**Western Irrigated Agriculture**

This data product summarizes the farm-structural characteristics for irrigated farms in the 17 Western States based on USDA's 2008 and 1998 Farm and Ranch Irrigation Surveys (FRIS) (see the Documentation for data sources and methods). The tables are grouped into 16 sections, ranging from total irrigation values (for all irrigated farms), to higher efficiency irrigation, to irrigated farms receiving financial/technical assistance designed to encourage onfarm water and energy conservation. All tables identify specific irrigation characteristics for four farm size classes, by State. For more details, see the Summary of Results. Files are organized by the following sets of tables. For details about the contents of each set, see below the set listing.

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**Documentation**

*Background*

Irrigation is critical to agriculture in the United States: nearly 55 percent of the value of all crops sold comes from irrigated farms accounting for only 30 percent of all harvested cropland (USDA/NASS, 2007 Census of Agriculture). In the process, agriculture accounts for over 80 percent of water consumed (i.e., withdrawn from surface- or groundwater sources and lost to the immediate water environment through evaporation, plant transpiration, incorporation in products or crops, or consumption by humans or livestock).

Irrigation is particularly important for agriculture in the Western United States, where irrigated farms accounted for 60 percent of all crop sales in 2008, and 75 percent of U.S. irrigated cropland acres. Farms in the 17 Western States use a wide variety of irrigation systems, about 36 percent of irrigated acres are irrigated with gravity-based systems (e.g., gated-pipe furrow systems or flooding entire fields) and 67 percent are irrigated with pressure-sprinkler systems (e.g., center-pivot sprinkler or drip/trickle systems). (Some acres are irrigated with both system types.) To improve irrigation efficiency, Federal and State agencies and local water management districts have provided financial and technical assistance to producers to improve water delivery on farms (such as the lining of open-ditch irrigation systems) and/or promote more efficient application technologies (such as low-pressure sprinkler irrigation systems). About 18 percent of irrigated farms in the West participated in these programs during 2003-08.

Most irrigated farms in the West are small farms (under $250,000 in annual sales), as are most farms that receive financial assistance to improve irrigation efficiency. But larger farms ($250,000 or more in annual sales) use the most irrigation water, and the largest 15 percent of irrigated farms ($500,000 or more in annual sales) account for 66 percent of total farm water applied in the West. Farm-size classes are defined to be consistent with the ERS farm typology (see Structure and Finances of U.S. Farms: Family Farm Report, July 2010) in place when the source data were collected. ERS has since revised its typology (see Updating the ERS Farm Typology, April 2013). Financial and technical assistance programs that target larger farms more heavily may conserve more water and better meet environmental and other policy objectives. For more details, see the Summary of Results.

*Data Source and Scope*

Data in the 158 tables highlight the structural characteristics of western irrigated agriculture across four farm-size classes based on data from USDA's 2008 Farm and Ranch Irrigation Survey (FRIS). Where available, the tables also have tabs with similar data from the 1998 FRIS.

Structural characteristics were summarized only for irrigated agriculture within the 17 contiguous Western States for several reasons. First, these States dominate irrigated agriculture in terms of the number of irrigated farms, as well as the extent of irrigated acreage, water use, and value of irrigated farm sales. Second, much of irrigated agriculture in the 31 Eastern States (while economically important regionally) occurs largely as supplemental irrigation, while in many parts of the West, crop production may not be an option without irrigation. In addition, while water reallocation can be a contentious issue across the U.S., it is especially so in the more arid western States.

The four farm-size classes used for this analysis were defined using "total farm sales" from the 2007 Census of Agriculture, carried over to FRIS (by observation). Farm-size classes are defined to be consistent with the ERS farm typology (see Structure and Finances of U.S. Farms: Family Farm Report, July 2010) in place when the data were collected. ERS has since revised its typology (see Updating the ERS Farm Typology, April 2013).

**Farm-size class definitions used to examine structural characteristics of irrigated agriculture**

| **Farm-size class (1 through 4)1 based on total farm sales** | **Corresponding ERS farm typology definition2** |
| --- | --- |
| 1 = Small ($0 to $99,000) | Includes ERS's retirement, residential/lifestyle, and lower sales/farming occupation groups |
| 2 = Medium ($100,000 to $249,999) | Medium sales, farming-occupation group |
| 3 = Large ($250,000 to $499,999) | Large family farm group |
| 4 = Largest ($500,000 and greater) | Very large family farm group |
| 1Farm-size classes were defined using the value of the total farm sales variable from the 2007 Census of Agriculture applied to the 2008 FRIS data (by observation). 2Nonfamily corporate farms could not be identified with FRIS data. For more information on the ERS farm typology, see Structure and Finances of U.S. Farms: Family Farm Report, July 2010. Source: USDA, Economic Research Service. | |
|  | |

*Methodology, Data Reliability, and Measures of Accuracy*

Sampled observations for FRIS were selected from irrigated farms and ranches identified in the 2007 Census of Agriculture (23,089 farm operations across all 50 States, with 6,769 farm operations from the 17 Western States). For a detailed explanation of FRIS sample design characteristics, coverage, statistical methodology, estimation, response rates, and reliability measures, see Appendices A and B for FRIS on the NASS website.

For this analysis, three additional data reliability issues deserve some attention. First, for each of the summary data tables, a cell value of "d" indicates "insufficient data for publication." Consistent with USDA/NASS data disclosure requirements for FRIS, summarized data could be published only if the summary statistic was based on five or more represented farms. For most summary tables, the FRIS sample size was more than sufficient across farm-size classes by State to meet this test. Disclosure "d" appears across farm-size classes for only a few summary tables, namely those tables summarizing a statistic for a subtopic area, like pumping (energy) costs by farm-size class for farms using gasoline rather than electricity to power well pumps.

Second, for such key variables as the number of irrigated farms, acres irrigated, and water applied (total and by water source), values by State for the "total" column in the appropriate summary tables are equivalent to values reported in the FRIS report for corresponding State-level summary tables. Thus, the summarized data tables present a farm-size "structural" view of irrigation characteristics reported in the FRIS report.

Third, for all data tables summarizing a weighted-average statistic, coefficient of variation (CV) statistics were computed by farm-size class and by State (and region). Coefficient of variation values were computed as [(standard error of the estimate divided by the estimate) x 100], and reported in the appropriate data tables using \* for CV < 25; \*\* for 25 < CV < 50; \*\*\* for 50 < CV < 100; and \*\*\*\* for CV > 100. For most summary tables, CV values across farm-size classes across the Western States were generally less than 25 and most often less than 50, indicating relatively low variability of irrigation characteristics within most farm-size classes.

**2008 FRIS irrigated farm numbers by farm-size class, 17 Western State**

| **FRIS sample results** | **Farm-size class 1 (small)** | **Farm-size class 2 (medium)** | **Farm-size class 3 (large)** | **Farm-size class 4 (largest)** | **Total/all farm-size classes** |
| --- | --- | --- | --- | --- | --- |
| Actual FRIS farm observations | 1,201 | 908 | 1,081 | 3,579 | 6,769 |
| NASS expanded (represented) farms | 97,667 | 20,260 | 14,026 | 23,893 | 155,846 |
|  | | | | | |

### *Reference Date*

This document was prepared on June 7, 2013.

# Summary of Results

A summary of the table findings are presented for the 2008 Farm and Ranch Irrigation Survey (FRIS):

1. [Aggregate Irrigated Farm Values by Farm Size](http://cmsv2.usda.net/data-products/western-irrigated-agriculture/summary-of-results/#section1)
2. [Weighted-Average Irrigated Farm-Size Statistics](http://cmsv2.usda.net/data-products/western-irrigated-agriculture/summary-of-results/#section2)
3. [Weighted-Average Farm Irrigation Costs by Farm Size](http://cmsv2.usda.net/data-products/western-irrigated-agriculture/summary-of-results/#section3)
4. [Irrigation Technologies by Farm Size](http://cmsv2.usda.net/data-products/western-irrigated-agriculture/summary-of-results/#section4)
5. [Higher-Efficiency Irrigation by Farm Size](http://cmsv2.usda.net/data-products/western-irrigated-agriculture/summary-of-results/#section5)
6. [Irrigation Water Management Practices by Farm Size](http://cmsv2.usda.net/data-products/western-irrigated-agriculture/summary-of-results/#section6)
7. [Barriers to Irrigation System Improvements by Farm Size](http://cmsv2.usda.net/data-products/western-irrigated-agriculture/summary-of-results/#section7)
8. [Producer Participation in Irrigation-Related Public Financial Assistance Programs by Farm Size](http://cmsv2.usda.net/data-products/western-irrigated-agriculture/summary-of-results/#section8)

### 1.  Aggregate Irrigated Farm Values by Farm Size (Tables 1-1 to 1-14)

**Irrigated farms (table 1-1).** Most irrigated farms in 2008 were small farms. Out of 156,000 irrigated farms (FRIS total expanded farms) in the Western States, 63 percent had less than $100,000 in total farm sales, while nearly 76 percent had sales of less than $250,000. Just less than 25 percent had farm sales greater than or equal to $250,000 and only 15 percent of irrigated farms had sales greater than or equal to $500,000. Utah and New Mexico had the largest share of small irrigated farms, both at 93 percent. States with a slightly higher share of larger irrigated farms were all in the Plains region, with a heavier dependence on groundwater use. Kansas, Nebraska, Oklahoma, Texas, North Dakota, and South Dakota show the highest percentage of larger farms with irrigation (Kansas, 63; Nebraska, 59; Oklahoma 41; Texas, 37; North Dakota, 64; and South Dakota, 43 percent). Irrigated farms in the West are generally larger (in terms of sales) than nonirrigated farms, averaging $1,427 per harvested acre versus $643 (NASS, 2007 Census of Agriculture).

**Total irrigated farm sales (table 1-2).** Of the $67.1 billion in 2007 farm sales (for 2008 FRIS irrigated farms in the West), 92 percent were from farms with sales above $250,000 and 85 percent from farms with sales above $500,000. Smaller irrigated farms (farm sales (FS) < $250,000) accounted for only 8 percent of total irrigated farm sales. These distributions were characteristic of most Western States, except Arizona and California, where 94-96 percent of farm sales were from larger irrigated farms (FS > $250,000). In Montana, Utah, and Wyoming, total farm sales are more uniformly distributed across the four farm-size classes. Overall, the largest 15 percent of irrigated farms in the West accounted for 85 percent of 2007 farm sales from irrigated farms. (For this FRIS data, only farm sales value was for 2007—all other FRIS statistics are for 2008.)

**Total farm acres, harvested cropland and pastureland acres (tables 1-3 to 1-5).** Over time, larger farms have accounted for increasing shares of total crop and pastureland acres on irrigated farms in the West. In 1998, larger irrigated farms (FS > $250,000) accounted for 56 percent of total farm acres on irrigated farms. But in 2008, larger irrigated farms accounted for 70 percent of total farm acres on irrigated farms. This farm concentration is evident across most of the western States, with exceptions for Colorado, Montana, New Mexico, Oregon, and Utah, where concentration has also occurred, but at a much slower pace. The largest concentration of farm acres for irrigated farms exists in Arizona, Kansas, Nevada, North Dakota, and Texas. Total farm acres for the larger irrigated farms range from 80-92 percent of farm acres for all irrigated farms within these States. Nearly 81 percent of harvested cropland acres held by irrigated farms are associated with the larger irrigated farms in the West. For Arizona, California, Washington, Kansas, North and South Dakota, and Texas, these percentages are slightly higher (92, 86, 84, 90, 92, 86, and 87 percent, respectively). Pastureland acres for irrigated farms have also become more concentrated within larger irrigated farms westwide (increasing from 52 percent in 1998 to 66 percent in 2008). In California, Kansas, Nevada, and Washington, larger irrigated farms hold decidedly more pastureland acres than the westwide average (at 93, 87, 89, and 81 percent, respectively).

**Total farm irrigated acres (tables 1-6 and 1-7).** Larger irrigated farms account for most irrigated acres in agricultural production. Of the 39.9 million 2008 FRIS irrigated acres in the West, 77 percent are associated with larger farms (FS > $250,000), while at least 61 percent are associated with the largest farms (FS > $500,000). For eight States, including Arizona, California, Kansas, Nebraska, North Dakota, Oklahoma, Texas, and Washington, larger irrigated farms account for a significant share of irrigated acres (ranging from 80-90 percent). For several States, smaller farm size classes (FS < $250,000) account for 50 percent or more of irrigated acres, including Montana and Wyoming at 51 percent, and Utah at 62 percent. As expected, similar results exist for harvested irrigated cropland acres across the western States.

**Total farm water applied (table 1-8).** Larger irrigated farms accounted for an even greater share of farm water use. Farms with sales above $250,000 accounted for 79 percent of the 71.8 million acre feet (maf) of total farm water applied by 2008 FRIS irrigated farms in the West. In addition, the 15.3 percent of largest irrigated farms (FS > $500,000) accounted for 66 percent of total farm water applied. Smaller irrigated farms (FS < $250,000), nearly 76 percent of all irrigated farms, accounted for only 21 percent of total farm water applied.

The share of farm water applied by larger irrigated farms is much more dramatic for eight States, including Arizona, California, Kansas, Nebraska, North Dakota, Oklahoma, Texas, and Washington, where larger farms (FS > $250,000) account for 83-91 percent of total farm water applied. For these States alone, irrigated farms with sales above $500,000 (12 percent of all irrigated farms in the West) account for 47 percent of total farm water applied in the West (about 33.5 maf out of 71.9 maf).

In Utah and Wyoming, it is smaller irrigated farms (FS < $250,000) which account for a higher percentage of total farm water use—61 and 53 percent respectively.

#### Farm Water Applied by Source and Farm Size

**Total groundwater applied (table 1-9).** While groundwater accounted for only 48 percent of all farm water use westwide in 2008, nearly 88 percent of groundwater use was by larger irrigated farms (FS > $250,000), with 72 percent of all groundwater being applied by the largest farms (FS > $500,000). Smaller irrigated farms (76 percent of all irrigated farms) accounted for only 12 percent of groundwater use on irrigated farms across the West in 2008.

Groundwater-dependent States (dependent upon groundwater for at least half of their farm water use)—including Kansas, Nebraska, Oklahoma, New Mexico, Texas, and North Dakota—are not the States where the largest farms account for the greater groundwater-use shares. Rather, the heavily surface-water-dependent States—Arizona, California, Colorado, Idaho, and Washington—are the States where the largest farms account for the greater groundwater-use shares. About 85-91 percent of the groundwater use for each of these States was applied by the larger irrigated farms (FS > $250,000), which likely use groundwater as a supplemental water supply to support more extensive-margin irrigated agriculture.

**Total onfarm surface water applied (table 1-10).** While total surface water accounted for 52 percent of water use by farms westwide, onfarm surface water accounted for only about 14 percent in 2008. Onfarm surface water is relatively less important for larger farms than either groundwater or water from off-farm surface supplies. For the West, larger irrigated farms (FS > $250,000) accounted for 65 percent of onfarm surface water use, while farms with sales above $500,000 accounted for 52 percent. However, for Arizona and California, larger irrigated farms accounted for 88 and 82 percent of onfarm surface-water use. For both States, the largest irrigated farms (FS > $500,000) accounted for a significant share of onfarm surface-water use (85 and 75 percent). For Idaho, Kansas, Nebraska, Texas, and Washington, the share of onfarm surface water accounted for by larger irrigated farms is not as significant. However, even for these States, the shares are greater than 50 percent.

**Total off-farm surface water applied (table 1-11).** Westwide, off-farm surface water use (publicly supplied water) accounted for 38 percent of all farm water use in 2008. Water from publicly supplied off-farm sources is used more heavily by larger irrigated farms (FS > $250,000) than is water from onfarm surface sources. Larger irrigated farms accounted for 74 percent of off-farm surface-water use, while the largest farms (FS > $500,000) accounted for 64 percent. Again, larger irrigated farms in Arizona, California, Idaho, Oklahoma, Texas, and Washington accounted for the largest shares of off-farm surface-water use in 2008 (92, 89, 72, 87, 88, and 84 percent). Irrigation in Arizona, California, Idaho, and Washington together accounted for 62 percent of all off-farm (publicly supplied) surface-water use in the West.

#### Farm Irrigated Acres by Water Source and Farm Size

**Acres irrigated with groundwater (table 1-12).** Westwide, 61 percent of total farm-irrigated acres (24.3 million acres out of 39.9 million acres) were irrigated with some groundwater in 2008. Larger irrigated farms (FS > $250,000) account for 86 percent of such acres. For all Western States, larger irrigated farms dominate acres irrigated with groundwater. Larger irrigated farms in Arizona, California, Idaho, Kansas, Nebraska, North Dakota, Texas, and Washington account for the largest shares of groundwater-irrigated acres (ranging from 86-91 percent).

**Acres Irrigated with onfarm surface water (table 1-13)**. Westwide, 15.6 percent of total farm-irrigated acres (6.0 million acres out of 39.9 million acres) were irrigated with some water from an onfarm surface water supply in 2008. Larger irrigated farms account for the largest share of acres irrigated with onfarm surface water for 15 of the 17 western States. This is particularly true for Arizona, California, and Nebraska, where the larger irrigated farms account for 81-87 percent of irrigated acres using onfarm surface water. Smaller irrigated farms (FS < $250,000) account for the largest share of acres irrigated with onfarm surface water in New Mexico and Utah. Five States, including Kansas, New Mexico, Oklahoma, North Dakota, and South Dakota each irrigate less than 100,000 acres with water from onfarm surface-water sources.

**Acres irrigated with off-farm surface water (table 1-14).** For all Western States, 30 percent of total farm irrigated acres in 2008 (12.1 million acres out of 39.9 million acres) were irrigated with some water from an off-farm surface-water supply (generally publicly-supplied water). Larger irrigated farms in Arizona, California, Nebraska, North Dakota, Oklahoma, Texas, and Washington account for the largest shares of acres irrigated with off-farm publicly-supplied water (ranging from 80-91 percent). Smaller irrigated farms (FS < $250,000) account for the largest share of acres irrigated with off-farm surface water in Colorado, Montana, Utah, and Wyoming (ranging from 53-65 percent).

### 2.  Weighted-Average Irrigated Farm-Size Statistics (Tables 2-1 to 2-10; Tables 3-1 to 3-9)

**Value of 2007 farm sales per irrigated farm (table 2-1).** The average value of farm sales (2007) for FRIS irrigated farms was $430,236 per irrigated farm in the West. However, the westwide average is really not all that telling. The real story exists in average irrigated farm sales value across farm-size classes. About 63 percent of irrigated farms (those with FS < $100,000) had an average total farm sales value of $20,000 per irrigated farm in 2007, while 15 percent of irrigated farms (those with FS > $500,000) had an average total farm sales value of nearly $2.4 million per irrigated farm. By State, the average sales value per irrigated farm (for all farm-size classes) ranged from $92,100 for Utah to $748,600 for Oklahoma. For the smallest size class (FS < $100,000), average sales per irrigated farm ranged from $11,200 for Utah to $55,500 for Kansas. For the largest farms (FS > $500,000), average 2007 sales ranged from $1.1 million for Montana to $3.9 million for California. (Again, for this FRIS data, only farm sales value was for 2007—all other FRIS statistics are for 2008.)

**Total farm acres per irrigated farm (table 2-2).** For all Western States, the average acres per FRIS irrigated farm was 1,028 in 2008, ranging from 244 acres for the smallest farm size to 3,297 acres for the largest. For comparison, the 2007 Census of Agriculture reported average total farm acres for irrigated farms in the West at 904 acres, ranging from 304 acres in California to 2,735 acres in Wyoming. However, average farm acres from both sources include the influence of rangeland, that is, privately owned/leased pastureland and grazing lands. (The numbers exclude lands leased under a government grazing permit.)

Across States, average farm acreage in irrigated farms varies dramatically. For the smallest irrigated farms (FS < $100,000), average farm acres ranged from 92 acres for California to 979 acres for Wyoming in 2008. For the largest irrigated farms (FS > $500,000), average farm acres ranged from 1,350 acres for California to 23,258 acres for Nevada.

**Total irrigated acres per irrigated farm (table 2-3).** Irrigated acreage across the West averaged 256 acres per FRIS irrigated farm in 2008 versus 200 acres in the 2007 Census of Agriculture. FRIS size varies from an average 47 irrigated acres for the smallest irrigated farms (FS < $100,000) to 1,020 acres for the largest (FS > $500,000). Because statistics for farm irrigated acres remove the "rangeland" influence, the farm-size variability for average irrigated acres across States is more meaningful. For the smallest irrigated farms, average irrigated acres ranged from 27 acres for Arizona and New Mexico in 2008 to 137 acres for Wyoming. For the largest irrigated farms, average irrigated acres ranged from 628 acres for South Dakota to 2,057 acres for Nevada.

**Harvested cropland acres per irrigated farm (table 2-4).** With exceptions for Kansas, North and South Dakota, average harvested cropland acres per irrigated FRIS farm mirror fairly closely the effects of farm size on average irrigated acres per irrigated farm. Harvested cropland averaged 342 acres across the West in 2008, ranging from 44 acres for the smallest irrigated farms to 1,415 acres for the largest irrigated farms. Average harvested cropland acres also vary significantly across States, ranging from 89 acres per irrigated farm for Utah to 1,541 acres and 1,852 acres for Kansas and North Dakota in 2008. For the smallest size class, average harvested cropland acres per irrigated farm ranged from 20 acres for California and New Mexico to 253 acres for North Dakota. For the largest farms, average harvested cropland acres ranged from 677 acres for Utah to 3,300 acres for North Dakota.

#### Weighted Average Irrigated Acres by Water Source and Farm Size

**Groundwater irrigated acres per irrigated farm using groundwater (table 2-5).** Across the West, groundwater-irrigated acres averaged 357 acres per irrigated farm using groundwater in 2008, ranging from 46 acres for the smallest farm-size class to 897 acres for the largest. However, significant variability exists across States. For example, for the smallest size class (FS < $100,000), average groundwater-irrigated acres (for farms using groundwater) ranged from 15 acres for Oregon to 154 acres for Colorado. For the largest farm-size class (FS > $500,000) the average ranged from 374 acres for Wyoming to 1,494 acres for Arizona. For all the West, the average farm size in groundwater-irrigated acres is generally higher across size classes than for surface-water-irrigated acres. The exception here is the smaller farm-size classes. This difference likely reflects differences in economic efficiency requirements across water sources—groundwater irrigation is generally more expensive.

**Acres irrigated using onfarm surface water, per irrigated farm using onfarm surface water (table 2-6).** For all western States, farm acres irrigated with onfarm surface water averaged 165 acres per farm using onfarm surface water in 2008, ranging from 52 acres for the smallest size class to 510 acres for the largest. Again, significant variability exists across States. For the smallest size class (FS < $100,000), average per-farm acres irrigated with onfarm surface water ranged from 20 acres for Texas to 175 acres for Wyoming. For the largest class (FS > $500,000), average acres ranged from 160 acres for Nebraska to 1,772 acres for Nevada. Across the West, the average acres irrigated using onfarm surface water is less than the corresponding farm-size statistic for groundwater-irrigated acres. However, for several States, average acres irrigated with onfarm surface water are higher than average acres irrigated with groundwater. For these States —Nevada, Oregon, and Wyoming (with Wyoming being the more significant)—this difference in average farm size between groundwater- and onfarm surface-water-irrigated acres likely reflects a greater dependence on onfarm surface-water use for flood irrigation of hay and/or pastureland.

**Acres irrigated using off-farm surface water, per irrigated farm using off-farm surface water (table 2-7).** Average acreage irrigated using water from off-farm water suppliers (publicly supplied water) was 172 acres in 2008 across the West, ranging from 43 acres for the smallest farm-size class to 888 acres for the largest. Here, average acres for the smallest class (FS < $100,000) is less than the equivalent average for either groundwater or for onfarm surface water. At the same time, average acres using off-farm surface water for the largest farms (FS > $500,000) is greater than the equivalent average for onfarm surface water and near equivalent to the average for groundwater-irrigated acres. These results suggest that greater dependence on more expensive water (pumped groundwater or purchased off-farm water) likely promotes increased size for irrigated farms. Finally, average acres irrigated with off-farm surface water varied widely across States in 2008. For the smallest size class, the average ranged from 15 acres for California to 126 acres for South Dakota. For the largest class, the average ranged from 439 acres for Nebraska to 1,989 acres for New Mexico.

#### Weighted-Average Water-Use Statistics by Farm Size

**Total farm water applied per irrigated farm (table 2-8).** Total water applied per Western irrigated farm averaged 513 acre-feet in 2008. Water use ranged from 82 acre-feet for the smallest irrigated farms (FS < $100,000) to 3,268 acre-feet for the largest (FS > $500,000). For all size classes, Utah and New Mexico had the lowest applied water rates per farm, averaging 197 acre-feet per irrigated farm for Utah and 233 acre-feet for New Mexico, while Arizona had the highest rate at 2,240 acre-feet per irrigated farm. For the smallest farm-size class, total water applied ranged from 35 acre-feet per irrigated farm (Texas) to 275 acre-feet (Wyoming). For the largest size class, applied water ranged from 751 acre-feet per irrigated farm (South Dakota) to 11,454 acre-feet (Arizona). However, these averages reflect the greater degree of extensive-margin irrigation/water use typical of larger irrigated farms.

**Irrigation application rates--total and by water source (acre feet/acre) (tables 2-9 and 2-10; tables 3-1 to 3-9).** The largest irrigated farms (FS > $500,000) tend to be the more intensive-margin irrigation operations —that is, their average water application rates (acre-feet per acre) tend to be slightly greater. Irrigated farms in Arizona, California, Nevada, New Mexico, and Washington influence this result more so than irrigation in the other Western States. For all West, the average water application rate was 1.7 acre-feet per irrigated acre in 2008, 1.6 acre-feet for the smallest size class and 1.8 acre-feet for the largest. For all size classes, application rates varied significantly across States, ranging from 0.8 acre-feet per irrigated acre (Nebraska and South Dakota) to 4.6 acre-feet per acre (Arizona), reflecting differences in crops grown, climate, technologies, and water costs.

Across the West, intensive-margin water use tends to be greater for surface-water irrigation (particularly for water applied from off-farm sources). The application rate for groundwater averaged 1.4 acre-feet per acre in 2008, ranging from 1.4 acre-feet for the smallest farms to 1.5 acre-feet for the largest. The application rate for off-farm surface water averaged 2.3 acre-feet per acre, ranging from 1.7 acre-feet for the smallest farms to 2.6 acre-feet for the largest. Application rates for onfarm surface water generally fall between rates for groundwater and for off-farm surface water. So, barring consideration of crops irrigated (and all other factors), intensive-margin water-use statistics suggest that groundwater could be more efficiently applied than irrigation using surface-water sources. This is understandable, given that groundwater is generally the higher cost irrigation alternative.

### 3.  Weighted-Average Farm Irrigation Costs by Farm Size (Tables 3-10 and 3-11; Tables 4-1a to 4-6c; and Table 5-1)

**Purchased water costs ($/acre and $/acre foot ) (table 3-10 and 3-11).** Costs for publicly supplied water averaged about $53.04 per acre (or $23.52 per acre-foot) across the West in 2008. However, this average ranged from $26.02 per acre ($15.06 per acre-foot) for the smallest irrigated farms (FS < $100,000) to $71.07 per acre ($27.17 per acre-foot) for the largest (FS > $500,000). States range widely in their water costs, both in total and by size of farm. In addition, because of differences in applied water rates, the range of values for purchased water cost per acre differs from costs per acre-foot across States. Average purchased water costs (for all farm sizes) ranged from $8.49 per acre for South Dakota (or $4.66 per acre-foot for Wyoming) to $122.54 per acre for Arizona (or $70.44 per acre-foot for Oklahoma). For the smallest farm-size class, average purchased water costs ranged from $8.63 per acre for Texas (or $6.48 per acre-foot for Wyoming) to $77.91 per acre for Arizona (or $39.84 per acre-foot for California). For the largest irrigated farms, purchased water costs ranged from $4.77 per acre for South Dakota (or $3.04 per acre-foot for Wyoming) to $126.62 per acre for Arizona (or $83.83 per acre-foot for Oklahoma).

**Irrigation energy (pumping) costs; total and by energy source ($ per acre) (Table 4-1a to 4-6c).** Field-level irrigation water is generally delivered and/or applied using either a gravity-based system or a pressurized system (which uses a pump). Irrigation pumping costs vary by the energy source used to power the pump (electric, natural gas, diesel fuel, gasoline, or use of LP gas, propane, or butane). For the West, irrigation pumping costs across all energy sources averaged about $63.37 per acre in 2008, ranging from $48.18 per acre for the smallest irrigated farms (FS < $100,000) to $67.70 per acre for the largest (FS > $500,000). These costs also vary across States, ranging from $18.50 per acre (South Dakota) to about $102.00 per acre (Texas and Arizona). Variability in average pumping costs is greater for smaller than for the largest irrigated farms. For example, average pumping costs (across all energy sources) for the smallest size class ranged from $21.86 per acre for South Dakota to $144.06 for Arizona. For the largest size class, average pumping costs ranged from $16.73 per acre for South Dakota to $105.75 for Texas.

For 2008, average irrigation pumping costs vary across power sources, but are relatively uniform across farm sizes for all power sources except for natural gas, and for LP gas, propane, or butane. For these power sources, pumping costs for larger farms were as much as $18 − $20 higher than for smaller irrigated farms. Westwide, for 2008, wells or pumps powered by natural gas were the higher cost source for irrigation pumping, averaging $91.08 per acre (compared with $57.30 for electricity, $69.31 for diesel fuel, $67.66 for gasoline, and $46.18 for LP gas, propane, and butane). However, pumping costs for natural gas powered pumps ranged from $75.75 per acre for the smallest farms (FS < $100,000) to $94.90 for the largest (FS > $500,000). Pumping costs for other power sources are relatively uniform across farm sizes throughout the West, with the smallest differences by size class for electric-powered pumps.

Pumps powered by electricity were, by a significant margin, the dominant power source for wells and/or pumps across farm-size classes in 2008. Nearly 78 percent of Western irrigation pumps used electricity: 90 percent for the smallest farms and 74.2 percent for the largest. Electric pumping costs vary significantly across States by farm size. For the smallest farms, pumping costs ranged from $15.84 per acre (South Dakota) to $127.73 (Arizona). For the largest farms, pumping costs ranged from $16.15 per acre (South Dakota) to $100.56 per acre (Arizona).

Pumps powered using natural gas accounted for 9.0 percent of all irrigation pumps westwide in 2008, with pumping costs for the smallest farms (FS < $100,000) ranging from $66.97 per acre for Texas to $96.13 per acre for Oklahoma. For the largest farm-size class, pumping costs using natural gas ranged from $30.91 per acre for New Mexico to $154.94 per acre for Arizona.

Pumps powered using LP gas, propane, or butane accounted for less than 1 percent of all irrigation pumps in the West in 2008. Pumping costs for the smallest farms using this energy source averaged $29.75 per acre westwide. For the largest class of farms, these pumping costs ranged from $19.92 per acre (Oklahoma) to $189.76 per acre (Washington).

Pumps powered using diesel fuel accounted for 11.2 percent of all irrigation pumps westwide in 2008. Pumping costs for the smallest farms using this energy source ranged from $19.31 per acre (Wyoming) to $121.71 per acre (Oklahoma). For the largest farms, these average costs ranged from $22.13 per acre (South Dakota) to $190.03 per acre (Nevada).

Pumps powered using gasoline also accounted for less than 1 percent of all western irrigation pumps in 2008. Among the smallest farms, pumping costs for this energy source averaged $25.84 per acre; while averaging $135.30 per acre for the largest farms.

**Irrigation maintenance and repair costs ($ per acre) (Table 5-1).** Irrigation maintenance and repair costs averaged $18.35 per acre across the West in 2008. While these costs are relatively uniform across farm size, they do vary significantly across States. For the smallest farms (FS < $100,000), irrigation maintenance and repair costs ranged from $4.88 per acre (Nebraska) to $48.73 per acre (Arizona). For the largest farms (FS > $500,000), average irrigation maintenance and repair costs ranged from $5.10 per acre (Wyoming) to $29.21 per acre (Washington).

### 4.  Irrigation Technologies by Farm Size (Tables 6-1 to 6-13; Tables 7-1 to 7-16; and Table 10-1)

Sprinkler and gravity irrigation (farm numbers and acres irrigated). The 2008 FRIS identifies acres irrigated for four broad irrigation system/technology categories: gravity-based systems, sprinkler systems, drip/trickle systems, and subirrigation systems. FRIS also identifies irrigated acres that have been laser-leveled. Gravity irrigation technology can be subdivided into four field water-application systems: water applied through furrow-gravity application, between borders or within basins, uncontrolled flooding, and "other" gravity systems. In addition, gravity-based field-application systems can be characterized by multiple field-level water-conveyance (delivery) methods: lined or unlined open-surface ditch delivery, underground pipe delivery, and above-ground pipe (including gated-pipe) delivery.

Sprinkler irrigation technology can be subdivided across low-, medium-, and high-pressure sprinkler irrigation for center-pivot and linear-move systems, and into side-roll, wheel-move, or "other" mechanical-move systems. Low-pressure sprinkler systems operate with an average water pressure under 30 pounds per square inch (PSI), while medium-pressure systems range from 30 to 59 PSI and high-pressure systems rate 60 PSI or greater. In addition, sprinkler technology can be identified for hand-move systems and for solid-set or permanent systems.

Drip/trickle irrigation technology includes surface and subsurface drip, and low-flow micro-sprinkler systems. Subirrigation technology involves the use of a water delivery or drainage system designed to maintain the aquifer water table at a predetermined depth (within the crop root zone). Laser-leveled irrigation involves grading and earthmoving to eliminate variation in field gradient using a laser-guided system. Laser-leveling helps control water advance through the field and improves uniformity of water distribution. For a more detailed explanation of irrigation technologies, see the ERS Irrigation Glossary at: [http://webarchives.cdlib.org/sw1rf5mh0k/http://www.ers.usda.gov/Briefing/WaterUse/glossary.htm](http://webarchives.cdlib.org/sw1rf5mh0k/http:/www.ers.usda.gov/Briefing/WaterUse/glossary.htm).

FRIS data indicates that a different story exists when looking at the number of farms using particular irrigation technologies versus the irrigated acres associated with these technologies. Across all technology classes, smaller farms (FS < $250,000) dominate in the total number of farms for each technology class across the West. This should not come as a surprise, since most irrigated farms are small farms. Smaller irrigated farms represent about 69 percent of all irrigated farms using a sprinkler irrigation system, 77 percent of farms using a gravity system, 78 percent of farms using drip/trickle irrigation, and 91 percent of farms using subirrigation. However, larger farms tend to irrigate more acres by technology type, especially for pressurized irrigation technologies.

For sprinkler irrigated acres in the West, 82 percent were irrigated by larger farms (FS > $250,000) in 2008, with 65 percent irrigated by the largest farms alone (FS > $500,000). Across States, the share of sprinkler irrigation by larger farms (FS >$250,000) ranged from 44 percent (Utah) to 92 percent (Kansas).

For drip/trickle irrigation, 86 percent of all drip/trickle acres were irrigated by larger farms, with 79 percent irrigated by the largest farms (FS> $500,000). By State, the share of drip/trickle acres irrigated by larger farms (FS >$250,000) ranged from 67 percent (Kansas) to 86 percent (for Arizona and California). Across all farm-size classes, about 82 percent of drip/trickle-irrigated acres are in California (2.2 million out of 2.7 million acres westwide). Within California, 80 percent of drip/trickle-irrigated acres are on the largest irrigated farms (FS > $500,000).

For gravity and subirrigation systems, the structural distributions are somewhat different. Here, acres irrigated for the West are less skewed toward larger farms (FS >$250,000), particularly for flood-irrigated acres. For furrow gravity systemswestwide, the acres-irrigated only moderately favors larger farms, at 75 percent. Across States, however, this share ranges from 30 percent for Utah to 90 and 94 percent for California and Arizona, respectively. For furrow gravity systems, five States—Colorado, Idaho, Montana, Utah, and Wyoming—have acreage distributions favoring smaller farms (FS < $250,000). But these States account for only 15 percent of furrow gravity acres irrigated in the West.

For flood irrigation systems, the acres irrigated only slightly favors larger farms, at 62 percent. For Arizona, California, Kansas, and Texas, larger farms (FS > $250,000) accounted for more than 75 percent of flood irrigated acres. For Arizona and California, this percentage increases to more than 90 percent for larger irrigated farms. However, in 7 of the 17 Western States, smaller farms accounted for a higher share of flood irrigated acres than do larger farms—Colorado, Idaho, Montana, New Mexico, Oregon, South Dakota, and Utah—these States account for 43 percent of flood-irrigated acres in the West. Smaller-farm shares ranged from 13-14 percent for Arizona, California, and Washington to 83 percent for South Dakota and nearly 70 percent for Utah.

For sub-irrigation systems across the West, acres irrigated with these systems are slightly skewed toward larger farms (FS > $250,000) at 63 percent. However, across States, shares by farm-size are not able to be estimated due to disclosure criteria. Three States alone—California, Idaho, and Montana—account for 87 percent of subirrigated acres.

For laser-leveled irrigated acres (10-1), the westwide distribution again favors larger farms (FS> $250,000), which account for 83 percent of these acres. The largest farm-size class (FS > $500,000) accounts for 72 percent of laser-leveled, gravity-irrigated acres westwide. Across States, the share for larger farms (FS > $250,000) ranges from 46 percent for Idaho to 100 percent for Nebraska. Only three Western States—Colorado, Idaho, and Utah—have distributions favoring smaller farms. These three States combined account for only 6 percent of all laser-leveled irrigated acres across the West.

### 5.  Higher-Efficiency Irrigation by Farm Size (Tables 6-1 to 6-13; Tables 7-1 to 7-16; Tables 11-1 to 11-4; and Tables 12-1 to 12-9)

Farm-level irrigation technologies vary widely in their efficiency potential. Irrigation application efficiency here refers to the relative amount of applied water that gets taken up through plant consumptive-use—in general, the ratio of plant consumptive-use to actual water applied. Uncontrolled flood irrigation is widely recognized as the least efficient irrigation system, generally below 50 percent but potentially as low as 35 percent (Negri and Hanchar, 1989). In general, gravity-based irrigation efficiencies range from 35 to 80/85 percent, with higher efficiencies for improved gravity systems. These improved systems may involve distributing water across a field using furrows, between borders, or within a basin, in combination with a lined or piped field water-delivery system, cablegation or surge-flow water application, or with the use of gravity water-management practices, such as use of tailwater reuse pits, furrow-diking, alternate-row irrigation, or limited-irrigation set times. Pressure or sprinkler-based system efficiencies range from 50 to 90/95 percent, with low-pressure systems, low-energy precision application (LEPA), and drip/trickle systems capable of efficiencies as high as 85-95 percent. The higher the irrigation-application efficiency, the more onfarm water-conserving the irrigation technology tends to be.

FRIS acres irrigated by technology were used to structure "higher efficiency" irrigation technology classes, separately for pressure-based sprinkler irrigation and for gravity irrigation. For both of these classes, acres irrigated across irrigation technology subcategories were summarized for three different levels (or definitions) of a "higher efficiency" technology class. The purpose of the three alternative definitions is to provide a likely estimate of a relative range of "higher efficiency" irrigation across the 17 Western States.

#### Higher-Efficiency Pressure/Sprinkler Irrigation by Farm Size (Tables 7-1 to 7-16; Tables 11-1 to 11-4)

More efficient pressure-irrigation definition (1) includes only acres irrigated with drip/trickle systems, accounting for about 2.7 million acres westwide in 2008. Under this definition, smaller irrigated farms (FS < $250,000) which make up nearly 76 percent of all irrigated farms across the West, account for only 10 percent of the higher efficiency irrigation (drip/trickle irrigated acres) in the West. Slightly more than 78 percent of drip/trickle-irrigated acres (or 2.1 million acres) are irrigated by the largest farms (FS > $500,000). However, drip/trickle-irrigated acres accounted for only 12 percent of all pressure-sprinkler-irrigated acres for the largest irrigated farms. In addition, under definition (1), higher efficiency pressure irrigation accounted for only 10 percent of all pressurized irrigation in the West.

More efficient pressure-irrigation definition (2) includes acres irrigated with low-pressure sprinkler irrigation systems (those operating with PSI < 30) and acres irrigated with drip/trickle systems. Expanding the scope of the "efficient irrigation" definition to include low-pressure sprinkler systems increases these irrigated acres westwide to about 14.1 million irrigated acres, accounting for 52.6 percent of all pressure-irrigated acres in the West. Again, about 87 percent of these acres westwide (or 12.2 million acres) are irrigated by the larger irrigated farms (FS > $250,000). Under definition 2, the "higher-efficiency" irrigation rating for smaller irrigated farms (FS < $250,000) averages about 39.7 percent, while for larger irrigated farms (FS > $250,000) the rating averages about 55.4 percent of all pressure-irrigated acres. Westwide, this "efficient irrigation" definition accounts for just 35 percent of all farm-irrigated acres.  
  
More efficient pressure-irrigation definition (3) includes all low- and medium-pressure-sprinkler irrigated acres (for systems operating with a PSI < 60) and acres irrigated with drip/trickle systems. While this is a relatively "broad" definition, it does provide a reasonable estimate (based on FRIS data) of an "upper bound" for higher-efficiency pressurized irrigation in the West. This definition accounted for 21.9 million irrigated acres, or about 82 percent of all pressurized-irrigated acres westwide, and about 55 percent of all farm-irrigated acres westwide. Most of these acres (18.8 million acres, or 86 percent) are irrigated by larger irrigated farms (FS > $250,000). However, even given this skewed distribution, the higher-efficiency irrigation rating for the smaller irrigated farms (FS < $250,000) averages 65.8 percent, while for larger irrigated farms (FS > $250,000) the rating averages about 85.5 percent of all pressure sprinkler-irrigated acres.

In summary, based on 2008 FRIS data and given the alternative efficient irrigation definitions, "higher-efficiency" pressure-sprinkler irrigation in the West likely ranges between 53 percent (definition 2) and 82 percent (definition 3) across all irrigated farms. The irrigation efficiency rating for definition 2 likely represents a reasonable lower-bound estimate. However, the efficiency rating for definition 3 as the upper bound could be too broad. Even so, FRIS irrigation technology data imply that room likely still exists for conservation improvement in irrigation water-use efficiency across pressure sprinkler-irrigated agriculture in the West. Across farm-size classes, the relative improvement "potential" is slightly greater for smaller irrigated farms (FS < $250,000) than for larger farms (FS > $250,000)—as much as 60 and 45 percent, respectively, when based on efficient irrigation definition (2). However, larger irrigated farms irrigate many more acres, so the conservation effect could be much greater for these farms.

#### Higher-Efficiency Gravity Irrigation by Farm Size (Tables 6-1 to 6-13; Tables 12-1 to 12-9)

More efficient gravity-irrigation definition (1) includes furrow gravity-irrigated acres involving the use of an above- or below-ground pipe or a lined open-ditch field water-delivery system. In other words, furrow gravity irrigation, in this case, is defined as "more efficient" because the irrigation system more efficiently delivers water to the field. Based on this definition, 38.9 percent of all gravity-irrigated acres across the West are defined as efficient or 5.7 million acres out of 14.6 million gravity-irrigated acres. Nearly 77 percent of these more efficient furrow-irrigated acres are on larger irrigated farms (FS > $250,000). In addition, for larger irrigated farms, efficient furrow-irrigated acres account for an average of 44.2 percent of all gravity-irrigated acres, compared with 27.5 percent for the smaller irrigated farms (FS < $250,000). Clearly then, given this definition, larger farms are likely more irrigation efficient on gravity-irrigated acres than are smaller gravity-irrigated farms.

More efficient gravity-irrigation definition (2) broadens the efficient gravity irrigation definition (1) to include gravity-irrigated acres for flood irrigation that occurs between borders or within basins, but limited to farms using laser-leveled acres and using a pipe or a lined open-ditch field water delivery system. Nearly 85 percent of these additional gravity-irrigated acres are with larger irrigated farms (FS > $250,000). Westwide, this definition of efficient gravity irrigation still accounts for only 45.4 percent of all gravity-irrigated acres (6.6 million acres out of 14.6 million acres). In addition, the overall higher-efficiency irrigation rating increases to 52.4 percent for larger irrigated farms, while remaining just under 32 percent for the smallest irrigated farms. Clearly, the addition of laser-leveled flood-irrigated acres—with its higher capital costs— had a greater impact on larger irrigated farms than on smaller farms.

More efficient gravity-irrigation definition (3) further broadens the efficient gravity irrigation definition (1) to include all flood-irrigated acres supplied with water by an above- or below-ground pipe or a lined open-ditch field water delivery system. While definition (2) restricts the additional efficient gravity irrigation to flood-irrigated acres associated with farms using laser-leveling technology, definition (3) includes all flood irrigation associated with acres irrigated using a pipe or lined open-ditch field water delivery system. Westwide, definition (3) includes an additional 2.6 million acres as "efficient" gravity irrigation, increasing the share of higher-efficiency gravity irrigation in the West to 56.7 percent (nearly 8.3 million irrigated acres out of 14.6 million acres). This efficiency rating for gravity irrigation remains much higher for the largest irrigated farms (63.9 percent) than for the smallest irrigated farms (41.1 percent).

In summary, based on 2008 FRIS data and given the alternative definitions for efficient gravity-irrigation, "higher-efficiency" gravity irrigation in the West could likely range from 39 to 57 percent. Efficient gravity definition (1) likely provides a reasonable lower-bound estimate. However, it is uncertain whether the better upper-bound estimate of higher-efficiency gravity irrigation is definition (2), definition (3), or somewhere between (2) and (3). Still, an estimated range of either 39 to 45 percent based on definition (2) or 39 to 57 percent based on definition (3) implies that considerable room exists for conservation improvement in irrigation water-use efficiency across gravity-irrigated agriculture in the West. Given the efficient gravity irrigation definition (2), the relative improvement "potential" for gravity irrigation is much greater for the smallest irrigated farms than for larger farms (68 percent versus 48 percent). The difference between higher-efficiency gravity irrigation and similar statistics for pressure-sprinkler irrigation is that gravity irrigation is generally more uniformly distributed across farm-size classes. Therefore, because smaller farms irrigate a significant share of gravity-irrigated acres in the West, a water conservation program that emphasizes improved gravity irrigation may promote a more uniform conservation effect across farm-size classes.

### 6.  Irrigation Water Management Practices by Farm Size (Tables 8-1 to 8-13; Tables 9-1 to 9-9; and Tables 13-1 to 13-13)

Two farm-level water management items in the 2008 FRIS further illustrate the potential for conservation improvement across farm-size classes for western irrigated agriculture. The first relates to the extent producers participate in gravity water management practices. The second item, relevant across all irrigated agriculture, addresses irrigation water management intensity, that is, the level at which producers apply water management at the intensive margin, or the degree of sophistication used in determining when to apply irrigation water for a given crop. Applying water when the crop requires it and only as much as the plant requires for crop consumptive use (excluding any salt leaching requirement) will significantly improve irrigation efficiency.

**Producer participation in gravity water-management practices (Table 8-1 to 8-13 and Tables 9-1 to 9-9).**For the 2008 FRIS, producers reported participating in up to ten gravity water management practices. Gravity-irrigated acres were reported for use of tailwater-reuse pits, surge-flow or cablegation irrigation, limited-irrigation techniques (that is, using limited irrigation set times and/or number of irrigations), alternate-row irrigation practices, water-soluble polyacrylamide, restricting runoff by diking end-of-field, shortened furrow length, use of mulch or other types of row cover, laser-leveling the field, and use of special furrow water management practices (including wide-spaced bed furrowing, compact furrowing, or furrow diking). Polyacrylamide (or PAM) is a water-soluble soil amendment that, when added to irrigation water, stabilizes soil and waterborne sediment. PAM reduces irrigation-induced soil erosion, enhances water infiltration, improves the uptake of nutrients and pesticides, reduces the need for furrow reshaping, and reduces the need for sediment control below the field.

Westwide, only about 52 percent of gravity-irrigated farms use one or more of the gravity water management practices. Larger irrigated farms apply these practices (65-69 percent) more frequently than do smaller farms (45-56 percent). In addition, relative to total gravity-irrigated acres, gravity irrigators have a low participation rate with any particular gravity water management practice (ranging from 1 percent for the use of mulch or other types of row cover to 16 percent for a laser-leveled field). Additionally, across the West, only 8 percent of gravity-irrigated acres use tailwater-reuse systems, about 2 percent use surge-flow or cablegation systems, 15 percent use limited-irrigation practices, 10 percent use alternate-row irrigation, 3 percent use PAM, 7 percent use special-furrow water management practices, and 15 percent use end-of-field diking. Low participation in these practices is consistent across farm-size classes, although larger irrigated farms generally account for at least 50 percent of the overall participation in onfarm water-management practices. These results suggest significant potential for conservation improvement with respect to gravity-irrigated agriculture in the West.

Farm-size distributions of gravity water management practices vary significantly across the Western States. In the case of tailwater-reuse pits, for example, in Arizona, California, Colorado, Nebraska, New Mexico, Texas, and Washington, larger irrigated farms (FS > $250,000) account for a significant share of gravity-irrigated acres using such recovery systems: 54-58 percent in Washington and Texas; 62-70 percent in Colorado and New Mexico; and 86-95 percent in Arizona and California. For Nevada, Utah, and Wyoming, smaller irrigated farms (FS < $250,000) account for a more significant share of gravity-irrigated acres using a tailwater-recovery system, ranging from 54 percent in Utah to 80 percent in Wyoming.

For surge-flow or cablegation systems, larger irrigated farms dominate in California, Arizona, Kansas, Nebraska, and Texas (ranging from 56 percent of acres irrigated with these systems for Texas to 100 percent for Arizona, California, and Kansas). Smaller irrigated farms account for the greater share of these systems on gravity-irrigated acreage in Utah.

Limited-irrigation practices (limiting irrigation set times and/or number of irrigations), together with the practice of end-of-field diking (discussed below), are the second most used gravity water-management practices (accounting for 15 percent, or 2.2 million acres out of 14.6 million gravity-irrigated acres). Larger irrigated farms dominate in the use of limited irrigation practices in Arizona, California, Kansas, Nebraska, Oklahoma, and Texas (ranging from 81 percent for Kansas to 95-100 percent for Texas and Oklahoma). Smaller irrigated farms dominate the use of limited-irrigation practices in Colorado, Idaho, Montana, New Mexico, Oregon, and Utah (ranging from 53 percent for Idaho to 77 percent for Montana and New Mexico).

Westwide, alternate-row irrigation is practiced on slightly less than 10 percent of gravity-irrigated acres. California, Nebraska, and Texas account for the largest shares of gravity-irrigated acres using this practice (16, 45, and 9 percent). Across the West, larger irrigated farms use this practice more extensively, except in Idaho, Utah, and Wyoming. In these States, smaller irrigated farms use this practice more extensively than do larger farms (ranging from 51 percent for Wyoming to more than 78 percent for Utah).

The dominant use of polyacrylamide (or PAM) occurs in Idaho, Washington, and California, where PAM accounts for 13, 32, and 2 percent of gravity-irrigated acres. These States account for 61 percent of all gravity-irrigated acres using PAM westwide (223,242 acres out of 368,918 acres). For Idaho, California, Oregon, Washington, and Wyoming, larger irrigated farms (FS > $250,000) are the dominant users of PAM (ranging from 55 percent for Idaho to 90 percent for Oregon and Washington, to 100 percent for California). Idaho, the State with the largest number of acres using PAM (100,579 acres out of 368,918 acres for the West), is also the only State where these acres are more uniformly distributed across farm-size classes.

Special furrowing practices involve the use of wide-spaced bed furrows, compacted furrows, and/or furrow diking. These practices reduce soil erosion and improve water infiltration. Westwide, about 7 percent of gravity-irrigated acres (or 1.0 million acres out of 14.6 million acres) use these practices. California, Colorado, Texas, and Wyoming account for 0.7 million acres, or 69 percent of the gravity-irrigated acres using these practices in the West. In these States, with the exception of Colorado, larger irrigated farms account for most of the acres on which these practices are used (ranging from 61 percent in Wyoming to 91 percent in California). For Colorado, Montana, Oregon, and Utah, smaller irrigated farms account for much of the acreage in these practices.

End-of-field diking is used to restrict field water runoff. In 2008, together with the application of limited-irrigation practices (discussed above), end-of-field diking was the second most-used gravity water management practice [accounting for 2.2 million acres (15.1 percent) out of 14.6 million gravity-irrigated acres] across the West.  Nearly 1.7 million acres (or 77 percent) using this practice are in Arizona, California, Nebraska, and Texas.  California alone accounted for nearly a million acres (44.4 percent of the acres in the West) using end-of-field diking.  Nearly 84 percent of the acres with end-of-field diking are on larger irrigated farms (FS > $250,000), likely because diking the end-of-fields is a fairly capital-intensive practice.

Mulch or other types of row cover are used to help reduce field evaporative losses.  This practice is used on only 207 thousand gravity-irrigated acres across the West (1.4 percent).  Most of the acres for this practice are in California and Nebraska (accounting for 58 percent).  Nearly 66 percent of the acres applying this practice are on larger irrigated farms (FS > $250,000).

Laser-leveled gravity-irrigated acres eliminates variation in field gradient ─ smoothing the field surface and often reducing field slope ─ to help control water advance and improve uniformity of soil saturation across the field.  Laser-leveling a field is the most frequently used gravity water-management practice. Nearly 2.4 million acres were laser-leveled across the West in 2008 (16.3 percent of all gravity-irrigated acres). Nearly 65 percent of these acres (1.5 million) were in Arizona and California ─ with California accounting for 1.2 million acres. More than 1.7 million of these acres were gravity-irrigated on the largest irrigated farms (FS > $500,000). Laser-leveling a field is capital intensive, so it is understandable that larger farms apply this practice more frequently than smaller farms.

**Producer decisions on irrigation water-management intensity (Tables 13-1 to 13-13).**FRIS reported information on irrigation water management intensity based on producer decisions on the use of practices that help determine when and how much water to apply to a crop. This information was available only on a "farm-level participation basis," not on an acreage basis. Therefore, the following summary results reflect the percentage of FRIS farms using alternative means of deciding when and by how much irrigation water to apply.

In general, the more conventional means of deciding onfarm irrigation decisions tend to prevail across the West. Both "observing the condition of the crop" and "feel-of-the-soil" are by far the dominant means used by irrigators. Nearly 72 percent of irrigated farms across the West simply observe the condition of the crop, and 42 percent judge irrigation water needs by just feeling the soil. The next level of reported water-management intensity involves using crop calendar schedules (used by 27 percent of irrigated farms) or simply applying water whenever it is delivered to the farm "in-turn" by the local water-supply organization (14 percent). Use of media reports on crop water needs or following the lead of one’s neighbor when making irrigation decisions are the two conventional means least used (applied by only 10 and 8 percent, respectively, of irrigated farms in the West).

With the exception of using media reports on crop water needs, all other conventional means of deciding when and how much to irrigate are heavily favored by smaller irrigated farms. Westwide, of the irrigated farms using "observed condition of the crop" as a means to making irrigation decisions, 72 percent are smaller farms (FS < $250,000), with the smallest farms (FS < $100,000) accounting for 57 percent. Likewise, smaller farms make up nearly 71 percent of the farms using "feel-of-the-soil," 87 percent of farms applying water when it is "delivered in-turn," and 81 percent of farms using a "crop calendar schedule." At the same time, even though use of "media reports on crop water needs" in the irrigation decision is uniformly distributed across farm-size classes, overall, less efficient means of onfarm water-management generally characterizes smaller irrigated farms (FS < $250,000) in the West.

Only about 17 percent of irrigated farms in the West use one or more modern means of deciding when and how much irrigation water to apply (including use of soil- and/or plant-moisture sensing devices, commercial irrigation scheduling services, and/or computer-based crop-growth simulation models). In addition, use of these more intensive water-management practices is relatively uniformly distributed between smaller and larger irrigated farms (55.4 and 44.6 percent). However, both the level of use and farm-size distributions varies significantly across these management-intensive means of making onfarm irrigation decisions.

Westwide, only 9 percent of irrigated farms reported using soil-moisture sensing devices. In aggregate, the farm-size distribution for this decision tool is relatively uniform between smaller and larger irrigated farms (51 and 49 percent). However, as a share of all irrigated farms, a slightly greater share of the larger irrigated farms (18 percent) use soil-moisture sensing devices than do smaller irrigated farms (6 percent).

Less than 3 percent of irrigated farms across the West used plant-moisture sensing devices to help determine when or how much to irrigate during the 2008 crop season. These farms were relatively uniformly distributed across farm-size classes, ranging from 44 percent among smaller farms and 56 percent among larger farms. However, nearly 50 percent of the irrigated farms using this practice in their irrigation decisions were from California.

Westwide, only about 9 percent of irrigated farms use commercial irrigation-scheduling services to decide on when or how much water to apply. Nearly 40 percent of the irrigated farms using these services are larger farms (FS > $250,000).

Computer-based crop-growth simulation models (the most management-intensive means of deciding when and how much to irrigate) are used by only 1.4 percent of irrigated farms in the West. However, 66 percent of the irrigated farms using such models are, surprisingly, smaller farms [with 59 percent among the smallest irrigated farms (FS < $100,000)]. One logical reason for this is that in a water-restricted environment, it becomes very important to be able to more efficiently manage a smaller water-right allocation.

In aggregate, irrigated farms in California, Kansas, and Nebraska make more extensive use of the more modern management-intensive means of deciding when and how much irrigation water to apply than do irrigated farms elsewhere in the West. Even so, for each of these more management-intensive decision tools, variability exists across States.

For "soil-moisture sensing devices," westwide distribution is relatively uniform between smaller and larger irrigated farms (51 versus 49 percent). In eight Western States irrigated farms using such devices are mostly smaller farms, with the shares for smaller farms within these States ranging from 51 percent for Montana to 84 percent for Utah. But, in nine States—Arizona, Colorado, Kansas, Nebraska, Nevada, North and South Dakota, Texas, and Wyoming—irrigated farms using soil-moisture sensing devices are generally larger farms, with shares for farms using these devices for these States ranging from 54 percent (South Dakota) to 90 percent (Arizona).

For "plant-moisture sensing devices," larger farms across the West account for the use of this irrigation decision tool only slightly more so (56 percent) than do smaller farms (44 percent). In nine States, more of the smaller farms used this decision tool than did larger farms, ranging from 51 percent (Colorado) to 100 percent (South Dakota and Wyoming). For eight of the Western States, larger irrigated farms were the dominate user of this decision tool, ranging from 57 percent for Arizona to 100 percent for Nebraska, New Mexico, North Dakota, and Oklahoma.

For irrigated farms using "commercial irrigation scheduling services," most are smaller farms (across eleven of the Western States), with shares ranging from 55 percent (South Dakota) to 88-92 percent (Montana and Wyoming). But in five States, irrigated farms that use an irrigation-scheduling service are generally larger farms, with shares for these farms ranging from 67 percent for Oklahoma to nearly 80 percent for Kansas and Texas.

For irrigated farms using "computer-based crop-growth simulation models," most are smaller farms (accounting for 66 percent of the farms using this practice) across the West. There are seven States —California, Idaho, Montana, Nebraska, Nevada, Oregon, and Utah—with smaller farm shares for this practice ranging from 55 percent (Nebraska) to 99 percent (Utah). But in nine States—Arizona, Colorado, Kansas, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, and Washington—most farms using this water-management practice are larger farms, with shares for these farms ranging from 55 percent for Washington to 100 percent for Arizona, Colorado, Oklahoma, and Texas.

Summary 2008 FRIS data indicate that less management-intensive/less water-use efficient means to decide when and how much irrigation water to apply still dominates much of Western irrigated agriculture. This inefficiency in onfarm irrigation water-management is particularly significant for smaller irrigated farms. Most irrigated farms use conventional means of deciding when and how much water to apply. Less than 17 percent of irrigated farms make use of the most water management-intensive/water-efficient means to irrigate. Even for the largest irrigated farms (FS > $500,000) less than 32 percent make use of the most modern means of deciding when and how much to irrigate. Again, there likely exists significant potential for water conservation improvement within irrigated agriculture across much of the West.

### 7.  Barriers to Irrigation System Improvements by Farm Size (Tables 15-1 to 15-9)

The relatively slow rate of change in the adoption of more efficient irrigation technology systems reflects the impact of barriers to farm-level irrigation system improvements. FRIS reports data on up to eight specific factors that restrict implementation of farm-level irrigation system improvements that might reduce energy and/or conserve water. FRIS producers were asked to identify all barriers that apply to their farm operation, including one or more of the following:

1. Have not investigated improvements  
2. Risk of reduced yield or poorer quality crop yield from not meeting water needs  
3. Physical field/crop conditions limit system improvements  
4. Improvement(s) will reduce costs, but not enough to cover installation costs  
5. Cannot finance improvements, even if they reduce costs  
6. Landlord(s) will not share in the cost of improvements  
7. Uncertainty about future availability of water, and  
8. Will not be farming this place long enough to justify new improvements.

Westwide, with the exception of "landlords not sharing in the cost of improvements," any other particular barrier to irrigation system improvement is generally more of a problem for smaller irrigated farms (FS < $250,000) than for larger irrigated farms (FS > $250,000). For example, 84 percent of the irrigators identifying "uncertainty about future water availability" as a barrier to irrigation system improvements were smaller irrigated farms. This small-farm predisposition to barriers ranges from 51 percent for "landlord will not share in the cost of improvements," to 87 percent for "cannot finance improvements." However, for farms identifying "lack of landlord participation in cost-sharing irrigation improvements," these farms were more uniformly distributed between smaller and larger farms (51 and 49 percent, respectively).

Across the West, three barriers to system improvements stand out as more important across all irrigated farms: "have not investigated improvements" (22 percent of FRIS irrigators); "improvement installation costs are greater than benefits," i.e., perceived benefits do not cover installation costs (17 percent); and "lack of financing ability" (19 percent). For smaller farm-size classes (FS < $250,000), these three barriers are more limiting for a greater number of farms than are all other barriers. For larger farms (FS > $250,000), the dominant perceived barriers to irrigation system improvements are "improvement installation costs are greater than benefits" and "investigating improvements were not a priority at the time" (accounting for 12 and 15 percent of larger farms, respectively).

In other words, lack of "perceived economic benefits" or "financing", and "not investigating the merits of system improvements" are the prominent barriers to irrigation system improvements across irrigated farms in the Western States. These results suggest a substantial conservation payoff from increased extension/education efforts on the economic merits of more efficient irrigation systems and from alternative private/public financing options, particularly for smaller irrigated farms. Such efforts could also help focus implementation of water conservation programs in meeting desired regional resource and small-farm policy objectives.

FRIS-listed barriers to irrigation system improvements are cited more often, almost universally across all Western States, by smaller irrigated farms than by larger irrigated farms. However, among larger irrigated farms there were several State-specific exceptions worth noting. First, in Nebraska, Nevada, and Texas, it was larger farms (FS > $250,000) more so than smaller farms (FS < $250,000) that were identified as being more concerned with the "risk of reduced yield or poorer quality yield from not meeting crop water needs" as a barrier to system improvements (60 percent for Nebraska, 62 percent for Texas, and 65 percent for Nevada). Second, of the farms reporting "physical field and/or crop conditions" as a barrier to irrigation system improvements, more larger farms recognized this barrier than did smaller farms in Nebraska (58 percent), Texas (71 percent), and Kansas (80 percent). Third, "economics of improvements" and "lack of financing" were concerns identified more with larger farms than with smaller farms in Oklahoma (54 percent) and Kansas (60 percent). Fourth, "uncertainty about future water supply" was a greater concern for larger farms than for smaller farms in only Washington (80 percent) and Oklahoma (87 percent). Finally, for a number of States (Arizona, California, Kansas, Nebraska, and Oklahoma), it was larger farms that were more concerned with the "lack of landlord participation in the sharing of improvement costs" (ranging from 63 percent for Oklahoma to 83 percent for California and Nebraska). However, for most Western States, FRIS information indicates that barriers to irrigation system improvements were identified more frequently by smaller irrigated farms than by larger farms.

### 8.  Producer Participation in Irrigation-Related Public Financial Assistance Programs by Farm Size (Tables 16-1 to 16-8)

The 2008 FRIS sheds insight into irrigation-improvement investments partially funded with public financial assistance across farm-size classes. However, FRIS information on farm participation in public financial assistance programs is available only on a "farm-level participation basis," not on an acreage basis.

Westwide, FRIS results indicate that only about 18 percent of irrigated farms participated in any public financial assistance program for irrigation or drainage improvements between 2003 and 2008. These conservation program participants were fairly evenly distributed between smaller irrigated farms (FS < $250,000) (at 54 percent) and larger farms (FS > $250,000) (at 46 percent). However, it is the smallest farms (FS < $100,000) (at 36 percent) and the largest farms (FS > $500,000) (at 31 percent) that are the more frequent financial assistance program participants.

Only in Kansas, Nebraska, North Dakota, and Texas did larger farms (FS > $250,000) participate significantly more frequently than smaller farms in public financial assistance programs for irrigation improvements (71, 64, 76, and 68 percent). The participation rate was nearly 50-50 between small and large irrigated farms for Arizona, California, Oklahoma, Oregon, and South Dakota. For the remaining Western States, smaller irrigated farms (FS < $250,000) accounted for a larger share of overall public financial assistance program participation (ranging from 67 percent for Nevada to 83 percent for New Mexico). For Nebraska, the largest irrigated State in 2008 (in terms of acres), public financial assistance program participation varied between smaller irrigated farms and larger farms by 36 and 64 percent, respectively.

Federal programs have accounted for a greater level of financial assistance program participation across the West (16.5 percent of FRIS farms) than have State and local water-management/water-supply districts (2.7 percent). Among Federal program participants, a greater share of farms (57.6 percent) participated in financial assistance programs through USDA (for example, EQIP) than participated (at 3.1 percent) through non-USDA Federal programs (for example, through Environmental Protection Agency or Bureau Of Reclamation). Of USDA program participants, 48.9 percent were smaller farms (FS < $250,000). Of non-USDA Federal program participants, 84 percent were smaller farms. Of irrigated farms participating in State and/or local financial assistance programs, 42 percent were smaller farms.

Westwide, while participation in USDA financial assistance programs for irrigation improvements have been fairly evenly distributed between smaller farms (48.9 percent) and larger farms (51.1 percent), the level of participation varies widely across Western States. Participation was relatively even between smaller and larger farms in Arizona, California, Colorado, Idaho, Oregon, South Dakota, and Utah. For five States (Montana, Nevada, New Mexico, Washington, and Wyoming) farms participating in USDA financial assistance programs for irrigation improvements were more frequently smaller farms (generally accounting for more than 60 percent of participating farms in those States). There were also five States (Kansas, Nebraska, North Dakota, Oklahoma, and Texas) where farms participating in USDA financial assistance programs for irrigation improvements were more frequently larger farms (generally accounting for 69-80 percent of participating farms in those States).