STUDIES ON CONJUNCTIVE USE OF SURFACE AND GROUND WATER RESOURCES THE GHATAPRABHA IRRIGATION PROJECT, KARNATAKA BY CENTRAL GROUND WATER BOARD

Central Ground Water Board
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Introduction : -

Conjunctive use implies the planned and coordinated harnessing of ground and surface-water resources so as to achieve optimal utilisation of total water resources.

The ground water may be used to supplement surface-water supplies to reduce peak demands for irrigation and other uses, or to meet deficits in years of low rainfall. On the other hand, surplus surface water may be used in over-draft areas to increase the ground-water storage by artificial recharge. Surface water, ground water or both, depending on the surplus available, can be diverted from areas plentiful to water-deficit areas. In recent years, increasing canal and stream flows from augmentation wells is gaining currency.

Better understanding of irrigation methods, irrigation intervals, crop requirements salinization, etc. is of much importance to successful implementation of conjunctive use project.

Irrigation – Concepts & Understanding :-

Irrigation is the artificial supply of water for agriculture, the controlled distribution and the removal of excess water to natural drains, after it has been put to optimum use.

A key element in the definition of irrigation is that the facilities for irrigation are *man – made, man – managed and man – used* with the aim to divert water from a source and to bring it to fields via a network of irrigation canals or pipes, and to evacuate excess water to outside the production unit via a drainage network to ensure or improve agricultural production.

Of the total land area cultivated in the world only 20% is irrigated, which produces more than 40% of the world's agricultural output. The traditional method of surface (gravity) flooding is still the most widely used irrigation method. Water is spread across the land using basin, border or furrow methods. More than 95% of all irrigation is done this way.

Irrigation practices are methods to spread water from a conveyance network of pipes or channels as uniformly as possible over the plot and in the soil in order to supply the crops. The irrigation water infiltrates from the top soil into the soil reservoir to wet the usable root zone of the crops.
The methods for wetting the root zone are, to:

Surface irrigation	:	run the water over the surface so that it infiltrates into the soil
Sub-surface irrigation	:	pass water into the soil at depth until capillary action raises
Overhead irrigation	:	water sprayed over the field in such a way that it damages neither crop nor soil.

The required amount of *timing of irrigation* supplies is governed by climate, crops (type and growth stage), and the soil and soil moisture characteristics.

The *climate* governs the rate of evaporation of the water. The type of *crops* determine the use of water by the crops. One of the factors that determine the frequency of irrigation supplies is the capacity of the *soil* to retain water and make it available to the crops.

Other important aspects that have to be taken into account in delivery of water for irrigation is the efficiency of the method of field irrigation (surface, sprinkling or drip systems) and the supply of water form the source to the fields.

Depths to which mature plants will extract available moisture from deep, fertile and well – drained soils from Root depth is given below

Crop	Depth (cm)	Crop	Depth (cm)
Alfala	180	Sweet potato	120
Orchards	180	Carrots	90
Grapes	180	Peas	90
Sorghums, grains	180	Pepper	90
Tomatoes	180	Corn	90
Maize	150	Beets	90
Melons	150	Beans	60
Small grains	150	Cabbage	60
Beans	120	Pasture	60
Citrus	120	Potatoes	60
Cotton	120	Spinach	60
Sugar beets	120	Onions	30

The Irrigation Interval

The purpose of water for crops is to bring back the moisture content in the root zone up to field capacity after the readily available moisture (RAM) has been used. The period in days required for the crop to consume that amount of water is called the irrigation interval.

The maximum allowable irrigation interval (T in days) can be calculated as follows:

$$T < (RAM / ET_c)$$

Where:

- RAM is the readily available moisture in mm
- T is the irrigation interval in days
- ET_c is the crop evapotranspiration in mm/day

IRRIGATION METHODS

There are some basic methods of irrigation, most of which have several variations. The basic components and operation for each are:

(i) **Basin**

A level area of any size or shape bounded by borders and without any depression, which cannot be readily drained. The borders retain all the applied water for a sufficient time to obtain a relatively uniform depth of infiltration over the area and then the remaining water is drained off the surface and used to irrigate an adjacent basin. Water is lost mainly by deep percolation and evaporation.(Fig.1)

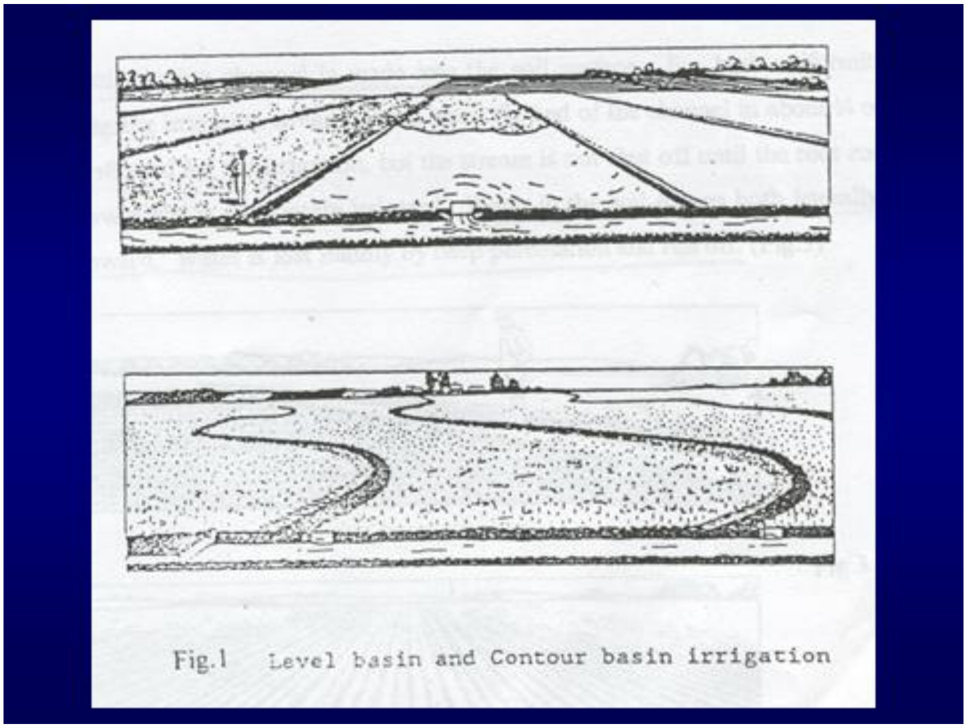


Fig.1 Level basin and Contour basin irrigation

(ii) Border – strip

A slopping area, usually rectangular, bounded by borders that guide a water layer as it flows down the bordered strip. There should be little or no slope at right angles to the flow direction. The inflow is usually cut off when the advance flow has moved 0.6 to 0.9 of the distance down the strip. Water is lost mainly by deep percolation and runoff. (Fig.2)

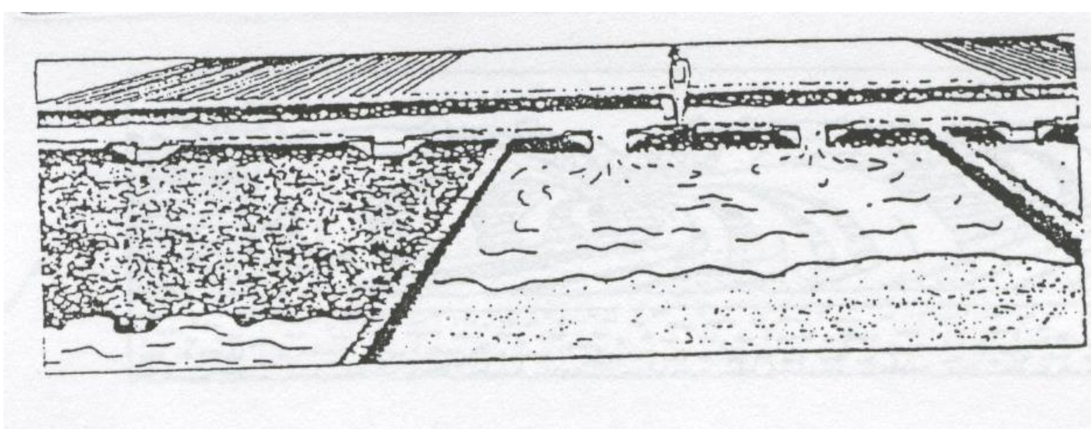


Fig.2

Figure 2

(iii) Furrow or corrugation

A small sloping channel is made into the soil surface. For high uniformity or wetting the irrigation stream should reach the end of the channel in about ¼ of the time allotted for the irrigation, but the stream is not shut off until the root zone at the lower end is adequately irrigated. Water in the soil moves both laterally and downward. Water is lost mainly by deep percolation and run off. (Fig.3)

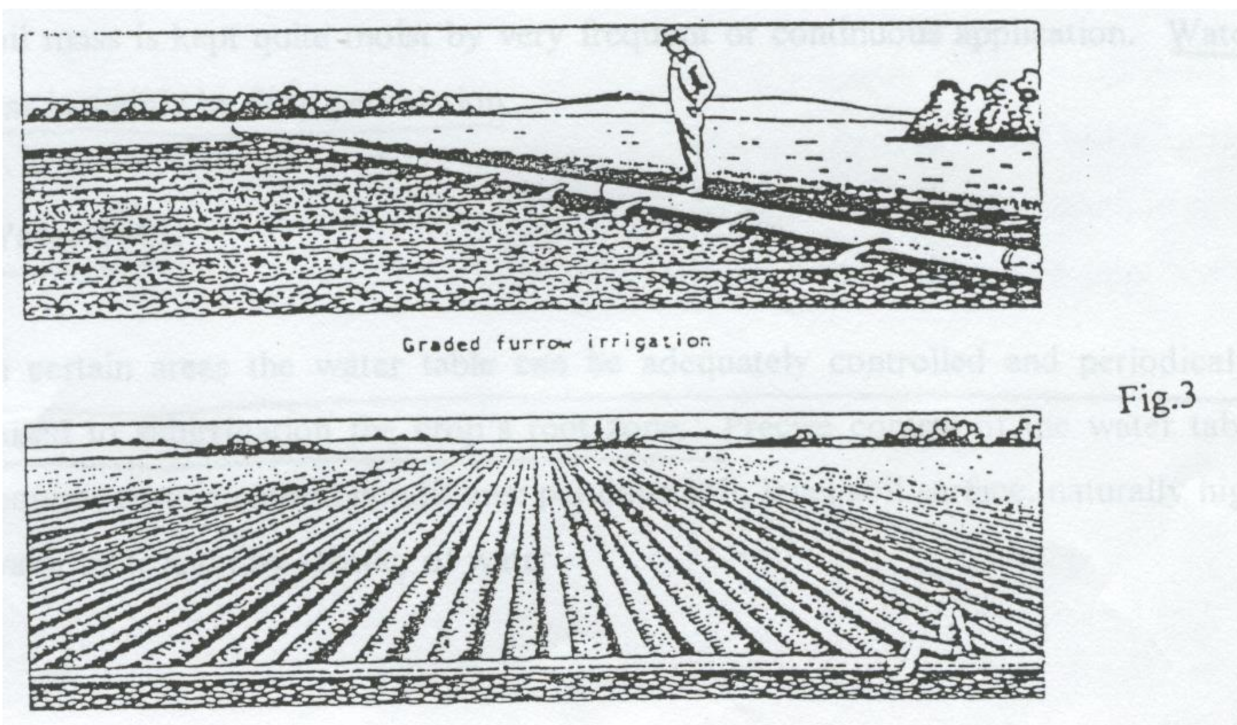


Figure 3

(iv) **Sprinkler**

Any device spraying water over the soil surface. Water discharged from a sprinkler into the air should infiltrate the soil where it fails, but it should not saturate the soil surface. For high uniformity of wetting, the spray patterns from adjacent sprinkler must be properly overlapped. Evaporation, wind drift and deep percolation are main causes of loss of water. (Fig.4)

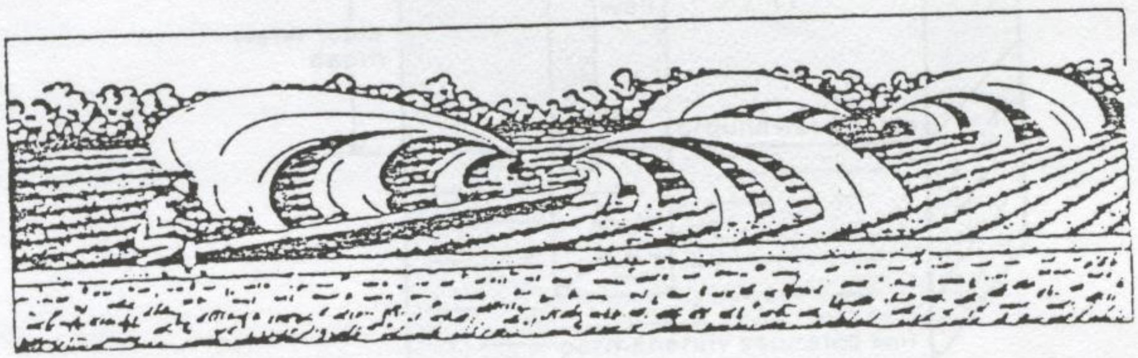


Figure 4.

(v) **Trickle (or drip) emitter**

A device used in trickle (or drip) irrigation for discharging water at very low rates (less than 10-15 liters per hour through small holes in tubes, placed near the soil surface. Water moves through soil both sideways and downward away from the point of application to form a "bulb" of wet soil. Typically, only a portion of the soil mass is kept quite moist by very frequent or continuous application. Water loss is mainly be deep percolation.

(vi) Water Table

In certain areas the water table can be adequately controlled and periodically raised to sub irrigation the crop's root zone. Precise control of the water table requires certain natural conditions: pervious soil, level soil surface, naturally high water table and low salinity of water.

Groundwater Table

Part of the water applied to the soil surface drains below the root zone and feed deeper soil layers which are permanently saturated. The top of the saturated layer is called groundwater table. (Fig.5)

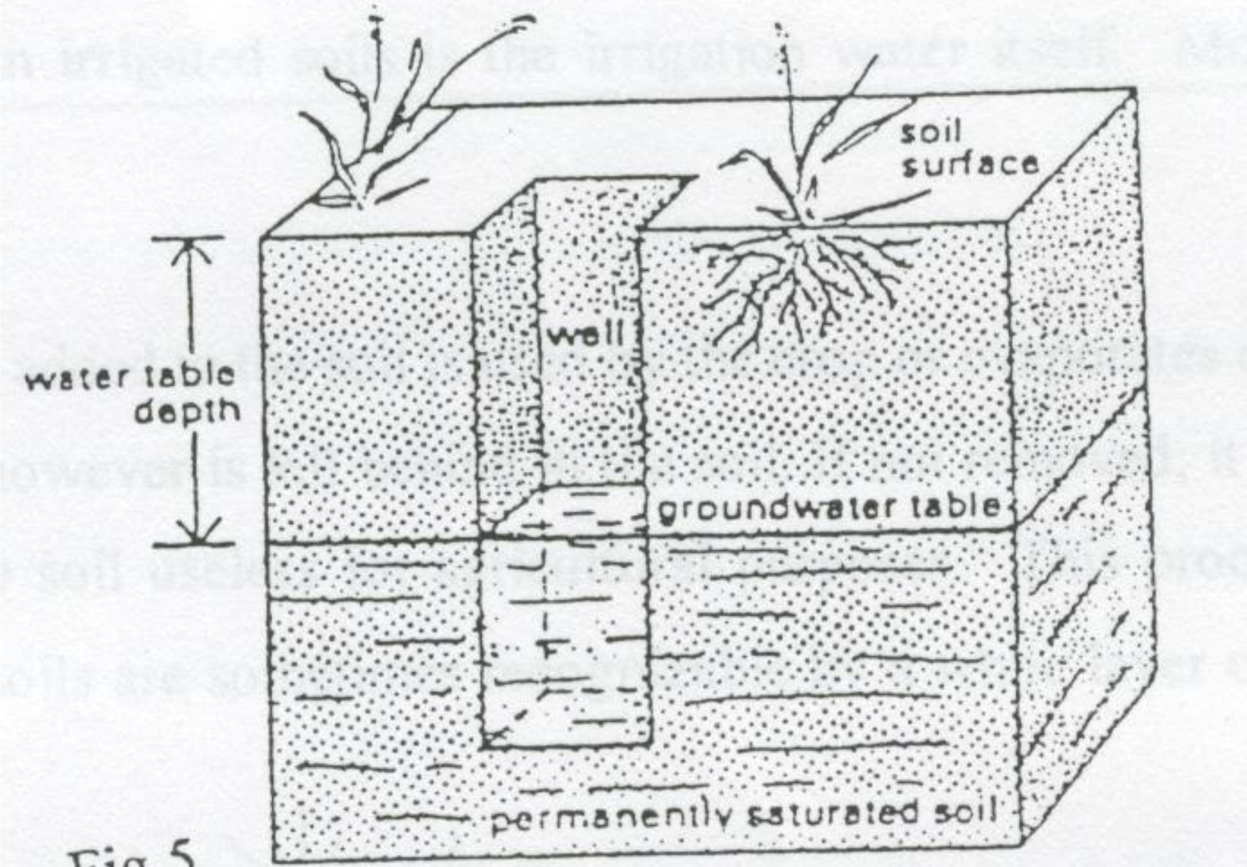


Fig.5

The depth of the ground water table varies from place to place mainly due to topography and from time to time. Following heavy rainfall or irrigation, the groundwater table rises.

It may even reach peak levels and saturate the root zone. If prolonged, this situation can be disastrous for the crops which cannot resist " wet feet" for a long period. The groundwater table lowers when water is extracted from the ground water reservoir because of evaporation, uptake by the plants, recovery by human interference via pumps, or by natural ground water flows.

Water can also move upwards because of the sucking capacity of the small pores or capillers rise. In fine textured soils (clay), the upward movement of water is slow because of the great resistance, but it covers a long distance. On the other hand, in coarse textured soil (sand) the upward movement of water is fast but covers only a short distance.

Salinity Control and Leaching Requirement

A soil may be rich in salts because the parent rock from which it was formed contains salts. Seawater is another source of salts in low lying areas along the coast. A very common source of salts in irrigated soils is the irrigation water itself. Most irrigation waters contain salts.

After irrigation, the water added to the soil is used by the crop or evaporates directly from the moist soil. The salt, however is left behind in the soil. If not removed, it accumulates in the soil and makes the soil useless for agricultural purposes. This process is called salinization. Very salty soils are sometimes recognizable by a white layer or dry salt on the soil surface. (Fig.6)

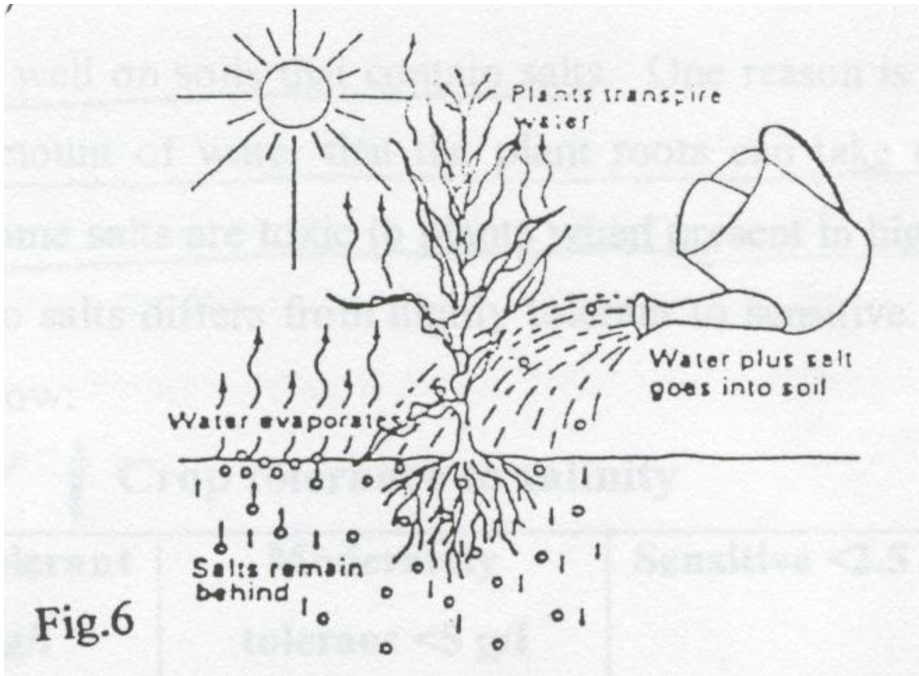
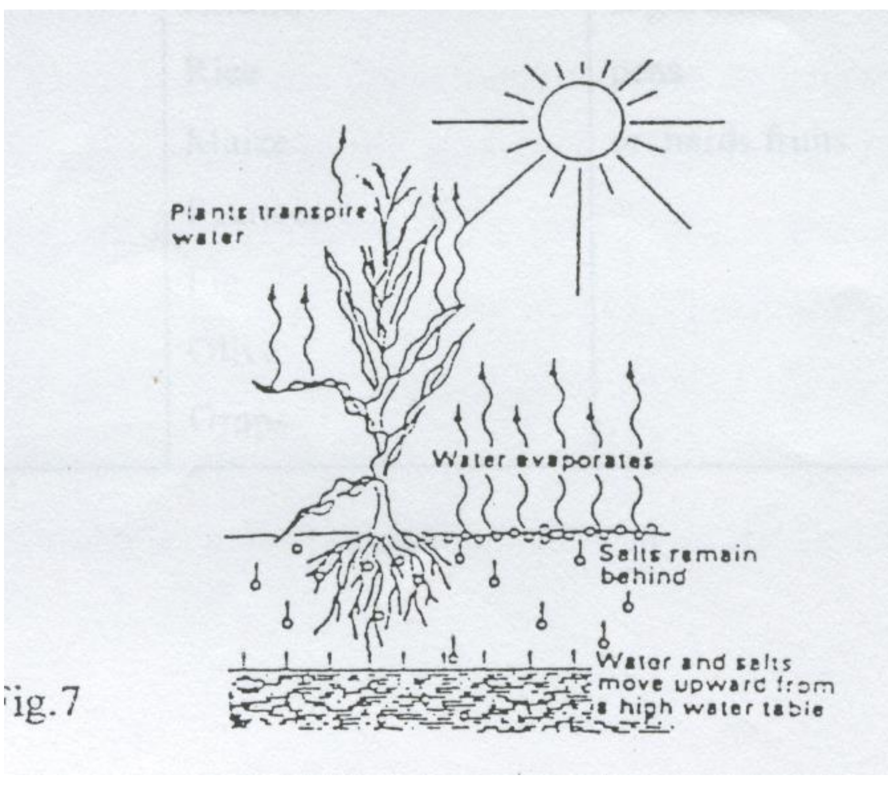


Fig.6

Salty groundwater may also contribute to salinization. When the water table rises (e.g. following irrigation in the absence of proper drainage), the salty groundwater may reach the upper soil layers and, thus, supply salts to the root zone. (Fig.7)



ig.7

Fig.7

Soils that contain a harmful amount of salt are often referred to as salty or saline soils. Soil or water that has a high content of salt is said to have a high salinity. Water salinity is the amount of salt contained in the water and may be expressed in grams of salt per litre of water (g/l) or in milligrams per litre (which is the same as parts per million p.p.m.). However, the salinity of water and soils is easily measured by means of an electrical device. It is then expressed in terms of electrical conductivity: millimhos/cm. A salt concentration of 1 gram per litre is about 1.5 millimhos per cm.

The salt concentration in the water extracted from a saturated soil (called saturation extract) defines the salinity of the soil. If this water contains less than 3 g/l the soil is said to be non saline. If it exceeds 12 g/l, then the soil is said to be highly saline.

Most crops do not grow well on soils that contain salts. One reason is that salt causes a reduction in rate and amount of water that the plant roots can take up from the soil. Another reason is that some salts are toxic to plants when present in high concentrations. The tolerance of crops to salts differs from highly tolerant to sensitive. Some examples are given in the table below:

Crop tolerance to salinity

Highly tolerant < 10 g/l	**Moderately tolerant <5 g/l**	**Sensitive <2.5 g/l**
date palm	Wheat	red clover
barely	Tomato	peas
sugar beet	Oats	beans
cotton	Alfalfa	sugarcane
asparagus	Rice	peas
spinach	Maize	orchards fruits

	Potatoes Fig Olive Grapes	

Improvement of saline soils implies the reduction of the salt concentration of the soil to a level that is not harmful to the crops. To that end more water is applied to the field than is required for crop growth. This additional water infiltrates into the soil and percolates through the root zone. During percolation, it takes up part of the salts in the soil and transports these to deeper soil layers. In fact the water washes the salts out of the root zone. This washing is called leaching.

The additional water required for leaching must be removed from the root zone by means of a subsurface drainage system. If not removed, it could cause a rise of the groundwater table which would bring the salts back in the root zone. Thus, improvement of saline soils includes essentially leaching and sub-surface drainage.

To prevent salinization of the topsoil, salts have to be washed down which is known as leaching. The leaching requirement is the ratio between the drainable excess and the quantity of irrigation water applied to keep the salt content in the root zone below the crop tolerance level. The tolerance level is found from relations between crop yield and the salt concentration of the saturation extract.

Back Ground to Studies

Conjunctive use

After independence, a number of irrigation projects were launched under 5 year Plans (commencing form 1950-'51), a steady growth can be seen in irrigation under various major, medium and minor irrigation schemes from 22.60 million Ha. (1950-'51) to 76.52 million Ha. By the end of 7th Five Year Plan (1985-'90). The estimated ultimate irrigation potential of the country is of the order of 113.50 million Ha, out of which a potential of about 83.01 million Ha. has already been created till the end of 1992-'93. Nearly 60 percent of the available cultivable land of 180 million Ha. of the country is proposed to be brought under irrigation since the launching of the first Five Year Plan. In some of the major projects, irrigation is in vogue for more than two-three decades and the ayacuts have been stabilised with the farmers enjoying all the benefits including access to uncontrolled use of surface water through the canals in the case of those in the upper and middle reaches of the projects. With the availability of surface water almost throughout the year, farmers found it rarely necessary to use the ground water with the result that ground water utilisation became almost nil. The net result was a rise in ground water levels, gradually building up the water table, giving rise to water logging conditions.

This water level rise result in the restricted circulation of air, decline in the levels of oxygen and increase in the content of carbon dioxide in the root zone of plants, thereby affecting the productivity of crops. In addition, water logging also results in salinity of the soils by way of direct evaporation of water from the soil and the accumulation of salt in the top soil ground surface, rendering it infertile. Thus, the land gradually becomes useless in course of time, thereby affecting the agricultural production of the country.

Conjunctive use deals with the utilisation of saline ground-water resources, by mixing them in suitable pro-portions with fresh water to bring down the salinity of the mixture within usable limits. The advantage of ground water over the surface water reservoirs are

1. Surface reservoirs are lost for ever once they are silted up. While under-ground storage spaces remain practically unaffected by development.
2. Yield from ground-water sources is more dependable.
3. The physical and chemical quality of ground water is more uniform than that of surface water.
4. Subsurface storage is possible, without loss of water-spread area of surface reservoirs.
5. Ground water can be put to use where and when it is required, without risk of seepage and evaporation losses during storage and transmission

6. A ground-water-development scheme has a short gestation period
7. There is no ecological hazard as in surface projects
8. As large-scale supplies for industries and urban areas are generally derived form multicentred extraction points, in times of war they are less liable to complete destruction than dams.
9. The cost of storing water underground is less than the cost of surface storage works.

Notwithstanding the many advantages mentioned above, there are some constraints which restrict the exploitation of ground water and necessitate creation of surface reservoirs. These are:

1. Not all areas are bountiful in ground-water resources and such areas have to depend on surface water.
2. Saline ground-water areas need surface water.
3. Wells are liable to interfere adversely when large supplies are to be met, and create land subsidence on excessive withdrawals.
4. Development of ground water needs energy. While surface water is available by gravity flow.
5. It is physically not possible to divert underground all the surface water, even if the operation were profitable
6. Surface-water reservoirs serve multiple uses such as flood control, power generation, navigation, etc.
7. Surface water is generally low in mineralisation

The beneficial effects of conjunctive use in canal commands are:

1. Use of ground water helps reduce peak demands for irrigation, size of canals, and hence construction costs.
2. Supplemental supplies from ground water ensure proper irrigation scheduling, raising multiple crops, and early sowing, even if rainfall is delayed.

3. Increased water resources ensure supply to tail-end areas and areas of higher elevation.

4. Ground-water exploitation lowers the water table and reduces danger of water logging and consequent wastage of water for leaching of soils. Saving is effected due to reduction in size of drainage network, as a result of reduced subsurface outflow.

5. Surface and subsurface outflows are minimised, causing reduction in peak runoff and flood discharge.

6. When conjunctive use is integrated with an artificial recharge project, need for lining canals is reduced as seepage from canals recharges ground water

7. During period of peak water demand, irrigation requirements can be met by surface – water sources so the power saved can be diverted to other sectors.

However, there are some constraints and deterrents in implementing conjunctive use programmes:

1. Possibility of deterioration in ground-water quality due to influx of salts leached down from the soil, which may be quite marked as a result of recycling within cones of depressions and/or upward and lateral migration of saline water into fresh – water zones in response to pumping.
2. Increased power consumption to sustain pumpage from wells, possible dislocation of ground water supplies due to power failure in critical periods, and decrease in pump efficiencies due to large fluctuations in water levels.
3. Operation, supervision and control of conjunctive – use and artificial – recharge projects are more complex.
4. Administrative difficulties in evolving acceptable and equitable water rates, providing motivation and incentives to accept ground – water use when surface water is available

Studies on Conjunctive use of surface and ground water resources the Ghataprabha Irrigation Project, Karnataka by Central Ground Water Board

A study conducted by the Command Area Division of the Ministry of Water Resources, Government of India in 37 canal command areas in the country has revealed that out of about 97 lakh Ha. under irrigation, an area of about 7.18 lakh Ha. has been affected by salinity and an area of 7.43 lakh ha. by water logging. It has also been estimated that a loss of nearly 10 to 30 percent in agriculture production occurs when the water table rises within 3.0 m. From the land surface.

In order to arrest further deterioration of land as well as to reduce water logging and to arrest rising water table conditions, it was thought to examine the possibility of conjunctive use of surface and ground water wherever feasible as one of the remedial measures. In 1990, Ministry of Water Resources entrusted the Central Ground Water Board to take up pilot project studies in six canal commands of the country covering various hydrogeological environs, namely (i) Sarda Sahayak Command, IU.P., (ii) Indira Gandhi Nahar Pariyojana State I, Rajasthan, (iii) Mahi-Kadana Canal Command, Gujarath, (iv) Hirakud Command, Orrissa, (v) Tungabhadra Command, Andhra Pradesh and Karnataka and (vi) Ghataprabha Commoand, Karnataka. The parts of Belgaum and Bijapur District of Karnataka

Objectives of the studies :-

The projects studies were taken up with the aim of achieving the following objectives :

- Evaluation of the hydrogeological situation and quantification of the different components of the water balance in the canal command area.
- Identify critical areas from the point of view of water logging and soil salinity in the command area.

- To evolve a suitable plan for controlling the problem of rising water table in the area by adopting suitable techniques of conjunctive use of surface – and ground water and proper drainage.
- Prepare sector wise plans for development of ground water resources in conjunction with surface water.
- Work out cost estimates for the total command area under ground water development plans and calculate the benefit – cost ratio.

Study methods and Work Plan adopted :

The objectives were achieved by a set of following activities

Collection and processing

- Hydrologic, Hydrometeorologic and Hydrogeologic data
- Establishment of Key Observation wells in the study area for monitoring of water levels and it’s chemical quality
- Remote Sensing and Satellite Imagery studies for demarcation of potential areas for ground water development, waterlogged and soil salinity areas.
- Construction of exploratory wells and piezometers/ shallow water table wells to fill data gaps for modelling.

Analysis and Interpretation

- Hydrogeological data to decipher aquifer geometry and estimate the ground water potential and it’s availability in space and time.
- Surface water and canal flow data and estimate surface water availability in space and time.
- Demand of water for irrigation, drinking and other uses in space and time and project these demands to the year 2025 A.D. as per the present growth rate.

- To match demand with availability and to evolve a planning strategy for the development of ground water command wise.
- Develop a simulation model for the area to study the ground water development programmes.
- Refine the ground water development strategy in the light of simulation studies to evolve a plan for optimum development.
- Design different ground water structures for optimum development as per models results.
- Suggest alternate canal operation strategies
- Suggest ways and means for the operationalisation of the conjunctive use plan
- Work out the cost-benefit analysis of the development plan.

LOCATION AND AREAL EXTENT OF TEH STUDY AREA :

The study area (Fig.8) is bounded by the Krishna River in the north, Maharashtra State to the west, the confluence of Krishna River and Malaprabha River in the east and the water divide or the basin boundary between Ghataprabbha and Malaprabha Rivers in the south. The total area taken up for the studies is 10370 sq.km. The existing Canal Command Area is served by Ghataprabha Left Bank Canal (GLBC) and six branch canals. The net command area is 1,61,871 ha.. The canal system provides irrigation to parts of four taluks in Belgaum and three taluks of Bijapur districts. The proposed Right Bank canal will irrigate 1,55,559 ha. covering parts of six taluks in Belgaum and four taluks in Bijapur districts.

Ghataprabha River, which is a tributary of Krishna River and is one of the important rivers of Karnataka, the river has been harnessed for its irrigation potential by constructing a dam at Hidkal in Hukeri taluk. The average annual rainfall in the area is about 650 mm.

The *major crops* grown in the area are Paddy, surgarcane, Ragi, Bajra, Jowar, Maize, Pulses, Groundnut, Cotton and Oilseeds. In the canal command area, irrigation water is generally given through canals by june end or July first week. The cropping pattern followed in the command is 40% Khariff, 40% rabi and 20% bi-seasonal. The crops grown during kharifff are paddy, sugarcane, cotton, jowar, maize, groundnut, sunflower and pulses. During rabi, the major crops grown are sugarcane, cotton, Jowar and pulses are the major bi-seasonal crops.

Rise in Water Levels

The following figure 9 indicates, the water levels rise immediately after the release of canal water, almost runs flat during the period of canal operations and thereafter there is a fall especially in the canal command. In middle reaches of the canal the water levels reach a peak by November and decline starts by April when the canal water stops, while the peak is reached by January and decline starts by March 94 end. In the tail end, receives insufficient water from canals. It is possible that due to insufficient canal water for irrigation, the wells are pumped during the period which results in decline of the water levels.

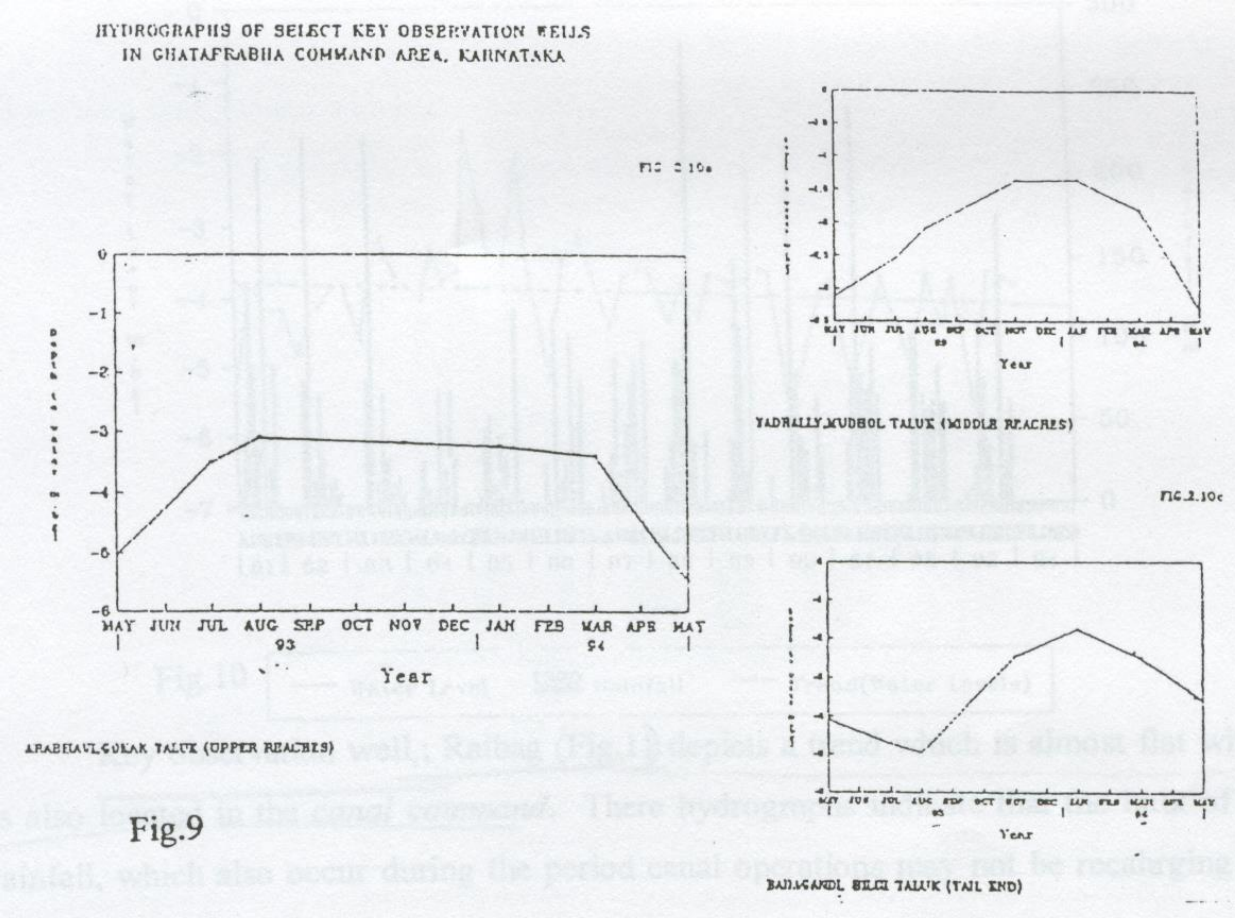


Figure 9

2.2.6. WATER LOGGING :

Water logging conditions occur due to shallow water level conditions which is due to poor drainage or due to excess irrigation. An area is considered as waterlogged when the water level is within 2 m bgl. In the project area, water is generally released in June/July and waterlogging conditions set in by August which increases progressively over the area by November month. During the year 1993 – 94` canal water was released in the first week of July 1993, waterlogging conditions were observed over an area of 143 sq.kms which increased to 344 sq.km by August 1993 and to 580 sq.kms November 1993. This suggests that the buildup of the water levels in Bijapur part is gradual and waterlogging conditions are first seen in part of Belgaum district which forms the head and middle reaches of the canals. The waterlogged areas are delineated.

Key observation well; Arabhavi (Fig.10) shows that the trend is almost flat with a very little fall in the slope and the well is situated in the *canal command*.

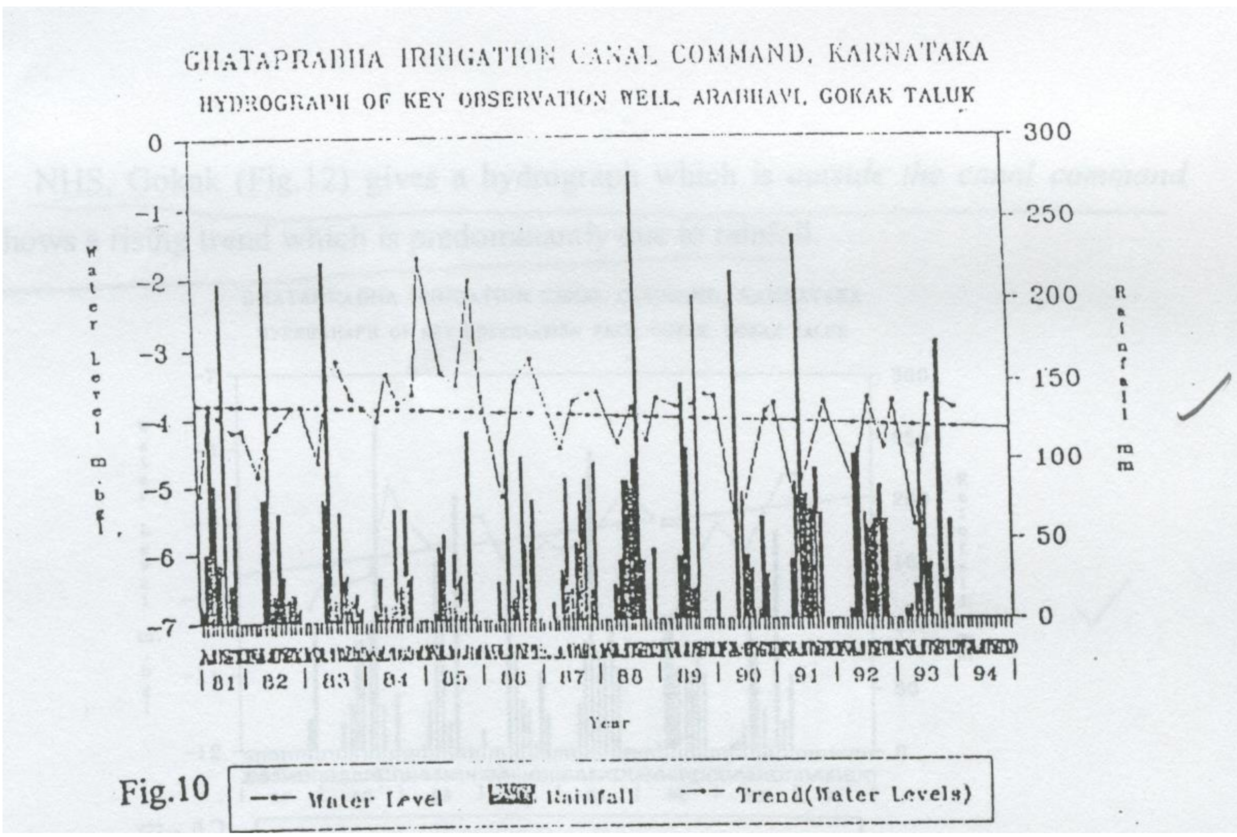


Fig.10

Key observation well,; Raibag (Fig.11 depicts a trend which is almost flat which is also located in the *canal command*. There hydrographs indicate that the bulk of the rainfall, which also occur during the period canal operations may not be recharging the ground water.

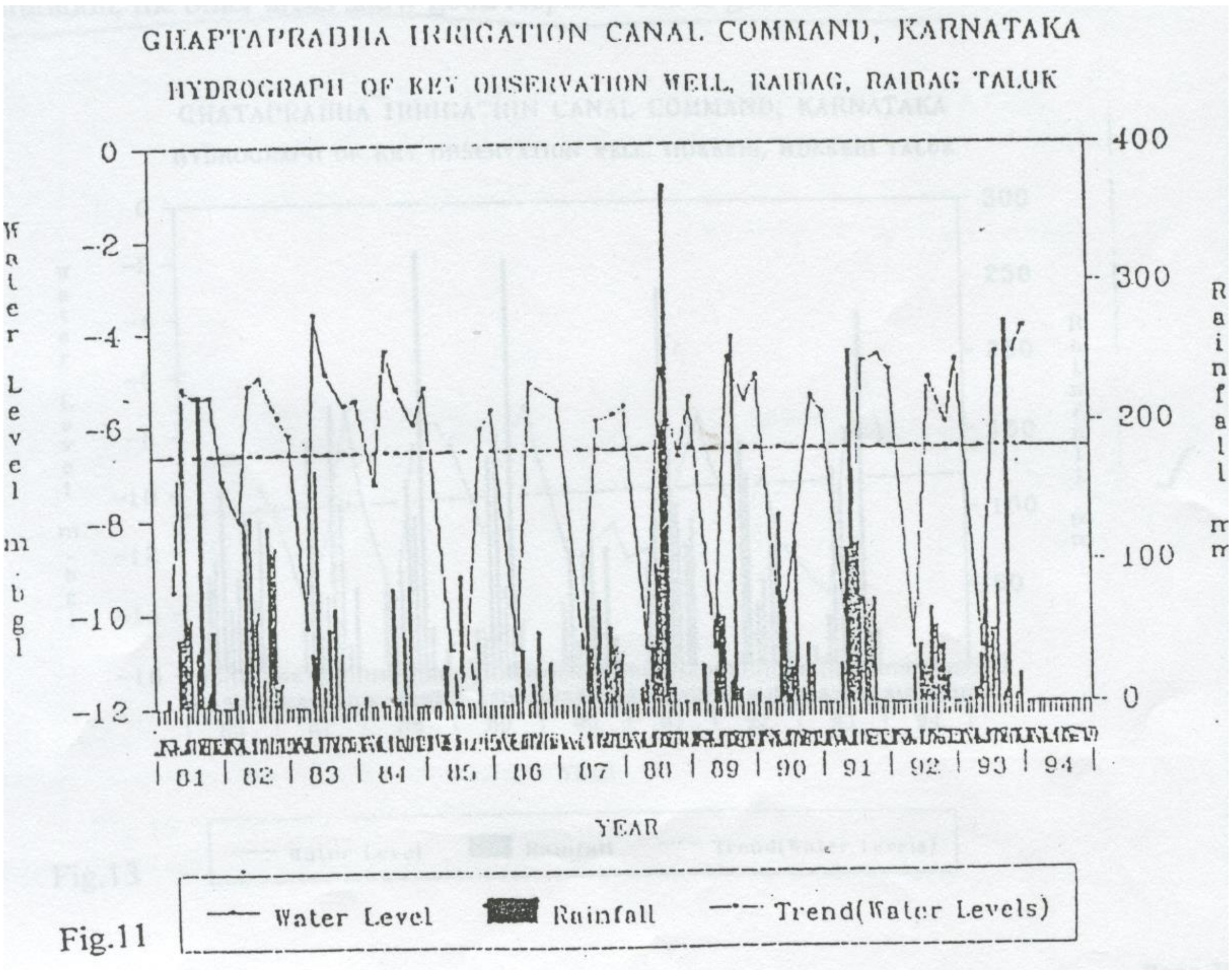


Fig.11

NHS, Gokak (Fig.12) gives a hydrograph which is *outside the canal command* and shows a rising trend which is predominantly due to rainfall.

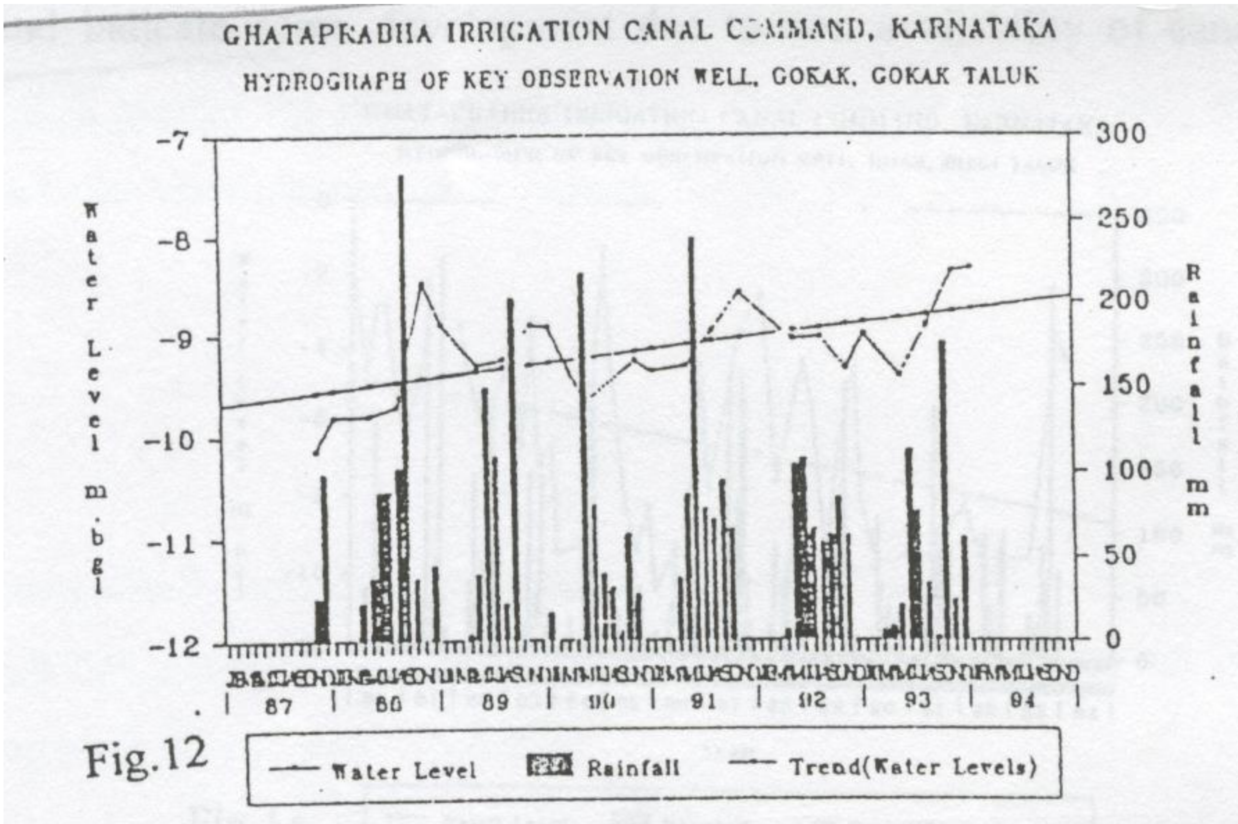


Fig.12

Another typical hydrograph, which shows a rising trend is that of Hukkeri (Fig.13) which again is due to rainfall. While in the canal command some sort of dynamic balance has been reached due to waterlogging conditions observed annually because of saturation, the other areas show good response due to good rainfall.

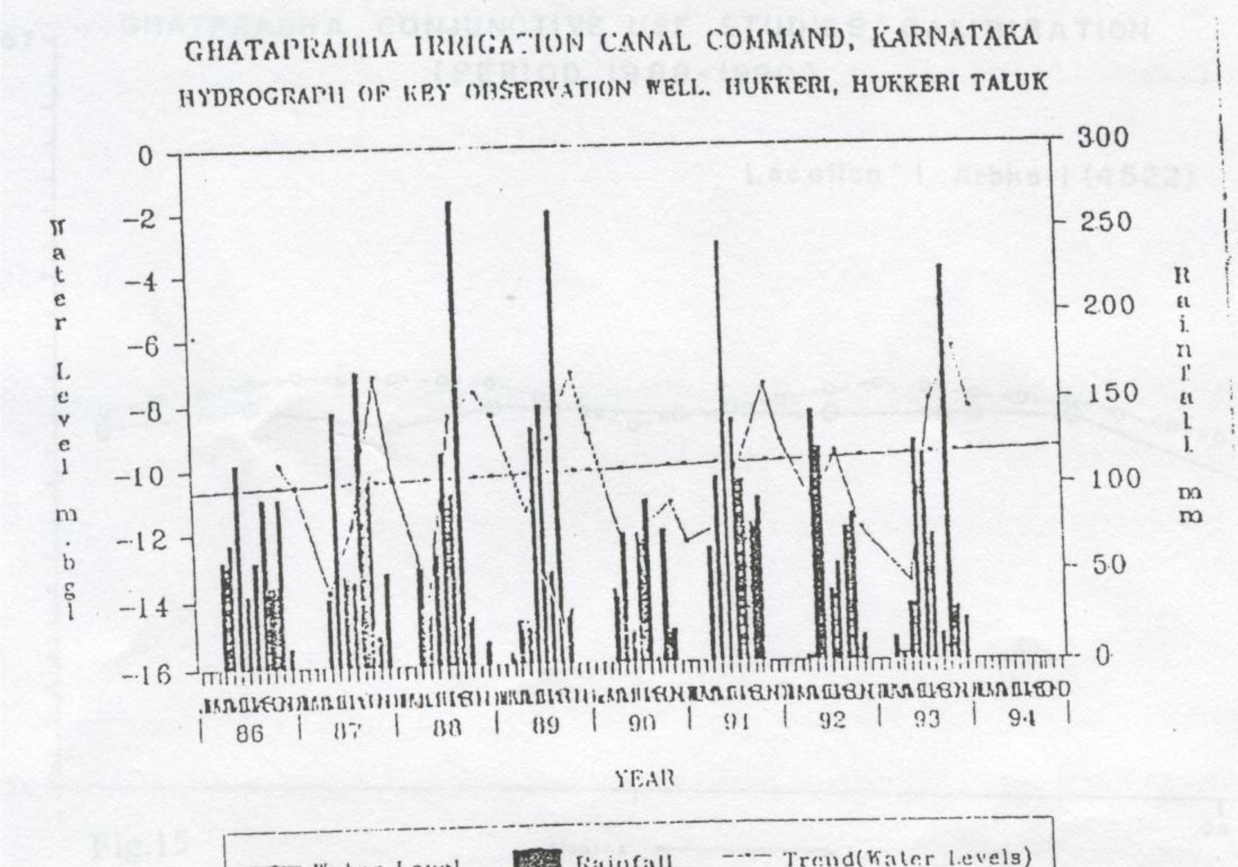


Fig.13

Fig .14 depicts key observation Well, Bilgi which shows a declining trend over the years in spite of good monsoons. The well is located toward the *tail end of the command* and indicate some development due to non availability of canal water for irrigation.

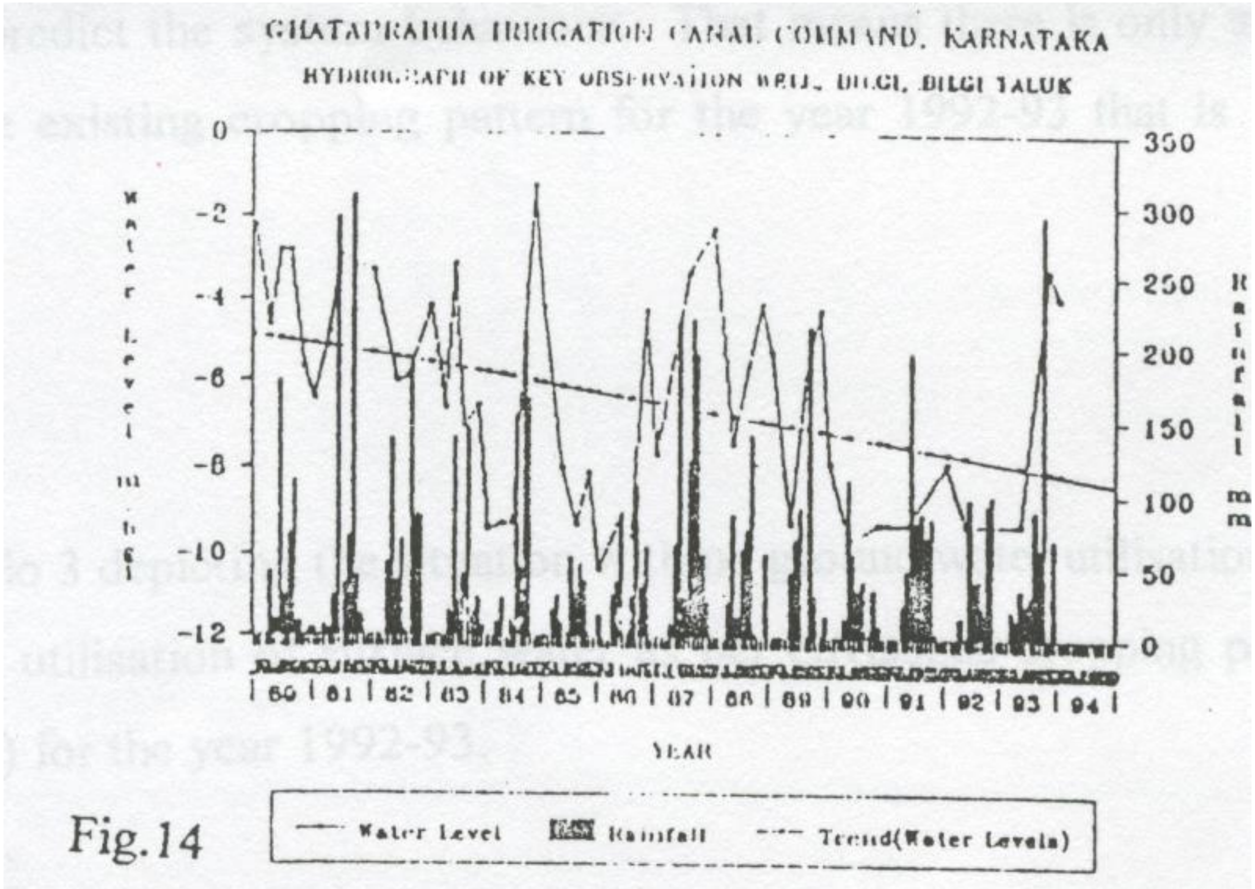


Fig.14

Modelling and Generation of Scenarios

After the model has been calibrated, with the historical data and is presented below in Fig.15 & 16.

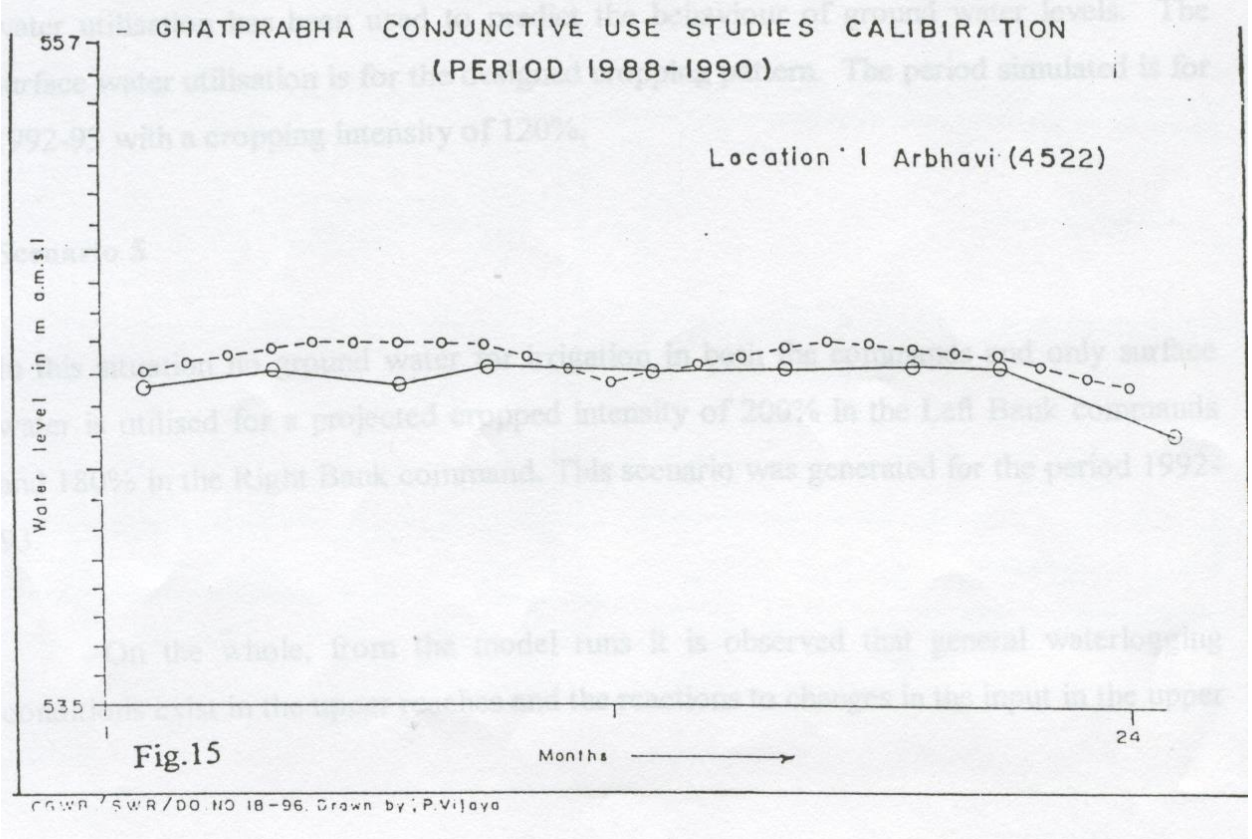


Fig.15

Developing Scenarios :

Generated various scenarios by imposing certain modifications in terms of recharge as well as draft from the system.

It was proposed to generate the following five scenarios, depicting various imposed changes on the aquifer system pertaining to the canal command area and presented e scenarios in the fig.

Scenario 1

Under this scenario, the present existing system of water is to be modelled for five years period (1988-93). The ground water and surface water utilizations based on the existing cropping patterns (84%). Taking into account the seepage and the return flows from applied irrigation

Scenario 2

In scenario 2, the model situation is that no ground water utilisation is in the canal command and to predict the system behaviour. That means there is only surface water utilisation with the existing cropping pattern for the year 1992-93 that is for one year only.

Scenario 3

The scenario 3 depicting the situation with no ground water utilisation in the canal command and the utilisation of surface water as per envisaged cropping pattern (120% cropping intensity) for the year 1992-93.

Scenario 4

Under scenario 4, the model situation is that no ground water utilisation in the existing Left Bank canal and the proposed Right Bank canal commands and only surface water utilisation has been used to predict the behaviour of ground water levels. The surface water utilisation is for the designed cropping pattern. The period simulated is for 1992-93 with a cropping intensity of 120%.

Scenario 5

In this situation no ground water for irrigation in both the commands and only surface water is utilised for a projected cropped intensity of 200% in the Left Bank commands and 180% in the Right Bank command. This scenario was generated for the period 1992-93.

On the whole, from the model runs it is observed that general waterlogging conditions exist in the upper reaches and the reactions to changes in the input in the upper reaches is quire prominent. The combined hydrographs generated for scenarios 1 to 5 are depicted in figures 17,18,19,20.

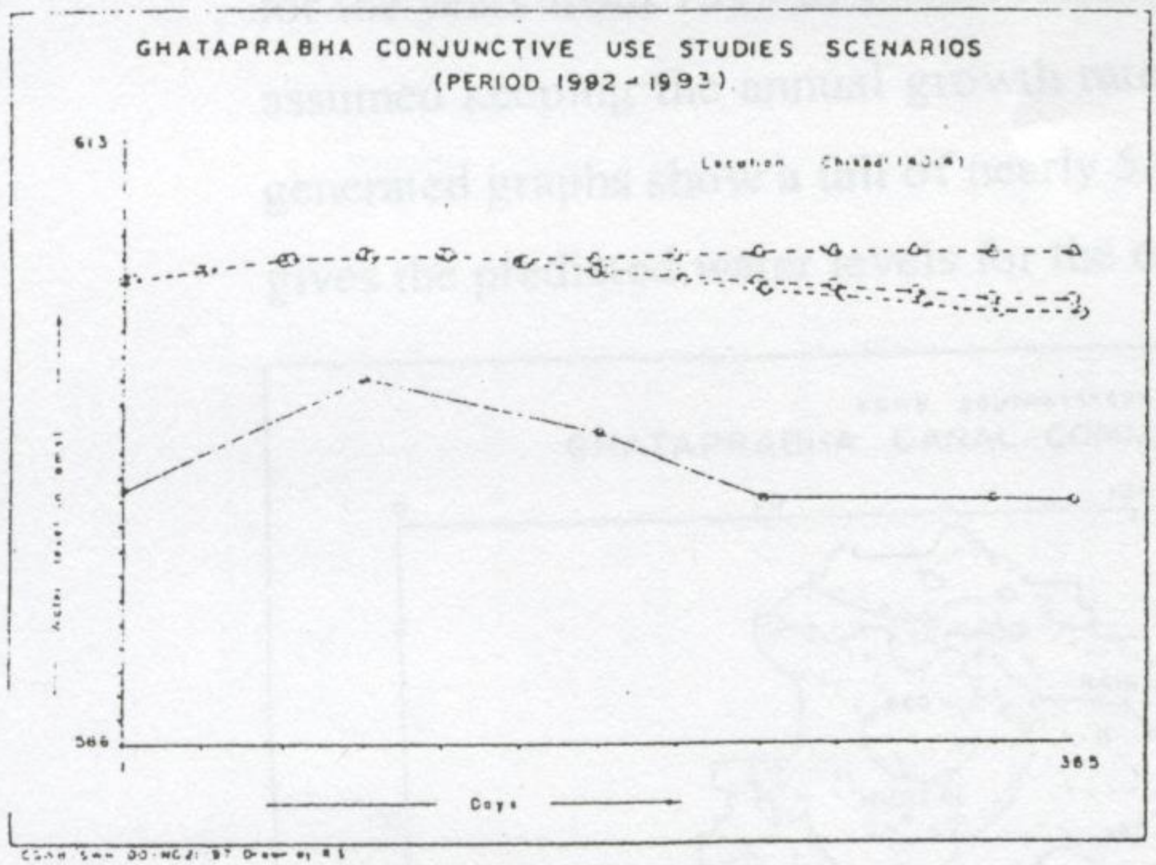


Fig. 17

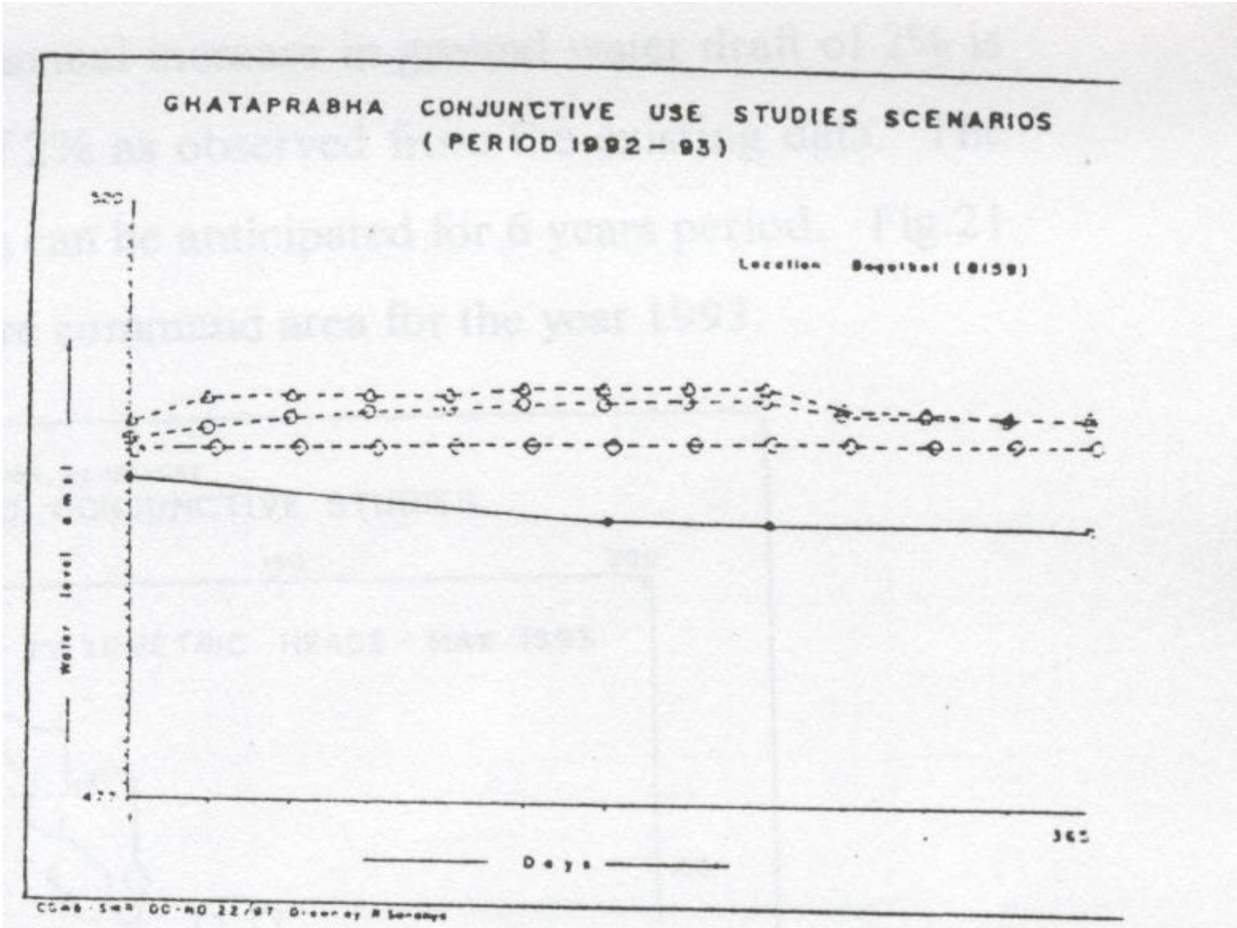
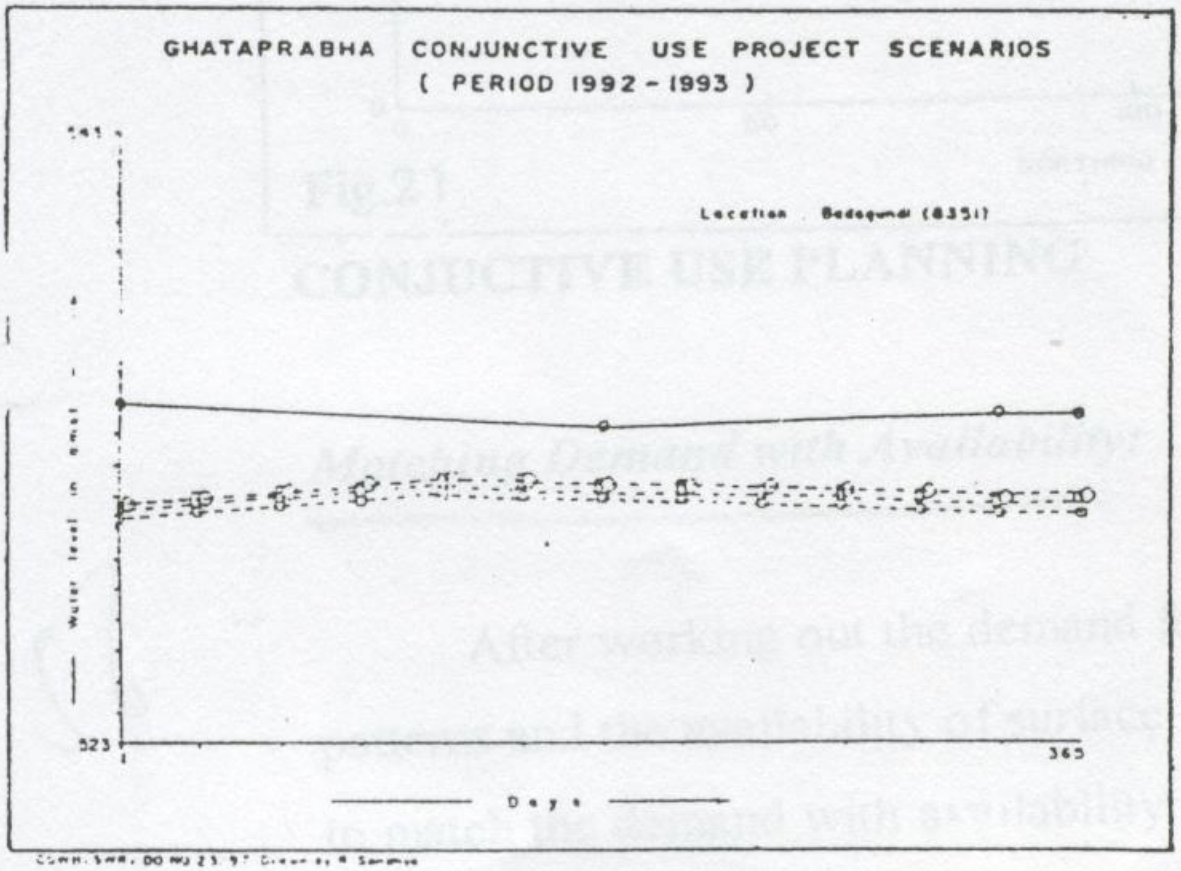

GHATAPRABHA CONJUNCTIVE USE STUDIES SCENARIOS
(PERIOD 1992 – 93)
Water level amsl
365
Days

Fig.18



GHATAPRABHA CONJUNCTIVE USE PROJECT SCENARIOS
(PERIOD 1992 - 1993)
523
1
365
Days

Fig.19

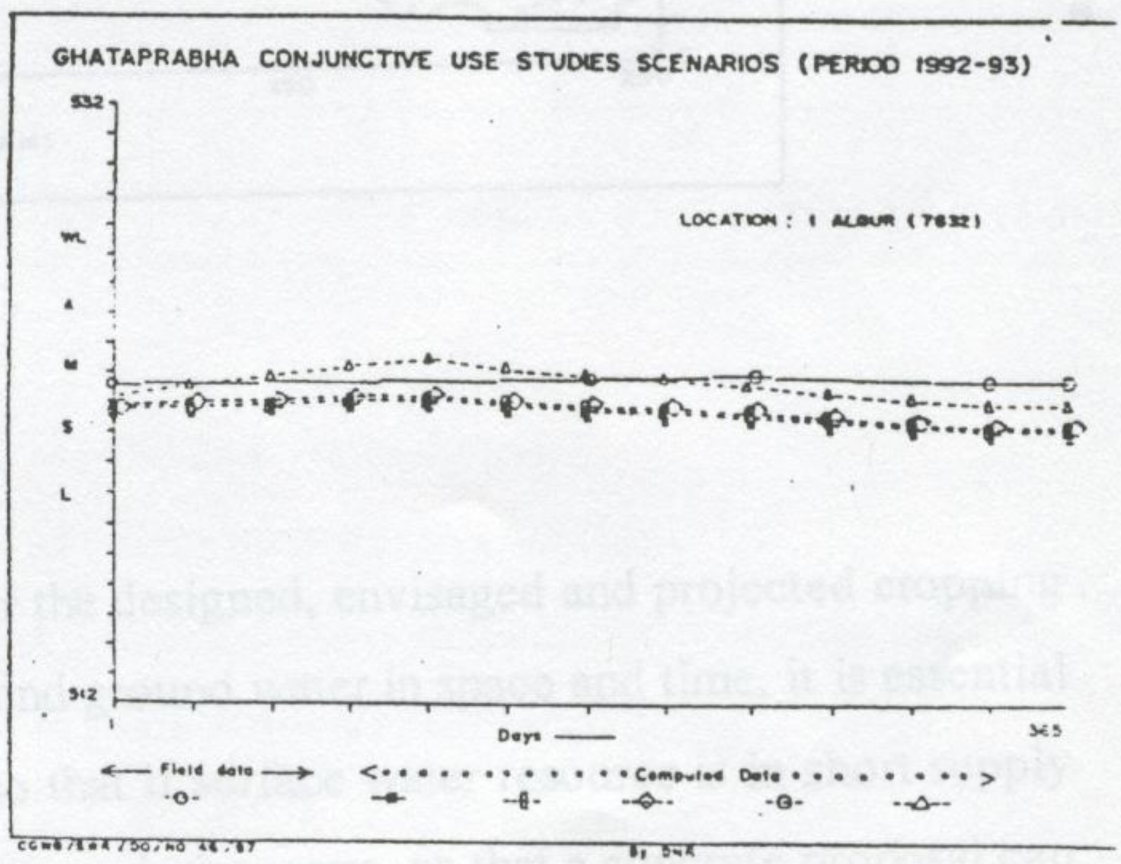

GHATAPRABHA CONJUNCTIVE USE STUDIES SCENARIOS (PERIOD 1992-93)
LOCATION : 1 ALBUR (7632)
WL
A
M
S
L
532
512
1
365
Days
Field data
Computed Data

Fig.20

Prediction of water levels: Prediction of water levels has been attempted keeping the recharge same that is assuming same annual rainfall and canal seepages etc. as inputs for the years from 1993 to 1998. Here an annual increase in ground water draft of 2% is assumed keeping the annual growth rate of 2% as observed from the existing data. The generated graphs show a fall of nearly 5.0m can be anticipated for 6 years period. Fig.21 gives the predicted water levels for the entire command area for the year 1993.

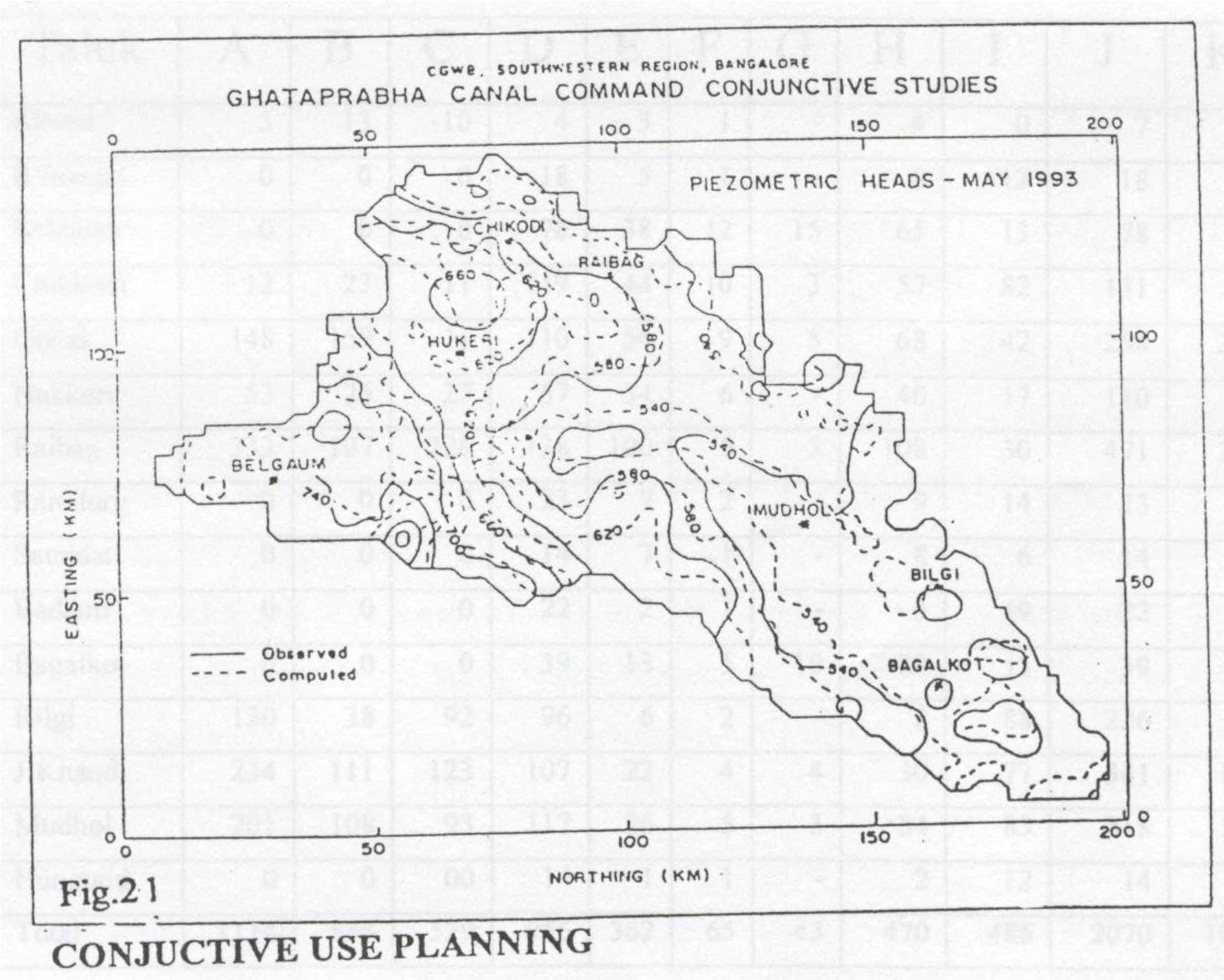


Fig.21

CONJUCTIVE USE PLANNING

Matching Demand with Availability:

After working out the demand for the designed, envisaged and projected cropping patterns and the availability of surface and ground water in space and time, it is essential to match the demand with availability so that if surface water resource is in short supply the demand can be met from ground water and vice versa, so that a concrete proposal can be drawn for a conjunctive use plan for optimal utilisation of the water resources of the area.

The demand and availability of water for irrigation, domestic and industrial uses at present was worked out based on the existing cropping pattern (84% cropping intensity for irrigation (1992 – `93) are given below

DEMAND AND SUPPLY OF SURFACE AND GROUND WATER (MCM)

Taluk	A	B	C	D	E	F	G	H	I	J	K	L
Athani	3	13	-10	4	3	1	-	4	0	7	17	-10
B'hongal	0	0	0	18	5	1	-	6	12	18	6	-12
Belgaum	0	0	0	78	38	12	15	65	13	78	65	13
Chikkodi	12	23	-11	119	44	10	3	57	82	131	80	51
Gokak	148	159	-11	110	54	9	5	68	42	258	227	31
Hukkeri	53	26	27	57	34	6	-	40	17	110	66	44
Raibag	333	107	226	138	100	5	3	108	30	471	215	256
Ramdurg	0	0	0	23	7	2	-	9	14	23	9	14
Saundati	0	0	0	14	7	1	-	8	6	14	8	6
Badami	0	0	0	22	2	1	-	3	19	22	3	19
Bagalkot	0	0	0	39	13	5	10	28	11	39	28	11
Bilgi	130	38	92	96	6	2	-	8	88	226	46	180
J'Khandi	234	111	123	107	22	4	4	30	77	341	141	200
Mudhol	201	108	93	117	26	5	3	34	83	318	142	176
Hungund	0	0	00	14	1	1	-	2	12	14	2	12
Total	1114	585	529	956	362	65	43	470	486	2070	1055	1015

A : Surface water availability
B : Surface water demand
C : Surface water surplus/defecit
D : Ground water availability
E : Ground water demand for irrigation
F : Ground water demand for domestic use

G : Ground water demand for industrial use	H : Ground water demand total
I : Ground water surplus/defecit	J : Total SW & GW available
K : Total SW & GW demand	L : Total SW & GW surplus/deficit

The water demand for the envisaged cropping intensities of 120, 200 and 240% were also worked out. However, considering the type of area and the yields of dug wells and bore wells and the type of aquifers, only the water demand from the surface water resources were worked out, whereas the groundwater can be used to meet the deficits in supply. It is also to be ensured that the ground development should not exceed a certain limit and in years of low rainfall or during lean years, the canal flows may be reduced which means reduced recharge from applied irrigation to groundwater. In such a situation there are possibilities of overdevelopment conditions developing temporarily.

CONJUNCTIVE USE MECHANISM

The water demands computed for various cropping intensities for the two commands have shown that for the Left Bank canal command a cropping intensity of 200% seems to be feasible with the utilisation of ground water to the tune of 173.40 MCM. Higher cropping intensity of 240% is not practical because of increased ground water utilisation to the tune of 468.00 MCM which may create over developed conditions. In case of Right Bank Canal Command, where irrigation facilities are still to be developed, there can be two possible development plans.

(i) Confining the irrigation plan to 120% cropping intensity which will need a total water requirement of 950.29 MCM at the head reaches, leaving the excess water if any for downstream utilisation to meet the eventualities for domestic and industrial needs. This will also ensure certain base flows in the river without utilizing all the available resources.

(ii) Increasing the cropping intensity to 180% which will utilize completely the available surface water and also require utilisation of ground water to the tune of 223.70 MCM.

Time Schedule for Ground Water Irrigation :

With the suggested conjunctive use plan, a pumping of 173.40 MCM of ground water is involved in the Left Bank and 223.00 MCM in the Right Bank canal command areas (if development plan II is adopted), which means that a total of 397.00 MCM of ground water is to be pumped from both the commands in the study area. To make it feasible and economical, ground water has to be pumped in Khariff season when power is available as well as during rabi when there will be sufficient demand. Due to canal seepages and return flow from applied irrigation to ground water regime, there will be induced recharge created by the draft of ground water without causing heavy draw-downs. The taluk wise ground water demands/drafts during khariff and rabi and bi-seasonal seasons are given in the following tables for various cropping intensities.

GHATAPRABHA COMMAND CONJUCTIVE USE STUDIES

CONJUNCTIVE USE PLAN

GHATPRABHA LEFT BANK CANAL COMMAND **CROPPING INTENSITY : 140%**

WATER UTILISATION (MCM) **(AREA IRRIGATED IN HECTARES)**

TALUK	KARIFF SEASON			RABI SEASON			BISEASONAL			TOTAL UTILISATON		TOTAL AREA IRRIGATED
	SW	GW	TOTAL	SW	GW	TOTAL	SW	GW	TOTAL	SW	GW	
ATHANK	6.54	-	6.54	12.70	-	12.70	13.06	-	13.06	32.30	-	6,984
CHIKODI	2.77	20.00	22.77	29.10	20.00	49.10	32.44	-	32.44	64.31	40.00	16,525
GOKAK	37.45	11.50	47.45	87.33	11.50	97.33	120.36	-	120.36	245.14	23.00	50,940
RAIBAG	63.55	-	63.35	120.00	-	120.00	108.63	-	108.63	291.98	-	63,773
JAMKHANDI	36.08	15.00	51.08	88.00	15.00	103.00	79.93	-	79.93	204.01	30.00	48,160
MUDHOL	40.39	20.00	60.39	81.82	20.00	101.82	116.53	-	116.53	238.74	40.00	48,287
BILGI	29.74	20.00	49.74	62.09	20.00	82.09	73.59	-	73.59	165.42	40.00	35,138
TOTAL	**98.97**	**111.40**	**210.47**	**291.54**	**111.40**	**403.04**	**321.89**	**-**	**321.89**	**712.40**	**222.80**	**2,18,761**

GHATAPRABHA COMMAND CONJUCTIVE USE STUDIES

CONJUNCTIVE USE PLAN

GHATPRABHA LEFT BANK CANAL COMMAND **CROPPING INTENSITY : 180%**

WATER UTILISATION (MCM) **(AREA IRRIGATED IN HECTARES)**

TALUK	KARIFF SEASON			RABI SEASON			BISEASONAL			TOTAL UTILISATON		TOTAL AREA IRRIGATED
	SW	GW	TOTAL	SW	GW	TOTAL	SW	GW	TOTAL	SW	GW	
RAIBAG	7.63	15.50	23.13	16.00	15.50	31.50	18.67	-	18.67	42.30	31.00	14.638
CHIKODI	3.09	13.25	16.34	27.76	13.25	41.01	28.91	-	28.91	59.76	26.50	22,510
GOKAK	31.50	35.35	66.85	75.02	35.35	110.37	85.68	-	85.68	192.20	70.70	58,160
MUDHOL	22.40	25.00	47.40	49.28	25.00	74.28	55.97	-	85.97	127.65	50.00	37,852
RAMDURG	1.95	-	1.95	5.38	-	5.38	5.88	-	5.88	13.21	-	3,224
SAUNDATTI	1.20	-	1.20	3.29	-	3.29	3.65	-	3.65	8.14	-	2,086
BAGALKOT	18.30	10.75	29.05	63.97	10.75	74.72	70.24	-	70.24	152.51	21.50	44,666
BADAMI	4.61	9.80	14.41	16.64	9.80	26.44	17.84	-	17.84	39.09	19.60	13,660
HUNGUND	3.92	-	3.92	14.80	-	14.80	15.18	-	15.18	33.90	-	8,886
HUKERI	5.54	1.75	7.29	19.40	1.75	21.15	19.87	-	19.87	44.81	3.50	13,079
TOTAL	**216.32**	**86.50**	**301.32**	**481.04**	**86.50**	**566.04**	**544.54**	**-**	**544.54**	**1241.90**	**173.00**	**2,69,807**

Note : Surface water requirement at the field level (Gross). Add conveyance losses of 25% total surface water to be made available at head reaches will be 950.00 MCM.

GHATAPRABHA COMMAND CONJUCTIVE USE STUDIES

CONJUNCTIVE USE PLAN

GHATPRABHA LEFT BANK CANAL COMMAND **CROPPING INTENSITY : 200%**

WATER UTILISATION (MCM) **(AREA IRRIGATED IN HECTARES)**

TALUK	KARIFF SEASON			RABI SEASON			BISEASONAL			TOTAL UTILISATON		TOTAL AREA IRRIGATED
	SW	GW	TOTAL	SW	GW	TOTAL	SW	GW	TOTAL	SW	GW	
RAIBAG	11.41	15.50	26.91	23.98	15.50	39.48	63.44	-	63.44	98.83	31.00	15,596
CHIKODI	4.64	13.25	17.89	41.66	13.25	54.91	89.70	-	89.70	136.00	26.50	26,514
GOKAK	47.24	35.35	82.59	112.50	35.35	147.85	288.31	-	288.31	448.05	70.70	73,366
MUDHOL	33.64	25.00	58.64	73.88	25.00	98.88	184.88	-	184.88	292.40	50.00	47,130
RAMDURG	2.94	-	2.94	8.12	-	8.12	19.90	-	19.90	30.96	-	4,836
SAUNDATTI	1.78	-	1.78	4.92	-	4.92	12.20	-	12.20	18.90	-	3,130
BAGALKOT	27.24	10.75	37.99	96.00	10.75	106.75	226.54	-	226.54	349.78	21.50	61,702
BADAMI	6.91	9.80	16.71	24.88	9.80	34.68	58.54	-	58.54	90.33	19.60	15,660
HUNGUND	5.89	-	5.89	22.35	-	22.35	51.00	-	51.00	79.24	-	13,328
HUKERI	5.11	1.75	6.86	29.10	1.75	30.85	63.96	-	63.96	98.17	3.50	18,742
TOTAL	**146.80**	**111.60**	**258.20**	**437.39**	**111.50**	**548.75**	**858.47**	**-**	**1058.47**	**1642.66**	**223.33**	**2,80,004**

Financial Aspects of Ground Water Development

From the statistical data available there are about 31000 dug wells and about 3000 bore wells are present, for which the investment has already been made. Most of these well are used to supplement irrigation from the canal during periods of water shortage, or, as in the case of perennial crops like sugarcane, to sustain the crops during summer months. As such the cost of production and the value of the produce of the crops per hectare are based on the surveys carried out in the Gokak branch canal of the study area under National Water Management Project, Dept.. of Irrigation, Government of Karnataka and it varied from Rs.11,200 to Rs.31,500 for sugarcane and from Rs.3525 to Rs.24000 for irrigated dry crops respectively.

For computations for the *benefit* after the project is implemented the *cost* of construction of the bore well, down to a depth of 80 m. (recommended), the provision of providing submersible pumps, pump house, cost of energisation are taken into account. The present probable costs based on the NABARD norms are given below;

(a)	(i)	cost of drilling, bore well of 6" dia.		
		down to 80.00m at Rs.200/m		Rs.16,000.00
	(ii)	cost of casing M.S pipe 10.m		
		@ Rs.300/m.		Rs. 3,000.00
	(iii)	cost of development		Rs. 500.00
	(iv)	cost of mobilization		Rs. 200.00
				Rs.19,700.00
(b)	(i)	cost of submersible pump 5 HP		Rs.15,300.00
	(ii)	cost of accessories		
		(1)	control panel	Rs. 2,300.00
		(2)	cable wire (60-70m)	Rs. 1,140.00

(3)	G.I pipes, bends etc. (50-70m)	Rs. 6,950.00
(4)	Installation charges	Rs. 600.00
(5)	energisation charges	Rs. 1,200.00
(6)	taxes	Rs. 1,400.00
(7)	capacitors & transport	Rs. 450.00

		Rs.29,300.00

(c)	cost of pump house or shed (2.5 m x 2.5 m x 2.1 m)	Rs. 5,300.00
(d)	pipeline for well command	Rs. 3,100.00
	Total investment towards	------------------
	Bore well, pump etc is a + b + c + d	Rs.57,400.00

The lifetime for the bore well is taken as 20 years, and for pump nine years. It is presumed that the pump will be replaced after 9 years. In case of other accessories, the lifetime is supposed to vary from 20 years to 25 years. The repayment of the loan (in case it is given to the individual farmer) is supposed to be completed before 11-15 years for bore wells and for other dug wells it is 9 years. The total investment including pump sets etc. for the project is Rs.939.06 million or Rs.93.9 crores. The investment is found to be economical at 14% interest with the cost – benefit ratio varying from 1.25 to 5.34 and the net present value (NPV) varying from 0.33 to 139.93 and the Internal Rate of Return (IRR) varying from 0.20 to 7.20%.