Trends in Golf Course Water Use and Regulation in California

With more water use regulation a certainty, determining reasonable water budgets for different climate zones is vital.

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Water is an important issue in California and many other parts of the United States. According to the California State Department of Finance, by 2030, California is projected to have 17 million more people, growing from 35 to 52 million. Efforts are under way and must be expanded to make sure that water is used more efficiently in every aspect of our lives. Water is also a political issue with a number of groups representing different segments of the economy and the population, including agricultural production and urban areas; Northern California and Southern California; economic, social and environmental interests; and state and federal water interests.

Recommended water use

Where do golf courses fit in this complicated landscape? **Golf courses need to project a genuine image that they are not wasting water, and they must be able to show how much water they need to do business.** What is a fair amount of water for golf course use? Information in this summary paper begins to get at best estimates of golf course irrigation water use in Southern California and some of the issues and challenges associated with determining what is a fair amount of water.

Legislation and memoranda in California since 1990 (Table A.1) indicate a trend for large landscapes, including golf courses, to be placed on a water budget in the future. Large-landscape water budgets in California will be based on:

[reference evapotranspiration × ET adjustment factor] × landscape area,

where ET (evapotranspiration) adjustment factor means a factor, such as 0.8, that, when applied to reference ET, adjusts for plant factors (crop coefficients) and irrigation efficiency, two major influences upon the amount of water that needs to be applied to the landscape (16).

Reference evapotranspiration

Landscape water regulators will require accurate estimates of reference ET to develop objective and fair water budgets which may be in contrast to estimates of reference ET used for routine and operational applications on golf courses and other landscapes. Reference ET estimates used by water regulators are important because they affect estimates of golf course irrigation use which are used in developing water budgets. Reference ET (or reference crop ET) is defined as the ET rate of an actively growing reference crop, not limited by soil water content, and having specified plant and biophysical characteristics. It serves as an evaporative index and can be used in the crop coefficient (K_c) approach for calculating crop evapotranspiration under standard conditions (ET_{crop}) (3). Reference ET from clipped, cool-season grass is denoted ET_o while the same from full-cover alfalfa is denoted as ET_r. Usage of the two reference crops is generally divided among the western States. The American Society of Civil Engineers (ASCE) has recently developed the ASCE Standardized Reference Evapotranspiration Equation and calculation procedures to bring commonality to calculating ET_o and ET_r and to provide a standardized basis for determining or transferring K_c for agricultural and landscape use (1). The basis of the standardized reference ET equation is the ASCE Penman-Monteith equation.

In California, the most-commonly accepted source of ET_o data is the California Irrigation Management Information System (CIMIS) (7), an integrated network of over 120 automated weather stations located at key agricultural and municipal sites throughout the state. CIMIS uses the modified Penman equation with a wind function, also called CIMIS Penman equation, to estimate ET_o. In addition to CIMIS ETo, CIMIS also provides ET_o values estimated using the Penman-Monteith equation. Studies have shown that there are no significant differences between Penman-Monteith and CIMIS ET_o. The reference crop at most CIMIS stations is a 4.7-inch tall, cool-season grass (an irrigated pasture) that is transpiring near the maximum rate. A few CIMIS stations report ET_r. Currently, there are very important efforts to increase the ability to accurately estimate CIMIS ET_o in municipal areas and microclimates.

Water budgets in Southern California

Generally speaking, large-landscape water budgets, including golf courses, will be in the range of 80% ET_o × landscape area. It should be noted that the State Model Water Efficient Landscape Ordinance (Model Ordinance) (16) includes a provision that allows “recreational areas,” such as golf courses, to use a specified amount of additional water above the Maximum Applied Water Allowance which is 80% ET_o x landscape area. This is an appropriate provision for golf courses. One of the few examples that is published in the scientific literature is Devitt et al. (9), who conducted a 2-year study in Las Vegas, Nev. and reported that overseeded bermudagrass maintained on a fairway had 29% higher ET actual than overseeded bermudagrass maintained in a park. The difference in ET actual between the golf course and park sites was attributed to cultural management, in particular, fertilizer input.

How does golf course irrigation water use compare to a water budget of 80% ET_o x landscape area? To answer this question, annual irrigation water use was estimated for hypothetical 18-hole golf courses in three Southern California climates: southern coastal marine climate (Irvine); transition climate between marine and desert climates (Riverside); and Southern California low-desert climate (Indio; Palm Springs area).

Annual irrigation water use was estimated and a water budget was calculated by using the methods and information in Table A.2, which use monthly average ET_o and monthly K_cs; the results are shown in Table 1 on the next page. Because monthly K_cs are basically not available for most of the country, the reality is that water regulators and golf course superintendents will need to use best-estimate annual K_cs in conjunction with average yearly ET_o. An example of a step-by-step calculation using average yearly ET_o and best-estimate annual K_cs is shown in Table A.5. Note that in calculating the water budget in Table A.5, different best-estimate annual K_cs were used for each part of the golf course (greens, tees, fairways, and roughs) to provide a more accurate estimate of annual irrigation water use for the entire golf course.

Table 1. Estimated annual irrigation water use and water budget calculations for 18-hole golf courses located in three southern California cities, based on monthly average ET_o, annual normal precipitation, and monthly crop coefficients (K_c).

	Irvine	Riverside	Indio: Irvine K_c[z]	Indio: Tucson K_c[y]
	Optimal turfgrass performance[x]			
A. Annual irrigation water use (acre feet)	395	490	686	769
B. (Average yearly ET_o x 110 acres) (acre feet)	455	517	655	655
C. Calculation for water budget: (*A*/*B*) x 100	87%	95%	105%	117%
	Water conservation (80% optimal)			
D. Annual irrigation water use (acre feet)	316	392	549	615
E. Calculation for water budget: (*D*/*B*) x 100	69%	76%	84%	94%

[z] See citation number 14 and Table A.4.

[y] See citation number 5 and Table A.4.

[x] Well-watered conditions.

Reasonable expectations

A water budget in the range of 80% $ET_o \times$ landscape area is very achievable for a golf course located in the southern coastal marine climate (Irvine). As one moves inland to a transition climate between marine and desert climates (Riverside), the same budget is probably achievable, but it may require some extra attention to efficient irrigation water use. Some suggestions are included at the end of this summary paper.

Based on these estimates, a golf course in the low-desert climate (Indio; Palm Springs area) of Southern California probably would have considerable difficulty achieving a water budget based on 80% $ET_o \times$ landscape area. However, two comments should be made. First, increasing irrigation efficiency above the 70% used in these estimates (Table A.2) and reducing the irrigation water requirement are achievable. One example is that Zoldoske (17) reported that five golf courses changed existing sprinkler systems with replacement nozzles and the estimated total gross water savings for all golf courses, without adjusting for useful rainfall, was 99.8 acre-feet of water, or 6.5 percent of applied water. It was also shown that the distribution uniformity of the original irrigation system was increased from 73% to 85% by only replacing nozzles. The second point is that the Coachella Valley Water Management Plan (Palm Springs area) sets a minimum water conservation goal of 5% by 2010 for golf courses existing in 1999; the minimum water conservation goal for golf courses built after 1999 is on a case-by-case basis (8). The last comment about these estimates is that using crop coefficients developed in Tucson, Ariz., for fairway-quality bermudagrass in summer and bermudagrass overseeded with ryegrass in winter is a reasonable practice on golf courses located in the Palm Springs area.

Estimates and limitations

The figures presented here are best estimates for irrigation water use and are probably within range. However, like any estimate, there are limitations which water regulators should be aware of when estimating golf course irrigation water use for developing water budgets. As an example, it has been reported in the scientific literature that a number of factors affect turfgrass water use and thus crop coefficients, including turfgrass species and/or variety, canopy characteristics, mowing height, nutrition, irrigation frequency, and the procedure used to estimate ET_o (5, 9). Crop coefficients also can be affected, to a more limited extent, by climate, especially wind speed and humidity (3). Another issue affecting crop coefficients is that some published crop coefficients were developed under non-standard conditions (periods of drought) which could lead water regulators to develop unnecessarily restrictive water budgets. Thus, it would be desirable for the scientific community to develop crop coefficients under standard conditions (well-watered) for purposes of standardization and transfer (1, 3, 5). Lastly, it is important that the reference ET that was used to develop crop coefficients is suitable with the reference ET that is being used, or adjustments should be made (1).

In the not-too-distant future, water budgets based on $ET_o \times$ landscape area will be mandated for large landscapes, including golf courses. However, some issues need to be addressed. From the water agency standpoint, some concerns are:

- cost effectiveness of water-use regulation
- installation of dedicated landscape irrigation meters
- accurate estimates of ET_o in the various urban microclimates around CIMIS weather stations
- inclusion of use of private wells and recycled water in water budgets

In the meantime, those who own, manage and enjoy golf courses should consider the following suggestions.

- Develop respectful communications with water districts, local and state government agencies, environmental organizations, all the various segments of the Green Industry, and universities.
- Communicate the social, economic and environmental benefits of golf courses and large landscapes such as parks and greenbelts in the highly urbanized lifestyle of California.
- Have the best-possible irrigation system, with the highest-possible distribution uniformity.
- Irrigate according to ET_o, agronomic and golf needs.
- If possible, use recycled water. Unfortunately, demand is greater than the current infrastructure can supply.
- Remember, golf course superintendents are considered some of the best irrigators in the green industry.
- Where a water budget cannot be met, a tiered water-pricing structure (the price of water increases as more over-budget water is used) seems fair. That is, treat water like a commodity.
- It seems reasonable to give a golf course a water budget and then give personnel the flexibility to deal with it rather than mandating restrictions on what and how much one is allowed to plant.
- If necessary, consider reducing water used on roughs and then fairways, and consider reducing the size of the overseeded area.
- Find out what your water budget would be if the water district declared a drought; develop a contingency plan.

Summary points

- In the future, governmental agencies and water regulators will be developing water budgets which will affect water use for golf courses and other large landscape areas.
- It is essential that water regulators have accurate estimates of reference ET, turfgrass crop coefficients, and reasonable estimates of irrigation system distribution uniformity since these parameters affect estimated golf course irrigation water use which is the basis of a water budget.
- Golf courses need to project a genuine image that they are not wasting water, and they must be able to show how much water they need to do business.
- Superintendents can contribute toward conserving water while maintaining turfgrass by taking steps now to improve irrigation efficiency, establish water budgets, and demonstrate good stewardship by documenting water use. This way, Superintendents will be ahead of the game when shortages roll around.

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APPENDIX

Table A.1. Highlights of legislation and memoranda concerning landscape irrigation water conservation.

AB 325 1990 Water Conservation in Landscaping Act

Model Water Efficient Landscape Ordinance

- Maximum Applied Water Allowance (MAWA) = 80% $ET_o \times$ landscape area.
- Provides a provision for specified additional water above MAWA for recreational areas.
- Applies to all new and rehabilitated landscape projects that require a permit.
- All existing landscape areas that are one acre or more shall have a landscape irrigation audit at least every 5 years if it appears the site is using more than MAWA.
- Cities and counties could adopt the Model Ordinance, adopt their own ordinance, or issue findings that no ordinance was necessary. If no action was taken, the Model Ordinance automatically went into effect January 1, 1993.
- A study published in 2001 indicated that the Model Ordinance has not been as effective as hoped.
- Basically, there is a need for more consistency in standards, implementation, and post-construction follow-up.

Best Management Practice 5 (BMP 5)

Large Landscape Conservation Programs and Incentives
[1 of 14 BMPs listed in the **Memorandum of Understanding (MOU)** Regarding Urban Water Conservation in California as amended April 8, 1998]
California Urban Water Conservation Council (CUWCC)

- Water suppliers, who are signatories of the MOU, develop water use budgets for large landscapes of commercial/industrial/institutional (CII) sites that have dedicated irrigation meters. Golf courses are considered CII sites.
- Signatory water agencies can exempt from implementation of BMP 5 for several reasons; one reason is that it can be shown to be not cost-effective given prevailing conditions.
- Water suppliers develop a water budget based on ET_o, ET adjustment factor, and landscape area.

  ET adjustment factor is a scaler ranging between 0% to 100% (i.e. 0.0 to 1.0 in decimal form) that indicates the percentage of ET_o to be used in a water budget.

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Table A.1 *(continued)*. Highlights of legislation and memoranda concerning landscape irrigation water conservation.

Best Management Practice 5 (BMP 5) *(continued)*

- Water budget cannot exceed 100% $ET_o \times$ landscape area. Currently, most water suppliers are using a budget that ranges from 80% to 100% $ET_o \times$ landscape area.
- Agencies conduct landscape water use surveys at CII landscape sites with mixed-use water meters or non-metered sites.
- Also includes programs to support water budget and water survey programs including education and encouraging installation of dedicated irrigation meters.
- Signatories of the MOU, who are water suppliers, represent 70% of the urban water deliveries in California.

Urban Water Management Planning Act
Water Code Section 10610-10610.4

SB 610 2002: An Act to amend sections of the Water Code

- Requires the Department of Water Resources (DWR) to take into consideration if an urban water supplier has submitted an updated urban water management plan when determining if the supplier is eligible for DWR-administered funds.
- The Act defines several elements of a plan including it to address water conservation measures. Urban suppliers can meet these requirements by addressing **14 demand management measures (DMMs)** which are consistent with the 14 BMPs of the MOU of the CUWCC.
- The fifth DMM (E), Large Landscape Conservation Programs and Incentives will probably have similar provisions to BMP 5, along with being codified.

AB 2717 2004: An Act Relating to Water Conservation

- Bill requires that the California Urban Water Conservation Council (CUWCC) convene a stakeholders workgroup composed of public and private agencies and associations to evaluate and recommend proposals for improving the AB 325 Model Water Efficient Landscape Ordinance and additional matters.
- The stakeholder workgroup may report to the Governor and the Legislature by December 31, 2005.

Table A.2. Methods and information used to calculate annual irrigation water use and a water budget for 18-hole golf courses.

1. Based on a GCSAA report (10), calculations involved 3.1 acres of greens, 3.7 acres of tees, 43.7 acres of fairways, and 59.5 acres of roughs (a total of 110 acres). The hypothetical golf courses in Irvine and Riverside had cool-season turfgrass greens and warm-season turfgrass tees, fairways and roughs. Tees were overseeded in Irvine during October through June and tees and fairways were overseeded in Riverside during October through May. All greens, tees, fairways and roughs for the Indio golf course were warm-season turfgrasses that were overseeded during October through April.

2. Monthly turfgrass water use (technically, turfgrass water requirement) was individually estimated (in inches) for each GC area (greens, tees, fairways, and roughs) by using the crop coefficient (K_c) approach for calculating crop evapotranspiration under standard conditions (ET_{crop}) (3). The calculation is $ET_{crop} = K_c \times ET_o$, where standard conditions are considered optimal or well-watered. Calculations involved monthly average ET_o for each city (Table A.3) (7) and monthly K_cs developed in Irvine, Calif. for cool- and warm-season turfgrasses maintained under general turfgrass use conditions (Table A.4) (14). Cool-season turfgrass K_cs were used for months when warm-season turfgrasses were overseeded. For Indio, monthly K_cs developed in Tucson, Ariz. for overseeded bermudagrass maintained under fairway conditions also were used (Table A.4) (5). The Irvine K_cs, based on CIMIS ET_o (the modified Penman equation with a wind function), and the Tucson K_cs, based on the FAO Penman-Monteith equation, were not adjusted for use with CIMIS ET_o. Though the use of K_cs developed in Irvine has been generally adopted state-wide, it should be noted that they are best used only for the southern coastal marine climate of California. More discussion about K_cs is included in this paper under "Estimates and Limitations".

   Many people would prefer to calculate annual turfgrass water use by using average yearly ET_o and best-estimate K_cs; 0.8 is commonly used for cool-season turfgrasses and 0.6 to 0.7 is commonly used for warm-season turfgrasses (see Table A.5, line G). The average yearly ET_o for Irvine, Riverside, and Indio is 49.63, 56.37, and 71.40 inches, respectively (Table A.3) (7). An example calculation for a golf course located in Riverside, Calif. is provided in Table A.5. The calculations basically follow the information in numbered points 1 to 9, but especially 3 to 9.

3. Annual turfgrass water use was estimated for each GC area (in inches) by summing monthly turfgrass water use estimates.

4. Annual turfgrass water use estimates were adjusted for annual normal precipitation for each GC area (in inches) by subtracting 25% of annual normal precipitation from annual turfgrass water use estimates. It should be noted that the Model Ordinance (16) allows for no more than 25% of annual normal precipitation to be considered effective irrigation. Annual normal precipitation for Irvine (Santa Ana), Riverside, and Indio is 13.84, 10.67, and 3.15 inches, respectively (Table A.6) (15).

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Table A.2 *(continued)*. Methods and information used to calculate annual irrigation water use and a water budget for 18-hole golf courses.

5. Annual irrigation water use (technically, irrigation water requirement) was estimated for each GC area (in inches) by adjusting the estimates in number 4 for irrigation efficiency. Irrigation efficiency was set at 70%. This value is not unreasonable, considering the information in Table A.7 (12). However, this information also shows that irrigation efficiencies above 70% are achievable.

6. No provision for leaching was made. This is consistent with the Model Ordinance (16). However, the Model Ordinance is currently under review (AB 2717, Table A.1) and it is possible that a leaching allotment addition provision can be set up that is similar to the Third Management Plan for Phoenix Active Management Area 2000-2010 (4). In this plan, operators of a turf-related facility may apply for an allotment addition if the water supply used for landscape watering contains at least 1,000 ppm total dissolved solids. Calculations for the allotment additions are based on a standard leaching-fraction equation.

7. Annual irrigation water use was estimated for each GC area (in acre feet) by first converting estimates in number 5 to feet and then multiplying these estimates (annual irrigation water use in feet) by the number of acres shown in number 1.

8. Annual irrigation water use was estimated for each golf course (in acre feet) by summing annual irrigation water use estimates for each GC area. This value is shown in Table 1 under optimal turfgrass performance, line A. Generally speaking, most golf courses irrigate in a range between 100% to 80% optimal. Therefore, annual golf course irrigation water use was estimated for the 80% optimal level by multiplying the optimal level by 0.8. This value is shown in Table 1 under water conservation, line D.

9. Water budget calculations were made to compare estimated annual golf course irrigation water use (in acre feet) to (average yearly ET_o x 110 acres) (in acre feet). Average yearly ET_o (Table A.3) was converted to feet from inches then multiplied by 110 acres; line B in Table 1 shows the results of these calculations. The water budget calculations are shown in lines C (optimal) and E (80% optimal) in Table 1. They are the result of the following calculation: {estimated annual golf course irrigation water use on 110 acres [in acre feet]/[average yearly ET_o x 110 acres (in acre feet)]} × 100.

Table A.3. Monthly average reference crop evapotranspiration (ET_o) for three southern California cities[z].

Month	Irvine	Riverside	Indio
	inches		
January	2.18	2.49	2.44
February	2.49	2.91	3.31
March	3.67	4.16	5.25
April	4.71	5.27	6.85
May	5.18	5.94	8.67
June	5.87	6.56	9.57
July	6.29	7.22	9.64
August	6.17	6.92	8.67
September	4.57	5.35	6.85
October	3.66	4.05	5.00
November	2.59	2.94	2.95
December	2.25	2.56	2.20
Total	49.63	56.37	71.40

[z] See citation number 7.

Table A.4. Monthly crop coefficients (K_c) for turfgrasses developed in Irvine, California and Tucson, Arizona .

	Irvine K_c[z]		Tucson K_c[y]
Month	Cool-season turfgrass	Warm-season turfgrass	Fairway quality bermudagrass overseeded in winter
January	0.61	0.55	0.78
February	0.64	0.54	0.79
March	0.75	0.76	0.86
April	1.04	0.72	0.90
May	0.95	0.79	0.85
June	0.88	0.68	0.78
July	0.94	0.71	0.78
August	0.86	0.71	0.82
September	0.74	0.62	0.83
October	0.75	0.54	–
November	0.69	0.58	0.82
December	0.60	0.55	0.79

[z] See citation number 14.

[y] See citation number 5.

Table A.5. Estimated annual irrigation water use under optimal conditions and a water budget calculation for an 18-hole golf course located in Riverside, Calif., based on average yearly ET_o, annual normal precipitation, and best-estimate annual crop coefficients (K_c).

A. Average yearly ET_o = 56.37 inches (4.7 feet)

B. Annual normal precipitation = 10.67 inches

C. Irrigated turfgrass = 110 acres

D. Irrigation efficiency = 70%

	Greens	Tees	Fairways	Roughs
E. Acres	3.1	3.7	43.7	59.5
F. Turfgrass	Poa annua creeping bentgrass	Bermudagrass overseeded Oct. to May	Bermudagrass overseeded Oct. to May	Bermudagrass
G. K_c	0.8	0.75	0.75	0.65
H. Turf water use (inches) = [*A* (inches) x *G*]	45.1	42.3	42.3	36.6
I. 25% precipitation (inches) = *B* x 0.25	2.7	2.7	2.7	2.7
J. Turf water use adjusted for 25% precipitation (inches) = (*H*-*I*)	42.4	39.6	39.6	33.9
K. Irrigation water use (inches). If irrigation efficiency = 70%, then *K* = (*J*/0.7)	60.6	56.6	56.6	48.4
L. *K* converted to feet = (*K*/12)	5.1	4.7	4.7	4.0
M. Annual irrigation water use (acre feet) = (*E* x *L*)	15.8	17.4	205.4	238.0
N. Annual golf course irrigation water use (acre feet) = sum of *M* for greens, tees, fairways and roughs	477			
O. ET_o x 110 acres (acre feet) = *A* (feet) x *C*	517			
P. Calculation for water budget = (*N*/*O*) x 100	92%			

Table A.6. Precipitation normals for three southern California cities[z].

Month	Irvine[y]	Riverside	Indio
	inches		
January	3.18	2.47	0.78
February	3.05	2.39	0.68
March	2.78	2.19	0.47
April	0.67	0.60	0.06
May	0.25	0.25	0.06
June	0.11	0.10	0.01
July	0.02	0.03	0.10
August	0.12	0.17	0.20
September	0.34	0.26	0.21
October	0.36	0.26	0.12
November	1.17	0.78	0.18
December	1.79	1.17	0.28
Total	13.84	10.67	3.15

[z] See citation number 15.

[y] Data not available for Irvine. These data are from Santa Ana, Calif..

Table A.7. Irrigation system distribution uniformity (DU) for golf courses.[z]

Sprinkler type	System quality: Excellent (achievable)	Good (expected)	Poor (if lower than this, consider not scheduling)
	Estimated DU (%)		
Rotary sprinklers	80	70	55
Spray sprinklers	75	65	50

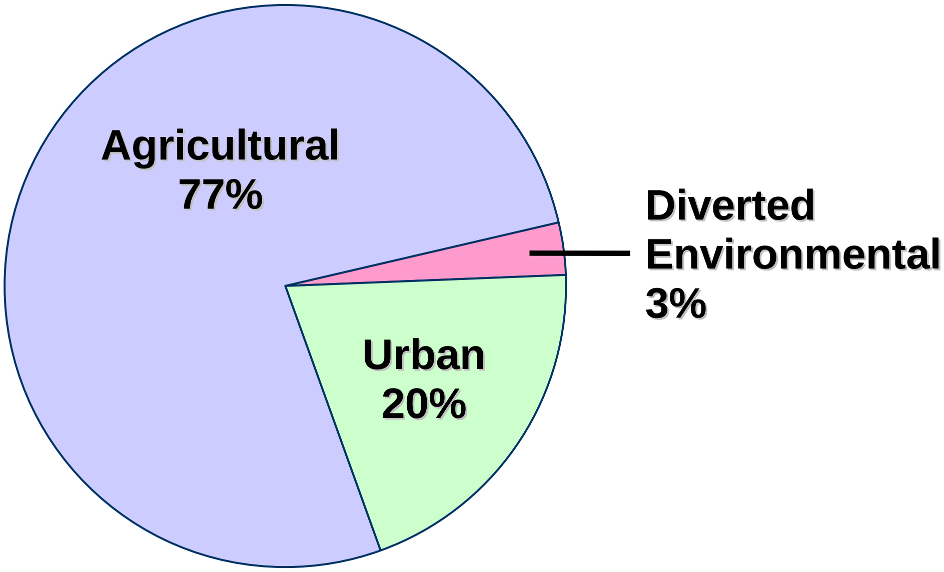
[z] Adapted from citation number 12.

Table A.8. Irrigation system distribution uniformity (DU)[z]

Sprinkler type	System quality: Excellent	Very good	Good	Fair	Poor
	Estimated DU (%)				
Fixed spray	70	65	55	50	40
Rotor	75	70	65	60	50
Stream rotor	85	80	75	65	55
Impact	75	70	65	60	50

[z] Adapted from citation number 11.

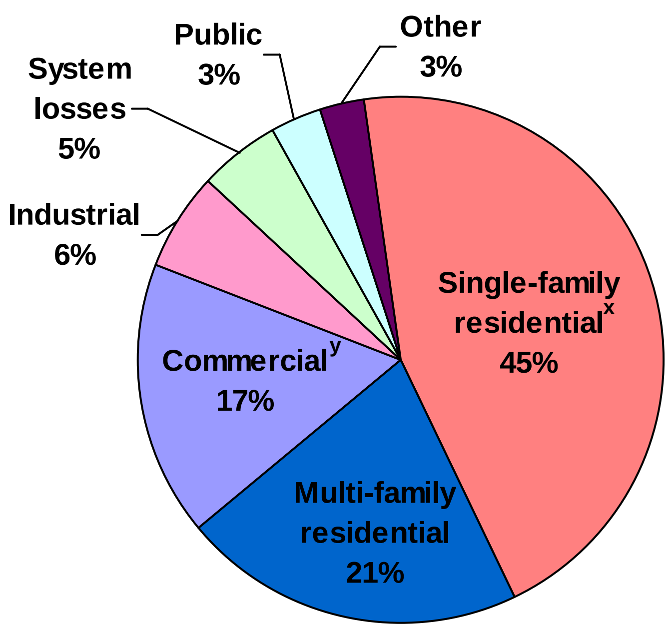
Figure A.1. State-wide distribution of applied water use[z].



[z]Adapted from citation number 6.

Note: “Agriculture applies the greatest quantity of water because of the tremendous number of acres producing agricultural crops throughout California. Managed wetlands use is a small percentage of applied water, but overall environmental water use (including in-stream flows) is equivalent to agriculture.”

Figure A.2. Breakdown of water use in the Metropolitan Water District of Southern California service area[z].



[z]Adapted from citation number 13.

[y]Golf courses are included in the commercial sector.

[x]The American Water Works Association conducted a study in 14 cities across the USA during 1996 to 1999 and reported that North American households included in the study use approximately 146,000 gallons annually. Of this amount, 42% is used indoors while 58% is used outdoors (see citation number 2).