

Methodology

STUDY GROUPS AND MONITORING

The study team recruited participants who live 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. The XS Group is composed of residents who converted at least 500 square feet (sqft) of traditional turfgrass to xeric landscape as well as residents who installed new xeric landscaping. To clarify, in this region, xeric landscaping is principally composed of a combination of desert-adapted shrubs, trees, some ornamental grasses, and mulch (often rock). A \$0.45 per square foot incentive helped the property owner by absorbing some, but not the majority, of the cost of the conversion. Homeowners were required to plant sufficient vegetation so that the xeric landscape would at a minimum have 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 was capped for each residence at \$900 for 2,000 sqft; however, many residents converted more landscape than that which qualified for the incentive with the cap. Indeed, the average area converted in this study group was 2,162 sqft. A total of 472 properties were enrolled in the Study as XS Group participants. Aerial photographs, supported by ground measures, were used for recording areas. As a supplement to the main experimental group, 26 multi-family and commercial properties were submetered as well.

In return for the incentive, XS Group residents agreed to ongoing monitoring of their water consumption. This was accomplished in two ways. First, mainmeter data was taken from standard monthly meter reading activity (this was for assessing water use at the entire single-family residence level). Second, residents agreed to installation of a submeter that monitored irrigation consumption on a portion of the xeric landscape. Submeters were typically read monthly, as with mainmeters and were used to study per-unit area application of water comparatively. The area monitored by the submeter was called the Xeric Study Area. Study areas were tied to irrigation zones and stations. Virtually all study properties have in-ground irrigation systems and controllers to avoid the presence or absence of these as a major confounding factor. This experimental control is important because it has been noted that the presence of automated irrigation is highly associated with increased water usage for residential properties (Mayer and DeOreo⁸ et al. 1999) apparently because such systems make irrigation more likely to occur regularly versus hand-watering. Having participants in both groups possess automated systems also avoids the potential bias of more heavily turf-covered properties being more likely to be fully automated, thus having higher consumption as was the case for Bent¹ 1992 (as identified in Gregg⁴ et al. 1994). All areas of each property were broken down into landscape categories. For example, a XS Group property might have monitored (via the submeter) xeric landscape and unmonitored xeric, turf, garden, and

other (non-landscaped) areas. Square footages were recorded for each of these respective 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 on the xeric species present, plant canopy coverage at the site, components of the irrigation system, and per-station flow rates.

Staff trained in the identification of locally used landscape plants collected data on plant size and species present.

Plant canopy coverage was calculated by first taking the observed plant diameters, 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 was then multiplied by the quantity of those species of 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 for that area.

Data on the components of irrigation systems was collected by staff trained in the different types of irrigation emitters available (ex. drip, microsprays, bubblers, etc.). Staff then ran individual stations and watched meter movement to get the per-station flow rates.

The Turf Study (TS) Group is composed of properties of more traditional landscape design, where an average 2,462 sqft of the landscaped area was of traditional turfgrass (most commonly Fescue). Mainmeter data was collected in the same manner as for the XS Group. 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 (only “exclusively turf” monitoring configurations were used in per-unit area landscape analyses). TS participants enrolled voluntarily, without an incentive and agreed to yearly site visits as above. Other data on irrigation systems was collected in a manner similar to that for the XS Group properties. 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 this study. For this reason, sampling bias was of reasonable concern to SNWA. To address this, a third subset of non-contacted Comparison Groups was created to evaluate potential biases. Comparison properties were properties with similar landscape footprints and of similar composition to the TS group and pre-conversion XS Group and were in the same neighborhoods as these treatment properties. This control group was also subject to the same water rates, weather, and conservation messaging as the treatment groups. Having this group also permitted SNWA to evaluate the combined effects of submetering and site visits on the treatment groups.

GENERAL DATA METHODS, STRATEGIES, AND STATISTICS

Several different data analysis methods were applied in the course of the study. Details of each can be found in the corresponding subsections below. Broadly, analysis methods fell into the categories of pre- vs. post-treatment evaluations, comparative analyses of different treatment groups, analyses to determine variables associated with consumption, and assorted cost-benefit analyses. Statistical methods employed include descriptive statistics (ex. means, medians, etc.), tests for differences in means assuming both normally distributed data (*t*-tests) and non-normally distributed (i.e., non-parametric) data (*Mann-Whitney U*-tests), as well as techniques employing established economic principles and multivariate regression (some details of regression models are included in Appendix 2). In means comparisons, statistical significance was determined to occur when the probability of a Type I error was less than 5% ($\alpha=0.05$). Presentation of data involving calculations of differences in values (for example, means differences) may not appear to add up in all cases, due to rounding. Types of data analyzed include mainmeter consumption data, submeter consumption data combined with area data (i.e., application per unit area data), flow-rate data, cost data, survey responses, and assorted demographic and Clark County Assessor's Office data. Consumption data was gathered by the aforementioned purveyor entities and assembled by SNWA. Most other data was collected by SNWA (Aquacraft Inc. also performed some analyses on consumption and data logger collected data under contract to SNWA). In many analyses, data was scatterplotted and objective or subjective outlier removal done as deemed appropriate. Finally, in some cases, data analysis was expanded upon to include attempts at modeling. These endeavors are elaborated on in other parts of the manuscript.

PRE/POST ANALYSES

For each property and year where complete monthly consumption records were available, these were summed to provide yearly consumption. Data for each XS Group property was assembled from the five years before conversion (or as many records as were available; only properties having converted from turf to xeriscape were in this analysis sample) and as many years post-conversion as records permitted up through 2001. These data sets permitted comparison of total yearly consumption before and after the landscape conversion. The impact of submetering and site visits could also be evaluated by comparing mainmeter records for the TS Group pre- and post-installation of landscape submeters. Differences could be further confirmed by comparing the change in total household consumption following the conversion or submetering event for the XS and TS groups respectively against the change in consumption for non-contacted, non-retrofitted properties of similar landscape composition. The general analysis strategy for Objective 2 of the approved Scope (Appendix 1) is summarized in the following tables (Tables 1 and 2):

TABLE 1: Planned Pre-/Post-Retrofit Analyses for XS Group

	Pre-retrofit (kgal/yr)	Post-retrofit (kgal/yr)	Difference in Means (kgal/yr)
Xeriscape Treatment			
Comparison			
Difference in Means (kgal/yr)			

TABLE 2: Planned Pre-/Post-Retrofit Analyses for TS Group

	Pre-retrofit (kgal/yr)	Post-retrofit (kgal/yr)	Difference in Means (kgal/yr)
Submetered Conventionally Landscaped Treatment			
Comparison			
Difference in Means (kgal/yr)			

ANALYSES OF SAVINGS OVER TIME AND SEASONS

Objective 3 directs SNWA to measure the variability of water savings over time and across seasons. In the approved Scope, this was anticipated to involve comparing the XS, TS, and Comparison Groups to derive savings estimates in the manner specified in the tables that follow (Tables 3 and 4):

TABLE 3: Planned Post-Retrofit Analyses for XS Group Across Time

	First Year's Consumption (Y1)	Third Year's Consumption (Y3)	Difference in Means (kgal/yr)
Xeriscape Treatment			
Comparison			
Difference in Means (kgal/yr)			

TABLE 4: Planned Post-Retrofit Analyses for TS Group Across Time

	First Year's Consumption (Y1)	Third Year's Consumption (Y3)	Difference in Means (kgal/yr)
Submetered Conventionally Landscaped Treatment			
Comparison			
Difference in Means (kgal/yr)			

Since in most cases, meters were read monthly or at least bimonthly, SNWA is able to provide an analysis exceeding the level of detail originally specified in the Scope. Specifically, the longevity of savings from conversions for *each* year following the conversion could be evaluated, thus the following new table specifies the more in-depth level for the “over time” analyses called for in Objective 3:

TABLE 5: Enhanced Post-Retrofit Analyses for XS Group Across Time

Mean 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)					
Comparison Group (kgal/year)					
Difference in Means (kgal/year)					

TABLE 6: Enhanced Post-Retrofit Analyses for TS Group Across Time

Mean 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)
Submetered Conventionally Landscaped Treatment (kgal/year)					
Comparison Group (kgal/year)					
Difference in Means (kgal/year)					

Recruitment of properties for the XCS spanned a couple of years. For this reason, in order to evaluate true changes over time, the first year after each conversion was designated as Y1, the second as Y2, and so forth. As such, consumption data for a property starting in, for example, 1995, was designated as belonging to Y1, but for a different property starting in 1996, 1996 was Y1. In this way, the impact of different start years was corrected for and multiyear analyses could be considered on a more common basis. This permits inferences to be made about how landscape water consumption and savings change over time as plants in the xeric areas mature. It is also the reason the sample size appears to diminish for the XS Groups from Y1 to Y5. It is not that there was heavy loss of sample sites, rather that fewer sites were in existence for a total of five years owing to early enrollment. A similar effect is seen in the TS Group. There is no data for Y5 for the TS Group because enrollment for that Group started later than for the XS Group.

Savings from xeriscape may be greatest in summer when evapotranspirational demand is greatest for all plants, but so to an extreme degree in southern Nevada for turfgrasses (Source: University of Nevada Cooperative Extension). In considering how savings may be different across seasons, the Scope (Appendix 1) directs the SNWA to certain prescribed analyses (Tables 7 and 8):

TABLE 7: Planned Summer Post-Retrofit Analyses for XS Group

	Pre-Retrofit Summer Consumption (kgal/month)	Post-Retrofit Summer Consumption (kgal/month)	Difference in Means (kgal/month)
Xeriscape Treatment			
Comparison Group			
Difference in Means (kgal/month)			

TABLE 8: Planned Summer Post-Retrofit Analyses for TS Group

	Pre-Retrofit Summer Consumption (kgal/month)	Post-Retrofit Summer Consumption (kgal/month)	Difference in Means (kgal/month)
Submetered Conventionally Landscaped Treatment			
Comparison Group			
Difference in Means (kgal/month)			

Because of the resolution available by submetering, even more detailed data pertaining to application of water to turf and xeriscape through seasons is available in the comparative per-unit area irrigation analyses (see following section and Comparison of Per-Unit Area Water Application between Turfgrass and Xeric Landscape in *Results and Discussion*).

COMPARATIVE PER-UNIT AREA IRRIGATION ANALYSES

Submeter consumption data combined with measurement of the irrigated area permitted calculation of irrigation application on a per-unit area basis (gallons per square foot, which can also be expressed as precipitation inches equivalents) for most study participants. In this way, exacting measures of consumption for irrigation of xeric and turf landscape types could be measured. The sample size (N_s) is the product of the number of months or years of data and the number of valid submeter records analyzed. Sample sizes for specific analyses appear in *Results and Discussion*. Only records for submeters that monitored turf exclusively were included in per-unit area analyses involving the TS Group so that other landscape types would not confound calculation of results.

No prescribed analyses of submeter consumption data appear in the Scope. The two basic sets of analyses selected by SNWA were (i.) a comparative analysis of annual application to xeric and turf areas and (ii.) a comparative analysis of monthly application to xeric and turf areas. The analytical setup of these appears in Tables 9 and 10 respectively. Secondary analyses comparing usage to theoretical reference ET demand projections follow the basic comparisons and appear in *Results and Discussion*.

TABLE 9: Planned Comparative Analysis of Turf and Xeric Per Unit Area Annual Application

	Per Unit Area Application (gallons/square foot/year)
Submetered Turf (TS Group)	
Submetered Xeriscape (XS Group)	
Difference (gallons/square foot/year)	

TABLE 10: Planned Comparative Analysis of Turf and Xeric Per Unit Area Application for Each Month

	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)												
Submetered Xeriscape (XS Group)												
Difference (gallons/square foot/month)												

MULTIVARIATE ANALYSES TO IDENTIFY SIGNIFICANT SOURCES OF VARIABILITY

Objective 4 of the Scope (Appendix 1) directs SNWA to assess variability of water use amongst the study participants and identify what factors contribute to that variability. Potential sources of variability originally specified for investigation in the Scope included the following:

- Number of members in the household
- Age of occupants
- Number of bathrooms
- Income
- Home value
- Percentage of xeriscaping
- Xeriscape density
- Turf type
- Type of irrigation
- Lot size
- Landscapeable area
- Existence of a pool
- Flow rates
- Water use factors

As the XCS developed, additional potential factors were assessed. A complete listing of data recorded is included in Appendix 3 (not all data was collected for all properties in the study).

Preliminary investigations focused on some of the above variables from a principally univariate analysis perspective (DeOreo⁹ et al. 2000, Sovocool¹⁰ et al. 2000, Sovocool and Rosales¹¹ 2001, Sovocool¹² 2002). The advantage of this was that it permitted rapid quantification and association of target variables' influences on participant water use, especially at the per-unit area scale. However, the most sophisticated way to deal with a study of this type where there are a number of potential independent associations of several predictor variables to a dependent variable is by the application of multivariate regression analysis methods. This permits so-called "partial regression" of independent variables to the target dependent one, here water consumption. Multiple regression for estimation can be expressed in the general multiple regression equation as follows:

$$\hat{Y}_i = \hat{a} + \hat{b}_1 * X_{1i} + \hat{b}_2 * X_{2i} + \dots + \hat{b}_{ni} * X_{ni} + \epsilon$$

Where \hat{Y} is the estimated dependent variable, \hat{a} is the y-axis intercept, \hat{b} is each estimated beta partial regression coefficient representing the independent contribution of each independent variables' influence on \hat{Y} , X is each independent variable up to the n th variable, i is the time period and ϵ is the error term for the model.

Multicollinearity between X variables violates the underlying assumptions of regression models and can be dealt with by setting limiting tolerance thresholds of similarity in contribution of variability to a regression model. This, in turn, permits identification and possible exclusion of such highly collinear and possibly inappropriate independent variables. The most significant variables can then be quantified and their relative vector and magnitude of association on the

dependent variable can be deduced, ultimately yielding an explanatory multivariate model of how such variables may contribute to water consumption. Such variables are explored for association to total household consumption and xeric landscape submeter consumption in the results section in two distinct modeling exercises.

ECONOMIC ANALYSES

Objective 5 of the Scope mandates quantification and measurement of capital costs and maintenance costs of the conversion. In the summer of 2000, data on landscape maintenance economics was obtained via surveys sent to study participants. The survey helped quantify both labor hours and direct costs associated with landscape choices. For details on the survey and methodology, consult Hessling¹³ (2001). Three hundred surveys were returned for analysis. Results of these were tabulated and compiled, and analyses proceeded from there.

By the very nature of the study methodology, it was recognized at the outset that a simple comparison of the XS and TS groups would likely fail to demonstrate the economic considerations with respect to maintenance of the whole landscape level as most residents' landscapes were composed of multiple landscape types (at the least, both xeric and turfgrass areas). This led to an analytical method of comparing the costs of landscape maintenance based on the relative percentages residents had of turf and xeric areas respectively.

The water bill savings associated with conversion projects were calculated based on the Las Vegas Valley Water District's water rates as they currently stand (in early 2004). Savings were calculated by modeling bills for a typical fifth decile (midrange in consumption) home where the average yearly consumption is 208,057 gallons and for such a home doing an average (according to data collected for the Water Smart Programs single-family sector in early 2004) 1,615.8-sqft-conversion from turfgrass to xeric landscape (note the difference in this average size conversion relative to that of the XS Study Group; conversion sizes, along with lot sizes, have diminished over time in this area). Bills were modeled on a monthly basis and all charges were applied that actually appear for customers. An example output of this model appears in Appendix 4.

As directed in the Scope (Appendix 1), the financial viability of xeriscape conversions was explored. This necessitated looking at the economics of conversions from the homeowner and SNWA perspectives. Hessling¹³ (2001) attempted some of these initially. A follow-up analysis from these same perspectives was performed in the writing of this report and is included in *Results and Discussion*. The homeowner perspective included an estimative Net-Present-Value (NPV)-based modeling approach to determine when return on investment (ROI) was achieved and details on this model appear in Appendix 5. This same model is used to determine the incentive level necessary to induce change (Objective 6) by making some assumptions about what timeframe is acceptable for owners to achieve ROI. The approach used for the SNWA perspective is to consider alternative sources of water and use the cost associated with these to determine the maximum amount SNWA should pay to help convert grass to xeric landscape.