USDA Natural Resources Conservation Service
U.S. DEPARTMENT OF AGRICULTURE

Irrigation Technical Note
Practice Code 449

Irrigation Water Management Plan - Small Farms and Gardens

Description

Irrigation Water Management (IWM) is the process of determining and controlling the volume, frequency, and application rate of irrigation water. IWM helps the irrigator to properly manage irrigation water application, while implementing an environmentally friendly and economically viable conservation practice.

Purposes

IWM can accomplish one or more of the following purposes:

- Improve irrigation water use efficiency.
- Minimize irrigation-induced soil erosion.
- Protect surface and ground water quality.
- Manage salts in the crop root zone.
- Manage air, soil, or plant microclimate.
- Improve poor plant productivity and health.
- Reduce energy use.

Flow Rate and Volume Measurement

To properly apply IWM an irrigator must possess the ability to measure the flow rate and volume of irrigation applications. There are various methods available to help producers accomplish this. Available upstream and downstream distances, cost, telemetry capability, pipe size, and water quality may all be factors in the type of device used and location of installation.

A flowmeter is the most used device. Flowmeters are typically installed near the discharge of the pump, but could also be installed at other locations.

Irrigation Scheduling

Irrigation Scheduling determines when to irrigate and how much water to apply during each application. Application amount, rate, and timing are scheduled to replace soil moisture used by the crop, allowing sufficient capacity for storage of additional moisture from effective precipitation. Base the timing of irrigation on one or more of the following methods:

Drip tape irrigation on crop growing beds

- Soil moisture monitoring techniques
- Soil moisture sensors
- Appearance and feel
- Plant monitoring (critical growth stage)

Base the volume (depth) of water needed for each irrigation event on the following, depending on each crop or field:

- Available water-holding capacity of the soil for the crop rooting depth
- Management Allowable Depletion
- Current soil moisture status
- Current crop/forage growth stage
- Distribution uniformity of the irrigation event

Estimating Soil Moisture with Sensors

Electronic sensors can be used to measure or estimate the amount of water in the soil. There are stationary or portable sensors. Stationary sensors can be placed at selected locations and predetermined depths throughout the field. Portable probes can be used in multiple locations.

Estimating Soil Moisture by Appearance and Feel

Soil moisture is typically sampled at 6 inches and then every 12 inches to the rooting depth of the crop (Table 1). Use the Estimating Soil Moisture by Feel and Appearance publication (Estimating Soil Moisture) to determine the soil moisture deficit for the crop root zone. Apply the amount of water required to raise the soil-water content to field capacity.

The soil texture at each depth must be known to use this method. Soil texture can be determined by the feel method (https://ww.nrcs.usda.gov/sites/default/files/2022-11/texture-by-feel.pdf) or by referencing the NRCS Web Soil Survey (https://websoilsurvey.nrcs.usda.gov/).

Example: Net irrigation event of 3.1" will refill the root zone.

Sample Depth	Zone	USDA Texture	AWHC* for Zone	Soil Moisture Depletion**	% Depletion
6"	0-12"	Sandy Loam	1.4"	1.0"	70
18"	12-24"	Sandy Loam	1.4"	0.8"	55
30"	24-36"	Loam	2.0"	0.8"	40
42"	36-48"	Loam	2.0"	0.5"	25

** *Available Water Holding Capacity*
*** Determined by "feel and appearance method"*

Crop Rooting Depth

Rooting depths vary with crop species and may be affected by compaction or hardpans. Rooting depth determines the volume of soil from which the crop can draw water and is important to determine the depth to which the soil must be wetted when irrigating[2].

Table1: Rooting Depth of Common Crops

Shallow (6-12")	Moderate (18-24")	Deep (>36")
Beet	Brussels sprouts	Asparagus
Broccoli	Cabbage	Lima bean
Carrot	Cantaloupe	Pumpkin
Cauliflower	Cucumber	Sweet potato
Celery	Eggplant	Watermelon
Greens	Pea	Winter squash
Herbs	Potato	
Onion	Snap bean	
Pepper	Summer squash	
Radish	Sweet corn	
Spinach	Tomato	

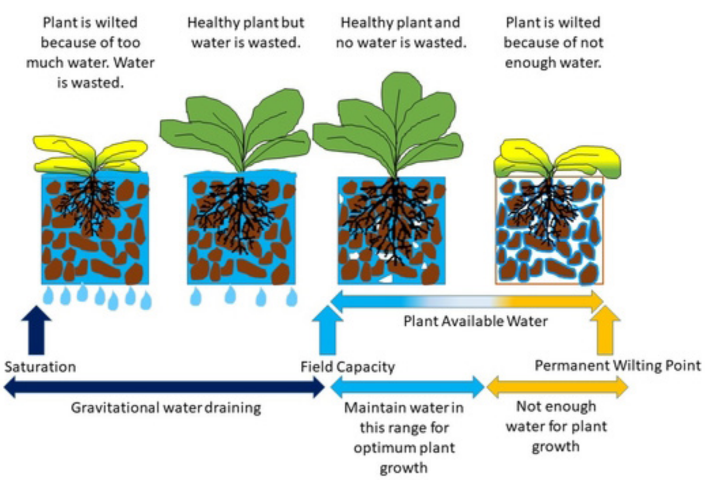
Resource: Midwest Vegetable Production Guide

Available Water Holding Capacity

Available water holding capacity (AWHC) is the maximum amount of water the soil can hold that can be absorbed by plants. The plant available water is between field capacity and the permanent wilting point.

The total available water holding capacity for a given location depends on soil texture, organic matter, and rooting depth[2]. Compaction will reduce irrigation infiltration and affect plant available water.

Different soil types have different AWHCs. Coarse soils, such as sands, have relatively larger pore space and do not hold as much water as fine textured soils, such as clays. Refer to the Estimating Soil Moisture by Feel and Appearance publication (Estimating Soil Moisture) for AWHC by soil type.
It is estimated that for each percent of organic matter



in the top 12" of soil, moisture-holding capacity is increased by thousands of gallons per acre (~380 gallons per 1,000 square feet). Soils with high water-holding capacities require less frequent irrigation than those with low water-holding capacities. However, when soils are irrigated less frequently, a greater amount of water must be applied per application to meet crop needs[2]. Monitor soil moisture to ensure that crops receive adequate water – in the range between field capacity and before reaching the crop's wilting point.

Plant Monitoring (Critical Growth Stage)

Crops require an adequate supply of moisture throughout their entire growth for production and the most efficient use of water.

While the frequency and amount of water varies according to individual crop, its age, current soil moisture, soil type, and weather conditions, generally 1 to 2 acre inches of water are required each week. One acre-inch is 27,154 gallons of water (623 gallons per 1,000 square ft).

Most crops are sensitive to water stress during one or more critical growth periods in their growing season. Moisture stress during a critical period can cause an irreversible loss of yield or product quality. Nearly all vegetable crops are sensitive to drought during two periods: two to three weeks before harvest and during harvest.

Critical periods must be considered with caution because they depend on plant species as well as variety. Some crops can be moderately stressed during noncritical periods with no adverse effect on yields. Other plants require mild stress to set and develop fruit for optimum harvest time (weather or market). Table 2 lists several crops and critical growth stages.

Table 2: Critical growth stage of common crops

Crop*	Critical Stage
Broccoli, Cabbage, Cauliflower, Lettuce	Head Development
Carrot, Radish, Beet, Turnip, Sweet Potato	Root Enlargement
Sweet Corn	Silking, Tasseling, and Ear Development
Cucumber, Eggplant, Pepper, Melon, Tomato	Flowering, Fruit Set, and Maturation
Bean, Pea	Flowering, Fruit Set, and Development
Onion	Bulb Development
Potato	Tuber Set and Enlargement
Summer Squash	Bud Development and Flowering
Greens, Spinach	Continuous

**Planting and stand establishment represent a most critical period for adequate water when transplanting.*

Management Allowable Depletion (MAD)

MAD is the percentage of the soil available water holding content that can be depleted between irrigation events without serious plant moisture stress. Only a portion of the AWHC of a soil is easily used by a crop before water stress develops3. The average MAD for high value vegetable crops grown in the Midwest is 25% for shallow rooted crops, 30% for moderately rooted crops, and 40% for deep rooted crops.

The amount and frequency of irrigation water to apply to crops can be calculated by knowing the MAD, soil texture and associated AWHC, crop rooting depth, and the crop water needs for the current growth stage. Refer to the datasheet on page 8 of this plan for an example irrigation schedule.

Transplants and Direct Seeded Crops

Plant growth stage influences the susceptibility of crops to drought stress. Irrigation is especially useful when establishing newly seeded or transplanted crops. Irrigation after transplanting can significantly increase the plant survival rate, especially when soil moisture is marginal and the evapotranspiration rate is high. Irrigation can also increase the uniformity of emergence and final stand of seeded crops[2].

For seeded crops, reduce the rate of application and the total amount of water applied to avoid crusting. If crusting is present, use low application rates and small amounts of irrigation water to soften the crust while seedlings are emerging[2].

Application System Distribution Uniformity

How much water is being putting on? In addition to irrigation water, it is also important to track the amount of precipitation at your farm with rain gauge(s). Depending on the size of your operation, multiple gauges might be needed.

Determining the amount of irrigation water that was applied, depends on the method of application:

- Sprinkler / mini-wobbler – place multiple collection devices (tuna cans or rain gauges) where you plan to apply. Apply water for a determined amount of time but less than what will be needed to see how much water is collected in each device. Multiply appropriately to determine the amount of water planned (i.e.,

Drip irrigation on transplanted crops.

water was on for 15 minutes and 0.25 inches was collected equals running it for about an hour to get 1.0 inch).
- Drip Tape – collect water from 2 holes each at the start, middle and end of the bed. Run for a determined amount of time to figure out how much was applied and adjust up or down to meet needs.
- Flow meter – use flow meter to determine amount of water being applied.

Continue to monitor if water is being applied uniformly and at planned rates across all areas. If not using flow meters, pay attention to water pressure as it can vary through the day.

Irrigation-Induced Erosion

Water, as rainfall or irrigation, unable to infiltrate the soil will likely result in runoff. Soil lacking adequate structure and / or with compaction, especially on a slope, will likely result in runoff. Excessive amounts of runoff cause erosion. This is most noticed with little rills or gullies in fields. Sedimentation at the base of slopes is also a sign of erosion.

If the amount of water being applied causes erosion, reduce the rate of water being applied at any one time by half and then apply the other half 12-24 hours later. Improving aggregate stability and infiltration or adding mulch, will also reduce erosion.

Water Quality

Irrigation water quality directly affects crops, soils and the environment. Testing irrigation water can help prevent potential adverse impacts by properly treating the water prior to application. This is especially true in high tunnel systems where irrigation is the only source of water. Crops grown outside are less affected by irrigation water sources since they experience dilution from precipitation.

A water sample should be sent to a laboratory that is equipped to test water for agricultural irrigation purposes. At a minimum, the analysis should include alkalinity, pH, soluble salts, hardness and heavy metals.

Based on the water test results, apply filters to the irrigation system and/or amendments to the water prior to application, as needed.

Irrigation and Mulching

Mulches used on many farms are either synthetic or natural. Consider mulch product and type when planning for crop irrigation.

Synthetic: Plastic mulch

Lay plastic mulches over moist soil. Irrigate the field if soil moisture is not adequate prior to laying the mulch[1]. Plastic mulch is not permeable. If irrigating mulched crops throughout the season, lay drip tape under plastic mulch to apply water directly to the soil surface. If irrigating with overhead sprinklers, monitor soil moisture to check that crops receive adequate water.

Synthetic: Landscaping fabric

Commercial landscaping fabric is often used on farms for weed control. It is permeable yet can partially obstruct rain or irrigation water. Lay landscaping fabric over moist soil. Lay drip tape under the fabric for the best direct application of water to the soil surface.

Drip irrigation and cilantro transplants.

Drip irrigation under beans.

Natural: Straw, hay, compost, wood chips, wool and other biodegradable natural materials.
Natural materials can improve soil moisture and irrigation efficiency by moderating soil temperatures and reducing evaporation from soil surfaces.

When using synthetic and natural mulches, it can be hard to visually see soil moisture. Drip tape can become clogged by soil or minerals in the source water or cut by equipment. It is important to monitor soil moisture regularly to ensure water is adequately meeting crop needs.

Water Table Contribution

The depth to the water table can change depending on the time of year. If the water table is within 6 feet of the surface during the growing period, then the amount of irrigation water needed may be less than anticipated due to capillary action.

Determine water table depth by measuring the water level in a nearby shallow well or dig a representative hole. If a shallow water table exists, closely monitor the soil moisture at the lower depths of a crops root zone to avoid over-watering.

Other Considerations

Increased crop residue left on the field will reduce the potential for irrigation-induced erosion, increase the infiltration of water into the soil, and reduce evaporation from the soil surface.

Avoid operating heavy equipment on wet soils to minimize soil compaction.

Adequate crop rotation is important to prevent disease and pest pressure.

Consider crop species selection in situations where drought or water deficits are recurrent.
Consider irrigation water management to maintain or improve soil health by following a soil management system that creates a favorable habitat for soil microbes by:

- Minimizing soil disturbance - physical, chemical, and biological
- Using plant diversity in the rotation to increase diversity below ground
- Keeping a living root growing year-round as much as possible
- Keeping the soil covered with residue and growing plants year-round

Manage water so it does not drift or come in direct contact with surrounding electrical lines, supplies, devices, controls, or components that could cause loss of electrical power or the creation of an electrical safety hazard to humans or animals.

Consider how the interruption of power to irrigation systems from load control, interruptible power schedules, repair and maintenance downtime, and harvest downtime may change the plans for irrigation water management.

The use of new technologies for data collection such as drones, advanced imaging technology, remote sensing technology, yield monitoring, and data logging to calculate water use can lead to more efficient water application.

The use of energy saving technologies, such as low energy precision application irrigation and use of alternative energy sources can result in significant energy saving versus conventional methods. It is the

Clogged drip tape from unfiltered well water.

Drip irrigation tape under landscaping fabric.

responsibility of organic producers to ensure that all permissible activities, design, materials used, and material specifications are consistent with the USDA National Organic Program.

Mini-wobbler irrigation system.

Record keeping

The remaining pages of this document must be completed to customize the Irrigation Water Management Plan to an operation.

Good record keeping is a best management practice for all farming operations and can help improve yields and profits.

If a NRCS program payment is scheduled for Irrigation Water Management (449), the record keeping is required. Documentation must include this Irrigation Water Management Plan and a record of the items listed below for each irrigation event.

- Location
- Date
- Crop
- Method to determine soil moisture
- Plant growth stage
- Available water capacity
- Soil moisture depletion
- Amount of water applied
- Rainfall/climate considerations

References

- [1]Indiana Field Office Technical Guide (FOTG) Standard (449) Irrigation Water Management.
- Midwest Vegetable Production Guide for Commercial Growers, 2022.
- Estimating Soil Moisture by Feel and Appearance, USDA-NRCS, April 1998.
- Indiana High Tunnel Handbook, Purdue Extension Service, HO-296, August 2018.
- [2] Irrigating Vegetable Crops, University of Massachusetts Vegetable Program, 2013.
- [3] Basics of Irrigation Scheduling, University of Minnesota, 2019.
- ▯ National Engineering Handbook, Irrigation Guide, USDA-NRCS, September 1997.

Additional Resources

- Crops - Greenhouse and Indoor Production Resources, Purdue Extension Service. https://mdc.itap.purdue.edu/newsearch.asp?subCatID=425%20&CatID=10
- Fruit Growers News – Specialty Crop Irrigation: A Video Alternative to Educational Meetings, Purdue University and Michigan State University, May 2020 https://fruitgrowersnews.com/news/specialty-cropirigation-a-video-alternative-to-educationalmeetings/
- Best Management Practices for Irrigating Vegetables, Rutgers Cooperative Extension, 2002 https://njaes.rutgers.edu/drought/pdfs/BMPIrrigating-Vegetables.pdf

RESET

Originally developed by Indiana NRCS, Marion County SWCD and Urban Soil Health

United States Department of Agriculture

Office: ______ Planner: ______

Address: ______

Contact Information: ______

IRRIGATION WATER MANAGEMENT PLAN DATASHEET - SMALL FARMS & GARDENS

GENERAL INFORMATION

Participant: ______ County: ______

Farm: ______ Tract: ______ Contract #: ______

IRRIGATION HISTORY & EXISTING COMPONENTS

Existing Garden/Fields: # Fields/Plots ______ # Systems ______ Total Area ______ acres

Garden/Field Type: ☐ Rows ☐ Beds ☐ High Tunnel ☐ Other: ______

Water Source:

- ☐ City / Municipal
- ☐ Domestic Well
- ☐ Shared Well
- ☐ Irrigation Well
- ☐ Irrigation Reservoir
- ☐ Pond
- ☐ Other: ______

Pressure Source:

- ☐ City / Municipal
- ☐ Pressure Tank
- ☐ Direct Pump
- ☐ Gravity

Operating Pressures If Known:

Minimum ______ PSI

Typical ______ PSI

Maximum ______ PSI

Avg Source Flow Rate: ______ GPM *(If Known)*

Is Electricity Available on Site? ☐ Yes ☐ No

Past Irrigation History *(type/frequency/amount or rate/crops/production/issues/challenges/other information)*

SOILS & CROP INFORMATION

Data from Web Soil Survey

Map Unit Symbol ______

Map Unit Name ______

Potential Crops & Growing Season

Spring ______

Summer ______

Fall ______

Winter ______

Representative Soil Profile

Crop Roots	Depth	Texture	AWHC
Shallow	6"	Sandy Loam	0.72 "
Moderate	18"	Silty Clay Loam	3.12 "
Deep	36"	Silty Clay Loam	6.72 "

AWHC - Total Available Water Holding Capacity.

Example Irrigation Schedule - No Rainfall

Crop Needs	Crop Roots	MAD, %	Amount	Frequency
	Shallow	25.0	Amend Soil "	every < 1 days
1.50	Moderate	30.0	0.86 "	every 4 days
in/wk	Deep	40.0	2.57 "	every 12 days

PLANNED SYSTEM INFORMATION

REQUIRED: Attach Irrigation Site Plan Map

Planned System Components (Optional/If Known):

- ☐ *441 Microirrigation*
  - ☐ Surface ☐ Subsurface
  - ☐ Drip Tape
  - ☐ Micro Sprinkler
  - ☐ Other: ______
- ☐ *533 Pumping Plant*
  - ☐ Electric
  - ☐ Solar
- ☐ *430 Irrigation Pipeline*
  - Diameter: ______ "
  - Material: ______
- ☐ *436 Irrigation Reservoir*
  - ☐ Storage Tank
- ☐ *558 Roof Gutters*
  - ☐ Trench
  - ☐ K-Style

In-season water needs determined by:

- ☐ Soil Moisture Sensors
- ☐ Soil Appearance & Feel Method
- ☐ Plant Monitoring
- ☐ Computerized Irrigation Scheduling

Applied water volume/rate determined by:

- ☐ In-Line Flowmeter w/Totalizer
- ☐ Duration of Irrigation

Application Rate: 0.26 in/hr

System Efficiency: 85.0 %

Time to Apply 1.50 ": 6.8 hr

Other Planned Conservation Components (Optional):

- ☐ Cover Crop
- ☐ Mulching
- ☐ Residue Mgmt
- ☐ Crop Rotation
- ☐ Pollinator Habitat
- ☐ Other : ______
- ☐ Nutrient Mgmt
- ☐ Integrated Pest Mgmt
- ☐ High Tunnel System
- ☐ Low Tunnel System
- ☐ Raised Beds

Fertigation/Chemigation planned on system?

☐ Yes ☐ No

Backflow Prevention Type: ______

*Backflow prevention measures (sufficient air gap or an appropriately rated valve) are **required** for systems utilizing in-line chemigation or fertigation.*

CERTIFICATION

This plan was developed with best available information, but may require operator adaptability to changing conditions.

I have read and understand the operation and maintenance requirements associated with this manangement plan

Operator/Landowner: ______ Date: ______

Sketch of irrigation system