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Application of the Simplified Landscape Irrigation Design Estimation (Slide) Rule for Outdoor Water Conservation for the Industrial, Commercial, and Institutional (Ici) Sector

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Abstract: In times of water scarcity, water conservation measures from authorities are primarily directed to the residential sector—homeowners and renters who engage in individual activities to reduce water consumption. Business owners, manufacturers, and institutional workers—the ICI sector, generally, do not receive targeted information and education on water savings measures, and when they do, the information, typically, refers to indoor technologies, and behavior choice. In answer to this shortfall, this research illustrates how the ICI sector might engage in outdoor water conservation and, thus, realize water savings using the well-established Pittenger's Simplified Landscape Irrigation Design Estimation (SLIDE) formula that estimates outdoor water conservation/savings for the lesser studied industrial, commercial, and institutional (ICI) sector. We applied the SLIDE formula five diverse climate areas in Texas to demonstrate the potential water savings in each, as well as identifying the type of water technology measures that yielded the greatest water savings for outdoor ICI landscapes. Overall, the greatest water savings for outdoor ICI landscapes was realized through *smartscape* design with *soil moisture sensors-SMS technology*, second best. Our findings will provide ICI facility owners/managers with knowledge and examples of a simplified system for quantitative decision making when considering choices among technologies and/or practices toward outdoor water conservation for their own facilities.

Keywords: water scarcity; water conservation; SLIDE formula; landscape design-IC sector; water conservation technologies-IC sector; landscape irrigation; outdoor water technologies; drought mitigation

1. Introduction

1.1. The Challenge

The industrial, commercial, and institutional (ICI) sector includes a wide range of facilities. *Institutional* facilities are primarily comprised of elementary, secondary and high schools, universities, libraries, government buildings, hospitals, correctional facilities, and courthouses. *Commercial* facilities include office buildings, restaurants, fast food restaurants, grocery stores, privately-owned hospitals, laundries, golf courses, churches, auto repair shops, car washes, retail stores, lodging, and so forth, while *industrial* facilities include diverse types of factories and manufacturing facilities. The diversity in facility types and, thus, end usage amounts of water supplies make benchmarking conservation efforts difficult in the ICI sector (Seneviratne 2007; Pittenger 2013; Jones 2022).

The paucity of water conservation research in the industrial, commercial, and institutional (ICI) sector is attributed to other diverse challenges such as data deficiencies of water use by facility types in the ICI sector. Unlike the residential sector where individuals live in single- or multi-family unit dwellings—thus, making it easier for water districts and water utilities to provide education and information about water conservation technologies and measures—facilities within the ICI sector are widely diverse and owners and managers are difficult to reach. This complicates benchmarking efforts, and results in limited data only applicable to particular facilities (Seneviratne 2007; Pittenger and Shaw 2013; Jones 2022).

Additionally, while best management practice materials and/or technical reference manuals might provide facility owners, managers and contractors with guidance for water conservation projects, information materials are, generally, not available. Furthermore, there are low numbers of water conservation demonstration projects in the ICI sector for facility owners and managers to observe and, thereby, increase awareness available technologies and potential water and cost savings. Finally, because water supplies are still disproportionately inexpensive, water conservation projects often take lower priority because of a longer return of investment (Seneviratne, 2007).

1.2. A Simplified Technique for Demonstrating the Potential for Water Savings in the IC Sector in Diverse Climates

Through scenario analyses, applying Pittenger's Simplified Landscape Irrigation Design Estimation (SLIDE) formula, this research demonstrated, quantitatively, the potential for outdoor water savings in five selected Texas cities in diverse climate regions. The overall goal was, that by informing and assisting ICI facility owners and managers of the relative ease in actually calculating water savings using Pittenger and colleagues' (2012; 2013; 2014) simplified tool—the SLIDE formula—that they, in turn, may take this knowledge and calculate their own potential water conservation/savings for their facilities for readily available, low-cost outdoor water savings technologies, measures and/or practices in the institutional and commercial (IC) sector of municipal water provision.

A region's climate-type is an important consideration in water supply/conservation planning because it ultimately determines a state's weather and, consequently, the probability of drought and the availability of water for various uses. This research is not a case study of Texas, *per se*, but because of its size spanning over 800 miles both north to south and east to west, the state has a wide range of climatic conditions over five diverse geographic regions and is illustrative, especially of the Sunbelt states of the U.S. having similar conditions. Of the 10 major Köppen Climate Types, Texas boasts four—hot and cold desert, semi-desert/steppe, and subtropical; only the interior cold and hot climate types as well as the cold, subarctic tundra, polar and marine and Mediterranean conditions of the U.S. West Coast do not apply (TWDB 2012; 2022).

2. Background and Context of the Industrial, Commercial, and Institutional (Ici) Sector

Of the total residential and ICI subsectors together, the municipal sector is expected to experience increased water demand from approximately 5.2 million to 8.5 million acre-feet by 2070 (TWDB 2022). In meeting this challenge, water conservation efforts have, heretofore, focused on the residential subsector, primarily consisting of single-family and multi-family homes where the bulk of population growth has occurred, and where ongoing residential water conservation strategies are estimated to provide an additional 650,000 acre-feet of municipal water supply savings by 2070 (TWDB 2022) [(one-acre foot=325,852 gallons)]. However, while strides have been made in the residential subsector, untapped potential still exists for water conservation in the non-residential industrial, commercial, and institutional (ICI) sector of municipal water provision (Hoffman 2013; Mansur and Olmstead 2012). Currently, this sector accounts for over one-third (34 percent) of municipal water provision, or approximately 1.7 million acre-feet, and uses about 8 percent of the total water supply statewide (TWDB 2022). Though this is a relatively low percentage today, the ICI subsector is expected to increase substantially over the next 50 years (TWDB 2022).

Despite these challenges and recognizing yet untapped potential in water savings in the ICI sector, choices of outdoor water saving technologies were identified that are readily available, relatively easy to use, and affordable by ICI owners/managers. Application of the SLIDE rule was then applied to each technology in each of the five diverse climate regions of Texas to identify which technologies were most likely to produce the highest water-saving and cost-effective solutions. In this way, possible potential outdoor water savings were identified and suggested for the IC sector.

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2.1. Water Usage in the ICI Sector for Outdoor Landscapes

The volume of water used for outdoor application varies across the state and the nation depending on variables such as climate, soil type, precipitation, geographic locations, economic profile of a location, time of the year, and type of facility. The variation of use by location is illustrated by a study that showed Dallas single-family residents using 40 percent of water for the outdoors, while Houston residents only using 18 percent (Sierra Club 2015). Most water usage for outdoor irrigation is for irrigating turf grasses.

In two studies conducted by Texas A&M *AgriLife* Research Extension, researchers looked at acreage of landscaped areas across Texas and identified acreage of irrigated landscapes that applied to commercial and institutional sectors. The acreage included: 1) municipal landscapes, for instance parks, at 209,811 acres, with approximately 104,906 of those acres being irrigated; 2) business and commercial landscapes at 228,776 acres; and 3) educational and institutional landscapes at 26,511 acres. All together municipal, commercial, and institutional landscapes totaled around 360,193 acres—all using irrigation. By applying a conservative number of 14.2 inches of average water need statewide, these three sectors together used approximately 426,230 acre-feet of water. This amount of acre feet would imply that outdoor water usage accounts for 35 percent of the municipal sector, excluding the residential sub-sector (TAMU 2015a,b).

Examples of these types of landscapes and associated acreages include: 1) green businesses, such as nurseries, green houses, and sod providers at 114,247 acres using 0.414 million acre-feet, and 2) golf courses at 115,000 acres using 0.364 million acre-feet. When the estimated total of acre-feet of water for the green industry and golf courses is combined with municipal, commercial, and institutional landscapes, a total of 1.2 million acre-feet of water is used for outdoor irrigation, or approximately 25 percent of municipal water use, excluding outdoor water use associated with single and multi-family homes. In other words, outdoor water usage for non-residential purposes accounts for a large part of the water budget in Texas and is forecasted to increase over time (TAMU 2015a,b).

2.2. Readily Available Outdoor Water Conservation Technologies

Volumes of outdoor water use vary not only by facility type, but also by the time of year. During summer months, outdoor water use may account for 40 to 60 percent of total water use in Texas (White *et al.* 2004) while during winter months, outdoor water use is usually minimal. It is clear, particularly in the summer months, Texans are using a significant amount of water to irrigate lawns, and, further, people are irrigating inefficiently. A three-year study by White and colleagues (2004) monitored 800 residential outdoor irrigation practices in Waco, Texas and found that approximately 50 percent of the participants were watering in excess. Similarly, Guy Fipps, founder of "Water My Yard" which uses evapotranspiration (ET) rates and weather data to inform efficient irrigation practices, claims that most automatic irrigation systems are improperly programmed and over-irrigate 20 to 50 percent (from Fipps, 2001 as reported in Harrington and Lacewell, TWRI 2015).

Because large volumes of water are being used on landscapes, and a high percentage of those landscapes are being over-watered, opportunities have surfaced for reducing water use by applying various outdoor water efficient technologies. We focused on readily available and relatively low-cost water saving technologies for the IC sector. These include: soil moisture sensor systems (SMS); evapotranspiration (ET) controllers, rain harvesting, and *smartscape* design (i.e., drought-tolerant, native landscape designs). (Each is compared in our Results sections for water savings and implementation cost.)

2.2.1. Soil Moisture Sensor Systems (SMS)

Soil moisture sensors (SMS) are known as a type of "smart controller" and use soil moisture data as the primary variable to decide if the landscape needs irrigation. Soil moisture sensors are placed at the root zone and transmit moisture content data to the irrigation control system. The SMS system will bypass a scheduled irrigation event if moisture content is above the specific threshold. Usually just one sensor will suffice, however, for large landscapes, additional sensors are recommended. Soil moisture sensors may easily be connected to an existing irrigation system controller.

Studies conducted in central Florida found that, on average, homes with soil moisture controllers reduced water used on the landscape by 65 percent compared to irrigation systems with an automatic timer (Haley et al. 2007; Dukes and Haley 2012). In other SMS research, water savings were achieved without decreasing turf grass quality below “acceptable” levels (Dukes *et al*. 2008). Another study found that during drought conditions, soil moisture controllers had an average of 72 percent irrigation savings and a 34 percent water savings compared to homeowners who used an automatic irrigation system (Cardenas-Lailhacar *et al.* 2010). Thus, SMS technology, has consistently been able to demonstrate significant reductions in water usage for landscape irrigation. Typically, soil moisture sensor controllers range from $280 to $1,800. Differences in pricing depend on product manufacturers and end users, either residential or commercial customers (Crook 2004; Gotcher et al. n.d.).

2.2.2. Evapotranspiration (ET) Controllers

Evapotranspiration (ET) controllers, also referred to as, climate-based controllers, or “smart controllers,” use local weather data and evapotranspiration rates to adjust irrigation schedules. Evapotranspiration rates account for the amount of water a plant will lose. Based off ET rates and weather data, ET controllers will irrigate accordingly. Pannkuk *et al.* (2010) found, using potential evapotranspiration data to water lawns, that 800 homes in their study had the potential to save, on average, 24 million gallons (91 million liters) to 34 million gallons (129 million liters) of water per year. For example, the City of Frisco, Texas uses ET rates and weather station data to inform residents when they need to water their lawns, and in 2010, city officials found that for 25 out of 52 weeks in the year, supplemental irrigation was not necessary (Tarrant Regional Water District 2014).

Some studies on ET controllers, however, have resulted in conflicting data, and concluded that ET controllers might *increase* outdoor water use. A study conducted in two locations in Florida—Wimauma and Gainesville—found that both ET controllers selected for the study overestimated irrigation by up to 30 percent in summer months (Rutland and Dukes 2012a,b). Other studies have identified similar overwatering results (DeOreo *et al.* 2016; Sovocool *et al.*, 2006). Nonetheless, the Alliance for Water Efficiency (AWE) suggests that ET controllers on average do save 23 to 34 percent of water usage, on average, based on a study with 21 different study sites (Davis and Dukes 2014). Most ET controllers cost between $250 and $900, while professional grade ET controllers range between $900 and $2,500 (Gotcher *et al*. n.d.).

2.2.3. Rainwater Collection Systems

Rainwater harvesting simply captures precipitation runoff from a roof using a rain barrel or cistern placed below a prominent rain gutter, attached to a vertical down-drain. Rainwater harvesting offsets outdoor water use associated with landscapes, gardens, ponds, fountains, and outdoor equipment washing. The Texas Commission on Environmental Quality also allows rainwater harvesting for potable use, following proper treatment and procedures (TAC Ch. 290 Sub. Ch. D).

In a 2006 study by the Texas Rainwater Harvesting Evaluation Committee, the Texas Water Development Board (TWDB), found that an estimated two billion gallons of water could be generated in a Dallas-sized metropolitan area if 10 percent of each homeowner’s roof area was used to harvest rainwater. Further, an estimated 38 billion gallons of water might be conserved if 10 percent of all homeowners’ roof areas in Texas were used for rainwater harvesting.

Many cities are offering rebates and other economic incentives for the use of rain barrels or providing classes in how to assemble a low-cost rain barrel at home (University of Florida, 2008). For the larger landscapes that are often associated with the IC sector, it is more common practice to use rain cisterns, which are essentially large barrels that capture more water due to a typically larger roof size in the IC sector. Rain cisterns may be above or below the ground. Rain cisterns cost start at about $1,500 and can range up to $10,000 (FRHI 2009).

2.2.4. Landscape Design and Materials Selection-Smartscape

Several terms describe a water-conserving landscape. Among them are *xeriscaping*, low water use, drought tolerant, *waterwise*, *smartscape*, and desert landscaping; in this research we use the term, *smartscape.* The principal objectives in a low-water use landscape design include: 1) using native, drought-tolerant plants which may reduce the water use by 50 to 100 percent; 2) minimizing plants that require large volumes of water; 3) grouping plants with similar water needs together; 4) designing effectively, using the natural slopes of the landscape to capture rain water or water run-off from roofs; 5) amending soils with organic matter/compost to ensure longevity of plants while reducing water needs; and, 6) adding mulch around plants and flower beds to retain more soil moisture (Rymer n.d.).

Research conducted by Sovocool and colleagues (2006) in Las Vegas produced models indicating that outdoor water use decreased an average of 55.8 gallons per year (211.2 liters per year) for every square foot of turf landscape converted to drought tolerant landscape. The study also found that turf took more time and cost to maintain than a smartscape. The study concluded that turf took 8.2 hours per month and $680 per year to maintain, while smartscape took 6 hours per month and $474 per year to maintain. Landscape conversion costs are dependent upon the area, the contractor, and scale of the project; however, on average, the cost ranged from approximately $.50 to $2.04 per square foot conversion (Sovocool et al. 2006; Rymer n.d.).

3. Methodology

We chose comparative, scenario analyses approach using Pettinger's Simplified Landscape Irrigation Demand Estimate (SLIDE) formula for four popular, readily available, relatively low-cost outdoor water-saving technologies given hypothetical outdoor water budgets. Our purpose was to compare the four outdoor technologies against each other to illustrate potential savings in physical amounts of water used as well as dollar cost of water usage.

Scenario analyses was advantageous as it is a process of analyzing possible future events by considering alternative possible outcomes. Scenario analyses does not try to show one exact picture of the future; instead, it presents several alternative future options. Consequently, one might consider an array of possible future observable outcomes (Hassani 2016). In this case, the ICI facility owner/manager might obtain more meaningful and purposeful quantitative information for decision making concerning his/her choices toward various water conservation technologies.

3.1. Climate Variation of the Study Areas

3.1.1. Humid, Subtropical-Upper Coast/Coastal Plains

The city of Houston, located in east Texas, lies in the flat Coastal Plains region, about 50 miles from the Gulf of Mexico. The climate is humid subtropical with morning humidity values in the summer averaging over 90 percent and afternoon values exceeding 60 percent. Temperatures are moderated by the influence of the Gulf of Mexico which results in mild winters. Annual average precipitation totals about 54 inches with local convection storms, movements of weather fronts, and hurricanes being major sources (TSHA 2022-23).

3.1.2. Humid, Subtropical-Interior Hill Country

Located in the interior south-central region of the state, the cities of Austin and San Antonio experience average annual precipitation amounts between 24 and 36 inches, with San Antonio—approximately 80 miles southwest of Austin—being the drier of the two. The climates are considered humid subtropical with hot summers and relatively mild winters; however, the two cities are more centrally located with the western edges stretching along the Balcones escarpment, forming the rolling Texas Hill Country (TSHA 2022-23).

3.1.3. Humid, Subtropical-North Central Prairies (Steppe) and Lakes

In north-central region of Texas, the city of Dallas is characterized by a humid subtropical climate, typical of the southern Great Plains of the U.S., having distinct four seasons with mild winters and hot summers. Precipitation varies considerably, ranging from less than 20 to more than 50 inches, yearly (TSHA 2022-23).

3.1.4. Cold Desert/Trans-Pecos

Lastly, the city of El Paso resides in the westernmost region of Texas in the Trans-Pecos climate zone. El Paso has a transitional climate between cold desert climate with hot summers, usually with little humidity, and cool, dry winters. Of all five cities, El Paso is the driest with less than 14 inches of rainfall per year (TSHA 2022-23).

3.2. The SLIDE Rule

For the five cities in our study areas—Houston, Austin, San Antonio, Dallas, and El Paso—we applied the Simplified Landscape Irrigation Demand Estimation (SLIDE) rule to, four—readily available, relatively low-cost—outdoor water saving technologies, discussed above, using existing water quantities to compare savings and cost. The advantages of choosing and employing the SLIDE rule include:

1) its simplicity in application and interpretation, by replacing the need for a large data base, and reducing the number of factors or variables;
2) its accommodation of new plants;
3) its recognition of being scientifically and conceptually sound, having been assimilated and applied in research for more than 20 years;
4) its consistent provision of reliable numbers for calculations;
5) its wide geographic and climatic application (Pittenger 2012; 2013; 2014).

3.2. Using the SLIDE Rule for Calculations

Prior to comparing the five scenario analyses for the four outdoor technologies, it was first necessary to perform several preliminary calculations. The first round established a water demand by creating a water budget for an existing landscape using the Simplified Landscape Irrigation Demand Estimation (SLIDE) formula developed by Dennis Pittenger from the University of California's, Division of Agriculture and Natural Resources. Leaders in developing the SLIDE application also include Roger Kjelgren and colleagues (2015) of the Utah State University Extension Center for Water Efficient Landscaping (2014), Richard Beeson from the University of Florida Extension Center, and David Shaw, University of California, a colleague of Pittenger's. The formula for the SLIDE rule is as follows:

Irrigation Demand (in gallons)

$$\sum [(ET_o \text{ x } PF_{1\text{-}x})_{J\text{-}D} - (P \text{ x } 0.5)_{J\text{-}D} \text{ x } LA_{1\text{-}x}] \text{ x } 0.623 \div DU \text{ x } LR_{ES,T}$$

Where,

ET_o = Historic average monthly evapotranspiration (inches).
(Here, the annual ET_o to derive an annual estimation was used).
$PF_{1\text{-}x}$ = Plant factor average for the plant categories, for $_{J\text{-}D,}$ January through December.
P = Historic average precipitation in inches for each month, $_{J\text{-}D,}$ January through December.
$LA_{1\text{-}x}$ = Landscape area devoted to a respective plant category, 1 through x (square feet).
0.623 = Factor to convert units to gallons.
DU = Distribution uniformity of irrigation application, assumed 0.7 (70% efficient).
$LR_{ES,T}$ = Leaching requirement needed only for water taken from portions of an aquifer or those with similar salinity levels (*not applicable and not included).*

Preliminary calculations were as follows. First, a hypothetical landscape of two acres was created with a design that assigned a percent cover of plant types (trees, turf, shrubs/bushes, and flowers). Calculations were then made for space required for the acreage of each plant type group used.

Next, each plant group has a *plant factor* value (PF) (sometimes referred to as a crop coefficient), which describes the plant's watering needs in order for the plant to perform acceptable appearance and function. The concept of the PF value is a generally accepted measure in research and application (Pittenger 2012; 2013; University of California n.d.). The PFs used for this study were yearly averages.

It was also important to note that plant factors can be very specific based on the species of plant (Pittenger and Shaw 2013; University of California n.d.); however, for the purpose of this research, Table 1 displays plant factors that were representative of all plant types in a particular group.

Table 1. Existing Landscape Plant Cover for Outdoor Scenario Analysis.

PLANT TYPE	PERCENT COVER	SQUARE FEET COVER[1]	PLANT FACTOR[2]
Trees	05%	4,356	0.6
Turf (warm species)	60%	52,272	0.6
Hardscape	05%	4,356	0.0
Shrubs/Bushes	20%	17,424	0.6
Flower Beds	10%	8,712	0.8
TOTAL	100%	87,120	0.59[3]

[1] assuming 2 acres. [2] of existing total water budget. [3] weighted average.

Third, a reference evapotranspiration rate (ETo) was established which assumes how much water will transpire and evaporate in a given time, and at a given location according to a reference crop (e.g., turf grass, at a fixed height, fixed surface resistance, and an assumed amount of sunlight) in specific climatic conditions (Irmak and Haman, 2015). Therefore, by using plant factors (PF), in addition to an ETo, one can estimate the total landscape water needs more accurately. For example, flower beds have a plant factor of .8 and require, roughly 80 percent of the ETo to have an acceptable appearance and growth, and therefore will need more water than, say, turf grass. Table 2 reports the estimated evapotranspiration and precipitation rates for the five Texas cities in order to estimate water needs for the hypothetical landscapes in the different climate zones in Texas. (Due to the scale of this analysis, other factors, such soil type and depth, were not taken into consideration.) In addition, an overwatering factor of 30 percent was selected based on research literature that consistently points to the practice of the overwatering of lawns (Endter-Wada 2008; TAMU 2015a,b).

Table 2. Evapotranspiration and Precipitation Rates for Five Texas Cities for Outdoor Scenario Analysis.

	EVAPO-TRANSPIRATION RATE (Average)	PRECIPITATION+	CONVERSION FACTOR (unit to gallons)	DISTRIBUTION UNIFORMITY OF IRRIGATION
Houston	54.9	47.7	0.623	0.7
Austin	57.5	33.2	0.623	0.7
San Antonio	58.2	30.1	0.623	0.7
Dallas	55.9	34.8	0.623	0.7
El Paso	79.3	08.6	0.623	0.7

+inches average for 2014-18.

Data from Tables 1 and 2 were incorporated into scenario analysis using the SLIDE formula and comparisons are reported below in the next section.

4. Results: Comparison of Outdoor Technologies

4.1. Water Budgets: Water Usage/Water Leakage

The existing landscape water budget called for a significant amount of water for ornamental use. In Table 3 below the columns representing estimated "Total Water Usage" and "Total Water Usage, Estimated Leakage" resulted from preliminary calculations related to water irrigation for an IC facility using the SLIDE formula. The first two columns represent the amount of supplemental water needed to satisfy the landscape according to the associated *crop coefficients*, *ET rates*, and *precipitation values*. However, literature shows that overwatering normally occurs (Endter-Wada *et al.* 2008; Hermittee and Mace 2012; Carenas-Laihacar *et al.* 2010; Burns 2015). Thus, a *30 percent overwatering factor* was applied to obtain total annual existing water use for an ICI facility. The comparative analysis uses the second column of data that reflects the 30 percent overwatering/leakage factor.

Table 3. Existing Outdoor Landscape Water Budget for an IC Facility with Associated Cost in Five Texas Cities with Distinctive Climate Zones.

	EXISTING WATER USAGE*	**EXISTINGWATER USAGE/ OVERWATERING/ LEAKAGE***	**AVERAGE PRECIPITATION+**	**COST ($250 per 50,000 gallons)**
Houston	1,211,404	1,574,824	29	$7,874
Austin	2,260,254	2,938,329	54	$14,691
San Antonio	2,496,125	3,244,962	60	$16,224
Dallas	2,043,773	2,656,904	49	$13,284
El Paso	5,311,632	6,905,121	127	$34,525

*gallons per year +inches per year.

4.2. Comparative Outdoor Technologies for an IC Facility in Each Study Area

4.2.1. Using Soil Moisture Sensors (SMS)

This scenario assumed that nine soil moisture sensors (SMS) covered 11 percent of the total square foot area of two acres. The investment cost for this SMS technology was around $3,250. Table 4 reports that, in this scenario applying SMS technology, water savings were significant at approximately 65 percent while the return on investment was under one year for this technology. This would allow an IC facility owner and/or manager to lower costs of operating the facility annually by employing this water reduction technology.

Table 4. Comparative Scenario Results for Savings in an IC Facility Landscape Water Budget Employing ***Soil Moisture Sensors (SMS)*** for Five Texas Cities in Distinctive Climate Zones.

	EXISTING WATER USE*	**LANDSCAPE WATER USE WITH SMS***	**WATER SAVINGS***	**PERCENT WATER SAVINGS (per year)**	**COST SAVINGS (per year)**
Houston	1,574,824	551,188	1,023,636	65%	$4,942
Austin	2,938,329	1,028,415	1,909,914	65%	$9,769
San Antonio	3,244,962	1,135,736	2,109,225	65%	$9,795
Dallas	2,656,904	929,916	1,726,988	65%	$7,572
El Paso	6,905,121	2,416,792	4,488,328	65%	$19,679

*gallons per year.

4.2.2. Using Evapotranspiration (ET) Controllers

The inconsistent water savings data associated with ET controllers make this technology less reliable than the consistent savings associated with soil moisture sensors. However, when used correctly, this technology has the potential to reduce water use significantly. The percent reduction used for the ET controller technology averages between 24 to 34 percent savings, as identified by Alliance for Water Efficiency (AWE, 2009).

Table 5 reports that under the ET scenario, the investment cost for this technology was relatively low at about $850 annually with a return on investment of less than a year. Overall, an estimated 29 percent of water savings in water consumption resulted in significant cost savings, especially for the city of El Paso.

Table 5. Comparative Scenario Results for Savings in an IC Facility Landscape Water Budget Employing ***Evapotranspiration*** ***(****ET) Controllers* for Five Texas Cities in Distinctive Climate Zones.

	EXISTING LANDSCAPE WATER USE*	LANDSCAPE WATER USE WITH ET CONTROLLERS*	WATER SAVINGS*	PERCENT WATER SAVINGS+	COST SAVINGS+
Houston	1,574,824	1,118,125	456,699	29%	$2,283
Austin	2,938,329	2,086,214	852,115	29%	$4,260
San Antonio	3,244,962	2,303,923	941,039	29%	$4,705
Dallas	2,656,904	1,886,402	770,502	29%	$3,852
El Paso	6,905,121	4,902,636	2,002,485	29%	$10,012

*gallons per year +approximate per year.

4.2.3. Rainwater Harvesting

Potential water savings from a rainwater harvest system was determined by: 1) configuring the necessary size and cost of the system by assuming a roof/catchment area of 10,000 square feet, 2) using precipitation data from the five cities under examination, and 3) estimating the size of the barrel necessary to capture average monthly rain fall was determined. It was assumed that the cistern would be made of fiberglass at a standard price of $0.75 per square feet for the material was used. Additional costs assumed included the cost of the gutters, the box washer, pumping system for reuse, and disinfection system.

Table 6 reports that rainwater catchment systems yielded the lowest water savings at the highest cost. Rainwater catchment technologies appear to be more appropriate for smaller scale IC or residential landscapes, not for large, multi-storied buildings. In addition, rainwater harvesting systems are only relevant for some cities, while other cities, such as El Paso, demonstrate a very low ability to harness this technology due to low precipitation events. Further, rainwater catchment systems usually have operational, and maintenance associated with the system, particularly the larger rain cistern, adding to the reasons that make this technology less effective. Finally, the time and cost it takes to repair a system often results in people negating the system all together. Therefore, the smaller systems used by homeowners appear to be a more viable alternative until technology makes it more feasible for ICI facilities as well as education for maintenance personnel on sustaining the systems.

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Table 6. Comparative Scenario Results for Savings in an IC Facility Landscape Water Budget Employing ***Rainwater Harvesting*** for Five Texas Cities in Distinctive Climate Zones.

	PROJECT COST	EXISTING LANDSCAPE WATER USE*	LANDSCAPE WATER USE WITH RAINWATER HARVESTING*	WATER SAVINGS*	PERCENT WATER SAVINGS+	COST SAVINGS^
Houston	$21,070	1,574,824	1,277,474	297,351	19%	$1,487
Austin	$17,320	2,938,329	2,731,368	206,961	7%	$1,035
San Antonio	$14,320	3,244,962	3,057,326	187,636	6%	$938
Dallas	$17,320	2,656,904	2,439,969	216,935	8%	$1,085
El Paso	$6,070	6,905,121	6,851,510	53,610	1%	$268

*gallons per year +approximate per year ^annual after Return on Investment (ROI).

4.2.4. Smartscape Design

The scenario for this design was calculated by revisiting the Simplified Landscape Irrigation Demand Estimation (SLIDE) formula. The *smartscape* landscape represented a more drought-tolerant design landscape by decreasing turf coverage, changing overall plant cover, and changing plant coefficient factors that associated with more drought tolerant plants.

We chose a weighted plant factor with *smartscape* of .30 as compared to the plant factor (PF) in Table 1 where the traditional landscape had a plant factor (PF) of .59. Our parameters and assumptions for calculation appear in Table 7 below.

Table 7. Parameters and Assumptions for *Smartscape* Landscape Plant Type, Cover and Factor Using SLIDE Rule.

PLANT TYPE	PERCENT COVER	SQUARE FEET OF COVER (2 acres)	PLANT FACTOR
Trees	5%	4,356	0.6
Turf (warm species)	20%	1,7424	0.6
Hardscape/gravel*	**25%**	**21,780**	**0**
Natives*	**50%**	**43,560**	**0.3**
TOTAL	100%	87,120	Weighted Average .30

*Amended from Table 1 to reflect materials used in *Smartscape* design.

Given the parameters and assumptions from Table 7, the table below describes an existing landscape budget for comparison with water how usage and cost, as well as, time toward return on invest for each technology and practice (Table 8). The *smartscape* design resulted in *the greatest reduction in water use* and, on average, saved 78 percent of total water use, assuming that watering does not occur. The downside of this approach centered on the higher up-front cost of around $1.50 per square foot (Rymer n.d.) or around $100,000 applying it to the two-acre case scenario. However, annual maintenance and maintenance cost were reduced with a more native landscape by about one-third of the “existing” landscape scenario (Sovocool 2005).

In the modeled scenario, the average return on investment was 8 years, however, taking into account annual operating and maintenance savings, the landscape redesign has the potential to provide an additional $9,000 during the 8-year payback period.

Table 8. Comparative Scenario Results for Savings in an IC Facility Landscape Water Budget Employing ***Smartscape Landscape Design for*** Five Texas Cities in Distinctive Climate Zones.

	EXISTING LANDSCAPE WATER USE*	**LANDSCAPE WATER USE SMARTSCAPE***	**WATER SAVINGS***	**PERCENT WATER SAVINGS+**	**COST SAVINGS^**
Houston	1,574,824	247,475	1,327,349	84%	$6,636
Austin	2,938,329	597,767	2,340,562	80%	$11,702
San Antonio	3,244,962	769,705	2,475,257	76%	$12,376
Dallas	2,656,904	501,251	2,155,653	81%	$10,778
El Paso	6,905,121	2,557,967	4,347,153	63%	$21,735

*gallons per year +approximate per year ^annual after Return on Investment (ROI).

Table 9 below summarizes all outdoor results and demonstrates that converting turf to native plant species (e.g., *smartscape*) appears to be the *most efficient long-term solution* in terms of annual water savings and cost. Turf grasses are often not suited in the areas they are planted and, therefore, use more water than a local environment is able to provide through normal rainfall events. Landscape conversions to *smartscape* are timely and costly but, in the long run, the conversion provides cost savings and time savings associated with maintaining a landscape. *Soil moisture controllers (SMS)* were the most *cost-effective solution* and resulted in the *second* largest water savings. The short-term payback made this the first option for landscapes that do not plan to reduce turf. *Evapotranspiration (ET) controllers* had a short payback with significant water and cost savings. However, compared to other smart technologies like SMS controllers, *ET controllers* saved fewer amounts of water overall. Therefore, this technology *ranked third* for IC facility owners with large amounts of turf. Lastly, the *rain harvesting systems* had the longest pay back, expensive up-front cost, and smaller water saving capacities; however, there is still large potential to offset dependency on local water sources with rainwater. Rainwater harvesting is highly recommended for areas who get regular rain events, and less applicable in drier climates such as El Paso.

Table 9. Summary and Ranking of Estimated Cost Savings in Four Outdoor Water Conservation Technologies in an Institutional and Commercial (IC) Facility (average annual).

Highest Project Cost/ Highest Cost Savings in Water Usage **NATIVE/DROUGHT TOLERANT LANDSCAPE DESIGN**	**Low Moderate Project Cost/ High-Cost Savings in Water Usage** **SMS CONTROLLERS**	**Low Project Cost/ Moderate Savings in Water Usage** **ET CONTROLLERS**	**High Moderate Project Cost/ Low-Cost Savings in Water Usage** **RAINWATER HARVESTING**
Estimated project cost: $100,000	Estimated project cost: $3,245	Estimated project cost: $850	Estimated project cost: $15,000
Water savings: 2,697,431 gallons 10.210.887 liters 78%	Water savings: 2,070,390 gallons 7.837.279 liters 57%	Water savings: 1,053,357 gallons 3.987.390 liters 29%	Water savings: 192,500 gallons 728.692 liters 8%
Water cost savings: **$13,487**	**Water cost savings:** **$10,352**	Water cost savings: $5,267	Water cost savings: $962
Advantages: Large water savings, low maintenance, low annual O&M cost, low dependence on municipal water	Advantages: Cheaper, effective, accurate, fast ROI	Advantages: Cheaper, can reduce water usage on landscapes	Advantages: Rainwater harvesting can still offset outdoor water use up to 20% in areas with higher rain events in Texas.

Disadvantages: Time-intensive project, slow ROI, expensive upfront cost	Disadvantages: Soil moisture sensors may not be accurate in very arid climates	Disadvantages: Studies have demonstrated these technologies can result in over-watering, and in some cases using more water than previous irrigation system.	Disadvantages: Associated operational and maintenance time and cost of the system; Long ROI, and high initial cost implementing the system.

5. Conclusion

There is not a "one size fits all" solution when it comes to choosing the proper technology for outdoor water savings and conservation (Gleick *et al*. 2003; Gregg *et al*. 2007). Rather, success is likely to be the result of multiple solutions working together, and tailor-made for an IC owner's particular set of circumstances. Given that cycles of prolonged drought will occur throughout the world, government leaders and water managers at all geographic scales will, no doubt, seek to develop potential in all sectors of a political economy to meet the future water demand. For the most part, in the U.S., as in other developed countries, conservation efforts have been focused, and relatively successful, in the residential sector; however, we propose that abundant opportunities for additional efficiency in water conservation may still be realized for institutional and commercial facilities.

The aim of this research was to demonstrate water savings through conservation technologies available to owners and managers in the ICI sector using comparative, scenario analysis in five diverse climate regions in Texas. While the owners and managers of ICI facilities may have a "feel" for the different technologies presented, this research quantifies outcomes by applying the Simplified Landscape Irrigation Design (SLIDE) formula. The results increase awareness and understanding of the potential for outdoor water conservation/savings in the industrial, commercial, and institutional (ICI) sector. The selected technologies and/or practices are currently available, have a relatively low cost, and are likely to be easy to implement.

For *outdoor* scenario analysis, existing water data was employed for five selected cities in diverse climate zones—Houston, Austin, San Antonio, Dallas, and El Paso—to create a hypothetical ICI facility water budget for each zone. Applying Pettinger's SLIDE formula for each water saving/conservation technologies in each of the zones demonstrated that the greatest water saving scenario was accomplished by converting an existing landscape to a *smartscape* (native) landscape design, although the downside of this technology is that it required a high upfront capital outlay in the first year. Nonetheless, the *smartscape* design was shown to reduce water usage by 78 percent, with an 8-year return on investment. Furthermore, savings in cost and time for landscape maintenance would gradually accrue over this 8-year time period.

For facility owners who might prefer to keep their existing landscape, in lieu of the expense to convert an entire landscape to more drought tolerate plants, soil moisture controllers (SMS) could potentially provide a 68 percent water savings and are seen to be relatively low-cost, depending on scale of usage, making this technology a second-best choice in water conservation/savings. Next in line, evapotranspiration (ET) controllers may result in a 57 percent water savings on existing landscapes with a one-year return on investment. Rainwater harvesting, the lowest-cost alternative, yielded only an 8 percent savings in water conservation in our overall analysis

Thus, the major challenge in 21st century for conserving water usage exists, not only for Texas and the relatively dry High Plains of the U.S., but also in other regions of the world having similar climate characteristics and/or population pressures (Gleick *et al*. 2003; Glenn *et al*. 2015). Water managers will face untold challenges in water conservation management to ensure adequate water supplies for residents, food production/agriculture/irrigation, and industry, commerce, and institutions. It is hoped that this demonstration in comparative scenario analyses for five diverse climate regions using a simplified calculation tool—the SLIDE formula—will inspire and assist owners and managers of IC facilities to estimate their own potential outdoor water savings through available, low-cost, water conservation technologies.

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