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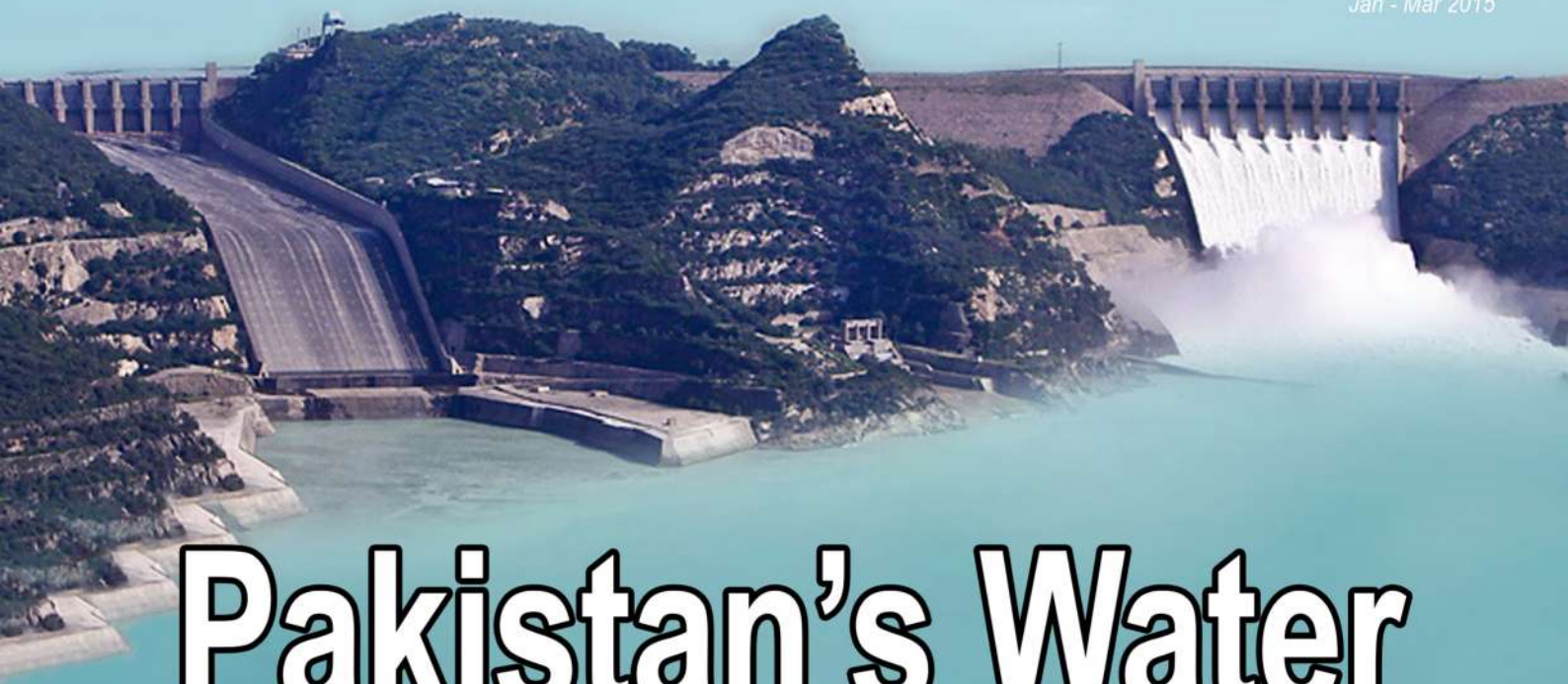

Pakistan's Water Availability & Requirement

p/5

A Publication of
The Institution of
Engineers, Pakistan

M.A. Jinnah

"If Pakistan is to take its proper place among the progressive nations of the world, it will have to take up good deal of leeway in the realm of scientific and technical education which is so necessary for the proper development of the country and the utilization of its resources. The establishment of institution like the Institute of Engineers will greatly stimulate technical research and help in disseminating available information. The Institute of Engineers will not only benefit the engineers themselves by improving their technical knowledge but also bring lasting benefit to public services which they are called upon to perform.

I wish the Institute every success".

(Quaid-e-Azam's message to the first inaugural meeting of the Institute of Engineers on 20th June 1948)

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Pakistan's Water Availability and Requirement

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Abstract
Agriculture is the back bone of Pakistan's economy. The major input of agriculture is water. Agriculture is neither sustainable nor dependable source of income without water. Pakistan receives on the average 148 MAF of water per annum from snow, glacier melt and monsoon rains. About 80% water is generated in summer during three months and only 20% during nine months. This necessitates the storage of water for carry over from summer (kharif) season to winter (Rabi) season for sowing and maturing crops. Pakistan has storage only 11% of its annual flows against 40% world average.
The storage capacity of the reservoirs: Mangla, Tarbela and Chashma built in 1970's is depleting due to siltation. Pakistan's agriculture economy receives shocks during droughts and floods due to inadequate storage capacity. Ground water about 50 MAF is being pumped out from the sweet water aquifer to supplement the surface water. This is also not sustainable.
Pakistan's population is increasing and the water availability per capita is decreasing. The country is becoming water scarce. On average 30 MAF of water flows down the last barrage Kotri every year into sea. If the water can be stored, it can irrigate 20 M. Acres of virgin land available in the country. Pakistan has the oldest and largest contiguous irrigation network which needs up gradation. Pakistan's agri produce is one of the lowest in world. It needs to be increased to feed the growing population. Storage of water can mitigate floods, ensure food security and sustained economic growth.

Introduction
And we made every living thing of water *(Al-Quaran 21:30)*

Water is life and an important element of National security. According to Water experts, Pakistan is leading towards severe water crises. The 11th Five Year Plan (2013-2018) for the water sector highlights water requirements, its development, as well as a management issues. Water is vital for sustainable development. Eight out of the ten Millennium Development Goals (MDGs) are water related. Numerous sectors including health, agriculture, energy and biodiversity are all linked to water. It is a key requirement for generating rural livelihoods, growing food, strengthening industry, promoting service sector growth, and ensuring the integrity of ecosystems.

1. Water Availability
Pakistan's water resources comprise surface water and ground water:
a) **Surface Water**
Pakistan is Arid to semi Arid country. The Indus River System receives an annual inflow of about 148 Million Acre Feet (MAF) of water, mostly derived from snow and glacial

melting and rainfall. Pakistan receives snowfall in Northern areas during winter, rainfall is mostly with monsoon during
b) July – August and partly with westerly disturbances in winter.

Its magnitude and place of occurrence varies in the country. The mean annual precipitation ranges from less than 100 mm in parts of the Lower Indus Plain to over 750 mm near the foothills in the Upper Indus Plain.

Pakistan is dependent on the three western rivers of the Indus (including Kabul), Jhelum and Chenab. Post-Tarbela (1976-2008) flows (Indus at Kalabagh, Jhelum at Mangla and Chenab at Marala were 146.64 MAF. The three eastern tributaries of the Indus, Ravi, Sutlej and Beas, were allocated to India for its exclusive use. Currently there is no flow of water from India to Pakistan through these eastern rivers, as India has built storage dams on them except a small run-off generated in their catchments within Pakistan or in case of floods when their dams are full. Fig-1 shows river system of Pakistan.

Since the commissioning of Tarbela Dam in 1976, there has been no concerted effort to develop additional surface water resources of Pakistan. After commissioning of Mangla and Tarbela dam and regulating facility provided by Cheshma reservoir, canal diversions of the four provinces of Pakistan increased as in Table-1.

Canal Diversions Pre and Post Dams of Four Provinces

Provinces	Pre Dam 1960-67	Post Dams 1976-2000	% Increase
Punjab	47.69	54.01	13.25
Sindh	35.56	44.47	25.06
KPK	4.66	6.16	32.19
Balochistan	0.48	1.80	375.00
Total	88.39	106.44	19.92

Water availability in Pakistan is 1011 m^3 per capita / year (2014); Fig-2. This is already well below the 1,700 m^3 per capita/year, threshold for water stressed conditions. Thus Pakistan is already fast moving into a condition of 'water scarcity'. This situation is likely to deteriorate in future as the gap between supply and demand widens.

By 2025 water availability is expected to fall to 500 m^3 per capita/year. Water available for future development is 30 MAF of river flow. However the gross additional water demand (at the farm gate) for all sectors will be about 28 MAF (20 MAF for agriculture and 8 MAF for municipal water supply, rural potable and sanitation, industry and the environment).

c) **Ground Water**

Ground water is now recognized as a vital natural resource, which has, interalia, played a key role in poverty alleviation in rural areas in Pakistan. Ground water is particularly the most dominant and reliable source for domestic water supply in cities and towns of Pakistan for meeting crop water requirement during stress periods. The average annual contribution as a result of conjunctive use of surface and ground water in the form of agriculture production is more than $ 10 billion out of the total share of about $ 35 billion attributable to agriculture in the national economy.

Sectoral uses of ground water in four provinces are given in Table-2

Sectoral Uses of Ground Water in Four Provinces

Province	Water Uses (MAF) 2007				
	Irrigation	Water Supply	Industry	Misc	Total
Punjab	40.0	2	0.8	0.2	43.0
Sindh	4.2	0.5	0.4	0.1	5.2
KPK	1.4	0.3	0.2	0.1	2.0
Balochistan	0.5	0.2	0.1	-	0.8
Total	**46.1**	**3.0**	**1.5**	**0.4**	**51**

Pakistan is extracting 51 MAF from acquifers and has already crossed the sustainable limit of safe yield. This over mining and pollution of acquifers has resulted in secondary salinization and the presence of fluorides.

2. Water Demand

Pakistan's population is projected to reach 221 million by the year 2025. Population rise, rapid urbanization and better socio-economic conditions, will bring about increasing pressure on water resources.

a) Agriculture

Fig-3 shows the land use map of Pakistan. The total area of the country is 196.7 Million Acres (MA) of which 52.4 MA

is designated as cultivated area. About 48.2 MA cultivated land is served by irrigated water, while the remaining 4.2 MA is rain fed. Almost 90 percent of water resources are being used to meet crop water demand. Increases in agricultural production to meet the needs of a rising population, will require additional water. Based on population growth projections, by 2025 an estimated additional 20 MAf will be needed at the farm gate (assuming a 50 percent increase in crop yields from non-water inputs) and 37 MAF at the canal head.

b) Municipal Use

The current total water use for domestic and municipal purposes in both urban and rural areas is estimated at 4.5 MAF. By 2025 requirements for water supply, rural potable water and sanitation requirements are estimated to be 8 MAF.

c) Industry

There are over half a million large and small industrial units in the country, of which nearly 120,000 are engaged in textile, chemical, fertilizer, tanneries and other manufacturing and processing activities. The current water use by all industries and mines is estimated to be 3.5 MAF. This is expected to rise to 4.8 MAF by 2025.

d) Environment

In order to ensure adequate water throughout Pakistan for wetlands, environmental protection and increased irrigated forestry, about 1.7 MAF water will be required by the year 2025.

When Indus Water Treaty was signed with India, there was no awareness about environmental flows. India was given the entire waters of river Bias, Ravi and Sutleg without any consideration of their committed uses. Because of no flows at all in these rivers, the areas fed by them: Lahore Distt, Lower Bari Doab Canal, Bahawalnagar are worst hit due to shortage of water and are pumping ground water without its recharge. The historical city of Lahore's existence would be threatened because of shortage of domestic water supply. People's health would be effected due to the salts present in the ground water. An environmental study needs to be carried out.

Environmental studies were carried out for the area d/s of Kotri barrage. Quantity of water required for agriculture, domestic and environmental use has been worked out. Five thousands cusecs perennial flow is required for d/s uses in addition to 5 MAF on average per year for washing out the salts from the delta area. These days no project is approved unless the environmental flows of the downstream area are ensured.

e) Global Warming

The slow but continuous process of climate change and global warming is affecting river water supply, which is becoming unpredictable. According to a World Bank report on Water Economy of Pakistan, there will be dramatic decreases in the river flows after fifty years period of glacial retrect during which time river flows may increase exacerbating the already serious problems of flooding and drainage. This variability of flows presents serious challenges in the use and distribution of water which have to be met through careful management. The task of meeting these challenges gains added urgency in view of changing patterns of water needs as a result of agricultural diversification, accelerated pace of urbanization, industrialization, increasing pollution of surface and ground waters and environmental compulsions.

f) Per Capita Storage

Pakistan's storage capacity is only 1032 m^3/person compared to Australia's 5,000 m^3/person and the USA's of 6,150 m^3/person. Furthermore it is continuously being reduced because of sedimentation, and is negatively impacted by global warming and high levels of evaporation.

g) Productivity per Unit of Land

Pakistan's productivity per unit of land is one of the lowest in the world. This is despite the reasonably good potential that exists in Pakistan to enhance productivity. Progressive farmers in Pakistan have obtained yields of close to 60 mounds/acre compared to 8 mounds/acre by small farmers. Knowledge-based interventions and continuous support to small farmers are needed to enhance productivity. Given the global food shortage and high prices, Pakistan must improve its average productivity per unit of land, particularly for small farmers.

Table-3

Productivity per unit of land.

France	7.60 T/ha
Egypt	5.99 T/ha
Saudi Arabia	5.36 T/ha
Punjab (India)	4.80 T/ha
Punjab (Pakistan)	2.30 T/ha
Pakistan Av.	2.24 T/ha

Fig-4 shows the increase of Gross Domestic Product with time due to increased water availability.

3. Sedimentation of Reservoirs

Prior to construction of storages at Mangla, Chashma and Tarbela, country's water availability in Rabi and Kharif were 12% and 88% respectively. With the storages the percentage carry over from Kharif to Rabi increased from 12 to 21%.

The original live storage capacities of Tarbela, Chashma and Mangla were 9.69 MAF, 0.72 MAF and 5.6 MAF respectively (total 15.77 MAF) which regulated the seasonal river flows by storing the surplus water in summer and releasing it in winter. The storage capacities are gradually decreasing due to sedimentation at the rate of 0.126 MAF per annum. Tarbela has already lost its storage (year 2013) by 3.11 MAF, Mangla 0.85 MAF and Chashma 0.46 MAF. By year 2025, 5.96 MAF storage would be lost. Table-4 gives the storage capacities of the three reservoirs. On average 200 M tons of sediments is deposited each year in Tarbela reservoir which reduces its capacity by 0.11 MAF/year. Fig-5 shows a cross section through the delta of Tarbela reservoir.

Table 4
Storage and Sedimentation of Reservoirs

Several studies have been carried out for sediment management in Tarbela. Presently it is unfeasible to flush out sediments from the reservoir. Moreover, the negative impacts of the sediments on the downstream projects are enormous. Mangla dam has been raised by 30ft to add 2.88 MAF to its storage.

4. Bridging Gap between Water Demand and Supply

a) Water Storage

In order to meet future water requirements, it is necessary to create large storage dams on the Indus River. The Federal Government through WAPDA has launched comprehensive integrated water resource and hydropower development plan. Under this programme water storage / reservoir sites of about 20 MAF capacity, and sites with a power potential of 30,000 MW, have been identified Pakistan.

b) Storage Need

Pakistan is an arid country. The rainfall with monsoon is mainly during two months July &August. The max snow glacier melt is also during three months June, July and August. There is wide variation of river flows from year to year and from one season to another.

Fig.6 shows the max flows during 100 days, about 80% during Kharif season and rest of the nine months only 20% during Rabi season. In order to meet the agriculture water requirement for both the Kharif and Rabi crops, storages for seasonal carry over water are necessary.

Fig.7 shows Pakistan's storage viza viz other countries. Pakistan has not built any major storage dam since 1975, the completion of Tarbela dam. The existing storages are depleting due to sedimentation. Fig.8 shows escapages below Kotri to sea. This highlights the need of storages.

There are many run of rivers Hydropower sites on Indus, but large storages sites are only three; Kalabagh, Diamer Basha and Skardu. Skardu dam site is not feasible due to huge socio environmental and strategic impact. Kalabagh Dam with storage of 6 MAF and 3600 MW power potential is ready for construction waiting the consensus of the provinces. Diamer Basha Dam with storage of 6.4 MAF and power potential of 4500 MW is ready for construction with all the approvals but waiting for the financial commitment. Land is being acquired and infrastructure at site is being built. Construction of Kurram Tangi dam has been started. Mohmand dam and Akhori dam feasibility and design is being completed. Construction Tarbela 4th Extension 1450 MW and Dasu run of river Hydropower project phase-I 2150 MW has been started. Govt of Pakistan has entrusted Wapda to construct 12 small to medium dams in all the provinces of Pakistan.

Reservoir	Live Storage Capacity MAF		Storage Loss	
	Original	Year 2013	Year 2013	Year 2015
Tarbela	9.69 (1974)	6.58 (68%)	3.11 (32%)	4.16 (43%)
Mangla (Post Raising)	5.6 8.24 1967 (2012)	7.39 (90%)	0.85 (10%)	1.16 (20%)
Chashma	0.72 (1971)	0.26 (36%)	0.46 (64%)	0.64 (89%)
Total	18.65	14.23 (76%)	4.42 (24%)	5.96 (37%)

c) Water Conservation:

i. Lining of Canals/Distributaries:

Water Conservation can be achieved to some extent through lining of canals and distributaries in saline ground water zones. Properly designed and constructed lined channels can help save substantial quantities of precious water and ensure better command, equitable distribution of water and allow for increased channel capacities, The Lower Jhelum canal carries clean water from Mangla Lake but generally runs through lands underlain by saline ground water, Lining of this canal is being considered as a part of pilot programme for water conservation besides new proposals for lining of the three main canals in Sindh, i.e Rohri Canal, Rice Canal and Dadu Canal of Sukkur Barrage. Wapda has been entrusted with lining of Muzafargarh canal and D.G.Khan canal.

ii. Utilization of Flood Water/Hill Torrents:

The flood flow of all rivers and hill torrents of Balochistan alone has been estimated to be about 10 million acres. Rud koi (flood irrigation) system is being practiced in D.G Khan and D.I. Khan districts, storage work on Kaha hill torrent and others has been started.

d) On Farm Water Management:

i. Improvement of Water Courses:

Most of the water loss in Pakistan takes place at the farm level – principally as seepage from watercourse bed and sides and as percolation from fields below the root zone. A significant amount of irrigation water (20-25 percent) is lost during application because of uneven fields and poor farm design. Improvement of watercourses is taking place under the On-Farm Management Program. This would reduce field losses and improve the availability of water at the farm gate.

ii. High Efficiency Irrigation System:

Agricultural practices such as zero tillage, furrow-bed-irrigation systems and high efficiency irrigation system (including sprinkler and drip), would go a long way to increase conservation and water productivity. Precision land leveling is being carried out under the On-Farm Management Program. 11th Five year Plan (2013-18) will also promote Laser Land Leveling Services (LLLS) and high efficiency irrigation through Public-Private Partnerships (PPP). The Water Conservation and Productivity Enhancement through High Efficiency (Pressurized) Irrigation Systems Project aim to promote better agricultural practice by installing sprinkler /drip irrigation systems on 291,249 acres. The Federal Government is allocating Rs.18 billion for this project. Under 11th Five Year Plan (2013-18) this strategy will be continued, its scope expanded and also include command areas of recently taken up small and medium dams in the four provinces of Pakistan.

e) Treatment of Drainage Water / Effluent

Saline effluent from Sindh and Baluchistan is disposed of through canals and rivers into the sea. It is estimated that some of this water and about half of the groundwater can be used to supplement shortfalls in canals water supplies for crop production by adopting appropriate management practices or by treatment. This has to be adopted carefully to avoid secondary salinization. Efforts will be made by the provinces and WAPDA on a more extensive basis to convert this water into an economic resource. Saline water treatment plant for 40 cusecs has been set up by WAPDA along Right Bank outfall drain (RBOD) in Dadu District.

Drainage water treatment is mainly concerned with the removal of toxic elements from water. It could therefore be re-used, particularly by the Agriculture and industry. To reinforce the supply side, a new culture / program need to be promoted to reuse such water.

f) Operation and Maintenance of Infrastructure

WAPDA is responsible for construction and operation and maintenance of the large, multi-purpose reservoirs and inter-provincial link canals. Provincial Irrigation Departments (PIDs) are responsible for O&M of barrages main canals and the distributaries above outlets (moghas). O&M of watercourses and field channels are the responsibility of farmers. Drainage systems normally developed by WAPDA are handed over to PIDs for operation and maintenance.

The efficiency of delivery of the canal systems is low, ranging from 30% to 60% from canal head to the farm gate. Inefficient water delivery and water use also mean that, in reality, water does not reach users towards the tail-end of the system. In fact, inequity in the distribution of surface water-due to deliveries less than designed levels, poor O&M and even illegal diversion is a major concern. The gap between O&M expenditure and recoveries through water charges is high (44%) and

increasing which is another major concern.

Construction of irrigation system in the Indus Basin was started by the British engineers in the middle of the 18th century. The system has progressively deteriorated because of aging, inadequate maintenance and overstressing of the channels and structures. In most cases the canals have been run beyond their designed capacities in order to meet the enhanced water demand. This affects the channel regime and operational safety of hydraulic structures.

Many of the hydraulic structures have outlived their useful life and are now susceptible to serious damages. The collapse of outfall structure of Balloki Sulemanki Link and regulatory structure of Marala Ravi Link canal raised serious concerns about the state of health of the system. The recent damages at Sukkur, Taunsa and Jinnah Barrages have further heightened the concerns regarding the safety of the barrages which are the most important components of the irrigation network. The surveys have revealed that many important structures including barrages and canal head works are in precarious state and need urgent rehabilitation. Some projects have already been taken up whereas others wait funding.

To meet national sustainable development goals and tackle specific water challenges, Pakistan needs to make higher investments in water infrastructure, treatment plants, irrigation systems, hydropower plants, storage enhancement, drainage and reuse/recycling of non-consumptive water, and other related areas.

In the 11th Five Year Plan (2013-18) efforts to enhance surface storage, including construction of small, medium and large dams, will be intensified by the Federal and Provincial Governments. Assets protection will be facilitated by addressing on a priority basis, the deferred maintenance of existing infrastructure. Four barrages are being rehabilitated and upgraded in Punjab. Sukkur barrage in Sindh is being rehabilitated.

5. Value of Water Flowing to Sea

Fig.8 shows on the average 30 MAF of water flows down to sea. The value of this water which is not being stored due to lack of adequate storage, is estimated to US$ 3.2 billion. The value added cost of agriculture production will be US$ 9 billion. In addition the flood mitigation benefits will be US $ 1 billion on average per year. Construction of additional storage facilities will bring fringe benefits to the country which will ensure socio-economic uplift of the people.

6. Irrigated Agriculture and its Difficulties

Pakistan has the oldest and largest contigious irrigation system in the world. Pakistan's irrigation and drainage system is now in dire state. Despite substantial budgetary input, it is facing a shortage of resources and suffering from servere and worsening operational problems.

The Indus Basin Irrigation System, the prime source of Pakistan's water resources, comprises the Indus river, its main tributaries, and three major reservoirs (Tarbela, Mangla and Chashma). River water is diverted by barrages and weirs into main canals and branch channels, distributaries, and minors. Fig.9 shows the schematic diagram of the irrigation network. Groups of farms are served by watercourses, connected to the system at "moghas". There are 19 barrages, 11 Link Canals and 55 main canals total length of main canals and distributaries is 16000 KM and length of water courses is more than 1 million Kilometers.

IRSA estimates the water availability for every following season. Provincial Irrigation Departments (PIDs) inform IRSA of their respective water demands at specific locations. WAPDA on receiving the indents from IRSA releases water from reservoirs to meet demands as closely as possible. Limited reservoir capacity of the system does not allow full regulation of rivers for irrigation. Pakistan's problems are common to many irrigation systems like waterlogging and salinity, over-exploitation of fresh groundwater, low efficiency in delivery and use, inequitable distribution, unreliable delivery, and insufficient cost recovery.

The Indus Basin has flat topography, poor natural drainage, porous soils, and a semi-arid climate with high evaporation. In such an environment, irrigation without adequate drainage has led to rising water tables and salinity. Increases in diversion of river flows, and seepage from canals, watercourses and irrigated farms have led to gradual rise in groundwater levels.

The cropped area of Pakistan was 21.82 M.Ha in 1990-91. By 2008-09 the cropped area increased to 24.12 M.Ha and since then has decreased a little to 22.45 M.Ha in 2012. Crop water requirement is influenced by various factors such as cropping pattern, crop varieties, crop duration (sowing and harvesting time), weather and climatic conditions of the

area, type of soil, irrigation methods, amount of availability of water, non-water inputs used, size of land holdings etc.

The present cropping intensity in Pakistan is more than 150%, against original designed 80% of the canal system which justifies demand for increased water allowance. Due to rigid and un-flexible irrigation system, there is a general shortage of water and irrigation supply which do not suffice for meeting the annual water requirements of most crops, especially during hot summer month when evaporation is high.

7. Policy Frame Work

7.1 Policies will aim at:

a) Setting goals for water use, protection and conservation.

b) Addressing the serious management challenges faced and modernizing and updating institutional structures to meet these effectively. The national water policy should be adopted on a priority basis. This will facilitate to formulate an appropriate legislative frame work.

7.2 Legislative Frame Work: A special committee comprising of water experts and other specialists should be constituted to review the existing laws and make recommendations for possible improvements. In case of any shortcomings in existing legislation, the committee should recommend new water laws for better management of the resources.

7.3 Regulation: Regulatory policies and instruments should be formulated to support:

- Reducing water wastages.
- Checking pollution of fresh water storages.
- Regulating ground water extraction.
- Conserving water in all sub sectors.
- Reducing non-revenue water in these sectors.
- Assessing accurately the availability of surface water, rain water and ground water and its most economic and optimal use.
- Initiating detailed geophysical surveys to assess the quality and quantity of ground water.
- Economizing and enhancing surface storage and regulating ground water recharge.

7.4 Integrated Water Resources Management (IWRM)

The integrated water resources management approach helps to manage and develop water resources in a sustainable and balanced way, taking account of social, economic and environmental interests. It recognizes the many different and competing interest groups, the sectors that use and abuse water, and the needs of the environment. The integrated approach co-ordinates water resources management across sectors and interest groups, and at different scales, from local to international. It emphasizes involvement in national policy and law making processes, establishing good governance and creates effective institutional and regulatory arrangements as routes to more equitable and sustainable decisions. A range of tools, such as social and environmental assessments, economic instruments, and information and monitoring systems, support this process.

8. Conclusions of Recommendations

i) Tackle water scarcity issue through both augmentation and conservation i.e by constructing medium and large dams, making more efficient and sustainable use of water and existing irrigated areas.

ii) Major water sector's policies and strategies should be based on the principles of Integrated Water Resources Management (IWRM).

iii) Control the impact of water logging, salinity and floods hazards.

iv) Regulated ground water pumpage and its management.

v) Capacity building of water sector institutions; establish effective organization and management mechanisms through institutional reforms and private sector participation.

vi) Develop knowledge-based water resources management.

vii) Implement policies for sustainable and productive use of water.

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Figure 1

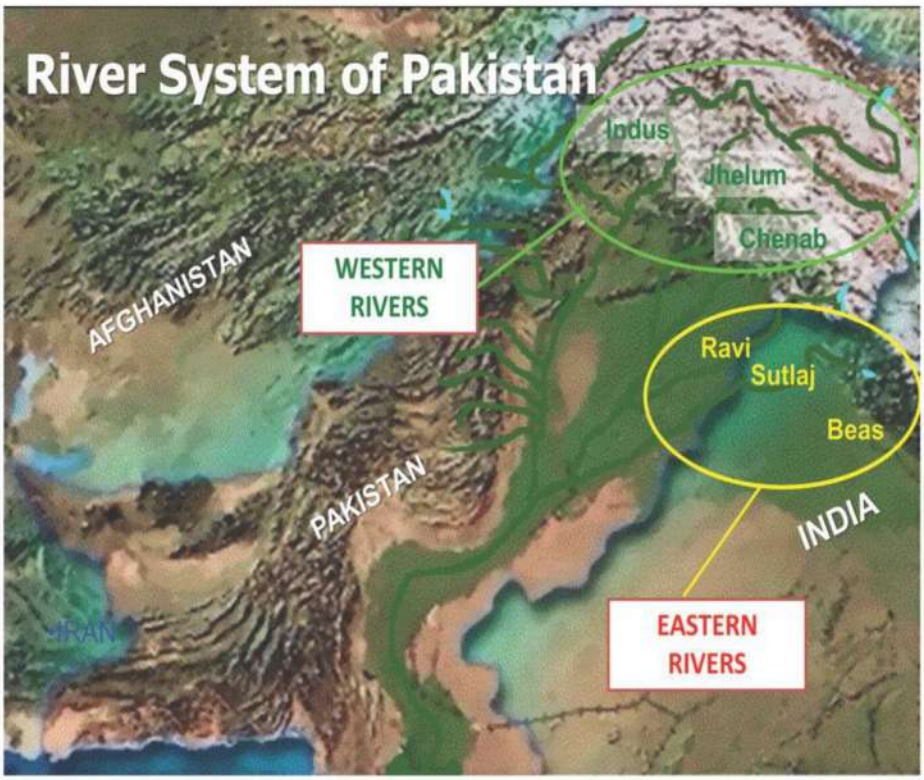
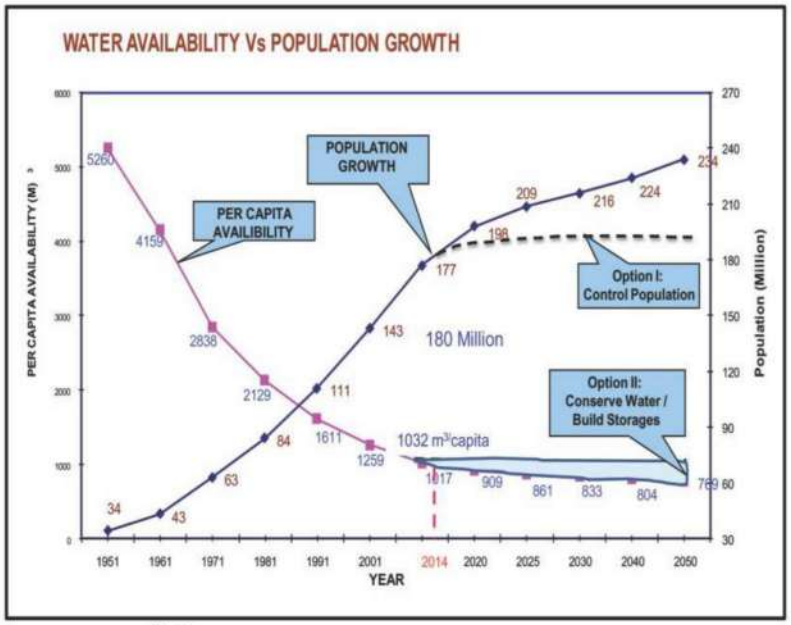


Figure 2

WATER AVAILABILITY vis-a-vis POPULATION



Source:
Population: Population Census Organization Pakistan
Water Availability: 180 BCM

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Figure 3

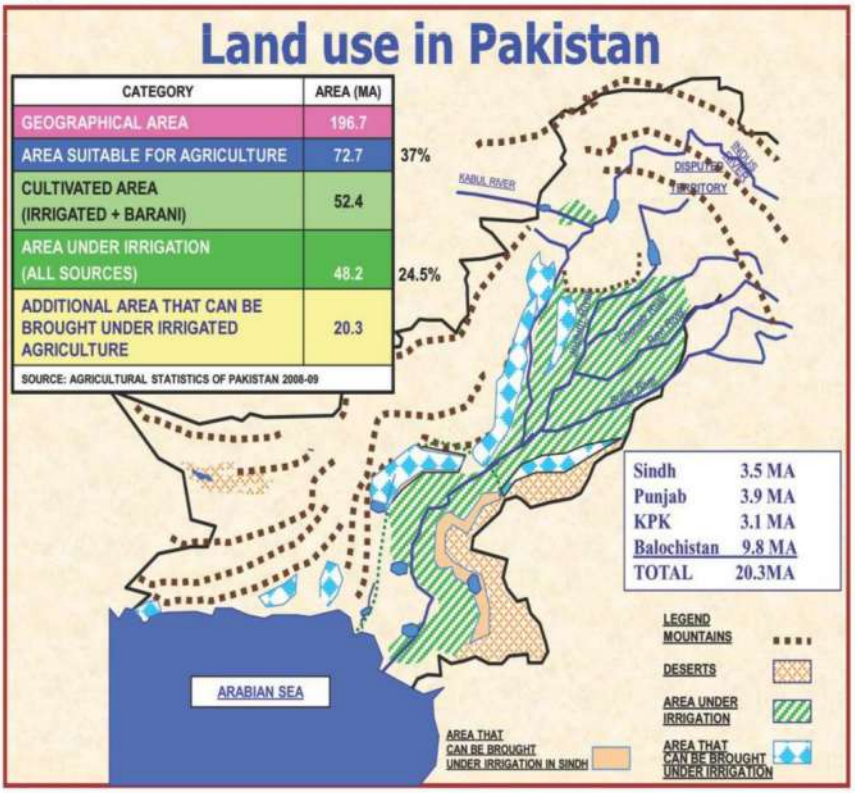

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Figure 4

- The World Bank had conducted this study in 1965 through a study group headed by Pieter Lieftinck.
- The study states that " a new reservoir the size of Tarbela dam will have to be built every decade for the foreseeable future"

Figure 5

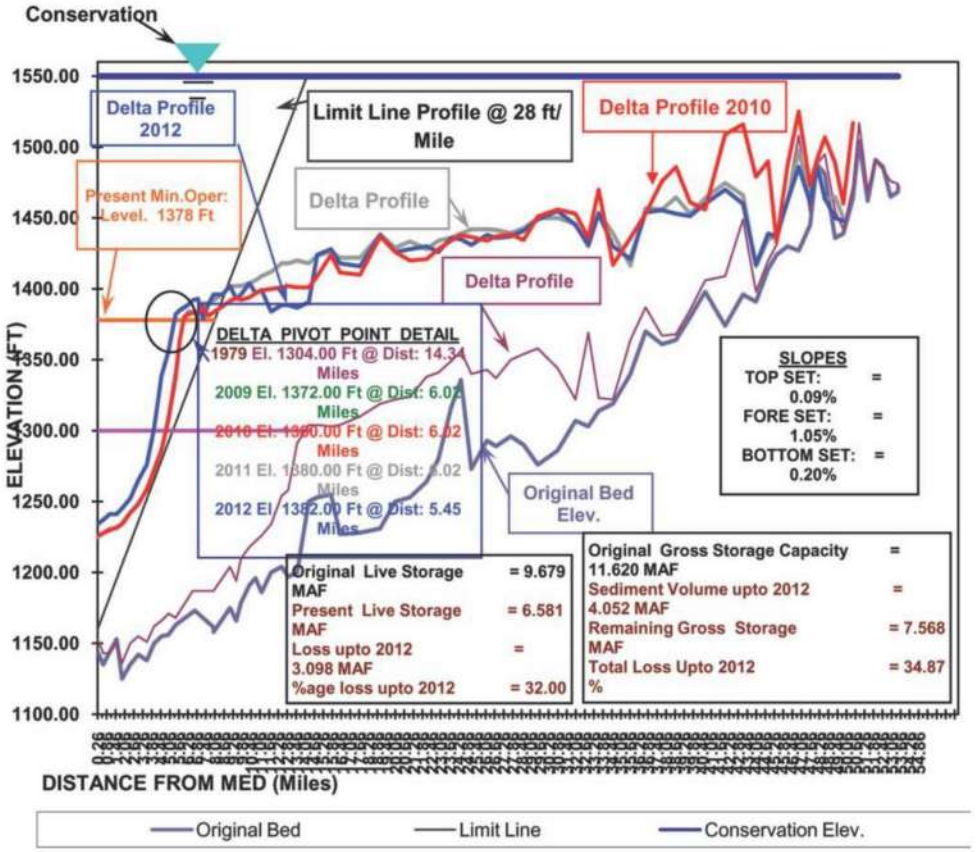
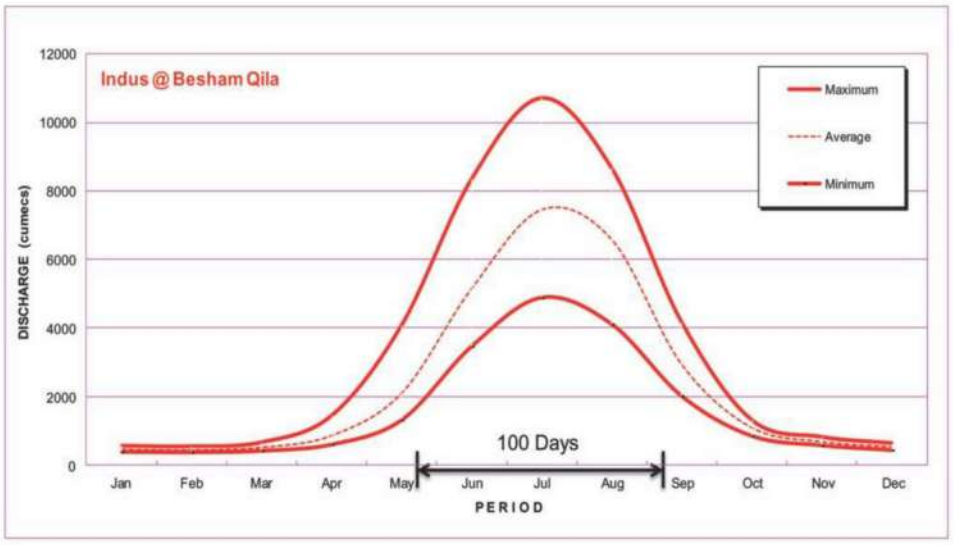


Figure 6

UPPER INDUS BASIN WATER VARIABILITY



Availability – 100 days, 80% of inflow, rest 20% comes in the rest of the year
Variability - Minimum 92 MAF (113.5 BCM) to Maximum 180 MAF (222.1 BCM)
Uncertainty

10

Figure 7

Average Annual Flow and Storage Capacity of Dams of some Major River Basins

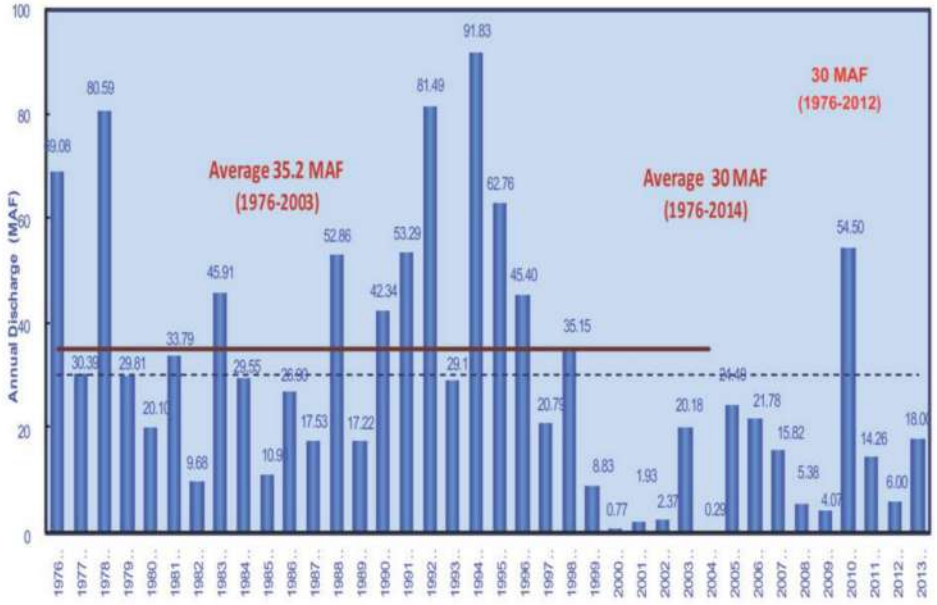
RIVER BASIN	AVERAGE ANNUAL FLOW (MAF)	NO. OF DAMS	LIVE STORAGE CAPACITY (MAF)	%AGE STORAGE
Colorado	12	3	59.62	497
Nile	47	1	132	281
Sutlej Beas	32	5	11.32	35
Yellow River	345	7	68.95	20
Pakistan Indus System	145	3	15.75	11*
World Average	20,000	-	8,000	40

** Post Mangla Dam Raising (2012)*

14

Figure 8

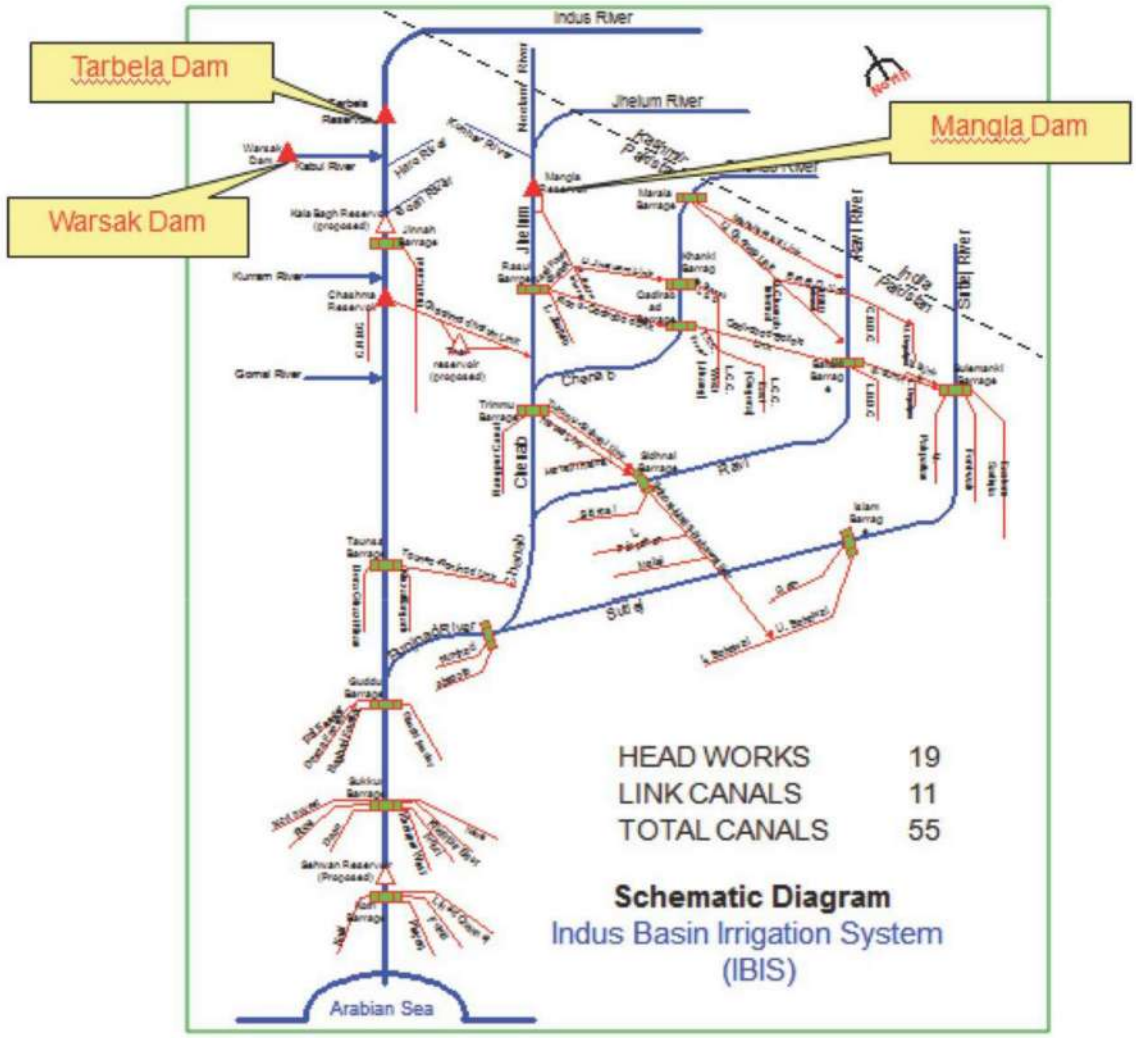
Escapage below Kotri (MAF) to Sea



Source: WRMD WAPDA based on data supplied by Govt. of Sindh

19

Figure 9


Tarbela Dam
Warsak Dam
Mangla Dam
Indus River
Jhelum River
Arabian Sea
HEAD WORKS 19
LINK CANALS 11
TOTAL CANALS 55
Schematic Diagram
Indus Basin Irrigation System
(IBIS)

Sustainable Measures for Mitigating Damages Caused by Floods/Rains to Civil Works

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Abstract.
District Jaffarabad which is also the food basket of Baluchistan (Pakistan) was hit by a calamity by the torrential and unprecedented monsoon rainfall in September 2012. The drainage network was severely damaged causing breaches in the canals resulting in breakdown of the entire irrigation and drainage network. The flood badly affected the built-up structures, buildings, houses and etc. The population and livestock was displaced and exposed to vagaries of nature.

A survey team from Pakistan's, Council for Works and Housing Research (CWHR) visited District Jaffarabad in November 2012 and carried out condition survey of civil works to highlight sustainable and socially acceptable measures for mitigating damages to civil works caused by floods/rains in District Jaffarabad, Baluchistan.

Data related to the floods were collected, meetings were held with the officials of local administration as well as local people, physical inspections were conducted and samples of construction materials were collected from different locations in District Jaffarabad and tested at CWHR.

The root cause of all damages to civil works was undisputedly the sub-standard quality of construction. Unrealistic cost estimates during the planning and implementation of civil works led to compromise in the quality of construction.

This paper highlights the cost estimates for major construction inputs, i.e. excavation works, cement concrete works, plaster works and masonry works, adopted for District Jaffarabad and those adopted by other federally controlled government organizations of Pakistan. On conducting a comprehensive rate analysis on these major construction inputs it was concluded that the cost estimates adopted by construction works in District Jaffarabad were 150% less than the prevailing market rates.
Some recommendations are outlined emphasizing the infrastructure planners' ways and means to control unrealistic costing as one of the key sustainable measure for mitigating damages to civil works structures caused by floods/rains in District Jaffarabad, Baluchistan, Pakistan.

Introduction

Jaffarabad District is one of the 30 Districts of the Baluchistan Province. The district is located in the south-east of the Quetta City, the provincial capital of Baluchistan, sharing its southern boundaries with Sindh Province (i.e. Districts Larkana and Jacobabad) and Nasirabad District of Baluchistan, in the North. (Figure 1).

The lively hood of the entire population of District Jaffarabad depends upon the Canal System that comprises of the main Pat Feeder Canal, its distribution network, the Rabi Canal,

Uch Canal, Manjuthi Canal, main Kirthar Canal and its distribution network. The drainage network comprises of Haridin Drain, (commonly known as Saem Nallah) Carrier Drains 1 & 2 and Outfall Drain. On the basis of statistical probability, District Jaffarabad is under high risk of flooding. (Figure 2)

The reported population of district Jaffarabad in 1998 was 433,000 and the projected population by the end of 2012 was estimated to be 667,000. Area-wise District Jaffarabad ranks 2nd smallest district in Baluchistan and has an area of 2,445 square kilometers. Agriculture and livestock is the main productive sector of the District with 90% of a total potential area for cultivation. This district is highly productive in agriculture sector and main source of water is canals from Indus River. The average yield of major crops in District Jaffarabad is high as compared to other areas of Pakistan. However, forests and growth of trees are practically non-existent.

All major towns and villages of the district are linked with a network of metallic roads. In addition, there is a railway station at Dera Allah Yar which connects Jaffarabad to the rest of Pakistan. An overview of civil works and infrastructure of District Jaffarabad is outlined at Table: 1

Table1: Overview of civil works and infrastructure of District Jaffarabad

i.	Road Network (Metalled/Black Topped)	1,100 KM
ii	Canals and Drainage Network	2,985 KM
iii	Number of Pacca Houses	5,420 Nos.
iv	Number of Semi-Pacca Houses	7,599 Nos.
v.	Number of Katcha Houses	47,845 Nos.
vi	Number of Government Primary Schools	824 Nos.
vii.	Number of Government Middle Schools	43 Nos.
viii.	Number of Government High Schools	34 Nos.
ix.	Filter Plants	45 Nos.
x.	Number of Hospitals	3 Nos.
xi.	Number of Rural Health Centers	1 Nos.
xii.	Basic Health Units	31 Nos.
xiii.	Dispensaries and auxiliary health related units	50 Nos.

Figure 1: Districts of Baluchistan Province

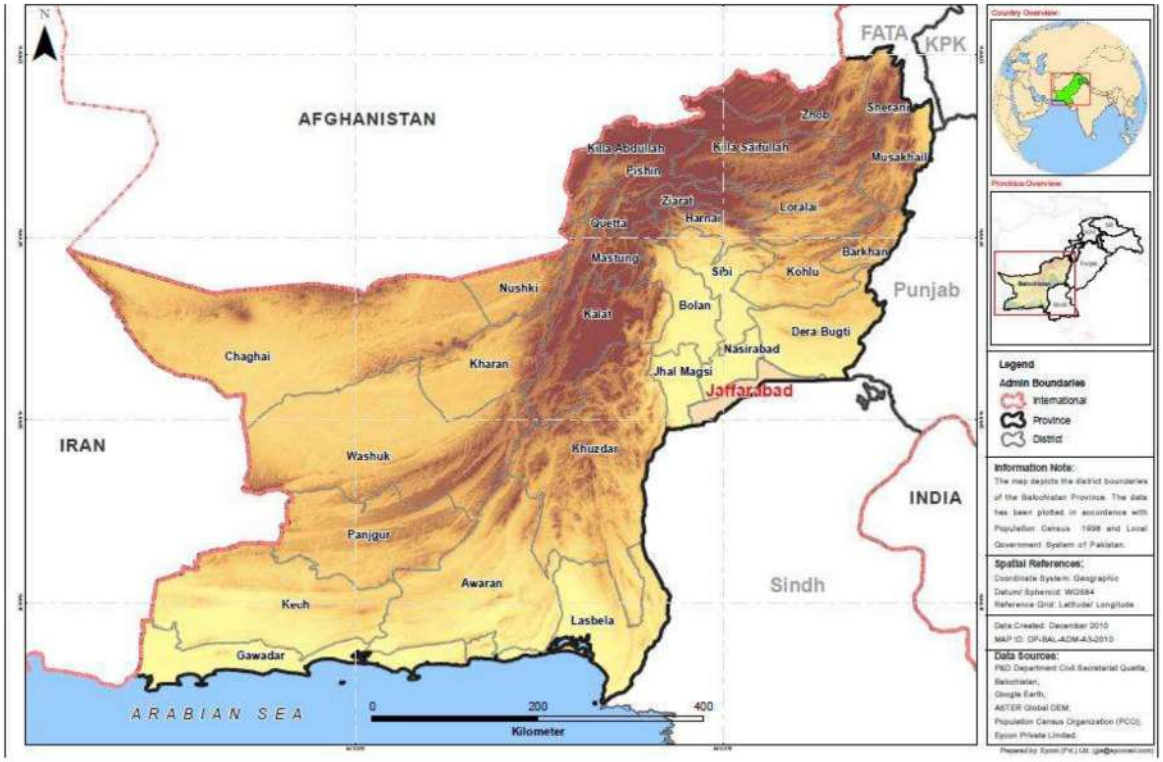
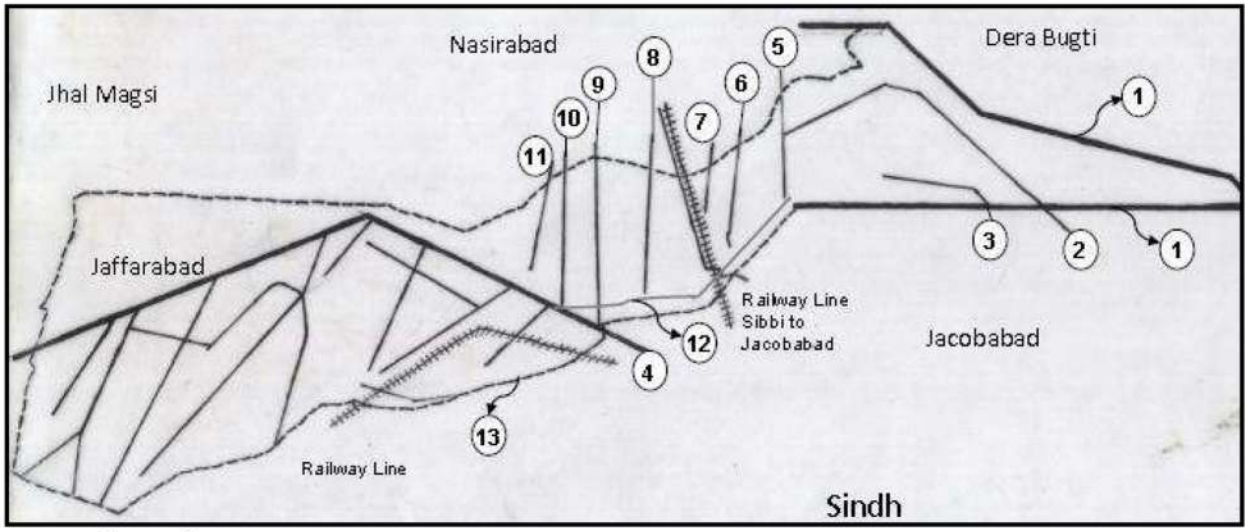


Figure 2: Irrigation and Drainage Network of District Jaffarabad



Legend:

1.Pat Feeder Canal
2.Uch Canal
3. Shahi Canal
4. Kirthar Canal
5. Naseer Branch
6. Jadier Branch
7.Timpal Branch
8. Jhatpat Branch
9. Muhabbat Branch
10.Balan Branch
11. Hari Branch
12. Haridin Drain (Saem Nallah)
13. Boundary of District Jaffarabad

Background of Flooding in District Jaffarabad

Monsoon 2012 was a calamity for District Jaffarabad due to heavy rainfall. The drainage network to drain away the flood water was already in a dilapidated state due to damages caused during the 2010 floods. Further devastations were caused due to the following reasons:

1st spell of rains (6th to7 th September 2012) caused flash floods from Marri Bugti Hill Torrents that rushed towards the Pat Feeder Canal. The torrents created a pond along the right bank of the Pat Feeder Canal with significant depth of water.

2nd spell of rain (9th to 10th September 2012) was unprecedented and almost 375 mm of rain was recorded in the catchment area including adjoining areas of Sindh. This caused damages to the Flood Irrigation System.

The pond created along the right bank of Pat Feeder Canal rose to an abnormal height that resulted in breaches at the right bank.

On 11th September, 2012, three breaches were developed in Pat Feeder Canal at Kalani, Hairdin and Penhwari that submerged Sohbatpur, Dera Allah Yar and dozens of other villages.

The main breach in Pat Feeder Canal was reported to be about 40 feet wide. Rabi Canal the 1st defense to Pat Feeder Canal was completely washed away or severely damaged.

Flood waters from Pat Feeder Canal caused breaches in Uch Canal, Shahi Canal and Manjuthi Canal at several locations that inundated many low-lying villages.

Kirthar Canal was breached at several places as torrents from Sindh continued to lash the areas. The canal had a capacity of about 3,000 cusecs but upto 15,000 cusecs of flood water was flowing into it from the Sindh side.

Figure 3: An Aerial View of District Jaffarabad taken on September 14, 2012

In order to avert serious damages to the main canal, the flood flows were diverted to distribution networks. Since there was no demand for irrigation water, the diverted water damaged the embankments at tail ends of various distributaries.
(Figures 2 and 3)

Post Flooding Phase

The vulnerability of civil works is dependent on construction methods and building materials. Even with measures to flood proof buildings, water will tend to find its way through weak points within the wall such as cracks and voids in the mortar jointing, brickwork or renderings. Floodwater causes widespread damage to roads, floors, walls, finishes, services and structural damages. Some of the effects of floodwater on building structure and on the health of the occupants are as follows:

- Contamination by sewage and the sediments from both watercourses and blocked drains.
- External walls will be dirty and may be permanently stained.
- Damp conditions may lead to the growth of moulds that can damage the building and present a health hazard.
- Buildings with excess moisture, poor ventilation and exposed to standing floodwater can be breeding grounds for moulds that have potential to cause health hazards.
- Corrosion can occur due to chemical contaminants.
- Flooding can change hydrostatic pressure due to waves and cause scouring/undermining the foundations.
- Masonry and concrete are unlikely to be severely damaged by contact with floodwater. However saline/brackish water may cause surface powdering and flaking of soft brickwork. Lightweight concrete may expand and contract depending on moisture content so wetting and drying may cause some cracking.
- Timber swells and may distort on wetting causing damage to other parts of the structure.

Timbers that become wet and cannot dry may be at risk of decay in the long term.

- Renderings containing cement are unlikely to suffer damage. However, plasterboards will be damaged beyond repair and require to be removed.

The impact of floodwater in District Jaffarabad in September 2012 was devastating for the road network, building structures and other miscellaneous civil works. Some examples are depicted in Figures 4 to 11.

Figure 4: Flood Water on both sides of National Highway (N-65) leading to Dera Allah Yar, Jaffarabad.

Figure 5: A view of village settlement inundated in flood water/stagnant since September 2012. Location along N-65 near the border of Baluchistan/Sindh.

Figure 6: Hair Din Drain meant for carrying drainage water of the city Dera Allah Yar showing damaged banks and reduction of its capacity Baluchistan/Sindh.

Figure 7: In order to safeguard the town of Dera Allah Yar from total inundation and destruction, the National Highway N-65 was cut through to avoid backflow of water. This allowed the water to flow across the N-65. Location near the border of Baluchistan/Sindh.

Figure 8: Contamination by sewage and the sediments from both watercourses and blocked drains. (Block of latrines for villagers)

Figure 9: Marks of flood water can be seen upto window level at a Rural Health Center. The flood water has eroded the concrete plinth beam and discolored the brick wall.

Figure 10: Decay, discoloring and wearing of surface finishes of Masonry at a local school.

Figure 11: External walls of the local school are permanently stained and damp conditions likely to be health hazardous

Objectives of the Study

Survey of damages to buildings, houses and other civil works structures, to assess the causes of damages, identification of construction materials, local construction practices with an objective to suggest sustainable measures to mitigate similar destruction in future.

Methodology Adopted

The following methodology was adopted:

i. Review of technical and reference documents related to District Jaffarabad.
ii. Collection of secondary and tertiary data related to floods in Jaffarabad.
iii. Meetings with local officials.
iv. Physical Inspection and condition surveys at different locations.
v. Collection of samples of construction materials (raw) as well as finished products.
vi. Market survey and cost estimation of construction inputs for District Jaffarabad.

Scope of this Paper

Since the root cause of all damages to civil works was undisputedly the sub-standard quality of construction, therefore this paper is primarily focused on the aspect and impact of unrealistic cost estimates prepared during the planning and implementation of civil works that led to compromise in the quality of construction.

Quality of Construction Materials

Durability of buildings and roads largely depend on the quality of construction materials best suited to the local environment. District Jaffarabad has an advantage of effective road network and hence most of its building materials are transported except for some locally produced katcha bricks. Since the agricultural activities of the District is very high, the ground water level is normally high and salinity in the ground water and clay make them undesirable for use in construction. Table 2 shows some of the commonly used construction materials and the source of supply from other cities.

Table 2: Major Construction Materials Used In District Jaffarabad and Source of Supply.

	Name of Material	Source
1	Cement, generally Ordinary Portland Cement	Jacobabad, Quetta,
2	Sand (Fine Aggregate)	Jacobabad, Quetta
3	Coarse Aggregates or Crushed Aggregates	Jacobabad, Quetta
4	Sun-Dried or Un-Fired Clay Bricks	Locally produced in Jaffarabad, Jacobabad
5	Fired Clay Bricks (Pacaa Bricks)	Quetta, Sibi, Rahim Yar Khan, Jaffarabad.
6	Roof Clay Tiles	Quetta, Sibi, Jacobabad
7	Steel Reinforcement	Jacobabad, Quetta
8	Steel Girders	Jacobabad, Quetta
9	T-Iron Girders	Jacobabad, Quetta

Some random samples of bricks collected from Dera Allah Yar (Jaffarabad) were tested at the CWHR laboratories. The test results revealed that the quality of the stock being supplied to local stockiest from different sources was not satisfactory. The partially burnt clay tiles and bricks were sold in the market at the cost of fully burnt clay bricks. This not only caused financial loss to buyers, but the durability of the buildings constructed using such bricks was compromised and vulnerable to damages.

Similarly, Sulphate Resistant Cement (SRC) is generally not used for concrete construction in Jaffarabad; only Ordinary Portland Cement (OPC) is being used, which unfortunately is not able to protect the exposed brick masonry or concrete from salt attacks.

In general, there are no testing laboratories in District Jaffarabad where quality of the construction materials could be tested before utilizing them. Quality testing of construction materials is most essentially required for all post flood rehabilitation and reconstruction activities.

Cost Estimation for Civil Works Programmes.

During the course of discussions with various officials of the line

departments involved in the development and maintenance works for District Jaffarabad, it was revealed that cost estimates for Civil Works Programmes were computed on the basis of Baluchistan's Composite Schedule of Rates (CSR) 1998 with a general premium of 47% for all items except steel, for which the premium rate was 127%.

The basis for preparing cost estimates on the above criteria is unrealistic and it is quite likely that in order to meet development/maintenance targets within the departments estimated costs, the quality of materials and construction is compromised substantially. These factors have caused damages to the civil works in District Jaffarabad as substandard materials and construction quality could not sustain the pressures caused by flooding and rains in 2010 and 2012.

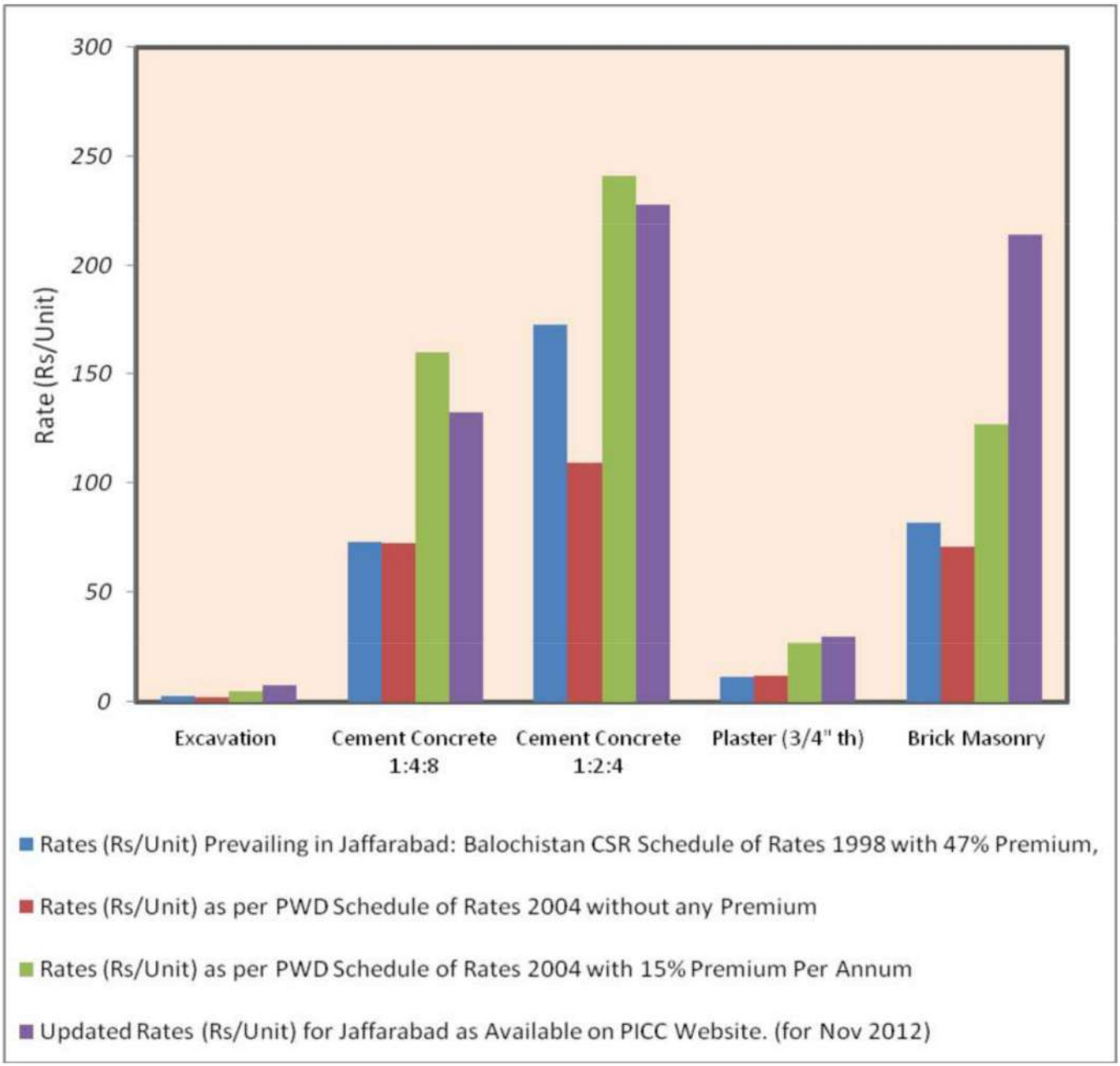
It is worth mentioning here that the PWD Schedule of Rates 2004 is commonly adopted by most of the organizations working under the Federal Government (Pakistan) with a minimum premium of 120%. On the other hand, the Pakistan Engineering Council has established Pakistan Institute of Costs and Contracts (PICC) that works out the rates of about 2500 basic input items for construction and nearly 950 composite item rates related to development works for different districts and regions of Pakistan. The PICC updates the data on monthly basis and is posted regularly on their website.

In order to draw out a comparison of the cost estimates currently prepared for District Jaffarabad and those normally used by Federal Government Organizations, rate analysis was carried out on 5 major construction inputs, i.e. Excavation, Cement Concrete (Mix Ratio by volume 1:4:8), Cement Concrete (Mix Ratio volume 1:2:4), ¾" thick plaster and Brick Masonry. Summary of the rates per unit (in Pak Rupees) are tabulated in Table 3 and graphically represented as Figure 12.

Table 4.10: Comparison of Rates for Major Construction Inputs (For District Jaffarabad in November 2012)

Description	Excavation	Cement Concrete 1:4:8	Cement Concrete 1:2:4	Plaster (3/4" th)	Brick Masonry
	Rates [Rs/CFT]	Rates [Rs/CFT]	Rates [Rs/CFT]	Rates [Rs/SFT]	Rates [Rs/CFT]
As per Baluchistan CSR Schedule of Rates 1998 with 47% Premium,	2.63	72.94	172.6	11.67	82.08
As per PWD Schedule of Rates 2004 without any Premium	2.18	72.91	109.71	12.32	71.27
As per PWD Schedule of Rates 2004 with 15% Premium Per Annum	4.796	160.402	241.362	27.104	127.424
Updated for Jaffarabad as Available on PICC Website. (for Nov 2012)	7.54	132.55	227.96	29.99	214.19

Figure 12: Graphical Comparison of Rates for Major Construction Inputs (For District Jaffarabad in November 2012)



Conclusions

The item rates for construction works adopted by Baluchistan Government for District were unrealistic and almost 150% less than the prevailing market rates.

Recommendations

In order to ensure good and safe construction practices, the cost estimates prepared by government departments must be based on realistic cost estimates. The Government of Baluchistan must review their item rates and Premiums based on Composite Schedule of Rates 1998 and adopt the rates that are scientifically documented after thorough research and published regularly on monthly basis by the Pakistan Institute of Cost and Contracts (PICC).

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A Comparative Study of Various Concrete Mixes

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Abstract
Cement concrete being a heterogeneous material, is susceptible to large variations in its properties, especially, compressive strength. Compressive strength of concrete largely depends on the selection of proportions of the ingredients and method of batching. Other factors which affect the strength of concrete are water/cement ratio, method of mixing, compaction and curing. There are several methods for selection of concrete mix proportions, ACI and DOE (British) methods being the most popular. In Pakistan, use of nominal concrete mixes and volumetric batching are commonly in practice. A comparative study of various concrete mixes has been conducted demonstrating that weigh-batched and properly designed mixes produce satisfactory results; whereas, level of confidence for nominal mixes is low. Use of plasticizer was not considered. Volumetric batching should be discouraged because at even higher costs it does not produce the desired strength. Gradation of coarse and, especially, fine aggregate, has a major effect on the compressive strength of concrete.

1. Introduction

Cement concrete, commonly known as concrete is a heterogeneous material comprising Portland cement, Fine Aggregate or Sand, Coarse Aggregate or crushed stone and water. In Pakistan, concrete is a prime building construction material after bricks. On small to medium public sector projects and private residential buildings normally concrete is specified in terms of proportion of its constituents, e.g., 1:2:4 (i.e., one part Cement, two parts Fine Aggregate and four parts Coarse Aggregate). This is termed as nominal mix. On projects designed by consultants, concrete is specified in terms of compressive strength, e.g., 22 MPa (3,000 psi) cylinder (3,750 psi, cube) compressive strength at an age of 28 days; which is still achieved by volumetric batching and with some control over amount of mixing water and use of water reducing agents.

The same nominal mix (e.g., 1:2:4) may produce different compressive strengths owing to variations mainly in water/cement (w/c) ratio, gradation of fine aggregate and its Fineness Modulus (FM) and gradation of coarse aggregate and its shape & maximum (nominal) size (such as ½ inch = 13mm). Besides, method of mixing concrete, curing temperature, nature of curing, period of curing, method of placement and compaction as well as method of taking test specimen (cylinders or cubes) and testing may introduce variation in compressive strength.

2. Concrete Mix Design Methods

It is very difficult to produce concrete of consistent quality by using nominal mixes. This

necessitates for such a methodology for determination of proportions of cement, fine aggregate, coarse aggregate and water so as to ensure a definite minimum compressive strength at the age of 28 days. These procedures are termed as concrete mix design methods. Although there is a variety of concrete mix design methods, the most popular and widely used are American Concrete Institute (ACI) method and Department of Environment (DOE) or British method of concrete mix design.

3. The Study

A comparative study of various concrete mixes was conducted by the authors in Material Testing & Field Control Laboratory, Military Engineers Services (MES), Quetta Cantonment. Use of plasticizers (water reducing agents) was not considered and w/c ratio was fixed as 0.6 to simulate field conditions. The following concrete mixes were included in the study:

- American Concrete Institute (ACI) Method for Selecting Proportions of Normal Concrete
- Department of Environment (DOE)/British Method of Concrete Mix Design
- Nominal Concrete Mix (Weight-Based)
- Nominal Concrete Mix (Volume-Based)

4. Materials

Ordinary Portland Cement (OPC) Type-I was used in the study. The Brand of cement used was "DG Cement". The natural sand available from Ghaza Bund (situated about 40 km NW of Quetta) was found to be too fine (FM=0.919) to make good concrete. Stone dust (manufactured sand) from Kuchlak crushing plant (situated at about 30 km West of Quetta) was blended with Gaza Bund sand in proportion of 50:50 to obtain a fine aggregate having FM Value of 2.83. The gradation of blended fine aggregate conformed to BS 882: 1992 specifications. The gradation is not given here due to space limitations.

Coarse Aggregate in the form of crushed sand stone, having ¾" maximum size, from Kuchlak crushing plant was used in the study. This did not exactly conform to either ASTM C 33-1993 or BS-882: 1992. The deviation from the specifications was minor; therefore did not warrant blending of the coarse aggregate.

For determination of proportion of constituent materials of concrete certain material properties should be known. These material properties, as found after laboratory testing, have been listed in Table 1.

Table 1: Properties of Materials for Concrete

MATERIAL	PROPERTIES			
CEMENT	Specific Gravity	=	3.15*	
FINE AGGREGATE	Specific Gravity	=	2.57	
	Absorption	=	1.969	%
	Fineness Modulus (FM)	=	2.83	
COARSE AGGREGATE	Maximum Size	=	19	mm
	Dry Rodded Unit Weight (SSD)	=	1602	kg/m
	Specific Gravity	=	2.60	
	Absorption	=	0.596	%

* Standard value as reported in technical literature.

Various methods for selection of concrete mix proportions (mix design) considered in this study are described in brief as follows.

5. American Concrete Institute Method for Selecting Proportions of Normal Concrete

Also known as ACI Method, it is based on the approach that for a given maximum size of a Coarse Aggregate, the water content (in kilograms per cubic meter) determines the workability of the mix, regardless of the mix proportions. Quantity of coarse aggregate in the mix is dependent on the maximum size of coarse aggregate and fineness modulus (FM) of fine aggregate. Water cement ratio is determined from the strength requirements and exposure conditions. This method is logical and straightforward.

6. Department of Environment (DOE)/British Method of Concrete Mix Design

The DOE method of concrete mix design has been published by the Building Research Establishment, Department of Environment of United Kingdom. In this method, the free water/cement ratio for a target mean strength is determined based upon type of cement and angularity of coarse aggregate. The required water content depends on the maximum size of coarse aggregate and workability. The total aggregate content is determined from the difference between the wet density of concrete and cement & water content. The proportion of fine and coarse aggregate is determined from a set of curves involving parameters like w/c ratio, workability and maximum size of coarse aggregate. British

method is comparatively complex.

7. Weight-Based and Volume-Based Nominal Mixes

Weight-based nominal proportioning such as 1:2:4 is straight-forward as, 1 kg of cement, 2 kg of fine aggregate and 4 kg of coarse aggregate will produce 1:2:4 concrete mix. Volumetric batching is achieved by using a measuring box (such as one foot cube) and mixing them in the required proportions. Quantity of water required in both the cases is based upon w/c ratio which is fixed to obtain a certain compressive strength and workability range. Guidelines for both types of nominal mixes are given in some Indian handbooks.

Proportions of materials for the above four types of concrete mixes, determined by using respective concrete mix design methods, are summarized in Table 2. Some interesting material facts such as fine to coarse aggregate ratios in the total aggregates and total aggregate to cement ratio are presented in Table 3.

Six 150mm (6") cubes for each mix were cast and cured in the laboratory. A set of two cubes was tested at the ages of 7, 14 and 28 days. Since all the specification relating to testing of concrete, except ACI, use compressive strength of 150mm cubes, cube crushing strength is used. A reduction factor of 0.8 was applied to the cube strength to obtain the corresponding cylinder strength. The compressive strengths of various concrete mixes at the age of 28 days only are reported in Table 4, due to space limitations.

Table 2: Concrete Mix Proportions

MIX NO.	CONCRETE MIX DESIGN METHOD	PROPORTIONS (kg)				VOLUME (m3)	FRESH DENSITY** (kg/m^3)
				AGGREGATES			
		WATER	CEMENT	FINE	COARSE		
1	**ACI (American)**	**205**	**342**	**735**	**988**	**1.000**	**2,270**
2	**DOE (British)**	**225**	**375**	**674**	**971**	**1.000**	**2,245**
3	**Nominal 1:1½:3 (Wt.)**	240	400	600	1200	1.082*	**2,251**
		222	**370**	**553**	**1106**	**1.000**	
4	**Nominal 1:1½:3 (Vol.)**	255	425	520	1037	1.011*	**2,215**
		251	**418**	**511**	**1037**	**1.001**	

Specified 28-days Concrete Cube Strength= 26 MPa (3,750 psi)
Cylinder (f_c') .....= 21 MPa (3,000 psi)
Slump .....= 75-100 mm (3-4 inch)

Water/Cement (w/c) Ratio = 0.6

* *These recipe type prescribed nominal mix proportions may not produce exactly 1.000 m^3 of concrete.*
* *Estimated. These calculated fresh weights have been adjusted to 1.000 m^3.*

Table 3: Material Ratios (by weight)

MIX NO.	CONCRETE MIX DESIGN METHOD	TOTAL AGG.	FINE AGG. RATIO	COARSE AGG. RATIO	TOTAL AGG./CEMENT RATIO
1	ACI (American)	1,723	43%	57%	5.0
2	DOE (British)	1,645	41%	59%	4.4
3	Nominal 1:1½ :3 (Wt.)	1,659	33%	67%	4.5
4	Nominal 1:1½ :3 (Vol.)	1,548	33%	67%	3.7

Table 4: Compressive Strengths of Various Laboratory Cured Concrete Mixes

CONCRETE MIX	28 DAY CUBE COMPRESSIVE STRENGTH							
	Specified		Required Average		Laboratory Cured			
							Percent of	
	MPa	Psi	MPa	Psi	MPa	Psi	Specified	Req. Ave.
ACI (American)	26	3,750	31	4,500	32.06	4,649	124%	103%
DOE (British)	26	3,750	32	4,600	31.69	4,595	123%	100%
Nominal 1:1½: 3 (Wt.)	26	3,750	30	4,350	28.49	4,131	110%	95%
Nominal 1:1½: 3 (Vol.)	26	3,750	30	4,350	26.27	3,809	102%	88%
Observed Slump (mm)	ACI .....= 75 (3 inch) Nominal (Wt.)= 100 (4 inch)				DOE .....= 90 (3.6 inch) Nominal (Vol.)= 110 (4.4 inch)			

These are Laboratory results which may reduce further depending upon the standard of quality control and curing conditions, among others, in the field. Considering 15% reduction in the laboratory results while producing concrete in the field, the estimated 28 day cube compressive strength for various mixes under study would be as given in Table 5.

The compressive strength would have been lower if the gradation and FM of natural sand were not improved by blending with stone dust (manufactured sand).

This emphasizes on the importance of gradations of both fine and coarse aggregates and FM of fine aggregate.

8. Concrete Mix Efficiency (CME) Twenty eight day compressive strength in psi developed in a concrete per pound of cement, has been introduced as Cement Efficiency, E_C (psi/Lb). Similarly, ratio of twenty eight day compressive strength in psi to Cost of materials in Pak Rupees (PKR) for producing one cubic meter concrete, has been termed as Financial Efficiency, E_f (psi/PKR). Likewise, ratio of twenty eight day compressive strength to the specified strength has been termed as Strength Efficiency, E_s. Product of these three efficiencies is termed as Concrete Mix Efficiency ($CME = E_C \times E_f \times E_s$). CME has been calculated in Table 6. The higher CME depicts more efficient mix in terms of use of cement, overall cost and compressive strength. ACI method produces the most **economical mix and British** method follows closely. Nominal Mix 1:1½:3 both by weight and volume are not as economical, the latter being less than half as efficient than ACI method.

Table 5: Estimated Compressive Strengths of Various Field Cured Concrete Mixes

CONCRETE MIX	28 DAY CUBE STRENGTH				Variation from Specified Strength	REMARKS
	Laboratory Cured		Field Cured (Estimated)			
	MPa	Psi	MPa	psi		
ACI (American)	32.06	4,649	27.25	3,952	+5.39%	Acceptable
BRITISH	31.69	4,595	26.94	3,906	+4.15%	Acceptable
Nominal 1:1½: 3 (Wt.)	28.49	4,131	24.22	3,511	-6.36%	May be used for less important work
Nominal 1:1½: 3 (Vol.)	26.27	3,809	22.33	3,238	-13.66%	Unacceptable

Review of technical literature reveals that concretes having 114 MPa (16,500 psi) cylinder compressive strength had been produced and used in the United States during late 20th century (1993). But recently, concrete having a compressive strength of 207 MPa (30,000 psi) has been used in a Bridge in the US.

Table 6: Concrete Mix Efficiency (CME)

CONCRETE MIX	Cement (Lbs)	28 Day Strength (psi)	Cost (Rs.)	Cement Efficiency (E_C)	Cost Efficiency (E_f)	Strength Efficiency (E_s)	Concrete Mix Efficiency (*CME*)
A	C	D	E	F=D/C	G=D/E	H=D/3750	I=FxGxH
ACI	754	3,952	2,030	5.241	1.947	1.054	10.76
DOE	827	3,906	2,140	4.723	1.825	1.042	8.98
Nominal (Wt.)	816	3,511	2,162	4.303	1.624	0.936	6.54
Nominal (Vol.)	922	3,238	2,310	3.512	1.402	0.863	4.25
Prices of Materials as in December 2006:	Cement = Rs. 200 / bag (50 kg)			Coarse Sand = Rs. 16 / Cft Coarse Aggregate = Rs. 23 / Cft			

With such international standards and advancement in technology elsewhere, it is painful to note that we are still unable to achieve even 16.5 MPa (2,400 psi) cube crushing strength with 1:2:4 nominal mix; which is still being specified by most of public departments.

9. Conclusions and Recommendations

This experimental evidence has demonstrated that a concrete properly designed in accordance with widely accepted/practiced concrete mix design methods such as ACI or DOE gives the desired compressive strength in laboratory as well as in the field. Whereas, nominal or recipe-type concrete mixes do not meet the basic criterion of specified strength and are even costlier to produce due to richer cement content.

A continuing research effort is required at the university level to explore local materials, develop standard generalized charts of material properties and evaluate the effect of local factors such as temperature, etc.

The concept of Concrete Mix Efficiency (CME) has been introduced; which suggests that properly designed and weigh-batched concrete should be used invariably on all projects, so as to have more confidence in performance of structures and cut down the cost of producing concrete.

Weight-based nominal mixes may be used on medium sized works with proper control on added-water. Weigh-batching in the field could be achieved by calculating volumes of materials from their weights corresponding to one bag of cement, and preparing separate measuring boxes for coarse and fine aggregates. Whereas, volumetric nominal mixes should be avoided as far as possible and could be used on small works with lot of caution. It cannot be overemphasized that the gradation of coarse and fine aggregates plays a vital role in strength development, as fine

(e.g., Ravi) sand yields lower strength and coarse sand (e.g., Lawrencepur) gives good results.

On Large projects (e.g., with value exceeding Rs. 100 million), use of batching plants, transit mixers and concrete pumping equipment should be made mandatory.

10. Acknowledgement

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How To Deal With Water Shortages In The Country

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The looming water scarcity in the country is a cause of great concern. The total water availability per capita per year is now less than 1000 cu meters. 50 years ago the quantity available per capita was over 5000 cu meters, and at that time we were water affluent country.

The population of West Pakistan in 1950 was about 37.5 million and now it has reached more than 180 million.1000 cu meter/capita or below are considered water stressed and water deficient countries, which can result in water disputes between various riparians. The water availability is not uniform through the year and most of the water in the rivers flows in the summer season, therefore it is necessary to store surplus water to be used in low flow months. In Pakistan the water scarcity is further compounded since the country has developed very little storage capacity. The present storages are only 10 percent of the total flow, while the world average storages is about 40 percent. Because of lack of storage an average of 30 MAF water goes into the sea. This average is based on post Tarbela flows, and also includes the recent drought years. Thus 20 percent of the already scarce resource is lost since we cannot store it.

IRSA the organization represented by all the four Provinces, which controls the irrigation water distribution in the country has in their recent report warned about lack of sufficient storage and they have urged the Government to even stop all development work in the country for the next some years and invest the available money to create more storage reservoirs.

The related issue is that canal water is being provided to the farms for instance in Punjab at a nominal flat rate of Rs. 135 per acre per annum. The water obtained from tubewells cost about Rs. 3000 per acre per annum. In my discussion with a World Bank representative, he stated that why should any Bank provide money for a water Project in Pakistan, where there is no arrangement for recovering the money spent on water projects. In order to clarify this, in Punjab where 22 million acres are cultivated under canal irrigation, the total revenue assessed as Abiana in a year is only Rs. 2.5 billion, the actual collection was merely Rs. 1.01 billion in 2014, which works out to Rs. 50 per acre per year. When a Farmer has to practically pay nothing for the canal water, this free water is therefore not being used in any efficient manner and a lot of precious asset is being wasted. Similar attitude is noticed in the use of water for municipal and industrial purposes, where no conservation is applied and wastages are increasing.

In order to save the country from the dooming situation, the following actions are absolutely vital:

1. Create storage particularly on the River Indus, so that our storage capacity is increased from 10 percent of the flow to 20 percent in the next 10 - 15 years. The work on these must start immediately.

2. Increase Abiana to Rs. 1500 per acre per annum, which would still be less than half of what is spent on Tubewell water. If the farmers will use the water carefully, wastage will be reduced, and better irrigation practice will be introduced, which will result in highest crop intensity. The Irrigation Department revenue will increase, for instance in Punjab it will go up from Rs. 2 billion/year to Rs. 20 billion/year. With this extra money the maintenance of the system will improve, plus free extension service can be provided to small farmers for improving their yield with less water use. Dependence on tubewells will be reduced. This increase in revenue will also attract the international Banks funding for the water sector.

3. The public awareness and attitude towards development and conservation of water for irrigation and other consumptive uses needs to be boosted, media can play an important role in this. As regards storage of water, a careful decision making on highly urgent basis is essential. Presently three large storage projects are in a stage that their construction can be started. These are Kalabagh Dam (6 MAF storage), Basha Dam (8.1 MAF) and Munda Dam (1.29 MAF). These projects will also provide about 9000 MW of cheap electricity. The construction of these projects has not started due to various impediments, although the Projects are well engineered and very feasible. The merits and impediments for each of these are summarily discussed below:

Kalabagh: It is the most thoroughly engineered project, has been studied by World's top experts, reviewed by top level International Panels of Experts, and thoroughly appraised by the World Bank. The project is located in the middle of load centres, is easy to approach, and no long distance transmission lines are required. It has been ready for construction since mid eighties and international financing from World Bank, Asian Bank etc. can still be easily arranged. However some political interference has come in the way from two Provinces, KPK and Sindh. The KPK objections were that the Kalabagh Dam reservoir will aggravate flooding of important city of Nowshera and the reservoir will displace some population, while they do not see any benefits from the Project. These objections have been thoroughly studied and it has been concluded that Kalabagh reservoir by itself does not cause any threat to Nowshera, since the reservoir elevation is 915 feet, while Nowshera is at elevation 940 feet. It has also been found that even without Kalabagh Dam if the floods of Kabul and Swat river get synchronized flooding of Nowshera does happen. In order to overcome this, it has been proposed that along with Kalabagh, Munda Dam should be built, which will fully control the exiting threat of flooding.

A very important aspect for KPK, which is not being registered is that KPK cannot use their share of water from Indus, since the river is at least 50 feet below the lands in KPK and will require prohibitively expensive pumping to lift it. The Kalabagh Dam will be able to provide a high level outlet from its reservoir and water will reach the lands in KPK through a gravity flow. No other dam on Indus can enable KPK to utilize their entitled share of water. This factor by itself is a great benefit for KPK, therefore if properly discussed and understood, the usefulness of the Kalabagh Dam for KPK cannot be over ignored.

The objections of Sindh province are not very clear. Their general feeling is that there is no surplus water in Indus which can be stored. The stated objections are that Kalabagh will hold water and therefore the water flow downstream of Kotri will reduce which will cause environmental damage to the mangroves and the shrimps which breed in mangroves. The other fear is that low flow below Kotri will cause sea water intrusion and damage lands below Kotri. These objections have also been studied by local as well as international experts and they have concluded that a flow of 8 MAF must go downstream of Kotri every year to meet the environmental requirements. Presently an average of 30 MAF is going downstream of Kotri and goes into the sea. 6 MAF storage at Kalabagh therefore will not create any adverse conditions. There is another objection which is not so much documented, in that the Kalabagh Reservoir is located in another Province which may steal the share of downstream Province. This fear is typical of all downstream riparians and therefore must be addressed. It was for this reason that the Government created the organization IRSA (Indus River System Authority), which has representation from all the Provinces. These senior nominees of each province take a joint decision as to how much water to release for each Province in accordance with

their agreed share. This sharing is more critical when the river flows are less than anticipated. It is understood that IRSA in its 22 years of functioning has always worked with consensus and so far there has not been any complaint by Sindh for lesser share of water nor has been referred to Council of Common Interest (CCI).

It appears that if these objections from various Provinces should be discussed at a high level meeting with Prime Minister presiding and a joint decision is taken in the interest of the country considering the future scenarios when water shortages will be very painful. Similar effort, as was done in 1992 for Water Accord between the Provinces should produce a good result. Building dams take 6 – 8 years, therefore the matter cannot be postponed any further.

Basha Dam Another mega Dam Basha is also ready for construction for the last some years. International Consultants have designed the dam and top Panel of Experts have reviewed the design. The dam is very high 272 metre, (892 feet), to be constructed in RCC (Roller Compacted Concrete) and will be the highest RCC dam in the world. No Province has any objection to its construction and GOP is therefore very keen to start it in preference to Kalabagh Dam. However there are some hurdles in its implementation. Firstly its cost of about 12 – 14 Billion Dollars is very high and will need good financial support from international funding agencies like World Bank, ADB etc. So far this financial support is not forthcoming, World bank feels that the location of the dam is in a disputed territory therefore they are reluctant to invest. ADB was initially very keen to invest, but are waiting for commitment of funding by other agencies. Chinese Government is also being approached, but their interest in the Project is still unknown. USAID had agreed to help, and they are carrying out independent environment and resettlement validation studies to verify the work already done so that other financing agencies develop more confidence about the Project. Another aspect of the Project which is causing apprehensions, is the far location of the Project. The KKH will need to be repaired and upgraded for approach to the site, where millions of tons of construction material have to be transported. Some 140 km of KKH will have to be rebuilt, since that part of KKH will be submerged in the reservoir. Moreover very long transmission lines in difficult terrain will have to be installed to transmit the electricity. All these issues add to the high cost of the Project. However since it is a good feasible project, with large reservoir must be built. Lets hope the finances can be arranged.

Munda Dam
This site on Swat River has been studied for many years. It will be a 213 meter (700 feet) high dam with a storage capacity of 1.29 MAF and power of 800 MW. It was allotted to a private developer who had optimized its design for power production. Subsequently KPK Government objected and demanded that the irrigation and flood control must also be included in the design, which did not suit the private developer. The Project was given to WAPDA for its development as a multipurpose dam. The French Development Agency has offered to support the Project, and they have already released some funds for completion of design and tender documents. A commitment from Government to expedite the Project is still awaited.

Further Incentives for Confidence Building
In order to give further incentive for confidence building, it is proposed that a royalty charge of 5 percent be imposed on the revenue from these large Projects. The amount gathered through royalties should be distributed to the affected Province. For instance Kalabagh Dam will produce 10 billion kWh of electricity every year. The revenue from the electricity will be about Rs. 100 billion / year. If 5 percent of this amount i.e. Rs. 5 billion is available every year, Rs. 2 billion out of this can be used for improving the condition of mangroves nurseries, and if considered necessary by Government of Sindh, this money can also be used for building another Barrage downstream of Kotri to dispel threat of sea water intrusion. Rs. 2 billion every year to improve environment and irrigation infrastructure in Sindh will be very useful investment. Similarly the other 3 billion rupees from Kalabagh can be shared by KPK and Punjab for similar environmental mitigation and improvements. Such a royalty will further increase substantially after Basha Dam is built. This type of provision is now used internationally particularly in North Africa for shared projects between the riparians even on country-wise basis.
From the above discussion, it is obvious that Pakistan has to prepare itself for its water security on an urgent basis. The situation of water availability will gradually become even more critical with approaching global warming,

when the glacier melting will gradually reduce the inflow in the rivers particularly Indus. The construction of big reservoir to store water which is presently going into the sea is the most important step. It is obvious that the first big reservoir which is the most feasible in all respect is through Kalabagh Dam, whose construction should be started immediately, followed as soon as possible by Basha Dam. No wrongly placed political arguments should hamper the water security of the country. The incentive suggested in the Paper should help in developing consensus. These Projects will also produce large hydropower which make these projects highly economical as well.

Quotation

- In the first place God made idiots, This was for practice. Then he made school boards.

Mark Twain

- A good teacher, like a good entertainer first must hold his audience; s attention. Then he can teach his lesson.

John Hendrik Clarke

- The gift of teaching is a peculiar talent, and implies a need and a craving in the teacher himself.

John Jay Champan

- A poor surgeon hurts one person at a time. A poor teacher hurts [a whole classroom]

Ernest Bayer

Testing Of Large Oil-Filled Power Transformers

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Introduction

In the power systems, transformers are one of the most important components.

Large oil-filled power transformers are quite expensive ones. For instance in a hydro power station, the most costly single item is Generator and price wise, Transformer is the 2nd most costly item. In view of this, testing of transformer deserves special considerations.

IEC 60076 Part-1 and Part-2 give a list of all tests (Type Tests, Routine Tests and Special Tests) which should be performed on the Transformers.

It is emphasized that the person, or persons, who are witnessing the tests regarding Large Transformers must be very experienced and they must be having full knowledge about testing of transformer. Further, they must be very dutiful and vigilant. Since all Factory Tests on a single transformer takes many days (for instance recently all the Factory Tests were performed on a 98.7MVA, $\frac{525}{\sqrt{3}}/15.75\ kV$ Single Phase Transformer and it took 5 complete days. Further there was one particular test which took 24 continuous hours) so at least two persons should be there to witness the tests. One of them can witness the tests during day time while the other person can witness tests during night time.

Any lethargy on the part of the person who is witnessing the tests can have dire consequences. For instance during 1975 it came to the knowledge of WAPDA persons, who were witnessing the tests on "Distribution Transformers", that although the nameplate on the Transformer was indicating that it was a 200kVA transformer but the 24-hours loading test was showing that it was merely 150kVA transformer. The manufacturer had already sold hundreds of such transformers to WAPDA. Then WAPDA took up the matter with the Manufacturer (which is a very famous brand) and the latter had to return the extra money which he had taken in an unscrupulous way. Actually for the long 24 hours tests, the inspector who was supposed to be present was missing during night time and the manufacturer was misleading the said inspector by saying that the transformer had successfully passed the 24 hours test, while in reality it had not.

TESTS

All major electrical equipments (for example Alternator and Power Transformers etc) have to be tested prior to their commercial operation. There are various types of tests, which are indicated in national and international standards (for example B.S.S is a national standard while I.E.C is an international standard). It is added here that these standards are somewhat different from one another. Consequently only that standard should be followed which is indicated in the Contract's Technical

Specification. The various types of Tests are explained in the following lines:

Type Tests
These tests which are indicated in the standards are carried out to ascertain that as regards the design, size, materials and manufacture, the equipment complies with the specific characteristics and operation requirements. These tests are conducted in renowned and approved laboratories (for instance KEMA of Neitherland). For a particular type of equipment, these tests are only done on one equipment and subsequently any customer of that equipment will take a photo copy of the Tests Results. He cannot ask the Manufacturer to carry out the Type Tests again. These Test Reports will remain valid for all years to come, as long as the design of the particular equipment remains the same.

Routine Tests
These tests which are also indicated in the standards are carried out on each equipment and are usually performed in the manufacturer's works and these are also known as Factory Tests. Invariably, these are witnessed by the purchaser or his representatives as well as Consultant representatives.

Special Tests
In the standards, these tests are also indicated but these need mutual agreement between the Purchaser and the Manufacturer. For large transformers some of the Special Tests are usually demanded by the purchaser.

Commissioning Tests
These tests are also indicated in the standards and these are carried out on the equipment when it has been installed at site.

Factory Tests on Large Transformers
Based on their kVA or MVA ratings, there are various categories of transformers which are explained in the following Table.
In IEC 60076-1 and IEC 60076-2 a list of all Tests (i.e. Type, Routine and Special Tests etc) can be found. However for the guidance of the reader, various Routine Tests, which are also called Factory Tests, are given below:

(a)
Measurement of winding resistance

(b)
Measurement of voltage ratio and check of voltage vector relationship.

(c)
Measurement of impedance voltage/short circuit impedance (principal tapping) and load loss.

(d)
Measurement of no load loss and current.

(e)
Measurement of insulation resistance.

(f)
Dielectric tests and these constitute the following.

(f1)
A separate source power frequency voltage withstand test.

(f2)
An induced voltage withstand test.

(f3)
A full wave lightning impulse test for the line terminal.

(g)
Temperature rise test.

(h)
Tests on On-load Tap Changer where applicable.
For detailed procedure of each test, the reader may refer to above mentioned IEC standards.

Table 1

Type of Transformer	MVA Range	Highest System Voltage
Distribution	Upto 1 MVA	11kV
Industrial substation, ONAN type	6 to 20 MVA	33 to 66kV
Large Units Type, ONAF type	20 to 50 MVA	66 to 132kV
Large Units, OFAF, OFWF	50 to 300 MVA	132 to 500kV

Note: "ONAN" stands for Oil Natural, Air Natural while "OFAF" stands for Oil Forced Air Forced. "OFWF" stands for Oil-Forced, Water Forced.

Temperature Rise

The highest working temperature depends on the class of insulating material. The temperature rise in windings is measured by resistance, while in oil it is measured by a thermometer.

As per IEC 60076-2, clause 4.2 the following are the specified values: Top oil temperature = 60 K (i.e. KELVIN) Average winding temperature rise for Transformers type 'ONAN' or 'ONAF' = 65 K Average winding temperature rise for Transformers type 'ODWF' =70K

Permissible tolerances in test values

There are some permissible tolerances for the values which are given by the Test Results and these are indicated in Table-2 below.

Conclusion and recommendation

Since large transformers are very expensive therefore the Testing should be done in a careful way. Before performing the tests, it must be verified that all the measuring meters have a "calibration certificate" from some Approved Laboratory. On such a "Calibration Certificate" the expiry date of the validity is also given and the same should be checked.

Since testing of large transformers is usually done during day as well as night, purchaser of the transformer must send four persons for witnessing the tests. Two persons will witness during day and the other two will witness during night.

All the 4 persons who will witness the tests from the purchaser's side must be fully conversant with IEC 60076-1 and IEC 60076-2. It goes without saying that they must be very experienced and dutiful.

References

IEC 60076-1 (2011 issue): Power Transformers – General.

IEC 60076-2 (2011 issue): Temperature rise for liquid – immersed transformers.

Table No. 2: Permissible Tolerances in Test Values

Item	Tolerance
1. Voltage ratio at no load on the principal tapping (rated voltage ratio)	± 0.5 of the declared ratio or a percentage equal to 1/10 of actual percentage impedance voltage at rated current, whichever is lower.
2. Impedance voltage at rated current (principal tapping) (a) Two winding transformers (b) Multiwinding transformers	±10 percent of the declared impedance voltage ± 10 percent of the declared impedance voltage for one pair of windings ± 15 percent of the declared impedance voltage for a second specified pair of windings Tolerance to be agreed and stated for further pairs of windings.
For tappings other than principal tapping 3. Loss (a) Total losses (b) Component losses	+ 10 percent of the total losses + 15 percent of each component loss provided that the tolerance for total losses is not exceeded.
4. No load current	+ 30 percent of the declared no load current
5. Efficiency	In accordance with tolerance on losses
6. Regulation	In accordance with the tolerances on impedance voltage and load losses.

Rehabilitation of 18MW Naltar V HPP Forebay Structure

Engr. Sheikh Shahid Iqbal

Project and Location

The 18 MW Naltar IV Hydropower Station is located at Naltar River in Naltar Valley, a tributary of Hunza River joining Hunza River near Nomal Village, situated 28 Km north of Gilgit City in Gilgit-Baltistan Province. Engineering Procurement and Construction (EPC) Contract was signed in October 2002, between Northern Area Public Works Department (NAPWD), Government of Pakistan (the Client), and China Liaoning International Corporation (Group) Holdings Limited (CLIC) Peoples Republic of China (The Contractors). The Consultancy Contract for Design Review and Construction Supervision for the Project was signed in June 2004, between NAPWD, Government of Pakistan and Associated Consulting Engineers ACE (Pvt) Ltd, in association with Development and Management Consultants DMC; the consultants.

1. Main Components

Main components of the Naltar Hydropower Project include: Concrete Tyrolean Weir (Dam), de-silting basin with gravel trap, power channel, forebay, penstock, powerhouse, 66 kV transmission line and switchyard.

A reinforced concrete (RC) bridge on River Hunza at Nomal Village and 12 km long access road from KKH to the weir site are also included in the EPC Contract.

2. The Forebay
(Balancing Reservoir)

Structure's Geometry:

The forebay structure comprise of main water retaining reinforced concrete walls all around the perimeter, and 500mm thick concrete floor. The structure is approximately 150m long – in the east-west (upstream to downstream) direction, by 70m wide – in the north south direction. Refer figure 1. A photo of the site before construction of the structure is provided at the end.

Joints:

Expansion joints are provided between the wall panels at spacing ranging from about 12m to 15m, and between the wall base slab and concrete (inert) floor panels.

Main Walls:

The main reinforced concrete walls retain hydrostatic head average about five meters. Structural thickness of the stem varies from 400mm at the top to 750mm at the bottom. Thickness of the wall base slab is the same as the floor (500mm).

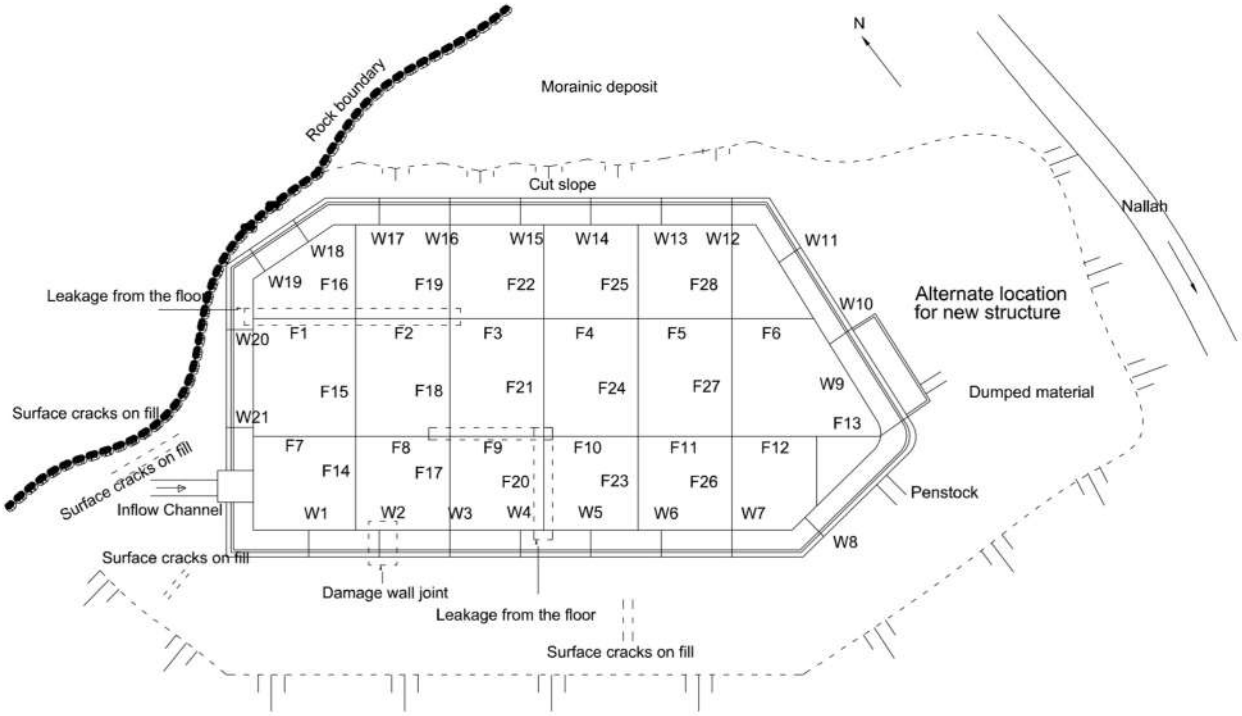

Figure 1 – (Approximate) General Layout Plan of the Forebay Structure.

4. Geology at Forebay Structure

The structure is resting on heterogeneous mixture of soils and rock fragments (Morainic Deposits) composed of boulders (small to large sizes) surrounded by fine matrix of silt / clay with different composition. While most part of the structure is seated on excavated rock, some part near the upstream is placed on compacted fill material obtained from the excavation.

5. Leakage Problem Jan 2011

The project was commissioned in mid 2007 and was operating normally. Problem of leakage from the expansion joints of the Forebay Walls and expansion joints between wall base slab and concrete floor panels was first reported by the client in January, 2011. River flow was at minimum at that time, and water level in the forebay was maintained at lesser than three meters, which facilitated remedial of leakage problem. M/s Imporient Chemicals Lahore, recommended by the consultants ACE, successfully carried out the remedial works. The narrow joints were treated with 'Chemrite Injection – XP' and wider cracks with 'Chemdure 31'. Both the material swells many times on coming in contact with water.

6. Subsequent Leakage Problem

When the water level in the forebay remained at its maximum level for many months, leakage from many other expansion joints was observed in Jan 2012. On the request from the clients, an inspection visit to the project was arranged by the consultants comprising a Chief Geologist and Principal Structural Engineer.

7. Consultants Findings and/or Recommendations

Cause of Differential Settlements:

July to August 2010 experienced exceptionally heavy rains and major flood in the Naltar River. Silt laden flood water was allowed into the forebay structure which caused (non-uniform) accumulation of silt in (generally) the northern half of the forebay structure. Due to the difference of loading on the floor panels and Wall Base, and other factors discussed later, different amount of immediate settlements at the expansion joints occurred. Leakage caused by the differential settlements, apparently washed away part of fines from under the floor at many places, which aggravated the problem. In consequence the waterstops at different locations of the structure were stressed and ruptured initiating leakage from expansion joints between floor and wall base, and between wall panels.

Other Contributing Factors of Leakage:

(a) – In January 2012, an earthen ramp was constructed for access of machinery into the forebay, causing difference of horizontal and vertical loading on wall panels and the floor, (b) – Floor slab of the structure cannot sustain non-uniform loading resulting from silt deposit and machine loading (such as the excavators used for de-silting).

(c) – Water pounding outside the structure also probably contributed to washing out of fines from under the structure. (d) – In winter minimum ambient temperature in this area is about -8°C. Shrinkage of concrete could be another contributing factor that stressed the waterstops.

Probable Solutions Considered:

a) Retrofitting of the Existing Structure,
b) Direct Water Supply to Penstock,
c) Permanent Divide Wall constructed in the Existing Structure,
d) Discarding the existing and building new (Secondary) Structure,

Discussion:
(a) Retrofitting the Structure: This is the accepted option. (1) – Retrofitting the existing structure requires dry condition, long closure period and consequent power shutdown. Construction of bypass arrangement [First construct bypass inlet channel off-taking from the left at upstream, and new (auxiliary) structure at the left on downstream side of the existing forebay] also required. (2) – Provide connection of bypass penstock with the existing penstock]. Later divert the flows to the auxiliary structure, and repair the existing structure in dewatered condition. (3) – Due to the various involved uncertainties, EPC Contract was considered more feasible approach for implementation.
(b) Direct Water Supply:
This was not accepted due to hydraulics and E&M considerations.
(c) Permanent Divide Wall:
A permanent concrete Divide Wall (West / upstream to East / downstream) capable to withstand unbalanced hydrostatic pressure to contain the water supply for the penstock, will physically divide the structure into two (Northern and Southern) chambers. As the Inlet Channel and the Penstock falls in the Southern Chamber this chamber may only be retained. The (larger and more damaged) Northern part may be scrapped. The rehabilitation of the Southern Chamber is needed anyhow. Since the construction of the permanent Concrete Divide Wall and rehabilitation of the Southern Chamber will need closure for more or less equal period of time. This option was not endorsed.
(d) Discarding the Structure:
This option was not adopted mainly due to considerations of economics and constraints of space.

8. Rehabilitation of Structure

Well before September 2014 the bypass Inlet Channel, Auxiliary Forebay and Penstock (junction) Connection were ready. An EPC Contract was awarded to a Chinese petty contractor who remained connected with the project construction a decade ago. The repair works sequence adopted by the contractor was as follows.

- **Diversion:**

Flows were diverted to the new (auxiliary) forebay. The power generation was reduced to less than half the installed capacity. One power unit was shut down. Other two operated at lesser capacity.

- **Dewatering:**

The forebay structure was dewatered through the flushing outlet.

- **Access:**

An earthen ramp constructed at the left side from downstream of the structure leading to inside the forebay, for access of machinery, materials and workers. On two sides of the ramp, wall was there. On the right side gabions were placed to vertically contain the fill slope within a narrower strip.

- **Test:**

Exercising engineering judgment, pounding [Surface Water Test] carried out at selected locations on base slab area including joints to assess the seepage / leakage at specific location.

- **Cement Grouting in Floor:**

In the middle of 500mm thick floor slab panels contained between expansion joints, 500mm deep drilling is carried out by 50mm diameter rig. Cement grouting is performed by injecting cement paste by grouting machine. The injection is continued till the cement grout appeared on the surface of base slab from next hole. Total of 89 holes were drilled and injected with cement grout. This treatment on base slab portion was carried out mainly on right sides from the centre line of structure, where settlement was observed in some base slabs panels. Probably this portion of base slab lies on backfill. Total about 1800 cement bags were consumed in this operation.

- **Epoxy Grouting Wall Base Joint:**

At the joints between wall base and floor slabs, steel nails fitted with pressure nozzles were fixed on either sides of joints in depth of 200mm. Approximate spacing of steel nails being 300mm. Joint sealant chemical (epoxy + resin) then injected through pressure with spray gun type machine. The process requires that sealant is continuously injected into the joints until it appears on the slab surface through the next drilled hole

and immediately sets in foam like shape. Grouting operation is then shifted to the next injection hole. Quantity of epoxy consumed in this operation is not reported.

- **Epoxy Grouting in Wall Joints:**

All the vertical joints between wall panels are expansion type. Epoxy grouting at the joints comprised drilling fine nozzles into the wall near the crack / leaking joint, at about 150mm (±). The epoxy was used with a thinner to keep it flowing for the time span required to reach the desired location. The grouting operation proceeded from bottom to top. Epoxy injected at the required pressure in lower nozzle and pressure maintained until the epoxy starts flowing out of the upper nozzle. The grouting pressure is stopped at this stage, nozzle plugged tightly, and grouting operation shifted to the upper nozzle. The process is continued until sealing of the crack / joint completes. This operation was carried out at more than thirty locations.

9. Feedback

The work was completed in slightly over one month working about 10 hours daily. After the retrofitting operation, the flows were re-diverted to the main forebay. Pond level is maintained at normal. No problem is observed.

Fig 2 – View before and after construction of the Forebay / Balancing Reservoir Structure and penstock leading to powerhouse.

10. Photographs


TOYOTA

Privatizing Heavy Electrical Complex

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The first strategic sale by the present government has been finalized as Heavy Electrical Complex (HEC), a unit of State Engineering Corporation, is likely to be handed over to Cargill Pakistan Holdings, a trader based at Karachi by May 2015. It is a total sell-off of the Company (with 96.6% shares to be divested whereas remaining 3.4% will be allocated to its employees) at a throw-away price and without commitment on the part of buyer to continue to operate the Company's existing manufacturing facility.

Earlier, the Privatization Commission (PC) had approved HEC reserve price as Rs 500 million against expected proceeds of Rs 1,475 million as worked out by the PC-appointed financial advisors on the basis of appropriate market value of land, machinery and other assets. Approval was also obtained by PC to sell the huge industrial complex to the sole bidder, against the rules, procedures, norms and precedence. Ironically, the bidder has not accepted reserve price, and PC has failed to negotiate sale price with the party. Consequently, the matter has been referred now to the Cabinet Committee on Privatization (CCOP) for a final decision.

In all, three parties were qualified to bid in response to the current divestment process that has been going on for more than a year. These included Fauji Fertilizer Company, Elahi Group of Companies and Cargill Pakistan Holdings; though none has the experience or background of running a similar or any engineering industrial unit that should have been the pre-requisite for pre-qualification. The due diligence was carried out by all the three parties but only Cargill participated in bidding on due date. Given the conditions, it seems that the prospective investors were interested only in valuable real estate belonging to the HEC, as the factory is located in a front-line industrial estate, with all requisite infrastructure facilities.

In such case, manufacturing of sophisticated electrical equipment could come to a halt, and related technology it assimilated and corresponding expertise it developed over the decades will go down the drain, impacting the growth of power sector. Privatization of six major engineering industrial units of State Engineering Corporation since 1992 has produced dismal results. Total proceeds of these six transactions amounted to a paltry sum of Rs 140 million, or $1.38 million in today's price, which was hardly ten percent of their total assets, notwithstanding annual

revenues of tens of millions rupees these state-owned enterprises (SOEs) generated during pre-privatization period. These were prime industrial units and most of these were profitable at the time of divestment. Karachi Pipe Mills, Pakistan Switchgear and Textile Machinery Co are closed ever since private investors took over, while Metropolitan Steel Corporation and Quality Steels have, of late, started nominal operations after closure for many years. Pioneer Steel Mills is the only unit in business since its take-over at a token price by original owner before nationalization of the mills.

The HEC was established at Hattar Industrial Estate in the Khyber Pakhtunkhwa with the Chinese economic and technical assistance at a cost of Rs 1,158 million. Its installed capacity is to produce 148 Nos. power transformers of capacity ranging from 6.3 MVA to 40 MVA for 132 and 66 kV electricity transmission systems, which is translated into factory's total production capacity of 3,000 MVA. Spread over an area of 291,374 sq. meters (72 acres), the factory has integrated and largest engineering, production and testing facilities—-the only of its kind in the country—-procured from China, Germany and Switzerland. It has indeed made Pakistan self-reliant in the electrical capital goods required for power sector.

Since commencement of commercial operations in 1997, the HEC has manufactured and delivered 276 power transformers of various capacities and sizes valuing Rs 7,012 million to the DISCOs, K-Electric and industry. In addition, it repaired and rehabilitated 104 transformers at Rs 574 million. The Company has now orders in hand for manufacturing and supply of power transformers valuing Rs 62 million, whereas orders worth Rs 989 million are in pipeline. In addition, these power transmission companies have placed orders on HEC for the repair and rehabilitation of old power transformers.
The Company secured orders for new transformers in strong competition with manufacturers in Germany, Bulgaria, Romania and China. Product diversification has been on cards, and recently the HEC has developed high-module step-down transformers of 160 MVA and 250 MVA. An average yearly sales is of Rs 800 million, while it suffered losses in some years primarily due to low capacity utilization and on-going privatization process. Currently, total assets of HEC are worth Rs 1,694 million, whereas total liabilities are only of the size of Rs 486 million, and total manpower strength is 222 that would be offered Golden Handshake Scheme (GHS) or Voluntary Separation Scheme (VSS) by the PC.

Engineering industry is highly capital intensive and involves long gestation period. There are high costs of technology and building-up of inventory of imported materials and components for a long time. The HEC is one of the high-tech industries of great strategic importance, and requires to be dealt differently, allowing public sector to continue to play its role in the industrial development and achieving self-reliance in strategic areas. Realizing the need of adopting a different methodology to divest HEC, instead of a direct sell-off, it was decided in 1990s to explore the possibilities of establishing a joint venture with world-renowned companies already active in a similar field. The spadework to identify such companies and to invite them to agree to invest in the HEC both as equity and technology partner was done by the State Engineering Corporation.

Concerted efforts were made in this direction, and logically, first a proposal was made to the Chinese partners, in the last quarter of 1995, to convert their loan into equity participation, thus taking over the management. The proposal was discussed at the government level also and, subsequently, at the Pak-China Joint Economic Commission meetings held at Beijing and Islamabad. Though the initial response of the Chinese was encouraging, there could be no further headway. Then, the major global key players in the field were contacted, and, fortunately, three giants namely Siemens, ABB and Skoda showed their individual willingness in the late 1996-early 1997 to form a proposed joint venture with the HEC, in a bid to finally acquire the HEC through privatization.

Since then the Complex has been on active privatization list by PC, but efforts to divest it repeatedly failed due to short-sighted policies of the government and long unsuccessful privatization process, having adversely affected the Company's performance too. PC initiated privatization process in November 2005, when response from the multinational companies like Siemens Pakistan, ABB Switzerland and Areva T&D France was forthcoming. Most of these companies had completed due diligence at that time, which is considered essential prior to making investment of this size and nature. In response to advertisement released in May 2006, PC therefore received

EOIs and statements of qualification from ten interested parties including Siemens, ABB, Areva, Iljin Heavy Industries (South Korea), Pak Electron (PEL), Imperial Construction (ICC), Noor Financial, Shahzad International, Sahfi Associates and Lahore Propylene Industries.

However, it was only in November 2008 that the CCOP approved Company's valuation and allowed the bidding. Most of these companies had meanwhile lost interest, and only PEL, Iljin and another local company participated. Again, PC could not take a decision and re-invited proposals in April 2010. This time three companies namely Alstom Grid, Areva T&D and Niagara Mills (Faisalabad) submitted Expression of Interest (EOIs). In July 2011, transaction structure for the HEC was finalized but there was no further headway towards privatization process, due to reason not made known, until January 2014 when EOIs were invited once again resulting in a single bid, from a palm oil importer. What a shame!

(The writer is retired Chairman of the Heavy Electrical Complex, Ministry of Industries and Production, Government of Pakistan)

Better Preserve What You Already Possess

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I have no doubt in my mind that the Prime Minister is desirous of solving the vital energy crises sooner than later. All resources, material and human, must have been activated to accomplish the difficult task. At this juncture, I am high lighting some of the vital issues and their practical and sustainable solutions with the hope that the Prime Minister's dreams and mission can be fulfilled in the best interest of the nation. The most expansive and damaging threats to Energy supply networks are;

- Theft at all levels
- Weakness in revenue collection

Even the Ministry of Water and Power have admitted that losses in power have reached an alarming level of about 45%. No utility can survive when its annual losses are over Rs: 100 billion. Another factor contributing to the deteriorating situation of the power sector is nonpayment of utility bills which has resulted in massive circular debt which at present moment is being reported around Rs. 750 Billion. There is a solution to manage this mess but here again the writ of the government will determine the outcome.

The theft mafia is too strong and no amount of administrative arrangements will help to arrest the energy theft. The utility theft is known to have departmental patronage and unless human intervention is eliminated no improvement will be possible. It is very well known that all electric meters are made to run 5-25 % faster which means that the bill paying consumers are being penalized for the benefit of the thieves. Secondly the stolen power is transferred to the bills of the non paying consumers which are mainly the government departments. To make up for the losses because of these channels of theft the government is made to pay subsidy or special grants which again, one way or the other, gets passed on to the bill paying consumers or other taxpaying citizens.

The gas sector is also plagued with problems similar to the power sector. The gas net work too old and lot of gas is wasted through leakage in the system. Theft of gas is also quite rampant. According to the data provided by the two gas companies the estimated amount of UFG (Un Accounted for Gas) is 108,683 MMCF/year. At the present tariff of gas, gas companies are suffering losses over billions per year.

The most practical, dependable and potent option to reduce losses is to rely on formidable, Energy Efficincy technical solutions which are being successfully employed the world over. A smart Metering Network (AMI) with

prepaid provision and two way communication system is the only answer. The installation of this system will eliminate, to a great extent, the element of human intervention. The monitoring system will enable the managing agency to immediately detect any interference with the energy network right at the control centre and take necessary remedial measures and catch the culprits. There will be no need to generate utility bills as the consumer would use prepaid smart card for the operation of the meters. Not only the recovery of utility bills will become wholesome but the revenue will also become available in advance. The consumer will use only that much energy for which the payment has already been made. It is pertinent to note that if the losses in the present situation are not controlled these will only multiply with more generation in the system. Hence the Prepaid Smart Metering Network will not only control the present theft and ensure 100% revenue collection for the power used, the system will give enhanced benefits for all times to come. It is an expansive undertaking, 23 million electric meters are in use and the complete power network can be furnished with Prepaid Smart Metering Network with a cost of about U.S.$ 5 billions and program will take 3-4 fours for completion. In the present generation scenario the Prepaid Smart Metering Network will save up to 2000 MW and the utility of this system will become more and more profitable with more generation.

Similarly by replacing about 6 million gas meter with Smart Metering Network with an invest of around U.S.$ 1.5 billions the losses due to theft and other reasons can be controlled resulting in saving of 100,000MMCF/year. Through a leakage detection and reduction program with an investment of U.S.$ 300 millions for SNGPL there can be saving of gas to the tune of 3,000MMCF/year.

The government owned, 10 thermal plants are very old worn out. These are presently generating at around 23% capacity. A comprehensive rehabilitation, up gradation and optimization program with an estimated investment of U.S.$ 300 millions the generation capacity of these plants in 12-18 months. With a similar program for Hydro Power plants they can produce around 950MW additional power with an investment of U.S.$ 200 millions in 12-18 months. The NTD Grid also requires extensive up gradation which it is estimated can be achieved with an investment of U.S.$ 500 millions resulting in saving of power to the tune of 1300-3600 MW in a short period of 12 to 18 months.

Replacement of presently used incandescent bulbs with high load factor energy savers and street lights with LED lights can save another 1375 MW in the existing network. An attractive financial model can be developed for the consumers for the replacement of existing light fixtures.

The **Energy Efficiency Programs** discussed will result in the saving of around 7000 MW power and over 100,000 MMCF/years of gas in the existing networks and these capacities will further enhance corresponding to additional generation and additional supply of gas in the coming days. With the implementation of these energy Efficiency Programs not only the power & gas shortages will be mitigated in the most economical manner and shortest time but also the economic health of the power & gas sector will improve impressively.

It is learnt that proposals from private sector with total foreign investment and under a unique repayment model, :PAY AS YOU EARN" are already with the ministry of Water & Power and Ministry of Petroleum & Natural Resources and implementation can commence immediately making a great impact on energy supply situation within a period of 9-18months.

Quotation

- A university should be a palce of light, of liberty and of learning.

Benjamin Disraeli

- Advice is seldom welcome; and those who want it the most always like it the least.

Lord Chesterfield

- The more virtuous any man is, the les easily does he suspect others to be vicious.

Cicero

- Good manners are the art of making those people easy with whom we converse. Whoever makes the fewest persons uneasy is the best bred in the company.

Janathan Swift

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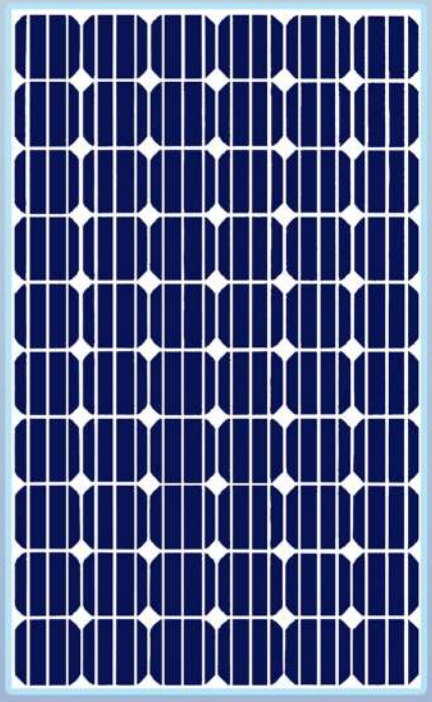

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