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RECLAMATION
Managing Water in the West

Water Operations and Maintenance Bulletin

Effective Operations - Fine-Tuning Your System

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Contents

Effective Operations - Fine-Tuning your System

For this issue of the Water O&M Bulletin, we are focusing on specific actions that can be taken to ensure safe and efficient delivery of water and power. Bureau of Reclamation staff manages much of this work in regional, area and field offices with support from the Technical Service Center and the Office of Policy and Administration's Asset Management Division.

Operation activities have an annual cycle. The spring brings watering up and then watering down follows in the fall. Regardless of the time of year, it is vital that all operations focus on safety, prevention, and efficiency.

This bulletin contains some helpful content on the following topics:

- Safety information to integrate into your watering up and watering down processes.
- An overview of how effective operations can reduce the occurrence of costly emergency maintenance, followed by an in-depth example of a common O&M problem for canals: seepage.
- Ideas on how to modernize your controls and improve your irrigation systems lead to better efficiency and cost savings.

By thinking about and implementing the information and ideas shared in this bulletin, you can contribute to the health of Reclamation's assets and help protect the reliability of water and power delivery in the West.

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About this Bulletin

The Water Operation and Maintenance Bulletin and subject index is available at: www.usbr.gov/assestmanagement/WaterBulletins

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On the Cover:

The Madera Canal runs north from Friant Dam in California near Fresno. It has a capacity of 1,000 cubic feet per second.

Irrigation water pumped up from the East Low canal in Washington.

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Plan to Avoid Problems

A little preparation can avoid a lot of hassles—or worse!—later. For all phases of your operations from starting up through to shutting down, plan your actions in advance. Take a deep breath and think about best practices.

Communicate to Be Safe

Entity-wide notifications about watering up, changes in operations, or watering down are vital so everyone is aware of what is going on. Have the correct permits. Notify every water district staff member, water users, and everyone else who may be affected. This ensures the safety of the project, personnel, and anyone near or operating the system.

Think about potential hazards for any action. Develop a job hazard analysis for each activity and note the particular types of dangers. For example, going into a vault may require confined space permits and specific procedures. Traveling canals may require preparing for varied terrain, snakes, and other hazards.

Follow Your Guidelines

Help prevent damage by adhering to your system's documented procedures when operating gates, valves, pumps, and control facilities. Your facility plan should include the Standing Operating Procedures (SOP), Design Operating Criteria (DOC), or Operating Instructions. These are developed specifically for your project and facility and should be followed to prevent damage. DOCs are the designers' specifications for operating, maintaining, watering up, and down your facilities. SOPs are the facility operating procedures and include information on operating mechanical equipment. Follow these instructions to turn the system on and off. SOPs should include details such as the fill and drain rates, gate and valve openings and closings, powering up and down procedures, as well as safety issues such as lock out/tag out processes.

Prepare in Advance

For both stopping and starting a system, you need to make sure you have the right tools and equipment at hand. Think through the process:

- What equipment will be needed?
- How will the water flow be controlled?
- Who will do what task?
- How will tasks and status be communicated?

Water is pumped from the Columbia River into Cold Springs Canal,

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Go Slow

Remember, slow but steady will win the race every time. Both pipelines and canals need to be filled and drained slowly. Filling slowly will help you ensure new features are performing as intended. Avoiding sudden changes in velocity will generally avoid serious water hammer surges. To avoid creating a vacuum leading to pipe collapses, ensure air valves are open when filling or draining. Find out what the maximum acceptable filling and draining rate is for each pipeline, canal, and lateral. If you do not know, work with your supervisor or watermaster to ensure that these are defined.

Pipelines and Valves

Rapid filling can trap air in pipelines as air vents cannot let air out of the pipeline fast enough. To prevent damage, it is absolutely necessary to closely observe air valves during filling and to adhere to the DOC when operating valves, pumps, and control facilities.

Avoiding sudden changes in velocity will generally avoid water hammer surges. Surges occur when flow rates change and hydraulic transients or sudden upsurges or downsurges change the total pressure in a piping system. Extreme transient pressures can result from rapidly opening or closing valves—or even just changing the valve settings (accidentally or planned), starting or stopping pumps, and unstable pump turbine characteristics.

Fill slowly

Operate valves slowly

Shut down slowly

Opening and closing valves too rapidly can build pressure, which can literally blow pipe out of the ground or collapse the pipe—causing extensive damage.

Canals and Gates

Canal protective structures are designed to accommodate turbulence from changing water velocity, depth, or flow paths. Always open headwork gates slowly so that turbulence does not sweep beyond the check structure. Open all gates slowly to control the filling and minimize waves in each canal reach.

The general rule of thumb is no more than a foot per day or six inches per hour. Filling the canal too fast can cause large waves that can cause scour damage to the canal prism.

Consult your documentation for specific operations. Check to ensure that the turbulence downstream from the check gate structure does not extend past the length of the concrete transition, as this scours unprotected canal sidewalls. If the water is too turbulent, lower the gates until a backwater is developed. After the flow has stabilized and any turbulence has disappeared, set the gate at the desired position and continue to open gates.

The Lind Coulee siphon in Washington.

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As you dewater canals, look for:

- **Seepage**
- **Cracks**
- **Displacement of concrete lining**

If you see these symptoms under normal dewatering conditions, immediately stop dropping the water level and address the problem.

Start Up Safely

As the system starts up, watch for issues carefully. If a problem occurs, immediately stop changing the water level and address the problem.

Pipelines and Valves

The initial filling and testing is the most critical period during the life of the pipeline. Normally, fill at a lower rate than the maximum pumping capacity of the system (a generally safe procedure is to keep velocity under 0.25 foot per second). However, this is a general rule, and you need to consult your system's documentation to avoid exceeding the air vents' capacity.

Use extreme caution during this time and carefully follow guidelines and manufacturers' instructions. Closely observe air valves and listen to the air valves to make sure they are allowing enough air into the pipes. This is usually a whistling or high-pitch tone but get to know your system's normal noise so that you can hear a difference if something changes.

Use pressure gauges to monitor where the water is in the pipeline to determine when the water level is high enough to close the air valve. If you know how high the water is in your line, then you will know when the air valve should close. You should have an idea of how long it should take for water to reach portions of the pipe—so any levels below this may indicate problems, such as closed valves or other constrictions or leaks. Use the sectionalizing valves, bypass valves, or other equipment to control flow and prevent cavitation. When refilling a large pipeline, use the bypass piping and valves to equalize the head (pressure in the pipe) on both sides of the valve.

Ensure there are no wet spots or depressions on the ground—which could indicate pipeline problems.

Canals and Gates

Before watering up, go through the canal system to ensure that all channels and wasteways are ready to receive water.

Before watering up any canal, lateral, or sub-lateral, remove debris any other obstructions in canals and larger laterals. For example, farmers may have placed fences in dewatered canals to contain livestock. Inspect and clean out canal under drains yearly or following heavy precipitation events. Under drains (typically round or box concrete culverts that pass under fill sections of canal where the canal crosses a natural drainage feature) are often filled with sediment or not maintained, which can lead to seepage or other problems.

Pumping Plants

Use the special dedicated filling pump as noted for each facility. These pumps are designed to ensure that water enters the system at the correct rate when filling.

The "C" canal in Klamath Falls, Oregon.

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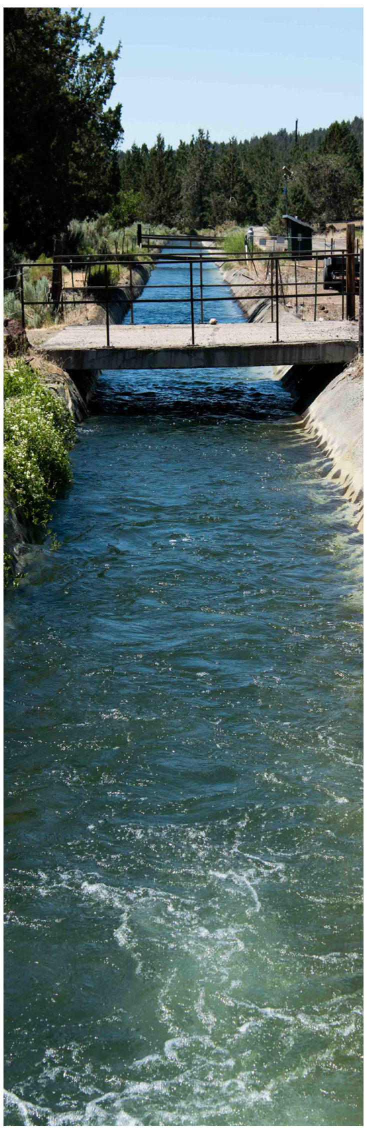

Put the System to Bed Wisely

Ending the season on the right note will help prepare for next season. Determine where the water is going at the end your system for the end of the season.

Pipelines and Valves

The drain rate should be slow enough so that it does not exceed the air valve's capacity to let air into the pipe. Do not drain faster than the bypass or smaller valves can take. Typically, don't drain more than 16 feet per second velocity through the operating valves. If you are flushing the line, you need a minimum flush velocity.

Make sure that pipelines are protected from materials, animals, or anything entering the pipeline. When the pipeline is full of water, there usually is not a problem, but empty or intermittently filled drains could invite animals or sediment.

In a warm, nonfreezing climate, keep pipes full of water at all times during the non-irrigation season. In a cold, freezing climate, all the pipes must be drained and kept empty during the cold months or buried below the frost line. Farm distribution pipelines should be drained at the end of the irrigation season, through deliveries and blowoffs, to remove as much water as practicable from the system before freezing weather begins. Small localized areas of the pipe may be left full as determined by the design and operating documents. This is, of course, not possible on municipal and industrial systems which operate year-round or in pipeline systems in a flood plain, as this may cause the pipe to float out of the ground. These systems are designed with freeze protection, and some flow should always be maintained to combat freezing. If conditions have changed since the system was designed and flows cannot be maintained, the system must be protected from freezing, especially the air release valve and pressure-reducing valve.

During the non-irrigation season, put protective barriers over the inlet and outlet ends of large pipelines to prevent people and vehicles from entering the pipelines and over smaller pipelines to prevent rodents from entering the lines during the non-irrigation season. Siphons under roads should also be protected, especially if they are left full of water. Protective barriers should be placed at each end of the siphon to prevent small children or animals from entering the structures.

Canals

Draining or dewatering the canal too fast can also cause problems, such as cracked or displaced concrete panels in concrete lined canals (from pressure differences between the water level in the canal and the water level in the soil) or sloughing and erosion of the canal prism in earth lined canals.

Pumping Plants

Drain the system slowly to avoid scour. Ensure that oil and grease is filled and pumps are winterized. For example, ensure that the space heaters are on if the pumps require it. Schedule maintenance and replacement during this off-season if possible.

An irrigation canal near Blythe, California.

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Run Smoothly and Efficiently

From design to decommissioning, operations and maintenance (O&M) accounts for 80 percent of the costs over the life of any asset from the canal down to the nuts and bolts of a system. Effective operations can reduce the need for emergency maintenance. For example: operating a gate incorrectly can damage the gate structure or hoisting equipment and could lead to a gate failure requiring emergency maintenance and costly repair bills. Conversely, effective maintenance can avoid operational problems. An example: If a gate's lifting assembly is not lubricated properly, the gate may not operate when needed. In this case, a lack of preventative maintenance could even jeopardize the safety of the canal or dam.

- Key O&M considerations are:
- Document operation conditions
- Document maintenance repairs
- Conduct on-going visual inspections
- Conduct periodic inspections of systems, including inspections after potentially damaging events
- Test equipment
- Plan for emergencies or system component failure
- Review O&M, Condition Assessments are performed by one office removed from the operator
- Consider all types of maintenance, focusing on ensuring reliability
- Plan for extraordinary maintenance through maintenance management plans and Major Rehabilitation & Replacement (MR&R)

O&M activities should be planned and ongoing, but storms or other disruptions will require more maintenance. For example, after storms, inspect and clean out places (such as canal underdrains) where sediment could accumulate or where there could be any other storm damage. Earthquakes can also cause subtle or unseen damage, and this should be checked soon after the event. The longer that problems go undetected the more damage could occur.

All these aspects and more contribute to keeping our facilities running smoothly and efficiently.

	Operations Tasks	Maintenance Tasks
Planning	Preparing and updating annual operating plan Forecasting runoff conditions for river/ power operations Coordinating operatiooms with electrical and hydrological operations of other dams/powerplants in the western United States	Inspecting facilities and equipment on planned cycles.
Operating	Monitoring instrumentation Sedimentation monitoring	Repairing facilities damaged by operating releases Refinishing the surfaces of everything from dam gates to office building
Mechanical Equipment	Exercising mechanical equipment on a regular basis to ensure its ability to operate through full cycle	Lubricating equipment at prescribed intervals Replacing fluids, filters, and seals on operating equipment at regular intervals Periodic tear down, inspecting, and rebuilding pumps and equipment
Emergencies	Responding to emergencies	Examining and repairing equipment and facilities after the emergency as needed.
Safety and Security	Evaluating facility security Complying with health and safety codes Ensuring staff and visitor safety	Handling and managing hazardous materials Retrofitting facilities to comply with safety requirements

Canal Seepage

We worry about a dripping faucet, but do we notice the small leaks and water loss and waste in the canal? Canals seep—whether lined or not. This seepage may threaten the canal's integrity and should be noted and monitored carefully for any changes. Seepage can erode soil particles below the ground surface within the embankment and foundation (called internal erosion). Active internal erosion is a serious threat to the integrity of a canal embankment and can result in breach if not adequately addressed. Seepage can also raise the water level within the foundation or embankment, which reduce stability and can also result in a breach.

Seepage is more likely to cause concerns:

- Where differential settlements and cracking may have occurred
- Along flaws created by burrowing animals or decaying tree root systems
- Along embankment penetrations such as laterals, turnouts and buried utility crossings
- Where canal lining has failed or is in disrepair
- Where unauthorized embankment modifications have been made (e.g., excavations into the embankment).

When changes in seepage conditions are observed early, intervention measures can be taken to stop or slow the progression of a developing failure, including:

- Lowering the stage in the canal
- Constructing filter berms and drains
- Grouting beneath a concrete liner or grouting the embankment/foundation
- Repairing liners
- Using cutoff walls

When internal erosion may be a concern—and particularly when it is not feasible to unwater a canal—then repairs that safely collect seepage into engineered features can help protect infrastructure and can often be implemented relatively quickly. These types of repairs include sand filter and gravel drainage zones. A berm should be constructed above the filter and gravel zones to resist seepage pressures and keep the sand and gravel in place.

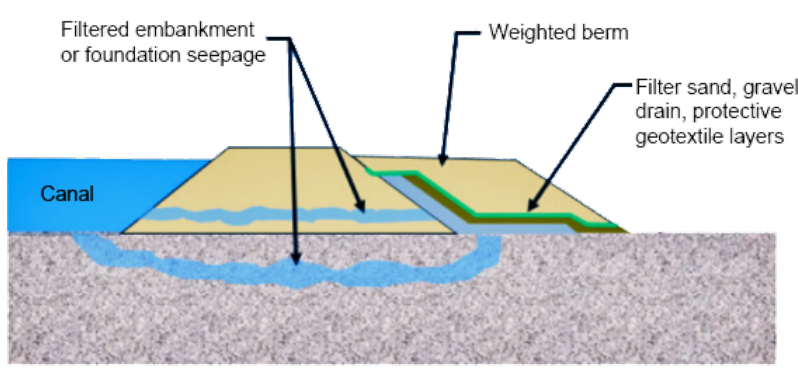
Often, additional repairs are necessary for long-term improvements if the embankment and/or foundation materials are believed to be compromised. Liner repairs ranging from crack filling to full replacement (or constructing a new liner if one isn't already present) may be feasible, particularly if the canal can be unwatered. Divers have repaired cracks and have grouted beneath concrete liners in full canals, but the costs can be very high.

Grouting repairs should be conducted by highly experienced personnel to avoid damaging the embankment and worsening conditions (e.g., hydrofracturing soils, lifting or cracking concrete lining).

Cutoff walls are very good at limiting lateral seepage flow, but do not impede seepage from migrating downward. Cutoffs are most effective if it is desired to intercept flaws in the embankment and/or foundation and if the wall can be terminated in a relatively impervious foundation stratum.

Even if seepage is not a precursor to a failure, it indicates areas where more efficient operations could help save water and improve operational flexibility and increase safety. Methods to reduce seepage include:

- Earth linings
- Overlay existing lining with geomembrane or concrete
- Replace or install a new canal lining
- Crack repair of existing concrete lined canal
- Concrete panel replacement
- Cutoff wall
- Grouting



Typical filter berm configuration

More Information

Canal O&M Guide: Embankments Evaluation and Monitoring of Seepage and Internal Erosion, FEMA, May 2015

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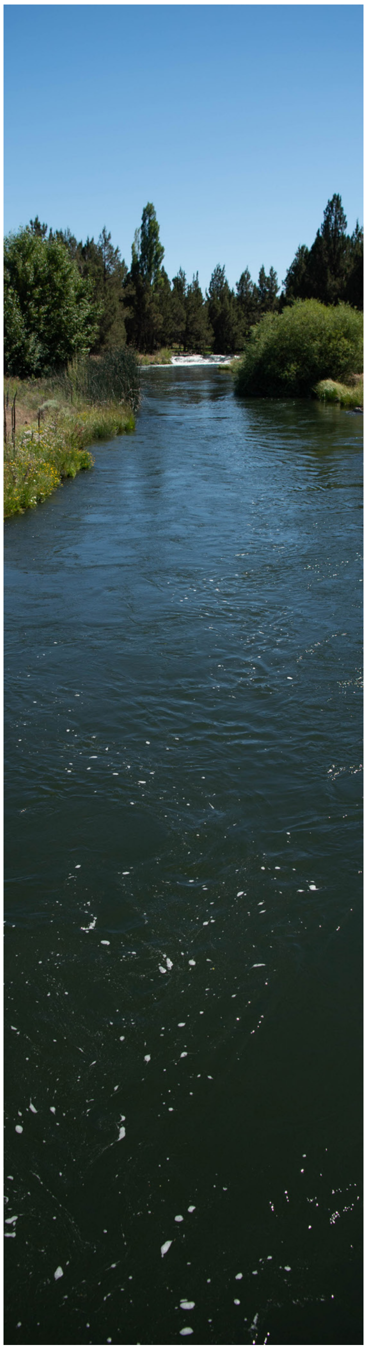

Modernize Your Controls

With increasingly complex canal system requirements and higher costs for water, power, and construction, you need the most efficient and beneficial operation possible. How can you get greater delivery flexibility and increased efficiency? By expanding control systems, you can enhance your canal operations to: improve service to water users, conserve water through increased efficiency, reduce operation and maintenance costs, increase delivery flexibility, and provide more responsive reaction to emergencies—and save money in the long run.

Understand Your System

Understanding how your canal system works and its particular requirements is the first and most important step in planning to upgrade your control systems.

- Is your system driven by supply or demand? When a system has a variable and uncertain supply (such as storm drainage systems or a system with a flashy stream and no storage), operate individual structures to monitor and maintain stable conditions at upstream points, while systems that have a steady supply but must meet variable and uncertain demands should be configured so that structures respond to changes in downstream conditions.
- What is the water schedule? Is it predicted and arranged in advance and then adjusted? How much flexibility do you need?
- What kind of operations were your canal pools designed to support?
  - Projects designed to operate with a constant depth at the downstream end of each pool are able to convey the maximum steady flow in a small canal prism which keeps the initial construction cost low. These systems work well to meet supply-oriented objectives. Canal pools designed to have constant depths maintained at the upstream end are more expensive to build (since the downstream end of each pool is very deep at low flow), but they respond readily to varied demands by downstream water users. Automation can help either type of system.
  - Forcing demand-oriented operations on a canal designed for supply-oriented use is difficult under manual control, but automation may make these operations possible. Automation may also enable more sophisticated operations, such as controlled volume, which enables the water volumes in pools to be varied more dramatically to give flexibility to respond to a variety of needs, including complex operations targets and abnormal, and emergency conditions.
- Can you predict operations or do you need to react? Predictions can be used in manual systems or can be incorporated into automated systems to enhance operations.
- What does your delivery infrastructure look like? Pipelines respond almost immediately to flow changes, as pressure changes move through pipes rapidly. Canal systems, on the other hand, respond to flow changes slowly and changes can take a long time to stabilize. Canals with numerous check structures and lots of pools can stabilize more quickly if pools are managed simultaneously (which becomes practical with automation).

Explore Control Methods

A canal system can be controlled by:

- Local manual—on-site control by a human operator (ditchrider)
- Local automatic—on-site control by control equipment without human intervention
- Supervisory—control from central headquarters with different levels of participation by the watermaster
- Combined—combination of the above methods

Each canal control method has its own characteristics and advantages. You do not need to know the nitty-gritty details of each control equipment system, but you do need to know how each method works and what would be the best fit for your situation. Control fundamentals and selection of an appropriate control method are discussed more extensively in the Canal Systems Automation Manual.

More Information

Canal Systems Automation Manual (Volume 1 discusses fundamentals of canal operation and automation: www.usbr.gov/tsc/techreferences/mands/mands-pdfs/CanalSysAuto1.pdf, and Volume 2 gives more specific information for designs and retrofits: www.usbr.gov/tsc/techreferences/mands/mands-pdfs/CanalSysAuto2.pdf).

Hands-on hydraulics lab workshop: Modern Methods in Canal Operation and Control, (see the Technical Service Center's Training Page: www.usbr.gov/tsc/training/training.html).

Canal Operations and Strategies for Successful SCADA Systems (see Water O&M Bulletin #242 www.usbr.gov/assetmanagement/WaterBulletins/242-June%202017.pdf).

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Plan Your Upgrade

To plan your system, begin with your objectives and needs. Clearly identify specific expectations and goals. How will your system work? What are your operating criteria? What physical and operational constraints need to be considered?

Prepare your system using site investigations, operation studies, and equipment considerations. Then determine the feasibility of these possible upgrades based on the estimated costs of the new control system and the benefits achieved. When project feasibility has been confirmed, final design details are prepared. Specifications are written for procurement, installation, and acceptance testing of the control system equipment. On-site preparations update or modify the canal facilities as required to interface with the new control system. Then, control equipment is installed, calibrated, and tested. To ensure the equipment will operate as designed, testing is required before and after installation. After the system becomes operational, equipment must be properly maintained to keep outages to a minimum.

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Improve Irrigation Efficiency

Parts of the System

Increasing the amount of water available that can be used beneficially in a system (called irrigation efficiency) might help irrigators maintain production levels while freeing up a portion of water supplies for other purposes. Think about efficiencies in three areas: storage, delivery, and application.

Source/Storage System Efficiency

Storage, or supply system efficiency, is the percent of available supplies released to the distribution system. It is usually fairly high. Losses from the supply system include losses from the reservoir such as water surface evaporation, seepage losses, or water-loving vegetation (phreatophytes). Consider working with the storage system to determine new methods of efficiency, such as covering a portion of the reservoir with solar panels, addressing seepage losses, or maintaining vegetation.

Delivery System Efficiency

Delivery, or distribution system efficiency, is the percent of canal system inflows delivered to field turnouts. Losses from the canal and lateral system include seepage, operational spills or waste, phreatophytes, and water surface evaporation. If water deliveries are not available at the frequency, flow rate, and duration required to satisfy crop water use requirements, yields will be lower. In-system storage (such as on-farm holding ponds) can enhance delivery reliability rather than over-supplying a delivery canal to ensure that irrigators in the lower reach of the canal are not shorted. Depending on the local hydrogeology and ground water management, irrigation water could be supplemented with groundwater pumping, which could reduce relying on over-supplying canal flows and could improve the system's capability to respond to demand changes.

Ways to improve canal efficiency include:

- Using linings or piping to limit seepage losses
- Installing and improving automated control structures to avoid spills
- Ensuring delivery reliability
- Embedding flexibility and workflows within the system to respond quickly and effectively to demand changes

Application Efficiency

Application efficiency, such as on-farm irrigation system, is the percent of deliveries to the field turnout used beneficially. Losses may include deep percolation or seepage below the crop root zone, tail water runoff, operational spills or waste, surface evaporation, and/or seepage from farm ponds.

Improving on-farm efficiency reduces water demand. Irrigation methods have varying ranges of efficiency.

Overall System Efficiency

To truly understand efficiency, you need to consider the system as a whole, as every part of the system interacts and depends on the other parts. For example, converting a field from surface irrigation to a center pivot sprinkler equipped for low pressure operation and with drop nozzles would increase irrigation efficiency. However, after more farms convert, then the district needs to be able to handle the mechanical and electrical systems needed for the mass conversion, as instantaneous unplanned shutdowns could lead to increased operational spills.

When determining irrigation efficiencies, it is crucial to consider the many factors at play within the watershed basin and the irrigation district. For example, canal spills, overland irrigation runoff and groundwater return flows could be important water supply components for down-gradient water users. Factors such as degradation of water quality need to be considered. Recognize that improving on-farm and conveyance efficiencies might not necessarily result in water "savings" when viewed from a basin-wide perspective.

Every irrigation system is unique, and no universal solution will meet every need and solve all challenges. Look at the big picture and avoid arbitrary assumptions. What worked well in the past may not be the most effective system now or in the future. Examine new technologies and techniques to find better solutions. To successfully improve the overall efficiency of the irrigation system, a rational and unbiased approach is essential:

1. Recognize and define the physical boundaries of the irrigation system, both in time and space.
2. Identify all beneficial uses, not just primary uses.
3. Monitor and measure system waters.
4. Recognize the changing needs of water users/customers.
5. Compare energy requirements for alternatives.
6. Recognize negative impacts of alternatives.
7. Weigh costs/benefits.
8. Focus on optimal returns—what will give you the most bang for the buck?
9. Ensure your staff can work with the new technologies.

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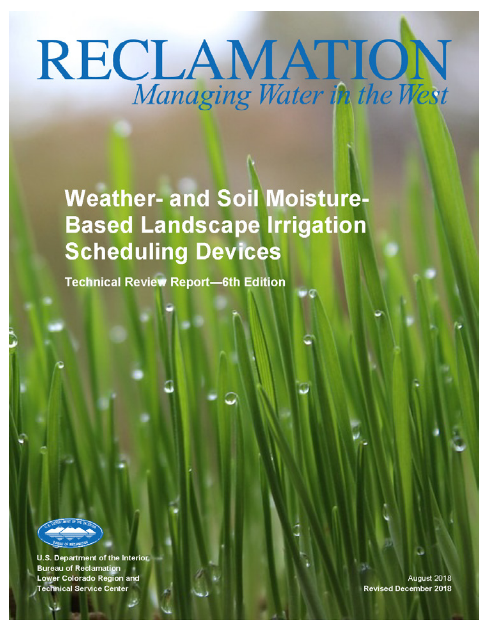
Smart Irrigation Systems

Smartcontrollers control a sprinkler system like a thermostat controls heating and cooling devices. The controller can determine how much water the sprinkler should deliver based on weather and/or soil moisture conditions. This can conserve water and reduce pollution from irrigation runoff.



Since 2004, Reclamation's Southern California Area Office has maintained a report on smartcontrollers. The updated 6th edition report, made available through the WaterSMART Website, provides technical background on smartcontrollers and how they function, as well as product information from 25 companies. The report also summarizes smartcontroller certification and testing processes and presents an unbiased overview of available products. Irrigation districts, water agencies, and others looking to increase their knowledge of smartcontrollers, or those interested in developing a smartcontroller incentivization program, might find the information within the report useful.

This report is available at:
www.usbr.gov/watersmart/docs/2018/6thEd_
WeatherSoilMoistureBasedLandscapeIrrigationSchedulingDevices_Dec2018.pdf