

Results and Discussion

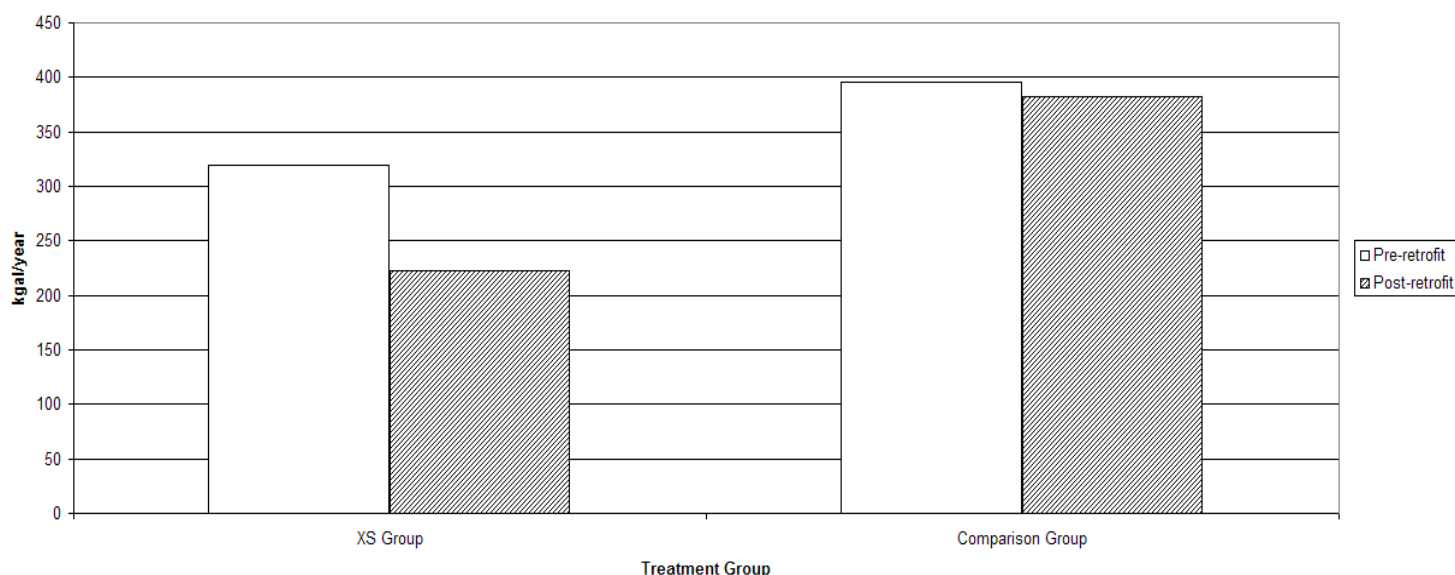
REDUCTION IN TOTAL HOUSEHOLD WATER CONSUMPTION FOLLOWING CONVERSION TO XERISCAPE

Results for the XS Group pre/post-conversion comparisons are shown in Table 11 and Figure 1.

TABLE 11: Pre-/Post-Retrofit Analyses for XS Group

	Pre-retrofit (kgal/yr)	Post-retrofit (kgal/yr)	Difference in Means (kgal/yr)	t-tests (* denotes significance)
Xeriscape Treatment n=321	Mean=319 Median=271	Mean=223 Median=174	96* (30% reduction from pre-retrofit)	t=16.8* p<0.01
Comparison n=288	Mean=395 Median=315	Mean=382 Median=301	13 (3% reduction from pre-submetering)	t=1.85 p=0.07
Difference in Means (kgal/yr)	76*	159*		
t-tests (* denotes significance)	t=4.32* p<0.01	t=9.69* p<0.01		

FIGURE 1: Pre-/Post-Retrofit Consumption for XS and Comparison Groups



Mean monthly consumption for the residences dropped an average of 30% following conversion. A dependent *t*-test demonstrates that the reduction in usage is highly significant ($t=16.8$; $p<0.01$).

Though individual performance may vary greatly, the overwhelming majority of homes in the study saved water following the conversion (285 out of 321 analyzed). This finding of about a third reduction in consumption is nearly identical to findings from a study of residences in Mesa, Arizona (Testa and Newton² 1993). It may be that a reduction of about this percentage may be anticipated to occur when the average single-family residence built in the late 20th century does an average-size conversion in the southwestern United States. The large savings are likely in part because the great majority of water consumption goes to outdoor irrigation in this region. In this study, the average savings realized was 96,000 gallons per year per residence.

The difference in consumption of the pre-retrofit homes to the non-contacted comparison homes is shown in Table 11 and Figure 1. As demonstrated, a *t*-test of consumption between these two groups shows there was significant difference in initial consumption between the two groups (*t*=4.32; *p*<0.01), suggesting self-selection bias. This is not surprising since recruitment of study participants was voluntary. People who were already conserving more were apparently more likely to enroll and agree to convert a portion of their respective properties. This does not however invalidate the results, as (i.) this incentive-based approach is essentially the same as the approach used for enrolling people in the actual program SNWA has (see Appendix 5) and, more importantly (ii.), there is no compelling evidence that the Comparison Group experienced significant reduction over the same time period so the savings are likely attributable exclusively to the landscape conversion.

The analysis procedures in the Scope (Appendix 1) suggest that the impact of submetering on outdoor irrigation may be revealed by comparing consumption at the conventionally landscaped properties with submeters (the TS Group) to that for the associated comparisons for that Group. The data appearing in Table 12 fulfill this prescribed Scope treatment.

TABLE 12: Pre-/Post-Retrofit Analyses for TS Group

	Pre-submetering (kgal/year)	Post-submetering (kgal/year)	Difference in Means (kgal/yr)	t-tests (* denotes significance)
Submetered Conventionally Landscaped Treatment n=205	Mean=352 Median=303	Mean=319 Median=268	34* (10% reduction from pre-retrofit)	t=5.08* p<0.01
Comparison n=179	Mean=364 Median=314	Mean=347 Median=296	17* (5% reduction over timeframe)	t=2.08* p<0.05
DIFFERENCE IN MEANS (KGAL/YR)	12	28		
T-TESTS (* DENOTES SIGNIFICANCE)	t=0.52 p=0.60	t=1.41 p=0.16		

There are two potential issues though with trying to consider this analysis an evaluation of the effectiveness of submetering. First, submetering is typically studied where the scenario is one where water consumption through the submeter is relayed to end-use customers and where the customers are billed for it. Without consumption data and billing, the residents in this study have received no price signal to encourage them to read the meter or reduce consumption. This theory corresponds with what staff members have observed in the field with respect to the behavior of customers. Most participants apparently did not even think about the meter until it was time for their yearly site review and often they stated they had forgotten it was even there. So here, the dynamic of submetering is rather unique and the impact most likely minimal.

The second consideration, at least as potentially significant, is the fact that participants had been exposed to annual site visits, which is likely a more important variable in terms of modifying behavior (no conservation training or formal education took place at site visits, though staff members did answer questions posed to them). Indeed, the Comparison Group provides for a good gauge of the impacts on treatment groups due to site visits. Initially, results seem to suggest a reduction of possibly up to 34,000 gallons annually associated with visits and submetering ($t=5.08$; $p<0.01$) though, as revealed in the next analyses, this impact appears to be only temporary (seen only in the first year, Table 15) and is probably in actuality much more negligible given half the “reduction” also appears to have taken place in the control group ($t=2.08$, $p<0.05$). The control group reduction may be due to background conservation at the community level.

With respect to understanding how submetering with consumption billing may be of conservation benefit, a national research effort (Mayer et al. 2004¹⁴), supported in part by SNWA, has just been completed which provides much more insight into the benefits of submeters for water conservation purposes (also see Rosales¹⁵ et al. 2002).

ASSESSMENT OF SAVINGS POTENTIAL ACROSS TIME AND SEASONS

For the XS Group, significant reduction in total yearly consumption took place immediately following conversion and remained relatively stable at that decreased level through subsequent years, showing no erosion with time (Table 13 and Figure 2). In every year, the XS Group consistently had lower consumption than the Comparison Groups, and this was statistically significant (Table 13). This suggests that conversions are a viable way to gain substantial water savings over at least a medium-term timeframe and quite possibly over a long one as well. It also resolves questions about whether or not xericape takes more water in the first year following conversion (apparently the answer is no) and it suggests that, at least over the medium-term, there is no erosion of savings obtained from conversions due to residents’ response to growth of plants in their xeric areas.

For the XS Group, the relative reduction in consumption became even more pronounced in the summer (Table 14) where, savings averaged 13,000 gallons per summer month (Table 14: $t=18.5$; $p<0.01$) versus an average of 8,000 per month over the entire year. It should be noted that a very small, but statistically significant reduction of 1,600 gallons per month appears to have also taken place in the Comparison Group during the summer (in a pre- vs. post-comparison of the study timeframe, Table 14: $t=1.98$; $p<0.05$). Overall, the results are consistent with the theory that xeric landscapes save the most during the summer. The comparative per-unit analyses that follow reveal why this is the case.

In considering savings stability over extended time, it was found that the submetered TS group only demonstrated significantly decreased consumption for the first year following retrofit, after which savings were not significant (Table 15; statistics in table). This initial reduction might be due to residents' interest in the research and in conservation when new to the study, this wearing off with time. Again, it is important to recall that in no single year was the consumption statistically different from the comparison group properties. The submetered TS Group did have significantly lower consumption in the summer, with a savings of 3,300 gallons per month (Table 16: $t=3.78;p<0.01$) whereas the comparison group to the TS Group showed no such reduction (Table 16: $t=1.03;p=0.31$). However, there was no difference in average monthly summer consumption between the submetered properties and the controls after the retrofit (Table 16: $t=1.03;p=0.31$). Overall the results in Table 15 seem to reflect the finding that little enduring change in consumption was achieved by the TS Group over time despite submeter installation.

FIGURE 2: Pre-/Post-Retrofit Consumption for XS Group Across Time

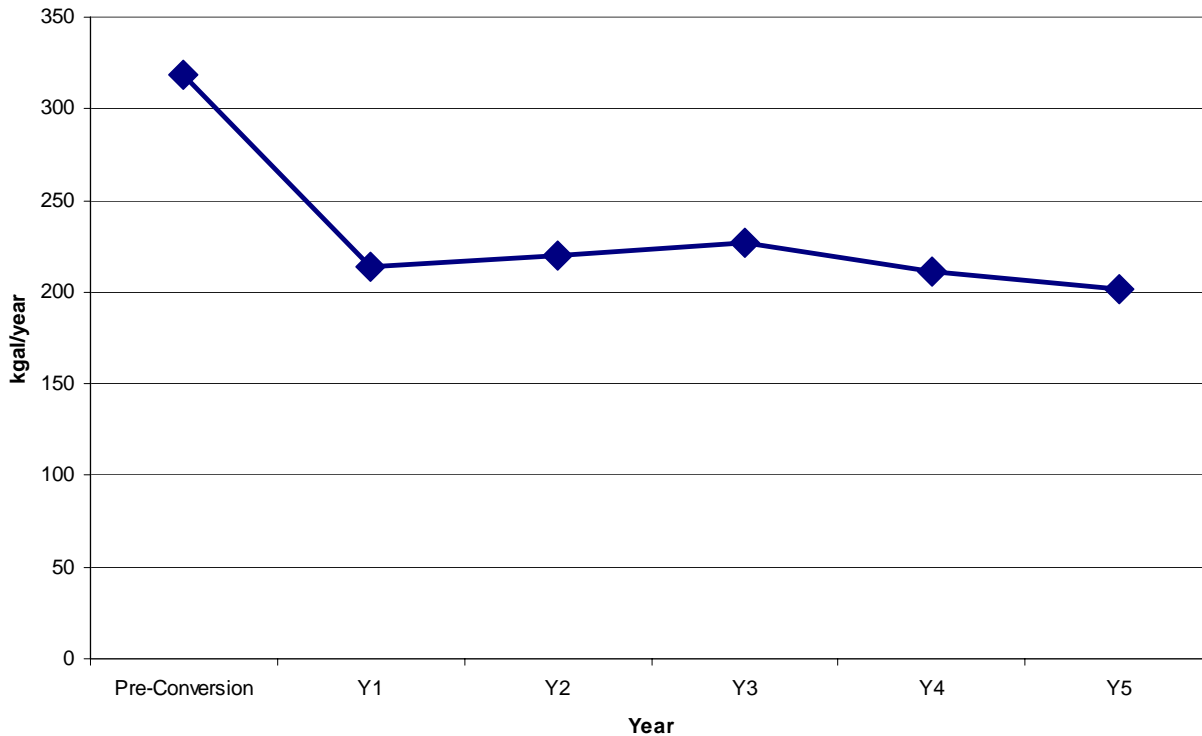


TABLE 13: Enhanced Post-Retrofit Analyses for XS Group Across Time

Post-retrofit Consumption	First Year Post-retrofit (Y1)	Second Year Post-retrofit (Y2)	Third Year Post-retrofit (Y3)	Fourth Year Post-retrofit (Y4)	Fifth Year Post-retrofit (Y5)
Xeriscape Treatment (kgal/year)	214^Δ (32% reduction from pre-retrofit) n=320	220^Δ (30% reduction from pre-retrofit) n=318	227^Δ (28% reduction from pre-retrofit) n=306	211^Δ (33% reduction from pre-retrofit) n=211	202^Δ (36% reduction from pre-retrofit) n=61
Comparison Group (kgal/year)	372 n=280	387 n=275	383 n=260	362 n=183	345 n=54
Difference in Means (kgal/year)	158	167	156	151	143
t-tests (* denotes significance)	t=9.98* p<0.01	t=9.29* p<0.01	t=9.08* p<0.01	t=8.02* p<0.01	t=4.85* p<0.01

Treatment group values with a ^Δ are significantly lower than pre-retrofit value.

TABLE 14: Summer Post-Retrofit Analyses for XS Group

	Pre-Retrofit Summer Consumption (kgal/month)	Post-Retrofit Summer Consumption (kgal/month)	Difference in Means (kgal/month)	t-tests (* denotes significance)
Xeriscape Treatment n=321	Mean=38 Median=31	Mean=25 Median=19	13*	t=18.5* p<0.01
Comparison Group n=288	Mean=47 Median=38	Mean=46 Median=35	1.6*	t=1.98* p<0.05
Difference in Means (kgal/month)	9*	21*		
t-tests (* denotes significance)	t=4.23* p<0.01	t=10.1* p<0.01		

TABLE 15: Enhanced Post-Retrofit Analyses for TS Group Across Time

Post-submetering Consumption	First Year Post-submetering (Y1)	Second Year Post-submetering (Y2)	Third Year Post-submetering (Y3)	Fourth Year Post-submetering (Y4)	Fifth Year Post-submetering (Y5)
Submetered Conventionally Landscaped Treatment (kgal/year)	291^Δ (6% decrease from pre-submetering) n=228	312 (1% increase from pre-submetering) n=229	317 (2% increase from pre-submetering) n=228	315 (2% increase from pre-submetering) n=146	No Data Available
Comparison Group (kgal/year)	332 n=170	357 n=173	351 n=167	351 n=108	No Data Available
Difference in Means	41	45	34	36	
t-tests (* denotes significance)	t=2.28 p=0.02	t=2.39 p=0.02	t=1.65 p=0.10	t=1.40 p=0.16	

Treatment group values with a ^Δ are significantly lower than pre-submetering value.

TABLE 16: Summer Post-Retrofit Analyses for TS Group

	Pre-Submetering Summer Consumption (kgal/month)	Post-Submetering Summer Consumption (kgal/month)	Difference in Means (kgal/month)	t-tests (* denotes significance)
Submetered Conventionally Landscaped Treatment n= 205	Mean=41.7 Median=34.0	Mean=38.5 Median=31.0	3.3*	t=3.78* p<0.01
Comparison Group n=179	Mean=42.0 Median=36.0	Mean=41.0 Median=34.7	1.0	t=1.02 p=0.31
Difference in Means (kgal/month)	0.3	2.5		
t-tests (* denotes significance)	t=0.97 p=0.92	t=1.03 p=0.31		

COMPARISON OF PER-UNIT AREA WATER APPLICATION BETWEEN TURFGRASS AND XERIC LANDSCAPE

Annual application

Annual per unit area irrigation application data summaries are found in Table 17 and Figures 3 and 4. There was a great difference in the annual water application to turf and xeric landscape areas (Table 17 and Figure 3). Turf received an average of 73.0 gallons per square foot annually (117.2 inches), while xeriscape received on average, just 17.2 gallons (27.6 inches) each year (only 23.6% of the amount of water applied for turfgrass maintenance). The difference was thus 55.8 gallons per square foot per year (89.6 inches), and this was found to be highly significant assuming a normal distribution of data ($t=27.0$; $p<0.01$).

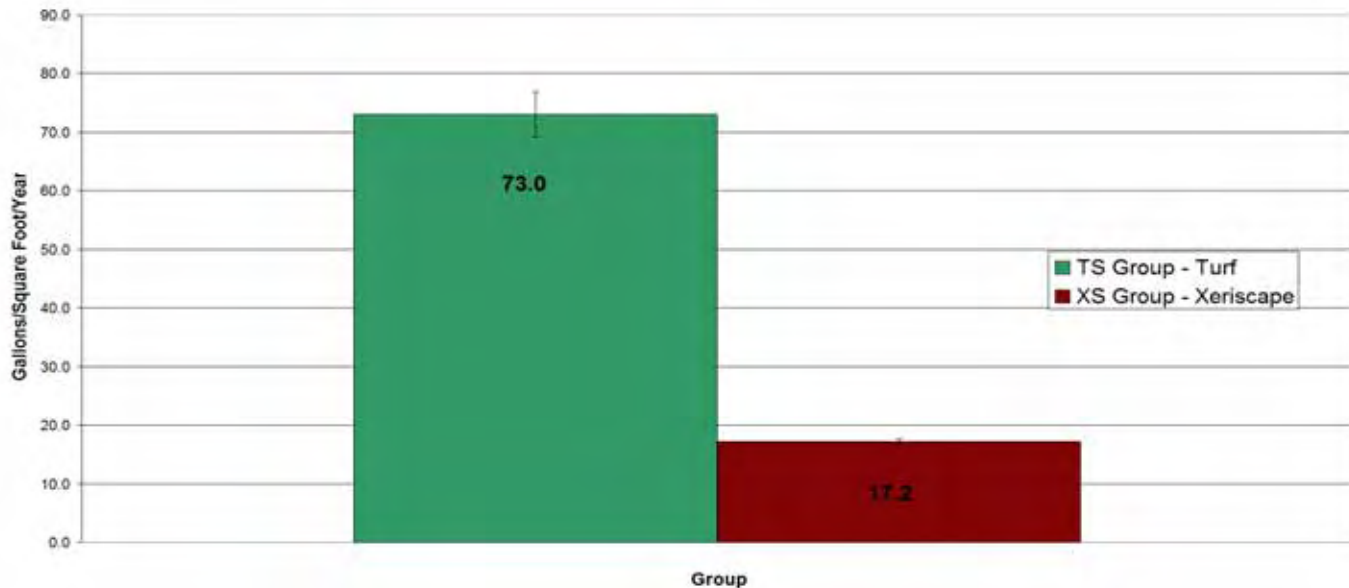
TABLE 17: Annual Per-Unit Area Application to Turf and Xeriscape

	Per Unit Area Application (gallons/square foot/year)	Per Unit Area Application (inches/year)	Sample Distribution Statistics
Submetered Turf (TS Group) $n_s=107$	Mean=73.0 Median=64.3	Mean=117.2 Median=103.2	Standard Deviation=40.0 Skewness=1.17 Kurtosis=1.36
Submetered Xeriscape (XS Group) $n_s=1550$	Mean=17.2 Median=11.5	Mean=27.6 Median=18.5	Standard Deviation=18.6 Skewness=3.14 Kurtosis=14.9
Difference (gallons/square foot/year)	Mean=55.8	Mean=89.6	
t-tests (* denotes significance)	$t=27.0^*$ $p<0.01$		
Levene's Test (* denotes significance)	$F(1, 1655)=130.3^*$ $p<0.01$		
Mann-Whitney U Test (* denotes significance)	$U=10177$ $z=15.2^*$ $p<0.01$		

Detailed statistics were not generated for the small set of multifamily and commercial sites; however, the average consumption on those xeric areas where viable data could be collected was 16.7 gallons per square foot per year ($n_s=22$). This suggests the use of xeric landscape in these sectors may result in similar savings as that observed above on a comparative landscape basis

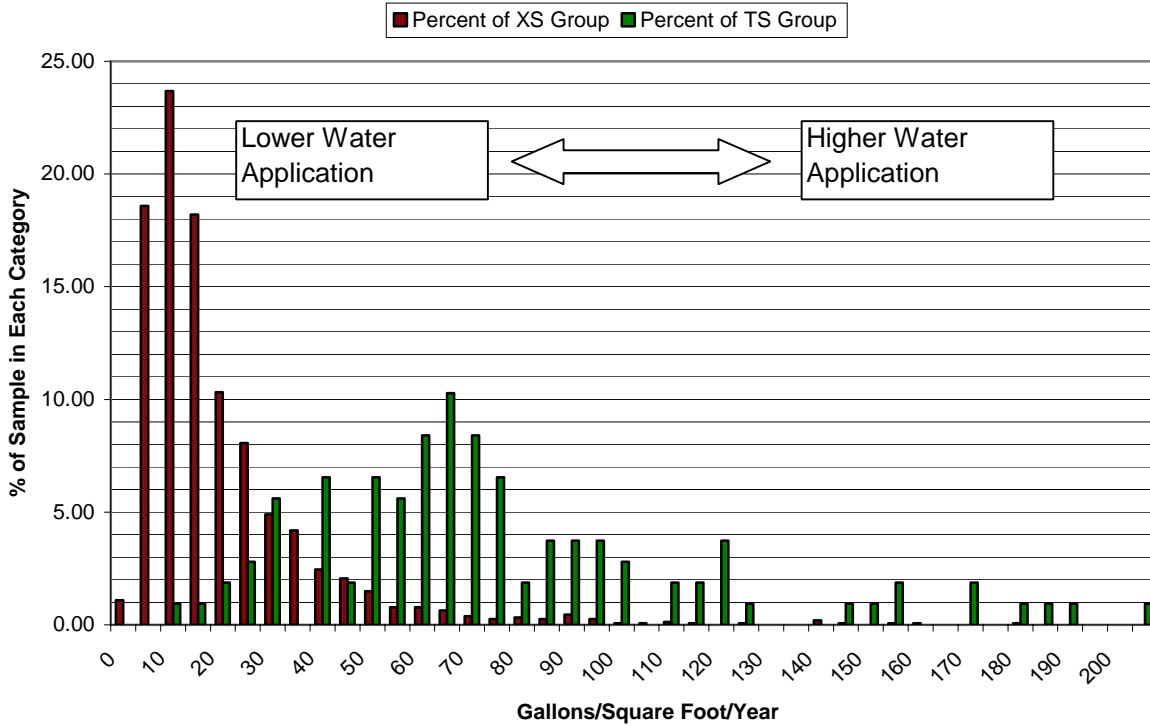
(i.e., savings of ca. 55.8 gallons per square foot annually versus what application would have been for turf).

FIGURE 3: Annual Per Unit Area Application to Turf and Xeriscape



Distinct differences in the sample distributions for the XS and TS irrigation data were of concern from a statistical analysis perspective. Both distributions had features strongly suggesting data was not distributed homogeneously across the two groups (Table 17 and Figure 4). In particular, the XS Group data was heavily skewed with the vast majority of participants using very little water. Turf application, while indeed skewed, appears almost normal compared to xeric application, which is very heavily skewed (skewness = 3.14) and peaks sharply (kurtosis=14.9) at the lower end of the distribution. This is because the vast majority of XS participants used a *very* small amount of water to irrigate their xeric areas, while a handful used greatly more volume on theirs. Because *t*-tests assume normality, the atypical and non-congruent distributions were of sufficient concern to justify running a Levene’s Test simultaneous with the *t*-tests to assess the potential need to apply non-parametric analytical techniques (though in practice the need for normality is lessened with large sample sizes due to the tendency of such a collection of data to mimic a normal distribution; aka. the central limit theorem). Indeed, the Levene’s Tests demonstrated significant differences in the distributions [Levene $F(1,1655) = 130.3; p < 0.01$]. This suggested the need to backup the findings with non-parametric approaches. *Mann-Whitney U* (a summation and ranking based approach to the problem) was chosen as a good backup test. Associated *z* statistics for this test with corresponding probabilities are thus reported with the results in Table 17 as supporting evidence for statistical difference in irrigation application between the groups.

FIGURE 4: Distribution of Annual Per Unit Area Application Data for Turf and Xeriscape



Monthly Application

Monthly submeter data summaries for the XS Group and exclusively monitored turf TS Group participants appear in Table 18. It should be noted that at times the interval between reads stretched over more than one month and thus the dataset for the monthly data is slightly different than that for the above annual comparison as only consumption data deemed complete and assignable to a given month could be included (sometimes consumption across a two-month gap was averaged to fill the gap). There were issues with resolution in monitoring because typically at least a thousand gallons had to pass through the meter between reads in order for the consumption figure to be advanced and registered by the reader, and sometimes this did not happen for XS Group submeters monitoring relatively small areas due to low consumption. Both these factors likely result in slight inflation of monthly consumption values for both groups and this indeed appears to be manifest if monthly averages are summed across the year (i.e., this per unit area consumption figure is slightly higher than the annual one calculated in the previous section). Still, on a monthly basis the data is generally valid and valuable in comparative analyses and in comparing water application to irrigation requirements. Per-unit area application data is displayed graphically in Figure 5.

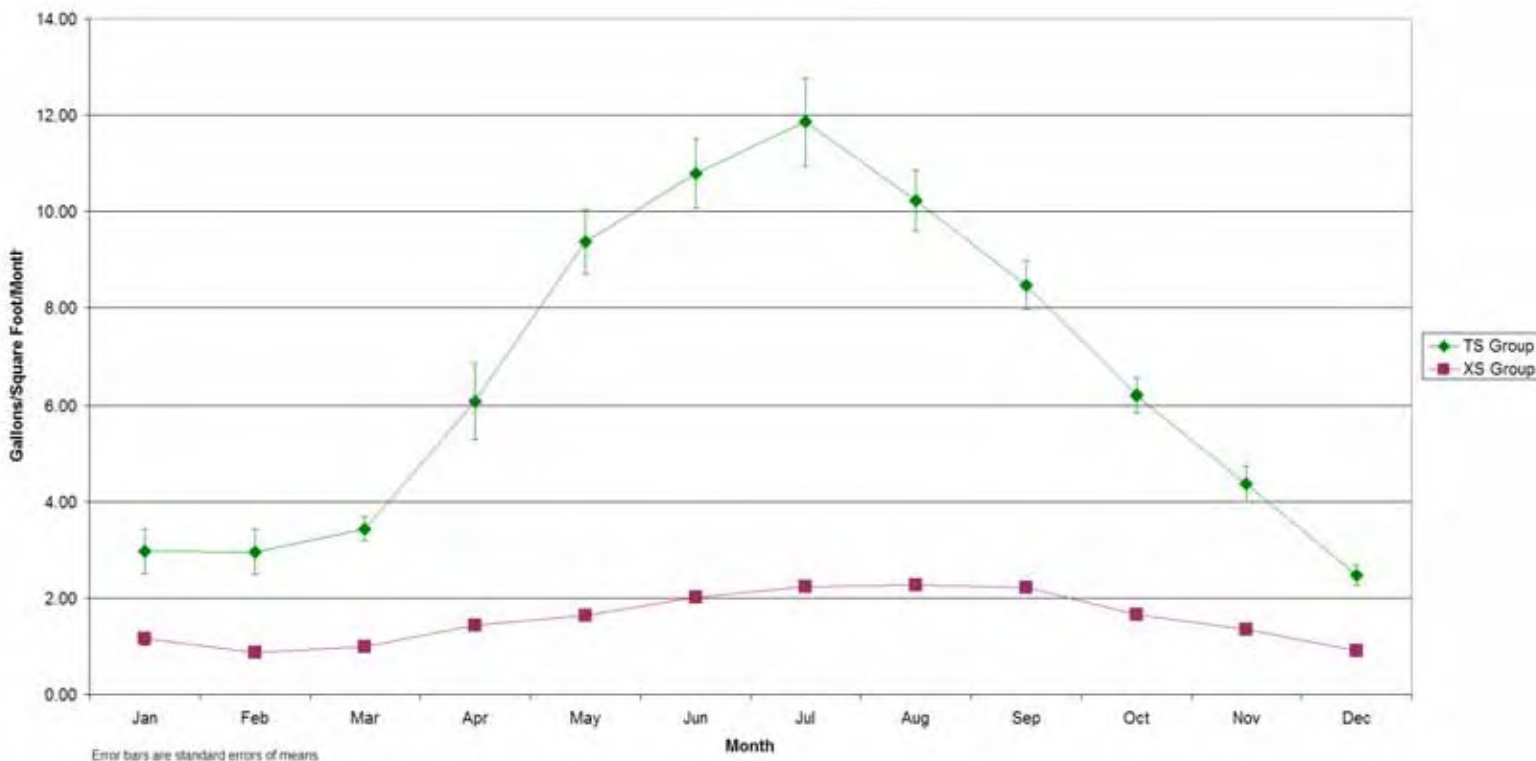
TABLE 18: Monthly Per-Unit Area Application to Turf and Xeriscape

	Jan Gal/SqFt	Feb Gal/SqFt	Mar Gal/SqFt	Apr Gal/SqFt	May Gal/SqFt	Jun Gal/SqFt	Jul Gal/SqFt	Aug Gal/SqFt	Sep Gal/SqFt	Oct Gal/SqFt	Nov Gal/SqFt	Dec Gal/SqFt
Submetered Turf (TS Group)	2.97	2.96	3.44	6.07	9.37	10.79	11.86	10.23	8.47	6.20	4.37	2.47
	2.11	2.06	3.29	4.85	7.86	9.38	10.50	8.71	7.15	5.29	3.50	1.96
	n _s =85	n _s =85	n _s =85	n _s =88	n _s =93	n _s =93	n _s =95	n _s =96	n _s =99	n _s =105	n _s =107	n _s =106
Submetered Xeriscape (XS Group)	1.16	0.87	0.99	1.43	1.64	2.01	2.24	2.27	2.22	1.66	1.35	0.91
	0.46	0.43	0.57	0.83	1.08	1.30	1.40	1.39	1.27	1.02	0.77	0.48
	n _s =1291	n _s =1337	n _s =1377	n _s =1409	n _s =1412	n _s =1421	n _s =1431	n _s =1456	n _s =1496	n _s =1519	n _s =1534	n _s =1534
Difference (Gallons/Sqft)	1.81	2.09	2.45	4.64	7.74	8.78	9.62	7.96	6.25	4.54	3.02	1.56
t-tests (* denotes significance)	t=73.36* p<0.01	t=7.52* p<0.01	t=13.33* p<0.01	t=9.92* p<0.01	t=29.87* p<0.01	t=27.7* p<0.01	t=26.22* p<0.01	t=21.96* p<0.01	t=13.15* p<0.01	t=17.59* p<0.01	t=13.45* p<0.01	t=9.39* p<0.01
Mann-Whitney U Tests (* denotes significance)	U=23499 z=8.84* p<0.01	U=18127 z=10.54* p<0.01	U=15959 z=11.27* p<0.01	U=14225 z=12.14* p<0.01	U=6824 z=14.49* p<0.01	U=4415 z=15.10* p<0.01	U=6062 z=14.89* p<0.01	U=9776 z=14.13* p<0.01	U=12307 z=13.91* p<0.01	U=14501 z=14.04* p<0.01	U=25290 z=11.98* p<0.01	U=31202 z=10.62* p<0.01

Note: bold gal/sqft values are means; regular font gal/sqft values are medians

The first, most obvious finding from the graph is that, turf application exceeds xeric application by a large statistically significant margin in every month. Ultimately, this is what constitutes the large annual savings seen at the annual landscape application and total home consumption levels.

FIGURE 5: Monthly Per-Unit Area Application for Turf and Xeric Areas

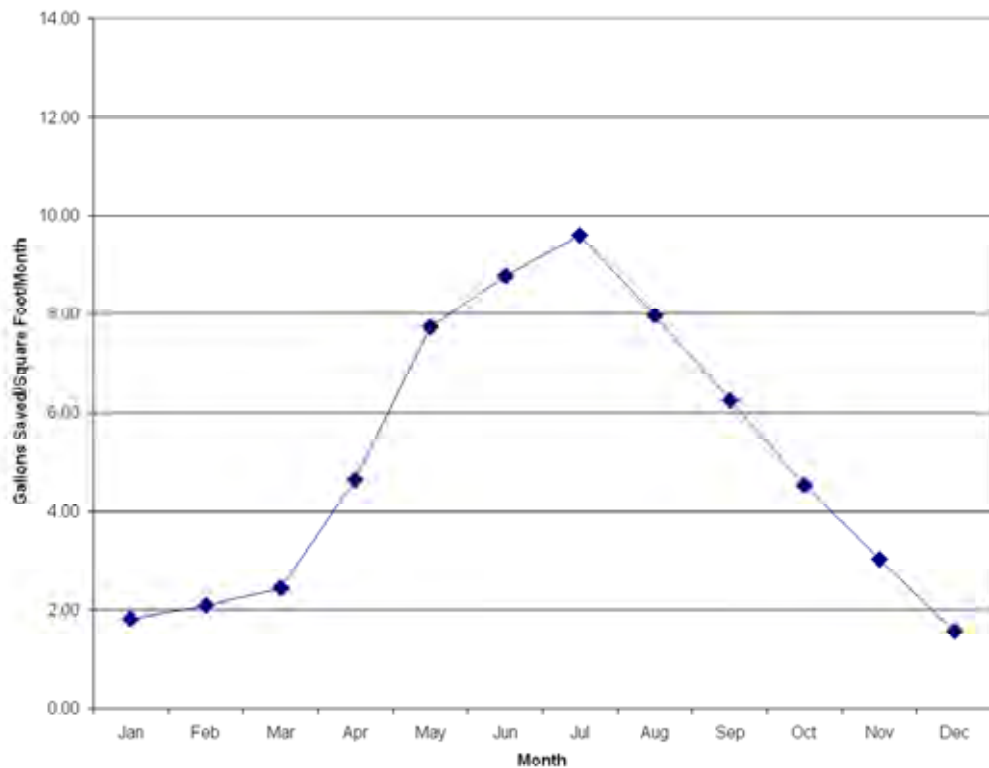


The data also suggests, among other things, that the reason for the aforementioned enhancement of savings during the summer is because turf application peaks drastically in the summer whereas application to xeriscape does not. A graph of the difference between the groups (Figure 6) demonstrates this is the case, and the observed pattern in savings obtained each month parallels the pattern observed for turfgrass application (Figure 5). It appears that the reason xeriscape saves so much water in this climate is related as much to the high demand of turfgrasses vs. plantings of most other taxa as it is to any inherent aspect of xeric landscape *per se*. Furthermore, inefficiencies in spray irrigation system design, installation, and operation further contribute to the savings of having xeric landscape in place of turf because these inefficiencies even further drive up application to the turfgrass to the point that it is much higher than the rate of evapotranspiration over the same timeframe (Figure 7).

Additional inferences can be made about the application of water to turfgrass areas by the participants. Specifically, on average, whereas they irrigated relatively efficiently in the spring, with the onset of summer temperatures in May, residents quickly increased their application, ultimately going way above ET_0 . Moreover, they tended to stay well above ET_0 through November. While it is expected that due to system inefficiencies, a high K_c for Fescue (Source: Cooperative Extension Office), leaching fraction considerations, and other factors, application usually would tend to exceed ET_0 for turfgrass locally, the pattern suggests that

overall people irrigate relatively efficiently in spring as the weather warms and ET_o rises, probably due to the immediate feedback they receive as the grass yellows in response to moisture deficits. As they observe their landscape beginning to show visible signs of stress due to deficit irrigation, they increase their application accordingly. However, in May, they appear to start overreacting to the increasing stress and increase irrigation to well over the requirement. In fall, they do not however appear to respond in a correspondent way “coming down the curve,” probably because they do not have the same sort of visual feedback mechanism as they do in spring (i.e., they do not view the grass being “too green,” wet, nor the occurrence of runoff as something amiss). The result is a long lag in returning to application rates more closely approximating ET_o in the fall and early winter (Figure 7).

FIGURE 6: Monthly Per-Unit Area Savings (Turf Area Application– Xeric Area Application)



It is more difficult to make similar types of inferences with respect to xeric area application. While there is research under way on a variety of desert taxa to attempt to quantify irrigation demand and there have been generalized attempts to model or approximate xeriscape need based on observations and fractions of reference ET_o , at this time it would be risky to make highly specific inferences. The relative flatness of the xeric curve in Figure 5 does though seem to suggest that residents may irrigate xeric areas inefficiently as they seem to show little response to demands of different seasons.

FIGURE 7: Monthly Per-Unit Area Application to Turf and Reference Evapotranspirational Demand

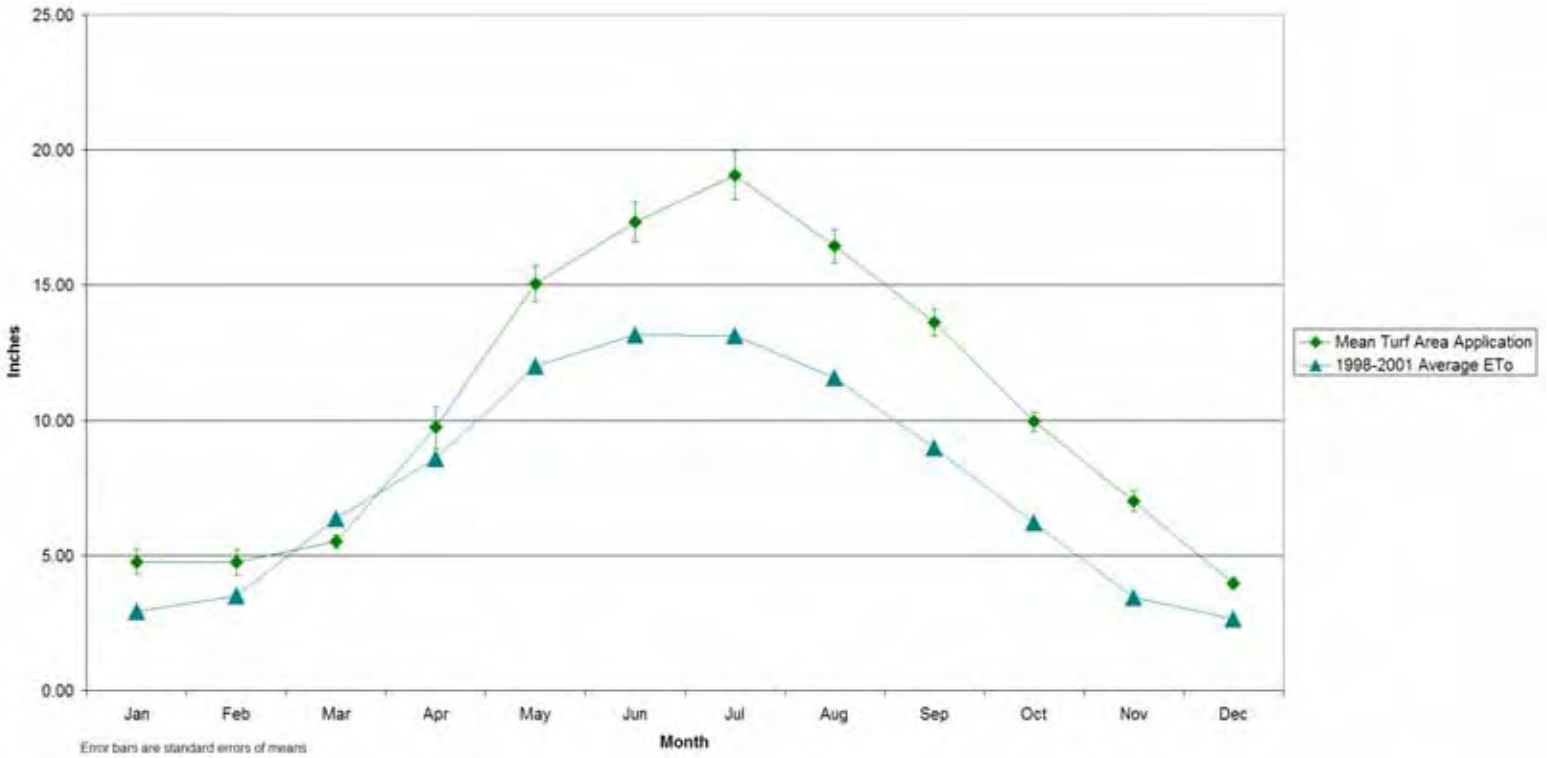
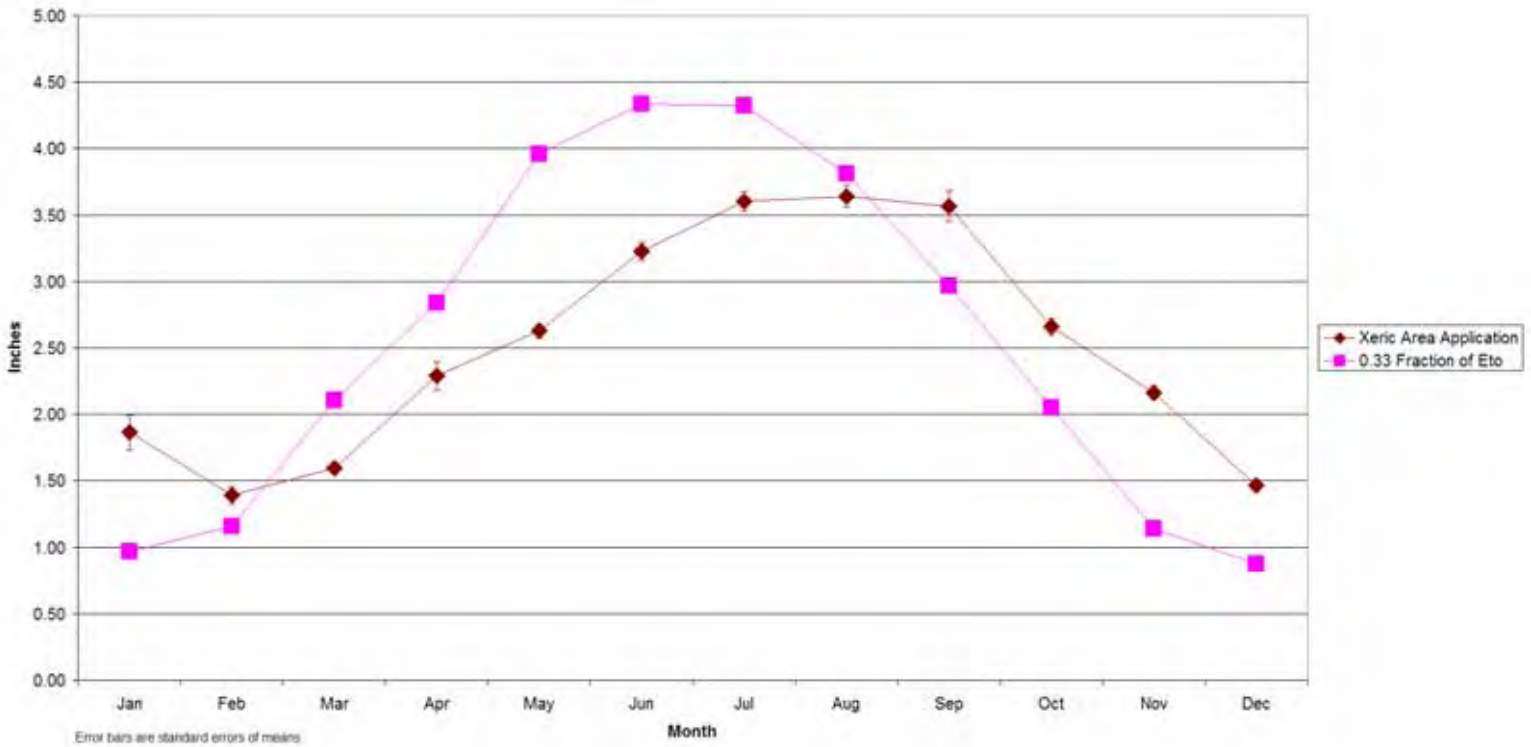


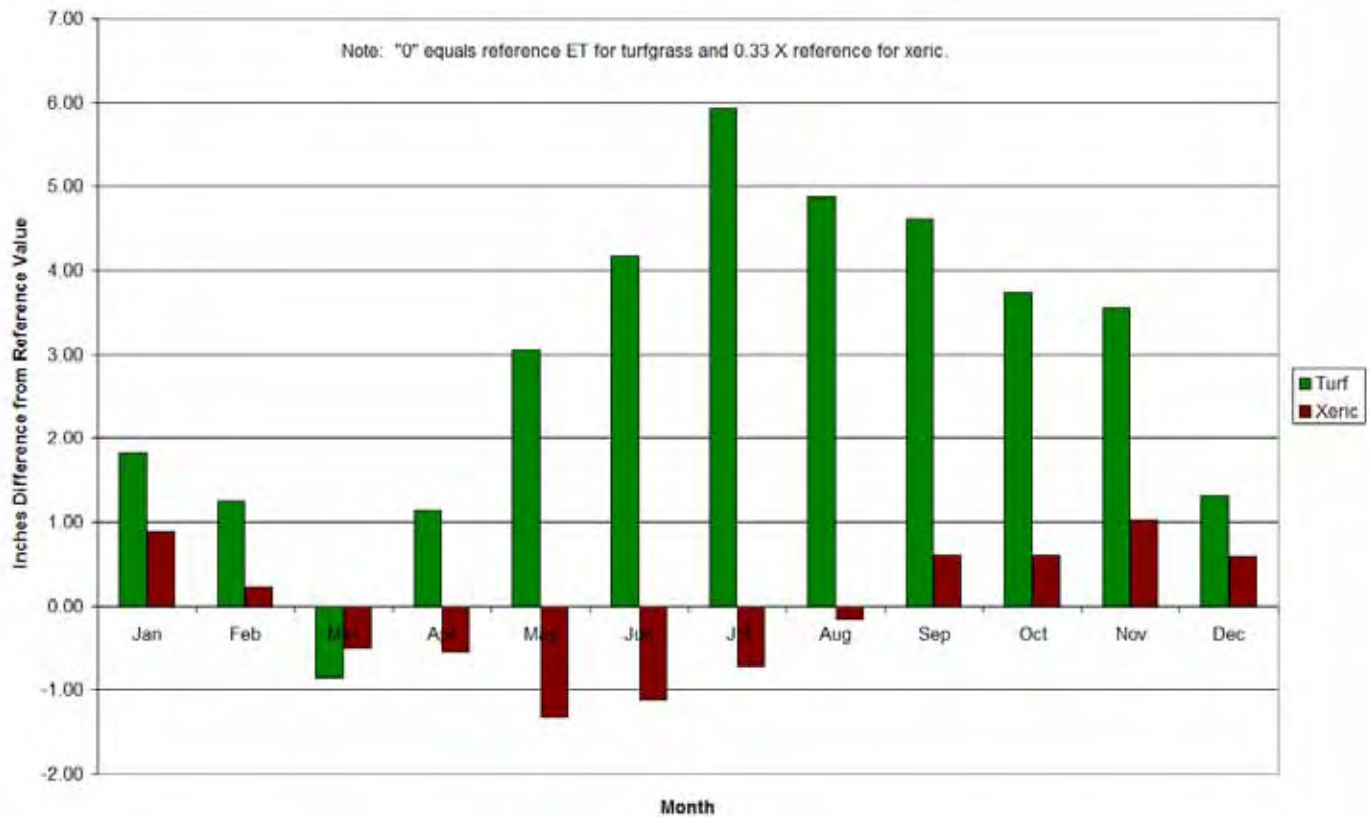
FIGURE 8: Monthly Per-Unit Area Application to Xeric Areas and 1/3 of Reference Evapotranspirational Demand



If one does assume a sometimes-used local “rule-of-thumb” which states that xeriscape requires about a third of what turf needs, one can compare per-unit area application for xeriscape and this modified reference value (Figure 8). Using a one-third ET_0 value is not out-of-line with modification approaches employed by the Irrigation Association¹⁶ (2001) or WUCOLS¹⁷ (2000) for estimating needs of low-water-use woody taxa in high-temperature southwestern regions. It is quite noteworthy that the summation of monthly xeric-area application values yields a yearly xeric-area application usage of 30.1 inches per year - nearly identical to the summation of monthly $.33(ET_0)$ values, which is 30.5 inches. This would appear, initially at least, to suggest that this rule of thumb may work quite well on average for approximating xeric landscape usage over broad spatial and long temporal scales, even if it may not precisely work in a given month.

Normalizing these aforementioned potential reference values and the absolute departure from these in observed water application may reveal insights about when during the year the greatest absolute potential savings can be obtained. In Figure 9, this is done such that the absolute difference between mean application and respective references is quantified and displayed. Here, “0” (reference) is ET_0 for turf and $.33(ET_0)$ for xeric landscape respectively.

FIGURE 9: Absolute Departure in Irrigation Application from Derived Respective Reference ET_0 Values (Turf and Xeric Areas)



Even with the xeric reference but a third of ET_0 , it appears that, in addition to the differences due to plant usage, much more water is wasted in application to turfgrass than to xeric landscape. The

greatest waste for turfgrass occurs in the period of May through November. Thus, any improvements in turfgrass irrigation efficiency during this timeframe will have the greatest absolute impact in terms of water conservation. Interestingly, the greatest absolute potential for savings for xeric areas is not during this period, but rather from September thru January. Indeed to look upon the graph, one might initially conclude that residents under-irrigate xeric areas in spring and summer. Caution should be observed though in this type of reasoning as the $.33(ET_0)$ reference is only theoretical and developed here as a guideline. That stated, the findings may suggest that, on average, little potential exists during the spring and summer for significant water savings by irrigation improvements to xeriscape. Finally, on an absolute basis, little total potential appears to exist for squeezing additional conservation out of xeric landscapes as, considered over the span of an entire year, xeric area irrigation appears to be efficient.

In contrast, opportunities to save great volumes of water appear to exist for turf areas throughout most of the year. Significant overwatering appears to occur May through November; efficiency improvements will yield the most absolute benefit during this period of the year. But how does the issue appear when one considers the problem through the perspective of *when can the most readily obtainable savings be achieved?*

Considering absolute irrigation departure from reference as above gives insights into the total potential to save water through a variety of irrigation improvements. However, there is also the question of how much water could be saved principally by relatively simple improvements in *controller management*. Figure 10 is such an attempt to view the problem through this framework, where the blue line is ET_0 for turf and $.33(ET_0)$ for xeric areas respectively, and is equivalent to 100% of each respective types reference value or “perfect efficiency.” Absolute values for inches application were normalized by converting them to percent departure from normalized respective reference values. In this way the relative departure from these aforementioned references is displayed as a percent value.

FIGURE 10: Relative Departure in Irrigation Application from Derived Respective Reference ET_0 Values (Turf and Xeric Areas)

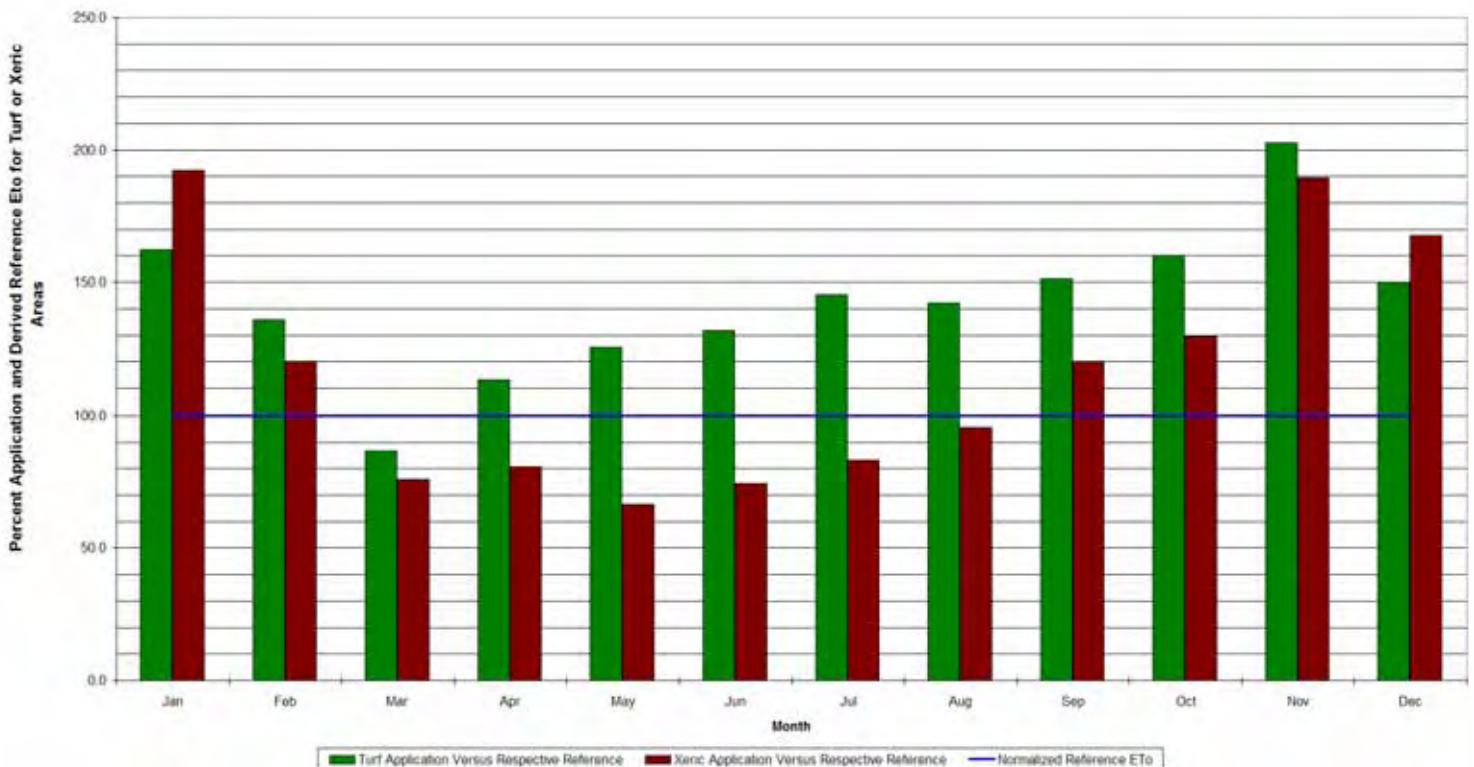
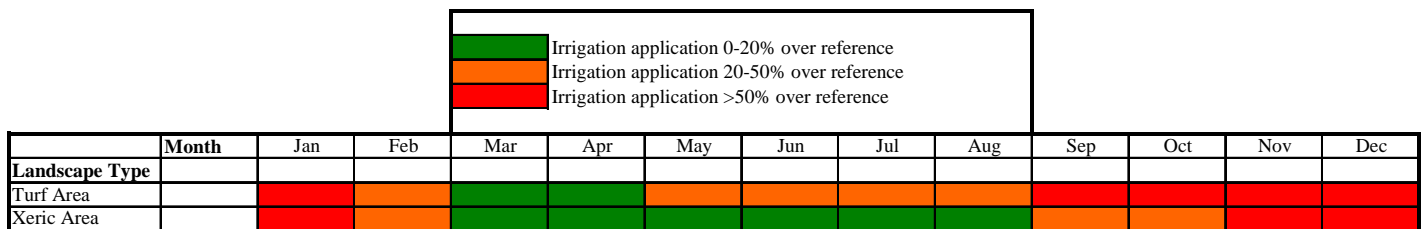


Figure 10 may suggest that there are specific times of the year when people irrigate both turf and xeric landscapes more or less efficiency than the ideal. As interpreted from Figure 10, the most inefficient irrigation, in a relative sense, may actually occur during non-peak months if efficiency is defined to be the difference between theoretical requirement and application. Expanding on this type of analysis and breaking the above relative departure values into efficiency classes yielded a summary of when people appear to irrigate most and least efficiently (Figure 11).

FIGURE 11: Relative Departure in Irrigation Application from Derived Respective Reference ET₀ Values (Turf and Xeric Areas)



It is well understood that, in practice, there is no such thing as a perfectly efficient irrigation system and, for this reason, the green designation in Figure 11 includes relative applications ranging from subreference values to those up to 20% above reference (this allows that there is typically a need in practice to compensate for lacking distribution uniformity in irrigation systems).

Interpretation of Figure 11 suggests that both xeric and turf areas are irrigated relatively efficiently in the spring. Irrigation efficiency for turfgrass areas starts to decline in May to the point where significant waste starts to occur and this continues until about September. In contrast xeric irrigation continues to be quite efficient during this time. Around September, turf is starting to be very inefficiently watered, in a relative sense, owing to residents’ failure to respond to the lower rate of evapotranspiration and decrease irrigation accordingly. A similar, if less severe, pattern is observed for xeric area irrigation, where at this time, these areas are also beginning to be irrigated inefficiently, probably for the same reason. By November, both xeric and turfgrass areas are, on average, being severely over-irrigated and this pattern continues through the cool season until February. Finally, efficiency starts to recover and both areas are actually being irrigated under suggested reference values by the end of March.

It needs to be acknowledged that some of this conclusion includes theoretical and speculative reasoning, especially considering the lack of data on xeric landscape water requirements and the fact that in actuality stress impacts, including those from water stress, lag in woody vegetation (Kozlowski et al. 1990¹⁸) so efficiency as considered here is much harder to gauge. Nevertheless, again, failure of residents to more effectively tie controller management (irrigation frequency and duration) to the changing environmental conditions appears to be one of the most pressing reasons for efficiency losses in both study groups, it is just to a lesser extent (and much lesser absolute impact in gallons) for those with more xeriscape.

This set of analyses provides SNWA with quantitative data on what parts of the year it should focus its strongest controller-management-oriented conservation messaging. This could be considered the “low hanging fruit” in terms of water conservation; it is where messaging to effect changes that may not require significant work and monetary investments on the part of residents may produce significant water conservation results. To recap, the findings in this section suggest the most value can be obtained by targeting controller-management messaging to the late summer and early fall as people begin to depart from “reasonable” efficiency values owing to their collective failure to adjust irrigation down for the cooler, low ET season. Reemphasis of this messaging should continue all winter long.

The exploration of application per-unit area vs. reference values is important for making inferences about management efficiency of water application. This; however, should not obscure the result that on average, per-unit area, xeric landscapes in this study received much less water in totality (Figures 3 and 4) and the pattern of received irrigation showed much less tendency towards “peaking” (Figure 5) than those areas planted with turf.

SOURCES OF SIGNIFICANT VARIABILITY IN SINGLE-FAMILY RESIDENTIAL CONSUMPTION

As explained in Methodology, multivariate regression analyses were employed to identify and quantify sources of variability of mainmeter and xeric submeter data. Specifically, variables in the combined study groups are explored for association to total household consumption and, for the XS Group, to xeric landscape submeter consumption. Regression modeling proceeded with the goal being to yield an optimum combination of the highest reasonable R-squared value with due consideration given to maximizing the degree to which the model was “complete” (to the extent possible given the available collected data). Details of the final selected multivariate regression models appear in Appendix 2. Explanation and discussion of each variable included follow for each of the respective models.

Presented models are only designed to broadly assess variables’ impacts. The models presented here are “estimation” models as defined (see *Methodology*). These models are not intended for use as “engineering” or “computational” type model applications whereby collecting certain data one could be reasonably certain that the answer yielded would closely approximate the real consumption at a given property.

Variability in Annual Residential Consumption

Discussions of the selected independent variables included in the annual consumption model for the dependent variable *annual residential consumption* (labeled MAINMETE) follow. Overall, the annual consumption model appears to be a very good “fit” (adjusted $R^2=0.80$) for this type of work (Nelson³ 1994, Gregg⁴ et al. 1994, Gregg¹⁹ et al. 1999). This is likely due as much to the strong tie between outdoor usage (and the ability of independent variables associated with outdoor use to be practically measured) as to any design elements or analytical methods associated with the study. While relatively strong for the sample size, it must be stressed that this model’s utility is mostly in terms of helping to uncover and, to some extent, explain variables discreet associations with consumption at single-family residences. Quantifications of these associations in the multivariate context are limited to only those variables deemed significant.

TOTALTUR

Definition of Variable:

The total amount of turf at a residence in square feet as determined by research personnel. This includes all turf regardless of whether it is part of a submetered area and regardless of what type of grass it is.

Results and Discussion:

This was the most significant variable by far ($t=14.86$), and was found to be strongly positively associated with single-family residential consumption. It is a principal component of the model, contributing the bulk of its strength ($\beta=0.622$). The results suggest that consumption increases roughly 59.1 gallons annually for each square foot of turf at the average home. It then increases *further* if the grass is Fescue (the impact of Fescue vs. other grasses is further explored below). Since the alternative grass is almost always Bermuda, the result suggests the average application rate for this warm-season grass by the study participants is about 59 gallons per square foot (see variable FESCUE for more discussion on this).

It should be noted that earlier multivariate work attempted to deduce the influence of landscape type by scrutinizing how much xeric landscape was found at a residence (DeOreo⁸ et al 2000). While this is an acceptable approach, the amount of turfgrass present appears to be much more closely correlated with total annual consumption and, when included, typically displaces xeric area as a significant variable in the final models developed. Furthermore, since the amount of xeriscape was not significant in multivariate context (nor were other individual landscape types) it should be understood that the savings developed by SNWA’s Water Smart Landscapes program are mostly due to it, in essence, being a turf-removal program more than an alternative-landscape-promotion program. The results also suggest further significant lowering of household consumption probably would not be yielded by permitting the owner to get a rebate for turf removal at the expense of a quality landscape (for example, incentivizing the aforementioned “zeroscapes” at a higher SNWA incentive rate since they have no vegetation and theoretically require no water – this has been suggested by some). Since the xeric area contribution to annual consumption is so small, the substantial loss in quality of life yielded for the small gains in

conservation realized by effectively hardscaping landscape areas makes the argument for choosing hardscape in place of xeriscape for water conservation a position difficult to defend.

TOTVAL

Definition of Variable:

The dollar value of the single-family residential study property as specified in the Clark County Assessor's Office database. This should not be considered to equate to a home's market value.

Results and Significance:

The assessed monetary value of the property, like the amount of turf at a residence, was a very highly significant variable in the model ($t=5.45$). It is reasonable to assume that higher value properties are associated with higher consumption because (i.) they are likely to contain larger homes with typically larger, possibly more extravagant water-intensive landscapes and (ii.) they are, by nature, likely to be inhabited by people of greater wealth who are less sensitive to the price of water and thus more likely to use a greater volume of it. In a multivariate context, annual water consumption on average increases ca. 2.1 gallons alongside each dollar increase in Assessor's Office property value.

That increased wealth is associated with greater individual consumption is a well-understood tenant of economics and is a well-established concept in understanding persons' household utility consumption patterns. The impact of wealth in a similar context was explored by Gregg¹⁹ et al. (1999) where the impact of neighborhood wealth was a significant factor in determining water usage.

NLTHOMEA

Definition of Variable:

The age of the residence is calculated as the difference between the analysis year (2004) and the year of construction as recorded in the Clark County Assessor's Office database. This should not automatically be taken to be the age of the landscape or even, necessarily, the exact age of the specific study residence due to the way many developments are built as components of phases in this community.

Results and Significance:

This was a quite significant variable ($t=2.67$) and one easily worthy of inclusion in the model. On average, consumption increased ca. 1600 gallons for each additional year older the property was.

There are several potential reasons for this. First, older properties in the Las Vegas area tend, on average, to be larger and the ratio of hardscape footprint to landscapeable area is lower. Next, older properties are more likely to incorporate landscape elements heavy on traditional themes (i.e., large areas of turfgrasses) in contrast to newer residences with landscapes built in a time where water conservation began to be a significant consideration (in the 1990s restrictions on the amount of turfgrass that could be installed at single-family residences were passed). Older properties are more likely to have irrigation systems that incorporate lower-efficiency devices and

fixtures (ex. brass spray heads). Finally, as irrigation systems age they inevitably become less efficient and more likely to leak.

Aspects of indoor use also likely contribute to the pattern. The installation of high-efficiency, low-flow fixtures and appliances after being legally mandated is anticipated to have contributed to newer properties having, on average, lower consumption. Also, as fixtures wear they may leak for some time without notice (toilet flappers for example) so, without timely maintenance, older properties are more likely to have continuous indoor leaks further contributing to higher consumption. The increased efficiency gains in homes with newer fixtures have been well documented (see Mayer and DeOreo⁸ et al. 1999) and the overall finding that older homes tend to have higher water consumption is not surprising.

APROXINC

Definition of Variable:

Approximate total household income as revealed by 2001 survey data. To make the income survey question less intimidating, and more likely to generate valid, significant numbers of responses, the potential answers were categorical with ranges and it was explicitly stated that this question was optional. Analysis proceeded based on the mean values of response ranges. While a great number of participants did respond, many of course did not and income is, unsurprisingly, the most limiting of independent variables in the multiple regression.

Results and Significance:

It is to be expected that, everything else being equal, increasing household income would on average be associable with higher per-household consumption of all commodities. This is the case for water as well in this multivariate model, which suggests that, on average, annual consumption may increase on average ca. 3000 gallons for every \$10,000 rise in income level ($t=2.16$). Some may be surprised this should be given the fact that indoor water use is relatively constant per capita across a range of conditions and thus the sensitivity of the relationship between water consumption and price is usually considered to be rather muted. But, while water is indeed inelastic by common economic standards, in the Southwest, where a high proportion is used outdoors, it may be considered to be more discretionary in nature, especially when that outdoor use is for irrigation of landscapes (instead of crops), which are after all just ornamental. Certainly this study suggests that income is an important consideration in water consumption, as have others. Furthermore, higher incomes could be considered to be well correlated with large houses, large landscapeable areas, and more lush landscapes, all of which further drive up consumption in their own right.

There was considerable discussion between the principal author and some reviewers as to whether or not the income data should be included in the model. The arguments for inclusion were that it was found to be a significant variable in most comparisons, it is a different indicator than home value in that the former is more indicative of wealth and the latter is more indicative of actual disposable income (which could be spent on water use beyond necessity), and that removing it significantly weakens the model. The arguments for removing it include the supposition that often people give erroneous or fictional answers to questions about income, that income is potentially highly covariate with home value, that home value is really a better proxy variable for

income (and indeed in many studies using multiple regression it has been used for this purpose), and that its deletion does not weaken models such as this. Finally significant improvement in model sample size would be obtained by removing income as many people opted not to report it and thus it is very limiting to the model's available degrees of freedom.

The author considered the arguments for and against inclusion of income data carefully and proceeded to investigate the relationship between income and home value. The results of a correlation analysis between these two variables showed relatively little correlation ($R^2 = 0.288$) as did a scatterplot of the data. Nonetheless, the concern was valid enough (and the possibility of significantly more degrees of freedom of sufficient interest) to justify creation of an incarnation of the model without income as an independent model variable. This exercise however resulted in an increase in the standard error of the estimate (i.e., an increased error of over 7,000 gallons per year) and a drop in the overall model fit (adjusted $R^2 = 0.740$). However, most tellingly, the B values were off significantly from what one would expect (ex. Variable POOL B = 27.8; yearly evaporation in gallons per year is far in excess of this). Based on these findings it was decided that the APPROXINC variable should remain in the model.

FESCUE

Definition of Variable:

Whether or not the turfgrass present at a residence is Fescue or an alternative turfgrass. This is a binary (i.e., "dummy" in the vernacular) variable indicating presence (1) or absence (0) of a variable's specified condition.

Results and Significance:

Fescue grasses (which are widely popular cool-season grasses found in local landscapes) have been observed to require large volumes of water in the Las Vegas area (ca. 91 inches), over 62% more annually than the other somewhat less popular warm-season Bermuda grass (requiring ca. 56 inches; calculations for both grasses are based on data from the local Cooperative Extension Office). Locally, Fescue is much less drought tolerant than Bermuda and has a correspondingly higher K_c value (the July K_c value for Fescue is calculated to be a very high 1.10 whilst only being ca. 0.71 for non-overseeded Bermuda; Source: University of Nevada Cooperative Extension Office).

Furthermore, being a cool-season grass, Fescue is capable of active photosynthesis all year long with sufficient irrigation and management, which is no doubt the reason for its desirability; it can yield an attractive green year round. Bermuda on the other hand usually goes into dormancy in the winter and it is likely many people curtail irrigation at dormancy so its total yearly application is even further reduced relative to Fescue. While there are of course different requirements for different types and morphologic forms of grasses (ex. tall vs. short fescue), the general finding that the cool-season grasses require more water than the warm season ones is well understood and this apparently translates into residences with Fescue having, on average, higher annual consumption at the household level ($t=2.09$) (note: most residences had at least some turfgrass integral to their landscapes). Based on the multivariate analysis, a residence with Fescue may on average use more than 25,000 gallons more annually than one with a lower-water-use grass.

There is another possible inference that may be made. The submeter data is heavily dominated by Fescue landscapes and thus the highlighted gallons-per-square-foot application rates are probably at or near the actual *for Fescue*. It should be noted though that from the model, one might infer that in situations where there is not Fescue at the site, the B value of 59.1 may be the typical application rate, in gallons per square foot per year, for Bermuda installed at a residence. Though this derived value of 59.1 gallons per square foot per year (94.9 inches precipitation equivalents) is somewhat suppositional, and no doubt not exact given the standard error of the model, it appears to be a very reasonable average application rate that could be expected locally for Bermuda grass.

PARCEL SIZE

Definition of Variable:

The size, in square feet, of the parcels of study residences as specified in the Clark County Assessor's Office database.

Results and Significance:

In the final version of the model, parcel size was technically not significant ($t=1.79$); however, it was positively correlated with higher residential consumption in most multiple regressions developed so it is included here. It is reasonable to assume that, on average, residences associated with larger parcels are more likely to have higher consumption because they would be expected to have (i.) more, possibly lush, landscape (they are also more likely to have a pool) and (ii.) typically larger homes situated on them. Both of these would be anticipated to raise consumption due to larger residential landscapes having higher total outdoor irrigation requirements and larger houses being more likely to be inhabited by more or, perhaps, simply more heavily consuming, residents.

POOL

Definition of Variable:

The total water surface area of pools and spas in square feet at residences as measured by research personnel. For residences without pools this variable equates to zero.

Results and Significance:

As with parcel size, pool surface area was not significant in the final most complete version of the model ($t=1.70$), but often cropped up as significant in alternative models as being positively correlated with higher consumption. It is reasonable to include this variable as it is to be expected that the more evaporative water surface area outside at a residence owing to a pool and/or spa, the higher the evaporative water loss at the residence and the greater the need, in gallons, to replenish it.

TOTALOCC

Definition of Variable:

The total number of occupants at each study property in the analysis year (2001) as determined by survey.

Results and Significance:

Though not a statistically significant independent variable in the final model ($t=1.62$), and only occasionally significant in alternatives, the number of people living at the residences was ultimately included, as it lends explanatory strength to the model ($\beta=0.524$) and it is logical to assume that consumption does increase with more people living at a location. That it is not statistically significant is actually a testament to the dominance of outdoor end uses in determining total yearly consumption at single-family properties in this region.

TOTALLAN

Definition of Variable:

The total landscapeable area at a property. This includes areas with landscape as well as areas potentially landscapeable.

Results and Significance:

This variable is difficult to interpret and was not significant in this particular model ($t=-1.41$). The only reason for its inclusion is the sheer number of times it cropped up as significant in different alternative models. Here, however its sign is inverse of what would be anticipated (that greater landscapeable area would lead to higher consumption). It may be that it captures the inverse of the building and hardscape footprints, but this is only theory. check from here on...

Variability in Annual Consumption for Irrigation of Monitored Xeric Landscape

A model of yearly consumption for the monitored xeric component of landscapes for XS Group homes was also developed to attempt to evaluate the impacts of variables listed in the Scope (Appendix 1). The developed model has a much lesser fit than the total consumption model (adjusted $R^2=0.40$), in part, one speculates, because other important but non-quantified or hidden variables are not included (one possible example – detailed data on controller management which may be more associated with management of turf rather than xeric areas). For this reason, no attempt is made to quantify impacts in a multivariate context as above, but rather the goal is to identify variables likely associated with xeric area consumption (for some attempts at quantification using univariate approaches consult Sovocool and Rosales¹¹ 2001).

Despite the limitations due to the weaker model, many variables did appear significant in most if not all modeling attempts, and these are discussed below in a format similar to the above discussion on annual consumption. The same strength of association denotation as used for the annual consumption model is applied to the xeric areas variable discussion as well. See introduction to *Sources of Significant Variability in Single-Family Residential Consumption* for more information.

TOTALCAN

Definition of Variable:

The total canopy coverage in the monitored xeric area of the XS Group properties, in square feet. This is calculated by first taking the observed plant diameters from the 2001 site review, dividing this number by two to get radius, then applying the formula for getting the area of a circle ($A=\pi r^2$). This area result is then multiplied by the quantity of those plants observed to be at that size. The summation of all areas of all plants of all size classes in the study area is the total canopy coverage.

Results and Significance:

It is reasonable to expect that total plant canopy coverage within the monitored xeric area would positively correlate to the total amount of water applied to that area as plant leaf surface area (evapotranspirational area) is the principal locale of water loss from vegetation. To replace this loss, areas with higher plant coverage should theoretically require more water and it should be expected that residents would respond by irrigating these more (via both longer run times and having irrigation systems of greater application capacitance). Examination for a link between total canopy coverage and total yearly consumption for xeric areas in a multivariate context confirms a significant association ($t=4.31$; the relationship between coverage and per unit area consumption was also noted and explored in Sovocool and Rosales¹¹ 2001). One acknowledgement; this is a relatively simplistic finding, which does not fully explain the relationship between consumption and the taxa present and species' specific water use characteristics (this was beyond the practical scope of this investigation). Data on specific xeric species' water requirements is needed for this and this area remains worthy of more in-depth research.

AVGFLOWR

Definition of Variable:

The arithmetic average flow rate, in gallons per minute, of all irrigation stations servicing monitored xeric landscape for each of the XS Group properties.

Results and Significance:

It has long been suspected that within the range of lower flow types of irrigation systems used to irrigate xeric areas, those capable of delivering water relatively faster via high-flow emitters may contribute to higher water consumption, especially when used by someone less knowledgeable about how to irrigate with different types of emitters. For this reason, SNWA's current Water Smart Landscapes program limits individual emitters to a maximum output of 20 gph as part of the program requirements (Appendix 5). Based on this research, this concern appears well-placed as the model shows stations with higher average flow rates are indeed associated with higher consumption in this study ($t=4.14$). Typically, such station configurations may have one or more of the following conditions: sprays used for xeric-area irrigation, incorporation of high-flow emitters (such as turf bubblers), use of microsprays, stations composed of mixed types of irrigation emitters, and individual stations irrigating large and/or lush expansions of xeriscape (an exploration of how emitter class relates to average flow rates also appears in Sovocool and

Rosales¹¹ 2001; this manuscript suggested a strong association between irrigation system design and xeric area consumption as well).

STUDYA

Definition of Variable:

The xeric study land area (in square feet) monitored via submeter for XS Group properties.

Results and Significance:

It is logical to assume that, on average, the more area monitored by the submeter, the greater the consumption through that meter, and the significant association between monitored xeric-study area and total yearly consumption ($t=3.08$) is consistent with this expectation (for further exploration of per-unit area savings, see *Comparison of Per-Unit Area Water Application between Turfgrass and Xeric Landscape*).

TOTVAL

Definition of Variable:

The dollar value of the residence as specified in the Clark County Assessor's Office database. This should not be considered the same as the home's market value.

Results and Significance:

There was a positive association between the total value of the property and total consumption for xeric area consumption ($t=2.94$). A discussion of how this variable tends to be positively associated with water consumption appears above in the discussion of the annual consumption model. It is worthwhile to again emphasize that given water use for residential landscapes can ultimately be considered discretionary, higher homeowners' wealth (here, evidenced by higher property value) may be anticipated to lead to greater consumption for landscape irrigation.

PARCEL SIZE

Definition of Variable:

The size, in square feet, of the parcel of a study residence as specified in the Clark County Assessor's Office database.

Results and Significance:

The parcel size of the residence was significantly inversely associated with consumption for xeric area irrigation ($t=-2.78$). This result was unexpected, as a relationship or mechanism acting to result in a link between parcel size and the irrigation of xeric areas on that parcel is not immediately obvious. The possibility that there is an inverse relationship between xeric study area and parcel area was examined, but this is not the case (rather, as would be expected, larger properties tended to be positively correlated with larger study areas, though this relationship is weak; $R^2=0.064$). Likewise, the theory that perhaps larger parcels had xeric areas that might be sparser in terms of canopy was examined and rejected (the data does not support this).

Discussion and consideration of other findings led to some other possible explanations. One possibility is that those residences with larger parcels were more likely to incorporate native, lower-water-requirement plants in their landscapes. Some data supports the theory that owners of large properties may indeed make more use of native taxa, but only marginally so (the properties in the top 10% in parcel size had an average of 10.9% of their plant palette composed of native vegetation; the average for the rest of the properties was 6.9%).

Another theory is that larger xeriscape installations may be more likely to necessitate the need for a contractor, who is more likely to install a properly designed drip system and, as suggested by the findings linking station flow rate to consumption and (as revealed below) “drip-only” systems are more likely to result in lower total yearly consumption than those piecemealed together with multiple types of emitters. Since those residents doing larger xeriscape conversion projects were found to be more likely to use a contractor, there is some evidence supporting this second theory.

Perhaps the most likely reason for this finding is that people with smaller parcels are more able to afford to consume more water outdoors. To understand this reasoning better, consider an example of two sets of land, one acre each, in a similar area and climate each with all landscapeable area landscaped. One has a single residence upon it, the other acre, more subdivided, supports five homes (and thus is composed of five parcels). One would conclude, usually correctly, that the outdoor consumption for the *total area* would be greater for the one-home case, owing to its maintaining a greater amount of landscaped area (more of the available area is consumed as development in the five-homes case). But what about total water consumption for irrigation on a *per-parcel* basis? Each of the family income streams in the five-homes-per-acre case support less irrigated area than that for the single home on the one acre. Thus, each of these five owners can afford to support more discretionary water use as their respective landscape irrigation “shares” are less than for the one owner supporting all of that area. As a result, the owners of the smaller parcels may use more irrigation water per parcel than in the alternative case, and this may be what is being observed here (internal research by SNWA has shown that subdivision tends to result in higher per-parcel usage while decreasing usage for the total equivalent area).

Without more information, these are only hypotheses. At this time, while the inverse relationship between parcel area and xeric area consumption stands, the mechanism behind the relationship is not completely understood.

DRIP

Definition of Variable:

Presence (1) or absence (0) of an exclusively drip irrigation system irrigating the xeric study area. This is a binary variable.

Results and Significance:

This is a different type of measure of the influence of irrigation system design on total xeric area water application. Specifically evaluated was whether the presence of a “true” drip system (no bubblers, microsprays, mixed systems) was associated with xeriscapes with lower consumption than others. The model does support this theory, with a significant finding that such “drip-only”

xeriscapes do have lower consumption ($t=-2.27$). As suggested by Sovocool and Rosales¹¹ 2001, such systems typically have the lowest flow rates (average per-station flow rate = 4.0 gpm) of the types used to irrigate xeric landscape, so if run similar amounts of time to other systems, it would be expected that these would output lower total volume over a year. Based on the data, it does seem likely that many residents run their systems without careful consideration as to which kind of emitters they actually have, in turn resulting in systems composed exclusively of true drip emitters being associated with the least amount of water consumed over the year. Since slow application rates are generally the preference in irrigating drought-tolerant vegetation (this is especially the case with woody taxa) and because landscapes with “true” drip systems had the lowest consumption, this finding may be worthy of future considerations relevant to SNWA’s Water Smart Landscapes program.

DONTKNOW

Definition of Variable:

Whether or not the respondent was knowledgeable about the level of enforcement of local restrictions designed to reduce water waste. This binary variable indicating presence (1) or absence (0) of understanding was adapted from part of an alternative answer to a question asking respondents if they felt enforcement of water waste provisions was “too lax,” “good,” or “too strict.” In addition to these responses, residents taking the survey were also given the option of answering “Don’t Know” if they did not have any sense of how aggressively water waste regulations in the area were enforced.

Results and Significance:

Theoretically a person’s viewpoints on water waste enforcement could tie into how diligently they practice good irrigation management. Recognizing this, the study staff formulated a question addressing this for the survey implemented in 2001. In preliminary analyses (Sovocool¹² 2002) there really was not a difference in per-unit area irrigation for xeriscapes between those respondents answering “too lax” and “good” (only two people said enforcement was “too strict” resulting in no ability to tie this to consumption with any statistical precision, though this is quite telling of how the community viewed enforcement in 2001). However, interestingly there was a difference between respondents with any kind of an opinion and respondents who had no sense of the issue. This suggested at the time that *awareness* of enforcement of water waste regulations may be a principal motivator to conserve, regardless of one’s viewpoint on how appropriate the level of enforcement is. The recurrence of this basic result, here in a multivariate scheme (i.e., those answering “don’t know” were associated with higher consumption in the regression model; $t=2.13$) suggests that sensitizing the public about enforcement of water waste restrictions may be a powerful motivator for achieving outdoor water conservation.

FINANCIAL SAVINGS ASSOCIATED WITH CONVERSION PROJECTS AND COST EFFICIENCY

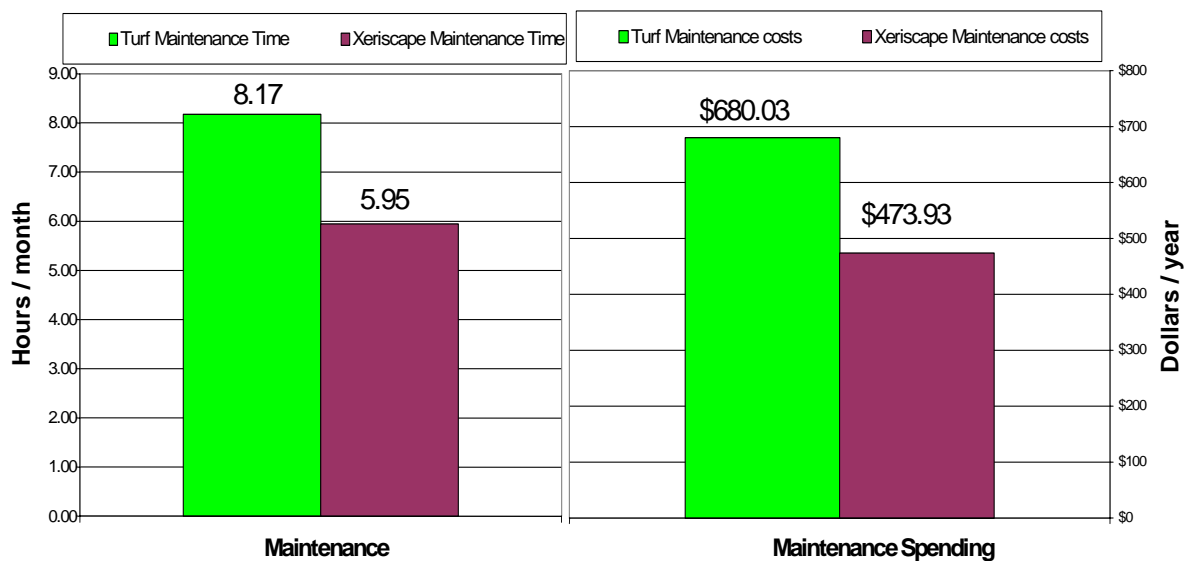
As explained in the methods section, the research scope included a mandate to study some of the economics of xeriscape conversions, as this has been left relatively uninvestigated to date. Specifically, the directives were to quantify costs associated with the conversion and the subsequent maintenance of the xeriscape and to develop estimates as to what incentive level

would theoretically be necessary to entice people into doing conversion projects. Collection and analysis of this data is explained in *Methodology*, below, and in *Appendices 5* and *6*. Results are as follows below, starting with the conversion costs findings.

The average cost of the conversion for those converting in the XS Group was obtained via data collected on parts and materials, as well as contractor receipts. The average cost for all participants was \$2,881.21 for 1,862.1 sqft converted (\$1.55 per square foot for 91 participants sampled). The average cost for those who did the conversion themselves was \$2,428.31 for 1,766.22 sqft (\$1.37 per square foot), and the cost for those hiring a contractor was \$4,076.88 for 2,115.22 sqft (\$1.93 per square foot). These dollar amounts for costs and dollar valuations are as they stood in the late 1990s and have likely climbed slightly by today. As might be anticipated, it appears that residents may on average be more likely to hire a contractor for larger conversion projects.

Landscape maintenance requirements constitute a significant cost in labor and dollars directly spent. The relative amount of xeriscape at a residence figured prominently in landscape maintenance reductions for both these costs (Figure 12). For those who had at least 60% of their landscapeable area as xeric landscaping, maintenance savings of about one-third were realized versus those with 60% or more turf. The average difference is 2.2 hours/month in labor and \$206 per annum in direct expenditures (N=216). Landscape maintenance savings are value added on top of water bill savings. This serves to greatly enhance the attractiveness of xeriscape to the customer. Hessling¹² (2001) provides a detail of the capital costs and savings obtained.

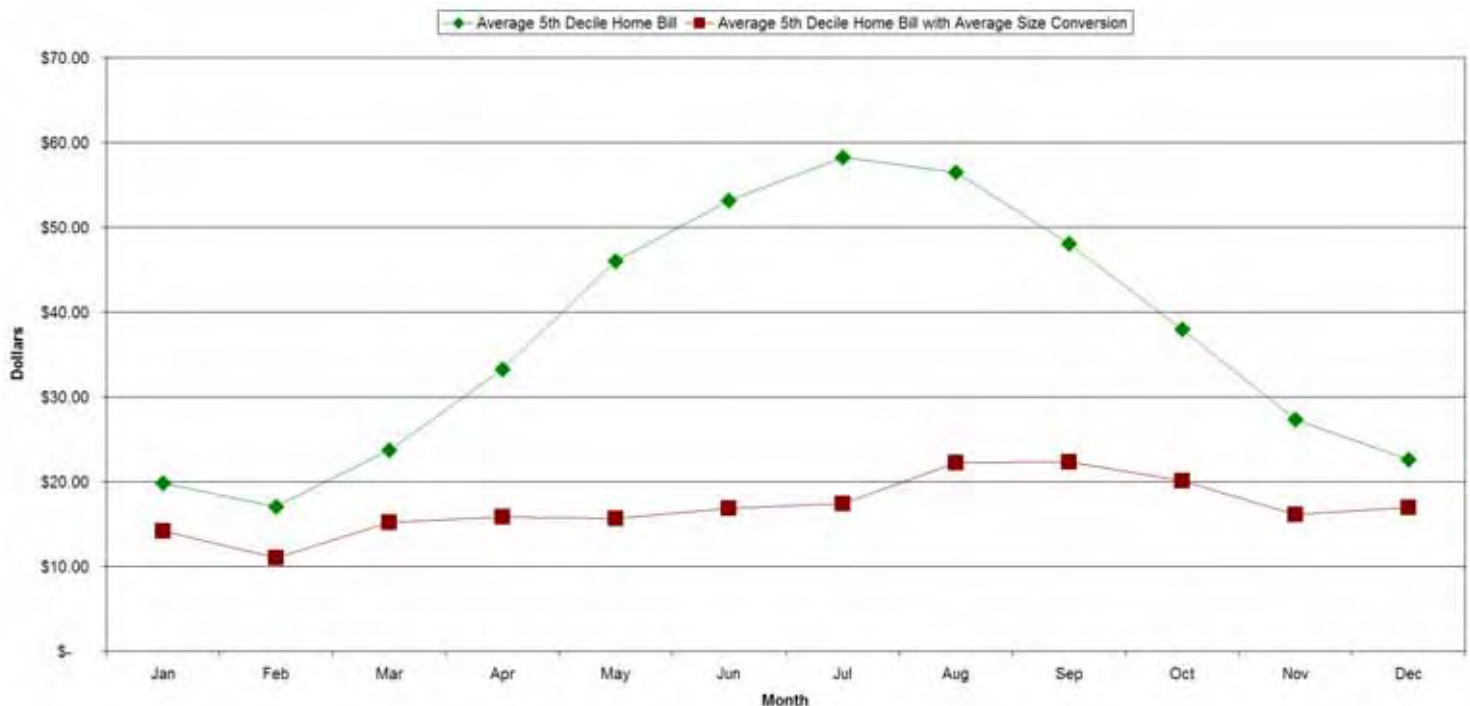
FIGURE 12: Average Monthly Maintenance Time and Annual Direct Expenditures for Participants Having At least 60% Turf or Xeriscape



Bill savings for a typical mid-consumption range customer were modeled as explained in *Methodology* and in Appendix 4. Results show that there is a large difference in the monthly bills between a modeled residence with and without the conversion throughout the majority of the year (Figure 13). The total difference in the annual cost for water between these two homes using the current (2004) rate structure is \$239.92 - a significant savings attributable to the conversion (nearly \$0.15 per square foot converted per annum). It should be noted that this savings of 54% in total annual water charges is greater than would initially be anticipated from consumption savings data (Figure 6). This is because the Las Vegas Valley Water District, as well as the other SNWA member agencies, uses a tiered, increasing block rate structure.

Increasing block 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 (i.e., per gallon), water becomes. The high per-unit area application to turfgrass results in residences with more grass typically crossing thresholds into higher billing rate strata much more frequently and this in turn exacerbates their water costs per unit and, ultimately, their total costs. In this case, the difference in per-unit water charges for the two fifth-decile homes, with all charges considered over the entire year is about \$0.28 per thousand gallons (i.e., there is a 13% difference; effective prices of \$1.85 vs. \$2.13 per thousand gallons, respectively). The comparison highlights the utility of tiered rate structures as a conservation tool and for promotion of xeriscape as a conservation tactic.

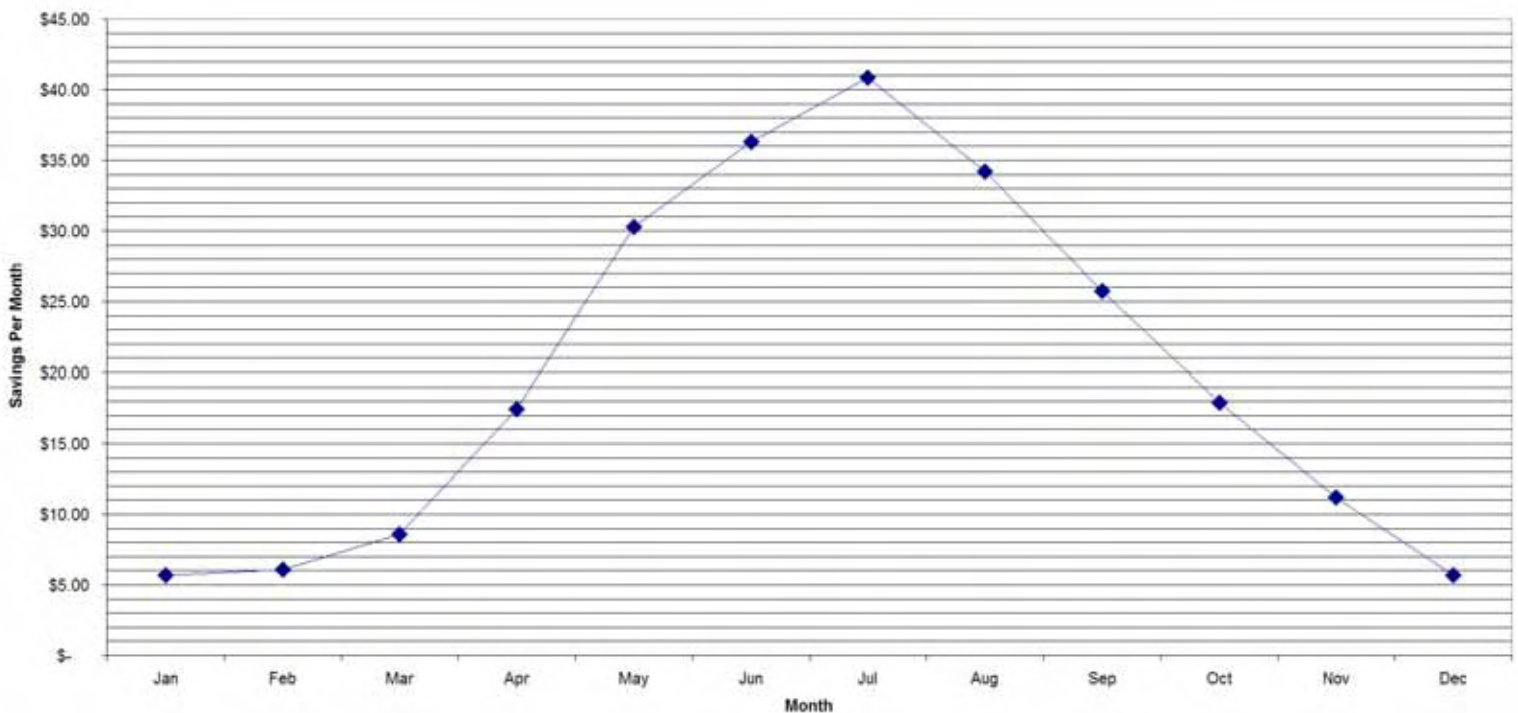
FIGURE 13: Modeled Monthly Water Bill for a Typical Las Vegas Area Home and The Same Home with an Average-Size Conversion



The expected water bill savings a resident of a typical home would realize from doing an average-size conversion of turfgrass to xeriscape (anticipated monthly savings – including tier rate impacts) is thus as illustrated in Figure 14. As can be seen, the typical monthly water bill savings range from a low of \$5.68 (25%) in December to a high of \$40.84 (70%) in July, again reemphasizing that the greatest savings obtained by having xeric landscape are realized in the extremes of summer in this area. The savings obtainable serves to create a strong price signal to convert, especially when coupled with the incentive offered by SNWA currently (\$1.00 per square foot for qualifying residential conversions).

As suggested by Figures 13 and 14, on average xeriscape not only results in significant savings in water utility charges, it also makes the charges more manageable as they no longer “peak” to anywhere near the extent they did under the “no-conversion” condition. For the “no-conversion” model, the low-consumption month to high-consumption month ratio is 1:2.93 (the peak month is July). For the same house with the conversion, the ratio is 1:1.58 and the peak is pushed out to September owing to the difference in xeric irrigation pattern (Figure 8). For homes proximal to the modeled condition, xeriscape conversions appear to make paying monthly bills easier because the peak is (i.) greatly attenuated and (ii.) potentially pushed out until later in the year, so it does not parallel other local utility bills which peak in the summer (power, for example).

FIGURE 14: Modeled Monthly Water Bill Savings for A Typical Las Vegas Area Home Completing an Average Size Conversion



ESTIMATED APPROPRIATE LEVEL OF FINANCIAL INCENTIVE

Homeowner Perspective

Hessling¹³ (2001) performed analyses of the financial viability of SNWA's xeriscape conversion program, "Southern Nevada Xeriscapes" (since revised and renamed to "Water Smart Landscapes"). It should be noted that at the time Hessling did his analysis, the program paid recipients an incentive of \$0.40 per square foot. He presented a Net Present Value (NPV) analysis demonstrating that, from the homeowner perspective, the return on investment by SNWA's conversion facilitation program is two to three years for a resident and that the incentive is not really required to induce change as the NPV is positive, even when no incentive is rewarded. See Hessling's manuscript for additional details.

A constructed model (Appendix 5) using a similar approach (and more recent data) seems to support the finding that no incentive is theoretically necessary for a typical do-it-yourself xeriscape conversion where subsequent financial savings in landscape maintenance are realized. However, the incentive may be important in a variety of other situations. The scenario, similar to the one used by Hessling as well as others, was explored by the model developed by SNWA (Appendix 5). Some of the most common scenarios explored, with findings from model outputs, are summarized in Figure 15.

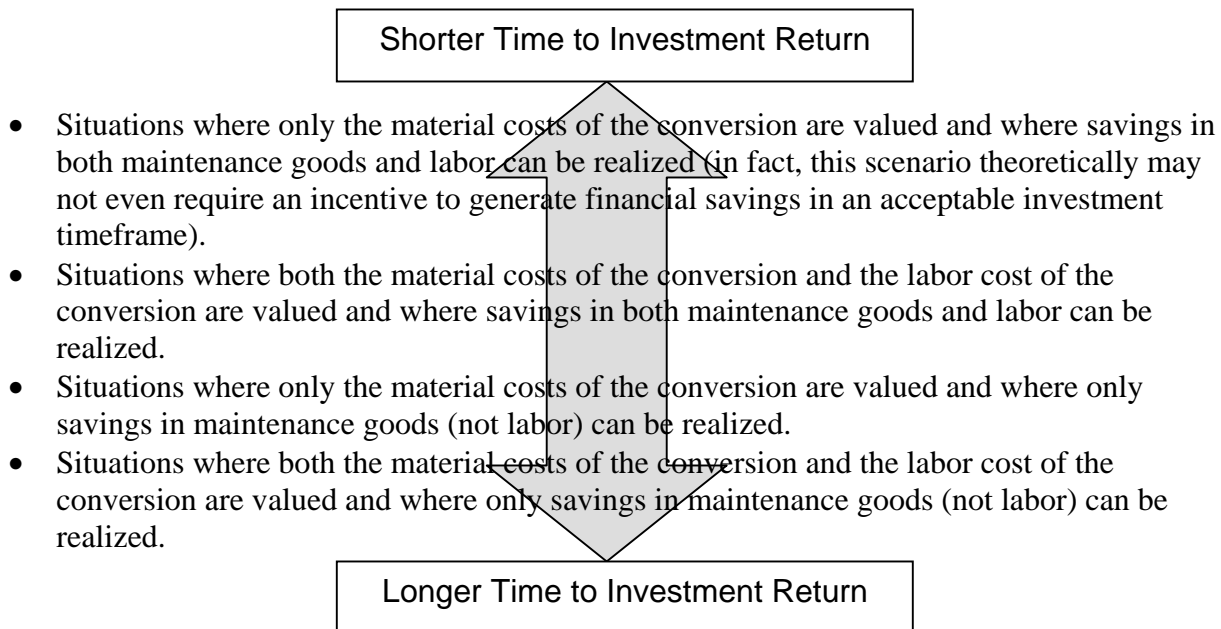
In Figure 15, there are four different scenarios modeled (see explanation below), and each scenario has four associated results (*Methodology* and Appendix 5). The outputs associated with each exercise are: the average payback time (at a dollar per square foot) for a typical home doing a typical conversion (see Appendix 5), the average payback time without an incentive, the incentive required for a 3-year return on investment (ROI), and the incentive required for a 5-year ROI. Special note should be made regarding the expression of payback times. The display is not the range of payback times given the combination of scenario conditions, rather, it reflects that the expected average payback time falls sometime between the years shown. The model is based on annual, not monthly data thus the need to display outputs in this manner. The "incentive required" outputs, are simply average model outputs and are not to be considered appropriate for any one condition; their value is principally in comparative analyses between scenarios and in broad generalizations.

The summary (Figure 15) is designed to facilitate inferences about the economics of the conversion project. Along the horizontal axis are the "Only Conversion Material Costs" and "Conversion Material Costs + Labor" titles. The first scenario condition refers to situations where only the direct costs for materials, supplies, rentals, and other such items are considered. Residents doing their own xeriscape conversion might consider this to be their scenario if they consider only the real financial outlays paid and don't consider their time spent on the conversion to be a real financial cost. In contrast, the "Conversion Material Costs + Labor" condition includes a valuation of the time to actually do the conversion, which naturally lengthens the payback time. This perspective is more appropriate for those who consider the labor outputted by

themselves to be a true financial expenditure. It is also the appropriate model perspective to consider if the project is performed by a contractor.

Along the vertical axis of Figure 15, are the titles “Only Maintenance Goods Conserved” and “Conserved Maintenance Goods and Labor.” Similar to above, the “Only Maintenance Goods Conserved” condition reflects consideration of savings associated with only direct expenditures on things such as fertilizer, replacement irrigation parts, occasional replacement of capital items such as shovels, etc. (so long as the conversion is significant enough to yield savings in these areas; see the discussion surrounding Figure 12). The category “Only Maintenance Goods Conserved” would be most appropriate for people who do not consider the savings in labor obtained by having some of their area as xeriscape to be equivalent to a monetary outlay, situations where not enough of the total landscape area is converted to obtain this type of savings, or when a landscape maintenance company, which may or may not realize the savings, is either unwilling or unable to pass on labor savings to the customer as realized by the landscape retrofit. Again, there is an alternative category for the consideration of realized maintenance savings in labor costs resulting from the conversion. The maintenance savings plus labor savings category, “Conserved Maintenance Goods and Labor,” is most appropriate when enough of the yard has been converted that real savings in maintenance labor can be realized and when the owner attaches value to this. It would also be appropriate when the homeowner’s landscape company passes on realized labor savings to him or her.

The matrix of results developed (Figure 15) permits some inferences to be made about what scenarios turn around financially the fastest and are thus most readily facilitated by a landscape conversion incentive. In increasing order of time to payback (i.e., the first bulleted scenario is the most readily facilitated) these are:



Considering that the optimal price point for the first three of these scenarios is probably covered by the current incentive level, but not the old \$0.40-per-square-foot incentive, it may be that the SNWA hit upon a critical threshold value in stimulating the marketplace when it went to the

\$1.00 per-square-foot level in 2003. A recent surge in program interest in the residential sector is consistent with this (Appendix 5). Even in the fourth scenario, the current incentive level shortens the payback time such that the project might be deemed affordable by many people (see the associated 5-yr ROI). While few, if any, residents do a detailed economic assessment of the payback time for their respective xeriscape conversion projects, the dollar per square-foot is almost certainly perceived to make conversion projects much more “affordable,” plus there is significant symbolic value to the \$1.00-per-square-foot figure versus the past sub-dollar incentive levels.

If the payback time outputs presented in this model are close to reality, it may be that SNWA’s Water Smart Landscapes program will continue to experience high interest until a point where materials, supply (i.e., practically convertible turf), or services associated with the conversion project come to be in short supply and/or become expensive enough to cause feedback such that program enrollment is slowed.

FIGURE 15: Summary of Economics of Typical Single-Family Xeriscape Conversion Projects Under Different Scenarios

	Only Conversion Material Costs	Conversion Material Costs + Labor
Only Maintenance Goods Conserved (or when labor savings not realizable)	Avg. Payback Time at \$1.00 per SqFt: <div style="border: 1px solid black; padding: 2px; display: inline-block;">3-4 Years</div>	Avg. Payback Time at \$1.00 per SqFt: <div style="border: 1px solid black; padding: 2px; display: inline-block;">5-6 Years</div>
	Avg. Payback Time Without Incentive: <div style="border: 1px solid black; padding: 2px; display: inline-block;">5-6 Years</div>	Avg. Payback Time Without Incentive: <div style="border: 1px solid black; padding: 2px; display: inline-block;">8-9 Years</div>
	Incentive Required for 3-Year ROI: <div style="border: 1px solid black; padding: 2px; display: inline-block;">\$1.03/SqFt</div>	Incentive Required for 3-Year ROI: <div style="border: 1px solid black; padding: 2px; display: inline-block;">\$2.23/SqFt</div>
	Incentive Required for 5-Year ROI: <div style="border: 1px solid black; padding: 2px; display: inline-block;">\$0.14/SqFt</div>	Incentive Required for 5-Year ROI: <div style="border: 1px solid black; padding: 2px; display: inline-block;">\$1.34/SqFt</div>
Conserved Maintenance Goods and Labor	Avg. Payback Time at \$1.00 per SqFt: <div style="border: 1px solid black; padding: 2px; display: inline-block;">1-2 Years</div>	Avg. Payback Time at \$1.00 per SqFt: <div style="border: 1px solid black; padding: 2px; display: inline-block;">2-3 Years</div>
	Avg. Payback Time Without Incentive: <div style="border: 1px solid black; padding: 2px; display: inline-block;">2-3 Years</div>	Avg. Payback Time Without Incentive: <div style="border: 1px solid black; padding: 2px; display: inline-block;">4-5 Years</div>
	Incentive Required for 3-Year ROI: <div style="border: 1px solid black; padding: 2px; display: inline-block;">None Req.</div>	Incentive Required for 3-Year ROI: <div style="border: 1px solid black; padding: 2px; display: inline-block;">\$0.91/Sqft</div>
	Incentive Required for 5-Year ROI: <div style="border: 1px solid black; padding: 2px; display: inline-block;">None Req.</div>	Incentive Required for 5-Year ROI: <div style="border: 1px solid black; padding: 2px; display: inline-block;">None Req.</div>

SNWA Perspective

The financial viability of SNWA's Water Smart Landscapes Program is difficult to assess as resource alternatives available to the Authority against which this "water option" may be measured are diverse and have widely divergent respective costs (SNWA²⁰ 2003). Furthermore, availability of water resources is not constant and shortage or surplus conditions can exist which can make using these as standards against which conservation programs can be measured again difficult. A prime and current example of this is the drought that the Lower Colorado River Basin is experiencing which is currently impacting SNWA (SNWA Drought Plan²¹ 2003). In these types of situations, the economics of conservation programs are obviously enhanced, and it is against this backdrop that the economics of the Water Smart Landscapes Program is being considered in this study.

In Hessling's analyses¹³, the drought had not yet been recognized and designated as such and SNWA had no drought policies in place at the time of the analysis. He grounded his analysis in comparing the marginal cost of water in the Southwest to the marginal benefit realized by the incentive program. In doing so, he concluded that the cost of the incentive program at the time was just offset by its resource value, and the program was thus a worthwhile initiative (see analysis for details).

In 2004, a reanalysis of the Water Smart Landscapes Program was done to consider the economic viability of it in the face of the drought and the current resource and program incentive values. Given the current scarcity of local water resources, the drought, and the fact that SNWA is now approaching the point of withdrawing its full Colorado River allotment (SNWA²⁰ 2003), the Las Vegas Valley Water District has recently paid \$9,500 per acre-foot for undeveloped groundwater rights in the local basin and, furthermore, views this purchase as a bargain (LVVWD²² 2003). Because the largest purveyor member in the SNWA is willing to pay this amount currently for undeveloped, non-administered water rights, this should be a good alternative price for comparing the cost effectiveness of the program on a per-square-foot basis (not including administrative and advertising costs).

It follows that to estimate the savings yielded by the program in dollars per square foot, the above marginal cost of water, converted to a square-foot basis, can be multiplied by the savings per square foot yielded by the conversion as below:

$$\$9,500 \text{ per acre-foot} \times 325851 \text{ gallons per acre-foot} \times 55.8 \text{ gallons per sqft yield} = \$1.627 \text{ per sqft}$$

The cost calculation is slightly more complex, as the SNWA not only spends the \$1.00 per square foot to incentivize the conversion, but it also forgoes the yield it would have claimed on this amount had it invested it. The mature yield of municipal bonds in February 2004 is used as this alternative rate. Thus the true cost per square foot for SNWA can be estimated as:

$$\$1.00 \text{ per sqft expended} + (\$1.00 + 4.65\% \text{ mature interest yield if invested instead}) = \$1.047$$

The cost-effectiveness of the program can then be calculated as the difference between these values:

$\$1.627 \text{ per sqft saved} - \$1.047 \text{ per sqft saved} = \$0.58 \text{ per sqft net positive value to SNWA}$

The analysis suggests that for each dollar the SNWA is spending for the incentive, it is bringing in \$1.58 and that the program appears as such to be a good deal from a financial perspective for SNWA. The ca. 37% net positive value means the program should be financially advantageous even with addition of the program advertising and administration costs which have not to date been quantified.

In considering the theoretical maximum that SNWA could pay for the program (a component of Objective 6), it should be noted that \$1.627 is not the maximum as, again, the yield of the alternative investment must be considered. Subtracting out this missed or forgone yield results in a figure of \$1.55 and this is the theoretical maximum price SNWA could currently justifiably sustain. Again, the actual maximum would be anticipated to be lower due to program administration costs.