Watershed Management

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Module No. # 03

Lecture No. # 11

Rainwater Harvesting and Roof Catchment System

Namaste and welcome to the video course on Watershed Management. In today's lecture; module number: three, lecture number: eleven, we will discuss the rainwater harvesting systems and roof catchment.

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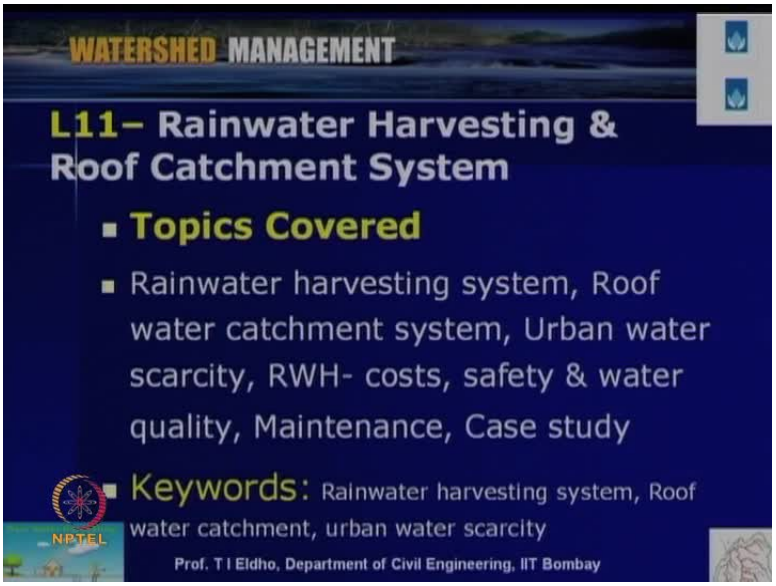

So, some of the topics covered today will be rainwater harvesting system, roof water catchment system, urban water scarcity, rainwater harvesting system-costs, safety and water quality, maintenance and two case studies. Some of the important key words for today's lecture include rainwater harvesting system, roof water catchments and urban water scarcity.

So, in the last lecture we were discussing about the rainwater harvesting systems. So, we have seen that the rainwater harvesting systems can be of three types. One is the rooftop

based; second one is the open space; like, what is there in say open areas, gardens and other place. And then, third type can be the watershed based.

So, depending upon the area where we have to go for the rainwater harvesting system, we can have a one of this or an integrated approach by considering either rooftop and the open space or combining all these within the perspective of a watershed management within the watershed.

So, we have seen the details about the various hydrological, hydrogeological aspects. And then, also the artificial recharge aspects as far as the, especially rainwater harvesting in open areas and the watersheds related issues we have seen in the last lecture. So, one of the important aspect of rainwater harvesting, especially in cities in water scarce areas like arid and semi-arid regions, islands and coastal regions is rooftop based rainwater harvesting.

So, the various design related issues we have already discussed as far as the rainwater harvesting is concerned. So, today we will concentrate on the rooftop rainwater harvesting. So, rooftop rainwater harvesting as we have discussed in the last lecture, it is a technique through which rainwater is captured from roof catchments and stored in reservoirs.

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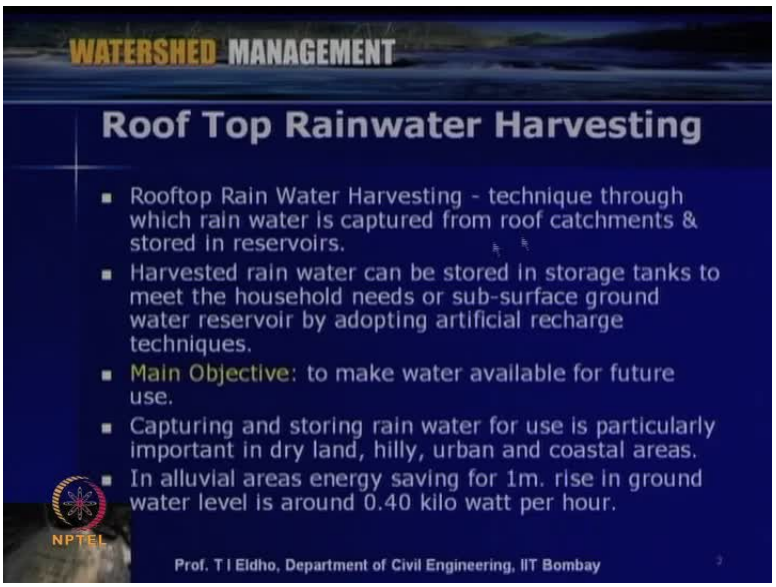

So, here the rainwater harvesting system, we are harvesting the rainwater either from the roof or the open space or on a watershed scale. So, as far as rooftop catchment is concerned, so we consider rooftop as the catchment and we capture this water and collect it and then either store it for the direct use. So, harvested rainwater can be stored in storage tanks to meet the household needs directly; say especially in dry region, arid region or semi-arid regions or coastal regions or islands, so where water problem is there. Or, we can also recharge to the subsurface; I mean, as ground water. So, it will be recharged to the ground water system by adopting the artificial recharge techniques.

So, it is other than the natural recharge. So, we are providing specific structures, so that there would be more recharge, so-called an artificial recharge will takes place. So, the main objective of rooftop based rainwater harvesting is to make water available for future use. So, as we have discussed, say the rainfall is concerned, it may be available only for few months say in India, say for example, three to four months most of the places and then the spatial variation.

So, whatever, whenever rainfall takes place we are trying to capture it through harvesting. And, then we, so that we can use it for future use say in the dry season, so that sufficient water will be available.

So, capturing and storing rain water for the use is particularly important in dry land. As I have already mentioned, hilly regions where say immediately after rainfall, all the water drains out due to the high slope. Then, urban and coastal regions; so, coastal regions especially say in a ground water say wherever the aquifer is affected by the sea water ingress, there we can directly harvest this say rainwater and then directly use from the rooftop or we can recharge to reduce the sea water ingress.

So, now in alluvial areas, say for example, if you can recharge, so other than directly utilize, if you can recharge and then in say, if there is a raise of water table say by 1 meter, then say the pumping cost can be reduced by 0.4 kilowatts per hour.

So, that way, it will be also... energy saving will takes place. So, if you can recharge and then in the aquifer system in the water table raises, then definitely there is the saving of the energy so that, what will be used for the pumping purpose.

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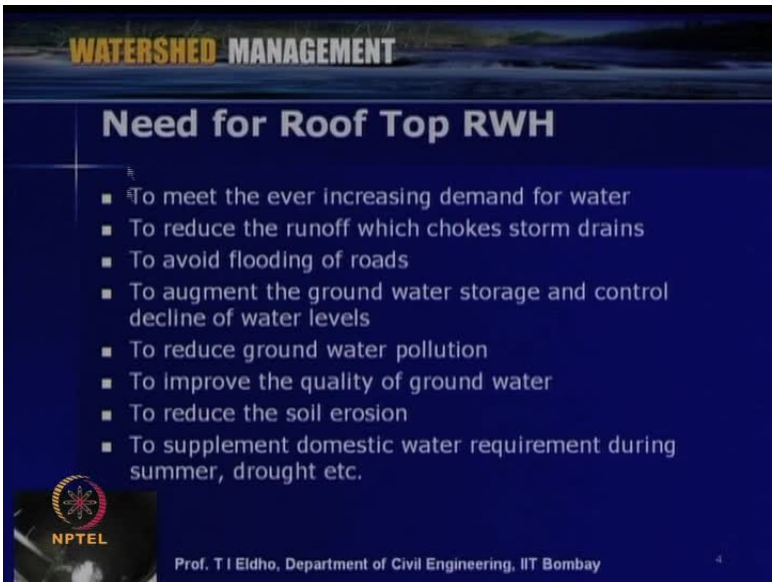

So, within the perspective of rainwater harvesting, we have already seen the various aspects of rainwater harvesting. Now, within the perspective, rooftop rainwater harvesting. So, why we need to go for rooftop based rainwater harvesting? So, some of the needs are listed here.

To meet the ever increasing demand for water; say especially in city regions and say arid and semi-arid regions, and with the increasing population and industrial developments, the water increase is growing up. So, that way we can say, other than the natural recharge either we are recharging further through artificial means or we are storing the rainwater directly. Then, to reduce the runoff which chokes storm drains.

So, you can see that especially in urban areas like a, city like Mumbai and other coastal cities, in most of the monsoon season there is flooding problem. So, if you can, say reduce the runoff coming from the urban areas by means of say rainwater harvesting, then we can see that the, whatever the runoff coming through the drains will be reduced. And, that way we can reduce the flooding problem. So, that way to avoid flooding of roads and other areas, so that would be an indirect advantage of this rainwater harvesting.

Then, to augment the ground water storage and control decline of water levels. So, as we discussed, so when we are doing the recharge other than the natural recharge through

artificial means, then we are increasing the recharge, then the ground water levels goes up. So, that is another need.

Then to reduce ground water pollution, so the rainwater is one of the purest form of water. So, without any kind of pollution, so if we can recharge that water to the ground water, then whatever the polluted ground water will be, the pollution will be decreased.

Then, to improve the quality of ground water; so, that way we can improve the quality of ground water. Then, to reduce the soil erosion; especially, say in open areas or a watershed, if you can provide the various structures for artificial recharge, then we can see that soil erosion can be reduced. And moreover, say when the, say the water flowing through the, say coming from the rooftop is reduced through means of rainwater harvesting. Then also the flow will be, runoff will be reduced. So, that will also give the advantage of reducing the soil erosion.

Then, to supplement domestic water requirement during summer, drought, etcetera; so, if you are directly storing the rainwater in tanks or say other structures, then we can directly utilize that water for the drought period or summer season. And, so that way, say two aspects. One is directly storing in tanks or other structures or we can recharge. So, that way, there are number of say advantages and then these are some of the important needs as far as the rooftop based rainwater harvesting is concerned.

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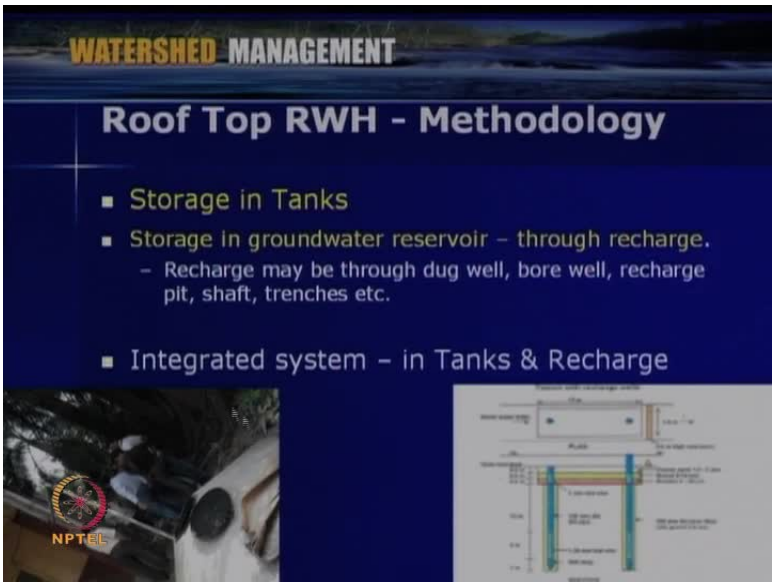

So, as I mentioned, the rooftop rainwater harvesting can be of two types. So, the methodology can be, so directly we can store in tanks. So, you can see that, whatever directly coming from the, in the building, they can collect through the gutters, the pipelines and then directly save. After filtration, we can store it in a tank as shown in this photograph and then directly we can utilize.

And, the second way is, say the storage in ground water reservoir. So, what we can do? We can collect the rainwater and then, say after some filtration we can pass into various recharge structures like dug well, bore well, recharge pit, shaft, trenches, and etcetera. And, that can be put into this, so that, so it will be recharging to the aquifer system. So, that is another way as far as the rooftop based in water harvesting is concerned.

And then, say depending upon the area we can go for both. I mean an integrated system, say some part of the water can be collected in tanks and some water can be used for recharging to the aquifer system. So, an integrated approach is also possible as far as rooftop rainwater harvesting is concerned.

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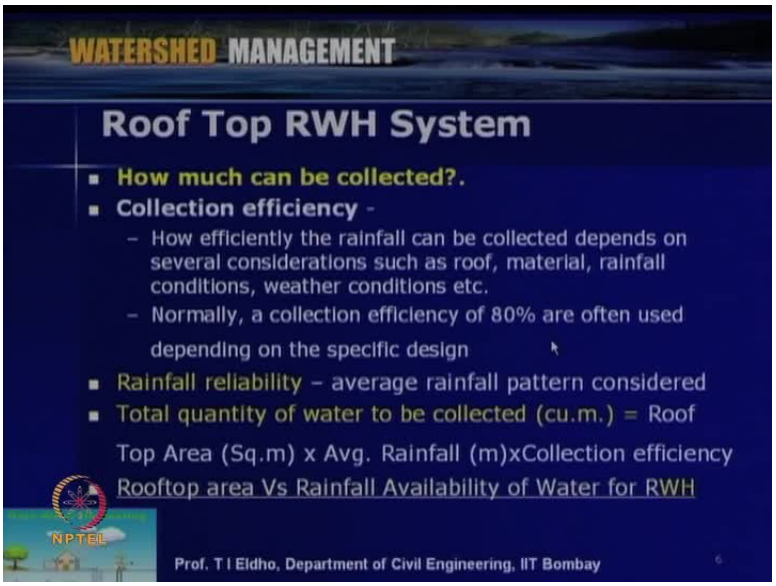

So now, say we have already discussed rainwater harvesting system and its design aspects in the last lecture. So, very similar way as far as rooftop rainwater harvesting system is also concerned. Say, we have to see how much area is there from which water can be collected. And then, how is the rainfall pattern and then how much is the in the

collection efficiency are depending upon the runoff coefficient. We can identify how much water can be collected for a given rooftop area. So, the question is how much water can be collected as far as rooftop rainwater harvesting system is concerned. So, this depends upon the collection efficiency as I mentioned.

So, how efficiently the rainfall can be collected depends on several considerations such as what kind of roof, what kind of roof material, what is inclination of the roof, etcetera. And then, what are the rainfall conditions, what is the intensity of rainfall, what is the duration of the rainfall like that. And then, weather conditions like what is the temperature, what is the humidity. So, depending all these conditions, say the collection efficiency varies from place to place and also it depends on the season.

And then, normally, say for normal conditions we can see that about eighty percentage collection efficiency. We can achieve depending upon the specific design. So, if, say for example, if thousand millimeter rainfall is annually available, we can store, say we can think of harvesting about eight hundred millimeter of this rainfall for a given, say the rooftop catchment.

And then, as I mentioned, the collection… The… how much can be collected depends upon the rainfall reliability. So, that means average rainfall pattern and what is the intensity duration, etcetera. So then, say as far as a catchment is concerned, the rooftop is concerned, we can find out total quantity of water that can be collected in cubic meter is equal to rooftop area, say in square meter multiplied by average rainfall, say annual rainfall into collection efficiency.

So, this equation gives how much water can be collected as far as rooftop based rainwater harvesting system is concerned. So, you can see that. See, if collection efficiency, say for example, if it is 80 percentages or 0.8, then say how much be collection depends upon the rooftop area and then rainfall availability, say as far as that particular location is concerned.

So, we can prepare, say depending upon the rainfall pattern and how much roof area. So, that is constants. So, that way we can identify when we design a rooftop based rainwater harvesting system is this much water can be either collected in tanks or this much water will be available for the artificial recharge.

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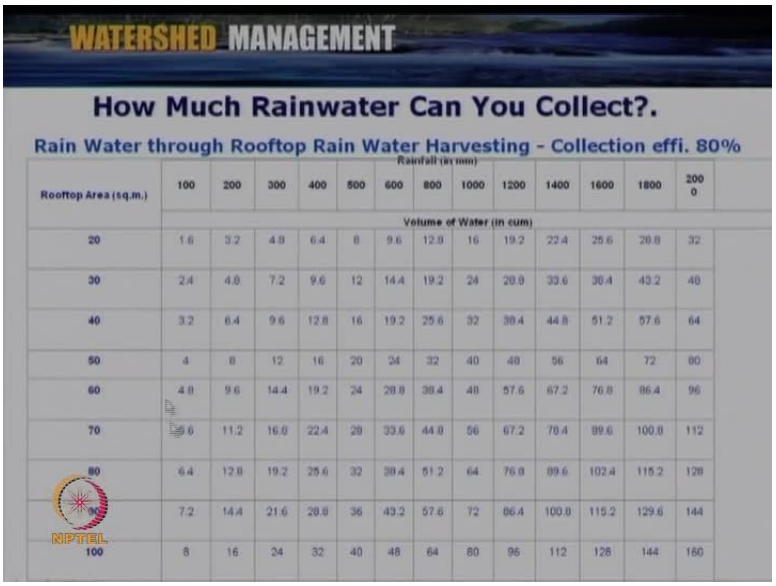

So, that way we can have a table, say for various rooftop areas and though for various rainfall, annual rainfall conditions. So, if you assume a collection efficiency of 80 percentage, we can prepare a table like this. And, directly we can identify how much volume of water, say in cubic meter can be harvested, say as for the even rooftop area. So, that way we can directly identify.

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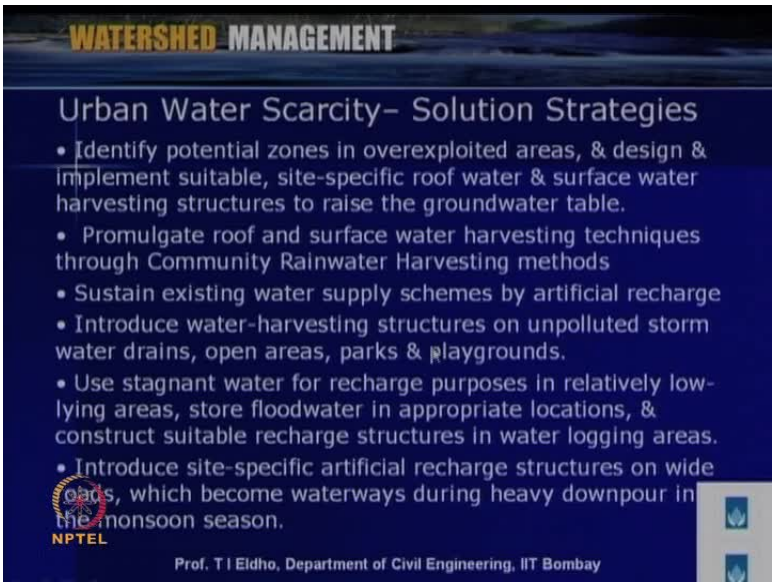

So now, say before going further as far as the various design aspects of rooftop rainwater harvesting system, so let us have a brief look into the urban water problems. So, what are the Solution Strategies?

So, many of the urban cities, especially say for example, in a… where developing countries like India, say cities like Delhi, Chennai, all these cities have water scarcity problem. So, say especially the areas where directly the water is obtained from the ground water system. So, this, say rain, the rooftop based rainwater harvesting system is a good technology as far as the, to solve the water related problems.

So, we can use, say the solution strategies. As far as solution strategies are concerned, we can identify the potential zones in overexploited areas. And, design and implement suitable site-specific roof water and surface water harvesting structures to raise the ground water table.

Say, this is very much possible in places like Chennai, Delhi, Chandigarh, etcetera; where, so much of groundwater is used for the domestic and industrial purposes. Then, as another strategy we can promulgate roof and surface water harvesting techniques through community rainwater harvesting methods.

So, it is, say the initiative should be community based initiative. So, all the people should come in, say come together so that, say village or city based, say for particular city based or urban watershed based scheme we can develop. So that, we can, that will be a solution as far as the urban water scarcity is concerned.

Then, sustain existing water supply scheme by artificial recharge. So, as I mentioned, say for example, due to the efforts of various Government and Non-Government organizations in places like Delhi and Chennai in the last few years, say huge efforts were put as far as the rainwater harvesting is concerned. So, that you have as shown good impacts as far as the water availability is concerned. Especially, cities like Delhi and Chennai. So, that way we can sustain existing water supply scheme by artificial recharge.

And then, introduce water harvesting structures on unpolluted storm water drains, open areas, parks and playgrounds so that, so other than the normal infiltration taking place

recharge taking place to the aquifer system. And, we are increasing their recharge through various means. So, that way we can, say increase the water availability. And, that will be a solution strategy as far as urban water scarcity is concerned.

And then, use stagnant water for recharge purposes in relatively low lying areas, store flood water in appropriate locations and construct suitable recharge structures in water logging areas.

So, if you can store water for say with some pressure, then you can see that more recharge will be taking place to the aquifer system. So that, that will increase the water table, ground water table. And, that can be another solution strategy as far as urban water scarcity is concerned.

Then, we can introduce site specific artificial recharge structures on wide roads, which become waterways during heavy downpour in the monsoon season. So, actually this technique has been implemented by Delhi Government, in many parts of Delhi state, especially on road sides. So, that has been found to be very successful.

So, since lot of area is there and that area we can stop the water and then allowed to recharge to the to the ground water; so, that where the ground water table level will be increased.

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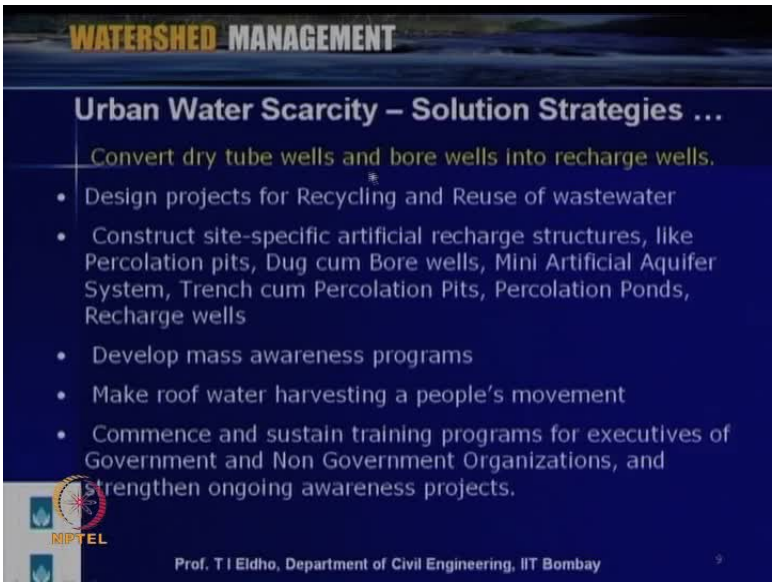

So, then some of the other solution strategies include, convert dry tube wells and bore wells into recharge wells. So, we can see that due to over drafting of the water from the ground water system many of the tube wells and bore wells goes into dried condition, so that tube wells and bore wells, we can utilize for, utilize as recharge well. And then, design projects for recycling and reuse of wastewater. So, recycling and reuse and water conservation we will be discussing in detail in the later part of this course.

So, we can also say use the various techniques as far as recycling and reuse is concerned. Then, construct site specific artificial recharge structures like a percolation pits, dug cum bore wells, mini artificial aquifer systems, trench cum percolation pits, percolation ponds, recharge wells, etcetera.

So, then another important aspect is that, say rain is, say obviously, say as per, say average annual rainfall condition most of time, most of the years, it will be available. And, area is there of rooftop as a catchment is available. So, only thing is that people have to actively do this rainwater harvesting schemes at various locations. So that, many times people do not understand or do not know what are the advantages of such systems.

So, it is always better to go for a mass awareness programs, either Government level or Non-Government of to say organizational levels or education institutions level, so that a mass awareness comes, more people will be interested in this kinds of rooftop rainwater harvesting or other types of rainwater harvesting systems.

Then, make roof water harvesting as a people movement. So, actually, say this is what is happened in Chennai and other regions in Tamilnadu. So, due to, say the various Government rules and regulations plus say lot of awareness program, mass movement has been taken place in the last few years in Chennai and other regions in Tamilnadu. And then, we can see that most of the, say houses or most of the land areas where rainwater harvesting is possible, many locations is it has been done. So, that way, if you can make the rooftop or rainwater harvesting as a people movement, then it will be a huge success.

Then commence and sustain training programs for executives of Government and Non-Government Organizations and strengthen ongoing awareness projects. So, say many of the, say agencies, say which are not so familiar or not experts in the area of rainwater

harvesting, say various agencies who are expert in this rainwater harvesting schemes can give training programs, then say give a seminars, lectures, etcetera. So that, this awareness can be improved, say can be spread to all the public and the Government organizations. So, that will lead to the rainwater harvesting schemes.

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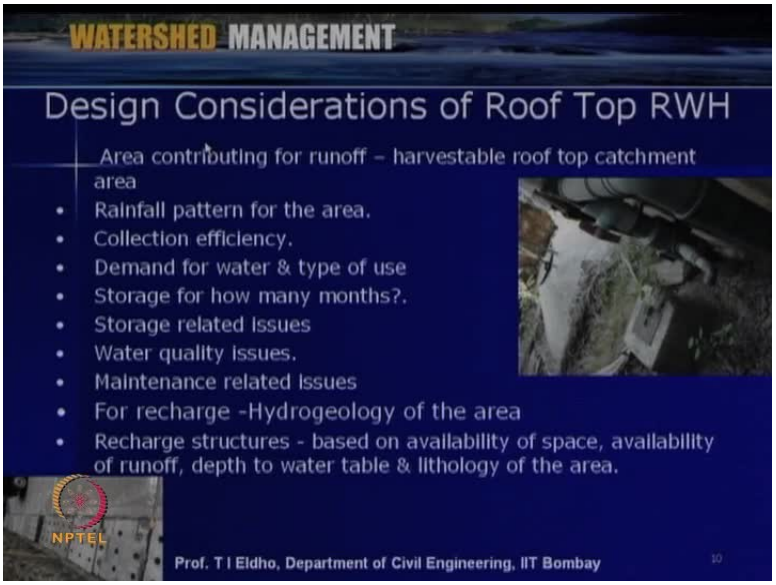

So, that way if you, when it becomes a people movement, definitely the efforts will be much better. So now, let us see what are the important design considerations as far as rooftop rainwater harvesting is concerned.

So, as we have already seen, depends upon how much is the area, how much is the rainfall and how much is the collection efficiency. So, based upon these three important aspects, some of the design considerations I have listed here. So, first one is area contributing for runoff, so that means the harvestable rooftop catchment of the area.

Then, rainfall pattern for the area; so, whether it is four months or eight months or how many months per year and how many days in a year and then what is the intensity of rainfall. Then, collection efficiency; so, as I mentioned whether it is a, say we can achieve about 80 percentage in as far as rooftop rainwater harvesting is concerned. And but, when it goes to say open space, it will may go to 50 to 60 percentage and then in a, say watershed based, say rural rainwater harvesting is concerned. It may be 30 to 50 percentage. So, like that, say the collection efficiency varies.

Then, demand for water and type of use; so, say in especially arid and semi-arid regions, so where the rainfall is very less, then whatever rainfall is there we can go for harvesting it. And then, we can say improve the water availability. So, this is a typical examples what is done by mister Rajendra Singh in Rajasthan villages, many of the Rajasthan villages where massive rainwater harvesting is done so that the… say even for arid regions or semi-arid regions we can make it the water availability better.

And then, another important aspect is the type of use. Type of use means, whether the water which we are harvesting, say especially rooftop rainwater; what we are harvesting, whether it is using for domestic purpose like drinking and other purposes or whether we are using only for agriculture purposes or for recharge purposes. So, like that, depending upon the type of use we have to have better schemes. Say for example, if we are going for the say domestic purposes, then we need the pure water.

So, that way, we have to go through cycle of say filtration, then say disinfection either through using say chlorination or ultraviolet systems and then maybe we have to again further go for boiling. So, like that depending upon the type of use, the design considerations will change.

Then, another issue is how, say for say for example, in a city like a Mumbai where we are having rain for four months, then say we can decide for how many more months we want to either store water for the dry months, dry period. So, we have to decide for how many months we have to go for storage.

Then, storage related issues; so, as I mentioned, whether we are going to store in a, say tanks like ferrocement tanks or sintex tanks or what kind of tanks. So, depending upon that, we have to do the design.

Then, we have to see the water quality issues. So, as I mentioned, say if the roof is concrete, then the water will be much better. But, if it is asbestos roof we have to be very careful. So, like that the quality of the water available, what is harvested, that also we have to take care.

Then, what kind of maintenance we have to go for the particular system? That depends upon the design. So, whether we go for a very good design with all the aspects, then the

maintenance required will be say maybe once in a year or two times in a year. But, if the design is poor, maybe on weekly basis or monthly basis we may have to do the maintenance.

Then, say as far as recharge is concerned; when we are designing a recharge structure, then we have to see that the hydrogeological aspects. So that, how much water can be put to the aquifer system through various schemes like recharge pit or tube well or bore wells. So, this depends upon the hydrogeology of their area.

So, then recharge structures is based on the… Recharge structures are based on availability of space, availability of runoff, depth to water table and a lithology of the area. So, these are some of the important design considerations as far as rooftop rainwater harvesting is concerned.

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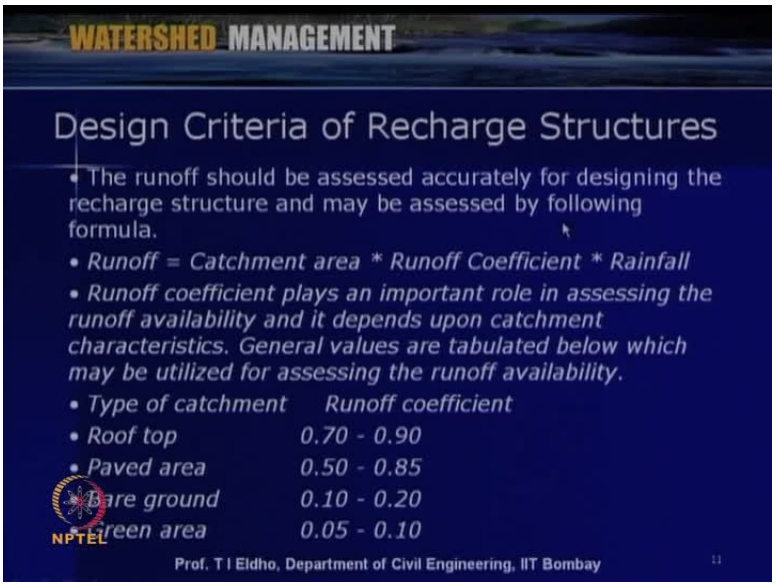

So now, as far as design criteria, say if you are going to do a recharge for a particular area, then we have to see the various aspects. Then, say the runoff should be assessed accurately for designing their recharge structures. And then, may be assessed by the following formula, which we already seen. Runoff is equal to catchment area into runoff coefficient into rainfall.

And then, runoff coefficient plays an important role in assessing the runoff availability and it depends on upon the catchment characteristics. So, this how issue, we have seen in

the last lecture. So, depending upon the type of catchment, the runoff coefficient varies. Say for example, depending upon the type of roof this can vary from 0.70 to 0.90. And then, paved area; it can vary from 0.50 to 0.85. Bare ground is 0.10 to 0.20. Green area is 0.05 to 0.01. So, like that, these runoff coefficients can vary from area to area.

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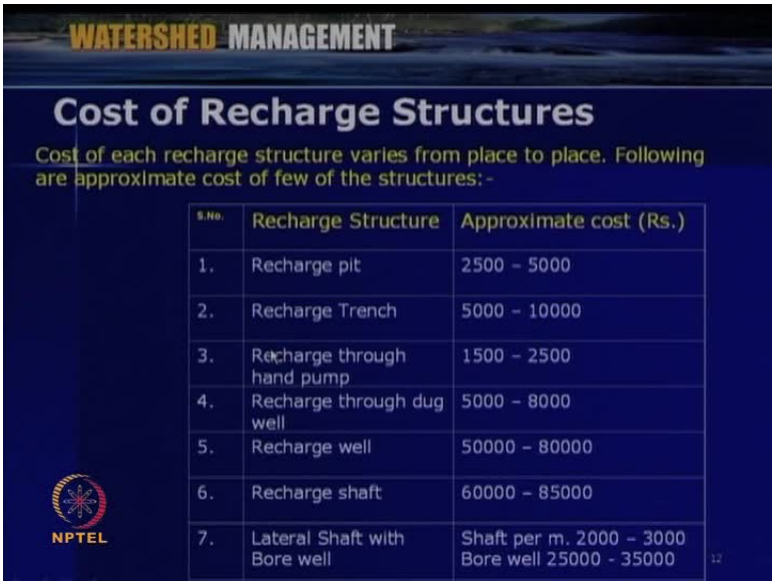

So now, say when we are going to for, especially for recharging the aquifer system, so we have to design the specific recharge structures. So, we have seen various structures like, whether it is a recharge pit or recharging trench or say bore well or dug well, so like that. So, the cost depends upon various conditions. So, like that the locality; that means in cities the cost may be more; in rural area cost will be less.

Then, say what kind of soil or what kind of geological nature as far as when we are making a pit or a trench. So, the cost of each recharge structures vary from varies from place to place. Say, some of the approximate cost I have listed here. So, like recharge pit it may vary from rupees 2500 to 5000; recharge trench vary from 5000 to 10000. So, like that, say this is I cannot specifically say that this will be the correct cost as far as a structure is concerned. So, this varies from location to location and then depending upon the soil geological and other parameters.

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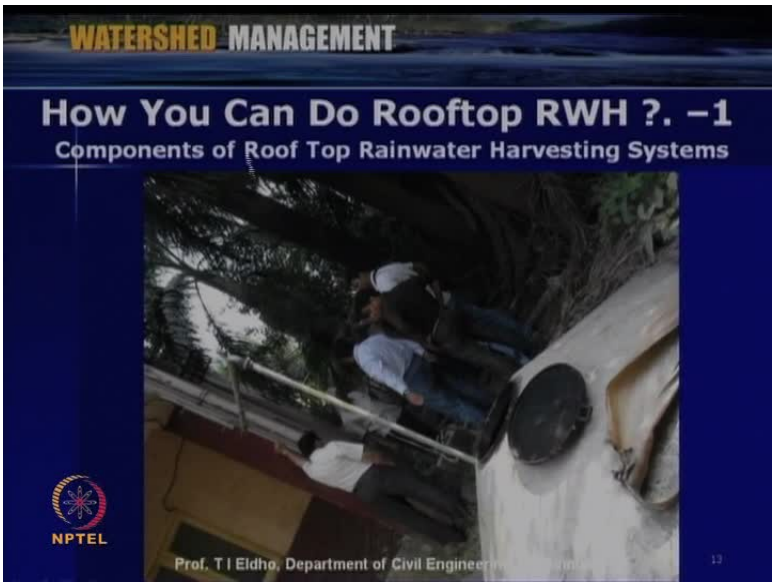

So now, within this perspective, within the issues, which we have discussed, now let us see how we can do rooftop based rain water harvesting system. So, we have already seen that there are mainly three components. One is the rooftop catchment. So that, what we are, say through which, what we are, the rainfall what we are collecting. So, that is the rooftop, the catchment. And then, that is the first component.

Then, second one is the collection. So, if this is the building, then the top of this is the catchment. And then, collection is we have to collect the water through gutters and then through pipelines. So, this is the collection systems. So, that is a second component. So, first one is a catchment; second one is the collection system through pipelines.

And then, third one is the storage system. So, if you are going for direct way say storage, then a tank like this is a ferrocement tank. So, what is the size of the tank and various other aspects of the design on the tank. So, like that, mainly three components. One is the catchment, collection system and the storage system.

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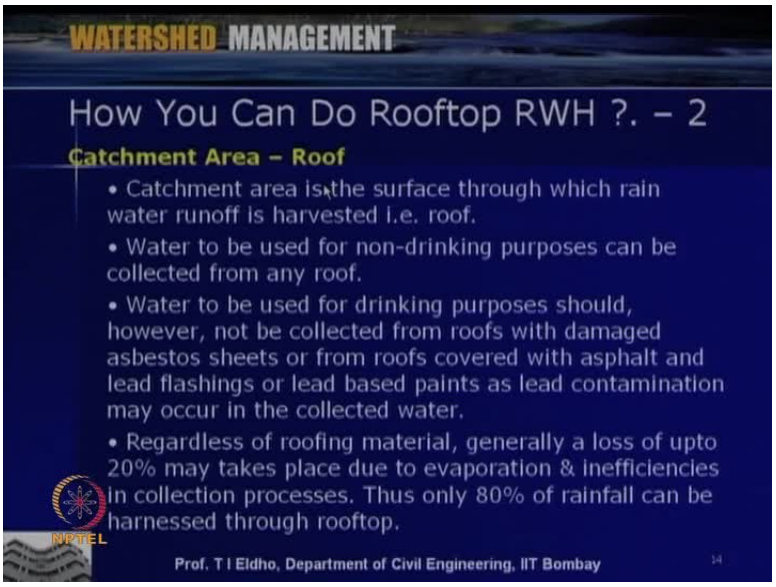

So, as far as the catchment area, so as I mentioned it is mainly the roof. So, the catchment area is the surface through which the rainwater runoff is harvested. That is the roof. So, water to be used for nondrinking purpose can be collected from any type of roof.

So, if you are going to recharge the to the aquifer system, of course the quality of water should be good. But, say for example, if you are going to use that collected water for irrigation purposes, then we do not have to worry much. So, we can collect the water from any kind of roof. Then, water to be used for drinking purposes should however not be collected from roofs with damaged asbestos sheets or from roofs covered with asphalt and lead flashings or lead based paints, as lead contamination may occur in the collected water.

So, say whenever rainfall takes place, it is the pure water, but when it, say where it falls depending upon the roof type. So, the contamination can takes place. Say for example, if it is a, as far as say covered roof or asbestos roof, then many components like lead or other heavy metals can say mix with the rainwater. So, that will due to contamination. So, we should be careful, so what kind of say roof which we are having. And then, accordingly we have to decide, whether that water can be used for domestic purpose or only agriculture purpose or say to recharge to the aquifer system.

Now, regardless of the roofing material, generally a loss of up to 20 percentage may takes place due to evaporation, and inefficiencies in collection processes. So, thus only, generally about 80 percentage of rainfall can be harnessed through the rooftop catchment system. So, that is generally, approximately we can collect about 80 percentage of the rainfall, say what is coming on the rooftop.

So now, say second component is, say we have to collect this water from the roof and then we have to send through an appropriate system, so, either for storage in a tank or for recharge purpose.

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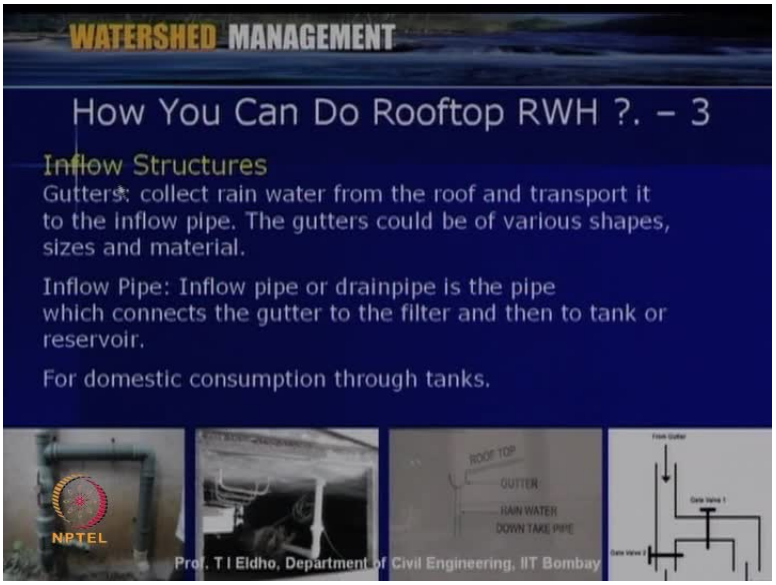

So, that the inflow, the inflow structures are important. So, some of the important inflow structures include gutters. So, this gutters, say it is generally on the side of the roof so that, this gutters collect rainwater from the roof and transport it to the inflow pipe. So, you can see that whatever is collected, so that will be coming through this pipe.

So, the gutters could be of various shapes, sizes and materials. So, like aluminum or say PVC type, different types are possible as far as gutter is concerned. And then, say once the water is flowing through the gutter, then we have to collect it through pipe. So, that is so-called inflow pipe. So, that this is the inflow pipe or this is the inflow pipe coming to the storage tank. So, this is the, from the gutter water is coming and then coming through

the pipe here. So, inflow pipe or drainpipe is the pipe, which connects the gutter to the filter and then to the tank or to the reservoir.

So, the inflow pipe, say design you have to do appropriately, so that we can see that if this is water coming through, this is the gutter. So, where the water is collected and from the gutter, now water is entering to the, through the pipe. So that, now that will be coming to a filter or other kinds of system.

So, the inflow structure structures are very important. So, we have to design it appropriately. So, from the pipe, say inflow pipe the water may go through a filter and then that can be either used for storage or for recharge purpose.

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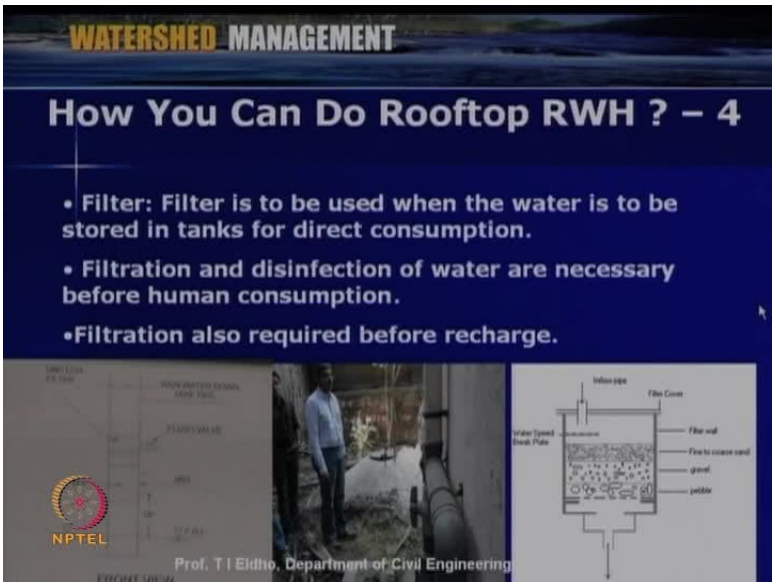

So, now as I mentioned, filtering is a very important. Since, even though say the first rain, first two, three rains, we can flush it out. But, still there will be, especially in city regions there will be dust and then lot of other beddrop and other things as far as the rooftop is concerned. So, a filter is always needed, even if we are going for recharge purpose.

So, a filter is to be used when the water is to be stored in tanks for direct consumption or whether even if it we are going for recharge. So, we can see that, say different types of filters are available. So, we can see that water is collected. And, through the collection system, what is coming to a tank, where the filter material is put. So, this is the inflow

pipe. So, here this is typical, say filter material is put. So, here the, this is the filter wall and then fine to coarse sand and this put on the top, then gravel and just below that and then pebble below that. So, from that, now, say after the filtration the water will be collected to the tank where the water will be stored for either direct use or for recharge.

So, we can see that this filter can be either of this sand material or the gravel and pebble material like this or we can, nowadays in a combat form the filter is available. So, like, say for example, one of the scheme; here we can have a module, say here this is a module which is put in the collection pipe itself, say like here geotextile or PVC type material. Various materials are available nowadays. So, through which water will be passing for storage. So, here we can see that, say this is now the water is coming and now the flush valve and then the water will be going through the filter system.

So now, say when we design the rainwater harvesting, as I mentioned the first flush, first two, three flush, we as first two, three rainfall flush should be should not be allowed to collect or it should not be allowed to recharge, since it contains lot of dust and other pollution. So, what we can do? We can have a valve here, so that say during the, when the monsoon or when the rainfall comes, we can close this valve. And, so that first two, three rainfall is concerned, the all the collected water will be going out through this pipe. So, that will not be collected at all. So, that is able, we will consider as polluted water.

And then, after two, three flushing, say removing this, say the water coming from first few rainfalls, then we can close the valve towards this and open towards the tank, so that the water will be passing through a filter system. And then, that can be used for storage in tanks or we can use it for the purpose of recharge.

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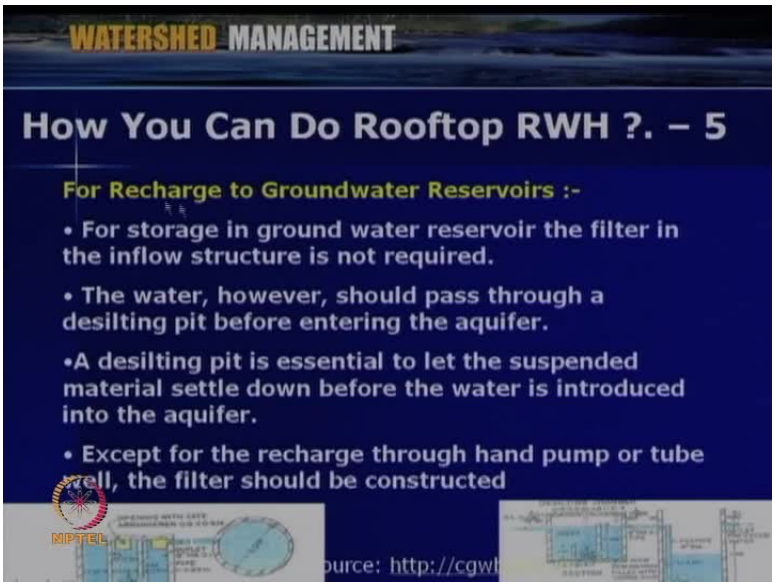

And now, so that is, say that is the way the design is done. Now, say if you are going to recharge the groundwater, the water to the groundwater reservoirs. Then for storage in ground water reservoir, the filter in the inflow structure, say very good filter is not required, but of course we need to, it should go through somewhat small filter or a sedimentation process.

So, the water however should pass through a desilting pit before entering the aquifer system. So, you can see that this is our dug well through which we are going to recharge. So, the water is coming, inflow is coming like this. And, it is a… desilting pit and through which the, whatever the silt, all these things will be setting down here and then the pure water will be allowed to go to the dug well where it is allowed to recharge.

So, either we can give a filter or we can give a desilting pit like this. So that, the suspended material settles down before the water is introduced to the aquifer system. Except for the recharge through hand pump or tube well, now filter should be constructed. So, if a filter to be given, we can give a filter somewhere here, say may be after desilting; so that, the filter water will be allowed to recharge to the aquifer system.

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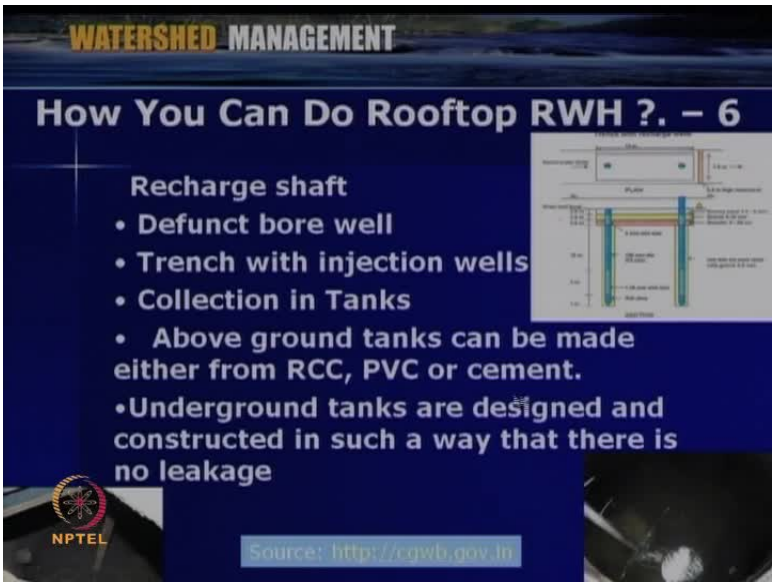

So, now say, we have seen say water is coming from the catchment, I mean roof catchment to through the collection pipes. And then, after filtration or desilting we can use the water for the purpose of storage or for the purpose of recharging. So, if we are going to recharge, the recharge different, say we can use recharge shafts say defect defunct bore wells, trench with injection wells, so like that. So, this is a trench and then there are two injection wells within the trench. And, that will be allowed to recharge the aquifer system. And, now also, if we are going for collection tanks, say for example, we can see that, now the, before the monsoon starts, this tank will be clean, then the water will be coming through to the tank and that will be stored. Then, we can have a pumping mechanism here, through which a water which can be pumped for the purpose, what is an, what we are using for. Underground tanks are designed and constructed in such a way that, there is no leakage.

So, we have to take care, so that the tanks can be either rain forced concrete or ferrocement or PVC type tanks. So, that way, depending upon the money which can be spent and the space and then the duration, the design consideration, we can use particular systems.

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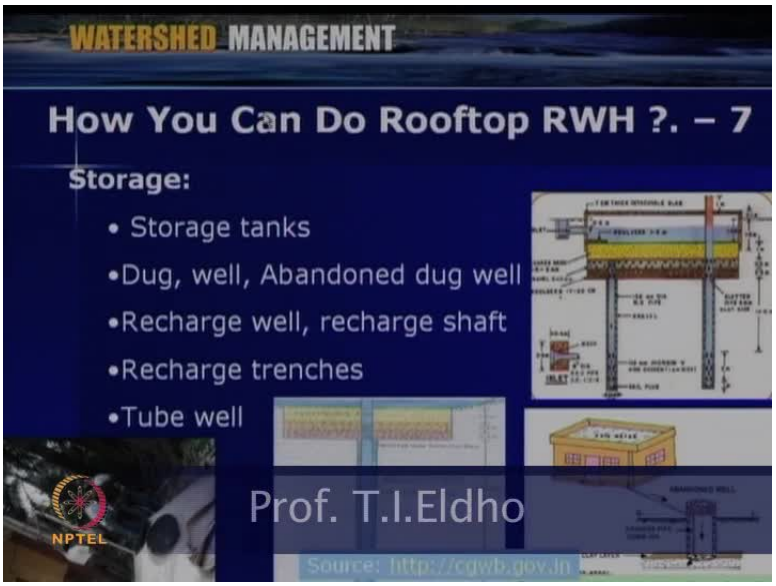

So now, say as far as storage is concerned, so as I mentioned, we can have storage tank and then we can, say use allow the water to go through the recharge wells, dug well, abandoned dug well or recharge well or recharge shaft or recharge trench. So, you can see that, we can have trenches surrounding the building like this. And then, also we can, abandoned well, this is a scheme and then this is a recharge shaft. So, here the, with this the water will be, say allowed to recharge to the aquifer system.

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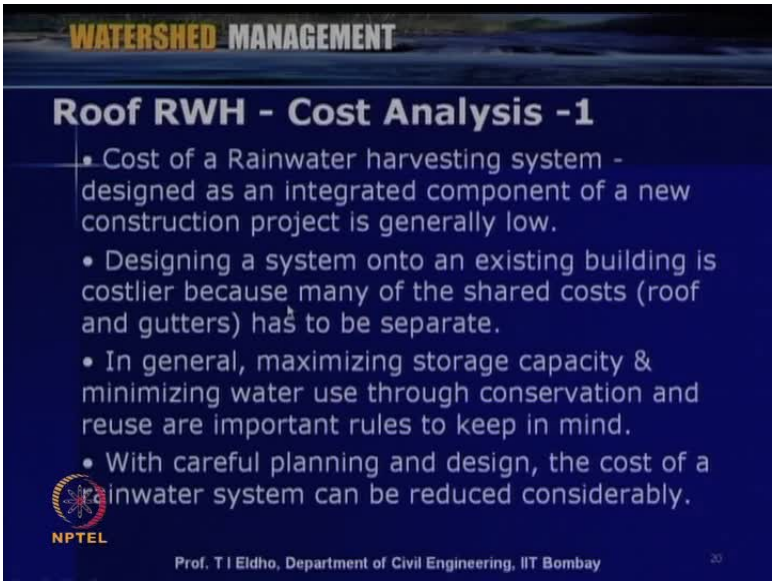

Now, let us see what is the cost of rooftop based rainwater harvesting system. So, as I mentioned, the cost depends upon the location and then also depending upon what kind of design we are planning to do. So, we can have very good design where the cost may be slightly more or we can go for what kind of; say, it depends upon how much money we can, how much capital is there.

So, the cost of a rainwater harvesting systems designed as an integrated component of a new construction project, generally it will be low. Now, a building is already constructed, then in that process if you are planning in advance, rainwater harvesting, a rooftop rain based rainwater harvesting system. Then, we can do all the arrangements, then while doing the construction itself, especially plumbing itself, so that there is the, all the, say the drains coming from the roof can be put in an appropriate way. So, that can be our collection systems.

And, a designing a system onto an existing building is costlier. Since, so if an existing building, there is no effective way of collection. And, say collection of the rainwater, then we have to, have a new system to be developed. So, because many of the shared costs like roof and gutters has to be separated as far as the old building is concerned.

In general, maximizing storage capacity and minimizing water use through conservation and the reuse are important rules to keep in mind. So, say we want to maximize the storage and minimize the water use; so, that way and we will be do the cost analysis.

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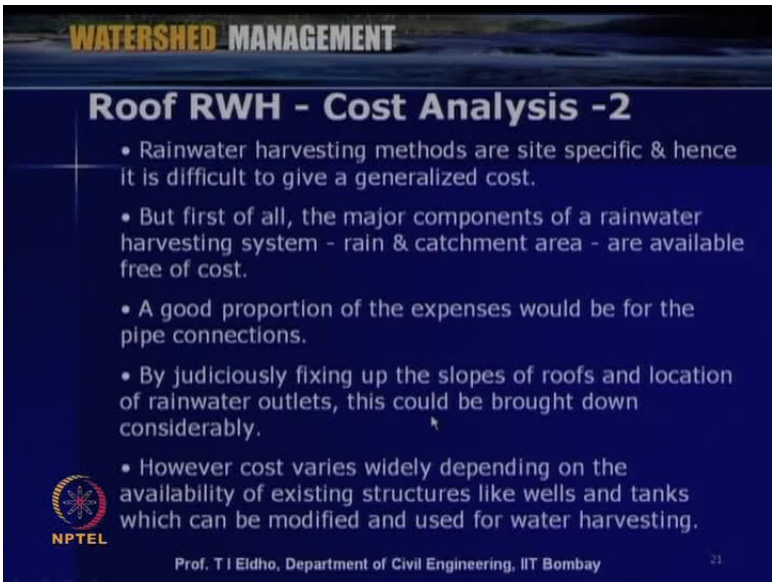

Now, with careful planning and design, the cost of a rainwater system can be reduced considerably. So, we can, say we have to do a preliminary analysis of the site and then we have to see how much rainwater is possible to harvest. And then, say we have to design the system appropriately so that, an appropriate design can reduce the cost considerably as usual for any kind of design is concerned.

So now, say the rainwater harvesting methods are site specific as I mentioned. Hence, it is difficult to give a generalized cost. So, this depends upon the location and many other parameters. But first of all, the major components of rainwater harvesting system like rain and catchment area are available free of cost. So, this is the most important aspect.

That is, the initially there is no need of capital as far as a rain is taking place naturally. And then, you are having already the rooftop as the catchment. So, these are already available free of cost. Only we have to go for a collection system and then we have to go for the storage or the recharge system. So, a good proportion of the expenses would be for the pipe connections as I mentioned, especially in the collection of the rainwater and then, of course storage.

So, by judiciously fixing up the slopes of roofs and location of rainwater outlets, this could be brought down considerably. However, cost varies widely depending on the availability of existing structures like wells and tanks, which can be modified and used

for water harvesting. So, if there are tanks are available and then or if some dug wells are available, which we can use for the artificial recharge and then the cost can be considerably reduced.

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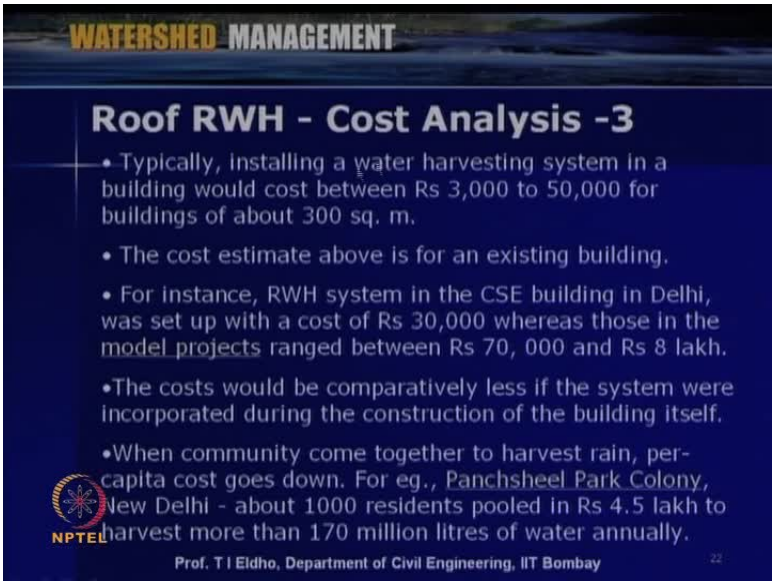

Typically, installing a water harvesting system in a building would cost between say rupees 3,000 to 50,000 for building of about three hundred square meters. So, this is a, say an approximate rate. As I mentioned, it varies from location to location. So, it varies, say it can be generally between rupees 3,000 to 50,000.

The cost estimate above is for an existing building. So, this is for an existing building. So, when we are doing it for a, during the construction, then the cost can be, again can be reduced. Say for example, rainwater harvesting system in the Center for Science and Environment building in Delhi was set up with a cost of 30,000 rupees, whereas those in the model projects, say other projects ranged from 70,000 to 8,00,000.

So, this drastically varies from location to location. Then, the cost would be comparatively less if the system were incorporated during the construction as I have already mentioned. Then, when community come together to harvest rain per capita cost goes down.

Say for example, if there is a housing colony; so, colony wise when we are going for total rainwater harvesting system, then the cost can be considerably reduced. So, since

same scheme can be adopted by all the houses in the colony. And then, even recharge pit; we can have common recharge techniques or a filtration is concerned, we can have formal common system. So, like that the cost can be considerably reduced. Say for example, for Panchsheel Park Colony in New Delhi, about thousand residents pooled in only rupees 4.5 lakhs to harvest more than 170 million liters of water annually.

So you can see that, say thousand residents came together, so the cost has gone drastically down and then there is a much better rooftop based rainwater harvesting system, especially say in Delhi area, they went for recharging system. Now, say these are as far as; these are the issues as far as the costs are concerned.

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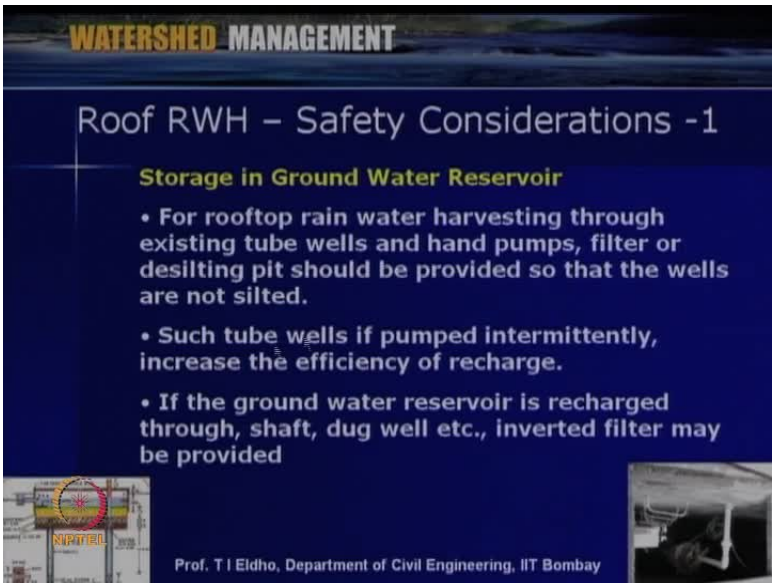

Now, let us look, say some of the safety considerations as far as the rooftop based rainwater harvesting is concerned. So, if you are going to store water in a ground water reservoir, so then for rooftop rainwater harvesting through existing tube wells and hand pumps, the filter or desilting pit should be provided, so that the wells are not silted.

So, the existing, if you are going to harvest the water and then put to the aquifer systems through existing tube wells or bore wells, then we should be careful. So, it should be passed through a… Say filtration is essential, so that the existing well wells are not silted.

Now, such tube wells if pumped intermittently increase the efficiency of recharge. So, it is not only recharging through the system, intermittently we can pump out also, so that the efficiency of recharge will be increased, since some of the silt will be coming out.

Then, if the ground water reservoir is recharged through shaft, dug well, etcetera, the inverted filter may be provided. So, here we can see a system where the water is collected and after the sedimentation, the it, the water is going through a pipe through a filter. And then, this is connected to an existing tube well, where this tube well, say sometimes used for say pumping also. And, whenever excess rainfall is coming, water is coming, then that is used for recharge purpose. So, both dual purpose tube wells; this is a dual purpose tube well, so otherwise we can construct structures like this.

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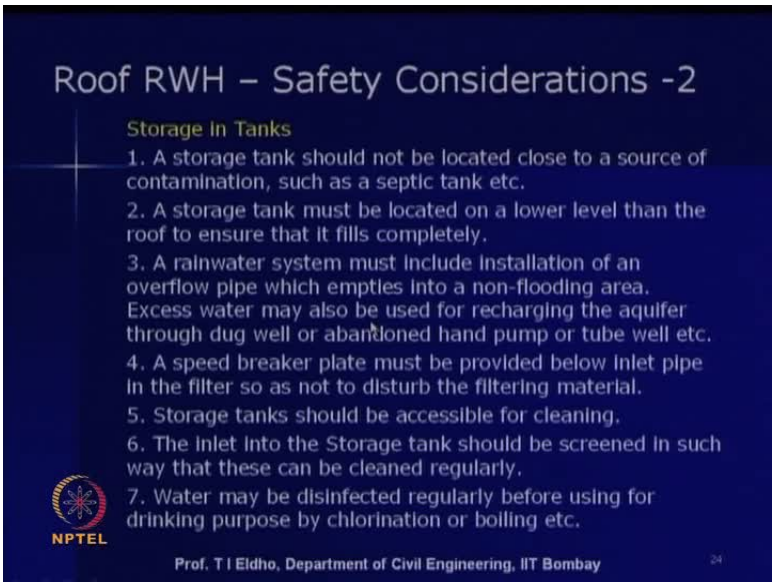

So, now instead of recharging, say if you are going for storage in tanks, some of the important safety considerations which we have to adopt as far as rooftop based rainwater harvesting is concerned.

A storage tank should not be located close to a source of contamination, such as a septic tank. Then, a storage tank must be located on a lower level than the roof to ensure that it fills completely. Then, a rainwater system must include installation of an overflow pipe which empties into non-flooding area, excess water may be used for recharging the aquifer system through dug well or abandoned hand pump or tube wells.

Then, you can see that most of the, say wherever high intense rainfall is there. Then, the flow through the plasson pipe will be much higher. So, we have to give a speed breaker plates; that is provided below the inlet pipe in the filter, so as not to disturb the filtering material. So, if the water flow to the filtering material in a velocity is very high, then the filter material will be affected and that itself will be going through with the water. So, we have to provide some speed breaker.

Then, storage tank should be accessible for cleaning, regular cleaning is required, say before monsoon definitely one cleaning is required. And then, depending upon the this the recharge or depending upon the use we may have to clean that tank, say the storage facility, then the inlet into the storage tank should be screened in such a way that, this can be cleaned regularly. Water may be disinfected regularly before using for drinking purpose by chlorination or boiling. So, these are some of the important safety consideration as far as the rooftop based rainwater harvesting is concerned.

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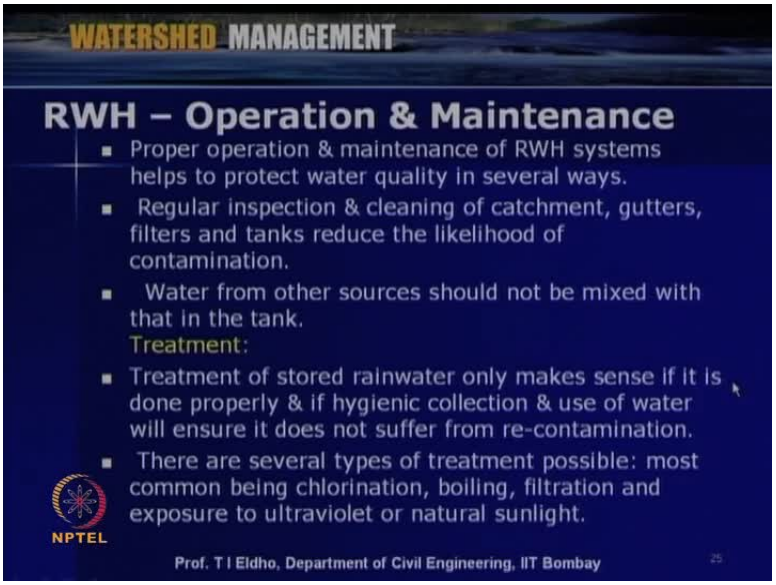

Now, some of the operation and maintenance issues; here I am, I have listed. So, proper operation maintenance is required, regular inspection and cleaning of catchment, gutters, filters and tanks reduce the likelihood of contamination. So, that is an important point. And, water from the source should not be mixed with that in the tank. So, other sources like, if the water supplied through pipes that should not be mixed with the harvested rainwater.

Then, as far as treatment is concerned; treatment of stored rainwater only makes sense if it is done properly if hygienic collection. And, use of water will ensure, it does not suffer from recontamination. So, recontamination should not take place. We should be careful and there are several types of treatment possible like chlorination, boiling, filtration, then exposure to ultraviolet or natural sunlight, etcetera. So, these are some of the operation and maintenance aspects as far as rooftop based rainwater harvesting are concerned.

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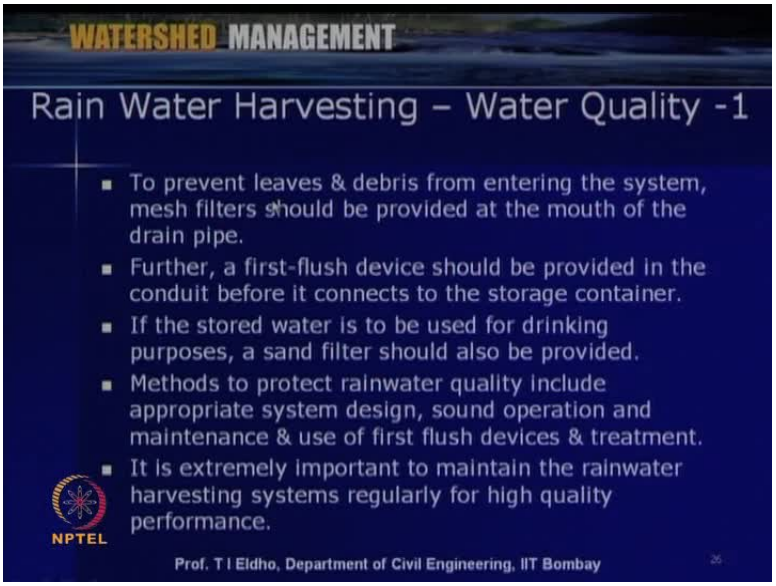

Now, before going to case studies, let us have a look some of the water quality issues. So, to prevent leaves and debris from entering the system, mesh filters should be provided, especially at the mouth of the drain pipe. Then, as I mentioned, the first flush device should be provided in the conduit before it connects to the storage tank containers.

So, if the stored water is to be used for drinking purpose, then a sand filter is essential. Then, methods to protect rainwater quality include like appropriate system design, sound operation and maintenance. Then, it is extremely important to maintain the rainwater harvesting system regularly for high quality performance. So, the quality depends upon the maintenance of the system.

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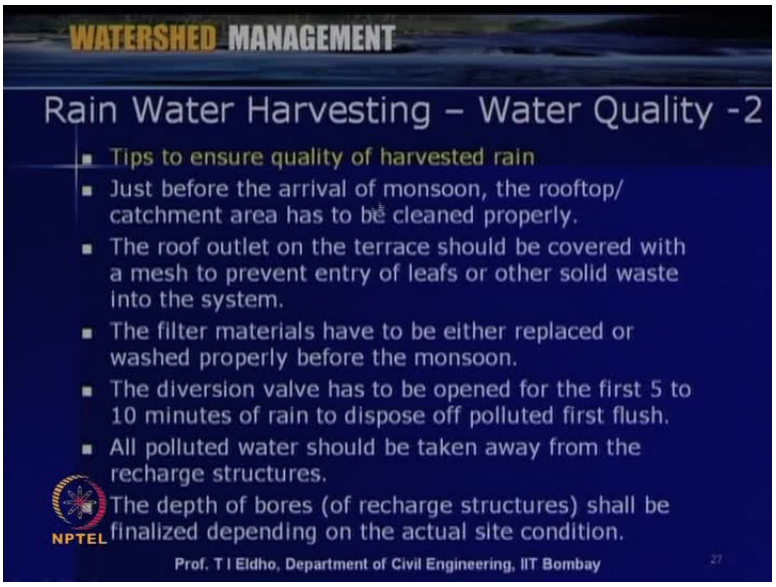

Then, some of the tips to ensure a good quality of harvested rainwater include just before the arrival of monsoon, the rooftop and catchment should be cleaned properly, the roof outlet to the terrace should be covered with a mesh to prevent entry of leafs and other materials. Then, the filter materials have to be either replaced or washed properly. Then, the diversion valve has to be opened for the first five to ten minutes to dispose the polluted first flush. Then, no polluted water should be taken away from the recharge structures. And then, the depth of bores shall be finalized depending upon the actual site conditions. So, these are some of the water quality issues.

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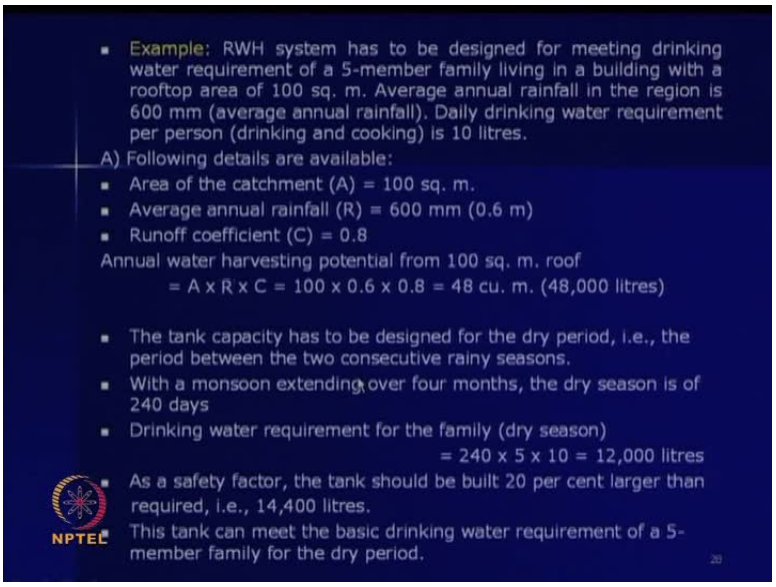

Now, say here, say if you want to design, this is a simple problem. Say, a rainwater harvested system has to be designed for meeting drinking water requirements for five member family in a building with a rooftop of hundred square meters. Average annual rainfall in the region is, say 600 millimeter. Daily drinking water requirement per person is consider as ten liters.

Then, here we can see that catchment area is 100 square meters, rainfall is 0.6 meter and collection efficiency is 0.8. Then, we can find the average annual water harvesting is 48 cubic meter.

So, then, say if you consider, say for example, above two hundred and forty days of dry period, then we can identify how much is to be collected for drinking purpose. So, then if it is given 20 percentage extra, then it can be 14,400 liters. So, we have to design accordingly.

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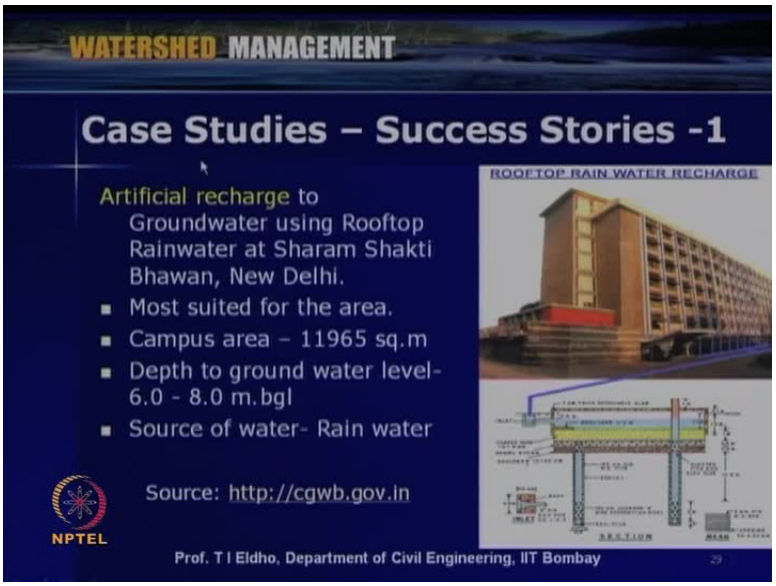

So, to case studies here, I want to present one of the success stories as far as artificial recharge is concerned. So, first one is artificial recharge to groundwater using rooftop. So, this is the Shakti Bhawan in New Delhi. So, the campus area is about thousand two hundred square meter. Depth to groundwater before recharging was 6 to 8 meter below ground level.

So, here this is the system. So, you can see that varies through various pipelines are collected and then they through to injection wells and recharge trench, the water is infiltrated down to the aquifer system.

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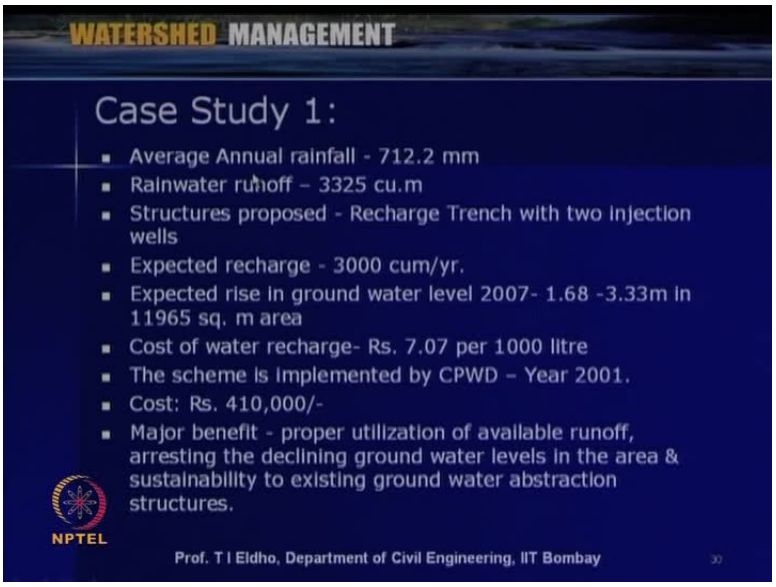

So, average annual rainfall is about 712.2 millimeter, rainwater runoff is approximately calculated as 3325 cubic meter. Structure proposed is recharge trench with two injection wells. Expected recharge is about 3000 cubic meter per year. So, the studies in 2007 shows that there is about 1.68 to 3.33 meter rise in the area in ground water table. And, cost of the water was calculated as rupees 7.07 per thousand liter.

So, the total cost when it was implemented by, say central PWD in 2001 was about 4.1 lakh. So, major benefit is proper utilization of available runoff, arresting the declining groundwater levels in the area and sustainability to existing ground water abstraction structures.

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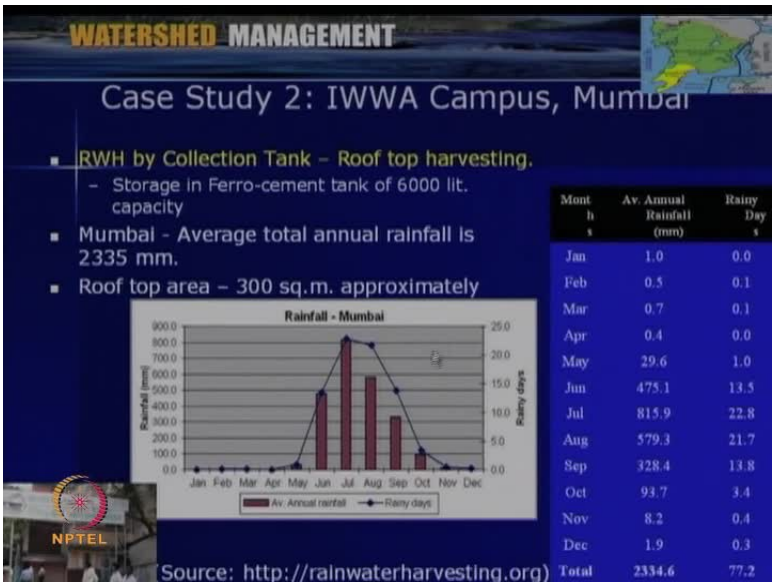

Months	Av. Annual Rainfall (mm)	Rainy Days
Jan	1.0	0.0
Feb	0.5	0.1
Mar	0.7	0.1
Apr	0.4	0.0
May	29.6	1.0
Jun	475.1	13.5
Jul	815.9	22.8
Aug	579.3	21.7
Sep	328.4	13.8
Oct	93.7	3.4
Nov	8.2	0.4
Dec	1.9	0.3
Total	2334.6	77.2

So, this is the recharge based case study. Second one is a collection type case study. So, this is in Mumbai, Indian water was association campus. So, here the storage is done in a ferrocement tank of about 6000 liter. And, Mumbai rainfall average is 2335 millimeter. The rooftop area is about three hundred square meters. So, the design is based upon this data.

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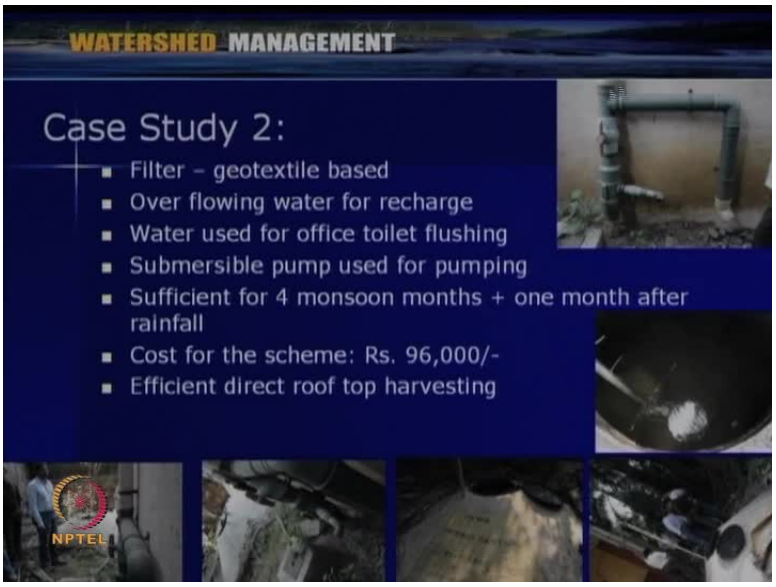

Then, filter material is… here, this is the collection system, this is the filter material, the geotextile based system. And then, the over flowing water for recharge, say water is

collected in a tank like this. So, this water is used for toilet flushing as far as the building is concerned.

So, this water was found to be sufficient for four monsoon months plus another one month after the rainfall. So, one month rainfall storage and they could do and the cost was about 96000. So, this is another efficient direct rooftop harvesting as far as storage is concerned.

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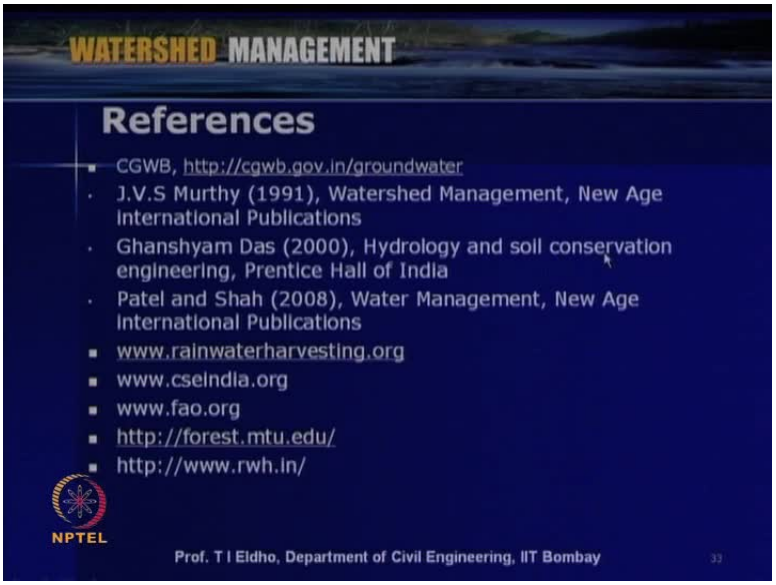

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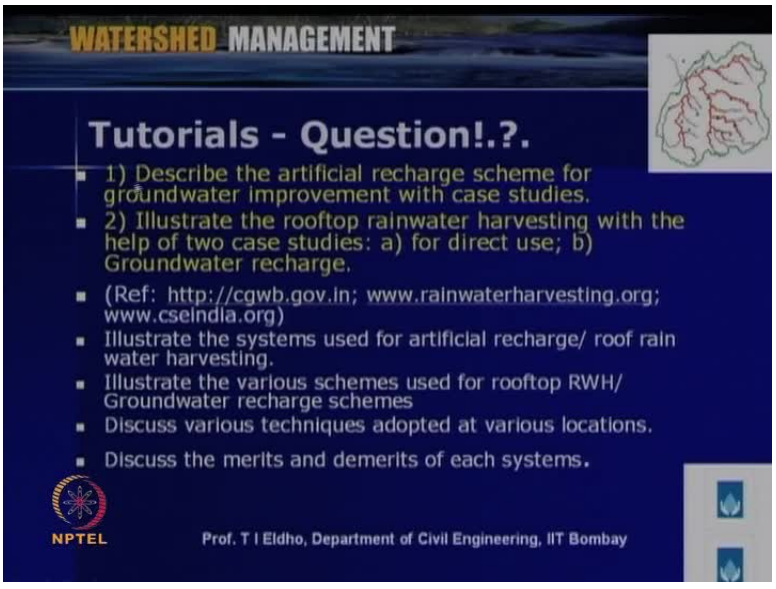

So, for today's lecture some of the important references are listed here. Then, as a tutorial question, say two questions I have put here. "Describe the artificial recharge scheme for ground water improvement with case studies". "Illustrate the rooftop rainwater harvesting with the help of two case studies for direct use and groundwater recharge". So, you can see number of case studies in central ground water board website; www.rainwater harvesting. org website and cseIndia website.

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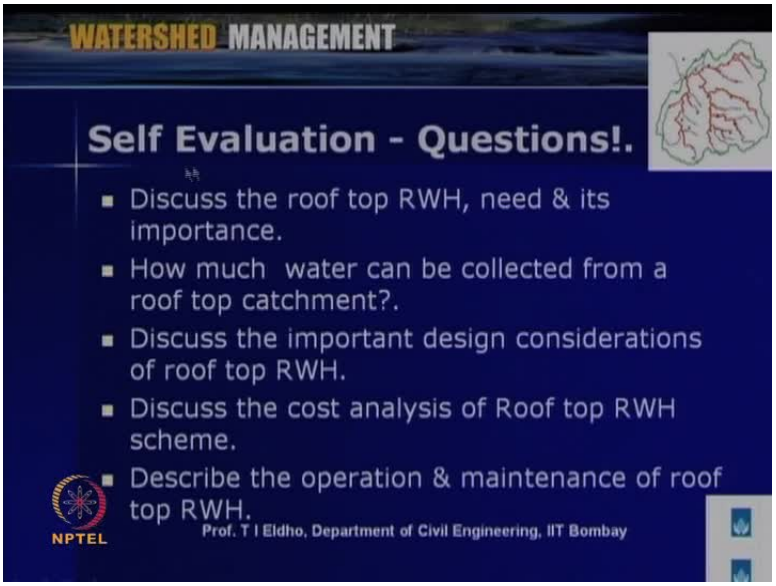

So, you can illustrate the system with various schemes and then discuss various techniques adopted and discuss the merits and demerits of each system. So, few self-evaluation questions like "Discuss the rooftop rainwater harvestings, then needs and its importance"; "How much water can be collected from a rooftop catchment?"; "Discuss the important design considerations of rooftop rainwater harvesting system"; "Discuss the cost analysis of rooftop rainwater harvesting scheme"; "Describe the operation and maintenance of rooftop rainwater harvesting systems.

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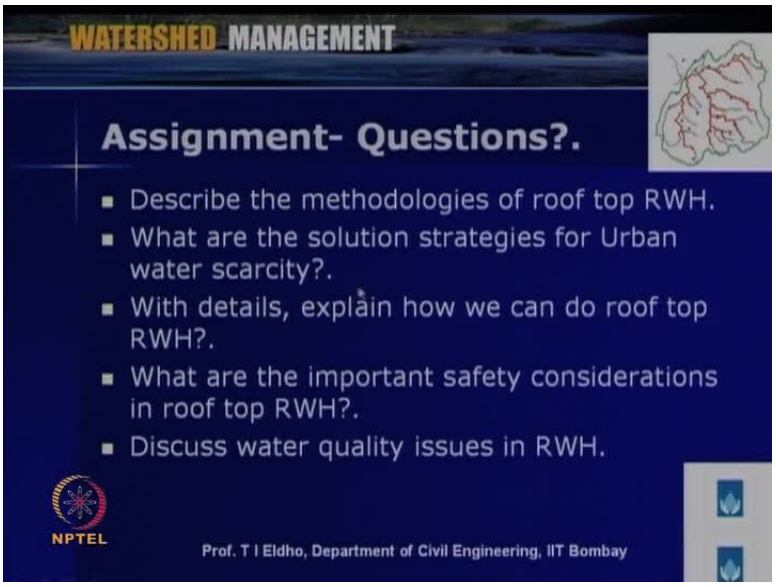

Then, for assignment there are few questions. "Describe the methodologies of rooftop rainwater harvesting system"; "What are the solution strategies for urban rainwater scarcity?"; "With details, explain how we can do rooftop rainwater harvesting"; "What are the important safety consideration in rooftop rainwater harvesting?" and "Discuss water quality issues in rainwater harvesting".

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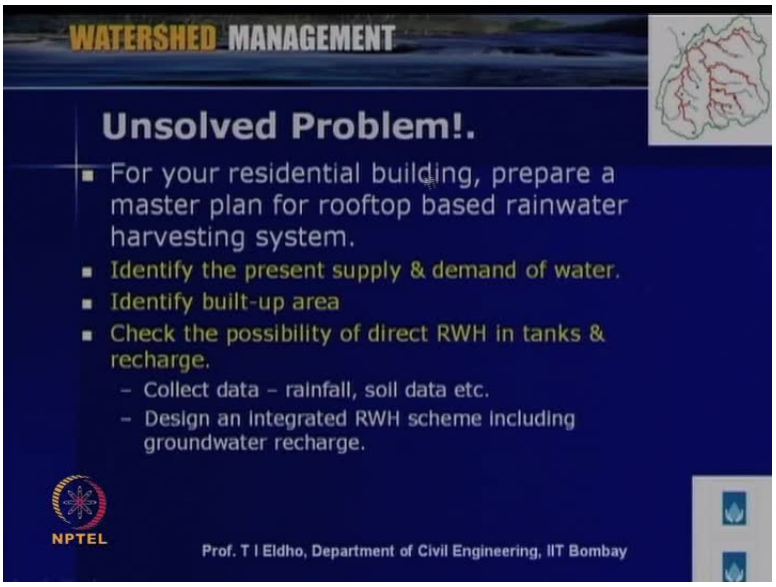

So, these for…, the answers for all these questions. You will get through, if you go through the today's lecture. So, finally one unsolved problem. For your residential

building where you are staying, prepare a master plan for rooftop based rainwater harvesting system. So, you can identify what is the present supply water is coming from, where and what is the demand for your building. Then, we can identify the buildup area and check the possibility of direct rainwater harvesting or you can go for recharge. So, collect all the data related to rainfall, soil, data, and etcetera. Then, design an integrated rainwater harvesting system including some storage in tanks or some; say the option for ground water recharge.

So, with this, today's lecture on say rainwater harvesting, especially rooftop based catchment system is finished. So now, the module number three on the integrated, say watershed management schemes also over.

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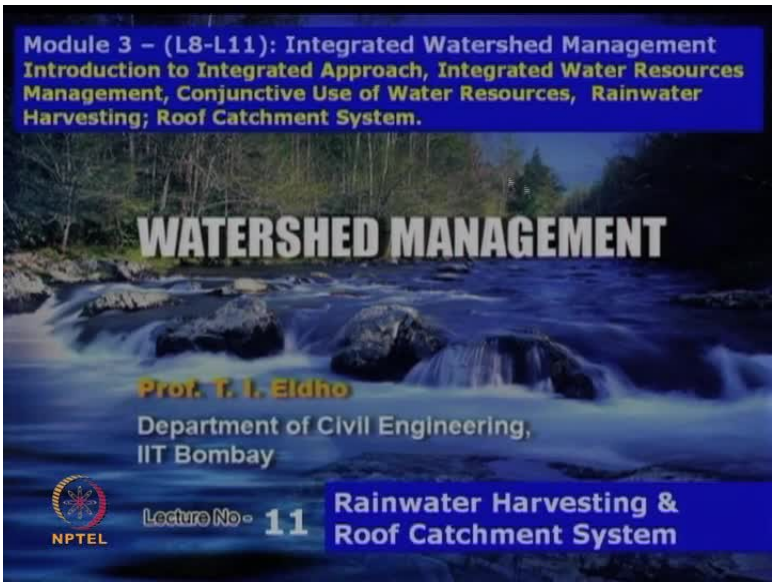

So, we have seen, we have got about four lectures in this module on "Introduction to integrated watershed management". So, various aspects of the scheme, this module has been discussed in the four lectures, as we have seen in the last four lectures. Thank you.