

3.8 Water level, water temperature, irrigation and drainage

In a flooded area or where the groundwater table is high, changes of water level and water temperature substantially affect ground surface characteristics. In an aqueous system with a shallow bottom, the heat capacity of the system increases with increases in the water level. In a high moor, apparent changes in the aerodynamic characteristics and evaporation efficiency of the ground surface are observed along with the rise and fall of the water level. To calculate the heat storage rate of a water body, water level and water temperature must be measured. Abrupt changes in these provide information on the horizontal movement of water. For irrigated farmlands, the amount irrigated or drained for the evaluation of water budget has to be understood beforehand. For some systems, the inflow and outflow of dissolved or non-dissolved carbon and nitrogen that results from irrigation or drainage cannot be ignored in evaluating the water budget for each system.

The water level is the height of the water surface in relation to a reference surface. A method of monitoring a ruler perpendicular to the water surface by visual or by time-lapse camera observation is so fundamental and reliable that it can be applied to the calibration of sensor measurements. There are various water level sensors that operate on different measuring principles. These are used in accordance with the magnitude of the water level fluctuation. These instruments are also used as lysimeters and pans to measure the evaporation rate, and for hydrological observation weirs to measure the flow rate, which is introduced later.

As in the atmosphere, water experiences thermal stratification. As is the case of air temperature (or soil temperature), water temperature measurement needs to take the measuring height (depth) into consideration. Where the water level fluctuates rapidly and substantially, the device must allow the temperature detector to move up and down along with the water level.

A regional estimate of irrigation water is drawn up for a comprehensive irrigation planning. Regarding flux observation on individual paddy lots, a researcher must measure the amount of irrigation and drainage for each lot. In Japan, because farmlands where a land consolidation project has been carried through are irrigated directly from water channels by lot, it is easy to measure the irrigation rate. For drainage, however, water is disposed of not only by surface drainage but also by subsurface drainage through permeation. Accordingly, it is not easy to figure out the drainage rate for farmlands unless underdrain systems such as closed conduits are sufficiently developed.

3.8.1 Water level

Types of instruments

There are two methods of measuring water level. One is to measure the distance from a reference point above the water surface to the water surface; the other is to measure the distance from a reference point below the water surface up to the water surface.

Float water level meter

The water level is determined by the motion of the float. Because the up-and-down motion of a float can be converted into the rotation of a pulley shaft, continuous measurement is possible using a simple instrument. The instrument requires frequent maintenance to ensure its accuracy, as it contains many moving parts.

Ultrasonic water level meter

The distance to the water surface is figured out based on the reflex time of an ultrasonic pulse that is shot at the water surface. The instrument has no moving parts, so it requires little maintenance. Even so, regular inspections must be conducted to ensure that the ultrasonic path is unobstructed. Because acoustic waves are used, corrections may need to be made by understanding the temperature dependence of the acoustic velocity, but a compensation circuit is usually built in to deal with this problem. In some cases in which the difference in temperature between a sensor and a water body like in a well is significant, the compensation accuracy may be less than in conventional cases.

Laser water level meter

A laser is aimed at the water surface, and the distance to the water surface is calculated based on the arrival time of the reflected light. A laser displacement gage is used to obtain measurements in millimeters. If the target water is clear, the laser may penetrate the water instead of reflecting off the water. This can cause error. To prevent this, a plain float is used, with the laser directed to reflect off the float.

Capacitive water level meter

The water level is measured on the principle that the electrostatic capacity between electrodes is proportional to the volume of some fluid. Those that are commercially available have electrodes ranging from 0.5 to 2 m in length. Because the measurement range covered by one sensor is narrower than that of other instruments, fluctuations in water level should be investigated in advance so that the right instrument with an optimal length of electrode can be selected.

Hydrostatic water level meter

This instrument calculates the hydraulic pressure from diaphragm displacement, and then converts it into the water level. The atmospheric pressure needs to be measured simultaneously. However, certain

types of instruments require no correction for atmospheric pressure, the negative-pressure side is open to the atmosphere. Inherent to diaphragms is the fact that those with high pressure resistance have poor resolution.

Measuring method

The sensor must be securely fixed to a firm post so that the water current does not cause it to move. When using a large temperature-dependent sensor, devise a sunshade so that solar radiation does not reach the sensor directly. For ultrasonic and laser sensors, protect the sensing volume with a solid pipe or mesh tube to keep objects such as leaves from entering the space between the sensor and the water surface. However, especially in the case of the ultrasonic sensor, the dimensions of the detection area need to be checked in advance in the operation manual or other resources so that the above-mentioned pipe or mesh tube itself does not interfere with the sensing volume. Hydrostatic water depth meters that require atmospheric pressure correction measure the atmospheric pressure in addition to the hydrostatic pressure. If the water depth is too small for a hydrostatic water depth meter to take proper measurements, the apparent water depth can be increased by digging into the bottom surface, inserting a solid pipe, and deploying the sensor in the hole.

The water level and the distance from the reference point to the sensor zero-point are periodically measured and compared with output data of the sensor so that problems of the sensor, if any, can be fixed. At a relatively small body of water, such as a paddy, the water may be blown leeward at times of strong wind. For this reason, the water level at more than one observation point in a paddy needs to be recorded on each visit to the site.

Calibration

Both ultrasonic and laser water level meters can be calibrated indoors, where a proper flat plate is prepared and measurements are taken by varying the distance to the target plate. Among capacitive and hydrostatic water level meters, those for a small range can be calibrated indoors with the help of a water tank or a bucket. For a sensor equipped with a temperature compensation circuit, the accuracy should be confirmed by comparing the output data with the water level that is periodically observed onsite by a researcher.

3.8.2 Water temperature

Types of instruments

As is the case for air temperature and soil temperature, water temperature is measured mostly by thermocouples, thermistors, and platinum resistance thermometers. The characteristics of each are given in Sections 3.3 “Air temperature” and 3.5.1 “Soil temperature”.

Measuring method

To measure water temperature at a constant water depth below the water surface, the sensor is hung from a float. To make measurements at a constant water depth above the water bottom, a weighted sensor is suspended in the water with a float. In either case, the float and the sensor should be covered entirely with a tubular net to prevent wind and current from carrying away the device. Also, caution should be exercised to keep the sensing unit from touching the net.



Photo 3.8-1 Use of a float in measurement of paddy water temperature. (Mase paddy flux site)

Tips!

Before the plants in a rice paddy start growing, the water temperature is relatively uniform because the water bottom serves as a heat source. When plants grow thickly, the water surface serves as a heat source, which allows thermal stratification to occur in the paddy. Measuring the water temperature at more than one depth is useful for analyzing changes in the heat storage flux of a water body.

Tips 3.8-1

Calibration

A water bath is used for calibrating water temperature sensors, in a manner similar to that of air temperature sensors. (See Section 3.3 “Air temperature”.)

3.8.3 Irrigation and drainage

Types of instruments

The flow rate is the basic variable to be measured for studying irrigation and drainage. When the flow rate is approximately 1 to 2 Lmin⁻¹ and there exists a sufficient elevation drop, the flow rate can be directly measured using a bucket, a beaker, and a stop watch. However, long-term continuous measurement of the flow rate requires the following instruments.

Weir flow meter

Running water is collected in a weir with a rectangular or triangular notch (measuring weir). The flow rate is calculated from the amount of water that spills out of the notch and the water level in the weir (Photo 3.8-2). The water level sensor should be selected according to the weir depth. The relationship between the water level and the flow rate is determined by the notch shape. Flow rate formulas for triangular weirs, that is, weirs with a right triangular-shaped notch, and for rectangular weirs, that is, weirs with a rectangular-shaped notch, are provided in the Japanese Industrial Standards (JIS) (JISK0094: <http://www.jisc.go.jp/>). For irrigation and drainage measurements, a tank with a notch is usually deployed. For example, in direct irrigation from a pipeline, water flowing out of the spigot is stored temporarily in this tank, and the water level in the tank is measured.

Parshall flume flow meter

Parshall flume flow meters are also used for open channel flow rate measurements. The Parshall flume is a Japanese hand-drum shaped structure, and the flow rate is measured using the property that the water surface becomes elevated within the narrow segment of the flume (Photo 3.8-3). Because the configuration of the Parshall flume does not allow much dirt to accumulate, it requires less maintenance than tank style weirs.

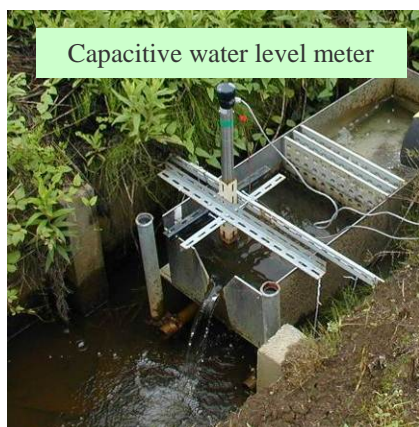


Photo 3.8-2 An example of drainage discharge measurements with the use of a tank style weir (triangular weir). (Mase paddy flux site)



Photo 3.8-3 An example of installation of a Parshall flume for the measurement of the flow rate of an open channel flow. (Photograph: Courtesy of Senecom, Inc.)

Water meter

If the maximum flow rate within a pipeline is on the order of the flow rate of tap water, a propeller type water meter can be used. A paddlewheel water meter, which is frequently used for household applications, is simple in its construction, low in price (a few thousand yen each), and rarely breaks down. However, agricultural water is not free of objects and impurities such as algae, which can cause the water meter to breakdown. Therefore, water meters are often not well-suited for use in agricultural water. As for

electromagnetic water meters, they are expensive, however, they contain no moving parts, giving them a broader range of application than propeller type water meters. Finally, warranty conditions need to be reviewed for both types of water meters as the use of drinking water is presumed by the manufacturers.

Measuring method

Initially, 1) the types of irrigation and drainage at the field and 2) the locations of the intake or drainage outlet and the elevation drop need to be assessed. If the head drop between the intake or drainage outlet and the water surface is large, install a tank style weir in that space. If there is sufficient water pressure inside the pipeline, install the tank near the water outlet and introduce water into the tank with a hose. For deployment of a Parshall flume, set it directly in an open channel. If the channel width is larger than the flume inlet width, the channel needs to be narrowed gradually from the upstream region to the flume inlet by creating an embankment or using other means. Therefore, in general, a Parshall flume is not well-suited for use in a concrete channel. Regardless of whether a weir or a Parshall flume is used, it needs to be deployed as designed (usually horizontally) in order to accurately calculate the flow rate from the water level. Furthermore, a weir must be securely anchored to a scaffolding pipe or other object so that it will not be shifted by the water flow. In this procedure, the flow rate during heavy rainfall and the weight of the weir full of water need to be thoroughly taken into consideration. As for water meters, they should be installed directly to spigots with reducer or increaser pipes or similar devices as necessary. The water level in a weir or a Parshall flume should be measured at 10 to 30 minutes intervals using a capacitive or hydrostatic water level meter. As auxiliary data, record the irrigation and drainage conditions during each site visit.

Calibration

Prior to the use of an unconventional weir, create a water-level-discharge curve by evaluating the relationship between the water level and the discharge based on measurements. For measuring the flow rate, water that flows out of the weir within a given time interval should be collected in a bucket, and the collected water should be subsequently measured with a graduated cylinder. When employing a water level sensor, calibration needs to be performed in advance with the above-mentioned calibration procedure for water level sensors. It is also effective to check the water level and flow rate outputs while the sensor is deployed at the site.