RICE
PRODUCTION HANDBOOK

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University of Arkansas System

MP192

ARKANSAS RICE CHECK-OFF

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Chapter

10

Water Management

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An adequate supply of good quality irrigation water is needed for optimum rice production. Proper management of irrigation is critical for overall profitability, management of diseases (such as rice blast), nutrient management (such as nitrogen and phosphorus), weed management and insect management. Growers need to have a good grasp of the capabilities and limitations of their irrigation system to ensure rice can be flooded in a timely manner. Knowledge of the quality and quantity of irrigation water is required for proper water management.

Determining Water Needs

A water supply is adequate for a given field if you can:

- Flush in two to four days;
- Flood in three to five days; and
- Maintain a continuous flood for the entire season.

Management Key

Flush if necessary for stand establishment or weed control.

Recommended minimum and desired pumping rates (gallons per minute per acre [GPM/acre]) are based on different soil textures (Table 10-1). To determine pumping rate for your field, multiply your field acreage by the value given for your soil type (e.g., 50-acre sandy loam field times 25 GPM/acre = 1,250 GPM). If you already know your pump capacity and field acreage, Table 10-2 can be used as a guide for determining whether your pump capacity is sufficient to maintain an adequate flood on your field. For example, if a well is pumping 1,200 GPM and rice is grown on a silt loam soil with a pan, this well should not be used to irrigate more than 120 acres of rice. Since most fields

Table 10-1. Recommended pumping rates for different soil textural groups.

	(GPM†/Acre)	
Soil Textural Group	Minimum	Desired
Silt loam – with pan	10	10
Sandy loam	15	25
Silt loam – no pan	10	15
Clay and silty clay	15	20

† GPM = gallons per minute.

Table 10-2. General guide for irrigable acreage for different soil textural groups at various pump capacities.

	Irrigable Acreage			
Pump Capacity (GPM)†	Silt Loam – With Pan	Silt Loam – No Pan	Clay and Silty Clay	Sandy Loam
400	40	27	20	16
600	60	40	30	24
800	80	53	40	32
1,000	100	67	50	40
1,200	120	80	60	48
1,400	140	93	70	56
1,600	160	107	80	64
1,800	180	120	90	72
2,000	200	133	100	80
2,200	220	147	110	88
2,400	240	160	120	96
2,600	260	173	130	104
2,800	280	187	140	112
3,000	300	200	150	120

† GPM = gallons per minute.

may have more than one soil texture, use these pumping rates only as a general guide for determining needed pumping capacities.

Table 10-3 shows the operating time required to pump 1 inch of water on different size fields at different pumping rates. This is useful for estimating the amount of pumping time required for a given situation. For example, a well discharging 1,000 GPM will need 36 hours to produce enough water to apply 1 inch to 80 acres (80 acre-inches).

Management Key

Select fields that hold water adequately and keep acreage within the limits of pumping capacity.

Table 10-3. Hours of operating time to pump one acre-inch of water.

Pumping Capacity (GPM†)	Surface Acres							
	20	40	60	80	120	160	200	240
	Time (Hours)							
200	45	91						
400	23	45	68	91				
600	15	30	45	60	91			
800	11	23	34	45	68	91		
1,000		18	27	36	54	72	91	
1,200		15	23	30	45	60	76	91
1,400		13	19	26	39	52	65	78
1,600		11	17	23	34	45	57	68
1,800			15	20	30	40	50	60
2,000			14	18	27	36	45	54
2,200			12	17	25	33	41	49
2,400			11	15	23	30	38	45
2,600				14	21	28	35	42
2,800				13	19	26	32	39
3,000				12	18	24	30	36
3,200				11	17	23	28	34
3,400					16	21	27	32
3,600					15	20	25	30
3,800					14	19	24	29
4,000					14	18	23	27
4,200						17	22	26
4,400						17	21	25
4,600						16	20	24
4,800							19	23
5,000							18	22

† GPM = gallons per minute.

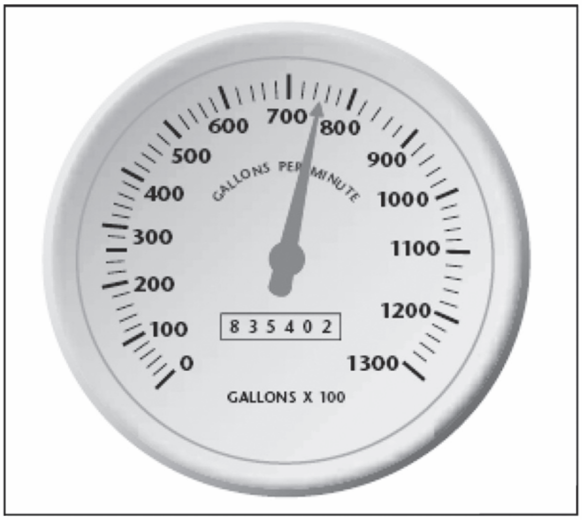
Determining Pump Flow

A good method of determining pump discharge is to use an inline flow meter. Many irrigation equipment dealers handle flow meters and can provide cost and proper installation information. There are many different styles, but the most common is a propeller-style mechanical flow meter. Currently, cost-share is available from the Natural Resource Conservation Service (NRCS) for flow meters. Proper installation is very important to ensure accurate readings and good service from the flow meter. It is most desirable to have at least 5 to 10 feet (sometimes more) of straight pipe before any bends or flow direction changes for accurate reading. However, even when this criterion cannot be met, results are still more accurate with a flow meter than with manual measurements. Flow meters measure both flow rate and the total volume of water applied (referred to as a totalizer).

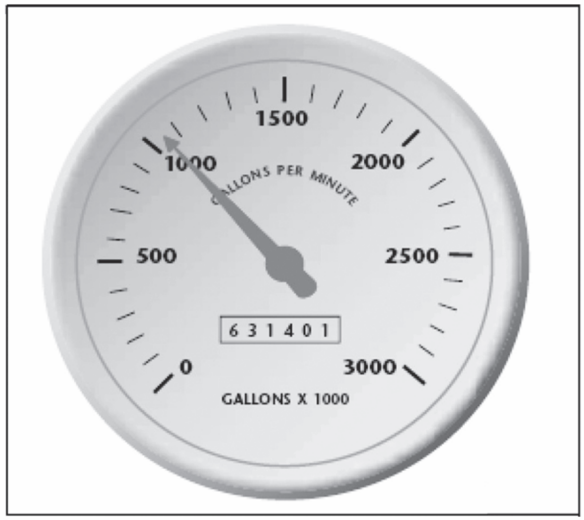
While most flow meters are permanently installed, a portable flow meter can be used to monitor the flow of more than one pumping plant. Most flow meters are equipped with a totalizer that records the total quantity of water pumped much like an odometer for a vehicle. This provides useful water management information that can also be used to document irrigation water requirements. Flow meters can be ordered with many different totalizer measurement unit types, such as gallons, acre-foot and acre-inches. Acre-inch totalizers are

Table 10-4. Hours of operating time to pump one acre-inch of water.

Volume	equals
1 gallon (gal)	8.33 pounds (lbs)
1 cubic foot (ft^3)	7.48 gal
1 acre-foot (ac-ft)	325,851 gal
1 acre-inch (ac-in)	27,154 gal
1 ac-in	3,630 ft^3
Flow	**equals**
1 cubic foot per second (cfs)	448.83 gallons per minute (GPM)
1 cfs	1 ac-in per hour
1 GPM	0.00223 cfs
1 GPM	0.00221 ac-in per hour
1 liter/second (L/s)	15.83 GPM
1 cubic meter/minute (m^3/min)	264.2 GPM
1 cfs for 1 hour	1 ac-in
542 GPM for 1 hour	1 ac-in

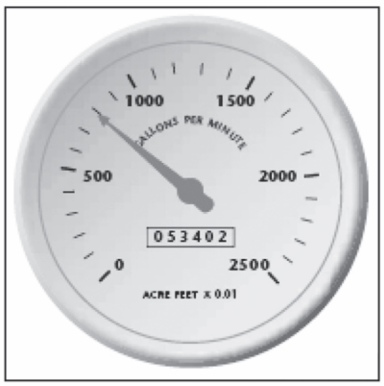


Standard 8-inch dial face with gallons totalizer. Add two zeros to the six-digit number.
Dial face reading = 83,540,200 gallons.

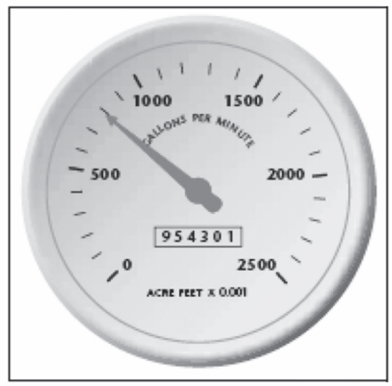


A 10-inch dial face with gallons totalizer. Add three zeros to the six-digit number.
Dial face reading = 631,401,000 gallons.

Dial with cubic feet per second indicator and acre-ft totalizer. Place a decimal point three places to the left.
Acre-ft = 835.402



Acre-ft totalizer. Place a decimal point two places to the left.
Acre-ft = 534.02



Acre-ft totalizer. Place a decimal point three places to the left.
Acre-ft = 954.301

Figure 10-1. **Flow meter dial types and how to read them (Source: Sheffield and Bankston 2008. LSU AgCenter Pub. #3082, *Irrigation Flow Measurement*).**

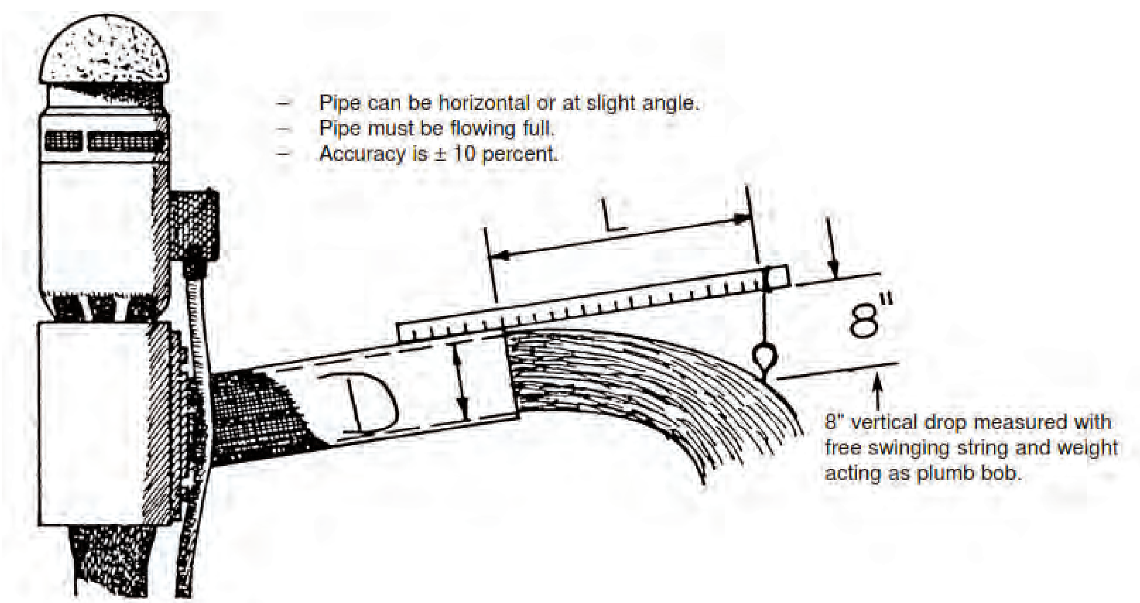
the most useful measure because the math to convert to application rate is the simplest, and the end unit is the most useful for irrigation. Table 10-4 shows conversions between different units of water measurement. The most common unit for totalizers is gallons, and there are 27,154 gallons in an acre-inch of water.

If a flow meter is not available, the discharge rate can be estimated by the plumb bob method described in the following section (Photo 10-1, Table 10-5 and Figure 10-2). When the water discharges from a vertical riser, the flow rate can be estimated with a vertical measurement (Figure 10-3 and Table 10-6).

Photo 10-1. **Manual measurement of pump flow using a yardstick and plumb bob.**

Table 10-5. **Pump flows calculated from yardstick and 8-inch plumb bob measurements.**

	Inside Diameter of Pipe (D) – Inches										
	4"	5"	6"	7"	8"	9"	10"	11"	12"	13"	14"
Inches	Flow (GPM)										
	64	100	144	196	256	324	400	484	476	676	784
4	96	150	216	294	384	486	600	726	864	1014	1176
6	128	200	288	392	512	648	800	968	1152	1352	1568
8	160	250	360	490	640	810	1000	1210	1440	1690	1960
10	192	300	432	388	768	972	1200	1452	1728	2028	2352
12	224	350	504	686	896	1134	1400	1694	2016	2366	2744
14	256	400	576	784	1024	1296	1600	1936	2304	2704	3136
16	288	450	648	882	1152	1458	1800	2178	2592	3042	3428
18	320	500	720	980	1280	1620	2000	2420	2880	3380	3920
20	352	550	792	1078	1408	1782	2200	2662	3168	3718	4312
22	384	600	864	1176	1536	1944	2400	2904	3456	4056	4704
24	416	650	936	1274	1664	2106	2600	3146	3744	4394	5096
26	448	700	1008	1372	1792	2268	2800	3388	4032	4732	5488
28	480	750	1080	1470	1920	2430	3000	3630	4320	5070	5880
30	512	800	1152	1568	2048	2592	3200	3872	4608	5408	6272
32	544	850	1224	1666	2176	2754	3400	4114	4896	5746	6664
34	576	900	1296	1764	2304	2916	3600	4356	5184	6084	7056



Measuring Procedure: Extend yardstick parallel with discharge pipe until 8" plumb bob barely touches the water stream. Measure length (L) and pipe inside diameter (D) which is less than the nominal pipe diameter.

Formula: Gallons per minute = the inside diameter squared x the length in inches.

GPM = D x D x L

Example: Discharge Pipe – 10 inches (D)
Discharge Length – 14 inches (L)

GPM = 10 x 10 x 14
GPM = 1400

Note: Discharge pipe must be full and plumb bob length must be 8" for this method to be accurate. See Table 10-5 for flow rates at various measurements.

Figure 10-2. **Illustration of the manual measurement of pump flow.**

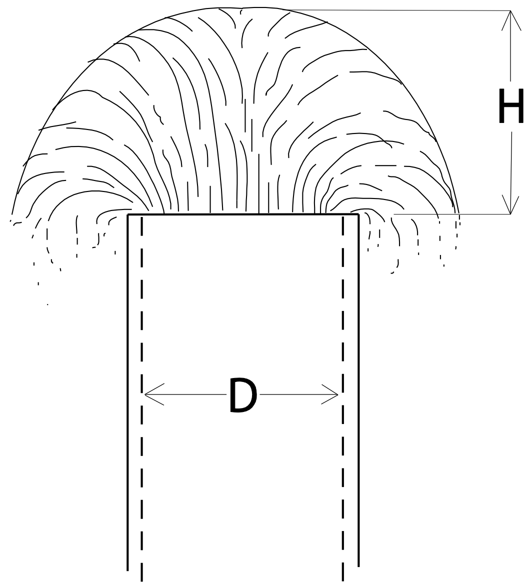


Figure 10-3. Flow from a vertical pipe or casing.

Table 10-6. Flow from vertical pipes or casings.

	Diameter of Pipe (D) (in)						
	4	6	8	10	12	14	16
Water	gallons per minute (GPM)						
3	135	311	569	950	1394	1898	2479
4	161	369	687	1115	1612	2194	2866
6	202	469	872	1415	1975	2688	3511
8	236	548	1025	1640	2281	3104	4055
10	265	621	1155	1840	2547	3466	4528
12	294	685	1275	2010	2789	3796	4958
14	319	740	1380	2170	3014	4103	5359
16	342	796	1480	2370	3224	4388	5732

Source: Irrigation Water Measurement, Louisiana State University.

However, the accuracy is usually very poor because of the difficulty in obtaining a good measurement of the vertical height. A more accurate measurement is usually obtained if a hydrant is installed on the riser, creating a horizontal discharge. A joint of pipe inserted in the hydrant stabilizes the flow and makes the plumb bob method possible.

Pumping Cost

The total cost for pumping irrigation water is influenced by several factors. Taxes, insurance, interest, depreciation, maintenance and energy must all be considered as real costs. Energy is usually more than 50 percent of the total pumping cost over the life of an irrigation pumping plant.

Table 10-7 presents typical energy use values for various energy sources and different pumping depths. Since energy prices can vary from season to season, current energy prices should be applied to the energy use values to calculate actual cost. Energy use values vary due to motor or power unit design, wear and matching to load. The values are presented as a guide for comparison.

Table 10-7. Fuel use comparison.

	Typical Fuel Consumption Per Ac-In for Different Pumping Depths†			
Power Unit Type	25'	50'	75'	100'
Electric (KWH)‡ (Conventional vertical hollow shaft)	4.0	8.0	12.0	16.0
Electric (KWH) (Submersible)	4.5	9.0	13.5	18.0
Diesel (GAL)	0.3	0.6	0.9	1.1
LP Gas (GAL)	0.5	1.0	1.6	2.1
Gasoline (GAL)	0.4	0.8	1.2	1.6
Natural Gas (CCF)	0.6	1.1	1.7	2.2
NOTE: Typical fuel consumption can vary ± 20 percent due to motor or power unit design, wear and matching to load.				

† The pumping plant performance values used in the calculations are based on Nebraska Standards and Arkansas pumping plant tests. The values for gasoline, LP and natural gas include a 5 percent drive loss, while no drive loss is considered for electric. All values assume 75 percent pump efficiency. Typical fuel consumption is based on the system performing at 80 percent of the best performance possible. Pumping depth is depth to water when pumping.

‡ GAL is abbreviation for gallon; KWH is abbreviation for kilowatt hour; CCF is abbreviation for 100 cubic feet.

Management Key

Carefully analyze differences in energy costs. Select and use another energy source where economically justified.

Because an irrigation system influences irrigation efficiency, the amount of water required for a rice field varies. Typical values for the amount of water pumped in a season have been determined for different irrigation systems (Table 10-8). The values may vary but can be used as a guide for determining seasonal water use.

Tables 10-7 and 10-8 can be used to estimate energy costs as well as to compare actual energy costs to what is presented as typical. This information can be useful for evaluation of water management practices.

Table 10-8. **Typical water use amounts applied to rice by irrigation system.**

Irrigation System	Irrigation Water Applied (ac-in/ac)
Zero grade	19
Precision grade	32
Non-precision grade	32
Multiple inlet	24
Sprinkler or center-pivot	19

Source: Rice Research Verification Program. Note: there is limited data on sandy soils; expect much higher water use for these soil types. No soil type difference was found in this dataset. Data from sprinkler or center-pivot rice is very limited (Source: Vories et. al., 2011).

Example scenario:

You are considering converting an existing diesel pumping plant to electricity or natural gas. The rice field soil type is predominately clay. The pumping depth for the well is 100 feet. You have a diesel power unit with diesel at $3.52 per gallon. Typical energy use from Table 10-7 is 1.1 gal/ac-in. Typical water use from Table 10-8 is 32 ac-in/ac.

Maintaining diesel unit, the estimated energy cost is:
1.1 gal/ac-in × 32 ac-in/ac × $3.52/gal = $123.90/ac

Estimated Energy Cost if Unit is converted to electricity:
Typical energy use from Table 10-7 for a vertical turbine is 16 KWH/ac-in.
16 KWH/ac-in × 32 ac-in/ac × 0.10 cents/KWH = $51.20/ac

Estimated Energy Cost if Unit is converted to Natural Gas:
Typical energy use from Table 10-7 for natural gas power unit is 2.2 CCF/ac-in.
2.2 CCF/ac-in × 32 ac-in × $1.00/CCF = $70.40/ac

For more information on pumping irrigation water, contact your local county Extension office.

Management Key

Choose the electric rate structure best suited for specific pumping situations and allow the electric company to control the well if water supply is adequate.

Well Operation

The basic approach to rice irrigation is to flush if necessary to obtain an acceptable rice stand and establish the initial flood at beginning tillering (4 to 5 leaf; 6 to 10 inches tall). A shallow flood depth of 2 to 4 inches should be maintained until about two weeks prior to harvest unless there is a reason for draining, such as for straighthead control. If the field has conditions favorable for rice blast disease or blast develops in the field, the flood depth should be increased after midseason to a depth of 4 to 6 inches to help suppress the disease. Research has shown a major reduction in the severity of rice blast when a deep flood is maintained during reproductive growth (See Chapter 11, Management of Rice Diseases). If cultivars are selected that are resistant to blast, then it is not necessary to increase flood depth.

If the well continues operating until the last levee is flooded, a significant amount of water can be wasted as runoff. Determining when to stop a well so that the water in transit will fill the remaining levee area requires experience. This depends on field size, soil type and well capacity. Table 10-1 can be used as a guide. If the pumping rate is near the recommended minimum, the water should be 90 percent down the field before the well is turned off. When the pumping rate is near the desired value, you can typically turn the well off when the water is 70 to 80 percent down the field. Some growers find that they can better establish the initial flood by filling up the bottom levee pad first and then stair-stepping the flood back up the field by raising the levee gates.

Electric companies offer a variety of rate structures that are suited to particular situations. Consult with your electric company representative to determine the best rate structure. Significant energy savings (20 to 30 percent) are usually possible when the electric company is allowed to turn off an electric service for two to four hours during the daily peak load periods (often referred to as load management programs). Some electrical utilities are allowing customers access to the control system so that pumps can be controlled by customers during the off-peak time periods, providing remote pump operation at no additional cost. Table 10-1 can be used as a guide to determine if enough pumping capacity exists to take advantage of load control programs. It is suggested to use load management for two- and four-hour shutdowns if the pumping rate is closer to the desired value than the minimum value.

Power units operate over a wide range of speeds (1,500 to 2,400 RPM). The best fuel consumption performance is usually obtained over a much narrower range of speeds (1,600 to 1,900 RPM). Recent research by the University of Missouri reported 1,350 RPM as the lowest cost of water speed and 1,550 RPM as the highest, as a general recommendation across all diesel engine types. It is best to determine the most economical operating speed and run the unit at this setting whenever possible. Other factors, such as desired pump speed and load on the power unit, must be considered. This information can be determined from pump and power unit performance specifications available through irrigation equipment dealers. Reviewing this information with a dealer can be helpful, particularly when operating a new well installation or a power unit that you are not familiar with. It is also important to make sure the gearhead ratio is correct to ensure that the pump is turning at the desired speed. A portable tachometer is a good tool for verifying both engine and pump speed.

Management Key

Service and check out the pumping plant before the pumping season to prevent costly pumping delays.

Irrigation Water Quality

While ample irrigation water is necessary for a productive rice crop, poor quality water can cause soil-related problems that negatively impact rice. Some of the predominant soil-related problems that affect rice include salinity (high soluble salts), zinc deficiency, phosphorus deficiency and excessive sodium (which causes poor soil physical conditions).

Salinity is most often associated with arid or semi-arid regions of the world, such as in the southwestern USA. However, salinity problems are common in the rice-producing regions of Arkansas in some circumstances. The poor drainage characteristics of the soils in Arkansas that allow them to be efficient for rice production also contribute to the problems associated with salinity.

Salinity results from adding salt to soils, usually in irrigation water, faster than it is removed by natural processes, such as surface runoff and downward percolation. Irrigation water is the major contributor of soluble salts in Arkansas but excessive nutrient additions from fertilizers, manures or waste materials may also contribute to the accumulation of salts. The types of soluble salts that usually contribute to salinity problems include calcium, magnesium, sodium, chloride, sulfate and nitrate.

In addition to the effect on rice production, irrigation water that contains excessive levels of chloride can lead to chloride toxicity in soybeans. Rice is very sensitive to chloride and nitrate salts at the seedling growth stage. Sodium problems are usually native to particular soils such as the Foley, Lafe, Hillemann and Stuttgart soil mapping units. However, isolated cases of water containing excess sodium have been observed. Excessive sodium may cause poor physical conditions of the soils which can interfere with crop stand establishment.

Zinc and phosphorus deficiencies are usually associated with alkaline (high pH) soils, particularly on silt loam soils. Alkaline soils are created by irrigating with water that contains high concentrations of calcium and magnesium bicarbonate. When the water enters the field, the bicarbonates are converted to calcium and magnesium carbonate (lime) which are then deposited in the field. The soil pH increases in the field where the carbonates (lime) are deposited. A soil pH gradient is usually created such that the soil pH is higher near the water inlet and decreases down the slope.

Management Key

Proper soil sampling is critical to identifying areas of the field that may require zinc or phosphorus fertilizer to prevent deficiencies. Water samples are also useful for identifying irrigation wells that may contribute to the development of these problems.

It is possible to develop both salinity and alkalinity problems in the same field. Correct diagnosis of problems concerning irrigation water quality is critical for effective management. Water quality testing is an important step in diagnosing existing problems and identifying potential problems. Several values are helpful in evaluating the quality of a particular water source. These include calcium concentration, bicarbonate concentration, chloride concentration, electrical conductivity (EC) and sodium absorption ratio (SAR). Table 10-9 provides a brief guide for evaluating water quality. The calcium and bicarbonate

Table 10-9. **General rice irrigation water quality.**

Water Quality Variable	Level Considered to Cause Concern†	Concern
Calcium (Ca)	> 60 ppm (> 3 meq/L)	Together can cause soil pH increases near water inlet and inflow areas; causing zinc or phosphorus deficiency in silt loam soils.
Bicarbonate (HCO_3)	> 305 ppm (> 5 meq/L)	
Electrical Conductivity (EC) [after lime deposition]	> 770 ppm (> 1200 µmhos/cm; 1.2 dS/m)	Causes high soil salinity which can injure and/or kill seedling rice.
Chloride (Cl)	> 100 ppm (> 35 meq/L)	Contributes to measured EC level (see above). High Cl alone may pose a problem for soybeans in rotation.
Sodium Adsorption Rate (SAR)‡	> 10	Causes sodic soil which has poor physical condition.

† Lower levels can cause injury in some cases.
‡ SAR = Na$\sqrt{[(Ca + Mg)/2]}$, where Na, Ca and Mg are in meq/L.

concentrations provide an estimate of the amount of lime that will be deposited, and predictions can be made concerning the change in soil pH with long-term use. Electrical conductivity is a measure of the total salts that are dissolved in the water, which allows an estimate of the potential for salinity injury to rice with use of the water.

Chloride concentration is important because of the potential for chloride toxicity to soybeans and because it often is the major contributor to high electrical conductivity. The SAR is a ratio of sodium to calcium and magnesium. This number provides an estimate of how much sodium is in the water relative to calcium and magnesium. The SAR allows the prediction of whether sodic (high sodium) soils are likely to develop with long-term use of the water.

The University of Arkansas conducts water quality testing for a small fee that includes a computer prediction of any long-term effects that may result from using the irrigation water. This analysis includes effects of various crop rotations, soil texture and water management alternatives.

Once a water source has been tested, retesting is usually not necessary for at least five years. However, earlier retesting may be necessary when crop problems develop that may be related to water quality or when the pumping rate or depth changes significantly.

Management Key

Contact your local county Extension office for water quality testing if there is no recent history.

For more information on management of saline or alkaline soils, refer to Chapter 9, Soil Fertility, or to University of Arkansas Soil Test Note No. ST003, *Management of Soils With High Soluble Salts*.

Establishing Levees

An accurate levee survey is important to ensure proper control of water (Photo 10-2). Levees have traditionally been established using laser grading equipment. More growers are utilizing Global Positioning Systems (GPS) with Real Time Kinematics (RTK) to survey and design levees. A topographic survey is conducted with GPS-RTK equipment, and desktop software is used to determine levees based on the interval and smoothing. Levee designs are saved as line features for guidance and can be saved for future years.

All surveying instruments should be properly adjusted and checked for accuracy. Be careful not to exceed the operating range or distance of the equipment. A levee

Photo 10-2. **Surveying levees in a rice field.**

elevation difference of no more than 0.2 foot is generally recommended. This difference is increased on steeper fields when narrow distances between levees present a problem for combine operation. Pre-marking levees on clay soils and establishing levees as soon as conditions allow can reduce water loss from levee seepage. Levee gates should be installed early in the event flushing is necessary and also to provide outlets to avoid levee washouts if heavy rainfall occurs. One gate per levee is usually adequate. Two gates may be necessary in small loop levees near the water source and in larger bays (greater than 10 acres) to ensure adequate water control. If using multiple inlet irrigation, levee gates should be set higher than those for cascade flow.

Management Key

Survey levees on 0.2-foot intervals when possible. Establish a levee base as early as possible (before seeding) on clay soils. An accurate survey is critical to effective water management.

Land Grading

Precision land grading is desirable for reducing the number of levees in a field and for improving the field for furrow irrigation. Fewer levees means more productive flooded field area. If you are considering precision grading, make certain that cut areas won't expose subsoil with undesirable properties. Before grading, determine the soil mapping unit of the field by consulting your county soil survey available from NRCS. Extreme caution should be taken before grading if the soil mapping unit is Lafe, Foley, Hillemann or Stuttgart as these soils contain high sodium levels below the surface ranging in depth from 6 inches to 4 feet or greater. For these soils, take deep soil samples in 6-inch increments and compare sodium levels to the "cut sheet" to ensure that high sodium levels are not exposed in the leveling process of cutting and filling. Another option is to use "warped surface" grading where the cross grade is not zero but is adjusted with a computer to get the best fit and graded with GPS-RTK enabled earthmoving equipment.

Even for other soil mapping units, it is recommended to take several deep (greater than 6 inches) soil cores or samples, but especially if a problem soil is suspected. If soil salinity, sodium or other problems are encountered after leveling, then the addition of poultry litter has shown good results for improving rice yields on cut soil areas.

Additional information on management of precision-graded soils is given in Chapter 9, Soil Fertility. More recently, there are new land-grading techniques that can optimize the cut and fill ratios and provide an "economic" land-grading plan rather than a precision-graded field to uniformly set tolerances.

When a field is precision graded, it is recommended that a slope of no less than 0.05 percent (0.05 foot per 100 feet) should be provided in at least one direction. A slope of 0.1 percent (0.1 foot per 100 feet) is the general recommendation because it provides good drainage and is often easier to construct and maintain than flatter slopes. It is also recommended to consider putting a field to grade in only one direction (i.e., zero cross slope) if it doesn't require a significant amount of extra dirt work. Building a permanent pad or elevated road on one or more sides of a field should also be considered in the grading plan. Settling often occurs in the deeper fill areas following a grading job. If possible, touch up these areas before planting or provide field drain furrows for improved drainage. The land-grading design should consider the type of drain outlets and the number required for the field. If possible, it is best to provide an outlet point for every 20 acres.

It is not usually desirable to precision grade a field to zero slope (zero-grade) in all directions unless continuous rice production is planned. Rotation crops will usually perform better on zero-grade fields that are not over 50 acres in size. It is also critical that the perimeter ditch around the field have unrestricted drainage at its outlet(s). Another consideration for the rotation crop would be to plant on a slightly raised bed but still install a network of drain furrows in the field.

Yearly preplant field leveling or smoothing is essential for seedbed preparation, surface drainage and maintaining optimum flood depths. A landplane or float should be used to remove reverse grades, fill "potholes" and smooth out old levees, rows or ruts in a field. **Rice can germinate under either soil or water, but not both.** Therefore, maintaining a field surface that provides good drainage is important for stand establishment; controlling weeds, diseases and insects; maintaining desired flood depths; and providing a dry field for harvesting.

Water Delivery to Fields

Ditches and canals are sometimes used for water delivery to fields. There is a certain amount of water loss associated with seepage and evaporation from ditches. In addition, canals and ditches require continuous maintenance. Replacing ditches and canals with either surface or underground pipe is desirable when possible. Installing pipe not only eliminates seepage and evaporation losses but also provides more accurate water control and may return land back to production.

Management Key

Replace ditch and canal water delivery systems with pipe or tubing when possible.

Flexible irrigation tubing ("poly pipe") may be used to replace ditches and canals. The tubing is designed for low pressure and comes in various thicknesses that have different pressure capacities. If water will flow in the ditch or irrigation canal, then the tubing should be applicable to the situation. The minimum thickness recommended for this application is 9 mil. This can be an alternative when installing underground pipe is not affordable.

Multiple Inlet Irrigation

The basic concept of multiple inlet irrigation is to proportion the irrigation water evenly over the whole field at one time. The proportioning is accomplished by placing irrigation tubing across each paddy (area between levees) and releasing water into each paddy at the same time through holes or gates in the tubing. Tubing can be placed along the side of the field (side-inlet; Photo 10-3) or through the field (Photo 10-4) depending on the location of the irrigation source (Figure 10-4). This can be done on fields with straight levees and also on fields that have contour levees.

Multiple inlet irrigation provides the potential for improved water management in the following ways:

- Ability to establish flood quicker – increased fertilizer and herbicide efficiency;
- Reduce pumping time during season;
- Reduce pumping cost;
- Reduce amount of water pumped;
- Reduce water runoff from field;

Photo 10-3. Multiple inlet irrigation with tubing placed as side-inlet.

Photo 10-4. Multiple-inlet rice irrigation with tubing placed through the field.

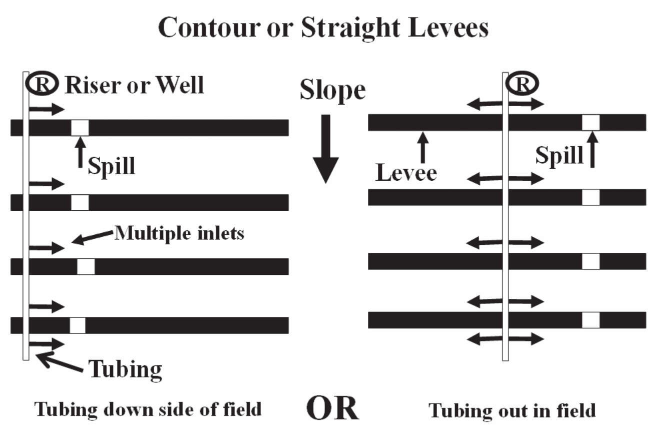


Figure 10-4. Comparison of multiple inlet irrigation setup with tubing placed along the field edge in a side-inlet design (left) and down the middle of the field in a traditional multiple inlet setup (right).

- Reduce irrigation labor;
- Reduce "cold water effect";
- Avoid risk of levee washout from over-pumping top levees;
- Reduce problems associated with scum and algae buildup in levee spills (gates);
- Reduce risk levee washout during heavy rainstorms; and
- Ability to capture rainfall.

Management Key

Set levee gates higher with multiple inlet irrigation so rainfall can be captured. Proper use of multiple inlet irrigation can reduce pumping costs by 25 to 50 percent.

Less time is required to establish a permanent flood when it is possible to put the water in at different points down the field. Once a flood is established with multiple inlets, the levee gates can be set above the desired flood depth so that more rainfall can be held on the field. Inlets to individual levees can provide more precise water control for situations, such as when there are one or more levees that seem to dry out faster. The flow to these levees can be increased independently of the other levees to avoid excessive pumping on the rest of the field. Multiple inlet irrigation is possibly more easily managed on precision graded fields that have uniform acreage between the levees, but it can still offer improved water management on non-graded fields.

One important management change that must occur to be successful with multiple or side-inlet irrigation is to limit water going over the spills from pumping and rainfall. If multiple-inlet fields are pumped up and water cascades through the spills and is managed the same as a conventional rice field, no pumping time savings will be recognized. In multiple-inlet fields, spills become emergency overflows to keep levees from failing during large storm events.

Management Key

In multiple-inlet fields, spills should be used as emergency overflows only. Don't allow water to cascade through spills when irrigating or water savings will be reduced.

Information from field demonstrations and producer experiences indicates that multiple inlet irrigation provides an average reduction in labor of 30 percent and an average reduction in pumping of 25 percent. Some producers who are using multiple inlet irrigation on sandier fields feel that it has reduced pumping by up to 50 percent. This is very possible under certain conditions, but most producers will experience about a 25 percent savings, and in some situations there may be a minimal reduction in pumping savings. Producers who aren't experiencing a significant reduction in pumping still use it for the other benefits it offers, especially the irrigation labor savings.

A few potential disadvantages or problems that can occur with multiple inlet irrigation are:

- Cost of riser bonnets (universal hydrants) and irrigation tubing;
- Initial installation of irrigation tubing and initial adjustment of the inlets (holes or gates);
- Floating, moving and twisting of irrigation tubing early in the season;
- Working around or over irrigation tubing with field equipment (i.e., spraying levees);
- Animal damage to tubing; and
- Removal and disposal of tubing.

Discussions about these problems/disadvantages with producers using multiple inlet irrigation indicate that most are willing to deal with these problems because of the advantages offered.

To establish multiple inlet irrigation for a field, a grower needs a good estimate or measurement of the pumping capacity at the field and the field acreage. The pumping capacity (GPM) is divided by the field acreage to get the ratio of GPM per acre. The estimated or measured acreage in each paddy is then multiplied by this ratio to determine the amount of water to proportion into each paddy. Following is an example of this process:

Example:

Pumping capacity = 1,500 GPM
Field Acreage = 100 acres
1,500 GPM divided by 100 acres = 15 GPM/acre
4-acre paddy: 15 GPM per acre x 4 acres = 60 GPM
7-acre paddy: 15 GPM per acre x 7 acres = 105 GPM

The required flow to each paddy is provided either through several punched holes or a few adjustable gates. Either will work, but the adjustable gate seems to be easier to manage. The most common adjustable gate has a 2.5-inch opening that can be shut completely off or left open to flow approximately 75 GPM. Producers report that the best way to manage the gates is to adjust gates on the first irrigation so that all the paddies flood up evenly. Only small adjustments should be needed during the rest of the growing season. Also, when flooding up fields, do not pump the level up to the levee gate; leave room for rainfall capture 1 to 3 inches ("freeboard").

Example:

105 GPM for a 7-acre paddy / 75 GPM per gate = 1.4 gates

Round up to 2 gates; punch 2 holes (2.5 in.); and install a blue gate in one to regulate flow.

The 9 to 10 mil tubing is recommended for multiple inlet irrigation, and the suggested sizes for different flow rates are as follows:

- 12 inch – less than 1,200 GPM;
- 15 inch – 1,200 to 2,200 GPM; and
- 18 inch – greater than 2,200 GPM.

When the slope is steep enough that the flow causes the water to surge in the tubing, the tubing should be choked at various locations down the slope to hold water up grade. This can be accomplished by several methods including choke ropes, clamps, half barrels, etc.

Management Key

A rule of thumb is that each 2.5 inch hole or blue gate provides a flow of 75 GPM.

The tubing is usually placed over the levees or along the side of the field on the permanent pad. In both cases, it is recommended that the tubing be placed in a shallow trench when it is installed to prevent the pipe from rolling and twisting. In some fields where an outside levee is pulled, it is possible to place the tubing in the borrow ditch on the inside of this levee. When crossing the levees, the tubing should go straight over without any angle in order to avoid twisting of the tubing. On firm levees, some of the levee top should be knocked off into the barrow ditch to provide a smooth ramp across the ditch so the tubing won't twist. The tops of fresh or sandy levees should not be knocked off. They will usually settle enough from the weight of the water and tubing, so some soil should be shoveled from the field into the barrow ditch. On sandier levees it may be necessary to put a plastic spill under the tubing at the levee crossing to better avoid levee washout.

If the tubing is laid further out in the field, a short pipe might need to be placed under the tubing at the low side of each levee pad, as a culvert, to ensure water can flow under the tubing. When placed out in the field, the tubing is more likely to float and move which can cause the tubing to twist at the levee. To help prevent unwanted movement, some type of stake can be placed on both sides of the tubing, or a piece of PVC pipe can be driven through the tubing. Once the rice increases in size, it will help keep the tubing from moving.

When the tubing is laid on the permanent pad, it is critical that it be placed on the flat area in a shallow ditch to avoid rolling or twisting. In this application, the water will tend to flow to the low end of the tubing. It may be necessary to make some humps under the tubing with mounded soil, pipe, buckets, barrels, etc., as it goes down the slope to help hold the water back to the high side of the field. This can also be accomplished by using some type of rope or strap around the tubing to squeeze or choke down on the tubing in order to restrict the water flow. It is also recommended that small holes be punched in the air pockets that form in the tubing once it is laid. These holes can be punched with pencil or ink pen points, wire flags, toothpicks, etc. The idea is to punch a small hole rather than cut the tubing, so caution has to be taken if a pocket knife is used.

Furrow-Irrigated Rice

Furrow-irrigated rice presents unique challenges to rice production but, in the right situations, can be done successfully. Furrow-irrigated rice (a.k.a. "row-rice") is most suitable on fields that are difficult to maintain a flood or severely sloping land that requires many levees. Often these severely sloping fields have levees so close that there is effectively very little paddy rice in the field. This system eliminates the need for levees, which reduces labor, facilitates easier harvest and may reduce wear-and-tear on harvesting equipment. Further, interest has increased on precision-graded land with an interest in minimizing equipment passes and overall management costs.

Photo 10-5. Furrow-irrigated rice field at grain fill with rice drilled at an angle across beds.

Cultivar Selection

In furrow-irrigated rice, blast disease is of serious concern. Therefore, it would be wise to select a cultivar that is less susceptible to blast. Choose a hybrid or select a less-susceptible variety that makes disease easier to manage with a fungicide. **Please note that in some situations, a disease such as blast may not be effectively managed with fungicides.**

Standard cultivar performance trials do not provide dependable predictions of performance for row rice production. Modern breeding programs focus on cultivars intended to perform optimally in flooded conditions – these cultivars may not necessarily perform similarly in the absence of a flood (see Table 11-1 for cultivar reactions to diseases).

The general expectation is that similar yields to conventional rice production can be achieved, but growers should be prepared for a 10 percent yield reduction in row rice production depending on field conditions and management capabilities. The goal of this system is to achieve increased profit margins by reducing input costs in other areas that offset the potential yield loss.

Seed Treatments

Insecticide and fungicide seed treatments should be used in upland rice. Rice water weevil is less of a concern than in flooded rice, but grape colaspis and billbug can be incredibly damaging in upland rice situations. A seed treatment containing a neonicotinoid insecticide, such as CruiserMaxx® Rice, NipsIt INSIDE® or NipsIt® Rice Suite, is recommended to protect against these pests in upland rice.

Drainage is improved with the use of furrows, but much of the field will have standing water after a rain or irrigation event. In conditions with a combination of standing water and cool temperatures, seedling diseases can negatively impact rice growth and lead to stand loss. Fungicide seed treatments provide short-term protection to combat and allow for plants to “outrun” seedling diseases.

Planting Furrow-Irrigated Rice

Furrow-irrigated rice should be planted at a higher density than would be recommended for the same variety in a flooded system. Add 10 percent to the seeding rate for furrow-irrigated rice. To plant furrow-irrigated rice, use a drill with spacing no greater than 7.5 inches.

Adjust the press wheels to provide adequate but not excessive down pressure for their locations relative to the furrow and the bed so that the drill “fits” the furrows and beds. That is, provide more down pressure for furrows and reduce it for beds. Oftentimes the planting depth will be deeper on the beds than the furrows, but as long as the rice is covered with soil, it should be acceptable. Avoid planting the beds too deep (greater than 1.5 inches).

Fertility Management

Nitrogen

Nitrogen efficiency in furrow-irrigated rice systems is still being evaluated. At this time, multiple options appear favorable depending on field conditions and management considerations (Table 10-10). Where possible, it is recommended that furrows be end blocked to keep tailwater on the field after an irrigation event. Collected tailwater does not have a detrimental effect as with other row crops, and the standing water can assist with management of the system. Water management will also affect nitrogen management.

In fields with shallow slopes, holding as much water in the field as possible will increase nitrogen efficiency. For these shallow sloped fields, apply the recommended

Table 10-10. Suggested nitrogen (N) management programs for furrow-irrigated rice.

Field Characteristic	Preflood† N (Prior to First Irrigation)	2nd Application	3rd Application	4th Application
Shallow Slope (0.1'/100') or less)	100% preflood N‡	100 lbs urea 14 days later (upper area of field only)		
Steep Slope (0.1'/100') or greater)	50% preflood N‡	50% preflood N‡ 10 days later	100 lbs urea 7-10 days later	
Spoon-Feed (all situations)	100 lbs urea	100 lbs urea 7 days later	100 lbs urea 7 days later	100 lbs urea 7 days later

† Preflood N timing refers to the typical 4-5 leaf rice growth stage at which the flood is normally established after nitrogen fertilizer application – this term is used for consistency across rice systems.
‡ Preflood N refers to optimum preflood N rate, NOT the rate applied prior to flood in a split application typically used for varieties in flooded rice production systems.

single preflood N rate as urea to the entire field. Approximately two weeks later, an additional 100 pounds of urea should be applied to the upper portion of the field that does not remain moist at all times – this may range from the upper 1/3 to upper 1/2 of the field.

In fields with steeper slopes that are able to hold very little water, the strategy necessarily changes, and "spoon-feeding" is preferred. In these situations, dividing the N fertilizer into smaller, more frequent applications is recommended. At the 5-leaf stage, apply 100 pounds of urea and irrigate the field. After this, make additional 100-pound urea applications weekly, for a total of four applications – it is preferred that each application go out immediately prior to an irrigation event.

Another alternative is to apply half of the single preflood N rate prior to the first irrigation, with the remainder applied 10 days later as plant N demand increases. Finally, apply an additional 100 pounds of urea near midseason and at least 7 to 10 days after the previous N application.

If there are doubts about the water and field management, then more frequent and smaller N applications should be used.

Management Key

Furrow-irrigated rice requires, at minimum, an additional 100 pounds of urea than flood irrigated rice to achieve maximum yield potential.

Phosphorus

Phosphorous availability to rice is significantly increased when a permanent, continuous flood is applied. Therefore, when using furrow or overhead irrigation methods, P deficiency might be more prevalent in areas with high pH (>7.0). Soils that have a combination of low soil test P and high pH should be monitored closely for P deficiency symptoms, especially following N applications when rice experiences periods of rapid growth.

Weed Management

The lack of a flood changes weed management for rice considerably. However, repetitive irrigation can increase herbicide activation, and ground-rig applications are possible. This may call for multiple residual herbicides to be applied slightly later in the growing season to compensate for the lack of weed suppression accomplished by the establishment of a permanent flood.

A good program for conventional rice in upland conditions may include Command applied at planting as a pre-emergence herbicide; followed by Propanil + Bolero® early post-emergence; followed by Ricestar® HT + Facet® or a similar program that provides residual grass control multiple times throughout the season. Permit® or Permit Plus® should be included as needed for nutsedge control. The reduced need for aquatic weed control in furrow-irrigated rice is often replaced by the need for multiple applications of grass and broadleaf herbicides. Care should be taken to follow labeled cut-off dates and timings for certain herbicides and pre-harvest intervals (see MP44, MP519 or product label).

For Clearfield® rice in furrow fields, Command followed by Clearpath®; followed by Newpath®; followed by Beyond® may be a sufficient program. Many producers find the length of residual offered by Newpath® in Clearfield® rice to be a good fit in furrow and overhead irrigated scenarios; however, care should be taken not to rely solely on the ALS chemistry to prevent resistance.

Note: Mentions of specific products do not constitute endorsements and are only provided as examples.

Disease Management

Aerobic conditions created by upland rice production are more favorable for development of rice blast disease. There is known risk to planting fields to cultivars rated very susceptible, susceptible or moderately susceptible for blast. The safest option is to select a highly resistant cultivar, as fungicides may not be able to control neck blast on furrow-irrigated rice under some conditions for susceptible cultivars.

All commonly grown varieties have some level of blast susceptibility and should be scouted regularly to manage for this disease – even more so than flooded fields. Upland rice fields can be more easily managed with resistant cultivars (i.e., hybrids). Do not forget, a new pathogen race may even attack resistant rice cultivars.

In an upland rice production system, you need to be prepared to treat with a fungicide unless resistant cultivars are used. In a blast season, upland rice should be managed very carefully because of its increased susceptibility to blast disease. Two well-timed fungicide applications should be made: the first as heads begin to emerge from the boot (boot split to 10 percent heading) and the second approximately 7 days later when ~70 percent of the head is out of the boot.

Sheath blight and other minor diseases are typically of little concern in upland rice. However, cultivars susceptible to kernel smut and false smut will still require preventative treatments, particularly if the season is cool and wet. Moreover, remember that these two diseases are aggravated with high nitrogen fertility and late planting, especially false smut.

See Table 11-2 for a list of disease ratings for selected cultivars. Extreme care should be taken if growing a cultivar susceptible (S) to blast. Cultivars rated as very susceptible (VS) should not be considered for production under upland conditions.

Management Key

If planting blast-susceptible cultivars in furrow-irrigated rice, multiple fungicide applications are needed for management of blast disease but still may not be sufficient in certain situations.

Insect Management

As mentioned earlier, the use of an insecticide seed treatment is strongly recommended in furrow rice. Grape colaspis can result in significant stand loss (and the larvae feed underground, so no foliar options are available). Insecticide seed treatments will protect plants from rootworm and wireworm infestations, which can be a problem in furrow rice. Also, billbugs tunnel into rice plants near the base and can result in blank heads – severe infestations have been observed causing 10 percent yield loss across the field.

Insecticide seed treatments should help reduce issues with this pest. Neonicotinoid seed treatments (CruiserMaxx Rice or NipsIt INSIDE) may be the best options for upland rice. Rice stink bug (RSB) management will remain similar to that for flooded rice with a threshold of 5 RSB per 10 sweeps the first 2 weeks of heading and 10 RSB per 10 sweeps the next 2 weeks.

Irrigation Management

Irrigation

Shallow beds should be used for furrow-irrigated rice. Beds should be just adequate to convey water down the furrows without breaking over. In clay soil types, the beds can be extremely shallow, because the preferential flow of water follows the cracking nature of the soil, which dominates the movement of water in a furrow-irrigated field. Thus, in a clay soil, the bed height is very forgiving. However, in silt loam soils, a bed that is too shallow will break over easily, creating water stress in unirrigated rows. If bed height is too aggressive, then the rice plants on the top of the bed will not receive adequate water if the soil seals and does not wick across the bed easily. This will limit nitrogen and water availability and also prevent herbicide activation, so bed height is critical to success in furrow irrigation.

Set implements as shallow as comfortable to ensure a successful furrow for the season. If rotating with soybeans, consider using the existing furrows or dressing them up. This will result in a firmer bed and more established furrow. Beds can be established in the fall if desired to allow for earlier planting and less spring field work. Do not double up planting on the ends near the poly pipe, and consider adjusting down pressure to help maintain furrow integrity.

Depending upon soil type and elevation change down the furrow, a wider bed may be preferable if water soaks across beds easily. Bed widths of 30 to 60 inches are acceptable; however, in silt loams that seal, it is suggested to use 30-inch beds to provide more soil area for irrigation water to contact. Bed height and width choice are driven by equipment availability, soil type and land slope. Use the combination that works best for the conditions. Larger beds on some soil types can have difficulty wicking moisture across the entire bed. In some situations with certain irrigation sources, water chloride content (salts) can evaporate from the top of the beds and cause injury to rice.

Next, fields should have adequate capacity with a reliable irrigation pumping plant to irrigate the field in 24 to 30 hours for a 2.5 to 3 acre-inches per acre set. Both gated pipe and lay-flat polypipe have been used successfully in furrow-irrigated rice. The irrigation pipeline and sets should be planned with computerized hold selection (CHS), such as Pipe Planner (www.pipeplanner.com) to ensure that water is uniformly applied across the crown of the field. Since furrow irrigation on rice is started much earlier in the season than other crops, it has been our experience that the irrigation water can erode the shallow beds much worse in rice. Lowering the max head pressure to a range of 1.5 to 2.0 feet while maintaining high distribution uniformity should help maintain furrows.

Additionally, it is suggested to use surge irrigation in furrow-irrigated rice, especially if soil sealing is experienced during the season in silt loams or in clays if set times are long or it is difficult to get the water to advance through the field. Surge irrigation improves the down-furrow uniformity, thus improving water delivery to the rice plants at the tail end of the field. If end blocking does not impound water over a significant part of the field, then surge irrigation should be used. For fields where end blocking results in a large area of impounded tailwater, a surge valve may provide less benefit. However, in either situation, a surge valve should help to keep the upper area of the field saturated longer as the irrigation water cycles from one side of the field to the other.

Manage irrigation so that only a small amount of tailwater is created, or if end blocked, terminate the advance before the water reaches the flooded rice so that the recession (remainder of the water) replenishes the flood of the end blocked furrows. Large volumes of tailwater leaving a furrow-irrigated rice field indicate a problem with water management or infiltration. Seek the corrective remedies mentioned above.

Initial research on furrow-irrigated rice has indicated that this method, when properly managed, can use 10 percent to 40 percent less water than conventional flood-irrigated rice. However, if soil sealing is excessive or sets are not managed, furrow-irrigated rice can quickly become excessively irrigated.

Water use for furrow-irrigated rice has the *potential* to be less than for flood-irrigated rice depending on rainfall, soil type and environmental conditions. It should be noted that in some studies comparing furrow and flood irrigation, it was difficult to achieve similar yields with furrow irrigation to those achieved with flood irrigation. However, variations in agronomic management of these fields may have played a greater role than simply irrigation management.

General recommendations for improving irrigation in furrow-irrigated rice include the use of end blocking the field. This can be done by blocking the drains and, in some cases, constructing a "tail levee" at the bottom of the field to back water in the field, resulting in the lower end of the field holding some level of flood throughout the season. Also, irrigation should occur more frequently in furrow rice.

Rice is different than other row crops because the rooting depth is very shallow, and thus there is much less soil water available to the plants than in other row crops. Application rates in furrow irrigation are typically between 2 to 3 acre-inches per acre, but in furrow-irrigated rice, the target application rate should be near 1.0-1.5 acre-inches per acre. Measure flow from wells or pumps to ensure adequate irrigation volumes are being applied. A surge valve can assist in getting the correct irrigation volume applied to a field or set.

Maintaining adequate soil moisture will require irrigating every 2 to 3 days, generally. Soil moisture sensors are a useful tool in furrow-irrigated rice. Watermark™ sensors or other soil moisture sensors can be used to track the soil water balance, monitor rice water demand and ensure irrigations are effective in furrow-irrigated rice.

Place sensors at shallow depths. For example, if using Watermark sensors, place shallow sensors at 4 inches or 6 inches and 8 inches. Place at least one sensor at 12 inches and/or 24 inches to monitor any subsoil moisture change. Generally, sensor readings for depths past 12 inches will not change during the season, so make decisions based on the shallow sensor readings. Sensors should be placed in the top center of the bed soon after rice emerges so sensor installation does not damage rice roots. Damaged plants may not represent the water use of undamaged plants in the field.

Irrigation in silt loams and clays should not exceed 40 cb. Zero cb is saturated, so keeping sensor reading in single digits is not recommended, but do not allow sensor readings to exceed 40 cb. A good result is keeping levels near field capacity (28 to 32 cb) or in a range of 20 to 30 cb for most soils. Experience with soil moisture monitoring has shown that even a 2- to 3-day schedule may not be adequate for periods of the season when rice plants are at peak transpiration.

Sensors are also helpful to decide if irrigation can be delayed if rain is expected in the near future. With all types of sensors, monitor the trend of the sensor readings; the upper sensors should respond to irrigation and plant water use. A good result is a repeatable pattern within a range of the sensors' readings that correlate to visual observations about crop condition.

Irrigation practices for furrow-irrigated rice will vary widely depending on soil type, field slope, irrigation capacity and the cultivar being grown. Use the tools mentioned and adapt the furrow irrigation system that is successful for the conditions.

Management Key

In furrow-irrigated rice, use shallow beds, computerized hole selection, irrigate every 2 to 3 days and monitor irrigation with soil moisture sensors. Figure out what works for your soil type.

Irrigation Termination

Little information is available for determining the timing of irrigation termination for furrow rice systems. Care should be taken not to terminate irrigation too early and risk drought-stressing plants as they fill remaining kernels. As a general rule, keep irrigating until the crop reaches maturity. Irrigation will be necessary longer in upland rice than in flooded rice – flooded fields have saturated soil that will take more time to dry out. If using sensors, stop when the plants stop using water and the trends flat-line.

Budgeting for Furrow Versus Flood Irrigation

Budgeted costs differ among rice production systems (conventional, Clearfield, hybrid and Clearfield hybrid) for flood and furrow irrigation. Expenses and revenue can vary greatly for individual fields and farming operations. Initial field setup and management are the driving factors, and the greatest differences can be seen between fields using the previous year's beds to eliminate tillage passes versus creating new beds specifically for furrow-irrigated rice.

Notable differences in costs associated with flood versus furrow irrigation are in regard to tillage and field passes, nitrogen fertilization, herbicide program, fungicide program and application costs. For certain inputs, higher costs are associated with furrow irrigation due to the inclusion of additional nitrogen to offset losses, additional herbicides to improve residual weed control, additional fungicide applications primarily for control of blast disease and additional application costs. These additional inputs may not always be needed but should be included in conservative budgets.

Sprinkler-Irrigated Rice

Sprinkler irrigation of rice is very limited in Arkansas. Although crop insurance coverage is now available to growers, an increase in interest and acreage of this production system has not been observed. Research and experience show that the best potential is either on clay or sandy loam soils that are relatively free of johnsongrass. Many silt loam soils tend to crust, which causes excessive runoff and inadequate infiltration in the soil, so deep tillage, soil amendments, manure application and sprinkler package changes may be necessary to improve infiltration. Center pivots need to be modified for use in rice, and the operation of the irrigation system and crop management are different than for other row crops. Center-pivot systems for rice should be able to provide a minimum of 7.5 GPA to grow rice and have a sprinkler package that is appropriate for rice. Most importantly, the tire package and/or traction system should be appropriate for the field conditions. Span lengths of 180 feet or less are recommended to minimize tower weights so the pivot system can traverse the wetter soil moisture conditions. In extreme cases, additional axles, track systems and boombacks are available options. Consult your pivot dealer to ensure the system will be adequate for rice production before committing to this production system.

Pivot operation is more frequent for rice than for other row crops during the vegetative stage, and be prepared to operate the pivot every day during panicle initiation and heading. A pivot that is not able to deliver adequate water either due to pump capacity, speed or breakdowns can lead to drought stress and can result in decreased yields.

Weed control is different in sprinkler-irrigated rice because the flood is not present to suppress weed pressures typically not experienced in flood-irrigated rice. The weed control program will be similar to a conventional flooded rice field, but there may be more frequent applications needed. There are fewer rescue options available, so be prompt with herbicide applications, apply when weeds are small and rotate herbicide chemistries. Pivot-irrigated rice fields should be scouted for blast and brown spot the same as in flooded fields and fungicides applied as needed. If disease pressure is expected, plant cultivars that are resistant to blast and other diseases. There is also a possibility that certain disease problems could be increased when the foliage is wetted at the frequency associated with sprinkler irrigation.

The following recommendations should be considered for sprinkler rice:

- For soils that tend to crust or seal, deep tillage, manure application, soil amendments and sprinkler package and irrigation management changes should be considered.
- Use a residual herbicide program.
- Be certain sufficient water is available during reproductive growth (after joint movement).
- Be prepared to use multiple broadleaf herbicides at midseason.
- Plant rice cultivars with blast resistance.

Additional information on pivot rice can be found at Circles for Rice, an industry supported program and web site on pivot rice by Valmont. There is a Center Pivot and Linear System Rice Production Guide that provides additional information about the mechanics of growing pivot rice that can be obtained through Valmont dealerships (www.circlesforrice.com). References to specific companies do not imply endorsement by the University of Arkansas or imply approval or the exclusion of other products or companies that provide information, equipment or services for sprinkler rice. Additionally, many of the recommendations for furrow-irrigated rice discussed above may be appropriate for sprinker-irrigated rice.

Intermittent Flood or Alternate Wetting and Drying (AWD)

What Is Alternate Wetting and Drying?

Alternate wetting and drying (AWD) is also known as intermittent flooding. AWD is the practice of flood initiation and recession. It was first developed at the International Rice Research Institute (IRRI). As a rice flood management practice, AWD is used to maximize rainfall capture and reduce irrigation pumping while maintaining grain quality and yield.

AWD consists of flooding a field to a reasonable depth and allowing the flood to naturally subside to the soil surface via infiltration and evapotranspiration. This subsidence can be a mud (or drier) consistency at the soil surface before reflooding, depending on field specifics including soil texture and irrigation capacity.

The timing, frequency and extent of the wetting and drying cycles depend on rice growth stage, prevailing weather and field conditions and grower comfort level with the practice. After holding the initial flood for 3 weeks, it is common to refrain from applying a flood for five or more days between wet-dry cycles when using AWD. A full flood is maintained at panicle initiation (green ring) and at flowering, when rice is most sensitive to water stress.

Potential Benefits

Mid-South producers have shown that when properly managed, AWD can reduce irrigation use while having no negative impact on grain yield (Massey et al. 2014). Up to 1 gallon of diesel fuel may be saved for every acre-inch of groundwater that is not pumped or is offset by the capture of rainfall (Hogan et al. 2007). Edge-of-field runoff is also reduced (Martini et al. 2013). Lastly, both methane gas emissions and arsenic levels in grain are reduced when AWD flooding is practiced where the soil becomes aerobic for a short period of time (Linquist et al. 2014).

Potential Risks

Reduced grain yield and/or quality may result from water stress and/or reduced control of pests, particularly grasses and diseases. Water stress will occur if the field is allowed to dry too much and/or if the flood is not re-established in a timely manner, as can occur with undersized wells, irrigation system failure and/or human error. Late-planted rice (late May and June) is susceptible to disease and should not be managed using AWD flooding.

Getting Started

First, determine if AWD flood management works with your conditions and management style. Determine this on a small field, using a single dry-down period similar to that used for straighthead control.

Only use AWD on fields that meet the following criteria:

1. Weed, disease and/or insect issues should be well known and low risk for AWD candidate fields. Selected fields should be low risk for difficult to control weed pressures.
2. Fields should not have a history of blast incidence.
3. AWD should not be attempted on lighter textured soils – only on silt loam and clay-textured soils.
4. AWD fields must use Multiple Inlet Rice Irrigation (MIRI) or zero-grade rice irrigation systems. A field irrigated using only levee-gate (cascade) flood distribution is not suitable for AWD. Use of MIRI ensures that flooding can be done in the least amount of time. MIRI plans can be developed by the University of Arkansas "Rice Irrigation" mobile app or the web-program "Pipe Planner™" offered by Delta Plastic.
5. The field should have the irrigation capacity to establish an initial flood in a short period of time (~3 days) using MIRI. The irrigation source should meet recommended capacity of 15 to 20 gallons per minute per acre for silt loam and clay soils. A reliable irrigation source is critical so that reflooding can be accomplished within 24 hours. Additionally, fields that can be serviced by more than one pumping plant provide assurance of this capacity. Divide fields into smaller sets to meet flood time criteria.
6. Hybrid rice offers additional protection against disease, particularly blast, and should be considered when evaluating and learning AWD until one is comfortable with the practice before attempting it with cultivars more susceptible to disease (Hardke et al. 2016).
7. Levee gates should be raised 1 to 2 inches to create freeboard between the full flood level and top of the gate; this greatly improves capacity to capture rain and reduce pumping.
8. Flood depth gauges aid in AWD flood management and are highly recommended (Massey 2012).
9. Thorough training and oversight of field personnel new to AWD flood management is highly recommended.

Pest Control in AWD

While more AWD-specific research is needed, experience suggests that pest control programs that are effective under a continuous flood also work under AWD. Follow university recommendations.

Weeds: With the effective herbicide programs now available, continuous flooding for weed suppression is not necessary in most cases (Norsworthy et al. 2008, 2011). For example, barnyardgrass control remains as effective using AWD as with continuous flooding (Scherder et al. 2002).

Insects: Follow university recommendations.

Diseases: Use of crop rotation, disease-resistant rice hybrids and varieties and preventative fungicide applications when needed are recommended.

Table 10-11. Alternate wetting and drying (AWD) rice flood management practices for delayed flood, drill-seeded rice production in the Mid-South.

Rice Growth Stage	Flood Status	Agronomic Activity	Comments
Planting to four-leaf	None.	Weed control: Pre-emergence plus early post-emergence herbicide program featuring residual herbicides. Disease: Seed treatment using broad-spectrum fungicide(s). Insects: Insecticide seed treatment for rice water weevil and grape colaspis control.	Follow standard university cooperative extension pest control recommendations.
First tiller (4-5 leaf rice)	Initiate and maintain flood as normal.	Apply herbicide(s) and fertilizer as normal prior to initial flood.	Hold flood for 3 weeks to stabilize nitrogen and to allow canopy closure to aid in weed suppression.
Three weeks after initial flood	AWD flood.	Begin AWD flood by halting irrigation and allow flood to subside naturally. Re-establish flood when mud appears in top third of paddy, do not allow soil to form cracks. Repeat cycle. Apply post-emergence weed control as needed, per university recommendations.	If new to AWD, begin with single dry down as recommended for straighthead control. The ultimate number of wet-dry cycles is a function of weather, field, soil conditions and producer comfort with AWD.
Panicle initiation (Green ring)	Full flood.	Establish and maintain flood 5 days before and 7 days after panicle initiation (green ring).	Rice is sensitive to water stress during this growth stage. Do not allow flood to dry.
Optional: Midseason N application	Shallow flood.	Apply mid-season N fertilizer to a shallow flood, if needed after panicle initiation AND 3 weeks after preflood N incorporation. Maintain stable flood condition for 5 days.	Resume AWD flood management after nitrogen applied.
Early to late boot	AWD flood.	Apply broad-spectrum fungicides for disease prevention, per university recommendations.	Reflood whenever mud appears in top third of paddy; do not allow soil to form cracks.
Heading and Grain Fill	Full flood.		Establish and maintain a full and permanent flood from 3 days prior to 50% heading until 25 days after 50% heading for long-grain cultivars (35 days for medium-grain cultivars).

Fertility Management

Properly managed AWD should not influence nutrient management in regard to rates and timings of fertilizer application. By following the above university guidelines for AWD, no changes are needed to nitrogen (N) fertility management. A single preflood N fertilizer application simplifies water management through the season. A continuous flood should maintain well saturated soils for a full 3 weeks following preflood N application to ensure efficient N uptake by rice plants. If a two-way split N management plan is used for conventional cultivars, the midseason N application should be applied into the floodwater, which is maintained for at least 5 days following application.

Resources

Multiple-Inlet Irrigation for Rice, 2004.
Available at http://msucares.com/pubs/publications/p2338.pdf

Multiple Inlet Approach to Reduce Water Requirements for Rice Production, 2007.
Available at http://www.ars.usda.gov/sp2UserFiles/Place/50701000/cswq-0215-174368.pdf

Video on Side Inlet Rice Irrigation, 2012.
Available at https://www.youtube.com/watch?v=XR2JNspMXkk

References

Massey et al. 2014. Farmer adaptation of intermittent flooding using multiple-inlet rice irrigation in MS. *Ag. Water Mngt*. 146: 297-304.

Hogan et al. 2007. *Estimating Irrigation Costs*. University of Arkansas Coop Ext. Ser. pub no. FSA28. Available at http://www.uaex.edu

Martini, et al. 2013. Imazethapyr and imazapic runoff under continuous and intermittent irrigation of paddy rice. *Ag. Water Mngt.* 125:26– 34.

Linquist et al. 2014. Reducing greenhouse gas emissions, water use and grain arsenic levels in rice systems. *Glob Chang Biol.* 21(1):407-17.

Hardke et al. 2016. *Arkansas Rice Cultivar Testing*, 2014-2016. University of Arkansas Div. of Agriculture, Available at http://uaex.edu/farm-ranch/crops-commercial-horticulture/rice/RIS%20176%20AR%20Rice%20Cultivar%20Testing%202016.pdf

Massey. 2012. *Installation and Construction of Rice Flood Depth Gauges*, Available at http://msucares.com/pubs/infosheets research/i1358.pdf

Norsworthy et al. 2008. Imazethapyr use with and without clomazone for weed control in furrow-irrigated, imidazolinone-tolerant rice. *Weed Tech.* 22:217–221.

Norsworthy et al. 2011. Weed management in a furrow-irrigated imidazolinone-resistant hybrid rice production system. *Weed Tech.* 25:25–29.

Scherder et al. 2002. B.R. Wells Rice Research Studies 2002. AAES Res. Series. 504. Pp. 156-164.

Irrigation Termination

Current recommendations for draining the flood from the rice fields as predicted by the Rice DD50 program is 25 days after 50 percent heading for long-grain cultivars, 30 days for medium-grain cultivars and 35 days for short-grain cultivars. While there are situations that may not require the 25-day duration, earlier draining can negatively impact rice grain yields on some fields (Table 10-12). Grain yields were substantially lower when drained 14 days after heading than when drained 28 days after heading at Stuttgart and Pine Tree. When averaged across three years and four locations, the response was consistent for all four varieties evaluated (Figure 10-5). Little rainfall and rapid soil drying conditions allowed the early drain treatments to dry below permanent wilting point (15 percent volumetric moisture content) during the time before the recommended drain time (Figures 10-6 and 10-7).

This indicates that the soil moisture became limiting during the latter part of grain filling and influenced yield. Thus, it is important to ensure adequate moisture for the rice plant throughout the grain-filling process. Some clay soils that are poorly drained may benefit from early draining. A general rule is that if fields

Table 10-12. Influence of drain timing on rice grain yields on two silt loam soils.

Drain Timing	Grain Yield			
	RREC†		PTBS†	
	2004	2005	2004	2006
dah‡	bu/A			
14	189	176	209	146
21	195	188	213	--
28	212	195	218	239
35	198	198	226	202
LSD	11	15	10	14

† RREC = Rice Research and Extension Center; PTBS = Pine Tree Branch Experiment Station
‡ dah = days after 50% heading
Source: Richards et al., 2006. p. 298-303. B.R. *Wells Rice Research Studies 2005*. Ark. Agr. Exp. Sta. Res. Ser. 540.

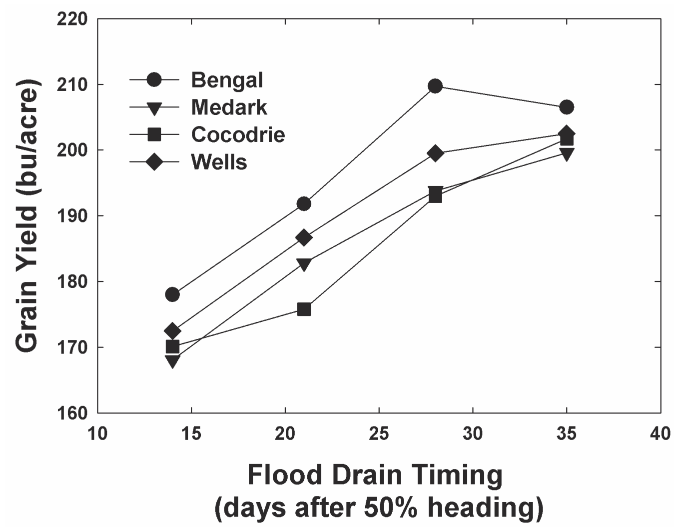


Figure 10-5. Influence of drain timing on grain yields of four rice cultivars, 2004-2006.

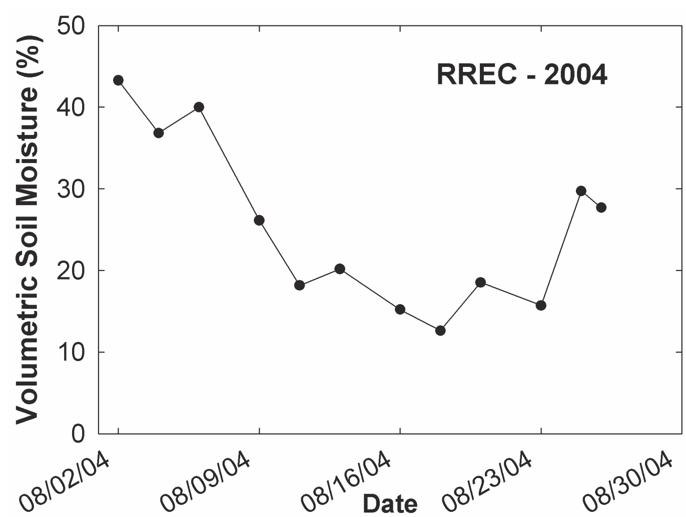


Figure 10-6. Soil moisture content following draining 14 days after heading at the Rice Research and Extension Center during 2004.

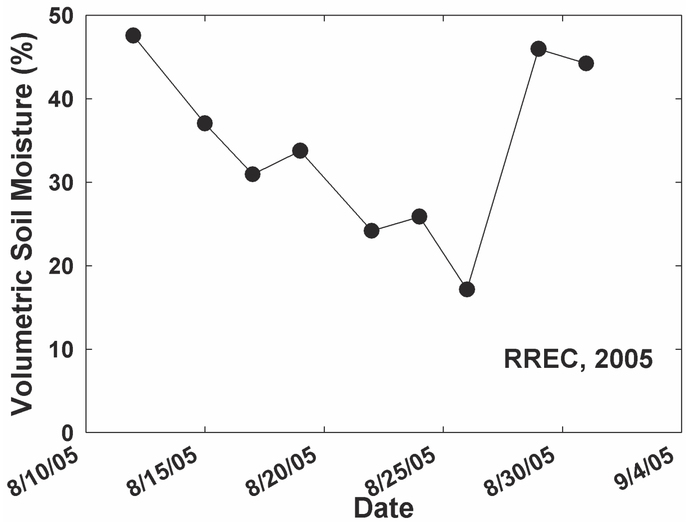


Figure 10-7. Soil moisture content following draining 14 days after heading at the Rice Research and Extension Center during 2005.

are never dry at harvest, even when little or no rainfall occurs, these fields are candidates for earlier draining. There is certainly some economic benefit to prevent rutting during harvest whenever possible. However, weather patterns are difficult to predict and caution should be used when draining early. Reduced yields resulting from early draining on clay soils has been observed when little or no rainfall occurs after draining.

Research indicates that it may be possible to stop pumping as early as 14 days after heading if the field will retain a flood for 7 to 10 days after pumping is ceased. If the weather forecast at 10 to 14 days after heading predicts temperatures above 95°F and no rain, then the flood should be maintained. There are some physical considerations for this practice. When fields are allowed to dry rather than utilizing a draining event, levees often dry to the point of reducing the efficiency of levee gate removal. Some soils become "hard" enough that removing the gates becomes more laborious than what is desired. Therefore, many producers prefer to hold the water until the time to drain.

Management Key

Drain as early as feasible to reduce pumping costs but maintain adequate soil moisture throughout the grain-filling stage.

Utilizing Surface Water for Irrigation in Critical Groundwater Areas

Critical Groundwater Designations

Several areas in rice-producing regions of Arkansas have been declared "Critical Groundwater Areas" (Figure 10-7) by the Arkansas Natural Resources Commission (ANRC) under the authority of the Arkansas Groundwater Protection and Management Act (https://www.anrc.arkansas.gov/divisions/water-resources-management/groundwater-protection-and-management-program/). A critical groundwater area may be declared by ANRC for unconfined aquifers, such as the alluvial aquifer that underlies much of Eastern Arkansas, when the water table exhibits an average decline of one foot or more annually for a minimum of five years and/or water levels have been reduced such that 50 percent or less of the formation is saturated.

While the Arkansas Groundwater Protection and Management Act allows for regulation, the ANRC has chosen to address critical groundwater areas with education and voluntary efforts such as state income tax credits and USDA financial incentive programs, such as EQIP, which are administered by the federal agency, the Natural Resource Conservation Agency (NRCS). Once an area is designated, producers who convert from ground to surface water use within the area can receive tax credits amounting to 50 percent of project costs through the Water Resource Conservation and Development Incentives Act. Landowners converting to surface water use outside critical areas are limited to a 10 percent credit.

State Income Tax Credits for Groundwater Water Conservation in Critical Areas

Under the authority of ANRC Title 14, state income tax credits (https://static.ark.org/eeuploads/anrc/title 14.pdf) are available for the following practices in critical groundwater decline areas: 1) water impoundment (reservoir) construction that creates water storage of 20 acre-feet or more with a tax credit not to exceed the lesser of 50 percent of the project cost incurred or $90,000, 2) substitution of surface water for groundwater as an irrigation source with a tax credit not to exceed the lesser of 50 percent of the

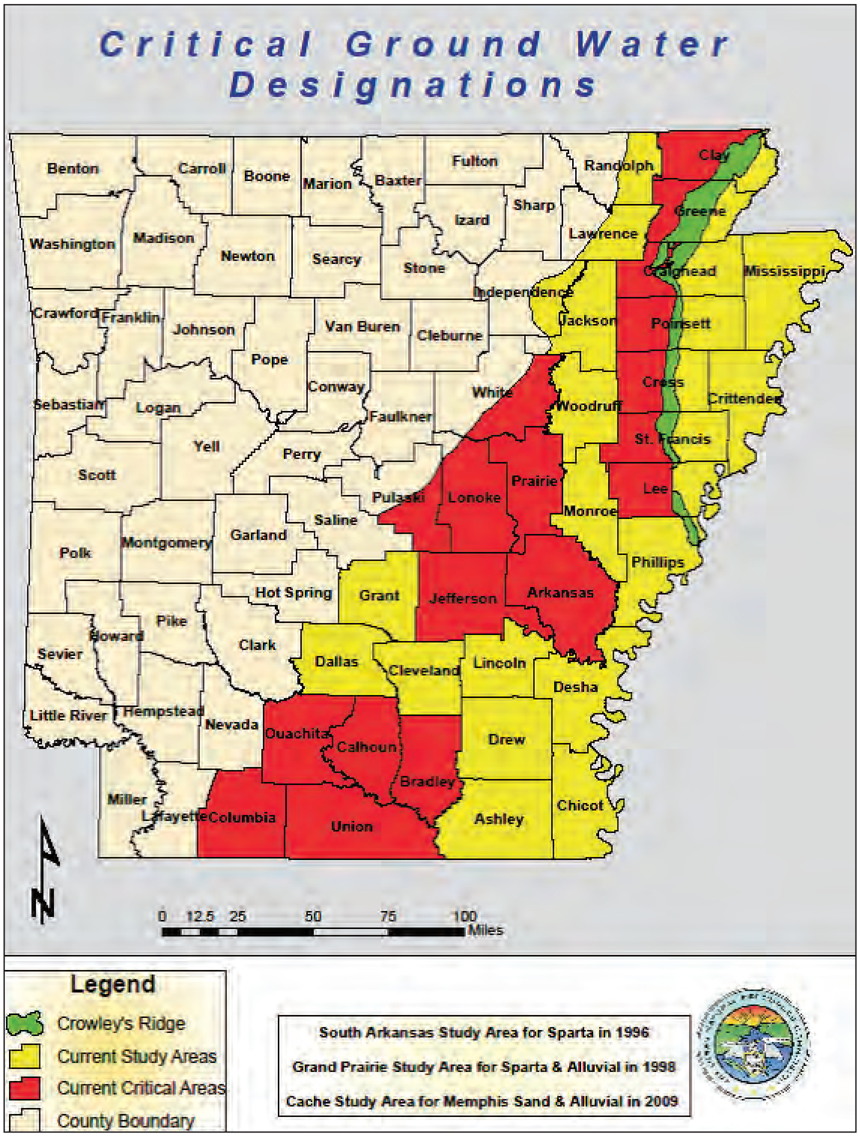


Figure 10-7. A map depicting Critical Groundwater Areas in Arkansas. Courtesy of Arkansas Natural Resources Commission.

project cost incurred or $27,000, 3) Precision Land Leveling with a tax credit not to exceed the lesser of 50 percent of the project cost incurred or $27,000, and 4) water metering.

It should be noted that the maximum tax credit for a single year is $9,000 but that credits can be spread over a maximum of nine consecutive years. Also, applications must be approved before any installation activities occur, with the exception of metering, or eligibility is forfeited. Additionally, a taxpayer qualifying for the tax credits provided under this program is entitled to a deduction in an amount equal to the project cost less the total amount of credits to which the taxpayer is entitled. For eligibility requirements, forms and more details, contact ANRC at http://www.anrc.arkansas.gov/ or (501) 682-1611.

Federal Soil and Water Conservation Financial Incentive Programs

Several water conservation practices are available for rice growers through USDA and the Natural Resources Conservation Service under the Conservation Title of the farm bill. One such program is the Environmental Quality Incentives Program or EQIP. One of the nine primary issues being addressed through EQIP is water quantity and irrigation in critical groundwater areas.

To apply for EQIP, the application must include an Irrigation Water Management Plan. Signup for these programs is continuous and involves an application process with applications being selected through an annual ranking system. For more information about these programs, contact your local USDA Service Center or visit http://www.nrcs.usda.gov/wps/portal/nrcs/site/ar/home/.

Surface Water Storage and Water Reuse

A surface collection and irrigation storage system is a planned, systematic irrigation system that allows for the collection, storage, control, movement and reuse of runoff water from previous irrigation or storm water runoff events. The NRCS offers financial assistance through their programs to design and install systems.

The ability to capture, store and reuse irrigation water on farm offers many advantages including:

- Greater control and flexibility of water supply for irrigation.
- Reduced groundwater dependence and energy costs from pumping.
- Reduced off-farm impacts on water quality by capturing sediment and nutrient losses in runoff.

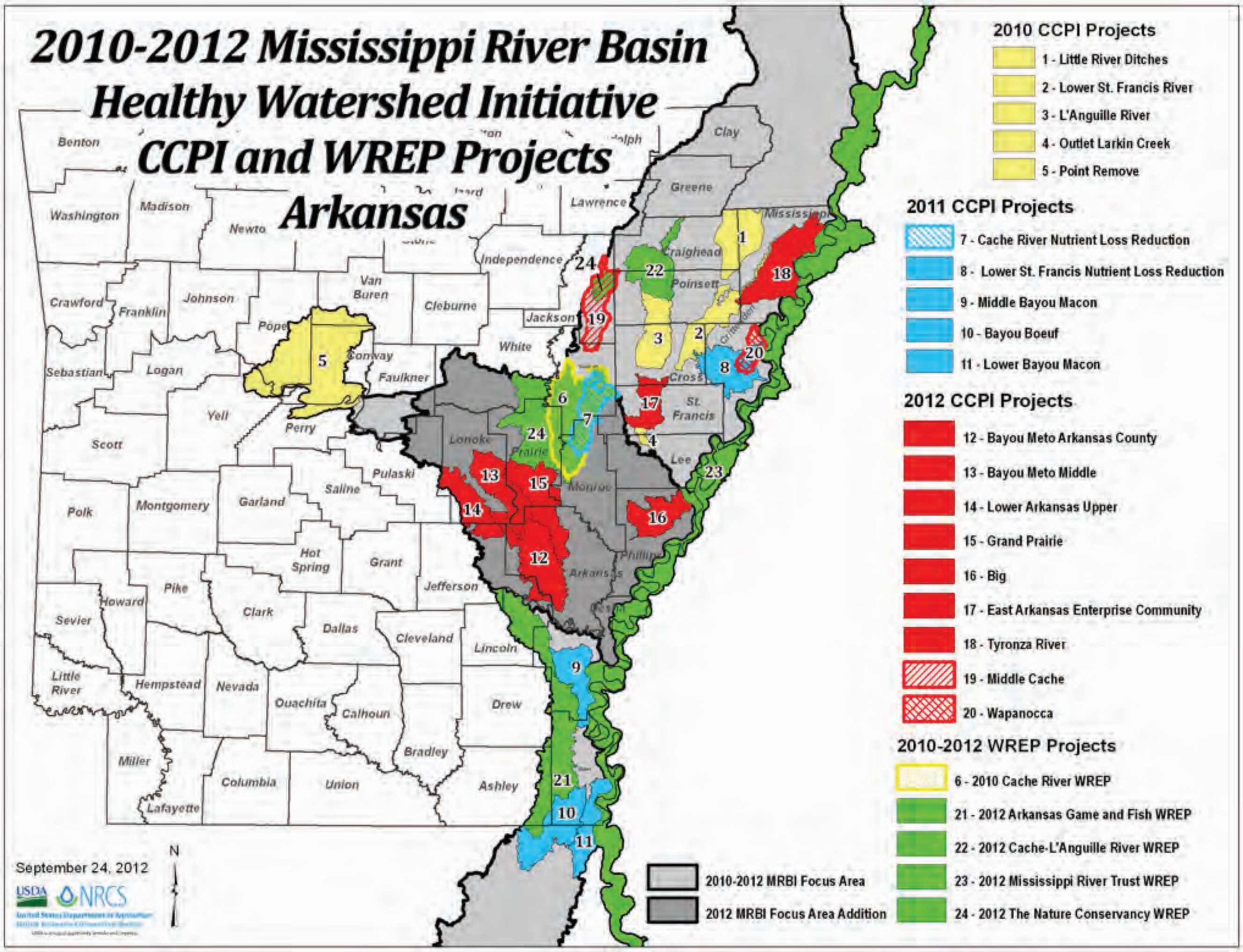


Figure 10-8. **Location of Mississippi Healthy River Basin Initiative (MRBI) project areas in Arkansas. Courtesy of NRCS.**

The main disadvantages of developing on-farm collection and surface storage are the large capital investment required for construction and taking land out of production. However, the tax credit and financial incentive programs described above can help defer costs.

While the surface water collection and storage systems may have a unique design for each different farm, they may have some common elements including an irrigation reservoir, tailwater recovery ditches, conveyance ditches or underground pipeline, pumping stations and irrigation risers. For example, a surface collection and storage system designed and cost-shared by NRCS would include several individual conservation practices linked together as a package:

- A drainage or tailwater recovery ditch at the bottom of a field (Photo 10-6),
- Surface drainage piping, main and laterals,

Photo 10-6. **A typical tailwater recovery ditch.**

- Conveyance ditches from recovery pit to storage reservoir,
- Storage reservoir (Photo 10-7),
- Pumping plants,
- Irrigation pipeline.

Photo 10-7. An on-farm irrigation reservoir constructed with financial assistance through the EQIP program. Courtesy of NRCS.

These components may include but are not limited to ditches, culverts, pipelines, water control and/or grade stabilization structures, or other erosion control measures, as needed. The NRCS offers technical assistance in the design of surface water collection storage systems, and their financial assistance programs allow for the cost-share of all these components.

Irrigation water stored in on-farm reservoirs has four main sources including:

- Precipitation harvesting
- Water reuse from tailwater recovery ditches that capture runoff from irrigation and precipitation
- Relift from streams, bayous and rivers for riparian right owners
- Purchase of irrigation water from irrigation districts

Keys to Water Management Success

- Keep acreage within the limits of pumping capacity.
- Select fields that hold water adequately.
- Establish a smooth field surface that provides a good seedbed, drainage and water control.
- Contact your county Extension office for water quality testing if there is no recent history.
- Use multiple inlet irrigation on fields to improve water management and adjust levee gates to hold rainwater and act as overflow when levees are full.
- Be certain of accurate levee survey, proper levee construction and correct gate installation.
- Survey levees on 0.2-foot intervals when possible.
- Establish a levee base as early as possible (before seeding) on clay soils.
- Where choices exist, attempt to seed longer-season cultivars on fields with good water-holding capacity.
- Service and check out the pumping plant before the pumping season to prevent costly pumping delays and in-season repairs.
- Carefully analyze differences in energy costs. Select and use another energy source where economically justified. Use a meter in conjunction with electric and fuel bills to determine the cost of water for each pump. Use this information to service pumps or make changes to pumping plants.
- Choose the electric rate structure best suited for specific pumping situations. Cost savings are available for irrigation systems that can withstand peak load shutdowns (two to five hours per day).
- Work with equipment dealers on proper pump bowl selection, motor matching and operation of pumping plants. Improper pump selection and power unit selection can increase pump costs by two to three times. New pump installations should be within 80 percent of the Nebraska Pump Standards.
- Consider use of timers or pump control technology to manage irrigation pumps. Pump monitors are available to control pumps and document pump performance.
- Use a flow meter to measure water use. Using more than 19 inches on zero-grade fields and 32 inches on contour and straight levees may indicate a problem.
- Replace ditch and canal water delivery systems with pipe or tubing when possible.
- Flush if necessary for stand establishment or weed control.
- Maintain a shallow flood of 2 to 4 inches from beginning tillering until two weeks prior to harvest. For cultivars susceptible to rice blast disease, flood to a depth of 4 to 6 inches after midseason. Consider ceasing pumping on the field in preparation for harvest 14 days after heading if there is an adequate flood on the field to prevent drought stress during grain fill.
- Drain or allow to dry down if necessary for straighthead, scum or possible rice water weevil control.
- Aim to operate irrigation system so that no water leaves the field during pumping events and small rain events.
- Consider the use or conversion to surface water for irrigation. A decrease in pumping cost may be realized.

Critical Water Management Situations

Situation	Rice Stage	Recommended Practice or Precautions
After dry-seeding, no moisture for germination.	Rice not germinated.	Flush as quickly as possible, being sure surface water does not stand for more than 2 days. Use multiple water inlets if possible to reduce flush time.
Soil surface is crusted.	Rice germinated but not emerged.	Flush to soften crust before rice emerges or lose their penetrating power.
Residual herbicides have been applied, soil surface has become dry, weeds are germinating.	Rice has germinated and may be emerged.	Flush to activate herbicides.
Barnyardgrass has become drought stressed and is less than 4-leaf.	Rice may or may not be emerged.	Flush and apply herbicide before grass gets too large.
Barnyardgrass has become drought stressed and is less than 4-leaf.	Rice may or may not be emerged.	Flush and apply herbicide before grass gets too large.
Barnyardgrass has become too large, drought stressed or was not controlled.	Rice is 6" to 8" tall.	Flood, treat with Clincher, Ricestar or Regiment and maintain flood.
Seedling rice has tipburn and dying before flooding (salinity injury).	Rice has emerged but may be less than 8" tall.	Dilute the salts by flushing and don't let soil surface dry.
Rice has turned chlorotic within 2 to 4 days after flooding (high pH, Zn deficiency).	Rice is 6" to 10" tall.	Drain immediately, apply zinc and, after recovery, add N; reflood to shallow depth.
History of straighthead.	Rice is about 2 to 3 weeks prior to internode movement. (Consider DD50 drying time frame.)	Drain before DD50 first drying date to allow the soil to dry thoroughly until rice plants are drought stressed; then reflood, preferably before ½-inch internode elongation.
Not enough water; severe drought stress.	Rice can be in various stages.	Flush over quickly, then close gates and raise flood to desired depth as water becomes available.
Nitrogen applied on dry soil.	Rice is 3 weeks old.	Flood as soon as possible but within 7 days to place N below soil surface.
Nitrogen applied into flood.	Rice is at internode elongation.	Prefer flood to be low with little water movement. Delay pumping for 24 hours after N application.
Sprangletop or large barnyardgrass.	Rice is tillering to internode elongation (IE) stage.	Apply Clincher into floodwater. Flood must be maintained for suppression.
Drought, pumping flow rate is low.	Rice near heading.	Use multiple inlets; clean out algae in flow pattern to ensure sufficient water as heads emerge.
Preparation for harvest	Rice is about 10 to 14 days after heading; heads beginning to drop and some heads beginning to ripen.	Consider ceasing pumping on field in preparation for harvest 10 to 14 days after heading if there is an adequate flood on the field that would prevent drought stress during grain fill. However, if temperatures are exceedingly hot, then continue pumping 5 to 7 days.

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