A STUDY OF CONJUNCTIVE USE IN CHANDRA CANAL COMMAND IN NEPAL

A DISSERTATION

submitted in partial fulfillment of the
requirements for the award of the degree
of
MASTER OF ENGINEERING
in
WATER RESOURCES DEVELOPMENT

By
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CANDIDATE'S DECLARATION

I hereby declare that the work which is presented in this dissertation **"A STUDY OF CONJUNCTIVE USE IN CHANDRA CANAL COMMAND IN NEPAL"** in fulfillment of the requirement for the award of Degree of Master of Engineering in (WRD-Civil) in Water Resources Training Centre, University of Roorkee is an authentic record of my own work, carried out during the period from 16th July, 2000 to 08th December, 2000. under guidance of **Dr. G.C. Mishra**, Professor, W.R.D.T.C., University of Roorkee, Roorkee.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree or diploma.

SRyadav

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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NOTATIONS

NOTATION	DESCRIPTION
ACG (g)	Acceleration due to gravity
ALIFT	Lift from ground surface to canal full supply level
ALPHA(α)	Fraction of pumped water used locally.
B.C.R.	Benefit cost ratio
C_e	Unit cost of energy
CE(CENERGY)	Cost factor for energy
COSTB	Cost of boring
COSTT	Cost of transportation
COSTEL	Last cost of excavation
COSTENL	Last cost of energy in pumping
COSTPL	Last cost of pump and tubewell accessories
COSTTL	Last cost of transportation
D	Diameter of pipe
D_1	Distance of well from no flow boundary
D_2	Distance of well from the stream
DELTAR	Discrete Kernel coefficient for recharge
DRAW	Drawdown
ERF	Error function
ERFC	Complimentary error function
f	Coefficient of friction
FWELL	Well field
GNP	Gross National Production
I	Number of rows of wells
ISTAR	Costilier well to be drop
J .	Number of wells in a row
l	Length of pipe line
M/C	Main canal

N	Number of real and imaginary wells
NWELL	Number of well in a row
NTIME	Number of time of pumping
PAI	π
PLOSS(PL)	Pipe loss due to friction
PRECOST	Present cost
PW	Real pumping well
PWF	Present worth factor
Q_p	Constant pumping rate
Q_r	Recharge rate
QRD	Recharge when there is no flow boundary
R_w	Radius of well
RADP(R)	Radius of the pipe
R.C.C.	Reinforced cement concrete
RIW	Recharge image well
S(r,t)	Drawdown at a radial distance r from the well at the end of time t
S_w(Aver.)	Average drawdown
STATL	Static lift
T	Transmissivity
TLENGTH	Transportation length of pipe from well to the Canal
YCW	Distance between two rows
WIDTH	Distance between no flow boundary and river
WUA	Water user association
β	Diffusivity
ϕ	Storage coefficient
$\delta(i,j,n)$	Discrete Kernel coefficient at j^{th} well when pumping is done at i^{th} well in n^{th} time period

SYNOPSIS

The Chandra canal system is an old canal running since 1926 off-taking from Trijuga river, a tributary of the river Koshi, in Saptari district in Nepal. Because of water deficiency during non-monsoon period , the land resources in the command area of the canal are not fully utilised, and only limited surface water is being supplied to the command area .According to existing cropping pattern during rabi season, the water deficit during 2^{nd} half of December to Ist half of February is 1 cumec. There is no other perennial river except the river Koshi which flows at a depth of 10 m below the full supply level of the canal. Water also can not be pumped directly from the river which contains lot of fine silt even during lean flow period. However, ground water can be used for irrigation. Therefore, it is proposed to withdraw ground water by constructing a battery of wells to augment main canal supply. Part of the water pumped can be applied locally in the upstream side where there exists a good aquifer and the remaining pumped water can be transported through the existing canal to the command area in the downstream.

The aquifer is a finite aquifer bounded by river Koshi in one side and a low permeable zone on the other side. The aquifer is otherwise homogeneous. Applying image well theory , and Theis well function, discrete kernels have been generated for drawdown and induced recharge from the stream due to pumping the aquifer. Applying Duhamel's principle, the drawdowns at various well locations have been computed.

Twenty number of wells each with 50 liter per second capacity are required for the conjunctive use to irrigate the command area of 7345.0 ha. The pumps are to be operated continuously. The topography of the area is uneven. The feeder Chandra canal is a lined canal in this reach. It is required to locate these twenty wells so that the cost of the water to be supplied for the conjunctive is minimum. The cost is comprised of cost of excavation, cost of pump, cost of energy, cost of transportation to the feeder canal . The life period of the project is thirty years.

Wells located closely interfere with each other leading to more consumption of energy. If they are located at a large distance, the cost of transportation increases. In the study the aim is to find the optimal locations of these twenty wells so that combined cost construction pumping and transportation is minimum. It is also required to know the rate of stream depletion due to pumping.

A systematic search has been adopted and locations of the twenty most economical wells have been identified from 36 locations forming a rectangular grid. The cost of implementation of the project calculated on the basis of present worth with discount rate of 10% is Rupees 9155,000 . Out of this, the cost of excavation is Rs. 480,000 , the cost of pump and tube well accessories etc. is Rs. 6604,000 , the cost of energy is Rs. 323,000 and cost of transportation is Rs. 1748,000 .

Because of additional irrigation water supply more crops can be grown and current yield can be increased. From the study it is found that the benefit cost ratio is 3.25

Since after stoppage of pumping the induced recharge continues to enter the aquifer, the total volume of water pumped is contributed by the river only. The aquifer contribution in the beginning of pumping is replenished by induced recharge.

CHAPTER – 1

INTRODUCTION

1.1 GENERAL

Water is an integral component in all aspect of life. Its availability, though apparently plentiful, is however spatial. The demand for water is increasing from year to year with the ever growing population. The quantity and quality of available water resources have long been recognized as a limiting factor in the development of arid and semiarid regions.

Providing assured water supply for irrigation is becoming a difficult task with limited source and uneven distribution of water in space and time. Depending on a single source for any purpose is very much unreliable and the idea of using water from two or more alternate sources in conjunction with one another safely and economically is drawing attention of planners, engineers and decision makers. The source can be surface water impounded in a reservoir or runoff in the river extracted through diversion schemes like weirs, barrages etc, or groundwater lifted from unconfined aquifers and deep confined aquifers or water imported through inter basin transfer.

Conjunctive use is also being practiced to mitigate the problem of water logging by going in for more pumping of groundwater, wherever ground water table is above or very nearer to ground surface.

Therefore, the operation of surface and ground water sources in a way, which enhances their combined output, has been described as conjunctive use.

The Ist step in making plan for utilization of the available surface and ground water resources of a basin is to make an accurate assessment of the available surface and ground water resources. It is, therefore, in areas where surface water resources are not enough to meet the irrigation requirement the ground water resources can be exploited to supplement the surface water resources. For this aquifers may be used for drawing water in non monsoon and are allowed for recharge during monsoon before they are pumped again. Withdrawal of water should be done keeping the water balance of the region in mind i.e. safe yield.

Questions pertaining to the use of ground water resources require the establishment of proper relationship between pumpages and water level changes both in time and space and for doing so, investigations of the hydrologic properties of aquifers and aquitards, their dimensions in space and the boundaries are of utmost importance. Thus, there is a necessity to determine the hydrological parameters like transmissivity, leakage factor and storativity etc. with reasonable accuracy. For these purposes, pumping or recovery tests are performed on the wells penetrating into the water-bearing strata in the surface.

Conjunctive use involves various decision parameters such as cropping pattern, canal capacities, capacity and spacing of wells, extent of canal lining, drainage requirement, level at which ground water should be maintained etc. This requires system study so that several trial design are evaluated and the economic response of each is calculated. However, in the absence of system studies some specific decisions may be taken by comparing the economics of the various alternatives.

1.2 CONJUNCTIVE USE

1.2.1 The Concept

Conjunctive use implies coordinated and harmonious development of surface and ground water for meeting the water requirements by optimally utilizing the total available water resources.

(i) The concept recognizes the unified nature of water resources as a single natural resource, although the method of exploitation may involve both surface and groundwater structures.

(ii) The process takes advantage of the interactions between the surface and groundwater phases of the hydrological cycle and also the natural movement of ground water in planning the use of waters from the two phases.

1.2.2 The Objective

The conjunctive use of surface and ground water sources may be practiced in order to attain one or more of the following objectives:

(i) A higher total amount of supply,

(ii) Better regulation of the combined system using storage volume of aquifer,

(iii) Savings in evaporation losses from surface reservoirs,

(iv) Higher flexibility in supply according to the demand curve, by evening out peaks in stream flow and pumping ground water as and when needed,

(v) Use of augmentation tubewells discharging directly into the canal, and there by supplementing the supplies,

(vi) Mixing of different quality water, either in the supply system or in the aquifer to reduce salinity,

(vii) Augmenting low flows in rivers by artificially recharging the aquifer.

1.3 THE OBJECTIVE AND SCOPE OF THE STUDY

The objective of this study is to augment water supply of Chandra irrigation system by providing batteries of wells normal to main canal in middle reach command area so that Rabi season deficit of irrigation water can be made.

Present study has been taken to solve different problems such as (I) to find drawdown by converting finite areal extent of the aquifer (as study aquifer area is bounded by a no flow boundary and stream in parallel) to infinite areal extent using image well theory, (ii) to find recharge coming from the stream to the aquifer and (iii) optimization (i.e. minimization) of total present worth cost of water pumping and supply from augmentation well to the canal by considering RCC pipes conveyance and pumping cost etc. and computation of B.C.R..

1.4 DATA COLLECTION AND ANALYSIS

To meet the above objective of the study following data are collected.

The discharge records of the river Trijuga (the sources of the project) in different months, existing and the proposed cropping pattern of the command area , climatic data , cost estimation data and other related data . The pertinent data are collected from District Irrigation office , Saptari , Nepal .

Using these data a conjunctive use study has been done for supplying water for irrigation during non-monsoon period in Chandra canal command.

CHAPTER –2

LITERATURE REVIEW

2.1 GENERAL

Literature dealing with the concepts of conjunctive use of ground water reservoirs and surface water facilities is more extensive and is available since long. However, most of the literature dealing with conjunctive use has been of a qualitative nature and has dealt water related issues primarily of a local nature.

The complexities of the problem of conjunctive operation of ground and surface water facilities were explored by some early writers who recognized that the two resources were really a single system and that economic advantages could be had by operating the system as a complete unit.

Jindal and Khepar (1980) have studied the problem of optimum spacing of augmentation tubewells along the canal. They have assumed seepage from canal recharges the aquifer. The cost of the pipeline as conveyance system from the well to the canal was calculated considering the induced recharge, whereas it should have been calculated for the total water pumped from the well.

Chawla and Hazarika (1982) have studied the problem for a single well, where the drawdown in the well was related to the distance of the well from the canal and duration of continuos pumping. They, instead of minimizing the total annual cost of pumping (as done by Jindal and Kheper), the cost of pumping the unit volume of net water drawn from the ground water reservoir was minimized.

Chawla and Ansari (1989) have studied the optimum spacing among the finite number of wells installed in a row parallel to the canal and distance of the well from the canal such that unit cost of net water pumped from the ground water reservoir is minimized. They have considered the pvc pipe line for conveying the water from the wells to the canal. They pointed out that number and spacing among the wells do not affect the induced seepage. The distance from canal is not affected by annual pumping hrs. optimal spacing is affected by the discharge of each well.

Authors who have dealt with the problem of conjunctive use of ground and surface water system such as Clenderen (1954), Thomas (1957), Macksond (1961), and others, have discussed the economic advantages of such combination and have pointed out its effectiveness in the conservation of sizeable volume of water.

Todd has dealt with the basin management by conjunctive use, which involves the coordinated and planned operation of both surface water and ground water reservoirs to meet water requirements in a manner whereby water is conserved. According to him, with an optimum coordinated operation, of storage and distribution, the unit cost of water supply can be minimized.

2.2 GROUND WATER PUMPING

2.2.1 General

Conjunctive use of surface and ground water requires pumping of ground water to supplement surface water during lean periods. This may be done through augmentation wells or by direct irrigation wells. Augmentation wells are used to pump ground water for augmenting the canal supplies and utilize canal distribution system for the purpose. Direct irrigation wells on the other hand, have their own water distribution system and operate independent of the canal system. Commands of direct irrigation wells are normally outside the canal command.

In the system of conjunctive use of surface water and ground water, the augmentation wells prove more efficient than direct irrigation wells as separate and exclusive power feeders can supply uninterrupted power supply and existing distribution network of canals can be used. Augmentation wells could be of large capacity, which would be more economical. Large capacity direct irrigation wells may present problems of management as discharge of large capacity wells can not be handled by individual farmers having small and fragmental land holdings.

2.2.2 Location of Augmentation Wells

Augmentation wells are located along or perpendicular to the canals and ground water is pumped into the canal. If the distance of augmentation tubewells from the canal is closer, then the circulation of water form canal to well starts which results in the wastage of energy because part of the pumped water is drawn from the canal due to induce seepage from the canal. So the well located near the canal will draw less water from the ground water aquifers. When the well is moved away from the canal the induced seepage is reduced but the cost of the conveyance structure from the well to the canal will be more. Such problem does not arise when the canal is lined.

In this study batteries of wells have been placed perpendicular to the Main Canal in such a way that the total cost of water supply to the main canals from the ground water reservoir, which includes the cost of energy for pumping water and the capital cost of pipe lines from wells to the canal, is the minimum.

The optimum spacing of augmentation wells among themselves will depend upon several parameters including the aquifer parameters, duration of continuos pumping and the time gap between two consecutive pumping, unit cost of pipe line, energy cost and the depth of the water table.

2.2.3 Flow Towards Well Near Parallel Boundaries

In this study augmentation wells perpendicular to canals have been assumed to be placed in the middle reach command area of main canal because in rest area transmissivity of aquifer is not good.

In the middle reach the aquifer is bounded by no flow boundary (hill on right side of M/C) and stream (Koshi river on left side of M/C) in parallel. Therefore, Theis's assumption that the aquifer is of infinite real extent is no longer valid.

For analysis of flow in such aquifer, the principle of superposition has been used. According to this principle the drawdown caused by two or more wells is the sum of the drawdown caused by the each individual well. By assuming a series of imaginary wells, or images, the aquifer of finite extent has been transformed into one of seemingly infinite extent so that the equation of Theis can be applied to this substitute system.

Real wells and image wells are equidistant from the boundaries and are located on either side of a line at right angles to the boundary. The image well is the reflection of the real well with the boundary as mirror plane.

In the event of two parallel boundaries, two image planes are considered (which behaves as two mirrors kept in parallel) which lead to an infinite set of images as shown in Fig 2.1. However, in practice, pairs of image wells are added until the next pair has

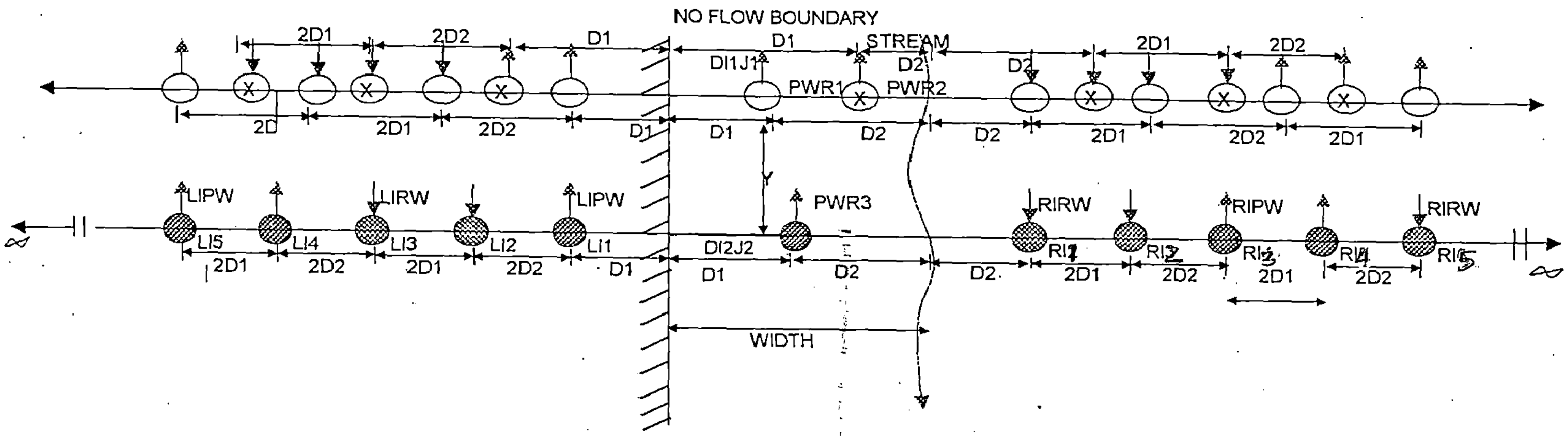


FIG: 2.1 IMAGE WELLS

PWR= REAL PUMPING WELL
RIRW=RIGHTSIDE IMAGE RECHARGE WELL
RIPW=RIGHTSIDE IMAGE PUMPING WELL
LIRW=LEFTSIDE IMAGE RECHARGE WELL
LIPW=LEFTSIDE IMAGE PUMPING WELL
D1=DISTANCE OF NO FLOW BOUNDARY(HILL) FROM PWR
D2=DISTANCE OF STREAM FROM PWR
↑ = REAL OR IMAGE PUMPING WELLS
↓ = REACHARGE IMAGE WELL

negligible influence on the real wells. The image well theory can be applied to such cases by taking into consideration the successive reflections on the boundaries.

The image well is of opposite nature to that of the real (pumping) well in the case of a recharge boundary and of the same nature as the well in the case of a barrier boundary. When working the images through one image plane, the other image plane may be masked.

For example as shown in Fig. 2.1, image wells R_{I_1} and L_{I_1} are images of the pumping well (PW) due to the boundaries i.e. recharge boundary (R) and no flow boundary (B) and are recharge image well and pumping image well respectively. Masking B, image well R_{I_2} which is the image of L_{I_1} due to R can be found and is a recharge image well. Masking R, image well L_{I_2} and L_{I_3} which is the images of R_{I_1} and R_{I_2} respectively due to B can be found and are recharge image well. Masking B, image well R_{I_3} and R_{I_4} which is the images of L_{I_2} and L_{I_3} respectively due to R can be found and are pumping image well. Similarly other images can be found.

As recharge image well causes a negative drawdown it has been taken as negative. Similarly drawdown caused by pumping image well has been taken as positive as the drawdown is increased by the presence of the barrier. There will be interference's of wells among themselves.

In the beginning discharge for wells will be drawn from aquifer storage but after equilibrium the entire discharge will be drawn from the stream only.

2.3 DRAWDOWN

The differential equation governing the axis symmetric unsteady flow of water to a well in a homogeneous, isotropic and confined aquifer of infinite areal extent is

$$\frac{\partial^2 s(r,t)}{\partial r^2}+\frac{1}{r}\frac{\partial s(r,t)}{\partial r}=\frac{\phi}{T}\frac{\partial s(r,t)}{\partial t} \qquad \text{...........(2.1)}$$

where, s(r,t) is the drawdown at a radial distance r from the well at the end of time t. The solution of the above differential equation when QP quantity of water is withdrawn from the aquifer at r=0, with boundary condition s(∞,t)=0 and $|2\pi r\frac{\partial s}{\partial r}|_{r\to 0}=-Qp$, and initial condition s(r,0)=0 , is given by

$$s(r,t)=\frac{Qp}{4\pi T}\int_{\frac{r^2}{4\beta t}}^{\infty}\frac{e^{-u}}{u}du$$

$$=\frac{Qp}{4\pi T}E_1\left(\frac{r^2}{4\beta t}\right) \qquad (2.2)$$

If pumping continuous at a unit rate the drawdown, designated as K_s (t) is given by

$$K_s(t)=\frac{1}{4\pi T}\int_{\frac{r^2}{4\beta t}}^{\infty}\frac{e^{-u}}{u}du$$

$$=\frac{1}{4\pi T}E_1\left(\frac{r^2}{4\beta t}\right) \qquad (2.3)$$

If pumping at a rate of $1/\in$ for a continues period of $\in$ at t = 0,i.e. if we pump unit impulse quantity at t = 0 i.e. the drawdown K_s (t) is given by

$$k_s(t)=\frac{d}{dt}(K_s(t))$$

$$=\frac{1}{4\pi Tt}\exp\left(\frac{r^2}{4\beta t}\right) \qquad (2.4)$$

The rate of pumping may vary with time due to various reasons such as pumping capacity, fluctuation in power supply to the pump motor, etc. In order to take into the variable pumping rate the time span is discretised into a number of uniform time steps of size Δt. The rate of pumping is assumed to be constant during each time step which may vary from step to step. The drawdown is given by

$$s(r,t) = \int_0^{\Delta t} \frac{Qp\tau d\tau}{4\pi T} \frac{e^{-\frac{r^2}{4\beta(t-\tau)}}}{t-\tau} + \int_{\Delta t}^{2\Delta t} \frac{Qp}{4\pi T} \tau d\tau \frac{e^{-\frac{r^2}{4\beta(t-\tau)}}}{t-\tau} + \ldots\ldots + \int_{(n-1)\Delta t}^{n\Delta t} \frac{Qp}{4\pi T} \tau d\tau \frac{e^{-\frac{r^2}{4\beta(t-\tau)}}}{t-\tau}$$

or,

$$s(r,n\Delta t) = \frac{Qp^{(1)}}{4\pi T} \int_0^{\Delta t} \frac{e^{-\frac{r^2}{4\beta(n\Delta-\tau)}}}{n\Delta t-\tau} d\tau + \ldots + \frac{Qp(\gamma)}{4\pi T} \int_{(\gamma-1)\Delta t}^{\gamma\Delta t} \frac{e^{-\frac{r^2}{4\beta(n\Delta-\tau)}}}{n\Delta t-\tau} d\tau + \ldots + \frac{Qp(n)}{4\pi T}$$

$$\int_{(n-1)\Delta t}^{n\Delta t} \frac{e^{-\frac{r^2}{4\beta(n\Delta-\tau)}}}{n\Delta t-\tau} d\tau \qquad (2.5)$$

Thus the drawdown can be expressed as

$$s(r,n\Delta t) = \sum_{\gamma=1}^{n} \frac{Qp(\gamma)}{4\pi T} \int_{(\gamma-1)\Delta t}^{\gamma\Delta t} \frac{e^{-\frac{r^2}{4\beta(n\Delta-\tau)}}}{n\Delta t-\tau} d\tau \qquad (2.6)$$

Substituting

$$\frac{r^2}{4\beta(n\Delta t-\tau)} = u$$

$$\frac{r^2}{4\beta u} = n\Delta t - \tau$$

$$\frac{r^2}{4\beta u^2} du = d\tau$$

$$s(r,n\Delta t) = \sum_{\gamma=1}^{n} \frac{Qp(\gamma)}{4\pi T -} \int_{\frac{r^2}{4\beta(n\Delta t-(\gamma-1)\Delta t)}}^{\frac{r^2}{4\beta(n\Delta-\gamma\Delta t)}} \frac{e^{-u}}{u} du$$

$$s(r,n\Delta t) = \sum_{\gamma=1}^{n} \frac{Qp(\gamma)}{4\pi T} - \left\{ \int_{\frac{r^2}{4\beta(n-\gamma+1)\Delta t}}^{\infty} \frac{e^{-u}}{u} du - \int_{\frac{r^2}{4\beta(n-\gamma)\Delta t}}^{\infty} \frac{e^{-u}}{u} du \right\}$$

$$= \sum_{\gamma=1}^{n} \frac{Qp(\gamma)}{4\pi T} \left\{ E_1\left(\frac{r^2}{4\beta(n-\gamma+1)\Delta t}\right) - E_1\left(\frac{r^2}{4\beta(n-\gamma)\Delta t}\right) \right\} \qquad (2.7)$$

Let us define as unit pulse kernel for drawdown for pumping quantity in Δt

$$\delta(r,n,\Delta t) = \int_0^{\Delta t} \frac{e^{-\frac{r^2}{4\beta(n\Delta t-\tau)}}}{(n\Delta t - \tau)} \frac{d\tau}{4\pi T} \frac{1}{\Delta t} \qquad (2.8)$$

Integrating

$$\delta(r,n,\Delta t) = \frac{1}{4\pi T \Delta t} \left\{ E_1\left(\frac{r^2}{4\beta n \Delta t}\right) - E_1\left(\frac{r^2}{4\beta \Delta t(n-1)}\right) \right\} \qquad (2.9)$$

$\delta(r,m,\Delta t)$ is the discrete pulse Kernel for the drawdown at a radial distance r from the well at the end of mth time step is given as

$$\delta(r,m\Delta t) = \frac{1}{4\pi T \Delta t} \left\{ E_1\left(\frac{r^2}{4\beta m \Delta t}\right) - E_1\left(\frac{r^2}{4\beta \Delta t(m-1)}\right) \right\} \qquad (2.10)$$

The drawdown at the end of nth time step is given by

$$s(r,n,\Delta t) = \sum_{\gamma=1}^{n} Qp(\gamma)\delta(r,n-\gamma+1) \qquad (2.11)$$

where,

Qp(γ) = rate of pumping during γth time step.

In this study the aquifer is bounded by two boundaries in parallel and hence image theory has been applied to convert the finite areal extent to infinite areal extent. According to principle of superposition the drawdown caused by two or more wells is the sum of the drawdown caused by the each individual well.

So here in this study to calculate discrete Kernel coefficient of well fields (Fig.2.1), it has been assumed that pumping is being done at ith well and observation is being taken at jth point. The ith well in the finite aquifer is equivalent to infinite number of image wells comprising of recharge and discharge wells in the aquifer of infinite areal extent. The respective wells are located at DI_1J_1 and DI_2J_2 from the no flow boundary.

Therefore discrete Kernel coefficient at jth point, considering the one real wells and all image wells on both sides of the hydrologic boundaries is given by

$$\delta_f(i,j,n) = \delta(r_{ij},n) + \sum_{P=1}^{NP} \delta(r_{pj},n) - \sum_{R=1}^{N_R} \delta(r_{Rj},n) \tag{2.12}$$

where,

r_{ij} = distance between the ith pumping and jth observation point

$\delta_f(i,j,n)$ = discrete Kernel coefficient of finite areal extent.

r_{pj} = distance between pth image pumping well and jth observation point.

Np = total number of image pumping wells.

$R_{R,j}$ = distance between Rth image recharge well and jth observation point.

N_R = total number of image recharge wells.

2.4 INDUCED RECHARGE

Induced infiltration where supplied by a perennial stream ensures a continuing water supply even though overdraft conditions may exist in near by areas supplied only by natural recharge. The method has proved effective in unconsolidated formations of permeable sand and gravel hydraulically connected between steam and aquifer. The amount of water induced into the aquifer depends on the rate of pumping, permeability, type of well, distance from surface stream, and natural ground water movement. It is

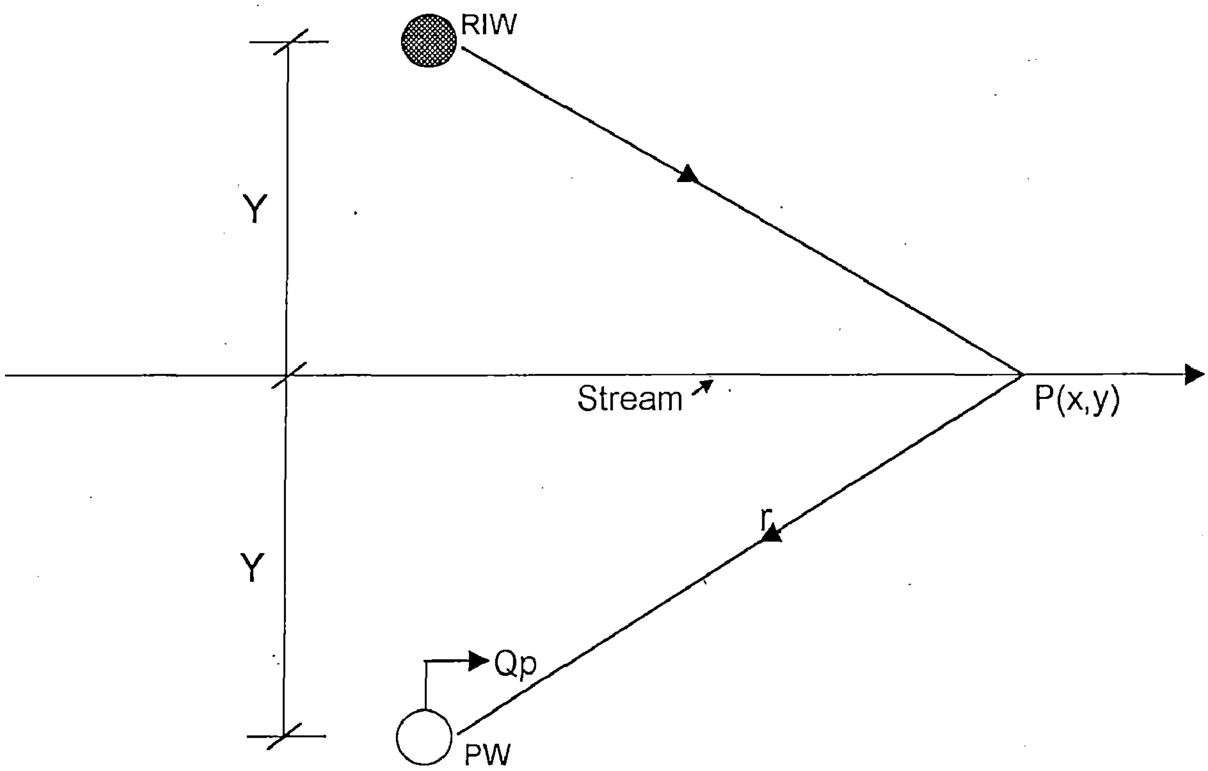


Fig. :- 2.2 Single well near recharge Boundary important that the velocity of the surface stream be sufficient to prevent silt deposition from sealing the streambed.

The percentage of pumped water diverted from a source of recharge (stream) depends upon the hydraulic properties of the aquifer, the distance of the recharge boundary from the pumping well and the pumping period

When water is pumped from a well, with constant rate Qp, which is located at a distance y from a river as shown in figure 2.2.

The induced recharge from the river entering to the aquifer in given by

$$Q_r = -2\int_{-\infty}^{\infty}\left\{(kDdx)\frac{Qp}{4\pi T}e^{-\frac{x^2+y^2}{4\beta t}} \times \frac{2y}{x^2+y^2}\right\}$$

$$Q_r(t) = \frac{Qp}{\pi}\int_{-\infty}^{\infty} e^{-\frac{x^2+y^2}{4\beta t}}\frac{y}{x^2+y^2}dx$$

$$= \frac{Qp}{\pi}2y\int_{0}^{\infty} e^{-\frac{x^2+y^2}{4\beta t}}\frac{dx}{x^2+y^2} \qquad (2.13)$$

Response due to unit impulse is given by

$$k(t) = \frac{2y}{\pi}e^{-\frac{y^2}{4\beta t}}\frac{1}{4\beta t^2}\sqrt{4\beta t}\int_{0}^{\infty} e^{-v^2}dv$$

$$= \frac{y}{\sqrt{\pi}}e^{-\frac{y^2}{4\beta t}}\frac{1}{4\beta t^2}\sqrt{4\beta t}\frac{2}{\sqrt{\pi}}\int_{0}^{\infty} e^{-v^2}dv \qquad (2.14)$$

where, error function = erf(x)= $\frac{2}{\sqrt{\pi}}\int_{0}^{x} e^{-v^2}dv$

and erf (∞) =1

Recharge rate from stream is

$$Q_r(t) = Q_p \left[1 - erf\left(\frac{y}{\sqrt{4\beta t}}\right)\right] = Qp\, erfc\left(\frac{y}{\sqrt{4\beta t}}\right) \tag{2.15}$$

Time t is measured since onset of pumping

$\beta = T / \phi$

$T = Transmissivity\,(m^2 / day)$

$\phi = Storage\,coefficient$

CHAPTER –3

STUDY AREA

3.1 GENERAL

The project area lies in the Terai region within Saptari district of Sagermatha zone in Nepal. Terai region extends almost throughout the length of the country and covers approximately 23% of Nepal's area. This is the region which yields bulk of the country's agricultural produce. The project area has large fertile alluvial sloping land. The land utilization statistic of Saptari district shows that there is very little scope for harnessing more land for cultivation. The food requirements are necessarily expected to grow continuously and required agriculture production has, therefore, necessarily to come from increasing intensity of cropping and irrigation and using modern practice for intensive agriculture for increased productivity. The country is heavily dependent on agriculture, in which almost 94% of the economically active population is engaged in producing 60% of the GNP Table 3.1 shows estimate of land use.

3.2 LOCATION

The project area is located in the Western section of the Koshi river basin between latitude $26^0 25'$ N and $26^0 45'$ N and between longitude $86^0 44'$ E and 86^0 57'30″ E, and forms a part of the eastern Terai lands of Nepal. The location and project are shown in Fig. 3.1 and 3.2.

Chandra canal, which supplies water to the project area, running since 1926, is an old canal off-taking from Trijuga river, a tributary of the Koshi. The command area lies

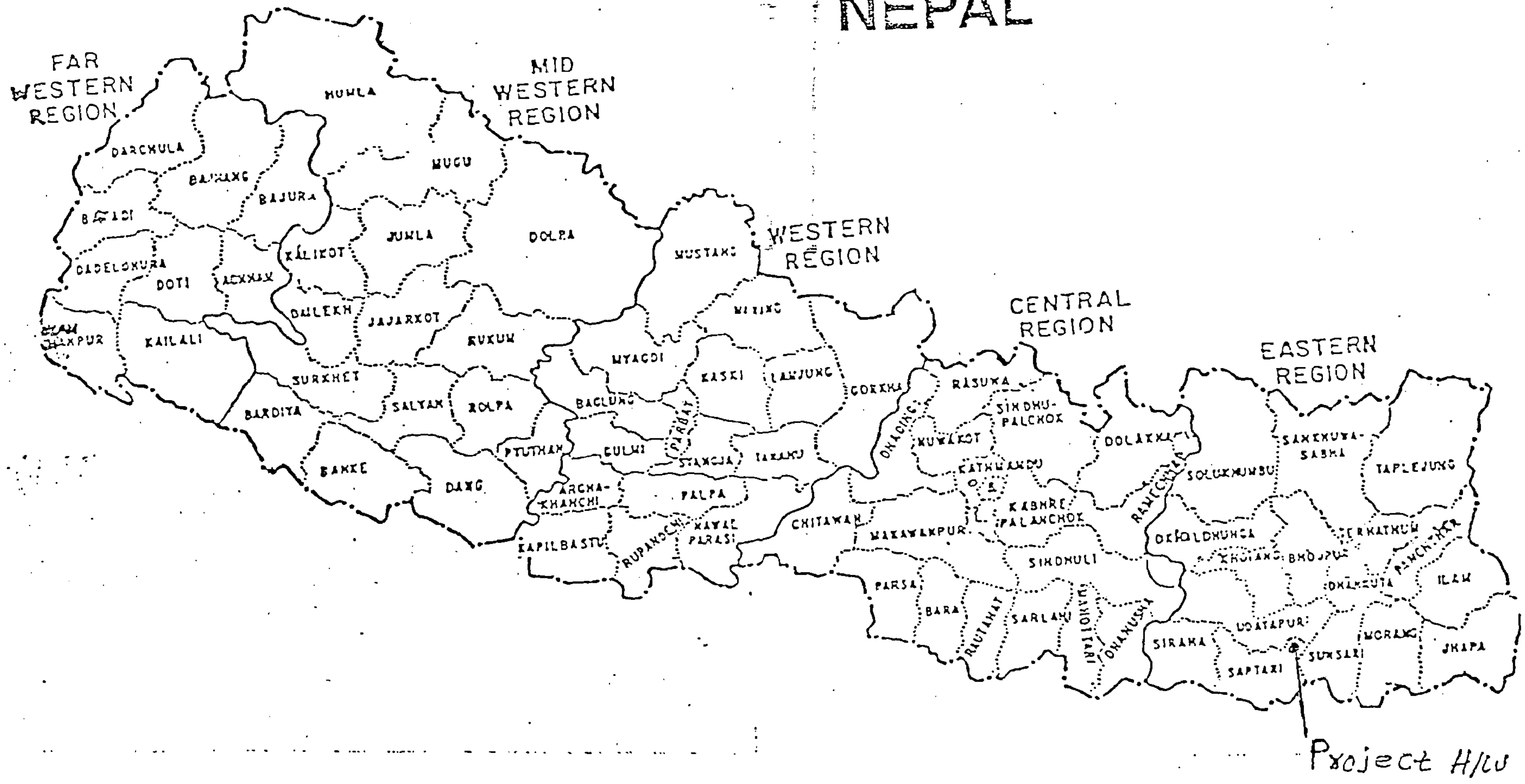
Table 3.1 Area under Cultivation in Saptari District

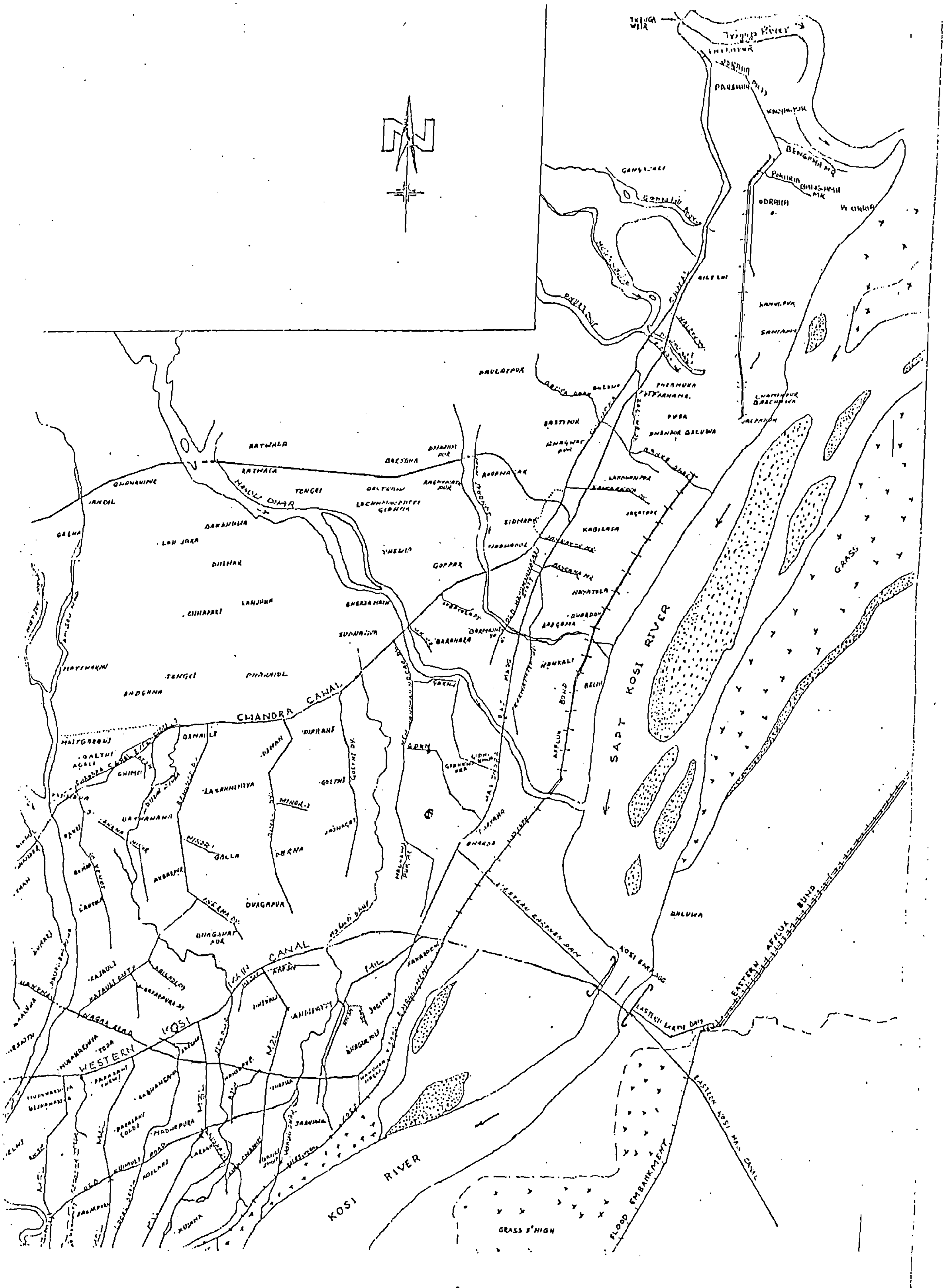
Land use area under	Total cultivated land		% land use of total cultivated land	
	Low land in ha	Up land in ha	Low land	Up land
Seasonal crops	74472	8646	97.37	77.81
Current fallow	358	564	0.47	5.08
Fruits	313	558	0.40	5.02
Permanent pasture	164	296	0.21	2.67
Private forest, grass	162	174	0.22	1.56
Miscellaneous	1015	874	1.33	7.86
Total	76484	11112	100.00	100.00

The present land use pattern of the project area is reported as below:

		Percent
1.	Cultivated land, including ridges	80
2.	Grass land, including dikes of ponds and slopes of streams	7
3.	Forests, including bamboo thickets	4
4.	Villages	4
5.	Ponds, rivers	3
6.	Roads and miscellaneous	2
	Total	100

NEPAL


FAR WESTERN REGION
MID WESTERN REGION
WESTERN REGION
CENTRAL REGION
EASTERN REGION
HUMLA
DARCHULA
BAJHANG
BAJURA
MUGU
JUMLA
DOLPA
KALIKOT
DADELDHURA
DOTI
ACHHAM
DAILEKH
JAJARKOT
KAILALI
RUKUN
SURKHET
SALYAN
ROLPA
BARDIYA
BANKE
DANG
MUSTANG
MYAGDI
KASKI
LAMJUNG
GORKHA
BAGLUNG
PARBAT
GULMI
SYANGJA
TANAHU
PYUTHAN
ARGHA-KHANCHI
PALPA
KAPILBASTU
RUPANDEHI
NAWAL PARASI
CHITAWAN
RASUWA
SINDHU-PALCHOK
NUWAKOT
DHADING
KATHMANDU
DOLAKHA
RAMECHHAP
KABHRE PALANCHOK
MAKAWANPUR
SINDHULI
PARSA
BARA
RAUTAHAT
SARLAHI
MAHOTTARI
DHANUSHA
SIRAHA
SOLUKHUMBU
SANKHUWA-SABHA
TAPLEJUNG
TERHATHUM
PANCHTHAR
ILAM
OKHALDHUNGA
KHOTANG
BHOJPUR
DHANKUTA
UDAYAPUR
SAPTARI
SUNSARI
MORANG
JHAPA
Project H/Q



Project Area

Table 3.2

Data of annual rainfall of project area

Annual Precipitation (mm)			
Stations			
Year	Rajbiraj	Siraha	Lahan
1972	1323	1110	1137
1973	-	1310	1471
1974	1610	1724	2106
1975	1146	1905	2158
1976	1244	1443	1594
1977	958	1251	1628
1978	1066	1409	1152
1979	1541	1213	1289
1980	1342	1634	1107
Mean	1279	1444	1516

The monthly distribution of average and 75 percent dependable rainfall is as below:

Month	During month			Cumulative		
	Average rainfall 75%deendable			Average 75% dependeble		
	Rainfall		Rainfall	Rainfall		Rainfall
	mm	mm	%	mm	mm	%
June	231	189	16.9	231	189	16.9
July	355	292	26.2	586	481	43.1
August	330	271	24.3	916	752	67.4
September	192	158	14.2	1108	910	81.6
October	69	57	5.1	1177	967	86.7
Non-monsoon months.	184	149	13.3	1361	1116	100.0

from north to south between the Koshi in the east, hill in the north and northwest, khando river in the west and western koshi canal in the south.

3.3 CLIMATE

The project area has a humid subtropical monsoon climate. Temperature in the project area remains high (40^0C) during the dry months of April, May and June. 80% of annual rainfall occurs in the months of June, July, August and September due to southeasterly monsoons.

Data of annual rainfall for the period 1972-80 for Rajbiraj, located in the project command and Lahan and Sirha, just adjacent to the project area are given in Table 3.2.

3.4 TOPOGRAPHY

The command area has east and southward average slope of 1 in 800. The ground elevation ranges from 100 m north to 73.5 along the western Koshi canal on the southern limit of the command.

3.5 GEOLOGY

The chandra canal is a contour canal, which irrigates on its east and south side only i.e. left side only. Sub-surface geological studies carried out reveal that the lithological units, which are mainly composed of sand and gravel of varying thickness in 11.50 km reach of the main canal and represent channel deposits and sand and clays in down command area which is due to flood plain deposits.

3.6 HYDROLOGY

Koshi is the principal river in the east of the project area. Trijuga river (source of water for project) is a perennial river with varying discharge. Other rivers in the command area are flasy river only.

Presently Rabi crop intensity is 45%. Since last year the project is under joint management. Now WUAs want to increase Rabi crop intensity to 65% by searching other alternatives for required water demand. According to present cropping pattern there will be about 1.0 cumec deficit of water for fortnightly requirement for about 63 days Appendix I-3

According to earlier investigations augmentation of low flow in the river by constructing storage reservoir is not possible due to lack of sufficient reservoir area. also taking Koshi river water directly is not possible as she flows through deep. So the deficiencies in irrigation water for Rabi season has to be meet by planned and controlled exploitation of ground water.

Augmentation of main canal in middle reach chainage 8 km seems to be economical as investigations show that middle and above reach of command area have only good aquifers. In middle reach command area transmissivity and storage coefficient are 5000 m^2/day and 0.20 respectively.

CHAPTER-4

COST FUNCTION

4.1 TUBEWELL

The cost of constructing a tube well depends on the capacity and depth of the tube well and the type of function to be performed by the well. The capital cost mainly consists of

(i) Cost of tube well construction and

(ii) Cost of pumping set and its accessories

Besides the cost of material considerable amount is spent on preliminary systems, transportation of material, lowering of well assembly, development of the well and construction of pump house etc.

The analysis of cost has been carries out using the rates obtained from the project office. The cost of construction of tube well and pump is shown in Table 4.1(details for diameter and length is in Appendix -I)

4.2 TRANSPORTATION (CONVEYANCE) SYSTEM

Two type of conveyance system may be used (i) open channel and (ii) pipe line.

(i) In this study open channel transportation has not been considered as it will be costly and unfeasible due to land contour.

(ii) Pipe line

R.C.C. hume pipe for transportation of water from pumping well point to main canal has been considered in this study because it can be constructed locally as required. Here very good quality of fine and coarse aggregates is available.

Table : 4.1 Cost of pump etc (Construction and cost of tubewell)

Description	size	quantity	Rate Rs./unit	Amount Rs.
1. Slotted pipe	20 cm	20 m	1750.00	35000.00
2. Housing pipe	30 cm	40 m	1800.00	72000.00
3. Gravel packing	—	15 m3	500.00	7500.00
4. Bail plug	20 cm	1 no.	700.00	700.00
5. Sockets	20 cm	6 nos.	500.00	3000.00
6. Sockets	30 cm	10 nos.	600.00	6000.00
7. Reducer	20*30 cm	1 no.	1500.00	1500.00
8. Well cap	30 cm	1 no.	400.00	400.00
9. Centering guide	20 cm	4 nos.	700.00	2800.00
10. Delivery pipe	20 cm	10 m	1200.00	12000.00
11. Clamp	30 cm	1 no.	800.00	800.00
12. Development	—	30 hrs.	550.00	16500.00
13. Transformer	40 kva	1 no.	55000.00	55000.00
14.Survey	—	p.s.	2000.00	2000.00
15. Transportation of material	—	p.s.	3000.00	3000.00
16. Panel board etc.	—	p.s.	20000.00	20000.00
17. Misllaneous expenses (Transmision line etc.)	—	p.s.	12000.00	12000.00
Total const. Cost				250200.00
Submersible pump with accessories	30 H.P.	1 no.	80000.00	80000.00
Grand total				330200.00

Table: 4.2 Cost of R.C.C pipe line

Inside dia. M 1	Thickness mm 2	No. of collars in 100m 3	cost of pipe per 100 m Rs. 4	cost of collars per 100 m Rs. 5	Total cost per 100 m Rs. 6	cost including laying etc. 15% more than col.6 7	cost per m Rs.
0.25	25	49	28000.00	5000.00	33000.00	37950.00	380.00
0.35	32	39	50000.00	6300.00	56300.00	64745.00	648.00
0.4	33	39	65000.00	8500.00	73500.00	84525.00	845.00
0.5	35	39	80000.00	10000.00	90000.00	103500.00	1035.00
0.6	38	39	108000.00	11000.00	119000.00	136850.00	1369.00

Cost of R.C.C. pipe for different diameters are shown in Table 4.2.(Calculation of diameter is in appendix -I)

4.3 MAINTENANCE AND OPERATION CHARGE

Operation and maintenance charges for tube well and pipeline are assumed to be 4% of capital cost.

4.4 ENERGY I.E. COST OF PUMPING DURING TIME STEP N AT LOCATION J.

The energy cost of pumping water and delivering the same to the canal consists of

(i) The energy cost of pumping water (i.e. lifting) from water table / piezometric level i.e. considering static lift (G_1 as shown in Fig 4.1).

(ii) Energy for additional lift caused due to average drawdown, S_w (average)

(iii) Energy used in overcoming frictional resistance (neglecting other losses) in the pipe line transportation system, PL and

(iv) Energy used in lifting water upto F.S.L. of canal from the ground level, (G_2 as shown in Fig.4.1).

Annual cost of energy per tubewell is given below :

(a) For local application

$$\text{Cost } P_1 = \frac{\alpha \text{ x } \gamma_w x \text{ c}_e x 0.746 x \sum_{n=1}^{N} Q_p^{(j,n)} x (G_1^j + S_w(average))}{75 x E_p x E_m x 3600}$$

$$= \text{Rs. CE x } \alpha \text{ x } \sum_{n=1}^{N} Q_p^{(j,n)} \text{ x } (G_1\ (j) + S_w\ (\text{aver.}))$$

(b) For outside application

$$\text{Cost } P_2 = \text{Rs. CE x } (1\text{-}\alpha) \text{ x } \sum_{n=1}^{N} Q_p\ (j,n) \text{x } (G_1^{(j)} + G_2^{(j)} + PL + S_w(\text{aver.}))$$

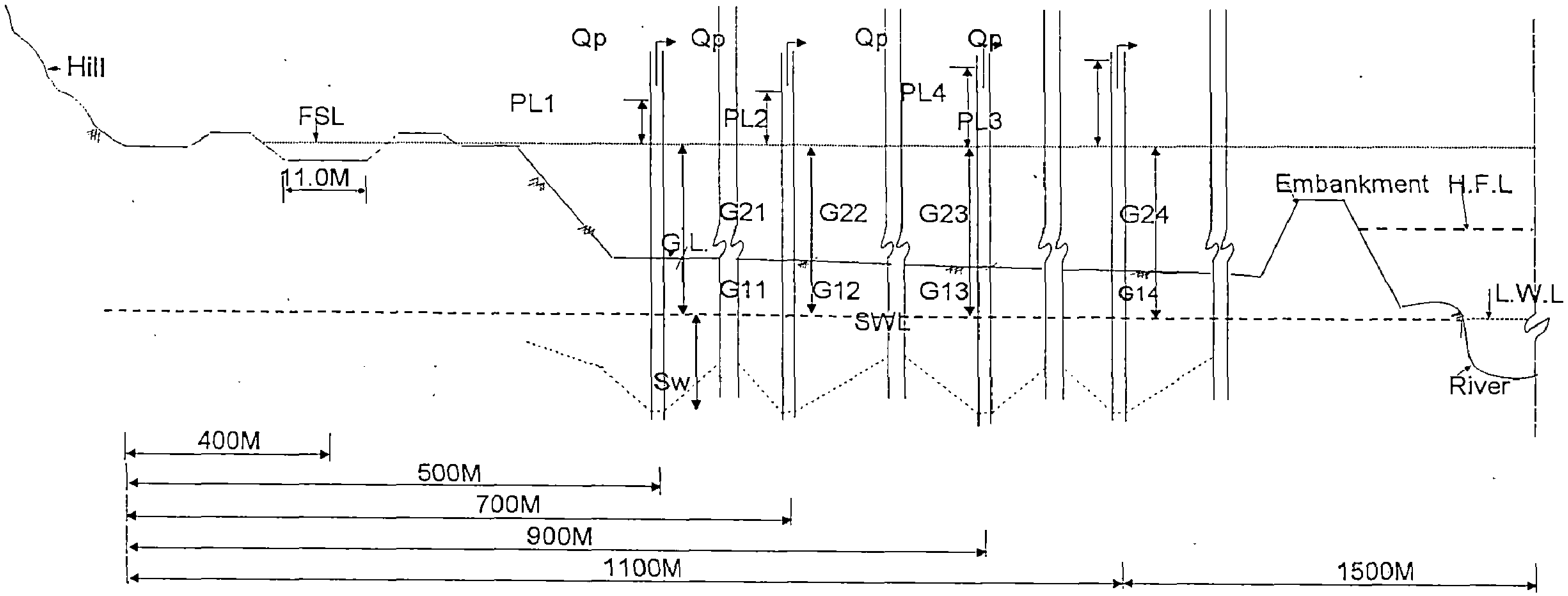


FIG. :4.1 -Wells showing different elevation

Where,

α	= percentage of water used in tubewell area.
C_e	= cost of energy (Rs. 4. / kwh)
E_p	= efficiency of pump (0.80)
E_m	= efficiency of motor (0.85)
r_w =	unit weight of water (1000 kg/m^3)

75 and 0.746 are conversion factor for h.p. and kilowatt respectively.

Q_p (j,n) = pumping rate at jth well during nth time step (m^3/sec).

$$S_w(aver) = \frac{S_w(j,n) + S_w(j,n-1)}{2}$$

$$S_w(j,n) = \sum_{\gamma=1}^{n} Q_p(i,\gamma)\delta(i,j,n-\gamma+1)$$

PL = pipe line losses. (detail calculation is in appendix-I)

$$PL = \text{pipe loss due to friction} = \frac{4flv^2}{2gd}$$

$$PL = \frac{4fxlxQ_p^2}{2.g.2Rx\pi^2R^4} = \frac{flQ_p^2}{\pi^2 gR^5}m$$

Where,

F	= coefficient of friction (0.006)
l	= Length of pipe line in m
Q_p	= constant pumping rate in m^3/week
R	= Radius of pipe in m
g	= Acceleration due to gravity in m/week^2
g	= 9.81 x (3600 x 24 x 7)^2 m/week^2.

4.5 COST OF TUBEWELL BORING

Cost B = C_1 x depth (j) + C_2 x 0.5 x depth(j)^2

where,

C_1 = constant cost of excavation 1

C_2 = 10% of C_1 to take care of incremental cost due to lift.

4.6 SINGLE PAYMENT PRESENT WORTH FACTOR

In order to workout cost of water supply capital cost of the pumping and maintenance of pipe have to be converted into present worth cost. So these have to be multiplied by present worth factor (PWF). PWF is given by

$$P.W.F. = \frac{1}{(1+i)^n}$$

Where,

i = discount rate

n = life in year.

4.7 PRESENT WORTH COST OF WATER SUPPLY

i) For local application;

Total cost = cost P_1 x PWF + Cost B + Cost T + M Cost x PWF.

ii) For outside application;

Total cost = cost P_2 x PWF + Cost B + Cost T + M Cost x PWF.

4.8 ECONOMIC EVALUATION

The objective of the irrigation project is to minimize project cost and to check its benefits cost ratio. Augmentation well project requires large investments. An investment on a project is economically justifiable only if it shows a profit. It is, therefore, important that the project is analysed from the economic angle and its profitability assessed.

Economic analysis is performed in a series of steps. Economic evaluation includes the determination of total benefits and total costs. The various methods used to carry out the economic analysis of well and pump project include (i) the benefit cost method, (ii) the present worth method and (iii) the internal rate of return method (Annual cost method).

Here in this study the present worth method has been used to find minimum cost of irrigation water supply. Benefit cost ratio method is used analytically after the economical locations of wells are identified.

4.8.1 Benefit Cost Ratio (B.C.R.) Calculation

It is given by

$$\text{Present worth benefit} = \text{PWB} = \sum_{i=1}^{n}\left(\frac{P}{F}, i, t\right)B_t$$

$$\text{Present worth cost} = \text{PWC} = \sum_{i=1}^{n}\left(\frac{P}{F}, i, t\right)C_t$$

i.e. $\frac{P}{F} = \frac{1}{(1+i)^n}$

where,

P	= present worth benefit or cost
F	= Future benefit or cost.
B_t	= Total benefit at the end of n years
C_t	= Total cost at the end of n years
n	= Life of the project, here 30 years assumed
i	= Discount rate (10% taken).

4.8.2 Present Worth Benefit

Incremental benefit / year = net return from crops after implementation of the project (Table 4.3 detail analysis is in appendix I-5) minus (-)

Net return from crops without project (Table 4.4 see I-6) = 56968950 – 8720210 = Rs. 48248740

For 30 years total incremental benefit = Rs. 30x48248740 = Rs. 1447462200

In the project about 60% rabi season water is available from surface water, only 40% of above total benefit has been considered for this study due to wells supply.

$$\text{Present worth of total benefit} = \frac{0.40 \text{ x } 1447462200}{(1+0.1)^{30}} = Rs.33180785.86$$

4.8.3 Present Worth Cost

Present worth cost from computer program (Table 6.3) = Rs. 9155000.00

Present worth maintenance cost of above @4% =Rs. 366200.00

Taking 40% of annual maintenance cost = 0.4 x 1000000 = 400000 (at present maintenance cost per year of the project is Rs. 1000000)

$$\text{Present worth maintenance cost} = \frac{30 \text{ x } 400000}{(1+0.1)^{30}} = \text{Rs.} 687702.64$$

Total present worth cost = Rs. 10208902.64

$$\text{Benefit cost ratio} = \frac{33180785.86}{10208902.64} = 3.25.$$

Table : 4.3 Total Rabi crop cost with project

Crops	crop area in ha	unit cost in Rs./ha	Amount Rs.
1. Wheat	4520	6145.00	27775400.00
2. Oilseed	1695	5360.00	8915700.00
3. Pulse	565	10100.00	5706500.00
4. Vegetables	565	25790.00	14571350.00
Total return			56968950.00

Table : 4.4 Total Rabi crop cost without project

Crops	crop area in ha	unit cost in Rs.	Amount Rs.
1. Wheat	4520	1305.00	5898600.00
2. Oilseed	452	3960.00	1789920.00
3. Pulse	113	9130.00	1031690.00
Total return			8720210.00

CHAPTER – 5

METHOD OF SOLUTION AND COMPUTER PROGRAMS

5.1 GENERAL

The total cost of water pumped from the groundwater reservoir is function of aquifer parameters, cost of well (pump etc.), cost of excavation, cost of conveyance system and energy, operational parameters such as continuous running hours and total annual (seasonal) operating hours and position of wells in relation to canal and spacing among the wells. For a given set of aquifer conditions there will exist a unique combination of all other variables for which total cost of water supply will be minimum.

The difficulty of solving the problem as such is that the operational parameters and cost parameters will be subject to constraints specific to each site conditions. For example the operational parameters will depend on the type of rotation of irrigation application in the system, schedule of power availability, total quantity of water to be pumped etc. The cost parameters will depend on the type of conveyance system used for transportation of water. Here in this study R.C.C. hume pipe has been taken as conveyance system.. The diameter of the pipe for the transportation system is a function of discharge only. A common line with different diameter for different discharge has been taken so that friction loss in pipe will be minimum.

In this study wells have been considered to take water from the aquifer which will be replenished by stream and rainfall. It has been assumed that there will be no seepage from canal as it is lined in this reach. The aquifer has been assumed to be homogeneous and isotropic as only one value of transmissivity and one value of storage coefficient are available.

5.2 METHOD OF SOLUTION

As there is no seepage from canal to the aquifer, the first well in each row has been placed near to the canal, so that cost of transportation will be minimum. Nine rows (batteries) of wells perpendicular to canal having four wells in each row have been placed. 200 m spacing among wells have been given so that maximum area of middle reach (having good aquifer) can be tapped and some water can be utilized in this reach (i.e. locally) also.

Image well theory (as the well field area is bounded by two parallel boundaries) has been used to convert finite areal extent to infinite areal extent aquifer and drawdown has been found using Kernel coefficients. The Kernel coefficients for drawdown are computed using Theis well function and method of superposition for the infinite number of image recharge and pumping wells.

Similarly to find recharge coming from stream to the aquifer, only left side image wells (i.e. right side of stream) have been considered, because image wells will on other side have no effect.

Systematic search has been applied to find best location of 20 wells among 36 wells (as given in well field, Fig. 5.1), so that total cost of pumping and supplying water will be minimum.

5.3 COMPUTER PROGRAM

The program consists of three main program, four subroutine sub-program and two function sub-program.

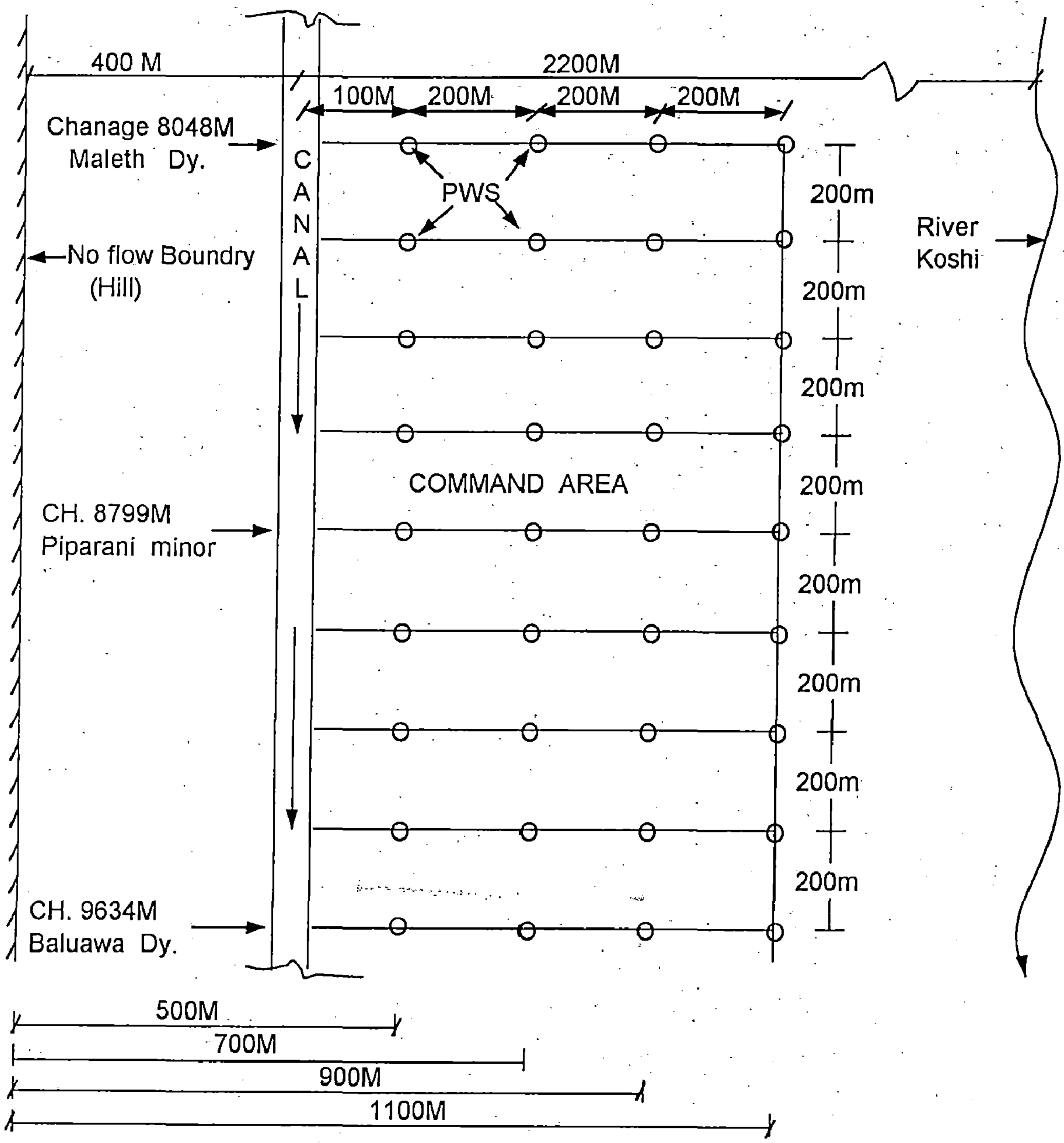


Fig. :- 5.1 Wells Location

5.3.1 Function Subroutine Exponential Integral $E_1(x)$

This sub-program is used to find the well function i.e. exponential integral, given by

$$E_1(x) = \int_x^\infty \frac{e^{-u}}{u} du$$

where,

$$x = \frac{r^2}{4\beta t} = \frac{r^2\phi}{4Tt}$$

The integral can be expanded as a convergent series so that above equation becomes.

$$E_1(x) = -0.5772 - \ln x + x - \frac{x^2}{2.2!} + \frac{x^3}{3.3!} - \ldots\ldots\ldots$$

It was found that for x greater than unity the series converges very slowly and takes too much computational time.

Gautschi and Cahill have expressed the well function which is an exponential integral in the polynomial form and is specifically suitable for computer application. They have expressed the function for two ranges of x as follows :

For $0 \leq x \leq 1$

$$E_1(x) = a_o - \ln x + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4 + a_5 x^5$$

Where,

a_o = -0.57721566 a_1 = 0.99999193

a_2 = -0.24991055 a_3 = 0.05519968

a_4 = - 0.00976004 a_5 = 0.00107857.

CHAPTER – 6

RESULTS AND DISCUSSIONS

The aquifer, being homogeneous, discrete kernels have been generated using image well theory for converting the finite to an infinite aquifer and then adopting Theis well function. Sufficient number of images have been considered on either side of the two hydrological boundaries i.e. the no flow boundary on one side and the stream on the other side.

Had the aquifer been non-homogeneous, a ground water flow model would have been used to generate the kernel coefficients. If a ground water model is used to generate the unit pulse response function coefficient, application of the image theory is not required. The unit response function coefficients are generated at the nodes of a rectangular grid. These nodal points are the possible sites of constructing a well.

Assuming a time step size for the prescribed value of T and ϕ, unit response function $\delta(i, j, n)$, n varying from 1 to pumping period, have been generated and stored. These coefficients have been generated only for once.

Considering irrigation water requirement in the project area, the total number of wells are ascertained.

Deficit water requirement in the project area of 11300 ha during winter season (65% cropping intensity) for wheat, pulse, oilseed and vegetables is 1 m^3/sec. To get this much discharge 20 wells of 50 lps capacity are needed.

In this study a network consisting of square grid with 36 nodes has been selected and δ (i,j,n), i = 1, 36 and j = 1, 36, and n = 1, 9 have been generated. The time step size has been taken as one week.

The coefficients δ (i,j,n), for i=1,1;j=1,36 are presented in Table 6.1. δ (i,j,n), represents the drawdown at the point j at the end of time step n due to withdrawal of a unit quantity at node i during first time step and no withdrawal thereafter. For finding the optimal 20 wells first it is assumed that 36 well exist one at each node. The pumping at a node influences the drawdown at other nodes. Therefore, if a well is deleted at a node, the drawdown will be influenced at all other nodes. Out of these 36 wells, 16 wells have to be dropped so that the cost of pumping and supplying water will be minimum. To achieve this goal a systematic search has been adopted and the 20 most economical wells have been identified. While finding optimal well locations the present worth cost has been considered assuming 10% interest rate. The life of the project has been taken as 30 years.

The 16 wells to be dropped in sequence so that remaining wells are economical are given in Table 6.2. The final optimal locations of the well, are given in figure 6.1.

The cost of excavation , cost of pump and tube well accessories , cost of energy , cost of transportation and total cost are shown in Table 6.3.

Benefit cost ratio (B.C.R) has been calculated as presented in chapter 4.8. According to calculation total present worth of benefit is 33180785.86 and present worth of total cost (including maintenance) is 10208902.64 and the benefit cost ratio (BCR) is 3.25.

When pumping is done in the vicinity of a river, in the beginning, water is taken from the aquifer storage, but as pumping continues part of the pumped water is taken from the stream. With time contribution of aquifer to pumping decreases and contribution of stream increases. After stoppage of the pumping, the stream recharge continues till the water level in the stream and water table in the aquifer become equal. So eventually all the water pumped only comes from the stream storage. The water which is taken from the aquifer storage during the beginning of pumping is replenished from the stream storage after stoppage of pumping. The variation of induced recharge when all the 20 economical wells operate are as shown in Table 6.4. The induced recharge increases with time. It also increases for some time after stoppage of pumping. After attaining a peak value, it decreases and in the end the recharge rate decreases monotonically to zero. It is found that the recharge volume is 0.9999 of water pumped at the end of 150 weeks from the onset of pumping. The variation of induced recharge with time is presented in figure 6.2. The induced recharge is also presented in nondimensional form in figure 6.3. The sudden jump in recharge rate occurs at the end of 9 weeks when pumping is stopped as actual recharge rate is divided by cumulative pumped quantity.

```
c       ************************************************************
C                          TABLE:6.1
C       SAMPLE RESULTS OF DISCRETE KERNEL COEFFICIENTS FOR COMPUTATION
C       OF DRAWDOWN AT J=1,36 AND PUMPING AT I=1,1
c       ************************************************************
        2600.000000     35000.000000     2.000000E-01     1.000000E-01
        30240.000000          9
        500.000000       700.000000       900.000000      1100.000000
        500.000000       700.000000       900.000000      1100.000000
        500.000000       700.000000       900.000000      1100.000000
        500.000000       700.000000       900.000000      1100.000000
        500.000000       700.000000       900.000000      1100.000000
        500.000000       700.000000       900.000000      1100.000000
        500.000000       700.000000       900.000000      1100.000000
        500.000000       700.000000       900.000000      1100.000000
        500.000000       700.000000       900.000000      1100.000000
         DRAWDOWN
        J=            1
        1.209956         1.274974         1.318383         1.351230
        1.377650         1.399688         1.418510         1.434843
        1.449182
        J=            2
        1.866759E-01     2.613180E-01     3.094672E-01     3.450665E-01
        3.732943E-01     3.966321E-01     4.164526E-01     4.335940E-01
        4.486083E-01
        J=            3
        8.831150E-02     1.497135E-01     1.924440E-01     2.250962E-01
        2.514614E-01     2.735018E-01     2.923542E-01     3.087361E-01
        3.231323E-01
        J=            4
        4.224721E-02     8.933786E-02     1.256536E-01     1.546725E-01
        1.786823E-01     1.990494E-01     2.166320E-01     2.320026E-01
        2.455650E-01
        J=            5
        2.076637E-01     2.888067E-01     3.395542E-01     3.765472E-01
        4.056470E-01     4.295867E-01     4.498526E-01     4.673406E-01
        4.826351E-01
        J=            6
        1.401788E-01     2.118347E-01     2.588684E-01     2.938837E-01
        3.217525E-01     3.448478E-01     3.644941E-01     3.815050E-01
        3.964185E-01
        J=            7
        7.542088E-02     1.343825E-01     1.761245E-01     2.082414E-01
        2.342713E-01     2.560827E-01     2.747695E-01     2.910267E-01
        3.053263E-01
        J=            8
        3.764918E-02     8.288528E-02     1.183626E-01     1.469061E-01
        1.706107E-01     1.907662E-01     2.081943E-01     2.234480E-01
        2.369193E-01
        J=            9
```

```
 1.088072E-01   1.805870E-01   2.278875E-01   2.630894E-01
 2.910929E-01   3.142940E-01   3.340303E-01   3.511220E-01
 3.661104E-01
 J=          10
 8.180045E-02   1.452209E-01   1.890626E-01   2.223832E-01
 2.492023E-01   2.715850E-01   2.907180E-01   3.073433E-01
 3.219584E-01
 J=          11
 5.047245E-02   1.027004E-01   1.416138E-01   1.721770E-01
 1.972267E-01   2.183653E-01   2.365638E-01   2.524526E-01
 2.664660E-01
 J=          12
 2.728013E-02   6.739497E-02   1.004729E-01   1.276367E-01
 1.504490E-01   1.699829E-01   1.869556E-01   2.018636E-01
 2.150653E-01
 J=          13
 5.612454E-02   1.147156E-01   1.567896E-01   1.891983E-01
 2.154659E-01   2.374865E-01   2.563708E-01   2.728218E-01
 2.873137E-01
 J=          14
 4.375665E-02   9.556871E-02   1.345705E-01   1.652481E-01
 1.904050E-01   2.116489E-01   2.299560E-01   2.459581E-01
 2.600889E-01
 J=          15
 2.906086E-02   7.178685E-02   1.064104E-01   1.345506E-01
 1.580482E-01   1.781114E-01   1.955244E-01   2.108176E-01
 2.243667E-01
 J=          16
 1.679441E-02   4.967162E-02   7.911020E-02   1.041219E-01
 1.255212E-01   1.440615E-01   1.603018E-01   1.746509E-01
 1.874153E-01
 J=          17
 2.718719E-02   7.140388E-02   1.071278E-01   1.359965E-01
 1.600140E-01   1.804822E-01   1.982353E-01   2.138294E-01
 2.276537E-01
 J=          18
 2.163916E-02   6.078616E-02   9.390672E-02   1.212346E-01
 1.442368E-01   1.639833E-01   1.811938E-01   1.963625E-01
 2.098422E-01
 J=          19
 1.497835E-02   4.732033E-02   7.673008E-02   1.017993E-01
 1.232848E-01   1.419339E-01   1.583040E-01   1.728007E-01
 1.857256E-01
 J=          20
 9.073529E-03   3.402337E-02   5.903724E-02   8.132131E-02
 1.008888E-01   1.181226E-01   1.333902E-01   1.469921E-01
 1.591684E-01
 J=          21
 1.219351E-02   4.312604E-02   7.208847E-02   9.697143E-02
 1.183778E-01   1.370102E-01   1.534081E-01   1.679659E-01
```

```
1.809767E-01
J=          22
9.842477E-03   3.726893E-02   6.412616E-02   8.768221E-02
1.081840E-01   1.261597E-01   1.420564E-01   1.562171E-01
1.689038E-01
J=          23
6.991234E-03   2.970273E-02   5.355838E-02   7.516927E-02
9.431981E-02   1.112967E-01   1.264173E-01   1.399507E-01
1.521152E-01
J=          24
4.375078E-03   2.195085E-02   4.224948E-02   6.146159E-02
7.890321E-02   9.459195E-02   1.086943E-01   1.213925E-01
1.328524E-01
J=          25
5.025991E-03   2.515012E-02   4.757950E-02   6.833464E-02
8.693327E-02   1.035447E-01   1.184261E-01   1.318106E-01
1.438920E-01
J=          26
4.098050E-03   2.197221E-02   4.277631E-02   6.242594E-02
8.023911E-02   9.626509E-02   1.106918E-01   1.237112E-01
1.354916E-01
J=          27
2.962247E-03   1.780391E-02   3.628998E-02   5.431884E-02
7.095855E-02   8.609434E-02   9.981675E-02   1.122594E-01
1.235550E-01
J=          28
1.896804E-03   1.342465E-02   2.916250E-02   4.519235E-02
6.034793E-02   7.433554E-02   8.713400E-02   9.880878E-02
1.094502E-01
J=          29
1.894190E-03   1.411397E-02   3.071418E-02   4.746956E-02
6.322255E-02   7.772690E-02   9.099624E-02   1.031154E-01
1.141838E-01
J=          30
1.556009E-03   1.243064E-02   2.783234E-02   4.369646E-02
5.878460E-02   7.277790E-02   8.564188E-02   9.743054E-02
1.082232E-01
J=          31
1.138862E-03   1.019592E-02   2.388766E-02   3.844496E-02
5.253975E-02   6.575602E-02   7.799207E-02   8.925861E-02
9.960707E-02
J=          32
7.415175E-04   7.805102E-03   1.946844E-02   3.241373E-02
4.525209E-02   5.746609E-02   6.887840E-02   7.944966E-02
8.919880E-02
J=          33
6.501923E-04   7.601988E-03   1.935008E-02   3.244338E-02
4.545147E-02   5.785520E-02   6.948058E-02   8.028794E-02
9.029262E-02
J=          34
```

```
5.371153E-04    6.736513E-03    1.763995E-02    3.003787E-02
4.249733E-02    5.446422E-02    6.573453E-02    7.624718E-02
8.600264E-02
J=          35
3.967622E-04    5.576710E-03    1.527453E-02    2.665271E-02
3.829245E-02    4.959507E-02    6.031535E-02    7.036246E-02
7.971643E-02
J=          36
2.615750E-04    4.318958E-03    1.258579E-02    2.270586E-02
3.330871E-02    4.375446E-02    5.375317E-02    6.318030E-02
7.199258E-02
```

```
C        **********************************
C        TABLE 6.2- 16 WELLS TO BE DROPPED
C        **********************************

         RADIUS OF THE PIPE=   2.000000E-01
         FRICTION COEFFICIENT=   6.000000E-03
         COST OF PUMP ETC  COST OF EXCAVATION,1&2
          330200.0000          100.0000                10.0000
         COST OF ENERGY  COST OF TRANSPORTATION
                .0163          380.0000
         LOCAL APPLICATION OF PUMPED  WATER
                .2500
         QPRATE=   30240.000000
         5.000000        5.200000        5.400000        5.600000
         NUMBER OF YEAR CONSIDERED=30
         UNIT TIME PERIOD=ONE WEEK
         TOTAL COST OF WATER SUPPLY IF 36 WELL OPERATE
         1.888646E+07
         COST WHEN WELLS ARE DROPPED IN SEQUENCE
         1.847234E+07    1.839603E+07    1.832041E+07    1.824552E+07
         1.847035E+07    1.839396E+07    1.831844E+07    1.824383E+07
         1.846902E+07    1.839262E+07    1.831716E+07    1.824271E+07
         1.846826E+07    1.839186E+07    1.831644E+07    1.824208E+07
         1.846801E+07    1.839161E+07    1.831621E+07    1.824187E+07
         1.846826E+07    1.839186E+07    1.831644E+07    1.824208E+07
         1.846902E+07    1.839262E+07    1.831716E+07    1.824271E+07
         1.847035E+07    1.839396E+07    1.831844E+07    1.824383E+07
         1.847234E+07    1.839603E+07    1.832041E+07    1.824552E+07


C        **********************************************************
C        TABLE 6.3 THE COST OF PUMP & ACCESSORIES,COST OF EXCAVATION,
C        COST OF ENERGY, COST OF TRANSPORTATION AND TOTAL COST
C        **********************************************************
         IF ONLY THE MOST COSTLIEST  WELL TO BE  DROPPED
         THE WELL TO BE DROPPED=        20
         LEAST COST=   1.824187E+07
         COST ANALYSIS
         COSTENL=  638868.600000
         COSTEXL=  840000.000000
         COSTPL=   1.155700E+07
         COSTTL= 5206000.000000
         TOTAL COST=   1.824187E+07
         TOTAL COST   WELL TO BE DROPPED AT LOCATION
         COSTPL  COSTEXL  COSTENL  COSTTL  COSTFL
 .175981E+08                   16
 .11227E+08     .81600E+06     .61529E+06     .49400E+07     .17598E+08
```

.169547E+08		24		
.10897E+08	.79200E+06	.59211E+06	.46740E+07	.16955E+08
.163122E+08		12		
.10566E+08	.76800E+06	.56984E+06	.44080E+07	.16312E+08
.156700E+08		28		
.10236E+08	.74400E+06	.54776E+06	.41420E+07	.15670E+08
.150289E+08		8		
.99060E+07	.72000E+06	.52694E+06	.38760E+07	.15029E+08
.143880E+08		32		
.95758E+07	.69600E+06	.50622E+06	.36100E+07	.14388E+08
.137489E+08		4		
.92456E+07	.67200E+06	.48727E+06	.33440E+07	.13749E+08
.131098E+08		36		
.89154E+07	.64800E+06	.46836E+06	.30780E+07	.13110E+08
.125429E+08		19		
.85852E+07	.62400E+06	.44568E+06	.28880E+07	.12543E+08
.119768E+08		15		
.82550E+07	.60000E+06	.42381E+06	.26980E+07	.11977E+08
.114112E+08		23		
.79248E+07	.57600E+06	.40237E+06	.25080E+07	.11411E+08
.108464E+08		11		
.75946E+07	.55200E+06	.38178E+06	.23180E+07	.10846E+08
.102818E+08		27		
.72644E+07	.52800E+06	.36139E+06	.21280E+07	.10282E+08
.971834E+07		7		
.69342E+07	.50400E+06	.34214E+06	.19380E+07	.97183E+07
.915499E+07		31		
.66040E+07	.48000E+06	.32299E+06	.17480E+07	.91550E+07

```
C        **********************************************************
C        TABLE 6.4-VARIATION OF INDUCED RECHARGE WHEN 20 WELLS OPERATE
C        ***********************************************************
      2600.000000    35000.000000    2.000000E-01          150
         .262E+05        .262E+05
         .274E+05        .274E+05
         .279E+05        .279E+05
         .282E+05        .282E+05
         .284E+05        .284E+05
         .286E+05        .286E+05
         .287E+05        .287E+05
         .288E+05        .288E+05
         .289E+05        .289E+05
    1       .7099E+03       .7000E+08      .0012
    2       .1222E+05       .1400E+09      .0101
    3       .3528E+05       .2100E+09      .0194
    4       .6328E+05       .2800E+09      .0262
    5       .9282E+05       .3500E+09      .0307
    6       .1223E+06       .4200E+09      .0337
    7       .1509E+06       .4900E+09      .0356
    8       .1783E+06       .5600E+09      .0368
    9       .2043E+06       .6300E+09      .0375
   10       .2281E+06       .7000E+09      .0419
   11       .2398E+06       .7700E+09      .0440
   12       .2385E+06       .8400E+09      .0438
   13       .2309E+06       .9100E+09      .0424
   14       .2206E+06       .9800E+09      .0405
   15       .2091E+06       .1050E+10      .0384
   16       .1974E+06       .1120E+10      .0363
   17       .1859E+06       .1190E+10      .0342
   18       .1748E+06       .1260E+10      .0321
   19       .1642E+06       .1330E+10      .0302
   20       .1542E+06       .1400E+10      .0283
   21       .1447E+06       .1470E+10      .0266
   22       .1358E+06       .1540E+10      .0249
   23       .1274E+06       .1610E+10      .0234
   24       .1195E+06       .1680E+10      .0220
   25       .1121E+06       .1750E+10      .0206
   26       .1052E+06       .1820E+10      .0193
   27       .9869E+05       .1890E+10      .0181
   28       .9259E+05       .1960E+10      .0170
   29       .8686E+05       .2030E+10      .0160
   30       .8148E+05       .2100E+10      .0150
   31       .7644E+05       .2170E+10      .0140
   32       .7171E+05       .2240E+10      .0132
   33       .6728E+05       .2310E+10      .0124
   34       .6311E+05       .2380E+10      .0116
   35       .5921E+05       .2450E+10      .0109
   36       .5554E+05       .2520E+10      .0102
   37       .5211E+05       .2590E+10      .0096
```

38	.4888E+05	.2660E+10	.0090
39	.4586E+05	.2730E+10	.0084
40	.4302E+05	.2800E+10	.0079
41	.4036E+05	.2870E+10	.0074
42	.3786E+05	.2940E+10	.0070
43	.3552E+05	.3010E+10	.0065
44	.3332E+05	.3080E+10	.0061
45	.3126E+05	.3150E+10	.0057
46	.2932E+05	.3220E+10	.0054
47	.2751E+05	.3290E+10	.0051
48	.2581E+05	.3360E+10	.0047
49	.2421E+05	.3430E+10	.0044
50	.2271E+05	.3500E+10	.0042
51	.2131E+05	.3570E+10	.0039
52	.1999E+05	.3640E+10	.0037
53	.1875E+05	.3710E+10	.0034
54	.1759E+05	.3780E+10	.0032
55	.1650E+05	.3850E+10	.0030
56	.1548E+05	.3920E+10	.0028
57	.1452E+05	.3990E+10	.0027
58	.1363E+05	.4060E+10	.0025
59	.1278E+05	.4130E+10	.0023
60	.1199E+05	.4200E+10	.0022
61	.1125E+05	.4270E+10	.0021
62	.1055E+05	.4340E+10	.0019
63	.9900E+04	.4410E+10	.0018
64	.9287E+04	.4480E+10	.0017
65	.8713E+04	.4550E+10	.0016
66	.8174E+04	.4620E+10	.0015
67	.7668E+04	.4690E+10	.0014
68	.7193E+04	.4760E+10	.0013
69	.6748E+04	.4830E+10	.0012
70	.6331E+04	.4900E+10	.0012
71	.5939E+04	.4970E+10	.0011
72	.5571E+04	.5040E+10	.0010
73	.5227E+04	.5110E+10	.0010
74	.4903E+04	.5180E+10	.0009
75	.4600E+04	.5250E+10	.0008
76	.4315E+04	.5320E+10	.0008
77	.4048E+04	.5390E+10	.0007
78	.3798E+04	.5460E+10	.0007
79	.3563E+04	.5530E+10	.0007
80	.3342E+04	.5600E+10	.0006
81	.3135E+04	.5670E+10	.0006
82	.2941E+04	.5740E+10	.0005
83	.2759E+04	.5810E+10	.0005
84	.2589E+04	.5880E+10	.0005
85	.2428E+04	.5950E+10	.0004
86	.2278E+04	.6020E+10	.0004
87	.2137E+04	.6090E+10	.0004

88	.2005E+04	.6160E+10	.0004
89	.1881E+04	.6230E+10	.0003
90	.1765E+04	.6300E+10	.0003
91	.1655E+04	.6370E+10	.0003
92	.1553E+04	.6440E+10	.0003
93	.1457E+04	.6510E+10	.0003
94	.1367E+04	.6580E+10	.0003
95	.1282E+04	.6650E+10	.0002
96	.1203E+04	.6720E+10	.0002
97	.1128E+04	.6790E+10	.0002
98	.1059E+04	.6860E+10	.0002
99	.9929E+03	.6930E+10	.0002
100	.9315E+03	.7000E+10	.0002
101	.8741E+03	.7070E+10	.0002
102	.8198E+03	.7140E+10	.0002
103	.7691E+03	.7210E+10	.0001
104	.7215E+03	.7280E+10	.0001
105	.6769E+03	.7350E+10	.0001
106	.6350E+03	.7420E+10	.0001
107	.5958E+03	.7490E+10	.0001
108	.5588E+03	.7560E+10	.0001
109	.5244E+03	.7630E+10	.0001
110	.4918E+03	.7700E+10	.0001
111	.4614E+03	.7770E+10	.0001
112	.4328E+03	.7840E+10	.0001
113	.4061E+03	.7910E+10	.0001
114	.3810E+03	.7980E+10	.0001
115	.3574E+03	.8050E+10	.0001
116	.3352E+03	.8120E+10	.0001
117	.3146E+03	.8190E+10	.0001
118	.2951E+03	.8260E+10	.0001
119	.2770E+03	.8330E+10	.0001
120	.2598E+03	.8400E+10	.0000
121	.2437E+03	.8470E+10	.0000
122	.2286E+03	.8540E+10	.0000
123	.2145E+03	.8610E+10	.0000
124	.2013E+03	.8680E+10	.0000
125	.1888E+03	.8750E+10	.0000
126	.1771E+03	.8820E+10	.0000
127	.1661E+03	.8890E+10	.0000
128	.1556E+03	.8960E+10	.0000
129	.1462E+03	.9030E+10	.0000
130	.1371E+03	.9100E+10	.0000
131	.1287E+03	.9170E+10	.0000
132	.1207E+03	.9240E+10	.0000
133	.1132E+03	.9310E+10	.0000
134	.1061E+03	.9380E+10	.0000
135	.9973E+02	.9450E+10	.0000
136	.9351E+02	.9520E+10	.0000
137	.8788E+02	.9590E+10	.0000

138	.8238E+02	.9660E+10	.0000
139	.7737E+02	.9730E+10	.0000
140	.7252E+02	.9800E+10	.0000
141	.6801E+02	.9870E+10	.0000
142	.6382E+02	.9940E+10	.0000
143	.5990E+02	.1001E+11	.0000
144	.5612E+02	.1008E+11	.0000
145	.5275E+02	.1015E+11	.0000
146	.4938E+02	.1022E+11	.0000
147	.4625E+02	.1029E+11	.0000
148	.4334E+02	.1036E+11	.0000
149	.4077E+02	.1043E+11	.0000
150	.3818E+02	.1050E+11	.0000

TOTAL QUANTITY PUMPED= 5443200.000000
QUANTITY TAKEN FROM THE RIVER= 5442622.000000
FACTOR= 9.998938E-01

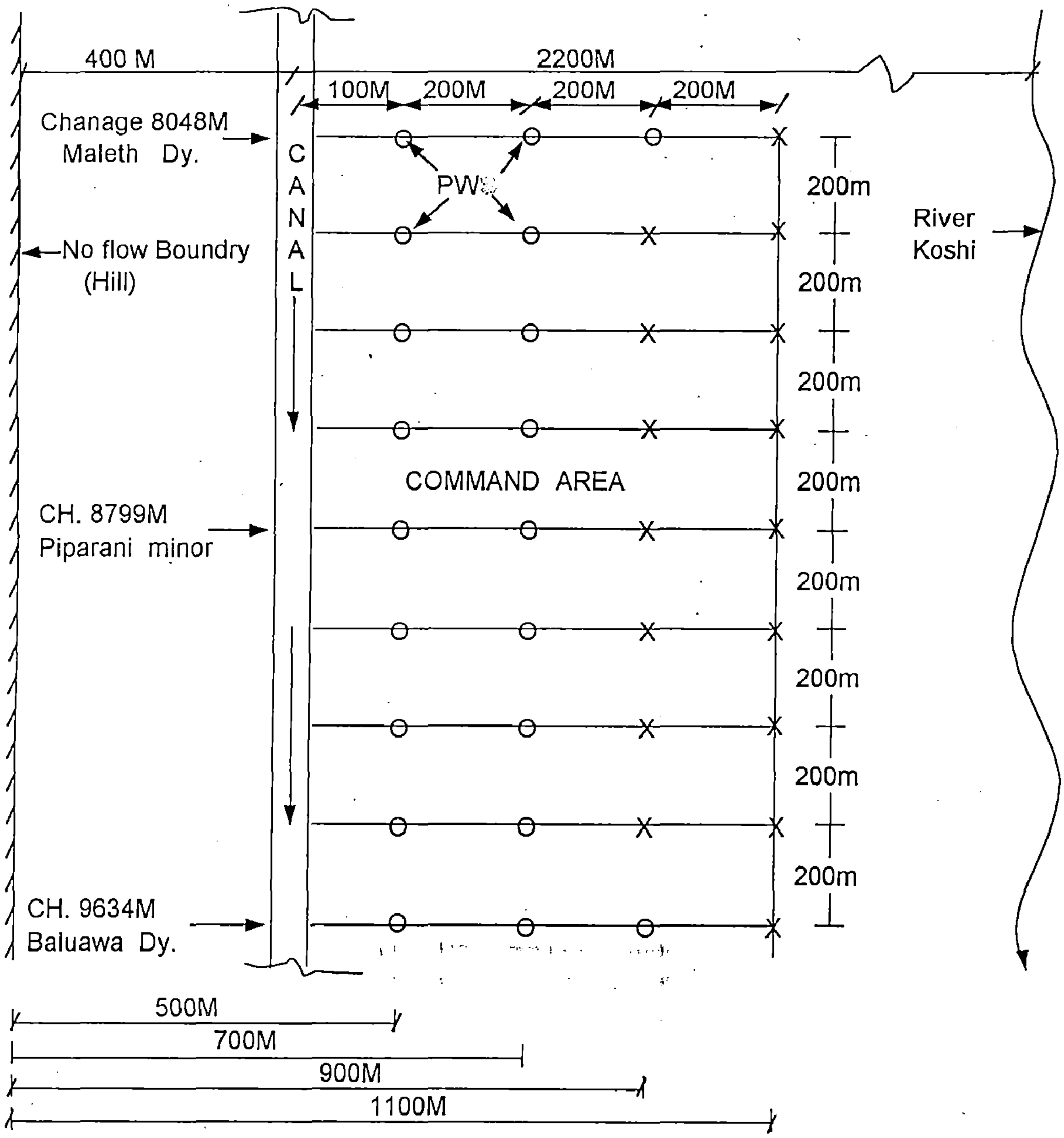


Fig. 6.1 Final location of wells

Fig. 6.2 Recharge Vs time

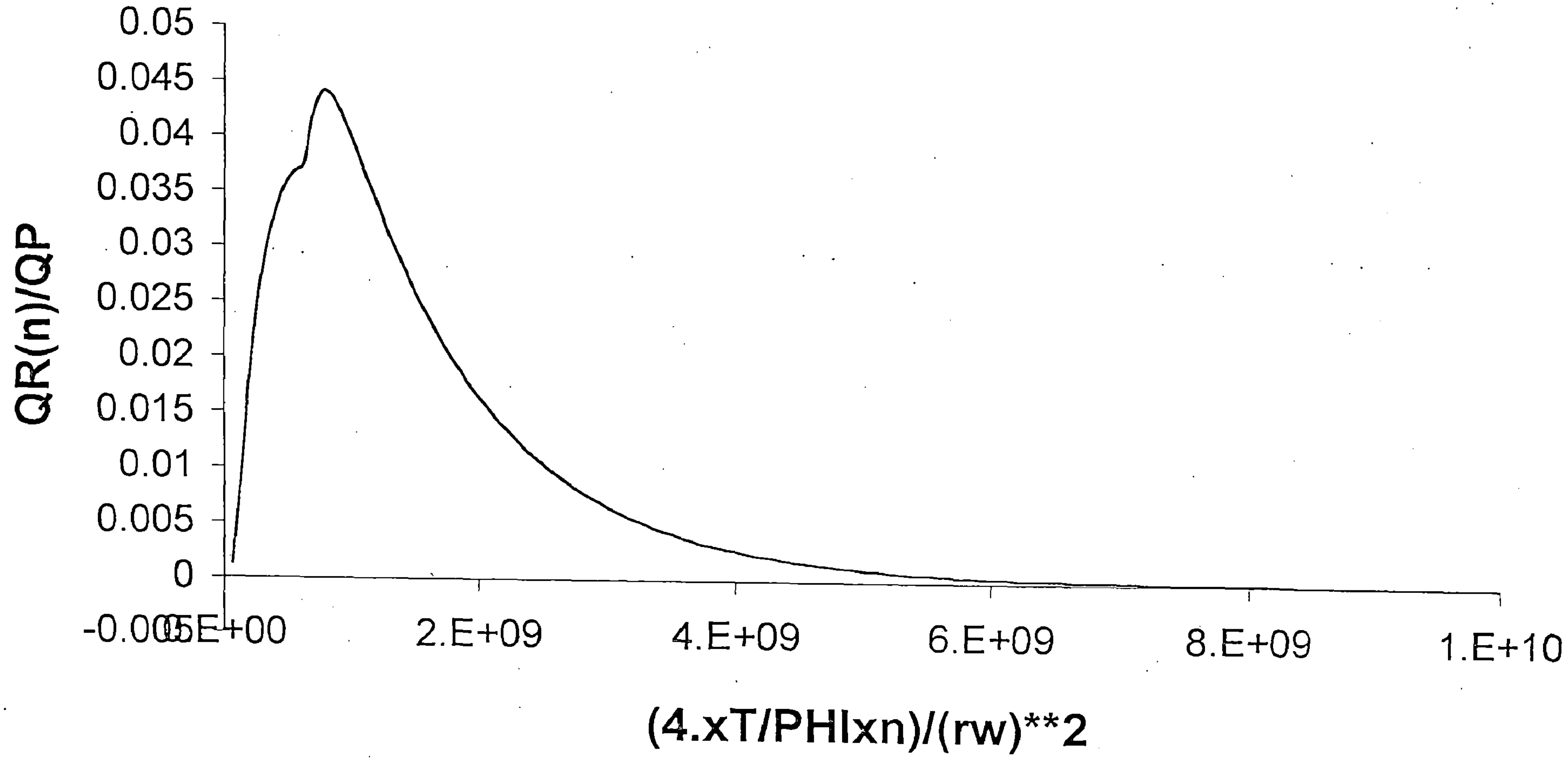
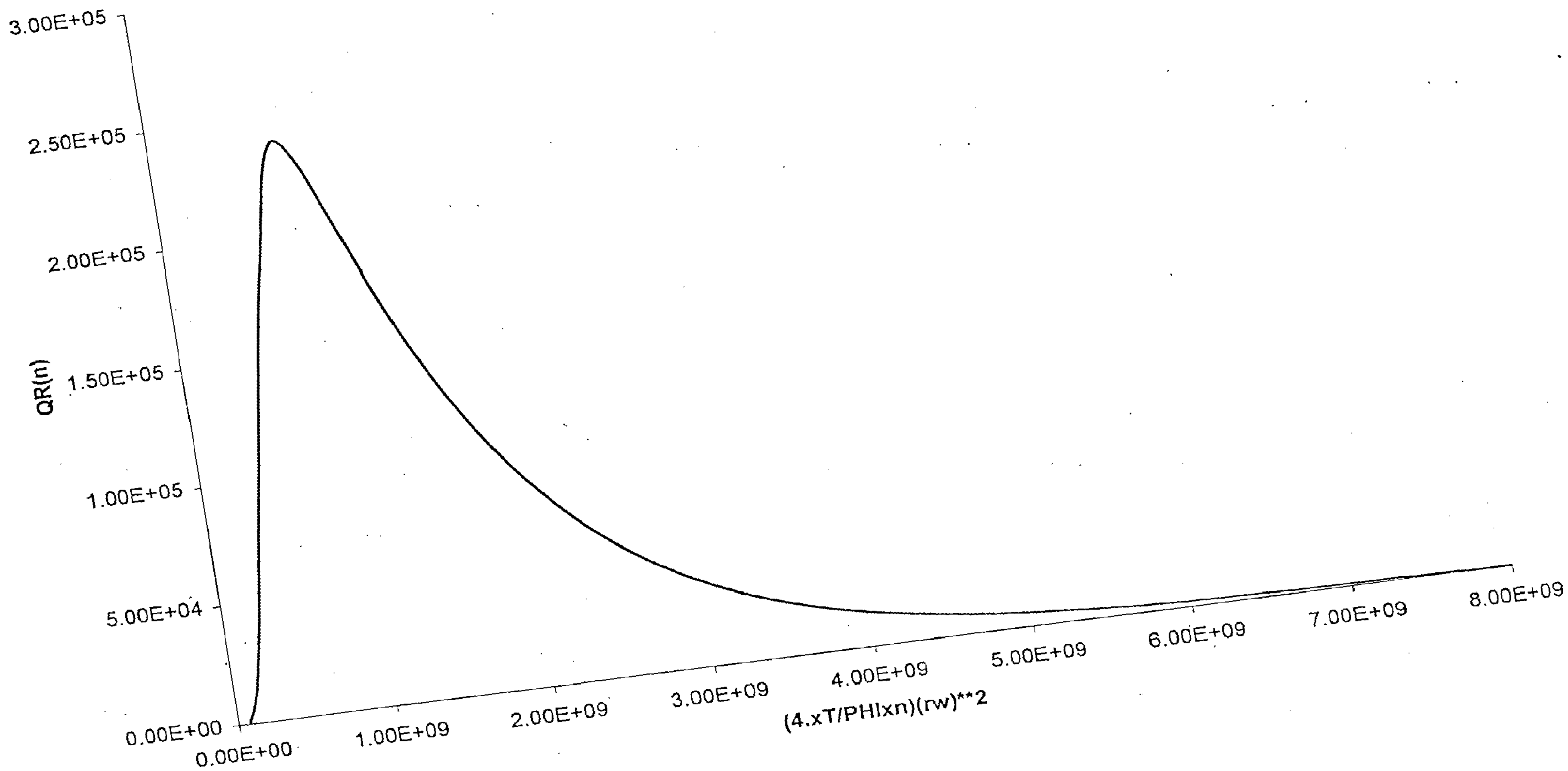


Fig. 6.3 Recharge in nondimensional form



CHAPTER – 7

CONCLUSION

Conjunctive use of surface and groundwater is one of the practical techniques to mitigate the shortage in canal supply subjected to constraint of steep variation in the river supply during the year. The underlying objective of conjunctive use of surface and groundwater is, generally to strengthen and supplement the canal irrigation system. The crop planning for a particular region depend not only on the availability of water, but also upon socio-economic factors, internal consumption needs, besides soil characteristics, topography, climatic condition, marketability of produce etc. Therefore, planning the conjunctive use of surface and ground water calls for greater ingenuity so as to exploit the total available resources to best advantage.

An efficient conjunctive use model has been developed using unit pulse response function coefficient. The study has been done for a finite aquifer bounded by a stream on one side and a no flow boundary on the other side. A systematic search program has been written to identify the most economical well from a cluster of wells. The model also compute induce recharge from the stream. Wherever a well operates in a finite aquifer bounded by a no flow boundary on one side and fully penetrating stream at the other side, all the water pumped is taken only from the stream storage.

The conjunctive use study is applicable to provide drinking water. The water should be pumped from the aquifer near the stream. It should not be pumped directly from the river.

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APPENDIX – 1 : DESIGN ASPECTS

APPENDIX – I

DESIGN ASPECTS

The design aspects have been presented for a maximum of 4 number of wells.

RABI SEASON WATER REQUIREMENT

Total command area of the project is 11300 ha. Cropping pattern and crop calendar of Rabi season are as shown in Table I-1. According to cropping pattern in the project area fortnightly water requirement in each month has been calculated as shown in Table I-3

From the table it is seen that surface water, is not sufficient to satisfy required water demand from December 2nd half to February Ist half. To satisfy the water requirement with 1:1 rotation together with surface water, about 1 cumec of water has to be withdrwan from ground water reservoir.

Well points have been designed to place them in the middle reach command area of main canal as from the investigation, the aquifer is good in this reach only. Water which will be utilized in the command area of the well field will be as shown in the Table I-2 From this it is seen that about 25% of total water pumped will be utilized in local area and rest 75% of pumped water will be transported from well to main canal for downstream command area utilization.

DESIGN OF NUMBER OF WELLS REQUIRED

Providing 50 lit/s discharging capacity tubewell, total number of tubewells required for 100 l/s of water demand is 20 numbers i.e. total number of tubewells $= \frac{1000}{50} = 20$ wells.

Table : I-1

Proposed cropping pattern and crop calendar in RABI SEASON. (total CCA =11300 ha.)

Crop and % area	period of sowing	period of growing fortnights	period of harvesting
1. Wheat-1 :-25%	NOV 1----15	8	MARCH 1---15
2.Wheat-2 :-15%	NOV 16---30	8	MARCH 16--31
3. Sunflower :-1%	NOV 1----15	9	MARCH 16--31
4.Linseed :-4%	NOV 1----15	8	MARCH 1---15
5. Mustard :-8%	NOV 1----15	8	MARCH 1---15
6. Gram :-5%	NOV 1----15	8	MARCH 1---15
7. Lintel :-2%	NOV 1----15	6	FEB 1---15
8. Potato :-4%	NOV 1---15	8	MARCH 1----15
9. Garlic :-1%	NOV 1---15	9	MARCH 16---31

Table :I-2 % OF LOCAL UTILIZATION

Rabi CCA and name of canal and water required in well points reach area :-

Sl.no	Chainage in m	Name of canal	C.C.A. in Rabi ha.	Length m	Discharage reqd lps
1.	8048	Maleth distributary	98.0	1200	49.0
2.	8574.00	Direct outlet	30.0	650	15.0
3.	8799.00	Piparani minor	99.0	1300	50.0
4.	9634	Baluwa distributary	279.0	3100	140.0

Total water to be used in this area =254.00 lps
i.e. About 25% of total water to be pumped

Table : I-3:- CROP WATER REQUIREMENT FOR RABI CROPS

1.Wheat -1 Period 01/11 to 28/02	days=106 (Sunflower,Linseed,lentil,garlic)								
sl.no.	Item	November		December		January		February	
		1	2	1	2	1	2	1	2
1	No. of days	15	15	15	16	15	16	14	14
2	Mid point	8	23	38	53	69	84	99	
3	% of growing season	7.60	21.70	35.90	50.0	65.10	79.30	93.40	
4	CU coefficient(K)	0.12	0.22	0.41	0.58	.77	0.90	0.63	
5	Pan evaporation losses Ep	43.0	43.0	51.0	54.0	34.0	35.0	46.0	
6	Consumptive use CU	5.16	9.50	20.91	31.32	26.18	31.50	29.0	
7	Normal effective rainfall	6.0	6.0	2.0	2.30	0.0	5.0	10.50	
8	Correction factor	0.93	0.93	0.93	0.93	0.93	0.93	0.93	
9	corrected N.eff. Rainfall	5.60	5.60	1.86	2.14	2.79	4.65	9.80	
10	Application ratio	0.86	0.86	0.86	0.86	0.86	0.86	0.86	
11	Effective rainfall	4.80	4.80	1.60	1.84	0.0	4.0	8.43	
12	Presowing	30.0	20.0	—	—	—			
13	NIR=6-11+12	30.36	24.70	19.31	29.48	26.18	27.50	20.57	
14	FIR=NIR/.85	30.72	29.06	22.72	34.68	30.80	32.35	24.20	

2.Wheat-2 period 16/11 to 15/03	Nos. of irrigation days=106								
sl.no.	Item	November		December		January		February	
		1	2	1	2	1	2	1	2
1	No. of days		15	15	16	15	16	14	14
2	Mid point		8	23	38	54	69	84	98
3	% of growing season		7.60	21.70	35.90	50.94	65.10	79.30	92.45
4	CU coefficient(K)		0.12	0.22	0.41	0.58	0.77	0.90	0.63
5	Pan evaporation losses Ep		43.0	51.0	54.0	34.0	35.0	46.0	46.0
6	Consumptive use CU		5.16	11.22	22.14	19.72	26.95	41.40	28.98
7	Normal effective rainfall		6.0	2.0	2.20	0.0	6.50	8.0	9.0
8	Correction factor		0.93	0.93	0.93	0.93	0.93	0.93	
9	corrected N.eff. Rainfall		5.58	1.86	2.05	0.0	6.05	7.44	8.37
10	Application ratio		0.86	0.86	0.86	0.86	5.200.86	0.86	
11	Effective rainfall		4.80	1.60	1.76	0.0	5.20	6.40	7.20
12	Presowing		30.0	20.0	—	—			
13	NIR=6-11+12		30.36	29.62	20.38	19.72	21.75	35.0	21.78
14	FIR=NIR/.85		35.72	34.85	23.98	23.20	25.60	41.18	25.62

Table I-3 continue

Potato	: -1 Period 01/11 to 28/02	days=106							
sl.no.	Item	November		December		January		February	
		1	2	1	2	1	2	1	2
1	No. of days	15	15	15	16	15	16	14	14
2	Mid point	8	23	38	53	69	84	99	
	% of growing season	7.60	21.70	35.90	50.0	65.10	79.30	93.40	
	CU coefficient(K)	0.12	0.22	0.41	0.58	.77	0.90	0.63	
	Pan evaporation losses Ep	43.0	43.0	51.0	54.0	34.0	35.0	46.0	
	Consumptive use CU	12.04	29.24	47.43	54.0	30.94	26.60	14.72	
	Normal effective rainfall	9.0	11.0	2.0	2.30	3.0	4.50	6.0	
	Correction factor	0.93	0.93	0.93	0.93	0.93	0.93	0.93	
	corrected N.eff. Rainfall	8.37	10.23	1.86	2.14	2.79	4.19	5.58	
	Application ratio	o.86	0.86	0.86	0.86	0.86	0.86	0.86	
	Effective rainfall	7.20	8.80	1.60	1.84	2.40	3.60	4.74	
	Presowing	30.0	20.0	—	—	—			
	NIR=6-11+12	34.84	40.44	45.83	52.16	28.54	23.0	9.98	
	FIR=NIR/.85	40.99	47.58	53.92	61.36	33.58	27.06	11.74	

GROSS IRRIGATION REQUIREMENT

	November		December		January		February	
	1	2	1	2	1	2	1	2
1. Wheat-1,sunflower,linseed, lintel,mustard,&gram=46%								
Area	5198	5198	5198	5198	5198	5198	5198	
FIR	35.72	29.06	22.72	34.68	30.80	32.35	24.20	
Discharge in cumecs	1.43	1.17	0.91	1.31	1.22	1.22	1.05	
2. Wheat-2 =15%								
Area		1695	1695	1695	1695	1695	1695	1695
FIR	—	35.72	34.80	23.98	23.20	25.60	41.18	25.62
Discharge in cumecs	—	0.47	0.46	0.30	0.31	0.31	.58	0.36
3. Potato=4%								
Area	452	452	452	452	452	452	452	
FIR	40.99	47.58	53.92	61.36	33.58	27.06	11.74	
Discharge in cumecs	0.15	0.17	0.19	0.20	0.13	0.10	0.04	
Total discharge in cumecs	1.58	1.81	1.56	1.81	1.69	1.63	1.67	0.36
Total discharge at head of canal taking 75% conveyance efficiency in cumecs	2.11	2.41	2.08	2.41	2.25	2.28	2.23	0.48
Avialable surface water	2.70	2.60	2.2	1.40	1.25	1.25	1.20	1.20
Ground water to be pumped	—	—	—	1.01	1	1.03	1.03	—

DESIGN OF R.C.C. HUME PIPE

Diameter for Different Discharge

Assume velocity of flow in pipe = 1.2 m/sec and it is assumed to be constant for all discharges.

i) For one well – i.e. for discharge 0.05 cumec

$Q = (\pi/4)\, D^2V$

$$D = \sqrt{\frac{4.Q}{\pi V}} = \sqrt{\frac{4x0.05}{\pi \text{ x } 1.2}} = 023 \text{ m}$$

Provide diameter of pipe = 0.25 m

ii) For two wells i.e. for discharge 0.10 cumec

$$D = \sqrt{\frac{4.01}{\pi \text{x} 1.2}} = 0.35 \text{ m}$$

Provide diameter of pipe = 0.35 m.

iii) For three wells i.e. for discharge 0.15 cumec

$$D = \sqrt{\frac{4x0.15}{\pi\ x1.2}} = 0.40m$$

Provide diameter of pipe = 0.40m

iv) For four wells i.e. for discharge 0.20 cumec.

$$D = \sqrt{\frac{4x0.20}{\pi \text{ x } 1.2}} = 0.46 \text{ m}$$

Provide diameter of pipe = 0.50 m.

Energy losses in pipe line

When a fluid flows through a pipe, certain resistance is offered to the flowing fluid, which results in causing a loss of energy. The various energy losses in pipes may be classified as

(i) minor losses and

(ii) major loses.

(i) The minor losses of energy are those which are caused on account of the change in the velocity of flowing fluid (either in magnitude or direction). In this study these have been neglected because in case of long pipe, these losses are usually quite small as compared with the losses of energy due to friction.

(ii) The major loss of energy, as a fluid flows through a pipe, is caused by friction. It may be computed by Darcy-weisbach equation given by

PL = pipe loss due to friction in m = $\frac{4flv^2}{2gd}$

$$=\frac{32fLQ^2}{\pi^2 gD^5}=\frac{fLQ^2}{\pi^2 gR^5}$$

where

f = coefficient of friction

L = Length of pipe line in m.

Q = discharging rate in m^3/sec.

D = diameter of pipe in m

g = acceleration due to gravity in m/sec^2

Energy loss in pipe for different conditions are :

Q =0.05 cumec = 0.05 x 3600 x 24 x 7 = 30240 m^3/ week

Here in this study, week has been taken as unit time.

$g = 9.81$ m/sec^2 = $9.81 \times (3600 \times 24 \times 7)^2 = 3.58833 \times 10^{12}$ m/week^2

$f = 0.006$.

Two cases have been considered. These are

Case I : Separate pipe line for each well :

(i) For one well

$$PL = \frac{fLQ^2}{\pi^2 \, g R^5}$$

Here

L = 100m

R = 0.25/2 m

$$PL_1 = \frac{0.006 x 100 x (30240)^2}{\pi^2 x 3.58833 x 10^{12} x (0.125)^5} = 0.51 m$$

(ii) For two wells

L_1 = 100 m and L_2 = 300 m

$$PL_2 = \frac{fQ^2}{\pi^2 \, gR^5}(L_1 + L_2) = 2.03 m$$

(iii) For three wells

L_1 = 100 m, L_2 = 300 m and L_3 = 500 m

$$PL_3 = \frac{fQ^2}{\pi^2 \, gR^5}(100 + 300 + 500) = 4.57 m$$

(iv) For four wells

L_1 = 100 m, L_2 = 300 m and L_3 = 500 m & L_4 = 700 m

$$PL_4 = \frac{fQ^2}{\pi^2 gR^5}(100+300+500+700) = 8.12m$$

Case II : Combined pipe line for all wells .

(i) one well

$$PL_1 = \frac{fL_1Q^2}{\pi^2 gR^5} = 0.51m$$

(ii) Two wells

L_1 = 100 m and R_1 = 0.35/2 m = 0.175 m

Q_1 = 2Q

L_2 = 200m and R_2 = 0.125 m

Q_2 = Q

$$PL_2 = \frac{fQ^2}{\pi^2 g}\left(\frac{2^2 L_1}{R_1^5} + \frac{L_2}{R_2^5}\right) = 1.40m$$

(iii) Three wells

L_1 = 100 m and R_1 = 0.20 m

Q_1 = 3Q

L_2 = 200 m and R_2 = 0.175 m

Q_2 = 2Q

L_3 = 200 m

Q_3 = Q

$$PL_3 = \frac{fQ^2}{\pi^2 g}\left(\frac{3^2 L_1}{R_1^5} + \frac{2^2 L_2}{R_2^5} + \frac{L_3}{R_3^5}\right) = 2.21m$$

(iv) Four wells

L_1 = 100 m, R_1 = 0.25 m and Q_1 = 4Q

$L_2 = 200$ m, $R_2 = 0.20$ m and Q_2 3Q

$L_3 = 200$ m, $R_3 = 0.175$ m and $Q_3 = 2Q$

$L_4 = 200$ m, $R_4 = 0.125$ m and $Q_4 = Q$

$$PL_4 = \frac{fQ^2}{\pi^2 g}\left(\frac{4^2 L_1}{R_1^5} + \frac{3^2 L_2}{R_2^5} + \frac{2^2 L_3}{R_3^5} + \frac{L_4}{R_4^5}\right) = 2.90m$$

From above it is found that providing one pipe line for all wells is economical because pipe loss is minimum in this case.

TUBEWELL DESIGN

The design is worked out taking into account hydraulic conductivity of the aquifer, total aquifer thickness available, screen entrance velocity, total drawdown in the tube well during pumping, depth of water table below ground and seasonal fluctuations in water table.

Design of a tube well involves selecting the appropriate dimensions of the various components and choosing the proper material to be used in its construction. A good design should aim at efficient utilization of the aquifer is, long useful life, low initial cost and low maintenance and operation costs.

Housing Pipe

The housing pipe is an enlarged section of the well casing at the top of the well and is used to accommodate the pump with enough clearance for installation and efficient operation. The housing pipe should be at least 5 cm more in diameter than the nominal diameter of the pump.

In this study according to lithology available the length of housing pipe is taken as 40 m, the diameter and thickness of the housing pipe (steel pipe) as recommend by

U.S.B.R. for 50 l/s discharge as given in Table I-4, are taken as 30 cm and 4.0 mm respectively.

Slotted Pipe

It is the most important component of a well. The size of the slot opening is governed by the size of the gravel or aquifer material, which are to be retained. The slotted pipes permit the water to enter the well from the aquifer. The slot size of the screen should be such that it retains at least 90 percent of the gravel.

Provide diameter of screen as 20 cm (as recommended by USBR. Table I-4). The percentage open area of the screen may be adopted as 20 percent.

Based on the permissible entrance velocity (Table I-4) the minimum slotted pipe length for a particular discharge in computed from the following relation :

$$L = \frac{Q}{A_0 V_e}$$

where

L = minimum length of the well screen, m

Q = maximum expected discharge capacity of well, m^3/sec

A_0 = effective open area per metre length of the well screen, m^2

V_e = entrance velocity at the screen, m/sec

Here in this study, assuming the effective open area of the available strainer, the length of slotted pipe is obtained.

D = 20 cm

Q = 50 l/sec = 0.05 m^3/sec

V_e = 3 cm/s(assuming) = 0.03 m/sec

$A_0 = \pi d \times 15/100 = 0.0942\ m^2$

Table: I.4

Diameter and thickness of housing pipes of tubewells for different sizes of turbine/submersile pumps

discharge l/min	Nominal diameter of pump . Cm.	Diameter of housing pipe. Cm.	Thickness of housing pipe . Cm.
475	12.5	15.0-20.0	1.5-3.5
1150	15	20.0-25.0	1.5-3.5
2275	20	25.0-30.0	2.0-5.0
4550	30	35	2.0-5.0
7500	35	40	2.0-6.0
11500	40	45	2.0-6.0

Recommended diameter of casing pipe and well screen

Discharge l/min	Casing pipe/ screen diameter. Cm	
	Minimum	Recommended
475	10	10
475-1125	15	15
1125-3000	20	25
3000-5250	25	30
5250-9500	30	35
9500-13300	35	40

Optimum screen Entrance velocities

Coefficient of permeability cm/sec	o.28	o.24	0.18	0.14	0.09	0.05	0.02
Optimum screen entrance velocities cm/sec	5.5	5.0	4.5	4.0	3.0	2.0	1.5

Calculation of Benefit and Cost ratio

Table I-5 Crop budget : Project with tubewell irrigation

Particulars	Unit	Crops			
		Wheat	Oilseed	Pulse	Vegetable
1. Return					
Yield	t/ha	2.2	0.6	0.7	11
rate	Rs./t	8000.00	15000.00	20000.00	4000.00
Return	Rs.	17600.00	9000.00	14000.00	44000.00
2. Expenditure					
seed	Kg./ha	90	9	25	1500
rate	Rs./kg	10.00	20.00	30.00	6.00
value	Rs.	900.00	180.00	750.00	9000.00
DAP	kg/ha	120	----	----	250
rate	Rs,/kg	15.00	—	—	15.00
value	Rs.	1800.00	—	—	3750.00
Chemicals					
N	kg/ha	60	—	15	70
rate	Rs./kg	15.00	—	15.00	15.00
value	Rs.	900.00	—	225.00	1050.00
P	kg/ha	30	—	15	30
rate	Rs./kg	17.00	—	17.00	17.00
value	Rs.	510.00	—	255.00	510.00
k	kg/ha	15	—	10	20
rate	Rs./kg	15.00	—	15.00	15.00
value	Rs.	225.00	—	150.00	300.00
Labour	md/ha	100	49	39	30
rate	Rs./md	40.00	40.00	40.00	40.00
value	Rs.	4000.00	1960.00	1560.00	1200.00
Animal	md/ha	39	20	12	30
rate	Rs./md	80.00	80.00	80.00	80.00
value	Rs.	3120.00	1600.00	960.00	2400.00
Total expenditure	Rs.	11455.00	3740.00	3900.00	18210.00
Net return	Rs.	6145.00	5260.00	10100.00	25790.00

Table : I.6 Crop budget : Future without project

Particulars	Unit	Crops			
		Wheat	Oilseed	Pulse	Vegetable
1. Return					
Yield	t/ha	1.2	0.5	0.6	7
rate	Rs./t	8000.00	15000.00	20000.00	4000.00
Return	Rs.	9600.00	7500.00	12000.00	28000.00
2. Expenditure					
seed	Kg./ha	100	9	25	2000
rate	Rs./kg	10.00	20.00	30.00	6.00
value	Rs.	1000.00	180.00	750.00	12000.00
DAP	kg/ha	50	----	----	80
rate	Rs,/kg	15.00	—	—	15.00
value	Rs.	750.00	—	—	1200.00
Chemicals					
N	kg/ha	15	—	—	30
rate	Rs./kg	15.00	—	—	15.00
value	Rs.	225.00	—	—	450.00
P	kg/ha	10	—	—	—
rate	Rs./kg	17.00	—	—	—
value	Rs.	170.00	—	—	—
k	kg/ha	10	—	—	—
rate	Rs./kg	15.00	—	—	—
value	Rs.	150.00	—	—	—
Labour	md/ha	88	44	33	30
rate	Rs./md	40.00	40.00	40.00	40.00
value	Rs.	3520.00	1760.00	1320.00	1200.00
Animal	md/ha	31	20	10	20
rate	Rs./md	80.00	80.00	80.00	80.00
value	Rs.	2480.00	1600.00	800.00	1600.00
Total expenditure	Rs.	8295.00	3540.00	2870.00	16450.00
Net return	Rs.	1305.00	3960.00	10100.00	11550.00

APPENDIX – II : COMPUTER PROGRAM

```
C        ************************************************
C                COMPUTER PROGRAM
C        COMPUTATION OF DRAWDOWN USING IMAGE & THEIS THEORY
C        *************************************************
$DebuG
         DIMENSION  NWELL(9),YCW(9),DD1(9,4), QP(36,9), DELTA(36,36,9)
         DIMENSION DRAW(36,0:9),FWELL(36), DRAW1(36,0:9)
         OPEN(1, FILE= 'ASIT2.DAT',STATUS='OLD')
         OPEN(2, FILE= 'ASIT4.OUT',STATUS='UNKNOWN')

         PAI=3.14159265
         READ(1,*) WIDTH,T,PHI,RW,QPRATE,NTIME
         WRITE(2,*)WIDTH,T,PHI,RW,QPRATE,NTIME
         READ(1,*)IMAX
C        IMAX=MAXIMUM NUMBER OF LINE
         READ(1,*)(NWELL(I),I=1,IMAX)
C        NWELL(I) =NUMBER OF WELL IN ITH ROW

         DO I=1,IMAX
         READ(1,*)(DD1(I,J),J=1,NWELL(I))
         END DO
         READ(1,*)(YCW(I),I=1,IMAX)
         DO I=1,IMAX
         WRITE(2,*)(DD1(I,J),J=1,NWELL(I))
         END DO

         MMAX=0
         DO I=1,IMAX
         MMAX=MMAX+NWELL(I)
         END DO


         DO I=1,MMAX
         FWELL(I)=0.
         END DO
         FWELL(1)=1
C        FWELL(5)=1. MEANS  A WELL EXISTS AT LOCATION 5
C        FWELL(5)=0. MEANS NO WELL EXISTS AT LOCATION 5

         DO I=1,MMAX
         DO K=1,NTIME
         QP(I,K)=QPRATE*FWELL(I)
         END DO
         END DO

         M1=0
         DO I=1,IMAX
         DO J=1,NWELL(I)
         M1=M1+1
         D1=DD1(I,J)
```

```
      D2=WIDTH-D1

      FIRST=0.

      DO NN=1,NTIME
      AN=NN
      CALL DISCK(T,PHI,D1,D2,RW,AN,RES)
      DELTA(M1,M1,NN)=(RES-FIRST)/(4.*PAI*T)
      FIRST=RES
      END DO
C     WRITE(2,*)(DELTA(M1,M1,NN),NN=1,NTIME)
      END DO
      END DO

      DO I1=1,IMAX
      DO I2=1,IMAX
      DO J1=1,NWELL(I1)
      DO J2=1,NWELL(I2)

      M1=0
      DO I=1,(I1-1)
      DO J=1,NWELL(I)
      M1=M1+1
      END DO
      END DO

      DO J=1,J1
      M1=M1+1
      END DO

      M2=0
      DO I=1,(I2-1)
      DO J=1,NWELL(I)
      M2=M2+1
      END DO
      END DO

      DO J=1,J2
      M2=M2+1
      END DO

C     WRITE(2,*)'M1=',M1
C     WRITE(2,*)'M2=',M2

      IF(M1.EQ.M2) GO TO 300

      DI1J1=DD1(I1,J1)
      DI2J2=DD1(I2,J2)
      Y1=YCW(I1)
      Y2=YCW(I2)
```

```
      FIRST=0.

      DO NN=1,NTIME
      AN=NN
C
      CALL DISCK1(T,PHI,WIDTH,DI1J1,Y1,DI2J2,Y2,AN,RES)
      DELTA(M1,M2,NN)=(RES-FIRST)/(4.*PAI*T)
      FIRST=RES
      END DO

300   CONTINUE
      END DO
      END DO
      END DO
      END DO

C     WRITE(2,*)'DISCRETE KERNEL'
C     DO I=1,MMAX
C     DO J=1,MMAX
C     WRITE(2,*)I,J
C     WRITE(2,*)(DELTA(I,J,N),N=1,NTIME)
C     END DO
C     END DO

      DO I=1,MMAX
      DO K=1,NTIME
      DRAW1(I,K)=0.
      END DO
      END DO

      DO J=1,MMAX
              DO N=1,NTIME
              SUM=0.
              DO NGAMA=1,N
              DO I=1,MMAX
              SUM=SUM+QP(I,NGAMA)*DELTA(I,J,N-NGAMA+1)
              END DO
              END DO
      DRAW1(J,N)=SUM
      END DO
      END DO

      WRITE(2,*)'DRAWDOWN'
      DO J=1,MMAX
C     WRITE(2,*)'J=',J
C     WRITE(2,*)(DRAW1(J,N),N=1,NTIME)
      END DO
C
C     COST OF PUMPING
```

```
C
C
      DO J=1,MMAX
      DRAW(J,0)=0.
      END DO

      DO J=1,MMAX
      DO N=1,NTIME
      DRAW(J,N)=0.
      END DO
      END DO


      DO NCAP= 1, NTIME
      DO J=1,MMAX
      DO NS=1,NCAP

              SUM=0.
              DO I=1,MMAX
              DO NGAMA=1,NS
              SUM=SUM+QP(I,NGAMA)*DELTA(I,J,NS-NGAMA+1)*FWELL(I)
              END DO
              END DO
              DRAW(J,NS)=SUM

      END DO
      END DO
      END DO

      WRITE(2,*)'DRAWDOWN'
      DO J=1,MMAX
      WRITE(2,*)'J=',J
      WRITE(2,*)(DRAW(J,N),N=1,NTIME)
      END DO

      STOP
      END
C
C     CALCULATION OF DISCRETE KERNEL COEFFICIENT
C             WHEN ONE WELL IS OPERATING

      SUBROUTINE DISCK(T,PHI,D1,D2,RW,AN,RES)
      PAI=3.14159265
      CON=4.*T/PHI
      TERM1=RW**2/CON

      U=TERM1/AN
      CALL EXI(U,EXFN)
      SUM=EXFN
```

```
            DO  N=2,100,4
            R2=(N-2)*D1+N*D2
            TERM2=R2**2/CON
            U=TERM2/AN
            CALL EXI(U,EXFN)
            SUM=SUM-EXFN
            END DO

      DO  N=3,101,4
      R3=(N-1)*D1+(N-1)*D2
      TERM3=R3**2/CON
      U=TERM3/AN
      CALL EXI(U,EXFN)
      SUM=SUM-EXFN
      END DO
            DO  N=4,98,4
            R4=(N-2)*D1+N*D2
            TERM4=R4**2/CON
            U=TERM4/AN
            CALL EXI(U,EXFN)
            SUM=SUM+EXFN
            END DO

      DO  N=5,99,4
      R5=(N-1)*D1+(N-1)*D2
      TERM5=R5**2/CON
      U=TERM5/AN
      CALL EXI(U,EXFN)
      SUM=SUM+EXFN
      END DO

      DO  N=1,99,4
      RL1=(N+1)*D1+(N-1)*D2
      TERML1=RL1**2/CON
      U=TERML1/AN
      CALL EXI(U,EXFN)
      SUM=SUM+EXFN
      END DO
            DO  N=2,100,4
            RL2=N*D1+N*D2
            TERML2=RL2**2/CON
            U=TERML2/AN
            CALL EXI(U,EXFN)
            SUM=SUM-EXFN
            END DO
      DO  N=3,101,4
      RL3=(N+1)*D1+(N-1)*D2
      TERML3=RL3**2/CON
      U=TERML3/AN
      CALL EXI(U,EXFN)
```

```
        SUM=SUM-EXFN
        END DO
                DO  N=4,98,4
                RL4=N*D1+N*D2
                TERML4=RL4**2/CON
                U=TERML4/AN
                CALL EXI(U,EXFN)
                SUM=SUM+EXFN
                END DO

        RES=SUM
        RETURN
        END
C
C       CALCULATION OF DISCRETE KERNEL COEFFICIENT
C           WHEN ALL WELLS ARE OPERATING
C
        SUBROUTINE DISCK1(T,PHI,WIDTH,DI1J1,Y1,DI2J2,Y2,AN,RES)
        PAI=3.14159265
        CON=4.*T/PHI
        D1=DI1J1
        D2=WIDTH-D1
        TERM1=((DI1J1-DI2J2)**2+(Y1-Y2)**2)/CON
        U=TERM1/AN
        CALL EXI(U,EXFN)
        SUM=EXFN

                DO  N=2,400,4
                R2=(N-1)*D1+N*D2+di1j1-di2j2
                TERM2=(R2**2+(y1-y2)**2)/CON
                U=TERM2/AN
                CALL EXI(U,EXFN)
                SUM=SUM-EXFN
                END DO

        DO  N=3,401,4
        R3=N*D1+(N-1)*D2+di1j1-di2j2
        TERM3=(R3**2+(y1-y2)**2)/CON
        U=TERM3/AN
        CALL EXI(U,EXFN)
        SUM=SUM-EXFN
        END DO
                DO  N=4,398,4
                R4=(N-1)*D1+N*D2+di1j1-di2j2
                TERM4=(R4**2+(y1-y2)**2)/CON
                U=TERM4/AN
                CALL EXI(U,EXFN)
                SUM=SUM+EXFN
                END DO
```

```
      DO  N=5,399,4
      R5=N*D1+(N-1)*D2+di1j1-di2j2
      TERM5=(R5**2+(y1-y2)**2)/CON
      U=TERM5/AN
      CALL EXI(U,EXFN)
      SUM=SUM+EXFN
      END DO

      DO  N=1,399,4
      RL1=N*D1+(N-1)*D2+di2j2-di1j1
      TERML1=(RL1**2+(y1-y2)**2)/CON
      U=TERML1/AN
      CALL EXI(U,EXFN)
      SUM=SUM+EXFN
      END DO
              DO  N=2,400,4
              RL2=(N-1)*D1+N*D2+di2j2-di1j1
              TERML2=(RL2**2+(y1-y2)**2)/CON
              U=TERML2/AN
              CALL EXI(U,EXFN)
              SUM=SUM-EXFN
              END DO
      DO  N=3,401,4
      RL3=N*D1+(N-1)*D2+di2j2-di1j1
      TERML3=(RL3**2+(y1-y2)**2)/CON
      U=TERML3/AN
      CALL EXI(U,EXFN)
      SUM=SUM-EXFN
      END DO
              DO  N=4,398,4
              RL4=(N-1)*D1+N*D2+di2j2-di1j1
              TERML4=(RL4**2+(y1-y2)**2)/CON
              U=TERML4/AN
              CALL EXI(U,EXFN)
              SUM=SUM+EXFN
              END DO

      RES=SUM
      RETURN
      END
C
C       CALCULATION OF WELL FUNCTION (EXPONENTIAL INTEGRAL)

C
      SUBROUTINE EXI(U,EXFN)
      X=U
      IF(X-1.0)10,10,20

10    EXFN=-ALOG(X)-0.57721566+0.99999193*X-0.24991055*X**2
     1 +0.05519968*X**3-0.00976004*X**4+0.00107857*X**5
```

```
      RETURN
20    CONTINUE
      IF(X- 80.)50,40,40
50    CONTINUE
      EXFN=((X**4+8.5733287*X**3+18.059017*X**2+8.6347608*X
     1 +0.26777373)/(X**4+9.5733223*X**3+25.632956*X**2+21.099653*X
     2 +3.9584969))/(X*EXP(X))
      RETURN
40    EXFN=0.
      RETURN
      END
```

```
C       ****************************************************
C       PROGRAMME FOR GENERATION OF DISCRETE KERNEL COEFFICIENT
C       *****************************************************
$DebuG
        DIMENSION  NWELL(5),YCW(5),DD1(5,5), DELTA(20,20,60)
        OPEN(1, FILE= 'ASIT5.DAT',STATUS='OLD')
        OPEN(2, FILE=' ASIT5.OUT',STATUS='UNKNOWN')
        OPEN(3, FILE='DISKER.DAT',STATUS='UNKNOWN')
C       ASIT5.FOR IS TO GENERATE DISCRETE KERNEL COEFFICIENT
        PAI=3.14159265
        READ(1,*) WIDTH,T,PHI,RW,NTIME
        WRITE(2,*)WIDTH,T,PHI,RW,NTIME
        READ(1,*)IMAX
C       IMAX=MAXIMUM NUMBER OF LINE
        READ(1,*)(NWELL(I),I=1,IMAX)
C       NWELL(I) =PROPOSED NUMBER OF WELL IN ITH ROW

        DO I=1,IMAX
        READ(1,*)(DD1(I,J),J=1,NWELL(I))
        END DO
        READ(1,*)(YCW(I),I=1,IMAX)
        DO I=1,IMAX
        WRITE(2,*)(DD1(I,J),J=1,NWELL(I))
        END DO

        MMAX=0
        DO I=1,IMAX
        MMAX=MMAX+NWELL(I)
        END DO


        M1=0
        DO I=1,IMAX
        DO J=1,NWELL(I)
        M1=M1+1
        D1=DD1(I,J)
        D2=WIDTH-D1

        FIRST=0.

        DO NN=1,NTIME
        AN=NN
        CALL DISCK(T,PHI,D1,D2,RW,AN,RES)
        DELTA(M1,M1,NN)=(RES-FIRST)/(4.*PAI*T)
        FIRST=RES
        END DO
        END DO
        END DO

        DO I1=1,IMAX
```

```
DO I2=1,IMAX
DO J1=1,NWELL(I1)
DO J2=1,NWELL(I2)

M1=0
DO I=1,(I1-1)
DO J=1,NWELL(I)
M1=M1+1
END DO
END DO

DO J=1,J1
M1=M1+1
END DO

M2=0
DO I=1,(I2-1)
DO J=1,NWELL(I)
M2=M2+1
END DO
END DO

DO J=1,J2
M2=M2+1
END DO

IF(M1.EQ.M2) GO TO 300

DI1J1=DD1(I1,J1)
DI2J2=DD1(I2,J2)
Y1=YCW(I1)
Y2=YCW(I2)

FIRST=0.

DO NN=1,NTIME
AN=NN
CALL DISCK1(T,PHI,WIDTH,DI1J1,Y1,DI2J2,Y2,AN,RES)
```

```
C       ***********************
C       CALCULATION OF RECHARGE
C       ***********************
        DIMENSION NWELL(9),YCW(9),DD1(9,4), DELTAR(36,150),QP(36),
     1  QRD(36),QR(36),QPP(36,150),QRR(150),RECF(150),TIMEF(150)
        DOUBLE PRECISION  DELTAR, QRD,QR,QPP,QRR
        OPEN(1, FILE= 'ASIT7.DAT',STATUS='OLD')
        OPEN(2, FILE=' ASIT7.OUT',STATUS='UNKNOWN')
C       ASIT7.FOR IS TO GENERATE DISCRETE KERNEL COEF. FOR RECHARGE
        PAI=3.14159265
        READ(1,*) WIDTH,T,PHI,NTIME,NPUMP
        WRITE(2,*)WIDTH,T,PHI,NTIME
        READ(1,*)IMAX
C       IMAX=MAXIMUM NUMBER OF LINE
        READ(1,*)(NWELL(I),I=1,IMAX)
C       NWELL(I) =PROPOSED NUMBER OF WELL IN ITH ROW

        DO I=1,IMAX
        READ(1,*)(DD1(I,J),J=1,NWELL(I))
        END DO

        READ(1,*)(YCW(I),I=1,IMAX)

        DO I=1,IMAX
C       WRITE(2,*)(DD1(I,J),J=1,NWELL(I))
        END DO
        TIMEFC=(4.*T/PHI)/(0.1**2)
        MMAX=0
        DO I=1,IMAX
        MMAX=MMAX+NWELL(I)
        END DO

        M1=0
        DO 111 I=1,IMAX
        DO 222 J=1,NWELL(I)

        M1=M1+1
        D1=DD1(I,J)
        D2=WIDTH-D1

        FIRST=0.
        DO 333 NN=1,NTIME
        AN=NN
        CALL DISCKR(T,PHI,D1,D2,AN,RES)
        DELTAR(M1,NN)=RES-FIRST
        FIRST=RES
333     CONTINUE

222     CONTINUE
111     CONTINUE
```

```
      DO M1=1,MMAX
C     write(2,*)M1
C     WRITE(2,*)(DELTAR(M1,NN),NN=1,NTIME)
      END DO
C     WRITE(2,*)'CALCULATION OF RECHARGE ONE WELL OPERATES'
      DO NGAMA=1,NPUMP
      QP(NGAMA)=30240.
      END DO
      DO N=1,NPUMP
      SUM=0.
      DO NGAMA=1,N
      SUM=SUM+QP(NGAMA)*DELTAR(4,N-NGAMA+1)
      END DO
      QRD(N)=SUM
      END DO
C     WRITE(2,*)DELTAR(1,1),DELTAR(1,2),DELTAR(1,3)
      DO N=1,NPUMP
      AN=N
      TERM=(WIDTH-DD1(1,4))/((4.*T/PHI*AN)**0.5)
      X=TERM
      CALL ERF(X,ERFXC)
C     WRITE(2,*)ERFXC
      QR(N)=30240.*ERFXC
      END DO
C     QR(N) THERE IS NO NOFLOW BOUNDARY, ONE WELL OPERATES
      DO N=1,NPUMP
      WRITE(2,567)QRD(N),QR(N)
      END DO
567   FORMAT(2E16.3)
      DO N=1,NPUMP
      DO M=1,MMAX
      QPP(M,N)=30240.
      END DO
      END DO


      DO N=NPUMP+1,NTIME
      DO M=1,MMAX
      QPP(M,N)=0.
      END DO
      END DO

      DO N=1,NTIME
      DO M=4,MMAX,4
      QPP(M,N)=0.
      END DO
      END DO
```

```
      DO N=1,NTIME
      DO M=7,31,4
      QPP(M,N)=0.
      END DO
      END DO


      DO 100 N=1,NTIME
      AN=N
      TIMEF(N)=TIMEFC*AN
      SUMP=0.
      SUMR=0.
C     WRITE(2,*)'N=',N
      DO M=1,MMAX
      SUM=0.
      SUM1=0.
      DO 300 NGAMA=1,N
      SUM=SUM+QPP(M,NGAMA)*DELTAR(M,N-NGAMA+1)
      SUM1=SUM1+QPP(M,NGAMA)
300   CONTINUE

C             write(2,*)'sum=',sum
              SUMR=SUMR+SUM
              SUMP=SUMP+SUM1
              END DO
              QRR(N)=SUMR
              RECF(N)=SUMR/SUMP
100   CONTINUE
      DO N=1,NTIME
C     WRITE(2,568) N,TIMEF(N),QRR(N),RECF(N)
      WRITE(2,569)N,QRR(N),TIMEF(N),RECF(N)
      END DO
568   FORMAT(I5,2F16.2,f10.4)
569   FORMAT(I5,E16.4,E16.4,F10.4)
      SUMP=0.
      DO I=1,MMAX
      DO N=1,NPUMP
      SUMP=SUMP+QPP(I,N)
      END DO
      END DO
      WRITE(2,*)'TOTAL QUANTITY PUMPED=',SUMP
      SUMQR=0.
      DO N=1,NTIME
      SUMQR=SUMQR+QRR(N)
      END DO
      WRITE(2,*)'QUANTITY TAKEN FROM THE RIVER=',SUMQR
      FACTOR=SUMQR/SUMP
      WRITE(2,*)'FACTOR=',FACTOR
      STOP
      END
```

```
         DO 333 NN=1,NTIME
         AN=NN
         CALL DISCKR(T,PHI,D1,D2,AN,RES)
         DELTAR(M1,NN)=RES-FIRST
         FIRST=RES
 333     CONTINUE

 222     CONTINUE
 111     CONTINUE


         DO M1=1,MMAX
 C       write(2,*)M1
 C       WRITE(2,*)(DELTAR(M1,NN),NN=1,NTIME)
         END DO
 C       WRITE(2,*)'CALCULATION OF RECHARGE ONE WELL OPERATES'
         DO NGAMA=1,NPUMP
         QP(NGAMA)=30240.
         END DO
         DO N=1,NPUMP
         SUM=0.
         DO NGAMA=1,N
         SUM=SUM+QP(NGAMA)*DELTAR(4,N-NGAMA+1)
         END DO
         QRD(N)=SUM
         END DO
 C       WRITE(2,*)DELTAR(1,1),DELTAR(1,2),DELTAR(1,3)
         DO N=1,NPUMP
         AN=N
         TERM=(WIDTH-DD1(1,4))/((4.*T/PHI*AN)**0.5)
         X=TERM
         CALL ERF(X,ERFXC)
 C       WRITE(2,*)ERFXC
         QR(N)=30240.*ERFXC
         END DO
 C       QR(N) THERE IS NO NOFLOW BOUNDARY, ONE WELL OPERATES
         DO N=1,NPUMP
         WRITE(2,567)QRD(N),QR(N)
         END DO
 567     FORMAT(2E16.3)
         DO N=1,NPUMP
         DO M=1,MMAX
         QPP(M,N)=30240.
```

```
      T=1.0/(1.0+0.3275911*X1)
      ERFX=1.0-(0.25482959*T-0.28449673*T**2+1.42141374*T**3-1.
     1 45315202*T**4+1.06140542*T**5)*EXP(-X1**2)
      GO TO 3
2     ERFX=1.
3     CONTINUE
      IF(XINDEX)6,7,7
6     ERFX=-ERFX
7     CONTINUE
C     WRITE(2,52)X,ERFX
C52   FORMAT(2F10.5)
      ERFXC=1.-ERFX

      RETURN
      END
```

```
C       ****************************************************************
C       COMPUTER PROGRAMME FOR COMPUTATION OF 20 MOST ECONOMICAL WELLS
C       ****************************************************************
$DebuG
        DIMENSION DRAW(36,0:9),STATL(36), DEPTH(36),TLENGTH(36),
     1  FWELL(36), QP(36,9), DELTA(36,36,9),ALIFT(36), ISTAR(36),
     2 PRECOST(0:36),COSTPL(36),COSTENL(36),COSTTL(36),COSTFL(36),
     3 COSTEXL(36)
        OPEN(1, FILE= 'ASEARF.DAT',STATUS='OLD')
        OPEN(2, FILE= 'ASEARF.OUT',STATUS='UNKNOWN')
        OPEN(3, FILE= 'DISKER.DAT',STATUS='OLD')

        PAI=3.14159265
        READ(1,*)RADP,F
        WRITE(2,*)'RADIUS OF THE PIPE=',RADP
        WRITE(2,*)'FRICTION COEFFICIENT=',F

        READ(1,*)CPUMP,CEXCAV1,CEXCAV2,CENERGY,CTRANS,ALPHA

        WRITE(2,41)
41      FORMAT(2X,'COST OF PUMP ETC',2X,'COST OF EXCAVATION,1&2')
        WRITE(2,42)CPUMP,CEXCAV1,CEXCAV2
42      FORMAT(3F20.4)
        WRITE(2,43)
43      FORMAT(2X,'COST OF ENERGY',2X,'COST OF TRANSPORTATION')
        WRITE(2,42)CENERGY,CTRANS
        WRITE(2,44)
44      FORMAT(2X,'LOCAL APPLICATION OF PUMPED  WATER')
        WRITE(2,42)ALPHA
C       WRITE(2,*)CPUMP,CEXCAV1,CEXCAV2,CENERGY,CTRANS,ALPHA
C       ALPHA=FRACTION OF PUMPED WATER USED LOCALLY
        READ(1,*) QPRATE,NTIME
        WRITE(2,*)'QPRATE=',QPRATE

        READ(1,*)MMAX
C       WRITE(2,*)MMAX
        WRITE(2,*)'STATIC LIFT FROM AQUIFER TO GROUND SURFACE'
        READ(1,*)(STATL(I),I=1,MMAX)
        WRITE(2,*)(STATL(I),I=1,MMAX)
        WRITE(2,*)'DEPTH OF EXCAVATION'
        READ(1,*)(DEPTH(I),I=1,MMAX)
        WRITE(2,*)(DEPTH(I),I=1,MMAX)
        WRITE(2,*)'TRANSPORTATION LENGTH'
        READ(1,*)(TLENGTH(I),I=1,MMAX)
        WRITE(2,*)(TLENGTH(I),I=1,MMAX)
        WRITE(2,*)'LIFT FROM GROUND SURFACE TO CANAL LEVEL'
        READ(1,*)(ALIFT(I),I=1,MMAX)
        WRITE(2,*)(ALIFT(I),I=1,MMAX)

        DO I=1,MMAX
```

```
      DO J=1,MMAX
      READ(3,*) (DELTA(I,J,N),N=1,NTIME)
C     WRITE(2,*) (DELTA(I,J,N),N=1,NTIME)
      END DO
      END DO
      WRITE(2,*)'NUMBER OF YEAR CONSIDERED=30'
      WRITE(2,*)'UNIT TIME PERIOD=ONE WEEK'
      PWF=1/(1.+0.10)**30
      ACG=9.81*(3600.*24.*7.)**2
      DO I=1,36
      ISTAR(I)=100
      END DO

C     ***************************************
C     CALCULATION   WHEN ALL 36 WELL OPERATES
C     ***************************************

      DO I=1,MMAX
      FWELL(I)=1.
      END DO

      DO I=1,MMAX
      DO K=1,NTIME
      QP(I,K)=QPRATE*FWELL(I)
      END DO
      END DO

C
C     COST OF PUMPING
C
C     CALCULATION OF DRAWDOWN
C

      DO J=1,MMAX
      DRAW(J,0)=0.
      END DO

      DO J=1,MMAX
      DO N=1,NTIME
      DRAW(J,N)=0.
      END DO
      END DO

C     I=PUMPING LOCATION
C     J=OBSERVATION LOCATION

      SUMP1=0.
      SUMP11=0.

      DO 500 NCAP= 1, NTIME
```

```
      DO 400 J=1,MMAX
      DO 300 NS=1,NCAP

              SUM3=0.
              DO 5  I=1,MMAX
              SUM2=0.
              DO 4 NGAMA=1,NS
              SUM2=SUM2+QP(I,NGAMA)*DELTA(I,J,NS-NGAMA+1)*FWELL(I)
 4    CONTINUE
      SUM3=SUM3+SUM2
 5    CONTINUE
      DRAW(J,NS)=SUM3
C     ************************************************************
C     CALCULATION OF DRAWDOWN AT ONE LOCATION AT ONE TIME IS OVER
C     ************************************************************
      PLOSS=4*F*TLENGTH(J)*(QP(J,NS)/(PAI*RADP**2))**2/(4.*ACG*RADP)
     1 *FWELL(J)
      AVER=(DRAW(J,NS)+DRAW(J,NS-1))*0.5
      TERM1=ALPHA*(AVER+STATL(J))*QP(J,NS)*CENERGY*FWELL(J)
      SUMP1=SUMP1+TERM1
      TERM11=(1.-ALPHA)*(AVER+STATL(J)+ALIFT(J)+PLOSS)
     1      *QP(J,NS)*CENERGY*FWELL(J)
      SUMP11=SUMP11+TERM11
300   CONTINUE
400   CONTINUE
500   CONTINUE

C     WRITE(2,*)'SUMP1=ANNUAL COST OF PUMPING:LOCAL APPLICATION'
C     WRITE(2,*)'SUMP11=ANNUAL COST OF PUMPING:OUTSIDE APPLICATION'
C     WRITE(2,*)SUMP1,SUMP11
C     SUM1=COST OF PUMPING

      PSUM1=(SUMP1+SUMP11)*PWF

      SUM2=0.
      DO J=1,MMAX
      SUM2=SUM2+(CEXCAV1*DEPTH(J)+CEXCAV2*0.5*DEPTH(J)**2)*FWELL(J)
      END DO

C     WRITE(2,*)'COST OF TUBE WELL BORING'
C     WRITE(2,*)SUM2
C     SUM2=COST OF TUBE WELL BORING

      SUM3=0.
      DO J=1,MMAX
      SUM3=SUM3+CTRANS*TLENGTH(J)*FWELL(J)
      END DO

C     WRITE(2,*)'COST OF TRANSPORTATION'
C     WRITE(2,*)SUM3
```

```
C         SUM3=COST OF TRANSPORTATION

          SUM4=0.
          DO J=1,MMAX
          SUM4=SUM4+CPUMP*FWELL(J)
          END DO

          PWTCOST=PSUM1+SUM2+SUM3+SUM4
          PRECOST(0)=PWTCOST
          WRITE(2,*)'TOTAL COST OF WATER SUPPLY IF 36 WELL OPERATE'
          WRITE(2,*)PWTCOST
          PREVCOST=PWTCOST
C         ****************************************************
C         SYSTAMATIC SEARCH FOR DROPPING THE UNECONOMICAL WELLS
C         ****************************************************
                                           DO M=1,MMAX
                                           FWELL(M)=0.

          DO K=1,NTIME
          DO I=1,MMAX
          QP(I,K)=QPRATE*FWELL(I)
          END DO
          END DO
          DO J=1,MMAX
          DRAW(J,0)=0.
          END DO

          DO J=1,MMAX
          DO N=1,NTIME
          DRAW(J,N)=0.
          END DO
          END DO

          SUM1=0.
          SUM11=0.
          DO NCAP= 1, NTIME
          DO J=1,MMAX
          DO NS=1,NCAP

                  SUM3=0.
                  DO  I=1,MMAX
                  SUM2=0.
                  DO  NGAMA=1,NS
                  SUM2=SUM2+QP(I,NGAMA)*DELTA(I,J,NS-NGAMA+1)*FWELL(I)
                  END DO
                  SUM3=SUM3+SUM2
                  END DO
                  DRAW(J,NS)=SUM3

          PLOSS=4*F*TLENGTH(J)*(QP(J,NS)/(PAI*RADP**2))**2/(4.*ACG*RADP)
```

```
     1  *FWELL(J)
        AVER=(DRAW(J,NS)+DRAW(J,NS-1))*0.5
        TERM1=ALPHA*(AVER+STATL(J))*QP(J,NS)*CENERGY*FWELL(J)
        SUM1=SUM1+TERM1
        TERM11=(1.-ALPHA)*(AVER+STATL(J)+ALIFT(J)+PLOSS)
     1        *QP(J,NS)*CENERGY*FWELL(J)
        SUM11=SUM11+TERM11
        END DO
        END DO
        END DO

        PSUM1=(SUM1+SUM11)*PWF

        COSTENL(M)=PSUM1

        SUM2=0.
        DO J=1,MMAX
        SUM2=SUM2+(CEXCAV1*DEPTH(J)+CEXCAV2*0.5*DEPTH(J)**2)*FWELL(J)
        END DO

        COSTEXL(M)=SUM2

        SUM3=0.
        DO J=1,MMAX
        SUM3=SUM3+CTRANS*TLENGTH(J)*FWELL(J)
        END DO

        COSTTL(M)=SUM3

        SUM4=0.
        DO J=1,MMAX
        SUM4=SUM4+CPUMP*FWELL(J)
        END DO
        COSTPL(M)=SUM4

        PWTCOST=PSUM1+SUM2+SUM3+SUM4
        COSTFL(M)=PWTCOST
        PRECOST(M)=PWTCOST
        IF(PRECOST(M)-PREVCOST) 1,2,2
1       ISTAR(1)=M
        PREVCOST=PRECOST(M)
        COSTMIN=PREVCOST
        FWELL(M)=1.
        GO TO 3
2       FWELL(M)=1.
3       CONTINUE
        END DO

        WRITE(2,*)'COST WHEN WELLS ARE DROPPED IN SEQUENCE '
        WRITE(2,*)(PRECOST(M),M=1,MMAX)
```

```
      WRITE(2,*)'IF ONLY THE MOST COSTLIEST  WELL TO BE  DROPPED'
      WRITE(2,*)'THE WELL TO BE DROPPED=',ISTAR(1)
      WRITE(2,*)'LEAST COST=',COSTMIN
      WRITE(2,*)'COST ANALYSIS'
      WRITE(2,*)'COSTENL=',COSTENL(ISTAR(1))
      WRITE(2,*)'COSTEXL=',COSTEXL(ISTAR(1))
      WRITE(2,*)'COSTPL=',COSTPL(ISTAR(1))
      WRITE(2,*)'COSTTL=',COSTTL(ISTAR(1))
      WRITE(2,*)'TOTAL COST=',COSTFL(ISTAR(1))

      WRITE(2,55)
55    FORMAT(2X,'TOTAL COST',2X,' WELL TO BE DROPPED AT LOCATION')
      WRITE(2,56)
56    FORMAT(2X,'COSTPL',2X,'COSTEXL',2X,'COSTENL',2X,'COSTTL',2X,
     1 'COSTFL')


      DO  333 LLL=2,16

      DO I=1,MMAX
      FWELL(I)=1.
      END DO

      DO 444  M=1,MMAX
      FWELL(M)=0.



              DO LL=1,LLL-1
              FWELL(ISTAR(LL))=0.
              END DO


      DO I=1,MMAX
      DO K=1,NTIME
      QP(I,K)=QPRATE*FWELL(I)
      END DO
      END DO


      DO J=1,MMAX
      DRAW(J,0)=0.
      END DO

      DO J=1,MMAX
      DO N=1,NTIME
      DRAW(J,N)=0.
      END DO
```

```
      END DO

      SUM1=0.
      SUM11=0.
      DO NCAP= 1, NTIME
      DO J=1,MMAX
      DO NS=1,NCAP

              SUM3=0.
              DO  I=1,MMAX
              SUM2=0.
              DO  NGAMA=1,NS
              SUM2=SUM2+QP(I,NGAMA)*DELTA(I,J,NS-NGAMA+1)*FWELL(I)
              END DO
              SUM3=SUM3+SUM2
              END DO
              DRAW(J,NS)=SUM3

      PLOSS=4*F*TLENGTH(J)*(QP(J,NS)/(PAI*RADP**2))**2/(4.*ACG*RADP)
     1 *FWELL(J)
      AVER=(DRAW(J,NS)+DRAW(J,NS-1))*0.5
      TERM1=ALPHA*(AVER+STATL(J))*QP(J,NS)*CENERGY*FWELL(J)
      SUM1=SUM1+TERM1
      TERM11=(1.-ALPHA)*(AVER+STATL(J)+ALIFT(J)+PLOSS)
     1         *QP(J,NS)*CENERGY*FWELL(J)
      SUM11=SUM11+TERM11
      END DO
      END DO
      END DO

      PSUM1=(SUM1+SUM11)*PWF

      COSTENL(M)=PSUM1

      SUM2=0.
      DO J=1,MMAX
      SUM2=SUM2+(CEXCAV1*DEPTH(J)+CEXCAV2*0.5*DEPTH(J)**2)*FWELL(J)
      END DO

      COSTEXL(M)=SUM2

      SUM3=0.
      DO J=1,MMAX
      SUM3=SUM3+CTRANS*TLENGTH(J)*FWELL(J)
      END DO
```

```
      COSTTL(M)  =SUM3

      SUM4=0.
      DO J=1,MMAX
      SUM4=SUM4+CPUMP*FWELL(J)
      END DO

      COSTPL(M)=SUM4

      PWTCOST=PSUM1+SUM2+SUM3+SUM4
      COSTFL(M)=PWTCOST
      PRECOST(M)=PWTCOST
      IF(PRECOST(M)-PREVCOST) 11,22,22
11    ISTAR(LLL)=M
      PREVCOST=PRECOST(M)
      FWELL(M)=1.
      GO TO 33
22    FWELL(M)=1.
33    CONTINUE

444   CONTINUE
      WRITE(2,111)PREVCOST,ISTAR(LLL)
      WRITE(2,112)COSTPL(ISTAR(LLL)),COSTEXL(ISTAR(LLL)),
     1 COSTENL(ISTAR(LLL)), COSTTL(ISTAR(LLL)),COSTFL(ISTAR(LLL))
111   FORMAT(5X,E16.6,17X,I5)
112   FORMAT(5E15.5)
333   CONTINUE

      STOP
      END
```

```
C         *******************************************************
C         ASIT5.DAT FOR CALCILATION OF DISCRETE KERNEL COEFFICIENT
C         *******************************************************
          2600.    35000.   0.20     0.1      9
          9
          4        4        4        4        4        4        4        4
4
          500.     700.     900.     1100.
          500.     700.     900.     1100.
          500.     700.     900.     1100.
          500.     700.     900.     1100.
          500.     700.     900.     1100.
          500.     700.     900.     1100.
          500.     700.     900.     1100.
          500.     700.     900.     1100.
          500.     700.     900.     1100.
          0.       200.     400.     600.     800.     1000.    1200.    1400.
1600.
```

```
C       ******************************************
C       DATA FOR RECHARGE AND FOR DRAWDOWN CALCULATION
C       ******************************************
        2600.   35000.  0.20    150     9
        9
        4       4       4       4       4       4       4       4
4
        500.    700.    900.    1100.
        500.    700.    900.    1100.
        500.    700.    900.    1100.
        500.    700.    900.    1100.
        500.    700.    900.    1100.
        500.    700.    900.    1100.
        500.    700.    900.    1100.
        500.    700.    900.    1100.
        500.    700.    900.    1100.
        0.      200.    400.    600.    800.    1000.   1200.   1400.
1600.
```

Asearf.dat

```
C         ******************************************************
C         INPUT DATAS FOR COMPUTATION OF 20 MOST ECONOMICAL WELLS
C         ******************************************************
          0.20    0.006
          323200. 100.      10.0     0.0163  380.     0.25
          30240.  9
          36

          5.    4.80  4.60  4.40
          5.    4.80  4.60  4.40
          5.    4.80  4.60  4.40
          5.    4.80  4.60  4.40
          5.    4.80  4.60  4.40
          5.    4.80  4.60  4.40
          5.    4.80  4.60  4.40
          5.    4.80  4.60  4.40
          5.    4.80  4.60  4.40
          60.   60.   60.   60.
          60.   60.   60.   60.
          60.   60.   60.   60.
          60.   60.   60.   60.
          60.   60.   60.   60.
          60.   60.   60.   60.
          60.   60.   60.   60.
          60.   60.   60.   60.
          60.   60.   60.   60.
          100.     300.     500.     700.
          100.     300.     500.     700.
          100.     300.     500.     700.
          100.     300.     500.     700.
          100.     300.     500.     700.
          100.     300.     500.     700.
          100.     300.     500.     700.
          100.     300.     500.     700.
          100.     300.     500.     700.

          5.0      5.20     5.40     5.60
          5.0      5.20     5.40     5.60
          5.0      5.20     5.40     5.60
          5.0      5.20     5.40     5.60
          5.0      5.20     5.40     5.60
          5.0      5.20     5.40     5.60
          5.0      5.20     5.40     5.60
          5.0      5.20     5.40     5.60
          5.0      5.20     5.40     5.60
```