Watershed Management

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Lecture No. # 09

Conjunctive Use of Water Resources

Welcome to the video course on watershed management in module number 3 - in lecture number 9, today we will discuss about conjunctive use of water resources.

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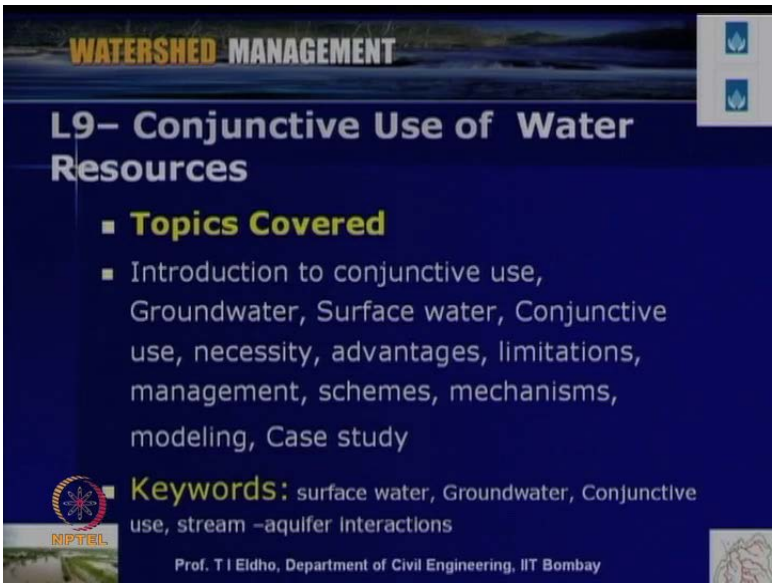

Some of the topics covered in this lecture include, introduction to conjunctive use, ground water, surface water, conjunctive use, necessity of conjunctive use, advantages and limitations of conjunctive use, then conjunctive managements, a conjunctive schemes and mechanisms and modeling, and finally, we will discuss a case study. Some of the important key words in this lecture include surface water, ground water, conjunctive use, stream-aquifer interactions.

As we discussed the last few lectures, watershed based water plans and water management is very complex. We have to deal with the various hydrological processes various other processes taking place within the watershed. As far as water availability is concerned, we can classify mainly into surface water and ground water. Some places say people use more surface water and some places depending upon the availability people use more ground water.

In today's lecture we want to discuss say, how we can optimally use this surface water and ground water. So called in a conjunctive use of surface water and ground water; so that we can have optimal utilization and better watershed management.

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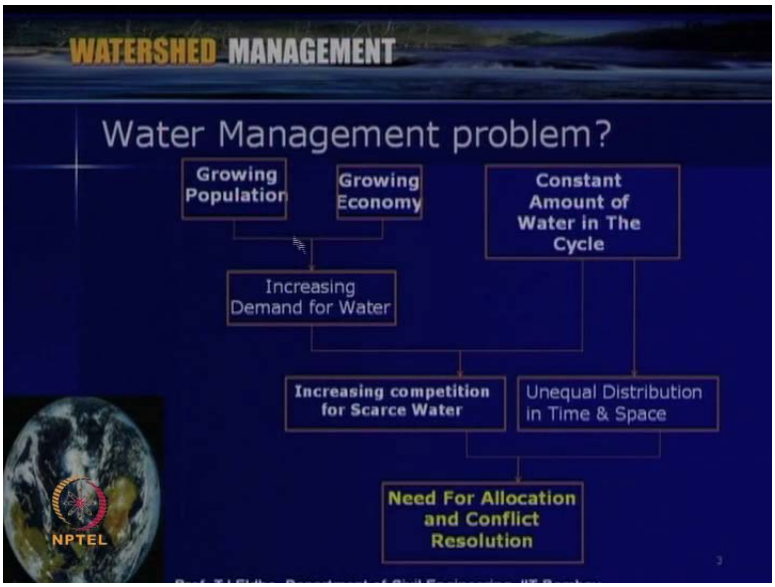

As we discussed the water management is a big problem, either say watershed based or river basin scale. So due to the various reasons like growing population, growing economy and various ecological and other needs. And then of course as we discussed in the previous lectures, there is the water is concerned this availability is almost constant amount of water in the water cycle. To meet these increasing demands for water, due to the growing population, developmental activities, growing economy and other things. So, there is increasing competition for this case water which is available. Say you can see that as we discussed there is unequal distribution in time and space.

As far as rainfall is concerned say, generally rain will be available about four to five months. And then space is concerned, it is say from one location to another location drastic variation is there. Due to all these reason, there will be always conflicts as far as the water use is concerned within a watershed or a within a river basin scale. We have to see that the water available water is allocated in an on an in an appropriate scale. So that, there is not much many conflicts and then if any conflicts are there, we have to resolve this conflicts in an amicable way.

As far as water availability or water resource is concerned, we can classify the water availability into surface water and ground water. So always a question comes where say depending upon the availability say, whether we want to use only surface water or only ground water. So, but in today's topic we want to see that how it we can utilize both in a in a better way.

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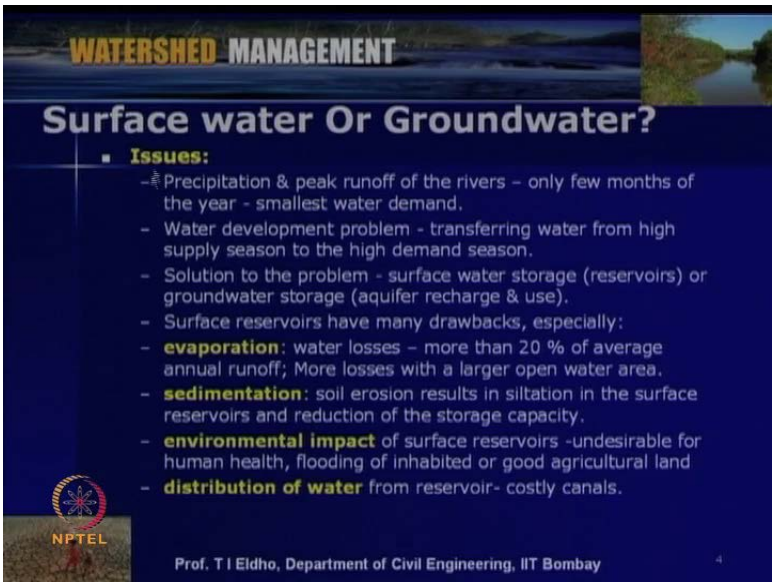

As far as the water utilizations are concerned either surface water, ground water the main issues are. As we discuss a precipitation and peak runoff the rivers only few months of the year and say actually during those time when rainfall is there then, water utilization is very small. When demand is small then the availability is plenty.

And then water development problem say like here, transferring water from a high supply season to high demand season. So, you can see that say summer season the there will be high demand, but then availability is less. We want to transfer the available water from high supply season to high demand season. And then solution to the problem like a surface water storage. So, whether we need to go for small reservoirs or large reservoirs or a ground water storage, whether we can go for aquifer recharge. And then how we can utilize this ground water, then say like this there are number of issues as far as whether when we discuss whether we have to utilize the surface water or ground water.

Now, let us consider the surface water availability say surface water in rivers lakes or reservoirs. There are number of drawbacks, say as far as surface water is concerned like huge evaporation losses will be there as far as surface water is concerned. Approximately say about 20 percent of the average annual runoff says we lose by in terms of evaporation. So, more losses with a large open water area, when the reservoir is a huge area. Then we can see that there will be more evaporation. then as far as surface water resource is concerned like a lakes or reservoirs.

Sedimentation is a major problem. As we discussed in one of the lecture soil erosion results or we say due to heavy rainfall or various other reasons soil erosion takes place. And then these sediments will be carried by the flowing water to the lakes or reservoirs or to the river. This soil erosion results in siltation in the surface reservoir. And then finally, there will be reduction in the storage capacity. So, that is another major issue as far as this surface water is concerned.

And then like say number of environmental problems will be there like an, if you are going to construct a large dam and then say the large area we have to utilize for reservoirs. Then there will be, we have to displace the people then lot of land will be flooded. With these kinds of environmental impacts like, undesirable for human health, flooding of inhabited or a good agricultural land, this can be another major issue as far as surface water is concerned. And then as far as distribution is concerned, with the from the surface water sources like a say reservoir, we have to construct say canal system say for say a kilometers of length.

Generally the construction of these canals and then maintenance is a very costly affair. Distribution of water as far as surface water is concerned say; these are some of the issues say like evaporation, sedimentation, environmental problems and distribution of water. And now if you consider the ground water, then of course is a generally we utilize the government water, wherever it is available in that you know on a local scale or a on a on a particular watershed scale or say where we consider. But of course, most of the time we need to pump the water available from the aquifer.

Generally we should have a power for that. And then also when the water aquifer level or water table goes say, drastically down then we need to use more power and then there is other issue. Then also say if you want to recharge the aquifer, then we have to construct say, if you are going for artificial recharge we have to construct some artificial recharge structures or we have to go for rain water harvesting type of structures. These are some of the important issues when we discuss, whether we have to go for surface water or ground water.

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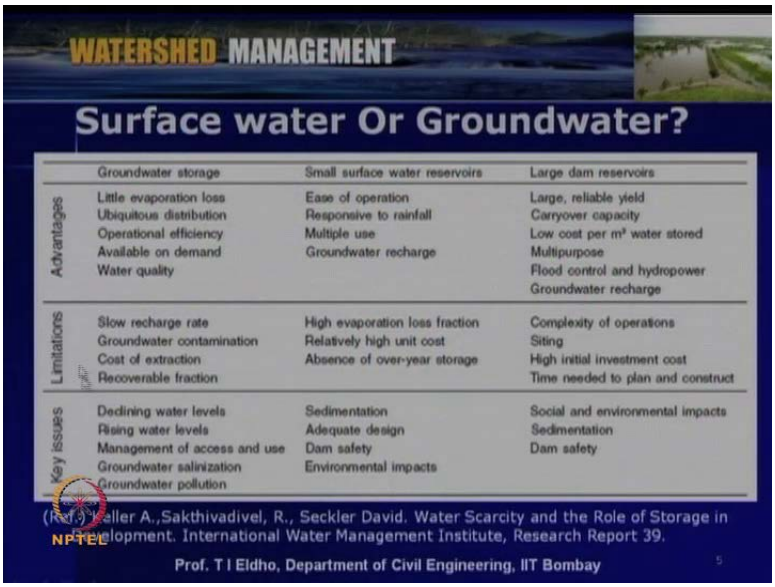

Now, say as far as surface water or ground water a question comes let us look into, what are the advantages? What are the limitations? And what are the key issues as discussed by Keller and others in a report of international water management institutes.

If you consider the ground water storage, then the advantages would be little evaporation loss then ubiquitous distribution. So, wherever we want we can get then operational efficiency available on demands and we will have better quality water. These are some of the advantage as far as ground water is concerned. Then if you store surface water in small reservoirs, then ease of operation responsive to rainfall. Even small rainfall will have sufficient water in these small reservoirs.

Then multiple uses say like an irrigation or water supply or other multiple uses. Then this also serves as ground water recharge. And then if you consider large dam reservoirs, then the advantages are there say, we have large storage there will be reliable yield, then we can carry over whatever the available to the scarce months or the other seasons. Then low cost per meter cube water stored then of course, multipurpose we can go for no it is not only source for water, but hydroelectric power project say production and other multipurpose, then for flood control and hydropower, then ground water recharge.

So, these are some of the advantages by considering either ground water or small surface water resources or large dam reservoirs. Now some of the limitations say, if you consider the ground water storage like slow recharge rates, then ground water contamination problem, cost of extraction, recoverable fraction. Like say for example, if you recharge say x quantity, then we may be able to say recover may be twenty percent or thirty percent of that. Then say as far as the small surface water sources are concerned limitations include high evaporation rates, then relatively high unit costs, then absence of over-year storage. So, we cannot store so much of water for say for the use of summer season.

Then large dam some of the limitations include complexity of operations, then where which is to be located, we have to relocate the people and then say the area we have to find out. Then high initial investments and a time needed to plan and construct. These are some of the limitations as far as ground water or small surface source or large source or surface source is concerned. some of the key issues like here ground water is concerned say, it is declining water level due to overuse rising water level in some regions, like management of say access and use as far as the ground water usage is concerned.

Then some places the ground water salinization takes place, they say the coastal aquifers especially there will be salt water intrusion problems. Then many locations ground water pollution problems and then so small sources are concerned like sedimentation, then adequate design, dam safety, environmental impacts. These are some of the key issues as far as small surface water resources. Then large surface water resources like the social and environmental impact like a large area to be ploughed and then here we have to resettle the people living in that area, then sedimentation issues, then dam safety.

These are some of the key issues when we consider the ground water storage or small surface storage or large dam reservoirs. Now a say let us come back to say, whether to utilize surface water, ground water. So, we have already seen the advantages of each say surface water, ground water, and then limitations and then what are the key issues as far as the say either use of surface water, ground water. Now earlier time say, before nineteen fifties say there were not much understanding, as far as the whether there is said interaction is taking place between surface water and ground water. Before nineteen fifties actually, the surface water source and ground water sources were dealt separately.

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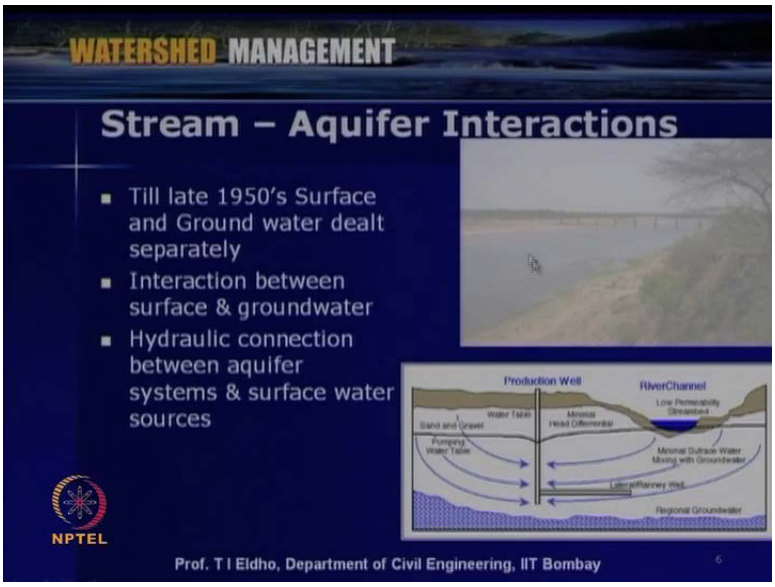

Since, these understanding of the interactions and related issues where very rare. That way then I would say lot of research studies showed, that there is constant interaction between surface water and ground water. Say for example, if this is a river then say nearby aquifers will be recharged by the river.

When say especially in monsoon season, when say good quantity of water will be flowing through the river. And similarly, when this in summer season when the say the water in the river will be level will be going down. Then what happens the nearby from the nearby aquifer systems water will be coming from the aquifer system to the river.

There is a constant interaction between surface water and ground water. We cannot separate surface water and ground water and then do a study. But we have to see its interactions so, the hydraulic connection between the aquifer systems and surface water sources are very important. We have to consider say, when we access the available source of water and then when we use the either surface water, ground water, we have to see. What will be the effect? Say if you are using the surface water only, then what will be the effect on ground water? And when if you are using only ground water, what will be the effect on the surface water sources?

In this figure, you can see that say if this is a channel river channel, then here there is a this is the aquifer system, then there is a well here. So, you can see that if you are say keep on pumping in this well, then the water available not only in this aquifer, but then you can see that say, the water will be say recharging through this river channel. And then say this water will be coming to the production well. Similarly as I mentioned say, if we are not a utilizing the aquifer say water, then say and if that river level is going down then there will be reverse flow taking place from the aquifer system to the river channel. That way lot of interaction takes place between the steam and aquifer, and that way we have to plan as far as the surface water and ground water utilization is concerned.

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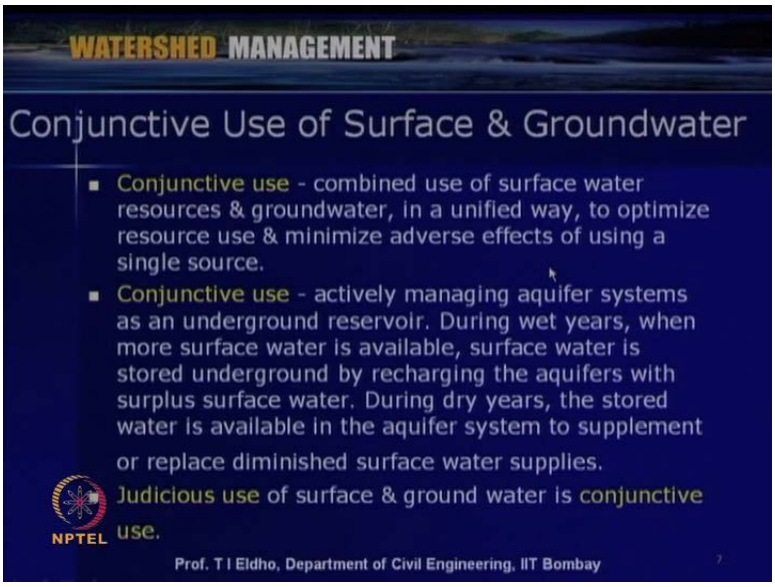

Now, let us come back to the topic on conjunctive use of surface water and ground water. Last few decades in most of the water resource plans, they say water resource planners always mention about the use of surface water and ground water together and then the term called conjunctive use came. We can define the conjunctive uses; combine the use of surface water resources and ground water resources. In a unified way to optimize the resource use, that means water use and minimize the adverse effect of using a single source.

Like say we are optimizing the both use of surface water and ground water. So that, it minimize the adverse effects of either using surface water or ground water. So that way, the conjunctive use says, what we are doing is, actively managing the aquifer system as an underground reservoir. The say aquifer system is acting as an underground reservoir during wet years when more surface water is available. Then what happens? Surface water is stored underground say there will be good recharge to the aquifer system.

By recharging the aquifers with the surplus surface water and during dry years say or in summer season, the stored water what is available in aquifer system. We can supplements or replace the diminished surface water supplies as we have seen in the previous slide. So, that way we can define the conjunctive uses judicious use of surface and ground water. So, that all the needs will be met in an in an optimal way.

So, that without affecting the either the surface water source or without affecting the ground water source or say without any adverse effects of either by use of one of the source. That is the way we can define the conjunctive use of surface water and the ground water. Now, as far as conjunctive use is concerned say, you may ask why we have to go for conjunctive use.

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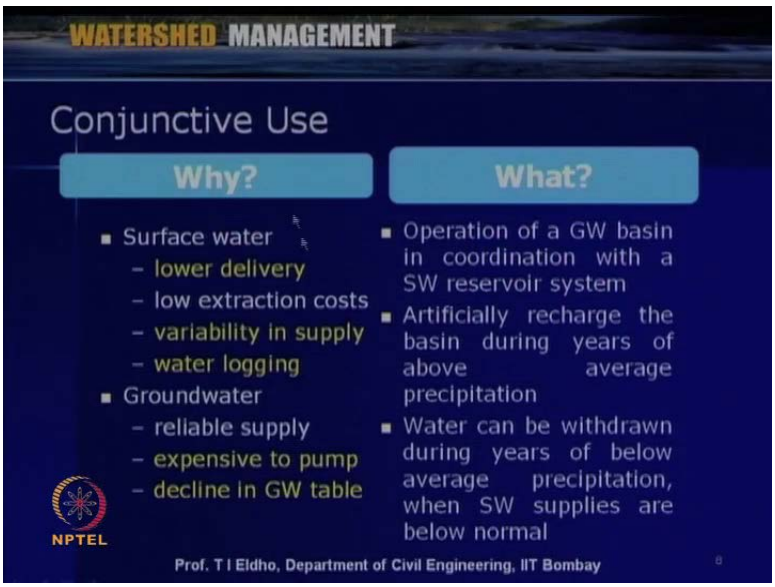

Here some of the things are listed here. Say for example, it is conjunctive use means conjunctive use of surface water and ground water. Surface water is concerned say we can easily get it. So, lower delivery we can have it and low extraction costs. So, we can easily either pump both under gravity we can get then variability in supply. There will be say variability as we discussed say, sometimes supply will be there surface water source sometimes, it may not be there. And then what can happen water logging? A lot of say, if some the water is not utilized in an appropriate way, then water logging the area will be saying flooded with water. And then its related issues as far as the agriculture are concerned. And then groundwater is concerned say, why we are going for ground water? Say always it is a reliable supply, but only problem is it is expensive to pump. And in much location, there is the ground water tables are going down. So, decline in ground water table.

And then as far as conjunctive use, what is conjunctive use? As I mentioned, it is operation of a ground water basin in coordination with a surface water reservoir system. So, that way say we are operating surface water and ground water. And then ground water is concerned, we artificially recharge the basin during the years of above average precipitation, when sufficient surface water where we go for more artificial recharge so, that we can use it later. Then water can be withdrawn during the years of below average precipitation when surface water supplies are below normal.

That is the answer, why we are going for conjunctive use and what is conjunctive use. Now within this perspective say, what the necessities of conjunctive use? So, we have we are looking for say, use of surface water and the ground water. What are the necessities? So, these issues are listed here.

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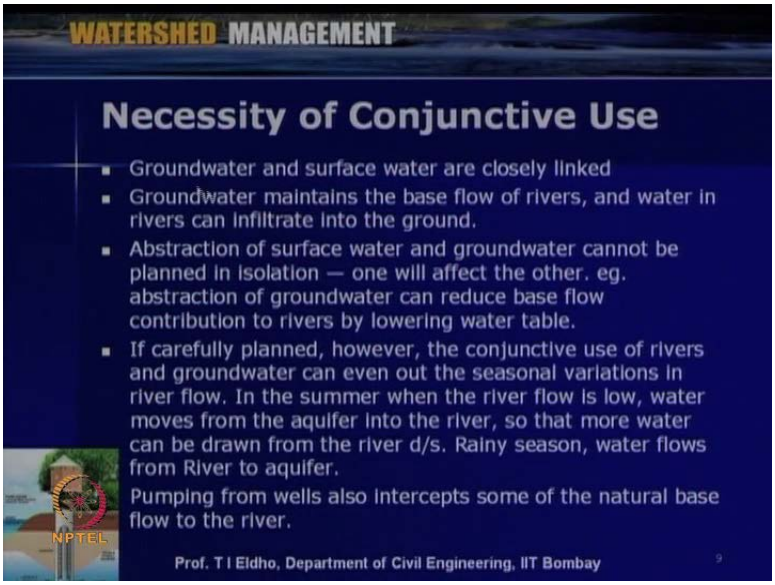

Like a as we discussed there is constant interaction between surface water and ground water, like a aquifer and say stream interaction as shown here. Ground water and surface water are closely linked. So, we have to see in any in a say conjunctive way of use. Then ground water maintains the base flow of rivers and water in rivers can infiltrate into the ground. So, that way we cannot separate. And abstraction of surface water and ground water cannot be planned in isolation. As we discussed there is interaction between aquifer and stream. So, or river. once say, when we are in say extracting water from aquifer.

The other source will be affected or when we over extracting surface water they will affect on the ground water. One will affect the other; say example abstraction ground water can reduce, base flow contribution to rivers by lowering the water table. So, these that is why we have to go for conjunctive use. Then if carefully planned, however, the conjunctive use of rivers and groundwater can even out the seasonal variations in river flow. As I mentioned whenever say more water surface water is available, we can go for say surface water and then also we can go for the recharging of the aquifer system.

And in the summer when the river flow is low, water moves from the aquifer into the river, so that more water can be drawn from the rivers. Especially on the downstream side say, in the upstream side if the aquifer is recharging, then downstream side the river will be getting more water and then rainy season water flows from river to aquifer. When the head is rising say water goes from river to aquifer. And then pumping from wells also intercepts some of the natural base flow to the river. Due to all these issues say, we have to go for conjunctive use. That is said the best way of utilization of the available water resource.

Now, say we can say even though say most of the time say we can we say either we go for surface water ground water conjunctive use. Why we are advocating the conjunctive use. There are number of advantages limitations are very very few, but advantages are many.

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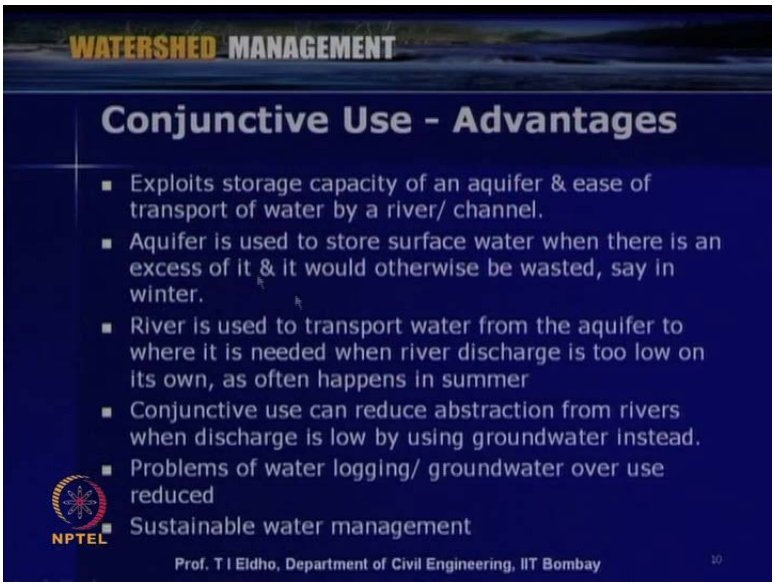

Some of the advantages, I have listed here in this slide. The conjunctive use says, through conjunctive use we can exploit storage capacity of an aquifer and there is ease of transport of water by a river or a channel. Especially in summer season, when the say upstream locations say, if the aquifer is giving water to the river that water will be available on the downstream side. Then aquifer is used to store surface water, when there is an excess of it and it will otherwise be wasted, say in the winter or during the monsoon season. So, that is another advantage. When river is used to transport water from the aquifer to where it is needed, when river discharge is too low on it is in on it is own.

As often happens in summer. So summer season say, the water from the aquifers will be going to the river system and especially on downstream side this water will be available as far as the river is concerned. Then conjunctive use can reduce abstraction from rivers, when discharge is low by using the ground water instead. There we can see that, the from the rivers when the say we can reduce the abstraction by using the ground water. Then problems of water logging ground water over use, we can reduce. In an optimal way, when we plan surface water and ground water, water logging can be drastically reduced, then salinization can be reduced, then say the salinity introduction can be reduced. So, and also the ground water over use can be reduced.

That way finally the advantage of finally, what I can say is that, say this is the conjunctive use is the best way of sustainable water management as far as any watershed or a river basin is concerned. These are some of the advantages, as far as conjunctive use is concerned. So, now as I mentioned only few limitations are there. Some of the limitations I have listed here.

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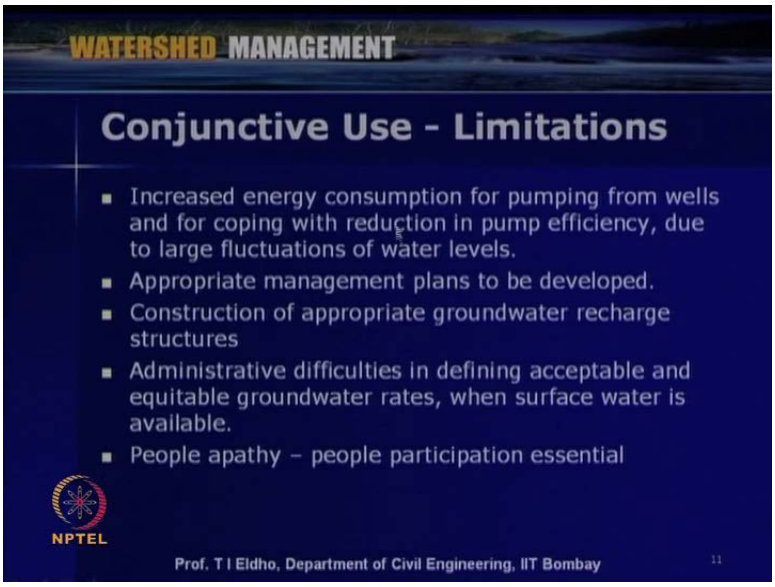

So, there is a increased energy consumption for pumping from wells. For example, if surface water is available in plenty and still if we are going for ground water, then we have to use energy for pumping. So, that can be as I mentioned as one of the limitation. Depending upon say, if there is reduction in pumping efficiency then large fluctuations of water levels all these can happen. Then appropriate management plans to be developed for the given watershed or a given river basin. We have to appropriately plan, whether we use this much percentage of surface water or this much percentage of ground water so, that optimal use will be there. Then construction of appropriate ground water recharges structures. As we discussed during monsoon season say, we have to increase the recharge through artificial recharge structures.

So, that way we have to construct appropriate ground water recharge structures. It is coasts to be covered, then administrative difficulties in defining acceptable and equitable ground water rates, when surface water is available. If we are going for conjunctive use for a on a watershed scale on a river basin scale, we have to define this much percentage should be from surface water, this much percentage should be from the ground water. So, we have to assess out these and then we have to come up with appropriate conjunctive use plans. Due to that there can be some administrative difficulties. And then say one of the major problems in say in advocating, the conjunctive use is people apathy. Especially farmers, if surface water is available they will never bother to go for ground water. Since of course, pumping is required and then say they will prefer to use the surface water.

So, we have to educate the people, we have to inform give sufficient information that why we have to go for conjunctive use. what are the advantages conjunctive use. So, that way say none of these conjunctive use projects will not be successful without appropriate people participation. people participation is very essential as far as the development of a conjunctive use plane for a watershed or for a river basin scale. Now based upon this discussion, let us see what the important challenges are as far as conjunctive use is concerned.

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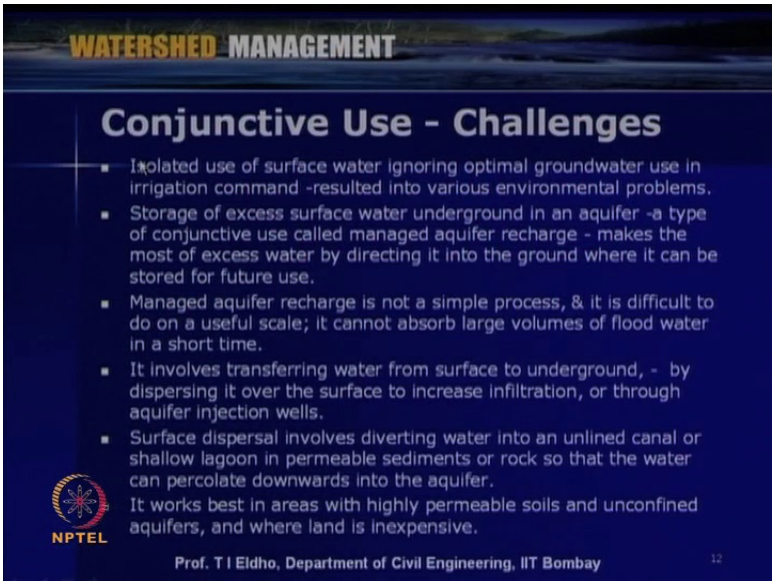

Some of these issues are listed here. So, like isolated use of surface water ignoring optimal ground water using irrigation command may result into various environmental problems. We have to go for an appropriate plan as far as conjunctive use is concerned. Then storage of excess surface water underground in an aquifer say, called managed aquifer recharge so, this makes most of the excess water by directing it into the ground water.

We have to develop appropriate system, as far as the recharging is concerned. This manager aquifer recharge is not a simple process. It is a very difficult to do on a useful scale, as its artificial recharge depends upon many factors like type of soil, type of aquifer system, type of say artificial structures, which we develop.

Then also this involves, transferring water from surface to underground. By dispersing it over the surface to increase infiltration or through aquifer injection well, we need to develop appropriate system for this. Then surface dispersion dispersal involves diverting water into an unlined canal or shallow lagoon in permeable sediments or rock. So, that water can percolate downward into the aquifer system.

We need to have a say appropriate system say like unlined canal or a say basin or lagoon, where through which or we can say go for artificial recharge so, that more water will be recharged to the aquifer system and then that will be available for further use. It was best in areas with highly permeable soils so, as I mentioned geology is one of the important factor as far as the artificial recharge is concerned. Wherever, highly permeable soil is there then it is easy to recharge the water. Especially in unconfined aquifers, but say a confined aquifer again recharge are not so easy.

We have to identify, where the recharge area for the confined aquifer system is and or we have to go for through infiltration say, deep wells for recharging of the confined aquifer system. This is some of the important challenges, as far as the conjunctive use of surface water and ground water is concerned.

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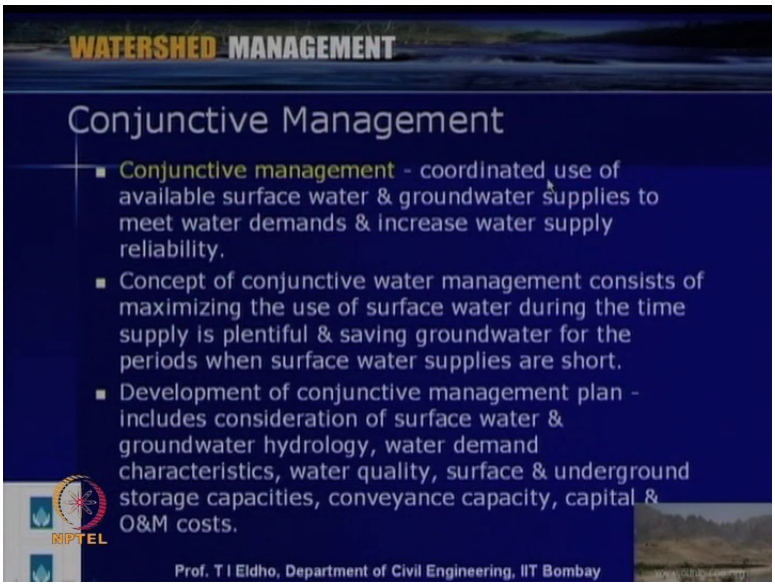

Now say with respect to this conjunctive use, we can now say define what conjunctive management is? So conjunctive management say, as we discussed the conjunctive management is coordinated use of available surface water and ground water supplies to meet water demands and increase water supply reliability. So, this is actually when we are said, we are developing some management plan so, that water availability will be say there throughout the time and then there will be optimal say use and optimal demand management.

Then say the conjunctive management is a concept of conjunctive water management say, it consists of conjunctive water management consists of maximizing the use of surface water during the time supply is plentiful. And saving ground water for the periods, when surface water supplies are short. This is the essence of conjunctive managements. In this we have to develop conjunctive management plans, as I mentioned depending upon the watershed or depending upon the river basin. We have to consider various issues and then develop appropriate conjunctive management plan.

The conjunctive management plan develops development include, consideration of surface water and ground water hydrology. So, we have to see the rainfall pattern, we have to see the geological characteristics, hydro geological pattern, then water demand characteristics.

How much water is needed? For what purpose water is needed? And when it is needed, whether say what season farmers need more water then water quality. Water quality is very important. If the polluted water is recharged through the aquifer system, then the aquifer system will be contaminated. We have to be very careful in the artificial recharge. And then a surface and underground storage capacities we have to see, when a conveyance capacity as far as either through the river or channel is concerned or canal system is concerned, we have to see.

Then how much capital is available to invest, as far as the conjunctive management for an either on a watershed basis or a or on a say river basin scale. And then of course say, once the plan is developed, how we can implement it? And then how we can say operate it? And then how we can maintain it? All this includes say the cost also very important, how much we can invest? And then how we can say retrieve some of the cost? And then how we can effectively operate it, and manage it or maintain it.

Now, in any of this conjunctive management say, we set the objectives according to the necessity of the particular watershed or particular say river basin, which we consider.

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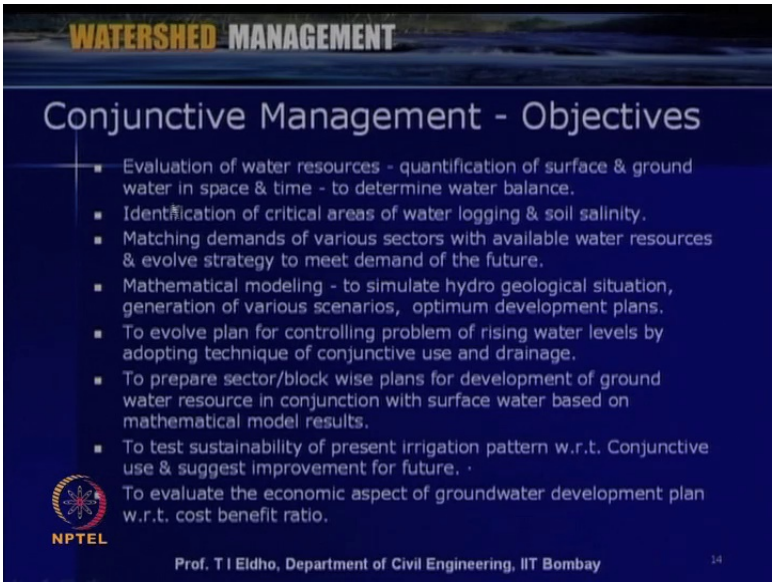

Some of the important objectives as far as conjunctive management are listed here. Say like evaluation of water resources so, we have to evaluate we have to quantify the surface and ground water in space and time. That means variation with location and then variation with a time to determine the water balance. We can first determine the water balance and then develop an appropriate conjunctive management plan, then identification of critical areas of water logging and soil salinity. If already a watershed or a river basin is already affected by water logging, then we have to assess that area and then we have to go for management plans for that.

Then matching the demands of various sectors with available water resource and evolve strategy to meet demand of the future. We have to make appropriate plans. So, that the present demands and then future demands can be met using the conjunctive management plans. Then most of the time say, as far as even the surface water is concerned we can estimate the availability, but ground water is concerned it is very very difficult to estimate how much water is available. So that way, we have to go for mathematical modeling.

The mathematical through mathematical modeling, we can simulates the various situations various scenarios. Mathematical modeling to simulate hydro geological situations, generation of various scenarios and then we can go for optimum development plans. Mathematical model has an important role in conjunctive management plans. Then to evolve plan for controlling problems of rising water levels by adopting technique of conjunctive use and drainage. Wherever, the water logging problem is there, we have to develop appropriate drainage system so that water logging can be reduced. Then to prepare say, sector or block wise plans for development of ground water resource in conjunction with surface water based on mathematical model results. That can be another objective, then to test sustainability of present irrigation pattern.

What is existing irrigation pattern? Whether is it is sustainable and then whether if you go for conjunctive use say, that will improve the situation. And based upon all these, we can say whether we can improve the future water availability. Then to evaluate the economic aspect of ground water development plans say, when we develop the plans for the conjunctive use. We have to see the economical aspects. So, whatever we are investing whether we get it back through the benefits.

Most of the time, we can conduct a cost benefit analysis and then say when the benefit is more than the cost so that way we can see that, whether the project will be viable even though it may be taking many years for that. But we have to asses; we have to do an economic analysis to see whether the conjunctive management plans are giving says appropriate results. Then say as far as conjunctive use is concerned, we can go for different schemes. It can be. So, it is optimal use of surface water and ground water. As far as surface water availability is concerned, we can directly use from the river lakes or the reservoirs. Then ground water is concerned, we can we have to pump from the appropriate using dug wells or the tube wells depending upon the location and availability.

As far as when we develop plans or schemes for conjunctive use say, our main aim is say whenever more water is available we want to recharge that surplus into the underground to the aquifer system. In most of the way conjunctive use plans the trust is for artificial or aquifer recharge. So, how much we can recharge. So, that we can utilize whenever scarcity is there. That is the basic principle as far as the conjunctive use is concerned.

That way they say, in any of the important schemes of conjunctive use the major trust will be on aquifer recharge, like a basin recharge injection wells.

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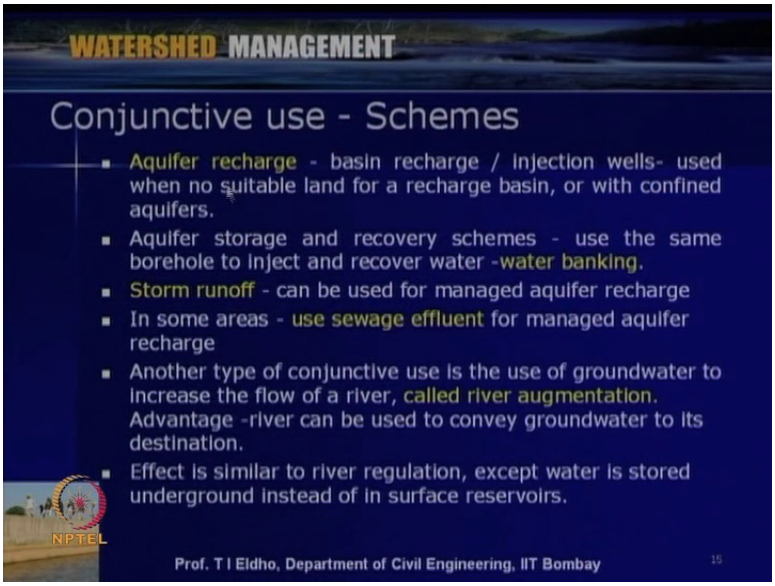

We use these for when no suitable land for a recharge basin or with a confined aquifer system. So, we can go for basin recharge or injection wells then aquifer storage and recovery schemes. Say whether we can use the same boreholes to inject and recover water, just like we can use the term called water banking. Through a same well say when surplus water is available, we inject to the aquifer systems. And then when scarcity is there during summer season, we can pump back the water in that aquifer system through the same borehole. That is called water banking.

Then say especially in most of the watershed say, the storm runoff whether we can effectively utilize it for recharging aquifer systems. Through natural recharge improve the natural recharge or we can go for the artificial recharge structures. Then also depending upon the area, whether we can use the sewage effluent say especially the effluent is good quality after the various treatment processes. If it can be used for recharge, then many locations we use especially in a semi arid and arid regions we can utilize the sewage effluent for recharging. And while recharging this when this say, this treated water goes through the aquifer system, then also lot of water quality will be improved through various processes like a biological activities and then filtration etcetera.

And then another type of conjunctive use is the use of ground water to increase the flow of a river called river augmentation as I mentioned. If the aquifer is recharging back to the river on upstream side so, that more water will be available on the downstream side of the river that is called river augmentation. The advantage is that river can be used to convey ground water to its destination like a on the lower regions. Then say the effect is similar to what river regulation, except what water is stored in underground instead of the surface reservoir.

Surface reservoir directly we utilize for say either through canal system or pipes system, but in say wherever we say called river augmentation. We directly through gravity, the water will be coming back to the river from the up streams of sides from the aquifer system to the downstream of the river system.

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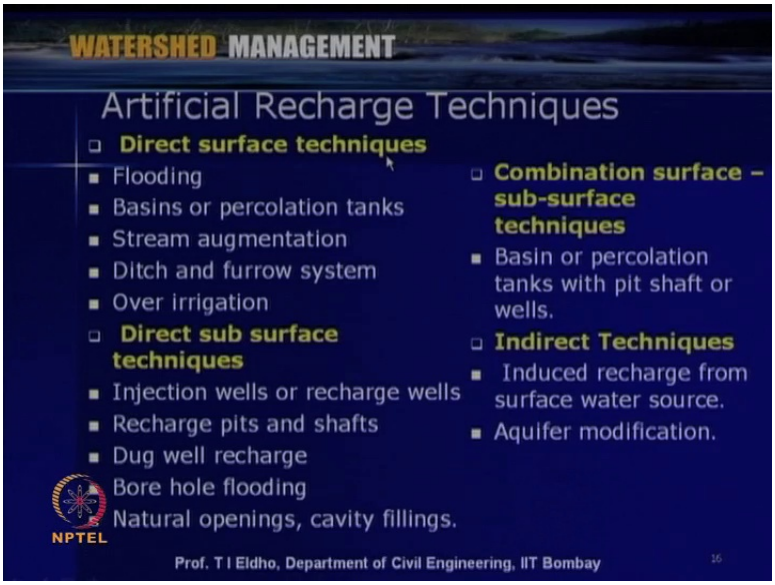

These are some of the schemes as far as conjunctive use plans are concerned. So now as I already mentioned that say, recharging is one of the important aspects as far as the conjunctive use is concerned. Other than improving the natural recharge, which is possible when rainfall or when the precipitation takes place. So, we can also go for artificial recharge structures. Number of techniques is there as far as recharge is concerned. Like some of the important techniques are listed here. So, like direct surface techniques like flooding, basins or percolation tanks, stream augmentation, ditch and furrow system over irrigation.

Then direct sub surface techniques like injection wells or recharge wells, recharge pits and shafts, dug well recharge, bore hole flooding, natural opening, cavity fillings, etcetera. And combination of surface and sub-surface techniques like a basin or percolation tanks with pit shaft or wells. Then indirect techniques like induced recharge from surface water source, then aquifer modification. So, these are some of the artificial recharge techniques, which we can utilize to improve the percolation or to the recharge to the aquifer system. That we can utilize when surplus surface water is there so, that can be recharged to the aquifer system and that can be used later, when scarcity is there.

This we will be discussing more about this artificial recharge techniques in say, later lectures say we will be having detailed discussion about artificial techniques later. Now as far as say as we discussed earlier, they say the water use is mainly in the irrigation sector. Most of the time, if we can utilize the conjunctive use as far as the irrigation is concerned, that is our main thrust. So, how we can use the conjunctive use, as far as irrigation development is concerned.

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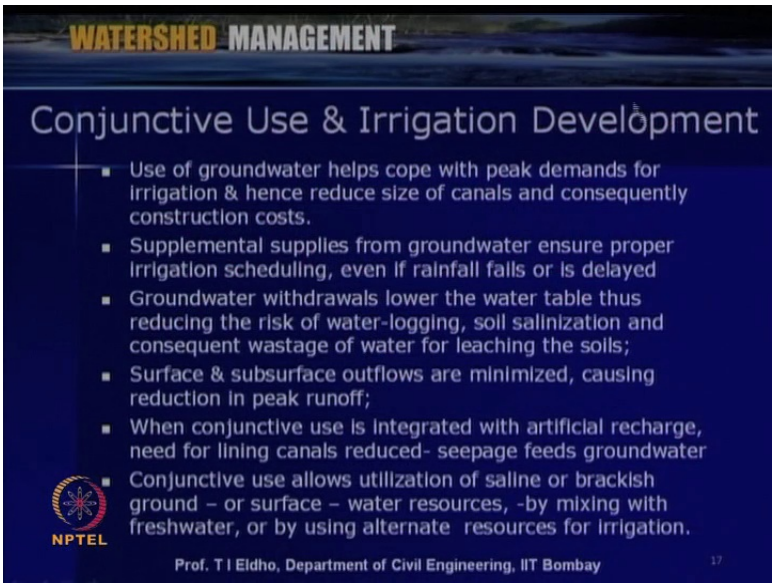

Some of the important issues are listed here, as far as irrigation development is concerned. Conjunctive use of say surface and water and ground water say, we can use in irrigation development. So, that use of ground water helps, cope with peak demands for irrigation and hence reduce size of canals and consequently construction costs, as far as surface water utilization is concerned. Then we can go for supplemental supplies from

ground water to ensure proper irrigation scheduling even if rainfall fails or it is delayed. Especially in rain fed agricultural area, we can go for say the ground water supply compared to small check dams or reservoirs.

That way we can improve the or we can go for proper irrigation schedule by conjunctive use. Then ground water withdrawals lower the water table, thus reducing the risk of water logging soil salinization and the consequent wastage of water for leaching the soils. Say we can see that lot of agricultural land become waste land, due to the water logging and salinity problem.

If you say use the ground water on an appropriate way say, as far as water use is concerned. Then we can recover this water logged or waste land, through appropriate managerial measures including the say using more ground water and then developing appropriate drainage patterns. Then surface and sub-surface outflows are minimized causing reduction in peak runoff. We can use say; we can reduce the peak flow as far as surface flow is concerned so, that flooding problems can be reduced. then a say like that we can improve the total water utilization, then when conjunctive use is integrated with artificial recharge needed for lining of canals can be reduced. Say depending upon the area we say, we can say if whatever water is received through the canal system that can be consider as say to the going through the aquifer system.

That is recharging the system. So, that way the lining goes can be reduced. Then conjunctive use allows utilization of saline or brackish ground or surface water resources, by mixing with the fresh water or by alternative resource for irrigation. Sometimes the saline water is there or brackish water is there from ground water surface water, we can mix it and utilize on a in an appropriate way in a for irrigation development. So, that way a conjunctive use will be more appropriate as far as irrigation development is concerned. Now we can say while developing a conjunctive use plan, we have to see various issues we have to develop a management plan as far as the particular watershed or particular river basin is concerned. What are the important issues?

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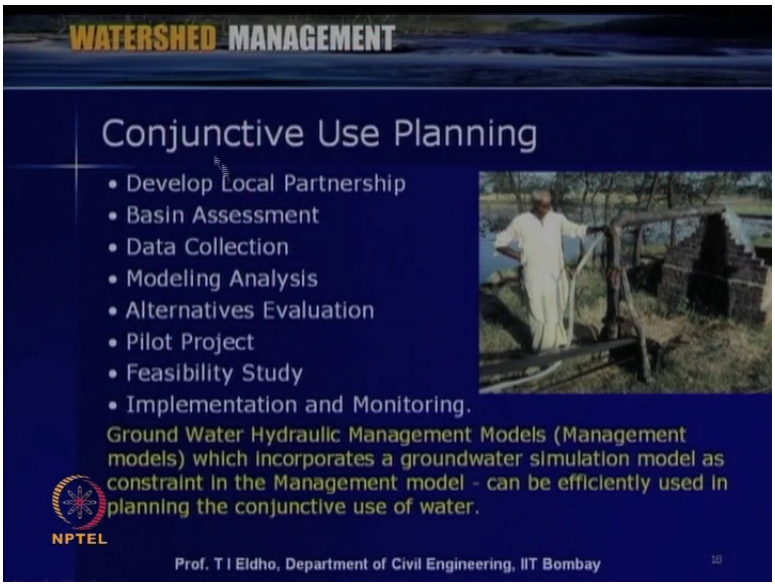

We have to see the various issues what we what are listed here. So, like we have to develop local partnership. As far as the people in that village or watershed we have to come say, we say you take their help and through them only these various schemes to be developed. You have to develop local partnership and then we have to assess the basin. We have to see what say surface water availability, ground water availability and then how much is the demand. Then we have to collect various data like hydro geological aspects, then the soil electrical aspects, then hydrological say data, all those things we have to collect. And then say we have to develop appropriate models as I mentioned say, modeling analysis to be done to develop appropriate plans.

And then depending upon the plans, whatever we have developed we have to evaluate each of these plans and then see which we use the most optimal say cost benefit cost ratio. That we can take care the best plan, and then say we can develop a pilot project so, that the other people in that area will be attracted to that. So, pilot project can be done say, either say district level or state level. That say other people will be attracted to this kinds of project. And then we have to develop say, detailed feasibility plan or feasibility study for the area to develop appropriate conjunctive use plan. And then next stage is we have to implement the best plan best developed plan. And then we have to constantly monitor whether that is working perfectly fine and then whether it is giving the optimal outputs.

So, that way say most of the time we need to go for modeling. Like in ground water hydraulic management models, management models which incorporates say, hydrologic model and ground water simulation models. And various constraints in the management model can be efficiently used in the planning of the conjunctive use of water. So, we have to go for mathematical modeling and development of especially, simulation and optimization models for appropriate say development plans for conjunctive use as far as the area is concerned.

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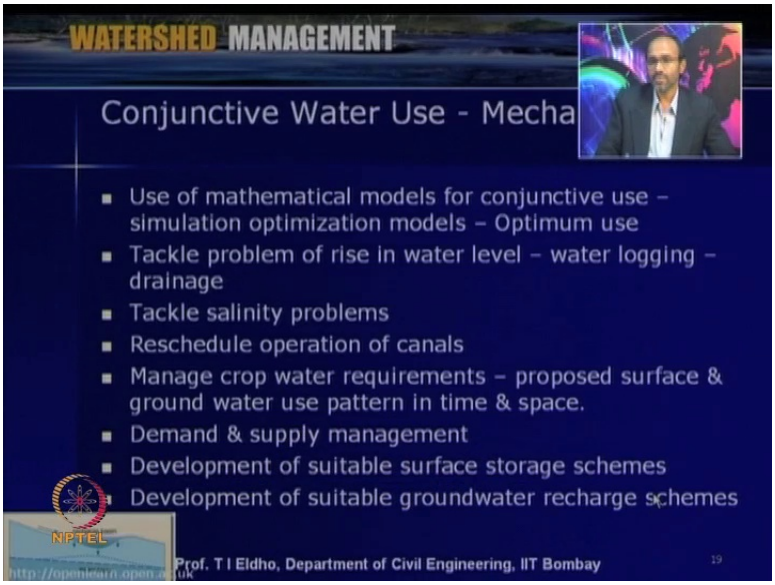

Now say let us see, what are the important mechanisms through which we can adopt through conjunctive water use. Some of the mechanisms, I have listed here like we can develop mathematical models for conjunctive use. Like considering the simulation, as far as the hydrological aspects, ground water aspects, and then we can go for optimizations. So, that we can I mean meet the demands and supply and so that we have to optimum use. We can develop an appropriate mechanism through mathematical model, as far as the conjunctive use is concerned then we have to we can tackle problem for rise in water level. So that water logging a problem can be reduced, this will be through use of ground water or development of appropriate drainage plans.

Then we can tackle the salinity problems say, depending upon the area then reschedule the operation of canals, that appropriate mechanism can be developed. Then manage crop water requirement proposed surface and ground water use pattern in say depending

upon the location. I mean in space and in time. So, we can develop appropriate management plans.

Finally, say in all these we can do conjunctive use is demand and supply management. So, that sustainable development is or sustainable management is possible. That development of suitable surface storage schemes a small scale or large scale, then development of suitable ground water recharge schemes. That surface surplus water available in the monsoon season rainy season can be utilized for artificial recharge.

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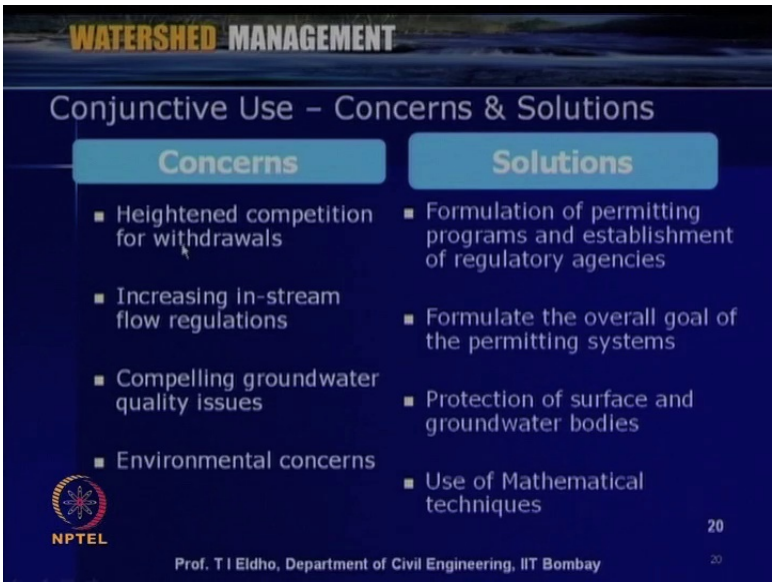

Now, let us see as far as conjunctive use is concerned, what the major concerns are when we implement when we go for conjunctive use. And then what are its solutions? Say for example; say as far as say surface water ground water is concerned, where you heightened competition for withdrawals depending upon the area watershed say between the stakeholders. So, that the solution will be can formulate a permitting programs and establish appropriate regulatory agencies and water user groups and say that kind of mechanism. So, that the problems can be reduced.

Then increasing in-stream flow regulations say, we can go for formulates the overall goal of permitting systems. We can develop, then compelling ground water quality issues. Ground water quality we have to keep so, that way we can go for protection of surface and ground water bodies. Then environmental concerns, we can say develop areas plans

and then say assess those plans through mathematical techniques. We can find out appropriate plans and then implement it and then find the appropriate measures. Then say as we have discussed always modeling helps in conjunctive management.

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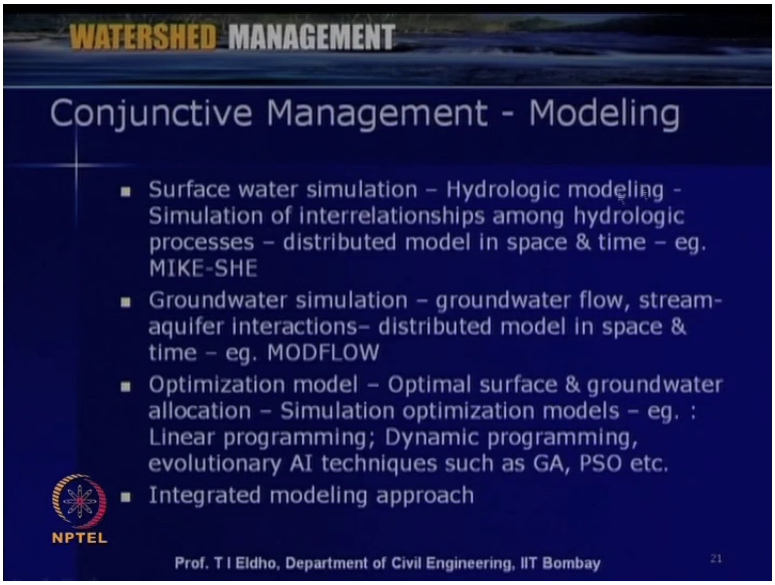

If we consider surface water is concerned, we have to we can go for surface water simulation using hydrologic modeling. Then simulation of inter relationships among various hydrological processes, we can go for distributed or lumped models in space and time. Say for example, available models like mike-she over other models we can utilize. Then ground water is concerned, we can we have to assess the ground water availability quantity and then also the quality issues also we have to deal. So, ground water flow stream aquifer interactions, though we can go for distributed models in space and time. Say like model like mudflow will be very useful. Even mudflow can take here with respect to the interaction of surface water and ground water also, and then say as far as optimal use is concerned, optimization model like optimal surface and ground water allocation.

Then simulation optimization models say like optimization model, like a linear programming dynamic programming. Then evolutionary algorithms like a genetic algorithm, particle sum optimization, like that we can utilize the AI techniques also as far as optimization is concerned.

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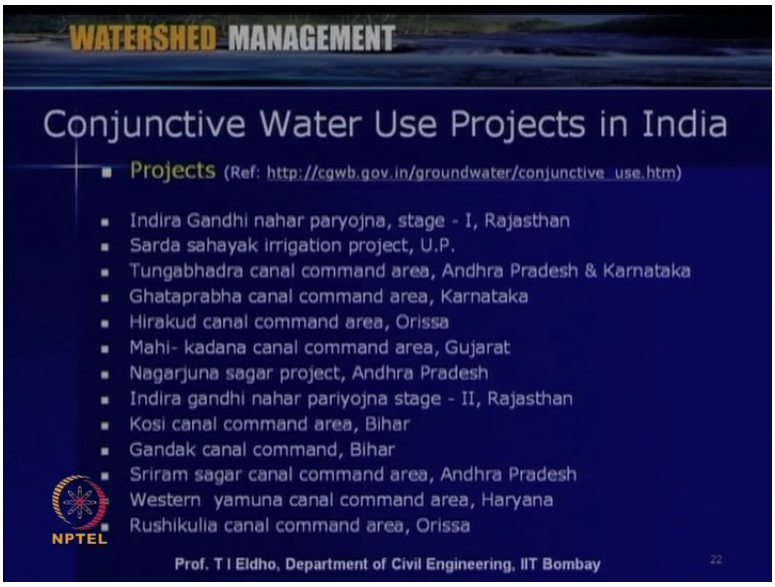

Then we can integrate both the simulation and optimization model so, that we can have better modeling tools, as far as the conjunctive management is concerned. Now say as far as India is concerned, conjunctive water use say there are numbers of projects have been implemented at various locations. And a central ground water board and central water communication or monitoring of these projects, and lot of funding are also given for these types of projects. Some of the important projects, I have listed here.

These projects details are available in the central ground water board website. Like indira gandhi nahar paryojna project, then sarda sahayak irrigation projects in UP, tungabhadra canal command area, then ghataprabha canal command area, hirakud canal command area. So, like that numbers of projects are listed under the conjunctive water use plans and these details are available in the central ground water board websites.

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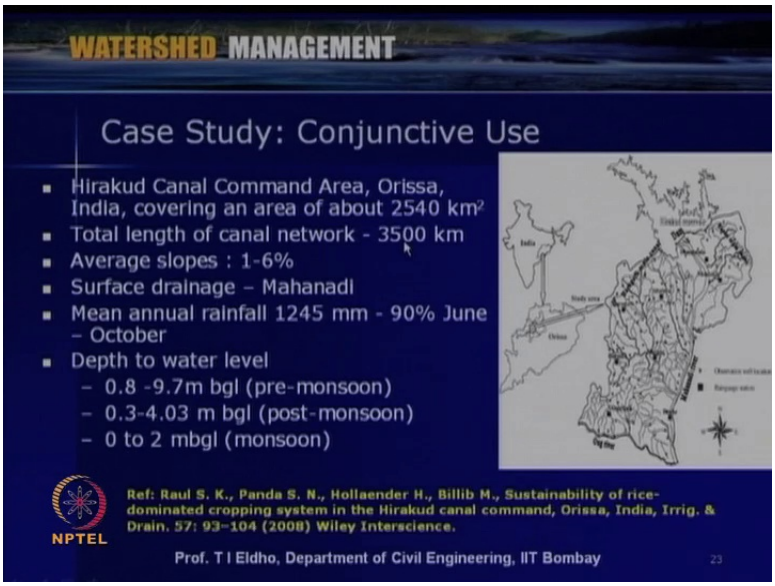

Before closing today's lecture, let us briefly look into one case study. As reported by in the website of central government water board and reported by raul and others in their paper. The case study of conjunctive use is the hirakud canal command area in Orissa, covering an area of approximately 2540 square kilometer. You can see that this is Orissa state and this is the catchment area. And total length of canal network is about 3500 kilometer. This area is concerned average slope is 1 to 6 percent and surface drainage say mainly the Mahanadi and its tributaries the river network.

Then mean annual rainfall in the area is approximately 1245 millimeter. And most of these rainfalls are obtained during June to October monsoon season. Then say the depth to water level is concerned in most of these area the during pre-monsoon, the water below ground water say is pre-monsoon to varies from location to location 0.8 to 9.7 meter. Post-monsoon it varies from 0.3 to 4.03 meter and during monsoon the water level rises. So below ground level, it is varying from 0 to 2 meter during monsoon reason.

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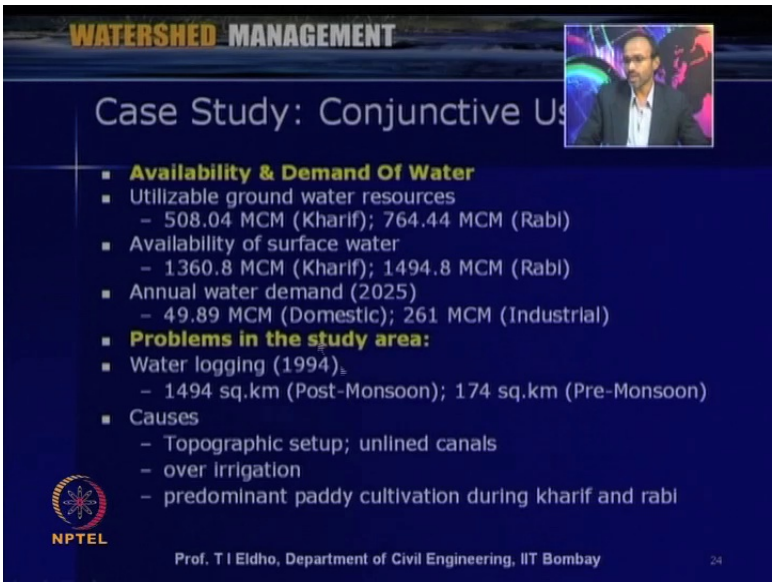

That way says, larger area is water logged especially in monsoon season. As far as availability and demand is concerned utilizable ground water resource is about 508 million cubic meter in kharif season. I mean during say the rainy season, then 764 million cubic meter in rabi season. I mean in say, after the rainfall the during the summer season. So, availability of surface water is 1360 million cubic meter and 1495 million cubic meters during rabi season.

And annual water demand is say about say 2025. And then other demands like say, 50 million cubic meter for domestic then 261 million cubic meter for industrial. by 2025 this will say the demand increases. some of the problems in the study area is water logging as per 1994 statistics post monsoon about say 1400 or 1500 square kilometer or say water logging problems are reported. And pre-monsoon 174 square kilometer is reported. Like some of the causes include topographic set up, say less slope in the area unlined canal systems, over irrigation, then predominantly paddy cultivation in this area.

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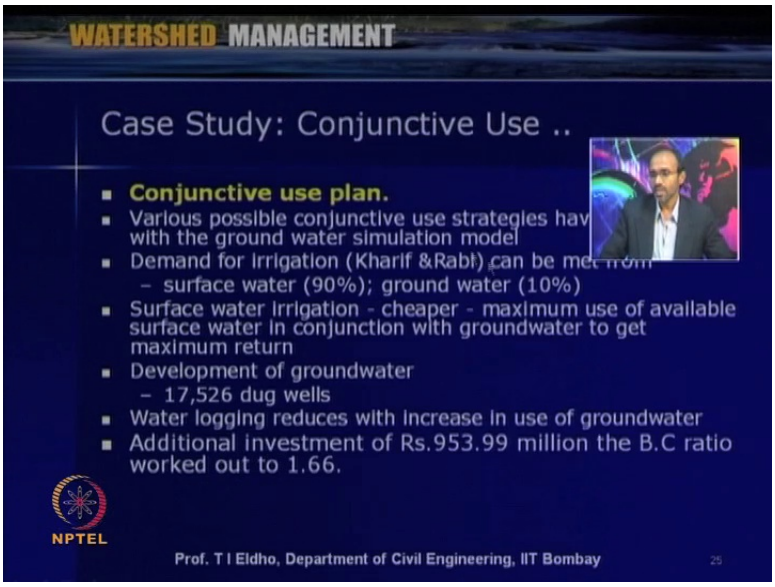

These are the some of the courses; as far as problems in this area are concerned like water logging salinization. Then conjunctive use detail plans were made. So, various possible conjunctive use strategies have been tested, with ground water simulation model in the area a model has been developed by the authorities. Then demand for an irrigation kharif and rabi can be met from, the surface water about 90 percent of the demand can be met from the surface water and ground water about 10 percent. This is one of the optimal plans. Then surface water irrigation cheaper, in this say this is water is readily available.

Maximum use of available surface water in conjunction with ground water to get maximum return. That is some of this plans were developed. And development of ground water, as say as the development a large number of dug wells are proposed say more than 17500 dug wells are proposed. And then the studies showed that water logging reduce with the increase in use of ground water. For this, huge capital investment is needed. About 95 million rupees required for this additional investment as far as this conjunctive use plan is concerned. And, but of course, the once this is invested than within few years time the benefit cost ratio say worked out to be more than 1.6

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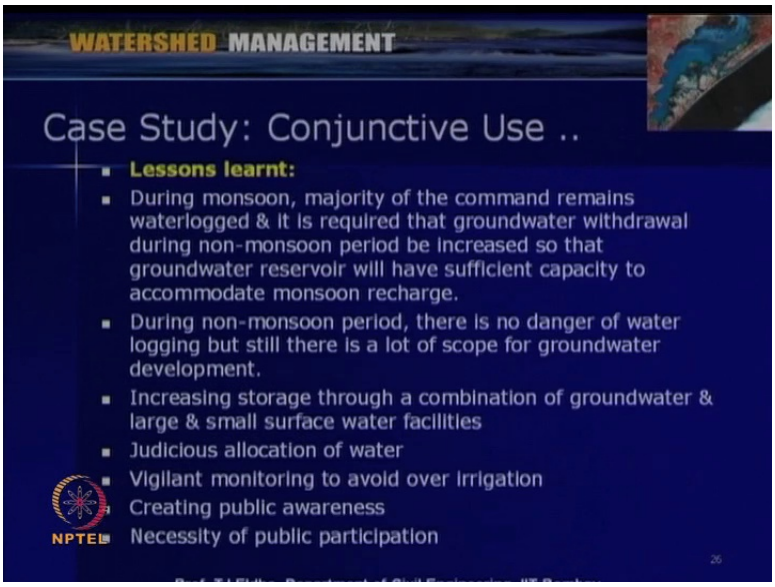

Some of the important lessons learned from this case study include say, during monsoon majority of the command remains water logged and it is required that ground water withdrawal during the non-monsoon period be increased. So, that ground water reservoir will have sufficient capacity to accommodate the monsoon recharge. Whatever the water is say, more water available during monsoon season that we want to recharge. That way recharge plans were made for this case study. And during non monsoon period, there is a non danger of water logging, but still there is lot of scope for ground water development.

As I mentioned say as per the optimal plans 90 percent should be utilized from the surface water, 10 percent from the ground water. Lot of scope is there to say for groundwater development. Then increasing storage through combination of ground water and large and small surface water facilities. So, that is say more say recharging for the aquifer system and judicious allocation of the water. That is one of the plan, which we have seen 90 percent say from the surface water and 10 percent from the ground water. And then area wise also, we have to see judicious allocation then vigilant monitoring to avoid over irrigation then creating public awareness. That is very important in these kinds of conjunctive use projects, then necessity of public participation.

We the farmers should participate in the say the project. Otherwise, we cannot achieve the optimal plans as far as the conjunctive use is concerned.

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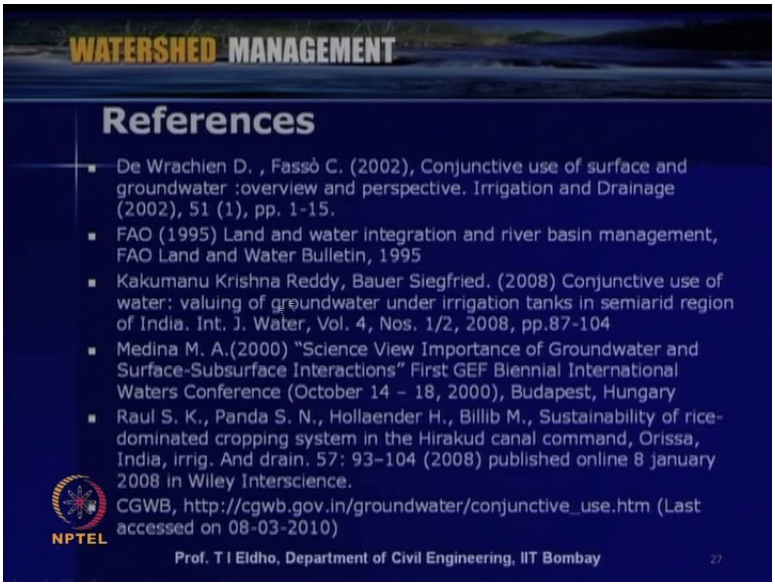

Some of the important references used in today's lecture are listed here, related to the conjunctive use. Then say before closing say, some tutorial questions assignment and self evaluation questions are here.

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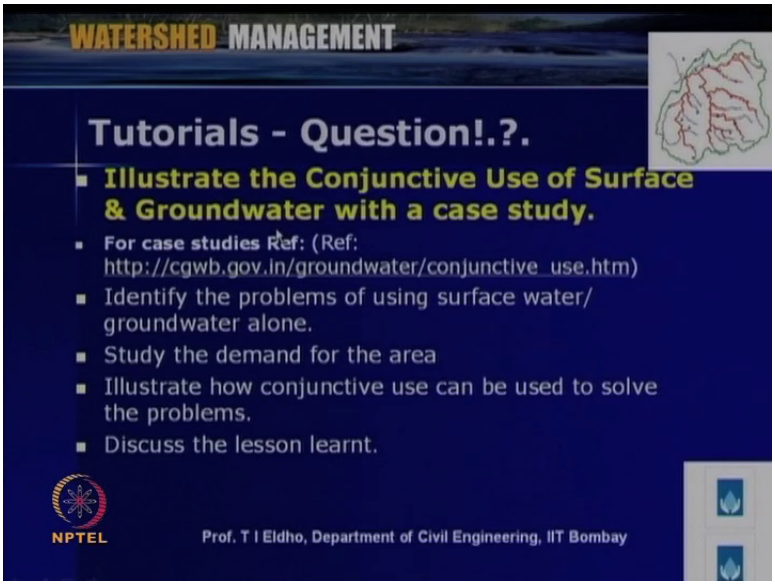

The tutorial question illustrates the conjunctive use of surface and ground water with a case study. As I mentioned this website of central ground water boards number of case studies is listed. So, you can go through it and develop a case study for conjunctive use. In the case study, we can identify the problems of using surface water only or ground water only. Then study the demands for the area, which is we are looking as a case study. Then illustrate how conjunctive use can be used to solve the problems for the area. Then say you can discuss what are the lessons learned, as far as that area is concerned.

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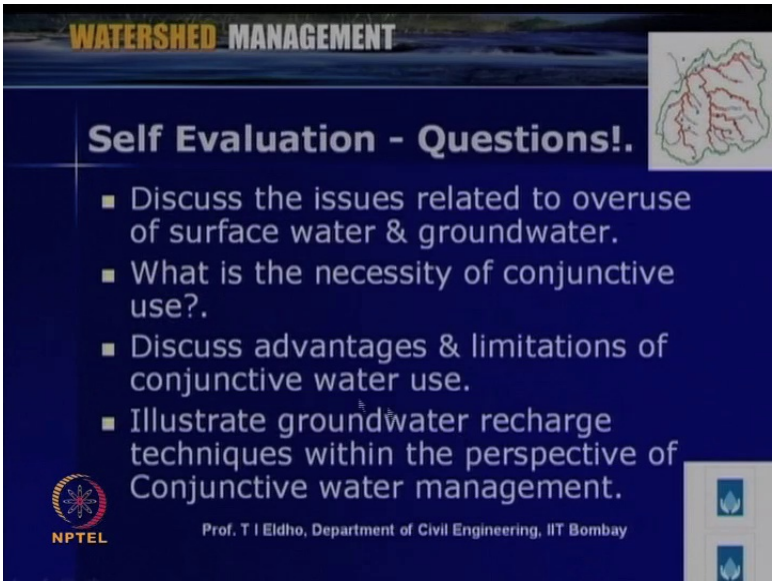

Then few self evaluation questions, discuss the issues related to overuse of surface water and ground water. What is the necessity of conjunctive use? Discuss advantages and limitations of conjunctive water use. Then illustrate ground water recharge techniques within the perspective of conjunctive water management.

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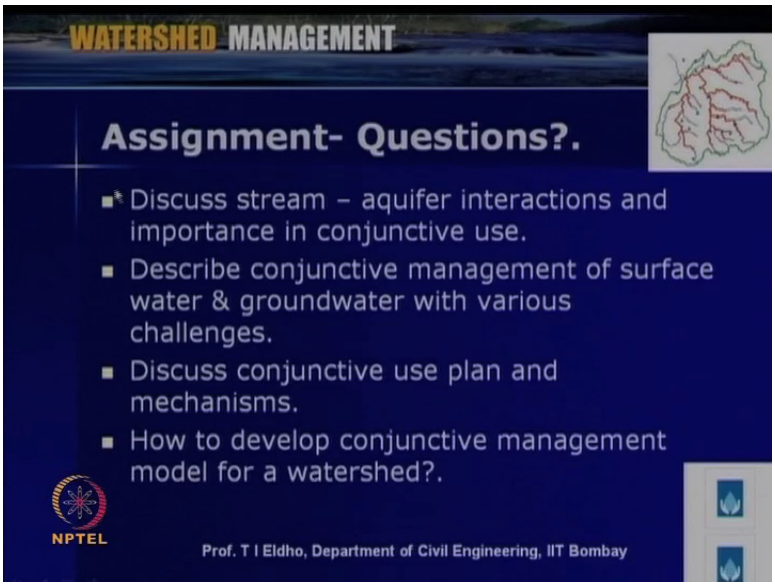

Most of these issues related issues we have discussed in today's lecture. Then few assignment questions, discuss stream aquifer interactions and importance in conjunctive use. Describe conjunctive management of surface water and ground water with various challenges. Discuss conjunctive use plan and mechanisms. How to develop conjunctive management model for a watershed?

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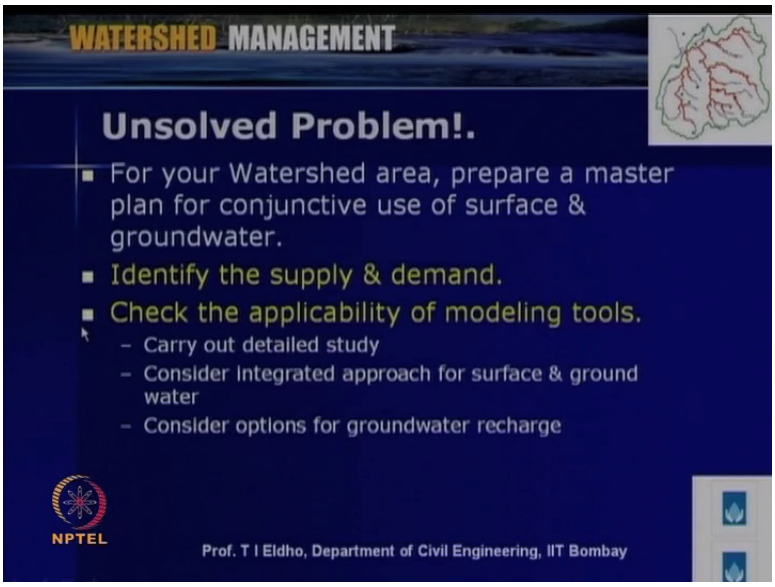

Related topics also we have discussed in today's lecture. Finally, just like an unsolved problem for your watershed area say, you can prepare a master plan for conjunctive use by considering the surface water and ground water. You can assess for that particular area, how I considering the irrigation demand. And then other demand say, what is the how much is water is demand is there. And how much is the supply from various sources like surface water sources or ground water sources. And then say, we can we can develop an appropriate model say by considering the ground water and say surface water. We can conduct detailed studies and develop an appropriate plan.

An integrated approach for surface and ground water by using the mathematical modeling. Then say, we can look into the various options for ground water recharge for the particular area is concerned. So, say this you can try for your watershed area. So now, with this today's lecture is over. Further, we will discuss the rain water harvesting and top water harvesting in the coming lectures in this module, thank you.