Irrigation Water Management for Ohio

OHIO FARM BUREAU

Producer Guide for the Development and Implementation of a Systematic Water Management Program

August 2007

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Table of Contents

IRRIGATION WATER MANAGEMENT FOR OHIO

SECTION 1: INTRODUCTION

Water Management

Water management is an important element of irrigated crop production. The use of an efficient irrigation system and the development and implementation of a systematic water management program can help maintain profitability in a time when energy costs continue to rise. Efficient water management can also reduce the impact of irrigated crop production on off-site water quality.

A systematic water management program answers the questions of when to irrigate, how much water to apply during an irrigation cycle and how best to apply the water (rate of application, method, etc.).

Improved management of irrigation water can provide multiple benefits:

- **Conserve limited water supplies**
- **Reduce the impact of irrigation on water quality**
- **Enhance producer net returns.**

Water Conservation

Water savings through improved management of irrigation supplies are considered essential to meeting future water needs for agriculture. Expanding water demands for municipal, industrial, power production, agricultural, recreational and environmental purposes increasingly compete for available water supplies. The efficient and wise use of freshwater resources is critical to meeting the current and future demand for water.

Water Quality

Improved water management can help to minimize the offsite water quality impacts of irrigated crop production. A poorly managed irrigation system may cause environmental problems by transporting pesticides, nutrients and sediments to surface and ground water resources. To reduce nonpoint source pollution caused by leaching and runoff, and to ensure that water resources are utilized as effectively as possible, irrigation systems should be managed so that the timing and amount of applied water match crop water uptake as closely as possible.

Economic Return

Management practices for the use of irrigation water can help increase efficiency and uniformity of water application and reduce the cost to pump and distribute irrigation water. Reducing the expenditures for energy, chemicals and labor, while enhancing revenues through higher crop yields and improved crop quality is possible with improved water management.

Because each farm is unique, producers must evaluate their irrigation system to determine the water management tools and techniques most suitable for them.

Irrigation System Management Variables

- **Frequency of Irrigation**
- **Application Amount and Timing**
- **Irrigation System Efficiency**
- **Method and Timing of Chemical Application**

SECTION 2: TIMING AND AMOUNT

Irrigation Scheduling

Proper irrigation scheduling is the application of water to crops only when needed and only in the amounts needed; that is, determining when to irrigate and how much water to apply. With proper irrigation scheduling, crop yields will not be limited by water stress from droughts and the waste of water and energy used in pumping will be minimized.

For many crops in Ohio, rainfall is the principal source of water. However, for high value crops, many producers are turning to irrigation to supplement precipitation. In order to maximize profits, irrigation water must be applied on a schedule that makes the most efficient use of water and energy.

The objective of irrigation is to maintain a favorable plant water environment to optimize crop growth. In reality, all irrigation cycles are scheduled, whether by sophisticated control systems, water availability or just the producers' hunch as to when water is needed. Experienced producers know how long it takes to get water across their fields and are proficient in avoiding crop stress. The difficulty lies in applying only enough water to fill the effective root zone without unnecessary deep percolation or runoff. A number of methods, devices, techniques and aids are available for use by producers to assist them to schedule irrigation (see Table 1).

Growers schedule irrigation using one of several criteria:

- **Intuition**
- **Calendar days since the last rainfall or irrigation**
- **Crop evapotranspiration**
- **Soil moisture**

Soil and Crop Properties

Effective irrigation scheduling requires knowledge of the properties of the soil where the irrigated crops are being grown as well as characteristics of the crops being grown. Soil texture, organic matter content, soil structure and permeability influence the ability of the soil to intake, hold and release water.

The soil system is composed of three major components: solid particles (minerals and organic matter), water with various dissolved chemicals, and air. The percentage of these components varies greatly with soil texture and structure. An active root system requires a delicate balance between the three soil components; but the balance between the liquid and gas phases is most critical, since it regulates root activity and plant growth process.

Knowledge of the predominant soil type in each field receiving irrigation water provides insight into the available water holding capacity. By combining knowledge of soil water holding capacity with the soil water depletion status, crop irrigation can be scheduled.

Crop characteristics influencing irrigation management options include crop water demand and effective root zone depth. Crop root depth is primarily influenced by plant genetics, restrictions within the soil horizon and maturity stage of the crop. Irrigation water that penetrates below the crop roots constitutes deep percolation and should be minimized.

Irrigation Scheduling Methods

Water application management by irrigation scheduling is a critical factor when determining the economic and cultural value of irrigation. A successful irrigation manager needs to know when to start irrigating and how much water to apply. The methods and tools available to help producers identify or predict irrigation need can be grouped into three basic categories.

Methods and tools available to help producers identify or predict irrigation need:

- **Plant Stress Measurement**
- **Soil Moisture Measurement**
- **Predictive Models**

Table 1: Methods and tools used to schedule irrigation.

Method	Measured Parameter	Equipment Needed	Irrigation Criterion	Advantages	Disadvantages
Plant observation	Soil moisture content by indirect observation	None	Soil moisture content	Indicator of plant water stress	Plants stressed and growth impacted before wilt observed
Hand feel and appearance of soil	Soil moisture content by feel	Hand probe	Soil moisture content	Easy to use; simple; can improve accuracy with experience	Low accuracy; field work involved to take samples
Gravimetric soil moisture sample	Soil moisture content by taking samples	Auger, caps, oven	Soil moisture content	High accuracy	Labor intensive including field work; time gap between sampling and results
Tensiometers	Soil moisture tension	Tensiometers including vacuum gauge	Soil moisture tension	Good accuracy; instantaneous reading of soil moisture tension	Labor to read; needs maintenance; breaks at tensions above 0.7 atmosphere
Electrical resistance blocks	Electric resistance of soil moisture	Resistance blocks, AC bridge (meter)	Soil moisture tension	Instantaneous reading; works over larger range of tensions; can be used for remote reading	Not sensitive at low tensions; needs some maintenance and field reading
Water budget approach	Climatic parameters: temperature, radiation, wind, humidity and expected rainfall, depending on model used to predict evapotranspiration	Weather station or available weather information	Estimation of moisture content	No field work required, flexible; can forecast irrigation needs in the future, with same equipment can schedule many fields	Needs calibration and periodic adjustments, since it is only an estimate; calculations cumbersome without computer

Plant Observation

The visual appearance of the plant is a good indicator of plant water stress. By the time most agricultural crops show wilt symptoms, a reduction in yield has already occurred. Growth ceases in many crops before visual wilting occurs and yield reduction may have occurred for some time before wilting is observed.

Time lags associated with the application of irrigation water can also present a problem. Because several zones might be irrigated from a single pump, the irrigation system may not be able to quickly replenish water in the crop root zone. Many hours or even days may be needed. The need to irrigate must be anticipated because of irrigation system limitations.

Soil Moisture Measurement

Direct knowledge of soil moisture content allows producers to schedule irrigation before the moisture level has declined to the point of plant stress. Available methods and devices differ in reliability, cost, and labor intensity. A general description of each follows:

Feel and Appearance of Soil - The "feel" method involves estimating soil moisture by feeling the soil. This method is easy to use, and many producers schedule irrigation this way. A shovel, soil auger or push tube can be used to obtain a soil sample from a depth of 8 to 9 inches to the bottom of the rootzone. The soil sample is squeezed between the thumb and index finger to form a ribbon. Soil type and the experience of the individual making the measurement will indicate the relative amount on moisture in the soil. It is important to note that because the feel method is subjective with poor reliability, it is not recommended and should be used only as a last resort.

Gravimetric Method - The gravimetric method is most useful for calibrating other devices that measure soil moisture. With this method, soil moisture is determined by taking a soil sample from the desired soil depth, weighing it, drying it in an oven for 24 hours at 220 degrees F, and then re-weighing the dry sample to determine how much water was lost.

This method is simple, reliable, and gives an exact measurement of soil moisture, but it is not practical for scheduling irrigation because it takes a full day to dry the sample. In a soil that dries quickly, irrigation may be needed before the results of the measurement are obtained.

Tensiometer - A tensiometer is a sealed, airtight, water-filled tube with a porous tip on one end and a vacuum gauge on the other. Tensiometers measure soil moisture suction (expressed as tension). This value is equivalent to the force or energy required for a plant to extract water from a soil.

Tensiometers are used by placing them in the field so that the porous tip is located within the root zone and wetted zone of the plants being irrigated. When correctly placed in the soil, the water in the instrument comes to equilibrium with the water in the soil by flowing through the ceramic cup. At equilibrium, the water tension in the instrument is equal to the water tension in the soil and read directly from the vacuum gauge.

The tensiometer is a fairly simple instrument that will work well if it is properly installed and in good operating condition. Because the instrument measures the soil moisture tension that the plants are experiencing, tensiometers can be used to schedule irrigation when the soil moisture tension is low, before plant water stress occurs.

Tensiometers are best suited for use in coarser textured soils such as sand, loamy sand, sandy loam and coarser-textured loam and sandy clay loam.

Electrical Resistance Blocks - Electrical resistance blocks consist of two electrodes enclosed in a block of porous material. The block is often made of gypsum, although fiberglass or nylon is sometimes used. Electrical resistance blocks are often referred to as gypsum, resistance or moisture blocks.

Resistance blocks work on the principle that water conducts electricity. When properly installed, the water suction of the porous block is in equilibrium with the soil moisture suction in the surrounding soil. As the soil moisture changes, the water content of the porous block also changes. The electrical resistance between the two electrodes increases as the water content of the porous block decreases. The resistance of the block can be related to the water content of the soil by the calibration curve.

The producer must know the soil moisture-holding capacity to make full use of the data obtained from the gypsum blocks. When scheduling irrigation times with electrical resistance blocks, the soil type will determine when irrigation should be started based on the percent of soil moisture depletion. Electrical resistance blocks work best in fine textured soils such as silts and clays.

Neutron Probe - The neutron probe is an electronic instrument with a radioactive source that is lowered into the soil in an access tube installed in the soil. The neutron probe indicates soil moisture by detecting hydrogen in soil moisture. A counter reads the number on neutrons that are reflected by the hydrogen in the soil. This number is used to calibrate the moisture content.

With good calibration, neutron probes are one of the more accurate devices available for measuring the amount of moisture in the soil. Neutron probes are used by researchers, consultants, and large landowners with high cash crops for water conservation and to measure soil moisture. Because of the cost, a neutron probe is not as practical as other methods for on-farm use.

Phene Cell – The Phene cell works on the principle that a soil conducts heat in relation to its water content. By measuring the heat conducted from a heat source and calibrating the conductance versus water content for a specific soil, the Phene cell can be used reliably to determine soil moisture content. Because the Phene cell is placed at the desired soil depth, a separate cell is needed for each depth at each location to be monitored. For irrigating small acreages, the total cost of using the Phene cell is less than that of the neutron probe. For large acreages, the neutron probe may be more cost effective.

Time Domain Reflectometer - Time domain reflectometry involves installing two or three parallel rods or stiff wires, called waveguides, into the soil to the depth at which the average water content measurement is desired. The rods are connected to an instrument that sends an electromagnetic pulse (or wave) of energy along the rods. The rate at which the wave of energy is conducted into the soil and reflected back to the soil surface is directly related to the average water content of the soil.

SELECTING THE APPROPRIATE SOIL MOISTURE MEASURING DEVICE

In general, tensiometers and electrical resistance blocks offer the best combination of cost-effectiveness and reliability for measurement of soil moisture for irrigation. Tensiometers are best suited for sandy, sandy loam, and loamy soil textures, while electrical resistance blocks work best in silty or clayey soils.

Manufacturers of these devices provide calibration charts and recommended ranges for fresh water irrigation. The calibration curves and recommendations supplied by the manufacturer are developed for general conditions and are not adequate for specific soil conditions and fields. It is best to calibrate the soil moisture measuring devices being used for the major soils being irrigated.

Water Budget - Checkbook Method

The water budget or checkbook method is simply an accounting procedure similar to the bookkeeping required to balance a checking account. If the balance on a given date and the amounts of transactions are known, the current balance can be calculated at any time. In addition, the time when all funds would be withdrawn can be determined so that an overdraft is avoided.

For irrigation scheduling, soil moisture is balanced. The amount of water that is used by the crop is analogous to writing checks. The water that enters the soil as rain or irrigation is analogous to depositing funds in a checking account. By keeping records of these transactions, it is possible to know how much water is in the soil at anytime.

The water budget worksheet method is operated just like balancing a checkbook.

After determining an initial soil moisture deficit (current checkbook balance), daily adjustments are made on a soil moisture balance worksheet to account for crop water use (withdrawals) and rainfall or irrigation (deposits). Crop water use is estimated from tables based on maximum daily air temperature and the amount of time since crop emergence. Crop water use increases the deficit while rainfall and irrigation reduce the deficit. Application of irrigation water is scheduled so the soil moisture deficit will not reach a level that will stress the crop.

The checkbook method involves keeping a soil moisture balance for one or more locations in the field. Several things influence the soil moisture balance including soil type, crop type and growth stage, and various weather factors. Since not all of these can be accounted for by using the checkbook method, it is important to use some type of instrument to measure soil moisture in the field.

The advantage of the checkbook method compared to using only soil moisture readings for scheduling irrigation is that the crop water use tables can be used to plan future crop water use based on weather forecasts. In addition, soil moisture measurements do not have to be made as often since they are used primarily to verify the checkbook balance.

Irrigation Management Strategy

Deciding when to irrigate to optimize production is a daily judgment decision requiring consideration of several factors, many of which change as the crop develops. Figure 1 presents the daily decision process used by producers to efficiently schedule irrigation.

General Guidelines for Water Management Plan Development

Spring - Make sure the soil in the germination and early growth root zone is moist at the time of planting. Irrigate to wet this zone if necessary. As the plants grow, moist soil is necessary for the proper development of the roots.

Critical Growth Stage – Reduce the allowable soil moisture deficit to minimize the risk of not meeting the crop's water needs and causing economic yield losses. Project crop water needs 2 to 3 days to avoid plant stress prior to irrigation. Consider the weather forecast when scheduling irrigation to reduce the potential for chemical and/or nutrient leaching in the event of a rainfall.

Maturity – Increase allowable soil moisture deficit. Managing for a larger soil moisture deficit near crop maturity will not cause crop stress and will reduce the irrigation water needs, saving pumping costs and conserving the irrigation water supply.

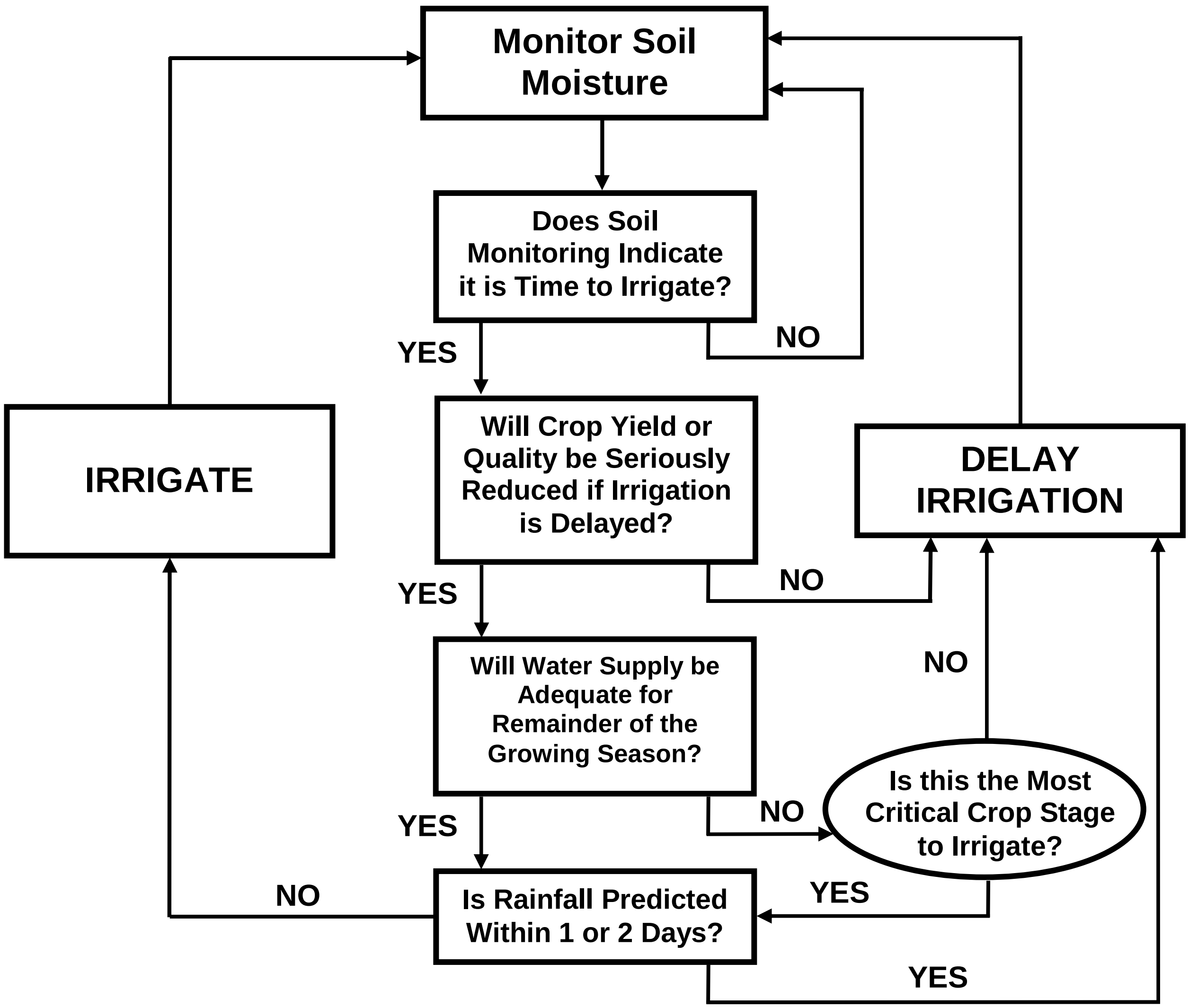

Figure 1. Decision process used to efficiency schedule irrigation.

SECTION 3: MANAGEMENT AND TECHNOLOGY

Irrigation System Management

Proper management of an agricultural irrigation system is an integral part of an irrigation water management program. Increasing energy costs and decreasing water supplies point out the need for better, more efficient irrigation water management. Water measurement is one of the first steps in a total water management program.

Water Measurement and Conservation

An understanding of an irrigation system's capacity to deliver water is a very powerful piece of information, one that allows the producer to take a scientific approach to the irrigation process, achieve greater control and begin conserving water without compromising crop yields. First and foremost, all producers who irrigate their crops need to know the water application rate (inches per hour or inches per irrigation cycle) of their irrigation system.

Good irrigation management requires that the producer know how much water the irrigation system delivers to the crop over a given period of time. The duration or frequency of irrigation can be adjusted to make sure that the amount of irrigation water applied equals the amount of soil moisture the plants need. Water measurement also allows the producer to monitor the total applied water over the growing season. Regular review of records can help identify system problems (broken underground pipe, plugged subsurface drip irrigation emitters, well or pump problems, etc.).

Many tools and techniques are available to producers to help them determine the amount of irrigation water they apply. Common methods range from the direct measurement of the length of time it takes to fill a container of known volume to the installation of commercial flow meters (See shaded text box below). The choice of method to use is determined by the volume of water being measured, the necessary accuracy of the measurement and the overall cost to the producer.

Irrigation Water Measurement Tools and Techniques

DIRECT MEASUREMENT

- Using a stopwatch, determine the length of time required to fill a container of known volume.
- Measure the depth of water applied for a given period of system operation (Rain gauges, cans, and straight-sided buckets).

PIPELINE FLOW (INSIDE THE PIPE)

- Propeller meters are one of the most common, convenient and accurate devices available for measuring irrigation water. Propeller meters are in-line devices that relate flow velocity and pipe cross sectional area to a given flow rate, volume or both.
- Pitot tubes
- Constricted Flow Meters
  - Venturi
  - Nozzel
  - Orifice Plate

PIPELINE FLOW (OUTSIDE THE PIPE)

- Ultrasonic
- Acoustic

Improved Technology and Management

Management practices and irrigation technologies are available to enhance the efficiency of applied irrigation water (Table 2). Irrigation improvements often involve upgrading existing irrigation systems to one with higher application efficiency. These improvements may require capital, energy or increased management costs however the additional labor savings will justify installation of the improved system. Improved water management practices, such as irrigation scheduling and water-flow measurement are generally required to achieve the maximum potential of the irrigation system.

Table 2. Comparison of conventional verses improved irrigation technology and management practices.

System	Conventional Technology or Management Practice	Improved Technology or Management Practice
Pressurized Application Systems		
Pressure Requirements	High pressure, typically above 60 pounds per square inch (psi).	Reduced pressure, often 10 – 30 pounds per square inch (psi).
Water Distribution	Large water dispersal pattern.	Narrow water dispersal through sprinkler droptubes, improved emitter spacing and low flow systems.
Automation	Handmove systems manually operated.	Self-propelled systems with computer controlled water application.
Versatility	Equipment limited to specific crops and used only for irrigation.	Equipment used on multiple crops with numerous uses (irrigation, chemigation, frost protection, crop cooling).
Water Management		
Assessing Crop Water Needs	Judgement estimates.	Soil moisture monitoring, plant monitoring, weather–based computations.
Timing of Applied Water	Fixed schedule.	Water applied as needed by the crop, managed for profit not yield, managed to improve effectiveness of rainfall.
Measurement of Water	Not metered.	Measured.

SECTION 4: CHEMIGATION SAFETY

Chemigation Safety Measures

The earliest work using chemicals through sprinklers was the injection of a fertilizer into the irrigation system and applying it with irrigation water (fertigation). Herbigation followed when herbicides were applied through a sprinkler system. The injection of other chemicals came into use -- insecticides for insectigation, fungicides for fungigation, and nematicides for nematigation. The terminology was combined and simplified and the general term "chemigation" evolved.

Chemigation, the application of an agricultural chemical to the soil or plant surface with an irrigation system is most commonly used in conjunction with sprinkler or drip irrigation systems. Chemigation is a safe, effective, low-cost way to apply agricultural chemicals on irrigated land provided precautions are taken to prevent contamination of the water source. Contamination of a water supply can occur if proper safety devices are not installed and maintained on the chemical injection and irrigation equipment.

Chemigation Safety Hazards

Three specific chemigation safety hazards to guard against are:

1. An unexpected shutdown of the irrigation pumping plant due to mechanical or electrical failure while it is unattended, causing concentrated chemicals or mixture of chemicals and water to flow or be siphoned back into the water supply.

2. An irrigation pumping plant shutdown while the injection equipment continues to operate, possibly causing concentrated chemicals or a mixture of water and chemicals to backflow into the water supply, and/or cause an undesirably high concentration of chemicals in the irrigation system.

3. The chemical injection system stopping when the irrigation pump continues to operate, possibly causing water to backflow through the chemical supply tank causing it to overflow and spill onto the ground.

Chemigation Safety Equipment

To protect the water supply, start by installing the proper chemigation equipment. Then inspect and maintain the equipment to insure that it's working properly. Finally, manage the chemigation system for safe and effective chemical application.

Chemical injection is not just putting chemicals into an operating irrigation system and applying it to a field. When any chemical is applied through an irrigation system, there are safety devices that must be used on the irrigation system and the injection equipment. The safety equipment protects against contamination of the general water supply and chemical spills from the chemical supply tank.

Power Interlock - The chemical injection system must be interlocked or inter-connected with the irrigation system power supply or water supply so that it will shut down anytime the irrigation system or pumping plant stops operating or the water flow is disrupted. This prevents pumping the chemical mixture from the supply tank into the irrigation pipeline after the water flow stops.

For irrigation pumps driven by internal combustion engines, the chemical injection pump can be belted to the drive shaft or an accessory pulley of the engine. Other alternatives include operating the injection equipment off the engine electrical system or using the power source of the sprinkler system drive. In all cases, it is essential that the injection pump stops when the irrigation pump stops and water is no longer flowing.

For irrigation systems with electrically driven irrigation pumps, a separate, small electric motor is commonly used to power the chemical injection pump. Controls for the two electric motors need to be interlocked so the injection pump will be shut off whenever the motor on the irrigation pump stops.

Another type of injection pump utilizes flowing water pressure to power the pump. When the water flow stops, the injection pump also stops. This type of chemical injection pump would be interlocked simply by the way in which it operates.

If chemical flow from the supply tank could possibly continue after system shutdown, a solenoid valve should be provided in the chemical supply line, preferably on the suction side of the injection meter. The solenoid valve must be interlocked and powered by the irrigation system control panel, water supply pressure or the injector power supply.

Irrigation Pipeline Check Valve and Vacuum-Relief Valve - Check and vacuum-relief valves (anti-siphon devices) are needed in the irrigation pipeline. They keep water and/or a mixture of water and chemical from draining or siphoning back into the irrigation water supply. Both of these valves must be located between the water supply and the port where the chemical is injected into the irrigation pipeline.

The check valve should be located between the irrigation water supply and point of chemical injection. The check valve must have positive closing action (spring loaded to prevent flow back into the irrigation water supply), a watertight seal and must be easy to repair and maintain. Check valves should be installed with fittings that allow easy removal for maintenance and repair.

The vacuum-relief valve should be located between the irrigation water supply and the check valve. The vacuum-relief valve allows air to enter the pipeline when the water flow stops. This prevents the creation of a vacuum (behind the check valve) that could cause siphoning of the water/chemical mixture back into the irrigation water supply.

Irrigation Pipeline Low Pressure Drain - An automatic low pressure drain should be placed on the bottom of the lowest point of the irrigation pipeline between the pump and the check valve. The drain must open automatically whenever the irrigation pump stops to prevent any water/chemical mixture from entering the water supply in the event that the check valve leaks. The drain should discharge at least 20 feet from the water supply, and the flow should be directed away from the water supply. A hose or pipe may be needed to direct the discharge from the drain to the desired distance.

Irrigation Pipeline Inspection Port - An inspection port must be located between the water supply and the check valve. The port allows visual inspection of the check valve for leaks or malfunction. In many cases, the vacuum relief-valve connection can serve as the inspection port.

Irrigation Pipeline Low Pressure Shut Down Switch - The irrigation system must contain a low pressure shut down switch, or device with similar operating characteristics, on the irrigation pipeline. The switch will shut down the irrigation and the chemical injection systems when the operating pressure drops to an unsatisfactory level for proper agricultural chemical application.

Chemical Injection Line Check Valve - The chemical injection line must contain a double, positive-closing, check valve system that will prevent irrigation water from flowing back through the chemical line and overflowing the chemical supply tank. One of the check valves should be located on the chemical supply line as close as possible to the point of chemical injection into the irrigation pipeline. If the chemical injection pump does not have an internal check valve, a second check valve should be installed on the chemical injection line.

Check valves in the chemical injection line are needed to:

- stop the flow of water from the irrigation system into the chemical supply tank if the injection system stops functioning and
- prevent gravity flow from the chemical supply tank into the irrigation pipeline after an unexpected system shutdown.

If these check valves are omitted and the injection pump stopped, irrigation water could possibly flow back through the chemical line into the chemical supply tank, overflow the tank causing a spill around the irrigation well. If chemical in the supply tank is allowed to flow into the irrigation pipeline by gravity or be siphoned when the irrigation system is not operating, it could create a potential danger to the crop or leak into the ground. The chemical then may eventually move into a surface water source or down through the soil to the groundwater.

Suggested Chemigation Safety Equipment to Minimize Risk of Water Supply Contamination

Power and System Interlock

- Interlocking of irrigation and injection pumps

Irrigation Pipeline Equipment

- Check valve
- Vacuum-relief valve
- Low pressure drain
- Inspection port
- Low pressure shut down switch

Chemical Injection Line Equipment

- Chemical injection line check valve

SECTION 5: MANAGEMENT PRACTICES TO ENHANCE IRRIGATION WATER MANAGEMENT

Principles:

- Manage irrigation to maximize water application efficiency.
- Minimize the transport of chemicals, nutrients and sediment from the soil surface or the plant root zone to protect water quality.

Select from the following list of irrigation water management practices those most applicable to your operation to achieve the principles stated above.

Irrigation Scheduling

Schedule irrigation to maximize benefits to crop, taking into consideration rainfall and crop need. Supplemental irrigation is a cost-effective technique to ensure a sufficient quantity of water is available to meet crop needs when rainfall is inadequate. Water application should be adjusted according to climate, soil texture and daily weather conditions.

- Develop an irrigation plan based on the recommendations for crop water needs.
- Monitor soil moisture before and after each irrigation cycle.
- Implement irrigation plan taking into account factors such as rainfall, evapotranspiration, stage of crop development and soil moisture.
- Contact a qualified professional to assist in irrigation scheduling.

Water Application

Verify that the irrigation system is delivering the volume of water needed at the appropriate rate. Adjust irrigation system and the operation of the irrigation system to match water needs.

- Monitor irrigation application and uniformity of water applied.
- Contact a qualified professional to assist in the determination of irrigation system application efficiency.
- Improve the uniformity of irrigation water application by changing the type of irrigation equipment, timing irrigation to periods of low winds, modification of operating pressure or enhanced irrigation system maintenance.
- Adjust application rate to match soil infiltration rate to avoid runoff and minimize ponding.
- Minimize deep percolation water loss by applying water according to crop water use and soil moisture.

Type of Equipment

Select the most efficient irrigation system possible. Irrigation systems vary in efficiency of volume of water used and the amount of energy required to operate. To use water most efficiently, irrigation water should be placed where plants absorb water – the roots. The goal is to maintain plant transpiration and to decrease water loss through evaporation.

- Evaluate the efficiency of the total irrigation system.
- Contact a qualified professional to assist in the determination of irrigation system application efficiency.
- Upgrade irrigation equipment to improve delivery and application efficiency where feasible.

Timing of Spray Irrigation

Adjust the timing of irrigation to maximize the uniformity of application. Spray irrigation taking place on a windy day can reduce application uniformity resulting in some areas of the field receiving too much water and others too little water. Likewise, irrigation water that evaporates into the air during application on hot sunny days is also wasted.

- Operate sprinkler system on calm days to minimize drift and off-target application.
- Avoid operation of sprinkler system on hot sunny days to minimize water loss due to evaporation.

System Design

Use an irrigation system that is appropriately designed and sized. The irrigation system should be of sufficient size, shape and capacity to meet the specific water needs of the crop, fits in with the existing farm infrastructure, long-term farm plans and the management skill of producer.

- Consult with a qualified irrigation system designer on system design.
- Select a pumping plant with the maximum efficiency for the irrigation system operating conditions.
- Use low-pressure irrigation systems whenever possible.

Maintenance of System

Visually inspect the irrigation system to ensure that there are no leaks and water is not being wasted.

- Establish an irrigation system inspection program.
- Repair leaks as soon as they are discovered.
- Replace all worn spray nozzles and emitters.
- Inspect all components of the chemigation system before each use.

Record Keeping

Document all water application and system management/maintenance activities. Keeping good records a very important component of operating, managing and maintaining a crop irrigation system. Good records can avoid crop problems and improve profitability.

- For all irrigated crops, record the crop type and location.
- Record the date of each irrigation cycle and the amount of water applied.
- Record the date and results each time the irrigation system is evaluated for application uniformity.
- Record the date of all system inspections and repairs that impact application uniformity and leaks.

Chemigation

Install, inspect and maintain all safety devices and equipment associated with chemigation. Chemigation can be an effective and environmentally safe method of applying agricultural chemicals to soil or plants. An irrigation system that applies water uniformly and with proper safety devices and management practices must be used to ensure safety.

- Before injecting any chemical through an irrigation system, read and carefully follow all chemical label instructions and precautions.
- Inspect all components of the chemigation system before each use and repair or replace any defective components.
- Adjust irrigation schedule to account for water applied during chemigation and avoid chemigation when the crop does not need additional water.
- Monitor and inspect chemigation equipment and safety devices regularly to determine proper function. Replace all worn or nonfunctional components as needed.
- Calibrate the injection equipment with the irrigation system to be sure the proper rate of chemical is applied.
- Record the date of all chemigation equipment calibrations and inspections.
- Handle all chemicals carefully around source of irrigation water to avoid possible contamination.
- Follow good housekeeping practices - Clean up spills or leaks immediately.
- Install secondary containment structures around all chemical storage areas and supply tanks.

SECTION 6: SELF-EVALUATION

ANSWER THE FOLLOWING QUESTIONS IN RELATION TO YOUR EXISTING IRRIGATION PRACTICES. THESE QUESTIONS ARE DESIGNED TO ASSIST YOU IN THE IDENTIFICATION OF AREAS WHERE YOU MAY BE ABLE TO MAKE ADJUSTMENTS TO INCREASE WATER USE EFFICIENCY, IMPROVE WATER QUALITY AND ENHANCE PROFITABILITY.

Irrigation System

Is your irrigation system appropriately designed and sized for your operation?

Do you measure the amount of water applied by your irrigation system?

How efficient is your irrigation system?

How evenly does your irrigation system apply water within the field?

Is your irrigation system operating at the design pressure in the field?

Do you routinely inspect and maintain all components of your irrigation system?

Irrigation Management

Do you use an irrigation scheduling tool to modify irrigation applications?

How well do you match your irrigation interval and volume of water applied to the crop requirements and soil limitations?

Do you modify your irrigation application in response to weather conditions?

Do you adjust the timing of your irrigation application to maximize the uniformity of application?

Do you have surface water runoff due to irrigation practices?

Do you measure, record and compare crop yield/quality/returns and the volume of water applied?

Chemigation

Have you installed all recommended chemigation safety equipment?

Do you adjust your irrigation schedule to account for water applied during chemigation?

Do you routinely inspect and maintain all safety devices and equipment associated with chemigation?

Do you routinely calibrate the chemical injection equipment?

Record Keeping

Do you record the crop type and location of all irrigated crops?

Do you document all water application and system management/maintenance activities?

Do you record the date of chemigation equipment calibrations and inspections?

Have you developed an emergency management plan to follow in case of a spill or fire?

APPENDIX 1

CONTACTS FOR ADDITIONAL INFORMATION OR ASSISTANCE

Contacts for Additional Information or Assistance

Ohio Coastal Nonpoint Source Pollution Control Program
(www.dnr.state.oh.us/soilandwater/programs/coastalnonpoint/default/tabid/8861/Default.aspx)

Matt Adkins, Coastal NPS Coordinator
ODNR, Division of Soil & Water Conservation
105 West Shoreline Drive
Sandusky, OH 44870
Phone: 419.609.4102
Fax: 419.609.4158
E-mail: matt.adkins@dnr.state.oh.us

Ohio Watershed Programs
(www.dnr.state.oh.us/soilandwater/water/watershedprograms/default/tabid/9192/Default.aspx)

Greg Nageotte, Nonpoint Programs Coordinator
ODNR, Division of Soil & Water Conservation
2045 Morse Road, Building B – 3
Columbus, OH 43229-6605
Phone: 614.265.6619
Fax: 614.262.2064
E-mail: greg.nageotte@dnr.state.oh.us

NOAA Office of Ocean and Coastal Resource Management – Coastal Nonpoint Pollution Control Program (http://coastalmanagement.noaa.gov/nonpoint/welcome.html)

David M. Kennedy, Director
Office of Ocean and Coastal Resource Management
National Oceanic and Atmospheric Administration (NOAA) - Ocean Service
1305 East West Highway
Silver Spring, MD 20910
Phone: 301. 713.3155 x200
E-mail: david.kennedy@noaa.gov

Great Lakes Commission (www.glc.org)

Great Lakes Commission
Eisenhower Corporate Park
2805 S. Industrial Hwy, Suite 100
Ann Arbor, MI 48104-6791
Phone: 734.971.9135
Fax: 734.971.9150

APPENDIX 2

FORMS TO ASSIST IN RECORD KEEPING

Irrigation System Description

Field/Plot/Track Identification Number	System Description *(Type of irrigation system, operating pressure, nozzle size, spacing, etc.)*	Soil Moisture Monitoring Technique Used

This sheet may be duplicated to make additional copies for your records

Irrigation Cycle Record Sheet

Field/Plot/Track Identification Number ______________ **Number of Irrigated Acres** ______________

Crop ______________ **Planting Date** ______________ **Emergence Date** ______________

Soil Type ______________ **Source of Irrigation Water** ______________

Date *(mm/dd/yr)*	**Irrigation Time**			**Amount of Water Applied**	**Notes**
	Start Time	**End Time**	**Total Minutes**		

This sheet may be duplicated to make additional copies for your records

Irrigation System Inspection / Management / Maintenance Record Sheet

Field/Plot/Track Identification Number	Date *(mm/dd/yr)*	Visual Inspection	Application Uniformity Check	System Calibration	System Maintenance	Actions Taken

This sheet may be duplicated to make additional copies for your records

Chemigation Cycle Record Sheet

Field/Plot/Track Identification Number ____________ **Number of Irrigated Acres** ____________

Crop ____________________ **Planting Date** ________________ **Emergence Date** ________________

Soil Type ___________________________ **Source of Irrigation Water** ______________________

Date *(mm/dd/yr)*	**Chemigation Time**			**Amount of Water Applied**	**Notes**
	Start Time	**End Time**	**Total Minutes**		

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Chemigation System Inspection / Management / Maintenance Record Sheet

Field/Plot/Track Identification Number	Date *(mm/dd/yr)*	Visual Inspection	Application Uniformity Check	Injection System Calibration	System Maintenance	Actions Taken

This sheet may be duplicated to make additional copies for your records