1987 Census of Agriculture

AC87-RS-1

Volume 3 RELATED SURVEYS

Part 1

Farm and Ranch Irrigation Survey (1988)



U.S. Department of Commerce BUREAU OF THE CENSUS

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If you have any questions concerning the statistics in this report, call: (301) 763-8555 Division Chief (301) 763-8560 Special Surveys Branch (301) 763-1113 General Information (301) 763-8558 Statistical Methodology

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Farm and Ranch Irrigation Survey (1988)

Issued May 1990



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PURPOSE AND SCOPE OF THE SURVEY

The 1988 Farm and Ranch Irrigation Survey was conducted to supplement the basic irrigation data collected from all farm and ranch operators in the 1987 Census of Agriculture. This survey was conducted to provide detailed data relating to on-farm irrigation practices without burdening all farm and ranch operators. These data include statistics on acres irrigated by category of land use, acres and yields of irrigated and nonirrigated crops, quantity of water applied and method of application to selected crops, acres irrigated and quantity of water used by source, acres irrigated by type of water distribution systems, and number of irrigation wells and pumps. Included also are irrigation expenditures in 1988 for maintenance and repair of irrigation equipment and facilities; purchase of energy for onfarm pumping of irrigation water; investment in irrigation equipment, facilities, and land improvement; and costs of water received from off-farm water suppliers.

Irrigation data from this survey and from the 1987 Census of Agriculture provide a relatively complete and detailed picture of irrigation in the conterminous United States.

The irrigators sampled for this survey were selected from irrigated farms and ranches identified in the 1987 Census of Agriculture excluding all irrigators in Alaska and Hawaii, also abnormal and horticultural speciality farms in the 48 conterminous States. Therefore, 25,782 irrigators were excluded from sample selection. Most of the excluded irrigated farms were horticultural speciality farms and accounted for 1,616,599 acres irrigated or 3.5 percent of the land irrigated in 1987.

In addition, results of the survey show that 13,272 irrigators in 1987 with 1.6 million acres irrigated discontinued irrigating for 1988. No attempt was made to identify and select new irrigators for 1988.

Selected irrigation data for on-farm irrigation have been collected in the census of agriculture since 1890. A census of farms reporting irrigation in the 1900 Census of Agriculture was authorized by Congress. Surveys of irrigation in humid areas were taken in connection with the 1954 and 1959 censuses. The 1988 Farm and Ranch Irrigation Survey is the third survey devoted entirely to the collection of on-farm irrigation for the conterminous United States. The 1979, 1984, and 1988 Farm and Ranch Irrigation Surveys collected similar data using similar methods and procedures of data collection and processing.

AUTHORITY AND AREA COVERED

The census of agriculture is authorized under the provisions of Title 13, United States Code. Section 182 authorizes the Secretary of Commerce to conduct surveys deemed necessary to furnish annual or other data on the subjects covered by the census. The 1988 Farm and Ranch Irrigation Survey was conducted under the provisions of this section.

FARM DEFINITION

Since 1850, when minimum criteria defining a farm for census purposes were first established, the farm definition has been changed nine times. The current definition is any place from which \$1,000 or more of agricultural products were produced and sold or normally would have been sold during the census year.

WATER RESOURCES AREAS MAP

The map shows water resources areas delineated on the basis of county boundaries that approximate actual basin boundaries based on topographic drainage characteristics. Data are tabulated separately for each of the 18 water resources areas shown on the map.

PERCENT OF NORMAL PRECIPITATION MAP

The map shows the areas of the conterminous United States where other than a normal amount of rain fell during 1988. This map is included for reference purposes only.

TABULAR PRESENTATION

Table 1 shows farms and acres irrigated for the censuses of 1964 through 1987 for each State summarized by census divisions and regions. Tables 2 through 24 present detailed irrigation data collected in the survey from irrigators who reported irrigated land in the 1987 Census of Agriculture, and who also irrigated in 1988. Table 25 presents data for farm operators who irrigated in 1987, but discontinued irrigation either temporarily or permanently in 1988 while continuing to operate a farm or ranch.

Tables 2 through 25 present data from the 1988 Farm and Ranch Irrigation Survey separately for each of the 27 principal irrigating States, all other States combined, and for each of the 18 water resources areas.

Additional text tables are shown in the General Explanations.

ELECTRONIC DATA DISSEMINATION

The 1988 Farm and Ranch Irrigation Survey data are available on computer tapes and diskettes. Agriculture census and historical farm and ranch irrigation survey data are not available on these tapes or diskettes. Separate files are available for 1987 Census of Agriculture data on tape, diskette, and CD-ROM. Computer tapes and diskettes are sold by the Customer Services Branch, Data User Services Division, Bureau of the Census, Washington, DC 20233 (telephone (301) 763-1400).

SPECIAL TABULATIONS

Custom designed tabulations can be developed to individual user specifications on a programming cost reimbursable basis. Inquiries about special tabulations should be directed to the Chief, Agriculture Division, Bureau of the Census, Washington, DC 20233.

CENSUS DISCLOSURE RULES

In keeping with the provisions of Title 13, United States Code, no data are published that would disclose the operation of an individual farm. However, the number of farms and ranches in a given size category or other classification is not considered a release of confidential information and is provided even though other information is withheld.

DEFINITIONS AND EXPLANATIONS

Definitions and explanations of selected terms used in the tables are further defined in the General Explanation.

ABBREVIATIONS AND SYMBOLS

The following abbreviations and symbols are used throughout the tables:

- Represents zero.
- (D) Withheld to avoid disclosing data for individual farms.
- (NA) Not available.
- (S) Withheld because estimate did not meet publication standards on the basis of either the response rate, (associated relative standard error) or a consistency review.
- (Z) Less than half the unit shown.
- cwt Hundredweight.
- WRA Water Resources Areas.

GENERAL EXPLANATION

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PLANNING AND DEVELOPMENT

Planning for the survey started in 1986 with a review of the two previous farm and ranch irrigation surveys. Letters were sent to individuals in water-related government organizations, industry, and academic positions to solicit their comments on questionnaire content and format. Presentations were made to several associations seeking their comments. All responses were reviewed and categorized to evaluate data collection feasibility and priority needs.

The same basic methods and procedures used in taking the 1984 Farm and Ranch Irrigation Survey were followed with the 1988 survey in order to maintain comparability and efficiency of data collection and processing. The 1988 sample size was increased to 19,324 irrigators selected, up from 16,546 irrigators selected in the 1984 survey to allow for publishing detailed data for an additional seven States. The content of the form was changed to include additional data such as number of times irrigation water was applied and the categories of acres irrigated by use of sprinkler system was expanded. Several data items included in the 1984 survey were eliminated or simplified.

METHOD OF ENUMERATION AND DATA COLLECTION

The 1988 Farm and Ranch Irrigation Survey was conducted by mail and supplemented by telephone calls to selected nonrespondents. A sample of 19,324 irrigators was mailed in January 1989. The initial mail packet included a report form, a transmittal letter requesting a prompt response, and a pamphlet explaining why the survey was being taken. The operators were asked to complete and mail the report form to the Bureau of the Census. The initial mailing was followed by four mail follow-ups between the second week of February and the first week of May. The first and third mail follow-ups consisted of a reminder letter, while the second and fourth follow-ups included report forms. Telephone calls were made at the conclusion of the enumeration period to all nonrespondents with large irrigated acreage as reported in the 1987 Census of Agriculture. Data collection was completed in June 1989 with a 78 percent response. For a description of the adjustment for nonresponse, see *Statistical Methodology*.

DATA PROCESSING

All report forms were reviewed prior to data keying to identify inconsistencies and to ensure that the data could be keyed. Major inconsistencies, incorrect entries, blank forms, and large irrigation cases were reviewed by statisticians and corrected before data keying. Data from each report form were processed through a detailed computer edit. The edit imputed missing data and made adjustments based on similar size farms within the same geographic area. Data entries of large magnitude and data items changed significantly in the computer edit process were again reviewed by statisticians.

Prior to publication, tabulated totals were reviewed to identify remaining inconsistencies and potential coverage problems. Comparisons were made to 1987 census data and other check data. Selected report forms were reviewed and problem entries were either verified or corrected.

COMPARABILITY OF DATA

Data users need to be aware that differences exist between the expanded results of the 1988 Farm and Ranch Irrigation Survey and published data from the 1987 Census of Agriculture. Some of these are:

1. The survey does not include irrigators in Alaska, Hawaii or horticultural speciality and abnormal farms in the 48 conterminous States. The effect of the excluded farms is:

	Irrigated farms	Acres irrigated
1987 U.S. totals Excluded from survey	291,628 25,782	46,386,201 1,616,599
survey	265,846	44,769,602

- 2. The survey includes data only for operators who irrigated in both 1987 and 1988. Operators in some areas, especially the Eastern States, irrigate intermittently according to moisture needs. Operators having irrigation capabilities may not irrigate depending on the amount of rainfall for a particular year or geographic area. The number of operators who irrigated in 1987 but discontinued irrigation in 1988, are tabulated in table 25 by reason of discontinuance.
- 3. Some operators reported that they had been misclassified as irrigators and did not irrigate in either 1987 or 1988.

An estimated 11,046 operators with 1,092,959 acres irrigated in 1987 were classified as irrigators in the 1987 census but reported that they did not irrigate in 1988 nor in 1987. In addition to errors in processing data, some operators misreported or misinterpreted the questions. Most of the operators misreporting irrigation in the 1987 census reported irrigation of small acreages of vegetables, fruits and nuts, tobacco, potatoes, or berries. Small amounts of water were applied to these crops at the time of transplanting.

- 4. Some respondents indicated that they had quit farming, retired, moved, gone bankrupt, etc., since 1987. After analytical review of the 1988 receipts, an estimated 13,272 operators accounting for 1,610,888 acres irrigated in 1987 were dropped from processing because they were no longer farming. Special care was taken with large cases to ensure that they were not erroneously dropped due to reorganization or name change rather than discontinuing agricultural operations.
- 5. New irrigators in 1988 (not included in the 1987 census) did not have a chance of being selected in the sample and, therefore, are excluded from the survey. It is believed that the impact of new irrigators is probably minimal. This conclusion is supported by comparisons between the 1982 and 1987 censuses which show little change in acres of irrigated cropland harvested.

When comparing the number of farms and irrigated acres between the 1988 survey and the 1987 census published U.S. totals, most of the differences are for operators reporting less than 100 acres irrigated. This is expected since the excluded horticultural farms average about 40 acres irrigated per farm and the other categories of discontinued or excluded irrigators generally are smaller than average irrigators. Table A shows acres irrigated in the 1988 survey (expanded) compared with U.S. totals from the 1987 census. The expanded survey accounts for 99.6 percent of all land reported as irrigated in the 1987 census and all irrigation characteristics associated with that land.

Table A.	Comparison of Irrigated Farms and Acres by
	Acres Irrigated: 1988 Survey With 1987 Cen-
	sus

	1988 survey (expanded)		
Item	Total	Percent of 1987 census totals	1987 published U.S. totals
Land irrigatedfarms	223,943	76.8	291,628
acres	46,199,161	99.6	46,386,201
1 to 9 acresfarms	38,523	47.3	81,551
acres	186.841	63.2	295.653
10 to 49 acresfarms acres	58,928	77.4	76,149
	1,406,863	77.5	1,815,521
50 to 99 acresfarms acres	28,998	85.3	33,993
	2,027,371	85.2	2,378,681
100 to 199 acres farms acres	33,083	88.8	37,235
	4,626,827	89.4	5,176,452
200 to 499 acres farms acres	40,517	99.8	40,614
	12,580,132	100.0	12,579,955
500 to 999 acres farms acres	16,573	107.7	15,389
	11,280,870	108.5	10,398,151
1,000 acres or morefarms	7,321	109.3	6,697
acres	14,090,257	102.5	13,741,788

DEFINITIONS AND EXPLANATIONS

This section provides definitions and explanations of selected items that are used on the report forms or in the tables. A facsimile of the 1988 Farm and Ranch Irrigation Survey report form is found in the appendix.

Water Resources Areas (WRA)

Data from the 1988 Farm and Ranch Irrigation Survey were tabulated by WRA. Boundaries of these areas are shown in figure 1 on page XIX. These boundaries are essentially the same as the water resources regions (WRR) as delineated and defined in the past by the U.S. Water Resources Council. The areas differ somewhat from the regions because of the method used for boundary delineation. Region boundaries are delineated on the basis of topographic drainage characteristics, whereas, areas are delineated on the basis of county boundaries which approximate actual drainage-basin boundaries.

Geographic descriptions of each water resources region that can be used to approximate the area included in each water resources area are:

01 New England Region— The drainage within the United States that ultimately discharges into the Bay of

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Fundy and the Atlantic Ocean. These points of discharge are located within and between Maine and Connecticut; Long Island Sound and the St. Francis River, a tributary of the St. Lawrence River.

02 Middle Atlantic Region—The drainage within the United States that ultimately discharges into the Atlantic Ocean, whose point of discharge is located within and between New York and Virginia, and the Richelieu River, a tributary of the St. Lawrence River.

03 South Atlantic-Gulf Region—The drainage that ultimately discharges into the Atlantic Ocean, whose point of discharge is located within and between North Carolina and Florida; and the Gulf of Mexico, whose point of discharge is located within and between Florida and Mississippi, including the Pearl River.

04 Great Lakes Region—The drainage within the United States that discharges into the Great Lakes system, including the Lakes' surfaces; and the St. Lawrence River as far east as, but excluding the Richelieu River.

05 Ohio Region—The drainage of the Ohio River, excluding that of the Tennessee River.

06 Tennessee Region—The drainage of the Tennessee River.

07 Upper Mississippi Region—The drainage of the Mississippi River above the mouth of the Ohio River, but excluding the drainage of the Missouri River above a point immediately below the mouth of the Gasconade River.

08 Lower Mississippi River—The drainage of the Mississippi River below the mouth of the Ohio River, but excluding the drainage of the Arkansas, White, and Red Rivers and above the points of highest backwater affects of the Mississippi River in those parts; and the coastal streams, other than the Mississippi River, that discharge into the Gulf of Mexico from the boundaries of, but excluding the Pearl and Sabine Rivers.

09 Souris-Red-Rainy Region—The drainage within the United States of the Souris, Red, and Rainy Rivers.

10 Missouri Region—The drainage within the United States of the Missouri River above a point immediately below the mouth of the Gasconade River and the Saskatchewan River.

11 Arkansas-White-Red Region—The drainage of the Arkansas River above the point of highest backwater affect of the Mississippi River, the Red River above the point of highest backwater affect of the Mississippi River, and the White River above the point of highest backwater affect of the Mississippi River near Peach Orchard Bluff, AR.

12 Texas-Gulf Region—The drainage that discharges into the Gulf of Mexico from and including Sabine Pass to, but excluding the Rio Grande and the Lower Rio Grande Valley.

13 Rio Grande Region—The drainage within the United States of the Rio Grande; the San Luis Valley, North Plains, San Augustine Plains, Mimbres, Estancia Jonado del Muerto, Tularosa, Salt, and various smaller closed basins; and the Lower Rio Grande Valley.

14 Upper Colorado Region—The drainage of the Colorado River above the Lee Ferry Compact Point, which is about 1 mile below the mouth of the Paria River; and the Great Divide closed basin.

15 Lower Colorado Region—The drainage within the United States of the Colorado River below the Lee Ferry Compact Point, which is about 1 mile below the mouth of the Paria River; the Rios Yaqui, Magdelena, Sonoita, and other lesser streams that ultimately discharge into the Gulf of California; and the Animas Valley, Wilcox Playa, El Dorado Valley, and other smaller closed basins.

16 Great Basin Region—The drainage of the Great Basin that ultimately discharges into Utah and Nevada.

17 Pacific-Northwest Region—The drainage within the United States that ultimately discharges into the Straits of Georgia and Juan de Fuca and the Pacific Ocean. The point of discharge is within Washington and Oregon, including the Columbia River.

18 California Region—The drainage within the United States that ultimately discharges into the Pacific Ocean, whose point of discharge is within California, which includes the Central Valley; and that portion of the Great Basin and other closed basins in California.

Irrigated Farms

Irrigated farms or ranches are those with any agricultural land irrigated in the specific calendar year. The acreage irrigated may vary from a very small portion of the total acreage in the farm or ranch to irrigation of all agricultural land in the farm or ranch.

Acres Irrigated

Acres irrigated are the acreage of agricultural land to which water was artificially applied by controlled means to include preplant, partial, supplemental, and semi-irrigation. Land flooded during high water periods was to be included as irrigation only if the water was diverted to agricultural land by dams, canals, or other works.

Sprinkler Irrigation

Sprinkler irrigation is divided into four areas to reflect current trends in irrigation. The center pivot method has by definition, high pressure delivery which has water at 60 psi or greater, low pressure is any system that uses water at less than 60 psi. The mechanical-move systems are classified as either low energy precision application (lepa) where the water is delivered below the leaf canopy or as all other.

On-Farm Surface Supply

On-farm surface supply is water from a surface source not controlled by a water supply organization. It includes sources such as streams, drainage ditches, lakes, ponds, and reservoirs on or adjacent to the operated land.

Off-Farm Water Supply

Off-farm water supply is water from off-farm water suppliers, such as the U.S. Bureau of Reclamation; irrigation districts; mutual, private, cooperative, or neighborhood ditches; commercial companies; or community water systems.

Acre-Feet of Water

An acre-foot of water is the quantity of water required to cover 1 acre to a depth of 1 foot. This is equivalent to 43,560 cubic feet or 325,850 gallons.

Flowing or Artesian Wells

Flowing or artesian wells are wells which flow freely and provide water used for irrigation without pumping. There were no provisions made on the report form to report flowing or artesian wells. Therefore, all of these wells had to be identified during the processing of the survey from remarks or other indications made by the respondent. Where respondents indicated a well was flowing or artesian and did not require pumping, it was classified to be free flowing.

All flowing or artesian wells were excluded from pumping data on tables 9 and 10. This should be taken under consideration when using data from these two tables.

Land in Farms

Acreage designated in the tables as "land in farms" consists primarily of agricultural land used for crops, pasture, or grazing. Also, it includes woodland and wasteland not actually under cultivation or used for pasture or grazing, provided it was part of the farm operator's total operations. Large acreages of woodland and wasteland held for nonagricultural purposes were deleted from individual reports during the processing operations. Land in farms is an operating unit concept that includes land owned and operated as well as land rented from others. Land used rent free was to be reported as land rented from others. All grazing land, except land used under government permits on a per-head basis, was included as "land in farms" provided it was part of a farm or ranch.

Total Cropland

Total cropland includes all harvested cropland, cropland used only for pasture or grazing, and other cropland.

Cropland Harvested

Cropland harvested is land from which crops were harvested or hay was cut; and land in orchards, citrus groves, vineyards, nurseries, and greenhouses. Land from which two or more crops were harvested was counted only once, even though there was more than one use of the land.

Cropland Used Only for Pasture or Grazing

Cropland used only for pasture or grazing is land used only for pasture or grazing that could have been used for crops without additional improvement. Included also was all cropland used for rotation pasture and land in government diversion programs that were pastured. However, cropland that was pastured before or after crops were harvested was to be included as harvested cropland rather than cropland for pasture or grazing.

Other Cropland

Other cropland includes cropland not harvested and not grazed which was used for cover crops, soil-improvement crops, land on which all crops failed, cultivated summer fallow, idle cropland, and land planted in crops that were to be harvested after the survey year.

Woodland

Woodland includes natural or planted woodlots or timber tracts, cutover and deforested land with young growth which has or will have value for wood products, land planted for Christmas tree production, and woodland pastured. Land covered by sagebrush or mesquite was to be reported as other pastureland and rangeland or other land.

Other Land

Other land includes land in house lots, barn lots, ponds, roads, and wasteland.

Market Value of Agricultural Products Sold

The market value of agricultural products sold represents the gross market value before taxes and production expenses of all agricultural products sold or removed from the place in 1987 regardless of who received the payment. It includes sales by the operator as well as the value of any shares received by partners, landlords, contractors, and others associated with the operation. The market value of agriculture products sold represents the sum of all crops including nursery products, and livestock and poultry and their products. It does not include income from farmrelated sources, such as customwork or agricultural services, or income from nonfarm sources. These data were taken from the 1987 Census of Agriculture report form for the sample survey respondents.

The market value of agricultural products sold in 1987 does not necessarily represent the sales from crops harvested in 1987. Data includes sales from crops produced in earlier years and excludes some crops produced in 1987, but held in storage and not sold in 1987. For crops sold through a co-op which made payments in several installments, only the total payments received in 1987 were to be reported.

Acres and Quantity Harvested

If two or more crops were harvested from the same land during the year, the acres would be counted for each crop. Therefore, the total acres of all crops harvested generally exceeds the acres of harvested cropland. The exception to this procedure is hay crops. When more than one cutting of hay was taken from the same acres, the acres were counted only once, but the quantity harvested included hay from all cuttings. For interplanted crops or "skip-row" crops, acres were to be reported according to the portion of the field occupied by each crop.

If a crop was planted but not harvested, the acreage was not to be reported as harvested. These acres were to be reported in the "land use" section under the appropriate cropland items — cropland used only for pasture or grazing or other cropland.

Acres of land in bearing and nonbearing orchards—citrus or other groves, vineyards, and nut trees—were to be reported as harvested cropland regardless of whether the crop was harvested or failed. However, abandoned orchards were to be reported as cropland idle, not as harvested cropland or for the individual crop acreage.

Crop Unit of Measurement

Respondents were instructed to report each crop in the same unit of measure in all areas. For example, corn for grain or seed was reported in bushels shelled, and rice was reported in hundredweight.

Farms by Standard Industrial Classification

Irrigated farms and ranches are classified by standard industrial classification (SIC), as described in the 1987 SIC Manual. This classification was designed to promote uniformity and comparability for statistical data collected by various agencies. An establishment (farm, ranch, nursery, greenhouse, etc.) primarily engaged in crop production (major group 01) or livestock production (major group 02) is classified in the three- or four-digit industry group which accounts for 50 percent or more of the total value of sales from agricultural products. If the total value of agricultural products sold by an establishment was less than 50 percent from a single four-digit industry, but 50 percent or more from the products of two or more four-digit industries within the same three-digit industry group, the establishment was classified in the miscellaneous industry of that industry group; otherwise, it was classified as a general crop farm in industry 0191 or a general livestock farm in industry 0291.

All farms in the 1987 census were classified by SIC. Classifications of irrigated farms by selected SIC groupings are shown in table 21. The SIC code was obtained from the 1987 Census of Agriculture report form for survey respondents.

Leading Irrigating States

For purposes of comparability with the 1984 Farm and Ranch Irrigation Survey a line has been added to each table showing, where available, irrigation data for the 17 Western States for 1984. These states are: Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming. Data are tabulated separately for each state.

In response to irrigation expansion in recent years in other States, separate data is being provided for Georgia, Illinois, Michigan, Minnesota, Mississippi, Missouri, and Wisconsin. Table B shows the 27 leading States in irrigated land according to the 1987 Census of Agriculture.

Abnormal Farms

Abnormal farms were not included in the survey universe. These are institutional farms, experimental and research farms, and Indian reservations. Institutional farms include those operated by hospitals, penitentiaries, churches, schools, grazing associations, etc. In 1987, 613 abnormal farms accounted for 415,905 acres irrigated or less than 1 percent of all acres irrigated in the United States.

STATISTICAL METHODOLOGY

Universe

The universe for the survey included all irrigated farms identified in the 1987 Census of Agriculture except farms in Alaska and Hawaii, plus horticultural specialty and abnormal farms. The farms excluded by definition represent 8.8 percent of the total number of irrigators and 3.5 percent of the irrigated land reported in the 1987 census. The universe does not include farms that began operating in 1988

Table B. Leading I	Irrigation States:	Census Years	1987,	1982, and	1978
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Occurrent is sure		Acres irrigated			1987 cumula-		
Geographic area	1987	1982	1978	1987	1982	1978	U.S. total
United States	46,386,201	49,002,433	50,349,906	(X)	(X)	(X)	100.0
20 leading States	42,936,801	45,963,550	47,551,277	(X)	(X)	(X)	92.7
California	7,546,091	8,460,508	8,505,824	1	1	1	16.4
Nebraska	5,681,835	6,039,292	5,682,931	2	2	3	28.6
Texas	4,271,043	5,575,553	6,947,079	3	3	2	37.8
Idaho	3,219,192	3,450,443	3,475,392	4	4	4	44.8
Colorado	3,013,773	3,200,942	3,430,860	5	5	5	51.3
Kansas	2,463,073	2,675,167	2,685,757	6	6	6	56.6
Arkansas	2,406,338	2,022,695	1,683,413	7	8	10	61.8
Montana	1,996,882	2,023,003	2,069,531	8	7	7	66.1
Oregon	1,648,205	1,807,882	1,880,833	9	9	9	69.6
Florida	1,622,750	1,585,080	1,979,814	10	11	8	73.1
Washington	1,518,684	1,638,470	1,639,189	11	10	12	76.4
Wyoming	1,517,891	1,564,576	1,661,558	12	12	11	79.7
Utah	1,161,207	1,082,328	1,168,621	13	14	14	82.2
Arizona	913,841	1,097,825	1,195,727	14	13	13	84.1
Nevada	778,977	829,761	881,151	15	15	16	85.8
New Mexico	718,449	807,206	890,610	16	16	15	87.4
Louisiana	646,677	693,698	681,056	17	17	17	88.8
Georgia	640,256	575,306	462,850	18	18	19	90.1
Mississippi	636,842	430,901	308,694	19	20	22	91.5
Missouri	534,795	402,914	320,387	20	21	21	92.7

or had succeeding irrigators in 1988 (an operator who, since 1987, took over control of an irrigating farm through sales, rental, or other arrangements). The universe does not include farms not irrigating in the 1987 census but possibly irrigating in 1988. The universe included some operations erroneously identified as irrigating in the 1987 census either due to reporting or census processing errors. Table C provides counts of the initial mailout, the final processed and tabulated reports, and the 1987 farms eligible for the survey.

Sample Design

The 1988 survey sample was designed to provide reliable estimates with an average relative error of 10 percent or less for the United States, for each of the 18 water resource areas (WRA), the 27 leading irrigating States, and the 21 remaining combined contiguous States. The estimates for this survey are based on a probability sample of farms that irrigated in 1987 and were identified in the 1987 Census of Agriculture. The total sample of 19,324 irrigators represented approximately 7.3 percent of the 265,846 irrigated farms reported in the survey universe and accounted for 34.1 percent of the 44.8 million acres of irrigated land.

The sample included all farms identified as irrigating 1,500 acres or more in Missouri, Montana, Nebraska, Oklahoma, Oregon, and Washington; 2,000 acres or more in Arkansas, Colorado, Georgia, Idaho, Michigan, and Texas; 2,500 acres or more in Florida, Kansas, and Mississippi; 3,000 acres or more in Arizona and California; 5,000 acres or more in Nevada; and 1,000 acres or more in

all other States. A total of 2,013 farm operations were included in the sample with certainty. All other irrigated farms were stratified on the basis of: State, water resources area, and number of irrigated acres. The strata assignment based on the number of irrigated acres differed from State to State. Within each of these strata, an independent systematic sample of farms was selected. A higher probability of selection was assigned to the farms with more irrigated acres. From these strata, a total of 17,311 farms were selected.

Estimation

The survey used two types of statistical estimation procedures. These estimation procedures accounted both for selection of the survey sample and for nonresponse to the questionnaire. These procedures were used because not all census irrigators were requested to provide the survey data items and not all irrigators responded to the survey despite numerous contact attempts. The survey estimates were computed by weighting the data for each respondent irrigator by an expansion factor that was the product of the sample weight and the whole farm nonresponse weight.

The whole farm nonresponse weight was used to expand the survey data to account for the irrigators who did not respond to the survey for whatever reason and for the survey questionnaires that were undeliverable (postmaster returns). For each leading irrigating State, a noninteger nonresponse weight was calculated at the stratum level and assigned to each respondent record. The noninteger nonresponse weight was the ratio of the total number of

Table C. Irrigated Farms: 1988 Survey and 1987 Census

	1988 survey					1987 census					
	Initial mailout counte		Final reports processed and tabulated				Bubliohod totalo		Sample universe ¹		
Geographic area	initia mai	miliai mailout counts		Unexpanded		Expanded		rublished totals		Cample universe	
	Farms (number)	1987 acres irri- gated (1,000)	Farms ² (number)	Acres irri- gated (1,000)	Farms ³ (number)	Acres irri- gated (1,000)	Farms (number)	Acres irri- gated (1,000)	Farms (number)	Acres irri- gated (1,000)	
Conterminous United States	19 324	15 278	13 850	11 066	238 710	46 199	289 727	46 236	265 846	44 770	
27 leading irrigating States All other States	17,953 1,371	14 854 424	12 888 962	10 794 272	220 307 18 403	45 181 1 018	257 742 31 985	45 156 1 079	242 243 23 603	43 758 1 012	
Arizona Arkansas California Colorado Florida	753 337 1 824 594 1 045	636 347 2 639 634 1 198	475 247 1 343 459 695	408 272 2 094 403 989	3 918 5 778 50 427 12 782 7 117	840 2 755 7 562 3 212 1 460	4 241 7 269 58 868 14 913 11 981	914 2 406 7 546 3 014 1 623	4 021 7 097 55 857 14 549 8 293	823 2 393 7 292 2 960 1 405	
Georgia Idaho Illinois Kansas Louisiana	522 644 575 376 280	292 768 165 409 162	301 488 434 267 169	166 547 139 331 125	4 413 15 387 1 024 7 395 3 214	646 3 125 194 2 594 675	4 985 16 620 1 635 7 352 3 929	640 3 219 208 2 463 647	4 496 16 197 1 229 7 196 3 555	619 3 106 196 2 460 641	
Michigan Minnesota Mississippi Missouri Montana	1 048 657 745 863 488	248 229 382 536 651	755 471 505 623 366	189 168 449 306 377	2 384 1 844 1 727 2 076 8 565	314 334 756 587 1 883	3 755 2 425 2 012 2 823 9 520	315 354 637 535 1 997	2 858 2 126 1 833 2 556 9 385	295 349 634 529 1 966	
Nebraska Nevada New Mexico North Dakota Oklahoma	636 643 737 184 409	595 600 427 89 224	453 463 542 114 239	391 337 275 55 161	21 018 2 195 5 877 669 2 205	5 698 576 697 162 489	22 596 2 221 7 022 809 3 029	5 682 779 718 168 478	22 466 2 179 6 862 769 2 788	5 669 722 655 165 470	
Oregon South Dakota Texas Utah Washington Wisconsin Wyoming	919 180 694 558 933 633 676	713 111 794 389 606 243 767	699 136 486 427 694 486 551	514 80 555 207 448 205 608	11 961 1 643 16 379 10 276 13 779 1 221 5 033	1 471 363 4 450 1 140 1 529 272 1 398	14 411 1 869 19 806 11 143 15 437 1 850 5 221	1 648 362 4 271 1 161 1 519 285 1 518	13 198 1 817 18 684 10 982 14 580 1 505 5 165	1 539 356 4 216 1 101 1 418 279 1 500	

¹Excludes Alaska, Hawaii, and abnormal and horticultural specialty farms.

²Includes 444 farms that discontinued irrigation since 1987.

³Includes 14,767 farms that discontinued irrigation since 1987.

sample cases to the total number of responding cases within a stratum. The procedure used for calculating the nonresponse weight assumed that the survey respondent and the nonrespondent irrigators within a stratum had similar characteristics.

The sample weight expanded the survey data to estimate universe totals as if a complete census of irrigators had been conducted. All respondent survey records received a sample weight. The sample weight was calculated based on a ratio estimation procedure, using two variables in two steps. The ratio estimation procedure was used to obtain agreement between survey estimates and census values of irrigated acres. The first variable was the number of irrigated farms enumerated in the 1987 Census of Agriculture. The second variable was the number of irrigated acres enumerated in the 1987 Census of Agriculture. First the ratio of census irrigated farm counts to survey irrigated farm counts was calculated. The inverse of this value was approximately equal to the probability of selecting an irrigating farm for a given stratum. Next the ratio of census irrigated acres to survey irrigated acres was calculated. The sample weight was a product of these two ratios. Since total irrigated acres for each State was the final control total used in the estimation, the survey based total farm counts will differ slightly from 1987 census irrigated farm counts for each State. The final weight, the product of the sample weight and the whole farm nonresponse weight, was randomly rounded to an integer weight for tabulation. If, for example, the final weight for the number of irrigators in a particular stratum was 7.2, then one-fifth of the irrigators in this stratum were randomly assigned a weight of 8 and the remaining four-fifths received a weight of 7. The survey total for a given characteristic was

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estimated by multiplying the data value by the corresponding sample farm final weight and summing over all sample farms for respective geographic area.

Survey Error

The statistics in this report are estimates derived from a sample survey. There are two type of errors possible in an estimate based on a sample survey —sampling and non-sampling. Sampling errors occur because observations are made only on a sample, not on the entire population. The sample selection, estimation, and nonresponse estimation procedures contribute to the sampling errors. Nonsampling errors exist even in a complete census and can be attributed to such sources as questionnaire design, data processing, survey coverage, and imputation for missing data. Sampling and nonsampling errors are kept to a minimum for the certainty stratum, as the data values were obtained directly from questionnaires and telephone follow-up. The "accuracy" of a survey result is determined by the joint effects of sampling and nonsampling errors.

Sampling Errors

Variability in the estimates of the survey items was due to the sample selection procedure, the sample estimation procedure, and the nonresponse estimation procedure. Sampling error was estimated by using the random group method of variance estimation. Each responding sample farm in a State was randomly assigned to a random group based on its order of selection. Sixteen random groups were used except in two States where, due to the small number of allocated sample cases, eight and four groups were used, respectively. Each random group contained the same sample strata as the original sample with the eligible cases allocated to the stratum similar to that of the original sample. An estimate of the total was computed from each random group and the variation among these random group estimates was used to estimate the overall sampling error. Estimates of sampling variability, expressed as percent relative standard errors (percent), are presented in table D. The survey sample was one of a large number of possible samples of the same size that could have been selected using the same sample design. Estimates derived from the different samples would differ from each other. The difference between a sample estimate and the average of all possible sample estimates is called the sampling deviation. The standard error or sampling error of a survey estimate is a measure of the variation among the estimates from all possible samples, and thus is a measure of the precision with which an estimate from a particular sample approximates the average result of all possible samples. The percent relative standard error of an estimate is defined as the standard error of the estimate divided by the value being estimated multiplied by 100. If all possible

samples were selected, each of the samples were surveyed under essentially the same conditions, and an estimate and its standard error were calculated from each sample, then:

- 1. Approximately 67 percent of the intervals from one standard error below the estimate to one standard error above the estimate would include the average value of all possible samples.
- 2. Approximately 90 percent of the intervals from 1.65 standard errors below the estimate to 1.65 standard errors above the estimate would include the average value of all possible samples.

The computations necessary to construct the above confidence statements are illustrated in the following example. Assume that the estimated number of irrigated acres of a certain item is 669,813 and the relative standard error of the estimate is 1.6 percent (0.016). Multiplying 669,813 by 0.016 yields 10,717, the standard error. Therefore, a 67-percent confidence interval is 659,096 to 680,530 (i.e., 669,813 plus or minus 10,717). If corresponding confidence intervals were constructed for all possible samples of the same size and design, approximately 2 out of 3 (67 percent) of these intervals would contain the figure obtained from a complete enumeration. Similarly, a 90-percent confidence interval is 652,130 to 687,496 (i.e., 669,813 plus or minus 1.65 x 10,717).

Nonsampling Errors

Nonsampling errors arise from incorrect or incomplete data reporting, misinterpretation of questions, imputation of missing data, and inaccurate processing of data. Careful efforts were made to keep errors introduced during clerical and electronic processing to a minimum through the use of quality control, verification, and check measures on specific operations. All such errors are in addition to sampling errors, and are independent of the sample design.

Some data reported may be incorrect as a result of the misinterpretation of a question or because of the use of estimates in reporting. Respondents may have failed to provide all of the information requested. In some cases, the respondent may have indicated the presence of an item but not the amount. Data were reviewed for inconsistencies. Changes were made to data items which appeared to be inconsistent with other items. Imputations were made for missing data on acres irrigated, quantity of water used, method of water distribution, quantities of crops harvested, maintenance and repair costs, cost of water received from off-farm water suppliers, and depths, capacities, and energy cost of well pumps. If a respondent discontinued irrigation, no imputations were made for expenditures on irrigation facilities, method of deciding when to apply water, and other irrigation uses on the place such as the application of fertilizer, chemicals, or water to prevent freeze damage.

Table D. Relative Standard Error (Percent) for Selected Irrigation Data: 1988

				Acres i	irrigated			Expenses for irrigation				
Geographic and water resources areas	Irrigated farms	Acres in farms	Totai	Cropland harvested	By sprinkler systems	By gravity flow	Acre-feet of water applied, all sources	Wells used in 1988	Pumps, all types	Energy used for pumping	For wells, pumps, equipment, and facilities	Maintenance and repair
Conterminous United States	1.4	1.0	.5	.3	.6	.7	.5	1.5	1.3	.8	1.9	2.0
27 Leading irrigation States	1.4	1.0	.5	.3	.6	.7	.5	1.5	1.3	.8	2.0	2.0
17 Western States	1.4	1.1	.5	.4	.7	.7	.5	1.7	1.5	.9	2.2	2.1
All other States	4.2	4.2	2.5	2.5	2.4	11.0	2.5	7.7	4.9	3.4	11.5	3.7
Arizona	10.5	8.3	1.0	.9	4.1	1.0	1.2	3.6	2.8	2.9	7.2	2.6
Arkansas	9.4	3.4	2.1	2.1	8.6	2.2	4.4	2.7	3.3	4.9	7.7	5.3
California	1.5	2.7	.8	.5	.9	1.1	.9	4.9	3.3	1.6	4.4	4.5
Colorado	4.9	5.9	6.3	2.0	4.1	9.1	6.1	3.0	4.2	3.8	12.8	4.1
Florida	4.2	2.2	.6	.6	1.7	3.2	.4	5.3	4.1	2.4	4.5	1.5
Georgia	10.7	7.3	2.2	2.3	2.8	5.6	3.7	7.4	5.4	4.3	15.5	5.5
Idaho	3.2	2.6	1.0	1.2	1.4	3.9	2.0	2.9	2.3	1.7	5.3	3.1
Illinois	2.5	1.9	.7	.7	.7	.8	1.0	1.5	2.1	1.5	5.0	1.7
Kansas	7.8	7.1	1.2	1.4	2.3	3.1	2.0	1.6	2.1	2.8	8.0	13.4
Louisiana	8.8	2.5	1.6	1.6	6.0	2.5	3.0	5.0	4.8	4.3	8.7	1.4
Michigan	1.0	3.3	1.6	1.6	1.4	48.5	1.7	6.6	3.9	1.7	5.9	1.7
Minnesota	1.4	1.7	1.1	1.1	1.1	2.9	.9	1.4	1.0	1.0	5.9	1.5
Mississippi	5.8	3.5	.7	.7	3.2	1.1	2.4	1.2	1.0	1.2	6.0	2.1
Missouri	3.3	5.5	1.3	1.2	5.0	1.6	1.8	1.4	2.3	1.8	6.1	4.7
Montana	4.9	3.1	1.0	1.1	2.8	1.3	1.8	30.3	12.3	4.2	6.8	3.9
Nebraska	3.1	4.2	1.3	1.3	2.5	3.1	1.5	2.8	2.3	3.2	11.1	2.9
Nevada	5.0	5.3	.9	.9	2.0	1.1	1.6	5.0	4.6	3.1	11.7	6.7
New Mexico	4.7	3.6	.8	.7	1.3	1.9	.8	3.5	3.8	2.5	4.6	1.6
North Dakota	7.1	11.3	2.4	2.5	3.2	11.7	3.4	3.1	4.3	3.4	12.4	5.6
Oklahoma	3.2	3.8	1.7	1.3	4.8	1.9	3.2	5.0	4.7	3.9	19.1	2.6
Oregon	4.9	1.7	.7	1.1	1.7	.5	.8	7.2	6.2	1.2	6.1	1.1
South Dakota	8.3	18.0	1.9	1.8	2.1	13.2	2.2	3.5	3.5	2.3	6.0	3.9
Texas	6.1	10.1	1.2	1.3	4.2	1.9	1.6	4.0	3.9	2.4	10.4	4.5
Utah	4.8	9.3	1.4	1.6	3.3	2.2	2.1	24.7	7.9	4.9	10.0	3.5
Washington	4.4	7.3	1.1	1.1	1.3	3.5	1.4	11.6	5.1	.9	7.3	2.5
Wisconsin	.8	1.4	.3	.3	.3	56.8	.6	.6	1.1	.9	6.7	1.4
Wyoming	2.5	2.4	.5	.4	3.2	.5	.7	5.1	3.7	4.0	3.8	2.5
WATER RESOURCES AREAS												
WRA 01 New England WRA 02 Mid-Atlantic WRA 03 South Atlantic-Gulf WRA 04 Great Lakes WRA 05 Ohio	18.0 10.2 3.4 5.7 10.1	17.3 4.2 1.8 4.2 9.9	4.0 2.0 .5 1.3 4.5	4.4 2.0 .5 1.3 4.1	4.2 2.1 .9 1.3 4.3	15.5 47.2 3.1 33.2	12.3 2.9 .3 1.1 3.4	27.4 5.1 4.4 3.9 19.9	8.9 5.9 3.3 3.4 17.8	10.8 3.0 1.9 1.0 12.5	14.5 11.8 3.9 6.3 29.1	6.9 3.8 1.3 1.6 16.8
WRA 06 Tennessee	15.3	2.0	.4	.5	.4	5.2	1.3	.1	5.8	1.5	12.0	3.8
WRA 07 Upper Mississippi	3.0	.7	.2	.2	.7	.1	.2	.7	.6	.6	3.5	.7
WRA 08 Lower Mississippi	5.7	4.1	1.9	1.8	4.4	2.5	3.6	2.5	2.0	5.0	9.1	5.4
WRA 09 Souris-Red-Rainy	.6	(Z)	.1	.1	.1	(Z)	(Z)	.2	.1	.1	.6	.1
WRA 10 Missouri	1.6	5.3	1.1	1.2	2.7	2.2	1.5	2.6	2.3	2.7	5.7	6.8
WRA 11 Arkansas-White-Red	4.3	7.5	1.0	1.1	3.3	2.3	1.9	3.1	2.6	2.9	8.7	3.4
WRA 12 Texas-Gulf	7.7	4.5	1.8	2.2	5.8	2.7	2.1	6.9	6.1	3.1	12.5	6.2
WRA 13 Rio Grande	5.8	10.7	7.0	1.4	4.3	8.0	7.8	6.0	14.5	12.0	12.0	18.6
WRA 14 Upper Colorado	12.2	4.8	1.8	1.6	10.3	1.8	1.1	4.4	4.0	1.0	12.0	2.3
WRA 15 Lower Colorado	8.4	3.9	.6	.7	.9	.8	1.5	4.1	3.4	4.6	8.2	3.6
WRA 16 Great Basin	5.7	3.0	.4	.3	.4	1.2	.6	7.4	1.0	.3	1.1	.5
WRA 17 Pacific Northwest	3.6	2.3	.3	.2	1.3	.5	.3	2.6	2.0	.5	2.8	1.3
WRA 18 California	1.6	10.2	3.2	2.0	3.0	4.7	3.5	8.0	6.1	5.1	10.9	13.4

QUALIFICATIONS OF THE DATA

Analysts reviewing the returned report forms and results of the computer edit detected a few inquiries which were not uniformly interpreted by all respondents. Data users should be aware that respondent interpretation of some inquiries may affect the final results in their use of these selected statistics. Clarification of data items with potential and data impacted by unique problems or definitions are provided below.

Irrigated land—Irrigated land is defined as "all land watered by artificial or controlled means." No attempt has been made to define the degree or intensity of irrigation. Therefore, the figures for irrigated land include land with as little as 1 inch of water applied as well as land having several feet of water applied.

Nonirrigated crop yields—Data users are reminded that the nonirrigated crop yield averages in table 16 are for nonirrigated crops harvested from farms having land irrigated and may not be comparable with crop yield averages for nonirrigated farms.

Estimated quantity of water applied—Most water used for irrigation is not metered or measured accurately. Therefore, the quantity of water data are on the basis of best estimates provided by irrigators. Generally, in areas of water scarcity such as southern California and Arizona, irrigators are more likely to be able to provide quantities of water used than in Mountain States such as Montana, Wyoming, and Idaho where scarcity of water is less of a problem. Furthermore, in the Mountain States where water from snow melt is diverted for use in season, the amount of water used may at best be a rough estimate, seldom a measured figure.

Application of commercial fertilizers or pesticides in irrigation water—This inquiry was intended to measure the number of farms adding or mixing fertilizer and pesticides to irrigation water as it was being conveyed or distributed to the crop. The tabulated results may overstate this practice because some irrigators have misinterpreted the inquiry to include conventional application of fertilizer and pesticides to the irrigated crop as well as applying chemicals directly into the irrigation water, which carries them to the crop.

Cost of water received from off-farm water suppliers—Irrigators receiving water from off-farm water suppliers are generally required to pay for the water in charges, fees, or assessments. The dollar amount for cost of water was one of the more frequently omitted items on the report form. Computer edit procedures called for imputing an estimate for cost of water based on other reports from the same geographic area. If there were any indications written on the report form that the water was received free, no cost of water was imputed. It is possible that the final tabulated results for this item are overstated, because it was not possible to distinguish cases where the respondent received free water from cases where the cost amount was omitted in error, leading to imputation of a dollar amount. At the national level 17 percent of the farms reporting cost and 19 percent of the total dollar amount was imputed.

Irrigation wells—Some farm operators reported wells used only for domestic purposes or livestock, as wells "not used" in 1988, meaning not used for irrigation. Where identified for domestic purposes or livestock use, the entry was deleted. Data users are reminded that there are additional wells reported as not used in 1988, but capable of being used, which may be for domestic purposes or livestock use only.

Artesian wells—A specific entry space was not provided for artesian wells. During processing, all wells which were indicated to be free flowing or artesian were removed from the pumped well section and tabulated as flowing or artesian wells. The data for well pumps excludes any pumps which may have actually been used to pump water from artesian wells.

Irrigation pumps—The inventory figures for number of irrigation pumps on farms reported in table 10 include reserve pumps not actually used in 1988, but excludes any pumps on wells not used in 1988. By definition, flowing or artesian wells do not have well pumps.

Expenditures for maintenance and repair and investment in irrigation facilities and equipment—The expenditure data reported are expenditures that occurred only in 1988.

Some respondents found it difficult to separate expenditures for maintenance and repairs from investment in irrigation facilities and equipment as defined on the report form. For example, replacement of worn out sprinkler nozzles, pumps, and motors could be considered either as repair cost or investment in new equipment. Therefore, data users are reminded that the distinction between the two expenditure categories is blurred for some respondents.

Dollar amounts for maintenance and repair costs were one of the more frequently imputed items in computer edits. Farms with more than 25 acres irrigated or 10 acres irrigated by wells were subjected to imputation of costs if the none box and dollars of repair cost were blank. At the national level, 16 percent of the farms reporting repair cost and 17 percent of the total dollar amount for maintenance and repair costs were imputed.

Water management practices for operators using gravity irrigation— This question was not asked in previous irrigation surveys nor had it been tested. **Reason for discontinuance of irrigation since 1987**—This inquiry was not reported for 24 of the 443 respondents in the survey, who utilized irrigation in 1987 but not in 1988. Therefore, the data by reason of discontinuance shown in table 25 reflects the expansion of reported entries. Some respondents reported multiple reasons while others were blank.

SUMMARY AND CONCLUSIONS

Irrigated Crops

The principal crops irrigated in the conterminous United States in 1988, according to results of the 1988 Farm and Ranch Irrigation Survey, were corn for grain or seed with 8.0 million acres, alfalfa hay with 5.1 million acres, cotton with 4.0 million acres, wheat with 3.5 million acres, and orchard land with 3.5 million acres. These five leading irrigated crops accounted for 57 percent of the acreage of all irrigated crops. The average irrigated yields were 143 bushels of corn per acre, 4.4 tons of alfalfa hay per acre, 905 pounds of lint per acre for cotton, and 64 bushels of wheat per acre.

Total land irrigated by 223,943 irrigators included in the 1988 survey was 46.2 million acres. The leading State in total acreage of irrigated land is California with 7.6 million acres, followed by Nebraska with 5.7 million acres, and Texas with 4.5 million acres.

Method of Irrigation

There were 46.2 million acres irrigated by different water distribution systems in 1988. Approximately 1.1 million acres were irrigated by more than 1 of the 11 distribution systems listed on the report form. Of the total acres irrigated by all types of distribution systems, 27.4 million acres were irrigated by gravity flow systems and 18.4 million acres by sprinkler systems.

Comparisons with the 1979 and 1984 Farm and Ranch Irrigation Surveys show that sprinkler systems were used to irrigate 40 percent of the total land irrigated in 1988 compared with 38 percent in 1984 and 37 percent in 1979. Gravity flow systems were used on 59 percent of the land in 1988 compared to 61 percent in 1984 and 63 percent in 1979.

In acres irrigated by sprinklers, center pivot low pressure systems were used to irrigate 6.6 million acres of the 18.4 million acres irrigated by sprinklers. Next were center pivot high pressure systems with 4.8 million acres, all other mechanical move systems with 2.9 million acres, and hand move systems with 2.7 million acres.

Estimated Quantity of Water Applied

Irrigators estimated that a total of 84.1 million acre-feet of water was applied to the 46.2 million acres irrigated in 1988 in the conterminous United States for an average of 1.8 acre-feet per acre irrigated. Table E shows the average acre-feet of water applied per irrigated acre over the last 20 years. The average amount of water applied per acre in the 27 principal irrigating States ranged from a high of 4.4 acre-feet in Arizona to a low of 0.7 acre-feet in Georgia and Michigan. The average for the remaining 21 Eastern States was 0.7 acre-feet.

Table E. Average Acre-Feet	of	Water	Applied	Per	Irri-
gated Acre					

Year and source	Amount applied
1988 Farm and Ranch Irrigation Survey 1984 Farm and Ranch Irrigation Survey 1979 Farm and Ranch Irrigation Survey 1974 Census of Agriculture 1969 Census of Agriculture	1.82 1.80 1.86 2.09 2.11

Special tabulations of data for farms having only one of the four kinds of distribution systems sprinklers, gravity, drip, or subirrigation show noticeable differences in the amount of water applied per acre by each system. For example, farms using only sprinkler systems applied 1.3 acre-feet per acre irrigated compared with 2.1 acre-feet for farms using only gravity flow systems (see table 5).

For the conterminous United States, results of the survey show that on rice, alfalfa hay, cotton, land in vegetables, and land in orchards farmers apply heavy amounts of water averaging over 2.0 acre-feet per acre irrigated while on corn for grain, wheat, barley, Irish potatoes, and other hay amounts between 1.0 and 2.0 acre-feet are applied. Soybeans, peanuts, and tobacco have less than 1.0 acre-feet of water applied per acre irrigated.

Source of Water

There was a total of 46.2 million acres irrigated by water from all sources in 1988. Approximately 9.5 million acres were irrigated with water from more than one of the three sources listed on the report form. About 26.8 million acres (56 percent) were irrigated from farm irrigation wells, 15.0 million acres (31 percent) from off-farm water suppliers, and 6.0 million acres (13 percent) from on-farm surface sources.

Of the 84.1 million acre-feet of water estimated to be used for irrigation in 1988, 40.5 million acre-feet (48 percent) was pumped from wells, 34.9 million acre-feet (41 percent) was provided by off-farm water suppliers, and the other 8.9 million acre-feet came from on-farm surface sources. Table F shows how these data correspond to previous farm and ranch irrigation surveys.

Farm	1988	1984	1979
Total	84.1	82.7	93.1
Acre-feet (millions)	40.5 48	36.2 44	43.2 47
On farm: Acre-feet (millions) Percent	8.9 11	10.2 12	8.8 10
Off farm: Acre-feet (millions) Percent	34.9 41	36.2 44	41.0 44

Table F. Irrigation Water Used by Source: 1988, 1984, and 1979

The average amount of water applied per acre varies significantly by source. Land irrigated from wells averaged 1.5 acre-feet applied per acre, while land irrigated from off-farm water suppliers averaged 2.3 acre-feet applied. Sprinkler irrigation is more related to the distribution of well water, while gravity flow systems are generally used to distribute water from off-farm water suppliers. However, for purposes of water economy and efficiency of water use, the trend by irrigators has been toward greater use of sprinkler systems over the past decade.

Irrigation Wells

There were irrigation wells capable of being used on 116,236 farms. Of these, 341,710 wells were pumped in 1988, 27,700 were idle, and 4,162 were artesian or free flowing. The 345,872 irrigation wells used supplied 40.5 million acre-feet of water to 26.8 million acres of land, for an average of 117.0 acre feet per well and an average of 77.4 acres irrigated per well. Farms with wells used in 1988 average 3.1 wells per farm. Over 63 percent of the farms using wells in 1988 used one or two wells, but the majority of wells used (54 percent) are on the 21,387 farms using five or more wells per farm, indicating the impact of the large irrigators on statistics. For the conterminous United States, pumped wells averaged 226 feet in well depth, 134 feet in pumping depth, and 757 gallons per minute in pumping capacity.

Irrigation Expenditures

Pumping costs—There was a total of 482,880 irrigation pumps of all kinds used on 149,647 farms in 1988 and irrigated 33.8 million acres of land. These pumps were powered by fuels and electricity costing irrigators a total of \$1,041 million or an average of \$6,956 per farm or \$31 per acre irrigated. The principal power source used was electricity for which \$713 million was spent to power 282,472 pumps and irrigate 19.0 million acres at an average cost of \$38 per acre. Next was natural gas which cost irrigators \$160 million to power 53,449 pumps and irrigate 5.7 million acres at an average cost of \$28 per acre, followed by diesel fuel which cost \$128 million to power 75,987 pumps and irrigate 7.0 million acres at an average cost of \$18 per acre. Table 11 presents more information on the other fuels used to power irrigation pumps. Due to the low response rate to the total quantity of fuels used, the data estimates for all fuels are not suitable for publication. Table 11 shows suppression(s) for the energy used.

Cost of water from off-farm water suppliers—The 34.8 million acre-feet of water received from off-farm water suppliers to irrigate 15.0 million acres cost irrigators \$504 million for an average cost of \$14.45 per acre-foot of water or \$34 per acre irrigated.

Maintenance and repair cost—Expenditure for maintenance and repairs totaled \$396 million on 158,761 farms for an average of \$2,491 per farm.

Investment in irrigation equipment, facilities, and land improvement—Investment in irrigation equipment, facilities, and land improvement in 1988 totaled \$616 million for an average of \$7,533 per farm. The principal investment was in the purchase of irrigation equipment and machinery, which totaled \$435 million and represents 71 percent of total investment. The next three categories were \$73 million (12 percent) spent for new well construction and well deepening, \$55 million (9 percent) spent for construction of permanent storage and distribution systems, and \$53 million (9 percent) spent for land clearing and leveling.

Discontinuance of Irrigation in 1988

An estimated 14,767 farmers, who had irrigated a total of 0.8 million acres in 1987 according to the census of agriculture, did not irrigate in 1988. The majority of these operators reported that their discontinuance was not permanent (80 percent).

Land Laser Leveled for Irrigation

An estimated 15,369 farmers reported that they had 3.0 million acres of land that had been laser leveled for irrigation purposes. Since this was the first time that this question has been asked, there are no means of comparing the reliability of this data.