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USDA LTAR Common Experiment measurement: Irrigation water applied

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Abstract

Irrigation is the amount of water applied to a field or plot per unit area. Irrigation supplements rainfall to provide adequate soil moisture for successful crop production. Irrigation is a vital component of agriculture in the western and central United States and is becoming more prevalent throughout the United States. Different types of irrigation are used across the United States (e.g., overhead (linear or pivot), sprinkler gun, subsurface drip, surface drip, or gravity/furrow/flood). Using a flowmeter on the main distribution pipe is recommended for measuring irrigation amounts. To adequately measure irrigation in research plots, the characteristics of the distribution pipe for each individual plot must be considered.

Materials

Flow rate can be calculated by measuring the fluid velocity in a conduit of a known cross-sectional area.
$Q = V \times A$, where
Q = flow rate, cubic feet per second (cfs)
V = velocity of the liquid, feet per second (fps)
A = cross-sectional area of flow, square feet (ft^2)

Flowmeters measure the water velocity in a pipe. An accurate measurement of the inside diameter is essential for correct flow rate calculations.

Electromagnetic flowmeters are recommended for the LTAR Common Experiment; they use the principle of Faraday's law of electromagnetic induction to measure liquid velocity. The operation principle states that a magnetic field produces an electric signal in a moving conductor directly proportional to the velocity of the conductor. The fluid must be electrically conductive, such as natural water, and flows through the magnetic field creating a voltage, which is used to measure and calculate the flow velocity of water in a pipe.

Data collection - Equipment

1 A flowmeter with a totalizer that displays the cumulative flow volume is recommended. The totalizer tracks the cumulative volume of irrigation water and the duration of its application.

2 Flowmeters are available from various manufacturers (e.g., McCrometer, Inc., Hemet, CA, USA).

3 Flowmeters should meet two criteria:

1) accuracy of ±2% of flow rate over the entire range of tested flows and
2) repeatability of ±0.5%, defined as the percent deviation of flow rate from average accuracy at each data point (IDWR 2017).

4 Electromagnetic meters should generally be installed at a length of at least three pipe diameters upstream and downstream of any obstructions, although the manufacturer's specifications may state different requirements. For example, given a 3-inch pipe diameter, install the flowmeter at least 3 × 3 = 9 inches upstream and downstream.

Note

Obstructions may include tees, elbows, valves, pumps, and changes in pipe diameter.

5 Chemical injection ports must not be upstream of a meter or meter transducer location. These distances are reducible using a flow straightener, which is a device to reduce turbulence and ensure flow in a straight line.

6 If the pipe is not full, the flowmeter will over-register the flow. Full pipe flow is indicated by positive pressure with minimal amounts of air or gas present (IDWR 2017).

7 A one-pipe diameter increase downstream of the flowmeter can be used to ensure full pipe flow if necessary.

8 An air-relief valve should be atop the pipe.

- This air vent will allow air to escape the pipeline, preventing water hammer or blockage.
- It will also allow air to enter the lines as water leaves at shutdown and can be very helpful in determining if full-pipe flow conditions exist.

9 Flowmeters can be mounted horizontally or vertically.

- Some flowmeters require an external DC power supply. External power supply options may include an AC/DC transformer, external battery with solar panel, or other charging source.
- The amount of power supplied must meet the manufacturer's specification for DC input voltage sufficient to maintain the meter in a continuous sampling mode.

10 For the LTAR Common Experiment, electromagnetic flowmeters that can collect and transmit flow data remotely are recommended.

11 Some popular brands of flowmeters (e.g., McCrometer) have built-in technology that allows for reliable remote meter reading and comes preassembled on new meters for simplified installation.

12 Alternatively, flowmeters can be connected to a data logger that is part of a larger telemetry system. A given telemetry system needs a minimum of a data logger (e.g., CR1000x from Campbell Scientific), antenna, and power source (solar panel or battery or both).

13 Recommendations on data logger integrity follow the general recommendations for water quantity variables. Please refer to the "Data logger integrity" section in the *USDA LTAR Common Experiment measurement: Best practices for collection, handling, and analyses of water quantity measurements* protocol.

Data collection - Site Maintenance

14 Potential pitfalls associated with these measurements include the presence of air bubbles, which can cause magnetic flowmeters to read artificially high velocities and hence volumes.

15 Specific to center pivot systems, another error occurs when the equipment is powered on or is moving without the application of water. For example, managers may move or "walk" the center pivot without applied water. In these instances, it helps having the flowmeter and a GPS sensor that indicates movement.

16 Periodically check the rate-of-flow indicator. It should be stable to the point of easily being read.

17 Some movement is normal, but if the indicator is erratically oscillating, disturbances exist and meter accuracy decreases.

18 For center pivot irrigation, check the meter flow rate against the system design flow rate, which is the sum of the design flow rate for each nozzle.

19 In addition, periodically check the air-relief valve mounted atop the pipe. If it is closed, the pipe is full; if it is not closed, the pipe is likely not flowing full.

20 At least annually, measure the uniformity of irrigation application amounts according to approved protocols (ASABE, 2020).

21 Site maintenance should follow the general recommendations for water quantity variables. Please refer to the "Site maintenance" section in the *USDA LTAR Common Experiment measurement: Best practices for collection, handling, and analyses of water quantity measurements* protocol (Baffaut et al., 2024).

Data processing and quality control

22 Data processing includes conversion between units. Important conversions include 450 gpm = 1.0 cubic feet per second (cfs) = 1.0 acre-inch/hour; 27,000 gallons = 1.0 acre-inch of water.

23 Irrigation efficiency is a common metric computed from measured irrigation flow data, and represents the amount of water a crop uses divided by the amount of water applied or diverted from an irrigation source. It is evaluated by examining the relationship of (Q x t = a x d) (flow rate × time = area irrigated × depth of water applied).

24 In addition, for overhead systems (linear or center pivot), motion often co-occurs with irrigation water application, so it helps having a GPS sensor on the equipment to sense this motion. Furthermore, check irrigation amounts against recommended application rates, which are often published for a given crop by the local extension office.

25 Following the installation of the flowmeter and associated telemetry, time and labor requirements are limited to data processing and quality control.

26 Data quality should follow general recommendations for water quantity variables. Please refer to the "Data quality" section in the *USDA LTAR Common Experiment measurement: Best practices for collection, handling, and analyses of water quantity measurements* protocol.

Data file formats and metadata

27 Formats include text files or user-created spreadsheets and databases.

28 Data file formats and metadata should follow the general recommendations for water quantity variables. Please refer to the "Metadata" section in the *USDA LTAR Common Experiment measurement: Best practices for collection, handling, and analyses of water quantity measurements* protocol.

29 In addition, specific types of metadata required for irrigation amount measurements include data and time of irrigation water application, area of irrigated region, crop, irrigation well location (latitude, longitude), irrigation source water description or characterization (NRCS

1997), irrigation application method, distance of flowmeter from pipe obstruction, pipe diameter, and flowmeter type and manufacturer.

Recommendations for data collection

30 Table 1. Summary of recommendations for measuring irrigation amounts.

A	B	C
Attribute	**Preferred**	**Minimum**
Spatial scale	Both	Plot
Frequency	Every 15 min or less	Per event
Covariate metrics	Precipitation measured at the same frequency Source water quality (see Water Quality primary metrics)	

Protocol references

American Society of Agricultural and Biological Engineers (ASABE). 2001. Test procedure for determining the uniformity of water distribution of center pivot and lateral move irrigation machines equipped with spray or sprinkler nozzles. https://www.canr.msu.edu/uploads/235/67987/ASAE_S436.1.pdf

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