Paper No. 260

ROLE OF HYDROPOWER IN MANAGEMENT OF POWER CRISIS IN PAKISTAN

By

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SYNOPSIS

Presently total power generation capacity in Pakistan is about 19500 MW, out of which Hydel has a share of 37% and Thermal and others 63%. Since three decades, considerable share of electric power is being born by Tarbela and Mangla constructed under IBP. No major hydropower dam has been built after completion of Tarbela in 1975. Pakistan is exploiting only about 6464 MW out of total hydropower potential of 54343 MW. Although, many hydropower projects are at different stages of planning, design and construction yet there is a need to plan and formulate the implementation priorities of the cheap hydropower. About 85% of oil and the allied products are imported to meet the national requirement. In the year 2007-08, the import bill had gone up to US$ 1.25 billion. If cheap hydropower is not added to the system, the tariff of electricity produced with imported fuel would become unaffordable.

Diamer Basha Dam is one of the hydropower projects ready for implementation to solve the water storage and energy crisis on long term basis. The 272 m high RCC dam will be the highest RCC dam in the world. The large chunk of 4500 MW installation at Diamer Basha Dam will go a long way in reducing the demand-supply gap in the future years.

The paper describes the planning and construction for hydel power in Pakistan and significance of Diamer Basha Dam in future if the energy crisis is to be resolved on long term basis. Diamer Basha dam shall have cascading effect on downstream projects.

INTRODUCTION

Energy is the most problematic issue in the world and Pakistan is also facing electric power crisis these days. There is an acute electric power shortage since last few years and the problem is on an increasing trend. The power crisis forced hundreds of industries to shut down operations, affecting industrial production and the livelihoods of thousands of families. The country may plunge into more energy crisis in the coming years due to rising electricity demand following increasing sale of electrical and electronic appliances on lease finance.

Pakistan is an energy deficient country and needs a quantum jump in electricity generation to avert the possibilities of load-shedding in future due to gap between demand and supply of electricity at peak hours. The government is trying its level best to fulfill increasing requirements. In the last few years, Pakistan, India, Bhutan and Nepal have prepared plans for a large number of Hydro Power Projects in the Himalayas. Several hundred dams are now proposed for the region, which could lead to capacity additions of over 150,000 MW in the next 20 years (Figure-1). All these countries have built dams in the Himalayas in the past to generate hydropower and to store water for irrigation and other needs. Among India's earliest multipurpose projects was the Bhakra Nangal Dam, a rim station project on the Satluj, a tributary of the Indus, with an installed capacity of 1200 MW, completed in 1962. Pakistan built the 1000 MW Mangla and the 3478 MW Tarbela dams. Bhutan undertook the construction of the 336 MW Chukha project (1986-88) with the Indian government's help, while Nepal also built several small and medium

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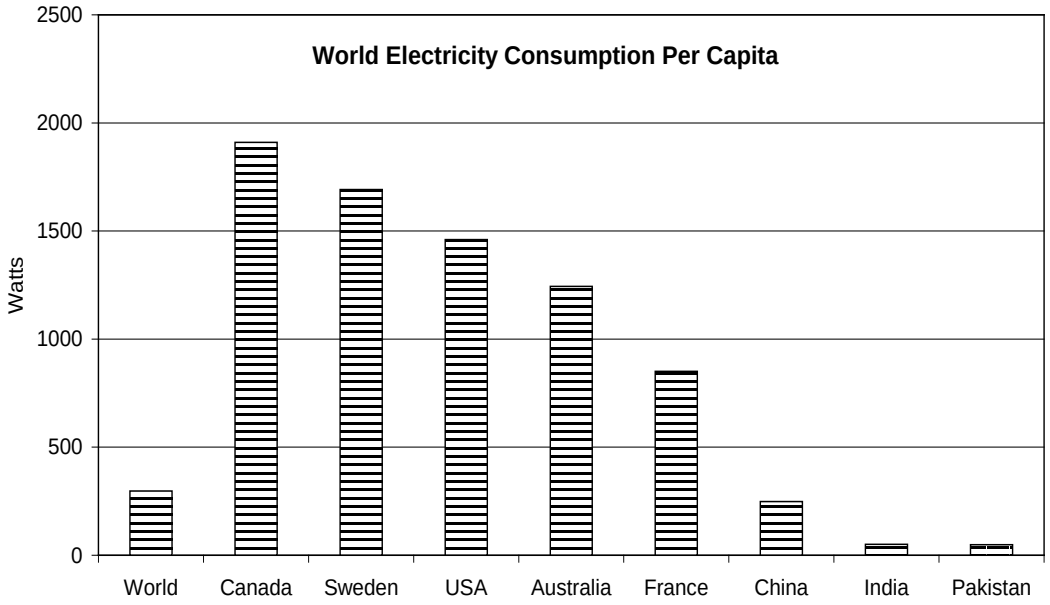
projects in the 1960s – 70s. The construction of big dams had slowed in the last decade due to a variety of reasons, including the tremendous opposition they faced from affected people and strong critiques of their development effectiveness. Today there is a renewed push for these projects, several of which are already under construction. Hydropower constitutes an important source of power for all four countries.

Table-1: Existing, Under Construction, and Planned Hydropower Project

	Nepal		Pakistan		Bhutan		India (Himalayan Region)	
	No. of Projects	Capacity (MW)	No. of Projects	Capacity (MW)	No. of Projects	Capacity (MW)	No. of Projects	Capacity (MW)
Existing	15	545	6	6,385	5	1,480	74	15,208
Under Construction	2	84	7	1,405			37	17,765
Planned	37	26,324	35	33,769	16	15,693	318	93,615
Total	54	26,953	48	41,559	21	17,173	429	126,588

Pakistan ranks 35th in the world in the electricity consumption and 31st in electricity production. Following figure shows the per capita power consumption of some of the countries of the world. Pakistan is amongst the lowest.

Figure-2 List of countries by electricity consumption

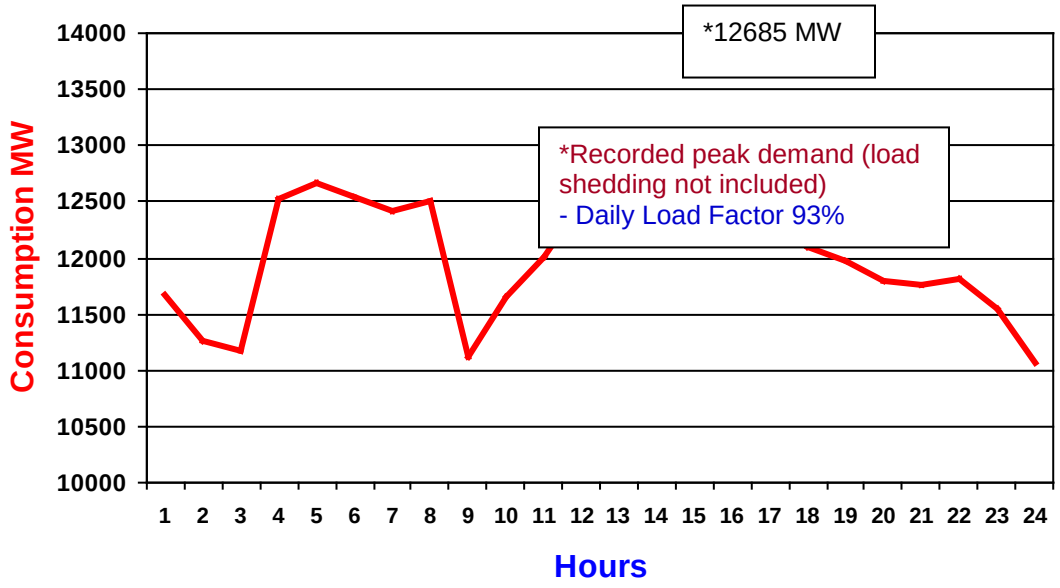


It is estimated that demand and supply of electricity in Pakistan may widen to the extent of over 5,500 MW in the near future. This shall translate into load-shedding on a large scale in the years to come if the situation is not properly handled. Table-2 shows the month-wise demand and supply position for the last one year while Figure-3 shows the load curve for a typical summer day.

Table-2 Month-wise demand and supply position (2007)

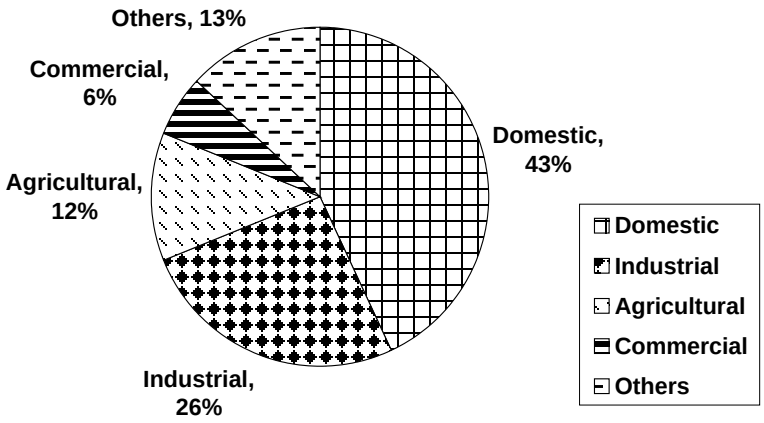
Month	Computed Peak Demand (MW)*	Corresponding Supply (MW)	Surplus/deficit (MW)
Oct-07	13737	14092	355
Nov-07	12401	11590	-811
Dec-07	12154	9679	-2475
Jan-08	12255	9104	-3151
Feb-08	12123	10122	-2001
Mar-08	13682	9845	-3837
Apr-08	15124	11568	-3556
May-08	16649	11195	-5454
Jun-08	17398	12442	-4956
Jul-08	17715	12822	-4893
Aug-08	17272	12751	-4521
Sep-08	17852	13637	-4215
Oct-08	15766	12982	-2784

Figure-3: Typical Load Curve (on August 1, 2008)



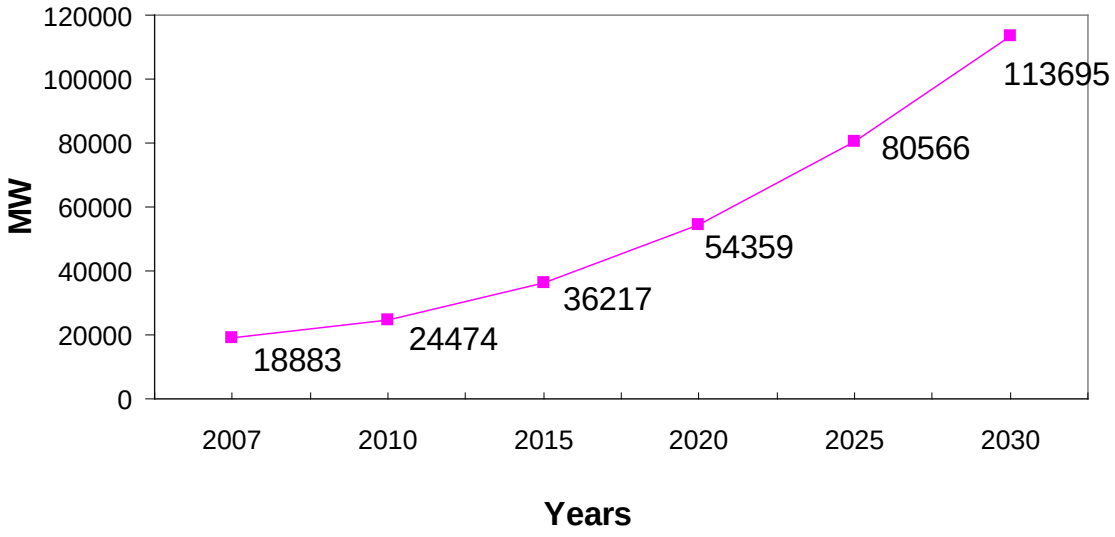
Out of total power production, the industrial sector consumes only 26 percent and domestic sector consumes about 43% as shown in the following diagram.

Figure-4: Consumption of Energy in Pakistan



Demand of the power has also increased due to better living conditions and rapid use of electrical appliances. The gap between the demand and power available is due to certain reasons like no major hydropower station after Tarbela, less availability of power from IPPs, increase in power consumption growth rate, non installation of new generating units by private sector. Figure-5 shows the projected power demand in the future with the average growth rate of 8%.

Figure-5 Peak Demand Projections (whole Country) 2007-30



IMPORTANCE OF HYDEL DEVELOPMENT

Hydroelectric power supplies about 715,000 MW or 19% of world electricity. Apart from a few countries with an abundance of hydro power, this energy source is normally applied to peak load demand, because it is readily stopped and started. It can also provide a high-capacity, low-cost means of energy storage, known as "pumped storage".

In the context of the world's energy and water resources scenario, the optimal utilization of the available hydro potential needs the utmost priority. Notwithstanding the initial higher investment to construct hydropower plants, their recurring annual costs are insignificant as compared to the thermal plants. Further, they save a lot of foreign exchange spent on import of fuel oil. This is a clean source of renewable power.

Pakistan is endowed with very large renewable energy resources in the form of hydropower. This potential is estimated about 54,343 MW. Out of this, only 6464 MW has been exploited to date through Warsak, Mangla, Tarbela, Ghazi Barotha and some other small stations. Presently total power generation capacity in Pakistan is about 19500 MW. The cost of power supply from Independent Power Producers (IPPs) is Rs.6.8/unit whereas Mangla generation cost is Rs. 0.1/unit and Tarbela cost is Rs. 0.25/unit. The access to energy has now become expensive. Therefore, in order to keep the prices within reasonable limits and to keep our Industry competitive with world market, we should install hydel power stations on large dams to tap this cheap source. We need to supply electricity to thousands of villages which are still devoid of this essential modern day need. For poverty alleviation and to sustain our agro based economy, we urgently need to build storages and produce cheap hydel power.

If Pakistan have spare base power (which is cheap) it can also be used for pumped storages. At present, Pakistan does not have any pumped storage. However it can be developed if we have cheap thermal power (coal) spare off peak hours.

For Pakistan, the corner stone of self reliance in power sector development is optimal utilization of hydel resources. Hydropower is the most important, non polluting renewable source of energy. Major Hydroelectric stations in the world are summarized in the following table.

Table-3: Major Hydroelectric Stations of the World

Sr. No.	Name	Country	Year of Completion	Total capacity (MW)	Max Annual Electricity Production (TW-hour)
1.	Three Gorges Dam	China	2009	22500	>100
2.	Itaipu	Brazil/Paraguay	1984/2003	14000	90
3.	Guri	Venezuela	1986	10200	46
4.	Grand Coulee	USA	1942/1980	6800	22.6
5.	Tarbela	Pakistan	1976	3478	13
6.	Mangla	Pakistan	1967	1000	-

Recent years have seen a renewed push for building hydropower projects in the Himalayas. Massive plans are underway in Pakistan, India, Nepal and Bhutan to build several hundred dams in the region, with over 150,000 MW of additional capacity proposed in the next 20 years in the four countries. If all the planned capacity expansion materializes, the Himalayan region could possibly become the highest hydropower regions in the world.

PLANNING BY WAPDA

WAPDA established in 1958, was entrusted with an agenda, which included generation, transmission and distribution of power. It serves 88 percent of all electricity customers in Pakistan and has been the principal power generation, transmission and supply system in the country. It has a customer base of over 10 million.

Performance data of the recent years has shown that the growth rate in Power demand has been much higher than WAPDA plans. WAPDA has planned to construct a number of thermal stations on fast track basis to alleviate this problem. It is expected that power supplies would satisfactorily improve in next two years but the thermal power being much more expensive than hydropower, the pressure on tariff will substantially increase.

WAPDA is constantly in pursuit of cheap hydel power generation and working on many low, medium and high head projects in the country to overcome the issue on long term basis. Following summary shows the hydropower undertaken by WAPDA.

Table-4: Hydropower in Operation and Undertaken By Wapda

Sr. No.	Description	Capacity (MW)
1.	In Operation	6464
2.	Under Construction	1422
3.	Five Mega Hydropower Projects (Basha, Kalabagh, Kurram Tangi, Akhori, & Munda)	9523
4.	Projects Under Studies	20727
	Total	38136

RANKING STUDY ON UPPER INDUS BASIN

Ranking study of run of the river projects was carried out by WAPDA with the help of MONENCO in early eighties. During the last decade WAPDA compiled some documentation and feasibility studies of a number of projects on the tributaries of main rivers. The hydroelectric inventory and ranking studies show that an ultimate installed capacity at major schemes in Upper Indus Basin is of the enormous range while total hydropower potential at Indus River and its tributaries is 41766 MW. Table-5 shows the list of some of the identified sties on Upper Indus River and its tributaries. The upper Indus includes the reach of the river from proposed Kalabagh dam site to the control line upstream of its confluence with Shyok River. Sixteen potential hydropower sites in this reach were Identified and studied. The average annual run-off at Skardu is 24 MAF. An earth rockfill dam 230 m high at Skardu located some 10 miles downstream of confluence with Shigar River can provide a gross storage of 15.52 MAF but with unacceptable environmental problems.

Table-5 Ranking of Hydropower Scheme on River Indus & its Tributaries

Rank	Scheme	River	Power (MW)
1	Diamer Basha	Indus	4500
2	Dasu	Indus	4000
3	Bunji	Indus	6000
4	Thakot	Indus	2800
5	Pattan	Indus	2800
6	Yulbo	Indus	3000
7	Rakhiot	Indus	670
8	Kalangai	Swat	256
9	Kohala	Jhelum	1100
10	Munda	Swat	740
11	Karot	Jhelum	240

The river valley u/s Basha is relatively wide and has a considerable storage potential with an average annual run-off of 54 MAF. The river after Basha drops a further 470 m to enter Tarbela reservoir. The valley is narrow in this reach and offers sites for the development of run-of river plants at Dasu, Pattan and Thakot. With the exception of storage at Yogu, Skardu and Basha all other hydroelectric schemes on the Indus River would be run-of river projects which would benefit from regulation at the upstream reservoirs. Figure 6 shows the profile of Indus River and

ranking of hydroelectric projects. From LOC to Kalabagh dam site river Indus has a drop of about 2500 m which makes it attractive for a number of hydropower project sites.

DIAMER BASHA DAM PROJECT

Diamer Basha Dam Project (DBDP) ranks as one of the high priority schemes for optimal use of the renewable energy resource available on the Indus River. The 272 m high RCC dam would be built on River Indus about 40 miles downstream of Chilas in the northern area The large chunk of 4500 MW installation at DBDP will go a long way in reducing the demand-supply gap in the future years.

Initial Feasibility Report of Diamer Basha Dam Project was prepared by Canadian Consultants "Montreal Engineering Company (MONENCO) during 1981-1984. WAPDA appointed Local Consultants in December, 1989 for up-gradation of the Initial Feasibility Report. The work on the project was stopped in January 1990. In 2002 WAPDA appointed M/S NEAC Consultants for up-gradation of the Initial Feasibility Study. The Upgraded Feasibility Report of the Project was submitted by M/s NEAC on 31st August, 2004. International Panel of Experts declared that the Project is technically feasible. The contract for review of Feasibility Studies, Detailed Engineering Design and preparation of Tender Documents awarded to M/S Diamer Basha Consultants (DBC). The DBC mobilized on 5th September, 2005 and the assignment was completed by June, 2008.

Salient Features

- LOCATION — 40 km downstream of Chilas
- MAIN DAM:
  - Maximum Height — 272 m
  - Type — Roller Compacted Concrete (RCC)
- DIVERSION SYSTEM — 2 No. Diversion tunnels; 1 No. Diversion channel; Upstream and Downstream Cofferdams
- MAIN SPILLWAY:
  - No. of gates — 14
  - Size of gate — 11.5 X 16.24 m
- RESERVOIR LEVEL — 1160 m
  - Gross capacity — 8.1 MAF (10.0 BCM)
  - Live capacity — 6.4 MAF (7.9 BCM)
  - Min. operation level — El. 1060 m
- OUTLETS:
  - Low level — 2
  - Sluicing — 5
- POWERHOUSE(S): — 2
  - Total installed capacity — 4500 MW
  - Location and type — Toe of the Dam (one each on the right and left side)

No. of units	12 each of 375 MW
Average generation	18,000 GWh/year

- ESTIMATED COST (Year 2009) US$11.34 Billion

EIRR	18.1%
Cost Benefit Ratio	2.49
Cost Pay back	7.5 Years

Figure-7 presents layout of Diamer Basha Dam Project.

The river shall be diverted through two diversion tunnels during dry flow season and through open cut channel on the right saddle in the wet season. Coffer dams shall be constructed u/s and d/s before diverting the river. About 50 m of river alluviums shall be excavated to lay the foundation of the dam on sound bed rock. The dam shall comprise of 31 blocks each about 35 m wide. The low cement concrete shall be transported through conveyor belts and compacted by rollers. The aggregates and water shall be chilled to reduce the heat of hydration.

Figure-8 shows the cross section of the dam through the spillway which is located on the top of the dam in the centre. The flip bucket shall dissipate the energy of water flowing over its crest. The dam is about 200 m wide at base.

Figure-9 shows the longitudinal section of the dam. It is 1006.5 m long at crest. It has 7 low level outlets; two for supplementing the irrigation demand and 5 for flushing out of sediments. The dam has been designed to withstand max credible earthquake of 0.46 g.
The environmental impact of Diamer Basha Dam is minimal as compared to the other large hydropower projects.

Cascading Effect on Other Projects and Tarbela
It is also pertinent to state that the development of DBDP is essential to establish the economic viability of the proposed downstream hydropower schemes at Dasu, Pattan and Thakot. In other words, construction of DBDP is a pre-requisite to exploit the downstream hydropower resources on the Indus River up to Tarbela reservoir. The DBDP will increase the total hydro generation capacity of the system to above 11000 MW. Even then the overall exploitation will be about 24% of the total hydro potential. The conjunctive operation of the two reservoirs, Diamer Basha and Tarbela, will facilitate an average annual generation of 18097 GWh at DBDP and an incremental power generation of 1111 GWh at Tarbela.

With construction of DBDP, the share of hydropower in the system generation mix will improve thus contributing to one of the major policy objectives of rationalizing electricity prices in the long term.

Besides enhancing electricity supply, the project will contribute to alleviation of acute water shortage in Indus Basin Irrigation System (IBIS) caused by progressive siltation of on-line reservoirs and addition of new irrigation schemes. The conjunctive operation of Tarbela and Diamer Basha reservoirs will also increase annual average water supply to IBIS by 8.0 BCM (6.4 MAF).

Benefits
The main benefits of Diamer Basha Dam are:

- Significantly enhance water storage capability of the Indus River system by adding about 8 Billion m^3 of live storage.

- Generating about 18,000 GWH of energy per annum from its installed capacity of 4,500 MW. Additional 1111 MW at Tarbela.
- Cascading effect on d/s hydropower projects.
- Reduction of dependence on thermal power, thus saving foreign exchange.
- Increasing useful life of the downstream Tarbela reservoir by trapping large amount of sediment.
- Alleviation of flood damage of the Indus River
- Creation of massive infrastructure leading to overall socio-economic uplift of the area and standard of living of people.

Present Status

Feasibility studies were completed by NEAC consultants in 2004 which were later updated by Diamer Basha Consultants. Detailed Engineering Design & Tender Documents were prepared in 2008. Hydraulic Model Studies were also completed in 2008. Detailed Environment Impact Assessment and Cultural Impact Assessment have been done while Resettlement Action Plan and Environmental Management Plans have also been prepared. PC-I for construction stage US$ 11.34 Billion forwarded to Planning Division through Ministry of Water and Power. PC-I for Land Acquisition & Resettlement has been approved by ECNEC in November 2008 for Rs. 60 Billion. Arrangement of finances from the foreign donor agencies for the construction of the project is under process.

LOW HEAD HYDEL POWER STATIONS

Pakistan has a potential of about 800 MW of low head hydel power. There area a number of sites on canals and tributaries of main rivers. Out of twenty (20) barrages we have low head hydel power station only on Chashma (180 MW) and 96 MW power station is being installed on Jinnah barrage.

CONCLUSIONS

- Pakistan has hydropower potential of the order of 54,000 MW.
- Although hydropower plants are time and cost intensive, yet after initial years of debt repayment, the cost of production is very cheap.
- If cheap hydropower is not added to the system the electricity would become unaffordable and Pakistan Industry shall become non-competitive. More load shedding shall have to be done in future.
- Diamer Basha Dam can play a major role in meeting the power demand.
- Diamer Basha's average annual generation shall be 18097 GWh at DBDP and an incremental power generation of 1111 GWh at Tarbela. It shall have cascading effect on d/s projects.
- Hydropower is helpful for peaking and meeting the daily load variation.
- Hydropower is a clean, environment friendly and renewable source of energy.
- Low Head Hydel Power Stations should also be installed at barrages and canals.

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Figure-1 Dams in the Himalayas

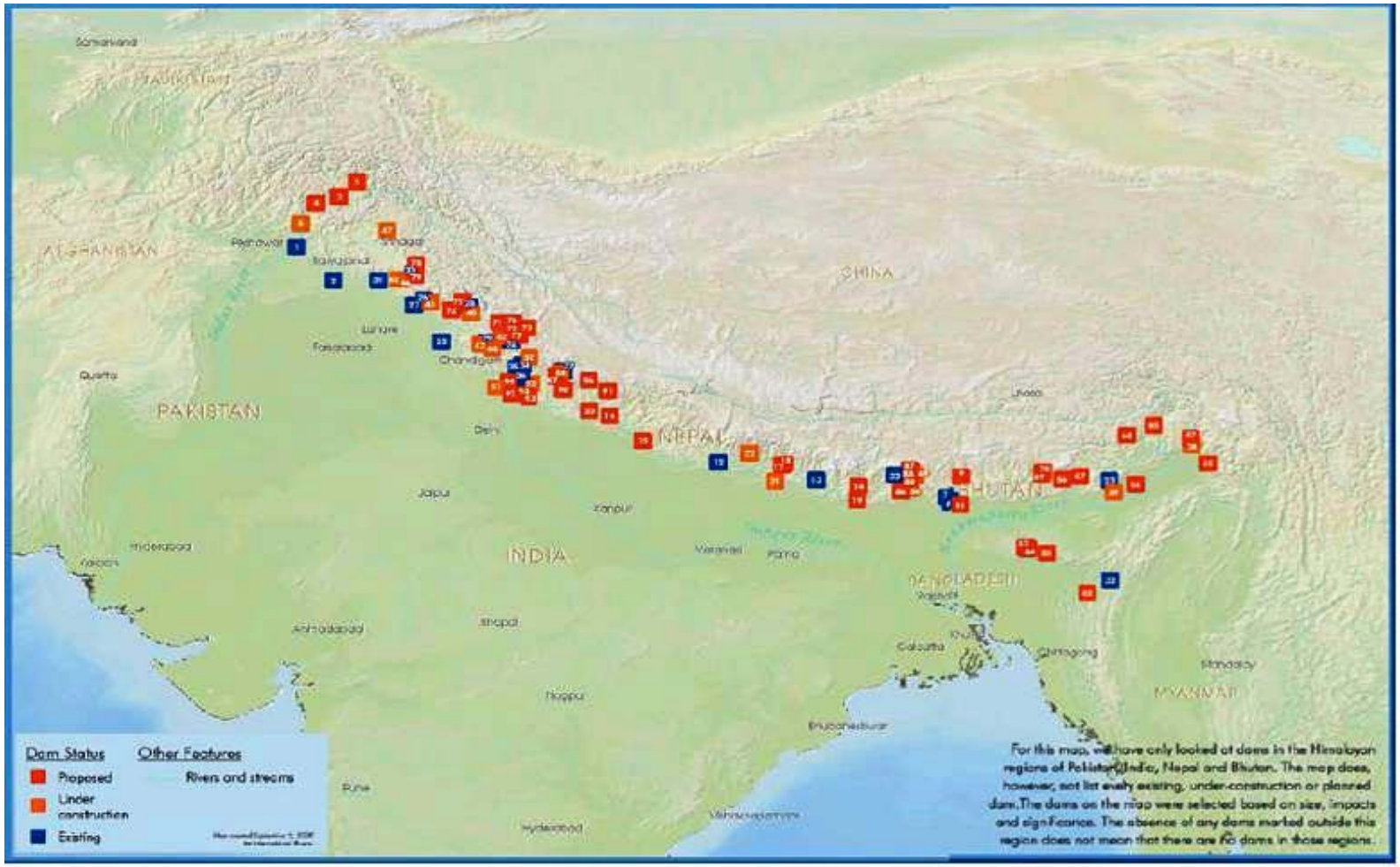


Figure-6 Profile of Indus River

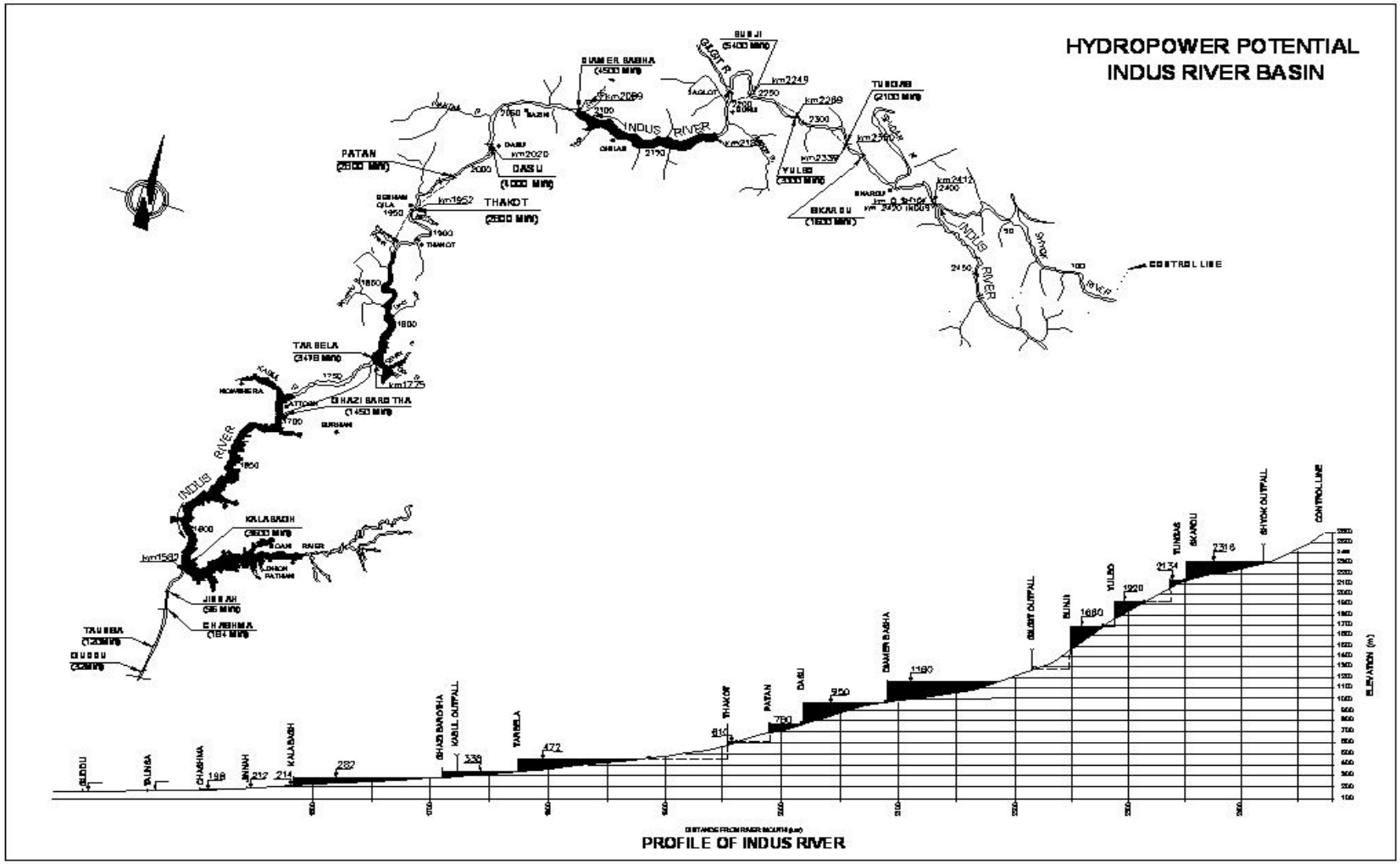


Figure-7 Diamer Basha Dam Project Layout

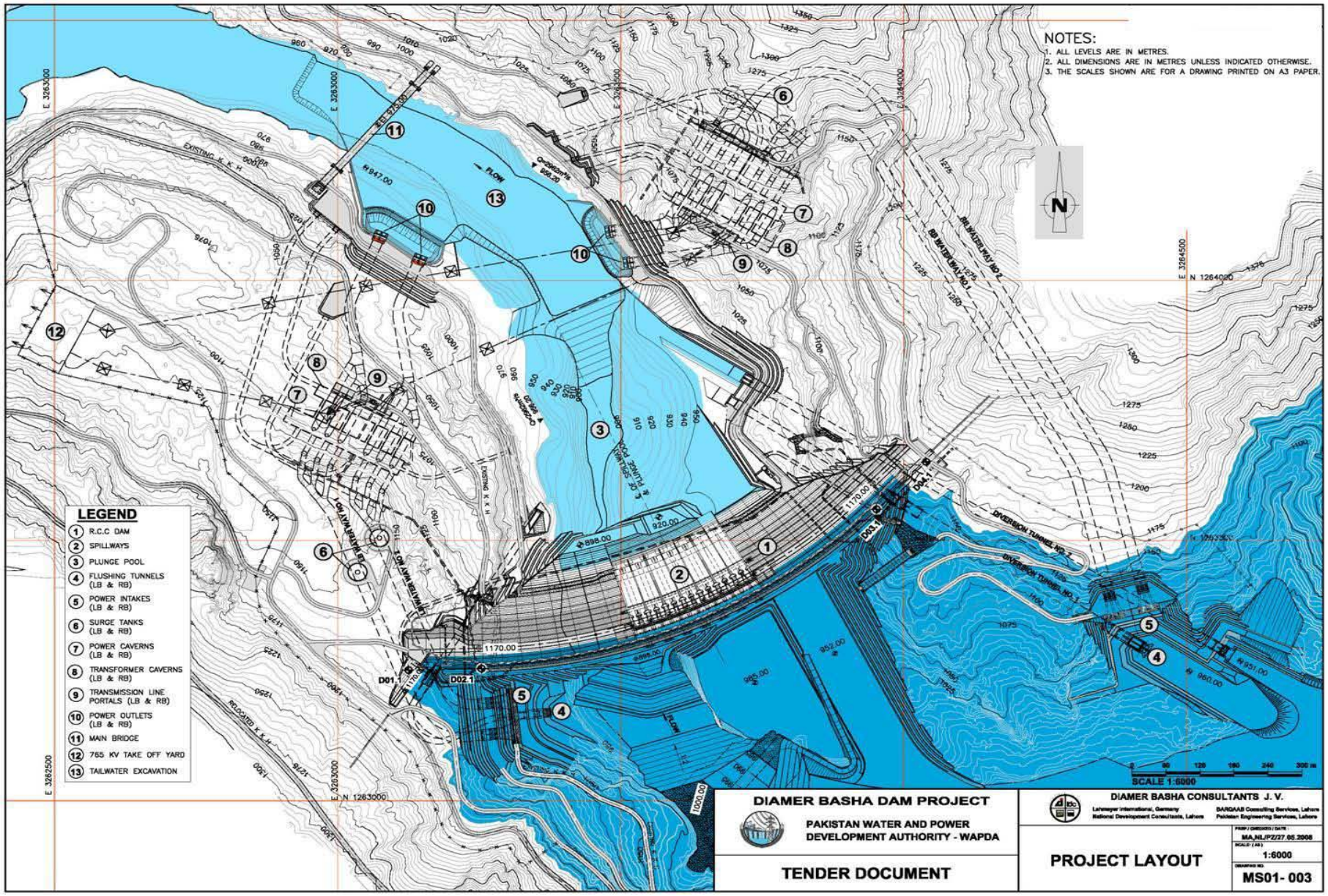


Figure-8 Cross Section of Diamer Basha Dam (Through Spillway)

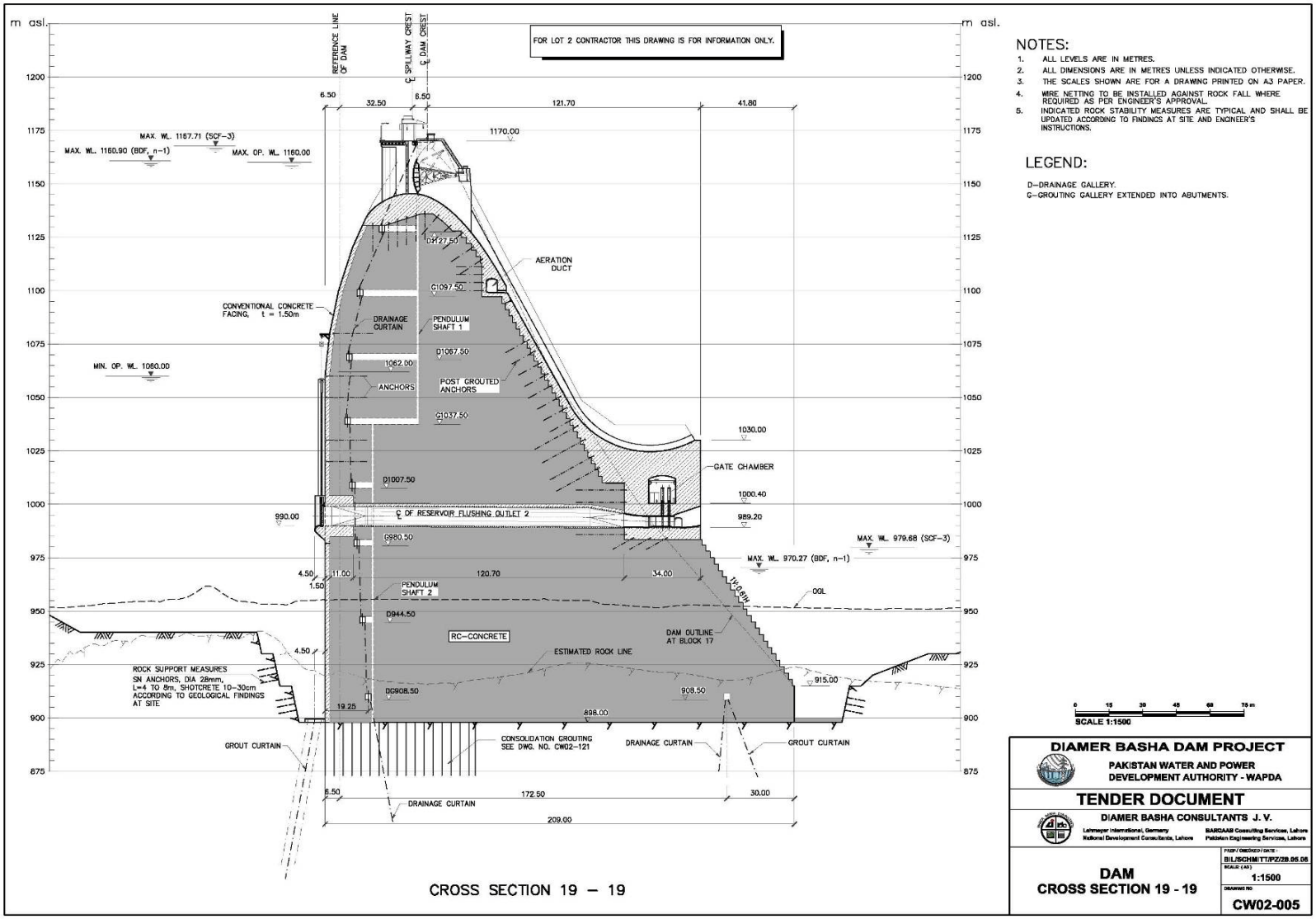
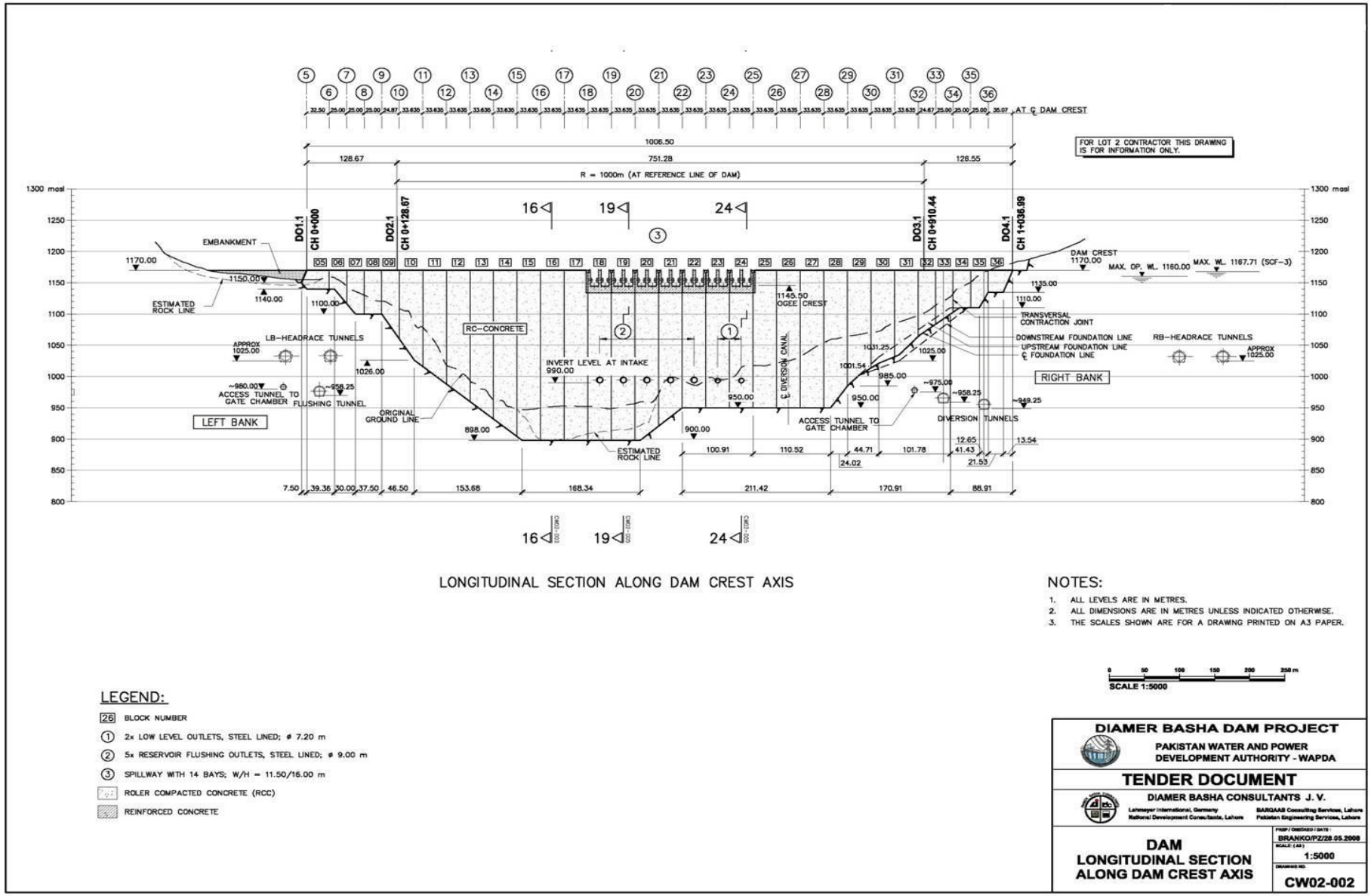


Figure-9 Diamer Basha Dam Longitudinal Section



LONGITUDINAL SECTION ALONG DAM CREST AXIS

NOTES:

1. ALL LEVELS ARE IN METRES.
2. ALL DIMENSIONS ARE IN METRES UNLESS INDICATED OTHERWISE.
3. THE SCALES SHOWN ARE FOR A DRAWING PRINTED ON A3 PAPER.

SCALE 1:5000

LEGEND:

- 26 BLOCK NUMBER
- ① 2x LOW LEVEL OUTLETS, STEEL LINED; ø 7.20 m
- ② 5x RESERVOIR FLUSHING OUTLETS, STEEL LINED; ø 9.00 m
- ③ SPILLWAY WITH 14 BAYS; W/H = 11.50/16.00 m
- ROLER COMPACTED CONCRETE (RCC)
- REINFORCED CONCRETE

DIAMER BASHA DAM PROJECT

PAKISTAN WATER AND POWER DEVELOPMENT AUTHORITY - WAPDA

TENDER DOCUMENT

DIAMER BASHA CONSULTANTS J. V.

Lahmeyer International, Germany — National Development Consultants, Lahore — BARQAAB Consulting Services, Lahore — Pakistan Engineering Services, Lahore

DAM LONGITUDINAL SECTION ALONG DAM CREST AXIS

PROP / CHECKED / DATE: DIRANKO/PZ/28.05.2008

SCALE (A3): 1:5000

DRAWING NO.: CW02-002