WATER MEASUREMENT

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Summary

Water measurement can be a valuable management tool for monitoring pumping plant performance and for evaluating field irrigation efficiency. The Arizona Groundwater Management Act imposes another reason for measuring water in Active Mangement Areas and Irrigation Non-Expansion Areas; the acre-feet of groundwater pumped must be reported annually.

There are obstacles to accurate water measurement but many measurement devices from which to choose. The key will be selection of the best device for each physical situation, grower preference, and accuracy required.

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Why Measure Water?

Sharply increasing energy costs provide one reason for measuring water. Two ways to reduce these costs are to improve pumping plant performance and increase field irrigation efficiency. Monitoring of pumping plant performance and evaluation of field irrigation efficiency both require water measurement.

In the Active Management Areas and Irrigation Non-Expansion Areas, designated under the 1980 Groundwater Management Act, there will soon be another reason to measure water. The law requires an annual report of the acre-feet of groundwater pumped. In the Active Management Areas, water measurement accuracy will be particularly important because of the Water Duty and Groundwater Withdrawal Fee.

Anticipated Problems

Many growers are well aware of the problems of measuring water accurately. These problems must be identified so that the necessary corrective steps may be taken and the best water measurement device selected. The most common difficulties encountered are sand production, entrained air or gas bubbles, partly full pipes, close plumbing and pipe obstructions, combined flows, changing pumping rate, and flat ditches with little freeboard. These problems can be solved but particular combinations may require substantial changes in the pump discharge arrangement.

Water Measurement Devices Overview

There is one important distinction to be made concerning water measurement devices; some measure volume (acre-feet) directly but most measure rate of flow (gallons per minute, cubic feet per second, or miner's inches). The law requires a report of volume pumped. If rate measurements are made, some system must be used to totalize the flow over the time of pumping during the year.

Basically, measurements can be made either in a pipeline or in an open ditch. Pipeline devices include the propeller-type meter, velocity device, venturi, and the end-cap orifice. Open channel methods are the weir, flumes such as the Parshall, "cut-throat", and "critical depth", and "sill" or modified broad-crested weir. Among all these, the propeller-type is the only one which measures volume directly; all the rest must be combined with some totalizing method. This list omits such methods as the trajectory and ditch float which are probably not satisfactory for most situations. Also omitted are certain other devices used for industrial applications. Some of these may become useful in agriculture.

Pipeline Devices

For practical purposes, all pipeline devices require a full pipe, no appreciable entrained gas bubbles, and prescribed distances upstream and downstream from the point of measurement.

Propeller-type meters indicate directly the volume pumped in acre-feet. They are, however, vulnerable to wear and failure due to sand in the water. Special bearings are available to improve performance under these conditions. Sand wear will cause the propeller-type meter to read too low; entrained gas bubbles will cause the meter to read too high. Straightening vanes are often necessary where upstream pipe lengths are insufficient to allow accurate measurement without the vanes.

Velocity devices, called pitot tubes, indicate a pressure caused by the velocity. This pressure may be observed with a water column manometer, or with electronic equipment. In most cases, the flow rate for the appropriate pipe diameter must be read from a graph or table.

The venturi senses pressure differences caused by a specially-designed constriction in the discharge pipe. The greater the flow velocity, the greater the pressure difference. This difference can be indicated either with a water column manometer or by electronic means.

The end-cap orifice has been used traditionally in the well drilling industry. The pressure behind a sharp-edged circular orifice at the end of the discharge pipe is observed as the height of a water column in a transparent tube. Tables and graphs are available for reading the flow rate for the appropriate orifice size and pipe diameter.

Open Channel Devices

In general, all open channel devices must have free flow conditions, that is, there must be enough drop in the water surface at the point of measurement that the device isn't flooded by the downstream water level. Flow rate can be read on a gauge mounted upstream from the device. Stage recorders can be used to record the rate of flow over a specified time period.

The weir requires the most drop in water surface of all the devices in order to maintain free flow conditions. Weirs may be rectangular, trapezoidal, or triangular. Flow rate is obtained by reading the gauge and referring to a table.

Flumes require less drop than a weir and hence, well operate in flatter ditches. The Parshall flume has been used by irrigation districts for many years. More recent developments have been the "cut-throat" and "critical-depth" flumes. The latter is particularly adaptable because computer calibration techniques have been developed by Dr. Replogle at the U.S. Water Conservation Laboratory. The name "critical-depth" is a misnomer because all the open channel devices discussed here require hydraulic critical depth flow conditions.

The "sill" or modified broad-crested weir, was also developed at the U.S. Water Conservation Laboratory. The device consists of a raised section in a concrete-lined ditch, with a ramp to accomplish flow transition smoothly. Rate of flow can be read directly from an upstream gauge specially marked for the particular sill height.

Totalizing Volume

The propeller-type meter indicates volume directly; rate of flow devices require some means of totalizing flow over time. Totalizing can be accomplished mechanically, electronically or with a shunt. At least one product is available commercially for totalizing mechanically the volume of flow through an open channel rate device. Electronic totalizers are currently used for industrial applications. Any of the pipeline rate of flow devices could be combined with a small household water meter in a small parallel or shunt line. Accuracy would depend on a known and constant relationship between the flow rate through the main pipeline rate device and that through the household meter shunt line. No commercial meters of this type are currently available.

It may be possible to use the electric utility meter for totalizing flow through a rate of flow device of any kind. This could be accomplished by observing the kilowatt hours of energy consumed in pumping a volume of water during a short calibration period. Thereafter, acre-feet pumped could be calculated from the energy consumption using the calibration value. The calibration value, however, will change if the water level in the well or discharge conditions cause the pump to shift on the operating curve. Pump wear would also cause the calibration value to change. If the electric meters are used for totalizing, frequent calibration and systematic records will be necessary.

Accuracy Range

The accuracy range required for management purposes depends on the needs of the manager. The accuracy to be required under the Groundwater Management Act is under study and has not yet been established.

Practical field accuracy is appreciably less than test laboratory accuracy. The laboratory accuracy of many devices is in the range of $\pm$ 2 percent. Under practical field conditions, diligence will be required to assure $\pm$ 10 percent. In some cases, even $\pm$ 15 percent may be difficult to achieve. Higher field efficiencies are attainable, of course, if necessary.