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Single-Zone Thermodynamic Modelling of a Four Stroke Natural Gas Spark Ignition Engine

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Abstract- This paper presents single zone thermodynamic simulation of closed part of spark ignition engine based on the Java Computer Applet. In the present work , finite Heat Release with Heat transfer library of the Applet has been used to find out indicated performance parameters at wide open throttle (WOT) condition for four stroke four cylinder 2.5 L dedicated natural gas engine, compression Ratio is 11, at various engine speeds (1000, 1500, 2000, 2500 & 3000 rpm). The same engine was also tested on dynamometer to determine the brake power at the same engine speeds at WOT condition. Brake power obtained through simulation was compared with the experimentally obtained brake power. The theoretical results obtained through simulation model are in close agreement with measured data. The results are almost matching up to 2000 rpm and at higher speeds i.e. from 2000 rpm to 3000 rpm the maximum deviation of around 7% has been found at 3000 rpm. The main reason of deviation at higher speeds may be due to the use of engine friction model which calculates engine friction based on motored engine.

Keywords- Single-zone model, Heat release analysis; Spark ignition engine

I. Introduction

Computer based thermodynamic & fluid dynamics models have long been used for predicting engine performance & emissions. The aim with modelling IC engines is: to predict engine performance without having to conduct tests, and to deduce the performance of parameters that can be difficult to measure. [1] remarked that the design of an engine and its controlling strategy often culminates as a trade-off between efficiency, emission and many practical constraints and modelling is a tool to envisage the performance of particular design. Mathematical models for spark ignition engines can be divided broadly in two groups- thermodynamics-based (single &multi zones) and fluid dynamics–based (CFD based). Other labels associated to thermodynamic-based models are: zero-dimensional, phenomenological and quasi-dimensional. In zero-dimensional (ZD) models Empirical Heat Release Models are used wherein time is the only variable (resulting in ordinary differential equation). As no flow modelling exists so geometric features of the fluid motion cannot be predicted in ZD models. In phenomenological models additional detail beyond the energy conservation equations is added for each phenomenon in turn and in quasi-dimensional models some specific geometric features, e.g., the spark-ignition engine flame or the diesel fuel spray shapes, are added to the basic thermodynamic approach. Separate sub models are also used for turbulent combustion to derive a Heat Release Model, [2].

Fluid dynamic-based models are often called multidimensional models owing to their intrinsic ability to provide in depth geometric information on the flow field based on solution of the governing flow equations. These models solve numerically the equations for mass, momentum, energy and species conservation in three dimension (Navier-Stokes equations), in order to predict the flame propagation. As these equations are dependent on spatial co-ordinates, so these equations take the form of partial differential equations. The progression of engine models starts from the ideal cycle calculations in the 1950's to simple component matching models in the 1960's, full thermodynamic models during the late 1970's, and multi-zone & multidimensional combustion models in the 1980's and 1990's as described by [3].

II. Single Zone Thermodynamic Modelling

Single-zone (Zero Dimensional) model is based on the First law of thermodynamics and can be used as either predictive or diagnostic tool. The model does not account for combustion chamber geometry except in global manner through volume (V). Combustion in single-zone model can be approximated as heat addition process and the heat addition is specified as a function of crank angle CA (as predictive tool). The outcome of the model is temperature and pressure which is the function of crank angle. The heat release-time curve employed (combustion rate model) is a Semi Empirical Weibe function or Cosine curve, it describes the fraction of mass of fuel consumes which depends upon crank angle. The model does not involve any flow field detail, so geometric features of fluid motion cannot be predicted. In single zone model analysis, it is assumed that the specific internal energy of the charge is a function of temperature only. The cylinder-gas composition is modelled assuming as uniform and gas mixture is perfect. Average gases properties are assumed with no distinguish between burned & unburned gases. The heat transfer coefficient is calculated by Woschni correlation. The model, it is supposed that the unburned and burned gasses mix within no time. [4] are of the view that these models are fast and cheap in terms of computation.

A. Mathematical Formulations

When applied to closed part of the engine and ignoring the crevice mass flow, the first law of thermodynamic may be written as

$$\delta Q_{add} - \delta Q_{loss} - \delta W = dU \qquad (1)$$

Where

$$\delta Q = \delta Q_{add} - \delta Q_{loss}$$

δQin = Total amount of heat input to cylinder by combustion of fuel per cycle = mf LHV

δQadd = Total amount of heat added from the fuel to the system.

Upon differentiating, (1) becomes

$$\delta Q_{add} - \delta Q_{loss} - PdV = \frac{C_v}{R}\left(PdV + VdP\right) \qquad (2)$$

With respect to crank angle θ, (2) can be written as

$$\frac{dP}{d\theta} = \frac{\gamma-1}{V}\frac{dQ_{add}}{d\theta} - \frac{dQ_{loss}}{d\theta} - \frac{\gamma PdV}{Vd\theta} \qquad (3)$$

Where the rate of heat release as a function of crank angle is given as

$$\frac{dQ_{add}}{d\theta} = \frac{Q_{in}dx_b}{d\theta} = \frac{Q_{in}}{\theta_d}\left(1-x_b\right)\left[\frac{\theta-\theta_s}{\theta_d}\right]^{n-1} \qquad (4)$$

Where xb is the Weibe function which is used to determine the mass fraction burned Vs crank angle using finite heat release model. The Weibe function is described as

$$x_b\left(\theta\right) = 1 - \exp\left[-a\left\{\frac{\theta-\theta_s}{\theta_d}\right\}^n\right] \qquad (5)$$

Where θ is crank angle, θs is start of heat release, θd is duration of heat release, n is Weibe form factor and a is Weibe efficiency factor. Values of n = 3 & a = 5 are best fit to the experimental data.

$$\frac{dP}{d\theta} = \frac{\gamma-1}{V}\left[\frac{dQ_{in}dx_b}{d\theta} - \frac{dQ_{loss}}{d\theta}\right] - \frac{\gamma PdV}{Vd\theta} \qquad (6)$$

Where dQw/dθ is heat transfer rate at any crank angle θ to the exposed cylinder wall

$$\frac{dQ_{loss}}{d\theta} = \frac{h_g(\theta)A_w(\theta)(T_g(\theta)-T_w)}{N} \qquad (7)$$

Equation (8) is known as Newtonian convection equation and is used to determine the heat transfer rate at any crank angle (θ) to the exposed cylinder wall at any engine speed N. Alternatively the (7) may also be written as

$$\frac{dQ_{loss}}{d\theta} = \frac{hgAw}{\omega}(T_g - T_{w)}\frac{\pi}{180} \qquad (8)$$

Where dQloss is differential heat transfer to cylinder wall, hg is instantaneous area averaged heat transfer coefficient; Aw is exposed cylinder area which is the sum of cylinder bore area, the cylinder head area and the piston crown area, Tg is cylinder gas temperature, Tw is cylinder wall temperature, ω

is engine Speed (rad/sec) and N is engine Speed (rpm)

$$\frac{dP}{d\theta} = \frac{\gamma-1}{V}\left[\frac{dQ_{in}dx_b}{d\theta} - \frac{hA}{\omega}(T_g - T_w)\frac{\omega}{180}\right] - \frac{\gamma PdV}{Vd\theta} \qquad (9)$$

The area of the cylinder can be calculated using the crank slider model (Fig. 1.) as

$$A = \frac{\pi}{2}b^2 + \pi b\frac{s}{2}\left[R + 1 - \cos\theta + (R^2 - \sin^2\theta)^{\frac{1}{2}}\right] \qquad (10)$$

Where, R = L/a,

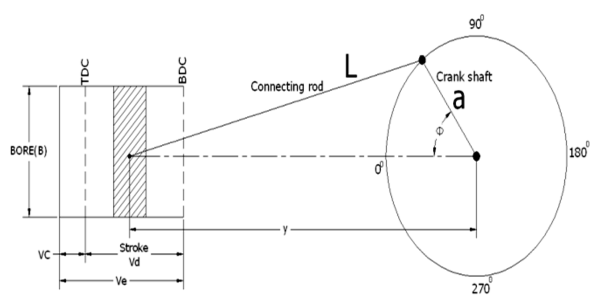

Fig. 1. Crank slider Model

The temperature of the gas, Tg, will be an average temperature. The heat transfer coefficient given by Woschni is:

$$h = 3.26b^{-0.2}P^{0.8}T^{-0.55}v^{0.8} \qquad (11)$$

By using the above equations indicated quantities can be determined. To convert the indicated performance to brake performance, it is necessary to predict the frictional losses. The total frictional work of engine comprises of three components, pumping work, rubbing friction work and accessories work.

To evaluate frictional mean effective pressure of automotive four stroke engines following correlation has been employed by Alla (2002).

$$FMEP\ (bar) = 0.97 + 0.15\ [N/100] + 0.05\ [N/1000]2 \quad (12)$$

Equation (12) is used by Heywood (1998) and Richard (1999), to determine frictional mean effective pressure (FMEF) of motoring four-stroke four cylinders engine. The brake mean effective pressure (BMEP) can be found by using the following equation.

$$BMEP\ (bar) = IMEP - FMEP \quad (13)$$

Where IMEP is the indicated mean effective pressure, which is the work delivered to the piston over the compression & expansion stroke, per cycle per unit displacement volume. The brake power is then determined by the following equation.

$$Brake\ Power\ (KW) = BMEP \times Vd\ [N/2] \times n\ \{for\ 4 - stroke\} \quad (14)$$

Where, Vd is the engine displacement, N is engine revolution per minute and n is the number of cylinders.

In order to determine the heat input Qin in (J), the mass of the fuel entering the cylinder has to be calculated. The equivalence ratio can be defined as

$\Phi = (mf/ma)\ act/\ (mf/ma)\ s$

$$\Phi = (mf/ma)\ act/\ (mf/ma)\ s \quad (15)$$

$$ma, act = \Phi\ (mf/ma)s * ma,act \quad (16)$$

$$Qin = HHVfuel * mf, act \quad (17)$$

However in the simulation lower heating value has been used as input condition

qin = Qin/mass of gas mixture inducted, which may be written as [5]

$$= \Phi Fs/1 + \Phi Fs * [qc - 3890\ (\Phi - 1)] \quad for\ \Phi > 1 \quad (18)$$

$$qin\ (kJ/kg\ mix) = \Phi Fs/1 + \Phi Fs * qc \quad for\ \Phi \le 1 \quad (19)$$

Where qc is the heat of combustion of fuel (here LHV)

For hydrocarbon fuel

$$\gamma = 1.4 - 0.16\ \Phi \quad (20)$$

The mass of air can be expressed from displacement volume

$$ma, act = \rho Vd \quad (21)$$

TABLE I
CONDITIONS FOR SIMULATION

Parameters	Values
Pressure inside manifold (near intake valve)	0.98 bar
Inlet temperature T_i	323 K (experimental value)
Mean cylinder wall temperature	423 K
Specific heat ratio γ	Using Eq-20
Air density ρ_{air}	1.2 kg/m^3
Equivalence ratio Φ	1
Heat of combustion of methane (q_c) LHV	50.01 MJ /kg
q_{in} (kJ/kg $_{mix}$)	Using Eq-18
Stoichiometric Fuel-air ratio of methane (F_s)	0.05814
Spark timing (θ_s)	35deg bTDC
Duration of combustion (θ_d)	60 degaTDC
Weibe efficiency factor (a)	5
Weibe form factor (n)	3
Engine Geometric Parameters	
Stroke (S)	95 mm
Bore (b)	91.1mm
Connecting rod length mm	158mm
Compression ratio (r)	11
Engine speed	1000, 1500, 2000, 2500, 3000 rpm

III. SIMULATION RESULTS & DISCUSSION

Figs. 2-5 show the simulation results i.e. indicated work, indicated mean effective pressure, indicated power and maximum pressure obtained though single zone thermodynamic heat release model using Woschni heat transfer correlation. These figures illustrate the increasing trends of all the quantities with increase in engine speed. Fig. 6 shows the calculated brake power based on (12)~(14) at various engine speeds. The brake power obtained through single-zone computational model was compared and verified against the experimentally measured brake power in Fig. 7. The computational results are in close agreement with measured data. The results are almost matching up to 2000 rpm; however at higher speeds i.e from 2000 rpm to 3000 rpm the maximum deviation of around 7% has been found between simulation & experimental results, which is well within the published data [6], [7], [8]. The simulation results start departing from the experimental results at 2000 rpm to 3000 rpm with maximum 7% over prediction at 3000 rpm. The main reason of deviation at higher speeds may be due to the use of engine friction model which calculate engine friction based on motoring the engine. Further in actual engine, natural gas with 87% methane has been used while in the model simulation 100% methane has been employed

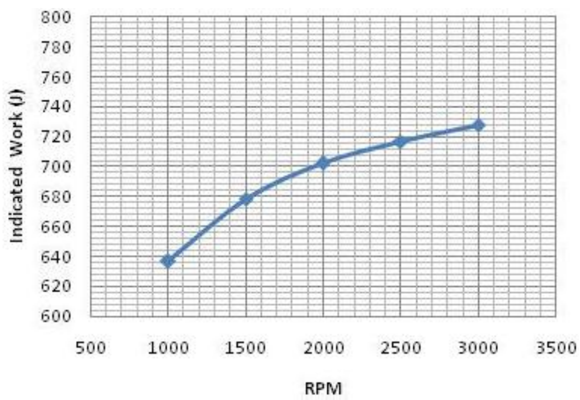

Fig. 2. Indicated work Vs Engine speed

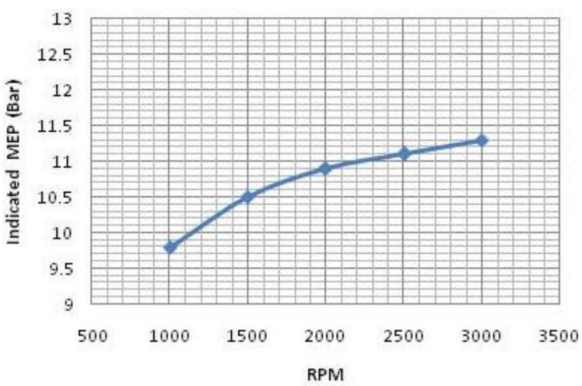

Fig. 3. Indicated `mean effective pressure (IMEP) Vs Engine speed

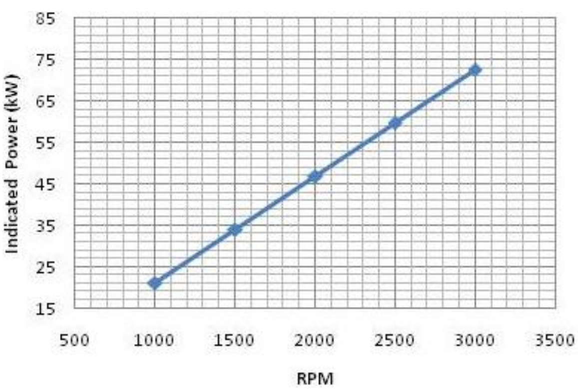

Fig. 4. Indicated power Vs Engine speed

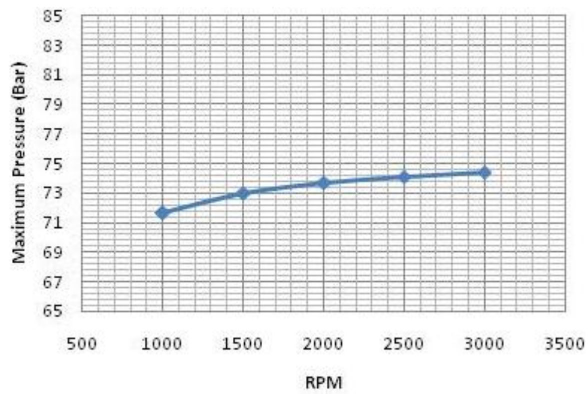

Fig. 5. Maximum pressure Vs Engine speed

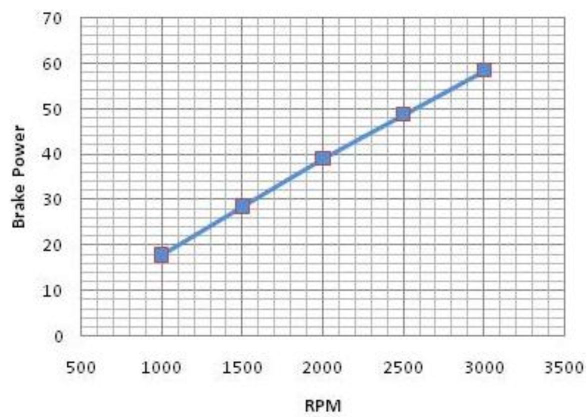

Fig. 6. Calculated brake power based on (12)-(14) at various engine speeds

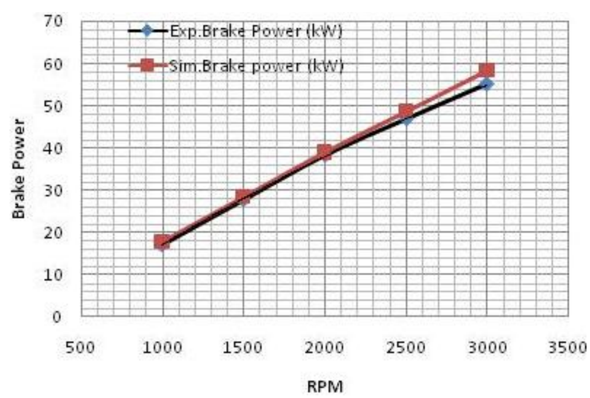

Fig. 7. Comparison of experimental & Simulation results

IV. Conclusions

Single-zone thermodynamic model is simple model based on the first law analysis which can safely be used during the early stages of engine development to determine the performance of the engine. As no flow modeling exists so geometric features of the fluid motion cannot be predicted in the model. Comparisons have been made between computational results obtained though the model and experimental results to confirm the reliability and accuracy of the model for predicting brake power of spark ignition engine running on natural gas. The computational results are in close agreement with measured data. The results are almost matching up to 2000 rpm; however at higher speeds i.e from 2000 rpm to 3000 rpm the maximum deviation of around 7% has been found between simulation & experimental results, which is well within the range.

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Isolation and its Purification of Laccaic Acid Dye from Stick Lac and study of its (Colour Fastness) Properties and Reflactance on Silk Fabric Dyed with Heavy Metal Mordants

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***Abstract*-**Dye from stick lac was extracted, isolated and purified to remove wax and shellac which were removed as by products. Dye extracted was purified and applied on silk fabric using four different heavy metal mordants (Potash alum, potash Chrome alum, copper sulfate and ferrous sulfate) by using Metamordanting method of dyeing. Colour fastness properties (fastness to washing, rubbing. light and heat) were studied with the aid of grey scale for metamordanted and control silk fabrics. Reflactance of all the dyed fabrics was also noted. ʎmax and absorbance of dye were determined by spectrophotometer. Results showed that mordant dyeing increased the uptake of dye on silk fabrics. The results of colour fastness properties were from best to excellent.

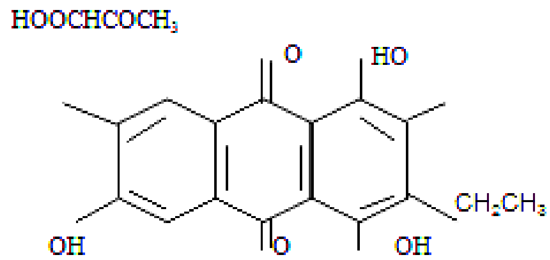
***Keywords*-**Mordant. Reflectance, Isolation, Wax, Shellac.

I. Introduction

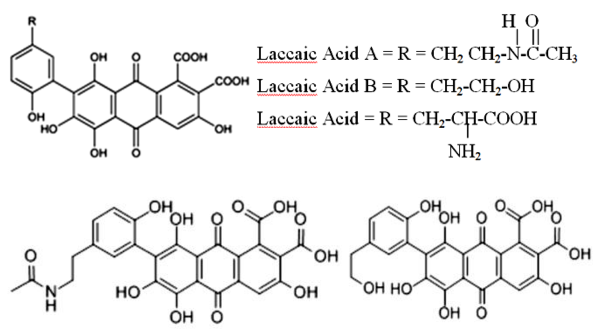
A dye can generally be described as a coloured substance that has an affinity to the substrate to which it is being applied. It adheres to the fabrics like cotton, silk, linen, woolen, leather and many other materials. Dyes are of two types i) synthetic dyes and ii) natural dyes. As synthetic dyes cause environmental problems in textile and leather processing industries being major environmental polluters in the World. Many of synthetic dyes are carcinogenic and allergenic. It is the need of hour to use dyes and chemicals which are environment friendly and are less polluting [1], [2], [3]. Natural dyes have been known for a long time. These dyes not only come from flowering plants and vegetables but also from animal and insect sources like fungi, lichens and insects like shellfish [4], [5]. Lac dye is also one of the animal dyes. Natural dyes produce different subtle and soft colours on the yarn and fabrics and are gaining momentum day by day [6], [7].

Insect dyes are obtained from the body of the insects. They live on different plants to get food colour and produce dye in the abdomen of the insect. The ancient dye stuff (lac) is obtained from the dried bodies of an insect coccuslaccae (LacciferLacca) found on twigs of certain trees of South Asian countries, which secretes Lac resin [6], [8], [9]("Lac,").

Lac is chemically very similar to carmine, carminicacidkernes or kermesic acid based partially on these findings, the following structural formula for laccaic acid has been proposed.

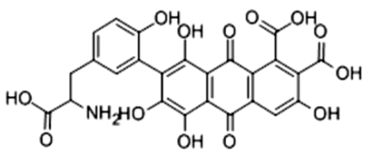


This formula was studied by Schmidt in 1887 who investigated the colouring matter of the lac dye and gave it the name of Laccaic acid. Latter on it was found that there are four compounds found in lac designated as A, B,C and D [8]. Laccaic acid A is most abundant *and* the major compound [10], [11], [12].Laccaic acid A, B, and C are very similar but differ at a single point that is illustrated in the following formulas. Laccaic acid D is also called Xamhokermesic acid *and* closely resembles kermcsic acid in structure:

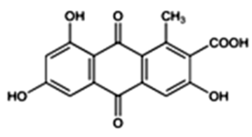


Laccaic Acid A

Laccaic Acid B



Laccaic Acid C



Laccaic Acid D

It may be noticed that structures A, B, and C differ at a single point only.

Lac dye and Shellac has many applications in different fields. Lac dye is natural food pigment because of its approval from FDA. Shellac is used to coat apples and other fruits to make them shinner to improve its shelf life. It is used in cosmetics for making lipsticks and eye brow pencils and in sunscreen emulsions [13]. Lac dye is used for dyeing the fabrics usually wool and silk [14], [15], [16].

Shellac is also used in varnishes, extensively in food finishing, coating of candies and pharmaceutical tablets to protect against moisture and to seal off active ingredients. It is used to some extent as a leveling resin in some formulations& printing inks. It is used in vilons and other varnishes and is soluble in alcohol ("Lac,").

Use of natural dyes particularly insect dyes is gaining interest for dyeing and application in biological staining [14]. Pure insect dyes are highly valuable. Pakistan policy makers should show interest in propagation and applications of these dyes as these are environment friendly and create source of income for people living in rural areas.

Present work includes the extraction and purification of laccaic acid, study of its application on silk fabrics and colour fastness properties [17], [18], [19]. Most natural red colour dyes are highly soluble in water. So colour fastness to washing of lac dye was found quite low. In order to improve its colour fastness properties heavy metal mordant method was conducted. In which metal ions can act as acceptors to electron donors to form coordinate bonds with dye molecule which is insoluble in water [10], [3].

Most of the colour of the plant origin is anthrocyanides, flavonoid and carotenoids.

II. MATERIALS & METHODS

2.1 Instrumentation

IR spectrometer model “bruket OPUSTUM Nicolet IR 200 200 (USA).D400 IR dyeing machine (SDL Atlas England). Launderometer (Roaches). Oven Ci 3000 – Xenon. Weatherometer, (Atlas Enland). Water bath. Grey scales for staining (ISO 105 A03). Grey scale for change in shade (ISO 105 A02.). Crockmeter (SDL Atlas England). Multifiber (DW). Twiglac.

2.2 Chemicals & Reagents

Potash alum, Potash chrome alum, copper sulfate, ferrous sulphate, detergent, SDC standard soap (without optical brightener), distilled water, sodium carbonate, sodium chloride (AR Grade).

2.3 METHOD

2.3.1 Isolation of Lac Dye

Source: Fresh twig lac was plucked and collected in the month of June from the branches ofberri (Zizzyphous) tree which were found to grow in campus of PCSIR Phase-1, Housing Society, Canal Road, Lahore. Many branches were infected with insect laceiferlacca.

Lac (Shellac) was separated from the twigs and branches manually with the help of spatula. Fibrous material of branches, twigs, debris and infected sects were sorted out. 500 gms of natural shellac thus obtained was coarsely ground in mortar and added 5000 ml of water. Stirred it well for 3 to 4 hours. It was then filtered through coarse mesh sieve washing the residual lac on the sieve with 100 ml water. The dark red filterate solution was filtered through Buckner funnel, covered with filter cloth. The dye solution was finally centrifuged till clear solution of red dye was obtained. The clear solution was decanted carefully into conical flask [6], [18], [10], [20], [21]. The clear red filtrate was acidified with conc. hydrochloric acid to pH 1-2 till red dye was precipitated. It was stirred for 2-3 hours by magnetic stirrer then centrifuged. The precipitated dye was separated from supernatant liquor. The precipitated dye was removed and transferred to petri dish for drying. The dried dye had still waxy touch, so finally it was extracted with hexane to remove any waxy material. Laccaic acid dye 3.4% was obtained by applying above mentioned process.

2.3.2 Isolation of Wax, Aleuritic Acid

Dye free lac (residual lac) was extracted with hexane in the Soxhlet apparatus. Hexane soluble material containing wax and aleuritic acid was made free from hexane by distillation. The hexane free solid material was taken in diethyl ether and added ethanol drop wise, Wax was precipitated and separated from the solvent mixture. The solvent was distilled off and white fluffy material aleuritic acid was obtained.

2.3.3 Dyeing with Lac Dye

Dyeing is the process of colouring textile fibres and other materials, in such a way that the colouring matter becomes an integral part of materials (fabrics etc.) rather than a surface coating. Dyeing was completed with 2% lac dye solution without and with mordant (metamordanting technique). The liquor ratio of (fabric and water) during dyeing was 1:20. Before dyeing silk fabric was wetted with wetting agent. Temperature was maintained at 100^{o}C. Dyeing was completed in 1 hour. After dyeing silk fabrics were washed, squeezed and dried at room temperature.

2.3.4 Dyeing with Mordants

The processing agent which can make link between cloth and dye is known asmordant which is derived from a Latin word 'mordate' means to bite [22]. Mordant may be added in three different ways (I) Premordanting when fabric is treated with mordant before dyeing (2) Metamordanting in which mordant is added during dyeing of fabric and (3) Postmordanting when fabric is treated with mordant solution after dyeing. Metamordanting technique was used during this study using heavy metal mordants (Potash alum, potash chrome alum, copper sulphate and ferrous sulphate) [23], [24].Wet fabrics were dipped into 2% lac dye solution. The liquor ratio during dyeing was 1:20. The temperature of dye bath was maintained at 100^{o}C and total time for dyeing was 1 hour. After 45 minutes of dyeing different mordants of 0.1M strength were added to the dyeing bath for fifteen minute, then fabrics were rinsed, washed and squeezed and dried at room temperature.

2.3.5 Colour Fatness to Washing

Dyed silk fabrics and multifibre DW were cut into 4 X 10 cm size pieces and sewed with each other from one side in such a way that their faces were adjacent to each other. Soap solution made by adding 5gm soap per liter of water, under specified conditions of time and temperature, were added to different steel containers fixed in launderometer having liquor ratio 50:1. Change in colour or the specimen and staining of adjacent fabrics (DW multifibre) was assessed with the help of grey scale. Results of colour fastness to washing are shown in Table I (1006, 1990).

2.3.6 Colour Fastness to Dry and Wet Rubbing

Colour fastness to dry and wet rubbing of metamordanted dyed silk, fabrics were performed with the help of crockmeter instrument. For this test different silk fabrics of 5 cm x 14 cm were fastened by means of clamps to base board of the testing device. The standard cloth was first rubbed in dry condition and then in wet condition in to and fro motion in a straight line along a track 10 cm long on surface of fabrics 10 times in 10 seconds with a downward force on 9 N. Fabrics were, dried at room temperature. Change in shade of the dyed fabrics and staining of the rubbing cloth was assessed with the help of grey scale. The results of colour fastness to rubbing are given in Table II (1006, 1990).

2.3.7 Colour Fastness to Light

Colour fastness to light was carried out with instrument weatherometer by Atlas according to ISO 105 standard procedure B02, in which Xenon arc lamp was used as an artificial light source, representative of natural day light D65. Silk fabrics of measurement 7 cm x 12 cm were exposed to D65 light and result of colour fastness to light against blue wool were noted with the help of grey scale. Change in shade was noted. Results obtained are tabulated in Table II.

2.3.8 Colour Fastness to Heat

Colour fastness to dry heat fastness for all silk fabrics was performed by hand iron. Silk fabrics were pressed for five minutes at specific temperature with and without mordants. Results are shown in Table II.

2.3.9 Reflectance of Silk Fabrics

IR spectrometer, model–Bruker OPUSTM Nicolet IR 200 (USA) was used for recording reflectance in the infra region for silk cloths dyed with Iac dye with and without mordants. The spectrum of laccaic acid dyed fabrics was recorded on the above mentioned IR spectrometer [25].

2.3.10 Procedure

Silk fabrics were put on the lens of IR spectrometer and noted the reflectance peaks of the dyed silk fabrics. Results & discussion are given in Table III.

III. RESULTS & DISCUSSION

The grey scale results of the silk fabrics dyed with lac dye (control) and dyed with different heavy metal mordants are given in Table I & II for colour fastness to washing, dry and wet rubbing fastness, light and heat.

TABLE I
COLOUR FASTNESS TO WASHING FOR SILK FABRIC DYED WITH HEAVY METAL MORDANT AND WITHOUT MORDANTS (CONTROL)

Sr. No.	Observed dyed	Diacetate	Cotton	Nylon	Polyester	Polyacrylic	Wool	Change in shade
1.	Control	4	3-4	5	4-5	4-5	4	2-3
2.	Potash alum	4-5	4	5	5	5	4-5	3-4
3.	Potash chrom alum	5	4-5	5	5	5	4-5	3
4.	Ferrous sulfate	4-5	4	5	5	5	4-5	3
5.	Cooper sulfate	4-5	4	5	5	5	4-5	2-3

Colour fastness to washing was observed for control silk fabric (dyed with lac dye on silk) and silk fabrics dyed with four heavy metal mordants using metamordanting method respectively. For control fabrics the values for colour fastness to washing did not gave good results, because dyeing on fabric does not adhere on the fabric, resulting light colour shades with different concentration of dye. Application of different heavy metal mordants not only increase the depth of shade on fabrics but also change the colour of the dye. Potash alum gave move (purplish) colour. $CuSO_4$ gave grayish move colour while potash chrome alum gave dark pinkish move colour. Reason is that heavy metal mordants increase the binding capacity of the dye to the fabric.

So in metamordanting process of dying the dye is absorbed on the fiber followed by the formation of an insoluble complex with metal ions showing bathochromic shift. So some of the dye is lost became of formation of this insoluble complex in the dye bath itself. So this phenomena bring about a decrease in the effective dye concentration in the dye bath.

For washing tests all the values for change in stain and change in shades were noted and are shown in Table I.

3.1 Change in Staining

On diacetate staining strip of multifibre, (DW) lac dye control gave good 4 rating, while potash alum, ferrous sulfate and copper sulfatemordanted silk fabrics gave best 4-5 rating while excellent results rating 5 were observed with potash chrome alum. On cloth staining strip of multifiber gave rating 3-4 satisfactory results for control (fabric dyed with lac dye) where no mordant was used. Potash alum, potash chrom alum, ferrous sulfate and copper sulfate gave good 4 rating on grey scale. On Nylon strip of multifiber all the five silk fabric dyed with Iac dye and silk fabrics mordanted with potash alum, potash chrom alum, ferrous sulfate and copper sulfategave excellent rating i.e. 5. Polyester strip ofmultifiber showed 4-5 best rating with control fabrics and 5 excellent rating with potash alum, potash chrom alum, ferroussulfate and copper sulfatemordants silk fabrics. Polyacrylic strip showed same results as for polyester stip, while wool strip gave 4 good rating with control silk fabric and 4-5 best rating with other four metamordanted silk fabrics.

3.2 Change in Shade

When change in shade of original dyed fabrics (control) and mordant treated fabric, was observed, it was found that control fabric (dyed with lac dye) gave 2-3 i.e. poor rating potash alum mordanted silk fabric gave 3-4 i.e. satisfactory rating. Potash chrom alum and ferrous sulfate mordanted silk fabrics gave 3 rating while copper sulfate mordantedsilk fabric also gave 2-3 poor rating.

3.3 Results of Grey Scale for Rubbing Fastness, Light Fastness and Heat Fastness

Rubbing fastness was performed according to ISO 105 X 12 by ISO method with instrument crockmeter. Roth dry and wet rubbing along warp and weft were noted with standard cloth fabric. Similarly light fastness was performed according to ISO 105 standard procedure B02 while heat fastness with hand iron.

TABLE II
RESULTS OF RUBBING FASTNESS, LIGHT FASTNESS AND HEAT FASTNESS ON SILK FABRICS DYED WITH AND WITHOUT HEAVY METALS MORDANTS

Sr. No.	Name of Fabric	Rubbing Fastness				Light Fastness	Heat Fastness (Dry)
		Dry Rubbing		Wet Rubbing			
		Warp	Weft	Warp	Weft		
1.	Control	4-5	4-5	4	3-4	4	4
2.	Potash alum	5	5	4-5	5	4-5	4-5
3.	Potash chrom alum	5	5	4	4-5	4-5	4-5
4.	Ferrous sulfate	5	5	4	4	4	4-5
5.	Cooper sulfate	4-5	5	4-5	4	4-5	4-5

3.4 Results of Dry Rubbing Fastness

Dry rubbing fastness of lac dye gave best 4-5 results along warp and weft while with potash alum, potash chrom alum and ferrous sulfate mordanted silk fabrics gave excellent 5 results on grey scale along warp as well as weft. With CuSO4 mordant, dry rubbing gave best 4-5 results along warp and excellent 5 results along weftside of the silk fabrics. In all the cases where rubbing was performed with control fabric gave low grey scale rating and low quality level of dyeing as compared to rubbing performed by the application of metal mordants.

3.5 Wet Rubbing Fastness

Wet rubbing fastness of control fabric gave better 4 rating along warp and satisfactory 3-4 rating along weft. Potash alum gave best 4-5 rating along warp and excellent rating 5 along weft potash chrom alum and ferrous sulfate both gave good 4 rating along Warp and 4-5 best, (good) 4 along weft respectively. Copper Sulfate gave 4-5 best results along warp and 4 (good) along left side of the silk fabric.

3.6 Result of Colour Fastness Light

According to Table II colour fastness to light with control fabric gave 4 (good) results. Potash chrom alum and copper sulfate dyes silk fabrics gave 4-5 best, rating for colour fastness to light.

3.7 Results of Colour Fastness to Light

Colour fastness to heat have 4 better rating for control fabric (dyed with lac dye soln.) and best results for potash alum, potash chrom alum, ferrous sulfate and copper sulfate mordanted silk fabrics. Results of washing fastness light fastness and colour fastness showed low grey scale rating with control silk fabrics dyed with lac dye.

3.8 Results of Reflective Peaks

IR reflectance peaks of spectra of dyed fabrics with and without mordants are given in Table III.

TABLE III
RESULTS OF REFLECTANCE PEAKS OF DYED SILK FABRICS WITH AND WITHOUT MORDANTS

Dye	Frequency cm^{-1} Dyed silk with mordant				Dyed silk mordant	Intensity	Assignment
	A	B	C	D			
550	640	665	520	700	724.41	Var	4
1000	1000	1000	1040	1000	1016	Wk	Amine
-	1090	1100	1100	1110	1094	-	-
1260	1240	1240	1210	1280	1238	Med	Carboxylic acid
1400	1400	1410	1430	1410	1408	Str	C=O
1630	1690	1690	1590	1520	1505	Med	Arene
-	-	2430	-	-	2360	-	-
2850	2700	-	2890	2890	-	-	-
2950	-	-	2950	2950	-	-	-
330	-	3000	-	-	-	-	-

A=Chrom alum, B=Copper sulphate, C=Ferrous sulfate and D=Potash alum.

IV. CONCLUSION

The use of natural dyes, particularly insect dyes is gaining interest again for natural dyeing of fabrics and other applications in food, pharmaceuticals and cosmetics industries. The results show that mordanted dyeing with lac is more applicable because colour uptake on silk fabrics increases and results are best to excellent. Lac dye is environment friendly and creates source of income for people living in rural areas. Researchers, policy makers and industrialist should make efforts to popularize the use of lac dye fabrics among the masses.

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Spatial and Temporal Assessment of Groundwater Behaviour in the Soan Basin of Pakistan

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Abstract-The assessment of groundwater potential for any region is very important for its sustainable management. However, the groundwater potential of the Soan basin - a sub basin of the Indus basin, has not been assessed after 1981, though large scale water resources development and exploitation activities have been carried out during the last two decades. A study was undertaken in the Soan basin to assess its spatial and temporal variability of groundwater potential and to propose measures for its sustainable management. Water-table data at 193 monitoring points were collected from 2003-2006. Long-term records 1960-2005 of rainfall at different stations, basin outflows and data on water resources development in the area were collected. There is a high spatial and temporal variation in rainfall over the basin. The rainfall pattern has changed over the basin, resulting in reduced basin outflow especially after 1984. After the drought of 1997-2000, the rainfall situation improved however, no significant increase in the basin outflows was observed. Since 1981, the groundwater utilization has increased significantly due to about 95% increase in the population. The number of open wells, hand pumps and tube wells has increased by 39, 186 and 96%, respectively over the last two decades. The increased abstractions of groundwater, reduced rainfall, and basin outflow have resulted in depletion of groundwater. The average water-table drop in the basin is 3.75 m over the last 25 years with an average drop rate of 0.15 m per year. However, in areas away from the river and recharging sources, the water-table drop is much higher, mainly due to more abstraction than recharge. In the areas, where water storage facilities such as small dams, mini dams and ponds were developed, a rise in water table has also been observed. On an average, the annual rainwater potential of the basin is 3.44 x 10^9 m^3, whereas only 80 x 10^6 m^3 (less than 3%) have been harnessed so far through construction of small dams, mini dams and ponds. Under the present water scarcity conditions, there is a need to initiate integrated water resources management programs with a site specific focus on rainwater harvesting. If no mitigation measures are undertaken, the groundwater depletion is expected to jeopardize the future agriculture and socio-economic development.

Keywords—Water-table depletion, Rain water, Basin outflow, Sustainable management

I. INTRODUCTION

Globally, groundwater comprises one third of the freshwater resources. However, the rapidly shrinking surface water resources due to over exploitation, all over the world, has placed tremendous pressure on groundwater, which is now depleting in many parts of the world [1]-[9]. Pakistan has the largest contiguous irrigation system of the world, where 75% agricultural lands, mostly in the Indus basin are irrigated. The annual water supply through this network is around 163 x 10^9 m^3, commanding an area of about 16 million hectares (Mha). The irrigation system was designed for about 60% cropping intensity which is now over 170%. The increase in cropping intensity could have become possible by exploiting groundwater. Due to increased population, urbanization, and industrialization, the per capita water availability has reduced from 5600 m^3 to 1200 m^3 over the last fifty years [10]. Surface water supplies and rainfall have become inadequate to meet the crop water requirement. As a result, the groundwater resources are being exploited to supplement the irrigation supplies. The recent drought 1997-2000 in the country reduced the canal water supplies and further increased the pressure on the groundwater. About 25% of the cultivated area is rainfed as it entirely depends on rainfall for crop production. Rainfed areas are concentrated in Pothwar Plateau, northern mountains and northeastern plains forming the largest contiguous block of dry-land farming in the country. The Pothwar region lies between the Indus and Jhelum rivers stretching over an area of 18,200 km^2, out of which about 6,100 km^2 is cultivated [11]. The rainfall occurrence in the area is quite erratic with a high spatial and temporal variation, causing great difficulties in raising crops due to uncertainty in water supplies [12], [13].

Only a few studies have been conducted in the past to asses the groundwater potential in the Pothwar plateau [14], [15], [16]. Since then a number of water resources development and exploitation activities such as construction of small dams (610,000-9,130,000 m^3 storage capacity), mini dams (12,000-120,000 m^3 storage capacity), ponds (<12,000 m^3 storage capacity), soil and water conservation activities, open wells, hand pumps and tubewells have been carried out by public and private sectors. However, out of the total rainwater potential of 4.32 x 10^9 m^3, all these efforts could harvest only 120 x 10^6 m^3 [17], [9], [18] and a large amount of water (about 4.2 x 10^9 m^3) is lost as surface runoff annually. This not only results in loss of precious water, but also causes erosion of the top fertile soil [18], [19], [20]. Due to implementation of water resources development and management schemes particularly after 80s, the groundwater has developed mostly in small pockets (mainly perched water), especially in the vicinity of completed dams [21], [18]. The number of open wells has therefore, increased manifolds due to availability and accessibility groundwater [18]. However, due to irrational pumping/withdrawal of water, and decreased rainfall during the last decade, the water table has been falling rapidly [22]. Moreover, the status of groundwater has not been investigated in the area after 1981. The assessment of groundwater potential is very important for its sustainable management and future planning particularly, after continuous agricultural development, population growth, urbanization and changing hydrological regimes. This study was conducted in the Soan basin, a tributary of the Indus basin, to investigate the spatial and temporal Behaviour of groundwater and to propose measures for its sustainable management.

II. METHODOLOGY

2.1 Description of the Study Area

The Soan river basin is a major hydrological unit of Pothwar Plateau with a drainage area of 11,085 km^2 (55% of the Pothwar area).

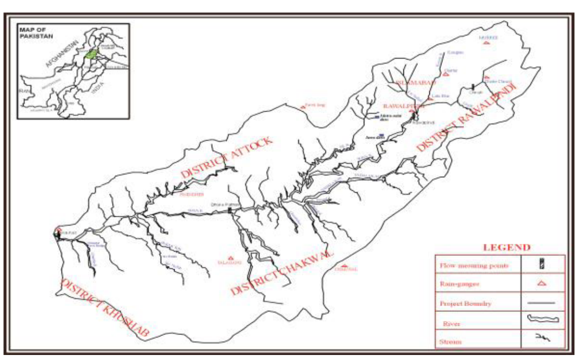

Fig. 1. Location map of the Soan basin

The basin falls between latitude 32° 45' to 33° 55' north and longitudes 71° 45' to 73° 35' east and is bounded by Haro basin, Murree-Jhelum Section, Pind Sultani and Makhad areas Fig. 1. The area falls in the districts of Attock, Chakwal, Khushab, Rawalpindi, and Islamabad having semi-arid to sub-humid climate with hot summers and cold winters except Murree, which has a humid climate. The average annual rainfall in the area varies from 250 mm to 1800 mm, the maximum in the north and minimum in the south-west. In the north-eastern parts of the area, the temperature falls below the freezing point from December to February, whereas in the western parts, the temperature is quite high in summer. However, the winter is relatively mild. The area has a complex geologic history of mountain-building, alluvial and loessial deposition and erosional cycles. The north-eastern part of the basin is covered by Himalayan foot-hills whereas the southern boundary is marked by salt range. The rest of the basin is formed by high upland Plateaue. The Soan river, a left bank tributary of the river Indus, drains most of the area. Almost all of its flow is generated within its boundaries forming a monsoon fed stream with a minor contribution from snow-melt and return flow. The Soan river originates in the south-western range of the Murree hills, flowing through hills, it enters the plains. Flowing in the south-west direction, it joins the river Indus at about 16 km upstream of Ka1abagh. Table I and II show the major perennial tributaries of the Soan river and the areas of the basin, respectively. The occurrence of groundwater in the area, as elsewhere, is controlled by climatic and geological conditions. Precipitation is the ultimate source of groundwater recharge, either taking place by direct infiltration or by lateral percolation from streams. The lithology varies significantly across the space and generally consists of alternate layers of clay, sand, and gravel with different combinations and depths. The depth of permeable material varies significantly from 7 to 174 m with an average of 64 m. The aquifer discharge varies from 0.016 to 0.6 lps, with an average of 0.19 lps. The permeability varies from 9.1 x 10^{-7} to 6.4 x 10^{-5} m/sec with an average of 1.22 x 10^{-5} m/sec, and the porosity varies from 4 to 42% with an average of 38% [16]. Agriculture is the main economic activity of the inhabitants having more than 60% rural population. The principal crops are wheat (*Triticum aestivum*), maize (*Zea mays*), sorghum (*Sorghum bicolor*), barley (*Hordeum vulgare*), moong (*Vigna radiate*), masoor (*Lens culinaris*), groundnut (*Arachis hypogaea*) and fruits such as citrus (*Citrus aurantium*), olive (*Olea euopaea*), and guava (*Psidium guajava*). The soils are generally fertile however, undulating topography, high spatial and temporal variability of rainfall are the major limiting factors in agriculture and socio-economic development.

TABLE I
MAJOR TRIBUTARIES OF THE SOAN RIVER

Left Bank Tributaries		Right Bank Tributaries	
S.No.	Name	S.No.	Name
1	Ling River	1	Korang River
2	Pane and Nala	2	Sil-I (Fatehjang Sil)
3	Ghambhir River	3	Sil-II (Pindi Gheb Sil)
4	Ankar Kas	4	Lei Nullah
5	Leti Nala		
6	Gabhir River.		

Source: [16].

TABLE II
AREAS OF THE SOAN BASIN

S.No.	City	Total area (km^2)	Area in the Soan basin (km^2)	Area in Soan basin (%)
1	Islamabad	906	720	79.5
2	Rawalpindi	1682	1682	100
3	Kahuta	1096	388	35.4
4	Kotli Satian	304	276	90.6
5	Murree	434	221	50.9
6	Gujar Khan	1457	300	20.6
7	Chakwal	3120	1696	54.4
8	Talagang	2932	2701	92.1
9	Pindi Gheb	1865	1865	100.0
10	Jand	2043	321	15.7
11	Fateh Jang	1249	145	11.6
12	Khushab	4011	771	19.2

2.1 Data Collection

The groundwater data in terms of water-table fluctuation provide information about recharge and abstraction of the area. There is however, no permanent system in the basin to monitor the groundwater. The basin was divided into grids of 7 km x 7 km and 193 groundwater monitoring points were selected (at least one in each grid), including open wells, tubewells and hand pumps, depending upon the topographic and hydrologic features of the area. The locations of these points were marked by Global Positioning System (GPS) and the water table was recorded with a water-table recorder from 2003 to 2006. Reference [16] carried out monitoring of water table in the basin from 1976 to 1981 by selecting 127 open wells. These water-table data were used as benchmarks for the present study. The primary data were collected from the field and secondary from various agencies working in the area. The daily rainfall data were collected from nine stations; seven being operated by Irrigation and Power Department, one by Pakistan Meteorological Department and one by Water Resources Research Institute (WRRI), National Agricultural Research Council. The long-term historical record was also available at these stations. The data were analyzed to determine the trends of rainfall over the years as well as in different parts of the basin. The discharge data were collected from Water and Power Development Authority (WAPDA).

III. RESULTS AND DISCUSSIONS

3.1 Groundwater Status

The groundwater contours (water level above mean sea level) show that the groundwater flow follows the topography of the area as well as the drainage pattern Fig. 2.

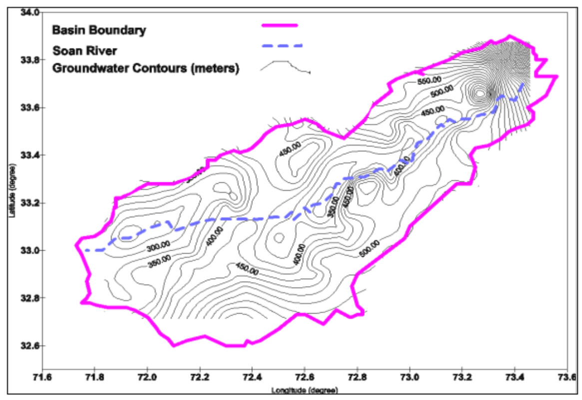

Fig. 2. Groundwater levels and flow behaviour in the Soan basin

The water table varies significantly in the basin and may be categorized in five different zones Fig. 3.

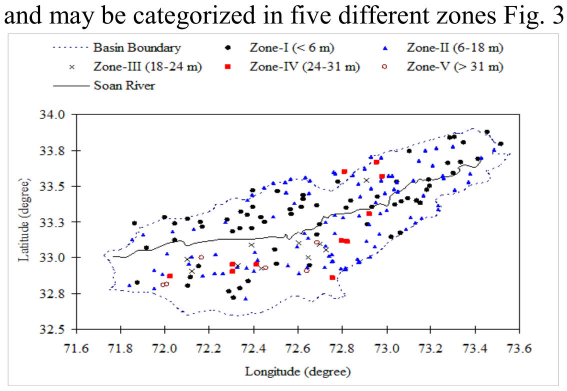

Fig. 3. Zoning of groundwater in the Soan basin after monsoon 2004

The Zone-I consists of shallow wells having water table within 6 m. The zone occupies about 34% of the monitoring points and are scattered all over the basin. However, these points are mostly near the main river and its tributaries or in the vicinity of recharge sources such as dams and ponds. The groundwater is pumped mostly by centrifugal pumps. In Zone-II, the water-table depth varies from 6 to 18 m, comprising about 53% of the monitoring points. These groundwater sources are generally located away from the main river and are scattered near the basin boundary. Rawalpindi and Islamabad also fall in this zone. In Zone-III, the water table varies from 18 to 24 m and is mainly located in tubewell pumping areas. The water-table depth in Zone-IV is from 24 to 31 m, mostly pumped with tubewells. This zone extends towards basin boundary and south-western parts, including Pindi Gheb, Talagang and Chakwal. The wells having water-table depth more than 31 m are in Zone-V, which are mainly located on the western side of the basin. The maximum water-table depth of 61 m has been recorded in this zone. The water-table data measured through 127 open wells, monitored by the WAPDA in 1981 [16] were also analyzed. Fig. 4 shows that the groundwater level varies over the entire area and may be categorized into three zones.

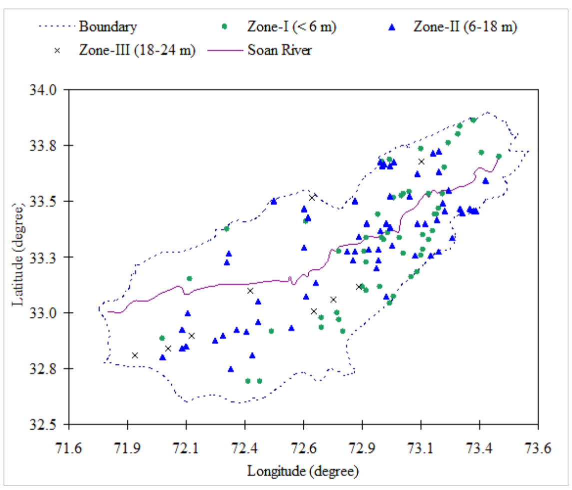

Fig. 4. Zoning of groundwater in the Soan basin after 1981

In Zone-I, the water table lies within 6m depth and about 41% of the monitoring points fall in this zone. These sources are mainly located near the rivers, in the upper parts of the basin, and a few in the south-western areas. About 50% of the monitoring points had water table within 6-18m depth (Zone-II). These sources were scattered over the entire basin, most of these are located near the river. Zone-III represents the water table up to 24m depth. These points were located in Rawalpindi, Islamabad, and south-western areas. The maximum water-table depth observed in 1981 was 24m towards the south-western boundary, whereas in the present study, it is up to 61m depth, indicating a significant water-table decline in the basin.

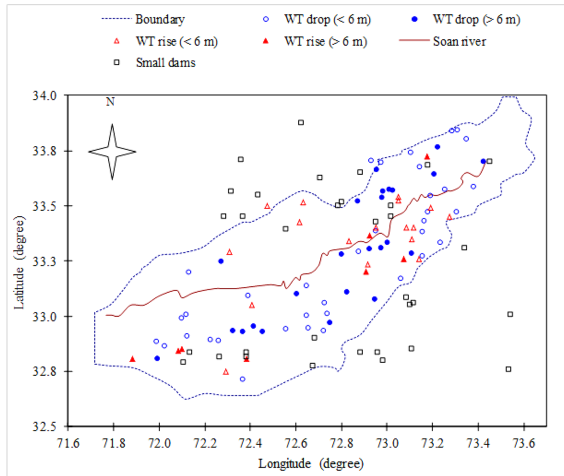

Fig. 5. Groundwater behaviour (depletion and rise) in the Soan basin (WT: water table)

Many studies in different parts of the world have shown that the groundwater exhibits significant spatial and temporal variability relative to other water-cycle variables [23], [24], [25]. A comparative analysis of the water tables in the years 2004 Fig. 3 and 1981 Fig. 4 shows significant changes during the last two decades Fig. 5. In some areas, the water table has dropped significantly being close to the basin boundary and being away from the recharging sources (river, dam etc.) such as Talagang, Chakwal, and most parts of Rawalpindi and Islamabad. The average drop observed during the first two years of monitoring i.e. 2003 and 2004, is more than 0.40 m. The major areas of depletion are under tubewell pumping such as Islamabad and Rawalpindi, where more than 300 tubewells are pumping water. Similarly, due to significant water-table drop in southern-western part of the basin, there is an increasing trend for the installation of deep wells to meet water requirements. [22] and [26] also indicated that the water table dropped by 12.5 to 23 m in Rawalpindi and by 10 to 20m in Islamabad. However, in areas where rainwater harvesting activities were implemented, a rise in groundwater level has also been observed [18], [21]. The water table recorded in 1981 and from 2003-2006 is given in Fig. 6.

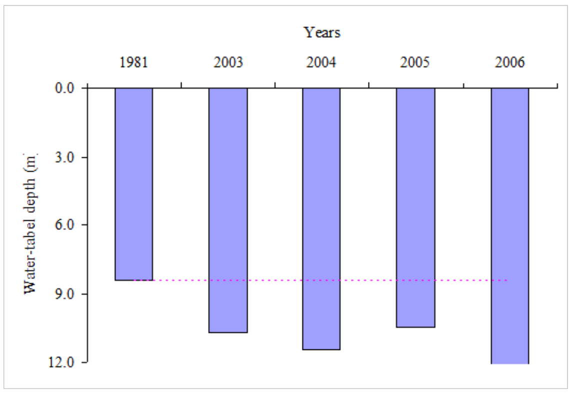

Fig. 6. Average water-table behaviour in the Soan basin from 1981 to 2006

The water-table decline in the basin is 3.75 m over the last 25 years showing an average drop of 0.15m per year. However, in some areas, the drop is more than 6m. This may be attributed to the changing rainfall pattern and continuous increase in abstraction rate due to growing population and urbanization.

3.2 Rainfall Pattern in the Study Area

A detailed knowledge of the rainfall behaviour, in both time and space, is vital for better design and planning of water resources development and management activities as well as conservation of moisture in the soil. The average monthly rainfall pattern was studied from 1960-2005 by dividing the data in two periods i.e. 1960-80 and 1981-2005. The reason for this fragmentation is the significant development in socio-economic conditions that took place in the later period. The monthly rainfall data at different stations from 1960-1980 and 1981- 2005 are given in Tables III and IV, respectively.

TABLE III
AVERAGE MEAN MONTHLY AND MEAN ANNUAL RAINFALL AT THE MONITORING STATIONS IN THE SOAN BASIN (1960-1980)

Stations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Murree	119	146	143	133	90	147	322	282	145	74	31	54	1685
Rawalpindi	55	78	79	49	47	59	233	263	93	24	18	32	1028
Fatehjang	30	49	56	35	23	33	195	221	47	14	12	25	738
Chakwal	30	37	50	32	33	30	147	133	51	15	9	18	583
Talagang	23	29	48	26	30	34	147	141	51	8	9	15	559
Kahuta	47	60	62	43	25	38	175	203	75	18	12	22	781
Pindi Gheb	26	30	47	33	23	27	121	73	43	12	8	17	459
Tamman	17	17	29	12	10	13	75	83	11	12	8	5	291
Lawa	13	15	15	19	9	18	63	70	20	15	5	5	267
Minimum	13	15	15	12	9	13	63	70	11	8	5	5	267
Maximum	119	146	143	133	90	147	322	282	145	74	31	54	1685
Average	40	51	59	42	32	44	164	163	59	21	12	21	710
Standard deviation (±)	32	41	37	36	25	41	80	82	41	20	8	15	438

TABLE IV
AVERAGE MEAN MONTHLY AND MEAN ANNUAL RAINFALL AT THE MONITORING STATIONS IN THE SOAN BASIN (1981-2005)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Murree	29	44	128	122	69	102	300	261	115	76	34	27	1307
Rawalpindi	52	80	83	51	28	61	257	307	94	29	12	32	1088
Fateh Jang	43	71	75	50	28	43	184	209	85	29	12	26	854
Chakwal	22	30	41	42	14	14	63	91	53	18	5	16	411
Talagang	29	46	60	28	24	45	101	96	57	15	5	24	531
Dhoke Chiniot	63	92	98	64	34	64	296	274	119	50	29	57	1241
Chattar Bagh	76	104	110	88	42	87	348	367	128	46	23	48	1466
Lohi Bher	57	92	78	58	24	65	226	294	100	37	13	46	1087
Makhad	42	54	87	57	39	35	97	126	54	28	18	22	659
Minimum	22	30	41	28	14	14	63	91	53	15	5	16	411
Maximum	76	104	128	122	69	102	348	367	128	76	34	57	1466
Average	46	68	84	62	34	57	208	225	89	37	17	33	960
Standard deviation (±)	18	26	26	28	16	27	102	100	29	19	10	14	367

There are high spatial and temporal variations of rainfall over the basin. About 70% rainfall occurs during the monsoon season (July to September) whereas rest falls in spring and winter seasons. Fig. 7 and 8 show a general trend of reduced rainfall in the later period i.e. 1981-2005, particularly for Chakwal, the trend of reduction in rainfall is pronounced from May to August. In Murree, the reduction in rainfall is more in the months of January and February as compared to other months. However, in Rawalpindi, an increase in rainfall is pronounced in the later period during the months of July and August, whereas in other months of the year, the rainfall is almost the same in both periods Fig. 9.

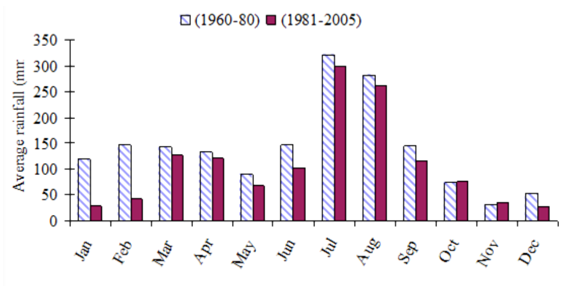

Fig. 7. Average mean monthly rainfall pattern at Murree

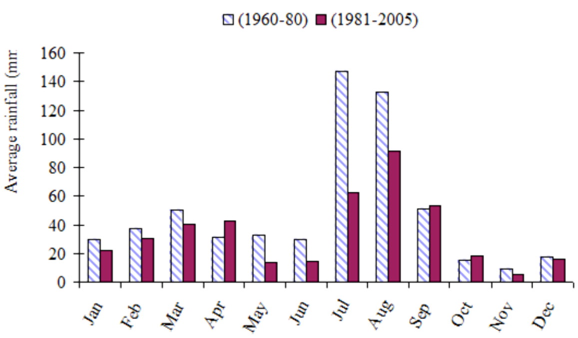

Fig. 8. Average mean monthly rainfall pattern at Chakwal

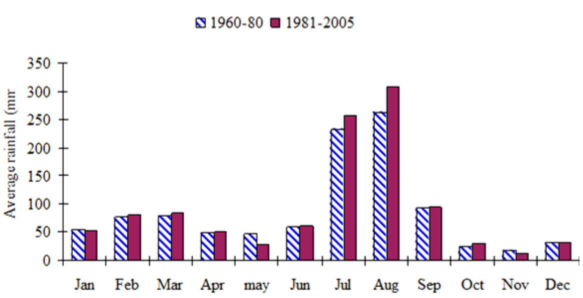

Fig. 9. Average monthly rainfall pattern at Rawalpindi

Fig. 10 and 11 show the long-term average annual rainfall at Murree and Chawkal during the two periods. At Murre (high rainfall area), the average rainfall from 1981-2005 is 366 mm less than the average rainfall of 1960-1980. However, at Chakwal, the reduction in average rainfall during the later period is 140 mm. The overall change in rainfall pattern over the entire basin Fig. 12 shows a decrease in rainfall in the south-eastern parts, especially in Murree (-38%), Chakwal (-29%) and Talagang (-5%) areas, and an increase in rainfall in the north-western parts i.e. Fatehjang (+18), Rawalpindi (+10%) and Makhad (+24%) areas. The change in rainfall pattern extends over the entire basin and may be attributed to population growth, urbanization, deforestation, and land use changes etc. The impacts of these changes are well reflected in the stream flows and resultant impact on groundwater resources.

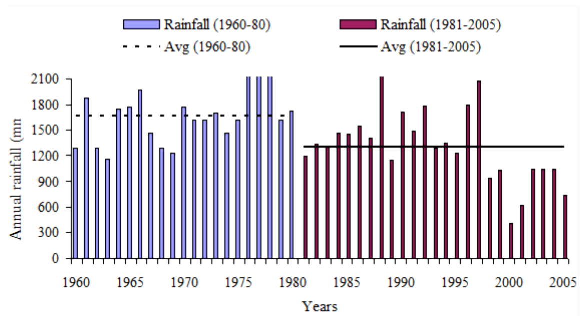

Fig. 10. Annual rainfall pattern at Murree from 1960-80 and 1981-05

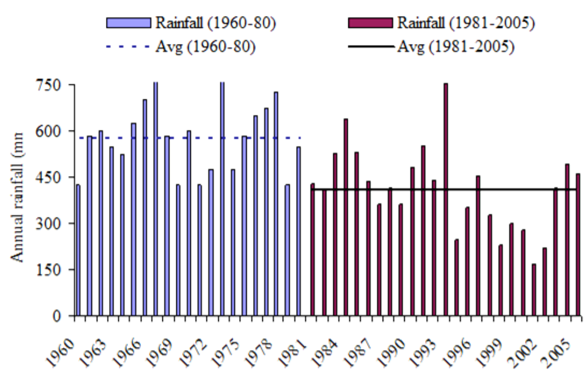

Fig. 11. Annual rainfall pattern at Chakwal from 1960-80 and 1981-05

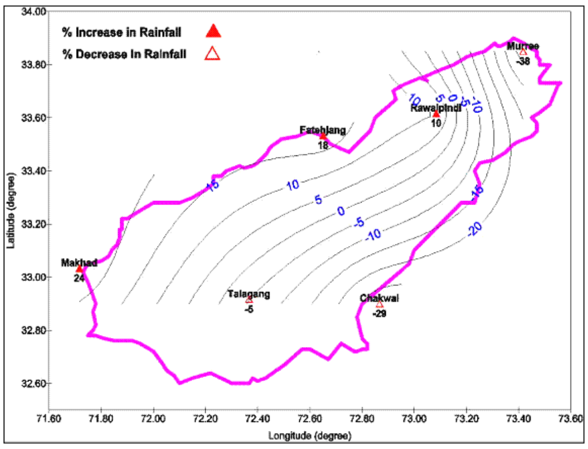

Fig. 12. Changes in rainfall pattern in the Soan basin from 1960-2005

3.3 Basin Inflow

The major stream draining the basin is the Soan river and several small streams and rivers, which join it before its confluence with the Indus river. The drainage basin is so formed that all runoff is generated within the boundaries of the study area, either through overland flow or stream base flow. The discharge measuring points were selected in a way to get maximum information about the runoff potential of the basin as well its various sub-basins. These points were Chirah, Rawalpindi, Dhoke Pathan, and Makhad which are located at 32, 64, 192, and 264 km along the length of the Soan river, respectively. The annual discharge at these points from 1960 to 2005 is given in Fig. 13. The long-term annual flow pattern at these stations shows that the flow rate increases as the river flows towards the basin outflow point. The mean annual discharge at Makhad varies from 38 to 228 m^3/sec.

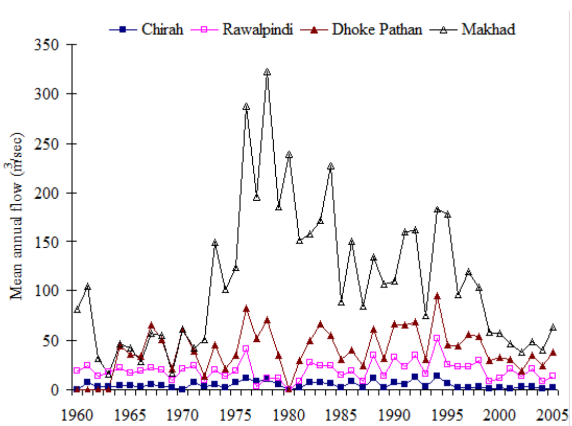

Fig. 13. Annual flow pattern at different sections of the Soan river

The flow at Makhad was the highest between 1975 and 1980, since then it is gradually decreasing mainly due to reduced rainfall and development of rainwater harvesting storages in the catchment.

3.4 Basin Outflow

The historical data on basin outflow were analyzed from 1960 to 2005. The mean annual outflow at Makhad, the basin outlet Fig. 14 shows that the discharge varies over the entire period with an average annual discharge of 109 m^3/sec, whereas the average annual runoff potential is estimated at 3.44 x 10^9 m^3.

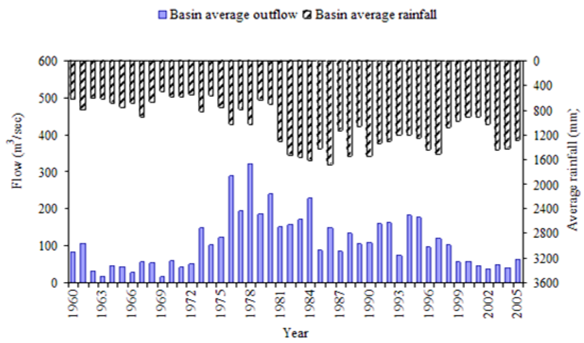

Fig. 14. Average annual rainfall and outflow of the Soan basin at Makhad

However, a continuous decrease in discharge has been observed especially after 1984 and the lowest outflow was observed during the last few years, which reached upto 50% of the average annual flow (average of 45 years). Although an increase in the basin rainfall is seen after drought period 1997-2000 however, there is no significant rise in the basin outflow. The reduced outflow and changing rainfall pattern has significant impacts on groundwater potential in the basin.

3.5 Rainwater Potential and Storage

On the basis of average annual basin outflow (109 m^3/sec), about 3.44 x 10^9 m^3 leaves the area every year, nearly 70% during the months of July to September. In order to utilize this rainwater, many water harvesting and water resources development activities have been carried out by various organizations. There are 32 small dams in the area with a storage capacity of 120 x 10^6 m^3, out of which 40% dams fall in the Soan basin with a storage capacity of about 80 x 10^6 m^3 (less than 3% of the total potential). Therefore, a large proportion of water is still being drained without any use. Similarly, Soil Conservation Department has constructed mini dams and ponds, mainly for agricultural uses, especially after 90s Table V.

TABLE V
Water resources development by the provincial agencies in Pothwar (Nos.) after 1990

Mini Dams	Ponds	Open wells	Hand Pumps	Tubewells	Lift pumps
1,000	1,100	2,163	1,722	159	979

Source: Sattar (personal communication, 2008)

The present storage capacity of mini dams in the basin is about 3.21 x 10^6 m^3. Due to construction of these dams and ponds, significant changes in cropping pattern took place in the area that further led to increased groundwater exploitation [18]. No significant increase in agricultural area however, occurred during the last twenty five years although some of the rainfed areas came under irrigation due to construction of small and mini dams as well as open wells. Most of the agriculture is practiced by traditional methods and is dependent on rainfall, as the developed storage facilities are not being utilized properly [18]. The development of housing societies during the last decade has been the major factor for limited agriculture development in the region.

3.6 Increased Groundwater Utilization

[16] reported that in 1981, the groundwater pumped through open wells and tubewells was 72 x 10^6 m^3. The groundwater utilization however, has now increased manifolds by installation of tubewells, open wells and hand pumps Table III. Moreover, large scale groundwater utilization activities have also taken place by the private sector. The participatory appraisal survey in the area has indicated that the number of tubewells, open wells and hand pumps have increased by 39, 185 and 96%, respectively during the last 25 years. The population increased from 2.49 million to 4.84 million during this period. The population and socio-economic activities that increased markedly during the 25 years, are heavily dependent on groundwater resources. As there is no groundwater regulatory framework in Pakistan, therefore, any farmer (mostly large farmers) can install any number of tubewells, anywhere, at any depth and can pump any quantity of water at any time. Due to indiscriminate installation of tubewells, the groundwater is depleting, resultantly increasing the tubewell installation and operational costs. In certain cases, the most commonly used centrifugal pumps become uneconomical due to increased water-table depth, making it inaccessible to every farmer. The small farmers therefore, have to depend on other farmers for purchase of water. They do not get water at the time of their need due to one or the other reasons. Moreover, the dugwells, which are mostly owned by small farmers, and are the sole source of water for their domestic use, and small-scale agriculture, are drying up, forcing the farmers, either to sell their land or fetch water from far away places. The mini dams and ponds have been constructed by the individual farmers with the financial assistance of the government. These can only be constructed by those farmers who can afford to spare land and can share the cost of construction (30% of the total cost). Mostly, the small and poor farmers are unable to avail such facilities. However, the small dams are constructed by the government completely. After construction, the government establishes the water rights (*warabandi*) for the farmers of the command area depending upon their land holdings, and charges them based on the area irrigated [18]. The projected estimates (at a growth rate of 1.9%) show that the population would double in the next 25 years and the water demand would increase accordingly Fig. 15.

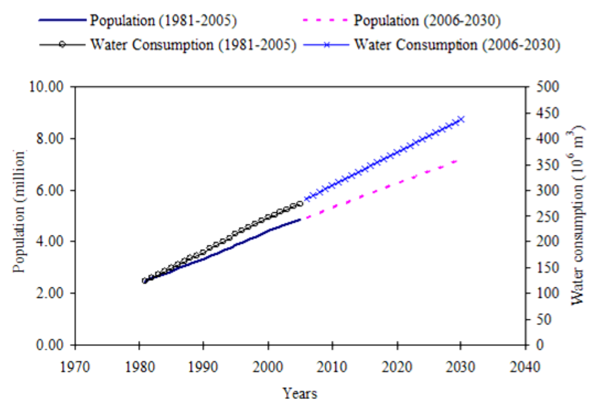

Fig. 15. projected population growth and drinking water demand

The maximum increase in population would be in Islamabad and Rawalpindi cities (heavily urbanized areas), accommodating about 52% of the basin population in 12% of the geographical area. The groundwater is mainly being used for domestic and agricultural purposes followed by livestock, poultry and industry. About 50% of human water demand is being met from groundwater, 47% from dams and 3% from springs. Since surface water resources are mostly unsuitable for human consumption due to various contaminants such as agricultural chemicals, animal and human waste, therefore, the groundwater is the only sources for potable water.

According to the assessment survey in 1981 [16], the sustainable usable potential of the groundwater in the basin was 99 x 10^6 m^3 against the then annual use of 74 x 10^6 m^3. Considering a water table drop of 3.75 m since 1981 and construction of open wells, hand pumps and tubewells Table V associated with about 95% population increase Fig. 15, it may be concluded that the present status of groundwater utilization in the area is beyond its sustainable limit.

To plan proper exploitation, management and utilization of water resources in a rational way, proactive administration of future groundwater depletion is essential [27]. [28] sees high potential in local groundwater management, in addition to other measures that regulate groundwater. A regular groundwater monitoring system however, is very important. This will help identify the most depleting zones and to plan remedial measures accordingly.

IV. REMEDIAL MEASURES

Sustainable groundwater management requires a balance between recharge and abstraction. This can be achieved by enhancing the groundwater recharge through rainwater harvesting (construction of small and mini dams etc.), soil and water conservation measures, watershed management activities etc. and by adopting high efficiency irrigation systems such as drip and sprinkler.

4.1 Rainwater harvesting

There are many suitable sites in the area where small dams could be constructed. The government of Punjab has constructed 32 small dams in the regions and 19 more are under construction. These dams could irrigate more than 1470 ha, in addition to meeting the domestic and livestock needs. Besides supplying water for irrigation, these dams have many indirect benefits such as; recharge the groundwater, provide water for domestic and municipal purposes, control floods and soil erosion, develop fish culture, and also provide recreational activities [18]. Low-lying areas of the Pothwar Plateau also contain many perennial and non-perennial channels. Mini dams/ponds may be constructed every few kilometers to cut off these channels and to collect some low-lying surface flow. These dams also act as delay action dams and fulfill the purpose of check dams. Mini dams/ponds are generally earth filled with masonry control structure and spillway.

4.2 Watershed management

A major feature of watershed management is the construction of contour bunds/trenches and the plantation of appropriate plant species within the catchments. This reduces the rate of runoff by trapping and delaying the water, some of which is taken up by the plants, consequently reducing the level of silt carried in the overland flow. The watershed management practices also enhance recharge to the groundwater aquifer by increasing infiltration.

4.3 Soil-water conservation

The occurrence of rainfall in the area is quite erratic and its spatial and temporal variation is very high. Several options are available to conserve and to efficiently utilize the moisture depending upon the frequency and intensity of rainfall, topography of the area, soil type, and crops grown etc. Retention of rainfall as soil moisture mainly depends on the infiltration characteristics of the soil, opportunity time, the moisture storage capacity of the soil, soil surface conditions, vegetative cover and land slope. In general, all cultural practices which reduce runoff and erosion result in increased storage of the soil moisture. Contour farming, strip cropping and conservation tillage are important mechanical practices employed to store soil moisture.

4.4 Improving irrigation efficiency

Another way to reduce the stress on the groundwater is to improve the efficiency of the irrigation system. Presently, the farmers use obsolete methods of irrigation resulting in poor application and distribution efficiencies. The most of the barani areas are undulated and e most of the irrigation systems are surface or gravity systems, which typically have efficiency less than 50%. This means that less than 50% of the water applied to the field is used by the crop, while more than 50% is lost by surface runoff, evaporation, and deep percolation of water that moves through the root zone. Therefore, gravity irrigation is not feasible in these areas. Moreover, cost of pumped water is quite high and the available water is not only inadequate but is also unreliable. Therefore, this scarce resource should be utilised most judiciously and efficiently.

The sprinkler and drip irrigation techniques have been successfully introduced in Pakistan, and are particularly well suited to such water scarce barani (rainfed) areas. The higher cost of these systems is justified through associated production of high value vegetable and orchard crops. Application efficiencies can be very high, in the order of 75 to 90%, permitting almost full use of the scarce available water supplies. An additional advantage as compared with surface irrigation is that, efficient irrigation can be carried out even where topography is undulated and soil is of light texture, as is the case in most of the barani areas. However, an integrated approach is required to harness the maximum rainwater and to minimize the groundwater use.

V. CONCLUSIONS

Large scale water resources development and exploitation have taken place in the Soan basin associated with about 95% increase in population during the last 25 years. The long-term rainfall data 1960-2005 have shown that rainfall pattern over the basin is changing and the basin rainfall and outflow is decreasing particularly after 1984. Although after drought period 1997-2000, the rainfall situation improved but no significant rise in basin outflow is observed. The utilization of groundwater has increased for domestic and agriculture purposes followed by livestock, poultry and industry. The increased use of groundwater associated with changing rainfall pattern and declined basin outflow, have resulted in drop of water table. On an average, the water table has dropped by 3.75 m in the basin from 1981-2006 with an average drop of 0.15 m per year. However, in the areas away from river and recharge sources, the water-table drop is much higher mainly due to installation of deep wells. Therefore, the present groundwater abstraction is beyond its sustainable level. In the areas, where rainwater harvesting/storage activities were carried out, water table has raised leading to development of more number of open wells, tubewells and hand pumps. On an average, the annual rainwater potential of the basin is 3.44×10^9 m^3, whereas only 80×10^6 m^3 (less than 3%) could have been harnessed so far through small/mini dams and ponds. There is need to harness the maximum rain water through integrated water resources management approaches. This would not only contribute to groundwater recharge in the basin but would also supplement the water supplies to meet future water demand for various uses.

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Reduction of Color Images using Averaging Functions

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***Abstract*-**In this paper, a color image reduction algorithm is implemented that makes use of averaging functions to reduce the images without decomposing them to RGB channels. Penalty functions are used to find out the most optimal averaging function that provides least error between original and reconstructed image. Simulation results show that the implemented algorithm reduces the size of the color images so that can be transmitted at low cost. The average values of MSE, MAE and SSIM in case of reduction of the 12 test images used our simulations are 250.73, 8.47 and 0.7217 respectively. Moreover, this scheme also does well when the test image is corrupted with noise.

***Keywords*-**Averaging Functions, Image Reduction, Penalty Functions, Noise Reduction, Subsampling.

I. INTRODUCTION

Image reduction is an area of considerable importance in the field of image processing. Reduction is the process of changing the resolution or dimensions of the image to make it smaller in size, while keeping as much information as possible. Image reduction can be used to accelerate computations on an image or just to reduce the cost of its storage or transmission. It is a frequently performed operation in computer graphics, multimedia and electronic publishing [1].

Image reduction can be carried out by many methods. These methods can be divided in two groups. In the first group, the image is divided into blocks. The reduced image is made by combining the results of the algorithm in each block. For the second group, the image is considered in a global way [2], [3].

It means that it is treated as a whole. In the scheme implemented in this paper, the first group of algorithms (i.e. local algorithms) has been focused. Simple reduction algorithms can be designed working with small pieces of the image. When the reduced images are reconstructed, there exists some error between reconstructed and original image. The implemented scheme will provide image reduction using averaging functions such that the error between original and reconstructed images is minimum.

II. IMAGE REDUCTION TECHNIQUES

The most basic image reduction techniques are provided in this section. Their brief description is given as under:

A. Cropping

Cropping is the simplest way by which the size of an image can be reduced. It is useful only where a certain portion of an image is important enough to use. The rest of the image is discarded. The data loss caused by cropping cannot be retrieved. But uncropping is possible in two cases:

- Original copy of the image is safe
- Undo information is not deleted

B. Scaling

Scaling is also termed as Resizing. It is mainly concerned with number of pixels per inch (ppi) when the image is printed on paper. Scaling does not change the resolution of the image. It only shrinks or expands the pixels. So the image is not actually small rather it appears to be small. If the image is scaled to be enlarged, the pixels become increasingly visible, making the image appear soft if pixels are averaged or jagged if not averaged [4], [5].

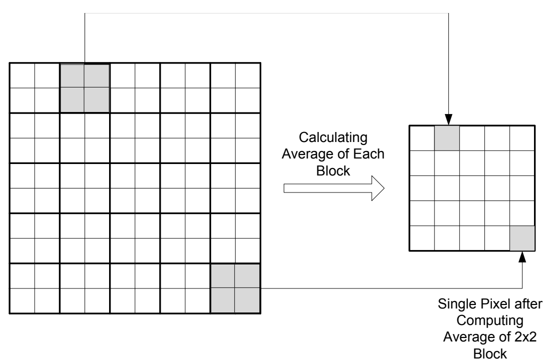


Fig. 1. Simple Image Reduction using Averaging Functions

C. Pixel Skipping/Subsampling

Pixel skipping or subsampling can reduce the size of an image by deleting pixels evenly throughout an image. For example, if an image is to be reduced by half in each dimension, every other row and column of pixels in the image must be deleted. This method is fast but it produces artifacts especially in color images [6]. It produces checkerboard effect in images when a higher order of reduction is to be achieved.

D. Pixel Averaging

The averaging functions (i.e. arithmetic mean, geometric mean, etc.) can be used for image reduction in such a way that original image is divided into blocks and each block is replaced by its average. For example, if an image is divided into 2x2 blocks as shown in Fig. 1, then computing average of each block will reduce the size of original image to one half [7]. For 3x3 blocks, size of the image will be reduced to one third of the original image.

III. AVERAGING FUNCTIONS

There are several types of averaging functions that are used in image processing. A few of these functions are:

A. Arithmetic Mean

The arithmetic mean is commonly known as *mean* or *average*. For a set of samples $\{x_i\}$, the arithmetic mean $\bar{x}$is calculated as:

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad (1)$$

Arithmetic mean smoothes local variations in the images. It also reduces the noise by blurring the image.

B. Geometric Mean

The geometric mean of a sequence $\{a_i\}_{i=1}^{n}$ is given as:

$$G(a_1, \dots, a_n) = \left(\prod_{i=1}^{n} a_i\right)^{1/n} \qquad (2)$$

It means that,

$$G(a_1, a_2) = \sqrt{a_1 a_2} \qquad (3)$$

$$G(a_1, a_2, a_3) = \sqrt[3]{a_1 a_2 a_3} \qquad (4)$$

and so on. Geometric mean achieves more smoothing effect in images as compared to the arithmetic mean, but it tends to lose image detail in the process.

C. Harmonic Mean

The harmonic mean $H(x_1, \dots, x_n)$ of n numbers x_i (where i=1,....., n) is the number H defined by:

$$\frac{1}{H} = \frac{1}{n}\sum_{i=1}^{n} \frac{1}{x_i} \qquad (5)$$

The special cases of n=2 and n=3 are given as:

$$H(x_1, x_2) = \frac{2x_1x_2}{x_1 + x_2} \qquad (6)$$

$$H(x_1, x_2, x_3) = \frac{3x_1x_2x_3}{x_1x_2 + x_1x_3 + +x_2x_3} \qquad (7)$$

and so on. The harmonic mean provides good results for salt noise and Gaussian noise, but fails in case of pepper noise.

D. Maximum

The largest value of a set or function is termed as *maximum*. The maximum of a set of elements $A = \{a_i\}_{i=1}^{N}$ is denoted as $maxA$ or $max_i a_i$, and is equal to the last element of a sorted (ordered) version of A. For example, given the set {3,5,4,1}, the sorted version is {1,3,4,5}, so the maximum is 5.Maximum selects the brightest pixel in each block. So, as a result, the reduced image is brighter than the original image.

E. Minimum

The smallest value of a set or function is termed as *minimum*. The minimum of a set of elements $A = \{a_i\}_{i=1}^{N}$ is denoted as $minA$ or $min_i a_i$, and is equal to the first element of a sorted (ordered) version of A. For example, given the set {3,5,4,1}, the sorted version is {1,3,4,5}, so the minimum is 1. The maximum and minimum are the simplest order statistic functions. Minimum selects the darkest pixel in each block. So, as a result, the reduced image appears to be darker than the original image.

F. Median

Median is an order statistic function that gives the *middle* value $\tilde{x}$ of a sample. It means that the value $\tilde{x}$is such that an equal number of samples are less than and greater than the value (for an odd sample size), or the average of the two central values (for an even sample size). For example, for data set {1,2,3,4,5}, median is equal to 3. Similarly, for data set {1,2,3,4,5,6}, median is equal to 7/2=3.5. Median is frequently used in image processing because it provides reduction in certain types of noises. Median filters have been used in the rovers in Mars in both navigation and science tasks.

G. Mode

Mode is the most common value obtained in a set of observations. For example, for a data set {3, 7, 3, 9, 9, 3, 5, 1, 8, 5}, the mode is 3. Similarly, for a data set {2, 4, 9, 6, 4, 6, 6, 2, 8, 2}, there are two modes: 2 and 6. A data set with a single mode is said to be unimodal. A distribution with more than one mode is said to be bimodal, trimodal, etc.

IV. METHODOLOGY

In the color image reduction algorithm implemented here, a number of different averaging functions are used. A color image is divided to *n*x*n* blocks.

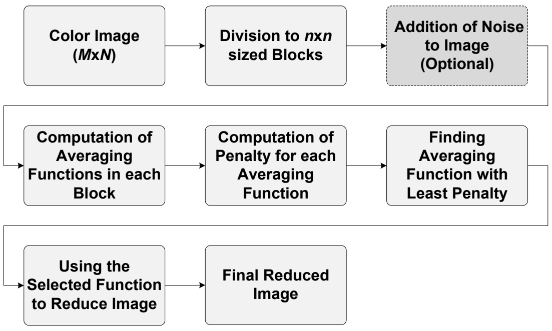


Fig. 2. Block Diagram of the Reduction Algorithm

The scheme mentioned in [7] splits the image to R, G, and B channels before applying the aggregation functions but this reduction algorithm does not do that. The averaging function that minimizes the penalty function is selected. Penalty function used in the reduction algorithm is given below:

$$P(x,y) = \sum_{i=1}^{n}\sum_{j=1}^{n}\left(|x_{Cij} - y_C|\right)^2 \tag{8}$$

This reduction algorithm does not have to decompose the image and then concatenate it at the end. Moreover, instead of 5 averaging functions (Arithmetic Mean, Geometric Mean, Maximum, Minimum and Median), 7 aggregation functions have been utilized including Harmonic Mean and Mode. A block diagram of implemented algorithm can be found in Fig. 2.

V. SIMULATION RESULTS

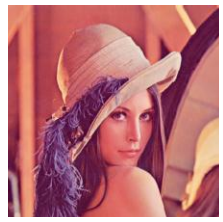
Twelve different color images (standard and common) were tested in MATLAB R2011b using reduction algorithm of color image reduction. All the test images are in TIFF and JPEG format and have different resolutions. Parameters of analysis are MSE, MAE and SSIM to compare original and reconstructed image [8]. The standard images used here can be found at http://www.imageprocessingplace.com/root_files V3/image_databases.htm.

A. Reduction Algorithm

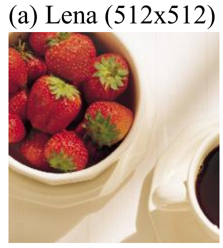
Fig. 3 shows test color images that are to be reduced. The images have different resolutions but they are scaled such that they *appear* almost equal in size. Fig. 4 gives reduced images and Fig. 5 gives reconstructed images. Table I provides MSE, MAE and SSIM [9] to check the quality of reconstructed images.

B. Response to Noise

This reduction algorithm responds greatly if the original image has been corrupted by salt and pepper or speckle noise. The averaging functions, especially arithmetic mean, geometric mean and median are known for removing the noise from images leaving them with a blurring and smoothing effect [10].


(a) Lena (512x512)


(b) Madril (512x512)


(c) Strawberries (664x664)


(d) Peppers (384x512)


(e) Library (360x480)


(f) Flowers (312x420)


(g) Chalk (1040x1040)


(h) Fruit (576x768)


(i) Balloons (548x548)


(j) Candy (852x1280)


(k) Grapes (576x768) (l) Berries (1068x1600)

Fig.3. Original Test Images

Fig. 6(a) shows the image corrupted with salt & pepper noise. Fig. 6(b) and Fig. 6(c) show the reduced and reconstructed images using subsampling and implemented algorithm. Similarly, Fig. 6(d) shows the image corrupted with speckle noise. Fig. 6(e) and Fig. 6(f) show the reduced and reconstructed images using subsampling and implemented algorithm.

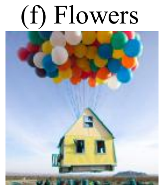


(a) Lena (b) Madril (c) Strawberries

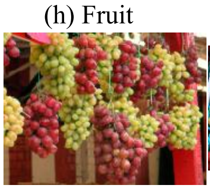


(d) Peppers (e) Library (f) Flowers





(g) Chalk (h) Fruit (i) Balloons


(j) Candy (k) Grapes (l) Berries

Fig. 4. Reduced Images (n=4)

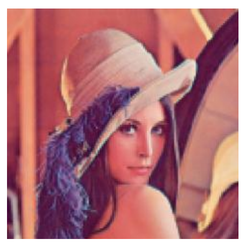
TABLE I

ERRORS AND STRUCTURAL SIMILARITY

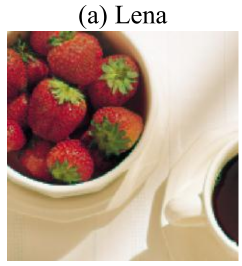
Image	MSE	MAE	SSIM
Lena	131.61	6.55	0.7685
Mandril	623.45	17.87	0.4381
Strawberries	122.96	4.96	0.7976
Peppers	81.28	4.34	0.8606
Library	470.63	10.79	0.6632
Flowers	203.02	6.69	0.8296
Chalk	135.75	6.03	0.7592
Fruit	282.02	10.40	0.6661
Candy	359.84	12.62	0.5432
Balloons	162.09	4.95	0.8618
Grapes	206.51	8.34	0.7323
Berries	229.64	8.14	0.7409

VI. CONCLUSIONS

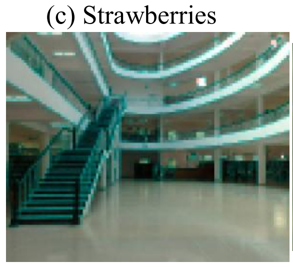
The main purpose of this paper is to use the aggregation functions for color image reduction. In this context, an image reduction algorithm based on averaging and penalty functions has been implemented. This reduction algorithm is compared with the most commonly used image reduction method i.e. subsampling. It is found that reduction algorithm implemented in this paper is better for color image reduction. The implemented method efficiently filters out the speckle and salt & pepper noise from the images.




(a) Lena (b) Madril



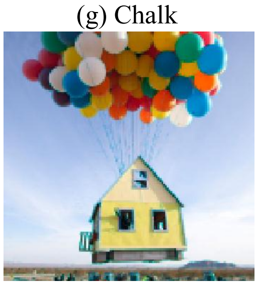

(c) Strawberries (d) Peppers




(e) Library (f) Flowers

(g) Chalk

(h) Fruit



(i) Balloons

(j) Candy

(k) Grapes

(l) Berries

Fig. 5. Reconstructed Images

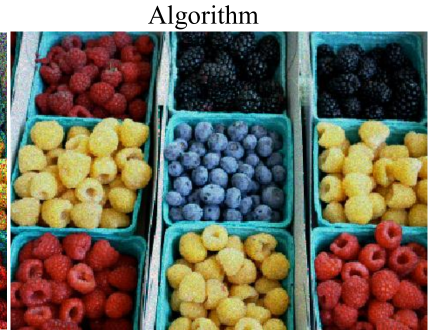
(a) Image with Salt & Pepper Noise

(b) Result of Subsampling

(c) Result of Implemented Algorithm

(d) Image with Speckle Noise

(e) Result of Subsampling



(f) Result of Implemented Algorithm

Fig.6. Response to Noise

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Investigation of Groundwater Quality for Irrigation in Karak District

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***Abstract*-**Groundwater is one of the important resources for irrigation in many parts of the world. The contamination of groundwater and lack of parity between groundwater extraction and recharge has posed a serious threat on its use. It is due to deteriorating groundwater quality and depleting water table. The purpose of this research is to investigate the groundwater for irrigation qualitatively and quantitatively for Karak District. Public awareness and economic prosperity of the people in this district is also aimed.

To serve this end, 24 groundwater samples were collected for determining the concentration of major ions like Sodium (Na), Potassium (K), Magnesium (Mg), Calcium (Ca), Carbonate (CO3) and Bicarbonate (HCO3). Commonly used parameters like Sodium Absorption Ratio (SAR), Soluble Sodium Percentage (SSP), Residual Sodium Carbonate(RSC), Permeability Index (PI), Magnesium Absorption Ratio (MAR) and Kelly's Ratio (KR) were determined for assessment of groundwater quality for its use in irrigation.. Secondly, the crop-water need was also calculated using software CropWat 8.0 for windows to ensure sustainable use of groundwater for irrigation. Rainfall, cropping pattern, crop intensity, soil type and humidity data was collected for this purpose.

The results of irrigation water parameters show that the groundwater is suitable and sustainable for its use in irrigation in Karak District if certain measures like creation of organizational setup and sustainable management are taken to handle the problems.

***Keywords*-**Irrigation, parameters, Groundwater, Karak, Index, CropWat

I. INTRODUCTION

Land degradation and other environmental problems have resulted due to excessive use of groundwater [1]. Wells are going out of range owing to the fact that water level is lowered a lot that has made pumping expensive. These problems took place because the exploration of wells exceeded the management of groundwater [2]. The groundwater is deemed fit if plants and animals do not affect due to mineral constituent of the water [3]. Salts damaged plants physically and chemically. The physical damage is done by limiting growth of plants by osmotic process and chemically by the effect of hazardous substances through metabolic processes. Developing countries could not develop management of groundwater owing to numerous reasons [4]. The situation is further aggravated by secondary salinization that is tied with the use of poor quality water [5]. Soils are largely affected by salts that have characterized the ecology of Indus Basin. These problems have threatened the use of groundwater for agriculture. The lack of information is a major impediment in the way of groundwater management. Also the information relating to various variables like withdrawal quality, water availability and ground are nonexistent. Keeping the statistics of groundwater is a first step in managing the groundwater [6]. Number of tube wells their utilization facts and total groundwater pumped is listed in different estimates that exist in Pakistan [4]. The depletion of water table takes place in Khyber Pakhtunkhwa and Baluchistan. 1% of GDP needs to be spent on water resources in Pakistan to avoid worse situation. The current spending on GDP 0.25% is deplored by the World Bank.

This paper is aimed to investigate groundwater in Karak and analyze its suitability for irrigation in district Karak. This study is associated with the qualitative analysis of groundwater and quantitative analysis of water needs of crops with respect to irrigation. The chemical evaluation is aided by statistical analysis to help evaluate the groundwater chemistry. In addition to that, groundwater quality is affected by irrigation and to protect and evaluate groundwater, it is necessary to unearth the hydrochemical characteristics of groundwater. In order to evaluate the groundwater quality, 24 samples were examined and ionic concentration of Sodium, Calcium, Potassium, Magnesium, Carbonate and Bicarbonate were found. It is followed by the application of irrigation water parameters to check it for normality. The crop water requirements (CWR) were also determined to know whether amount of water required for crops is provided or insufficient supply of water is in place. Besides that, being a semi-arid, the knowledge of CWR is needed to ensure full justice with sustainable irrigation. For that purpose temperature, relative humidity, wind speed, sunshine hours and rainfall were collected from district Karak.

A. Geography of Study Area

The district Karak has an area of 2650km² and comprises of three tehsils. Tehsils Banda Daud Shah has an area of 744 km², tehsils Karak has an area of 1050km² while tehsils Takht-e-Nasrati has an area of 856km² (see Map 1) The population is estimated as 610,000 according to Khyber Pakhtunkhwa development statistics and a population density of 230 persons per km².14% comprises urban population whereas 86% is rural population [7]. Sedimentary rocks, sandstone and salt rocks characterizes Karak valley. The rock formations consists of Chinji formation that consists of reddish shale and sandstone, Nagri formation consists of predominantly "sandstone with occasional shale beds, DhokPathan formation consists of sandstone, shale and conglomerates and Soan formation consists of reddish brown shale and brown sandstone. Northern side of the Karak district has an aquifer that is characterized by saline water.

B. Climate of Research Area

Karak has a varying precipitation and temperature seasonally with semi-arid situation. Temperature rises in summer and drops in winter. Average annual precipitation is 524mm. The months of June to November gives 70% precipitation whereas 30% precipitation comes in the months of December to May. Summer rains are of high intensity with short time period whereas winter season has low intensity rains with long periods. Summer is hot with monsoon in the month of May to June while winter is too cold owing to the western wind.

II. Materials and Methods

To conclude the groundwater elementalogyin the district Karak under natural conditions, 24 groundwater samples were obtained from shallow and deep wells/tube wells in the area. The concentration of chemicalionswas analyzed in the laboratory. A statistical relation of coefficients among different ions shown in Table V. The ionic concentration of Na, K, Ca, Mg, CO_3 and HCO_3 were determined in this regard besides determining PH concentration. Fig. 2-6 shows the ion scatter diagram for groundwater sample in this regard. The irrigation water parameters were calculated using (1)-(6) after the ionic concentration is found. The values of SAR, SSP, RSC, MAR, PI and KR after calculation were compared with FAO limits. The CWR was determined using CropWat 8 for windows after feeding rainfall, sun hours, humidity, wind, soil data etc. The results for irrigation water and rainfall contribution were achieved in this regard.

III. Results and Discussion

A. Physical Parameter and Ions Chemistry of Groundwater

In current hydrochemical research, 24 samples were collected and examined for physical and different chemical parameter like Na, Ca, K, Mg, CO_3 and HCO_3. PH is the measure of acidity or alkalinity of water and hence determines its suitability for irrigation purposes. The PH value was recorded for 24 samples in district Karak to determine the suitability of water. An abnormal value of PH may cause problems to irrigation equipment's like pipe corrosion and nutritional imbalance. The values are tabulated in the Table I and the recorded PH value revealed that the PH was found within the prescribed limit of FAO except few stations where it was above the prescribed limit Table IV.

The chemical parameters were checked against the desirable limits as prescribed by FAO. The desirable limits are also indicated in the Table IV along with statistical analysis to help examine and evaluate this hydrochemical analysis. The irrigation water quality determination is dependent upon the information on groundwater chemistry. That in turn leads to the application of irrigation water parameters. The results indicated that in most of the locations, groundwater is suitable for irrigation Table II.

Hydrochemical evaluation is also supported by statistical analysis to help examine the groundwater evaluation and display information. The correlation coefficient is shown in Table 5.; a linear relationship between two variables is measured by its direction and strength. A high positive correlation coefficient was found among Mg, CO_3, HCO_3, and Ca. A high positive correlation was also found between Na and K and between Ca and CO_3. Scatter diagram shown in Fig. 1-4 shows that the scatter diagram falls below the trend line (1:1). In scatter graph, it is showed that the metals are inducing close association among each other.

B. Irrigation Water Parameters

Various groundwater qualities parameters have been used to check the suitability of Groundwater for irrigation purpose. The chemical parameters are found and then a complete examination of groundwater takes place with irrigation water parameters that judge the water quality for irrigation. Various parameters, discussed earlier like Sodium Absorption Ratio (SAR), Soluble Sodium Percentage (SSP), residual Sodium Carbonate (RSC),Magnesium absorption ratio (MAR), Permeability Index (PI) and Kelly's Ratio (KR,) were calculated to find out the suitability of groundwater. The values of Groundwater quality parameters are shown in the Table III. The classification scheme shown in the Table II shows the percentage of samples in the safe zone or suitable for irrigation as per irrigation water quality criteria. All the measurements were taken in milliequivalent per liter (meq/l). The desirable limits along with statistical analysis are also shown in the Table IV displaying the information about Groundwater evaluation.

SAR is the measurement of effect of Sodium ion concentration relative to Calcium and Magnesium ions and it indicates the negative effects of these ions on soil. When the SAR value increases, it effects the soil aeration. The SAR values of all the 24 samples were calculated work shown in Table 3 using the (1), [5].

$$SAR= \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}} \qquad (1)$$

The minimum and maximum values of SAR are 0.30 and 7.37 meq/l with a mean value of 1.84 and SD (standard deviation) of 2.04. Its suitability was also checked as per categorization of Richards, 1954 and according to the categorization, excellent category ranges from a SAR value of <10meq/l, marginally suitable value ranges from 10-18meq/l, doubtful category ranges from 18-26meq/l and unsuitable category includes a SAR value greater than 26meq/l. After checking the values, it was concluded that 100% samples were of excellent category and none of the sample was labelled as marginally suitable, doubtful or unsuitable Table II. So the Groundwater was deemedfit for irrigation on the basis of SAR value.

Higher concentration of RSC induces higher PH and effects water for irrigation. An abnormal value may affect the soil fertility and higher value of RSC may induce precipitation of Magnesium that may increase Sodium concentration. The RSC values of all the 24 samples were calculated work shown in Table III using the (2), [5].

$$RSC = (CO_3+HCO_3) – (Ca+Mg) \qquad (2)$$

The minimum and maximum values of RSC were found to be -5.37 and 11.00Meq/L with the mean value of 1.87 and a SD (standard deviation) of 4.65. According to Richards, 1954 [5] categorization, the water sample having RSC value less than 1.25 is considered good, doubtful category ranges from 1.25-2.5 and a water sample is considered unsuitable when the value exceeds 2.5. The results were evaluated that revealed that 58.33% samples were of good quality, 8.33% were of doubtful category and 33.33% were of unsuitable category. Most of the samples were deemed fit for irrigation while few were deemed unfit for irrigation especially in MithaKhel where RSC value was highest and found as 11.00meq/l where in Dagarnari, Surdag, Shanawa Gudi Khel, Amberi kali, main Bogara and Latember, the calculated SAR values were 9.8, 5.77, 6.66, 9.56, 9.01 and 5.10Meq/L respectively and the values were too high making it unsafe for irrigation. On the whole, the water was found fit for irrigation with maximum samples 58.33% found good and 8.33% samples were doubtful Table II.

Magnesium absorption ratio is an important parameter for measuring water quality for irrigation. When Magnesium content becomes high in water, it becomes toxic for irrigation. Here in the study area, Magnesium absorption value was calculated shown in Table III for all 24 samples, using the (3), [8].

$$MAR = Mg \times 100 / (Ca + Mg) \qquad (3)$$

The minimum and maximum value was calculated as 4.74 and 68.76 % respectively with a mean value of 29.71 and a standard deviation of 15.77 Table IV. Ayers [8] shows that the samples exceeding 50% are unsuitable for irrigation and less than 50% makes it suitable for irrigation. The calculated values indicated that 91.67% samples were found below 50% so these were fit for irrigation while 8.33% samples were exceeding 50% so those were unfit for irrigation due to higher Magnesium ratio Table IV. Most of the samples were fit for irrigation and few showed slight increase in Magnesium.

Sodium hazard is measured by Soluble Sodium Percentage (SSP) by measuring Sodium accumulation that may cause harm to irrigation process. Soil structure disorder, aeration and infiltration may take place. SSP is calculated to measure these hazards and depict picture Groundwater chemistry. SSP was measured for all 24 samples shown in Table III using the 4, [4].

$$\%Na = \frac{(Na+K)x100}{(Ca+Mg+Na+K)} \qquad (4)$$

The minimum and maximum values were calculated as 8.64 and 85.89% respectively with a mean of 47.33 and a standard deviation 22.18. According to Wilcox, 1955, excellent category ranges from 0-20%, good category ranges from 20-40%, permissible category ranges from 40-60%, doubtful category ranges from 60-80% and more than 80% makes an unsuitable category. After calculating the values, it was established that 16.66% samples comprised excellent category, 25% samples comprised good category, 29.16% samples comprised permissible category, 16.66% samples comprised doubtful category and only 12.5% samples comprised unsuitable category Table II. Few samples showed higher SSP including Zebi, MohabatKhel and Ahmad Abad where SSP exceeded 80% mark and hence comprised unsuitable category. On the whole most of the samples were deemed fit for irrigation.

Soil permeability is affected by consistent use of Irrigation water and to measure this, PI was calculated in all 24 samples of study area shown in Table III using the (5).

The content of Calcium, Magnesium, Sodium and Bicarbonate in soil besides the use of Irrigation water for longer periods, effects soil permeability. Long term use of irrigated water contributes towards the effecting of soil permeability. Resultantly soil type, HCO3 (Sodium Bicarbonate) and TDS (total dissolved solids) are the constituents that are affected (Gabriel and Sheriff, 2011). PI more than 75% belongs to class I (suitable) category while PI in a range of 25-75% belongs to class II (unsuitable) category. The following (5) was used to determine PI.

$$PI = (Na + HCO3) x100 / (Ca + Mg+Na) \qquad (5)$$

The minimum and maximum value was calculated as 32.55 and 99.07 % respectively with a mean value of 67.29 and a standard deviation of 22.18 Table IV.

The class II samples are deemed unfit for Irrigation while class I are deemed fit for Irrigation. . When PI value is greater than 75%, it is suitable for Irrigation and secondly when the value is in the range of 25-75%, it is unsuitable so according to this classification 50% of samples are deemed fit for Irrigation and the remaining 50% were in the range of 25-75% so deemed unsuitable.

Kelly's Ratio is another parameter to measure and gauge the Groundwater quality suitability for Irrigation purposes. The value of less than 1 belongs to safe (suitable) category while KR greater than 1 belongs to unsafe (unsuitable) category. So it is used to judge the water quality for Irrigation. It is calculated using the following (6).

$$KR = Na/ (Ca + Mg) \qquad (6)$$

The minimum and maximum value was calculated as 0.07 and 4.21Meq/L respectively with a mean value of 0.8025 and a standard deviation of 1.14. According to Kelly, 1963, when the value of water sample is less than 1, it is suitable for Irrigation and when the value exceeds 1, it is unsuitable for Irrigation. According to this classification, 83.33% samples are fit for Irrigation and the remaining 16.66% samples were unfit for Irrigation.

C. Water Quantity for Irrigation

The study was conducted to check the physibility of water quantity for irrigation purpose in our research area. Crop Water Need (CWR or ET_c)is the amount of water required to reimburse the loss of water through evapotranspiration. It may also be stated that the crops requires water for growth and to provide crops with optimum water, is crop water need (FAO, 1986). The elements that crops water requirement (CWR) depends upon are the climate (cloudy climate requires less water than hot climate), the crops type (there is a difference of crop water need for each crop) and growth stage of the crop (mature crops need more water) [10]. Irrigation is required when rainfall is insufficient to compensate for the water lost by evapotranspiration. The primary objective of irrigation is to apply water at the right period and in the right amount [11]. By calculating the soil water balance of the root zone on a daily basis, the timing and the depth of future irrigations can be planned [5].

The results for all crops were calculated by the software. The data was collected from Agriculture Research CenterKarak where rainfall, humidity, wind speed, sun hours and others are measured. An average total of 543.09mm annual rain is measured in the last 10 years in the area with an average humidity of 57% and average minimum temperature of 15.8°C and average maximum temperature of 28.7°C. The average wind speed was 84km/day and sun hours were measured as 12.3 hours a day.

The reference evapotranspiration (ET_o) was calculated as 4.35mm/day on the average. Resultantly, the Crop Water Requirement was calculated like the CWR of wheat comes out to be 325.4 mm in the season. The crop water need met by effective rain is 128.1mm whereas shortage of 196.1mm is met from Groundwater. Likewise, the results of seasonal crop water need for all crops are listed in the Table VI that shows the Crop Water Requirement. When the shortfall is met from the groundwater, it causes a continuous water table drop and it has constantly taken place in the area with many wells dried after use. This situation requires sustainable groundwater management which is to maintain a balance between extraction and recharge. The statistical evaluation is shown in Table VII that shows a mean value of 391.21.

By utilizing CropWat software for Windows 8, we figured out the crop water demand. The reference evapotranspiration can be determined by simply entered the climate data. Later on the soil, crop and monthly rainfall data was entered and resultantly, ETC and irrigation required was computed directly by the software. The Crop Water Requirement can be calculated on daily basis but in this study it is calculated on 10 days period basis. The results calculated showed the amount of water required for crops besides the water provided by rainfall and received from irrigation. Hence the groundwater in district Karak has to fulfill the vacuum created by rainfall. It is an opportunity for farmers of the locality to preserve the already depleting water resources by knowing the CWR.

The Crop Water Requirement of 8 crops namely wheat, barley, gram, rape and mustard, Jawar, Bajra, maize and groundnut was determined as the results are tabulated in the Table VI. The results show the total crop water need and that required from irrigation.

IV. CONCLUSIONS

Our research reveal that the groundwater of district Karak generally claimed to be fit for irrigation however the abnormal values of RSC, SSP and PI at some stations reduce the suitability of groundwater for Irrigation but to sum up all these, it is concluded that the water was found suitable for Irrigation in the study area. Secondly the rainfall contribution to the Crop Water Requirement has compelled Groundwater to meet the required deficiency and it is depleting Groundwater resources drastically. It is recommended to preserve the Groundwater by efficient use of water for Irrigation.

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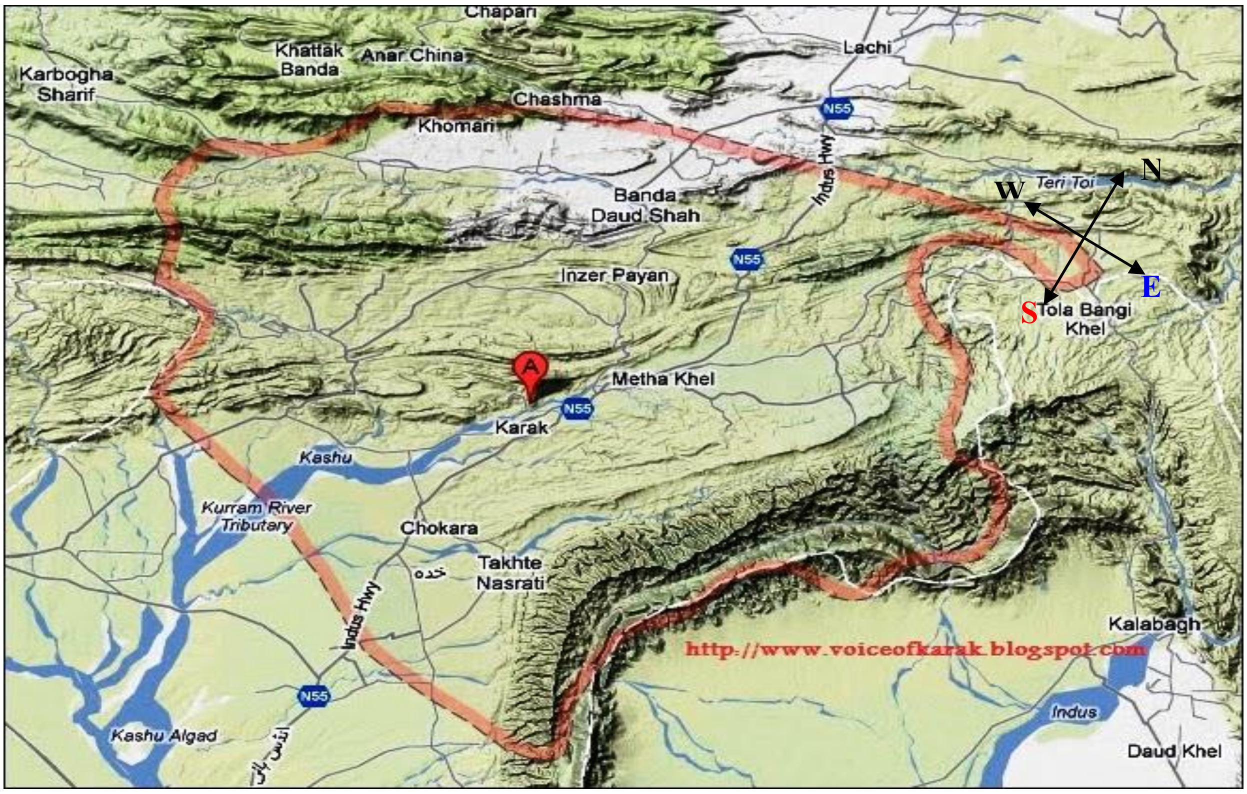

Fig.1. Map of Study Area

TABLE I
PH CONCENTRATION IN GROUNDWATERSAMPLES

Sr. #	Code	Location	Temp ^{0}C	PH
1	IC	Isek Chontra	25.1	8.3
2	PS	Palosa Sar	27.3	8.1
3	KK	Kandu Khel	29.2	7.9
4	SA	Sabir Abad	28.1	7.9
5	MK	Mitha Khel	30.1	9.0
6	TK	Talab Khel	23.5	7.9
7	GMK	Ghundi Mirhan Khel	25.3	8.0
8	K	Karak	27.6	8.3
9	KM	Kamangar	29.5	8.3
10	TD	Thordand	28.7	7.9
11	Z	Zabi	27.9	8.1
12	L	Latember	24.8	8.3
13	S	Surdag	25.9	8.3
14	DN	Dagar Nari	28.6	8.4
15	AK	Amberi Kale	29.2	8.5
16	SGK	Shanawa Gudi Khel	28.9	8.3
17	ZK	Zarkai	27.7	8.2
18	MB	Main Bogara	28.7	8.1
19	AA	Ahmad Abad	29.5	8.6
20	MK	Mohabat Khel	29.4	8.2
21	SS	Shah Saleem	27.8	8.4
22	GK	Ghondi Kala	27.4	8.0
23	SK	Shadi Khel	25.3	8.3
24	T	Topi	27.1	8.5

TABLE II
CLASSIFICATION SCHEME

Classification scheme	Categories	Ranges	Percent of Samples
SAR(Richards 1954)	Excellent/suitable	<10	100%
	Marginally Suitable	10-18	0%
	Doubtful	18-26	0%
	Unsuitable	>26	0%
RSC(Richards 1954)	Good	<1.25	58.33%
	Doubtful	1.25-2.5	8.33%
	Unsuitable	>2.5	33.33%
MAR(Ayers and Westcot, 1985)	Suitable	0-50	91.67%
	Unsuitable	>50	8.33%
%Na(Wilcox,1955)	Excellent	0-20	16.66%
	Good	20-40	25%
	Permissible	40-60	29.16%
	Doubtful	60-80	16.66%
	Unsuitable	>80	12.52%
PI(Ragunath, 1987)	Class2(unsuitable)	25-75	50%
	Class1(suitable)	>75	50%
KR(Kelly,1963)	Suitable	<1	83.33%
	Unsuitable	>1	16.66%

TABLE III
IRRIGATION WATER PARAMETERS & IONIC CONCENTRATION

Sr. #	Code	Location	Na	K	Ca	Mg	CO_3	HCO_3	SAR	SSP	RSC	PI	MAR	KR
1	IC	IsekChontra	0.869	1.64	2.80	0.80	0.37	1.33	0.64	41.13	-1.94	45.34	22.22	0.241
2	PS	PalosaSar	0.62	0.85	1.65	0.95	0.45	1.10	0.54	35.96	-1.05	51.82	36.53	0.23
3	KK	KanduKhel	0.91	0.33	4.56	0.91	0.65	2.85	0.55	18.47	-1.97	40.59	16.63	0.167
4	SA	Sabir Abad	0.41	0.21	3.20	0.50	0.45	1.55	0.30	14.35	-1.7	40.26	13.51	0.11
5	MK	MithaKhel	0.61	1.21	5.90	2.10	0.75	18.25	0.30	18.53	11.00	56.70	26.25	0.07
6	TK	TalabKhel	1.23	1.45	2.47	1.54	0.50	4.50	0.86	40.05	0.99	63.95	38.40	0.306
7	GMK	Ghundi Mirhan Khel	1.47	1.01	8.13	1.15	0.60	8.96	0.68	21.08	0.28	41.51	12.4	0.15
8	K	Karak	1.13	0.04	10.45	1.92	3.92	10.66	0.45	8.64	2.21	32.55	15.52	0.10
9	KM	Kamangar	7.45	3.21	15.3	3.21	5.53	7.61	2.44	36.54	-5.37	39.32	17.34	0.40
10	TD	Thordand	3.56	4.92	11.65	2.41	3.29	5.67	1.34	37.62	-5.10	33.71	17.14	0.25
11	Z	Zabi	6.29	3.89	1.34	0.81	2.31	3.00	6.06	82.52	3.16	95.04	37.67	2.92
12	L	Latember	2.14	4.56	1.14	2.51	2.41	6.34	1.58	64.73	5.10	80.44	68.76	0.58
13	S	Surdag	2.39	6.74	2.09	0.91	3.56	5.21	1.95	75.2	5.77	86.68	30.33	0.79
14	DN	DagarNari	1.75	3.46	2.19	1.72	4.50	9.21	1.25	57.12	9.80	84.53	43.98	0.44
15	AK	Amberi Kale	1.50	2.36	1.62	2.15	3.12	10.21	1.09	50.50	9.56	89.09	57.03	0.39
16	SGK	Shanawa Gudi Khel	2.01	3.81	1.99	0.89	1.50	8.04	1.675	66.89	6.66	99.07	30.9	0.69
17	ZK	Zarkai	1.45	0.14	3.01	0.15	1.13	4.01	1.15	33.54	1.98	75.00	4.74	0.45
18	MB	Main Bogara	1.14	3.43	2.01	1.84	2.17	10.76	0.82	54.27	9.01	88.58	47.79	0.29
19	AA	Ahmad Abad	7.37	4.81	1.57	0.43	0.21	0.93	7.37	85.89	-0.86	88.94	21.5	3.68
20	MK	MohabatKhel	5.78	2.13	0.97	0.40	0.19	0.77	6.96	85.23	-0.41	93.11	29.2	4.21
21	SS	Shah Saleem	3.17	3.29	1.13	0.81	0.14	0.99	3.23	76.98	-0.81	81.48	41.75	1.63
22	GK	Ghondi Kala	1.75	0.92	2.00	1.50	1.11	1.37	1.32	43.27	-1.02	55.62	42.8	0.5
23	SK	ShadiKhel	1.00	0.04	2.10	0.22	0.10	2.05	0.93	30.95	-0.17	73.27	9.48	0.43
24	T	Topi	0.55	1.33	0.99	0.45	0.33	1.02	0.65	56.62	-0.09	78.38	31.25	0.38

TABLE IV
SUMMARY STATISTICS OF ALL PARAMETERS

Parameter	**Unit**	**Minimum**	**Maximum**	**Mean**	**SD**	**Desirable limits**	**Remarks**
PH	-	7.9	9.0	8.23	0.23	6.5-8.4(FAO)	83.33% fit
Na	Mg/L	.43	171.35	54.193	49.642	0-900(FAO)	100% fit
K	Mg/L	1.564	263.53	90.879	72.618	0-78(FAO)	54.16% fit
Ca	Mg/L	19.40	306.00	75.217	76.236	0-400(FAO)	100% fit
Mg	Mg/L	1.83	39.162	15.392	9.97	0-60(FAO)	100% fit
CO_3	Mg/L	3.00	165.90	49.113	47.671	0-30(FAO)	50% fit
HCO_3	Mg/L	46.97	113.3	336.49	273.97	0-600(FAO)	83.13% fit
SAR	Meq/L	0.30	7.37	1.84	2.04	<18	100% samples are suitable
SSP	%	8.64	85.89	47.73	23.39	0-60	70.82% samples are Suitable
RSC	Meq/L	-5.37	11.00	1.87	4.65	<1.5	58.33% samples are of good category
PI	%	32.55	99.07	67.29	22.18	>75	50% samples are suitable
MAR	%	4.74	68.76	29.71	15.77	0-50	91.76% samples are suitable
KR	Meq/L	0.07	4.21	0.8025	1.14	<1	83.33% samples are suitable

TABLE V
CORRELATION COEFFICIENTS AMONG DIFFERENT IONS

	Na	**K**	**Ca**	**Mg**	**CO_3**	**HCO_3**
Na	1.000					
K	0.5278	1.000				
Ca	0.2208	-0.0519	1.000			
Mg	0.1138	0.2683	0.6050	1.000		
CO_3	0.2699	0.4401	0.5400	0.7169	1.000	
HCO_3	-0.1987	0.0676	0.3932	0.6328	0.4728	1.000

TABLE VI
CORP WATER REQUIREMENTS

Crops	**Location**	**ETC(mm)**	**Effective rain(mm)**	**Irrigation required(mm)**
Barley	Karak	202.7	99.9	103.2
Wheat	Karak	325.4	128.1	196.1
Gram	Karak	311.4	129.9	183.8
Rape & Mustard	Karak	288.9	128.4	159.6
Maize	Karak	359.1	202.8	204.6
Jawar	Karak	520.8	287.5	235.7
Bajra	Karak	470.4	252.7	267.2
Groundnut	Karak	651.0	330.1	322.6

TABLE VII
STATISTICAL EVALUATION OF CWR

Statistical evaluation of CWR	
N	8
Mean	391.21
SD	145.55
SE Mean	51.459
Minimum	202.70
Maximum	651.00

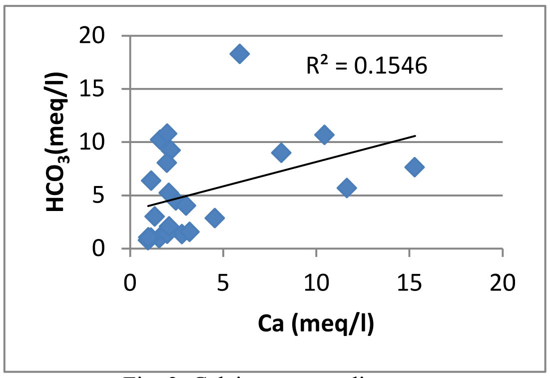

Fig. 2. Calcium scatter diagram

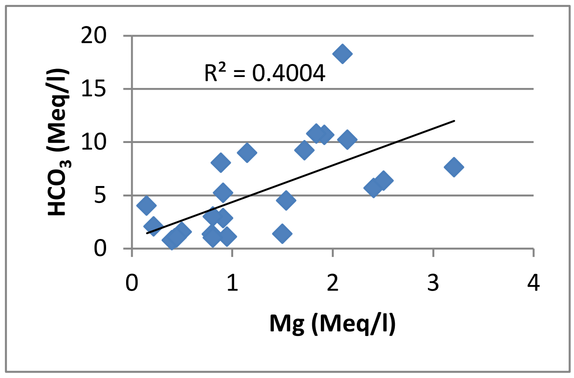

Fig. 3. Magnesium scatter diagram

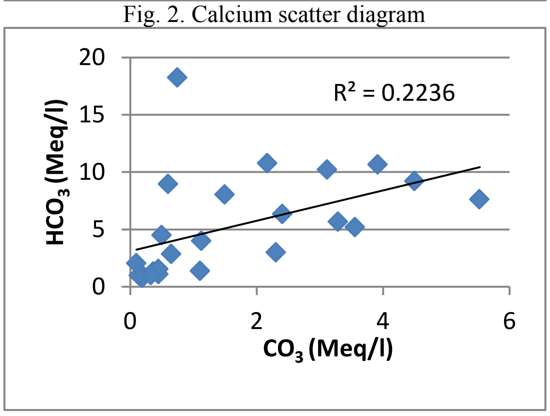

Fig. 4. Carbonate scatter diagram

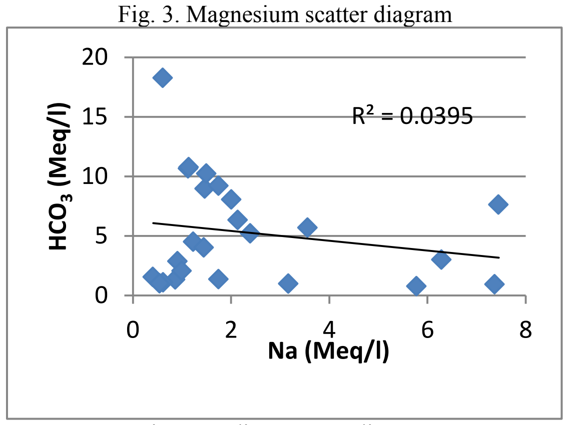

Fig. 5. Sodium scatter diagram

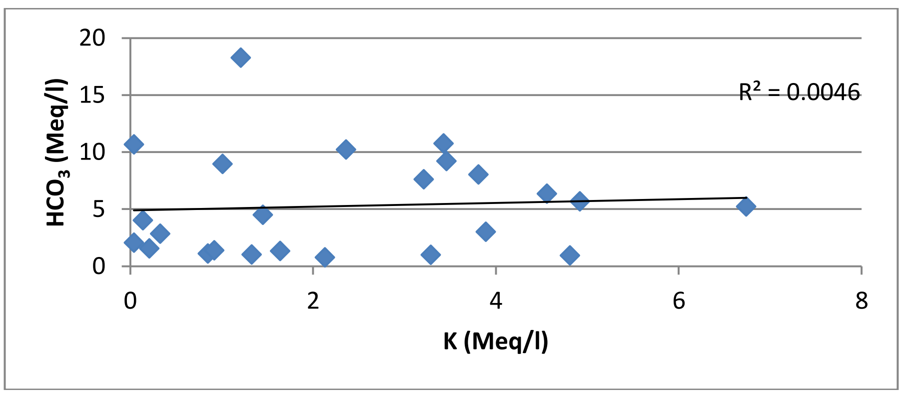

Fig. 6. Potassium scatter diagram

Fig. (2)-(6) shows Ion scatter diagram for groundwater sample in the study area (trend line shows average between ions

Assessment of Flows in a Glaciated Region-Shigar River Basin, Pakistan

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Abstract-Glaciers are the product of nature and 68% of global fresh water is in the form of glaciers. The glacier melting rate has increased due to global warming and it has been estimated by the scientists that more than three quarters of the present day glaciers will disappear within the next fifty years. In the present study an attempt has been made to investigate the change in temperatures and its impact on flows of Shigar River which is located in the northern areas of Pakistan. An analysis of time series of temperature, precipitation and discharge data showed upward trend. A well known rainfall runoff, snow and glacier melt University of British Columbia Watershed Model (UBCWM) was used to simulate the flows at Shigar River. The inputs of UBCWM are the daily maximum/minimum temperature, precipitation and physiographic characteristics of the watershed. The glacier cover over the watershed was retrieved using MODIS Moderate-Resolution Imaging Spectro Radiometer (MODIS) and found to be 2400 (km^2). The well calibrated and validated UBC watershed model (1998, 2001 and 2002 respectively) was used for future flows prediction. The calibration and validation results were 94 and 91 percent for year 1998 and 2002 respectively. The mean annual maximum and minimum temperature trends were used to project next ten years. The projected results were then put in the model to determine the flows after ten years. The simulation showed 4 % increase in flows with respect to the validating year 2002 flows due to projected increase in temperatures and predicted flows of year 2012.

Keywords-Climate change, UBC Watershed Model, Shigar River Basin, river flows, Pakistan

I. INTRODUCTION

Pakistan is an agricultural country and its economy is dependent on the significant Indus irrigation system [1]. A country of five rivers is facing water issues related to extreme water shortage and heavy floods. Pakistan has disputes over the unequal distribution of water resources among its own Provinces [2]. The availability of water resources are affected by the impact of climate change and its variability which influences the agriculture and power generation capacity. Therefore, for proper planning and better management of water resources, it is important to estimate their availability in future. [3] states that the changing climate has strong impact on river flows in Pakistan. This will result in higher rate of snow and glaciers melting for few years with major increase in river flows and then there will be permanent loss in flows from the Upper Indus Basin (UIB) glaciers. The Indus plains of Pakistan are most fertile zones and are irrigated by the Indus River and its tributaries. The glacier melt contribute more than 50% to the total flows of the Upper Indus Basin [4]. It is vital to monitor and forecast runoff from snow and glacier melt in the Upper Indus Basin. [3] shows that the changing climate impact is clearly indicated by the glacier and snow melting as glaciers are retreating due to global warming. In the present study an attempt has been made to investigate the change in temperatures and its impact on flows of Shigar River located in the northern areas of Pakistan. To achieve this, time series of maximum and minimum temperature trends were determined and projected for next ten years. These projected daily maximum and minimum temperatures were used as basic input to University of British Columbia Watershed Model (UBCWM) to estimate the river flows for present and future.

II. DESCRIPTION OF STUDY AREA

Shigar River is a small right bank tributary of the Indus River and meets the Indus at Gol (Skardu valley) which is about 30 km downward from Skardu. The Shigar Basin lies within the Latitude range of 35.2°N to 37°N and Longitude range of 74.5°E to 76.5°E respectively as shown in Fig. 1. The Shigar River Basin is located between the Karakoram Mountains and Masherbrum Range Baltistan i.e. situated in Northern areas of Pakistan. The Shigar Basin has border with China and Shyok River Basin in the East, Hunza River in the North and Indus River Basin in the South and West. Shigar River's flows are contributed from glacier melt of Baltoro, Biafo and Chugolugma glaciers. Thus the Shigar River Basin drains the glacier melt of most important glaciers of the Karakoram Range. Its entire catchment river inflows have been influenced by the action of glaciers [4]. The valley is deep in its upper reaches but widens near its mouth [4]. The drainage area of Shigar River Basin is 7382 km^2. The daily runoff data at Shigar River is available for 18 years 1984-2002 from discharge measuring station at Shigar River (35°20'- 75°45'). The mean annual flow at Shigar River gauging station is about 194 m^3/sec (cumecs) and the unit runoff is about 29 cumecs/1000 km^2 [5]. The stream flows in Shigar River is mainly fed by glacier melt and has strong influence by extreme seasonal variability. The other contributions to the River flows are due to snow melting which increases in summer due to rise in temperatures. The Watershed has an elevation range of 2200 to 8611 m.a.s.l. The mean elevation of the Watershed is 5405 m.a.s.l. and the highest peak is K2. The Shigar Basin has total glacier area of 2240 km^2 [4] which is 30 % of the total watershed. The Baltoro, Biafo & Chugolugma are the main glaciers.

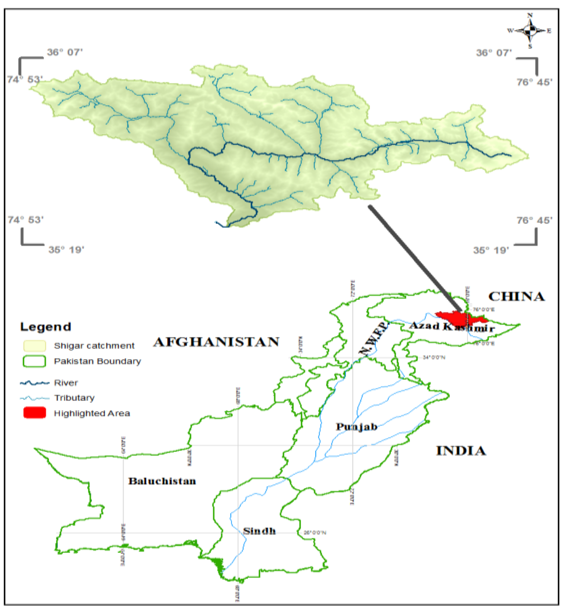

Fig. 1. Location of Shigar Basin

III. CHARACTERISTICS OF STUDY AREA

The Shigar basin laid completely in Pakistan, in the HinduKash Karakoram Himalyan (HKH) region. The 2nd highest mountain peak K2 in HKH region has an altitude of 8611, m.a.s.l and the lowest altitude is at Shigar Bridge is 2204 m.a.s.l. According to the Koppen-Geiger climate classification, the Shigar falls in a cold desert region, that receives little precipitation with dry climate with and variability in daily temperature range. The massive glacier mountains form a barrier to the movement of Monsoon stroms, which impose little storms effect in HKH region. In Shigar basin the main glacier Baltoro has area more than 700 km^2. The hydrological regime is less affected by monsoon and major contribution in stream flows is due to snowmelt and glaciers melt [6]. The winter precipitation due to western patterns provides excessive snowfall for the nourishment of glaciers of HKH region [7]. The precipitation behavior is not uniform at high altitudes of KHK region. The winter snow and then the glaciers start melting from April and continue till July. The mean temperatures showed a uniform pattern in the UIB catchment. [8] have assessed both precipitation and temperature over the past 100 years. Considering the long term data at Gilgit, Skardu and Srinagar, there is considerable increase in precipitation and winter temperatures while the summer temperatures showed a cooling pattern [8]. These varying climate change have direct impact on the availability of water resources. The mountain height reduces the interruption of the monsoon whose effect weakens towards the North West. Over the UIB, maximum annual precipitation falls in winter and spring and originates from the west. Monsoonal storming brings rear rain to trans-Himalayan areas and contribute reasonable during summer months, but all the precipitation is not originate from monsoon storms [9]. Climatic variables are strongly influenced by altitude.

The HKH stores a very relevant amount of water in its extensive glacier cover at higher altitudes (about 16 300 km^2), but the lower reaches are very dry. Especially in the Central and Northern Karakoram, the lower elevations receive only occasional rainfall during summer and winter. The state of the glaciers also plays an important role in future planning, shrinking glaciers may initially provide more melt water, but later this amount will be reduced. On the other hand, growing glaciers store precipitation, reduce summer runoff, and can generate local hazards. These differences could be caused by increases in precipitation since the 1960s [8] and a simultaneous trend toward higher winter temperatures and lower summer temperatures [8].

IV. MODEL DESCRIPTION

The Shigar River Basin was modeled using the University of British Columbia Watershed Model (UBCWM), developed and used by Dr. M. C. Quick and A. Pipes in 1972 on Fraser River system in British Columbia at UBC Civil Engineering Mountain Hydrology Group [10]. The earlier UBCWM was in DOS version [11], [12] and it has been customized into the latest Windows version by Quick and his co-workers with the combined funding from the BC Disaster Relief Fund, the BC Science Council, and BC Hydro [13]. The UBCWM uses the hourly or daily point value data of precipitation and maximum and minimum temperature as input to calculate the stream flow. The precipitation is taken in millimeters and temperature in degree Celsius. The model uses the historic flows, observed physically by gauging station at the outlet of the watershed to compare the model simulation. The daily or hourly flow data is measured in cubic meter per second. The UBCWM was designed for mountainous areas where meteorological data is sparse and mostly available at valley stations. The model uses the area-elevation band theory to deal with the orographic gradient of precipitation and temperature. The model also provide the information about the characteristics of watershed like snow cover area, snow water equivalent, energy available for snowmelt, evapotranspiration and interception losses, soil moisture, groundwater storage and surface and sub-surface components of runoff for each elevation band and also mean value over the watershed

The physical description of watershed is done under a set of variable parameters for each assigned elevation bands such as mean band area, mean band elevation, glacier area, north south orientation, forested area, forest density impe rmeable fraction of soil. The schematic flow structure of UBCWM is illustrated in Fig. 2.

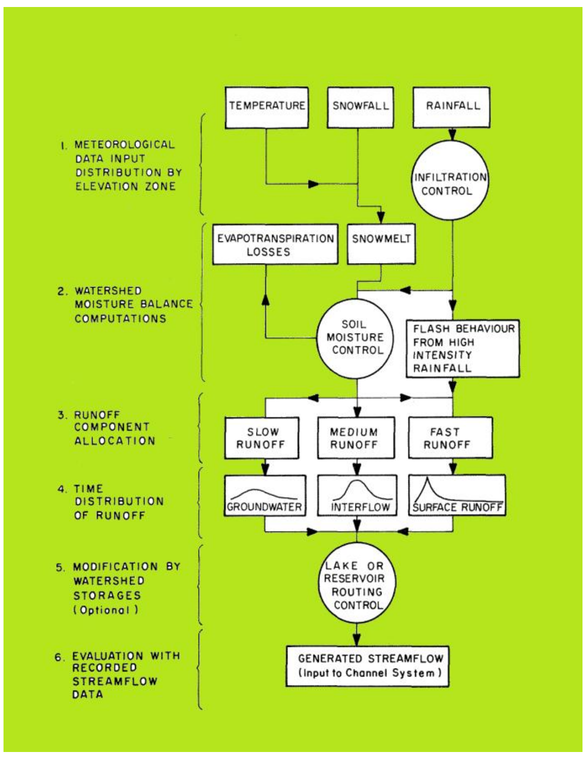

Fig. 2. Schematic Flow Structure of UBCWM [12]

The UBCWM comprises of three sub model. The first model is related to metrological data and it distributes the point data of precipitation and temperature over the mid-elevation points of each elevation band in the watershed. The precipitation is controlled by critical temperature and falls either in the form of snow or rainfall. The melting of snow cover area and glacier extent is also controlled by this model. The second model deals with the soil moisture and indicates the behavior of watershed. It divides the watershed inflows into four types: fast as surface, medium as interflow, slow as upper groundwater and very slow as deep groundwater. The third model is related to routing and it generates the distribution of runoff components. It is based on linear storage reservoir theory. It assures the conservation of mass and water equilibrium. The UBCWM is conceptual and continuous hydrological model. It is a semi-distributed model. The UBCWM has been successfully applied for real time forecasting and research studies in different climatic regions of the world. The model has also been performing well in the Himalayas and Karakoram ranges in India and Pakistan.

V. HYDROLOGICAL STUDIES USING THE UBCWM

The UBCWM has been successfully applied for real time forecasting and research studies over dams and various watersheds over the world. Some of major studies are listed below:

North Saskatchewan River: Forecasting model development, Prairie Provinces Water Board, 1972-74.

- Fraser River Forecasting System: Continuing development and use since 1972 to present, for BC Ministry of the Environment.
- Columbia River: Design flood estimation for the Revelstoke Project: PMF and Diversion Floods, BC Hydro, 1974
- Columbia River: Mica Dam. Development of Operational Procedure. (with A. Pipes and with W. Goines and D. Druce of BC Hydro.), 1976
- Peace River: Design Flood studies for possible downstream developments, BC Hydro, 1973 and 1975.
- Columbia River: Murphy Creek Design Flood Study, BC Hydro, 1976-81.
- Upper Indus River: Development of forecasting system, World Meteorological Organisation, 1987, and IDRC , with BC Hydro, 1988 to 1996, and ongoing
- Campbell River: Hourly Rainflood Forecasting System, for BC Hydro, 1992-93, and ongoing.
- Sutluj River, India: Development of Forecasting System, for Indian Institute of Hydrology, United Nations Development Program, 1993.
- Kootenay River. Consultant to Acres International. Derivation of PMF for the Brilliant Dam, 1998

The UBCWM has been selected to achieve the objectives of this research study. The reasons to choose this model over the other hydrological models are: 1) the model has been applied successfully over the numerous worldwide hydrological projects, 2) the UBCWM runs with minimum daily or hourly temperature and precipitation data at point and 3) the model has been used by at many projects to forecast daily inflows.

VI. UBCWM Design Constraints

The UBCWM is preferably designed to estimate and forecast watershed response in mountainous areas. The UBCWM is conceptual and continuous hydrological model. It is a semi-distributed model. The hydrological response of mountainous watershed is dependent on the elevation and it is the most important variable in the description of mountain runoff [11] therefore the model uses area-elevation zones concept. The model is divided into area-elevation bands. The watershed can be divided up to twelve bands, however from operation manual, it is suggested four to eight are enough to describe a watershed. The physical characteristics of watershed are defined separately for each elevation band under the set of variable parameters. The UBCWM is designed to run from minimum climate data as data is sparse in high elevation mountains and most of the data is available from Valley Station. Due to this constraint, model is provided with the ability to interpret the point meteorological data to mid elevation of each zone therefore data is distributed to each specified elevation bands. This data distribution is based on the assumption that temperature and precipitation are described by elevation and area therefore Elevation relationship to temperature and precipitation are defined in the model.

The snow cover data is not available at most of the stations. Therefore daily precipitation data is used to develop snow accumulation map by the model and distribute the rainfall by elevation over the watershed.

A. Datasets Used

The temporal data included climate and discharge data. Climatic data are being observed by Pakistan Meteorological Department (PMD) since 1955. The rivers of Pakistan have been gauged by Water and Power Development Authority (WAPDA) since 1960. Daily maximum & minimum temperatures and precipitation data from the Skardu Meteorological Station, located at an elevation of 2230 m near Shigar catchment, was obtained from PMD for the period 1961-2002. The daily stream flows data of gauging station, located at an elevation of 2204 m at Shigar Bridge from 1985-2002 was collected from WAPDA. The stations with their measuring variables are listed in Table I.

TABLE I
WEATHER& DISCHARGE STATION WITH MEASURED VARIABLES

Station	Long. (°E)	Lat. (°N)	Elev. (m.a.s.l)	Var.	Resol.	Avail. since (years)
Skardu	75°-31'-35"	35°-19'-47"	2230	Max/ Min Temp., Ppt.	Daily	1961-2002
Shigar	75°-25′-00″	35°-20′-00″	2204	Disch.	Daily	1985-2002

The spatial data consisted of terrain elevation and snow cover/glacier extent. To describe the characteristics of the Shigar Basin the Digital Elevation Model (DEM) available from ASTER was downloaded from the website http://srtm.csi.cgiar.org. The Shuttle Radar Thematic Mapper (SRTM) data with 3 arc-second resolution (= 90 meter) was acquired due to its precision and accuracy. Fig. 3 is representing the location of Shigar Basin in 2 two SRTM tiles of Aster DEM.

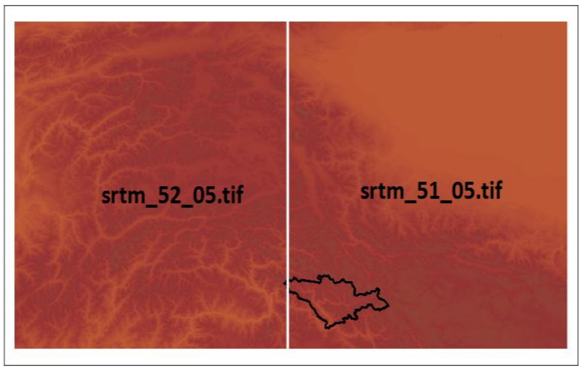

Fig. 3. Extents of STRM Tiles for Shigar Basin

The downloaded STRM tiles were first mosaic and then clipped to reduce the size for the Shigar Basin. The data processing of clipped terrain model was done using the Arc Hydro extension of ArcGIS. The watershed was delineated using the batch command under the watershed processing tool shown in Fig. 4. The initial resolution of DEM raster was of 3 arc seconds (approximately 90 m in North-South direction) and in Degree, geodetic datum WGS84 (geographic coordinate system). The area lying under the mask of watershed was extracted for further division of DEM into elevation bands.

The initial geographic coordinate system of clipped DEM raster was projected into UTM43 North, geodetic datum WGS84 having raster cell size of 500 meter. The extracted DEM of Shigar Catchment was divided into elevation bands as per the requirement of UBC watershed model. To get the areal characteristics of the Shigar Basin under each elevation class, the DEM was reclassified into elevation bands with the spatial analyst tool of ArcGIS. The low and high value range of elevation in raster DEM were 2179 and 8566 m.a.s.l. The raster DEM was reclassified into 8 elevation bands with an equal interval of 500 meter as shown in Fig. 4. The reclass raster was converted into polygon and further polygons were dissolved according to the defined elevation zones. Finally, the area of each elevation was calculated.

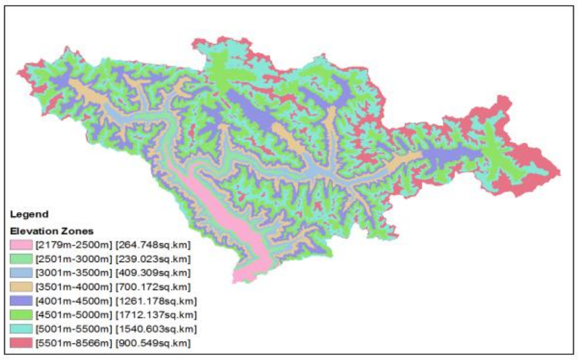

Fig. 4. Classification of Shigar Basin into Elevation Bands

The area-elevation (Hypsometric) curve is a graphical representation of the relationship between elevation and area of a basin [14]. The area under the hypsometric curve is the hypsometric integral and is used to calculate the hypsometric mean elevation [15]. To develop the hypsometric curve for Shigar Basin, the calculated area and elevation zone data in ArcGIS were plotted as shown in Fig. 5. The each elevation zone, area, count of cells and hypsometric mean elevation are listed in Table II.

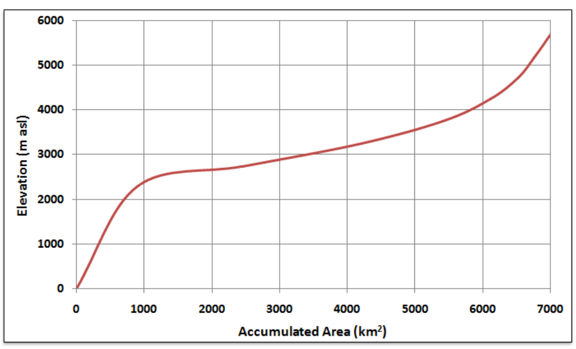

Fig. 5. Area-elevation (Hypsometric) Curve for the Shigar Basin

TABLE II
BASIC FEATURES OF SHIGAR BASIN ELEVATION ZONES

Elevation band (No.)	Minimum Elevation (m)	Maximum Elevation (m)	Count of cells (No.)	Area (km^2)	Hypsometric Mean (m)
1	2179	2500	32685	265	2290.4
2	2501	3000	29509	239	2732.3
3	3001	3500	50532	409	3233.7
4	3501	4000	86441	700	3744.8
5	4001	4500	155701	1261	4238.0
6	4501	5000	211375	1712	4724.4
7	5000	5500	190198	1541	5170.4
8	5501	8566	111179	901	5744.7

B. Hyrdological Regime of Shigar River Basin

The climatological data used of year 1998 for modeling the Shigar River Basin is illustrated in Fig. 6 in terms of maximum & minimum temperature and precipitation. According to [16] the Shyok, Hunza and Shigar River falls in glacier regime, their combined flows contribute an average less than 30 % of flows in the Indus River. There is positive correlation between runoff and maximum temperatures in these catchments [17], [8]. The observed runoff at Shigar gauging station was compared with the maximum temperature and precipitation for the simulation year 1998. The visual analysis proved that there exist a strong correlation between the summer runoff and maximum temperature as shown in Fig. 7.

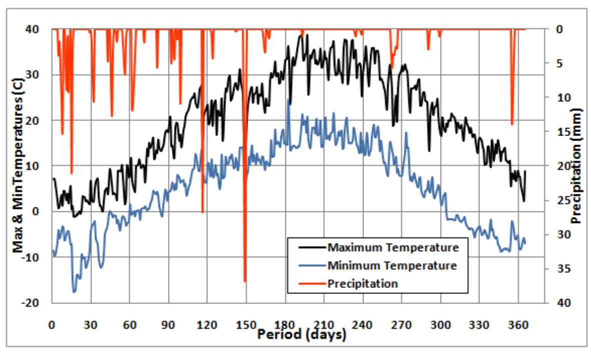

Fig. 6. Maximum/Minimum Temperature and Precipitation at Skardu Meteorological Station for the year 1998

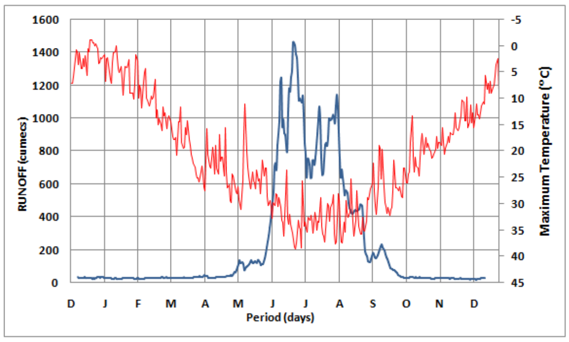

Fig. 7. Comparison of Observed Maximum Temperature and Runoff at Skardu Meteorological Station and Shigar Gauging Station for the year 1998

Whereas there was contrasting insignificant correlation between the precipitation and runoff shown in Fig. 8. A negative or poor relation existed between the runoff and precipitation. Hence the temperature pattern in summer has great impact on trends in runoff. Thus, the rise in global temperatures will increase the runoff initially but falls sharply due to retreating glacier mass [19].

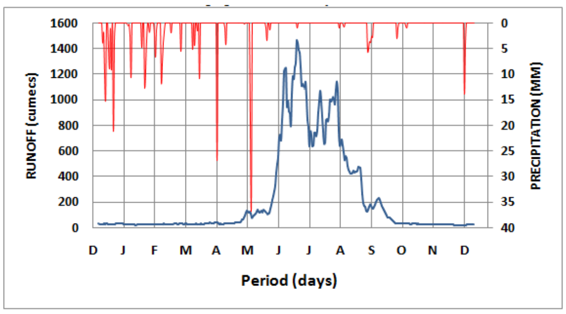

Fig. 8. Comparison of Observed Precipitation and Runoff at Skardu Meteorological Station and Shigar Gauging Station for the year 1998

C. Snow Cover/Glacier Extent

The snow cover/glacier extent is the vital parameter in UBC watershed model indicating the snow cover feature of a basin. Snow Cover / glacier extent was obtained from daily satellite images of MODIS (Moderate-resolution Imaging Spectro radio meter). There are two sensors equipped with this satellite, Aqua and Terra which pass at different times of the day. There are different products available by MODIS. For this study, the readily processed snow tiles by the "MODIS Snow & Sea Ice Global Mapping Project" of NASA were used. The geo-correction and classification has already been made by the NASA. The MODIS Snow Cover Daily L3 Products (MOD10A1) can be downloaded free of charge from NASA (http://modis-snow-ice.gsfc.nasa.gov). The daily data is available in compressed Hierarchical Data Format-Earth Observing System (HDF-EOS) format and size varies between 0.5 and 2.5 MB. The daily MOD10A1 snow products are tiles of gridded data which consists of (1200 x 1200) km^2 area. The spatial resolution of tile (cell size) is about 500 m and tile is in the sinusoidal projection [19], [20], [21], [22]. A single tile is sufficient to cover the Shigar catchment and it falls in h24v05 tile. The MODIS standard snow-cover products–providing snow extent and albedo–are useful, as input to models [23]. The historic MODIS imageries were downloaded and processed for year 2002 before using in the UBC watershed model. The MODIS Reprojection tool (MRT) was used to convert sinusoidal HDF data into Geo-Tiff format with WGS84 Datum and UTM projection (Zone 43). The Shigar catchment area was extracted from the Geo-Tiff tiles. The raster cells with clouds or undefined data were corrected through temporal interpolation. The daily statistics (snow/ no snow) per elevation zone was analyzed. The snow depletion curve was calculated by smoothing through 9 daily moving averages which is the plot between percent snow cover and time as shown in Fig. 9.

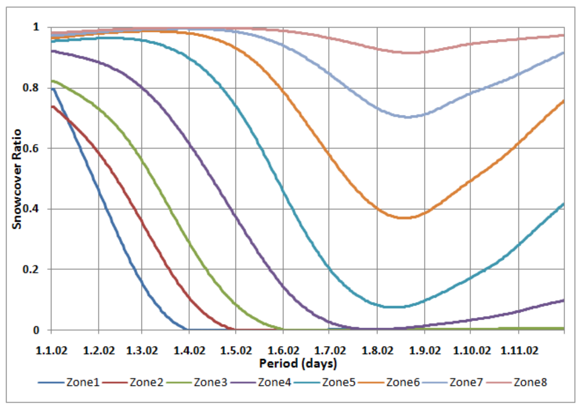

Fig. 9. Observed/smoothed Snow Depletion Curve after Cloud Cover Elimination Area for the Shigar Catchment in 8 zones year 2002

VII. METHODOLOGY

The flow chart in Fig. 10 shows the entire methodology used in this study. The calibration of model parameters was carried out for the Shigar catchment. In order to find a set of best tuned set of parameters for the hydrological model, a two-step calibration approach was applied to find the best parameters within a wide range of acceptable values, in order to identify the driving parameters in the different sections of the hydrograph, find the overall level of each parameter and establish a baseline of best-match by giving the available input variables. To reduce the temporal variability and restrict the parameters to reasonable values, while keeping the achieved goodness of fit as much as possible. Model calibration was performed for years 1998 and 2001 where inflow data at the Shigar gauging station was available. All calculations were carried out "year round", i.e. from 1st January to 31st December. The Best suited Calibrated parameters are listed in Table III along with their description as they are described in the UBCWM user Manual. The range and default values of parameters defined in Manual are also shown. The parameters describing the characteristics of study area are listed in Table IV.

TABLE III
BEST-SUITED CALIBRATED PARAMETERS OF UBCWM FOR SHIGAR BASIN

Parameter	Range	Default	Best suited value	Description
P0SREP	-1.0 to 1.0	0.0	0.25	Adjustement to precipitation when average temperature <0 (snowfall)
P0RREP	-1.0 to 1.0	0.0	1	Adjustement to precipitation when average temperature >A0FORM (rain)
A0EDDF	0.0 to 0.5	0.2	0.2	Potential evapo transpiration factor in mm/day
P0GRADL	0 to 20	5	6	Precipitation gradient factor (%) for elevations below E0LMID
P0GRADM	0 to 20	0	0	Precipitation gradient factor (%) for elevations below E0LHI
P0GRADU	0 to 20	0	0	Precipitation gradient factor (%) for elevations above E0LHI
E0LMID	-	-	4500	Elevation at which P0GRADM is effective (m)
E0LHI	-	-	5500	Elevation above which P0GRADU is effective (m)
P0EGEN	-	100	100	Impermeable area factor
P0PERC	0 to 50	15	7	Groundwater percolation in mm/day
P0DZSH	0.0 to 1.0	0.5	0.5	Deep zone share fraction

TABLE IV
FINAL DESCRIPTION OF SHIGAR WATERSHED FOR FLOW SIMULATION IN UBWCM

Band	1	2	3	4	5	6	7	8
Midelevation band (m)	2339	2750	3250	3750	4250	4750	5250	6783
Band area (km^2)	265	240	410	700	1261	1712	1540	900
Forest fraction	0.3	0.5	0.5	0	0	0	0	0
Density of canopy	0.5	0.5	0.5	0	0	0	0	0
Orientation	1	0.5	0.5	0.5	0.5	0.5	0	0
Glacier area (km^2)	0	0	0	0	88	650	1120	860
Glacier Orientation	0	0	0	0	0.2	0.9	1	1
Impermeable fraction	0.1	0.1	0.1	0.13	0.15	0.18	0.2	0.2
Precipitation adjustment	0	0	0	0	0	0	0	0

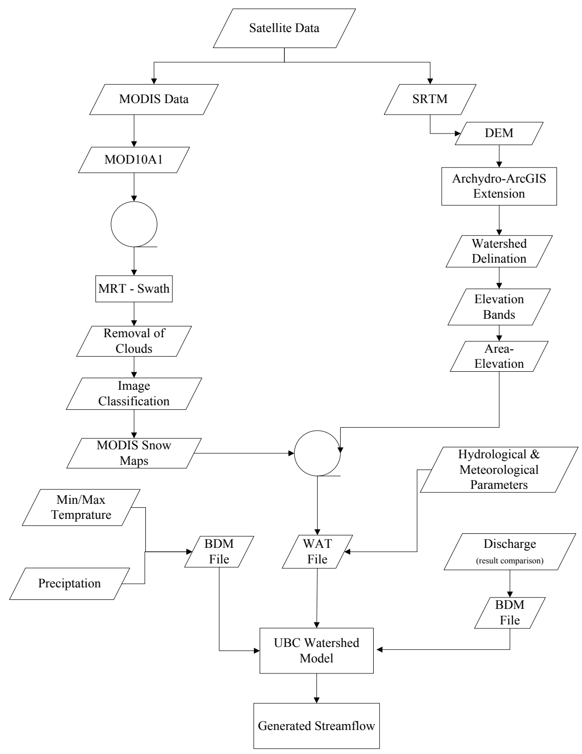

Fig. 10. Research Methodology Flow Chart

VIII. CALIBRATION RESULTS

The performance of UBC watershed model can be checked by "Statistical" and "Graphical" options. The statistical accuracy of the UBC watershed model was determined by the comparison of observed and simulated discharges. The accuracy assessment of the model was determined by the following coefficients:

i. The Coefficient of Efficiency, $e!$ compares the shape and volume of estimate hydrograph to the observed hydrograph.

$$e! = 1 - \frac{\sum_{i=1}^{n}(Qobs_i - Qest_i)^2}{\sum_{i=1}^{n}(Qobs_i - \overline{Qobs})^2} \quad (1)$$

Where,

$$\overline{Qobs} = \frac{1}{n}\sum_{i=1}^{n} Qobs$$

n = the number of days for daily runs
Q_{obsi}= the observed daily discharge on day i
Q_{esti}= the computed daily discharge on day i

ii. The Coefficient of Determination $d!$ relates the shape of estimated hydrograph to the observed hydrograph.

$$d! = 1 - \frac{\sum_{i=1}^{n}(Qobs_i - (b \cdot Qest_i + a))^2}{\sum_{i=1}^{n}(Qobs_i - \overline{Qobs})^2} \quad (2)$$

Where,

$$a = \frac{1}{n}\left\{\sum_{i=1}^{n} Qobs_i - b\sum_{i=1}^{n} Qest_i\right\} \quad (3)$$

$$b = \frac{\sum_{i=1}^{n}(Qobs_i)(Qest_i) - \frac{1}{n}\sum_{i=1}^{n} Qest_i \sum_{i=1}^{n} Qobs_i}{\sum_{i=1}^{n}(Qest_i)^2 - \frac{1}{n}\left(\sum_{i=1}^{n} Qest_i\right)^2} \quad (4)$$

Where n is the number of days for daily runs, Q_{obsi} is the observed daily discharge on day I and Q_{esti} is the computed daily discharge on day i. R^2approaches 1 as the root mean square prediction error decreases to 0. An efficiency of 1.0 indicates a best fit between the observed and computed hydrographs. The coefficient of Determination relates how well the shape of calculated hydrograph corresponds to the observed hydrograph.

The UBC Watershed Model was applied in the present study for year round (January to December) calculation of outflows for year 1998 and 2001. The Coefficient of Efficiency and Coefficient of Determination for the year 1998 were 0.93 and 0.94 respectively and for the year 2001, they were 0.86 and 0.89 respectively which are quiet reasonable and acceptable. A graphical representation is very important to indicate the behavior of watershed for visual judgment. The calibrated years 1998 and 2001 are represented in the Fig. 11 and 12 respectively.

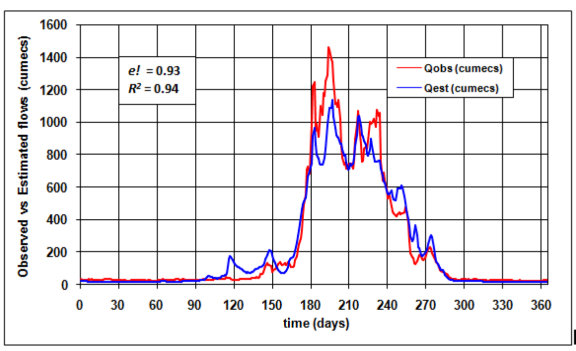

Fig. 11. UBCWM Calibration year 1998 for Shigar River

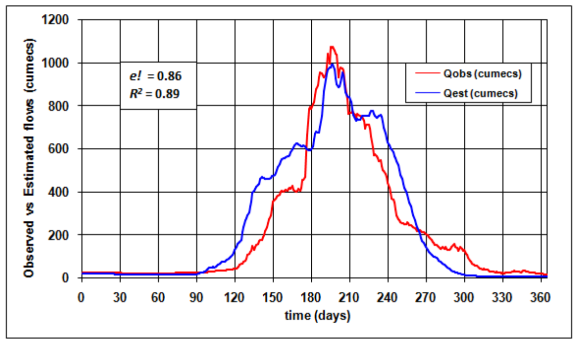

Fig. 12. UBCWM Calibration Year 2001 for Shigar River

The temporal distribution of various components of runoff in Shigar River at Shigar stream gauging station is illustrated in Fig. 13. These components include glacier melt flow, snow melt flow, flow due to rainfall and ground flow. The distribution of the computed average daily flow of 221.38 cumecs for year 1998 is given in Fig. 15. The observed flow for year 1998 is 230.52 cumecs. The major contribution to the runoff is from glacier melting about 46% as listed in Table V. The snow melt and groundwater discharge 52% also cover significant part of total runoff, whereas the amount of rainfall runoff is relatively not so considerable.

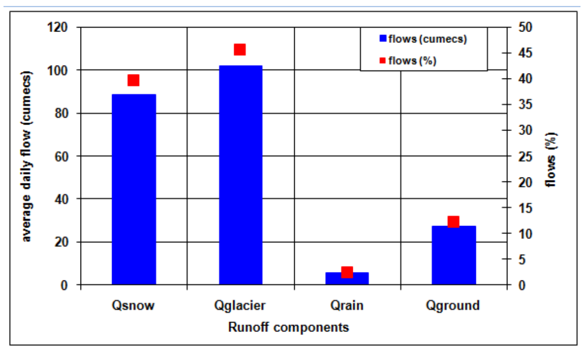

Fig. 13. Runoff Components Determined from UBCWM Calibrated Year 1998 for Shigar River

TABLE V
DISTRIBUTION OF COMPONENTS OF FLOWS FOR THE CALIBRATION YEAR 1998 AT SHIGAR RIVER

	Flow (cumecs)	Percentage (%)
Snow	88.5	40
Glacier	102.5	46
Rainfall	5.6	3
Ground water	27.4	12
Total	221.4	100

A. Validation Results

After the reasonable calibration of model, the results were validated for year 2002 using the discharge data at Shigar River for comparison of estimated inflows by the model. In the validation period 2002, the maximum air temperature of 38.6 °C was observed in August and a precipitation event of 10.8 mm occurred in February. The snow covered area was smaller at the start of the simulation period due to less precipitation Fig. 10. In the lower zones the snow started melting earlier due to increase in temperature. In the upper zones the glacier start melting in the beginning of May. The highest peak of the measured runoff was observed in August. The accuracy results showed Coefficient of Determination and Efficiency as 0.91 as shown in Fig. 14. The validation simulation of year 2002 matched closely to the measured discharge of former years. The perfect match between computed and observed flows was obtained using the same calibrated parameters. The result listed in Table VI for Shigar River in UIB shows that the model calibration is acceptable.

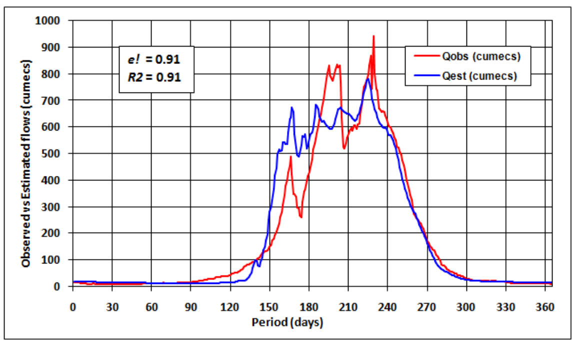

Fig. 14.Validation of UBCWM for Year 2002 at Shigar River

TABLE VI
STATISTICAL SUMMARY OF SHIGAR BASIN AFTER UBC VALIDATION FOR THE YEAR 2002

Year	Coefficient of Efficiency	Coefficient of Determination	Observed flows (m^3/s)	Computed flows (m^3/s)	Difference between Observed and Estimated (m^3/s)	Percentage flow difference
2002	0.91	0.91	192.6	198.53	-5.93	3.07% Q_{obs}

The contribution of flows in Shigar River for validation period 2002 in cumecs and percentage are listed in Table VII. The maximum contribution is by glacier melt which is 64 % due to less snow cover depicted Fig. 10 and minimum contribution is by rainfall that is 1% only. Hence the Shigar Basin in glacier regimes is responsive to temperature trends. Fig. 15 shows the contributions in outflows in Shigar River for the validation period 2002.

TABLE VII
CONTRIBUTION OF FLOWS FOR THE VALIDATION YEAR 2002 FROM UBCWM SIMULATION

	Flow(cumecs)	Percentage (%)
Snow	47.4	24
Glacier	126.3	64
Rainfall	1.1	1
Ground water	23.8	12
Total	198.5	100

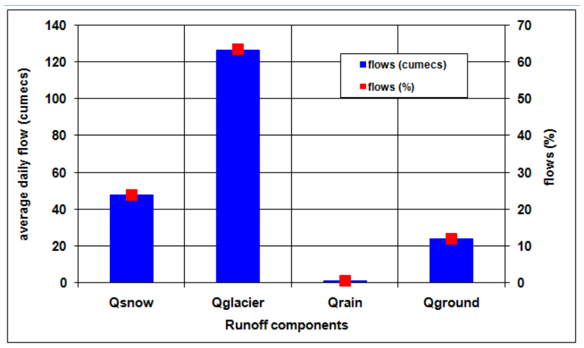

Fig. 15. Runoff Components Determined from UBCWM Validation Year 2002 for Shigar River

IX. APPLICATION OF UBCWM UNDER CLIMATE CHANGE

The long term daily temperature and precipitation data was available at Skardu Meteorological Station from year 1961-2002.The discharge data was also available at Shigar River gauging station from year 1985-2002. The mean annual temperature, mean annual precipitation and mean annual discharge trends were analyzed over the past 40 years. The data was analyzed by placing a linear least square trend line to the annual deviation from the mean and assessing the significance of trends. Over the long period 1961–2002, there has been a significant increase in mean annual temperature at Skardu of 0.24 °C per decade. Fig. 16 shows a striking increase in mean annual temperature and hence significant warming at Skardu can be registered

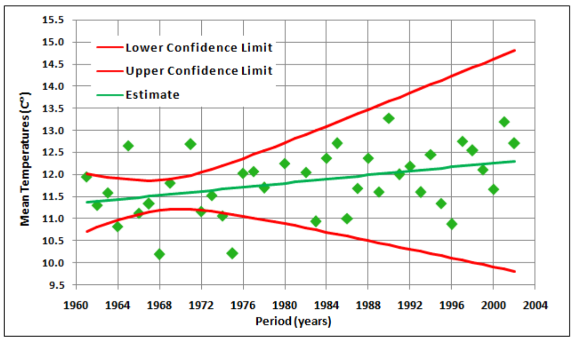

Fig. 16. Mean Annual Temperature Trends at Skardu Meteorological Station (1961-2002)

On the basis of long term daily precipitation data 1961-2002 at Skardu, there is no significant change in annual precipitation over the last forty years as shown in Fig. 17. An increase of 47% flows in 17 years at Shigar River since 1985 has been observed as shown in Fig. 18.

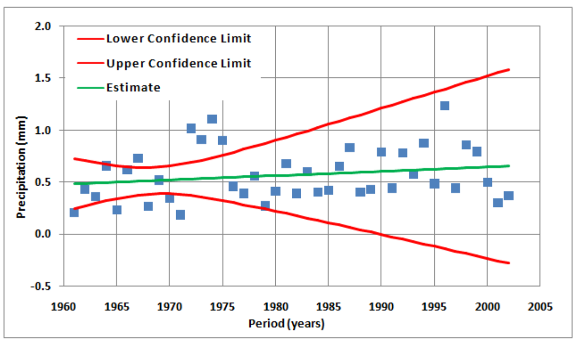

Fig. 17. Mean Annual Precipitation Trends at Skardu Meteorological Station (1961-2002)

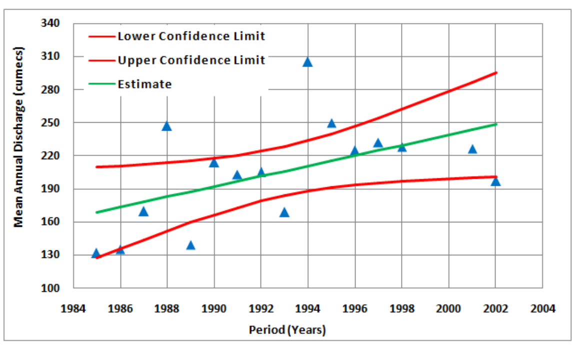

Fig. 18. Mean Annual Discharge Trend at Shigar River Gauging Station (1985 – 2002)

The trends in mean annual maximum and minimum temperatures at Skardu over the period 1961-2002 were investigated for future climate prediction. Fig. 16 shows that there is an increase of 0.56°C per decade in mean annual maximum temperature at Skardu since 1961-2002. There is contradicting reduction in annual minimum temperature of -0.079 °C per decade. Both the trends were projected for the next ten year using the linear trend line up to 2012 as the UBC watershed model accept the daily minimum and maximum temperature. The daily minimum temperature of year 2002 was multiplied by a factor -1.5% and similarly the daily maximum temperature was multiplied by factor 2.77 % to get the projected temperatures of 2012 on the basis of determined trends in minimum and maximum temperatures as shown in Fig. 19 and 20 respectively.

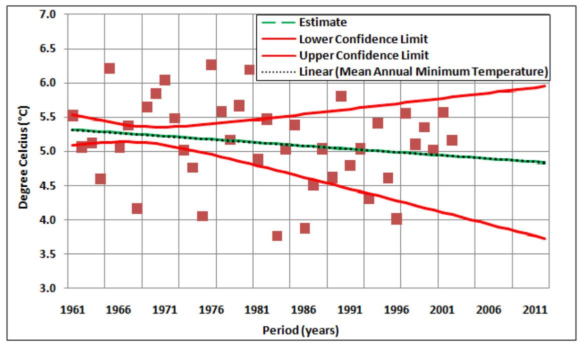

Fig. 19. Projection of Mean Annual Minimum Temperatures w.r.t Base Period (1961-2002)

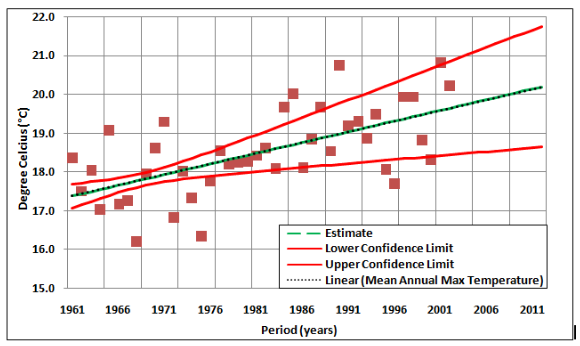

Fig. 20. Projection of Mean Annual Maximum Temperatures w.r.t Base Period (1961-2002)

As Shigar River is the important tributary of Indus River, it is important to estimate the future flow contribution due to changing climate pattern and melting of glaciers. After the satisfactory statistical results were achieved, the model was used to generate the flows for next ten years using the projected temperatures. The projected maximum and minimum temperatures were used as input in the UBC watershed model using the same calibrated WAT file for assessment of flows for next ten years 2012. As there is no significant trend exist in annual precipitation, therefore the input precipitation were kept the same as that were observed in 2002 at Skardu Meteorological Station. All the calibrated parameters were kept fixed. The projected flows for the next ten years in 2012 are 201.4 cumecs which are represented in Fig. 21. Like calibration and validation inflows, the major contribution in predicted inflows is from glacier melting which is 65% of the total inflows. Thus, projected hydrological flows are clearly sensitive to the climate inputs. The volume and percentage distribution of various components of predicted inflows by UBCWM for year 2012 are listed in Table VII. The use of projected temperatures rather than measured may affect the performance of the model. This result demonstrates a dominant use of a physically based runoff generating method when applied to water resource planning studies. The Overall Increase in flows is 4 percent with respect to base year 2002. The rainfall and groundwater component flows remains the similar because the input precipitation and geographical parameters of basin were kept same as that of year 2002 for flows predication of year 2012. The main focus was to consider the affect of temperature on the flow regime generated by the glaciers. The predication duration is only after 10 years.

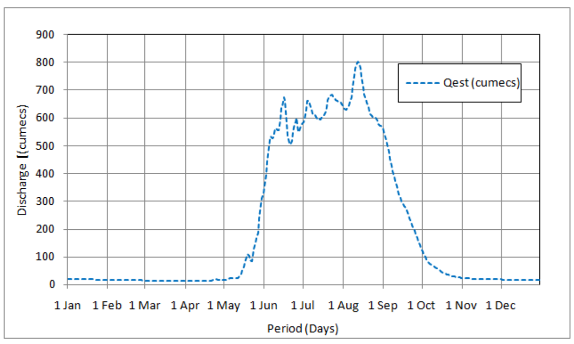

Fig. 21. Predicted Flows at Shigar River for year 2012 using UBCWM

TABLE VIII
DISTRIBUTION OF COMPONENTS OF PREDICTED FLOWS FOR YEAR 2012 AT SHIGAR FROM UBCWM SIMULATION

	Flow (cumecs)	Percentage (%)
Snow	46	23
Glacier	131	65
Rainfall	1.1	1
Ground water	23.3	11
Total	201.4	100

TABLE IX
OBSERVED AND ESTIMATED/PREDICTED FLOWS FOR RISING AND ENDING OF FLOWS TIME PERIOD IN JULIAN DAYS

Year	Observed Flows (Cumecs)	Estimated/ Predicted Flows (Cumecs)	Observed-Estimated (Cumecs)	Duration Starting to Ending (Julian Days)	Coefficient of Efficiency	Coefficient of Determination
1998	377.92	368.91	8.09	90 – 290	-0.05	0.76
2001	370.5	421.9	-51.9	90 – 300	-6.26	0.83
2002	365.61	378.47	-12.86	135 – 285	-0.76	0.67
2012 Predicted	-	453.13		135 – 285	-	-

X. CONCLUSIONS

The University of British Columbia Watershed Model (UBCWM) was developed and used by M.C. Quick and A. Pipes in 1972 for daily stream flow forecasting at the Fraser River system in British Columbia (Quick and Pipes, 1972). In this research study, UBCWM windows version 1.1 was applied in the UIB on Shigar River for year round (January to December) 1998-2002. The following conclusions were drawn from the study:

- Analysis of temperature, precipitation and runoff time series data showed positive trends as shown in Fig. 17, 18 and 19 respectively. They are increasing with the rising global warming. The mean annual temperature showed an increase of 0.24 C per decade at Skardu for record of 40 years 1961-2002. For annual precipitation, there is no considerable rise in trend as rainfall is scarce in this region. The effect of climate change has also been investigated. The trend of annual discharge showed increase in runoff volume up to 80 cumecs in 17 years 1985–2002.However it is not easy to predict the runoff response to climate change in such a daily varying runoff.
- Relationships have been established between temperature, precipitation and runoff. The summer runoff and summer temperature are strongly correlated, hence Shigar Basin is sensitive to temperatures which is depicted in comparison graphs of temperature and runoff Fig. 8. The visual temperature-runoff relation suggests seasonal increase runoff in summer due to glacier melt. In glaciated Shigar Watershed, the runoff and precipitation are poorly or negatively correlated as lowest precipitation occurs in this region Fig. 9. Since 1961 the annual maximum temperatures have increased by 0.56 °C per decade while there has been a reduction in annual minimum temperatures of

0.079 °C per decade at Skardu. The decrease in minimum temperature may change a part of precipitation falling as snow. Thus overall there is warming trend in winter due to increasing maximum temperature and a cooling summer due to decrease in minimum temperatures.

- Geographic Information System (GIS) is very useful in describing the characteristics of watershed otherwise; characteristics like watershed delineation, area, elevation bands, hypsometric elevation mean have to be computed manually which are subjected to human error and physically very hard job to perform.
- There is enormous amount of information available in GIS, the most represented databases of watershed are extracted on terrain and ecology. In this research, topographical characteristics of Shigar watershed were established from GIS information. The basin was accurately divided into 8 bands according to each 400 meter elevation interval.
- After examining the statistical and graphical analysis of Shigar Watershed, it is concluded that UBCWM is well calibrated and validated. The computed model flows fits well to the recorded flows. There is a perfect match and correlation replicating the main features of hydrographs.
- The UBCWM was able to simulate recorded flows in Shigar Watershed with an average coefficient of efficiency 0.895 and coefficient of determination 0.915 for the years 1998 and 2001. The difference between observed and calculated flow was 8.05% for two years.

The major contribution in Shigar River is due to glacier melting about 40% as the basin is more sensitive to varying temperatures thus the increase in trends give more input energy for higher melting rate of snow and glaciers. The rainfall is less in Shigar Basin therefore its effect or contribution is not prominent in UBCWM simulations. The reasonable calibrated and validated statistics indicate that the model can be applied for future water resource studies. Due to projected climatic change, the model predicted 4 percent more flows for 10 next ten years with respect to the validated year.

X. RECOMMENDATIONS

In this study, the trends of temperature and precipitation have been analyzed using the meteorological data of Valley Station which may be not representative for higher elevations. The flows may also be computed by considering the future precipitation changes. It is suggested to investigate that how the glaciers in Shigar Basin will behave in future with respect to the global warming. The flows data have not been gauged at Shigar River since 2002, it is recommended to predict more precisely the hydrological flows in poorly gauged highly altitude basin as storing tremendous amount of water. The computation of future flows should also include the impact of change in precipitation. Since after 2002, the stream gauging station at Shigar River is inoperative due to flood. Therefore it is recommended to correlate Shigar River flows with a nearby recording gauge.

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Production Planning and Control of Assembly Process for the High Tech Products

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***Abstract*-**Global competition, marvelous achievement in technology and quick fix solutions compels manufacturers to use standard techniques in production settings. The presented work is related to the planning and control assembly process for high tech products. The assembly line has been balanced using heuristics approaches of largest candidate rule, kilbridge and wester method and ranked positional weights. After initial analysis, three algorithms give the same balanced efficiency and balance delay. The simulation routines have been written in software; model verified and validated spreadsheet and discussion with case company. Significant performance parameters have been evaluated and effects on the responses have been established and prioritized according to their importance. It has been observed that setup time comes out to be the most sensitive parameter followed by quality level and process time at global level, while total production, cycle time and average delay in queue identified important at local level. The utilization of the resources is the least sensitive parameter found in the company. It is recommended to use temporary storage buffers, fixed launching sequence in different models, keeping less than six percentage losses (quality related) and balanced efficiency by implementing line balancing techniques.

***Keywords*-**Assembly process, Cycle time, High tech manufacturing, Manufacturing simulation, Setup time reduction

I. INTRODUCTION

For customer's satisfaction, the competition of improving the productivity with high level of quality is always demanded. The rapid advancement in the technology has reduced the product lead time. This has created a great competition among the manufacturing industries. This justifies the competition among the industries and in turn continuous improvement in their manufacturing system design by taking engineering decision making.

One of the most important tools for improving manufacturing system is line Balancing (LB). It has been developed 1970 and its refinement over the decades has made it one of the most widely used tools in the world leading industries [1]. In this technique the system is designed in such a way that overloading and under utilization can be minimized. Line balancing along with simulation provides a strong tool for analyzing system design. The focus of current research is to analyze existing line balancing techniques in industries involved in the assembly of multi-items. The impediments faced during the assembly of these products are the processing sequence of tasks are subject to precedence constrains. The sub components are not manufactured well in time to meet the fixed target for the final delivery of these components and hence it delays the production of the final component. Some of the manufacturing equipments are over loaded, whereas others are under-utilized. There is a need to investigate bottlenecks in the existing system in systematic manner. Furthermore, there is no exact calculation about the capacity of the existing set up (the set time is assumed here the change over time), which makes it difficult for the management to set exact targets.

This research focuses to overcome these issues. Local industry has been selected which consists of four assembly lines. After preliminary analysis, it was identified that "safety hose" assembly line required attention to improve productivity. The assembly line consisted of manual assembly stations. There was need to pay attention to improve the design, which would aid the management to cope the shop floor activities effectively. The main objective of this paper is: a) line balancing of the manual assembly line with classical line balancing methods in order to stream line the production; b) developing a simulation model of the existing system to identify key performance parameters which would affecting the system; c) to prioritize the input parameters using matrix formation.

II. LITERATURE REVIEW

In flow line production there are many separate and assembly operations to be performed on the product. It is generally the case that the product must be manufactured at some specified production rate in order to satisfy demand for the product. Whether we are concerned with performing these processes and assembly operations on automatic machines or manual flow lines, it is desirable to design the line so as to satisfy all of the foregoing specifications as efficiently as possible. The ongoing literature of assembly line, related issues and mathematical relationships has been comprehensively reviewed in [1]. The line balancing problem is to arrange the individual processing and assembly tasks at the workstations so that the total time required at each workstation is approximately the same. Total Work Content is the collective of all then work elements to be done on the line. Let T_{wc} be the time required for the total work content. Hence, total work contents consist of elements given in (1).

$$T_{wc} = \sum_{j=1}^{n_e} T_{ej} \quad (1)$$

The work performed at the station consists of one or more of the individual work elements and the time require is the sum of the times of the work elements done at the station. It should be clear that the sum of the station process times should equal the sum of the work element times given in (2).

$$\sum_{i=1}^{n} T_{si} = \sum_{j=1}^{n_e} T_{ej} \quad (2)$$

The cycle time is the ideal or theoretical cycle time of the flow line, which is the time interval between parts coming off the line. The design value of T_c would be specified according to the required production rate to be achieved by the flow line in (3).

$$T_c \leq \frac{E}{R_p} \quad (3)$$

The precedence constraints also referred to as "technological sequencing requirements." The order in which the work elements can be accomplished is limited. In addition to the precedence constraints described above, there may be other types of constraints on the line balancing solution. The balance delay sometimes also called balancing loss; this is a measure of the line inefficiency which results from idle time due to imperfect allocation of work among stations. It is symbolized as d as in (4) and can be computed for the flow line.

$$d = \frac{nT_c - T_{wc}}{nT_c} \quad (4)$$

The balance delay is often expressed as a percentage rather than as a decimal fraction in E. The balance delay measures the inefficiency from imperfect line balancing. Several methods have been considered for solving the line balancing problem. These methods are heuristic approaches in the form of algorithms, meaning that they are based on logic and common sense rather than on mathematical proof. The manual methods under study are:1) Largest-candidate rule; 2) Kilbridge and Wester method and 3) Ranked positional weights method. In our case, these heuristics have been used for balancing of assembly system.

Today's customers are becoming more and more aggressive in demanding new products and services within a short period of time [2]. In broader spectrum, [3] provided a strategic picture of the automobile industry in local environment. Taxonomy developed for US small manufacturing industries in which emphasis placed on competition priorities i.e. cost, delivery, flexibility and quality is proposed by [4]. The work of [5] is also significant in which relative importance and competitiveness strength of different Chinese manufacturing companies have been investigated empirically. The authors have found that innovation, after sales service, quality and flexibility are the most important competitive priorities among Chinese enterprises. Elements of mass customization for fast productions systems have been reviewed by [6]. Scale, cost, quality and time in a row is the targets and also paradigms where business is managed. Mass customization is the one of these modern means to achieve these goals. It is customizing product to individual customers and producing those with principles of mass production. The key issue is customer focus. Fast production means delivering products to customer faster than the lead time of the whole manufacturing process in order to satisfy customers. This can be achieved by utilizing standardized methods and modularized product structure. Companies are continuously forced to improve their performance in order to create VA customers and to remove NVA activities and simulation tool is best for modeling of these issues [7]. As companies seek to provide product faster, cheaper and better than the competitors, they have realized that they cannot do it alone. In the new era of production, strategic priorities rather than cost contained focus have proved to be important for competition namely: quality, dependability, flexibility, customer service, after sales service, supply chain management etc. Some supported use of IT related technologies which have proved to be vital for successful competition as it can facilitate the attainment of these strategic targets [8].[9] identified global characteristics of agility which can be applied to all aspects of enterprises: flexibility, responsiveness, speed, culture of change, integration and low complexity, high quality and customized products and mobilization of core competition [9]. The major contribution of [10] is the spelling out of meaning and definition of Advanced Manufacturing (AM). There is still issues of time based competition, quality and innovation for the companies. The use of various performance indictors in a systematic and coherent manner either at tactical or strategic level is required further analysis. Some of the key governing parameters are, time, quality, cost, maintenance, workers, schedules, waiting time, productivity, cycle time, utilization of resources, percentage of good parts i.e. yield. The parameters of interest related to the study are being used for the building of model.

III. Process Description And Modeling

The product under study is safety hose pipe which is used in different machines for the fluid transmission. The pressure of the fluid is normally greater than the one atmospheric. That is why the quality as well as reliability issues are required. The main elements of the product consists of steel pipe, rubber pipe and copper connectors. The steel pipe used as core and the rubber pipe is for insulation while the connectors are used for the assembly with the other parts of the machine. The manual assembly line of consists of the following processing steps:

1) The steel pipe of high grade and flexible is received at pipe assembly station.
2) The rubber pipe of high quality is also received at pipe assembly station.
3) The steel pipe is inserted inside the rubber pipe through air pressure.
4) The length of rubber pipe is kept larger than the steel pipe before insertion after completing the process the extra length is cut down.
5) Both ends of the assembled pipe are marked for the connecter fitting.
6) Connectors come from the inventory
7) Visual inspection of connector is done.
8) The connectors are assembled with pipes.
9) The assembled pipe is passed through metrology and hydro testing.
10) Identification number is marked on each pipe and then packed it in the delivery boxes.

The process sequence of the production line is given below in which positions and precedence links are described.

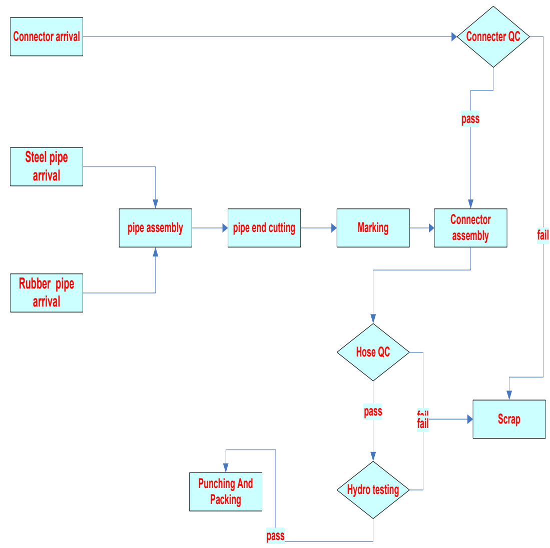


Fig. 1. Process flow diagram

Traditional line balancing methods and simulation has been used. Three techniques explored has been modeled using Largest Candidate rule, Kilbridge & Wester method and ranked positional weight methods).These techniques are based on the algorithms (the complete algorithms are beyond scope of work and only results have been described) and the line balanced before simulation study. The reason is to optimize the assembly line prior so that to focus on other performance measures. After balanced line, simulation as a tool for the study has been implemented. The collected data from the local industry is used for developing of the model. After developing the model it has been verified with the existing practices in the local industry. It has been observed that the base model is ideal and different experiments of effecting parameters are required to overcome the associated impediments. The validation of the modified model is done with "what if" effects with the base model of the assembly line. After the discussion on the results we are able to get some useful results which may improve the overall performance of the assembly line.First the assembly line has been balanced using algorithms: a) Largest Candidate Rule, b) Kilbridge and Wester Method and c) Ranked positional Weights [11]. After the line balancing with classical methods, simulation platform Arena has been used for experimentation. Interestingly, balance efficiency is same and it is required for company to stream line the single model assembly line to maximum balance i.e. 82.9%as given in Table I.

TABLE I
LINE BALANCING METHOD RESULTS

	Largest Candidate Rule	Kilbridge and Wester Method	Ranked Positional Weights Method
Line Efficiency	82.9%	82.9%	82.9%
Balance delay	16.75%	16.75%	16.75%

In order to analyze system completely i.e. queue length at each station, production information etc and its effects on the assembly system, a comprehensive treatment is required. A simulation using what-if scenario, various scenarios have been established and results communicated to the case company. The next section describes the generic mathematical model developed for the process time, quality level and setup time; which have been identified sensitive to the assembly system.

IV. MATHEMATICAL MODELING AND ANALYSIS

The mathematical model of the existing case study is given below. The model is with 'K' independent variable .The mathematical expression of the model is;

$$Y_i=\beta_0+\beta_1X_{1i}+\beta_2X_{2i}+\beta_3X_{3i}+ \ldots + \beta_KX_{Ki} +E_i \quad (5)$$

Where

Y_i=Response of the model.
β_0=Y- Intercept.
β_1=Slope of Y with variable X_1, holding variables X_2, X3,……….,X_K constant
β_2= Slope of Y with variable X_2, holding variables X_1, X3,……….,X_K constant
β_3= Slope of Y with variable X_3, holding variables X_1, X2,……….,X_K constant
β_K= Slope of Y with variable X_K, holding variables X_1,X_2,……….,X_{K-1} constant
E_i=Random Error

During manual assembly operations, each operator work at each work station. The process time is obtained by time study. The working time in the factory is 720min per day and the process time for each work station is determined for process time and modeled for appropriate distribution given in Table II.

Following assumptions are made during the simulation:

- Assembly line never starved;
- Set up time is not considered
- Twenty minute time without any brake;
- Not any maintenance time included in the simulation model;
- All operation are not includes any insignificant breakdowns.

TABLE II
TIME DISTRIBUTIONS FOR PROCESS

Station #	Process time	Distribution
01	Steel Pipe arrival	NORM(42,1)
02	Rubber Pipe Arrival	NORM(38,1)
03	Pipe Assembly	TRIA(24,25,26)
04	Pipe End Cutting	EXPO(27)
05	Marking	NORM(36,1)
06	Connector Arrival	UNIF(35,36)
07	Connector QC	EXPO(16)
08	Connector Assembly	NORM(35,1)
09	Hose QC	NORM(46,1)
10	Hydro Test	TRIA(28,30,32)

The transportation of material is also done by the workers their selves. Now the base model was run according to the provided input parameters. The following abbreviations has been used

TABLE III
SOME PERFORMANCE INDICATORS ASSEMBLY LINE
(INITIAL ANALYSIS)

Station #	Performance Measures	Abbreviations	Values
01	Total Production	TP	21 parts
02	Average Delay in Queue	ADQ	110.95 sec
03	Max Delay in Queue	MDQ	225.64 sec
04	Max. number of parts in queue	MPQ	53 parts
05	Max Utilization	MU	98.7%
06	Min Utilization	Min U	57.75%
07	Number of parts rejected	--------	4 parts
08	Cycle time	TC	56.67 sec
09	Balance efficiency	Eb	82.5%

The following observations are obtained during the line balancing simulations Table III, which cannot be obtained using the classical line balancing methods. Utilization of each station is also being able to be determined. The cycle time is marginally less than the obtained in the classical methods. This difference is due to insignificant break downs and setup times. It is clear from the model that the maximum queue is formed at the Hose QC station. It means this is the main Bottleneck station in this production line. It is shown that what- if effect of changing the process time of Hose QC..The following parameters have been changed in the base model of the Safety Hoses, I) Process Time (PT); II) Quality Level (QL) and III) Set up Time (SuT).

A. Model for PT

The mathematical model for the all KPI can be generalized as; the response of all the KPI can be determined by the generic equations which are elaborated (rest of models is similar and details not provided):

$$Y_i=\beta_0+\beta_1X_1+\beta_2X_2+ \beta_3X_3 +E_i \quad (6)$$

Where, $X1=X_{PT}$, $X2=X_{QL}$, $X3=X_{SuT}$.

Here X_2 and X_3 are kept constant while the response for all KPI can be expressed as Ei=it is the random error,

For TP

$$Y_{TP}= \beta_0+\beta_{PT}X_{PT}+E \quad (7)$$

$\beta_{PT=}$ Slope of Y_{TP} with variable X_{PT} holding X_{QL} and X_{SuT} constant.

For ADQ

$$Y_{ADQ}= \beta_0+\beta_{ADQ}X_{PT}+E \quad (8)$$

$\beta_{ADQ=}$ Slope of Y_{ADQ} with variable X_{PT} holding X_{QL} and X_{SuT} constant.

For MDQ

$$Y_{MDQ}= \beta_0+\beta_{MDQ}X_{PT}+E \quad (9)$$

$\beta_{MDQ=}$ Slope of Y_{MDQ} with variable X_{PT} holding X_{QL} and X_{SuT} constant.

For PR

$$Y_{PR}= \beta_0+\beta_{PR}X_{PT}+E \quad (10)$$

$\beta_{PR=}$ Slope of Y_{PR} with variable X_{PT} holding X_{QL} and X_{SuT} constant.

For MPQ

$$Y_{MPQ}= \beta_0+\beta_{MPQ}X_{PT}+E \quad (11)$$

$\beta_{MPQ=}$ Slope of Y_{MPQ} with variable X_{PT} holding X_{QL} and X_{SuT} constant.

For MU

$$Y_{Mu}= \beta_0+\beta_{MU}X_{PT}+E \quad (12)$$

$\beta_{MU=}$ Slope of Y_{MU} with variable X_{PT} holding X_{QL} and X_{SuT} constant.

For MinU

$$Y_{Min\,U}= \beta_0+\beta_{MinU}X_{PT}+E \quad (13)$$

$\beta_{MinU=}$ Slope of Y_{MinU} with variable X_{PT} holding X_{QL} and X_{SuT} constant.

For TC

$$Y_{TC}= \beta_0+\beta_{TC}X_{PT}+E \quad (14)$$

$\beta_{TC=}$ Slope of Y_{TC} with variable X_{PT} holding X_{QL} and X_{SuT} constant.

B. Effect of Changing PT

The utilization of Hose QC is 98.7% and the next Hydro Testing station is 57.27%. The process time of Hose QC is NORM 46,1.Making the assumption is that what effect on the overall performance measures with 20% reduction in the performance time of the Hose QC. The following responses are obtained:

1) Effect of PT on TP: It is clear from the graph Fig. 2 that with reducing the 20% value in the PT of Hose QC the 25% boost up is observed and it goes if we reducing the values up to 60% then the trend become smooth and corresponding slope is also recorded.

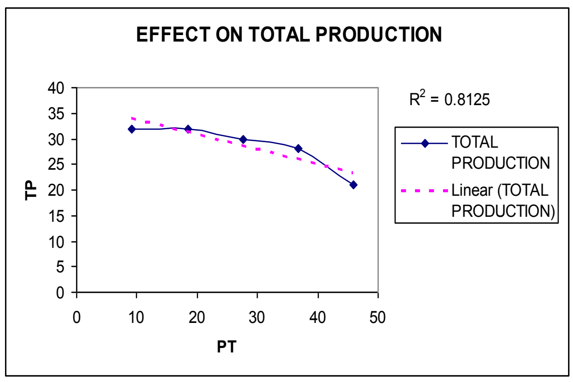


Fig . 2. PT Vs TP

2) Effect of PT on ADQ and MDQ: The trend shows that with the change of PT up to 20% reduction in ADQ is 14% and this goes reducing with the TP up to 60%. This is the reason that utilization of next station has been increased. The same change in MDQ has been observed that is 14 % reduction with the reduction of 20% in TP as in the case of ADQ. The change becomes almost smooth around 60% reduction in TP and is shown in Fig. 3.

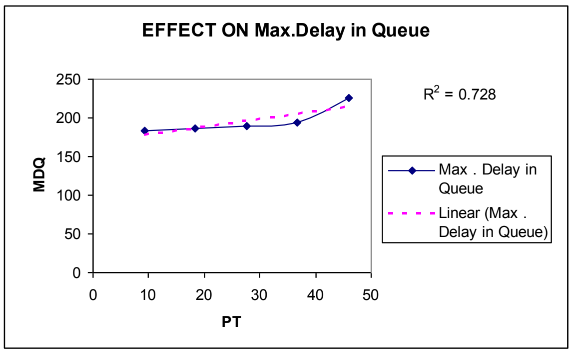
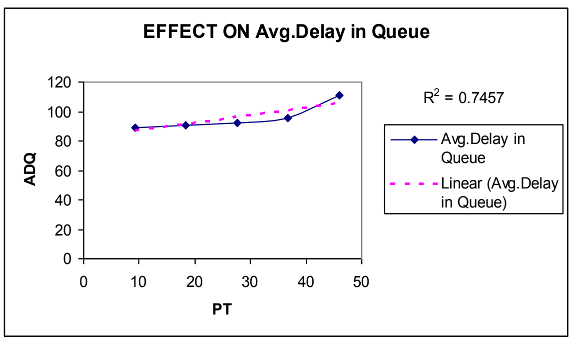
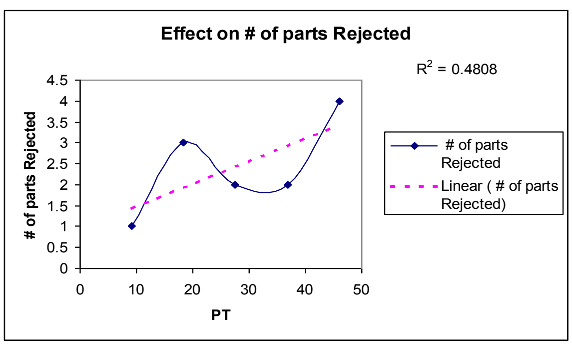


Fig. 3. PT Vs ADQ and MDQ

3) Effect of PT on Number of Parts Rejected and MTQ: The numbers of rejected parts are also reduced with change in the TP as shown in Fig. 4. This trend is not smooth because of the probabilistic and it becomes almost 50% at 60% reduction in TP. The total production is based on the reduction of queue length which is because of maximum number of parts in queue. It is very clear that at 60% reduction in TP, the reduction in MPQ is about 50% and it is a significant change.





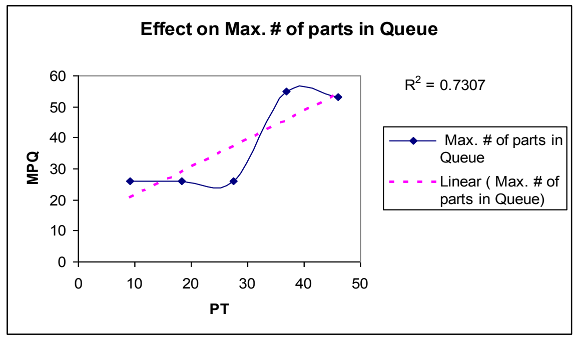
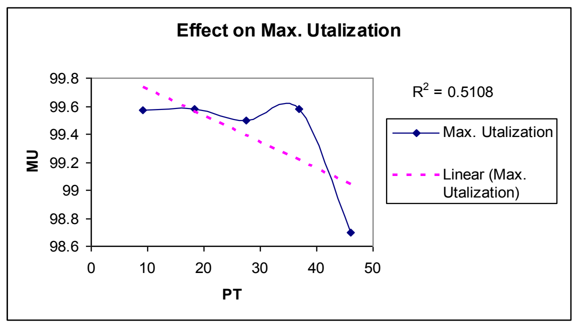
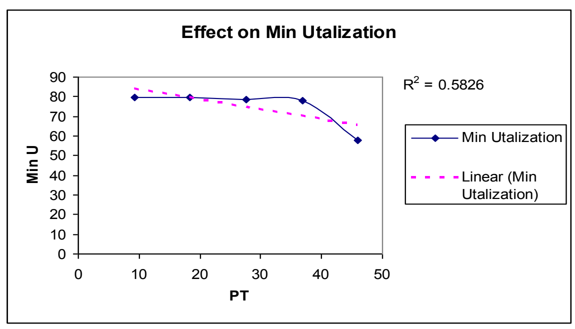


Fig. 4. PT Vs Number of parts rejected and MPQ

4) Effect of PT on MU, Min U and TC: The maximum utilization is not changing with the change of TP, because the utilization is very high in Fig. 5. MU increased up to 2% at 60% reduction in TP. The main target is the Min U of Hydro Test station which is being increased up to 22% with the reduction 60% reduction in TP. Then it is almost same with the change in TP. The TC also reduces about 50% at the changing of PT up to 60% reduction. Then it becomes almost same. The over-all effect of changing the process time seems to be very significant for the production line.





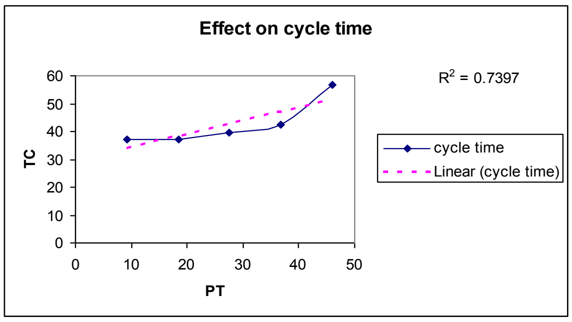
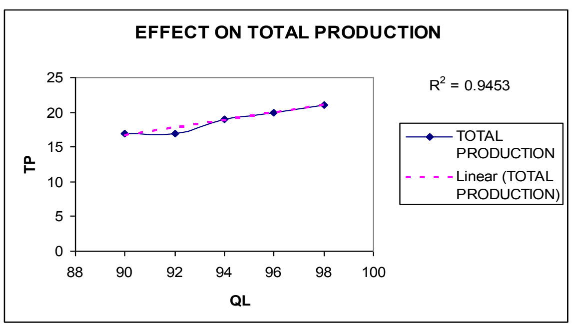


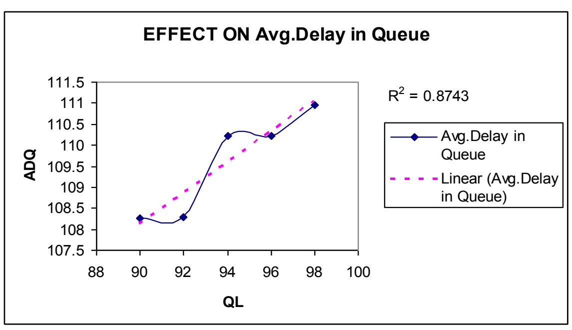
Fig. 5. PT Vs MU and Min U and TC

C. Effect of Changing QL

In the process diagram we have three inspection stations which have 2% (98% Quality Level) parts rejection. Now we see what effect the Quality level of the said stations effects if we increase the rejection rate as 4% (96% Quality Level); 6% (94% Quality Level); 8% (92% Quality Level) and 10% (90% Quality Level). After changing the Quality Levels the following effects on the performance measures have been observed:

1) Effect of QL on TP, ADQ and MDQ: If the quality level reduces only 2% the 5% reduction in TP is observed and it becomes smooth at 8% reduction in QL. It is seen in Fig. 6 that the change in the TP is directly proportional to the QL for specific case. The change in ADQ is showing random behavior with the change in QL and not affected. The change effected minor on the ADQ. The MDQ is at minimum at 98% QL and then it become smooth at the level of 96% to 92% and onward.





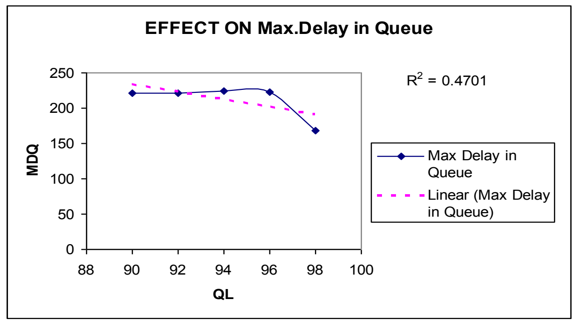
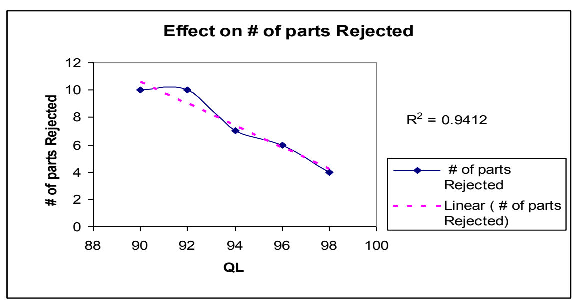


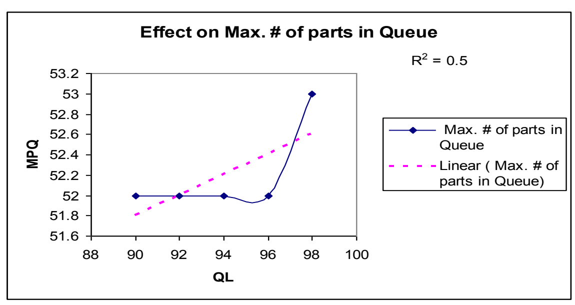
Fig. 6. QL Vs TP, ADQ and MDQ

The trend also shows that the minimum delay is at higher quality level and it goes down if we changed downward.

2) Effect of QL on Number of Parts Rejected and MPQ And Mu: It is very obvious that if the quality level in any production line reduces it effects upon the number of rejection, the same thing is observed as given in Fig. 7 but the glaring thing is that the rejection is increases 50% with changes of 2% reduction in the QL and it goes on increases with more reduction in QL. The effect on the MPQ by the changing QL is also not very smooth. As the maximum utilization is already very high then it is not affected by the changing the QL.

3) Effect of QL on Min U and TC: The QL as shown in Fig. 8 influence on the minimum utilization as it reduces the minimum utilization also reduces. Just 6% reduction in the QL the reduction in Min U is about 15%. The TC is also impacted by the QL very much; it is also an indicator of low production.





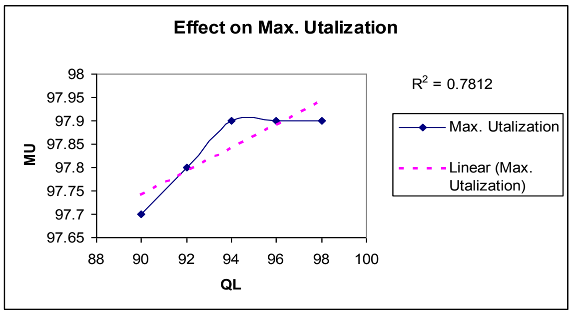


Fig. 7. QL Vs Number of parts Rejected, MPQ and MU

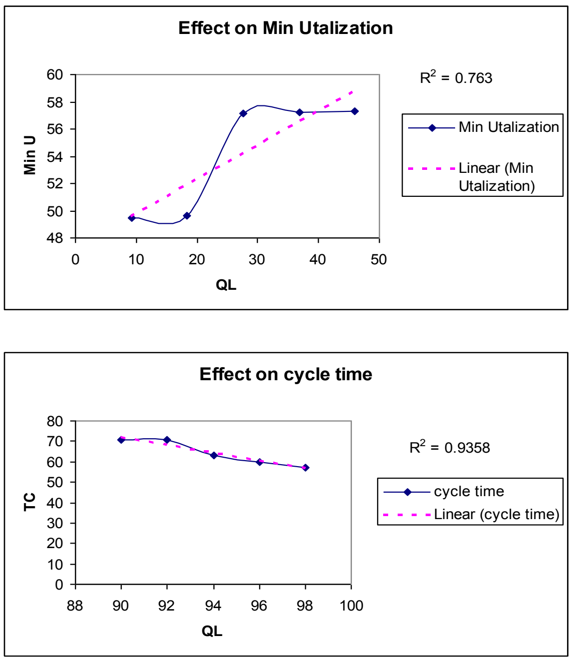
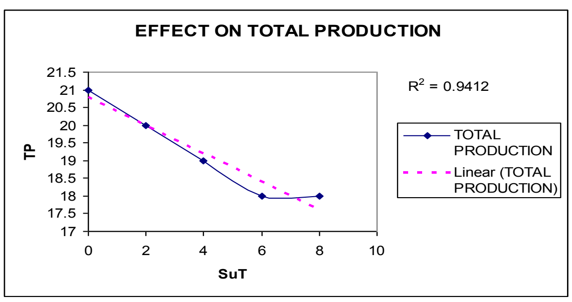
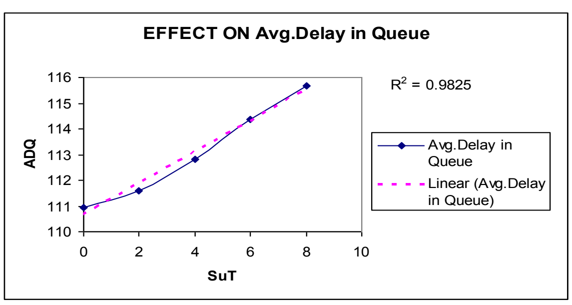


Fig. 8. QL Vs Min U and TC





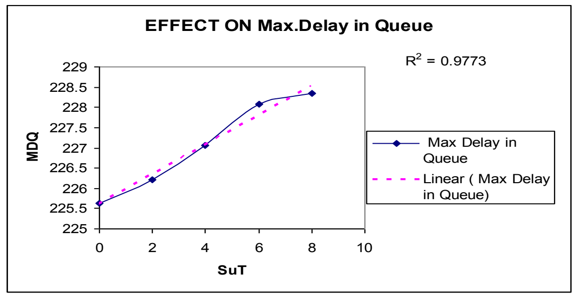
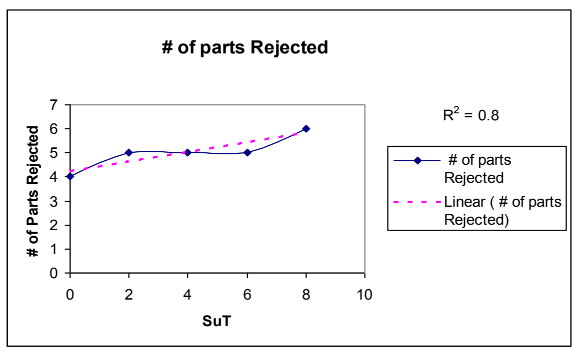


Fig. 9. SuT Vs TP and ADQ and MDQ

D. Effect of Changing SuT:

Initially the consideration was that the set up (Change over) time considered is zero second. But the set up time effects the line balancing. So, we made another assumption of changing setup time from 0 sec to 2 sec. 4 sec. 6 sec and 8 sec to analyze the effects on the performance measures. After changing the above parameters in the base model; following effects were observed.

1) Effect of SuT on TP and ADQ: Set up time is also impacting upon the TP of the production line. It is clear from the Fig. 9 that the change of 2sec the change in TP is 5% reduction and at 4sec it is 10% at 6sec the change is 15% in TP. After 6 sec the change in the graph stopped and it continued until it reached 18 sec. It is obvious that the change in ADQ will be increased as the SuT time added up in the ADQ .The trend in the graph shows that the change is directly related to SuT and over all change is about 5%.The similar effect as observed in ADQ by the change of SuT. As, it is added up in MDQ, the overall change is about 3%.



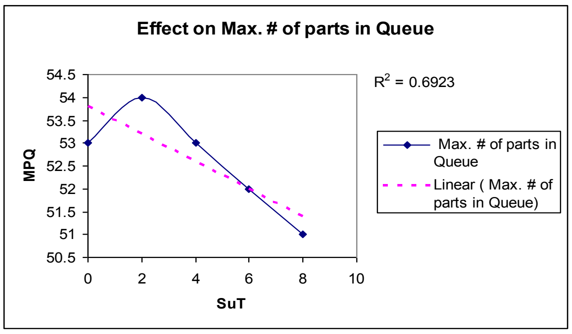
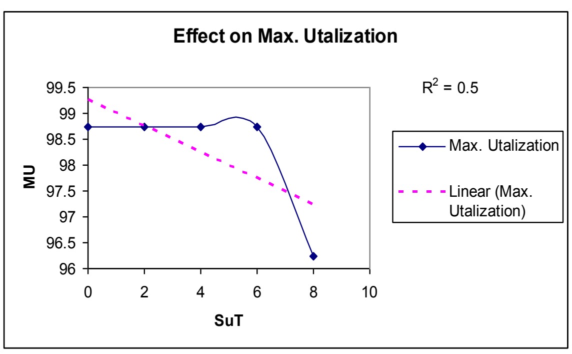


Fig. 10. SuT Vs Number of parts Rejected and MPQ

2) Effect of SuT on Number of Parts Rejected and MPQ: The SuT is increasing the number of parts rejected. The change is 10% increase with increase of 2 Sec in SuT. It becomes smooth up to the 6sec as shown in Fig. 10 and then number of parts rejected goes on increasing. The performance parameter cannot directly be related with SuT, because the number of parts rejected is probability based parameter. The trend in this graph shows that with the increase of 2 sec in SuT, the MPQ increases 2% then this go down with the increase of SuT. At 8 sec of SuT the change in MPQ is 6% down.

3) Effect of SuT on Mu, Min U and CT: The trend in Fig. 11 shows that the impact of SuT on the maximum utilization starts at 8sec and it goes increasing. This may be due with addition of time to all the station. The SuT decreases the Min U, as in the above case. It may be due to the increasing the process time of each station.

4) Effect of cycle time: The cycle time increases 5% with the increase of just 2 sec in SuT. It is going to increased till the increase in 6sec of SuT and then become smooth. The increase of cycle time means that the overall production goes increase. The effect of Set Up (Change over) time was initially ignored in the model, but actually it impacts the production. In the manual assembly line of Safety Hoses, the management did not analyzed the effect that is why the over production does not meet the actual target.



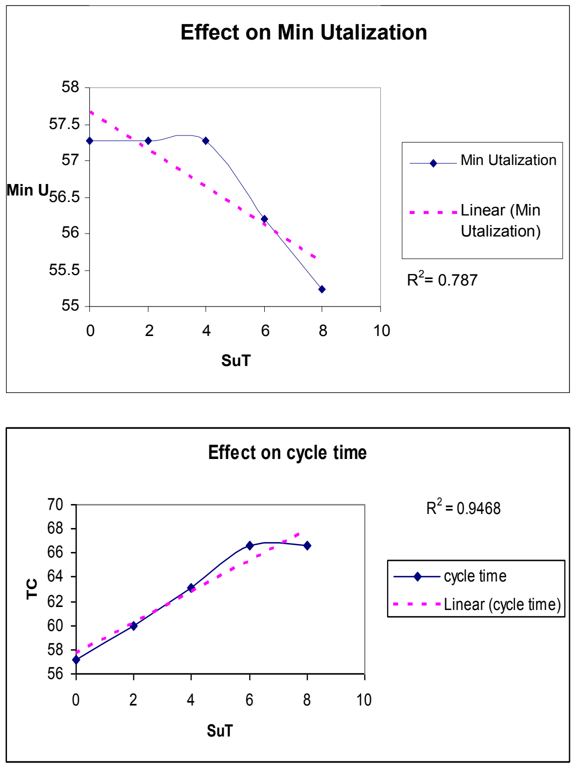


Fig. 11. SuT Vs MU, Min U and CT

Through the Simulation technique we are able to predict the effect of change over time throughout the production.

V. Sensitivity Scores and Results

After analyzing the effects, we get the trend of improving the line balancing through various set of experiments. For this purposes we have assumed the slope ranges of each effect having the different scores; if slope range (%) = 0~30, sensitivity score is 1, slope range (%) = 31~60, Sensitivity score is 2, slope range (%) = 61~80, Sensitivity score is 3 and if slope range (%) = 81~100, Sensitivity score is 4. Now the slope values from the effect graphs have been placed against each slope with corresponding sensitivity scores and are given in the following Table IV.

TABLE IV
SLOPES OF PERFORMANCE INDICATORS AND SCORES

Sr.#	Effect of	Slope	Score
01	Changing PT on TP	81.25	4
02	Changing PT on ADQ	74.57	3
03	Changing PT on MDQ	72.8	3
04	Changing PT on Number of parts rejected	48.08	2
05	Changing PT on MPQ	73.07	3
06	Changing PT on MU	51.08	2
07	Changing PT on Min U	58.26	2
08	Changing PT on CT	73.97	3
09	Changing QL on TP	94.53	4
10	Changing QL on ADQ	87.43	4
11	Changing QL on MDQ	47.01	2
12	Changing QL on # of parts rejected	94.12	4
13	Changing QL on MPQ	50	2
14	Changing QL on MU	78.12	3
15	Changing QL on Min U	76.3	3
16	Changing QL on CT	93.58	4
17	Changing SuT on TP	94.12	4
18	Changing SuT on ADQ	98.25	4
19	Changing SuT on MDQ	97.73	4
20	Changing SuT on # of parts rejected	80	3
21	Changing SuT on MPQ	69.23	3
22	Changing SuT on MU	50	2
23	Changing SuT on Min U	78.7	3
24	Changing SuT on CT	94.68	4

The above sensitive parameters have been combined in matrix form useful for the company to analyze the impact of each parameter on the output given in Table V. The scores have been added as row sum and assigned as global sum because they are very critical influencing the performance. The three performance indicators of process time, quality level and setup time gave an insight of the system. According to the case problem, setup time comes out to be most sensitive parameter followed by quality level and process time. Here it is required to balance the line first because it has major role for productivity.

TABLE V
FINAL SENSITIVITY MATRIX RESULTS

	TP	ADQ	MDQ	#PR	MPQ	MU	Min U	CT	G. sum
PT	4	3	3	2	3	2	2	3	22
QL	4	4	2	4	2	3	3	4	26
SuT	4	4	4	3	3	2	3	4	27
L. Sum	12	11	9	9	8	7	8	11	

At local level company need to focus on total production and best way to achieve is concentration on cycle time and minimizing delays in the queues and processes.

VI. CONCLUSIONS AND RECOMMENDATIONS

It has been observed that by using line balancing, the assembly line has been balanced with an efficiency of 82.9% with balance delay equals 16.75%. Performance parameters have been obtained from literature and discussion with the case company and significant ones have been evaluated i.e. process time, quality level and setup time (change over time). The existing scenario has been modeled and recorded given in Table III. It is found that hydro testing is underutilized giving 57% of utilization and is precedent by hose QC which is overloaded. Target for the process time of hose QC has been set. Quality level for existing model is 98% and it has been designed with different experiments to get realistic picture inside that what should be the minimum quality level for operating the system from the results we see that up to the 94% reduction in quality level, the system operates at the optimal level and the production shows worst impact if we reduced more quality level. Similarly the setup time impacts upon the key performance indicators and the optimal level for this case study comes out six seconds. It is evident that with the decrease of process time, the total production increases impart positive impact in reducing ADQ, MDQ and MPQ. This is also very important to note that maximum refined output parameters are obtained at 60% of Eb. Quality level reduction up to 94% shows minor effect on the total production and over 94% of quality level it start giving low total production. The SuT also important input parameter which cannot consider in classical methods but exists in real system, and after deliberations with the case company, it is suggested to incorporate different set up times and it is evident that total production reduces with increase SuT. It is also established that change occurs up to 6 seconds in SuT and similar behavior of SuT upon ADQ, MDQ, and MPQ has been observed too. Cycle time have the same behavior, ultimately we can describe the whole situation as that the 6 sec is the optimal point for SuT in the current case. The effects of changes are analyzed that what level of sensitivity occurs upon key performance indicators with the changes of input parameters and also what is the level of sensitivity for the input parameters as the slops of each effect. It is recommended that company producing high tech parts focus on:

- SuTis found the most sensitive parameter with maximum time is six seconds. It is recommended to use some temporary storage buffers and cycle time to be set according to the work content time and fixed launching sequence be used for optimal utilization.

- Quality level to be maintained at 94% and if it goes down, reworking or even scrap rate increases. It is recommended that for mass production, six sigma quality initiatives to be initiated.
- Balanced assembly line and assigning workers to the workstation is the third important parameter. Using some standard techniques like largest candidate rule, Kilbridge and Wester method, properly balance assembly line.

The future work includes incorporating of the cost factor like material, energy and operating cost, variable schedules in two shifts, breakdown modeling and stoppage of the assembly line, line pacing issues.

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