National Green Building Standard™

2015 UPDATE

Home Innovation RESEARCH LABS™

Substantiating Documents

May 15, 2015

Edison Electric Institute

Power by Association℠

PC021

Issues with using Source Energy Estimates in ASHRAE (and other) Building Codes

Steve Rosenstock, P.E. and Chuck Foster, Esq.

ASHRAE 90.2 Task Group

April 5, 2013

Overview

- Introduction
- A Review of Where Codes / Standards Are
- What happens when looking "Upstream" for Different Energy Sources
- What about other Upstream Factors?
- Conclusions

EEI

Introduction

Introduction (1a)

- The issue of "site energy " versus "source energy" goes back to the 1970's.
- EPCA 1975 – Federal law that required appliance energy efficiency standards to be based on "point of use" or site energy metrics and measurements.
- There have been many other federal energy efficiency laws that have been signed into law, such as:

EEI

Introduction (1b)

- ECPA 1978
- NAECA 1987
- EPACT 1992
- EPACT 2005
- EISA 2007
- AEMTCA 2012
- What do they all have in common?

Introduction (1c)

- All of the laws either set new equipment efficiency standards, required DOE to study or set new appliance efficiency standards, or expanded the scope of DOE efficiency activities (to make ASHRAE Standard determinations, for example).
- **None of them ever set a standard that was based on source energy estimates.**

Introduction (1d)

- We understand the appeal of "looking upstream" at source energy estimates to get a sense of possible larger impacts outside of a building or building site boundary.
- **However, there are numerous problems with using source energy (or emissions) estimates that are so great as to prevent achieving a consensus for an ASHRAE Standard.**

EEI

Section 2: A Review of Where Codes and Standards Are

Codes / Standards (2a)

- **What do the following standards have in common?**
- ASHRAE 90.1 (1975 – 2013)
- ASHRAE 90.2
- ASHRAE 189.1 (2009, 2011)
- ICC-700 (National Green Building Standard) (2008, 2012)
- IECC Commercial Code (2003, 2006, 2009, 2012)

Codes / Standards (2b)

- **Answer:**
- Except for the IECC, they are all consensus-based ANSI Standards.
- They do not use source energy estimates for any mandatory/prescriptive requirements, or for any optional performance paths (ASHRAE 189.1 does use CO_2e emissions in its performance path).
- So what about the others?

EEI

Codes / Standards (2c)

- IECC – Residential
  - Uses 1 estimated annual value for electricity and 1 estimated annual value for all fossil fuels in the exception to the performance path.
- IGCC – Chapter 6
  - Uses **26** estimated values for electricity and **3** different estimated values for fossil fuels (one for natural gas, one for fuel oil, and one for propane).
  - The electricity estimates are based on sub-regional power pools and 2005 information. **18** of the 26 estimates are lower than the IECC estimate.

EEI

Section 3: What Happens When you Look Upstream?

EEI

Looking Upstream (3a)

- What if ASHRAE 90.2 used source estimates?
- Key Question: Which numbers do you use? The following entities have studies with estimates:
  - NREL (June 2007 NREL/TP-550-38617)
  - AGA (EA 2009-3)
  - EPA (August 2009 for Portfolio Manager)
  - DOE (2007-2012 TSD's for appliance standards)
- Numbers are all over the place (e.g., as low as 1.01 for fuel oil, etc) and different from the IECC/IGCC.

EEI

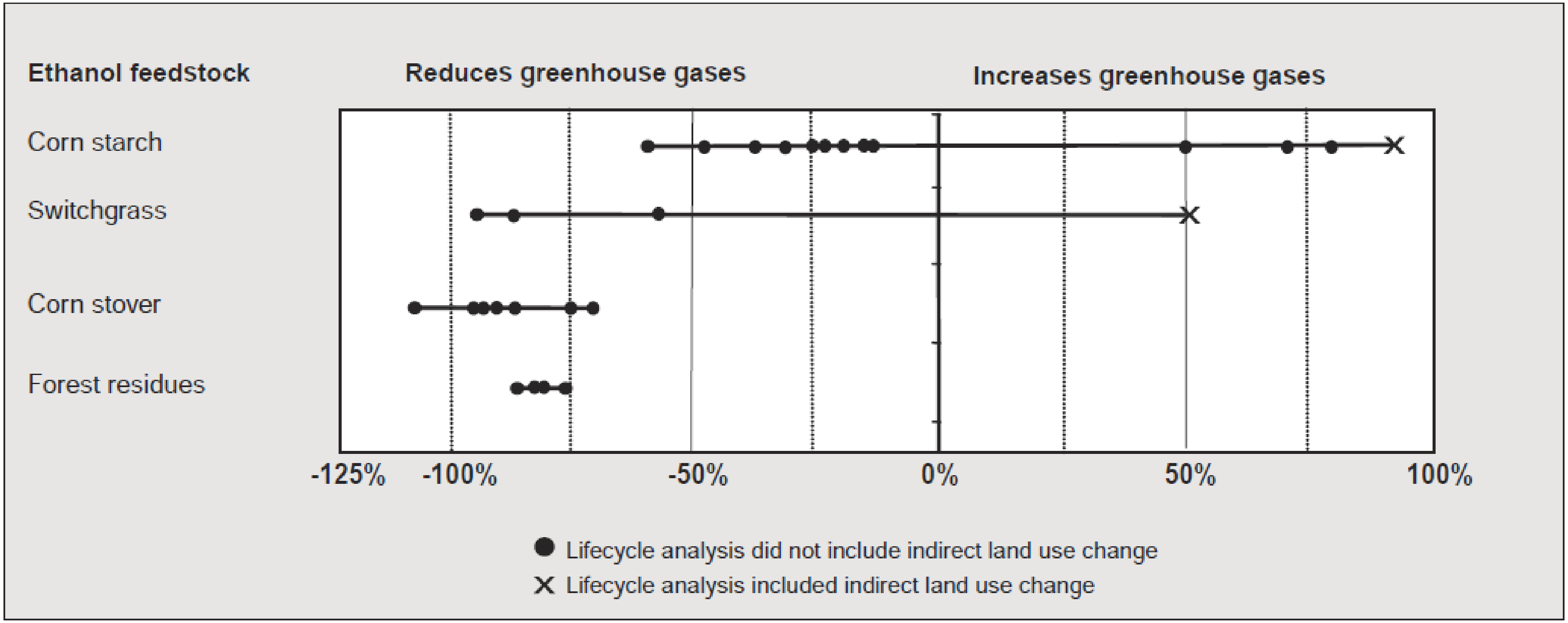
Looking Upstream (3b)

- Now, let's think out of the box:
- What uses more "life cycle" energy – gasoline or ethanol?
- The US General Accounting Office (GAO) looked at the issue in its August 2009 report "Biofuels – Potential Effects and Challenges of Required Increases in Production and Use" (GAO-09-446).
- "Overall, the estimated lifecycle greenhouse gas emissions biofuels compared with fossil fuels in these studies ranged from a 59 percent reduction to a 93 percent increase in greenhouse gas emissions for corn starch ethanol, a 113 percent reduction to a 50 percent increase for cellulosic ethanol, and a 41 percent to 95 percent reduction for biodiesel."

Looking Upstream (3c)

- From the GAO report:

Figure 5: Estimated Lifecycle Greenhouse Gas Emissions of Ethanol as Compared with Gasoline



Source: Figure based on data from 12 key studies conducted by DOE, USDA, and academic researchers.

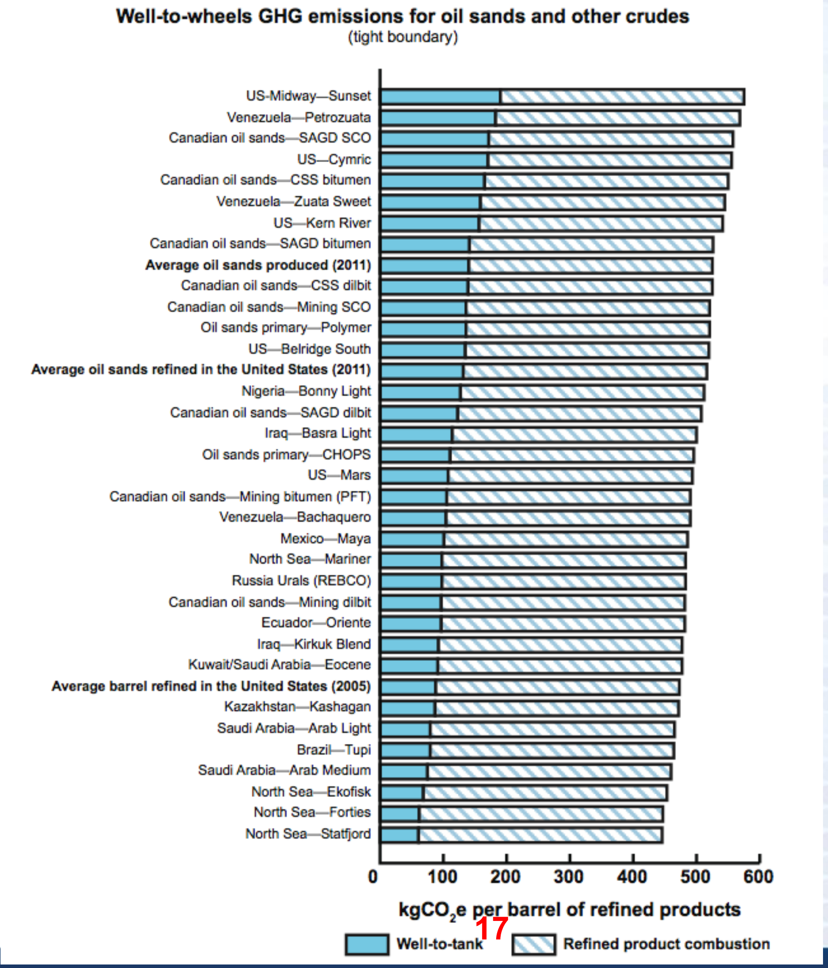
Looking Upstream (3d)

- In terms of other fuels, where did the fuel oil come from? Oil Sands? Deepwater? Where was it refined?

Thousand Barrels of Crude Oil Per Day Imported into the U.S.				
COUNTRY	2011	2001	2001 Rank	Change
CANADA	2,149	1,356	2	58%
MEXICO	1,216	1,394	3	-13%
SAUDI ARABIA	1,099	1,611	1	-32%
NIGERIA	968	842	5	15%
VENEZUELA	951	1,291	4	-26%
IRAQ	470	795	6	-41%
ALGERIA	378	11	29	3336%
COLOMBIA	303	260	9	17%
ANGOLA	294	321	7	-8%
BRAZIL	259	13	27	1892%
ECUADOR	178	113	13	58%
KUWAIT	147	237	11	-38%
RUSSIA	105	0	NA	NA
CONGO (BRZ)	58	40	16	45%
CAMEROON	31	3	33	933%

Looking Upstream (3e)

- CERA 2010 study on Oil Sands:



Looking Upstream (3f)

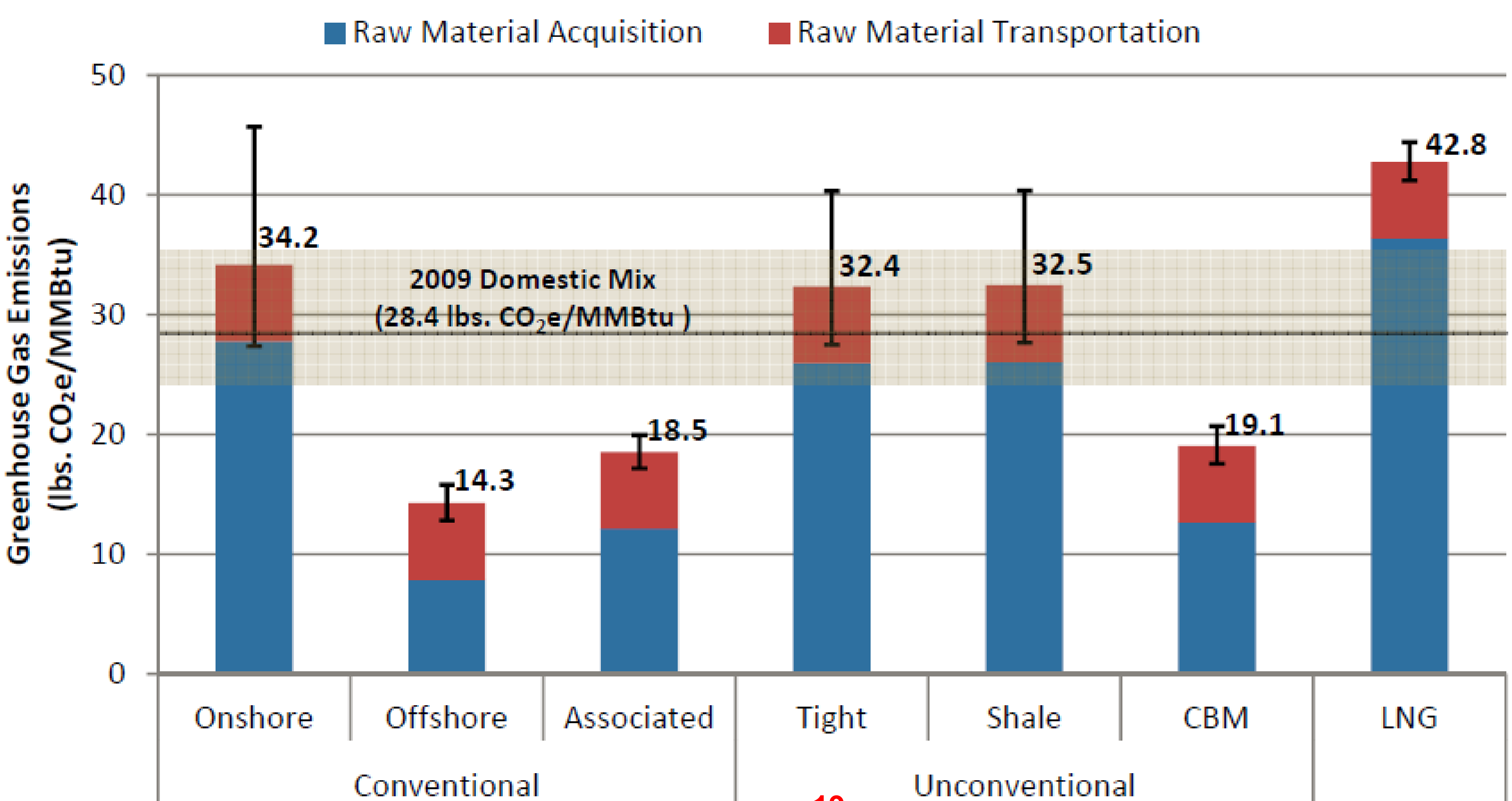
- Other studies of interest for other energy:
- DOE / NETL-2011/1522, "Life Cycle Greenhouse Gas Inventory of Natural Gas Extraction, Delivery, and Electricity Production" (October 24, 2011)
- Detailed study of different production methods.
- The following pages show key graphs:

EEI

Looking Upstream (3g)

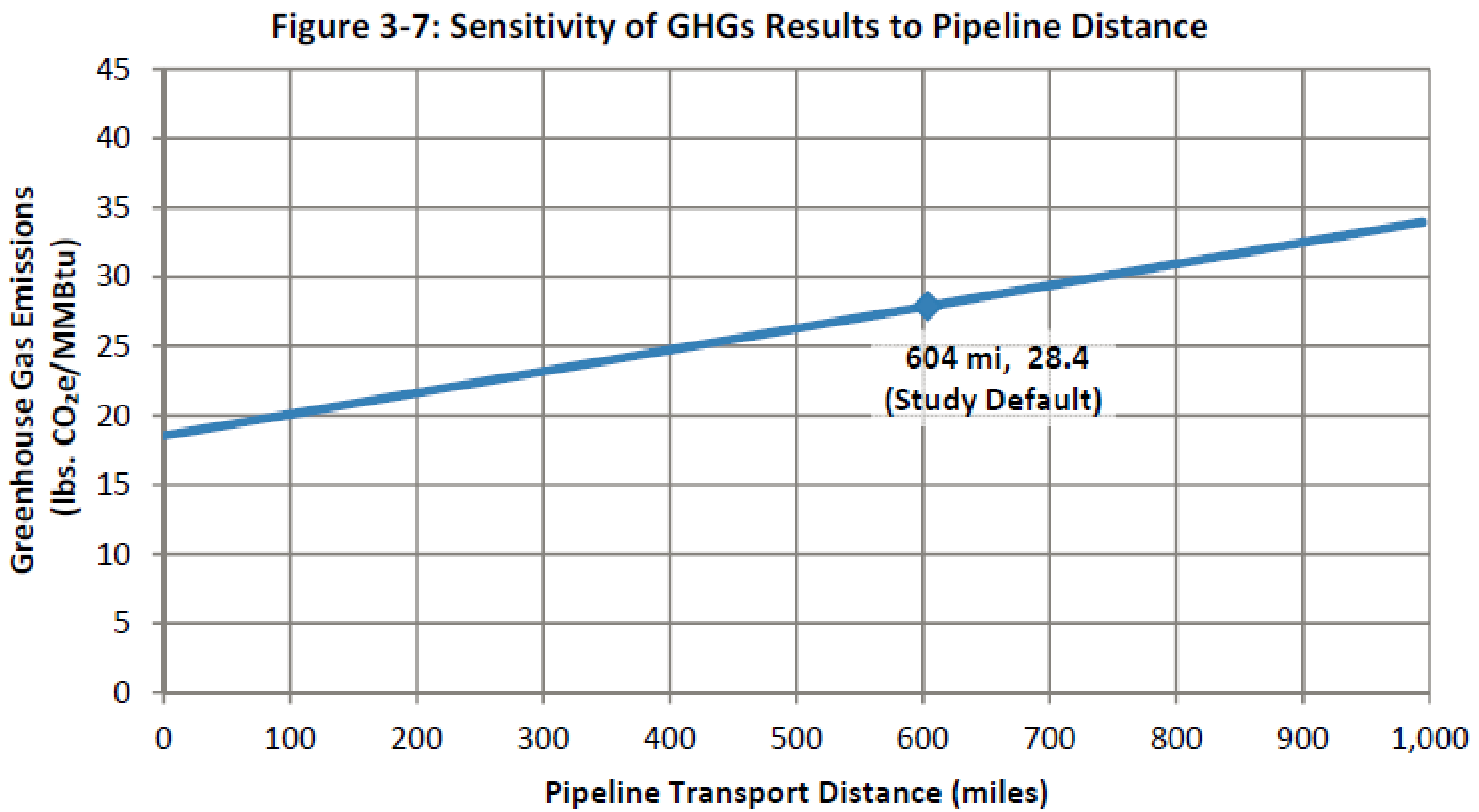
- Significant difference in energy/emissions for different types of production:

Figure 3-1: Upstream Cradle-to-gate Natural Gas GHG Emissions by Source



Looking Upstream (3h)

- Differences based on pipeline distance:



Looking Upstream (3h2)

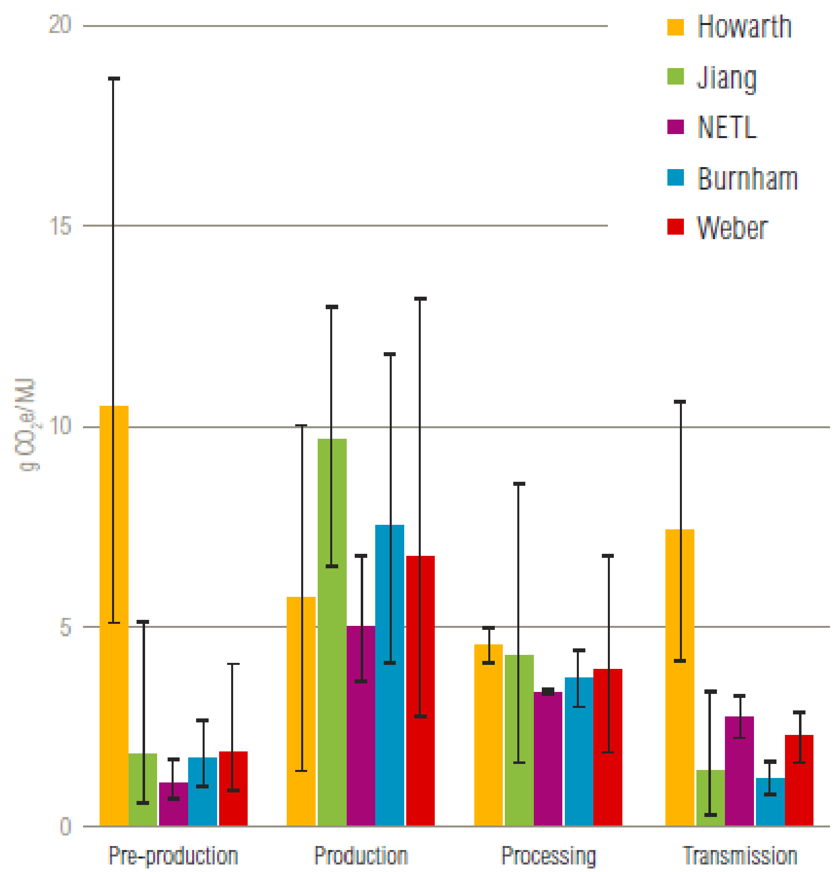
WRI Working Paper April 2013

"Clearing the Air: Reducing

GHG Emissions from U.S.

Natural Gas Systems"

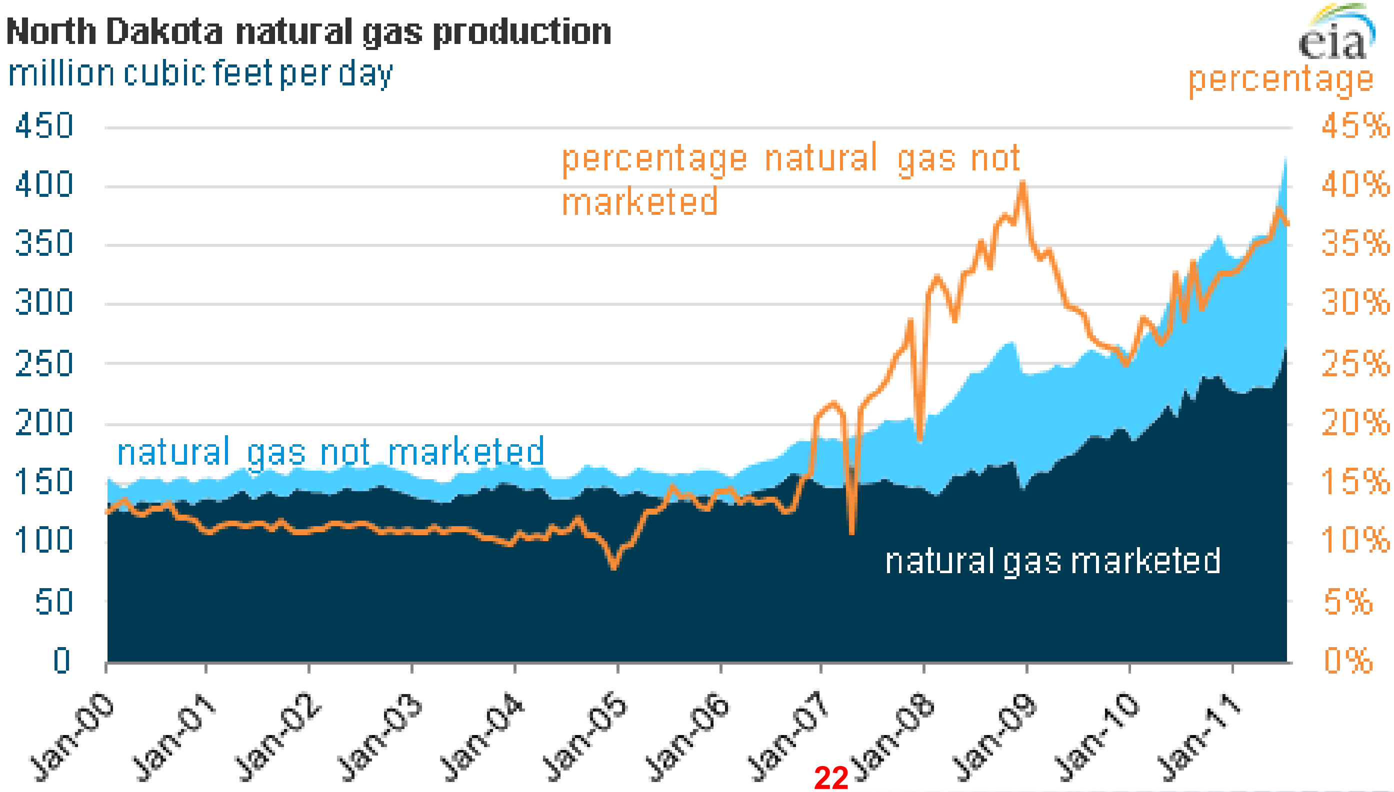
Figure 4 | Upstream GHG Emissions from Shale Gas, by Life Cycle Stage



Sources: NETL (2012), Jiang et al. (2011), Howarth et al. (2011), Burnham et al. (2011), and Weber and Clavin (2012).

Looking Upstream (3i1)

- Local issues (EIA, 11/23/11) "**Over one-third of natural gas produced in North Dakota is flared or otherwise not marketed**"



Looking Upstream (3i2)

- ND Department of Mineral Resources 03/15/13 Report https://www.dmr.nd.gov/oilgas/directorscut/directorscut-2013-03-15.pdf
- "Additions to gathering and processing capacity are keeping up with the percentage of gas flared holding at 29%. The historical high was 36% in September 2011."
- https://www.dmr.nd.gov/oilgas/stats/Gas1990ToPresent.pdf

Date	MCF Produced	MCF Sold
3-1998	4,690,198	4,154,477
1-2013	24,584,184	16,611,332

Looking Upstream - Electric (3j1)

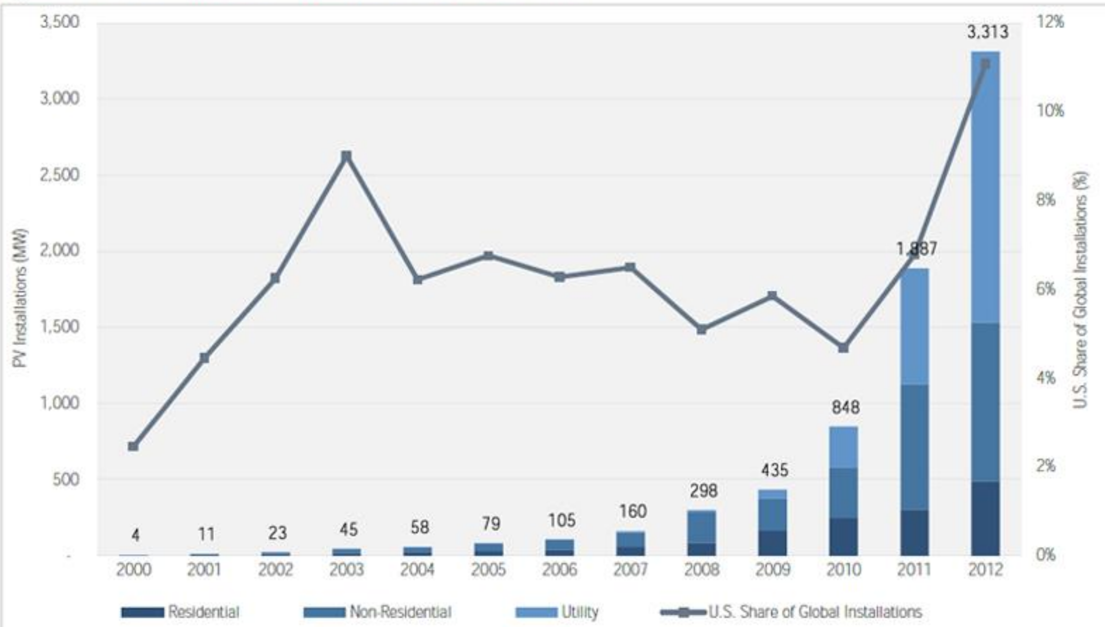
Records Set for Solar Electric Energy

- Over 3,300 MW (3.3 GW) of utility side and customer –side solar energy systems were installed in 2012 (76% increase > 2011).
- August 14, 2012 – 1st day the CA grid was served by over 1 GW of solar energy (1003 MW).
- CA record: on March 10, 2013, the CA Grid was served by 1,656 MW (1.65 GW) of solar energy production.
- According to FERC, 424 MW of solar systems were installed in January & February 2013.

PC021

Looking Upstream - Electric (3j2)

Figure 2.1 U.S. PV Installations and Global Market Share, 2000-2012



Installations (MWdc)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Residential	1	5	11	15	24	27	38	58	82	164	246	302	488
Non-Residential	2	3	9	27	32	51	67	93	200	213	336	826	1,043
Utility	0	3	2	3	2	1	0	9	16	58	267	760	1,781
Total Installations	4	11	23	45	58	79	105	160	298	435	848	1,887	3,313

(Written permission received on 4/10/2013 from SEIA)

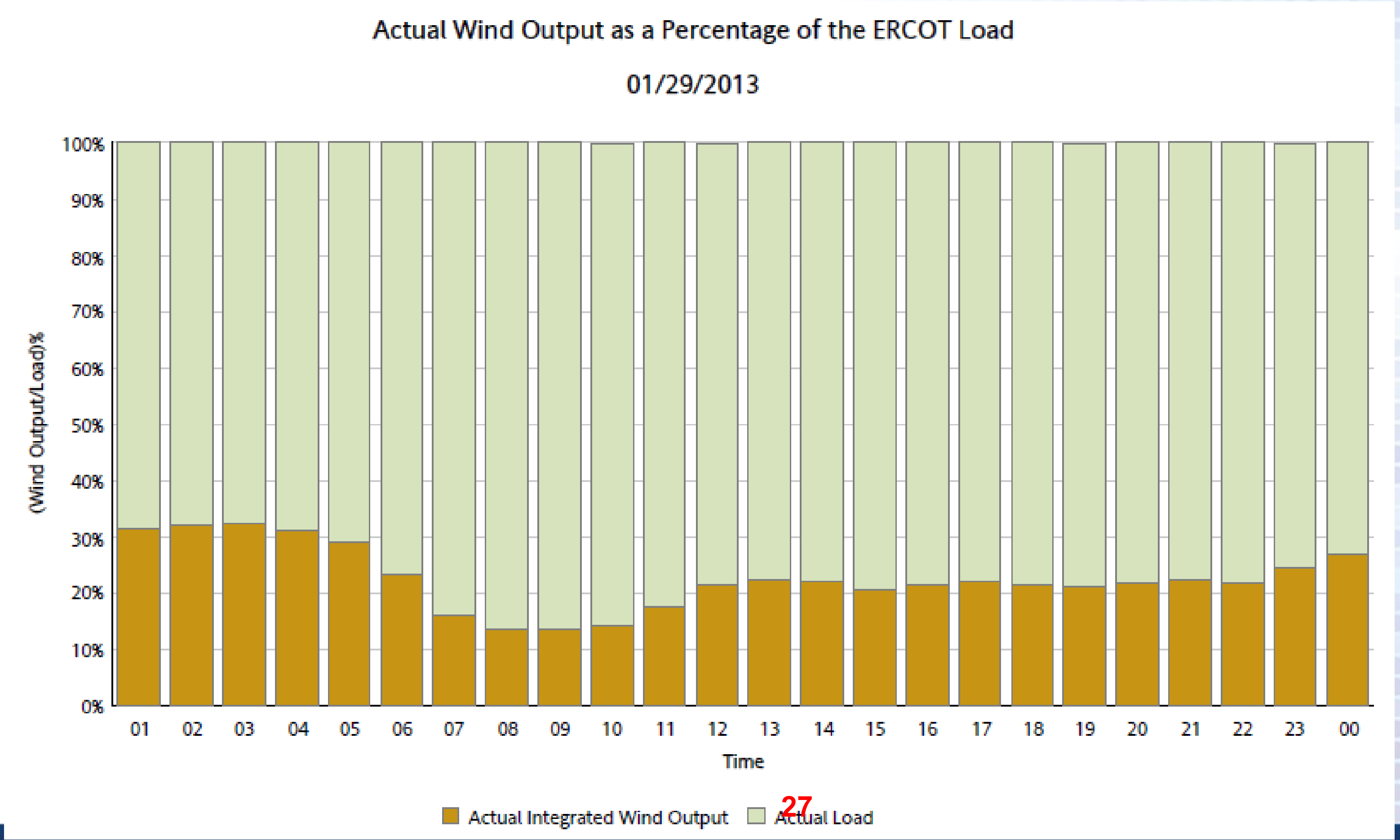
Looking Upstream - Electric (3k)

- **Records Set For Wind Electric Energy**
- Over 12,600 MW (12.6 GW) of wind turbines were installed in the US in 2012 – a new record. Total in US: Over 60 GW
- Over 5,200 MW (5.2 GW) of wind turbines were installed in December 2012 (tax credit was due to expire….).
- California ISO reports new wind generation record: 4,196 MW (AWEA Blog, 04/09/2013)
- 958 MW of wind turbines were installed in the US in January & February of 2013, according to FERC reports. The following page shows a graph from ERCOT on a very windy day….

EEI

Looking Upstream - Electric (3l1)

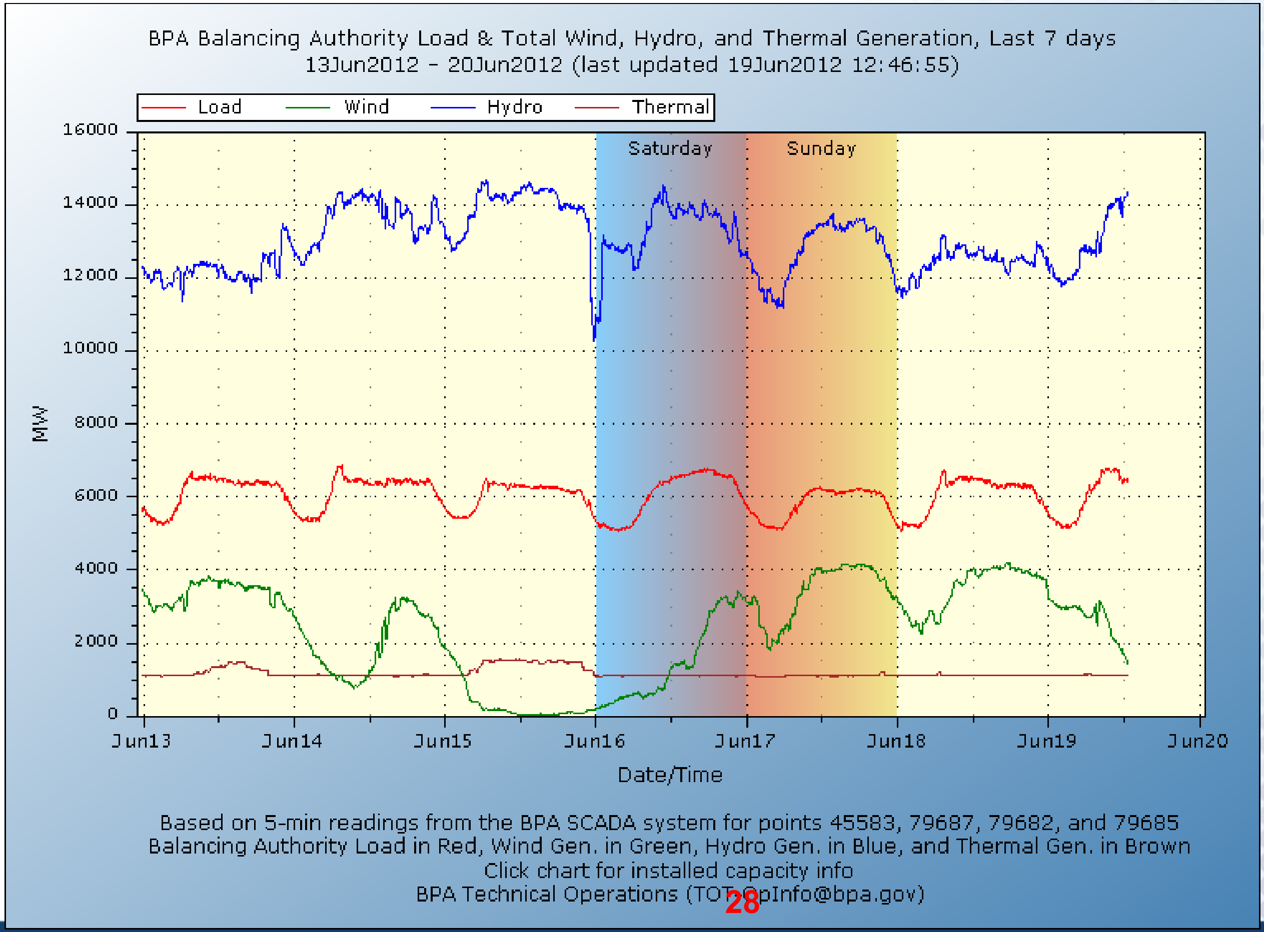
ERCOT Wind Integration Report 01/29/13



PC021

Looking Upstream - Electric (3|2)

BPA Wind Integration Report June 2012



Looking Upstream - Electric (3m)

- According to AWEA, the Top Ten states for new capacity installations in 2012 include:
  1. Texas (1,826 MW)
  2. California (1,656 MW)
  3. Kansas (1,440 MW) {wind = 11.4% of use in 2012}
  4. Oklahoma (1,127 MW) {wind = 10.5% of use in 2012}
  5. Illinois (823 MW)

  6. Iowa (814 MW) {wind = 24.5% of in-state use in 2012}
  7. Oregon (640 MW) {wind = 10.0% of in-state use in 2012}
  8. Michigan (611 MW)
  9. Pennsylvania (550 MW)
  10. Colorado (496 MW)

EEI

Looking Upstream - Electric (3n)

- **Other Records Set**

- WA: On Feb. 12, 2013, wind turbines provided **23.5%** of the electricity used during the entire day by customers of PSE.

- CO: Xcel Energy report that wind turbines provided 1,960 MW of power on Jan 16, 2013 (around 1 AM), meeting **51%** of the load at that time. In 2012, wind power produced **16%** of the electricity used by Xcel customers.

- TX: On 2/9/13, wind power produced 9,481 MW and met **27.5%** of the load at peak. During that day, wind was always meeting over **23%** of the load.

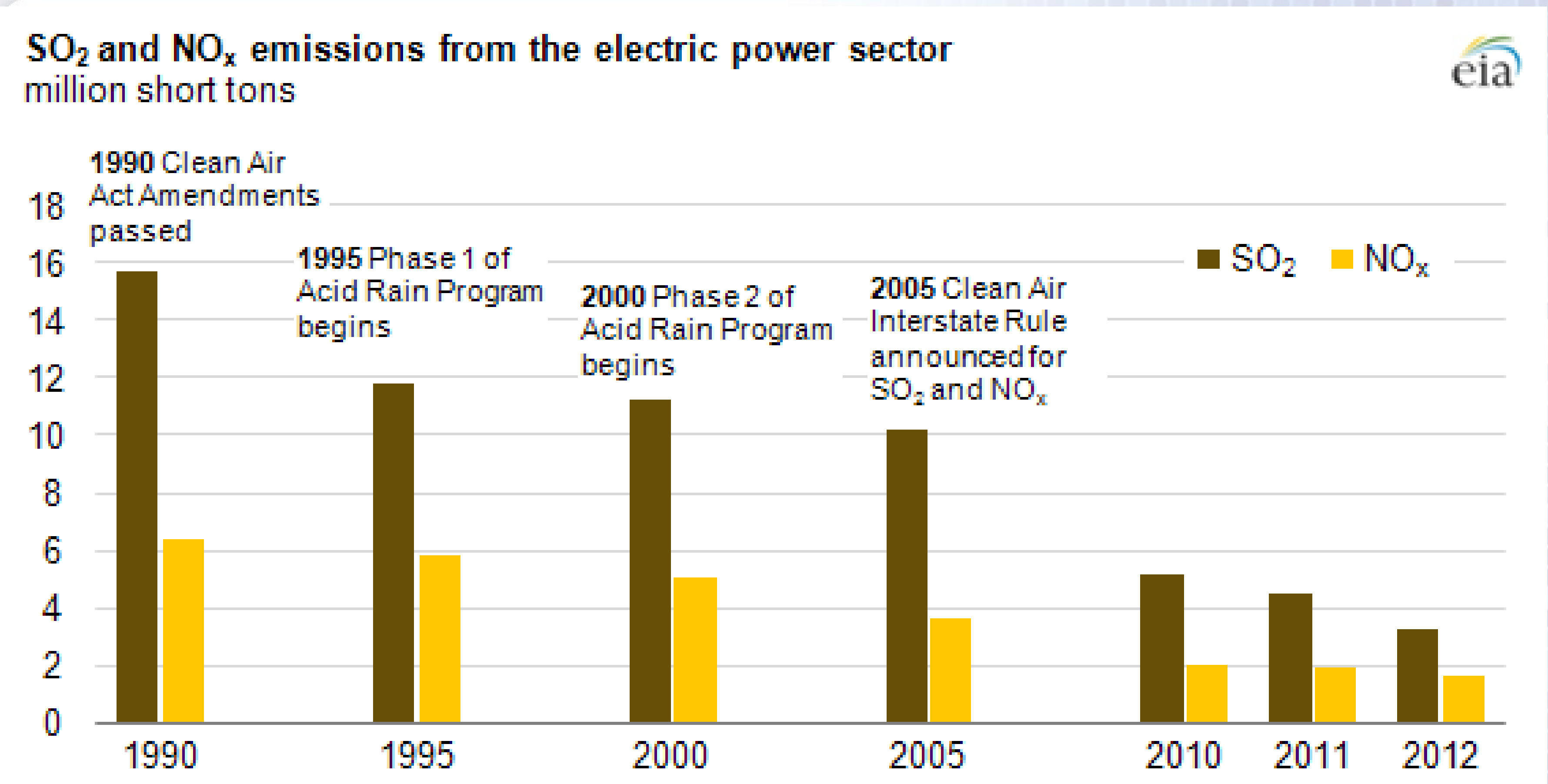
EEI

Other Generation (30)

- **Coal**
- Coal produced about 37.4% of the US power in 2012
- Generation from coal has declined **25%** over the past 5 years
- 9,300 MW of coal-fired generation were retired in 2012
- 27,000 MW are scheduled to be retired by 2016
- About 60,000 MW are scheduled to be retired by 2022.
- Overall CO2 emissions from electric generation in 2012 were below 1997 levels (while production increased by 16.1%).

PC021

Emissions Decline (3p)



Section 4: What about Other "Upstream Factors"?

Other Upstream Factors (4a)

- **Other entities are looking other upstream factors:**
- Life Cycle Assessments (LCA) for Materials
- Argonne National Lab GREET model for transportation
- They are looking at the product manufacturing energy and product transportation (delivery) energy as well as end-use or operational energy use.
- This has been called “embedded” or “embodied” energy.
- Should these be considered as well?

EEI

Other Upstream Factors (4b)

- Nokia April 2005 study, “Stage I Final Report: Life Cycle Environmental Issues of Mobile Phones”:
- “The product manufacture phase accounts for approximately **60%** of the total energy consumption in the case of light user scenario and about **54%** in the case of heavy user scenario”
- “The use phase accounts for approximately 29% of the total energy consumption in the case of light user scenario and about 35% in the case of heavy user scenario”
- Transportation was about 11% (6% from 1st tier suppliers to assembly plant; 5% from plant to the 1st customer)

EEI

Other Upstream Factors (4c)

- Items for consideration:
- Think about a heavier but more efficient appliance. What if the increase in production and/or transportation energy use cancel out end-use energy savings?
- What if they <u>increase</u> the estimated life cycle energy usage? Or:
- [(+Delta Prod) + (+Delta Trans)] > (-Delta End Use)

EEI

Conclusion / Summary

- When you look upstream, there are multiple variables and multiple inputs that lead to multiple outputs and multiple estimates.
- There isn't one number for any energy source. There is a range of estimates with a very high variance / standard deviation. Estimates vary by hour, day, month, year, production, type of energy delivery, and location.
- "When you save at the site, you always save at the source" (at least for the energy supply chain).

EEI

Q and A

- The floor is open!

Landscape Irrigation Best Management Practices

May 2014

Prepared by the Irrigation Association and American Society of Irrigation Consultants

Chairman: John W. Ossa, CID, CLIA, *Irrigation Essentials, Mill Valley, California*
Editor: Melissa Baum-Haley, PhD, *Municipal Water District of Orange County, Fountain Valley, California*

Committee Contributors (in alphabetical order):
James Barrett, FASIC, CID, CLIA, *James Barrett Associates LLC, Roseland, New Jersey*
Melissa Baum-Haley, PhD, *Municipal Water District of Orange County, Fountain Valley, California*
Carol Colein, *American Society of Irrigation Consultants, East Lansing, Michigan*
David D. Davis, FASIC, *David D. Davis and Associates, Crestline, California*
Brent Q. Mecham, CAIS, CGIA, CIC, CID, CLIA, CLWM, *Irrigation Association, Falls Church, Virginia*
John W. Ossa, CID, CLIA, *Irrigation Essentials, Mill Valley, California*
Dennis Pittenger, *Cooperative Extension, U.C. Riverside, Riverside, California*
Corbin Schneider, ASIC, RLA, CLIA, *Verde Design, Inc., Santa Clara, California*

The Irrigation Association and the American Society of Irrigation Consultants have developed the *Landscape Irrigation Best Management Practices* for landscape and irrigation professionals and policy makers who must preserve and extend the water supply while protecting water quality. The BMPs will aid key stakeholders (policy makers, water purveyors, designers, installation and maintenance contractors, and consumers) to develop and implement appropriate codes and standards for effective water stewardship in the landscape.

The following professionals provided valuable contributions to the document during 2013:

Luis Andrade, CLIA, *Ewing, Houston, Texas*
Don C. Blackwell, CIC, CID, CLIA, *Advanced Irrigation, Inc., Pacific, Washington*
Chris Butts, *Georgia Green Industry Association, Epworth, Georgia*
Baine Carruthers, *QLM, Inc., Gastonia, North Carolina*
Matt Cline, CIC, *Teacher's Landscaping & Irrigation, Olathe, Kansas*
Stephen Geckeler, CLIA, *Aqua-Lawn, Fairfield, Connecticut*
Mel Grills, *Mr. Lawn Irrigation, Greenwood, Missouri*
Deville Hubbard, *Hadden Landscaping, Plano, Texas*
John Moore, *California Landscape Contractors Association, Sacramento, California*
Theodore J. Moriarty, CIC, CID, CLIA, *Smart Watering Company, West Roxbury, Massachusetts*
Ivy Munion, ASIC, *The I.S.C. Group, Inc., Livermore, California*
John J. Newlin, CIC, CLIA, *Quality Sprinkling Systems, Inc., North Ridgeville, Ohio*
Jon Peters, *Baseline, Inc., Boise, Idaho*
Brian E. Vinchesi, ASIC, CID, CIC, CLIA, CGIA, CLIM, CLWM, *Irrigation Consulting Inc., Pepperell, Massachusetts*

The following professionals provided critical review and input during the process:

Robert Dobson, CID, CIC, CLIA, *Middletown Sprinkler Company, Middletown, New Jersey*
Allan Schildknecht, CID, *Irrigation Hawaii, Ltd., Kaneohe, Hawaii*
William Smillie, *Landscape Water Management, Nipomo, California*
Scott Sommerfeld, *East Bay Municipal Utility District, Oakland, California*
Kent Sovocool, *Southern Nevada Water Authority, Las Vegas, Nevada*
David Wright, *The Church of Jesus Christ of Latter-day Saints, Salt Lake City, Utah*

Contact Information:

Irrigation Association
6540 Arlington Blvd.
Falls Church, VA 22042
Tel: 703.563.7080
Fax: 703.536.7019
www.irrigation.org

American Society of Irrigation Consultants
4660 South Hagadorn Road, Suite 110F
East Lansing, MI 48823
Tel: 508.763.8140
Fax: 866.828.5174
www.asic.org

Table of Contents

Foreword

The Irrigation Association [IA] and American Society of Irrigation Consultants [ASIC] have developed these landscape irrigation best management practices [BMPs] to promote efficient use of water in the managed landscape. There are a number of stakeholders including: water purveyors, system owners, irrigation consultants/designers, contractors, irrigation managers and landscape professionals as well as state, federal and public agencies, code developers, and building officials.

Managed landscapes, while highly visible users of water, provide ecological, economical and recreational benefits. It is the stakeholders' responsibility to advocate for efficient irrigation and to incorporate and promote all reasonable practices that minimize water consumption and waste. The broad and comprehensive nature of the best management practices and related practice guidelines define the elements of an efficient irrigation system and responsible water management. Specific benefits include:

- Enjoining the water purveyor and the landscape and irrigation industries in water planning and development of local strategies to manage irrigation water use.
- Improving irrigation efficiency to optimize water use in both existing and new landscapes.
- Reducing energy costs of treating and pumping water.
- Providing criteria to achieve the desired results of water use efficiency that fit the purpose and function of the managed landscape.

Landscape Irrigation Best Management Practices includes:

- Three BMPs that address the design, installation and management of irrigation systems.
- Practice guidelines that address ways to effectively implement the respective BMPs and can be adapted locally.
- Appendices that provide related information for the implementation or understanding of the BMPs.

The BMPs and related practice guidelines provide the basis for sensible, informed decision making regarding regional water use and potential response to drought.

As professionals engaged in making decisions about how water is used, it is important to consciously seek to evolve fundamental attitudes and values to better serve the community.

John W. Ossa, CID, CLIA
Chairman, Landscape Irrigation BMP Task Group

Section 1: Introduction

1.1 Purpose

The primary purpose of a landscape irrigation system is to deliver supplemental water when rainfall is not sufficient to maintain the turfgrass and plant materials to meet their intended purpose. A quality irrigation system and its proper management are required to efficiently distribute water in a way that adequately maintains plant health while conserving and protecting water resources and the environment. Assuring the overall quality of the system requires attention to system design, installation, and management. In particular, this includes the following:

- The irrigation system shall be designed to efficiently deliver water to the landscape.
- The irrigation system shall be installed according to the irrigation design specifications.
- The irrigation system shall be managed to maintain a healthy and functional landscape while conserving and protecting water resources.

1.2 Definitions

1.2.1 Landscape Irrigation Best Management Practice

Landscape irrigation BMPs improve water use efficiency, protect water quality and are sensitive to the watershed and environment. Landscape irrigation BMPs are economical, practical and sustainable, and they will maintain a healthy, functional landscape without exceeding the minimum water requirements of the plants or the maximum water allowance where applicable.

1.2.2 Practice Guidelines

Practice guidelines are recommended practices or principles that aid in successfully accomplishing the related BMP. The practice guidelines are meant to be a guide to develop criteria that address site-specific landscape irrigation needs. It is the responsibility of the framers of such specifications to adapt the guidelines to meet their local needs.

1.3 Qualified Irrigation Professionals

The implementation of these irrigation BMPs and practice guidelines requires a commitment from qualified irrigation professionals. "Qualified" includes being formally trained, certified, licensed where required, having successful experience completing projects of similar scope, or other similar qualifications that meet state and local requirements.

IA certifies individuals in design, contracting, and management of irrigation systems. The ASIC recognizes professional irrigation consultants [PIC] as irrigation professionals who have been peer reviewed and board approved for the design and management of irrigation systems. The best results come when there is collaboration between landscape and irrigation disciplines.

A listing of certified individuals can be found on IA's website at *http://www.irrigation.org*.

A listing of professional irrigation consultants can be found on the ASIC website at *http://www.asic.org*.

There may also be regionally appropriate certifications.

The BMPs as described in this document recognize there are other licensing and certifying organizations in the irrigation industry but these programs stand on their own merit and were not evaluated for this document.

Section 2: Landscape Irrigation Best Management Practices

To assure the overall quality of the irrigation system and to promote irrigation efficiency; the following best management practices need to be implemented.

BMP 1: Design the Irrigation System for Water Use Efficiency

The irrigation system shall be designed to deliver water precisely and efficiently to maintain the function and purpose of the managed landscape while complying with any local limitations and requirements.

BMP 2: Install the Irrigation System to Meet the Design Criteria

The irrigation system shall be assembled and installed according to the irrigation design specifications, locally applied codes and standards, and manufacturers' product requirements. The qualified irrigation contractor or installer shall execute the installation per the plans and specifications and be capable of quality workmanship and the safe use of proper equipment.

Each BMP and the practice guidelines that support them were developed to meet the criteria of the following tenets of best management practices. To be effective, a BMP must

1. *Be applicable to any location, while allowing for site-specific conditions.*
2. *Protect the watershed and water quality and conserve water resources.*
3. *Be sustainable by allowing for improvement through adoption of new technology, knowledge, and innovative solutions.*

BMP 3: Manage Landscape Water Resources

To conserve and protect available water resources, the management of the irrigation system will optimize the efficient use of water to maintain a healthy and functional landscape with optimal irrigation system performance. This entails careful and active management of the system and adherence to all applicable watering limitations within the jurisdictional area. Management includes active irrigation system maintenance, scheduling, monitoring, and evaluation of water use, landscape health, and appearance.

> "A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise."
>
> Aldo Leopold
> *A Sand County Almanac*, 1949

Section 3: Practice Guidelines

All water resources are important and these practice guidelines will hold true for projects that use water supplied by a purveyor as well as on-site developed water resources. Vital to water efficient design and management is a plant palette that is appropriate to the region and soils that have been properly prepared. Knowledgeable landscape water management must focus on how the soil and irrigation work together creating the foundation for a healthy landscape. Not all of the listed guidelines will be implemented on each site, but the landscape water manager needs to be aware of the ones that have specific application.

PG 1: Practice Guidelines for Designing an Irrigation System

Practice guidelines can be used to develop site-specific irrigation plans, details and specifications while optimizing system efficiency. Implementation of these guidelines is best done as a collaborative effort between landscape and irrigation practitioners and the authority holding jurisdiction. The practice guidelines shall be compatible with state and local laws, rules, regulations, codes, or ordinances.

The irrigation designer shall perform a project analysis and a comprehensive site inventory as part of the design process to ensure that the irrigation system is designed to efficiently apply water, which enables the effective management and protection of water resources.

The landscape irrigation BMPs are principles that work interdependently with each other to efficiently use water. The Practice Guidelines may be adapted in principle to suit the constraints and opportunities inherent in water issues that are best solved on a local basis.

The landscape irrigation best management practices and practice guidelines should work in harmony with local or state initiatives such as California's Model Water Efficient Landscape Ordinance or state licensing

1. Irrigation Design Package

1.1 Project Analysis and Basis of Design

a. Include statement or narrative that identifies the assumptions used for design purposes such as: water sources to be used, need for a temporary system, total landscape water demand based on area, effective rainfall, water window, assumed irrigation efficiency and energy constraints for system operation.
b. Confirm the irrigation design plan accounts for local water laws or regulations, permitting requirements and applicable codes.
c. Convey how the system should be operated to use water resources efficiently to achieve the desired function of the landscape.
d. Select product preferences.
e. Identify a project budget and phasing.

1.2 Plan Submittal

a. When required, a complete plan package including the design, details and specifications shall be submitted to the appropriate governing agency for approval prior to installation of the system.
b. Typically, the irrigation designer submits plans to the client for package submittal with a landscape design.

1.3 Other

a. Consider future needs such as expansion of the system to accommodate further development.
b. The irrigation designer shall verify that a detailed controller map showing the location of sprinklers, valves and valve zones, etc., for the irrigation system is provided to facilitate water management and maintenance.
c. When the irrigation system needs to be inspected after installation or commissioned to verify proper performance, the irrigation designer should be involved in that process. See appendix A for additional information.

Minimum Plan Requirements

- The graphic presentation of the diagrammatic design shall include clear and concise reproducible drawings with all components sized, symbolized and keyed in a distinctive manner.
- Drawings are to be at a suitable scale to be clearly legible and have a north arrow.
- Sheet sizes are to match whole package documentation.
- Complete installation details shall accompany the drawings. Details to be project specific.
- Written specifications unique to the project shall supplement the drawings detailing materials and workmanship to be used in the installation.

2. Site Inventory

2.1 Identification

a. Weather considerations
   1) Historical temperature and rainfall data
   2) Prevailing wind direction and speed
b. Physical features
   1) Base area measurements (square footage)
   2) Site grading and drainage plans
   3) On-site water bodies/water features
   4) Conservation, utility or right-of-way easements, etc.
   5) Buildings, decks, parking lots, roadways and other structures
   6) Roof-top gardens, living walls, etc.
   7) Walkways, patios and other secondary hardscape features
   8) Exterior lighting plan when available
   9) Location of site utilities when available
c. Hydrozone areas
   1) Soil type (e.g., clay, loam, sand, etc.) and soil profile if applicable
   2) Exposure: sun/part shade/full shade — consider seasonal variation
   3) Reflected light and/or heat from adjacent building or hardscape
   4) Plant materials
      - Type of turfgrass
      - Annual color/bedding plants
      - Herbaceous perennials
      - Ground cover
      - Trees, shrubs/woody plants
      - Desert or drought tolerant plants
   5) Sloped areas/topography
   6) Special situations, such as building overhangs, on-structure planting such as green roofs or living walls, container planters, shallow planting areas, etc.

2.2 Calculations

a. Estimate water requirement.
   1) Identify the peak water demand month during the growing season (greatest reference ET and least rainfall).
   2) Estimate plant-water requirement for each hydrozone and/or irrigation zone by modifying the reference ET with appropriate plant factors that consider the functional purpose and aesthetic quality intended. Sum the total water need for each hydrozone and/or irrigation zone to calculate the landscape water requirement.
   3) Where water budgets are used to influence the landscape design, verify that the landscape water requirement is less than the landscape water allowance or allotment including expected irrigation efficiency. See appendix B for more information.

There are regional variations in key terminology and methodology; for example:

California's Model Water Efficient Landscape Ordinance uses "maximum applied water allowance," or MAWA.

Sustainable Sites Initiative uses "baseline water requirement," or BLWR.

4) If the water requirement is greater than the allowance, consult with the landscape architect or designer to make landscape modifications or adjust plant performance expectations within specific hydrozones.
5) Estimate any leaching fraction needed when a lower quality water source is used.

b. Establish water window and frequency.
1) Reasonable water windows should be less than 10 hours during normal conditions.
2) Irrigation frequency should be appropriate for the climate, soil type and plants used in the landscape including the establishment period.
3) Comply with local watering restrictions.
4) Water source, size and pressure and/or pump sizing must be considered.
   - If the water source and point of connection [POC] already exist, determine the water window that will be needed to meet peak demand.
   - For new water connections, the water window is used to determine the required capacity of the water tap or POC.

c. Calculate base irrigation schedule.
1) Determine minutes of run time for each irrigation zone to meet peak demand.
2) Compare total minutes of run time to water window.

2.3 Minimum Design Requirements

a. Provide separate irrigation zones to meet unique water requirements for each identified hydrozone.

b. Follow manufacturers recommendations for equipment performance.

2.4 Additional Considerations

a. Note if special trenching or installation techniques are required.

b. Identify existing specimen or heritage trees or other special features.

c. Consult with landscape designer to identify additional efficient water-use strategies in the landscape.

> ***Intent:*** *The irrigation system shall be designed to facilitate installation and the long-term maintenance of the system as the landscape matures. Where systems are to provide a temporary plant establishment service or are for a specific function such as leaching, hardware appropriate to that function and longevity requirement shall be selected.*

3. <u>Select Water Sources for the Irrigation System</u>

3.1 Identification

a. Consider all sources of legally available water on-site that can be used for irrigation and will help minimize the amount of potable water to be used for irrigation.
1) On-site developed water
   - Rainwater harvesting
   - Storm water capture
   - Graywater
   - Process water
   - Foundation water
   - Air-conditioning condensate

2) Municipally reclaimed water (abide by local codes and constraints)
3) Groundwater
4) Surface water such as lakes, streams, rivers or canals
5) Potable water supply
6) Identify class of contaminant in water supply (e.g., particulate, biological, chemical)
7) Other

b. Show source of water and POC for irrigation system.
1) Exact location/address of each POC specifying water source/type
2) Type, size and length of meter service piping
3) Meter type and size
4) Static pressure and available flow
5) Pump station or booster pump location and performance requirements (flow and pressure) when required
6) In freezing climates, provide a method to winterize the system.

c. Dedicated irrigation-only meters and flow sensors (sizes and locations).

d. Backflow prevention assemblies (type, size, and location).
1) Locate downstream of POC on potable water service.
2) Place in non turfgrass areas where possible and accessible for servicing.
3) Protect the backflow assembly from vandalism or theft.
4) Protect the backflow assembly from freezing where necessary.

3.2 Calculations

a. For municipal water supplies, calculate maximum safe flow rate.
1) The maximum allowable pressure loss through the meter should be less than 10 percent of the static pressure at the meter.
2) The maximum flow rate through the meter should not exceed 75 percent of the maximum safe flow through the meter (refer to charts for the specific type of meter).
3) The velocity of the water through the service line supplying the meter should not exceed 7.0 feet per second.

b. For on-site developed water sources.
1) Calculate reliable yield for all available water sources.
2) Determine practical storage capacity for the water sources to match climatic conditions.
3) Match available water and storage with water requirements.

Local plumbing codes and water purveyor service rules shall determine appropriate backflow type. Designer shall specify enclosure if required.

3.3 Additional Considerations

a. Comply with all state and local laws regarding alternate water sources.
b. Comply with all state and local laws regarding storage tanks and/or reservoirs.
c. Use lowest acceptable quality of water and supplement with higher quality of water when necessary.
d. Assure water quality will not harm plant growth and development.
e. Provide cost-benefit analysis for using alternate water sources and help the owner make an informed decision.

4. Irrigation Components

4.1 Identification

a. Appropriate emission device for each zone
   1) Sprinkler zones
   2) Drip/microirrigation zones
b. Valves sizes and locations
   1) Remote control zone valves
   2) Manual and specialty valves
c. Pipe layout including sizes, main line and lateral lines
d. Controller(s) and location(s)
e. Sensor types and their locations
   1) Weather sensors such as solar radiation, temperature, rain, and/or freeze sensors
   2) Soil moisture sensors
   3) Flow sensors
f. Drip/microirrigation devices
   1) Drip valve, pressure regulator, filter assembly
   2) Supply/exhaust manifold location
   3) Flush plugs and/or air/vacuum relief valves
   4) Emitter flow rate and spacing if using inline drip tubing
   5) Tubing depth
   6) Lateral row spacing

4.2 Design Requirements

a. Use symbols indicating the location of the various irrigation components.
b. Specify manufacturer, model, type and size of all components.
c. Develop a key of the symbols to facilitate plan reading.
d. Provide specific installation details for all components.
e. Provide written site-specifications for the project including general conditions.

5. Sprinkler Selection and Spacing

5.1 Identification

a. Select specific sprinkler heads and nozzles to apply water uniformly to the target area.
b. Select products suitable to the landscape requirements.
c. Select products to facilitate long-term reliability and serviceability.
d. Select products that are compatible with the quality of the proposed water source.

5.2 Calculations

a. Calculate the precipitation/application rate of the sprinklers for each zone.
b. For turfgrass areas, specify a minimum low quarter distribution uniformity [DU_{lq}] based upon size and geometry of the area.

5.3 Minimum Design Requirements

a. Do not exceed manufacturer's sprinkler spacing recommendations.
b. Design system so sprinklers operate within manufacturer-recommended operating pressure.
c. Use matched precipitation rate sprinklers (+/– 5 percent) within a zone.
d. Design system to target each planting area with no overspray of impervious surfaces or adjacent planting areas. Prevent runoff of water from the site.

e. Space sprinklers a minimum of 2 inches from hard surface edges but farther than 2 inches where possible to minimize overspray, back-splash or wind drift.
f. Specify a pop-up height of the sprinkler to clear interference from vegetation.
g. Include protective covers/lids specifically designed for use on athletic fields for sprinklers in "play" areas such as athletic fields.
h. Include purple markings on sprinklers and valves when using municipally reclaimed water sources.
i. Design the system to avoid or eliminate low-head drainage.
j. Avoid above ground fixed risers near pedestrian walkways, bicycle paths, etc.

5.4 Additional Considerations

a. If pressure exceeds equipment recommended operating range, use pressure regulating equipment to optimize performance.
b. Use lower precipitation rate sprinklers on slopes or heavy soils to reduce runoff potential.
c. Use check valves to control low-head drainage.
d. In areas of high vandalism use vandal-resistant products and parts to minimize potential damage or theft of the sprinklers.
e. Use drip irrigation instead of spray sprinklers in narrow or complex shaped areas.

6. Valves and Valve Boxes

6.1 Identification

a. Remote control zone/station valves
b. Manual isolation valves
c. Pressure-regulating valves appropriate for the water source
d. Specialty valves
    1) Pressure relief valves
    2) Air release valves
    3) Quick coupling valves
    4) Drain/flush valves
    5) Strainers and filters

6.2 Calculations

a. Designate an acceptable operating pressure range (minimum to maximum).
b. Calculate the flow rate for each zone control valve.

6.3 Minimum Design Requirements

a. Install valves to accommodate identified hydrozones.
b. Size the zone control valve so that flow through the valve is within the manufacturer's stated flow range and so that pressure loss does not exceed 10 percent of static pressure.
c. Install valves either above grade or below grade in a valve box large enough to service or access.
d. Valve box location should consider safety and aesthetics of the site, along with long-term durability of the valve box.
    1) Keep valve boxes out of athletic fields or recreation areas where they may interfere with use or aesthetics of the area.
    2) Keep valve boxes out of pedestrian or equipment pathways.
e. Use valve boxes colored purple when using municipally reclaimed water or as applicable by code.

f. Install the valve and valve box over a layer of coarse stone or gravel for stability and drainage. Maintain a physical separation (air space) between the layer of stone/gravel and the valve.
g. Valves installed at or below grade shall be enclosed in a valve box with sufficient strength to withstand the loads reasonable to expect in the installation location.

6.4 Additional Considerations

a. Install a master valve on larger systems.
b. When pressure is excessive (greater than 15 percent above recommended operating pressure), the following equipment could be used:
    1) Pressure-reducing valve(s) at point of connection
    2) Pressure-regulating device that can be added to the zone control valve
c. Specify zone control valves with flow control.
d. Specify fittings to allow for the easy removal of the remote control valve for servicing if necessary.
e. Use isolation valves on larger systems to facilitate servicing.
f. Install chemigation or fertigation equipment downstream of an approved backflow prevention assembly.
g. Consider locking lids on all valve boxes.

7. <u>Pipes and Fittings</u>

7.1 Identification

a. Type of pipe to be used for main lines and laterals lines:
    1) Polyvinyl chloride [PVC] polyethylene [PE], high-density polyethylene [HDPE] or other
    2) Pipe classification shall be indicated on plan key and specifications.
    3) The pipe shall be clearly marked with the manufacturer, size, schedule and/or pressure rating.
b. Colored pipe shall be used when required by code:
    1) Purple pipe for reclaimed or alternate water sources
    2) Brown or UV resistant pipe for aboveground installation (usually on steep slopes)
c. Minimum size for each pipe section
e. Type of fittings to be used for main lines and for laterals
f. Type of swing joint to be used with each type of sprinkler head

7.2 Calculations

a. Pressure loss for the "worst-case" zone. This may be the largest zone and/or the farthest zone from the POC and/or the zone with the greatest elevation change.
b. Flow in plastic pipe operating at full system capacity
    1) Velocity shall not exceed 5 feet per second for pipes 3-inch diameter or smaller. For pipes larger than 3-inch diameter the velocity should be lower.
    2) Pressure variation within a zone shall have less than 10 percent variation.
    3) Surge pressures in the main line shall be less than the safety factor of the piping.

7.3 Minimum Design Requirements

a. Piping
    1) The working pressure rating of the mainline pipe should be a minimum of 200 psi or at least twice the anticipated design pressure of the system, whichever is greater.
    2) Mainline piping should be sized to optimize pressure/flow conditions and should have the same pressure rating throughout.

3) Lateral pipes should have a pressure rating at least two times the operating pressure of the sprinklers.
4) Lateral piping should be sized to minimize pressure losses and optimize flow conditions.

b. Depth of pipe bury

1) The minimum depth of soil cover shall conform to local codes and/or as shown or listed in the drawings, details or specifications. When pipe bury is not listed on the plan, the generally accepted practice for pipe bury is the following.

Minimum cover measured from the top of pipe (or as specified)		
	Main line {in.}	Lateral lines {in.}
Residential	12	8
Commercial	18	12
Under vehicular paving	24	24

2) Backfill shall not have rocks or debris greater than ½-inch in size next to the pipe.

c. Fittings

1) Pipe fittings and connections shall be suitable for the type of pipe, exposure, operating pressure and flow applications.
2) Gasketed fittings on piping shall have restraints or thrust blocking.
3) HDPE fittings that are fusion or socket joined shall have the same dimension ratio [DR] as the pipe.
4) Fittings for PE pipe shall be insert-type or compression-type, suitable for the size and pressure rating of the system and using suitable clamps.
5) Threaded PVC pipe for nipples shall be Schedule 80 or better.

7.4 Additional Considerations

a. Sleeving and conduits

1) Under vehicular paving, pipe shall be installed in a sleeve made of a permanent rigid material (e.g., PVC at least Schedule 40 or Class 160, whichever is strongest).
2) Sleeving should be twice the size of the piping or wiring bundle that it will hold (2-inch pipe in a 4-inch sleeve and wires that fit in a 1-inch conduit shall have a 2-inch sleeve).
3) Pipe and wire shall be in separate sleeves.
4) Conduits for wiring should be laid parallel, not stacked, to facilitate future service with horizontal separation between the conduits.
5) Sleeving should extend a minimum of 2 feet beyond the edge of hard surfaces.
6) Subject to local authority holding jurisdiction.
7) Pipe sleeves should be marked for future location.

b. Fittings

1) Fittings for PVC
   - Fittings 4 inches and larger shall be gasketed fittings, preferably ductile iron.
   - Fittings 3 inches and smaller shall be gasketed, solvent welded or push-on style.
2) For PE pipe, worm gear clamps shall be used exclusively in sizes 1½-inch and larger.
3) Connection to sprinklers
   - For sprinklers with a ½-inch inlet, flexible swing pipe assembly or swing joints shall be used.

- For sprinklers with a ¾-inch inlet and larger, use swing joints that are made with rigid piping and multiple elbows to allow for multidirectional adjustment.

8. Drip/Microirrigation

The rate of soil drying and the elements that influence the drying of the landscape edge may be significantly different than the middle areas of an irrigation zone.

8.1 Identification

a. Statement of intent: Identify if system is intended as a permanent system for long-term maintenance or a temporary system for plant establishment, after which it is to be abandoned. State what period of time constitutes "plant establishment."
b. For design purposes, identify the soil type.
c. Identify emitter types for various hydrozones.
   1) Specify pressure-compensated emission devices to improve overall uniformity.
   2) Identify flow rate and operating pressures.
d. Water quality
   1) Identify the proper type of filtration.
   2) Identify the need for chemical additives.
   3) See table 1 for water quality recommendations.

8.2 Calculations

a. The water delivery rate should be proportional to the plant type and size.
   1) Application rate per zone
   2) Management allowed depletion factor
   3) Monthly zone run times based on local historical evapotranspiration [ET]
b. Create a separate schedule for plant establishment.

8.3 Minimum Design Requirements

a. Create separate drip irrigation zones for each hydrozone type where drip irrigation will be used. Don't mix subsurface drip with other drip areas.
b. Keep drip/microirrigation zones separate from other sprinkler zones.
c. Emitter placement
   1) For line-source drip irrigation, provide emitter and row spacing guidelines based on soil type and site conditions.
   2) For subsurface line-source drip irrigation, provide guidelines for location of subsurface drip irrigation laterals from hardscape edges and uncontained landscape areas.
   3) For point-source emitter systems, emission points to new plants should be located midway between the edge of the root ball and the crown of the plant.
   4) For permanent drip irrigation systems, provide sufficient emitters to wet at least 70 percent of the mature root zone.
   5) Provide isolation valves to separate drip lines used for establishment from those to be used for long-term maintenance.
   6) On slopes, locate the majority of emission points on the upslope side of the plant crown.

The emission product and system layout is based on plant density. A grid layout tends to be employed in high density plantings, while point source placement is used in lower density plantings.

   7) Where soil texture, tilth, or slope are likely to induce runoff, provide for small basins to mitigate runoff.

d. Piping
   1) Systems shall be looped (where practical) to improve system hydraulics and mitigate possible contamination of tubing if system is damaged. Avoid any dead ends that cannot be flushed.
   2) On slopes, run the tubing on contour to the slope to keep each run of the tubing at approximately the same elevation.
   3) For line-source systems, expand row spacing over approximately the lower third of a slope. Conversely, compress row spacing at the top of the slope.
   4) Ensure main and lateral sizing will allow for proper flushing.
   5) Specify trench filling and compaction method for subsurface drip irrigation installation.

e. Pressure regulation
   1) Pressure shall be regulated to the manufacturer's recommended range for distribution hardware.
   2) Pressure regulation devices shall be sized for the design flow rate of the irrigated zone and should accommodate flow rates during system flush.

f. Filtration
   1) Identify class of system contaminant: particulate, organic or chemical.
   2) If filtration element is a screen filter, specify mesh size and equivalent micron rating.
   3) If filtration element is a disk filter, specify mesh size and equivalent micron rating.
   4) If filtration is by media filter, identify media sand sizes and their micron equivalent.
   5) Identify acceptable pressure loss through filter and threshold for maintenance event.

g. Flush valves
   1) Install flush valve in a valve box.
   2) Follow the manufacturer's recommendation for maximum system size per flush valve.
   3) Multiple flush points on a zone may be necessary for large or complex shape areas.
   4) Ensure adequate flow is available to remove contaminant during flush/back flush as appropriate.
      - Suggested flushing velocity for potable water is 1 foot per second.
      - Suggested flushing velocity for nonpotable water is 2 feet per second.

h. Air/vacuum relief and check valves line-source installations
   1) Use air/vacuum relief valves to minimize ingestion of contaminants into distribution piping.
      - All laterals within the elevated area shall be connected with an air relief valve except for emitters that incorporate a check valve and meet manufacturer requirements for proper operation.
   2) Follow manufacturer's recommendation for maximum system size per air relief valve.
   3) Determine air vent sizing by the operating flow rate for relatively flat sites.
   4) Determine air vent sizing in accordance to the maximum drainage flow rate for sites with slopes and varied topography.
   5) Install check valves in the headers and footers to mitigate lateral drainage to the low point if not included in the emitter device; accompany the check valve with an air relief valve at the highest location within the (sub) section of the zone.

8.4 Additional Considerations

a. Consider differing plant-water requirements, root zone-depths and slope. Use separate drip/microirrigation zones where practical.
b. Recommend the use of the same emitter type and output within a zone.
c. Recommend a fitting at the flush valve to accommodate a pressure gauge.
d. Utilize a visual pop-up indicator to verify the drip/microirrigation zone is pressurized and operating. Locate this system operation indicator within a foot of the flush valve.
e. For trees and shrubs it may be necessary to place tubing (permanently or temporarily) on top of rootballs during establishment to hydrate root ball.
f. Management strategies
    1) Recommend the installation of a water meter or flow sensor, where possible, to capture data for management purposes.
    2) Recommend a controller with capability of multiple start times or cycle/soak feature to deliver pulse irrigation for establishing and sustaining a wetted pattern as well as achieving optimum irrigation efficiency.
    3) Establish system maintenance protocols.
        - Based on water quality, consider installation of chemical-injection system to address tubing /emitter maintenance.
        - Identify vertebrate and insect control strategy.
        - Identify strategy to manage soil salinity, when necessary.
g. Special considerations for subsurface drip irrigation [SDI]
    1) When designing subsurface drip, the primary movement of water through the target root zone will be by capillarity rather than gravitational.
    2) Nutrient management must be considered based on climate conditions.
    3) For seeded areas, provide guidelines for the use of temporary overhead spray to augment seed germination.
    4) For sod, provide guidelines for ensuring adequate soil moisture in advance of sod installation.

Table 1.

Water Quality Assessment

Water Quality – Irrigation water should be assessed to determine its suitability for irrigation. This is done in order to recommend water treatment when required. The assessment should identify the chemical characteristics of the water and address possible problems with soil salinity and plant health caused by the use of the water. The following table includes water quality tests to be completed before designing or installing a system when non-potable water sources are considered for use.

			Level of concern	
	Units	**Low**	**Moderate**	**High**
pH		<7.0	7.0–8.0	>8.0
Electrical conductivity [EC]	dS/m	<0.75	0.75–3.0	>3.0
Total dissolved solids [TDS]	mg/L	< 500	500–2,000	>2,000
Suspended solids	mg/L	<50	50–100	>100
Nitrate nitrogen [NO_3]	mg/L	<5	5.0–30	>30
Iron [Fe]	mg/L	<0.2	0.2–1.5	>1.5
Hydrogen sulfide [H_2S]	mg/L	<0.2	0.2–2.0	>2.0
Manganese [M_n]	mg/L	<.01	0.1–1.5	>1.5
Boron	mg/L	<0.7	0.7–3.0	>3.0
Chloride	mg/L	<142	142–355	>355
Chloride	meq/L	<4.0	4.0–10.0	>10.0
Sodium	Adj SAR	<3.0	3.0–9.0	>9.0
Bacteria count	# / mL	<10,000	10,000–50,000	>50,000
Escherichia coli [E. coli]	CFU			<100 CFU /100 mL

Adapted from Hanson et al., 1994 and Hassan, 1998

9. Controllers and Wiring

9.1 Identification

a. Controllers shall list manufacturer, model number, and station count and how it will be installed in the field.
b. Wiring shall identify the gauge of wire and insulation rating for underground installation.
c. Coverage depth for wires
   1) Wires and cables carrying up to 30 volts shall be installed with a minimum of 12 inches of cover.

2) For irrigation controller output cables carrying more than 30 volts (such as decoder-to-solenoid) and where the controller is UL-listed as a "power limited power source" (Class 2 or Class 3), minimum depth of burial is 12 inches.
3) For wires and cables carrying more than 30 volts, follow local and national codes.

9.2 Minimum Design Requirements

a. Controllers
   1) Specify the location of the controller(s) on the plans.
   2) Specify any required sensors.
   3) Ensure the controller features include multiple programs, multiple start times, sensor inputs, lithium battery to retain programs during power outages, etc.
   4) Controller map to denote the boundaries of each irrigation zone (differentiated by using colors). The controller map should be developed by the designer and handed off to the installer.

Sensors

1) Rain, freeze, and/or wind sensors can suspend irrigation during weather conditions that are unfavorable for irrigation.

2) Soil moisture sensors will monitor soil moisture and can suspend or initiate irrigation depending on the soil moisture conditions.

A separate common wire from the controller to each hydrozone type will provide flexibility in the use of sensors to manage the irrigation system.

b. Wiring
   1) All underground wires shall be insulated copper conductors and UL-listed for direct burial.
      - Low voltage wiring (less than 30 volt) to control valves shall be type PE or type UF.
      - Gauge of wire shall meet manufacturer's recommendations depending on length of run.
      - Wiring for two-wire systems shall be specifically manufactured for the control system being used.
      - Use of decoder-to-solenoid cable (paired multicolored wires in a single cable) may be appropriate on two-wire systems.
   2) Wires must be installed to allow for expansion and contraction, using
      - "Snaking" the wire on straight runs.
      - Wire loops at bends.
      - Expansion coils at connections or at the solenoid valve location.
   3) Electrical connections
      - All electrical connections shall incorporate a solid mechanical connection of the copper conductors using a UL-listed device and a waterproof kit for electrical insulation of the mechanical connection.
      - Connector assemblies shall be listed under UL 486D.
      - Grounding, when required, shall follow the detailed plan, manufacturer's recommendation, and local and national codes.

9.3 Additional Considerations

a. Controllers
   1) Use smart controllers that can incorporate ET information or sensor inputs to initiate or suspend irrigation and that can adjust irrigation schedules to meet plant water needs.
   2) Use controllers that can be monitored remotely or send alarms to notify the water manager of flow problems in the field.
   3) When selecting a controller that has two-way communication such as Internet access, consider units that track and report levels of water usage.

Smart Controllers

Smart Water Application Technologies [SWAT] is a collaborative initiative between water providers and the irrigation industry. SWAT identifies irrigation products that can improve irrigation efficiency and writes testing protocols to validate manufacturer claims for product performance.

Reports are available for climate-based smart controllers, soil moisture sensors and rain sensors, and testing protocols have been written for irrigation sprinklers and nozzles.

Performance reports and summaries are posted at www.irrigation.org/SWAT.

b. Wiring
   1) Wire splices should be in valve boxes so they can be readily located.
   2) Wire shall be in electrical conduit meeting local codes using sweep ells when installed into the controller location.
   3) For two-wire systems, specify appropriate tools for wire stripping.
   4) If the controller location is at a low point, ensure adequate drainage of the conduit and pull boxes.
   5) Wireless sensors (rain, soil moisture, flow, etc.) shall follow manufacturer's recommendations for proper operation and installation.

10. <u>Controller Maps and Base Schedule</u>

10.1 Controller map

a. The controller map should be developed by the designer as part of the design package and handed off to the installer on new projects.
b. The controller map should be modified in the field after the project has been installed.
c. The controller map should denote the boundaries of each irrigation zone (differentiated by using colors.) See appendix D for an example.
d. The controller map should correlate with the stations on the controller showing
   1) Area of the irrigation zone
      - Station number
      - Square footage
      - Plant type or water use category
   2) Location of point of connection, meters, sensors, etc.
e. The controller map should be laminated and placed adjacent to or within the controller.

10.2 Base Schedule

a. Base schedule should be for a week of peak demand showing:
   1) Amount of water to be applied
   2) Precipitation rate of the zone
   3) Minutes of run time and number of cycle starts
   4) Seasonal adjust settings for other periods of the growing season
   5) Flow rate of the zone
b. Settings to be used if a smart controller is installed
   1) For weather-based controllers
      - Soil type and slope
      - Plant factors
      - Precipitation or application rates
   2) For soil moisture-based controllers
      - Settings for the soil moisture sensor to initiate or suspend irrigation
c. Base schedule information should be posted adjacent to or within the controller.

10.3 Record Keeping

a. Provide copies of the updated record drawings to owner, owner's representative, and landscape and irrigation managers.
b. Irrigation designer shall store electronic copies of the plans for a minimum of three years.

PG 2: Practice Guideline for Installing an Irrigation System

A qualified irrigation contractor shall be selected to install the irrigation system based on the requirements of PG 2. The irrigation contractor shall test the completed system to verify that the system operates according to the design criteria.

The following practice guideline helps meet the requirements of BMP 2. PG 2 intends to facilitate the development of minimum requirements and expectations for the proper installation of an efficient irrigation system. The successful implementation of these guidelines is best done as a collaborative effort between practitioners, property owners and governing agencies to meet local conditions and circumstances that will protect the watershed while maintaining a viable and functioning managed landscape. The means, methods, and outcomes derived from these guidelines should seek to be economical, practical, and sustainable.

The contractor shall adhere to the following:

1. <u>**Prior to Installation**</u>

1.1 Contact all appropriate utility companies prior to beginning installation to locate underground utilities including gas lines, electrical, telephone, cable TV, and so forth. Installation shall not start until all underground utilities are located and marked.

- a. The contractor/installer shall coordinate with the property owner to locate, identify and mark all privately owned underground utilities.
- b. The following free notification services are available: call 811 or www.call811.com.

1.2 Prior to beginning the installation, verify that the water sources, various points of connection (including pump stations), flow rate, and static and dynamic pressures meet design criteria. If there is a discrepancy, notify the irrigation designer to make irrigation design modifications.

1.3 Review irrigation plans and actual site conditions prior to installation. Provide submittals where required by plans and specifications. Substitution of materials must be pre-approved prior to installation. Inform the designer of conflicts and obstacles not shown on design (such as hardscape features, plantings, utility boxes, etc.) and review possible solutions.

1.4 Obtain any required permits prior to beginning the installation.

2. <u>**During Installation**</u>

2.1 Irrigation systems shall be installed in a manner conforming to the irrigation design plans and specifications, the design intent, applicable codes and standards, in conformance to the manufacturers' installation instructions.

2.2 Avoid disturbing and damaging existing trees, shrubs, and other plant material including root systems from construction and installation activities.

2.3 Inform the property owner or his/her representative and irrigation designer of unusual or abnormal soil conditions that may impact the design and management of the irrigation system.

2.4 Ensure sediment and erosion control measures are included in the scope of work and comply with local codes and regulations.

2.5 Ensure all sprinklers and valve boxes are set to proper grade and that valve boxes are properly supported.

2.6 Wire the valves in a logical sequence (for example, walking order clockwise from the controller) for ease of maintenance and management.

2.7 Make all necessary final sprinkler adjustments to avoid unwanted overspray and to ensure sprinklers are precisely set to water only the target areas.

3. <u>Following Installation</u>

3.1 Test the irrigation system to verify the operating pressure and ensure that there are no leaks and components are adjusted correctly to meet the design criteria.

3.2 Program the irrigation controller with the irrigation schedule that will meet the landscape water requirement for the current time of year. The schedule will take into account site conditions and will mitigate runoff. Produce a written copy and post the controller settings so they can be used for review and reference.

3.3 Explain to the end user (owner, owner representative, or landscape maintenance personnel) the location and operation of the controller, valves, sensors, pressure regulators, backflow device, sprinkler heads, and drip/microirrigation devices. Inform the owner of features and capabilities of the system and furnish product literature, warranties, or operating manuals.

3.4 Provide the end user (or owner) with recommendations and schedule for irrigation system maintenance.

a. Maintaining proper operation of system components
b. Winterization procedures (including spring start-up) where applicable
c. Testing of backflow prevention assembly per local code
d. Periodic visual inspection of the system while operating
    1) Leaks
    2) Missing or broken components

Irrigation Association Consumer Bill of Rights

Preamble: IA reminds you to exercise your rights when making an irrigation purchasing decision.

Hiring a Contractor: The right to hire only licensed irrigation contractors in states that require licenses • The right to hire only those contractors certified by IA's nationally recognized Select Certified Program • The right to examine a contractor's past work and to check references.

Insurance: The right to hire a contractor who is insured for liability, workers compensation, and bonded (if applicable).

Workmanship: The right to quality workmanship, as presented in the *Landscape Irrigation Best Management Practices* and *Irrigation, Sixth Edition* • The right to know that all construction codes are being followed and that the proper backflow prevention device has been installed, as per local code.

Contract and Payment: The right to negotiate a contract that includes specific descriptions of work to be done, materials to be used, a written guarantee, and form of payment including payment schedule prior to the start of the project • The right to insist that all changes, additions and deletions to the contract are in writing • The right to redress in court if the contract is broken.

3) Sprinklers out of adjustment
4) Drip irrigation filter and flush valve
5) Others

3.5 Record Drawings

a. Contractor shall designate and maintain a set of construction plans to become the field record drawings and shall record any deviations on a daily basis.
   1) Convert the schematic layout to portray the precise physical location of all piping, sprinklers, valves and other installed components.
   2) Show measurements from fixed or permanent locations such as building corners, man holes, electrical/utility boxes, street lights, etc., to facilitate locating the irrigation components in the field.

b. Upon completion of installation, deliver the field record drawings to the irrigation designer so that the construction documents can be updated to reflect the "as-constructed" condition of the irrigation system.
   - Sprinkler locations
   - Remote control and other valves
   - Sleeving
   - Sensor locations
   - Main line and lateral line routing
   - Routing of wires
   - Drip irrigation flush plugs
   - Major tree locations

c. Contractor shall keep on file a set of construction documents and field record drawings for a minimum of three years.

PG 3: Practice Guideline for Landscape Water Management

The purpose for having an irrigation system is to support the health and viability of the managed landscape by delivering supplemental water to the plants when natural precipitation is not adequate. The irrigation skills and horticultural knowledge required for implementation of best practices come from proper training, experience, and continuous monitoring of the soil-water-plant relationship. Effective landscape water management is one way landscape and irrigation professionals demonstrate responsible stewardship of water resources.

The following guidelines cover the key elements of landscape water management: communication, system maintenance, water budgeting, irrigation scheduling, monitoring and evaluation of water use, irrigation system performance, and landscape health and function. All of these elements are interdependent. Water efficient landscapes are created by appropriate design and installation, but landscape water management and appropriate horticultural practices are what produce and ensure desired results.

The Art and Science of Water Management

Water management can be as simple as turning the water off, but maximizing the potential of a landscape while reducing its water use can be complex. The correct amount of water can be quantified — it is science-based. Proper management, however, is both a science and an art. A skilled water manager has in-depth knowledge of multiple disciplines and may utilize advanced technology to improve water use efficiency.

The Management-Maintenance Connection

Proactive system maintenance will ensure the integrity of the irrigation system. As the landscape matures, and plants mature, the system may require adjustment and enhancement to meet the design intent for the landscape. System maintenance and repair shall seek to support site management objectives. Depending on company structure, one person, or many individuals, may be qualified to perform multiple management functions.

1. **Communication and Accountability**
The water manager, property owner, and landscape maintenance personnel need to work together to achieve the desired results.

1.1 Communication Among Key Players

a. Property owner/agent should ensure a loop of communication exists with the industry professionals to implement proper site and water management.
b. Property owner/agent and the landscape water manager should engage the water purveyor as a resource. The water purveyor may provide rebates, system evaluations, and water efficiency and conservation initiatives.
c. Recommendations
    1) Establish a regular interval to review contract performance and resource use.
    2) Authorize an amount of money that can be spent to perform unforeseen repairs.
    3) Provide the landscape water manager access to water bills and records for each project.
    4) Develop a drought/water shortage contingency plan.

> ***Key Players***
>
> *Identify who has the authority to implement change.*
>
> *Identify who shall make changes to the irrigation scheduling.*
>
> *Identify relevant regulatory agencies – such as National Pollutant Discharge Elimination System [NPDES] permits.*

1.2 Landscape Water Manager Responsibilities

a. Communication
    1) Water manager shall advise and educate field personnel on their role in managing resources and meeting the owner's expectations (see "Monitoring" section).
    2) Coordinate maintenance activities that will affect water use efficiency.
    3) Determine who has authorization to make changes to the system, the irrigation schedule and emergency service calls.
b. Documentation
    1) Establish a record keeping system.
        - Track weather conditions.
        - Track water usage.
        - Track system maintenance activities (see "Maintenance" section).
    2) Perform on-site observations/verify existing conditions (see "Evaluation" section).
    3) Identify quantitative and qualitative metrics for the site.
    4) Identify and understand special conditions.
        - Site usage (special events, maintenance activities, etc.)
        - Water source and new water sources
        - Drought/water shortage conditions
c. Calculations
    1) Estimate site water usage (see "Section 3: Water Budgeting").
    2) Develop irrigation schedules (see "Scheduling" section).
    3) Develop a system maintenance budget for owner approval.

d. Recommendations
   1) Utilize technology
      - Technology helps the manager do a more thorough and complete job.
      - Online/Internet-based technology allows for more rapid response to problems.
   2) On a new site design, feedback with the designer may be beneficial to improve overall efficiency.

1.3 Outcomes of Communication Tools

a. Accountability of stewardship
   1) Is the correct amount of water being used?
   2) Is the site in compliance with any watering restrictions?
   3) Are other resources being used wisely?
b. Relationship and trust
   1) Increased communication among key parties
   2) Improved corporate image for both owner and contractor
c. Preserve assets in cost-effective strategy
   1) Healthy and vibrant landscapes
   2) Reduction of hardscape maintenance requirements
      - For example, parking lots, sidewalks, roadways, fencing, etc.

2. Maintenance

Regular and routine maintenance of the irrigation system is best accomplished if directed by the irrigation manager to assure that the system operates optimally. The maintenance schedule will ensure that the proper replacement components are used when required, and a plan to respond to unforeseen problems such as vandalism can keep the system working well and minimize wasted water.

2.1 Initial Steps

a. Establish a periodic and routine maintenance schedule to inspect and report performance conditions of the irrigation system to the end-user/owner/owner's representative.
b. Create and post at the controller a station/zone map for ease of system inspection and controller programming. In the absence of an as-built or record drawing, include the location of key components such as controllers, main shutoff valve, isolation valves, remote control valves, filters and any sensors or decoders.

2.2 Periodic Maintenance

a. Review the system components periodically (i.e., annually or as determined by the water manager) to verify the system functionality.
b. Inspect and verify that the backflow prevention device is working correctly and have it tested as required.
c. Inspect and verify that the water supply and pressure meet system operational requirements for optimal system efficiency.
d. Adjust valves for proper flow, closing speed, and operation as needed.
e. Inspect and verify pressure regulators are properly set and adjusted (if installed).
f. Test system wiring for continuity and integrity, and document readings.
g. Establish a winterization protocol (if required based on climate) and a corresponding process for system activation in the spring.

2.3 Ongoing Maintenance

a. Review the system components regularly (i.e., weekly) to verify the efficient operation and uniform distribution of water:
   1) Examine and clean filtration as needed.
   2) Inspect and verify proper operation of the controller. Confirm correct date/time input and functional backup battery where used.
   3) Inspect and verify that sensors used in the irrigation system are working properly.
   4) Inspect and verify that sprinkler heads are operating at recommended pressures and are properly adjusted — nozzle size, arc, radius, level and attitude with respect to slope.
   5) Ensure that plant material is not blocking or interfering with the operation or output of sprinkler heads.
   6) Inspect drip irrigation zones, check the pressure regulator, service the filter and flush laterals to remove silt and foreign matter. Inspect for clogged and missing emitters or damage to the tubing and make repairs.
   7) Repair or replace broken pipe or malfunctioning components and restore the system to its optimal performance capabilities.
   8) Test and adjust all repairs.
      - Complete repairs in a timely manner to support the integrity of the irrigation system.

b. Ensure that replacement parts will perform the same as original equipment.
   1) Sprinklers or nozzles used for system repairs will maintain matched precipitation rate within the hydrozone.
   2) Valves will have the required performance features to meet site conditions such as flow requirements, pressure, and water quality.
   3) Document maintenance procedures and findings.

2.4 Additional Considerations

a. A thorough maintenance program will extend the useful life of the irrigation system.
b. Good horticultural practices and irrigation management are needed to sustain the efficient use of water.
c. Changes and modifications to the irrigation system will be necessary as the landscape matures.

Note: *Field personnel should not make changes to equipment without performing a site evaluation and communicating with the water manager.*

3. <u>Water Budgeting</u>

Water budgeting, when used as a landscape water management tool, allows the water manager to plan or anticipate the amount of water required to maintain a healthy and functional landscape (see more in appendix B). The total landscape water requirement is based upon summing the water requirement for each irrigation zone or type of hydrozone in the landscape. The landscape water requirement is based on real-time weather conditions using reference evapotranspiration data adjusted with appropriate plant factors and site rainfall. The manager can utilize meter readings to compare the amount of water applied based on the irrigation scheduling to the calculated water requirements. Adjustments can be made to the schedule as necessary to maintain an acceptable plant appearance within the water allowance. Measured water usage is compared to both the landscape water requirement and the landscape water allowance. It is recommended that this comparison be done at least monthly but more often to determine if adjustments to the irrigation schedule need to be made.

3.1 Landscape Water Requirement

a. The landscape water requirement is determined by summing the water requirement for each irrigation zone or hydrozone in the landscape:

$$LWR = WR_{H1} + WR_{H2} + WR_{H3} + \text{etc.}$$

where

LWR = landscape water requirement {gallons}

WR_{H1} = hydrozone water requirement

b. Estimating the water requirement of a hydrozone uses the following information:

$$WR_H = \frac{((ET_o \times PF) - R_e) \times LA \times 0.623}{IE}$$

where

WR_H = hydrozone water requirement {gallons}

ET_o = evapotranspiration for the time period {in.}

PF = plant factor or turfgrass factor for the hydrozone

R_e = rainfall that is effective within the root zone {in.}

LA = landscape area {ft^2}

0.623 = conversion factor to gallons

IE = irrigation efficiency (an expected efficiency that reflects management skill for scheduling, sprinkler performance and maintenance. It is not the same as distribution uniformity.) For example:

- 90 percent efficiency is about 11 percent more water
- 80 percent efficiency is about 25 percent more water
- 75 percent efficiency is about 33 percent more water
- 70 percent efficiency is about 42 percent more water
- 65 percent efficiency is about 54 percent more water

c. Using water meter readings, determine if the irrigation schedule is applying the correct amount of water by comparing water usage with the amount calculated by the above equation.

3.2 Actions

a. Collect water meter readings and rainfall data for the same period as the estimated landscape water requirement.
b. Compare water usage to the estimated landscape water requirement.
c. Observe plant health and soil moisture conditions.
d. Recommend adjustments to the irrigation schedule if needed.
e. Document results.

3.3 Additional Considerations

a. An additional amount of water will be needed to leach any salt accumulation because of poor water quality.
b. Determine how to maximize the benefit of rainfall to reduce irrigation water.
c. If the site has multiple water sources then use the lowest quality water first.

4. Scheduling

Scheduling landscape irrigation is a process that requires knowledge of the irrigation system's performance characteristics (application rate, distribution uniformity, etc.), soil type and soil water properties, plant root depth, and plant water requirements to determine when and how much water should be replaced. The irrigation schedule is dynamic. It is influenced by rainfall events and seasonal weather patterns. Aspects of irrigation scheduling to maximize efficiency and effectiveness include: total run time for each zone, dividing total run times into multiple cycle-start programs to eliminate or minimize runoff, and the frequency of watering events to minimize plant-water stress. Schedules can be simple single program configurations or more complex multiple programs running stacked in sequence or overlapped running concurrently. The irrigation manager must understand the capabilities of the irrigation system, the soil and soil water properties, variations in root zone depth, solar exposure, the intended purpose and function of the landscape, and the plant water requirements in order to properly determine an irrigation schedule.

Technologies are available that monitor weather or soil moisture conditions and auto-adjust irrigation schedules based on factors that the manager enters into the controller. These controllers can operate with manual schedule adjustments, by percentage of preprogrammed watering times that are based on observed weather changes, or by input from weather, soil moisture, or flow sensors.

4.1 Communication

a. Determine if there are any constraints regarding time of day or day of the week for irrigation.
    1) Use of the site (such as sporting events, mowing schedule, etc.)
    2) Watering restrictions in place by water purveyor
b. Expectations for landscape appearance and water conservation potential
    1) What is the intended level of aesthetic acceptance (stress level)?
    2) Is water use at or below the planned amount?
c. Desired benefits
    1) Water use efficiency
    2) Runoff reduction
    3) A more robust plant health
    4) Sound root system
    5) Reduce weed, disease, and other pest problems

4.2 Documentation

a. If not assigned, determine an appropriate water window for irrigation.
b. Utilize information from site evaluation to be used for scheduling (see "Site Evaluation" section).

4.3 Actions

a. Create an irrigation schedule (see appendix C for more information).
    1) How much water should be applied?
        - Based on weather data and calculated plant water requirement since last irrigation or rainfall
        - Based on allowed soil moisture depletion
        - Based on the soil's ability to move water by capillarity
        - Account for rainfall effectiveness.
        - Does it fit within the landscape water allowance?

2) How long are the run times?
    - Total run time is based on the application rate of the irrigation equipment.
    - Use multiple cycle-starts to prevent runoff.
        (i) Based on soil type, amount of organic matter present and compaction
        (ii) Consider slope and compaction issues.
        (iii) Application rate of the equipment
        (iv) As a rule of thumb when observing runoff, reduce subsequent cycles by 20 percent.
            1. Irrigation equipment has a minimum amount of run time required to effectively apply water to all of the area.
            2. Site observations of runoff collected during evaluation activities provides valuable information to use for calculating cycle-soak scheduling.
    - Does the irrigation schedule fit within the watering window?
        (i) Comply with time of day watering.
3) How often should irrigation be scheduled?
    - Best practice is to irrigate when soil moisture has been depleted to a predetermined threshold that does not contribute to unplanned plant stress.
        (i) Run times remain constant, but the interval between irrigation days changes.
    - Regular interval or designated days of the week.
        (i) The irrigation days are constant but the run time changes to match the amount of water extracted by the plants usually based on modified ET information.
        (ii) Comply with any mandatory watering restrictions for day or days of the week.
4) Special considerations
    - Incorporate personal experience of managing the site with the calculated schedules to assure water use effectiveness.
    - If water sources have high salts, additional irrigation events are needed to flush the harmful salts out of the root zone.

b. Program the controller
    1) Understand the features of the controller to facilitate scheduling and management.
    2) If using smart controller technologies, program the controller with site-specific information such as soils, plant type, irrigation performance, etc.
    3) Set inputs to on-site sensors such as rain shutoff devices, soil moisture sensors, wind sensors, or freeze sensors to inhibit irrigation when it is not conducive for effectiveness.

c. Fine tune controller program
    1) After initially programming a conventional or smart controller
        - Evaluate water content in the root zone using a soil probe.
        - Determine if the zone is too wet, too dry or just right.
    2) Make small incremental adjustments to the controller settings about two weeks apart and retest until the water content in all zones is correct.
    3) Take rain fall into account where appropriate.

Irrigation Effectiveness

Irrigation efficiency is irrigation water beneficially used compared to the amount of irrigation water applied or supplied to the site and is expressed as a percentage.

Distribution uniformity is not a measure of efficiency but rather a way to characterize the evenness of application of water to the planted area and is expressed as a decimal value. In landscape irrigation, this has greatest importance in turfgrass areas.

Irrigation Effectiveness is achieved when the plant water requirement has been supplied without runoff or deep percolation. High distribution uniformity is essential to applying the least amount of water to meet the plant water requirements. Irrigation scheduling is applying the right amount of water at the right time to maintain a healthy landscape.

4.4 Additional Actions

a. Research and utilize irrigation scheduling programs that fit needs.
b. Create a method to adjust irrigation schedules quickly and appropriately.
c. Compare proposed schedule with current schedule (feedback loop) with the original designer/company, where possible.
d. Use soil moisture sensor systems and rain/wind/freeze sensors as bypass devices to suspend irrigation if it is not needed or the weather is not conducive to effective irrigation.

5. <u>Monitoring</u>

The water manager measures water usage and compares it to the estimated water requirement based on current weather conditions. The water manager works alongside with the landscape manager to assesses the overall landscape health and appearance to determine if irrigation is effective by physically checking soil moisture in the root zone and documenting other potential horticultural problems such as nutrient needs, pest management, etc. The irrigation manager makes adjustments to the irrigation schedule as needed to respond to current soil moisture conditions including responding to drought or water shortages. The information collected during ongoing monitoring provides the data to communicate with interested parties and provides the basis for scheduling refinements.

5.1 Communication

a. Are the expectations realistic for what's available (resources, money, water, personnel, restrictions and ordinances, etc.)?
b. Water budget comparison feedback loop
    1) Is the water being used within the expected water budget?
    2) Is the water budget realistic and/or flexible? If the water budget is static, modifications to expectations or management may need to vary.
c. If there are drought or water shortages, is a drought management plan being followed?

5.2 Documentation

a. Obtain past water use records.
   1) Three years of historical usage is recommended.
b. Obtain past weather data.
   1) Use local or nearby weather and ET data from a reliable source.
      - Identify sources of real time weather information; and ET data.
      - Monitor drought conditions.
c. If using on-site harvested or collected water sources, note the following.
   1) Document current water levels in storage tanks.
   2) Water test reports
      - Safety of the water — protect people
      - Quality of the water — not too harm plants
   3) Observe changes to water supply and pressure including pump station functionality.

5.3 Measurement

a. Record water usage.
   1) Monitor water usage frequently and at regular intervals.
      - Read meters on a regular basis (at least monthly during growing season).
      - If meters are not available, measure applied irrigation water using precipitation gauges in the irrigated area.
b. Monitor and record on-site rainfall.
c. Monitor soil conditions and root zone.
   1) Record soil moisture based on soil core sample or sensor reading.
   2) Measure soil compaction with an infiltrometer or similar tool.
   3) Verify root zone depth and soil conditions.
   4) Does the amount of soil moisture within the root zone concur with the expectations?

5.4 Action

a. Observe plant health and record problems identified.
   1) Stress — signs of underwatering
      - Identify indicator plants.
   2) Ponding — signs of saturated soils caused by too much water
   3) Weeds, diseases, and pests
b. Compare calculated water need to water applied to refine your schedule.
c. Compare current water usage using real-time weather data to historical water usage.
d. Compare water usage to forecasted water need to see if it is on track or if corrective action needs to be taken.
e. Develop a soil moisture balance sheet to maximize beneficial rainfall.
f. As plant material matures or changes to the landscape occur, ensure that system modifications are implemented by following the *Landscape Irrigation Best Management Practices* PG1 (design) and PG2 (installation).
   1) Ensure that system modifications are in response to changing site conditions.
   2) In accordance with any applicable local codes or mandates.

5.5 Additional Considerations

a. Install a dedicated irrigation meter or private sub-meter to improve management capability.
b. Explore new technology for monitoring soil conditions and root zone conditions.

6. Site Evaluation

An evaluation is a (periodic) review of system performance resulting in adaptive management and initiates recommendations for scheduling, maintenance and monitoring. The irrigation manager inspects the irrigation system to verify that system maintenance procedures are being followed, that equipment is working optimally and that landscape plantings are properly considered when scheduling irrigation. A review of system performance assists the irrigation water manager, owner or end-user to develop an effective irrigation water management plan.

A site evaluation will also forecast requirements for a maturing landscape and assess whether the system in its present configuration will continue to meet the overall objectives of the site.

6.1 Communication

a. Establish the goal and purpose of performing a system evaluation.
b. Share the irrigation system performance results.
c. Make recommendations on changes that might be needed.

6.2 Documentation

a. Water supply
    1) Source(s) (potable, groundwater, rainwater catchment, recycled, etc.)
    2) Expected reliability and availability of alternate water sources.
    3) Verify that backflow prevention has been tested and conforms to code.
b. Soils
    1) Texture (sand, loam, clay)
    2) Preliminary estimate of water holding capacity/infiltration rate
    3) Examine soil profile of the root zone.
    4) Measure depth of root zone.
c. Landscape
    1) List of plant types/turf types
    2) Assess condition of plants — by species and by hydrozone.
d. Review existing irrigation system.
    1) Sprinkler/drip type used in system
    2) Identify irrigation zones.
        - Visual inspection of how well system is operating
            (i) Patterns
            (ii) Wet/dry spots
            (iii) Poor plant health
            (iv) Overall level of system maintenance
        - Do irrigation system zones conform to the identified hydrozones?

6.3 Measurement

a. Water supply
    1) Quality of water (pH, salinity, hardness, etc.)
    2) Quantity (available gpm)
b. Soils
    1) Drainage or compaction problems
    2) Consistency of soil type throughout the site
c. Landscape
    1) Determine water requirement for each plant type.
    2) Measure hydrozone area.
    3) Identify sloped areas.

d. Review existing irrigation system.
   1) Consistency in sprinkler type/nozzle and spacing within a zone
      - Estimated precipitation rate
      - Estimated distribution uniformity
      - Recommend catch can test as needed

6.4 Actions

a. Draw conclusions based on
   1) Soils/drainage/compaction issues.
   2) Irrigation design issues.
      - Improper irrigation zones
      - Improper pressure
      - Poor coverage
      - Overspray
   3) Landscape issues.
   4) Improper plant usage.
   5) Mixed irrigation zones.
   6) Water quality issues.
   7) System maintenance issues including age of components.
   8) System functionality issues.
      - Limited programming capacity, lack of sensors, etc.
   9) System management issue.
      - How well are the system and its components being utilized?
b. Recommendations based on
   1) Most critical issues that need to be addressed.
   2) Return on investment when implementing recommendations.

6.5 Communication Feedback

a. Accountability
   1) Owner
      - Final/financial decision maker
   2) Water manager
      - Develops irrigation schedule/program
      - Develops maintenance tasks and intervals

6.6 Additional Considerations

a. Create a maintenance routine including documenting inspections completed.
b. Assess plant material functionality and or placement within hydrozone.
c. Suggest the testing of the soil and follow recommendations for amendments or other remediation practices such as aeration.
d. Suggest the use of technologies, which will help reduce water use and improve irrigation management.
e. Link original design concept to maintenance tasks. See appendix A for more information about inspecting and/or commissioning an irrigation system.

References

Stetson, L.E. and B.Q. Mecham, eds. 2011. *Irrigation,* 6th ed. Falls Church, VA: Irrigation Association.

Von Bernuth, R.D. and B.Q. Mecham, eds. 2013. *Landscape Irrigation Auditor*, 3rd ed. Falls Church, VA: Irrigation Association.

EPA WaterSense. Refer to the irrigation products and outdoor pages website at www.epa.gov/watersense/.

Source of local historical or current evapotranspiration [ET_o] data (if available): Refer to the "ET Connection" on the Irrigation Association's website at www.irrigation.org/.

Soils data: USDA Natural Resource Conservation Service [NCRS], www.nrcs.org.

Climate data: www.ncdc.noaa.gov.

Rogers, D., F. Lamm, and M. Alam. 2003. Subsurface drip irrigation systems [SDI] water quality assessment guidelines. KSU Publication #2575. Manhattan, KS: Kansas State University. Available at www.ksre.ksu.edu. Accessed 11 March 2014.

Appendix A

Irrigation System Inspection and Commissioning

General:
To assure that the irrigation system has been installed according to plans and specifications, and that the equipment is performing optimally for the site, the system shall be inspected or observed periodically during construction for compliance. Commissioning of the irrigation system is a process whereby the performance of the system can be observed and measurements obtained to verify proper operation and scheduling that meets the contractual obligations. Where required, water usage as the result of scheduling can be compared to the water budget or allowance.

Qualified Inspector/Commissioner:
The person or team doing the inspection and commissioning shall be qualified and demonstrate competence through education, training, experience and/or certification in landscape irrigation and landscape water management. The designer of the system or qualified irrigation manager may be permitted to act as the inspector/commissioner of the landscape irrigation system and shall be objective and independent from the contractor responsible for the work being inspected. Examples of qualified individuals include those who are certified by the Irrigation Association as a certified irrigation designer, certified landscape water manager or certified landscape irrigation auditor. Likewise, professional irrigation consultants are accredited professionals by the American Society of Irrigation Consultants. Other programs may exist that would qualify a person or team to perform inspections and commissioning that would be acceptable to the project owner or the authority having jurisdiction. Possible conflicts of interest shall be disclosed to all parties.

Equipment:
The inspector/commissioner shall have all of the necessary equipment to perform the required inspections and commissioning. The equipment shall be properly calibrated.

Inspection vs. Commissioning:
Inspection is to verify the physical presence of the components and that it has been installed correctly. Commissioning is about verification of functionality and operation.

"Inspect what you expect."

Inspections:

- Field inspections shall take place during and after construction while the contractor is on site to verify that irrigation system components have been properly supplied and installed according to the plans and specifications used for installation. Sometimes this is also referred to as construction observation and could be part of the contracted services with the irrigation designer.
- Record drawings shall be maintained with changes to the approved plans by the contractor and available for periodic inspection as needed.
- See the included example worksheets for performing an inspection and noting acceptance, deficiencies, and if corrections are completed.

Commissioning:

- A commissioning plan shall be developed specifically for the project that will identify the following:
    - The turfgrass areas and related irrigation zones will be observed for proper operation.
    - The specific irrigation zones that shall have performance measurement using catch devices to determine precipitation rate (used for scheduling purposes) and distribution uniformity (if required).
    - **Additional data to be collected**
        - Record meter readings if available as part of the audit process.
        - Operate each drip zone and take pressure readings at the beginning and end of the piping run and record pressure.
        - Verify that controller is properly wired and all pertinent sensors are properly configured and wired into or communicating with the controller.
        - Take ohm readings for each station to verify wiring integrity and record at the controller for future reference.
        - Verify that the irrigation map is consistent with the controller settings for each station.
        - Verify that information about the controller settings/schedule is available at the controller so settings can be restored if necessary.
- Review the current irrigation schedule to
    - Assure the run times are proper for the amount of water needed.
    - Assure that cycle and soak times are utilized to avoid runoff.
    - Where required, compare water usage for current schedule with water budget or allowance based upon real time ET information or soil moisture readings.
    - Verify that information about the controller settings/schedule is available at the controller so settings can be restored if necessary.
- Prepare reports outlining the findings of the commissioning activity within 30 days after verification of the system operation and performance.
    - Precipitation rate for each sprinkler zone/station
    - Quality of the system based upon low-quarter distribution uniformity
    - Deficiencies that need to be corrected
    - Schedule to measure system performance to assure maintenance is being properly completed.
- Other documents:
    - Verify that record drawings of the irrigation system and installation are completed and copies are available to the property owner, property manager and landscape water manager.
    - Operator's manual that includes the basis of design and system operation, equipment list including manufacturer, model number and size and the intent of how the system should be managed including an irrigation system for peak demand showing station run times and watering days (Copies should be available to the property owner, property manager and who will be managing the irrigation system.)
- Contact information for system design, installation and maintenance

Example forms for recording system settings and performance are included to facilitate the inspection and commissioning of the irrigation system.

References

Von Bernuth, R.D. and B.Q. Mecham, eds. 2013. *Landscape Irrigation Auditor*, 3rd ed. Falls Church, VA: Irrigation Association.

Auditing Guidelines. Available at: www.irrigation.org/Certification/CLIA/Audit_Requirements.aspx. Accessed 11 March 2014.

ASABE Standards. 2014. X626: Uniformity test for landscape irrigation systems. St. Joseph, MI: ASABE.

Irrigation System Inspection

Project Name_________________________ **Location**______________________________

Date of Inspection_____________________ **Inspector**_____________________________

Item Description	Acceptable	Deficient	Corrected
Water Source			
Point of connection size matches plan			
Flow rate matches plan			
Pressure matches plan			
Backflow prevention installed per plan and code			
Water meter / flow meter installed			
Pump station (if applicable) meets plans and specs			
Controller			
Installed per specifications—manufacturer, model, number of stations, grounded properly			
Wiring matches specifications			
Sensors installed and functioning			
Rain shut off device			
Soil moisture sensor(s)			
Flow sensor			
Other (list)			
Controller programmed with date and time			
Irrigation map posted by controller			
Mainline Piping			
Depth of bury meets plans and specs			
Manual valves			
Installed as per plan and specs			
Installed in valve boxes properly set			

Note: If equipment or components are not required, mark as N/A not applicable.

Irrigation Zone/Station Inspection

Project Name__________________________ **Location**_______________________________

Date of Inspection_____________________ **Inspector**______________________________

Zone/Station Number________

Item Description	Acceptable	Deficient	Corrected
Sprinklers			
Sprinkler type and model match plan			
Sprinkler nozzles are correct			
Sprinkler spacing as per plan			
Sprinkler installed correctly (tilt, distance from hard edge, correct depth)			
Valve			
Valve matches plan, specifications and size			
Valve box properly set and identified			
Valve flow control properly adjusted			
Pressure regulator installed and adjusted			
Wire connections meet specifications			
Piping			
Proper pipe type and size is installed			
Depth of bury meets plan and specs			
Trenches backfilled, compacted and grade level			
Sprinkler Activation			
Sprinklers are adjusted correctly (arc and distance)			
Sprinklers are activated by controller			

Note: Items not installed can be marked N/A for not applicable

Other observations:

Drip Irrigation Inspection

Project Name_________________________ **Location**______________________________

Date of Inspection_____________________ **Inspector**_____________________________

Zone/Station Number________

Item Description	Acceptable	Deficient	Corrected
Emitters			
Emitter type and model match plan			
Emitter location around plants			
Valve			
Valve matches plan, specifications and size			
Valve box properly set and identified			
Filter installed and serviceable			
Pressure regulator installed			
Wire connections meet specifications			
Piping			
Proper pipe type and size is installed			
Piping is anchored or buried as per specifications			
Flush plugs are installed			
Drip Irrigation Activation			
Drip system is activated by controller			

Note: Items not installed can be marked N/A for not applicable

Other observations:

Appendix B

Landscape Water Budgeting

Landscape water budgeting is a process of comparing the landscape water allowance to the estimated landscape water requirement. The calculation is done using reference evapotranspiration data and an adjustment factor to modify the ET. The adjustment factor should be a reflection of the available water for maintaining the landscape or other goals that are established by the owner of the project or a green initiative such as EPA WaterSense program, LEED, Sustainable Sites or local ordinances such as California's Model Water Efficient Landscape Ordinance. Many programs use the peak demand month (highest reference evapotranspiration and least amount of rainfall) to determine the landscape water allowance, therefore influencing the type of plants that should be used and area and type of turfgrass. Most programs have an extra allowance of water for turfgrass areas used as sports fields. This is becoming a common practice for new landscapes.

Landscape water budgeting can also be used as a management tool to estimate the amount of water the existing landscape requires and then compare to water usage. For most existing landscapes the adjustment factor of 0.80 works well, especially in semi-arid or temperate areas. In the very arid or desert areas, the adjustment factor would likely be less to reflect the available water supply and the type of plants that are used in the landscape.

Landscape water allowance

Following is a general formula for calculating a landscape water allowance for any time period:

$$LWA = ET_o \times AF \times LA \times 0.623 \times LF$$

where

LWA = landscape water allowance {gallons}

ET_o = reference evapotranspiration for the time period {in.}

AF = an ET adjustment factor can be used as follows:

- Normally ≤ 1.0, reflecting water needs of the plant material.
- The maximum water a purveyor or regulatory authority will provide or allow to be used for landscape irrigation. It is typically set between 0.60 and 0.80, depending on the available water supply or to promote conservation.
- A higher adjustment factor should be used for turfgrass areas that are used as sports fields, typically between 0.80 and 1.00 depending on the turf species.

LA = area of the irrigated landscape {ft^2}

0.623 = conversion factor to convert inches to gallons of water.

LF = leaching factor (optional), greater than 1.0 based on water quality and soil type. This is an optional multiplier used in cases of poor water quality (i.e., recycled, surface, or brackish sources).

To estimate the landscape water requirement the calculation would be similar to the following as found in "Practice Guideline 3, Landscape Water Management" and factors in effective rainfall for the site as well as an expected irrigation efficiency to account for less than perfect management and sprinkler system performance.

Landscape water requirement

The landscape water requirement is determined by summing the water requirement for each irrigation zone or hydrozone in the landscape:

$$LWR = WR_{H1} + WR_{H2} + WR_{H3} + \text{etc.}$$

where

LWR = landscape water requirement {gallons}

WR_{H1} = hydrozone water requirement

Estimating the water requirement of a hydrozone uses the following information:

$$WR_H = \frac{((ET_o \times PF) - R_e) \times LA \times 0.623}{IE}$$

where

WR_H = hydrozone water requirement {gallons}

ET_o = evapotranspiration for the time period {in.}

PF = plant factor or turfgrass factor for the hydrozone

R_e = rainfall that is effective within the root zone

LA = landscape area {ft^2}

0.623 = conversion factor to gallons

IE = irrigation efficiency

- 90 percent efficiency is about 11 percent more water
- 80 percent efficiency is about 25 percent more water
- 75 percent efficiency is about 33 percent more water
- 70 percent efficiency is about 42 percent more water
- 65 percent efficiency is about 54 percent more water

To determine the landscape water requirement for the landscape, follow the previous calculation for each type of hydrozone in the landscape and sum the totals for each hydrozone type.

Ultimately the water manager would compare water usage to the allowance. The manager can also determine if the irrigation has been effective by observing the landscape plant material for expected appearance and health.

Appendix C

Basic Landscape Irrigation Scheduling

Irrigation scheduling for landscapes has many complex facets that need to be considered when doing effective irrigation management. Additional information is available in *Irrigation, Sixth Edition*, chapter 13, which discusses the following issues in more detail:

- The landscape water requirement has to account for the water needs of multiple plant types and microclimates found in the landscape compared to an agricultural monoculture not easily influenced by its surroundings.
- Many landscapes deal with disturbed soils that are often imported and layered and require extensive amendment and tillage to make a suitable planting medium.
- Water providers often impose watering restrictions that have to be considered when creating irrigation schedules.
- Irrigating the landscape must meet the purpose or functionality of the landscape as well as maintain an aesthetic appeal.

The irrigation of turfgrass gets perhaps the most attention within a landscape and frequently is the target for many water purveyors when there are water shortages. Therefore, the discussion will be focused on turfgrass irrigation followed by a discussion about the irrigation of other parts of the landscape such as trees, shrubs, ground covers, and flower beds. The principles used to calculate a proper schedule for the turfgrass are applied to all areas of the landscape. Consideration for the amount of water needed by different plants, the density or complexity of the landscape, and the method water is applied to the landscape, are used to create an irrigation schedule.

Landscape Irrigation Scheduling Steps

The steps for creating a landscape irrigation schedule include the following:

- depth of irrigation
- when to irrigate
- how much to irrigate
- how long to irrigate
- restriction or limitation compliance

Depth of Irrigation to Apply

To determine irrigation depth, the user must first identify the soil texture so that the available water-holding capacity of the soil is known. The second step is to determine the depth of the root zone [Z_r]. This step can be aided by using a good soil probe to take several soil cores to observe the presence of roots at various depths. The roots that can be seen by the eye are counted as the root depth and usually more roots are in place to extract water than are visible. Also, it should be remembered that rooting depth can be influenced by irrigation timing. For example, if the area being examined has been watered daily, it may never have developed deeper roots.

The product of available water and root zone depth would be the *total* amount of water held in the root zone. However, only a portion of this is available to the plant because at a certain level of moisture extraction the plant would be stressed. This percentage level separating nonstressed conditions from the commencement of stressed conditions is referred to as allowable depletion. Management allowed depletion [MAD] is a percentage determined by the irrigation manager and depends on soil texture and plant physiology. Generally most practitioners use a MAD of 50 percent or 0.50, which means minimal stress for the plants. If there is managed stress or deficit irrigation is being implemented, the MAD value will be higher.

For most landscapes the goal is to maintain a healthy appearance and functionality of the landscape. Certain levels of stress, then, are acceptable and desirable from a water conservation standpoint. Generally speaking for most landscapes, depleting the available water by 50 percent is acceptable and is called the management allowable depletion. Based upon the soil type and rooting depth of the hydrozone, the following equation can be used to determine a depth of water to be applied:

$$d_{max} = AW \times Z_r \times MAD$$

where

d_{max} = maximum irrigation depth {in., mm}
AW = available water {in., mm}
Z_r = root zone depth {mm}
MAD = management allowed depletion

The concept of MAD is to use the water most readily available to plants first and minimize the amount of stress the plants may experience as they approach the wilting point to get all of the available water. Using MAD also means that irrigation will be more frequent but the amount of water to be applied will be less per irrigation.

When to Irrigate

Allowable depletion is used to determine the frequency of irrigation. During the time of peak water demand such as midsummer, the frequency for turfgrass irrigation could be every two or three days depending on the soil texture and root depth. For extremely arid climates and depending on the type of turfgrass, the irrigation interval could be daily, such as on a golf course. But during the early spring and into fall and winter, the frequency or interval of irrigation could be stretched to every five to seven days, and as the plants go into dormancy it could be every 10 days or more. Even though the interval may seem like an unusually long time, the object of irrigation is to refill the soil reservoir for only the amount that has been extracted. This process is very dependent on plant water demand as plants respond to changing weather.

How Much to Irrigate

The amount of water to apply to the landscape is frequently determined by using evapotranspiration [ET] information and modifying it to better represent the type of plants grown in the landscape as shown in the following equation. Identifying a source of real-time ET information along with appropriate plant or turf factors to modify the reference ET will allow the irrigation manager to create and adjust the irrigation schedules to meet plant water needs. It is best if this is done on a daily basis so as to not exceed the allowable depletion of the soil moisture as previously discussed. Estimating the landscape water requirement or plant water requirement is done as follows:

$$ET_L = ET_o \times K_L$$

where

ET_L = landscape or plant water requirement {in.}
ET_o = grass reference ET information {in.}
K_L = landscape coefficient {decimal}

One approach is to pick a fixed amount of water that would correspond to allowable depletion, 0.50 inch for example. If the plant or turfgrass water requirement is 0.25 inches per day as determined by the use of ET data, the irrigation interval would be every two days. If the plant water requirement is 0.17 inches per day, the frequency of irrigation would be every three days; or if the water need is 0.10 inches per day, irrigation would occur every fifth day. When this approach is used, the number of minutes of run time for each station will remain the same, but the irrigation interval or number of days between irrigation events will change.

Another approach is to use ET information for each day, apply the proper crop or landscape coefficient, and add it up for the number of days in the interval. This would be a fixed-day or interval method. For example if the water requirement for three days were 0.15, 0.22, and 0.19 inches, the amount of water to apply on the irrigation day would be 0.56 inches. The next three-day period could perhaps have a water requirement of 0.47 inches. As can be seen, the amount of water is fluctuating and therefore the number of minutes to apply the water will also need to be changed. When the interval period is fixed because of restrictions that have been imposed by a water utility, or a site has an inadequate water supply, or usage of the site dictates when irrigation can occur such as sporting events, the amount of water to apply will change as the weather changes. Ideally the interval or frequency of irrigation will be close to the managed allowable depletion during peak demand times.

There are a number of other variations for scheduling landscape irrigation, but these two methods, either fixed-amount or fixed-day, are most often used. Typically, in a minimal stress management regime, one-third to one-half of the water within the root zone will be depleted before irrigation or rainfall refills the soil reservoir (maximum allowed depletion). When deficit irrigation practices are implemented, more of the root zone will need to be refilled requiring longer run times. Otherwise, only a part of the root zone will be recharged with water if there are restrictions in place.

Once the amount of water to be applied has been determined, the irrigation manager will subtract any effective rainfall since the previous irrigation to determine if irrigation will still need to be applied or it can be eliminated or postponed for a period of time to maximize the benefit of the rain.

How Long to Irrigate

The number of minutes of run time needed to apply a targeted amount of water is a function of how fast the water is being applied to the landscape, known as precipitation rate or application rate [PR]. Ideally the precipitation rate should be determined from a “catch can” test but otherwise can be determined by the flow rate of the sprinkler nozzle and the spacing pattern of the sprinkler heads in a zone or area. Once the plant water requirement has been determined, the precipitation rate of the sprinklers is used to determine the run time needed to apply that amount of water. This is the number of minutes that will need to be programmed into the controller.

The basic equation for calculating irrigation run times is as follows:

$$RT = \frac{ET_L \times 60}{PR}$$

where

RT = run time for individual station or zone {min}
ET_L = landscape or plant water requirement {in.}
60 = conversion to minutes from hours
PR = precipitation rate of sprinklers {in./h}

Example: Calculating minutes of run time

The reference ET for a given period is 0.62 inches of water, and the species factor used in the landscape coefficient for the grass is 0.70. The sprinkler system applies water at 1.34 inches per hour. How many minutes of run time are required?

Step 1. Determine the plant water requirement [ET_L].

$ET_L = ET_o \times K_L$

$= .62 \times .70$

$ET_L = .43$ in.

Step 2. Determine irrigation run time [RT].

$$RT = \frac{ET_L \times 60}{PR}$$

$$= \frac{.43 \text{ in.} \times 60}{1.34 \text{ in./h}}$$

RT = 19 min

Once the run time has been determined, depending on the type of sprinklers being used, the water being applied will be at a rate faster than the intake rate of the soil. In order to mitigate or eliminate runoff, the concept of "cycle-and-soak" is used. This technique will take the number of minutes and break it up into several cycles of shorter duration with a waiting period between cycles to allow the water to infiltrate or percolate into the root zone and then apply some additional water. On coarser soils, one or two cycles are all that might be needed, and on finer soils three or four cycles would be used with adequate soak time. In the above example, using spray sprinklers on a fine or heavy soil might have four irrigation cycles with five minutes of run time duration and 30–40 minutes of soak time between cycle starts. That would amount to 20 minutes of run time, which is roughly equivalent to the calculated run time of 19 minutes.

Controllers

The controllers or timers for turf and landscape irrigation are utilized on small to large landscapes and usually located on-site. Larger landscapes often utilize computerized central control similar to large agricultural operations. Typically the controller is programmed to activate the sprinkler system to apply water to the various zones or areas of the landscape. Controllers can be classified as low, medium, and highly sophisticated. A simple ("low") controller may have many features, but the schedule must be manually adjusted for changing weather conditions. A "medium" sophisticated controller can make some automatic adjustments to the schedule, for example changing the number of minutes of run time of the base schedule by a certain percentage on a monthly basis triggered by the calendar date. Unusual variations of real-time conditions from the historical average will require a manual adjustment. A "highly" sophisticated controller (also known as a "smart" controller) automatically adjusts the frequency of irrigation or the run time or number of cycles based on current growing conditions influenced by the weather, including rainfall. These systems automatically make the adjustments based on the inputs used to describe each hydrozone within the landscape project.

Some controllers are programmed for fixed irrigation intervals with fixed run times that can be changed manually. Other controllers use fixed irrigation intervals or fixed run times, but the run times or intervals are relatively easy to change. The smart controllers (weather-based and/or soil moisture based), once programmed with the correct inputs, will adjust the schedule automatically; however, they may have to comply with mandated restrictions on when to irrigate and how long the irrigation system should run.

For many years, irrigation scheduling was done simply by choosing watering days, start times, and duration of run time with very little regard for knowing the plant water requirements or the amount of water in the soil reservoir. Because of competing demands for water resources, the expectation is to use water wisely and efficiently. New controllers and the use of sensors have enabled managers to improve water management.

References

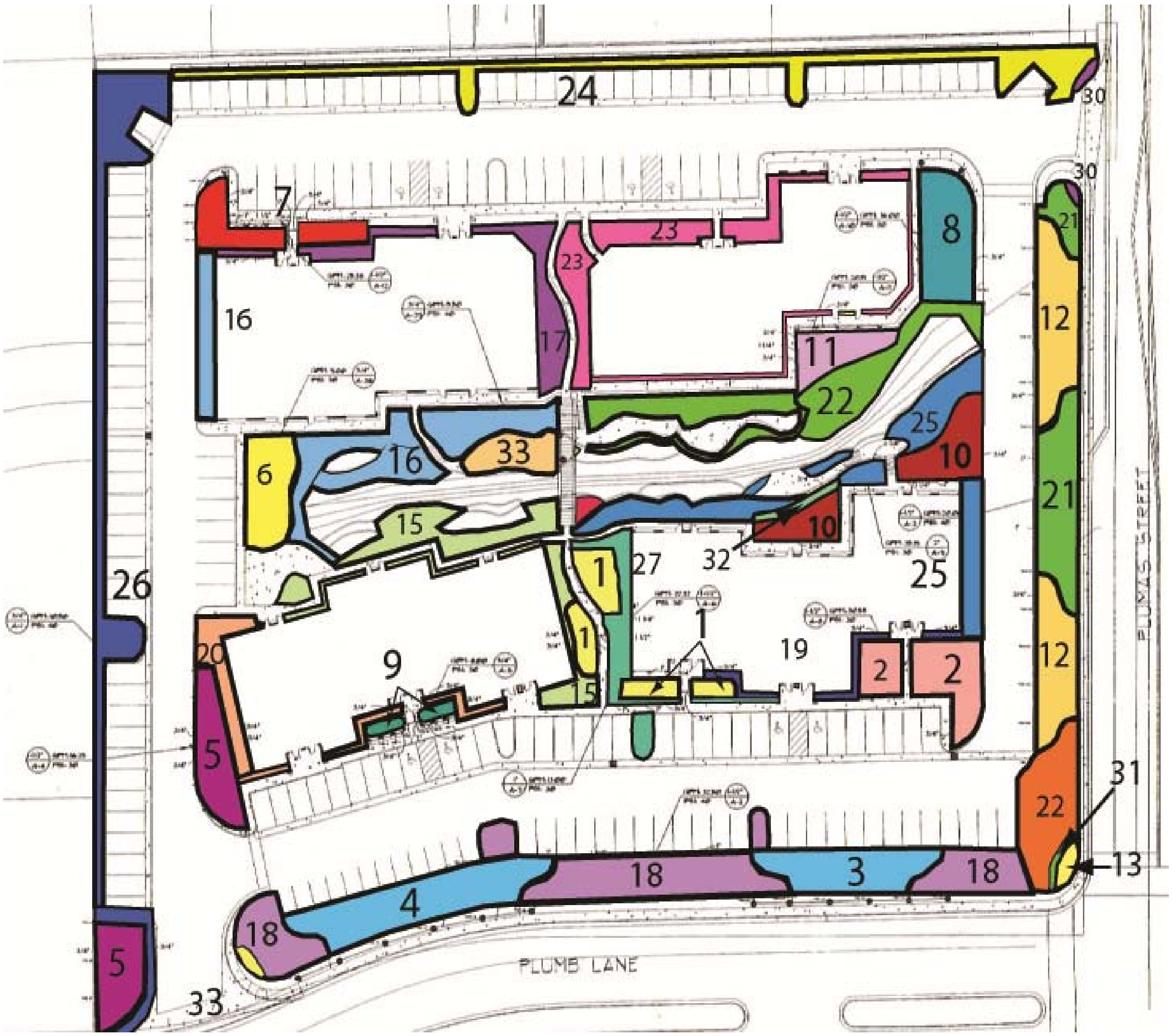
Stetson, L.E. and B.Q. Mecham, eds. 2011. *Irrigation,* 6th ed*.* Falls Church, VA: Irrigation Association.

Von Bernuth, R.D. and B.Q. Mecham, eds. 2013. *Landscape Irrigation Auditor*, 3rd ed. Falls Church, VA: Irrigation Association.

Appendix D

Controller Map and Station Data Form

An example of a controller map showing by color and controller station number the locations of each irrigation zone. The following station data collection form provides detail about each irrigation zone that can assist in the maintenance and management of the irrigation system.



Station Data Collection Form Example

Job Name:________________________________ Controller Designation:________________________________

Sta.	Plant Type				Soil Type					Slope			Sprinkler						Exposure			
	T	GC	ST	N	S	SL	L	CL	C	FM	MM	SS	SP	GR	IR	SR	RN	DR	SH	PS	FS	RH
1																						
2																						
3																						
4																						
5																						
6																						
7																						
8																						
9																						
10																						
11																						
12																						
13																						
14																						
15																						
16																						
17																						
18																						
19																						
20																						
21																						
22																						
23																						
24																						
25																						
26																						
27																						
28																						
29																						
30																						
31																						
32																						
33																						
34																						
35																						
36																						

T = Turf/Flowers
GC = Gnd. Cover
ST = Shrub/Tree
N = Natives

S = Sandy
SL = Sandy Loam
L = Loam
CL = Clay Loam
C = Clay

FM = Flat
MM = Med.
SS = Steep

SP = Spray
GR = Gear Rotor
IR = Impact Rotor
SR = Stream Rotor
RN = Rotating Nozzle
DR = Drip

SH = Shade
PS = Part Sun
FS = Full Sun
RH = Reflected

SOUTHERN NEVADA
HOME BUILDERS
ASSOCIATION
THOSE WHO BELONG...CARE

John Ritterpusch
Assistant VP Energy and Green Building
NAHB
1201 15th St. NW
Washington D.C. 20005

John:

Recently the Southern Nevada Water Authority (SNWA), the agency in Southern Nevada responsible for securing and conveying adequate water supplies to the region, brought to our attention a Public Proposal Report that the Outdoor Power Equipment Institute (OPEI) is advancing. The concepts noted in the report are of concern to the SNWA and have caught the attention of our association.

The Southern Nevada Home Builders Association (SNHBA) has been a close partner with the SNWA in dealing with potentially serious water shortages in the arid and drought-impacted region of the Las Vegas Valley. In this regard, I want to share with you and others who are considering the proposals set forth by OPEI our take on those, and the potential impacts on future development and growth in Southern Nevada. Michael Mittleholzer, with whom we have worked closely on so many matters in the past, suggested we share our thoughts with you.

In the early stages of the long drought which began in 2003, SNHBA and other stakeholders worked closely with SNWA, to implement a policy that limited the use of turfgrass for ornamental purposes. Why turfgrass? SNWA research has shown that lawns receive four times as much water as other water-efficient landscapes that may include trees, shrubs, flowers, vines and other adapted plants. **These policies not only mitigated water demand, they quelled calls for a moratorium on growth and new construction**. These policies have had no impact on quality of life and a positive impact on economic productivity. In fact, both builders and homebuyers are free to plant some turfgrass and to select from a palette of more than 500 other plants for their landscapes. The Water Smart landscape provisions, more than any other initiative, have allowed the Las Vegas region to reduce our use by almost 29 billion gallons between 2002 and 2012 while allowing homebuilders to create housing for nearly 500,000 new residents that have located in Southern Nevada since the policy went into effect.

Appropriately used, turfgrass does provide numerous benefits, but at a cost. Numerous studies have shown that better adapted plants can provide most or all of the functions of turfgrass with lower demand for water, fertilizer, fuel and maintenance.

The National Green Building Standard (NGBS) has thus far provided for the earning of points with landscape plans that have turf limitations. These appear in section 403.6, and elsewhere. These have been optional and allowed for regional diversification. They have worked successfully in conjunction with turf limits to provide for appropriate reward in water-scarce regions such as ours. OPEI's suggested modifications would essentially eliminate a homebuilder's ability to use turf reduction policies as a path to these points, reduce the total points for turfgrass reduction to just 2, and provide even more points for a so-called "bee lawn" (essentially another OPEI invention). This is part of a broad

4175 S. Riley St., Suite 100 Las Vegas, NV 89147 702-794-0117 Fax 702-794-2439 www.snhba.com

scale OPEI campaign to impugn any measure that may negatively impact the market for their membership's products. There are other suggested changes in the document to further promote turfgrass too numerous to list.

In regions where there is already policy to limit the use of turfgrass, using the NGBS would necessitate a special set of calculations and assessments at each home being built, yet not change the outcome due to the regulatory environment. This additional difficulty may be a disincentive that results in builders shunning the NGBS in regions where water-scarcity has become a driving force.

The NGBS should encourage regional flexibility by allowing both approaches and should appropriately incentivize and reward builders for doing so. SNHBA believes that a NGBS policy which allows flexibility makes more sense. It avoids the pitfalls of a one size fits all policy. Most importantly, it allows policy makers in the arid Southwest to encourage water smart policies as we move into unchartered grounds as the serious consequences of climate change are already impacting water usage in many areas of the West. Three years ago you and I had a conversation concerning the NGBS and a somewhat related topic; this current proposal brings that conversation back into focus.

Nat Hodgson

Executive Director
SNHBA

4175 S. Riley St., Suite 100 Las Vegas, NV 89147 702-794-0117 Fax 702-794-2439 www.snhba.com

This presentation premiered at WaterSmart Innovations

watersmartinnovations.com

watersmart
INNOVATIONS

Single Family Residential Water Use Before and after Drought Code Restrictions

Mitchell Morgan
Kent Sovocool
Michael Drinkwine

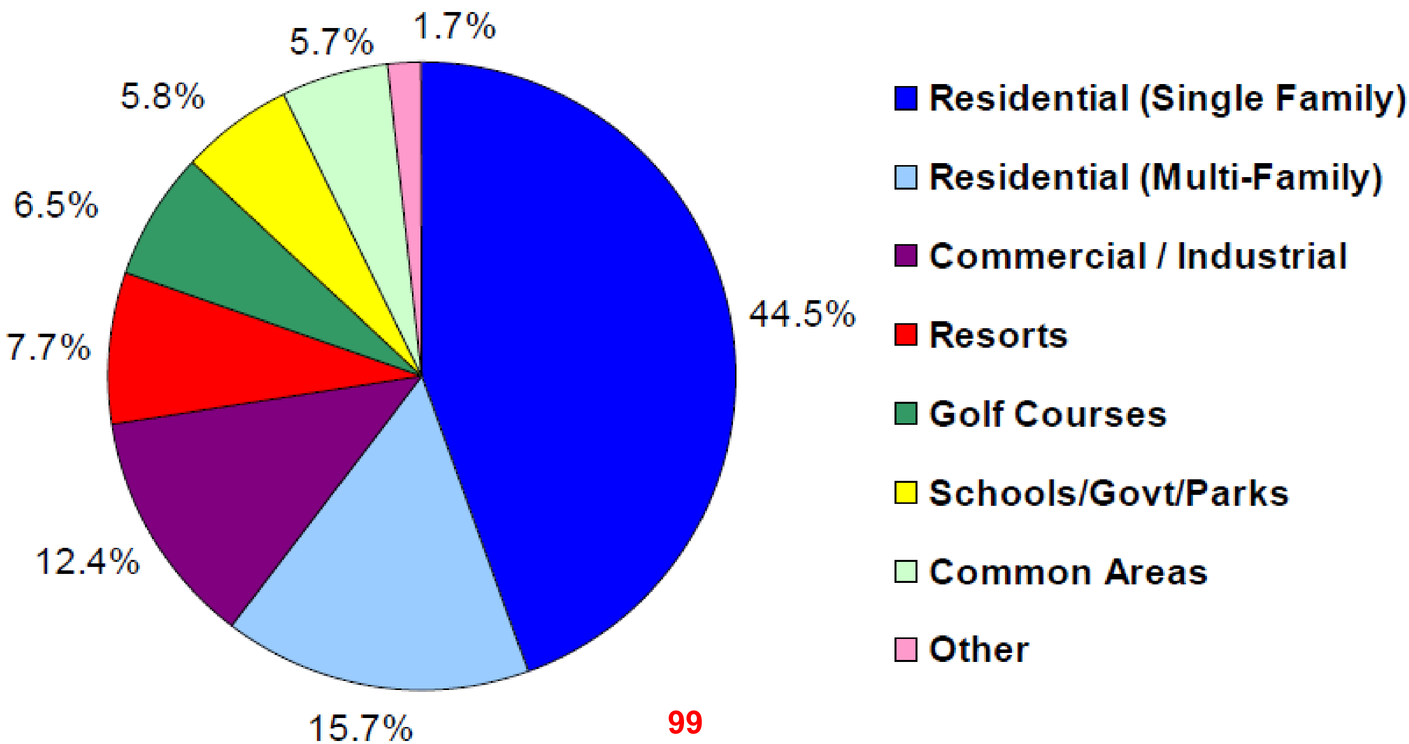
Water Smart Innovations 2014

Las Vegas Valley Responds to Drought

- By 2002 it became clear that the Colorado River system had settled into a multi-year drought and we needed to respond.
- In 2003 the various municipalities in the Las Vegas Valley passed drought mitigating ordinances, largely centering on turf restrictions for new construction.
- Turf is prohibited in front yards and is limited to a maximum of 50 percent the landscape area in backyards.
- These were made permanent in 2005.
- This study was done to quantify the savings in water use from the landscape development policy.

Water Use By Sector

2012 SNWA Service Area
Municipal Metered Water Consumption



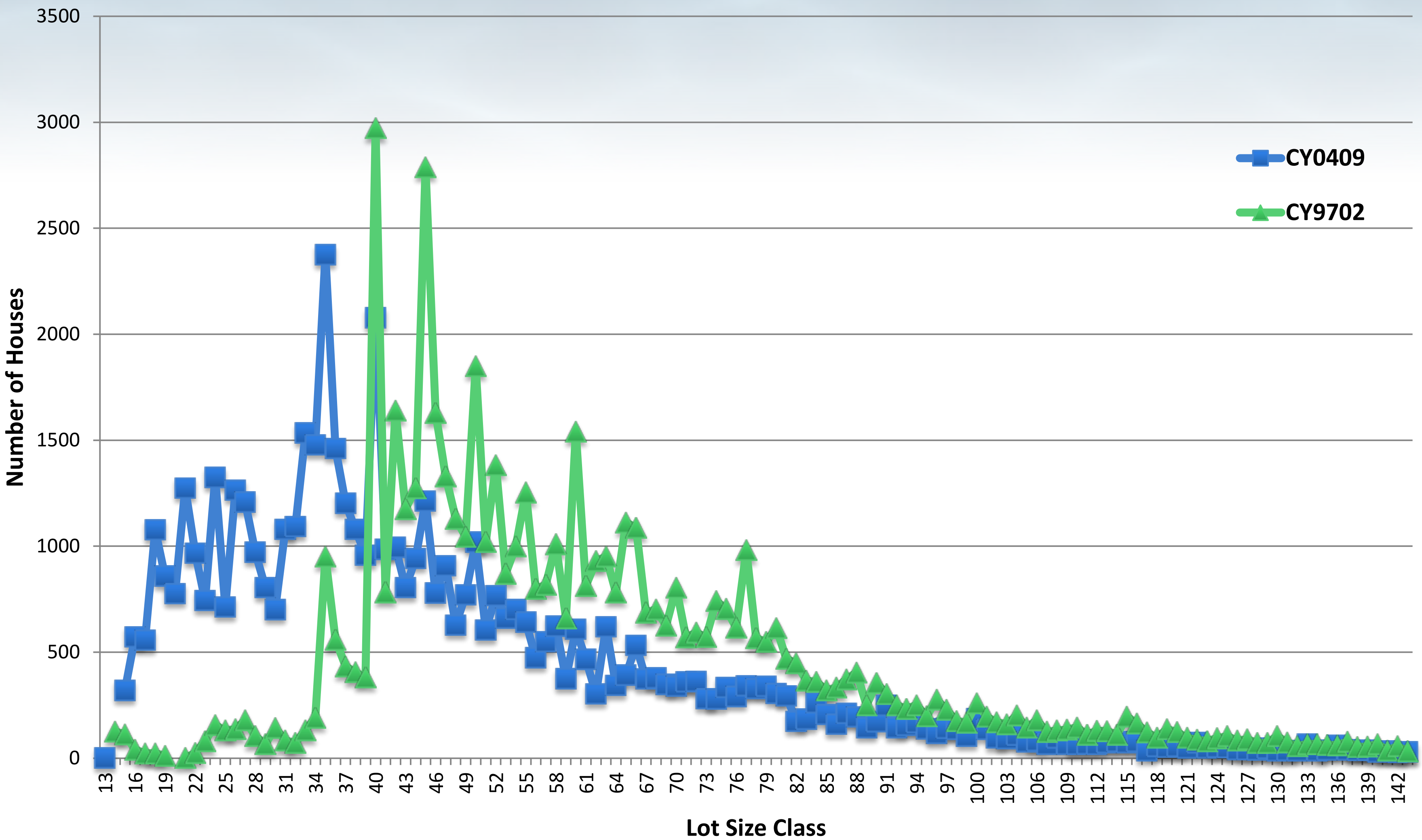
Methods

Selection Process

- Started from a pool of over 100,000 active single family residential (SFR) accounts that had use for every month in 2012.
  - This eliminates “Snow Bird” & “Fire Bat” seasonal residents.
- Divided into two groups: those constructed six years prior to 2003 and those built in the six years after (designated CY9702 & CY0409).
- Removed any that participated in our rebate programs.

Lot Size Distributions

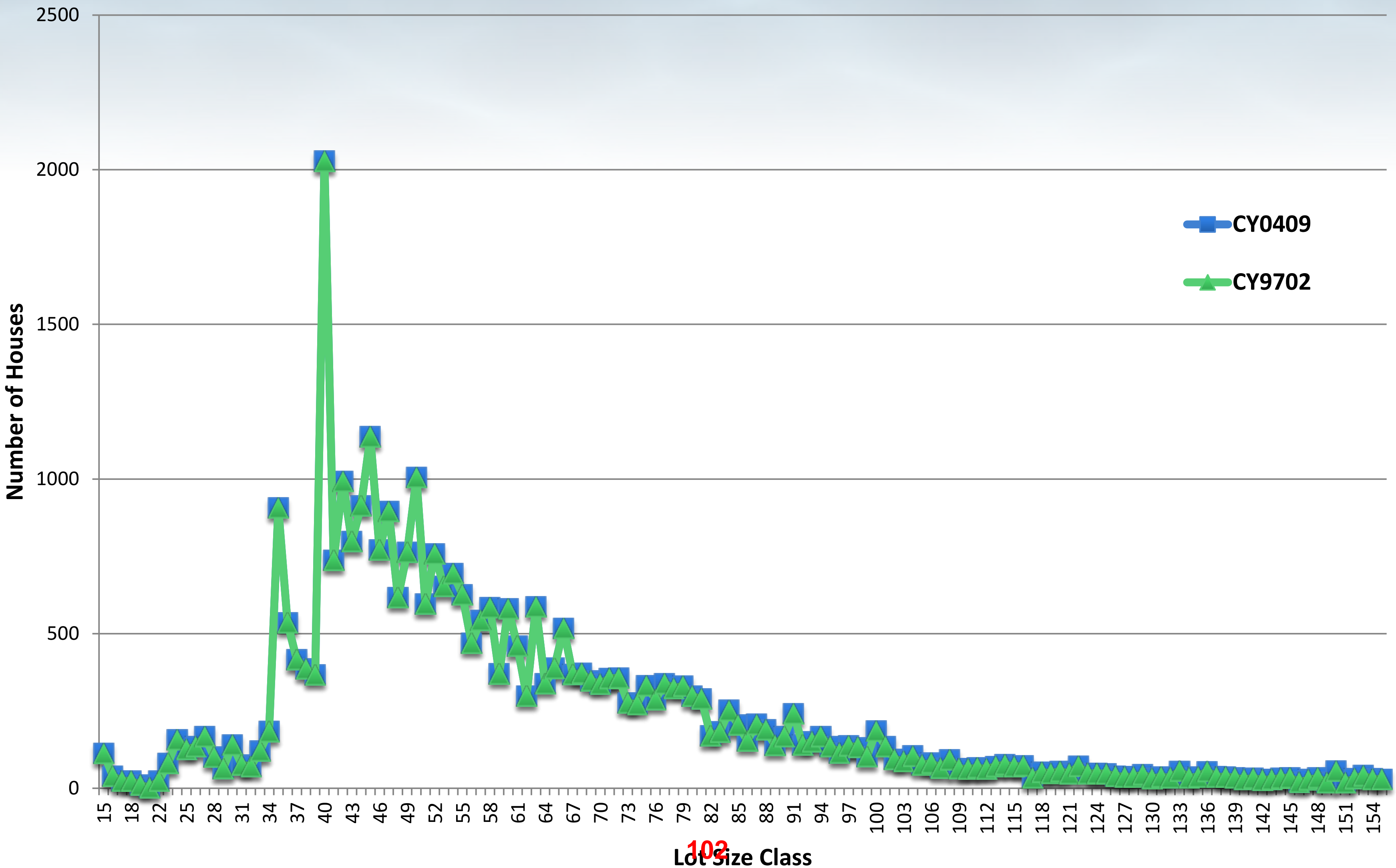
PC038



101

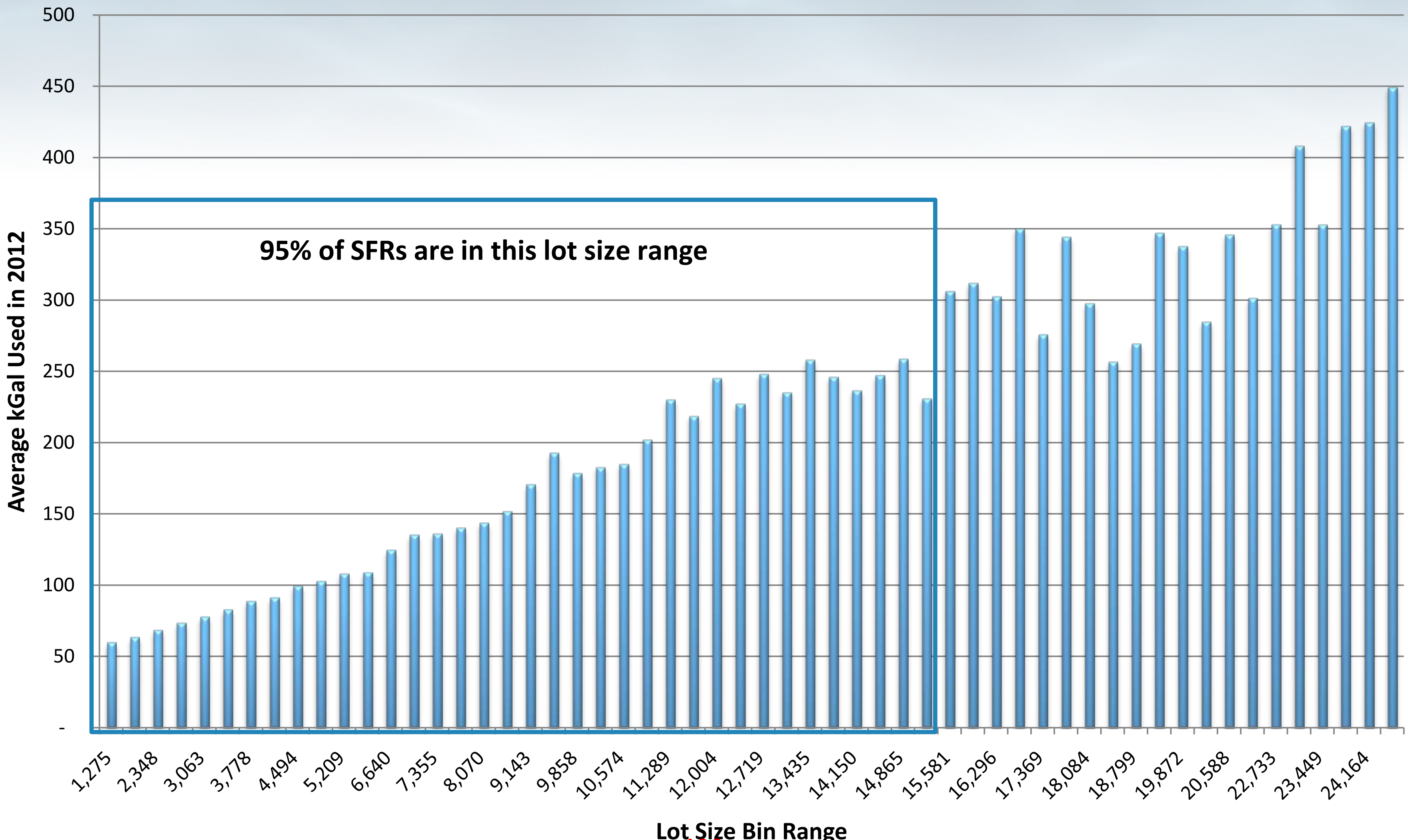
PC038

Sample Lot Size Distribution



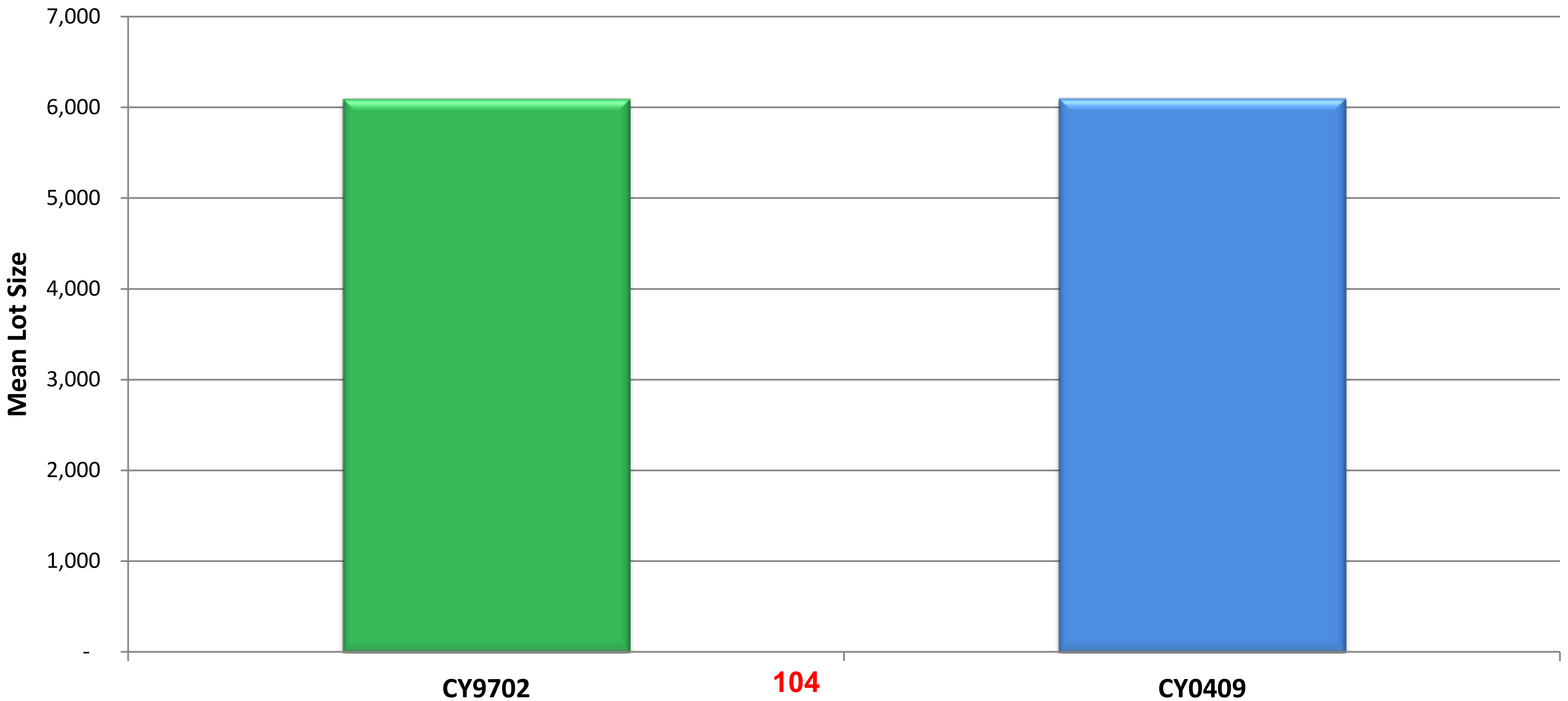
PC038

Average of Total by Lot Size Range



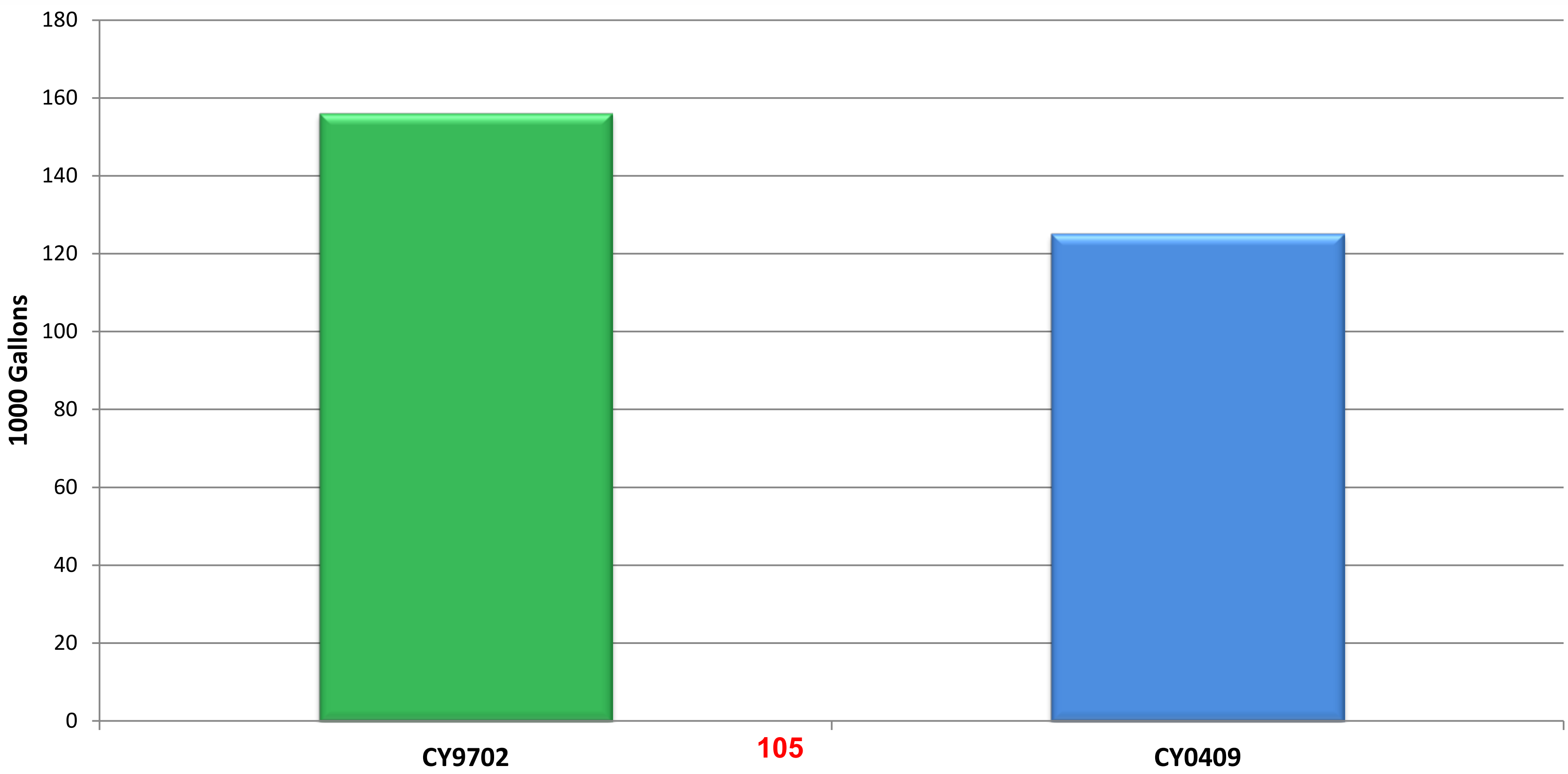
Final Sample

- Just over 34,000 residences in each group
- Lot size averages nearly equal with p > .91



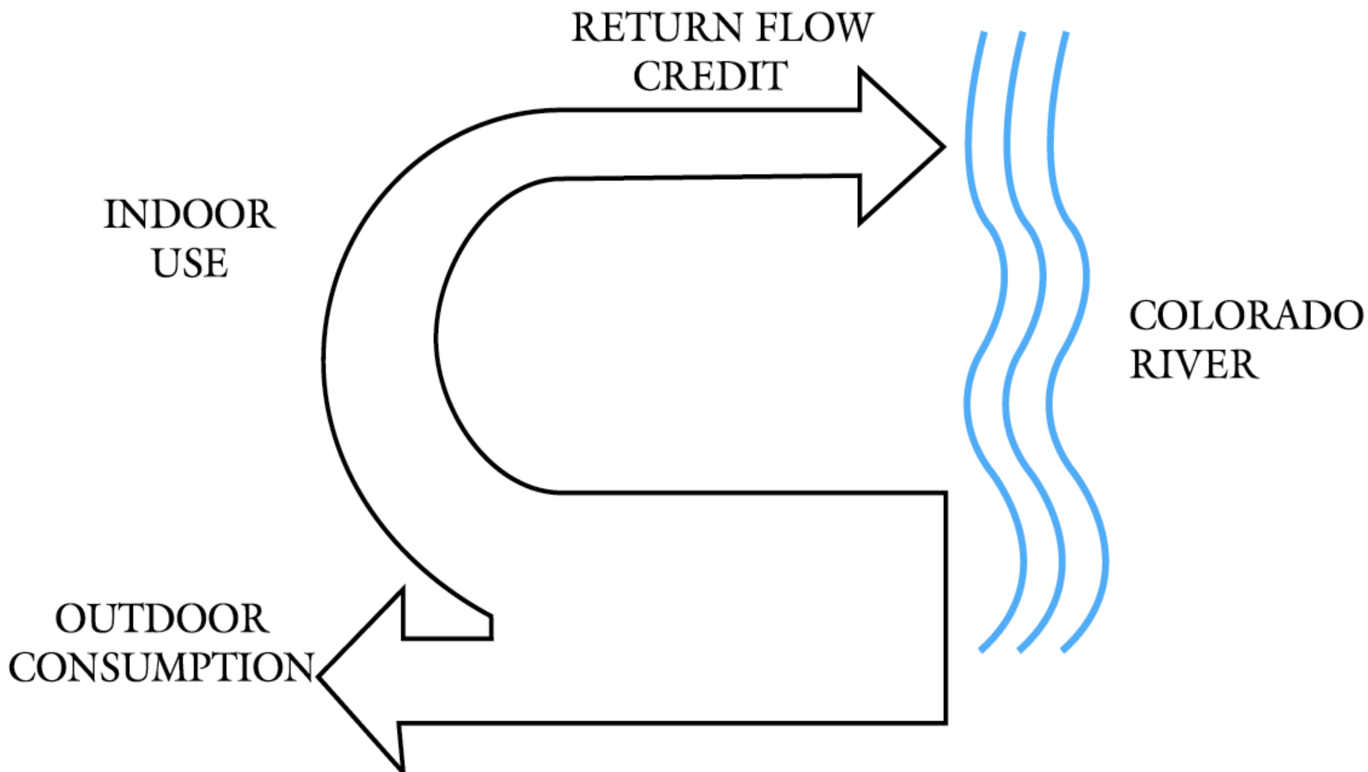
Average Total 2012 Use

19.8% Reduction, $p < 0.00$



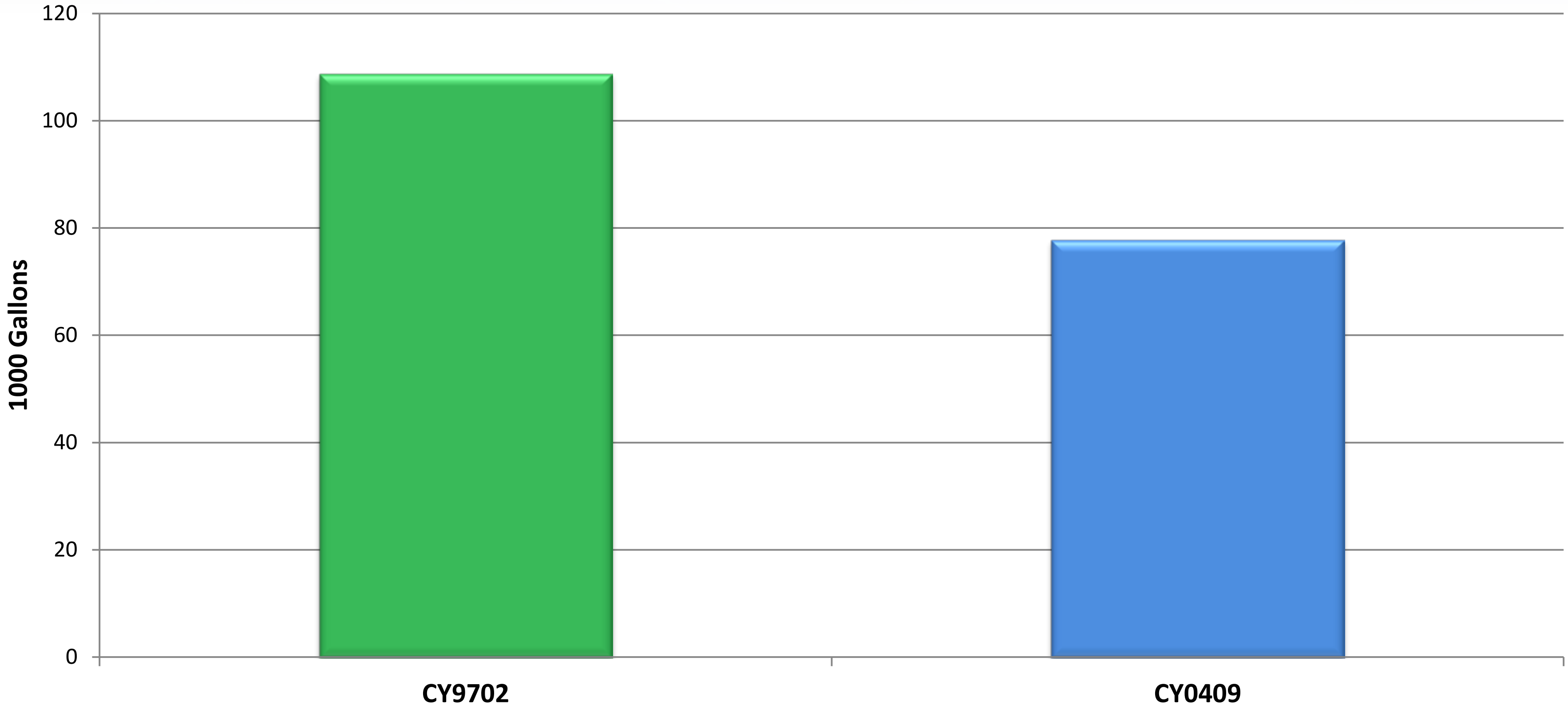
Targeting Consumptive Use

- For SNWA consumptive use is all outdoor use as we get return flow credits for all indoor use.



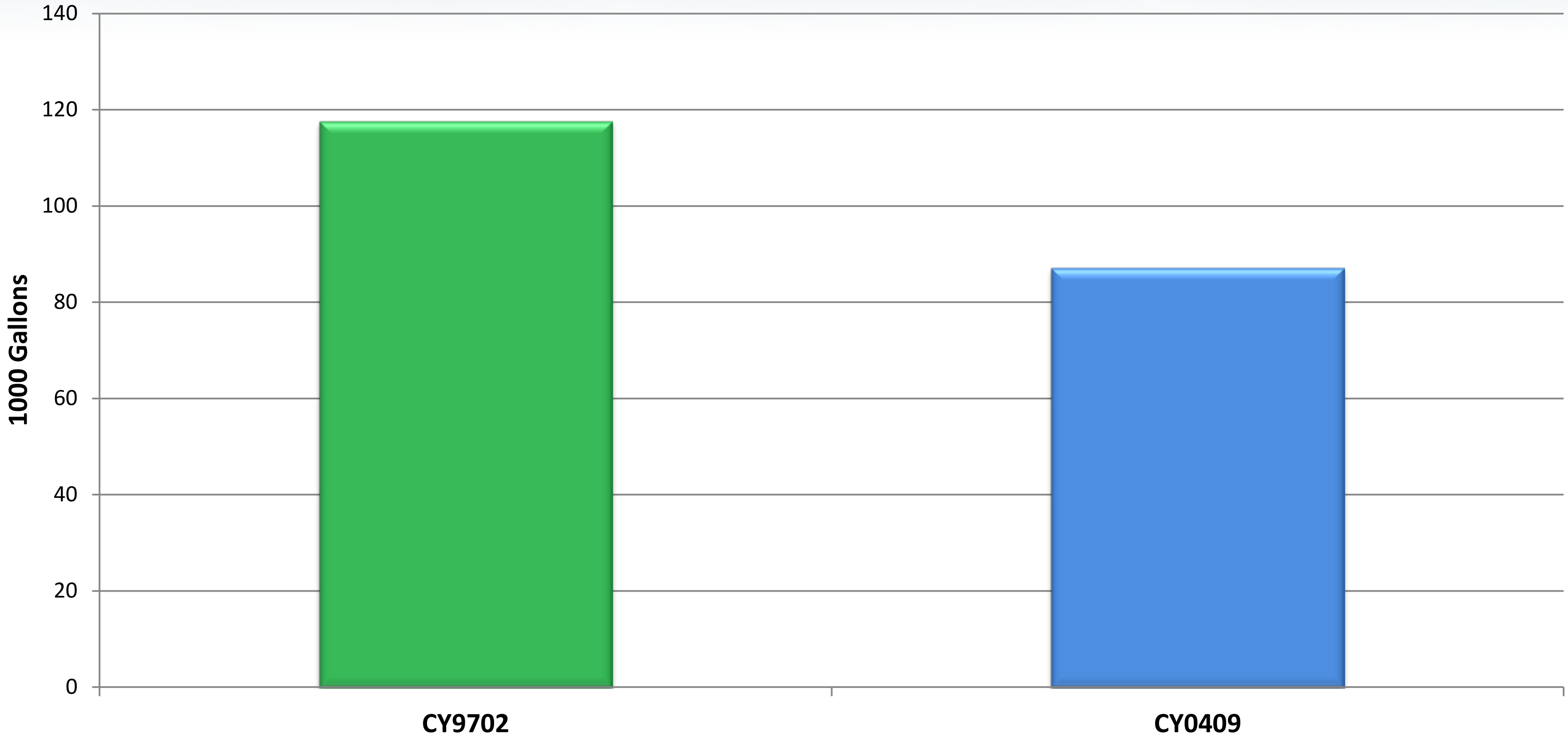
Average Outdoor 2012 Use

28.5% Reduction, $p < 0.00$

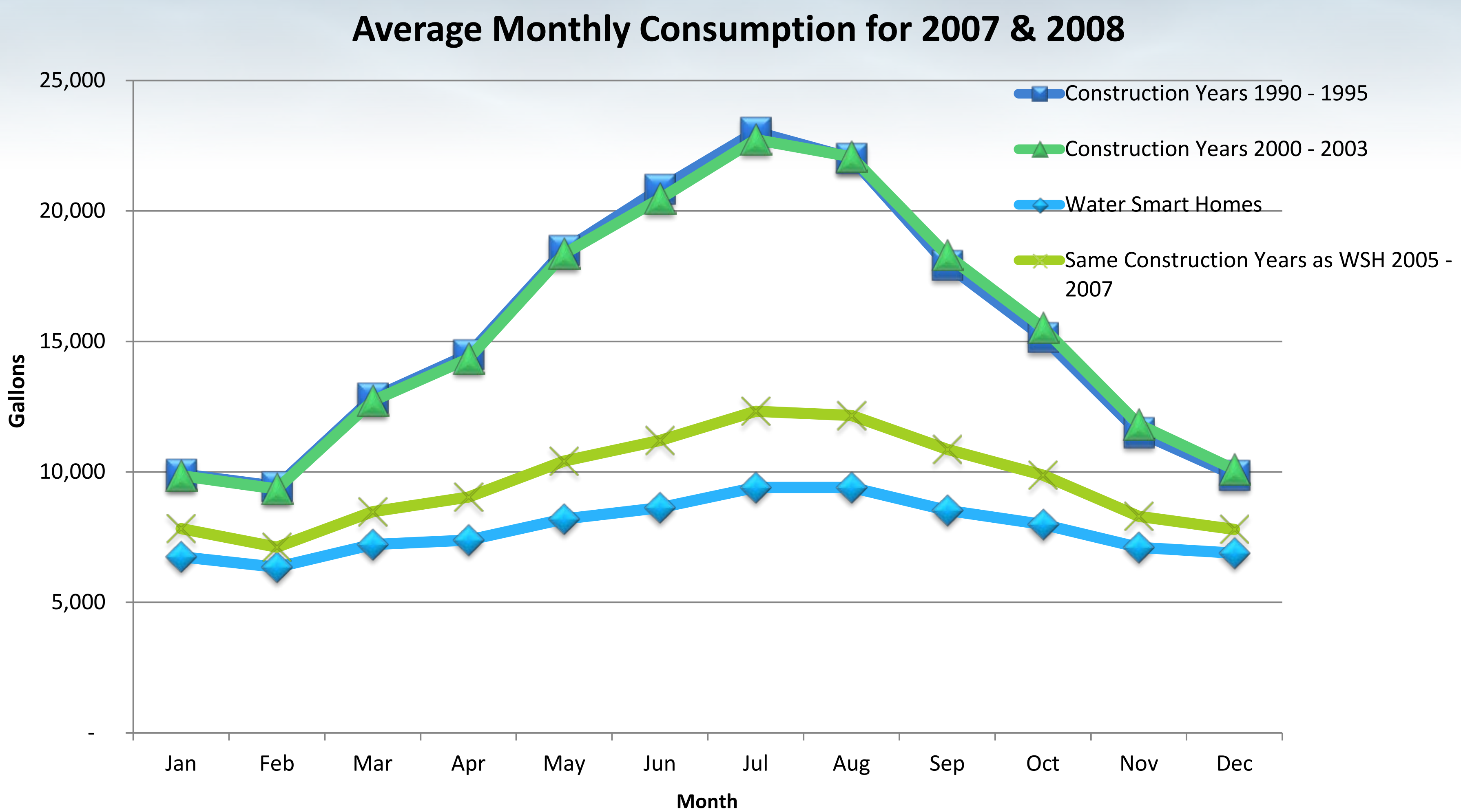


Average Outdoor 2012 Use

25.9% Reduction, $p < 0.00$

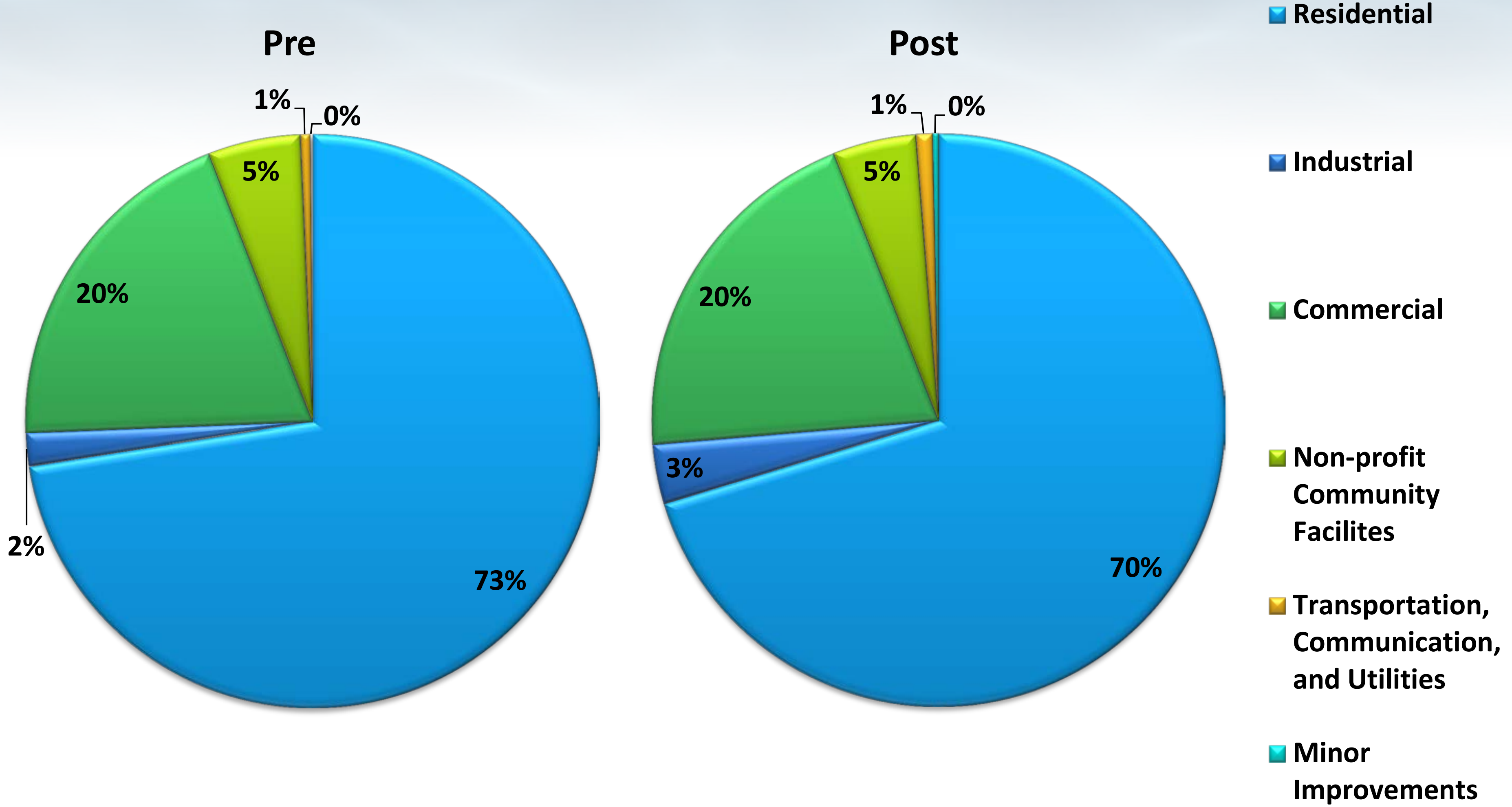


Limited Indoor Savings



Average 2011 & 12 Pre / Post Consumption By Land Use Source

PC038



Conclusions

- We’re here to kick ass and chew bubblegum.
  - And we’re all out of bubblegum.
- Targeting outdoor use is crucial for SNWA in terms of reducing consumptive use, but also because indoor efforts yield small returns.
- While we’ve made great strides with single family residences we really need to start looking at getting other sectors more involved.

Conclusions

- Post-drought code constructed homes used about 31,000 gallons less than those built before.
  - Nearly a 20% total decrease.
  - Consumptive use between 25% - 28% decrease.
- Water Smart Homes had a 49% decrease over pre-code construction.
  - This is an average difference of 91,731 gallons annually.

Questions?

http://office.microsoft.com/en-us/templates/
water-waves-design-slides-with-video-TC101881344.aspx

Xeriscape Conversion Study

Final Report

SOUTHERN NEVADA
WATER AUTHORITY

SNWA Member Agencies

- *Big Bend Water*
- *City of Boulder City*
- *City of Las Vegas*
- *City of Henderson*
- *City of North Las Vegas*
- *Clark County Water Reclamation District*
- *Las Vegas Valley Water District*

2005

By

Kent A. Sovocool
Senior Conservation Programs Analyst
Southern Nevada Water Authority

With data processing assistance from

Mitchell Morgan
Assistant Management Analyst
Southern Nevada Water Authority

Funded in part by a grant from
Bureau of Reclamation
U.S. Department of Interior

Table of Contents

Table of Tables

Table of Figures

Abstract

The authors present a manuscript covering the Southern Nevada Water Authority's (SNWA) multi-year Xeriscape Conversion Study, which was funded in part by the Bureau of Reclamation - Lower Colorado Regional Area[1].

Xeriscape (low-water-use landscaping) has held the promise of significant water savings for a number of years, but how much exactly it can save, especially as a practical residential landscape concept has been a point of debate and conjecture. Lacking to date has been a truly experimental quantitative study in which per-unit area application data has been gathered to quantify savings estimates (for a variety of reasons, most research has been limited to the total household level, with comparisons involving homes that are mostly xeriscape or traditional landscaping). Recognizing the need for more exacting (and locally applicable) savings estimates, SNWA conducted a study that could yield quantitative savings estimates of what a xeriscape conversion facilitation program could yield under real world conditions.

The experimental study involved recruiting hundreds of participants into treatment groups (a Xeric Study and a Turf Study Group and control groups), as well as the installation of submeters to collect per unit area application data. Data on both household consumption and consumption through the submeters was collected, as well as a wealth of other data. In most cases, people in the xeric study group converted from turf to xeriscape, though in some cases recruitment for this group was enhanced by permitting new landscapes with xeric areas suitable for study to be monitored. Portions of xeric areas were then submetered to determine per-unit area water application for xeric landscapes. The TS Group was composed of more traditional turfgrass-dominated landscapes, and submeters were installed to determine per-unit area application to these areas as well. Submeter installation, data collection, and analysis for a small side-study of multi-family/commercial properties also took place.

Results show a significant average savings of 30% (96,000 gallons) in total annual residential consumption for those who converted from turf to xeriscape. The per-unit area savings as revealed by the submeter data was found to be 55.8 gallons per square foot (89.6 inches precipitation equivalents) each year. Results showed that savings yielded by xeriscapes were most pronounced in summer. A host of other analyses covering everything from the stability of the savings to important factors influencing consumption, to cost effectiveness of a xeriscape conversion program are contained within the report.

An abbreviated summary of the report's findings appears as the *Executive Summary and Conclusions* section (pg. 60).

[1]This report with written and electronic appendices satisfies a deliverables requirement pursuant the applicable funding agreement with the Bureau of Reclamation (Cooperative Agreement #5-FC-30-00440). SNWA gratefully acknowledges BOR for its funding assistance with this project.

Keywords: *water conservation, xeriscape, xeric, landscape conversion, desert landscape low-water-use, plants, landscape, irrigation, residential water consumption, outdoor water use, submeter, irrigation controller, resource conservation, incentive programs, utility, water resources.*

Acknowledgements

There have over the course of this study been so many contributors to this research that thanking each of them individually is an impossibility; however. the authors would like to express their gratitude to individuals in the following groups and organizations without whom this research would not have been possible.

- The study participants without whom no data could have been collected.
- The Southern Nevada Water Authority (SNWA) and the numerous personnel who have supported and promoted this research. The authors especially thank members of the Conservation Division, present and past, which have supported this research over the years.
- The member agencies of the SNWA listed on the cover. Special thanks go to Boulder City, the cities of Henderson and North Las Vegas, and the Las Vegas Valley Water District for the reading of meters and submeters related to the study.
- The SNWA Xeriscape Conversion Study Team and all those who have contributed to study recruitment, data collection, and data processing.
- Aquacraft, Inc. for preliminary analyses and collection of trace flow data.
- The Bureau of Reclamation Lower Colorado River Office and members of this office who helped facilitate funding for the research.
- Those whom have reviewed and commented on the Xeriscape Conversion Study and the results. The authors graciously acknowledge the contributions of reviewers of the final manuscript. Final manuscript reviewers included SNWA personnel in the Conservation and Resources Divisions, members of the Las Vegas Valley Water District’s Resources Division, a contractor to the SNWA, and outside reviewers at the City of Austin, Texas. The Bureau of Reclamation also had the opportunity to comment on a draft prelude to final submission.
- Those organizations that have acted as a forum for exhibiting this research.
- Those who have worked for the study in the past and have gone on to other things.
- Those who have supported the research and the research personnel in other capacities.

Introduction and Background

XERISCAPE AND WHAT IT MAY MEAN FOR WATER CONSERVATION

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

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

The term "xeriscape" was invented by Nancy Leavitt, of Denver Water (a public utility) in the early 1980s as a fusion of the Greek word "xeros" (meaning dry or arid) and landscape. Denver Water trademarked the term shortly thereafter though it has entered the English vernacular over the last 20 years as the concept has spread globally.

So promising was xeriscape, that water purveyors and others interested in conservation began actively promoting xeriscape in place of traditional landscape as early as the mid-80s as part of water conservation strategies. The need to better understand its true effectiveness as a conservation tool led to a host of studies being conducted in the 1990s, which have generally pegged savings associated with xeriscape at between 25% and 42% for the residential sector (Bent[1] 1992, Testa and Newton[2] 1993, Nelson[3] 1994, Gregg[4] et al. 1994). The variation in savings estimates is due to a large number of factors ranging from the different climates of each study locality, different local definitions of xeriscape, and different study methodologies employed.

The work done to this point has greatly advanced the water conservation community's ability to evaluate, modify, and justify programs to encourage the use of xeriscaping as an integral component of water conservation plans. Utilities, water districts, cities, counties, and states are beginning to promote xeriscape as a cost-effective, mutually beneficial alternative to traditional turfgrass-dominated landscapes. Recently, this interest has increased at the national level, and this study is part of that evolution. Interest is further enhanced at the time of publication of this report due to a significant drought impacting the Colorado River Basin and much of the western United States.

NEVADA'S COLORADO RIVER RESOURCES AND THE SPECIAL IMPORTANCE OF OUTDOOR WATER CONSERVATION

The Colorado River serves as the lifeblood for many of the communities of the southwestern United States, permitting society to flourish, despite the harsh, arid conditions that often define it. It serves the needs of millions within the region and its yearly volume is entirely divided up by the Colorado River Compact[5] and subsequent legislation and legal decisions, known as the "Law of the River" that specify allocations for each of the states (and Mexico) through which it flows. Among other things, the Bureau of Reclamation – Lower Colorado Region (BOR-LCR) is charged with maintaining an adequate and established allocation of water for each of the states in the arid Lower Basin. Since water demand management is ultimately accomplished at local levels, BOR-LCR actively partners with entities that divert Colorado River water to encourage conservation. In southern Nevada, the major regional organization meeting this criterion is the Southern Nevada Water Authority (SNWA).

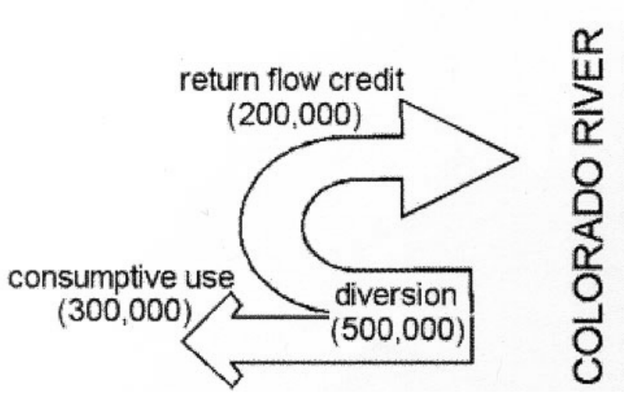
In 1991 the SNWA was established to address water on a cooperative local basis, rather than an individual water purveyor basis. The SNWA is committed to managing the region's water resources and developing solutions that ensure adequate future water supplies for southern Nevada. The member agencies are the cities of Boulder City, Henderson, Las Vegas, North Las Vegas, the Big Bend Water District, the Clark County Water Reclamation District, and the Las Vegas Valley Water District. As southern Nevada has grown into a metropolitan area and a world-famous vacation destination, so too have its water needs. The SNWA was created to plan and provide for the present and future water needs of the area.

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

Southern Nevada's climate is harsh. The Las Vegas Valley receives only 4.5 inches of precipitation annually on average, has a yearly evapotranspirational (ET) water requirement of nearly 90 inches, and it is one of the fastest growing metropolitan areas in the United States. Clark County, the southernmost county in Nevada, has a population in excess of 1.6 million people and has been experiencing extremely strong economic growth in recent years with correspondent annual population growth averaging in excess of 5% percent. The primary economic driver of Clark County's economy is the tourism and gaming industry, with an annual visitor volume in excess of 30 million people per year. Today more than 7 out of every 10 Nevadans call Clark County home.

Consumptive use (use where Colorado River water does not return to the Colorado River) is of paramount interest to SNWA (specifically, consumptive use is defined by SNWA as the summation of yearly diversions minus the sum of return flows to the River). A 1964 Supreme Court Decree in Arizona v. California verified the Lower Basin apportionment of 7.5 million acre feet (MAF) among Arizona, California, and Nevada, including Nevada's consumptive use apportionment of 300,000 acre feet per year (AFY) of Colorado River water as specified initially in the Colorado River Compact[5] and Boulder Canyon Project Act[6]. Return flows in Nevada consist mainly of highly treated Colorado River wastewater that is returned to Lake Mead and to the Colorado River at Laughlin, Nevada. With return flow credits, Nevada can actually divert more than 300,000 AFY, as long as the consumptive use is no more than 300,000 AFY (see diagram below). Since Colorado River water makes up roughly 90% of SNWA's current water-delivering resource portfolio, it means that in terms of demand management, reduction of water used outdoors (i.e., water unavailable for accounting as return flow) is much more important in terms of extending water resources than reduction of indoor consumption at this point in time.

Diagram Showing Dynamic of Diversions, Return Flow Credits (from indoor uses) and Consumptive Use



Since most of the SNWA (Authority) service area contains relatively scarce local reserves (there are little surface or groundwater resources) and since, as explained above, its Colorado River apportionment is limited, the organization has an aggressive conservation program that began in the 1990s. The Authority has been committed to achieving a 25% level of conservation (versus what consumption would have been without conservation) by the year 2010 (note though that soon this goal will be revised to probably be even more aggressive in the immediate future due to the drought). In 1995, the SNWA member agencies entered into a Memorandum of Understanding (MOU) regarding a regional water conservation plan. The MOU, updated in 1999, identifies specific management practices, timeline, and criteria the member agencies agree to follow in order to implement water conservation and efficiency measures.

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

THE RESEARCH STUDY

The potentially large water savings attainable with the broad-scale use of xeriscaping and the fact that associated reductions are in consumptive-use water makes xeriscape of paramount interest for both BOR and SNWA. For this reason, a partnership between BOR and SNWA was formed to investigate the savings that could be obtained with a program to encourage converting traditional turfgrass landscape to xeriscape. This was formally implemented as a Cooperative Agreement[7] in 1995. With its signing, a multi-year study of xeriscape was born, which has come to be known as the SNWA Xeriscape Conversion Study (XCS). As delineated in the most recent version of the Scope (Appendix 1) for this agreement, the objectives of the Study are to:

- Objective 1: Identify candidates for participation in the Study and monitor their water use.
- Objective 2: Measure the average reduction in water use among Study participants.
- Objective 3: Measure the variability of water savings over time and across seasons.
- Objective 4: Assess the variability of water use among participants and to identify what factors contribute to that variability.
- Objective 5: Measure the capital costs and maintenance costs of landscaping among participants.
- Objective 6: Estimate incentive levels necessary to induce a desired change in landscaping.

SNWA assembled a team to support the XCS, and field data was collected through 2001 with the draft final report finished in 2004 (intermediate reports outlined some of the major conclusions). By agreement, the SNWA agreed to provide the raw data collected for possible use in national research efforts by BOR (data was included with the final version of this manuscript submitted to BOR).

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 DeOreo[8] 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 Bent[1] 1992 (as identified in Gregg[4] et al. 1994). All areas of each property were broken down into landscape categories. For example, a XS Group property might have monitored (via 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% (α=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 (DeOreo[9] et al. 2000, Sovocool[10] et al. 2000, Sovocool and Rosales[11] 2001, Sovocool[12] 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:

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

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 *nth* variable, *i* is the time period and $\in$ 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 Hessling[13] (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. Hessling[13] (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.

Results and Discussion

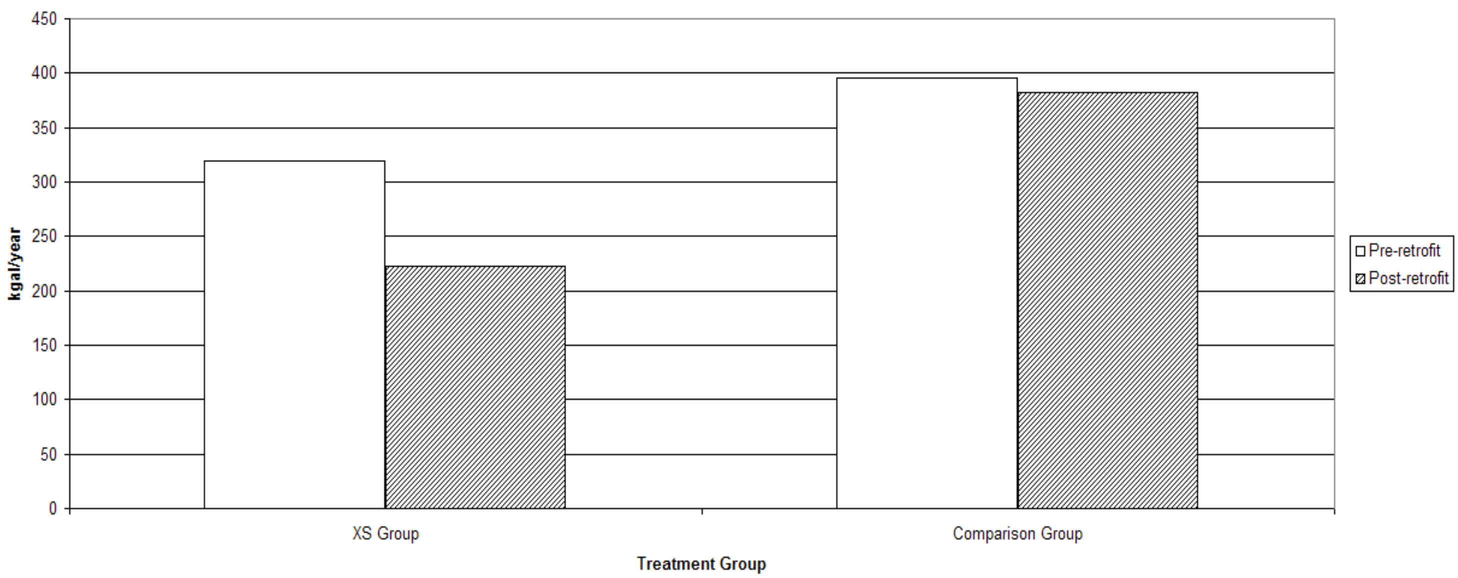
REDUCTION IN TOTAL HOUSEHOLD WATER CONSUMPTION FOLLOWING CONVERSION TO XERISCAPE

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 Newton[2] 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. 2004[14]), 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 Rosales[15] 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

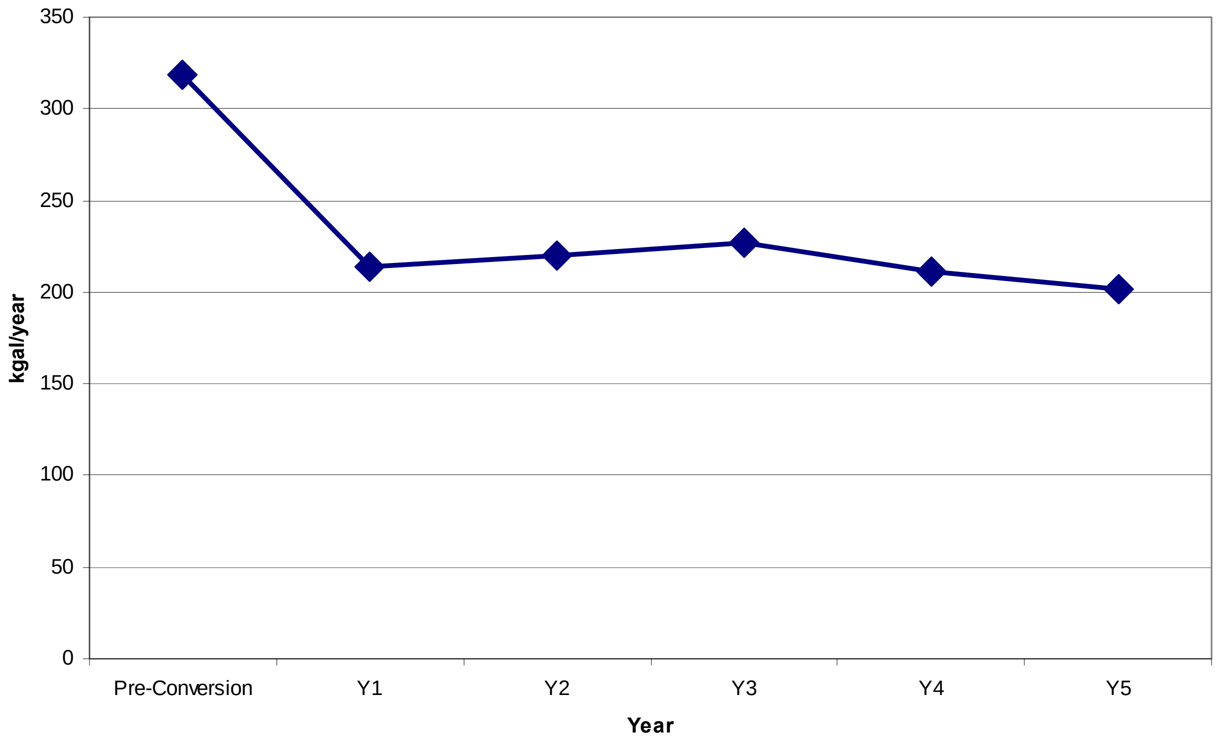


TABLE 13: Enhanced Post-Retrofit Analyses for XS Group Across Time

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**$^{\Delta}$ (32% reduction from pre-retrofit) n=320	**220**$^{\Delta}$ (30% reduction from pre-retrofit) n=318	**227**$^{\Delta}$ (28% reduction from pre-retrofit) n=306	**211**$^{\Delta}$ (33% reduction from pre-retrofit) n=211	**202**$^{\Delta}$ (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 $^{\Delta}$ 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**$^{\Delta}$ (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 $^{\Delta}$ 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

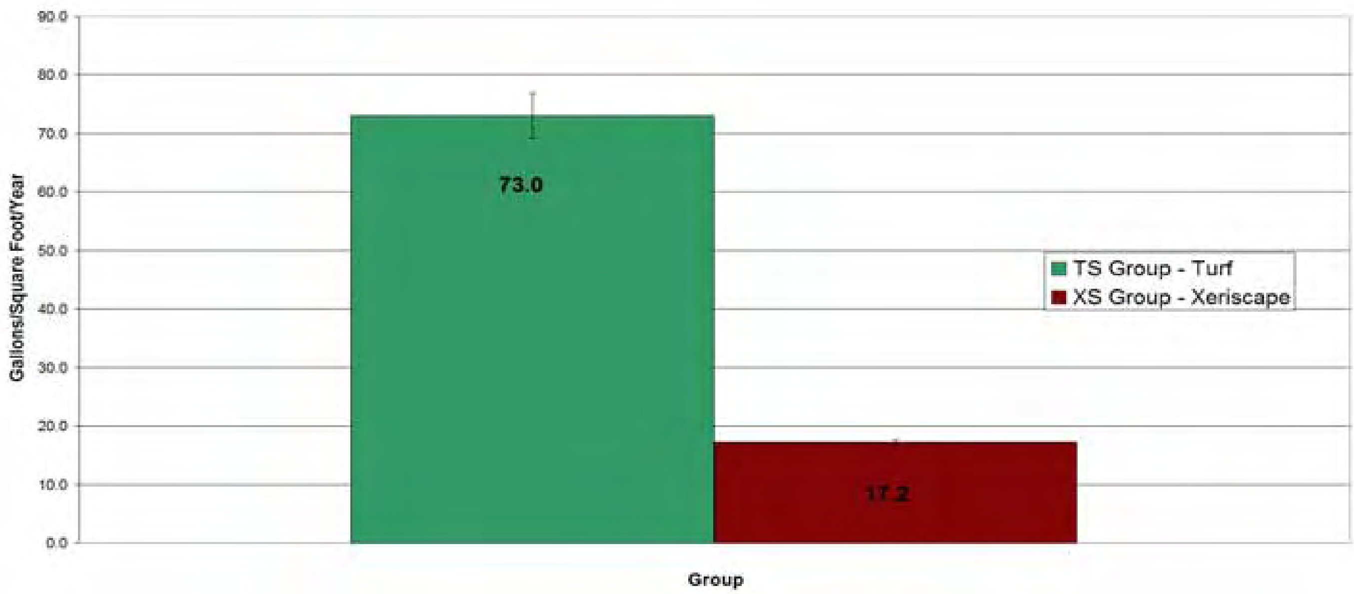
Annual per unit area irrigation application data summaries are found in Table 17 and Figures 3 and 4. There was a great difference in the annual water application to turf and xeric landscape areas (Table 17 and Figure 3). Turf received an average of 73.0 gallons per square foot annually (117.2 inches), 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**		

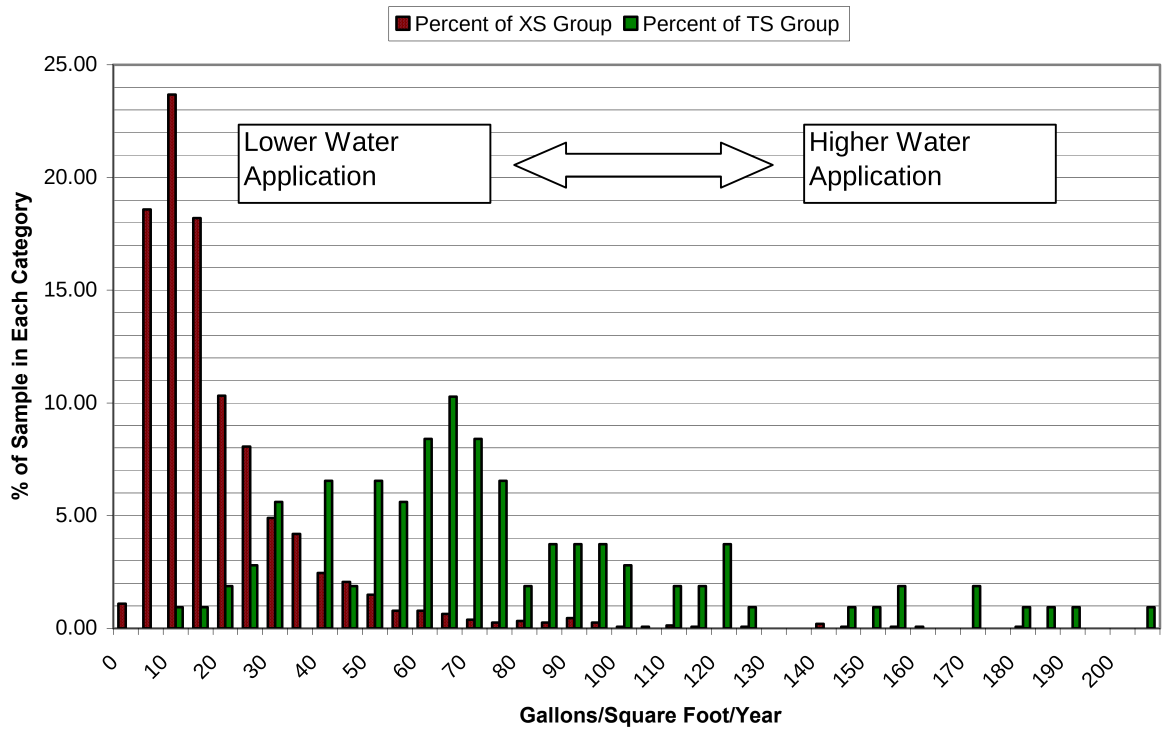
Detailed statistics were not generated for the small set of multifamily and commercial sites; however, the average consumption on those xeric areas where viable data could be collected was 16.7 gallons per square foot per year (n_s=22). This suggests the use of xeric landscape in these sectors may result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

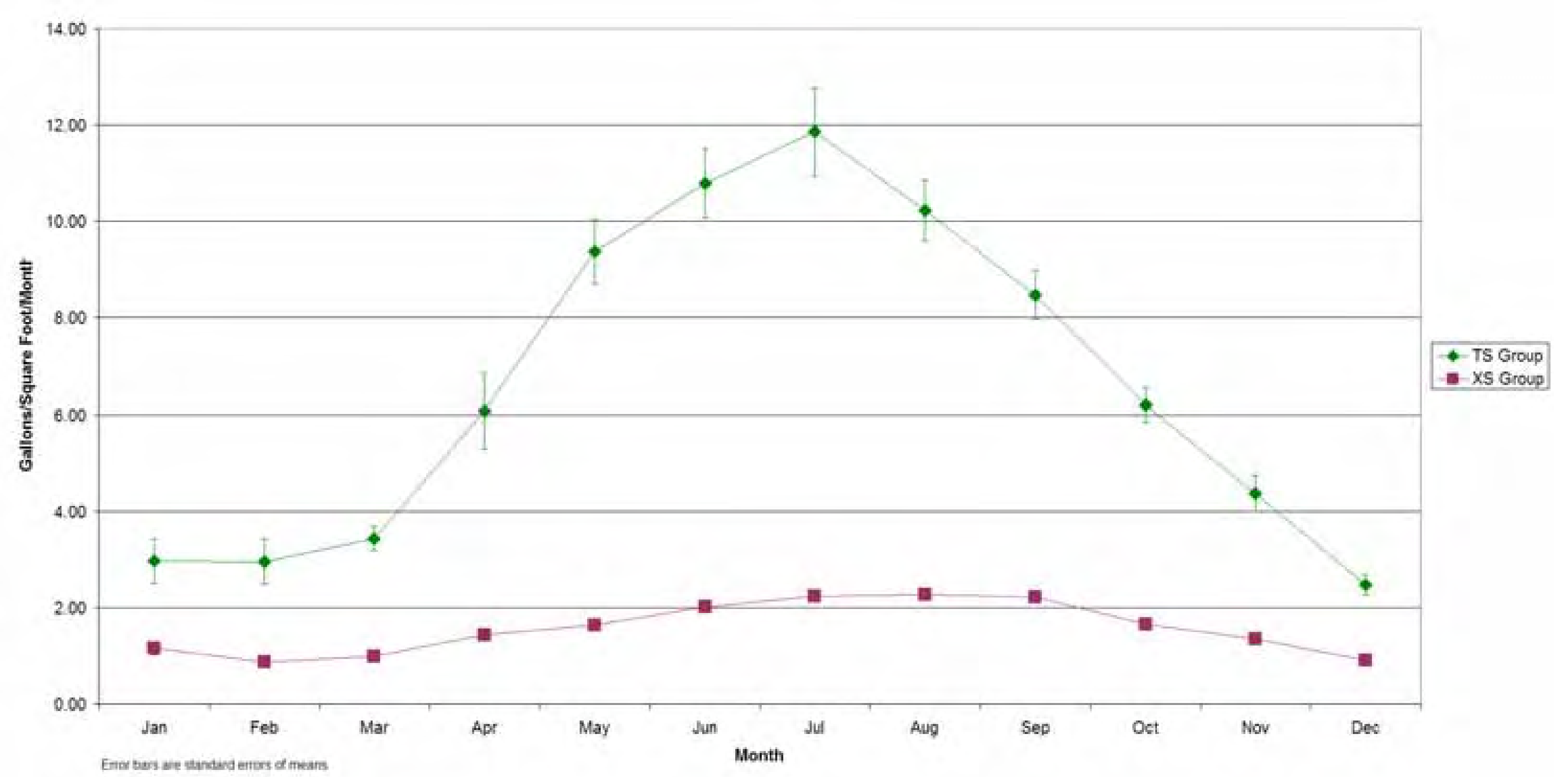
TABLE 18: Monthly Per-Unit Area Application to Turf and Xeriscape

	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.

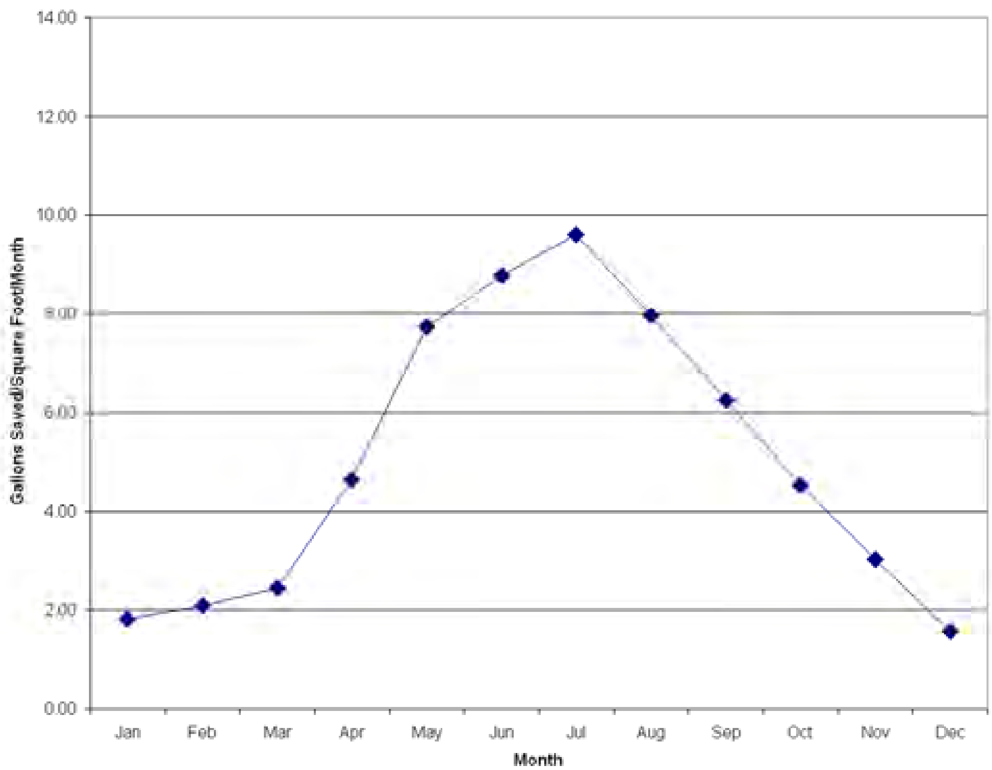
FIGURE 5: Monthly Per-Unit Area Application for Turf and Xeric Areas



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_o. Moreover, they tended to stay well above ET_o 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_o 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

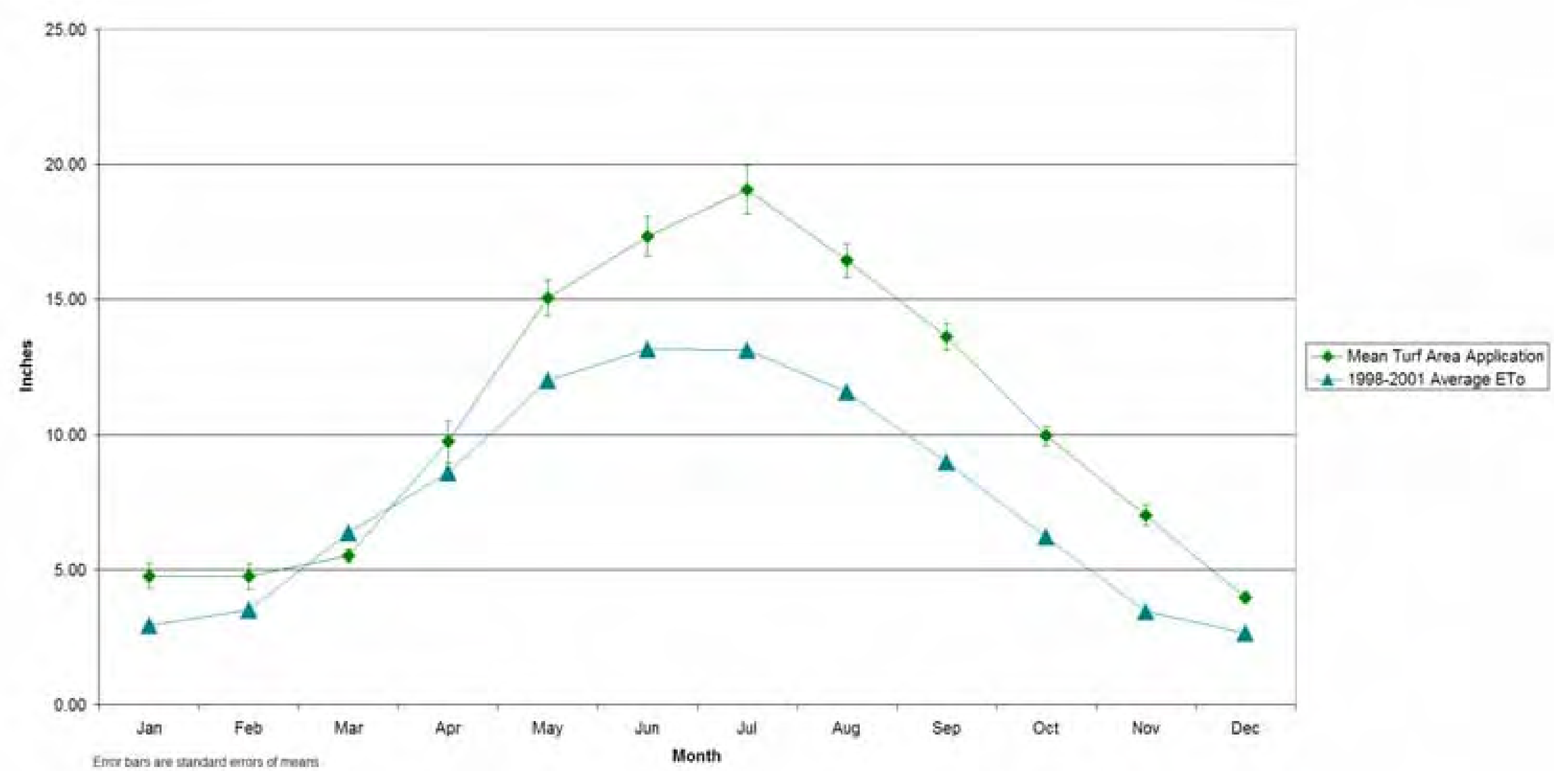
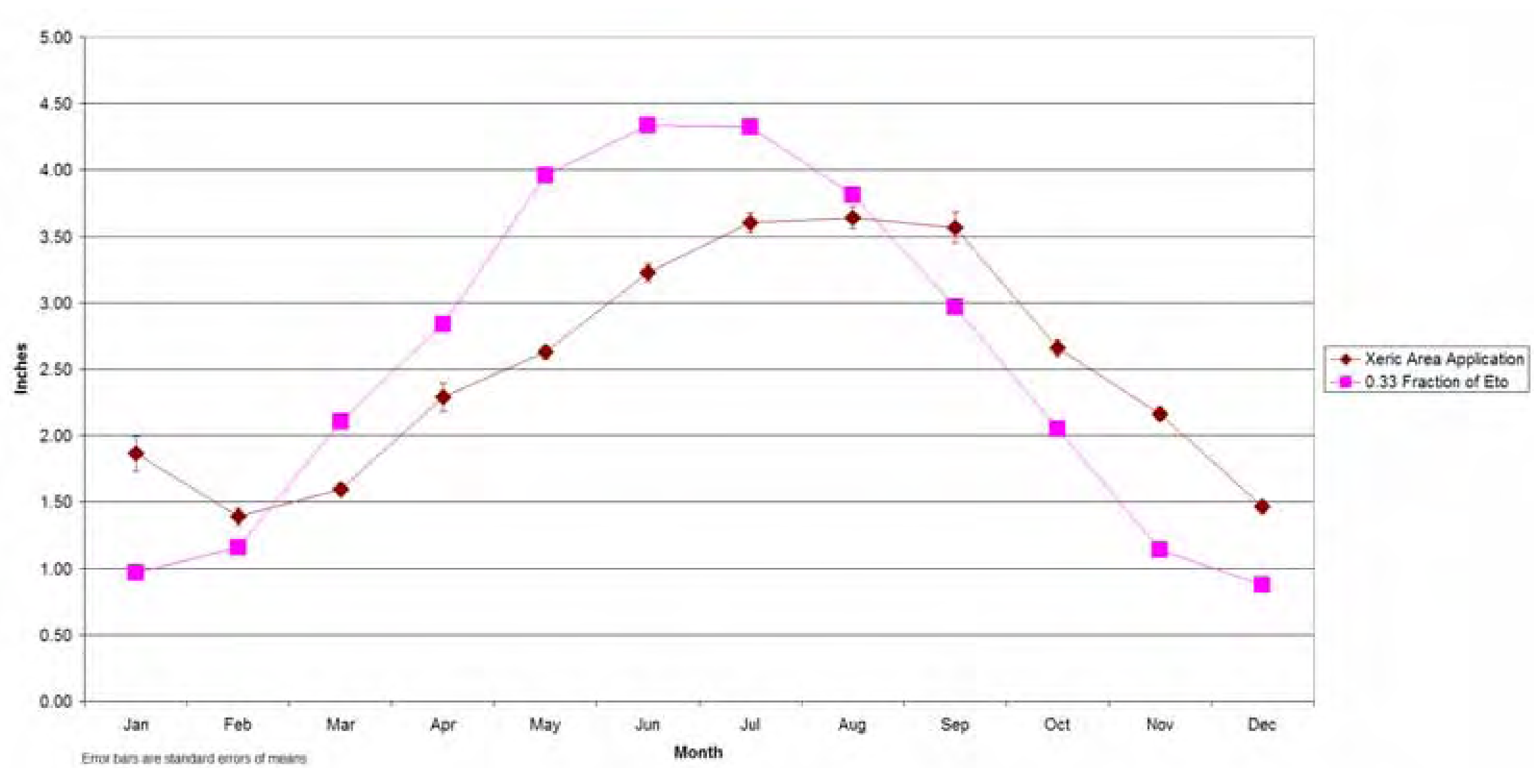


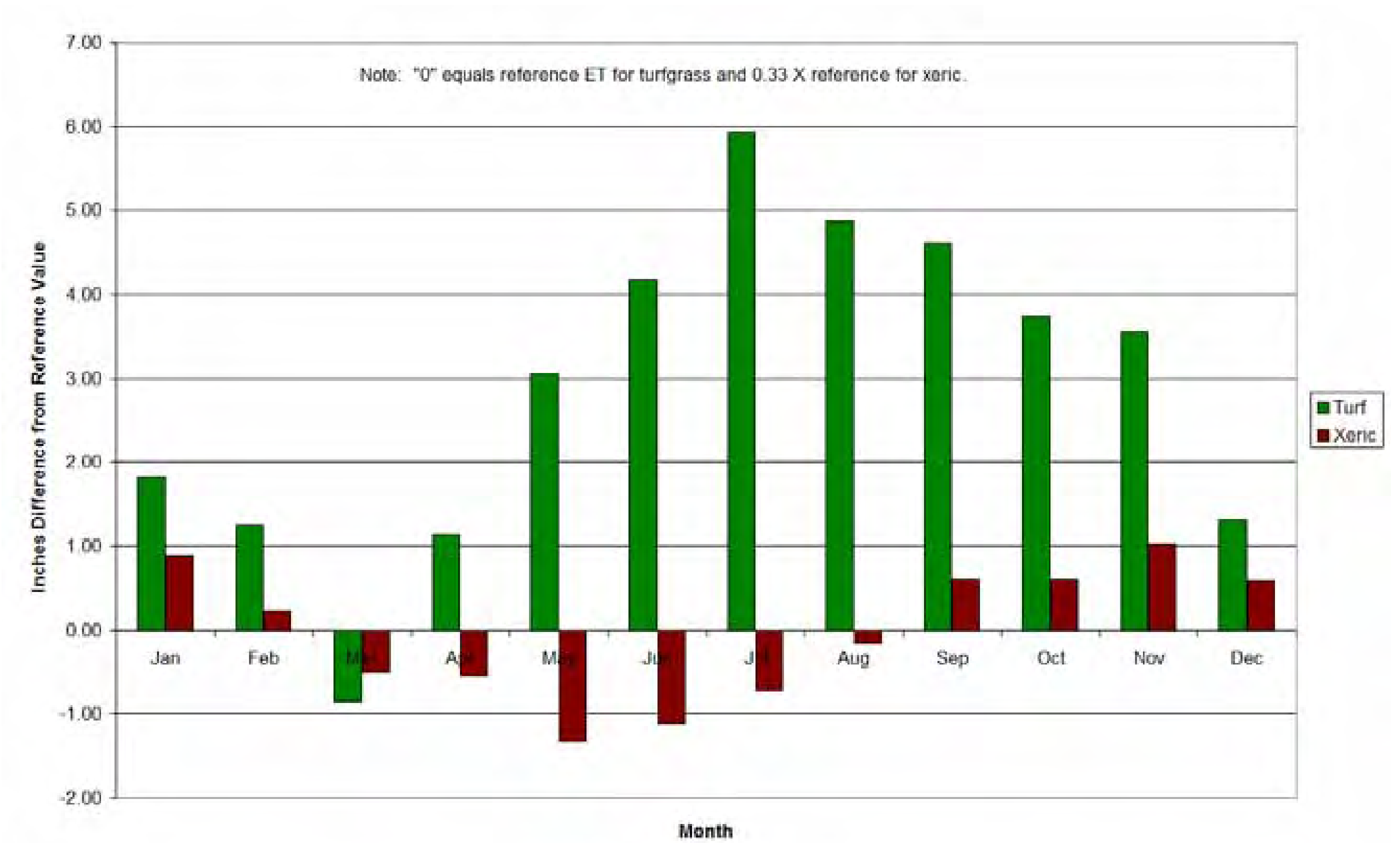
FIGURE 8: Monthly Per-Unit Area Application to Xeric Areas and 1/3 of Reference Evapotranspirational Demand



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_o value is not out-of-line with modification approaches employed by the Irrigation Association[16] (2001) or WUCOLS[17] (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_o) 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_o for turf and .33(ET_o) 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_o for turf and .33(ET_o) 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)

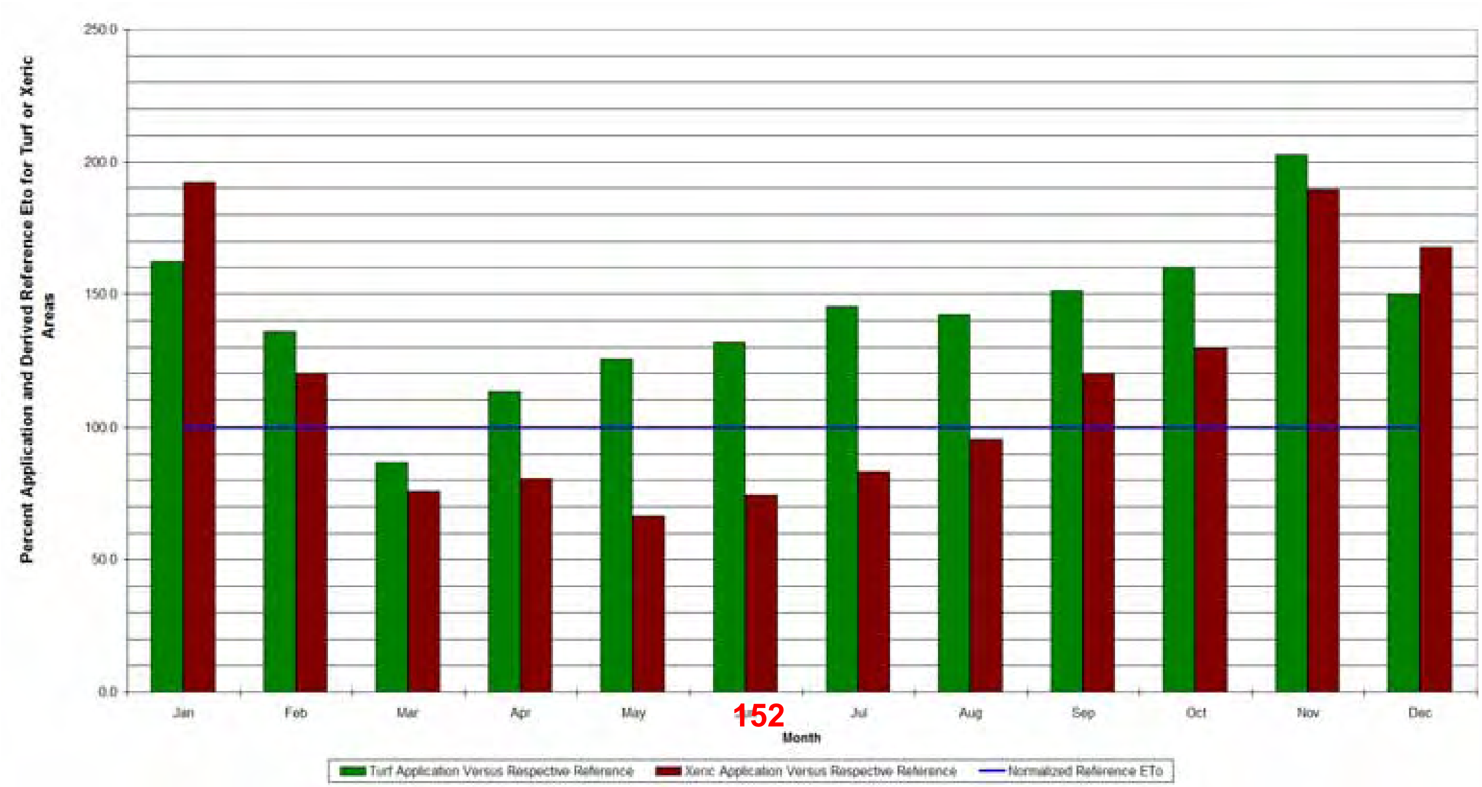
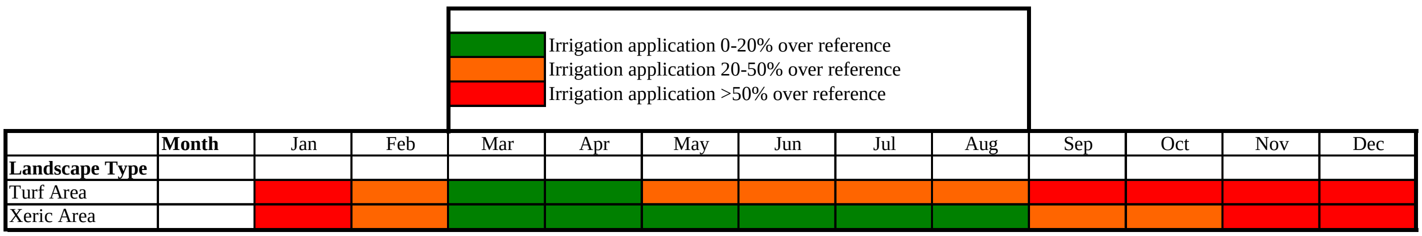


Figure 10 may suggest that there are specific times of the year when people irrigate both turf and xeric landscapes more or less efficiency than the ideal. As interpreted from Figure 10, the most inefficient irrigation, in a relative sense, may actually occur during non-peak months if efficiency is defined 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 ET_0 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. 1990[18]) 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 (Nelson[3] 1994, Gregg[4] et al. 1994, Gregg[19] 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.

<u>TOTALTUR</u>

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 (β=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 (DeOreo[8] 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 Gregg[19] 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 DeOreo[8] et al. 1999) and the overall finding that older homes tend to have higher water consumption is not surprising.

<u>APROXINC</u>

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.

<u>FESCUE</u>

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 lusher, 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 (β=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 Rosales[11] 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 Rosales[11] 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

Rosales[11] 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.

<u>DRIP</u>

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 Rosales[11] 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.

<u>DONTKNOW</u>

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 (Sovocool[12] 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.

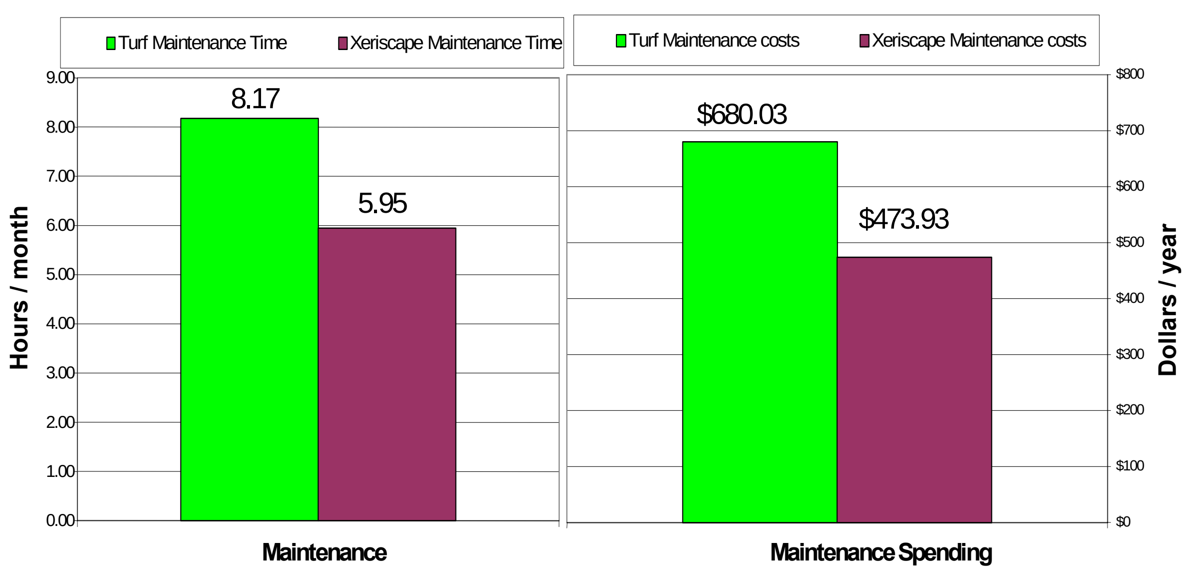
FINANCIAL SAVINGS ASSOCIATED WITH CONVERSION PROJECTS AND COST EFFICIENCY

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. Hessling[12] (2001) provides a detail of the capital costs and savings obtained.

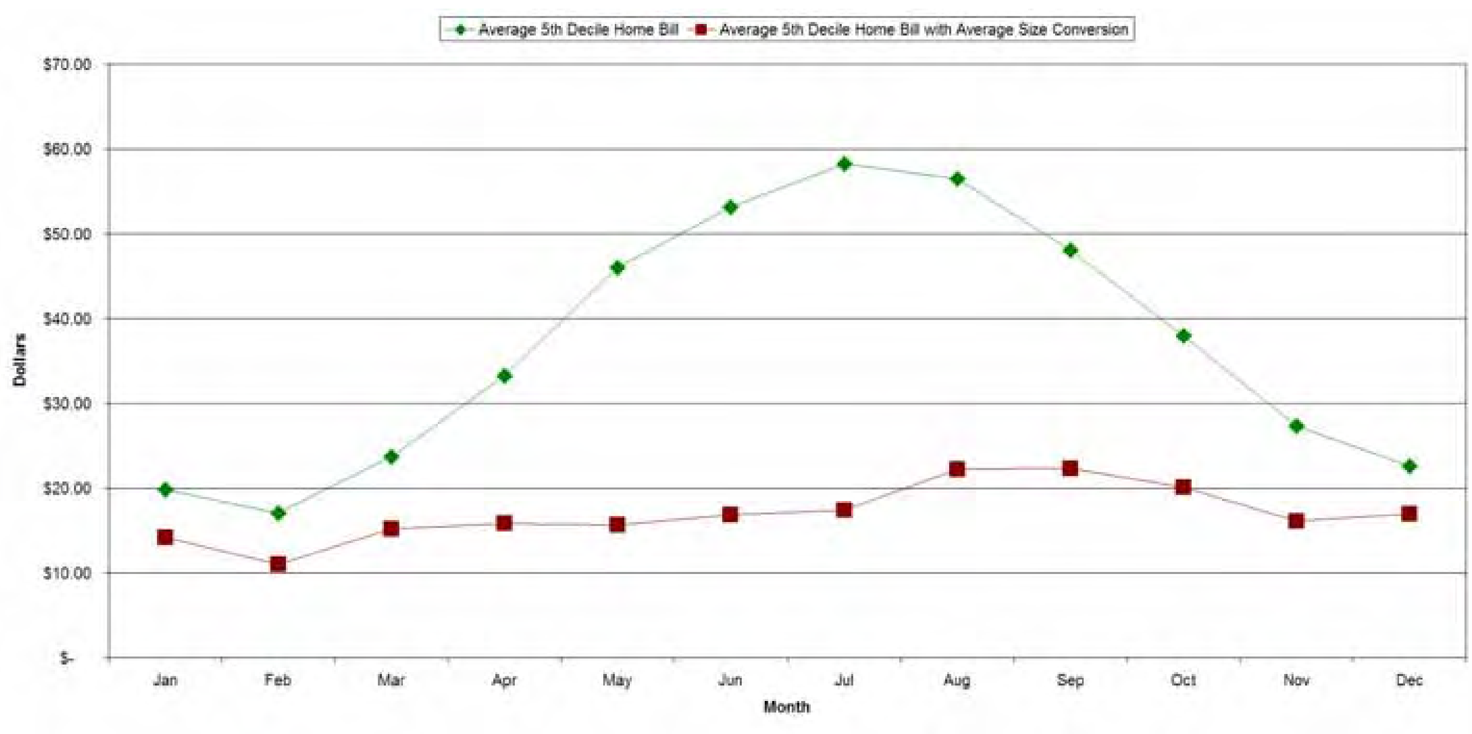
FIGURE 12: Average Monthly Maintenance Time and Annual Direct Expenditures for Participants Having At least 60% Turf or Xeriscape



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.

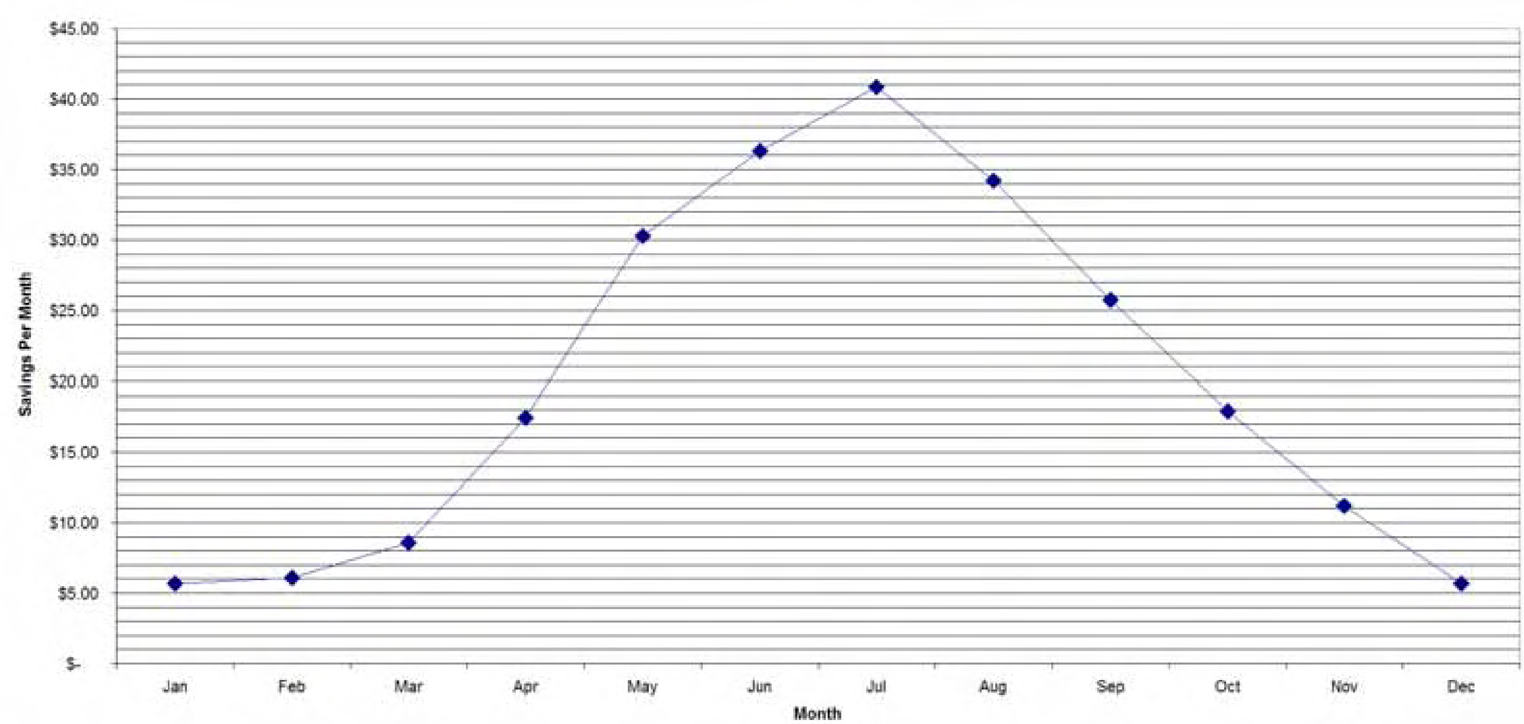
FIGURE 13: Modeled Monthly Water Bill for a Typical Las Vegas Area Home and The Same Home with an Average-Size Conversion



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

Hessling[13] (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 xericape 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:

Shorter Time to Investment Return

- Situations where only the material costs of the conversion are valued and where savings in both maintenance goods and labor can be realized (in fact, this scenario theoretically may not even require an incentive to generate financial savings in an acceptable investment timeframe).
- Situations where both the material costs of the conversion and the labor cost of the conversion are valued and where savings in both maintenance goods and labor can be realized.
- Situations where only the material costs of the conversion are valued and where only savings in maintenance goods (not labor) can be realized.
- Situations where both the material costs of the conversion and the labor cost of the conversion are valued and where only savings in maintenance goods (not labor) can be realized.

Longer Time to Investment Return

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: 3-4 Years Avg. Payback Time Without Incentive: 5-6 Years Incentive Required for 3-Year ROI: $1.03/SqFt Incentive Required for 5-Year ROI: $0.14/SqFt	Avg. Payback Time at $1.00 per SqFt: 5-6 Years Avg. Payback Time Without Incentive: 8-9 Years Incentive Required for 3-Year ROI: $2.23/SqFt Incentive Required for 5-Year ROI: $1.34/SqFt
Conserved Maintenance Goods and Labor	Avg. Payback Time at $1.00 per SqFt: 1-2 Years Avg. Payback Time Without Incentive: 2-3 Years Incentive Required for 3-Year ROI: None Req. Incentive Required for 5-Year ROI: None Req.	Avg. Payback Time at $1.00 per SqFt: 2-3 Years Avg. Payback Time Without Incentive: 4-5 Years Incentive Required for 3-Year ROI: $0.91/Sqft Incentive Required for 5-Year ROI: None Req.

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 (SNWA[20] 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 Plan[21] 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 analyses[13], 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 (SNWA[20] 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 (LVVWD[22] 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 per acre-foot X 325851 gallons per acre-foot X 55.8 gallons per sqft yield = $1.627 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 per sqft expended + ($1.00 + 4.65% 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 per sqft saved - $1.047 per sqft saved = $0.58 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.

Executive Summary and Conclusions

The major conclusions of this research are as follows:

1. Xeriscape conversion projects can save vast quantities of water at single-family residences. Homes in this study saved an average of 96,000 gallons annually following completion of an average-size conversion project. This is a savings of 30% in total annual consumption; a finding in line with those yielded by other research studies in this region.

2. Over the long timeframe of this study, total yearly savings have neither eroded nor improved across the years. On average, household consumption drops immediately and quickly stabilizes.

3. There is an enormous difference in application of water to locally used turfgrasses and xeric landscape by residents. On average, each year residents applied 73.0 gallons per square foot (117.2 inches) of water to grow turfgrass in this area and just 17.2 gallons per square foot (27.6 inches) to xeric landscape areas. The difference between these two figures, 55.8 gallons per square foot (89.6 inches) is the theoretical average savings yielded annually by having xeriscape in lieu of turf in this area. This is a *substantial* savings (76.4%) when considered in the context of the available residential water conservation measures. A sub-study of other commercial properties with xeriscape found the average application to xeric areas by these customers to be essentially equivalent to that observed for the residential customers.

4. Over the course of a year, the difference in application between turf and xeric areas varies in a predictable bell-shaped-curve manner, with the greatest difference occurring in summer. This is because turf irrigation peaks to a much greater extent in summer than xeric irrigation. The difference in irrigation between these two types of landscape varies from as little as 1.56 gallons per square foot for the month of December, on up to 9.62 gallons per square foot for the month of July.

5. In comparing irrigation application to the reference evapotranspirational rate (ET_o), it was found that on average application to turf exceeded ET_o in every month except March, exceeding it the most May through November. In contrast, xeric application remained well below ET_o year round.

6. The author experimented with using a locally invoked “rule-of-thumb” which holds that xeric plantings require about a third of the evapotranspirational rate as needed for turf. In comparing this developed reference, $0.33(ET_o)$, to application, it was found that these values were, in absolute terms, somewhat close month to month and very close over the entire year. In comparing this developed reference to application, it was found that xeric application was below $0.33(ET_o)$ half the year and above it the other half of the year (September-February).

7. Relative to questions about irrigation management and the potential for further efficiency gains, findings associated with conclusions 4 through 6 and subsequent analyses led the author to the suggest that (i.) the greatest absolute savings from assorted improvements in irrigation will be realized in the summer, but (ii.) the most readily obtained efficiency improvements (i.e., not requiring capital outlays) yielded from better controller management may be obtained September through January, as this is the period when a lot of residents fail to successfully decrease irrigation in response to lower irrigation requirements (for both types of landscape).

8. Multivariate regression modeling was used to help discover some of the factors associated with variability in water consumption at single-family residences. These are:
   i. The amount of turf at the residence (positive correlation).
   ii. The property value of the residence (as indicated by the local assessor's office; positive correlation).
   iii. The age of the residence (positive correlation).
   iv. The total income of the property's residents (positive correlation).
   v. Whether or not the turfgrass present at the residence is Fescue (a locally popular cool-season grass; positive correlation). As a side-result from one of the multivariate analyses, Bermuda grass may be receiving approximately 59 gallons per square foot per year – certainly less than the application for the much more common cool-season grass in this study.

   Some variables which were significant in many other incarnations of the model (but not the final model) include parcel size, surface area of open water for pools and spas, the total number of occupants living at the residence, and total landscapeable area.

9. A similar approach was used to identify some of the factors associated with variability in irrigation application to monitored xeric areas. These are:
   i. The total canopy coverage within the xeric area (positive correlation).
   ii. The average per-station flow rate of the installed irrigation system serving the xeric area (positive correlation).
   iii. The size of the xeric area (positive correlation).
   iv. The property value of the residence (positive correlation).
   v. Parcel size (inverse correlation).
   vi. Whether or not the irrigation system was exclusively a drip irrigation system (i.e., not composed of microsprays, bubblers, other higher flow emitters, or combinations of emitters; inverse correlation).
   vii. Whether or not the resident responsible for managing irrigation at the home is knowledgeable about enforcement of local provisions prohibiting outdoor water waste (inverse correlation).

10. Tracking of the costs residents incurred when converting their landscapes from turf to xeric landscape revealed that at the time of the study, the average conversion cost was $1.55 per square foot across all of the conversion projects for which data was available. The average cost for those who did the work themselves was $1.37 per square foot, and for those employing a contractor, it was $1.93 per square foot. All of these costs are probably higher today due to inflation and a strong market for conversion projects.

11. In comparing those with 60% or more of their landscape as xeric landscaping and those whose landscape was 60% or more turf, it was found that those with the majority as xeriscape condition enjoyed a 2.2 hrs-per-month reduction in landscape maintenance and an additional $206 per annum savings in direct maintenance expenditures as well. This represented a savings of about a third in total landscape labor and maintenance expenditures, respectively.

12. A model of two identical homes, one near the average for consumption (technically in the fifth decile for consumption), the other the same, but having completed an average-size conversion, revealed the following:
    i. The annual water bill savings yielded by landscape conversion projects can be large. For the Las Vegas Valley Water District customer modeled, the annual financial savings was $239.92 (figure includes all applicable surcharges). This equates to a savings of nearly $0.15 per square foot.
    ii. This is a large savings of 54% in total annual charges for water consumption. This level of savings is elevated over what might have been initially anticipated due to an aggressive tiered water rate structure. The effective average fifth-decile annual water charges with all surcharges added would be $2.13/kgal for the typical traditional home and $1.85/kgal for the one having completed the average-size conversion.
    iii. The savings vary by season as expected by the findings associated with the submeter data. Whereas the bill payer of the home having done the conversion saved 25% ($5.68) in charges for December vs. the typical homeowner, the same individual would realize an enormous savings of 70% ($40.84) for July. One of the great benefits of xeriscape is that it drastically mediates "peaking" in summer, making summer bills much more affordable for households, especially since power bills also peak in summer.

13. A model was also created to explore payback time and the appropriateness of the financial incentive. This revealed that payback time varies in part on whether or not homeowners do the work themselves or enlist the assistance of a contractor and whether or not savings in maintenance labor is actually realized. Modeling proceeded such that different combinations of these scenarios were explored. The results suggest that in most situations the current SNWA incentive is sufficient to help facilitate conversions such that there is an acceptable time to return on investment (ROI) for the homeowner. In order of increasing time to ROI from the point of conversion, with a dollar-per-square foot incentive from SNWA, these are as follows:
    - Situations where only the material costs of the conversion are valued and where savings in both maintenance goods and labor can be realized (average payback time of one to two years).
    - Situations where both the material costs of the conversion and the labor cost of the conversion are valued and where savings in both maintenance goods and labor can be realized (average payback time of two to three years).

- Situations where only the material costs of the conversion are valued and where only savings in maintenance goods (not labor) can be realized (average payback time of three to four years).
- Situations where both the material costs of the conversion and the labor cost of the conversion are valued and where only savings in maintenance goods (not labor) can be realized (average payback time of five to six years).

14. An economic analysis of the cost-efficiency of SNWA's Water Smart Landscapes Program suggests that in theory the program is cost-efficient and could be bringing in the equivalent of $1.58 for each $1.00 spent on rebate incentives (a 37% positive return) by way of effectively freeing up local water resources for immediate use. When the opportunity cost is included in the calculation, it is determined that the theoretical maximum incentive SNWA should be currently willing to pay in 2004 dollars is $1.55 per square foot (the actual maximum is less due to program administration costs). In practice, this means it is probably not cost-effective to raise the incentive further at this time as the level necessary to yield a 3-yr ROI for those not yet facilitated to convert (i.e., the final bulleted scenario in Conclusion 13) equates to $2.23, an incentive level far in excess of the theoretical top-out point for an incentive provided by SNWA. Furthermore, in the majority of modeled scenarios, the dollar per-square-foot is sufficient incentive for homeowners to justify the landscape conversion project.

References

1. Bent, 1992. East Bay Municipal Utility District. CA (data recapitulated from citation in Reference 4).

2. Testa, A. and Newton, A., 1993. An Evaluation of a Landscape Rebate Program. *AWWA Conserv'93 Proceedings*, December. 1763 – 1775. Mesa, AZ.

3. Nelson, J., 1994. Water Saved By Single Family Xeriscapes. *1994 AWWA Annual Conference Proceedings*, June. 335-347. North Marin Water District, Novato, CA

4. Gregg, T. et al., 1994. *Xeriscaping: Promises and Pitfalls*. City of Austin. Austin, TX.

5. Colorado River Compact of 1922. United States of America. H. Doc 605, 67th Cong., 4th Sess.

6. Boulder Canyon Project Act. 1928. United States of America. H. Doc 642, 70th Cong., 2nd Sess.

7. Cooperative Agreement No. 5-FC-30-00440, 1995. Cooperative Agreement Between Bureau of Reclamation and Southern Nevada Water Authority for Research Investigation of Implementation of Xeriscape.

8. Mayer, P. and DeOreo, W. et al., 1999. Residential End Uses of Water. AWWA Research Foundation. U.S.A.

9. DeOreo, W., Mayer, P., Rosales, J., 2000. Xeriscape Conversion for Urban Water Conservation. *National Irrigation Symposium Proceedings*, November. Phoenix, NM.

10. Sovocool, K., Hessling, M., and Rosales, J., 2000. Residential Xeriscape: Answering Some Common Questions on Water and Landscape Maintenance Savings by Field Research. *New Mexico Xeriscape Conference 2000 Proce*edings, October. Albuquerque, NM.

11. Sovocool, K. and Rosales, J., 2001. A Five-year Investigation into the Potential Water and Monetary Savings of Residential Xeriscape in the Mojave Desert. *2001 AWWA Annual Conference Proceedings*, June. Washington D.C. Southern Nevada Water Authority, NV.

12. Sovocool, K., 2002. Subtle Mediators of Water Savings in Xeriscape Conversion Projects. *AWWA 2002 Water Sources Conference*, January. Las Vegas, NV. Southern Nevada Water Authority, NV.

13. Hessling, M., 2001. Turf Landscapes versus Xeriscapes: Analysis of residential landscapes in the Las Vegas Valley, Nevada. Master's Project. Duke University, NC.

14. Mayer, P., Towler, E., and DeOreo, W., et al., 2004. National Multiple Family Submetering and Allocation Billing Study. Aquacraft, Inc., and East Bay Municipal Utility District, CA.

15. Rosales, J., Weiss, C., and DeOreo, W., 2002. The Impacts of Submetering on Water Usage at Two Mobile Home Communities in Las Vegas, Nevada. *AWWA 2002 Water Sources Conference*, January. Las Vegas, NV. Southern Nevada Water Authority, NV.

16. *Predicting and Estimating Landscape Water Use*. The Irrigation Association. April 2001.

17. *A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California – The Landscape Coefficient Method and WUCOLS III*. University of California Cooperative Extension and California Department of Water Resources. August 2000.

18. Kozlowski, T., Kraper, P., and Pallardy, S., 1990. *The Physiological Ecology of Woody Plants*. Academic Press, Inc., San Diego.

19. Gregg, T. et al., 1999. *Xeriscaping: Sowing the Seeds for Reducing Water Consumption*. City of Austin. Austin, TX.

20. *SNWA 2003 Water Resources Plan*. Southern Nevada Water Authority. 2003.

21. *SNWA Drought Plan.* Supplement to *SNWA 2003 Water Resources Plan*. Southern Nevada Water Authority. 2003.

22. *Agreement Between Ruffin Gaming, LLC, Ruffin Vegas, LLC and the District for the Purchase of 300 Acre-feet of Certificated and Permitted Groundwater Rights for An Amount Not To Exceed $2,850,000*. Las Vegas Valley Water District Board of Directors Agenda Item #8. Las Vegas Valley Water District. April 2003.

Appendices

Appendix 1: Attachment A (Scope of Work) for BOR Agreement 5-FC-30-00440 as Revised 11/19/98

APPENDIX 2: MULTIVARIATE MODEL DETAILS

Note: Detailed definitions of variables and units for with each variable for both of the below models appear in the corresponding sections within *Sources of Significant Variability in Single-Family Residential Consumption.*

TABLE 19: Multivariate Regression Model of Annual Single-Family Residential Consumption

Regression Summary
Dependent Variable: MAINMETE (i.e., annual consumption registered through mainmeter)
R^2=0.80889235; Adjusted R^2=0.80046113
F(9,204) = 95.940; p<0.0001
Std. Error of Estimate=76890

Variable	Beta	Std. Error of Beta	B	Std. Error of B	*t*(204)	p - level
Intercept			-90852.6	25413.77	-3.57494	0.000437
POOL	0.060698	0.035627	51.3	30.13	1.70371	0.089959
TOTALTUR	0.622464	0.041887	59.1	3.98	14.86045	0.000000
TOTALLAN	-0.145252	0.102765	-5.5	3.90	-1.41344	0.159051
APPROXINC	0.073217	0.033839	0.3	0.14	2.16370	0.031649
FESCUE	0.068672	0.032854	25756	12322.71	2.09020	0.037839
TOTVAL	0.281661	0.051686	2.1	0.39	5.44950	0.000000
PARCELSI	0.214206	0.119536	5.9	3.28	1.79197	0.074620
NLTHOMEA	0.117091	0.043809	1600.6	598.85	2.67274	0.008132
TOTALOCC	0.52416	0.032356	8860.4	5469.42	1.61999	0.106780

TABLE 20: Multivariate Regression Model of Annual Xeric Study Area Consumption

Regression Summary
Dependent Variable: SUBMETER (i.e., annual consumption registered through submeter)
R^2=.64787230; Adjusted R^2=.41973852
F(7,178) = 18.394; p<0.0001
Std. Error of Estimate=32272

Variable	Beta	Std. Error of Beta	B	Std. Error of B	*t*(178)	p - level
Intercept			-7697.6	8973.436	-0.85782	0.392144
STUDYA	0.211132	0.068633	6.4	2.087	3.07623	0.002427
TOTALCAN	0.299352	0.069467	9.2	2.126	4.30934	0.000027
DONTKNOW	0.122082	0.57381	10922.2	5133.663	2.12756	0.034750
TOTVAL	0.213746	0.072592	0.4	0.137	2.94447	0.003667
PARCELSI	-0.211758	0.076239	-1.5	0.524	-2.77756	0.006064
AVGFLOWR	0.265679	0.064116	3637.4	877.802	4.14372	0.000053
DRIP	-0.133730	0.058997	-13615	6006.406	-2.26674	0.024609

APPENDIX 3: RAW DATA

Raw data for possible further analysis is included in the file "BORdata.mdb." A copy of this Microsoft Access database file is being included on disk with submission of this report to BOR. Below is the data description and dictionary for the file (this is also saved on disk).

Xeriscape Conversion Study Data Description

1. **tblCustomerList – 716 Records,** basic customer information.
   a. ClientID – SNWA Customer identification number
      i. Number – Long Integer
      ii. Primary Key
   b. Program – Indicates if the property is a xeriscape or turf study site
      i. Text – 50
      ii. XS = Xeriscape Study, TS = Turf Study
   c. FirstName – Property occupant's first name
      i. Text – 50
   d. LastName – Property occupant's last name
      i. Text – 50
   e. Address – Address of property
      i. Text – 50
   f. City
      i. Text – 50
   g. Zip – Postal code
      i. Text – 5
   h. HomePhone
      i. Text – 50
   i. WorkPhone
      i. Text – 50
   j. Comments – Optional comment field
      i. Memo
   k. OwnerChange – Indicates if there has been a change in the ownership of the property.
      i. Boolean
   l. FollowupMonth – Number of the month the property has been assigned to schedule an annual follow-up site visit.
      i. Text – 2
   m. AccountNum – LVVWD / SNWA account number assigned to the property
      i. Number – Long Integer
   n. ServiceArea – Indicates if the customer receives service from LVVWD or one of the other entities.
      i. Text – 50
      ii. S = LVVWD Service, O = Outside Entity.

o. Agreement – Date the customer signed the agreement to become a participant in the study.
    i. Date/Time
p. FinalReview – Date final inspection site visit was conducted after the installation of the submeter.
    i. Date/Time
q. Status – File quality status indication.
    i. Text – 50
r. FileQuality – Quality rating of file information
    i. Text – 50

2. **tblAllSubmeterData – 2667 Records,** customer's submetered consumption data.
    a. nltClientID – SNWA Customer identification number
        i. Number – Long Integer
        ii. Primary Key
    b. nitYear
        i. Number – Integer
        ii. Primary Key
    c. txtEntity – Indicates which water provider services the customer
        i. Text – 5
    d. txtProgram – Indicates if the property is a xeriscape or turf study site
        i. Text – 2
        ii. XS = Xeriscape Study, TS = Turf Study
    e. nstJan – January submeter consumption in gallons
        i. Number – Single Precision
    f. nstFeb – February submeter consumption in gallons
        i. Number – Single Precision
    g. nstMar – March submeter consumption in gallons
        i. Number – Single Precision
    h. nstApr – April submeter consumption in gallons
        i. Number – Single Precision
    i. nstMay – May submeter consumption in gallons
        i. Number – Single Precision
    j. nstJun – June submeter consumption in gallons
        i. Number – Single Precision
    k. nstJul – July submeter consumption in gallons
        i. Number – Single Precision
    l. nstAug – August submeter consumption in gallons
        i. Number – Single Precision
    m. nstSep – September submeter consumption in gallons
        i. Number – Single Precision
    n. nstOct – October submeter consumption in gallons
        i. Number – Single Precision
    o. nstNov – November submeter consumption in gallons
        i. Number – Single Precision

p. nstDec – December submeter consumption in gallons
    i. Number – Single Precision
q. nstTotal – Total yearly submeter consumption in gallons
    i. Number – Single Precision

3. **tblAOX2 – 702 Records,** parcel information from Assessor's database
    a. ClientID – SNWA Customer identification number
        i. Number – Long Integer
        ii. Primary Key
    b. PLDECKSQF – Pool decking square footage
        i. Number – Single Precision
    c. STORAGESQF – Storage area square footage
        i. Number – Single Precision
    d. PAVE1SQF – Paved area one square footage
        i. Number – Single Precision
    e. PAVE2SQF – Paved area two square footage
        i. Number – Single Precision
    f. PATIO1SQF – Patio one square footage.
        i. Number – Single Precision
    g. PATIO2SQF – Patio two square footage
        i. Number – Single Precision
    h. PATIO3SQF – Patio three square footage
        i. Number – Single Precision
    i. GARAGE1SQF – Garage area 1 square footage
        i. Number – Single Precision
    j. GARAGE2SQF – Garage area 2 square footage
        i. Number – Single Precision
    k. CARPORTSQF – Carport area square footage
        i. Number – Single Precision
    l. FIRSTFLSQF – First floor footprint square footage
        i. Number – Single Precision
    m. TOTALHS – Total of all hardscape areas
        i. Number – Single Precision
    n. PARCEL – Assessor's parcel number
        i. Text – 11

4. **tblETDatawithCustomerIDs – 716 Records,** total monthly and annual evapotranspiration rates for 2001 by month correlated with SNWA client identification numbers.
    a. ClientID – SNWA Customer identification number
        i. Number – Long Integer
        ii. Primary Key
    b. ETType
        i. Text - 50
    c. JanET
        i. Number – Single Precision

d. FebET
    i. Number – Single Precision
e. MarET
    i. Number – Single Precision
f. AprET
    i. Number – Single Precision
g. MayET
    i. Number – Single Precision
h. JunET
    i. Number – Single Precision
i. JulET
    i. Number – Single Precision
j. AugET
    i. Number – Single Precision
k. SepET
    i. Number – Single Precision
l. OctET
    i. Number – Single Precision
m. NovET
    i. Number – Single Precision
n. DecET
    i. Number – Single Precision
o. TotalET
    i. Number – Single Precision

5. **tblETDatawithCustomerIDsAvg – 716 Records,** average monthly and annual evapotranspiration rates for 2001 by month correlated with SNWA client identification numbers.
    a. ClientID – SNWA Customer identification number
        i. Number – Long Integer
        ii. Primary Key
    b. ETType
        i. Text – 50
    c. JanAvgET
        i. Number – Single Precision
    d. FebAvgET
        i. Number – Single Precision
    e. MarAvgET
        i. Number – Single Precision
    f. AprAvgET
        i. Number – Single Precision
    g. MayAvgET
        i. Number – Single Precision
    h. JunAvgET
        i. Number – Single Precision

i. JulAvgET
  i. Number – Single Precision
j. AugAvgET
  i. Number – Single Precision
k. SepAvgET
  i. Number – Single Precision
l. OctAvgET
  i. Number – Single Precision
m. NovAvgET
  i. Number – Single Precision
n. DecAvgET
  i. Number – Single Precision
o. TotalAvgET
  i. Number – Single Precision

6. **tblInstalledCanopy – 447 Records,** total of square feet of plant coverage of xeriscape participants upon installation of the landscape.
  a. ClientID – SNWA Customer identification number
    i. Number – Long Integer
    ii. Primary Key
  b. InstCanopyArea – Installed plant canopy square feet.
    i. Number – Single Precision

7. **tblParcelInfo – 702 Records,** Information from Clark County Assessor's office database extracted November 2002.
  a. ClientID – SNWA Customer identification number
    i. Number – Long Integer
    ii. Primary Key
  b. ParcelNum – Assessor's office parcel number
    i. Text – 11
  c. ParcelSize – Size of parcel in square feet
    i. Number – Single Precision
  d. CONSTYR – Construction year
    i. Number – Integer
  SALEPRICE – Last Sales price
    ii. Number – Long Integer
  e. LYTOTAL – Last years assessed value land and improvement
    i. Number – Long Integer
  f. SALEDATE – Last sales date (Year)
    i. Text - 6
  g. nltHomeAge – Age of home calculated by construction year from the year 2001.
    i. Number – Long Integer

8. **tblResults – 603 Records,** collection of landscape areas, yearly water consumption data, other site, and customer information
    a. nltClientID – SNWA Customer identification number
        i. Number – Long Integer
        ii. Primary Key
    b. Program – (TS = Turf Study Participant, XS = Xeriscape Study)
        i. Text – 50
    c. Converted – Area converted if XS participant
        i. Number – Single Precision
    d. Pool – Square footage of pool surface if present
        i. Number – Single Precision
    e. GardenMon – Square footage of garden area where the irrigation is monitored by the submeter
        i. Number – Single Precision
    f. GardenUnmon – Square footage of garden area where the irrigation is not monitored by the submeter
        i. Number – Single Precision
    g. Other – Square footage of other undeveloped property area. No irrigation, plants, or hardscape present.
        i. Number – Single Precision
    h. Study – Total xeriscape area where irrigation is monitored by the submeter. Applies to XS participant only.
        i. Number – Single Precision
    i. TurfMon – Square footage of turf grass where irrigation is monitored by the submeter.
        i. Number – Single Precision
    j. TurfUnmon – Square footage of turf area where the irrigation is not monitored by the submeter
        i. Number – Single Precision
    k. XeriMon – Square footage of xeriscape where irrigation is monitored by the submeter. (Applies to Turf Study Group)
        i. Number – Single Precision
    l. XeriUnmon – Square footage of xeriscape area where the irrigation is not monitored by the submeter.
        i. Number – Single Precision
    m. TotalLandscape – Total of all landscapable area on the property.
        i. Number – Single Precision
    n. TotalEvaporative – Total of all landscapable area with pool area added.
        i. Number – Single Precision
    o. dtt2001SR – Date of final annual visit conducted in 2001.
        i. Date/Time
    p. AgeOfXeriscape – Age of xeriscape in days calculated by the difference in days between the post submeter installation inspection and the final 2001 follow-up site visit.
        i. Number – Long Integer

q. TotalXeriArea – Total of all xeriscape areas, monitored and unmonitored.
    i. Number – Single Precision
r. Status – File quality status indication.
    i. Text - 50
s. TotalCanopy – Total of all plant canopy areas as of the 2001 annual site visit.
    i. Number – Single Precision
t. nitYear
    i. Number – Integer
u. txtEntity – Water agency that services the customer.
    i. Text - 5
v. Submeter2001 – Total gallons used in the year 2001 through the submeter
    i. Number – Single Precision
w. Mainmeter2001 – Total gallons used in the year 2001 through the main meter
    i. Number – Single Precision
x. pctGarden – Percent of total landscape area in garden
    i. Number – Single Precision
y. pctXeri – Percent of total landscape in xeriscape
    i. Number – Single Precision
z. pctTurf – Percent of total landscape area in turf
    i. Number – Single Precision
aa. pctOther – Percent of total landscape in other non-landscaped area
    i. Number – Single Precision
bb. pctPool – Percent of total landscape area in pool
    i. Number – Single Precision
cc. pctXeriRank – Xeriscape study participants were divided into ten percent ranges based upon percentage of landscape in xeriscape and given a ranking.
    i. Number – Single Precision
dd. XeriDensity – Percent of plant coverage per square foot of xeriscape.
    i. Number – Single Precision
ee. TurfType – Type of turf (Bermuda, Fescue, etc.) on property if present.
    i. Text – 50
ff. BarrierType – Type of weed barrier present if Xeriscape study participant.
    i. Text – 50

9. **tblSurveyInfoOfInterest – 603 Records,** Responses to survey questions. Each possible response is listed as a separate field. The responses are grouped where appropriate.
   a. CLIENTID – SNWA Customer identification number
       i. Number – Long Integer
       ii. Primary Key
   b. SurveyAnswered – "Yes" or "No" Indicates if the customer answered any of the questions on the survey.
       i. Text – 3
   c. CLOCKADJ – How many times per year the irrigation clock was adjusted
       i. Number – Byte

d. INCBILL – How much of an increase in the monthly bill would produce conservation?
    i. Number – Integer
e. RESPAGE – Respondent's age
    i. Number – Byte
f. Respondent's gender
    i. MALE
        1. Number – Byte (1 = Yes, 0 = No)
    ii. FEMALE
        1. Number – Byte (1 = Yes, 0 = No)
g. Respondent's marital status
    i. MARRIED
        1. Number – Byte (1 = Yes, 0 = No)
    ii. SINGLE
        1. Number – Byte (1 = Yes, 0 = No)
    iii. WIDOWED
        1. Number – Byte (1 = Yes, 0 = No)
h. RETIRED – Indicates if respondent is retired or not
    i. Number – Byte (1 = Yes, 0 = No)
i. NATIVE – Native to southern Nevada?
    i. Number – Byte (1 = Yes, 0 = No)
j. AGE65PLS – Number of residents at the property age 65 and older
    i. Number – Byte
k. APROXINC – Median of a range of household income
    i. Number – Long Integer
l. Respondent's opinion on Water Waste enforcement
    i. DONTKNOW
        1. Number – Byte (1 = Yes, 0 = No)
    ii. GOOD
        1. Number – Byte (1 = Yes, 0 = No)
    iii. LAX
        1. Number – Byte (1 = Yes, 0 = No)
    iv. STRICT
        1. Number – Byte (1 = Yes, 0 = No)
m. Highest Education Level
    i. ASSOCDEG – Associate's degree
        1. Number – Byte (1 = Yes, 0 = No)
    ii. BACHDEG – Bachelor's degree
        1. Number – Byte (1 = Yes, 0 = No)
    iii. GRADDEG – Graduate degree
        1. Number – Byte (1 = Yes, 0 = No)
    iv. HSDEG – High school degree
        1. Number – Byte (1 = Yes, 0 = No)

v. SOMECOLL – Some College
1. Number – Byte (1 = Yes, 0 = No)
vi. SOMEGRAD – Some graduate education
1. Number – Byte (1 = Yes, 0 = No)
vii. TECHTRAD – Technical or trade school
1. Number – Byte (1 = Yes, 0 = No)
viii. ADTECTRN – Advanced technical training
1. Number – Byte (1 = Yes, 0 = No)
n. Type of Grass at residence
i. BERMUDA
1. Number – Byte (1 = Yes, 0 = No)
ii. FESCUE
1. Number – Byte (1 = Yes, 0 = No)
iii. BUFFALO
1. Number – Byte (1 = Yes, 0 = No)
iv. BFMIX – Bermuda / Fescue Mix
1. Number – Byte (1 = Yes, 0 = No)
v. UNKNOWN
1. Number – Byte (1 = Yes, 0 = No)
vi. NONE
1. Number – Byte (1 = Yes, 0 = No)

10. tblSurveryTotBath – 623 Records, total number of bathrooms on the property
a. ClientID – SNWA Customer identification number
i. Number – Long Integer
ii. Primary Key
b. Bathrooms
i. Number – Single Precision

11. tblSurveyTotOccupants- 341 Records, total number of occupants in the household at the time of the survey.
a. nltClientID – SNWA Customer identification number
i. Number – Long Integer
ii. Primary Key
b. TotalOccupants
i. Number – Integer

12. tblIrrigationData – 355 Records, Irrigation system components for each property were assessed, and each property assigned to one of the following categories.
a. ClientID – SNWA Customer identification number
i. Number – Long Integer
ii. Primary Key
b. AvgFlowRate – Average flow rate of all stations
i. Number – Single Precision
c. BubblerDrip – Irrigation system is composed of bubbler and drip systems
i. Number – Integer (1 = Yes, 0 = No)

d. BubblerDripSpray – Irrigation system is composed of bubbler, drip, and spray systems
    i. Number – Integer (1 = Yes, 0 = No)
e. Bubblers – Irrigation system is composed of bubblers
    i. Number – Integer (1 = Yes, 0 = No)
f. BubblerSpray – Irrigation system is composed of bubbler and spray systems
    i. Number – Integer (1 = Yes, 0 = No)
g. Drip – Irrigation system is composed of drip systems
    i. Number – Integer (1 = Yes, 0 = No)
h. DripOff – Irrigation system is composed of drip systems with one or more other irrigation zones turned off
    i. Number – Integer (1 = Yes, 0 = No)
i. DripMicro – Irrigation system is composed of drip and micro-spray systems
    i. Number – Integer (1 = Yes, 0 = No)
j. DripPopup – Irrigation system is composed of drip and popup spray systems
    i. Number – Integer (1 = Yes, 0 = No)
k. DripSpray – Irrigation system is composed of drip and spray systems
    i. Number – Integer (1 = Yes, 0 = No)
l. Hose – Irrigation is done with a hose
    i. Number – Integer (1 = Yes, 0 = No)
m. Microspray – Irrigation system is composed of micro-spray systems
    i. Number – Integer (1 = Yes, 0 = No)
n. Sprays – Irrigation system is composed of spray systems
    i. Number – Integer (1 = Yes, 0 = No)
o. BubblerDripPopup – Irrigation system is composed of bubbler, drip, and popup spray systems
    i. Number – Integer (1 = Yes, 0 = No)
p. DripMicroPopup – Irrigation system is composed of drip micro-spray and popup spray systems
    i. Number – Integer (1 = Yes, 0 = No)
q. DripPopupSpray – Irrigation system is composed of drip, popup spray, and spray systems
    i. Number – Integer (1 = Yes, 0 = No)
r. DripPopupRotor – Irrigation system is composed of drip, popup spray, and rotor systems
    i. Number – Integer (1 = Yes, 0 = No)
s. DripLaser – Irrigation system is composed of drip and laser tube systems
    i. Number – Integer (1 = Yes, 0 = No)
t. DripSoaker – Irrigation system is composed of drip and soaker hose systems
    i. Number – Integer (1 = Yes, 0 = No)
u. DripTurfBubbler – Irrigation system is composed of drip and turf bubbler systems
    i. Number – Integer (1 = Yes, 0 = No)
v. DripFountain – Irrigation system is composed of drip systems, and a fountain refill is controlled with the irrigation clock
    i. Number – Integer (1 = Yes, 0 = No)

13. **tblMulches – 715 Records,** mulch and weed barrier information
    a. ClientID – SNWA Customer identification number
        i. Number – Long Integer
        ii. Primary Key
    b. txtMulch – Typical type of mulch
        i. Text - 18
    c. txtMulchSize – Typical size of mulch
        i. Text - 50
    d. txtMulchColor – Typical color of mulch
        i. Text - 6
    e. nstMulchDepth – Depth of mulch in inches
        i. Number – Single Precision
    f. yntWeeds – Indicates if excessive weeds are present
        i. Boolean
    g. yntSlope – Is a steep slope present?
        i. Boolean
    h. yntTraffic – Is there heavy traffic in landscape?
        i. Boolean
    i. yntAlkali – Indicates if excessive alkali deposits present at surface.
        i. Boolean
    j. txtBarrierType – Type of weed barrier
        i. Text – 20
    k. txtBarrierColor – Color of weed barrier
        i. Text – 6
    l. yntBarrierShowing – Is the barrier showing at surface?
        i. Boolean
    m. txtWear – Extent of wear
        i. Text – 6
    n. txtLocationType – Wear location type
        i. Text – 16

14. **tblMainmeterConsumption – 4318 Records,** Gallons used per customer per month as measured by the property's main service meter.
    a. nltClientID – SNWA Customer identification number
        i. Number – Long Integer
        ii. Primary Key
    b. nitYear
        i. Number – Integer
        ii. Primary Key
    c. txtEntity – Indicates which water provider services the customer
        i. Text – 5
    d. nstJan – January consumption in gallons
        i. Number – Single Precision
    e. nstFeb – February consumption in gallons
        i. Number – Single Precision

f. nstMar – March consumption in gallons
    i. Number – Single Precision
g. nstApr – April consumption in gallons
    i. Number – Single Precision
h. nstMay – May consumption in gallons
    i. Number – Single Precision
i. nstJun – June consumption in gallons
    i. Number – Single Precision
j. nstJul – July consumption in gallons
    i. Number – Single Precision
k. nstAug – August consumption in gallons
    i. Number – Single Precision
l. nstSep – September consumption in gallons
    i. Number – Single Precision
m. nstOct – October consumption in gallons
    i. Number – Single Precision
n. nstNov – November consumption in gallons
    i. Number – Single Precision
o. nstDec – December consumption in gallons
    i. Number – Single Precision
p. nstTotal – Total annual consumption in gallons
    i. Number – Single Precision

15. **tbl2001PropAreasOK4 – 673 Records,** Property area information as recorded for the year 2001.
    a. nltClientID – SNWA Customer identification number
        i. Number – Long Integer
        ii. Primary Key
    b. Converted – Area converted from turf to xeriscape. Refers to "XS" Participants only.
        i. Number – Single Precision
    c. Pool – Pool area if applicable
        i. Number – Single Precision
    d. GardenMon – Garden area where irrigation is being monitored by the submeter
        i. Number – Single Precision
    e. GardenUnmon – Garden area where irrigation is unmonitored by the submeter
        i. Number – Single Precision
    f. Other – Square footage of other undeveloped property area. No irrigation, plants or hardscape present.
        i. Number – Single Precision
    g. Study – Total xeriscape area where irrigation is monitored by the submeter. Applies to XS participant only.
        i. Number – Single Precision
    h. TurfMon – Square footage of turf grass where irrigation is monitored by the submeter.
        i. Number – Single Precision

i. TurfUnmon – Square footage of turf area where the irrigation is not monitored by the submeter
    i. Number – Single Precision
j. XeriMon – Square footage of xeriscape where irrigation is monitored by the submeter. (Applies to xeriscape study Group)
    i. Number – Single Precision
k. XeriUnmon – Square footage of xeriscape area where the irrigation is not monitored by the submeter.
    i. Number – Single Precision
l. TotalEvaporative – Total of all landscape areas plus pool area.
    i. Number – Single Precision
m. TotalLandscape – Total of all landscape areas.
    i. Number – Single Precision
n. dtt2001SR – Date of 2001 follow-up site visit
    i. Date / Time
o. AgeOfXeriscape – Age of xeriscape in days calculated by the difference between the post submeter installation inspection and the final 2001 follow-up site visit.
    i. Number – Long Integer
p. TotalXeriArea – Total of all xeriscaped areas
    i. Number – Single Precision
q. TotalGarden – Total of all garden areas
    i. Number – Single Precision
r. TotalTurf – Total of all Turf areas
    i. Number – Single Precision
s. PctGarden – Percent of total landscape area in garden
    i. Number – Single Precision
t. PctXeri – Percent of total landscape in xeriscape
    i. Number – Single Precision
u. PctTurf – Percent of total landscape area in turf
    i. Number – Single Precision
v. PctOther – Percent of total landscape in other non-landscaped area
    i. Number – Single Precision
w. PctPool – Percent of total landscape in pool
    i. Number – Single Precision
x. PctXeriRank – Xeriscape study participants were divided into ten percent ranges based upon percentage of landscape in xeriscape and given a ranking.
    i. Number – Long Integer

16. **tblTurfOnlySubMonthly – 107 Records,** monthly submeter consumption data and per square foot usage for turf study group of participants. Note – this usage is limited to those TS participants where ONLY turf was irrigated with submeter-monitored usage.
    a. ClientID – SNWA Customer identification number
        i. Number – Long Integer
        ii. Primary Key
    b. Year
        i. Number – Integer

c. Entity – Water purveyor that serves the customer
    i. Text – 5
d. FileQuality – Quality rating of file information
    i. Text – 10
e. Status – Customer status
    i. Text – 7
f. TurfMon – Square feet of grass where irrigation is monitored by the submeter
    i. Number – Single
g. JanCons – January submeter consumption in gallons
    i. Number – Single
h. FebCons – February submeter consumption in gallons
    i. Number – Single
i. MarCons – March submeter consumption in gallons
    i. Number – Single
j. AprCons – April submeter consumption in gallons
    i. Number – Single
k. MayCons – May submeter consumption in gallons
    i. Number – Single
l. JunCons – June submeter consumption in gallons
    i. Number – Single
m. JulCons – July submeter consumption in gallons
    i. Number – Single
n. AugCons – August submeter consumption in gallons
    i. Number – Single
o. SepCons – September submeter consumption in gallons
    i. Number – Single
p. OctCons – October submeter consumption in gallons
    i. Number – Single
q. NovCons – November submeter consumption in gallons
    i. Number – Single
r. DecCons – December submeter consumption in gallons
    i. Number – Single
s. JanGalSF – Gallons used per square foot of turf in January
    i. Number – Single
t. FebGalSF – Gallons used per square foot of turf in February
    i. Number – Single
u. MarGalSF – Gallons used per square foot of turf in March
    i. Number – Single
v. AprGalSF – Gallons used per square foot of turf in April
    i. Number – Single
w. MayGalSF – Gallons used per square foot of turf in May
    i. Number – Single
x. JunGalSF – Gallons used per square foot of turf in June
    i. Number – Single
y. JulGalSF – Gallons used per square foot of turf in July
    i. Number – Single

z. AugGalSF – Gallons used per square foot of turf in August
    i. Number – Single
aa. SepGalSF – Gallons used per square foot of turf in September
    i. Number – Single
bb. OctGalSF – Gallons used per square foot of turf in October
    i. Number – Single
cc. NovGalSF – Gallons used per square foot of turf in November
    i. Number – Single
dd. DecGalSF – Gallons used per square foot of turf in December
    i. Number – Single

17. **tblTurfOnlySubYearly – 107 Records,** yearly submeter consumption data and per square foot usage for turf study group of participants. Note – this usage is limited to those TS participants where ONLY turf was irrigated with submeter-monitored usage.
    a. ClientID – SNWA Customer identification number
        i. Number – Long Integer
        ii. Primary Key
    b. Year
        i. Number – Integer
        ii. Primary Key
    c. Entity – Water purveyor that serves the customer
        i. Text – 5
    d. TurfMon – Square feet of grass where irrigation is monitored by the submeter
        i. Number – Single
    e. GalSqFt – Gallons used per square foot of turf per year
        i. Number – Single
    f. YearlyCons – Total submetered consumption for the year.
        i. Number – Single
    g. FileQuality – Quality rating of file information
        i. Text - 8
    h. Status – Customer status
        i. Text – 7

18. **tblXeriOnlySubMonthly – 1550 Records,** monthly submeter consumption data and per square foot usage for xeriscape study group of participants. Note – this usage is limited to those XS participants where ONLY xeriscape was irrigated with submeter-monitored usage.
    a. ClientID – SNWA Customer identification number
        i. Number – Long Integer
        ii. Primary Key
    b. Year
        i. Number – Integer
        ii. Primary Key
    c. Entity – Water purveyor that serves the customer
        i. Text – 5

d. ConvNew – Indicates if the property's xeriscape was a new installation or a conversion of grass to xeriscape.
    i. Text – 4
e. Status – Customer status
    i. Text – 7
f. FileQuality – Quality rating of file information
    i. Text – 10
g. XeriMon – Square feet of xeriscape where irrigation is monitored by the submeter
    i. Number – Single Precision
h. JanCons – January submeter consumption in gallons
    i. Number – Single Precision
i. FebCons – February submeter consumption in gallons
    i. Number – Single Precision
j. MarCons – March submeter consumption in gallons
    i. Number – Single Precision
k. AprCons – April submeter consumption in gallons
    i. Number – Single Precision
l. MayCons – May submeter consumption in gallons
    i. Number – Single Precision
m. JunCons – June submeter consumption in gallons
    i. Number – Single Precision
n. SepCons – September submeter consumption in gallons
    i. Number – Single Precision
o. OctCons – October submeter consumption in gallons
    i. Number – Single Precision
p. NovCons – November submeter consumption in gallons
    i. Number – Single Precision
q. DecCons – December submeter consumption in gallons
    i. Number – Single Precision
r. JanGalSF – Gallons used per square foot of xeriscape in January
    i. Number – Single
s. FebGalSF – Gallons used per square foot of xeriscape in February
    i. Number – Single
t. MarGalSF – Gallons used per square foot of xeriscape in March
    i. Number – Single
u. AprGalSF – Gallons used per square foot of xeriscape in April
    i. Number – Single
v. MayGalSF – Gallons used per square foot of xeriscape in May
    i. Number – Single
w. JunGalSF – Gallons used per square foot of xeriscape in June
    i. Number – Single
x. JulGalSF – Gallons used per square foot of xeriscape in July
    i. Number – Single
y. AugGalSF – Gallons used per square foot of xeriscape in August
    i. Number – Single

z. SepGalSF – Gallons used per square foot of xeriscape in September
    i. Number – Single
aa. OctGalSF – Gallons used per square foot of xeriscape in October
    i. Number – Single
bb. NovGalSF – Gallons used per square foot of xeriscape in November
    i. Number – Single
cc. DecGalSF – Gallons used per square foot of xeriscape in December
    i. Number – Single

19. **tblXeriOnlySubYearly – 1550 Records,** yearly submeter consumption data and per square foot usage for xeriscape study group of participants. Note – this usage is limited to those XS participants where ONLY xeriscape was irrigated with submeter-monitored usage.
    a. ClientID – SNWA Customer identification number
        i. Number – Long Integer
        ii. Primary Key
    b. Year
        i. Number – Integer
        ii. Primary Key
    c. Entity – Water purveyor that serves the customer
        i. Text – 5
    d. ConvNew – Indicates if the property's xeriscape was a new installation or a conversion of grass to xeriscape.
        i. Text – 4
    e. XeriMon – Square feet of xeriscape where irrigation is monitored by the submeter
        i. Number – Single Precision
    f. YearlyCons– Total submetered consumption for the year.
        i. Number – Single
    g. GalSqFt – Gallons used per square foot of monitored xeriscape per year
        i. Number – Single
    h. FileQuality – Quality rating of file information
        i. Text – 10
    i. Status – Customer status
        i. Text – 7

20. **tblPlantList – 538 Records,** list of plants used to verify xeriscape participant's compliance with minimum canopy standards for program participation and classification of landscape plants in subsequent follow-up visits.
    a. PlantID
        i. Number – Long Integer
        ii. Primary Key
    b. Genus
        i. Text - 50
    c. Species
        i. Text - 50

d. Var/Cult – Variety or cultivar of plant
    i. Text - 50
e. Common Name
    i. Text - 50
f. Width – Expected mature width of the plant
    i. Number - Single
g. Height – Expected mature height of the plant
    i. Number - Integer
h. Plant Habit – Type of plant (shrub, tree, etc.)
    i. Text - 50
i. H20Use – Rated plant water needs.
    i. Text – 50

21. **tbl2001HomeSales – 45 Records,** data provided by SalesTraq. Information related to home sales in Southern Nevada area in the year 2001 by zip code.
    a. Zipcode
        i. Text – 5
        ii. Primary Key
    b. NumberSold – Number of homes sold in zip code
        i. Number – Single Precision
    c. MedianPrice – Median price of homes sold in zip code
        i. Number – Single Precision
    d. AvgPrice – Average price of homes sold in zip code.
        i. Number – Single Precision
    e. AvgPricePerSqFt – Average Price per square foot of homes sold in zip code.
        i. Number – Single Precision
    f. AvgSize – Average size of homes sold in zip code.
        i. Number – Single Precision
    g. Volume – Total value of homes sold in zip code
        i. Number – Single Precision
    h. AvgAge – Average age of homes sold in zip code
        i. Number – Single Precision

22. **tblMeterInfo – 716 Records**
    a. ClientID – SNWA Customer identification number
        i. Number – Long Integer
        ii. Primary Key
    b. MeterNum – Serial number stamped on submeter by manufacturer
        i. Text – 50
    c. Installed – Date submeter was installed by contractor
        i. Date/Time
    d. Cost – Cost of meter installation
        i. Number – Single Precision
    e. RetrofitNum – AS/400 account number assigned to submeter
        i. Number – Long Integer

f. Location – approximate location of submeter on site.
   i. Memo

APPENDIX 4: INFORMATION ON SINGLE-FAMILY RESIDENTIAL WATER BILL MODEL

A model was used to explore the differences in water consumption charges for a typical fifth decile in consumption LUC 110 property (single-family home) and one doing an average-size conversion. The model assumes the properties are in the Las Vegas Valley Water District's service area and subject to its regular service rules. A typical 5/8-inch-meter size was assumed (meter size in large part determines rate per consumption unit). Rates for each tier and the size of the tier rate block appear below in the screen shot of the actual modeling processes for the model used in this report. As demonstrated, within a given billing cycle the rate for the first 5,000 gallons is $1.05/kgal, the *next* 5,000 gallons after the initial 5000 costs $1.75/kgal, the next 10,000 gallons after these first 10,000 gallons is $2.38/kgal and so on (for billing purposes, the utility rounds to the nearest thousand gallons). In addition to the direct charges for the water, SNWA purveyor members bills commonly include a service charge, a commodity charge, and a reliability charge and these are reflected in the model below, so that the outputs are reflective of actual bills. A 30-day billing cycle was assumed.

In practical terms, the calculation of outputs in the model and the savings is derived by multiplying the expected average savings per square foot per month that would be yielded by a conversion (as calculated from Table 18) by the average-size conversion and then subtracting this from the fith-decile consumption level. This yielded the costs with having done the conversion (below called "Total Bill). In contrast, the cost without doing the conversion (i.e., "Average Fifth-Decile bill without reduction") is shown under the "did conversion" scenario. The difference between these, highlighted in red, is the anticipated monthly bill savings yielded from having completed the conversion project.

<u>Water Bill Calculator Screen Shot</u>

Meter Size: 5/8 | ☑ Residential | Percent Reduction 0% | Select Entity: LVVWD Current | Average SF WSL Conversion (n=3651): 1615.8

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Totals			
		10670	9369	12255	16174	21107	23447	25084	24519	21788	18112	13738	11795	208.057	5th Decile average consumption		
		1.81	2.09	2.45	4.64	7.74	8.78	9.62	7.96	6.25	4.54	3.02	1.56		Average Gallons Per SqFt Reduction		
		2925	3377	3959	7497	12506	14187	15544	12862	10099	7336	4880	2521	97691	Avg Gal / SqFt Reduction * Avg SF WSL Conversion		
Tier Rates	Tier Blocks	8	6	8	9	9	9	10	12	12	11	9	9	110366	Avg 5th Decile Cons - (Reduction * Avg WSL Conversion)		
1.05	5	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	5.25	63.00			
1.75	5	4.80	1.74	5.77	6.43	6.30	7.46	7.94	8.75	8.75	8.75	6.75	7.48	80.93			
2.38	10								3.94	4.02	1.85			9.81			
3.02	20													0.00			
	Water Cost	10.05	6.99	11.02	11.68	11.55	12.71	13.19	17.94	18.02	15.85	12.00	12.73	153.74	Price Per 1000 Gal. Annual	$	1.39
3.669	Service Charge	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	3.67	44.03			
0.05	Commodity Charge	0.39	0.30	0.41	0.43	0.43	0.46	0.48	0.58	0.58	0.54	0.44	0.46	5.52			
0.25%	Reliability Surcharge	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.06	0.06	0.05	0.04	0.04	0.51			
	Total Bill	14.15	10.98	15.14	15.83	15.69	16.88	17.38	22.25	22.33	20.11	16.16	16.90	203.79	Price Per 1000 Gal. Annual	$	1.85
		19.85	17.08	23.71	33.25	45.98	53.18	58.22	56.48	48.08	37.98	27.32	22.59	443.72	Average 5th Decile bill without reduction	$	2.13
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Total Savings with Red		

APPENDIX 5: INFORMATION ON HOMEOWNER PERSPECTIVE MODEL

The model is a dynamic Net Present Value Model that calculates the NPV of the project in future years. It does this by computing the difference in the yield by converting to xeriscape to the costs (water and maintenance) incurred by keeping turfgrass over the years.

"Conversion cost" and "awarded incentive" are products of the associated rates and the square feet converted. These are onetime costs. The "interest rate" is the discount or alternative rate (i.e., the rate associated with the loss incurred by spending money on the conversion rather than placing it in an interest-bearing account). The "average yearly rate increase" is the long-time average increase in water costs. "Yearly maintenance savings" is a product of the "Labor Savings" and "Direct Maintenance" variables (which are themselves calculated in a manner similar to "awarded incentive," however, these savings are yielded each year). "Average total bill savings for a year" is not automatically calculated, but entered either by use of real data or modeled bill savings (see Appendix 4). Model Outputs are "NPV" and "Year." Year 0 is the year of the conversion.

This model can directly yield the payback time with and without the incentive. By iterative process one can then develop what the input variables values would need to provide for a positive NPV at a given year. This is how the values for the third and fifth-year ROIs were developed for Figure 15. Example inputs and outputs are given below. In this case, at $1.00 per square foot, the conversion reached a positive NPV between years one and two.

In terms of yielding the actual data in Table 15, the following were used as data sources:

"Square Feet Converted" – This was the average conversion size for SNWA's Water Smart Landscapes Program in early 2004.

"Incentive Level" – This was the $1.00 per square foot incentive level for almost all single-family conversion projects in SNWA's Water Smart Landscapes Program in early 2004 (also see Appendix 5).

"Conversion cost" – This was the conversion cost as revealed by survey. This was one of the variables that were modified to reflect whether or not one did the conversion themselves or utilized contract assistance. Rates for each of these scenarios were developed based on compilation of receipts from both types of installations.

"average total bill savings for a year" – This was the yearly savings as provided by a model of the Las Vegas Valley Water District for a LUC 110 property in the fifth decile (mid-range) of consumption (see Appendix 4 for details on this model).

"interest rate" – This was the interest rate of a home equity loan in early February 2004.

"average yearly rate increase" – This is the average yearly rate increase for the Las Vegas Valley Water District over the long term. In practice, the District has often gone significant periods of time without a rate increase and then increased them much more than 3%, but this was the most practical method of doing the calculation for purposes of creating the model.

"Labor Savings" – This was adapted from Hessling[12] (2001). This savings was effectively turned on or off to see the impacts of the situations when labor savings are and are not realized. See text for additional information.

"Direct Maintenance" – This rate was derived from the maintenance survey data and is per Hessling[12] (2001).

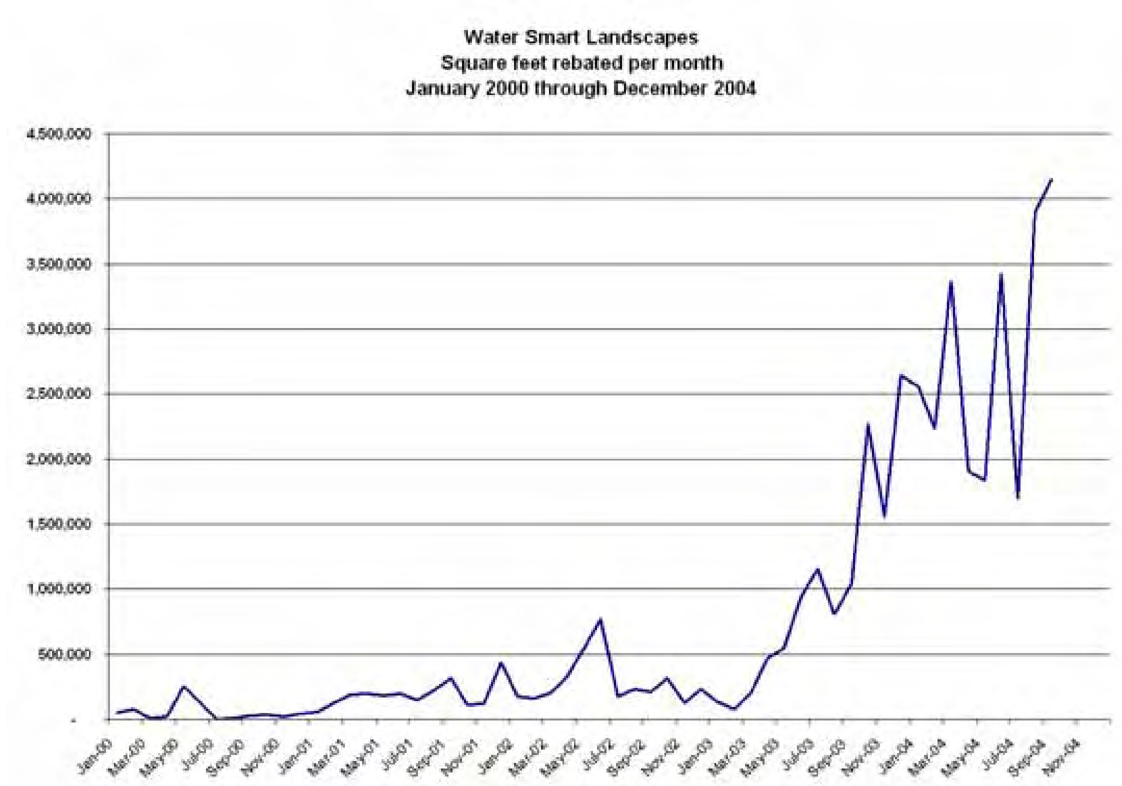
Examples of Homeowner Perspective Model Inputs and Outputs

Inputs:	Type
Square Feet Converted	1616
Incentive level	$1.00
Conversion cost:	$1.37
conversion cost:	$2,213.92
average total bill savings for a year:	$240.00
awarded incentive:	$1,616.00
interest rate:	6.32%
average yearly rate increase	3.00%
Labor Savings	$0.20
Labor Savings	$323.20
Direct Maintenance	$0.11
Direct Maintenance	$177.76
Yearly maintenance savings	$500.96

NPV	**Year**
($2,070.88)	0
($636.58)	1
$751.63	2
$2,095.24	3
$3,395.67	4
$4,654.31	5

APPENDIX 6: INFORMATION ON SNWA'S WATER SMART LANDSCAPES PROGRAM

Growth of Program:



See Program Application (following)

Other Studies on Xeriscape

Bent, 1992. East Bay Municipal Utility District. CA.

Testa, A. and Newton, A., 1993. An Evaluation of a Landscape Rebate Program. *AWWA Conserv'93 Proceedings,* December. 1763 – 1775. Mesa, AZ.

Nelson, J., 1994. Water Saved By Single Family Xeriscapes. *1994 AWWA Annual Conference Proceedings*, June. 335-347. North Marin Water District, Novato, CA

Gregg, T. et al., 1994. *Xeriscaping: Promises and Pitfalls*. City of Austin. Austin, TX.

DeOreo, W., Mayer, P., Rosales, J., 2000. Xeriscape Conversion for Urban Water Conservation. *National Irrigation Symposium Proceedings*, November. Phoenix, NM

Summary Municipal Turf Provisions and NGBS

The loss of the ability for turf limitations to count untoward points in the NGBS may well have deleterious impacts on interest in using the standard in the West. The anticipated impacts in the Las Vegas, NV area have already been noted by the Southern Nevada Homebuilders Association (as evidenced by the letters), but these are anticipated for jurisdictions from Texas to California.

The reason is that most turf provisions related to quantity are expressed in some manner as a percent of the landscape area. For example, here is one for Palm Springs, CA, for Section 8.6.0.0.6.0 (a) (6):

> (6) On single family residences, turf shall be limited to a maximum of 15 percent of the total landscaped area. This restriction shall only apply to the front and side street frontage yards.

In El Paso, TX it's as follows for Section 15.13.130 (B)

> B. Turf grass for residential sites after June 1, 2002, shall not be used for more than fifty percent of the total area to be landscaped (front and back yard).

In Thousand Oaks, CA it will be as per Resolution 116

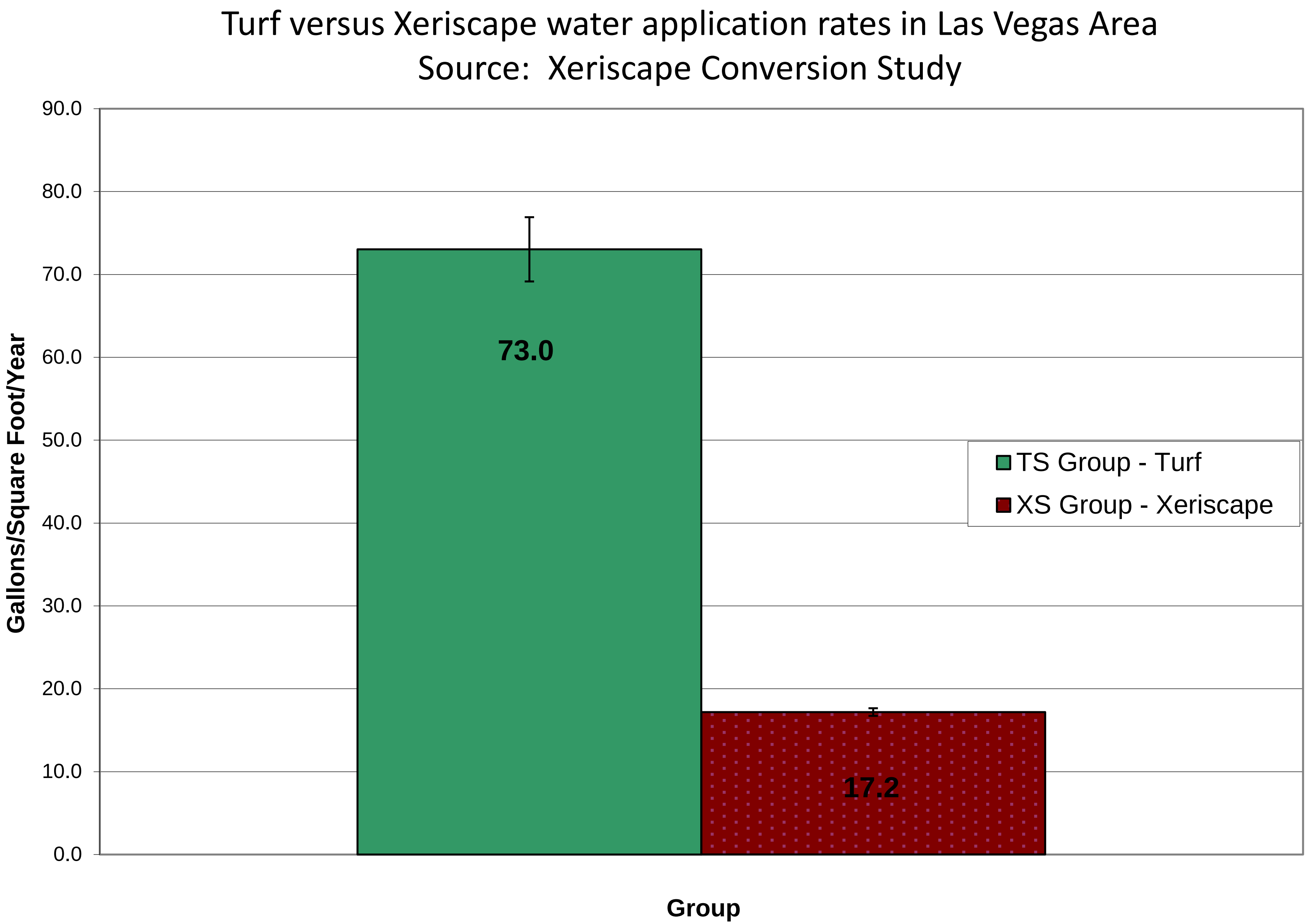
> Water conservation through the use of appropriate horticultural practices shall be provided for in all landscape designs. Lawn areas shall be minimized and in no case exceed fifteen percent (15%) of the landscape area, unless approved for a specific recreational area use (Ie. sports fields, picnic areas, etc.).

And so on. Based on the number of inquiries for information to SNWA it is reasonable to expect that at least 30 metropolitan areas in CA may be looking at additional turf limitations due to drought in the region.

The common element for all these is that the reduction is in a percentage basis, which the NGBS recognized. While for small developments or custom construction the idea of the EPA WaterSense Water Budget Tool (WBT) might have some appeal, based on its reception by builders in Las Vegas, it is not really practical for tract homes construction. This however is one off the most common types of single-family residential practices construction in the West.

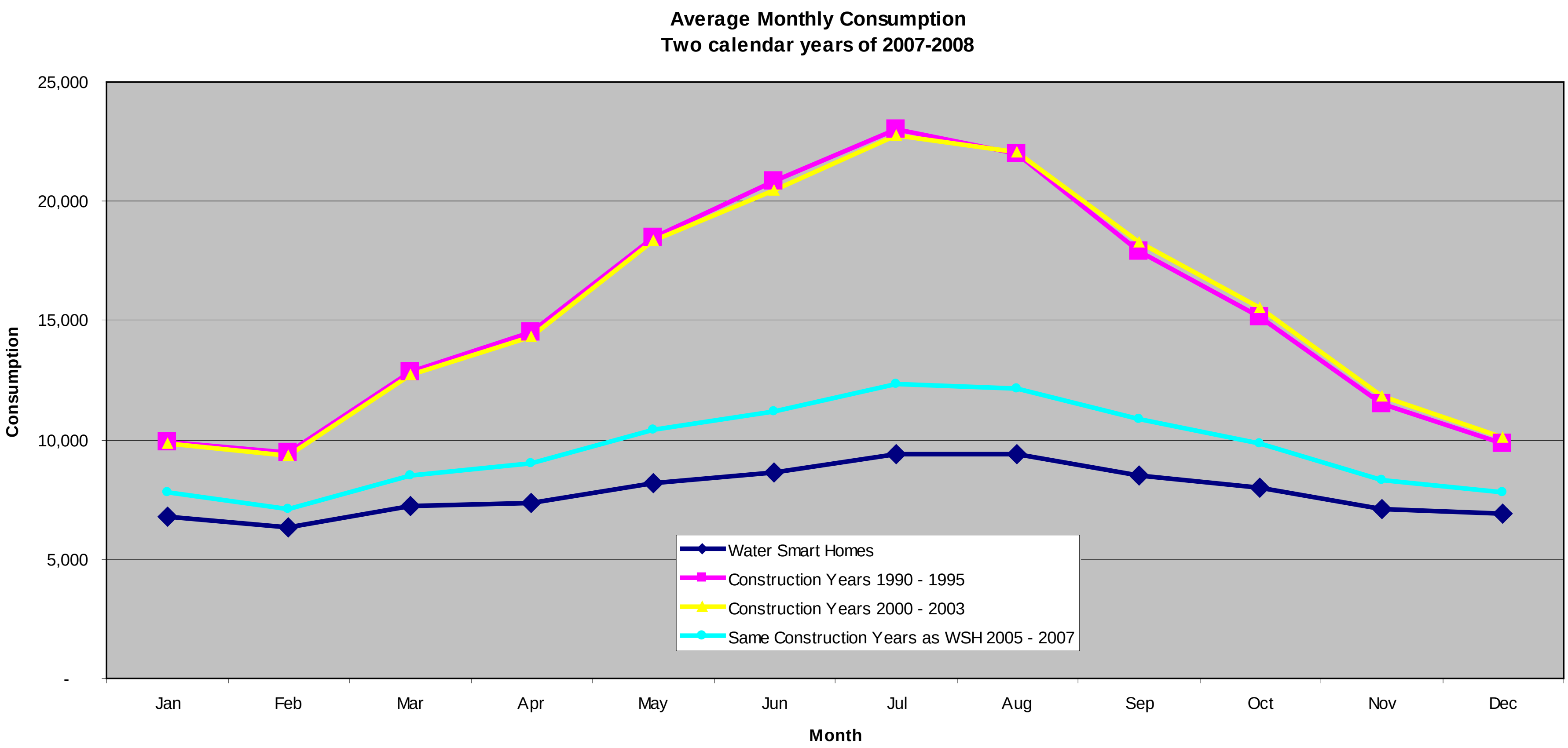
OPEI and other turfgrass benefited industries perceive, possibility correctly, that the WBT in practical terms results in more on the ground turfgrass, as least at a national level, but they are pushing this agenda without apparently any regard to the impacts on builders that would otherwise use the standard but (a) are subject to a regulatory environment of turf limitation and (b) build in tracts where they consider a simple percent reduction (or for Las Vegas, prohibition) an easier way for making the requirements of the standard for new development.

Not allowing the NGBS may thus be less of interest in these areas or may be considered a negative by jurisdictions in those areas. The flexibility to utilize the water budget and turf limitations should be preserved in the NGBS for the sustainability of communities in these growing areas and even the standard itself.


Turf versus Xeriscape water application rates in Las Vegas Area
Source: Xeriscape Conversion Study
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Gallons/Square Foot/Year
73.0
17.2
TS Group - Turf
XS Group - Xeriscape
Group

Monthly Consumption Water Smart Homes Comparison

PC038



Alternative proposal re: bee habitat and turfgrass

- Turfgrass in of itself is damaging to bee populations it's a monoculture after all and does not provide habitat benefits of flowering plants.
- Only lawns infested with other plants do this. And even then they don't come close to matching native plantings.
- Homeowners can't and won't maintain these plantings.
- Programs devoted to conversion not related to water efficiency are often for pollinators as well as wildlife.
- While this sounds good (intentional infestation), in practice it's a wording trick. You only get the credit if you do the negative thing first. Why?
- SNWA's proposal modification improves pollinator habitat by requiring the same ratio (10%) of planted areas be composed of non-invasive plantings specifically flowering and nectar producing while ditching the pre-loaded native of the turfgrass. (note though you can still have turfgrass)

"Bee turf" related research demonstrating the harmful impacts of turfgrass on pollinators.

Dobbs, E.K. (2012). Turfgrass management alternatives: Predators, pollinators, and native wildflowers. Kentucky Turfgrass Council Short Course, Louisville, KY.

Dobbs, E.K. (2012). Insect biodiversity and ecosystem services associated with naturalized roughs. Central Kentucky Ornamental and Turfgrass Association, Lexington, KY.

Dobbs, E.K. (2011). Insect biodiversity and ecosystem services associated with naturalized roughs. Turf Management (PLS 515) guest lecturer, University of Kentucky, Lexington, KY.

Dobbs, E.K. (2011). Golf course biodiversity and Operation Pollinator. University of Kentucky Annual Turfgrass Field Day, Lexington, KY.

Dobbs, E.K. (2011). Golf course biodiversity and Operation Pollinator. Bluegrass Golf Course Superintendents Association Meeting, Arlington, KY.

Resources for converting from lawns to bees / invertebrate habitat

http://www.usda.gov/wps/portal/usda/usdahome?navid=usdabees

http://umaine.edu/gardening/master-gardeners/manual/ecology/how-to-create-a-bee-friendly-landscape/

http://www.xerces.org/wp-content/uploads/2012/06/conserving_bb.pdf

https://www.wildflower.org/collections/collection.php?collection=xerces_honey

http://www.xerces.org/

http://blogs.scientificamerican.com/brainwaves/outgrowing-the-traditional-grass-lawn/

http://www.greencastonline.com/operationpollinator/getinvolved.aspx

http://www.operationpollinator.com/golf/

BTEC
Biomass Thermal Energy Council

1211 Connecticut Ave NW, Suite 650 • Washington, DC 20036-2701
202-596-3974 tel • 202-223-5537 fax • www.biomassthermal.org

Home Innovation Research Labs
400 Prince George's Blvd.
Upper Marlboro, MD 20774
Email: standards@HomeInnovation.com

April 20, 2015

RE: BTEC Statement on the 2015 National Green Building Standard™

The Biomass Thermal Energy Council (BTEC) appreciates the opportunity to share our perspective on the 2015 Green Building Standard™ and its treatment of residential renewable thermal energy.

BTEC is an association of biomass fuel producers, forest landowners, appliance manufacturers, combined heat and power project developers, thermal energy utilities, district energy system operators, supply chain companies, universities, agencies, and non-profit organizations. Collectively, our diverse membership of businesses and organizations views biomass thermal energy as a proven, renewable, responsible, clean and energy-efficient pathway to meeting America's energy needs.

Thermal energy, or heat delivered in the form of energy, is derived from many sources; within the renewable energy portfolio, these sources are biomass, solar and geothermal. Thermal energy accounts for as much as 40% of the U.S. total energy consumption; the total surpasses this figure in several regions of the country. [i]

Biomass thermal energy investments provide immediate value for homeowners, industries, businesses, and communities. Examples of biomass thermal projects and technologies include heating of homes, businesses, schools, hospitals, commercial and industrial buildings; district heating of campuses; densely developed commercial and industrial parks; neighborhoods and city centers; domestic hot water for large consumers such as laundries; industrial process heat for companies in food processing, metallurgy, and pharmaceuticals; and combined heat and power projects that produce both heat and electricity for consumers. In recent years, several states have recognized the widespread benefits of conversion from high-cost heating oil appliances to biomass, not only in terms of job creation but also in terms of lowering consumer costs and reducing pollution. For example, both Maine, through Efficiency Maine's Home Energy Savings Program, and Massachusetts, through its Commonwealth Woodstove Change-Out, have launched rebate programs[ii] to reduce high home fuel costs through promoting the installation of advanced and efficient biomass heating systems.

The proposed NGBS standards feature inconsistencies with regards to renewable heating sources. These standard mismatches limit builders' and homeowners' options and flexibility unnecessarily towards designing energy and resource efficient residences. In fact, the NGBS promotes renewable heating practices that—on first appearance—run counter to the certification's purpose in encouraging sustainability and energy efficiency practices for new and renovated homes.

The following two inconsistencies on renewable home heating sources dilute the NGBS standards and provide unclear guidance to professionals and owners who depend on them to reduce environmental impacts and promote renewable energy sources:

- Chapter 9, Indoor Environmental Quality, Section 901.2.1, awards various point totals for code-compliant wood-burning stoves and heaters, whereas section 901.2.2 awards the highest total, **seven points** for non-installation of woodstoves, pellet stoves and masonry heaters. These adjoining sections, taken together, provide unclear guidance on installing clean, highly efficient wood-burning technologies. In fact, several wood-burning appliances achieve the highest efficiencies available for renewable heating. Furthermore, maintaining different point classes for installation and non-installation make no sense when taking in consideration widely-available, clean, wood-burning technologies that meet NGBS principles.
- Chapter 11, Remodeling, Section 11.901.2.2 repeats this inconsistency in providing the highest number of points, **seven points**, for the non-installation of woodstoves, pellet stoves and masonry heaters. As noted for 901.2.1 and 901.2.2, these adjoining sections, taken together, provide unclear guidance on installing clean, highly efficient wood-burning technologies. As mentioned before, many wood-burning appliances achieve the highest efficiencies available for renewable heating. Furthermore, maintaining different point classes for installation and non-installation make no sense when taking in consideration widely-available, clean, wood-burning technologies that meet NGBS principles.

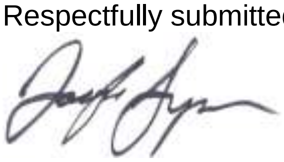
Should the NGBS purport to promote renewable energy sources, it should consider awarding its *highest level of credit towards the use of renewable heating technologies*. For this reason, BTEC proposes eliminating the point total for non-installation for both chapters. There is no need to exclude a class of technologies with high resource efficiency or to discourage adoption of safe, renewable biomass heating systems, including pellet stoves and boilers. The optimal standard should incentivize renewable technology adoption without encouraging non-installation or suggesting unclear or even counter-productive guidance.

As stated previously, the deployment of biomass thermal energy, rather than restriction, fulfills the same objectives of the NGBS standards in terms of:

- Increasing resource and energy efficiency
- Reducing fossil-fuel based energy through the deployment of renewable energy sources, of which biomass comprises a main category
- Improving health through reducing emissions of certain air pollutants such as sulfur dioxides, PM 2.5, and mercury, as compared to fossil fuels
- Lowering emissions of greenhouse gases due to the low carbon intensity or near carbon neutrality of biomass

BTEC offers its full support in adapting the 2015 NGBS to capture the full benefits of all proven, renewable resources including biomass thermal technologies and welcomes future opportunities to work with you in this process.

Respectfully submitted,



Joseph Seymour
Executive Director, Biomass Thermal Energy Council

[i] https://www.biomassthermal.org/resource/pdfs/heatne_vision_full.pdf , http://energy.gov/public-services/homes/heating-cooling , http://energy.gov/sites/prod/files/2013/11/f5/building_trends_2010.pdf , http://www.eia.gov/todayinenergy/detail.cfm?id=10271
[ii] http://www.efficiencymaine.com/at-home/home-energy-savings-program/hesp-incentives/ and http://www.masscec.com/programs/commonwealth-woodstove-change-out

1211 Connecticut Ave NW, Suite 650 • Washington, DC 20036-2701
202-596-3974 tel • 202-223-5537 fax • www.biomassthermal.org

Home Innovation Research Labs
400 Prince George's Blvd.
Upper Marlboro, MD 20774
Email: standards@HomeInnovation.com

April 20, 2015

RE: BTEC Statement on the 2015 National Green Building Standard™

The Biomass Thermal Energy Council (BTEC) appreciates the opportunity to share our perspective on the 2015 Green Building Standard™ and its treatment of residential renewable thermal energy.

BTEC is an association of biomass fuel producers, forest landowners, appliance manufacturers, combined heat and power project developers, thermal energy utilities, district energy system operators, supply chain companies, universities, agencies, and non-profit organizations. Collectively, our diverse membership of businesses and organizations views biomass thermal energy as a proven, renewable, responsible, clean and energy-efficient pathway to meeting America's energy needs.

Thermal energy, or heat delivered in the form of energy, is derived from many sources; within the renewable energy portfolio, these sources are biomass, solar and geothermal. Thermal energy accounts for as much as 40% of the U.S. total energy consumption; the total surpasses this figure in several regions of the country. [i]

Biomass thermal energy investments provide immediate value for homeowners, industries, businesses, and communities. Examples of biomass thermal projects and technologies include heating of homes, businesses, schools, hospitals, commercial and industrial buildings; district heating of campuses; densely developed commercial and industrial parks; neighborhoods and city centers; domestic hot water for large consumers such as laundries; industrial process heat for companies in food processing, metallurgy, and pharmaceuticals; and combined heat and power projects that produce both heat and electricity for consumers. In recent years, several states have recognized the widespread benefits of conversion from high-cost heating oil appliances to biomass, not only in terms of job creation but also in terms of lowering consumer costs and reducing pollution. For example, both Maine, through Efficiency Maine's Home Energy Savings Program, and Massachusetts, through its Commonwealth Woodstove Change-Out, have launched rebate programs[ii] to reduce high home fuel costs through promoting the installation of advanced and efficient biomass heating systems.

The proposed NGBS standards feature inconsistencies with regards to renewable heating sources. These standard mismatches limit builders' and homeowners' options and flexibility unnecessarily towards designing energy and resource efficient residences. In fact, the NGBS promotes renewable heating practices that—on first appearance—run counter to the certification's purpose in encouraging sustainability and energy efficiency practices for new and renovated homes.

The following two inconsistencies on renewable home heating sources dilute the NGBS standards and provide unclear guidance to professionals and owners who depend on them to reduce environmental impacts and promote renewable energy sources:

- Chapter 9, Indoor Environmental Quality, Section 901.2.1, awards various point totals for code-compliant wood-burning stoves and heaters, whereas section 901.2.2 awards the highest total, **seven points** for non-installation of woodstoves, pellet stoves and masonry heaters. These adjoining sections, taken together, provide unclear guidance on installing clean, highly efficient wood-burning technologies. In fact, several wood-burning appliances achieve the highest efficiencies available for renewable heating. Furthermore, maintaining different point classes for installation and non-installation make no sense when taking in consideration widely-available, clean, wood-burning technologies that meet NGBS principles.
- Chapter 11, Remodeling, Section 11.901.2.2 repeats this inconsistency in providing the highest number of points, **seven points**, for the non-installation of woodstoves, pellet stoves and masonry heaters. As noted for 901.2.1 and 901.2.2, these adjoining sections, taken together, provide unclear guidance on installing clean, highly efficient wood-burning technologies. As mentioned before, many wood-burning appliances achieve the highest efficiencies available for renewable heating. Furthermore, maintaining different point classes for installation and non-installation make no sense when taking in consideration widely-available, clean, wood-burning technologies that meet NGBS principles.

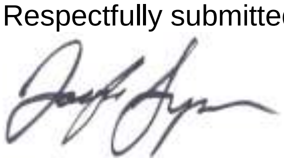
Should the NGBS purport to promote renewable energy sources, it should consider awarding its *highest level of credit towards the use of renewable heating technologies*. For this reason, BTEC proposes eliminating the point total for non-installation for both chapters. There is no need to exclude a class of technologies with high resource efficiency or to discourage adoption of safe, renewable biomass heating systems, including pellet stoves and boilers. The optimal standard should incentivize renewable technology adoption without encouraging non-installation or suggesting unclear or even counter-productive guidance.

As stated previously, the deployment of biomass thermal energy, rather than restriction, fulfills the same objectives of the NGBS standards in terms of:

- Increasing resource and energy efficiency
- Reducing fossil-fuel based energy through the deployment of renewable energy sources, of which biomass comprises a main category
- Improving health through reducing emissions of certain air pollutants such as sulfur dioxides, PM 2.5, and mercury, as compared to fossil fuels
- Lowering emissions of greenhouse gases due to the low carbon intensity or near carbon neutrality of biomass

BTEC offers its full support in adapting the 2015 NGBS to capture the full benefits of all proven, renewable resources including biomass thermal technologies and welcomes future opportunities to work with you in this process.

Respectfully submitted,



Joseph Seymour
Executive Director, Biomass Thermal Energy Council

[i] https://www.biomassthermal.org/resource/pdfs/heatne_vision_full.pdf , http://energy.gov/public-services/homes/heating-cooling , http://energy.gov/sites/prod/files/2013/11/f5/building_trends_2010.pdf , http://www.eia.gov/todayinenergy/detail.cfm?id=10271
[ii] http://www.efficiencymaine.com/at-home/home-energy-savings-program/hesp-incentives/ and http://www.masscec.com/programs/commonwealth-woodstove-change-out