UNIT – 3

CONCEPT:-

Storage schemes, as already mentioned, are those wherein the water is stored when available (say monsoon months) and drawn from the storage during lean periods. A reservoir created upstream of a dam constructed on a river provides the storage in such schemes. The purposes for which such schemes are constructed include:

- Irrigation
- Power generation
- Water supply
- Flood control
- Navigation
- Recreation

A scheme which serves more than one of the above purposes is termed as a multipurpose project. The extent to which the requirements of the various purposes can be met depends on the compatibility of the purposes. Thus power generation is the most compatible with other purposes in as much as it does not involve any consumptive use of water. The water released for power generation can always be used for other purposes. Likewise, flood control is the least compatible as this requires availability of empty storage space in the reservoir, while other purposes require availability of water.

PLANNING FOR A STORAGE SCHEME

The main elements of a storage scheme are the dam, spillway, the reservoir. One therefore has to decide the type of dam to be constructed, the type of spillway as well as the reservoir storage capacity. The scheme may be for storing water during the wet season and using it during the lean period in the same year or for using it during the next year also. While the former is called "within year carryover storage", the later is referred to as "over year carryover storage".

Planning for the elements of a storage scheme requires extensive data and investigations to optimize the benefits. These include:

- Estimation of demand – The storage scheme The water these for different purposes the project is supposed to fulfill has to be estimated separately. Since the projects take a long time in completion and are supposed to serve for a fairly long period, the projected population has to be estimated while estimating the demand.
- Hydrologic studies including sedimentation – These include long term data on stream flow, evaporation, water quality, sedimentation, downstream water rights etc. The water availability can only be estimated based on these investigations. Spillway capacity determination and sedimentation of the reservoir is also based on these investigations.

- Geologic studies – The nature of foundations and abutment and the availability of construction material near the site which determine to a large extent the suitability of a given type of dam is a primary objective of these investigations. Further determination of the suitability of the reservoir site, stability of its rim and the possibility of landslides also requires detailed geological investigations.
- Economic aspects – One of the major guiding principles in any project is its cost effectiveness. Estimation of the costs and benefits of the project in economic terms is required for any decision making. Both the capital and recurring costs need to be considered. The benefits cannot always be evaluated in monetary terms as these include the direct benefits as well as called indirect ones. Some of the indirect costs and benefits can be assessed by using a suitable metric wherever possible.
- Social aspects – The construction of a major project at any site is likely to have significant social impact. This may include beneficial effects such as the improved economic conditions, creation of employment opportunities etc. Some adverse effects like submergence of land, increased noise and other activity will also be a part of this. All these impacts need to be evaluated.
- Environmental impact – The environmental impact assessment of any major project has become one of the most important considerations nowadays. The factors to be considered in carrying out an environmental impact analysis are numerous and include things such as submergence of agricultural land, submergence of forest land and its effect on flora and fauna in the region, the loss of biodiversity, the impact of the project on the overall water regime including downstream channel etc. A well carried out study can at times result in some modification of the project plan which minimizes any adverse environmental impact while keeping the beneficial impacts nearly the same.

INVESTIGATIONS

Each of the aforesaid investigations requires a large amount of data and time. All the data required will normally not be available to start with and needs to be collected – an exercise which can be very costly and time consuming. Further, there are likely to be many alternative schemes possible at or close to a given location, each requiring additional data. In order to save time and expenses therefore, investigation for such project are made in three stages.

Preliminary Investigations

These are investigations carried out considering all the above mentioned aspects with the existing data. Some additional data may also be collected without spending much time and with lesser accuracy. The purpose of this is to screen out some alternatives which are considered poor and prepare a short list of promising alternatives and decide upon the additional data to be collected.

Feasibility Investigations

This stage involves collecting data with the desired accuracy and analysis of the alternatives shortlisted as a result of the preliminary investigations. This stage also will cover all the pertinent aspects of the project and forms the basis of a provisional selection of the project plan.

Detailed Investigations

Once the provisionally selected plan is approved, detailed investigations for the same have to be carried out. Fixing up the size of various components of the project, their design incorporating any additional information as well as collecting more data as required are all part of this stage. The planning for construction is also part of the work to be carried out.

DETERMINATION OF RESERVOIR CAPACITY

For Conservation Purposes

The storage capacity required to support a given firm yield can be obtained using the mass curve. Mass curve is a plot of the cumulative inflow into the reservoir – usually in million hectare metres – over a period of time. The time is generally taken over a period of years.

To determine the storage capacity, historical streamflow records are examined to identify the most adverse sequence and hence to identify the critical period. The critical period begins after a preceding high flow period when the reservoir gets full and ends when the reservoir is refilled after the drought period. The mass curve for this period is plotted. The slope of this curve at any time represents the inflow rate at that time. Likewise, a demand line will have a slope equal to the demand rate. To determine the storage capacity required, a line with a slope equal to the demand rate is drawn starting at the beginning of the critical period till it cuts the mass curve again (AB in Fig.7.1). The maximum ordinate between the mass curve and the demand line (CD) then yields the storage required for this demand rate. In case there are more than one critical periods on record, this exercise may be carried out for all of them and the largest value of storage adopted.

For Flood Control

Flood control requires empty storage space in the reservoir and hence the procedure for determination of such space is somewhat different. The major factor in flood control projects is to limit the peak overflow from the reservoir, which is dictated by considerations of the safe carrying capacity of the downstream channel and prevention of flooding of downstream areas. The procedure used for this is of flood routing through the reservoir. This has been discussed later alongwith the discussion on spillways. The only point to be noted is that if empty space is available in the reservoir then it will be filled up first and the outflow during this period will be zero. Once the water in the reservoir attains the level of the spillway crest, the procedure is similar to that discussed therein. The outflow hydrograph will thus start at a later time and its peak will be lower compared to what it would have been if the reservoir was full to start with. The outflow hydrograph with different values of empty space can be obtained and the one which has a peak equal to that desired on the downstream side then gives the storage to be reserved for flood control.

SEDIMENTATION OF RESERVOIRS

The creation of a reservoir in a river results in reduction of water surface slope and velocities on the upstream side. Consequently the sediment transporting capacity of the stream is reduced and sediment gets deposited in the reservoir. This tends to reduce the storage capacity of the reservoir and is usually accounted for by reserving a portion of the storage for sediment deposition. Sedimentation also determines the useful life of a reservoir.

The sediment deposition depends on the quantity of sediment brought by the river, the size of the reservoir and sluicing arrangements. Since sediment load comes from erosion of the catchment, reduction in rate of sedimentation of a reservoir can be achieved by an appropriate catchment management programme to prevent the erosion. Sluicing through low level outlets in the dam to flush the deposited sediment and construction of detention basins for sediment at the inlet of the reservoir are other measures which can be useful.

Graphical method:

1. Prepare a mass inflow curve from the flow hydrograph of the site for a number of consecutive years including the most critical years (or the driest years) when the discharge is low.

2. Prepare the mass demand curve corresponding to the given rate of demand. If the rate of demand is constant, the mass demand curve is a straight line. The scale of the mass demand curve should be the same as that of the mass inflow curve.

3. Draw the lines AB, FG, etc. such that (i) They are parallel to the mass demand curve, and (ii) They are tangential to the crests A, F, etc. of the mass curve.4. Determine the vertical intercepts CD. HJ, etc. between the tangential lines and the mass inflow curve. These intercepts indicate the volumes by which the inflow volumes fall short of demand.

4. Assuming that the reservoir is full at point A, the inflow volume during the period AE is equal to ordinate DE and the demand is equal to ordinate CE. Thus the storage required is equal to the volume indicated by the intercept CD.

5. Determine the largest of the vertical intercepts found in Step (4). The largest vertical intercept represents the storage capacity required.

The following points should be noted. (i) The capacity obtained in the net storage capacity which must be available to meet the demand. The gross capacity of the reservoir will be more than the net storage capacity. It is obtained by adding the evaporation and seepage losses to the net storage capacity.

(ii) The tangential lines AB, FG; etc. when extended forward must intersect the curve. This is necessary for the reservoir to become full again, If these lines do not intersect the masscurve, the reservoir will not be filled again. However, very large reservoirs sometimes donot get refilled every year. In that case, they may become full after 2-3 years.(iii) The vertical distance such as FL between the successive tangents represents the volume of water spilled over the spillway of the dam.

Analytical method

1. Capacity of the reservoir is determined from the net inflow and demand.
2. Storage is required when the demand exceeds the net inflow,the total storage required is equal to the sum of the storage required during the various periods.
3. Collect the stream flow data at the reservoir site during the critical dry period. Generally, the monthly inflow rates are required. However, forvery large reservoirs, the annual inflow rates may be used.

4.Ascertain the discharge to be released downstream to satisfy water rights or to honour the agreement between the states or the cities.
5. Determine the direct precipitation volume falling on the reservoir during the month.
Estimate the evaporation losses which would occur from the reservoir „The pan evaporation data are normally used for the estimation of evaporation losses during the month.5. Ascertain the demand during various months.
6.Determine the adjusted inflow during differentmonths as follows:Adjusted inflow = Stream inflow + Precipitation -Evaporation – Downstream Discharge
7. Compute the storage capacity for eachmonths.Storage required = Adjusted inflow – Demand
8. Determine the total storage capacity of thereservoir by adding the storages required foundin Step 7.
9.The yield from a reservoir of a given capacity can be determined by the use of the mass inflow curve
10. Prepare the mass inflow curve from the flow hydrograph of the river.
11. Draw tangents AB, FG, etc. at the crests A, F, etc. of the mass inflow curve in such a way that the maximum departure (intercept) of these tangents from the mass inflow curve is equal to the given reservoir capacity.
12.Determination of Yield of a Reservoir

Sediment Management:
Maximum efforts should water should be released so that less sediments should retain in reservoir. Following options are: –
1. Catchment Vegetation
2. Construction of coffer dams/low height barriers
3. Flushing and desilting of sediments
4. Low level outlets / sediment sluicing
5. Catchment vegetation
6. Wooden barriers
7. Stepped watershed for sediment control
8. Flushing of sediments from reservoir
9. Mechanical desilting from reservoir
10. Sediment sluicing

FLOOD ROUTING

Flood routing through a reservoir involves determination of the outflow over the spillway and change in reservoir elevation corresponding to a given inflow hydrograph. Any inflow into the reservoir causes a change in the reservoir elevation as well as in outflow and the continuity equation dictates that the inflow must equal the outflow plus the change in storage. This forms the basis for flood routing. The known quantities being the inflow hydrograph, the reservoir elevation versus storage curve and the reservoir elevation versus the spillway discharge curve.The basic book keeping equation can be written as $(I_1 + I_2)\Delta t/2 - (O_1 + O_2)\Delta t/2 = (S_2 - S_1)$

where Δt is a interval of time, I, O and S are the inflow, outflow and storages respectively with the subscript 1 corresponding to the beginning and 2 to the end of the time period respectively.To carry out the process, a suitable time interval is chosen, beginning at the start of the inflow hydrograph. The inflows at the beginning and end of this interval are obtained from the inflow hydrograph. The initial reservoir level – usually the same as the spillway crest level – being known, the outflow and storage corresponding to this is read from the relevant curves. A value for the reservoir elevation at the end of the period is then assumed and the outflow and storage corresponding to this are also read. If these values satisfy the continuity equation as given above then this becomes the reservoir elevation at the end of the period, otherwise the trial elevation is revised till the above equation is satisfied. This value then gives the elevation and outflow at the end of the time period. With these values as the initial values, the process is repeated for the next time interval and so on till the whole of the outflow hydrograph has been obtained. This computation also yields the maximum reservoir elevation.

Storage Schemes	Storage schemes, are those wherein the water is stored when available (say monsoon months) and drawn from the storage during lean periods.
Flood routing	Flood routing through a reservoir involves determination of the outflow over the spillway and change in reservoir elevation corresponding to a given inflow hydrograph.
Mass curve	Mass curve is a plot of the cumulative inflow into the reservoir – usually in million hectare metres – over a period of time
Storage Reservoirs	Storage Reservoirs: Storage reservoirs are also called conservation reservoirs because they are used to conserve water. Storage reservoirs are constructed to store the water in the rainy season and to release it later when the river flow is low
Flood Control Reservoirs	Flood Control Reservoirs: A flood control reservoir is constructed for the purpose of flood control. It protects the areas lying on its downstream side from the damages due to flood.
Retarding Reservoirs	A retarding reservoir is provided with spillways and sluiceways which are ungated. The retarding reservoir stores a portion of the flood when the flood is rising and releases it later when the flood is receding.
Detention Reservoirs	A detention reservoir stores excess water during floods and releases it after the flood. It is similar to a storage reservoir but is provided with large gated spillways and sluiceways to permit flexibility of operation.
Distribution Reservoirs	Distribution Reservoirs: A distribution reservoir is a small storage reservoir to tide over the peak demand of water for municipal water supply or irrigation. The distribution reservoir is helpful in permitting the pumps to work at a uniform rate. It stores water during the period of lean demand and supplies the same during the period of high demand.
Minimum pool level	The minimum pool level is the lowest level up to which the water is withdrawn from the reservoir under ordinary conditions
Maximum water level (MWL)	The maximum water level is the maximum level to which the water surface will rise when the design flood passes over the spillway
Full reservoir level	The full reservoir level (FRL) is the highest water level to which the

(FRL)	water surface will rise during normal operating conditions.
Live/useful storage	The volume of water stored between the full reservoir level (FRL) and the minimum pool level is called the useful storage. It assures the supply of water for specific period to meet the demand.
Dead storage	The volume of water held below the minimum pool level is called the dead storage. It is provided to cater for the sediment deposition by the impounding sediment laid in water. Normally it is equivalent to volume of sediment expected to be deposited in the reservoir during the design life reservoir
Valley storage	The volume of water held by the natural river channel in its valley up to the top of its banks before the construction of a reservoir is called the valley storage. The valley storage depends upon the cross section of the river
Bank storage	This storage is developed in the voids of soil cover in the reservoir area and becomes available as seepage of water when water levels drops down. It increases the reservoir capacity over and above that given by elevation storage curves.
Flood/Surcharge storage	The storage between maximum reservoir level and full reservoir levels. It varies with spillway capacity of dam for given design flood
Design yield	The design yield is the yield adopted in the design of a reservoir. The design yield is usually fixed after considering the urgency of the water needs and the amount of risk involved
Average yield	The average yield is the arithmetic average of the firm yield and the secondary yield over a long period of time
Secondary yield	This is the quantity of water which is available during the period of high flow in the rivers when the yield is more than the safe yield
Safe yield	This is the maximum quantity of water which can be supplied from a reservoir in a specified period of time during a critical dry year

A **reservoir** (from French *réservoir* – a "tank") is a storage space for fluids. These fluids may be water, hydrocarbons or gas. A reservoir usually means an enlarged **natural** or **artificial lake**, **storage pond** or **impoundment** created using a dam or lock to store water. Reservoirs can be created by controlling a stream that drains an existing body of water. They can also be constructed in river valleys using a dam. Alternately, a reservoir can be built by excavating flat ground or constructing retaining walls and levees.

Tank reservoirs store liquids or gases in storage tanks that may be elevated, at grade level, or buried. Tank reservoirs for water are also called cisterns.

Underground reservoirs are used to store liquids, principally either water or petroleum, below ground.

Reservoirs dammed in valleys

A dam constructed in a valley relies on the natural topography to provide most of the basin of the reservoir. Dams are typically located at a narrow part of a valley downstream of a natural basin. The valley sides act as natural walls, with the dam located at the narrowest practical point to provide strength and the lowest cost of construction. In many reservoir construction projects, people have to be moved and re-housed, historical artifacts moved or rare environments relocated. Examples include the temples of Abu Simbel[1] (which were moved before the construction of the Aswan Dam to create Lake Nasser from the Nile in Egypt), the relocation of the village of Capel Celyn during the construction of Llyn Celyn,[2] and the relocation of Borgo San Pietro of Petrella Salto during the construction of Lake Salto.Construction of a reservoir in a valley will usually need the river to be diverted during part of the build, often through a temporary tunnel or by-pass channel.[3]

In hilly regions, reservoirs are often constructed by enlarging existing lakes. Sometimes in such reservoirs, the new top water level exceeds the watershed height on one or more of the feeder streams such as at Llyn Clywedog in Mid Wales.[4] In such cases additional side dams are required to contain the reservoir.

Where the topography is poorly suited to a single large reservoir, a number of smaller reservoirs may be constructed in a chain, as in the River Taff valley where the Llwyn-on, Cantref and Beacons Reservoirs form a chain up the valley.[5]

Coastal reservoirs

Coastal reservoirs are fresh water storage reservoirs located on the sea coast near the river mouth to store the flood water of a river.[6] As the land based reservoir construction is fraught with substantial land submergence, coastal reservoir is preferred economically and technically since it does not use scarce land area.[7] Many coastal reservoirs were constructed in Asia and Europe. Saemanguem in South Korea, Marina Barrage in Singapore, Qingcaosha and Plover Cove in China, etc are few existing coastal reservoirs.[8]

Bank-side reservoir

Where water is pumped or siphoned from a river of variable quality or size, bank-side reservoirs may be built to store the water. Such reservoirs are usually formed partly by excavation and partly by building a complete encircling bund or embankment, which may exceed 6 km (4 miles) in circumference.[9] Both the floor of the reservoir and the bund must have an impermeable lining or core: initially these were often made of puddled clay, but this has generally been superseded by the modern use of rolled clay. The water stored in such reservoirs may stay there for several months, during which time normal biological processes may substantially reduce many contaminants and almost eliminate any turbidity. The use of bank-side reservoirs also allows water abstraction to be stopped for some time, when the river is unacceptably polluted or when flow conditions are very low due to drought. The London water supply system is one example of the use of bank-side storage: the water is taken from the River Thames and River Lee; several large Thames-side reservoirs such as Queen Mary Reservoir can be seen along the approach to London Heathrow Airport.[9]

Service reservoir

Service reservoirs[10] store fully treated potable water close to the point of distribution. Many service reservoirs are constructed as water towers, often as elevated structures on concrete pillars where the landscape is relatively flat. Other service reservoirs can be almost entirely underground, especially in more hilly or mountainous country. In the United Kingdom, Thames Water has many underground reservoirs, sometimes also called cisterns, built in the 1800s, most of which are lined with brick. A good example is the Honor Oak Reservoir in London, constructed between 1901 and 1909. When it was completed it was said to be the largest brick built underground reservoir in the world[11]and it is still one of the largest in Europe.[12] This reservoir now forms part of the southern extension of the Thames Water Ring Main. The top of the reservoir has been grassed over and is now used by the Aquarius Golf Club.[13]

Service reservoirs perform several functions, including ensuring sufficient head of water in the water distribution system and providing water capacity to even out peak demand from consumers, enabling the treatment plant to run at optimum efficiency. Large service reservoirs can also be managed to reduce the cost of pumping, by refilling the reservoir at times of day when energy costs are low.

Direct water supply

Many dammed river reservoirs and most bank-side reservoirs are used to provide the raw water feed to a water treatment plant which delivers drinking water through water mains. The reservoir does not merely hold water until it is needed: it can also be the first part of the water treatment process. The time the water is held before it is released is known as the *retention time*. This is a design feature that allows particles and silts to settle out, as well as time for natural biological treatment using algae, bacteria and zooplankton that naturally live in the water. However natural limnological processes in temperate climate lakes produce temperature stratification in the water, which tends to partition some elements such as manganese and phosphorus into deep, cold anoxic water during the summer months. In the autumn and winter the lake becomes fully mixed again. During drought conditions, it is sometimes necessary to draw down the cold bottom water, and the elevated levels of manganese in particular can cause problems in water treatment plants.

Hydroelectricity

In 2005 about 25% of the world's 33,105 large dams (over 15 metres in height) were used for hydroelectricity.[18] However of 80,000 dams of all sizes in the U.S., only 3% produce electricity.[19] A reservoir generating hydroelectricity includes turbines connected to the retained water body by large-diameter pipes. These generating sets may be at the base of the dam or some distance away. In a flat river valley a reservoir needs to be deep enough to create a head of water at the turbines; and if there are periods of drought the reservoir needs to hold enough water to average out the river's flow throughout the year(s). Run-of-the-river hydro in a steep valley with constant flow needs no reservoir.

Some reservoirs generating hydroelectricity use pumped recharge: a high-level reservoir is filled with water using high-performance electric pumps at times when electricity demand is low, and then uses this stored water to generate electricity by releasing the stored water into a low-level reservoir when electricity demand is high. Such systems are called pump-storage schemes.[20]

IMPORTANT QUESTIONS:-

1. Give a definition of reservoir? Explain the classification of reservoirs
2. a) Explain various types of dams with a neat sketch
   b) Explain how we will select a good site for various types of dams
3. a) Explain reservoir Yield
   b) How do you estimate the capacity of reservoir using mass curve
4. Explain the classification of dams based on material used for their construction and give the classification of dams according to use
5. a) Give the necessity of storage works
   b)Explain Zoned Embankment Dam & Rock fill Dam
6. The following information is available regarding the relationship between trap efficiency and capacity-inflow ratio for a reservoir

Capacity/inflow Ratio	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Trap Efficiency	87	93	95	95.5	96	96.5	97	97.2	97.3	97.5

Find the probable life of the reservoir with an initial reservoir capacity of 30 million cubic meters, if the annual flood inflow is 60 million cubic meters and the average annual sediment inflow is 36,00,000 KN. Assume a specific weight of sediment equal to 12 KN/m^3. The useful life of the reservoir will terminate when 80% of initial capacity is filled with sediment