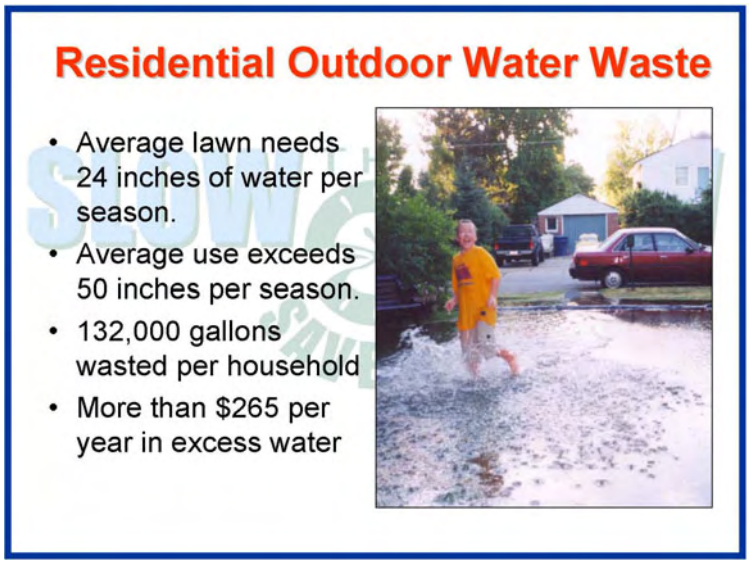
SAVING UTAH WATER IN THE FIFTH YEAR OF DROUGHT

Earl K. Jackson, Professor, Utah State University Extension
Paula Mohadjer, Water Conservation Officer, Jordan Valley Water Conservancy District

ABSTRACT

Utah is the second driest and one of the fastest growing states in the nation. Residents have enjoyed inexpensive water for many years but the current water supply will not meet future demand. In 1999, the "Slow the Flow, Save H2O" water conservation education program was initiated by Jordan Valley Water Conservancy District. TV and radio ads taught correct irrigation scheduling, water wise landscaping, and a toll-free telephone number was established for scheduling a free irrigation water audit at their home. This program is now in its fifth year and irrigation system audits and water use records of over 4,500 residential and 120 large water user sites have been completed by Utah State University Extension interns. The average resident uses twice as much water as a healthy lawn requires. Parks, churches, apartments and schools studied were more wasteful than homeowners, using nearly three times as much water than required. The year following a site evaluation, participants were able to reduce their water use by 20-60%. The turf water requirement (net evapotranspiration, ET) for the Salt Lake City area was confirmed at near 24 inches of water per season at the Demonstration Gardens located at the Jordan Valley Water Conservancy District Headquarters and is the value used for percent waste calculations.

Participants in this six-county Utah study use culinary water for both lawns (67% outdoors) and drinking water (33% indoors). The average distribution uniformity (DU) of the irrigation system was 52% with a precipitation rate (PR) of 1.4 inches per hour for fixed popup spray heads (range of 3.7 inches to 0.7 inch per hour at the 95% confidence level). For rotor heads, the average distribution uniformity was 58% with an average precipitation rate of 0.7 inches (range of 2.3 inches to 0.1 inch per hour). The average root depth of the bluegrass lawns was only 5.6 inches. The average residential hose connection has a water pressure of 73 pounds per square inch with a hose output of 8.2 gallons each minute.



INTRODUCTION

Utah is one of the fastest growing states, while also being the second driest state in the nation. Enough people are added to the population to make a new city the size of Salt Lake City (160,000) about every three years (Utah Division of Water Resources, 2003). It is also the third most urban state in the nation with about 80% of the population living along the Wasatch Mountain Front in six counties (Wahlquist, 1981). With wise planning by the pioneers and several reservoirs completed by the U.S. Bureau of Reclamation (usually with a two year irrigation supply), Utah has enjoyed inexpensive water for many years. The Utah Division of Water Resources indicates that the national average cost per 1000 gallons of culinary water is $1.96 while in Utah it is only $1.15 per 1000 gallons (Utah Division of Water Resources, 2003). The price of water in 2002 varied greatly between cities as shown in the accompanying Table. With cheap water and a pioneer heritage of making the desert bloom, citizens have a passion for green lawns with gardening as the number one hobby in the state. Consequently, residents have developed poor watering habits for the landscape without regard to conservation and the water requirement for healthy turf. Many residents give their lawns a shallow watering every day and have little knowledge of the problems caused by overwatering the landscape. Much of the extra water either runs off the hardscape into the nearest storm drain or percolates down through the soil carrying fertilizers and pesticides into the shallow aquifers. As a result of the population growth, water demand is increasing in a state that has a limited new water supply. The current water supply will not meet future demand of the growing population. Because of this, there is a strong need for citizens to develop a long-term water conservation ethic to assure enough water for future generations and to reduce non-point source water pollution. The **'Slow the Flow, Save H_2O'** water conservation program including the residential water check procedure was designed to help Utah citizens use water more wisely in the landscape.

Estimated Water Costs (per 1,000 gallons)

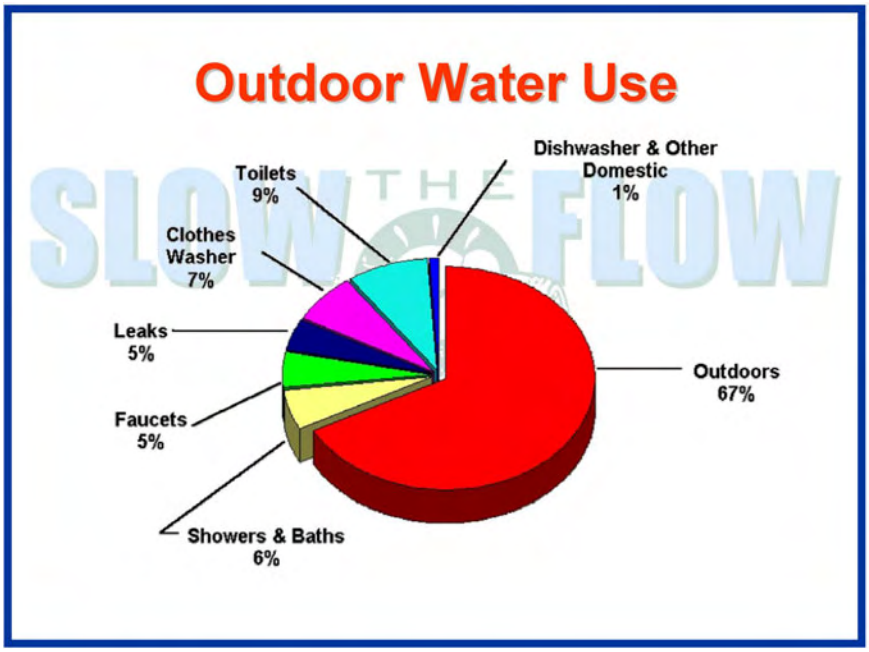
Reno	$3.39
Los Angeles	$2.22
Park City	$2.20
Las Vegas	$1.65
Albuquerque	$1.41
Denver	$1.14
Sandy	$0.99
Salt Lake City	$0.87
Provo	$0.75

Water Conservation Education

Outdoor water use clearly represents the greatest opportunity for residential water savings. In 1998, the Utah State Legislature passed the "Water Conservation Plan Act" which required all water conservancy districts and water retailers with over 500 service connections to submit water conservation plans to the Utah Division of Water Resources. Most of the conservation plans focus on outdoor water use since about 67% of the culinary water along the Wasatch Front is used in the landscape. In 1999 the Jordan Valley Water Conservancy District initiated the "**Slow the Flow, Save H_2O"** water conservation program in Salt Lake County. They were joined by the Central Utah Water Conservancy District, Salt Lake City Public Utilities and Utah State University Extension in magnifying this program. As part of the overall conservation effort, the Water Check program is a personalized water conservation education program. We found that conservation efforts can be most effective when consumers are well informed from a one-on-one session at their own home.

RESULTS FROM RESIDENTIAL SITES

Outdoor Water Use



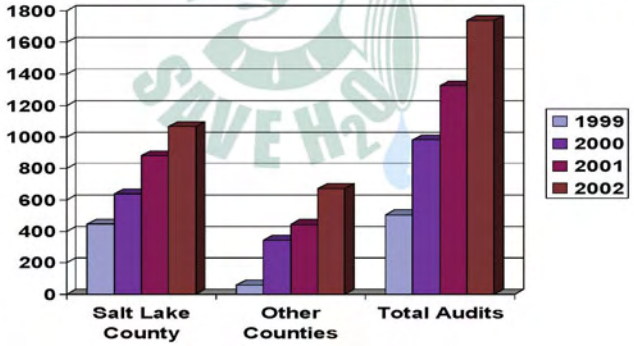
Most residential properties along the Wasatch Mountain Front use drinking water for irrigating lawns, flowers and other outdoor plants. Many random surveys of residential properties before 1999 indicated that about 50% of a household's water is used outdoors; but these included properties that may not have maintained a green lawn in the back yard. In the water check program where citizens asked for help in maintaining their landscape (front and back), we found that 67% of residential water was used outdoors. The average landscape size in Salt Lake County was 8,555 square feet on a lot of 12,941 square feet. For this size property, the average household used 257,539 gallons of water per year or 706 gallons per day per household. This equates to using 9.48 acre inches per year instead of the commonly number used by the public of one acre foot per year (12 acre inches) for a family of four. With this amount of water used in the landscape the water check program wanted to document the amount of water wasted and concentrate on outdoor water conservation education of the public.

What Is a 'Water Check'?

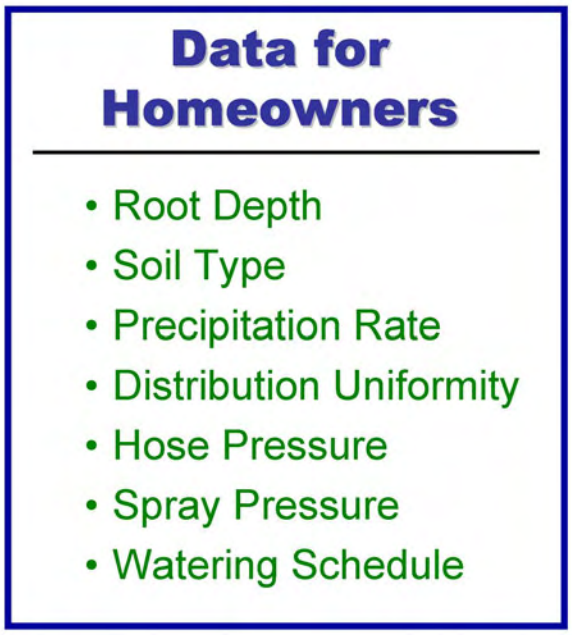
The **'Slow the Flow, Save H_2O'** water conservation program includes the 'Water Check' program which is a personalized evaluation of the landscape and irrigation system by a trained Utah State University Extension Intern at the request of a home owner. The landscape water evaluation is a free service to the public funded by the Central Utah Water Conservancy District (CUWCD), the Jordan Valley Water Conservancy District ([JVWCD), and their partnering water districts and state Agencies. Appointments are scheduled by calls to a toll free **'Slow the Flow, Save H_2O'** telephone line. Television and radio advertising is professionally created and changed each year. The Water Check

Number of People Who Have Had Water Checks From 1999-2002

	1999	2000	2001	2002	Total
Salt Lake County	446	638	882	1066	3032
Other Counties	59	344	444	673	1520
Total Audits	505	982	1326	1739	4552



educational program is promoting a new ethic of efficient outdoor, culinary water use. A landscape 'Water Check' evaluation of a residential sprinkler system results in a customized watering schedule for the resident. It is a modified water audit following the methods and terminology of the Irrigation Association (The Irrigation Association, 2002). Site evaluation takes about an hour depending upon the lot size and number of irrigation zones. After the initial walk-through, turning on every irrigation zone and evaluating evident problems, a series of tests are conducted on the watering system to determine how much water the system puts out (precipitation rate), the soil type and absorption rate (infiltration rate), and the evenness of the water application (distribution uniformity or efficiency). The resident then receives a personalized lawn watering schedule for the entire growing season. Residents are encouraged to perform routine maintenance on the irrigation system to optimize efficient and uniform operation.



Water Checks Accomplished

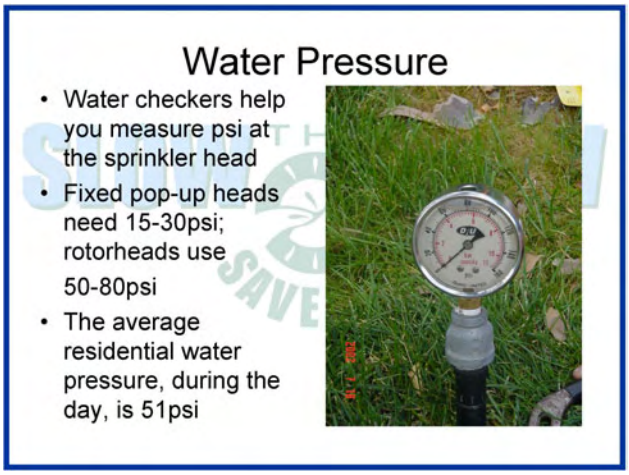
The water check program has become very popular in Utah. Citizens realize that it is a great bargain to have a person come to their home and evaluate the irrigation system and the landscape resulting in a personalized watering schedule. The water check program was started in Salt Lake County which contains over 45% of Utah's population (Wahlquist, 1981). Since 1999, trained Utah State University Extension Interns have accomplished 4,552 residential water checks in 48 cities within six urban counties. Residential data has been compiled on location, people in household, lot size, irrigated landscape size, hose water pressure, hose water flow, soil texture, root depth, precipitation rate, distribution uniformity, pressure at head (both fixed popup and rotor), and calculated irrigation schedule (Rosenkrantz, 2003).

Inefficient Sprinkler Systems

Efficient irrigation is an important water conservation goal. Overwatering not only wastes water, but it weakens and kills more plants than underwatering. Another wasteful practice seen all too often is misapplication of water, resulting in rotted fences and house siding, flooded sidewalks and rivers of water wastefully flowing down gutters. The average distribution uniformity (efficiency) of both fixed popup heads and the larger rotor heads on residential properties is near 56%. A properly installed irrigation system should be a minimum of 70% efficient. An efficient irrigation system is also based on zoning plants with similar water needs together and using the irrigation method that waters each zone most efficiently. Turf and non-turf areas need separate zones because of the differing water needs. As a rule of thumb, shrub areas require about one-half as much water as turf areas.

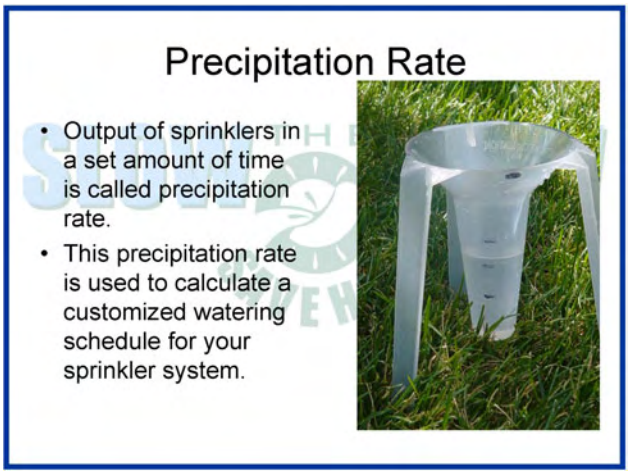
High Water Pressure

We found high water pressure to be a major problem in every city and county. Homes with in-ground sprinkler systems should have pressure regulators installed. The average residential water pressure measured during the day at a sprinkler head is 51 pounds per square inch (psi), which is too high for the typical fixed popup sprinkler head and increases misting and evaporation. Nearly all fixed popup sprinkler heads are manufactured for use between 15 and 30 psi of water pressure. With the fixed popup heads, misting and evaporation was evident on most residential systems. On the other hand, the large rotor sprinkler heads usually work best at pressures greater than 60 psi. The average hose connection has a water pressure of 73 pounds per square inch with a hose output of 8.2 gallons each minute. If you use the hose to wash down a driveway for 15 minutes, you have sent 123 gallons of culinary water down the storm drain.



Precipitation Rate

Precipitation rate is a measurement of how much water is emitted from a sprinkler head over time. It is measured either in inches of water per hour (like a rain storm) or in gallons per minute. The average residential fixed popup head puts out 1.4 inches of water per hour. We found a range in precipitation rates from 3.7 inches per hour down to 0.7 inch per hour. Most soils can not absorb water at this fast of an application rate. Sprinklers generally apply water faster than a very heavy rain storm (classified by weathermen at 0.5 inches/hour). It should be determined how long it takes each sprinkler zone to put out ½ inch of water. The average system output is 1.4 inches/hour, therefore the sprinklers need to run for 21 minutes on sandy or loam soils to put out ½ inch of water. With a clay soil, split the 21 minutes into three cycles of 7 minutes applied about one hour apart. The larger rotor type heads on the average have a precipitation rate about half (0.7 inches per hour) the rate of fixed popup heads. Citizens are also encouraged to select watering times that maximize availability to the turf (recommended watering between 6 p.m. and 10 a.m.) and minimize evaporation and drift losses from wind and high system pressure. Initial catch cups (cone with metal stand) used in this program were from the Irrigation Association. During the last two years the cones with plastic legs (U.S. Bureau of Reclamation) were used. There was very little variation in water measurement when the two styles of cups were compared side by side as shown in the picture above.

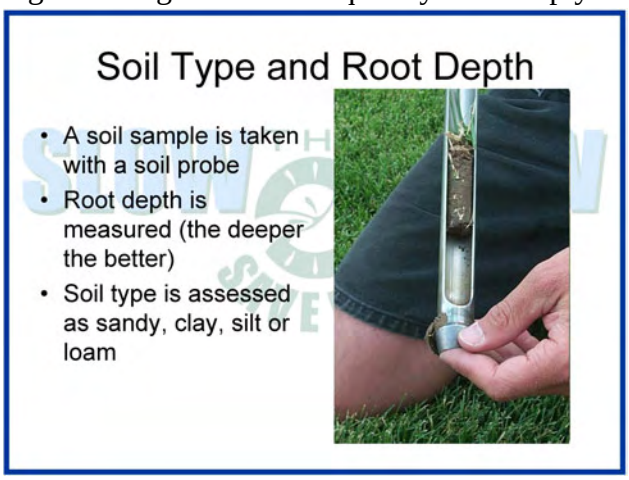


Households that water with hand-held hoses generally use less water outdoors than households with in-ground sprinkler systems and automatic timers, and tend to water when the grass needs water. They usually use only one sprinkler head at a time so they have less water running onto the hardscape. They also tend to water infrequently and deep into the root zone. We tested twenty different hose-end sprinklers and compared their precipitation rate and distribution uniformity at 50 psi. Most of these sprinkler heads were in the range of 0.2 to 0.5 inches per hour. The homeowner would therefore be able to leave the hose sprinkler on for about an hour

to deliver the 0.5 inch of water required in the above watering schedule. We also found most distribution uniformities to be above 60%, with one brand toping the list at 85% efficiency.

Poor Watering Habits

The importance of deep roots should not be overlooked. A shallow watering every day is about the worst thing you can do for your lawn because it keeps the roots short, which then forces watering every day in July and August to keep the lawn from going dormant. Citizens are taught to irrigate turf infrequently and deeply to promote deep healthy root systems. Deep roots have a major impact on water conservation and the ability of turfgrass to grow well in dry weather. Promoting deep rooting gives plants a much larger water reservoir from which to draw. This allows irrigation frequency to be reduced as in the schedule outlined below. With a uniform soil and proper irrigation, a bluegrass lawn should have a root system 12 to 18 inches deep. The average residential lawn has a root system only 5.6 inches deep. The deeper the root system, the more days you can wait between irrigations. The great majority of the residents do not understand the turf water requirement (evapotranspiration, ET) and how to change their timer/controller based on this.



Landscape and Soil Types

The type of landscape one has can be an important determinate for the amount of water used outside. Salt Lake County landscapes are about 75% turf or more. Most homeowners have considerable investments made in the design and establishment of home landscaping, and take considerable pride in it. Unfortunately, the typical home owner pays little attention to soil preparation before establishing the landscape. There appears to be no uniform soil texture for a residential yard in Salt Lake Valley. Homes are built on the benches and hills with sandy soils and in the valley where clay-type soils dominate. For soil textures, this study found that 53.2% of the residential sites had clay-type soils, with 34.3% sandy-type soils and only 12.5 % had silty-type soils. A soil that is predominately sand can have water retention problems, while a clay-dominated soil will have problems with water infiltration. As part of the watering schedule, water cycling was promoted for those sites with slopes and/or clay-type soils. The amount of water applied during an irrigation event is dependent upon the application (precipitation) rate and the run time. Where infiltration rates are low, multiple run cycles may be required to avoid excessive runoff. Multiple run cycles should be

Customized Water Schedule

- Sprinkler run time is based on precipitation rate measurements, soil type, and slope
- Run time remains the same but watering intervals change monthly

MONTH	INTERVAL
Startup until April 30	Once Every 6 Days
May	Once Every 4 Days
June	Once Every 3 Days
July	Once Every 3 Days
August	Once Every 3 Days
September	Once Every 6 Days
October 1 to Shutdown	Once Every 10 Days

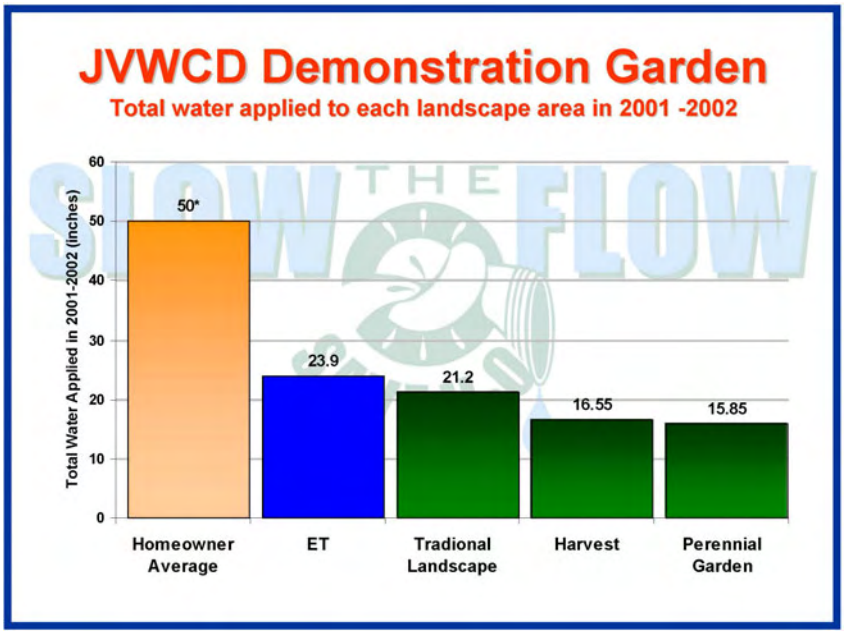
separated by soak times lasting about an hour each. Residents were taught that soils have a modifiable water-holding capacity and practices like aerification and adding amendments help promote deep rooting.

Recommended Watering Schedule

In order to simplify a watering schedule for the homeowners, a schedule was developed based on an interval between deep irrigations (with the accompanying recommendation that at least ½ inch of water be applied at each irrigation) and ET values over the past thirty years. This makes it so that ET calculations need not be made on a daily or weekly basis by the residential participants. Adjusting the timer monthly to better follow this demand curve will save water and money. It took two years of discussions with various agencies and water districts before everyone could agree to the schedule based on interval between irrigations. Now, during the fifth year of drought, all agencies recommend this schedule. If followed, this schedule will bring the homeowner's water use down near the turf water requirement (net ET of 24 inches per growing season). As with any irrigation schedule, there is a need to know the precipitation rate of a zone.

Demonstration Gardens at JVWCD

The Conservation Demonstration Gardens located at the Jordan Valley Water Conservancy District headquarters was designed and built to be an educational tool for the community. The Neighborhood Garden emphasizes proper landscape design, irrigation technologies, and low water use plant selections. The Neighborhood Garden features six themed landscapes demonstrating water efficient practices. Each theme yard has its own water meter that monitors the actual amount of water being used. The challenge was to water efficiently for the typical Utah landscape demonstrating that it is possible to irrigate at the turf evapotranspiration level (ET), called in this paper the 'turf water requirement'. The graph at the right indicates that the Traditional Landscape yard which is mainly bluegrass lawn, can be kept green and healthy with less than 24 inches of water a year. If some of the lawn area is replaced by various types of plants, water use can be reduced significantly.



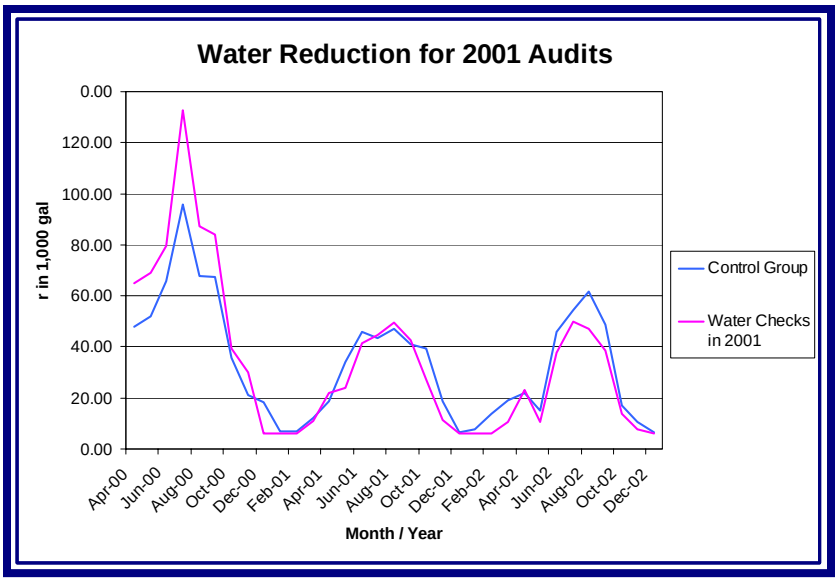
Xeriscape Type Landscapes

A series of workshops was advertised to the public on reducing residential grass areas and establishing areas of native plants - Xeriscape type landscapes. A total of 76 participants from Salt Lake City gave permission for us to follow their water use records (Jackson, 2000). All of them indicated an interest in water conservation both for the lawn and gardens. The average outdoor water use by this group over a five year period was 28.2 inches for the growing season (April 1 through October 15th). With the 30 year average turf water requirement at 24 inches (net ET), the group was only 12% over net ET. Only twelve residents went through the expense of renovating their lawn area into a true Xeriscape landscape. Before the landscape conversion, the group's average was 25.9 inches of water per season indicating irrigation at only 5% over net ET. After the landscape conversion, the average resident reduced their water use by 32% (significantly below the turf water requirement). The average lot size in Salt Lake City is 12,941 square feet with an average

landscape area of 8,555 square feet. This average landscape, if all in grass, would require 131,918 gallons of water over the season to maintain a green healthy lawn. At Salt Lake City 2003 prices, the water would cost $415.43. Each of the citizens converting their landscape to a Xeriscape type landscape saved an average of $99.60 per year by saving water.

Culinary Water Waste at Residential Sites

Along the Wasatch Front, a green healthy lawn requires about 24 inches of water either from rain or irrigation, evenly spread out during the growing season which is usually April through about October 15th. Application of irrigation water should follow the recommended irrigation schedule above. The standard is known as the turf water requirement (called ET for evapotranspiration) which is 24.7 inches of water or 15.42 gallons per square foot of turf for the entire growing season. After four years of drought conditions in Utah during 1987 to 1990, we had normal to wet years without any lawn watering restrictions. The average resident applied nearly 57 inches of water to the lawn during 1996 and 1997 (Jackson, E. K. and Hinton A. C. 2002). This is 224% of the standard lawn water requirement (ET = 100%). In 1999 another drought cycle started and 2003 is the fifth year of this cycle. During the last three years, the average resident in this water check program used 50 inches of water or 201% of the standard. This is less water used than during the wet cycle but still very wasteful. This means on the average, residents use twice as much water as the turf-based landscape requires.



Residential Water Savings

The percent of water saved after a residential water check varies by the customer group, the year of the water check and the location along the Wasatch Front. The year following a water check, the group served by Salt Lake City Public Utilities reduced their water use by 12.3%. Those having a water check during 1999 served by the retail section of Jordan Valley Water Conservancy District reduced, (usually with larger landscape size than in Salt Lake City) reduced their water use 28% during 2000. Residents having a water check during 2000 (982) over a three county area had an average reduction of nearly 18% the year following the water check. Those residents who took out part of their front lawn and put in perennial plants or shrubs (a Xeriscape type landscape) reduced their water use by 32% on the average. If each resident in this early study reduced their water use again this year by just 15%, it would save 70,210,140 gallons of water (215 acre feet).

The water reduction graph (on the preceding page) represents the continued drought situation in Utah and the response of the citizens having a water check. The blue line represents a randomly selected residential control group that reduced their water use during 2001 and 2002 from their 2000 level. The red line represents the 882 citizens in Salt Lake County who received a water check by the USU interns during 2001. When we evaluated the water use records the year before the water check (red line in 2000), they used more water than the average citizen (random selection of 300 homes without a water check) represented by the blue line. Those who called

the water check hot line for help the following year (2001) used 35% more water during 2000 than the control group. The water check program reached the target high water user resident.

The water check group used slightly less water during 2001 than the control group, but since the group received water checks May through August it was difficult to document an immediate reduction in water use. The drought continued into a fourth year (2002) and all of the residents (water check group and control group) reduced their total water use from the 2000 level. The following year, the water check group used 31% less water than the control group with the major savings coming during July and August. Most of the savings came from paying attention to irrigation scheduling, tuning up the sprinkler system to improve the distribution uniformity, and purchasing more modern controllers with a rain delay devise and cycling their 0.5 inch water application.

Effects of Over Watering a Landscape

The following four photographs document the deterioration of a landscape over a two year period due to inefficient irrigation and over watering. The lawn was green and the trees healthy when the first picture was taken early spring. This homeowner turns on the sprinkler system every morning. Too much water is being applied too quickly (high precipitation rate), causing excessive runoff and shallow rooting of turf. Shallow rooting of turf often results in drought stress during hot summer months. Turf can be "trained" to grow deeper roots. Every irrigation should moisten the soil to a depth of 8 to 12 inches but then given time for the surface to dry. Give your lawn the footprint test; walk across the grass and if your footprints are visible, your grass needs watering. Water starts running off this property 16 minutes after the sprinklers start and continues to run down the gutter for 14 minutes after the sprinklers are turned off. By the end of the season the fertilizer and pesticides used had either been washed off into the storm drain, or washed down through the soil into the ground water.

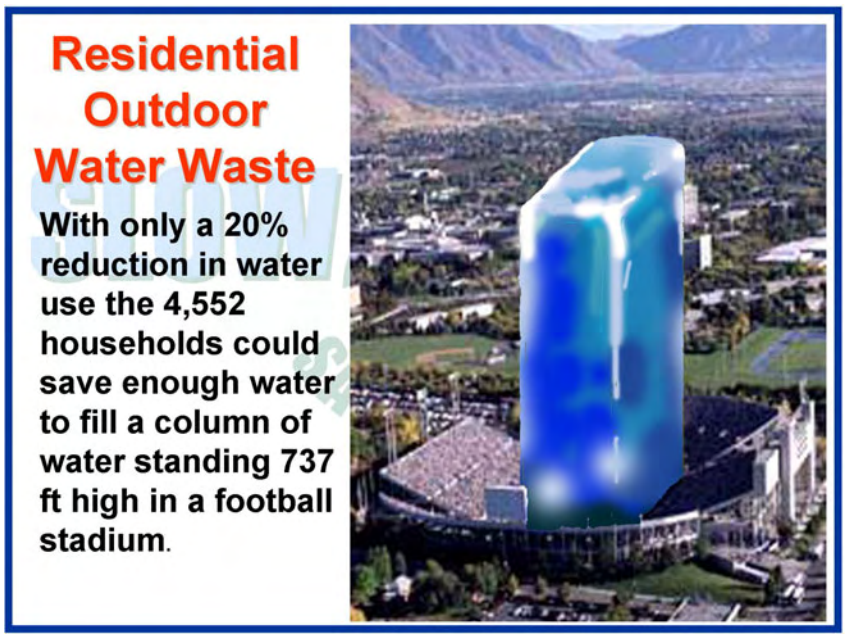
Weeds then invaded the lawn shown in this picture taken the following spring. Weed seeds germinate and establish quickly in an over-watered lawn. When properly irrigated and fertilized, most turf will out-compete weeds. Unsightly bleaching and salt accumulation on wood fences blemish a landscape. Sprinkler heads must be properly adjusted to avoid spraying fences and buildings.

Trees and shrubs have different water requirements than turf. Ideally, sprinkler systems are designed with distinct watering zones for lawn areas versus garden and tree areas to accommodate different water demands. Trees need less frequent irrigation than turf. In this landscape both the pine tree and the maple tree died from over watering. The shrubs then became chlorotic.

Besides plants, other elements of a landscape suffer from improper irrigation. This concrete sidewalk cracked due to frost heave in an overly wet subsoil. The homeowner continued to over water during the late growing season, when watering should be tapered off. Efficient irrigation saves more than water. Proper watering saves money, time, fertilizer, pesticides, effort, and frustration.

Residential Water Savings through the Water Check Education Program

The playing area of a football field is about the size of one acre. The total amount of water that could be saved by the participants in the Water Check program during the past four years, is graphically portrayed as a column of water in a football stadium. If all the participants (4,552) reduced their water use by only 20% next year, the combined water saved would be 737 acre feet.



FUNDING

CENTRAL UTAH WATER CONSERVANCY DISTRICT

[CUWCD, www.cuwcd.com]

The Central Utah Water Conservancy District is a water wholesaler conveying water supplies from high mountain sources to storage facilities and treatment plants. From there, the water is sold and distributed among the many municipal and irrigation water user companies throughout the District. This District represents the citizens of a ten county area in the administration, sale, and delivery

of water developed by the federal Central Utah Project. As part of the Central Utah Project Completion Act, the District was given the charge to conserve 49,000 acre-feet of water per year. CUWCD contributes funding to "Slow the Flow, Save H2O" including the Water Check program as part of its continuing commitment to wise and efficient water use.

JORDAN VALLEY WATER CONSERVANCY DISTRICT [JVWCD, www.jvwcd.org]
Jordan Valley Water Conservancy District (JVWCD) is the largest municipal water district in Utah, serving most of Salt Lake County outside of Sandy City and Salt Lake City. JVWCD is primarily a wholesaler of water to other cities and improvement districts within Salt Lake County. The water district recently adopted a new aggressive water conservation goal of reducing per capita water use 25% by 2025. In order to meet this goal, JVWCD has implemented several water conservation programs under the slogan "**Slow the Flow, Save H_2O"**. The water check program for both residential and large water use properties is part of this conservation program.

UTAH STATE UNIVERSITY EXTENSION [USU, www.extension.usu.edu]
Our mission is to provide a link between Utah State University and the citizens of Utah that enhances the economic, educational, and environmental quality of life. Extension "Extends Utah State University to You". The genius of the USU Extension Service is embodied in the unique educational delivery system. Our Extension Agents focus on the needs and problem of the people in each county, which make the programs relevant to critical community issues. We specialize in giving people the tools they need to sustain independence by making educated choices. Education is our top priority. We have worked diligently to preserve the enviable reputation of providing unbiased, factual information. USU Extension agents and trained college interns service the 'Water Check Program' for the many water districts and their partners.

METHODS AND MATERIALS

The term 'water check' was used because the general public was wary of the term audit. Water audit methods determining the distribution uniformity, precipitation rate, water pressure, etc. follow the guidelines established by the Irrigation Association (*IA Handbook, 1996*). The guidelines are summarized in the "Landscape Irrigation Auditor Training Manual. The procedures were originally developed by the Irrigation Training and Research Center (ITRC) at California Polytechnic State University as part of their landscape water management program.

Catch cups used during 1999 and 2000 were from ITRC supplied in the water audit kits. Catch cups supplied by the U.S. Bureau of Reclamation were used in the later water checks.

The Utah Division of Water Resources has calculated the Net ET for the past 50 years at a Salt Lake County weather station maintained by Utah State University Extension along with weather records from the Salt Lake City Airport. The average net ET for the area is 22.9 inches of water during the growing season. Our net ET value averaging three weather stations along the Wasatch Front local term for Utah Mountainous area with the urban population) is 24.7 inches. A typical Utah lawn has an irrigation water requirement beginning in mid-April, rises to a peak in July, and then falls rapidly until mid-October. The summer rainfall pattern for the past ten years averages 8.4 inches during the growing season and the rest of the lawn water requirement is through irrigation, usually using culinary water. The turf water requirement used to compare water use in the water check program has been estimated using a 30 year average of three weather stations in Salt Lake County. Data is summarized by county in Research Report 145 by the Utah Agricultural Experiment Station. The average

evapotranspiration for turf is calculated at 24.7 inches of water required for the growing season of April 1st through October 15th to maintain a green lawn. Water use in this report compares the residential consumptive use to 24.7 inches.

BIBLIOGRAPHY

Ervin, E., *Drought Avoidance Aspects and Crop Coefficients of Kentucky Bluegrass and Tall Fescue Turfs in the semiarid West*, Crop Science, Vol. 38, pp. 788-7955, 1998

Hill, R., *Consumptive Use of Irrigated Crops in Utah*, 2nd Ed., Agricultural Experiment Station, Logan, Utah, 1998.

Jackson, E. K. and Hinton A. C. 2002. *Water Waste Along the Wasatch Front*. Proceedings of Western Region County Agents Professional Improvement Conference. Las Vegas, Nevada. pp 19.

Jackson, E. K. 2000. *Residential Water Check Report 2000*. Report to the Water Districts, unpublished report, Utah State University Cooperative Extension Service, Salt Lake City, Utah.

Rosenkrantz, S. G. 2003. *Report on the Water Check Program - Analysis of Salt Lake City Audits*. Report for Master's Degree, Utah State University, Logan, Utah..

The Irrigation Association, *Certified Landscape Irrigation Auditor Training Manual*, 2002. Falls Church, Virginia.

Utah Division of Water Resources, *Utah's M&I Water Conservation Plan - Investing in the Future*, Salt Lake City, Utah 2003.

Utah Division of Water Resources, *Identifying Residential Water Use - Survey Results and Analysis of Residential Water Use for Thirteen Communities in Utah*, Salt Lake City, Utah, 2003.

U.S. Geological Survey, *Estimated Use of Water in the United States in 1995*. USGS Circular Survey No. 1200.

Wahlquist, W.L., 1981 *Atlas of Utah*: Provo, Utah, Weber State College, Brigham Young University Press, p300.

Earl K. Jackson, Professor
Utah State University Extension
2001 South State Street, # S1200
Salt Lake City, Utah 84190-2350
Phone: (801) 468-3170
earlj@ext.usu.edu