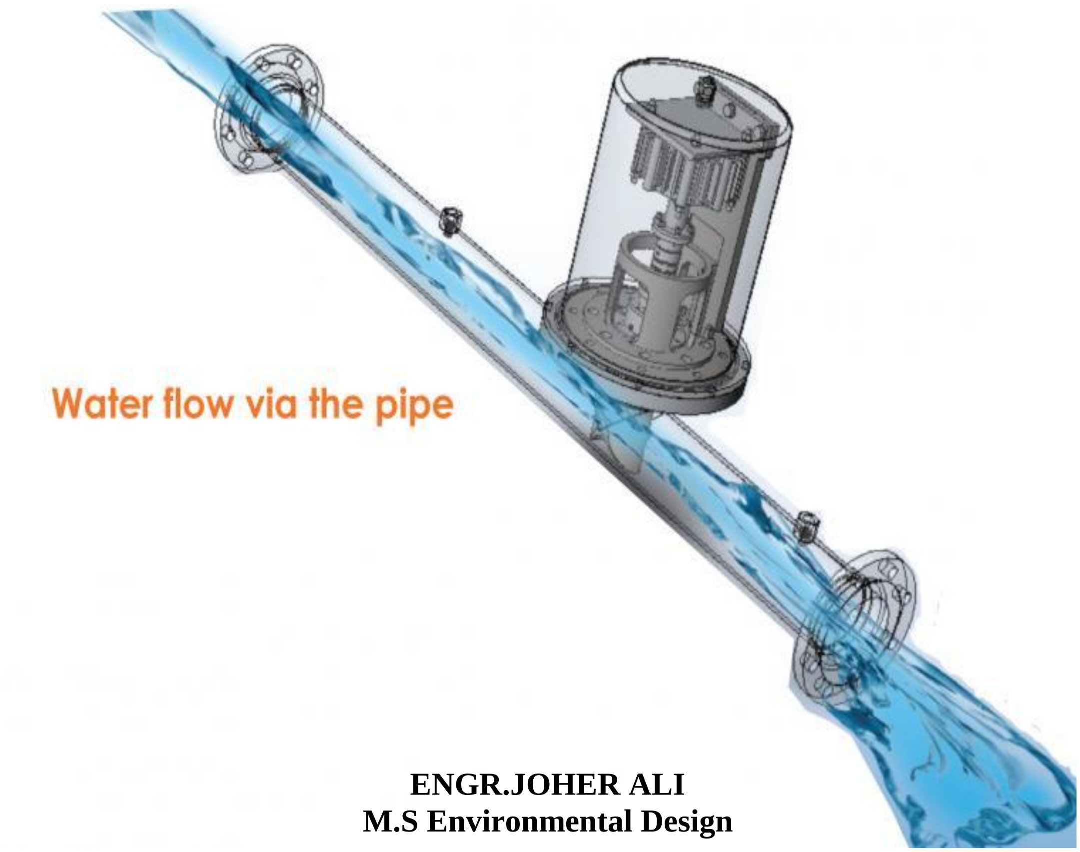
EXPLORING THE HYDRO POWER POTENTIAL THROUGH EXISTING WATER SUPPLY LINES FROM SIMLY DAM TO ISLAMABAD CITY UNDER GRAVITY FLOW

A Case Study



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ABSTRACT:

Renewable energy is the most popular subject nowadays, particularly utilizing multiple options to generate alternate energy through various options. Hydropower is one of the best sources and can play a major role among available renewable energy sources. Pakistan possesses considerable hydropower potential in its existing Indus basin water resources systems. Nevertheless, one of the paramount and appropriate locations are the water supply systems, which can be explored for hydropower generation either located before or after the water treatment plant or distribution network. In the water supply lines, the excess water pressure is dissipated in sedimentation/coagulation tanks and ultimately sending them in the main conduction lines. Nonetheless, this superfluous water pressure potential can be tapped by installing a hydro-turbine system for converting potential energy into electrical energy.

For current case study, the existing water supply lines from Simly dam runs on gravity to Islamabad city through 3 Nos main conduction line having diameter of 48”, 36” & 36” as main water supply conduction lines. It has been estimated that flow under gravity flow has been analyzed and hydropower potential has been explored to generate an electric energy potential of @ 2.046 Mega Watt (MW). Hydropower through this process can about PKR 310 Million/year contributing huge economic benefits in cutting power bills of CDA..

Keywords: Renewable Energy, Hydropower, Water Supply Line, Water Pressure

1. INTRODUCTION

Energy crises are phenomena which are generally observed across the globe, particularly in the 3rd world countries of Asia and Africa continents. Conservation of water and energy has gained prime importance for the last few decades, and has become imperative in resolving such issues. In last two decades oil and natural prices have increased manifold and has made renewable energy sources more as a domineering alternate.

One of the four fundamental requirements of human being are – food, water, energy and environment

Per capita electricity consumption

World	2,000 kWh/year (average)
USA	10,500 kWh/year
Sweden	12,500 kWh/year
Norway	21,000 kWh/year
Pakistan	300 kWh/year

Hydropower is a renewable energy source most widely used all around the world through installation of hydropower plants. There are three types of hydropower facilities, **Impoundment, diversion, and pumped storage** and even **on water supply network** wherever possible. The advantages of these facilities compared to run of the river hydropower plants could also be summarized to draw real term benefits.

Pakistan is also facing acute energy shortages since a decade. Though the country posse's immense renewable energy potential in many forms and particularly in hydropower, which tantamount to nearly 55,000 MW, and only 6,700 MW has so far been tapped.

2 PRINCIPLE OF HYDROPOWER IN WATER SUPPLY SYSTEMS

Increase in oil and natural gas prices by 500% in last 15 years has made renewable energy sources more important than ever. Hydropower as a renewable energy source has become almost inevitable to be used as one of the best source as alternate source of energy around the world.

Hydropower through run of the river is the most common phenomena, how installation of hydropower plants on water supply network has established a wide usage area in Europe (Table 1). For example, in Switzerland 90 small hydropower plants were installed on the municipal water supply network of the country (Table 2) and Austria. While Turkey uses hydropower energy through their drinking water supplies systems (Figure 1). Hydropower is a principle to convert potential or kinetic energy into electricity and the advantages of these facilities compared to river-type hydropower plants could be summarized as follows:

- All civil works are present, which will reduce the investment cost in the order of 50%
- The facility has no significant environmental impacts and it has a guaranteed discharge through the year.
- The generated electricity is used in the water supply system and the excess electricity is retailed to the government.
- There is no land acquisition and significant operating costs.

Existing study aims to display the possible benefits of installing hydropower turbine in the water supply lines. This could be an alternative clean energy solution to reduce the consumption of energy supplied by the national electric grid mostly fed by energy mix i.e. fossil fuels, which induces minimum of CO^2 emissions in the atmosphere. In present study, utilization of the hydropower plants in existing water supply systems has been discussed; about the hydropower potential of the water supply system of Edremit in Turkey has been analyzed.

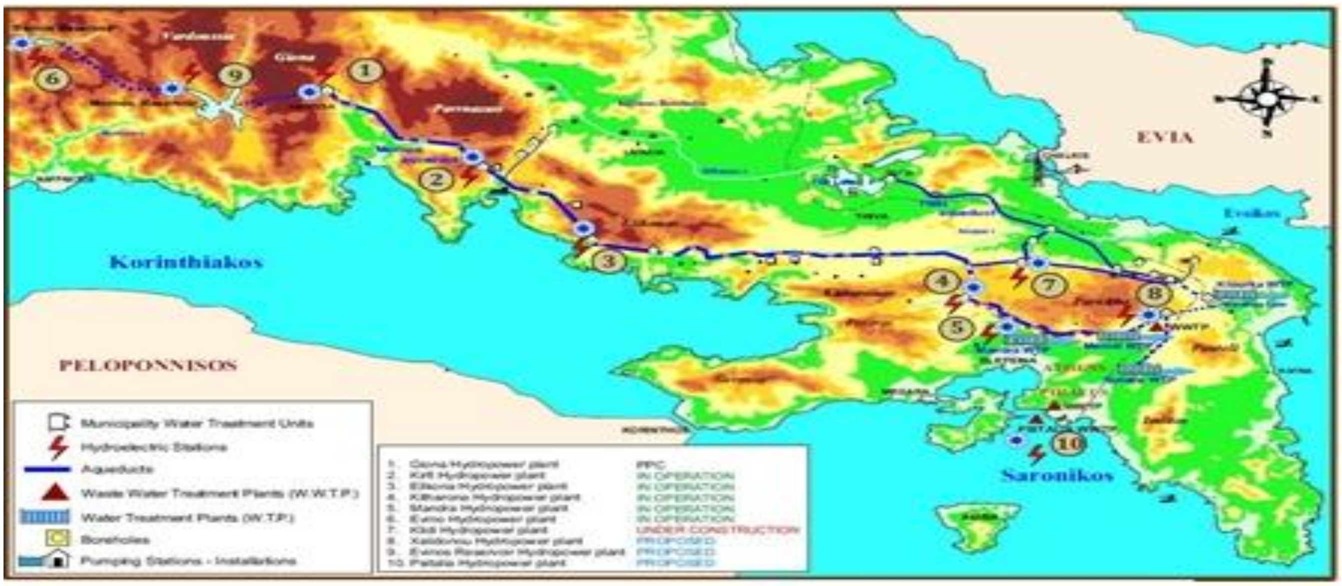
Table 1. Some examples of hydropower plant installation on water supply lines in Europe. Data source: [1]

Plant Name	**Country**	**Design discharge (m3/s)**	**Gross head (m)**	**Output (kW)**	**Production (MWh/year)**
Vienna Mauer	Austria	2	34	500	364
Mühlau	Austria	1.6	445	5,750	34,000
Shreyerbach	Austria	0.02	391	63	550
Poggio Cuculo	Italy	0.38	28	44	364
La Zour	Switzerland	0.30	217	465	1,800

Table 2. Multipurpose schemes in Switzerland: operating and remaining potential. Data source:

Water network type	Potential type	Number of sites	Output (MW)	Production (GWh/year)
Drinking water	Operating	90	17.8	80
	Remaining	380	38.9	175
Treated waste water	Operating	6	0.7	2.9
	Remaining	44	4.2	19

Figure.1 Global Picture of Hydropower Generation from Water Supply Lines (Turkey)



Completed works Name of City	Country	[kW]	Number of sites Generated
Giona -PPC	Turkey	8500	90
Elikona	Turkey	650	5.03
Kirfi	Turkey	760	5,86
Kithaironas	Turkey	1200	5.73
Mandra	Turkey	630	4.90
Evinos	Turkey	820	4.00

3. METHODOLOGY

A typical water supply system is composed of water source and storage, supply lines, water treatment plant, storage tank and distribution network (Fig. 2). The objective of water supply systems is to guarantee the delivery of adequate amount of good quality water to the inhabitants of the region. However, energy is needed to achieve this objective which requires operating water pumping and operation of water treatment plants. The supply lines transport the water from storage to treatment facilities and ultimately send treated water to storage tanks. It should be noted that the water supply lines have certain limitations for the created pressure. For example, In Turkey, the static pressure should be in the range of 20-80 m head, and if the upper limit of the pressure is exceeded along the pipe line, pressure reduction valves or tanks are used to dissipate the excess pressure head. Based on the estimations of Bank of Provinces, there is a 30 MW hydropower potential in the existing pressure reduction and storage tanks in Turkey.

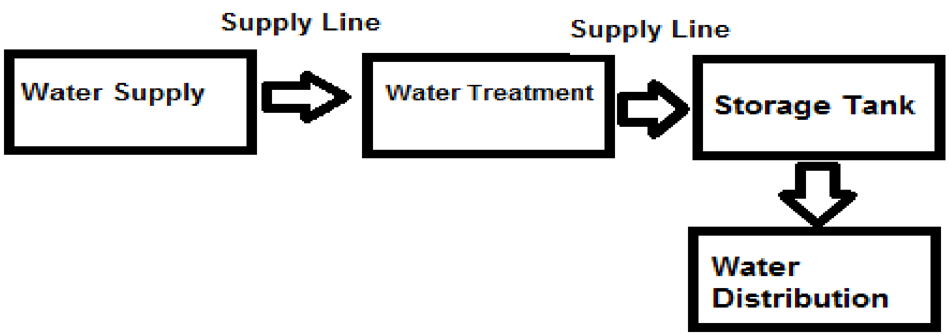


Fig. 2. Flow diagram of a typical water supply system

The shares of water supply sources in Turkey, with a capacity of 5.16 billion m^3 in 2006, are as follows: 36% dam reservoirs, 27% groundwater reservoirs, 27% springs, 6% rivers and 4% lakes [5]. The domestic water demand is expected to increase from 6.2 billion m^3 in 2007 to 26 billion m^3 in 2030 (Fig.2). There are totally 43 municipal water supply dams in operation and the distribution of these dams across the country is shown in Fig.3. The municipal dams are distributed over 23 cities and the most of them are in the big cities like Ankara, Istanbul and Izmir.

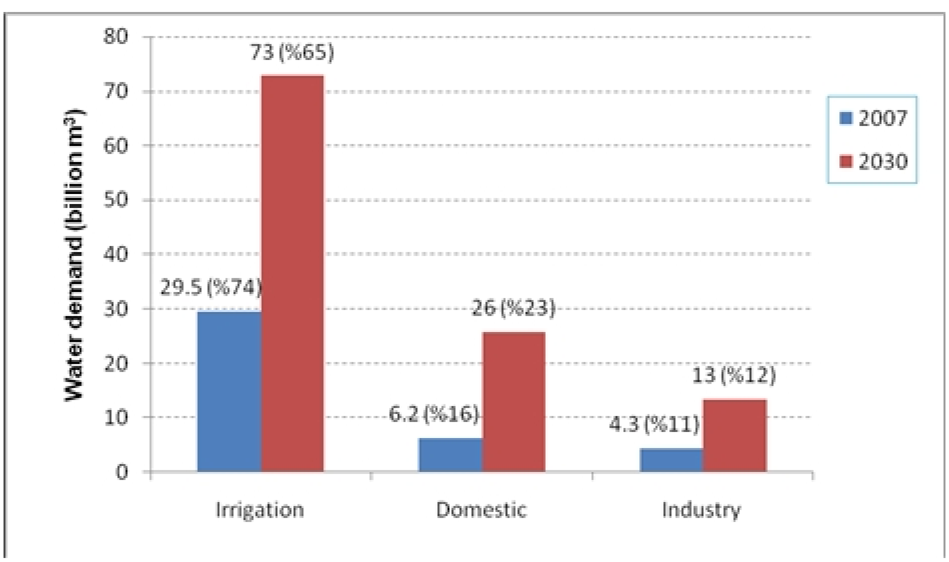


Fig. 2. Water demand of Turkey by sectors for 2007 and 2030 (projection by DSI)

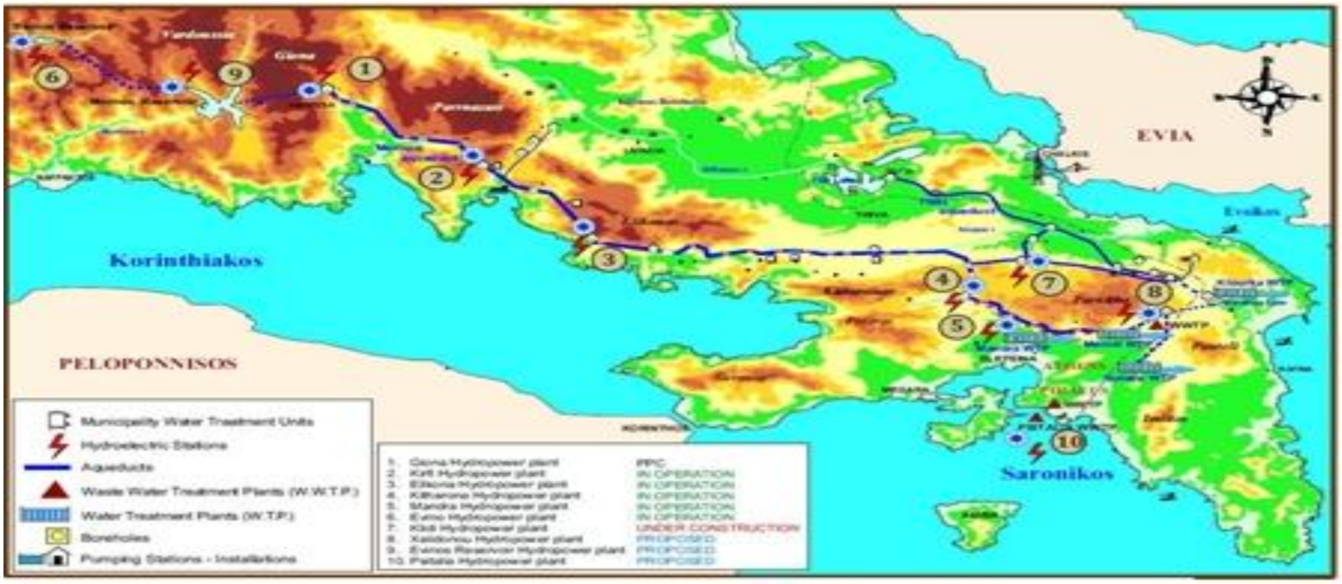


Fig.4 Water supply Sources in Turkey 2008 and the location of the case study.

Hydro-turbines convert the water pressure into mechanical shaft power, which can be used to drive an electrical generator, or other machinery. The available power is proportional to the product of pressure head and water discharge. Modern hydro-turbines can convert as much as 90% of the available energy into electricity. The installed capacity Power (*P)* (kW*)* of a hydropower plant is calculated from:

$$P\ (kW) = Q\ (m^3) \times H\ (m) \times \Delta H\ (m) \times \eta$$

Where *Q (*m^3/s*)* is the discharge, H_n (m) is the net head (m), η is the η is the sum of the turbine and generator efficiency and *g* is the acceleration of gravity, Δ*H* (m). The annual energy generation *E* (kWh/year) of a hydropower plant is obtained from difference between two points is high and the excess pressure head is dissipated in lines. In these structures, the pressure head is dissipated to atmospheric pressure by creating water jets. However, the pressure head could be removed from the system by installing a hydro-turbine. Then, the excess energy will be converted into useful electrical energy.

3. Simly Dam Water Supply System: A Case Study in Islamabad

Simly Dam is situated on the north Aegean coast of Islamabad (Fig.3).The water used in the city for domestic and commercial purposes is supplied from the Simly Dam and a local spring located on Soan river and Mount Ida, the water is carried through three water supply lines having an elevation ranging between 80-868 m. The overall discharge is carried through 03 main conduction ductile MS pipelines to regulate the pressure of the flow at a rate of 1.44 m^3/s, having diameter of 48", 36" & 36" in a length of 30 km (Fig.4). The pressure heads of the pressure lines are presented in Table 3.

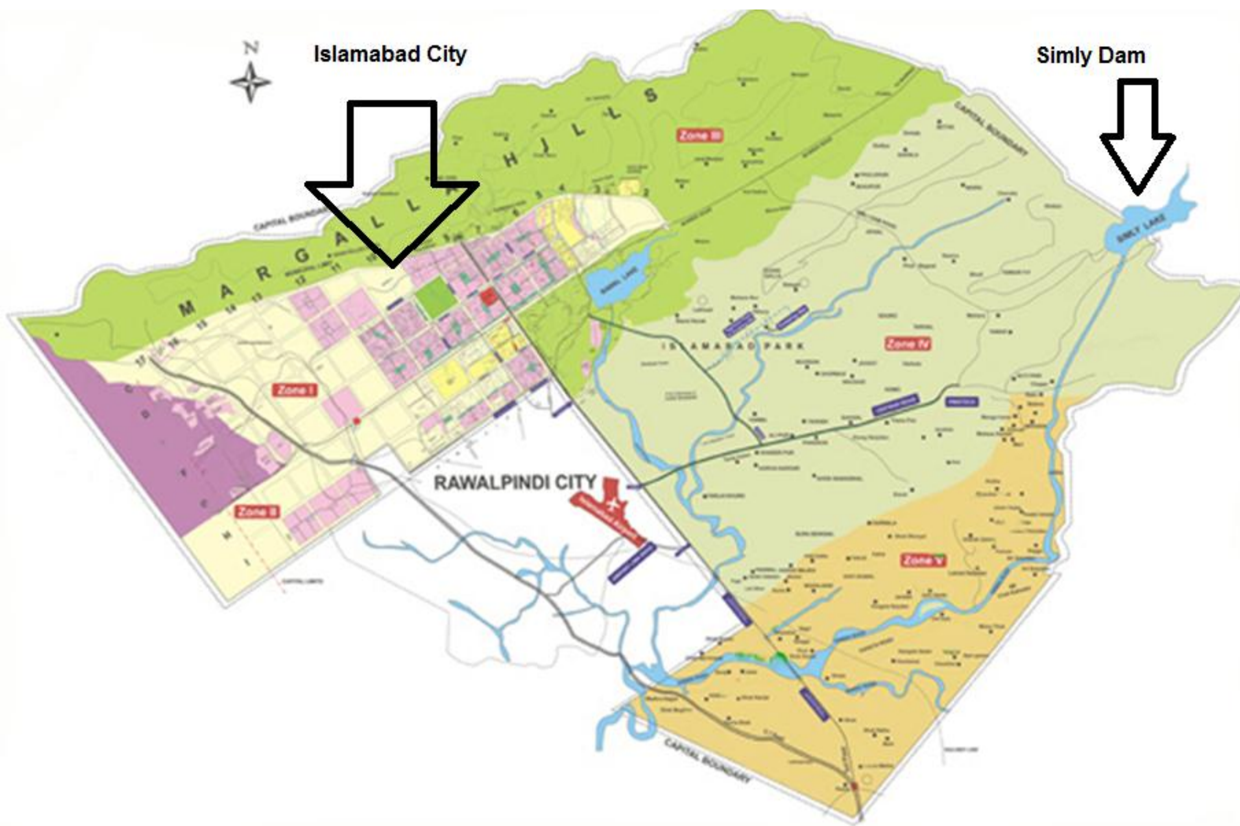
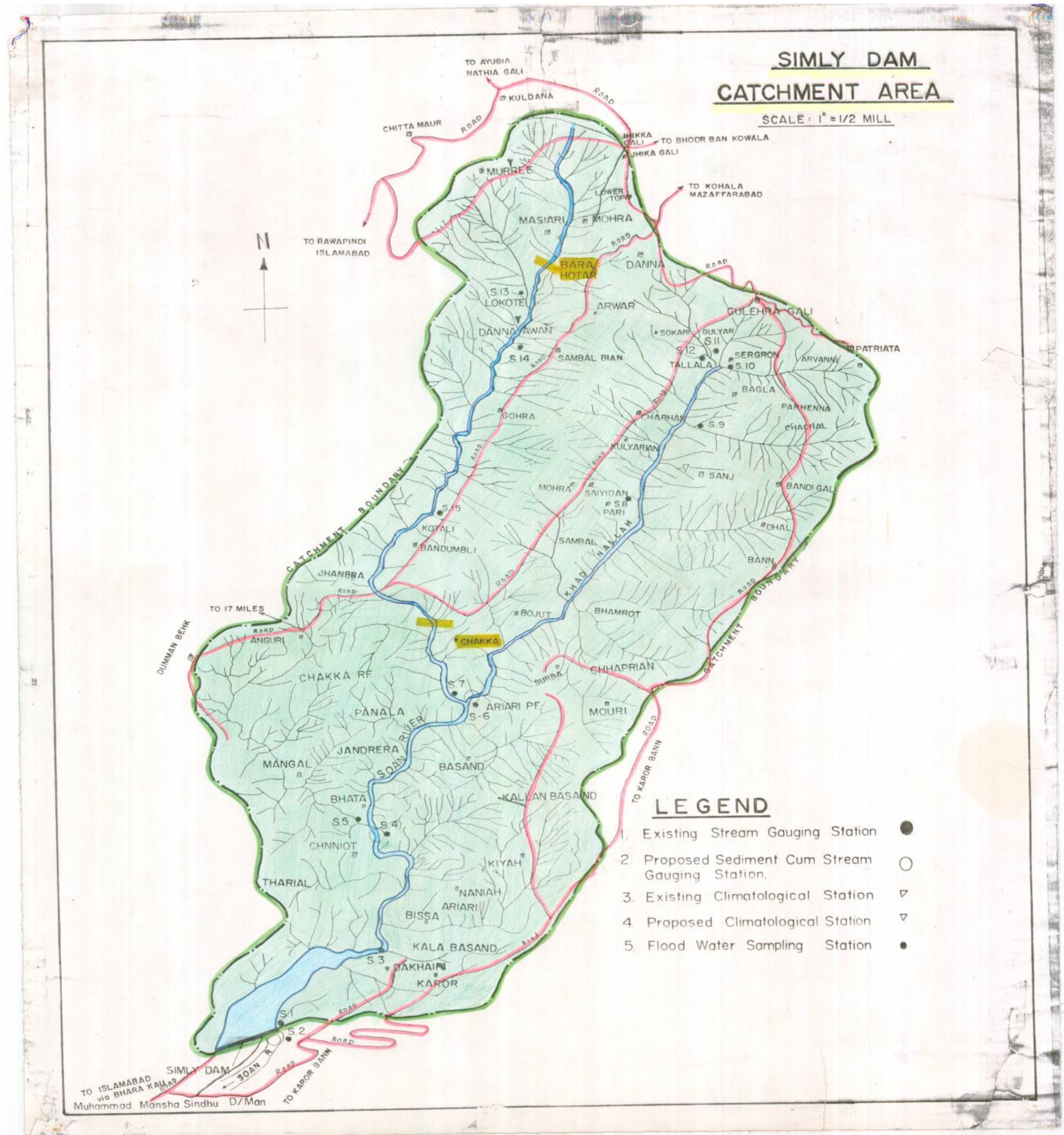


Fig.3 Islamabad City


SIMLY DAM
CATCHMENT AREA
SCALE : 1" = 1/2 MILL
N
TO AYUBIA NATHIA GALI
KULDANA
CHITTA MAUR
MURREE
TO BHOOR BAN KOWALA
JHIKA GALI
TO KOHALA MAZAFFARABAD
TO RAWAPINDI ISLAMABAD
MASIARI
MOHRA
BARA HOTAR
DANNA
ARWAR
GULEHRA GALI
PATRIATA
SAMBAL BIAN
SERGRON
TALLALA
BAGLA
GOHRA
CHARHAN
KULYARIAN
SANJ
MOHRA
SAIYIDAN
PARI
BANDI GALI
KOTALI
BANDUMBLI
SAMBAL
BANN
JHANBRA
CATCHMENT BOUNDARY
TO 17 MILES
ANGURI
BOJUT
BHAMROT
CHAKKA
CHAKKA RF
CHHAPRIAN
ARIARI PF
MOURI
PANALA
JANDRERA
SOAN RIVER
BASAND
MANGAL
BHATA
KALLAN BASAND
CHNNIOT
KIYAH
THARIAL
NANIAH
ARIARI
BISSA
KALA BASAND
DAKHAIN
KAROR
SIMLY DAM
TO ISLAMABAD via BHARA KAU
TO KAROR BANN
Muhammad Mansha Sindhu D/Man
LEGEND
1. Existing Stream Gauging Station
2. Proposed Sediment Cum Stream Gauging Station.
3. Existing Climatological Station
4. Proposed Climatological Station
5. Flood Water Sampling Station

SALIENT FEATURES OF THE SIMLY DAM

Location	35 km North-East of Islamabad.	On Soan River
Construction	Started	1972
	Completed	1982
Purpose	Water Supply for Islamabad.	
Project	Local Currency only	Rs.643.443 Million
Reservoir	Normal Conservation Level	EI.2310 SPD
	Total Catchments Area	150 Sq Km
	Max.Length	6 KM
	Max Depth from Dam Top	150 Ft
	Area	468 Acre
	Useable Capacity (I.2310)	25,367 Acre Ft
	Useable Capacity (EI.2315)	27,708 Acre Ft
	Dead Storage Capacity (EI.2233)	5,407 Acre Ft
Embankment Dam	Type	Zoned Earth & Rock-fill
	Crest Length	1,010 Ft
	Crest Width	30 Ft
	Crest Elevation	2,330 Ft SPD
	Max. Height at Deepest Foundation	263 Ft
Spillway	Overflow Weir	110 Ft at Crest
	Discharge Capacity	45,000 Cusecs
	Gates (3 Nos)	32 x 25 Ft
	Energy Dissipation	Chute & Two Basins in Tandem
Auxiliary Spillway	Free Overflow Weir	459 FT at Crest
	Crest Height above approach Channel	7 Ft SPD
	Crest Elevation	2,317 Ft SPD
	Discharge Capacity	35,800 Cusecs
Outlet Works	Diameter	6 Ft
(Water Supply Tunnel)	Length	590 Ft
Diversion Tunnel	Shape	Horse Shoe
	Length	594 Ft
	Diameter	28 Ft
	Lining	R.C.C
R,C,C Conduit	Shape	Horse Shoe
	Length	344 Ft
	Diameter	28 Ft
Drainage Gallery	Size	5x7.5 Ft
	Length	432 Ft

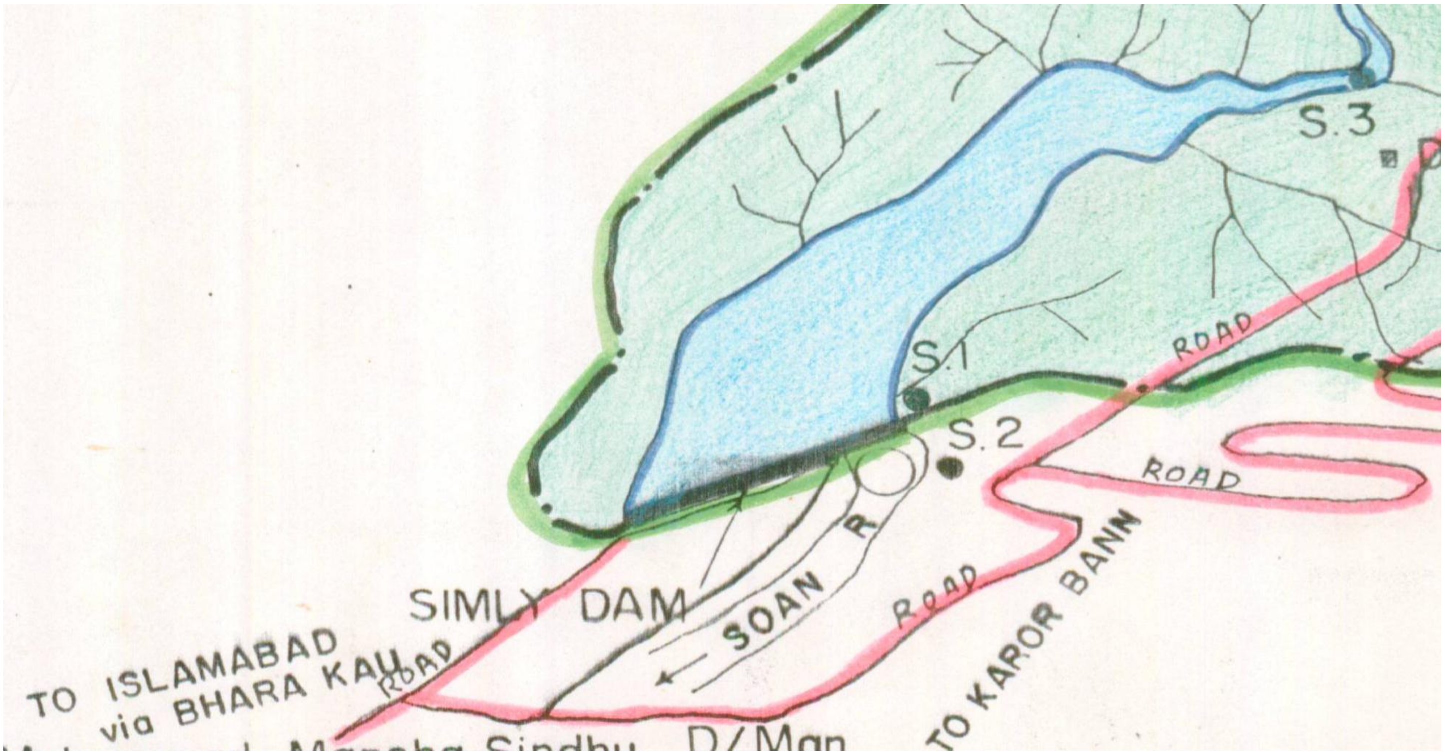
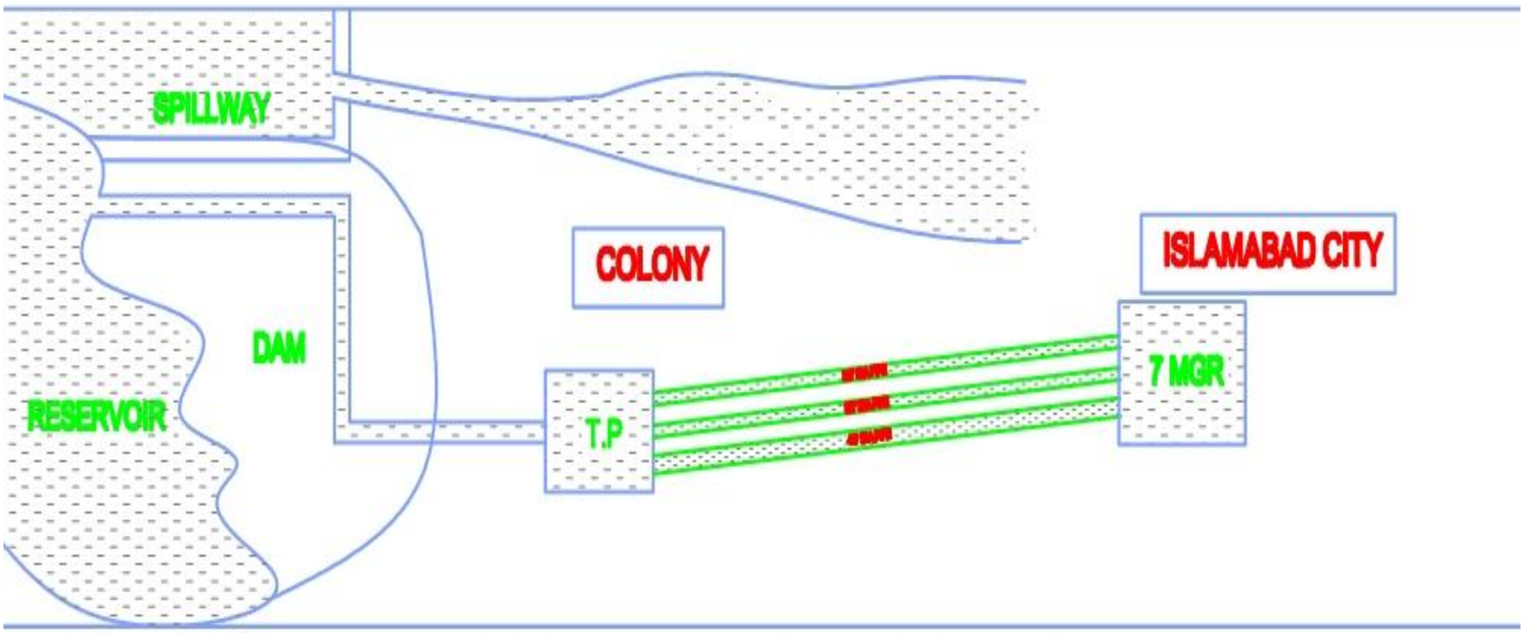


Fig.4 Water supply Sources in Islamabad and the location of the case study



SIMLY DAM WATER SUPPLY STATUS

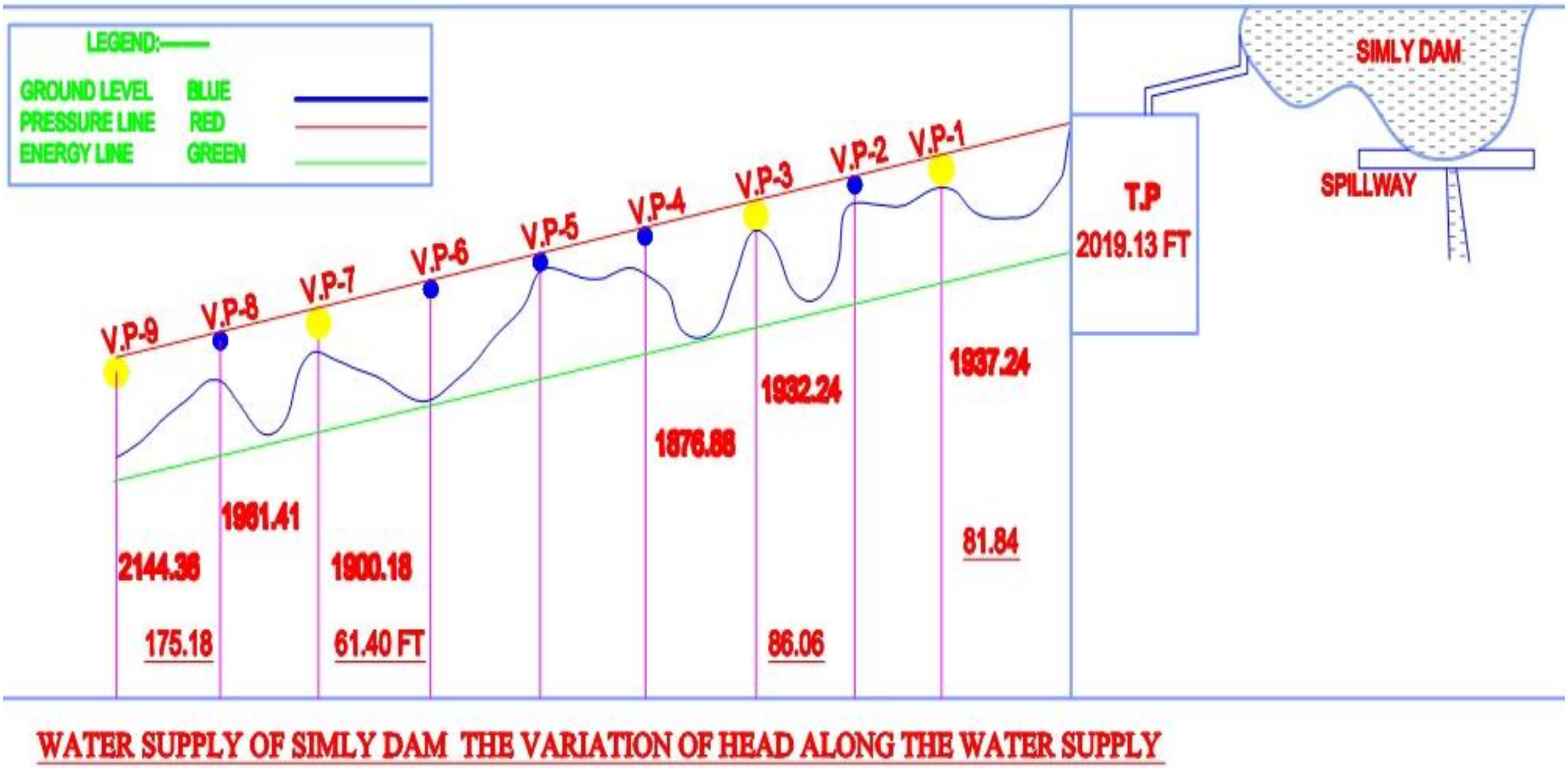


Fig.5 Water supply system of Simly Dam and the variation of the supply lines

Table. 3. **HYDROPOWER DESIGN CHARACTERISTICS OF SIMLY DAM WATER SUPPLY**

From Simly Dam Source Main Conduction Line	From Treatment Plant Daily Flow (MGD)	Discharge Q(M3)	VP*-I Head(M)	VP-IV Head(M)	VP-VIII Head(M)	VP-IX Head (M)	VP-I (kW)	VP-IV (kW)	VP-VIII (kW)	VP-IX (Kw)
48” Ductile Pipe line	18	0.765	24.39	22.86	19.81	53.35	132.937	124.598	290.782	724.568
36”Ms Pipe line	8	0.340	24.39	22.86	19.81	53.35	59.083	55.377	129.237	143.125
36”Ms Pipe line	8	0.340	24.39	22.86	19.81	53.35	59.083	55.377	129.237	143.125
Total	**34**	**1.444**	**73.17**	**68.58**	**59.43**	**160.05**	**251.10**	**235.35**	**549.26**	**1010.82**

Total Discharge Q(M3)	**1.444**
Total Power (kW)	**2046.53**

**VP= Valve pit*

Table. 4 **CDM ANNUAL CARBON INCOME**

Tentative Generation of CERs & Annual Carbon Income for the 10 Years From Simly Dam Water Supply Line HPP

Sr. No	Project	Capacity (MW)	Power Gen (MWh)	CERs (tCO2)	Annual Carbon Income (@ US$14 per CER)	Status	Date of Start	Date of Completion
1	**HPP From SD**	2.046	10,754	8,603	$ 120,442	Under Study	Nov-14	Sep-16
	Total	**2.046**	**10,754**	**8,603**	**$ 120,442**			

Total **CERs (tCO2)**	**8,603**
Total Income Amount USD from 10 Years	**1,445,307**

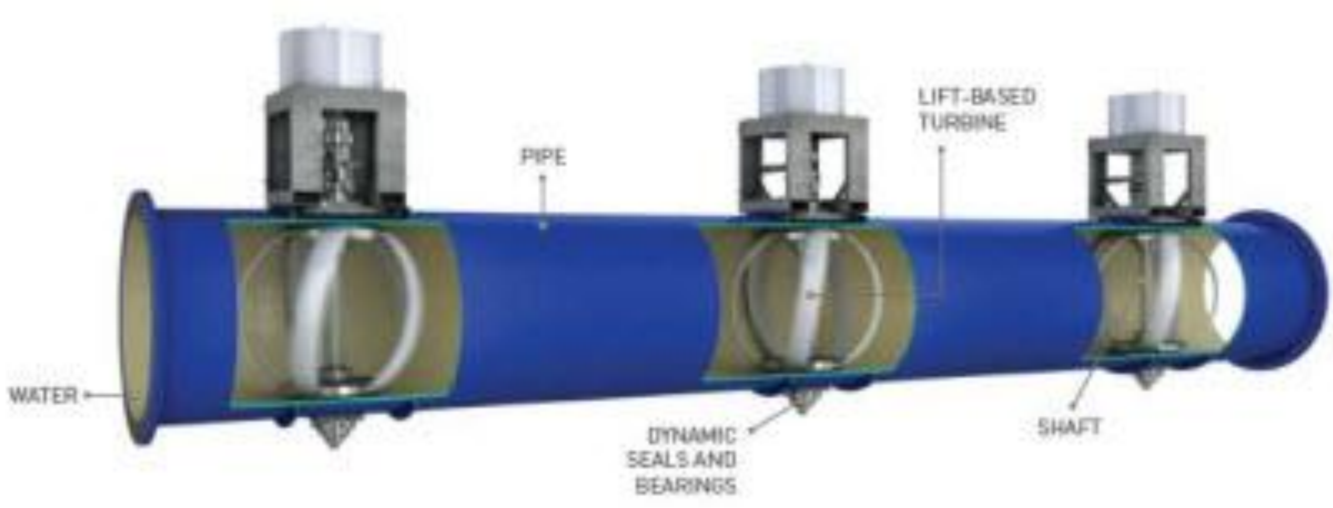
CDM

Climate change has emerged as one of the greatest threats to the planet and Pakistan is also rated as one of the hardest hit countries by climate change according to the World Bank. As result, combating climate change is becoming one of the top priorities of the Government and international organizations. The first compliance based mechanism for dealing with climate change was achieved through the introduction of the Kyoto Protocol in 1997 and the establishment of its three flexibility mechanisms: Joint Implementation (JI), Clean Development Mechanism (CDM) and Emissions Trading (ET). Following ratification of the Kyoto Protocol in 2005, Pakistan became a signatory to the Kyoto Protocol in January 2005 as it came into force. Only the CDM is applicable to Pakistan as a developing country.

In keeping with the goals of the Kyoto Protocol, Pakistan would like to identify appropriate projects in the country which will achieve the double-aims of the CDM

- To reduce the costs of curtailing Greenhouse Gases (GHG) emissions by providing incentives to industrialized countries to invest in clean energy technologies and energy efficiency in developing countries
- To enhance the efforts of the developing countries to achieve sustainable development

The excess pressure heads in water pipelines in form of potential energy can be converted into useful way by rotating blades of hydro-turbine to create energy (Fig.5). The pressure head of the pressure lines was taken as design head for the hydro turbine installation and the design discharge is selected as 1.44 m^3/s (Fig.7). The electricity price is about PKR 14/kWh in Pakistan for the June 2014 and the price was used in determining the economic benefit of the hydropower schemes. As the operation of water supply system already exists, therefore there will be no extra operational cost. The annual maintenance cost is estimated to be 1% investment cost of hydropower plant. This cost has been considered in the calculations of economic benefit in Table 4.



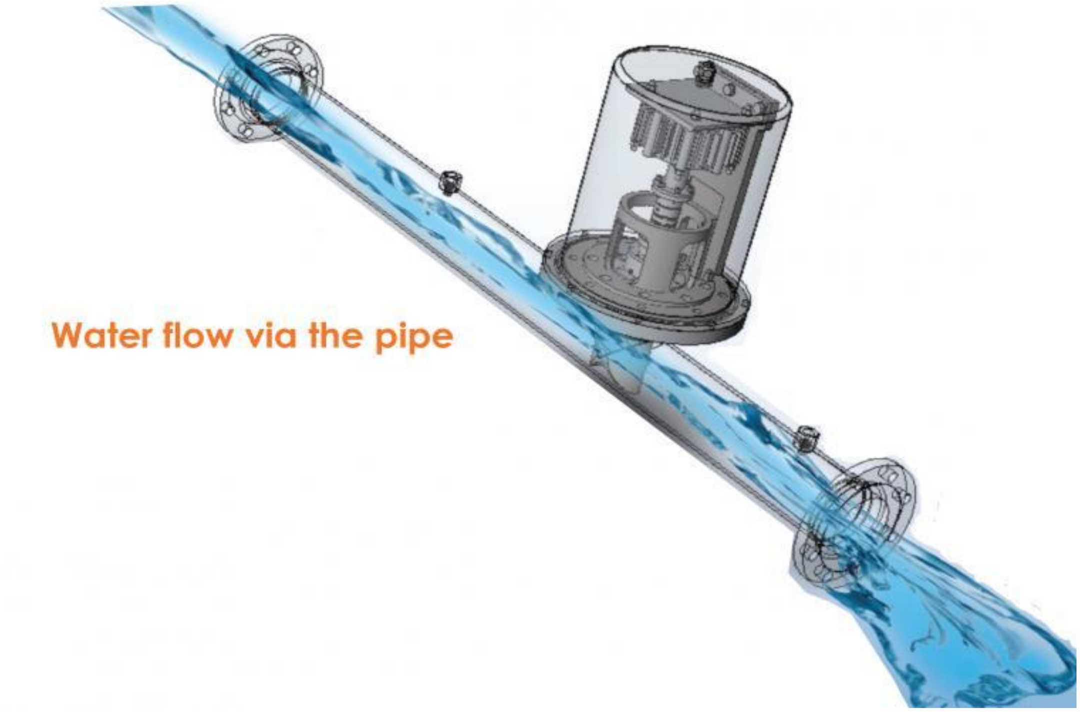


Fig.5 Hydropower generation in the Main conduction lines

The water supply system of Simly Dam has an electric energy potential of 14,935,800 GWh/year, corresponding to about Pak Rs. 136 Million /year economic benefit. The financing of the project would be supplied from CDA Self finance or International funding organizations like World Bank and ADB.

Table 5. Economic Analysis of the Proposed Project

Table 5.Economic Analysis of The Proposed Project	
Total Installed Capacity (kW)	2046
The hours in operation (h/year)	7300
Annual Energy (kWh/year) Million	14.93
Cost of the investment (Pak Rs. Million)	205
Annual Benefit (Pak Rs. Millions)	136.00
Payback period (year)	1.50

Conclusions

Utilization of the existing hydropower potential in water supply networks has been analyzed. The proposed facility has numerous advantages compared to run of the river-type hydropower plants. The new energy laws and the economic aspects of Islamabad will create an opportunity to develop this renewable energy potential. For this case study, the water supply system of Simly Dam has been investigated in a detailed manner. There are 03 Main conduction lines/ the water supply line and they have a power capacity of 2046 kW. The proposed project is ecologically sustainable and it will produce clean and feasible energy

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