Surface Water Hydrology
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Lecture – 11
Introduction to Evaporation and Evaporimeters

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Welcome to week 3. This week, we are going to start the different abstractions from the precipitation. So, once that precipitation falls on the ground, then it goes to different processes and before it creates some runoff and joins to the streamflow.

Now, there are different losses with respect to the runoff and those are called abstraction. In lecture 11 we will one such abstraction is the evaporation will be discussed and the evaporimeters through which these operations are measured.

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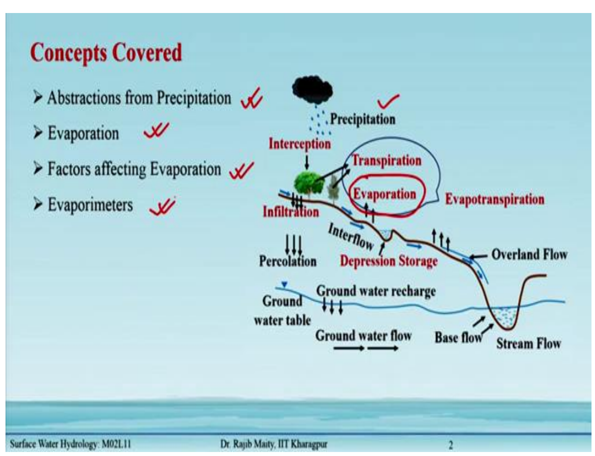

So, these are specific concepts covered in this class. The first one is the abstraction from precipitation, then we will take the evaporation factors that control the evaporation and the instrument evaporimeters through which we measure the evaporation is the concept that will be covered in this lecture.

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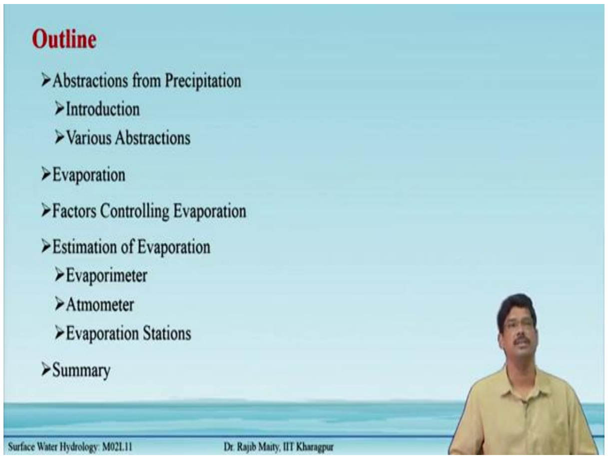

The outline of this lecture goes like this: In the first the abstraction from the precipitation we give some introduction and the various abstraction and processes, then evaporation factors controlling evaporation estimation of evaporation evaporimeters, atmometers evaporation stations, and then summary.

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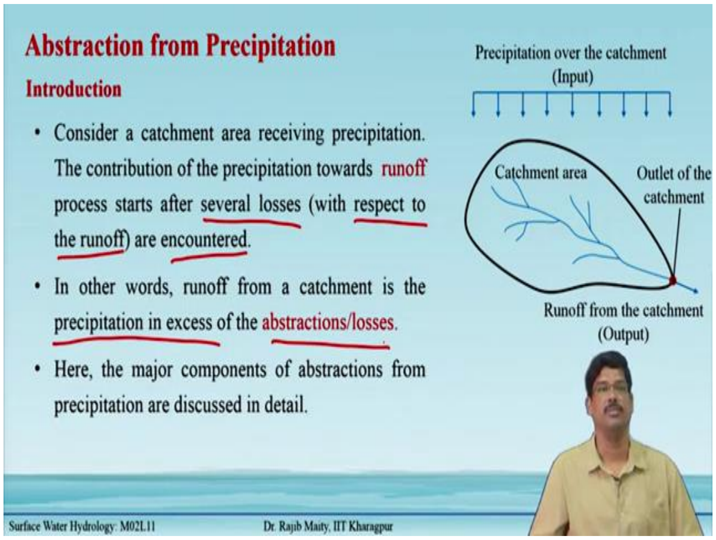

Abstraction from Precipitation

Introduction

Consider a catchment area receiving precipitation. The contribution of the precipitation towards the runoff process starts after several losses (with respect to the runoff) are encountered. In other words, the runoff from a catchment is the precipitation in excess. So, precipitation in excess or excess precipitation is sometimes called the abstraction or the losses precipitation excess of the abstraction. Here is the major component of the abstraction from the precipitation is discussed in detail.

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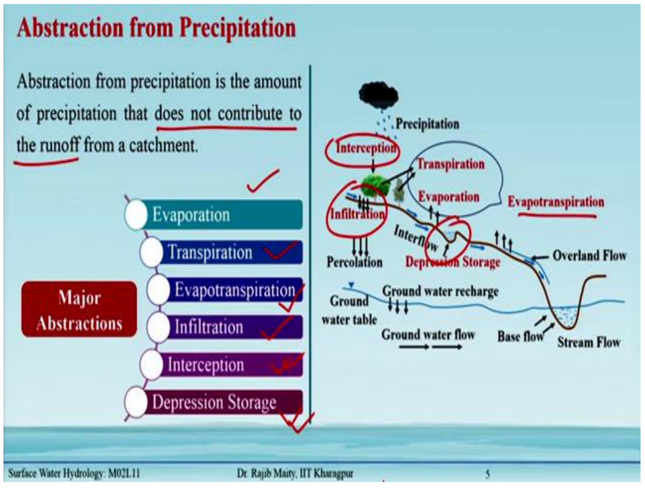

Abstraction from the precipitation is the amount of precipitation that does not contribute to the runoff. And there are different such components are there the major abstractions are it starts from the specific needs the evaporation and transpiration and these two combined do we call that evapotranspiration, then comes infiltration that goes below the ground, then interception.

Interception is basically, on the plant foliage it is an interceptor some part of the precipitation is intercepted and then comes the depression storage there are some local depressions are there, where the flow is stopped for some time. So, these are some of the major abstraction from the precipitation.

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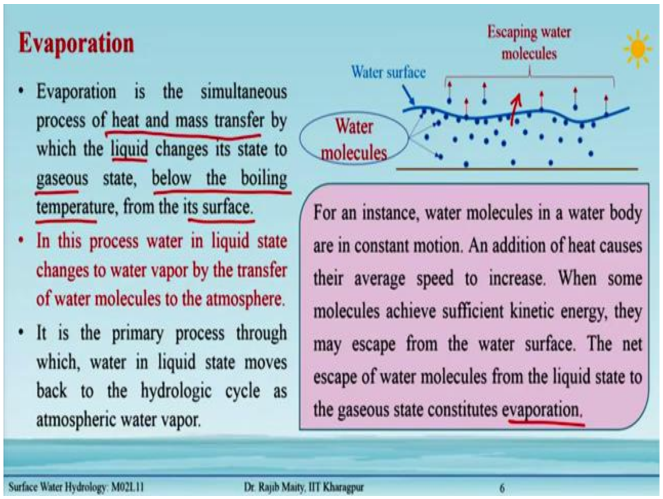

Evaporation

Evaporation is the simultaneous process of heat and mass transfer by which the liquid changes its state to a gaseous state, below the boiling temperature, from its surface. In this process water in liquid state changes to water vapor by the transfer of water molecules to the atmosphere. It is the primary process through which, water in a liquid state moves back to the hydrologic cycle as atmospheric water vapor.

On the water surface, there are water molecules near the surface due to the kinetic energy that is being received from the energy source here the major energy source is the sun. These water molecules are always in some constant motion and the addition of the heat causes the average speed to increase. When some molecules achieve sufficient kinetic energy, they may escape from the water surface that net escape from the water surface from the liquid state to the gaseous state that constitutes the evaporation it must have been the some of the molecules which are there in the atmosphere may also come back to the liquid to the waters water surface. So, some that are going away from the water surface something that is coming into the water surface. So, there is some net that is going outside this water surface that is constituting the evaporation and we have to remember that this process is below the boiling temperature.

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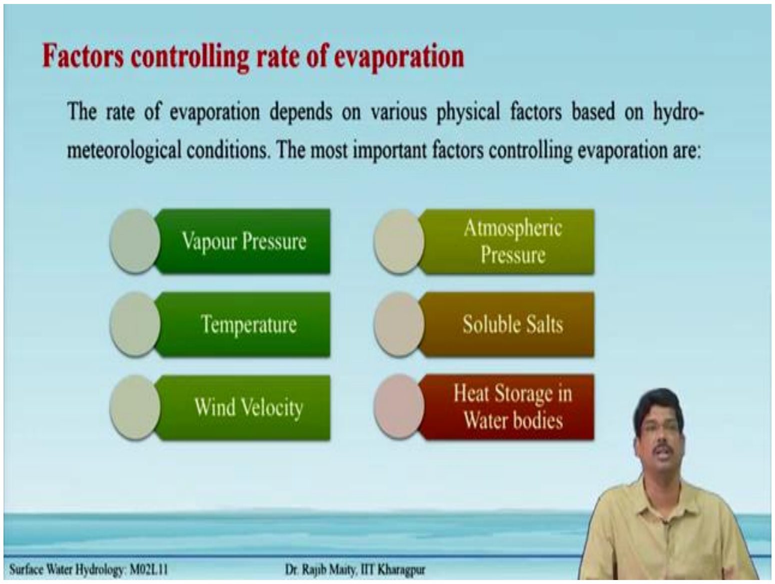

Factors controlling the rate of evaporation

The rate of evaporation depends on various physical factors based on hydro-meteorological conditions. The most important factors controlling evaporation are vapor pressure, temperature, wind velocity, atmospheric pressure, soluble salt, and heat storage in the water bodies.

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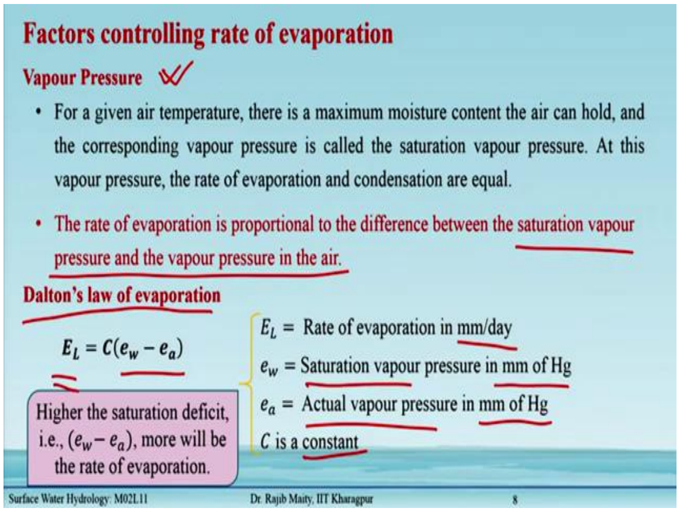

Vapour Pressure

For a given air temperature, there is a maximum moisture content the air can hold, and the corresponding vapour pressure is called the saturation vapour pressure. At this vapour pressure, the rate of evaporation and condensation are equal. The rate of evaporation is proportional to the difference between the saturation vapour pressure and the vapour pressure in the air.

More the gradient is more evaporation takes place and these are generally expressed through some common expression that is called the Dalton law of evaporation.

$$E_L = C(e_w - e_a)$$

E_L= Rate of evaporation in mm/day

e_w= Saturation vapour pressure in mm of Hg

e_a= Actual vapour pressure in mm of Hg

C is a constant,

Higher the saturation deficit, i.e., $(e_w - e_a)$ more will be the rate of evaporation.

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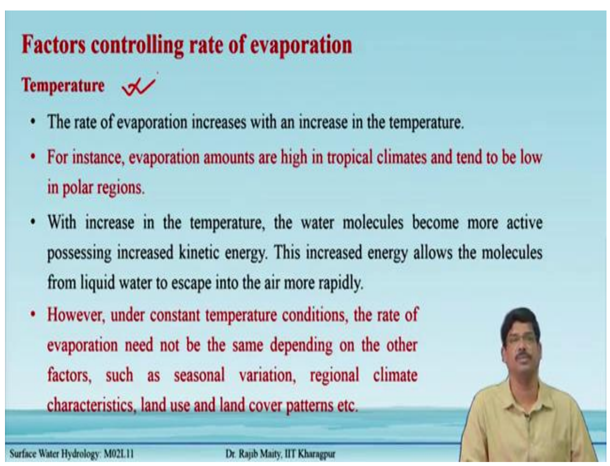

Temperature

The rate of evaporation increases with an increase in the temperature. For instance, evaporation amounts are high in tropical climates and tend to be low in polar regions. With an increase in the temperature, the water molecules become more active possessing increased kinetic energy. This increased energy allows the molecules from liquid water to escape into the air more rapidly. However, under constant temperature conditions, the rate of evaporation need not be the same depending on the other factors, such as seasonal variation, regional climate characteristics, land use, land cover patterns, etc.

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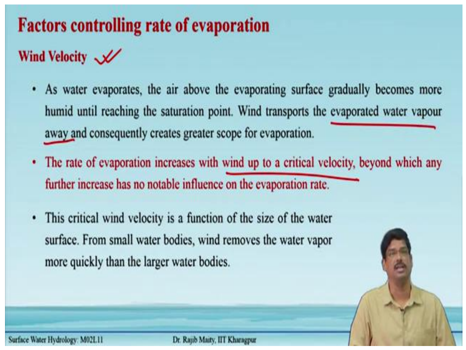

Wind Velocity

As water evaporates, the air above the evaporating surface gradually becomes more humid until reaching the saturation point. Wind transports the evaporated water vapour away and consequently creates greater scope for evaporation. The rate of evaporation increases with wind up to a critical velocity, beyond which any further increase has no notable influence on the evaporation rate.

This critical wind velocity is a function of the size of the water surface. From small water bodies, wind removes the water vapor more quickly than the larger water bodies.

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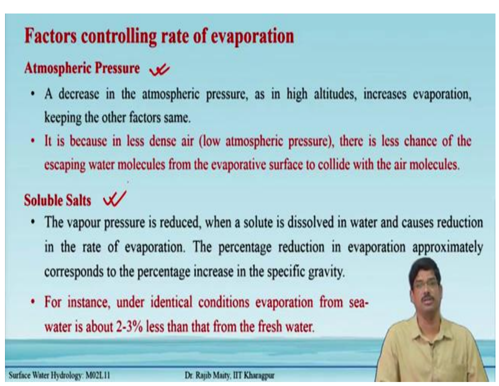

Atmospheric Pressure

A decrease in the atmospheric pressure, as in high altitudes, increases evaporation, keeping the other factors the same. It is because, in less dense air (low atmospheric pressure), there is less chance of the escaping water molecules from the evaporative surface colliding with the air molecules.

Soluble Salts

The vapour pressure is reduced when a solute is dissolved in water and causes a reduction in the rate of evaporation. The percentage reduction in evaporation approximately corresponds to the percentage increase in the specific gravity. For instance, under identical conditions evaporation from seawater is about 2-3% less than that from freshwater.

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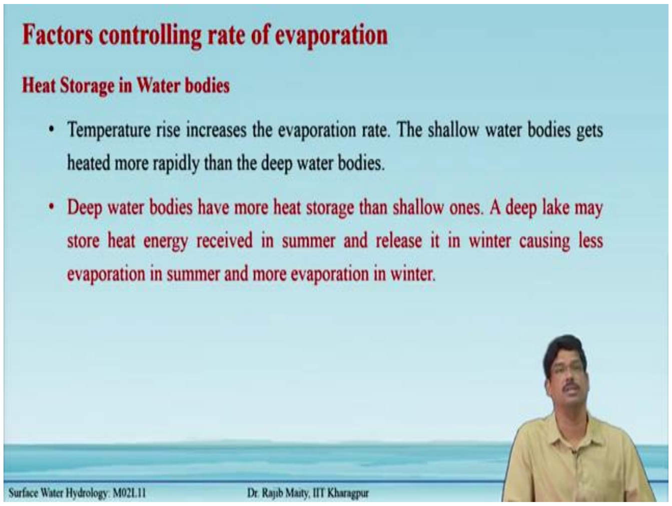

Heat Storage in Water bodies

Temperature rise increases the evaporation rate. The shallow water bodies get heated more rapidly than the deep-water bodies. Deep water bodies have more heat storage than shallow ones. A deep lake may store heat energy received in summer and release it in winter causing less evaporation in summer and more evaporation in winter.

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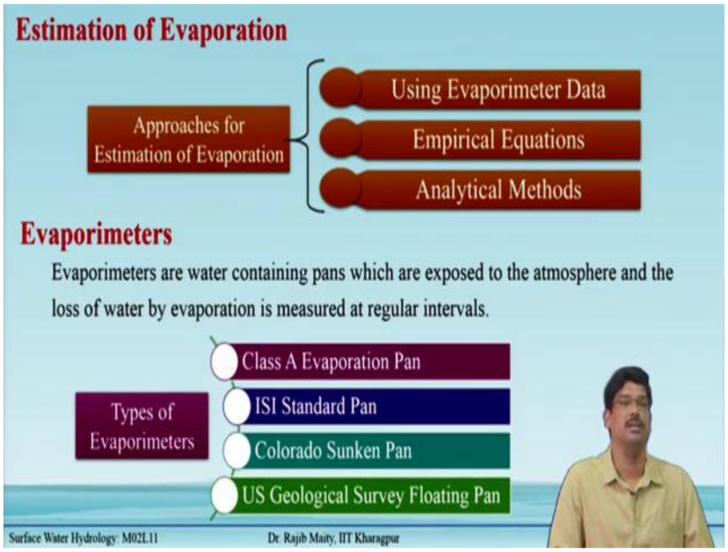

Estimation of Evaporation

The estimation of evaporation there are different approaches:

I. Using the evaporimeter data
II. Empirical equations
III. Analytical methods.

Evaporimeters

Evaporimeters are water-containing pans that are exposed to the atmosphere and the loss of water by evaporation is measured at regular intervals.

Different types of evaporimeters are available. Here the four different types are sown the Class A you have Evaporation Pan, ISI Standard Pan, Colorado Sunken Pan, and US Geological Survey Floating Pan.

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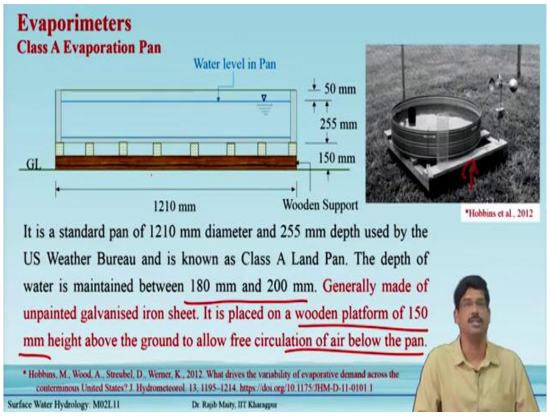

Class A Evaporation Pan

It is a standard pan of 1210 mm diameter and 255 mm depth used by the US Weather Bureau and is known as Class A Land Pan. The depth of water is maintained between 180 mm and 200 mm. Generally made of unpainted galvanized iron sheet. It is placed on a wooden platform of 150 mm height above the ground to allow free circulation of air below the pan.

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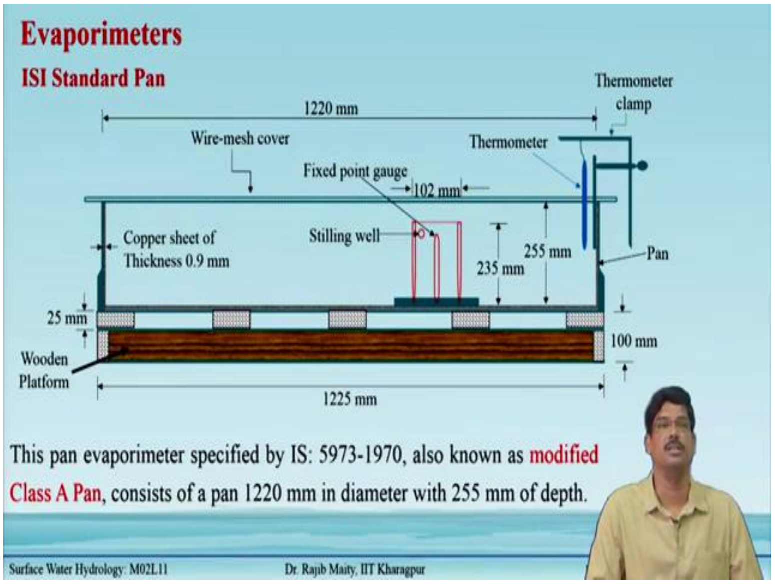

ISI Standard Pan

The ISI Standard Pan evaporimeters specified by this Indian standard 5973-1970 is also known as the modified Class A Pan and it consists of 1220 mm in diameter with 255 mm in the depth as you can see in this schematic diagram.

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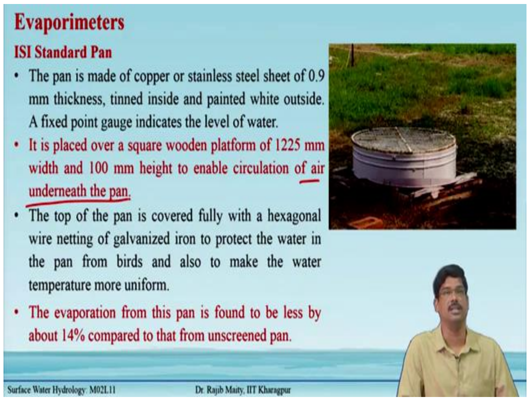

The pan is made of copper or stainless-steel sheet of 0.9 mm thickness, tinned inside, and painted white outside. A fixed-point gauge indicates the level of water. It is placed over a square wooden platform of 1225 mm width and 100 mm height to enable circulation of air underneath the pan. The top of the pan is covered fully with a hexagonal wire netting of galvanized iron to protect the water in the pan from birds and also to make the water temperature more uniform. The evaporation from this pan is found to be less by about 14% compared to that from the unscreened pan.

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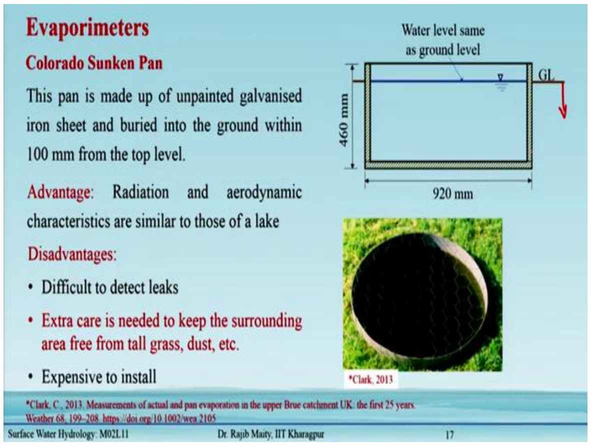

Colorado Sunken Pan

This pan is made up of an unpainted galvanized iron sheet and buried into the ground within 100 mm from the top level.

Advantage:

- Radiation and aerodynamic characteristics are similar to those of a lake

Disadvantages:

- Difficult to detect leaks
- Extra care is needed to keep the surrounding area free from tall grass, dust, etc.
- Expensive to install

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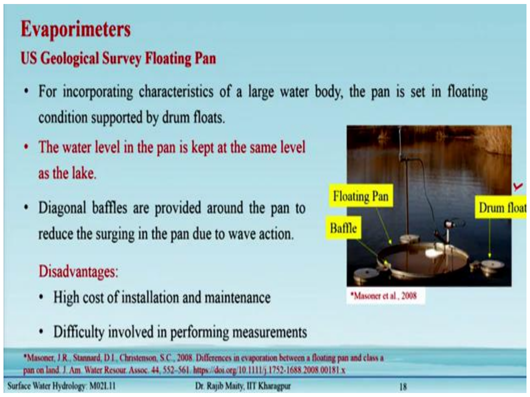

US Geological Survey Floating Pan

For incorporating characteristics of a large water body, the pan is set in floating condition supported by drum floats. The water level in the pan is kept at the same level as the lake. Diagonal baffles are provided around the pan to reduce the surging in the pan due to wave action. Disadvantages:

- High cost of installation and maintenance
- The difficulty involved in performing measurements

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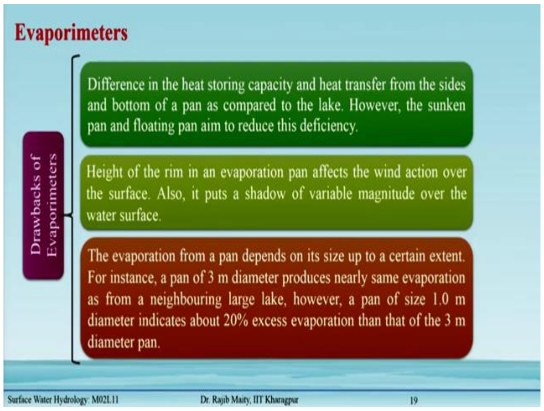

There are a few drawbacks for the upper evaporimeters

- The difference in the heat-storing capacity and heat transfer from the sides and bottom of a pan as compared to the lake. However, the sunken pan and floating pan aim to reduce this deficiency.
- The height of the rim in an evaporation pan affects the wind action over the surface. Also, it puts a shadow of variable magnitude over the water surface.
- The evaporation from a pan depends on its size up to a certain extent. For instance, a pan of 3 m diameter produces nearly the same evaporation as from a neighboring large lake, however, a pan of size 1.0 m diameter indicates about 20% excess evaporation than that of the 3 m diameter pan.

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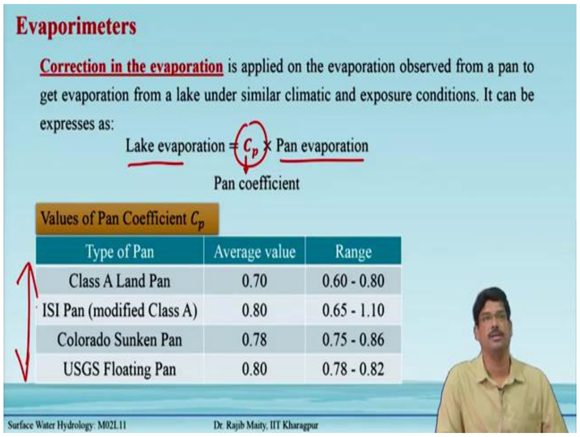

Correction in the evaporation is applied on the evaporation observed from a pan to get evaporation from a lake under similar climatic and exposure conditions. It can be expressed as:

$$\text{Lake evaporation} = \boldsymbol{C_p} \times \text{Pan evaporation}$$

Where C_P = Pan Coefficient

Table showing Values of Pan Coefficient Cp

Type of Pan	Average value	Range
Class A Land Pan	0.70	0.60 - 0.80
ISI Pan (modified Class A)	0.80	0.65 - 1.10
Colorado Sunken Pan	0.78	0.75 - 0.86
USGS Floating Pan	0.80	0.78 - 0.82

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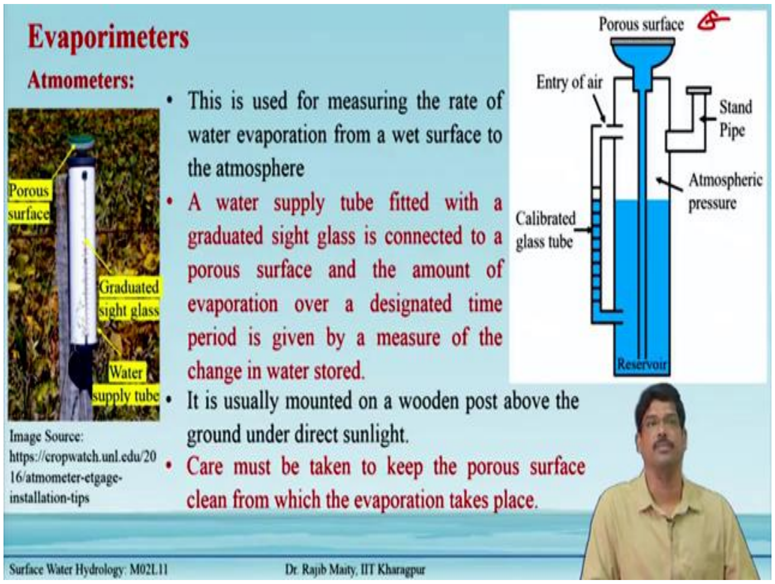

Atmometers:

There is another type of evaporimeters also known as atmometers. This is used for measuring the rate of water evaporation from a wet surface to the atmosphere. A water supply tube fitted with a graduated sight glass is connected to a porous surface and the amount of evaporation over a designated time period is given by a measure of the change in water stored. It is usually mounted on a wooden post above the ground under direct sunlight. Care must be taken to keep the porous surface clean from which the evaporation takes place.

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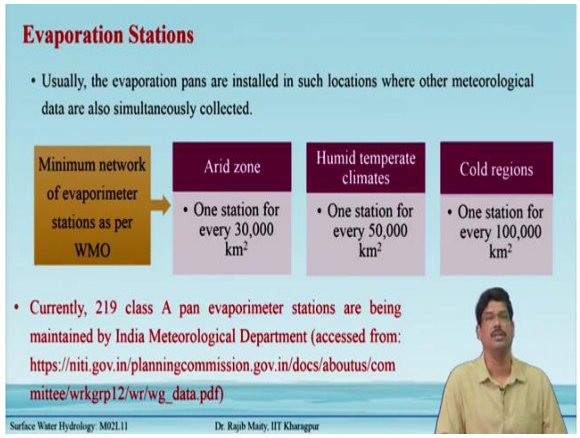

Evaporation Stations

Some standard guidelines by World Meteorological Organization how many evaporations pans are required for a region. So, usually, these pans are installed in such locations where the meteorological data are also simultaneously being collected. So, the minimum network for the perimeter stations is as per the WMO is like this

- In the Arid zone 1 station for every 30,000 kilometers square
- In the humid temperate climates, 1 station for every 50,000-kilometer square
- In the cold region 1 station for every 100000-kilometer square.

Currently, there are 219 Class A Pan evaporimeter stations is being maintained by India Metrological Department as per the record available.

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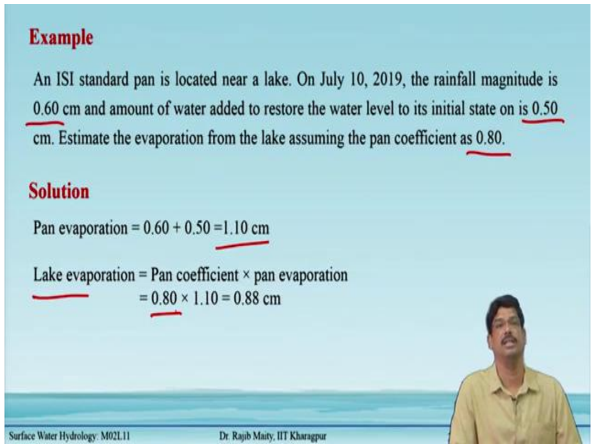

Example

An ISI standard pan is located near a lake. On July 10, 2019, the rainfall magnitude is 0.60 cm and the amount of water added to restore the water level to its initial state is 0.50 cm. Estimate the evaporation from the lake assuming the pan coefficient as 0.80.

Solution

Pan evaporation = 0.60 + 0.50 =1.10 cm

Lake evaporation = Pan coefficient × pan evaporation

= 0.80 × 1.10 = 0.88 cm

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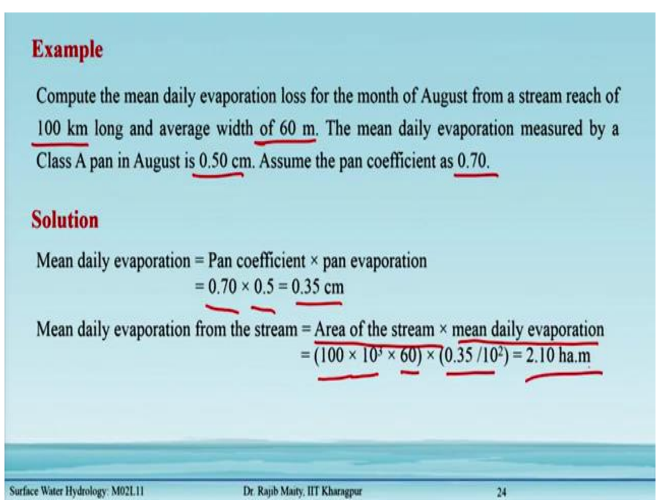

Example

Compute the mean daily evaporation loss for the month of August from a stream reach of 100 km long and average width of 60 m. The mean daily evaporation measured by a Class A pan in August is 0.50 cm. Assume the pan coefficient as 0.70.

Solution

Mean daily evaporation = Pan coefficient × pan evaporation

$$= 0.70 \times 0.5 = 0.35 \text{ cm}$$

Mean daily evaporation from the stream = Area of the stream × mean daily evaporation

$$= (100 \times 10^3 \times 60) \times (0.35 / 10^2) = 2.10 \text{ ha-m}$$

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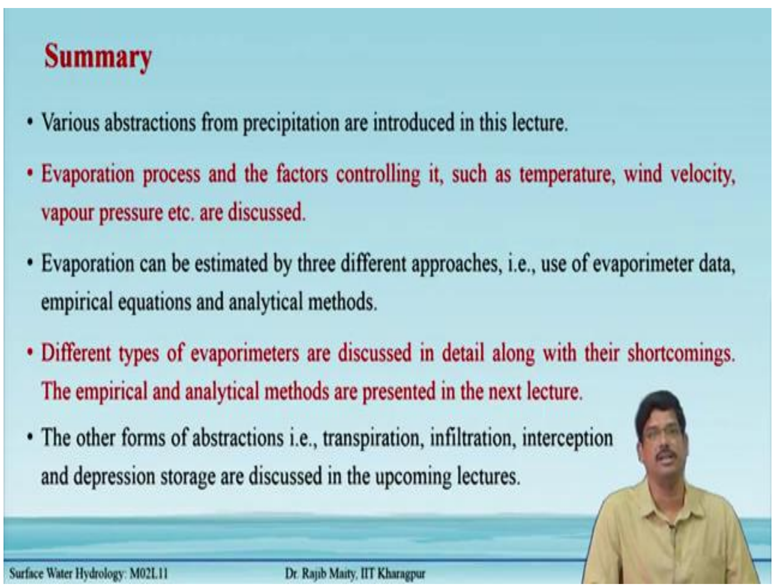

Summary

In summary, we learned the following points from this lecture:

- Various abstractions from precipitation are introduced in this lecture.

- The evaporation process and the factors controlling it, such as temperature, wind velocity, vapour pressure, etc. are discussed.
- Evaporation can be estimated by three different approaches, i.e., the use of evaporimeter data, empirical equations, and analytical methods.
- Different types of evaporimeters are discussed in detail along with their shortcomings. The empirical and analytical methods are presented in the next lecture.
- The other forms of abstractions i.e., transpiration, infiltration, interception, and depression storage are discussed in the upcoming lectures.