ON-FARM WATER MEASUREMENT AND EVALUATION

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ABSTRACT

Metering of farm water deliveries in the Imperial Irrigation District has always been a costly and difficult procedure. Due to existing structural and environmental conditions, many of the traditional methods of metering deliveries had in the past proved cumbersome or unsuccessful. With funding provided by the IID/MWD Water Conservation Program, a method for utilizing ultrasonic transducers for metering farm water deliveries under orifice flow conditions has been developed. These on-farm water level sensors were designed to be portable, environmentally rugged, solar powered, simple to operate and maintain, and visually unobtrusive to minimize vandalism. This paper describes the construction of the on-farm water level sensors and their function as a useful tool in providing rapid and accurate irrigation evaluations to farmers.

INTRODUCTION

The Imperial Irrigation District is currently involved in the IID/MWD Water Conservation Program both on-farm and system-wide. The Irrigation Management Unit is responsible for implementing the on-farm programs. Some of the current projects the Irrigation Management Unit is involved with include; tailwater-return systems, linear move systems, and the use of CIMIS to help with irrigation scheduling.

In 1995 the Irrigation Management Unit completed development of 15 portable meters. The meters record the amount of water entering a field through the delivery gate and the amount of tailwater leaving the field through the tailwater box. Fifteen fields can be monitored at any one time. The sensors remain in the field for an entire irrigation event. When the irrigation event is complete, they are moved to another field. Quality control hand readings are taken and compared to the sensors. This information is then processed and an irrigation evaluation is created.

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HISTORY

The water users in the Imperial Irrigation District order water one day in advance in 12-hour or 24-hour increments. The ditch tender arrives in the morning to "set" the order. The ditch tender takes three measurements: 1) water level upstream of the gate, 2) water level downstream of the gate, and 3) inches of gate opening. These measurements are input into a table based on an orifice flow equation. The ditch tender checks this gate two more times during the day to make sure the water user is "on-order." This existing method works well for general billing purposes and total water use accounting, but does not tell the whole story as it relates to water flow fluctuations throughout the day and night.

METERING DEVICE DEVELOPMENT

The Imperial Irrigation District needed a method of metering water deliveries that was reliable, accurate, affordable, and able to withstand environmental extremes of the Imperial Valley. Among the various meters considered, propeller meters were looked at first. Due to the high silt loads and the amount of moss in the irrigation water, propeller meters were ruled out as a reliable device for this type of application.

The Imperial Irrigation District had done extensive work in the past with broad-crested weirs to measure delivery flows into individual fields. They however had some problems. Because of our very low delivery pressure situation they were not widely applicable throughout the district. The engineering and construction costs were also prohibitive. With over 5,000 delivery points being measured with orifice flow equations, it was disturbing to measure water on a small subset of the gates using a different measurement method and then call it representative.

Also considered and discarded were pressure transducers and acoustic velocity meters. The pressure transducers do not lend themselves to moving between locations every few days. The membrane on certain types would dry up and then fail when the water reached the sensor. Sometimes an air bubble would form on the tip of the sensor and give a false reading. Also, the inlet to the membrane would often plug with silt and prevent water from reaching the sensor.

What was finally arrived at is a portable device that is easily moved between pre-calibrated sites. The major components of this metering device are ultrasonic level sensors for reading both upstream and downstream water levels and a linear transducer attached to the gate stem that measures gate position. These three sensors as well as ambient air temperature and battery voltage are input into a data-logger that logs a reading on a 10-minute interval. This data is later retrieved for graphing and analysis.

ADVANTAGES AND DISADVANTAGES

An advantage of this device is its ability to accurately measure flow without touching the water. The ultrasonic level sensors send a sound pulse to the water that determines the distance within 1/8-inch accuracy. This non-intrusive approach avoids many moss and silt problems inherent in the other devices. Environmental concerns were met by enclosing the meter in a waterproof and dust-proof container. This container has a tight seal and insulation on all sides. The harsh desert environment does not affect the equipment located inside. This device is portable and can be set up in less than one minute. This portability allows the $3200 value to be amortized over several sites. Meter brackets easily attach to existing gate structures without any gate modification. This bracketing also allows the meter to be locked to the gate structure.

Perhaps the greatest advantage of this type of device is the way in which it exactly duplicates the measurements of a Zanjero. Flow changes can be attributed directly to either pressure through the structure or gate position. This device gives us a more accurate picture of delivery flow behavior.

Some of the disadvantages encountered include floating debris below the sensors causing inaccurate readings. For this reason and others the Irrigation Management Unit has engaged in a quality control program to assure better evaluations. Technicians go to the gate operating during an irrigation event to measure by hand the two levels and gate position. These levels are recorded on the irrigation evaluation. From here analysts can compare readings and check for any inaccuracies.

IRRIGATION EVALUATIONS

Ultimately the delivery data coupled with tailwater data allows the Irrigation Management Unit to consider the total irrigation event and provide timely feedback and suggestions to water users. There are three groups that currently use the irrigation evaluations:

1. Farmer, Irrigation Foreman, Irrigator
2. IID Operations Staff
3. Irrigation Management Unit
4. Water Resources and Planners

Delivery and tailwater flow is recorded in 10-minute intervals and the water user is provided a hydro-graph of an Irrigation Event. This hydro-graph provides a dynamic picture of an irrigation event by measuring the total amount of water onto and off a particular field.

1) By examining an irrigation evaluation chart the water user can see the amount of water delivered and the amount of tailwater spilled and at what times this took place. From here the water user can decide if his irrigation practices are optimum and what options are available to conserve water delivered or tailwater if necessary.

2) By examining an irrigation evaluation chart the IID Operations and Divisions can see the amount of water delivered as calculated by the sensors and compare the flow to their own measurements. The sensors measure the same exact three components that the ditch rider measures, and in the same way. The three measurements; upstream level, downstream level, and gate position are measured directly in inches and charted. Fluctuations in flow are easily traceable to one of these three components shown on the evaluation chart. From here IID Operations can target certain laterals that fluctuate more than others can and determine if any measures need to be taken.

3) By examining an irrigation evaluation chart the IMU Unit can see the amount of water delivered and the amount of tailwater spilled for educational purposes. Depending on the demand for information, fields with certain crops, soil types, or special irrigation practices can now be accurately monitored. Ultimately, when enough irrigation evaluations have been completed this data may enhance or replace data currently used for IID delivery and tailwater averages.

4) Water Resources staff and District planners can see areas of the District that have unacceptable fluctuations and plan for mid-lateral reservoirs, automated gates, and lateral interceptors.

HYDRO-GRAPHS

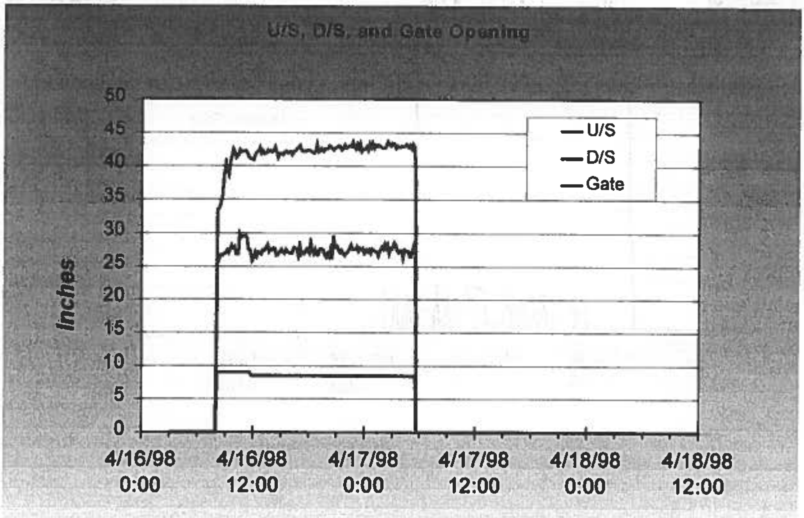


Figure 1. Water Measurement Components

Figure No. 1 shows the three components the meter is required to measure in order to get a flow measurement through a delivery structure. The top line (between 40 inches and 45 inches) is the upstream water level with respect to the gate, the second line (between 25 inches and 30 inches) is the downstream water level with respect to the gate, and the third line (between 5 inches and 10 inches) is the slide gate opening. The length of this irrigation event can also be determined. The gate was opened at 08:00 on 4/16/98 and closed at 06:00 on 4/17/98. These readings are taken at 10-minute intervals and stored for later retrieval.

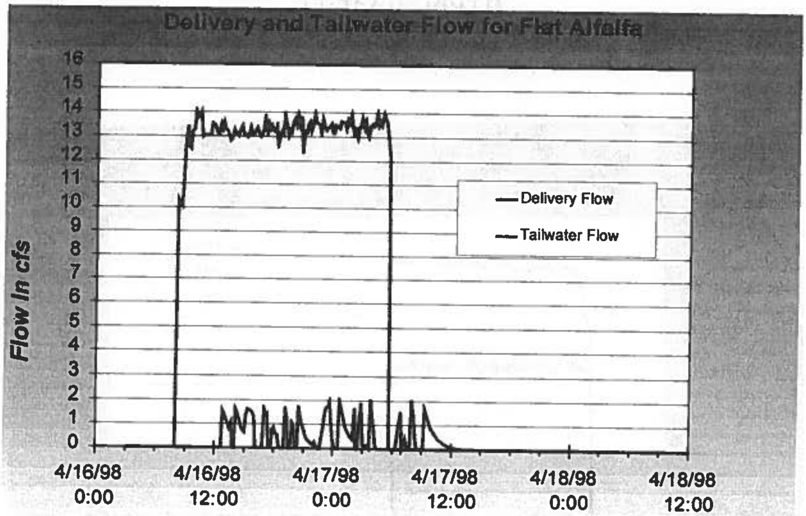
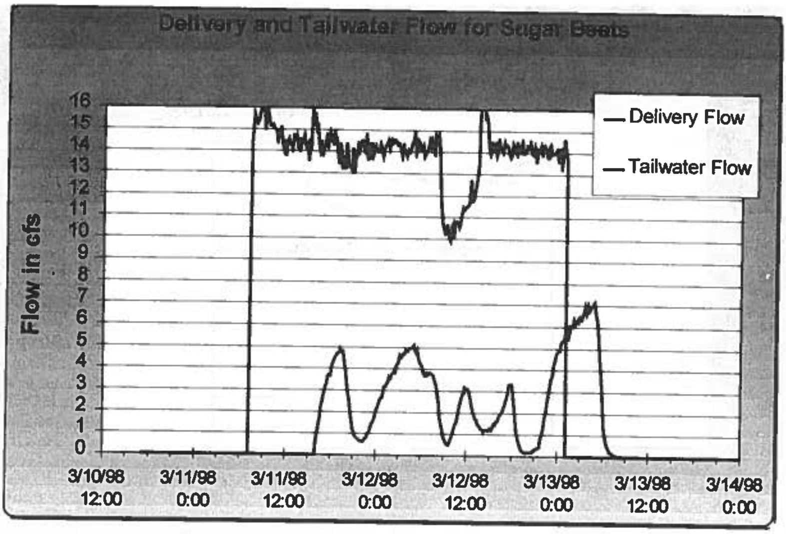


Figure 2. Flat Crop Irrigation Event

Figure No. 2 is an example of a flat crop irrigation event. This is a hydro-graph built from the previous three individual components; upstream level, downstream level, and gate position. These components are input into an orifice flow formula and flow can now be read directly in cubic feet per second (CFS) between 13 CFS and 14 CFS. The tailwater is also calculated with a weir formula and input into the hydrograph. The evenness of the delivery flow and the tailwater flow (below 2 CFS) are evident in this example.



Delivery Volume (AF) = 48.3 % TW= 20% Acres = 70
Tailwater Volume (AF)= 9.5 Order = 2d-15' In. App.= 8.3

Figure 3. Row Crop Irrigation Event

Figure No. 3 is an example of a row crop irrigation event. By calculating the acre-feet of water applied and the acre-feet (AF) of tailwater runoff, a more complete picture is formed. With this irrigation event there is some unevenness in the tailwater flow. The last set of tailwater is flowing more than the previous and may be combining with other sets causing a larger amount of tailwater near the end of the irrigation event. One way to prevent this is to order a "cut" in the water order amount that better matches the individual field's needs. An example of a cutback irrigation event is shown and explained in figure No. 6.

Included in Figure No. 3 are the original water order and the number of acres in the field. Analysts calculate inches applied from the acres and actual measured water amount. This information is taken to the field and discussed with the water user. The evaluation is left with the water user to serve as a tool to help with the next irrigation event.

By looking at the line representing the flow in CFS, a dip is noticeable. The flow dropped at 08:00 on 3/12/98. By looking at the individual components of this flow it will be possible to determine the cause of the flow.

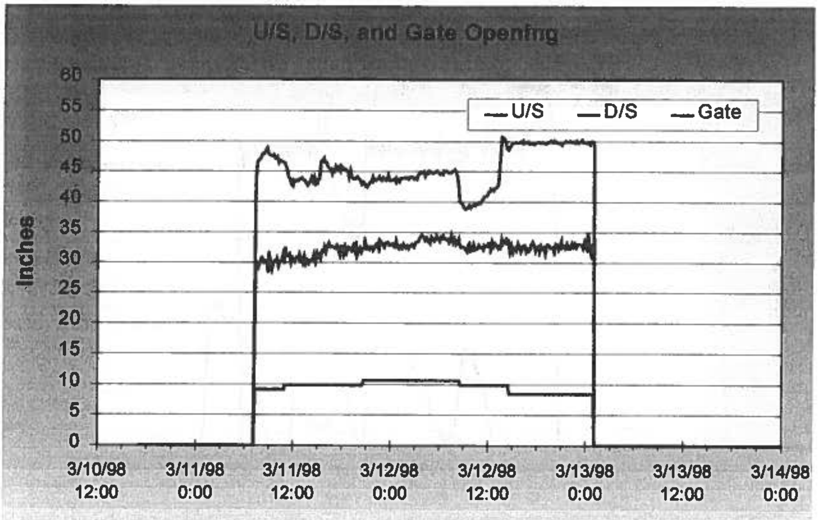


Figure 4. Row Crop Water Measurement Components

By looking at Figure No. 4 it is possible to see how the upstream level drops from 45 inches to 40 inches at 08:00 on 3/12/98. The pressure through the structure drops from 10 inches to 5 inches. This drop was reflected in the flow as shown in Figure No. 3. The flow at the same time dropped from 14 CSF to 10 CFS. Eventually the water level moves up (to 50 inches) and ordered flow is attained once again.

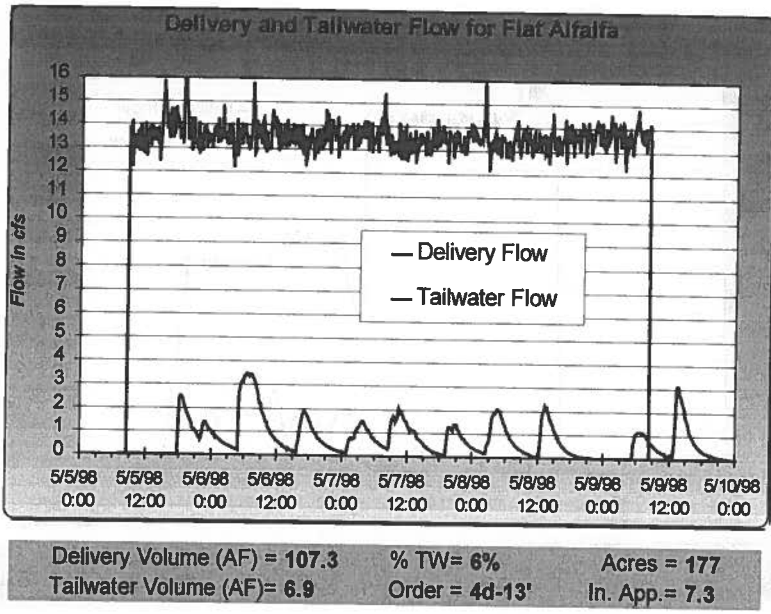


Figure 5. Flat Crop Irrigation Event

This is an example of a flat crop irrigation event. The flow and tail-water is even with very few larger peaks. This was a four-day irrigation event for a 177-acre field.

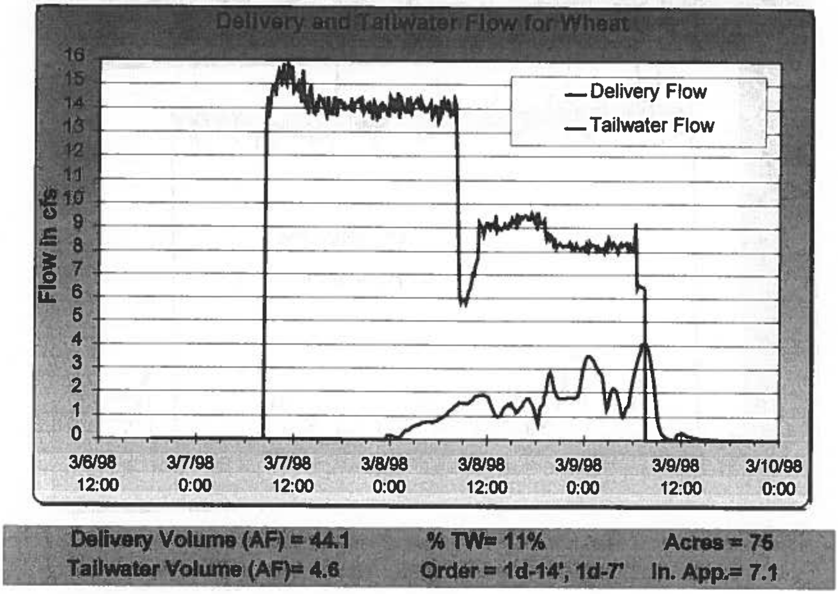


Figure 6. Flat Crop Irrigation Event

This is an example of a cutback irrigation. Anticipating the tailwater to build up, the water user requested a cutback irrigation. The water user ordered a 5 CFS cut. This caused the flow to drop from 14 CFS to 9 CFS. This allowed the water user to better manage the amount of tailwater.

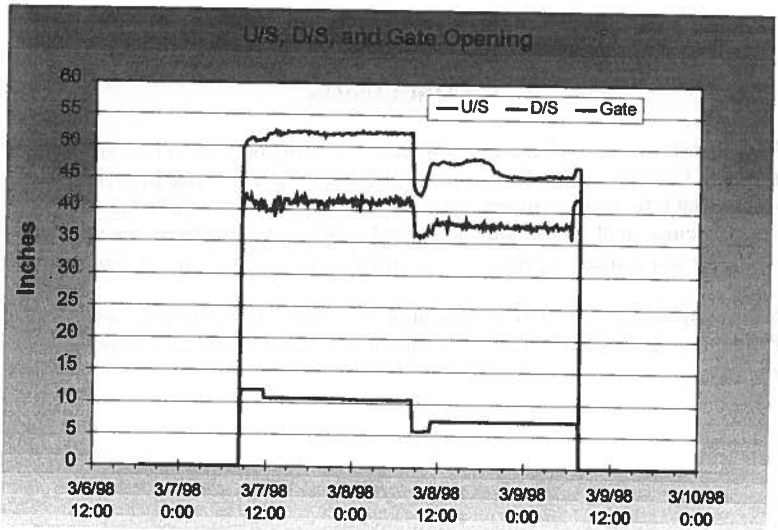


Figure 7. Flat Crop Components

By examining the flow components the reason the flow reduced from 15 CFS to 9 CFS can be determined. Note the pressure (or difference between upstream and downstream water level) stays about the same. The pressure stays around 10 inches but the gate has been lowered from 11 inches to 7 inches. This 4- inch change in gate opening caused the flow to drop.

CONCLUSION

The on-farm water level sensors have been and will continue to be a successful program. Our water users in this program benefit from this data in several ways. For the first time many growers can at a glance understand what is happening on their particular field. By looking at several irrigation events from one field the water user can recognize problems and true water conservation can begin.

New measuring devices may be available soon that are simpler and more affordable. This would be the next step into a broader water measurement program.