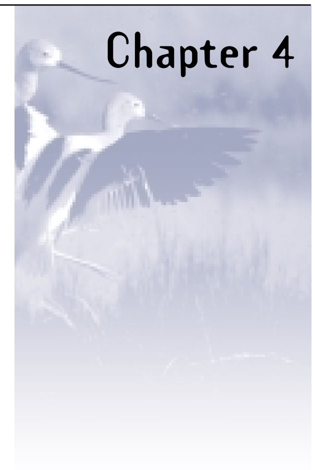


Chapter 4

Urban Sprawl: Impacts on Urban Water Use

Overview

Patterns of urban and suburban growth on the landscape are closely connected to water use. Over a specific geographic area, water-efficient land development can save significant quantities of water while less efficient land development—sprawl—often results in wasteful use. As populations and urban/suburban land development continue to expand across the Southwest, we should explore this connection closely.

This chapter clarifies the issue by providing a brief discussion of four basic questions:

- What exactly is urban sprawl?
- How are western cities sprawling?
- How does sprawl affect water use?
- How can smart development help?

In brief, all large southwestern urban areas are sprawling, many at tremendous rates. In some urban areas, sprawl results solely from an increasing number of residents. In others, sprawl is linked to higher per capita land consumption, typically around the rural perimeter.

Urban sprawl clearly affects water consumption. Typical low-density development (with the large lot sizes and acres of non-native turfgrass usually accompanying it) results in higher total water use as well as higher per capita water use.

A case study from Las Vegas reveals that a decrease in housing lot size over the past two decades resulted in a slow but steady drop in average per account water use. Another case study from Tucson shows that astounding water savings can be realized if new urban and suburban developments incorporate mixed uses, higher densities, water reuse, and water-efficient Xeriscape landscape design and irrigation practices. In sum, water use resulting from urban sprawl can be reduced by modifications to development densities (*e.g.*, lot sizes), the chosen type of developed landscape, and the source of landscape irrigation water.

These findings provide encouraging news for urban planners and water managers: water use efficiency improves through "smart development." Municipal zoning ordinances, land development standards, comprehensive plans, and inter-municipal regional plans all play key roles in creating sustainable development and, as a result, more sustainable water use.

"There is no lack of water here, unless you try to establish a city where no city should be."
–Edward Abbey

from Desert Solitaire (1968)

Heavily watered bluegrass lawn intended for business park aesthetics.
Photo by K.C. Becker.

Chapter 4

What Exactly Is Urban Sprawl?

"Sprawl" has many definitions. In general, it most often refers to low-density urban and suburban development of previously undeveloped rural land. One report describes sprawl as "low-density development beyond the edge of service and employment, which separates where people live from where they shop, work, recreate, and educate—thus requiring cars to move between zones."[1] Another report defines it as urban-like development outside central urban areas.[2] Some classify development as sprawl with reference to the magnitude of its impacts, including how far people must commute to daily activities, how much land area is consumed by non-residential uses (*e.g.*, infrastructure expansion), and the impact on the natural landscape.[3] Still others highlight "sprawl" as a growth rate: "rural acres lost as an urban area spreads outward over a period of time."[4]

Sprawling urban development. *Photo by K.C. Becker.*

One report[5] summarizes the common themes of various sprawl definitions:

- Segregated land uses
- Automobile-focused transportation
- Growth at the boundary of a metro area
- Lower residential and employment densities compared with areas closer to the central city
- Homogeneous populations
- Inability of local governments to cooperate and address negative aspects of sprawling growth

In sum, sprawl typically is a function of: (a) the population growth in a particular urban area and (b) how this population spreads itself across the land.

How Are Western Cities Sprawling?

All large western urban areas are sprawling, leading a national trend. Based on U.S. Census data from 1970 to 1990, the density of urban population across the United States decreased by 23 percent, while more than 30,000 square miles of once-rural lands were developed with urban and suburban land uses.[6] This newly developed area is three times the size of Vermont.

Using these Census data, the research team of Kolankiewicz and Beck calculated the amount of sprawl in the 100 largest urbanized areas in the U.S.[7] They differentiated between the two primary "sprawl factors": sprawl caused by an increase in per capita land use consumption, and sprawl caused by an increase in the number of residents.[8] In Table 4.1 the results reveal that

1 Sierra Club: Sprawl—The Dark Side of the American Dream, http://www.sierraclub.org/sprawl/report98/ (1998).
2 National Center for Policy Analysis: The Truth about Urban Sprawl, http://www.ncpa.org/ba/ba287.html (1999).
3 WOA!!: Sprawl, Growth Management, and Smart Growth, http://www.population-awareness.net/sprawl.html.
4 Kolankiewicz L, Beck R: Weighing sprawl factors in large US cities—analysis of US Bureau of the Census data on the 100 largest urbanized areas of the United States, http://sprawlcity.com/studyUSA/ (2001).
5 Johnson, M.P.: Environmental impacts of urban sprawl—a survey of the literature and proposed research agenda, Environment and Planning, 33:717-735 (2001).
6 Oregon Department of Land Conservation and Development: Indicators of Urban Sprawl, http://darkwing.uoregon.edu/~pppm/landuse/sprawl.html (1992).
7 Kolankiewicz & Beck. Although urban growth patterns may have changed somewhat since 1990, the study provides insight into the pace of sprawl.
8 The "sprawl apportionment" in the sixth and seventh columns of Table 4.1 resulted from applying the "Holdren method" to the Census data. *See* Appendix D of Kolankiewicz and Beck.

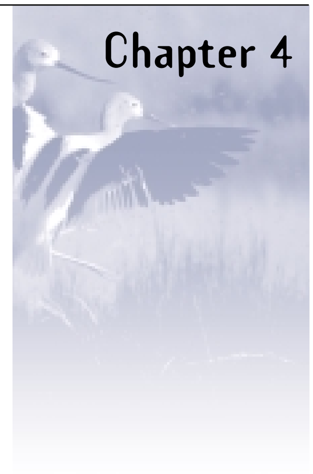


Table 4.1

Urban Sprawl from 1970 to 1990

(City-specific data extracted from Kolankiewicz and Beck study)

Urbanized Area (Ranked out of 100 cities in square miles of sprawl)	Sprawl Factors Percent Growth		Overall Sprawl		Sprawl Apportionment	
	Population	Per capita Land Consumption	Percent Growth in Land Area	Square Miles Growth	Population Growth Factor's Portion	Per capita Land Use Factor's Portion
Albuquerque (44)	67.1%	18.1%	97.4%	111.4	75.5%	24.5%
Denver (29)	44.9%	8.1%	56.7%	166.0	82.6%	17.4%
El Paso (51)	69.2%	9.1%	84.6%	101.0	63.0%*	37.0%*
Las Vegas (47)	194.6%	-35.3%	90.7%	109.9	100.0%	0.0%
Phoenix (9)	132.4%	-17.7%	91.3%	353.6	92.0%*	8.0%*
Salt Lake City (70)	64.7%	-16.3%	37.9%	69.8	100.0%	0.0%
Tucson (36)	96.9%	19.6%	135.4%	141.8	79.1%	20.9%

*Notes: * Adjusted to account for differential growth in urban core and urban fringe areas. In El Paso, 44 percent of land area growth was in the urban core, and 56 percent was in the urban fringe. 100 percent of the 44 percent urban core share and 34 percent of the 56 percent urban fringe share were due to population growth; thus 63 percent of the El Paso sprawl is related to population growth. In Phoenix, 100 percent of the 63.4 percent urban core share and 78 percent of the 36.6 percent urban fringe share were due to population growth; thus 92 percent of the Phoenix sprawl is related to population growth.* See *Appendix F of Kolankiewicz & Beck.*

some urban areas—including Las Vegas and Salt Lake City—sprawled primarily as a result of population growth. Others—like Albuquerque, Denver, El Paso, and Tucson—sprawled because of population growth and increasing per capita land consumption.

Using Albuquerque as an example, we see in Table 4.1 that its urban area was ranked 44th in terms of the total square miles of sprawl over the surrounding countryside (compared to 99 other urban areas in the study). Population growth in Albuquerque during the time period was 67.1 percent. The average amount of urban land for each resident grew by 18.1 percent. These latter two factors combined to cause the urbanization of 111.4 square miles of previously rural land and a 97.4 percent increase in the total land area covered. Albuquerque's geographic area doubled in size in just 20 years!

The final two columns of Table 4.1 indicate how much of this recent increase in the size of Albuquerque's urban area was attributable to population growth and how much to land use density patterns. The conclusion: 75.5 percent of Albuquerque's sprawl was related to population growth, while 24.5 percent was related to increased per capita land consumption.

Of the seven largest urban areas covered in the Smart Water report, during 1970-1990 Phoenix grew the most in absolute terms, covering over 350 additional square miles of land. However, like the other southwestern urban areas, population growth accounted for most of this land use consumption. As with Las Vegas and Salt Lake City, Phoenix's overall per capita land consumption actually decreased. These trends indicate that population growth, rather than low-density development, was the primary contributor to sprawl for these urban areas.

Another group of urban areas—Albuquerque, Denver, El Paso, and Tucson—experienced an increase in per capita land consumption as well as population growth. As a result, low-density sprawl was a significant portion of the newly developed area.

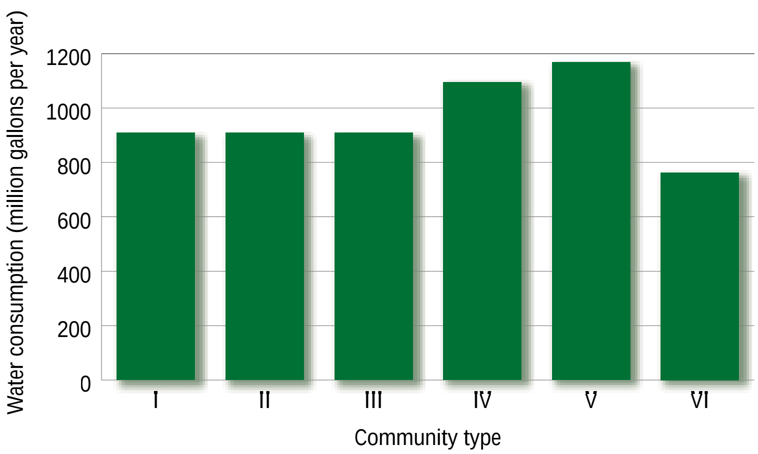
Chapter 4

How Does Sprawl Affect Water Use?

Both population growth and low-density land development increase absolute amounts of urban water consumption. Low-density development, however, often contributes to increases in *per capita* rates of water consumption—the telltale sign of decreased efficiency. This is due primarily to the fact that increased lot size often is accompanied by a larger amount of outdoor water use.

Figure 4.1

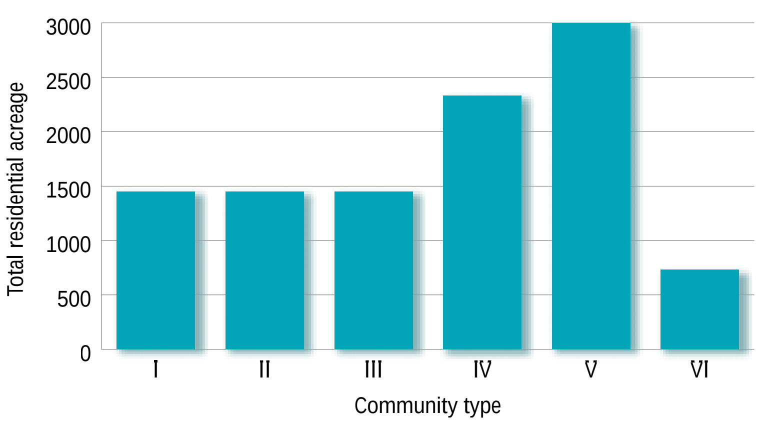
Annual Water Consumption by Community Type



Source: See Footnote 9.

Figure 4.2

Total Residential Acreage by Community Type



Source: See Footnote 9.

Housing Community Types Affect Water Use

For over thirty years, urban planners and water managers have known that housing types influence water use. The simple rule: Low-density development uses more water than high-density development.

A modeling study by the Real Estate Research Corporation compared the water consumption of residential developments with different densities.[9] The study looked at six distinct housing type and arrangement classifications, compared below in Figures 4.1 and 4.2. Although the study appears to have defined sprawl to mean simply "unplanned" development, the housing type variations offer useful definitions of low density and high density, something more useful to a modern "sprawl" definition.

The community types from this study are defined below:

I. Planned mix: housing types are 20 percent each of single-family conventional, single-family clustered, townhouses clustered, walk-up apartments, and high-rise apartments.

II. Combination mix: same housing types as I—housing arrangement 50 percent sprawl, 50 percent planned.

III. Sprawl mix: same housing types as I—housing arrangement 100 percent sprawl.

IV. Low-density planned: housing types are 75 percent single-family clustered and 25 percent single-family conventional.

V. Low-density sprawl: housing types are 75 percent single-family conventional and 25 percent single-family clustered.

VI. High-density planned: housing types are 10 percent single-family clustered, 20 percent townhouses clustered, 30 percent walk-up apartments, and 40 percent high-rise apartments.[10]

9 Real Estate Research Corporation: The Costs of Sprawl, Washington, D.C.: US Government Printing Office, 1974.
10 *Id.*

Table 4.2

Contribution of Residential Outdoor Water Use to Total Annual Residential Water Use, from Data-logged Samples

(adapted from REUWS)

Study Site	Sample Size	Outdoor Annual Use (kgal/home)	Indoor Annual Use (kgal/home)	Total Annual Use (kgal/home)	Percent of Annual Consumption due to Outdoor Use
Boulder	100	73.6	54.4	128.0	57.5%
Denver	99	104.7	61.9	166.6	62.8%
Phoenix	100	161.9	70.8	232.7	69.6%
Scottsdale	59	156.5	60.1	216.6	72.3%
Tempe	40	100.3	65.2	165.5	60.6%

The study concluded water consumption is lower primarily due to reduced lawn watering in higher-density developments. Community types I, II, and III have identical housing types and identical water consumption. This suggests that housing arrangement does not affect water consumption, whereas housing density does. Among six community types with the same population, annual water consumption varied proportionately with total residential acreage (Figures 4.1 and 4.2).

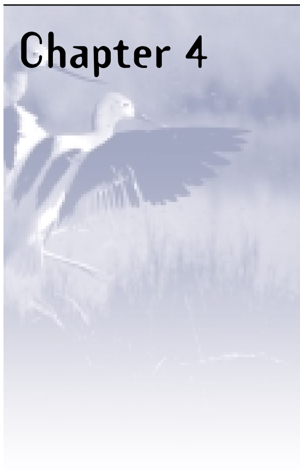
Outdoor Use Accounts for the Majority of Residential Water Use

A more recent study, the Residential End Uses of Water Study (REUWS), examined single-family residential water use in 12 cities, including Denver and Boulder, Colorado, as well as Phoenix, Tempe, and Scottsdale, Arizona.[11] These data highlight the significance of outdoor water use in total water consumption (Table 4.2). According to this study, outdoor use accounts for over half of all residential water in these western cities, ranging from 57.5 percent in Boulder, Colorado, to 72.3 percent in Scottsdale, Arizona.[12]

Bluegrass lawn of sprawling residential and commercial development on fringe of urban growth. *Photo by K.C. Becker.*

11 Mayer et al., Residential End Uses of Water Study (REUWS), AWWA Research Foundation, 1999.

12 Variations between outdoor use percentage results from REUWS and the estimates in the Smart Water Project result from differing data analysis methodology, significant differences in sample sizes, and different years of data collection (mid-1990s for REUWS; 2001 for Smart Water). Note: The outdoor use percentages in REUWS refer to percentage of total residential use, whereas the outdoor use percentage estimates reported in Chapter 3 (in Fig. 3.7) refer to percentage of total retail water sold to all sectors.



Water Use Correlates with Housing Lot Size

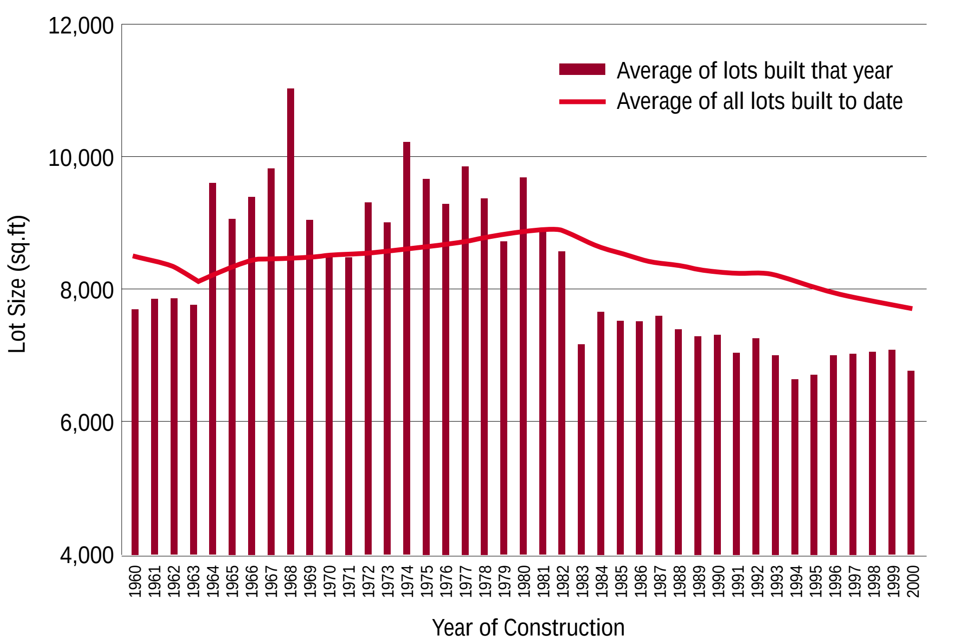
Data provided to Western Resource Advocates by the Las Vegas Valley Water District reveal a correlation between lot size and water use. Figure 4.3 shows average single-family residential (SFR) lot sizes in Clark County, Nevada, by year of construction. It shows a trend of relatively large lot sizes for residences built from the mid-1960s to the early 1980s, after which lot sizes decreased. The trend from the 1980s and 1990s was strong enough to greatly influence the “average” lot size over time. The line on Figure 4.3 represents the downward trend of Clark County’s average lot size.[13]

Figure 4.4 shows average SFR water consumption in 2001 by year of construction, with a trend of higher water consumption by residences built in the mid-1960s to the early 1980s and declining thereafter. The slopes of the increasing and decreasing trends in per household water use in Figure 4.4 are very similar to the increasing and decreasing average lot size line in Figure 4.3.

Combining the data from Figure 4.3 and Figure 4.4 reveals a notable year-by-year correlation between residential lot size and residential water consumption (Figure 4.5). Both trends increased through the 1960s and decreased throughout the 1980s and 1990s. The simple formula: larger lot size usually equates to larger landscaped area, thus more water consumption due to landscape watering.[14]

Figure 4.3

Average Single-Family Lot Sizes in 2001, by Individual Year and Overall, Clark County, Nevada



13 The average lot size line in Figure 4.3 represents the average size of all developed lots to date.
14 Note, however, water use is also dependent on the type of landscape. Larger lots need not yield higher water use if native landscaping is applied in lieu of turfgrass and other high-water-use vegetation.

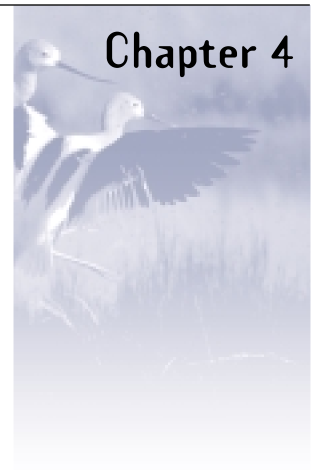


Figure 4.4

Average Daily Water Use in Gallons in 2001, Single-Family Homes by Year of Construction, Clark County, Nevada

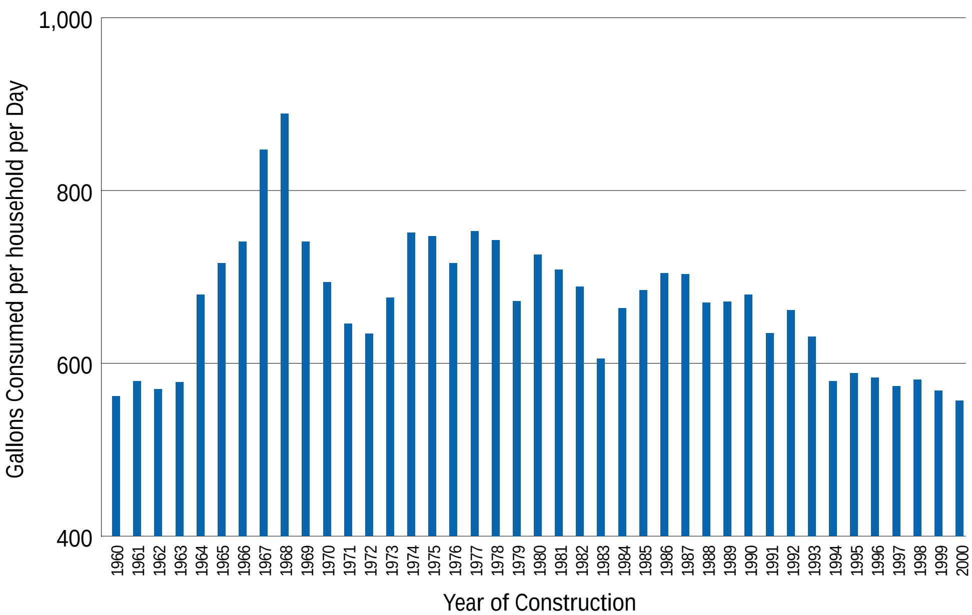
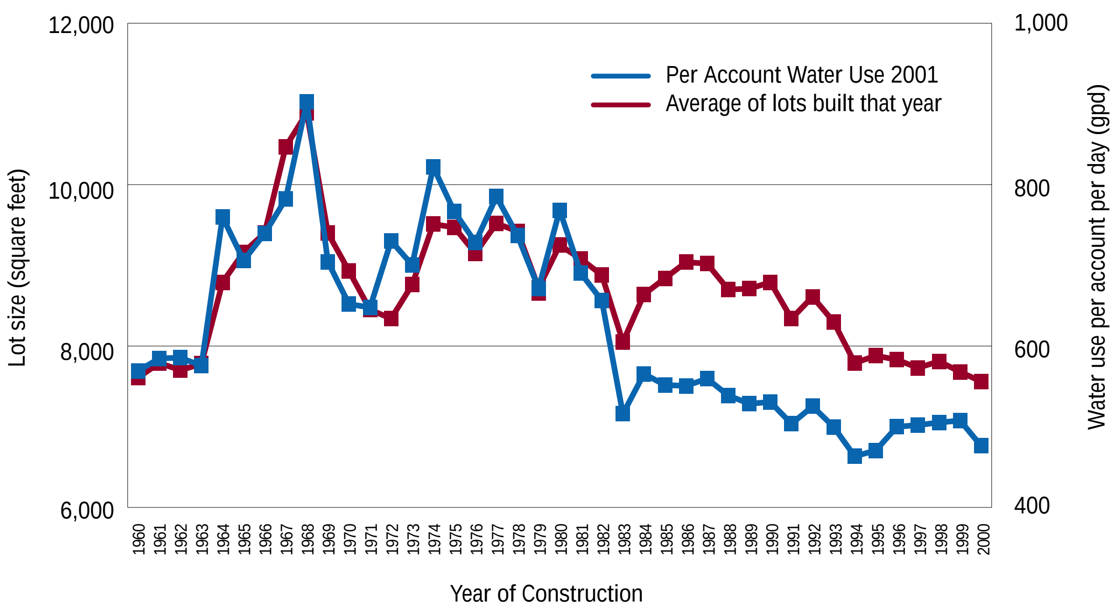
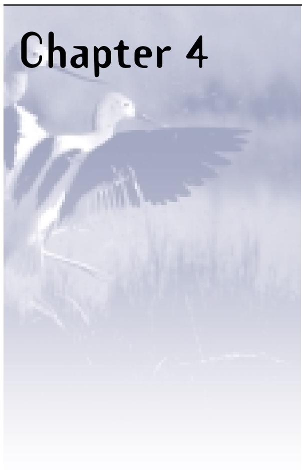


Figure 4.5

2001 Water Consumption per Residential Account by Year of Construction Compared with Average Single-Family Lot Size by Year of Construction, Clark County, Nevada





Chapter 4

How Can Smart Development Decrease Water Consumption?

Assuming that population growth in the Southwest will continue for many years to come, near-term water savings will result from minimizing water consumption in new and existing developments, through minimizing lot sizes, applying high-density mixed-use developments, maximizing infill development, and utilizing water-efficient landscape designs and watering practices. These types of "smart development" strategies can be incorporated into municipal zoning ordinances, development standards, and master plans.

An Example of Smart Development: the Community of Civano (Tucson, AZ)

The Community of Civano, a development in Tucson, Arizona, is highlighted as a state-of-the-art development in Chapter 2. Civano serves as an example of smart development with high urban water use efficiency. Through smart development planning, innovative housing and landscape designs, and the cooperation of the City of Tucson Water Department, the Community of Civano exemplifies municipal development that is both appealing to the community as well as very water-efficient. Although this type of development may involve higher upfront development costs to cover the use of energy/water-efficient materials and infrastructure, long-term benefits are realized through significant energy and water savings.

The following list provides a recap of some key aspects of the Civano development (described in Chapter 2)[15]:

- 1,145 acres at build-out;
- Four neighborhoods housing over 2,600 families at build-out;
- Mixed densities of mixed uses;
- Relatively small residential lot sizes (averaging less than 5,000 s.f.[16]);
- Pedestrian-friendly community design;
- Comprehensive Xeriscape landscapes on private lots and common areas;
- Reclaimed water delivery system serving all landscape irrigation (every residence has two water service lines/meters: one for potable water, one for reclaimed water);
- 35 percent of development area is dedicated as Sonoran Desert open space;
- Salvages native landscaping as the development expands;
- Onsite native landscape nursery that redistributes salvaged plant material (and uses reclaimed water for 98 percent of its total water use[17]);
- Minimized vehicle miles (which reduces traffic as well as impervious area).

A 2002 water use study reported that residents in the Civano development used an average of 52 gallons per capita per day (gpcd) of City of Tucson potable water in 2001.[18] Civano's SFR water consumption rate is less than half the average residential per capita consumption rate for the balance of Tucson.[19] Since all Civano outdoor water use is served with reclaimed water delivered separately by a City of Tucson water reuse project, this consumption rate is entirely for indoor uses. All of the Civano landscaped areas, which are primarily Xeriscaped yards and common

15 *See* "Unsprawl Case Study: Community of Civano, Arizona," by Terrain.org: A Journal of the Built and Natural Enviroments, (found at www.terrain.org) (August 2003).
16 Al Nichols Engineering, Inc., Civano and Tucson Residential Water Use, Revised, (prepared for the Community of Civano, LLC), August, 2002.
17 *Id.*
18 *Id.*
19 *Id.* Note: Data corroborated by the City of Tucson response to the Smart Water survey.

areas, are irrigated with the reclaimed water. Civano residents used only 25 gpcd of City of Tucson reclaimed water in 2001.

The Community of Civano development in Tucson, AZ. *Photo by Al Nichols.*

In sum, the 2001 combined residential water use in Civano (*i.e.*, potable and reclaimed water) was only 77 gpcd total, still well below per capita consumption rates throughout the Southwest.[20] When compared to most new developments throughout the Southwest, the potential water savings from this type of development are simply astounding.

Potential Urban Water Savings Generated by Smart Development

Comparing the regional SFR per capita potable water consumption rates reported in Chapter 3 (ranging from 107 gpcd to 230 gpcd) to the Civano potable water consumption rate (52 gpcd), we find that the average resident in southwestern cities uses two to four times as much potable water as the average Civano resident.[21] This huge disparity in water consumption can be attributed to the Civano dedication to Xeriscape designs, reclaimed water use, and higher densities of mixed-use development. Even if particular communities have limitations on the use of reused water due to state water law or infrastructure constraints, Civano's low total water use per capita (potable and reclaimed combined use of 77 gpcd) demonstrates that substantial water savings can be realized via a commitment to Xeriscape landscaping and higher density uses.

To illustrate the significance of potential water savings, we can make hypothetical estimations of total annual use in various southwestern cities if all existing SFR development in these cities mirrored the water-savings accomplishments of Civano-like developments (See Table 4.3 on next page).[22] This type of comparison can show us the potential benefits of smart development. Please note that the following estimations and comparisons only involve SFR development. If all other sectors (commercial, multi-family, industrial, and institutional) used similar water-efficiency strategies, the potential savings would be much greater.

20 The Civano development has been subsidized by the City of Tucson and thus does not represent a fully independent development example. Still, it effectively highlights the potential water use efficiency that can be gained from smart development strategies. Much of the City subsidy involved the extension of reclaimed water service to the community. Tucson already operates a sizeable water reuse operation, which is not yet the case in many southwestern cities. Many other new developments in Tucson also are implementing similar densities and Xeriscape designs, and yielding comparably low water use.

21 Note: All consumption figures reported in Chapter 3 represent potable water use (not reclaimed water use).

22 These water savings estimates are calculated as follows: First, multiply the water provider's total number of SFR accounts by the U.S. Census Bureau estimate of SFR household occupancy in that particular city (as listed in Appendix A) to establish a total SFR population in the district's service area. Then, multiply this SFR population by Civano's 52 gpcd figure. Then, multiply this total SFR-sector gallons per day figure by 365 to arrive at an estimated total annual SFR usage volume for the district's service area. Finally, derive a savings estimate by subtracting this estimated "Civano-based" SFR volume from the actual reported 2001 SFR usage volumes (from the Smart Water survey). The same approach is used for the estimates based on the combined potable and reclaimed water use (77 gpcd).

Using Las Vegas as an example from Table 4.3, assume that all existing SFR development within the Las Vegas Valley Water District's (LVVWD) service area had been developed in similar fashion as the Community of Civano. According to Smart Water survey results (as reported in Chapter 3), the LVVWD's average SFR per capita consumption in 2001 was 230 gpcd, with a total of 50,801 MG of potable water sold to SFR customers during the same year (204,398 SFR accounts). If these same accounts consumed potable water at the Civano rate of 52 gpcd, the LVVWD would save an estimated 39,318 MG per year (120,662 acre-feet). This amounts to a 77 percent reduction in SFR water demand. In case Las Vegas has some limitations on the amount of reclaimed water it can use, we also base estimated water savings on Civano's total per capita residential use of 77 gpcd. The LVVWD could still save roughly 33,795 MG of residential water (103,712 acre-feet), a 67 percent reduction! To put these hypothetical savings into perspective, the LVVWD sold 106,463 MG (326,722 acre-feet) of total retail water in 2001. Roughly one third of all LVVWD retail water would be saved under this hypothetical scenario!

These estimates only assess potential water savings in the single-family residential sector. If water-efficient smart development principles are applied to all consumer sectors, the potential for water savings might grow considerably. Although it is not realistic to assume that our urban areas will retrofit all existing developments to higher efficiency standards, it is conceivable that our municipalities can retrofit some existing developments and plan/design most *new* developments in ways that echo the objectives and strategies of the Civano Community and similar Tucson developments. Hundreds of thousands of acre-feet of natural river system water are at stake.

Table 4.3

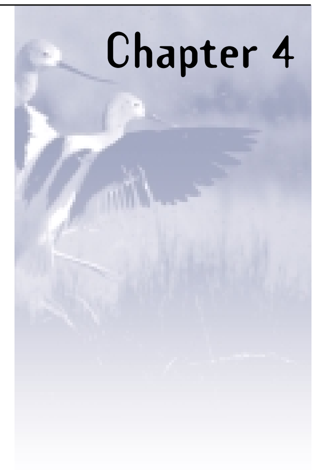
Hypothetical Water Savings if all Existing Residential Development in Various Southwestern Cities had Water Demand Comparable to that of Civano

[52 gpcd Potable Use]
[77 gpcd Potable & Reclaimed Use Combined]

City	2001 SFR per capita Water Use (gpcd)	2001 Total Retail Water Sold (MG)	2001 Retail Water Sold to SFR Customers (MG)	2001 Hypothetical Reduction in Annual SFR Water Demand [Assuming Comparable Water Reuse Service]		2001 Hypothetical Reduction in Annual SFR Water Demand [Assuming No Water Reuse Service]	
				Savings Volume (MG)	Percent SFR Reduction	Savings Volume (MG)	Percent SFR Reduction
Albuquerque	135	31,693	17,769	10,902	61%	7,601	43%
Denver	159	58,385	30,173	20,840	69%	15,555	52%
El Paso	122	33,639	19,953	11,443	57%	7,351	37%
Las Vegas	230	106,463	50,801	39,318	77%	33,795	67%
Phoenix	144	100,194	50,147	32,215	64%	23,595	47%
Tucson	107	34,392	18,507	9,550	52%	5,245	28%

Sources and Notes: The 2001 system data reported in the first three columns are drawn directly from the Smart Water survey and the SFR data analysis reported in Chapter 3. The hypothetical savings were derived by comparing Smart Water analysis results to the Civano water consumption rates reported in document prepared by Al Nichols Engineering, Inc.*[23]

23 Al Nichols Engineering, Inc., Civano and Tucson Residential Water Use, Revised, (prepared for the Community of Civano, LLC), August, 2002.

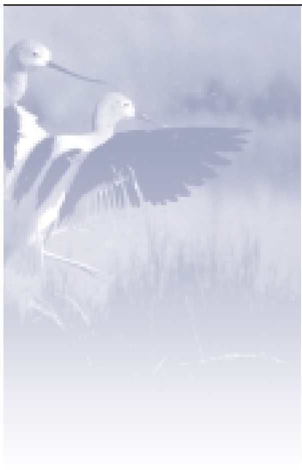


Conclusion

Low-density land development and inefficient urban landscape design can result in wasteful water use, primarily due to comparatively large amounts of water used for outdoor landscape irrigation. With urban populations continuing to grow throughout the Southwest and water supply remaining finite, careful urban planning and "smart development" are becoming more and more critical.

Although per capita water consumption and even per capita land area development are decreasing in some urban areas, the overall effect of population growth on sprawl and total water consumption continues. However, even if population growth continues in the Southwest, we have a choice about how we develop our urban landscapes.

Urban design strategies, including infill development and higher-density mixed-use development, help maximize water efficiency. Incorporating other water efficiency measures into such developments augments the potential water savings (*e.g.*, via use of Xeriscape standards, reclaimed water distribution systems, etc.). Developments that incorporate design strategies similar to that of the Civano development in Tucson illustrate how smart development can yield significant water savings.



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