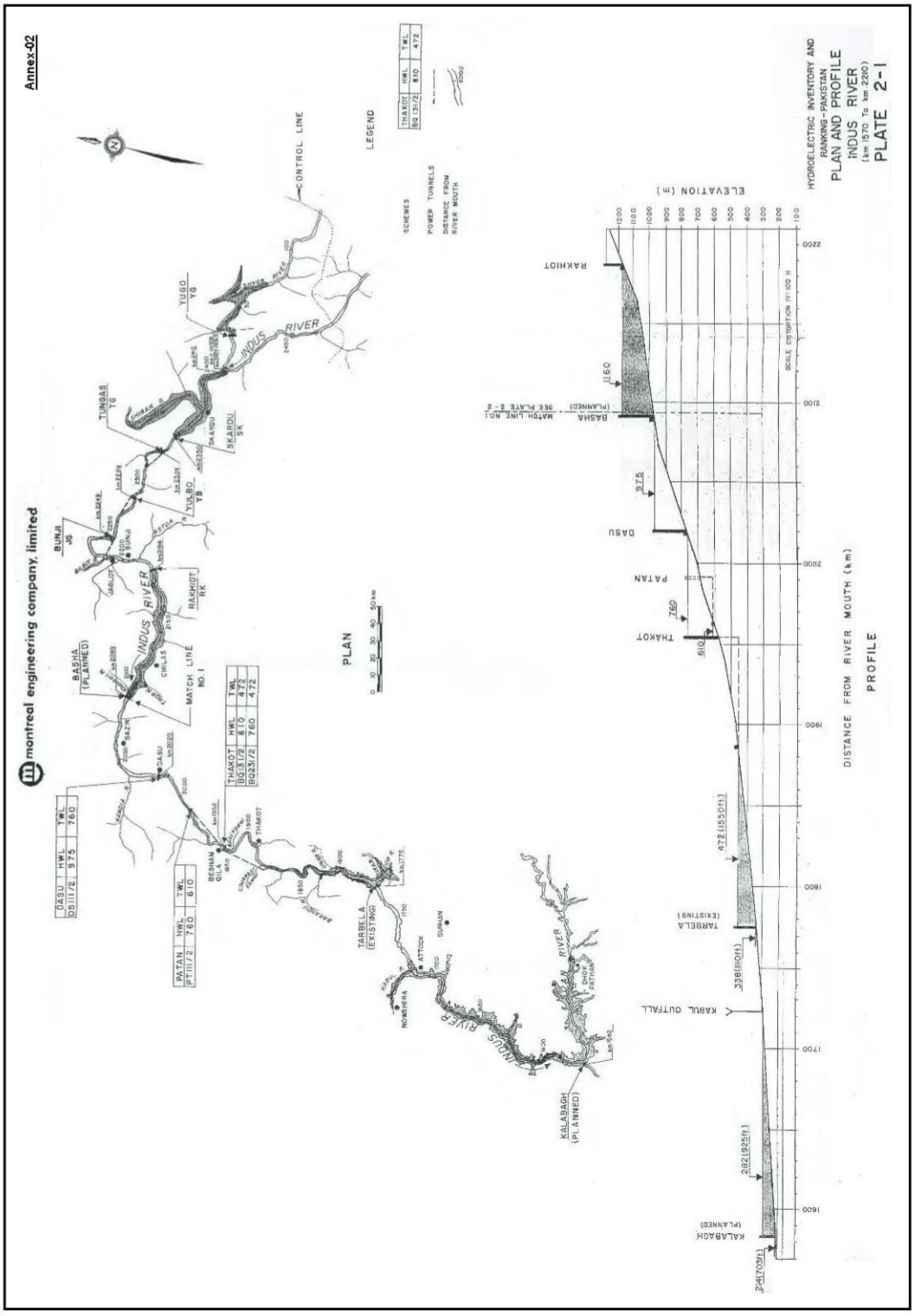
7. Pakistan Economic Energy 2015-16: Chapter 14-Energy, Government of Pakistan, Islamabad.

ANNEXES
01 THROUGH 09

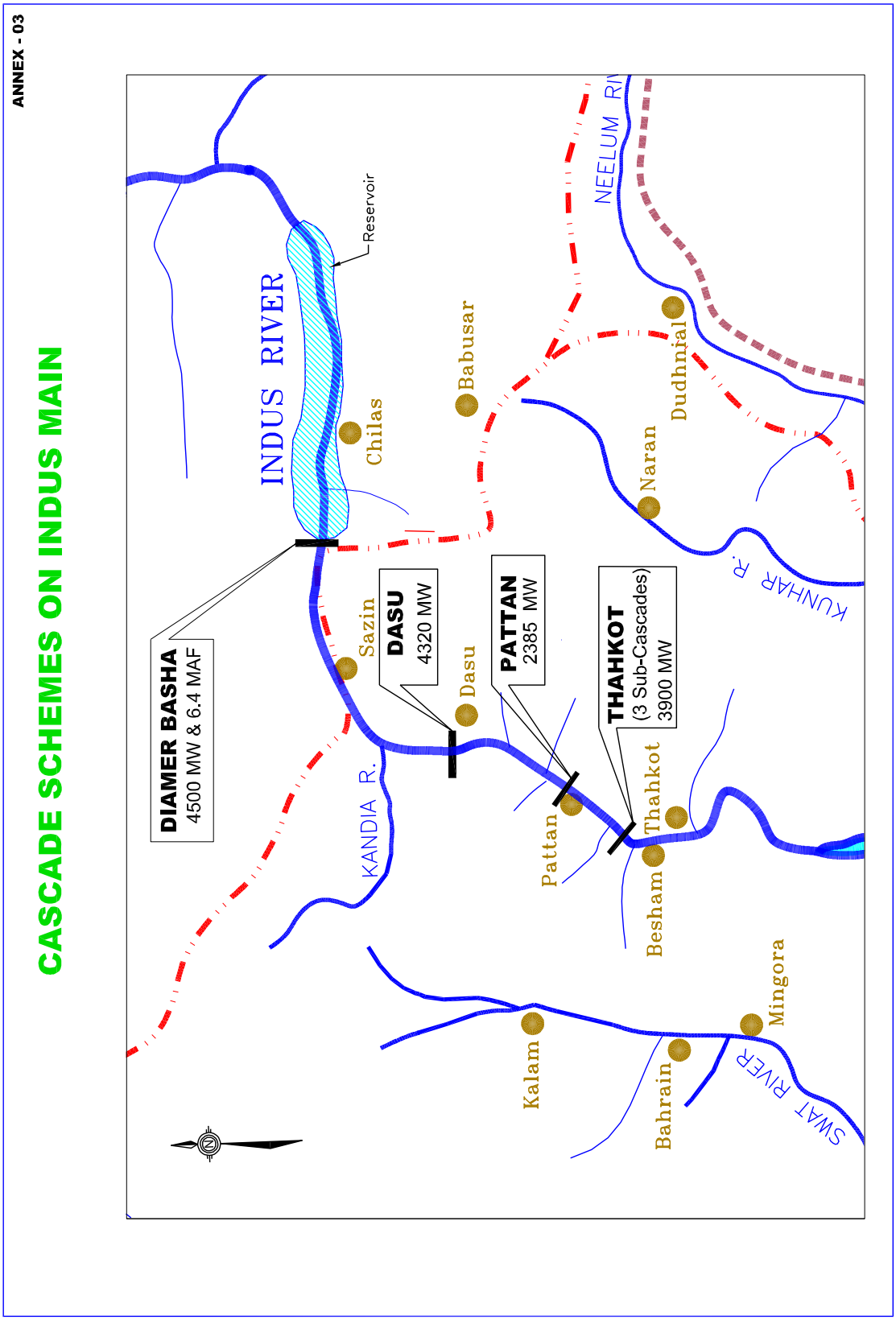
Annex-01


ANNEX - 01
LOCATION MAP OF IDENTIFIED HYDROPOWER SITES IN
UPPER INDUS AND JHELUM RIVER BASINS
AFGHANISTAN
PAKISTAN
LINE OF CONTROL (LOC)
INDUS RIVER
SHYOK RIVER
SHIGAR R.
ASTOR R.
GILGIT R.
HUNZA RIVER
ISHKUMAN R.
YASIN R.
GHIZAR R.
GOLEN GOL
MASTUJ R.
CHITAL R.
KABUL R.
SWAT RIVER
PANJKORA R.
NEELUM RIVER
JHELUM RIVER
MAHL RIVER
PUNCH R.
KANSHI R.
KUNHAR R.
SIRAN R.
DOR R.
HARO R.
SOAN RIVER
INDUS RIVER
YULBO 3000 MW
BUNJI 7100 MW
BASHO 28 MW
HARPO 33 MW
SAT PARA 18 MW, 0,09 MAF
NALTAR-I 18 MW
DIAMER BASHA 4500 MW, 6,4 MAF
PHANDER 80 MW
KARGAH 248 MW
KARRANG 498 MW
MATILTAN 84 MW
GOLEN GOL 106 MW
LAWI 70 MW
BASERAL KALAM 135 MW
KALAM ASRIT 197 MW
ASRIT KEDAM 260 MW
KEYAL 122 MW
DUBAIR KHWAR 130 MW
DASU 4320 MW
SPAT GAH 567 MW
PALAS VALLEY 621 MW
PATTAN 2800 MW
KHAN KHWAR 72 MW
THAKOT 2800 MW
MADYAN 146 MW
SHARMAI 115 MW
MUNDA 740 MW, 0,68 MAF
DARGAI 20 MW
JABBAN 20 MW
MALAKAND-III 81 MW
TARBELA 3478 MW, 7,01 MAF
TARBELA 4th Ext. 960 MW
WARSAK 243 MW
GHAZI BAROTHA 1450 MW
AKHORI 600 MW, 6,0 MAF
ISLAMABAD
PESHAWAR
ALLAI KHWAR 121 MW
JAGRAN 30 MW
NEELUM-JHELUM 969 MW
SUKI KINARI 840 MW
PATRIND 150 MW
CHAKOTHI HATTIAN 153 MW
KOHALA 1100 MW
HERIGHAL 53 MW
MAHL 245 MW
AZAD PATTAN 222 MW
KAROT 240 MW
SEHRA 65 MW
KOTLI 100 MW
GULPUR 100 MW
RAJDHANI 132 MW
NEW BONG 79 MW
MANGLA 1000 MW, 4,5 MAF
JINNAH 96 MW
CHASHMA 184 MW, 0,81 MAF
KALABAGH 3600 MW, 6,1 MAF
KURRAM TANGI 83 MW, 0,9 MAF
GOMAL ZAM 18 MW, 0,3 MAF
Skardu
Shigar
Chilas
Babusar
Dasu
Sazin
Palas
Besham
Mingora
Kalam
Bahrain
Chitral
Dadahiy
Naran
Chakothi
Kohala
Durban
Nowshera
Munda
N

Annex-02

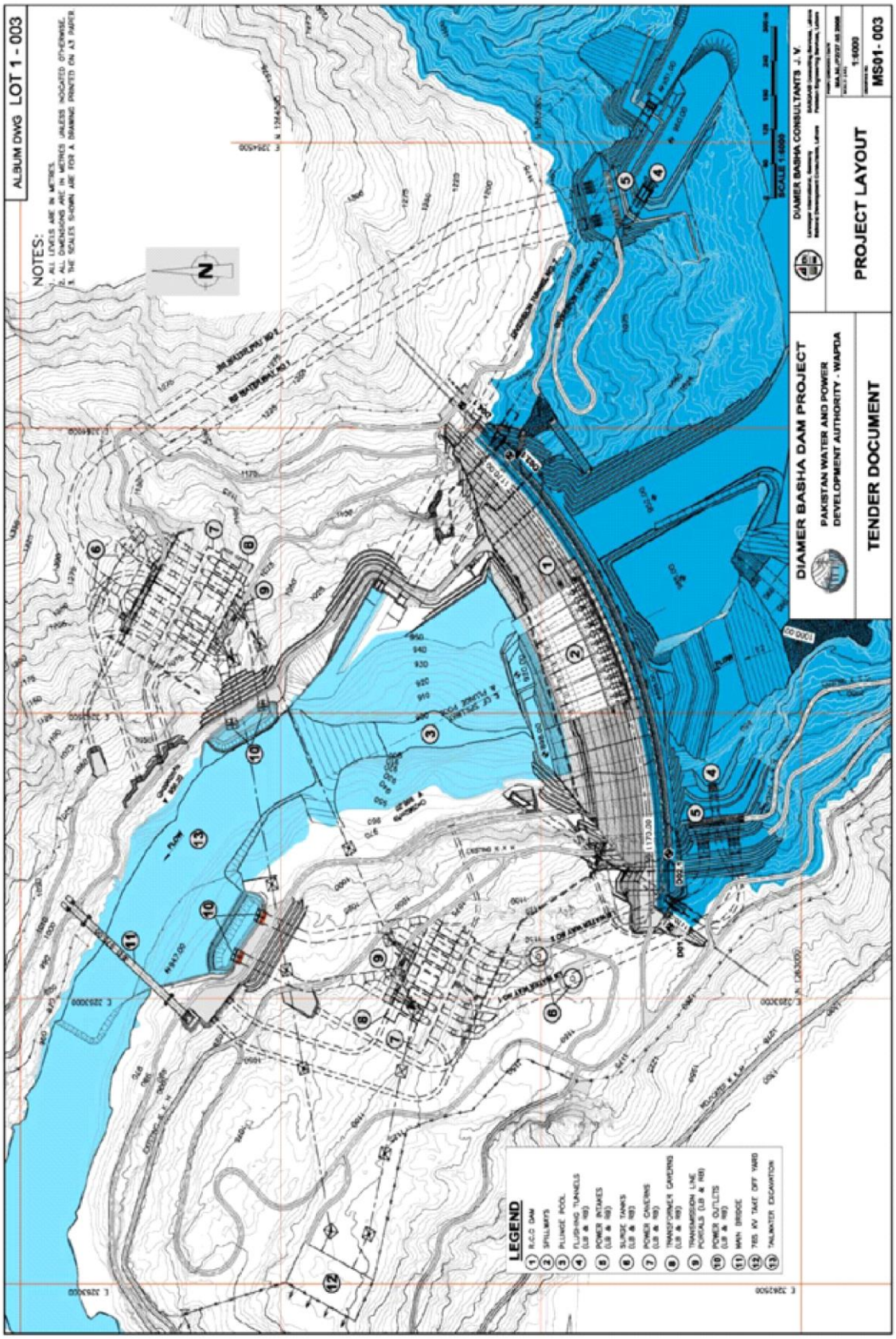

Annex-02
montreal engineering company, limited
HYDROELECTRIC INVENTORY AND RANKING-PAKISTAN
PLAN AND PROFILE
INDUS RIVER
(km 1570 To km 2290)
PLATE 2-1
LEGEND
SCHEMES
POWER TUNNELS
DISTANCE FROM RIVER MOUTH
CONTROL LINE
PLAN
PROFILE
ELEVATION (m)
DISTANCE FROM RIVER MOUTH (km)
INDUS RIVER
KABUL RIVER
KALABAGH (PLANNED)
TARBELA (EXISTING)
BASHA (PLANNED)
DASU
PATAN
THAKOT
RAKHIOT
TUNGAS
SKARDU
TUNJRO
BUNJI
TUGO
BESHAM QILA
ATTOCK
SURJAN
NOWSHERA
CHOI PATHAN
MATCH LINE NO. 1
MATCH LINE NO.1 (PLANNED) SEE PLATE 2-2
KABUL OUTFALL
472 (1550 ft)
338 (1110 ft)
282 (925 ft)
241 (790 ft)
DASU HWL 975 TWL 760
PATAN HWL 760 TWL 610
THAKOT HWL 810 TWL 472
THAKOT BQ 131/2 810 472
THAKOT BQ 131/2 760 472
THAKOT BQ 235/2 760 472

Annex-03


ANNEX - 03
CASCADE SCHEMES ON INDUS MAIN
INDUS RIVER
Reservoir
NEELUM RI
Chilas
Babusar
Dudhnial
Naran
KUNHAR R.
DIAMER BASHA
4500 MW & 6.4 MAF
Sazin
DASU
4320 MW
Dasu
PATTAN
2385 MW
THAHKOT
(3 Sub-Cascades)
3900 MW
KANDIA R.
Pattan
Thahkot
Besham
Kalam
Bahrain
Mingora
SWAT RIVER

Annex-04

DIAMER BASHA DAM PROJECT
LAYOUT & SALIENT FEATURES

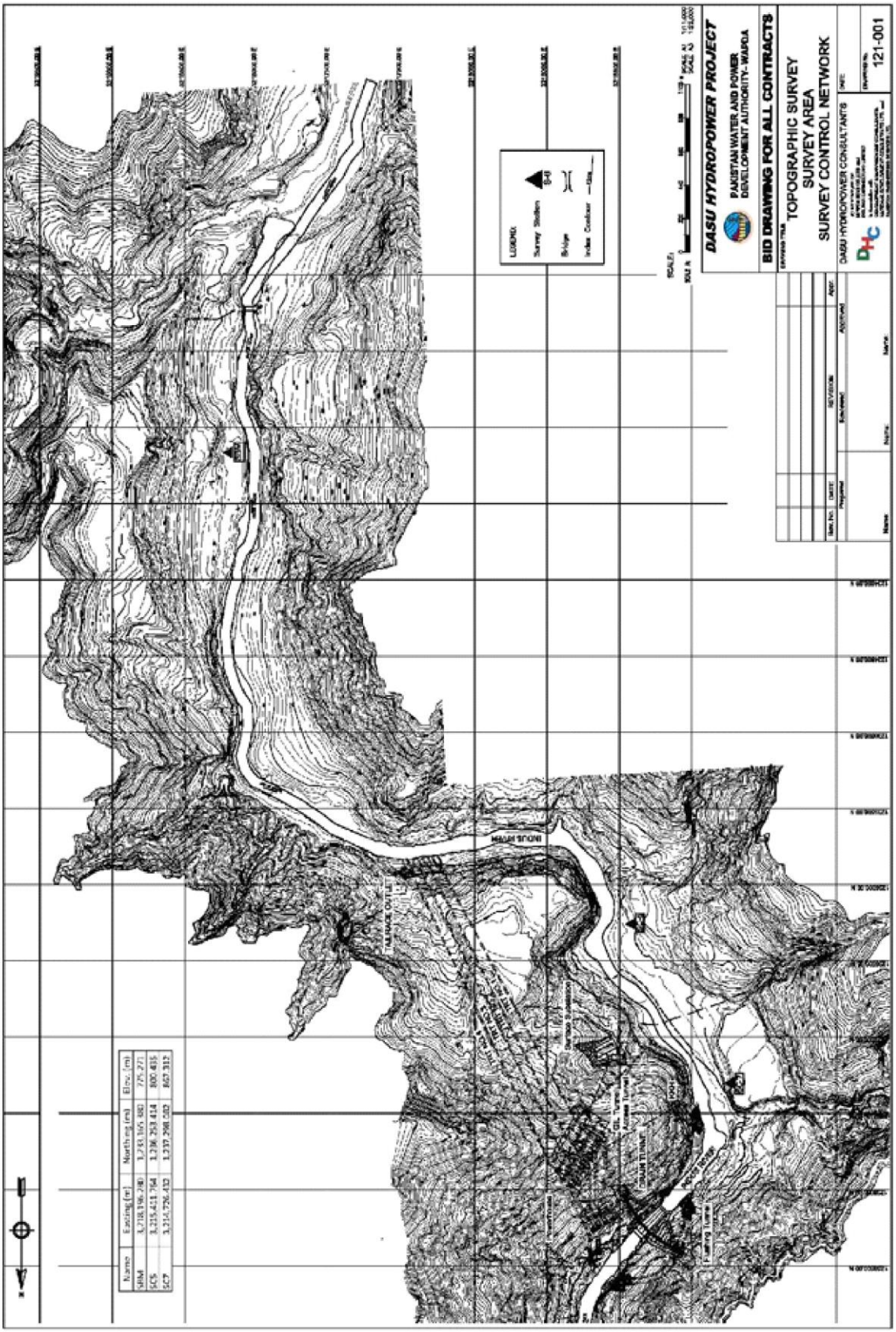

ALBUM DWG LOT 1 - 003
NOTES:
1. ALL LEVELS ARE IN METERS.
2. ALL DIMENSIONS ARE IN METRES UNLESS INDICATED OTHERWISE.
3. THE SCALES SHOWN ARE FOR A DRAWING PRINTED ON A3 PAPER
N
LEGEND
1 R.C.C. DAM
2 SPILLWAYS
3 PLUNGE POOL
4 FLUSHING TUNNELS (LB & RB)
5 POWER INTAKES (LB & RB)
6 SURGE TANKS (LB & RB)
7 POWER CAVERNS (LB & RB)
8 TRANSFORMER CAVERNS (LB & RB)
9 TRANSMISSION LINE PYLONS (LB & RB)
10 POWER OUTLETS (LB & RB)
11 MAIN BRIDGE
12 765 KV TAIL OFF YARD
13 TAILWATER EXCAVATION
DIAMER BASHA CONSULTANTS - J. V.
SCALE 1:4000
PROJECT LAYOUT
1:5000
MS01- 003
DIAMER BASHA DAM PROJECT
PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY - WAPDA
TENDER DOCUMENT

DIAMER BASHA DAM PROJECT
SALIENT FEATURES

Location:	40km downstream of Chilas Town (GB)
Main Dam:	
Maximum Height Above Rock Foundation	272m
Type	Roller Compacted Concrete (RCC)
Maximum Probable Flood	49,410 m^3/s
Spillway (Ogee type with chute and flip bucket): -	
No of Gates	14
Size of Gates	11.5 x 16.2m
Reservoir: -	
Maximum Conservation Level	1160m masl
Minimum Operation Level	1060m masl
Storage Capacity:	
• Gross	8.1 MAF (10.8 BCM)
• Live	6.4 MAF (7.9BCM)
Powerhouse(s):	
Number	2
Total Installed Capacity	4500 MW
No. of Units	12 (6 each)
Location and Type	Underground, one each on the right and left bank with 6 units of 375 MW each
Average Annual Generation At Site	18,100 GWh
Construction:-	
Stage I (Main Dam & Appurtenants)	8 Years } About 10 years with overlapping
Stage II (Power Generation Facilities)	6 Years }
Investment Cost (Updated December 2016):	
Stage I (Main Dam & Appurtenants)	US$ 5.1 Billion (Excluding IDC)
Stage II (Power Generation Facilities)	US$ 5.6 Billion (Including IDC)
Total	**US$ 10.7 Billion**

Annex-05

DASU HYDROPOWER PROJECT
LAYOUT & SALIENT FEATURES

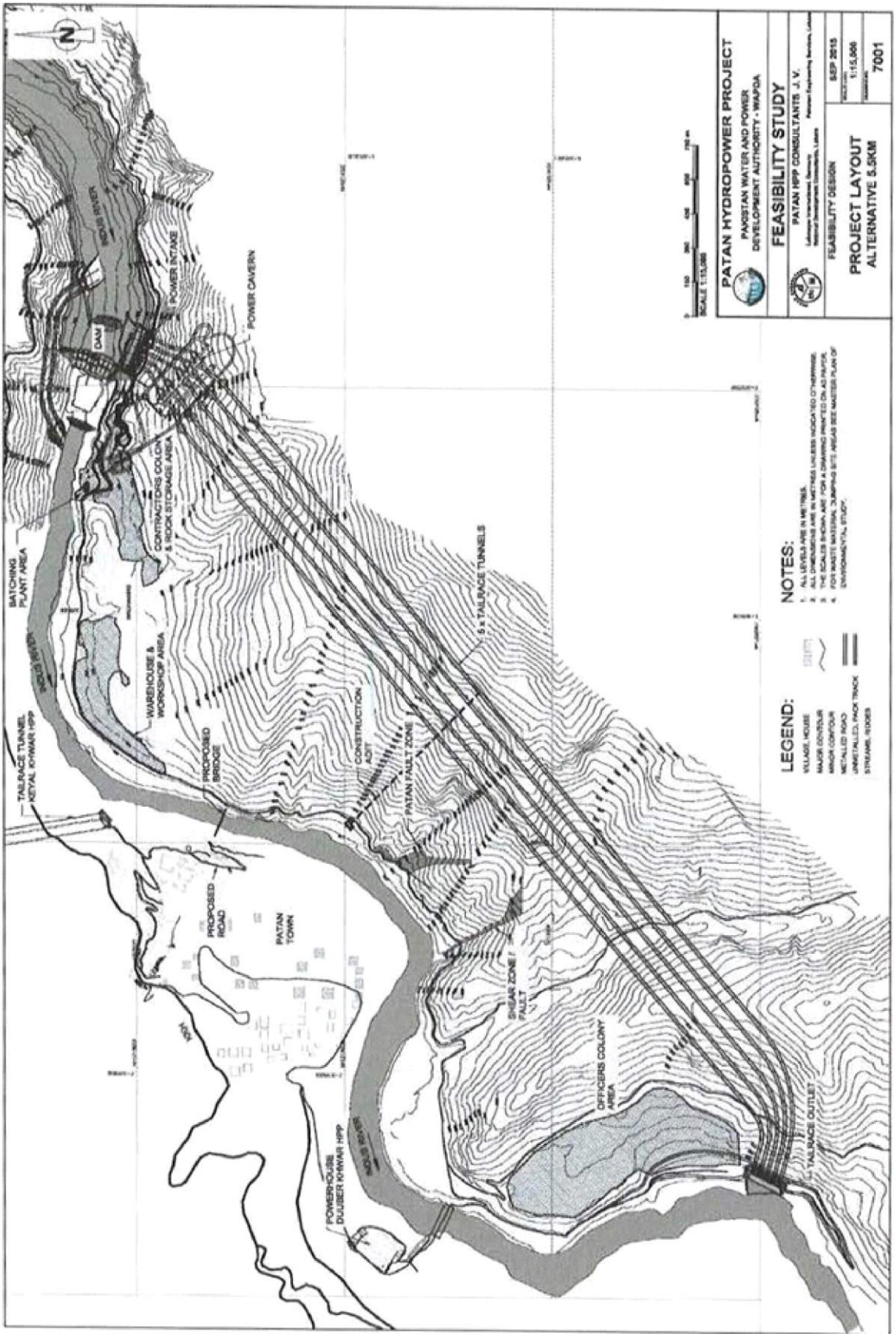

DASU HYDROPOWER PROJECT
PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY- WAPDA
BID DRAWING FOR ALL CONTRACTS
TOPOGRAPHIC SURVEY
SURVEY AREA
SURVEY CONTROL NETWORK
DASU HYDROPOWER CONSULTANTS
121-001
LEGEND:
Survey Station
Bridge
Index Contour
INDUS RIVER
PATAN
DASU
Name | Easting (m) | Northing (m) | Elev. (m)
MN4 | 1,718,196.780 | 1,745,165.682 | 775.271
SCS | 1,715,471.764 | 1,736,763.414 | 800.415
SC7 | 1,715,726.432 | 1,737,298.052 | 867.319

DASU HYDROPOWER PROJECT
SALIENT FEATURES

Location:	7 km upstream of Dasu Town (KP)
Main Dam:	
Maximum Height Above Rock Foundation	242m
Type	Roller Compacted Concrete (RCC)
Maximum Probable Flood	51,957 m^3/s
Spillway (Ogee type with chute and flip bucket):-	
No of Gates	8
Size of Gates	16.5x22.4m
Reservoir: -	
Maximum Conservation Level	950 masl
Minimum Operation Level	900 masl
Storage Capacity:	
Gross	1.14 MAF (1.41 BCM)
Live	0.66 MAF (0.82 BCM)
Power House:	
Installed Capacity:	
Stage I (6x360 MW)	2160 MW
Stage II (6x360 MW)	2160 MW
Total	4320 MW
Location	Underground on left bank
Average Annual Generation:-	
Stage I	12000 GWh (with about 20% pre-DBDP reduction)
Stage II (Full Development)	21500 GWh (with about 15% pre-DBDP reduction)
Construction Period: -	
Stage I	5-6 Years } Overall 13 years with gap between two stages
Stage II	3-4 Years }
Investment Cost (March 2014): -	
Stage I	US$ 4.86 Billion
Stage II	US$ 1.89 Billion
Total	**US$ 6.75 Billion**

Annex-06

PATTAN HYDROPOWER PROJECT
LAYOUT & SALIENT FEATURES

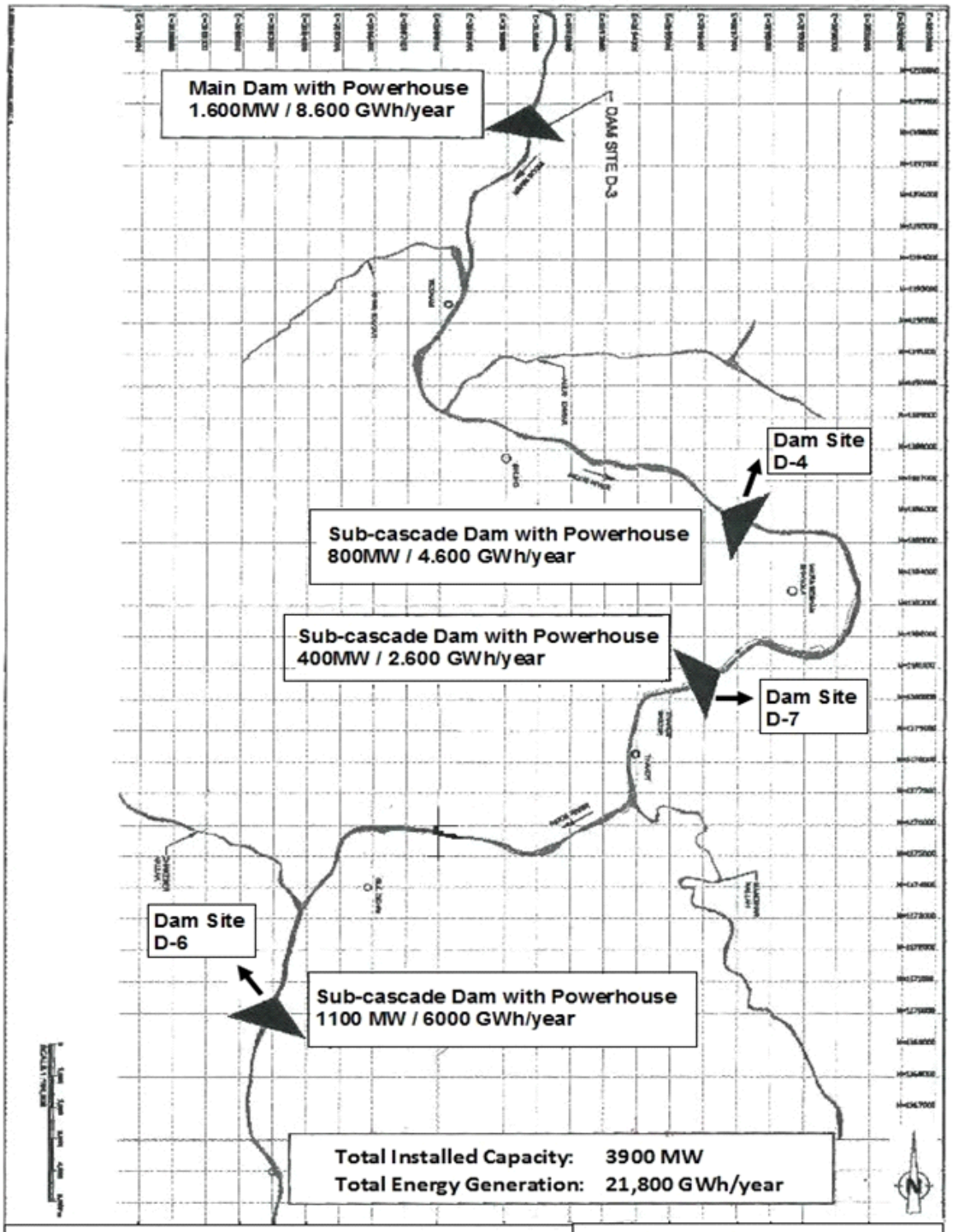

PATAN HYDROPOWER PROJECT
PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY - WAPDA
FEASIBILITY STUDY
PATAN HPP CONSULTANTS J.V.
FEASIBILITY DESIGN
SEP 2015
PROJECT LAYOUT
ALTERNATIVE 5.5KM
1:15,000
7001
SCALE 1:15,000
NOTES:
1. ALL LEVELS ARE IN METRES.
2. ALL DIMENSIONS ARE IN METRES UNLESS INDICATED OTHERWISE.
3. THE SCALES SHOWN ARE FOR A DRAWING PRINTED ON A3 PAPER.
4. FOR WASTE MATERIAL DUMPING SITE AREAS SEE MASTER PLAN OF ENVIRONMENTAL STUDY.
LEGEND:
VILLAGE, HOUSE
MAJOR CONTOUR
MINOR CONTOUR
METALLED ROAD
UNMETALLED, PACK TRACK
STREAMS, RIVERS
N
INDUS RIVER
DAM
POWER INTAKE
POWER CAVERN
CONTRACTORS COLONY & ROCK STORAGE AREA
BATCHING PLANT AREA
WAREHOUSE & WORKSHOP AREA
INDUS RIVER
TAILRACE TUNNEL KEYAL KHWAR HPP
PROPOSED BRIDGE
CONSTRUCTION ADIT
5 x TAILRACE TUNNELS
PATAN FAULT ZONE
PROPOSED ROAD
PATAN TOWN
KKH
SHEAR ZONE / FAULT
OFFICERS COLONY AREA
POWERHOUSE DUBBER KHWAR HPP
INDUS RIVER
TAILRACE OUTLET

PATTAN HYDROPOWER PROJECT
SALIENT FEATURES

Location:	4 km upstream of Pattan Town (KP)
Main Dam:	
Maximum Height Above Rock Foundation	122m
Type	Roller Compacted Concrete (RCC)
Maximum Probable Flood	48,500 m^3/s
Spillway (Ogee with chute and flip bucket): -	
No of Gates	6
Size of Gates	16.5x22.8m
Reservoir: -	
Maximum Conservation Level	762.8 masl
Minimum Operation Level	752.8 masl
Storage Capacity: -	
Gross	0.22 MAF (0.27 BCM)
Live	0.06 MAF (0.07 BCM)
Power House: -	
Installed Capacity	2385 MW (10 Units of equal capacity)
Location	Left bank underground with 5.5 km network of 5 tailrace tunnels
Average Annual Generation	12500 GWh (with about 15% pre-DBDP reduction)
Construction Period	**7 Years**
Total Investment Cost (2015):	**US$ 5.2 Billion**

Annex-07

THAKOT HYDROPOWER PROJECT
LAYOUT & SALIENT FEATURES


Main Dam with Powerhouse
1.600MW / 8.600 GWh/year
DAM SITE D-3
Dam Site
D-4
Sub-cascade Dam with Powerhouse
800MW / 4.600 GWh/year
Sub-cascade Dam with Powerhouse
400MW / 2.600 GWh/year
Dam Site
D-7
Dam Site
D-6
Sub-cascade Dam with Powerhouse
1100 MW / 6000 GWh/year
Total Installed Capacity: 3900 MW
Total Energy Generation: 21,800 GWh/year
N
Thakot Hydropower Project
Tentative Layout for Preferred Development

SALIENT FEATURES OF THAKOT HYDROPOWER
(Based on Conceptual Planning)

Location: Indus River reach from tailwater of Pattan Hydropower Project to headwater of Tarbela Dam Project.

Preferred Development Concept:

Through main dam and three sub-cascades for harnessing about 96% (177m) of the gross head of 185 m available between tailwater of Pattan (658 masl) and maximum operation level of Tarbela (473 masl).

Basic Features of Preferred Development: -

Sr. No.	Project Component (With Powerhouse at Toe)	Full Supply Level (masl)	Tailwater Level (masl)	Gross Head (m)	Installed Capacity (MW)	Average Annual Generation (Gwh)
1.	Main Dam (Site D-3)	658.0	5890	69.0	1600	8,600
2.	Sub-cascade Dam I (Site D-4)	581.0	544.0	37.0	800	4,600
3.	Sub-cascade Dam II (Site -7)	544.0	522.5	21.5	400	2,600
4.	Sub-cascade Dam III (Site-6)	522.5	473.0	49.5	1100	6000
			Total	**177.0**	**3900**	**21,800**

Annex-08

DIAMER BASHA DAM PROJECT

ESTIMATED ANNUAL GENERATION COST UNDER TWO STAGE DEVELOPMENT

(Based on December 2016 Updated Cost)

Sr. No.	Item	Estimated Cost (US$ Million)
I.	Annual Amortization of Investment Cost: -	
1.	Local currency @ 12% Over 25 Years (7267 x 0.1275)	926
2.	Foreign Currency @ 8% Over 25 years (3912 x .0937)	367
3.	**Sub-Total I (1+2)**	**1293**
II.	Annual O & M Cost Including 0.02% Insurance Charges: -	
1.	Main Dam & Appurtenants	15
2.	Power Generation Facilities	23
3.	Water Use Charge @ Re 0.25 per kWh of 18100 GWh (US Cents conversion at parity rate of Rs. 105)	43
4.	**Sub-Total II (1+2+3)**	**81**
III.	**Total Annual Cost (I+II)**	**1374**
IV.	Average Annual Generation (Gwh): -	
1.	At Site	18,100
2.	Downstream Cascading Effect	13,020
3.	**Total**	**31,120**
V.	Generation Cost / kWh (US Cents): -	
VI.	i. At Site Generation Basis (III ÷ IV (1)]	7.6
	ii. Gross Generation Basis Including Cascading Effect [III ÷	4.4

	IV (3)]	

Annex-09

COMPARATIVE INSTALLATION AND GENERATION COSTS

Sr. No.	Type	Construction Cost (US$ / kW)	Generation Cost (US Cents / kWh)
1.	Hydropower (Storage)	2500	7.7
2.	Thermal: -		
	i. Natural Gas	500	9.6
	ii. Coal (Imported)	1800	10.4
	iii. Liquefied Natural Gas (LNG)	800	11.8
	iv. Furnace Oil	1000	16.7
3.	Nuclear	3000	13.0

Source: *JICA, October 2015*

Paper No. 332

BUNJI HYDROPOWER PROJECT OPPORTUNITIES AND CHALLENGES

Engr. Abdul Khaliq Khan

BUNJI HYDROPOWER PROJECT OPPORTUNITIES AND CHALLENGES

by

Engr. Abdul Khaliq Khan

Abstract

Bunji Hydropower Project comprises a 200 m high RCC Dam across River Indus about 45 km by road from Gilgit and 7 km d/s of Shangus Village. The stored water will be conveyed by 5 tunnels each 7.8 km long to an underground power station located 6 km southeast of confluence of Indus and Gilgit rivers. The power station will house 20 turbines and generating units with total installed capacity of 7,100 MW. Annually about 25 billion units of electricity would be generated at very economical cost. The cheap electricity produced at Bunji will help lowering the tariff and reducing load-shedding in the country.

The Intake structure has to be built on left bank in geologically unstable rocks. The power tunnels have to cross Main Mantle Thrust Fault (MMT) having disturbed rock length of about 1.5 km. Special measures are needed to safeguard the safety and sustainability of tunnels against high magnitude earthquake. Indus River carries 110 m tons of sediment load every year which more the 50% sand posing serious abrasion hazard to the turbines. Special repair facilities are needed at the site.

This paper describes how these and few other challenges are being resolved in design and construction of the project.

1. General

The power house of proposed Bunji Hydropower Project is located on the Indus River about 45 km east of Gilgit town in the Northern Areas of Pakistan. Its location and configuration make it one of the most important hydropower projects of Pakistan (see Fig.1). The geologic setting at project site is highly complex and poses several design and construction challenges.

The Bunji Project was first identified by Montreal Engineering Company (MONENCO) who had been engaged by Government of Pakistan (GoP) in 1981 to identify and study potential sites to maximize water storage and hydropower generation. The inventory report submitted by MONENCO in November 1984 included 25 major potential sites on main rivers. Nine of these projects are located on Indus river: Dasu, Basha, Pattan, Raikot, Thakot, Bunji, Skardu, Tungas and Yulbo. Bunji was proposed by MONENCO to be a 210 m high dam to be built after Basha and Dasu projects and to be followed by Thakot and Pattan hydropower projects.

In January 2001 the GoP approved WAPDA's "Water Resources and Hydropower Development Vision 2025 Programme" to meet the increasing water and power demands of the country. Bunji hydropower project is included in Phase III of this programme and has been identified as the single largest hydropower project in the country. Considering the complexity of subsurface conditions and the size of required investments the project may have to be built in two or three stages.

A pre-feasibility study was made in 2005 followed with a feasibility study by a joint venture of foreign and local firms in 2008. The report on detailed design was issued in

Dec. 2010 wherein a 200 m high dam with 7100 MW installed capacity of power station has been recommended.

The development of the project over 25 years of studies is shown in following table;-

Project Feature	MONENCO 1984	Pre-feasibility 2004	Feasibility 2009	Detailed Design 2010
Type of Dam	CFRD	RCC	RCC	RCC
Dam Height (m)	210	180	199	200
No. of Power Units	6	12	16 or 20	20
Installed Capacity (MW)	1,290	5,400	5,680	7,100

The information in above table reflects that appropriate and adequate investigations alongwith a due-diligence review can offer enhanced benefits of the project. A number of technical issues have been addressed by the Bunji Consultants in their report and it is to be emphasized that some of them need further studies, reviews and decision making.

2. Project Description

Salient features of the Bunji project are given in Table-1 and a brief description is as follows:-

A 200 m high roller compacted concrete gravity dam has been adopted. The dam will be constructed at an upstream location from the earlier identified site given in the Feasibility Report. The new site was selected to avoid the potential large landslide on the right bank initiated by fast drawdown of the reservoir for flushing.

The dam includes provision for annual flushing of accumulated sediments from the reservoir. Mid-Level and Low-Level Outlets are provided to lower the reservoir for operation of the flushing.

A 22 km long reservoir will be formed that will flood part of the existing Skardu Road. About 16 km of Skardu Road will be re-aligned over the areas which are to be inundated and also at the Dam site where it must pass above the crest level of the dam structure.

Two diversion tunnels shall be driven on right bank. Due to lack of access to portal areas, the tunnels will be accessed via an access adit to their mid-point and excavated toward river.

Spillway capacity is provided by a centrally located spillway structure with six bays over the crest of the dam.

Five No. 11.6 m diameter Headrace Tunnels have been provided with an intake structure upstream of the left abutment of the dam.

An Underground Powerhouse on the left side, west of Sarkund ridge, will be built consisting of:

- One surge shaft for each headrace tunnel.
- Two pressure shafts and tunnels serving each surge shaft.

- Ten high pressure tunnels that lead from each pressure shaft and bifurcate to deliver water to each turbine.
- An underground powerhouse 28 m wide x 61 m high x 560 m long with 20 No. Francis Turbine units of 355 MW and total installed capacity of 7,100 MW.
- The tailrace comprises 5 No. 11.6 m diameter tunnels in the first 450 m rock portion to an open cut channel in glacial fluvial deposits for a length of 1100 m upto river Indus.

A general layout of the project is shown in Fig. 2. The layouts of dam and power house components are shown in Fig. 3 & 4 respectively.

3. Hydrology

River flow data at Kachura gauging station near Skardu is available since 1970. The mean monthly flow is 1,137 m^3/s. The analysis of computed discharge at dam site shows that the 1 in 100 year and 1 in 1000 year flood values are 7,245 m^3/s and 7,713 m^3/s respectively. The statistical estimate of 1 in 1,000 year return period GLOF based flood at dam site is 22,400 cumecs. It has been adopted as design flood for the spillway.

Between 1850 and year 2000 there have been 44 reported Glacial Outburst Flood (GLOF) events. The biggest was Shimshal river event in 1884 that had brought about 40,000 cumecs discharge.

The peak flow of an extreme landslide breach flood has been assessed as 36,000 m^3/s at the dam site. This flow excludes normal run-off. A subjective estimate of the return period of such an event is over 10,000 years. This has been adopted as the Safety Check Flood.

A dam break analysis was made to assess the potential impacts downstream. The scenario is considered a remote possibility but the study is a normal requirement for large dams. The peak outflow for the more conceivable event of Abutment Breach would be of the order of 95,400 m^3/s. With the Abutment Breach case the nearby villages of Shahtot and Hanuchal would not be flooded. The flood wave would travel at an average rate of 50 km/hr and take about 2 hours to travel the 130 km distance to the proposed Diamer Basha reservoir.

The flood on downstream side is rapidly attenuated as the flood water is temporarily stored in the river valley. At the Diamer Basha reservoir the peak discharges of the flood waves will have reduced to 53,200 m^3/s.

4. Sedimentation

The catchment area up to the proposed dam site is 114,890 km^2 and an average sediment yield of 950 tons per km^2. For comparison the sediment yield at Tarbela is 1,190 tons per km^2.

The estimated average annual quantity of sediments is 110 million tons. Mathematical modeling based on 2009 data has shown that annual flushing would be required for 15 days.

Bunji is a high head (about 410 m) hydroelectric project, it is therefore desirable that sand particles above 0.0625 mm are not entrained in the power tunnels and turbines. No sand traps are provided due to space constraints on left bank. The designer anticipates that 22 km long reservoir will act as sand trap and that annual flushing will keep sediments adequately away from the power intakes.

The river flow hydrograph at Bunji dam site is affected by snow melt and the flow varies significantly over very short period of about 10 days. These rapid changes in flow can cause sudden increase in sediment transport towards power intakes. The Panel of Experts deployed for the project suggested that a bypass tunnel for diversion of high concentration discharges should be considered for reducing turbine erosion. Two large diameter tunnels about 10 km length would be required which is not only expensive but also demands additional time in project completion. WAPDA considered that benefit of proposed bypass scheme is not certain. The project consultants therefore did not include bypass tunnels in their final design.

5. Geotechnical

5.1 Rock Structure

Bunji project lies in the Nanga Parbat Haramosh Syntaxes which is a folded structure associated with the contact zone between the Indian and Eurasian plates. This contact zone is known as Main Mantle Thrust (MMT). The Headrace tunnels pass through the MMT as well as the Raikot-Sassi Fault Zone. The crushed rock zone between the two faults is estimated to have a width of about 1.5 km along the tunnels.

The Project is located partly in rocks from the Kohistan Arc terrain Iskere gneiss and partly in the rocks of the Indian Plate Amphibolites. The Headrace Tunnels cross from one terrain to another and in the process cross the MMT. A geological section of Headrace Tunnel Alignment is shown in Fig. 5.

A rapid rate of uplift 7.0 mm/year across MMT accompanied by equally high erosion, has exposed deep seated basement rocks of the Indian plate. Recent studies have shown that an active fault zone marks the present boundary between the two tectonic stratigraphic units. This active fault has been termed the Raikot Sassi Fault Zone (RSFZ)

The rock at dam site area has been investigated and explored by a total length of 1650 m of drill holes and 4 exploratory adits. The existing Iskere Gneiss reveals isotropic intact rock strength of 30 to 70 MPa and average modulus value of 23 GPa which is considered competent as foundation of a 200 m high dam.

The discontinuity sets D2 and D4 approximately strike across the river and dip steeply downstream and upstream respectively. They are more prominent on the right bank and may pose wedge instability on rock cut slopes. The discontinuities D3 are more common on the left bank. They strike approximately parallel to the river and dip approximately 55^0 towards the valley. This setting therefore, requires special attention and consideration with regards to the stability of the left abutment.

The area of Power Intake Structure and Surge Shaft are not fully investigated due to the difficulty with access to Sarkund Ridge and the high cover up to 2,000 m above the headrace tunnels.

About 1 to 1.5 km part of the five headrace tunnels are expected to pass through the MMT/Raikot Sassi Fault Zone which is geotechnically most critical with heights of overburden of approx. 870 – 1620 m.

The MMT/RSFZ dips at 70 – 80^0 towards the west. Various rock mass conditions ranging from competent to highly fractured were observed in surface mapping and borehole logs. Adjacent to the upper contact of MMT/RSFZ amphibolites and gneiss were highly fractured. Around the lower contact, the boundary is still not clearly known (see Fig. 6).

Adequate information on the rock mass properties and in situ stress and groundwater conditions is not known therefore a realistic estimate of costs and construction time is uncertain. Such knowledge can however only be gained by an exploration adit and if possible a limited full scale excavation in a critical zone.

The project consultants had proposed a 1650 m long exploratory adit near Burchi village. The panel of experts suggested to extend this adit toward HRT and shifting this adit to the alignment and gradient of the Bunji Access Tunnel (BAT). To reach the MMT about 1100 m length would have to be excavated making total length of exploratory adit to be about 2100 m. With an excavation rate of say 4 m/day the adit excavation would take about 2 years**. It is prudent that exploratory adit alongwith BAT should be completed before the main contract so that findings from these investigations are utilized for optimization of the HRT design and construction work.**

More than 2000 discontinuity measurements were taken during the scan line surveys made for the detail design. Three sets of widely spaced joints have been identified in the Powerhouse area. One of them is steeply dipping into the valley side. The pattern of discontinuities results in the development of large rock blocks which may become detached from the steep slopes and may fall towards the valley floor. Proper measures shall have to be taken to avoid damage caused by such rock falls. However no systematic pattern of stress relief joints has been observed and the problem is not expected to be formidable.

The development of geologic section from Intake to the powerhouse across the Sarkund mountain is interpretative, projected and speculative because 50% of the area is covered by 3 to 5 meters of overburden and the subsurface investigation are lacking.

From the various surveys and investigations to date, it is anticipated that the MMT zone to be encountered by the proposed headrace tunnels will comprise highly fractured rock with closely-spaced (60 to 200 mm) to very closely-spaced (20 mm to 60 mm) joint sets.

The report of consultants indicates a water elevation of 2,057 m in borehole FZ-04 and 2112 m in borehole FZ-05. It is unclear at the present time whether these water levels in the two boreholes are perched water within the fault, or represent a ground water level typical of the amphibolite to the west of the main MMT.

5.2 Rock Strength Properties

The modified Hoek-Brown failure criterion (Hoek et al, 2002) is a well-recognized method for the assessment of the strength of rock masses. For the rock at the dam site the equivalent secant Mohr Coulomb strength parameters at a confining pressure of 0.2 MPa are Cohesion 0.7 MPa and Friction angle 60 degrees as typical values for the dam site. For these typical rock properties, the rock mass modulus is 13.3 GPa.

For Headrace tunnels, the equivalent Mohr-Coulomb strength parameters at the same confining pressure are a cohesion of 0.5 MPa and an angle of friction of 58^0. The equivalent rock mass modulus is considered to be 7.0 GPa.

The Equivalent Mohr Coulomb Strength Parameters for the Powerhouse are: Cohesion 1.3 MPa and Friction angle 62^0.

The Consultants have proposed that plate bearing tests should be undertaken within the adits which will provide a direct assessment of the in-situ rock mass modulus. Plate jacking tests were planned but have not been executed in two of the adits at the Dam site and in the Headrace tunnel adit. In the absence of this information the Consultants have proposed an estimated value of 30 GPa based on the Hoek et al (2002) equation.

Hydrofracturing and overcoring tests are also required in the Headrace tunnel and the Powerhouse cavern areas to determine the in-situ stresses in the rock. The in-situ stresses are not known at present and could have a significant bearing on the Headrace tunnel and Powerhouse complex design.

Confirmation of the area of contact between the headrace tunnels and the MMT awaits the excavation of exploratory adit into the area. This adit has not been completed so far and hence there is gap in information on MMT.

5.3 Seismic Hazard

The project is located in seismically active area. According to the project consultants the Operational Basis Earthquake (OBE) with a return period of 100 years peak horizontal acceleration at the river level can be taken as 0.2 g (possibly varying in the range from 0.14 g to 0.24 g).

The Maximum Credible Earthquake (MCE) can be taken as 0.43 g at the river level (possibly varying in the range from 0.35 g to 0.52 g).

It is seen that the Consultant is giving a range of accelerations to be expected and not giving definite values for design of various structures. The construction supervision engineer will have to carry out further work to decide the seismic design factors. Further on the displacements caused by a major earthquake occurring on MMT or Sarkund Ridge Fault are given as “upto one meter” by judgment and not by determination. It will be prudent to get the “seismic study” by Bunji Consultants got reviewed by a seismo-tectonic expert.

6. Opportunities & Challenges

Bunji Hydropower Project has special importance due to its location and certain unique geotechnical features. The powerhouse is located 8 km east from Jaglot and 45km from Gilgit. The Gilgit town is the hub of three distinct cultures i.e Hunza, Gilgit and Baltistan. The construction activities at Bunji project which will continue for over a decade shall give a strong boost to the economic activity in and around Gilgit and Jaglot. We know that Mangla and Tarbela Dam projects brought great economic progress & prosperity to the nearby towns of Dina and Ghazi respectively. It can be confidently foreseen that in the years to come Jaglot will expand to district level and Gilgit will become a mega city with universities, hospitals and trade centers.

Bunji on completion will be the largest power-station in Pakistan with installed capacity of 7,100 MW. It will generate about 25,000 GWh annually which means annual revenue of about Rs. 225 billion. The total project cost is US$ 1350 Billion with benefits/cost ratio of 1.48:1. The project promises a payback period of just seven (7) years. Afterwards it would be a large income generating machine and an asset to keep the tariff down.

The Bunji project will produce cheap power in abundance. It can be anticipated that there would be no load shedding for atleast next one decade after completion of Bunji HPP and most likely no load shedding for several years thereafter if timely investments are made in other hydropower projects of WAPDA’s Vision 2025 program.

There are two known glacial lakes (Chong Khumdan/Kichik Khumdan) in catchment areas of Bunji. The GLOF impact at Bunji is higher than at Diamer Basha Dam and all other downstream projects on Indus. This is so because the river valley is narrow from Skardu to Bunji and then widens upto DBD site where flood gets attenuated. In the extreme situation of safety check flood there will be some overtopping of the dam crest. It might be scaring at that time but the dam is designed to withstand it safely.

The dam safety check flood has been determined on the basis of historical records. Field investigation on GLOFs and Landslide Floods are lacking. With this gap in investigational studies and the upcoming risks and hazard of climate change, it has become very important to carry out additional studies on urgent basis.

Bunji is a run of river project and its storage for peaking is only 93 Mm^3. The annual average sediment load is 110 million tons. Provision has been made of mid-level and low level outlets for sediment flushing. It has been estimated that 15 days flushing would be required to keep the sediments away from entering the turbines. Still about 0.3 kg/m^3 of silt & clay size suspended sediments shall enter the turbines and cause erosion of critical parts. The Consultants anticipate that repairing of one or two turbines shall be required every year. They have suggested to establish a factory near powerhouse site which can also handle similar job requests from DBD and Dasu projects.

In the face of the magnitude of turbine erosion problem at Bunji, it is prudent to carry out further studies and research aimed at,

a) Reducing sediment entry into headrace tunnels and turbines.

b) Exploring latest technology in metallurgy for design of runners that can resist abrasion better.

c) Innovative design of runners & turbines parts that will produce better streamlined flows.

About 240 km upstream of Bunji project a storage dam named Shyok dam is planned to be built on Shyok river, a tributary of Indus river. At Shyok the annual average sediment load is 42.6 Million short tons which will be trapped in its reservoir and cause reduction of sediment load at Bunji project. Resultantly, the turbine abrasion at Bunji will be reduced. As such Shyok Dam should be built as soon as possible.

The headrace tunnels of Bunji project cross main-mantle thrust fault (MMT) which has a fault influence zone of about 1.5 km. Rocks in this zone are foliated, fractured and weak. Ground water level may also be high. Construction of tunnels through this weak zone would be very hazardous. During the life time of the project a big earthquake may occur and cause movement of surrounding rocks. The safe design of headrace tunnel and its liner in the fault influence zone is a challenge. Various options have been considered including the construction of a larger diameter tunnel in the affected zone with highly reinforced and thicker concrete lining. Inside a steel liner to the designed tunnel size may be constructed with provision of strong and flexible joints. The scheme is workable but not without several questions. Another option could be to build the downstream part of HRT few meters lower than the upstream part. Between the two parts would be a shaft with flexible joints at its top and bottom. The overall tunnel design in MMT zone is yet to be finalized.

Excavation of 39 km length of headrace tunnels (7.8x5) in granitic gneiss rock on upstream side and amphibolites on downstream side alongwith 1.5 km of fractured, foliated and mylonized rocks in MMT under an overburden of 900 to 2200 m is challenging job. Consultants estimated a construction schedule time of nearly 11 years. This construction time can be reduced if several work faces are opened via access adits. The topography is not favourable to permit location of such adits. A good solution proposed by consultants is to construct an access tunnel (Bunji Access Tunnel) somewhat parallel to HRT's and takeoff access adits from BAT to HRT's at 4 locations. It will add cost to the project but that will be offset by savings in project construction time.

On completion of Bunji construction works in tunnels the BAT can with some supplemental work be changed into a traffic tunnel. This tunnel will reduce the travel distance from Gilgit to Skardu by 50 km which ultimately will result in large savings in logistics

At the site of main dam, the maintenance stop-logs to the flushing and mid-level outlets will need to be guided into the grooves by diver operating about 65 m under water, diving under time limits and extremely low visibility. This is obviously not a good arrangement and should better be modified with some arrangement without the need of divers.

7. RECOMMENDATIONS

7.1 A number of bore holes at Bunji dam site and powerhouse area were proposed but could not be drilled before finalization of Bunji Design Report. These holes should be drilled so that the new information could be used for refinement of design.

7.2 The geological conditions and rock strength parameters are not fully known for the rocks to be traversed by HRT and most importantly for MMT/RSFZ area. An exploratory adit from the Burchi village towards HRT was proposed but could not be implemented during the currency of Bunji Consultants. Excavation of this exploratory adit and the insitu geotechnical testing inside the adit should be carried out preferably before the tendering process of main project.

7.3 Bunji access tunnel (BAT) alongwith four access adits to provide work faces are a prerequisite before the start of excavation for headrace tunnels. Since BAT will also be used for investigations of geological conditions, construction problems and insitu rock testing, it should be constructed in advance of the main contract.

7.4 The seismo-tectonic report of the Bunji project should be got reviewed by some internationally known expert.

7.5 The construction of Bunji dam would require provision of large quantity of pozolanic material which is not locally available. Alternate arrangements should be thoroughly studied and proposal for procurement of suitable material should be planned well in time.

7.6 In the next about two decades more than 50 turbine runners will be installed for Dasu, Basha, Bunji and Pattan hydropower projects on river Indus. Bunji Consultants have recommended that a manufacturing factory for repair and refurbishment of runner units should be established at site. Other locations and modes could also be considered. It is recommended that a seminar on manufacturing of turbine runners in Pakistan should be arranged to study the possibilities and challenges.

8. References

8.1 An Appraisal of Resources and Potential Development by HARZA Engg. Co. Intl., September 1963.

8.2 Program for Development of Surface Storage in the Indus Basin and Elsewhere within West Pakistan by Chas. T. Main Intl. Inc., August. 1966.

8.3 Water & Power Resources of Pakistan – World Bank Study, P. Lieftinch, 1967.

8.4 Indus Special Study – World Bank Report on Multi-purpose Study on Water and Power Resources Development, 1967.

8.5 Hydroelectric Inventory Ranking and Feasibility Studies for Pakistan by Montreal Engineering Co. Canada, November 1984.

8.6 Pre-Feasibility Report of Bunji Hydropower Project, 2004.

8.7 Feasibility Report of Bunji Hydropower Project, March 2009.

8.8 Detail Design Report of Bunji Hydropower Project, December 2010.

Table-1: Salient Features of Bunji Hydropower Project

Parameter	Value
Dam Height & Type	200 m – RCC gravity
Gross head	445 m
Design flow (Power Intake)	1,900 m^3/s
Catchment Area	114,890 km^2
Design flood	22,400 m^3/s (1,000 yr GLOF)
Safety check flood	36,000 m^3/s (landslide)
Reservoir length when full	22 km
Reservoir volume when full	252 M m^3
Reservoir top water level (full)	1,685 m
Reservoir minimum operating level	1,675 m
Spillway crest elevation	1,669 m
Spillway gate size	18 m wide x 16 m high
Mid-level sluice gate size/number	6 m wide x 12 m high; 5 nos.
Sluicing gates invert elevation	1,565 m
Sluicing gate size/number	6 m wide x 12 m high, 4 nos.
Number & size of Headrace tunnels	2 no. 10 m wide x 10 m high 'horseshoe' section
Environmental Flow discharge	21 m^3/s
Power Cavern Size	28 m wide x 61 m high x 560 m long
No. of Units	20
Total Installed Capacity	7,100 MW
Annual Power Generation	24,760 GWh

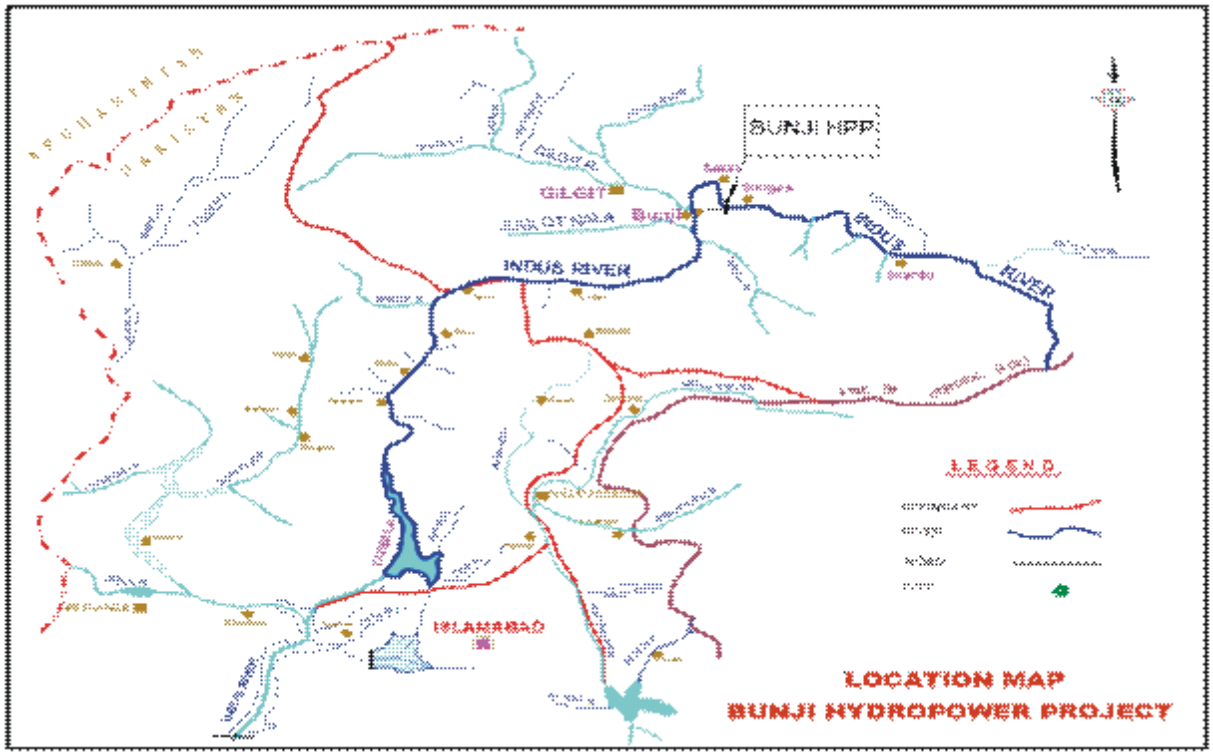


Figure 1: Project Location Map

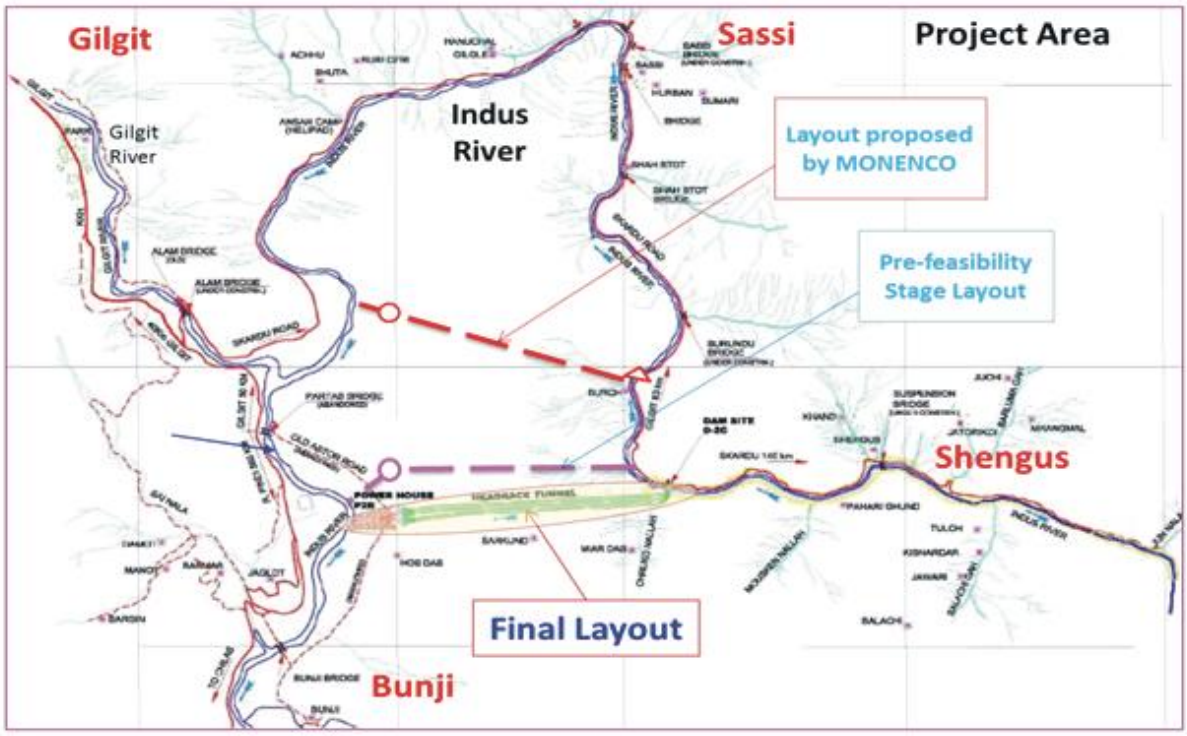


Figure 2: Project Layout

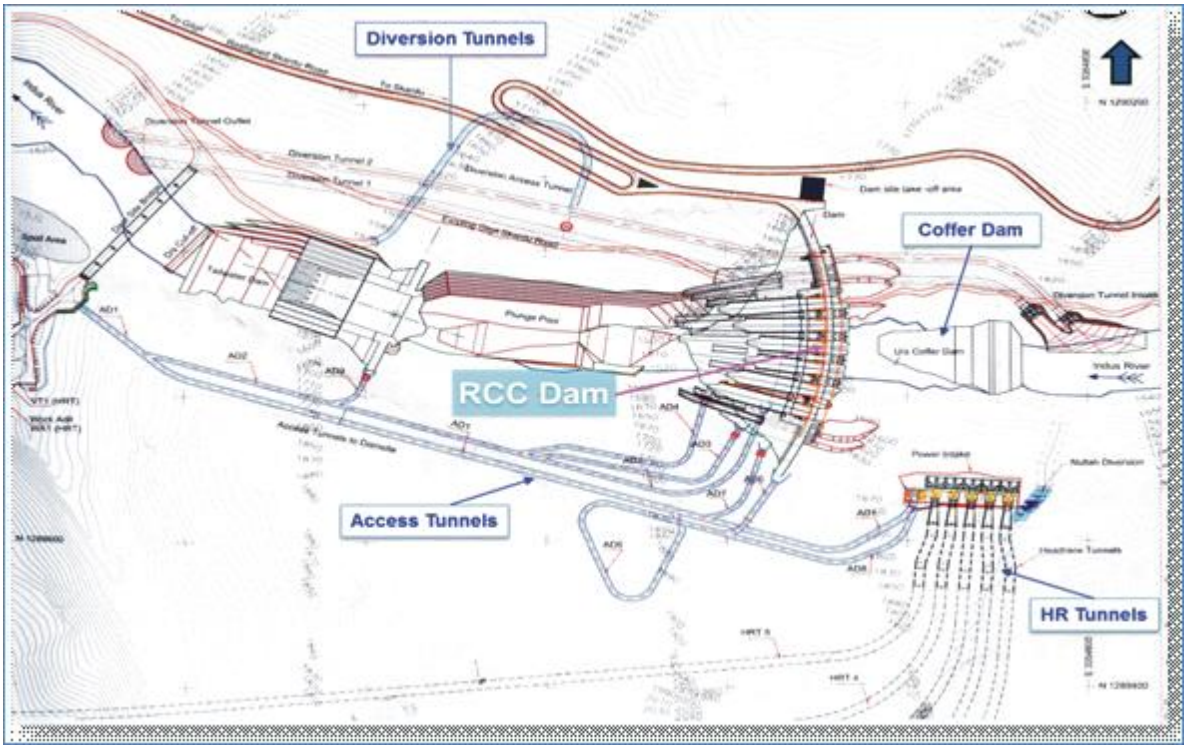


Figure 3: Layout of Dam Components

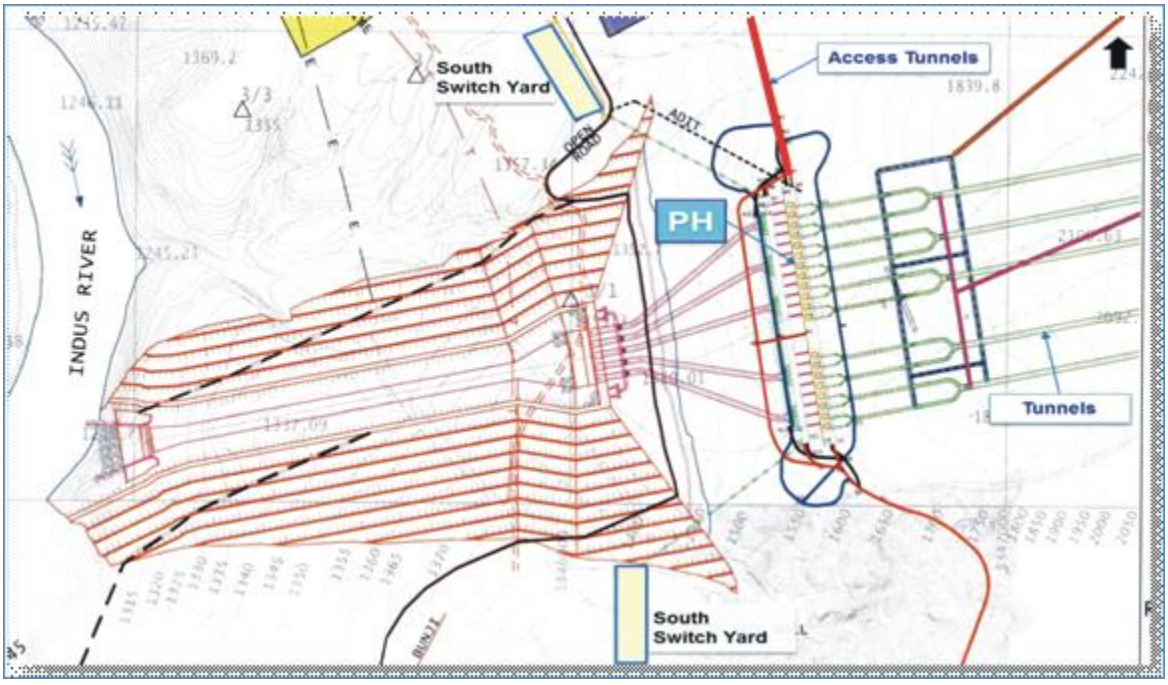


Figure 4: Layout of Powerhouse Components

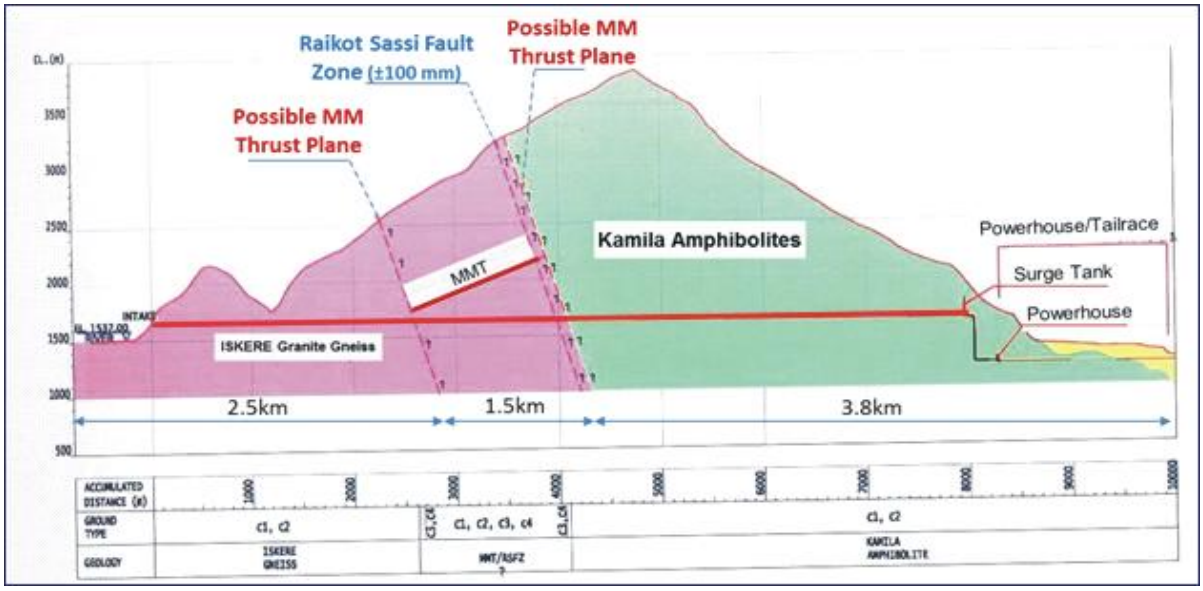


Figure 5: Headrace Tunnel Alignment - Geological Section

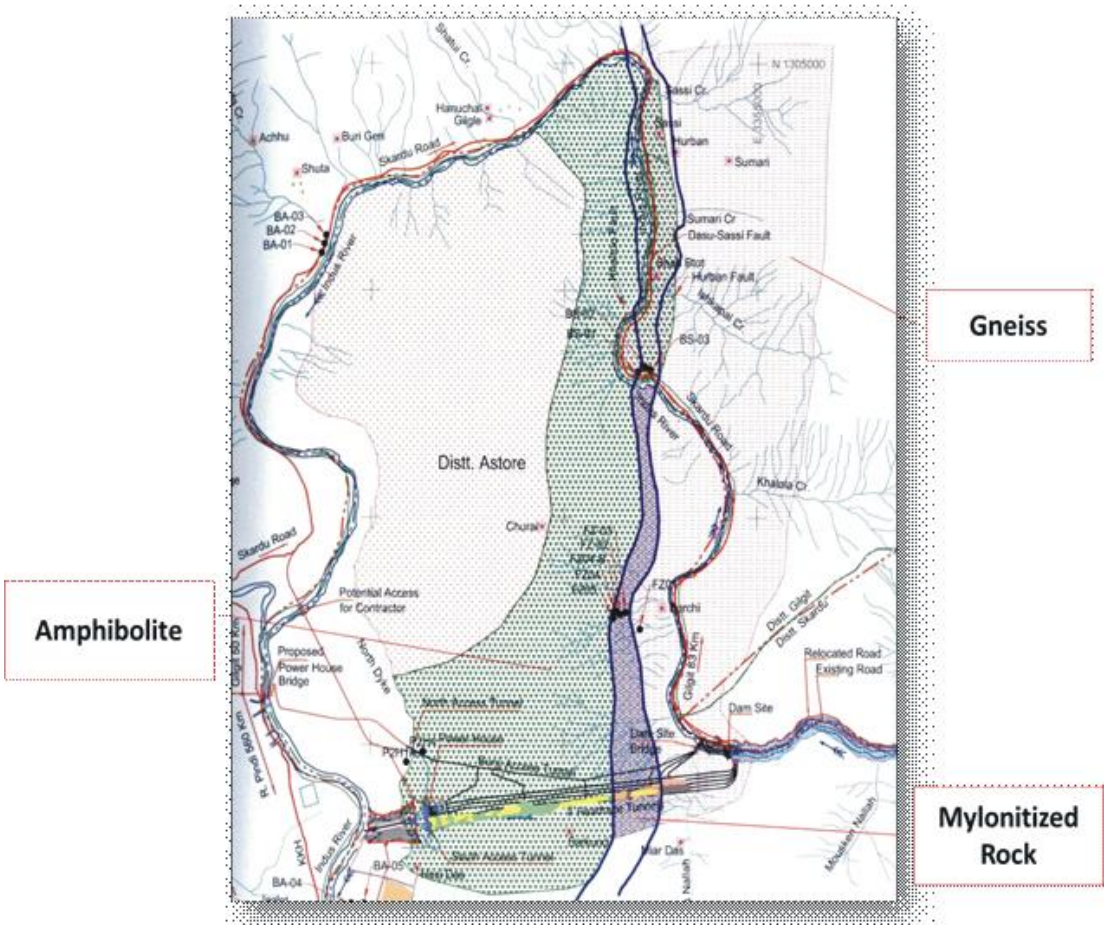


Figure 6: Surface Geology of Fault Zone Area

Paper No. 333

OPTIMIZATION OF PATAN HYDROPOWER PROJECT ON RIVER INDUS

Engr. Dr. Izhar-ul-Haq & Engr. Muhammad Abid Sheikh

OPTIMIZATION OF PATAN HYDROPOWER PROJECT ON RIVER INDUS

By

Engr. Dr. Izhar ul Haq[1], Engr. Muhammad Abid Sheikh[2]

Abstract

River Indus enters into Pakistan at an attitude of 8430 ft. and debouches into the plains at about 1000 ft. extension. In the mountainous stretch of 8500 km the drop in level is 7400 ft. It has many sites with aggregate potential of more than 40,000 MW of hydropower. Most of the sites are run of river with a small storage. There are only four sites for mega storages; Tarbela, Basha, Kalabagh and Shyok where multipurpose projects can be built. After the ranking study of potential sites, now feasibility and detailed studies are being carried for the projects. Since the resources are scarce, the feasibility has to consider all the alternate sources of power production. The cost (including all the construction and O&M) benefits are analyzed at the discounted rate and found that the hydropower is the most economical option as compared to the coal fired on the gass feulled power station.

Due to significant variation of river flows, capacity optimizations of high head run of the river and storage projects is an important aspect to be considered in feasibility. The economic parameters cost benefit ratio and economic internal rate of return favour a range of installed capacity varying from 1300 m^3/s to 3200 m^3/s for the Patan hydropower project. The parameters of the hydropower station were then optimized on the basis of rated discharge. This fixes the size of the hydraulic structures. Tunnels, Turbines and the size of the power house for optimal energy production at minimum unit cost of generation. This paper describes the optimization of Patan hydropower project.

General

Pakistan has an estimated hydropower potential of 100,000 MW. About 60,000 MW has so far been identified and is under different stages of study. Pakistan has exploited yet only 7000 MW which is about 12% of the identified potential. With total installed capacity of 22000 MW from all sources, the contribution of hydel power is 1/3 against 2/3 of thermal. Indus River alone has hydropower potential more than 40,000 MW.

WAPDA carried out ranking study of Hydropower Projects through Montreal Engg. Company (MONENCO) in 1984. Fig-1 represents corridor of river Indus hydropower projects. Fig-2 gives the cascade projects on river Indus. Basha Dam Project was ranked as number one project after Kalabagh Dam Project. Basha and Dasu dams have been designed and are at implementation stage. Bunji Hydropower project has also been planned and designed.

Diamer Basha (DBD) Project

Diamer Basha (DBD) Project is 272 meter high Roller Compacted Concrete Dam. It has a gross storage of 8 MAF and installed capacity of 4500 MW. It would not only provide the much needy 6.4 MAF of live storage of water for irrigation and 18 billion units of power at the site but shall have cascading effect on all the downstream hydropower projects due to its regulated releases of water. It would trap substantial amount of river sediments for about 35 years thereby extending the life of the downstream projects.

1 Advisor Wapda

2 CE (HEPO) Wapda

Prefeasibility of the project was carried out in 1984. Feasibility of the project was prepared in 2005 and detailed design completed in 2008. Fig-3 presents layout of DBD. Capacity optimization of Diamer Basha Dam has been carried out within the limits of irrigation releases. Diamer Basha Dam Project being a storage project would be operated on irrigation demand in conjunction with Tarbela Dam Project. Tarbela Dam shall be operated at higher level to produce more electricity while meeting the irrigation demand with the water released by DBD.

Rated discharge from DBD is 2800 m^3/s and mean annual flows at DBD site is 1977 m^3/s (50.56 MAF/annum).

Although the project is economically robust and technically sound yet the International Financial Institutions are not interested to finance the project due to certain reasons. Land has been acquired and project offices and colony has been nearly completed. Government of Pakistan (GoP) is going to start the construction of the dam with its own resources.

Dasu Dam Project

Dasu Dam 243 meter high Roller Compacted Concrete Dam, 80 km downstream of the DBD project, is a run of river project with storage about 1 MAF. Initially the project was planned by utilizing rated flows of 2600 m^3/s for an installed 4320 MW and mean annual energy of 21300 GWh. Phase-1 of Dasu Project (2160 MW) has been started with loans from International Financial Institutions. Land acquisition is underway and offices, colony, road diversion are being built. Its 2nd Phase shall be completed after Diamer Basha Dam Project, as more regulated flows would be available. Fig-4 gives the layout plan of Dasu Project.

For Phase-I, the rated discharge is 1300 m^3/s to generate 2160 MW with four units. The 2^{nd} Phase would be started as post DBD as with DBD reservoir, additional flows would be available during winter period to meet downstream irrigation demand. It has been found attractive to make optimum utilization of power resources by enhancing capacity by 1080 MW with installation of two additional units. The ultimate capacity of 5400 MW and mean annual of 26300 GWh would be generated with 10 units and rated discharge of 3250 m^3/s. The mean annual discharge at Dasu dam site is 2080 m^3/s (53.2 MAF/annum).

Patan Hydropower Project Layout Optimization

Patan hydropower Project with 102 m high Roller Compacted Concrete Dam on Indus river is to be located near Patan Town, 40 km downstream of Dasu hydropower project. During Feasibility study, various layouts of Patan hydropower project have been considered. Initially it was proposed to construct underground power house with 18 km headrace tunnels crossing Main Mantel Thrust (MMT) fault and Patan Fault. Wapda's preferred alternate is to have powerhouse with shorter headrace tunnel to avoid MMT and Patan Fault. Fig.5 shows the layout plan of Patan hydropower project. The other structures Dam, Spillway and Power Intakes were the same. Two other layouts with 5.5 km & 11 km head race tunnels were also considered. The layout with the shortest head race tunnels about 4.5 km was selected as it would generate electricity at the lowest unit cost. This would not only avoid crossing active MMT but also result in shorter construction time and lower construction cost.

Patan Hydropower Project Optimization of Installed Capacity

The objective of optimization exercise is to establish the preferred rated power discharge of the Patan hydropower project. The aim of project sizing is to achieve an optimum capacity of the power plant and the waterways and powerhouse by utilizing the maximum sustainable potential of the site as the project is to be developed for its interconnection to National Grid.

The benefits and costs are estimated for various design discharges and the plant capacity is optimized on the basis of marginal cost and average cost of the generated unit. The decision

criterion is the option that results in the maximum Net Present Value (NPV) or in other words the project size is increased to a point where the incremental benefits equal incremental costs. The project power benefits are quantified on the basis of cost of an equivalent thermal plant. The capacity optimization has been carried out for Post Basha and Dasu Hydropower project. The rated flow for upstream Dasu hydropower project and Diamer Basha powerhouses have also been considered for capacity optimization of Patan HPP.

Patan HPP will operate generally as a "run-of-river" plant, with the possibility of hourly and daily regulation to meet peak demands during the lower flow periods. The calculations of energy generation over the range of rated discharges from 650 m^3/s to 3,900 m^3/s have been estimated. The energy generation for various rated discharges are presented in table below.

Table – 1: Power and Energy for Rated Discharges

Rated Discharge (m^3/s)	Installed Capacity (MW)	Annual Average Energy (GWh)	Plant Factor (%)
650	568	4980	100
1,300	1,11 5	8800	90.1
1,950	1,650	10640	73.6
2,600	2,173	12050	63.3
2,800	2,385	12,500	59.8
3,250	2,686	13250	56.3
3,900	3,191	14130	50.5

Annual operation and maintenance (O&M) costs of the Patan HPP have been set at:

- 0.75% of civil works costs + 2.0% of E&M equipment costs.
- The economic useful lifetimes were set at 40 years for the Patan HPP civil works and 20 years for the E&M equipment.

Comparison with Thermal Alternatives:

The active storage of the Patan reservoir is relatively small (circa 86 Mm^3) compared to the average inflow from the River Indus of circa 200 Mm^3 per day. Therefore only hourly and some daily flow regulation will be possible during the lower flow seasons. This regulation during the lower flow days will allow the plant to operate in parallel, or in tandem, with the upstream Dasu plant to cover peak demand periods if so required.

The generation characteristics of the Patan HPP are dependent on the seasonal river flows, on the operating policy of the reservoir and on the rated discharge of the hydropower component. This relationship between river flows and rated discharge is represented by the flow duration curve in Fig. 5.

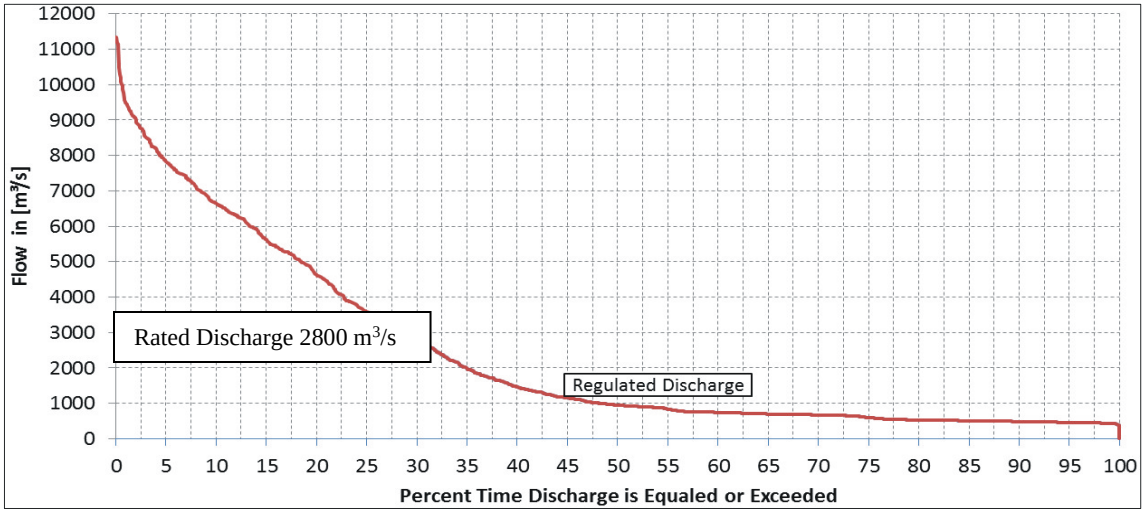


Figure – 5: Flow Duration Curve Indus River at Patan Dam site

Higher rated discharges increase the discharges available for energy generation. For incremental increase in rated discharge, the corresponding incremental energy is relatively small. When river discharges are at or above the rated discharge, energy generation is continuous at the maximum generation capacity.

The type of thermal plant that will compete with a hydro power scheme like Patan will depend on the type of fuel available. Two types of fuel are considered as alternative to Patan power generation:

- Gas from both indigenous and external sources. The indigenous reserves comprise both conventional and shale. It is variously reported that conventional reserves will be depleted within the next 10 to 15 years. External sources of gas include Iran and Turkmenistan via pipeline and Qatar, Papua New Guinea and Australia via LNG shipping.
- Coal from both indigenous and external sources. The indigenous reserves are reported to be huge - of the order of 185 billion tonnes. These reserves are mostly concentrated in the south of the country and would be sufficient to satisfy national electricity demand through the present millennium and beyond. External sources include the Republic of South Africa, Indonesia and Australia.

Both a Combined Cycle Gas Turbine (CCGT) Plant, fueled by natural gas, and a supercritical steam power plant fuelled by coal will be adopted as the yardstick thermal plants" against which the Patan HPP will be compared.

For the Comparison with the Patan HPP, the following thermal plant cost and performance parameters have been adopted:

For the natural gas fuelled CCGT

Capital costs (including equipment, civil, etc)	625 EUR/kW installed
Annual fixed O&M cost	1.5% of capital cost
Variable O&M cost	1.9 EUR/MWh
Fuel consumption	*207 m^3/MWh*

Station energy use	*2.8%*

For the coal fired supercritical steam plant

Capital costs (including equipment, civil, etc)	1,333 EUR/kW installed
Annual fixed O&M cost	2.0% of capital cost
Variable O&M cost	3.0 EUR/MWh
Fuel consumption	0.39 m^3/MWh
Station energy use	4.0%

It was assumed that the CCGT would be located sufficiently close to the demand centre as to avoid significant transmission line costs. However, given that the coal fired plant would be located close to the fuel source, the same transmission line costs as those for the HPP were included in its costs.

The installed capacity of the thermal alternative should be such that the firm capacity of the national generating system with the thermal alternative (but without the Patan HPP) is identical to the firm capacity of the national generating system with the Patan HPP (but without the thermal alternative). In the present study, the firm capacity of the equivalent thermal power plant was assumed to correspond to the hydropower capacity (equivalent base capacity) at Patan which is exceeded 95% of the time. For the range of rated discharges, the installed capacity and energy generation of the thermal alternative are as follows:

For each rated discharge of the Patan HPP, streams of costs were set up covering the period 2014 to 2064. The costs covered planning and design costs, construction costs, equipment costs, transmission line costs, replacement costs and O&M costs. These costs were discounted to the base year 2014. The same was done for the equivalent thermal plant which was set to enter operation in the same year as the Patan HPP. Fuel costs of the thermal plant were calculated as those required to generate the same average annual energy as the Patan HPP.

The discounted costs and benefits were calculated with the following assumptions:

- Discount rates of 10%
- Natural gas prices of 12 US$/MMBtu
- Coal prices of 125 US$/t

The costs covered planning and design costs, construction costs, equipment costs, transmission line costs, replacement costs and O&M costs. These costs were discounted to the base year 2014. Fuel costs of the thermal plant were calculated as those required to generate the same average annual energy as the Patan HPP.

The discounted costs and benefits were calculated with the following assumptions:

- Discount rates of 10% and 12%
- Natural gas prices of 12 US$/MMBtu.
- Coal prices of 125 US$/t and 150 US$/t.

The above results show that the other economic parameters, benefit cost ratio (B/C), Unit Generation Cost and Economic Internal Rate of Return (EIRR) favour a range of installed capacity for 1,300 m^3/s to 3200 m^3/s.

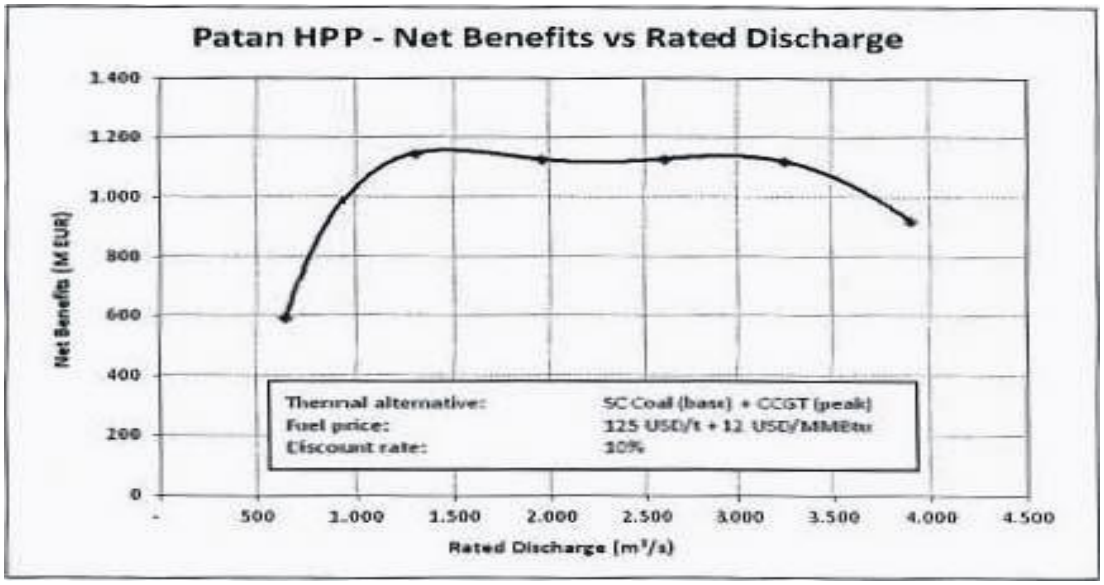


Figure – 6: Flow Duration Curve Indus River at Patan Dam site

Table –2: Economic Parameters For Various Capacities

Q_{rated}	Power	Energy	Discounted		B/C	Net Balance B-C	Unit	EIRR
			Costs	Benefits	Ratio		Cost	
(m^3/s)	(MW)	(GWh)	M US$	M US$		M US$	US cent	(%)
650	568	4979	895	1698	1.9	803	4.54	22.4
1300	1115	8800	1307	2859	2.19	1550	3.83	24.3
1950	1650	10638	1700	3263	1.88	1523	4.51	20.0
2600	2173	12053	2038	3564	1.75	1524	4.83	18.4
2800	2385	12500	2127	3649	1.72	1530	4.90	18.0
3250	2686	13253	2292	3806	1.66	1514	5.08	17.4
3900	3191	14134	2667	3914	1.47	1246	5.75	15.2

The above table indicates that net benefits are in same range for rated discharges of 1300 m^3/s to 3250 m^3/s. For Patan Hydropower Project the selected rated discharge of 2,800 m^3/s, is same as that of upstream DBD but lower than 3250 m^3/s design discharge for Dasu HPP.

Conclusion: The optimized project would produce more energy at less cost per unit. It would have the following generating characteristics:

- Annual Energy = 12,500 GWh,
- Installed capacity = 2,400 MW
- Plant Factor = 59.5%
- Unit cost = Cents 4.9

References:

Ranking and Inventory of Hydropower Projects on Indus River and its Major Tributaries in Pakistan by Monenco-WAPDA in 1984.

Feasibility Study of Diamer Basha Dam Project.

Feasibility Study of Dasu Hydropower Project.

Feasibility Study of Patan Hydropower Project.

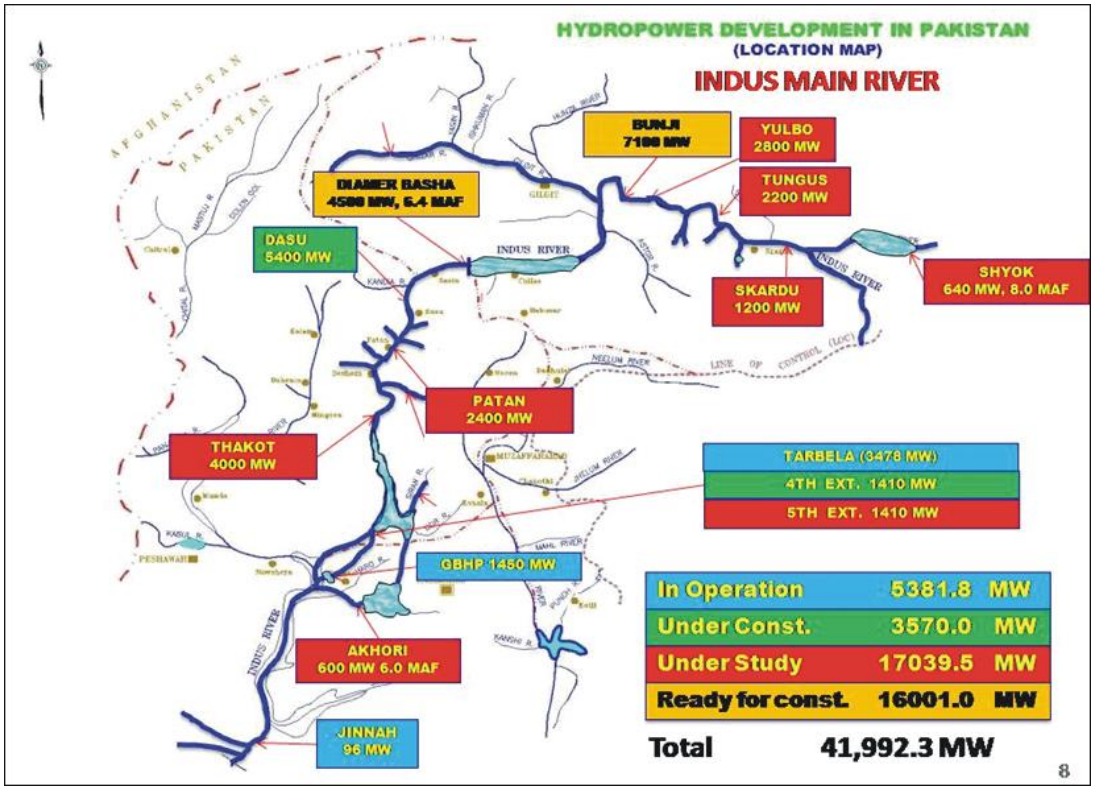


Figure 1: Hydropower Projects On Indus River

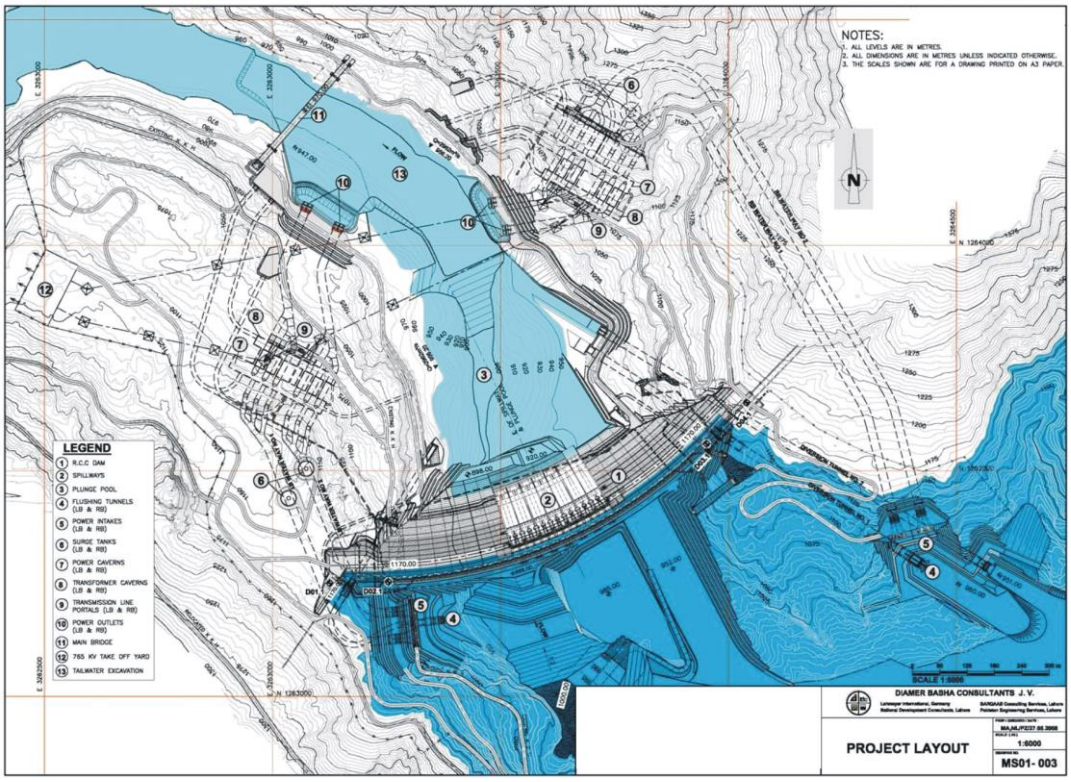


Figure 2: Project layout Diamer Basha Dam Project

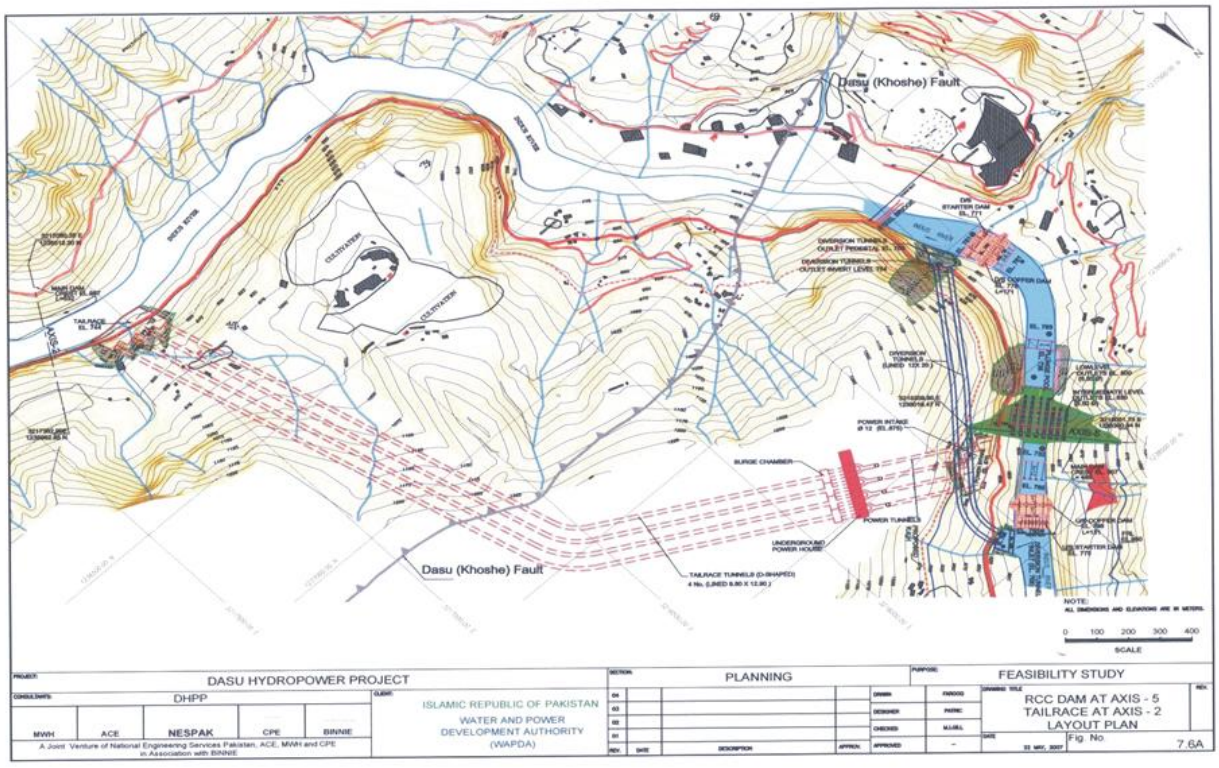


Figure 3: Project layout Dasu Dam Project

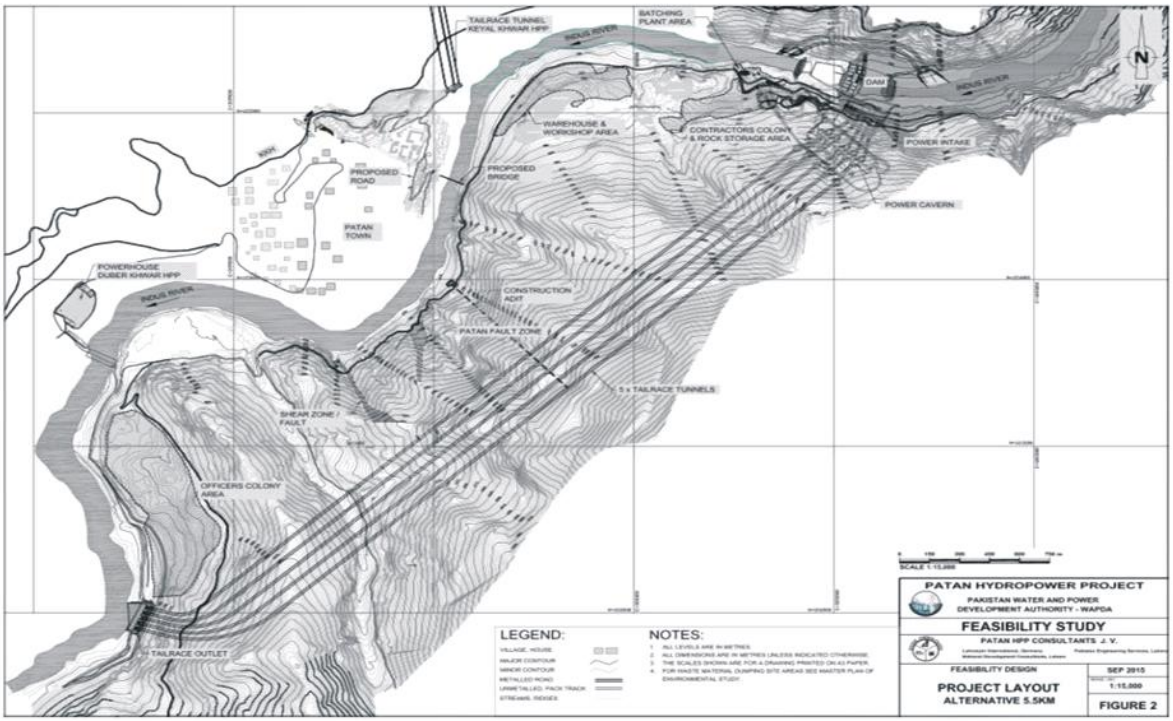


Figure 4: Project layout Patan Dam Project

Paper No. 334

720MW KAROT HYDROPOWER PROJECT

Engr. Iftikhar ul Haq

720MW KAROT HYDROPOWER PROJECT

By

Engr. Iftikhar ul Haq[1]

1. Introduction

720 MW Karot Hydropower Project is being constructed on River Jhelum about 74 km upstream of Mangla Dam. It is fourth level of 5 cascade hydropower projects on River Jhelum. Karot HPP is designed to produce 3206 GWh. It is being built on BOOT basis by a Chinese lead Consortium, viz; Karot Power Company Private Ltd. (KPCL) on a concession of 35 years including construction period of 5 years. Total estimated cost is US$ 1.8 Billion.

Electric power is a stimulator for the socio-economic uplift of the country. However, only about half of the country's population has access to electricity. After the creation of Pakistan, the country faced numerous problems including dearth of electrical power. Hydropower development in the IndoPak subcontinent started in 1925, with the construction of the Renala 1 MW hydropower station. After a decade, the 1.7 MW Malakand-I hydropower station was built, which was later upgraded to a 20 MW capacity. Subsequently, in 1953, the 20 MW Dargai hydropower station was commissioned. At the time of independence, Pakistan inherited a very small power base of only 60 MW capacity for its 31.5 million people. At the time of creation of WAPDA in 1958, the country's total hydel potential capacity was enhanced to 119 MW. Under the Indus Water Treaty in 1960, it was decided that Pakistan is entitled to 142 MAF (Indus 93, Jhelum 23 and Chenab 26) of water utilization. Subsequently, 240 MW Warsak, 1000 MW Mangla and 3478 MW Tarbela Hydropower Projects were constructed.

Unfortunately, Pakistan's energy market investment in hydelpower generation has been in confusion and paradoxes for more than a decade, and no significant progress has been achieved so far. The Government is now trying to facilitate private investors to promote hydel power generation in the country. Hydropower is a primary domestic source of energy. Pakistan is endowed with a hydel potential of approximately 60,000 MW (Water and Power Development Authority [WAPDA], 2013), most of which lies in the Khyber Pakhtunkhwa, Northern Areas, Azad Jammu and Kashmir and Punjab.

In Pakistan, the hydropower projects in public sector are developed through WAPDA, SHYDO/PEDO, HEB of AJ&K and Water and Power Department of Gilgit-Baltistan etc. whereas PPIB deals with hydropower projects in the private sector. PPIB is a professional/experienced facilitator for private sector and encourages for development /implementation of hydropower projects. Brief introduction of PPIB has been provided in later sections.

2. Hydropower Potential in Pakistan

There is a significant hydropower potential (about 60,000 MW) in Pakistan, but only about 12% of this potential is being utilized and the remaining potential is still untapped. Many projects have been planned in the past to utilize this potential but still most of the hydropower sites have not been developed yet. Figure 1 presents categorization of hydropower potential in terms of available basins, rivers, and small hydel potential sites available in the country. The Indus River Basin contains almost 75% of all hydropower potential in Pakistan.

---

[1] Managing Director, Engineering General Consultants EGC (Pvt. Ltd.), Pakistan

Following table shows the summary of province vise projects status;

Table 1: Summary of Province vise Projects Status

Sr. No.	Province	Capacity (MW)				
		In Operation	Under Construction	Under Study	Identified	Total
1	PUNJAB	1,698	96	5,216	179	7,189
2	SINDH	-	-	69	122	191
3	KHYBER PAKHTOON KHWA	4,176	1,516	10,821	8,333	24,846
4	GILGIT BALTISTAN	82	18	12,700	7,862	20,662
5	AJ & K	1,436	1,211	2,776	702	6,330
TOTAL:		**7,392**	**2,841**	**31,582**	**17,198**	**59,218**

Following figure shows the distribution of about 60,000 MW potential among different major River Basins of Pakistan.

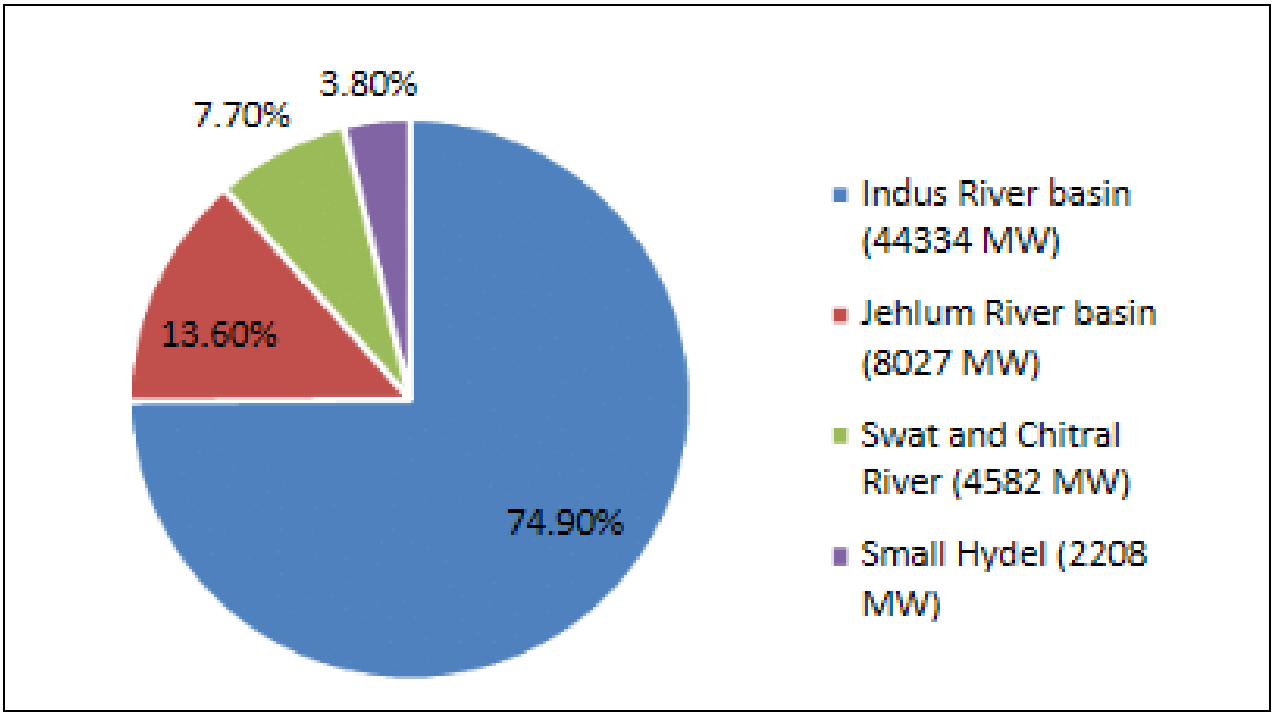


Figure 1: Distribution of hydropower potential in Pakistan (WAPDA, 2013)

Figure 2 represents the site locations of hydropower development projects in Pakistan, mainly covering the northern areas.

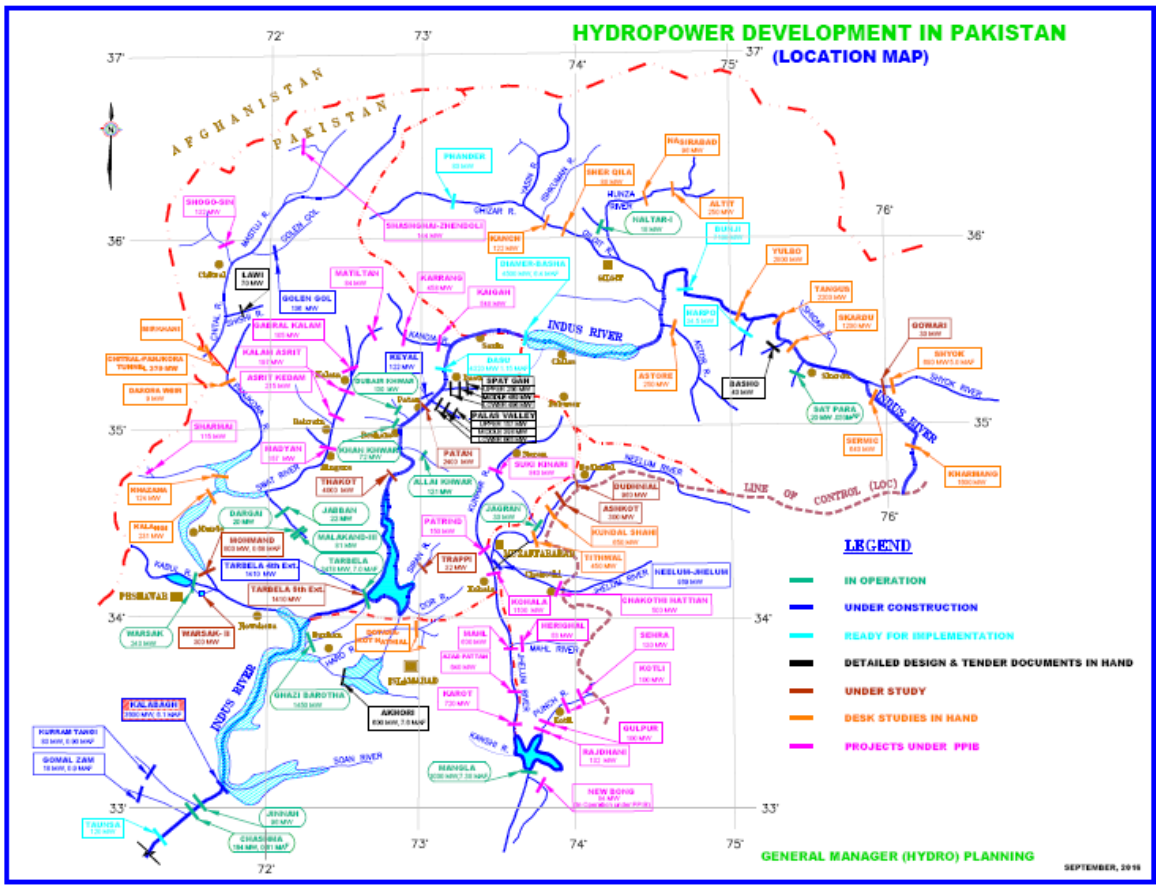


Figure 2: Site location map of hydropower projects

Jhelum River is one of the largest rivers of Indus Basin River Systems. It rises from north-eastern Jammu and Kashmir and is fed by glaciers. Neelum River, the largest tributary of the Jhelum, joins it near Muzaffarabad, as does the next largest, the Kunhar River of the Kaghan valley. It is then joined by the Poonch and Khanki River on the left and right side respectively, before flowing to Mangla main reservoir in Mirpur District.

The Karot Hydropower Project (Karot HPP) is one of several large Run of the River power projects that have been studied and proposed to utilize the waters from the Himalayas which flow in a number of large rivers.

3. Project History

In 1975, under a grant from the Canadian International Development Agency (CIDA), WAPDA started to prepare a ranking study of a number of cost effective hydropower power schemes, with a view to meeting the long-term power needs of Pakistan. The study was conducted by an integrated interdisciplinary team comprising of specialists provided by the Consultant (MONENCO) and staff of HEPO WAPDA. This study was completed in 1983.

In November, 1984, Karot Hydropower Scheme upstream of Mangla Dam was proposed for conducting feasibility study. Later, in 1994, GTZ of Germany and HEPO, WAPDA were entrusted with a task of conducting further studies of medium size schemes on Jhelum River basin. GTZ / WAPDA prepared and submitted a report in December, 1994 titled,

"Comprehensive Planning of Hydropower Resources in Jhelum River Basin". In this Report, a 240MW run-of-river scheme, just downstream of Karot Bridge was proposed. No work on this Project was ever done till it was taken over by PPIB to be offered as an IPP to the private sector.

A group of Pakistani and Chinese sponsors were awarded Letter of Interest, after an International Competitive Selection Process in March, 2007. They signed a contract on August 21, 2007, after ICB, with a Consortium of Consultants for carrying out the feasibility study and preparation of a Bankable Feasibility Report, which was submitted in 2009. The said consortium comprises of the following:

a. SMEC International (Pty) Ltd. Australia.

b. Engineering General Consultants EGC (Pvt.) Ltd. Pakistan.

c. Mirza Associates Engineering Services (Pvt.) Ltd. Pakistan.

Project feasibility was prepared by the above consortium after carrying out detailed field investigations and office studies. Power generation was estimated 720 MW. Based on the results of these investigations and studies, a Feasibility Level Project layout, which is technically sound and economically viable was proposed.

As per the study conducted by MONENCO in 1984 the envisaged net head was 51m and rated capacity of 93 MW for design discharge of 215 m^3/s. The work done by GTZ Germany in 1994 had presented a rated capacity of 240 MW with net head of 51 m for design discharge of 550 m^3/s in their report. Whereas, the Feasibility Study Consultants in 2009 proposed power generation to be 720 MW with design discharge of 1,200 m^3/s and gross head of about 79 m.

4. Present Situation

Karot HPP is "Run of the River" hydropower project under construction on Jhelum River. The project is being developed in the private sector under the Power Policy 2002 on a Build-Own-Operate Transfer (BOOT) basis with an expected concession period of approximately 35 years, which includes the construction period of 5 years and the operation period of 30 years, after which the ownership of the project will be transferred to the Government of Punjab, Pakistan.

The feasibility stage tariff was determined by NEPRA on 11th December 2012 and the Letter of Support ("LOS'') was issued subsequently by PPIB on 29th August, 2013. The development of the Project is being undertaken on a BOOT basis by the Karot Power Company (Private) Limited (KPCL). The Implementation Agreement between PPIB and KPCL was signed on September 20, 2016.

Karot Power Company Private Limited (KPCL) comprises of Three Gorges South Asia Investment Limited (TGSAIL), a subsidiary of China Three Gorges Corporation (CTGC), owner and operator of world's biggest hydropower project that produces 22,500MW in China Three Gorges Hydropower Project and Associated Technologies (Pvt.) Ltd of Pakistan.720 MW Karot Hydropower Project is the first investment by China Three Gorges Corporation in Pakistan in renewable sector and the first hydropower funded and built by a Chinese company in Pakistan which will be another milestone in cooperation in clean energy between China and Pakistan. The Project has been listed as the "Actively promoted Project" in the China – Pakistan Economic Corridor (CPEC) since 2014.

Karot HPP development is on "Engineering, Procurement and Construction" (EPC) basis and the EPC Contract has been awarded to a Consortium comprising Yangtze Three Gorges Technology and Economy Development Co., Ltd (TGDC – Engineering and Construction) and China Machinery Engineering Corporation (CMEC - procurement) at the beginning of 2015.

They will produce the detailed Project design and construct the Project. The EPC contractor is wholly owned by CTGC. The EPC contract commencement date was December 2016 and the proposed completion date is November 2021.

5. Private Power & Infrastructure Board

The Private Power and Infrastructure Board (PPIB) was established in 1994 as an extension of the Ministry of Water and Power. The mandate of PPIB is to act as a "One Window Facilitator" to promote private sector participation in the power sector of Pakistan. In 2012 PPIB was made a statutory organization through Private Power and Infrastructure Board Act 2012 (Act VI of 2012). As per its mandate, PPIB facilitates investors in establishing private power projects and related infrastructure, executes Implementation Agreement (IA) with Project Sponsors and issues assurances and guarantee on behalf of Government of Pakistan.

PPIB is currently handling nine (09) advanced stage power projects of 9590 MW in the private sector which are included in the list of CPEC. These power projects are also diversified in fuel mix (imported coal, local coal, Thar coal and hydel). Furthermore, these power projects are also diversified in terms of location and due consideration has been given to utilize local fuels. The following figure illustrates the fuel vise break up of PPIB projects under CPEC.

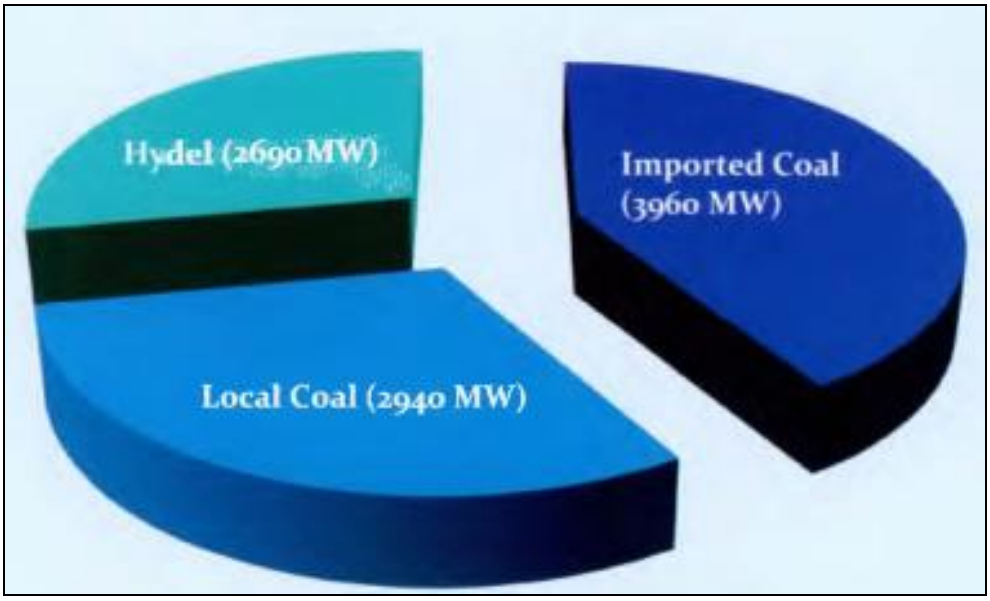


Figure 3: Fuel vise Break-up of CPEC Projects

Following three projects are under the "Hydel" category of PPIB under CPEC projects;

- Karot Hydropower Project 720 MW
- Suki Kinari Hydropower Project 870 MW
- Kohala Hydropower Project 1100 MW

6. Location of Karot HPP

The Karot Hydropower Project site is on the Jhelum River at 1km upstream (U/s) of Karot bridge at the junction of Punjab province and AJK in the north-eastern part of Pakistan, 55km away from Islamabad in the west and 74km away from Mangla Dam in the south. Islamabad-Kahuta-Kotli road leads to the site of Karot HPP. The location of the project site in relation to Islamabad and Mangla Dam is illustrated in Figure 4.



Figure 4: Location of Karot Hydropower Project

Karot HPP is the fourth level of five-cascade hydropower stations planned for Jhelum River in Pakistan, the previous ones are Azad Pattan, and the next is Mangla.

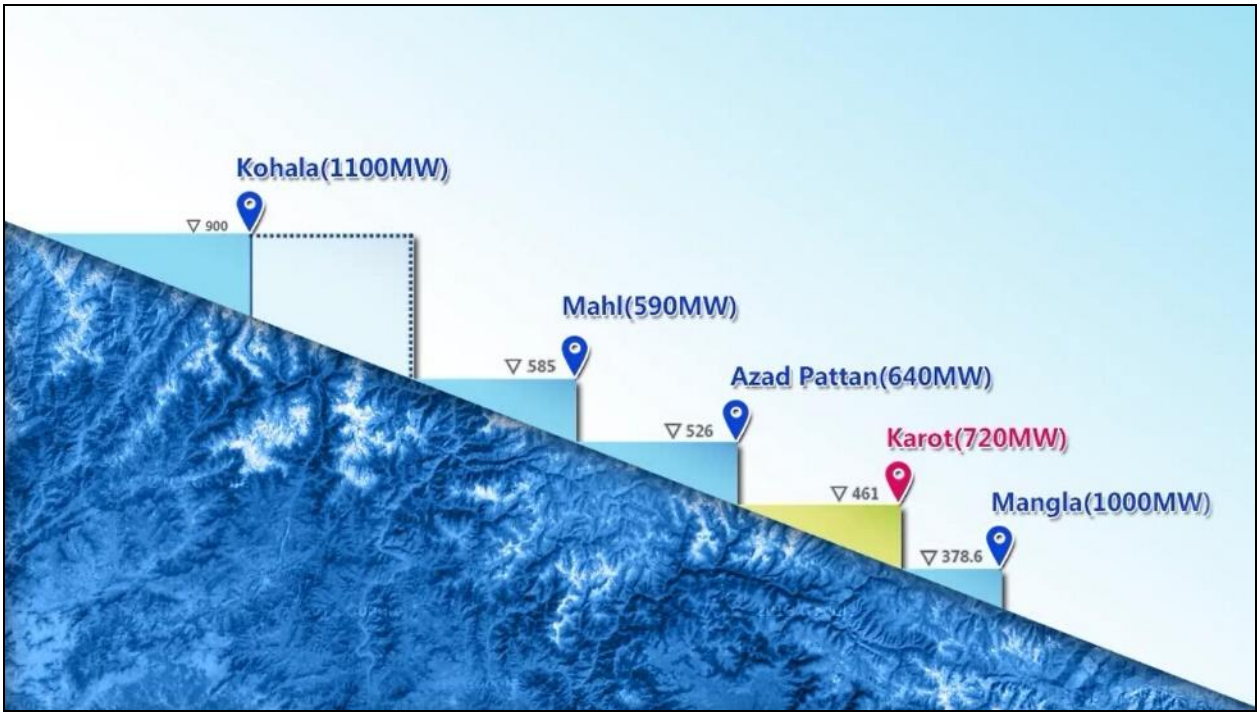


Figure 5: Cascade hydropower development on main Jhelum River

7. Adopted Scheme

The 720MW Karot Hydropower Project is designed exclusively for power generation under Build Own Operate Transfer (BOOT) basis with a concession period of 30 years. It has an asphalt core rock-fill dam of 95.5 m height, a separate spillway, intake structure, 3 diversion tunnels, 4 power tunnels and a surface power house containing 4 x 180 MW Francis turbines with installed capacity of 720 MW and mean annual electricity output of 3206 GWh.

The EPC Contract's construction period is 5 years plus Defects Notification Period of 2 years for civil works and 3 years for E & M Works. Trial run and commercial operation is planned at the end of 5th year.

The Civil Works and E & M Works are two separate Contracts with Civil Works Contractor bearing the responsibility to coordinate with the E & M Contractor for timely delivery of the project. Following are the EPC Contracts:

1. **Engineering and Construction Contract:** Three Gorges Economy Development Company (TGDC)
2. **Equipment Supply Contract:** China Machinery & Electric Company (CMEC)

Following figure illustrates the main Project Layout;

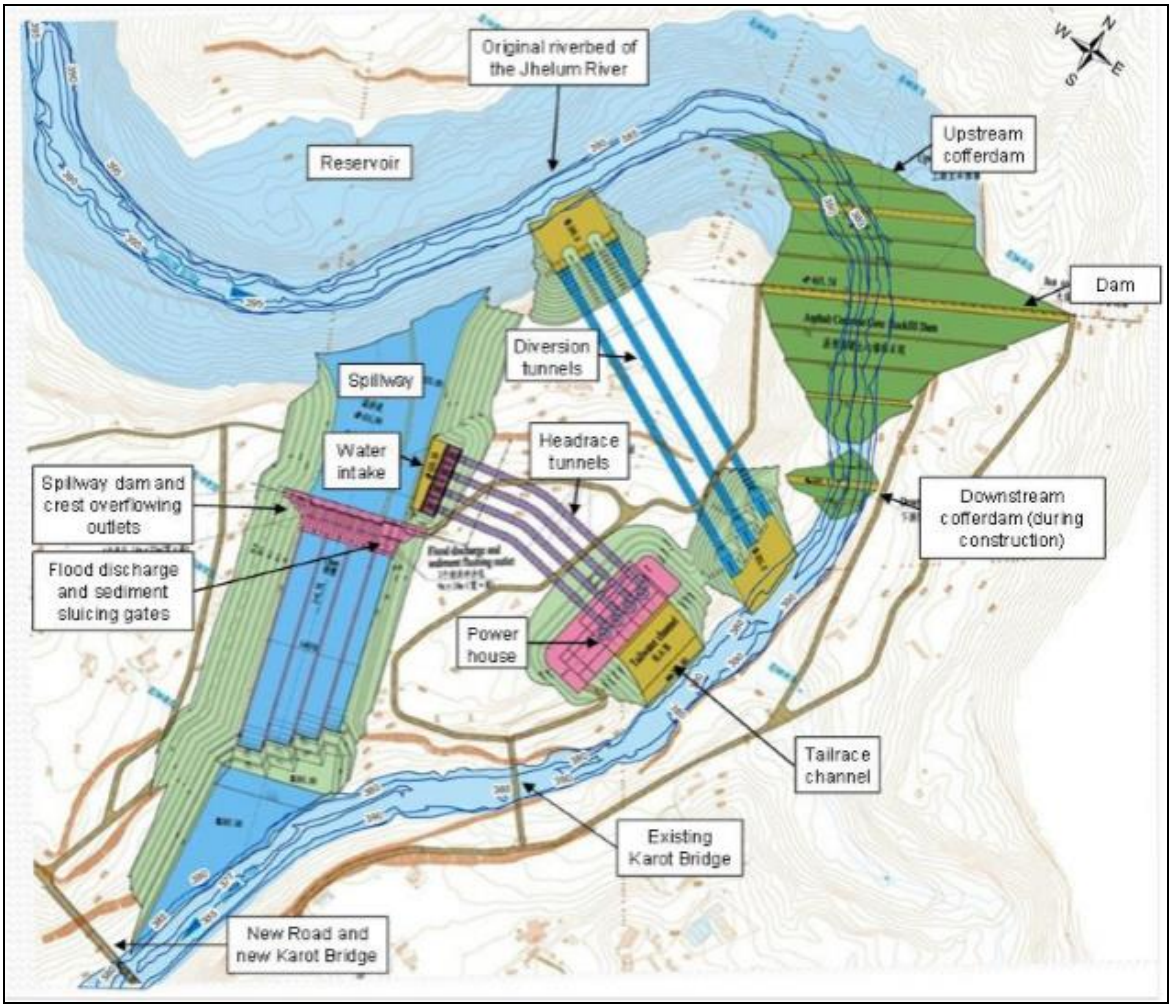


Figure 6: Main Project Layout of Karot HPP

7.1 Salient Features of the Karot HPP

Following are some of the principal features of the Karot HPP;

Table 2: Salient Features of Karot HPP

Items	Units	Quantity or Characteristic
Catchment Area	Km^2	26,700
Mean Annual Flow	m^3/s	819
Normal Water Level	m asl	461
Dead Water Level	m asl	451
Sediment Flushing Water Level	m asl	446
Storage at Normal Water Level	M m^3	152
Flood Water Level	m asl	467.06
Installed Capacity	MW	720
Mean Annual Energy	GWh	3174
Dam Type		Asphalt Concrete Core Rock Fill Dam (ACRD)
Dam Crest Elevation	m asl	469.5
Max. Dam Height	m	95.5
Length of Dam Crest	m	460
Spillway Crest Elevation	m asl	439
No. of Bays & Size	No., m	6 & 14×22 (W×H)
Sediment Outlet Crest Elevation	m asl	423
No. of Bays & Size	No., m	2 & 9×10 (W×H)
Power House Type		Surface
Power House Size (length×width×height)	m×m×m	164.9×27×60.5
Turbine Type		Francis
No. of Turbines	No.	4
Construction Period	Months	60
Defects Notification Period	Months	36
Total Project Cost	Billion US$	1.8

Following figures illustrates the Main Dam section, spillway section and sediment outlet section.

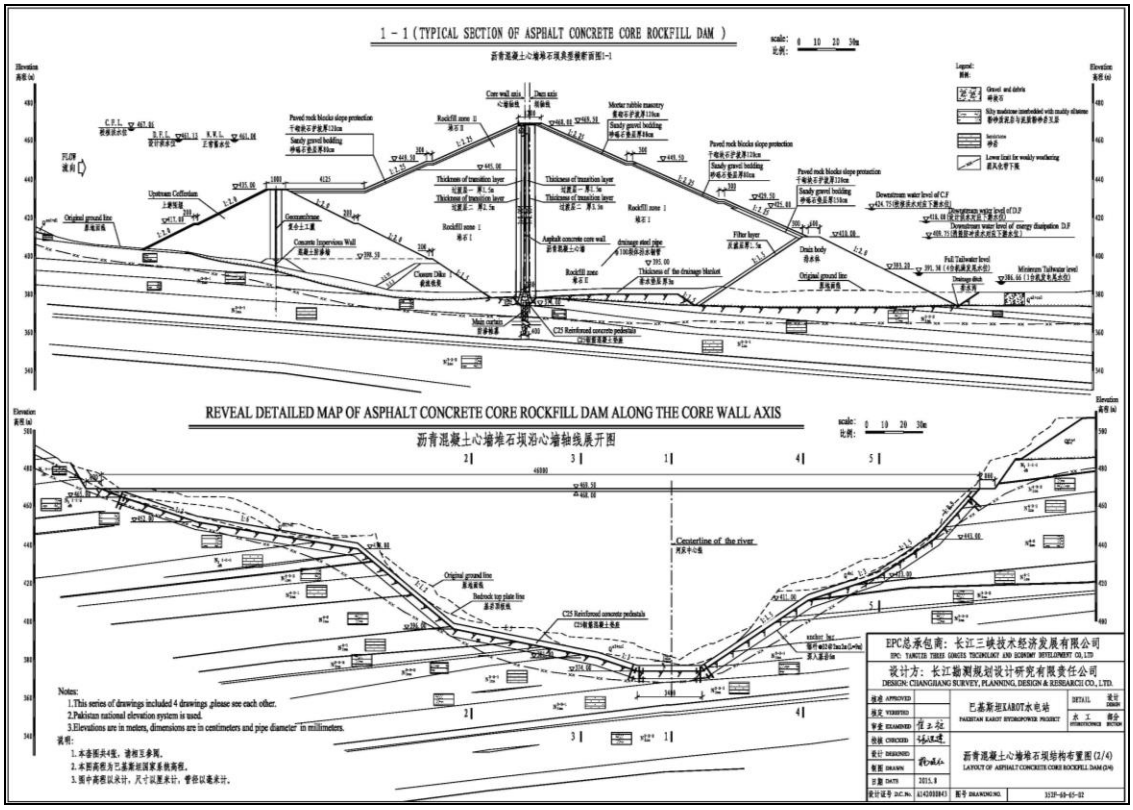


Figure 7: Section through Dam, and cross section at Dam axis.

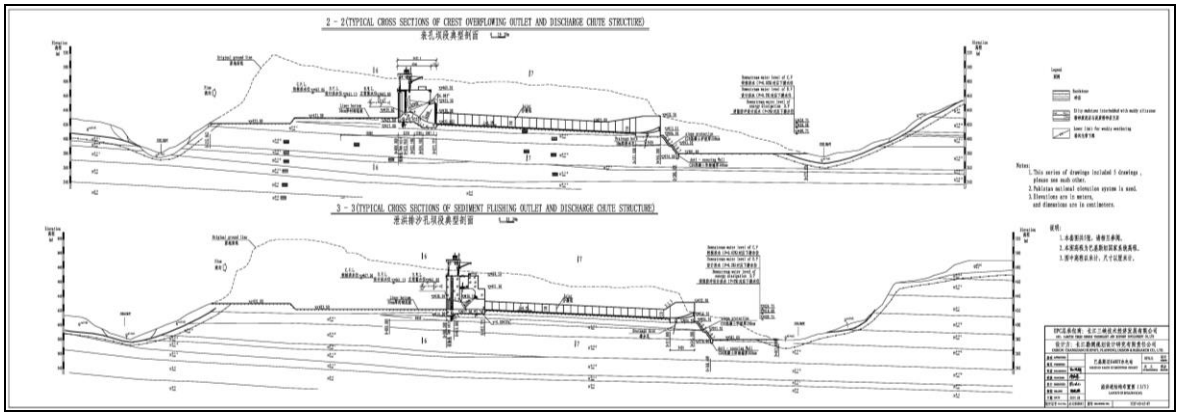


Figure 8: Section through spillway and sediment outlet.

8. Summary

- 720 MW Karot HPP is “Run of the River” hydropower project under construction on Jhelum River, being developed in the Private sector under the Power Policy 2002 on a Build-Own-Operate Transfer (BOOT) basis with an expected concession period of approximately 35 years, which includes the construction period of 5 years and the operation period of 30 years, after which the ownership of the project will be transferred over to the Government of Punjab, Pakistan.

- Karot HPP is the first investment by China Three Gorges Corporation in Pakistan in renewable sector and the first hydropower funded and built by a Chinese company in Pakistan.
- The dam site controls the drainage area of 26,700km^2; having long term average runoff of 819m^3/s and long term average annual runoff of 25.83 billion m^3. The project is a single power generation task hydropower complex, with reservoir's Full Water Level (FWL) of 461m, reservoir storage at FWL of 152 million m3.
- In order to ensure the necessary reservoir balancing storage and safeguard the normal water intake to generate electricity, the sediment flushing outlets are arranged in the spillway near the power intake.
- Asphalt Concrete Core Rockfill Dam (ACCRD) has been proposed, which is more adaptable to the geological conditions, anti-seismic feature is better, the excavated materials can be used as dam construction material and the quantity demand for concrete aggregate is less.
- The ground powerhouse will avoid large cavern, geological risk is smaller, and the investment can be better controlled.
- The total duration of constructing of Karot HPP is 5 years (60 months). The period from the commencement of the project to the time when the installation and trial operation of the first unit is completed is 53 months. Defects Liability Period is 36 months.
- Critical paths would be the construction of ground powerhouse and unit installation during construction of the main project.
- Principal Features of the project include;
    - 95.5m high asphaltic core rockfill dam
    - Gated chute spillway on right abutment
    - Sediment flushing outlet incorporated within the spillway structure
    - 720MW power station
    - 4 hydropower tunnels and associated intake structure
    - 3 diversion tunnels

Paper No. 335

ASSESSING IMPACT OF INFRASTRUCTURE ON PAKISTAN ECONOMY

Mr. Muhammad Ali & Mr. Waheed Anjum

ASSESSING IMPACT OF INFRASTRUCTURE ON PAKISTAN ECONOMY

By

Mr. Muhammad Ali[1] and Mr. Waheed Anjum[2]

Abstract

Energy, water, transport, digital communications, waste disposal networks and facilities, are the essential ingredients for any modern economy. The improvement and investment in these sectors lead to positive and significant impact on economic growth. In this study, we have estimated physical infrastructure stock on Pakistan economy by using data from 1975-76 to 2014-15. The result shows electricity generation, water availability and telecommunication positive impact on Pakistan economy.

Keywords: Infrastructure, economic growth, electricity, water, telecommunication.

1. INTRODUCTION

There are various factors contributing in economic growth of any country. Pakistan's economy is mainly agriculture economy but other sector's are also playing their effective role in economic development and growth. From these sectors, infrastructure has vital role in the development of the economy. It has both direct and indirect impact through various channels. All economic activities are due to this sector. It is a fixed capital investment through government and other institutions. Telecommunication, transportation, utilities, waste removal, education, health care, research and development, training facilities etc. are mainly considered as infrastructure. On the other hand, transport includes roads, ports, railway, airplane and utilities (electricity and water). Infrastructure sector is the key element in performing economic activities. It facilitates reliable services, low-cost, minimum time in goods delivery and ultimate leads towards increased productivity and profitability of the country.

In Pakistan, infrastructure development varies over-time. Due to its low development, it reduces production and impacted consumption of the household sector, therefore, reducing overall welfare. Infrastructure is key role in economic growth and development. There is need for strategic planning of the projects and programs specifically in the energy sector to maximize the effectiveness of the development plants. There is some hope of CEPEC that the investment in this sector will lead to Pakistan's economy on right path of development and economic growth in near future.

The historical statistics published by various institutions show the real picture of this sector. The following table represents decade wise growth rates of different infrastructure indicators. There is fastest growth in electricity generation during 1980s largely because of Tarbela Dam. On the other hand, per capita water availability for agriculture sector has declining trend over the last four decades. There is road expansion during 1980s decade as compared to other decades. The telecommunication sector is playing important role in its expansion over-time following increased usage of mobile phones. In 2010-11decade, there is negative growth rate of infrastructure variables. Only two indicators have positive growth rate (mobile phones and water availability).

1 Author, Senior Economist, Economic Studies Division (ESD), NESPAK, Lahore.

2 Senior Economist, NESPAK.

Per capita electricity generation has the largest negative growth during this period. The table represents this situation in detail.

Table 1: Growth Rate of Different Types of Infrastructure (Decade-wise-Percentage)

Indicators	1970s*	1980	1990	2000s	2010-11	2014-15
Per Capita GDP Growth	2.7	2.9	1.8	2.8	0.3	1.59
Per Capita Electricity Generation (Gwh)**	6.1	7.4	2.3	1.9	-26.4	-1.00
Per Capita Water Availability (MAF)	-1.5	-1	-1.2	-2.3	0.5	1.5
Length of Roads (Kilometers)	4	6.3	3.9	0.5	-0.5	1.45
Telecommunications	7.8	11.1	11.3	0.2	-5.4	-4.23
- Number of Telephone Lines (per 1000						
Mobile Phones availability (per 1000 people)	45.7***		72.3	4.9	5.45	

Source: World Development Indicators, World Bank, Pakistan Economic Survey, Government of Pakistan

*From 1975-76 to 1979-80, **Adjusted for transmission losses, ***From 1995-96 to 1999-2000

The objectives of this paper are :

- Impact of infrastructure on economic growth.
- Determine which types of infrastructure are more effective than other ones The paper is organized as follows :

Section-1 gives a brief introduction of the paper by describing and discussing the main objective of the paper.

Section-2 describes the literature review.

Section-3 represents data sources and detail methodology.

Section-4 describes the results and discussion while final concludes the paper and some policy recommendations..

2. LITERATURE REVIEW

Investment in infrastructure plays an important role in the economy of Pakistan. There are various studies conducted by different researchers regarding its importance. It is proved both theoretically as well empirically that economy cannot grow until its sectors do not improve.

The paper by Straub and Terada-Hagiwara (2011) represents the state of infrastructure in developing Asian countries. They applied two approaches (growth regressions and growth accounting) to analyze the link between infrastructure, growth, and productivity. Further the paper also describes the impact of infrastructure on growth and poverty reduction. It has both direct and

indirect impact. The increase in stock of infrastructure capital leads to productivity of other factors. The other indirect impact deals with technology improvement which leads toward infrastructure progress. It works through various channels like labour productivity gains which result in

improved information and communication technologies that further reduces time wastage in commuting to work and stress, better education, and health facilities.

The paper elaborates that the infrastructure stocks in developing Asian countries growing at a significant pace over-time. The findings show that their levels are below than world average in terms of quality and quantity. There is positive impact on economic growth due to accumulation of stock of infrastructure in different dimensions. It also describes cross country analysis which shows that for most infrastructure indicators, the growth rate of stocks has positive and significant impact on per capita GDP average growth rate. The growth accounting technique on the other hand, shows positive and significant effects of infrastructure on TFP growth only in some countries like the Republic of Korea, Thailand for telecom and electricity indicators.

Canning and Pedroni (2004) paper investigates the effects of infrastructure on long-run economic growth using panel data from 1950 to 1992. Their findings show that there is long-run growth effects in the development of infrastructure but some variations exist among individual countries. By taking all countries, the overall results show that telephones, electricity generating capacity and paved roads are provided at close to the growth maximizing level on average.

The paper by Pierre-Richard Agenor and Blanca Moreno-Dodson (2006) investigates various channels through which public infrastructure development affects growth. Besides other factors, in this paper it is also highlighted durability of private capital, production of health and education services. There are various studies regarding effects of health and education but recently macro-economists have investigated their implications for growth. There is described the endogenous growth model to illustrate the link between health infrastructure and growth with transitional dynamics and optimal allocation of public expenditure. It also reinforces the evidence obtained by Straub and Terada-Hagiwara (2011).

The impact of infrastructure of main three sectors (Services, Agriculture & Manufacturing) was investigated by Rioja (2004) by using panel data of seven Latin American countries in 1960s and 1990s. The study findings showed that the countries that are in developing phase have the greatest gain if investment in infrastructure is raised during this period.

Sanchez-Robles (1998) has estimated cross-country analysis using quantity of public infrastructure stock instead of public expenditure on infrastructure. The findings show positive and significant relationship. The author further stressed on the efficiency of public investment for optimal absorption.

3. DATA AND METHODOLOGY

3.1 Data Source and Econometric Procedure

Data for the study has been collected from various sources. These sources are:

- Economic Survey of Pakistan (Various publications)
- State of Pakistan
- World Development Indicators (WDI) by World Bank database

Data is collected from 1975-76 to 2014-15. Data for all variables is taken annually for this period. For current study, we will use growth regression analysis for the assessment of infrastructure on economic growth in Pakistan. We will see how physical infrastructure stock on impact of economic growth. For this purpose, we have used growth regression technique:

$$gt = \beta ot + \beta itZit + \beta jtKjt + et$$

While

i = 1, 2,……..,m

j = 1, 2,…….,n

Where

gt = growth rate of real per capita GDP

Zt = Vector of control variables

Kt = Vector of physical infrastructure variables

For the control of the economy, we have used these variables, agriculture growth rate, nominal interest rate and mean years of schooling. On the other side, for physical infrastructure, the following variables have been used in our analysis :

- Per Capita Electricity Generation (Gwh).
- Per Capita Water Availability (MAF).
- Length of Roads (Kms).
- Telephone Lines (including mobile phones) per 100 people.

4. RESULTS AND DISCUSSION

In this chapter, we will present our analysis findings regarding impact of infrastructure on economic growth. The econometric analysis of impact of growth of different types of infrastructure on the growth of real per capita GDP are presented in table-2. Firstly, we have estimated the exogenous variables like agriculture growth, nominal interest rate and mean year of schooling. With these variables each infrastructure variable is included in oLS regressions separately in equation (2) to (5) respectively. Then all different infrastructure indicators are added sequentially in equation in (6) to (8).

The result of the model indicates the high level of significance exists in case of electricity generation indicator. The other indicators (telecommunications and water availability) also significant at 5% and 10% respectively. The other indicators roads and highway shows no significant in our analysis. It may indicate that country has been perhaps over investment in this sector. The exogenous variable agriculture growth is significant in all estimation. The other variable also represent significant level at some extent.

These results are presented in the following table in detail.

Table-2: Results of Regression Analysis on Infrastructure and Growth

Variables	1	2	3	4	5	6	7	8
Constant	4.024*	2.567***	4.356*	1.823	3.954*	2.945**	**1.552**	1.412
	(2.612)	(1.957)	(2.965)	(1.314)	(2.612)	(2.437)	**(1.264)**	(1.134)
Agriculture Growth Rate	0.284*	0.282*	0.302*	0.234*	0.295*	0.321*	**0.286***	0.285*
	(4.620)	(4.943)	(4.972)	(4.225)	(4.544)	(6.356)	**(6.087)**	(5.992)
Nominal Interest Rate (%)	-0.324*	-0.241***	-0.325*	-0.19***	-0.326*	-0.251*	**-0.16*** **	-0.16***
	(-2.875)	(-2.273)	(-3.017)	(-1.854)	(-2.852)	(-2.744)	**(-1.817)**	(-1.812)
Growth Rate of Mean Years of Schooling	0.436*	0.412*	0.432*	0.553*	0.441*	0.303**	**0.351***	0.357*
	(2.606)	(2.795)	(2.684)	(3.886)	(2.587)	(2.531)	**(3.182)**	(3.184)
Growth Rate of Electricity Generation Per Capita	-	0.123*	-	-	-	0.161*	**0.161***	0.153*
	-	-3.213	-	-	-	-5.192	**-5.615**	-5.435

Variables	1	2	3	4	5	6	7	8
Growth Rate of Per	-	-	0.171***	-	-	0.324*	**0.326***	0.321*
Capita Water Availability	-	-	(1.943)	-	-	(4.591)	**(5.042)**	(5.031)
Growth Rate of Per	-	-	-	0.021**	-	-	**0.018***	0.021*
Capita Availability of Telephones and Mobiles	-	-	-	(2.316)	-	-	**(2.685)**	(2.687)
Growth Rate of Length	-	-	-	-	0.031	-	-	0.034
of Roads	-	-	-	-	(0.426)	-	-	(0.586)
Adjusted-R2	0.524	0.623	0.557	0.663	0.502	0.736	**0.775**	0.768
F-Statistics	12.651*	11.972*	11.323*	14.098*	9.274*	16.425*	**18.121***	15.531*
DW-Stat	2.298	2.371	2.448	2.031	2.291	2.065	**2.645**	2.551
SC-Value	3.708	3.592	3.688	3.475	3.806	3.365	**3.237**	3.324

Note: *, **,*** indicates level of significant at 1%, 5% and 10%. Values in parentheses represent t-ratios, SC-Value is the Schwarz criterion value.

5. CONCLUSION AND POLICY RECOMMENDATIONS

Physical infrastructure plays a vital role in economy of Pakistan. In this study, we have estimated to check the impact of physical infrastructure stock (electricity generation, telecommunications, water availability and road access) on real per capita GDP. The study shows that investment in power generation, telecommunications and availability of water for agriculture has significant role in economic growth of Pakistan. On the other hand, roads and highway has no significant impact on its economy although there is increase in its investment in PSDP over-time.

There is need of priority change diverting investment from other sectors toward power and agriculture water availability to increase economic growth of the country. There may be some impact in investing in railways and expansion of road network than development on motorways and expressways.

Further, we can infer from our estimation that infrastructure stock accumulation has positive impact on economic growth. A large investment is needed in electricity, telecommunication, transport and water supply to boost Pakistan economy. Demand for infrastructure will increase as due to increase in urbanization and CEPEC projects under consideration. Government has to take steps in priority sectors to be investing under PSDP. The major portion of investment is needed to be invested in power generation sector.

REFERENCES

Agenor, Pierre-Richard and Moreno-Dodson, Blanca (2006), “Public Infrastructure and Growth: New Channels and Policy Implications”.

Blanca Sanchez-Robles (1998), “Infrastructure Investment and Growth: Some Empirical Evidence”, Contemporary Economic Policy, Vol. XVI, Jan.1998, 98-108.

Canning, David and Pedroni, Peter (2004), “The Effects of Infrastructure on Long-Run Economic Growth”.

Straub, Stephane and Terada-Hagiwara, Akiko (2011), “Infrastructure and Growth in Developing Asia”, Asian Development Review- Volume 28, Number 1.

Rioja F. (2004), “Infrastructure and Sectoral Output along the Road to Development”, International Economic Journal, Vol.18, No. 1, 49-64.

LISTING OF PAPERS PRESENTED IN VARIOUS SYMPOSIA OF PAKISTAN ENGINEERING CONGRESS

LISTING OF PAPERS PRESENTED IN VARIOUS SYMPOSIA OF PAKISTAN ENGINEERING CONGRESS

VOLUME / SR. NO.	TITLE OF SYMPOSIUM / PAPER	NAME OF AUTHOR
Volume I	**HOUSING PROBLEMS OF WEST PAKISTAN**	
	FEBRUARY, 1957	
1.	Introduction to Housing Problems	S. A. Rahim
2.	Social Aspects of Housing	M. H. Shah
3.	Some Financial and Administrative Aspects of Housing	Khan Bashir Ahmad Khan
4.	Slum Clearance	Irshad Ahmad
5.	Urban Development in West Pakistan	Mazhar Munir
6.	Aspects of Rural Housing	Muhammad Afzal Khan
7.	Building Materials	A. A. Jamal-ud-Din
8.	Low Cost Houses	Ghias-ud-Din Habib
9.	Essential Services and Development Cost	Mukhtar Ahmad
10.	Principles of Architectural Designing	Naseer-ud-Din Murat Khan
Volume II	**FLOODS IN WEST PAKISTAN**	
	FEBRUARY, 1958	
11.	Causes of Floods in the Indus Basin	S. N. Naqvi
12.	Forecasting	Wirasat Ullah Khan
13.	Effects of Floods and Remedial Measures Suggested	Mian Alim-ud-Din
14.	Effect of Floods on the Economy of the Country	Abdul Aziz Anwar
15.	Effect of Floods on Communications: a) Roads b) Railways	A. A. Jamal-ud-Din & M. M. Zubair
16.	Prevention and Control of Floods	Mian Muzaffar Ahmad
17.	Soil Conservation – A Measure of Flood Control	H. J. Asar
18.	Disposal of Floods	Sardar Allah Bakhsh
19.	Forestry in Relation to Flood Preservation	Muhammad Ihsan-ur-

	and Control in West Pakistan	Rehman Khan
20.	Impact of Floods on Water Resource Development	I. A. Zafar
21.	Floods in the Arid Zones of West Pakistan	G. A. N. Starmans
Volume III	**WATER-LOGGING AND SALINITY IN WEST PAKISTAN** **FEBRUARY, 1959**	
22.	Tile Drainage	M. Saeed Minhas
23.	A Correlation of Resistivity Variations in Saline and Non-Saline Water Bearing Formations	R. A. Shamsi
24.	Application of Electrical Resistivity Method to Investigate Sub-Surface Geology with Special Reference to Hafizabad Reclamation Area	Maqsood Ali Shah Gilani
25.	A New Conception on the Water-Logging and Salinity Problem of Rechna Doab	Dr. Nazir Ahmad, Dewan Ali and Afaq Ahmad
26.	Physiographic History of Land Formation in West Pakistan	Syed N. A. Z Hussaini
27.	Economic Effects of Water-Logging and Salinity in West Pakistan	Aziz A. Anwar
Volume IV	**ENGINEERING EDUCATION IN PAKISTAN** **FEBRUARY, 1960**	
28.	Ideals for Engineering Education in Pakistan	Dr. Mubashir Hasan
29.	Education and Training in Engineering Colleges	Dr. Akmal Hussain
30.	Proposal for a Pakistan College of Mines	Robert L. Burns
31.	The Place of Workshop Practice in Engineering Education	William Arthur Mellors
Volume V	**PLANNING AND EXECUTION OF ENGINEERING PROJECTS IN PAKISTAN** **MARCH, 1961**	
32.	Role of Research in Engineering Projects	Dr. Mushtaq Ahmad
33.	Design Office-Practice	Mohi-ud-Din Khan
34.	Engineering for Modern Contracts and Construction	Daren G. Thiel
35.	Mechanization of Construction Operations	Mian Masud Ahmad

36.	Consulting Engineering Practice in Pakistan	I. A. Zafar
Volume VI	**SEDIMENTATION PROBLEMS AS A RESULT OF INDUS BASIN WORKS** **APRIL, 1962**	
37.	The Sedimentation of Mangla Reservoir	Binnie, Deacon and Gourley
38.	The Sediment Problems on the Indus at Tarbela	John B. Drisko
39.	Silt Trap Efficiency of Reservoirs with Special Reference of Tarbela and Mangla Dams	Dr. Nazir Ahmad
40.	Reduction of Mangla Reservoir Sedimentation by Watershed Management	James C. Ringenoldus
41.	Silt Trap Efficiency of Vegetative Cover in the Catchment Area	Amir Ahmad Khan
42.	Sediment Problems in the Indus Basin Part-II Sedimentation in River Channels and Floodways	S. S. Kirmani
43.	Changes in River Regime as a Result of Link Canals	R. K. Lewis
44.	Some Salient Features of Silt Ejector in a Fluvial Channel Based on Hydraulic Model Studies	Mushtaq Ahmad and Muhammad Ali
45.	A Review of Sediment Problems and Possible Solutions	V. A. Koelzer and Marcel Bitoun
46.	The Present and Future of Silt Excluding Devices	Mohi-ud-Din Khan
47.	Sampling and Analysis Technique for Suspended Sediment	M. M. Sadiq
Volume VII	**WATER-LOGGING AND SALINITY IN WEST PAKISTAN** **OCTOBER, 1963**	
48.	History and Magnitude of Water-logging and Salinity Problems in Former Punjab, West Pakistan	M. A. Lateef and R. A. Shamsi
49.	Salinity and Groundwater Conditions in the Lower Indus Plains, Sukkur-Guddu Right Bank and Khairpur-Lower Indus Project	T. N. Jewitt
50.	Water-Logging and Salinity as Factors Limiting Agricultural Production in West Pakistan	Muhammad Hussain and Nur-ud-Din Ahmad

51.	Sodium Hazard of Punjab Groundwaters	C. A. Bower and M. Maasland
52.	Results of Geologic and Groundwater Investigations in the Punjab Plain, West Pakistan	Z. U. Kidwai, W. V. Swarzenski
53.	The Programme of Investigations in the Former Sindh	A. P. S. Forbes, G. R. Hoffman and Sir M. MacDonald
54.	Economic Investigation as related to Drainage with Special Reference to Khairpur	P. E. Naylor
55.	WAPDA Programme of Water-Logging and Salinity Control for West Pakistan	M. Badr-ud-Din
56.	Development of Groundwater in the Indus Plains	M. Maasland, J. E. Priest and M. S. Malik
57.	Conjunctive Use of Surface Water and Groundwater Supplies in the Principal Canal Irrigated Areas of West Pakistan	Charles S. Hazen
58.	Review of Reclamation Activities and Methods and Suggested Measures for Water-logging and Salinity Control	Muhammad Hussain and H. A. Nishat
59.	Efficacy of and Dependence on Tubewells as a means of Providing Additional Supply Necessary for Controlling Salinity and Reclaiming Waterlogged Areas	Sarwar Jan
60.	A Study of the Rise of Groundwater and its Salinity in the Irrigated Areas of Indus Plains	Dr. Nazir Ahmad
61.	Performance of Salinity Control and Reclamation Project No. 1 Rechna Doab	Mian Shamim Ahmad, H. S. Zaidi and Badr-ud-Din

Volume VIII **CONSULTING AND CONTRACTING PRACTICES IN PAKISTAN**

MARCH, 1965

62.	Consulting and Contracting Practices in Pakistan	B. M. Abbas
63.	Consulting and Contracting Practices in Pakistan	A. V. Karpov
64.	Engineering Resources of Pakistan	A. A. Abidi
65.	Consulting and Contracting Practices in Pakistan	G. H. Vaughan Lee
66.	Considerations in the Establishment of a Pakistan Association of Consulting Engineers	G. T. Macarthy

67.	Consulting Services	Khawaja Azeem-ud-Din
68.	The Role of Private Consulting Firms in Modern Water Resources Development	E-Montford Fucik
69.	Administration of Large Contracts	J. R. Gwyther
70.	Construction Contracts and Law	S. M. R. Abidi
71.	Contracting Practice in Pakistan	Mangla Dam Contractors
72.	Consulting and Contracting Practices in Pakistan	Brig. Ahmad Khaleeli

Volume IX **ROLE OF ENGINEERING RESEARCH IN DEVELOPING ECONOMY OF PAKISTAN OCTOBER, 1966**

73.	Importance of Nuclear Power Generation in the Developing Economy of Pakistan	Masnoon S. Ahmad
74.	Nuclear Engineering Research for Development of Nuclear Power in Pakistan	Muhammad Yusuf
75.	Role of Research in Railways of Developing Countries	C. A. Vali
76.	Development of Building Research in West Pakistan	Mian Muhammad Hanif
77.	Role of Research in the Control and Use of Water	Mushtaq Ahmad
78.	Hydraulic Research in West Pakistan	Khalid Mahmood
79.	Hydraulic Model Research for Indus Basin Project	C. Van Beesten
80.	Research on Water and Land for Survival	Dr. Nazir Ahmad
81.	Water Conservation Studies for West Pakistan	Dr. Nazir Ahmad
82.	Impact of Irrigation Research on the Developing Economy of West Pakistan	Muhammad Hussain & Nur-ud-Din Ahmad

Volume X **BRIDGES**
FEBRUARY, 1968

83.	The Technique of Steam Curing of Concrete	Mian Saeed Ahmad
84.	The New Challenge in Bridge Building	Abdus Salam
85.	Some Design Aspects of Thatta Shujawal Bridge on the Indus	Mohi-ud-Din Khan
86.	Foundations for Thatta Shujawal Road Bridge on the Indus	A. L. Quadri and Mohsin H. Shaikh
87.	Correction Factor for Evaluation of	Fateh Ullah Khan

	Discharge by Manning Formula in Bridge Design	
88.	Partial Prestressing for Highway Bridges	Dr. Jorg Peter
Volume XI	**WATER RESOURCES DEVELOPMENT 1969**	
89.	Planning the Development of Pakistan's Water Resources	Sarfraz Khan Malik
90.	Planning Irrigation Requirements	Sh. Muhammad Afzal
91.	Drainable Surplus Problems in Irrigated Areas	P. I. Druty
92.	Study of Water-Logging Problems of West Pakistan with Electric Analogue Computers	Maqsood Ali Shah Gilani
93.	The Economics of Land Reclamation in the Sindh	C. E. Finney
94.	Some Problems of Groundwater Resources of West Pakistan	Dr. Nazir Ahmad
Volume XII	**PROBLEMS OF ENGINEERING PROFESSION IN PAKISTAN 1971**	
95.	Floods and Cyclones in East Pakistan	B. M. Abbas
96.	Engineering Consultancy and Contractual Services in Pakistan	Muhammad Omar
97.	The Making of an Engineer	Manzur Ahmad
98.	Development of Consultants and Contracting Professions in Pakistan	I. A. Zafar
99.	The Participation of Engineers in National Development	Imtiaz Ali Qazilbash
100.	Of Engineers and Accounts	Riyaz H. Bokhari
101.	Training Needs of Engineering Profession	S. M. Rafi Ahmad
102.	An Engineer in Search of an Image	Sh. Nisarul Haq
Volume XIII	**PLANNING FOR NATIONAL OBJECTIVES 1972**	
103.	Planning of Highways for National Objectives	Inam Bari Pervaize
104.	Streamlining the Public Services for the Tasks of National Objectives	M. Iftikhar-ud-Din
105.	Organizing Earthmoving and Construction	S. Nisar ul Haque

	Equipment for Achieving National Objectives	
106.	The Challenge of Power Supply in People's Era	Mian Fazal Ahmad
107.	Manpower Planning	K. M. Butt
108.	Evaluation of Projects ; An Administrative Missing Link	Masood Hassan
109.	People's Works Programme, Planning and Development at Local Level	Abdul Latif Mirza
110.	Development of Steel Industry in Pakistan	Fida Rahim
111.	Do's and Don'ts in Infra-structural Planning	Sarfraz Khan Malik
Volume XIV	**UTILIZATION OF NATURAL RESOURCES IN PAKISTAN FOR SELF RELIANCE** **1974**	
112	Role of Pakistan's Natural Gas Industry Towards Self Reliance in the Energy Economy	A. Samad
113	Supply and Demand of Chemical Fertilizers	Dr. W. M. Butt
114	Energy Resources of Pakistan	M. Masih-ud-Din
115	Phosphate Deposits of Pakistan	S. Tayyab Ali Shah
Volume XV	**TARBELA DAM PROBLEMS AND SOLUTIONS** **1975**	
116	History of Tarbela from Inception to Substantial Completion	Riaz Nazir Tarar
117	Seepage Control at Tarbela Dam through Upstream Blanket	Amjad M. Agha
118	A Study in Dam-Break Flood	Sh. Abdul Rahman and Khalid Javed
119	Modern Techniques of Vigilance and Repairs on Large Dam	Ch. Altaf Hussain
120	Economic Effect of Tarbela Mishap	Irshad Ahmad
121	Hydraulic Model Studies for Tarbela Dam	Mushtaq Ahmad and Ch. Muhammad Ali
122	Tarbela Dam Project	Sheikh Ahmad Hassan
Volume XVI	**LOW-COST STRUCTURES** **1978**	

123.	Aspects of Low Cost Urban Construction in Pakistan	Z. Mian, K. Mahmood and S. T. Wasti
124.	Self-Reliance in Low Cost Rural Development	N. M. Awan
125.	Economy in Low Cost Housing	Muhammad Sharif Ahmad
126.	A Study of the strength of Effect of Sand on the Compressive Stabilized Soil Blocks	Ahmad Mukhtar Khan
127.	Primary School Buildings Requirements and Design	K. Mahmood and S. Khalifa
128.	Economical Design of Masjid Dome	Sh. Wajeeh-ud-Din, Bakhtiar Ali and Muhammad Azim
129.	Towards Low Cost Buildings	Kennerth G. Old
130.	Determining Minimum Cost Cross - Sections for Lined Channels	Tom Trout
Volume XVII	**ENGINEER'S ROLE IN PLANNING EXECUTION AND MANAGEMENT OF PROJECTS** **1982**	
131.	Essentiality of Project Management in Developing Economics	Khalid Mohtadullah
132.	Some Management Aspects of SCARP-I	Dr. N.M. Awan
133.	Planning of Flood Protection Works	Muhammad Aslam Chohan
134.	Revised Action Programme for Irrigated Agriculture in Pakistan	M. Badr-ud-Din
135.	SCARP Planning in Northern Indus Plains	Ch. Ata-ur-Rehman
Volume XVIII	**RURAL DEVELOPMENT** **OCTOBER, 1985**	
136.	Strategies of Rural Development in Pakistan	M. S. Cheema
137.	Public Tubewells Vs. Private Tubewells	Ramiz Ahmad Mailk
138.	Enhancing Water Availability to Farmers for Achieving Higher Cropping Intensity – A New Approach	Nazar Muhammad, M. I. Shaheed and S. M. A. Zaidi
139.	Non-conventional Energy Options for Rural Electrification in Pakistan	Mushtaq Ahmad Bhatti
140.	Rural Roads in the Punjab	Rana Akhtar Ali Chohan
141.	Impact of Salinity Control and Reclamation	Dr. N. M. Awan

	Projects on Rural Development	
142.	Sanitation and Drainage in Rural Areas of Pakistan	Rana Muhammad Saeed Ahmad Khan
143.	Drinking Water Supply Coverage to Rural Areas in Pakistan	S. M. Ashraf
144.	Farm Machinery and its Role in Development	Sikandar M. Khan
145.	Maintenance, Operation and Construction of SCARP Tubewells with Special Reference to SCARP II	Sh. Abdul Hamid Arif
146.	Electrification of Villages	Abdul Aziz Chaudhry
Volume XIX	**ENERGY CRISIS 1985-86**	
147.	Energy Conservation	Sadaqat Hassan Mir
148.	Development of Thermal Power	Ch. Arshad Zaman
M 149.	Medium Term Strategy of Hydroelectric Development in Pakistan	Saeed Akhtar Niazi
150.	Mini Hydro Power Development in Pakistan	M. R. Chaudhry
151.	Energy Loss Reduction in WAPDA Power Distribution System	Daud Beg
152.	An Overview of Energy Position in Pakistan	Muhammad Irfan Akhtar
153.	Energy Conservation in Air-Conditioning	Syed Qamar Raza Naqvi
154.	Renewable Energy Options to Overcome Energy Crisis in Pakistan	Mushtaq Ahmad Bhatti
155.	Necessity of Nuclear Energy for Pakistan	Dr. Arshad Muhammad Khan
156.	Research Programme for Solar Energy	Dr. Syed Wajahat Ali
Volume XX	**QUALITY CONTROL AND MATERIALS 1986-87**	
M 157.	Evaluation of Mortar / Concrete Mix-Ratio Analysis Method	Dr. Irshad Ahmed
158.	Quality Control on Construction Material	Muhammad Afzal Bhatti
159.	Material Prospection for Dams	Dr.Izhar-ul-Haq
160.	Quality Control in Pakistan Industries - Present Situation	Anwar Saleem
161.	Quality Control Programme in Construction of a Nuclear Facility	Shafqat Rabbani

162.	Effectiveness of Pakistan Steel's Slag in Controlling Alkali Silica	Ghulam Hussain
163.	Improved cast in the Service of Engineers	J. K. Jaffery
Volume XXI	**HYDEL POWER IN PAKISTAN 1987-88**	
	Key Note Address	Dr. Izhar-ul-Haq
164.	Hydro Power Potential of Pakistan	Dr. Izhar-ul-Haq and K. F. Sheikh
165.	Hydro Electric Power Projects Construction Planning and Implementation in Inaccessible Northern Areas of Pakistan	Brig. Ijaz-ud-Din Khan
166.	Socio-Economic Imperatives of Hydro-Electric Development in Pakistan	Mian Fazal Ahmad
167.	Micro Power Plant Programme in Pakistan	Anwar A. Junejo and Zafar Iqbal
168.	Planning Strategy for Development of Hydro-Power in Pakistan	Muhammad Zakaria
169.	Small Scale Power Generation in Private Sector with Special Reference to Small Hydel Power Generation	L. A. Jaffery
170.	Construction Planning of Small Hydro-Power Projects Financing-Contract Packaging Project Schedule	S. M. Kirmani
171.	Indigenous Development to Exploit Hydel Potential in Pakistan	Dr. M. Y. Akhtar
172.	Kundal Shahi Hydel Scheme	Khalid Yamin
Volume XXII	**OPERATION AND MAINTENANCE OF COMPLETED PROJECTS 1989-90**	
	Key Note Address	R. K. Anver
M 173.	Historical Review of Development in Design, Operation and Maintenance of Barrages in Relation to Surface Flow	Dr. Mushtaq Ahmad
174.	Operation and Maintenance of Canals	R. K. Anver and R. Haq
175.	Operation and Maintenance of Completed SCARPS	Hamid Ullah Khan, Syed Rehmat Ali and Muqarrab Khan
176.	Operation and Maintenance of Dams	Dr. Izhar-ul-Haq
177.	SCARP Planning, Operation and Maintenance	Nasir Ahmad

178.	Modern Telecommunications on Pakistan Railways	Khalid Qasim
179.	New Concept in Modern Signalling Maintenance Methods	Wasif Roheel
180.	Maintenance of Drainage Systems	Syed Mansoob Ali Zaidi, Haroon Shami and Muhammad Mehdi Zaidi
Volume XXIII	**FLOOD MANAGEMENT IN PAKISTAN JULY, 1994**	
	Key Note Address	E. I. Johri
181.	Floods in Indus Basin, Their Control and Management	Riaz-ul-Haq
182.	Management of 1992 Floods Through Mangla Reservoir	Muhammad Afzal and Abdul Ghani
183.	On the Study of 1992 Floods and its Effects on Punjab	Syed Ali Rizwan and Faiz Ahmad Chishti
184.	Role of Marginal Bunds in Flood Fighting – A Case Study of Cutting of Marginal Bunds During Floods of 1992 at Trimmu and Punjnad Head works	B. A. Shahid and A. S. Shakir
185.	Floods and Roads in Indus Basin	E. I. Johri
186.	Floods Frequency Analysis at Some Typical Discharge Measuring Site of Pakistani Rivers	Syed Ali Rizwan
187.	Flood Forecasting and Warming Problems in Pakistan	Abdul Majeed
	MANAGEMENT OF HILL TORRENTS IN PAKISTAN DECEMBER, 1995	
188.	Watershed Management in Japan	Yoichi Kishi
M 189.	Management of Kaha Hill Torrent	Syed Mansoob Ali Zaidi
190.	Problems in Disaster Prevention in Developing Countries	Masayuki Watanabe
191.	Harnessing of Hill Torrents in Pakistan: A Conceptional Analysis	Sabir Ali Bhatti, Muhammad Nasir A. Khan
192.	Flood Management of Hill Torrents in Pakistan	Dr. A. S. Shakir, Asrar-ul-Haq and Dr. B. A. Shahid
193.	Status of Rod Kohi System Management-A Case Study	Dr. M. Shafiq, M. Z. Ikram & Muhammad Ahmad

194.	Role of Small Dams in Stream Flow Regulation	Abdul Ghaffar
195.	Potential for Efficient Utilization of Hill-Torrents for Crop Production in Dera Ghazi Khan	Munir Ahmad, Asif Ali Bhatti & Muhammad Aslam
196.	Participatory Approaches in Integrated Watershed Management	Moujahed Achouri
197.	Upper Kaha Hill Torrents Management	Muhammad Azam, Bashir Ahmad Mian
198.	Flood Management of F. P. Bund Complex	Government of Sindh I & P Department
199.	Range Management in D. G. Khan	Forest Department D. G. Khan
200.	Rod Kohi System in D. I. Khan Division	I & P Department D. I. Khan, Govt. of N.W.F.P.
Volume XXIV	**IMPACT OF POWER POLICIES ON SOCIAL AND PRODUCTIVE SECTORS 1996**	
	Key Note Address	Ch. Ikram Ullah
201.	Power Growth in Pakistan	Capt. Khalid Sajjad
202.	Evaluation of the 1994 Private Power Policy	Javid Akhtar
203.	A Discourse of Thermal Generation Policy, Private Sector Vs. Public Sector	Iqbal Ashraf
204.	Impact of Privatization of Power on Agriculture	Dr. Muhammad Yaqoob Bhatti
205.	Impact of Hydel Policy on the Power Tariff in Pakistan	Mohi-ud-Din Khan
206.	Impact of Power Policies on Social and Production Sector	Rehmatullah Javed
Volume XXV	**ENVIRONMENTAL PROTECTION AND RESOURCE CONSERVATION MAY, 1998**	
	Key Note Address	Dr. Izhar-ul-Haq
207.	Environmental and Social Soundness Assessment of 700 MW Thermal Power Plant	Javed A. Aziz and Rafiq Shad
208.	Nitrate, Fecal Coliform and Pesticides in Shallow Groundwater of Raiwind, Lahore, Pakistan	Shahzad Afzal, M. Farooq, M. Hammad Atique Khan, Muhammad Ismail Khan & Karamat Ali
209.	Pakistan in the Grip of Deficient	Ahmad Nawaz Cheema

	Contemporary Environmental Technologies	
210.	Ghazi Barotha Power Project – A Case Study in Environmental Protection and Resource Reservation	Khurshid Ghias Ahmad
211.	Salinity Extent and its Management in Punjab	M. Azhar Javaid, Ch. Karamat Ali and Dr. Muhammad Javed
212.	Environment Conservation of Wetlands in Pakistan	Dr. Izhar-ul-Haq, Muhammad Arshad & Javaid Zaheer Iqbal
213.	Drainage and Environment Evaluation of Past Interventions and Future Strategies in Pakistan	Asrar-ul-Haq, Dr. Bagh Ali Shahid and Dr. Abdul Sattar Shakir
M 214.	Conservation of Water Resources of Pakistan	Dr. Izhar-ul-Haq and S. Tanveer Abbas
215.	Environment and Cancer	Mumtaz Hussain
216.	Eco-Impacts of Toxic Pesticides	Mumtaz Hussain
Volume XXVI	**NEED FOR HYDRO-POWER DEVELOPMENT TO SOLVE ENERGY CRISIS APRIL, 1999**	
	Key Note Address	Ch. Ghulam Hussain
217.	Hydro-Electric Power Potential Identified Under Pakistan-German Technical Cooperation with GTZ Additional to Potential on Main Stem of River Indus	Herbert Kuntz
218.	Role of Low Head Hydro Power Potential to Meet the Energy Crisis in Pakistan	Mahmood Ahmad Malhi and Muhammad Farooq Ahmad
219.	Available Data Banks and Information on Hydro-Power	Dr. J. J. Victoria
220.	Facilitation of Hydro-Power Development by Independent Power Producers	Riaz Nazir Tarar
221.	Feasibility Studies Ready for Involvement of Private Investment Under 1998 Power Policy	G. M. Iliass and Javed Rashid
222.	Development of Hydro-Power to Meet Energy Crisis of the Country	Ghulam Abbass and Fayyaz Asghar
223.	Manpower Requirement in Hydro-Power Engineering	Dr. J. J. Victoria and Dr. Muhammad Latif
224.	Optimization of Hydro-Electric Projects	Ch. Altaf-ur-Rehman

Volume XXVII	**TRANSPORTATION ENGINEERING AND RELATED ISSUES IN PAKISTAN** **JANUARY, 2001**	
	Key Note Address	Ch. Ghulam Hussain
225.	Transport Policy and Allied Issues	Mian Ghias-ud-Din
M 226.	Rutting of Asphalt Concrete Pavements	Haroon I. Shami, Jim Hall
227.	Policy Option for Pakistan Railways	Syed Akhtar Ali Shah
228.	Indus Waterway as an International Outlet to Sea for Land Locked Central Asia	Mohi-ud-Din Khan
229.	An Introduction to Super Pave Asphalt Concrete Mix Design System	Haroon I. Shami, Jim Hall
230.	The Scenario of Public Transportation in Khuzdar	Aftab Ahmad Farooqi, Rab Nawaz and Muhammad Raza Mehdi
231.	Construction Costs of National Highways	Sadaqat Hasan Mir
232.	Lahore-Islamabad Motorway (M-2) Experience – Lessons and Improvements for Future Projects	Syed Waqar Haider
Volume XXVIII	**WATER CRISIS IN PAKISTAN AND SOLUTIONS** **DECEMBER, 2003**	
	Key Note Address	Engr. R. K. Anver
233.	Groundwater Resource of Pakistan and its Management	Muhammad Farooq Khan Niazi & Abdul Hafeez
234.	Role of Barani Areas in Mitigation of Water Crisis in Pakistan	Muhammad Iqbal Lone & Fayyaz Ul Hassan
235.	Indus River System Authority Water Resources Management Drought Mitigation Strategy	Mian Hafiz Ullah
236.	Reuse of Waste Water for Sustainable Management of Water Resources	Dr. M. A. Q. Jahangir Durrani
237.	Water Crisis in Pakistan and Solutions	Fateh Ullah Khan
238.	Anatomy of High Power Tariff	Saeed Akhtar Niazi
239.	Mitigating Water Shortage by Making Tarbela a Sustainable Reservoir	Amjad Agha and Akram Khan
240.	Demographic Influences on Land and Water Resources and Food Sustainability Concerns : Vision 2050	M. Azhar Javed, M. Tariq Yamin, Ch. Karamat Ali, Rashid Minhas

241.	A Transparent Plan for Meeting Water Shortage in Pakistan	Mohi-ud-Din Khan
M 242.	Development of Surface Water Resources	Dr. Izhar-ul-Haq and M. Mushtaq Chaudhry
Volume XXIX	**URBAN DEVELOPMENT WITH FOCUS ON HOUSING** **DECEMBER, 2006**	
	Key Note Address	Engr. Shahzad Jamil Sheikh
M 243.	Urban Development with Focus on Housing	Sheikh Abdur Rasheed
244.	Housing Issues in Urban Development of Pakistan	Prof. Dr. Syed Shabih-ul-Hassan Zaidi
245.	Urban Development in Pakistan – Beyond Housing	Maqbool Illahi
246.	Urban Planning in Pakistan	Manzoor Ahmad
247.	Urban Development Planning of Mega Cities a must Integrated Master Plan for Lahore – 2021	Sabir P. Chohan
248.	Urban Housing Development in Pakistan – A Case Study of Lahore Metropolitan Area	Prof. Dr. Ihsan-ullah Bajwa, Ijaz Ahmad, Zareen Khan
249.	PHATA – Land Use Plan	Kamil Khan Mumtaz
250.	Low Income Housing Strategies in Pakistan with Focus on Urban Housing	Muhammad Ali Tirmizi
251.	Performance of Masonary Buildings During 8th October 2005 Hazara – Kashmir Earthquake in Pakistan	S. H. Farooq, Prof. Dr. M. Ilyas
252.	Urban Development with Focus on Housing	Abdul Halim Paracha
Volume XXX	**PROCUREMENT AND CONTRACT MANAGEMENT** **MARCH, 2008**	
	Key Note Address	Engr. R. K. Anver
253.	Evaluation of Procurement Procedures for Works and Goods in Pakistan	Ch. Ghulam Hussain, S. A. Kasmani
254.	Contribution of Pakistan Engineering Council for Standardization of Procurement Documents and Procedures	Mahboob ul Muzaffar
255.	Overview of the 1999 FIDIC Contract Forms and the MDB Contract	Mushtaq Ahmad Smore

256.	Dispute Resolution Under Engineering Contracts	Balal A. Khwaja
257.	Effects of WTO Regulations on Construction and Engineering Services of Pakistan	M. Mazhar-ul-Islam
258.	Procurement of Consultants' Services	Ijaz Ahmad Khan
259.	Need for Updation of Procurement and Contract Administration	Abdul Qayyum
Volume XXXI	**SYMPOSIUM ON "GENESIS OF POWER CRISIS AND ITS MANAGEMENT IN PAKISTAN"** **JULY, 2009**	
	Key Note Address	Engr. R. K. Anver
260.	Role of Hydropower in Management of Power Crisis in Pakistan	Dr. Izhar ul Haq, Engr. Khawar Munir
261.	Introduction of New Technologies for Renewables and Demand side Management in the Power Sector in Pakistan	Prof. Dr. Zahir Ahmad Fikri
262.	Genesis of Power Crisis and its Management in Pakistan	Amjad Agha
263.	Power Crisis, Causes and Management	Engr. Riaz Ahsan Baig
264.	Self Generation to Combat Power Crisis	Dr. Engr. Javed Yunas Uppal
265.	Genesis of Power Crisis and its Management in Pakistan – Public Private Partnership to Mitigate Power Crisis	Dr. Allah Bakhsh Sufi, Zahid Hussain Khan, M. Javaid Iqbal
266.	Genesis of Power Crisis and its Management in Pakistan	Engr. Tahir Basharat Cheema
267.	Natural Gas Transmission and Distribution Infrastructure Development in Pakistan and its Role in Power Generation	A. Rashid Lone
268.	Barriers in Renewable Energy Deployment in Pakistan	Syed Tahawar Hussain
269.	Renewable Energies – An Ultimate Solution to Overcome Power Crisis of Pakistan	Muhammad Ahmad Riaz, Sana Amin
Volume XXXII	**INTERNATIONAL WORKSHOP ON FLOOD** **MARCH, 2011**	
270.	Holistic Approach to Selection of Design Floods for Large Dams	Mr. Kamran Emami

271.	Management of High Floods	Dr. Izhar ul Haq
272.	Flood 2010: The Event, Issues and Way Forward	Engr. Asrar-ul-Haq, Engr. S. Mansoob Ali Zaidi
273.	Adaptive Flood Management	Mr. Kamran Emami
274.	Flood 2010 – A Probe, A Quest	Usman-e-Ghani
275.	Flood 2010 - Losses and Future Scope of the KP Dairy Sector	Prof. Dr. M. Subhan Qureshi
276.	Experiences in Flood Emergency Action Plan	Dr. Mohammad Ali Banihashemi
277.	Re-examining Flood Management Measures for Sindh	Iqtidar H. Siddiqui
278.	Promoting Creativity and Innovation in Flood Projects by Value Engineering	Mr. Kamran Emami
279.	Provision of Safe Drinking Water for Flood Affected Areas	Dr. Muhammad Anwar Baig, Irfan Ahmad Qureshi
280.	Pakistan Flood 2010: An Opportunity to Build Back Better	Prof. Dr. S. Shabih-ul-Hassan Zaidi
281.	Floods in Pakistan 2010 (Lesson Learned & Way Forward) in Agriculture Sector (A Success Story)	Prof. Dr. M. Ashfaq (T.I), Dr. Ehsanullah
282.	Flood 2010 in Pakistan and Its Damages	Ch. Ghulam Qadir
283.	Management of Flood 2010: Lessons Learnt and Improvement Strategies	Rab Nawaz
284.	Yangtze Floodplain Restoration and Basin Management – Progress and Lessons Learned Post The 1998 Flood	Dr. Lifeng Li
Volume XXXIII	**SYMPOSIUM ON "CHANGING ENVIRONMENTAL PATTERN AND ITS IMPACT WITH SPECIAL FOCUS ON PAKISTAN"** **JULY, 2011**	
285	Changing Climatic Patterns and their Impacts with Special Focus on Pakistan	Jawed Ali Khan
286	Integrated Water Resource Management in Pakistan	Dr. Allah Bakhsh Sufi, Zahid Hussain, Syed Javed Sultan, Imran Tariq
M-287	Global Warming in the context of Pakistan: Major Concerns and Remedial Strategies	M. Munir Sheikh, M. Mohsin Iqbal, Ghazanfar Ali,

		Arshad M. Khan
288	Climate Change and its Realities for Pakistan	Ali Hasnain Sayed
289	Change of Environmental Patterns and its Impact with Special Reference of Pakistan	Engr. Raqib Khan
290	Climate Change and its Impact with Special Focus in Pakistan	Zia Mustafa
291	Aquatic Bio Diversity Management of Khwar Projects – A Case Study	Attia Dastgir, Ishteqaq A. Kaukab, Dr. Muhammad Siddique
292	Economic Impact of Climate Change on Agricultural Sector of Punjab	Uzma Hanif, Dr. Rafique Ahmad, Dr. Kauser Abdullah Malik, Dr. Shabib Haider Syed
293	Climate Change: Emissions and Sinks of Greenhouse Gases in Pakistan	Akhtar Nawaz Khan, B.M. Ghauri, R. Jilani, Said Rahman
Volume XXXIV	**SYMPOSIUM ON "EMERGING PHENOMENON OF UNTIMELY RAINS / FLOODS – 2011 IN PAKISTAN"** **DECEMBER, 2012**	
294	Adaptation to Untimely Floods	Kamran Emami, Saeed Pourshahidi
295	Estimating Flood – 2010-2011 Extent Using Satellite Remote Sensing Data in Pakistan	Badar Ghauri
296	"Emerging Phenomenon of Untimely Rain Floods in Sindh and Ways to Mitigate their Damaging effects	Jam Mitha Khan
M-297	An Appraisal of 2011 – Rain / Flood Damages in Sindh	Asjad Imtiaz Ali, Javeed Iqbal Bokhari, Qazi Tallat M. Siddiqui
298	Multihazard Vulnerability Scenario for Disaster Risk Management in Karachi	Yawer Ansari, Amir Sohail
299	Unprecedented 2011 Rains / Floods in Pakistan and Actions Needed	Engr. Zafar Iqbal
300	Rainfall Deluge Management – A Case Study of Sindh Province in Pakistan	Muhammad Idris Rajput
301	Disastrous Effects of Rain 2011 in Sindh, Pakistan	Dr. Bakhshal Khan Lashari,

		Zarif Iqbal Khero
302	Managing Floods in Pakistan : From Structural to Non-Structural Measures	Dr. Asad Sarwar Qureshi
303	Integration of Disaster Risk Reduction (DRR) into Water Sector	Ahmed Kamal
304	Pakistan Proposed Approach to Flood Control and Management Based on 2010 Experience	Engr. Riaz Nazir Tarar
Volume XXXV	**SYMPOSIUM ON "ROLE OF ENGINEERS IN ECONOMIC DEVELOPMENT AND POLICY FORMULATION IN PAKISTAN"** **DECEMBER, 2013**	
305	Role of Engineers in Economic Development and Policy Formulation	Engr. Abdul Khaliq Khan, Dr. Izhar-ul-Haq, Umair Manan
306	Role of Engineers in Economic Development and Policy Formulation Focus on Major Water Storages	Engr. Riaz Nazir Tarar
307	Impediments in the Role of Engineers in Economic Development	Dr. Engr. Javed Yunas Uppal
308	The Role of Engineers in Economic Development and Policy Formulation (A Wandering Habitué / A Thrust in Baffle)	Engr. Usman-e-Ghani
309	Role of Engineers in Economic Development and Policy Formulation	Sardar Muhammad Tariq
310	Role of Engineers in Economic Development and Policy Formulation	Dr. Muhammad Nadeem
311	The Role of Engineers in Sustainable Development	Dr. Asad Sarwar Qureshi, Atif Nawab
312	Role of Engineers in the National Economic Development Prosperity	Dr. Muhammad Anwar Baig, Nauman A. Baig
313	Role of Engineers in Economic Development and Policy Making of a Country	Sohail Ali Naqvi, Ali Hasnain Syed
Volume XXXVI	**"CONTRACT ADMINISTRATION AND MANAGEMENT IN PAKISTAN"** **OCTOBER, 2014**	
314	Contract Administration in Pakistan and FIDIC Rainbow 1999	Engr. Abdul Qayyum

315	Procurement of Civil works and Evaluation of Bids	Engr. Ijaz Ahmad Khan
316	Claims under FIDIC Contracts, Edition 1999	Engr. Mushtaq Ahmad Smore
317	Arbitration Act, 1940	Engr. Balal A. Khawaja
318	Dispute Resolution under Construction Contracts of Hydropower Projects of Pakistan	Engr. Nasir Hanif, Engr. Muhammad Amin, Engr. Hashim Hanif
319	Regulatory Frameworks for Procurement of Consultancy Services	Engr. Mazhar ul Islam
320	Role of the Engineer in FIDIC Based Construction Contract	Engr. Mian abdul Sattar

Volume XXXVII

ANNUAL SYMPOSIUM ON MEANS OF TRANSPORTATION – PRESENT AND FUTURE

JANUARY, 2015

321	Use of Transport Models for Mass Transit Studies	Engr. Abdul Basit Sheikh
322	Pilot Project for Inland Water Ways Navigation System in the Reach between Nowshera and Daud Khel	Engr. Muhammad Jabbar
323	History of Railways in Sub-Continent and Rail Transport in Pakistan	Engr. Abdul Aziz Ch.
324	Concept of Sustainable Truck Ports and Determination of their Locations in Lahore	Engr. Musharraf A. Khan, Prof. Dr. Tanvir Iqbal Qayyum
325	Pakistan Railways Past, Present and Future	Muhammad Zia Ullah
326	Effect of Heavy Axle Loading on Pavement Performance on National Highways Network in Pakistan	Dr. Shafeeq Ahmed, Dr. Shahab Khanzada
327	Integrated GIS-GPS System for Rail Operations Management	Muhammad Ziyad Rasheed, Ahmad Sallar, Naveeda Ahmad, Mariam Masood, Mubasher Nawaz, Ahmed Hassan
328	Development of Improved Road Crash Data Collection Mechanism for Traffic Police Lahore	Engr. Maryam Nawaz, Prof. Dr. Tanvir Iqbal Qayyum