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USAID ENERGY POLICY PROGRAM

STEP-1 DUE DILIGENCE REPORT

REHABILITATE AND UPGRADE MANGLA HYDROELECTIC POWER STATION

June 2011

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MANGLA HYDROELECTRIC POWER STATION
Step 1 Due Diligence, Phase III

1. INTRODUCTION

The goal of the USAID energy program in Pakistan, focusing on the power sector, is to support the Government of Pakistan (GOP) in adding power generating capacity available to the National Grid, decrease losses in delivery of electric power to customers and increase cost recovery from them. This will be achieved through investment in infrastructure, support to institutional reform through technical assistance and promotion of new technology.

The program is being implemented in three phases. Phase I supports power plant repairs and efficiency improvements, replacement of existing tube well pump motors with more efficient power saving models, and technical assistance to help reform the power distribution companies. Phase II funds two multipurpose dam projects to generate electricity, store water and control flooding.

Phase III aims to support GOP in its longer term national development plans by making available funds to provide and promote investments in high-priority, high visibility major energy projects. It will also look at new technology initiatives in a way that encourages IFI, other donors and private sector funding and engages all relevant USG agencies (e.g., OPIC, EXIM). Technical Assistance will also be provided to develop institutional capacity and support energy sector reforms that will encourage public and private investment in the sector.

Energy projects under Phase III will be chosen based upon:

1) **Technical feasibility** -
a) Will the proposed intervention actually contribute significantly to meeting Pakistan's energy and other vital development needs, while improving the country's energy security?
b) Does the project use domestic or imported resources?
c) Does the project result in energy diversification?

2) **Cost** –
a) Is the cost reasonable?
b) Can the project's full financing be arranged in a timely fashion?

3) **Overall effect** –
a) Is the project high visibility?
b) Is it a high priority for Pakistan?
c) Will the power generated and other benefits be worth the time and money?

All projects identified for USG support undergo a two-step Due Diligence process. In Step 1 existing documents and other information is reviewed for adequacy to apply selection criteria

and make a recommendation to USG. Step 2 is an in-depth analysis of any additional information required for a USG decision on the project.

As part of the assistance to be provided by USAID under Phase III, GOP has requested funds for WAPDA, the project implementing agency, to rehabilitate and upgrade the 1,000MW hydroelectric power station at the Mangla Dam.

USAID tasked AEAI to conduct the Step 1 Due Diligence and confirm facts from WAPDA, evaluate whether the project meets the USAID criteria described above, highlight any particular risk or concern that needs to be mitigated or addressed and to make a recommendation.

2. SUMMARY

Description:	The Mangla Dam was built in 1960s and Power Station was added incrementally to a total of 1,000MW. The equipment at the power station is old, becoming increasingly unreliable and needs to be replaced.
Benefits:	Restore reliability of 1,000MW hydropower generation and provide additional 25% to 50% more power to the grid. Increase return on investment made to raise the Dam.
Cost :	Immediate need is $2 Million for a Feasibility Study of the proposed project and $13 Million to reimburse cost of parts. The estimated cost of the refurbishing project is $506 Million.
Schedule:	6 years, including feasibility study.
Implementation:	The Feasibility Study will lead to project design, tender documents and contracts for supply and construction.
Risks:	Plant output will reduce during 4 years of the project. The cost estimate for repair of civil structures is not certain. Raising the reservoir level has also raised resettlement issues.

The Mangla Dam is on the River Jhelum, about 120 km (by road) East of Islamabad in Mirpur District of Azad Jammu and Kashmir (AJK) and was built during 1961 to 1967 as the first water storage project under the Indus Basin Treaty between Pakistan and India.

The 1,000 MW hydroelectric power plant at Mangla has 10 power generating units of 100MW each and delivers around 5,000 GWh each year to the National Grid – enough electricity to power a million homes in Pakistan.

A project to raise height of the Dam and increase water storage capacity was completed in 2010. The increased water storage at the Dam, besides making available more water has also increased the pressure of water at turbines in the power house.

The Consultants for raising the Dam estimated that the extra head and water can potentially produce additional 640 GWh of energy and recommended upgrade of the power plant.

The equipment at the power station is old and its efficiency and dependability is low. Some equipment failures have occurred and WAPDA has recently replaced generator parts for almost $6 Million. It is opportune to refurbish and upgrade the entire power station but there are options to study before deciding what to do.

WAPDA has contracted a joint venture of M/s Montgomery Watson Harza (MWH) of USA and National Engineering Services (NESPAK) of Pakistan to carry out a Feasibility Study and recommend the best option for refurbishing the plant. The Consultancy Agreement was signed on 27 April 2011 for Rs 163 million ($2 million) and the study is expected to be completed in six months, or before end of this year. Following agreement and approval of the refurbishing plan, the detail design, planning, PC I approval[1] and procurement process will take two years and the estimated project implementation schedule is to start replacing units in 2013.

The proposed project will restore reliability of an iconic and large power station at an increasingly visible location[2] and improve energy security of the Country. WAPDA engineers and Pakistani consultants will gain valuable experience from their involvement and local contractors will get opportunity to improve their capacity. The preliminary cost benefit estimates are positive but till options are investigated and remedial works are identified, as is proposed to be done during the Feasibility Study, it is early for funding commitments.

The immediate request for assistance is to allocate $2 Million for the Feasibility Study that has started and will be completed this year, reimburse $6 Million for recent repairs, and agree to pay for repairs needed over next two years – estimated at $7 Million.

3. RECOMMENDATION

USAID approve $15 Million to assist WAPDA in the project to rehabilitate and upgrade the Mangla hydroelectric power station.

The funds will reimburse WAPDA for the repair of Unit 5, pay for continued repair and replacement of parts, as and when needed over next two years, and cover cost of the Feasibility Study that will provide the optimal plan to rehabilitate the entire power station.

USAID also approve Step 2 Due Diligence for the proposed project to monitor the Feasibility Study and report progress to USAID.

This Step 1 Due Diligence Report and recommendations are based on findings of a site visit and information provided by members of the WAPDA-USAID Task Force for the project.

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[1] - Government approval document for project plan and budget

[2] - Mangla was a monumental project for Pakistan in the 1960s and is still the second largest hydropower plant in the Country – after Tarbela. Many people displaced by the reservoir immigrated to UK and their remittances back home have formed a rich local community. An international consortium is constructing a 'resort city' at Mangla.

4. BACKGROUND

Water disputes with India followed soon after creation of Pakistan in 1947 and the Indus Basin Treaty was signed in 1960 through international mediation. A single line sketch of the irrigation system under the Indus Basin Treaty is at **Annex 1.**

Mangla Dam was the first large water storage project to support irrigation in Pakistan under the Treaty. The multipurpose Dam is primarily meant to replace water supplies from 3 eastern rivers (Sutlej, Ravi and Beas) that were ceded to India and to store water on the River Jhelum. Power generation is an additional benefit and consequently the designation of being a 'multipurpose' Dam.

The Mangla Dam is on the River Jhelum, about 120 km (by road) East of Islamabad in Mirpur District of Azad Jammu and Kashmir (AJK) and was built during 1961 to 1967. Geographic location is 33-08 N and 73-38 E.

The prominent structures at Mangla are the Main Dam and the Jari Dam (a dyke to contain the reservoir), two spillways for out flow regulation, an intake structure with 5 power and irrigation tunnels, a 1,000 MW power station comprising 10 units, with two units on each tunnel, and a tailrace canal called the New Bong Canal. The water from the power station goes back to the river bed through this canal which is 7620 m long.

*Trivia: An 84 MW **private hydropower** plant is under construction on this New Bong Canal downstream of the Mangla power station. It will utilize the head created by difference in height between the canal close to the power plant and the river bed.*

The power station was completed in four stages. Initially four units of 100 MW each (4 x 100 MW) were commissioned in 1969. Two more units were added (2 x 100 MW) in 1974. Another two (2 x 100 MW) were added 1981. The plant attained its maximum capacity of 1000MW with the final extension of units of units 9 & 10 (again 2 x 100 MW) in 1994. The power station has since been delivering around 5,000 GWh each year to the Grid – enough electricity to power about a million homes in Pakistan. A view of the Power Plant is at **Annex 2**. *The spray is water that has to be released for irrigation - it bypasses the turbine and is 'sprayed' in the air to dissipate the stored energy.*

Mangla reservoir capacity has reduced due to accumulation of silt over the years. The 'live'[3] storage capacity, the water that can be used, decreased to less than 4.7 Million Acre Feet[4] (MAF) from original capacity of 5.9 MAF - a reduction of about 20% over the last 40 years. A project to raise height of the Dam by 40 feet and increase water storage capacity was

[3] - The 'dead' storage of water in a reservoir allows for marine life to continue and for settling sediments
[4] - An acre foot of water will cover an acre, about the size of a football field, to a depth of one foot

completed in 2010. Besides making available more water this has also increased pressure of water available to turbines in the power house.

The main dam is now (after raising) 3400 m long and almost 150 m high with reservoir area of 320 sq. km. Original surface area of the filled reservoir was about 260 sq. km. The rise of 40 feet (13 m) provides additional water storage of 2.9 MAF, which is almost 50% of reservoir original capacity[5]. The live storage capacity at Mangla will increase to 7.6 MAF when the reservoir is filled to its new maximum level.

During high water flow seasons, when the reservoir is full and water is plenty, the Mangla power station can generate 1,150 MW against the rated capacity of 1,000MW. Such overloading is built in the original design capacity. Conversely, when reservoir level is low and during lean flow periods, the plant capacity reduces to 500 MW or less.

The Consultants for raising the Dam estimated that the extra head and water can potentially produce additional 640 GWh of energy and recommended upgrade of the power plant.

WAPDA engineers are convinced that it is now opportune to refurbish and upgrade the power station. The equipment is old and its efficiency and dependability is low whereas the hydraulic parameters have changed – extra height and more water is now available. An improved power station will also gain greater benefit and put to more efficient use the investments already made in raising the Dam. The project will restore reliability and prevent the possible failure of a large hydropower station, increase generation capacity to the national grid and potentially obviate the addition of $128[6] Million each year to the Circular Debt plaguing the sector.

The fact that the equipment at the power station is old and that its efficiency and dependability is low is established; and it is also true that the power station needs to be refurbished and upgraded; however, there are options to study before deciding what to do and how to do it.

WAPDA has contracted a joint venture of M/s MWH (USA) – NESPAK (Pakistan) to carry out a Feasibility Study and recommend the best option for the plant. The Consultancy Agreement was signed on 27 April 2011 for Rs 163 million ($2 million) and the study is expected to be completed in six months, or before end of this year. After completion of the Study and decision on the optimal solution, detail engineering design, cost estimates, Government approvals and preparation of tender documents will be undertaken. This will be followed by an international competitive procurement process to select suppliers and contractors. The project to supply, erect, construct, install, test and commission the refurbished and upgraded plant will take 4 years. The estimated cost is $506 Million, most of which will be in foreign exchange.

The proposed rehabilitation and upgrade project will restore reliability of an iconic power station at an increasingly visible location and improve energy security of the Country. WAPDA engineers and Pakistani consultants will gain valuable experience from their involvement and local contractors will get opportunity to improve their capacity. The preliminary cost benefit

[5] - the volume of water stored in the top 1 foot is far greater than that in 1 foot at lower depths in a valley
[6] - 640 million units @ $0.20/unit from a thermal IPP

estimates are positive but till all factors are actually investigated and remedial works are fully identified, as is proposed to be done during the Feasibility Study, it is premature to make a specific funding commitment to the project estimated to cost over $0.5 Billion.

An issue at the moment is that although the Dam height has been raised, the reservoir has not yet been filled to its new increased capacity because almost 40,000 people living along the original limits of the reservoir have to move. Alternate arrangements that were planned and agreed to with the affected population have not been implemented owing to various reasons. A sketch showing expansion of the reservoir area, which has resulted in requiring resettlement of population, is at **Annex 3**.

5. JUSTIFICATION

The machines at Mangla are old and WAPDA is concerned about their decreasing reliability. The first 6 units are over 30-40 years old – the generally accepted useful life of such equipment. Continuing to operate these old machines requires more frequent downtime and less operational reliability besides the fact that spares are hard to find. Some information on the equipment at the power plant is at **Annex 4**.

The raising of Mangla Dam has made available additional 2.9 MAF of water and increased the water head at turbines by 40 feet. This additional volume and pressure of water can be better utilized in new machines to generate more energy.

WAPDA's concern regarding station reliability is valid. In 2009 a fire in the cable tunnels closed the entire station for a month. Unit No. 5 was recently shut down due to fault in Generator Winding and Stator Core and has been repaired at cost of almost $6 Million but full load tests are continuing and manufacturer has recommended that these be replaced. The power station engineers agree and have also asked the plant management to have another complete set of winding and core in stock as Unit No. 6 is also vulnerable to similar faults. Given the dilapidated condition of equipment, the power station will be making demands for repair costs over the coming couple of years (while plans for refurbishing mature) and funds need to be in place to pay for them as and when required. The cost of replacing a set of Stator Winding and Core is $5 Million. Assurance of availability of funds will prevent operators running the machines to the ground and prevent breakdowns resulting in extended loss of capacity at the plant.

A unit at Mangla shut down for a month (when water is available) means $1.4 Million loss in revenue to WAPDA and $13 Million addition in PEPCO's payment bills[7].

The power units at Mangla were fabricated on technology of the 1950s. Considerable development has taken place in design and fabrication to maximize efficiency of turbines, generators, transformers and associated equipment and in available materials. Computer aided design, manufacturing techniques and improved insulation and construction materials have produced higher efficiency ratings of electrical and mechanical equipment. An upgrade of the

[7] - assuming $0.02 cents for hydro power and $0.20 a unit from a thermal IPP

power station is required to regain reliability, optimize available water resources and ensure safe and sustainable operation of the power plant. To implement this option in the most efficient and prudent manner, experts have to study the options and recommend the optimal solution.

The Mangla Joint Venture (MJV), Consultants for the Mangla Dam Raising Project, during their study carried out preliminary power and energy simulations for upgrading of the power plant. They concluded that the old power plant should be refurbished and upgraded to gain full benefit from the investments already made in raising the height of the Dam.

6. THE PROJECT

The aging Mangla Hydroelectric Power Station has to be rehabilitated. Two options are under consideration. The first is to upgrade all the 100MW generators and related electrical equipment – but not the turbines. The existing turbines are designed to operate safely up to the rating of 125 MW whereas the Generators overload capacity is limited to 15%. This option will result in increasing plant capacity to 1,250 MW but will retain the old foundation, embedded parts and the turbines.

The other option is to replace and upgrading the generators and the turbines and all related equipment to get plant capacity of 1,500 MW. This latter option seems to be the preferred option but a Feasibility Study is essential to evaluate cost and benefits of both options and to arrive at the optimal solution[8].

The consultants selected by WAPDA to study and recommend options at Mangla are MWH of USA and NESPAK of Pakistan. The Consultancy Agreement was signed on 27 April, 2011. The time for finalization of study is 6 months.

The Consultants is to:

Determine the maximum power potential at the Mangla Dam after its raising, keeping in view the projected hydrology and that outflows are regulated by the need of agriculture.

Identify options for obtaining optimum power output (MW) and energy (GWh) from Mangla Power Station post raising scenario without any major change in the existing civil structures.

Identify the electro-mechanical equipment of Power House and Switchyard which needs Refurbishment/Replacement under each option.

Study the existing Control, Instrumentation and Protection (of equipment from operational damage) Systems and propose upgrade and modernization.

Study the condition of all power and control cables and make recommendations.

[8] - the project cost estimates are based on the latter option

Assess the state and estimate remaining useful life of the electro-mechanical equipment not being replaced.

Assess condition of concrete structures related to the Embedded Parts of Turbines and Generators, etc., to confirm their suitability for another 50 years life as well as their compatibility with higher capacity Generating Units.

Assess suitability of power evacuation from Power House to Switchyard through overhead lines (recently constructed on emergency basis after damage of HV cables in tunnel) and recommend the most safe and reliable permanent solution.

Assess the auxiliary supply arrangements and recommend optimal solution.

Assess suitability of the existing 200/30 Ton Crane in light of proposed works.

The actual rehabilitation and upgrade project will follow results of the study.

7. IMPLEMENTATION PLAN

A tentative plan has been conceived to refurbish and upgrade the units at Mangla Power Station but the actual work and methodology will be determined by the Feasibility Study. A more accurate schedule will be available on completion of the Study before end of the year. The tentative proposed Implementation Plan is:

Activity	Tentative Schedule		
	Start	**End**	**Duration**
Feasibility Study	May 2011	Nov 2011	6 Months
WAPDA Review & Final Report	Nov 2011	Dec 2011	1 Month
Hiring of Consultants for Design, Tender Documents and PC-1	Jan 2012	Jun 2012	6 Months
Detail Design, Preparation of Tender Documents, PC-1 & Pre-qualification of Contractors	Jun 2012	Nov 2012	6 Months
Appointment of Consultants for Construction Supervision	Nov 2012	Dec 2012	2 Months
PC-1 approval process	Nov 2012	Feb 2013	3 Months
Final design review, bidding & award Contract	Mar 2013	Aug 2013	6 Months
Supply/Construction/Commissioning	Sep 2013	Jun 2017	46 Months

There is a sequence to these activities but there is also an overlap. Aspects and elements of an activity can be initiated before completion of the previous one to expedite the overall project schedule. Time will be of the essence for this project as each day of downtime at the station loses around $300,000 in revenue for WAPDA, and if the hydropower power is replaced with

thermal power, will add about $3 million – assuming 2 cents a unit from hydro and 20 cents a unit from thermal – to the circular debt plaguing the power sector of the Country.

8. COST

Immediate need:

Cost for preparation of Feasibility Report		$ 2 Million
Cost of parts		$ 6 Million
Estimated cost of parts required		$ 7 Million
	Total:	$ 15 Million

Rehabilitation Project Cost Estimate:

Detailed Design, Tender Documents and PC I		$ 6 Million
Consultants for Procurement and Supervision		$ 25 Million
Supply/Construction Project		$475 Million
	Total:	$506 Millions

This estimate is based on presumed cost of replacing all turbines, generators and related equipment but the figure could change if international market price of such equipment take a major swing - either way - and will certainly go up if unforeseen major civil works are required.

9. RISKS

Loss of Capacity

The project is expected to take 4 years to complete and that means 4 high water seasons at risk of not being used to capacity – and possibly having to burn expensive imported oil elsewhere to make up that loss. When machines have to be shut down for repair, they will probably be down at least two at a time as two machines are fed by the same tunnel resulting in aggregate loss of 200MW of power. In certain other cases of repair or rehabilitation, greater capacity will be lost and at times, the entire station may need to be closed down. This will happen for months at a time over the four year construction period. Assuming 30% loss of capacity at the plant over the 4-year period of repair, and that thermal power replaces the units lost, one could add about $1 billion to cost of project.

However, a study is being commissioned to look at such issues and construction plans and schedule will attempt to minimize loss of capacity.

Resettlement

The civil works to raise the height of the Mangla Dam was completed in 2010. However, filling of the reservoir to the new mean-sea elevation of 1,242 ft has not yet been achieved. This is owing to resettlement problems. There was to be a new township to house the people that

had to be moved but the township is not yet been built. WAPDA offered to rent houses for those affected but the offer has been rejected. Another problem is access to Chohan and Kharak (see **Annex 3**).

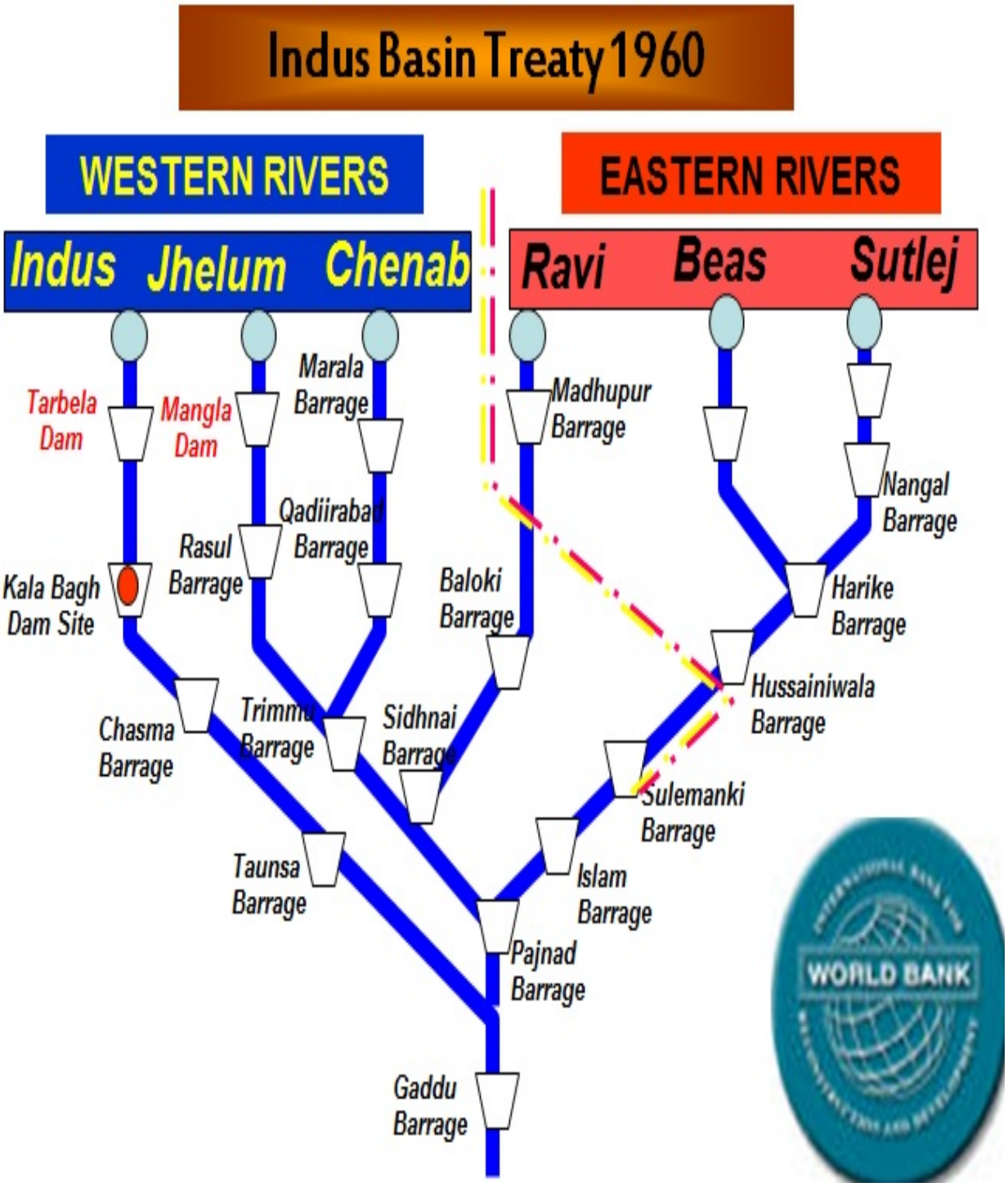
Till the access dykes are built and new townships are completed to satisfaction of the displaced people, resettlement will remain an issue and the reservoir will not be filled to the new design capacity.

Structures and Foundations

All civil structures, foundations and embedded parts are in place for 30 to 50 years. WAPDA has attempted to estimate the work and cost involved in improving their condition and made requests for proposals and budgetary price estimates to various international firms specialized in refurbishing old plants but has not received any adequate response. All are reluctant to provide an estimate without knowing the actual condition of the foundations and civil works.

The upcoming study will attempt to get a better idea of the state of these civil works and structures and embedded parts. Till such time the uncertainty – and the risk of possibly incurring higher costs for the project - will remain.

USAID review of this Step 1 Due Diligence Report will determine Step 2


Indus Basin Treaty 1960
WESTERN RIVERS
EASTERN RIVERS
Indus
Jhelum
Chenab
Ravi
Beas
Sutlej
Tarbela Dam
Mangla Dam
Marala Barrage
Madhupur Barrage
Nangal Barrage
Qadiirabad Barrage
Rasul Barrage
Kala Bagh Dam Site
Baloki Barrage
Harike Barrage
Hussainiwala Barrage
Chasma Barrage
Trimmu Barrage
Sidhnai Barrage
Sulemanki Barrage
Taunsa Barrage
Islam Barrage
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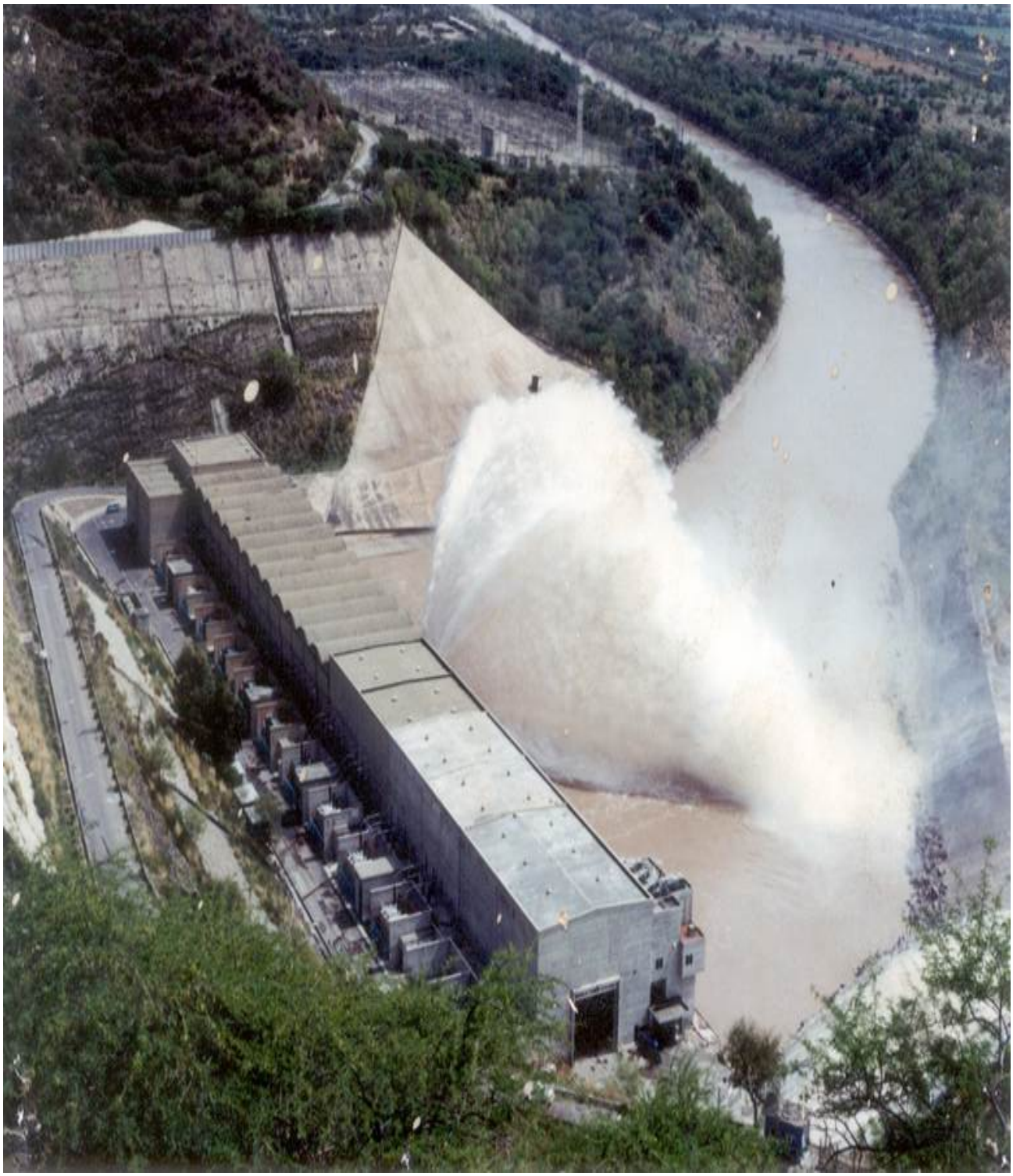
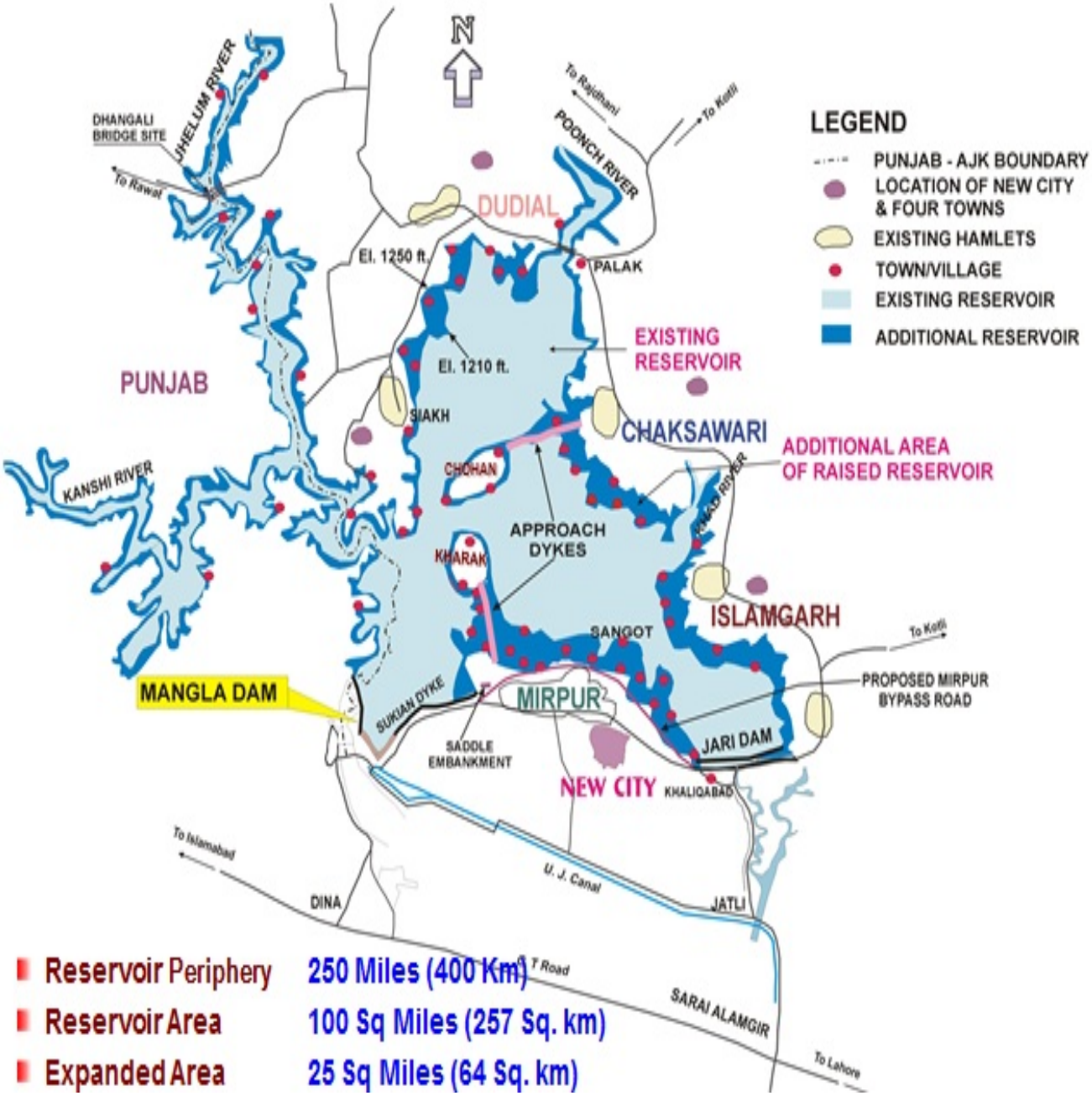
Gaddu Barrage
WORLD BANK



MANGLA DAM RAISING PROJECT

MANGLA RESERVOIR



Basic design features of the hydropower units at Mangla Power Station

Turbine	**Units 1-4**	**Units 5-6**	**Units 7-8**	**Units 9-10**
Type	---------- Francis-Vertical Shaft ----------			
Rated Output (BHP)	138,000	138,000	138,000	138,000
Maximum Output (BHP)	198,000	198,000	198,000	198,000
Rated Head (Ft. of Water)	295	295	295	295
Rated Discharge (Cusecs)	4,550	4,515	4,307	4,515
Efficiency (%)	93.2	93.2	93.2	93.2
Manufacturer	Mitsubishi Japan	CKD Blansko (Czech.)	Escherwyse-ACEC Belgium	CKD Blansko (Czech.)
Generators				
Rated Output MVA / MW Overload Capacity	125 / 100 115%	125 / 100 115%	125 / 100 115%	125 / 100 115%
Terminal Voltage (KV)	13.2	13.2	13.2	13.2
Rated Speed (RPM)	166.7	166.7	166.7	166.7
Generator Insulation	Class-B	Class-F	Class-B	Class-F
Manufacturer	Hitachi Japan	PRAHA (Czech.)	Hitachi Japan	PRAHA (Czech.)

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