Golf Course Environmental Profile

Volume II

Water Use and Conservation Practices on U.S. Golf Courses

With Forewords by Greg Norman, World Golf Hall of Fame Member, and David S. Downing II, CGCS, 2008 GCSAA President

GCSAA

Environmental Institute for Golf

The Environmental Institute for Golf is the philanthropic organization of the Golf Course Superintendents Association of America.

Golf Course Superintendents Association of America

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Volume II
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Funded by:
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and
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Our Mission

GCSAA is dedicated to serving its members, advancing their profession and enhancing the enjoyment, growth and vitality of the game of golf.

Environmental Institute for Golf

The Environmental Institute for Golf is committed to strengthening the compatibility of the game of golf with our natural environment.

Acknowledgments

The Golf Course Superintendents Association of America and The Environmental Institute for Golf wish to thank:

The Toro Foundation for providing a grant to help fund this research.

The thousands of golf course superintendents who took the time and effort to complete the survey.

Golf's allied associations for their support in this endeavor.

Foreword

Measuring the Sustainability of Golf

The game of golf touches millions of people worldwide, from those of us who regularly enjoy the thrill of a perfect shot to those who have dedicated their careers to design, build and maintain golf courses for us to enjoy. All of us associated with the game must realize that our commitment to environmental sustainability is crucial to the future of the game.

The Golf Course Environmental Profile Project is a key component to charting our sustainable future. Few other industries have committed to evaluating the operation of their properties in the way golf is doing through this process. *The Water Use and Conservation* report, the second report in the series, provides important data regarding water management within the United States. Through this effort, the golf course industry is stepping up and providing an inside look at the environmental aspects associated with the game and, most importantly, its water use and conservation methods.

Water management on the golf course drives to the heart of sustainability. Golf course superintendents invest considerable resources to provide optimal playing surfaces that meet golfer expectations. However, in order to ensure sustainability, we must have conservation awareness, and continue to be efficient and wise when using water resources.

This assessment will allow golf courses to express current sustainability practices, establish goals, and continually track our progress for the future.

Regards,

Greg Norman
Advisory Council Chair
The Environmental Institute for Golf

Foreword

Achieving Progress through Participation

Golf has a strong track record when it comes to research. For many years, the industry has analyzed, measured and investigated a broad spectrum of issues, giving it the basis to make informed and high-quality decisions.

One area of strength has been in the evaluation of the environment. Since the early 1980s, millions of dollars have been pledged by a variety of organizations, universities and businesses to better understand golf's potential impact on the environment. This effort has been invaluable in developing programs and best management practices to ensure golf's environmental compatibility. In recent years, the Environmental Institute for Golf and the Golf Course Superintendents Association of America have committed to establish baseline information for the golf industry through the Golf Course Environmental Profile Project.

This Water Use and Conservation report provides information about golf's water use, conservation practices and irrigation systems. The data will facilitate setting goals and objectives for the industry that will advance our techniques and encourage new technology. It will allow for strong communication platforms and education programs to promote continued progress for golf. This report, along with the results of the first phase on land use and environmental stewardship, put us well on our way to establishing important baseline information and providing a factual look of golf's environmental practices.

I thank the more than 2,500 golf course superintendents who participated in the Water Use and Conservation survey. Your commitment to this project makes a strong statement as professionals and for the industry. The Golf Course Superintendents Association of America and its 21,000 members understand the importance of meeting golfer expectations and the investment of resources required to ensure playability.

Water is a precious resource, and it is our responsibility to use it judiciously so that future generations will continue to enjoy the benefits of these facilities. Through our efforts the industry will be able to demonstrate sustainability through the wise and professional use of our most precious resource – water.

David S. Downing II, CGCS
2008 GCSAA President

Executive Summary

GCSAA's Golf Course Environmental Profile is a data collection project that provides new insight into the property features, management practices and inputs associated with golf courses across the United States.

Water Use and Conservation Practices on U.S. Golf Courses is the second report produced from the project. The first report was the *Property Profile and Environmental Stewardship of Golf Courses* released in November 2007. These reports are available at www.eifg.org.

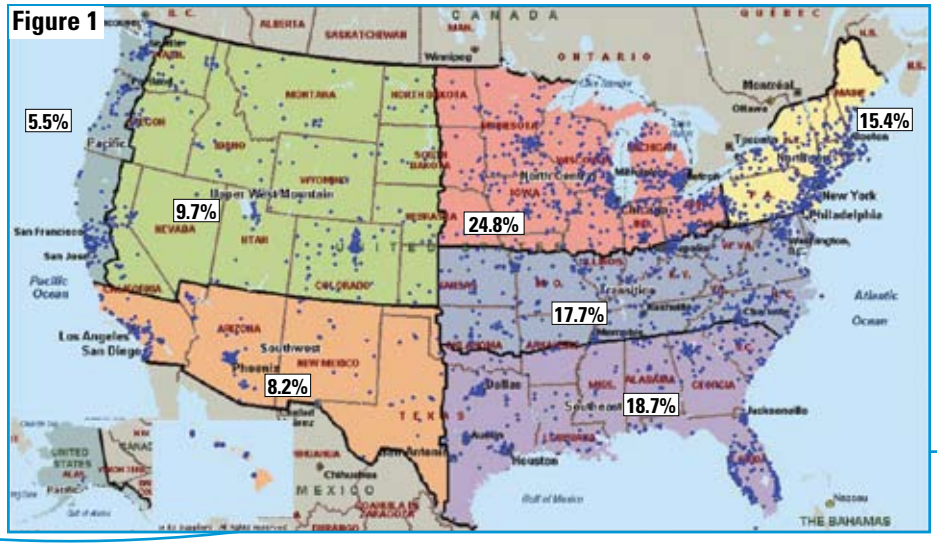
This volume provides the most accurate portrayal of water use and conservation practices on golf courses in the United States. It establishes a definitive baseline that will be compared to data from future surveys to identify change over time. It will help to guide the golf industry's agronomic and environmental initiatives in the future.

The objectives of the water use and conservation survey were to measure:

- Number of irrigated turfgrass acres for the U.S. and in agronomic regions
- Total water use in the U.S. and in agronomic regions
- Water cost averages for the U.S. and in agronomic regions
- Water sources used for irrigation
- Recycled water use in the U.S. and in agronomic regions
- Water quality
- Irrigation system characteristics
- Water management and conservation practices

Superintendents at all golf facilities in the U.S. (16,797) were invited to participate in the survey. A total of 2,548 golf facilities participated in the survey, accounting for 15 percent of the nation's superintendents. Analysis of returned surveys indicated that there was statistically valid representation of all types of golf facilities – public, private, resort, municipal, 9-hole, 18-hole, etc. Golf courses were stratified by agronomic region, course type and number of holes.

Figure 1 – Agronomic regions and total percentage of survey participation among golf facilities by region.



Executive Summary

Highlighting the report are the following results:

- There are an estimated 1,504,210 acres of maintained turfgrass (greens, tees, fairways, rough) on golf facilities in the U.S.[1] An estimated 1,198,381 acres or 80 percent of maintained turfgrass are irrigated.

- Approximately 80 percent or 80 acres of an average 18-hole golf course's 100 acres of maintained turfgrass are irrigated.

- From 2001-2005, an estimated net total of 31,877 acres of irrigated turfgrass were added to existing golf facilities in the U.S.

- The greatest net gain in irrigated acreage occurred in the North Central and Northeast regions, where 13,513 and 8,442 new acres were irrigated, respectively. The Southwest region had an estimated net decrease of 12 acres.

- From 2003-2005, the average water use for golf course irrigation in the U.S. was estimated to be 2,312,701 acre-feet per year.
  - That equates to approximately 2.08 billion gallons of water per day for golf course irrigation in the U.S.
  - According to the U.S. Geological Survey's "Estimated Use of Water in the United States in 2000" report, approximately 408 billion gallons of water per day are withdrawn in the U.S. Golf course irrigation accounts for 0.5 percent of this total.[2]

- Water use varies significantly by agronomic region.
  - An average 18-hole golf facility in the Southwest region uses an average of 4 acre-feet of water per irrigated acre per year and an 18-hole golf facility in the Northeast region uses an average of 0.8 acre-feet of water per irrigated acre per year.

- Annual irrigation water cost also varies significantly by agronomic region.
  - Golf course facilities in the Southwest region had the highest water costs – approximately $107,800 per year for an average 18-hole golf course.
  - 18-hole golf facilities in the North Central, Northeast and Transition regions had the lowest water costs, paying $4,700, $6,300 and $6,900 per year, respectively.

- Multiple sources are utilized for irrigation water and many golf facilities have more than one source available for irrigation. Most 18-hole golf facilities utilize surface waters like ponds, lakes or on-site irrigation wells. Approximately 14 percent of golf facilities use water from a public municipal source and approximately 12 percent use recycled water as a source for irrigation. Specific water sources for 18-hole courses as indicated by participants are noted below:
  - 52 percent use water from ponds or lakes.
  - 46 percent use water from on-site wells.
  - 17 percent use water from rivers, streams and creeks.
  - 14 percent use water from municipal water systems.
  - 12 percent use recycled water for irrigation.

Executive Summary

- As previously noted, 12 percent of 18-hole courses use recycled water for irrigation. The most common reason cited for not using it was a lack of an available source for recycled water as indicated by 53 percent of respondents.

- In general, irrigation water quality is acceptable or better in all agronomic regions, although there are golf facilities in all agronomic regions that face significant agronomic challenges due to the quality of their irrigation water.

- Approximately 46 percent of 18-hole golf facilities treat their irrigation water or distribute products via the irrigation system. The most common products distributed through the irrigation system are wetting agents and fertilizers.

- Nearly all 18-hole golf facilities use multiple irrigation scheduling techniques to aid in making water application decisions.

- Most facilities utilize direct observations of turfgrass and soil conditions to aid in irrigation scheduling decisions. Approximately 35 percent routinely utilize evapotranspiration data and approximately 3 percent use soil moisture sensors to aid in irrigation scheduling.

- Superintendents at 18-hole golf facilities utilize numerous methods to conserve water. The top three conservation methods and the percent of golf facilities utilizing that method are: wetting agents (92%); hand watering (78%); and keeping turfgrass drier (69%).

- An estimated 25 percent of all 18-hole golf facilities are subjected to recurring annual water allocations. Facilities in the Southwest (40%), Upper West/Mountain (39%) and Southeast (36%) are most likely to be subjected to a recurring annual irrigation water allocation.

- From 2001 to 2005, 16 percent of 18-hole golf facilities in the U.S. were subjected to mandatory irrigation water restrictions more stringent than the normal recurring annual irrigation water allocation for at least one year. Facilities in the Northeast and Upper West/Mountain agronomic regions were more likely to experience more stringent restrictions.

- Approximately 28 percent of 18-hole golf facilities in the Northeast agronomic region have written drought management plans, more than any other agronomic region.

Introduction

This report focuses on golf facility water use and conservation. Past research examined property features, such as acreage, land use and turfgrass species, as well as environmental stewardship efforts. Future research will examine nutrient use, pesticide use, energy use and environmental practices in order to evaluate change over time.

Since 2004, golf course superintendents, golf industry leaders, golf association leaders, environmental advocates, university turfgrass scientists and environmental regulators have participated in meetings, symposiums and conferences hosted by **The Environmental Institute for Golf (The Institute)** to discuss environmental issues facing the golf industry and identify future research, education and outreach needs. The group reached several important conclusions about the environmental aspects of golf, including:

- The golf industry did not have comprehensive national data on the property features, management practices, and inputs associated with golf courses and golf course maintenance.
- Although many individual golf courses are environmentally proactive, there was no systematic process in place to document current practices or track changes that the golf industry nationwide has made to protect and enhance the environment.
- A reliable environmental review of golf facilities was needed to provide an in-depth look into the golf industry, land and water management, and environmental stewardship practices on a national basis.

In 2006, the **Golf Course Superintendents Association of America (GCSAA)** initiated a project, funded by The Institute through a grant from **The Toro Foundation**, to collect data nationally on the property features, management practices, and inputs associated with golf courses and golf course maintenance. A series of surveys will be conducted over multiple years to collect the data. The surveys will be repeated so that change in golf courses and golf course maintenance practices over time can be measured.

The first survey was conducted in 2006, and the first report, *Property Profile and Environmental Stewardship of Golf Courses*, was published in November 2007 in *Applied Turfgrass Science*, a peer-reviewed scientific journal. The water use and conservation survey, the second survey of the series, was conducted in late 2006. The scientific manuscript presenting the results of the water use and conservation survey was published in *Applied Turfgrass Science* in 2009.

Both the *Property Profile and Environmental Stewardship of Golf Courses* and *Water Use and Conservation Practices on U.S. Golf Courses* reports and journal articles are available for online viewing or downloading on The Institute's Web site at **www.eifg.org**.

Methodology

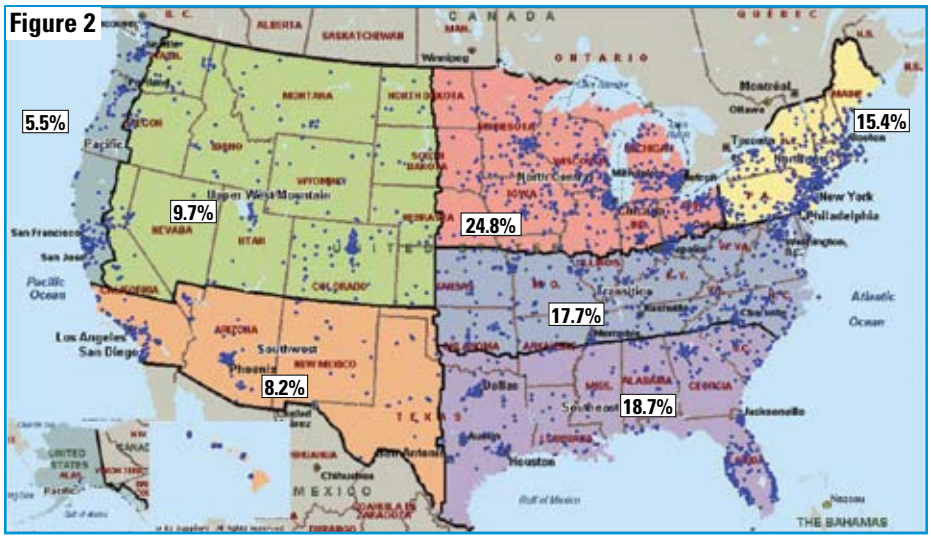
Input on the survey questions was collected from golf, environmental, academic and regulatory sources. GCSAA staff drafted survey questions, which were reviewed and revised by a group of golf course superintendents, golf association leaders and environmental advocates.

The National Golf Foundation (NGF) was contracted to conduct the survey, manage the recruitment of participants and complete the analysis of the data in collaboration with GCSAA. The NGF adheres to The Code of Marketing Research Standards developed by the Marketing Research Association.[3] The NGF refined and formatted the survey instrument for online and paper versions.

An attempt was made to contact and invite superintendents at 16,797 golf facilities nationwide to complete the survey. Surveys were distributed via e-mail and U.S. Postal Service in October 2006. In addition, reminders to complete and submit the survey were sent by e-mail and mail. Surveys were accepted until late November 2006.

A total of 2,548 usable surveys were returned, yielding a 15 percent return rate. The analysis classified the golf courses by agronomic region, course type (daily fee, municipal or private) and number of holes. Agronomic regions were determined by grouping geographic areas with similar climatic characteristics, and boundaries were drawn using county borders. Analysis of the returned surveys indicated that a proportional sample of all types of U.S. golf facilities was received (Appendix Table 1).

Figure 2 – Agronomic regions and total percentage of survey participation among golf facilities by region.



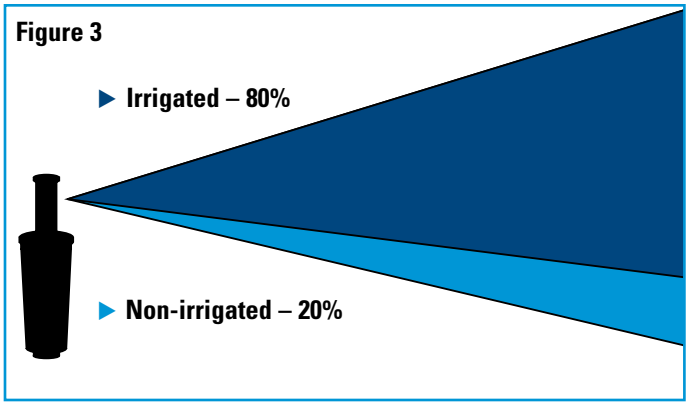
Data were analyzed to run descriptive statistics and explore relationships between the variables such as agronomic region, course type and number of holes. Where 18-hole equivalent data are presented, data within a region were averaged over facility type and budget. The number of 18-hole equivalents in the U.S. is 14,969, and was determined by taking the total number of golf holes and dividing by 18.[4]

Survey Results

Irrigated Turfgrass Acres on U.S. Golf Facilities

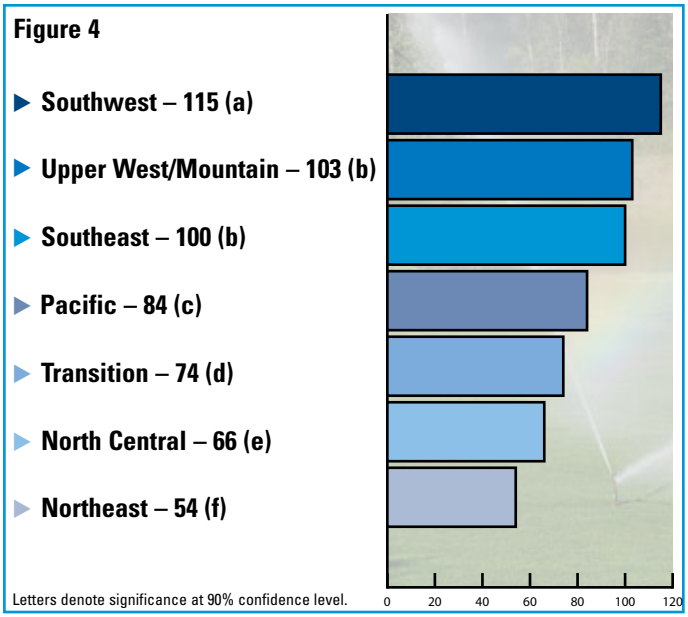
There are an estimated 2,244,512 total acres of land on golf facilities in the U.S., including 1,504,210 acres of maintained turfgrass and 740,302 acres of non-turfgrass landscapes, buildings and parking lots.[1] There are an estimated 1,198,381 acres of irrigated turfgrass, which is approximately 80 percent of the maintained turfgrass acres. The number of acres of irrigated turfgrass increases as the number of golf holes increases (Appendix Table 2).

Figure 3 – Percentage of irrigated and non-irrigated maintained turfgrass acreage.



- An average 18-hole facility irrigates approximately 80.7 acres of turfgrass out of an average of 150 acres. Irrigated acres for select features as reported by participants is as follows (Appendix Table 3):
  - 3.7 acres of greens
  - 3.4 acres of tees
  - 30.7 acres of fairways
  - 33.8 acres of rough
  - 5.6 acres of practice areas
  - 3.5 acres of clubhouse grounds
- Nationally, nearly 100 percent of greens, tees, and fairways are irrigated. Approximately 64 percent of turfgrass in the rough and 74 percent of turfgrass used for the driving range/practice areas are irrigated.
- There are significant differences in the number of irrigated turfgrass acres among agronomic regions. In the Southwest region, there are approximately 115 acres of irrigated turfgrass compared to approximately 54 acres in the Northeast region (Figure 4, Appendix Table 4).

Figure 4 – Irrigated turfgrass acres for average 18-hole golf facilities in the U.S. by agronomic region (Appendix Table 4).



Water use varies across agronomic regions due to climatic conditions, including temperature, sunlight intensity and rainfall, species of turfgrass grown and length of growing season. Turfgrasses grown in the Southwest agronomic region require irrigation for year-round playability because of low rainfall and high temperatures. Rainfall is more consistent in the Pacific, Transition, North Central and Northeast agronomic regions, and supplemental irrigation is needed only during dry periods of the growing season.

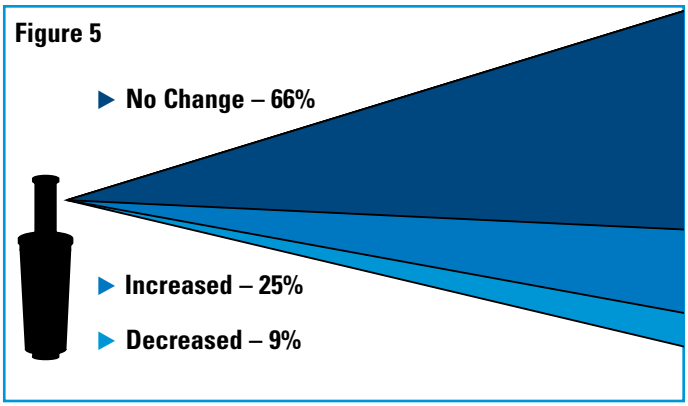
Changes In Irrigated Turfgrass Acres

From 2001-2005, approximately 25 percent of 18-hole golf facilities in the U.S. have increased their irrigated turfgrass acres and 9 percent have reduced irrigated turfgrass acres. Approximately 66 percent of 18-hole golf facilities have had no change in number of irrigated turfgrass acres (Figure 5, Appendix Table 5).

For those 18-hole golf facilities that changed irrigated turfgrass acreage:

- The average increase was 13 acres.
- The average decrease was 12.3 acres.

Figure 5 – Changes in irrigated turfgrass acres from 2001-2005 for U.S. 18-hole golf facilities (Appendix Table 5).



From 2001-2005, an estimated 31,877 acres of irrigated turfgrass were added to existing golf facilities in the U.S. The greatest net gain occurred in the North Central and Northeast regions, where 13,513 and 8,442 new acres were irrigated, respectively. The Southwest region had an estimated net decrease of 12 acres (Figure 6).

Based upon additional feedback from golf course superintendents, the net gain in irrigated turfgrass acres is due to golf facilities converting non-irrigated rough to irrigated rough to meet the demands of golfers.

Figure 6 – Estimated change in irrigated acres from 2001-2005 in the U.S. by agronomic region.

Figure 6

Acres	*Agronomic Regions							
	NE	NC	Trans	SE	SW	UW/ Mtn	Pac	U.S. Total
Increase	10,091	16,635	8,301	6,005	3,085	3,151	1,397	48,664
Decrease	1,649	3,112	3,552	3,633	3,097	828	905	16,787
Net Change	8,442	13,523	4,749	2,372	-12	2,323	492	31,877

*** Agronomic regions: NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

Irrigation Water Use

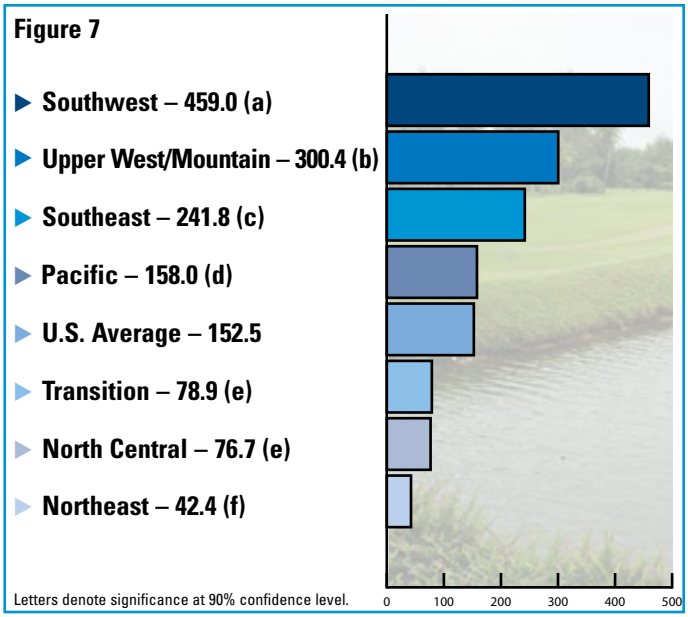
From 2003-2005, the average total water use for golf course irrigation in the U.S. was estimated to be 2,312,701 acre-feet of water per year. Using water use data nationally, an 18-hole golf course uses an average of 152.5 acre-feet of water per year to irrigate 80.7 acres of turfgrass. This is an average of 1.9 acre-feet of irrigation water per irrigated acre (Figure 7, Appendix Table 6).

- *One acre-foot or 12 inches of water over one acre equals 325,851 gallons.*

- *Water use figures for 18-hole facilities are based upon the following measures: 50 percent metered, 37 percent estimated, 13 percent both.*

- *50 percent of 18-hole golf facilities are required to report water use volumes to a state or local governing entity.*

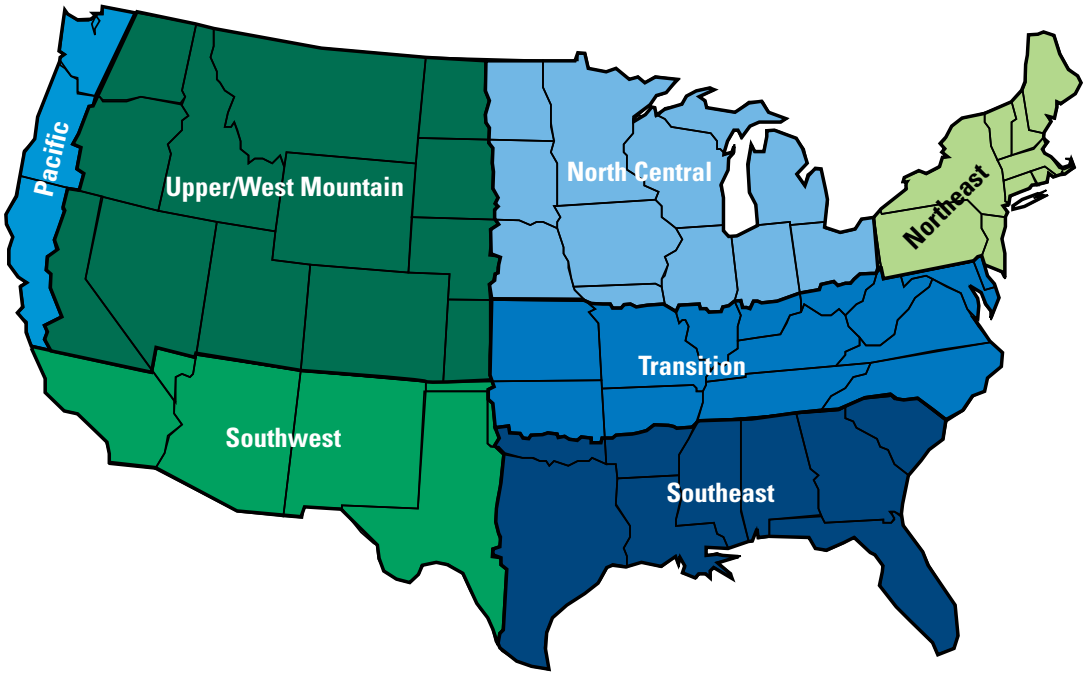
Figure 7 – Average water use in acre-feet for 18-hole golf facilities in the U.S. by agronomic region (Appendix Table 6).



Irrigation Water Use Across Agronomic Regions

Water used for irrigation on golf courses varies significantly across agronomic regions. Arid areas of the country have higher water demands due to the climate, continual turf growth and because courses are open for golf use throughout the year. Water use was compared across agronomic regions by water use per acre, per number of holes (9, 18 and 27) and total use per agronomic region (Appendix Table 6).

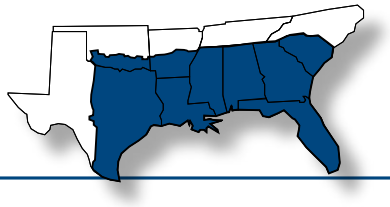
The statements below are summarized from data in Appendix Tables 1, 4 and 6.



Southeast

The Southeast agronomic region has the greatest water use per agronomic region. This is due to the large number of golf facilities, climate and year-round turf growth.

- An 18-hole facility in the Southeast agronomic region irrigates, on average, 100 acres of turfgrass.
- An 18-hole facility in the Southeast agronomic region irrigates with an average 241.8 acre-feet annually.
- An 18-hole facility in the Southeast agronomic region irrigates with 2.4 acre-feet (29 inches) of water per irrigated turfgrass acre annually. This is lower than the Southwest and Upper West/Mountain region and higher than the other regions on a per-acre basis.
- In the Southeast agronomic region, there are 3,518 golf facilities that include 9-hole, 18-hole and greater-than-18-hole golf facilities.
- The total irrigation water use for all facilities in the Southeast agronomic region is estimated to be 801,105 acre-feet per year.

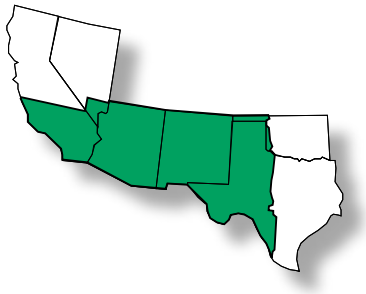


Irrigation Water Use Across Agronomic Regions

Southwest

The Southwest agronomic region has the greatest use of irrigation water per acre, the largest irrigated acreage per 18-hole golf facility and uses the second greatest total volume of water per agronomic region.

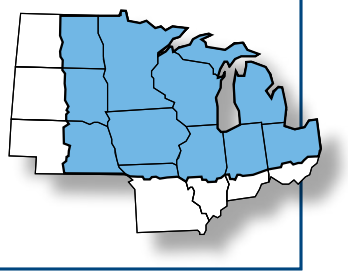
- An 18-hole facility in the Southwest agronomic region irrigates, on average, 115 acres of turfgrass.
- An 18-hole facility in the Southwest agronomic region irrigates with an average 459 acre-feet annually.
- An 18-hole facility in the Southwest agronomic region irrigates with 4 acre-feet (47.9 inches) of water per irrigated turfgrass acre annually.
- There are 1,272 golf facilities in the Southwest agronomic region including 9-hole, 18-hole and greater-than-18-hole golf facilities, approximately 7.5 percent of the total nationally.
- The total irrigation water use for all facilities in the Southwest agronomic region is estimated to be 553,442 acre-feet per year.



North Central

The North Central agronomic region has more facilities than any other region. The water use per irrigated acre is comparable to the Transition region and is significantly lower than all other regions except the Northeast. Because of the relatively large number of facilities, it ranks third in the total water use per region.

- An average 18-hole facility in the North Central agronomic region irrigates, on average, 66 acres of turfgrass.
- An 18-hole facility in the North Central agronomic region irrigates with an average of 76.7 acre-feet annually.
- An 18-hole facility in the North Central agronomic region irrigates with 1.2 acre-feet (13.9 inches) of water per irrigated turfgrass acre annually.
- There are 4,238 golf facilities in the North Central agronomic region including 9-hole, 18-hole and greater-than-18-hole facilities.
- The total irrigation water use for all facilities in the North Central agronomic region is estimated to be 313,037 acre-feet per year.

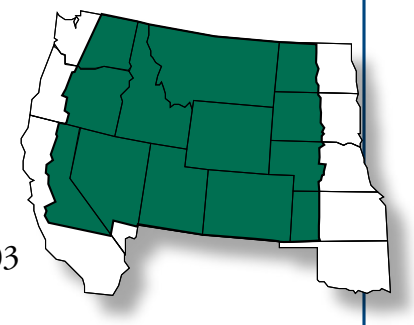


Irrigation Water Use Across Agronomic Regions

Upper West/Mountain

The Upper West/Mountain agronomic region uses slightly more water per acre than golf facilities in the Southeast region but less per acre than those in the Southwest region.

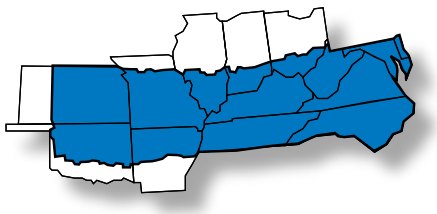
- An average 18-hole facility in the Upper West/Mountain agronomic region irrigates, on average, 103 acres of turfgrass.
- An 18-hole facility in the Upper West/Mountain agronomic region irrigates with an average of 300.4 acre-feet annually.
- An 18-hole facility in the Upper West/Mountain agronomic region irrigates with 2.9 acre-feet (35 inches) of water per irrigated turfgrass acre annually.
- There are 1,100 golf facilities in the Upper West/Mountain agronomic region, including 9-hole, 18-hole and greater-than-18-hole facilities.
- The total irrigation water use for all facilities in the Upper West/Mountain agronomic region is estimated to be 214,603 acre-feet per year.



Transition

The Transition agronomic region has similar water use per irrigated acre as the North Central region. Overall use is lower because the region does not have as many golf facilities when compared to the North Central region.

- An average 18-hole facility in the Transition agronomic region irrigates, on average, 74 acres of turfgrass.
- An 18-hole facility in the Transition agronomic region irrigates with an average of 78.9 acre-feet annually.
- An 18-hole facility in the Transition agronomic region irrigates with 1.1 acre-feet (12.8 inches) of water per irrigated turfgrass acre annually.
- There are 3,116 golf facilities in the Transition agronomic region including 9-hole, 18-hole and greater-than-18-hole facilities.
- The total irrigation water use for all facilities in the Transition agronomic region is estimated to be 206,829 acre-feet per year.

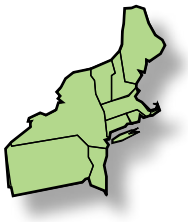


Irrigation Water Use Across Agronomic Regions

Northeast

The Northeast agronomic region has the lowest water use per acre, lowest irrigated acreage per 18-hole facility and the second lowest total water use per geographic region.

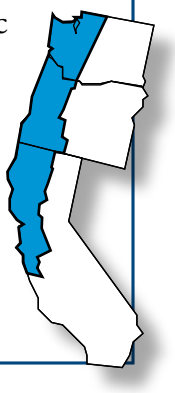
- An average 18-hole facility in the Northeast agronomic region irrigates, on average, 54 acres of turfgrass.
- An 18-hole facility in the Northeast agronomic region irrigates with an average of 42.4 acre-feet annually.
- An 18-hole facility in the Northeast agronomic region irrigates with 0.8 acre-feet (9.4 inches) of water per irrigated turfgrass acre annually.
- There are 2,871 golf facilities in the Northeast agronomic region including 9-hole, 18-hole and greater-than-18-hole facilities.
- The total irrigation water use for all facilities in the Northeast agronomic region is estimated to be 102,581 acre-feet per year.



Pacific

The Pacific agronomic region irrigates with the lowest total volume of water among the regions due to the climate and relatively low number of facilities.

- An average 18-hole facility in the Pacific agronomic region irrigates, on average, 84 acres of turfgrass.
- An 18-hole facility in the Pacific agronomic region irrigates with an average of 158 acre-feet annually.
- An 18-hole facility in the Pacific agronomic region irrigates with 1.9 acre-feet (22.6 inches) of water per irrigated turfgrass acre annually.
- There are 682 golf facilities in the Pacific agronomic region including 9-hole, 18-hole and greater-than-18-hole facilities.
- The total irrigation water use for all facilities in the Pacific agronomic region is estimated to be 94,115 acre-feet per year.



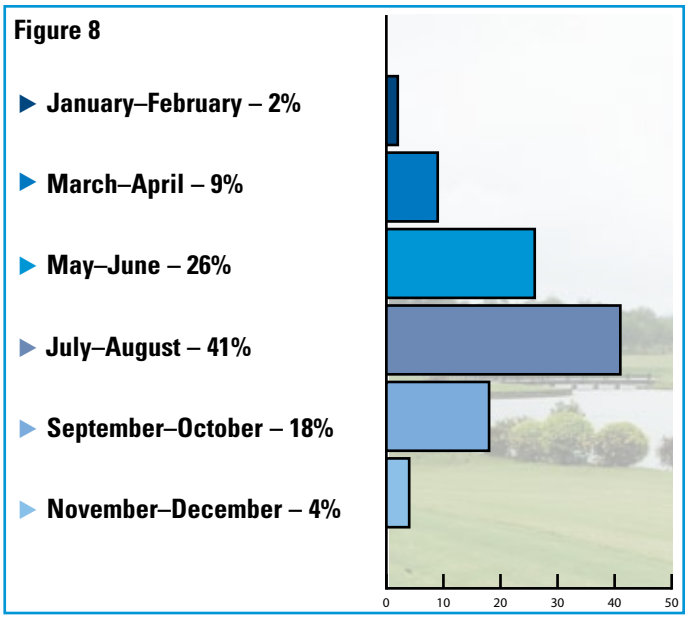
Monthly Irrigation Water Use

On a national basis, approximately 85 percent of irrigation water is used from May through October. Nearly half (41 percent) of the water use during that period is used during July and August (Figure 8, Appendix Table 7).

Monthly water-use patterns vary by agronomic region, with water use concentrated in May to October in the Northeast, North Central, Transition, Upper West/Mountain and Pacific agronomic regions.

In the Southeast and Southwest regions, water use is spread more evenly throughout the year because of year-round evaporative demand, turf growth and golf course use.

Figure 8 – Average 18-hole golf facility water use in the U.S. (percentage of total irrigation by month) (Appendix Table 7).

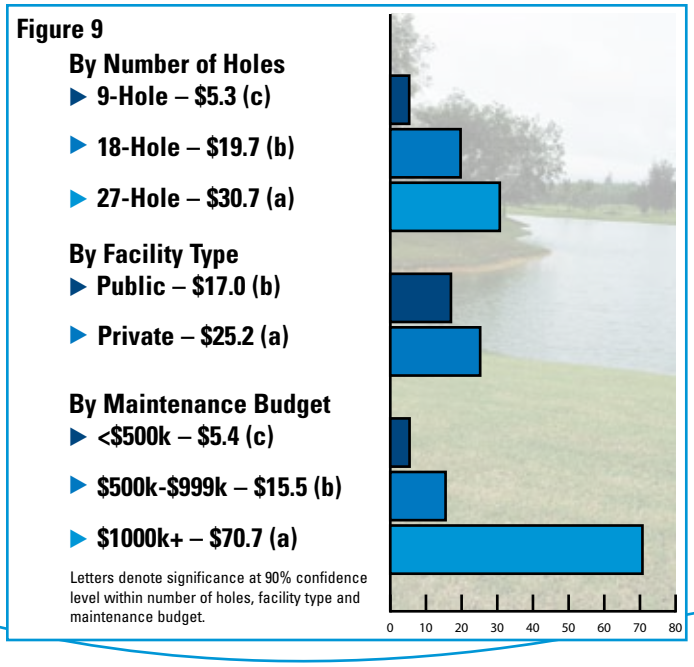


Irrigation Water Expenditures

Annual expenditures for irrigation vary by agronomic region, number of golf holes at the facility, maintenance budget and course types.

- As the number of holes increase at a golf facility, significantly more is spent on water for irrigation.
- Private facilities spend more on water for irrigation than public facilities.
- Golf facilities with higher budgets spent significantly more on water. Those with maintenance budgets exceeding $1,000,000 spend more than four times the amount on water than those with less than $1,000,000 budgets. There is a higher proportion of golf courses with maintenance budgets greater than $1,000,000 located in the Southwest and Southeast regions. These facilities have a longer growing season, year-round turf growth, higher demands for water and, as a result, higher maintenance budgets.

Figure 9 – Irrigation water cost for the average golf facility in the U.S. (average total expenditure by number of holes, facility type and maintenance budget – in thousands of dollars).

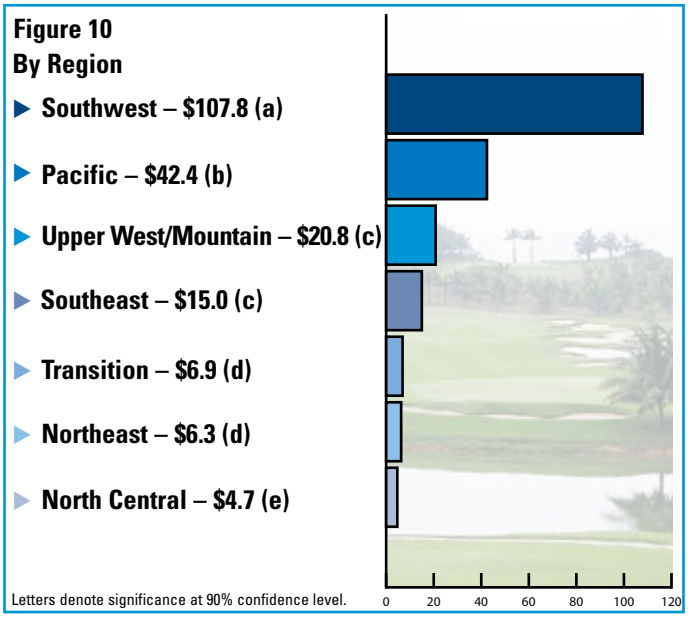


Irrigation Water Expenditures by Agronomic Region

Survey participants were asked to identify the expenditure for the purchase of water for irrigation. Costs associated with operating pumps or delivery systems are not included in the expenditures reported in this survey. Irrigation water expenditures vary significantly among the agronomic regions for 18-hole golf facilities (Appendix Table 8).

- 18-hole golf facilities in the Southwest region spend significantly more for irrigation water than golf facilities in any other agronomic region, an estimated $107,800 dollars.
- The agronomic regions with the lowest expenditures for irrigation water are the North Central ($4,700), Northeast ($6,300) and Transition ($6,900) regions.

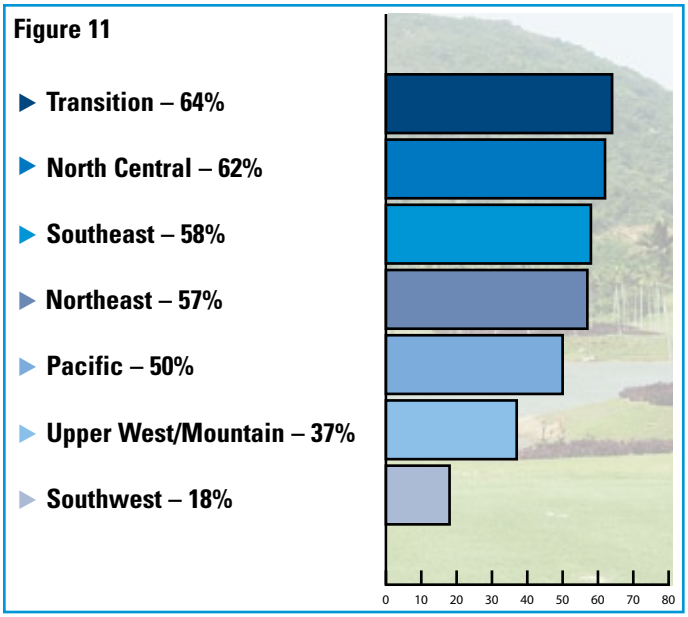
Figure 10 – Irrigation water cost for average 18-hole golf facilities in the U.S. by agronomic region (in thousands of dollars).



Irrigation Water Expenditures

At least 50 percent of golf facilities in all regions, except the Southwest and Upper West/Mountain regions, do not pay for irrigation water (Appendix Table 8). This can be attributed to the differences in the amount of precipitation and relative abundance of surface and/or groundwater in each region.

Figure 11 – Percentage of 18-hole golf facilities that do not pay for water in the U.S. by agronomic region (Appendix Table 8).



Changes in Water Expenditures

Survey participants were asked to identify changes in water costs from 2001-2005. Water costs have increased over this period for 53 percent of golf facilities, stayed the same for 43 percent, and decreased for 4 percent (Appendix Table 9).

- Irrigation water cost was most likely to have increased for golf facilities in the Southwest and Pacific regions and stayed the same in the Northeast, Transition and Southeast regions.
- The average percentage increase was greatest in the North Central agronomic region at 45 percent and smallest in the Transition region at 15 percent.
- The percentage of golf facilities that experienced a decrease in irrigation water cost ranged from 6 percent in the Transition, Southwest, and Upper West/Mountain regions to 2 percent in the Pacific region.

Cost of Irrigation Water from Various Sources

Average annual expenditures for irrigation water from different water sources for an 18-hole golf facility in 2005:

Municipal water – $52,400
Recycled water – $44,400
Well water – $6,900
River, streams, etc. – $4,600
Open waters (ponds, lakes, etc.) – $3,900

Note: Expenditures are associated with water costs only and do not reflect cost to operate pumps or the delivery system.

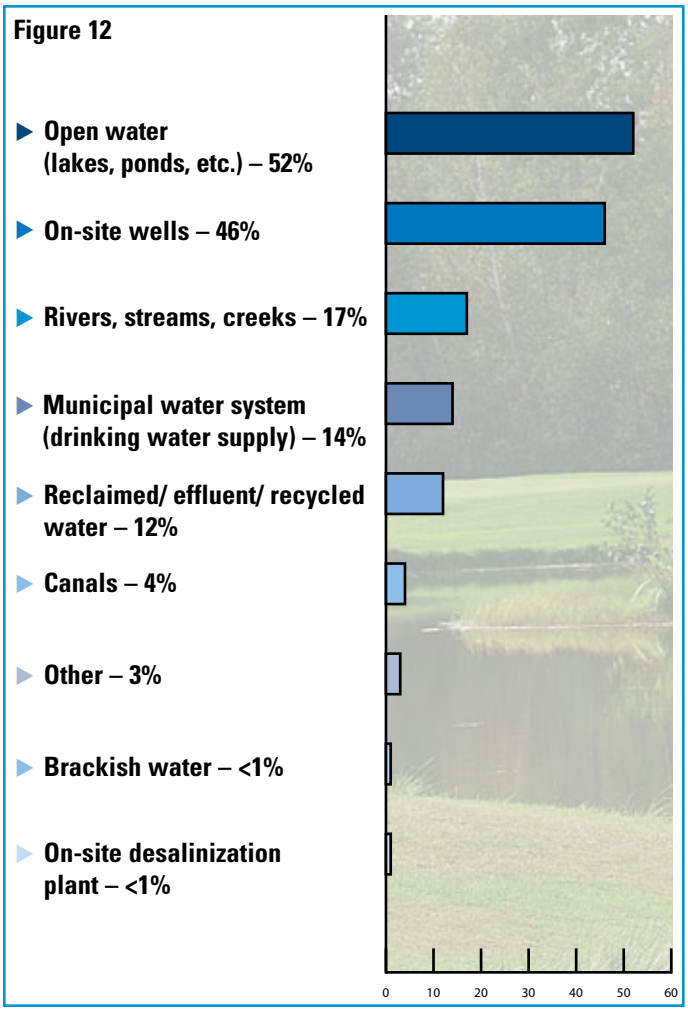
Irrigation Water Sources

Golf facilities utilize multiple sources for irrigation ranging from surface water (ponds, lakes, streams) and ground water sources to water provided by a local municipality (Appendix Table 10).

Many golf facilities have more than one source of water to use for irrigation. Most of the water for 18-hole golf facilities comes from surface waters such as ponds or lakes, or on-site irrigation wells.

Approximately 14 percent of irrigation water is supplied by municipal drinking water sources, and 12 percent of golf facilities nationally use recycled water as an irrigation source.

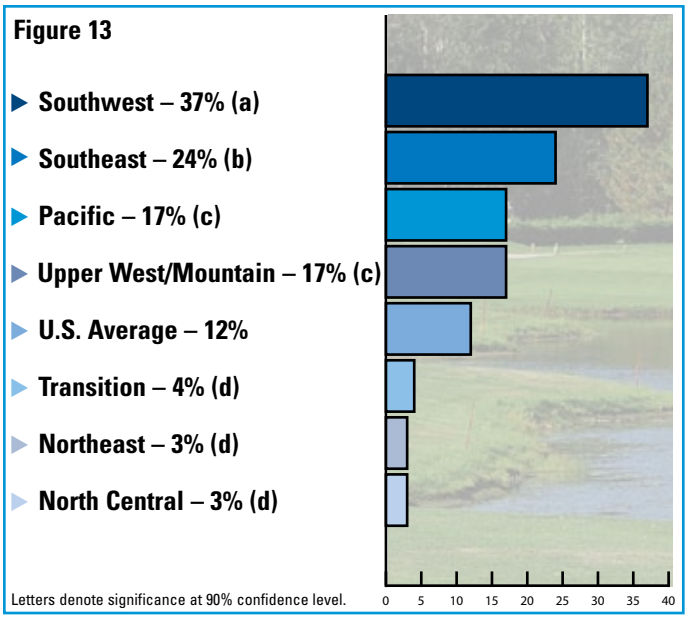
Figure 12 – Irrigation water sources for average 18-hole golf facilities in the U.S. (Appendix Table 10).



Recycled Water Use

Recycled water, often called effluent or reclaimed water, is produced by water treatment facilities and sold for irrigation or other purposes. Approximately 12 percent of golf courses nationally use recycled water as a source for irrigation. The use of recycled water varies significantly by agronomic region. More golf facilities in the Southwest (37 percent) use recycled water as an irrigation source than any other region. The Southeast region has the next highest use with 24 percent of golf course facilities using recycled water. Recycled water use is significantly lower in all other regions (Figure 13, Appendix Table 10).

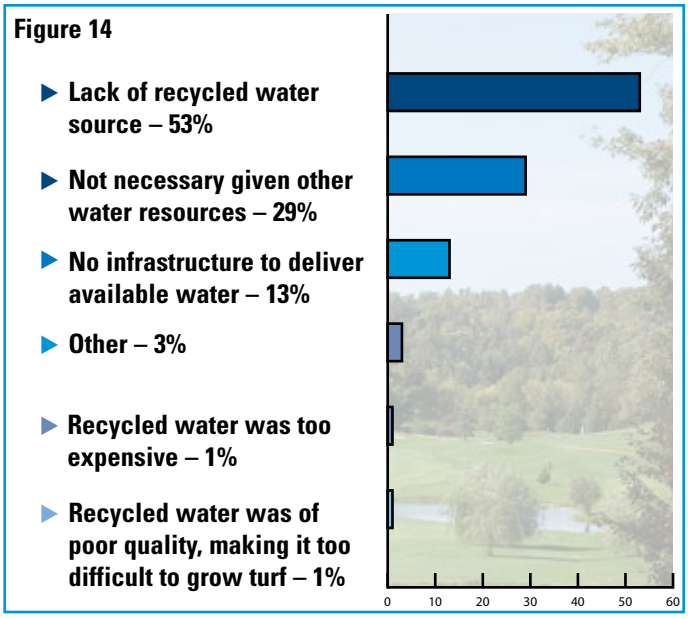
Figure 13 – Percentage of golf facilities that use recycled irrigation water in the U.S. by agronomic region (Appendix Table 10).



Survey respondents were asked to identify why they were not currently using recycled water. The most common reason cited for not using recycled water (by 53 percent of respondents) was the lack of a source. Other responses were:

- Not necessary given other water resources (29%)
- No infrastructure to deliver available recycled water (13%)
- Recycled water was too expensive (1%)
- Recycled water was of poor quality making it too difficult to grow turfgrass (1%) (Figure 14)

Figure 14 – Reasons cited for not using recycled water for irrigation by percent of U.S. golf facilities.



- *Private and public golf facilities showed no difference in recycled water use, but more golf facilities with a greater number of holes and higher maintenance budgets used recycled water for irrigation.*
- *Recycled water was a more prevalent water source for golf facilities in the Southwest (37 percent) than in any other agronomic region.*
- *The Southeast agronomic region ranked second in its use of recycled water with 24 percent of golf facilities using it for irrigation.*
- *Use of recycled water for irrigation was significantly lower in the Northeast (3 percent), North Central (3 percent), and Transition (4 percent) agronomic regions.*

Irrigation Water Quality

Many golf course superintendents include irrigation water quality testing as part of their turfgrass management program. Golf facilities with more holes, higher budgets and private facilities are more likely to test the quality of their irrigation water.

- More than half of the 18-hole golf facilities in the Southwest, Southeast, and Upper West/Mountain agronomic regions have had their irrigation water analyzed since 2003.
- Irrigation water quality was generally acceptable or better in all agronomic regions for growing turfgrass. There are individual golf courses in each agronomic region that face challenges with irrigation water quality.
- Irrigation water quality, as determined by total dissolved solids, sodium absorption ratio, pH, and residual sodium carbonate, was poorest in the Southwest agronomic region (Figures 15a and 15b, Appendix Table 11).

Figure 15a – Total dissolved solids in irrigation water for golf facilities in the U.S. by agronomic region (Appendix Table 11).

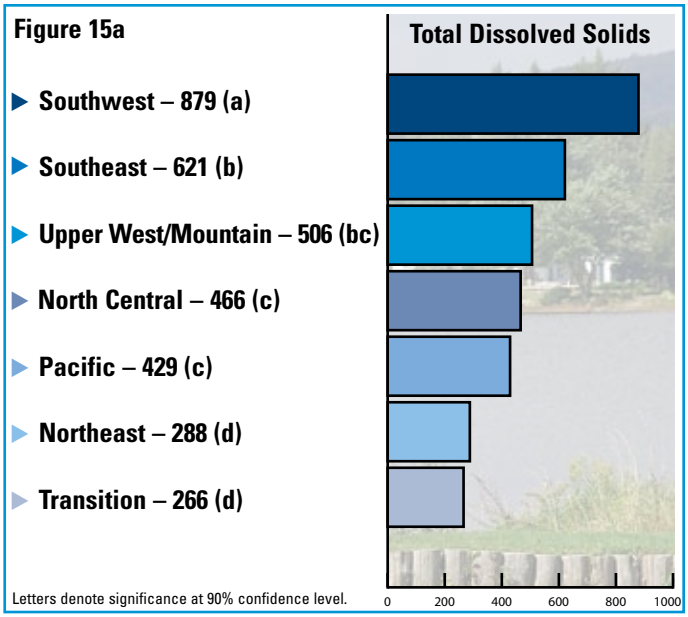
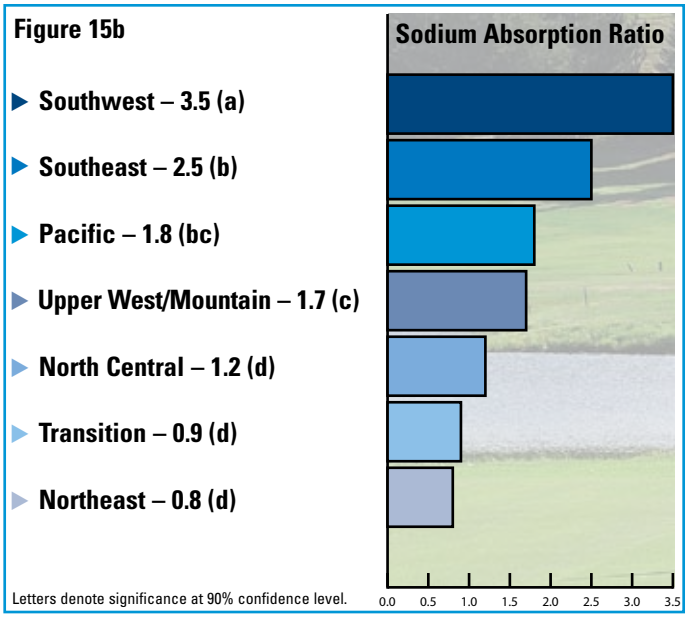


Figure 15b – Sodium absorption ratio for irrigation water for golf facilities in the U.S. by agronomic region (Appendix Table 11).

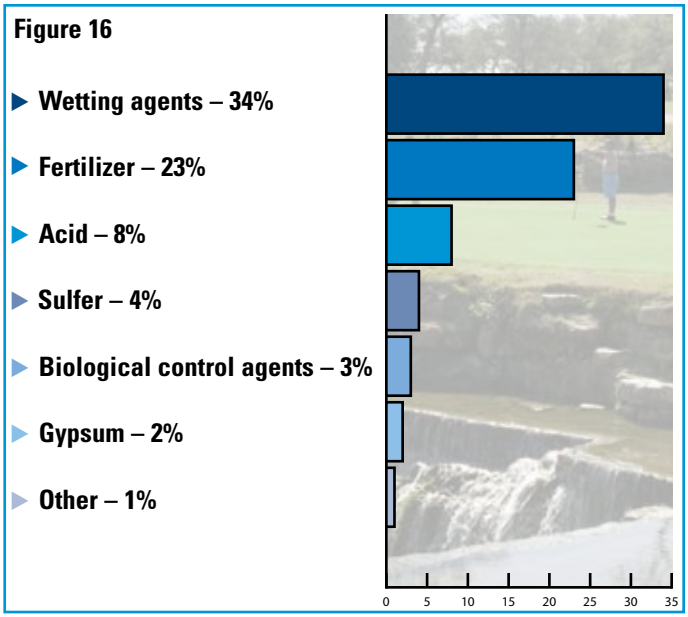


Irrigation Water Treatments and Products Delivered Through the Irrigation System

Approximately 46 percent of 18-hole golf facilities treat irrigation water or add products for distribution with irrigation water through the irrigation system as part of their turfgrass management programs (Figure 16, Appendix Table 12).

- The most common products delivered through the irrigation system are wetting agents and fertilizers.
- The use of wetting agents and fertigation units increases at 18-hole facilities as the maintenance budget increases.
- More than 70 percent of 18-hole golf facilities with annual maintenance budgets less than $500,000 do not treat irrigation water or deliver products through their irrigation system.
- The majority of 18-hole golf facilities using wetting agents and fertigation units are in the Southeast and Southwest agronomic regions.

Figure 16 – Water treatments and products delivered through the irrigation system at 18-hole golf facilities in the U.S. (Appendix Table 12).



Irrigation Systems

Golf facilities with irrigation systems that are fully automatic or semi-automatic are more common than those controlled manually (Appendix Table 13).

- Only 9 percent of public golf facilities and 2 percent of private golf facilities use manual irrigation systems.
- Fully automatic irrigation systems are found on 80 percent of 27-hole facilities, 75 percent of 18-hole facilities and 33 percent of 9-hole facilities.
- Golf facilities with 18 or more holes, private facilities and those with maintenance budgets greater than $1,000,000 are more likely to have a fully automatic irrigation system.

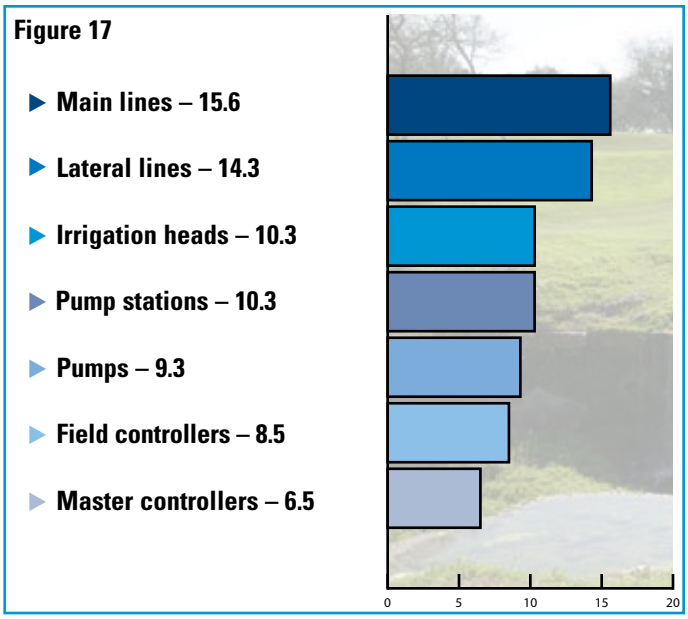
Age of Irrigation System Components

Survey participants were asked to identify the age of various components of their irrigation systems.

- Main and lateral lines are the oldest components typically, averaging 16 and 14 years old respectively.
- Master controllers are much newer – only about 6.5 years old on average (Figure 17).

- *Nearly one-half of 18-hole facilities added new software to better control irrigation from 2001–2005.*
- *Sprinkler heads (new and additional) and new nozzles were the most common improvement measures 18-hole facilities installed from 2001–2005.*

Figure 17 – Average age (years) of irrigation system components in the U.S. averaged over all golf facilities.



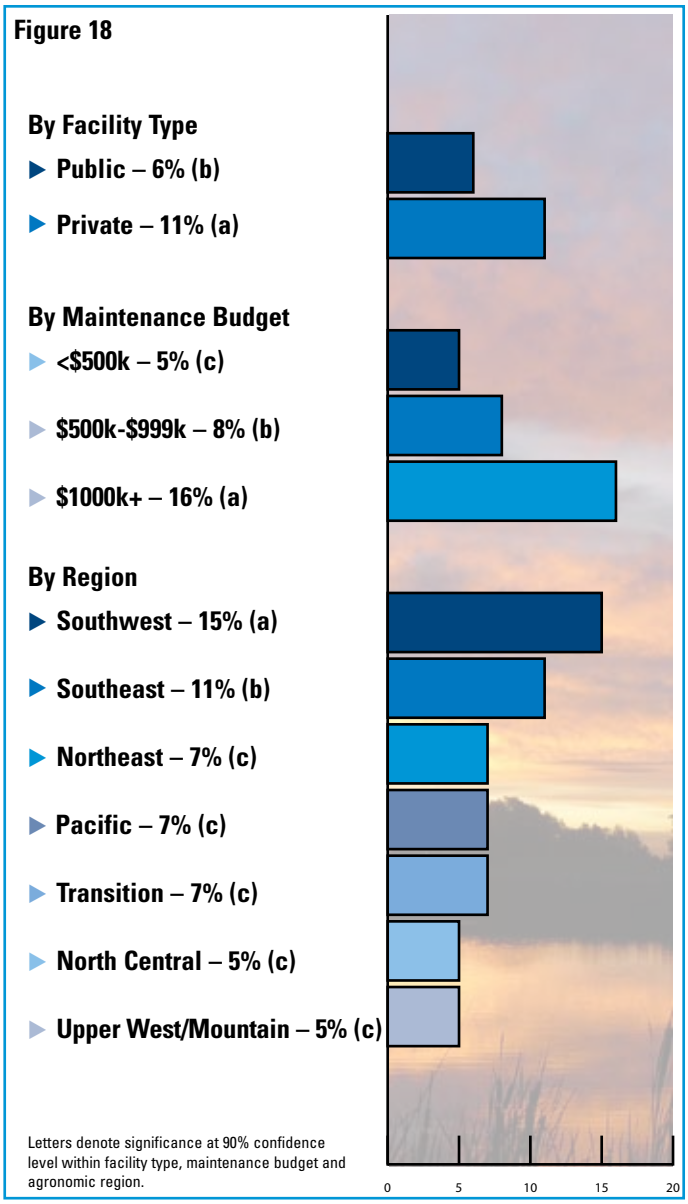
Irrigation Systems

System Audits

From 2001–2005, approximately 8 percent of 18-hole golf facilities nationally had their irrigation systems audited by a certified irrigation auditor.

- Irrigation system audits are more prevalent among private facilities and facilities with larger maintenance budgets.
- Irrigation system audits are more common in the Southwest and Southeast agronomic regions, where 15 percent and 11 percent, respectively, have conducted an audit. In other regions, 5 to 7 percent of 18-hole golf facilities have conducted an irrigation system audit.
- For those 18-hole golf facilities that conducted an irrigation audit, the average overall distribution uniformity for the irrigation system was 72 percent.

Figure 18 – Percent of golf facilities that have conducted an irrigation system audit by facility type, maintenance budget and agronomic region.

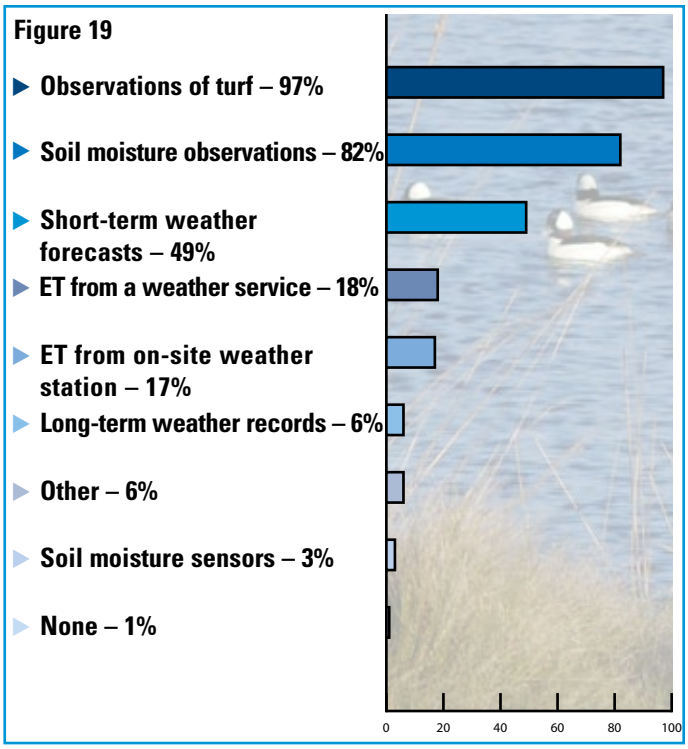


Irrigation Water Management and Conservation

Survey participants were asked to indicate techniques used to determine when to irrigate and how much water to apply to the golf course. Nearly all 18-hole golf facilities use one or more techniques to aid in scheduling irrigation. The majority of 18-hole golf facilities directly observe the turf and soil moisture to aid their irrigation scheduling decisions.

Short-term weather forecasts also play a role in the decision-making process for nearly half of the participants. Evapotranspiration (ET) readings from a local weather service or on-site weather station were used by approximately 35 percent of the respondents. Soil moisture sensors were only used by approximately 3 percent of survey respondents. At the time the survey was conducted, soil moisture-sensing technology had limited capabilities resulting in the low adoption rate by superintendents (Figure 19).

Figure 19 – Percent of 18-hole golf facilities in the U.S. that used the listed irrigation scheduling technique.



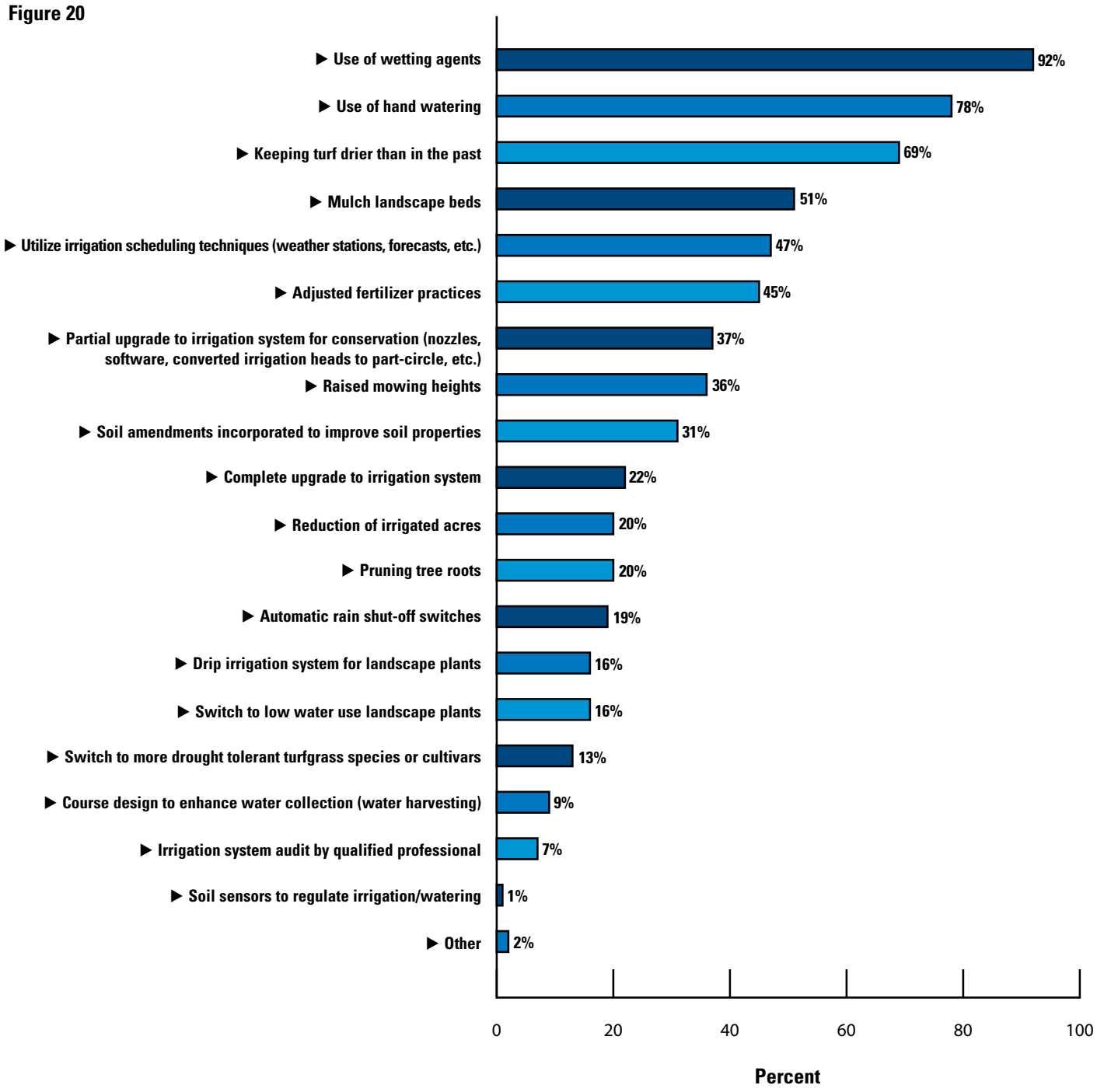
Irrigation Water Conservation Methods

Survey participants were asked to describe practices utilized to conserve irrigation water. Nearly all 18-hole golf facilities have incorporated several practices to conserve irrigation water (Figure 20, page 31). The top three practices are:

- The use of wetting agents (92%)
- Hand-watering (78%)
- Keeping turfgrass drier than in the past (69%)

Irrigation Water Management and Conservation

Figure 20 – Percent of 18-hole golf facilities in the U.S. that use the listed irrigation water conservation method.

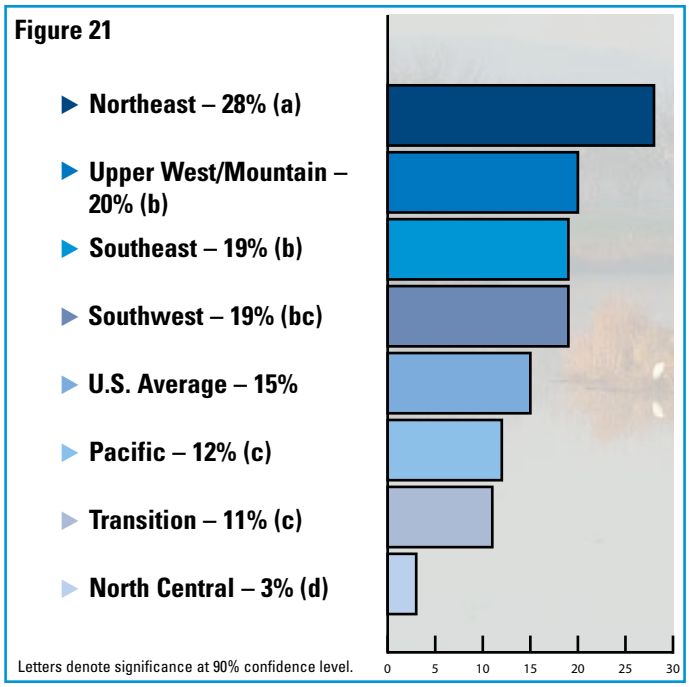


Written Drought Management Plans

Written drought management plans provide superintendents with a documented procedure to reduce irrigation water use during drought. These plans can be developed on a voluntary basis and also can be required by a government entity. Approximately 15 percent of 18-hole golf facilities in the U.S. have a written drought management plan (Figure 21, Appendix Table 14). Sixty-three percent of 18-hole golf facilities that have developed a plan were required to do so by a state or local governing authority. Private golf facilities and those with an annual maintenance budget greater than $500,000 are more likely to have a written drought management plan.

There are differences among the agronomic regions for 18-hole golf facilities that have written drought management plans. Twenty-eight percent of 18-hole golf facilities in the Northeast agronomic region have written drought management plans and are more likely to have them than any other agronomic region (Figure 21, Appendix Table 15).

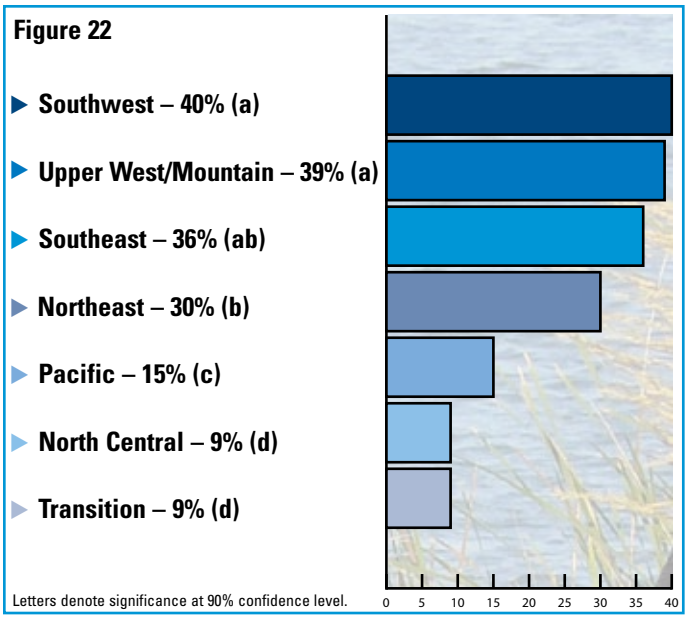
Figure 21 – Percentage of 18-hole golf facilities that have a written drought management plan in the U.S. by agronomic region (Appendix Table 15).



Irrigation Water Allocations and Restrictions

An estimated 25 percent of all 18-hole golf facilities are subject to a recurring annual irrigation water allocation. Recurring annual irrigation water allocations are most common on 18-hole golf facilities in the Southwest (40%), Upper West/Mountain (39%), Southeast (36%), and Northeast (30%) agronomic regions (Figure 22, Appendix Table 15).

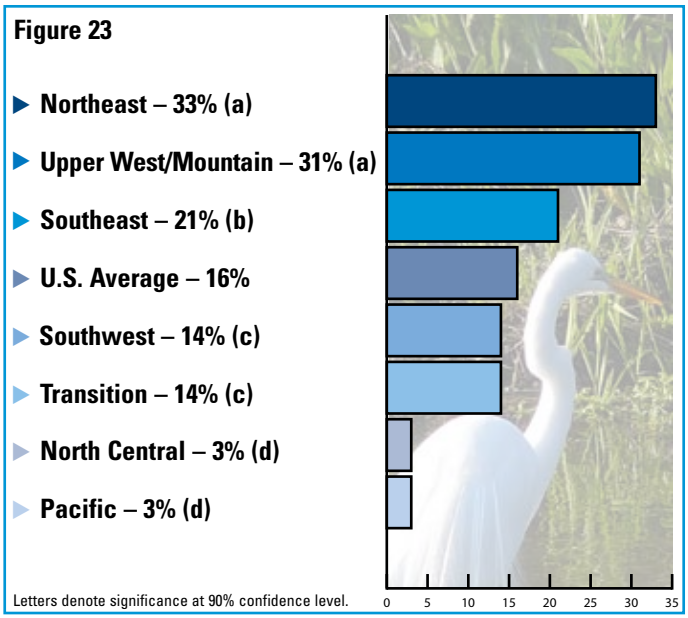
Figure 22 – Percentage of 18-hole golf facilities subjected to an annual recurring irrigation water allocation in the U.S. by agronomic region.



Additional Mandatory Irrigation Water Restrictions

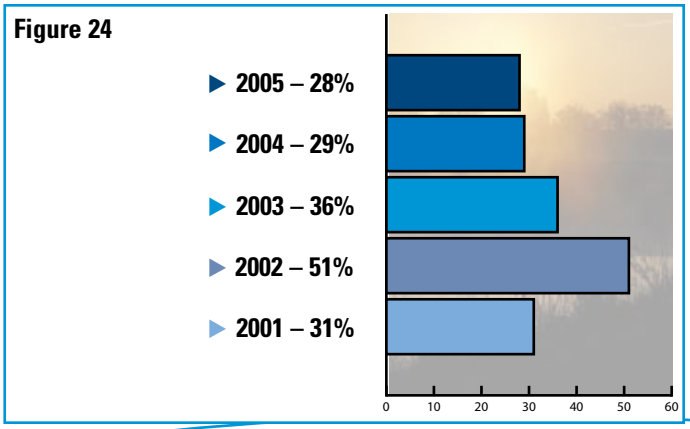
From 2001-2005, 16 percent of U.S. golf facilities were subject to mandatory irrigation water restrictions that were more stringent than normal recurring irrigation water allocations (Figure 23, Appendix Table 15). These additional mandatory restrictions have been more common in the Northeast (33%) and Upper West/Mountain (31%) agronomic regions.

Figure 23 – Percentage of 18-hole golf facilities subjected to additional mandatory irrigation water restrictions in the U.S. by agronomic region.



In the period of the study, 2001 to 2005, 2002 saw the highest percentage of golf facilities (51%) impacted by additional mandatory irrigation water restrictions (Figure 24).

Figure 24 – Percentage of 18-hole golf facilities subjected to additional mandatory irrigation water restrictions by year in the U.S.



Conclusions

This survey has provided the GCSAA and The Institute a baseline for water use and conservation on golf facilities in the U.S. and the means to document change over time. The water use and conservation survey results, in conjunction with results of the property profile and environmental stewardship of golf courses survey, present an accurate portrayal of land use and water use on golf facilities in the U.S.

Golf facilities are economic, environmental and recreational assets to local communities. Water is essential for golf. Communities derive direct value from the water applied to golf facilities by generating an economic return while adding social and environmental benefits. Water availability, cost and quality of the water used for irrigation remain important issues for the long-term sustainability of golf in the U.S., particularly in the Southwest. This report indicates that golf course superintendents and the golf industry are well positioned to professionally manage and protect water resources in the future.

Golf facilities must proactively conserve water. Conserving water on golf facilities is essential to becoming a sustainable business. The GCSAA and The Institute are providing research, education, best management practices, membership standards and other resources to assist golf facilities in advancing their environmental sustainability. Optimizing the acreage of irrigated turfgrass, implementing best management practices, utilizing technology to make water application decisions, conducting an irrigation system audit along with an audit of the non-golf course water uses at the entire facility are key to becoming responsible users of water.

The GCSAA supports working collaboratively with the golf industry, citizens, communities and all levels of government to develop practical public policy related to water issues.

Economic Data

Golf facilities play an important role within their communities not only as an environmental asset and a recreational resource, but also as a significant economic contributor. The golf industry provides considerable value to national and local economies. A 2005 economic survey[8] of the industry indicates:

- *Golf attracted more than 40 million participants in 2005.*
- *The U.S. golf economy generated $76 billion of goods and services in the year 2005. This is larger than newspaper publishing ($50.1 billion), performing arts and spectator sports ($64.7 billion), and the motion picture and video ($73.9 billion) industries.*
- *Golf generated a total economic impact of $195 billion in 2005, creating approximately 2 million jobs with a wage income of $61 billion.*
- *The amount of charitable giving attributed to the game of golf in the U.S. was estimated to be $3.5 billion in 2005.*

Irrigated Turfgrass Acreage in the U.S.

Nationally, golf facilities irrigate approximately 80 percent of the maintained turfgrass acres. Golf facilities located in areas of limited water supplies should irrigate only the turfgrass essential for the play of the game.

Overall, irrigated turfgrass acreage increased in the five-year period from 2001-2005. This is due to the extension of irrigation into the rough in the Transition, North Central and Northeast regions. Given the relative availability and low cost of water in these regions, this trend is likely to continue in the future as irrigation systems are updated in order to meet the expectations of golfers for improved playing conditions.

Conclusions

- There are an estimated 2,244,512 total acres of land on golf facilities in the U.S., including 1,504,210 acres of maintained turfgrass and 740,302 acres of non-turfgrass landscapes, buildings and parking lots.[1]

- There are an estimated 1,198,381 acres of irrigated turfgrass, which is approximately 80 percent of the maintained turfgrass acreage.[1]

- From 2001-2005, an estimated 31,877 acres of irrigated turfgrass were added to existing golf facilities in the U.S. The greatest net gain occurred in the North Central and Northeast regions, where 13,513 and 8,442 new acres were irrigated, respectively. The Southwest region had an estimated net decrease of 12 acres.

Acreage estimates for lawns in the U.S., including golf courses, is approximately 31.7 million acres as reported in 2005 within NASA's earth observatory features section.[5]

Golf's 1,198,381 acres of irrigated turfgrass would account for approximately 3.2 percent of the 31.7 million total estimated acres of lawns.

Irrigation Water Sources

Golf facilities utilize multiple water sources for irrigation, and the most commonly used water sources for 18-hole golf facilities are listed below. Golf courses should maximize the use of non-potable water to irrigate golf courses when economically and practically feasible. Most golf course facilities utilize open water or on-site irrigation wells as a source for water. Approximately 12 percent of golf facilities utilize recycled water as a source for irrigation water and 14 percent use potable water from a municipal source for irrigation.

- 52% – open water (lakes, ponds, etc.)
- 46% – on-site wells
- 17% – rivers, streams and creeks
- 14% – municipal water systems
- 12% – recycled water

Irrigation Water Use Nationally

From 2003-2005, the average water use for golf course irrigation in the U.S. was estimated to be 2,312,701 acre-feet of water. The U.S. Geological Survey (USGS) estimated total water withdrawals in the U.S. in 2000 at 457,000,000 acre-feet and agricultural irrigation water use, including golf courses, at 153,000,000 acre-feet. Irrigation water use on U.S. golf courses is estimated to be 0.5 percent of the annual total water withdrawal for the country and 1.5 percent of the estimated annual total agricultural irrigation water use.

USGS estimates between 80 and 100 gallons of water use per day per person.[7]

In 2005, the population estimate for the U.S. was 295,896,000. Using a 100-gallon, per-day per person value for the population equates to approximately 33 million acre-feet per year of water for personal/home use in the U.S.

Conclusions

According to Golf Digest's 2007 Golf and The Environment Survey:

- *Forty-one percent of the golfers surveyed felt that the amount of water used on a golf course should only be enough to keep the grass alive, not make it green and lush.*
- *Seventy-five percent felt that golfers should be willing to play on brown grass during periods of low rainfall, but 72 percent felt that golf courses should be uniformly maintained throughout the year for the enjoyment of golfers and enhancement of scenery.*

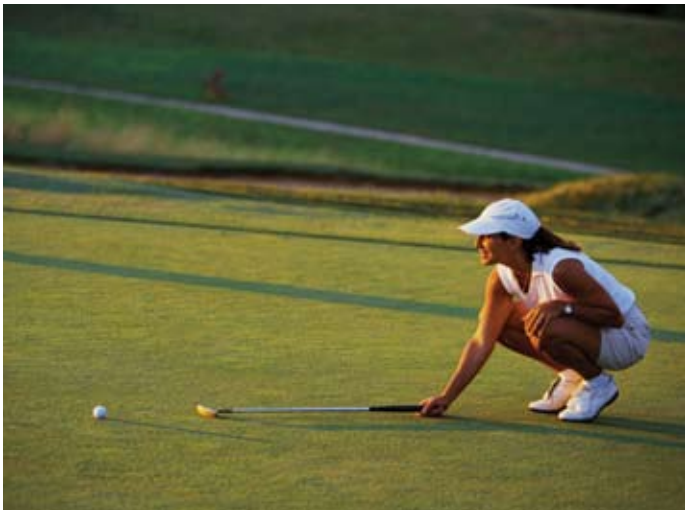
Recycled Water Use for Irrigation

The use of recycled water is a win-win proposition for the golf course industry. Golf course facilities provide a valuable long-term customer for local treatment facilities, and the turfgrass is an effective biological filter to further treat the water. Water quality, particularly salt content, can be a long-term problem for golf facilities if they have no other source of water or no control over the quality of the recycled water they receive for irrigation. The golf industry should strive to maximize the use of recycled water when the availability, quality, and cost are sustainable for the golf facility and it is practical given the local water resources available. Results of this survey indicate that the reason recycled water is not utilized more is because it is not available.

- Recycled water is used as an irrigation source by 12 percent of golf facilities in the U.S. More facilities in the Southwest (37%) and Southeast (24%) regions are using recycled water as compared to other regions.
- The most common reasons cited for not using recycled water was the lack of a source by 53 percent of respondents, not necessary given other water resources (29%), no infrastructure to deliver available water (13%), recycled water was too expensive (1%), recycled water was of poor quality making it too difficult to grow turf (1%) and other (3%).

Irrigation Water Management and Conservation

Superintendents at nearly all 18-hole golf facilities utilize information from multiple sources as part of their decision-making process for scheduling irrigation. Most facilities utilize direct observations of turfgrass and soil conditions. Approximately 35 percent routinely utilize evapotranspiration data, and approximately 3 percent use soil moisture sensors to aid in irrigation scheduling. Golf course superintendents should take advantage of technology as part of the irrigation decision-making process to conserve water. The utilization of data from soil sensors for irrigation scheduling decisions is likely to increase in the future as the equipment becomes more reliable and affordable.



Conclusions

Superintendents at 18-hole golf facilities utilize numerous methods to conserve water. The top three conservation methods and the percent of golf facilities utilizing that method are: wetting agents (92%); hand watering (78%); and keeping turfgrass drier (69%).

Irrigation Water Expenditures

Eighteen-hole golf facilities in the Southwest region spend significantly more for irrigation water than 18-hole golf facilities in any other agronomic region, an estimated $107,800 annually. The agronomic regions with the lowest expenditures for irrigation water are the North Central, Northeast and Transition regions, spending $4,700, $6,300 and $6,900, respectively.

Golf facilities use multiple sources of water for irrigation. The average annual expenditure for common sources of irrigation water are listed below. Expenditures do not include pumping or irrigation system operation costs.

- Municipal water – $52,400
- Recycled water – $44,400
- Well water – $6,900
- Rivers, streams, etc. – $4,600
- Open waters (ponds, lakes, etc.) – $3,900

Irrigation Water Quality

In general, irrigation water quality is acceptable or better in all agronomic regions, although there are golf facilities in all agronomic regions that face significant agronomic challenges due to the quality of their irrigation water. The Southwest region has the poorest quality of irrigation water compared to other regions.

Irrigation Water Treatments

Approximately 46 percent of 18-hole golf facilities treat their irrigation water or distribute products via the irrigation system. The most common products distributed through the irrigation system are wetting agents and fertilizers. The majority of facilities using irrigation water treatments or distributing products through the irrigation system are located in the Southwest and Southeast agronomic regions.

Irrigation Systems and Audits

Golf facilities should utilize irrigation system audits as a means to increase the effectiveness of the irrigation system and conserve water. Approximately 8 percent of 18-hole golf facilities nationally have had their irrigation systems audited by a certified irrigation auditor since 2001. More golf course facilities should take advantage of an irrigation system audit to become more responsible users of water. For those that conducted an audit, the average distribution uniformity was 72 percent. This lies within the average of 70 to 85 percent measured on golf courses by Kah and Willig.[6]

Conclusions

Fully automatic irrigation systems are found on 80 percent of 27-hole and 75 percent of 18-hole golf facilities. New sprinkler heads and nozzles were the most common improvements installed, and nearly 50 percent of 18-hole golf facilities added new control systems from 2001-2005.

Written Drought Management Plans

A written drought management plan provides a documented procedure to reduce the use of irrigation water during drought. These written plans are a helpful tool for individual golf facilities and are valuable for the golf industry in developing practical public policy at the local and state level. Approximately 28 percent of 18-hole golf facilities in the Northeast agronomic region have written drought management plans, more than any other agronomic region. Written drought management plans should be adopted by golf facilities that are subject to drought cycles.

Irrigation Water Allocations and Restrictions

An estimated 25 percent of all 18-hole golf facilities are subjected to recurring annual irrigation water allocations. Facilities in the Southwest (40%), Upper West/Mountain (39%) and Southeast (36%) are most likely to be subjected to a recurring annual water allocation.

From 2001 to 2005, 16 percent of 18-hole golf facilities in the U.S. were subjected to mandatory irrigation water restrictions more stringent than the normal recurring annual irrigation water allocation for at least one year. Facilities in the Northeast and Upper West/Mountain agronomic regions were more likely to experience more stringent restrictions. Access to irrigation water will continue to be a primary issue for the golf industry. Written drought management plans, practical public policy and water conservation will be important to the future sustainability of individual golf facilities and the golf industry in general.

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Appendix

Table 1. Number of golf facilities, percent of total number of golf facilities, completed surveys received, percent of the total completed surveys received, response rate within the category and margin of error for agronomic region, course type, and number of holes.

	Golf facilities		Completed surveys*			
	Number**	% of total no.	Number received	% of total	Response rate (%)***	Margin of error (%)****
Region						
Northeast	2,871	17.1	391	15.4	13.6	3.9
North Central	4,238	25.2	630	24.8	14.9	3.0
Transition	3,116	18.6	449	17.7	14.4	3.6
Southeast	3,518	20.9	475	18.7	13.5	3.5
Southwest	1,272	7.6	208	8.2	16.4	5.2
Upper West/ Mountain	1,100	6.5	247	9.7	22.5	4.6
Pacific	682	4.1	140	5.5	20.5	6.2
Type						
Daily fee	9,408	56.3	1,147	45.2	12.2	2.3
Municipal	2,460	14.7	443	17.4	18.0	3.5
Private	4,831	28.9	950	37.4	19.7	2.4
No. of holes						
9	4,557	28.5	284	11.2	6.2	4.7
18	9,965	62.2	1,893	74.5	19.0	1.7
27+	1,487	9.3	363	14.3	24.4	3.8

*** The total number of completed surveys was 2,548.**

**** The total number of golf facilities was 16,797.**

***** Response rate is the percentage of the total number of completed surveys received for each region, course type and course classification (9, 18 or 27+ holes).**

****** At 90% confidence interval.**

Table 2. Irrigated turfgrass acres, irrigation water expenditure, water expenditure per irrigated turfgrass acre, and percentage of golf facilities using recycled water in the U.S. by golf facility characteristic.

Golf facility characteristic	Irrigated turfgrass (acres)*	Water expenditure (US$)*	Water expenditure/ irrigated turfgrass acre (US$)	% of golf facilities using recycled water*
No. of holes				
9	26c	5,300c	204	5c
18	81b	19,700b	243	12b
27	127a	30,700a	242	19a
Facility type				
Public	77b	17,000b	221	12
Private	88a	25,200a	286	12
Maintenance budget				
< $500,000	63c	5,400b	86	8c
$500,000 to $999,999	91b	15,500b	170	13b
$1,000,000 or >	111a	70,700a	637	24a

***Within a column and golf facility characteristic, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 3. Number of irrigated acres and percentage of total irrigated acres by golf course component for an average 18-hole golf facility in the U.S.

Component	Irrigated acres	% total irrigated acres
Greens	3.7	4.6
Tees	3.4	4.2
Fairways	30.7	38.0
Rough	33.8	41.9
Practice area	5.6	6.9
Clubhouse grounds	3.5	4.3
Total	80.7	99.9

Table 4. Irrigated turfgrass acres, water use, and water use per irrigated turfgrass acre on an average 18-hole golf facility by agronomic region.

	Agronomic region*						
	NE	NC	Trans	SE	SW	UW/Mtn	Pac
Irrigated turfgrass (acres)**	54f	66e	74d	100b	115a	103b	84c
Water use (acre-feet)**	42.4f	76.7e	78.9e	241.8c	459.0a	300.4b	158.0d
Water use/ irrigated turfgrass acre (acre-feet)	0.8	1.2	1.1	2.4	4.0	2.9	1.9
Water use/irrigated turfgrass acre (inches)	9.4	13.9	12.8	29.0	47.9	35.0	22.6

*** Agronomic regions: NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 5. Changes in irrigated turfgrass acres on U.S. golf facilities since 2001.

Changes in turfgrass acres since 2001	Agronomic region*							
	US	NE	NC	Trans	SE	SW	UW/Mtn	Pac
% increased**	25	33a	28ab	25b	18c	16c	26ab	28ab
Avg. increase (acres)	13.0	14.0	20.5	10.7	5.1	16.7	9.5	7.7
% stayed the same**	66	60c	66abc	66abc	71a	70ab	63bc	60c
% decreased**	9	7b	6	9ab	11ab	14a	11ab	12ab
Avg. decrease (acres)	12.3	9.4	14.1	14.5	10.0	17.9	8.2	12.7

*** Agronomic regions: US, United States; NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 6. Average and total water use in acre-feet for 9-, 18- and 27-hole golf facilities in the U.S. and by agronomic region.

	Agronomic region*							
	US	NE	NC	Trans	SE	SW	UW/ Mtn	Pac
Facility type	Acre-feet							
9-hole								
Avg. water use	48.2	13.8	52.5	24.9	54.0	99.7	89.9	66.3
Total water use	219,376	10,625	73,813	20,118	34,311	27,440	38,950	14,125
18-hole								
Avg. water use**	152.5	42.4f	76.7e	78.9e	241.8c	459.0a	300.4b	158.0d
Total water use	1,518,070	74,733	181,900	152,750	521,093	352,950	175,827	58,816
27-hole								
Avg. water use	386.2	84.4	164.2	164.9	580.9	988.9	394.5	325.7
Total water use	575,255	17,223	57,324	33,961	245,701	173,052	26,826	21,174
Total water use	2,312,701	102,581	313,037	206,829	801,105	553,442	241,603	94,115

*** Agronomic regions: US, United States; NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 7. Water use by two-month periods for an average 18-hole golf facility in the U.S. and within each agronomic region.

	Agronomic region*							
	US	NE	NC	Trans	SE	SW	UW/Mtn	Pac
	% water use**							
January - February	2	0d	0d	1c	8a	6b	1c	1c
March - April	9	6d	5d	10c	15a	13b	10c	7c
May - June	26	27ab	27a	25bc	23d	24c	27ab	25bc
July - August	41	50a	49b	42d	26f	29e	41d	45c
September - October	18	16d	18c	19a	18bc	20a	19ab	19ab
November - December	4	1e	1f	3c	10a	8b	2d	3cd

*** Agronomic regions: US, United States; NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 8. Irrigation water expenditure and water expenditure per irrigated turfgrass acre for an average golf facility, and the percentage of 18-hole golf facilities that do not pay for water by agronomic region.

	Agronomic region*						
	NE	NC	Trans	SE	SW	UW/ Mtn	Pac
Irrigation water expenditure (US$)**	6,300d	4,700d	6,900b	15,000c	107,800a	20,800c	42,400b
Water expenditure/ irrigated turfgrass acre (US$)	117	71	93	150	937	202	504
% golf facilities that do not pay for water	57	62	64	58	18	37	50

*** Agronomic regions: NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 9. Changes in water cost on U.S. golf facilities since 2001.

Changes in water cost since 2001	Agronomic region*							
	US	NE	NC	Trans	SE	SW	UW/Mtn	Pac
% of golf courses with increased costs**	53	42c	61b	44c	47c	72a	41c	69a
Avg. % of cost increase	40	19	45	15	32	30	31	22
% of golf courses with no change**	43	54a	35b	50a	50a	22d	53a	29c
% of golf courses with decreased costs	4	4	4	6	3	6	6	2
Avg. % of cost decrease	33	23	31	39	36	26	39	76

*** Agronomic regions: US, United States; NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 10. Percentage of golf courses that use various types of irrigation water sources in the U.S. and within each agronomic region.

	Agronomic region*							
	US	NE	NC	Trans	SE	SW	UW/Mtn	Pac
Water source	%**							
Open water (lakes, ponds)	52	64b	55c	74a	62b	8e	24d	17d
Wells	46	41bc	62a	32c	45b	46b	37c	49b
Rivers, streams, creeks	17	22a	16b	16b	12c	4d	28a	15bc
Municipal water supply	14	16c	7d	18bc	8d	31a	13c	25ab
Re-use water (effluent, reclaimed)	12	3d	3d	4d	24b	37a	17c	17c
Canals	4	2d	1e	1e	3cd	9b	18a	6bc
Brackish water	<1	<1	0	<1	<1	0	0	1
On-site desalinization plant	<1	0	0	0	<1	0	0	0
Other	3	2	3	2	2	3	7a	5a

*** Agronomic regions: US, United States; NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 11. Water characteristics for golf facilities in the U.S. and within each agronomic region.

Water characteristic	Agronomic region*						
	NE	NC	Trans	SE	SW	UW/Mtn	Pac
Total dissolved solids (TDS) (ppm)**	288d	466c	266d	621b	879a	506bc	429c
Sodium absorption ratio (SAR)**	0.8d	1.2d	0.9d	2.5b	3.5a	1.7c	1.8bc
pH**	7.2d	7.6b	7.4c	7.4c	7.7a	7.7a	7.5bc
Residual sodium carbonate (RSC)**	0.3a	0	0.5a	0	0.6a	0	1.7a

*** Agronomic regions: NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 12. Water treatments or products delivered through irrigation systems at golf facilities in the U.S. and within each agronomic region.

Water treatment/ delivery system	Agronomic region*							
	US	NE	NC	Trans	SE	SW	UW/Mtn	Pac
	%**							
Wetting agents	34	35bc	27	25	42ab	49a	35b	30c
Fertigation	23	19c	5e	11d	50a	48a	27b	13c
Acid injection	8b	7b	9b	2d	10ab	15a	11ab	0d
Sulfer burner	4	0c	1c	0c	6b	12a	7ab	8ab
Biological control agents	3	2b	3b	2b	3b	10a	3b	1b
Gypsum	2	0b	1b	0b	2b	10a	6a	6a
Other	1bc	1bc	1bc	0c	1bc	2ab	1bc	1bc
None	54	57b	66a	70a	36cd	28cd	46c	62ab

*** Agronomic regions: US, United States; NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 13. Percentage of U.S. golf facilities that have fully or semi-automated, manual or other types of irrigation systems by golf facility characteristic.

Facility characteristic	Degree of automation			
	Fully automated	Semi-automated	Manual system	Other
	%*			
No. of holes				
9	33b	41a	25a	1
18	75a	18b	7b	0
27	80a	15b	5b	0
Facility type				
Public	70b	21a	9a	0
Private	86a	12b	2b	0
Maintenance budget				
< $500,000	58c	29a	12a	1
$500,000 to $999,999	88b	10b	2b	0
$1,000,000 or >	97a	2b	1b	0

***Within a column and golf facility characteristic, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 14. The percentage of golf facilities that have a written drought management plan and are subject to a recurring annual water allocation by golf facility characteristic.

Facility characteristic	Written drought management plan (%)*	Recurring annual water allocation (%)*
No. of holes		
9	9	18c
18	15	23b
27	20	27a
Facility type (18-hole)		
Public	13b	19b
Private	19a	28a
Maintenance budget (18-hole)		
< $500,000	9b	17c
$500,000 to $999,999	19a	26b
$1,000,000 or >	22a	36a

***Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**

Table 15. The percentage of 18-hole golf facilities that have a written drought management plan, are subject to recurring annual water allocation and are subject to temporary additional mandatory water restrictions more stringent than normal water allocation.

	Agronomic region*							
	US	NE	NC	Trans	SE	SW	UW/ Mtn	Pac
	%**							
Drought management plan	15	28a	3d	11c	19b	19bc	20b	12c
Recurring annual water allocation	25	30b	9d	9d	36ab	40a	39a	15c
Temporary additional mandatory water restrictions more stringent than normal water allocation	20	33a	3d	14c	21b	14c	31a	3d

*** Agronomic regions: US, United States; NE, Northeast; NC, North Central; Trans, Transition; SE, Southeast; SW, Southwest; UW/Mtn, Upper West/Mountain; Pac, Pacific.**

**** Within a row, values followed by the same letter are not significantly different from one another. Letters denote significance at the 90% confidence level.**