PRICING POLICY FOR IRRIGATION WATER

A THESIS

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WATER RESOURCES DEVELOPMENT

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled 'Pricing Policy for Irrigation Water' in fulfilment of the requirement for the award of Degree of Doctor of Philosophy, submitted in the Department of Water Resources Development Training Centre of the University, is an authentic record of my own work carried out during the period from February 1978 to August 1983 under the supervision of Dr. Bharat Singh and Dr. G.N.Yoganarasimhan.

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ABSTRACT

Development of Irrigation involves heavy investments. Lack of rational pricing policy has led to many misgivings. This may be attributed to the complexities involved in the process as well as inadequate attention by planners and policy makers. This study is a modest effort in this direction.

After review of the various principles of pricing and their applicability, it is seen that value or benefit based pricing is more appropriate than the cost based price. The economic and social preferences guiding the pricing policy have been identified alongwith their interaction. The following is a statement of objectives for evolving the pricing policy.

1. Efficient use of irrigation water
2. Equitable sharing of the benefit from use of irrigation water
3. Social equity including income distribution
4. Economic growth and Regional Development.

Recovery of cost has not been included explicitly in the statement of objectives. The same is implied while considering the share of the investor in the benefit and also in the objective of economic growth.

The cost and benefit parameters needed for pricing are obtained after putting water to maximum value uses. The value of water is increased with multipurpose use for hydropower

generation as well as with conjunctive use of surface and ground-water. The additional net benefits from the feasible complementarily is considered as contributing to the value of irrigation water. The case study of Ramganga Multi-purpose Reservoir Project has been done for illustration. Optimization techniques including variable resource and parameteric linear programming has been used. Demand curves have also been derived for irrigation water for the project.

The production function approach for pricing on the basis of marginal value product has shown that the feasible range of water use is limited and does not provide a practical solution for water charges.

The value and cost of water form the basis for pricing including the cost recovery aspect. Value productivity from individual crop production, the income a farmer gets from use of irrigation water is a measure of his ability to pay. The ability to pay pricing recognises the contribution of the farmer to the national objectives and allows an equitable share to him.

Equity and social welfare have been considered from the view point of the society as well as the farming community. The increase in social welfare can be said to be

$$\text{Increase in welfare} = \text{Expected increase in income} - \text{Risk premium} + \text{Distribution effect}$$

Quantitative evaluation of risk in irrigated agriculture is done using the expected income-variance framework. Quadratic programming is used for obtaining the E - V frontier. A method has been evolved to compensate the weaker section of the farming community whose capacity to risk aversion is low and hence has a lower expected income. An analytical framework has been developed to obtain the preferential weightages for the small, medium and large farmer groups. A method of redistribution has been suggested involving no reduction in the revenue. Basing on the risk and redistribution discriminatory pricing has been suggested. The impact of pricing on cost recovery aspect is brought out. The recommended pricing policy considers equitable sharing of the benefits from the use of irrigation water among all participants viz the government and the various sections of the farming community.

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CHAPTER -1

INTRODUCTION

1.1 PRICING PROBLEM

Irrigation water management has been based essentially on managing the supply. The impact of use of irrigation water on the economy depends on proper utilisation of the supply. Since irrigation water is put to use by the farmers, their requirements and preferences must be considered and should receive due emphasis in the management, consistent with other objectives of development. Management through demand has been recognised as most desirable. Pricing plays a very important role in management as a means to control and influence investment criteria.

The way irrigation systems are built and water used, can be considerably improved through a proper pricing policy. There is virtually total absence of such policy even among developed countries. The pricing policy has not received the attention it deserves.

In absence of a rational pricing policy, the water charges are levied somewhat in an arbitrary and discretionary manner. Unduly low pricing has been the order of the way. The coalition of the beneficiaries and political considerations coupled with adhocism and soft attitude of officials may be attributed for such a situation. Such a system continues to thrive because higher water prices adversely affect the interests of a sizeable group, which has considerable political influence. Politicians, engineers, bureaucrats do not take a hard line attitude against this anomalous situation. The burden due to low pricing of water falls on the entire nation. The people at large (rest of the nation) would not like to force this issue since individual gains would not be perceptible.

Organised groups are effective in getting through the projects for construction as well as ensure that they do not have to pay high prices. Planners have been advocating pricing of irrigation water on the basis of normative economic theory of marginal cost pricing.(18). However such pricing has not received favour with decision makers due to want of adoptability and acceptability.

1.2 PRESENT POLICIES AND PRACTICES

1.2.1 The Irrigation Commission of India (1972) (28) have reviewed the irrigation rates and the considerations on which these are fixed. Irrigation is a State subject. There is considerable diversity in the systems for levying irrigation charges in different states. The rate charged are on crop area basis. In some states charged on year to year basis. In eastern part, long term agreements upto ten years are made. There is no uniform basis for irrigation charges. The Planning Commission and other central authorities have been impressing the state governments for a rational pricing system. However social and political forces have been active against increase in the water rates. Though there have been some revisions, these are minor compared to the problem size. The water charge varies not only from State to State but from one part to another and from one project to another within a state itself.

Table 1.1 shows the prevailing water rates in different parts of the country. There is large variability in the prices. The water charges vary from as low as Rs.3.71 in Tamil Nadu to Rs.123.55 in Gujarat per hectare of irrigated paddy. Though some variation is understandble, the basis for fixation is not known.

The Commission has recommended benefit or income based pricing rather than cost based price. ' The irrigator is primarily interested in the net gain from irrigation, and to him, the cost incurred in making water available is of little consequence. His willingness to pay for water varies in proportion to the gain that he expects from its use. From the irrigator's point of view, therefore, water rates should be related to the benefit which irrigation confers rather than to the cost of irrigation projects.'(28).

As far back as 1959, National Council of Applied Economics Research in their report have summarised that the only sound basis for fixing irrigation rates is the net additional benefit after irrigation over net benefit before irrigation. The condition of majority of cultivators who own small holdings is to be kept in mind by the State while fixing water rates.(72).

Table 1.1

Water Rates for Principal Crops in Various States of India for Flow Irrigation

Rs.per hectare

Sl. No.	Name of State	Rice	Wheat	Cotton	Sugar-cane	Garden Orchards
1.	Andhra Pradesh	74.13	49.42	49.42	74.13	-
2.	Bihar	40.76 to 77.80	33.45 to 44.46	-	122.27 to 211.19	25.92 to 40.76
3.	Gujarat	74.13 to 123.55	74.13 to 103.78	-	585.65 to 850.05	
4.	Haryana	49.42 to 74.13	19.77 to 61.78	29.65to 61.78	49.42 to 98.84	61.78
5.	Karnataka	49.42 to 74.13	44.48	44.48	197.69 to 296.53	88.96
6.	Madhya Pradesh	39.54 to 59.31	37.06 to 49.42	39.54	98.80 to 148.20	98.84
7.	Maharashtra	50.00 to 100.00	75.00 to 150.00	250.00	750.00	-
8.	Orissa	59.31	22.23	37.06	66.69	44.46
9.	Punjab	48.19 to 48.83	13.59to 29.13	32.54to 38.92	66.72 to 81.55	15.86 to 51.40
10.	Rajasthan	34.60to 61.78	29.65to 37.06	49.42to 61.78	74.13to 86.49	83.93
11.	Tamil Nadu	3.71 to 61.78	9.98 to 61.78	3.71 to 49.42	11.12 to 74.13	7.41 to 74.13
12.	Uttar Pradesh	41.83to 98.84	44.48to 99.84	9.88 to 39.54	34.69 to 197.69	14.38 to 99.84
13.	West Bengal	Kharif Rs.49.42, Rabi 59.30 and Summer 239.45 per hectare of any crop				

1.2.2 United States

The Bureau of Reclamation constructs irrigation projects and is responsible for proper use of the irrigation water including assigning rights and pricing. Irrigation projects were undertaken in the early 20th century to open up the arid west to settlers by providing land and irrigation facilities to make them economically viable. However the philosphy of such projects have been that costs should be repaid in full. The Reclamation Act 1902 required users to pay the construction cost in a period of 10 years. No interest is charged. However with passage of time, when costlier projects have to be taken up, the forms of repayment were made liberal. In 1914, this period was lengthened to 20 years and in 1926 to 40 years. The Act 1939 drastically revised the policy itself from repayment of cost to charges based on the concept of ability to pay (USBR 1972) (90), (Hanke and Davis, 1973),(37).

The Reclamation Project Act of 1939 authorizes allocated costs to be repaid from power revenues. This made possible to undertake more irrigation projects. Repayments are based on the irrigators' ability to pay over a period of 40 years. This Act also modified the criteria for feasibility. The Benefit Cost criteria with the underlying principle of 'benefits and costs to whomsoever they may accrue' is a bold step in this Act and revolutionised the project economics. The flood control and navigation costs are nonreimbursable.

The Act of 1962 provided for a development period upto 10 years, during which payments are deferred (90).

1.2.3 Though cost based pricing, more specifically marginal cost pricing has been advocated, its actual applicability has been rare specially under Govt. management.

The Canal de Provence Water Authority, a public utility company undertook the development of water resources of the Verden River in South France. The Company has adopted the theory of marginal cost pricing with the following characteristics -

i) a two parts tariff, with a capacity fee per litre/second and a charge for each cubic meter consumed.

ii) Higher rate for peak period use.

iii) Rate increase with the distance from the source.

The area is divided into three blocks for this purpose. Details of rates charged and the calculations for the variations are not available.

1.3 SCOPE OF STUDY

1.3.1 The complexities in evolving and adopting a rational pricing policy are many. Efforts have been made in this study to identify the various factors and their interaction affecting such a policy. This important problem cannot be dealt in an arbitrary and adhoc manner as its financial and management implications are quite large.

1.3.2 Pricing is an integral part of the economic systems. In the second chapter of this thesis, the various concepts available from economic theories and principles are analysed bringing out their relevance and applicability. The part played by the various economic and noneconomic factors are analysed to provide a framework.

1.3.3 Pricing can be cost based or benefit based. The implications of these alternatives are brought out. The concept of demand curve for determining value and its application to irrigation water has been studied in the third chapter. The Ramganga Multipurpose Project has been taken up as a case study for illustration. The value of water is obtained after the same is allocated to high value uses by optimization. The production function approach for water valuation and pricing is analysed. The concept of willingness to pay and ability to pay are also brought out.

1.3.4 Valuation of water in a multipurpose system is more complex. Highest possible value must be obtained by suitable planning strategies like conjunctive use of surface and ground waters. It has also been possible to improve on the value of water by evolving operating policy to maximise the net benefits from irrigation and power. Parametric linear programming is used for this purpose. The cost allocation for purpose of recovery are done. The above aspects including evolving price on the basis of cost, value and ability to pay are discussed in the fourth chapter.

1.3.5 Social equity considerations play a very decisive role in pricing. Risk and distribution of income have great impact on the measure of welfare. The fifth chapter deals with quantitative evaluation of risk inherent in irrigated agriculture using the expected income-variance framework. Quadratic programming is used for obtaining the efficient E-V frontier. A method has been evolved to compensate the smaller farmers who have low risk aversion capacity and hence lower mean income.

1.3.6 The sixth chapter deals with the social objective of income distribution, which is of paramount importance in developing countries. Analytical framework for deriving the extent of preferential treatment and the values of such weightages is developed. A method of redistribution has been suggested such that there is no reduction in the pricing revenue but results in an equitable distribution of the benefits among the various groups of beneficieries categorised as small, medium and large farmers. Basing on the risk and income distribution, discriminatory pricing has been derived. The impact of pricing on regional development and economic growth are broughtout.

1.3.7 The pricing policy evolved is based on the framework for equitable sharing of the benefits from the use of irrigation water among all the participants viz. The government who constructs and manages the system and the farming community who use the water not only for their own gains but also contribute to the national objectives. Further sharing of the benefits among various economic sections of the users is made considering the social preferences. The impact of pricing on cost recovery is brought out. All these aspects are included in the concluding chapter. Conclusions and suggestions for further studies are made.

CHAPTER-2

OBJECTIVES OF PRICING

2.1 GENERAL

Pricing of irrigation water is of considerable interest to planners. Price refers to the monetary value of the commodity at which it can be freely traded. Equity requires that users of irrigation water pay for its use. However there is no clear policy pronouncement regarding pricing of irrigation water. Even the ' Principles and standards of water and related land resources' of Water Resources Council USA,(92) has not been able to provide any specific policy statement in this respect. The following is the extract of the relevant portion.(92,P.18).

> ' Reimbursement and cost sharing policies shall be directed generally to the end that identifiable beneficiaries bear an equitable share of cost commensurate with beneficial effects received in full cognizance of the planning objectives. Since existing cost sharing policies are not entirely consistent with this approach to planning water and land resources, these policies are being thoroughly reviewed after which changes will be recommended '.

Planners and economists have laid great emphasis on a rational pricing policy. Efforts made in this regard so far have not brought out any specific policy guidelines. This itself shows the large complexities involved in the process. Socio political forces have kept the water prices low. How far such low prices are rational must be evaluated with specific criteria for evaluation. It is said that low pricing of water has been responsible for inefficient use of the water resources.

2.2 ROLE OF PRICING

For evolving a suitable pricing policy, it is necessary to have a complete understanding of the role it plays in the overall context of water resources development projects and its impact on the objectives of development. The pricing policy must be compatible with the objectives of project investment. The effect of pricing on the various activities both economic and noneconomic should be clearly brought out.

Fig.2.1 presents a flow chart showing the various steps involved in the planning and implementation of WR Projects. The chart also shows the various activities which are affected by pricing of the output. The interdependancies and linkages are also shown. The purpose of a water resource project is to change the water availability in a stream both in space and time by construction of storage reservoirs, diversion headworks etc., so that the water resources could be put to more beneficial use. In this process physical features like dams, barrages, canal system are provided. These measures consume resources like land, labour, and capital. The primary output from a project is irrigation water, hydroelectric energy, flood damage mitigation etc. Most of these primary outputs of the project are in the form of intermediate goods. Irrigation

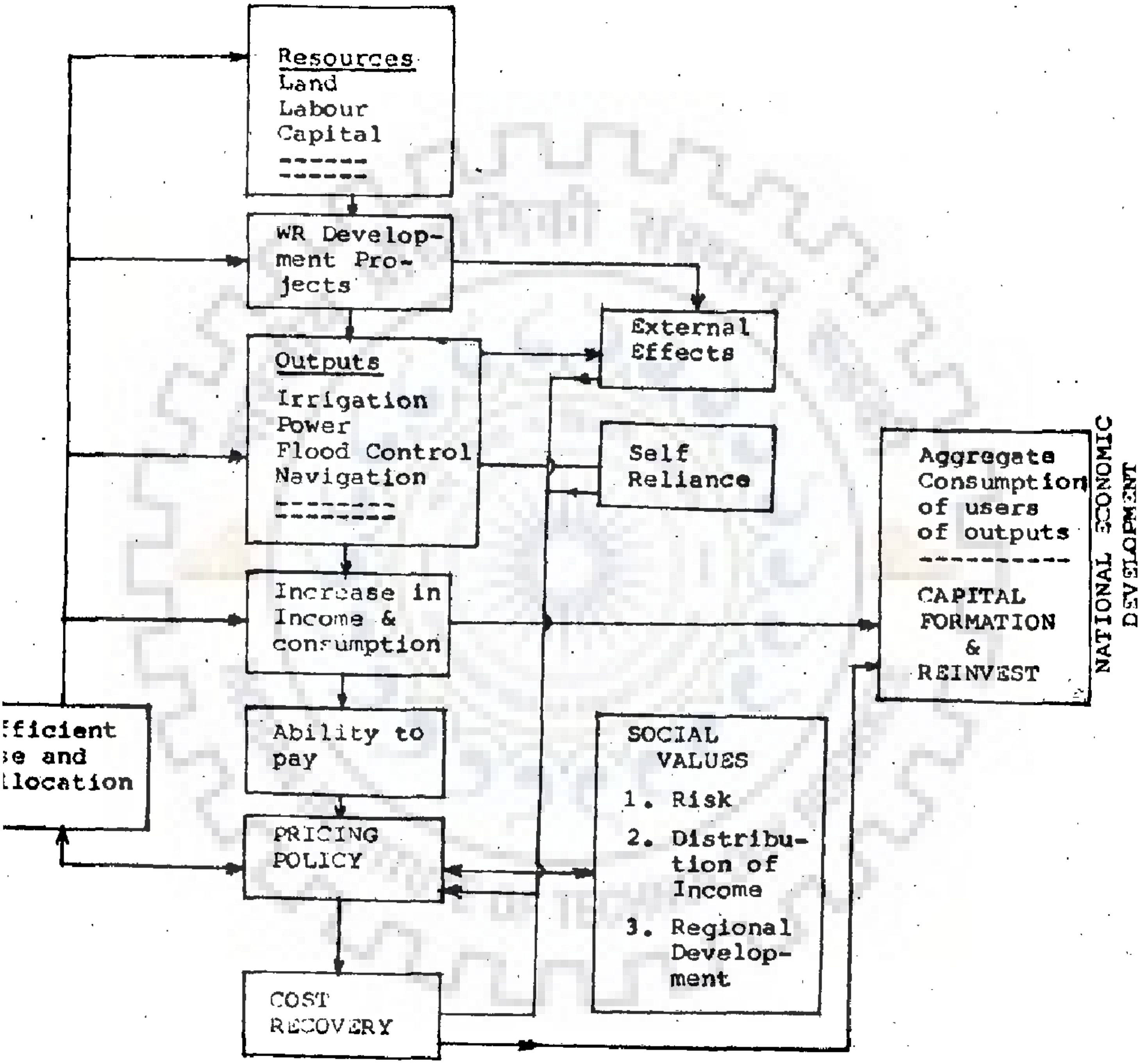


Fig. 2.1 FLOW CHART: WR PROJECT OUTPUT PRICING

water is again used as an input to irrigated agriculture, to produce marketable consumer products. The problem is to determine what price is to be charged to this primary output viz. irrigation water.

As a matter of social equity, it is considered necessary that the persons who benefit from public investments should pay for these services or contribute towards the cost of these services. Of course this obligation may not apply when the beneficiaries or the users cannot be easily identified or segregated, also when objectives other than economic development are included. (Howe, 1971) (40). It is often presumed that the pricing scheme will substantially affect the total quantities of water used, and the time pattern of water use. The pricing also affects the financial receipts of the undertaking. Before trying to evolve a pricing system, it is felt necessary to review the general economic principles of pricing and consider their applicability to water.

2.3. ECONOMIC CONCEPTS

The purpose of economic theory is to provide the goods and render services that people want. Such theories are very general in concept and provide the basic framework for further analysis. The best economic system supplies the most of what is wanted most (Galbraith, 1974) (26). In a perfect market situation pricing has a very important function. Pricing allocates goods and services among those who desire them.

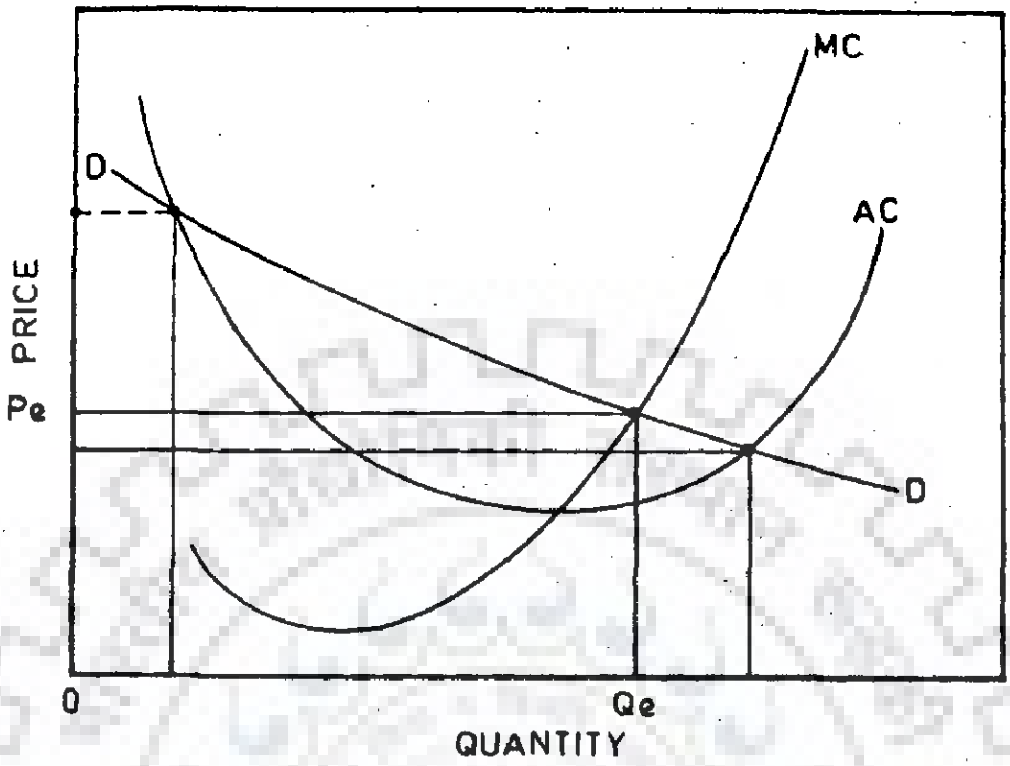
Proper pricing discourages excessive consumption of a commodity and induces desired supply of the commodity. A competitive pricing system signals producers with regard to the goods and services which consumers want, thereby stimulating producers to allocate optimally the resources of production among alternative uses. The usual market mechanism considers the objective of economic development to attain economic efficiency.

2.3.1. Marginal Cost Pricing

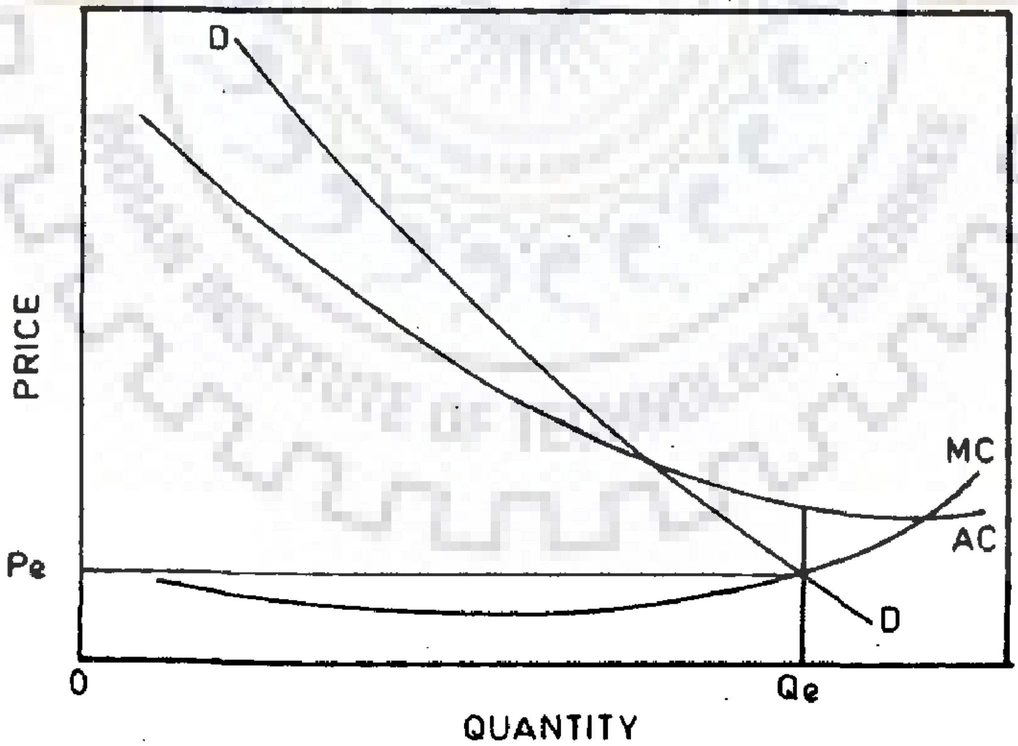
In the theory of markets, economic efficiency is achieved under a system of marginal cost pricing. The most desirable level of output for a competitive firm is the one at which the price is equal to the marginal cost of production. Incremental output will be produced only if there is demand to clear this additional output by payment of the full cost of producing this additional output.

The most efficient price is located when the marginal cost curve intersects the demand curve as shown in Fig.2.2. This concept is same as the equilibrium price concept, since marginal cost curve is nothing but the usual supply curve of the firm.

Planners usually advise that the outputs of government projects should be priced at their short run marginal cost of production (Herfindahl and Kneese, 1974) (38). In the Fig.2.2, marginal cost is represented by curve MC, the demand is represented by line DD. The most efficient price is Pe, the equilibrium price at the level of production of Qe. Marginal cost



(a) RISING AVERAGE COST



(b) FALLING AVERAGE COST

FIG. 2·2- MARGINAL COST PRICING

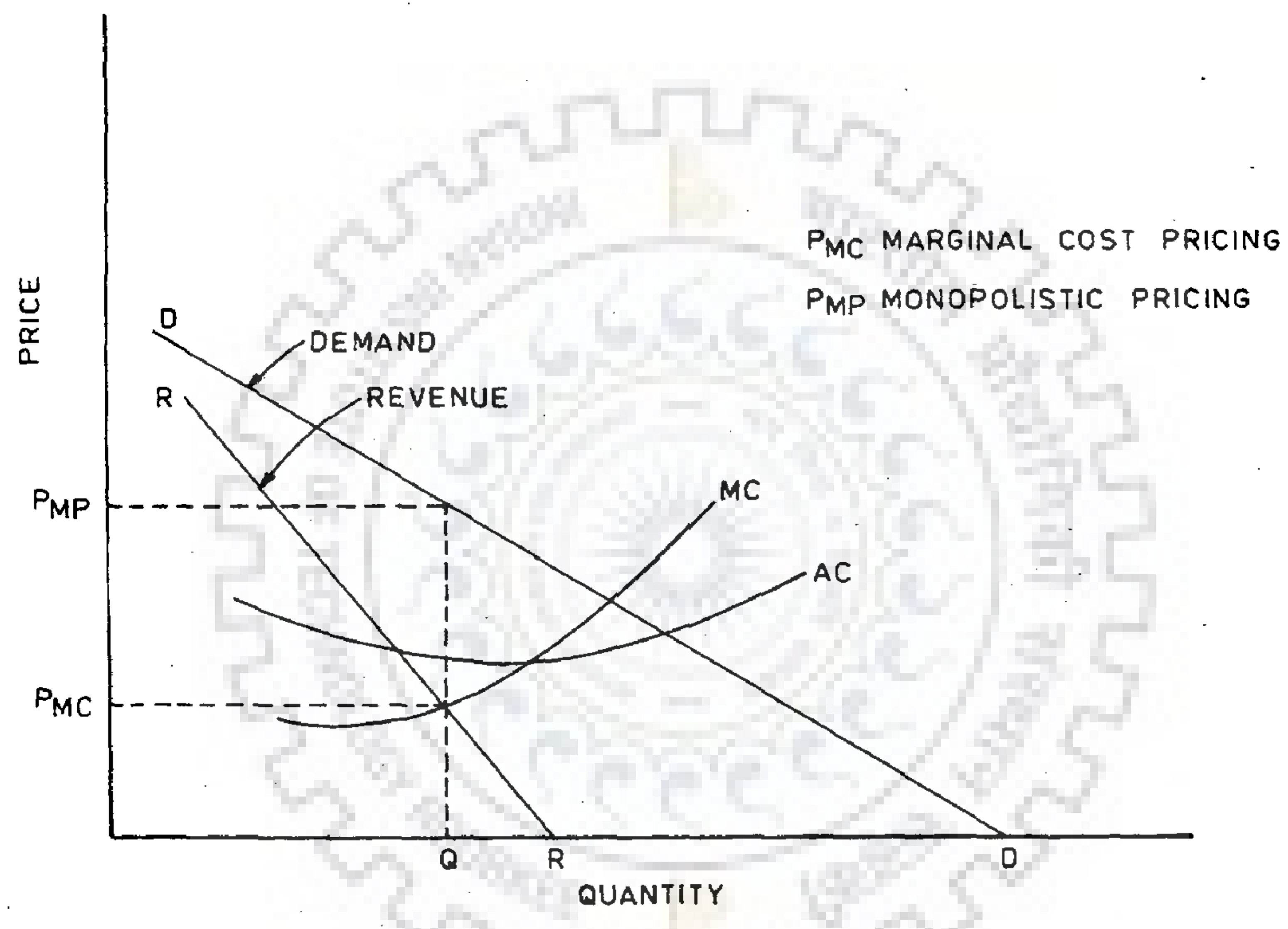
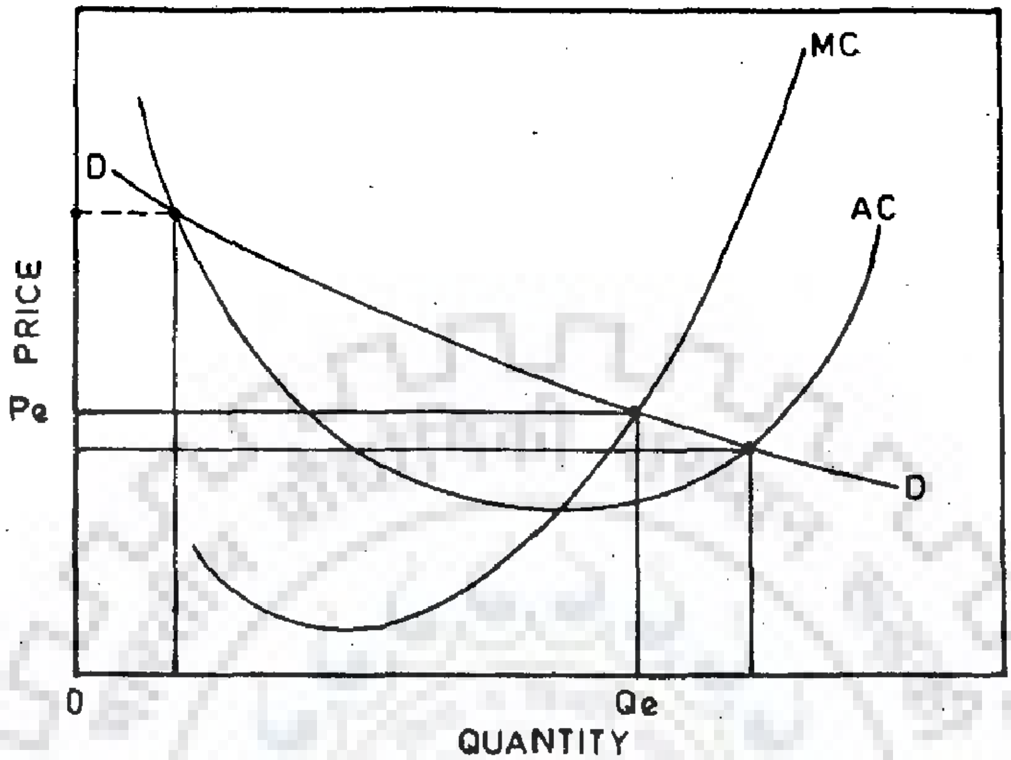
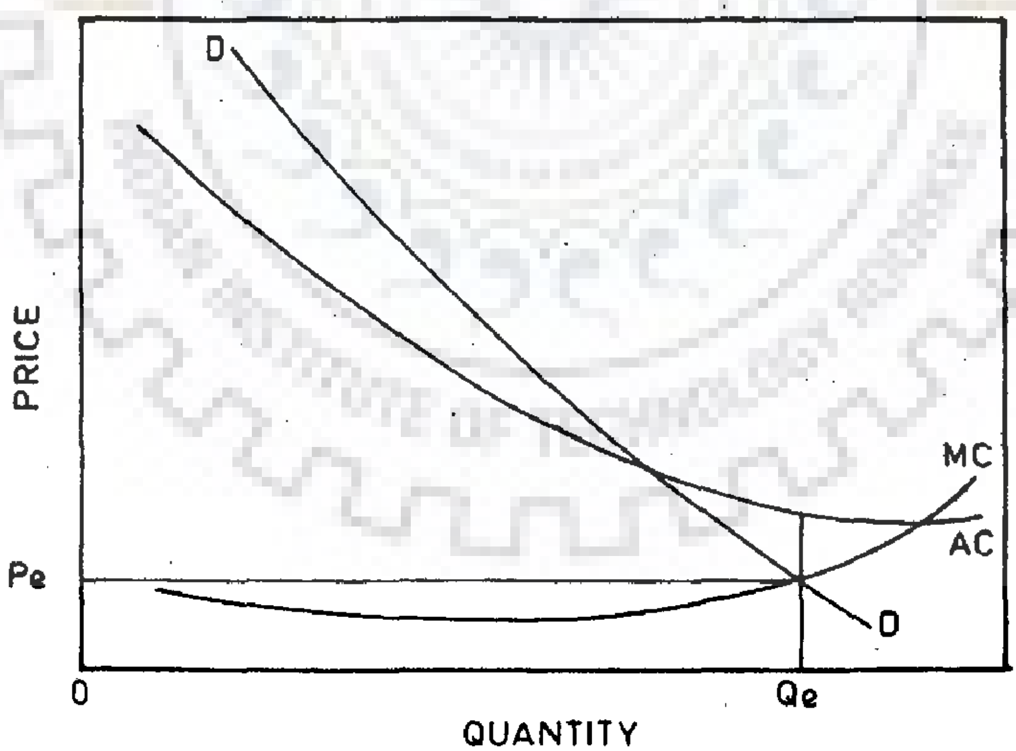


FIG 2·3 MONOPOLY PRICING



(a) RISING AVERAGE COST



(b) FALLING AVERAGE COST

FIG. 2·2- MARGINAL COST PRICING

pricing, ensures that the scale of development is optimum. However marginal cost pricing is not a direct vehicle for recovery of cost. The marginal cost depends on the type of enterprise and the shape of the MC curve, which can have any shape depending on the economy of scale, a characteristic of the particular enterprise. The average cost (AC) curve has a direct bearing on the aspect of cost recovery. With marginal cost pricing, two cases are encountered. In case of increasing cost industry, in which the marginal cost curve is above the AC curve and on the rising limb, the cost recovered is more than the capital cost and the firm is left with a definite profit. In such case the total revenue exceeds the total cost. In case of a decreasing cost industry, the MC curve is below the AC curve. Charging marginal cost fails to recover the cost (Fig.2.2).

2.3.2 Monopolistic Pricing

Hoggan et al (1976) (43) have advocated monopoly pricing when the objective is to recover the cost. Under pure monopoly conditions, there exists a single seller of a particular product for which there are no good substitutes (Leftwich, 1960) (56). Also changes in prices and outputs of other goods sold in the economy does not affect the monopolist and his products. Water resources development is usually concentrated in the public sector, it may therefore be worthwhile to consider the public sector as the monopolist to examine the economic principles behind monopolistic pricing.

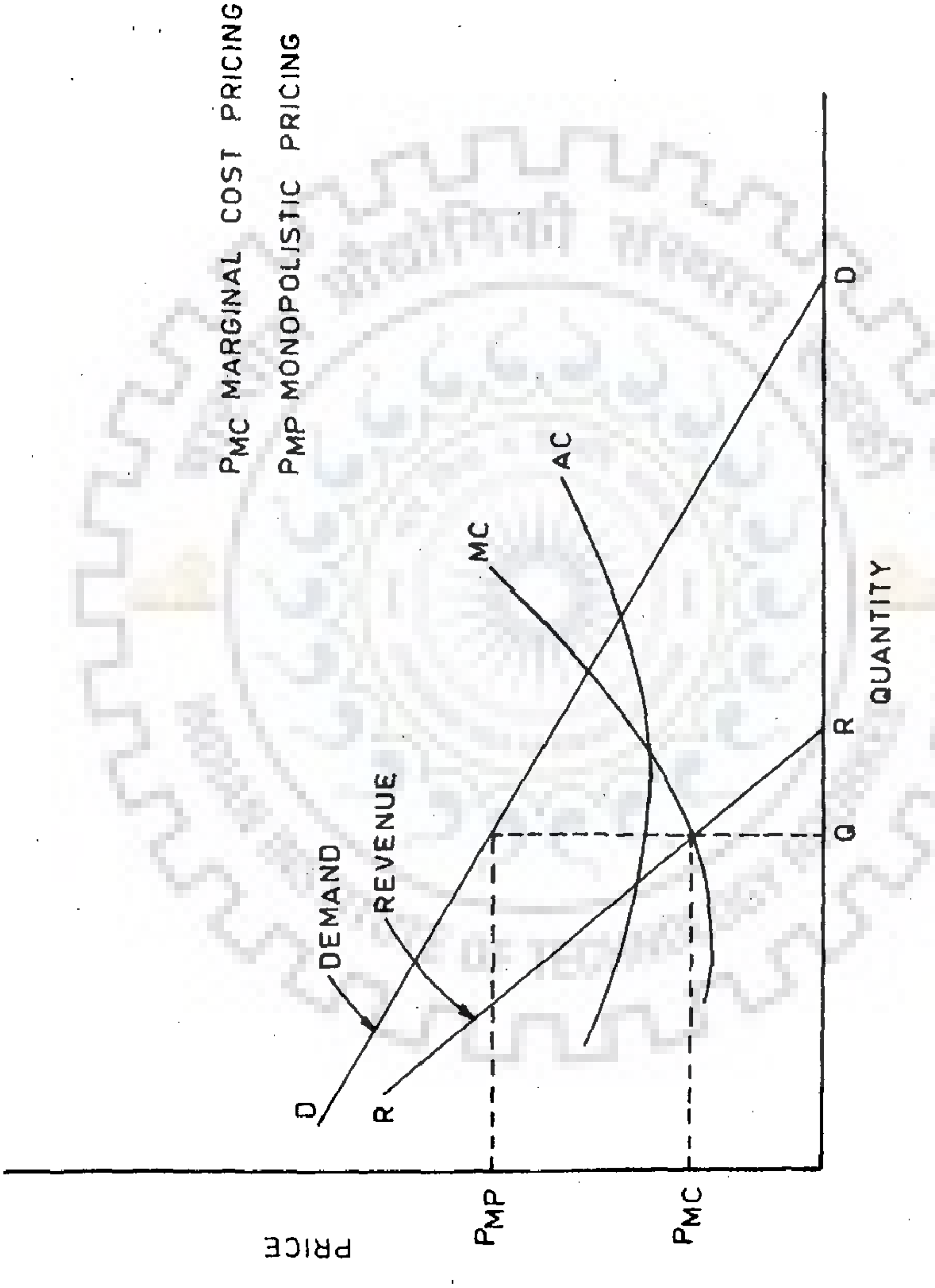


FIG 2.3 MONOPOLY PRICING

In a monopoly situation, the price of the good is artificially raised by the monopolist and this restricts higher level of production. The price charged is equal to marginal revenue instead of the marginal cost (Fig.2.3). If marginal cost is less than marginal revenue, additional units of production decrease profits. When the primary objective is to raise money or profit maximisation, monopoly pricing is the most effective. However, from the view point of the consumers, it is the least desirable system. The monopolist builds a less than optimum scale of plant. Monopolistic pricing can be adopted for marketing nonrenewable resources where conservation is desired. When the Govt. is the monopolist, then two options are open :

i) The Scale of development is decided by other consideration, viz. marginal benefit equals marginal cost. Pricing also need be done from consideration other than raising money.

ii) In case of stock resources, it is necessary to restrict its extraction. Monopoly by Govt. ensures conservation of the resources. Pricing need not be on the basis of monopolistic situation, but on the basis of marginal cost. Since at the marginal cost pricing, the demand will be higher than the production, rationing has to be introduced. Such a system is vogue in India for cooking gas, electrical energy; sometimes for coal, fuel oil etc.

2.3.3 Average Cost Versus Marginal Cost Pricing

Marginal cost price is instrumental in clearing the market but may not result in recovery of full cost in a desirable way. Average cost pricing ensures ' full cost recovery' but may result in nonoptimal development or utilisation. Hence in either of the cases some more considerations must be taken to ensure both economic efficiency and cost recovery.

The above principles for pricing are based when prices are determined on cost basis. Such pricing is a characteristic of both private and public enterprises. Some economists advocate short run marginal cost pricing where the objective is to clear the market. In an existing irrigation system, the short run marginal cost is equal to the operation and maintenance charges which are normally a very small part of the project costs. The short term approach assumes that the capacity of the project is fixed and that the price and output management are aimed at making the best use of that capacity. Short term approach does not result in full cost recovery and the investor is left with a negative balance.

Full cost pricing requires determining prices so as to cover average costs and sometimes to include a return on the capital as well. Long term marginal cost pricing provides necessary framework for this purpose. In case of industry, the new plant pricing is a form of longrun marginal cost pricing (Shone, 1975) (83).

2.3.4 Short-run vrs Long Run

Short term marginal cost pricing would vary from project to project and also in the same project from one location to another. The quantum of information required to pursue such a policy on the part of the project authorities is enormous. Such prices are volatile and unstable as these have to be adjusted to changing conditions. Short term costs also do not reflect the true cost of providing the facility.

Prices fixed with long term considerations are normally insensitive to cycling fluctuations in demand. These respond only to gradual changes as brought about by technological developments and other policy considerations. Such prices are stable. Long term pricing is suitable for both public and private enterprise where maximizing growth is the priority objective rather than immediate profit maximization (Galbraith, 1974). (26).

2.4 PRINCIPLES OF WATER PRICING

Bergmann and Boussard (1976) (4) have summarized the various principles of irrigation water pricing as follows on the basis of specific objectives -

i) To cover only the working costs of the system.

ii) To provide total or partial reimbursement of public investment and to cover the working expenses.

iii) To charge marginal cost

iv) To allocate the benefits of irrigation between farmers and the community at large.

The first three cases are based on cost, whereas the fourth is based on benefits. According to the economic models discussed, the first case relates to short term marginal cost pricing with intention of charging only the working expenses. The price of water is comparatively low and therefore includes a subsidy. The second case considers cost reimbursement taking into account the capital investment as well. This is similar to the average cost pricing principle. The third case is the usual marginal cost pricing which would in this case mean the long term marginal cost.

The last case refers to charging on the basis of benefits. The increase in agricultural income resulting from irrigation projects is usually quite substantial and it is but natural that the users pay (or part with) a portion of this increased income towards the services provided.

From the foregoing discussions, it is apparent that charging can be either cost based or benefit based. A third category can be a combination of both.

A review of literature suggests that though there are clear economic theories available for pricing, a consensus on a systematic frame work for water pricing is still far away.

At this stage it is necessary to examine the special characteristics of ' irrigation water ' to apply the appropriate philosophy. The economic theories are based on a proper market situation. It is necessary to identify the market imperfections so that these can be duly taken care in further analysis. These are discussed below -

i) Irrigation water is not a marketable good. It is an intermediate good and is used as an input in a further production process viz. irrigated agriculture.

ii) There is lack of well defined property rights.

iii) Irrigation water can be recycled. It is therefore difficult to use a common unit of usage.

iv) The commodity has the nature of a public good(Loucks, 1981) (61).

v) Large externalities are associated.

In the absence of market prices for irrigation water, cost based pricing is not considered rational. Cost based pricing is suitable where there is a well defined demand for the good. Since irrigation water is an intermediate or producer good, its demand would depend on the profitability of the subsequent production process. Hence benefit based pricing is considered more rational and realistic. The policy statement of principles and standard also stresses pricing based on benefits. We cannot ask the farmers to pay for any mistakes of the Planners and Engineers. So cost based pricing is not considered correct.

In the benefit based pricing, it is necessary to determine the value of water in the production process. Young and Bredehoeft (1972) (99) in their economic model to simulate the response of irrigation water users to variations in water supply and costs, have also used this concept. ' The response of the water using firm to alternative supply and cost conditions depends on its production possibilities and on the revenues and costs associated with these conditions. The concept of willingness to pay is the most rational of imputing value of intermediate goods. The concept and procedure evolved for the purpose are discussed in the subsequent chapters. Though willingness to pay is a realistic method for evaluating benefits from use of irrigation water, for purpose of pricing, some additional considerations need be taken into account. The concept of ability to pay takes into account such other factors and is a measure of the price that can be charged. This has been detailed in the next chapter.

Ability to pay pricing is not the end of this exercise. Pricing has much larger role to play and has to satisfy other relevant objectives. Ability to pay pricing serves the most important function of pricing. A user of irrigation water will not use water unless he is able to pay for, the same purpose served by marginal cost pricing. By ability to pay pricing, the available water will be utilised. Efficient use of water would result in release of water for more additional area. This is equivalent to construction of new project or creation of additional capacity resulting in conservation of resources. This is shown by the linkage on the left side of the flow diagram.

Traditionally, investments in water resources sector in general and in irrigation development in particular, are made by the public sector. The political philosophy behind this is that irrigation development has large developmental impact on the society. In other words, investments in water resource projects produce widespread economic benefits and has multiplier effects. Other arguments in favour of public investment are that such projects have large impacts on other social objectives like (a) income distribution, (b) social well being, (c) merit wants, (d) economic growth and regional development. WR projects have also large externalities. The outcome of a WR project is such widespread and diverse that it is very difficult to identify the actual beneficiaries and to charge them for the services rendered. The secondary outputs are not easily identifiable and directly marketable. Hence private investment is practically excluded except very small enterprises like tubewells where the outputs are somewhat controllable.

The investment in public WR projects is fruitful only when the output of the project is fruitfully utilised by the users. In irrigation projects the user farmers have large responsibility in proper utilisation of the created potential. In other words, the investor and the user are partners in the progress. The expectations of both the partners should be considered. The benefits from the enterprise must be equitably shared by the two partners. The expectation of the investor is to recoup as much of the capital as possible including a suitable return. The users expect to be fully rewarded for their efforts in this regard. While meeting these expectations it is to be ensured that the original objectives of development including economic development are not sacrificed.

2.5 SOCIAL OBJECTIVES

In addition to the above economic efficiency criteria, the pricing must take into consideration social and political values. The single most important reason for want of a rational pricing policy is that the farmers do not have the ability to pay, specially the small farmers. However it can be said with certainty that much of the benefits from lower pricing go to large farmers. With irrigation development, the general income of all farmers go up. However the increase in income of large farmers is much more than small farmers, with the result that the disparity in income increases. The pricing policy must consider distribution of income and equity as one of its important objective to make acceptable to the social and political values.

Crop production and specially irrigated agriculture involves large number of activities as well as uncertainties regarding the prices of food grains. Any pricing of irrigation water must consider the risk involved and provide suitable risk discount in the chargeable price of water.

For public investments and even for large industrial enterprises, the long term objective is not only of maximizing profit but should provide a suitable framework of growth.

In case of public investment, the growth would mean economic growth and may not be confined to the growth of the specific sector only. In any case growth would mean reinvestment of the return. Income by the Govt. is considered more desirable than the money accruing to the private beneficiaries. The reinvestment by Govt. has a larger perspective of nation building. Hence recovery of as much cost as possible with a view for reinvestment and economic growth is a very relevant objective of pricing.

The interdependency between ability to pay and recovery of cost need be properly identified. Projects with larger ability to pay are therefore more desirable. This aspect need be reflected in the process of economic evaluation and consequent selection of projects. Higher pricing has adverse effect on the objective of regional development since the revenue collected goes to the Govt. treasury and the nation at large. Suitable institutional measures could be devised to reflect the objective of regional development in the pricing policy to make it acceptable by user region.

2.6 SUMMARY

From the discussion of the overall system of WR development project, the following objectives are considered most important from the view point of evolving a pricing policy.

1) Efficient use of the resource viz. irrigation water
2) Equitable sharing of benefits
3) Income distribution and social equity
4) Economic growth and regional development.

These objectives have been explictly considered in evolving a pricing policy in the subsequent chapters.

CHAPTER-3

ECONOMIC VALUE OF WATER

3.1 INTRODUCTION

It was shown in Chapter-2 that for intermediate goods, value based pricing is more rational. A proper evaluation of value is of paramount importance. Marglin (1966) (66) has defined value as the amount that a perfectly rational user of a publicly supplied good would be willing to pay for it. The value of intermediate goods and services is measured by their total value or productivity as inputs to the producers (here the users of irrigation water) of the final consumer products (here agricultural produce). The intermediate product from the plan enables the producers to increase production of final consumer goods and in the process there is increase in net income. Value, which reflects the users' willingness to pay, is in turn represented by a demand curve relating the quantity of good taken at a series of different prices.

3.2 DEMAND CURVES

The concept of demand curve is the focal point in economic theory. This concept has been advocated by planners for measuring the benefits (value) of outputs of a firm. The aggregate consumption or the national economic benefits are considered as the addition in the use of the output valued in terms of willingness to pay of the users. In practice, it is not possible for the planner to measure the actual demand situation. The values are to be imputed. The alternative imputation techniques are discussed here.

3.3 METHODOLOGY

3.3.1 Residual Imputation

Irrigated agriculture can be considered as a production process. Water is one of the various inputs. The concept of residual imputation is based on two postulates -

1) the market prices of all other inputs are equal to its value marginal productivity (VMP)

2) the total value of output can be divided into shares assigned to each input as per its marginal productivity, and the output is completely exhausted. This postulate is the well known Euler's theorem (Herfindahl and Kneese 1974) (38).

Considering a production process requiring n inputs, quantity of each input Qi, and representing in a mathematicl form, the total value product

$$T\ V\ P = \sum_{1}^{n} VMPi\ .\ Qi$$

$$= \sum_{1}^{n-1} VMPi.\ Qi + VMPn.\ Qn.$$

$$\text{or}\quad VMPn.\ Qn = TVP - \sum_{1}^{n-1} VMPi.\ Qi.$$

Where the n^{th} input is irrigation water whose value is not known and is to be imputed. The VMPn is the marginal value product for unit of water and represents the value or the willingness to pay of the user. While using the procedure of residual imputation, some of the assumptions and pitfalls should be borne in mind (Young 1979) (100).

i) If any of the variable resource is inadvertently omitted or not adequately accounted for, its contribution gets assigned to water with consequent increase in the value of water.

ii) If any of the inputs are subsidized or there is price support to commodities, the value of water gets inflated.

iii) Euler's postulate holds good under ideal conditions at a particular level of resource use and for a particular mix of inputs.

iv) The assumption that the marginal productivity of other inputs equal their marginal productivity is seldom achieved for want of proper information as well as other uncertainties inherent in agriculture.

3.3.2 Alternative Cost Approach

The principle of alternative cost for valuation of a commodity has been widely used. It is normally possible to obtain the same outputs by alternative means, which may be substantially different from the one under consideration. The cheaper of the two alternatives will naturally be selected. The benefits from the plan selected is limited to the cost of the next cheapest alternative that would have been taken up in absence of the project selected. For example, it is possible to obtain irrigation water by ground water pumping as an alternative to surface water supply. The value of surface water would therefore be limited to the cost of providing the same from ground water pumping.

3.3.3 Out of the above two methods, the alternative cost approach is resorted to as a last resort. However it is always desirable to limit the benefits to the alternative cost. The residual imputation method is suitable and is same as the value added approach recommended in the Principles and Standard,(1973) (92) for imputing the value of agricultural water supply. In principle this measures the maximum willingness to pay for project water of the direct beneficiaries and hence the contribution to national income.

3.4 INDIVIDUAL AND AGGREGATE DEMAND CURVES

Unlike flood control a public or common goods, irrigation water for purpose of deriving the demand curve is an individual good. Demand curve can be synthesized for a individual farm, for an irrigation system,for a project or a region by summation. The smallest unit is the farm. The individual demand curve of a farmer for irrigation water, shows the relationship between quantities of irrigation water, the farmer would use and the amount he is willing to pay. As is the usual characteristic of demand curve, it slopes downwards since successive incremental quantities have lower values. To determine the aggregate demand curve of a project, the first step is to determine the individual demand curves. Because of the very large number of farms situated in the command of a project, it would be an Herculean task to obtain such large number of individual demand curves. To simplify the procedure, a representative farm is taken for analysis. If the representative farm averages out the behaviour of all the farms, then the demand patterns would be identical.

The demand curve of an average farmer of size A is represented by **DfDf** with a maximum demand Qf and maximum price of Pf vide Fig.3.1. If there are n such farms or when the total area served by the Project is n. A, the project demand curve is given by D_p D_p with maximum quantity of Qp(= n.Qf) but have the same maximum ordinate of Pf. The derived demand curve is the normative demand curve, its derivation being based on the theory of firm. While deriving the demand curve, it is assumed that quantities and prices of all other inputs remain unchanged with use of varying quantity of water.

3.5 MATHEMATICAL MODEL

Demand curve can also be defined as depicting the maximum price that a rational user is willing to pay for use of a specified quantity of water. This definition leads to formulation of an optimisation model. The objective is to maximise the willingness to pay at a particular level of water use.

$$\text{Max } Z = CX$$

$$\text{Subject to } AX \leq B$$

$$X \geq 0$$

The vector C is the willingness to pay when water is used for irrigated crops. The constraint set inter alia can include apart from ensuring the adequacy of water to meet the crop water requirements, land constrains can set a limit to water quantity. Variable resource programming is done by changingthe quantity of water to obtain various points in the demand curve.

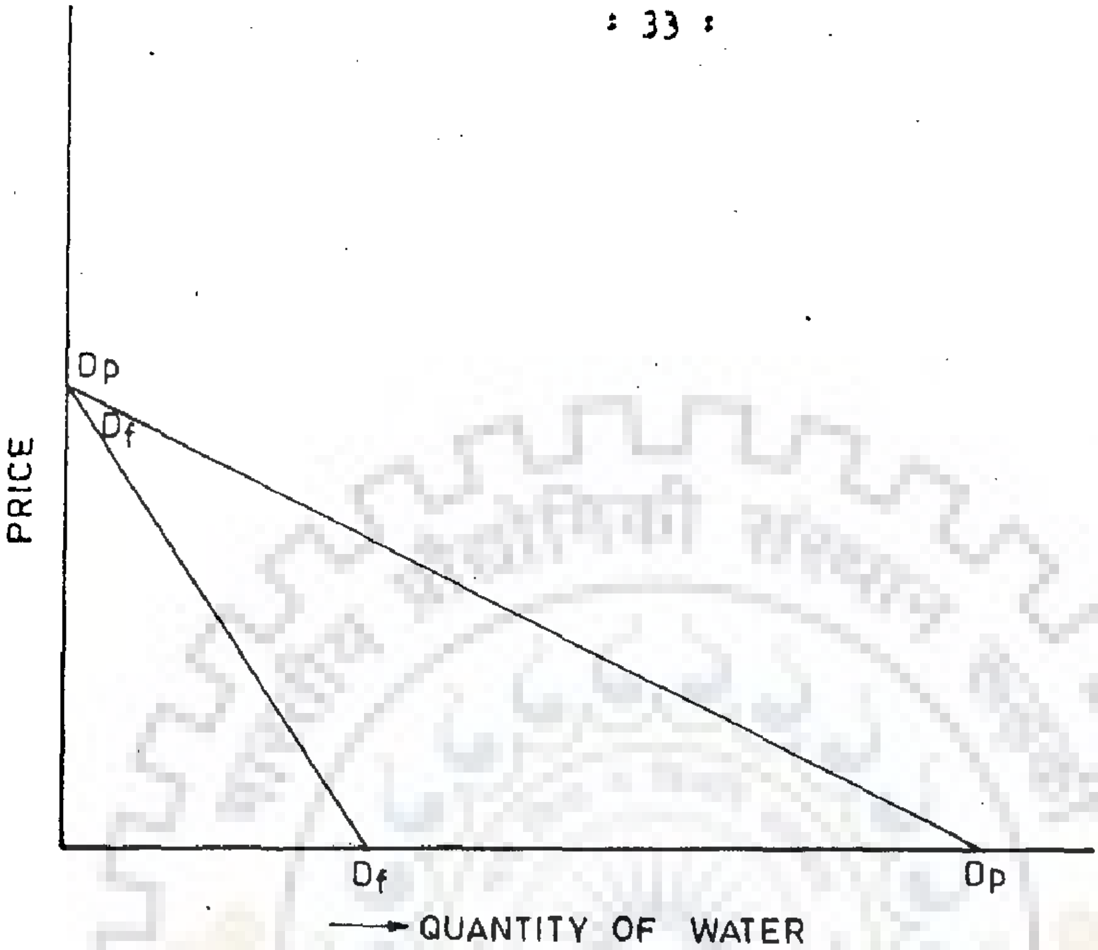


FIG 3·1 INDIVIDUAL & AGGREGATE DEMAND CURVES

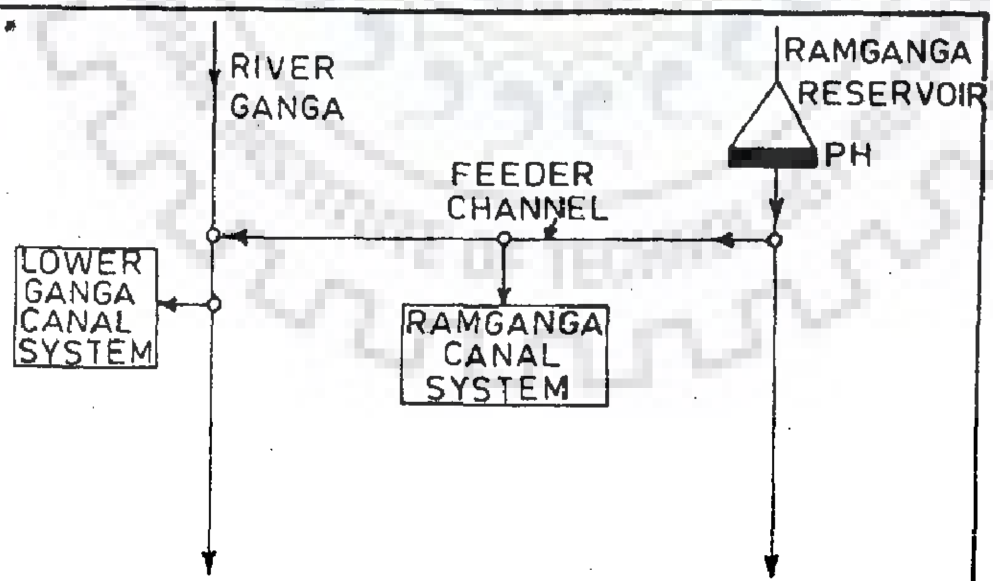


FIG 3·2 SCHEMATIC DIAGRAM

3.5.1 Seasonal Demand Curves

The quantity of water required varies from month to month. When water has competitive use e.g. for generation of hydropower, seasonal demand curve can be used to determine the releases each period from a multipurpose reservoir such that the benefits from multipurpose use is maximised. Efforts were therefore made also to determine the monthly demand curves. The actual model and its application to the project under study are detailed in the subsequent paragraphs.

3.6 CASE STUDY

The demand function of water for irrigation from the Ramganga Reservoir is proposed to be derived. The salient features are given vide Appendix to this Chapter. The Ramganga reservoir is primarily meant to stabilise and intensify irrigation of the lower Ganga Canal system. This system receives its water from the run-of the river flow of River Ganga. The flow during the monsoon season from June to November are quite high. The reservoir releases are for intensifying rabi cultivation from December to May. The schematic diagram is shown vide Fig.3.2. The operation of the reservoir has therefore two distinct periods viz. the filling period from June to November and release period from December to May. The reservoir is expected to be full by end of October.

3.6.1 Reservoir Yield

When the available stream flow record is of short duration, it is possible to generate from this record, additional ' equally likely sequences' for larger periods. The synthetically generated sequence and the historical data have the same statistical properties. The mean, standard deviation, skew and serial correlation for the two series are presumed to be same. Number of mathematical models are available for the purpose. The Thomas Fiering model has been used in this case.

Stream flow data is available for a period of 17 years from 1961 to 1977 and are analysed. Generation of flow sequence for a period of 40 years is done by the Natural Series as well as the Square root series. The Natural Series is selected for use. The annual flows are analysed by frequency analysis and the 75 percent dependable annual flow is obtained and is found to be 1907 MCM. The monthly distribution of this annual flow is done in the same proportion of the average annual flow (Table 3.1).

The Ramganga reservoir has an active utilisable storage of 2165.5 MCM. Considering the 75 percent dependable flow and the evaporation losses it is found that the annual yield of the reservoir is 1907 MCM.

3.6.2. Irrigated Area

This model considers the impact of the Ramganga Reservoir on improving the irrigation system of the area served

Table 3.1

Mean Monthly Inflow to Ramganga Reservoir

Month	Historical flow series	Generated Flow Series		75% dependable flow*	Remarks
		Natural series	Square root series		
January	53.72	63.52	65.99	55.90	
February	66.75	73.33	68.25	64.53	
March	57.00	61.54	60.32	54.16	
April	36.32	41.90	38.31	33.71	
May	30.80	34.10	31.83	30.00	
June	87.20	94.42	93.26	83.09	
July	448.27	454.26	452.48	399.75	
August	636.48	607.37	615.96	534.49	
September	515.96	485.77	486.33	427.48	
October	147.08	135.55	134.06	119.28	
November	72.25	66.65	65.86	58.65	
December	53.43	49.67	48.32	43.71	
Total	2205.3	2168.08	2160.87	1907.00	

Project Efficiency = 0.45 Normalised Annual Yeild = 1907x0.45
= 850 MCM

*Based on frequency analysis of the Natural Series.

Table 3.2

Planned Irrigation in Lower Ganga Canal System

		Area in 10^3 Ha	
		Without Ramganga	With Ramganga
I	Kharif	179	348
II	Rabi		
	i) Wheat	198	282
	ii) Barley	30	43
	iii) Gram	46	65
	iv) Oilseeds	30	43
III	Perrinneal		
	Sugarcane	22	61
	Annual Irrigation	505	842

Table 3.3

Net Income from Irrigated Farming

Rs./ Hectare

Sl. No.	Item	Unit	Wheat Qty.	Rate	Amount	Oilseeds Qty.	Rate	Amount
1	2	3	4	5	6	7	8	9
1.	Fixed costs							
i)	Seeds	kg.	80	2.50	200.00	6	15.00	90.00
ii)	Fertilizer							150.00
	DAP	Kg.	40	2.60	104.00			
	NPK	Kg.						
	Potash	Kg.	20	1.20	24.00			
	Urea	Kg.	50	2.20	110.00			
iii)	Plant Protection	LS			50.00			30.00
iv)	Labour							
	a) Human	Days	80	6.00	480.00	60	6.00	360.00
	b) Bullock	Days	30	25.00	750.00	15	25.00	375.00
v)	Implements				50.00			30.00
vi)	Land rent				50.00			50,00
vii)	Miscellaneous				22.00			30.00
	Total				1840.00			1115.00
2.	Variable costs							
i)	Harvesting, threshing	Q	30	15.00	450.00	7	30.00	210.00
ii)	Irrigation labour				100.00			40.00
	Total				550.00			250.00
3.	Total cost of cultivation				2390.00			1365.00
4.	Value of Produce							
i)	Main Produce	Q	30	120.00	3600.00	7	350.00	2250.00
ii)	By products							
	Total				3600.00			2250.00
5.	Net Income				1210.00			885.00

Table 3.3 (Contd.)

Sl. No.	Item	Unit	Pulses			Potato		
			Qty.	Rate	Amount	Qty.	Rate	Amount
1	2	3	10	11	12	13	14	15
1.	Fixed Costs							
i)	Seeds	Kg.	10	6.00	60.00	200	15.00	3000.00
ii)	Fertiliser				105.00			750.00
	DAP	Kg.						
	NPK	Kg.						
	Potash	Kg.						
	Urea	Kg.						
iii)	Plant Protection	LS			30.00			150.00
iv)	Labour							
	a) Human	Days	50	6.00	300.00	200	6.00	1200.00
	b) Bullock	Days	12	25.00	300.00	15	25.00	375.00
v)	Implements				30.00			50.00
vi)	Land rent				50.00			50.00
vii)	Miscellaneous				40.00			75.00
	Total				945.00			5650.00
2.	Variable Costs							
i)	Harvesting, Threshing	Q	7	25.00	175.00	300	4.50	1350.00
ii)	Irrigation labour				50.00			50.00
	Total				225.00			1400.00
3.	Total cost of cultivation				1165.00			7050.00
4.	Value of Produce							
	i) Main Produce	Q	7	300.00	2100.00	300	30.00	9000.00
	ii) By products							
	Total				2100.00			9000.00
5.	Net Income				935.00			1950.00

Table 3.3(Contd.)

Sl. No.	Item	Unit	Gram Qty.	Gram Rate	Gram Amount	Sugarcane Qty.	Sugarcane Rate	Sugarcane Amount
1	2	3	16	17	18	19	20	21
1.	Fixed costs							
i)	Seeds	Kg.	50	4.00	200.00	100	15.00	1500.00
ii)	Fertiliser				190.00			
	DAP	Kg.				100	2.60	260.00
	NPK	Kg.				300	2.10	630.00
	Potash	Kg.				400	0.90	360.00
	Urea	Kg.				80	2.20	176.00
iii)	Plant Protection	LS			30.00			70.00
iv)	Labour							
	a) Human	Days	40	6.00	240.00	170	6.00	1020.00
	b) Bullock	Days	15	25.00	375.00	40	25.00	1000.00
v)	Implements				30.00			100.00
vi)	Land rent				50.00			50.00
vii)	Miscellaneous				35.00			55.00
	Total				1135.00			5295.00
2.	Variable costs							
i)	Harvesting, Threshing	Q	15	25.00	375.00	400	1.00	400.00
ii)	Irrigation Labour				50.00			100.00
	Total				425.00			500.00
3.	Total cost of cultivation				1560.00			5795.00
4.	Value of Produce							
i)	Main Produce	Q	15	175.00	2625.00			7600.00
ii)	By products							
	Total				2625.00			7600.00
5.	Net Income				1050.00			1805.00

by the Lower Ganga Canal. The area is bounded by the River Ganga on the North and River Jamuna in the South. Out of about 1,200,000 hectares available, about 500,000 hectares are under irrigation. It is possible to extend irrigation to further area if water could be made available. For purpose of this model, the area is restrictedto 500,000 hectares which is also the potential irrigated area with Ramganga Reservoir. Table 3.2 shows the area under irrigation and as was proposed, for the Ramganga Reservoir.

This model is restricted to optimise irrigation under surface water under the Lower Ganga Canal system. The marginal impact on other systems like Agra Canal, Ramganga Canal etc. have not been considered.

Six important crops commonly grown in the area have been selected. These crops are wheat, oilseeds, pulses, potato, gram and sugarcane. The primary purpose of the model is to determine the approximate value of water in irrigated agriculture and not necessarily to determine the optimum cropping pattern. Other crops which might be grown in relatively smaller areas will not materially affect the model results.

Relative profitability is the single important criterion for crop choices and optimum resources use. The net income from irrigated crops have been obtained from analysis of farm budgets.The cost of cultivation and product yields have been considered for average conditions. The details are given in Table 3.3. The net income from irrigated agriculture less the income from farming without irrigation is the net income. However since the latter is considered fixed, it does not affect the optimization results. The objective function maximizes the net income and allocates the available water to high value uses.

3.7. THE MODEL FORMULATION

3.7.1 The linear programming model is formulated to measure the impact of variation in irrigation water quantities for the various months.

The following notations are used.

n is the number of crops ($1 < i \leq n$)

m is the number of months ($1 < j \leq m$)

Xi Area of crop allocated to crop i.

Wij Consumptive use co-efficient for crop i during month j.

Ij Stream flow during the month j.

Yj Reservoir release during the month j.

R Annual reservoir yield

Ci Increase in income per Hectare of crop i.

The objective function is

$$\text{Max} \quad Z = \Sigma Ci\ Xi$$

The following constraints are used.

1) $\sum Wij.\ Xi - Yj \leq Ij \qquad i = 1, \ldots\ldots n$

and $j = 1, \ldots\ldots, m$

Table 3.4

Consumptive Use Coefficients(mm)

	Name of Crop	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
1.	Wheat	10	30	72	152	0	0	264
2.	Oilseeds	53	70	83	27	0	0	233
3.	Pulses	64	64	19	0	0	0	147
4.	Potato	64	65	50	0	0	0	179
5.	Gram	37	57	84	16	0	0	194
6.	Sugarcane	37	0	13	109	193	269	621

Table 3.5

available

Average Streamflows of River Ganga at Narora. MCM (with eff. 0.45)

December	125.1
January	111.1
February	61.27
March	59.49
April	58.32
May	83.88
	1499.16
	850.00
	1549.16

The water requirement of crops should be less than the water available from all sources, viz. reservoir releases plus the stream flows of river Ganga at Narora.

2) $\sum_{1}^{m} Yj \leq R$

The sum of the reservoir releases in different months should be less than the annual reservoir yield.

3) $\sum_{1}^{n} Xi \leq L$

Total area under different crops should be less than the total irrigated area.

4) $Li1 \leq Xi \leq Li2$

Area under each crop has lower and upper bounds.

3.7.2. Data Requirement

For uniformity of computations all quantities of water have been normalised to represent the consumptive use. To reduce all the flows and releases a project efficiency of 0.45 has been used. Accordingly the annual yield of the reservoir is 850 MCM.

The consumptive use co-efficients for the crops have been computed from metereological data and are tabulated vide Table 3.4. The total water requirement of crops is met from the Reservoir releases as well as the stream flow of River Ganga at the Narora headworks of the Lower Ganga Canal. The average stream flows are given in Table 3.5. as obtained from the Project Reports.

The crop area constraints have been used considering the prevailing cultural practices and the expected developments with irrigation. The foodgrain requirements of the area have also been considered.

3.8 MODEL IMPLEMENTATION

The above formulation maximises the total net income from irrigated agriculture and allocates the available water to the various activities. Standard linear programming has been used in the Dec 20/50 computer at the Regional Computer Centre, Roorkee University. The optimum cropping pattern and the corresponding reservoir releases are shown vide Table 3.6.

To obtain demand functions for each month variable resources parametric programming is resorted to. The water requirement of each month is met by the stream flow and the reservoir release. Additional constraint has been introduced to change the water availability in each month parametrically.

$\Sigma WiXi \leq Y1 + I1$ for month 1.

For each month the value of the R.H.S. is changed from low values to possible high values. The same is repeated for different months.

The dual variables to this constraint are the marginal values of water for the month at the particular level of water availability and represents the value of unit quantity of water. A set of marginal values are obtained. The values corresponding to each month for different quantities of water use are nothing but the monthly demand function. The values are tabulated vide Table 3.7. The demand function for the various months are shown in Figs.3.3 to 3.7. The annual demand curve is a stepped demand curve is shown in Fig.3.8.

3.9 WILLINGNESS TO PAY

The net income from irrigation water is represented in the demand curve. Willingness to pay for irrigation water represents the difference between the net income from irrigated cropping and the net income without irrigation. The values obtained from the demand curves must be adjusted to take into account the income from unirrigated farming.

The demand curves apart from providing a basis for pricing also provide the basic information, which aid in making decisions as indicated below.

1. To determine the quantities of irrigation to be put to use each month as well as for the entire cropping season.
2. To analyse how variation in water quantities affect variations in relative profitability of alternative crops and land use pattern.
3. To allocate available water among different purpose (e.g. Irrigation, Power) monthwise as well as seasonwise.
4. The monthly demand curves provides information on the relative values of water in different months to enable re-distribution wherever possible.

The actual use of these demand curves for the above purposes are illustrated in the next Chapter.

Table 3.6 - (a) Optimum Cropping Pattern

Sl.No.	Name of Crop	Area Hectares
1	Wheat	287,110
2	Oilseeds	5,000
3	Pulses	50,000
4	Potato	40,000
5	Gram	75,000
6	Sugarcane	42,890
	Total	500,000

(b) Reservoir Releases MCM

Dec.	7.10
Jan.	101.78
Feb.	247.70
March	437.02
April	24.45
May	31.99
	849.94
	or say 850.00

Res release + diversions from Ganga

Table 3.7

Marginal Value of Water - Demand Function

Q - Quantity in MCM

MV - Marginal Value Rs/$10^{}m^3$

Item	1		2		3		4		5	
	Q	MV	Q	MV	Q	MV	Q	MV	Q	MV
Month- December										
Reservoir	850.0	2.137	850.0	2.081	850.0	3.443	850.0	3.325	850.0	3.325
Flow	125.1	2.137	144.0	0.0	85.5	13.100	85.5	16.223	85.5	16.547
Release	7.1	2.137	0.0	0.0	24.5	16.551	14.5	19.547	4.5	19.547
Total	132.6		144.0		110.0		100.0		90.00	
January										
Reservoir	850.0	2.137	850.0	2.749	850.0	3.04	850.0	1.904		
Flow	111.1	2.137	111.1	7.28	111.1	8.925	111.1	18.546		
Release	101.78	2.137	98.9	10.029	58.9	11.865	38.9	20.450		
Total	212.88		210.0		170.0		150.0			
February										
Reservoir	850.0	2.137	850.0	0.0	850.0	0.0	850.0	0.0		
Flow	61.27	2.137	61.27	14.440	61.27	14.44	61.27	14.44		
Release	247.7	2.137	228.73	14.440	208.73	14.44	188.73	14.44		
Total	309.0		290.0		270.0		250.0			

Table 3.7(Contd.)

Item	1		2		3		4		5	
	Q	MV	Q	MV	Q	MV	Q	MV	Q	MV
Month - <u>March</u>										
Reservoir	850.0	2.137	850.0	2.219	850.0	2.219	850.0	2.219	850.0	0.00
Flow	59.5	2.137	59.5	0.682	59.5	0.682	59.5	0.682	59.5	1.232
Release	437.0	2.137	400.5	2.901	380.5	2.901	340.5	2.901	290.5	1.232
Total	496.5		460.0		440.0		400.0		350.0	
<u>April</u>										
Reservoir	850.0		850.0		850.0		850.0			
Flow	58.3	2.137	58.3	3.953	58.3	3.953	58.3	3.953		
Release	24.5	2.137	11.7	3.953	6.7	3.953	1.7	3.953		
Total	82.8		70.0		65.0		60.0			
<u>May</u>										
Reservoir	850.0	2.137	850.0		850.0		850.0		850.0	
Flow	83.9	2.137	83.9	2.836	83.9	2.836	70	2.836	50	2.836
Release	32.0	2.137	21.1	2.836	1.1	2.836	1.1	2.836	0	2.836
Total	95.9		105		85.0		71.1		50	

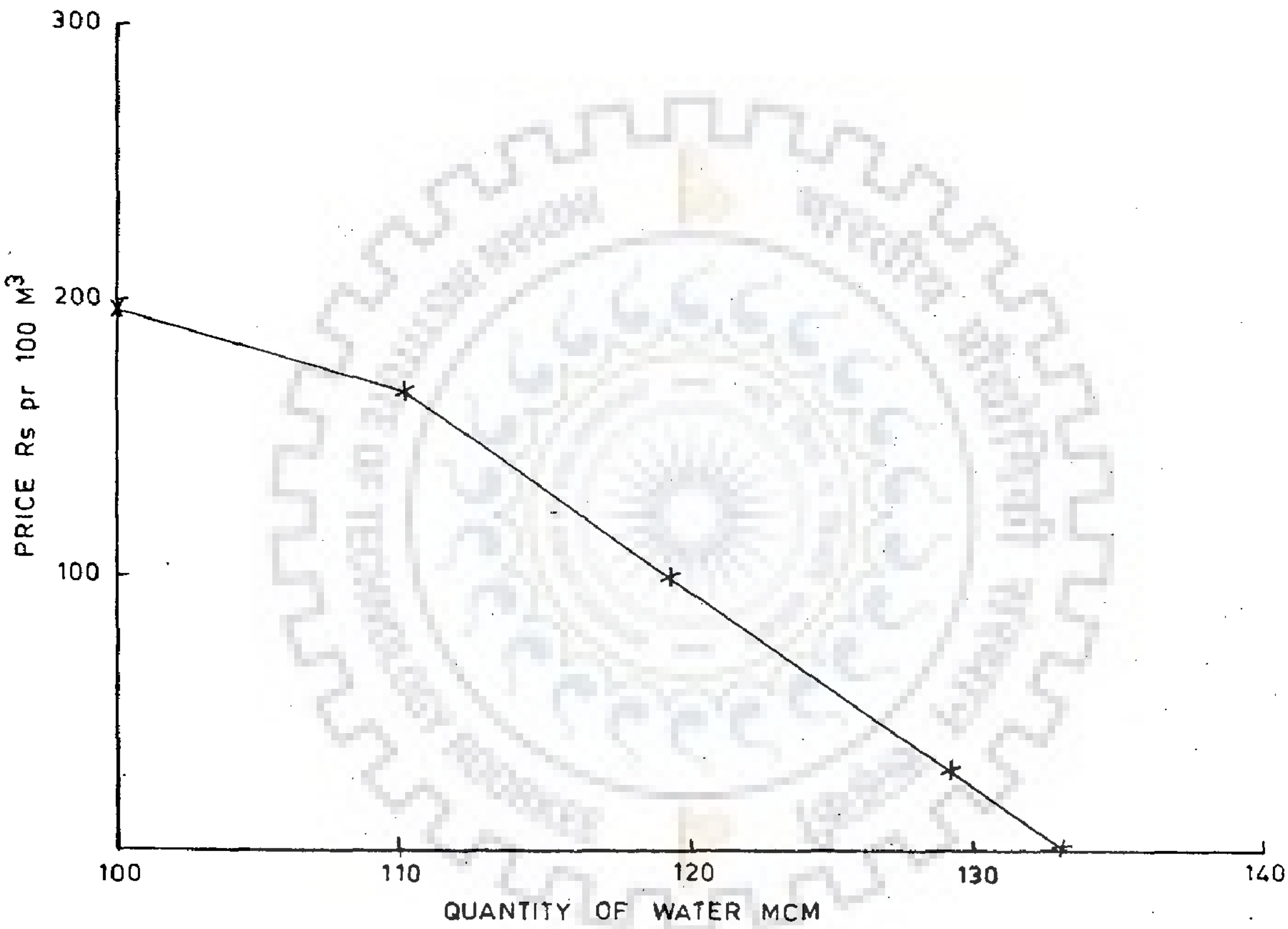


FIG. 3·3 DEMAND FOR IRRIGATION-DECEMBER

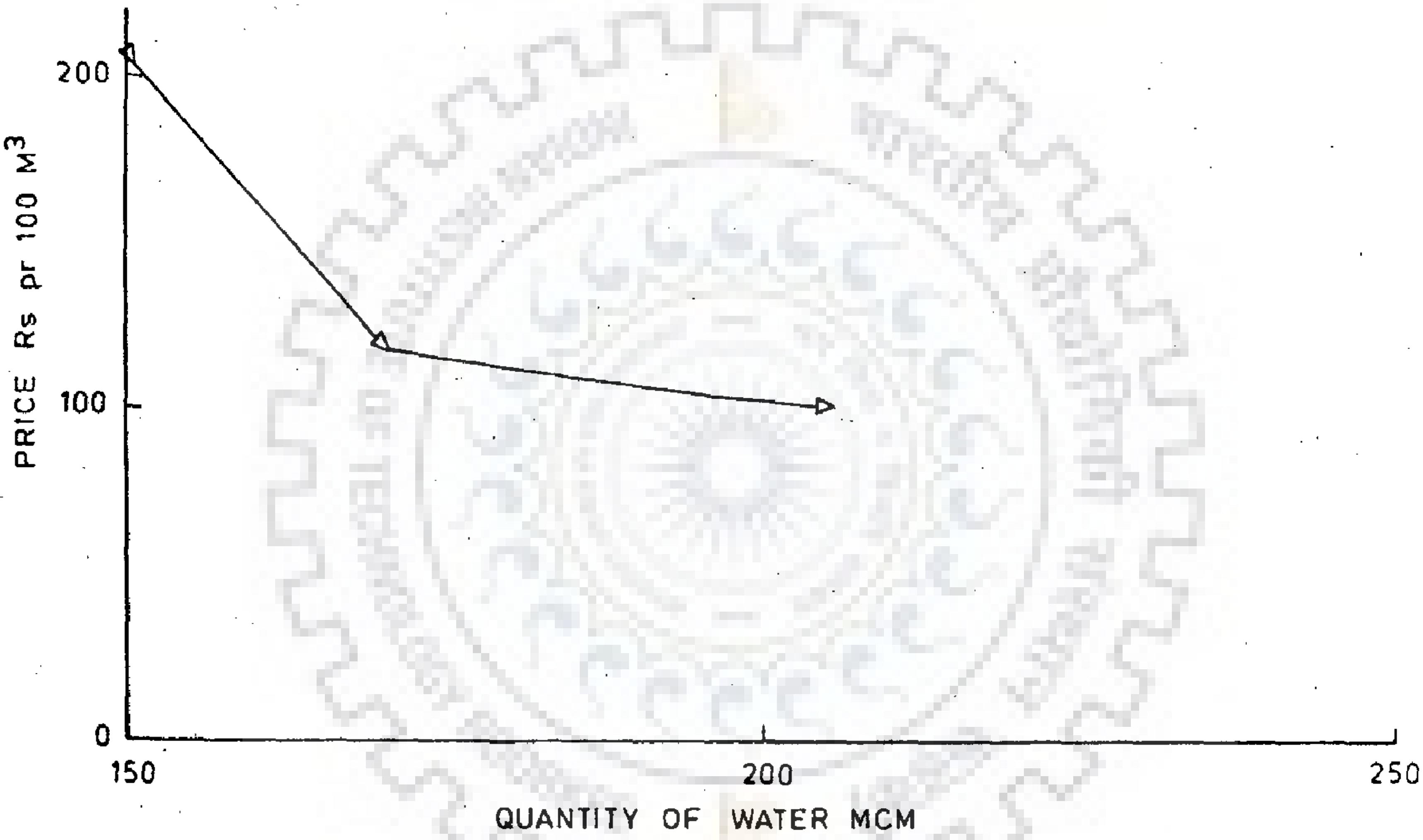


FIG. 3.4 DEMAND FOR IRRIGATION-JANUARY

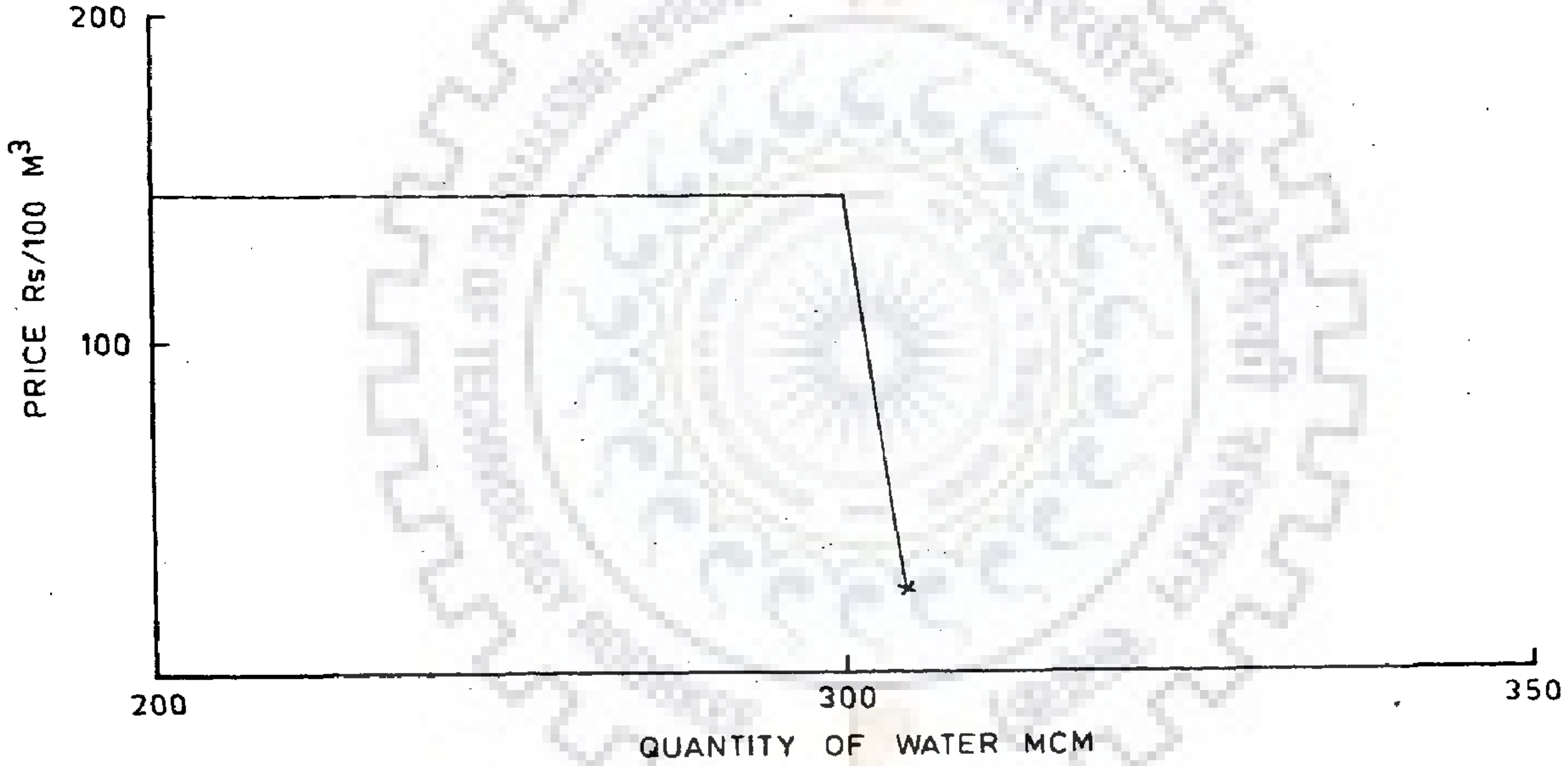


FIG. 3·5 DEMAND FOR IRRIGATION-FEBRUARY

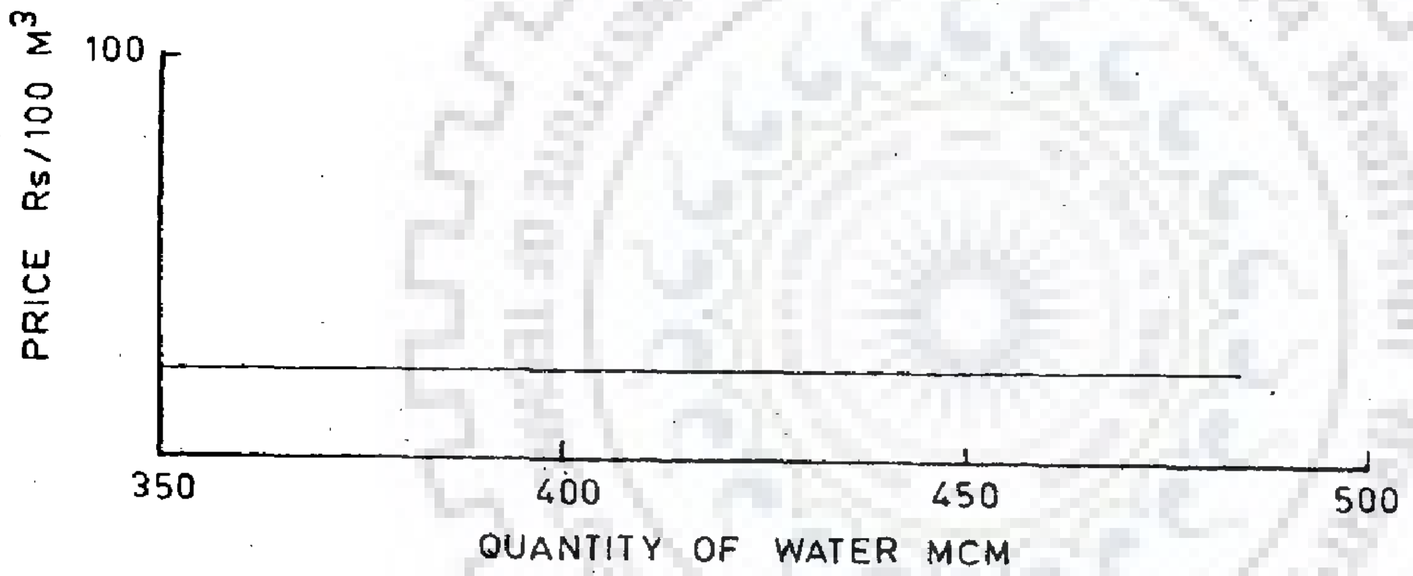


FIG. 3·6 DEMAND FOR IRRIGATION - MARCH

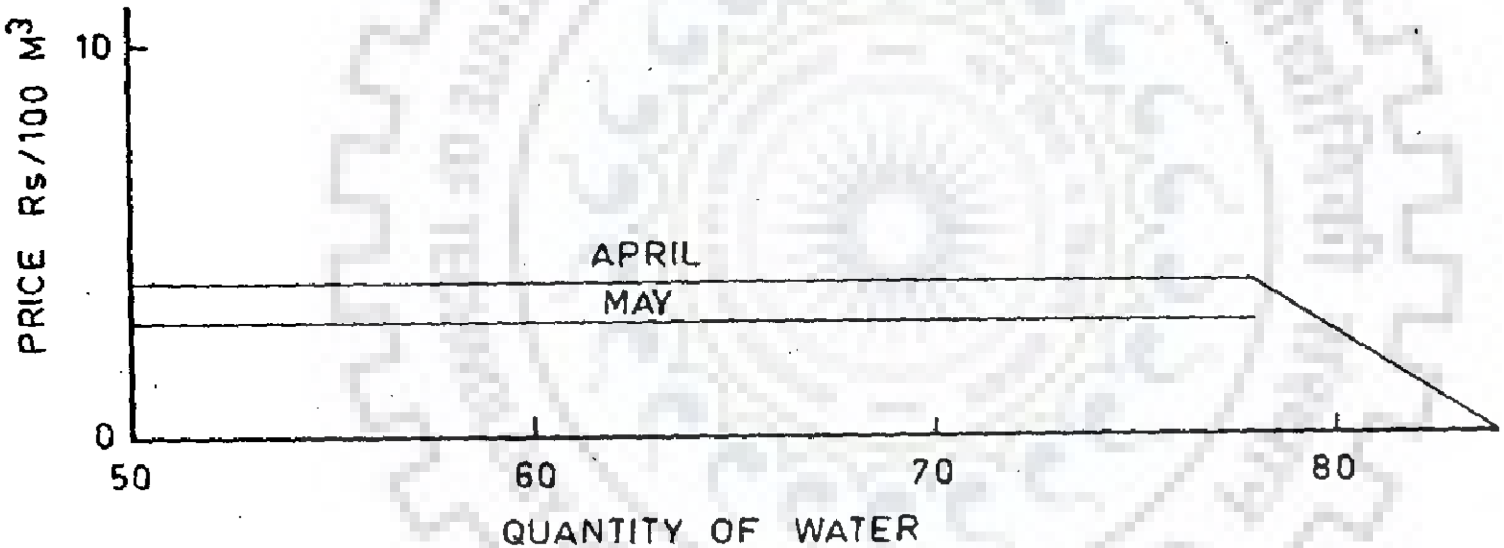


FIG. 3·7-DEMAND FOR IRRIGATION-APRIL & MAY

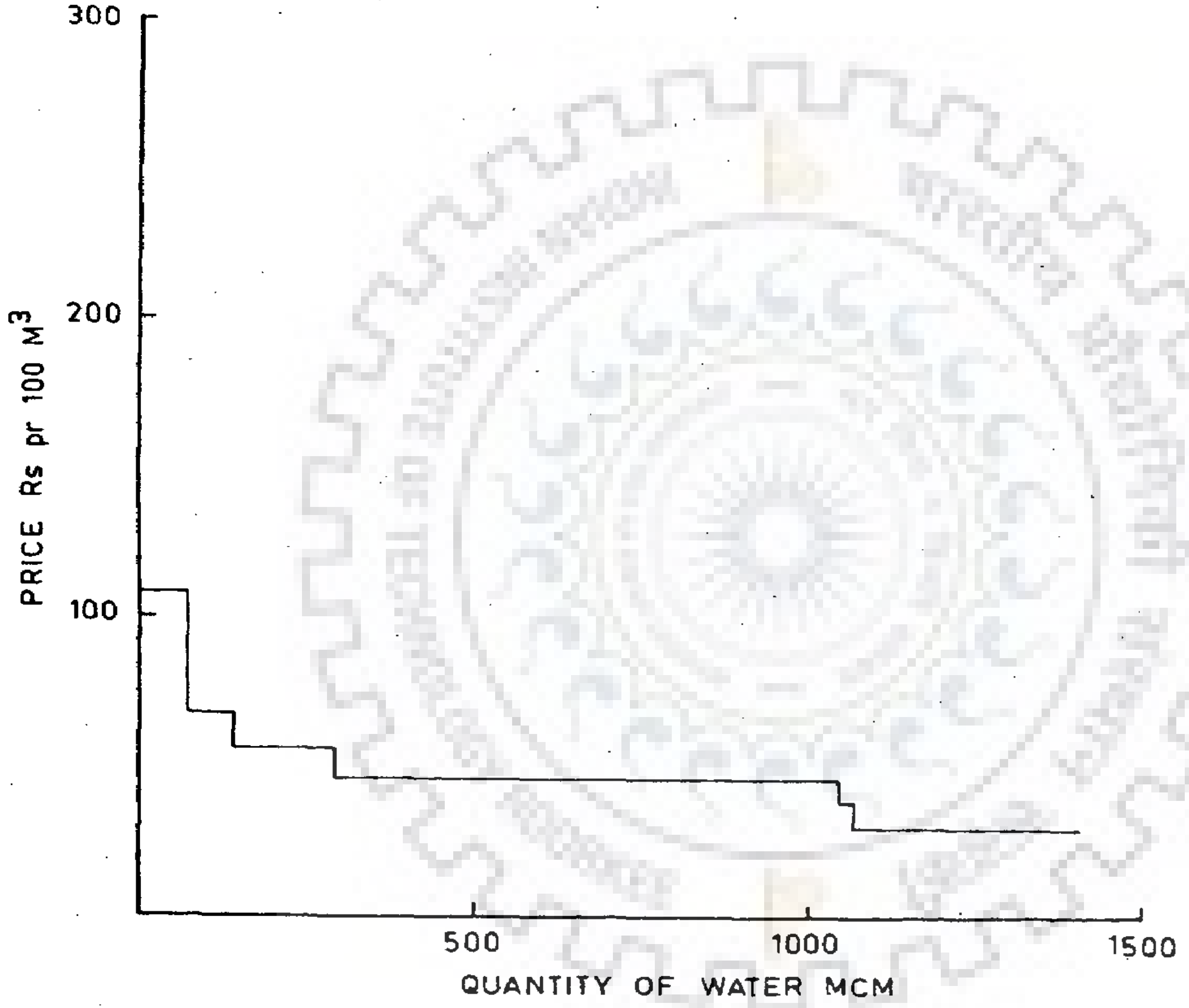


FIG. 3·8 DEMAND FOR IRRIGATION WATER LOWER GANGA CANAL

3.10 PRODUCTION FUNCTION APPROACH

One of the important objectives of pricing of irrigation water is its efficient use. The amount of water required for crop growth is guided by the evapotranspiration needs of the plants. The full evapotranspiration requirements of a crop (ET Crop) produces the potential crop yield. If the water availability is less, moisture stress develops with consequent reduction in yield. It has been established that certain amount of moisture stress can be allowed without corresponding adverse effect on the yield. It is proposed to bring out whether such a policy of deficit water supply is desirable and if so whether water pricing can be effective to achieve such a policy. If price could be related to the quantity ofwater demanded, a demand function can be synthesised and would serve a basis for pricing. As has explained in paragraph 3.4. the basic unit for deriving a demand function is the individual farm.

The farm is an organisational entity within which production takes place. The farmer is responsible to transform the various inputs into desired outputs, according to the technological process available to him. The most important objective of this production process is to maximize profit. The relationship between the inputs and outputs is given by the production function. Such a relationship gives the maximum amount of output that can be produced for any set of inputs under a given state of technology.

The potential yield of a given crop is an extremely complex function of climatic, nutritional and management inputs. Many of these inputs (variables) are uncontrollable. To develop any model, the uncontrollable variables have to be considered constant. The yield response of crops to various inputs like seeds, fertiliser, pesticides, water, management etc. can be expressed in the general form.

$$Y = Y\ (X1, X2, X3 \ldots\ldots Xn)$$

Where Y is the yield of crop.

X1,X2.... are the levels of various inputs. Developing water-crop yield relationships has to be done with all other inputs kept at fixed level and water alone as the variable input.

$$Y = Y\ (Xw\ /\ X1,\ X2\ \ldots\ldots\ldots)$$

Such a function can be developed only by experimental studies. Extensive work done by various investigators have been studied.

3.11 CROP MODELS

Different researchers have considered different water use parameters viz. field irrigation requirement,net irrigation requirement, evapotranspiration etc. to develop their models. However studies have established that the crop yield is related to ET. Stewart and Hagan (1973) (87) illustrated basic relations between crop growth and water use. They have outlined approaches for estimating crop yield from evapotranspiration. Downey (1972) (21), Yaron (1973) (95)

Hargreaves (1977) (35) have shown that plant growth is a function of factors that contribute to plant water stress and that stress situation occurs when the actual rate of ET is less than the potential rate. Therefore, of the various production function relationships studied, only those are selected, which have considered actual ET as the variable input for purpose of this review and analysis.

Stewart and Hagan (1973) (87) derived Y Vrs. ET functions from experiments on corn at Davis, California in 1971. They fitted a straight line by regression analysis. The straight line when extrapolated does not pass through the origin. This is attributed to non-growth related ET, specially during the early growth period of the crop. The intercept on the X axis could be more for water intensive crops like paddy which requires standing water. The linear relationship should be used with caution as its applicability is limited to the range of experimental values and should not be extrapolated. Hall and Butcher (1964) (33) considered intraseasonal water limiting conditions and postulated a multiplicative relationship between growth in different periods.

$$Y(q) = \prod_{k=1}^{n} \alpha\, k(\theta_k).\ Y_M\ (q_m\ )$$

where $Y(q)$ = ET, $\alpha k\ (\theta_k)$ Effect of moisture deficiency, as a function of (θk), being the soil moisture during period k.

$Y_M\ (q_m)$ = Maximum yield that can be obtained with the maximum quantity of water q_m

k = growing period index having n periods.

Dynamic programming was used to allocate the limited water. The above formulation is only a conceptual framework and are not based on field data.

Jenson (1968) (48) also suggested a multiplicative model by relating yield ratio (Y/Ym) to ET ratio (ET/E TP)-

$$\frac{Y}{Y_m} = \prod_{k=1}^{n} \left| \frac{ET}{ETP} \right|^{\lambda_k}$$ where ETP is the potential evapotranspiration

Where λ_k is the crop sensitive factor for period k which has to be determined experimentally.

Minhas et al (1974) (69) analysed the data from experiments on wheat crop in Delhi extending over a period of six years. The non-dimensional form of the production function developed is

$$\frac{Y}{Y_m} = \prod_{k=1}^{n} 1 - \left(1 - \frac{ET^2}{ETP^2} \right)^{\lambda b_k}$$

Where b_k is the crop sensitivity factor of water deficits during k^{th} period. The results showed large seatter.

Blank (1975) (6) used the experimental data from Colorado State University and tested an additive model and found out values of the sensitivity co-efficients for different periods. The additive function is

$$\frac{Y}{Y_m} = \sum_{1}^{n} A_i \frac{ET_i}{E\ Tmax\ i} + A_{n+1}$$

The values of the coefficients A_i obtained by him by regression analysis are shown below.

Sl.No.	A 1	A 2	A 3	A 4	R^2
1.	0.236	0.159	0.573	0.0	0.98
2.	0.213	0.113	0.352	0.246	0.98

Remarks - Crop Corn, 3 time periods

R^2 is square of the correlation co-efficient.

Hargreaves and Christiansen (35) analysed yield and water use data for a numberof crops like sugarcane, alfa-alfa, corn and forage crops. In order to standardise the data and compare the results, a nondimensional form of the production function was developed. Most of the yield data analysed indicated a relationship expressed by the equation.

$$Y = 0.8\,X + 1.3\,X^2 - 1.1\,X^3$$

Where Y is the yield ratio and X is ET ratio.

The Irrigation Research Institute, Roorkee and Indian Agricultural Research Institute, Delhi and other Agricultural Institutes of India have conducted experiments and have fitted quadratic functions.

The various production function put forth can be grouped as below -

1) Linear relationships
2) Stagewise Viz. multiplicative or additive models.
3) Quadratic and cubic functions.

1. Linear Relationship - The process of production follows the law of diminishing return. A linear relationship is applicable only to the range of experimental values and is not suitable for generalised use.

2. The stagewise models require determination of the response co-efficients during different growth periods. The data requirement is bothintensive and extensive. Further the interdependency between different periods is not fully reflected.

3. The quadratic and cubic function behave well with the physical process of production. The normalised non-dimensional forms are considered suitable for general use.

3.12 DEMAND FOR IRRIGATION WATER

Where the water requirement of crops is wholly met by irrigation, the amount of water that a rational farmer would use is guided by the shape of the production function, the price of yield and the cost (price) of irrigation water. A simple optimization model would be able to furnish the required information.

Objective function Max Z = Increase in net farm income

Subject to $Y = f(X)$, the production function.

or $\text{Max } Z = Y.\ P_y - X.\ P_x - C$ subject to $Y = f(X)$

where P_y = Unit price of crop.

P_x = Unit price of water

C = Cost of cultivation (excluding water)

C is considered constant since all other inputs are kept at fixed levels.

The Lagrangian function.

$$L = Y.\ P_y - X.\ P_x - C + \lambda\ (Y - F(X))$$

Where λ is the Lagrangian Multiplier

Differentiating.

$$\frac{\partial L}{\partial Y} = P_y + \lambda$$

$$\frac{\partial L}{\partial X} = - P_x + \lambda \frac{\partial F(x)}{\partial x} \quad \text{and} \quad \frac{\partial L}{\partial X} = Y - F(X)$$

Equating each of the expressions to zero, it follows that

$$\frac{\partial F(X)}{\partial X} = - P_x/P_y$$

Since the price of crop is known, it is possible to determine the various values of X for different levels of water application corresponding to different values of P_x, price of water. This relationship is the demand function of water. As the price of water increases, the demand decreases, the usual negative slope of the demand function.

Such a demand curve is known as the static factor demand curve because the level of other inputs are not changed with variation in quantity of water.

3.13 APPLICATION OF THE MODEL

Effort is made to apply the model to wheat, the main staple crop. A number of production functions suggested by various investigators were reviewed. A quadratic function as recommended by a study at Roorkee is selected (Goyal 1979)(31) The normalised production function is $y = 0.264 + 1.471\ x - 0.73324\ x^2$

where y is the yield ratio and x the ET ratio.

With y max = 30 Qts/ha and x_{max} = 29 cm.

The equation transforms to

$Y = 7.92 + 1.522\ x - 0.0262\ X^2$ which gives the relation between yield Y (qts/ha) and ET (in cm.).

$$\frac{dY}{dX} = 1.522 - 0.0524\ X = \frac{P_x}{P_y}$$

considering farm level price of wheat at Rs.120 per qtl.

$$P_x = 182.64 - 6.288\ X$$

or $\quad X = 29.04 - 0.159\ P_x$

The linear relationship is the demand curve for wheat indicating the various levels of water demand against water prices. P_x also represents the marginal value product (MVP). In fact the demand curve is nothing but the MVP as shown below.

Total value product = $Y.\ P_y$

Marginal value product = $\frac{dY}{dX}.P_y = P_x$

The MVP as represented by the demand curve represents the contribution of water to the production process and hence reflects its value and therefore is the willingness of pay of the users.

The static factor demand curve as synthesized from the production function has some special characteristics. While calculating the MVP, the incremental yield is fully attributed to water. However the user not only has to pay for the marginal unit but has to pay for the full quantity of water or $P_x.X$. From the total value, if the cost of all other inputs are deducted, the residual may not be sufficient to meet the water charges. As such the ' price' as obtained from the static factor demand curve does not represent the willingness for payment of the charges in its true sense. The capacity or ability to pay must be obtained to form a basis for pricing.

Willingness to Pay - Users would be willing to pay only when they have a residual left with them. The procedure of residual imputation as outlined need be used for each level for water use. The residual which can be termed net value product when divided by the quantity of water demanded, gives the net average value product and is a correct indicator of the capacity to pay.

The Table 3.8 shows the computation of the net average value product. The demand curve (MVP) and the AVP curve are superimposed and shown in Fig.3.9. The AVP curve is the upper limit of water pricing. Any price charged above this would make the irrigated farming un-economical and throw the farmer out of business. The two curves furnish much information on the state of water use.

At lower levels of water use, the yield or the total value product is so small that it is not able to meet the cost of other inputs. With 8 cm. of water use, the TVP just balances the cost and no residual is left to meet the cost of water. There is capacity to pay only at higher levels of water use which provide sufficient yield and higher total value product.

The point of intersection is important. Here the willingness to pay (MVP) and the capacity to pay (AVP) are same. The part of the demand curve to the left of this point is therefore not feasible from point of capacity to pay. On the right part of the curve the price charged can either on the basis of MVP or AVP. In case it is charged on the basis of AVP, the higher of

Table 3.8

MVP, AVP and Ability to Pay

Crop - Wheat

Rup..s per Hectare

Sl. No.	Price of water	Quantity of water x cm	Yield Y Qtl	Gross value product Rs.	Marginal value product	Cost of other inputs	Net values product	Net Average value product	Value of inputs including farmers share	Ability to pay Rs. per cm
1	150	5.67	15.70	1884		2091	(-)207	-36.5	2974	(-) 192.24
2	100	13.62	23.79	2855	122.14	2221	634	46.55	3094	(-) 17.55
3	60	19.98	27.88	3346	77.20	2286	1054	52.75	3159	9.36
4	30	24.75	29.54	3545	41.72	2312	1232	49.78	3185	13.67
5	20	26.34	29.83	3580	22.01	2317	1263	47.95	3190	14.81
6	10	27.93	29.99	3599	11.95	2320	1279	45.79	3193	14.54
7	5	28.70	30.00	3602	5.89	2320	1282	44.63	3193	14.25
8	0	29.02	30.00	3602	-	2320	1282	44.63	3193	14.25

$Y = 7.92 + 1.522\ x - 0.0262\ X^2$

$X = 29.06 - 0.159\ Px$

Y = Yield qtls/Ha

X = Qtl. of water cm

Px= Price of water

Py = Rs.120.00 per qtl.

Fixed cost Rs.1840.00 per Ha

Variable cost Rs.16.00 per Ha

the two, the quantity demanded for a specific price is given by the corresponding point on the demand curve. If price is charged corresponding to point A on the AVP curve, the quantity demanded is given by the point B on the demand curve. However for this quantity the AVP is given by point C. By such a process it leads to the point of intersection D. Any departure from the point of intersection leads back to the same point. Hence the equilibrium price charged is the point of intersection.

3.14 DISCUSSION OF RESULTS

Willingness to pay obtained from MVP, is not a direct measure of price that can be charged. The total value cannot be charged to the farmers. There should be sufficient incentive to the farmer to put water into proper use. The farmer should receive his due share towards the input, he puts into the enterprise in the form of family labour, and management skill. He should also get suitable return to the capital tied up in the enterprise. The ability to pay takes care of these factors. The ability to pay for various levels of water application are shown in Table 3.8. Ability to pay is a rational way of charging. The portion of the curve below the abscissa indicate negative marginal values. The maximum ability to pay is when it intersects the demand curve. As already indicated this point can be called the equilibrium price. The AVP and ability to pay curves are flat beyond the intersection point because of low marginal productivity. The relevant range of applicability is quite small. In this case the water application range is 26 to 29 cm corresponding to ability to pay range of Rs.17 per cum to Rs. 11 per cum. Evidently the most desirable one is 26 cm

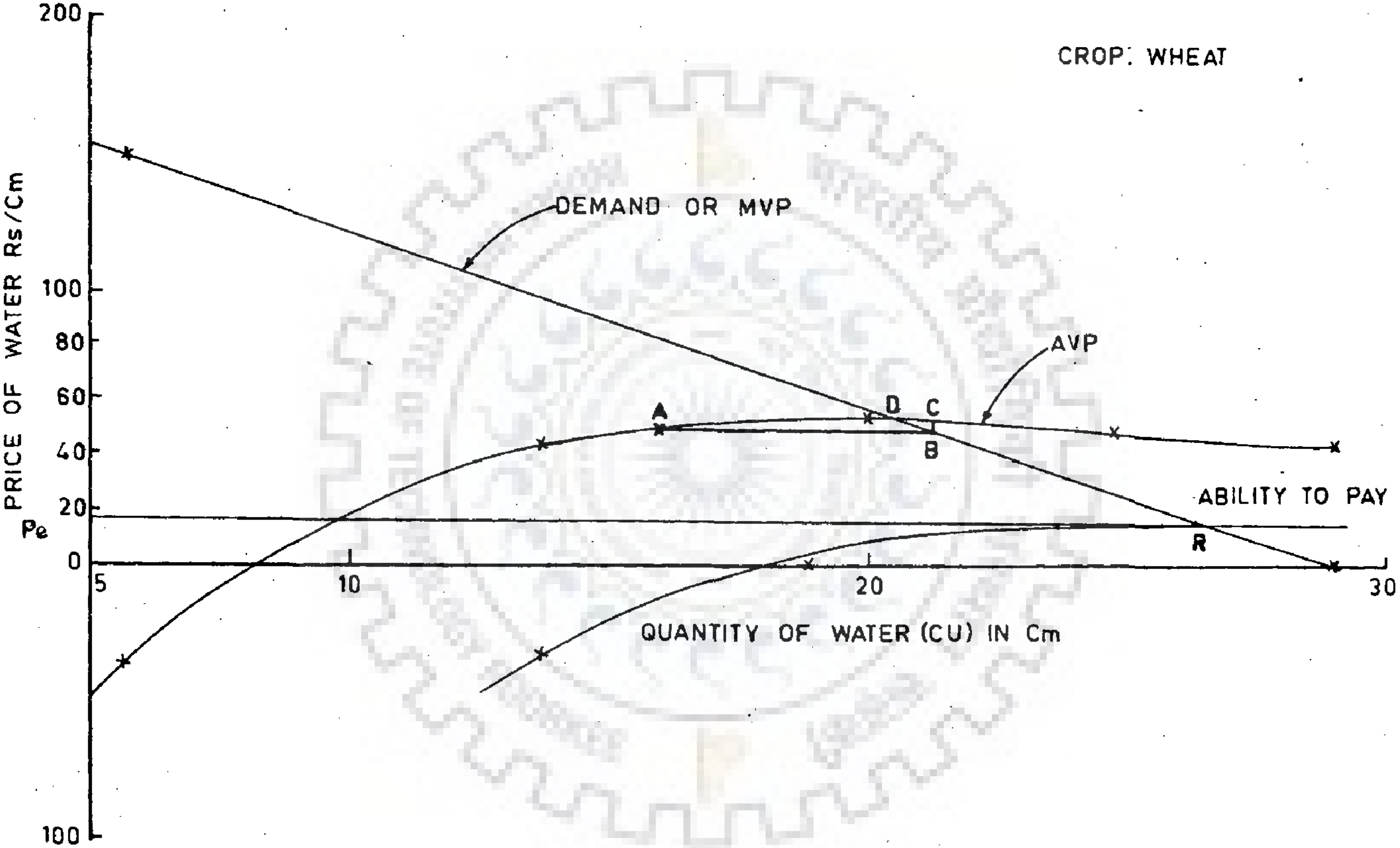


FIG. 3·9 – EQUILIBRIUM PRICE - PRODUCTION FUNCTION APPROACH at a price of 17. Water application X is about 90 percent of X_m or the ETcrop.

From the point of view of ability to pay, the quantity of water demanded is almost equal to the Xmax. Though this has been illustrated for one crop, the same is applicable in most of the cases since the shape of production function for different crops are not very different. Because of other uncertainties inherent in crop production, it may not be worthwhile to determine the optimum quantity of water from production function, which always approaches the maximum. Further the production functions are derived under laboratory (experimental farm) conditions and their use for decisions at farm level may lead to erroneous results.

The production function approach of deriving demand curve have been done and its applicability for pricing is discussed. It is seen that the quantity of water demanded is not sensitive to the pricing, since the range of price itself is small. The equilibrium price that can be charged is when the marginal value product equals the ability to pay.

3.15 VALUE OF WATER

The economic value of water in the first part of this chapter refers to the value from the view point of the invester or from the national accounting stance. Such valuation is necessary for economic justification as well as for pricing. However it is to be kept in mind, that water is put to use by the farmers and its value to the farmers is what is required for the purpose of pricing.

The additional income generated from irrigated farming is attributable to water. The value of water is obtained from the farm budgeting by the process of residual imputation described vide para 3.3. This is referred to as the ' Willingness to pay' or increase in net income. This can also be referred as the capacity to pay for water. These have been calculated for the six crops and tabulated vide Table 3.3.

The full willingness to pay cannot be charged to the beneficiaries. The value therefore must be obtained from the view point of the farmer and assess their ' ability to pay '.

3.16. ABILITY TO PAY

Ability to pay indicates the payment ability of the farmers for use of water. The difference between ' willingness to pay' and ' ability to pay ' is that the farming family is adequately rewarded for taking up irrigated farming. The farmer has to make additional investment towards purchase of inputs and must get a suitable return on this investment. In addition he must be compensated for his and his family labour that goes into the process of production. He mustalso be rewarded for his management capacity of the farm.

The sum total of all these compensations provided to the farmer can be termed the living allowance. Adequate allowance acting as incentive is essential for a meaningful use of irrigation water. The details of calculation of ability to in respect of the various crops are tabulated vide Table 3.9. Ability to pay forms the basis for subsequent analysis to arrive at the desirable pricing policy. In view of the very concept, the ability to pay refers to specific crop production and therefore is in terms of per unit area of irrigated farming of the crop.

Table 3.9

Ability to Pay

Rs. per Hectare

Sl No	Item	Wheat	Oilseeds	Pulses	Potato	Gram	Sugarcane	Remarks
1	2	3	4	5	6	7	8	9
1.	Cost of Cultivation							
	a) Fixed costs	1840	1115	945	5650	1135	5295	
	b) Variable costs	550	250	225	1400	425	500	
	c) Total	2390	1365	1165	7050	1560	5795	
2	Value of product	3600	2250	2100	9000	2625	7600	
3	Net Income	1210	885	935	1950	1050	1805	
4	Return to land	465	465	465	465	465	465	
5	Return to Management	121	89	94	195	105	180	10% of net income (3)
6	Imputed value of family labour	180	120	120	360	120	480	Value of family labor engaged in supervision not included in (1)
7	Return to Capital	107	62	53	317	70	261	@ 4.5% on investment 1(c)
8	Living Allowance (5+6+7)	408	271	267	872	295	921	
9	Ability to pay (3-4-8)	337	149	198	610	290	419	

APPENDIX 3.1

RAMGANGA PROJECT

Salient Features

1. Hydrology

Catchment Area	3025 sq.km.
Annual Rainfall	1550 mm
Mean Annual Runoff	2680 MCM
Maximum Probable Flood	12120 m^3/sec

2. Reservoir

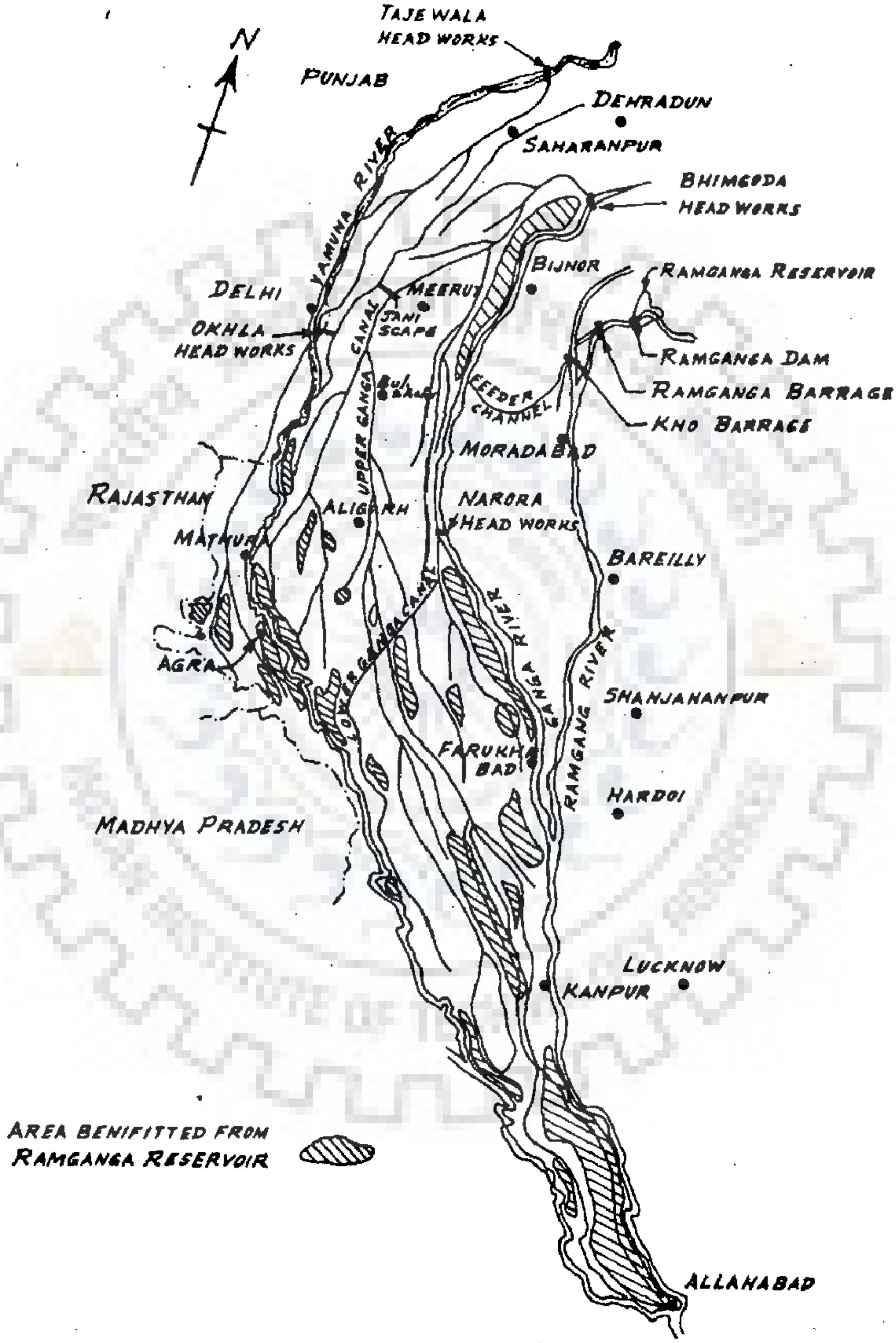
Normal Storage Elevation	365.30 m
Maximum Storage Elevation	366.90 m
Drawdown Elevation	324.60 m
Gross Storage Capacity	2443.00 MCM
Live Storage Capacity	2195.00 MCM
Reservoir Area at EL 365.30	78.30 sq.km.

3. Main Dam

Type	Earth and Rockfill
Top of Dam	372.00 m
Length at crest	630.00 m
Height above Foundation	127.50 mm
Side Slope(both u/s and d/s)	2.5 H : 1 V

4.	Chute Spillway	
	Design Flood Discharge	7607 m^3/s
	Crest Elevation	352.00 m
	Top of Gates	366.30 m
	Type of Gates	Radial (5x14.0 m)
5.	Power House	
	Installed Capacity	3 x 66 = 198 MW
	Turbine	Francis, Vertical Shaft
	Maximum net Head	108.85 m
	Minimum Net Head	54.86 m
	Maximum Discharge	235.6 m^3/s
6.	Feeder Channel	
	Length	82 km
	Discharge	151.50 m^3/s
7.	Cost of Construction	Rs.1708 x 10^6

Fig. 3.1.1 Index Map



INDEX MAP RAMGANGA RESERVOIR SCHEME

FIG.3·1·1

CHAPTER-4

MULTIPURPOSE USE

4.1 INTRODUCTION

Historically, decisions on valuation and allocation of water has been done on technical considerations of matching the available water with the requirements. It is customary to plan for a single purpose project with a primary purpose, then include other purposes to effect economy. With the advacement of economic theories and concepts and the growing demand for water, the need for greater efficiency in the use of water resources has challenged water planners to investigate and develop new methodologies. The improved computational capabilities in terms of techniques and computers gave a necessary phillip in this direction. A considerable volume of research has been directed to use economic theories and econometric techniques for analysis of water resources.

Maximum social welfare in a competitive situation is obtained when the consumers' surplus and the producers' surplus together are maximized. In such a situation the marginal cost of supplying water should be equal to the value of water in use of the last unit of water. Marginal cost is equal to the marginal value and is equal to the price. Samuelson termed this the 'net social pay off.' (Fig.4.1). Flinn and Guise (1970)(23), Guise and Flinn (1970) (32) used this concept in a hypothetical river basin for multipurpose and inter-regional allocation and pricing.

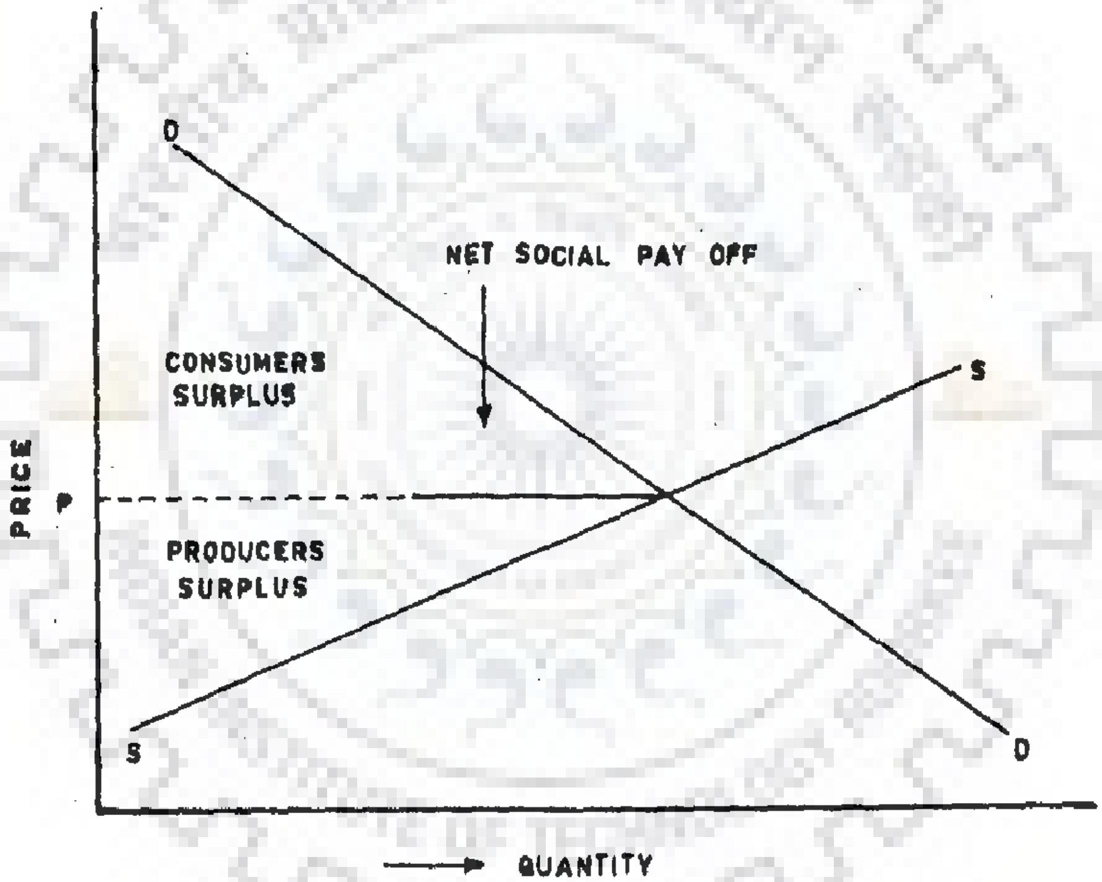


FIG.4·1- NET SOCIAL PAY OFF

4.2 MATHEMATICAL FORMULATION

Mathematically the net social product function is developed from the demand and supply curves. In case of linear demand and supply curves, (Fig.4.1).

Demand Curve $X = A - B\,P_d$ (4.1)

Supply Curve $X = A' + B'\,P_s$ (4.2)

or $P_d = \frac{1}{B}\,(A - X)$

and $P_s = \frac{1}{B'}\,(X - A')$

The social product function is the difference of these two

$$P = P_d - P_s = \frac{A}{B} + \frac{A'}{B'} - \left(\frac{1}{B} + \frac{1}{B'}\right) X$$

The same can be expressed in the form of

$$P = C - Q\,X, \quad X \geq 0$$

The area bounded by the curve is the net social pay off and is given by

$$\int_0^X P.\,dP = \int_0^X (C - QX)\,dX = CX - \frac{QX^2}{2}$$

In a constrained optimization problem, the objective function is $\text{Max } Z = CX - \frac{QX^2}{2}$ 4.3

Subject to $GX \leq R,\ X \geq 0$

Where the constraint structure provides the general restrictions of water availability, continuity constraints, institutional restraints and other requirements of the system.

In case of a project already in operation the supply is fixed. The capital cost of the project does not affect its subsequent operation studies. The operation and maintenance charges are small compared to the capital cost and the benefits. Further the operation and maintenance charges do not vary much with different mix of outputs and hence have been treated as constant, not affecting the optimisation.

The objective function is therefore concerned with the demand function and the consumers surplus, the producers' surplus being negligible (or nil) in case of the existing project. The objective function is quadratic and constraints are linear, and fit into the standard quadratic programming formulation. The objective function is a function of X and is in the quantity domain. What we are interested is the values or prices. In usual linear programming formulation, the dual variables give the required information on prices. However duality is not a property of quadratic programming.

The problem can be formulated in the price domain when the prices are the decision variables and are a part of the solution. The other method is to formulate in the quantity domain and once the quantities are obtained in the solution, the prices can be obtained from the demand functions. Both the formulation use the parameters of the linear demand functions, viz. the intercept and the slope. Flinn and Guise use the price domain for their analysis. In this study the objective function is in the quantity domain.

4.3 MULTIPURPOSE OPTIMIZATION

The above quadratic programming formulation was used to determine the multipurpose allocation. The demand curves for irrigation obtained in the previous chapter were used by fitting linear relationship to these. The main thrust of the problem is to simultaneously improve the power generation.

The Ramganga reservoir releases are used for generation of hydropower. The power house has an installed capacity of 198 MW consisting of 3 units of 66 MW each. The energy is fed into the Western U.P. Power grid, which consists of mostly run of the river power stations and thermal power stations. During the non-monsoon period, the low generation from run of the river plants are augmented by the generation from Ramganga power station. When power generation is considered only incidental to irrigation releases, the generation is fluctuating from very high to very low or even nil during some periods. A uniform generation improves the firm capacity of the system which is very desirable. It is proposed to improve the pattern of power generation to make it more uniform.

4.4. FORMULATION OF THE MODEL

The model for multipurpose use and optimal allocation is framed as below.

The objective function

$$Z = \left| \sum_{1}^{n} C_i X_i - \sum_{1}^{n} \frac{Q_i X_i^2}{2} \right| + \sum_{1}^{n} R_i X_i$$

The first part in the paranthesis represents the benefit from irrigation, viz. the net social pay off as explained in para 4.2 C_i and Q_i being the parameters of **linear** demand functions. The last term represents the benefits from hydropower generation. R_i represents the value of unit quantity of water when used for hydropower generation during the month i. X_i is the reservoir release during the i^{th} month, n being the total number of months.

The constraint sets are -

i) The energy generated in any month should not be less than a specified value. This value is expressed as a fraction (β) of the total generation.

$$K_j X_j \geq \beta \left| \sum_{1}^{n} K_i X_i \right| \text{ for } j = 1,\ldots\ldots,n; \text{ no.of months}$$

or $$(1-\beta) K_j X_j - \sum_{i \neq j}^{n} K_i X_i \geq 0$$

where

K_j is the power conversion factor for month j as explained below.

β is the fraction of the total generation required to be generated during each month.

ii) The total releases from the reservoir should not be greater than the annual yield of the reservoir.

$$\sum_{1}^{n} X_i \leq R$$

where R is the annual yield of the reservoir.

4.4.1 Data Requirement

The demand functions for various months obtained in the previous chapter have been used for the objective function. The project has already been constructed and is in the operation stage. The expenses for construction have been already incurred. The operation and maintenance costs can be reasonably considered constant since these are not expected to to vary with change in the pattern of releases. Accordingly the projects costs do not appear in the objective function.

The power conversion factors K represent the potential energy generation for unit quantity of stored water. The factor converts one MCM of water release during the month of to one megawatt month of energy generation. These factors are based on the assumed average reservoir level during the month as obtained from the reservoir operation schedule of the Ramganga Project Report. The variation of this factor is not significant and any small error that may be caused due to change in the operating policy is not likely to affect the results. The value varies from 0.6853 at full reservoir level to 0.542 at the minimum drawdown level.

4.5 DISCUSSION OF RESULTS

From the results obtained it is found that these are not commensurate with all the requirements.

i) The full resources are not utilised.

ii) The releases obtained from the model, are not compatible with the water requirement of crops during these months.

These deficiencies can be attributed to the single reason that the interdependencies between the water requirements of different months have not been properly reflected in the model. Flinn and Guise (1970) (23) have mentioned ' this interdependence is not necessary for application of the model. Competitive equilibrium conditions can still be found with interdependent demand relations. It should be noted that these are whole farm demand relationships and not single crop relationships'.

It may be made clear, even when they are whole farm demand relationships, the ultimate use is for crop and the period wise requirement of the crops cannot be ignored. A non-compatible mix of water releases will severely restrict the total irrigable area.

Use of demand function for multipurpose use has not been very encouraging. The concept of demand curve, consumers surplus, producers' surplus is not applicable to such demand curves. There has been some controversies in this issue. The use of the area above the price line, viz. the consumers surplus as social pay off and inclusion in the objective function does not appear to be alright.

In the usual market demand curve for consumer goods, the price at higher levels indicate the willingness to pay of the limited segment of well to do consumers. By paying a lower price, they save this amount at their valuation of the utility. In case of irrigation water, when the quantity of water is increased, its value decreases but the benefit from earlier units of water is not obtained at the higher values. Using consumer surplus in objective function may lead to erroneous results. However further insight and study is required in this direction for a more fruitful application of the economic theories.

4.6 SYSTEM CONCEPT IN MULTIPURPOSE PLANNING

The primary objective of a multipurpose plan is to attain economic use of water, to derive the best utility from the water resource and the related facilities created by the plan. In a multipurpose project to serve irrigation and hydropower generation, it would be desirable to have a full perspective of the overall plan forming the system. In deriving the operating policy all the elements of the system should be considered viz.

i) Conjunctive use of surface and ground water

ii) Pattern of power generation

4.6.1. One of the major problems of valuation of water has been its reusable characteristics. All the water supplied from the source is not consumed. A large part, in the form of seepage from canals, field channels, application losses, percolation requirements contributes to ground water or reappears as regeneration for subsequent use. Conjunctive use of surface and ground water has been used to recycle the seepage water to increase the overall consumptive use of water. Planning for irrigation cannot be done without a study of the ground water conditions. The ground water extraction requires energy for pumping. In a multipurpose project generating hydropower, it may be possible to use part of the energy for pumping. The purpose of this study is to show, how conjunctive use planning and management could improve the pattern of power generation as well.

The problem has been tackled in three distinct steps to bring out the differences in the policy instruments and the corresponding increase in the output levels and resource use.

Step -1 Optimises the combined use of surface water flows of river Ganga and the reservoir releases.

Step-2 Optimises the conjunctive use of surface and ground water for maximising crop production benefits.

Step-3 Aims at changing the pattern of reservoir releases and ground water pumping to a more desirable pattern of power generation.

4.6.2. Surface Water Optimization

The first step of surface water utilization has already been tackled in the Chapter-3. The maximum benefits and the corresponding cropping pattern and water use have been obtained from the linear programming formulation. The results are tabulated vide Table 3.6. The Ramganga reservoir has only been planned to optimize the surface water allowing ground water development to take place independently.

4.6.3 Conjunctive Use of Surface and Ground Water

The lower Ganga canal system serves the area bounded by the River Ganga on the North and River Yamuna in the South, an extensive part of the Gangetic plains, having large potential for ground water exploitation. A number of studies have been done by various organisation to assess the ground water potential. The Irrigation Research Institute, U.P. have conducted the studies as documented in their technical Memo No.39(1969) and Memo No.42(1971)(89). These studies essentially were conducted for the pre-Ramganga situation. The total area of the doab is 54700 sq.km. or 5.47×10^6 ha and is made up of unconsolidated fluiviatile formations comprising sand, silt, clay, and kankar with occasional beds of gravel. The area covered by the lower Ganga canal system is approximating 35 percent of the total area. The ground water potential including the recharge from surface irrigation is estimated to be 870 MCM.

By confining the area of interest to the lower Ganga canal system, the safe yield from ground water has been calculated as 870 MCM. The total C.C.A. available for utilisation is about 800×10^3 hectares against the irrigation potential of about 500×10^3 ha from surface irrigation alone. The surface water utilisation L.P. model has been suitably modified to include the ground water use. The monthwise reservoir releases and the monthwise ground water pumping and the crop areas are the decision variables. Suitable modification in the resource constraints are made to make use of the ground water. The optimum cropping pattern and the corresponding releases and ground water extractions are shown vide Table 4.1. The irrigated area increases from 500 x 10^3 hectares to 800 x 10^3 hectares. The net increase income from irrigated farming increases from Rs.626.44 to Rs.1058.66 x(10^6)with the use of ground water pumping. The power generated during the various months and the requirement for ground water pumping is shown vide Fig.4.2.

4.6.4. Multipurpose Optimization

In the two steps described above, no consideration was given to the pattern of power generation which was considered incidental to irrigation releases. In this important step it is proposed to modify the problem to account for power generation in a desirable way. Firm power generation is the primary purpose of any power plant. A fluctuating power generating system has limited value even in a grid. The Ramganga power plant can be able to provide an effective substitute to the run of the river plants if uniform, energy could be generated during the non-monsoon period. The present operating policy does not consider this aspect in the reservoir operation.

The step 3 therefore aims at changing the set of reservoir releases and the ground water pumping to improve power generation to a more uniform temporal distribution. Step 2 has already

Table 4.1

Optimum Cropping Pattern

Conjunctive Use of Surface and Ground Water

a) Cropping Pattern

	Crop	Area in Hectares
1.	Wheat	390,000
2.	Oilseeds	10,000
3.	Pulses	100,000
4.	Potato	100,000
5.	Gram	100,000
6.	Sugarcane	100,000
	Total	800,000

b) Reservoir Release and Ground Water Pumping (MCM of Consumptive Use)

Month	Res. Release	G.W. Pumping
Dec.	42.39	78.41
Jan.	51.79	177.87
Feb.	64.96	328.87
March	454.34	206.67
April	50.91	83.78
May	185.61	0.0
Total	850.00	870.67

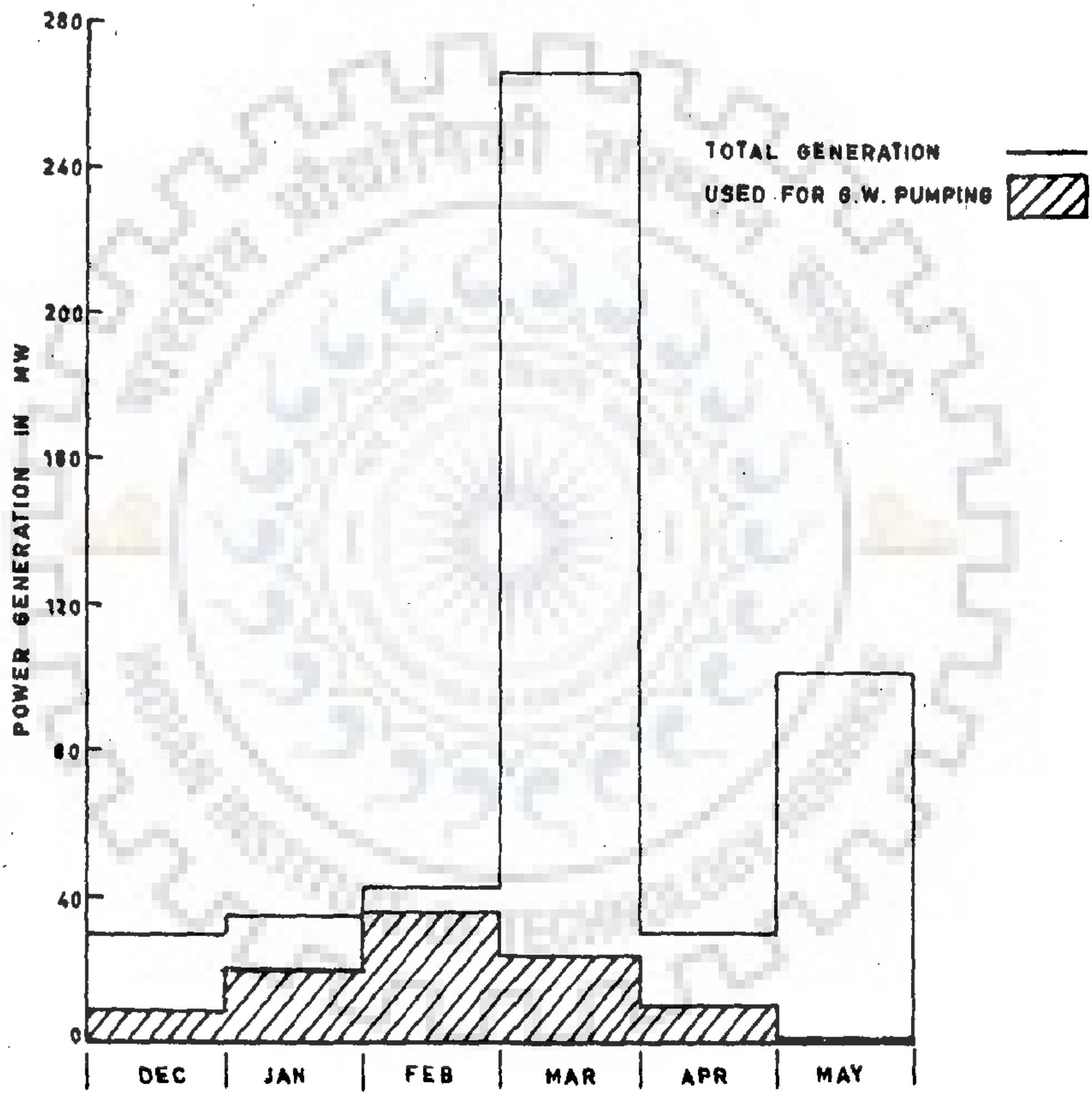


FIG.4.2-PATTERN OF POWER GENERATION

optimised the cropping pattern on the basis of total water availability from surface and ground water sources. In this step it is not intended to disturb this optimum strategy of irrigated agriculture. Only a redistribution and reallocation between the water supply sources is intended.

4.7 MODEL FORMULATION - CONJUNCTIVE USE AND POWER ROUTING

A linear programming model similar to the previous steps has been formulated. The objective is to maximise the net benefits from irrigation and power. The problem is considered as a multiobjective problem. Total requirement of water is not changed. The pattern of reservoir releases does not affect the cost or the irrigation benefits. However ground water pumping has both capacity charge as well as operation and energy charges. When the pattern is changed, the capacity requirement increases with consequent additional cost. By aiming at a better pattern of power generation, ground water pumping capacity increases. The purpose of this model is to determine the trade off between these two factors.

The generating technique of multiobjective formulation is adopted to obtain this trade off (Cohon and Marks, 1975)(14). The main controlling factor is the pattern of energy distribution. To account for this, a constraint is introduced such that the energy produced in any month should not be less than a specified proportion (β) of the total generation of the full season. The maximum value that can be assigned to β is $\frac{1}{n}$ where n is the number of months. $\beta = \frac{1}{n}$ represents an uniform generation.

Since the pumping of ground water has been considered as a part of this system, the energy requirement for pumping must be met from the hydropower generation. After making the full requirement of pumping the balance is only available to the grid which need be as uniform as possible. The distribution factor β is applied to the balance available to the grid and not to the total generation.

The objective function is to maximize the return from irrigated agriculture. All other requirements have been included in the constraint set. The final benefits from constrained irrigation and power generation net of costs have been computed from the alternative strategies.

Objective Function - Max Z = Increase in net income from irrigated farming.

$$Z = \sum_{1}^{n} V_i \, X1_i - \sum_{1}^{n} C_i \, X1_i$$

where

$X1_i$ is the area of crop i,

V_i is the net income from irrigation for crop i

C_i is the cost of cultivation for crop i

i = 1, ...n, n being no. of crops.

subject to the following constraints.

1) Irrigation water requirements should be less than the water available from all sources viz. river flows, reservoir releases and ground water pumping.

$A\,X1 \leq X2 + X3 + F$

or $AX1 - X2 - X3 \leq F$ for each month.

where X2 is the vector of reservoir releases

X3 is the vector of ground water pumping

F is the river flows

A is the consumptive use coefficients

2) Sum of the cropped area under different crops at any time should not exceed the land available.

$\Sigma X1_i \leq L$ where L is the total land available.

3) Sum of the reservoir releases should not exceed the reservoir yield

$\Sigma X2_j \leq Y$ where Y is the annual yield

4) Area under each crop is limited to a particular range.

$L_1 \leq X1 \leq L_2$ where L_1 and L_2 are the upper and lower bounds.

5) Sum of the ground water extractions should not exceed the recharge capability.

$\Sigma X3_j \leq W$, $j = 1, 2, \ldots\ldots,$ m being number of months.

where W is the ground water potential including the recharge from surface irrigation.

6) The energy generated from the irrigation releases will be used for ground water pumping as well as for feeding the grid. This constraint requires that the amount of power supplied to the grid shall have a specific distribution pattern among various months. The energy generated in any month P_j should be such that it would meet

the ground water pumping requirements. G_j and in addition the energy made available to the grid, should not be less than a specified proportion of annual energy supplied to the grid (E).

$$P_j \geq G_j + \beta E \text{ for } j = 1.........m$$

$$\text{or } K_j.X2_j \geq H_j.X3_j + \beta \Sigma K_j.X2\ j,\ j = 1,2......m$$

$$\text{or } K_j(1-\beta).\ X2_j - \sum_{t \neq j} K_t.X2_t - H_j.X2_j.\quad t=1,2,......,m.$$

Where K is the power conversion factor

and H is the power requirement factor for ground water pumping.

Data Requirement

The objective function includes the increase in net income from irrigated agriculture. The same data is used in the previous chapter has been used here. The objective function does not consider the benefit from power generation since the total amount of energy generated remains more or less the same. The model aims only at changing the pattern.

Irrigation water requirements for the six crops used have been computed vide table 3.4 of chapter 3. The total land available has been increased to 800 $x10^3$ hectares. Similarly suitable upper and lower bounds for different crops have been included.

The sum of the monthly ground water extractions should not exceed the ground water potential of 870 MCM for the area. The model considers the energy requirement for ground water pumping. The ground water level in the aquifer varies from a depth of 3 m to 15 m from the ground level. Considering an average head of 12 m for pumping, the energy requirement factor has been calculated for use in the energy constraints.

The value of β, is changed from a low value to the higher possible value of 0.167 in discreet steps to generate the alternatives. The parametric programming enables generate the different strategies. The availability of power to the grid is made fully uniform with $\beta = 0.167$. The reservoir releases and the corresponding ground water and power generation are tabulated vide Table 4.2 to 4.5. With a low value of β of 0.035, the level of firm power generation is only 14.32 MW and the corresponding maximum ground water pumping capacity is 328.87 MCM. As the value of β is increased to 0.167, the level of firm power increases to 70.07 MW, bring the maximum possible value and the corresponding requirement of ground water capacity is 475.44MCM. The power generated during the various months and their distribution are plotted for the various values of β are shown vide Fig.4.3 to 4.6. These also show the quantity of power used for ground water pumping, the balance being that available to the grid. The variations in the level of firm power and the corresponding pumping capacity with variation of β are shown vide Fig.4.7. This figure brings out the trade off between the two parameters viz. increase in pumping capacity requirement corresponding to unit increase in the firm power generation. Since the total energy potential of the reservoir is constant, the benefit is only from changing the secondary or dump energy

Table 4.2

Pattern of Power Generation

$\beta = 0.035$

Month	Reservoir Release MCM	Energy Generation MWM	Ground water pumping MCM	Energy Consumption MWM	Balance MWM	Remarks
Dec.	42.39	29.05	78.41	8.70	20.35	
Jan.	51.79	33.98	177.10	19.65	14.32	Minimum
Feb.	64.96	41.57	328.87	36.50	28.45	
Mar.	454.34	266.29	206.67	22.94	243.35	
Apr.	50.90	29.31	83.78	9.30	20.01	
May	185.61	100.63	0.00	0.00	100.63	
Total	850.00	500.85	868.00	97.09	427.11	

Table 4.3

Pattern of Power Generation

$\beta = 0.083$

Month	Reservoir Release MCM	Energy generation MWM	Ground water pumping MCM	Energy consumption MWM	Balance MWM	Remarks
Dec.	61.49	42.14	59.31	6.58	35.56	
Jan.	77.08	50.58	151.82	16.85	33.73	Minimum
Feb.	105.56	67.56	288.27	31.99	35.57	
Mar.	285.57	168.23	375.44	41.68	126.55	
Apr.	134.68	77.58	0.00	0.00	77.58	
May	185.61	100.64	0.00	0.00	100.64	
Total	850.00	506.73	875.00	97.10	409.63	

Table 4.4

Pattern of Power Generation

$\beta = 0.150$

Month	Reservoir release MCM	Energy generation MWM	Ground water pumping MCM	Energy Consumption MWM	Balance MWM	Remarks
Dec.	94.30	64.62	26.49	2.94	61.68	
Jan.	113.52	74.45	115.37	12.80	61.65	Minimum
Feb.	140.35	89.82	253.48	28.14	61.68	
Mar.	192.94	113.64	468.06	51.96	61.68	
Apr.	123.26	71.00	11.42	1.27	69.73	
May	185.61	100.60	0.00	0.00	100.60	
Total	850.00	514.13	875.00	97.11	417.02	

Table 4.5

Pattern of Power Generation

$\beta = 0.167$

Month	Reservoir Release MCM	Energy Generation MWM	Ground water pumping MCM	Energy consumption MWM	Balance MWM	Remarks
Dec.	104.93	71.91	15.38	1.77	70.14	
Jan.	125.39	82.28	109.49	12.16	70.12	
Feb.	153.54	98.27	253.77	28.18	70.09	
Mar.	208.57	122.85	475.44	52.78	70.07	
Apr.	121.70	70.09	0.00	0.00	70.09	
May	135.87	73.64	31.65	3.51	70.12	
Total	850.00	519.04	875.00	98.41	420.20	

Table 4.6

Marginal Analysis

Sl. No.	Item	Alternative Operation Policies			
		β=0.035	β=0.083	β=0.150	β=0.167
1	2	3	4	5	6
	I. Costs				
1.	Ground water pumping Capacity MCM/month	328.87	375.44	468.06	475.44
2.	Incremental capacity MCM/month		46.57	92.62	7.32
3.	Incremental annual cost Rs.x10^6		6.05	12.00	0.96
	II. Benefits from Hydropower				
1.	Firm power MW	14.32	33.73	61.68	70.09
2.	Incremental firm power MW		19.41	27.75	8.41
3.	Incremental benefits Rs.10^6		18.02	25.77	7.81
4.	Incremental net benefits Rs. 10^6		11.97	13.77	6.85
5.	Cumulative net benefits Rs. 10^6		11.97	25.74	32.59

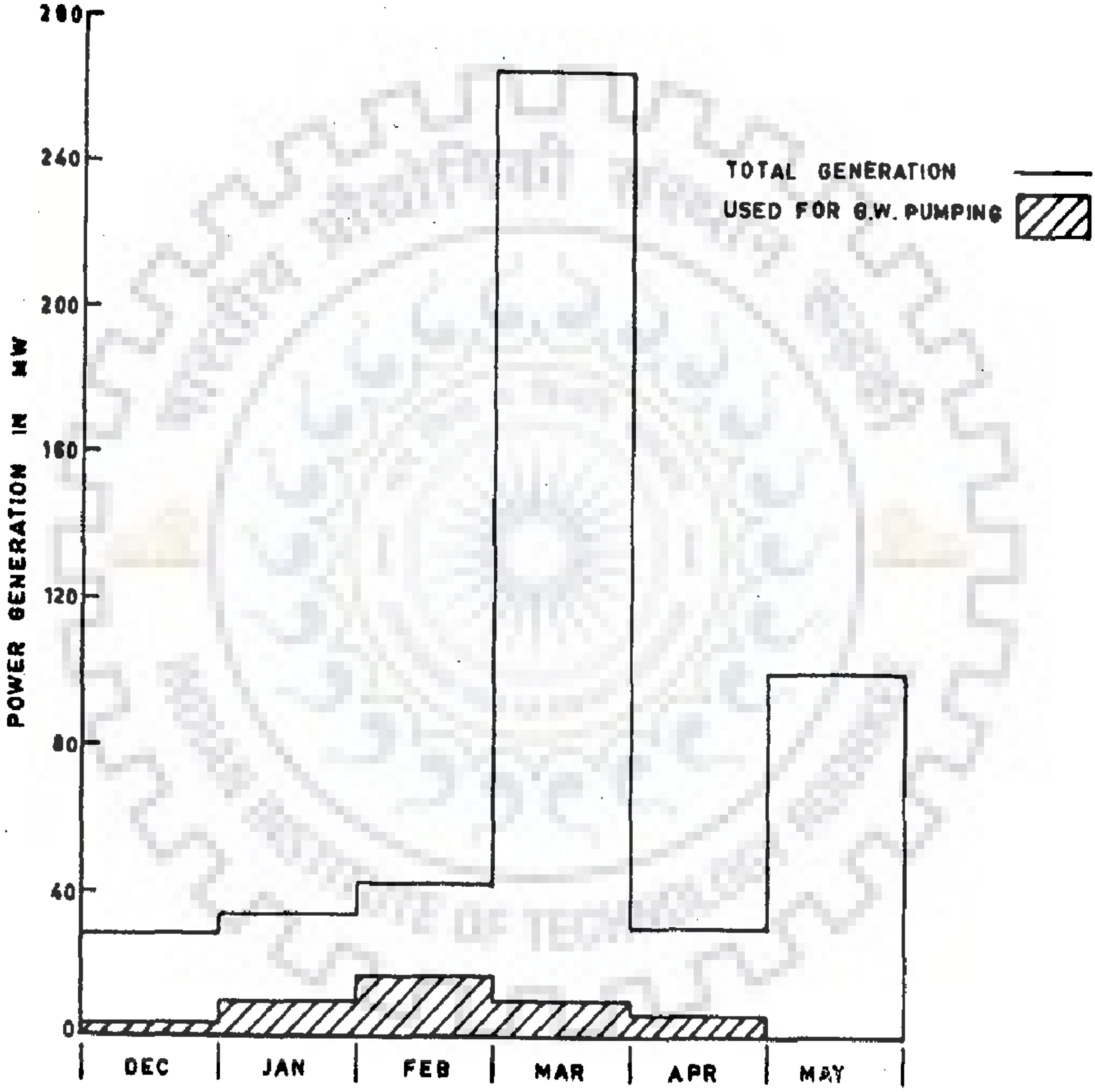


FIG.4.3 - PATTERN OF POWER GENERATION $\beta = 0.035$

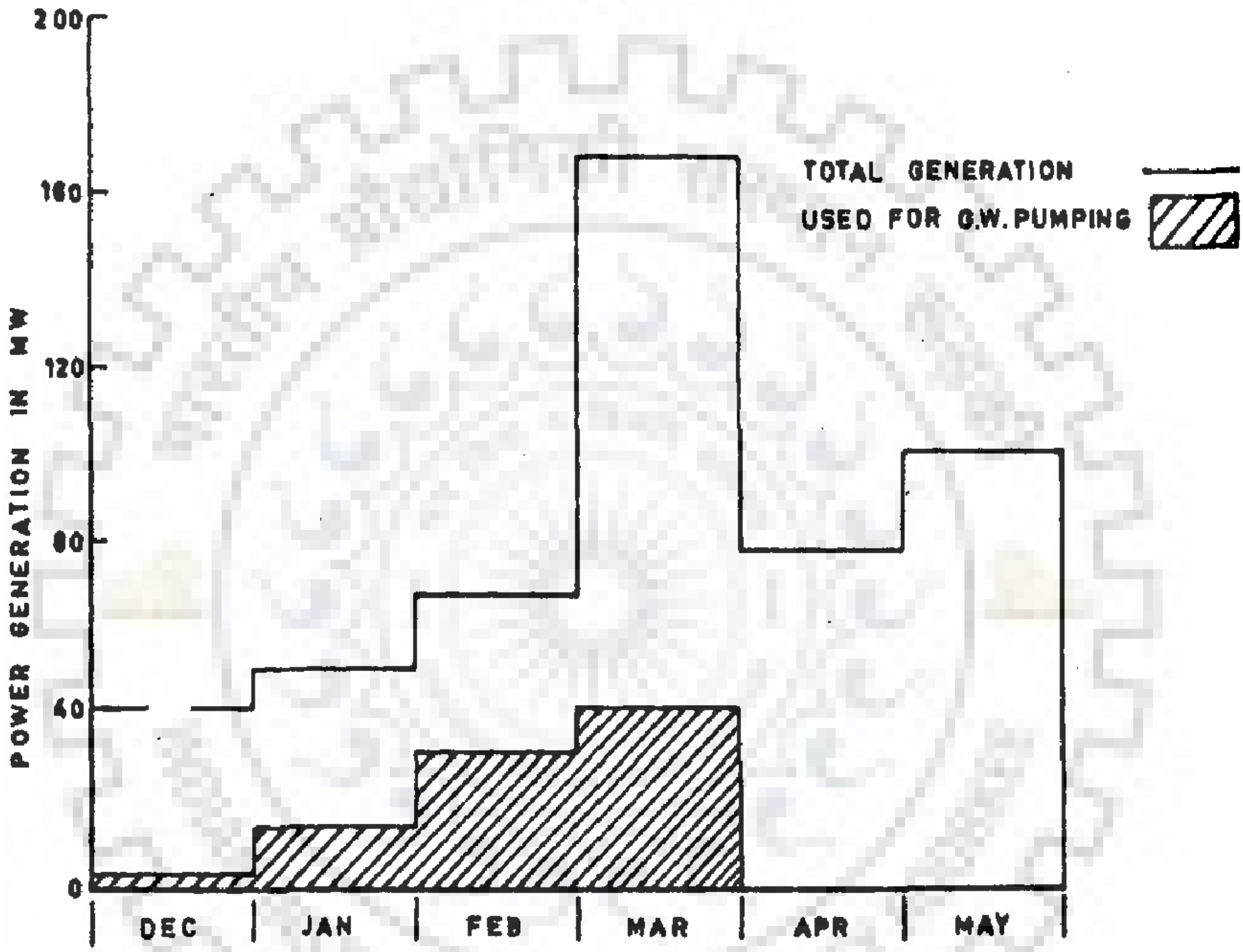


FIG.4·4 - PATTERN OF POWER GENERATION β = 0·083

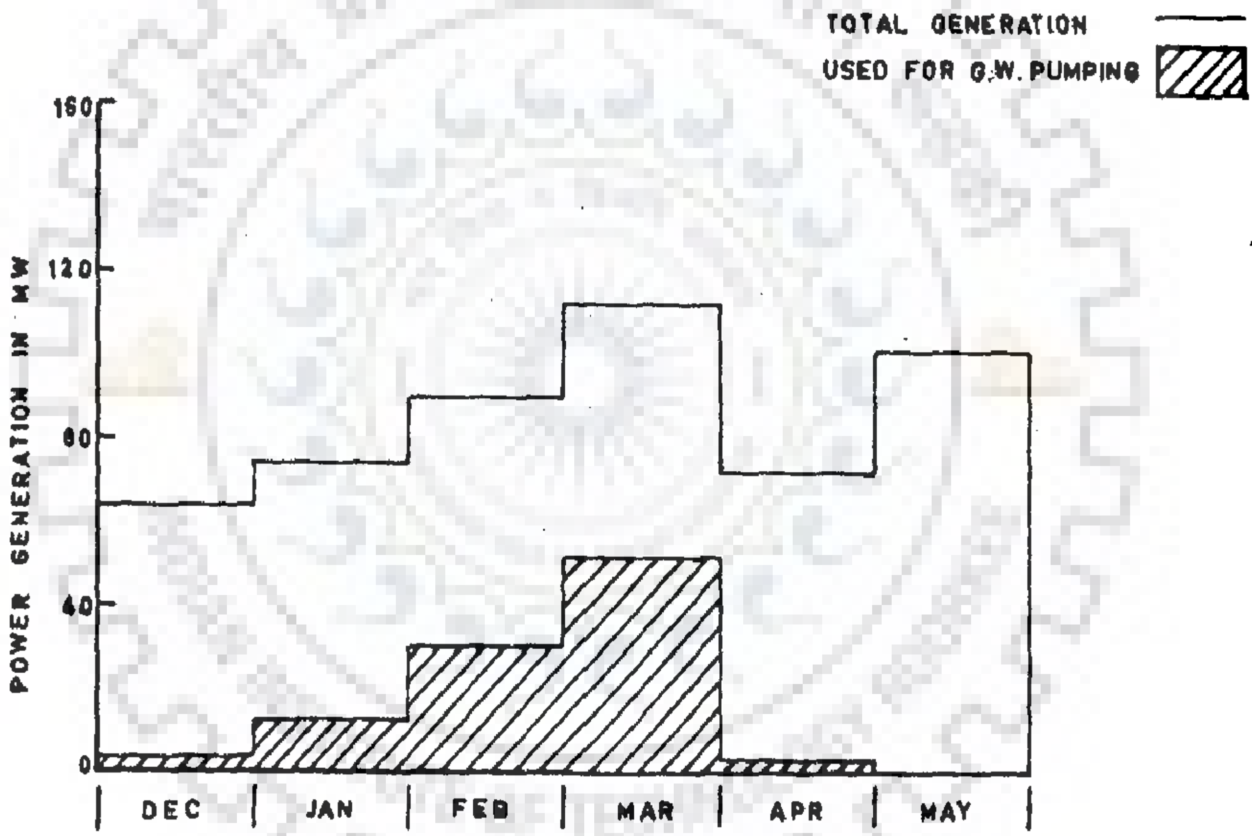


FIG.4·5-PATTERN OF POWER GENERATION $\beta = 0{\cdot}150$

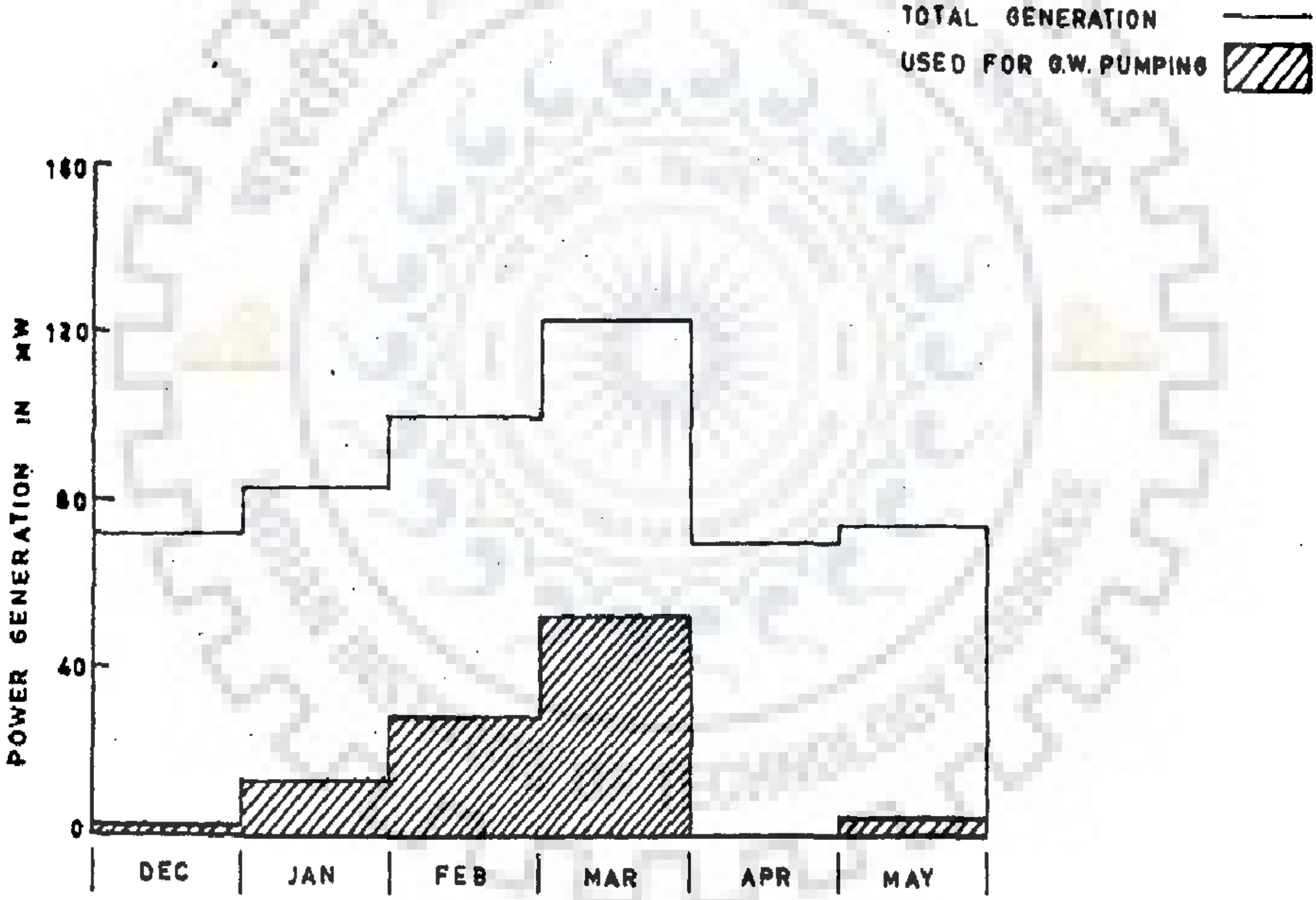


FIG.4·6 - PATTERN OF POWER GENERATION β = 0·167

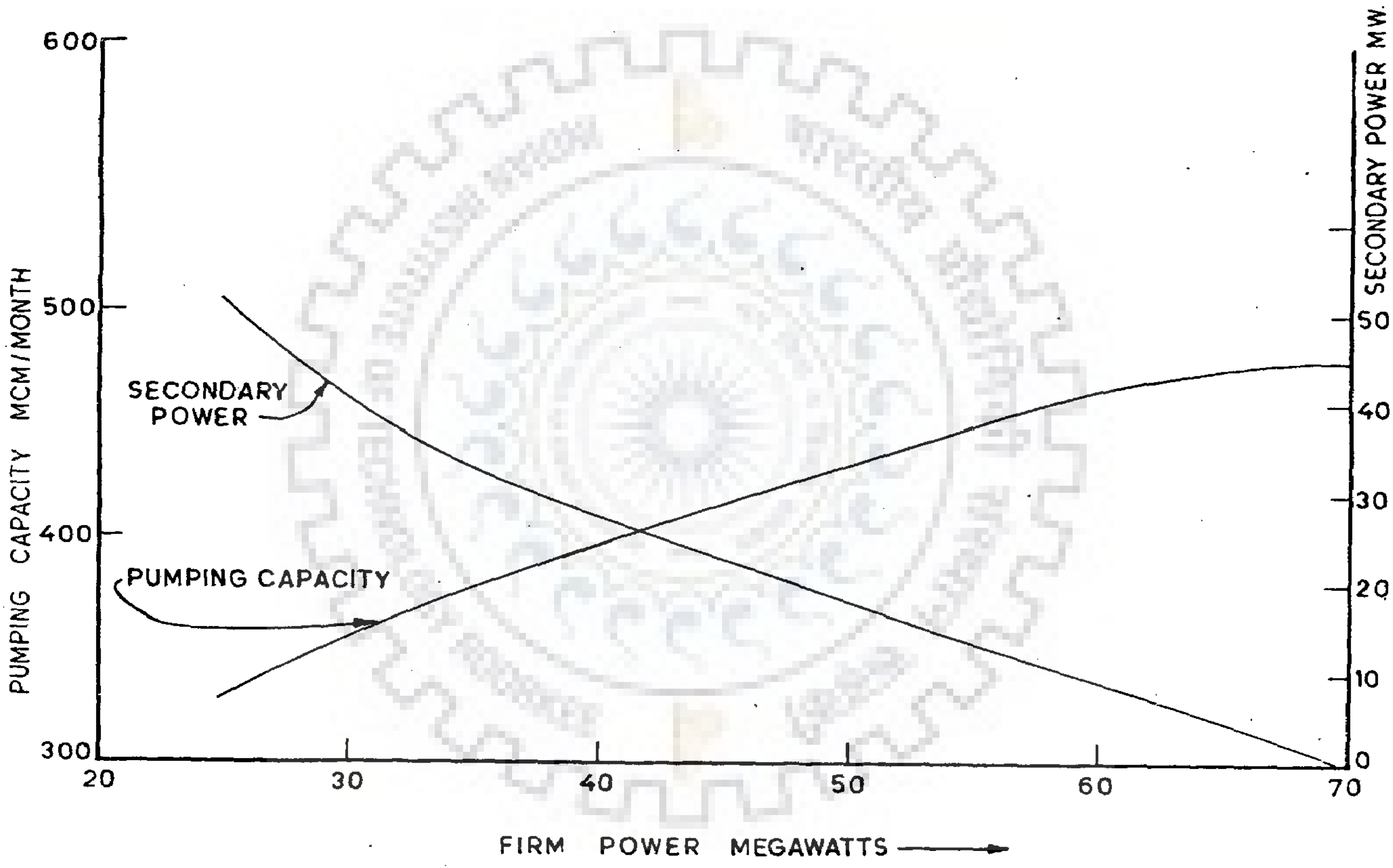


FIG. 4·7-FIRM POWER Vs PUMPING CAPACITY

to the more desirable firm energy. Due to the additional cost involved in raising the pumping capacity, additional benefit is obtained on thepower front. This investment, in fact, is on energy production rather than on ground water pumping. The model provides for meeting the full energy requirement for pumping. Though in practice, it may not be possible to direct use this generation for ground water pumping, nevertheless this arrangement makes the project self sustaining for power requirement of the irrigation system.

4.8 ECONOMIC CONSIDERATION

For selecting the optimum trade off between the level of firm power generation and the pumping capacity, economic considerations would prevail. The optimum strategy is that which maximizes the net benefit from the policy instrument. For this purpose, the comparison is made with the strategy developed in step 2. The additional (incremental) benefits and costs for the different combinations are computed. The results of the marginal analysis are shown in the Table 4.6. It can be seen that incremental net benefits are positive, indicating that it is desirable to the generate uniform energy.

Cost of increasing the ground water pumping capacity has been calculated at prevailing rates and annual cost has been calculated at discount rate of 10 percent. The benefits from power has been computed on the basis of conversion of secondary power to firm power.

The evaluation of benefits from hydropower need special attention. A distinction is made between the firm and secondary power. In case of hydropower the peaking capability has special significance. Though the present pricing policy of electricity does not differentiate among on peak, off-peak,firm or secondary power, the opportunity cost of each type is different and must be considered in imputing values.

The usual method of determining the opportunity cost of hydropower is the alternative cost approach to benefit evaluation. The opportunity cost of hydropower generation is the cost of the cheapest, alternative which would have been taken up in absence of the hydrostation. The most likely alternative is usually the thermal generation. Considering the present pricing is on the basis of thermal generation, the unit price of Re.0.18 per KWH has been considered. Because of the peaking capability, the hydropower is valued at 1.5 times the base lead price i.e. Rs.0.27 per KWH. The secondary energy is valued at its opportunity cost which is the saving in fuel consumption of thermal generation. The current price of Rs.0.065 per KWH has been considered. Conversion of secondary energy to firm peaking energy has a value of Rs.0.205 per KWH which has been considered.

The conversion of secondary to firm energy has a limit of β = 0.167. From marginal analysis it is seen that the incremental benefit is more than the incremental cost as the value of β is increased. The strategy corresponding to β = 0.167 is found to be most desirable.

4.9 VALUATION IN MULTIPURPOSE USE

Once the strategy corresponding to maximum net benefits is selected the next step is to determine the value of water in the different uses so that a suitable pricing system can be evolved. The problem is not so much of valuation but of cost sharing. From the optimum strategy the value per unit use of water as well as the cost per unit can be determined. Sharing of project costs by different purposes is usually done by the separable cost remaining benefit method. For purpose of pricing for cost recovery, the problem has to be tackled in a different perspective, specially where irrigation is a purpose. Since power generation is normally meant for commercial use, the pricing shall be on the basis of its opportunity cost in commercial use. The usual price charged should be able not only to fully recover the cost but also provide a return to the investment so that it can contribute to the capital formation. This will provide some relief to the other sectors of the project.

In view of the developmental nature of the irrigation sector, the cost recovery share of irrigation should be as small as possible consistent with the other objectives of development. After charging the other sectors 'as much as the traffic can bear' the residual is assigned to irrigation, similar to the concept of residual imputation discussed vide para 3.3.

The above concept is applied to the case study for all three steps to bring out the effect of conjunctive use and the effect of improved power generation. The cost of the Ramganga

Table 4.7

Cost and Value of Water

Million Rupees

Sl. No.	Item	I Surface water only	II Conjunctive use	III Improved power generation
1	2	3	4	5
1.	Annual cost of irrigation	176.33		
2.	Incremental annual cost		42.8	19.01
3.	Annual cost of irrigation	176.33	219.13	238.14
4.	Annual cost power	41.87	41.87	41.87
5.	Revenue from power	46.00	46.00	78.60
6.	Excess of power revenue over cost (5-4)	4.23	4.23	36.73
7.	Reduced annual cost of irrigation (3-6)	172.10	214.90	201.41
8.	Quantity of water MCM	1350	2225	2225
9.	Cost of providing water for irrigation Rs/cum	0.1275	0.0966	0.0905
10.	Annual benefit from irrigation Rs. 10^6	393.94	686.00	686.00
11.	Value of water Rs/cum	0.2918	0.3083	0.3083
12.	Value added Rs/cum	0.1643	0.3083	0.3083
13.	Net annual benefit (10-7)	221.84	472.10	484.59

Multipurpose project is first allocated to different purposes on the basis of separable cost remains benefit method. After deducting the revenue from power generation, the balance is assigned to irrigation water for purpose of cost recovery vide Table 4.7. The cost per unit of water for irrigation changes from Rs.0.1275 per m^3 in step 1 to 0.0905 in step 3. From cost recovery point of view, the per unit cost reduces by 30 percent a substantial relief to the irrigation users if they have to bear the cost.

4.10 DISCUSSION OF RESULTS

Before pricing is taken up, it is necessary to see that the value of water for irrigation is maximised with consequent benefits to the users. This is a part of the usual planning process. However the cost and value of water provide the necessary insight and framework for pricing, specially where recovery of cost is an objective or where the principle of marginal cost pricing is to be adopted.

As has been discussed in para 2.3, the long term marginal cost pricing represents a more realistic situation. From the national point of view, the construction of a new project provide a small increment to the total irrigation potential(Major 1977 (63). The unit cost of producing this incremental output can be taken as the long term marginal cost, similar to ' new plant pricing' in the industrial sector. The costs obtained vide table 4.7 provides the basic framework for pricing. Where volumetric charging is possible cost per unit quantity can be charged. However for large irrigation systems, volumetric charging has not been considered practicable. Charging on the basis of crop area is an established practice.

The water requirement of the various crops and the water charges are tabulated vide Table 4.8. The ability to pay calculated by vide 3.9 are also tabulated. It can be seen that there is wide variations in the two sets of values. If we charge on the basis of costs, some of the crops would become uneconomical and will not be cultivated at all, with consequent adverse effect on the society. If maximising the value of water would be the only consideration, then irrigated agriculture would require cultivating a single or two crops. For this purpose in any crop model, limits of crop acreages are put to obtain a desirable mix of crops. In this process, the water is put to values lower than the possible maximum. The new crops that are brought in are less desirable from the point of view of water use efficiency. Since cultivation of such crops is a social requirement, it would not be desirable to burden the cultivator for this purpose.

For purpose of cost recovery, the entire project is considered as a single entity and not each crop acreage. The impact of pricing policy on cost recovery is discussed in the concluding chapter.

Table 4.8

Cost of Water Vrs. Ability to Pay

Sl. No.	Item	Wheat	Oilseeds	Pulses	Potato	Gram	Sugar-cane
1.	Qty. of water per Hect. (10^3 Cum)	2.64	2.33	1.47	1.74	1.94	6.21
2.	Cost of providing water at 0.0905 per cum (Rs/Hectare)	238.92	210.86	133.03	157.47	175.57	562.00
3.	Ability to pay (Rs. per Hect.)	337.00	149.00	198.00	610.00	290.00	419.00
4.	Total cost if charged vide (2) above, Rs. 10^6	93.18	2.11	13.303	15.747	17.557	56.20

(Total Rs.198.09 x 10^6). This is slightly less than the value of Rs.201.41 vide Table 4.7 due to rounding errors.

CHAPTER-5

RISK AND UNCERTAINTIES

5.1 INTRODUCTION

The central decision in planning for irrigated agriculture whether in the planning stage or for operation, is to determine what types of crops would be grown. Physical and technological resource constraints provide an upper or lower bound to the crop acreages, the actual crops to be grown depends on economic factors. Much of the decisions are based on imperfect knowledge. Risk and uncertainty is associated with such decisions. In these situations the outcome cannot be predicted with confidence.

In decision theory literature, risk and uncertainty are treated separately. Risk refers to a situation where the probability distribution of the outcome is known. Where probability distribution is estimated from statistical data, decision making is said to take place under conditions of ' objective risk '. When it is approximately intuition or value judgement, it is said to occur under subjective risk. Uncertainty exists when the parameters of probability distribution cannot be determined i.e. the activities are not amenable to usual statistical analysis. Unless risk and uncertainty are properly considered, the realisation may significantly differ from the expectation. However risk and uncertainties are considered together and no explicit distinction is made in this study. The problem of water pricing in an irrigation system is always inter-related with the type of crops and extent of each crop to be grown. Whether it is a case of dry farming, unlimited irrigation water supply or limited supply, the objective of the farmer is to maximise profits. The variability of the net returns associated with crop production plays an important role in the decision. The net returns have a random component which needs be looked into.

Burt and Stauber (1971) (10) while analysing investment decisions have brought out the importance of including the variability of the net retuns as a decision criteria. Higher expected income is associated with higher levels of investment and with larger variability.

5.2 METHODOLOGY

The primary objective of public investment policy is welfare maximization. It may be worthwhile to analyse how the welfare is affected by risk and uncertainty. The aggregate welfare resulting from the outputs of an enterprise is the sum of the utilities that accrue to the users of the output. Considering expected income as a measure of utility, where no risks are involved.

$$W = W\ (\ \bar{Y}_1,\ \bar{Y}_2,\ \bar{Y}_3,\ \ldots\ldots\ \bar{Y}_i \ldots\ldots\ \bar{Y}_n\ )$$

where $\bar{Y}_i$ is the average income of ith individual.

For a risky situation the expected welfare

$$E(W) = W(\bar{Y}_1, \bar{Y}_2, \bar{Y}_3, \bar{Y}_i \ldots \bar{Y}_n) - E \left| \sum_{1}^{n} W_i (\bar{Y}_i - Y_i) \right|$$

(Scandizo, 1980) (80).

The second term is the social risk premium. It represents the expected reduction of welfare in a risky situation considering the statistical parameters governing the distribution of Y_i. The objective would be to reduce the risk premium to the possible extent.

Several methods have been put forth by different authors for considering the variabilities. Minimising the risk would improve the welfare. The risk premium enters the problem due to randomness in the expected value. The objective is to maximise the expected income while minimising the risk. As already indicated these two objectives are conflicting or competitive and both cannot be optimized at the same time. This leads to multiobjective optimization.

Despite the importance of risk minimization, the same has not explicitly been considered as an objective to be minimized in water resources systems analysis. Further if risk is to be considered as an objective in multi-objective framework, a fundamental requirement is the definition of a suitable quantitative index of risk (Nazar et al 1982) (73).

5.3 REVIEW OF METHODS

It has been accepted that stochastic models of decision making in complicated situations, specially with insufficient data and information, are closer to real events and processes than deterministic models. Use of stochastic models to water resources problems have been quite widespread in recent times. Though use of such methods have been quite extensive in hydrologic processes, their application to irrigation systems and crop planning have been limited.

5.3.1 Chance Constrained Programming Problems

The stochasticity of the event is considered as a constraint in the optimization model. One form of chance constrained stochastic linear programming model is given below (Koblin, 1977) (51) used as an agricultural production planning model.

$$\text{Min } Y = \sum_{1}^{n} C_i \; X_i$$

where C_i is the cost of production and X_i the area respectively of the ith crop for n crops.

Subject to the constraints.

i) $P \left[\sum_{1}^{n} C_i \; X_i \leq Y_1 \right] = \beta$

The probability that the cost of production of the desired crops is less than a prescribed value Y_1 is equal to β where $(1-\beta)$ is the admissible risk for which Y_1 has been planned.

ii) $P \mid \eta_i X_i \geq R \mid \geq \alpha_i, \; i = 1, \; .....n$

The probability that the total production of i^{th} crop should be more than the planned value R should be greater than α_i where $(1- \alpha_i)$ is the admissible risk for non fulfilment of production of the ith crop, η_i being the yield of crop per unit area.

iii) Usual resource constraints

In chance constrained problem, the probabilistic situation has been converted to a deterministic one.

5.3.2 Expected Income Variance

Decision problems often force individuals to choose between outcomes with various expected incomes and the variance associated with it. Under uncertain situations, a decision maker tries to maximise his expected utility which depends on the expected income and variance. There is general agreement among economists and farmers are assumed to maximize a myopic mean variance criteria in their decision making (Just 1980) (50). The mean variance utility approach is employed because of the interactability of handling correlated random variables with other approaches. Though this approach has been advocated by many investigators, its application to an actual real world situation is not found in the literature. Halter and Dean (1971) (34) applied the framework to a hypothetical case.

5.4 MODEL FORMULATION

The farmer's objective is to maximise utility under the mean variance framework. The decision problem can be represented by

$$\text{Max } Z = \mu - \phi\ \sigma$$

where

Z = expected utility

μ = mean or expected income per Hectare

σ = standard deviation of μ

ϕ = risk aversion coefficient.

Subject to usual resource constrains. The above model is for a single crop.

In actual practice, a farmer has to decide the most suitable crop mix. Each individual crop has an expected income and a variance associated with it. Because of the substitutability characteristic of the crops, the expected incomes are interdependent and there exists a correlation among the crops. The crop mix system proposed will have a system variance depending on the statistical parameters of the crop prices.

For a crop system, the mean and variance are given by

i) $\mu = \Sigma \mu_i X_i$

where

μ = expected income for the crop mix in an equivalent hectare.

μ_i = expected income if i^{th} crop.

X_i = proportion of the area (hectare) of the i^{th} crop.

ii) The variance of the system is given by

$$\sigma^2 = \sum_{i=1}^{n} X_i^2 \sigma_i^2 + 2 \sum_{i=1}^{n} \sum_{j=i+1}^{n} X_i X_j \sigma_i \sigma_j r_{ij}$$

where

σ_i^2 = variance of i^{th} crop.

r_{ij} = correlation between the expected incomes of crops i and j.

A normal distribution is assumed in the above formulation.

or $\sigma^2 = \lfloor X_i \rfloor \; | \sigma_i \sigma_j \gamma_{ij} | \; | X_j |$

where $| \sigma_i \sigma_j \gamma_{ij} |$ is the variance - co-variance matrix. Corresponding to a crop mix there is a value of μ and the corresponding value of variance. For maximizing the expected income, the search will be to get the minimum variance so that the utility is maximised. It is necessary to obtain the E-V relationship in which each point is an efficient point. Computation of sufficient points and then the envelope would give the efficient E-V frontier. This can be formulated as an multi-objective optimisation problem.

For a two objective problem of this sort, what is required is to generate sufficient number of efficient points to develop the E-V frontier or what is otherwise termed the product transformation curve (Major 1977, (63), Cohon and Marks 1975) (14). Though the objective is to maximise the utility $\mu - \phi\, \sigma$, the model is formulated to determine the minimum σ corresponding to an expected income. In this model formulation

Obj fn $Z = \mu - \sigma^2$

for the cropping system

Max $Z = \Sigma\, \mu_i X_i - | X_i | \; | \sigma_i \sigma_j \gamma_{ij} | \; | X_j |$

Subject to the land constraints. The total cropped area should be less than the land available. Limits on individual land constraints can also be included. Since the optimization problem involves minimizing variance, which is a quadratic function, quadratic programming is resorted. To generate the required number of points in the multiobjective frame work, an additional constraint is introduced. The expected income should be equal to K.

or $\Sigma \mu_i X_i = K$

The solution proceeds paramatrically starting with a small value of K and increasing it in steps until the maximum possible value is reached, after which the problem would be infeasible. The solution set shows the maximum difference between the desired expected income $\mu_i X_i$ and the variance. In other words it minimises the variance for the particular level of expected income.

5.5 APPLICATION OF THE MODEL

This study adopts the E-V concept and the associated assumption regarding the farmer's behaviour under uncertainty. Crop production involves uncertainty due to a variety of reasons. The major sources of uncertainty are the yields and prices. The efforts of farmers to maximise yields have certain specific characteristics. The randomness of yield is due to factors like climate, pests, management ability, cultivation practice, state of technology etc. Some of them are controllable and some are uncontrollable. The uncontrollable ones like climate cannot be accounted for. Randomness in the prices of other inputs is not very much. The prices of those inputs are no doubt subject to usual escalation due to inflation but are some what stable.

The uncertainty in prices of products is the most important factor considered by farmers in this respect and have been considered in the analysis. To determine the variability of prices, the time series has to be considered. The six crops that have been selected for the Ramganga Project have been considered in this study also.

The average net incomes from farming have been obtained from the farm budgets as given in chapter vide Table 3.3. For purpose of studying the variation, the time series of prices have been considered. The data for 10 years for these crops have been collected and listed. The farmer's expected income is influenced by the recent prices whereas the variance of the random component is that of the time series (Halter and Dean 1971) (34). Usually the standard deviation can be expressed as a proportion of the expected income.

The analysis of time series is done to determine the standard deviation of prices of individual crops and also the correlation between the prices. It is assumed that the expected income has a direct relation with the prices and that the standard deviation bears same proportion.

For consistency these are normalised to the expected income obtained for the previous analysis. The expected income, standard deviation and the correlation matrix used in this analysis are tabulated vide Table 5.1.

5.6 CASE OF UNLIMITED WATER

The intention is to develop E-V relationship for irrigated agriculture. The farmers behaviour when irrigation water

Table 5.1

Mean

Variance-covariance Matrix

Wheat	Oilseeds	Pulses	Potato	Gram	Sugarcane
Mean (Rs/Hectare)					
1210	886	933	1949	1050	1803
Standard Deviation (Rs./Hectare)					
391.6	354.0	233.0	553.0	210.0	407.00
Correlation matrix					
1.00	0.315	0.215	0.7649	0.25	-0.324
	1.00	0.815	0.315	0.62	-0.05
		1.00	0.415	0.89	-0.08
			1.00	0.31	0.0368
				1.00	-0.040
					1.00
Covariance matrix					
15.335	4.372	1.962	21.309	2.056	-5.167
	12.560	6.730	7.942	4.614	-0.721
		5.429	6.879	3.034	-0.474
			30.609	4.631	1.047
				4.410	-0.342
					16.565

Table 5.2

Mean Variance - Unlimited Water

Rs. per Hectare

Sl. No.	Mean μ	Std. Deviation σ	Wheat	Oilseeds	Pulses	Potato	Gram	Sugar-cane
				percent of area				
1	1100	141.4	17.86	0.00	10.4	0.00	29.8	26.2
2	1300	167.1	21.1	0.00	12.30	0.00	35.20	31.00
3	1500	216.8	28.0	0.00	0.00	3.00	18.62	51.10
4	1600	250.0	9.54	0.0	0.0	17.7	22.88	49.85
5	1800	315.3	0.00	0.00	0.00	34.7	7.10	58.10
6	1905	416.56	0.00	0.00	0.00	71.3	0.00	28.7

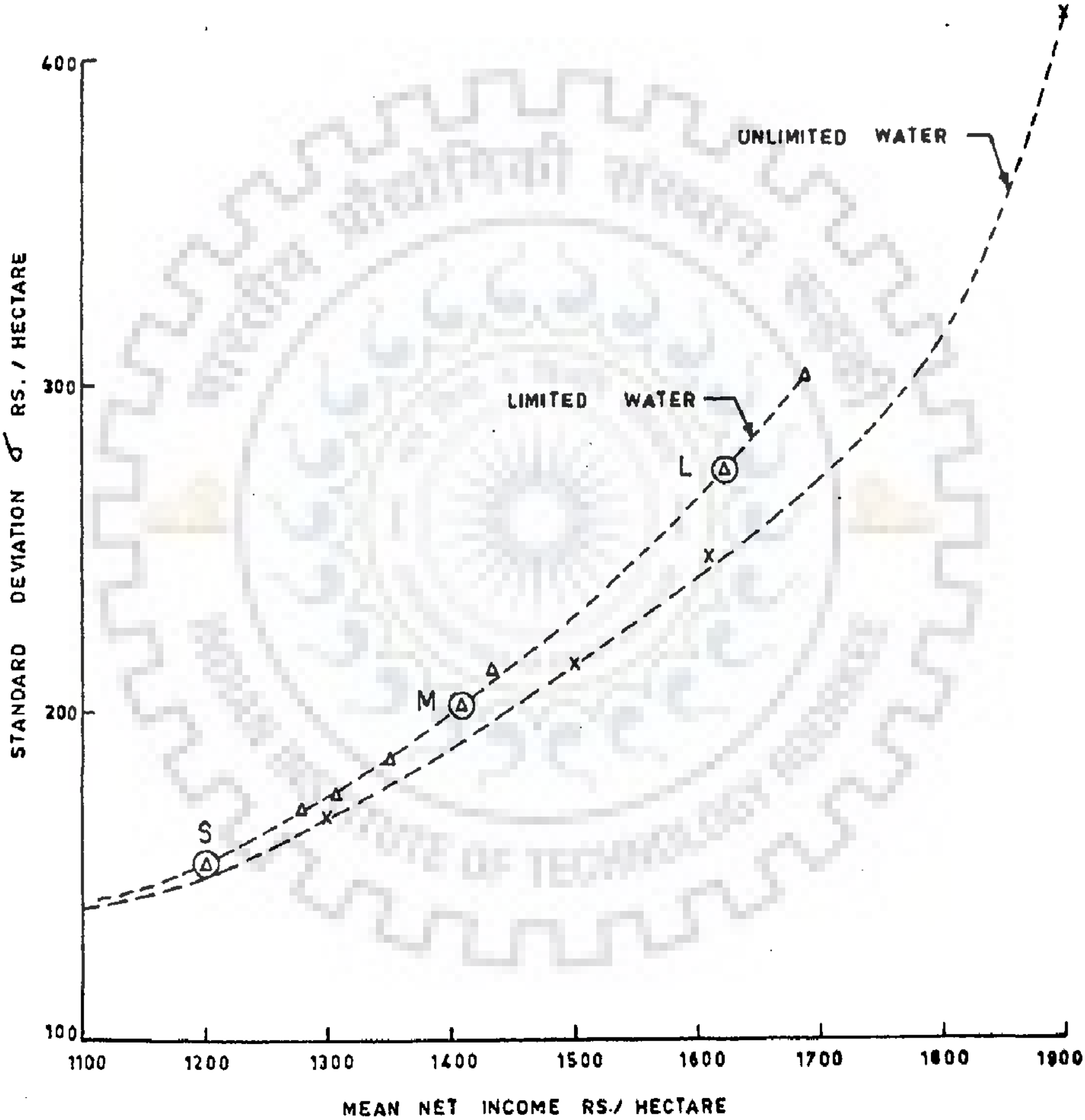


FIG. 5·1 - E - V. FRONTIER

is not a constraint is first considered. This is simpler than when water availability is limited.

The objective function is Max $Z = \Sigma \mu_i X_i - | X_i | \, | \sigma_i \sigma_j \gamma_{ij} | \, | X_j |$
Subject to land constraint.

In this formulation no individual crop constraints are included to see whether the obtained crop mix are realistic or not. The crop mix depends on the co-variance matrix. This formulation is different from the usual linear programming models where the objective is to maximize incomes and without suitable crop constraints may result in only single or two crops entering the solution. The quadratic programming formulation showed some very interesting results. The results are shown vide Table 5.2. The suitability of the optimum cropping mix for different levels of expected incomes are shown. As is natural, at very higher levels of expected income, more and more of high value crops enter the solution. The E-V frontier for this case is shown vide Fig.5.1.

5.7 CASE OF LIMITED WATER

An additional dimension is added to the problem, when the water availability constraint is included. This would mean that the water should also be allocated in order of priority to high value crops. Additional set of constraints as below are included.

Table 5.3

Mean - Variance

Limited Water

Sl. No.	Mean μ Rs/Ha	Std. Deviation σ Rs/Ha	Percent of area					
			Wheat	Oilseeds	Pulses	Potato	Gram	Sugarcane
1	2	3	4	5	6	7	8	9
1+	1205.2	154.06	22.81	0.0	23.92	0.00	28.21	25.06
2	1279.8	166.01	19.95	0.0	24.23	0.00	25.78	30.04
3	1303.9	167.61	21.17	0.00	12.34	0.00	35.35	31.14
4	1355.9	176.59	26.79	0.00	7.78	0.00	29.30	36.14
5+	1406.3	200.12	19.99	11.77	0.00	0.31	22.67	45.25
6	1421.9	216.63	32.68	14.43	0.00	4.99	8.17	39.73
7+	1622.5	275.22	10.49	10.47	0.00	27.75	8.30	42.95
8	1687.82	300.52	2.91	16.22	0.00	34.86	0.00	46.00

i) $\sum_i A_{ik} X_{ik} \leq I_k + R_k$ for k = 1,.....,m, no.of months

where A_{ik} is the water use co-efficient for ith crop during k^{th} month,

I_k is the river flow during month k

R_k is the reservoir release for month k

ii) $\Sigma R_k \leq R$ where R is the annual reservoir yield.

These two constraint sets ensure that the water requirement of crops are met during the various periods. The water availability data of Ramganga Project as used in Chapter 3 and 4 are used in this formulation.

The quadratic programming outputs are compiled and shown vide Table 5.3. The E-V frontier has been plotted and shown vide Fig.5.1.

The purpose of this analysis is to determine the extent of risk involved in crop production by individuals. The pricing of water must consider this element of risk. Further the risk aversion is different for different individuals or different groups. The relative risk aversion need be ascertained.

As has been indicated earlier, the benefits from the irrigation development are shared by the Government and the private users of irrigation water. When the number of users is large, and when the long life of a project is considered, the element of uncertainty may not be of importance so far the share of Government is concerned. However the benefits that accrue to the private users still involve risk to those individuals (Howe 1974) (40).

Since the overall benefits are shared, from consideration of equity it would be desirable, that this element of risk is also shared equitably, not only between the Govt. and users but among the various groups of users whose risk aversion capacities are different. It is proposed to use the results of the E-V framework for this purpose.

5.8 GROUP RISK AVERSION

The risk aversion varies from farmer to farmer depending on his capacity to absorb risk, which in turn depends on his economic conditions. To reduce the computational burden, and to bring out the risk effect on the benefits and then the pricing, the farming community can be divided into groups. The paying capacity, as a portion of the income also depends on the risk absorbing capacity. A large farmer can absorb larger variability of income from year to year and therefore can afford to cultivate high value crops with larger income (and variability).

By the risk analysis, the extent of disadvantage faced by a small farmer in contrast to his larger counterpart need be assessed to devise measures to counteract this undesirable situation. For purpose of grouping the farmers, the criterion generally used for small, medium and large is on the basis of land holdings. A small farmer has less than 2 Ha of land holding. The definition of small farmer is as per the practice adopted by Govt. of India. Though there is no specific criterion for medium farmer, a farmer with less than 5 Ha of land is considered in this category. Large farmers have more than 5 Ha of land.

5.9 CHOICE OF CRITERION

The E-V frontier has provided a framework, but it is necessary to identify the point or points in the curve which should satisfy other requirement. As already indicated the utility function is $u = \mu - \phi\,\sigma$ (vide para 5.4). However there are also other approaches to utility determination. The small farmer has less capacity to absorb risk. From an inspection of the E-V frontier (Fig.5.1) it can be said that the preference of the small farmer is in the lower part of the curve. The preference of a large farmer who has higher capacity to sustain uncertain situations would try to go to as much right of the curve as possible to increase his expected income. The preference of a medium farmer would be somewhere in the middle range. Though no quantitative criteria can be prescribed to identify the preferences from E-V frontier, some value judgement is necessary. In case where social [illegible] are concerned, subjective judgement has to compliment [illegible] is. The three points selected for the three groups of farmers are marked S,M and L respectively on the Fig.5.1.

The E-V framework provided guidelines in deciding the group preferences and the corresponding crop mixes that are likely to be adopted by the groups. For this analysis, the exact crop mix is not very important, what is required is to determine the relative disadvantage faced by a small farmer due to his low risk policy. For this purpose the utility of each group is determined as below.

Of the various approaches for determination of the utility function or imputing the value of ϕ, the approach of Thomas is considered for application.(Mass et al, 1966) (67). Thomas has suggested an insurance approach to determine the certainty equivalent for a uncertain situation. He has advocated formation of an equilization fund to take care of a possible sequence of unfavourable years. In otherwords if the benefits are allowed to accumulate in a fund and a constant value is withdrawn every year, then the risk is automatically taken care of. The fund may get exhausted during a sequence of low income years. The probability of the fund getting exhausted is α, then

$$\phi = \frac{r. \, V_\alpha}{\sqrt{2r}}$$

where

V_α is the normal deviate corresponding to α

σ is the standard deviation

r is the interest rate earned by the fund.

The interest rate is usually low and considering $\alpha = 0.05, r=0.04$

$V_\alpha = 1.645$, $\phi = 0.232$.

Here the utility value $U = \mu - 0.232\ \sigma$

The utility value corresponding to the different groups are shown in the following Table.

Table 5.4 - Utility under Risk

Category	μ	σ	U	$\Delta U = U_{max} - U$
Small	1205.2	154.06	1169.3	389.4
Medium	1406	200.00	1359.6	199.1
Large	1622.5	275.22	1558.7 (U_{max})	

As can be seen from the table because for higher risk bearing capacity, the large farmers can earn about Rs.199.1 per Ha and Rs.389.6 per Ha over a medium and small farmer respectively. The disadvantage of the smaller farmer in this regard need be properly considered for purpose of equity. The various measures that would correct this imbalance are -

i) Price support for high value crops and control of price of inputs so that the element of risk is reduced.

ii) Provide institutional arrangements for marketing facilities.

iii) Special subsidy to small farmers growing high value crops.

iv) Inproduce discriminatory water pricing.

The purpose of the above measures is to reduce the disparity in utility obtained from irrigated agriculture. It is neither possible not desirable to equalise the utility, as some portion of risk also depends on the managerial capability and enterpreneurship of the farmer.

5.10 PRICING OF WATER

It is proposed to reduce the extra burden on smaller farmers due to the additional risk to which they are exposed. The extent of compensation by pricing of water is a form of subsidy and as such should be as small as possible. Here again the value judgement has to be applied.

The ability to pay for the cropping patterns are determined for equivalent Ha. It is found that paying ability is approximately 25 percent of the remaining utility. Further in case of small farmers, the value of ΔU is about 25 percent of the utility.

Half of this percentage is proposed to be compensated by pricing. The details are shown vide Table 5.5. The net income after pricing for a small farmer changes from 894.16 to 933.04 and that for a medium farmer from 1063.87 to 1085.7 The net utility to large farmers remain the same at Rs.1198.24.

For this purpose discriminatory pricing system has to be introduced. To consider social equity such discriminatory pricing cannot be avoided. The discrimination as outlined here is only to compensate to a small extent the element of risk. By other institutional measure if the risk to smaller farmers is reduced, it is quite possible that they would be encouraged to undertake more risky ventures to increase their expected income which may result in a multiplier effect for adopting high value crops.

Discriminatory pricing is also necessary from consideration of distribution of income, which is taken up in the next chapter. The planning and management of a discriminatory pricing system is discussed in the concluding chapter.

Table 5.5

Risk Premium and Modified Paying Capacity

Rs. per Hectare

y	Mean Income μ	σ	Utility $= \mu - 0.232\sigma$	ΔU $(U_{max} - U)$	Percent	Paying capacity		Net Income after pricing	
						Without risk premium	With risk premium	Without risk premium	With risk premium
	2	3	4	5	6	7	8	9	10
	1205.2	154.06	1169.3	389.4	24.98	311.04	272.16	894.16	933.04
	1406.0	200.00	1359.6	199.1	12.77	342.13	320.30	1063.87	1085.7
	1622.5	275.22	1558.7	-	-	424.26	424.26	1198.24	1198.24

CHAPTER-6

DISTRIBUTION OF INCOME

6.1 GENERAL

The most important reason to keep the pricing of water low is attributed to the fact that small farmers are not able to bear the burden. Though such a reasoning is quite relevant in the national setting of distribution of income, the fact remains that low pricing also benefits the large farmers. In Indian context of planning, even though the per capita income in 30 years of planning has increased by 50 percent poverty persists. This persistance of poverty has been attributable to three primary reasons (Govt. of India 1981) (30).

i) Inadequate economic growth rate.

ii) Un-even distribution of income and consumption.

iii) High population growth rate.

The economic growth rate depends on appropriate use of the resources, it also makes a significant statement that without a desirable distribution of income, poverty will persist. A more favourable distribution of income is possible by suitable project choices to benefit the economically weaker section of the society. Selection of projects to make the pattern of production labour intensive, to maintain a suitable level of employment come under this category. The pattern of distribution can also be changed by redistribution by way of fiscal policies like taxes and subsidies.

Irrigation projects resulting in intensive agricultural operations increase production and provide large employment in the agricultural sector improving the distribution of income in favour of the poor.

The objective of economic development makes no distinction between recipients of benefits. A rich man's consumption counts as much as a poor man's (UNIDO 1972) (88). In an irrigation project, the benefits accruing to the users are almost in direct proportion to their land holdings. In such a situation the increase in income of a large farmer is much more than that of a small farmer. With the advent of irrigation, though there is increase in income of a small farmer, the overall pattern of income distribution proceeds in an unfavourable direction. Though some change is possible through fiscal policies like income tax, the agricultural income taxes are not high enough to have any significant impact. The purpose of this chapter is to evolve a suitable pricing policy of irrigation water to enable a more desirable distribution.

The basic concept of income distribution is that the incomes accruing to weaker sections are more valuable socially than those accruing to the rich. The main thrust of a suitable pricing policy is equitable sharing of the benefits between the Govt. and the users. By considering the objective of distribution, theequity would mean that Govt. is willing to sacrifice some of its share in favour of the weaker section. If irrigation pricing can contribute to this objective, then there will be saving in the Govt. expenditure by way of subsidies and other tax concessions normally provided on this account. Another way of meeting this objective is that the share of users can be redistributed such that weaker section gets a larger share. This is a problem of redistribution. A combination of these two measures can also be considered. One of the most important consequences of the approach is to determine the relative importance to be assigned to the income of the different groups. This would depend on the emphasis the national planners give to the objective.

6.2 ANALYTICAL FRAMEWORK

Income distribution considerations are of uncontroversial importance and specially so in developing countries. It may be worthwhile to consider this in the general framework of social welfare function which includes both economic efficiency and distribution of income (Scandizzo 1980) (80).

Considering the general form of social welfare function

$$W = W(Y_1, Y_2, Y_3, Y_i, \ldots Y_i, Y_g) \tag{6.1}$$

where W is the ordinal indicator of social welfare and Y_i is the income level of i^{th} user and Y_g the income of Govt. The above is considered to represent the situation without irrigation, additional welfare emnating from use of irrigation water is

$$dW = \sum_i \frac{\partial W}{\partial Y_i} \cdot dY_i + \frac{\partial W}{\partial Y_g} \cdot dY_g \tag{6.2}$$

where $\frac{\partial W}{\partial Y_i}$ is the marginal welfare (income) to the i^{th} individual and $\frac{\partial W}{\partial Y_g}$ is the marginal social welfare of Government income. Dividing both sides of expression (6.2) by $\frac{\partial W}{\partial Y_g}$

$$\frac{dW}{\partial W/\partial Y_g} = \sum_i \frac{\partial W}{\partial Y_i} \cdot dY_i \Big/ \frac{\partial W}{\partial Y_g} + dY_g \qquad (6.3)$$

The term $\frac{dW}{dY_i} / \frac{\partial W}{\partial Y_g}$ represents the marginal welfare of the i^{th} individual per unit change in marginal welfare of Govt. income. In other words, this term represents the importance attached to the income of i^{th} individual with respect to the income of Govt. The objective of income distribution distinguishes between incomes accruing to different individuals or groups depending on their levels of income. This distinction is provided by the value assigned to the above term.

Using $w_i = \frac{dW}{dY_i} / \frac{\partial W}{\partial Y_g}$ being the weightage attached to the marginal income of i^{th} individual,

$$\frac{dW}{\partial W/\partial Y_g} = \sum_i w_i \cdot dY_i + dY_g$$

$$= \sum_i w_i \cdot dY_i - \sum_i dY_i + (\Sigma dY_i + dY_g)$$

$$= \Sigma\, dY_i \; (w_i - 1) + dY \qquad (6.4)$$

It follows that the incremental welfare is equal to increase in welfare to all users including Govt. plus a weighted sum of incremental welfare to private users. The parameter w_i is the weight attached to the marginal income of

i^{th} beneficiary. When no distinction is made among users and Govt. $w_i = 1$ and the first term in (6.4) becomes zero.

Another approach to distinguish the utility to different groups is given by Murthy (1981) (71).

Murthy has used an exponential form of utility or welfare function.

$$U = B - A.\ Y^{(1-e)} \qquad (6.5)$$

where e is the elasticity of marginal utility, B and A are coefficients.

$$\frac{\partial U}{\partial Y}\Big|_{Y=Y_i} = -A.Y_i^{-e}(1-e) \qquad (6.6)$$

For derivation of weights some basic assumptions are required. The objective of distribution of income requires relative emphasis on income of different groups. It may be convenient to define the relative weights with respect to that of income of Govt. Supposing an annual income level of Y_m is considered to be the minimum desired level, such that the Govt. is indifferent towards the incremental income to this group or to Govt. The Government is willing to sacrifice rupee for rupee for increasing the income of this group. The income of higher group is less desirable and has a weightage less than one and the income of lower group is more desirable with a weightage higher than one. If the critical income level is Y_m, them

$$\frac{dU}{dY_i}\Big|_{Y_i=Y_m} = - A(1-e)\ Y_m^{-e} = 1$$

$$\text{or } A = - \frac{Y_m^{+e}}{(1-e)}$$

$$\frac{\partial U}{\partial Y_i} = - A\ (1-e)\ Y_i^{-e} = (\frac{Y_m}{Y_i})^e \qquad (6.7)$$

$\frac{\partial U}{\partial Y_i}$ is the weight w_i assignable to the i^{th} user group depending on the level of income. If $Y_i > Y_m$, the weight w_i is less than one and otherwise. The weight depends also on the value assigned to e, the elasticity of marginal utility. A value of e= 1 means that 10 percent increase in the income is associated with 10 percent decrease in the Govt. income. A higher value of e(say 2) mean that the marginal decrease in Govt. utility (rest of the nation) is twice than the marginal increase in the income of the specified individuals. It can be seen that the weight remains 1 for $Y = Y_m$ irrespective of the value of e.

The equation 6.4 can be rewritten as

$$dU = dY_g + \Sigma w_i\ dY_i$$

where w_i is the distributional weight, which is more than one for lower income groups and less than one for higher income groups and equal to one for the critical income group.

6.3 ESTIMATION OF DISTRIBUTIONAL WEIGHTS

The first step in estimation of distributional weights is to determine the critical income level or the cut off income level. The main objective of distribution is to reduce the proportion of people below the poverty line. The critical minimum income of poverty line is Rs.61.8 per month for rural India (1976-77 prices). The people at or below poverty line must have a higher weightage. The other indicator is the income of a small farmer. Since irrigated agriculture considers specifically farming, the numeraire corresponding to farming is considered appropriate as was considered under risk aversion. The recommendations of the planning commission of India are as follows.

Area (Ha)	1	1 to 5	5 to 20	Above 20
Weight	1.8	1.5	1.0	0.80

In other words the cut off level of income is in respect of farms having 5 to 20 Ha of land. This is a large range and for purpose of irrigated agriculture a cut off level of 5 Ha of irrigated land is considered suitable. This is a value judgement subject to changes. The weights determined from the Murthy's approach are calculated and tabulated below. The assumption is that income varies directly with the land holding. The classification of farmers is as same as discussed vide para 5.8.

As per this criterion, the farmers who hold less than 5 hectares get a positive (more than one) weightage. A farmer with about 5 hectares of irrigated land is considered a well-to-do farmer much above the poverty line. The weightage suggested is for a category of medium farmers with land holding for 2 to 5 hectares. In this process a farmer with 5 hectares gets the same preference as that applicable to a farmer with

2 hectares. Further subdivn. or a sliding scale can be provided. Further no distinction has been between different types of land depending on soil and land type. Average productivity is to be considered for a standard hectare of land. Classification to different categories need be done on the basis of this standard hectare as is used in land reforms.

DISTRIBUTION WEIGHTS

Category	Average land holding	e= 0.5	e=0.75	e=1	e=2	e =3
Small	0.77	2.55	4.07	6.49	42.12	273.4
Medium	3,2	1.25	1.40	1.5625	2.44	3.81
Large	8.95	0.747	0.646	0.559	0.312	0.174

The distributional weights as above has large variations. For example for e = 2, one rupee income to a small farmer is socially valued at Rs.42.12 where as the same is valued at 0.312 for a large farmer. The above weights are at large variance with respect to that suggested by the Planning Commission. The values suggested by Planning Commission somewhat corresponds to a value of e = 0.5. Which means that 10 percent increase in income of individuals, 5 percent sacrifice is to be made in the economic efficiency. Murthy has suggested a value of 3 which is very much on the higher side.

The primary use of the distribution weights is for economic appraisal of a project. The benefits derived by different groups are adjusted to obtain the benefits for economic analysis to determine the degree of desirability of a project.

Sinha and Bhatia (1982)(86) have used similar concept for evaluation of social benefit cost analysis. They have suggested a weightage of 1.2 for small farmers in evaluating social benefits towards the objective of distribution of income, for purpose of pricing needs careful attention. For example for e = 2, a small farmer is to be charged Re.1.00 against Rs.42.12 whereas a large farmer has to be charged three times the usual charge. This discrimination (120 times) is not a desirable policy. Such a system will render large farmers uneconomical and push them out of agriculture. This would also encourage large scale fragmentation of land holding, an undesirable effect.

Some investigators have suggested using the pattern of income tax as Government's preferences for distributional effect. Since income tax is a direct revenue to Govt., the concessions given to the lower income groups indicates the extent of preferential treatment to different groups.

Since pricing of water is only a subsidiary measure of income distribution, the discrimination should be as small as possible. The weightage should not be very perceptible to act as disincentive to irrigated agriculture even for large farmers. Distribution of income objective in evolving pricing means providing an indirect subsidy. As Lakadwala (1979) (53) points out, subsidies are nothing but negative taxes, can be resorted to only when it is essential to encourage the use. ' When the goods and services increase the earning power of the people, the case of such subsidy is weak'. This applies to the case of subsidised low price for irrigation water or fertilizer. When subsidy is provided to an identified group, it is a different matter.

Equity also requires that same price is paid for identical goods and services. Hence minimum discrimination consistent with the distribution objective is aimed at. To have consistency, it is proposed to use the same utility function to derive these weights. The weight is given by

$$\frac{\partial U}{\partial Y_i} = \left(\frac{Y_m}{Y_i} \right)^e$$

As already indicated e is the elasticity of marginal utility, a value of e = 1,2,3 would mean that for each increment of income to the individuals, there will be corresponding decrease in social utility amounting to one, two, three times respectively. Such large sacrifice in the utility to the society is not desirable. At e = 0 the utility is proportional to the income and there is no decrease in social utility because no distinction is made between incomes to different groups. Lower the value of e, there is less deviation from economic efficiency to meet distribution effects. Hence lower values of e are more desirable from the point of economic efficiency.

DISTRIBUTION WEIGHTS

	e = 1	e = 0.25	e = 0.1	e = 0.05
Small	6.49	1.596	1.206	1.119
Medium	1.5625	1.118	1.046	1.023
Large	0.559	0.865	0.943	0.971

Selection of weightages is a difficult task and depends on the value judgement of planners and must be acceptable to the decision maker. It is therefore considered appropriate to select alternative sets of weights to study the variations in the impacts. The two sets of weightages corresponding to e = 0.25 and e = 0.1 are used for further analysis.

6.4 DISTRIBUTION OF INCOME - METHODOLOGY

To achieve a desirable distribution of income, the weaker sections have to be charged less than large farmers. The price to be charged is adjusted depending on the weight attached to the group. The methodology is illustrated vide Table 6.1. For this purpose the distribution of irrigated land must be known. The method is illustrated for hypothetical case to bring out the resulting distribution. The assumed distribution of land is shown in col.3. The Table 6.1(a) is for the 1st set of weights corresponding to e = 0.25. Two alternatives are considered. In the first, adjustment is made for all the categories viz. decreasing the price for smaller farmers and increasing for the larger farmers. The calculations are for a equivalent hectare with a proportion of land of 0.58 : 0.20 : 22 for small : medium : larger farmers. The paying capacity are as per the cropping pattern determined in the previous chapter after allowing for the risk premium (vide Table 5.5).

It can be seen that as a result of distribution, the total revenue decreased from 315.25 to 264.11 Rs./equiv.hectare a decrease of 16 percent in Alternative I and a larger decrease of 21 percent in Alternative II.

Table 6.1

(a) Alternative Systems of Distribution of Income

Case A

Sl. No.	Category	Av. farm size	Percent Area	Paying capacity Rs/Hect.	Paying capacity Rs/Eq Hect.	Distribution weight	Alternative-1		Alternative-2	
							Price charged Rs/Hect.	Price charged Rs/Eq.Hect.	Price charged Rs/Hect.	Price charged Rs/Eq. Hect.
1	2	3	4	5	6	7	8	9	10	11
1.	Small	0.77	58	272.16	157.85	1.596	170.52	98.90	170.52	98.90
2.	Medium	3.2	20	320.30	64.06	1.118	286.50	57.30	286.50	57.30
3.	Large	8.95	22	424.26	93.34	0.865	490.49	107.91	424.26	93.34
	Total		100		315.25 100 percent		26[illegible] 8[illegible]	264.11 84 percent		249.54 79 percent

(b) Alternative Systems of Distribution of income

Case B

Sl. No.	Category	Av. farm size	Percent Area	Paying capacity Rs/Hect.	Paying capacity Rs/Eq Hect.	Distribution weight	Price charged Rs/Hect.	Price charged Rs/Eq.Hect.	Price charged Rs/Hect.	Price charged Rs/Eq. Hect.
1.	Small	0.77	58	272.16	157.85	1.206	225.67	130.89	225.67	130.89
2.	Medium	3.2	20	320.30	64.06	1.046	305.95	61.24	305.95	61.24
3.	Large	8.95	22	424.26	93.34	0.943	449.90	98.98	424.26	93.34
	Total		100		315.25 100 percent			291.11 92.3 percent		284.47 90.24 percent

Table 6.1(b) is for second set of weights corresponding to e = 0.1. The decrease in total revenue is 7.7 percent and 9.76 percent in Alternative I and II respectively.

The reduction in revenue depends on the set of weights and the proportion of land held by different groups. The reduction can be substantial with some specific combination or may be negligible with some other. Further such a system of distribution does not have significant impact on the overall distribution of income, as has been shown in the Lorenz curve described later in this chapter. The avoid such wide variations and to have a more favourable impact on the objective of Income Distribution, a policy of 'Redistribution of Income' is suggested.

6.5 REDISTRIBUTION OF INCOME

With the advent of irrigation, the economy of the region is changed with large changes in the economic activities. There is overall increase in production and consequent increase in income levels of all users. The benefits from irrigation goes to the users and by pricing, a portion is received by Government. The increased income to the region, the share of the project benefit is proposed to be distributed to the users. It is proposed to reformulate the problem as that of income redistribution. Income redistribution is a more effective and relevant method since the share of Govt. is not disturbed. With redistribution of the increased income a more meaningful distribution can be achieved.

6.5.1 The Model

It is necessary to distribute the increased income taking into consideration the social preference as reflected by the assigned weightages to different groups. In evolving the policy instrument some basic principles must be observed.

The initial income and also the distribution before irrigation can be represented by Y_0

$$Y_0 = (y_{01}, y_{02}, y_{03}, y_{0i}, \ldots \, y_{0m}) \qquad (6.8)$$

where y_{0i} is the initial income of i^{th} individual from a group of m beneficiaries.

With irrigation, the income changes. Assuming that a fixed pricing policy is adopted and that the increase in income and water prices are proportional to the initial income, the income can be represented by Y_1 such that

$$Y_1 = (y_{11}, y_{12}, y_{13}, \ldots . y_{1i}, \ldots \, y_{1m}) \qquad (6.9)$$

The vector Y_1 is the result of uniform, nondiscriminatory pricing policy. Y_1 will have the effect of changing the income distribution pattern and increase the disparity between groups. It is necessary to charge the income pattern from Y_1 to Y_2 by changing the pricing structure.

$$Y_2 = (y_{21}, y_{22}, y_{23}, \ldots \, y_{2i} \ldots , \, y_{2m}) \qquad (6.10)$$

where $y_{2i} = y_{1i} \pm \; p_i$

Choosing the vector p_i must satisfy some fundamental principles of social and economic order (Intriligator 1979)(44).

1) The first principle is that any individual with higher initial income will have a higher final income. This ensures the original ranking of income earning as well as ensures incentive for use of the resource.

$$\frac{\partial y_{2i}}{\partial y_{0i}} > 0$$

2) Each individual has higher income than his preproject income or $y_{2i} > y_{0i}$

3) The third principle is that the aggregate income of all individuals remains the same.

or $Y_2 = Y_1$

The basic approach to redistribution is to distribute the increased income or the surplus generated by irrigation to all the beneficiaries following some equitable criteria. Each user receives a share of this surplus and his final income is given by

$$y_{2i} = y_{0i} + \beta_i . Y_s$$

where $Y_s = Y_2 - Y_0$

β_i is the marginal income share of i^{th} individual

$\beta_i \geq 0$ and $\Sigma\beta_i = 1.0$

The problem is to determine the value of β_i for each individual or the group as the case may be.

6.5.2. Equality Income System

In the equality income system, each individual has equal claim over the generated income. Each user has the same expectation of capturing the entire surplus. In such case, the probability of his getting entire surplus is 1/m, here $\beta_i = \frac{1}{m}$. In this system each individual is supposed to be equally deserving irrespective of his initial income or his contribution to the generation of the surplus. Such a system may not be compatible with social justice so far as the irrigation system is concerned, even though it has a favourable impact on the income distribution.

In the context of water distribution from a project, David Seckler (1981)(81) has advocated the principle of equal rights for the use of water by all the inhabitants of the village. Water rights in the form of coupons are given to each family. He has the right to use the water or trade of with other users for a consideration of money through the water users association. The system has been tried in a small project ' Sukhomajri' in the village of same name and the system is named after the village.

The principle of ' equality income system' is similar to the above case. The water rights bestowed is independent of the family's land holding. Even landless villagers are entitled to use the water right. The farmers who make use of the water right for irrigation derive much more income than those who trade the rights. This system may also be applied to some of the common property situations like fisheries, grazing grounds etc. where the claim is on individual basis.

6.5.3 Proportional Income System

To account for the deservingness of an individual, the share of the additional income will be according to proportion of his contribution. If the initial (or the final) income is a measure of his using the irrigation water and consequent production then

$$\beta_i = \frac{y_{0i}}{Y_0} \quad \text{and} \quad y_{2i} = y_{0i} + i \frac{y_{0i}}{y_0} Y_s$$

such that $Y_2 = Y_0 + Y_s$

In this system, because of the proportionate increase in the initial income, the original income distribution is not changed. The objective of income distribution is not properly reflected in this method.

6.5.4 The author proposes to introduce additional considerations to have favourable effects on income distribution. Two methods are suggested.

6.5.5 Minimum Guaranteed Income

In this system the final income of any individual shall not be less than the critical minimum level. Out of the generated surplus, the share of the identified group whose income level is below the critical level is first separated out and the balance is shared by the rest. The remaining surplus $Y_{sr} = Y_2 - \Sigma \bar{Y}$ where $\bar{Y}$ is the initial income including the amount required to bring the income of the lower group to the base level.

$y_{2i} = \bar{y}$ for those below the critical level and

$y_{2i} = y_{0i} + \frac{y_0}{Y_0} \cdot Y_{sr}$ for others.

For individuals whose final income (without paying for water) is less than the critical level, they have to be paid subsidy in varying amount to make up for the deficit in income. This system has some inherent lacuna. The subsidy will discourage alternative useful employment. This also will attract unscrupulous people to be included in this group, detrimental to economic efficiency.

6.6 PREFERENTIAL SYSTEM

In the above systems described, the objective of income distribution has not been explicitly considered. The social preferences are reflected in the weightage for different groups. Unless a discriminatory, preferential system is evolved, income distribution is not met. While evolving the fundamental requirements must be observed. In the preferential system, the marginal shares are made a function of the weightage of the group. The share of an individual is not from the generated economic surplus but from the social surplus as obtained by weighting. The income generated is not equal to the actual economic (monetary) value but is adjusted to take account of the social preferences. The actual income, pricing and other parameters are in terms of the monetary values. Only for obtaining the value of β_i, the hypothetical social economic surplus is taken as the basis for distribution.

We have $y_{2i} = y_{0i} + \beta_i Y_s$

In this case $\beta_i = \frac{y_{2i}}{Y_{ss}}$

where $Y_{ss} = r_1 y_{21} + r_2 y_{22} + \ldots . r_i y_{2i} + \ldots r_n y_{2n}$

This ensures that

$\Sigma \beta_i = 1$, r_1, r_2 .... are the weightages.

Here Y_{ss} is the social surplus anologous to the social benefits and costs. This social surplus is used to derive the marginal income shares. The amount of revenue is not affected by the redistribution by suitable adjustment. The procedure is illustrated for the case study.

6.6.1 The fundamental principle of redistribution is to equitably share the surplus generated from the use of irrigation water. The three principles enunciated vide paragraph 6.5.1 are observed.

Instead of considering individual incomes which would make the problem size unusually large, it is made into different groups based on the income levels. The grouping has already been done for large, medium and small farmers on the basis of land holdings. The following steps are involved. The values obtained are shown vide Table 6.2. All the values are for the full group depending on the extent of area owned by the group. All the figures are for an equivalent hectare with the distribution of land as shown in column 3. The figures corresponding to column 4,5 and 6 are taken from Table 6.1. The

Table 6.2

Preferential System of Redistribution of Income

(a) Corresponding to Weightages Set I

Figures in Rs. per equivalent hect. corresponding the land distribution as in col.3.

Per-cent area	Initial income without irrigation	Utility with irrigation	Revenue paying capacity	Surplus	Distribution wt.	Accounting surplus	β_i $\frac{9}{\Sigma 9}$	Redistributed final income	Price (revenue)	Price per Ha
				(5-4-6)		7x8		$4+\beta_i . Y_s$	5-11	
3	4	5	6	7	8	9	10	11	12	13
58	269.7	655.63	157.85	228.1	1.596	364.05	0.592	557.33	98.3	169.48
20	93.0	267.55	64.06	110.49	1.118	123.52	0.200	190.17	77.38	386.90
22	102.3	342.91	93.34	147.27	0.865	127.39	0.207	202.87	140.04	636.54
	465.0	1266.08	315.25	485.86 (Y_s)		614.96		950.37	315.72	

(b) Corresponding to Weightages Set 2

58	269.7	655.63	151.85	228.1	1.206	275.09	0.519	521.86	133.67	230.46
20	93.0	267-55	64.06	110.49	1.046	115.57	0.218	198.92	68.63	343.15
22	102.3	342.91	93.34	147.27	0.943	138.88	0.262	229.60	113.31	515.05
	465.00	1266.09	315.25	485.86 (Y_s)		529.54			315.61	

monetary surplus available to the users is shown in column 7. The distributional weightages as obtained vide para 6.3 are listed in column 8. By use of these weightages, the economic surplus is converted to accounting surplus in col.9. The distribution of this accounting surplus is the marginal income share β. The redistributed final income, the corresponding revenue and the price per Ha are computed. It can be seen that the revenue from the small farmers group reduced from Rs.157.85 to Rs.98.3 whereas that of large farmers increased from Rs.93.34 to Rs.140.04 per equivalent hectare.

The main advantage of this system is that the total revenue of Rs.315.26 per equivalent hectare does not change.

Table 6.2b is computed with the alternative sets of weightages. The disparity in pricing is not very glaring in this case because of less variation in the weightages. As already discussed the effect of redistribution depends on the set of preferential weights and also the proportion of land held by each group.The objective of distribution is a national objective and as such these parameters should reflect the social preferences.

Accordingly it is necessary to study the national characteristics. The distribution of land holdings in India various from state to state, from one region to another. If we consider the local conditions, wide variations are expected in the results. It may be desirable to consider the land distribution for a larger base like a state, region or the country as a whole, so that the results could be used to derive the national or state parameters.

Table 6.3

Preferential System of Redistribution

(a) Corresponding to Weightage Set-1

Figs. in Rs. per Eq.Hectare

al e ut a-	Income with irrigation	Revenue paying capacity	Surplus (5-4-6)	Distribution weight	Accounting surplus (7x8)	β_i 9/Σ9	Redistribution final income $4+\beta_i.Y_s$	Price (5-11)	Price per Ha.	Remarks
	5	6	7	8	9	10	11	12	13	
	226.08	54.43	78.65	1.596	125.49	0.210	215.84	10.24	51.2	
	334.44	80.08	138.11	1.118	154.41	0.258	267.16	67.28	269.12	
	857.28	233.35	368.18	0.865	318.48	0.532	566.94	290.34	527.89	
	1417.80	367.86	584.94 (Y_s)		598.37	1.000	1049.94	367.86		
(b) Corresponding to weightage set 2										
	226.08	54.43	78.65	1.206	94.85	0.162	187.76	38.32	191.60	70 %
	334.44	80.08	138.11	1.046	144.46	0.246	260.14	74.29	297.18	92.8 %
	857.28	233.35	368.18	0.943	347.19	0.592	602.03	255.25	464.09	109.4 % of ability to pay
	1417.80	367.86	584.94 (Y_s)		586.50	1.000	1049.93	367.86		

I WITHOUT IRRIGATION —·—·—·—
WITH IRRIGATION
II WITHOUT REDISTRIBUTION ————
III WITH REDISTRIBUTION - - - - - - -

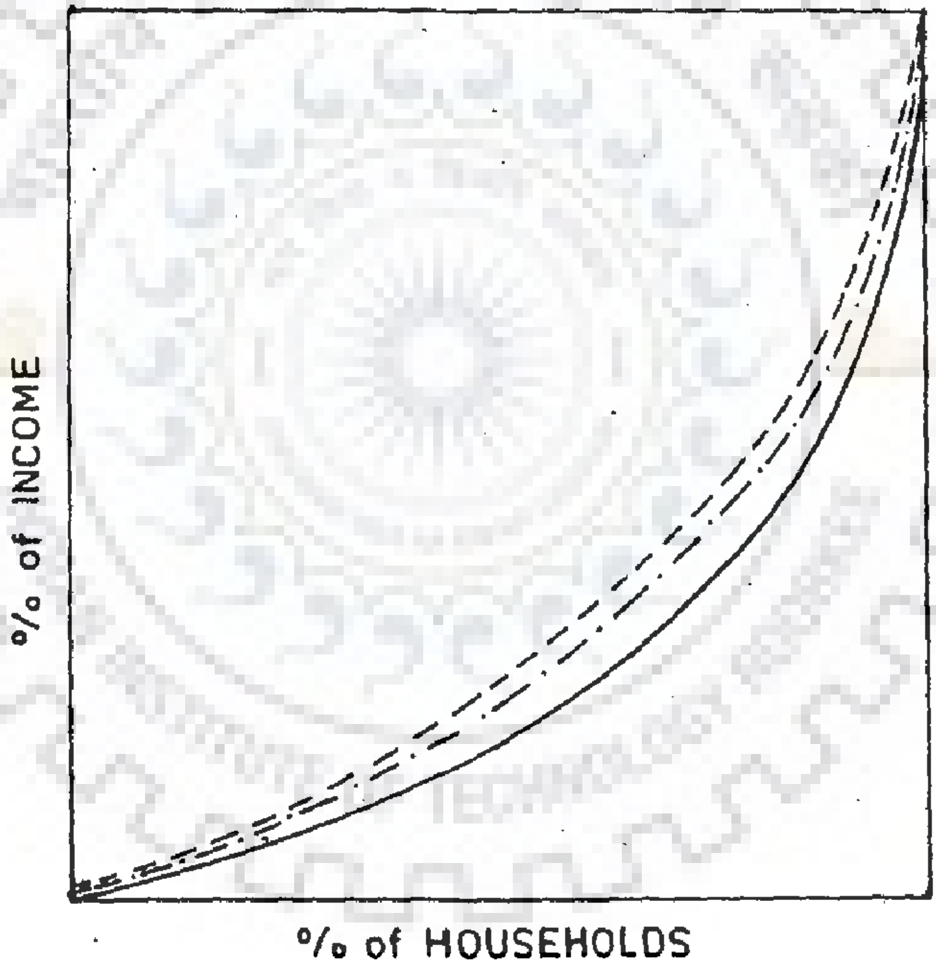


FIG. 6·1 - DISTRIBUTION OF INCOME-LORENZ CURVE

Though the average land holding is very small and the number of small farmers is very large, the land area held by them is not large. The table 6.4 shows the land area held by different groups. As a national average the land distribution of small, medium and large farmers is taken as 0.2,0.25 and 0.55 respectively.

The calculations for redistribution as in Table 6.2 are made for the revised land distribution and shown vide Table 6.3.

6.7 DISCUSSION OF RESULTS

Redistribution of income provides a proper framework for mobilising revenue from water with due consideration to the objectives. While selecting the set of preferential weights, the other fundamental principle ' equal charge for identical services' should not be lost track of. From the various alternatives considered, the results of 6.3 (b) would be considered more appropriate. The redistribution enhances the charges for large farmers by 9.4 percent only which would be considered reasonable, the corresponding reduction for medium and small farmers are 7.2 percent and 30 percent respectively.

The effect of distribution of income is not easy to be depicted by any index. The performance or change can be shown by the usual Lorenz curve depicting, the percentage of income against the percent of population. For a uniform distribution the 45° line would represent the situation.

As the curve approaches the ideal, the more it is desirable. The Fig.6.1 shows the different situations. With irrigation the income of large farmer increase at a higher rate and as such has an adverse effect on the distribution of income. The line moves farther. With the system of redistribution, it could be improved.

6.8 REGIONAL DEVELOPMENT

It is recognised that some of the inequalities between regions should be removed. The economic development of the backward regions and the country at large are complimentary to each other, the degree of complementarity depending on the disparities in the economic conditions among the regions. Large emphasis on equalisation, as in the case of distribution of income may adversely affect the overall national economic development. Where adequate regional development plans are lacking, the disparity widens. The best regional development programs aim at utilising the unutilised and underutilised resources of the region. Irrigation projects ideally satisfy this principle and opens of the area to the development scene which otherwise would have remained undeveloed (Kuiper,1971)(52).

The regional income benefits are the regional users' willingness to pay for system outputs minus what they pay (Major 1977) (63). A higher water pricing reduces the regional income. One of the reasons attributed in favour of more regional benefits is that this has a multiplier effect stimulating economic growth. When a consumer of the region receives additional income of Re 1.00, he will allocate this money between consumption and saving. If his ' marginal propensity to consume' (mpc) is 0.9, he will spend Re.0.9 and save Re.0.1. The amount he spends is received by another and the receiver spends Re.0.81 and saves Re.0.09. The process continues till the savings equal the original income. It can be shown that the value of multiplier is 1/1-mpc i.e. 1/(1.0-0.9)= 10. In other words when the process continues, the final regional income is 10 times the original income.

As pointed by Goodman (1982) (27), this is an oversimplification. The final income is at the end of the time series which may be quite long and when converted to its present value will reduce the effective income. Further a large part of the income may leak out of the region if the expenditure on consumption is in respect of goods and sources obtained from outsite the region. In economically backward regions, much of the income goes out of the region by way of purchase of goods and services from outsider the region. Hence the multiplier effect may not be of much significance.

In addition to the increase in income of the direct users of irrigation water, other beneficial effects accrue to the region due to the project construction and other complimentary activities. These are -

i) positive external effects

ii) increase regional employment

iii) more desirable population distribution

iv) diversification of regional economic base

v) income from construction as well operation and maintenance activities.

6.9 ECONOMIC GROWTH

Increase in consumption is necessary to improve the standard of living of a backward region. But increased consumption does not necessarily stimulate economic growth. For effective economic growth and consequent increased consumption, what is required is more investment to stimulate activities to make use of the undeveloped and underdeveloped resources of the region. Investment from the savings as well as investment from the public sector are desirable. Revenue received through water pricing is good source for such investment. Economic growth is stimulated when products from the region are export based. Export base theory assumes that the economic growth of an area occurs mostly as the result of activities that produce goods and services exported to outside the area itself. Activities generated in the area by forces external like tourism may also come under this category (Goodman 1982) (27).

Capital formation and subsequent public investment stimulates economic growth. Hence a higher (rational) pricing would be more desirable. The objective of regional development is adequately served by locating and constructing the project in the region. Rational pricing of water allows an equitable share of the benefits to remain in the region. As such no further adjustment or reduction in pricing is considered desirable. Economic analysis however should give higher weightage to regional benefits to make projects in weaker regions more attractive. However to stimulate further development, it may be worthwhile to consider investing the revenue receipts from water pricing within the region itself in various activities connected with irrigated agriculture and activities stemming from such activities like food processing and other agroindustries. This will also give a sense of involvement to the region and would offer inducement for accepting the pricing policy. The exact nature of institution to take care of this aspect need be worked out. The command area development agencies are well suited for this purpose. This will incidentally reduce financing from other sectors for regional development. A highly desirable supplementary reform, but one which would imply a major change in policy, would be a decision to allow project organizations to retain a substantial proportion of revenue from water charges for direct use in local reinvestment (Bottrall, 1982) (7)

Table 6.4

Distribution of Land Holdings (54)

S.No.	Category (hectare)	Percent Area	Average size (hectare)
1.	Less than 1.00	9.25	0.45
2.	> 1.00 upto 2.00	14.91	1.46
3.	> 2.00 upto 4.00	22.61	2.80
4.	> 4.00 upto 10.00	30.40	6.02
5.	More than 10.00	22.83	16.36

CHAPTER-7

CONCLUSIONS

7.1 INTRODUCTION

Irrigation development involves heavy public investments. Absence of rational pricing system has resulted in inadequate impact on the development objectives and financial return to the investment. Though economists and planners have been advocating for a suitable pricing policy, there has not been any acceptable result. In this thesis the economic theories applicable to pricing including public sector have been analysed. The various effects of pricing on all activities both economic and noneconomic have been identified as shown in flow chart (Fig.2.2). The interdependencies and linkages have been stated and analysed to arrive at a methodology to deal with the pricing problem.

Marginal cost pricing ensures optimum use of the output and has been advocated for water pricing. The basis for pricing can be categorized as -

I Cost Based

i) marginal cost pricing

ii) average cost pricing

II Value Based

i) productivity or benefit from use.

All the above policies were studied and applied to evaluate their suitability.

The pricing policy in addition to satisfying the economic theories for optimum use of resources and maximize economic efficiency must also satisfy other social and political objectives. Following is a statement of objectives selected.

1. Efficient use of irrigation water
2. Equitable sharing of benefits from use of irrigation water
3. Income distribution, social equity
4. Economic growth and regional development

Though recovery of cost of investment has not been included explicitly in the statement of objectives, the same is implied and is taken care of while considering the equitable sharing of the income from use of irrigation water.

7.2 METHODOLOGY AND RESULTS

The first step is to ensure that water is efficiently used i.e. put to high value uses. This is essentially a part of the planning process. However, the various cost and benefit parameters that are needed for pricing of water need be done under the situation where the value of water is maximised. The value of water can be increased with conjunctive use of surface and ground water. Similarly in multipurpose projects, additional benefits are derived, specially when generation of hydropower is included. In view of the developmental value of irrigation it is worthwhile to consider the excess power revenues as contributing to the value of irrigation water.

Though such a policy need not be binding, contribution from sectors like hydropower, industrial water supply etc. for irrigation could be considered to the extent of feasible complementarity through multipurpose use.

For intermediate good like irrigation water, which is put to use by the farmers, the farmer's viewpoint should dictate the pricing consistent with other requirements of the system. The ability to pay by the farmers from the increased income is the primary basis for pricing. In deriving a rational policy, compatability with all other objectives and requirements have been aimed at. These aspects have been brought out and a case study of Ramganga multipurpose project has been studied to illustrate the methodology.

Economic principles require demand curves to impute the value of water at different levels of water use. Demand curves represent the marginal value product. Demand curves have been synthesised for the project by parametric linear programming.

Production function approach for pricing on the basis of marginal value product has shown that for a large range, charging at the marginal value product of water would make irrigated agriculture uneconomical. The feasible range of water use is limited and does not provide a practical way for fixing water charges.

In determining the cost and value of water for the project, the study has been done in distinct steps to bring out the differences.

In the first step the optimum use of surface water is studied. Linear programming optimisation model gave the desirable crop mix. The cost of water is found to be Re.0.1275 per cum and has a value of Re.0.2918 per cum. In the second step conjunctive use of surface and groundwater was done and the cost of water reduced to Re.0.0966 per cum with increase in its value to Re.0.3083 per cum. By further improving the operation of the reservoir in conjunction with ground water pumping, it has been possible to convert the non-uniform hydro energy generation to more uniform firm energy with consequent increase in power benefits. The increase in the net benefits is considered as reduction in the cost to irrigation. The cost of water consequently reduced to Re.0.0905 per cum (vide Table 4.7).

The above unit costs form the basis for a cost based pricing and also to evaluate the cost recovery aspect. For irrigation water, price is linked with productivity. The cost and value obtained above refer to average project values from the investor's point of view. The value of water to the farmer user, is what he earns from the use of water in crop production. Productivity from individual crop production has been considered more rational to determine the ability to pay by the farmers. The increase in income with advent of irrigation need by equitably shared by the users and the investor. The investment in the project is primarily for the benefit of the farmer user and he must be adequately provided for towards his living and for his contribution to the national objectives. The net income from irrigated agriculture and the ability to pay in respect of each crop is shown vide Table 3.4.

The ability to pay pricing must be compatible with other social and political requirements. The most important reason for a low pricing is said to be the lack of ability to pay by small farmers. But in practice, the bulk of the benefit from low pricing goes to the large farmers.

The equity requirements from the view point of the Govt. as well as the users have been considered. The utility or welfare is affected by the risk inherent in agriculture and also by the income distribution requirements.

$$\text{Increase of welfare} = \text{Expected increase in income} - \text{Risk premium} + \text{distribution effect}$$

The mean-variance method is used to account for risk. Quadratic programming has been adopted to determine the mean-variance frontier, vide Fig.5.1. The small farmers have lower mean income due to their low risk absorbing capacity. A preferential pricing system based on the study is used not only to compensate the smaller farmers for their low risk aversion but also to enable them to undertake more risky ventures by adoption of high income crops. By this method, the mean income of a small farmer is increased from Rs.894.16 to Rs.933.04

and a medium farmer from Rs.1053.87 to Rs.1085.7 per hectare. The Government shares the risk to the extent of reduction allowed to the smaller farmers.

From the various ways of achieving distribution of income discussed in chapter 6, suitable weights have been selected for the desired preferential treatment. The weightages have been derived for the small, medium and large farmers are 1.206, 1.046 and 0.943 respectively. Based on these preferential weights, a method of redistribution is used so that the total revenue does not decrease. While considering the discriminative pricing, the fundamental principle of equal price for equal service is not lost sight of. The reduction amounts to a form of subsidy and is kept at a reasonable level so as not to encourage artificial fragmentation of land holdings. Considering the risk premium and redistribution of income, the charge to a small farmer is 57 percent, medium farmer 79 percent of the water charge for a large farmer. The objective of regional development and economic growth are achieved by construction of the project and intensification of irrigated agriculture. Further adjustment (reduction) in water pricing does not have any further significant beneficial effect.

The prices arrived at afterthe above considerations are shown in Table 7.1.

The economic evaluation for project justification or desirability considers benefits and costs to ' whomsover these may accrue'. Recovery of cost, therefore, does not have

Table 7.1

Price of Water

Rs. per hectare

Sl. No.	Name of Crop	Net Income from irrigated cropping	Ability to pay	Price to be charged		
				Large farmer	Medium farmer	Small farmer
1.	Wheat	1210	337	368.70	292.30	207.60
2.	Oilseeds	885	147	160.80	136.40	92.40
3.	Pulses	935	198	216.60	183.70	122.50
4.	Potato	1950	610	667.30	529.00	378.00
5.	Gram	1050	290	317.30	251.50	179.90
6.	Sugarcane	1805	419	458.40	363.80	259.70

any effect on the economic evaluation. From consideration of equity and from financial accounting purpose, cost recovery would be desirable. Even though recovery of cost is not explicitly spelt out, the impact of pricing on cost recovery need be exhibited at various stages of planning including the operation stage. The costs used for economic evaluation are not the same for purpose of cost recovery. The discount rate for purpose of cost recovery should be different in view of the investment being made for purpose of development in line with soft loans issued by financial institutions including World Bank. The impact of pricing on cost recovery is shown vide Table 7.2. for different interest rates of 10, 5 and 2 percent for the three different strategies. In the single purpose with only surface water use, the cost recovery is only 73.2 percent where as with conjunctive use the recovery is 97.55 percent and with improved operation, the recovery is 106.17 percent.

A project which is economically desirable is expected to meet the cost recovery criterion at a reasonable discount rate. This rate indicates the financial return on investment. This rate would vary from project to project. Projects which are only marginally feasible (B/C = 1.0), the return would be quite small. The practice in USA is not to charge any discount rate, which may not be desirable. A lower discount rate need be prescribed if recovery of cost is considered as an objective. The Conference of Ministers of Irrigation held in 1972 recommended an interest rate of 2 1/2 percent.

Table 7.2

Recovery of Cost

Million Rupees

Sl. No.	Item	I Surface Water Discount rate (percent)			II Conjunctive Use Discount Rate (percent)			III Improved power generation Discount Rate (percent)		
		10	5	2	10	5	2	10	5	2
1	2	3	4	5	6	7	8	9	10	11
I.	Cost of Irrigation Sector of the Project									
	i) Annual Capital	136.50	74.14	43.06	166.50	90.43	52.53	143.90	78.15	44.40
	ii) O and M	37.50	37.50	37.50	50.30	50.30	50.30	55.30	55.30	55.30
	iii) Total	174.00	111.64	70.56	216.80	140.73	102.83	199.20	133.45	99.70
II.	Cost Recovery with pricing of water	127.40	127.4	127.40	211.50	211.50	211.50	211.50	211.50	211.50
III	Percent Recovery	73.2	114.1	180.56	97.55	150.29	205.68	106.17	158.50	212.13

Since pricing is suggested on crop area and not volumetric basis, using more water than what is actually required cannot be ruled out. This calls for a water allocation and distribution system preferably demand based.

The pricing suggested are given in Table 7.1. It is seen that the price of water expressed as a percent of net income from irrigated cropping varies from 18 to 35 percent for large farmers.

In view of crop based water pricing, some effect on crop planning can be made by artificially increasing (or reducing) the water charges to make specific crops uneconomical (or attractive). However too much reliance on pricing for crop planning may have adverse effect on the state of irrigated agriculture. Other measures like support price for commodities, water allocation should complement in enforcing planned cropping pattern. The prices suggested are based on the ability to pay and are an upper limit. The practice in USA is to charge 75 percent of the ability to pay. The water pricing is based under certain assumptions which must be satisfied. It is presumed that the full requirement of water for the crops will be met from surface and ground water. The planning is under a system of conjunctive use where the reliability of supply is high. The price does not distinguish between surface and ground water sources.

As indicated in the alternative cost approach of benefit evaluation vide para 3.3.2. The cost of obtaining water supply from ground water by the farmer himself should be comparable with the charged prices. The average cost of ground water pumping is estimated at Re 0.2330 per cum of consumptive use. Considering the water requirement of wheat the cost from ground water pumping comes to Rs.615.00 per hectare against the suggested price of Rs.368.7 per hectare for large farmers. In view of the comparable prices large farmers would be induced to take up their own tubewell schemes for their independent use. Such private tubewells would be a welcome trend in the conjunctive use and could be encouraged by providing required infrastructural facilities.

The enforcing of discriminatory pricing needs special rules. The normal water rates should be the rates recommended for large farmers. Reduction of rates for small and medium farmers can be on ' ad valerom' basis. Identification of favoured group should be done at a certain point of time and further inclusion should have to be restricted. Rules for further inclusion need be framed indicating the authority who will approve.

Dual pricing is in vogue in a nation-wide scale for many essential food items like rice, sugar, cement etc. As such discrimantory water pricing is not expected to be difficult since people are already accustomed to such a practice in many other sectors.

The water pricing is based on the productivity and cost of cultivation. The variability in the prices has been accounted for to some extent by providing relief to the unfavoured. However there are number of other risks and uncertainties which affect production. Any reduction in productivity directly reduces the ability to pay for water. The pricing should be flexible and need be reviewed periodically. Further any loss of productivity in any year due to reasons not in the control of the farmers, suitable remissions need be provided. Some of the uncontrollable variabilities are -

i) Variability in the supply of water,

ii) Variability in the agro-climatic conditions,

iii) Nonavailability of rationed inputs like fertilizers, pesticides,

iv) Damage to crop by pests which could not be avoided,

v) Damage to crop due to natural calamities.

Authorities must be prescribed to grant remissions with guidelines in conformity with the general pricing policy.

7.3 CONCLUSIONS

From the analysis and results thereof, the following are the main conclusions -

1. Pricing on the value or productivity of water in crop production is preferred to a cost based pricing.

2. The benefit from use of water in crop production is equitably shared by the users and investors. The user is allowed full share for his contribution to national objectives.

3. Social equity demands discriminatory pricing to account for risk and income distribution effects. National/Regional parameters should be prescribed.

4. Recovery of cost need not be an objective. The impact of pricing on cost recovery should be exhibited in the feasibility studies. A lower discount rate than that used for economic evaluation need be prescribed for project feasibility.

5. Pricing policy guidelines should be prescribed for nationality and uniformity in pricing. The present water charges (Table 1.1) are much on the lower side and there is need for upward revision. The prices now suggested are given vide Table 7.1.

6. Crop area based pricing would not be an effective way for eliminating over irrigation. Demand based allocation and distribution should be enforced.

7.4 RECOMMENDATIONS FOR FURTHER STUDY

This study has also brought out related problems where further work in the area would be useful. These are listed below -

1. Adopting the suggested pricing need number of complementary activities. Suitable institutional, organisational and legal framework need be worked out for meaningful implementation.

2. The use of demand curves with consumers' surplus for purpose of water valuation and allocation has not been very encouraging. Monthly demand curves provide information on values during the month. The usual optimisation does not equalise the monthly marginal values due to the inherent interdependencies among the months for crop water use. More insight into the economical and analytical aspects would be useful.

3. For increasing the water use efficiency, charging by volumetric method has to be resorted to. Such a method requires large scale modifications in the present system both physical and management systems. Further studies in the direction are needed to keep abreast with the future planning perspectives.

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