ASSESMENT OF SOLAR PHOTOVOLTAIC WATER PUMPING OF WASA TUBE WELLS FOR QUETTA VALLEY AQUIFER

By

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Has been found satisfactory for the requirements of the degree of Master of Science in Environmental Engineering

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Muhammad Saydal Khan

Table of Contents

LIST OF ABBREVIATIONS

WASA	Water and Sanitation Agency
SPVWP	Solar Photovoltaic Water Pumping
NEPL	North East Pishin Lora Basin
PBS	Pakistan Bureau of Statistics
EAC	Equivalent Annualized Cost
LCW	Level Cost of Water Sodium
AC	Alternate Current
WPS	Water Pumping System
DC	Direct Current
CP	Centrifugal Pump
PMD	Pakistan Meteorological Department
CB	Cost Benefit Ratio

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The unplanned use of ground water resources has led to the deterioration of water quality and quantity in Quetta valley. Water shortage in the region was further aggravated by the drought that hit the area during 1998-2004, thereby forcing people to migrate from rural to urban areas. Influx of refugees caused rapid increase in population of Quetta valley that rose from 0.26 million in 1975 to 2.2 million in 2017. Due to increase in urban water demand and agricultural activities, the aquifer of Quetta Valley is under tremendous stress and water table is declining at an alarming rate. The Water and Sanitation Agency of Quetta (WASA) is monitoring groundwater levels since 1989. There are 423 tube wells in operation installed by WASA in addition to PHE, Irrigation and MES, which covers 60 % of the city's water demand.

This study aimed to assess the impacts of WASA tube wells on total discharge & water table in the valley aquifer and conducted cost benefit analysis of running these wells on SPVWP (solar photovoltaic water pumping) system. Study revealed that Quetta is geographically divided in two zones, Zarghoon and Chiltan. Water table decline rate in the Zarghoon zone was observed 2 to 5 m/yr and discharge have been reduced from 4 to 19 %, while the water table decline rate in the Chiltan zone was observed between 2 to 8 m/year and discharge have been reduced from 5 to 20 %. Quetta receives the highest average solar radiation (data from RETScreen), due to which solar photovoltaic pumping is potentially efficient and economical. The solar photovoltaic viability and cost benefit (C:B) analysis for these tube wells has been carried out using RETScreen software. Using data of these tube wells C:B ratio for different pumps have been analyzed and it was noted that for five different pumps with power capacities of 5.5 KW, 11 KW. 15 KW, 18.5 KW, 30 KW, The C:B is 2.05, 3.52, 2.92, 2.52 and 2.97 respectively, while their payback period is 3 – 5 years. Based on 30-tube wells data analysis, it is recommended that two pumps having capacities of 18.5 KW to be installed for shallow depth and 30 KW for deeper depth depending on their discharge.

Chapter 1

Introduction

1.1 Ground Water and its Importance

Groundwater is the water found underground in the cracks and spaces in soil, sand and rock. It is stored in and moves slowly through geologic formations of soil, sand and rocks called aquifers. Groundwater supplies are replenished, or recharged, by rain and snowmelt that seeps down into the cracks and crevices beneath the land's surface. In some areas of the world, people face serious water shortages because groundwater is used faster than it is naturally replenished. In other areas, groundwater is polluted by human activities.

Water in aquifers is brought to the surface naturally through a spring or can be discharged into lakes and streams. Groundwater can also be extracted through a well drilled into the aquifer. A well is a pipe in the ground that fills with groundwater. This water can be brought to the surface by a pump. Shallow wells may go dry if the water table falls below the bottom of the well. Some wells, called artesian wells, do not need a pump because of natural pressures that force the water up and out of the well. Extensive pumping from the ground cause the decline in water table and reduction in discharge (Ground Water Foundation., 2019)

1.1.1 Ground water reliance

Groundwater is a significant source of water to sustain life throughout history. Because it is buffered from short-term weather pattern fluctuations, groundwater has often been regarded a resource that is stable and safe. With efficient pumps and rural electrification, the worldwide extraction of groundwater increased from 312 km3/year in the 1960s to 743 km3/year in 2000. About 70% of this extraction is used in agriculture. About half of the consumption of national human water in urban regions is groundwater. Local, regional and global conflicts over groundwater resources arise with enhanced water use (Fienen et al., 2016)

Groundwater is a reliable resource that can be used whenever necessary. Groundwater is used worldwide, including Pakistan, for agriculture, drinking water supply, and business. Thirty-five percent of Pakistan's agricultural water needs are met from groundwater. Most of the supplies of drinking water come from the groundwater (Bhutta et al., 2010)

Pakistan with a population of 207 million losses most of the water available to it from the Indus river. The country faces shortfall of water and does not have enough storage capacity to last more than 30 days. The shortage of water asset and its deficiency typically Impacts in financial and medical issues.70% of the number of inhabitants in Pakistan is living in the rural zones of the country, where the head drinking water source is groundwater on account of safe wellspring of water. Baluchistan is the biggest of the four territories of Pakistan and the groundwater has been considered the main dependable wellspring of water to experience the developing requests. This country is moving from water-stressed to water scarce nation (Khan et al., 2013).

1.1.2 Ground water extraction

A pump is typically used to lift water from the ground and supply up to the point where it is needed. To operate these pumps large amount of energy is required. Different kind of pumps is used to extract water from the ground, like diesel water pumps, pumps run by grid electricity, solar photovoltaic water pumping system or pump runs by wind turbine (Rao et al., 2018)

There are more than 600,000 current private tube wells in Pakistan. The rise rate is twenty thousand tube wells per year. The private well working tube wells are discharged at 0.8 cusec (23 l / sec). Since 1998, the groundwater table has been dropping in almost every channel command. It shows that the present net abstraction of groundwater1 is greater than recharge. The growth of groundwater at the present rate is therefore unsustainable. The submersible motor pump along with their parts are displayed in figure 1.1(Bhutta et al., 2010)

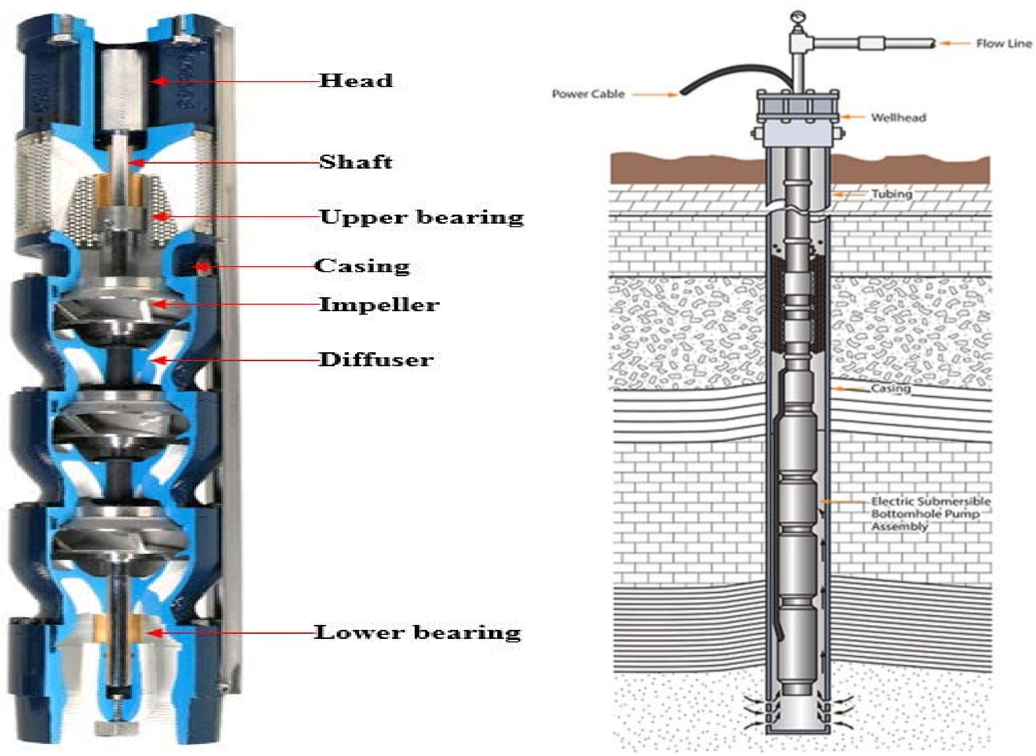

Figure 1.1. Submersible pump used by WASA for extraction of water

1.2 Renewable energy scenario of Pakistan

Pakistan is a developing nation, where electricity request has risen significantly because of populace blast and present-day development and has a deficit of 6500 MW among supply and demand in 2015. The country has a sustainable power source capability of 2,900,000MW for sun based, 346000 MW for wind 3000MW for biogas, 2000 for little hydropower and 1000MW for waste-to-vitality, with its share in complete present energy situation being under 1% (Wakeel et al., 2016).

1.3 Water Crisis in Quetta

Quetta city is located in northern Baluchistan near the Pakistan Afghanistan border with the latitude 30.20 and longitude 67.01 and at the elevation of 1682 meters. The population of this is approximately 2.27 million people according to the latest census of Pakistan (PBS). Quetta is likewise spelled Kuwatah which is a variety of Kozaint, a Pashto word signifying "Stronghold." It is trusted the city's name is gotten from the four forcing slopes (Chiltan, Takatu, Zarghoon and Murdaar) (Government of Baluchistan., 2015).

In the prevailing arid climate, the water supply of Quetta is mainly dependent on groundwater from an alluvial aquifer approximately 100 m deep below ground. Over pumping of more than 2,000 wells for water supply and irrigation at a pace that exceeds the natural recharge, leads to a scenario where the aquifer could be exhausted in less than 10 years if the present developments continue to be exploited (Asian Development Bank., 2000).

Key issues responsible for lowering water are, mining of groundwater, Neglect of Sailaba and Khushkaba farming systems, which induce recharge to the groundwater, Extension of huge subsidy in electric tariffs for tube wells consumers encouraging excessive mining of groundwater resources, Lack of initiative and/or infrastructure to use flood water for direct irrigation and groundwater recharge, Lack of effective wastewater treatment facilities resulting in increasing pollution loads in the freshwater streams and lack of an institutional arrangement for regulation, management and monitoring of water resources (Government of Baluchistan., 2015)

The water hardships of the three million population of Quetta are declining as time passes as the underground water level has exhausted to in excess of 300 meters, in some region of the city while the Water and Sanitation Agency (WASA) has shelled in finding a sensible course of action. Quetta requires roughly 100 million gallons of water each day to run routine issues, yet (WASA) could simply make sense of how to give 60 million gallons and the plotting is growing a result of quick surge in population (QWASA., 2018)

1.3 Solar photovoltaic water pumping system (SPVWP)

The need for alternative non-Conventional energy resources such as solar energy wind energy etc. has become an urgent n Matter. One of the most popular non-conventional power resources are solar energy power Plants which convert the solar energy or solar heat to electricity. The falling expense of solar panel is mainstreaming sunlight based pumping from Research stations to ranchers' fields. Empowered by the expanding moderateness of the Innovation, governments and universal improvement organizations are advancing sun powered Pumping over the creating scene .Solar pumps have long lifetimes, require insignificant Participation and upkeep, and have close to zero operational expense however a lot higher Capital Expense. Solar energy has an extra favorable position over petroleum derivatives: it Gives Outflows free power utilizing an inexhaustible wellspring of electricity ((Kishore et al., 2017).

The photovoltaic (PV) water pumping system is a standout amongst the most ordinary PV applications in creating nations and can possibly turn into a noteworthy power for social and monetary advancement. The utilization of photovoltaic as the power hotspot for pumping water is considered as a standout among the most encouraging territories of PV applications. The pumping water can be utilized in numerous applications, for example, household use, water for irrigation system and town water supplies. The setup of solar photovoltaic water pumping system is shown in figure 1.2. (Benghanem et al., 2018)

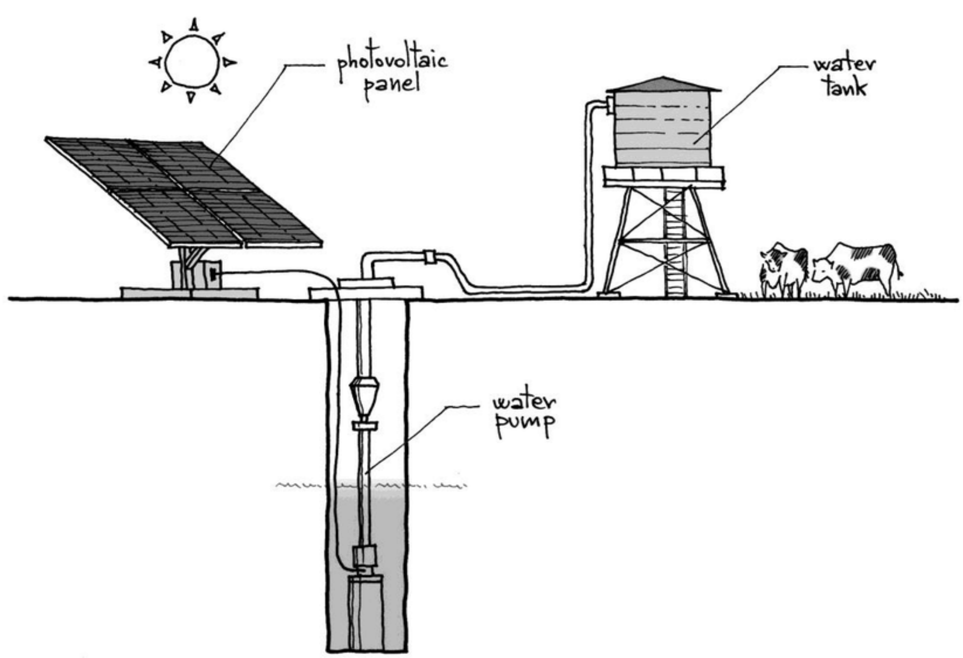

Figure1.2. Solar Photovoltaic Water Pumping System (SPVWP)

The photovoltaic innovation changes over episode sun based radiations falling On board into power. The sun based photovoltaic (SPV) frameworks are perfect, Commonsense and prudent to give capacity to family applications as expansion of Electrical cables to country zones. It has application in water pumps in remote Territories, reference points, hydrological estimating stations, microwave repeaters, driving of lighting signs, meters and so on. Maximum conversion efficiency of SPV Module is 4– 17% (Sharma et al., 2017)

1.3.1 Potential of solar photovoltaic water pumping in Quetta

The total share of electricity of Quetta Electricity Supply Company (QESCO) is 650-700 MW against demand of 1,620 MW, resulting in a shortfall of 970 MW. Quetta's altitude ranges above 1500 and reaches up-to 2500 and more towards the mountain resulting in higher solar intensity reaching its surface as compared to low altitude areas. It receives the highest average solar radiation, due to which solar photovoltaic pumping is potentially efficient and economical. The peak sunshine hours in the area are 2021 h/years, and the average annual radiation is about 7275 MJ/m^2, which is rich in solar energy resources (RETScreen)

1.4 Hypothesis and Objective of the Study

The growing population of Quetta valley and the increase in urbanization has a tremendous effect on the aquifer of this valley due to extreme discharge, which are still not sufficient to meet the demand .This study aims to know the impact of tube wells on discharge and water table and the assessment of solar photovoltaic water pumping system (SPVWP) for economical water pumping.

1.5 Objectives

a) Assessing the impact of tube wells on discharge and water table of Quetta valley aquifer

b) To conduct financial analysis of solar photovoltaic water pumping system

(SPVWP) in comparison with typical pumping system for WASA tube wells

Chapter 2

2 LITERATURE REVIEW

2.1 Ground Water Extraction of Quetta Valley

Extensive depletion of groundwater in urban areas can contribute to water shortages, land subsidence and water quality issues. Quetta Valley is Baluchistan province's largest population center in Western Pakistan. This region is arid and the main source of domestic and agricultural use is groundwater. This work suggests that over the past three decades, Quetta Valley has undergone a gradual decline in groundwater levels. Quetta's Water and Sanitation Authority (WASA) has been tracking groundwater levels since 1989 and water falls in some parts of the valley up to 24 meters in 30 years (Khan et al., 2013)

Over the decades, groundwater extraction has been developed exponentially, causing aquifer exhaustion and groundwater contamination. In Quetta Valley, precipitation estimates 217mm/year, with an extensive fluctuation. Yearly Evaporation is in the order 1750mm: the zone is mainly arid. The quick urbanization of Kuchlagh gave the chances to moving out the land and begging agri-business somewhere else; As well as discovering non-farming work in the territory – including leasing business property. A second point is that from the start there had been little enthusiasm for groundwater energize. The principle intercession had been the freely supported advancement of energizing repositories; the alleged 'defer activities dams'. These postpone activity dams have been developed in Baluchistan since the 1970s and now surpass 300. Their point is to block flood run-off and hold it for energize (Steenbergen et al., 2015)

This case study has been conducted in Quetta; the capital of the Baluchistan area is portrayed by low precipitation and is delegated dry to semi-dry locale. The bowl-moulded valley of Quetta is circumscribed by dry mountains including rocks of Triassic to Pliocene age. For the most part Westbound rain framework in winter to spring cause rain/snowfall. Later retentive dry spell Scenes (most recent two decades) especially obliged the circumstance of nature and trustworthy quality water in the district. Shake and soil connection just as anthropogenic impacts on accelerated water in channels descending to aquifers caused the extreme consideration of regular and man created tainting in groundwater. Aquifers due to optional breaking, week zones along bedding planed and disintegration of pits in limestone these qualities lie under usable breaking points for water system with the Exception of VS water. Water is sorted as phenomenal to great and great as far as possible for Water system dependent on Na% values. Both KI and PI likewise verify a large portion of the Water focuses are under usable breaking points for the water system. The recognized hydro Chemical facies are 1, 4, 6, 9, B and F. Which mirror that antacid earth surpasses alkalies, solid Acids surpasses frail acids, Blended sort (no cation, anion surpasses half), no overwhelming cation, anion types however water of VS is calcium chloride and sulfate type (kassi et al., 2014)

2.1.1 Water supply management

Both the water supply system and the source conclude the source of drinking water. Improved sources" include piped water, tap or stand pipe, hand pump, donkey pump / turbine, or well dug shielded. "Unprotected sources" include well dug, lake, river, canal or stream as well as other less prevalent sources such as supplied seller, tanker truck or bottled / canned water. Balochistan depends mainly on household piped water (25%) and well, lake or tank protected (13%). Sources that have not been improved (48%) include unprotected well or lake (24%) and river, canal or stream (17%) (Baluchistan MICS. 2004)

Groundwater utilization are not new in Baluchistan. Prior, groundwater utilization depend on open surface burrowed wells or common water Karezes and normal springs, however with a constrained degree. Nevertheless, with the accessibility of power, Heightening of tube well advancement, the capacity of water markets to give water in existence, Deal with the effect of water shortage and groundwater decrease, casual groundwater markets are rising in upland Baluchistan. Groundwater is the fundamental wellspring of the water system in upland Baluchistan and is primarily gotten through cylinder wells, dug wells, Karezes and springs. After some time, Tube well numbers have expanded fundamentally from 2500 in 1971 to 21,231 in 2008. This development quickened with the dry spell of 1998– 2005 and in light Of sub-discretionary groundwater the executives approaches which caused an extensive Number of groundwater sources, for example, Karezes, springs and cylinder wells to evaporate The normal decrease in water tables in the three upland regions was 75, 60, and 57 m in high, medium, and low height areas, respectively. The improvement of the groundwater showcase is the consequence of the joined impact of various climatic, financial, and natural elements. (Khair et al., 2012)

2.1.2 Recharge and discharge of aquifer

The region in the Valley of Quetta is arid and groundwater is the main source of water for both domestic and agricultural use. Geological features range from the early Jurassic to the Quaternary crop out in the Valley of Quetta. The left-lateral strike-slip fault of Chaman is active west of the Quetta Valley and defines the Indian Plate's western boundary, complicating the geological and tectonic past. In the Quetta Valley, two aquifers are identified: an unconsolidated alluvial aquifer and a bedrock aquifer. Water supply is largely dependent on groundwater, mainly derived from this alluvial aquifer. The bedrock aquifer consists of the limestone of the Shirinab and Chiltan formations and conglomerates of the Urak Formation. This aquifer is recharged in the surrounding mountain areas where these formations are exposed (khan et al., 2013)

This examination is going to get to and build up the pishin lora basin groundwater assets and to create situations for feasible water extraction in the Pishin Lora basin. They built a Catchment-based ceaseless (1998– 2005) precipitation spillover display for the upper east piece of the Pishin Lora basin (NEPL) watershed utilizing the Soil and Water Assessment

Tool (SWAT). The NEPL is a noteworthy watershed that covers a zone of 8,500 km2 Advanced Elevation Model (DEM; spatial goals: 90 m) was developed From the Shuttle Radar Topography Mission (SRTM) information. (2) Temporal and spatial Appropriations of temperature, relative dampness, wind speed, and solar-powered radiation were generated from the accessible climatic stations. The postpone activity dams were Developed for one primary reason, to increment invasion. As of now, water utilization in the NEPL is watched 400 × 106 M^3/year. Which surpasses our evaluations for reviving (361 × 106 M^3/year) (Sagin et al., 2010)

2.2 Economic Analysis of SPVWP

This study presents an economic analysis of diesel and PV water pumping systems in Cai ro, Egypt (Lat. 30 ° 2 ' 38 "North, Long. 31 ° 14 ' 9" East) for irrigation reasons. The nece ssary water demand, unit cost of separate parts and fuel cost, depending on the location p arameters, The research utilizes the HOMOR software and theoretical equations governing photovoltaic operation to obtain ideal system design and associated financial analysis for the necessary water demand, unit cost of various parts and fuel cost. Three water-pumping systems were regarded in the research; only PV, hybrid PV-Diesel and diesel the research showed the benefits of using photovoltaic energy in terms of the net current price and energy cost over that of the diesel generator. It also found that diesel pumps typically have a reduced cost of capital, but a very elevated cost of operation and maintenance. Solar is the contrary, with significantly greater capital costs but very small continuing operation and maintenance costs (Shouman et al., 2016)

Odhe et al. conducted another study to analyze financial reasonability of solar photovoltaic water pumps on fuel-based water pump in Jordon. The number of SPVWPS were five and they were of various sizes in the scope of 2.8–15 KWp were thoroughly examined. Three of them were comprising three various pumps converters with genuine examination information. While other two were bigger systems which utilized data, extrapolated from the information acquired from the other SPV system. Five fuel bases motor WPS of tantamount Limit were situated in the remote regions The results were: SPVWPS was increasingly conservative for proportionate water-driven energy, and Diesel pumping systems were progressively suitable for big scale. Solar water pump showed a less cost request for a specific head and supply design decreased financial suitability of SPVWPS. Underneath figures 2.1 and 2.2 shows the cost parameters influencing financial practicality of five SPVWPS (Odeh et al., 2006)

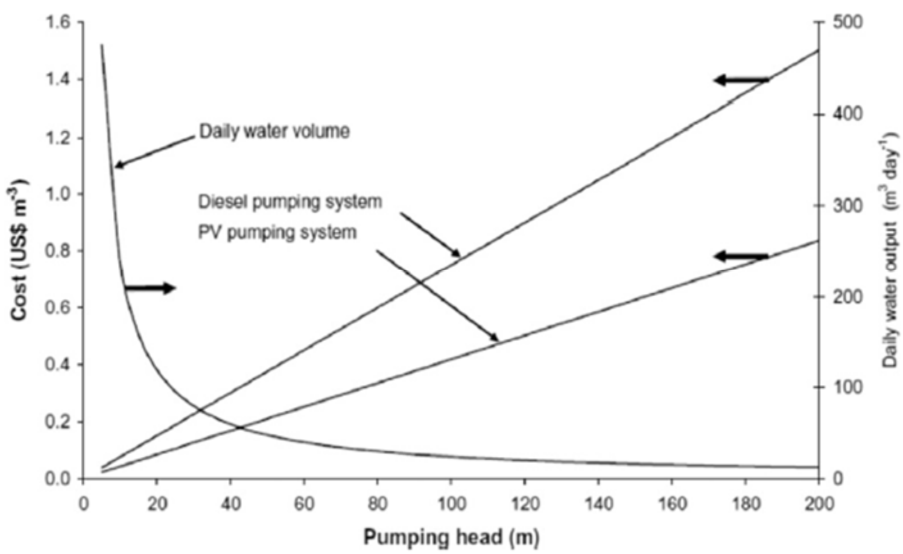

Figure 2.1. Water Cost volume based for daily discharge

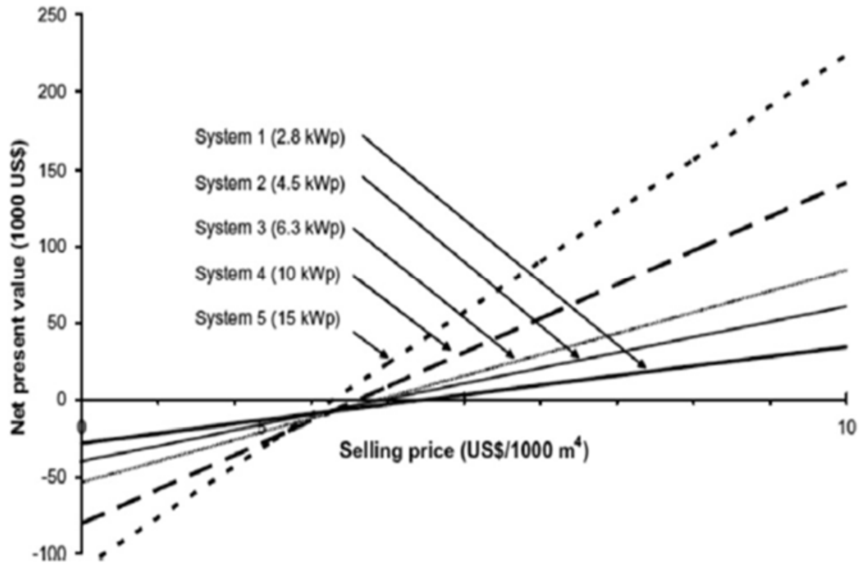

Figure 2.2. Values and selling price of different pumps

2.3 Efficiency of SPVWP

A research was conducted to explore the options for enhancing the efficiency PV modules. The findings reveal that water spraying can attain a PV effectiveness of 12.5 percent. In the event of a scheme without water spray over PV modules, the average flow rate at 16 m head on the exam day was about 479 l / h, whereas for the system covered with water it was 644 l / h. Water spraying on the photovoltaic components contributes to module cooling, thus improving the efficiencies of the scheme and subsystem (Abdolzadeh et al., 2009)

This study is based about the efficiency of a directly coupled DC powered PV water pumping scheme. The system works without electronic and battery checks. The efficiency of the motor-pump did not exceed 30 percent, which is typical of a direct-coupled photovoltaic pumping system yet such a system is suitable for low-head irrigation in remote areas. By choosing the size of the PV array, its orientation and motor-pump scheme, the system's efficiency can be improved (Mokeddem et al., 2011)

The efficiency of a PV-powered DC (PM) engine combined with a centrifugal pump at distinct solar intensities and respective cell temperatures was researched and evaluated by Mohanlal et al. Compared to calculated values, the experimental outcomes achieved are discovered to have a nice match between the PV array and the features of the electro-mechanical scheme. The writers noted that the performance achieved is 20 percent higher than the fixed tilted PV array by manual monitoring, i.e. by altering the orientation of the PV array, three times a day to face Sun (Kolhe et al., 2004)

This study evaluated the efficiency of a solar water pumping scheme composed of a photovoltaic array, a sun tracker, a permanent magnet (PM) DC engine, a helical rotor pump and discovered that system efficiency is improved by the addition of a maximum energy y point tracker (MPPT) and a sun tracker. The PV array assessment was conducted using PSPICE software (Chandel et al., 1996)

2.4 Power Rating of SPVWP

Another work was designed to build and tried a novel kind of PV fueled PDP. A pump was created with an ordinary power hesitance actuator as a main diver. Primary concept was effortlessness, reliable, cheaper and simple. The pump was designed for 50 liters of water / hour with a height of 2.4 m. The observed results were that the operation of the system can be enhanced by technological advancement (Wade et al., 2007)

Vick et al., studied the operation of Sunlight based PV fueled pumps at the, Taxes. They labelled them as M1 and M2 and were operated for low rates. while pumps name Q1 and

Q2, were operated for moderate stream 9 to 15 liters per minute with shallow pumping heads of 10 to30 meters. It is been observed that this kind of pumps provided 1650 and 3650 liters per day at the Siphoning heads of 70 meters and 30 meters. Figure 2.3, and 2.4 are the different parameters analysis based on these pumps (Vick et al., 2005)

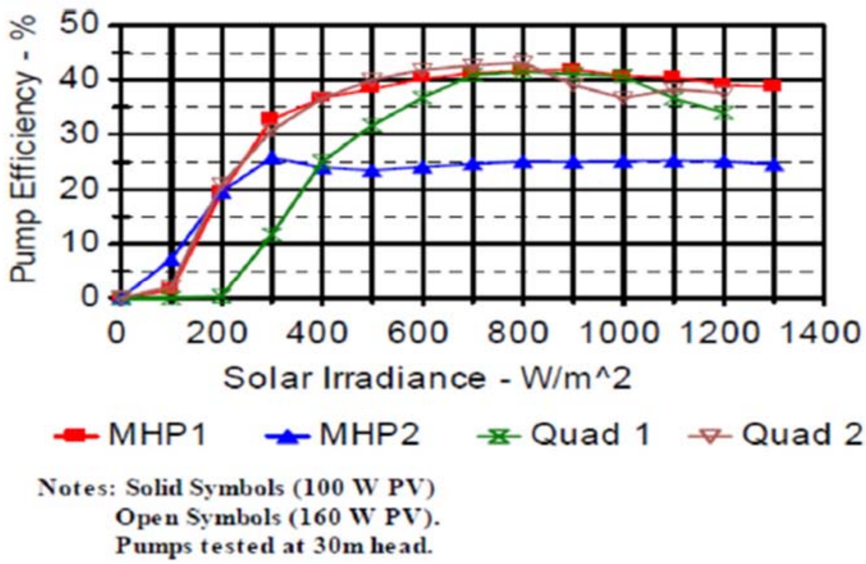

Figure 2.3 Calculated pump efficiency of different pumps at 30m head

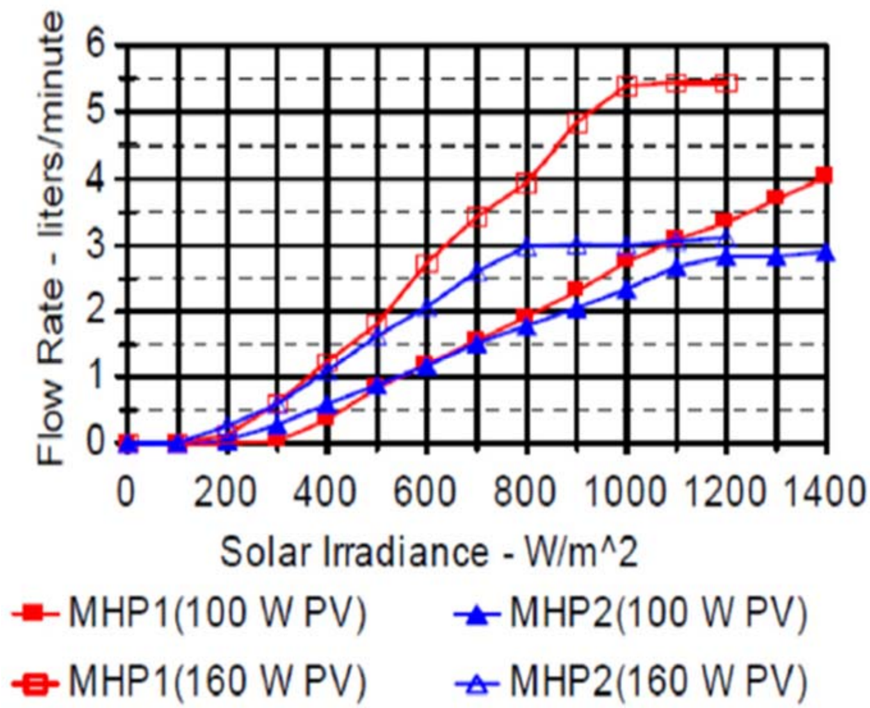

Figure 2.4. Measured flow rate of different pumps at 70 m head

The field tried the proficiency and execution of factors of two unique kinds of systems namely 1A and 2B. System 1A was composed of a submersible a synchronous with 1100 watts connected to a 3-phase CP , while the System 2B was consisting of a submersible BDC engine with a power of 600 Watts connected to an erratic pump . The Information of field test was approved with PC reenactment show Integrated Simulation an Environment Language. It was revealed that system B was more productive than system A. Operation of both systems in volume/day is Shown in Figure 2.5. Means and $\dot{Q}$ sim speak to the deliberate and reenacted volume stream rate amid the particular day Figure 2.6. Shows the deliberate and reenacted stream rate at the steady geodetic head plotted as a component of the DC power (PDC) for both the frameworks (Hans et al., 1996)

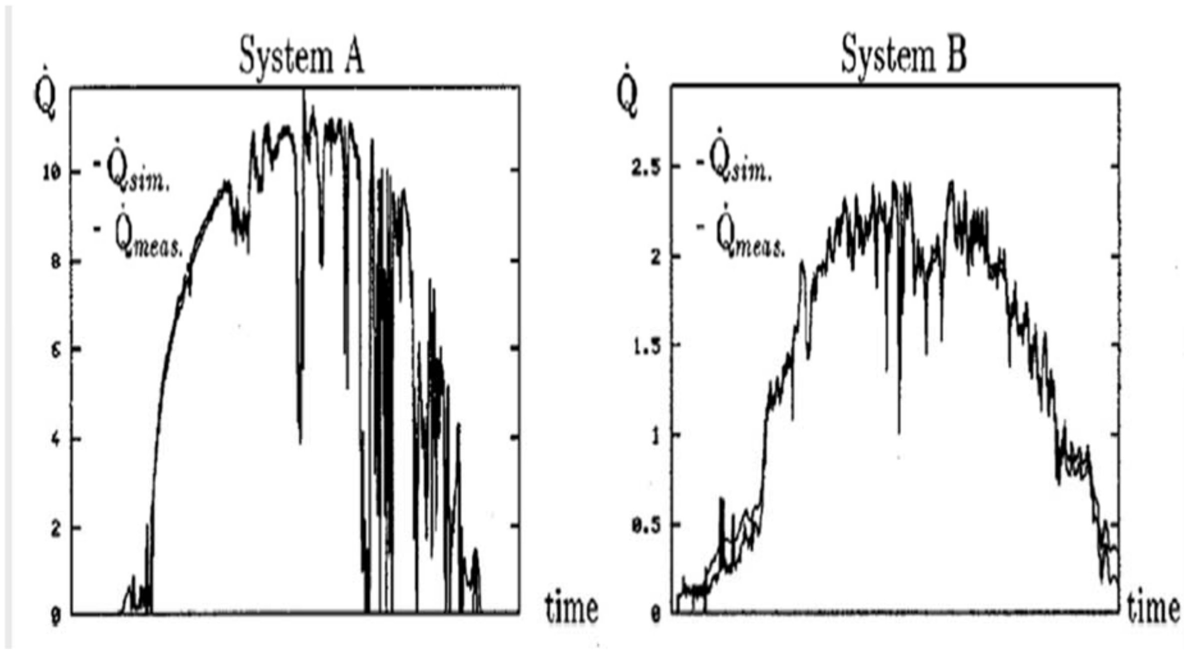

Figure 2.5. Flow rate of volume meter cube per hour of two frameworks per day

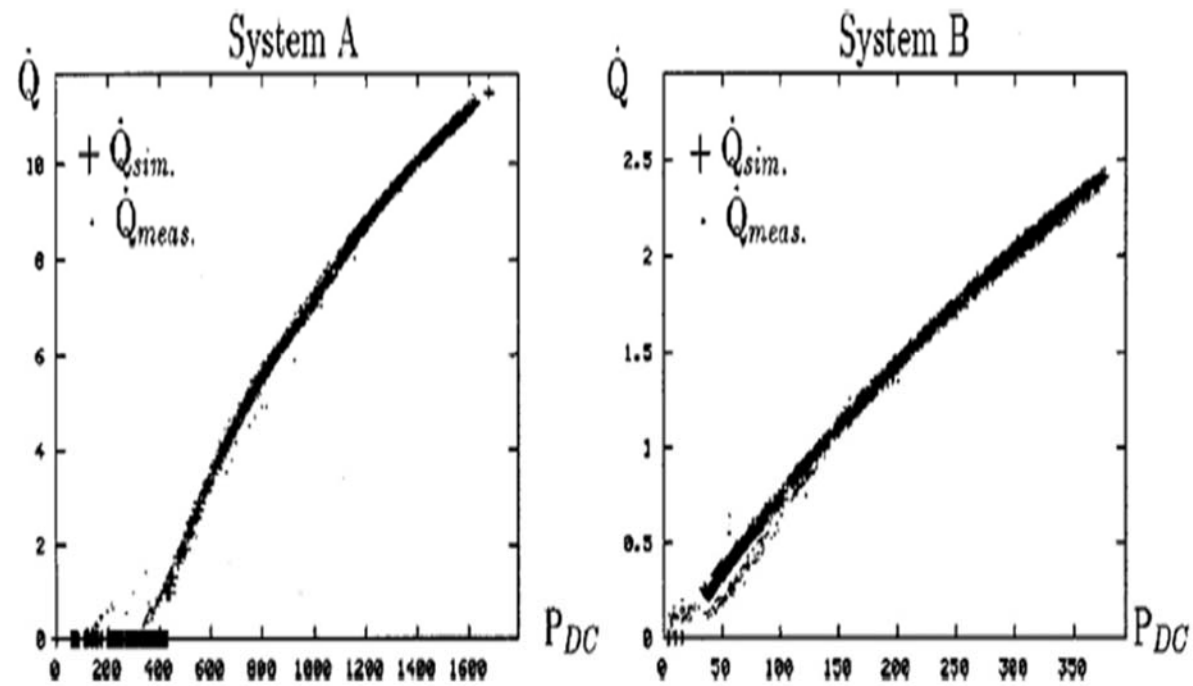

Figure 2.6. Flow rate of Volume meter cube per hour versus power dc of two frameworks

Another study observed the execution of two CPs. The first CP was a solitary stage pump with brushless DC motor (450W) and second was the multi-hole submersible pump specifically coupled with DC motor (400W). Four distinctive sites namely Algiers, Bechar, and Oranand Tamanras set were chosen in Algeria. They utilized a recreation show for both the CPs. It is found that for high head application a multi-Depression and multistage pump were the most proficient and reasonable. The performance of the pump was also impacted by local and whole setup. (Arab et al., 1999)

2.5 SPVWP Pumps Frameworks

This study is based on the execution of pumps with helical rotor pump which are driven by blower drive service engine and PV exhibit for animals watering and water system applications. They mimicked the execution of BDC engine and Pumping display utilizing the product PSI/e" and approved with exploratory outcomes. The detailed great assentation among the reproduced results. Critical enhancement in the proficiency estimation of solar driven pumps with BDC engine over brushed DC engine was accounted for (Langridge et al., 1996)

Researcher presents and explored the execution of sunlight-based PV fueled CP (Centrifugal Pump) driven by a traditional DC motor and Permanent Magnet Direct Current motor in their study. They announced that the PMDC motor based pumping framework was better and more effective as compared to the traditional DC engine-based system (Chandrasekaran et al., 2012)

To utilized a scientific model to investigate the execution of an SPVWPS Utilizing two distinctive drive frameworks for the greatest power from the PV array. An Independently energized DC motor and IM (Induction motor) were utilized to drive CP of the SPVWPS. They announced that control extricated by energized DC engine was more than the IM At all insolation level. In the instance of energized DC motor, directly associated with the PV exhibit, controlling of engine excitation brought about the expansion of intensity. The IM conveyed the greatest power by controlling the recurrence of voltage source inverter associated with the PV Exhibit (Zaki et al., 1996)

A study examined the execution of a PVPS. It was executed with and without MPPT utilizing different two DC engine drive systems. Hence the first framework cosist of a motor (PMDC) a dynamic pit for pump and Photovoltaic Cluster. The examination likewise expected to choose an appropriate framework to drive and coordinate the pumping load to display the misfortunes happening in the segments of PVPS. Appropriate coordinating of the drive system and load Guaranteed most extreme productivity of PV pumps at an explicit head. Modelling the misfortunes guaranteed productive power usage of pumps. It is also observed solar driven pumps dependent on that engine were more beneficial than IM. Figure 2.7 and 2.8 shows these qualities (Lujara et al., 1999)

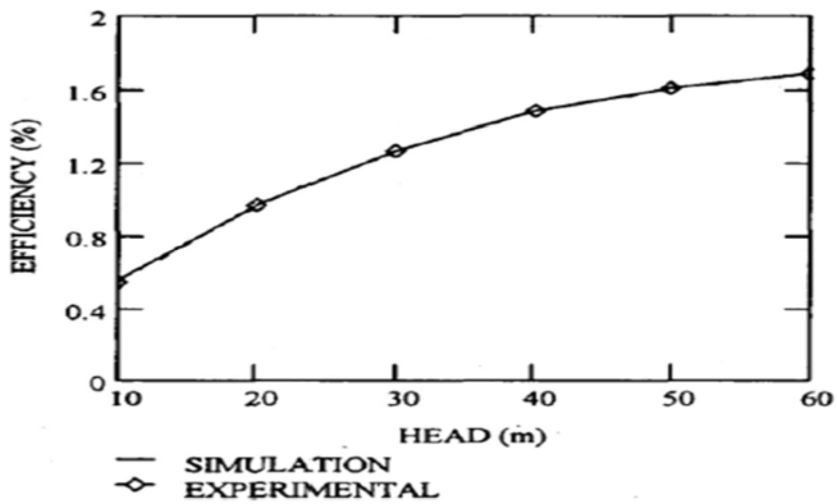

Figure 2.7. Efficiency of the permanent magnet DC motor drive system with maximum MPPT

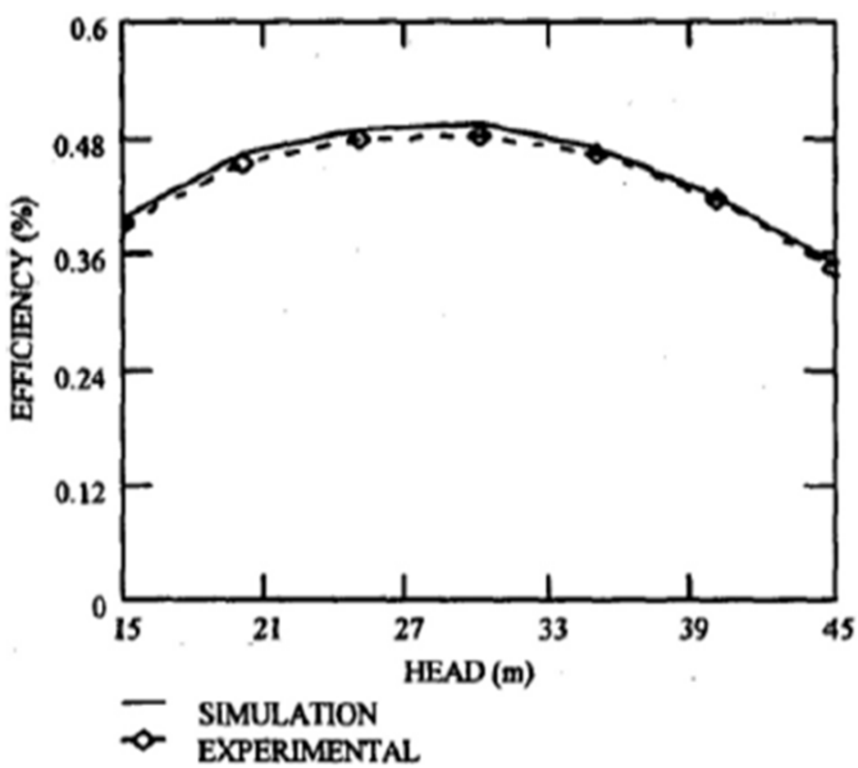

Figure 2.8. Induction motor drive system efficiency with MPPT

In a study the researchers examined the execution of PMDC engine coupled to CP for various cell temperatures and sun-oriented powers. The expansion in short circuit current was marginally with the expansion in the temperature of cell. The PV exhibit open circuit voltage diminished with an increment in cell temperature. Besides, the manual following of PV array expanded the yield of pump by 20% than the settled tilted array (Kolhe et al., 2004)

2.6 SPVWP Performance Evaluation

The execution of seven PV Pumping system under the meteorological states of India were Examined. They utilized 0.102m breadth submersible multistage diffusive pump (CP) driven by three-stage AC engine. The siphoning frameworks were introduced at seven distinct areas in Haryana, Tripura, Northern Rajasthan, Arunachal Prades Maharashtra, Western Rajasthan and Karnataka They announced that the productivity of all the PV pumping system decreased at off-plan head conditions. All the multi organize submersible CPs accomplished most extreme productivity at planned parameters. The normal everyday water yield was adequate to take care of the demand of water of a regular village (Chaurey et al., 1993).

Exploration of the solar driven pumps through examinations, PC displaying for proficiency, execution, a device put and utilized PV array, an MPPT and at three-phase Grundfos CR2-30 CP driven by PM DC motor in Australia . It was observed that the MPPT in the DC pumping system enhanced the sun-powered exhibit estimate and enhanced the system efficiency. Furthermore, for ideal performance, load quality and the PV array size ought to legitimately coordinate (Reshef et al., 1995)

Investigation of the specialized and monetary possibility of solar PV water siphoning framework to meet the water prerequisites for drinking, domesticated animals encouraging and water system reason.SPVWPS was the most plausible answer to meet water necessities thinking about meteorological states of Sudan (Omer et al., 2001)

In a study in Tunisia the researcher performed hypothetical and trial examination on the execution of remain solitary SPVWPS. The framework comprised of a PV generator, DC-DC converter. DC– AC inverter submersible pump, ASM and a capacity tank. The show comprised of the completely recently created model alongside MPPT law and variable. Furthermore, the pumping execution Qualities corrupted with the change in meteorological conditions. The trial examines demonstrated the best execution of the water pump amid midday Also the hypothetical and test results were in great understanding (Hamrouni et al., 2009)

This study is about to propose a basic method to utilize PV pumps produce's realistic apparatuses to ascertain the extreme stream rate from the pump causing little variety in the water level in the bore well. The got outcomes were approved with aftereffects of DASTPVPS programming and producer's realistic tool. It was announced that the aftereffects of the proposed method and that from the product device were in great agreement (Narvarte et al., 2000)

2.7 SPVWP Comparison with Conventional Energy Sources

This research evaluates the feasibility of a photovoltaic power plant for this purpose, the best site for project place is determined by comparing monthly average daily global solar radiation information from eight Pakistani cities and selecting Quetta city for the 10 MW plant. RETScreen power plant simulation demonstrates that if one axis monitoring technique is used, about 23.206 GWh of electricity can be produced in a year. The electricity based on PV is about 30.8 percent more costly than the electricity provided by the grid. Analysis of emissions showed that the suggested PV power plant prevented the production of 17,938 tons / year of carbon dioxide (Khalid et al., 2013)

In this study they attempted a pilot project, "An International program for field testing of Photovoltaic water pumps (PVP Program)", in some Asian and Latin American countries with the introduction of 90 PVPS of 180 kWp at chose locales to give consumable fresh water to the general population and cattle. So the continuous activity of photovoltaic pumps relied upon benefit, what's More, the simple accessibility of extra part (Posorski et al., 1996)

A study was carried out about the techno prudent achievability of SPVWPS in Nepal. They looked at three energy choices, Petro diesel and Jatropha based biodiesel land SPWS in the remote town at Barchen VDC of the Doti area Nepal. The examination was on the financial parameters, In particular, NPV (Net present value), EAC (Equivalent annualized cost**)** and LWC (Levelised cost of water pumping) and are portrayed in Fig. It was accounted for that with minimum subsidizing billing, the LWC per unit litre of pumping water utilizing 100% diesel and half biodiesel. This expense was accounted for far elevated than Solar driven water pumps. In addition, Solar driven water pump system was most alluring and energy efficient (Parajuli et al., 2014).

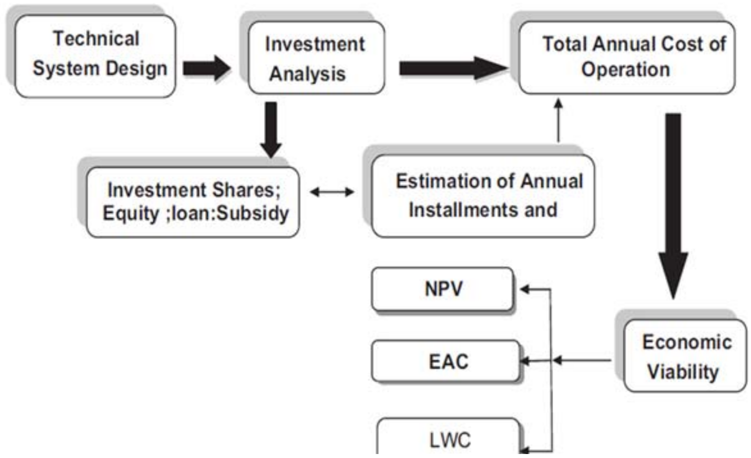

Figure 2.9. Approach for technical and financial analysis of the Solar PV pump

Another study examined the supportability of sun oriented photovoltaic water pumps. It suggested that simply lessening only expense of sun based boards and large scale manufacturing system would note guarantee the manageability of sunlight based PVPS over the long term. It was recommended that broadening the idea of "Suitable Technology" What's more, "village Level Operation and Maintenance (VLOM)". The researchers using these ideas, created distinct structures of a pumpe (Short et al., 2003).

2.8 Solar Radiation and RETScreen Analysis for SPVWP

This work provides the hourly mean solar radiation and standard deviation as inputs for simulating solar radiation over the course of one year. Monte Carlo simulation (MCS) method is used and MATLAB program is created using solar photovoltaic (SPV) to analyze the reliability of tiny isolated power scheme. This work is divided into two components. First, different techniques of solar radiation forecast are contrasted with the technique of hourly mean solar radiation (HMSR). Based on the anticipated electrical power generation, the comparison is carried out with real energy produced by the SPV scheme. Solar photovoltaic energy estimation using the HMSR technique is close to the real energy produced by the SPV scheme (Moharil et al., 2010)

This research concentrated on analyzing solar photovoltaic application for Pakistan's national industry where 6-7-hour blackouts are prevalent. The current research is performed using RETScreen software for six main towns of Pakistan named Karachi, Islamabad, Lahore, Multan, Quetta and Peshawar. These cities ' weather data is imported from NASA's reported RETScreen software database. Modeling research is assessed on the grounds of NPV, IRR, payback periods and decrease of GHG emissions acquired to highlight the feasibility of implementing solar PV leading to Pakistan's green growth. Results indicate that the implementation of a 5kW standalone solar photovoltaic system will l ead to 0.6-0.7 t CO 2 reductions in GHG emissions in various areas of Pakistan under the prevailing climate condition. The installation of solar photovoltaic systems will mainly contribute to the sharing of power loads, leading to an enhanced energy condition and decreased environmental concerns in the nation (Aamir et al., 2014).

RETScreen PV model has been upgraded to cover grid apps. These include systems for stand-alone, hybrid and water pumping. By offering initial estimates of the array, battery, or pump size, the program guides customers in designing their devices. By altering some parameters of the system, customers can rapidly screen the most efficient technology and system size based on the scheme load, weather condition and season of use. This article addresses different models (radiation, array, battery, entire system) used to forecast the output of energy from PV systems, given climate factors and system parameters (Thevenard et al., 2000)

Chapter 3

3 Material and Methods

After thoroughly studying literature related this research, the following steps described in flow chat are included in material and methods.

Figure 3.1. Showing steps followed in this study

3.1 Study Area

The study aims to analyze the assessment of solar photovoltaic water pumping of WASA tube wells for Quetta valley aquifer. This city is located in northern Baluchistan near the Pakistan Afghanistan border with the latitude 30.20 and longitude 67.01 and at the elevation of 1682 meters as shown in figure 3.2. The population of this is approximately 2.27 million people according to the latest census of Pakistan (PBS).

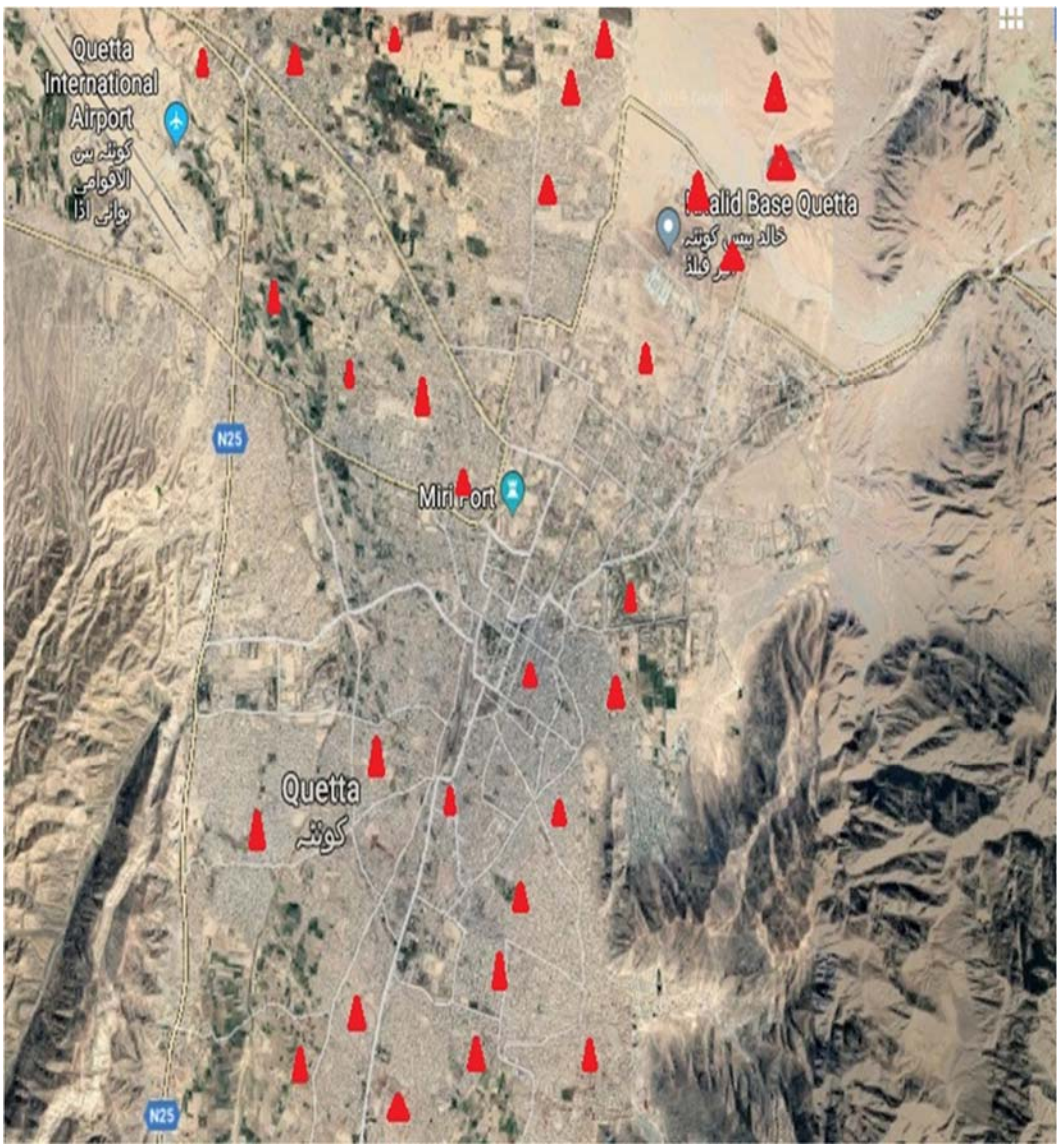

Figure 3.2. Google earth map of Quetta city and selected tube wells

3.2 Reason for Selection of Tube Wells

Quetta city is geologically divided in to two zones (Zarghon & Chiltan). The aquifer of this city mostly consist of alluvial soil and hard rocks, and the aquifer exists in the basin of Pishin. In all thirty-tube wells (fifteen from each zone) as tagged in figure 3.1, has been selected for this study.

3.3 Sampling Procedure of Different Parameter for the Study

The study involved different parameters to be sampled for which separate techniques were employed during sampling. Thirty different tube wells out of 423 tube wells were collected for each parameter as a sample. Data was collected from these sample tube wells. The collected data was compared to previous data of sampled tube wells. Which was provided by WASA (Water and Sanitation Authority) Quetta. The methodology used for each parameter is detailed in below outlines.

3.3.1 Location of tube wells

Finding the coordinates of the related tube wells GPS device mode GPSmap GARMIN 62 is used as shown in the figure 3.3. The Garmin 62s is an update of the GPSMAP the 60CSx, one of the most popular Outdoor GPS units. The unit features a new case design, updated hardware. The updated firmware adds features like the ability to load aerial photography and do paperless geocaching. The unit highlights are: Micro SD slot and substantial internal memory

Figure 3.3. Finding coordinates of selected tube wells in the field using GPSmap

3.3.2 Discharge measurement

The Discharge of the tube well has been measured by using ultrasonic flow meters model SUP-2000H as shown in the figure 3.4. Discharge was measured by placing the censor above and below on the pipe of tube well. The Ultrasonic Flow Meter's Transit Time measuring method requires relatively "clean" fluid to enable the sound waves to complete their circuit. The Ultrasonic Flow Meters may be operated in the Transit-Time mode.

Figure 3.4. Measuring the Discharge of selected tube wells using ultrasonic flow meter

3.3.3 Water table measurements

Water table of the related tube well has been measured using manual and sonic deep meter. Sonic water level meter use sound waves to measure water level in wells, while manual deep meter consists of a long wire attached to censor in the head when the censor hit the water table the alarming sound is produced and the water table is noted from the measurements on the wire. The sonic water level meter is an innovative approach for measuring water level in seconds without the use of down-hole probes or instrumentation, all while avoiding Cross-contamination imperial and metric units. The process is followed in the figure 3.5 & 3.6.

Figure 3.5. Water table measurement by manual deep meter

Figure 3.6. Water table measurement by sonic deep meter

3.3.4 Billing & energy consumption

The billing of the concerned tube well has been collected from the WASA Quetta to analyzed the energy consumption of the tube wells. The average of four bills from different tube wells like marriabad, gol masjid, nawa killi, chasma achozai have been chosen for analysis. Table 1 indicates the average monthly electricity consumption of these four tube wells.

Table 1. Average monthly electricity consumption of 4 tube well

Month	KWH units	Bill
Jan	19320	239124
Feb	19950	257496
March	17360	225706
April	18240	477545
May	15200	289342
June	15720	280769
July	14050	255308
August	18960	603296
September	16240	283701
October	14720	597234
November	16840	661389
December	15200	966765

3.4 RETScreen Software for Renewable Energy Analysis

The RETScreen software was introduced By Natural Resources Institute Canada in 2009. RETScreen International clean energy project analysis software is a method used by government, industry, and academia experts to support the decision to invest in renewable energy globally. This helps to determine production and power efficiency, costs, emission reductions, financial viability and risk of different types of Renewable Energy Technologies (RETs) and Energy Efficiency.

The RETScreen approach provides five steps in an organized and consistent way for proper economic feasibility assessment of alternative investment in renewable energy projects. The analytical measures are described below:

1. Step 1 — Energy Model: In the initial phase of the study, parameters are specified according to the specific location of the project, such as system type, proposed case technology (to be considered), charges (if applicable) and renewable energy sources. Determine the annual energy output or energy savings of RETScreen in response to the inputs.
2. Step 2 — Cost Analysis: planning the composition of annual and periodic costs for the proposed system and credits received from the renewable energy project with the interpretation of the energy model in the first step of the project.
3. Stage 3 — Assessment of greenhouse gas emissions (optional): here are some estimated GHG reductions due to the use of renewable technology.
4. Step 4 — Financial Summary: Specify financial criteria in this step related to energy costs, production credits, GHG reduction credits, tax incentives, inflation rate, discount rate, debt level and taxes. The main financial metrics (e.g. NPV, IRR, and SPB, among others) are calculated from the financial criteria to assess the project's feasibility. The financial review also includes a chart of net cash flow.
5. Step 5 — Sensitivity & Risk Analysis (optional): In this final step, we are evaluating many variables of financial estimation uncertainty that may affect the project's financial viability.

3.4.1 Solar data (RETScreen)

The solar-related data multiyear solar radiation and peak hours, feasibility and cost:benefit analysis has been taken from the RETScreen database shown in table 2. The peak sunshine hours in the area are 2021 h/years, and the average annual radiation is about 7275 MJ/m^2, which is rich in solar energy resources

Table 2. **Solar radiations received in Quetta valley**

Month	Solar radiation（kWh/m^2/d）	Surface temperature（°C）
1	3.42	6.45
2	4.25	9.17
3	4.78	15.61
4	6.25	23.63
5	7.03	29.51
6	7.75	33.75
7	7.00	34.04
8	6.64	32.11
9	6.42	28.90
10	5.42	21.46
11	4.11	14.51
12	3.33	8.73

3.4.2 **Solar photovoltaic design and efficiency** analysis

The solar photovoltaic analysis has been carried out on RETscreen. RETscreen is a software used for viability, cost-benefit analysis of solar-based projects, developed by Natural Resources Canada. It is available in more than 35 languages, and data have been obtained from 6700 database all around the world and NASA. The figure 3.7, below is the database of Quetta.

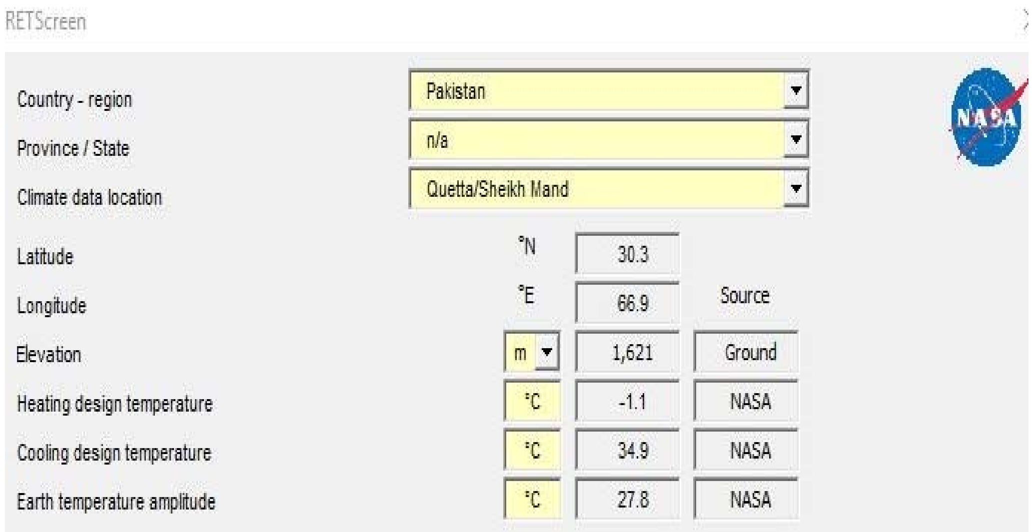

Figure 3.7. RETScreen database for Quetta valley

3.4.3 Benefit Cost (B:C) Ratio

The equation measures the net benefit-cost ratio (B:C), which is the ratio of the project's net benefit to price. Net benefits reflect the present value of annual income (or savings) with lower annual costs, while the expense is known as project equity. Profitable ventures are representative of ratios greater than 1. Compared to the productivity index, the net benefit-cost (B:C) ratio results in the same conclusion as the net present value measure.

$$\mathbf{BCR} = \frac{\mathbf{PV\ benefits}}{\mathbf{PV\ cost}}$$

Where:

$PV_{benefits}$ = present value of benefits

PV_{cost} = present value of cost

Chapter 4

4.1 Results and Discussion

Result and discussion of this study was based on the data collected from selected WASA Quetta tube wells. WASA fulfills approximately sixty percent of Quetta city water demand. For this purpose four hundred twenty three (423) tube well has been installed in two groundwater aquifer zones of the city limits. Based on previously explained methodology we want to asses different factors of these tube wells by selecting the sample tube wells in this area and apply model for selection of suitable solar system for water pumping.

4.2 Selected Area of Tube Wells Location

In order to calculate water pumpage, energy bills, quantify pump, and power requirements, thirty tube wells out of 423 were identified in Quetta city. Figure 4.1 shows the selected tube wells from different parts of the town as a sample to assess the variation in discharge, the annual decline in groundwater, and the supply and demand gap in order to propose converting the selected tube wells on to solar power (SPVWP).

Figure 4.1. GPS location of thirty selected tube wells in the study area

4.3 Geological Distribution of Quetta Valley

Quetta is geologically divided in two zones.

1 Zarghon **2 Chiltan**

4.3.1 Zarghoon zone

Zarghoon zone of Quetta valley is the southern side of the city, which consists of following areas like Pashtoonabad, Marriabad, Satellite town, Yousaf housing, Truck adda, Barech abad, Sabzal road, barech colony, k qambrani, imdad cinema, gol masjid shahbaz town and sabzal road.

4.3.2 Chiltan zone

Chiltan zone of Quetta valley is the northern side of the city, which consist of following areas like Nawa killi, Killi Shabak, Sra khula, Killi nasaran, Chasma achozai, Chiltan housing, Killi ibrhami, Al hadid school, Killi barat, Killi bazai, Kuchlak, Shabo and A.K road tube wells.

4.3.3 Lithology

The lithology of Quetta valley consists of two formations, hard rocks, and alluvial soil. Most of the city area has been Covered By alluvial aquifer, as shown in figure 4.2, and somehow the mountainside formation is hard rocks. The first layer of the alluvial aquifer is consists of gravel and Sand up to 130 m. The second layer start from 130 m to 140 m and its pure clay similarly. The third layer of the alluvial aquifer is Sand Gravel starts from the depth 140 m to 180 m, while the fourth formation of this aquifer is clay, which starts from the depth 180 m to 230 m. Similarly, the depth of structure from 220 m to 230 m is sand silt, and from 230 m, 240 m is clay.

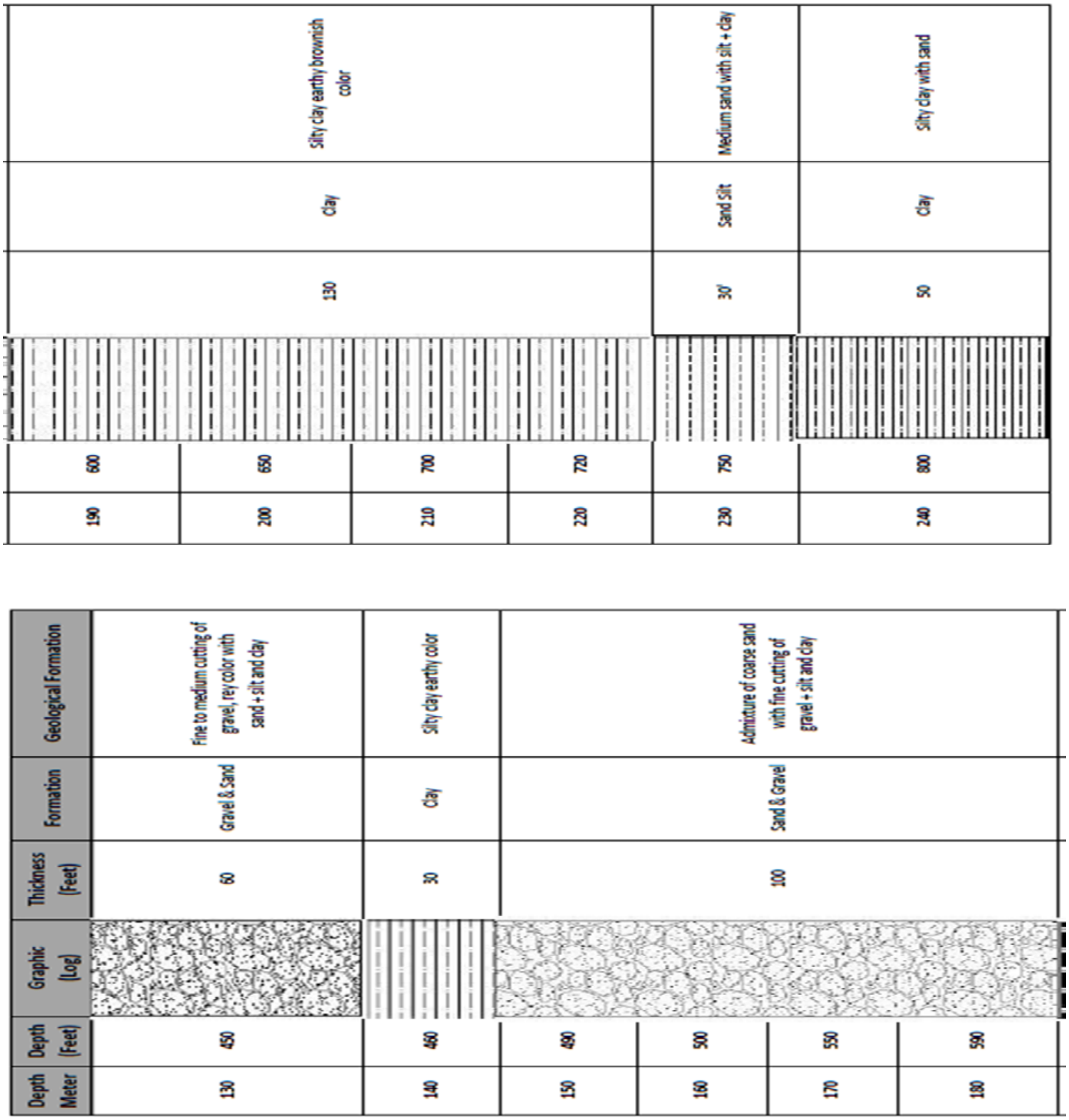

Figure 4.2. Aquifer lithology presenting in Quetta valley

4.4 Climate

Precipitation and temperature data have been collected from Pakistan meteorological department (PMD) for the last 20 years, as shown in figure 4.3, which shows that the average rainfall of Quetta city is 240 mm indicates the weather of this city is semi-arid. The average maximum temperature is recorded at 30 °C, and the average minimum temperature is 7 °C. Figure 4.3 shows the average annual rainfall recorded in the city in the previous two decades. While Fig 4.4, Describes the maximum and minimum yearly temperature from 1999 – 2018.

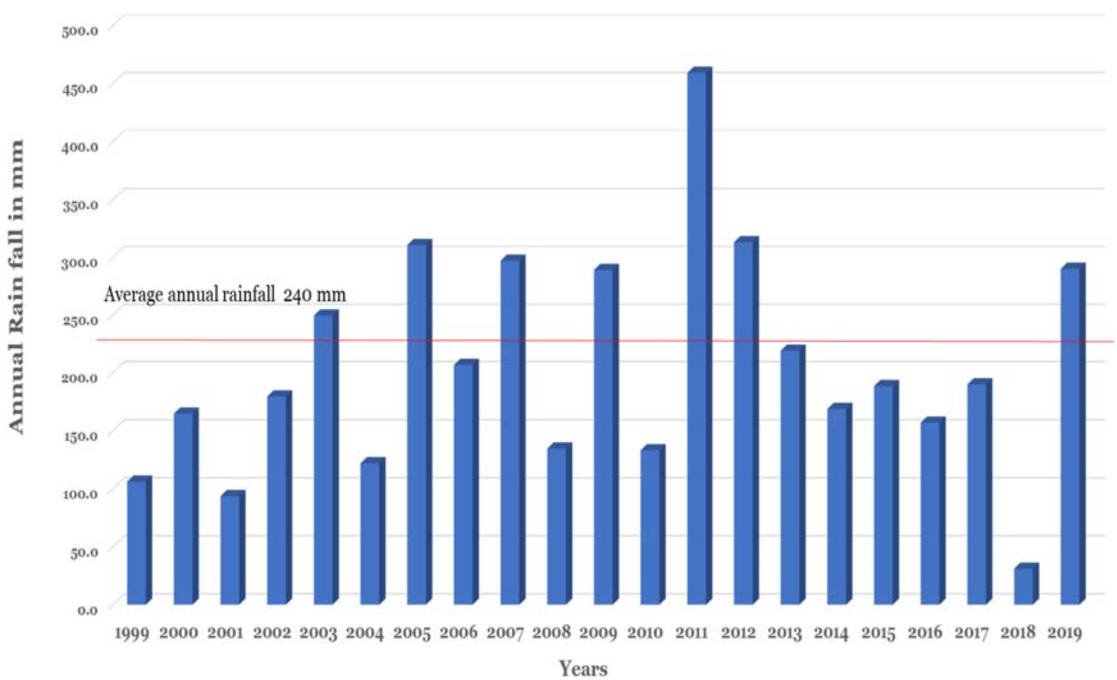

Figure 4.3. Mean annual rainfall data collected by PMD in Quetta valley for last 20 years

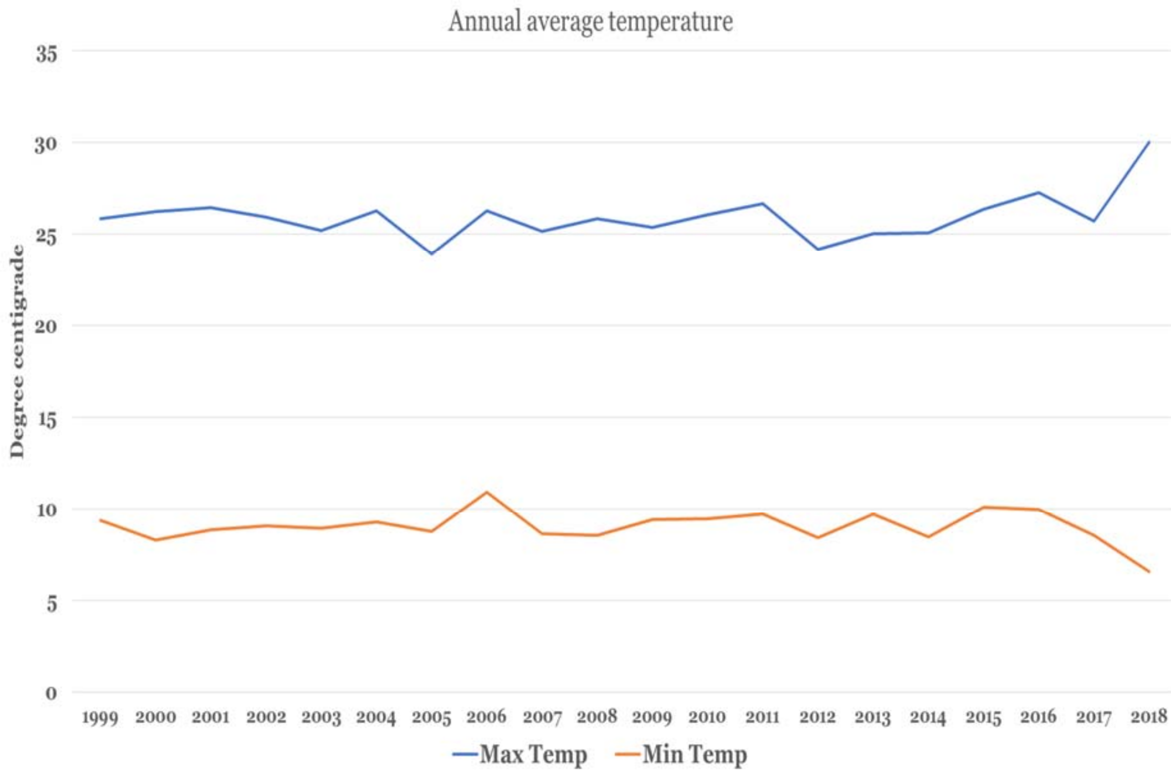

Figure 4.4. Annual average temperature data of 20 years

4.5 Installation of Tube Wells in Last Two Decades

The growing urbanization of Quetta city and the gain in several housing schemes in Quetta leads the demand for water to its peak. A significant increase was observed in the installation of government and private tube wells to meet this demand, The total number of tube wells installed in the last two decades by WASA is 277 in Quetta valley to meet the consumer demand And every day need of the city water. The total number of tube wells installed yearly in the city in the last 20 years is shown in figure 4.5.

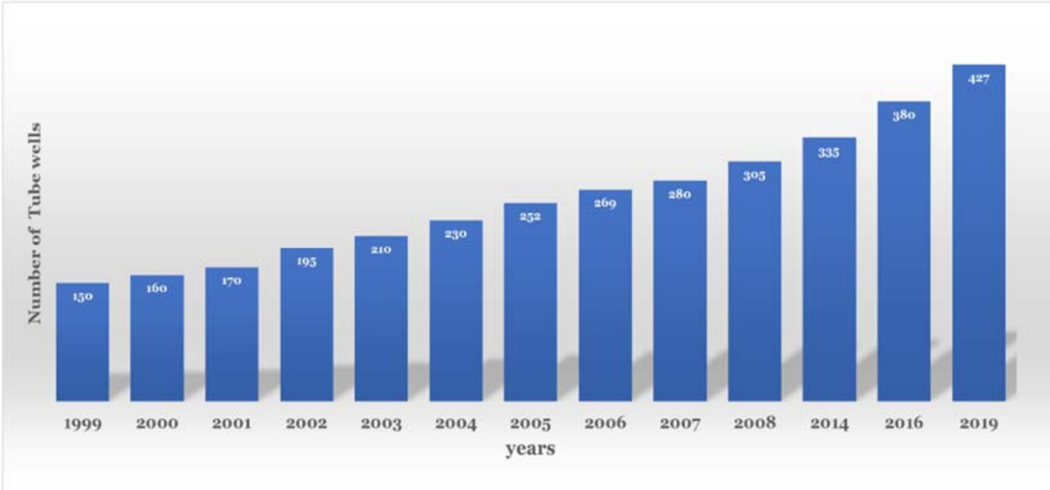

Figure 4.5. Tube wells installed from 1999 to 2019 by WASA

4.5.1 Total discharge by WASA Quetta

Quetta's demand for water has increased because of population growth. Water is currently being supplied to the city by tube-wells collecting fossil water. Total water extracted from the ground by WASA is approximately 21 million gallons/day, where 423 tube wells are in Operation. While figure 4.6 shows the discharge of water from the field in the last two decades by WASA.

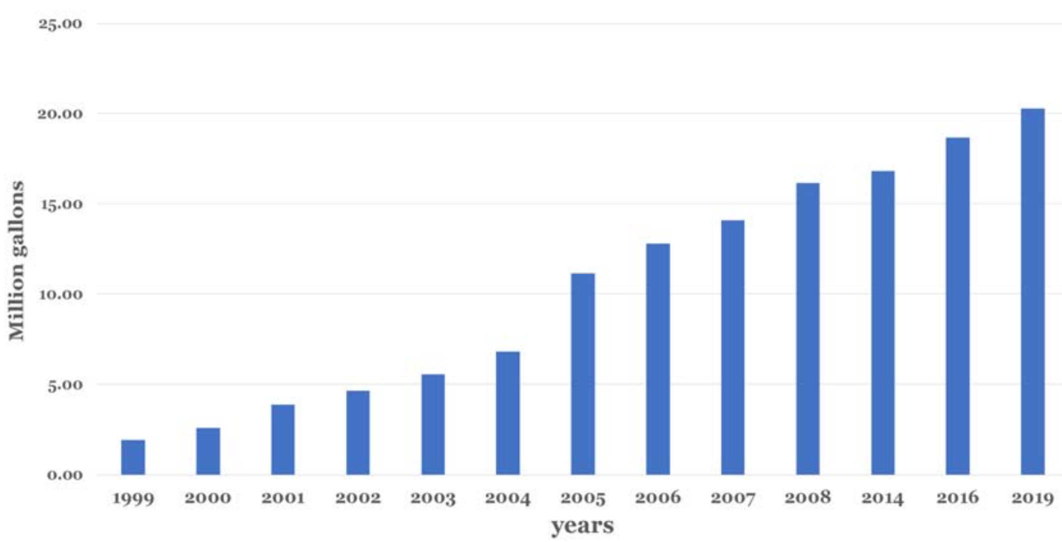

Figure 4.6. Total discharge of WASA tube wells for the period of 1999 – 2019

4.5.2 Variation in population and water demand

According to the census of 1998, the reported population of District Quetta was 760 thousand, and the designated annual Growth rate was calculated to be 4.13%. By applying the annual growth rate (4.13%) to the 1998 census, the projected population in 2010 is estimated to 1,235 thousand, which is an increase of 62.5%. According to the latest poll by the Pakistan Bureau of statistics in 2017, the Population of Quetta city was 2275 thousand. The figure, 4.7 and 4.8 show the graph of population growth and variation coming in Demand supply and Deficit from 1998 – 2017.

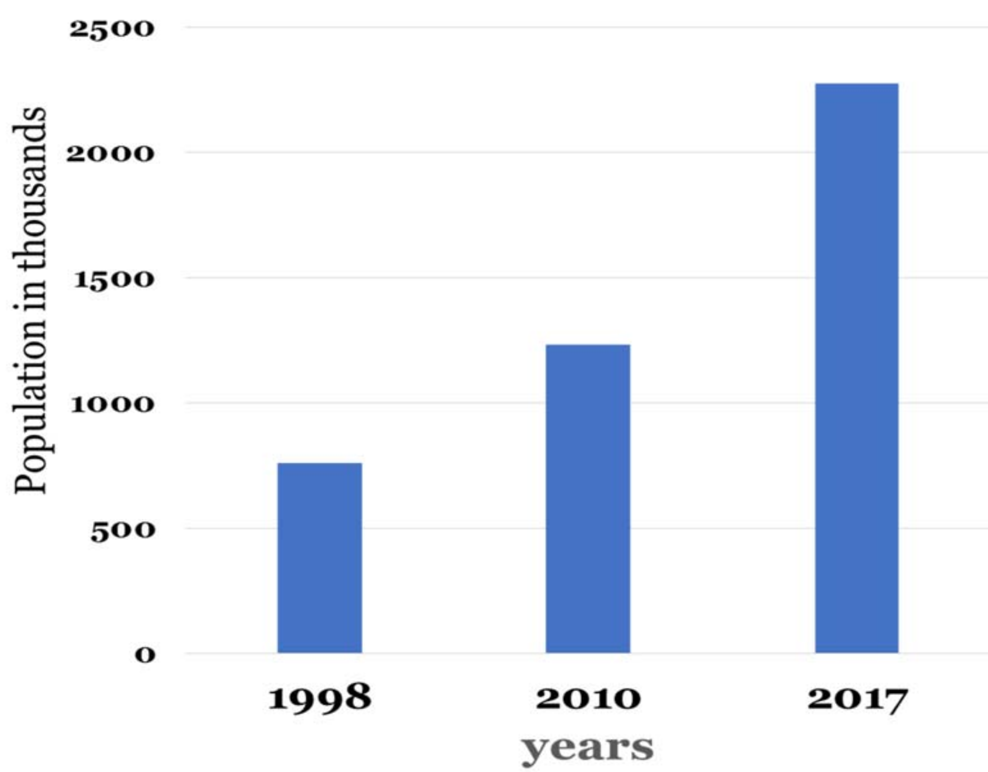

Figure 4.7. Population growth of Quetta city during 1998 - 2017

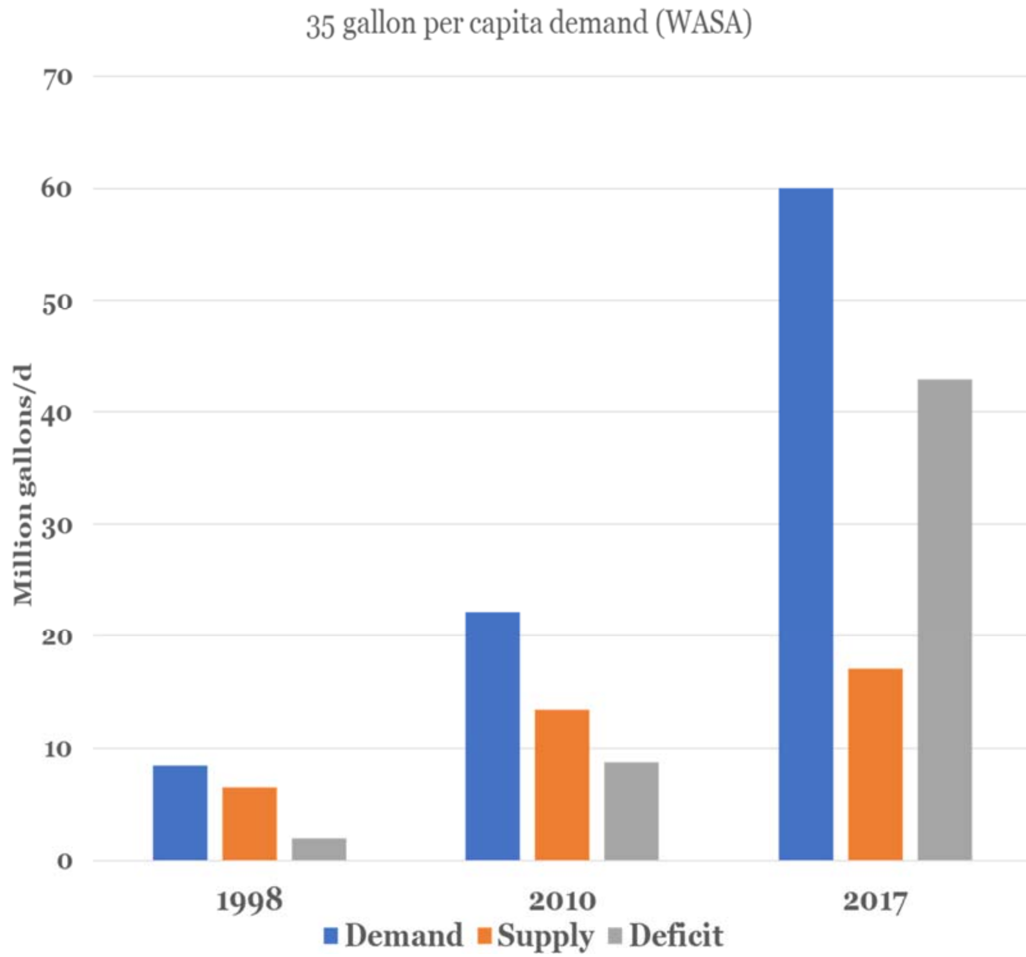

Figure 4.8. Demand of water supply and deficit by WASA

4.6 Zarghoon Zone

Zarghoon zone of Quetta valley is the southern side of the city, which consists of following areas like Pashtoonabad, Marriabad, Satellite town, Yousaf housing, Truck adda, Barech abad, Sabzal road, barech colony, k qambrani, imdad cinema, gol masjid shahbaz town and sabzal road tube wells as shown in table 3. These tube wells have been selected in this zone to study the variation coming in discharge and water table.

Table 3. Tube wells discharge and water table data for zarghoon zone

S.NO	Name of T/W	Date of Installation	Present Discharge GPM (US)	Initial Discharge GPM (US)	Depth of W/T present (M)	Depth of W/T recorded (M)	Total decline (M)
1	P ABAD	1987		240	159	41	118
2	Y HOUSING	2001	60	75	145	89	56
3	B COLONY	2001	132	150	135	57	78
4	M ABBAD	2002	140	167	126	61	65
5	K QAMBRANI	2003	138	145	98	49	49
6	I CINEMA	2004	75	90	111	64	47
7	G MASJID	2006	93	109	159	87	72
8	S TOWN	2006	74	92	121	87	34
9	D FARM CNT	2006	193	205	110	56	54
10	T ADDA	2006	92	102	141	79	62
11	SH TOWN	2007	79	95	81	53	28
12	MARRIABAD	2007	60	65	125	64	61
13	BA ABAD	2007	76	84	109	83	26
14	SABZI MANDI	2010	231	250	128	70	58
15	S ROAD	2015	30	33	140	97	43

4.6.1 Discharge reduction in Zarghoon zone

It has been observed that discharge of zone 1 is reduced 4 – 20 % in the following areas, as shown in figure 4.9. The maximum discharge reduction of twenty percent has been observed in Yousaf housing scheme, while the minimum discharge reduction of four percent was observed at killi Qambrani. Similarly the discharge of satellite town and Marri abad was reduced nineteen and sixteen percent respectively.

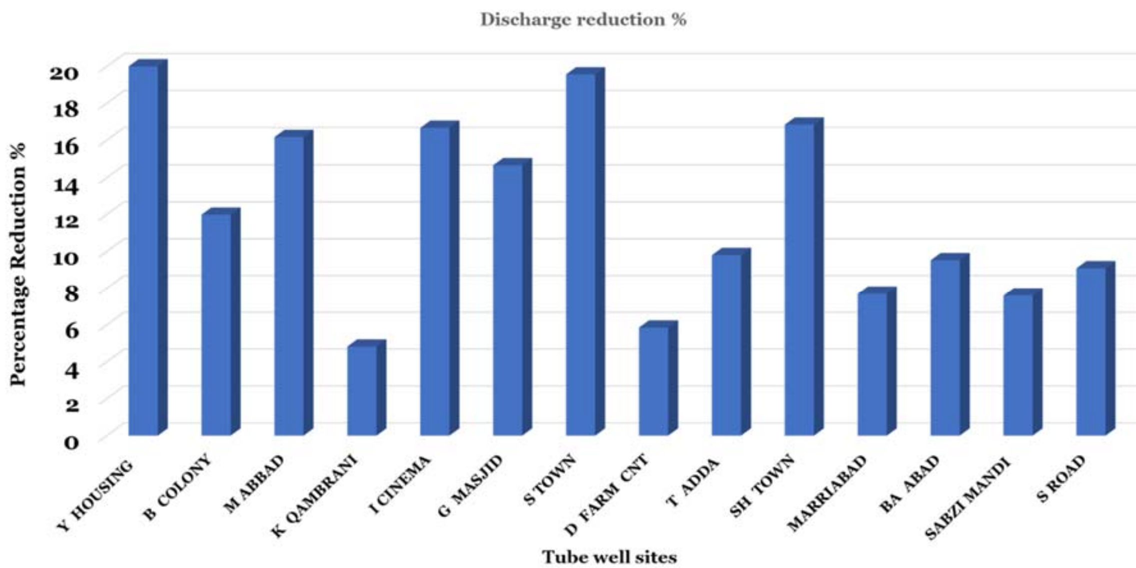

Figure 4.9. Discharge reduction in zone 1 (Zarghoon)

4.6.2 Variation in water table

Variation coming in the water table has been observed at various points in zone 1, as shown in figure 4.10. Water table declination rates have been recorded from their date of installation.

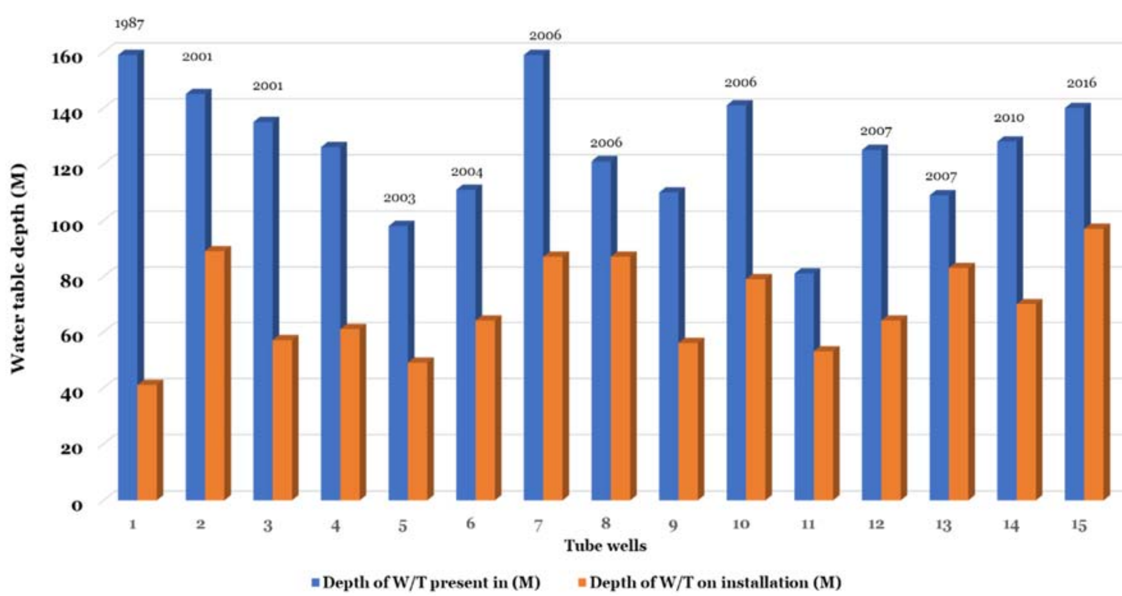

Figure 4.10. Variation in the water table observed in zone 1 during 2018 since its installation

4.6.3 Total declination in the water table

The declination rate was observed 2 – 8 m/year in various sampling points of zone 1. Figure 4.11 shows the Total declination in meter from 2000 – 2019, in these areas. The declination was higher at sabzal road tube well with a rate of 8 m/year, which is the southwest part of the city. Similarly, the declination was lower at barech abad with a rate of 2m/year, which is the southeast part of the Quetta city.

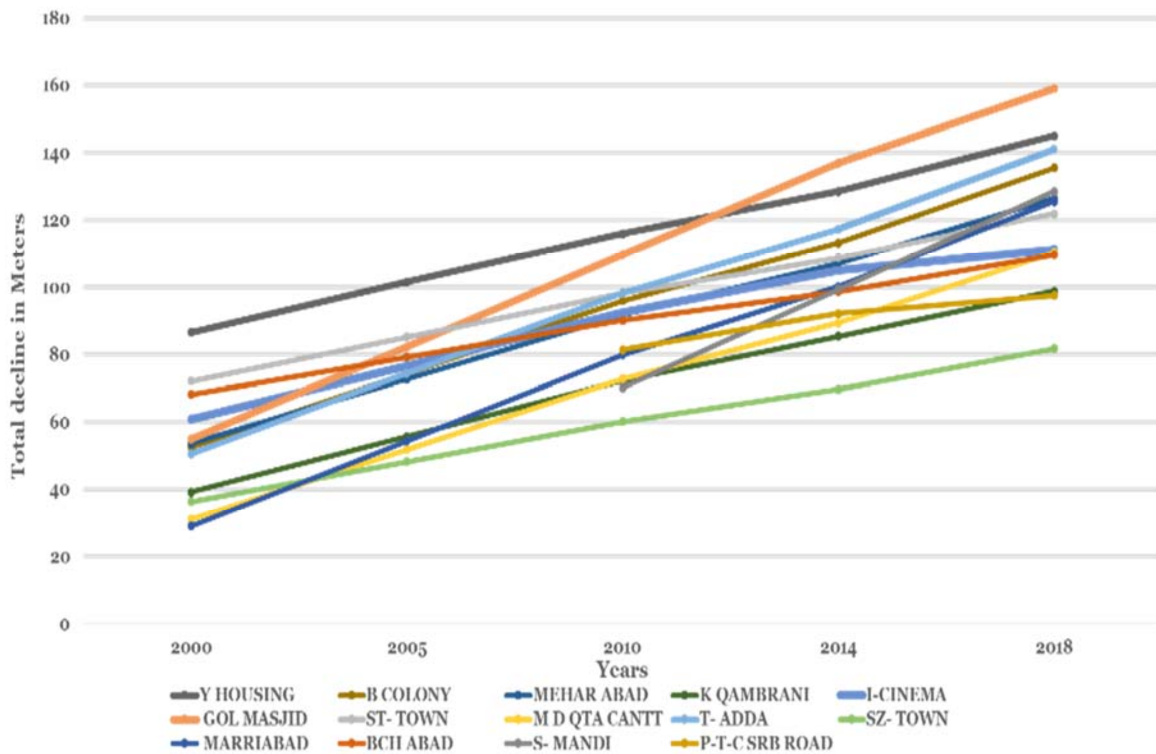

Figure 4.11. Total declination in water table from 2000–2018 in sampling points of zone 1

4.7 Chiltan Zone

Chiltan zone of Quetta valley is the northern side of the city, which consist of following areas like Nawa killi, Killi Shabak, Sra khula, Killi nasaran, Chasma achozai, Chiltan housing, Killi ibrhami, Al hadid school, Killi barat, Killi bazai, Kuchlak, Shabo and A.K road tube wells as shown in table 4. These tube wells have been selected in this zone to study the variation coming in discharge and water table.

Table 3. Tube wells discharge and water table data for Chiltan zone

S.NO	Name of T/W	Date of Installation	Present Discharge GPM (US)	Initial Discharge GPM (US)	Depth of W/T present (M)	Depth of W/T recorded (M)	Total decline (M)
1	N KILLI	1999	24	30	128	81	47
2	C- ACHOZAI	2000	61	73	104	51	53
3	SAMUNGLI	2001	112	120	51	28	23
4	K- NASARAN	2003	92	110	140	102	38
5	K- IBRAHIM	2003	78	85	144	100	44
6	AL HADID s	2003	94	98	80	59	21
7	C- HOUSING	2003	110	120	50	36	14
8	C- ACHOZAI	2003	102	109	134	100	34
9	K- BARAT	2004	82	100	86	48	38
10	K-BAZAI	2005	102	115	92	73	19
11	KUCHLACK	2007	20	25	135	100	35
12	SHABO	2008	78	89	103	80	23
13	A K ROAD	2013	38	40	91	60	31
14	K- SHABAK	2013	98	108	158	131	27
15	SRA KHULA	2016	100	108	304	292	12

4.7.2 Discharge reduction in Chiltan zone

It has been observed that discharge of zone 2 (Chiltan) is reduced 4 – 19 % in the following areas as shown in figure 4.12. The maximum discharge reduction of nineteen percent has been observed in nawa killi, while the minimum discharge reduction of four percent was observed at al hadid army public school Quetta cantt. Similarly, the discharge of kuchlagh and killi barat was reduced eighteen percent respectively.

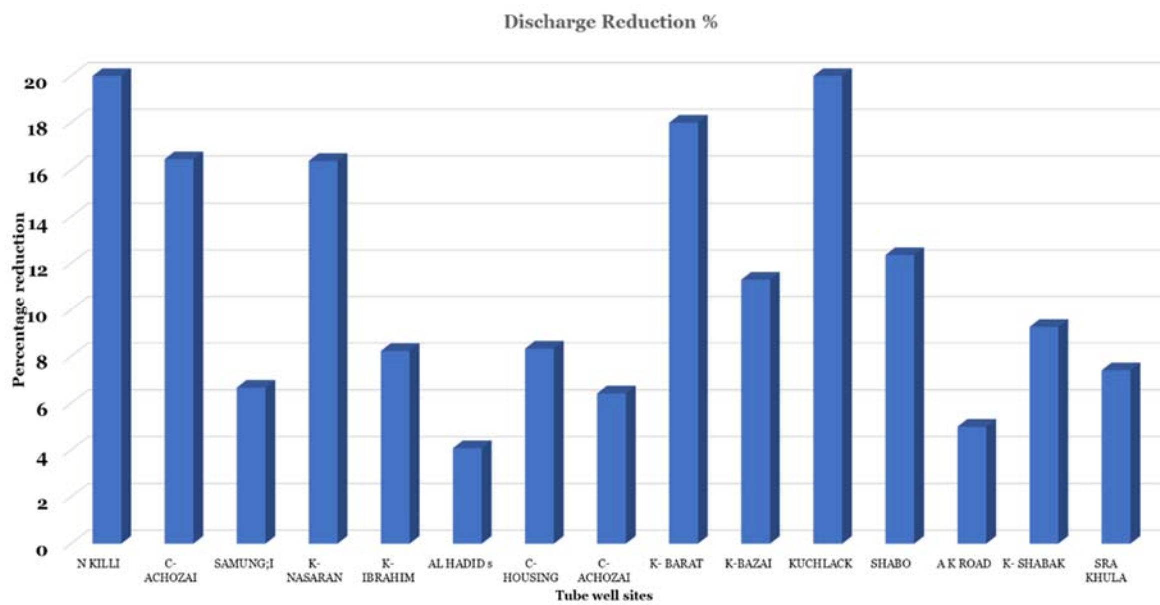

Figure 4.12. Discharge reduction in zone 2 (Chiltan)

4.7.3 Variation in water table

Variation coming in the water table has been observed at various points in zone 2, as shown in figure 4.13. Water table declination rates have been recorded from their date of installation.

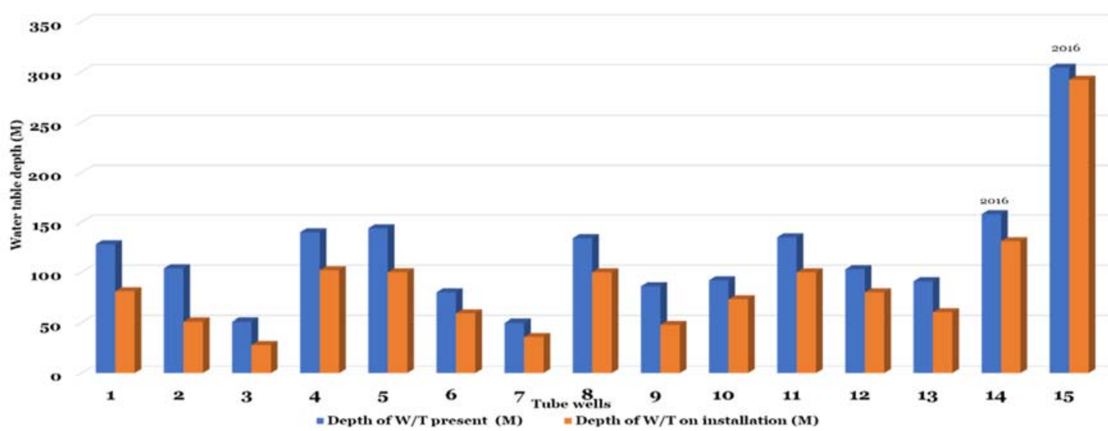

Figure 4.13. Variation in the water table observed in zone 2 during 2018 since its installation

4.7.4 Total declination in water table

The declination rate was observed 1.5 – 5 m/year in various sampling points of zone 2. Figure 4.14 shows the Total declination in meter from 2000 – 2019, in these areas. The declination was higher at Arbab Karam khan road tube well with a rate of 5 m/year, which is the western part of the city. Similarly the declination was lower at al hadid army public school and samugnli with a rate of 1.5 m/year .

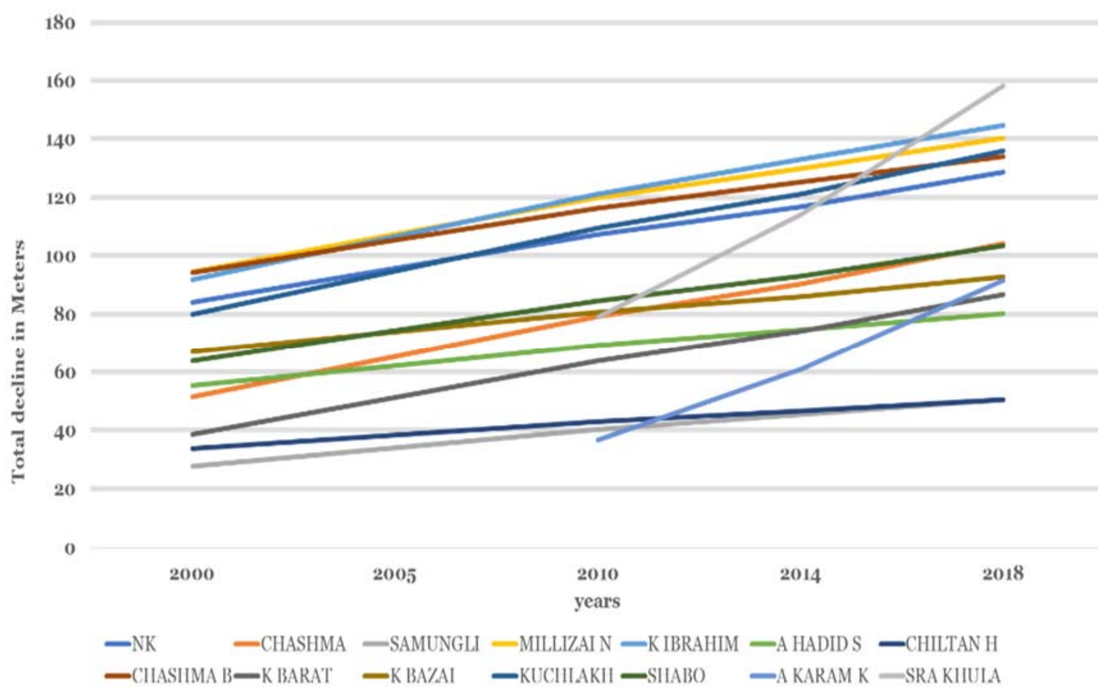

Figure 4.14 Total declination in water table from 2000–2018 in sampling points of zone 2

4.8 Energy Consumption and Bill Analysis

The average monthly energy consumption of WASA tube wells collected during January to December 2018 shown in table 3.1 (chapter 3) has been analyzed to find the price of per kilowatt-hour energy, as following:

Average units of energy consumed by 4 tube wells/month = **17360 KWH**

Average monthly bill = **225706 Rs**

Per kilo watt Rs = 225706/17360 = **13**

Average Dicharge = 60 GPM

Total discharge for the month = 60*60*9*30 = **972000 G/month**

Per unit discharge = 972000/17360 = 55 **G/KWH**

4.9 Pump Selection and Motor Power Capacity

The pump has been selected from the company name Lorentz. Pumps model and their motor power capacity is shown in table 5.

Table 4. Pumps model and motor power capacity

SR NO.	PUMP MODEL	POWER RATING		LPM	240	360	480	600	720	840	960
				LPS	4	6	8	10	12	14	16
		HP	KW	M³/Hr	14	22	29	36	43	50	58
1	KS80-0602	7.5	5.5	HEAD IN METERS	34	31	26	23	21	14	9
2	KS8E-1003	10	7.5		58	55	51	45	35	25	10
3	KS8E-1504	15	11		77	73	67	60	47	33	13
4	KS8E-1806	17.5	13		97	92	84	75	58	41	17
5	KS8E-2507	25	18.5		135	128	118	106	82	57	23
6	KS8E-4012	40	30		232	220	202	180	140	98	40

4.10 Electricity Rate Analysis

Electricity rate analysis has been defined by the power consumption of the motor and total operation hours in a day, as shown in table 6. The electricity rate, base case was set up to 14 (PKR) per KWh, and the operation time is 8 hours.

Table 5. Electricity rate, base case analysis for different loads

Specifications		Load (KW)				
		5.5	**11**	**15**	**18.5**	**30**
Energy Consumption	**Electricity Rate, Base Case (14PKR/kWh)(Annual)**	224840	449680	613200	756280	1226400
	Electricity Daily Consupmtion (kWh)(8hr)	44	88	120	148	240
	Electricity Annual Consumption (MWh)	16.06	32.12	43.8	54.02	87.6
	Inverter Capacity (kW)	8	15	21	25	37
	Inverter Efficiency	98%	98%	98%	98%	98%
	Load (in hp)	7.37561	14.751	20.1153	24.8089	40.2306

4.11 Selection of Photovoltaic Module

Modules have been selected from Yingli solar company due to their better efficiency and reliability. The total number of modules required and areas covered by these modules are defined in Table 7

Table 6. Total number of modules required and solar panel selection

Specifications		Load (kW)				
		5.5	**11**	**15**	**18.5**	**30**
Photovoltaic Modules	**Type**	Mono-si				
	Power capacity(DC System kW)	9.54	19.08	25.97	32.2	52
	Manufacturer	Yingli Solar				
	Model (1 Panel =265W)	Panda-YL265C-30b				
	Efficiency	16.20%				
	Nominal operating cell temperature	45				
	Temperature coefficient (%)	0.40%				
	Solar collector area (m2)	58.8	122.1	160.1	196.1	317
	Units (Total Solar Pannels)	36	74	98	120	194
	Net Annual GHG Emission Reduction (tCO2)	3	6	8.2	10.1	16.3

4.12 Cost-Benefit Analysis

Cost-benefit analysis for different pumps, as shown in Table 4.6, has been found by RETScreen software. The cost of the pumps and inverter was taken from the solar photovoltaic company name Lorentz, while the development cost, Labor cost, and miscellaneous expenses have been taken from the local consultants and contractors in the area.

Table 7. Cost: benefit analysis

Specifications		Load (kW)				
		5.5	**11**	**15**	**18.5**	**30**
Cost Analysis	**Development (PKR)**	200000				
	Well Pump (PKR)	100000	120000	130000	140000	150000
	Inverter (PKR)	48000	64000	72000	99200	120000
	Collector Support And Installation (PKR)	5986	9335	11737	13777	20641
	Labor Cost (PKR)	50000				
	Miscellaneous (PKR)	100000				
Financial	**Inflation rate**	9%				
	Discount rate	7.50%				
	Project Life	25				
	Total Initial Cost (PKR)	1,093,935	1,701,519	2,003,910	2,449,279	3,545,902
Financial Viability	**Simple Payback (years)**	5.1	3.6	3.6	3.6	3.2
	Equity Payback (years)	5.2	3.6	3.6	3.7	3.2
	NPV (Net Present Value) (PKR)	1,149,784	4,291,810	3,953,249	3,728,784	69,981,325
	Annual Life Cycle Savings (PKR)	98,664	368,282	339,230	319,784	599,071
	Benefit-Cost Ratio	2.05	3.52	2.92	2.52	2.97
	GHG Reduction Cost (PKR)	32,957	61509	41548	31775	36686

4.13 Loads, PV Units and Cost-Benefit Ratio

Total loads PV units and cost-benefit ratio for the different pump capacity like 5.5 KW, 11KW, 15 KW, 18.5 KW, and 30 KW is described in table 4.7.

Table 8. PV units, initial cost, and cost-benefit ratio for different combination

Load (KW)	Photovoltaics (Units)	PV Power Capacity (KW)	Total Initial Cost (PKR)	Cost Benefit Ratio
5.5	36	9.54	1,093,935	2.05
11	72	19.08	1,701,519	3.52
15	98	25.97	2,003,910	2.92
18.5	120	31.8	2,449,279	2.52
30	194	51.41	3,545,902	2.97

4.14 Cash flow analysis for

4.14.1 Case of 5.5 KW

The cumulative cash flow graph for 5.5 KW has shown in figure 35, in which payback time is five years with a cost:benefit ratio of 2.05. The inflation rate is applied 9 percent and the discount rate is 7.5 percent.

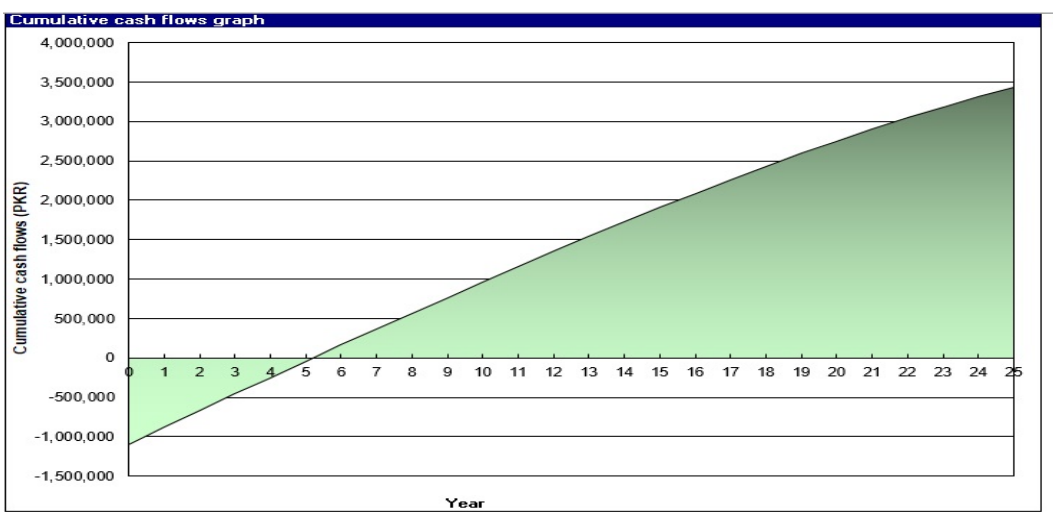

Figure 4.15. Cumulative cash flow graph 5.5 KW

4.14.2 Case of 11 KW

The cumulative cash flow graph for 11KW has shown in figure 36, in which payback time is 3.5 years, with a cost:benefit ratio of 3.52. . The inflation rate is applied 9 percent and the discount rate is 7.5 percent.

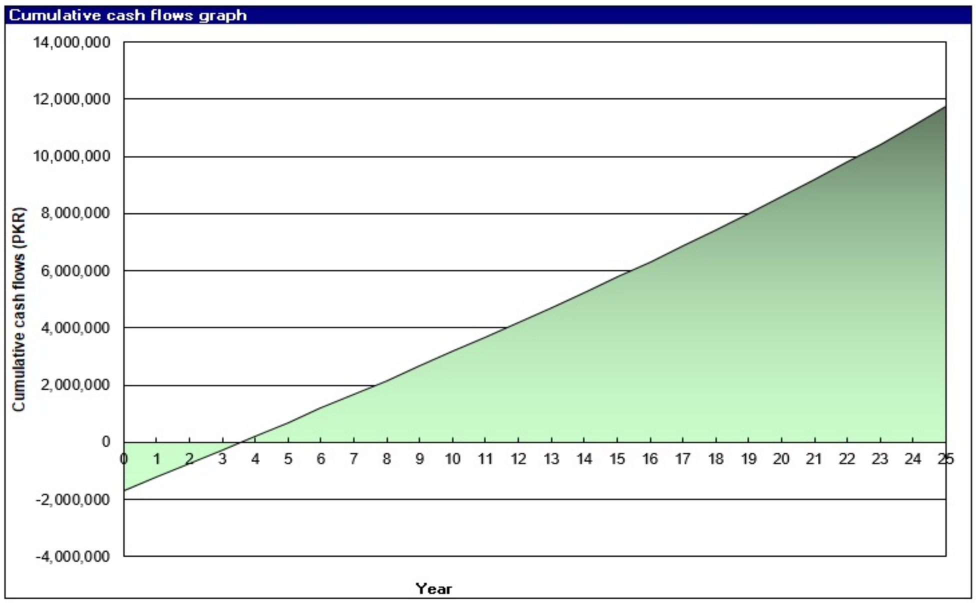

Figure 4.16 Cumulative cash flow graph 11 KW

4.14.3 Case of 15 KW

The cumulative cash flow graph for 15 KW has shown in figure 36, in which payback time is 3.5 years with a cost:benefit ratio of 2.92. . The inflation rate is applied 9 percent and the discount rate is 7.5 percent.

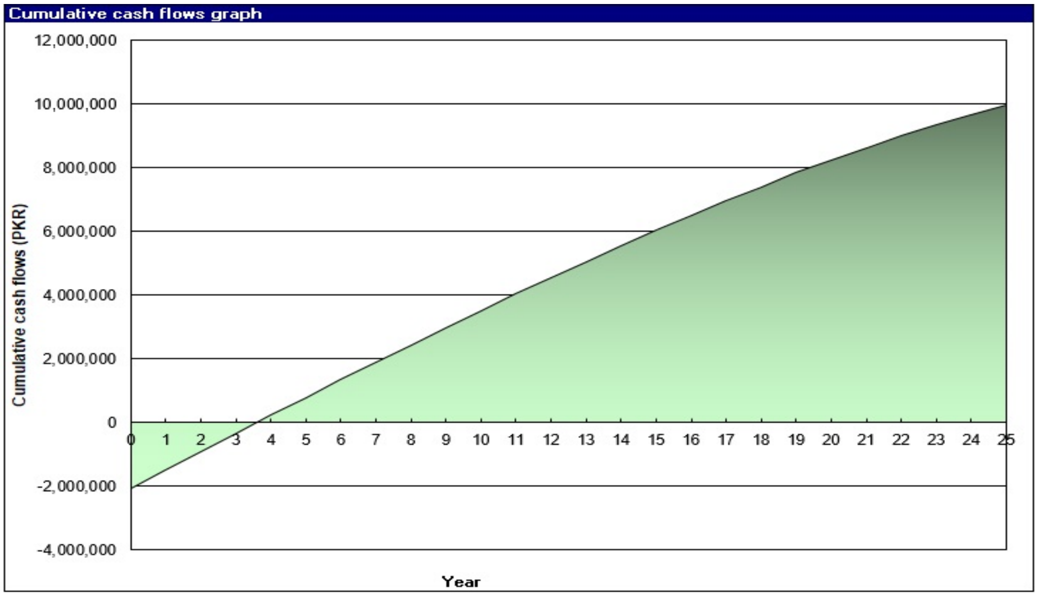

Figure 4.17. Cumulative cash flow graph 15 KW

4.14.4 Case of 18.5 KW

The cumulative cash flow graph for 18.5 KW has shown in figure 36, in which payback time is four years with a cost-benefit ratio of 2.52. The inflation rate is applied 9 percent and the discount rate is 7.5 percent.

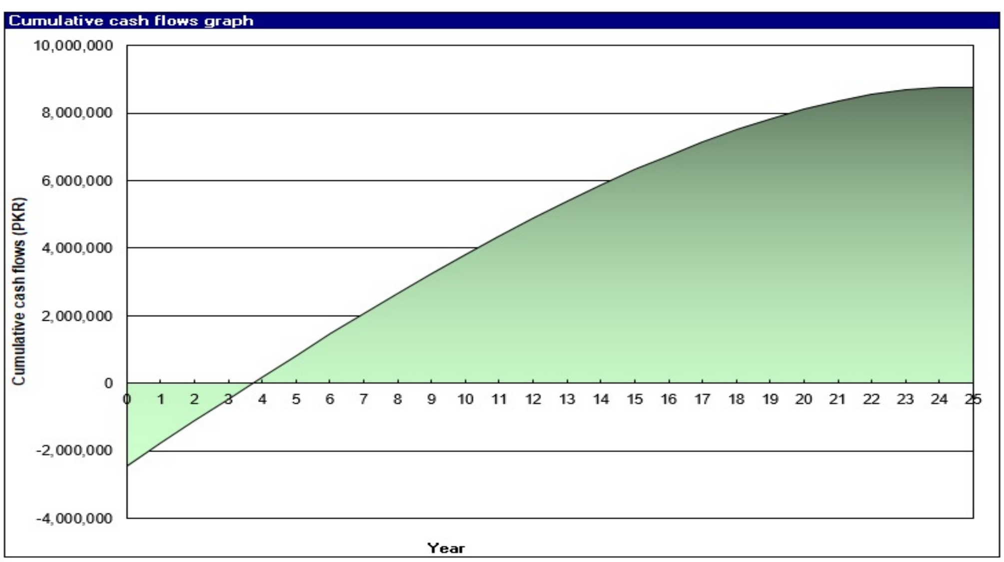

Figure 4.18. Cumulative cash flow graph 18.5 KW

4.14.5 Case of 30 KW

The cumulative cash flow graph for 30 KW has shown in figure 36, in which payback time is three years with a cost:benefit ratio of 2.97.The inflation rate is applied 9 percent and the discount rate is 7.5 percent.

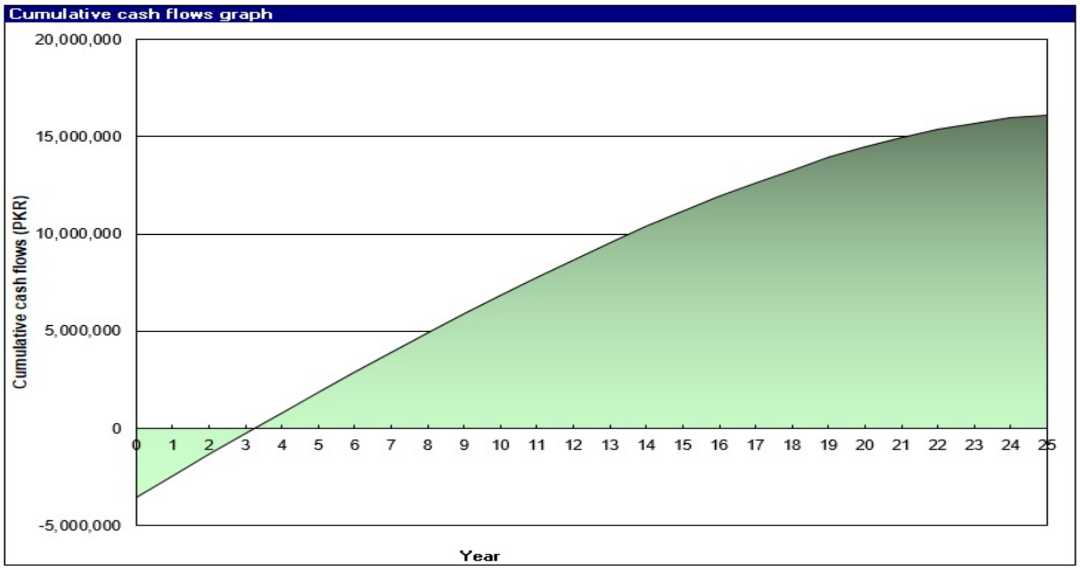

Figure 4.19 Cumulative cash flow graph 30 KW

The solar photovoltaic viability and cost benefit analysis for these tube wells has been carried out and the proposed pumps for this study is 18.5 KW and 30 KW. Total capital cost for these two pumps are 2.4 and 3.6 million rupees with a payback time of 4 and 3 years respectively.

Chapter 5

5. Conclusions & Recommendations

5.1 Conclusions

This study has been conducted on WASA tube wells of Quetta valley to find out the variation coming in discharge water table and to asses a solar photovoltaic water pumping (SPVWP) viable and financial analysis. The conclusion of the study are following as

1. Daily peak solar radiation in the area is 7 to 8 hours which is rich in solar energy
2. Water table decline rate is 2 – 8 m/yr. with Discharge reduction of 4 - 20 % in Quetta valley
3. The total replacement cost of 30 tube wells to SPVWP is 99.79 Million (PKR) with Payback time of 3 – 5 years
4. Cost benefit ratio is between 2.05 – 3.92 for SPVWP
5. Solar water pump extract water at day time so the low yielding borehole has time to refill

5.2 Recommendation

The detailed analysis of discharge reduction water table fluctuations and solar photo photovoltaic financial analysis was carried out and following are the recommendations for future study

- SPVWP should be recommended in water deficit zone of Pakistan because of their efficiency, reliability and cost benefit ratio
- The efficiency of SPV should be increased to achieve better results
- SPV system require large area, so compact systems should be preferred
- SPV requires regular cleaning
- Temperature of SPV should be maintained by sprinkling water

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