Module
1

Principles of Water Resources Engineering

Lesson
2
Concepts for Planning Water Resources Development

Instructional Objectives

On completion of this lesson, the student shall be able to know:

1. Principle of planning for water resource projects
2. Planning for prioritizing water resource projects
3. Concept of basin – wise project development
4. Demand of water within a basin
5. Structural construction for water projects
6. Concept of inter – basin water transfer project
7. Tasks for planning a water resources project

1.2.0 Introduction

Utilisation of available water of a region for use of a community has perhaps been practiced from the dawn of civilization. In India, since civilization flourished early, evidences of water utilization has also been found from ancient times. For example at Dholavira in Gujarat water harvesting and drainage systems have come to light which might had been constructed somewhere between 300-1500 BC that is at the time of the Indus valley civilization. In fact, the Harappa and Mohenjodaro excavations have also shown scientific developments of water utilization and disposal systems. They even developed an efficient system of irrigation using several large canals. It has also been discovered that the Harappan civilization made good use of groundwater by digging a large number of wells. Of other places around the world, the earliest dams to retain water in large quantities were constructed in Jawa (Jordan) at about 3000 BC and in Wadi Garawi (Egypt) at about 2660 BC. The Roman engineers had built log water conveyance systems, many of which can still be seen today, *Qanats* or underground canals that tap an alluvial fan on mountain slopes and carry it over large distances, were one of the most ingenious of ancient hydro-technical inventions, which originated in Armenia around 1000BC and were found in India since 300 BC.

Although many such developments had taken place in the field of water resources in earlier days they were mostly for satisfying drinking water and irrigation requirements. Modern day projects require a scientific planning strategy due to:

1. Gradual decrease of per capita available water on this planet and especially in our country.
2. Water being used for many purposes and the demands vary in time and space.

3. Water availability in a region – like county or state or watershed is not equally distributed.
4. The supply of water may be from rain, surface water bodies and ground water.

This lesson discusses the options available for planning, development and management of water resources of a region systematically.

1.2.1 Water resources project planning

The goals of water resources project planning may be by the use of constructed facilities, or structural measures, or by management and legal techniques that do not require constructed facilities. The latter are called non-structural measures and may include rules to limit or control water and land use which complement or substitute for constructed facilities. A project may consist of one or more structural or non-structural resources. Water resources planning techniques are used to determine what measures should be employed to meet water needs and to take advantage of opportunities for water resources development, and also to preserve and enhance natural water resources and related land resources.

The scientific and technological development has been conspicuously evident during the twentieth century in major fields of engineering. But since water resources have been practiced for many centuries, the development in this field may not have been as spectacular as, say, for computer sciences. However, with the rapid development of substantial computational power resulting reduced computation cost, the planning strategies have seen new directions in the last century which utilises the best of the computer resources. Further, economic considerations used to be the guiding constraint for planning a water resources project. But during the last couple of decades of the twentieth century there has been a growing awareness for environmental sustainability. And now, environmental constrains find a significant place in the water resources project (or for that matter any developmental project) planning besides the usual economic and social constraints.

1.2.2 Priorities for water resources planning

Water resource projects are constructed to develop or manage the available water resources for different purposes. According to the National Water Policy (2002), the water allocation priorities for planning and operation of water resource systems should broadly be as follows:

1. Domestic consumption
   This includes water requirements primarily for drinking, cooking, bathing, washing of clothes and utensils and flushing of toilets.

2. Irrigation
   Water required for growing crops in a systematic and scientific manner in areas even with deficit rainfall.

3. Hydropower
   This is the generation of electricity by harnessing the power of flowing water.

4. Ecology / environment restoration
   Water required for maintaining the environmental health of a region.

5. Industries
   The industries require water for various purposes and that by thermal power stations is quite high.

6. Navigation
   Navigation possibility in rivers may be enhanced by increasing the flow, thereby increasing the depth of water required to allow larger vessels to pass.

7. Other uses
   Like entertainment of scenic natural view.

This course on Water Resources Engineering broadly discusses the facilities to be constructed / augmented to meet the demand for the above uses. Many a times, one project may serve more than one purpose of the above mentioned uses.

1.2.3 Basin – wise water resource project development

The total land area that contributes water to a river is called a Watershed, also called differently as the Catchment, River basin, Drainage Basin, or simply a Basin. The image of a basin is shown in Figure 1.

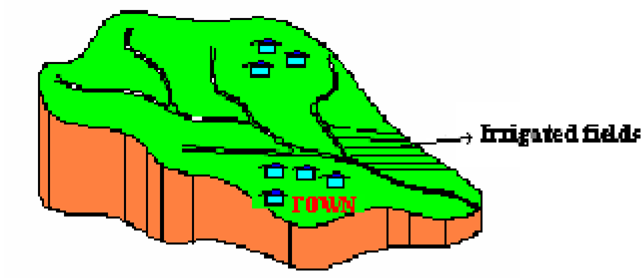

Figure 1. A typical Water Shed

A watershed may also be defined as a geographic area that drains to a common point, which makes it an attractive planning unit for technical efforts to conserve soil and maximize the utilization of surface and subsurface water for crop production. Thus, it is generally considered that water resources development and management schemes should be planned for a hydrological unit such as a Drainage Basin as a whole or for a Sub-Basin, multi-sectorially, taking into account surface and ground water for sustainable use incorporating quantity and quality aspects as well as environmental considerations.

Let us look into the concept of watershed or basin-wise project development in some detail. The objective is to meet the demands of water within the Basin with the available water therein, which could be surface water, in the form of rivers, lakes, etc. or as groundwater. The source for all these water bodies is the rain occurring over the Watershed or perhaps the snowmelt of the glacier within it, and that varies both ***temporally*** and ***spatially***.

Further due to the land surface variations the rain falling over land surface tries to follow the steepest gradient as overland flow and meets the rivers or drains into lakes and ponds. The time for the overland flows to reach the rivers may be fast or slow depending on the obstructions and detentions it meet on the way. Part of the water from either overland flow or from the rivers and lakes penetrates into the ground and recharge the ground water. Ground water is thus available almost throughout the watershed, in the underground aquifers. The variation of the water table is also fairly even, with some rise during rainfall and a gradual fall at other times. The water in the rivers is mostly available during the rains. When the rain stops, part of the ground water comes out to recharge the rivers and that results in the dry season flows in rivers.

Note:

Temporal: That which varies with time
Spatial: That which varies with time

1.2.4 Tools for water resources planning and management

The policy makers responsible for making comprehensive decisions of water resources planning for particular units of land, preferably a basin, are faced with various parameters, some of which are discussed in the following sections.

1.2.4.1 The supply of water

Water available in the unit

This may be divided into three sources

- Rain falling within the region. This may be utilized directly before it reaches the ground, for example, the roof – top rain water harvesting schemes in water scarce areas.

- Surface water bodies. These static (lakes and ponds) and flowing (streams and rivers), water bodies may be utilized for satisfying the demand of the unit, for example by constructing dams across rivers.

- Ground water reservoirs. The water stored in soil and pores of fractured bed rock may be extracted to meet the demand, for example wells or tube – wells.

Water transferred in and out of the unit

If the planning is for a watershed or basin, then generally the water available within the basin is to be used unless there is inter basin water transfer. If however, the unit is a political entity, like a nation or a state, then definitely there shall be inflow or outflow of water especially that of flowing surface water. Riparian rights have to be honored and extraction of more water by the upland unit may result in severe tension.

Note: Riparian rights mean the right of the downstream beneficiaries of a river to the river water.

Regeneration of water within the unit

Brackish water may be converted with appropriate technology to supply sweet water for drinking and has been tried in many extreme water scarce areas. Waste water of households may be recycled, again with appropriate technology, to supply water suitable for purposes like irrigation.

1.2.4.2 The demand of water

Domestic water requirement for urban population

This is usually done through an organized municipal water distribution network. This water is generally required for drinking, cooking, bathing and sanitary purposes etc, for the urban areas. According to National Water Policy (2002), domestic water supplies for urban areas under various conditions are given below. The units mentioned "lpcd" stands for Liters per Capita per Day".

1. 40 lpcd where only spot sources are available
2. 70 lpcd where piped water supply is available but no sewerage system
3. 125 lpcd where piped water supply and sewerage system are both available. 150 lpcd may be allowed for metro cities.

Domestic and livestock water requirement for rural population

This may be done through individual effort of the users by tapping a local available source or through co-operative efforts, like Panchayats or Block Development Authorities. The accepted norms for rural water supply according to National Water Policy (2002) under various conditions are given below.

- 40 lpcd or one hand pump for 250 persons within a walking distance of 1.6 km or elevation difference of 100 m in hills.
- 30 lpcd additional for cattle in Desert Development Programme (DDP) areas.

Irrigation water requirement of cropped fields

Irrigation may be done through individual effort of the farmers or through group cooperation between farmers, like Farmers' Cooperatives. The demands have to be estimated based on the cropping pattern, which may vary over the land unit due to various factors like; farmer's choice, soil type, climate, etc. Actually, the term "Irrigation Water Demand" denotes the total quantity and the way in which a crop requires water, from the time it is sown to the time it is harvested.

Industrial water needs

This depends on the type of industry, its magnitude and the quantity of water required per unit of production.

1.2.5 Structural tools for water resource development

This section discusses the common structural options available to the Water Resources Engineer to development the water potential of the region to its best possible extent.

Dams

These are detention structures for storing water of streams and rivers. The water stored in the reservoir created behind the dam may be used gradually, depending on demand.

Barrages

These are diversion structures which help to divert a portion of the stream and river for meeting demands for irrigation or hydropower. They also help to increase the level of the water slightly which may be advantageous from the point of view of increasing navigability or to provide a pond from where water may be drawn to meet domestic or industrial water demand.

Canals/Tunnels

These are conveyance structures for transporting water over long distances for irrigation or hydropower.

These structural options are used to utilise surface water to its maximum possible extent. Other structures for utilising ground water include rainwater detentions tanks, wells and tube wells.

Another option that is important for any water resource project is Watershed Management practices. Through these measures, the water falling within the catchment area is not allowed to move quickly to drain into the rivers and streams. This helps the rain water to saturate the soil and increase the ground water reserve. Moreover, these measures reduce the amount of erosion taking place on the hill slopes and thus helps in increasing the effective lives of reservoirs which otherwise would have been silted up quickly due to the deposition of the eroded materials.

1.2.6 Management tools for water resource planning

The following management strategies are important for water resources planning:

- Water related allocation/re-allocation agreements between planning units sharing common water resource.
- Subsidies on water use
- Planning of releases from reservoirs over time
- Planning of withdrawal of ground water with time.
- Planning of cropping patterns of agricultural fields to optimize the water availability from rain and irrigation (using surface and/or ground water sources) as a function of time
- Creating public awareness to reduce wastage of water, especially filtered drinking water and to inculcate the habit of recycling waste water for purposes like gardening.

- Research in water management: Well established technological inputs are in verge in water resources engineering which were mostly evolved over the last century. Since, then not much of innovations have been put forward. However, it is equally known that quite a few of these technologies run below optimum desired efficiency. Research in this field is essential for optimizing such structure to make most of water resource utilization.

An example for this is the seepage loss in canals and loss of water during application of water in irrigating the fields. As an indication, it may be pointed out that in India, of the water that is diverted through irrigation canals up to the crop growing fields, only about half is actually utilized for plant growth. This example is also glaring since agriculture sector takes most of the water for its assumption from the developed project on water resources.

A good thrust in research is needed to increase the water application efficiently which, in turn, will help optimizing the system.

1.2.7 Inter-basin water transfer

It is possible that the water availability in a basin (Watershed) is not sufficient to meet the maximum demands within the basin. This would require Inter-basin water transfer, which is described below:

The National water policy adopted by the Government of India emphasizes the need for inter-basin transfer of water in view of several water surplus and deficit areas within the country. As early as 1980, the Minister of Water Resources had prepared a National perspective plan for Water resources development. The National Perspective comprises two main components:

a) Himalayan Rivers Development, and

b) Peninsular Rivers Development

Himalayan rivers development

Himalayan rivers development envisages construction of storage reservoirs on the principal tributaries of the Ganga and the Brahamaputra in India, Nepal and Bhutan, along with interlinking canal systems to transfer surplus flows of the eastern tributaries of the Ganga to the west, apart from linking of the main Brahmaputra and its tributaries with the Ganga and Ganga with Mahanadi.

Peninsular rivers development

This component is divided into four major parts:

1. Interlinking of Mahanadi-Godavari-Krishna-Cauvery rivers and building storages at potential sites in these basins.
2. Interlinking of west flowing rivers, north of Mumbai and south of Tapi.
3. Interlinking of Ken-Chambal rivers.
4. Diversion of other west flowing rivers.

The possible quantity of water that may be transferred by ***donor basin*** may be equal to the average water availability of basin minus maximum possible water requirement within basin (considering future scenarios).

Note: A ***Donor basin*** is the basin, which is supplying the water to the downstream basin.

The minimum expected quantity of water for ***recipient basin*** may be equal to the minimum possible water requirement within basin (considering future scenarios) minus average water availability of basin.

Note: A ***Recipient basin*** is the basin, which is receiving the water from the Donor basin.

National Water Development Agency (NWDA) of the Government of India has been entrusted with the task of formalizing the inter-linking proposal in India. So far, the agency has identified some thirty possible links within India for inter-basin transfer based on extensive study of water availability and demand data.

Note:

The National Water Development Agency (NWDA) was set up in July, 1982 as an Autonomous Society under the Societies Registration Act, 1960, to carry out the water balance and other studies on a scientific and realistic basis for optimum utilization of Water Resources of the Peninsular rivers system for preparation of feasibility reports and thus to give concrete shape to Peninsular Rivers Development Component of National Perspective. In 1990, NWDA was also entrusted with the task of Himalayan Rivers Development Component of National Perspective.

Possible components of an inter-basin transfer project include the following:

- Storage Dam in Donor basin to store flood runoff
- Conveyance structure, like canal, to transfer water from donor to recipient basin
- Possible pumping equipments to raise water across watershed-divide

Possible implications of inter-basin transfer: Since a large scale water transfer would be required, it is necessary to check whether there shall be any of the following:

- River bed level rise or fall due to possible silt deposition or removal.
- Ground water rise or fall due to possible excess or deficit water seepage.
- Ecological imbalance due to possible disturbance of flora and fauna habitat.
- Desertification due to prevention of natural flooding (i.e. by diversion of flood water)
- Transfer of dissolved salts, suspended sediments, nutrients, trace elements etc. from one basin to another.

1.2.8 Tasks for planning a water resources project

The important tasks for preparing a planning report of a water resources project would include the following:

- Analysis of basic data like maps, remote sensing images, geological data, hydrologic data, and requirement of water use data, etc.
- Selection of alternative sites based on economic aspects generally, but keeping in mind environmental degradation aspects.
- Studies for dam, reservoir, diversion structure, conveyance structure, etc.
    - Selection of capacity.
    - Selection of type of dam and spillway.
    - Layout of structures.
    - Analysis of foundation of structures.
    - Development of construction plan.
    - Cost estimates of structures, foundation strengthening measures, etc.
- Studies for local protective works – levees, riverbank revetment, etc.
- Formulation of optimal combination of structural and non-structural components (for projects with flood control component).
- Economic and financial analyses, taking into account environmental degradation, if any, as a cost.
- Environmental and sociological impact assessment.

Of the tasks mentioned above, the first five shall be dealt with in detail in this course. However, we may mention briefly the last two before closing this chapter.

1.2.9 Engineering economy in water resources planning

All Water Resources projects have to be cost evaluated. This is an essential part of planning. Since, generally, such projects would be funded by the respective State Governments, in which the project would be coming up it would be helpful for the State planners to collect the desired amount of money, like by issuing bonds to the public, taking loans from a bank, etc. Since a project involves money, it is essential that the minimum amount is spent, under the given constraints of project construction. Hence, a few feasible alternatives for a project are usually worked out. For example, a project involving a storage dam has to be located on a map of the river valley at more than one possible location, if the terrain permits. In this instance, the dam would generally be located at the narrowest part of the river valley to reduce cost of dam construction, but also a couple of more alternatives would be selected since there would be other features of a dam whose cost would dictate the total cost of the project. For example, the foundation could be weak for the first alternative and consequently require costly found treatment, raising thereby the total project cost. At times, a economically lucrative project site may be causing submergence of a costly property, say an industry, whose relocation cost would offset the benefit of the alternative. On the other hand, the beneficial returns may also vary. For example, the volume of water stored behind a dam for one alternative of layout may not be the same as that behind another. Hence, what is required is to evaluate the so-called Benefit-Cost Ratio defined as below:

$$Benefit - CostRatio = \frac{AnnualBenefits(B)}{AnnualCost(C)}$$

The annual cost and benefits are worked out as under.

Annual Cost (C): The investment for a project is done in the initial years during construction and then on operation and maintenance during the project's lifetime. The initial cost may be met by certain sources like borrowing, etc. but has to be repaid over a certain number of years, usually with an interest, to the lender. This is called the Annual Recovery Cost, which, together with the yearly maintenance cost would give the total Annual Costs. It must be noted that there are many non-tangible costs, which arise due to the effect of the project on the environment that has to be quantified properly and included in the annual costs.

1.2.10 Assessment of effect on environment and society

This is a very important issue and all projects need to have clearance from the Ministry of Environment and Forests on aspects of impact that the project is likely to have on the environment as well as on the social fabric. Some of the adverse (negative) impacts, for which steps have to be taken, are as follows:

- Loss of flora and fauna due to submergence.
- Loss of land having agricultural, residential, industrial, religious, archaeological
importance.
- Rehabilitation of displaced persons.
- Reservoir induced seismicity.
- Ill-effect on riverine habitats of fish due to blockage of the free river passage

There would also be some beneficial (positive) impacts of the project, like improvement of public health due to availability of assured, clean and safe drinking water, assured agricultural production, etc. There could even be an improvement in the micro-climate of the region due to the presence of a water body.