GCSAA

Golf Course Environmental Profile

Phase II, Volume I
Water Use and Conservation Practices on U.S. Golf Courses

EIFG GCSAA USGA

Funded by the USGA through the Environmental Institute for Golf, the philanthropic organization of the GCSAA.

WATER USE

Golf Course Superintendents Association of America

Golf Course Environmental Profile

Phase II, Volume I

2014 Water Use and Conservation Practices on U.S. Golf Courses

The second phase of the Golf Course Environmental Profile was conducted
by the Golf Course Superintendents Association of America through
the Environmental Institute for Golf and funded
by the United States Golf Association.

Table of Contents

Foreword

Water Study Yields Key Results

The results from the latest national study of golf course water use and conservation are encouraging and demonstrate our industry's thoughtful environmental stewardship.

This report is also the latest step in a landmark project that speaks for the golf course management profession and represents the golf industry in a positive manner. Part of the multiyear Golf Course Environmental Profile project funded by the USGA through the Environmental Institute for Golf, this study helps us measure our industry's progress since the first study was conducted in 2006. It is vital that we communicate these results and our continuing efforts in the areas of water conservation and sustainable business practices.

The latest results provide us with key information about management practices in light of regulations pertaining to water use, drought restrictions and water quality protection. Water is a valuable resource to everyone, and it is keenly important that we continue our efforts to reduce water usage and specifically, potable water use. We have a responsibility — not only for the golf industry, but also for the planet we share and for future generations.

Our members care for the biggest asset of any golf facility — the golf course. We must continue our science-based training, utilize best management practices to lead and educate in this vital area, and convey the overall benefits of the game and the golf industry.

On behalf of your board of directors, I thank all the superintendents who took the time to take part in this study. Measured against the baseline data collected in 2006, these results provide valuable information to allow us to be stronger advocates for our profession and the golf industry as a whole.

John J. O'Keefe

John J. O'Keefe, CGCS
2015 GCSAA President

Executive Summary

National water use

- U.S. golf courses used an estimated 1.859 million acre-feet of water in 2013, a 21.8% decrease from 2.379 million acre-feet in 2005. (See the sidebar, "Acre-feet and gallons" below.)
- In 2013, golf courses used 1.44% of all irrigation water in the U.S. vs. 1.66% in 2005.
- Factors contributing to decreased water use include water conservation practices, voluntary reduction in irrigated acres and reduction in number of golf facilities.

Regional water use

- Water use varied among the U.S. agronomic regions, primarily because of differences in climate, number of facilities per region, length of the turf growing season and number of irrigated acres per golf facility.
- Variation in water use was also significant within each agronomic region, particularly in the Pacific, Southwest and Southeast regions, which have the most diverse climates.
- Median water volume used per 18-hole golf course was lowest (36.8 acre-feet/year) in the cool and rainy climate of the Northeast regions, and highest (398.4 acre-feet/year) in the arid and warm climates of the Southwest region. (See the sidebar "Why use the median?" on Page 4.)
- Regions with year-round turf growing seasons (Southeast, Southwest) had the highest water use, while regions with the shortest growing seasons (Northeast, North Central and Northern portions of the Pacific region) had much lower water use patterns.
- In regions with warm and/or dry climates, all golf course features were irrigated, resulting in higher numbers of irrigated acres and higher water use. In regions with moderate to heavy rainfall, many golf courses did not irrigate all features (particularly roughs), and water use was therefore lower.

Water budget and water efficiency

- Water budgets, which estimate the amount of water that should be used by a golf course, based on site-specific climatic conditions, were estimated for each survey respondent.
- The majority of survey respondents used water efficiently, by using less water than forecast by their water budgets.

Hand watering was the second most commonly used conservation practice by U.S. golf facilities in 2013, with 77% of survey respondents reporting its use. **Photo by Scott Hollister**

Conservation practices

- Adoption of almost all conservation practices has increased from 2005 to 2013, contributing significantly to water savings.

Water sources

- Usage of all water sources decreased from 2005 to 2013, except for recycled (reclaimed) water.
- Recycled water was used by 15.3% of survey respondents in 2013, compared to 10.9% in 2005.
- Increased use of recycled water allowed for reductions in the use of other water sources such as open water, rivers, streams and creeks, well water, and municipal (potable) water.

Acre-feet and gallons

One acre-foot is equal to 325,851 gallons of water, and is the equivalent of an acre of land covered with water to a depth of 1 foot.

The Southwest region includes the desert areas of Southern California. In 2013, a typical 18-hole golf course in this region had 103.1 irrigated acres. **Photo © Montana Pritchard**

Why use the median?

Much of the data presented in this report — such as acre-feet used, number of acres or cost of water — is in the form of a statistic known as the median. It is the value at which half of the population is higher, and half is lower.

The median is used to represent the most "average" number in a dataset, and is probably most familiar to those of you who track real estate prices (as in the "median price of new homes"), your child's weight and height or household income.

A different statistic that also represents the "average" is the mean. Although the mean and the median are frequently very close in value to one another, there are important differences.

First, they are calculated differently. While the median is computed by estimating the value at which half of the population is over, and half under it, the mean is the sum of all of the numbers in a dataset, divided by the number of values in the dataset.

Second, the two values perform differently when there are unusually high or low values compared to the rest of the dataset. When these are present, the dataset is said to be "skewed."

The mean has the disadvantage of being heavily influenced by very high or low values, so that it provides a distorted measurement of the "average" when the data is skewed. The median is less influenced and is, therefore, considered the best estimate of the "average" of a dataset when the data distribution is skewed.

Because the data from this survey tended to be skewed, with the bulk of the data bunched together on the low end of the scale and fewer values at the high end, the median is the most accurate estimate of average behavior for the water use, cost and acreage values presented in this report.

Cost of water

- Median costs for all water sources combined significantly increased nationwide from $204/acre-foot in 2005 to $298/acre-foot in 2013.
- The cost of municipal (potable) and recycled water increased significantly from 2005 to 2013, while the cost of open (lakes, ponds), canal, river and well water remained relatively flat. The most expensive source by far is municipal (potable) water, which rose from $783 to $1,329/acre-foot.
- The total cost of all water for an 18-hole golf course rose from 2005 to 2013, from a median of $13,645 to $23,870 per golf course. These costs varied dramatically from less than $100 to over $1 million per 18-hole golf course, depending on the location.

Introduction: Why do we need a golf course environmental profile?

In 2005, the Environmental Institute for Golf (EIFG) began to address the fact that the golf industry did not have comprehensive national data on management practices, property features and environmental stewardship on the nation's golf courses. This made it difficult to document current practices, or to track changes in the industry — information that would be valuable to golf course superintendents, golf industry leaders, turfgrass scientists and environmental regulators in their joint efforts to enhance environmental stewardship on the nation's golf courses.

To respond to this need, the Golf Course Superintendents Association of America (GCSAA) and the EIFG initiated a project to conduct a series of surveys to document water use, fertilizer use, pest management practices, energy use, environmental stewardship and property profiles. Known as the Golf Course Environmental Profile, the results were released from 2007 to 2012 and provided a baseline of information for use in the management of golf facilities. It also offered an opportunity to communicate golf's environmental efforts to the public.

Results were published in the peer-reviewed scientific journal *Applied Turfgrass Science* (recently renamed *Crop, Forage and Turfgrass Management*), as well as in *Golf Course Management* and online documents. All reports from phase one of the Environmental Profile project are available online (www.gcsaa.org/Environment/Environmental-Profile/Golf-Course-Environmental-Profile-Overview). A listing of the published articles appears in the "Further Reading" section of this report (Lyman et al. 2007, 2012a,b; Throssell et al. 2009a,b).

In fall 2014, the second phase of the Golf Course Environmental Profile began, with a follow-up set of surveys that mirrors the previous series. This new phase is being conducted by the GCSAA through the EIFG and funded by the United States Golf Association (USGA). The first survey to be released in the second phase focuses on water use and conservation practices, and explores trends, changes and progress that have been made since the initial water use survey was conducted eight years ago.

The objectives of the Water Use and Conservation Practices Survey were to document, characterize and/or quantify:

Projected regional water use, 2005 vs. 2013

Region	Acre-feet/year		% change
	2005	2013	
U.S.	2,378,558	1,859,021	-21.8
North Central	266,575	198,041	-25.7
Northeast	116,930	94,194	-19.4
Pacific	107,811	107,185	-0.6
Southeast	904,234	548,524	-39.3
Southwest	531,189	532,149	0.2
Transition	243,034	181,379	-25.4
Upper West/Mountain	208,785	197,548	-5.4

Table 1. Projected regional water use in acre-feet, 2005 vs. 2013.

Regional water use patterns for 18-hole golf courses

Region	Total water use/18-hole golf course (median acre-feet)			Median acre-feet/acre/year			Estimated annual water budget (median acre-feet/acre)	
	2005	2013	% change	2005	2013	% change	2005	2013
North Central	**62.5**	**53.1***	-15.0	**0.95**	**0.81***	-14.7	0.95	0.95
Northeast	40.1	36.8	-8.2	**0.74**	**0.63***	-14.9	0.77	0.73
Pacific	134.4	143.6	+6.8	1.59	1.69	+6.3	1.91	1.90
Southeast	**201.3**	**152.1***	-24.4	**2.10**	**1.56***	-25.7	1.60	1.57
Southwest	359.6	398.4	+10.8	**3.29***	**3.87**	+17.6	3.51	3.51
Transition	**63.2**	**48.5***	-23.3	**0.85**	**0.60***	-29.4	0.91	0.95
Upper West/Mountain	**227.7**	**205.8***	-9.6	2.20	2.07	-5.9	2.17	2.23

Table 2. Water use patterns for 18-hole golf courses, by region. For two of the three comparisons in the table (total water use and acre-feet/acre), values in bold type with the lowest value followed by an asterisk indicate a significant difference between the 2005 and 2013 values, at the 90% confidence level. There were no significant differences in estimated annual water budget between the two years.

Waters sources for U.S, golf courses, 2005 vs. 2013

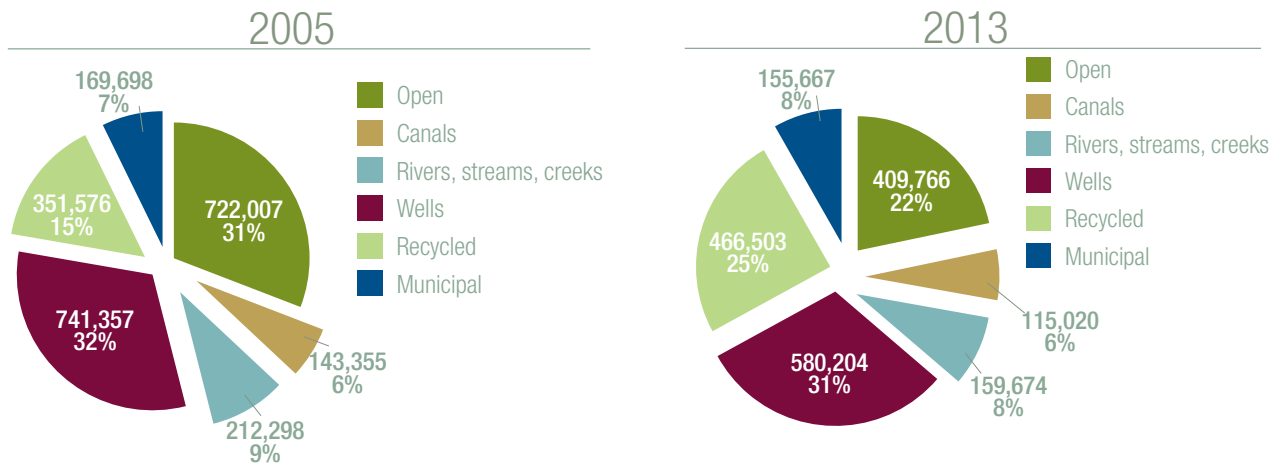

Figure 1. Total volume (in acre-feet/year) and percentage of each water source used on U.S. golf courses in 2005 vs. 2013.

Effect of golf facility size and type on water use

Golf course size	Acre-feet/acre of water use†		
	2005	2013	% change
9 holes	1.09 a	0.88 a	-19.3
18 holes	**1.33 ab**	**1.14 a***	-14.3
27+ holes	1.47 b	1.52 b	3.4
Golf course type			
Public	**1.37 a**	**1.23 a***	-10.2
Private	**1.29 a**	**1.14 a***	-11.6

†Within each two-column row (2005 and 2013 water use), values in bold type with the lowest value followed by an asterisk indicate that there was a significant difference between the 2005 and 2013 values, at the 90% confidence level. Reading down each column, values followed by the same letter are not significantly different at the 90% confidence level.

Table 3. Effect of golf facility size and type on water use.

- trends in water use on a national and regional scale
- the role of climate and weather in water use patterns
- the role of conservation and agronomic practices in water use patterns
- trends in the use of different water sources used and in the cost of water

Results

National water use trends

- U.S. golf courses used an estimated 1.859 million acre-feet of water in 2013, compared to 2.379 million acre-feet of water in 2005. This represents a 21.8% decrease, or an annual savings of 519,454 acre-feet compared to 2005 (Table 1).
- The greatest decreases in total water use occurred in the North Central, Northeast, Southeast and Transition regions.
- Water use remained relatively flat in the Upper West/Mountain, Southwest and Pacific regions.
- The overall decline in U.S. water use of golf courses was matched by declines in the use of all water sources except recycled (reclaimed) water (Figure 1).
- Recycled water was the only source whose use increased from 2005 to 2013. The greatest use of recycled water occurred in the Southeast and Southwest regions, which are also the regions with the highest water demand.
- The large majority of survey respondents used less water than forecast by their water budgets, although the Southwest and, to a lesser extent, the Southeast had a higher percentage of respondents who used more than their estimated water budgets (Table 2).
- Nine-hole golf courses tended to use the lowest volumes of water per acre, followed by 18-hole courses and, finally, 27+-hole courses (Table 3).
- Water use patterns were not significantly different for public vs. private golf courses.

Factors influencing national water use trends

A combination of factors was involved in the large and significant decrease in projected national water use between 2005 and 2013. These include:

Conservation practices

- The use of nearly all conservation practices has increased since 2005 (Table 4).
- Conservation practices, in combination with the acreage reductions itemized above, are the major contributors to the more than 500,000 acre-feet water savings observed from 2005 to 2013.

Voluntary acreage reductions

- An estimated 3,176 golf courses voluntarily reduced their acreages between 2009 and 2013, compared to 1,316 golf courses that reported voluntary acreage reductions from 2001 to 2005 (Table 5).
- As a result of the increasing popularity of reducing irrigated turf acreage as a conservation measure, the nation has seen a net decrease of 14,430 irrigated acres, with a resulting reduction in water use of 43,910 acre-feet.

Decrease in number of golf facilities

- In the eight years since the last survey was conducted, the number of golf facilities in the U.S. was reduced by 666, from 16,052 to 15,386 (Table 6).
- All regions except the Upper West/Mountain saw decreases in the number of facilities, although the North Central, Southeast and Transition regions saw the greatest changes.
- The reduced number of golf facilities in the U.S. resulted in a projected decrease of 53,489 acres and resulting water savings of 70,413 acre-feet/year.

Weather

- The national and regional weather data for 2005 vs. 2013 shows no significant differences in rainfall, temperature or evapotranspiration — despite a record-breaking drought in portions of the western U.S., and record-breaking rainfall in parts of the Southeast during these years.
- The lack of dramatic change between 2005 and 2013 is due to the sheer size and variation in weather patterns in each of the study's seven agronomic regions (see the sidebar, "Weather in 2005 vs. 2013" below.)

Weather in 2005 vs. 2013

Although portions of the Southwest region, such as Southern California, were severely affected by drought during 2013, other portions of the same region, such as San Antonio, Texas, had twice as much rain in 2013 as in 2005. When these differences in weather are averaged out across the entire region, the droughty locations tend to cancel out the wet locations, and vice-versa.

% facilities using water conservation practices

Water conservation practices	U.S.		North Central		Northeast		Pacific		Southeast		Southwest		Transition		Upper Mountain/ West	
	2005	2013	2005	2013	2005	2013	2005	2013	2005	2013	2005	2013	2005	2013	2005	2013
Wetting agents	88	94	90	96	84	87	86	94	91	95	76	91	91	94	90	98
Hand watering	72	77	65	71	70	74	80	86	69	74	72	79	85	86	74	81
Keep turf drier than in past	62	74	61	70	62	76	57	79	63	76	59	74	64	70	63	79
Mulch landscape beds	43	48	38	47	42	50	36	50	59	64	27	34	48	49	40	37
Use irrigation scheduling†		50	33	47	41	49	45	51	49	51	58	57	39	43	51	58
Adjust fertilizer practices	42	52	40	49	37	51	45	47	47	53	47	59	38	52	43	52
Soil amendments	29	40	22	34	35	48	25	33	34	44	33	37	27	44	34	39
Drip irrigation for landscape plants	13	16	4	6	6	7	18	27	15	18	38	47	9	9	32	30
Hand-held moisture sensors†		33		26		41		23		38		29		43		29
Increase no-mow acreage†		46		48		51		52		38		28		56		42

†Question not asked in initial survey.

Table 4. Percent of all facilities using various water conservation practices.

Voluntary changes in irrigated acreages

	2001-2005		2009-2013	
	Increase	Decrease	Increase	Decrease
Mean acres	13.4	12.0	9.9	11.1
Mean acre-feet	19.3	22.8	10.9	21.1
% in survey	24.0	8.2	13.6	20.6
Projected no. of golf courses nationwide	3,859	1,316	2,097	3,176
Projected national change in acreage	51,565	15,780	20,831	35,261
Projected national change in acre-feet	74,327	30,018	22,924	66,833
Projected national net change in acres	35,785		-14,430	
Projected national net change in acre-feet	44,309		-43,910	

Table 5. Voluntary changes in irrigated acreages, 2001-2005 vs. 2009-2013, and the impact on projected national water use.

Number of golf facilities affects water use

Region	Number of U.S. golf facilities				Projected change 2005-2013	
	2005	2013	Change	% change	Acres	Water (acre-feet)
North Central	4,127	3,925	-202	-4.9	-12,019	-10,203
Northeast	2,746	2,677	-69	-2.5	-3,747	-2,432
Pacific	655	638	-17	-2.6	-1,467	-2,874
Southeast	3,250	3,046	-204	-6.3	-21,828	-36,677
Southwest	1,224	1,201	-23	-1.9	-2,732	-10,132
Transition	2,961	2,795	-166	-5.6	-13,180	-10,777
Upper West/						
Mountain	1,089	1,104	15	+1.4	+1,485	+2,682
U.S.	16,052	15,386	-666	4.1	-53,489	-70,413

Table 6. Impact of reduced golf facility numbers on irrigated acreage and water use, 2005–2013.

Median water costs, 2005 vs. 2013

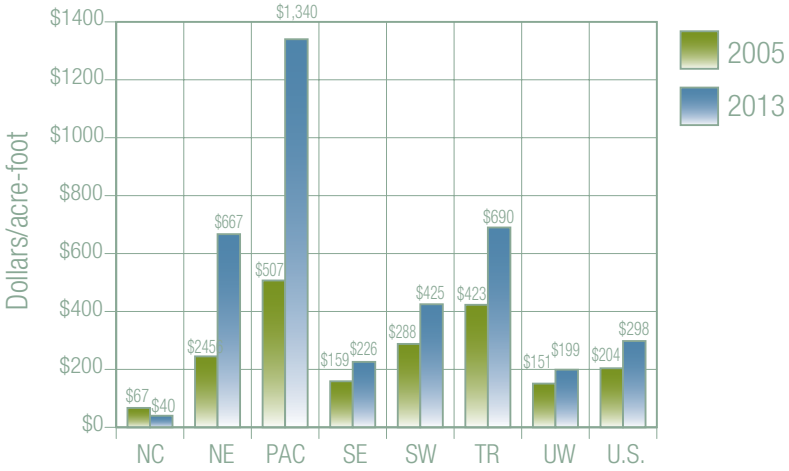

Figure 2. Median cost of all water sources (U.S. dollars) per acre-foot in 2005 vs. 2013. Abbreviations for regions: NC, North Central; NE, Northeast; PAC, Pacific; SE, Southeast; SW, Southwest; TR, Transition; UW, Upper West/Mountain.

Variation in growing season: North Central region

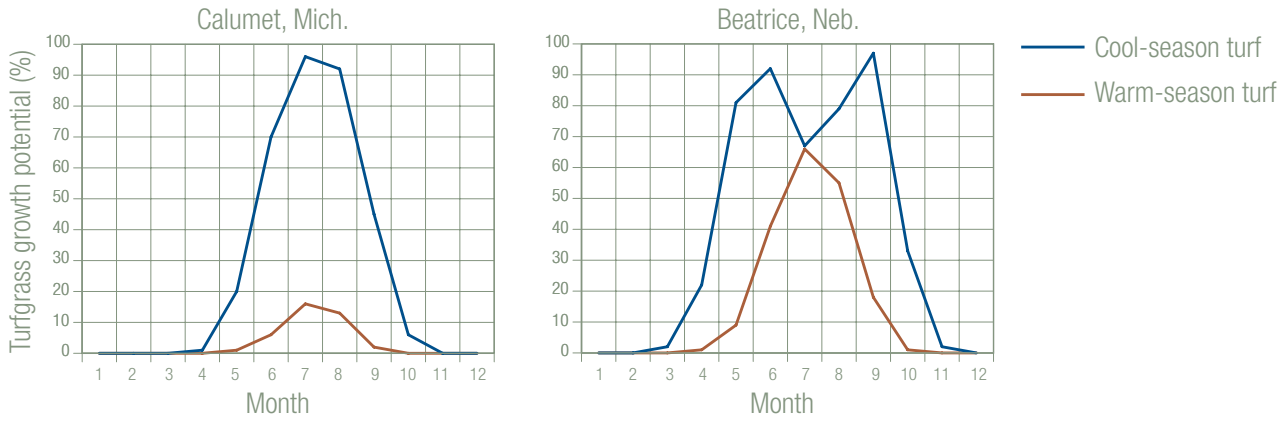

Figure 3. Variation in growing season in the North Central region. The turf growing season ranges from approximately five to seven months in length. Turf is considered to be actively growing when the growth potential for either cool-season turf (blue line) or warm-season turf (red line) is 20% or more.

Regional water use trends summary

The sections that follow provide detailed accounts of the water use patterns for each of the survey's seven agronomic regions. Some of the key regional trends include:

Current status

- There was dramatic variation in water use patterns among the nation's seven agronomic regions, and also within each region (Table 2).
- Climate was by far the most important factor influencing these diverse water use patterns.
- In addition to its impact on day-to-day water demand, climatic variation also resulted in important secondary forces that affected water use:
  - o Climate influenced the length of the growing season, which ranged from as little as four months in cooler climates, to 12 months in warmer climates.
  - o Climate influenced the number of irrigated acres. Facilities in cooler and wetter climates frequently do not irrigate roughs, while those in hot and/or dry climates irrigate all or almost all acres of the golf course, resulting in higher water use.
- The Pacific and Southwest regions had the most diverse climates and also had the greatest variation in water use patterns.
- Total water volume used per 18-hole golf course was lowest in the cool and rainy climates of the Northeast and Transition regions, and highest in the arid and warm climates of the Southwest region.
- Water costs per acre-foot varied widely among regions and also within regions. Costs per acre-foot were highest in the Pacific, Transition and Northeast regions, and lowest in the North Central region (Figure 2).
- Water costs for an entire 18-hole golf course were lowest in the North Central region and highest in the Southwest and Pacific regions (Table 7).

Median cost of all water for an 18-hole golf course, 2005 vs. 2013

Region	Total water cost/18-hole golf course (U.S. dollars)	
	2005	2013
North Central	**3,991**	**1,734***
Northeast	4,643	7,202
Pacific	**38,263***	**159,730**
Southeast	**18,025***	**28,854**
Southwest	**73,598***	**140,301**
Transition	**11,357***	**16,415**
Upper West/Mountain	15,960	20,431
U.S.	**13,645***	**23,870**

Table 7. Median cost (U.S. dollars) of all water for an 18-hole golf course in 2005 vs. 2013. Within each row, values in bold type with the lower value followed by an asterisk show a significant difference between the 2005 and 2013 values, at the 90% confidence level. Values that are not in bold type show no significant change from 2005 to 2013.

2005-2013 trends

- The greatest decreases in total water use per 18-hole golf course and in acre-feet/acre usage occurred in the Southeast and Transition regions (Table 2).
- Water use efficiency, as measured by comparing actual water use against the estimated water budget, improved between 2005 and 2013 for the nation as a whole, and for golf courses

Adopting and using recycled water

Region	% of facilities adopting recycled water		Acre-feet of recycled water used		
	2005	2013	2005	2013	Change
North Central	3.5	7.0	3,509	9,045	+5,536
Northeast	3.5	1.6	2,082	2,219	+137
Pacific	12.6	23.1	10,253	24,975	+14,722
Southeast	23.7	30.5	145,611	192,849	+47,238
Southwest	33.5	45.5	151,653	193,394	+41,741
Transition	5.3	6.5	12,682	18,856	+6,174
Upper West/Mountain	14.6	18.1	25,786	25,165	-621
U.S.	10.9	15.3	351,576	466,503	+114,927

Table 8. Adoption and use of recycled water.

Climate variation: North Central region

	Lowest	Highest
Water budget (acre-feet/acre)	0.4	4.1
Average temperature (F)	37.6	53.7
Rainfall (feet)	1.5	3.9
Active turf growth (months)	5	7

Table 9. Variation in climate in the North Central region. Temperature and rainfall values are based on 30-year normal annual average temperatures. Water-budget values are for 2013.

in the North Central, Northeast, Southeast, Transition and Upper West/Mountain regions (Table 2).

- The Southwest region, and to a lesser extent the Southeast region, had a higher percentage of respondents who used more than their estimated water budgets (Table 2). This is likely because these two warm climate regions depend more heavily on irrigation water than any other region, and as such, any inefficiencies in water use are magnified.
- The greatest increase in recycled water use occurred in the Southwest, Southeast and Pacific regions, indicating that this water source has been more widely adopted in regions with the hottest and/or driest climates (Figure 1, Table 8).

North Central Region

Climate

- Average temperatures in the North Central region are some of the coolest in the U.S., and have a relatively small range, from a low of 37.6 F to a high of 53.7 F, depending on the location (Table 9).
- Rainfall is moderate, with average levels ranging from 1.5 feet to 3.9 feet per year, depending on location (Table 9).
- The homogeneity in climatic conditions across this region results in a smaller range of water use and water budget values than most other regions of the country.
- In cooler areas of the North Central region such as Calumet, Mich., turf is actively growing for an average of five months per year, while in warmer locations such as Beatrice, Neb., active turf growth continues for approximately seven months (Figure 3).

Golf facility characteristics

- The North Central region had 3,925 golf facilities (26% of national supply) in 2013, which represents a decrease of 202 facilities since 2005 (Table 6).
- An 18-hole facility in the North Central region had 60.3 irrigated acres as compared to 80.2 irrigated acres for the nation as a whole (Table 10). Facilities in the North Central region have fewer irrigated acres mainly because many facilities in the region do not irrigate their roughs (Figure 4).

Irrigated acres: North Central region vs. U.S., 2013

Region	Median number of irrigated acres for an 18-hole facility						
	Greens	Tees	Fairways	Roughs	Practice area	Landscape	Total
North Central	3.51	3.16	26.4	21.6	4.28	1.98	60.3
U.S.	3.29	3.24	28.0	36.3	5.57	2.22	80.2

Table 10. Golf facility characteristics in the North Central region as compared to the United States in 2013. The sums of golf course individual features are not exactly equal to total acreage values because individual median values are not expected to sum exactly to total median values.

Median acres of irrigated fairways and roughs

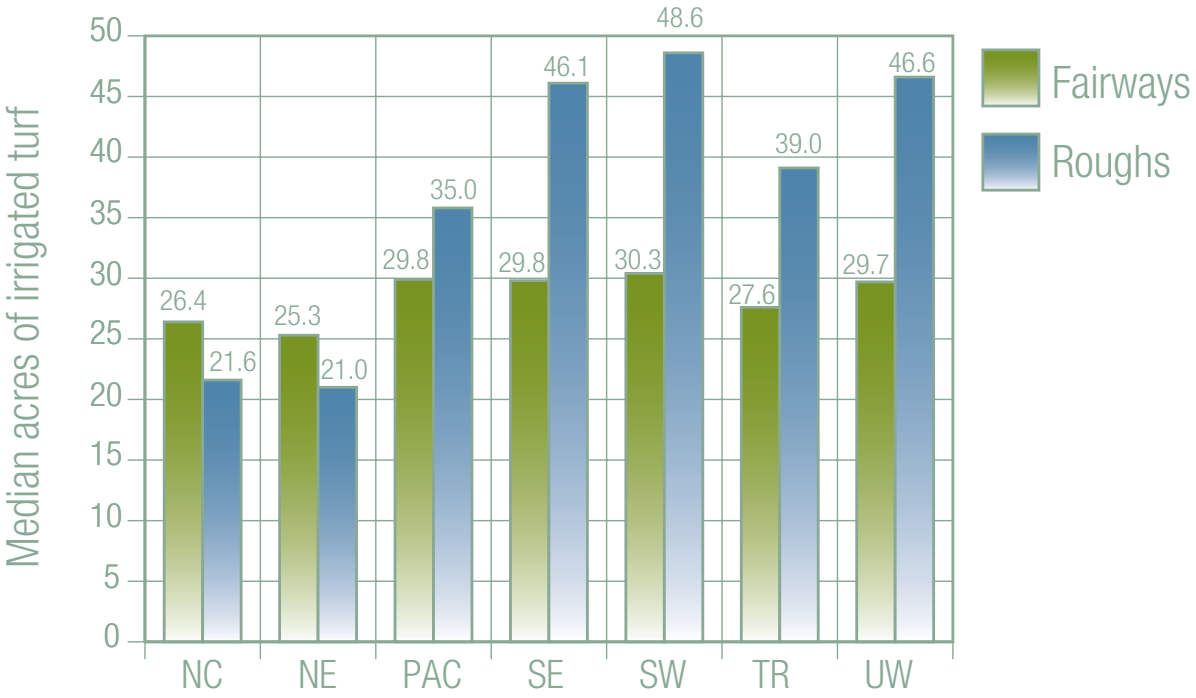

Figure 4. Median number of irrigated acres in fairways and roughs for a typical 18-hole golf course. Note that acreage for irrigated roughs varies dramatically from one region to the next. Abbreviations for regions: NC, North Central; NE, Northeast; PAC, Pacific; SE, Southeast; SW, Southwest; TR, Transition; UW, Upper West/Mountain.

Water use patterns

- Although the region had the highest number of facilities in the U.S. in 2013 (Table 6), cool and wet climates resulted in total water use of 198,041 acre-feet, or only 11% of the total amount used by the golf course industry (Tables 1, 11).
- From 2005 to 2013, water use across this region decreased by 25.7% (Table 11).
- Water use for an 18-hole golf course in 2013 varied within the region: 25% of all 18-hole courses used 32.4 acre-feet or less per year, 50% used 53.5 acre-feet or less and 75% used 88.2 acre-feet or less per year.
- These water use patterns are due to a combination of factors:
  - o The large drop in water use from 2005 to 2013 is due primarily to conservation efforts and improved water use efficiency.
  - o The region's climate (Table 9, Figure 3) also contributes significantly to these water use patterns. The moderate temperatures, adequate rainfall and five- to seven-month growing season allow facilities to irrigate fewer acres, with less water, for a smaller portion of the year than facilities in warmer, more arid climates.

Water use: North Central region

Water use/budget	Acre-feet		% change
	2005	2013	
Total water use for all regional facilities	266,575	198,041	-25.7
Median water use/18-hole facility	63.1	53.5	-15.2
Median water use/acre	0.95	0.81	-14.7
Median water budget/acre	0.95	0.95	

Table 11. North Central region water use patterns in 2005 vs. 2013.

Conservation practices

- Use of all water conservation practices has increased since 2005 (Table 4).
- In 2013, the percentage of golf courses using less water per acre than forecast by their water budgets (Table 11) had increased, indicating that water conservation efforts had had a positive effect.
- The most common conservation practices included, in order of popularity, use of wetting agents, hand watering, keeping turf drier than in the past, adjusted fertilizer practices and increasing no-mow acres.
- There was moderate adoption of hand-held moisture meters by 26% of respondents.

Water sources: North Central region, 2013

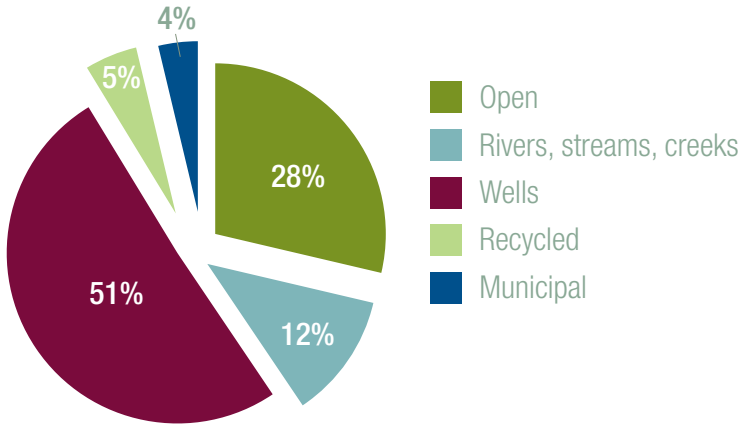

Figure 5. Percent of each water source used in the North Central region in 2013.

Water sources: North Central region

Water source	Total acre-feet		Change
	2005	2013	
Open water	80,160	52,130	-28,030
Rivers, streams, creeks	32,935	21,610	-11,325
Wells	130,035	92,242	-37,793
Recycled	3,509	9,045	+5,536
Municipal (potable)	11,418	6,794	-4,624

Table 12. Total acre-feet of the most commonly used water sources in the North Central region in 2005 vs. 2013.

Climate variation: Northeast region

	Lowest	Highest
Water budget (acre-feet/acre)	0.3	2.9
Average temperature (F)	38.4	56.2
Rainfall (feet)	2.7	4.6
Active turf growth (months)	6	7

Table 13. Variation in climate in the Northeast region. Temperature and rainfall values are based on 30-year normal annual average temperatures. Water-budget values are for 2013.

Water costs

- Water costs for an 18-hole golf course in the North Central region were the lowest among the nation's seven agronomic regions (Table 7). Twenty-five percent of all 18-hole courses paid $505 or less per year for water, 50% paid $1,734 or less and 75% paid $5,950 or less per year.

Water sources used

- The most common water sources used were well water and open water (lakes and ponds) (Table 12, Figure 5).
- With the exception of recycled water, there was a decrease in the use of all water sources (Table 12).

Northeast Region

Climate

- Average temperatures in the Northeast region are cool and have a relatively small range, from a low of 38.4 F to a high of 56.2 F, depending on the location (Table 13).
- Rainfall is moderate to substantial, with average levels ranging from 2.7 feet to 4.6 feet per year, depending on location (Table 13).
- The homogeneity in climatic conditions across this region results, as it does in the North Central region, in a smaller range of water use and water budget values than most regions of the country.
- In cooler areas of the Northeast region such as Bar Harbor, Maine, turf is actively growing for an average of six months per year, while warmer locations such as Greencastle, Pa., show active turf growth for approximately seven months (Figure 6).

Golf facility characteristics

- The Northeast region had 2,677 golf facilities (17% of national supply) in 2013, which represents a decrease of 69 facilities since 2005 (Table 6).
- There were 56.7 irrigated acres (the lowest number of irrigated acres in the U.S.) for an 18-hole facility, as compared to 80.2 irrigated acres for the nation as a whole (Table 14).

Irrigated acres: Northeast region vs. U.S., 2013

	Median number of irrigated acres for 18-hole facilities						
Region	Greens	Tees	Fairways	Roughs	Practice area	Landscape	Total
Northeast	3.66	2.79	25.3	21.0	3.53	1.91	56.7
U.S.	3.29	3.24	28.0	36.3	5.57	2.22	80.2

Table 14. Golf facility characteristics in the Northeast region as compared to the United States in 2013. The sums of golf course individual features are not exactly equal to total acreage values because individual median values are not expected to sum exactly to total median values.

Variation in growing season: Northeast region

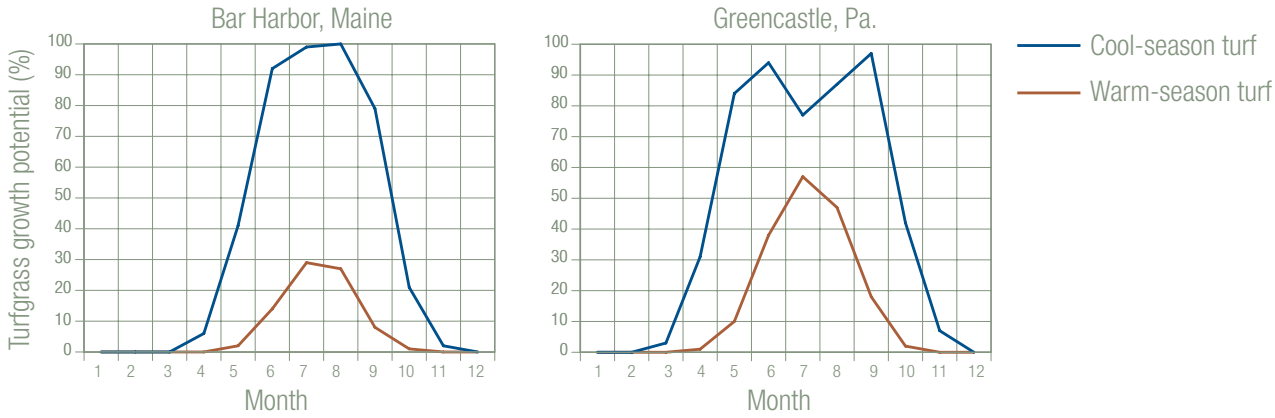

Figure 6. Variation in growing season in the Northeast region. The turf growing season ranges from approximately six to seven months in length. Turf is considered to be actively growing when the growth potential for either cool-season turf (blue line) or warm-season turf (red line) is 20% or more.

- The number of irrigated acres is low primarily because many facilities in the Northeast region do not irrigate their roughs (Figure 4).

Water use patterns

- Total water use for the region was 94,194 acre-feet, or 5% of that used by the golf course industry in 2013 — the lowest amount among the seven agronomic regions (Tables 1,15).
- From 2005 to 2013, water use across this region decreased by 19.4% (Table 15).
- Water use for an 18-hole golf course in 2013 varied within the region: 25% of all 18-hole courses used 23.1 acre-feet or less per year, 50% used 36.2 acre-feet or less and 75% used 56.7 acre-feet or less per year.
- These water use patterns are due to a combination of factors:
  - o The large drop in water use from 2005 to 2013 is primarily the result of conservation efforts and improved water use efficiency.
  - o The region's moderate temperatures, substantial rainfall and six- to seven-month growing season allow facilities to irrigate fewer acres with less water and for a smaller portion of the year than those in warmer, more arid climates.

Conservation practices

- Use of all water conservation practices has increased since 2005 (Table 4).
- In 2013, the percentage of golf courses in the Northeast region that used less water per acre than forecast by their water budgets (Table 15) had increased, indicating that water conservation efforts had a positive effect.
- The most common conservation practices included, in order of popularity, use of wetting agents, keeping turf drier than in the past, hand watering, adjusting fertilizer practices, and increasing no-mow acreage.
- Adoption of hand-held soil moisture meters has been above average, at 41% of respondents.

Water sources: Northeast region, 2013

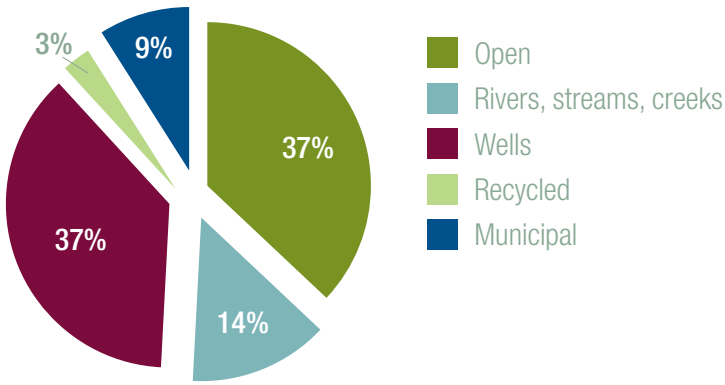

Figure 7. Percent of each water source used in the Northeast region, 2013.

Water use: Northeast region

Water use/budget	Acre-feet		% change
	2005	2013	
Total water use for all regional facilities	116,930	94,194	-19.4
Median water use/18-hole facility	40.5	36.2	-10.6
Median water use/acre	0.74	0.63	-14.9
Median water budget/acre	0.77	0.73	

Table 15. Northeast region water use patterns in 2005 vs. 2013.

Water costs

- Water costs for an 18-hole golf course were the second-lowest among the nation's seven agronomic regions (Table 7).
- Twenty-five percent of all 18-hole courses paid $2,200 or less per year for water, 50% paid $7,200 or less and 75% paid $23,625 or less per year.

Water sources used

- The most common water sources used were well water and open water (lakes and ponds) (Figure 7).
- With the exception of recycled water, there was a decrease in the use of all water sources (Table 16).

Water sources: Northeast region

Water source	Total acre-feet		Change
	2005	2013	
Open water	42,609	29,115	-13,494
Rivers, streams, creeks	11,305	10,867	-438
Wells	33,134	29,386	-3,748
Recycled	2,082	2,219	+137
Municipal (potable)	16,153	7,071	-9,082

Table 16. Total acre-feet of the most commonly used water sources in the Northeast region in 2005 vs. 2013.

Climate variation: Pacific region

	Lowest	Highest
Water budget (acre-feet/acre)	0.5	4.6
Average temperature (F)	34.0	62.1
Precipitation (feet)	0.8	14.2
Active turf growth (months)	4	11

Table 17. Variation in climate in the Pacific region. Temperature and rainfall values are based on 30-year normal annual average temperatures. Water-budget values are for 2013.

Pacific Region

Climate

- The Pacific region covers a diverse area of the U.S. that ranges from the hot Central Valley of California, to the long winters of Alaska, to the cool redwood forests of Oregon.
- Average temperatures have a large range, from a low of 34.0 F to a high of 62.1 F depending on the location (Table 17).
- Precipitation varies significantly, depending on the location, from some of the driest areas, which receive an average of only 0.8 foot per year, to some of the highest precipitation areas in the country, with a high of 14.2 feet per year (Table 17).
- Because of the variability in climatic conditions across this region, water use patterns also vary considerably.
- In cooler areas of the Pacific region such as Anchorage, Alaska, turf is actively growing for an average of four months per year, while in warmer locations such as Modesto, Calif., turf growth is active for approximately 11 months (Figure 8). This is the broadest range of growing conditions among the seven agronomic regions.

Golf facility characteristics

- The Pacific region had 638 golf facilities in 2013 (4% of national supply) in 2013. This represents a decrease of 17 locations since 2005 (Table 6).
- There were 82.1 irrigated acres for an 18-hole facility, as compared to 80.2 irrigated acres for the nation as a whole (Table 18). It is likely that in rainy locations within the region, many golf courses do not irrigate roughs, while in the drier locations, wall-to-wall irrigation is necessary.

Water use patterns

- Total water use for the region was 107,185 acre-feet, or 6% of that used by the golf course industry as a whole in 2013 (Tables 1, 19).
- From 2005 to 2013, water use across this region stayed relatively flat, with a decrease of less than 1% (Table 19).
- Water use for an 18-hole golf course in 2013 varied within the region: 25% of all 18-hole

Irrigated acres: Pacific region vs. U.S., 2013

Region	Median number of irrigated acres for 18-hole facilities						
	Greens	Tees	Fairways	Roughs	Practice area	Landscape	Total
Pacific	3.12	2.86	29.8	35.0	5.03	1.87	82.1
U.S.	3.29	3.24	28.0	36.3	5.57	2.22	80.2

Table 18. Golf facility characteristics in the Pacific region as compared to the United States in 2013. The sums of golf course individual features are not exactly equal to total acreage values because individual median values are not expected to sum exactly to total median values.

Variation in growing season: Pacific region

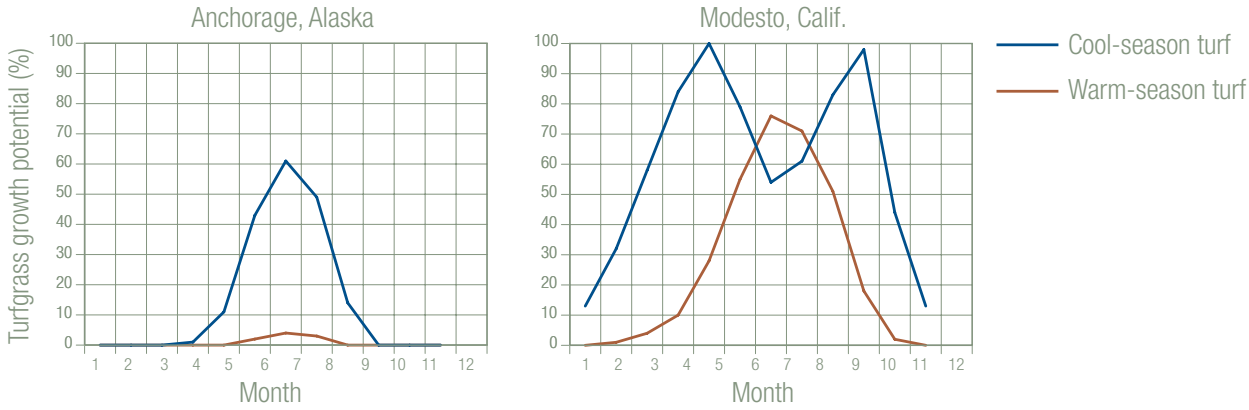

Figure 8. Variation in growing season in the Pacific region. The turf growing season ranges from approximately four to 11 months in length. Turf is considered to be actively growing when the growth potential for either cool-season turf (blue line) or warm-season turf (red line) is 20% or more.

courses used 89.1 acre-feet or less per year, 50% used 157.0 acre-feet or less and 75% used 276.5 acre-feet or less per year.

- These water use patterns are due to a combination of factors:
  - o The longer growing season in southern portions of this region results in increased water demand throughout the region.
  - o Hotter and drier locations have high water use per acre and more irrigated acres, which work together to create high water demand. The large volume of water required by these locations overwhelms the lower water use and lower irrigated acreage contribution of the region's cooler and rainier locations.
- Unlike regions in the northern U.S., the Pacific region did not see a decrease in overall regional water use (Table 1), water use per facility or acre-feet/acre (Table 2) from 2005 to 2013. Reasons for this trend include:
  - o The number of golf facilities has decreased by only 2.6% since 2005. As a result, water savings due to reductions in irrigated acreage are minimal.
  - o The region's heavy reliance on recycled water (approximately 25% of all water used) significantly reduces golf's use of potable water (Table 8). However, because recycled water typically has higher dissolved salt content than other water sources, an increase of 10%-15% in water use is usually required in order to leach soils so that salts do not accumulate to plant-damaging levels. Because much of the Pacific region is arid, rainfall cannot be relied on for leaching.
  - o Although changes in weather patterns seem to be a likely explanation for the observed trends, the national and regional weather data for 2005 vs. 2013 shows no significant

Water use: Pacific region

Water use/budget	Acre-feet		% change
	2005	2013	
Total water use for all regional facilities	107,811	107,185	-0.6
Median water use/18-hole facility	137.2	157.0	+14.5
Median water use/acre	1.59	1.69	+6.3
Median water budget/acre	1.91	1.90	

Table 19. Pacific region water use patterns in 2005 vs. 2013.

Water sources: Pacific region

Water source	Total acre-feet		Change
	2005	2013	
Open water	8,075	6,228	-1,847
Canals	14,583	5,291	-9,292
Rivers, streams, creeks	14,369	11,734	-2,635
Wells	32,352	29,891	-2,461
Recycled	10,253	24,975	+14,722
Municipal (potable)	11,053	20,101	+9,048

Table 20. Total acre-feet of the most commonly used water sources in the Pacific region in 2005 vs. 2013.

Water sources: Pacific region, 2013

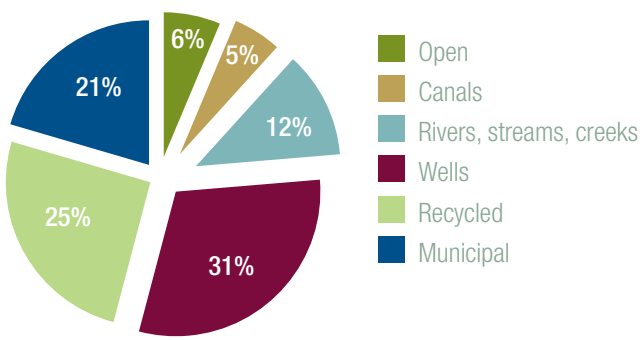

Figure 9. Percent of each water source used in the Pacific region, 2013.

Variation in growing season: Southeast region

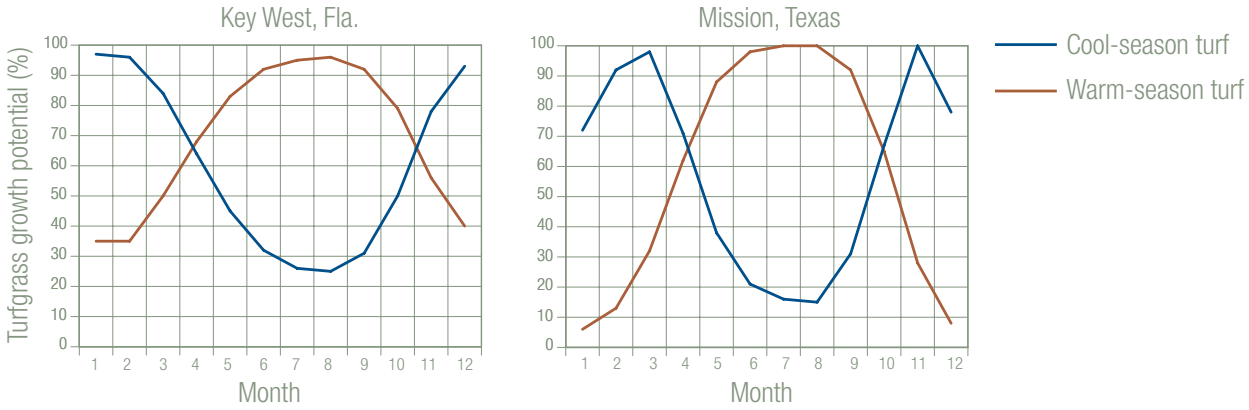

Figure 10. Variation in growing season in the Southeast region. The turf growing season is 12 months long in most locations. Turf is considered to be actively growing when the growth potential for either cool-season turf (blue line) or warm-season turf (red line) is 20% or more.

differences for either rainfall, temperature or water budget.

Conservation practices

- In 2013, the majority of golf courses used less water per acre than forecast by their water budgets (Table 19).
- Use of all water conservation practices has increased since 2005 (Table 4).
- The most common water conservation practices, listed in order of popularity, included use of wetting agents, hand watering, keeping turf drier than in the past, increasing no-mow acres, use of irrigation scheduling techniques and mulching landscape beds.
- Adoption of hand-held soil moisture meters was moderate at 23% of respondents.

Water costs

- Water costs for an 18-hole golf course in the Pacific region were the highest among the nation's seven agronomic regions (Table 7).
- Twenty-five percent of all 18-hole courses paid $69,350 or less per year for water, 50% paid $159,730 or less and 75% paid $367,915 or less per year.

Water sources used

- The most common water sources used were well water and recycled water (Figure 9).
- With the exception of recycled water and municipal (potable) water sources, there was a decrease in the use of all water sources (Table 20).

Southeast Region Climate

- Average temperatures in the Southeast region are the warmest in the country, and range very widely from 45.8 F all the way to 77.8 F, depending on location (Table 21).

Climate variation: Southeast region

	Lowest	Highest
Water budget (acre-feet/acre)	0.4	5.4
Average temperature (F)	45.8	77.8
Rainfall (feet)	1.7	5.7
Active turf growth (months)	12	12

Table 21. Variation in climate in the Southeast region. Temperature and rainfall values are based on 30-year normal annual average temperatures. Water-budget values are for 2013.

Irrigated acres: Southeast region vs. U.S., 2013

Region	Median number of irrigated acres for 18-hole facilities						
	Greens	Tees	Fairways	Roughs	Practice area	Landscape	Total
Southeast	3.13	3.57	29.8	46.1	6.99	2.86	96.8
U.S.	3.29	3.24	28.0	36.3	5.57	2.22	80.2

Table 22. Golf facility characteristics in the Southeast region as compared to the United States in 2013. The sums of golf course individual features are not exactly equal to total acreage values because individual median values are not expected to sum exactly to total median values.

- Rainfall varies from moderate to heavy, depending on location (Table 21).
- The climatic variability across this region led to a wide range of water budget and water use patterns.
- Turf is actively growing 12 months of the year in most locations in this region (Figure 10).

Golf facility characteristics

- With 3,046 golf facilities in 2013 (20% of the national supply), the Southeast region has the second-highest number of facilities in the nation (Table 6).
- From 2005 to 2013, the Southeast had a decrease of 204 golf facilities, representing a 6.3% loss, the highest in the nation (Table 6).
- There were 96.8 irrigated acres for an 18-hole facility, as compared to 80.2 irrigated acres for the nation as a whole (Table 22).
- Despite the rainy conditions in most areas of the Southeast, the high temperatures and the unpredictable frequency of rainfall make it necessary for almost all facilities to irrigate 100% of their turf acres.

Water use patterns

- Total water use for the region was 548,524 acre-feet, or 29% of the national total, making this region and the Southwest the highest water-using regions in the country (Tables 1, 23).
- Reasons for the region's high water use include the year-round growing season, high temperatures and high number of irrigated acres.
- Water use for an 18-hole golf course in 2013 varied within the region: 25% of all 18-hole courses used 86.2 acre-feet or less per year , 50% used 154.2 acre-feet or less and 75% used 275.9 acre-feet or less per year.
- Despite relatively high water use, the region's consumption of water has been reduced by 39.3% since 2005 (Table 23). This is the greatest water use reduction in the country. Factors involved in this decrease in water use include:
  - o The large decrease in the number of golf facilities since 2005, which resulted in more than 21,000 fewer irrigated acres (Table 6)
  - o Water conservation practices (Table 4), as described below
  - o Although changes in weather patterns seem to be a likely explanation for the observed trends, the national and regional weather data for 2005 vs. 2013 shows no significant differences for rainfall, temperature or water budget in the Southeast. Although some areas experienced record rainfall in 2013, other areas in the region received less-than-average accumulations. This large variation in rainfall across the region buffered much of the extreme weather experienced in some locations.

Water sources: Southeast region, 2013

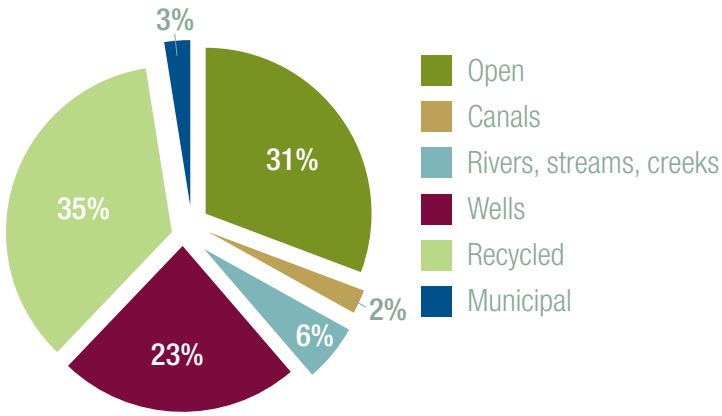

Figure 11. Percent of each water source used in the Southeast region, 2013.

Water use: Southeast region

Water use/budget	Acre-feet		% change
	2005	2013	
Total water use for all regional facilities	904,234	548,524	-39.3
Median water use per 18-hole facility	204.1	154.2	-24.5
Median water use/acre	2.10	1.56	-25.7
Median water budget/acre	1.60	1.57	

Table 23. Southeast region water use patterns in 2005 vs. 2013.

Water sources: Southeast region

Water source	Total acre-feet		Change
	2005	2013	
Open water	412,809	167,640	-245,169
Canals	21,866	12,822	-9,044
Rivers, streams, creeks	57,316	30,642	-26,674
Wells	217,577	127,824	-89,753
Recycled	145,611	192,849	+47,238
Municipal (potable)	22,706	13,731	-8,975

Table 24. Total acre-feet of the most commonly used water sources in the Southeast region in 2005 vs. 2013.

Variation in growing season: Southwest region

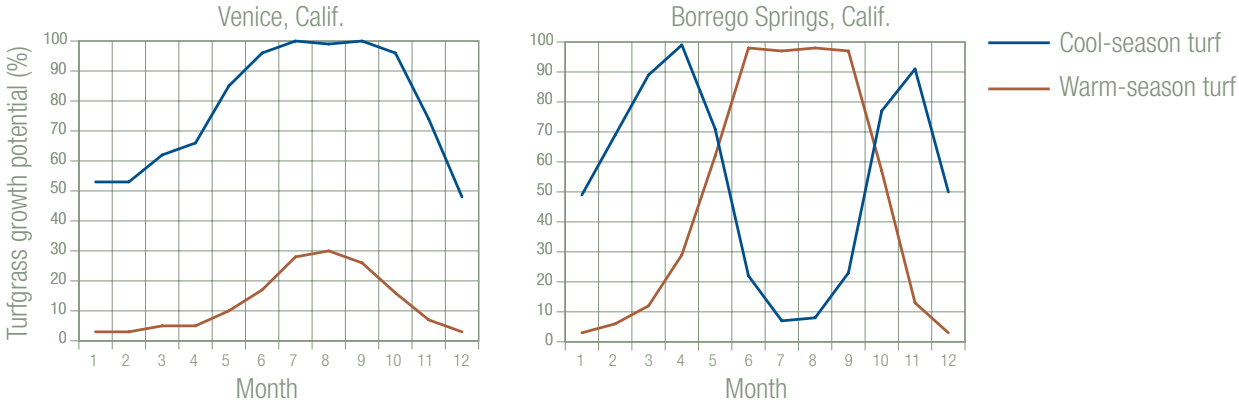

Figure 12. Variation in growing season in the Southwest region. The turf growing season is 12 months long in most locations. Turf is considered to be actively growing when the growth potential for either cool-season turf (blue line) or warm-season turf (red line) is 20% or more.

Conservation practices

- In 2013, approximately 50% of all golf courses used less water per acre than forecast by their water budgets (Table 23).
- Use of all water conservation practices has increased since 2005 (Table 4).
- The most common water conservation practices, listed in order of popularity, included use of wetting agents, keeping turf drier than in the past, hand watering, mulching landscape beds and adjusting fertilizer practices.
- There has been above-average adoption of hand-held soil moisture meters, at 37.6% of respondents.

Water costs

- Water costs for an 18-hole golf course were relatively low (Table 7).
- Twenty-five percent of all 18-hole courses paid $11,915 or less per year for water, 50% paid $28,900 or less and 75% paid $69,900 or less per year.

Water sources used

- The most common water sources used were recycled and open (lakes and ponds) water (Figure 11). With the exception of recycled water, there was a decrease in the use of all water sources (Table 24).
- The Southeast is second only to the Southwest in the volume of recycled water used (Table 8).

Southwest Region Climate

- Along with the Pacific region, the Southwest region encompasses many highly varied climates that range from the cool and dry Southern California coast, to the tropical climate of Hawaii, to the Sonoran Desert.

Climate variation: Southwest region

	Lowest	Highest
Water budget (acre-feet/acre)	1.8	6.3
Average temperature (F)	40.5	75.2
Rainfall (feet)	0.3	10.2
Active turf growth (months)	12	12

Table 25. Variation in climate in the Southwest region. Temperature and rainfall values are based on 30-year normal annual average temperatures. Water budget values are for 2013.

Irrigated acres: Southwest region vs. U.S., 2013

Region	Median number of irrigated acres for 18-hole facilities						
	Greens	Tees	Fairways	Roughs	Practice area	Landscape	Total
Southwest	3.07	3.42	30.3	48.6	6.61	2.88	103.1
U.S.	3.29	3.24	28.0	36.3	5.57	2.22	80.2

Table 26. Golf facility characteristics in the Southwest region as compared to the United States in 2013. The sums of golf course individual features are not exactly equal to total acreage values because individual median values are not expected to sum exactly to total median values.

- Average temperatures in the Southwest region are the second highest in the country and range very widely from 40.5 F to 75.2 F, depending on locations (Table 25).
- Rainfall varies from almost non-existent (in the desert regions) to very high (in Hawaii), depending on location (Table 25).
- The highly variable climates across this region resulted in a very broad range of water budget and water use values.
- Turf is actively growing 12 months of the year in most locations in this region (Figure 12).

Golf facility characteristics

- The Southwest region had 1,201 golf facilities in 2013 (8% of national supply) (Table 6).
- There was a decrease of 23 golf facilities, representing a 1.9% loss — one of the lowest in the nation — since 2005 (Table 6).
- There were 103.1 irrigated acres for an 18-hole facility, as compared to 80.2 irrigated acres for the nation as a whole (Table 26). The Southwest has the highest number of irrigated acres per facility in the country (Table 37).
- Because of the dry, hot weather that is typical throughout the region, it is necessary for almost all facilities to irrigate 100% of their roughs (Figure 4) and overall turf acreage (Table 37).

Water use patterns

- Total water use for the region was 532,149 acre-feet, or 29% of the national total, making this region and the Southeast region the highest water-using regions in the country (Tables 1, 27).
- Reasons for the region's high water use include the year-round growing season, high temperatures, low rainfall and high number of irrigated acres.
- Water use for an 18-hole golf course in 2013 varied within the region: 25% of all 18-hole courses used 285.1 acre-feet or less per year, 50% used 401.5 acre-feet or less and 75% used 565.4 acre-feet or less per year.
- Unlike regions in the northern U.S., the Southwest region did not see a decrease in overall regional water use, water use per facility, or acre-feet/acre from 2005 to 2013 (Tables 1, 2). Reasons for this trend include:
  - o The number of golf facilities has decreased by only 1.9% since 2005 (Table 6). As a result, water savings due to reductions in irrigated acreage are minimal.
  - o The region's heavy reliance on recycled water (approximately 35% of all water used) significantly reduces golf's use of potable water (Table 8, Figure 13). However, because recycled water typically has higher dissolved

Water sources: Southwest region, 2013

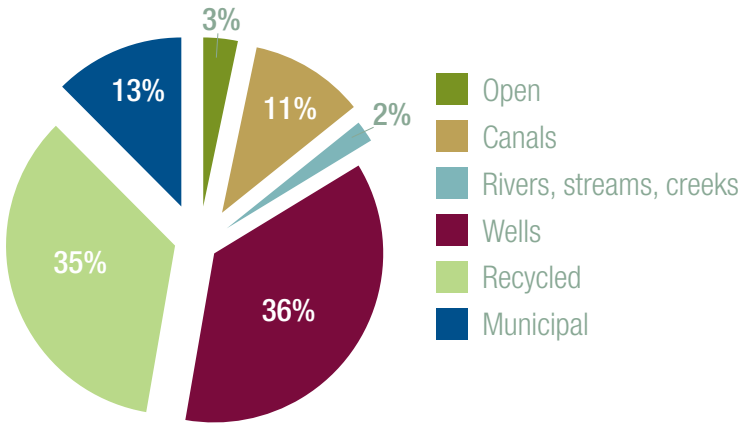

Figure 13. Percent of each water source used in the Southwest region, 2013.

Water use: Southwest region

Water use/budget	Acre-feet		% change
	2005	2013	
Total water use for all regional facilities	531,189	532,149	+0.2
Median water use per 18-hole facility	352.0	401.5	+14.1
Median water use/acre	3.29	3.87	+17.6
Median water budget/acre	3.51	3.51	

Table 27. Southwest region water use patterns in 2005 vs. 2013.

Water sources: Southwest region

Water source	Total acre-feet		Change
	2005	2013	
Open water	25,594	18,296	-7,298
Canals	65,576	60,808	-4,768
Rivers, streams, creeks	13,412	11,420	-1,992
Wells	226,782	202,430	-24,352
Recycled	151,653	193,394	+41,741
Municipal (potable)	73,118	69,201	-3,917

Table 28. Total acre-feet of the most commonly used water sources in the Southwest region in 2005 vs. 2013.

Climate variation: Transition region

	Lowest	Highest
Water budget (acre-feet/acre)	0.2	3.9
Average temperature (F)	47.2	68.6
Rainfall (feet)	2.0	7.1
Active turf growth (months)	9	9

Table 29. Variation in climate in the Transition region. Temperature and rainfall values are based on 30-year normal annual average temperatures. Water budget values are for 2013.

Variation in growing season: Transition region

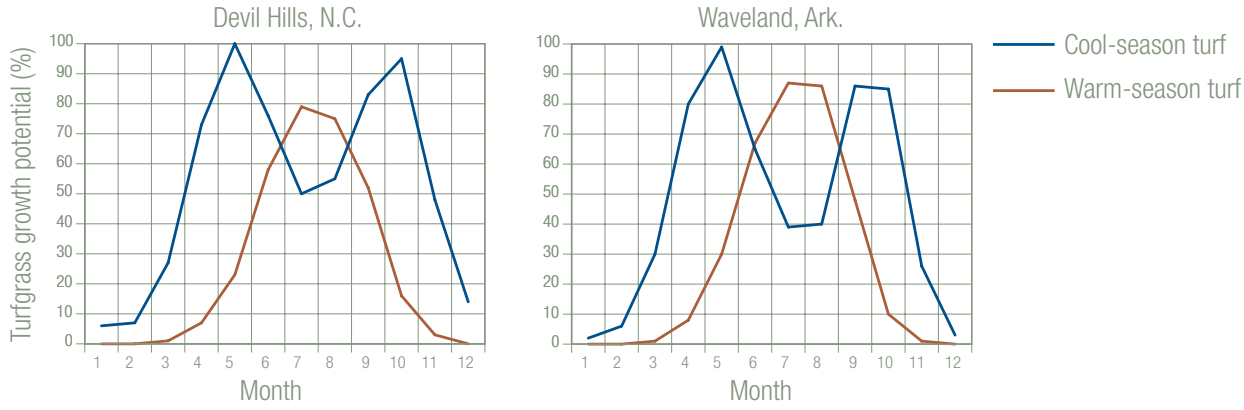

Figure 14. Variation in growing season in the Transition region. The turf growing season is nine months long in most locations. Turf is considered to be actively growing when the growth potential for either cool-season turf (blue line) or warm-season turf (red line) is 20% or more.

salt content than other water sources, an increase of 10%-15% in water use is usually required in order to leach soils so that salts do not accumulate to plant-damaging levels. Because much of the Southwest region is arid, rainfall cannot be relied on for leaching.

- Although changes in weather patterns seem to be a likely explanation for the observed trends, the national and regional weather data for 2005 vs. 2013 shows no significant differences for either rainfall, temperature or water budget.

Conservation practices

- In 2013, fewer than 50% of all golf courses used less water per acre than forecast by their water budgets (Table 27).
- Use of all water conservation practices has increased since 2005, except for use of irrigation scheduling, which remained at approximately 57% of all respondents (Table 4).
- The most common water conservation practices, listed in order of popularity, included use of wetting agents, hand watering, keeping turf drier than in the past, adjusting fertilizer practices, and using irrigation scheduling techniques.
- Adoption of hand-held soil moisture meters was moderate at 28.9% of respondents.

Water costs

- Water costs for an 18-hole golf course were the second highest in the nation (Table 7).
- Twenty-five percent of all 18-hole courses paid $60,300 or less per year for water, 50% paid $140,300 or less and 75% paid $326,400 or less per year.

Water sources used

- The most common water sources used were by far well water (36%) and recycled water (35%) (Figure 13).
- With the exception of recycled water, there was a decrease in the use of all water sources (Table 28).

Transition Region Climate

- Average temperatures in the Transition region are moderate, and vary only moderately across the region, from 47.2 F to 68.6 F (Table 29).
- This region has highly variable average precipitation rates, ranging from only 2.0 feet to as high as 7.1 feet per year (Table 29).
- The relative heterogeneity in climatic conditions across this region results in a larger range

Irrigated acres: Transition region vs. U.S., 2013

Region	Median number of irrigated acres for 18-hole facilities						
	Greens	Tees	Fairways	Roughs	Practice area	Landscape	Total
Transition	3.32	3.50	27.6	39.0	5.63	2.27	79.2
U.S.	3.29	3.24	28.0	36.3	5.57	2.22	80.2

Table 30. Golf facility characteristics in the Transition region as compared to the United States in 2013. The sums of golf course individual features are not exactly equal to total acreage values because individual median values are not expected to sum exactly to total median values.

of water budget and water use patterns than for most other regions of the country.
- Turf is actively growing nine months of the year in most locations in this region. There is little variation in the length of the growing season across the region (Figure 14).

Golf facility characteristics

- The Transition region had 2,795 golf facilities in 2013 (18% of national supply).
- There was a decrease of 166 golf facilities, representing a 5.6% loss — the second largest in the nation — since 2005 (Table 6).
- There were 79.2 irrigated acres for an 18-hole facility, as compared to 80.2 irrigated acres for the nation as a whole (Table 30).
- Because of the moderate temperatures and high rainfall in some areas of this region, some facilities do not irrigate all features of the golf course, particularly roughs (Figure 4, Table 37).

Water use patterns

- In 2013, total water use for the region was 181,379 acre-feet (10% of the national total) (Tables 1, 31).
- From 2005 to 2013, water use across this region decreased by 25.4% (31).
- Water use for an 18-hole golf course in 2013 varied within the region: 25% of all 18-hole courses used 27.2 acre-feet or less per year, 50% used 50.1 acre-feet or less and 75% used 92.3 acre-feet or less per year.
- These water use patterns are due to a combination of factors:
  - o The large drop in water use from 2005 to 2013 is due primarily to conservation efforts and improved water efficiency, as evidenced by the decrease in acre-feet/acre used during that time period.
  - o Water use was further reduced by the large decrease in number of golf facilities in the region (Table 6).
  - o The region's climate (Table 29) also contributes significantly to these water use patterns. The moderate temperatures, adequate rainfall and nine-month growing season allow facilities to irrigate fewer acres, with less water and for a smaller portion of the year than those in warmer, more arid climates.

Conservation practices

- In 2013, the percentage of golf courses using less water per acre than forecast by their water budgets (Table 31) had increased, indicating that water conservation efforts had a positive effect.

Water sources: Transition region, 2013

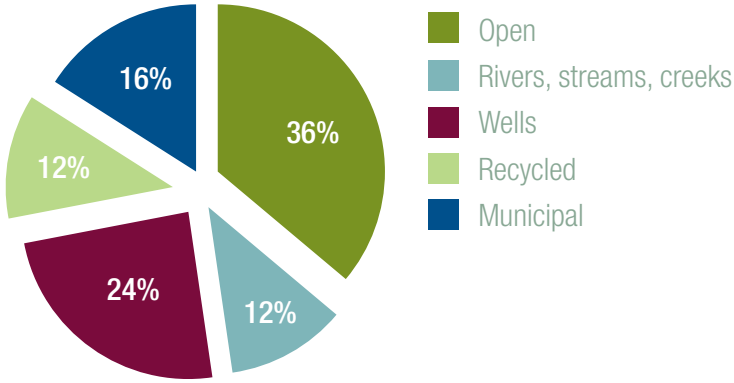

Figure 15. Percent of each water source used in the Transition region, 2013.

Water use: Transition region

Water use/budget	Acre-feet		% change
	2005	2013	
Total water use for all regional facilities	243,034	181,379	-25.4
Median water use per 18-hole facility	63.7	50.1	-21.4
Median water use/acre	0.85	0.60	-29.4
Median water budget/acre	0.91	0.95	

Table 31. Transition region water use patterns in 2005 vs. 2013.

Water sources: Transition region

Water source	Total acre-feet		Change
	2005	2013	
Open water	127,418	56,571	-70,847
Rivers, streams, creeks	31,310	18,138	-13,172
Wells	45,721	38,039	-7,682
Recycled	12,682	18,856	+6,174
Municipal (potable)	25,817	25,034	-783

Table 32. Total acre-feet of the most commonly used water sources in the Transition region in 2005 vs. 2013.

Climate variation: Upper West/Mountain region

	Lowest	Highest
Water budget (acre-feet/acre)	0.8	4.4
Average temperature (F)	34.4	64.6
Rainfall (feet)	0.4	4.9
Active turf growth (months)	5	9

Table 33. Variation in climate in the Upper West/Mountain region. Temperature and rainfall values are based on 30-year normal annual average temperatures. Water-budget values are for 2013.

Variation in growing season: Upper West/Mountain region

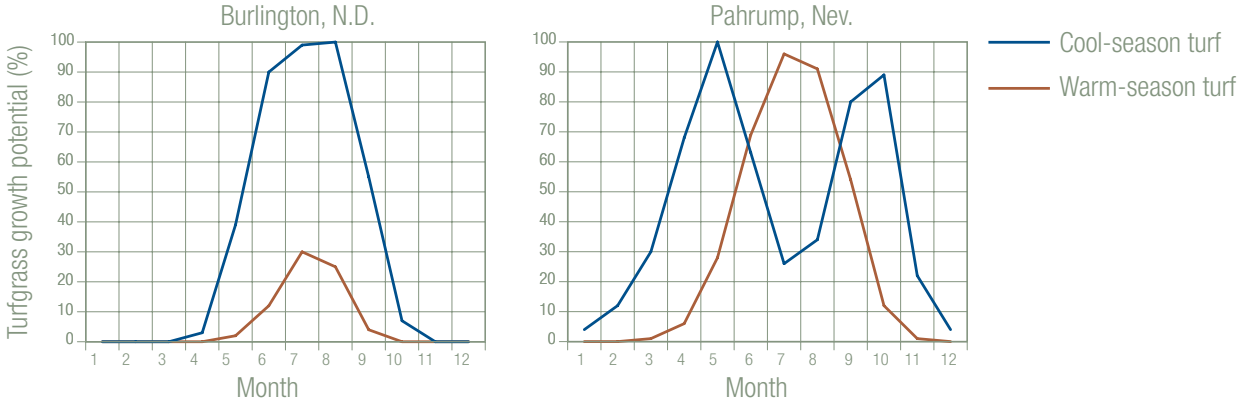

Figure 16. Variation in growing season in the Upper West/Mountain region. The turf growing season ranges from five to nine months in length. Turf is considered to be actively growing when the growth potential for either cool-season turf (blue line) or warm-season turf (red line) is 20% or more.

Water sources: Upper West/Mountain region, 2013

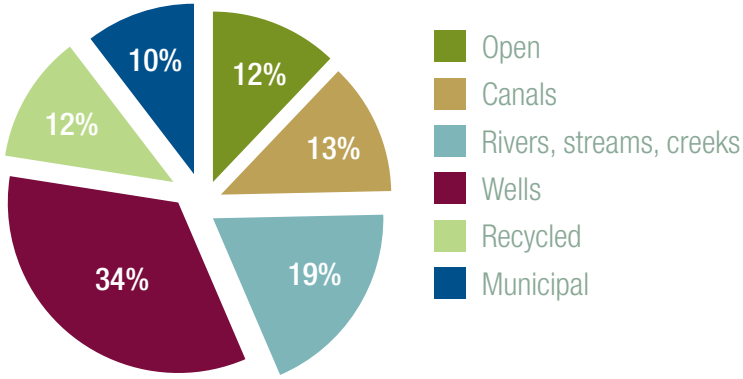

Figure 17. Percent of each water source used in the Upper West/Mountain region, 2013.

- Use of all water conservation practices increased from 2005 to 2013 (Table 4).
- The most common water conservation practices, listed in order of popularity, included use of wetting agents, hand watering, keeping turf drier than in the past, increasing the no-mow acreage and adjusting fertilizer practices.
- There has been above-average adoption of hand-held soil moisture meters, at 43% of respondents.

Water costs

- Water costs for an 18-hole golf course were moderate (Table 7), compared to other regions.
- Twenty-five percent of all 18-hole courses paid $4,900 or less per year for water, 50% paid $16,415 or less and 75% paid $55,400 or less per year.

Water sources used

- The most common water sources used were open (lakes and ponds) and well water (Figure 15).
- With the exception of recycled water, there was a decrease in the use of all water sources (Table 32).

Upper West/Mountain Region Climate

- The Upper West/Mountain region encompasses the largest of the agronomic regions in terms of area. Climates vary greatly, from the deserts of Nevada to the mountains of Colorado, to the cold winters of North Dakota.
- Average temperatures in the Upper West/Mountain region are comparatively cool from 34.4 F to 64.6 F (Table 33).
- Rainfall varies from quite low to moderate (Table 33).
- This climatic variability resulted in a broad range of water use patterns across the region.

Irrigated acres: Upper West/Mountain region vs. U.S., 2013

Region	Median number of irrigated acres for 18-hole facilities						
	Greens	Tees	Fairways	Roughs	Practice area	Landscape	Total
Upper West/Mountain	3.05	3.06	29.8	46.6	6.97	1.69	97.3
U.S.	3.29	3.24	28.0	36.3	5.57	2.22	80.2

Table 34. Golf facility characteristics in the Upper West/Mountain region as compared to the United States in 2013. The sums of golf course individual features are not exactly equal to total acreage values because individual median values are not expected to sum exactly to total median values.

- In cooler areas of the Upper West/Mountain region such as Burlington, N.D., turf is actively growing for an average of five months per year, while warmer locations such as Pahrump, Nev., show active turf growth for approximately nine months (Figure 16).

Golf facility characteristics

- The Upper West/Mountain region had 1,104 golf facilities in 2013 (7% of national supply).
- There was an increase of 15 golf facilities, from 1,089 to 1,104 from 2005 to 2013. This represents a 1.4% gain — the only region to see a gain since 2005 (Table 6).
- There were 97.3 irrigated acres for an 18-hole facility, as compared to 80.2 irrigated acres for the nation as a whole (Table 34).
- Because some of the areas of the diverse region receive little rainfall, it is necessary for many facilities to irrigate 100% of their turf acres (Figure 4, Table 37).

Water use patterns

- Total water use for the region was 197,548 acre-feet, or about 10% of the national total (Tables 1, 35).
- From 2005 to 2013, water use across this region decreased by 5.4% (Table 35).
- Water use for an 18-hole golf course in 2013 varied within the region: 25% of all 18-hole courses used 149.3 acre-feet or less per year, 50% used 208.3 acre-feet or less and 75% used 290.8 acre-feet or less per year.
- Although the Upper West/Mountain reduced water use by all measures, decreases were not as dramatic as those seen in regions to the east (Tables 1, 2), primarily because this is the only region where the number of golf facilities had increased, rather than decreased from 2005 to 2013. As a result, more water was used.

Conservation practices

- In 2013, the percentage of golf courses using less water per acre than forecast by their water budgets (Table 35) had increased, indicating that water conservation efforts had a positive effect.
- Use of most water conservation practices increased from 2005 to 2013, except for mulching of landscape beds and use of drip irrigation for landscape plants, both of which did not change substantially (Table 4).
- The most common water conservation practices, listed in order of popularity, included use of wetting agents, hand watering, keeping turf drier than in the past, using irrigation scheduling techniques and adjusting fertilizer practices.

Water use: Upper West/Mountain region

Water use/budget	Acre-feet		% change
	2005	2013	
Total water use for all regional facilities	208,785	197,548	-5.4
Median water use per 18-hole facility	232.5	208.3	-10.4
Median water/acre	2.20	2.07	-5.9
Median water budget/acre	2.17	2.23	

Table 35. Upper West/Mountain region water use patterns in 2005 vs. 2013.

Water sources: Upper West/Mountain region

Water source	Total acre-feet		Change
	2005	2013	
Open water	25,340	25,095	-245
Canals	38,511	26,053	-12,458
Rivers, streams, creeks	51,651	39,179	-12,472
Wells	55,755	70,368	+14,613
Recycled	25,786	25,165	-621
Municipal (potable)	9,433	21,548	+12,115

Table 36. Total acre-feet of the most commonly used water sources in the Upper West/Mountain region in 2005 vs. 2013.

- Adoption of hand-held soil moisture meters was moderate, at 28.6% of respondents.

Water costs

- Water costs for an 18-hole golf course were moderate (Table 7), compared to other regions.
- Twenty-five percent of all 18-hole courses paid $6,520 or less per year for water, 50% paid $20,430 or less and 75% paid $64,100 or less per year.

Water sources used

- The most common water source used was well water (34%) (Figure 17).
- This is the only region that did not increase its use of recycled water (Figure 1).
- With the exception of well water, there was a decrease in the use of all water sources (Table 36).

Factors in regional water use patterns

Climate

Long-term climatic conditions have a very large impact when water use patterns are compared from one agronomic region to the next.

- Precipitation varies from less than 1 foot in the

Irrigated acres: Typical 18-hole golf course, 2013

Region	Greens	Tees	Fairways	Roughs	Practice areas	Landscape	Total
North Central	3.51	3.16	26.4	21.6	4.28	1.98	60.3
Northeast	3.66	2.79	25.3	21.0	3.53	1.91	56.7
Pacific	3.12	2.86	29.9	35.0	5.03	1.87	82.1
Southeast	3.13	3.57	29.8	46.1	6.99	2.86	96.8
Southwest	3.07	3.42	30.3	48.1	6.61	2.88	103.1
Transition	3.32	3.50	27.6	39.0	5.63	2.27	79.2
Upper West/Mountain	3.05	3.06	29.8	46.6	6.97	1.69	97.3
U.S.	3.29	3.24	28.0	36.3	5.57	2.22	80.2

Table 37. Irrigated median acreage for typical 18-hole golf course in 2013. The sums of golf course individual features are not exactly equal to total acreage values because individual median values are not expected to sum exactly to total median values.

Median cost of water sources for all golf facilities

Water source	Total water cost/ acre-foot (U.S. dollars)	
	2005	2013
Canal	50.6	78.8
Municipal (domestic, potable)	**783***	**1,329**
Open (lakes and ponds)	107	64.1
Recycled	**188***	**321**
River	72.9	47.8
Well	82.5	76.7

Table 38. Median cost (U.S. dollars) of each water source per acre-foot for all golf facilities. Within each row, values in bold type with the lowest value followed by an asterisk indicate a significant difference between the 2005 and 2013 values, at the 90% confidence level. Values that are not in bold type showed no significant change from 2005 to 2013.

Southwest, to more than 14 feet/year in the Pacific region. (Tables 17, 25). This large difference in rainfall has the greatest impact on differences in regional water use patterns.

- Temperatures range from the Pacific region's 34 F, to the Southeast region's average of 78 F (Tables 17, 21). Higher temperatures increase turf water demand, and therefore have a significant impact on water use.

Irrigated acreage

- An 18-hole golf course in the Northeast has 56.7 irrigated acres, while one in the Southwest has almost double that amount at 103.1 acres (Table 37). This large discrepancy occurs because facilities in cooler and wetter climates frequently do not irrigate roughs (Figure 4) and sometimes do not irrigate practice areas.
- In contrast, in regions where the majority of facilities are exposed to hot and/or dry weather, (Southwest, Southeast, Upper West/Mountain, Pacific), all or almost all acres are irrigated (Figure 4), resulting in higher water use for these regions.

Length of growing season

- Climates with short growing seasons, such as those in the northern U.S., need to irrigate only four to seven months of the year. Little or no irrigation is necessary when turf is not growing, or is only slowly growing.
- In contrast, climates with long growing seasons, such as those in the southern tier of the U.S., support turf growth for the entire year. As a result, these golf facilities have to irrigate for the entire year and thus use more water.

Factors in the ability of regions to decrease water usage

Of the seven agronomic regions, five (North Central, Northeast, Southeast, Transition and Upper West/Mountain) saw significant reductions in total water use and acre-feet/acre values. Only two regions, the Pacific and the Southwest regions, showed increases in these values (Tables 1, 2). Factors involved in this pattern are presented below.

Change in number of golf facilities

- The regions with the greatest water savings were also the regions that have seen the greatest decrease in number of golf facilities since 2005 (Table 6). The decreased number of irrigated acres that resulted from this trend led to significant water savings in these regions.
- Conversely, the Southwest and Pacific regions saw some of the smallest decreases in number of golf facilities (Table 6). As a result, water savings resulting from fewer irrigated acres were lower in these regions.

Water sources

- From 2005 to 2013, use of all water sources decreased except for recycled (reclaimed) water (Figure 1).
- The greatest decrease was seen in the use of

open water (lakes and ponds), with a 43.2% reduction in use, followed by water from rivers, streams and creeks (24.8% reduction) and well water (21.7% reduction).
- The greatest reduction in potable (municipal drinking) water use occurred in the Northeast (9,082 acre-feet reduction) and the Southeast (8,975 acre-feet reduction).

Recycled water

- The use of recycled water has increased by 32.7% since 2005 and now makes up approximately 25% of all water used on golf courses in the U.S. (Table 8).
- Recycled water is the only source that has increased in volume nationally (Figure 1) and in six of the seven agronomic regions from 2005 to 2013 (Table 8).
- The Southeast and Southwest regions used, by far, the most recycled water, with an estimated 192,849 acre-feet and 193,394 acre-feet per year, respectively. These trends demonstrate that regions with the hottest and/or driest climates have incentives to adopt recycled water (Figure 1, Table 8).
- Recycled water was used by 15.3% of survey respondents in 2013. The greatest adoption of recycled water has occurred in the Southwest (45.5% adoption), Southeast (30.5% adoption) and Pacific (23.1% adoption) regions. (Table 8).
- Increased use of recycled water allowed reductions in the use of water from open water, rivers, streams and creeks, well water, and municipal (potable) water. However, recycled water should not be compared to other water sources on a one-to-one basis, because 10%-15% additional water is usually required in order to manage soil salts that are introduced to the soil in recycled water.
- It is important to recognize that, although recycled water has historically been viewed as a waste product, it is becoming a potential source for production of potable (drinking) water. Therefore, recycled water may become more scarce in the future, and golf courses using recycled water must continue to focus on integrating additional conservation measures.

Cost of water

- Median costs per acre-foot of water for all water sources combined has significantly increased nationally from $204/acre-foot in 2005 to $298/acre-foot in 2013 (Figure 2). Significant cost increases per acre-foot occurred in all regions of the country except North Central and Upper West/Mountain.
- From 2005 to 2013, median total water costs for an 18-hole golf course also increased significantly nationally and in all regions except the Northeast and the Upper West/Mountain (Table 7).
  - o On a national basis, 25% of all 18-hole golf courses spend $5,900 or less per year for water, while 75% of all 18-hole golf courses spend $96,700 or less annually.
  - o On a regional basis, water costs for an 18-hole golf course are by far the highest in the Pacific and Southwest regions, with median values of $159,730 per year and $140,301 per year, respectively (Table 7). Median annual costs are much lower for courses in the Southeast ($28,854), Upper West/Mountain ($20,431), Transition ($16,415), Northeast ($7,202) and North Central ($1,734) regions (Table 7).

Irrigation system improvements and scheduling methods

	% of courses	
	2005	2013
Irrigation system improvements		
New sprinkler heads	70	66
New nozzles	56	49
New software to control irrigation	38	37
Added sprinkler heads	53	36
Removed sprinkler heads	28	30
Convert irrigation heads to part circles	‡	32
Automatic rain shut-off switches	16	23
Drip irrigation for landscape plants	13	16
Complete irrigation system upgrade	20	14
Professional irrigation system audit	5	8
Irrigation system automation†		
Fully automated	63	69
Semi-automated	25	22
Manual system	1	8.8
Irrigation scheduling methods		
Observation of turf	96	94
Short-term weather forecasts	52	56
Hand-held soil moisture sensors	‡	29
In-ground soil moisture sensors	3	4
Evapotranspiration monitoring from weather service	15	13
Evapotranspiration monitoring from on-site weather station	14	18
Long-term weather records		5

†Fully automated: central control system/controlled remotely; semi-automated: field or satellite controls only — not centralized; manual system: no automation present.
‡Question not asked in 2006.

Table 39. Irrigation systems and irrigation scheduling methods reported by survey respondents for 2005 and 2013. Values represent the percent of facilities across the U.S. that report listed practice or equipment.

% golf courses with various water restrictions

Region	% with required water use reporting		% with recurring annual allocations		% with additional mandatory water restrictions	
	2005	2013	2005	2013	2005	2013
U.S.	48.4	55.0	21.7	30.3	15.8	10.7
North Central	57.7	62.3	11.5	23.5	4.4	2.1
Northeast	50.6	63.8	24.7	33.3	28.8	4.6
Pacific	28.9	25.0	13.7	15.0	2.0	13.9
Southeast	36.5	65.0	34.8	42.6	21.4	26.4
Southwest	57.2	53.3	36.4	40.8	11.8	18.6
Transition	35.4	48.4	10.4	23.4	14.5	4.2
Upper West/Mountain	50.9	36.0	36.1	34.7	31.3	19.1

Table 40. Percent of golf courses that have experienced various water use restrictions.

% of survey respondents with written plans for water-related issues

Region	Drought		Water management		Stormwater		Preventive irrigation maintenance	
	% w/plan	% required	% w/plan	% required	% w/plan	% required	% w/plan	% required
U.S.	14.1	44.5	16.8	40.5	13.9	63.0	20.5	11.3
North Central	4.6	12.7	7.0	12.7	8.0	54.3	16.5	3.6
Northeast	20.1	77.9	18.6	53.3	6.9	61.7	13.0	14.8
Pacific	16.9	22.7	18.0	22.9	12.5	80.0	21.9	5.3
Southeast	20.2	51.0	28.7	43.9	24.4	52.8	30.6	14.2
Southwest	27.6	35.9	29.2	51.2	30.5	74.5	33.2	20.9
Transition	8.0	46.2	13.5	37.1	9.8	65.2	17.4	13.8
Upper West/Mountain	18.9	23.0	16.3	41.3	15.6	70.9	19.3	4.6

Table 41. Percent of 2014 survey respondents who have written plans to deal with the issues listed above. For those respondents with written plans, the "% required" columns indicate the frequency with which those plans were required by state or local authorities. In the majority of cases, respondents developed plans voluntarily, even when not required to by authorities.

  - o Within each region, there is also a broad range of water costs, as described above.
- The median cost of municipal (potable) and recycled water increased significantly from 2005 to 2013, while the cost of open sources (lakes, ponds), canal, river and well water has remained relatively flat (Table 38). [TABLE38] The most expensive source, by far, is municipal (domestic or potable) water, which has risen to a median of $1,329/acre-foot.

Conservation

- Adoption of all water conservation practices increased from 2005 to 2013 (Table 4).
- The most commonly reported practice is the use of wetting agents (soil surfactants), which can modify water flow in soils, thus saving water through reduced runoff, more uniform movement of water and development of deeper-rooted plants that use water more efficiently.
- Other commonly used practices include precision hand watering, keeping turf drier than in the past, use of irrigation scheduling, adjusting fertilizer practices and mulching of landscape beds.
- Hand-held soil moisture sensors have grown in popularity over the past three years, with 29% of all survey respondents using them for irrigation scheduling purposes.
- Of those using hand-held soil moisture meters, 89% say they have had a positive impact on water savings, turf quality and overall operations.
- There was very little variation among regions in the types of conservation practices that have been adopted.

Irrigation management

- The most common improvements seen in 2013 were relatively inexpensive equipment purchases such as new sprinkler heads or new nozzles, as opposed to the much greater expense

of complete irrigation system upgrades or increased automation of the irrigation system (Table 39).

- Access to evapotranspiration (ET) data allows superintendents to more precisely determine how much water the turf needs. Obtaining ET data from onsite weather stations was adopted by 17.9% of survey respondents nationally (Table 39), but in warm and/or arid regions, it was much more popular, as demonstrated in the Southwest (47.7%), Pacific (37.4%) and Upper West/Mountain (33.3%) regions. Obtaining ET data from a weather service was also most common in the Southwest (24.1%) and the Upper West/Mountain (15.5%) regions (data not shown).

Regulation

- Regulation of water use has generally increased since 2005 (Table 40).
- The frequency with which annual recurring water allocations were imposed increased in all regions.
- Higher-water-use regions (Southeast, Southwest and Upper West/Mountain) had the highest percentage of courses with recurring water allocations. However, the biggest increase in the regulation of recurring annual allocations between 2005 and 2013 occurred in the traditionally lower-water-use regions (Northeast, North Central, Transition), where this type of regulation has been relatively rare in the past.
- In addition to following government-mandated regulations on water use, golf courses have also begun to set up voluntary internal guidelines (Table 41), with 14%-20% of all U.S. golf courses reporting the use of written water management plans. These plans were required by state and local authorities in some cases. However, the majority of respondents indicated that these management plans were developed voluntarily.

CONCLUSIONS AND RECOMMENDATIONS

Water is an increasingly limited resource that the golf course industry needs to effectively manage and conserve. The data collected in this survey indicates that the industry has taken significant steps since 2005 toward more efficient use of water, but there is room for continued improvement, especially in the following areas.

Facilities responding to 2014 survey

	U.S. golf facilities		Survey response	
	Number	% of total	Number responding	% of total respondents
All facilities	15,386	100	1,950	100
Region				
North Central	3,925	25.5	411	21.1
Northeast	2,677	17.4	270	13.8
Pacific	638	4.1	107	5.5
Southeast	3,046	19.8	383	19.6
Southwest	1,201	7.8	216	11.1
Transition	2,795	18.2	345	17.7
Upper West/Mountain	1,104	7.2	218	11.2
Type				
Daily fee	8,984	58.4	789	40.5
Municipal	2,480	16.1	353	18.1
Private	3,922	25.5	808	41.4
Holes				
9	4,152	27	160	8.2
18	9,827	63.9	1,478	75.8
27+	1,407	9.1	312	16.0

Table 42. Responses to the 2014 survey characterized by agronomic region, golf course type and number of holes. Data was weighted to compensate for under- or overrepresentation when compared to the U.S. golf course proportions. Facilities refer to a business location where golf can be played on one or more golf courses. Although the survey was conducted in 2014, the data reported by respondents is for 2013.

- *Identify a metric for monitoring water use efficiency.* Water budgets should be developed for each golf course, and should serve as the basis for site-specific golf course water management plans. An increasing number of cities and states are promoting such water budgets as the foundation for water conservation on landscapes (Bennett 2012; Carrow et al. 2007; California Code of Regulations 2009; Environmental Protection Agency 2014).
- *Reduce golf course acreages.* Voluntary golf course acreage reductions made since 2005 now result in water savings of approximately 43,910 acre-feet per year on a national scale. As the largest component of most irrigated golf courses, roughs and out-of-play areas are the obvious locations on which to develop turf acreage reduction plans.
- *Adopt tools to improve irrigation system efficiency.* Increased adoption of tools such as ET-based irrigation scheduling, soil moisture sensors and irrigation system audits will assist superintendents in water use reductions.
- *Install water meters.* Being able to measure water use allows baselines to be established and progress to be tracked. Though this can be a relatively expensive process, installation of water meters will be critical, especially in high-water-use regions of the country.
- *Adopt recycled water sources where available.* Extrapolating from survey results, more than 450,000 acre-feet of recycled water was used nationally in 2013. Increased efforts at the state and local levels are necessary to increase availability and infrastructure for delivery of this water source. It should be recognized, however, that recycled water may not be as readily available to golf courses in the future because water currently handled as wastewater may be diverted for use as drinking water in some areas.
- *Decrease plant-water demand.* Forgo overseeding and switch to more drought-tolerant turf types and lower-water-use landscape plants.
- *Increase golfer education.* Educate golfers about the need for water conservation and the concomitant changes in turf aesthetics that may result.
- *Work with regulators.* As documented by survey participants, state and local regulation of water use is on the rise in almost all regions of the country — a trend that is likely to continue, as water resources become scarcer. Involvement of the golf course industry in the development of water use regulations has resulted in more agronomically feasible regulations in many cases (Waltz and Carrow 2007). Continued industry involvement in the development of regulations is essential.

METHODOLOGY

Survey questions adhered as closely as possible to those in the 2005 survey. However, input from golf, environmental, academic and regulatory sources was integrated into the 2013 survey in order to clarify questions or to integrate information on new technologies and issues in golf course management.

PACE Turf was contracted to provide technical oversight of the survey, analyze and summarize the data, and to prepare reports for publication in peer-reviewed scientific journals, as well as in GCSAA publications and websites.

The National Golf Foundation (NGF) was contracted to refine and format the survey instrument for online use, conduct the survey, manage the recruitment of participants, collate the data and complete the analysis in collaboration with GCSAA and PACE Turf.

Survey response

Of the 15,386 golf facilities in the U.S. at the time the survey was completed in 2014, 13,786 U.S. golf courses managed by superintendents with available email addresses were identified by integrating GCSAA and NGF databases. An initial email invitation, which included a link to the online survey, was sent to prospective participants in October 2014, followed by three follow-up email reminders. A total of 1,950 completed surveys were received, which represents a 12.7% response rate (Table 42). This is roughly comparable to the 15.2% response rate from the 2006 survey. While both surveys targeted the same population, respondents in 2014 were not identical to those in 2006.

To gain insights into survey data, respondents were stratified by agronomic region (Figure 18, Table 42), as well as by golf course type, number of holes and green fees.

To ensure that the data was representative of the broad spectrum of golf facilities in the nation, responses were weighted so that the diversity in golf course size, type and geographic location were accurately reflected in the survey data.

Data analysis

Water use data was restricted to respondents who had on-site water meters (75% of participants) in order to achieve the most accurate information on water use. Other data (irrigated acreage, management practices, etc.) that did not rely on water use utilized the full dataset.

Two types of data were generated for this report. The first characterizes water use and conservation practices for the typical 18-hole golf course. To compute this data, the median was used. The second type of data uses the survey

Distribution of 2014 survey responses

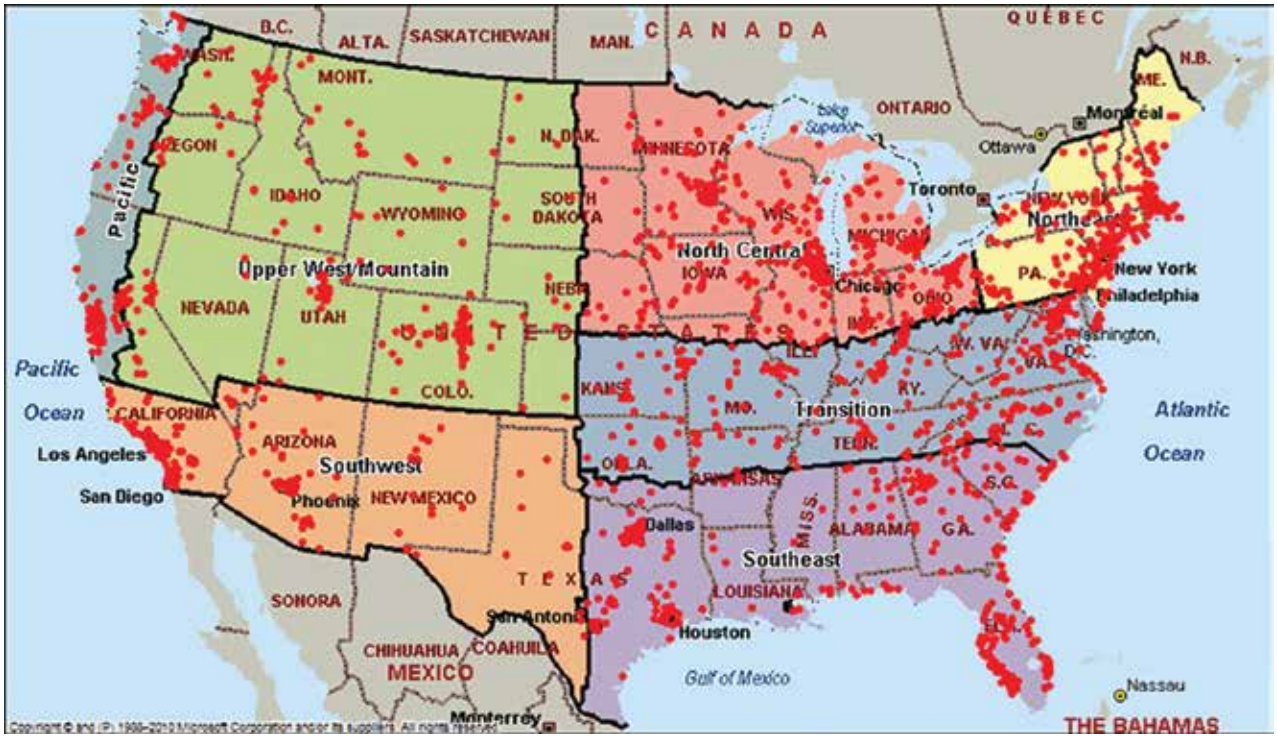

Figure 18. Distribution of 2014 survey responses across the survey's seven agronomic regions.

information to make projections about water use and conservation practices for the nation's golf courses as a whole. For this type of analysis, computations are based on the mean, rather than the median.

Climate and weather data

This report incorporates, for the first time, specific information on each survey respondent's climate and weather, thus providing greater insights on water use patterns. Each respondent's ZIP code was matched to 30-year average air temperature and precipitation data from the PRISM Climate Group at Oregon State University (PRISM Climate Group 2015) as well as to specific data for 2005 and 2013 (the years covered by the first and second water use surveys).

Water budgets

Water budgets are estimates of annual water use for a given location that are based on climatic factors at that site. They are gaining increasing popularity among regulators, legislators, turf managers and water use specialists as a means of monitoring water use. By comparing actual annual water use against the water budget, water conservation progress can be tracked. Ideally, the percentage of the water budget used will go down over time, as more water conservation efforts are implemented.

The water budget data presented here was calculated for each survey respondent's location using estimates of the reference evapotranspiration, precipitation distribution uniformity crop coefficient and leaching fraction. The equation used is based on the Environmental Protection Agency's Landscape Water Requirement equation (Environmental Protection Agency 2014). A detailed description of the methods used for calculating the water budget can be found in the sidebar, "How water budgets were calculated," on Page 30.

Further Reading

1. Allen, R.G., L.S. Pereira, D. Raes and M. Smith. 1998. Crop evapotranspiration — guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56. FAO, Rome. (www.fao.org/docrep/x0490e/x0490e00.htm). Accessed Oct. 27, 2015.
2. Ayers, R.S., and D.W. Westcot. 1985. Water quality for agriculture. FAO irrigation and drainage paper 29, rev. 1. Food and Agriculture Organization of the United Nations, Rome, Italy. (https://www.paceturf.org/reference/FAO_Handbook_29) Accessed Sept. 14, 2015.
3. Bennett, D. 2012. Lean and green: water efficiency in the Las Vegas golf industry. Pages 16-20. In: Golf's use of water: challenges and opportunities, a USGA summit on golf course water use. November 2012, Dallas, Texas. USGA, Far Hills, N.J. (http://usga.org/Course-Care/

Golf-and-the-Environment/Water/USGA-Water-Summit). Accessed Oct. 27, 2015.
4. California Code of Regulations, 2009. Model water efficient landscape ordinance. Title 23. Waters. Chapter 2.7. (www.water.ca.gov/wateruseefficiency/docs/MWELO09-10-09.pdf). Accessed Oct. 27, 2015.
5. Carrow, R.N., R. Duncan and C. Waltz. 2007. Best management practices (BMPs) and water-use efficiency/conservation plan for golf courses: Template and guidelines. University of Georgia, Crop and Soil Science Department, Griffin, Ga. (www.commodities.caes.uga.edu/turfgrass/georgiaturf/water/articles/bmps_water_cons_07.pdf). Accessed Oct. 27, 2015.
6. Environmental Protection Agency. 2014. The WaterSense Water Budget Tool. Version 1.02, July 24, 2014. (www3.epa.gov/watersense/water_budget). Accessed Oct. 27, 2015.
7. Kenny, J.F., N.L. Barber, S.S. Hutson, K.S. Linsey, J.K. Lovelace and M.A. Maupin. 2009. Estimated use of water in the United States in 2005: U.S. Geological Survey Circular 1344. (http://pubs.usgs.gov/circ/1344). Accessed Oct. 27, 2015.
8. Lyman, G.T., C.S. Throssell, M.E. Johnson, G.A. Stacey and C.D. Brown. 2007. Golf course profile describes turfgrass, landscape and environmental stewardship features. *Applied Turfgrass Science* doi:10.1094/ATS-2007-1107-01-RS
9. Lyman, G.T., M.E. Johnson, G.A. Stacey and C.D. Brown. 2012a. Golf course environmental profile measures pesticide use practices and trends. *Applied Turfgrass Science* doi:10.1094/ATS-2012-1220-01-RS
10. Lyman, G.T., M.E. Johnson, G.A. Stacey and C.D. Brown. 2012b. Golf course environmental profile measures energy use and energy management practices. *Applied Turfgrass Science* doi:10.1094/ATS-2012-0228-01-RS
11. Maupin, M.A., J.F. Kenny, S.S. Hutson, J.K. Lovelace, N.L. Barber and K.S. Linsey. 2014. Estimated use of water in the United States in 2010. U.S. Geological Survey Circular 1405. (http://dx.doi.org/10.3133/cir1405). Accessed Oct. 27, 2015.
12. PRISM Climate Group. 2015. Northwest Alliance for Computational Science & Engineering (NACSE), based at Oregon State University (www.prism.oregonstate.edu). Accessed Oct. 27, 2015.
13. Throssell, C.S., G.T. Lyman, M.E. Johnson, G.A. Stacey and C.D. Brown. 2009a. Golf course environmental profile measures water use, source, cost, quality, and management and conservation strategies. *Applied Turfgrass Science* doi:10.1094/ATS-2009-0129-01-RS
14. Throssell, C.S., G.T. Lyman, M.E. Johnson, G.A. Stacey and C.D. Brown. 2009b. Golf course environmental profile measures nutrient use and management and fertilizer restrictions, storage and equipment calibration. *Applied Turfgrass Science* doi:10.1094/ATS-2009-1203-01-RS
15. University of California. 2015. Turfgrass crop coefficients (Kc). University of California Center for Landscape and Urban Horticulture. (http://ucanr.edu/sites/UrbanHort/Water_Use_of_Turfgrass_and_Landscape_Plant_Materials/Turfgrass_Crop_Coefficients_Kc/) Accessed 9/14/15.
16. Waltz, F.C., and R.N. Carrow. 2007. Applied turfgrass water use efficiency/conservation: agronomic practices and building cooperation between industry trade associations and regulatory authorities. *Acta Horticulturae* 783:239-245.
17. Wilson, T.P., and D.F. Zoldoske. 1997. Evaluating sprinkler irrigation uniformity. CATI publication 970703. Center for Irrigation Technology. (http://cwi.csufresno.edu/wateright/evalsprink.asp) Accessed 9/14/2015.

How water budgets were calculated

The water budget (acre-feet/acre) for each respondent's location was calculated based on the Landscape Water Requirement (LWR) equation (Environmental Protection Agency 2014) shown below, with addition of a leaching fraction:

$$LWR = 1/DULQ \times [(ETo \times KL) - Ra] \times A \times Cu \times LF$$

Where:

- LWR = Landscape water requirement for the hydrozone (gallons/month)
- DULQ = lower-quarter distribution uniformity (dimensionless)
- ETo = Local reference evapotranspiration (inches/month)
- KL = Landscape coefficient for the highest water-using plant in that hydrozone (dimensionless)
- Ra = Allowable rainfall, designated by WaterSense as 25% of the site's peak monthly rainfall
- A = Area of the hydrozone (square feet)
- Cu = Conversion factor (0.6233 for results in gallons/month)
- LF = Leaching Fraction

For calculation of the LWR, the following modifications were made:

Units were changed from inches to feet for ETo and rainfall (Ra). Square feet were changed to acres for area measurements. As a result, the equation simplifies and the conversion factor (Cu) drops out.

ETo values for each survey location were computed using the Hargreaves ET equation (Allen et al. 1998), which provides reference evapotranspiration (ETo) estimates when only maximum temperature, minimum temperature and estimated extraterrestrial solar radiation based upon latitude are available.

KL = 0.7, which is midway between cool season (0.8) and warm season (0.6) values (University of California 2015).

DULQ = 0.7, which is midway between high and low irrigation efficiency for irrigation using rotors (Wilson and Zoldoske 1997).

Ra was computed using a daily water-banking algorithm assuming a root depth of 4 inches with a soil water holding capacity of 0.25 inch water per inch of soil. Rainfall exceeding the water-holding capacity of the soil was not banked. Evapotranspiration is subtracted from the soil water bank on a daily basis. If the soil water bank is overdrafted, it is assumed that irrigation is required to match the overdraft. Total water requirement from irrigation is the total overdraft computed on a daily basis and summed over the year.

GCSAA
www.gcsaa.org

EIFG
www.eifg.org

1421 Research Park Drive
Lawrence, KS 66049-3859
Toll Free 800.472.7878