A STUDY OF WATER SUPPLY FOR ISLAMABAD / RAWALPINDI

By

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The present major source of water supply to Islamabad / Rawalpindi, some industrial units and irrigation and domestic water supply for Haripur, Attock and Rawalpindi districts is from Khanpur Dam on Haro River.

HARO RIVER

Haro River (Karral) originates at an elevation of 9217 feet (AMSL) near the village Moshpuri. It drains the head reach i.e. the southern slopes of the Moshpuri hills. It then follows east to west direction till it comes to the foot hills at Malachh, where it is joined by several small streams draining the slopes of the hills around Nathia Galli. The surrounding hill peaks are as high as 9000 feet and remain snow clad for many months of the year. The mountain slopes are generally covered with pine trees at higher altitude with patches of shrubs at lower altitudes. The over burden on these slopes is predominantly clay mixed with small boulders and stones. From Malachh village onwards the general course of the river is north east to south west.

In its passage further down Haro is joined by a lare tributary, the Dhund Haro, on its left bank at an altitude of R. L. 2710 feet at mile 22 from Malachh. The Dhund Haro is the main contributory source of the Haro. The drainage of the north west slopes falls into the Haro, whereas the drainage of the south east slopes off the same hills and the hills bordering Changla Galli, Khaira Galli, Barian, Kuldanna, Murree and Ghora Galli falls into the Dhund Haro.

The “Nilan Nala” joins the main river on the right bank at 24 miles from Malachh and drains the north west and south east slopes of the hills in which the villages Karachh, Mohari, Riala and Bodla are situated above altitude of R. L. 5150 feet. The south eastern slopes of the hills lying at an altitude of R. L. 4500 feet to 3100 feet in which are situated, the villages of Jemhiri and Jari, drain into its right bank.

Further down, about ½ mile downstream of Khanpur town another major stream known as the “Nilan Kas” which drains about square miles of the catchment, joins the Haro river on the left bank. At Khanpur dam site Haro has a catchment area of about 308 square miles.

The Haro river at Khanpur dam drains an area which is roughly rectangular in shape (Figure-1) with a length of approximately 54 miles and an average width of 14 miles. The long axis of the drainage runs north west from its origin to Khanpur dam.

The upper reaches of Haro and its main tributaries are entrenched in “V” shaped valleys with steep side slopes. The topography of the upper basin is steep and mountainous. In the head reach upto Tupla village the bed slope is very steep being of the order of 510 feet / mile. The average slope of th Haro river below Tupla village is about 98 feet per mile. From the confluence of Haro (Karral) and Dhund Haro rivers, near the village Dotara to downstream of the R. C. C. slap bridge on Haro, the slope further gets flattened and is about 38 feet per mile.

The upper reaches of the catchment area are afforested with pines and thick under growth. The lower reaches are covered by bushes and shrubs and small trees. The total cachment area of Haro upto the R. C. C. bridge is about 130 square miles. From the point of hydrology the whole upper region may be treated as a good catchment under the influence of monsoon rains. The Haro river is partially snow fed by the melting snows of Murree and Nathia Galli hills, and the contribution is appreciable. The melting of snow during April-May swells the waters of the Haro. River flow and sediment data for the period 1960 – 2011 for gauging station located near Khanpur dam about 25 miles downstream of the R. C. C. bridge are available.

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- **KHANPUR DAM**

  In view of the requirements for local irrigation in Attock, Rawalpindi and Abbotabad districts as well as to meet with drinking and other utilities water requirement for the twin cities of Islamabad and Rawalpindi, Khanpur Dam was constructed in the year 1983 on Haro river, downstream of the confluence of its tributary Nilan Kas, with a design gross storage capacity of 1077076 acre feet and live storage capacity of 91562 acre feet. Salient features of this project are provided in Box-1.

BOX-1
KHANPUR DAM PROJECT
SALIENT FEATURES

Location	• 31 Miles (50 Kilometer) From Islamabad
River	• HARO
Purpose	• Irrigation and Water Supply
Year of completion	• 1983
RESEROVIR	
Catchment Area	• 308 Square Miles
Normal Reservoir Elevation	• 1982 feet (AMSL)
Minimum Reservoir Elevation	• 1910 feet (AMSL)
Gross Storage Capacity	• 107,076 AF
Live Storage Capacity	• 91,562 AF
MAIN EMBANKMENT DAM	
Type	• Earth and Rock fill
Bed Elevation	• 1825 feet (AMSL)
Crest Elevation	• 1992 feet (AMSL)
Crest Length	• 1560 feet
Maximum Height	• 167 feet
CHECK DAM	
Type	• Earth and Rock fill
Crest Elevation	• 1992 feet (AMSL)
Crest Length	• 632 feet
Maximum Height	• 70 feet
RIGHT SADDLE EMBANKMENT	
Type	• Earth fill
Crest Elevation	• 1992 feet (AMSL)
Crest Length	• 2324 feet
Maximum Height	• 54 feet
LEFT SADDLE EMBANKMENT	
Type	• Earth fill
Crest Elevation	• 1992 feet (AMSL)
Crest Length	• 1842 feet
Maximum Height	• 47 feet
SPILLWAY	
Type	• Ogee shaped
Design Discharge Capacity	• 166,000 Cfs
Crest Elevation	• 1947 feet (AMSL)
Gates	• Radial, 5 Nos. 40’ x 35’
IRRIGATION OUTLET SLUICE	
Length / inside diameter	• 66.5 feet / 6.5 feet
Discharge Capacity	• 550 Cfs

- With the passage of time the storage potential of Khanpur Dam is reducing gradually due to sedimentation. At present the live storage of the dam is 82080 AF, as such still now the loss of storage comes out of about 10.36%. Consequently the annual yield of the reservoir has dropped and shortages are experienced frequently. Also the full flood water potential can not be stored properly because of less storage capacity, hence the excess flood water has to be spilled over as shown in Box-2.

BOX-2
WATER AVAILABILITY[1]
AT
KHANPUR DAM PROJECT
(Live Storage Capacity 82,080 Acre Feet)

Sr. No.	Year	Annual Inflows (A. Ft.)	Annual Spills (A. Ft.)	Utilization
1	1988	330.080	198801	131279
2	1989	119.226	-	119226
3	1990	286.283	88644	197639
4	1991	393.099	275607	117492
5	1992	476.211	324618	151593
6	1993	157.376	24330	133046
7	1994	231.386	81275	150111
8	1995	270.329	98099	172230
9	1996	274.783	69948	204835
10	1997	489.752	299894	189858
11	1998	306.081	192767	113314
12	1999	106.995	-	106995
13	2000	120.532	-	120532
14	2001	89.145	-	89145
15	2002	75.526	-	75526
16	2003	213.841	17911	195930
17	2004	109.595	-	109595
18	2005	237.095	62000	175095
19	2006	138.794	-	138794
20	2007	108.476	43286	177442
21	2008	197.963	28138	169825
22	2009	143.170	17460	125710
23	2010	337776	189771	148005
24	2011	166528	7801	158727
Total (MAF)		5416392	1943565	3471945
Average (MAF)		225683	80982	144664

1. Ref. Fig-2.

- During the last 24 years of its operation annual inflows at Khanpur reservoir have averaged 225683 A. Feet with minimum and maximum inflow of 75526 A. Feet and 489752 A. Feet in 2002 and 1997 respectively (Box-2).

- From Box-2 it is clear that there is a need for an additional storage on Haro from the fact that of the 0.225 MAF average annual discharge as measured at Khanpur more than half of it flows unused to the Indus due to lack of regulation.

- **Water Supply To Islamabad and Rawalpindi From Khanpur Dam**
  Water Supply shares to Islamabad, Rawalpindi and other beneficiaries for allocation from Khanpur Dam Project as approved by ECNEC on 18th September, 1993 are given in Box-3.

BOX-3 WATER ALLOCATION AS APPROVED BY ECNCE (%Age Share)							
Sr. No.	**Description**		**MGD**	**AF / Annual**	**Ft. 3 / s**	**M 3 / s**	**Share**
I	Municipal / Industrial						
	1.1	Rawalpindi Town / Cantt.	70.10	94064	130.16	5.439	53.48%
	1.2	C. D. A. (Islamabad)	33.35	44752	61.92	5.439	53.48%
	1.3	Heavy Rebuild Factory / H. I. T.	1.08	1445	2.00	0.057	0.05%
	1.4	U. E. T. Taxila	1.08	1445	2.00	0.057	0.05%
	1.5	FECTO Cement Limited	1.18	1580	2.18	0.062	0.06%
	1.6	C. W. O. (Now P. M. O.)	0.54	723	1.00	0.028	0.02%
		Sub-Total (I)	107.25	144009	199.28	5.643	55.48%
II	IRRIGATION						
	1	Left Bank Canal	44.14	59241	89.30	2.528	24.68%
	1.2	Right Bank Canal	34.81	46750	70.65	1.999	19.65%
		Sub-Total (II)	78.95	105991	159.90	4.527	44.52%
		Total (I and II)	186.20	250000	359.18	10.170	100%

Presently a yearly average of 33,380 AF (41.2 Mm 3) has been supplied to Capital Development Authority for Islamabad and Rawalpindi out of total annual outflow of 106,048 AF (131 Mm 3) from Khanpur Dam during 2007 to 2009 as shown in Box-4. The rest has been utilized by other beneficiaries like FECTO, HIT, PMO, Punjab and KPK from Left and Right Bank Canals.

BOX-4 Water Supply to Islamabad / Rawalpindi from Khanpur Dam Project										
Year	**Annual Flow**			**Daily Average**			**Total Outflow of KDP**			
	Cfs	**AF**	**Mm 3**	**Cfs**	**Cms**	**MGD**	**Cfs**	**AF**	**Cms**	**Mm 3**
2007	16,545	32,817	40.50	45.58	1.29	24.55	52,928	104,983	1.499	129.55
2008	16,125	31,984	39.47	44.04	1.25	23.72	51.209	101,573	1.450	125.34
2009	17,815	35,336	43.60	48.81	1.38	26.29	56,258	111,588	1.593	137.70
Average	16,828	33,379	41.19	46.14	1.31	24.85	53,465	106,048	1,514	130.86
2007-09										

With the passage of time the storage capacity of Khanpur Dam is reducing due to siltation. It is anticipated that in the coming years, water availability from Khanpur Dam will change significantly, which may adversely affect the water supply to Islamabad and other beneficiaries.

- **Components of the Present Water Supply Scheme**

The Metropolitan Water Supply Project (Khanpur-I) is composed of the following main components.

(i)	Raw Water Reservior near Sangjani	953,400 cu. M (210 MGD)
(ii)	Water Treatment Plant near Sangjani	272,400 cu. M / day (60 MGD)
(iii)	Pump House for Islamabad	90,800 cu. M / day (20 MGD)
	Pump House for Rawalpindi	181,600 cu. M / day (40 MGD)
(iv)	Water Transmission Pipeline for	
	- Islamabad 0.9 m dia x 7 km	
	- Rawalpindi 1.4 / 1.0 m dia x 14 km	
(v)	Service Reservoirs for - Islamabad	22,700 cu. M (5 MG)
	- Rawalpindi 45,400 cu. M (10 MG)	

Clean water from treatment plant in Sangjani at El. 1716 feet (523 meter) is lifted to Islamabad and Rawalpindi in a Pump House through pumps of following ratings.

Item	Islamabad Duty		Rawalpindi Duty
Number	3 (1 standby) with provision for installation of 2 more pumps for Phase II Project		3 (1 standby) with provision for installation of 2 more pumps for Phase II Project
Type	Single stage, horizontal type, double suction Volute pumps		Single stage, horizontal type, double suction Volute pumps
Pumps Head	143.5 m		100 m
Static Head	122.9 m		85.5 m
Discharge	30.6 cu. M / min. each (10 MGD)		64.25 cu. M / min. each (20 MGD)
Motor	970 kW, 4 poles, 6600 V, 3 ph, 50 Hz, 1500 rpm		1400 kW, 6 poles, 6600 V, 3 ph. 50 Hz, 1000 rpm

(vi) The power requirement of 5. MW for the water treatment Plant is met from a 132 KV double circuit transmission lines from 220 KV Burhan Grid Station.

Aims and Objectives

- To supply water, by gravity, from Haro River to Islamabad and Rawalpindi, a dam is proposed to be constructed on Haro River near Dotara village, about 25.5 miles upstream of Khanpur Dam. The bed level of Haro River at this site is about 26.32 feet (802 meters). With a 400 feet (122 meters) high dam, the maximum reservoir level would be around 3000 feet (915 meter) leaving 32 feet of free board. Dotara Dam being located on a higher elevation can meet by gravity the present and future water supply requirements of Rawalpindi and Islamabad. It is very important because the Municipal and other uses of the Federal Capital Area are increasing day by day with population growth, increasing urbanization and industrialization. Diversion of water for Rawalpindi / Islamabad from Dotara Dam would be a relief to Khanpur dam to meet with similar increases in water supply of the local areas. Water availability at Dotara dam site is provided in Box-5.

BOX-5
WATER AVAILABILITY AT DOTARA DAM

SR. NO.	YEAR	HARO AT KHANPUR[1] (A. Ft.)	HARO AT DOTARA[2] (A. Ft.)
1	2	3	4
1	1988	330304	142031
2	1989	119307	51302
3	1990	286477	123185
4	1991	393365	169147
5	1992	476535	204910
6	1993	157484	67718
7	1994	231534	99563
8	1995	270513	116321
9	1996	274969	118237
10	1997	490085	210737
11	1998	306289	131704
12	1999	107067	46039
13	2000	120613	51864
14	2001	89205	38358
15	2002	75577	32498
16	2003	213986	92014
17	2004	109671	47158
18	2005	237257	102020

19	2006	138889	59722
20	2007	244109	104967
21	2008	198098	85182
22	2009	143267	61605
23	2010	33776	14585
24	2011	166528	71607
Avg		225683	97043

1. Haro at Khanpur = 308 Square Miles.
2. Haro at Dotara = 133 Square Miles.

The study shows that about 7.5 miles (12.26 Kilometer) vide mountainous range of Margala Hills separate Dotara dam site from Kot Hathial at El. 2100 feet (640 Meters) near Barako, Islamabad. In-between the Margala Hills, a depression area near Shahdara at El. 2550 feet (777 meters) is located which makes an ideal place for making an intermediate reservoir to be fed from Dotara Dam reservoir through about 8.4 Kilometer long gravity tunnel. From thereon, there is a steep gradient of more than 550 feet (167 meter) upto Kot Hathial (Ele. 2100 feet) where a lower reservoir can be inter-connected through a 3.86 Kilometer long tunnel. This reservoir will be the source point for CDA to obtain supply of water by gravity for Islamabad and Rawalpindi. The head between two reservoirs at Shahdara and Kot Hathial can also be utilized for hydel power generation as well. The layout of the proposed scheme is shown in Figure 3.

The longitudinal profile of the proposed arrangement of water supply to Islamabad and Rawalpindi as shown in Figure 4 is ideally suitable for a pumped storage scheme in which a large volume of water is stored at a height. When released during hours of peak system demand, the kinetic energy of falling water is used to drive turbines which, in turn drive power generators to create electricity. The used water is then stored in a lower reservoir and pumped back to the upper reservoir when the same generators perform as a motor to drive the pumps taking electricity from the power system during its low demand period. Thus the same water flows in a closed cycle between the two reservoirs requiring only to be replenished for small losses due to evaporation, seepage, etc.

- **BENEFITS OF A PUMPED STORAGE SCHEME**

A pumped Storage Power Plant has multifarious benefits to the power system as listed below :

- Low priced off-peak bulk energy storage.
- Economical peak generation.
- Environment friendly clean energy source capable of earning energy credits (ERs) under Clean Development Mechanism (CDM).
- Improved System Operation capability.
- Network voltage and power factor correction.
- System frequency regulation.
- Load uniformity for Thermal (Coal and FO based) and Nuclear Plants.
- Load following (variation and adjustment).
- Unit commitment (High availability).
- Fast intervention possible in case of Grid Faults.
- Spinning reserves.

- **OPERATING CHARACTERISTICS OF PUMPED STORAGE SCHEME**
  A pumped Storage Plant as shown in Box-6 can help a power system with all types of operational requirements as compared to limited operational capabilities of other types of power plants.

BOX-6
OPERATING CHARACTERISTICS OF GENERATING UNITS

CHAR-ACTERISTICS	NUCLEAR	STEAM TURBINE		GAS TURBINE	CONVEN'L HYDEL	PUMPED STORAGE
		COAL	OIL/GAS			
Normal Duty Cycle	Base	Base-Intermediate	Base-intermediate	Peaking	Base-Intermediate	Base-Intermediate
Unit Start-up Daily	x	x	√ Hot	√	√	√
Weekly	x	√ Cold	√ Cold	√	√	√
Cycling	x	x	X	x	x	x
Load Following	x	√	√	√	√	√
Quick Start (10 min)	x	x	X	√	√	√
Spinning Reserve	x	√	√	x	√	√
Frequency Regulation	x	√	√	x	√	√
Load Management	x	x	X	x	√	√

No x Yes √

- This pumped storage scheme, to be named after the famous mountainous Margala range, will comprise of an upper reservoir at Shahdara, a lower reservoir near Kot Hathial to be interlinked by a tunnel with a power plant at the lower end as shown in profile (Figure 3) of the scheme. Initial filling of these reservoirs will take place through a gravity tunnel between Dotara Dam and Shahdara Upper Reservoir which will subsequently supply water for Islamabad and to make-up the deficiencies of the scheme.

- The main components of the project, for which a feasibility study is to be carried out are :
  - A dam near Dotara village on Haro River.
  - A tunnel to transfer Haro River water Dotara Dam to Shahdara.
  - A dam at Shahdara.
  - A gravity tunnel to transfer water from Shahdara dam to a reservoir at Kot Hathial near Islamabad.
  - A hydel power house at Kot Hathial.

- A reservoir at Kot Hathial.

(i) DOTARA MAIN DAM

Haro river is a mountainous river. In its upper reach it flows through narrow and deep gorges. It glides from an altitude of 9258 feet at its source to about 2710 feet in Dotara area, at its confluence with Dhund Haro. The courses of the river are more or less parallel to the general strike of the strata which consists folded geological formations. On account of this the valley of this river consists of steep sloping banks for considerable length thus restricting the capacity of a storage reservoir in the upper reaches of the valley.

A search for a favourable reservoir site was successful in locating such a site near RCC Road Bridge on Haro (Figure-1), about 25.5 miles upstream from Khanpur dam and bout 1½ mile downstream of the Junction of Haro and Dhund Haro. Haro flows for about 27 miles before reaching Dotara. At this site it has a drainage area of about 133 Square miles.

The proposed Dam site is located downstream of the confluence of Karral Haro and Dhund Haro. The bed elevation of the Haro River at the site is about 2632 feet. This site is situated in Abbotabad District at a distance of 21 miles west of Ghora-Galli. It is linked via Haripur-Ghora Galli all-weather metalled road, which remains motorable through out the year, to the rest of country. Nearest important town is Lora, which is about 15 miles east of the site.

Preliminary reconnaissance of this stretch revealed that due to mild slope in the river bed the most suitable site for locating a dam capable of appreciably utilizing the potentialities offered by this river existed a the neighbourhood of the reinforced concrete slab bridge of the Haripur-Ghora Galli road on Haro river. The total length of the bridge is about 450 feet and R. L. of its deck is 2665 feet. Average river bed level at this site is 2632 feet. Upstream of the bridge, both the rivers have broad valleys.

The width of valley bottom between rock abutments is small (approximately 450 feet). The river is much wider above and below this section where it ranges between 1000 feet to 1500 feet. The left bank slopes about 1.0 vertical to 0.25 horizontal and the right bank slopes about 1 vertical to 1.5 horizontal. The dam at this site may be about 400 feet high, above the present river bed at elevation 2632 feet.

Bulk of the flood flow comes during the months of July to September. It is believed that a high dam at the Dotara site would easily store the entire annual runoff of Haro River and provide downstream regulation either on annual basis or by carryover storage from one year to the next. It is believed that construction of a dam at the site would be practicable. This Dam site is favourable, as the reservoir life would be longer due to less silt in the river. The large reservoir would be sufficient to carry over storage from high year to one of low runoff, thus improving the water supplies in the year to one of low runoff. Water supply benefits due to regulation flows would in time become very important especially considering the possible silting of Khanpur Dam.

GEOLOGY OF DAM SITE

The great thickness of sedimentary strata at dam site is comprised of limestone, which was deformed into floods of great amplitude, inducing faulting crumpling and crushing of the lime stone. Opening of joint planes of the limestone was observed at site. Bed rock is intermittently exposed above river level in both abutments. It extends through out the hill side slopes to great height.

The left abutment is a limestone cliff about 650 feet high with a steep slope. There is hardly any material on its slope.

On the right abutment there are granular deposits judged to be more than 10 feet thick extending from bed of the river at a gentle slope. Limestone rock is exposed at some spots on the abutment.

Location of the rock floor beneath the valley bottom is not known. It is judged that the valley fill consists of permeable sands and gravels with numerous boulders. Geological Investigations would be required to determine the suitability of rocks for dam Abutments.

By the construction of the reservoir some gardens and some ordinary cultivable land will be submerged. Provision would be made in the estimate to give equitable compensation to the owners of these gardens and land and, therefore, there will be no hardship to them.

SPILLWAY SITE

The spillway may be provided on the right flank of the dam. On the right abutment of the spillway, there would be a high ridge and on its left side would be the main dam. The bed rock is at shallow depth on which the spillway structure would safely be placed. Considering the topographic features it is assessed that at this location sufficient width would be available for the construction of an over flow spillway.

Project studies will also include estimates of flood flows, as these would be essential to the determination of the spillway capacity.

OUTLET WORKS SITE

A low level outlet through the left abutment will maintain required flows in the river, below the dam.

Improvements to the existing road from Ghora-Galli to site (21 miles) would be needed for the transport of construction equipment, material and supplies from other parts of the Country.

Road relocation near the dam site would provide an opportunity to, eliminate the existing deep cuts in hill sides, use scenic alignments and provide reservoir viewing locations.

(ii) Dotara – Shahdara Gravity Tunnel

Dotara Dam reservoir and Shahdara Upper Reservoir will be interconnected through a 2.5 meter dia about 8,4 Kilometer long low pressure tunnel having a gradient of about 1 in 550 for supplying water at a flow rate of 5.5 m^3 / s (194.25 cusecs) to meet with the requirement of water supply to Islamabad and for replenishment of losses in the two reservoirs. It will have a head work at Ele. 853 meter (2800 feet) with a screen and intake gate at Dotara reservoir and an outlet gate at Ele. 838 meter (2750 feet) at the end at Shahdara Upper Reservoir.

(iii) Shahdara Upper Reservoir (Near Islamabad)

A 70 meter (250 feet) high and 565 meter (1850 feet) long earth fill embankment dam at 33° - 47’ North and 73° - 11’ East in Shahdara valley (Figure-4) will make an upper reservoir of 34 mm^3 (27,550 AF) storage capacity which will be filled up by the gravity tunnel from Dotara Dam in the initial stage.

The surface area and storage capacity of the reservoir at various counter levels of the topographical sheets has been worked out with the help of a planimeter and by using trapezoidal formula. Figure-5 shows the reservoir surface area and storage capacity at various counter levels.

This size of upper Shahdara reservoir is very suitable for a seasonal (annual) pumped storage scheme when compared with the requirement of 2.2 Mm^3 (1784 A. Feet) for 5 hours daily peak generation and pumping back during rest of the day. The reservoir will operate between 835 meter (2740 feet) and 830 meter (2723 feet) to cater for both pumped storage scheme and water supply for the metropolitan.

A shaft spillway capable of passing maximum flow of full pumping capacity and probable maximum flood (PMF) in natural streams of the catchments area will be provided along with a low level outlet to pass the sediments collected during operation of the reservoir.

- **Pressure Shafts and Tunnel**
  An intake tower equipped with screen and gate at Shahdara Upper Reservoir will release 122 m^3/s through a 5.65 meter dia concrete lined two stage vertical shafts excavated about 200 meter deep within Margala Hills. A surge tower will be provided on top of the second stage shaft. The pressure shafts will end into two sections of sloping concrete lined pressure tunnels leading to steel lined sections with total length of about 3.86 Kilometer. The last section of pressure tunnel will split into four 3 meter dia penstocks before reaching the power station to feed four reversible generating units through separate inlet valves for turbines and discharge valves for centrifugal pumps. A 1.3 meter dia, pipe will off take from one of the penstocks for a small power house unit.

- **Diameter of Shafts Tunnels and Penstock**
  A single criterion for selection of tunnel diameter is to limit the head loss to a certain percentage. A more rigorous approach is to select several possible diameters, computing power and annual energy. This is compared with the cost of the penstock for each diameter and the optimum diameter is determined with the energy losses over the life span of the plant and cost of the penstock.

  The theoretical optimum diameter of the pressure tunnel can be computed from Manning equation for friction losses through pressure pipes :

$$\frac{h_f}{L} = 10.3 \frac{n^2 Q^2}{D^{5.335}}$$

Which yields to : diameter, $D = \left[\frac{10.3 n^2 Q^3 L}{h_f} \right]^{0.1875}$

Limiting head loss, h_f to 7% of gross head (H), the equation simplifies to :

$$D = 2.55 \left[\frac{n^2 Q^2 L}{H} \right]^{0.1875}$$

Where the values for Margala Pumped Storage Scheme are :

Q = Discharge in Tunnel = 122 m^3 / s

H = Gross Head = 195 meter

L = Length of Tunnel = 4060 meter

n = Manning's coefficient = 0.015 (for concrete / steel pipes)

- Tunnel Diameter, D = 5.65 meter

- Velocity in Tunnel, $V = Q / (\pi D^2 / 4) = 106 / (3.143 \times 5.65^2 / 4)$

  $= 4.86$ m / s

- **Hydro Power Potential**
  Power potential of the proposed scheme is calculated by using the formula :

  $P = n \times Q \times H$ KW

  Where P = Power potential in KW

  Q = Design Discharge = 122 m^2 / s

  H = Mean Net Head (with 7% loss) = 181.35 meter

  n = 8.5 to 9.0 = 9.0

  Power Potential from :

  (i) Margala Pumped Storage Scheme
  (122 m^3 / s for 5 hrs / day) = 200 MW

  (ii) Water Supply Scheme for Islamabad and Rawalpindi
  (6.5 m^3 / s for 14 hours) = 10 MW

(iv) Kot Hathial Lower Reservoir

A lower reservoir of about 4 Mm^3 (3243 A. Feet) capacity will be constructed next to the Pump Power Plant in Kot Hathial (33° - 45' North and 73° - 10' East) near Barakao in Islamabad (Figure-5). The reservoir built next to the Pump Power Plant at the end of the power tunnel will be a sub-surface type with concrete construction in order to minimize seepage of water. Besides storing about 2.2 Mm^3 (1784 A. feet) of water for 5 hours peak generation at a normal maximum level of 640 meter (2100 feet), it will also initially cater for 72.15 MGD water supply to Islamabad / Rawalpindi.

The inter-connection of this reservoir with the Bulk Water Supply System for the twin cities through a treatment plant will be made by Capital Development Authority. The reservoir will be provided with an over flow outlet discharging into Chang Kas.

(v) Pumping Power Station

The power station building will be situated on North Side of the lower reservoir at the foot of Margala hills near Kot Hathial. The power house will consist of four units each composed of generator / motor, turbine and centrifugal storage pump with disengaging device for disconnection from the main turbine shaft during generation mode. During the pumping cycle the shaft is reconnected and the generator acts as a motor to drive the centrifugal pump to lift water back from lower to upper reservoir. Each unit will also be provided with pressure relief value to release water surge in the pressure tunnel during full load rejection in generation mode.

A house unit will also be provided to generate 10 MW power from 6.5 m^3 / sec (72.15 MG / day) water supply for Islamabad. The power generated at 11 KV will be stepped upto 220 KV for inter connection with National Gird System through near by 220 KV University gird Station Near Bara Kao, Islamabad.

ECONOMICS OF MARGALA PUMPED STORAGE SCHEME

The following criteria govern the operation of a Pumped Storage Scheme.

(i) "Economic Dispatch"

(ii) "Must-Run" Operation.

Normally project operation is based on "Economic Dispatch", in which the plant is dispatched only if the value of the incremental on-peak thermal energy that would be displaced by the pumped storage project generation exceeds the cost based on the incremental pumping energy. However, during periods of high power demand and / or numerous plant outages, the project's capacity may be required so that the power system can meet its peak load requirements. In such cases the project may be operated even though relatively high cost energy may be required to refill the upper reservoir during off-peak hours. This is called Must-Run operation as opposed to Economic Dispatch. However, the Margala Pumped Storage Scheme, having a sufficiently larger upper reservoir, will operate a seasonal scheme minimizing the periods of "Must-Run Operation".

"Pump Storage Plants" are, however, sufficiently flexible to operate in any manner that will be most beneficial to a power system. They can follow load, provide spinning reserve, provide economical energy increase minimum load of coal and nuclear plants, and store surplus off-peak generation capacity.

As of today the power system in Pakistan is deficient in meeting with the energy demand for reasons other than insufficiency in installed generation capacity when compared with the load demand. Besides a desperate need to overcome these bottlenecks, a comprehensive program is in place for increasing the generating capacity in hydel, coal, nuclear and other thermal sectors so as to meet with the energy demand in future.

Annual addition of Net Generation in PEPCO System when compared with Load Demand upto 2029-2030 show that generating capacity will surpass the load demand in 2017-2018. Since then sufficient energy will be available to make a Pumped Storage Scheme (PSS) economically viable.

It is expected that by the year 2020, the system generating capability will match with the system peak demand eliminating load shedding altogether. In normal power systems the demand of above 75% of peak load remains only for 5-6 hours, when for the rest of the day actual load varies between minimum demands to 75%. This duration makes a pumped storage scheme economically viable when low cost surplus thermal power is utilized to pump and tore water in upper reservoir which when reversed to lower reservoir during system peak demand periods, produce hydropower substantially cheaper than high cost Furnace Oil (FO) based thermal plants.

BENEFITS FROM DOTARA DAM AND WATER SUPPLY PROJECT

- An upstream dam at Dotara, constructed as a carry over storage, would greatly improve the regulation of Haro River inflows by minimizing the spill of Khanpur Dam.

- Conjective operation of Khanpur Dam and the proposed Dotara Dam will help in satisfying the beneficiary water demand more efficiently with additional benefits of flood mitigation.

- Dotara Dam will enhance life of Khanpur Dam reservoir by reducing rate of its siltation.

- Gravity flow water supply to Islamabad will be available from Dotara Carryover Dam on Haro River to meet with the requirements of ever increasing population of the Capital.

- Saving in present electric consumption due to reduced pumping of water from Sangjani Pumping Station only for areas not feed able from Dotara Scheme thus reducing hefty electricity bill being paid by CDA to IESCO.

- Peaking energy of about 328 MKWh from 200 MW Margala Pss at 90% plant factor will be produced which will replace expensive thermal generation from FO fired plants and Rental Power Plants.

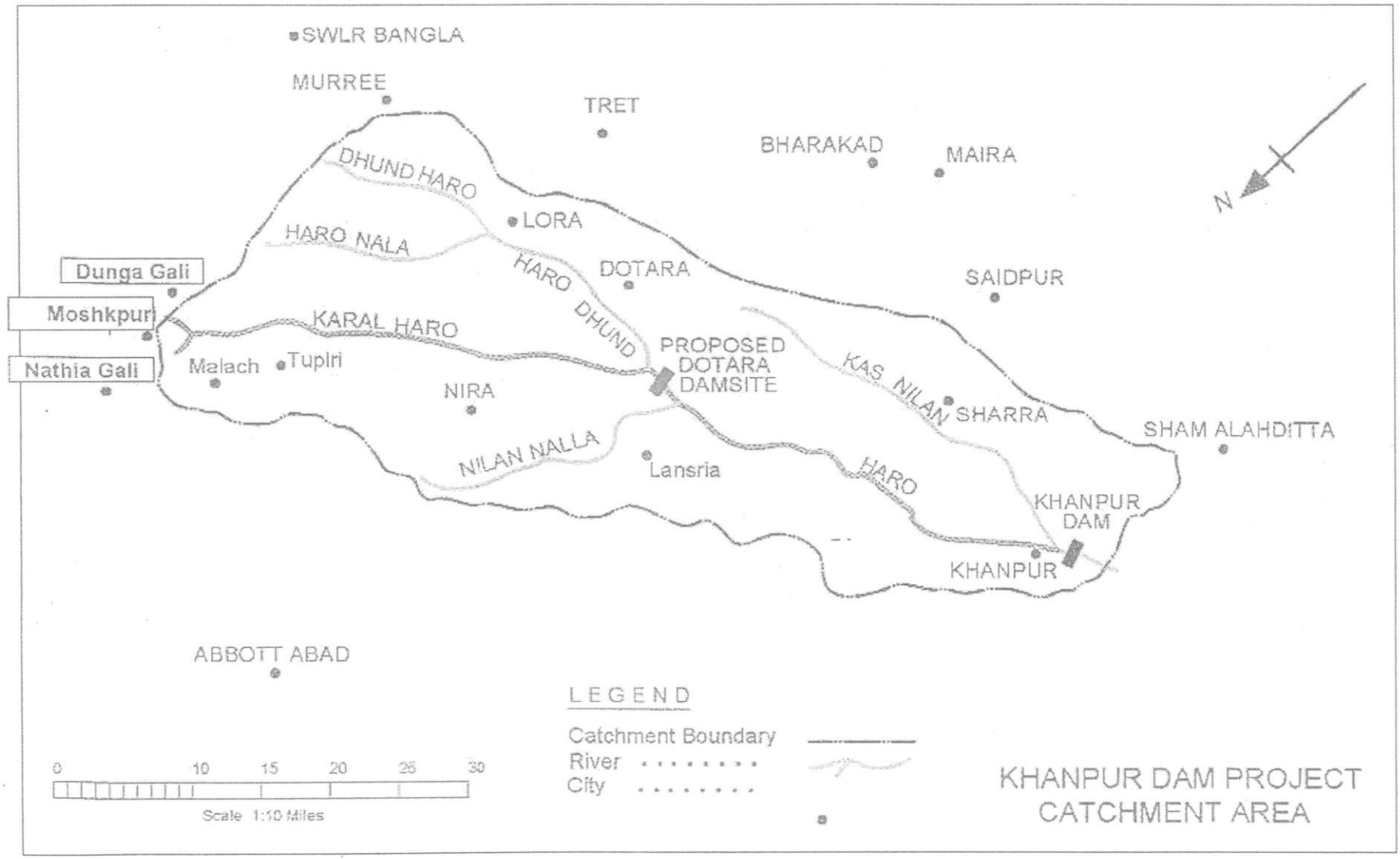
- Additional production of 1.5 MW from every cubic of water supply to Islamabad which will generate an annual income of about Rs. 445 Million from energy generation of 46 MKWh.

- The project will generate Carbon Credits Amounting to Rs. 350 Million (@ € 15 per ton) under Clean Development Mechanism (CDM) for producing about 390 MKWh of clean energy annually from pumped storage and water supply schemes.

- Forest Fires usually taking place in Margala National Park will be extinguishable from large reservoirs which will become available for feeding fire fighting water supply under special arrangements.

Recreational facilities like fishing, boating, water sports, camping, etc. near the capital besides generating income of the residents and improving their living standard by creation of two reservoirs in Shahdara and Kot Hathial and improvement of roads and allied infrastructure.

FIGURE-1


SWLR BANGLA
MURREE
TRET
BHARAKAD
MAIRA
N
DHUND HARO
LORA
HARO NALA
HARO DHUND
DOTARA
SAIDPUR
Dunga Gali
Moshkpuri
KARAL HARO
Nathia Gali
Malach
Tuplri
PROPOSED
DOTARA
DAMSITE
KAS NILAN
SHARRA
SHAM ALAHDITTA
NIRA
NILAN NALLA
Lansria
HARO
KHANPUR
DAM
KHANPUR
ABBOTT ABAD
LEGEND
Catchment Boundary
River
City
0 10 15 20 25 30
Scale 1:10 Miles
KHANPUR DAM PROJECT
CATCHMENT AREA

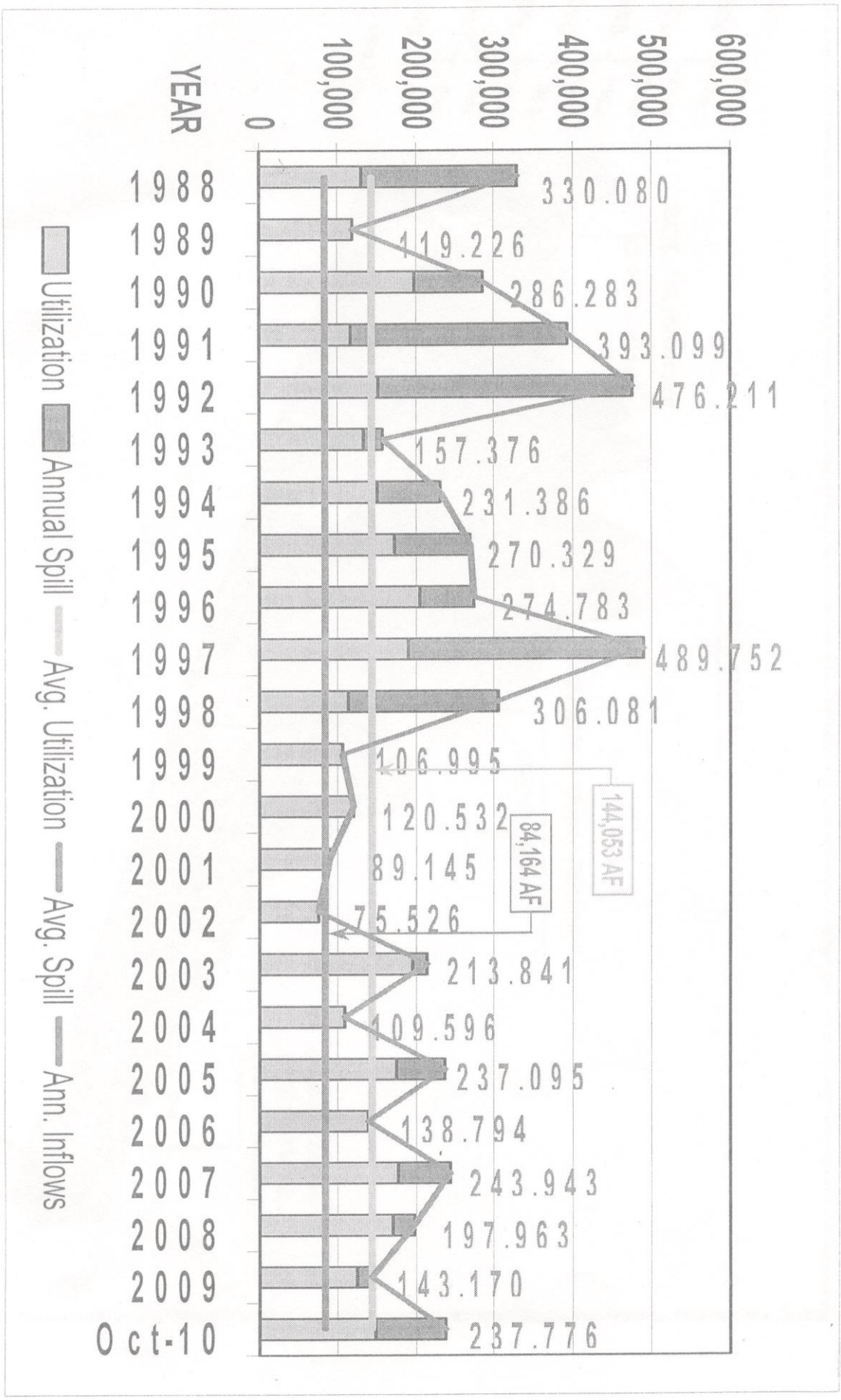

YEAR
0
100,000
200,000
300,000
400,000
500,000
600,000
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Oct-10
330.080
119.226
286.283
393.099
476.211
157.376
231.386
270.329
274.783
489.752
306.081
106.995
120.532
89.145
75.526
213.841
109.596
237.095
138.794
243.943
197.963
143.170
237.776
144,053 AF
84,164 AF
Utilization
Annual Spill
Avg. Utilization
Avg. Spill
Ann. Inflows

FIGURE-2

FIGURE-3

Salient Features of

DOTARA-ISLAMABAD WATER SUPPLY & MARGALA PUMPED STORAGE SCHEME

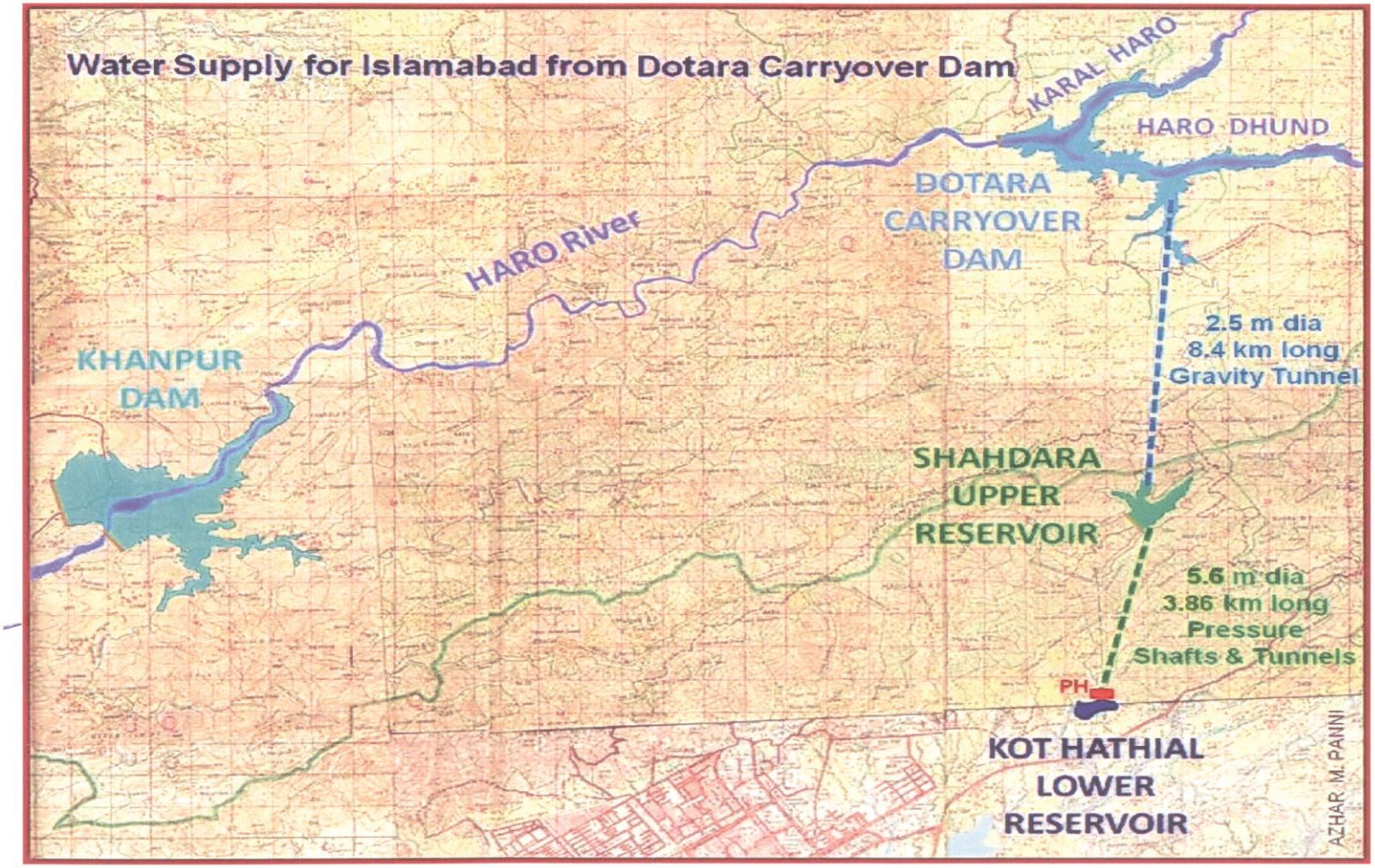
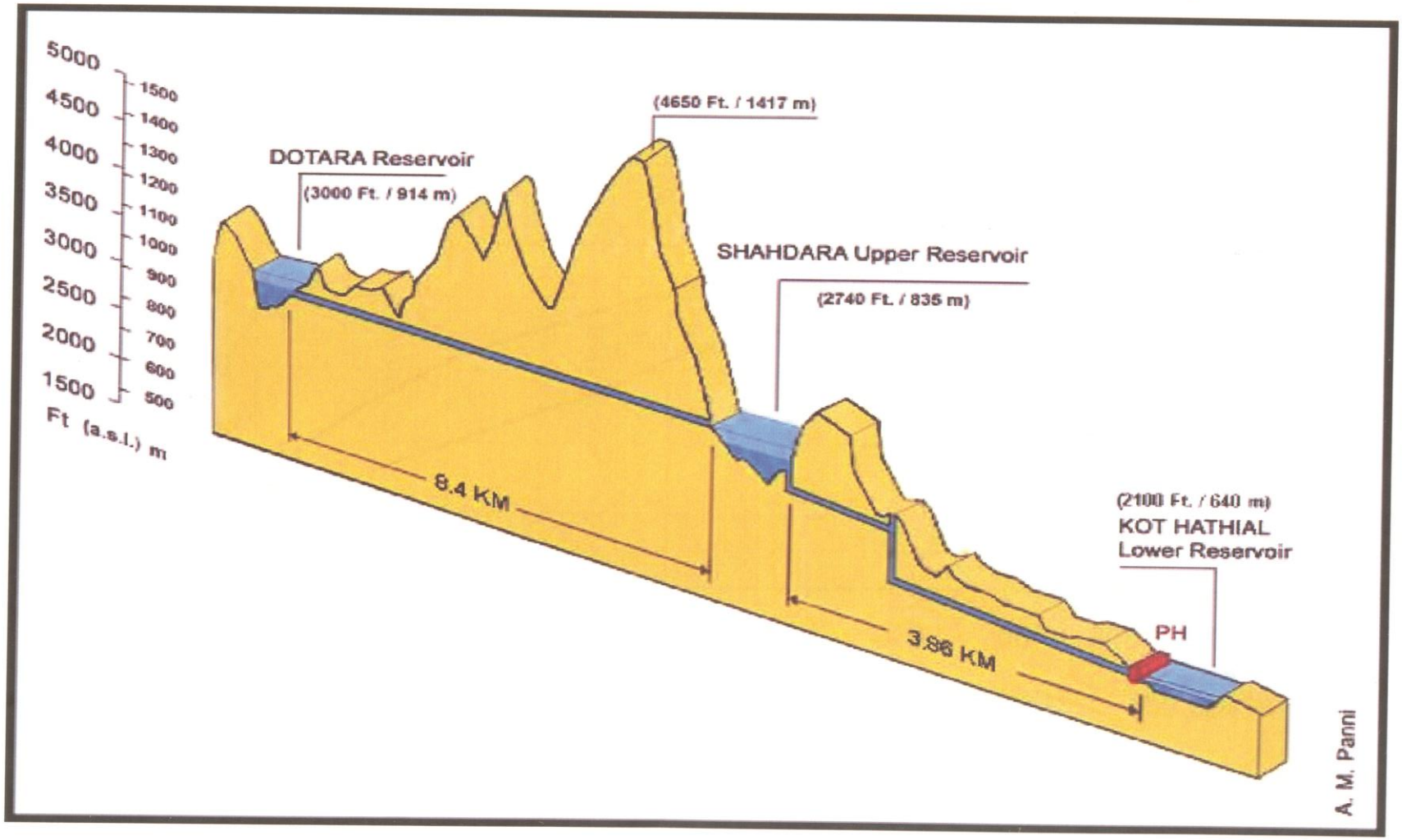


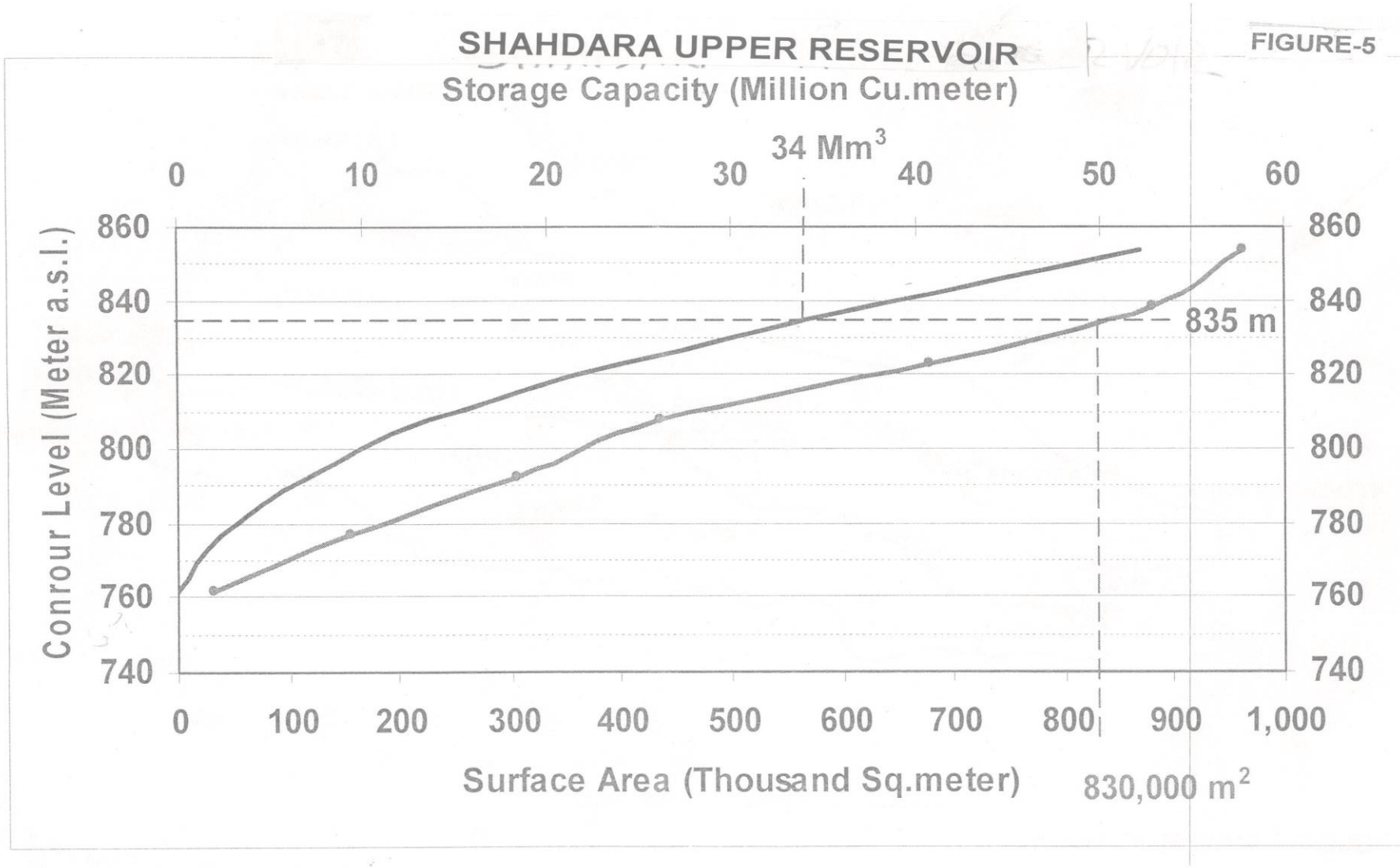
FIGURE-4

Layout of Dotara Water Supply & Margala Pumped Storage Scheme



Longitudinal Profile of Dotara Water Supply & Margala Pumped Storage Scheme

FIGURE-5


SHAHDARA UPPER RESERVOIR
Storage Capacity (Million Cu.meter)
34 Mm3
0
10
20
30
40
50
60
Conrour Level (Meter a.s.l.)
860
840
820
800
780
760
740
835 m
0
100
200
300
400
500
600
700
800
900
1,000
Surface Area (Thousand Sq.meter)
830,000 m2