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Design of Agricultural Irrigation Systems in Florida[1]

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Over two million acres of agricultural crops are irrigated in Florida. See IFAS Ext. Cir. 1030 (56) and Bul. 276 (39). This large acreage requires irrigation despite Florida's high annual rainfall because 1) typical sandy soils have low water-holding capacities; 2) rainfall is not uniformly distributed throughout the year; 3) many high-value specialty crops are grown and higher economic returns can be obtained by avoiding water stress; and 4) irrigation systems are extensively used for environmental modification, including freeze protection and crop cooling. See IFAS Ext. Cir. 940 (9).

Many different types of irrigation systems are used in Florida. Many different systems are required because of the great variety of crops, the relative availability of water, diverse hydrological conditions, variable soil characteristics, and ranges in system costs. Also, all irrigation systems are not adaptable to all types of crops and crop production systems. See IFAS Ext. Cir. 821 (34) and Cir. 1035 (44). In Florida, irrigation systems are used to provide water for crop evapotranspiration (ET), but also for many other purposes as well, such as freeze protection and crop cooling if required in a specific production system. See IFAS Ext. Cir. 940, *Uses of Water in Florida Crop Production Systems* (9).

The objective of irrigation system design is to develop a system of irrigation components that is capable of applying water (and often chemicals) in an efficient and timely manner in order to optimize crop production. Efficiency is defined broadly here to consider economic, labor, management, and production system constraints, as well as conservation of natural resources. See IFAS Ext. Bul. 247 (40). Timeliness refers to system capabilities which enable irrigations to be applied when required and in the amounts required to optimize crop production. See IFAS Ext. Bul. 249 (43). General irrigation terminology and terms related to irrigation in Florida are defined in Agricultural Engineering Fact Sheets AE-66, *Basic Irrigation Terminology* (32) and AE-45, *Glossary of Trickle Irrigation Terms* (71).

Design of irrigation systems specifies individual components and the conditions under which they will be operated. This includes the types of components required, their sizes, and other characteristics such as pressure ratings, resistance to chemicals to be injected, etc. Failure to consider all of these factors may result in the design of an inefficient irrigation system or system failure. For more information on the consequences of poor design, see Ag. Eng. Fact Sheet AE-73, *Potential Impacts of Improper Irrigation System Design* (63).

Standards for irrigation system design in Florida have been developed by three agencies: American Society of Agricultural Engineers (ASAE); Soil Conservation Service (SCS); and Florida Irrigation Society (FIS). Complete references to these standards are included in the list of references in this

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publication (1, 12, 13, 36). Copies of these standards are available from the developing agency.

Computer software has been developed by the University of Florida to help with the design and management of Florida irrigation systems. Water management utilities were published by Zazueta et al. (69) and continue to be developed. A complete list of available software is published in the *IFAS Microcomputer Software Catalog* (64).

Major components of irrigation systems must often be designed in groups for compatibility and efficiency. This publication discusses the major component groups of 1) control equipment; 2) water conveyance system; 3) water distribution system; and 4) pumping system. Selection of operating conditions (flow rates and pressures) is also discussed. This publication references many other publications which provide more information on specific aspects of irrigation system design in Florida.

SYSTEM COMPONENT GROUPS

Control Equipment

The objective of control equipment design is to specify components that will enable the irrigation system to be efficiently and safely managed and monitored in order to optimize crop production, conserve water and preserve water quality. Control equipment consists of the components required to regulate and monitor water and chemical applications to an irrigation system, and safety equipment required to protect the water supply from contamination. These include valves, pressure regulators, flow meters, backflow prevention systems, filters, pressure gauges, chemical injection equipment, and irrigation controllers.

Valves

Valves are required to control the filling of irrigation systems at pump startup, to control flows to the desired subunits of a system, and to allow flushing of irrigation pipes. Only properly pressure-rated irrigation valves must be used to avoid failures due to system pressure and hydraulic shock (water hammer) problems. Valve materials and components must be resistent to corrosion by the irrigation water and any chemicals injected during irrigation.

Valves must be properly sized to avoid excessive pressure losses. Normally, valves should be the same size as the pipeline in which they are installed. Installing smaller valves to save initial costs will result in higher operating costs for the life of the system due to friction losses.

Automatically-controlled irrigation systems will require the use of automatic valves. These may be controlled by electric solenoids or hydraulic pressures, depending upon the type of timer/controller used. Like manual valves, automatic valves should be selected based on friction loss and water hammer considerations.

For more information on valve types and selection, see IFAS Ext. Cir. 824, *Valves in Irrigation Systems* (19). For information on estimating and controlling hydraulic shock, see IFAS Ext. Cir. 828, *Water Hammer in Irrigation Systems* (7).

Pressure Regulators

Pressure regulators may be required to maintain the desired operating pressure in pipe flow systems. These valves are required when it is necessary to manage changing pumping conditions such as those due to changes in the water source or flow requirements to subunits of the irrigation system. Regulators are also required if some subsections of a system operate at different pressures than others.

Pressure regulators are often installed at either the irrigation pump outlet, the entrances to subunits, or at both locations. Pressure regulators may include slow opening and check valve features. The slow opening feature will allow an irrigation system to fill slowly upon pump startup, thus avoiding water hammer problems. The check valve feature will help to prevent backflow to the water source, thus helping to protect the water supply from contamination.

Because of their cost and the pressure losses which occur through them, pressure regulators should be used only when absolutely necessary. The system subunits should be designed to have as nearly the same pressure and flow rate requirements as possible to minimize the number of regulators. In some cases, field sizes, layouts, or slopes will not permit the same flow rate and pressure to be used for all subunits. Then, pressure regulators will be necessary. For more information on pressure regulating valves, see IFAS Ext. Cir. 824, *Valves in Irrigation Systems* (19).

Flow Meters

Flow (water) meters are required to properly manage irrigation systems, specifically to measure the amount of water applied at each irrigation. Meters may be located at the irrigation pump to total the water applications to the entire area irrigated, or they may be located at field subunits to accurately monitor applications to each individual subunit. Flow meters are also required to continuously monitor irrigation pumping efficiency, to indicate clogging problems when decreasing flow rates are measured, and to allow chemical injections to be accurately made when chemical concentrations in the irrigation water are important.

For more information on selection and applications of flow meters, see IFAS Ext. Bul. 207, *Agricultural Water Measurement* (58) and Ag. Eng. Fact Sheet AE-156, *Measuring Irrigation Water* (38). For information on the applications of specific types of flow meters, see the following IFAS Ag. Eng. Fact Sheets: AE-18, *Selection and Use of Impeller Meters for Irrigation Water Measurement* (50); AE-22, *Orifice Meters for Water Flow Measurement* (48); AE-25, *Weirs for Open-Channel Flow Measurement* (47); and AE-155, *Shunt Flow Meters for Irrigation Water Measurement* (37).

Backflow Prevention System

Florida law requires that a backflow prevention system be installed on most irrigation systems. Backflow prevention systems are always required when 1) chemicals are injected into an irrigation system, or 2) a public (municipal) water supply is used, whether or not chemicals are injected.

Check all applicable local, county, or municipal codes to determine the type of backflow prevention device required for public water supplies. Use a reduced-pressure zone backflow prevention device or an air-gap separation of the irrigation system from the water supply when chemicals are injected into irrigation systems that are connected to municipal water supplies.

No backflow prevention assembly is required if the water supply is not a public water supply (for example, if the water supply is an irrigation well, lake or canal) if no chemicals are injected into the irrigation system.

When the water supply is not a public water supply, the minimum backflow prevention system requires a check valve, low pressure drain, and vacuum breaker on the irrigation pipe to prevent water and chemicals from flowing back to the water source. It also requires interlocked power supplies to prevent chemical injection unless the irrigation water is flowing, a check valve on the injection line to prevent water flow to the chemical supply tank, and a positive shutoff valve on the chemical tank to prevent accidental drainage from the tank.

When Chemical Toxicity Category I pesticides are injected into irrigation systems and the water source is not a public water supply, a double check valve, low pressure drain, and vacuum relief valve assembly is required. These pesticides are marked with the keywords **Danger** or **Poison** on the label. When these pesticides are injected, 1) either reduced pressure principle backflow prevention devices or air-gap separations are required when a public (municipal) water supply is used; 2) only piston or diaphragm types of injection pumps are permitted for injection; and 3) pressure switches are required to shut off the injection pump when the irrigation system pressure drops to the point that uniformity of water application is affected.

The Environmental Protection Agency (EPA) requires that all pesticide products be labeled to clearly state whether injection into irrigation systems is permitted. Pesticide labels must also list the backflow prevention equipment requirements and application instructions. For more information on the Florida backflow prevention law and equipment requirements, see IFAS Ext. Bul. 217, *Florida Backflow Prevention Requirements for Agricultural Irrigation Systems* (52).

Filters

Almost without exception filters are required to prevent clogging of microirrigation systems. Filters remove small particles that may clog the tiny orifices in emitters. The type of filtration system required depends on the type of emitter used and the source and quality of the irrigation water. Filters should be selected based on emitter manufacturer's recommendations.

If manufacturer's recommendations are not available, use the equivalent of a 200 mesh screen filter for drip systems. A larger mesh (coarser screen) is normally acceptable for spray emitters, depending on the emitter orifice size. An 80 mesh screen is commonly used for many spray emitters. The mesh size selected should be small enough to remove all particles larger than ¼ the size of the emitter orifice. For more information on selection and use of screen filters, see Ag. Eng. Fact Sheet AE-61, *Screen Filters in Trickle Irrigation Systems* (25).

If organic matter is a problem when pumping from surface waters, media (sand) filters should be used as the primary filter, with a secondary screen filter. A strainer should be used on the pump intake to exclude as much organic matter as possible. Also, the intake should be positioned below the water surface to avoid floating debris, and above the bottom to avoid pumping sediment from the bottom of the pond or canal. Self-cleaning strainers for the pump inlet are available to prevent larger particles from entering the irrigation system.

When pumping from wells, screen filters alone are normally adequate unless large amounts of sand are being pumped. If large amounts of sand are being pumped, a vortex-type sand separator may be used, followed by a screen filter. Settling basins may also be used to remove large amounts of sand, but basins may cause problems if organic matter such as algae is present in the basins.

For more information on the design of settling basins, see Ag. Eng. Fact Sheet AE-65, *Settling Basins for Trickle Irrigation in Florida* (23). For more information on selection and applications of media filters, see Ag. Eng. Fact Sheet AE-57, *Media Filters for Trickle Irrigation in Florida* (22).

Pressure losses occur through all filters. These losses must be considered when an irrigation system is designed. Also, the pressure losses increase as the filter begins to clog. To operate properly, a filter must be cleaned periodically to maintain its effectiveness and to maintain pressure losses within acceptable limits. Cleaning can be done manually or by automatically backflushing the filter. Automatic backflushing can be based on a timer or on the increase in pressure loss across the filter that occurs as it begins to clog. The pressure loss method is preferred because it avoids unnecessary flushing when the filter is not clogged, yet also avoids large pressure losses through the filter.

The size and number of filters required depend on the irrigation water quality, the size of the smallest particle to be filtered, and on the flow rate. Filter manufacturer's recommendations should be followed for sizing filters and for selecting the number of filters required for the specific water quality and flow rate. If clogging occurs too frequently, additional filters should be added in parallel, so that each filters a portion of the water. Also, adding more filters or larger filters, so that the velocity of flow through each filter is reduced, will improve the filtration effectiveness.

Filtration may not be required when irrigation systems other than microirrigation systems are used. Y-strainers are often required on sprinkler systems to prevent flakes of limerock from plugging sprinkler nozzles when the Floridan aquifer is the source of irrigation water. Also, coarse strainers are often used on intakes of pumping systems to prevent debris from fouling or damaging pumps. Otherwise, filters are typically not required for sprinkler, surface, or seepage irrigation systems.

Pressure Gauges

Functioning pressure gauges are required to properly monitor the operation of pressurized irrigation systems. A minimum of one gauge at the pump discharge and one at each field subunit are required. When filters are used, two gauges, one on each side of the filter system, are required near the pump.

Pressure gauges allow quick checks of the irrigation system to be made. They allow the operator to check that the system is operating at the correct pressure, and therefore that the proper average amount of water can potentially be applied. Together with flow meters, pressure gauges also help detect leaks in pipelines or clogged emitters, and they provide a means of monitoring pumping efficiency.

Chemical Injection Equipment

Pressurized irrigation systems are often used to apply chemicals, especially fertilizers. Growers can obtain yield increases and minimize leaching losses (and pollution) by injecting nutrients and other chemicals through the irrigation systems. Many growers currently inject fertilizer through sprinkler and microirrigation systems. Chemical injection equipment is required to add the correct amount and rate of chemical. See IFAS Ext. Bul. 250 (4), Bul. 258 (33), Cir. 1033 (46) and Cir. 1039 (6).

Several types of chemical injectors are commercially available. These range from the low cost venturi devices and devices that inject on the suction side of centrifugal irrigation pumps to high cost diaphragm- or piston-type positive displacement pumps. The venturi and suction-side injection devices have the advantage of low cost. It is not possible to obtain a high degree of accuracy of injection rates with these devices, but sufficient accuracy can be obtained for injection of fertilizers where the total volume rather than the rate of injection is of primary concern. For more information on the types of chemical injectors available, see IFAS Ext. Cir. 864, *Chemical Injection Methods for Irrigation* (26).

If a high degree of precision is required such as during injection, pesticides that would be detrimental in other than known low concentrations, more precise injection methods must be used. These include the high precision but more costly positive displacement injection pumps such as diaphragm and piston type pumps. For more information on selection and applications of these high precision pumps, see IFAS Ext. Cir. 826, *Positive Displacement Pumps for Agricultural Applications* (16).

Microirrigation systems typically require injection of chemicals to prevent emitter plugging. See IFAS Ext. Bul. 258, *Causes and Prevention of Emitter Plugging in Microirrigation Systems* (33) and SS-AGE-805, *Water Quality Problems Affecting Microirrigation in Florida* (24). Microirrigation systems require high precision chemical injection pumps to precisely control biocides and water amendments used to prevent emitter plugging.

Irrigation Controllers

Irrigation controllers are devices which automatically turn the irrigation system and associated equipment such as chemical injection pumps on and off. Controllers are not mandatory for system operation, but they are time- and labor-saving devices. They are especially economical and efficient for management of microirrigation systems on Florida's sandy soils because of the requirement for frequent irrigations.

Controllers range in capabilities from simple timers which can turn a single valve on and off at pre-set times to complex computer controllers. Computer controllers are very complex systems that are programmable and have microcomputer capabilities. They can collect data from sensors, make calculations, and adjust water and chemical application schedules in response to plant needs.

Irrigation timers use clocks to turn irrigation systems on and off at pre-set times. This is done by switch closures at pre-set times to open and close solenoid valves and start or stop pump operations. Irrigation controllers can provide other functions besides those of a simple timer, including starting irrigations based on soil moisture sensors or climate factors, chemical injection control, recording times and amounts of water applied to each zone, sensing system problems and interrupting system operation due to low pressure or low flow rates.

Controller prices range from less than $50 for simple single-station timers to several thousand dollars for the more complex programmable controllers. Selection should be based on controller, water, and labor costs, the irrigation system complexity, and the number of tasks that are to be automated.

Understanding of irrigation scheduling is necessary to assess controller needs. For general information on scheduling irrigations in Florida, see IFAS Ext. Bul. 249, *Basic Irrigation Scheduling* (43), Bul. 254, *Irrigation Scheduling with Evaporation Pans* (60), Cir. 487, *Tensiometers for Soil Moisture Measurement and Irrigation Scheduling* (54), and Cir. 532, *Measurement of Soil Water for Irrigation Management* (49).

For information on specific crops and production systems, refer to the appropriate crop production guides or crop-specific publications. For example, for citrus, see Bul. 208, *Trickle Irrigation Scheduling for Florida Citrus* (59); for microirrigation of row crops, see Fact Sheet AE-72, *Microirrigation in Mulched Bed Production Systems: Irrigation Depths* (3); for microirrigation of tomatoes, see Cir. 872, *Irrigation Scheduling and Management of Micro-irrigated Tomatoes* (5). Other publications on specific crop production systems are included in the list of references to this publication.

For more information on irrigation controllers, see IFAS Ext. Cir. 670, *Computer Control of Mist Systems for Nursery Propagation Houses* (70), Cir. 688, *Control +: A Computer Controller for Irrigation Systems* (66), Cir. 705, *IR-CONTROL: A Computer Controller for Irrigation Systems* (67), and Zazueta and Smajstrla, *Microcomputer-Based Control of Irrigation Systems* (68).

Water Conveyance System

Water is conveyed from the pumping system to the distribution system in open ditches or pipelines. Ditches may be used for low-pressure (gravity-flow) systems such as flood or seepage systems, when permitted by topography, as in Florida flatwoods soil areas. When pressurized irrigation systems are used, water (and pressure) must be conveyed in pipelines. Water is typically not conveyed in pipelines when open ditches can be used because pipelines are much more expensive than ditches, especially for large flow rates.

Ditches may be either lined or unlined. Pipelines may be permanent or temporary (portable). The criteria for design of water conveyance systems are primarily economic, and include an analysis of the life expectancy of the conveyance system. The system that conveys the required flow rate at the lowest cost with the required life expectancy is normally chosen.

Open Ditches

Open ditches are used where water losses from the ditches are small or when the cost per unit of water is low. Losses occur due to deep percolation and evaporation (or ET). Lined ditches are used when deep percolation losses are large but evaporation losses are relatively small. Ditch liners may be concrete or plastic.

Ditch liners are not typically used in Florida because open ditch systems are used only in soils with restrictive layers or high water tables, both of which minimize deep percolation losses. Also, the cost of pumping water in Florida is relatively low. Open ditches are used in flood and seepage irrigation systems in Florida. However, many open ditches have been replaced with pipelines in semi-closed seepage systems to improve irrigation efficiency.

Pipelines

The mainline pipe in an irrigation system carries water from its source (normally at the pump discharge) to the field subunits where water is distributed to the crop. Conveyance losses are eliminated when pipelines are used. However, the cost per unit of water delivered favors the use of pipelines only when conveyance losses would otherwise be large, the cost of conveyance losses would exceed the pipeline cost, or pressurized irrigation systems are used.

There are several considerations in mainline pipe design: a) pipe materials; b) potential water hammer problems; c) pressure rating; and d) cost.

Pipe Materials

The preferred mainline pipe for permanent irrigation systems is poly-vinylchloride (PVC) for several reasons:

- low cost
- easy installation using either gasketed or glued fittings
- compatibility with chemicals typically injected into irrigation systems
- resistance to rust or corrosion, so that emitter clogging from this source is not a problem
- long life expectancy (approximately 40 years) when properly buried and protected against crushing by overburden pressures such as the weight of heavy vehicles.

PVC mainline and submain pipes are normally buried when permanently installed, because burying will greatly extend the useful life of the pipe. If PVC is not buried, it should be painted to protect it from the sun.

Steel pipe should be used near the pumping and control systems where pipes will be exposed to solar radiation and where extra strength is required because of the hydraulic shocks associated with pump startups. Steel pipe should be used under roadways where extra strength is required, or the PVC pipe should be placed within a sleeve (typically corrugated steel is used). Steel pipe is normally too expensive to use as mainlines for irrigation systems and PVC is a better alternative.

Aluminum pipe is primarily applicable only to portable systems where the pipe will be left on the surface. Uncoated aluminum pipe should never be buried because it will rapidly deteriorate in Florida's acid soils.

Water Hammer

To avoid water hammer problems in pipelines, water velocity should be kept low, normally less than 5′ per sec (fps) for other than experienced irrigation system designers. Under no conditions should velocities ever exceed 10 fps. Velocities in the range of 5 to 10 fps are sometimes used if:

- it is economical when both fixed and operating costs are considered
- pipe is properly pressure rated
- startup velocities are controlled by slow-opening valves
- thrust blocks are installed as required at tees, elbows, valves, or other points where hydraulic shocks may occur
- air relief valves are installed at all high points along the pipeline as required
- valves at the irrigation system subunits are not normally all closed at pump startup.

For more information on water hammer, see IFAS Ext. Cir. 828, *Water Hammer in Irrigation Systems* (7).

Pressure Rating

Mainline pipe must be properly pressure rated to withstand the normal system operating pressure plus that due to hydraulic surges (water hammer). Also, the pressure due to surges should normally not be allowed to exceed 28% of the pipe pressure rating.

Class 160 (160 psi pressure rated, or SDR 26) is normally adequately pressure-rated when velocities are kept below 5′ per sec (fps). Higher pressure ratings may be required if higher velocities are used.

Cost

Mainline pipe sizes should be selected based on cost and the previously discussed water hammer considerations. The cost of the energy consumed by friction losses should not exceed the amortized cost of the next larger-sized pipe. The economic analysis should consider the additional pumping costs associated with smaller pipe sizes, fuel cost escalation for the life of the system, as well as any anticipated expansions of the system that would require greater flow rates in existing mainline pipes.

Friction loss tables that are used to estimate pressure losses for the selection of mainline pipes assume that the pipes flow full. Air relief valves should be installed at all high points along the pipes to ensure that air will not be trapped at these points, causing the pipes to flow less than full. Trapped air may also lead to water hammer problems when the air is suddenly displaced.

For more information on irrigation pipelines, see the appropriate ASAE, FIS and SCS standards. Also, see Agricultural Engineering Fact Sheet AE-69, *Fittings and Connections for Flexible Polyethylene Pipe Used in Microirrigation Systems* (14).

Irrigation Distribution Systems

Irrigation distribution systems are those components of irrigation systems which apply water to the irrigated areas. In seepage and flood irrigation systems, these are the lateral ditches or pipes that distribute water throughout the fields. In pressurized systems, these are the system subunits or zones. Subunits are the groups of emitters and lateral and manifold pipelines that operate at the same time.

Subunit design criteria are 1) uniformity of water application; and 2) economic considerations. Lateral ditches and pipes must be large enough and spaced closely enough that water is applied uniformly, but ditches and pipes must be small enough and widely enough spaced to be affordable. Absolute (100%) uniformity is impossible. Extremely high uniformities are costly. Tradeoffs of benefits from uniformities versus cost must be made. For more information on uniformity, see Agricultural Engineering Fact Sheet AE-43 (65), and Bulletins 256 (2), 265 (41) and 266 (42). For more information on system costs, see IFAS Ext. Cir. 821 (34), Bul. 276 (39), and Fact Sheets AE-30 (53) and AE-74 (35).

Pressurized (Sprinkler and Microirrigation) Systems

Pressure is normally regulated at the entrance to a subunit, especially for large field-scale systems. Control components located here are normally a valve (manual or automatic), pressure regulator, pressure gauge, and, for microirrigation systems, sometimes a secondary (screen) filter.

For sprinkler irrigation systems, high uniformity is achieved by designing pipelines so that the variation in flow rates between sprinklers within a subunit is small. Sprinklers must be properly spaced and the water distribution patterns from individual sprinklers must be selected to ensure high uniformity. In addition, prevailing wind conditions must be considered to ensure that uniformity remains high for typical prevailing winds. In general, maximum minus minimum flow rates from sprinklers in a subunit should not be greater than 10% of the average sprinkler flow rate in the subunit. Uniformity should be higher when chemicals are applied with the irrigation water since chemical application uniformity will be limited by the water application uniformity.

For more information on sprinkler irrigation systems, see IFAS Ext. Cir. 348, *Sprinkler Irrigation for Cold Protection* (27), and Cir. 804, *Center Pivot Irrigation Systems and Applications in Florida* (62).

For microirrigation systems the design water emission uniformity, EU, is defined as:

$$EU = 100\,[1.0 - 1.27\,C_v/\mathrm{Sqrt}(n)]\,Q_n/Q_a$$

where

- EU = subunit design emission uniformity (%),
- C_v = emitter manufacturer's coefficient of variation,
- Sqrt(n) = square root of the number of emitters per plant or 1.0, whichever is greater,
- Q_n = minimum emitter flow rate within the subunit (gph), and
- Q_a = average emitter flow rate within the subunit (gph).

The minimum acceptable subunit uniformity of water application (EU) should be 80% for Florida microirrigation systems. If chemicals (including fertilizers) are applied with the irrigation water, the water and chemicals should be applied more uniformly, thus the minimum acceptable uniformity is 90%. See ASAE (1), FIS (12, 13) and SCS (36) standards for acceptable uniformities of water application. See Agricultural Engineering Fact Sheet AE-70, *Principles of Microirrigation* (18), for more information on microirrigation system design considerations.

Subunit uniformity refers to the uniformity of water application, but it must be expressed in terms of pressure variation (loss) so that the designer can select pipe sizes. The relationship between flow variation and pressure variation depends on the emitter hydraulic characteristics, that is, how the individual emitter or sprinkler flow varies with pressure. These data must be obtained from the emitter manufacturer or by testing a representative sample of emitters. Manufacturing variation, C_v, between individual microirrigation emitters must also be considered in design, and these data should be provided by the emitter manufacturer.

The type of emitter used in a pressurized irrigation system affects the system design. Emitter hydraulic properties affect the allowable pressure losses in subunits, and manufacturer's variation and friction losses associated with emitter connections must be considered when microirrigation systems are designed.

Lateral pipes are pipes on which the emitters are mounted. They are typically rigid PVC pipe for permanent sprinkler systems, aluminum pipe for portable sprinkler systems, or flexible polyethylene (PE) pipe for microirrigation systems. Sprinkler laterals are typically buried for permanent systems and placed on the surface for portable systems.

Microirrigation laterals are typically installed on the soil surface or buried at shallow depths. When laterals are buried, small risers or flexible PE tubes usually supply water to the emitters on the surface. In some cases, both laterals and emitters are buried; however, emitters are normally not buried more than 1 to 3″ below the surface because upward capillary water movement in Florida's typical sandy soils is very limited.

Manifold pipes are pipes which feed the laterals. Manifolds are normally buried PVC pipe with risers to connect the laterals. Burial is required to prevent organic growths in the pipe and to protect it from deterioration in sunlight. Pipe is connected using solvent cemented or slip couplings. Short riser pipes are normally used to conduct water to lateral pipelines. Risers are normally constructed of either rigid PVC pipe or flexible PE or PVC tubing. Flexible tubing is preferred because it minimizes riser breakage, light cannot penetrate it, and it is protected against degradation by sunlight.

Manifolds are sometimes placed on the surface. This arrangement is often used for annual crops such as vegetables. Surface manifolds are often constructed from "lay-flat" collapsible hose which is similar in appearance to fire hose. The manifolds are then rolled up and stored between crop seasons.

Flush valves should be installed on the ends of manifolds to permit periodic manual flushing to minimize clogging problems. To adequately flush a manifold, a minimum velocity of 1 ft/sec should be provided. Normally the smallest manifold pipe size and flush valve required for commercial-scale installations is 2″ in order to obtain flow rates large enough to adequately flush the manifold.

Seepage Systems

For seepage irrigation systems, water is applied to lateral pipes or ditches, and it moves horizontally at rates that depend on the soil hydraulic properties. Depending on soil hydraulic properties, ditch spacings may range from 20 to 60′ in sandy soils and up to 300 feet in muck soils. Spacings are computed based on soil hydraulic properties, slope, water use rates, system efficiencies, and required water table heights. Nonuniformity in water table heights will result in nonuniform production since water moves up into the crop root zone by soil capillarity.

Seepage irrigation systems require flow rates of 5 to 10 gpm per acre depending on crop water use rates and irrigation efficiencies. Design of seepage systems requires calculating lateral spacings needed to maintain the required water table heights. Closer spacings produce greater uniformities, while wider spacings are less expensive. For more information on seepage irrigation, see IFAS Ext. Cir. 309-C, *Seepage Irrigation for Pastures* (28), Cir. 729, *Factors to Consider When Applying Seepage Irrigation and Drainage* (31), and Cir. 769, *Water Budgeting for High Water Table Soils* (30).

Surface Systems

Surface irrigation requires 1) applying water to wet the soil surface as quickly as possible and then maintaining water applications at rates approximately equal to infiltration rates until the required amount of water has been applied; or 2) continuously flooding the soil surface. In Florida, only two types of surface systems are used, crown flood irrigation of citrus and flood irrigation of rice.

In citrus crown flood systems, water is quickly applied to flood water furrows, then it is allowed to stand until the required depth has infiltrated, after which the excess is drained. The amounts and times depend on soil properties, bed widths between furrows, ET rates, and irrigation efficiencies. Normally, however, an irrigation requires 2 to 4 days.

In rice flood systems, the production areas are continuously flooded and the required water application rates depend on ET rates and irrigation efficiencies. Irrigation occurs continuously throughout the growing season until the fields are drained in preparation for harvest except when adequate rainfall occurs.

Pumping Systems

An irrigation pumping system must have sufficient capacity to irrigate all subunits to meet crop water requirements. Crop water requirements include evapotranspiration and other requirements such as cold protection or water required as a carrier for fertilizer applications, etc. See IFAS Ext. Cir. 822, *Atmospheric Parameters which Affect Evapotranspiration* (8) and Bul. 205, *Potential Evapotranspiration Probabilities and Distributions in Florida* (45).

The pump must have sufficient flow and pressure for the most extreme subunit conditions. The critical flow is that of the largest subunit. The critical pressure subunit is the most distant, the one at the greatest elevation, or which for other reasons requires the greatest pressure to deliver its water. Ideally, all subunits should be of about the same size and have about the same pressure requirements because an irrigation pump operates most efficiently at a single flow rate and pressure.

The total pressure that the pumping system must produce is the sum of the pressures required to operate the critical subunit, friction losses through the mainline (including all losses through valves, filters, meters, fittings, etc.), and elevation changes including pumping lift.

For surface water supplies and water at pumping levels of less than 20′ in wells, centrifugal pumps are the most economical option. Low-lift axial-flow (propeller) pumps may be required in seepage irrigation systems because of their high flow capabilities.

For water at depths greater than 20′ in wells, turbine pumps must be used. For large systems, deep-well turbines, with power units on the surface, are commonly used. For smaller units, submersible turbines are a less expensive option. With submersible turbines, electric motors are directly connected to the pumps and lowered into the well.

For automatic operation, turbine pumps have the advantage that they do not require priming for the pump to operate. Conventional centrifugal pumps require priming to operate. Although self-priming centrifugal pumps are available, they generally operate less efficiently than turbines. To avoid problems with loss of prime, turbines are recommended for systems that will start and stop automatically.

For automatic operation, electric motors are recommended as power units for drip irrigation systems. They have lower initial costs than internal combustion engines, especially for smaller sizes. There may be a demand charge on the electric bill for their use, especially for larger units. Most power companies now have off-peak rates for irrigation pumps. Some power companies have also eliminated stand-by or demand charges for off-peak users. Local power company policies will dictate actual costs.

Diesel power units are the most common type of internal combustion engines used for irrigation in Florida. They are more efficient than other types of internal combustion engines. Internal combustion engines are recommended when irrigation systems will be used for cold protection because of the possibility of electric power interruption and loss of pumping capability on cold nights.

For more information on pumping systems, see IFAS Ext. Cir. 832, *Pumps for Florida Irrigation and Drainage Systems* (20), Cir. 653, *Performance of Irrigation Pumping Systems in Florida* (55), and Ag. Eng. Fact Sheets AE-24, *Evaluating Irrigation Pumping Systems* (57) and AE-62, *Power Requirements and Cost Estimates for Irrigation Pumping* (51). For more information on wells, see IFAS Ext. Cir. 803, *Water Wells for Florida Irrigation Systems* (21).

SELECTION OF OPERATING CONDITIONS

The design of an irrigation system requires that the designer specify the system operating conditions. The operating conditions include the operating pressure and flow rate that must be provided by the pump.

Because the flow rate of a water emitter depends on pressure, selection of the operating pressure for a given type of emitter also determines the average flow rate for the system. Likewise, selecting the average flow rate determines the operating pressure required to achieve that flow rate.

Operating Pressure

The operating pressure of an irrigation system is the pressure at which the typical subunit operates. For gravity flow systems such as many flood and seepage systems, water is pumped into open ditches. In these cases, the only pressure required is the pressure needed to lift water from its source to its point of discharge and to overcome friction losses in the pipelines. If the water source is a well, lift also includes drawdown in the well. For all water sources, lift should be calculated based on the lowest expected water elevation so that pressures would then be adequate even under drought conditions.

For pressurized irrigation systems, including sprinkler, microirrigation, and seepage systems which convey and distribute water from pipelines, the operating pressure required includes lift, friction losses, and pressure required to operate the emitters. Lift is the difference in elevation from the water source to the emitters in the field, including drawdown. Friction losses include all losses in pipelines, valves, fittings, filters, and other components between the water source and the field subunits.

The pressure required to operate the emitters depends on the type of emitter used. For seepage and microirrigation systems, the emitter pressure is low, typically less than 30 psi. For sprinkler systems, the required pressure can range from 20 to 100 psi depending on the type of sprinkler selected.

High operating pressure increases the cost of operating an irrigation system because the pumping cost increases directly with the pressure that the pump operates against. Low pressure increases pipe costs because the allowable pressure loss to achieve a high degree of uniformity of water application is less, and this requires larger pipe sizes. The final decision on operating pressure selection must be based on economics. The optimum set of operating conditions will only result from a detailed cost analysis.

Flow Rates

Flow rates required for irrigation depend on many irrigation system and crop production system factors. For seepage irrigation, flow rates of 5 to 10 gpm per acre are required in order to establish and maintain a field water table. These values can range even wider depending on site-specific factors such as the permeability of restrictive layers, depth to water table, and time of year that the crop is grown.

For sprinkler irrigation, the required flow rate depends on the sprinkler application rate selected. Application rates typically range from 0.12 to 0.25" per hour (54 to 113 gpm per acre), although they may be larger if required for freeze protection. Smaller application rates will be required on heavier soils and steeper slopes in order to avoid runoff.

For microirrigation systems, flow rates required will vary depending on the type of emitters selected and emitter spacings. The flow rate from individual emitters in a drip irrigation system are rarely greater than 1 gallon per hour (gph). For spray emitters, flow rates typically range from 10 to 25 gph per emitter.

The flow rate required per acre can be as high as 30 to 40 gpm per acre if closely-spaced plants are drip-irrigated, and it will be much lower for widely spaced plants. For example, to drip irrigate a vegetable crop with 7,260 row feet per acre will require about 35 gpm if 0.5 gpm/100 ft drip tubing is used, while a crop with 5,000 row feet per acre will require 25 gpm per acre with the same drip tubing and only 15 gpm per acre if 0.3 gpm/100′ drip tubing is used.

For tree crops such as citrus, microspray emitters are typically used. Citrus trees will require 25 gpm per acre for 100 trees per acre and one 15-gph microspray emitter per tree, and 50 gpm per acre for 200 trees per acre. Sometimes even higher flow rates are used when microirrigation systems are designed for freeze protection.

For more information on flow rate requirements for specific crops, see the irrigation publications or crop production guides for those crops.

SUMMARY

Components of irrigation systems for crop production in Florida were defined. Design of control equipment, mainline pipes, system subunits, and pumping systems were discussed. Considerations in selecting irrigation system operating conditions, consisting of operating pressures and flow rates were presented. An extensive list of IFAS extension publications was provided for additional information on the design and installation of various system components.

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