CHAPTER - 6

METHODOLOGY AND SPECIMEN MODEL FORMULATION

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6.1 GENERAL

Kakrapar Left Bank Main Canal of Kakrapar weir consists of eight branch canals. Under each branch canal, there are number of minors and subminors, as discussed earlier. For this study, each minor under all branch canals of the main canal are selected for conjunctive use studies and optimization models are developed, wherein the objective function is subjected to the various constraints like area availability constraint, water requirement constraint, surface water availability and canal capacity constraints, ground water potential and capacity constraints, drainage requirement constraints, socio-economic constraints etc., as discussed in chapter 5.

Considering area availability constraints and crop calendar the optimal irrigation intensities can be evidently achieved, if enough water is available to satisfy crop water requirement. Irrigation intensities are considered with an increment of 10% depending upon the existing irrigation intensity. For special cases like the ones having the abnormally high irrigation intensities are tried with decrease of 10% depending upon the existing irrigation intensity. The year 1999-2000 is considered for this study. Monthly distribution of surface and ground water are considered for 10 different crops taken in the command area for all minors of all branch canals of Kakrapar left bank main canal.

6.2 METHODOLOGY

Various strategies adopted in the study are as follows:

Strategy 1

General Strategy Considering Unit Cost of Surface Water Charged to the Farmers by N.W.R.W.S. & K. Department of Government of Gujarat and Unit Cost of Ground Water

Under this strategy, the optimal net benefits are obtained by considering unit cost of surface water charged to the farmers by N.W.R.W.S. & K. Department, Government of Gujarat and unit cost of ground water as the cost coefficients in the maximizing objective function. Under this strategy economical comparison of surface water and ground water are carried out. This strategy is ideal as for the command area of existing irrigation schemes.

Strategy 2

Space Integration

Under this strategy, space integration of surface and ground water utilization are studied. Ground water and surface water are allocated to separate parcels of lands under different crop area. As the major ground water potential is exploited by private users, this strategy can be proved easier for practical implementation. Private well owners can be insisted for perennial crops (sugarcane) and Hot Weather Crop (vegetable) within only ground water exploitation and other farmers of the command area can have facility of surface water for seasonal crops (paddy).

Strategy 3

Space – Time Integration

Under this strategy, time and space distribution of surface and ground water are studied. With this strategy, both the surface water and ground water can be utilized in any season and wherever required. With this strategy more flexibility can be achieved and it may prove most cost effective.

6.3 FORMULATION OF SPECIMEN MODEL FOR STRATEGY 1 FOR THE YEAR 1999-2000

Based on model formulation, discussed in chapter Nos. 4 & 5 and appendices I, II & III, formulation of the model is carried out for each strategy for the year 1999-2000 for different irrigation intensities, e.g. between 130% and 200% with an increment of 10%. The model involves total 34 variables, out of which 10 are for different crop area, surface water releases for 12 months and ground water exploitation for 12 months of a year. Typical model formulation of Machhad minor of Navsari branch canal of K.L.B.M.C. for strategy 1, year 1999-2000 and irrigation intensity of 60% is briefly described as follows

OBJECTIVE FUNCTION

$$Max(Z) = 20071.38A_1 + 177844.50A_2 + 65262.50A_3 + 138750.50A_4 + 17930.92A_5 + 1932.25A_6 + 6890.91A_7 + 5491.61A_8 + 13599.25A_9 + 60000A_{10} - 749.35SW_1 - 749.35SW_2 - 749.35SW_3 - 360SW_4 - 360SW_5 - 360SW_6 - 360SW_7 - 360SW_8 - 360SW_9 - 360SW_{10} - 360SW_{11} - 360SW_{12} - 16707.25GW_1 - 16707.25GW_2 - 17457.25GW_3 - 17457.25GW_4 - 17457.25GW_5 - 17457.25GW_6 - 16040.58GW_7 - 16040.58GW_8 - 16040.58GW_9 - 16040.58GW_{10} - 16707.25GW_{11} - 16707.25GW_{12}$$

CONSTRAINTS

Surface Water Availability Constraint

The constraint equation is

$$SW_1 + SW_2 + SW_3 + SW_4 + SW_5 + SW_6 + SW_7 + SW_8 + SW_9 + SW_{10} + SW_{11} + SW_{12} \leq 294.3898 \text{ ha.m}$$

Canal Capacity Constraint

The constraint equations are,

$SW_1 \leq 130.02$ ha.m

$SW_2 \leq 130.02$ ha.m

: :

: :

$SW_{12} \leq 130.02$ ha.m

Ground Water Potential Constraint

The constraint equation is,

$$GW_1 + GW_2 + GW_3 + GW_4 + GW_5 + GW_6 + GW_7 + GW_8 + GW_9 + GW_{10} + GW_{11} + GW_{12} \leq 200 \text{ha.m}$$

Pumping Capacity Constraint

The constraint equations are,

$GW_1 \leq 1.386$ ha.m

$GW_2 \leq 1.386$ ha.m

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: :

$GW_{12} \leq 1.386$ ha.m

Drainage Requirement Constraint

$GW_1 + GW_2 + GW_3 + GW_4 + GW_5 + GW_6 + GW_7 + GW_8 + GW_9 + GW_{10} + GW_{11} + GW_{12} \geq 10$ ha.m

Area Availability Constraint

The constraint equations are,

$A_1 + A_2 + A_3 + A_4 + A_6 + A_7 + A_8 + A_{10} \leq 579$ ha

$A_1 + A_2 + 0.4A_3 + 0.75A_4 + A_5 + A_6 + A_7 + 0.8A_8 + A_9 + 0.9A_{10} \leq 579$ ha

$A_1 + A_2 + 0.9A_6 + A_7 + 0.8A_9 \leq 579$ ha

$A_1 + A_2 + A_9 \leq 579$ ha

$A_1 + A_2 + 0.7A_9 \leq 579$ ha

$A_1 + A_2 + 0.5A_5 + 0.37A_8 \leq 579$ ha

$A_1 + A_2 + A_5 + A_8 \leq 579$ ha

$A_1 + A_2 + A_5 + A_8 \leq 579$ ha

$A_1 + A_2 + A_5 + A_8 \leq 579$ ha

$A_1 + A_2 + 0.5A_5 + A_8 \leq 579$ ha

$A_1 + A_2 + 0.5A_3 + 0.75A_4 + 0.5A_7 + A_8 + 0.75A_{10} \leq 579$ ha

$A_1 + A_2 + A_3 + A_4 + A_6 + A_7 + A_8 + A_{10} \leq 579$ ha

Water Requirement Constraint

The constraint equations are,

$0.0340A_1 + 0.1040A_2 + 0.6000A_3 + 0.1270A_4 + 0.0805A_6 + 0.1000A_7 + 0.2500A_{10} - 0.2505SW_1 - 0.9360GW_1 \leq 0$

$0.0880A_1 + 0.1590A_2 + 0.6000A_3 + 0.1390A_4 + 0.1009A_6 + 0.0853A_7 + 0.0656A_9 + 0.2500A_{10} - 0.2505SW_2 - 0.9360GW_2 \leq 0$

: :

: :

$0.1120A_1 + 0.0850A_2 + 0.0450A_4 + 0.0164A_7 + 0.0828A_8 + 0.1500A_{10} - 0.2505SW_{11} - 0.9360GW_{11} \leq 0$

$0.08200A_1 + 0.0820A_2 + 0.6000A_3 + 0.0890A_4 + 0.0155A_6 + 0.0618A_7 + 0.0153A_8 + 0.2500A_{10} - 0.2505SW_{12} - 0.9360GW_{12} \leq 0$

Management Constraint

The constraint equations are,

$A_1 \leq 165.6000$

$A_2 \leq 0.0000$

$A_3 \leq 0.0000$

$A_4 \leq 0.0000$

$A_5 \leq 76.8000$

$A_6 \leq 0.0000$

$A_7 \leq 0.0000$

$A_8 \leq 0.0000$

$A_9 \leq 0.0000$

$A_{10} \leq 458.4000$

Socio – Economic Constraint

The constraint equations are,

$A_5 \geq 4.8000$ ha

$A_{10} \geq 28.6500$ ha

Non – Negativity Constraint

Area under a crop, A_j, surface water releases, SW_i and ground water drawal GW_i cannot be negative quantities.

$Aj \geq 0$

$SWi \geq 0$

$GWi \geq 0$

Similarly, the fuzzified matrix is also formed considering the fuzzified values of the right hand side of the above said constraints, the procedure within is explained in section 5.7

6.4 CHANGES IN CONSTRAINTS OF THE MODEL FOR DIFFERENT STRATEGIES

(1) The goal for strategy 1, i.e. general strategy, is to maximize the benefits, for this purpose both constraints, i.e. management constraints, which provide upper limit of crop constraint and socio – economic constraints which provide lower limit of crop area are used. While for strategy 2 and 3, the primary goal

is to maximize the crop production and then maximize the benefits. For this purpose, management constraints (Area "≤" type) and socio – economic constraints (Area "≥" type) are converted in to single constraint which suggests "=" type constraints for crop area, depending upon different irrigation intensities.

(2) For strategy 2, i.e. space integration, water requirement constraint differs from other strategies.

For space integration, some crops use ground water and other crops use surface water. Here, the water requirements of Sugarcane, Banana, Paddy and Grass are satisfied with only ground water and water requirements for Mango, Cabbage and Grass are satisfied with only surface water. So, for strategy: 2, water requirement constraint shown in specimen model formulation for the month of february changes as,

$$0.0880A_1 + 0.0159A_2 + 0.2500A_{10} - 0.9360GW_2 = 0$$
$$0.6000A_3 + 0.1390A_4 + 0.1009A_6 + 0.0656A_9 - 0.2505SW_2 = 0$$

Constraints for other months change accordingly.

(3) For strategy 3, i.e. space - time integration, only ground water in hot weather to all the crops is given. For kharif and rabi, only Mango, Cabbage and Grass are irrigated with surface water.

6.5 TYPICAL CONSIDERATIONS IN SENSITIVITY ANALYSIS

Using 10 years average evapotranspiration rate

The monthly evapotranspiration rate in the command area, which was observed in 1999-2000 was different from the average evapotranspiration rate of last 10 years, i.e. 1990-1991 to 1999-2000. Therefore, the water requirement of each crop based on historical data is determined and the deviation of the optimal, i.e. optimal net benefits, Rs./ha.m as a result, is observed.

Using the originally practiced cropping pattern in the Umbhrat branch canal command area, before the commencement of the project

This is carried out to observe the change in the net benefits. This is because the change in the cropping pattern due to the project, deteriorated the field conditions, especially the soil in the study area.

Using surface water restriction method prevalent in the Chaltan branch canal command area

In some cases like Chalthan branch canal, distribution of ground water is studied. With this surface water restriction method, ground water is used as far as possible and if the demand increases more than the available ground water, then surface water is to be given. With this strategy more and more ground water is used and water logging problem may be avoided.