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Strategy to be adopted in Preparation of National Water Resource Master Plan

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Abstract— Unlike other natural resources, water is a unique resource, which renews itself. It is due to its constant circulation in the ocean-atmosphere-earth-ocean system. No matter how much water is consumed in daily life, its amount seldom dwindles. With time and under certain conditions water regains its properties and becomes fit for reuse. This is probably the reason why water resources appear to be unlimited for a long time. The key consumer of fresh water is agriculture rather than industry. Irrigation of fields, orchards and estates claim almost 80% of the water consumed the world over. Unfortunately, 97.5% of all water resources on earth are salty. Consequently, fresh water including the one in glaciers accounts for only 2.5%. Even here the most accessible one is as little as 0.3% moreover the natural distribution is extremely uneven. This unevenness is aggravated by the still greater unevenness of the geographical distribution of human settlements. In this scenario the importance of National Water Policy is thus amply emphasized and well recognized by the rulers and emphasize the need for the of water resource master plans to be adopted by the countries become an issue of discussion. This article recommends the strategy to be adopted in water resource planning in the case of water has to be done for a hydrological unit such as a catchment area/river basin as a whole basin, or for a sub-basin. It further recommends that special multi-disciplinary coordination forum should be set up in regions to prepare comprehensive plans taking into account the needs of not only irrigation, but also the various other water uses so that the available water can be put to optimum use.

Index Terms— Agriculture, Hydraulical unit, Irrigation, Master plan, River basin, Strategy, Water resource.

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1 Introduction

WATER is one of the most important natural resources and is a key element in the socio-economic development of a country. The demand for water is continuously on the increase with the growth of population, industry and agriculture. However, the total amount of available water remains more or less constant. This is bound to lead to scarcity of water, if not today, in the foreseeable future. In order that such a scarcity does not occur and hamper the development of the country, it is very important to improve the efficiency of planning and management of our water resources. In other words, a water resources plan, consistent with the overall economic, social and environmental policies of the country, is an important element to ensure that water resources contribute to the country's development objectives.

Most development decisions today are multi-objective in nature, involving economic, social and environmental dimensions and values. However, until relatively recently, this fact was not seriously taken into consideration in planning for water resources development. Instead, economic development was considered to be a desirable end in itself, often with little regard to adverse effects on social or cultural systems and the natural environment. As the pace of economic development increases these effects can no longer be ignored. The need to formulate plans for water resources development in a rational way, the multi-disciplinary nature of water resources planning, development and use requiring co-ordination among various Government bodies concerned with water, and the need to minimize adverse environmental impacts due to water development activities have all added to the complexity of water sources development and management. Thus, the formulation of river basin master plan is not a straight forward procedure, nor is it an easy task. It involves consideration of a large number of factors related to various disciplines connected to water resources and an in-depth study and understanding of basin's developmental requirements, priorities and limitations. One reason for this lack of attention to master plan preparation may be the absence of any guidelines in this regard.

In order to assist the Irrigation and Water Resources Departments of the Asian countries, in the preparation of river basin master plans, an attempt has been made to formulate broad guidelines indicating the contents of such a plan, data requirements and broad possible approaches. While the guidelines are in not intended to be self-contained and complete in all respects, it is considered sufficient to serve as a pointer to the planner in choosing his directions of approach. In fact, the methodologies to be followed in specific cases vary and a generalization is not possible. A guideline like this can utmost indicate the requirements. The ways and means to achieve this in specific cases is left to the ingenuity of the planner and analyzers.

2 General

2.1 Objective

River basin planning concentrates the planning effort into the natural hydrologic unit, the river basin, and suggests that rational and integrated planning of the water resources in a basin is possible and is also essential. River basin planning offers

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a framework for bringing about integration in planning. Though easier said than done, such integrated planning brings about greater economies of scale and greater benefits from any investment or actions proposed in the river basin. The purpose of preparing river basin master plans may be enumerated as follows

- To prepare a long-term perspective plan for the development of the basin's water resources.
- To develop a comprehensive and integrated approach to the development of water and other natural resources using water with due regard to constraint imposed by configuration of water availability.
- To identify and set priorities for promoting water resources development projects.
- To formulate a short-term action plan consistent with the financial allocations and priorities of rulers action plans.
- To contribute towards the formulation of a long-term national master plan for water resources development.

2.2 Plan Period

Ideally, there should be a short-term programme or action plan covering the immediate 5-6 years and a long-term programme covering a period of not less than 20years. It may, therefore, be stated that a river basin master plan should cover a period of about 20-25 years, revised and updated every five years with an action plan for the next five years that would deal specifically with investment for the next five years. This five-year period is also consistent with the five-year plan period adopted for the country as a whole by the national planners.

Planning is a continuous process. Therefore, master plan should be reviewed and modified periodically to incorporate up-to-date information on various factors affecting decision-making. The hydrology may change with availability of more data, the demand projections may change with changes in the rate of growth anticipated, the capacity of the country to finance projects may change as the country develops and there may be changes in the social needs and priorities of projects as the outlook of people hangs. Even the goals and objectives may undergo changes. This revision, as indicated in the previous para for short-term action plans, may be carried out every five years.

In general a river basin master plan should cover, but not to be limited to, the topics listed in Annexure 1.

2.3 Data Requirement

The perspective of a comprehensive master plan requires vast amount of data relating to assessment of water and related resources, estimation of water needs, identification of projects and formulation and evaluation of plans. The exact data requirement will vary depending upon the particular study environments and approach chosen. In general, the data normally needed may be of the following category:

1. Topographical data such as topographical maps, aerial photographs
2. Hydrological data such as stream flow, snow data, watershed characteristics, sediment inflow rate, duration of flooding for various reaches of rivers
3. Meteorological data such as rainfall, evaporation, temperature
4. Geo-hydrological data such as aquifer characteristics, ground water elevation
5. Water quality data for both surface and ground water including sources of pollution and related information.
6. Environmental data such as flora, fauna, historical monuments, wildlife sanctuaries, fisheries
7. Land resources data such as land use, soil survey, land classification
8. Agricultural data such as cropping pattern, crop water requirement
9. Demographic data including urban and rural distribution, grouping by age, sex
10. Power demand survey data including alternative sources available, demand centers
11. Natural disaster data primarily for flood and droughts. These include disaster-prone areas, damage statistics, mitigation measures
12. Seismic data, especially at the vicinity of probable storages and structures
13. Industrial data especially for those that are water-intensive. The data include growth trends, water consumption, possible alternate sources
14. Inland water navigation data such as demand, alternate transport system available
15. Data on recreational prospects related to water resources development
16. Data on projects in the basin such as completed and on-going projects and their water consumption, potential projects identified including reconnaissance reports for major and medium projects. Data on flood control works carried out in the past and their performance.
17. Drainage works executed, evaluation. Data on drainage congestion problems including near the confluence point of tributary/sub-tributaries with main river, back of the embankment system due to continuous high stage of main river.
18. Geologic data such as formations, mineral deposits
19. Economic data related to project/plan evaluation.
20. Financial data such as those required for financial feasibility analysis and also data on sectorial allocation of plan outlays
21. Legal constraints such as inter-state/international agreements and tribunal awards.
22. Social environment such as water-related institutions, interest groups, public awareness

The above gives only a broad nature of data requirement. Emphasis on specific data varies from situation to situation. For example, the emphasis on the nature of data to be collected for a river basin in a predominantly arid region will be different from that for a river basin frequented by floods. The level of

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detail to be given in the master plan decides the extent of data collection. The planner has to decide these factors in individual cases.

3 APPRAISAL OF WATER RESOURCES

3.1 Purpose

The appraisal of available resources is a basic requirement in all resource planning exercises. Water resource planning is no exception. The purpose of appraising water resources is to determine the source, extent and dependability of supply and the character of water on which an evaluation of their future control and utilization is to be based.

Three aspects should be considered in appraising water resources, i.e., the quantity, the quality and the reliability of available water. In appraising the quantity, it is important to ascertain not only the total quantity available within a certain period of time, but also the distribution of the available quantity with respect to both area and time. In planning the utilization of water resources, the real distribution of available water often dictates the location of the various structures while seasonal distribution dictates their size. Quality of water is important especially for uses such as irrigation, domestic and industrial water supplies. Reliability of supply is an important aspect in deciding the value of water.

Water occurs as surface water and ground water. The division between the two is far from rigid. Surface water consists of direct surface run-off, augmented by a portion of ground water that moves laterally underground and enters water courses. The portion of precipitation that percolates deep down and join subterranean storage constitutes the ground water. Following is a brief discussion on the methods of appraisal of these two sources of water.

3.2 Surface Water

The appraisal of surface water resources generally includes estimation of

1. Annual run-off and its monthly/ten daily distribution
2. Aerial distribution of water resources within the basin
3. Flood flows
4. Low flows
5. Return flows
6. Sediment load.

For a reliable appraisal of water resources stream flow records for around 40 to 50 years are desirable. In case of short records, temporal extrapolation can be done using suitable techniques. While gauge-discharge observation taken once a day will be sufficient for most yield studies, gauge observations at shorter period (hourly to 6-hourly) are required for flood estimation studies. The data should be compiled carefully and checked for consistency. Suitable gap-filling techniques may be used in case the data records are incomplete. A clear statement should be made in the master plan on the nature, source, reliability and adequacy of the data used.

As already mentioned, in case the length of observed run-off data is insufficient, it may be necessary to obtain long-term data using suitable techniques. The usual methods adopted are:

- Statistical models to generate historical data by temporal extrapolation
- Generation of data using stochastic models and conceptual models.

In case where the length of stream flow data is not adequate, but the length of precipitation data is sufficiently long, a statistical correlation is developed between precipitation and run-off using concurrent data and this relationship is used along with long-term precipitation data to obtain long-term run-off data. This method is more widely used and is found to be fairly adequate for annual run-off and monthly run-off during monsoon months.

If the basin is hydrologically homogeneous, the precipitation-run-off relation developed at a station may be used to obtain run-off data at another station in the basin using corresponding rainfall data. Similarly, precipitation-run-off relation can be transferred from an adjacent hydrologically homogeneous basin to the study basin and used.

If long-term run-off data are available at a station in the basin, it can be used to extend the short-term run-off data at some other station in the same basin by correlating the run-off data of concurrent period at the two stations, following the same procedures used for precipitation-run-off correlation. In rare occasions, the long-term run-off data at a station may be reduced in the ratio of catchment areas or catchment areas and normal rainfalls at the two stations. But this method should be used very carefully and only in cases where the difference between the two catchment areas is small.

The techniques of data generation using stochastic models and conceptual models have reached an advanced stage of development. At present many models have been developed and perfected. Some of the stochastic models are autoregressive (AR), autoregressive and moving average (ARMA) etc. The choice of the model will depend on the importance of parameters to be modelled. Similarly there are various conceptual models available such as Stanford Watershed Model, Sacramento Model and Stream flow Synthesis and Reservoir Regulation Model which may be attempted for run-off data generation. The type of model chosen and its suitability should be discussed adequately.

Flood studies *are* concerned with the peak flows and/or the volume of flood flows. Methods commonly used for the estimation of flood are

- Unit hydrograph method
- Flood frequency analysis

Flood frequency analysis will not give the volume of flood flows and therefore, in situations where the volume of flood flow is also important, this method may not be suitable. A simple method called rational method is sometimes used to estimate the peak flood flow for very small drainage areas. In this method the peak flood discharge is calculated as the product of rainfall intensity and the area covered by rain and a coefficient is applied to the product to account for the losses

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by interception, detention and infiltration during the rain. For catchment necessarily be used. The underlying assumption regarding uniformity of rainfall restricts the use of unit hydrograph method to catchment areas not larger than about 5000 sq. km. If the catchment area is much larger than 5000 sq.km, then the area may be divided into suitable sub-catchments and separate flood studies may be carried out for each of them and may be finally synthesized. As already mentioned, the flood frequency analysis method will be useful only for estimating the peak flood discharge of a specific return period. The analysis is purely statistical and hence the limitations. A method to synthesize unit hydrograph at an ungauged station from the unit hydrograph derived at another station with comparable hydrological and meteorological catchment characteristics, is also available and can be attempted where suitable. Regional approach is also possible.

Estimation of sediment load and analysis of its effect are important since sediment deposition in reservoirs depletes their useful capacity and hence their performance. In a wider sense. The process has also effect on the river morphology. The rate of sedimentation may be obtained either from the sediment discharge observations or from hydrographic survey of existing reservoirs. The estimation of sediment rate from either of the above sources should take into account the differences in sediment producing characteristics of different catchments, effects of soil conservation measures, trends, projections and interception by upstream structures.

The reliability of appraisal of water resources largely depends on the adequacy and reliability of data used for the appraisal. Hence, master plan should evaluate the existing hydrological and meteorological network in the basin, the method of observations and discuss the adequacy and if necessary, suggest measures for improvements. There are guidelines issued by World Meteorological Organization in this respect

3.3 Ground Water

Ground water is an important source of water and its development is crucial especially in areas where surface water resources are scarce. In many regions, ground water is the only dependable water source for drinking as well as for irrigation. It is also important as a supplementary source to surface water.

The appraisal of ground water is much more complicated than that of surface water, because unlike surface water ground water is not confined to any channel or exposed to vision for a direct measurement. The basic information needed for assessing the ground water availability are the type and location of aquifer, their thickness/depth and their characteristics such as hydraulic conductivity and storage coefficient. These are obtained from water level observations in wells, surface geological mappings, test drilling and pumping test data. The most important formation required by the planner is the annual rate of recharge because in the long-run, the availability is restricted by the annual rate of recharge. Utilizable ground water is that portion of available ground water which can be economically developed and utilized with the available technological know-how. This should be assessed.

In certain areas, over pumping of ground water from aquifers may cause excessive lowering of water table resulting in undesirable adverse effects such as excessively higher cost of pumping, decrease in available yield, salinity intrusion and ground subsidence. Such areas should be identified and appropriate remedial measures should be recommended. The assessment of. Utilizable ground water should reflect these considerations.

The existing hydrogeological network for monitoring ground water levels should be reviewed and their adequacy discussed in the master plan with appropriate suggestions for improvement.

3.4 Quality of Water

An appraisal of water resources is not complete without a mention of the quality of the available water. The quality of water is greatly affected by the presence of minerals in soils and rocks through which the surface and ground water flows. But, with rapid industrialization and urbanization, the greatest threat to the quality of water is from urban and industrial waste effluent. Run-off from agricultural fields contaminated with pesticides and chemicals further aggravate the situation.
The investigation of quality of water depends upon the purpose of its use. Water used for drinking purposes should not contain any substances harmful to the health. Water for industrial use must be suitable for the specific processes involved in the particular industry. Irrigation water must not contain objectionable salts and other substances, dissolved and suspended beyond certain limits. Water bodies used for recreational purposes must be free from pollutants creating a nuisance and pathogenic bacteria while those for fish breeding should be free from toxic substances and must meet necessary standards regarding dissolved oxygen.

The general steps that may be followed in investigating the water quality in a basin, may be as follows

1. Compile all available data on stream and well water quality
2. Compile information on the sources of pollution such as industries and urban centers, sewage treatment plants and quality of effluents
3. List the existing and anticipated water use points and quality standards for each use
4. From (1) and 3) find out the possible water uses of untreated water estimate the probable cost of treatment
5. For ground water, explore the possibility of conjunctive use of brackish and sweet water.

The deterioration of stream water quality due to industrial and domestic effluents has increased the awareness regarding water quality among environmentalists and the public in general. Therefore, the planner has to devout particular attention to water quality management in river basin planning. Water quality modelling techniques can be used to determine the degree of treatment required, the relocation of waste discharge points, the amount of low flow augmentation required etc. In

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general, water quality models are complex; but often simplifying assumptions and approximations are made. For example, assumptions of steady state conditions are made in most water quality models even though it is essentially a transient phenomenon. Similarly, most models developed are deterministic and one dimensional. Most of them model only BOD and DO concentration. Some of the available models for water quality modelling are QUAL-IIE developed by the Army Corps of Engineers, USA, TOMCAT developed by the Thames Water Authority, UK and DIURNAL model developed by the United States Environmental Protection Agency. Since the subject is a specialized field, it would be appropriate to utilize the services of a well-qualified and experienced expert for this part of the planning study.

4 Appraisal of Land Resource

4.1 Purpose

For agricultural development, water and land resources form the most essential inputs. The availability of land decides both the potential and limitations of agricultural production. Therefore, in the formulation of a basin master plan, it is important to have an appraisal of available land resources in the basin and their limitations. The master plan should also discuss the planned growth of developed land areas and proposals for agricultural development. Possible alternate rational uses of agricultural land should also be considered and discussed.

The appraisal of land resources should include assessment of existing land use pattern, areas suitable for irrigation, areas requiring drainage and areas that can be reclaimed and used for cultivation. The required data are usually collected through land use surveys, land classification surveys and soil surveys.

Suitability of land for irrigated agriculture depends upon its physical and chemical properties and on socio-economic factors of the region. The physical and chemical properties of land which determine the degree to which lands can be put to agricultural use are the climate, soil, topography, drainage conditions etc. The socio-economic factors determine how far the people may be willing to adopt irrigated agriculture.

4.2 Land Use Pattern

Land use pattern describes the existing division of land under various categories such as forests, cultivable areas, fallow lands, areas not available for cultivation such as urban areas, and cropped areas. This will enable a ready assessment of the potential for agricultural development in the basin and to assess whether land resource is a constraint for development.

Land use data are usually available with the revenue authorities and no specific surveys are normally required. However, these data are seldom available basin-wise. They are compiled and published for revenue units such as a district/sub-division/block. Hence, approximation based on area may have to be made. Such approximations are permissible till more detailed surveys are taken up.

4.3 Land Classification Surveys

These surveys may be reconnaissance level surveys, semi-detailed or detailed surveys. Reconnaissance and semi-detailed surveys are sufficient for master plan preparation, while detailed surveys are carried out at the time of preparation of detailed project reports.

Reconnaissance surveys are intended to identify the general outline of land features and the extent of areas available for agricultural development. Topographic maps (scale 1:25000) along with data on existing land use pattern will suffice for this purpose.

Semi-detailed surveys are carried out to examine the land features more carefully and to locate potentially irrigable areas. Arable and non-arable lands are identified more accurately at this stage. A larger scale map, say 1:10,000 may be preferable for this analysis. Aerial photographs adjusted to the above scale may also be used.

4.4 Soil Surveys

Soil surveys are carried out to determine their fertility, crops that may be grown, yields that may be expected, irrigability of land, water delivery requirements, land development needs such as needs of drainage and specific reclamation practices. Soil survey should cover the following aspects of soil

- Physical properties such as color, texture
- Chemical properties such as pH, soluble salt, salinity, alkalinity
- Soil erosion
- Soil classification such as family, series, type phase
- Land capability classification
- Irrigability classification.

The suitability of land for sustained use under irrigation is determined and the basin is grouped into soil irrigability groups. Generally the soil has been classified into the following five class, according to increasing limitations of sustained use under irrigation

Class A - None to slight soil limitations
Class B - Moderate soil limitations
Class C - Severe soil limitations
Class D - Very severe soil limitations
Class E - Not suited for irrigation.

Land capability classification is basically an interpretive grouping of soils primarily meant for agricultural purposes. The classification is based on soil characteristics, external land features such as slope and environmental factors related to drainage such as drainage outlets, depth to water table etc. This classification indicates the suitability of lands for various crops and is of vital importance to planners. On the basis of the criteria given above, land is broadly classified as that suitable for cultivation or arable lands and that unsuitable for cultivation or non-arable lands. There can be further classification under each category depending upon their relative suitability or otherwise for agriculture.

In some basins, water logging and salinity may be major prob-

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lems. Maps showing areas liable to water logging and salinity along with depth of water table etc. should be prepared. These maps will be useful in planning crops and exploring possibility of conjunctive use of surface and ground water.

5 Population Forecast

Compilation of data on present population and its projection to the end of planning period are of vital importance in river basin planning. An accurate estimate of the future water demand depends on an accurate forecast of future population. The estimate of population is useful not only in assessing the water demand, but also in assessing the human resource potential in the basin. Every effort should, therefore, be made to have a fairly reliable estimate of present and future population on which the master plan can be based. Similar projection for livestock population is also required for assessing water requirement for livestock.

In our country, population census are taken once in every ten years. This gives very descriptive data on population such as rural and urban distribution, male-female break-up etc. However, the data given in the census reports are compiled for political divisions such as states, districts, urban agglomeration and so on. Therefore, in order to estimate the population for a river basin, approximations, perhaps based on area proportion may have to be made.

For reliable population projection, the following data are normally required

- Bench mark or base line population data
- Vital statistics which provide information on population changes such as births by age of mother, deaths by age of decedent, rates of marriages, school enrolment statistics, migration of population and so on

Bench mark data should contain at least as much detail as the final projection is to include. The normally required details are the growth rate of population, its density, literacy percentage, percentage of urban and rural population and work force.

Various methods are available for projecting population. The suitability of any method depends on the nature of data available. Some of the methods that can be used for projection of population are the mathematical method, the component method, the economic method and the analogy method.

The mathematical method allows past populations to be projected using linear or exponential extrapolation of a time series of historical values. This is the simplest and most widely used method. Other methods of mathematical extrapolation using historical values include those assuming a uniform growth of population, a uniform rate of growth of population or a decreasing growth rate of population.

In cases where detailed data on population are available, another method called component method (or Cohort survival method) may be used. In this method, the future changes in the various components constituting the population growth are worked out. The total population is classified by age and sex. Current birth and death rates are applied for each class and extrapolated into the future. Separate projection for migrant population, both in and out of the basin should be made where this component is likely to be significant. Composition of such migrant population and their economic status are also desirable information that may be assessed.

A third method of population projection called economic method treats population as dependent variable on economic activity. It takes into account future need for food, raw material, manufactured products and services in the total market area. On this basis a labor force required to satisfy the demand for local production is predicted which in turn is used to predict the population. This method may be useful for larger area like a country as a whole where the economic interrelationships between production canters may be analyzed using models like input-output model.

Analogy method is used when little or no demographic data is available. In this method, population is projected by transposing demographic figures for areas with comparable social and economic conditions. Since Asian countries are having fairly good demographic data, this method may not be generally required. However, for predicting migration component of population, analogy with migration experienced in similar project areas may be employed.

6 Agriculture

6.1 General

Agriculture plays an important role in the economic development of our country. Land and water form the two essential inputs to agriculture. These two resources and their assessment procedures have been discussed in earlier chapters. This chapter will discuss the aspects of agriculture that are important in the preparation of river basin master plans.

6.2 Present Status of Agriculture

A general survey of the basin's agricultural sector should be made to assess the present status of agricultural development in the basin. The assessment should include an appraisal of the performance of agricultural sector, appraisal of the important problems faced by the sector and a study of the trend of development of the sector in relation to the national planning framework. The survey should assess the extent of land under cultivation, crops grown, irrigation facilities available, crop yields, marketing facilities, rural population engaged in agriculture, alternate employment opportunities and willingness of the farmers to adopt improved methods and practices. An assessment of available credit facilities through agricultural financial institutions and existing agricultural extension services will also be desirable.

6.3 Demand Projections for Agricultural Products

Demand projections of agricultural products are usually made as a range of possibilities as they are dependent on population growth, government pricing policies, personal income and supply of commodities. The demand for particular commodi-

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ties depends on the food habits of the people and living standards. The demand for cash crops will depend on the existing and future potential for agro-based industries. Since it is difficult to obtain an accurate estimate of some of these variables, attempts should be made to estimate the range of demands for commodities.

Since the primary objective of planning increased agricultural production is to satisfy the nutritional needs of the population, this forms a rational basis for estimating the food production requirements. Knowing the per capita requirement of major commodities and population projection, the total food production requirement can be estimated.

7 Water Management System

It is essential to conduct an appraisal of the existing water management system in all major fields of water uses. This should include a description of the existing structural facilities available, water management practices and issues and problems. Information on the existing water use and management will enable the planner to assess the committed water uses and to arrive at net water available for further planning. It will also enable him to study the current practices and correct any deficiencies in future planning.

Irrigated agriculture is the biggest consumer of water in Asian countries. Other major water use sectors are domestic and industrial water supply, power generation, navigation, and recreation and low flow augmentation. With regard to irrigated agriculture, the area under irrigation from various sources such as surface and ground water sources, state-owned and privately-owned sources, irrigation from major, medium and minor projects, irrigation by flow and lift irrigation etc. may be compiled. Most of these information can be compiled from the agricultural statistics published by the respective administrations responsible for this. Information on other water uses may be available with local bodies, industrial establishments and other governmental/private organizations connected with water uses.

An inventory of the existing and on-going water resources structures and their capacities should be made. Data should be collected on their planned, created and utilized potential and the reasons for any underutilization of the potential created. Constraints in operating these structures and full utilization of the potential should be investigated. In the case of multipurpose projects, conflicts in the usage of the created facilities for various purposes should be studied.

An area of crucial importance is the irrigation methods currently practiced and their implications. Water delivery methods employed, such as rotational delivery, continuous delivery and delivery on demand, and their effectiveness in efficient use of water should be discussed. Existence and adequacy of proper drainage system and related problems should also be discussed in the master plan. A review should be made of the existing institutional arrangements for farmers' participation in the water management and standard of maintenance of irrigation and cross-drainage structures.

The master plan should also contain an account of the problems related to various water uses. Areas experiencing waterlogging and salinity problems should be identified. Equity in supply of irrigation water, especially to tail enders, conveyance losses, necessity of canal lining and efficiency of irrigation water use should be investigated and discussed. Similarly, problems associated with other existing water uses should also be identified and discussed.

8 Environmental Planning

8.1 General

The lack of environmental consideration in the planning of water resources projects can sometimes create severe impacts of irreversible nature on the environment, resulting in ecological destruction. In the last decade or so, wide recognition has been given to the existence of ecological problems associated with water resources development schemes. To ensure that these environmental concerns are dealt within the planning phase of project, procedures have been established in many countries which are called environmental impact assessments. Even in case when no planning of any water resources development scheme is envisaged in the immediate future in the basin, it is necessary to have environmental status reports prepared for each basin. These reports would serve as bench mark information for future planning.

8.2 Environmental Considerations

There are number of environmental parameters which are required to be considered and incorporated in the planning stage of the water resources projects. During the planning and feasibility assessment stages of river valley projects the following aspects need to be seriously considered:

1. Location aspects

Short term and long term impact and population/human settlements in the inundated watershed areas, impact on flora and fauna, impact on wildlife, impact on national parks and sanctuaries, impact on sites of monuments of historical, cultural and religious significance, impact on forests, agriculture, fishery, recreation and tourism etc.

The significance of considering these aspects is to ensure that the site selected is devoid of ecologically sensitive areas consisting of biosphere areas, national parks and sanctuaries and sites having rare/endangered species etc. to the extent possible.

2. Physical aspects

Landslides, siltation, groundwater recharge, water quality changes, land use patterns etc.

Physical aspects are considered to study the alterations in the surface flow patterns that may have far reaching impact on underground aquifer and their recharge.

3 Resource linked aspects

Resource trade-off, such as loss of optional land use to impoundment, mineral deposits, monuments inundated, dislocation of existing settlements etc

The evaluation of these aspects are necessary in view of large scale disruption due to creation of impoundment which may

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result inevitably in the adoption of alternative land uses.

4. Socio-cultural aspects

Population relocation requirements, identification of educational and vocational training programmes to be imparted to the affected population, resettlement areas for housing and other amenities for the resettled population.

Since relocation may strain/disrupt the social fabric of the affected population, consideration of these aspects is necessary to make the quality of life of the affected better or at least maintained at the same level as earlier.

5. Public health aspects

New health problems or vector patterns arising due to changes in water velocities, temperature, other physical change factors, adequate public health planning to create facilities for migrant construction workers.

6. Cost benefit analysis

Compensatory afforestation, restoration of land in construction areas, control of aquatic weeds, establishment of fuel depots to meet fuel requirement of the labour force, public health measures to control spread of water borne diseases etc.

The cost of proposed remedial and mitigative measures are to be included in the project costs.

8.3 Environmental Impact Assessment

8.3.1 Problem Identification and Formulation

Planning for water resources development is initiated in response to needs that already exist as well as to needs that are anticipated for the future. Translating needs into problem formulation is itself a complex process requiring techno-economic skills and political, institutional insights. A wide range of different situations may be encountered at this stage. Among some of the main problems and constraints that could have a direct impact on the problem formulation process are

- Administrative and hydrological boundaries usually do not coincide
- Time and budget allocations are often limited
- Various regulations and legislative requirements narrow the range of possible alternatives
- Water needs are determined exogenous to the planning process
- Adequate number of trained persons may not be available

8.3.2 Evaluation of Alternatives and Selection of Best Alternative

Of all the steps enumerated in the evaluation of the alternatives and the selection of the best alternatives the most important part of the Environmental Impact Assessment. A number of methods have been developed for conducting the environmental impact assessment. Some of the commonly used techniques are; (i) ad hoc method, (ii) check list, (iii) matrices, (iv) overlays, (v)networks, and (vi) modelling. Each method has its own advantages and limitations.

While ad hoc method gives broad qualitative information, the matrix method and modelling techniques using systems analysis are comprehensive and they present a wide range of alternate possibilities and their consequences in the decision maker's choices. Therefore, the technique that could be resorted to by any project authority would depend upon the available data, manpower and other resources.

8.3.3 Monitoring and Evaluation

Monitoring and evaluation has to be an integral part of the management process if water development projects are to be sustainable. As soon as the projects or the development plan becomes operational one of the issues of critical importance is analysis of performance, aimed at determining the extent on which the objectives of the project or development plan are being achieved. The environmental impact assessment, as such, is not a onetime affair. It has got to be carried out at regular intervals in order to study the environmental changes/implications of the development visa-a-visa the envisaged one. The constant environmental monitoring mechanism would assist the water resources planners to adopt suitable ameliorative measures where needed. Further it provides a valuable information base for planning future projects. The fundamental requirements for a water development project should have the following

- Timeliness
- Cost effectiveness
- Maximum coverage
- Minimum measurement error
- Minimum sampling error
- Absence of bias
- Identification of user's information.

9 Water Uses

9.1 General

Man uses water for a multitude of purposes. The important uses of water are: irrigation, hydropower generation, domestic and industrial use, inland navigation, fish and wild life preservation, and recreation. Flood management, though not a water use in the strict sense, also may be added to this, since it involves regulation of water and hence affects the availability for other uses. The estimation of future water demand by the various user sectors in the basin is an important aspect of master plan preparation. According to the National Water Policy of countries generally the priorities of water use should be

- Drinking water
- Irrigation
- Hydropower
- Navigation
- Industrial and other uses.

While considering the uses of water one should differentiate consumptive and non-consumptive uses. Under non-consumptive use is the generation of hydroelectric power, development of navigation and recreation, for which a certain rate of supply is required but not consumed except incidentally in evaporation and seepage losses.

Irrigation, industrial and domestic water supply are examples of consumptive use of water. Here also, a distinction should be made between actual consumption and water requirement. Taking the case of irrigation, all the water supplied is not consumed by plants. Quite a portion is wasted as surface run-off and lost through percolation which ultimately may return to the stream or add to the ground water storage. Similar is the case with other consumptive uses such as domestic and industrial use.

The return flow from consumptive uses described above join the stream at a downstream point and is available for further use. However, the quality of the return flow may be substantially different from the quality of intake water and may cause deterioration of water quality of stream. This aspect requires to be considered while accounting for the return flow as an available supply downstream.

Another aspect to be looked into is the complementarity between consumptive and non-consumptive uses. If complementarity can be brought about between consumptive and non-consumptive uses in time and space, much saving of water can be effected and the water use will be most optimal or nearly so. This will also result in considerable saving in the capacity requirements of dams, barrages etc.

9.2 Irrigation

Irrigation of land for agriculture represents one of the oldest and most important uses of water, next only to providing water for domestic purposes. The requirement of irrigation water arises out of the necessity to supplement water to the crops either due to aridity and drought or for ensuring the best possible crop returns. Estimates of future irrigation water requirement should be backed by a detailed land and agricultural survey. This should consider the suitability of land for irrigation, suitability and acceptability of cropping pattern and farming practices. Climate and type of soil are other related factors.

Cropping Pattern

The existing cropping pattern may undergo changes with the introduction of irrigation. The projected cropping pattern should take into account the agricultural productivity of land, climate and above all the farmer's choice. Experience in areas with similar characteristics will be a guidance in this regard. The cropping pattern is also likely to change with changing market conditions over the life of the project or the planning period. Such possible changes should be visualized and incorporated. In a large basin, different cropping patterns may have to be adopted for different regions or sub-basins. It may even vary from project to project.

Corp Water Requirement

The term water requirement of crops implies the total amount of water required at the field to mature the crop. It includes evapo-transpiration (ET), application losses and special needs and does not include transit losses. Special needs include requirement for puddling, transplanting, leaching salts etc.

The crop water requirement may be determined from data collected on yield vs. applied water from fields or experimental plots for specific crops in a specific locality having characteristic values of consumptive use and effective precipitation. If such data are available at field experiment stations in the basin or nearby areas with comparable characteristics, these should be used.

In the absence of such data, crop water requirement may be estimated from ET values. The ET may be measured directly by soil moisture depletion studies by conducting field experiments. Alternately, many formulae *are* available for computing potential evapotranspiration (PET). Some of the more commonly used formulae are the Blaney-Criddle, Christianson's and Penman's methods. The modified Penman method which is based on energy concept and aerodynamic principle, is considered more reliable. However this requires a large number of weather parameters such as humidity, wind velocity, radiation, sunshine hours etc. Ministry of Water Resources publication 'A Guide for estimating Irrigation Water Requirements' recommends either Christianson's method or modified Penman method depending upon data availability.

The Food and Agricultural Organization (FAO) of the United Nations has brought out a publication (No. 24) 'Guidelines for Predicting Crop water Requirement'. The method recommended by FAO considers ET, a crop coefficient, kc, to reflect the effect of crop characteristics and a correlation factor to take into account the effect of local conditions and agricultural practices on crop water requirement. The guidelines also give approximate ranges of crop evapotranspiration for different crops and may be used in case data necessary to compute ET are not available.

Irrigation Water Requirement

Irrigation water requirement of crops is the gross amount of water required to be applied through irrigation. Usually, it is only a part of the total crop water requirement and its amount will depend on the contribution from rainfall and the soil profile.

The part of rainfall falling directly in the agricultural field which contributes towards crop water requirement is called the effective rainfall. The effective rainfall can directly be determined by using suitable field lysimeters. The contribution of soil profile moisture towards crop growth will depend on the capacity of soil to hold water. There is no simple method to determine this and the determination itself is possible only when the ground water level is far below the root zone of crops so that there is no capillary effect.

The net irrigation water requirement is obtained by deducting effective rainfall and soil moisture contribution from crop water requirement. This is the irrigation water to be supplied at the head of field channel. The gross irrigation water requirement will include the seepage and other losses during conveyance. The conveyance losses will mainly depend on soil through which the canal runs and whether the canal is lined or unlined. The conveyance losses may amount to 30% to 40% of the water released at canal head and the total losses including field losses may be as high as 50% to 80%. Therefore, the master plan should critically discuss this issue and suggest suitable measures to reduce losses and increase irrigation efficiency. Lining of canals and alternate methods of irrigation like sprinkler irrigation may be costly propositions, but are worth studying for their economics.

9.3 Power Generation
The water use related to power generation comes under two categories: (i) the water requirement for hydroelectric power generation, and (ii) the cooling water requirement for thermal and nuclear power plants. The first one is mostly non-consumptive except for evaporation and seepage in storage whereas the second one is partly consumptive and partly non-consumptive.

Before planning for power, a power demand survey to predict the likely demand for power in the basin or other selected geographical areas to be served by the basin development, may be carried out. The projection should consider per capita usage at present, anticipated technological changes and projected population and industrial growth. The projected demand in excess of the potential of existing projects (hydro, thermal and nuclear) is to be used for planning.

Water requirement for hydropower generation should consider the total water available for generation, the amount and pattern of anticipated power loads and amount of regulation needed to meet load fluctuations and the quantum and pattern of water demand for other purposes. The estimates may be general in character, but should be reliable and in co-ordination with other water uses.

For thermal and nuclear power plants, the water requirement should be based on plant capacities and cooling water arrangements. A distinction may also be made between consumptive and non-consumptive uses. Measures for economical water use including recycling should also be analyzed.

Unlike other water uses, the planning for power cannot usually be restricted to the demand within a basin alone. The demand for a region or the nation as a whole is important rather than demand in a basin. Therefore, as a general rule, the planning should attempt to generate hydroelectric power where feasible. The excess power, if any, can always be used elsewhere through regional grids
.

9.4 Domestic and Industrial Use
Domestic and industrial water requirement should include drinking water requirements and other daily needs of urban and rural population, industrial needs, commercial needs, public needs such as fire hydrants and miscellaneous needs such as livestock, poultry, gardening etc. Out of all water uses, the domestic water supply has to be given the highest priority by the Governments when implementing National Water Policy.

Assessment of future demand for domestic water supply has to be based on the growth of population in the area to be served and its likely consumption of water per capita. The per capita consumption of water will depend on standard of living of the people, social customs and habits, accessibility of supply, quality available, climate, tariffs and economic and educational background. Universally accepted per capita requirement of domestic water for urban population will be 70 to 250 lit/capita/day (Ipcd) with an average of 140 Ipcd. The same for rural population can be taken as 25 to 70 Ipcd with an average of 40 Ipcd. These rates may be used as guidance along with the projected population figures for estimating the domestic water needs.

Industrial water use varies widely among industries. Statistics on average use per unit of production may be available with industries or concerned Government departments. Efforts should be made to collect such data at least for these industries which are water intensive such as paper and newsprint, coal mining, petrochemicals etc. Water demand projection for industries should be coordinated with studies of anticipated industrial expansion and should indicate the location, type of use as well as the amount, quality and location of-effluent discharge. Industries when set up will also create an accompanying demand of domestic supply to cater to the needs of new concentration of workers and their colonies. This demand should also be taken into account. The scope for industrial expansion in the catchment will primarily depend on the availability of cheap raw material and labor, transport facilities to demand centers and the general industrial policy of the regional entity. Information available with industry department and national plan document will provide some idea of the regional industrial growth prospects which may be utilized.

Commercial water requirements are computed based on the number of commercial establishments that are existing and are likely to come up to serve the projected population. An average rate per commercial establishment may be worked out based on survey on existing water use.

9.5 Minimum Flow Requirement
Maintenance of minimum flow in river is also to be considered as a water use since it restricts the quantity of water that can be diverted for other uses. Necessity to maintain minimum flow in river may arise out of the necessity to maintain water quality, river regime, maintenance of river eco-system or other public necessities such as bathing, drinking water for cattles etc. Minimum flow requirements at different points in the river system should be assessed and adequate provision should be made in the master plan to ensure this.

9.6 Aquatic and Wild life
The effects of the development and management of water resources on the environment available to aquatic and wild life need to be carefully considered in planning. Species are adversely affected by changes in environment to which they are accustomed. Cold water fish inhabit rapidly flowing stream. Reservoirs provide good habitat for warm water fishes while destroying habitat of cold water fishes. Reservoir submergence may affect the natural habitat of land oriented wild life.

A survey should be carried out for planned as well as existing and under construction projects to study the possible effects of

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planned development on the different species of fish and wild life in the catchment. If the study indicates any adverse effects, remedial measures should be incorporated in the plan to offset such adverse effects. The remedial measures may be in the form of providing fish ways and fish ladders, controlled release of water downstream, restriction in the drawdown of storage etc.

Apart from protecting the species, fish culture may be a commercially viable proposition in many reservoirs. The master plan should include an evaluation of the potential of inland water bodies for fisheries development. The factors influencing fish reserves and fish catch potential should be presented and discussed. Similarly, the local market demand for fish and export possibilities to other areas should also be discussed side by side.

10. Flood and Drainage Management

10.1 Flood Management

The scientific control and utilization of flood waters is an essential part of water resources development planning. Flood management can be visualized in two parts

- Mitigation of flood damages
- Utilizing the flood waters for beneficial uses.

There is no single method to deal with floods. A variety of structural and non-structural measures are available. Whatever the method or methods adopted, it should be understood that flood management strives to reduce the flood damages, but cannot eliminate the hazards from rare events.

Due to increasing pressure on land, there are demands for removal of waters from wet lands under the garb of removal of drainage congestion of these areas. Wet land areas should be properly identified in the catchment master plan and only peripheral areas of such wet land should be considered for removal of drainage congestion.

Geo-morphological studies should be taken up for those rivers with bank erosion problem. River channel process studies should be taken up for braided rivers. Embankment, constructed on many rivers are subsequently threatened by the erosive activity of the river, requiring costly anti-erosion works. Such reaches should be identified and studies taken on scientific basis to avoid or reduce such works in future.

For those river basins with mineral wealth, special attention would have to be paid in formulating flood management proposals for optimum utilization of mineral wealth.

Humans occupy and develop the flood plain as if the flood threat does not exist. With the overall development of the catchment, the activities of man in the flood plain are only likely to increase. Therefore river basin planning should foresee the likely trend of flood plain occupation and the consequent increased exposure of life and property to flood threats.

Flood control measures mainly come under two categories; structural measure and non-structural measures. Structural measures include reservoirs, embankments, levees, channel improvements etc. Non-structural measures include flood plain zoning, watershed management, flood forecasting and flood warning. In any given case, instead of a single measure, a combination of measures may be ideal and optimal. Studies to determine optimal combination of flood control measures may be carried out for each individual case. Corresponding to a given design flood of specific frequency, an equal degree of flood protection may be provided by various combinations of flood control measures. By determining the cost of attaining a given level of flood control by various combinations of measures, the least-cost combination can be determined. Usually, a marginal value analysis is carried out and the optimum is expressed as a function of frequency of design flood.

The magnitude of flood against which protection is to be provided is also important. The design flood magnitude will depend on the importance of the structure or area to be protected. Ideally, the scale of development should be related to the damage potential as well as to the local conditions and the one with maximum benefit-cost ratio should be chosen. However, such a procedure will require extensive data on damages due to floods of different frequencies and due to such factors as embankment failure etc. which may not be available in most cases. Generally the above difficulty addressed by adopting the below mentioned criteria being followed at present in many countries,

- Predominantly agricultural areas;-
  25-year frequency flood. When so justified a higher frequency flood or the observed maximum flood may be adopted
- Town protection works, important industrial complex etc.
  100-year frequency flood

10.2 Drainage Management

One of the problems requiring attention in river basin planning is the drainage of surplus water from waterlogged areas and other stagnant water bodies. Surplus water is as harmful to corps as inadequate water. Excess water in the root zone of crops will reduce the essential air circulation in this zone, affecting the growth of plant as well as yield. Water logging may also lead to salinity of soil making it unfit for cultivation. Sustained waterlogging is also an environmental and health hazard. Therefore, it is necessary that proper preventive and remedial measures be planned and incorporated in the master plan.

Excess water on the land may be due to a variety of reasons. Excessive rainfall, flooding, over irrigation, seepage from water bodies, poor soil drainage properties and adverse subsurface geological conditions are some of the important causes leading to waterlogging and drainage problems. Where land has a flat slope and in deltaic tracts subject to tidal ingress, the problem is very acute. In the preparation of the master plan, such areas should be identified and an action programme for a drainage system should be included.

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The methods used for drainage may be broadly classified as surface drainage and sub-surface drainage. It may also be a combination of the two. Topography, rainfall intensity, soil characteristics and irrigation methods are important factors which will decide the type and design of drainage system. In many cases, natural water courses may form part of the drainage system. In such cases, they should be properly remodeled for better efficiency. Sub-surface drains are costly and difficult to construct; but are efficient in draining sub-surface water. They may be used in conjunction with surface drains.

While the master plan should give provision for the drainage of waterlogged areas it should also indicate appropriate preventive measures in areas where such conditions have not yet developed. Lining of water distribution system, efficient on-farm water management, proper maintenance of surface drainage system are measures that will reduce the possibility of excessive recharge to ground water. Such measures can, therefore be advocated in areas where there is possibility that such conditions may develop. Conjunctive use of surface and ground water is also an efficient and effective method in such situations.

Unlike irrigation channels, the maintenance of drainage channels is usually poor. Maintenance is as important as design and construction for efficient functioning. Drainage system often gets clogged due to weed growth and silting up. Since the flow in drainage channels is usually varying in quantity and time, they are more subject to fast weed growth and silting. The master plan should emphasize this aspect.

10. Formulation Of Master Plan

10.1 Planning Objectives

Planning aims at consumer's welfare. The objectives of planning are to maximize the production of goods and services which will improve the quality of life of people. In the case of water resources projects, the consumer's utility is linked to such goals as economic development, job creation, environmental preservation, income redistribution and social well-being, to state a few important among them.

Water resources planning in most cases are multi-objective. Setting goals is an important step. They must be the right ones and unambiguously stated. Lang term and short term development objectives should be properly formulated with due regard to the overall national planning objectives, A discussion of the socio-economic scenario of the catchment including ethnic divisions, regional imbalances, backwardness, tribal status, etc., priority sectors of water use and related activities and constraints of development should precede the formulation of development objectives. The above discussion should bring out the problems in the water resources sector in the catchment. Problem identification and goal setting are two important and related steps in plan formulation.

13.2 Water Budgeting

Before embarking a formulation of detailed proposals for catchment plan, it would be necessary to check the availability of water to meet the anticipated demands, at least on a rough basis. This will ensure that the planning is within the available resources. This will also help in early conceptualization and formulation of proposals for alternate or additional sources through inter-basin transfers, recycling etc.

An estimate of the quantum of natural surface water as well as ground water available at various control paints in the basin should be made. The existing utilizations for various purposes should also be assessed. A distinction should be made between actual and planned utilization and the reason for the shortcomings should be properly accounted. With this information, an estimate of the present water balance scenario at various selected control points in the basin should be made.

Anticipated water demand for various time periods in future, 5 years, 10 years, 15 years etc. may be made and water balance carried out to check whether the availability matches the demand. The water budgeting may be carried out in two steps: first the deficit/surplus at each point may be assessed without considering any modifications in the flow pattern through measures proposed in the master plan. This will bring out the necessity for additional storages in certain reaches for which further investigations can be carried out. This will also indicate the necessity for additional resources through transfers, recycling etc. Since the water requirement for different uses are considered, it would be deal to consider the water quality also as an additional factor in the water budgeting.

10.3 Formulation of Alternate Developmental Scenarios

Generating alternate development scenarios is perhaps the most ill-defined, but nevertheless an important step in planning. It is a more creative step and experience is a valuable asset than any modern techniques. Various possible measures of water conservation and distribution, integration of their operation and management, conjunctive use of surface and ground water, possibilities of inter basin transfers are some of the possible courses of actions that may be considered in generating the scenarios. Environmental consideration including water quality aspects and provisions of interstate agreements are also to be kept in view. The alternatives should be able to achieve the objectives of planning. It may not always be possible to formulate a number of alternatives. In some cases, there may be a single alternative only to match the situation.

Identification of measures of water conservation and distribution is an important part of this step Potential water resources development projects should be identified through study of aerial photographs, topographic sheets, geological maps and possibly field trips. After the preliminary identification through office studies and field trips, reconnaissance level field investigations should be carried out for those projects which are considered feasible in the preliminary screening. These projects which are considered technically feasible should then be subjected to economic analysis and on this catchment an identified feasible set of projects are listed for further consideration in the generation of alternate scenarios. A preliminary screening of projects through judgment and/or through modeling can eliminate some clearly inferior and uneconomical projects right at the initial stage itself.

10.4 Evaluation of Alternatives

The consequences of alternate scenarios of development have to be evaluated in order to form a basis for deciding the final plan. This step is more well-defined. Modern analysis techniques such as systems analysis and mathematical modeling can be advantageously used in this step.

The various alternative scenarios are studied and the impacts on the developmental objectives are evaluated. Direct impacts include the benefits accruing to each user group and the costs incurred including adverse impacts on those affected by the development. The evaluation should, as far as practicable, take into account the secondary benefits and costs as well as intangible impacts.

10.5 Selection of Plan

For a planner, this is the last stage in planning. On the basis of the evaluation carried out a final plan of the several alternatives, is recommended for adoption. The choice may be straight forward in the case of a single objective. If multiple objectives are involved, a trade-off between levels of attainment of each objective may have to be carried out. The impacts on various objectives may be displayed as a score board which is a table that shows each alternative's impact on the various objectives. Based on this factual knowledge, a final choice can be made by the competent 'authority using judgment and relative importance of different impacts.

The above procedure sounds simple. In practice, there are many difficulties. First, the impact on various objectives may not be in commensurable terms. A common example in water resources is the evaluation of environmental impact. Secondly, the evaluation does not lead to a single optimum solution, but a large number of solutions. There are a number of methods developed to aid decision making which attempts to reduce the level of subjectivity involved although not possible to altogether eliminate. In most cases however, the situation becomes constrained and the solution becomes obvious by elimination.

10.6 Sequencing of Projects

Since all the projects identified in a comprehensive river basin plan cannot be constructed at the same time, it is necessary to accord priorities for their implementation. The criteria on which such priorities or ranks are assigned are many. Usually, maximization of present value of net benefits is a rational criteria commensurate with objective of economic benefit maximization. However, in the final choice, other factors such as relative urgency to meet basic human needs, regional development considerations, apart from political considerations also become equally important. Staged development of project is also included in this phase of the analysis

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10.7 Short-term Action Plan

The sequencing of projects over planning horizon as discussed above provides a convenient basis for formulating short-term action plans. Sequencing gives the time at which each project is to be taken up for implementation. The set of projects to be taken up in the immediate future is thus known. As discussed earlier, short-term plan of 5-year duration is convenient for many developing countries. Investment plans are then drawn up for this period for the implementation of the short-term plan. These investment plans should be tied to the national sectoral plan for water resources sector as far as financing is concerned.

10.8 Conjunctive Use of Surface and Ground Water

Water resource master planning should consider the optimal development of both surface and ground water. Treating them independently is not the best way to plan their utilization. On the other hand, they should be planned in an integrated manner so that their development and utilization become complimentary in space and time. Thus conjunctive use of surface and ground water has come to be accepted as an essential part of water resources planning. Therefore, the planner should investigate this aspect and incorporate in the master plan.

Possible situations where the conjunctive use of ground water with surface water appear advantageous are

- As a supplement to surface water in cases where the surface water alone cannot meet the full requirements of water in certain time periods or over the whole year
- To provide full irrigation during certain periods or crop seasons, the remaining periods/seasons being served by surface water
- To provide irrigation to certain pockets of the command, especially in the tail end of canals, where canal water supply considerably dwindles
- To control water logging and salinity in areas where excessive use of surface water will result in raising the water table close to root zone of crops
- Where exclusive use of ground water may cause lowering of water table and consequent salinity ingress as in coastal areas, use of surface water partly will ease the situations
- Where surface water is not adequate to meet the full needs, but ground water is saline, both can be mixed to tolerable limits and used.

The first requirement in planning conjunctive use is a thorough knowledge of the availability and distribution of surface and ground water. A water balance should then be carried out for the various sub- basins and at control points in the basin taking into consideration the possible effects of regulation through reservoirs. This will indicate whether the conjunctive use is to be planned throughout the year, during a certain period or in certain pockets of the command only depending upon the deficit conditions. Other factors relating to conjunctive use explained in the previous para should also be taken into account in deciding whether conjunctive use is to be planned and to what extent.

Having decided on the conjunctive use, the planner will have a number of alternative strategies for the extraction and use of

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ground water. The relative economies of the various alternatives are to be studied along with social and political implications before arriving at the final choice for execution. Modern techniques such as systems analysis and operations research discussed in the next paragraph can be used extensively in these studies.

10.9 Application of Systems Analysis

Water resources planning have been increasing in complexity with increase in the demand and consequent pressure on the available water resources. Application of modern techniques like systems analysis and mathematical modeling with the aid of fast digital computers can bring about considerable changes in the planning approach.

Systems analysis methods, both optimization and simulation, can be used in water resources planning. Simulation models are more widely advocated for water resources planning because of their versatility in complex situations compared to optimization methods which require many approximations for application in such situations. Optimization can however, be used for initial screening of projects and perhaps for detailed single reservoir planning. Nowadays, there is a wider acceptance for optimization cum simulation models which utilize the advantages of both the approaches.

Mathematical modeling is also exclusively used for the assessment and evaluation of environmental factors which have become an inseparable part of water resource planning. Other fields where mathematical modeling is widely used are hydrology, agronomy and water quality which are also related disciplines in water resource planning.

11. Conclusion

Every catchment has its own characteristic features and its own developmental requirements. The approach to planning in each case should follow these features and requirements. No hard and fast rules or step-by-step approach for general use is therefore possible or desirable. Priorities, policies and procedures may vary in specific cases. Therefore, a guideline like this can utmost indicate the broad requirements and specifics are left to the planners and analyzers.

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