EFFECTIVENESS IN REDUCING WATER DEMAND: LANDSCAPE-ORIENTED WATER CONSERVATION FOR KYLE, TEXAS

THESIS

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CHAPTER I

INTRODUCTION

Kyle, Texas and the Problem

On Friday, September 21, 2007, Kyle, Texas was named the No.1 "hot spot" for commercial investment and development in the Austin-San Antonio Corridor (Austin-San Antonio Growth Summit 2007). Kyle was also named the fifth fastest growing city in Texas (Austin Business Journal 2007) and is completely within Hays, the 39th fastest growing county in the United States (Blank 2007). According to the Kyle City Council, the May 2007 population was just over 25,000, with some estimates reaching the 30,000 mark (cityofkyle.com 2007). The U. S. Census Bureau (2007) set the 2006 population at 20,655. If the May 2007 number of 25,000 is correct, then Kyle has experienced a 21 percent growth rate in just one year. From 2000 to 2006, Kyle witnessed a 289 percent growth rate with the population increasing from 5,314 to 20,655.

Since the late 1990s, Kyle's population growth has been astounding (Table 1 and Figure 1). These impressive increases in population are having a direct impact on the availability of natural resources. A community that plans on continued success and economic growth must be able to accommodate its residents and industries with essential utilities.

Table 1. Population growth for Kyle, Texas (TWDBa 2007; TWDBb 2007)

Year	Population	Population Growth Rate (%)	Year	Population	Population Growth Rate (%)
1971	1,670		1989	2,211	-49 29
1972	1,712	2 51	1990	2,225	0 63
1973	1,756	2 57	1991	2,256	1 39
1974	1,800	2 51	1992	2,236	-0 89
1975	1,846	2 56	1993	2,321	3 8
1976	1,893	2 55	1994	2,576	10 99
1977	1,941	2 54	1995	2,488	-3 42
1978	1,990	2 52	1996	2,658	6 83
1979	2,041	2 56	1997	2,832	6 55
1980	2,093	2 55	1998	3,490	23 23
1981	2,338	11 71	1999	4,410	26 36
1982	2,432	4 02	2000	5,314	20 5
1983	2,756	13 32	2001	6,497	22 26
1984	3,125	13 39	2002	8,265	27 21
1985	3,536	13 15	2003	10,802	30 7
1986	4,000	13 12	2004	14,099	30 52
1987	4,176	4 4	2005	17,770	26 04
1988	4,360	4 41	2006	20,655	16 24

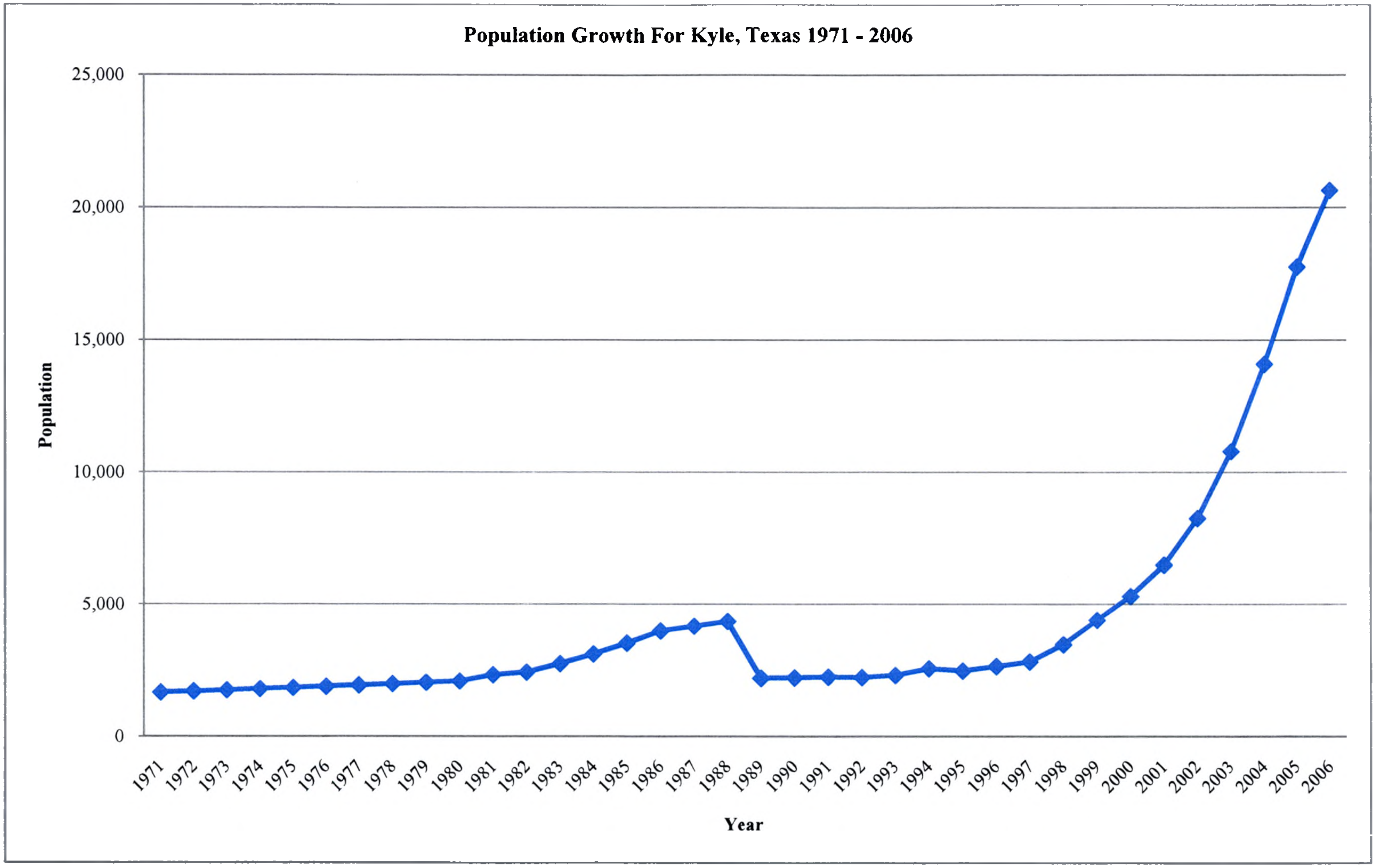

Figure 1. Population growth for Kyle, Texas: (TWDBa 2007; TWDBb 2007)

The desire to live in Central Texas attracts industry and development that strain the water supply or "the volume of raw water available to a population" (Gerston 2002). The regional resources are capable of adequately providing for smart growth, but a misguided scheme of development will deplete what water supplies are available. Overexploitation of water resources is not necessarily inevitable (Ostrom 2001); however, conservation measures are necessary to assure a secure future as regards water availability. Knowledge of these key elements would allow for an effective water plan and a sustainable future.

This research has provided an assessment of water conservation measures as applied to Kyle, Texas. Specifically, this investigation asked what the potential impact of residential landscape-oriented water conservation methods would be on a municipal water demand.

Purpose

"Until recently, the main solution to addressing water shortages was to exploit new sources of supply" (Inman and Jeffrey 2006). The significance of this research project was its analysis of the effectiveness of conservation in meeting the water needs of communities. The U.S. water industry has revenues of about $100 billion to $120 billion per year, which represents about 1 percent of GDP. In addition to monetary investments, there are "about 150,000 water, wastewater, and storm water organizations; plus, federal water offices at the national, regional, and state levels belonging to several agencies;

some 100 state water agency organizations, such as county agencies, special districts, commissions, and local water boards. The number of support sector establishments is unknown, but the sector comprises tens of thousands of consulting offices, lawyers, vendors, associations, knowledge providers, and other entities" (Grigg 2007). Conservation can ensure that these entities remain healthy and have available water.

Often the lengths that communities, states, and countries go to assure an adequate water supply cause legal issues and ill feelings among neighbors.

> "Water has played a crucial role in the location, function, and growth of communities. Conflicts over water have always involved competition among alternative uses or among geographical regions, and water has become the source of increasing controversy, as supplies fail to meet demand in many areas. This calls for the careful analysis of decisions pertaining to the allocation of water resources" (Arbues et al. 2003).

This statement is not only an endorsement of water allocation, but advocates the dire needs of proper conservation legislation and efforts to direct the public opinion towards a positive affirmation of voluntary water conservation. In all actuality, efficient and wise water use is a "win-win" situation, states Gerston, by "reducing demand on a natural resource, reducing water bills, and avoiding the capital costs of building more water utility capacity" (2002)

The significance of this project also lies in the fact that municipal water use has been projected to increase from 25 percent to 35 percent of the total state water use by 2050, and spikes in water use have been observed in summers months attributed to landscape irrigation (Gerston 2002). Therefore, the need for responsible water use concerning landscape-oriented irrigation is apparent. Flack found that "combined programs of conservation can be expected to reduce urban demand by as much as 25 – 30 percent over the long term, while voluntary and mandatory restrictions of various water uses provide an adequate short term conservation plan" (1980).

Research Question

The research question was whether residential landscape water conservation measures can make a meaningful impact on meeting a municipality's needs. Exploring the effectiveness of various residential conservation techniques, specifically those involving landscape irrigation, determined the potential impact of the measures in reducing water demand. The conceptual ideals of bringing water to the people can be convoluted if the water is not available; conservation at times of ample water supply would help ensure water would be available during times of drought. An assessment of the most effective conservation techniques can provide water managers and city officials with the confidence to apply these measures to reduce per capita water use, thus, reducing the likelihood and severity of future water shortages.

Study Area

Central Texas is one of the country's fastest growth areas, which ultimately begs the question of water use. A municipality with substantial growth rates is challenged to meet the water needs of a growing populous, while maintaining the integrity of the water source. The City of Kyle, Texas is an excellent example of a municipality dealing with these problems and is the focal point for this study.

Kyle, Texas is strategically located along Interstate 35 between Austin and San Marcos, Texas. This South-Central Texas community is situated in the northeast corner of Hays County (Figure 2) and is currently home to approximately 25,000 residents. Kyle and almost all of Hays County are located over distinct zones of the karst Edwards Aquifer and east of the aquifer on the Blackland Prairie (Figure 3). This location is unique in that groundwater is still available to Kyle without restrictions to lot sizes (Brock 2001). The region has two troublesome aspects to its precipitation pattern. First, the warmest months of the year are also among the driest (Table 2). The second major problem faced by water planners and managers in the sub-humid climate region is the extreme year-to-year variation in precipitation and water supply (Table 3). Wet years can be followed by dry years; droughts have a tendency to be more persistent than wet periods, and "the actual water supplies are even more variable than precipitation" (Earl, Dixon, and Day 2006).

Currently, Kyle's annual municipal water use is around 2,350 acre-feet, while the per capita daily consumption is approximately 100 gallons. Projections illustrate that in the next 30 years the total consumption will double and the population will have a 70 percent growth rate (TWDB 2007) (Figure 4).

Table 2. 1971-2000 Climate normals for San Marcos, Texas: average monthly temperature and average monthly precipitation (U.S. National Climate Data Center 2004)

	Precipitation	Temperature (°F)
January	2.05	49.9
February	2.21	53.9
March	2.09	61.6
April	2.85	68.2
May	5.31	75.6
June	4.84	81.5
July	2.12	84.4
August	2.65	84.4
September	3.46	79.7
October	4.03	70.5
November	3.17	59.9
December	2.41	52.1
Year	**37.19**	**68.5**

Table 3. Thirty years of San Marcos precipitation and Blanco River flow at Kyle (USGS 08171300): 1977 – 2006 (U.S. Geological Survey 2008, U.S. National Climate Data Center 2008)

Year	San Marcos Precipitation	Blanco River at Kyle ft/sec	Blanco River at Kyle Acre Feet
1977	27.69	197.20	142,800
1978	33.08	33.00	23,900
1979	38.74	254.70	184,400
1980	29.56	39.40	28,500
1981	49.62	219.60	159,000
1982	M*	59.00	42,700
1983	36.95	73.60	53,300
1984	M	18.30	13,200
1985	M	261.60	189,400
1986	41.57	266.90	193,200
1987	37.94	377.80	273,500
1988	21.5	42.90	31,000
1989	25.46	28.70	20,800
1990	M	45.00	32,600
1991	51.49	276.90	200,500
1992	46.57	486.00	351,900
1993	M	108.60	78,600
1994	40.85	77.20	55,900
1995	32.57	125.30	90,700
1996	28.21	7.15	5,200
1997	43.55	367.10	265,800
1998	58.51	394.70	285,800
1999	19.38	34.70	25,100
2000	M	59.50	43,100
2001	42.22	269.40	195,000
2002	46.16	438.30	317,300
2003	25.74	128.10	92,700
2004	52.68	395.40	286,300
2005	22.42	134.30	97,200
2006	26.36	6.60	4,800
Mean	**36.62**	**174.23**	**126,140**
median	**37.45**	**126.70**	**91,700**
s.d.	**10.94**	**148.26**	**107,344**

*M represents missing data

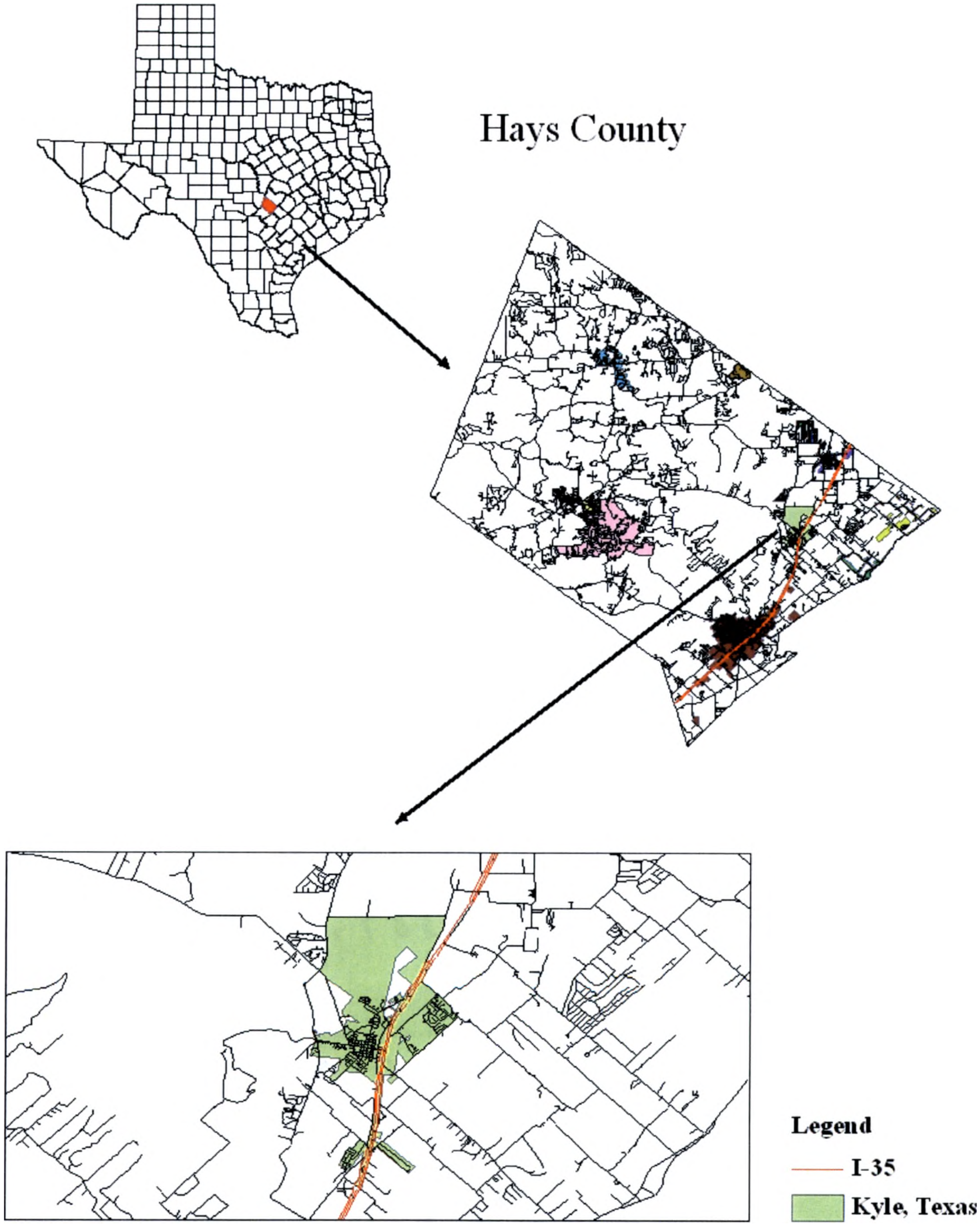

Figure 2. Location of Kyle, Texas

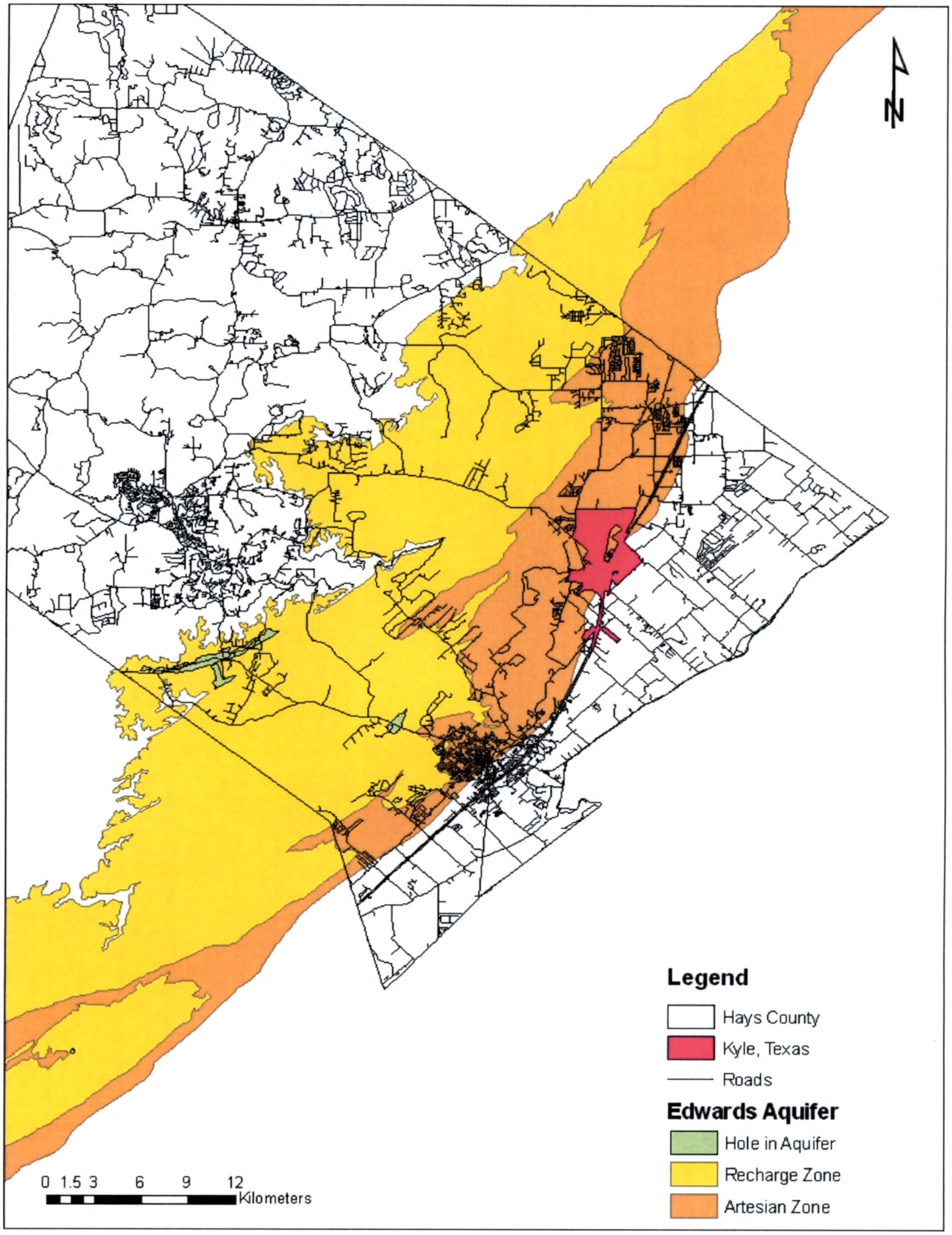

Figure 3. Kyle, Texas above the Edwards Aquifer

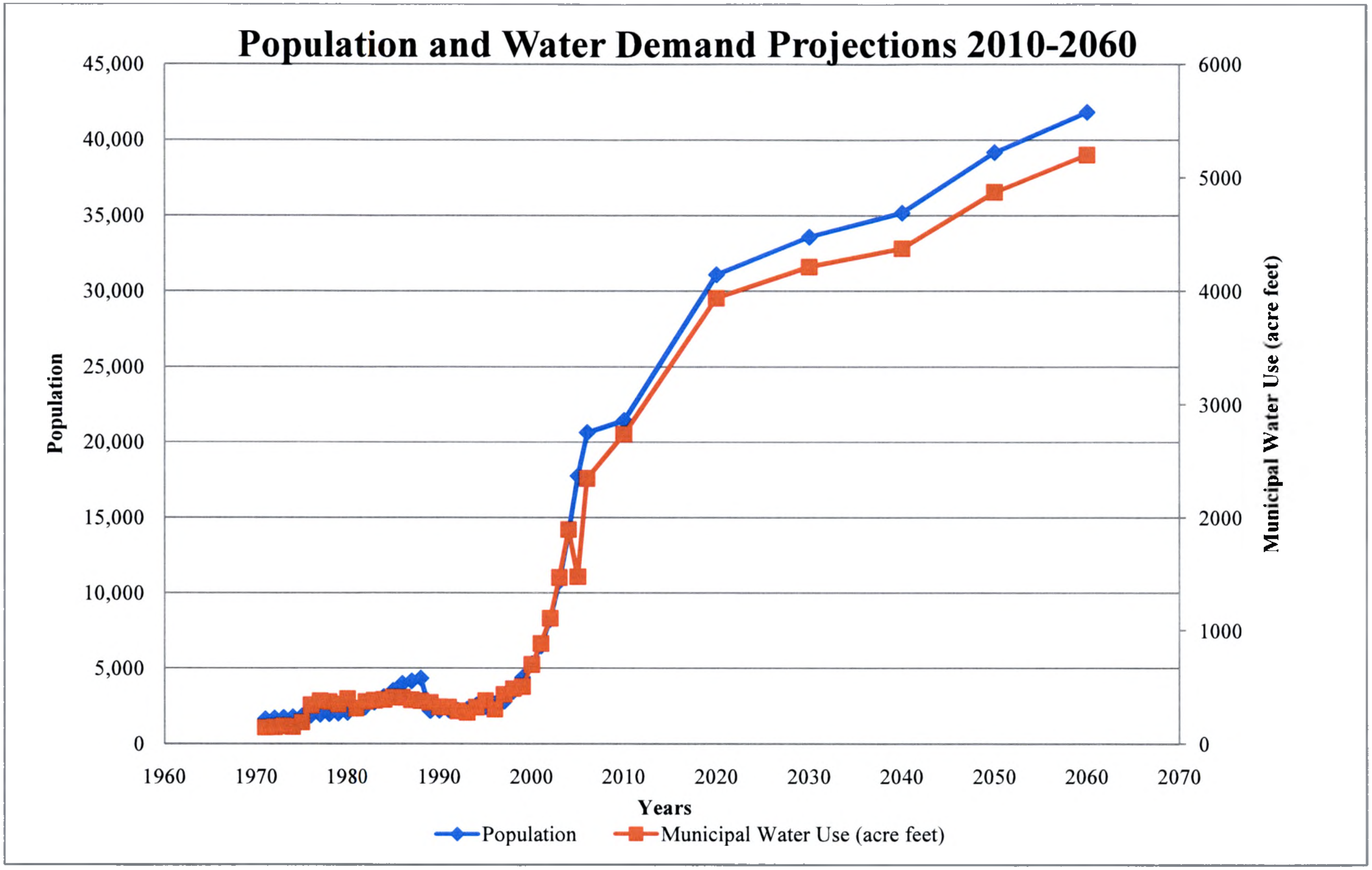

Figure 4. Population and water demand for the City of Kyle, Texas – 2010 to 2060 (TWDBb 2007)

Brief History of Development in Kyle, Texas

Founded in 1880, the City of Kyle began as a 200-acre railroad town for the International and Great Northern Railroad Company. As population grew to over 500, development began to adjust with the division of the 200 acres into 1,200 lots. In the 1960s, the city council moved to annex land north and south along the future Interstate 35 corridor to expand the city limits. It was here, in the northern properties, that Kyle's first subdivision Spring Branch I was established (Miller 1950; Collins 2002). Plum Creek and Spring Branch II were created by the annexation of three tracts of land to the northwest of downtown, and by the end of the 1980s, Kyle had expanded from the original 200 acres to almost 1,635 acres.

Central Texas in the 1990s saw a population boom from the industrial growth of the electronic semi-conductor industry. This tech-boom brought thousands of people to the area in just a few years; the Austin/Georgetown area metropolitan could not sufficiently accommodate such rapid growth. The City of Kyle, at the time, was well suited for providing some relief to the housing and land demands. The city's pre-plotted subdivisions of the 1980s allowed hundreds of new residents to capitalized on affordable housing, with the convenience of a shorter commute (Collins 2002).

This kind of growth required the possession of adequate water rights. The city council increased the annual acre-feet pumping rates from the Edwards Aquifer and obtained surface water supply to meet the present demands. Kyle has established itself along the I-35 corridor and will continue to grow. This 128-year old town has seen the rapid changes of the region and has adjusted accordingly. However, the need for more an assured reliable water supply is an issue today and will continue to be one as the city grows.

CHAPTER II

LITERATURE REVIEW

Water Conservation Studies

On the national scale, in-the-home water consumption on average is 80 – 100 gpd/p (gallons per day per person). Seventy to eighty percent of the country's water supply goes to agriculture, while 20 – 30 percent supports urban interests (Wodraska 2006). Agricultural production only involves approximately 1.8 percent of the U.S. population, yet this small percentage uses the water in support of the ever-expanding needs of U.S. inhabitants and agricultural exports.

The South-Central Texas region is associated with a sub-humid – sub-tropical climate. Its high precipitation variability results in extreme flood events as well as spells of drought (Earl and Votteler 2005). This relationship of extremes makes providing ample water supply a difficult task. An inverse power law describes the frequency of many events by stating that small events occur more often than large events; therefore, extreme drought conditions are inherently less frequent. Nevertheless, these extreme events can directly influence the surrounding communities and environment (Fonstad 2003; Foody 2003).

A common theme in the most recent literature dealing with water supply and demand issues appears to be a resounding advocacy for conservation. Various conclusions from the literature find that researching the conservation of a basic natural resource and the anthropogenic influences surrounding its use can lead to a higher quality of life (Grima 1972). Proper and ethical use of water resources leads to a morally appropriate conclusion: using less water means more water for all. Grima states that "emphasis on water demand management rather than on "supplies fix" makes it possible to improve the position of more communities with the investment resources that are actually available" (1972). Essentially, a municipality's growth should have a direct relationship to the available resources and the capacity to supply those resources for a specified amount of time. Providing alternative supply sources is not always viable. Rather, the conservation of present supplies should be the goal of a community looking to keep a healthy economy and flow of natural resources.

De Oliver (1999) found that water conservation was "very important" to 85.9 percent of Bexar County, Texas residents surveyed, while 80 percent recognized the need for year-round water conservation. Over 90 percent of those surveyed thought that conservation on an individual basis could make a difference towards community water conservation. This shows a strong social link between water and individuals. Conservation has the support to be a highly successful program, politically, but realistically old habits are hard to break. De Oliver continues in his research to find that the over-whelming support of "conservation as a policy has achieved the status of a valued aesthetic, so much so, that expressing notions to the contrary is socially undesirable. This aesthetic did not effectively translate into manifested response to a conservation program" (De Oliver 1999). However, the potential for acceptance is there. Hurd found that community awareness about how landscape options and alternatives can positively affect water use by reducing waste, "can lead to increased adoption of more water-conserving landscapes" (2006).

If implemented, residential water conservation (or individually based conservation) can make a difference. Over one-half of municipal water use can be attributed to residential use in communities with limited industrial activities (Howe and Linaweaver 1967). The watering of residential lawns is the single greatest household use of water throughout arid and semi-arid regions of the United States (Hurd 2006).

During the summer 2002 drought in Colorado, voluntary restrictions saved only 4 percent to 12 percent of use per capita, while mandatory restriction stages saved up to 56 percent in water use (Kenney et al. 2004). The level of water savings increases as the frequency of permitted watering days decline and as the time limits are tightened. Within the state of Colorado, a drought is defined as "a normal amount of moisture that is not available to satisfy an area's usual water-consuming activities" (Kenney et al. 2004). Therefore, as a population increases the measure of a drought's severity and reoccurrence increases.

Irrigation Systems

Lawn watering is the most significant residential water use; exacerbating the problem, automated systems were found to use more water than manually operated systems. A suggested reason for this relates to the associated timing devices that can be set for longer periods and more frequency than other modes of watering (Inman and Jeffrey 2006). Inman and Jeffrey were able to determine that a single-family household in Los Angeles, California with automated sprinkler systems consumed 11.2 percent more than households using a manual system (2006). These results display a direct endorsement of a moisture sensitive or strictly manual irrigation system, but indirectly support the importance of installing a low water use landscape. A large percentage of water is lost due to improper irrigation via automated systems. The flaws in these systems seem to be related to over-extending the watering duration attributed to human error.

Moisture sensitive irrigation systems ensure that watering is not prescribed during wet conditions, and is activated during a prescribed level of dryness (Goff 1995). Water waste during irrigation can be accredited to many factors, one of which is the operation of automatic irrigation systems without an operational shut-off device that accounts for soil moisture and rainfall (Pittman et al. 2004).

Residential Landscapes- Xeriscaping

"Xeros," Greek for dry or arid, combined with "landscape," creates the term "xeriscape," coined by Denver Water Company in 1981. The proper use of xeriscaping incorporates sound landscape planning and design, limitation of turfgrass to functional and appropriate areas of the lot, utilizing water efficient plants and efficient irrigation systems, soil amendments and mulch use, and appropriate landscape maintenance (Sovocool et al. 2006). Water utilities in cities such as El Paso, San Antonio, and Austin offer rebates for xeriscaping. In San Antonio, the Water-Saver Landscapes program offers a $0.10 per square foot rebate for approved landscaping; in 2001, an estimated 314 acre-feet of water at $253 per acre-foot were saved. The city of Austin operates on a credit system for high-volume users who allow for an irrigation audit of their landscape (Gerston 2002). This application of conservation can be implemented on any scale and over just about any section of irrigable area. In fact, water use has been found to have a positive correlation with irrigable area (lot size) per residence (Hanke and de Mare 1984).

Xeriscaping is essentially removing non-native, water-hungry turfgrasses and replacing them with vegetation that is able to remain healthy and withstand dry years with minimal watering. Hurd estimates that significant water savings (35% to 75% of current per capita water use based on a traditional bluegrass type landscape) can be obtained by "altering outdoor water use patterns" (2006) (Table 4, Table 5).

Table 4. Estimated annual water savings from water-efficient landscapes (Xeriscape™) in southern Nevada (Hurd 2006)

Landscape Type	**Annual Water Needs**
Newly-Planted Xeriscape	17 gallons/square foot
Mature Xeriscape with 50% coverage	22 gallons/square foot
Densely-planted with 100% coverage	25 gallons/square foot
Lawn	79 gallons/square foot
Potential Water Savings	54 gallons/square foot (nearly 70% less water than with traditional lawns) (Hurd 2006).

Table 5. Landscape types, water use, and upkeep costs (characteristics typical for New Mexico homes with 2,500 square feet of landscapable area) (Hurd 2006)

	100% Traditional Turfgrass	**½ Turfgrass and ½ water conserving**	**¼ Traditional Turfgrass and ¾ water conserving**	**no Turfgrass, 100% water conserving**
Water Use:	100,000 gallons/year	70,000 gallons/year	50,000 gallons/year	35,000 gallons/year
Water cost:	$300/year	$200/year	$150/year	$100/year
Maintenance Cost:	$1,200/year	$800/year	$500/year	$200/year
Maintenance Effort:	300 hours/year	200 hours/year	120 hours/year	50 hours/year

In addition to the obvious savings defined in the tables above, Hurd discovered that adjusting the pricing structure by raising water rates can potentially reduce water demand. Although politically unpopular, this increases the chance that individuals will implement conservation measures (2006).

Rainwater Harvesting

Rainwater harvesting is a conservation method that essentially utilizes rainwater from a collection system atop a roof for residential uses. Some Central-Texas cities have already promoted rainwater harvesting as a viable water conservation technique. The City of Austin offers up to $500 in rebates to homeowners that install rainwater harvesting equipment for landscape irrigation, while Hays County has loosened zoning density rules for homes with rainwater harvesting equipment (Gerston 2002).

Rainwater collection is a viable component of water conservation; after installing impoundments, an alumina plant in San Patricio was able to operate for 93 days following a wet spring without purchasing water from their municipal water district (Gerston 2002). Central Texas has quite a few examples of individuals and industries successfully using rainwater catchment systems as landscape irrigation sources (Table 6).

International acceptance of rainwater harvesting technology has had some success in developed countries. Along flood prone regions of the Rhine River in Germany, up to 90 percent of water saving technologies are federally subsidized, and every year approximately 100,000 new rainwater harvesting units are installed (Brunet 2005). In highly urbanized countries like Singapore and Japan, conservation groups advocate the use of modern technologies of catchment systems, and encourage subsidies to expedite further development (Thomas 1998; Murase 2003; Brunet 2005). In Australia, 17 percent of the population use rainwater harvesting equipment in some way, while 13 percent rely completely on the water collected for their daily water needs (Diaper 2004; Brunet 2005).

Table 6. Central Texas rainwater harvesting examples (Krishna 2005)

Site:	Capacity:	Catchment:	Demand:	Irrigation Usage:	# of tanks and Size: (in gallons)
H E B – Brodie Lane Austin, Texas	28,000 gallons	50,000 sq ft	Native and adapted plant landscape	100%	(2) 8,000 (2) 6,000
Municipal Utility District New Braunfels, Texas	n/a	n/a	Native and adapted plants	100%	(4) 1,000
Hays County Cooperative Extension Office San Marcos, Texas	2,350 gallons	2,500 sq ft	Demonstration garden	n/a	(1) 750 (1) 1,600
Edwards Aquifer Authority- San Antonio, Texas	2,500 gallons	1,135 sq ft	Landscaping	100%	(1) 500 (1) 2,000
J M Auld Lifetime Learning Center Kerrville, Texas	6,600 gallons	5,000 sq ft	Gardens	n/a	(2) 3,300
Menard ISD Elementary School Menard, Texas	1,000-gallon	600 square feet	Container garden and landscape	n/a	(2) 1,000
AMD/ Spansion- Austin, Texas	10,000 gallons	Facility's roof and building perimeter	Landscape	100%	(1) 10,000
Feather & Fur Animal Hospital Austin, Texas	12,500 gallons	Roof and parking lot	Turf Landscape	100%	(1) 12,500

CHAPTER III

THE COST OF WATER

Water Supply Projects

According to the Texas Water Development Board (TWDB), 78 percent of the total capital costs, or $23.9 billion, in the 2007 State Water Plan are a result of the water use of Regions C, H, and L, which comprise 62 percent of the projected population growth through 2060 (2007). Water management strategies and projects in cooperation with the TWDB within the state of Texas are established based on a Regional group. The City of Kyle is located along the northern most border of Region L (Figure 5). These groups are essentially the foundation in the development of state water plans; each group provides the TWDB with a water plan that accounts for strategies to meet regional water needs during a drought of record (TWDB 2007).

The 2007 State Water Plan cites estimates of $30.7 billion between 2007 and 2060 to fund state-wide water projects. This financial estimate is 58 percent higher than the 2002 estimation of $17.9 billion. The board states that the higher financial burden is directly related to issues revolving around "population growth, *lower volumes of existing water supply,* [emphasis added] and increased costs of construction material and fuel" (TWDB 2007).

Region L, also known as the South Central Texas Region, spans from the Gulf Coast to the Hill Country and encompasses 21 counties, including the two largest springs in Texas: the Comal and San Marcos. According to the 2007 State Water Plan, water supply projects for the region have a total capital cost of $5.2 billion between 2007 and 2060. The plan suggests the continual withdraw of aquifer water from both the Edwards and Carrizo-Wilcox to a total over 210,000 acre-feet a year, while conservation measures provide approximately 110,000 acre-feet annually. On the county scale, municipal water use in Hays County is projected to increase from 2,275 acre-feet in 2010 to 30,494 acre-feet in 2060 (TWDB 2007).

On the statewide basis, the planning groups determined the need for more than 4,500 individual water management strategies with a projected total of 9 million acre-feet annually of new water supply by 2060. However, the proposed applications are not completely viable, supplies are either not legally available or are not "physically connected" to current water infrastructure (TWDB 2007) (Table 7).

Table 7. State of Texas, Water management strategy recommendations- excluding major reservoirs, 3.3 million acre-feet per year projection of new water supply (TWDB 2007)

Management Strategy	Acre-feet per year by 2060
Municipal Water Conservation	617,000
Irrigation Conservation	1 4 million
14 new major reservoirs	1 1 million
Groundwater Reliance	800,000
Water Reuse	1 3 million
Desalination	313,000

The importance of water conservation strategies is generated from the reduction in capital cost associated with the measures. Ten percent of the total volume of water produced by recommended strategies is related to water conservation measures in Region L, and the costs needed to implement municipal water programs is relatively small only $9.9 million, with a statewide average of $254 per acre-foot.

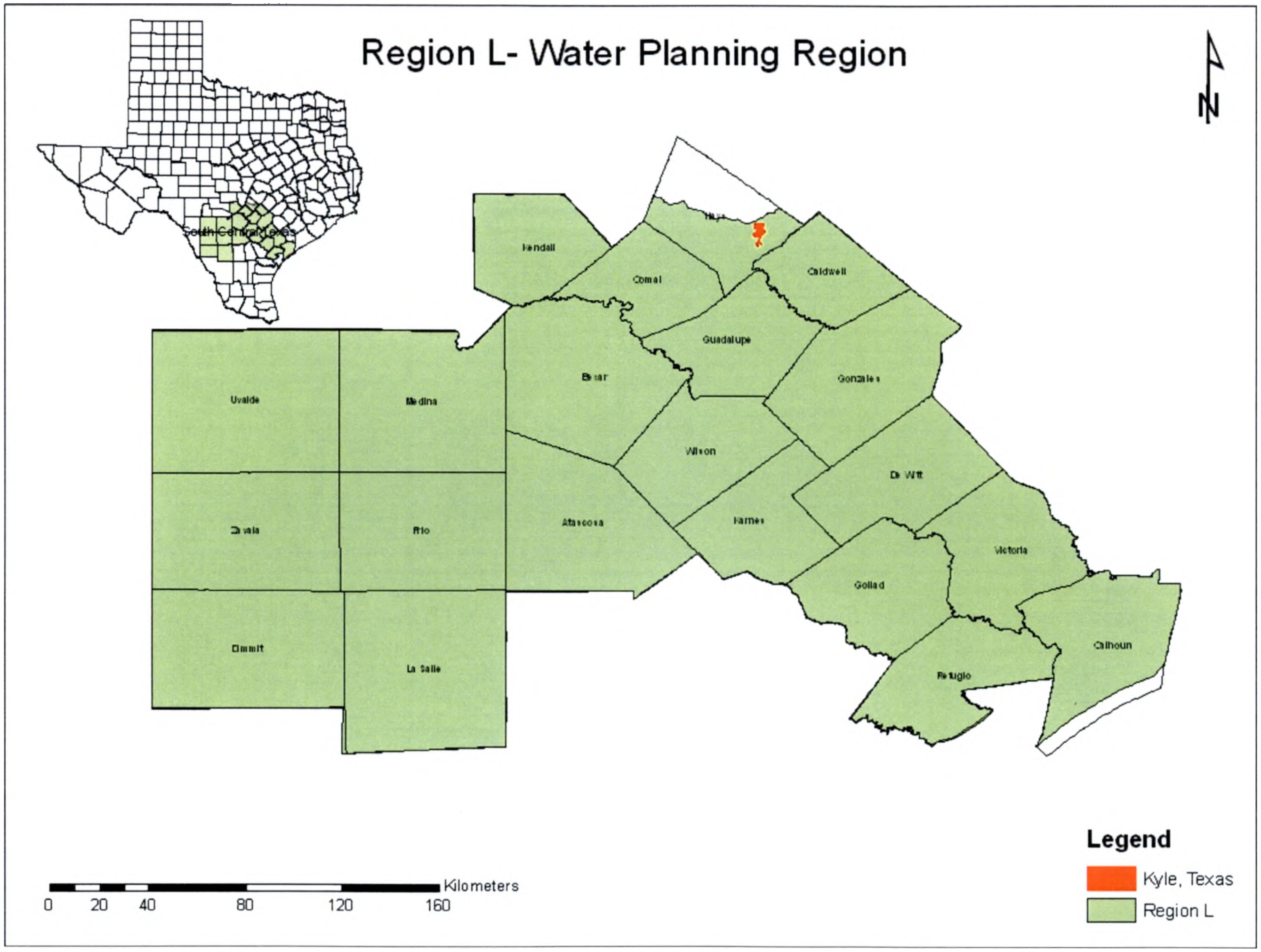

Figure 5. Regional L water planning group and the City of Kyle

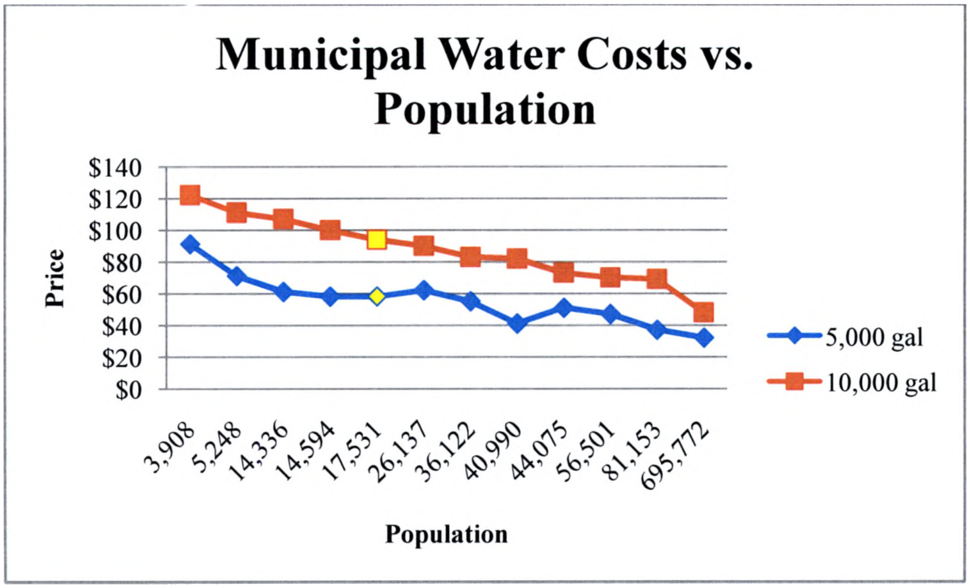

Figure 6. Increases in population show a relationship to a decrease in price (yellow markers represent Kyle, Texas data) (cityofkyle.com 2007)

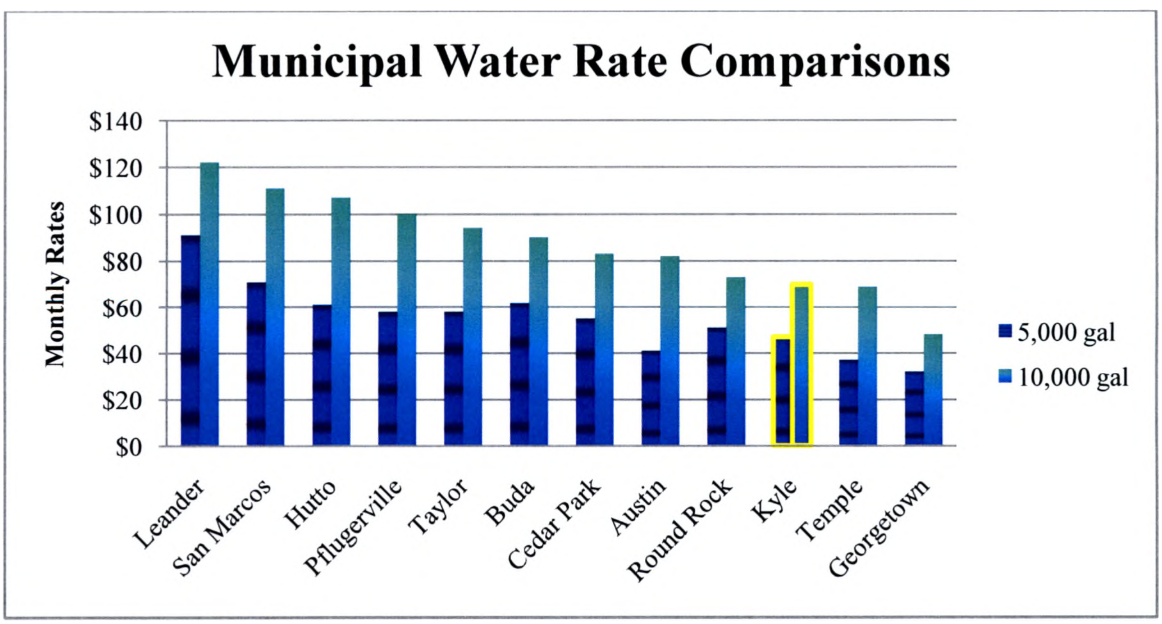

Figure 7. Regional municipal water rates comparison (cityofkyle.com 2007)

Municipal Water Rates

There are some disparities among municipal water rates within the region; a brief analysis reveals a price correlation between rates and population. As the population numbers increase, the price of water decreases (Figure 6, note: yellow markers represent Kyle). The price structure specifically for the City of Kyle appears to be on the lower end of the price range, and is in line with the other municipalities and their water rates (Figure 7). Kyle offers its residents a newly proposed pricing plan, initiated in 2007. The plan offers a total monthly rate of $47 for the first 5,000 gallons and $70 for usage in excess of 10,000 gallons (ciyofkyle.com 2008) (Table 8).

The analysis offers an investigation of municipalities as far north of Kyle as Temple and as far south as San Marcos. These findings are preliminary and an in-depth review of Central Texas water rate structure is beyond the scope of this research. However, a brief look into the price of water offers an idea of what current Central Texas residents are paying, and what effects conservation will have on the price. A cursory look at the data provided also shows a correlation between price and usage (Figure 8). As the price declines the gallons per capita per day use increases. The increase in rates with the increase in consumption could be an effective water conservation measure.

Table 8. Regional water rates, source, population, and 2004 water use amounts (cityofkyle.com 2007; TWDB 2007)

			Residential Water		Residential Sewer		Total Residential		2004 Water Use	
City	2005 population	Water Source(s)	5,000 gal	10,000 gal	5,000 gal	10,000 gal	5,000 gal	10,000 gal	Municipal (ac ft)	GPCD†
Leander	14,594	SW*	$59	$77	$32	$45	$91	$122	2,282	149
San Marcos	44,075	GW**/SW	$29	$50	$42	$61	$71	$111	6,030	124
Hutto	5,248	GW/SW	$33	$56	$28	$51	$61	$107	503	100
Pflugerville	26,137	SW/GW	$36	$59	$22	$41	$58	$100	3,675	130
Taylor	14,336	SW	$27	$44	$31	$50	$58	$94	2,403	151
Buda	3,908	SW/GW	$19	$31	$43	$59	$62	$90	530	131
Cedar Park	40,990	SW	$25	$40	$30	$43	$55	$83	7,434	168
Austin	695,772	SW	$13	$26	$28	$56	$41	$82	131,249	170
Round Rock	81,153	SW/GW	$26	$36	$25	$37	$51	$73	19,232	211
Kyle	17,531	SW/GW	$29	$43	$18	$27	$47	$70	1,895	120
Temple	56,501	SW	$17	$30	$20	$39	$37	$69	12,720	202
Georgetown	36,122	SW/GW	$16	$24	$16	$24	$32	$48	6,723	170

* SW – surface water
** GW – groundwater
† GPCD – gallons per capita daily

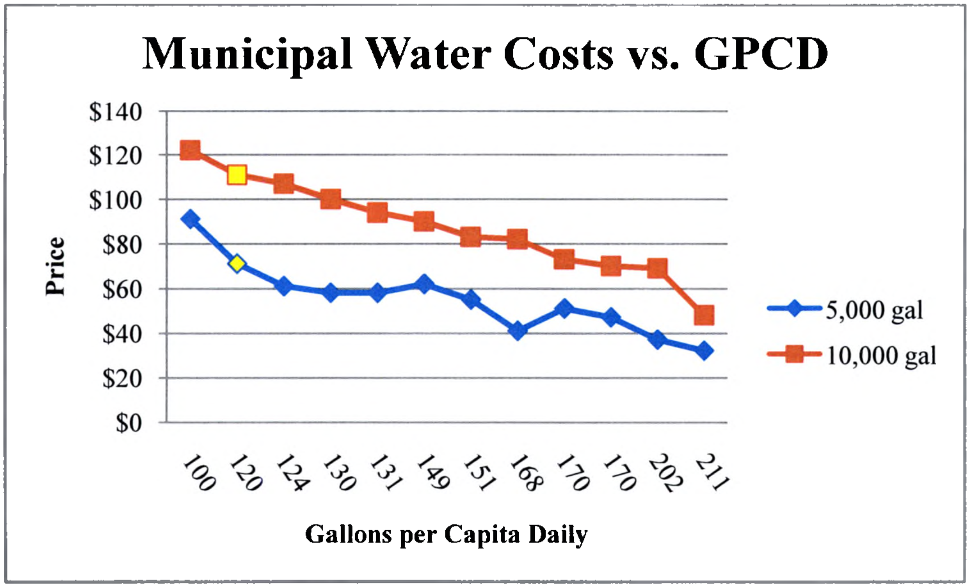

Figure 8. Increase in price relates to a decrease in consumption (cityofkyle.com 2007; TWDB 2007)

CHAPTER IV

WATER SUPPLY FOR KYLE, TEXAS AND THE EDWARDS AQUIFER AUTHORITY

Water Supply

The City of Kyle currently obtains their water from three sources: Barton Springs/Edwards Aquifer Authority (BSEAA – Groundwater), Edwards Aquifer Authority (EAA – Groundwater), and the Guadalupe-Blanco River Authority (GBRA – Surface Water). Between 2004 and 2007, Kyle received over 553 acre-feet annually from the BSEAA, approximately 1,130 acre-feet annually from the EAA, and over 907 acre-feet each year from the GBRA (Tobias 2007). Future water supply options will depend on these three, in addition to resources outside the region. Viable options, outside of conservation, could range from desalination to the utilization of the new water supply infrastructure projects proposed by the 2007 State Water Plan (TWDB 2007).

Presently, there are no recommended major or minor reservoirs within the region, which means that the water plan for Region L and the City of Kyle must look beyond its boundaries for new water resources. The best management practice would be to properly utilize the resources available in an equitable fashion, which will require conservation methods and reuse technologies.

The Edwards Aquifer Authority

Over the span of three years, Kyle withdrew more than 3,000 acre-feet from the Edwards Aquifer. With such heavy extraction, it would be remiss not to discuss the legislative framework of the entities residing over the aquifer. Dating back to the 1800s, groundwater was labeled "mysterious and occult," the belief was that groundwater and surface water were not connected (Kaiser 1987). There were distinct regulatory differences between surface and groundwater; surface water belonged to the state, groundwater belonged to anyone whose land was above it. Surface water use was permitted as a prior appropriation action ("first in time, first in right"), while ground water use was the "rule of capture" (Votteler 1998; Eckhardt 2008). After the 1950s drought, the Edwards Underground Water District was created. This body, which had no authority to restrict groundwater pumping, was given the task of protecting the resource by maintaining data records of the aquifer level fluctuations and other groundwater related reports (Eckhardt 2008).

In May 1993, the Edwards Aquifer Authority replaced the Edwards Underground Water District under Senate Bill 1477. The new agency was given regulatory authority in the act of issuing permits, regulating groundwater withdraws, and capping permits at 450,000 acre-feet annually, and a reduction in 2008 to 400,000 acre-feet (Eckhardt 2008; EAA 2008). Litigation over the elected versus appointed board members postponed the regulatory powers of the EAA until June 1996. The EAA now maintains the power to "manage, conserve, preserve, and protect the Aquifer, increase recharge, and reduce waste" (Eckhardt 2008).

CHAPTER V

METHODOLOGY

An accurate assessment of water conservation measures within a growing population requires the consideration of a number of factors. The relationship between population growth rates and projected water demand were defined to estimate the projected water usage and projected strain on current water supplies. In assessing the various conservation measures three specific practices were analyzed- xeriscaping, rainwater harvesting, and the installation of moisture sensitive sensors on lawn irrigation systems. For all these analyses, the mean monthly precipitation at San Marcos, the nearest weather reporting station with a long term climate record, was employed in the calculations (Table 2).

Irrigable Area

When applying xeriscaping and moisture sensitive irrigation, an irrigable area is needed. The irrigable area is defined as the area of the lawn that is available for landscape. Essentially, the house layout, driveways, and sidewalks are all subtracted from the total lot size to acquire an irrigable area. Each percentile range has an associated irrigable area, which accounts for the varying sizes of non-landscapeable surfaces.

Xeriscaping

To properly prescribe the conservation effectiveness of xeriscaping, an average lot size within the City of Kyle was derived using data from a host of sources. Information from various real estate agencies, developers, and city officials was used to ascertain the average square footage for residential landscapes. Based on analysis performed on experimental xeriscapes, the average savings per square foot of xeriscaping was applied to the average square foot of irrigable area. The experimental landscapes were portrayed within a model utilizing crop factors (*CF*), irrigation efficiency (*IE*), evapotranspiration (ET_O), and precipitation data (*P*). (*Eq 1*) From this, an estimation was derived to offer the amount of water conserved using xeriscaping as opposed to mesiscaping (traditional turfgrasses) (Greenbuilder.com 2006; Ponce 2008).

Eq 1

$$ET_O * CF = ET_L$$
$$ET_L - P = ID$$
$$ID / IE = \text{Water Demand (in)}$$

ET_O = Evapotranspiration
CF = Crop Factor
ET_L = Landscape Evapotranspiration
P = Precipitation
ID = Irrigation Demand
IE = Irrigation Efficiency

Rainwater Harvesting

Rainwater harvesting analysis involved strictly non-potable water to reduce the price factor; rainwater-filtering systems significantly add to the overall cost of the project and are unnecessary if the water is used only for lawn irrigation. The average roof size (r) was essentially determined by using the average square footage of floor plans and multiplying that by a coefficient of 0.8 to adjust for multiple storied houses (Brunet 2005). The roof size was then multiplied by monthly rainfall (p) and converted to gallons. (*Eq 2*)

Eq 2

$$h = r * 0.8 * p * 0.62$$

h = rainwater harvested (gallons)
r = roof size in ft^2
0.8 = collection efficiency rate
p = monthly rainfall (inches)
0 62 = conversion to gallons (TWDB 2005)

Approximately 0.62 gallons per square foot of catchment area per inch of rainfall can be captured over the catchment area of the roof. This collection surface is called the "footprint," and regardless of the pitch of the roof, the surface area is essentially a length times width (eave to eave and front to rear) measurement (Krishna 2005). The overall amount of water collected was assumed to be utilized only for landscape irrigation.

<u>Moisture Sensitive Irrigation</u>

Irrigation effectiveness was determined by using the average amount of water use for lawn irrigation based on average lot size and the number of wet periods vs dry periods. Moisture sensitive systems permit irrigation only during dry periods and shut off irrigation when the ground is wet. Based on data from the U. S. National Climatic Data Center, a certain number of days of precipitation per year was assigned to determine the number of days that would not need irrigation. Therefore, setting the irrigation system to operate during only times when water is actually needed, eliminated over-watering. The number of days that irrigation was prevented was a function of the number of days of precipitation and the potential evapotranspiration by the Penman method (Ponce 2008).

For the coolest six months, irrigation was cancelled on days with more than 0.10 inches of precipitation and during the warmer months on days greater than 0.25 inches. (*Eq 3* and *Eq 4*) For each equation, an average of the precipitation values (0.1 inches and 0.5 inches for *x*, 0.5 inches and 1 inch for *y*, 1 inches and 2 inches for *z*) was taken then divided by the threshold value of 0.1 for cooler months and 0.25 for warmer months. That value was then multiplied by the difference in the days between the precipitation values, which resulted in the total number of days for the associated precipitation value. Adding the values derived for *X*, *Y*, and *Z* will result in total days of precipitation.

Eq 3- cooler months

x = # of days $\geq$ 0.10	$((0.1 + 0.5) / 2) / 0.1(x - y) = X$
y = # of days $\geq$ 0.50	$((0.5 + 1) / 2) / 0.1(y - z) = Y$
z = # of days $\geq$ 1.00	$((1 + 2) / 2) / 0.1(z) = Z$
d = Total days of precipitation	$X + Y + Z = d$

Eq 4- warmer months

x = # of days $\geq$ 0.10	$((0.1 + 0.5) / 2) / 0.25(x - y) = X$
y = # of days $\geq$ 0.50	$((0.5 + 1) / 2) / 0.25(y - z) = Y$
z = # of days $\geq$ 1.00	$((1 + 2) / 2) / 0.25(z) = Z$
d = total days of precipitation	$X + Y + Z = d$

The methods associated with this project relate to the characteristics of the environment in which it occurs and will continue to undergo scrutiny and careful observation, as all methods have inherent limitations, errors, or hindrances. The most pragmatic approach to dealing with adverse factors in research is to be prepared, and articulate early in the project what provisions are appropriate in regards to management adjustments. Procedures of assessing validity, repeatability, reliability, and locational facts in measurement characteristics are the first step in analyzing a methodological approach.

CHAPTER VI

RESULTS

The results of this research were guided by the procedures described in Chapter V; the variables established are based on averages and percentile assignments. For instance, when computing the rainwater harvesting outcomes, an average home size in square feet was determined along with 25th percentile, 50th percentile, and the 75th percentile assumptions. When formulating outputs for the conservation methods of moisture sensitive irrigation and xeriscaping, an average, the 25th, the 50th, and the 75th percentile based on irrigable area in square feet were also processed.

In each conservation method, the housing population was needed. Using 2000 and 2006 census data, an estimation of housing units was acquired. The 2006 population was 20,655 (TWDB 2007) and 90 percent of Kyle residents lived in single-family residences (US Census Bureau 2007). Therefore, 18,590 people live in 5,773 housing units with an average 3.22 household size in Kyle, Texas (US Census Bureau 2007). For each percentile the associated water savings are computed with a fraction of the total housing units in Kyle. A percentile, in this study, only represents a fourth of the total sample, so a fourth of the total was assumed as the number of homes associated with that particular lot or home size. Essentially, 1,443.25 homes were used to compute the 25th, 50th, and 75th percentile values (Table 9).

Table 9. Sample housing size ranges for Kyle, Texas (trulia.com 2007; Moore 2008; Whisenant 2008)

Housing Size for Kyle, Texas (sq. ft.)								
Average:	1,073	1,439	1,683	1,863	2,010	2,340	2,596	2,918
2,159	1,088	1,449	1,699	1,907	2,010	2,340	2,604	2,918
25th percentile:	1,096	1,464	1,721	1,909	2,043	2,343	2,604	2,928
1,683	1,102	1,471	1,741	1,910	2,050	2,362	2,633	2,992
50th percentile:	1,150	1,502	1,743	1,915	2,061	2,362	2,658	3,071
2,007	1,176	1,504	1,750	1,915	2,099	2,365	2,659	3,110
75th percentile:	1,186	1,508	1,761	1,918	2,100	2,374	2,700	3,119
2,595	1,250	1,514	1,763	1,922	2,106	2,374	2,702	3,126
	1,252	1,550	1,766	1,943	2,106	2,400	2,724	3,150
	1,273	1,560	1,771	1,943	2,109	2,402	2,753	3,167
	1,281	1,561	1,771	1,944	2,172	2,406	2,754	3,224
	1,290	1,561	1,771	1,954	2,188	2,439	2,756	3,257
	1,296	1,564	1,773	1,954	2,190	2,450	2,776	3,264
	1,296	1,566	1,778	1,968	2,223	2,478	2,784	3,284
	1,322	1,567	1,822	1,974	2,260	2,501	2,786	3,300
	1,330	1,575	1,828	1,991	2,277	2,501	2,806	3,300
	1,332	1,606	1,831	1,991	2,287	2,531	2,819	3,304
	1,344	1,621	1,843	1,991	2,298	2,552	2,827	3,312
	1,352	1,627	1,843	1,998	2,300	2,554	2,828	3,366
	1,378	1,629	1,844	2,000	2,300	2,554	2,830	3,374
	1,378	1,638	1,844	2,002	2,318	2,564	2,837	3,596
	1,387	1,642	1,850	2,002	2,326	2,564	2,845	3,838
	1,395	1,659	1,853	2,002	2,331	2,594	2,845	4,021
	1,412	1,683	1,857	2,003	2,336	2,594	2,853	4,434

Rainwater Harvesting

When the rainwater harvesting water conservation technique was applied to the City of Kyle the results displayed a high level of water conservation. The analysis computed results for the average size home of 2,159 sq. ft., in addition to the homes that fall in the range of the 25th percentile (1,683 sq. ft.), the 50th percentile (2,007 sq. ft.), and the 75th percentile (2,595 sq. ft.).

Using 2,159 sq. ft. as the roof size multiplied by a collection efficiency rate of 0.8 (which also accounts for two-storied homes), multiplied by the average annual precipitation, and multiplied by a conversion rate to gallons of 0.62, the average size home in Kyle has the potential to collect 38,894 gallons each year with a monthly average of 3,241 gallons (Table 11). Using the same formula, but exchanging the home sizes according to the associated percentile range, collection per home size were derived. Homes in the 25th percentile are 1,683 sq. ft. and can collect up to 29,616 gallons annually. Homes in the 50th percentile range are 2,007 sq. ft. and have the potential to collect 35,317 gallons annually, and homes in the 75th percentile are 2,595 sq. ft. and can collect up to 45,664 gallons annually. Along with the annual harvest, the total number of acre-feet of water saved for the entire housing population of Kyle is computed with the associated percentage of the total municipal water use (2,350 acre-feet) potentially saved (Table 10). On average, the City of Kyle has the potential to reduce their mean annual total municipal water consumption by 29 percent if rainwater harvesting is initiated.

Table 10. Average monthly and percentile breakdown for rainwater harvesting

January		
Monthly Rainfall (in):	Monthly Harvest (gal):	
2.23	2,388	Average
	1,861	1st
	2,220	2nd
	2,870	3rd
February		
Monthly Rainfall (in):	Monthly Harvest (gal):	
2.06	2,202	Average
	1,717	1st
	2,047	2nd
	2,647	3rd
March		
Monthly Rainfall (in):	Monthly Harvest (gal):	
2.18	2,336	Average
	1,821	1st
	2,172	2nd
	2,808	3rd
April		
Monthly Rainfall (in):	Monthly Harvest (gal):	
2.28	2,441	Average
	1,903	1st
	2,269	2nd
	2,934	3rd
May		
Monthly Rainfall (in):	Monthly Harvest (gal):	
4.74	5,073	Average
	3,954	1st
	4,716	2nd
	6,097	3rd

Table 10. Cont.

June		
Monthly Rainfall (in):	Monthly Harvest (gal):	
5.22	5,588	Average
	4,356	1st
	5,194	2nd
	6,716	3rd
July		
Monthly Rainfall (in):	Monthly Harvest (gal):	
2.12	2,265	Average
	1,766	1st
	2,106	2nd
	2,723	3rd
August		
Monthly Rainfall (in):	Monthly Harvest (gal):	
2.22	2,380	Average
	1,855	1st
	2,212	2nd
	2,860	3rd
September		
Monthly Rainfall (in):	Monthly Harvest (gal):	
3.56	3,810	Average
	2,970	1st
	3,542	2nd
	4,579	3rd
October		
Monthly Rainfall (in):	Monthly Harvest (gal):	
4.15	4,440	Average
	3,461	1st
	4,128	2nd
	5,337	3rd
November		
Monthly Rainfall (in):	Monthly Harvest (gal):	
3.21	3,436	Average
	1,976	1st
	2,356	2nd
	3,046	3rd
December		
Monthly Rainfall (in):	Monthly Harvest (gal):	
2.37	2,534	Average
	1,976	1st
	2,356	2nd
	3,046	3rd

Table 11. Rainwater harvest totals for Kyle, Texas: average monthly precipitation

Average:
Annual Harvest (gal):
38,894
ac. ft/yr harvested for all of Kyle
689
% of Total Municipal Water Use
29%

25th Percentile:
Annual Harvest (gal):
29,616

50th Percentile:
Annual Harvest (gal):
35,317

75th Percentile:
Annual Harvest (gal):
45,664

Rainwater Harvesting: Variations in Precipitation

As previously noted, the South-Central region of Texas is known for its variation in precipitation patterns. When assessing water supply issues and conservation habits, there is a necessity to discuss the fluctuation in precipitation on a month to month basis. Using the San Marcos, Texas precipitation data from the National Climatic Data Center (NCDC), the 25th and 75th percentile ranges were derived for each month. The rainwater harvesting method utilized above employed a monthly average for defining possible water savings. Below are the results using the same calculations with drier monthly averages (25th percentile) and wetter monthly averages (75th percentile) (Table 12).

Table 12. 25th and 75th percentile precipitation probabilities (U.S. National Climatic Data Center 2004)

	Percentile:	
Month	25th	75th
January	0.73	2.86
February	0.75	3.10
March	0.84	2.90
April	1.11	3.96
May	2.54	7.22
June	2.23	6.60
July	0.27	3.01
August	0.56	3.72
September	1.61	4.73
October	1.06	5.67
November	1.10	4.44
December	0.74	3.40
Year:	13.52	51.59

The precipitation totals falling in the 25th percentile show a decline in harvesting estimates, while values within the 75th percentile show an increase in harvesting capabilities (Table 13 – 16). Based on average house size, a 63 percent decrease in annual harvesting capabilities is associated with the precipitation values at the 25th percentile range, and a 42 percent increase in harvesting estimates with precipitation values at the 75th percentile. In other words, the average home with average monthly rainfall collects 38,894 gallons annually, while months that are significantly drier catch only 14,499 gallons, and wetter months can collect 55,267 gallons. As the home size decreases the collection rate also decreases; conversely, as the home size increases the collection rate increases (Table 13 – 16).

Table 13. 25th percentile precipitation probability and associated harvesting capabilities

January		
Monthly Rainfall (in):	Monthly Harvest (gal):	Home: (sq.ft)
0.73	782	Average
	609	25th %
	727	50th %
	940	75th %
February		
Monthly Rainfall (in):	Monthly Harvest (gal):	
0.75	803	Average
	626	25th %
	747	50th %
	965	75th %
March		
Monthly Rainfall (in):	Monthly Harvest (gal):	
0.84	900	Average
	701	25th %
	836	50th %
	1,081	75th %
April		
Monthly Rainfall (in):	Monthly Harvest (gal):	
1.11	1,189	Average
	927	25th %
	1,105	50th %
	1,429	75th %
May		
Monthly Rainfall (in):	Monthly Harvest (gal):	
2.54	2,720	Average
	2,120	25th %
	2,528	50th %
	3,269	75th %
June		
Monthly Rainfall (in):	Monthly Harvest (gal):	
2.23	2,388	Average
	1,862	25th %
	2,220	50th %
	2,870	75th %

Table 13. Cont'd.

July		
Monthly Rainfall (in):	Monthly Harvest (gal):	Home: (sq.ft)
0.27	289	Average
	225	25th %
	269	50th %
	348	75th %
August		
Monthly Rainfall (in):	Monthly Harvest (gal):	
0.56	600	Average
	467	25th %
	557	50th %
	721	75th %
September		
Monthly Rainfall (in):	Monthly Harvest (gal):	
1.61	1,724	Average
	1,344	25th %
	1,603	50th %
	2,072	75th %
October		
Monthly Rainfall (in):	Monthly Harvest (gal):	
1.06	1,135	Average
	885	25th %
	1,055	50th %
	1,364	75th %
November		
Monthly Rainfall (in):	Monthly Harvest (gal):	
1.10	1,178	Average
	618	25th %
	737	50th %
	952	75th %
December		
Monthly Rainfall (in):	Monthly Harvest (gal):	
0.74	792	Average
	618	25th %
	737	50th %
	952	75th %

Table 14. Rainwater harvest totals for Kyle, Texas: 25th percentile monthly precipitation

Average:
Annual Harvest (gal):
14,499
ac. ft/yr harvested for all of Kyle
257
% of Total Municipal Water Use
11%

25th Percentile:
Annual Harvest (gal):
11,002

50th Percentile:
Annual Harvest (gal):
13,120

75th Percentile:
Annual Harvest (gal):
16,964

Table 15. 75th percentile precipitation probability and associated harvesting capabilities

January		
Monthly Rainfall (in):	Monthly Harvest (gal):	Home: (sq.ft)
2.86	3,063	Average
	2,387	25th %
	2,847	50th %
	3,681	75th %
February		
Monthly Rainfall (in):	Monthly Harvest (gal):	
3.10	3,320	Average
	2,588	25th %
	3,086	50th %
	3,990	75th %
March		
Monthly Rainfall (in):	Monthly Harvest (gal):	
2.90	3,106	Average
	2,421	25th %
	2,887	50th %
	3,733	75th %
April		
Monthly Rainfall (in):	Monthly Harvest (gal):	
3.96	4,241	Average
	3,306	25th %
	3,942	50th %
	5,097	75th %
May		
Monthly Rainfall (in):	Monthly Harvest (gal):	
7.22	7,732	Average
	6,027	25th %
	7,187	50th %
	9,293	75th %
June		
Monthly Rainfall (in):	Monthly Harvest (gal):	
6.60	7,068	Average
	5,509	25th %
	6,570	50th %
	8,495	75th %

Table 15. Cont'd

July		
Monthly Rainfall (in):	Monthly Harvest (gal):	Home: (sq.ft)
3.01	3,223	Average
	2,513	25th %
	2,996	50th %
	3,874	75th %
August		
Monthly Rainfall (in):	Monthly Harvest (gal):	
3.72	3,984	Average
	3,105	25th %
	3,703	50th %
	4,788	75th %
September		
Monthly Rainfall (in):	Monthly Harvest (gal):	
4.73	5,065	Average
	3,948	25th %
	4,709	50th %
	6,088	75th %
October		
Monthly Rainfall (in):	Monthly Harvest (gal):	
5.67	6,072	Average
	4,733	25th %
	5,644	50th %
	7,298	75th %
November		
Monthly Rainfall (in):	Monthly Harvest (gal):	
4.44	4,755	Average
	2,838	25th %
	3,385	50th %
	4,376	75th %
December		
Monthly Rainfall (in):	Monthly Harvest (gal):	
3.40	3,641	Average
	2,838	25th %
	3,385	50th %
	4,376	75th %

Table 16. Rainwater harvest totals for Kyle, Texas: 75th percentile monthly precipitation

Average:
Annual Harvest (gal):
55,267
ac. ft/yr harvested for all of Kyle
979
% of Total Municipal Water Use
42%

25th Percentile:
Annual Harvest (gal):
42,214

50th Percentile:
Annual Harvest (gal):
50,341

75th Percentile:
Annual Harvest (gal):
65,090

Irrigable Area

The results for irrigable area were determined by subtracting house size from the sum of the square feet of driveway and sidewalk space. For the average lot size in Kyle the irrigable area was 3,095 sq. ft., (Figure 9) lot sizes in the 25th, 50th, and 75th percentile range had an irrigable area of 2,513 sq. ft., 3,268 sq. ft., and 3,759 sq. ft., respectively (Figure 10 – 12).

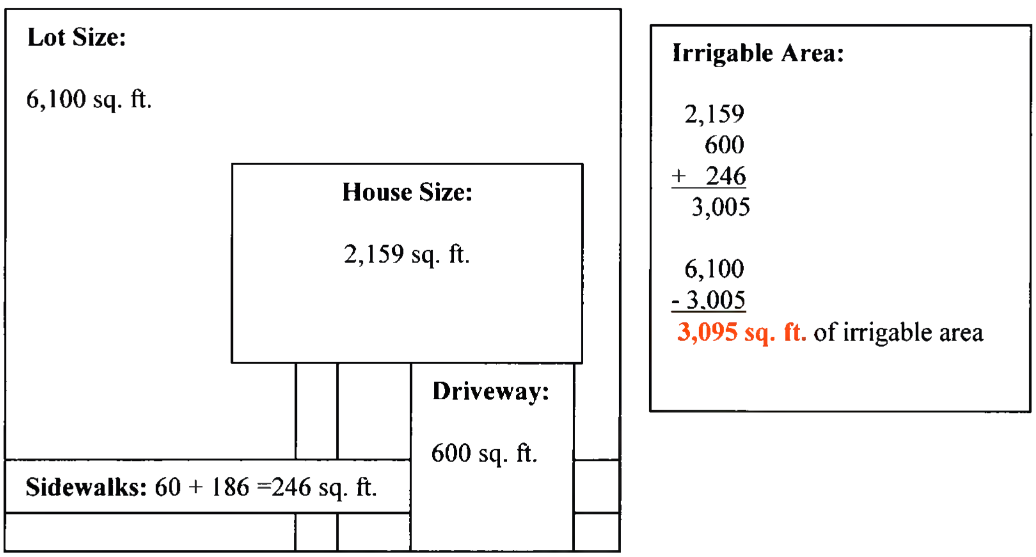

Figure 9. Average irrigable area calculations and diagram

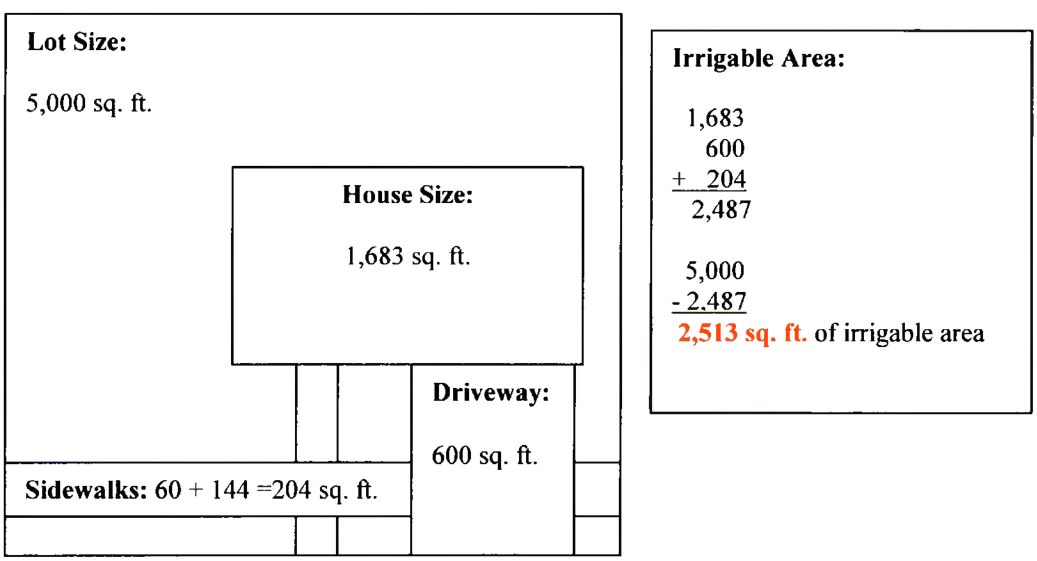

Figure 10. 25th percentile irrigable area calculations and diagram

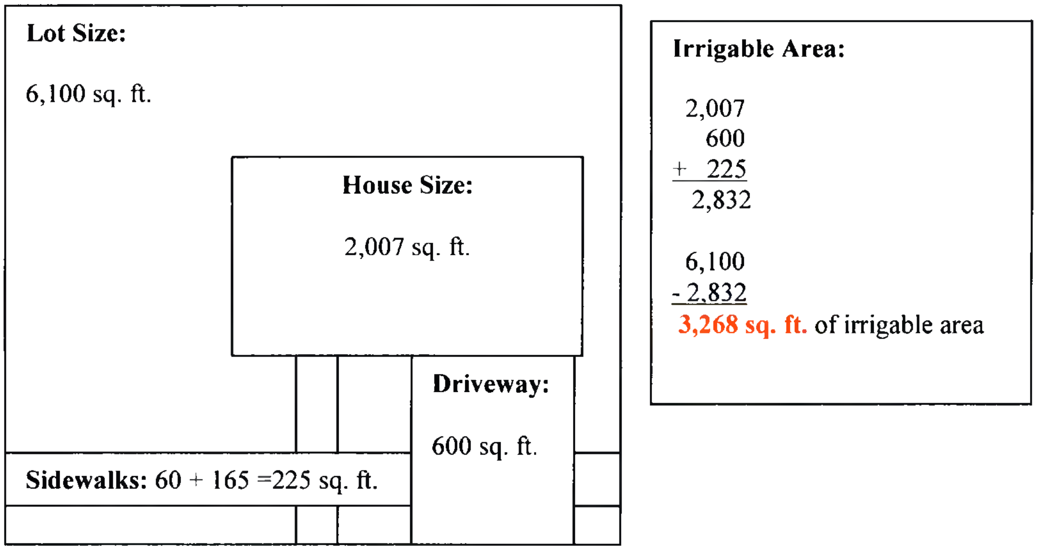

Figure 11. 50th percentile irrigable area calculations and diagram

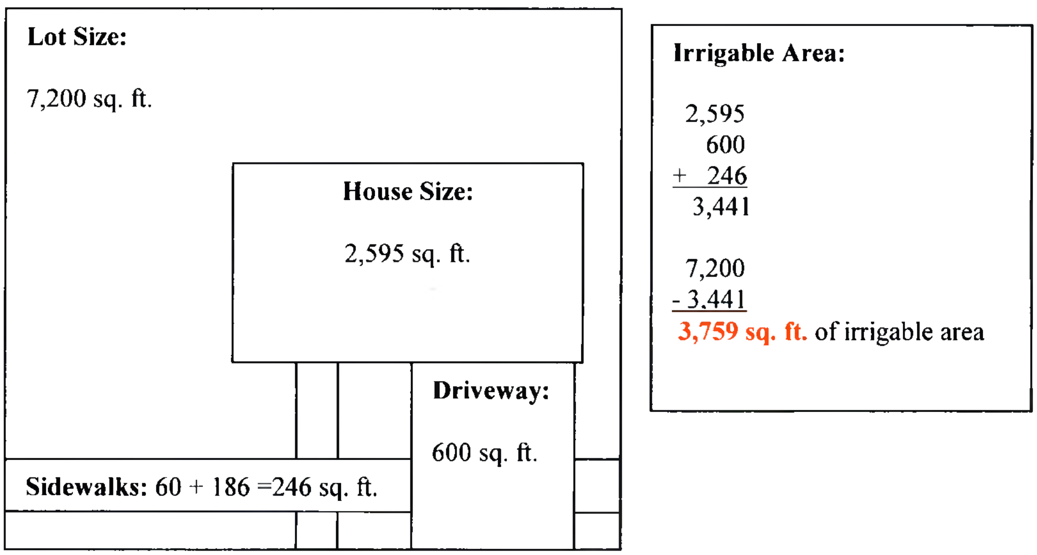

Figure 12. 75th percentile irrigable area calculations and diagram

Moisture Sensitive Irrigation

Based on the average irrigable area for Kyle, over 1,000 acre-feet, or 44 percent of the total municipal water use, could be conserved annually if moisture sensitive irrigation systems are installed on a citywide basis. The percentile ranges were applied to

1,443.25 homes to adjust for the sample size. With universal application, homes in the 25th percentile had the potential of saving over 207 acre-feet annually (9% of the total municipal water use), 50th percentile homes could save over 270 acre-feet (12%), and the 75th percentile homes could save over 310 acre-feet (13%). On an individual basis, average homes would save 57,799 gallons, 25th percentile homes would save 46,930 gallons, 50th percentile would save 61,030 gallons, and 75th percentile would save 70,200 gallons (Table 17).

The cooler months have a cancellation factor of 0.10 inches of precipitation and the warmer months 0.25 inches. Cancellation factors were derived from evapotranspiration rates associated with both cooler and warmer months. Cooler months have less evapotranspiration which require less precipitation for saturation. Warmer months have more evapotranspiration and require more precipitation for saturation. The cooler months (November through April) took the average between 0.1 and 0.5 inches for the number of days $\geq$ 0.10 inches, then divided by the precipitation threshold factor of 0.10 inches, then multiplied by the difference in days between 0.10 inches of rainfall and 0 50 inches. For the number of days $\geq$ 0.50 inches, 0.5 and 1 inches of precipitation were averaged and divided by the threshold, and multiplied by the difference in days between 0.50 inches and 1 inch. Finally, for the number of days $\geq$ 1.00 inches of rainfall, 1 inch and 2 inches of rainfall were averaged and divided by the threshold. Adding all three values derived the total number of days of precipitation for each month. The process for the warmer months was the same, except the precipitation threshold was 0.25 inches (Table 18 – 19).

Table 17. Moisture sensitive irrigation results

Moisture Sensitive Irrigation:					
	Average:	25^{th} Percentile:	50^{th} Percentile:	75^{th} Percentile:	Average Days:
House size:	2,159	1,683	2,007	2,595	18.81
Lot size:	6,100	5,000	6,100	7,200	Total Days:
Driveway/Sidewalk:	846	804	825	846	226
	Irrigable Area (sq. ft)	Saved gallons[*ψ]	Individually-based savings	% Municipal Water Use	Days of irrigation:
1) Average:	3,095	333,675,540	57,799.33	44%	139
2) 25^{th} Percentile:	2,513	67,732,361	46,930.44		Annual gal/ft^2 Saved
3) 50^{th} Percentile:	3,268	88,081,718	61,030.12		18.68
4) 75^{th} Percentile:	3,759	101,315,537	70,199.58		

Table 18. Month by month calculations for moisture sensitive irrigation: cool months

Cool Months:	Nov. - April			Days with No Irrigation Needed:	Days of irrigation:	gal/ft^2
Nov. Precip.	30	Precip Max:	Days:			
0.1	# days ≥	4.2	6.60			
0.5	# days ≥	2	9.00			
1	# days ≥	0.8	12.00	28	2	0.15
Dec. Precip.	31					
0.1	# days ≥	4	8.10			
0.5	# days ≥	1.3	4.50			
1	# days ≥	0.7	10.50	23	8	0.49
Jan. Precip.	31					
0.1	# days ≥	4.4	9.00			
0.5	# days ≥	1.4	7.50			
1	# days ≥	0.4	6.00	23	9	0.53
Feb. Precip.	28					
0.1	# days ≥	4	7.50			
0.5	# days ≥	1.5	6.75			
1	# days ≥	0.6	9.00	23	5	0.30
March Precip.	31					
0.1	# days ≥	4.5	9.60			
0.5	# days ≥	1.3	6.00			
1	# days ≥	0.5	7.50	23	8	0.49
April Precip.	30					
0.1	# days ≥	4.3	6.60			
0.5	# days ≥	2.1	9.00			
1	# days ≥	0.9	13.50	29	1	0.06

Table 19. Month by month calculations for moisture sensitive irrigation: warm months

Warm Months:	May - Oct.			Days with No Irrigation Needed:	Days of irrigation:	gal/ft²
May Precip.	31	Precip Max:	Days:			
0.1	# days ≥	6.3	3.60			
0.5	# days ≥	3.3	4.50			
1	# days ≥	1.8	10.80	**19**	**12**	**1.89**
June Precip.	30					
0.1	# days ≥	5.7	3.12			
0.5	# days ≥	3.1	5.10			
1	# days ≥	1.4	8.40	**17**	**13**	**2.09**
July Precip.	31					
0.1	# days ≥	3.1	2.28			
0.5	# days ≥	1.2	1.80			
1	# days ≥	0.6	3.60	**8**	**23**	**3.63**
Aug. Precip.	31					
0.1	# days ≥	3.5	2.40			
0.5	# days ≥	1.5	2.10			
1	# days ≥	0.8	4.80	**9**	**22**	**3.38**
Sept. Precip.	30					
0.1	# days ≥	4.9	3.72			
0.5	# days ≥	1.8	2.70			
1	# days ≥	0.9	5.40	**12**	**18**	**2.83**
Oct. Precip.	31					
0.1	# days ≥	4.9	3.48			
0.5	# days ≥	2	2.70			
1	# days ≥	1.1	6.60	**13**	**18**	**2.84**

Xeriscaping

The use of drought resistant and native species has been proven to effectively lower water demand for residential landscape needs. This study keeps with those findings and provides positive results in lowering water demand based on vegetation type. A key variable in the model was the crop factor and the species' associated drought tolerance; the lower the crop factor the higher the drought tolerance (Table 20). Tolerance was established from studies performed by the U.S. Department of Agriculture, while the crop factor analysis and application was derived from a study performed by the University of California and the state's Water Resources Department (Costello et al. 2000; US Department of Agriculture 2008).

For each calculated estimation of savings, an annual potential evapotranspiration of 88 inches was multiplied by a crop factor ranging from 0.1 to 0.9 to derive landscape evapotranspiration (Table 20). The landscape evapotranspiration was then subtracted from the total annual precipitation, which gives the irrigation demand. The irrigation demand is then divided by an irrigation efficiency of 0.8, which provides the water demand for the lawn in inches. The water demand divided by 12 and multiplied by 7.48 provides a simple conversion to gallons per square foot.

Table 20. Drought tolerance and crop factor (Costello et al. 2000; USDA 2008)

Drought Tolerance:	Crop Factor:
Buffalo grass HIGH	0.1 - 0.3
Zoysia HIGH	0.1 - 0.3
Bahia grass HIGH	0.1 - 0.3
Bermuda MED	0.4 - 0.6
Centipede grass MED	0.4 - 0.6
St Augustine: LOW	0.7 - 0.9
Ryegrass: LOW	0.7 - 0.9

Again, percentile ranges were divided along with an average irrigable area for the City of Kyle. Annual water demand in gallons per square feet, annual water demand in gallons per lot size, and the percentage of acre-feet contributed to, or reduced from, the total municipal water use, was determined for each crop factor ranging from 0.1 to 0.9. The percentage of municipal water use is based on the average annual amount of 2,350 acre-feet and is accurate only if every lot in Kyle initiated the prescribed level of xeriscaping.

The most effective crop factors for reducing water demand ranged between 0.1 and 0.3 and were associated with the high drought tolerant Buffalo and Zoysia grasses. All three crop factors computed a negative water demand, which can be interpreted as "no irrigation needed." Even the percentages associated with the total municipal water use were negative, some as low as -61 percent and as high as -15 percent, which indicate a significant reduction in municipal water use (Table 21 – 23).

Table 21. High drought resistance and low crop factor: crop factor = 0.1

Annual Water Savings on an Average Lot in Kyle, Texas (gal):		
	gal/yr	% of 2,350 af
Ave. Irrigable Area – 3,095 sq. ft.	67,089	51%
25th percentile - 2,513 sq. ft.	54,473	
50th percentile - 3,268 sq. ft.	70,839	
75th percentile - 3,759 sq. ft.	81,482	
Annual Water Savings (gal/sq.ft.)		21.68

Table 22. High drought resistance and low crop factor: crop factor = 0.2

Annual Water Savings on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2350 af
Ave. Irrigable Area – 3,095 sq. ft.	45,867	35%
25th percentile - 2,513 sq. ft.	37,242	
50th percentile - 3,268 sq. ft.	48,431	
75th percentile - 3,759 sq. ft.	55,707	
Annual Water Savings (gal/sq.ft.)		14.82

Table 23. High drought resistance and low crop factor: crop factor = 0.3

Annual Water Savings on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	24,646	19%
25th percentile - 2,513 sq. ft.	20,011	
50th percentile - 3,268 sq. ft.	26,023	
75th percentile - 3,759 sq. ft.	29,933	
Annual Water Savings (gal/sq.ft.)		7.96

Mid-range (moderate) crop factors of medium drought resistance are associated with Bermuda and Centipede grasses. The numbers ranged from reducing over 4,100 gallons per year to contributing 47,389 gallons per lawn. The numbers have quite a range based on lot size and the actual crop factor. A crop factor of 0.4 returned the potential of *reducing* municipal water use by 3 percent, while the high-end crop factor of 0.6 returned the potential of *contributing* 36 percent of the total municipal water use if every residential landscape implemented a moderately adapted drought resistant lawn (Table 24 – 26).

Table 24. Medium drought resistance and moderate crop factor: crop factor = 0.4

Annual Water Savings on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	3,424	3%
25th percentile - 2,513 sq. ft.	2,780	
50th percentile - 3,268 sq. ft.	3,616	
75th percentile - 3,759 sq. ft.	4,159	
Annual Water Savings (gal/sq.ft.)		1.11

Table 25. Medium drought resistance and moderate crop factor: crop factor = 0.5

Annual Water Demand on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	17,797	13%
25th percentile - 2,513 sq. ft.	14,450	
50th percentile - 3,268 sq. ft.	18,792	
75th percentile - 3,759 sq. ft.	21,615	
Annual Water Demand (gal/sq.ft.)		5.75

Table 26. Medium drought resistance and moderate crop factor: crop factor = 0.6

Annual Water Demand on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	39,018	29%
25th percentile - 2,513 sq. ft.	31,681	
50th percentile - 3,268 sq. ft.	41,199	
75th percentile - 3,759 sq. ft.	47,389	
Annual Water Demand (gal/sq.ft.)		12.61

The high-level crop factors ranging from 0.7 to 0.9 are associated with the low drought resistant grasses of Rye and the popular St. Augustine grasses. These crop factors resulted in low water saving yields and high contribution percentages. The crop factor of 0.7 for an average lot size in Kyle derived possibly the most accurate assessment of the water demands for St. Augustine grass. Approximately, nineteen gallons per square foot computed to 60,240 gallons annually, which if applied to the number of lawns in Kyle, would contribute to over 45 percent of the total municipal water use. The first percentile established a 37 percent contribution, while the second and third percentile resulted in 48 percent and 55 percent, respectively.

Crop factors of 0.8 and 0.9 produced higher numbers that provide some uncertainty in the methods. The average lot size for a crop factor of 0.8 had an output of 81,461 gallons per year, while the crop factor of 0.9 resulted in 102,683 gallons per year. With a crop factor of 0.9, on average, close to 80 percent (0.9 = 77%) of the total municipal water use is contributed solely to residential landscape water needs (Table 27 – 29). Knowing that municipal water use incorporates indoor and outdoor water utilization explains that these findings are not accurate, which leads to the assumption that all the other calculations involving other crop factors are also high. These issues and pragmatic attempts to address errors are discussed in detail within the next chapter of this document.

Table 27. Low drought resistance and high crop factor: crop factor = 0.7

Annual Water Demand on an Average Lot in Kyle, Texas (gal):		
	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	60,240	45%
25th percentile - 2,513 sq. ft.	48,912	
50th percentile - 3,268 sq. ft.	63,607	
75th percentile - 3,759 sq. ft.	73,164	
Annual Water Demand (gal/sq.ft.)		19.46

Table 28. Low drought resistance and high crop factor: crop factor = 0.8

Annual Water Demand on an Average Lot in Kyle, Texas (gal):		
	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	81, 461	61%
25th percentile - 2,513 sq. ft.	66,143	
50th percentile - 3,268 sq. ft.	86,015	
75th percentile - 3,759 sq. ft.	98,938	
Annual Water Demand (gal/sq.ft.)		26.32

Table 29. Low drought resistance and high crop factor: crop factor = 0.9

Annual Water Demand on an Average Lot in Kyle, Texas (gal):		
	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	102,683	77%
25th percentile - 2,513 sq. ft.	83,374	
50th percentile - 3,268 sq. ft.	108,422	
75th percentile - 3,759 sq. ft.	124,712	
Annual Water Demand (gal/sq.ft.)		33.18

Xeriscape: Variation in Precipitation

As in the rainwater harvesting method, xeriscaping values are highly dependent on the amount of moisture received. Using the same 25th and 75th percentiles as before, an annual total for both ranges was formulated and applied to the xeriscaping process to indicate fluctuations in demand based on precipitation (Table 30).

Table 30. 25th and 75th percentile- precipitation probability annual totals in inches (U.S. National Climatic Data Center 2004)

	Percentile:	Precipitation (in)
Month	25th	75th
January	0.73	2.86
February	0.75	3.10
March	0.84	2.90
April	1.11	3.96
May	2.54	7.22
June	2.23	6.60
July	0.27	3.01
August	0.56	3.72
September	1.61	4.73
October	1.06	5.67
November	1.10	4.44
December	0.74	3.40
Total	13.52	51.59

The water demand, for a xeriscaped lawn and for every crop factor, increased as the rainfall decreased. A dry year in the 25th percentile totaled 13.52 inches, which led to a significant increase in the level of demand (Table 31 – 39). However, a wet year in the 75th percentile totaled 51.59 inches, which resulted in large surpluses of water, meaning a lower demand (Table 40 – 48).

Table 31. 25th percentile: high drought resistance and low crop factor: crop factor = 0.1

Annual Water Savings on an Average Lot in Kyle, Texas (gal):		
	gal/yr	% of 2,350 af
Ave. Irrigable Area - 3,095 sq. ft.	11,382	9%
25th percentile - 2,513 sq. ft.	9,242	
50th percentile - 3,268 sq. ft.	12,019	
75th percentile - 3,759 sq. ft.	13,824	
Annual Water Savings (gal/sq.ft.)		3.68

Table 32. 25th percentile: high drought resistance and low crop factor: crop factor = 0.2

Annual Water Demand on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	9,839	7%
25th percentile - 2,513 sq. ft.	7,989	
50th percentile - 3,268 sq. ft.	10,389	
75th percentile - 3,759 sq. ft.	11,950	
Annual Water Demand (gal/sq.ft.)		3.18

Table 33. 25th percentile: high drought resistance and low crop factor: crop factor = 0.3

Annual Water Demand on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	31,060	23%
25th percentile - 2,513 sq. ft.	25,220	
50th percentile - 3,268 sq. ft.	32,797	
75th percentile - 3,759 sq. ft.	37,724	
Annual Water Demand (gal/sq.ft.)		10.04

Table 34. 25th percentile: med. drought resistance and moderate crop factor: crop factor = 0.4

Annual Water Demand on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	52,282	39%
25th percentile - 2,513 sq. ft.	42,450	
50th percentile - 3,268 sq. ft.	55,204	
75th percentile - 3,759 sq. ft.	63,498	
Annual Water Demand (gal/sq.ft.)		16.89

Table 35. 25th percentile: med. drought resistance and moderate crop factor: crop factor = 0.5

Annual Water Demand on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	73,503	55%
25th percentile - 2,513 sq. ft.	59,681	
50th percentile - 3,268 sq. ft.	77,612	
75th percentile - 3,759 sq. ft.	89,272	
Annual Water Demand (gal/sq.ft.)		23.75

Table 36. 25th percentile: med. drought resistance and moderate crop factor: crop factor = 0.6

Annual Water Demand on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	94,725	71%
25th percentile - 2,513 sq. ft.	76,912	
50th percentile - 3,268 sq. ft.	100,019	
75th percentile - 3,759 sq. ft.	115,047	
Annual Water Demand (gal/sq.ft.)		30.61

Table 37. 25th percentile: low drought resistance and high crop factor: crop factor = 0.7

Annual Water Demand on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	115,946	87%
25th percentile - 2,513 sq. ft.	94,143	
50th percentile - 3,268 sq. ft.	122,427	
75th percentile - 3,759 sq. ft.	140,821	
Annual Water Demand (gal/sq.ft.)		37.46

Table 38. 25th percentile: low drought resistance and high crop factor: crop factor = 0.8

Annual Water Demand on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	137,167	103%
25th percentile - 2,513 sq. ft.	111,374	
50th percentile - 3,268 sq. ft.	144,834	
75th percentile - 3,759 sq. ft.	166,595	
Annual Water Demand (gal/sq.ft.)		44.32

Table 39. 25th percentile: low drought resistance and high crop factor: crop factor = 0.9

Annual Water Demand on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	158,389	119%
25th percentile - 2,513 sq. ft.	128,604	
50th percentile - 3,268 sq. ft.	167,242	
75th percentile - 3,759 sq. ft.	192,369	
Annual Water Demand (gal/sq.ft.)		51.18

Table 40. 75th percentile: high drought resistance and low crop factor: crop factor = 0.1

Annual Water Savings on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2,350 af
Ave. Irrigable Area - 3,095 sq. ft.	103,189	78%
25th percentile - 2,513 sq. ft.	83,785	
50th percentile - 3,268 sq. ft.	108,957	
75th percentile - 3,759 sq. ft.	125,327	
Annual Water Savings (gal/sq.ft.)		33.34

Table 41. 75th percentile: high drought resistance and low crop factor: crop factor = 0.2

Annual Water Savings on an Average Lot in Kyle, Texas (gal):		
	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	81,968	62%
25th percentile - 2,513 sq. ft.	66,554	
50th percentile - 3,268 sq. ft.	86,549	
75th percentile - 3,759 sq. ft.	99,553	
Annual Water Savings (gal/sq.ft.)		26.48

Table 42. 75th percentile: high drought resistance and low crop factor: crop factor = 0.3

Annual Water Savings on an Average Lot in Kyle, Texas (gal):		
	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	60,746	46%
25th percentile - 2,513 sq. ft.	49,323	
50th percentile - 3,268 sq. ft.	64,142	
75th percentile - 3,759 sq. ft.	73,779	
Annual Water Savings (gal/sq.ft.)		19.63

Table 43. 75th percentile: med. drought resistance and moderate crop factor: crop factor = 0.4

Annual Water Savings on an Average Lot in Kyle, Texas (gal):		
	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	39,525	30%
25th percentile - 2,513 sq. ft.	32,092	
50th percentile - 3,268 sq. ft.	41,734	
75th percentile - 3,759 sq. ft.	48,004	
Annual Water Savings (gal/sq.ft.)		12.77

Table 44. 75th percentile: med. drought resistance and moderate crop factor: crop factor = 0.5

Annual Water Savings on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	18,303	14%
25th percentile - 2,513 sq. ft.	14,862	
50th percentile - 3,268 sq. ft.	19,327	
75th percentile - 3,759 sq. ft.	22,230	
Annual Water Savings (gal/sq.ft.)		5.91

Table 45. 75th percentile: med. drought resistance and moderate crop factor: crop factor = 0.6

Annual Water Demand on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	2,918	2%
25th percentile - 2,513 sq. ft.	2,369	
50th percentile - 3,268 sq. ft.	3,081	
75th percentile - 3,759 sq. ft.	3,544	
Annual Water Demand (gal/sq.ft.)		0.94

Table 46. 75th percentile: low drought resistance and high crop factor: crop factor = 0.7

Annual Water Demand on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	24,139	18%
25th percentile - 2,513 sq. ft.	19,600	
50th percentile - 3,268 sq. ft.	25,489	
75th percentile - 3,759 sq. ft.	29,318	
Annual Water Demand (gal/sq.ft.)		7.80

Table 47. 75th percentile: low drought resistance and high crop factor: crop factor = 0.8

Annual Water Demand on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	45,361	34%
25th percentile - 2,513 sq. ft.	36,831	
50th percentile - 3,268 sq. ft.	47,896	
75th percentile - 3,759 sq. ft.	55,092	
Annual Water Demand (gal/sq.ft.)		14.66

Table 48. 75th percentile: low drought resistance and high crop factor: crop factor = 0.9

Annual Water Demand on an Average Lot in Kyle, Texas (gal):	gal/yr	% of 2350 af
Ave. Irrigable Area - 3,095 sq. ft.	66,582	50%
25th percentile - 2,513 sq. ft.	54,062	
50th percentile - 3,268 sq. ft.	70,304	
75th percentile - 3,759 sq. ft.	80,867	
Annual Water Demand (gal/sq.ft.)		21.51

CHAPTER VII

DISCUSSION, POLICY RECOMMENDATIONS, AND CONCLUSIONS

Discussion

This study has found that rainwater harvesting, xeriscaping, and moisture sensitive irrigation are all positive modes of water conservation and have the potential to be plausible solutions for reducing the water demand of Kyle, Texas. As urban areas grow, the need for water supply will grow along side the population. In an effort to curb high price rates and shortages, water conservation proves to be a viable option. The purpose of this research was to quantify the statements above, which appears to have been accomplished. However, within each conservation method deployed some discussion of errors and improvements is required.

In discussing the results of xeriscaping, it became apparent that the findings associated with the high-end and low-end crop factors were disproportionate to reality. The low crop factors provided extremely low savings, while the high crop factors reported equally as high usage. A lower average lot size would provide numbers more closely related to the actual needs and potential savings of the lowest level of xeriscaping. A crop factor of 0.1 should result in a more than 100 percent saving of the highest crop factor. In fact, it comes very close to that figure. The high crop factor of 0.8 required approximately 110,400 gallons per year for sufficient irrigation, while the lowest crop factor of 0.1 had a savings of approximately 90,900 gallons per year. These numbers are very high, and not necessarily applicable to real-world use. However, this may simply mean that crop factors of this nature are neither obtainable nor possible for this region.

The mid-range crop factors ranging from 0.3 to 0.7 provided more accurate results for their associated turfgrass. St. Augustine grass requires a high yield of water, which is prescribed as approximately 81,650 to 110,400 gallons per year ("much irrigation needed"); conversely, Buffalo grasses are drought resistant and have an approximated savings of 33,400 gallons per year ("no irrigation needed"), and moderate grasses with a factor of 0.5 only require roughly 24,000 gallons annually, or "limited irrigation needed". These particular findings are prescribed based on some error, most of which are prevalent throughout all three methods, the use of averages, and percentile assumptions.

Averages and Percentiles

The averages and percentile assumptions related to housing size and lot size were derived from real estate data provided by realtors, both online and in person, which lead to a small sample size of only 192 homes. Unfortunately, this only represents 3 percent of the total housing units based on the estimation utilized in the study. A more accurate assessment of home size would be beneficial in determining all aspects of the methods, with especial attention to the rainwater harvesting method. A possibility in acquiring a more thorough and accurate count of homes would be the use of a survey system, in which individuals would be asked the size of their home.

Combining Water Conservation Methods

The efforts afforded to the application of moisture sensitive irrigation requires that the average amount of rainfall on an annual and monthly basis falls every year, which is known to not be the case. Particularly in this region, drought periods can have a persistent quality to them, which would alter the findings of this conservation method. During an average rainfall year, there is the potential savings of approximately 78,000 gallons annually per lawn, which would mean to maintain a healthy yard during a drought the associated savings would be reduced drastically.

The benefits of this research allow one to notice the effects of other modes of conservation. Despite the inherent and possible errors of the methods, if moisture sensitive irrigation was used in union with rainwater harvesting, then 50 percent of the water demand would be met with captured precipitation. If moisture sensitive irrigation is initiated with xeriscaping of a crop factor of 0.6 or lower then water demand would be met with minimal irrigation needs. Combining other methods can be just as advantageous for conserving water. For example, a moderately xeriscaped landscape with the addition of rainwater harvesting technology has the potential to maintain a negative water usage rate. Separately, these methods are impressive water savers, but together they provide a back up for drought years and an alternative to instances when one method is lacking.

Policy Recommendations

A fair market price could utilize these methods to further encourage wise use of water resources. The abuse of such a fragile, yet necessary resource, could lead either to a disastrous shortage or to irreversibly high rates, or both. The important aspect of policy is that individuals should be rewarded for implementing water conservation. Incentive or rebate programs for water conservation projects should be the goal of any reputable municipality looking to allow for a sustained quality of life. Efforts to ensure longevity and equity in incentive and rebate programs should come from a well-funded regional conservation district. These programs have the power to inform and teach a population of the importance of water conservation and other environmental programs, in addition to instilling a sense of gregariousness and community among the citizens.

A market perspective sees the municipalities placing demands on developers for environmentally friendly applications. However a "developers do what is required of them from a governmental and market perspective" (Whisenant 2008). Homeowners have the ability to do what is best for the property in the sense of what is attractive to the public, and provides a useful or comfortable setting for outdoor activity. If an alternative is available that offers all the desires of the homeowner, then a switch to a 'new way of thinking' is a possibility (Whisenant 2008). These market values and a comfortable setting are indeed a possibility in the midst of water conservation. For instance, rainwater harvesting and moisture sensitive irrigation require no change in turfgrass settings or landscapeable area. A combination of conservation measures or a matrix of all three would allow for the homeowner to tailor fit their efforts in union with their landscape desire The market will adjust accordingly to higher water prices that will develop from shortages. In an effort to maintain low costs for essential water needs, i.e. drinking, cooking, showering, cleaning, and some industrial activities, water conservation must be brought into a positive light at a societal level, government level, and market level.

Conclusions

This study has revealed the effectiveness of xeriscaping, rainwater harvesting, and moisture sensitive irrigation as water conservation techniques. The findings advocate the utilization of such methods to ensure ample water supply during droughts and shortages and to provide expected results for the city of Kyle, Texas. The next step in this research process would be to enlist a larger sample size and calculate the costs of the three methodologies. In addition, a social, political and psychological breakdown of perceptions regarding water conservation strategies for Kyle would benefit the study. These supplementary parameters would present stronger validation to the outcomes, and prescribe a level of acceptance to the measures based on the community's ideas of water conservation.

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