A FIVE-YEAR INVESTIGATION INTO THE POTENTIAL WATER AND MONETARY SAVINGS OF RESIDENTIAL XERISCAPE IN THE MOJAVE DESERT.

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Abstract

The authors present a selection of preliminary findings from a multiyear study quantifying the residential water and economic savings realizable by converting from traditional turfgrass to xeric landscaping in a southwestern United States desert community. Findings are presented for three scaling levels: the total residence (with mainmeter data), the comparative landscape level (turf versus xeric landscape, with submeter data), and within xeric landscape (also with submeter data). Findings cover: (1) post-landscape conversion water savings for the whole property versus pre-conversion consumption, (2) landscape maintenance savings (both hours and direct costs) for the whole property when xeriscape principles are applied, (3) annual per unit area (sqft) water consumption and bill savings for xeric areas versus traditional turfgrass, (4) the influence of system design and canopy coverage on xeric area water consumption, (5) the long-term savings potential of xeric landscape (with its potentially increasingly canopy) versus turfgrass. The results show xeriscape is promising and effective as a water conservation tool.

Introduction and Background

In the Mojave Desert of the southwestern United States, typically 60 to 90% of potable water drawn by single family residences in municipalities is used for outdoor irrigation. Thus, in this region, and indeed most of the entire Southwest, the most effective conservation measures are oriented towards reducing outdoor water consumption. A commonly considered method for accomplishing water conservation is to use xeriscape (low water-use landscaping) in place of traditional turf. Xeriscape is based on seven principles:

- Sound Landscape Planning and Design
- Limitation of Turf to Appropriate Areas
- Use of Water-efficient Plants
- Efficient Irrigation
- Soil Amendments
- Use of Mulches
- Appropriate Landscape Maintenance

These cardinal components have been explored and explained at great length in several texts and will not be considered in further detail here. The term “xeriscape” was invented by Nancy Leavitt, of Denver Water (a public utility) in the early 1980’s as a fusion of the Greek word “xeros” (meaning dry or arid) and landscape. Denver Water trademarked the term shortly thereafter though it has entered the English vernacular over the last 20 years as the concept has spread globally.

So promising was xeriscape, that water purveyors and others interested in conservation began actively promoting xeriscape as early as the mid-80’s as part of water conservation strategies. The need to better understand its utility as a tool led to a host of studies being conducted in the 90’s which have generally pegged savings associated with xeriscaping between 25 and 42% for implementation in the residential sector (Bent[1] 1992, Testa and Newton[2] 1993, Nelson 1994[3], Gregg[4] et. al. 1994). The variation in savings estimates are due to a large number of variables ranging from the different climates of each study locality to the methodologies employed.

The work done to this point has greatly advanced the water conservation community’s ability to evaluate, modify, and justify programs to encourage the use of xeriscaping as an integral component of water conservation plans. Utilities, water districts, cities, counties, and states are beginning to promote xeriscape as a cost-effective, mutually beneficial alternative to traditional turfgrass dominated landscapes. Landscapes dominated by turf are increasingly being viewed as incompatible with the natural environment, especially in desert regions. Recently, this interest has increased at the federal level, and this study is part of that evolution.

The Colorado River serves as the lifeblood for many of the communities of the southwestern United States, permitting society there to flourish, despite the harsh, arid conditions. It serves the needs of millions within the region and its yearly volume is entirely divided up by the Colorado River Compact which specifies allocations for each of the states (and Mexico) through which it flows. Against this rather divisional backdrop, the United States Bureau of Reclamation – Lower Colorado Regional Authority (USBR-LCRA) is charged with maintaining an adequate and established division of water for each of the states in the arid lower basin. Since water management is most effectively implemented at more local levels, USBR-LCRA actively partners with such entities to accomplish this task. In Southern Nevada, the major regional organization is the Southern Nevada Water Authority (SNWA).

In 1991, the SNWA was established to address water on a regional basis, rather than an individual water purveyor basis. The SNWA is committed to managing the region’s water resource and developing solutions that ensure adequate future water supplies for Southern Nevada. The member agencies are the cities of Boulder City, Henderson, Las Vegas, and North Las Vegas, the Big Bend Water District, the Clark County Sanitation District and the Las Vegas Valley Water District. As Southern Nevada has grown into a metropolitan area and a world-famous vacation destination, so too have its water needs. No single resource has had a more dramatic impact on shaping and defining of the area than water. The SNWA was created to plan and provide for the present and future water needs of all area residents.

Five different water purveyors provide potable water in most of Clark County. Big Bend Water District provides water to the community of Laughlin; the cities of Boulder City and Henderson provide water to their prospective communities. The Las Vegas Valley Water District provides water to the City of Las Vegas and to portions of unincorporated Clark County; the City of North Las Vegas provides water within its boundaries and to adjacent portions of unincorporated Clark County and the City of Las Vegas. The SNWA member agencies serve approximately 96% of the County's population.

Wastewater service in the Las Vegas region is provided by four different entities. The cities of Boulder City and Henderson provide wastewater service to their communities. The City of Las Vegas collects and treats wastewater for customers within its boundaries. The City of North Las Vegas collects its wastewater and then sends it to the City of Las Vegas for treatment. Clark County Sanitation District provides wastewater facilities for parts of unincorporated Clark County in the Las Vegas Valley and the community of Laughlin.

Southern Nevada receives only 4 inches of annual precipitation, has a yearly ET water requirement of nearly 90 inches, and has one of the fastest growing counties in the United States. Clark County, the southernmost county in Nevada, has a population well in excess of one million people and has been experiencing extremely strong economic growth in recent years with annual population growth averaging in excess of five percent. The primary economic driver in the Clark County economy is the gaming industry with an annual visitor volume in excess of 30 million people per year.

SNWA manages the 300,000 acre-feet that Nevada has allocated from the Colorado River (consumptive use apportionment) and approximately 200,000 acre-feet from return flow credits and groundwater aquifers. Nevada only receives 1.8% of the total river allocation as specified in the Compact.

For these reasons, SNWA has an aggressive conservation program that began in the 1990's. The Authority is committed to achieving a 25% level of conservation (versus consumption without conservation) by the year 2010. In 1995, the SNWA member agencies entered into a Memorandum of Understanding (MOU) regarding a regional water conservation plan. The MOU, updated in 1999, identifies specific management practices, timeline and criteria the member agencies agree to follow in order to implement water conservation and efficiency measures.

The programs or Best Management Practices (BMPs) listed in the MOU include water measurement and accounting systems; incentive pricing and billing; water conservation coordinators; information and education programs; distribution system audit programs; customer audit and incentive programs; commercial and industrial audit and incentive programs; landscape audit programs; landscape ordinances; landscape retrofit incentive programs; waterwaste management and recycling programs; fixture replacement programs; plumbing regulations and water shortage contingency plans. The BMPs provide the framework for implementing the water conservation plan and guidance as to the methods to be employed to achieve the desired savings.

The large savings of water potentially realizable with the broad-scale use of xeriscaping are thus of paramount interest for both USBR-LCRA and SNWA. For this reason, a partnership between the Bureau and SNWA was formed to investigate the savings that could be obtained with a program to encourage converting traditional turfgrass landscapes to xeriscapes. This was formally implemented as a Cooperative Agreement[5] in 1995. With its signing, a multi-year study of xeriscape was born which has come to be known as the SNWA Xeriscape Conversion Study (XCS). As delineated in the most recent version of the Scope[6] for this agreement, the objectives of the Study are to:

- Identify candidates for participation in the Study and monitor their water use.
- Measure the average reduction in water use among Study participants.
- Measure the variability of water savings over time and across seasons.
- Assess the variability of water use among participants and to identify what factors contribute to that variability.
- Measure the capital costs and maintenance costs of landscaping among participants.
- Estimate incentive levels necessary to induce a desired change in landscaping.

Within the limitations of a conference manuscript, much of the results pertinent to each of these objectives cannot be reviewed; rather it is the authors' desire to preview some of the highlights from preliminary findings of the Study. Furthermore, the XCS is still ongoing and many of the lines of investigation will not be concluded till the Study's completion (slated for end of 2001).

Methods

Overview of Study Methods

Study Groups and Monitoring

The study enrolled participants whom dwell in single family residences within the following entities' water jurisdictions: The Las Vegas Valley Water District (77% of the participants in the entire study group), Henderson (12%), North Las Vegas (9%), and Boulder City (2%).

There are a total of three groups in the XCS, the Xeriscape Study (XS) Group, the Turf Study (TS) Group, and a non-contacted Comparison Group. This manuscript highlights analyses regarding the XS and TS Groups.

The first, the Xeriscape Study (XS) Group is composed of residents who converted at least 500 square feet (sqft) of traditional turfgrass to xeric landscape. In this region, xeric landscaping is principally composed of a combination of desert-adapted shrubs, trees, some ornamental grasses, and mulch. A $0.45 per square foot incentive helped the property owner by absorbing some of the cost of the conversion. Homeowners were required to plant sufficient vegetation so that the xeric landscape would have a minimum 50% canopy coverage at maturity. This avoided the creation of unattractive "zeroscapes" composed exclusively of rocks, which could potentially act as urban heat islands. The incentive capped at $900 for 2000 sqft however many residents converted more than the capped amount. The average area converted was 2160 sqft. A total of

499 properties were enrolled in the Study as XS Group participants. Aerial photographs, supported by ground measures, were used for recording areas.

In return for the incentive, the residents agreed to ongoing monitoring of their water consumption. This was accomplished two ways. First, mainmeter data was taken from normal monthly meter reading. Secondly, residents agreed to installation of a submeter that monitored irrigation consumption on a portion of the xeric landscape. Submeters are read monthly, as with mainmeters. The area monitored by the submeter is called the Xeriscape Study Area. Study areas were thus tied to the irrigation stations. All Study properties have in-ground irrigation systems and controllers to avoid presence/absence of these as confounding factors. Having automated irrigation systems tends on average to increase water usage for residential properties (Mayer and DeOreo[7] et. al. 1999) apparently because it makes irrigation more likely to take place versus hand-watering. Having all participants in both groups possess automated systems avoids the potential bias of more heavily turf-covered properties also tending to be more likely fully automated and thus having higher consumption for this reason as was the case for Bent[1] 1992 (as identified in Gregg[4] et. al. 1994). All areas of each property were broken down into landscape categories. For example, a XS Group property might have monitored (via submeter) xeric landscape and unmonitorred xeric, turf, garden, and other (non-landscaped) areas among others. Respective square footages were recorded for each of these area types.

In addition to water consumption monitoring, residents agreed to a yearly site visit for data collection purposes. During site visits, information was collected that pertained to the xeric species identification, canopy coverage, components of the irrigation system, and per station flow rates.

The Turf Study (TS) Group is composed of properties with more traditional landscape design where an average 2462 sqft of the landscaped area was of traditional turfgrass (typically Fescue). Due to design challenges, the submeter was more commonly hooked to monitor a mixed type of landscape rather than just turf, though many did exclusively monitor turf. TS participants enrolled voluntarily, without an incentive and agreed to yearly site visits and metering as above. A total of 253 residences were recruited into the TS Group.

The enrollment of participant residences into the XS and TS groups was directly dependent on homeowners' willingness to participate in a water conservation study. For this reason, sampling bias is of reasonable concern to the SNWA. To address this, a third subset of non-contacted Comparison Groups was created and will ultimately be used to evaluate the effects of any potential biases. Comparison properties are not considered within this manuscript.

Analysis Methods for Topics Covered

Analyses evaluated here correspond to data associated with the Las Vegas Valley Water District (LVVWD) set of properties only. This is because this data was most readily available in a standardized format and because LVVWD customers constitute the bulk of the sample group. Data from the other participating customers will be incorporated into future reports. Unless otherwise noted, error bars represent standard errors of the mean. Supporting statistics are given when the authors view them appropriate and report these to the extent analyses have been completed. Univariate regression models are included to assist in conceptualizing impacts of system design and canopy coverage and are not intended as practical guides for estimation of per unit area yearly consumption.

Single-Family Home Level

Quantification of Outdoor Irrigation

Datalogger methods, where trace consumption events can be identified by recording the magnetic drive action of meters, were employed for brief (14-day) sampling regimes in Summer 1998 and Winter 2000. Following the recording period, records for each property were disaggregated into the flow events for each irrigation (or other water use) event. Ninety-five homes were analyzed using this flow trace approach. Datalogger analyses demonstrate seasonal influences of xeriscaping. Aquacraft Inc. provided support for datalogger analyses under contract to SNWA.

Pre/Post-Conversion Analysis

For each property, monthly consumption data provided by LVVWD was summed to get annual and average monthly consumption values for each year. Data for each XS home was assembled from the five years before conversion or (as many records as were available) and as many years post-conversion as records permitted. A total of 172 of these pre/post-conversion homes constitute the sample for the group. The "summer monthly" comparison was prepared by summing the monthly consumption records for May-September only and getting the average for this time frame. The rest of this data was assembled as above for the monthly average group. This extended "summer" range reflects the reality of the long high consumption period in Southern Nevada. For this reason the reported savings during summer are, if anything, conservative. For the 3rd year following conversion, a limited amount of available data dropped N to 47.

Analysis of Economics

In the summer of 2000, data on landscape maintenance economics was obtained via surveys sent to study participants. The survey examined both labor hours and direct costs associated with landscape choices. Three hundred surveys were returned for analysis

Landscape (Per Unit Area) Level

Comparative Consumption Data

Annual consumption on a per area basis was calculated. This was accomplished by summing the monthly consumption values for each submeter and dividing by the measured area that was monitored (i.e. the study area). In this way, exacting measures of consumption for each landscape type could be measured. The sample size (N_s) is the product of the number of years of data and the number of valid submeter records analyzed. Consumption is quantified as gallons per sqft per year. The reason for using a per year basis is that for some areas, the usage was often so low, that monthly consumption could be difficult to interpret. At least a thousand gallons had to be consumed for meter readers to advance the reading and often this did not occur within a given month for xeric study areas. For xeric areas N_s came to 627. For turf areas, only records for submeters that monitored exclusively turf were analyzed so that other landscape types would not confound measures. As a result, for turf, N_s was lowered to 50.

Comparative Irrigation Cost Data
For each year, the cost to irrigate a 100 sqft of xeric area and turfgrass was calculated. The water costs per month were figured as if the property owner had been billed for submeter consumption. With this data, the yearly cost to irrigate could be calculated by summing up the "billings" for the year and dividing by the area. This is expressed on a per 100 sqft basis for clarity. The irrigation costs properties are the same as those for the comparative consumption analyses so respective N_s values are the same. Using this approach, actual costs are better estimated than by summing up the yearly consumption and then calculating costs, because LVVWD applies a tiered rate billing system which is structured on a average daily usage basis within each billing cycle.

Xeric Area System Design and Consumption Data
Flow rates for each irrigation station could be calculated by measuring at a meter the amount consumed in gallons for a given time period (N=2936).

Since the monitored (submetered) xeric areas correspond to specific stations on the irrigation controller, the water consumed for each xeric portion and the mean flow for each of the stations serving that area can be compared. Consumption collated by mean station flow rate class is shown (N_s=269).

Xeric Area Canopy Coverage and Consumption Data
Since canopy coverage is known for each of the monitored areas, the impact of coverage on mean annual consumption can be calculated. Mean per unit area consumption vs. canopy coverage class is shown (N_s = 270).

Preliminary Results and Discussion

Findings at the Single-Family Home Level

Outdoor irrigation is the principal source of residential water demand in Southern Nevada. This is equally true for Study homes as demonstrated by datalogger information (Table 1). The data demonstrates that in summer and winter xeriscape conversion can reduce both the absolute amount and relative percentage of water consumed in outdoor irrigation. In Southern Nevada, the warm year-round temperatures result in no true "off" season for irrigation, extending the total annual savings obtained from xeric landscaping practices. The absolute mean difference between the TS and XS groups exceeded 270 gallons per day for the summer logging period. Xeriscaping significantly flattens peaking in the annual consumption pattern.

Table 1
Outdoor Irrigation Regime by Season and Study Group

	Summer Mean Daily Use (gpd)		**Winter Mean Daily Use (gpd)**	
End Use	**TS Group**	**XS Group**	**TS Group**	**XS Group**
Traditional Irrigation	710.1	298.2	200.1	88.9
Xeric Area Irrigation	incl'd above	133.2	incl'd above	45.6
Misc. Outdoor (exempting pools)	10.1	20.1	6.6	1.4
Outdoor Leaks	3.2	0.3	Acc't w/ in above	Acc't w/ in above
Outdoor Irrigation Total	**723.4**	**451.5**	**207.3**	**135.5**
Total for Residence	876.4	649.0	371.3	300.5
Outdoor Use (exempting pools) as a percent of Total Residential Use	**82.6%**	**69.6%**	**55.8%**	**45.1%**

Results for the pre/post-conversion comparisons are shown in Figure 1. Mean monthly household consumption dropped an average of 33% following conversion. This was identical to the findings from a study of residences in Mesa, Arizona (Testa and Newton[2] 1993). For the sample group as a whole, the reduction took place in the year following conversion and remained stable at that point through subsequent years, showing no erosion (Figure 2). This reduction became even more pronounced in the comparison of summer months (Figure 1). The extent of savings differences are still under exploration. Preliminary analysis suggests that factors such as size of the conversion and the size of remaining turf have strong impacts on the savings at any one household. Nonetheless, the water savings realized by participants are strong enough to result in different mean pre/post-conversion mainmeter consumption values. When the data is run through a Repeated-measures ANOVA differences are "very highly significant" [$F(1,177)$; $p<0.0001$].

Figure 1
Total Household Monthly (Main Meter) Consumption

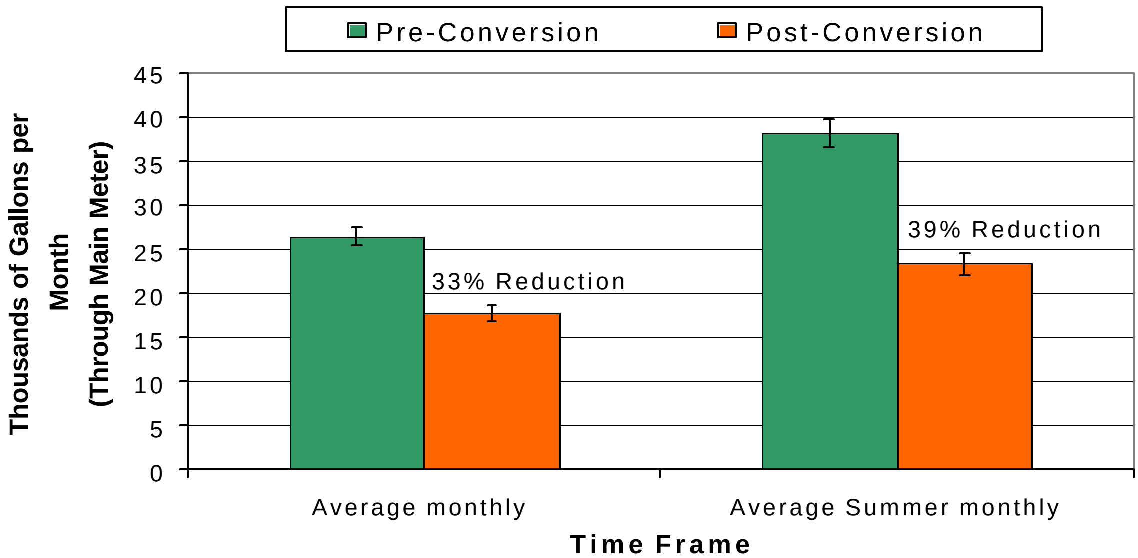
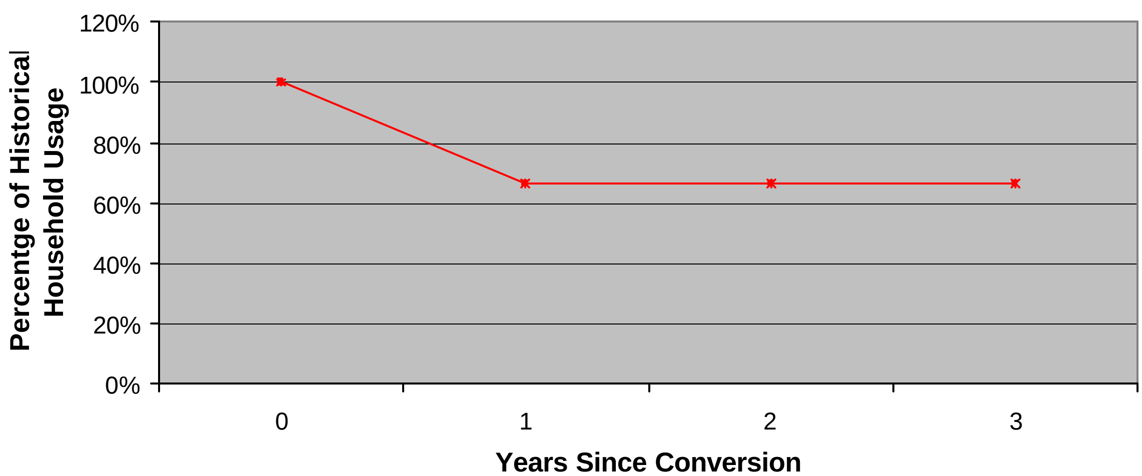
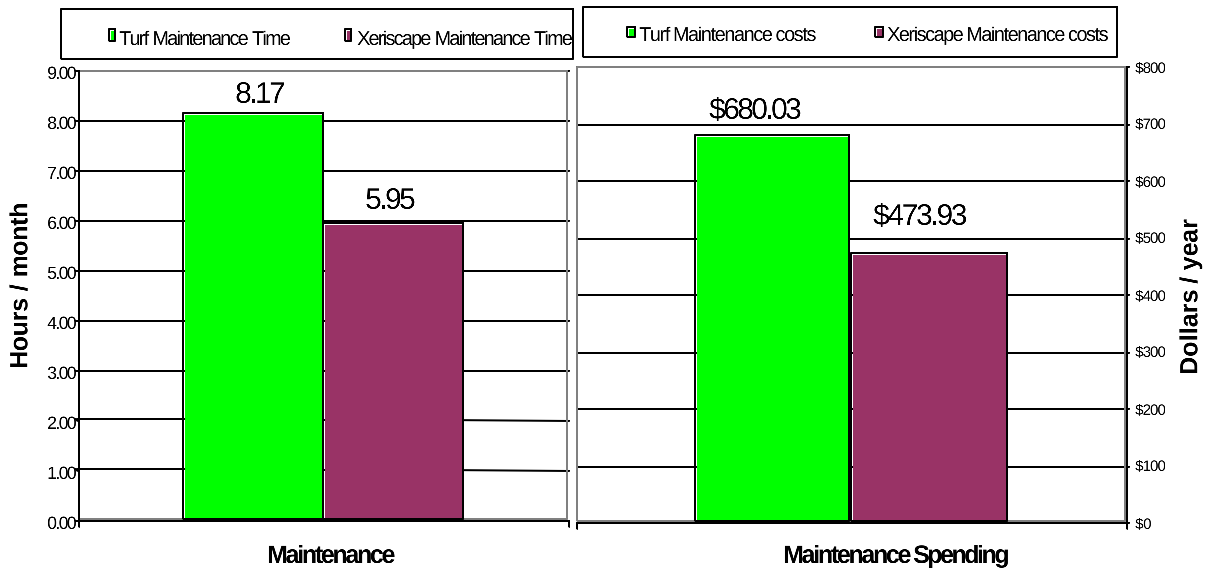


Figure 2
Total Annual Reduction in Whole Household Consumption Since Conversion Across Time



Landscape maintenance requirements constitute a significant investment in labor and dollars directly spent. Practicing xeriscape principles figured prominently in landscape maintenance reductions for both these (Figures 3 and 4). For those whom had at least 60% of their landscapeable area as xeric landscaping, maintenance savings of about a third were realized versus those with 60% or more turf. These are mean savings of 2.2 hours/month in labor and $206 per annum in direct expenditures. Landscape maintenance savings are value added on top water bill savings. This serves to greatly enhance the attractiveness of xeriscape to the customer.

Figures 3 and 4: Landscape labor requirement (hours per month) and maintenance spending (dollars per year) for homeowners with 60% or more Turf or Xeriscape

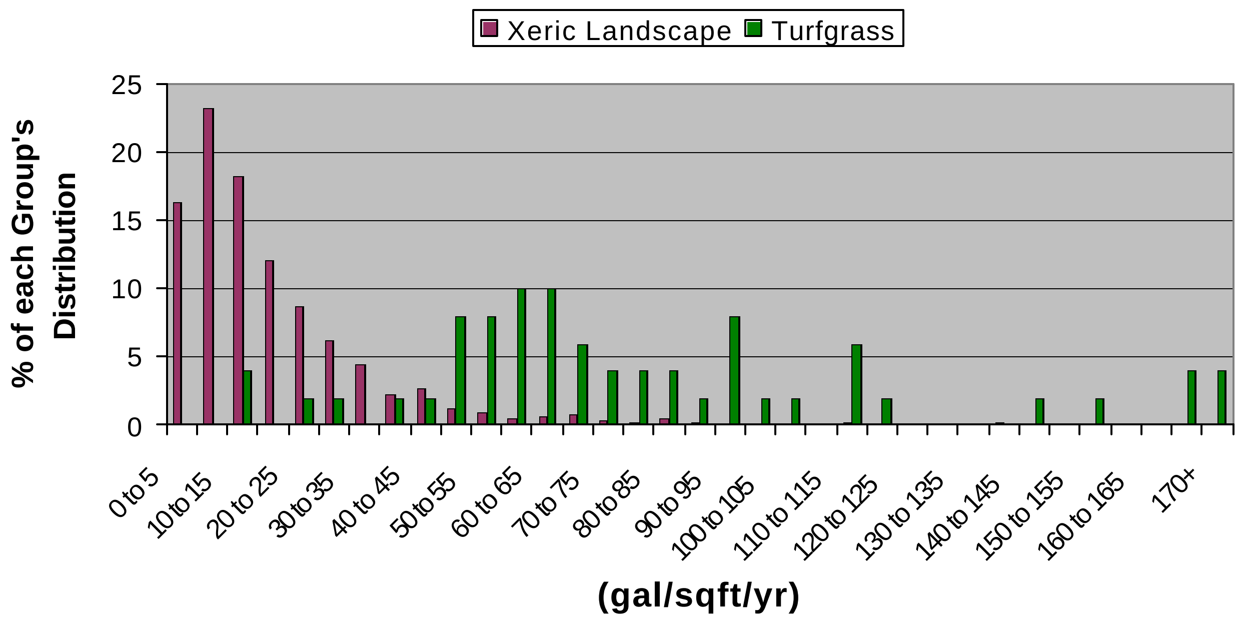


Comparative Findings at the Landscape (Per Unit Area) Level

A standardized histogram breaking down properties into per unit area annual consumption classes (gallons per square foot per year) for xeric versus turf landscape (Figure 5) shows that these two types occupy distinctly different consumption regimes. Recall that only submeters which monitored exclusively either xeric or turfgrass landscapes are included here so per unit area data is as exacting as possible. Xeriscape is generally confined to a narrow, low-value portion of the per unit area consumption spectrum. In stark contrast, turf has a much broader variance and occupies much higher regions of the scale. Clearly, xeric landscaping is associated with a lower, more constrained water consumption regime.

The means of per unit area consumption are shown in Figure 6. The results are indeed quite impressive. Although there is significant variability within both groups, on average, residential water consumption for turfgrass areas was over 4.5 times that of xeric landscape. Xeric landscapes are thus an excellent water conservation tool. In comparing the means to the distributions for both landscape types, it becomes apparent that a relatively few properties in each group use vastly more water on a per unit area basis than the bulk of the rest of the sample. This is supported by the medians for both groups being so much lower than the means (Turfgrass median: 67 gal/sqft/yr; Xeric median: 12.6 gal/sqft/yr). Due to the high consumption associated with a few individuals, averages for both groups were brought above that of the typical homeowner. This skewing is seen throughout most investigations of water use and is therefore not surprising. Indeed, in comparing the medians, the gap between xeric and turf landscape usage is stretched even further with annual application to xeric areas less than a fifth that of turfgrass. For this reason, per unit area estimates and savings estimates derived from Figures 6 and 7 are conservative.

Figure 5
Histogram of Per Unit Area Consumption

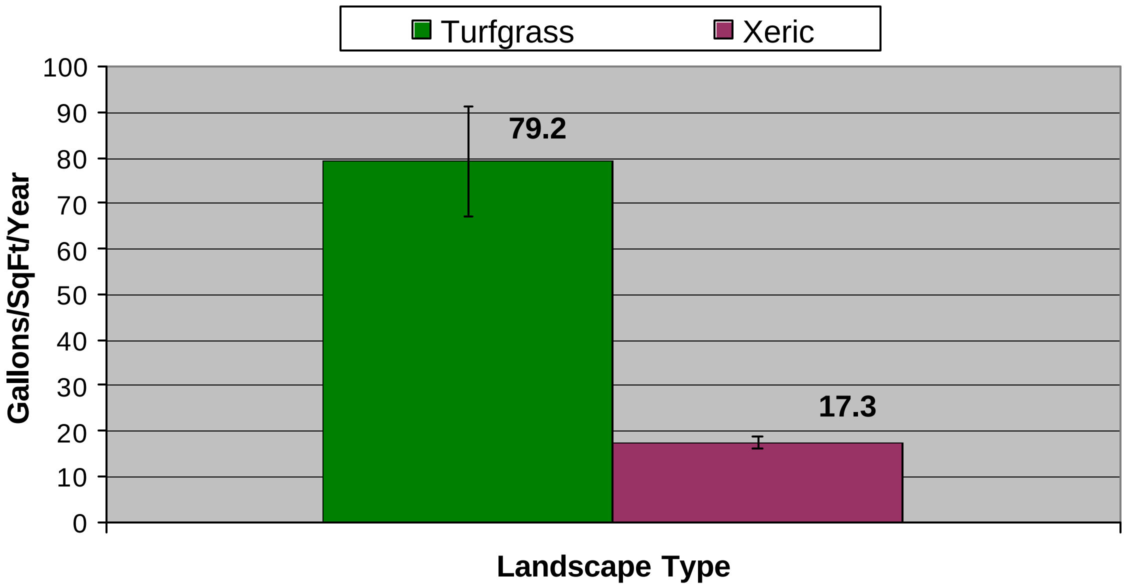


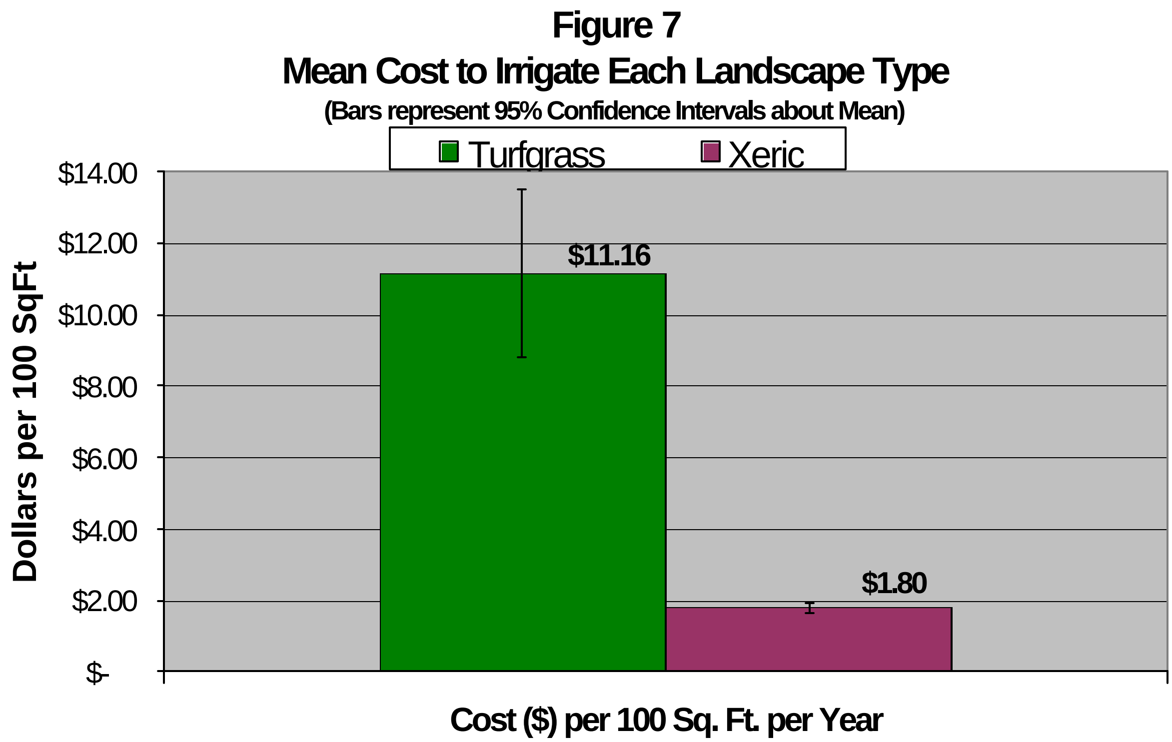
Total cost to irrigate a 100 square feet area shows a pattern similar to the consumption data (Figure 7). However, the difference in costs is relatively stronger than consumption. The cost of irrigating turf is about 6.2 times that of xeric landscaping. This illustrates the impact of LVVWD's tiered rate structure. Tiered rate structures (also called conservation rate structures) are setup such that the more a user consumes on an average daily basis within a cycle, the more expensive per unit water becomes. The higher per unit area consumption of turfgrass results in more heavily grassed residences typically crossing into higher rate structure billing thresholds and this in turn exacerbates the cost per unit area. It should be noted that while the respective sizes of xeric or turf landscape directly influence the per unit area savings, the sample landscapes compared suggest threshold impacts were a common enough influence to impact the mean. This demonstrates that financial savings due to xeriscape are likely greater than would initially be anticipated from consumption savings data. The comparison also highlights additional utility of tiered rate structures as a conservation tool and for promoting xeriscape.

Findings Regarding Variability Within Xeric Landscaping

Past studies have documented many physical, economic, and social variables that contribute influentially to water consumption and savings and a complete discussion of these is well beyond the scope of this paper. Each investigation of xeriscape lends more to our collective understanding of the factors mediating the savings that can be achieved with this landscaping practice. To this end, the authors report two physical variables which appear to contribute substantially to mediating the per unit area consumption for xeric vegetation.

Figure 6
Mean Per Unit Area Consumption for Landscape Types
(Bars represent 95% Confidence Intervals about Mean)





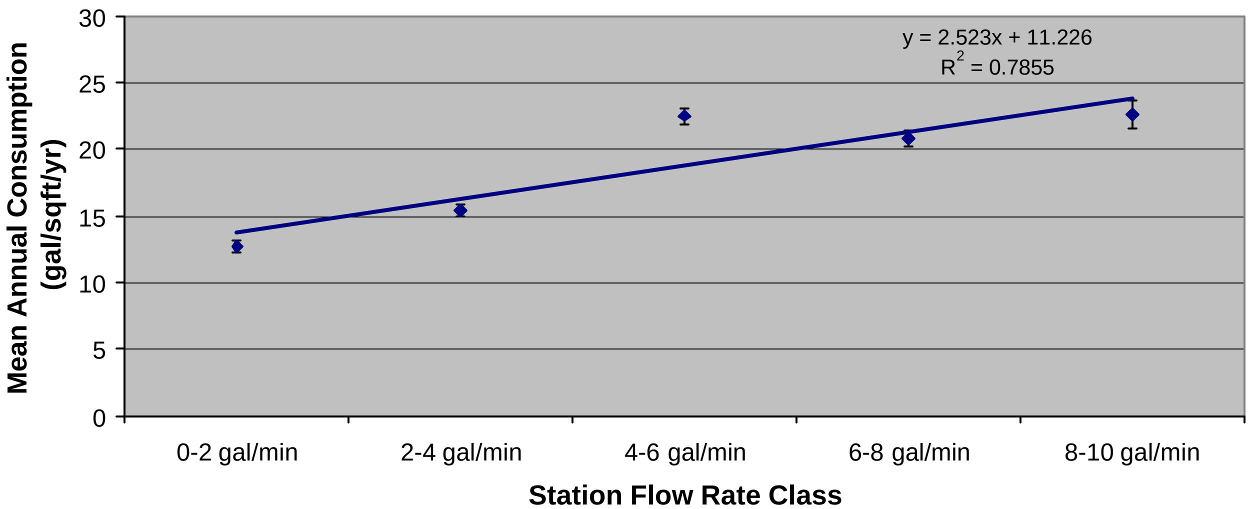
One important variable influencing consumption for xeric landscaping is the design of the irrigation system. Everything else being similar (including run-time), a lower flow system results in lower water application. A review of systems composed exclusively of one irrigation head type or emitter component (non-mixed for a single valve) revealed that whole station flow rates for drip were much less than for bubblers (aka. flood bubblers), and both these were lower than for turf irrigation systems (Table 2).

Table 2
Comparison of Mean Flow Rates for Stations Composed of a Single Head or Emitter

Head or Emitter Class	Station Flow Rate (gpm)
Assorted Drip Emitters	4.0
Bubblers	9.3
Rotors	11.4
Traditional Pop-ups	11.8

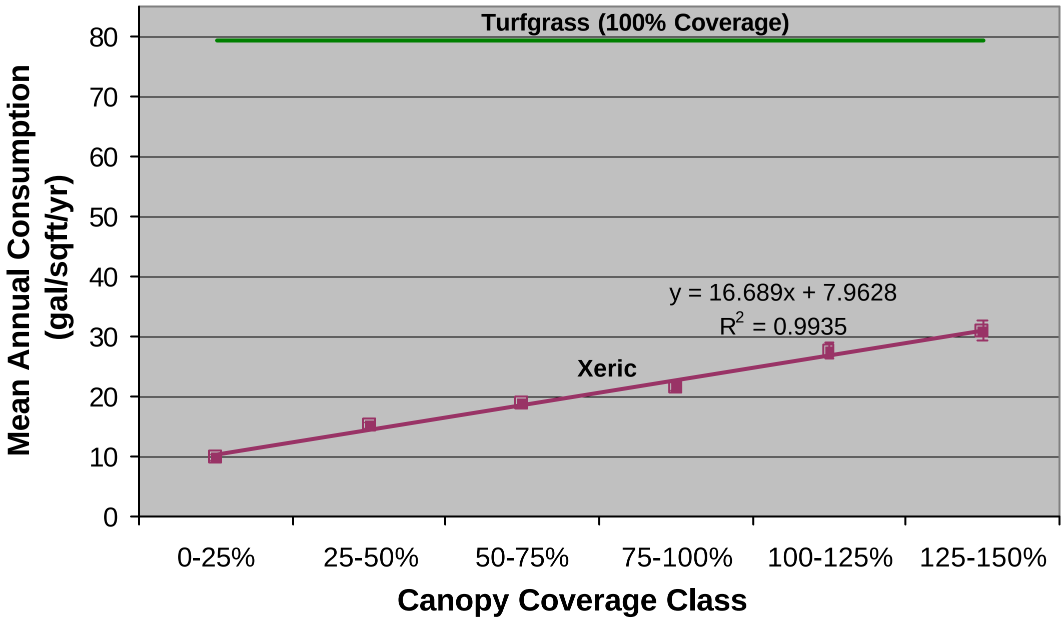
It appears that for xeric vegetation, irrigation system station flow rate (a function of the unified system design) ultimately influences annual consumption on a per unit area basis (Figure 8). The range suggests design may influence per unit area usage over a 10 gal/sqft/yr range which corresponds to up to ±30% of the 17.3 gal/sqft/yr mean. This is an intriguing finding, in that it actually provides proof of the irrigation system design's influence on total per unit area annual consumption.

Figure 8
Mean Per Unit Area Water Consumption For Xeric Study Areas vs. Irrigation System Design



The amount of canopy present in a xeric landscape should influence the watering requirements of the landscape. Whether or not higher plant density actually translates into increased water consumption, given the implications of the residents' irrigation behaviors and whether or not they adjust irrigation regime to match their perceived needs of the plant, has been of curiosity. Here, data is presented that suggests a tight relationship between the vegetation present and per unit area annual consumption (Figure 9). Unlike the irrigation system comparison, there is not necessarily an upper limitation to the canopy coverage variable, however, confining consideration to a 0 to 100% coverage range suggests canopy coverage may influence per unit area usage over an 18 gal/sqft/yr range corresponding up to ±58% of the mean.

Figure 9
Mean Per Unit Area Water Consumption for Xeric Study Areas vs. Plant Canopy Coverage



The above graph begs the question, could canopy growth throughout time erase the initially realized savings associated with converting turf to xeriscape? Both the graph and an upward trend in annual consumption per unit area over time (xeric consumption: 1998 = 14.0 gal/sqft/yr, 2000 = 18.1; N = 367; $p<.05$) demonstrate that canopy is a very strong input which influences xeric landscape consumption. However, the authors dismiss concerns over serious savings erosion because:

1. Even for xeric landscapes of high density (which here resulted from thick plantings), mean annual consumption per unit area does not reach half the mean of turf. Most landscapes are unlikely to exceed the upper coverage range on the graph. Indeed, this comparison topped out at the 125 – 150% range due to lack of sufficient samples of higher density for analysis.

2. Even if one assumed canopy coverage to be the exclusive causative agent driving consumption, the above results suggest typical xeric landscapes would have to achieve coverage well in excess of 400% to equilibrate to pre-conversion levels (i.e. when turf was there). The authors know of no examples of such residential landscapes in the natural world and can envision no irrigation system capable of supporting them.

3. In the grand scheme of things, xeric area canopy coverage does not appear to influence total household water consumption. While the influence on a per unit area level is distinct and should be considered when estimating savings due to xeriscape, if a household has turf, variation within the xeric portion tends to be swamped out do to

the tremendous absolute value and variability associated with the turfgrass (Figure 5). The already presented lack of erosion in total household savings over time (Figure 2) supports this theory. Additionally, no correlation exists between total residence percent reduction following conversion and the plant coverage within the low-water use zones (scatterplot not shown; $R^2 = 0.01$; N=170).

Summary and Concluding Remarks

To review the major findings presented, for this southwestern U.S. Mojave Desert community:

- Converting a portion of traditional turf to xeriscape reduces total water consumption for residences. The average (post-conversion) reduction was 33% (8800 gallons per month or 105,600 gallons annually) for residences that converted an average 2160 square feet. This savings appears stable over time.

- Properties with at least 60% of their respective landscapeable area as xeric vegetation zones realized, on average, a third reduction in landscape maintenance, both in hours (2.2 per month) and direct dollar outlays ($206 per year) as compared to residences with an equivalent relative amount of turfgrass.

- On a per unit area basis, annual water consumption was much lower for xeric landscape than traditional turf. On average, water consumption for turfgrass areas (at 79.2 gallons per sqft per year) is 4 to 5 times as high as for xeric landscape (17.3 gal/sqft/yr). This suggests that homeowners may save 62 gal/sqft/yr on average by converting turfgrass areas to xeric landscape. Financial savings are also substantial and further enhanced by tier rate structures for water billing.

- Within xeric landscape, both irrigation system design and plant coverage strongly influence per unit area annual consumption. Preliminary analyses suggest irrigation design influences mean per unit area annual consumption up to ±30%. Vegetative canopy coverage influences the same variable up to ±60% or more.

- Even if canopy coverage was the exclusive variable controlling per unit area consumption, it is impossible to obliterate the savings initially realized with xeriscape conversion projects at either the landscape or total residence levels.

The authors acknowledge that the variables, comparisons, and findings presented in this manuscript are not the exclusive arbitrators of xeriscape mediated water usage. For example, the all-important *behavioral* influences are not considered here. The authors specifically acknowledge socioeconomic and personal values contribute to behaviors in irrigation system management. As noted in the Scope[6], these are considered critical and are topics of study by the XCS. Ultimately all comparisons will be integrated into multivariate models as the authors and others (Gregg[4] et. al. 1994) have recognized that this is truly the best approach for study of the dynamic complexities of xeriscape.

That stated, the authors feel this is a unique and needed study of xeriscape, linking the impact of physical manifestations and spatial considerations to consumption in a practical real world setting. The ability to look at consumption on a per unit area basis with submeters has permitted several of the confounding indoor uses to be partitioned out and the true savings of xeriscape to be revealed. Some of the important variables associated with xeric area consumption have also been explained. The results of this study and others' support the authors' conclusion that xeriscape promotion is an efficient means for obtaining water conservation in areas where total household consumption is dominated by outdoor irrigation.

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