Sprinkler and Landscape- Final Report

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Abstract:

The goal of this project was to reduce potable water consumption in the home due to lawn irrigation. In homes that have moderate to exhibition quality lawns, irrigation above what nature provides is necessary. Due to the size of the average lawn (less than 2500 sq. ft.), these systems consume a great deal of water, and are in fact the single greatest waste of water in the home. In an age where are scarce, conservation should be priority number one. Thus we propose a two-pronged attack on this problem. First, it is necessary to reduce water consumed by the lawn. By using water-conserving plants native to the region, we significantly decrease water use in a natural and safe way. Secondly, we want to use rain to its full potential as an agent for watering the lawn. This is achieved by using weather and sensor data to accurately monitor the level of moisture in the soil. These ideas can be implemented cheaply in any home concerned with saving water and may some day serve as a cheap alternative for golf course turf management.

Main Body:

Xeriscaping

Xeriscaping comes from the Greek 'xeros', meaning dry. In some areas, such as Arizona and other Southwest states, the idea is taken literally as dry landscaping. In a home such as this, common irrigation and landscaping techniques are throw out in favor of developing a traditional desert landscape, one that needs no external irrigation aside from the precious little natural rainfall that the area receives.

In other parts of the country, the technique is used more liberally, relying more on careful plant selection, good planning and efficient irrigation. Xerigation is now a well-known, if not widely incorporated concept in all of the 50 states. Xeriscaping has now developed into an efficient scientific practice, one that can save the consumer both time and money, a system that will prolong the life of your home landscape while improving its health. A properly xeriscaped home will also continue to live during extended droughts, and will be able to use less water than a traditional lawn.

Xeriscaping relies on seven principles: Planning, Soil, Practical Turf, Appropriate Plants, Mulching, Efficient Irrigation, and Maintenance. By approaching your landscape in an ordered fashion, and by implementing the concepts found in each of these principles, you can design and develop a landscape that performs far better than a typical home.

With proper planning, you can identify early on the different zones of the landscape that will require both the least and most amounts of water. The first type of zone is a Very Low Water-Use Zone. This area includes decks and paved areas, areas that require no external watering. These areas are usually impermeable surfaces that create runoff. To improve the nature of your lawn, consider implementing permeable material such as paving stones or bricks. These allow water to seep into the root system of the adjoining turfgrass, encouraging a deep root system and helping to make the lawn more drought-resistant. Also, low-exposure, high-shade areas of the home are considered very low water-use zones. In our home, these will be regions on the west? side of the building where there will be a large number of coniferous trees that provide year-round shading from the western sun. These regions, once properly established, require little additional irrigation for the plants.

The second zone in the home is the Low Water-Use Zone. Areas that fall into this zone are those which will require some additional water than natural rainfall, but can conserve a great deal of water using simple, traditional landscaping techniques. AA common example of a Low Water-Use Zone is a plant bed or shaded turf areas. Water can be easily conserved in these areas by mulching, using drip irrigation, and by taking advantage of runoff (placing these areas at slightly lower elevation to collect the runoff). Appropriate choice of plants in this area can further minimize the water use.

The final water-use zone in the home is the Moderate Water-Use Zone. This zone is mainly exposed areas that have higher water requirements. Examples of this zone are turf, vegetable gardens, and other high-water plants. To conserve water, you should reserve the areas in the home of this zone to lawns and other focal points such as entryways. However, for all these water zones, good soil is important in the development of a water-conserving landscape.

Soil Quality is the second principle of xeriscaping. In order to conserve water, plants need to develop a deep root system. Up to 70% of the plants water is taken in in the first half of the root system, and by developing plants with deep roots, you keep more water in the soil, making plants more drought-resistant, and conserving more water in general. It is important, therefore, to develop a nutrient-rich soil for the plants to develop in. This usually requires some preparation beforehand in order to give your plants a proper root bed. The first step towards developing your root system is to send soil samples to your local or state Department of Agriculture. Almost every state has a Soil Testing Laboratory. For completeness, you should send two soil samples: one from the front yard and one from the back. Depending on how deep you will be watering to (usually 6" is the standard), remove a small amount of soil to a depth of about 4" over about ten different spots in the lawn, then mix them together thoroughly. Seal the samples in an airtight container and ship them to the lab. For most states, there is no fee for this procedure. Make sure to ask what they will be testing for. The labs do not usually test for every chemical needed, and some areas may require additional work (some alkaline soils need lime added to them).

Once you have received your soil test results, you should till to 6", incorporate topsoil, and then work in 4" of organic material containing the chemicals you need. As a general rule, most soils will require nitrogen and sulfur to be added as well. The preparatory work done here will give the plants you choose a healthy soil bed that will encourage deep roots systems.

The third principle of xeriscaping is the selection of practical turf areas. Since turf is the area of water consumption in the lawn, these areas should be limited and selection should be based on the general grade of the land and necessity toward the overall function of the home. The ideal turf area is a large, flat area that is roughly square in shape. This allows the area to be effectively watered using few heads, and with as little overlap and wasted water as possible. A poor turf area is long and narrow, or located on a slope. The first area requires a large number of heads, and creates waste water on adjoining concrete or other impermeable surfaces. The second type of area is poor because of the very nature of above-ground irrigation systems. The sloped turf area will create a great deal of runoff and very little soaking. This wastes a great deal of water since additional run time is needed to get the turf the water needed.

Once you have planned the turf areas in your lawn, you should select a proper grass type. The ideal grass you select should be both water-conserving and drought-resistant (once properly established). Of these, water-conservation is the most important option for a turfgrass. Your grass selection should be based on the climate other water-use options mentioned above. Also, the evapotranspiration rate (or EV rate) is an important measurement in determining the water-conservation properties of a turfgrass. The EV rate is a measurement of how much water is lost through the plants leaf system throughout the day; in essence, how much the plant "sweats". Your local Agricultural Extension Agent should be able to tell you which grass type is right for your area.

In the Southeastern United States, the dominant turfgrass is Bermuda. This particular strain is well-suited to hot weather, and displayed exceptional water-conservation and drought-resistant properties. In the coastal areas, where salt content inhibits the growth of Bermuda, St. Augustine is the dominant strain. This grass has longer blades and a less dense growth pattern which allows it to retain a great deal of water as it falls (minimal runoff). However, its tolerance to salt makes it the grass of choice.

In the Northeastern United States, a cooler grass type is required to survive the ground freeze that occurs during the winter. The dominant grass type in this area is the perennial ryegrass, which is well-developed to the climate of the area. Towards the southern end of the region, tall fescue is an excellent selection. In the Great Plains area, homes tend to use traditional native grasses such as buffalograss and gramagrass. These native grasses are the most drought-resistant of any of the grass types, but tend to go brown and dry during periods of drought.

The most difficult region to find a proper grass type is in the Transition Zone. This is the area of the United States starting in the northern part of Georgia to just north of Virginia and extending westward across the plains. This region is typically too cold in the winter to keep warm-season grasses alive, but too warm during the summer to promote healthy growth in the cold-season grasses. There are a variety of both warm and cold-season grasses that have both been adapted and bred to survive in this climate. Some of the dominant strains include Bermudagrass in the south of the region, fescuegrass in the north, and zoysiagrass in the middle region of the zone. Zoysiagrass is somewhat of a rarity, as it is too slow growing to bee effective in the southeast, and, being a warm-season grass, unable to survive outside of the Transition Zone. Therefore, existence of this plant as a turf is limited to the middle and south of the Transition Zone.

If you have questions concerning what grass is right for your lawn, construct a list of the qualities you are looking for in a turfgrass. Is water-conservation and drought-resistance the most important aspect of the lawn? Does the turf need to be able to withstand high traffic without breaking down, or would you prefer a quick-growing grass that can recover from significant damage quickly? Is cost an overriding factor? What quality lawn are you looking for? List the qualities you find important and contact your local Agricultural Extension Agent. They will be able to provide you with more information and help you determine the right grass for your needs.

In order to establish your turf area, you should follow the establishment procedures for your turf type as specified. Be certain to water the water properly during the development period, checking for weeds on a regular basis. If weeds develop at this point, they can choke out the turfgrass and become a permanent fixture on the lawn. Once the turf has established itself, cut the watering back until you establish a routine. More about irrigation techniques will be discussed later in this paper.

The next phase of xeriscape design is selecting appropriate plants for the remainder of the property space. Water conservation is the most important characteristic for a grass type in the xeriscape, but drought-resistance is the most important characteristic for plants and trees. The reasoning behind this is that plants and trees have a much wider root system than turf, allowing them to draw less water than turf. However, without proper care, these plants will develop their root systems outward instead of downwards, giving them less drought resistance than they are capable of. Trees generally draw up to 70% of their water in the first half of the root system. By encouraging the roots to grow downward, you stretch the vertical depth of the first half of the system. This increases the drought resistance of the tree.

With proper planning, a group of established drought-resistant plants can go the majority of the dry season with little to no external irrigation. Try to incorporate as much plant life into the property as possible. Examples of good xeriscape plants include crepe myrtles, Chinese and Japanese hollies, and hollies. You should also consider phasing in the permanent plants into the home. This gives the initial plants time to establish themselves and become drought resistance. This goes against the traditional thought of creating an immediate landscape, but phasing will make your property much more drought resistant in the end. This is also a more cost-effective solution, allowing you to add to the landscape as your budget allows.

When adding trees and other larger plants, you need to consider the immediate and permanent effects of those plants. Planting larger trees will give your home an immediate shade and energy benefit, while smaller tress will take around 5 years to fully develop. On the other hand, by planting smaller trees, you allow them to better establish their root system, improving the drought-resistance.

The fifth pillar of xeriscaping is mulching. By adding 2-4 inches of mulch to your beds, you help protect your plants from losing water by evaporation. It also helps to cover plant roots, shading them and cooling. The use of mulch also prevents the growth of weeds by not proving sunlight on the bed floor, killing weeds in the establishment phase. Additionally, as mulch decomposes, it returns nutrients into the soil, promoting healthy plant growth. The downside to this is that the mulch must be replenished every few years. Examples of mulching materials include peat moss, wood chips, clean straw, cocoa or pecan hulls, shredded bark, and pine straw. Mulching is an easy, yet essential part of xeriscaping, providing much needed protection to your landscape.

When choosing your mulch type, you should look both at aesthetics and at function. Fine textured mulches will trap more heat than coarser mulches, a consideration if winter protection is necessary. Having a compost pile on site is helpful, but not necessary. If using a compost pile, pull back the mulch in the bed area, work both mulch and compost into the bed area, then add additional mulch over top to return the bed to its original finish. Mulching is most critical in beds with shallow-rooted plants such as azaleas, rhododendrons, and dogwoods.

The sixth principle of xeriscaping, and the one that is most often abused, is efficient irrigation practices. If your lawn is small, it may not be large enough to constitute using a permanent irrigation system. If this is the case, you likely rely on a sprinkler system attached to a garden hose. These systems require a lot of work in order to deliver enough water to all areas of the lawn. If your lawn is larger, you may consider it necessary to implement a permanent irrigation system.

Permanent, above ground irrigation systems should only be used to irrigate turf and other high/moderate water-use zones. There are two main types of systems that can be used: automatic or manual system. Both these systems use an underground pipe grid to deliver water to the required areas. Automatic systems allow you to set the run time and duration, and the system will automatically turn on the valves at the appointed time. If you have this type of system, it is suggested to purchase some type of rain sensor (or additional sensors) in order to improve your water conservation. A manual sensor will require you open and close the valves manually. This type of system is often cheaper, requires more work, but can have good water usage.

For plant beds and individual plants, drip irrigation such as Rainbird's Xerigation® system can deliver a slow, steady water flow directly to the plant's root system. This is an advantageous system over above-ground irrigation because it delivers the water directly to the root system, where it can soak the root with little to no evaporation, delivering up to 90% efficiency. Drip irrigation is preferred for slopes where normal irrigation would create excessive runoff, since the slow delivery rate cuts erosion down significantly. Drip irrigation, like a permanent system, can be either automatic or manual.

More important than the type of irrigation used, however, is the manner in which irrigation is done. Most homeowners over-water their lawns very regularly, more so even during dry periods. Water your lawn only when the conditions dictate it. Most people are lulled into thinking that they should water their lawn according to the calendar, as so begin a process of over-watering that can lead to root rot and the erosion of valuable soil nutrients. Grass will lie flat after you step on it when it needs water, and may droop, look bluish-brown at the edges, and possibly fold or curl up.

When irrigation is done, it should be a complete thorough soaking, enough to reach the full root system. As a general rule, this is approximately 1" of water. You should perform a coffee-can test to determine the proper run time for your system. Place three coffee cans or other flat-bottomed containers at random places in your lawn. Run your irrigation system for fifteen minutes. With a ruler, measure the water depth in each of the cans and determine an average depth. Use the chart below to determine how long you should run your system, and repeat the procedure for each zone.

Average Water Depth in Cans

3/16"	1/4"	5/16"	3/8"	1/2"	5/8"	3/4"	1"	1-1/4"	1-1/2"
80	62	50	40	30	24	20	15	12	10

Number of Minutes to Deliver One Inch of Water in Cans

The time that you water your lawn is equally important. Most people waste valuable water by irrigating during the day, causing much of their water to be lost to evaporation. The best time to water is in the early morning or evening. Watering at night, once thought preferred, is now looked down upon because it can promote fungi growth. The best time then is about an hour before sunrise, allowing your system to complete its cycle and allow the soil to soak in the water before the sun can cause serious evaporation losses.

The final principle of xeriscaping is maintenance. You should care for your lawn on a regular basis. You should mow your lawn, preferably with a reel mower, regularly and at the maximum suggested height for the grass. Do not bag your clippings; rather, leave them on the grass so they can return nutrients to the soil. You should also fertilize your lawn lightly, two to three times a year from the late spring until the early fall. However, do not fertilize the lawn during droughts. If you are in the dry season, allow your grass to come out of the stress period before you add fertilizer. Mulched beds should have the mulch renewed on an annual basis. Remove as much of the old mulch as possible, and work the remainder of the mulch into the soil, and then add more mulch to the bed until you once more have 2”-4” of mulch covering the plants.

Xeriscaping is a valuable part of ecological conservation techniques. By taking advantage of natural environment, you can ultimately conserve and protect your lawn, giving it greater resistance to stress and drought, saving yourself money and resources.

Components of the Controller System

Weather Reach Receiver- $485- Weather data is broadcast to this system using a Motorola Flex paging system. This includes air temperature, wind speed, relative humidity and solar energy. These factors are used to calculate the ET (evapotranspiration) rate either of short, cut grass or of plant and crop life. This value is measured in inches per day of water lost in the lawn due to evaporation.

This system will be used in one of three ways for our smart sprinkler system.
ET Enable- The sprinkler controller is disabled by this system until a specific ET threshold is reached. Then the system is enabled to bring the water level back to the ET level.
ET Trigger- When the ET threshold is reached, the controller is told that irrigation is needed
RS-232- The sprinkler controller directly accesses weather and ET data through a serial port then it determines watering requirements.

This system may also be able to communicate with HAL to feed it weather data based on how the data is transmitted. HAL would then be able to display this anywhere in the home.

Sprinkler Controller- $300- This is one of the hardest items to select for the system. It must interact with both the weather and ET data as well as interface with the sensors in the ground. There are three broad options when selecting a controller.

High-End Commercial Controllers- Design to irrigate and manage not just large areas but multiple areas. Further, they offer the capability to do it all remotely through computers. They are highly programmable to meet any challenge and any need. They can communicate with anything from sensors to weather stations to other automation and computer programs. They generally offer CAD based programs as well to model your system in action and monitor the irrigation as it runs. One problem with this type of system is that it is too much for a residential irrigation system. It has too many options and interfaces to be practical for a homeowner's lawn. Generally they are designed for golf course irrigation control. Due to the large amount of flexibility and adaptability this system gives, it is not easy to set up. Certification classes are offered by the makers of these systems to train personnel to run the irrigation. It is usually a full-time job to manage a system such as this. The main problem with a system such as this is the cost. Since it offers so much, the price on this kind of a system starts at $100,000. This is the main factor that makes these highly impractical for residential use.

Standard Residential Controllers- The main draw of a system such as this is the ease of use. Once the cycle is set you can forget about it. Unfortunately, this offers no efficiency in watering and will often lead to over-watering of the lawn. It is compatible with a select few on-site sensors, but cannot account for evapotranspiration or other climatological data. They are relatively inexpensive though, and easily installed and maintained.

Programmable Controller- Like the Hunter ICC that we have selected for our system. The system schedule is programmed on a computer and then uploaded to the controller. It has direct connections for on-site weather sensors and can communicate with the weather reach receiver. It is customizable to accommodate from eight to 48 zones of control. Each zone receives its own scheduling as well. If some zones require less water or are using drip irrigation, then the run time can be modified to reflect the landscape's specific needs. Further, it can be programmed to allow for seasonal variances in watering needs. In this way, less water will be used during the winter when evapotranspiration is not as high.

Wind Gauge- $70- Just a cutoff switch for the system. When the wind speed is high, it causes the sprinklers to spray off-course. This may cause dry spots in the lawn or unnecessary watering of the driveway. The system stops watering when speeds rise to between 12 and 35 MPH and resumes when it drops to between 8 and 24 MPH. It connects in with the valves to shut them off directly.

Rain Gauge- $25- Another system that will connect in with the valves. It is another cutoff switch to stop watering if it begins raining. Once it stops, the valves are reopened. These devices claim to save between 25 and 40 percent of water use.

There are a couple types of rain sensors. The first is a disk-type sensor. A disk absorbs the water from rainfall then expands proportionally to the rainfall. The other type is a simple bucket-type that collects rainfall and measures the amount in a bucket. Both these devices can be used to control the system but since we are using the weather and ET data to do that it is only necessary that they function to tell the system whether or not it is raining.

Freeze Sensor- $25- A simple on-site temperature gauge that cuts off irrigation when the temperature drops below freezing. This insures that water will not freeze on the vegetation causing it to die. One idea may be to use an air temperature sensor to regulate the above-ground irrigation, and use a soil temperature sensor in the ground for the underground irrigation. This way, some areas will still receive the water they need if it is not cold enough for the ground to freeze.

Moisture Sensor- $200- Due to cost concerns and the accuracy of data (ET) received from the weather station about the lawn, moisture sensors will probably only be used in the flower and plant beds. They will serve as a valve cutoff when the moisture level is above the lower limit.

Benefits of moisture sensor:

1. Provide feedback on soil moisture level for correct scheduling of irrigation
2. Switching of irrigation controllers
3. Determine effectiveness of irrigation- monitor wastage through deep drainage
4. Evaluate/analyze plant demand for water
5. Detect leaching of nutrients
6. Assess the effectiveness of rainfall
7. Provide additional information on soil environments eg: soil temperature, pH
8. Save water by improving irrigation effectiveness
9. Reduce water wastage (40-50 percent)

Requirements for effective sensor use

1. Accurate and rapid measurement in reasonably open soils
2. Work from 100mm to 300mm
3. Not affected by soil nutrients
4. Dependable and consistent data (wet or dry)
5. Fully calibratable for any soil type
6. Output understood by controller
7. Sensor placement should reflect average moisture for the area being analyzed

The system we chose is BaseLine's WaterWatcher DPS-100. The most notable reason is cost. There are many different types of soil moisture sensors on the market. Most have far more capabilities than a home irrigation system would need or ever use. These features can make soil sensors prices soar as high as $25,000. The other benefits of this system include its ease of instillation and communication with the irrigation controller. It connects through the ground line of the valve controller to behave just like any of the on-site weather sensors. It is ideal to use on the site for gardens, shrubs, and flower beds. All these areas of the lawn will have moisture requirement different from the lawn so these can serve as a means to cater the moisture setting to specific areas of the landscape. The system is also easily set up. A dial setting on the box determines the moisture threshold to allow irrigation and the probe can be set at any depth to accommodate most root systems.

Additionally, this system may be necessary as a replacement for ET data systems when below ground, or drip irrigation is used. Most evapotranspiration takes place while the water is still near the top of the soil, but when the irrigation is delivered below ground, this value will not be reliable. Thus this system may serve as a replacement as it will take measurements at the below ground level of irrigation.

An interesting scientific benefit of adding this system may be to compare it to an evapotranspiration data system. These systems, while using radically different methods of analysis, essentially serve the same purpose of determining how much water is in the soil. Since both will be implemented in the same lawn, under the same conditions, it may serve as a side-by-side study of the two systems in action. By adding flow meters to the valves for each system, it can be determined which system uses more water and which system has more irrigation activity. Then an analysis of overall health of the vegetation in each area including a root-depth analysis should be able to determine both which system is most water efficient and which plants grow better under.

LEED Water Use Calculations

The following was taken from the LEED Reference Package 2.0 of June 2001. As this is one of the highest standards for water use and conservation, these calculations are necessary in order to show that a lawn design will adhere to LEED standards. Furthermore, these calculations are used in the calibration of the controller aspects of the sprinkler system in order to assure efficient irrigation management.

For LEED eligibility, irrigation volume must be calculated for the month of July on the designed system and then compared to that of a baseline system. The two possible points can only be attained by designing a system that uses no potable water.

Landscape Coefficient (K_L)- indicates volume of water lost. $K_L = k_s * k_d * k_{mc}$. A landscape coefficient should be calculated for each unique area of landscaping on the property.

Species Factor (k_s)- The individual water usage of plant species. Plants should be grouped into low, average, or high water usage groups based on data obtained from plant manuals for each species of plant. Table 1 lists the values for different vegetation types. If a species requires no water, then it is assigned a value of zero.

Density Factor (k_d)- This value reflects the number of plants and how densely they are packed together. Evapotranspiration increases with increased density of the irrigated area. Low valued landscapes are those which trees shade less than 60% of the area and the ground is less than 90% covered. Average ratings have near 100% tree shading or a full groundcover. Highly rated areas have both a full groundcover and nearly 100% shading from trees.

Microclimate Factor (k_{mc})- This factor concerns the climate conditions specific to the landscaped area. These include temperature, wind, and humidity. The average value is 1.0 and is applied to areas unaffected by buildings, pavement, reflective surfaces, and slopes. High values occur when these conditions are not met or there are windy conditions across the site. Low values are found in shaped areas and those areas protected from the wind.

Table 1: Landscape Factors

Vegetation Type		k_s			k_d			k_{mc}	
	low	avg	high	low	avg	high	low	avg	high
Trees	0.2	0.5	0.9	0.5	1.0	1.3	0.5	1.0	1.4
Shrubs	0.2	0.5	0.7	0.5	1.0	1.1	0.5	1.0	1.3
Groundcover	0.2	0.5	0.7	0.5	1.0	1.1	0.5	1.0	1.2
Mixed	0.2	0.5	0.9	0.6	1.1	1.3	0.5	1.0	1.4
Turfgrass	0.6	0.7	0.8	0.6	1.0	1.0	0.8	1.0	1.2

Calculating ET_L- The evapotranspiration rate of the specific landscape is calculated using K_L and the reference ET_0. The reference is a regional value based on the evapotranspiration for the month of July. This value can be found in regional weather data. For the Durham region, this value is six inches per month. July is used as the reference because it is the month where the most evapotranspiration takes place. To find ET_L, use: $ET_L = K_L * ET_0$.

Irrigation Efficiency (IE)- This coefficient represents the efficiency of the irrigation delivery system. It compares sprinkler systems to drip irrigation systems.

Table 2: Irrigation Types

Irrigation Type	IE
Sprinkler	0.625
Drip	0.90

Total Potable Water Applied (TPWA)- for a month over a given area of landscape is given by the equation: $TPWA = (A * ET_L) / IE$. This indicates that smaller landscapes, smaller ET_L values and larger IE values result in lower TPWA values.

After this is calculated, July's graywater harvest is subtracted from it to arrive at the test case value. If that value reduces the potable water use by 50% from the baseline case, then the system can be awarded one LEED point. If the system eliminates the use of potable water completely, then two LEED points may be awarded.

An interesting note on this calculation is that it does not account for rainfall. It assumes that all the irrigating will be done by the irrigation system. This assumes that the sprinklers run a full cycle three times per week. However, with the controller and sensor system we are planning on installing, it will only run a full cycle every two weeks. This reduces potable water consumption by a factor of six. With this great of a reduction, plus the addition of graywater and rainwater systems, it may in fact be able to run this system without potable water, but it will be impossible to determine until the house is functional and the rainwater harvest can be determined.

Installation Phase and Timeline

Installation of this system should coincide with the building of the home. However, it can be delayed as long as necessary as long as there are no plants or turfgrasses established. Installation will have to comply with NC standards for irrigation system construction. There is no need to have a professional, certified installer implement the system, as long as the work is done by the owner(s) of the home. The irrigation system timeline will be approximately two weeks of construction, adjustment, and initial set-up of the system. The landscaping for the home will have a more flexible timeline, depending on the available funds for the system. The goal for the landscape is to be not only water-conserving and drought-resistant, but to provide energy savings from passive solar heating and cooling. To fully realize these savings, the plants could, depending on the planting age, take up to 20 years to provide full savings.

Conclusion

With proper implementation of the systems and resources described, we can save a minimum of 50% over previous water consumption totals. The project is cheap, it is easy for anyone to implement and it works well. Further, any of these components can be retrofit to an existing system for easy savings. The best technologies are those which are immediately available and can therefore provide an immediate impact on the home.

Additional papers are attached as Appendices.