Best Management Practices For Irrigation Management

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Principal author: Reagan M. Waskom
Extension Water Quality Specialist
Colorado State University Cooperative Extension

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R.L. Croissant, Professor of Agronomy
J.J. Mortvedt, Extension Agronomist
G.A. Peterson, Professor of Agronomy
L.R. Walker, Extension Agricultural Engineer
D.G. Westfall, Professor of Agronomy

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Best Management Practices for Irrigation Practices

Colorado's 2.5 million acres of irrigated crop production are extremely important to the state's economy. However, poorly managed irrigation may cause environmental problems by transporting pesticides, nutrients, and sediments to water supplies. Concern about irrigation water is nothing new in Colorado, where irrigation uses about 80% of the 1.8 trillion gallons of water diverted annually in the state. Previously, these concerns centered only on water quantity; now, water quality is an important consideration in managing irrigation. To reduce nonpoint source pollution caused by leaching and runoff, irrigation systems should be managed so that the timing and amount of applied water match crop water uptake as closely as possible.

Best Management Practices (BMPs) for the use of irrigation water can help increase efficiency and uniformity and reduce contamination of water resources. Because each farm is unique, producers must evaluate their systems to determine which BMPs are suitable for their operations. Irrigation management BMPs include irrigation scheduling, equipment modification, land leveling, tailwater recovery, proper tillage and residue management, and chemigation safety (Figure 1).

The BMP Approach

Rather than legislate overly restrictive measures on farmers and related industries, the Colorado Legislature passed the Agricultural Chemicals and Groundwater Protection Act (SB 90-126) to promote the voluntary adoption of Best Management Practices. The act calls for education and training of all producers and agricultural chemical applicators in the proper use of pesticides and fertilizers. Voluntary adoption of BMPs by agricultural chemical users will help prevent contamination of water resources, improve public perception of the industry, and perhaps reduce the need for further regulation and mandatory controls.

BMPs are recommended methods, structures, or practices designed to prevent or reduce water pollution. Implicit within the BMPs concept is a voluntary, site-specific approach to water quality problems. This approach does not require replacements of major components of an irrigation system. Instead, it is suggested that equipment to manage the timing and amount of water applied be acquired as needed, and that the appropriate precautions be implemented during chemigation.

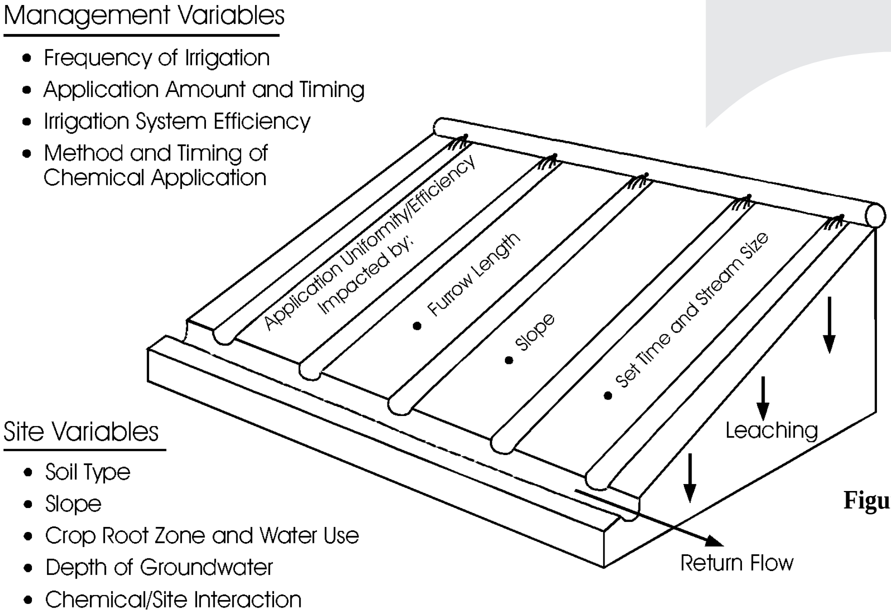

Figure 1. Management and site variables influencing pollutant losses from irrigated fields.

Source: US EPA, 1992.

Irrigation Scheduling

Proper irrigation scheduling, based on timely measurements or estimations of soil moisture content and crop water needs, is one of the most important BMPs for irrigation management. A number of devices, techniques, and computer aides are available to assist producers in determining when water is needed and how much is required (Table 1).

Irrigation scheduling uses a selected water management strategy to prevent the over-application of water while maximizing net return. In a sense, all irrigations are scheduled, whether by sophisticated computer controlled systems, ditch water availability, or just the irrigator's hunch as to when water is needed. Experienced producers know how long it takes them to get water across their fields and are proficient in avoiding crop stress during years of average rainfall. The difficulty lies in applying only enough water to fill the effective root zone without unnecessary deep percolation or runoff. Proper accounting for crop water use provides producers with the knowledge of how much water should be applied at any one irrigation event.

Table 1. Irrigation scheduling methods and tools

Method	Tools or parameters used	Advantages/disadvantages
Soil moisture monitoring (Indicates when and how much to irrigate)		
Hand feel and appearance	Hand probe	Variable accuracy, requires experience
Soil moisture tension	Tensiometers	Good accuracy, easy to read but narrow range
Electrical resistance tester	Gypsum block	Works over large range, limited accuracy
Indirect moisture content	Neutron probe/TDR	Expensive, many regulations
Gravimetric analysis	Oven and scale	Labor intensive
Crop canopy index (Indicates when to irrigate but not how much to apply)		
Visual appearance	Field observation	Variable accuracy
Water stress index	Infrared thermometer	Expensive
Water budget approach (No field work required, but needs periodic calibration since only estimates water use)		
Checkbook method	Computer/calculator	Indicates when and how much water to apply
Reference ET	Weather station data	Requires appropriate crop coefficient
Atmometer	Weather station data	Requires appropriate crop coefficient

Effective scheduling requires knowledge of:

- soil water-holding capacity
- current available soil moisture content
- crop water use or evapotranspiration (ET)
- crop sensitivity to moisture stress at current growth stage
- irrigation and effective rainfall received
- availability of water supply
- length of time it takes to irrigate a particular field.

The decision to irrigate should be based upon an estimate of crop and soil water status, coupled with some indicator of economic return. Proper scheduling may allow producers to reduce the traditional number of irrigations, thereby conserving water, labor, and plant nutrients. In some cases, the final irrigation of the season can be avoided through proper scheduling. This is especially advantageous from a water quality standpoint, because it is desirable to go into the off-season with a depleted soil profile. This leaves space for storage of precipitation in the crop root zone without unnecessary leaching or runoff.

Scheduling irrigation applications is often accomplished by using root zone water balance approaches. These methods use a “checkbook” or budgeting approach to account for all inputs and withdrawals of water from the soil. A simple mathematical expression can be written to illustrate this concept:

$$I + P = ET + D_r + R_o + (\theta_E - \theta_B)$$

where

I = irrigation water applied
P = precipitation
ET = evapotranspiration (soil evaporation + plant use)
D_r = drainage or percolation of water below the root zone
R_o = runoff
θ_E = the water content expressed as a depth of water at the end of a time interval
θ_B = the soil water content (depth) at the beginning of the time interval.

The beginning soil water content (θ_B) is generally estimated as field capacity if the root zone was fully wetted previously. Drainage (D_r) is estimated as the excess water applied above the field capacity depth. Precipitation is easily measured. The main unknown in the balance is ET. This information is generally available for crops in a specific area through local water districts, the Soil Conservation Service, or Cooperative Extension offices.

Producers should choose the scheduling method which best suits their needs and management capabilities. Regardless of the method used, some on-site calibration is required. Many producers find that irrigation services offered by crop consultants are the most cost-effective method of scheduling and managing their water.

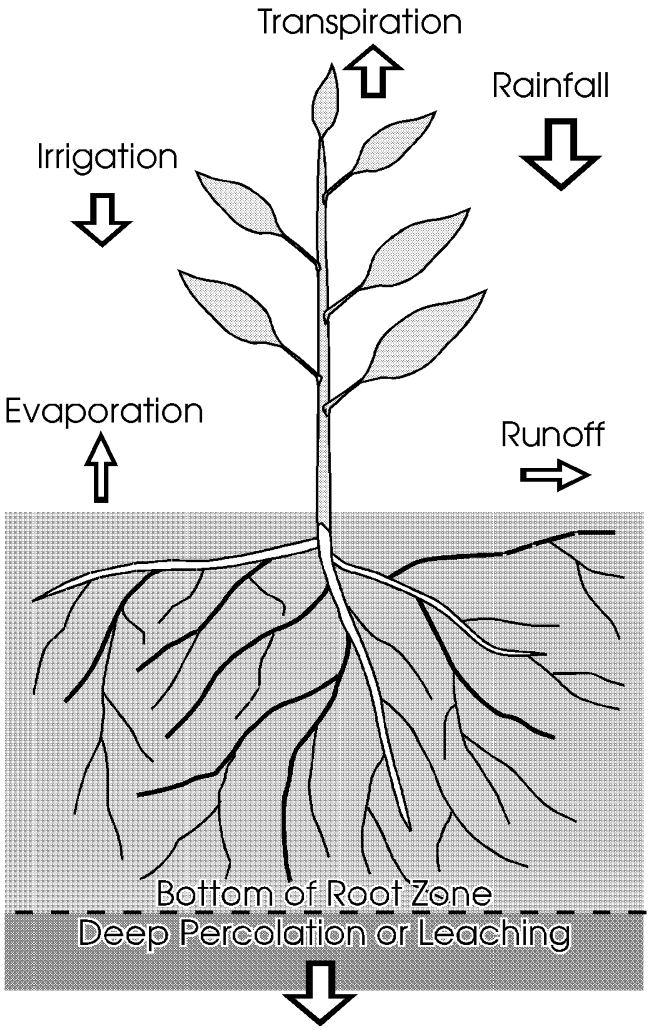

Figure 2. Source and fate of water in the crop system.

Soil and Crop Properties

Soil characteristics which affect irrigation management include the water intake rate, available water holding capacity, and soil erosivity. Soil texture, organic matter content, soil structure, and permeability influence these characteristics and may limit producers' management and system options. For this reason, no one type of irrigation system is universally more efficient than another.

Producers should know the predominant soil type in each field receiving irrigation water. The available water-holding capacity should be used with the current depletion status to schedule irrigation (Table 2). This soil information can usually be obtained from your local SCS office or county soils maps.

Crop characteristics influencing irrigation management options include crop water demand and effective root zone depth (Figure 2). Plants remove water from the soil by a process known as transpiration. Consumptive use refers to the amount of water transpired by the plant plus what is evaporated from the soil. It is known as ET and is usually the total amount of water transferable with a water right (Table 3). ET figures are usually available locally from weather services, Extension offices, or agricultural consultants. Accounting for crop ET between irrigations allows producers to determine how much water must be replaced in the soil profile.

Table 2. Typical available water-holding capacity of soils of different texture

Soil textural class	Inches of available water per foot of soil depth
Coarse sands	0.60 - 0.80
Fine sands	0.80 - 1.00
Loamy sands	1.10 - 1.20
Sandy loams	1.25 - 1.40
Fine sandy loams	1.50 - 2.00
Loam	2.20 - 2.50
Silty loams	2.00 - 2.50
Silty clay loams	1.80 - 2.00
Silty clay	1.50 - 1.70
Clay	1.30 - 1.50

Source: SCS Colorado Irrigation Guide, 1988.

Table 3. Estimated seasonal consumptive water use for selected crops and sites

Crop	Burlington	Delta	Greeley	Monte Vista	Rocky Ford
			inches of water		
Alfalfa	35.6	35.3	31.6	23.6	37.7
Pasture grass	31.1	30.8	26.6	19.8	32.9
Dry beans	19.2	-	18.4	-	-
Corn	26.0	25.8	21.7	-	27.7
Vegetables	-	21.6	17.7	11.5	22.2
Grain sorghum	21.5	-	19.5	-	-
Potatoes	-	-	28.1	16.5	-
Sugarbeets	30.0	31.0	29.3	-	32.7
Winter wheat	18.0	-	16.4	-	-
Spring wheat	-	18.1	-	12.7	14.1

Source: SCS Colorado Irrigation Guide, 1988.

Crop root depth is primarily influenced by plant genetics, restrictions within the soil horizon, and the maturity stage of the crop (Table 4). Irrigation water that penetrates below crop roots constitutes deep percolation and should be minimized. Shallow-rooted and young crops with undeveloped root systems present a difficult challenge under furrow or flood irrigation systems. If shallow-rooted crops are part of your production system, rotate with deeper rooted crops and manage agricultural chemicals carefully to decrease transport by deep percolation.

If the soil at a given site is sandy and depth to the water table is less than 10 feet, it is recommended that shallow-rooted crops not be grown under conventional furrow irrigation. Deeper rooted crops and higher efficiency irrigation methods will help minimize groundwater impacts under these conditions.

Table 4. Maximum rooting depths for selected crops under furrow irrigation

Crop	Root depth at maturity (ft)
Corn	3-5
Small grains	3-5
Onions	1-2
Sugarbeet	5-8
Alfalfa	5-15
Dry beans	2-3

Table 5. Approximate efficiency of various irrigation application methods

	Range	Mean
	- - - - - % efficiency	- - - - -
Conventional furrow	25-60	40
Surge	30-80	60
Sprinkler	60-95	75
Drip	80-95	90

Improved Irrigation Technologies

A number of technologies have been developed to apply water more uniformly without excessive waste. Among these are systems such as low-pressure center pivot, LEPA (Low-Energy Precision Application), surge, and micro-irrigation. These improvements may require capital, energy, or increased management costs, whereas the conventional surface systems often require only minimal maintenance of delivery systems. However, in some cases the additional labor savings will justify installation of improved systems.

Application efficiencies can vary widely among irrigation methods depending upon soil, crop, topography, climate, and management (Table 5). Irrigation efficiency can be expressed as the ratio of water needed for crop production, to the volume of water diverted for irrigation. Field level irrigation efficiency for a single application can be calculated as:

$$E_a = \frac{\text{volume of crop evapotranspiration}}{\text{volume of water applied to field}}$$

Changing from a high pressure center pivot to a low pressure system (<35 psi) can reduce pumping costs and increase efficiency if properly designed. LEPA systems operate at even lower pivot pressures and have different modes of operation, including chemigation nozzles. Significant trade-offs exist within these systems, such as runoff potential versus evaporation and drift losses. These considerations and pump requirements must be evaluated before upgrading a system.

Surge flow irrigation uses a valve to send a series of water pulses down alternating sets of furrows. This technique requires less total application, reducing runoff while increasing uniformity. When properly used, surge can save labor and water with no loss of crop yield. Irrigators currently using conventional furrow irrigation on coarse-textured soils, fine soils with cracking problems, or slopes in excess of 1% should consider installing surge valves as a BMP.

Micro-irrigation systems such as drip or micro-sprinklers offer the advantage of precise N and irrigation water management. Fertilizers and some pest control chemicals can be injected near the end of the irrigation set with excellent uniformity and little leaching. These systems are being used profitably in orchards, vineyards, and high value row crops. The high initial cost of installation and potential for clogging with poor quality water present obstacles for some producers. However, the high uniformity, efficiency, and low labor requirements offer significant advantages to irrigators short on water.

Delivery systems such as lined ditches and gated pipe, as well as reuse systems such as tailwater recovery ponds, can greatly enhance overall efficiency. Seepage from unlined ditches often results in losses of more than 25% of diverted water. When ditch water contains municipal effluent or added N fertilizer, NO_3 leaching from the ditch can be a problem. Lining ditches with concrete, plastic, or other materials may increase total efficiency and decrease contaminant loading. Similarly, the installation of pipeline to convey irrigation water can decrease evaporation losses and seepage. In many cases, the USDA can provide cost sharing funds to help install these BMPs. Surface delivery systems converted from open ditches to gated pipe provide a good opportunity to install other BMPs, such as flow meters or surge valves. If ditches cannot be lined for practical reasons, metering N fertilizer into irrigation ditches should be avoided.

Tailwater recovery systems can increase efficiency and reduce nutrient losses from furrow irrigated fields. Reusing tailwater may require a properly engineered system that involves significant costs, maintenance, and land requirements. Where tailwater reuse is feasible, it provides an excellent means of saving water, energy, and nutrients.

Managing Surface Irrigated Fields

Most surface irrigation systems have inherent inefficiencies due to deep percolation on the upper end and runoff at the lower end of the field. Equipment innovations can reduce these inefficiencies, but management decisions are very important. Efficient irrigation results when design and management enable producers to uniformly apply enough water to almost fill the effective crop root zone with minimal runoff. The correct amount of water to apply at each irrigation varies due to changes in root depth, soil moisture status, and the soil intake rate. The irrigation set size, stream size, set time, and length of run can be optimized by irrigators to improve efficiency (Figure 1). A well designed and properly managed surface system can attain efficiencies of 60% or better.

When irrigation is required, it is usually important to cover the entire field as quickly as possible. Irrigators should not be content merely to get the water to the end of the furrows, but should also consider how much water is applied and how it is distributed. Producers should think about surface irrigation in terms of depth of water applied to the field. The simple relationship AD=QT can be used to determine the amount of water applied by surface irrigation systems (Figure 3). For example, 1 cubic foot per second (cfs) applied for 2 hours will result in 2 inches of water applied to 1 acre.

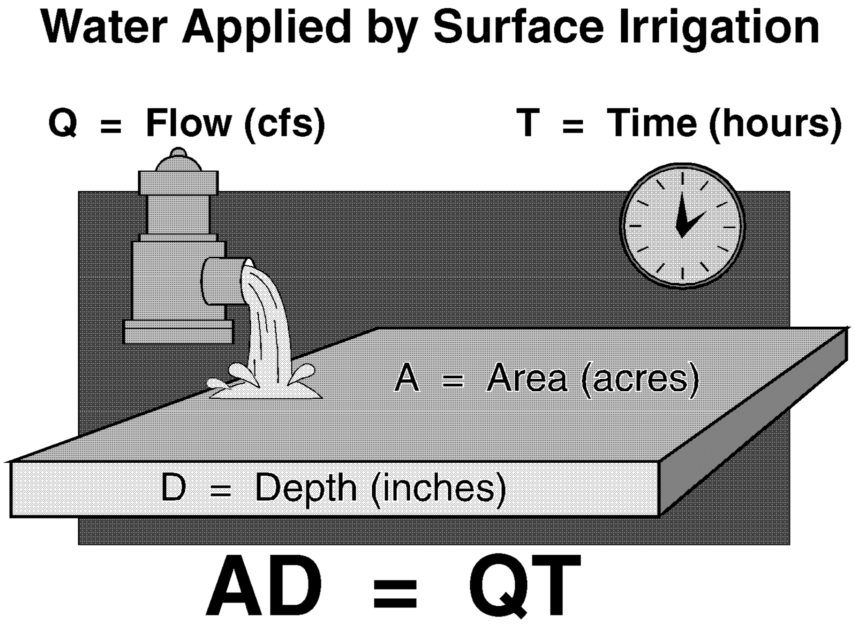

Figure 3. Method for determining amount of water applied by surface irrigation.

Irrigators need a method to measure or accurately estimate the amount of water applied to the field. Weirs or flumes can be used to measure water flow in open ditches. Flow meters can be installed in gated pipe systems, or irrigators can simply use a bucket and stop watch to estimate application via siphon tubes. Once application rate is known, producers can determine how much water is actually applied to the field. Balancing the time of set, area per set, and flow rate to apply the correct amount of water is an essential management practice for all irrigators.

Determining Leaching Hazard

The potential leaching hazard of a given site depends upon soil properties, management, irrigation method, and climatic factors. Depth to groundwater and the overlying geologic material influence the contamination potential of an aquifer. Due to the site-specific nature of these properties, applicators must determine the relative leaching hazard of each application site in order to select the appropriate BMPs. Operators with sites that have a moderate to severe leaching potential and a shallow water table (< 25 feet deep) should select the appropriate BMPs to decrease leaching hazard.

Information on the leaching and runoff potential of your particular site can be obtained from your local SCS office. Other agencies such as your water conservancy district and Cooperative Extension may be able to provide information to help you evaluate groundwater vulnerability at your site. A routine water analysis for bacteria and NO_3 can also help you to determine if your well water is a source of concern.

Increasing Uniformity

Improving water distribution uniformity is an important component of improving irrigation management. Determining distribution requires knowledge of the field, crop, and irrigation system. Producers should probe fields within 72 hours after irrigation to determine depth of application along the irrigation gradient. Checking for visual signs of plant stress can also indicate areas of poor water penetration. Most commonly, the upper end of the field is overwatered and the lower end underwatered (Figure 4). Management techniques that can be used to increase uniformity of application include decreasing row length, field leveling, and installing borders or blocked end furrows. Unequal water infiltration due to compaction

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* 1 cubic foot/second (cfs) $\cong$ 450 gallons/minute $\cong$ 1 acre inch/hour

caused by equipment traffic can be avoided by in-row ripping at cultivation or sidedressing. Excessive water intake on coarse soils early in the crop season can be reduced by driving all rows prior to the first irrigation.

Surface residues from crop stubble can either increase or decrease irrigation uniformity depending upon irrigation system type and characteristics. Sloping lands with low intake rate will benefit from increased surface residue. However, furrow irrigated fields with slow advance times may be difficult to manage under no-till or reduced tillage options. Compliance with USDA mandated conservation programs may require producers to shorten row lengths and increase stream size to achieve efficient irrigation under high residue farming systems.

Length of Run

Irrigation runs that are too long result in overwatering at the top of the furrow by the time the lower end is adequately watered (Figure 4). Furrow length should be based on actual water infiltration rates. The rate water penetrates into the soil is a function of soil texture, compaction, and furrow spacing. Infiltration rate will vary between irrigations and even during a single irrigation. However, after the water has been on the field for one to two hours, intake rate tends to remain constant and can be used to evaluate irrigation run distance.

As a guideline, irrigation runs on leveled fields should be approximately 660 feet on coarse-textured soils or 1,300 feet on fine soils. Sloping fields and compacted soils with lower intake rates may allow runs as long as 2,600 feet and still achieve acceptable uniformity. Improved application uniformity, as well as reduced runoff and deep percolation, result from optimizing irrigation run lengths.

Land Leveling and Border Systems

Land leveling can improve irrigation uniformity whenever non-uniform slopes contribute to runoff or deep percolation. Factors such as soil depth, subsoil characteristics, topography, and the economics of land leveling must be considered prior to any leveling, but especially when deep cuts are necessary. Contact your local SCS office for information on the advisability of leveling specific fields and for details on cost-share funding.

Border systems, blocked end furrows, and level basins permit water to be applied rapidly and evenly over the set without runoff. These systems are best suited to crops that are not damaged by flooding for short periods of time and on soils where infiltration rates are neither extremely low nor high.

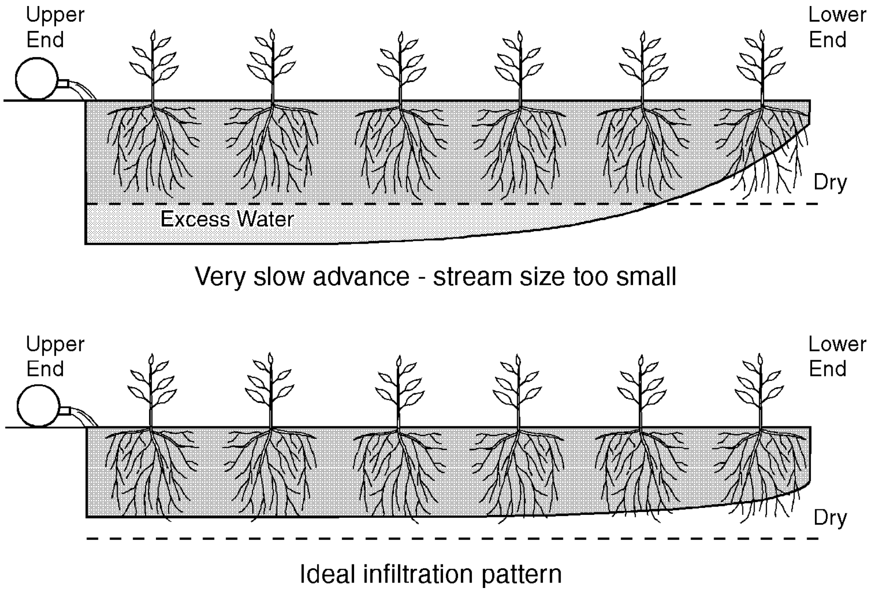

Figure 4. Infiltration patterns with furrow irrigation.

Source: Eisenhauer et al., 1991.

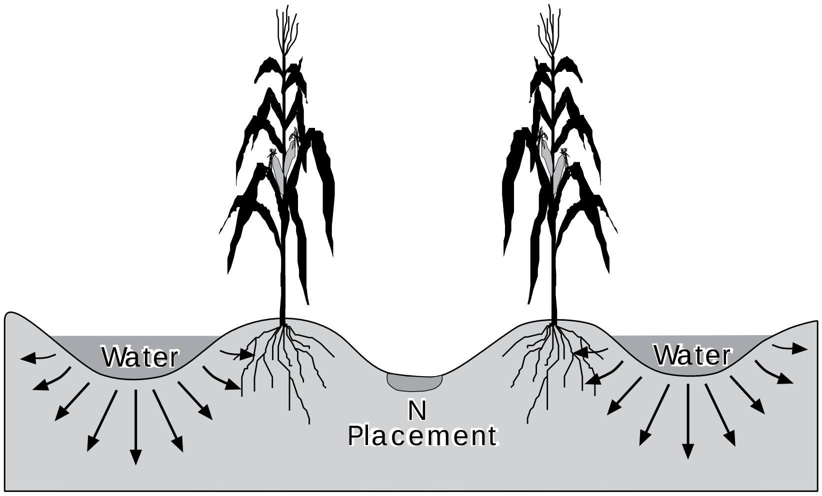

Figure 5. Typical irrigation water movement under alternate furrow N and water application

Managing Water Application

Irrigating every other furrow supplies water to one side of each row, resulting in a larger area being covered during each irrigation set. This can be especially useful during the first irrigation, when it may take considerably longer for water to get through the field. During dry years, irrigators should switch furrows at each irrigation to improve nutrient availability. Coupling alternate row N fertilizer placement with alternate row irrigation may also reduce downward movement of NO_3 (Figure 5). Another advantage of alternate row irrigation is that the soil profile of a recently irrigated field can store more rainfall within the root zone of the unirrigated rows, resulting in less leaching due to unexpected rainfall. Research has shown that crop yields compare favorably with fields receiving every row irrigation. Water savings realized by this method also may allow water-short producers to increase overall yields. Alternate row irrigation generally does not work well on steep slopes or on soils with poor intake rates.

Irrigation application rate and set time must be adjusted according to the soil intake rate and slope. Soils vary significantly in water infiltration rate, ranging from 2.0 to 0.2 inches per hour. Surface irrigators should experiment with different combinations of stream size and set times to achieve the greatest uniformity of water infiltration coupled with the least runoff. When selecting the optimum stream size, begin with the maximum stream size that does not cause serious erosion. In general, the maximum non-erosive stream size will decrease as slope increases (Table 6). Often, the optimum combination of stream size to set time is the one that advances water to the end of the furrow about half way through the total set time. However, this may vary with soil conditions.

Table 6. Maximum furrow stream size for various slopes

Slope (%)	**Stream size** (gpm)
0.20	50.0
0.40	30.0
0.75	17.0
1.25	10.0

Source: SCS Colorado Irrigation Guide, 1988.

Crediting Nitrate in Irrigation Water

Irrigation water containing nitrate (NO_3) can supply N to the crop since it is applied and taken up as the crop is actively growing. Water tests for NO_3-N should be taken periodically during the irrigation season to accurately calculate this credit. Multiply ppm NO_3-N by 2.7 by the amount of effective irrigation water applied (in AF) to the crop to determine pounds per acre applied in the irrigation water. Effective irrigation should be calculated based upon actual crop ET. Inexpensive quick tests are available for on-farm water testing. If a water sample is taken for laboratory analysis, it should be kept refrigerated, but not frozen, until it gets to the lab.

Table 7. N credit from irrigation water

	Effective Irrigation (acre inches)					
NO_3-N in water (ppm)	**6**	**12**	**18**	**24**	**30**	**36**
	(lb N/A)					
2	3	5	8	11	14	16
4	5	11	16	22	27	33
6	8	16	24	32	41	49
8	11	22	32	43	54	65
10	13	27	40	54	67	81
12	15	32	48	65	81	97
14	18	37	56	76	95	113
16	21	42	64	87	109	129
18	24	47	72	98	123	145

Limited Irrigation

Limited irrigation may be practiced by water-short producers to stretch their water resources and maximize returns. The water quality benefits of limited irrigation systems result from the reduced leaching and runoff that this approach dictates. Producers limit their use of water in this method to only a few well-timed and well-managed applications. Selection of crops capable of withstanding some drought stress is critical to tolerating drier than average years under limited irrigation.

Salinity Management

Leaching excess salts which are carried by irrigation water is necessary in some Colorado soils to avoid salt accumulation in the root zone. Typically, additional water (known as the leaching requirement) in the amount of about 5 to 15% of total consumptive use must be applied annually to leach soluble salts from the crop root zone. The leaching requirement can be calculated fairly precisely as a function of soil and water salinity. However, most irrigation systems in Colorado do not achieve efficiencies that warrant the addition of a leaching fraction.

Where leaching for excess salts is necessary because of poor quality water, it is essential that the leaching be done when soil NO_3 levels are low and crop N needs have been satisfied. Soils should never be intentionally leached within 72 hours after the application of any pesticide.

Managing Sprinkler Systems

Sprinkler system operators need to match application rates with infiltration rate and the slope of the soil. High application rates can result in surface runoff or in ponding and deep percolation losses. Low application rates can be inefficient due to excessive evaporation. Proper sprinkler system design is essential to achieve high efficiencies with minimal runoff or deep percolation. Irrigators should adjust application depths (speed of travel) to soil moisture depletion status. Soil moisture monitoring and irrigation scheduling are essential BMPs for managing water application on sprinkler irrigated fields.

Basin tillage with a dammer-diker or similar implement can be used to increase intake and reduce runoff on sloping fields with low infiltration rates under sprinkler irrigation. Basin size and the distance between basins should be adjusted according to slope and soil intake rate. In general, smaller basins and higher water delivery rates are best for very permeable soils. Short, wide basins tend to be more efficient than long, narrow ones.

Chemigation Safety

Chemigation, the process of applying fertilizers and pesticides through irrigation water, can be economical and effective if conducted properly. However, the major disadvantage of this method is the potential hazard to groundwater resulting from backflow of pesticides into wells or pesticide spills in close proximity to the well bore. Additionally, chemicals injected into irrigation water can move off the intended target by wind drift, runoff, or deep percolation.

On sandy-textured soils, splitting N fertilizer application by fertigation through sprinkler systems has been shown to increase crop yields and reduce NO_3 leaching hazard when irrigation water is applied at appropriate rates. On fine-textured soils, crop yields have not been shown to improve significantly by this method, but split application of N is still a BMP for environmental reasons. Fertilizer application through surge flow irrigation systems can be used effectively if tailwater recovery systems are employed. Liquid forms of fertilizer can be added through the system during late cutback cycles.

Knowledge of the correct amount of fertilizer needed per acre, water application rate, and the acreage under the surge valve are critical to proper calibration of the fertilizer injector and length of cycle. A high level of management is needed to ensure proper cutback cycle settings to avoid runoff and loss of N to surface waters. Conventional furrow irrigation systems are much more difficult to manage to ensure uniformity of application without runoff or leaching. For this reason, application of fertilizer via conventional surface irrigation is discouraged, especially in areas with coarse soils and shallow groundwater. Tailwater recovery and reuse should be employed on any chemigated field that produces significant amounts of runoff.

Pesticide application through irrigation water is restricted by the EPA under current labeling regulations. The EPA requires each chemical label to either specifically prohibit chemigation or to detail instructions for chemigation on the label. Chemigators should read all label precautions, paying close attention to the chemigation instructions. In Colorado, all chemigators operating closed irrigation systems must have a permit from the Colorado Department of Agriculture and also install backflow prevention valves, inspection ports, or check valves as appropriate. Producers chemigating through open systems where backflow cannot occur are not required to obtain permits to comply with the Colorado Chemigation Act, but still should observe the appropriate precautions.

Agricultural chemical handling and storage at the chemigation site are a potential source of groundwater contamination. Producers who store large volumes of chemical at the wellhead should install secondary containment to capture leaks or spills. All chemigation safety equipment should be inspected regularly and maintained in good operating condition. Additionally, poorly designed or maintained wells can act as direct conduits for chemicals into the groundwater. All wells where chemicals are handled nearby should be routinely inspected for evidence of damage. Annual water quality monitoring at operational chemigation wells can provide valuable information on the vulnerability of a well and a historic database to document water quality trends. Visual or audio well inspections by a pump or well maintenance company can usually help identify any needed improvements at the wellhead.

Chemical and Site Interaction

Agricultural chemicals vary significantly in their persistence, water solubility, and soil adsorption. A number of biological, chemical, and physical processes determine pesticide fate and persistence at a given site. Highly mobile chemicals may move rapidly to groundwater, even under situations where the leaching potential is not considered significant. A pesticide such as glyphosate is highly immobile, even when leaching hazard is high (Table 8).

Persistence, measured as the half-life, is an indicator of the period of time during which the pesticide is exposed to the forces of leaching. Persistence ranges from a few days to years depending upon chemical properties and degradation pathways. Adsorption and solubility of a chemical determine the rate of movement through the soil profile. Applicators need to be aware of these chemical properties to select pest management appropriate for a given site.

Avoid the use of mobile pesticides on fields with severe leaching potential. If possible, apply these chemicals after, rather than prior to irrigation. In situations where surface loss or leaching is highly probable, select non-chemical pest control alternatives such as tillage, rotation, or biological pest control.

Table 8. Characteristics and predicted mobility of selected pesticides

Pesticide	Half-life (days)	Sorption coefficient* (K_{oc})	Predicted Mobility
Dicamba	14	2	very mobile
2,4-D	21	20	moderately mobile
Atrazine	60	163	slightly mobile
Alachlor	10	190	slightly mobile
Metolachlor	20	201	nearly immobile
Malathion	1	1,800	nearly immobile
Glyphosate	30	10,000	immobile
Paraquat	3,600	100,000	immobile

* Higher sorption coefficient indicates a chemical is more likely to be held by the soil.

Summary

To maximize irrigation water efficiency and avoid waste or water quality impacts, producers should determine:

1. When irrigation water should be applied
2. How much water is needed to satisfy crop requirements
3. Application rate, set time, stream size, or set size required to apply the correct amount of water
4. Potential for agricultural chemicals to move from the target site due to irrigation practices.

This information should be used by irrigators to select irrigation methods and BMPs to conserve water and reduce unwanted water quality impacts from leaching or runoff. Obviously, all BMPs are not appropriate for every field and irrigation system. Producers must evaluate agronomic and economic factors to determine the feasibility of installing upgraded systems or management practices. In many cases, it is advisable to obtain professional help in evaluating options for improving irrigation systems.

Best Management Practices for Irrigation Management

Guidance Principle: Manage irrigation to minimize transport of chemicals, nutrients, or sediment from the soil surface or root zone to protect water quality.

Select the irrigation BMPs most feasible for your operation to achieve the above guidance principle.

General BMPs

2.1 Determine the relative leaching potential of your particular soil and site. Employ all appropriate BMPs on fields with severe leaching potential.

2.2 Monitor soil moisture by the feel method, tensiometers, resistance blocks, or other acceptable methods before and after each irrigation.

2.3 Schedule irrigation according to crop needs, soil water depletion, and water availability, accounting for precipitation and chemigation. Apply only enough irrigation water to fill the effective crop root zone.

2.4 Evaluate the efficiency of the total irrigation system from the pump or diversion to return flow or tailwater. Upgrade irrigation equipment to improve delivery and application efficiency where feasible.

2.5 Monitor irrigation application and uniformity of water applied.

2.6 Time irrigations to individual crop needs to eliminate unnecessary applications. Calculate the date of the final irrigation of the season to ensure the soil profile is largely depleted by crop harvest. Post harvest irrigation should be limited to meet the needs of specific operations only.

2.7 Analyze irrigation water quality periodically, and credit NO_3-N in water to crop requirements.

2.8 Avoid intentionally applying excess irrigation to leach salts until the growing crop has taken up fertilizer N. When leaching of soluble salts is necessary to maintain productivity, time leaching to coincide with periods of low residual soil nitrate.

2.9 Contact a qualified professional to help schedule irrigation and determine the application efficiency of your system, if necessary.

Flood or Furrow Irrigation BMPs

2.10 Maximize efficiency and uniformity on surface irrigated fields by installing surge flow irrigation, decreasing set time, leveling fields, or using tailwater recovery systems as appropriate. Producers currently using flood or furrow irrigation on coarse-textured soils should install sprinkler systems when feasible.

2.11 Use alternate furrow irrigation and N fertilizer placement on soils with severe leaching potential to reduce nitrate leaching to groundwater (see Figure 5).

2.12 Use fertigation to apply in-season N fertilizer with high efficiency irrigation systems only. Fertigation is strongly discouraged with conventional flood or furrow systems unless tailwater recovery systems are employed.

2.13 Line irrigation water delivery ditches to reduce seepage losses. Install pipelines to convey irrigation water where feasible.

Sprinkler Irrigation BMPs

2.14 Minimize deep percolation below the crop root zone on sprinkler irrigated fields by applying water according to crop evapotranspiration and soil moisture status.

2.15 Minimize surface runoff and increase uniformity on sprinkler irrigated fields by decreasing application depth or by changing nozzle and pressure configuration, height, or droplet size as appropriate.

2.16 Maintain sufficient surface residue to reduce overland water flow and increase moisture intake rate. Where practical, follow soil conservation practices such as minimum tillage or contour planting to reduce erosion of soil sediments containing nutrients or pesticides. Plant grass filter strips on the downhill side of any highly erodible fields to filter nutrients or other chemicals from runoff. Utilize basin tillage on sprinkler irrigated fields with slopes of 3 to 5% to reduce surface runoff.

2.17 Test systems periodically for depth of application, pressure, and uniformity.

Chemigation and Fertigation BMPs

2.18 Read the chemical label prior to application. Follow all label instructions and take careful note of the specific chemigation instructions. Chemigators also must follow the rules of the Colorado Chemigation Act.

2.19 Reduce water application rate to ensure no runoff or deep percolation occurs during chemigation sets. Avoid chemigation when additional water is not needed by the crop. Adjust irrigation schedule to account for water applied during chemigation

2.20 Monitor and inspect chemigation equipment and safety devices regularly to determine proper function. Replace all worn or nonfunctional components immediately.

2.21 Upgrade well condition to reduce the possibility of point source contamination at the wellhead. Handle chemicals carefully around the wellhead and chemigation site. Clean up any fertilizer or pesticide spill immediately to avoid well contamination.

For more information about irrigation management or for specific inquiries about BMPs, contact Colorado State University Cooperative Extension. They have publications, programs, and specialists available to help you answer questions about water quality.

Related source material from Colorado State University Cooperative Extension:

SIA	.508	Fertigation through surge valves
	.512	Fertigation: applying fertilizers through irrigation water
	.514	Nitrogen and irrigation management -- keys to profitable yields and water quality
	4.700	Estimating soil moisture for irrigation
	4.703	Drip irrigation for orchard crops
	4.704	Center-pivot irrigation systems
	4.707	Irrigation scheduling: the water balance approach
	4.708	Irrigation scheduling
	4.709	Tailwater recovery for surface irrigation
	4.711	Low pressure center-pivot sprinkler system
	4.712	Improving irrigation pumping plant efficiencies
	4.713	Applying pesticides through center-pivot irrigation systems
	4.715	Crop water use and critical growth stages
Bulletin	543A	Surge Irrigation Guide

Additional resources:
USDA, Scheduling irrigation: A guide for improved irrigation water management through proper timing and amount of water application, 1991.

USDA-SCS, Colorado Irrigation Guide, 1988.