

- 3.9** Always calibrate application equipment, including manure spreaders, to uniformly apply the planned amount.
- 3.10** Develop realistic yield goals and maintain yield records.
- 3.11** Schedule fertilizer applications to avoid periods when irrigation is being done for purposes of leaching, plant cooling, or frost control.
- 3.12** Use nitrification inhibitors when applying ammonium forms of nitrogen. Nitrate-nitrogen is most susceptible to leaching losses.
- 3.13** Use slow-release nitrogen fertilizers.
- 3.14** Incorporate surface-applied fertilizers immediately to reduce volatilization. This is particularly important for urea and ammonium-based nitrogen fertilizers applied to alkaline soils. Also important for manure.
- 3.15** On sandy, porous soils subject to rapid leaching, avoid applying large amounts of nitrogen at preplant or early-season whenever possible. Apply smaller amounts as needed during the growing season.

Special considerations for manure applications

- 3.16** Test manure or other waste materials for nutrient content, and reduce additional nutrients applied accordingly.
References 19, 21, and 41
- 3.17** Do not apply manure to frozen ground, especially on sloping fields.

**Special considerations for fertigation
(application of fertilizers with irrigation)**

3.18 Analyze irrigation water for compatibility with fertilizer to be applied. Ammonia injection raises pH and possibly causes soluble calcium and magnesium to coat the inside of pipes and to plug emitters. For phosphorus fertilizers, if the water contains appreciable amounts of calcium, any form of phosphorus will precipitate and coat pipelines and emitters. This possibility can be checked by mixing irrigation water and chemicals at application concentrations and normal temperatures and looking for evidence of precipitation.

References 43 and 73

3.19 Use fertigation properly and in accordance with state regulations. In Oregon, OAR 690-215-017 covers requirements for fertigation/chemigation equipment.

ASAE Standard EP409.1

Reference 76

3.20 Design and maintain irrigation system for good application uniformity. See also 2.19–2.21.

ASAE Standard S298.1 for sprinkler testing

ASAE Standard EP419 for furrow systems

ASAE Standard S346 for center-pivots

Contact your local NRCS/SWCD office

References 15 and 40

OBJECTIVE 4 **Manage crop protection program to minimize leaching and runoff of chemical residues**

The primary factors that affect an agrichemical's fate are the pesticide properties (its ability to adhere to soil particles, the rate at which it breaks down, how easily it dissolves, and how much it vaporizes), soil properties, site conditions, and application practices. Applied pesticides may evaporate, be carried off the field attached to soil particles or in solution, be broken down into other substances, or be taken up by plants or insects as intended. The definition of "pesticide residue" is found in Oregon Administrative Rule (OAR) 340-109.

Effective crop protection while limiting chemical leaching and/or runoff requires a management program. A major practice cited below is Integrated Pest Management (IPM) or Integrated Crop Management (ICM). These terms refer to a collection of management practices that reduces the overall dependency upon synthetic chemicals and increases the effectiveness of those that are used. This encompasses such practices as crop rotation, effective scouting for pests and disease, use of natural biocontrols, soil tillage and conditioning, and irrigation management.

Of particular importance to irrigated agriculture is chemigation. Chemigation is the practice of applying chemicals by injecting them directly into the irrigation water. There are special federal and state requirements concerning the proper implementation of chemigation equipment. The EPA and State of Oregon require all pesticide applicators to be registered.

OAR 603-57

Reference 6

For a technical overview of chemigation, see Reference 73.

Overall good practices

- 4.1 Understand the solubility and movement properties of pesticides and fertilizers in the soil in order to assess the risk of contamination of ground and surface water supplies.
References 24 and 27
- 4.2 Practice Integrated Pest Management techniques where applicable. (Contact your county office of the OSU Extension Service.)
- 4.3 Schedule pesticide applications for maximum effectiveness.
- 4.4 Maintain good records of all chemicals purchased, applied, and in storage, as well as field surveys for pest populations.
References 6 and 37
- 4.5 Read and follow all label instructions.
Reference 36
- 4.6 Transport and store chemicals properly.
Reference 36
- 4.7 Load and mix pesticides properly. Record concentrations and rates of individual applications.
Reference 36
- 4.8 Store and dispose of used containers properly. (The Oregon Agricultural Chemicals and Fertilizers Association sponsors a pesticide container recycling program. Contact your dealer or the OACFA.)
- 4.9 Maintain equipment properly to reduce spills or leaks.

- 4.10 Clean equipment properly after use.
References 36, 47, and 76
- 4.11 Calibrate application equipment.
Reference 76

Special considerations for chemigation

- 4.12 Analyze irrigation water for compatibility with chemicals to be applied by chemigation.
- 4.13 Use chemigation safely and according to regulations.
ASAE Standard EP409.1
OAR 690-215-017
Reference 76

OBJECTIVE 5 Reduce contamination of surface water by sedimentation

Surface soil movement from irrigation, wind, or rainfall creates the potential for contamination by sedimentation. Sediment is itself a contaminant, and also can carry chemicals to surface water. It is therefore important to minimize erosion and surface movement (note that practices that reduce movement may increase deep percolation and leaching).

Methods to reduce in-field erosion

- 5.1 Use cover crops on unprotected soils that are easily eroded by wind or water.
- 5.2 Manage crop residues and/or soil stabilizing crops to increase surface roughness and infiltration, and to decrease surface movement by wind erosion.
SCS National Practices 328, 344, 354

- 5.3** Install straw mulch in row-crop furrows. This practice is of particular importance for furrow irrigation of easily erodible soils.

SCS National Practice 484

References 22, 56, 63, and 87

- 5.4** Use reduced tillage, such as paraplow systems.

SCS National Practice 329

- 5.5** Grade the land to optimize field slopes for improved irrigation uniformity and reduced runoff with furrow irrigation systems.

SCS National Practices 464, 466

- 5.6** Install tailwater drop structures to spread out erosive energy in steeply sloping terrain.

SCS National Practice 410

- 5.7** Install buried tailwater drops and collection pipes.

- 5.8** Properly design, install, and maintain surface drainage systems.

ASAE Standards EP302, EP407

- 5.9** For furrow irrigation of erodible soils, treat irrigation water with polyacrylamide (PAM), a chemical that reduces erosion.

Reference 63

Practices to treat sediment-laden runoff water

- 5.10** Install sedimentation basins.

ASAE Standard S442

SCS National Practice 350

- 5.11** Install vegetative buffering (filter) strips.

SCS National Practice 393

5.12 Collect and reuse surface runoff.

ASAE Standards EP408.1, 369.1

SCS National Practice 447

Reference 85

OBJECTIVE 6

**Prevent aquifer
contamination at wellhead**

Wells are a direct link from the surface to ground water. Aquifer contamination can occur because of movement of nutrients or other chemicals from the surface through or along the well. Activities near the wellhead may introduce contaminants to the well; therefore, those activities should be identified and curtailed.

The 1986 amendment to the federal Clean Water Act (CWA) requires each state to develop guidelines for wellhead protection for public water supplies. A wellhead protection area is defined as: "The surface and subsurface area surrounding a water well or wellfield supplying a public water system through which contaminants are likely to move toward and reach such water well or wellfield." The Oregon Department of Environmental Quality (ODEQ) is the lead agency for this program and is responsible for developing educational as well as technical guidelines (references 69 and 86).

Abandoned wells must be properly filled and capped so there is no path from the surface to the aquifer. The Oregon Department of Water Resources (OWRD) is responsible for developing well construction, maintenance, and abandonment requirements. Well construction and abandonment generally are covered by Oregon State law (*ORS 537.505, 537.772, 537.775*) and administrative rule (*OAR 690-220*).

Special considerations for well construction and maintenance

- 6.1 Properly design and construct irrigation wells.
ASAE Standard EP400.1
- 6.2 Construct wells properly where there is the possibility of cascading flows contaminating a lower aquifer.
- 6.3 Identify and properly seal all abandoned and improperly constructed wells.
ORS 537.772, 537.775
Reference 1
- 6.4 Prevent back siphonage/flow of chemicals or nutrients down a well during or after chemigation.
ASAE Standard EP409.1
OAR 690-215-017
Reference 76
- 6.5 Do not store, load, or mix chemicals near a wellhead or other vulnerable place.
Reference 86

Summary

Improved irrigation system hardware and management may result in greater *distribution uniformity* and improve the potential for higher application efficiency. It follows that distribution uniformity is the first concern when improving irrigation system performance.

However, achieving high *application efficiency* ultimately depends on the management of the system, that is, knowing **when** and **how much** to irrigate. Irrigation scheduling techniques greatly enhance the irrigator's ability to manage water applications. Furthermore, it

is necessary to properly maintain irrigation equipment so that system performance is dependable and predictable.

Proper management of fertilizers and agrichemicals will limit their availability for leaching or runoff losses possibly contaminating ground and surface water supplies. Maintaining and calibrating all application equipment and careful record keeping are critical to a good management program.

The application of fertilizers and pesticides through irrigation water (chemigation) can be an effective and efficient mode of application. There are, however, federal and state requirements that must be met when operating chemigation equipment. Irrigators also must consider the role of cultural practices in irrigation performance, nutrient and pesticide management, and soil erosion (especially on sloped fields and on fields susceptible to wind erosion).

Groundwater contamination also may occur at or near a wellhead. Chemicals should not be stored, loaded, or mixed near a wellhead. In addition, wells should be properly constructed, maintained, and, if necessary, abandoned as required by the State Water Resources Department of Oregon.

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Appendix A. Irrigation Scheduling

An irrigation scheduling program consists of four elements:

(1) knowledge of the soils and crop, (2) a method of measuring soil moisture status, (3) a means of measuring or estimating daily crop water use, and (4) an estimate of the application efficiency of your irrigation system. With this information, a water balance (or budget) may be established for a given field, and you will be able to apply the correct amount of water at the right time.

The soil and crop information required are: soil water holding capacity, mature crop rooting depth or root zone depth, and allowable depletion (the percent of water stored in the root zone that is allowed to deplete before irrigation is required). This information may be determined from field experience and/or obtained from other sources including, but not limited to references 31, 32, 40, 74, and 83; the *SCS Engineering Handbook*, Section 15, Chapter 2; or your OSU Extension agent.

An accurate yet economical means of measuring soil moisture in the crop root zone is essential. To help irrigators decide on the appropriate equipment, a recent Pacific Northwest Extension publication, PNW 475 (reference 31), reviews and compares several tools for measuring and monitoring soil moisture.

There are several means by which daily crop water use (evapotranspiration or ET) can be estimated or measured. For evaporation measurement on the farm, a standardized evaporation pan is used, and daily evaporation is related to crop ET by the crop coefficient (reference 32).

Secondly, weather data may be used to calculate daily crop ET by the Modified Penman or Blaney-Criddle methods. An OSU Extension publication, EM 8530 (reference 5), published in 1992, provides monthly estimates of crop water use and irrigation requirements in Oregon for each region and crop. These estimates were calculated using the Modified Blaney-Criddle method along with weather data compiled from 244 existing National Weather Service stations in Oregon.

In addition, several automatic weather stations have been installed throughout Oregon by the U.S. Bureau of Reclamation and Bonneville Power Administration, which collect weather data and transmit the data via satellite to Boise, Idaho, where daily ET is calculated for all important regional crops. This system is known as Agrimet. Current Oregon Agrimet station locations include: Forest Grove, Corvallis, Bandon, Medford, Madras, Hood River, Christmas Valley, Lakeview, Ontario, Prairie City, Echo, Hermiston Research and Experiment Station, and Hermiston (Boardman). Your OSU Extension agent or local experiment station can be of assistance in supplying further information. Or contact the U.S. Bureau of Reclamation Conservation Program Manager in Boise, Idaho.

In general, the application efficiency of an irrigation system depends on the type of system. Application efficiency results from the amount of control the irrigator has over the ultimate distribution of water. It follows that surface irrigation systems generally are less efficient than sprinkle and drip irrigation systems.

Several publications are available that give an estimate of application efficiencies for different system types (reference 83, *SCS National Engineering Handbook*, Section 15, Chapter 2). Equipment design and maintenance and water management also play an important part in application efficiency and cannot be neglected. See Appendix B for definitions of *application efficiency* and *distribution uniformity*.

Appendix B. Irrigation Performance Measures

There are various means of numerically describing irrigation performance. Two of these are *application efficiency* (E_a) and *distribution uniformity* (DU).

Application efficiency is defined as the ratio of the volume of irrigation water beneficially used to the volume of irrigation water applied. Beneficial uses include supplying water to crops, cooling, frost protection, and leaching to control salinity in the root zone.

Distribution uniformity is a measure of how evenly water infiltrates the ground across a field during irrigation. It is expressed as a percentage between 0 and 100 and is defined as the ratio of the average depth of infiltration in the quarter of the field that receives the least water to the average depth of infiltration for the whole field. Good distribution uniformity is essential for reducing deep percolation if the entire field is to be watered sufficiently.

Appendix C. Glossary of Terms

- Aquifer** A geological formation capable of yielding usable quantities of water to wells or springs.
- Application efficiency** (Ea) A measure of how much of the water applied to a field during an irrigation is beneficially used. Beneficial uses include crop evapotranspiration (ET), frost control, leaching for salt control, and cooling. See Appendix B.
- Best management practices** (BMP) A generic term referring to schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of ground or surface water.
- Calibrate** To check and adjust application equipment so that the desired application rate is achieved.
- Cascading flows** Movement of water from a high aquifer to a lower aquifer through well boreholes.
- Chemigation** The application of formulated liquids or solutions of pesticides, herbicides, fungicides, fertilizers, or other agents through the irrigation system.
- Clean Water Act** (CWA) A federal enactment (1972) seeking to maintain the chemical, physical, and biological integrity of the nation's waters. Administrative authority is given to the U.S. Environmental Protection Agency (EPA), and requirements are carried out by the Oregon Department of Environmental Quality. Section 319 covers nonpoint source pollution.

Cutback irrigation	Reducing the inflow rate of irrigated furrows after the completion of advance.
Deep percolation	The movement of soil water past the crop root zone.
Distribution uniformity	(DU) A measure of how evenly water is applied/infiltrated in a field during an irrigation.
Evapotranspiration	(ET) The sum total of plant transpiration and soil surface evaporation in a cropped field.
Fertigation	The application of fertilizers through the irrigation system.
Flume	A flow measurement structure for use with open channels.
Integrated pest management (IPM)	A combination of pesticide and non-pesticide methods to control pests. Methods include cultural practices; use of biological, physical, and genetic control agents; and the selective use of pesticides.
Irrigation scheduling	A generic term used to describe a family of methods/techniques that aids a farmer in deciding when to irrigate and how much water to apply.
Leaching	The movement of chemicals through soil with water.
Nonpoint source	(NPS) Pollution caused by diffuse sources that are not regulated as a point pollution source.
OACFA	Oregon Agricultural Chemical and Fertilizer Association.

Polyacrylamide (PAM)	A synthetic chemical that can be applied with irrigation water to reduce erosion by increasing soil cohesion and causing sediments to clump loosely together.
Root zone	The effective depth of crop roots in the soil from which water is extracted.
Soil stabilizing crops	Crops planted specifically to reduce movement of surface soils due to wind or water erosion.
Surge-flow	A technique employed with furrow irrigation to increase uniformity and to reduce runoff by intermittently introducing pulses of irrigation water into a furrow.
SWCD	Soil Water Conservation District.
Tailwater	Irrigation runoff from surface-irrigated fields.
Wellhead	The surface and subsurface area surrounding a water well or wellfield supplying a public water system through which contaminants are likely to move toward and reach such water well or wellfield.

Appendix D. Additional Resources

Oregon State University

Agricultural Experiment Station
Director's Office
Oregon State University
Strand Agricultural Hall
Corvallis, OR 97331
541-737-4251

Agricultural Chemistry
Oregon State University
Ag. and Life Sciences 1007
Attn: Extension Pesticide Coordinator
Corvallis, OR 97331
541-737-1811

Marshall English
Bioresource Engineering
Oregon State University
116 Gilmore Hall
Corvallis, OR 97331
541-737-6308

Publication Orders
Extension & Station Communications
Oregon State University
422 Kerr Administration
Corvallis, OR 97331
World Wide Web—<http://www.wagcomm.ads.orst.edu/>

Oregon State University Extension Service
Contact county agent

David Philbrick
Program Leader
OSU Extension Energy Program
Oregon State University
Batcheller Hall
Corvallis, OR 97331
541-737-3004

Richard Topielec
Extension Energy Agent
Union County Office
OSU Extension Service
10507 N. McAlister Rd.
La Grande, OR 97850
541-963-1010

Others

Mark Hansen
Chairman of Container Recycling Program
Wilbur Ellis Company
503-227-3525

Oregon Agricultural Chemicals and Fertilizers Association
(OACFA)
503-370-7024

Oregon Department of Agriculture
Plant Division, Agriculture Building
635 Capital Street NE
Salem, OR 97310
503-378-3776

Oregon Department of Environmental Quality
811 SW Sixth Ave.
Portland, OR 97204
503-229-5913

Oregon Water Resources Department
3850 Portland Road NE
Salem, OR 97310
541-378-3741

University of Idaho Cooperative Extension System
Moscow, ID 83843
208-885-6639

U.S. Bureau of Reclamation
Conservation Program Manager
1150 N. Curtis Rd.
Boise, ID 83706-1234
208-378-5280

U.S. Environmental Protection Agency
Region 10
1200 Sixth Ave.
Seattle, WA 98101
206-553-1200

U.S. Natural Resource Conservation Service (formerly
Soil Conservation Service). NRCS assistance is accessed
through local Conservation Districts (SWCD)

Washington State University Cooperative Extension
Pullman, WA 99164
509-335-2811



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This publication was produced and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914. Extension work is a cooperative program of Oregon State University, the U.S. Department of Agriculture, and Oregon counties.

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