Urban Utilities Planning: Water Supply, Sanitation and Drainage
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Module - 12
Drainage and Recharge
Lecture - 56
Ground Water Recharge Part I

Welcome back to the final module of our course module 12, on Drainage and Recharge and lecture 56 would be on Ground Water Recharge and this is part I.

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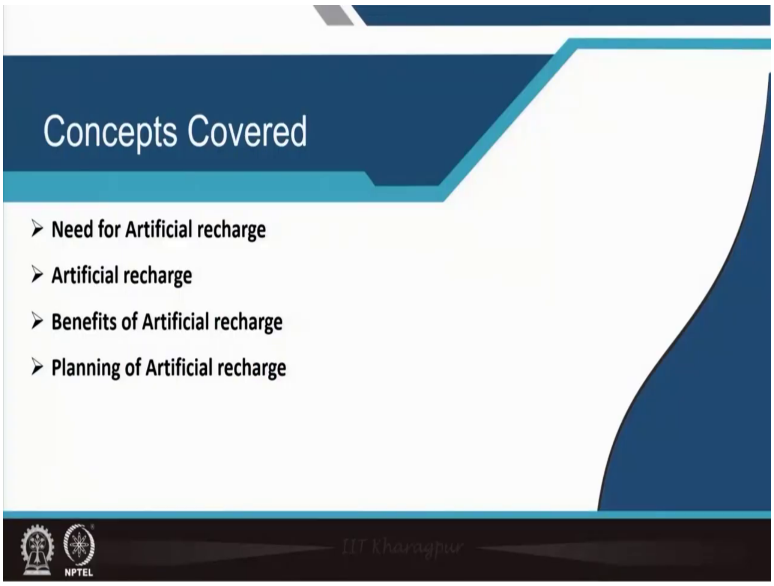

So, in this particular lecture the different concepts that would be covered are on need for artificial recharge, artificial recharges, benefit of artificial recharge and planning for artificial recharge.

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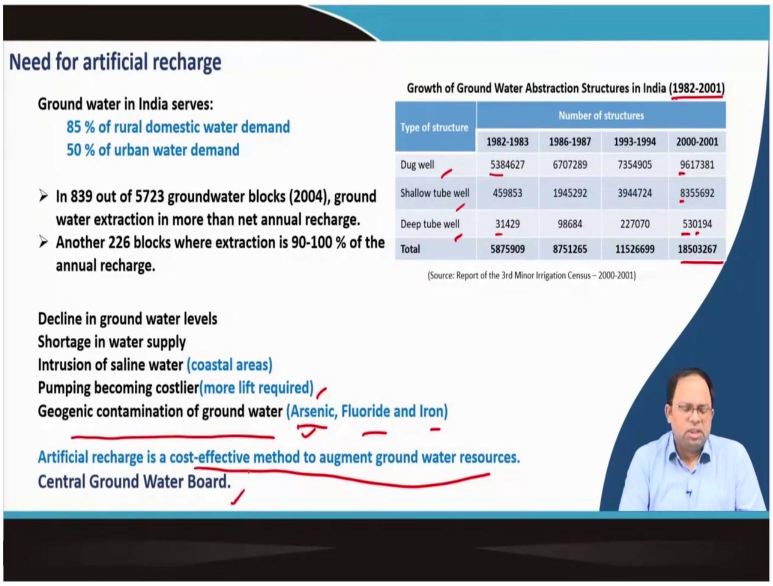

We have discussed about the different groundwater related issues in the Indian context and we know that groundwater in India serves around 85 percent of the rural domestic water demand and approximately 50 percent of the urban water demand.

Due to depletion of groundwater, there would be a lot of crisis in the coming days which is why we need to consider artificial recharges or we need to consider recharging of groundwater.

839 out of around 6000 groundwater blocks in 2004 was found to extract groundwater more than their net annual recharge so; which means, the groundwater table will go down and eventually the aquifer would be depleted.

Whereas, for another 226 blocks, it was found that extraction is about 90 to 100 percent of the annual recharge. So, around 1000 blocks out of approximately 6000 blocks are going to face severe shortage of groundwater.

Now, this is going to increase further. why? We see a tremendous growth of groundwater abstraction structures in India during the year 1982 to 2001. For example, we have dug wells, shallow tube wells, deep tube wells, using which we take out groundwater. The total number of dug wells during 1982 was around 53 lakhs whereas, it has now increased to 96 lakhs in the year 2001.

Shallow tube well were around 4,59,000 whereas, now it has increased to around 83 lakhs. Similarly, for deep tube well it was only 31,000 whereas, presently it is 5,30,194. This shows the rate at which we are extracting our groundwater.

This data is for 2001. Now it is might have further increased. That means, we will have other groundwater blocks also gradually getting depleted as well. So, that is why we need to be concerned.

What happens with the decline in groundwater levels? Firstly, there would be shortage in water supply, the coastal areas will show intrusion of saline water because there is no groundwater in the aquifers. Pumping will become costlier. So, the lower the groundwater table goes our existing pumps or deep tube wells will not be able to get the groundwater and we have to again put in much deeper deep tube wells and that will actually increase the cost of abstraction. Other thing is geogenic contamination of groundwater, which we are gradually finding because we are over abstracting and we are also using groundwater only in some cases. We are seeing the presence of arsenic fluoride and iron, which are usually present in very little quantity in groundwater.

But now because we are abstracting too much and we are reaching the lower levels of the aquifer and probably that is one of the reasons why the quantity of arsenic, fluoride and iron is also increasing in the groundwater. These are the different issues that we are facing in many parts of the country. That is why artificial recharge is required and it is the most cost-effective method to augment groundwater resources.

So; that means, instead of natural recharge which happens normally because of rainfall or precipitation and because gradually the water percolates into the soil, we have to consider artificial recharge to increase that percolation rate. The central groundwater board is the main body in India which actually looks about groundwater abstraction, utilization and all the different regulations and policies related to groundwater.

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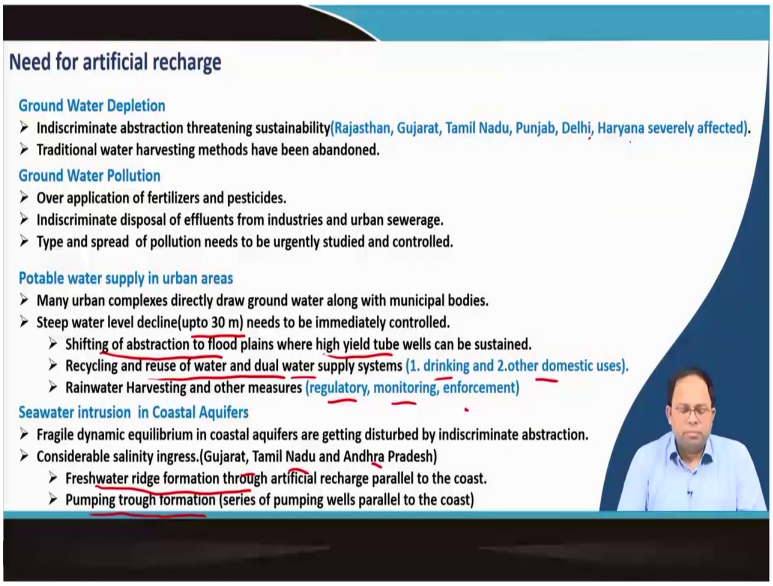

It is observed that the groundwater is gradually depleting in many states and that is particularly because of indiscriminate abstraction; that means, people are putting up deep tube wells and there is no record of the same. This is threatening the sustainability of the entire area and particularly in some of the states such as Rajasthan, Gujarat, Tamil Nadu, Punjab, Delhi, Haryana and so, on.

And traditional water harvesting methods that was earlier utilized has totally been abandoned and people are using more groundwater and deep tube wells which gives people an easy way out.

The groundwater pollution is another reason why we need artificial recharge. Too much application of fertilizers and pesticides is resulting in their infiltrating into the groundwater. Disposal of effluents from the industries and urban sewerage, are also reaching the groundwater. Thus, many of the groundwater aquifers are becoming unusable or in case we use them, then probably that would lead to lot of diseases. The type and spread of pollution within the groundwater aquifers also need to be modelled studied and eventually controlled. So, there has to be a lot of work to be done in that regard as well. Artificial recharge will actually help in providing alternative aquifers or alternatives to groundwater resources which can be used when current aquifers are getting polluted or becoming unusable.

50 percent of the water in urban areas is supplied from groundwater sources and many of the urban complexes; are drawing groundwater, because municipal bodies are not able to supply them the quantity of water they require.

So, along with municipal bodies these complexes are also putting in the deep tube wells and drawing water from the ground. Therefore we are seeing steep decline in water level, even up to 30 meters, where this kind of abstraction takes place.

What are the solutions to that? One solution could be instead of taking the groundwater out from those urban areas, where already the water table has gone down, if we can take the water from flood plains. Deep tube wells can be sustained in flood plains. So, if you can shift the abstraction points then probably this problem would be solved.

We can also recycle and reuse the waste water and we can use dual water supply systems as we have discussed earlier. One water supply system just for potable purposes and another for non-potable purposes. This will actually reduce the demand for groundwater. Finally, rainwater harvesting and other measures can be introduced and for that we require regulatory interventions, monitoring, enforcement and so, on.

Cases of sea water intrusion in coastal aquifers can be prevented to a certain extent using artificial recharge. We can form freshwater ridges or we can create pumping troughs.

Ridges increase the level of groundwater by recharging it with artificial recharge whereas, in pumping; using pumps we create troughs that will draw groundwater from other sources.

Gujarat, Tamil Nadu, Andhra Pradesh these are some of the states, where saline sea water intrusion is a problem.

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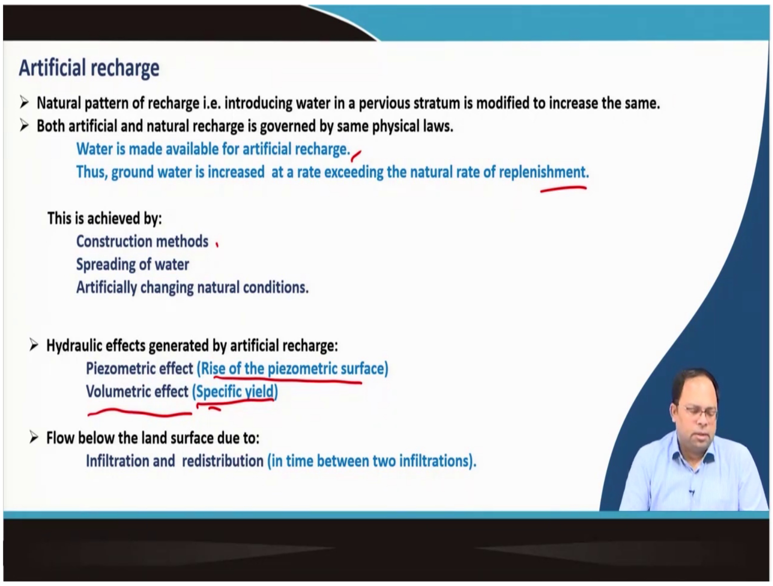

When we talk about artificial recharge, we are trying to replicate the natural recharge, i.e., we want to increase the rate of the natural recharge.

Both artificial and natural recharge is governed by the same physical laws.

When we want to increase the amount of water that is available for recharge we have to make it available and groundwater recharge is increased at a rate exceeding the natural rate of replenishment. That is why it is artificial recharge.

There are different engineering techniques for it. Broadly these could be categorized into three methods; one is construction methods; that means, we construct certain structures using which we can actually recharge groundwater maybe some wells. Then there could be spreading of water, where we spread the water over the ground surface which could be with some structures as well. This actually gives a larger surface for the water to percolate. Finally, by artificially changing natural conditions like creating pump troughs or groundwater ridges. Here we change the flow of groundwater in the aquifer and that actually helps in prevention of intrusion or maybe it will connect multiple aquifers and bring groundwater to one aquifer from another.

The two hydraulic effects generated by artificial recharge; piezometric effect that is the rise of the piezometric surface; i.e., rise of the groundwater table and the other is the volumetric effect; that means, we increase the specific yield of a particular aquifer. This means, we put in groundwater at a certain times of the year and use it at other times of the year.

So, instead of storing it in open reservoir, we are storing it inside ground. The specific yield of that particular aquifer is what we are concerned with.

Once the groundwater infiltrates, it also distributes i.e., it spreads in that particular area. So, sometimes we use techniques to actually prevent the spread so that the groundwater is retained in a particular aquifer. These are groundwater collection and conservation techniques. In other cases, we want groundwater to spread from one aquifer to another so, that the water is available in both the aquifers. So, both techniques are utilized.

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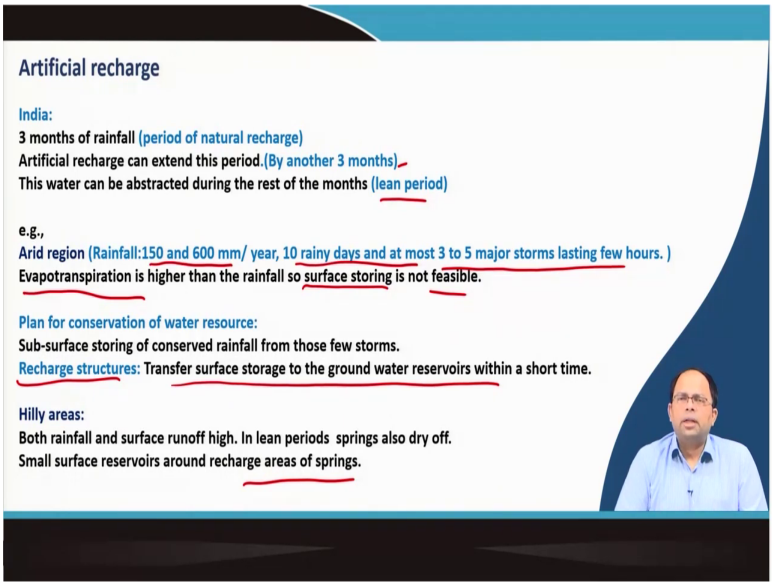

In India the rainfall period is roughly 3 months and artificial recharge will be able to extend this period by another 3 months. That means, the amount of infiltration can be extended from the 3 month period of rainfall by another 3 months by storing that rainfall water on the surface. This is possible using techniques like spreading or creating some recharge wells.

Because we are extending the infiltration time the total amount of water that is going into the ground is more and so, we can also increase our rate of extraction as well during lean periods.

For example, in arid regions of India the rainfall intensity is 150 to 600 milli meter per year and usually we have got only 10 rainy days and maybe 3 to 5 major storms lasting few hours. Most of this water flows away via channels or over the surface.

In these arid regions the evapotranspiration rate is also high. If we store the water on the surface, then it will fully evaporate. This is where groundwater recharge comes in.

Subsurface storing to conserve rainfall from these few storms can actually increase the groundwater level or the amount of groundwater that percolates in that area and could be utilized in other time periods. Recharge structures actually help in transferring surface storage to the groundwater reservoirs within a short period of time. That is the reason for designing engineered structures which actually shorten the process of percolation.

Similarly, in hilly areas we have both high rainfall as well as high surface run-off and in lean periods we see that many of the springs becoming dry in hilly areas. In this case, small surface reservoirs around the recharge areas of the springs can be created which actually helps in increasing the groundwater in that areas.

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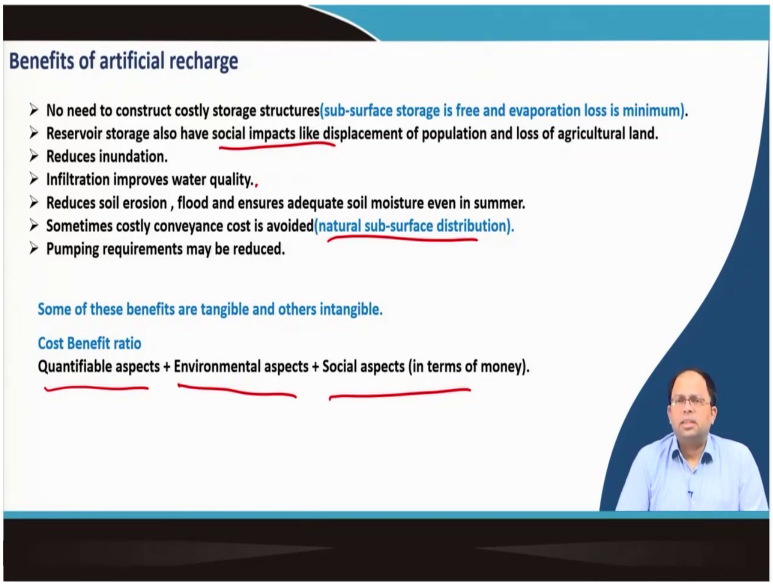

What are the benefits of artificial recharge. First, there is no need to construct costly storage structure. We usually create dams in the river and we also create large water bodies. So, we reduce on those particular cost since subsurface storage is free and evaporation loss is also minimum. Usually the effectiveness of subsurface storage is much better. So, storing the water in the ground is actually better than storing it on the surface.

Reservoirs storage also have some social impacts like displacement of the population and loss of agricultural land. Whenever, a dam or reservoirs is created, a huge area gets flooded and we have to replace people living there. These kind of social impacts are absent in groundwater recharge.

Groundwater storage reduces inundation if we increase infiltration; and also improves water quality. When more amount of water from the rain infiltrates, the water volume increases and the quality of water also gets better. This also reduces soil erosion, flood and ensures adequate soil moisture even in summer.

Sometimes costly conveyance cost is also avoided because we need to transfer water via pipelines if we store it in the surface. But if the water is stored in the ground, due to the hydraulic gradient there is natural or subsurface distribution; that means, the water travels below ground from one point to another and in both places the water will be available.

Pumping requirement may be reduced as well. So, these are the different benefits of artificial recharge.

Whenever we are evaluating any kind of projects related with groundwater recharge, some of the benefits are tangible and some will be intangible. Thus for cost benefit analysis for these kind of projects we need to understand that the quantifiable aspects has to be put in plus the environmental benefits has to be considered as well. Similarly, social aspects in terms of money also needs to be considered. All costs and benefits has to be evaluated in terms of money.

The money saved due to social benefits, environmental benefits and also the quantifiable benefits are required to justify projects.

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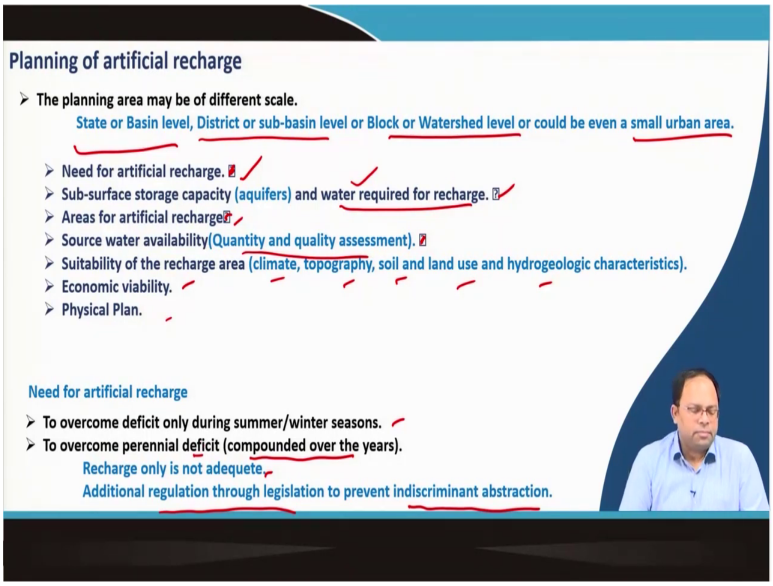

How do we plan for artificial recharge? The planning could be at different scales. We are mostly concerned with small urban areas, but it could be done at the state or basin level. It could be also done at the district or sub basin level or block or watershed level and even at the urban level. Thus, we can plan for artificial recharge at different levels of networks of recharge structures.

What are the different steps in this particular process? First thing is, weather there is a need for artificial recharge because excess recharge will create floods. Second is subsurface storage capacity and water required for recharge has to be both available. The third thing is, where are we going to recharge? How will we decide on or prioritize certain areas? Fourth is source water availability. Both quantity and quality assessment need to be done and we have to determine how much water is required for recharge and if water is available for that? Then suitability of the recharge area; that means, is the area suitable for recharge; considering climate, topography, soil, land use, hydro geologic characteristic. Then economic viability of the project and the physical plan of that particular project.

Why we need to recharge first of all? One reason could be to overcome the deficit during summer or winter season. The other is to overcome perennial deficits like; every year the groundwater table is going down because of abstraction. This deficit is compounded over the years. So, as you understand just recharge is not adequate and additional regulation through legislation is required which will prevent indiscriminate abstraction.

So, in some places just additional recharge is good enough because overall the demand and supply could be balanced whereas, for other areas we need to have some amount of prevention of groundwater abstraction.

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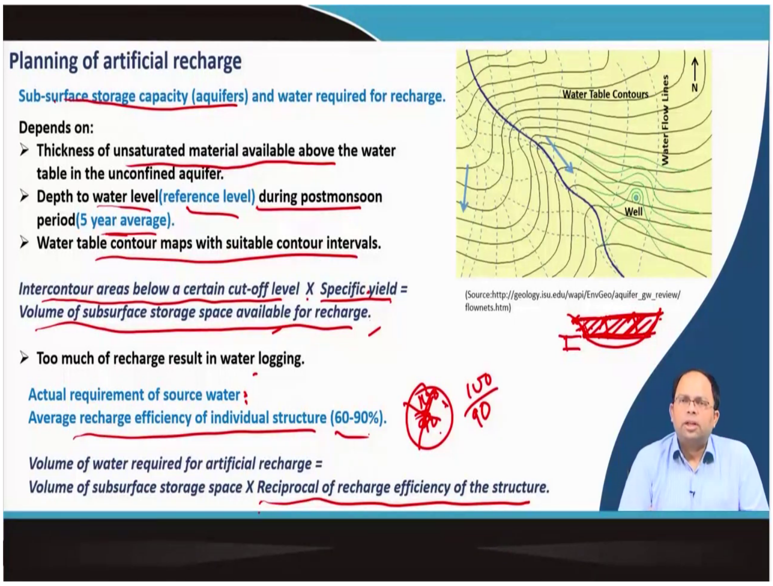

The important thing is the subsurface storage capacity and how much water is required for recharging that particular aquifer. The figure shows contour lines for groundwater table, that means at what level groundwater is available. So, each line may be at a distance of one meter and all the points connected by a single line have got groundwater at the same levels.

So, like a digital profile of a terrain as in digital elevation model, this actually gives the elevation of the groundwater table. When we compare two aquifers and we know the water table level, we can actually determine what is the difference in the depth between two levels, and the quantum of water required.

The subsurface storage capacity depends on the thickness of unsaturated material available above the water table in the confined aquifer. Which means how much amount of unsaturated material is there above the groundwater table, in that particular unconfined aquifer that actually determines the area, where the water would be stored.

Now depth of the water level is the reference level during post monsoon period and for 5 years average. This is the level after a normal monsoon season after normal recharge.

Water table contour maps with suitable contour intervals are prepared and what we determine is the inter-contour areas below a certain cut-off level. Let us assume that we want to take groundwater up till a particular level. So, this is the cut off level. In between this inter contour area how much amount of water could be stored that is what we are determining. Water is stored in the pores of the soil in that unsaturated material above.

Specific yield is actually the water that could be abstracted from a particular layer. And we can multiply that rate with this inter-contour volume and that actually will give us the total volume of subsurface storage space available for recharge.

So, the actual requirement of water is to fill this particular volume of soil. It also depends on the average recharge efficiency of individual recharge structure; i.e., if we put 100 litres of water in a recharge structure, based on its efficiency only a percentage of water actually gets into the ground.

So, let us assume that 60 to 90 percent is the efficiency of a particular structure. This be for many reasons. It could be losses of water from evaporation, some amount of water will not percolate and many other reasons.

Volume of water required for artificial recharge is equal to volume of subsurface storage space multiplied by reciprocal of recharge efficiency of the structure. This is the factor which we need to multiply to get the actual volume of water that would be required.

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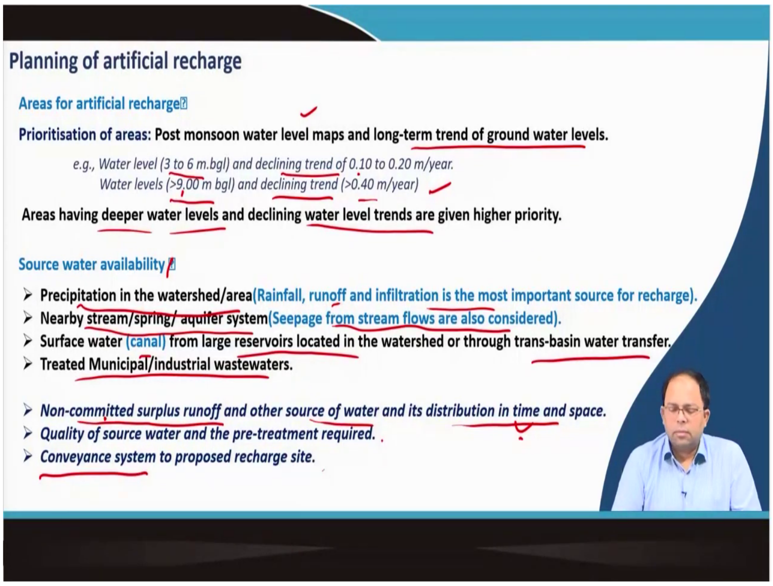

How will we determine where to recharge and also how do we prioritize between this area? So, usually before prioritizing we should consider the post monsoon water level maps and long-term groundwater level trend as well. We use both these values and we see what is the current water level post monsoon. So, for example, water level at 3 to 6 meter below ground level and declining trend of 0.1 to 0.2 meter per year; that means, every year there is a decline of the water table by 0.1 to 0.2 meter. There is another area where water table level is found to be less than 9 meter below ground level and the declining trend is 0.4 meter per year.

Then where we will recharge; obviously, the second one why? Because it is going down at a much faster space and also the level is lower. So, areas having deeper water levels and declining water level trends are given much higher priority.

Then, we have to make sure that source water is available. So, where do we get this water? The main water that we will use is precipitation in the watershed area.

In a particular catchment area or watershed area precipitation falls and then eventually flows as runoff. We need to capture this runoff and then use it for infiltration. This is the main source for artificial recharge. We can also go for nearby streams, springs or aquifer system and then we can consider seepage from the stream flows that will actually recharge the area.

If there is no water available locally we need to get water from somewhere else. So, we may use canals to bring in water to that area from some stored reservoirs or other areas. This is also called trans basin water transfer; that means, we are bringing water from other catchments as well.

Then, treated municipal and industrial wastewater can be reused for recharge. So, in all these cases the water that has to be made available for recharge has to be the non-committed surplus runoff and other source of water and we have to consider its distribution in time and space.

So, it has to be non-committed; that means, there is no other use for this water only then we will put it for recharge. If already we have estimated that treated waste water would go to a thermal power plant, that means, already there is a designated use for that water. So, we cannot assume that this water will come for recharge.

So, we need to make sure that there is adequate non-committed surplus run-off and other sources of water in the urban area and when it is available and where it is available. So, both time and space is also important. Quality of source water and pre-treatment requirement has to be also evaluated. So, this is also another issue. We cannot just put in any water we have to do some amount of treatment or we need to check if the water is of good quality only then we can allow it for recharge.

And finally, conveyance system to the proposed recharge site. So, the place where the water is available and the recharge site may be far away. So, we need to also design a conveyance system to take this particular water.

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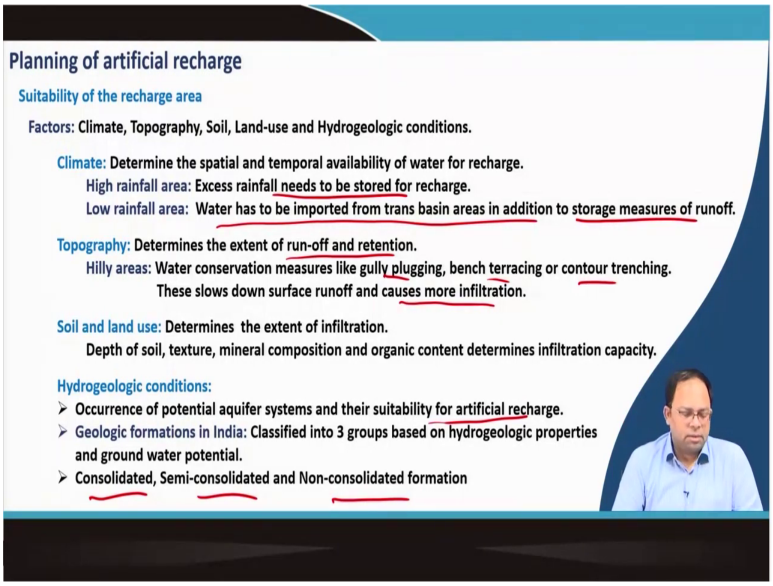

Then we need to check the suitability of the recharge area and the related factors which are climate, topography, soil, land use and hydrogeologic conditions. For example, climate determines the spatial and temporal availability of water for recharge; that means, at a high rainfall area, excess rainfall needs to be stored for recharge. In low rainfall area water has to be imported from trans basin areas in addition to storage measures for runoff. So, this is how climate of area actually influences the kind of recharge we can do in that particular area.

Similarly, topography determines the extent of runoff and retention in hilly areas. We need to consider water conservation measures such as gully plugging, bench terracing or contour terracing and this slows down the surface runoff and causes more infiltration.

It is not a simple task to plan for this entire recharge process. First, we need to prevent the water to flow away and then we need to store the water, then we make sure that the water infiltrates into the ground.

Soil and land use also plays a big role. Extent of infiltration depth of soil, texture of soil, mineral composition and organic content determines the infiltration capacity.

And then we have the hydro geologic condition like the potential aquifer system and the suitability for artificial recharge.

In India we have three classifications for this kind of aquifers. Consolidated, semi consolidated and non-consolidated formations, which actually influences the amount of recharge that could be done for this aquifer.

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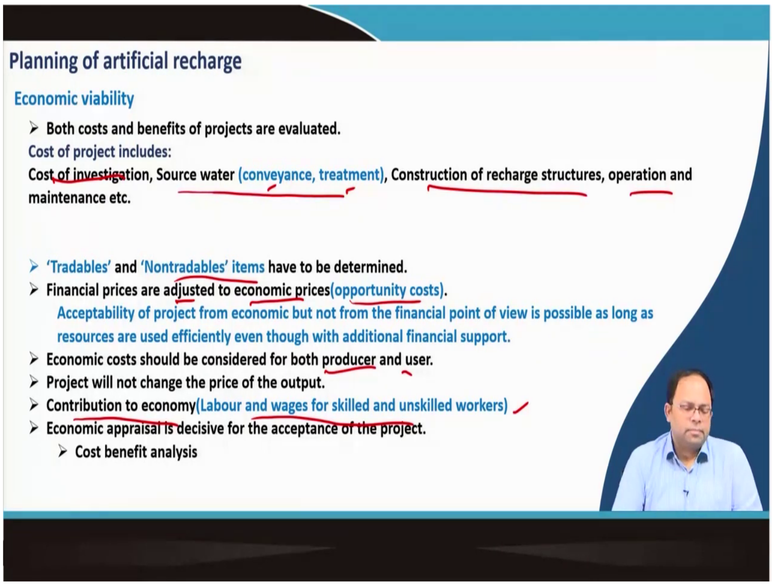

Then finally, if it is not economically viable then there is no point of doing this project. So, cost benefits of the projects are evaluated.

The cost of project includes everything like cost of the investigation or maybe cost of making the plans, then source water conveyance, treatment conveyance as well as treatment; that means, carrying of the water as well as treatment of that water before recharge. Construction of recharge structures, operation and maintenance of that recharge structure all these things are the cost of this particular project.

Whereas, that benefits of the projects as we are discussing earlier could be environmental benefits, social benefits. Sometimes those could be tradable and sometimes those could be non-tradable items; that means, we cannot put monetary cost to them and then we need to be careful about determining the cost of a project.

So, we need to understand the difference between financial price as well as the economic price and economic price also includes opportunity costs as well. Financial prizes are absolute, money numbers whereas, economic prizes considers all the different benefits and all the other costs that is there.

Acceptability of project from economic, but not from financial point of view is possible as long as resources are used efficiently even though with additional financial support.

Economic appraisal is decisive for the acceptance of the project. Without any kind of economic appraisal or cost benefit analysis we cannot go ahead with any kind of project. These kind of projects will also contribute to the economy; that means, there are some labour and wages for skilled and unskilled workers that we can consider because these are large scale projects, where we can involve a huge amount of people.

Thus there is spreading of the benefits from doing this kind of projects. The economic prices are based on the initial conditions and economic cost should be considered both by the producer and the user. So, one who is actually constructing and the one who would get the benefits both the producer and the user should consider economic cost instead of financial cost.

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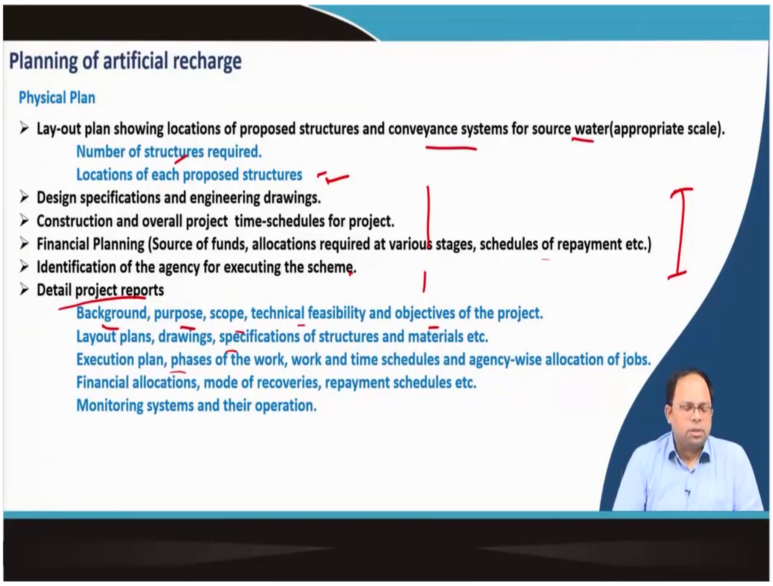

So, finally, if the project is financially viable we need to prepare the physical plan, that includes the layout plan showing locations of the proposed structures, conveyance systems and the source water.

So, how many structures are required? Usually, we use multiple structures and location of these particular structures are important and needs to be put in the map.

Then design specifications and engineering drawings for construction and overall project time schedules of the project are prepared. So, next is the construction management related part. Financial planning, sources of fund, allocation required at various stages, schedules of repayment and identification of agency for executing the scheme are also considered.

Next, the engineering part comes in or the project contract is awarded. As planners we can actually justify our project when the economic costs are viable.

So, what do we need to prepare? So, when we propose a particular project we make a plan for it, we need to do detail project report. So, we need to give the background purpose scope technical feasibility objectives of the project and layout plans drawing specifications of structures, execution plans, financial allocations, monitoring systems and all the details has to be provided in the DPR to justify before we start the project.

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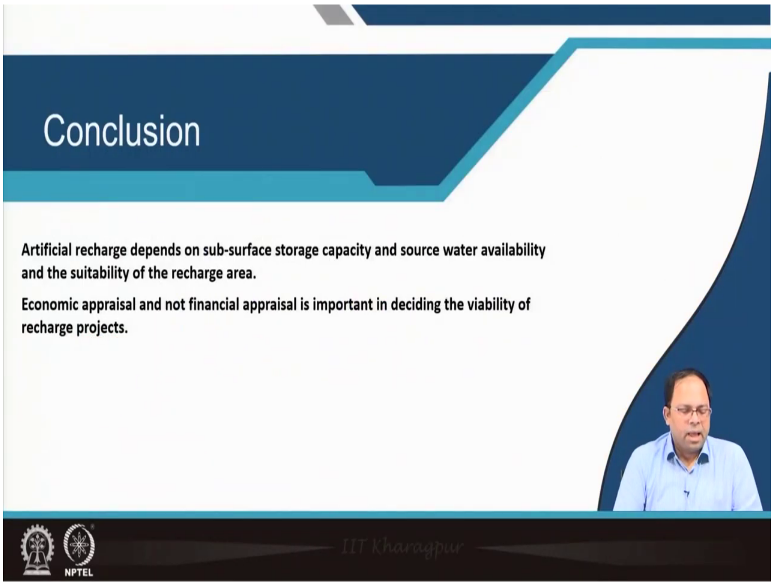

To conclude artificial recharge depends on subsurface storage capacity, source water availability and the suitability of the recharge areas. All these thing needs to be considered before we start any kind of an artificial recharge project. Economic appraisal and not financial appraisal is important in deciding the viability of recharge projects.

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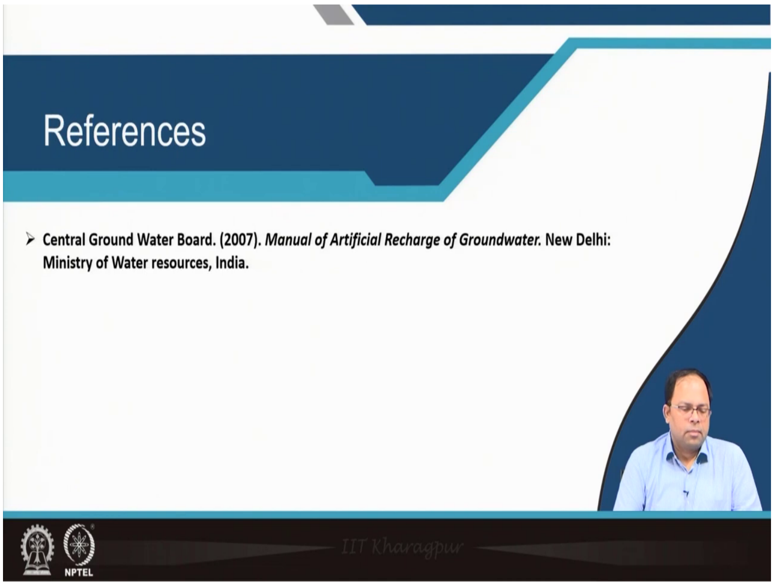

So, these are some of the references that you can use.

Thank you.