Evaluation of
Potential Best Management Practices
-
Turf Removal

Prepared for

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INTRODUCTION

Throughout the arid and semi-arid regions of California, landscape irrigation is a major component of per capita water use, conservatively accounting for 30% to 43% of total annual water consumption. Watering residential landscapes is the single greatest household use of water as well as more than half of urban use. Further, a correlation exists between cities with the highest levels of per capita water use and the predominant use of traditional turfgrass and hydrophilic landscapes (Hurd, 2006).

Identified within the *California Single Family Home Water Use Efficiency Study* (DeOreo et al., 2011), the average annual outdoor use was determined to be 190 gallons per day for the study group (Table 1). Annually, that is 87,000 gallons[1], ranging from 17,000[2] to 226,000 gallons per account, with an average residential irrigated area of 3,631 square feet (ft^2) and median area of 2,634 ft^2; 7,000 ft^2 for the average commercial site (Christian-Smith et al., 2012). With the conventional landscape containing 40% to 80% irrigated turfgrass area. By altering the landscape through a reduction of irrigated turfgrass area, outdoor water use patterns will vary. This can potentially yield significant water savings. Based on a typical residential site with a conventional cool season turfgrass landscape, studies have estimated a savings range from 35% to 75% of current per capita water use (Ferguson, 1987; Knopf, 2003; Sovocool, Rosales, and Southern Nevada Water Authority, 2004).

This Potential Best Management Practice (PBMP) Report attempts to delineate the water benefits (or detriments) attributed to the reduction of the conventional turfgrass intensive landscape and is inline with the California Urban Water Conservation Council's (CUWCC) landscape new-norm strategic focus. This PBMP candidate has been termed "Turf Removal."

WHAT IS MEANT BY TURF REMOVAL

"Turf Removal" is a term used by many water agencies to depict a landscape practice where turfgrass intensive existing landscapes are converted to alternative landscape designs yielding a potentially reduced "Landscape Ratio." Typically, these landscape designs include some combination of climate appropriate plants and (permeable) hardscape area. When rebating this practice, the term "cash for grass" has also been coined.

LANDSCAPE RATIO

The "landscape ratio" is the ratio of the theoretical irrigation requirement (TIR) to the reference requirement based on evapotranspiration (ET_O). Or, in other words, how much water a landscape needs based on plant type versus the replacement of a percent of water lost to evaporation and transpiration. The California Assembly Bill 1881, the Model Water Efficient

[1] The original 92,400 gallons per year was reduced to 87,000 when corrected for income levels based on census data.

[2] This is greater than the 10,000 gallons per year of lawn water use estimated by Vickers (2001) in her *Handbook of Water Use and Conservation*.

Landscape Ordinance (MWELO), suggests a maximum landscape ratio of 0.8 for existing landscapes[3] when calculating a site's Maximum Applied Water Allowance (MAWA).

Table 1. Comparison of outdoor daily mean water use for agencies in study group.

Agency	No. Single-Family Accounts	Mean Outdoor Daily Use	
		Gallons per day (gpd)	Percent of total use (%)
Davis Water Department	13,194	261	60%
East Bay Municipal Utilities District	306,950	129	44%
Sonoma County Water Agency	63,624	132	45%
Redwood City	15,777	101	36%
San Francisco Public Utilities Comm.	52,349	~0	0%
City of San Diego	217,893	166	53%
Irvine Ranch Water District	45,878	227	56%
Los Angeles Dept. of Water and Power	458,000	238	57%
Las Virgenes Muni. Water District	17,016	851	79%
San Diego County	84,213	217	54%
Weighted average		190	53%

Source: DeOreo et al. (2011).

The landscape ratio varies based on the proportion of the irrigated area that is high-water-using plants versus lower-water-using plants. To reduce the landscape ratio, climate-appropriate plants with lower crop coefficients (a.k.a. plant factor) can replace plants with higher crop coefficients. Plants with higher crop coefficients or plant factors are often referred to as high-water-using plants, whereas plants with lower crop coefficients or plant factors are often referred to as low-water-use or drought-tolerant plants. However, it may be more appropriate to call these plants low-water-need plants. While they can sustain adequate health and aesthetics with less water, unnecessarily overwatered can occur without proper management.

California's MWELO, reports plant factors for different types of landscapes based on the Department of Water Resources publication "Water Use Classification of Landscape Species" or WUCOLS (DWR, 2000). In WUCOLS, the plant-water needs are categorized into three levels, each with a plant factor range (Table 2). To determine the amount of water replacement needed by the plant, the crop coefficient (K_c), or plant factor, is multiplied by ET_O. This does not take into consideration, and should not be confused with, the additional water needed to compensate for irrigation system inefficiencies.

[3] While MWELO suggests a maximum landscape ratio of 0.7 for new landscape, the act of turf removal as a PBMP will occur at existing sites.

Table 2. Crop Coefficients (Plant Factors) used in discussion of landscape water use.

Plant-water need	Crop Coefficient (K_c) or Plant Factor
Low	0 to 0.3
Medium	0.4 to 0.6
High	0.7 to 1.0

Source: DWR (2009).

COMMON LANDSCAPE CONVERSION PRACTICE NAMES

Landscape conversion practices, inline with low theoretical irrigation requirements, have been given a number of different names as listed in Table 3 below. In addition to name variation by region, there are nuance differences within the practices or principals of each of these common low TIR landscape practices. Within California, the terms California Friendly and River/Bay-Friendly have been used by water agencies[4]. However, the most widely know name is Xeriscape™, which is a registered trademark of the City of Denver, Colorado. Xeriscaping has incurred some negative connotations with the public as it is often confused with Zero-scaping, which is a practice that has very few landscape plants.

Table 3. Common landscape conversion practice names.

Name	Location	Description
California Friendly Landscaping	Southern California	Promotes climate appropriate, drought tolerant, and native plants.
Bay-Friendly Landscaping	San Francisco Bay	Promotes the landscapes as part of a larger ecosystem/watershed. Emphasis on design and maintenance using sustainable practices. Principles: 1) Landscape locally, 2) Reduce green-waste, 3) Nurture the soil, 4) Conserve water, 5) Conserve energy, 6) Protect water and air quality, and 7) Create wildlife habitat.
River Friendly Landscaping	Santa Rosa and Sacramento	Promotes the landscapes as part of a larger ecosystem/watershed. Emphasis on design and maintenance using sustainable practices. Principles: 1) Landscape locally, 2) Reduce green-waste, 3) Nurture the soil, 4) Conserve water, 5) Conserve energy, 6) Protect water and air quality, and 7) Create wildlife habitat.
Xeriscape™	Began in Colorado, now known Nationally	Method of landscape design that minimizes water use. Registered trademark of the City of Denver, CO. Principles: 1) Use of drought resistant grasses and plants, 2) Reduced or limited turf, 3) Grasses and plants matched appropriately to soil composition, 4) Use of mulches, 5) Efficient irrigation, 6) Planning and design, and 7) Proper maintenance practices.
Zero-scape	National	Landscape consisting mostly of hard surfaces, with a few plants as accent features.

[4] The term Ocean Friendly has also been utilized by non-governmental organizations such as Surfrider Foundation and the Green Gardens Group.

WHY TURF REMOVAL AS A PBMP

Turf removal has been selected as a PBMP candidate due to the potential for water savings based on plant-water needs. Additionally, the following list of general benefits has become widely accepted as common general benefits when converting a turfgrass intensive landscape to a landscape with predominately climate appropriate plants:

- Reduction of water use based on plant-water needs[5]
- Native flowers attract pollinators
- Habitat diversity
- Reduction in fertilizer and pesticide requirements yielding a decrease in runoff pollution resulting in improved lake, stream, and coastal water quality

It is important to note that the water savings attributed to turf removal depends on factors beyond solely swapping one type of vegetation for another. Arguably more important than plant type is the irrigation system maintenance/upgrade and management for water efficiency. Researchers at the University of California, Riverside, Turfgrass Research Facility, have estimated that of the water saving benefits quantified from municipal turf removal rebate programs, two-thirds is the result of improved irrigation systems, while one-third is directly attributable to the conversion from turfgrass to a xeric landscapes. However, when reducing the overall landscape ratio to 0.5, the water savings is more evenly split, 50/50 (adapted from DeOreo et al., 2011).

When quantifying the benefits of the turf removal practice, there are a few assumptions made:

- Turf removal is recommended for non-functional turfgrass areas.
- Prior to the turf removal practice, the area is assumed to be live, well-maintained, and irrigated[6] turfgrass.
- The resulting watering system equipment, irrigated area, and schedule, has been appropriately modified.
- Following the removal of a turfgrass area, any exposed soil is covered by a 2” to 4” layer of mulch.
- Converted areas are permeable to air and water.
- Climate appropriate plants do not include invasive species[7].

POTENTIAL WATER SAVINGS IN CALIFORNIA

Since 2010, within Orange County, CA, more than 1 million square feet of turfgrass has been removed through the Municipal Water District of Orange County’s Turf Removal Program.

[5] On average, household consumption drops immediately and quickly stabilizes (Sovocool, 2005).
[6] A secondary assumption is that the irrigation source is municipally supplied potable water. This PBMP does not focus on the use of alternative sources for irrigation, such as municipally supplied recycled water or on site capture and reuse.
[7] For a list of invasive plants, refer to the California Invasive Plant Council at http://www.cal-ipc.org/.

Through analysis of the Turf Removal Program, the average turfgrass area removed (per meter) was roughly 2,000 ft^2 (n = 430 sites).

As part of the *California Single Family Home Water use Efficiency Study* (DeOreo et al., 2011), indoor and outdoor water usage was disaggregated for the 639 homes at which irrigation practices were identified across 10 water agencies. Through this analysis, the irrigable and irrigated area for each lot was identified, and the TIR and actual outdoor water use was determined. The landscapes parameters were divided into turfgrass, non-turfgrass plants and trees, low-water-using plants, and non-irrigated land (Table 4).

Table 4. Common landscape covers with crop coefficient and allowable irrigation efficiencies.

Ground Cover	**Crop Coefficient** ***(K_c)***	**Irrigation Efficiency Allowed** *(IE)*	**Combination Factor** ***(K_c)/ (IE)***
Turfgrass	0.8	71%*	1.13
Non-turfgrass plants	0.65	71%*	0.92
Vegetable garden	0.8	71%*	1.13
Low-water-need landscape	0.3	90%	0.33
Pool or fountain	1.25	100%	1.25
Non-irrigated ground	0	0	0

* An irrigation efficiency value of 0.71 was assumed since this is the minimum acceptable efficiency in the MAWA calculations.
Source: DWR (2009).

Of the sample homes that were determined to be irrigating or otherwise using a significant amount of water outdoors (n=639, 87%), the average annual outdoor use was 92.4 kgal per year, ranging from 17 to 226 kgal annually per account, with an average irrigated area of 3,631 ft^2 with a median area of 2,634 ft^2. For the overall study population (n=734), the average outdoor use was reduced to 82.0 kgal per year or 40%. The statewide average outdoor water use is 87.1, when corrected for income levels based on census data.

The comparison between TIR and actual water use resulted in 54% (60 kgal) if the irrigating homes are doing so in excess, or 42% (27.9 kgal) of the total study sample. The actual application rate for the irrigating sites was 58.3 inches, 138% of the average annual ET during that time. Over-irrigation was not evenly distributed. Large users more easily skewed irrigation water use than indoor use. For example, in this study, for the upper half of the irrigator sample, those using more than the median (67 kgal per year) account for 75% of the total outdoor use.

Excess irrigation can be considered in two ways: 1) water is applied beyond the plant-water needs and 2) excess water is applied to account for system inefficiencies. When a system has inefficiencies that the excess water application is compensating for, there will be areas of the landscape that are over-irrigated and areas that are appropriately or under-irrigated. Because this study assumed an irrigation efficiency value of 0.71, based on the minimum acceptable efficiency value in the maximum applied water allowance criteria (MAWA calculation), the true proportion of sample homes resulting in excess irrigation may be higher than reported. An efficiency of 0.71 in an existing system irrigating with spray heads is likely to be closer to 0.5.

Aquacraft developed an outdoor savings regression model to make projections of the likely impact on water use for the 8.24 million irrigating single-family residences in California (Aquacraft, 2011; DeOreo et al., 2011). The model is run for each of three unique scenarios, and the results are displayed in Table 5. The model scenarios are: (1) Reduced rate of over-irrigation by 50%, (2) Reduced average landscape ratio to 0.8, and (3) Reduce average irrigated area by 20%. The water savings projected through this model are compared to the baseline current statewide annual estimate of outdoor water use of 87.10 kgal, or 2.27 million acre-feet (MAF), and an annual estimate of 4.4 MAF of total water use.

Scenario 1 is based on reducing the rate of over-irrigation by 50%. This assumes the rate of over over-irrigation, 50.5%, can be reduced to 25.25% of households. This scenario would reduce the annual household estimate of 87.10 kgal per year to 62.15 kgal per year. This reduction would result in 28% of outdoor use or 14% of total use.

Scenario 2 is based on reducing the average landscape ratio to 0.8. A landscape ratio of 0.8 for the existing site is based on the MWELO recommendations. If the average actual landscape ratio is 0.96, this scenario assumes a 0.16 landscape ratio reduction. This scenario also assumes that the irrigation efficiency has been has been reduced by 50%. When combining scenarios 1 and 2, the annual household water use estimate of 87.10 kgal per year is reduced to 55.87 kgal per year. This reduction would result in 35% of outdoor use or 18% of total use. Teasing out the water savings from solely reducing the landscape ratio to 0.8, this change accounts for 6.28 kgal per year less water use, which is a 7% reduction of outdoor use or 4% total use.

Adjusting this to an average landscape ratio to 0.5, Scenario 2a assumes a 0.46 landscape ratio reduction. The water savings from just reducing the landscape ratio to 0.5 would account for 36.59 kgal per year less water use, which is a 42% reduction of outdoor use or 20% total use. When combining scenarios 1 and 2a the annual household water use estimate of 87.10 kgal per year is reduced to 25.56 kgal per year. This reduction would result in 71% of outdoor use or 37% of total use.

Scenario 3 is based on reducing the average irrigated area by 20%. The model reduced an irrigated area from 3,802 ft^2 to 3,042 ft^2. This scenario also assumes that the irrigation efficiency rate has been reduced by 50%, and the landscape ratio is reduced. When combining all three scenarios, the annual household water use estimate of 87.10 kgal per year is reduced to 46.69 kgal per year. When combining scenario 3 with 1 and 2a, the annual household water use is reduced to 16.38 kgal per year. This reduction would result in 81% of outdoor use or 42% of total use. Teasing out the water savings from solely reducing the irrigated area by 20%, accounts for 9.18 kgal per year less water use, which is a 10% reduction of outdoor use or 5% total use.

The scenarios above describe modeled hypothetical water savings. Figure 1 presents the TIR and corresponding potential percent water savings for varying the landscape ratio from 0.85 to 0.30. However, the actually water savings realized will likely be less.

Table 5. Estimated outdoor water savings for single-family residences in California.

Scenario	Water Use*		Savings		% Reduction	
	kgal per yr	MAF per yr	kgal per yr	MAF per yr	Outdoor use	Total** use
(1) Reduced rate of over-irrigation by 50%	62.15	1.62	24.95	0.63	28%	14%
(2) Reduced avg. landscape ratio to 0.8	80.82	2.13	6.28	0.16	7%	4%
(2a) Reduced avg. landscape ratio to 0.5	50.51	1.32	36.59	0.96	42%	20%
(3) Reduce avg. irrigated area by 20%	77.92	2.01	9.18	0.23	10%	5%
(1)+(2) Reduced rate of over-irrigation by 50% and avg. landscape ratio to 0.8	55.87	1.48	31.23	0.79	35%	18%
(1)+(2a) Reduced rate of over-irrigation by 50% and avg. landscape ratio to 0.5	25.56	0.67	61.54	1.59	71%	37%
(1)+(2)+(3) Reduced rate of over-irrigation by 50%, avg. landscape ratio to 0.8, and avg. irrigated area by 20%	46.69	1.22	40.41	1.02	45%	23%
(1)+(2a)+(3) Reduced rate of over-irrigation by 50%, avg. landscape ratio to 0.5, and avg. irrigated area by 20%	16.38	0.43	70.72	1.82	81%	42%

* Annual water use is income corrected based on statewide census data.
** Total use denotes the sum of both indoor and outdoor use.
Source: Adapted from DeOreo et al. (2011).

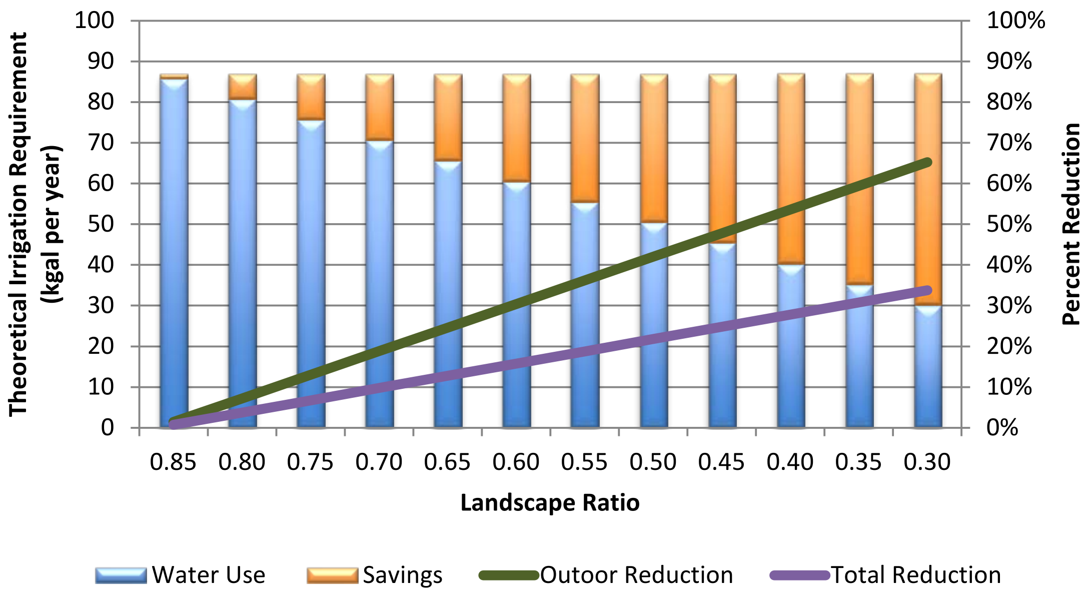

Figure 1. Theoretical irrigation requirement and potential reduction of water for various landscape ratios.

META-ANALYSIS OF STUDIES

The following meta-analysis is a culmination of evaluations of actual water savings from landscape modification programs implemented across the arid and semi-arid regions of the county. Many of these studies focus on turfgrass removal through the xeric landscape principles listed in Table 3. The findings of these studies are compiled in Table 6.

The studies present water savings in two ways: gallons of water saved (per day or per square foot) and percentage of savings. To best compare the water savings for differing areas of the country, the percentage savings are normalized. To do so, Sanford and Selnik's (2013) *Estimation of Evapotranspiration Across the Conterminous United States* (CUS) was utilized, as they compare actual evapotranspiration (ET) to precipitation (P) at the county level for the CUS. Through this research, they have developed a regression equation to estimate the mean annual ratio of ET to precipitation P, referred to as the ET:P ratio, for the CUS for the period 1971-2000. These estimates are based on climate and land-cover variables and detailed in Appendix A.

Figure 2 presents a map of the level of aridity as a fraction of precipitation lost to evapotranspiration, these ET:P ratios are listed at the county level for the entire CUS. Areas with very high rainfall and low-to-moderate temperatures are represented by an ET:P ratio of less than 0.20 (i.e. Pacific Northwest). An ET:P ratio of 0.30 to 0.50 includes high-elevation regions in the western U.S. (i.e. Cascade, Sierra, and Northern Rocky Mountains) because of moderate temperatures and/or high rainfall. The areas with a temperate climate have an ET:P ratio of between 0.50 and 0.70. The majority of the arid southwestern CUS usually has an ET that exceeds 0.80 of P.

The potential savings based on TIR for various western study areas is presented in Table 7. The ratio of ET:P ratio is used to normalize these potential savings, as not all of the western areas are the same level of arid. These potential savings can be compared to the actual water savings from Programs in Table 6. The average potential savings is between 45% and 49%, whereas the actual savings ranged from 16% to 42%.

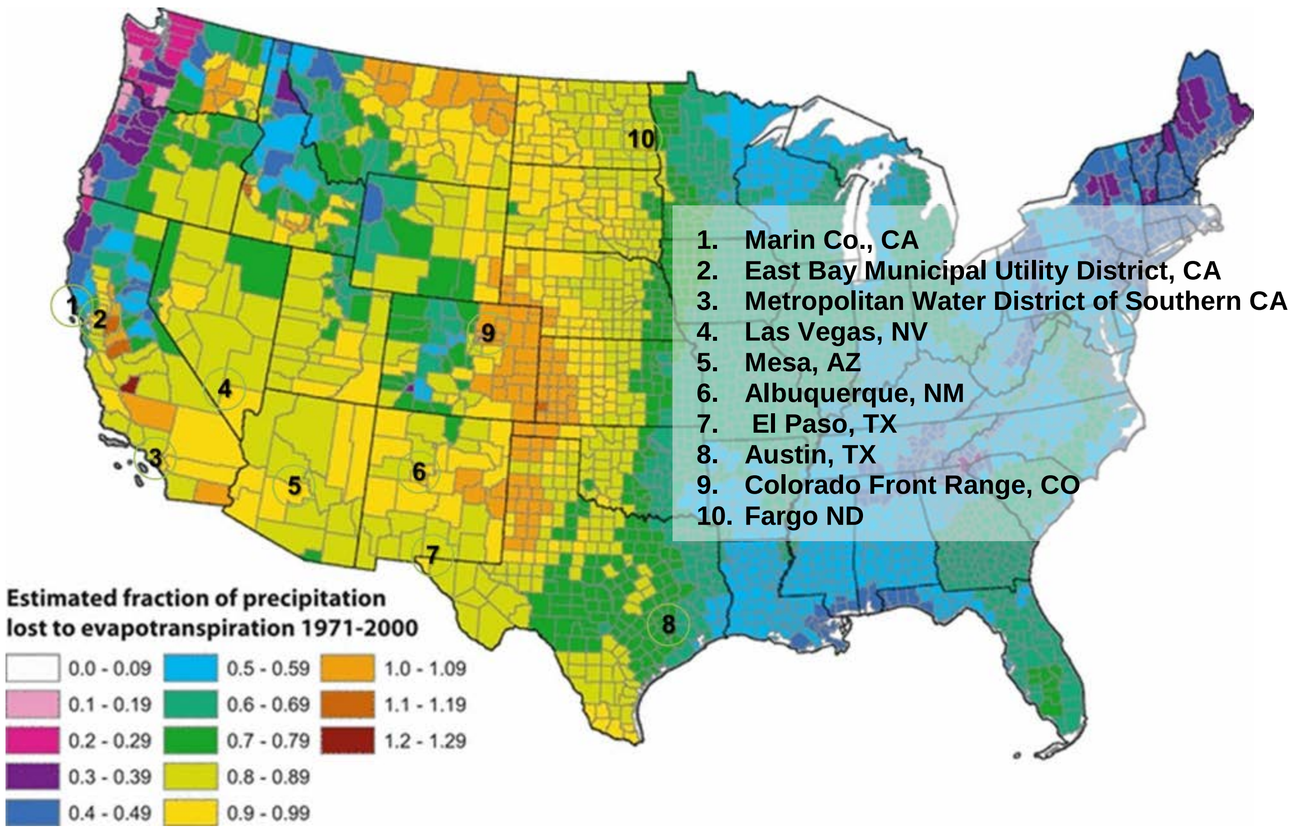

Figure 2. Estimation of fraction of Evapotranspiration Across the Conterminous United States Using a Regression With Climate and Land-Cover Data, 1971-2000: (A) Estimated mean actual evapotranspiration and (B) estimated fraction of precipitation lost to evapotranspiration

Source: Adapted from Sanford and Selnick (2013).

Table 6. List of study results and impact on actual water use.

Study Area	Notes	No. of Sites	Analysis Method	Actual Water Savings		
				Gallons per day	Gallons per square foot per year	Savings (%)
North Marin Water District, CA	Random sample with questionnaire assessing additional predictors	382	Multivariate	126 to 207	33	25%
East Bay Municipal Utility District, CA	Random sample	1040	Univariate	209	-	42%
Las Vegas, NV: 2005	Willing participants and matched control groups	499 (172)	Multivariate	263	56 to 62	30%
Las Vegas, NV: 2000	-	499 (95)	Multivariate	178	34 to 43	39%
Mesa, AZ	Selected rebate participants and a random control group	150	Univariate	142	-	33%
Albuquerque, NM	17% of homes had increased use	-	-	-	19	
El Paso, TX	-	385	-	-	18	
Austin, TX Phase I: 1992	Units selected from a program newsletter and bulk mailing with a 5% response rate	100 (small lots)	Univariate (blocking lot size)	107	-	40%
Austin, TX Phase II: 1993 (adj. for bias)	Units selected from a program newsletter and bulk mailing with a 5% response rate	100	Multivariate	67	-	16%
Colorado Front Range		167	Univariate	110	7	30%
Fargo, ND	-				1.9	29%

Table 7. Potential Savings based on theoretical water need for various western study areas.

Study Area	Annual Average			Theoretical Irrigation Requirement TIR (gallons per ft^2 per year)			Potential Savings based on TIR (Percent)		
	ET:P ratio	P (in/yr)	ET (in/yr)	No Conversion Kc = 0.8	Moderate Conversion Kc = 0.5	Substantial Conversion Kc = 0.3	Moderate Conversion Kc = 0.5	Substantial Conversion Kc = 0.3	Average
North Marin, CA	0.70	20	40	10	9	2	9%	81%	45%
East Bay M.U.D, CA	0.95	11	43	15	12	4	19%	75%	47%
Orange County, CA	0.95	15	47	15	12	4	18%	75%	47%
Las Vegas, NV	0.99	7	75	44	30	14	31%	67%	49%
Mesa, AZ	0.95	11	67	34	24	11	29%	68%	49%
Albuquerque, NM	0.95	8	38	13	11	3	16%	76%	46%
El Paso, TX	0.95	6	79	48	33	16	32%	66%	49%
Colorado Front Range	1.00	15	47	14	12	4	18%	75%	47%

National Xeriscape™ Demonstration Programs

Five arid or semi-arid communities in the western United States (Colorado Front Range centered at Denver, Colorado; Phoenix, Arizona; Austin, Texas; the Las Vegas area of southern Nevada; and Fargo, North Dakota) are collectively called the National Xeriscape™ Demonstration Program (NXDP). These were field projects on landscape water conservation pursued by the US Bureau of Reclamation. The intent was to provide a basis for landscape water efficiency future program decision-making. Highlights from their evaluation findings are listed below.

Colorado Front Range

The Yield And Reliability Demonstrated in Xeriscape™ (YARDX) study examined the regional effects of xeric landscapes within nine water utilities along the Colorado Front Range (Medina and Grumper, 2004). The YARDX study results were compared to similar studies of the NXDP.

YARDX demonstrated that properly planned and installed xeric landscapes save water. The project sites saved from 18 to over 50 percent of the water when compared with paired traditional landscape control groups. On new properties, YARDX results indicate that water savings in the 30-percentile range can routinely be achieved, assuming the property owners are committed to maintaining the savings. New property owners obtained their savings with a design scheme of approximately ¼ of the area with low water use plants, ¼ with moderate water use plants, and up to ½ of the area with traditional turf. Higher water savings could possibly be obtained with a design scheme of $^{1}/_{3}$-$^{1}/_{3}$-$^{1}/_{3}$.

The YARDX water savings from retrofits were slightly less than for new properties (generally 28 to 32 percent). Water savings in retrofits appear to vary with the amount of turf that remains in landscapes. Although YARDX retrofit participants were guided toward the $^{1}/_{3}$-$^{1}/_{3}$-$^{1}/_{3}$ design scheme, the actual water savings did not reach the anticipated savings of 50 percent. Additionally, pre-existing sites did not yield any water savings compared to the control group.

City of Austin

The City of Austin performed a multivariate research study of xeric landscape practices, water consumption, and water quality on 7,110 residential sites. Two samples were collected: the landscape sample and the questionnaire sample. Based on the research findings of this report regarding the landscape and social-economic factors associated with landscape conversions water savings, there is potential to reduce residential water consumption during the summer months by an average of 31 percent, with a minimum reduction of 16 percent. This percentage savings from the installation of turfgrass with a low plant factor (Buffalograss) and no grass landscapes is equivalent to approximately 175 gpd per unit, ranging from 130 to 180 gallons per day (Austin, 1993). A synthesis of these findings, with conservation research contributions from applied social-behavioral science, and the preliminary cost-effectiveness analysis are included in the lessons learned section of this PBMP Report.

Las Vegas

Las Vegas has the evaluations with the longest durations. In the comparison of water use in homes over the five-year period, a statistical analysis of outdoor water use in the combined study groups (n=93) resulted in a model of outdoor demand based upon three factors: total landscaped area, xeric landscape area, and home value. The model predicts that outdoor water use will decrease by 34 gallons per year for every square foot of turf landscape coverted. This model has an R^2 value of 0.55, which indicates that 55 percent of the variability in outdoor use can be explained by these three selected variables.

The trend for average household consumption was to drop immediately and then quickly stabilize, where the average water application per site was 73 gallons per ft^2 for turfgrass areas and 17 gallons per ft^2 for xeric landscape areas. Upon comparing irrigation application to the reference ET_O turf exceeded the TIR in all months except March, where program water application remained at or below the TIR (Sovocool, 2005).

Fargo
Xeriscape™ installation costs averaged $0.71 per square foot for retrofits and $1.11 per square foot for new starts. New starts demonstrated a water savings average of 29%, whereas retrofits demonstrated a higher average water use than the control sites. Annual maintenance costs for retrofit landscapes increased by 32% when compared to the control sites. Additionally, the new start maintenance cost increased 10% when compared to their respective control participants (Medina and Lee, 2006).

CONSIDERATIONS OF TURF REMOVAL

Multiple perspectives should be considered when recommending turf removal as a PBMP. The following section will provide a point/counter-point critique of the functions often attributed to turfgrass in the landscape.

Turfgrass provides at least three major benefits to human activities: functional, recreational, and ornamental.

- *Functional* uses of turfgrass include wind and water erosion control, thereby reducing dust and mud problems surrounding homes and businesses (Beard & Green, 1994). Grasses have the ability to function as vegetative filter strips that reduce the quantity of sediment transported into surface waters (Barfield and Albrect, 1982; Dillaha et al., 1988; Young et al., 1980). With regards to fire control, a well-maintained lawn can serve as an effective fuel break (Detweiler & Fitzgerald, 2006). Functional benefits, such as reduction of glare, noise, air pollution prevention, and heat buildup may also be achievable by other landscape materials. Metropolitan areas and suburban residences profit from the cool, green pleasant environment afforded from healthy landscapes that include a combination of lawns along with trees, flowers, and shrubs.

- *Recreational* uses of turfgrass are extensive, with common sports activities played on turfgrass including golf, lawn tennis, soccer, rugby, lacrosse, polo, and football. This report does not provide recommendations on the conversion of turfgrass to an alternative-playing surface. For a discussion of the use of synthetic turfgrass on sports fields, see the 2007 PBMP Report (Koeller, 2007).

- *Ornamental* or aesthetic attributes of turfgrass are also highly regarded. However, the aesthetic attributes of the landscape must be analyzed to differentiate between the benefits that result from turfgrass specifically versus a comprehensive landscape design.

The following sections provide insight relating to a number of the physical and practical considerations of turf removal as a PBMP. Many of these considerations arise from the turf industry's defense to this PBMP.

Erosion Control

According to the U.S. Department of Agriculture, more than two billion tons of topsoil are eroded annually from wind and rain dislodgement. Turfgrass provides effective erosion control as a result of its high shoot density[8] and root mass for soil stabilization. Turfgrass has been used extensively along roadsides for erosion control and as a stabilized zone for emergency stopping and repairs.

However, other effective measures for erosion control include both plant and design alternatives. Ground covers and shrubs, particularly those that spread by a robust root system, prevent erosion. Non-living practices include: Low-Impact Design (LID), mulching, and amending soil with compost[9] (USEPA, 1997).

If turf removal is recommended as a best management practice, it must include the condition that upon removal of turfgrass, bare soil is not an adequate alternative. Sediment losses were reported at 370% greater[10] from bare soil plots than vegetated areas during a 30-minute storm event (Gross et al. 1991). Additionally, it generally is recognized that a few large storms each year are responsible for most soil erosion losses (Menzel, 1991).

Runoff Control

Runoff water from urban areas is the primary contributor to dry whether nonpoint source surface water pollution. Nationally, about 67 million pounds of pesticides, herbicides, and fertilizer are applied to urban/suburban lawns annually. When deposited into nearby waterways through Municipal Separate Storm Sewer System (MS4) discharges, these pollutants can impair the waterways, thereby discouraging recreational use of the resource, contaminating drinking water supplies, and interfering with the habitat for fish, other aquatic organisms, and wildlife. In 2005, pollution caused over 5,000 beach closings and advisories in California, most of which resulted from dry-weather runoff (DWR, 2005).

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[8] Turfgrass shoot density is between 75 million to >20 billion shoots per hectare (Beard, 1973; Lush, 1990).

[9] Depending on the length and height of a particular slope, a 2- to 3-inch layer of mature compost, screened to ½ to ¾ of an inch and placed directly on top of the soil, has been shown to control erosion by enhancing planted or volunteer vegetation growth.

[10] Soil losses of 10 to 60 kilogram per hectare from turfgrass plots during a 30-minute storm that produced 76 millimeter per hectare of rainfall; soil loss for bare soil plots averaged 223 kilogram per hectare.

Mimicking the natural landscape will promote an approach to the urban landscape as a watershed, yielding increased infiltration at the site. These LID practices provide mechanisms and areas for runoff to be diverted into a vegetated channel, swale, or rain garden, or captured by a cistern for future use. The purpose is to keep the water on site and reuse it yielding multiple objectives and multiple functions. Ecological functions resulting from these LID principles add nutrients to be treated by the adsorption and absorption of the runoff water by the landscape.

A compelling counter-point towards the runoff control effectiveness of turfgrass: the combination of a high biomass matrix provides resistance to lateral surface water flow, thus slowing otherwise potentially erosive water velocities. Various other studies and reviews have also demonstrated or concluded that quality turfgrass stands modify the overland flow process so that runoff is insignificant in all but the most intense rainfall events (Beard and Green, 1994; Gross et al., 1990; Morton et al., 1988; Petrovic, 1990; Watschke and Mumma, 1989; Watson, 1985).

While turfgrass has the ability to function as vegetative filter strips, so do other landscape plantings with a high biomass matrix. It is the vegetative density and soil stabilization from root systems that greatly reduce the quantity of sediment transported into surface streams and rivers (USEPA, 1976). In fact, non-uniform vegetated plantings can provide benefits of reducing sheet-flow runoff and trapping strormwater pollutants (USEPA, 2002). Additionally, with the reduced need for fertilizers when planning climate appropriate plants, non-point source pollution runoff into local waterways is reduced.

What is neglected from the argument above is the disproportionally high amount of runoff that actually results from landscape irrigation rather than stormwater itself. Although the turfgrass lawn may hinder the transportation of sediment, it contributes to the transportation of nutrients when the runoff results from excessive or improper irrigation practices. It must be noted, however, the transportation of both sediment and nutrients can exist if the alternative landscape does not properly implement LID best practices.

Hardscape Area

When replacing turfgrass with hardscape, although the TIR becomes zero, permeability of the area is minimized, resulting in increased runoff unless LID principles are implemented. Such LID practices include permeable pavement systems and pervious concrete. However, it should be noted that pervious pavement systems are not suitable in the following:

- Slopes greater than 5%
- Areas with high wind erosion rates (USEPA 1999)
- Soils that have a rising water table or saline conditions
- Dispersive clay or low hydraulic conductivity soils

The void spaces between pavers (filled with sand or gravel) allow for infiltration and stormwater percolation to underlying soils, reducing runoff volumes, peak flows, and pollutant loads and facilitating groundwater recharge. The design of pervious hardscape areas should consider the reduction in permeability of the pervious surface over time due to sediment accumulation and clogging. Clogging of the void spaces will result in the area becoming impermeable. The smaller the void space or gap between the pavers is, the more readily it will clog. Refer to Appendix B for calculations to determine the required infiltration capacity of a soil surface, vegetated area, or pervious pavement for a selected design storm event.

Fire Control

With regards to fire-resistant landscapes, a well-maintained lawn can serves as an effective fuel break (Detweiler & Fitzgerald, 2006). Conversely, certain varieties of plants, including some native species, contain high amounts of oil. While this keeps them from needing a lot of water, it also makes them hazardous during fire.

The following, or similar, resources can be referenced when considering the recommended climate appropriate plants in fire prone regions:

- The Pacific Northwest Extension Service has published a user-friendly book on selecting fire-resistant plants for home landscapes (http://www.firefree.org/images/uploads/FIR_FireResPlants_07.pdf)
- The Metropolitan Water District of Southern California provides both a list of native fire-resistant plants (http://bewaterwise.com/fire02.html) and the Homeowner's Guide to Fire And Watershed Management at The Chaparral/Urban Interface by Klaus W. H. Radtke (http://bewaterwise.com/pdf_firewatershed.pdf)
- *Wildfire Zone* is an education and outreach program through the Cooperative Extension in San Diego County created to increase awareness of wildfire risks and hazards (http://www.wildfirezone.org/resources.asp)

Influence of Landscape on Regional ET

Early studies of landscape influence on ET rates compared trees and shrubs with grasses. Evapotranspiration rates increase with leaf area when under a positive water balance (Johns et al., 1983; Kim and Beard, 1987), resulting in increased water use by trees and shrubs per unit land area basis than turfgrass. For example, the major grasslands of the world are located in the semi-arid regions, whereas forests occur in regions with higher rainfall. This highlights the importance of selecting trees and shrubs that are climate appropriate. For example in Southern California, select native or Mediterranean varieties rather than tropical varieties.

Thus, it has been hypothesized that lowering regional average evapotranspiration rates through plant material selection, and subsequent sensible irrigation, will result in a reduction of transpirational cooling and increased heat loads on the surrounding buildings. In doing so, this would increase energy requirements for interior cooling of buildings (i.e. mechanical cooling such as ventilation and air conditioning).

When replacing turfgrass with other landscape plants, it is recommended that soil should be covered with a 2 to 4 inch layer of mulch. While mulch reduces evaporation of moisture from soil, the presence of some mulches may increases the radiant energy load on the under side of deciduous[11] shrubs and trees. Because deciduous plants have the majority of their stomata on the undersides of the leaves, the ET rate can be increased. A study compared crape myrtle (Lagerstroemia indica L.) grown in three different surfaces (bare soil, mulch, warm season turfgrass). The results found that the sensible heat and long wave radiation from the mulched area increased plant temperatures and, thus, the transpiration rate associated with the leaf air vapor pressure deficit (Zajicek and Heilman, 1991).

Through the Las Vegas turf removal *Water Smart Landscape Program*, the effects of water landscape modification on evapotranspiration rates was analyzed. The influence of the turf removal program seemed to have actually assisted in keeping the ET rates constant. During the eleven-year time span (Figure 3), the population increased 18.6%, whereas the ET did not significantly increase with the steady growth in population, as expected (Belli, 2011).

Figure 4 presents a side-by-side qualitative wetness tasseled cap comparison for the Summerlin area of Las Vegas in 1999 and 2009. In these images, the two years are set to the same wetness value scale. The orange, red, and purple shading characterized areas with little or no ET, and correspond to non-landscaped/desert areas. Yellow shading represents areas with moderate ET rates, while green shaded areas correspond with high ET rates. From these images, the increase in development can be observed. Comparatively, there are much more green shaded areas in the 1999 image than in the 2009 image. Most of areas that are green in 1999 appear as yellow in 2009, and the newly developed areas in 2009 are also in the yellow ET rate range.

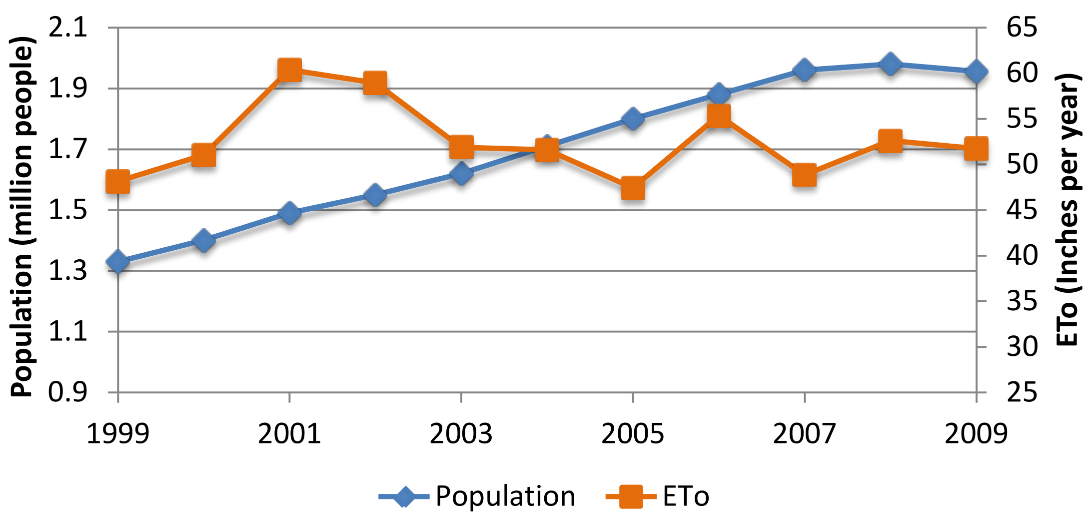

Figure 3. Las Vegas population versus ET rates.

Source: Adapted from Belli (2011).

[11] Deciduous trees and shrubs are those that lose all of their leaves for part of the year.

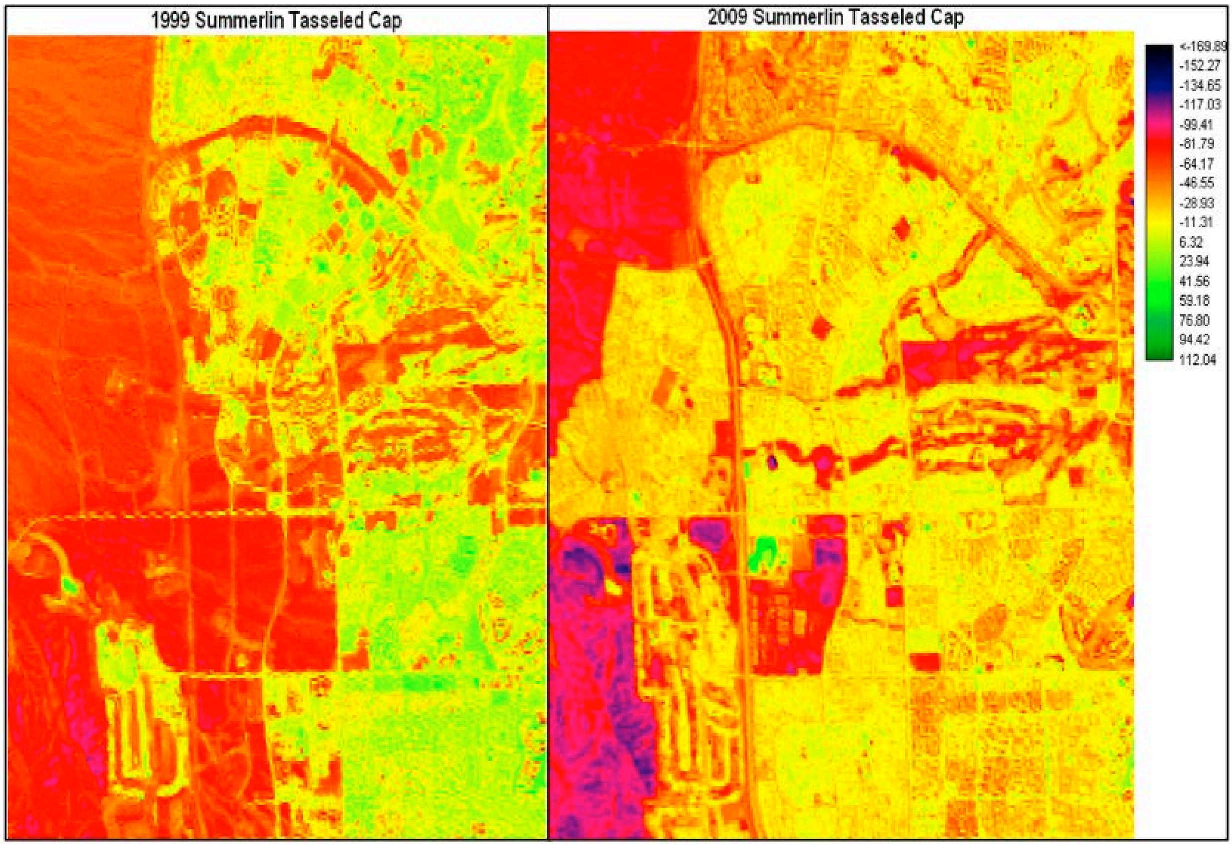

Figure 4. Qualitative wetness tasseled cap comparison for the Summerlin area of Las Vegas in 1999 and 2009.

Source: Belli (2011).

Plant-Water Needs

Table 2 presented the crop coefficient or plant factor ranges for the discussion of low, medium, and high plant-water needs. However, there is some confusion with the term "low water use". It should be noted that there is a difference between low water requiring and drought resistant.

Discussions have also arisen regarding the use of turfgrass alternatives, such as replacing a cool season turfgrass (K_c = 0.8) with a warm season turfgrass (K_c = 0.65) or even varieties of Buffalograss, which have a crop coefficient on the lower end of the plant factor spectrum. Although warm season varieties require less water and can go dormant in the winter months, with additional irrigation the turfgrass can maintain a non-dormant or semi-dormant appearance. Again, this is an issue of irrigation management and socio-behavioral preferences, which is much harder to control when the plant looks the same. For that reason, replacement of one type of turfgrass for another is not considered a recommendation within this PBMP.

Irrigation Management

When removing turfgrass and replacing it with climate conducive landscaping, the water savings actually results from a change in irrigation management, maintenance, and equipment. Studies in Las Vegas, NV where found to apply the TIR or less. Conversely, studies in Phoenix and Tempe, AZ and Albuquerque, NM found the xeric landscape sites applied an increase in water based on changes to watering behavior (management). The main cause for excessive landscape water use in most situations is the behavioral component. It should be noted that in most cases, the actual irrigation water use is greater than TIR due to improper irrigation practices and poor landscape designs, rather than any one major group of landscape plant materials.

Frequent pruning of plant material can hinder the water-conserving potential of desert-adapted plants that naturally grow as fine-texture and open-canopies. During seasonal transitions, many xeric species shed their leaves to reduce moisture for dormancy. Superfluous watering hinders this natural mechanism. The domestic irrigator may misunderstand the purpose for the molting and apply unnecessary irrigation or water to the point of inhibiting dormancy all together.

Drought-tolerant plants have the ability to withstand lesser amounts of water. However, with the application of superfluous irrigation, many drought-tolerant plants will maintain a more aesthetically pleasing appearance.

One way to promote irrigation management changes is to require an increased efficiency within the irrigation system. Increasing system and application efficiencies can result from proper scheduling (manually or through the use of a smart timer) or system design. Common high-efficiency irrigation system components, which are also considered as PBMP candidates, include high efficiency sprinkler nozzles (multi-stream multi-trajectory (MSMT) nozzles a.k.a. rotating nozzles) and drip irrigation. Drip irrigation has much lower application rates than conventional and MSMT sprinklers and can be appropriately used in landscape beds to effectively irrigate only the root zones (see more in the drip PBMP report). However, as with conventional irrigation systems, drip irrigation systems also require properly design, installation, and maintenance. Key areas that may hinder water savings potential when incorporating drip irrigation in turf removal projects include: degradation of emitters and lack of adjustment of emitters following plant establishment.

From the Albuquerque, NM study, researchers found higher water use in 17% of the sites (by as much as 10%) when compared to traditional landscapes, although the net savings was still 19 gallons per ft^2 (Table 6). The increase in use at these sites was attributed to several factors including pruning management, high planting densities, and water management regimes to encourage rapid growth.

> "Drought-tolerant species can tolerate drought ...but they grow slowly under droughty conditions and often are less aesthetically pleasing. What this means in terms of water management is that xeriphytic landscapes can induce residents to use more water than they would with traditional landscapes" (Addink, 2005).

SOCIO-BEHAVIORAL AND ECONOMIC INFLUENCE OF LANDSCAPE MODIFICATION

Drivers and motivations prompting landscape choices and changes include socio-behavioral and economic factors such as: water price; awareness of water shortage and/or drought concerns; perceived aesthetic attributes; landscapes of neighbors; municipal codes; the time, effort, and cost of making changes; and quality of life.

Consumer Preferences

In a study analyzing western consumer preferences for native plants, participants expressed an interest in native plant species utilized in naturalistic landscape styles with plant species diversity. The style of the landscape (naturalistic or traditional) accounted for 62% of the participant's positive ratings and was the most important factor. The plant material (native or non-native) was second most important with 21.9% of the relative importance attributed to this factor. Least important was the plant diversity (simple or mixed), which accounted for 16.2% (Zadegan et al., 2008). These findings were constant with consumer preferences for plant size, type of plant material, and design sophistication in residential landscaping studying by Hardy et al. (2000). It has also been concluded that people are willing to pay more for well-designed yards including native plants than for lawns, and that their increased willingness to pay exceeds any increase in costs associated with the native plantings (Helfand et al., 2006).

It should be noted, if the consumer is familiar with a plant, s/he is more willing to purchase it. However, ecological knowledge, determined in a Michigan study by using a proxy of environmental group membership, is not directly related to a higher willingness to pay (Helfand et al., 2006). This finding is consistent with a study of yard chemical use in San Francisco, where environmental group members resulted in an average increase of 1.7 times the probability of chemical use. It is suggested that "members of environmental organizations enjoy nuisance pest reductions, better looking yards, or more productive gardens more than others because, in spite of possibly stronger concerns about chemical runoff and exposure, they value outdoor environments more and take more precautions than others" (Templeton et al., 1999). This strong appreciation for outdoor aesthetics can be used advance the landscape new-norm, which has been highlighted as a strategic focus by the CUWCC.

One possible reason that the results in the literature may not reflect actual behavior is hypothetical bias; the tendency of people to overstate their willingness to pay for a good in hypothetical situations. Alternatively there may be barriers in place that hinder the behavior. Possible obstacles to alternative landscapes include local ordinances or subdivision rules that limit the kinds of plantings used in yards, the lack of understanding about the installation and maintenance of these designs, or the lack of native plants in the wholesale and retail nursery trade. The literature suggests the evidence of the potential marketability of these landscapes and that customers may respond positively to marketing of these landscapes.

The desirability of different landscapes reflects differences in preferences, backgrounds, experiences and attitudes, neighborhood characteristics, and financial constraints. A mail survey implemented in New Mexico characterized the range of landscape types that households currently have according to the mix of turfgrass and other vegetation types. Homeowners were then asked to select their "most preferred" landscape type (Table 8). Nearly 85% indicated a landscape of no more than 25% turfgrass (Hurd, 2006).

Table 8. Average share of homeowner reported landscape by type and by community.

Landscape type	Percentage of landscape
Traditional type lawn	10.8%
Water-conserving type lawn	10.6%
Traditional type trees and shrubs	10.1%
Water-conserving type trees and shrubs	10.7%
Flowers and vegetable gardens	7.1%
Native/natural desert landscape	18.2%
Rocks, gravel, and bare soil	33.6%
Other	2%

Source: Hurd (2006).

Barriers

As previously mentioned, changing water use behavior involves a number of socio-behavioral and economic factors. Landscapes are durable, long-term features of communities, and large-scale changes will likely be slow to materialize and must overcome a number of barriers.

From a policy perspective, the ability of private markets to provide ecologically beneficial results depends on whether individuals' willingness to pay exceeds the costs of installing and maintaining these yard designs. Alternative, non-turf intensive, landscape designs are marketable goods. A typical economic assumption is that if people are willing to pay for them, they should appear on the market. Nevertheless, this is not the landscape norm. It is reasonable to wonder whether customer predispositions towards conventional landscapes actually falsely reflect consumer desires, or whether there are currently obstacles to the market availability of these designs.

For example, availability of climate appropriate and native plants within the home centers and mass merchandisers with lawn and garden departments (big-box stores) is a barrier. As, big-box stores are where most residential landscape material is purchased. In efforts to overcome the barrier of plant availability, the Inland Empire Utilities Agency *Garden Friendly Program* partnered with Home Depot to promote climate appropriate landscape plant purchases through local events. These events resulted in an increase in purchases and awareness of climate appropriate plant availability.

In some cases, institutional barriers (such as homeowners association rules) may limit the use of these designs. In these cases, government or association action may be necessary to permit these landscapes. When landscape designers are not knowledgeable about these designs, there may be a role for new entrants to the market, for greater training in these designs in landscape architecture programs, or for extension work from universities to designers to demonstrate these possibilities.

Turf Removal Program Considerations

Designing, implementing, and refining turf removal programs should be guided by a socio-behavioral model such as the one presented in Figure 5. This model is derived from a combination of research findings relating to the impact of the social influence processes on conservation attitudes and behavior.

The customer involvement and satisfaction process from removing turfgrass and performing the associated best practices depicted in the model flows from a “psychological state of receptivity” to the “objective and subjective payoffs.” In addition to the tangible payoffs (i.e. reduction in water use and, therefore, a monetary savings), perceived payoffs (e.g. the subjective aesthetic appeal) are key to strengthening attitudes towards turf removal and water conservation. While, improved attitudes result in behavioral modifications, negative attitudes could have the opposite effect. Attitudes that result in behavior change in relating to turf removal include:

1) Intensifying the regularity of newly acquired practices to reduce water consumption
2) Expanding water saving behavior to include other water conservation practices
3) Showing greater concern for environmental protection by reduced outdoor chemical and water use
4) Promoting the benefits of the non-turfgrass intensive landscape to friends and neighbors (Hampton, 1985)

Additionally, as implied by the socio-behavioral model (Figure 5), when a program participant sets a goal to save water, there is a higher likelihood that they will actually lower their water use (i.e. manage the irrigation more effectively).

Receptivity to turf removal relies on influences of perceived norms such as neighborhood and social network communications about landscaping, purchase incentives, and advertising/promotion/education. Through a study of influential factors relating to NXDP landscapes, approximately 25% of program participants reported "conformity" to neighborhood standards, and 46% reported the availability of a rebate (Testa and Newton 1993).

Purchase incentives and promotion/education are the common components of the successful turf removal programs. The service components essential to sustain long-term behavioral success are: goal setting, feedback, and performance rewards. Service components can influence expectations, the watering practices, and other objective and subjective payoffs resulting from a turf removal program. It should also be noted that adoption tends to be is far greater in affluent neighborhoods.

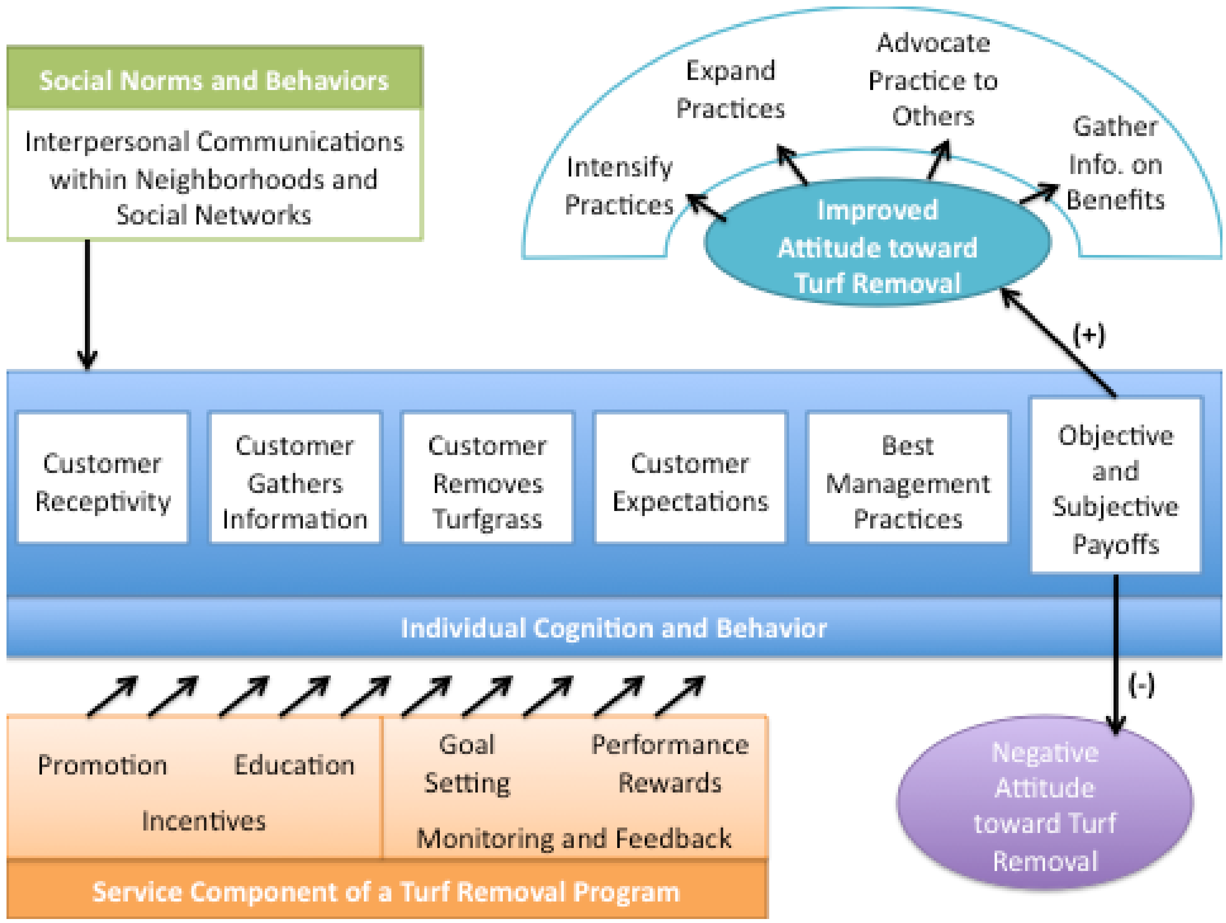

Figure 5. Socio-behavioral model of a Turf Removal Program.

Source: Adapted from Gregg and Curry (1995).

Market Value of Landscapes

Properly landscaped homes and businesses have been shown to benefit financially from higher resale values when compared to poorly landscaped residences.

In an evaluation of *Landscaping Quality and the Price of Single Family Houses*, Henry (1999) found that for homes in South Carolina with the same square footage and other house characteristics, selling prices were 6% to 7% higher if landscaping quality was judged excellent rather than good. The price premium obtained by upgrading landscaping from average to good was approximately 4% to 5%. These results were based on a detailed field survey of 218 single-family homes where the quality of the landscaping was evaluated both from the point of view of the type, size, and condition of plants, trees, etc., and how they were placed on the lot. The landscape quality tool included 30 individual features.

In an empirical investigation of *Landscaping and House Values*, Des Rosiers et al. (2002) investigated the effect of landscaping on house values, based on a detailed field survey of 760 single-family home sales transacted between 1993 and 2000 in the territory of the Quebec Urban Community. This survey focused on landscaping characteristics of homes and their immediate environment consisting of the adjacent neighborhood visible from the transacted properties. Environmental information was captured from the front and side of houses and includes 31 attributes dealing with tree as well as ground cover, flower arrangements, rock, plants, hedges, landscaped curbs, density of visible vegetation, as well as roof, patio, and balcony arrangements. Landscaping features were added to an array of physical, census, and access attributes.

This study concluded that while trees seem to be valued by most homeowners, a high percentage of ground cover (lawn, flower arrangements, rock plants, etc.) also commands a market premium; moreover, the price increases with an above-average ground cover, whereas a below-average one is detrimental. However, an above-average density of the vegetation visible from the property negatively impacts on prices. This is in line with previous conclusions regarding excessive tree cover and wild landscapes (Payne, 1973; Orland et al., 1992). Finally, a hedge, a landscaped patio as well as landscaped curbs all command a substantial market premium. Overall, the value of a well-landscaped single-family home results in a 7.7% market premium.

Table 9. Survey results of landscape aspects and the percent value that these aspects added to the home value.

Landscape aspect	Percentage of value added
Density	-2.2%
Landscape hedge	3.6% to 3.9%
Landscape patio (hardscape)	12.4%
Landscape curb	4.4%

Source: Adapted from Des Rosiers, et al. (2002).

Through a study of landscape plant material, size, and design sophistication on perceived home value, attendees at consumer home and garden shows across seven states (Delaware, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, and Texas) were surveyed (Behe et al., 2005). Design was characterized by three levels of sophistication ranging from planting only (primarily turfgrass) to multiple adjoining planter beds, islands, and trees. Design sophistication and plant size were the landscape factors that most affected value. Respondents considered a site with no landscape to be “lawn only” and a well-landscaped or sophisticated landscape to include color and large plants. The change in value (from no landscape to well-landscaped) ranged from 5.5% to 12.7%.

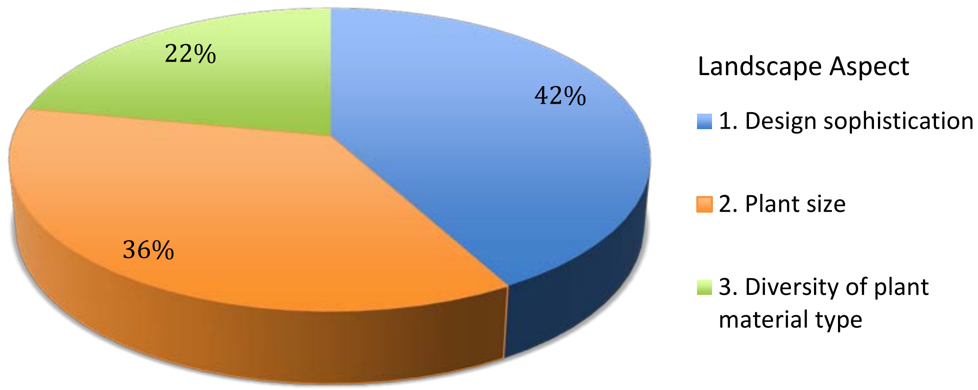

Figure 6. Survey results with the ranking of landscape aspects and the percent value that these aspects added to the home value.

Source: Adapted from Behe et al. (2005).

Industry Value

The above information can facilitate the realization of the relationship between house landscape and house value and, therefore, promote a new norm for landscapes in California. This landscape new norm can also add to the marketability of the services provided by professionals in the industry and maximize their business potential.

In a 1999 study of focus groups on *Public Perceptions of Landscape Design* conducted in Nebraska, it was found that improved communication between the landscape/irrigation contractor and from the homeowner is needed to make the most of the landscape design and customer satisfaction (Rodie and Paparozzi, 1999). The study also noted the need for client education in terms of understanding and appreciating the design process, the ultimate value of the design, and the requisite expertise to create and execute it.

The overall green industry is comprised of businesses involved in the production, distribution, and services associated with ornamental plants, landscape supplies, and equipment. Segments of this industry include wholesale nurseries, greenhouse and sod growers, landscape architects, landscape/irrigation contractors and/or maintenance firms, marketing intermediaries (i.e. brokers), horticultural distribution centers, retail garden centers, and home centers and mass merchandisers with lawn and garden departments, as well as other retail establishments selling plants and horticultural goods. Since the 1990s, the nursery and greenhouse sector has experienced considerable growth, albeit slowing somewhat during recession years. The landscape design, construction, and maintenance sector has resurged due to stronger economic conditions and the resurgence of building activity. Retail sales of horticultural goods have increased for both independent and chain/big-box store type retailers. Due to the increased presence of home centers and mass merchants in the lawn and garden marketplace, there has been considerable consolidation occurring within the marketplace.

The indirect effects of industry purchases and induced effects of employee household spending arising from new demand impacts the green industry. These estimates were computed using multipliers from the Regional Input-Output Modeling System (RIMSII) analysis system[12] (BEA, 2007). RIMSII is an enhancement to the method for estimating regional I-O multipliers known as the Regional Industrial Multiplier System developed by the Bureau of Economic Analysis.

The economic contribution of the green industry within California is detailed in Table 10 by listing the classification of the major sectors[13] associated with the turfgrass and lawncare industry. Turfgrass related activity in these sectors is a portion of the overall industry sectors. Figure 7 highlights the employment, value added, and output contributions of green industry sectors. The employment and value added[14] from the green industry contributes to 257,885 jobs[15] in the state of California, the highest nationally, followed by Florida at 188,437 jobs.

The contribution of the green industry to the Gross Domestic Product (GDP)[16] is a measure of the industry's importance to the overall economy. The total value added of the green industry nationally ($107.45 billion) represented 0.76 percent of U.S. GDP ($14,062 billion) in 2007. At the state level, this ranges from 0.2 to 1.6 percent. Within California, the value added by the green industry is approximately 0.85 percent (BEA, 2007).

The most reliable sources of economic information on the turfgrass industry is compiled from the Census of Agriculture and Economic Census. Based on the 2002 data, sod production created nearly $1.67 billion dollars in gross output. This represents approximately 3 percent of the total industry (Haydu et al., 2006). This sector's revenue share is relatively small when looking at the "product" rather than the "service" point of reference. The magnitude lies within the economic activity generated by sod production. Without sod production, there may be a reduced demand for lawncare services, retailing, and equipment manufacturing.

[12] An input-output model is a representation of the flows of economic activity between industry sectors within a region. The model captures what each business or sector must purchase from every other sector in order to produce its output of goods or services. Using such a model, flows of economic activity associated with any change in spending may be traced either forwards (e.g., spending generates employee wages which induces further spending) or backwards (e.g., purchases of plants that leads growers to purchase additional inputs -- fertilizers, containers, etc.).

[13] Sector is a grouping of industries that produce similar products or services. Most economic reporting and models in the U.S. are based on the Standard Industrial Classification system or the North American Industrial Classification System (NAICS).

[14] Value Added is the sum of total income and indirect business taxes. Value added is the most commonly used measure of the contribution as it avoids double counting of intermediate sales and captures only the "value added" to final products.

[15] Jobs or employment is a measure of the number of jobs required to produce a given volume of sales/production, usually expressed as full time equivalents, or as the total number including part time and seasonal positions.

[16] GDP is equivalent to the sum of value added by all industries, and alternatively represents gross output minus intermediate purchases of goods and services from other U.S. industries or imports.

Maintenance Costs

A 2004 evaluation looking at annual maintenance costs found that these costs ranged from \$0.34 to \$1.33 per square foot[17] (Medina and Gumper, 2004). Generally, maintenance costs for non-turfgrass intensive landscapes sites were less during the plant establishment years, although somewhat more during the plant maturation years. This suggests that as climate appropriate landscapes age, they may gradually require increased maintenance.

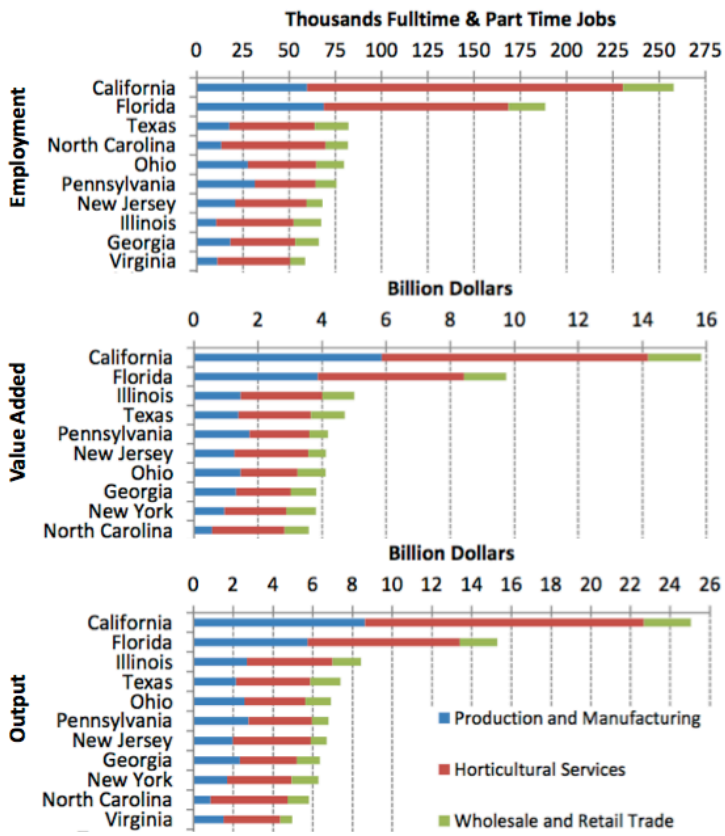

Figure 7. Employment, value added, and output contributions of green industry sectors, by state.

Source: Adapted from Hodge et al. (2011).

[17] For cost estimation, homeowner labor was computed at \$18 per hour.

Table 10. Classification of sectors associated with the turfgrass and lawncare industry including employment, payroll, and sales revenue.

Sector	Industry Sector (NAICS code)	Employment (jobs)	Payroll (million $)	Sales Revenues (million $)
Production and Manufacturing		***277,736***	***$8,773***	***$35,386***
Sod Farms	Nursery and Floriculture Production (11142)	262,941	$8,268	$27,139
Lawn Equipment Manufacturing	Lawn and Garden Tractor or Home Lawn and Garden Equipment Manufacturing (333112)	14,795	$506	$8,247
Horticultural Services		***631,511***	***$19,129***	***$82,452***
Lawncare Services	Landscaping Services (56173)	596,896	$17,389	$53,910
Landscape Architectural Service	Landscaping Architectural Services (54132)	34,615	$1,740	$4,365
Wholesale and Retail Trade		***292,962***	***$7,974***	***$82,452***
Lawncare Wholesale Stores	Lawn and Garden Equipment Supplies Stores (4442)	Wholesale and retail trade sector sales, payroll, and employment reflect share of business for horticulture product lines sales.		
Lawncare Retail Stores	Lawn and Garden Equipment Home Centers (44411)			
Total All Industry		***1,202,210***	***$35,876***	***$176,113***

Source: Adapted from Census Bureau (2007).

Cost Effectiveness of Turf Removal Programs

To evaluate the cost effectiveness of turf removal programs, this analysis assumes an average retail water price of $678 per acre-foot and an average net conversion cost of $1.60 per square foot. In calculating the investment recoup by the customer (Table 11), Scenario A accounts solely for water savings, Scenario B includes both the water savings and garden supply savings, and Scenario C includes the water savings, garden supply savings, and assumed labor cost savings. For this analysis, the baseline irrigation efficiency was 37.5%, with effective rainfall accounting for 25% of the plant water-needs and water savings is subdivided by regional ET_o as defined in Figure 8.

Turf removal rebates within in the state typically range from $0.30 to $1.00 per square foot. However, more recently, rebates have gained steam and been as high as $3.00 per square foot. Once the rebate level is above $1.00 per square foot however, the cost to the water agency may not be effective (Figure 9). Further the cost to the agency does not include staff time for program administration. Although in the 2013 *Water Use Efficiency Master Plan*[18] for the Municipal Water District of Orange County, their turf removal program was determined to have a meek benefit to cost ratio, the program is considered a gateway to other water savings opportunities with the long-term benefits and high interest from stakeholders.

Table 11. Estimated outdoor water savings for single-family residences in California.

		Cost to Agency ($/acre-foot)		Investment Recoup by Customer (years*)		
ET_o Region	Water Savings (gallons/ft^2)	Low Rebate ($0.30/ft^2)	High Rebate ($1.00/ft^2)	Scenario (A)	Scenario (B)	Scenario (C)
Coastal	32	363	907	76	10	4
Inner Coastal	39	298	745	38	10	4
Central	42	276	690	32	9	4
Desert	51	232	580	23	8	4

* Both agency and customer investments are amortized at a rate of 4%.
Source: Adapted from Hanak and Davis (2006).

[18] The Municipal Water District of Orange County 2013 Master Plan can be found at http://www.mwdoc.com/pages.php?id_pge=176

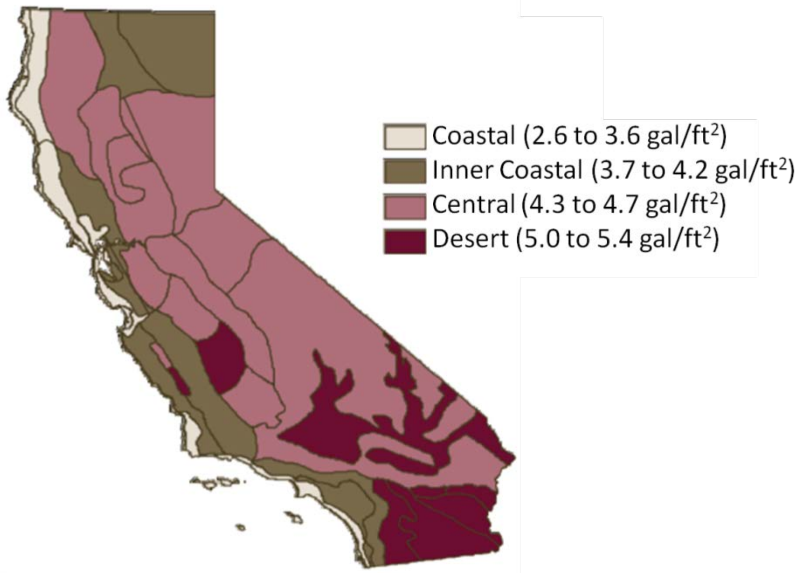

Figure 8. Summer turfgrass water requirements by ET_O region.

Source: Adapted from Sanford and Selnick (2013).

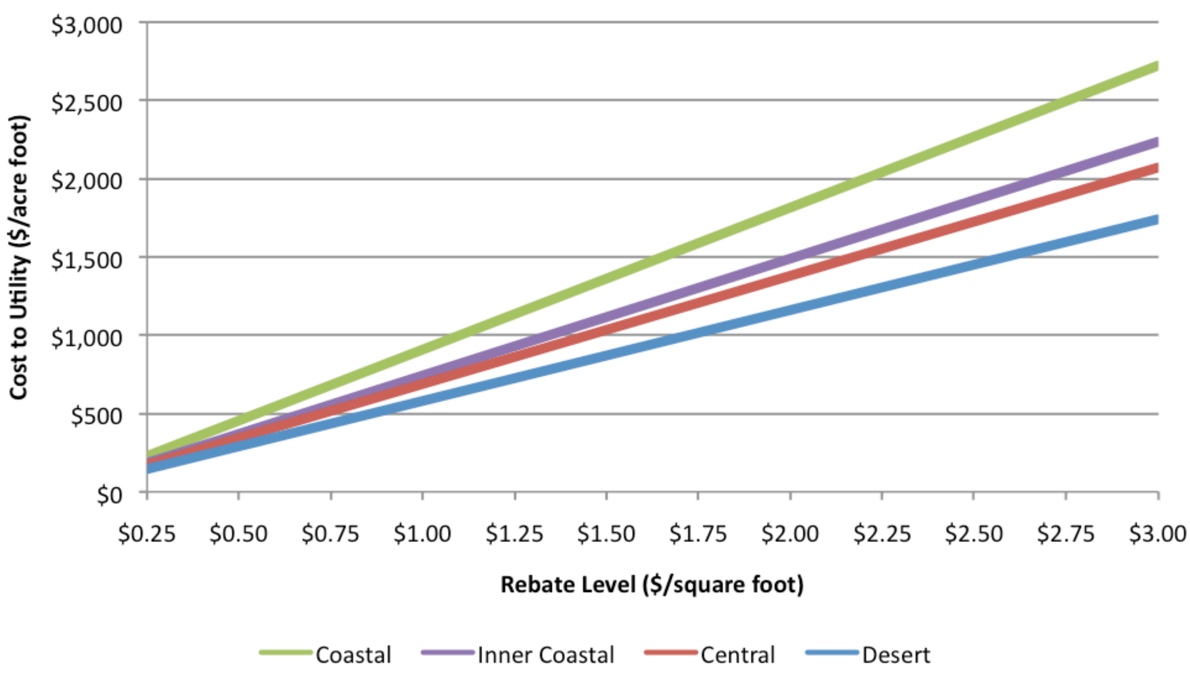

Figure 9. Increase in cost to agency with increase in rebate level.

Source: Adapted from Hanak and Davis (2006).

TURFGRASS ALLOWANCES

The U.S. Environmental Protection Agency has developed the *WaterSense Single-Family New Home Specification*, which promotes water-efficient practices to potentially yield a 20% reduction in water use. The landscape criterion specific to turfgrass allowances provides two options for builders. The landscape area should be designated to either:

1. Use a regionally appropriate amount of water as determined by a landscape budget
2. Contain no more than 40% turfgrass

Considering a 40% footprint of turfgrass within the landscape, the national average residential lawn area is nearly 2,500 ft^2 based on the landscape area[19] of an average lot size of 0.35 acres (USCB, 2007). This concurs with the previously stated turf removal area of approximately 2000 ft^2 found within the Orange County program where, in many cases, the entire turfgrass footprint was removed.

The updated Model Water Efficient Landscape Ordinance (MWELO), developed by the California Department of Water Resources and adopted in AB1881, establishes provisions for efficient water management practices for new and existing landscapes. The Maximum Applied Water Allowance (MAWA) is used as an upper limit for water use when setting a landscape budget, aimed at reducing the water use to the lowest practical amount.

However, within the MWELO, the ET adjustment factor (ETAF) of 0.7 (the result of a $K_c = 0.5$) actually only applies to rehabilitated landscapes[20] equal to or greater than 2,500 ft^2. The ETAF is determined by multiplying the average site K_c by the system efficiency (assumed to be 0.71), these being the two major influences controlling amount of water that needs to be applied to the landscape. For existing non-rehabilitated landscapes, the ETAF is 0.8, therefore, assuming a site average K_c of 0.6 (DWR, 2009).

Green building programs also address the turfgrass allowances. The U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED®) award points for limited conventional turfgrass landscapes. Build it Green California awards points for limiting turf within the landscape to less than 33% and requires any lawn area to have a water requirement less than cool season turfgrass (in this case warm season species are acceptable). East Bay M.U.D.'s Water Smart program limits turf within the landscape to 25% or less. MWDOC's Water Smart Home Certification Program awards points to landscapes with 40% or less turfgrass within the landscape.

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[19] A landscape area does not include footprints of buildings or structures, sidewalks, driveways, parking lots, decks, patios, gravel or stone walks, other pervious or non-pervious hardscapes, and other non-irrigated areas designated for non-development (e.g., open spaces and existing native vegetation).

[20] A rehabilitated landscape is any re-landscaping project that requires a permit , plan check, or design review, meets the requirements of Section 490.1, and the modified landscape area is equal to or greater than 2,500 square feet, is 50% of the total landscape area, and the modifications are completed within one year (DWR, 2009)

Around the country, other turfgrass allowances, predominantly in new landscapes include: Las Vegas, NV at 0% in the front yard and no more than 50% in the back yard up to 1,000 ft^2; Build Green Colorado requires landscape design to follow Xeriscape™ principles of practical turf areas; and El Paso, TX municipal code restricts new home turfgrass areas to 50%.

CONCLUSIONS

The key to saving water through a turf removal PBMP is in proper selection of low-water-need plant material and limiting the irrigation application to the new landscape. While it must be noted that even plants with low crop coefficients will consume large amounts of water if it is supplied to them, with proper scheduling, there is substantial water savings potential.

Although rebating turf removal at levels enticing to provoke action may not be cost effective from an agency perspective, this PBMP is in sync with the strategic focus of rebranding the California landscape norm.

Turf removal as a PBMP must be combined with the following caveats:

- Irrigation management for climate appropriate plants through proper programming and scheduling of irrigation timers
- Upgrade of irrigation system to reduce system inefficiencies (design and maintenance)
- Considerations for runoff, erosion, and fire control
- Considerations for the palate of material post turf removal. Limiting areas of bare soil and hardscape. Climate appropriate plants do not include invasive species
- Permeability assumptions extend to hardscape surfaces as well as weed barriers. Concrete, plastic sheeting, grout, and mortar are not considered permeable. For bricks and pavers to maintain permeability over time, it is recommended that the gap, or space, between pavers is approximately 50% the width of the paver

Management, including maintenance, is crucial for long-term sustainable success upon major landscape renovation. If site owners spend time and money landscaping through a landscape program or rebate process, without receiving education from the program about reduced water needs and appropriate maintenance, then the turf removal practice could exert a negative impact on water use efficiency. The additional service components suggested by the socio-behavioral model will influence the potential water savings that could be achieved through turf removal practices.

The effectiveness of landscape programs can be enhanced by designing in the service components of goal setting, monitoring/feedback, and performance rewards to supplement the typical components of advertising and promotion, education, and purchase incentives (rebates). Stronger return on investments (i.e. water savings and ease of implementation) from large-scale program development may be achieved if the power of social influence is leveraged through the acceptance of a landscape norm (market acceptance).

Turf removal may not be sufficient by itself to change the initial market acceptance and long-term market penetration of non-turf intensive landscapes. Limited customer receptivity (market demand) may pose a significant barrier to achieving the minimal market share necessary to justify climate appropriate plant promotion on solely economic grounds. A disregard for the power of social influence in the designing of non-turfgrass intensive landscape promotional programs may result in a significant lost opportunity.

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APPENDIX A.

The purpose of the evapotranspiration (ET) to precipitation (P) ratios for the conterminous United States (CUS) is to demonstrate the development and calibration of a regression equation that would apply to the entire CUS, and to make a map of estimated long-term mean annual ET for the CUS and an equivalent map of the ratio of ET:P. The regression equation was first developed using only climatic variables, but a second improved equation is also developed that included land-cover variables. Maps of the long-term mean annual ET and ET:P ratio should prove to be of great value to water managers planning for long-term sustainable regional water use, and the equation should be useful for examining the variability of ET at more local to state scales where such climate and/or land-cover data are available.

Table A-1. Regression Equation, Variables, Parameters, and Their Values Used to Estimate the Ratio ET/*P* for the Conterminous U.S.

Regression equation	$\mathbf{ET / P = \Lambda\,(\tau\,\Delta / (\tau\,\Delta + \Pi))}$											
	$\boldsymbol{\tau} = (T_m + T_o)^m / ((T_m + T_o)^m + a)$ $\Delta = (T_x - T_n) / ((T_x + T_n) + b)$ $\Pi = (P / P_o)^n$											
Climate variables	T_m, mean annual daily temperature (°C); T_x, mean annual maximum daily temperature (°C); T_n, mean annual minimum daily temperature (°C); P, mean annual precipitation (cm)											
Land-cover variables	$\Lambda = (1 + c\,L_d + e\,L_f + h\,L_s + j\,L_g + k\,L_a + r\,L_m)$ where L_i is the fraction of landcover type i within the area of calculation, and subscripts d, developed; f, forest; s, shrubland; g, grassland; a, agriculture; m, marsh											
	Climate Parameters						Land-Cover Parameters					
Parameter	**T_o**	**P_o**	**m**	**n**	**a**	**b**	**c**	**e**	**h**	**j**	**k**	**r**
Parameter value for climate-only regression	13.735	505.87	2.4721	1.9044	10,000	18.262	0.000	0.000	0.000	0.000	0.000	0.000
Parameter value for climate- and land-cover-based regression	17.737	938.89	1.9897	2.4721	10,000	18.457	0.173	0.297	0.094	0.236	0.382	0.400

Source: Sanford, W.E. and D.L. Selnick. (2013). “Estimation of Evapotranspiration Across the Conterminous United States Using a Regression With Climate and Land-Cover Data.” Journal of the American Water Resources Association, 49(1): 217-230.

APPENDIX B.

The required infiltration capacity of a soil surface, vegetated area or pervious pavement for a selected design storm event (with zero overflow) is calculated by:

$$Q_{peak} = k_h A_{\mathrm{inf}}$$

Where:

Q_{peak} = peak design runoff rate from the contributing catchment (m^3/s)
k_h = design hydraulic conductivity (m/s)
A_{inf} = surface area available for infiltration (m^2)

Hence:

$$\frac{CiA}{1000 \times 60^2} = k_h A_{\mathrm{inf}}$$

Where:

C = runoff coefficient as defined in Institution of Engineers Australia (2001)
i = probabilistic rainfall intensity (mm/hr)
A = total defined catchment area (m^2), i.e. the area of the treatment surface plus the surrounding contributing catchment area

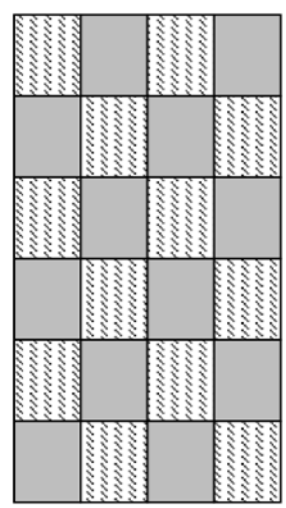
When considering impervious blockage within the catchment area:

$$\frac{CiA}{1000 \times 60^2} = k_h (1 - \psi) A_{\mathrm{inf}}$$

Where:

Ψ = infiltration surface blockage factor

This equation applies where the infiltration surface is located within the total defined catchment area. A blockage factor of 0.5 would need to be applied to account for the impervious concrete pavers interspaced with landscape material in the illustration to the right.

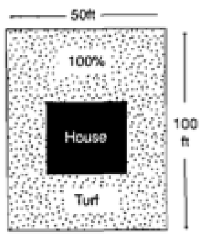


APPENDIX C.

Examples of landscapes types, including maintenance costs, presented to homeowners for preference selection (Hurd, 2006).

Landscapes types, water use, and upkeep costs

(Characteristics typical for New Mexican homes with 2,500 square feet of landscapable area)

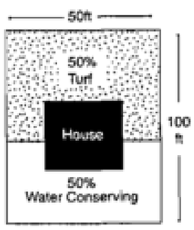


Type A: Traditional Turfgrass Landscape

Description: Composed predominantly of high water-using turfgrass (bluegrass), shrubs, flowers, gardens, and trees.

Characteristics:

Water Use:	100,000 gal/year
Water Cost:	$300/year
Maintenance Cost:	$1,200/year
Maintenance Effort:	300 hrs/year

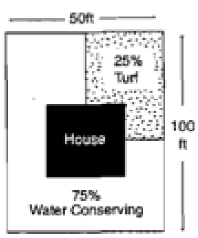


Type B: 1/2 Traditional Turfgrass, 1/2 Water Conserving

Description: Under this alternative, turfgrass area is cut in half and replaced with water-conserving types e.g., some shrubs, flowers, gardens, and drought-tolerant trees.

Characteristics:

Water Use:	70,000 gal/year
Water Cost:	$200/year
Maintenance Cost:	$800/year
Maintenance Effort:	200 hrs/year

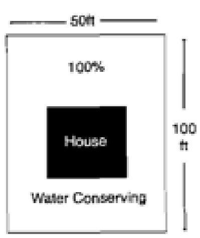


Type C: 1/4 Traditional Turfgrass, 3/4 Water Conserving

Description: Under this alternative, turfgrass area is cut by 75% and replaced with water-conserving types e.g., some shrubs, flowers, gardens, and drought-tolerant trees.

Characteristics:

Water Use:	50,000 gal/year
Water Cost:	$150/year
Maintenance Cost:	$500/year
Maintenance Effort:	120 hrs/year



Type D: No Turfgrass, 100% Water Conserving

Description: Under this alternative, there is no turfgrass, only 100% water-conserving types including drought-tolerant shrubs, flowers, trees, native vegetation, and rocks.

Characteristics:

Water Use:	35,000 gal/year
Water Cost:	$100/year
Maintenance Cost:	$200/year
Maintenance Effort:	50 hrs/year

Notes: Numerical figures varied across the sample in order to examine sensitivity to each of the factors. The ranges of values across survey versions for each landscape type are as follows:

Type A. Water use = 40,000–100,000 gallons/year; water cost = $120–$300/year; maintenance cost = $600–$1,200/year; maintenance effort = 150–300 hours/year

Type B. Water use = 25,000–70,000 gallons/year; water cost = $80–$200/year; maintenance cost = $400–$800/year; maintenance effort = 100–200 hours/year

Type C. Water use = 20,000–50,000 gallons/year; water cost = $60–$150/year; maintenance cost = $250–$500/year; maintenance effort = 50–120 hours/year

Type D. Water use = 15,000–35,000 gallons/year; water cost = $50–$100/year; maintenance cost = $100–$200/year; maintenance effort = 25–50 hours/year