WATER DEMAND AND CONSERVATION POTENTIAL OF VERDE VALLEY WELLS

WESTERN RESOURCE ADVOCATES

PROTECTING THE WEST'S LAND, AIR, AND WATER

Acknowledgements

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For over 25 years Western Resource Advocates has been one of the West's leading conservation groups protecting the region's air, land and water. We use the law, science and economics to craft innovative solutions to the most pressing conservation issues in the region. We work to transition electricity production away from conventional fossil fuel technologies toward clean, renewable energy and energy efficiency to end the electric industries contribution to climate change. We protect the health of Western rivers and lakes so they remain vibrant parts of our communities, support robust economies and provide a variety of recreational opportunities. We safeguard threatened landscapes and wildlife to leave a Western legacy for future generations.

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EXECUTIVE SUMMARY

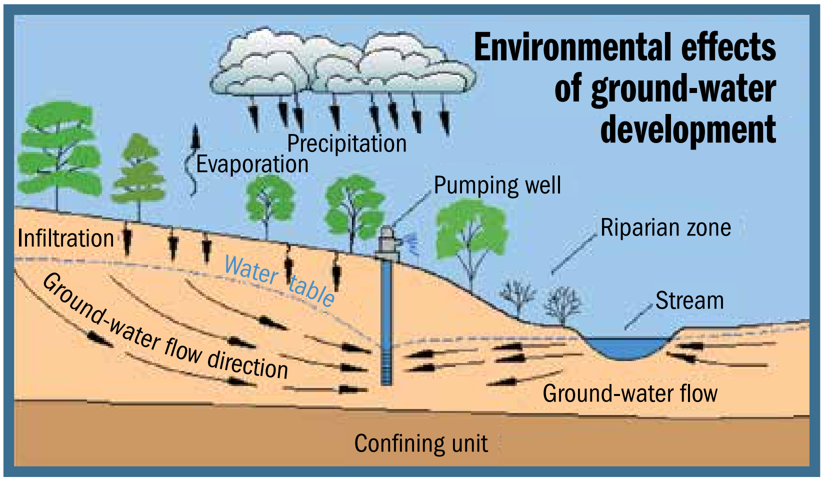
Groundwater pumping can have a significant impact on rivers and streams. The Verde River and its perennial tributaries are valuable resources to the Verde Valley and Arizona communities, providing water for irrigation, recreational opportunities such as fishing, and important habitat for wildlife. Rivers and streams also support economic opportunities, such as attracting visitors who watch birds and kayak. Protecting streams in the Verde Valley and throughout Arizona is in the interest of communities now and for future generations.

Western Resource Advocates (WRA) undertook this study to provide important information to the Verde Valley community on how wells in the area impact river and stream flow and on opportunities for well users to manage their water use to help keep rivers and streams healthy. A better understanding of well pumping impacts is critical to making water management decisions to protect the Verde River and its perennial tributaries.

Groundwater Pumping Reduces Flow in the Verde River and its Tributaries

In the Verde Valley, groundwater pumping from wells impacts stream flow and riparian vegetation. The degree of impact on rivers from groundwater pumping depends on many variables, including geologic features, well depth, pumping rate, and well location. A significant portion of stream flow in the Verde watershed is from groundwater that flows into the stream. When a well first begins pumping, the well withdraws water that is stored in the groundwater aquifer; however, over time, well pumping can change the direction of groundwater flow. As the well is pumped, stored groundwater is depleted, the water table falls, and the direction of groundwater flow can reverse, such that groundwater flows from the stream toward the well (Figure 1). In the extreme, this can result in the stream losing all its water to the aquifer, causing it to no longer flow.

Figure 1 **Effect of Well Pumping on Groundwater Flow**



Source: (U.S. Geological Survey 2015)

Little is known about the total water demand of wells in the Verde Valley with the exception of pumping from water provider wells, which are required to be reported annually to the Arizona Department of Water Resources (ADWR). Depending on the location of wells, research shows that groundwater pumping can have a significant impact on stream flow. For example, groundwater pumping impacts were reported in a U.S. Geological Survey (USGS) study and described in depletion maps in two USGS reports conducted in cooperation with The Nature Conservancy (TNC). In addition, research showed that by 2005, base flow at Camp Verde had decreased by about 10,000 acre-feet a year because of pumping between 1910 and 2005 and that it would continue to decrease in the future, depending on the amount of groundwater pumped (U.S. Geological Survey 2013a).[1]

WRA Developed a Methodology to Estimate Well Demand

WRA developed a methodology to estimate the demand and conservation potential of unmetered wells in two previous studies (Plateau Resources 2012; Western Resource Advocates 2014). For this current study, WRA applied the same methodology to wells pumping in the USGS 70% to 100% depletion zones of model layer 1 (shallow wells) of the Northern Arizona Regional Groundwater Flow Model (NARGFM). These zones are referred to as "stream impact areas" (SIAs) in this study (Figure 2).

The Majority of Wells in Stream Impact Areas Are Domestic

The majority of wells in stream impact areas are domestic, with total water demand comparable to that of other water-using sectors. There are multiple opportunities to reduce water use. **This investigation identified almost 3,000 wells in the stream impact areas, 88% of which are used for domestic purposes.** Sixty-five percent of these domestic wells serve older homes that likely have inefficient pre-1994 federal plumbing code fixtures. These older homes could affordably and easily use less water by replacing inefficient fixtures, representing a significant water conservation opportunity that would reduce groundwater pumping.

While most of the wells in the stream impact areas are domestic, their water demand is estimated to be just 25% of the total volume of well withdrawals, followed by agriculture (23%), water provider (22%), large outdoor residential (21%), and commercial/non-residential (9%). (Figure 3). This suggests that **many sectors could explore groundwater pumping reduction strategies to help reduce the use of water connected to rivers and streams in the Verde Valley.**

This study identifies groundwater demand-reduction strategies that could be implemented by well owners in SIAs and provides estimates of savings, costs, potential funding sources, and examples of successful programs. A first-tier approach to reduce groundwater demand should strive to target wells that supply a variety of users, including residences, businesses, and agriculture. These target wells serve:

1. older homes, particularly in the Cornville/Oak Creek and Camp Verde 90% to 100% SIAs
2. large residential outdoor irrigation in Camp Verde
3. flood-irrigated agriculture
4. water provider service areas
5. large non-residential users, such as schools

In addition to demand-reduction efforts, capturing and using rainwater and stormwater could augment water supplies and help replace well water. Rainwater and stormwater are renewable and free water sources.

Groundwater pumping's impact on stream flow is significant and increasing. **All water users in the Verde Valley have a stake in using water in a sustainable manner in order to protect local water supplies, maintain river flow, and support the local economy.** Providing the tools to promote more sustainable groundwater use is critical to the health of the Verde River, its tributaries, and communities.

Groundwater pumping reduction strategies include replacing inefficient plumbing fixtures, irrigating efficiently, using rainwater for outdoor uses, and repairing water leaks.

Chapter 1: INTRODUCTION
What are the impacts of well pumping on the Verde Valley?

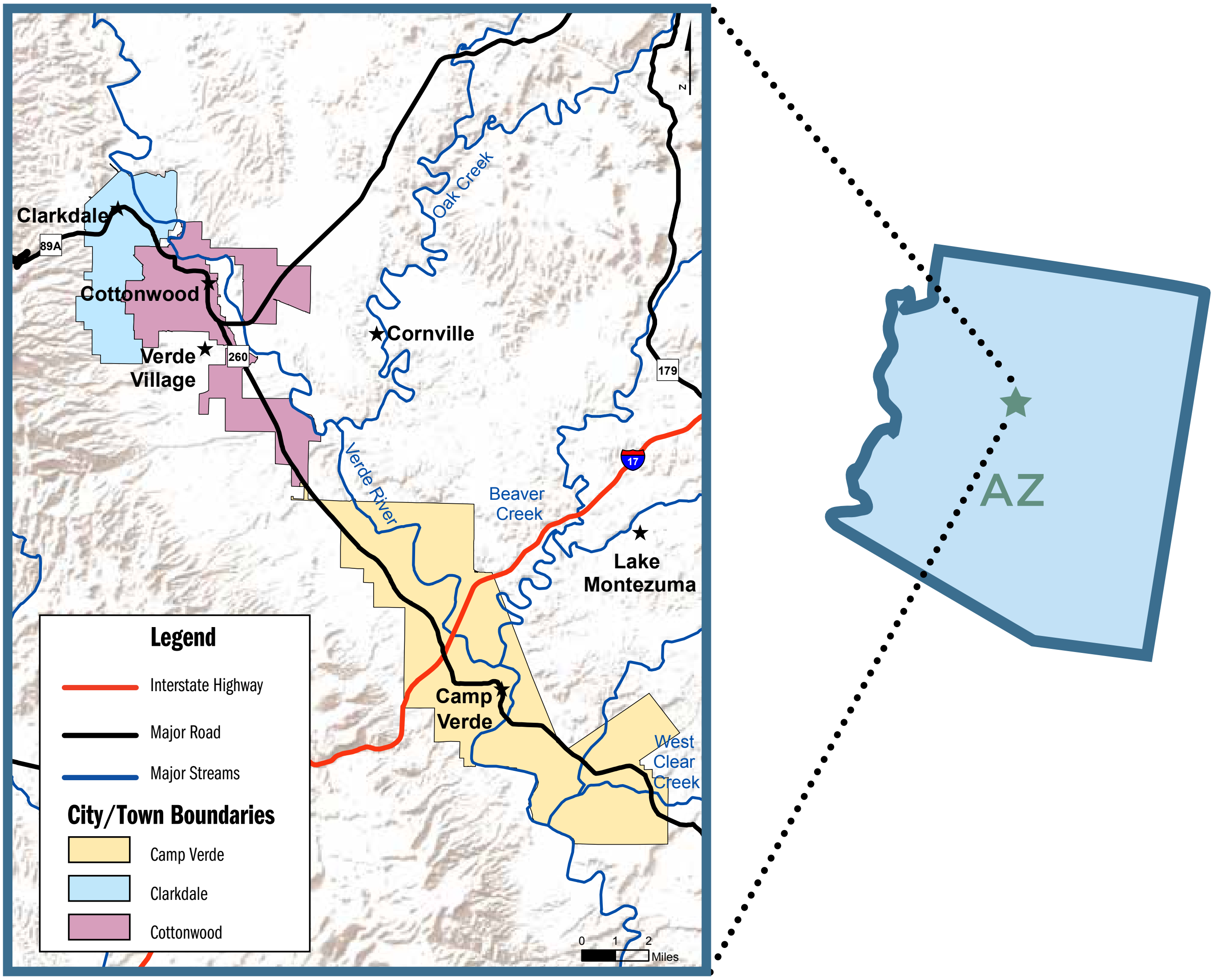
The Verde River and its Tributaries Are Important Natural and Economic Resources

The Verde River and its tributaries are critical natural and economic resources to Verde Valley communities and the residents of Arizona. The Verde River flows through central Arizona for 185 miles, from its origin in a complex of springs north of Prescott to its confluence with the Salt River northeast of Phoenix. In the Verde Valley, the Verde River flows through the incorporated communities of Clarkdale, Cottonwood, and Camp Verde. Several perennial streams, including Oak Creek, Beaver Creek, and West Clear Creek, contribute to the Verde River as it flows downstream to the southeast (Figure 2). The unincorporated communities of Cornville and Lake Montezuma are located along two of these tributary streams. The Verde and its tributaries support rich riparian areas, including one of the last Fremont cottonwood/Goodding willow forests in Arizona, and provide important habitat for otter, bald eagle, and several endangered fishes. In addition, the Verde River and its tributaries provide recreational opportunities that support a growing river-based local economy.

Groundwater Pumping Impacts Stream Flow

In the Verde Valley, surface water diversions for irrigation and groundwater pumping from wells impact stream flow and riparian vegetation. The degree of impact on rivers from groundwater pumping depends on many variables, including geologic features, well depth, pumping rate, and well location. A significant portion of stream flow in the Verde watershed is from groundwater that flows into the stream. When a well first begins pumping, the well withdraws water that is stored in the groundwater aquifer; however, over time, well pumping can change the direction of groundwater flow. As the well is pumped, stored groundwater is depleted, the water table falls, and the direction of groundwater flow can reverse, such that groundwater flows from the stream toward the well (Figure 1). In the extreme, this can result in the stream losing all its water to the aquifer, causing it to no longer flow.

Figure 2 **Verde Valley**



Sources: (Esri 2014); (U.S. Geological Survey 2014); (U.S. Census Bureau 2014)

A better understanding of which pumping is likely to have the greatest impact on surface flows is important in order to address and reduce impacts on streams. Unfortunately, very little is known about the pumping characteristics of wells in the Verde watershed because almost all are exempt from state well metering and reporting requirements.

Offering an Estimate of Water Demand by Well Users in Part of the Verde Valley

This report provides a first approximation of water demand by residential, water provider, commercial, and agricultural groundwater well users in certain areas of the Verde Valley using estimation methods developed by WRA in two previous studies (Plateau Resources 2012; Western Resource Advocates 2014) and information from two reports by the USGS, conducted in cooperation with TNC (Leake and Pool

2010; Leake and Haney 2010). These reports identify where groundwater pumping has the most impact on flows in the Verde River and its perennial tributaries. This study does not evaluate surface water use, including that delivered by Verde Valley ditch systems.

Offering Strategies to Help Well Users Reduce Their River Impact

This report also explores water demand-reduction strategies, including water conservation and improved efficiency. It is intended to be a resource to help water managers, decision-makers, and residents understand the impact of wells near the Verde River and its tributaries — and how that impact can be reduced. As an example of what actions might be taken using the information in this report, the Cochise Water Project (a nonprofit organization) replaced old, inefficient toilets in homes with private domestic wells near the San Pedro River in southeastern Arizona. Using the WRA demand methodology and a capture map for the San Pedro River similar to that shown in Figure 3, WRA estimates that over 50 acre-feet of water will remain in the aquifer through the Cochise Water Project toilet replacement program that reduced the amount of water used to flush inefficient toilets, with most of the replaced toilets located in areas with high impact on river flow.

Chapter 2: STUDY AREA
Identifying well users

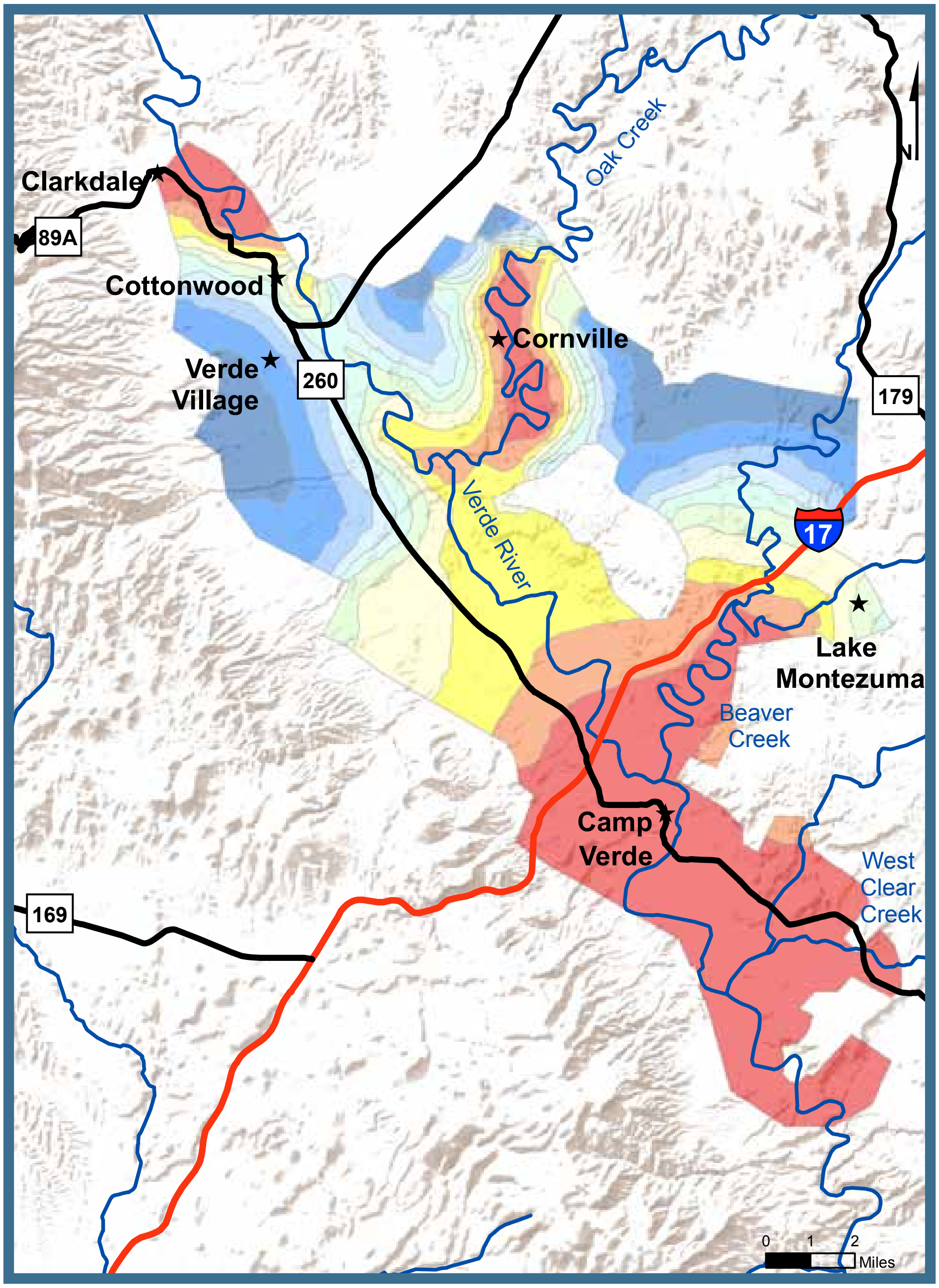
The U.S. Geological Survey and The Nature Conservancy applied the Northern Arizona Regional Groundwater Flow Model to investigate the effects of groundwater pumping on surface water flow and riparian vegetation in the Verde Valley. These reports presented general patterns of impacts resulting from well pumping durations of 10 and 50 years in the upper two NARGFM aquifer model layers: layer 1 and layer 2. This study uses the 50-year, model layer 1 pumping scenario because approximately 84% of the wells evaluated in the study area pump water exclusively from this layer (Lacher 2015).

In the Verde Valley, model layer 1 is composed of sedimentary material (the Verde Formation), while the underlying layer 2 is composed of volcanic rocks and sediments (lower basin fill).

Depletion Maps Show where Pumping Has a Faster and Slower Impact on River Flows

Figure 3 shows the percentage of stream, spring flow, and riparian evapotranspiration (ET) captured from a hypothetical well as a percentage of the well pumping rate after 50 years of constant pumping. For example, after 50 years, 90% to 100% of the water pumped from a well in the 90% to 100% depletion zone (the red area) would be water captured from stream flow and riparian ET. If the well pumped 10 acre-feet of water a year, the estimated reduction in stream flow and riparian ET would be 9 acre-feet of water per year after 50 years and eventually approach 10 acre-feet of water per year beyond 50 years (Verde Watershed Association 2011). The pumping response shown in Figure 3 is a general representation based on a large regional groundwater model and provides an understanding of where pumping has a faster and slower impact on surface water flow and ET.

Figure 3 Depletion After 50 Years of Well Pumping in Layer 1



Legend

- Interstate Highway
- Major Road
- Major Streams

Simulated capture of stream and spring flows and riparian evapotranspiration along the Verde River and its major tributaries as a percentage of pumping after 50 years of constant rate withdrawals from shallow wells.

- 0 - 10%
- 10 - 20%
- 20 - 30%
- 30 - 40%
- 40 - 50%
- 50 - 60%
- 60 - 70%
- 70 - 80%
- 80 - 90%
- 90 - 100%

Sources: See Figure 2; (Leake and Pool 2010)

Stream Impact Areas – Five Subareas Identified with the Number and Type of Wells

This study focuses on the water demand and conservation potential of wells and parcels of land located in the 70% to 100% depletion zones of the layer 1, 50-year pumping scenario identified by the USGS (Figure 3). For the study, these three zones where well water use has the greatest impact on water flow in rivers and streams are referred to as "stream impact areas" (SIAs). Five geographic subareas were identified: 1) Beaver Creek, 2) Camp Verde, 3) Camp Verde South, 4) Clarkdale/Cottonwood, and 5) Cornville/Oak Creek. The location of the subareas is shown in Figures 4–8.

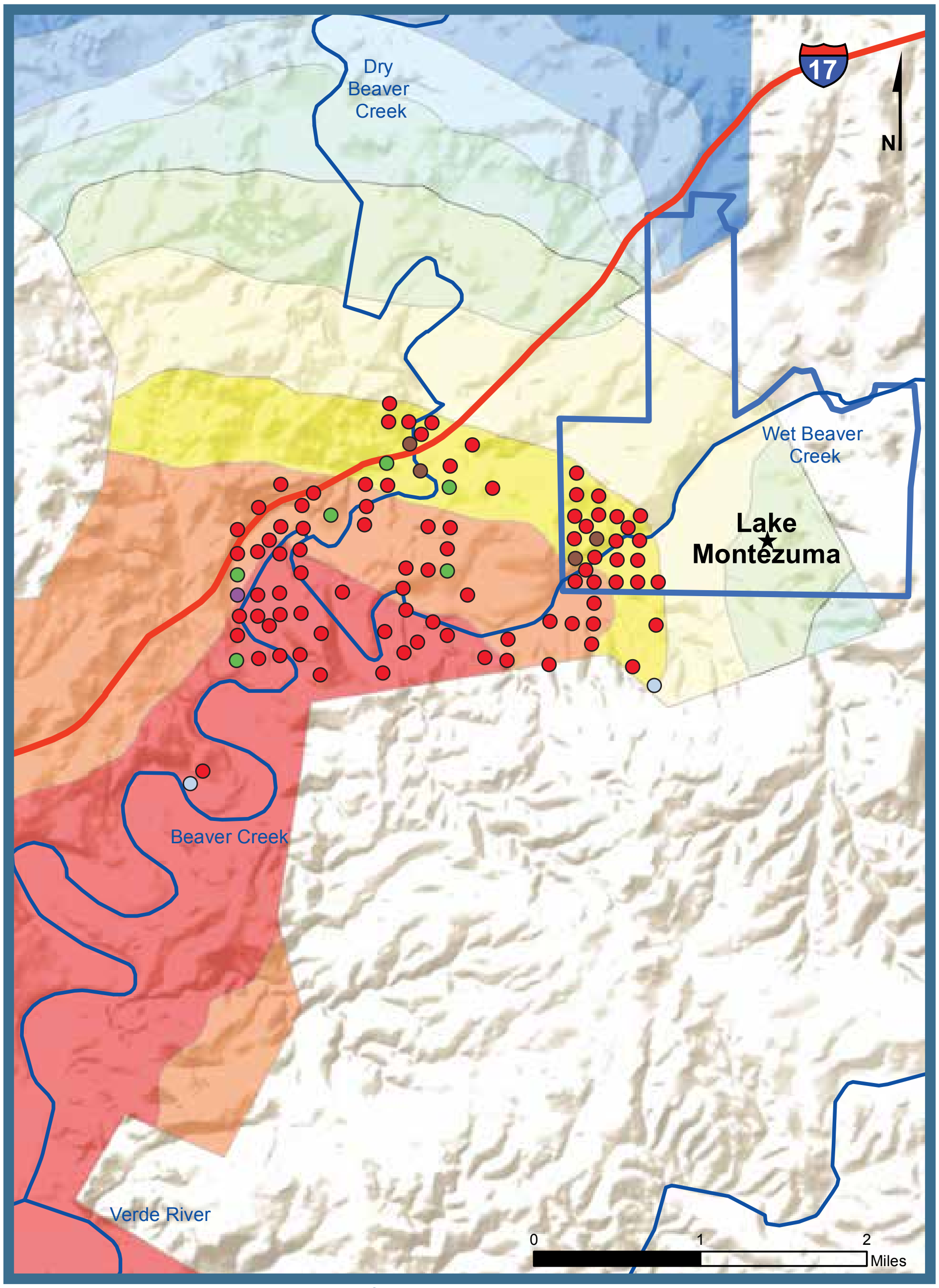
For each of the five geographic subareas, Western Resource Advocates evaluated the number and type of wells using Arizona Department of Water Resources well data. Figures 4–8 show well locations with the ADWR well code nomenclature and water provider service areas in the study area and provide a general indication of the number and type of wells. Both layer 1 wells and wells pumping below layer 1 are displayed. Note that each map well point may actually indicate multiple wells because ADWR well locations are accurate only to a 10-acre section of land. A complete accounting of wells in layer 1 is presented in Table 1, which shows the number and type of well in each SIA for each subarea.

Water Demand Must Be Estimated

Almost all the wells in the study area are unmetered and therefore demand must be estimated, requiring a number of assumptions and uncertainties described in detail in Appendix A. The demand estimation methodology developed and refined through WRA's two previous studies is applied here, with local modifications, and is intended to be a starting point for taking action to reduce pumping impacts on surface flow and riparian areas.

Estimating water demand based exclusively on the presence of a well is problematic for several reasons: a well may serve more than one household or use, the reported ADWR well use code may be incorrect, and use may change from the time the well was drilled. A better water demand indicator is county assessor parcel data, which is very robust for Yavapai County. This parcel data includes detailed parcel improvement types and dates of the improvement. Unfortunately, it is very difficult to connect a specific land parcel to a well because the ADWR well database reports well location only to a 10-acre section of land, not to a specific parcel. While more recent ADWR well registry data may include the parcel number, this is not the norm, nor is there a way to easily link the two sets of data.

Figure 4 **Beaver Creek Subarea Wells**



Legend

Well Water Use

- Irrigation
- Commercial
- Domestic
- Municipal
- Stock
- AZ Water Co. Rimrock System Service Area
- Major Stream
- Interstate Highway

Note that two or more wells occur at many locations. ADWR only reports well locations to the nearest 10-acre section.

Simulated capture of stream and spring flows and riparian evapotranspiration along the Verde River and its major tributaries as a percentage of pumping after 50 years of constant rate withdrawals from shallow wells.

- 0 - 10%
- 10 - 20%
- 20 - 30%
- 30 - 40%
- 40 - 50%
- 50 - 60%
- 60 - 70%
- 70 - 80%
- 80 - 90%
- 90 - 100%

Sources: See Figures 2 and 3; (Arizona Department of Water Resources 2015); (Arizona Water Company 2012)

Figure 5 Camp Verde Subarea Wells

Legend

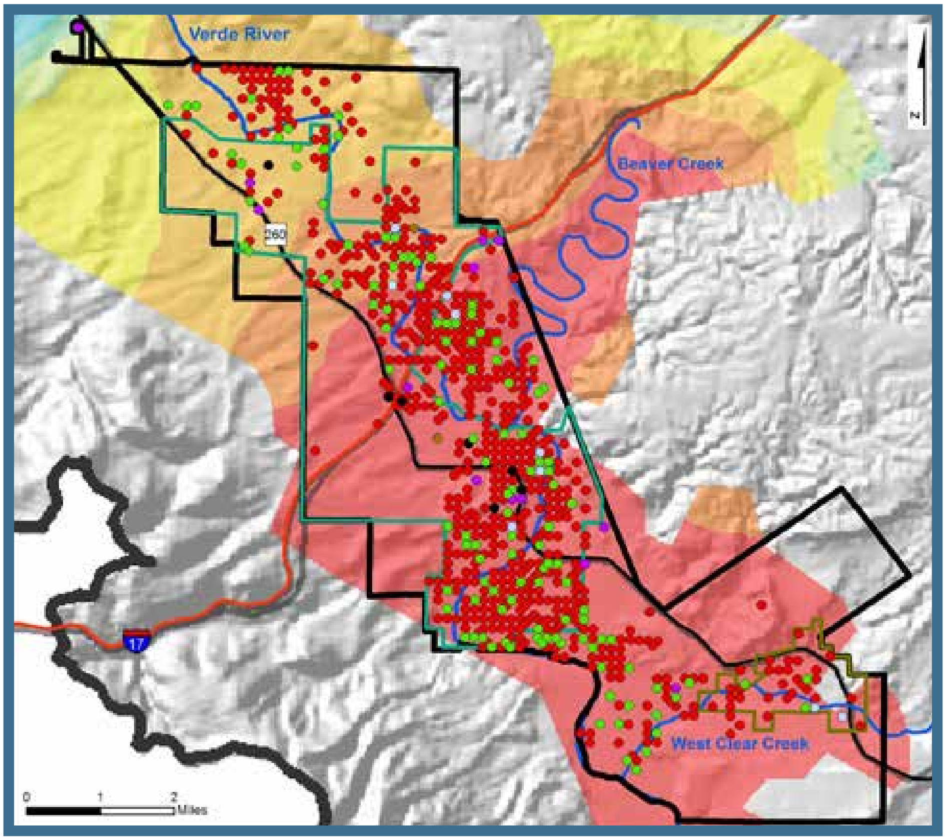
Well Water Use

- Irrigation
- Commercial
- Domestic
- Municipal
- Stock
- Camp Verde Incorporated Area
- Camp Verde Water System
- Verde Lakes Water Corp.
- Major Stream
- Interstate Highway
- Major Road

Note that two or more wells occur at many locations. ADWR only reports well locations to the nearest 10-acre section.

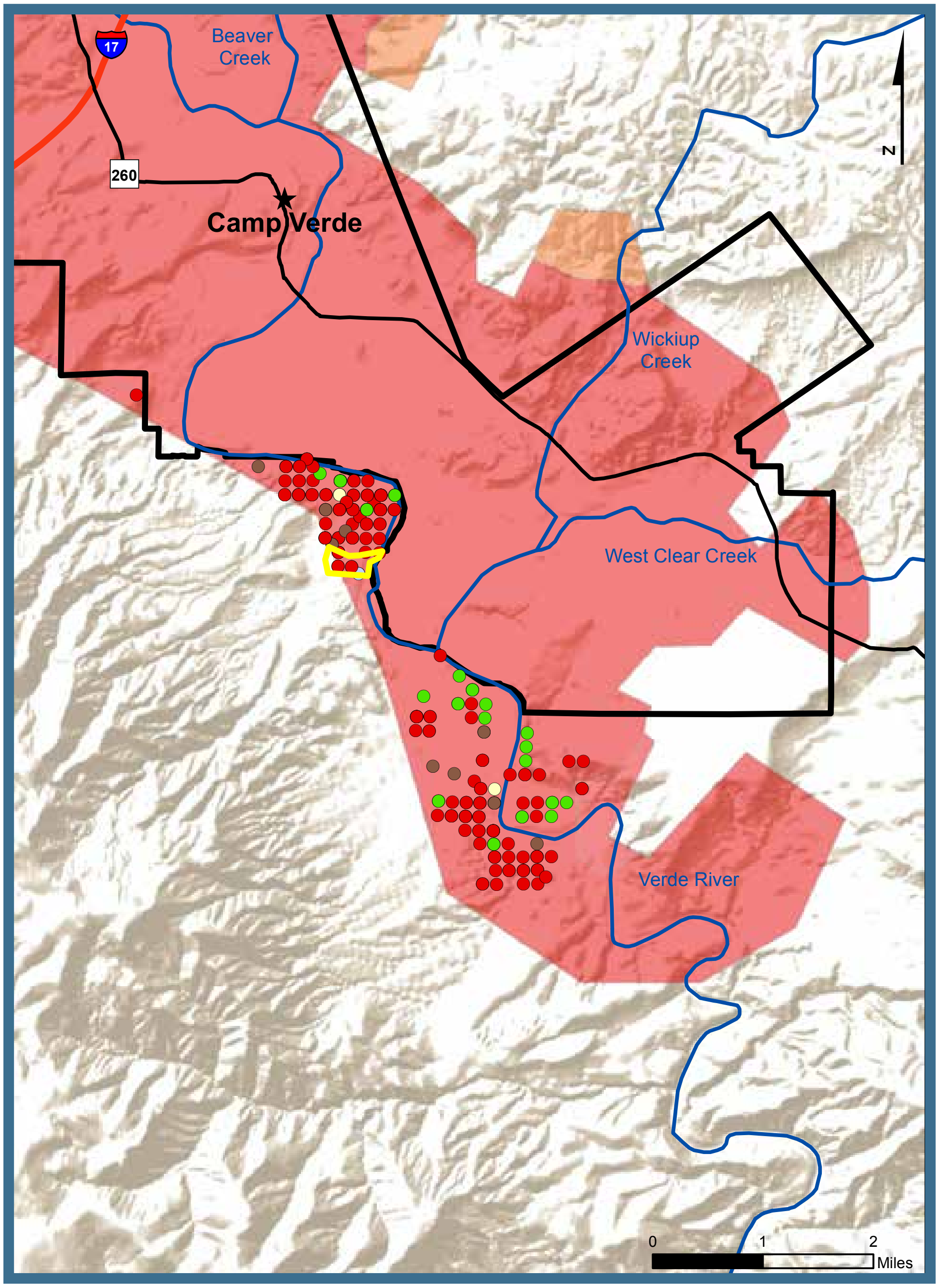
Simulated capture of stream and spring flows and riparian evapotranspiration along the Verde River and its major tributaries as a percentage of pumping after 50 years of constant rate withdrawals from shallow wells.

- 0 - 10%
- 10 - 20%
- 20 - 30%
- 30 - 40%
- 40 - 50%
- 50 - 60%
- 60 - 70%
- 70 - 80%
- 80 - 90%
- 90 - 100%



Sources: See Figures 2 and 3; (Arizona Department of Water Resources 2015)

Figure 6 Camp Verde South Subarea Wells



Legend

Well Water Use

- No Data
- Irrigation
- Domestic
- Municipal
- Stock
- Lake Verde Water Co. Service Area
- Camp Verde Incorporated Area
- Major Stream
- Interstate Highway
- Major Road

Note that two or more wells occur at many locations. ADWR only reports well locations to the nearest 10-acre section.

Simulated capture of stream and spring flows and riparian evapotranspiration along the Verde River and its major tributaries as a percentage of pumping after 50 years of constant rate withdrawals from shallow wells.

- 0 - 10%
- 10 - 20%
- 20 - 30%
- 30 - 40%
- 40 - 50%
- 50 - 60%
- 60 - 70%
- 70 - 80%
- 80 - 90%
- 90 - 100%

Sources: See Figures 2 and 3; (Arizona Department of Water Resources 2015); (Verde Lakes Water Corporation 2013)

Figure 7 Clarkdale/Cottonwood Subarea Wells

Legend

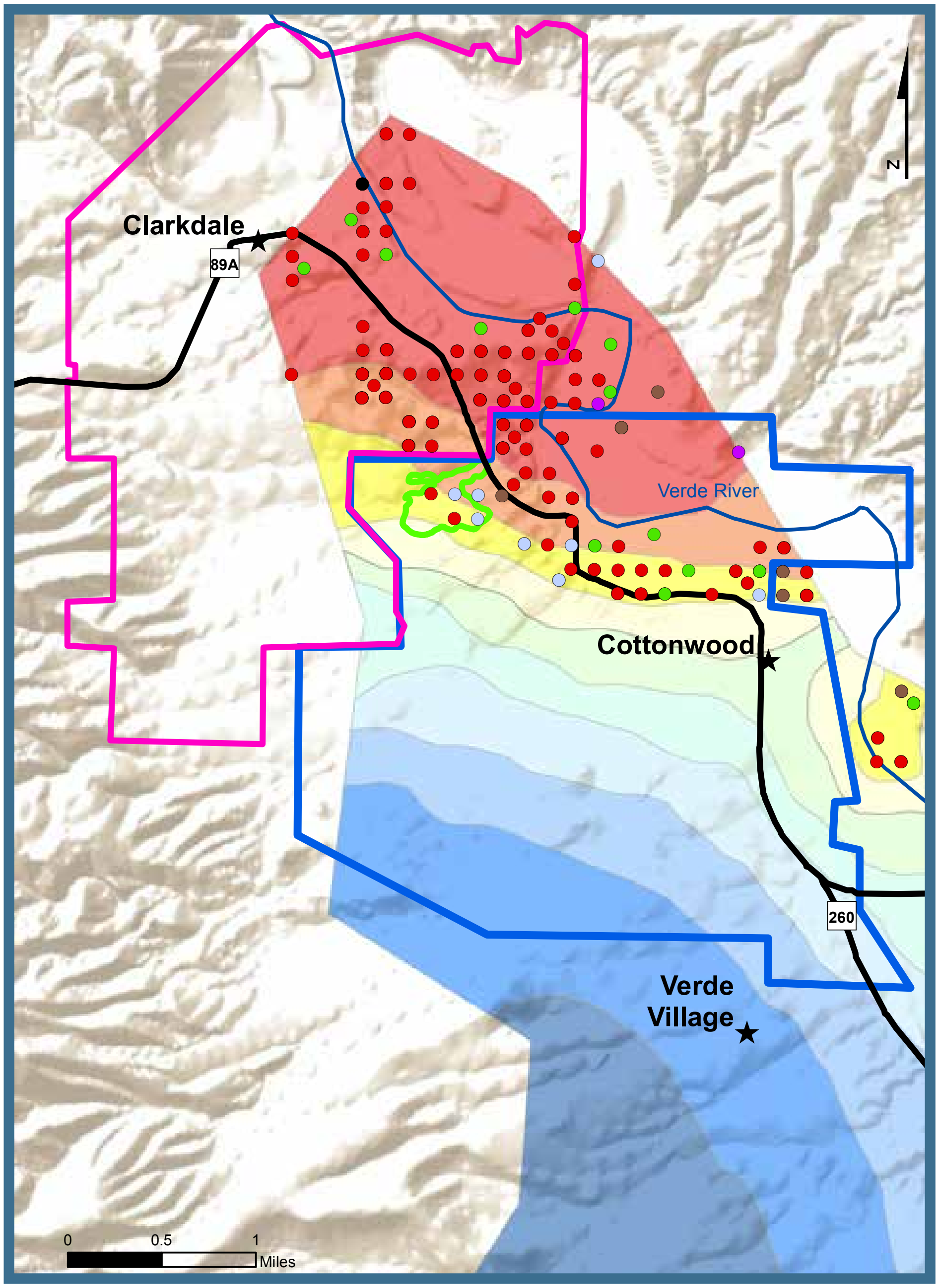
Well Water Use

- Irrigation
- Commercial
- Domestic
- Municipal
- Industrial
- Stock
- Clarkdale Service Area
- Cottonwood Service Area
- On the Greens Service Area
- Major Stream
- Major Road

Note that two or more wells occur at many locations. ADWR only reports well locations to the nearest 10-acre section.

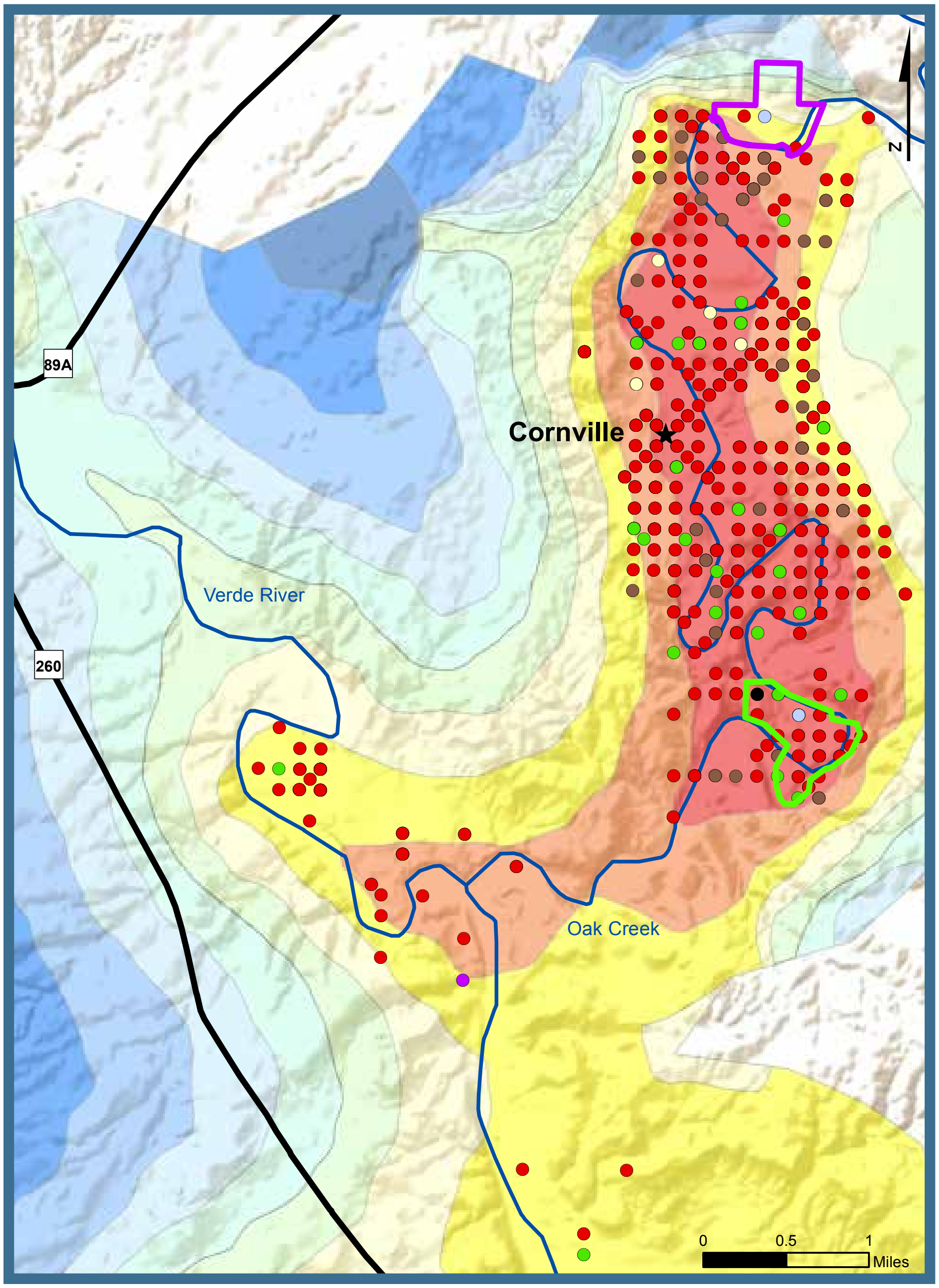
Simulated capture of stream and spring flows and riparian evapotranspiration along the Verde River and its major tributaries as a percentage of pumping after 50 years of constant rate withdrawals from shallow wells.

- 0 - 10%
- 10 - 20%
- 20 - 30%
- 30 - 40%
- 40 - 50%
- 50 - 60%
- 60 - 70%
- 70 - 80%
- 80 - 90%
- 90 - 100%



Sources: See Figures 2 and 3; (Arizona Department of Water Resources 2015); (City of Cottonwood, Arizona 2015); (Town of Clarkdale, Arizona 2015)

Figure 8 Cornville/Oak Creek Subarea Wells



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Well Water Use

- No Data
- Irrigation
- Commercial
- Domestic
- Municipal
- Industrial
- Stock
- Oak Creek Valley Service Area
- Oak Creek Public Service Area
- Major Stream
- Major Road

Note that two or more wells occur at many locations. ADWR only reports well locations to the nearest 10-acre section.

Simulated capture of stream and spring flows and riparian evapotranspiration along the Verde River and its major tributaries as a percentage of pumping after 50 years of constant rate withdrawals from shallow wells.

- 0 - 10%
- 10 - 20%
- 20 - 30%
- 30 - 40%
- 40 - 50%
- 50 - 60%
- 60 - 70%
- 70 - 80%
- 80 - 90%
- 90 - 100%

Sources: See Figures 2 and 3; (Arizona Department of Water Resources 2015); (Oak Creek Valley 2015); (Oak Creek Public Service 2015)

Table 1 Wells in Stream Impact Areas[a]

SIA	Commercial	Domestic	Industrial	Irrigation	Municipal	Stock	Total
			BEAVER CREEK				
90-100%	1	41		4	1		47
80-90%		32		2			34
70-80%		41		1		4	46
Subtotal	**1**	**114**		**7**	**1**	**4**	**127**
			CAMP VERDE				
70-100%	16	1558	12	144	11	10	1751
Subtotal	**16**	**1558**	**12**	**144**	**11**	**10**	**1751**
			CAMP VERDE SOUTH				
90-100%		155		18	2	14	189
Subtotal		**155**		**18**	**2**	**14**	**189**
			CLARKDALE/COTTONWOOD				
90-100%	2	90	1	6			99
80-90%		39		2	2	3	46
70-80%	1	31		4	2	1	39
Subtotal	**3**	**160**	**1**	**12**	**4**	**4**	**184**
			CORNVILLE/OAK CREEK				
90-100%	3	316		29		19	367
80-90%	1	180	1	10		15	207
70-80%		133		5		15	153
Subtotal	**4**	**629**	**1**	**44**		**49**	**727**
TOTAL	**24**	**2616**	**14**	**225**	**18**	**81**	**2978**

a Wells withdrawing water exclusively from layer 1 with the exception of Camp Verde, which was evaluated in a 2014 study that did not identify well depth or the number of wells in each depletion zone. Most Camp Verde wells are located within the 90-100% SIA. In the other geographic subareas 240 wells were identified as pumping below layer 1: 184 residential, 31 irrigation, 17 stock, 7 municipal, 1 commercial. Most of these deep wells are located in the Beaver Creek and Camp Verde South subareas. Deeper wells also deplete streamflow but at a different rate and location than layer 1 wells. See (Leake and Haney 2010).

Most wells in the SIAs are coded by ADWR as domestic, serving residential-type water uses. There are smaller numbers of irrigation, stock, municipal (water provider or Community Water System[2]), commercial, and industrial wells. Of the 1,751 Camp Verde wells, approximately 1,100 are within water provider service areas. Elsewhere, with relatively few water providers in the SIAs, only about 200 of the over 1,200 wells are located within service area boundaries. Private wells within service areas may be used for a variety of purposes or not at all, which affects demand estimates discussed in the following section.

Approximately 6,000 Residents in Stream Impact Areas Use Domestic Wells

The domestic well population within the study area is substantial. Using well data, adjusted for potential non-use of wells within water provider service areas,[3] it is estimated that approximately 6,000 residents use domestic wells, more than half of which are within the incorporated boundaries of the Town of Camp Verde. This is one-third larger than the population of the Town of Clarkdale. The number of wells and the associated population within and outside of water service areas varies greatly between the subareas (Table 2). In Cornville/Oak Creek, there are two small service areas with most of the population located outside their boundaries, while in Clarkdale/Cottonwood, the reverse is the case.

The domestic well population within the study area is substantial.

Table 2 Estimated Well Owner Population in Stream Impact Areas

Subarea	Within Service Area	Outside Service Area	Total
BEAVER CREEK	62	242	304
CAMP VERDE	1,456	1,929	3,385
CAMP VERDE SOUTH	22	357	378
CLARKDALE/COTTONWOOD	286	86	372
CORNVILLE/OAK CREEK	61	1,507	1,567
TOTAL	**1,887**	**4,121**	**6,006**

Note: Includes all wells.

Chapter 3: WATER DEMAND
How much water is consumed by well users?

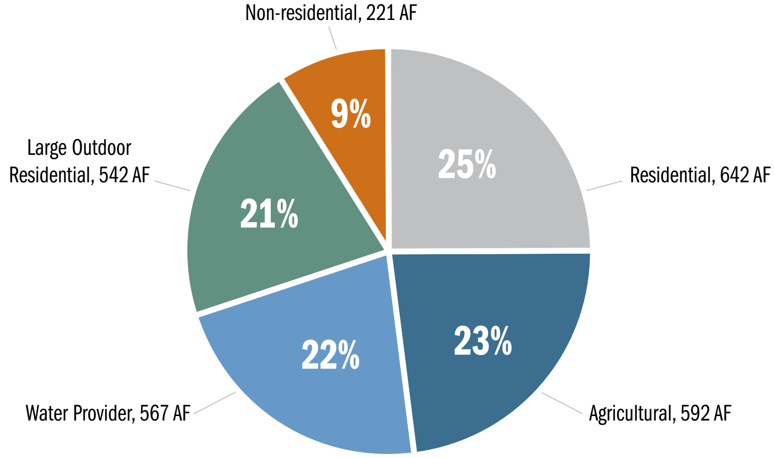
Groundwater well pumping in the stream impact areas is estimated at 2,430 acre-feet a year, which is substantial.

Only a handful of wells pumping in the stream impact areas (i.e., Community Water System wells) are required to meter and report water use to the Arizona Department of Water Resources. All other wells are exempt from these requirements; therefore, water demand must be estimated. Residential, commercial, and other non-residential demand was estimated using Yavapai County Assessor parcel data in combination with Community Water System data on file with ADWR and the Western Resource Advocates water use estimation methods from previous studies. Agricultural and large residential outdoor demand was estimated using a USGS survey conducted in 2010 and 2013.

Total Estimated Well Water Use by Five User Categories

Total estimated well water use by user categories in the study area is shown in Figure 9. Residential demand is the largest component, but demand by agricultural, water provider, and large outdoor residential users is similarly large, while commercial/non-residential demand is significantly smaller, at 221 acre-feet a year. Groundwater well pumping in the stream impact areas is estimated at 2,430 acre-feet a year, which is substantial. By comparison, the largest water provider in the Verde Valley, the City of Cottonwood, withdrew 1,664 acre-feet of groundwater in 2014.

Figure 9 **Total Well Use in Verde Valley Stream Impact Areas, circa 2014**



Total SIA Demand = 2,430 acre-feet/year

Note: AF = acre-feet

The methodology and estimates used to generate water demand for each water user category are summarized in the following sections and described in detail in Appendix A.

Domestic/Residential Water Demand

Residential wells comprise approximately 87% of the total wells in the stream impact areas and 25% of the estimated demand. Components of residential demand include interior use, "typical" outdoor water use, and "large" outdoor residential water use. "Non-typical" or large outdoor residential demand was evaluated separately, because there are conservation opportunities distinct from typical outdoor demand.

Residential wells comprise approximately 87% of the total wells in the stream impact areas and 25% of the estimated demand.

Housing Age Data Used to Estimate Interior Water Demand

The study uses a housing-age-based approach to estimate interior water demand, assuming homes built after passage and implementation of the 1992 U.S. Energy Policy Act have more water-efficient fixtures. **Studies show that residents of pre-1997 homes use about 69 gallons per person per day (GPCD), newer homes use 48 GPCD,** and homes retrofitted with high-efficiency fixtures use 41 GPCD (Table A-2). Housing age data are readily available from assessor records, but because wells cannot easily be linked to parcels within water provider service areas, demand estimates for these wells are shown as a range of new home/old home demand (Table 3). In addition, residential demand within water provider service areas was adjusted to account for wells that may not be in use or used only for part of the household demand (e.g., outdoor use), using a phone survey conducted in 2013 in Camp Verde (Table A-1).

Outdoor Water Use Assumed to Match Water Provider Data

Outdoor water use is harder to quantify because it is discretionary and can vary considerably from place to place. Since it is not possible to identify typical residential outdoor water use by remote imagery or even field investigation, WRA assumed that the percentage of "typical" outdoor water use for homes using wells is comparable to that of homes served by water providers. Analysis of water provider delivery records showed about 31% of water is used outdoors, with as much as 40% to 65% during the hottest and driest time of year (Table A-3, Figure A-1). It is estimated that older homes in the study area use about .26 to .28 acre-feet per household annually, or about 84,000 to 91,700 gallons. Newer homes use approximately .18 to .19 acre-feet annually, or 58,600 to 61,900 gallons. This equates to about 100 GPCD for residents in older homes and 69 GPCD for residents in newer homes (Table A-4).

31% of water is used outdoors, with as much as 40% to 65% during the hottest and driest time of year

Table 3 lists the aggregate housing age, wells, and demand estimates for each subarea.[4] **Of the 1,572 parcels for which there was housing age data, 65% are older, suggesting a significant opportunity to reduce demand through replacement of old plumbing fixtures.**

Most Residential Water Pumped in Camp Verde and Cornville/Oak Creek Subareas

Approximately 562 to 723 acre-feet of water is pumped for residential use from wells in the study area, with most occurring in Camp Verde and Cornville/Oak Creek. Pumping in the other areas ranges from 30 to 51 acre-feet. Deep wells (below layer 1) pumping outside service areas account for about 40 acre-feet/year of the total residential demand, with proportionally most of these wells located in Clarkdale/Cottonwood and Camp Verde South. However, these wells are likely still impacting the Verde River and its tributaries, but to a different extent and on a different time frame than wells pumping exclusively from layer 1.

Table 3 Estimated Total Residential Well Use in Stream Impact Areas[a]

Category	Estimated Number in Study Area	Use (AFY/household)[b]	Estimated Quantity of Use (AFY)
BEAVER CREEK			
Older (pre-1997) homes [c]	44	0.28	12
Newer homes [c]	33	0.19	6
Mobile Home Park [d]	30	0.19	6
No date [e]	20	0.19 to 0.28	4 to 6
Active wells inside service area (no date) [f]	26	0.03 to 0.33	4 to 6
Subtotal	**153**		**32 to 36**
CAMP VERDE			
Older (pre-1997) homes	440	0.28	123
Newer homes	200	0.19	38
Active wells inside service area (no date)	968	0.03 to 0.66	135 to 276
Subtotal	**1,568**		**296 to 437**
CAMP VERDE SOUTH			
Older (pre-1997) homes	104	0.28	29
Newer homes	77	0.19	15
No date	16	0.19 to 0.28	3 to 4
Active wells inside service area (no date)	11	0.03 to 0.33	2 to 3
Subtotal	**208**		**49 to 51**
CLARKDALE/COTTONWOOD			
Older (pre-1997) homes	34	0.26	9
Newer homes	11	0.18	2
Active wells inside service area (no date)	122	0.03 to 0.33	18 to 27
Subtotal	**167**		**30 to 39**
CORNVILLE/OAK CREEK			
Older (pre-1997) homes	405	0.26	105
Newer homes	224	0.18	40
No date	34	0.18 to 0.26	6 to 10
Active wells inside service area (no date)	25	0.03 to 0.33	4 to 5
Subtotal	**688**		**155 to 160**
TOTAL			**562 to 723**

Notes:

For simplicity, the aggregate housing age, number of wells and demand estimates for each subarea are listed. This information is also available for each SIA in each subarea with the exception of Camp Verde. AFY = acre-feet per year.

Subtotals and totals include all wells. Layer 1 demand is somewhat lower: 6 acre-feet less for Beaver Creek, 14 acre-feet less for Camp Verde South, 5 acre-feet less for Clarkdale/Cottonwood, 18 acre-feet less for Cornville/Oak Creek, and 43 acre-feet less in total.

a Assumes all houses are occupied.
b Residential use rates are from **Table A-4**. Ranges are used when home ages were not readily available.
c Home construction dates are from the Yavapai County (2013 and 2015) assessor.
d Yavapai County assessor parcel date used. No exterior use assumed based on aerial imagery.
e Unaffixed mobile homes without age data.
f Wells identified from ADWR dtatbase. Does not include wells below Layer 1. Use estimated using **Table A-1** survey results from (WRA 2014) applied to the total number of residential wells.

Large Outdoor Residential Water Demand

Large outdoor residential water demand was defined in the study area as irrigation of land larger than a third of an acre but less than two acres in size. USGS data from 2010 and 2013 that identified irrigated acreage, crop type, and irrigation method were used to identify areas served by well water. The demand estimation method includes an irrigation efficiency coefficient to generate an estimate of the amount of water necessary to apply to the land above the consumptive use of the crop, i.e., the "irrigation losses," which include evaporation, runoff, and percolation to the water table.

The study found 542 acre-feet of large residential outdoor water demand on 80 acres presumed to be using groundwater (Table A-6).

The study found 542 acre-feet of large residential outdoor water demand on 80 acres presumed to be using groundwater (Table A-6). Of this, 66.6 acres, with a water demand of 441 acre-feet, are located within the incorporated limits of Camp Verde. No areas were found in the Beaver Creek subarea. **By comparison there are approximately 800 acres of large residential outdoor demand served by ditch systems within the entire study area.** A variety of plants are irrigated, including grapes, pasture, and orchards, although turf and landscaping is the predominant use by far. It is estimated that flood irrigation is about 50% efficient, requiring twice the volume of water than the plant needs. By comparison, sprinkler irrigation is about 80% efficient and drip is 90%, meaning much less water needs to be withdrawn from the aquifer. Flood irrigation accounts for 92% of the large outdoor residential irrigated area. **The widespread use of inefficient flood irrigation shows that there is significant potential to increase water efficiency in large outdoor residential irrigation.**

Agricultural Water Demand

Agriculture was defined in the study area as commercial irrigation of plants for animal or human consumption on two or more acres of land. Similar to the approach for estimating large residential outdoor water demand, agricultural demand was estimated using acreage, crop type, irrigation method and water source identified by the USGS, and estimates of irrigation efficiency and crop consumptive use. About 100 acres of land are irrigated with well water, which have an annual water demand of over 590 acre-feet (Table A-7). Seventy-five percent of the irrigated lands are flood irrigated, representing 85% and 500 acre-feet of the water used. **Because flood irrigation is about 50% efficient, 250 acre-feet of the 500 acre-feet of water applied to crops is lost to evaporation, surface runoff, and percolation to the aquifer.** Most agricultural lands were found in Camp Verde, with none identified in the Beaver Creek subarea. By comparison, about 1,560 acres of agricultural lands are irrigated with surface water.

Commercial/Non-residential Water Demand

Some wells in the study area are associated with commercial or other types of non-residential uses, including public use, such as schools and national monuments. **In total, 131 non-residential well users were identified, with an estimated annual demand of 221.2 acre-feet (Table 4).** Of this, about 145 acre-feet are used within

Camp Verde and 41 acre-feet are used in the Cornville/Oak Creek subarea. The type and volume of use varies widely, such as recreation, auto sales, churches, offices, retail businesses, schools, and storage warehouses. There are relatively limited numbers of commercial/non-residential wells compared to residential wells; however, the water use of some individual non-residential users can be large. For example, the WRA Camp Verde study (Western Resource Advocates 2014) identified 98 acre-feet of annual well use by three large water users that provided their water use data. This included Camp Verde School District (74 acre-feet), Out of Africa Wildlife Park (13 acre-feet), and Cemex Sand and Gravel (11 acre-feet).

The current investigation identified additional large water users. The demand was estimated — not reported by the user — based on a number of sources and methods described in Table A-9. These include Oak Creek Elementary School (20 acre-feet) and Verde Valley RV and Camping Resort (8 acre-feet) in Cornville/Oak Creek; Dead Horse Ranch State Park (11 acre-feet) in Clarkdale/Cottonwood; and Montezuma Castle National Monument (9 acre-feet) in Beaver Creek.

Table 4 Non-residential Well Use in Stream Impact Areas

Subarea	Number of Wells	Estimated Use (AFY)
BEAVER CREEK 90-100%	1	8.8
BEAVER CREEK 80-90%	1	5.5
BEAVER CREEK 70-80%	4	5.4
BEAVER CREEK Subtotal		**19.7**
CAMP VERDE	90	**145.1**
CAMP VERDE SOUTH 90-100%	1	**0.05**
CLARKDALE/COTTONWOOD 90-100%	7	**15.1**
CORNVILLE/OAK CREEK 90-100%	9	3.6
CORNVILLE/OAK CREEK 80-90%	6	3.0
CORNVILLE/OAK CREEK 70-80%	12	34.6
CORNVILLE/OAK CREEK Subtotal		**41.2**
TOTAL	**131**	**221.2**

Notes:
See **Table A-9** for details on types of use and data sources
AFY = Acre-feet/year

Water Provider Demand

Community Water Systems Pump Substantial Amounts of Well Water

As shown, there is substantial water provider pumping within the stream impact areas, including in the highest stream impact area.

A number of water provider service area wells are located within the study area. These Community Water Systems are required to annually report to ADWR the water withdrawn from each service area well and the amount of water delivered to customers. However, smaller systems may lack customer delivery meters or even meters at the well and must estimate their withdrawals. Even larger systems may not submit complete information, and there is little enforcement if they do not. Table 5 shows the 2014 withdrawals from service area wells located within the study area. As shown, there is substantial water provider pumping within the stream impact areas, including in the highest stream impact area. For example, On the Greens in Clarkdale/Cottonwood serves a nine-hole golf course with a reported use of 92 acre-feet per year. Some wells pump water below layer 1, with aggregate groundwater withdrawals of 289 acre-feet. Other large withdrawals include those by Verde Lakes Water Corporation, White Hills Trailer Park (although this use is estimated), and City of Cottonwood.

Table 5 Reported Water Provider Well Use in Stream Impact Areas, 2014[a]

Subarea	System	Number in Study Area (Active)	Estimated Use (AFY)
CAMP VERDE 90-100%[b]	Buffalo Run MHP	1	12
	Camp Verde Water System Verde Lake Estates[c]	1	9.0
	Clear Creek MHP	1	4
	Montezuma Hts. Water	2	22.0
	Verde Lakes Water Corp	2	121.0
	White Hills Trailer Park	2	50.3
CAMP VERDE 80-90%	Rainbow Acres Community Water System	1	17.0
		CAMP VERDE Subtotal	**223.2**
CAMP VERDE SOUTH 90-100%	Lake Verde Water Co.	1	**19.3**
CLARKDALE/COTTONWOOD 80-90%	City of Cottonwood	1	35.7
	On the Greens[d]	2	102.0
CLARKDALE/COTTONWOOD 70-80%	City of Cottonwood[d]	1	93.1
		CLARKDALE/COTTONWOOD Subtotal	**230.7**
CORNVILLE/OAK CREEK 90-100%	Oak Creek Public Service[d]	1	55.4
CORNVILLE/OAK CREEK 70-80%	Oak Creek Valley Home Owners Assoc.[d]	2	38.8
		CORNVILLE/OAK CREEK Subtotal	**94.2**
TOTAL			**567.4**

Notes:
[a] Well pumping data from Community Water System Annual Reports submitted to the Arizona Department of Water Resources. The Yavapai Apache Nation may pump from wells in the study area but their location is not known
[b] Camp Verde water provider well locations were able to be assigned to individual SIAs
[c] Camp Verde Water System Mongini System wells are located outside the study area
[d] Wells drilled below Layer 1
MHP = mobile home park
AFY = Acre-feet/year

Reducing Pumping Decreases the Amount of Stream Flow Reduction

To the extent that pumping can be reduced regardless of the type of water user, particularly in the highest SIAs, there will be direct benefits to stream flow and riparian vegetation. For example, a well pumping 10 acre-feet a year in the 90% to 100% SIA would reduce stream flow and riparian ET by up to 9 acre-feet a year after 50 years. **Reducing that pumping to 5 acre-feet a year would halve the amount of stream flow reduction.**

There are a number of strategies that can be implemented to reduce the impact of SIA pumping on the Verde River, Oak Creek, and other perennial streams in the Verde Valley. The benefits to stream flow of a selected strategy can be estimated based on the water savings and well location. Strategies that could be implemented by each water using category are discussed in the following section.

Chapter 4: WATER MANAGEMENT STRATEGIES Options to reduce well impacts

Many well users understand that water is a limited resource and that overuse of their well can tax its ability to meet demand. In the study area, reducing pumping has a commensurate impact on river flow. Improving the understanding of the well-to-river relationship can provide a powerful incentive to well owners to use water more efficiently and augment well water supplies with rainwater and stormwater capture.

Providing Water Conservation Tools and Information to Well Owners Is a Key Strategy

Because well owners do not have access to the informational and water conservation resources that are available through a centralized water system (for example, water use and educational information included with a water bill), providing effective water conservation tools and information to well owners is a key strategy to reduce well pumping impacts. Water demand reduction and stormwater capture strategies that may be the most feasible for each water use category are discussed below. Strategies are presented for each water using category, from highest to lowest well water use.

The large number of older homes in the study area suggests there is potential to conserve significant amounts of water and reduce pumping by replacing inefficient fixtures and repairing leaks.

RESIDENTIAL

Interior Residential Opportunities

Replacing Older Toilets and Fixing Leaks Has the Greatest Water Savings Potential

The large number of older homes in the study area suggests there is potential to conserve significant amounts of water and reduce pumping by replacing inefficient fixtures and repairing leaks. The number of older homes exceeds the number of newer homes in all subareas, most notably in Camp Verde and Cornville/Oak Creek, where about 65% of homes with known housing age data are pre-1997 homes. **The greatest savings potential is by replacing old toilets and clothes washers and by fixing leaks.** Based on this information, if 25% of the 1,027 older homes were retrofitted and leaks repaired, a total of 18 acre-feet of permanent demand reduction could be achieved every year. Replacing toilets in the same number of homes (toilets account for the largest water use in an older house) would reduce demand by 7 acre-feet a year or over 100 acre-feet over the lifetime of a toilet.

Fixture replacement and leak detection programs are among the most common water provider residential conservation programs, but programs for homes on private wells are uncommon. However, in Arizona there are two excellent examples of successful programs: both Cochise County and the Cochise Water Project offer toilet replacement programs for homes with private wells located in the Sierra Vista Subwatershed (SVS), where groundwater pumping threatens flow in the San Pedro River.

Building Permits Could Require Efficient Fixtures for New Homes

In addition to existing homes, new home well-water demand could be reduced through building permits requiring installation of high-efficiency plumbing fixtures certified as WaterSense by the U.S. Environmental Protection Agency (EPA). Building permits can also require installation of hot water on demand systems that reduce water lost as the homeowner runs water waiting for hot water. This building permit requirement could also be extended to existing home major remodels. WaterSense fixtures are comparable in price to other fixtures and readily available at home improvement stores. **WaterSense new homes use 20% less water than an average new home (U.S. Environmental Protection Agency 2014).**

Target Area 1 Older homes and new residential construction in all stream impact areas

STRATEGY	
1 Plumbing fixture/toilet replacement and leak repair for older homes	
SAVINGS	29,200 gallons/home/year or more
COST	$122 to $250/unit[5]
FUNDING	County and private foundations
EXAMPLES	**Cochise County** provides rebates of $100/toilet from its general fund for replacement of pre-1994 toilets in the SVS. In 2009, the County estimated its program has saved over 30 acre-feet of water. **The Cochise Water Project** (a 501(c)(3) nonprofit) installs ultra-high-efficiency toilets (0.8 gallons/per/flush) for $95 anywhere in the SVS. Costs for near-stream homes with private wells have been lower. Over 1,000 toilets have been replaced, saving almost 32 acre-feet of water a year. **Arizona Municipal Water Users Association (AMWUA)** offers a free residential leak detection guide. Isolating leaks is most successful if use is metered, but there are many tips that can be used even without a meter.[6]
2 High-efficiency plumbing code or permit requirement for new or substantially remodeled homes	
SAVINGS	20% compared to a typical new home
COST	Low
FUNDING	Local government
EXAMPLES	Sierra Vista, Bisbee, Tombstone, and Cochise counties have adopted interior WaterSense New Home specifications in development codes.

Exterior Residential Opportunities

Irrigation Improvements, Low Water Use Plants, and Rainwater Irrigation Show Great Promise

Typical exterior demand in the study area is estimated to be about 31% of total residential demand, or approximately 19,500 to 29,300 gallons per home annually, depending on housing age. Exterior conservation programs typically involve improving irrigation efficiency, replacing high water use plants with low water use plants, and using harvested rainwater for irrigation. Determining potential overall water savings is difficult because landscape water use can vary significantly from household to household.

Landscape conversion and rainwater harvesting may be the most effective option for reducing typical outdoor water use in the study area, particularly for high water use landscapes. Planting climate-appropriate plants not only reduces water use but also saves maintenance costs and time. Rainwater harvesting can range from simple berms and channels that move storm runoff to planted areas (passive systems) or systems that store and distribute rainwater at a later time. These rainwater capture systems require a catchment area, such as a roof, patio, or driveway, and generally produce about 600 gallons of runoff for every 1 inch of rain falling on a 1,000 square foot catchment area. For many homes in the study area, this **rainwater capture yield would satisfy most, if not all, of their outdoor water demand.** For well owners, storage tanks can reduce the amount of time a well pump operates, thereby reducing wear, and provide a back-up non-potable water supply in the event of a power outage or pump failure. The Cochise Water Project estimated an average savings of 5,100 gallons/year from rainwater tanks.

Education, Rebates, and Building Permit Requirements Can Advance Wider Adoption of these Demand-Reduction Strategies

Landscape conversion and rainwater storage can involve up-front costs, and rebate and incentive programs are helpful in encouraging wider adoption. An initial strategy could involve providing "how to" information to homeowners through ongoing, hands-on workshops. Passive rainwater harvesting and a rain barrel rebate program could be implemented relatively inexpensively. The City of Tucson offers a small rebate for passive rainwater harvesting, and San Diego, Santa Fe, Tucson, and other communities offer rain barrel rebates. Rain barrels generally capture less than 100 gallons and cost around $75 to $150. While rain barrels do not store much water, they are inexpensive, easy to install, and raise awareness about water use, which often leads to additional conservation practices. In addition, building permits for new construction could require exterior conservation features, such as rainwater capture systems and efficient irrigation.

Target Area 2 All residential well owners

STRATEGY	
1 Low-water-use landscape and rainwater harvesting workshops and information	
SAVINGS	Conversion from grass to Xeriscape/native plants can reduce outdoor demand by 90% (Plateau Resources 2012). Rainwater harvesting savings depends on system design and landscape watering needs.
COST	Less than $10,000/year for program staff and materials.
FUNDING	Community/county cost-share agreement, potential assistance through Cooperative Extension.
EXAMPLES	**University of Arizona, Cochise County Cooperative Extension Water Wise** offers monthly workshops on a variety of topics, including rainwater harvesting, native plants, and a Xeriscape tour. [7]
2 Rain barrel rebates	
SAVINGS	650 gallons/year (Western Resource Advocates 2015)
COST	$12.50 to $25.00/barrel rebated
FUNDING	Multi-community cost-share agreement
EXAMPLES	**Tucson Water** has a popular rainwater harvesting rebate program with a graduated pricing structure that encourages large storage tanks. For 50-gallon rain barrels, it rebates a flat $12.50. [8] **The Cochise Water Project** provides closed system rain barrels for $50 that can be linked to other barrels, limited to two per household. [9]
3 Outdoor water use building permit or ordinance	
SAVINGS	Varies. Using harvested water in combination with a low-water-use landscape conversion could meet all exterior demand, an estimated 19,500 gallons/household/year for newer homes.
COST	Low
FUNDING	Local government
EXAMPLES	**Flagstaff Ordinance 2012-03** requires new residential construction to utilize passive rainwater harvesting techniques. **Cochise County Sierra Vista Subwatershed Conservation Overlay Zone** requires efficient sprinkler systems in new developments. **City of Sierra Vista Development Code (Article 151.16)** limits use of turf in new single-family residential developments to rear-yard areas only.

Agricultural

Almost 75% of Agricultural Lands Use Flood Irrigation, Offering Significant Water Saving Opportunities

Improving irrigation efficiency would result in significant water savings.

Although the amount of agricultural lands irrigated with groundwater (100 acres) is small in comparison to surface water irrigated lands (1,560 acres), almost three-quarters of the lands are flood irrigated, representing 500 acre-feet of annual use. Flood irrigation is inefficient, resulting in twice as much water withdrawn from the aquifer as is needed to meet the needs of the plants. Much of this excess irrigation water is lost to evaporation. Improving irrigation efficiency would result in significant water savings. There are only nine well-water flood-irrigated parcels in the study area. **If all parcels could be changed to sprinkler irrigation methods, pumping could be reduced by 190 acre-feet a year.**

Target Area 3

Nine flood-irrigated parcels

STRATEGY: Convert flood-irrigated lands to sprinkler irrigation or improve flood irrigation efficiency	
SAVINGS	Up to 190 acre-feet/year
COST	$1,500 to $4,000/acre for flood to sprinkler conversion; $3,000 for drip [10]
FUNDING	Federal grants
EXAMPLES	**The Nature Conservancy** works with Camp Verde ditch companies to improve the efficiency of diversions from the Verde River so that more water remains in the river and works with local farmers to improve on-farm efficiencies, including converting from flood- to drip-irrigation systems. They received almost $3 million from the federal Regional Conservation Partnership Program administered by the Natural Resources Conservation Service to implement conservation practices in the Verde Valley.

Water Provider

Larger Water Provider Systems Have the Ability to Use Water Rates and Incentives to Increase Conservation

Water providers withdraw 567 acre-feet of water annually within the study area. Water providers have the ability to use water rates and incentives, like water conservation programs, to reduce the water demand of their customers, although many lack the resources to do so. In particular, smaller, privately owned systems, including those regulated by the Arizona Corporation Commission, have constraints on their ability to set rates and recover costs.

In some cases, there may be the potential to manage individual well pumping within a water system to reduce pumping in sensitive areas, such as implementing a "first off/last on" policy that would shift most pumping to other wells, using wells in sensitive areas only when necessary — for example, during a short period of time in the summer when demand is highest. The City of Cottonwood pumped 129 acre-feet from two wells within the SIA in 2014 and, if feasible, could prioritize pumping from different wells that had less impact on river flows.

Water providers also have the opportunity to influence water demand in their service area. For example, On the Greens, a home and golf course community that delivers about 92 acre-feet of water to the Coyote Trails Golf Course, could conduct a golf course irrigation audit to ensure water is used as efficiently as possible.

Pumping can also be reduced by locating and fixing system leaks to reduce the volume of unnecessary pumping. This also reduces the amount of "non-revenue" water the provider pumps, which makes sound financial sense. Cottonwood has made significant progress reducing its system water loss.

Many Small Systems Lack Well and/or Customer Meters to Identify Leaks

Many small systems lack delivery meters, making it impossible to calculate how much water is lost between the well and the customer. Only four of the Verde Valley systems with wells in the study area appear to have both well and customer meters. Of these systems, Verde Lakes Water Corporation has high system loss. However, the cause of this loss, whether it is due to leaks (actual loss) in the system, non-use of pumped water due to elevated arsenic levels, or water accounting/meter problems (apparent loss), needs investigation.

Target Area 4

Large water providers

	STRATEGY
1	**Investigate system loss (Verde Lakes Water Corp.)**
SAVINGS	Depends on whether loss is actual or apparent. If actual, reducing losses to the industry standard of 10% could reduce withdrawals by 7 to 24 acre-feet/year based on past water use records.
COST	Leak detection survey and repair costs vary, depending on the location and cause of the leak.
FUNDING	Potentially though the Rural Water Association of Arizona or cost recovery through the Arizona Corporation Commission.
EXAMPLES	**The City of Cottonwood** acquired private water systems with high system loss and reduced losses from 45% to 11%, allowing 20% less groundwater pumping than when the systems were privately owned (Smart Cities Council 2015). **American Water Works Association (AWWA)** has excellent water loss control information and free water audit software. [11]
2	**Investigate the impact of and incentives to reduce pumping in sensitive areas through system management (Cottonwood)**
SAVINGS	Depends on feasibility and system management considerations – up to 129 acre-feet/year of relocated pumping.
COST	Depends on the need for hydrologic investigation and system operation modifications.
FUNDING	Water provider
EXAMPLES	**The City of Tucson** decreased pumping by 80% from its Tanque Verde Well Field in order to reduce impacts to a riparian area by implementing a "first off/last on" management policy that relies on pumping and water distribution from other well fields.

Large Outdoor Residential

Large outdoor residential irrigation is distinct from what is considered “typical” residential landscape irrigation as it can involve up to two acres of irrigation. This study found a variety of large outdoor residential irrigation from grass to orchards. As with agricultural irrigation, much of the large residential use is served by ditch systems; however, there are almost 67 acres of well-irrigated large outdoor residential lands with a demand of 542 acre-feet. With the exception of 14 acres, all other lands are flood irrigated.

If all the flood-irrigated lands were sprinkler irrigated, almost 150 acre-feet of water would not need to be pumped each year.

Improving Irrigation Efficiency of Flood-Irrigated Residential Land Could Save Substantial Water

Improving the irrigation efficiency of flood-irrigated residential land through improved irrigation scheduling or changing to sprinkler or drip irrigation could save substantial amounts of water. For example, if all the flood-irrigated lands were sprinkler irrigated, almost 150 acre-feet of water would not need to be pumped each year. However this conversion may not be economically feasible for residential well owners. A lower cost alternative is a landscape audit conducted by an irrigation specialist who would provide recommendations to improve efficiency, such as irrigating during early morning and evening rather than the hottest part of the day to reduce evaporative losses, seasonal irrigation adjustments, and identification of passive rainwater harvesting opportunities.

Target Area 5

Flood-irrigated parcels in Camp Verde

STRATEGY: Improve irrigation efficiency and scheduling through an audit program	
SAVINGS	11% reduction, equivalent to 48.5 acre-feet/year
COST	$300/acre-foot
FUNDING	Potentially through Natural Resources Conservation District or grants
EXAMPLES	**San Diego County Water Authority** conducted irrigation efficiency audits of high-demand multi-family landscaping that resulted in an 11% reduction in water use (A & N Technical Services 2011). Though Camp Verde parcels are single-family residential, the extent of the landscaped area and irrigation efficiency is likely similar.

Commercial/Non-residential

The Type of Water Use Varies for Non-residential Wells

The type of water use varies widely for non-residential wells, as shown in Appendix A. Restaurants, schools, offices, and recreation areas all have a unique water use footprint. However, there are some common uses, such as toilets and sinks, that could be addressed regardless of the type of business. There are a few low-cost water demand reduction options, including leak detection and repair of plumbing fixtures and irrigation systems, which could be accomplished through an outreach program, perhaps in conjunction with Cooperative Extension. Another alternative is to conduct water use audits of the highest water users to achieve the greatest "bang for the buck." Among the largest users are the Camp Verde and Oak Creek school districts, recreation/tourism sites, and a large RV park. Further investigation of water use at these sites would identify water savings opportunities that likely include improving irrigation efficiency and replacing inefficient plumbing fixtures.

There are a few low-cost water demand reduction options, including leak detection and repair of plumbing fixtures and irrigation systems.

Target Area 6 High-water users and leak detection for all users

	STRATEGY
1 High-water-user audits	
SAVINGS	Varies depending on conservation potential.
COST	Varies depending on a simple self-investigation (free) to a professional audit conducted by a trained technician and implementation of recommendations.
FUNDING	Potential assistance from Cooperative Extension (for irrigation efficiency), multi-community cost-share agreement, Yavapai County.
EXAMPLES	**Alliance for Water Efficiency** offers resources for commercial, institutional, and industrial water use. [12] **The Arizona Department of Water Resources** offers a simple water use checklist. [13]
2 Self-conducted leak detection	
SAVINGS	10,000 gallons per year or more
COST	Free materials are available, but there would be modest outreach, printing, distribution, and follow-up costs.
FUNDING	Multi-community cost-share agreement, Yavapai County
EXAMPLES	**Arizona Municipal Water Users Association** has a residential leak detection guide that is applicable to many non-residential water uses. It is most useful if water use is metered, but there are tips that can be used even if a meter is absent. [14] The **EPA** provides leak detection resources and information.[15]

All Well Users

Rainwater Use On Site Can Help Reduce Demand for All Well Users

Most of the strategies discussed above are related to reducing demand by conserving water. Another way to achieve reduction in groundwater pumping is to replace it with rainwater that is captured and used on site. This can be done at different scales, from individual homes or businesses to neighborhoods. As discussed in the Exterior Residential Opportunities section above, this practice can take a number of forms, from a storage system to passive rainwater harvesting that directs runoff from a catchment surface, like a roof or driveway, to irrigate a landscaped area. Additionally, this water can be directed to a basin or other feature, where it is available to return to and replenish the aquifer. This not only is a practice that should be considered by all well users, but could be adopted by the county or applicable community as a permit requirement for any new development.

Retaining water on site is the primary objective of "low-impact development" (LID) design that seeks to manage rainfall where it falls to mimic the site's predevelopment hydrology using design techniques to infiltrate and store runoff. This practice also improves water quality by capturing sediment and pollutants that might otherwise enter a watercourse. Information on aquifer benefits from LID practices is not widely available since this is a relatively new practice, and benefits are site-specific and dependent on a number of factors. One example is a street redesign in Los Angeles using LID features that resulted in infiltration of 5.4 million gallons of water a year.

Target Area 7

All well users

STRATEGY: Rainwater/stormwater capture	
SAVINGS	Varies depending on location, but can replace all outdoor well water use.
COST	Varies depending on design. A 1,100-gallon rainwater storage tank costs about $700, while a passive system installed by a homeowner could be less than $200 for materials.
FUNDING	Water Infrastructure Finance Authority of Arizona (for water systems and communities), Arizona Department of Environmental Quality (ADEQ), county or municipality.
EXAMPLES	The **City of Tucson** has a commercial rainwater-harvesting ordinance that requires harvested water to satisfy 50% of the landscape irrigation requirements [16] and a Green Streets policy that encourages the use of stormwater runoff for irrigation and infiltration. [17] An **Oak Creek Watershed Council** project funded by ADEQ involves working with private property owners to implement LID practices in the Sedona Settlers Rest neighborhood to infiltrate runoff into the ground and reduce erosion and pollutant runoff into Oak Creek. [18]

Chapter 5: CONCLUSION

Verde River stream flow is declining, in part due to groundwater pumping, reducing the quality and amount of riparian and wildlife habitat and recreational opportunities. This study provides a starting point to address the impact of wells pumping within the stream impact areas by quantifying the major water demand components and providing strategies that could be implemented to reduce impacts. The WRA methodology used for this report relies on a number of assumptions, but provides a first approximation of pumping and conservation potential.

Interestingly, residential, agricultural, large residential irrigation, and water provider wells have similar magnitudes of demand. This suggests **a good approach could involve multiple water-using sectors, beginning with demand in the highest depletion areas.** In addition, large commercial/non-residential water users offer a unique opportunity to reduce a significant amount of groundwater use at a single location. A first tier approach should involve:

1. older homes, particularly in the Cornville/Oak Creek and Camp Verde 90% to 100% SIA
2. large residential outdoor irrigation in Camp Verde
3. flood-irrigated agriculture
4. water provider service areas
5. large non-residential users, such as schools

In addition to demand reduction efforts, **rainwater and stormwater capture are critical to augment water supplies and replace well water use with a renewable and free water source.** Since shallow wells in the study area have a relatively direct connection to streams, maximizing rainwater use translates to river benefits.

Implementation costs are certainly a consideration, but the cost of doing nothing is huge, with the potential for significant loss of stream flow. This study identified lower-cost approaches to demand management, including cost-sharing agreements between communities, use of volunteers, free or low-cost informational resources, and grants. In addition, municipalities can use codes, ordinances, conservation districts, and building permit conditions to implement low-cost well-water demand reduction strategies.

All water users in the Verde Valley have a stake in using water in a sustainable manner in order to protect local water supplies, rivers, wildlife, recreation, and the local economy. While stream flow diversions are large, groundwater pumping and its impact on stream flow is significant and increasing. Providing the tools to promote more sustainable groundwater use is critical to the health of the Verde River, its tributaries, and communities.

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APPENDIX A: Water Demand Analysis

Residential, commercial, and other non-residential demand was estimated using Yavapai County Assessor parcel data in combination with Community Water System[19] data on file with the Arizona Department of Water Resources and Western Resource Advocates' water use estimation methods from previous studies (Plateau Resources 2012; Western Resource Advocates 2014). Agricultural and large residential outdoor demand was estimated using a USGS survey conducted in 2010 and 2013.

Domestic/Residential Water Demand

Residential wells comprise approximately 87% of the total wells in the stream impact areas and, as such, are an important constituent of stream flow impact. Components of residential demand include interior use, "typical" outdoor water use, and "large" outdoor water use. Some residential well uses may include livestock watering, but it was not possible to identify or quantify this use.

In addition to private residential wells outside areas served by water providers, private wells are also found within water provider service areas and were identified through ADWR well records. Residential demand within water provider service areas was adjusted to account for wells that may not be in use or used only for part of the household demand, using a phone survey conducted in 2013 in Camp Verde. A similar survey was attempted for this study but was unsuccessful in capturing a representative sample. The Camp Verde survey found that 49% of the wells served both interior and outside water use, 18% served interior use only, 16% served outside use only, 12% were not in use, and 5% served multiple homes for both interior and outside use (Table A-1).

Understanding the relative amount of water used indoors and outdoors is critical to assess water conservation potential and develop corresponding programs that save the most water. Water use varies seasonally, due primarily to increased residential outdoor water use during the warmer months but also due to seasonal residents.

Interior Demand

The WRA interior residential demand estimation methodology relies on housing age information available from assessor records. Outside of water provider service areas, it is straightforward to use parcel data because any occupied parcels must have a water supply/well. Within a service area, it is not readily feasible to determine the specific parcel served by a well due to the imprecision of the well location data. Without specific parcel data, housing age cannot be determined. For these wells, the demand estimate is the range of new home/old home demand. In the study area, the number of privately owned residential wells in service areas as a percentage of the total is large in Clarkdale/Cottonwood (73%) and Camp Verde (62%), but very small in the other subareas, ranging from 17% in Beaver Creek to 4% in Cornville/Oak Creek.

Table A-1 Results from 2013 Phone Survey of Camp Verde Residential Well Owners within Water Provider Service Areas[a]

WELL USE CATEGORY	RESPONDENTS[b,c]	
	Number	Percentage
Well supplies water to one home for both interior and exterior use	28	49%
Well supplies water to one home for interior use only	10	18%
Well supplies water to one home for exterior use only	9	16%
Well not in use[d]	7	12%
Well supplies water to multiple homes for both interior and exterior use[e]	3	5%
TOTAL	**57**	**100%**

Notes:

[a] The survey was conducted during November 2013 by locating all completed water supply wells in the service areas using current ADWR well registration records and removing the non-residential wells based on well owner name and/or reported well use. The remaining residential well owners were matched, if possible, to parcel owners in the area using current assessor records. Matched parcel owners were contacted using phone numbers listed on-line or in well registration documents.

[b] Does not include five well owners who were successfully contacted but either (1) refused to answer the survey; (2) indicated that there was no well on their property; or (3) could not understand the survey questions.

[c] Several well/parcel owners were not successfully contacted, either because no phone number was found on-line, the number found was no longer active, or no one answered the call. Active numbers were tried at least twice on different days if unsuccessful the first time.

[d] Four wells were determined not in use based on review of recent aerial imagery and parcel improvement records.

[e] Includes two shared wells that each serve two homes and a third shared well that serves an undetermined number of homes.

The interior demand estimation methodology assumes that residential interior water use is primarily dependent on housing age and associated plumbing fixture efficiency. Recent studies have evaluated changes in indoor water use across the United States, and each notes the importance of high-efficiency fixtures in reducing the water demands of newer homes (Aquacraft 2011a,b; Friedman et al. 2011; Great Western Institute 2010; Rashid et al. 2010).

For this study, per capita indoor water use was assumed to be higher in homes constructed before 1997 and lower in newer homes, based on fixture use rates reported by American Water Works Association (AWWA) in 1999 and Aquacraft in 2011.[20] AWWA's data are considered representative of the current indoor water use of pre-1997 homes in the study area, although certainly some older fixtures have been replaced with more efficient ones. The Aquacraft study looked at the indoor water uses of 1,000 homes built after 2001 in nine cities and are considered representative of the current indoor water use in newer homes. Although these studies were of homes served by water providers, indoor use is assumed to be comparable to that of well owners since most indoor use is nondiscretionary (i.e., most people do the same things with water inside their home — wash clothes, flush toilets, take showers). Findings from these studies, which measured individual fixture use, are provided in Table A-2. As shown, AWWA also found that retrofitting homes can reduce indoor use by 15% to 30%, depending on fixture/home age, which can reduce interior use to 41 GPCD.

Table A-2 Estimated Interior Water Use

HOME AGE	AVERAGE DAILY INTERIOR WATER USE (gallons per home)[a]									Daily Per Capita Use	Annual Interior Water Use (AFY)[b]
	Toilets	Clothes Washer	Showers	Faucets	Leaks	Other	Bathtubs	Dish Washer	Total		
Before 1997	42.7	34.7	26.8	25.2	21.9	3.7	2.8	2.3	160.1	69.3	0.18
1997 to present	21.8	22.9	23.7	19.9	15.6	2.4	2.8	1.5	110.6	47.9	0.12
Retrofit existing homes with high efficiency fixtures[c]	17.7	20.3	20.8	17.5	9.7	1.3	6.1	1.7	95.2	41.2	0.11

Notes:
[a] Assumes an average 2.31 persons per household based on 2010 U.S. Census data for the study area. Fixture rates were taken from (AWWA 1999) for pre-1997 homes and from (Aquacraft 2011a,b) for newer and retrofitted existing homes.
[b] Calculated by multiplying the total average daily interior water use by 365 and converting to acre-feet per year (AFY)
[c] Includes 1.28 gallon per flush toilets, 12 to 15 gallon per load clothes washers, 1.5 gallon per minute (gpm) shower heads and 0.5 gpm sink aerators.

Typical Outdoor Demand

Outdoor water use is harder to quantify because it is discretionary and can vary considerably from place to place. Because it is not possible to identify typical outdoor water use at residences by remote imagery or even field investigation, WRA assumed that the percentage of "typical" outdoor water use for homes using wells is comparable to that of homes served by water providers. This assumes that well users are as mindful of exterior water use as are those who pay a water bill since they pay energy and well maintenance costs associated with the volume of groundwater pumped. "Non-typical" or large outdoor residential demand was evaluated separately because there are conservation opportunities distinct from typical outdoor demand.

Residential outdoor use can be estimated by using monthly water provider delivery data. Because of the area's cool winter climate, it can be assumed that little water is used outdoors during this time of year and that the month of lowest winter use is indicative of year-round monthly indoor water use. Use above this level can be assumed to be due primarily to outdoor use. Monthly residential water use records were acquired for several, but not all, water providers in the study area, shown in Table A-3. Using this method, outdoor demand ranges from an average of approximately 28% of residential demand within the Clarkdale service area to 35% in the service area of Oak Creek Public Service, with the highest annual percentage of 42% in the Verde Lakes Water Corporation System. This approach provides a general approximation of outdoor use; while it is a widely used method, it may overestimate indoor demand since some water is likely used outdoors even in the coldest winter months. Recognizing this uncertainty, the average percentage of outdoor water use, 31%, was used as a proxy for the percentage of typical exterior well water use for all well owners within the study area. Outdoor watering served by Verde Valley ditch systems is not included.

Table A-3 Estimated Percentage of Outdoor Water Use by Water System Customers

Subarea/System	Year	Lowest Water Use Month	Highest Water Use Month	% Exterior Use
CAMP VERDE				
Camp Verde Water System	2012	December	June	25
	2011	February	August	20
	2010	December	June	22
Verde Lakes Water Corporation	2012	December	July	42
	2011	January	June	35
	2010	February	June	42
			Mean	**31**
CLARKDALE/COTTONWOOD				
Town of Clarkdale	2014	January	July	22
	2013	February	June	33
			Mean	**28**
CORNVILLE/OAK CREEK				
Oak Creek Public Service	2014	March	June	33
	2013	March	June	35
	2012	March	June	38
			Mean	**35**

Month-to-month exterior use variability is shown in Figure A-1. As expected, although the magnitude of outdoor use varies between the systems, the seasonal pattern is generally comparable, with outdoor use increasing in late spring and continuing through the hot summer months, followed by a decline in September as the monsoon rains wind down, increasing in October for some systems as drier weather returns, and declining into the late fall and winter months. During the hottest and driest time of year, outdoor water use can account for as much as 40% to 65% of the total residential demand. A water conserving annual water profile would be flatter, similar to that of the Camp Verde Water System. Peak summer use can be reduced by planting native plants and those adapted to arid conditions, harvesting rainwater, and improving watering efficiency.

Figure A-1 **Estimated Monthly Percentage of Residential Outdoor Water Use Served by Water Providers**

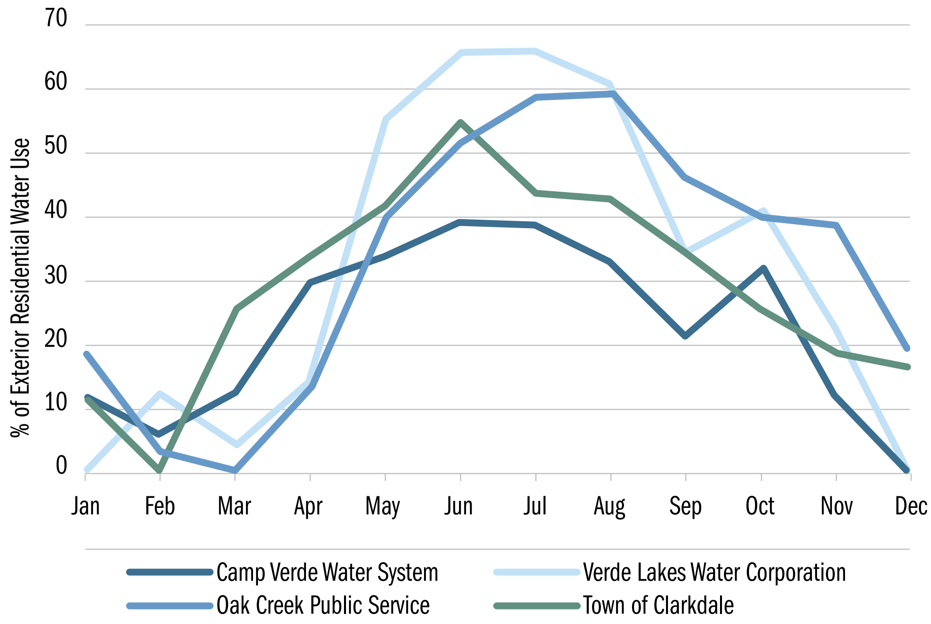


Table A-4 shows indoor and typical outdoor water use of Verde Valley well owners, assuming that 31% of the total residential demand is for outdoor purposes, as it is for the average water provider customer. Because the methodology incorporates higher interior use for older homes, using a percentage calculation results in a higher exterior water use for older homes compared to newer homes. This is consistent with trends in landscape preference over time, but may not be as representative of landscaping trends in more rural settings. Again, the methodology provides a first approximation of demand that should be further verified prior to initiation of an outdoor conservation program.

It is estimated that older homes in the study area use about .26 to .28 acre-feet per household annually, or about 84,000 to 91,700 gallons. Newer homes use approximately .18 to .19 acre-feet annually, or 58,600 to 61,900 gallons. This equates to about 100 GPCD for residents in older homes and 69 GPCD for residents in newer homes.

Table A-4 Estimated Residential Water Use by Well Owners

HOME AGE	ANNUAL WATER USE PER HOUSEHOLD (AFY)[a]			Total Daily Per Capita
	Interior[b]	Exterior[c]	Total Household	
BEAVER CREEK/CAMP VERDE/CAMP VERDE SOUTH[d]				
Before 1997	0.19	0.09	0.28	100
1997 to present	0.13	0.06	0.19	69
CLARKDALE/COTTONWOOD				
Before 1997	0.18	0.08	0.26	100
1997 to present	0.12	0.06	0.18	69
CORNVILLE/OAK CREEK				
Before 1997	0.18	0.08	0.26	100
1997 to present	0.12	0.06	0.18	69

Notes:

a Assumes persons per household of 2.49 for Beaver Creek/Camp Verde/Camp Verde South, 2.29 for Clarkdale/Cottonwood, and 2.3 for Cornville/Oak Creek based on 2010 U.S. Census data for the study area; AFY = acre-feet per year.

b See **Table A-2** for further information on interior residential water use rates.

c Exterior water use rates were calculated by assuming that 31% of the total annual residential water demand is for outdoor purposes. See **Table A-3** for further information on the percentage of exterior water use.

d The three geographic areas are consolidated here due to similar persons per household.

Total Residential Demand

Yavapai County Assessor Parcel records were used to identify residential parcels, housing age, and the type of improvements on each parcel. There are sometimes multiple uses at a given location — e.g., residential and commercial, residential plus a guesthouse or utility building — and an attempt was made to account for multiple residential units on parcels. For wells/homes (assuming one well per household) within water provider service areas for which housing age could not be assigned and for parcels outside service areas with "unaffixed" mobile homes that lack construction dates, a range of estimated residential demand is shown in Table A-5. The location of residential parcels with age data, non-residential parcels, and parcels without age data are shown in Figures A-2 through A-6. Of the 1,572 parcels for which there is housing age data, 65% are older, suggesting a significant opportunity to reduce demand through replacement of old plumbing fixtures.

Approximately 562 to 723 acre-feet of water is pumped from wells in the study area, with most occurring in Camp Verde and Cornville/Oak Creek. Pumping in the other subareas ranges from 30 to 51 acre-feet.[21] It is estimated that deep wells pumping outside service areas account for about 40 acre-feet/year of the total residential demand, with proportionally most of these wells located in Clarkdale/Cottonwood and Camp Verde South. These wells are still impacting the Verde River and its tributaries, but to a different extent and on a different time frame (Leake and Haney 2010).

Table A-5 Estimated Total Residential Well Use in Stream Impact Areas[a]

Category	Estimated Number in Study Area	Use (AFY/household)[b]	Estimated Quantity of Use (AFY)
BEAVER CREEK			
Older (pre-1997) homes [c]	44	0.28	12
Newer homes [c]	33	0.19	6
Mobile Home Park [d]	30	0.19	6
No date [e]	20	0.19 to 0.28	4 to 6
Active wells inside service area (no date) [f]	26	0.03 to 0.33	4 to 6
Subtotal	**153**		**32 to 36**
CAMP VERDE			
Older (pre-1997) homes	440	0.28	123
Newer homes	200	0.19	38
Active wells inside service area (no date)	968	0.03 to 0.66	135 to 276
Subtotal	**1,568**		**296 to 437**
CAMP VERDE SOUTH			
Older (pre-1997) homes	104	0.28	29
Newer homes	77	0.19	15
No date	16	0.19 to 0.28	3 to 4
Active wells inside service area (no date)	11	0.03 to 0.33	2 to 3
Subtotal	**208**		**49 to 51**
CLARKDALE/COTTONWOOD			
Older (pre-1997) homes	34	0.26	9
Newer homes	11	0.18	2
Active wells inside service area (no date)	122	0.03 to 0.33	18 to 27
Subtotal	**167**		**30 to 39**
CORNVILLE/OAK CREEK			
Older (pre-1997) homes	405	0.26	105
Newer homes	224	0.18	40
No date	34	0.18 to 0.26	6 to 10
Active wells inside service area (no date)	25	0.03 to 0.33	4 to 5
Subtotal	**688**		**155 to 160**
TOTAL			**562 to 723**

Notes:

For simplicity, the aggregate housing age, number of wells and demand estimates for each subarea are listed. This information is also available for each SIA in each subarea with the exception of Camp Verde. AFY = acre-feet per year.

Subtotals and totals include all wells. Layer 1 demand is somewhat lower: 6 acre-feet less for Beaver Creek, 14 acre-feet less for Camp Verde South, 5 acre-feet less for Clarkdale/Cottonwood, 18 acre-feet less for Cornville/Oak Creek, and 43 acre-feet less in total.

a Assumes all houses are occupied.

b Residential use rates are from **Table A-4**. Ranges are used when home ages were not readily available.

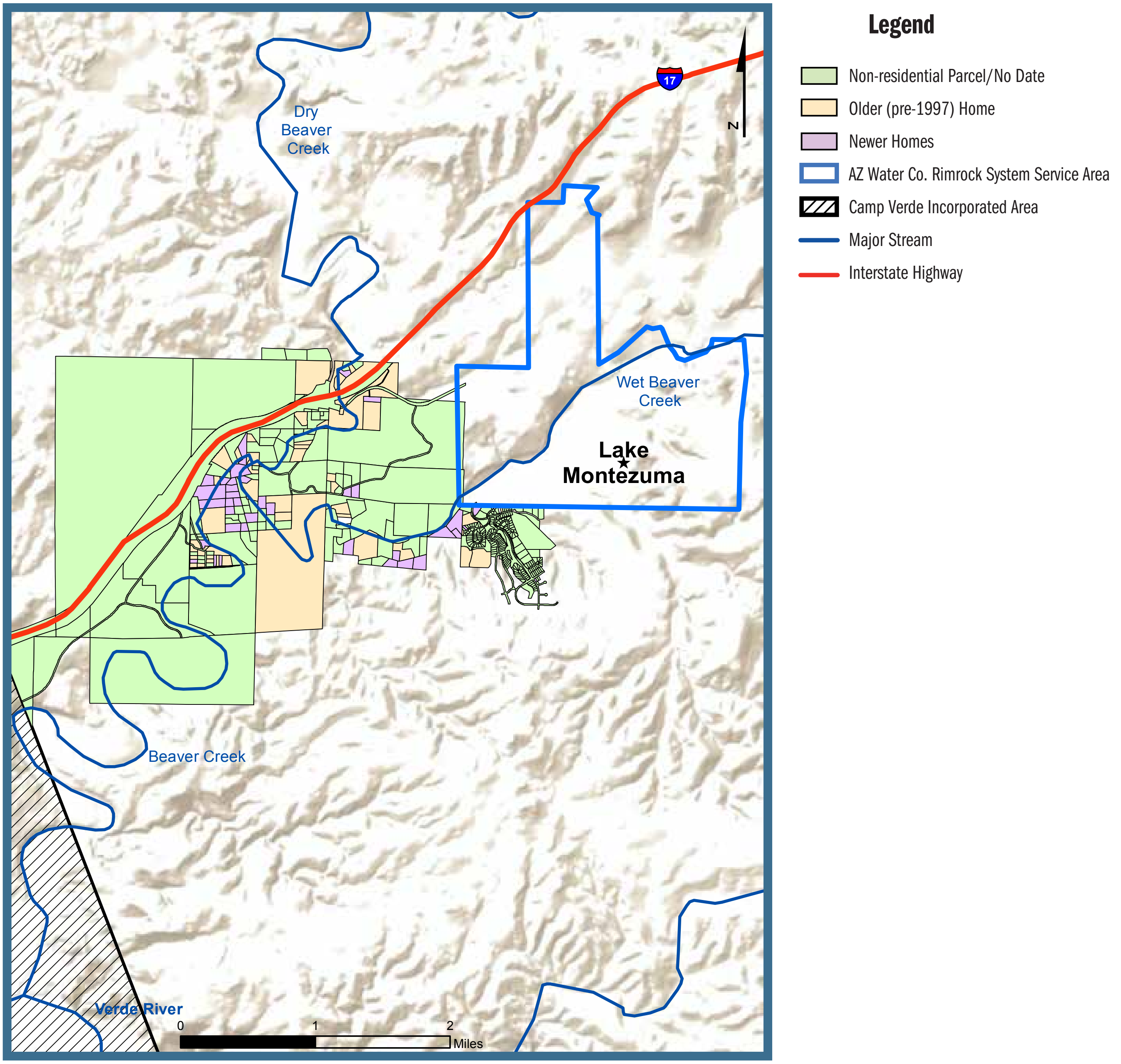
c Home construction dates are from the Yavapai County (2013 and 2015) assessor.

d Yavapai County assessor parcel date used. No exterior use assumed based on aerial imagery.

e Unaffixed mobile homes without age data.

f Wells identified from ADWR dtatbase. Does not include wells below Layer 1. Use estimated using **Table A-1** survey results from (WRA 2014) applied to the total number of residential wells.

Figure A-2 Beaver Creek Subarea Parcels



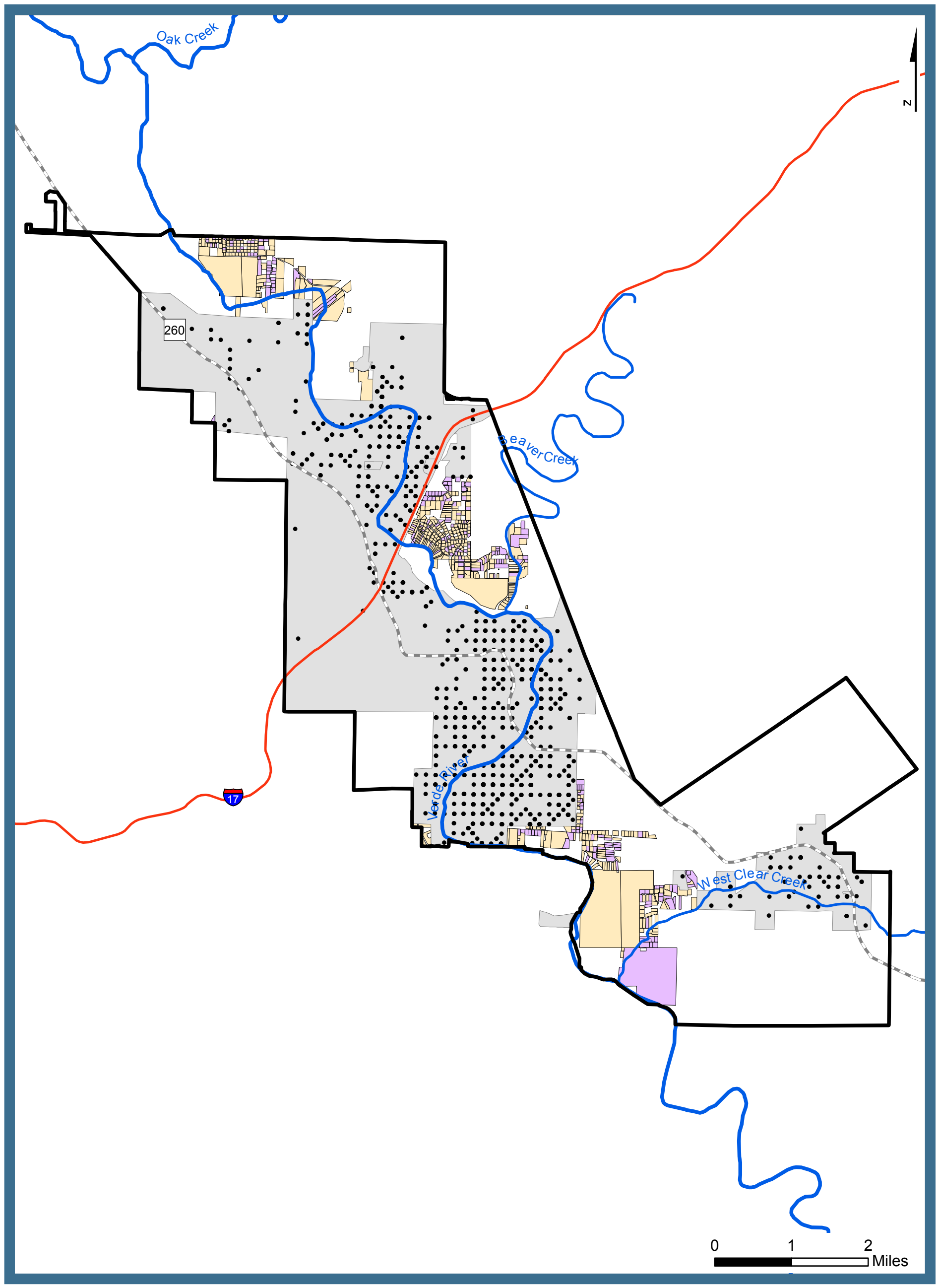
Sources: See Figure 2 ; (Yavapai County 2015); (Arizona Water Company 2012)

Figure A-3 Camp Verde Subarea Parcels

Legend

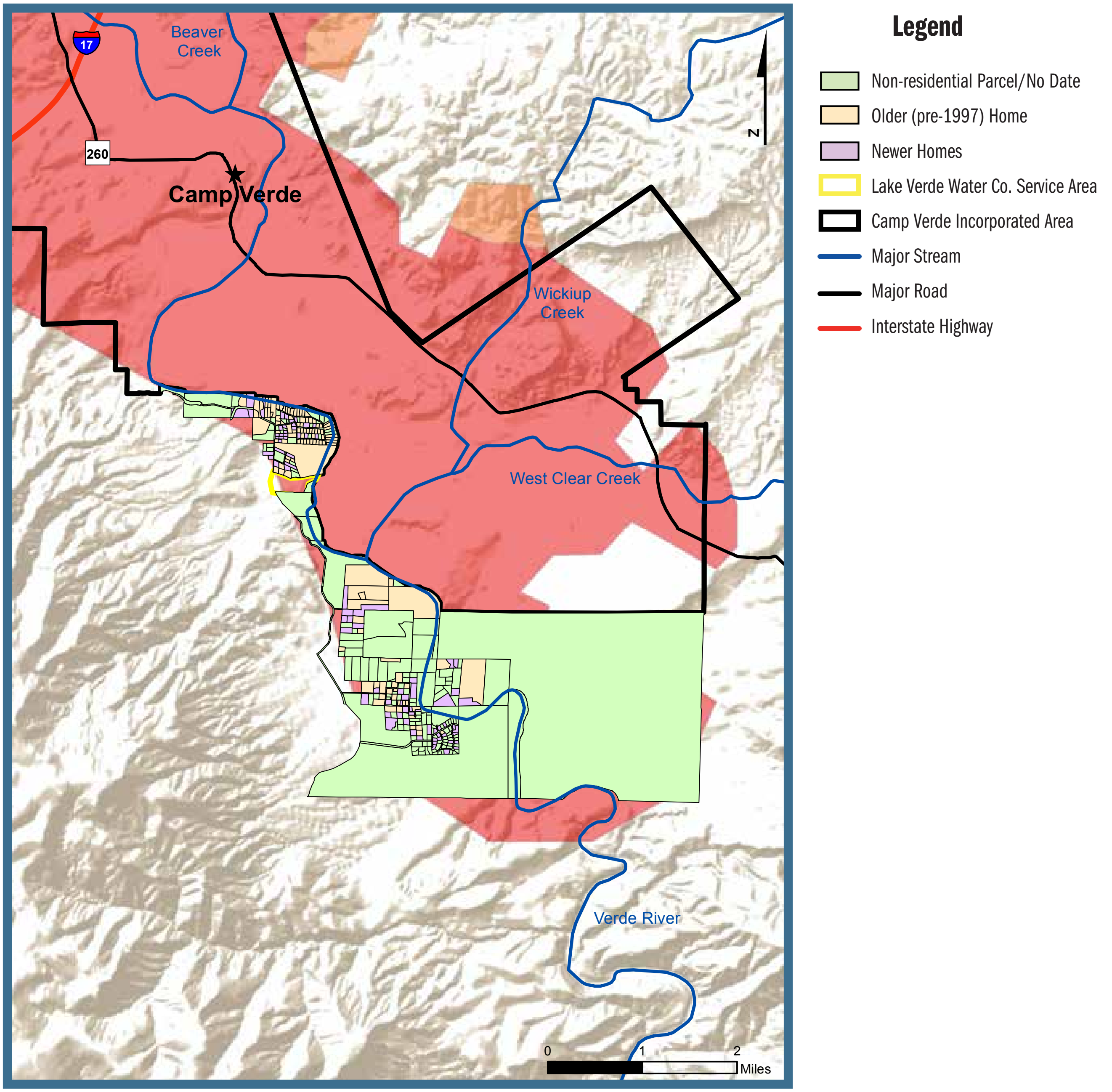
- Water Provider Service Area
- Older (pre-1997) Home
- Newer Homes
- Camp Verde Incorporated Area
- Major Stream
- Interstate Highway
- Major Road
- Water Supply Well

Note that two or more wells occur at some locations. ADWR only reports well locations to the nearest 10-acre section.



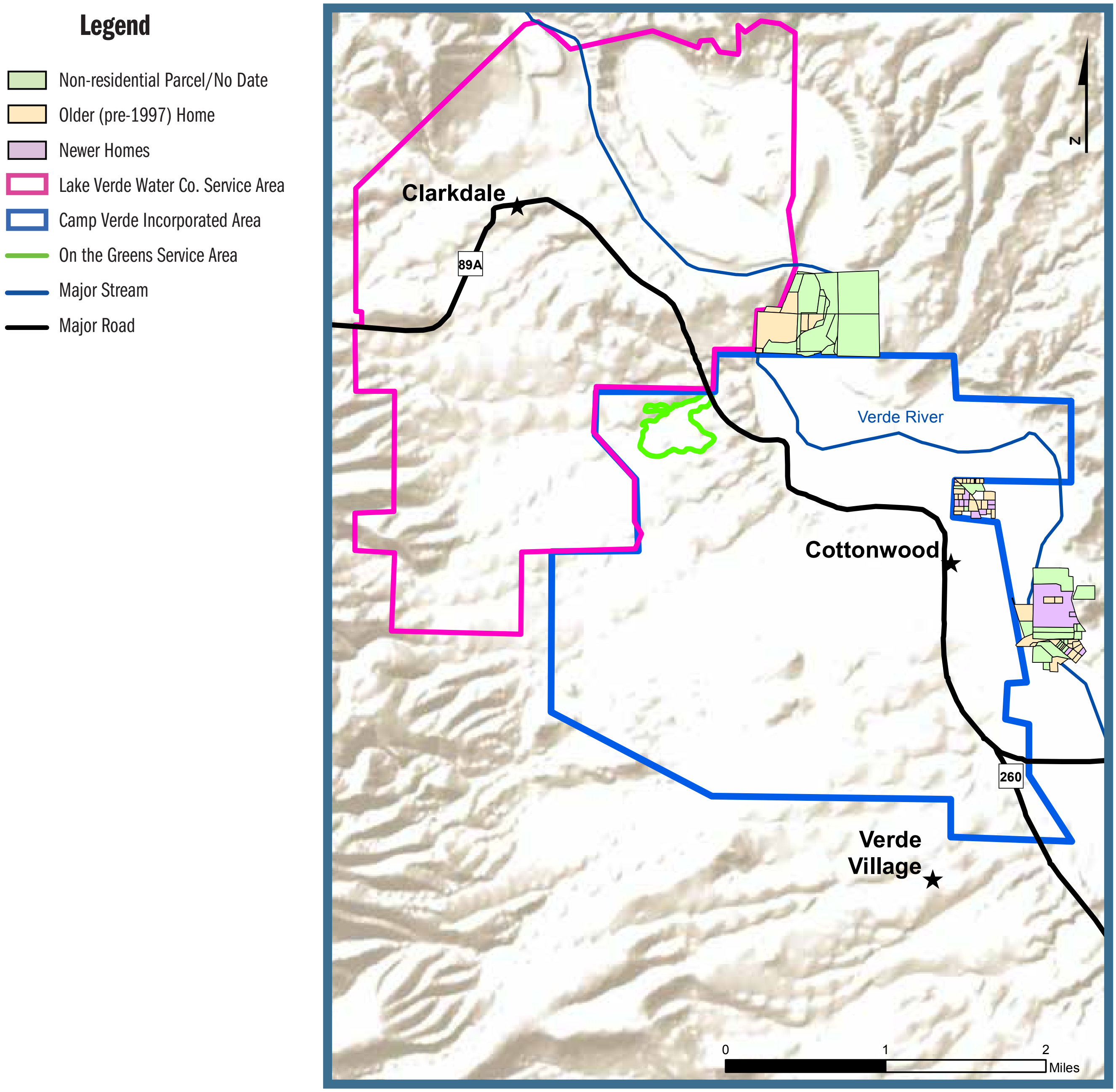
Sources: (Western Resource Advocates, 2014); (Arizona State Cartographer's Office 2013); (Yavapai County 2013); (U.S. Bureau of Reclamation 2010)

Figure A-4 Camp Verde South Subarea Parcels



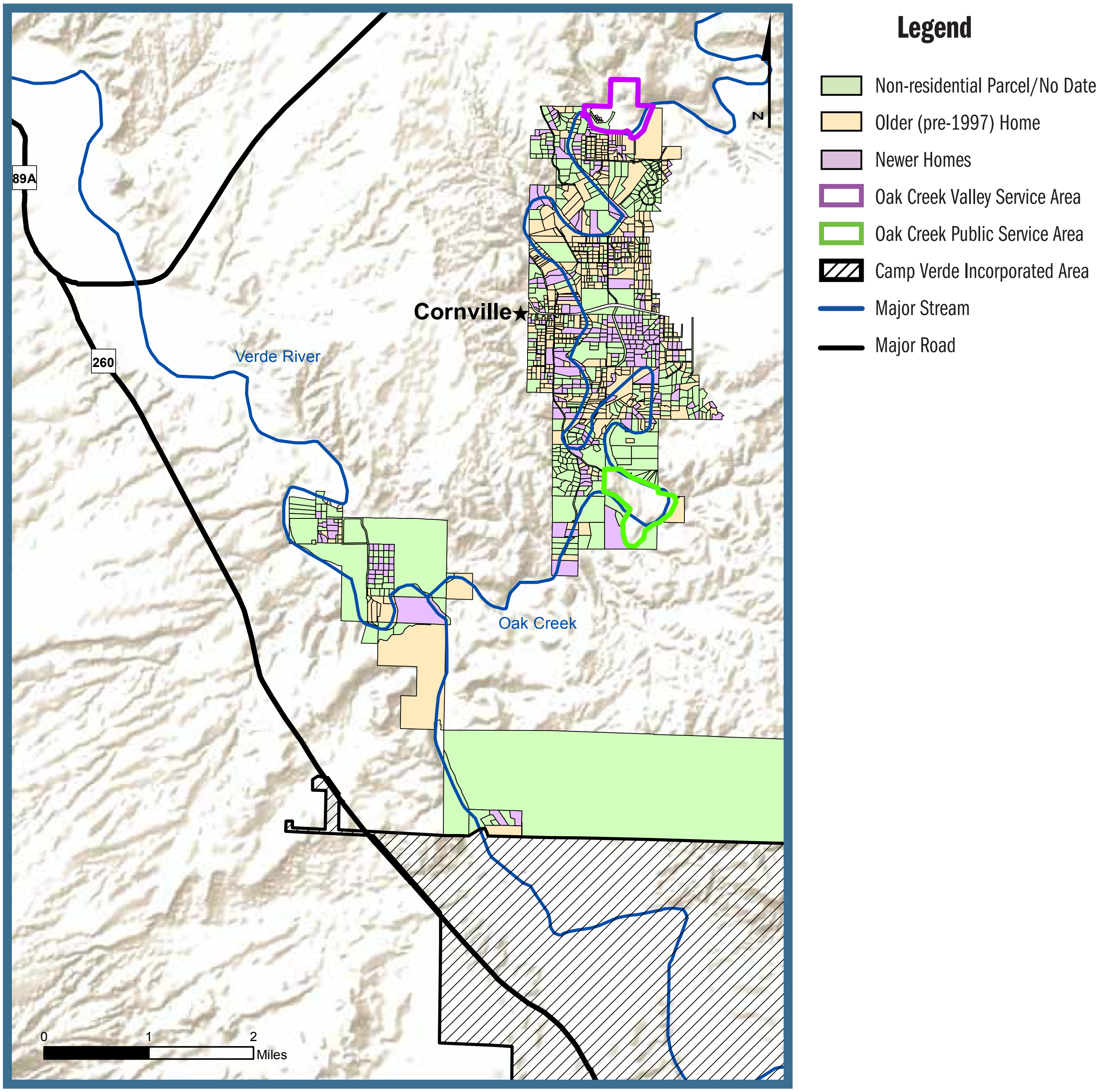
Sources: See Figure 2; (Yavapai County 2015); (Verde Lakes Water Corporation 2013)

Figure A-5 Clarkdale/Cottonwood Subarea Parcels



Sources: See Figure 2; (Yavapai County 2015); (City of Cottonwood, Arizona 2015); (Town of Clarkdale, Arizona 2015)

Figure A-6 Cornville/Oak Creek Subarea Parcels



Sources: See Figure 2; (Yavapai County 2015); (Oak Creek Valley 2015); (Oak Creek Public Service 2015)

Large Outdoor Residential Water Demand

In addition to typical outdoor water use, large outdoor residential water demand served by wells was examined, summarized in Table A-6. This study defines this demand as irrigation of land larger than a third of an acre but less than two acres, although some larger acreage was included in this category because it appeared to be a residential rather than an agricultural use. USGS data were used, which identified irrigated acreage using 2010 aerial imagery, followed by field investigation of accessible acreage in 2010 and 2013. Crop type and irrigation method were also identified. This data was used to screen out areas located within the boundaries of ditch companies, which are assumed to use surface water. It is possible that some irrigated land may use both ditch and well water, but it is not possible to determine the individual use of each. An irrigation efficiency coefficient was included to generate an estimate of the amount of water necessary to apply to the land above the consumptive use of the crop, i.e. the "irrigation losses."

The analysis found 542 acre-feet of large residential outdoor water demand on 80 acres presumed to be using groundwater. Of this, 66.6 acres, with a water demand of 441 acre-feet, are located within the incorporated limits of Camp Verde. No areas were found in the Beaver Creek subarea. By comparison, there are approximately 800 acres of large residential outdoor demand served by ditch systems within the entire study area.

A variety of plants are irrigated, including grapes, pasture, and orchards, although turf and landscaping is the predominant use by far. As shown in Table A-6, areas irrigated with drip and sprinkler are relatively efficient, while flood irrigation results in substantial amounts of irrigation losses. It is estimated that flood irrigation is about 50% efficient, requiring twice the volume of water that the plant needs. By comparison, sprinkler irrigation is about 80% efficient and drip is 90% efficient. Irrigation losses include evaporation, surface runoff, and percolation to the water table. It is outside the scope of this study to conduct the difficult quantification of how much of the irrigation losses associated with large residential outdoor water uses and agriculture return to the aquifer.

In addition to these areas, the USGS also identified smaller irrigated areas less than a third of an acre in size. These were considered to be accounted for as "typical" landscaping, although some areas included grape and pasture irrigation and could be an agricultural use.

Agricultural Water Demand

Agriculture was defined in the study area as commercial irrigation of plants for animal or human consumption on two or more acres of land. Similar to the approach for estimating large residential outdoor water demand, agricultural demand was estimated using acreage, crop type, irrigation method, and water source identified by the USGS, along with estimates of irrigation efficiency and crop consumptive use. About 100 acres of land are irrigated with well water that have an annual water demand of over 590 acre-feet (Table A-7). Seventy-five percent of the irrigated lands are flood irrigated, representing 85% and 500 acre-feet of the water used. Because flood irrigation is about 50% efficient, 250 acre-feet of the 500 acre-feet of water applied to crops are lost to evaporation, surface runoff, and percolation to the aquifer. Most agricultural lands were found in Camp Verde, with none identified in the Beaver Creek subarea. By comparison, about 1,560 acres of agricultural lands are irrigated with surface water.

Table A-6 Large Outdoor Residential Well Use, 2013[a,b]

	TYPE OF USE			USE COEFFICIENTS					
Category	Irrigation Method	Number of Areas Mapped	Total Irrigated Area (acres)	Watering Requirement (ft/yr)[c]	Irrigation Efficiency[c]	Water Demand (ft/yr)[d]	CROP CONSUMPTIVE USE (AFY)[e]	IRRIGATION LOSSES (AFY)[f]	TOTAL WATER DEMAND (AFY)[g]
CAMP VERDE									
Pasture[h]	Flood	4	5.8	3.1	50%	6.2	18	18	36
Turf/ Landscaping[i,j]	Flood	87	57.6	3.4	50%	6.8	196	196	392
	Sprinkler	3	3.2		80%	4.3	11	3	13
	Subtotals	**94**	**66.6**				**225**	**217**	**441**
CAMP VERDE SOUTH									
Pasture	Flood	2	1.5	3.4	50%	6.8	5	5	10
Horticulture	Drip	2	2.7	3.6	90%	4.0	10	1	11
Pasture	Sprinkler	1	0.7	3.1	80%	3.9	2	0	2
	Subtotals	**3**	**4.9**				**17**	**7**	**23**
CLARKDALE/COTTONWOOD									
Grapes	Drip	6	6.7	2.3	90%	2.6	15	2	17
Pasture	Flood	1	1.7	3.4	50%	6.2	6	6	12
Turf/ Landscaping[i,j]	Flood	1	4.5	3.4	50%	6.8	15	15	30
Orchard	Drip	1	0.4	1.7	90%	1.9	1	0	1
	Subtotals	**9**	**13.3**				**37**	**23**	**60**
CORNVILLE/OAK CREEK									
Grapes	Drip	1	0.5	2.3	90%	2.6	1	0	1
Pasture	Flood	1	1.4	3.4	50%	6.2	5	5	10
Turf/ Landscaping[i,j]	Flood	1	0.8	3.4	50%	1.9	3	4	7
	Subtotals	**3**	**2.7**				**9**	**9**	**18**
	TOTALS	**103**	**79.9**				**287**	**255**	**542**

Notes:

For simplicity, the aggregate housing age, number of wells and demand estimates for each subarea are listed. This information is also available for each SIA in each subarea with the exception of Camp Verde. AFY = acre-feet per year

a USGS initially identified acreages using 2010 aerial photography and verified through 2010 and 2013 summer field visits. Plateau further verified Camp Verde irrigation by analysis of high resolution aerial photography flown on May 28, 2013. Does not include previously irrigated areas that appeared on the 2013 imagery to be discontinued.

b Includes irrigated areas that each cover less than 2.0 acres. For simplicity, individual SIA information within subareas is not displayed.

c Average watering requirements from USDA (2013) and ADWR (2000); USGS (2013b) provided typical irrigation efficiencies.

d Calculated by dividing the watering requirement by the irrigation efficiency.

e Calculated by multiplying the total irrigated area by its watering requirement.

f Based on the total irrigated area, watering requirement and irrigation efficiency; can include evaporation, irrigation return flows and percolation.

g Calculated by adding crop consumptive use and irrigation losses.

h Includes about four acres of fallow lands possibly cropped later in the year by flood irrigation plus about two acres of lands that appeared partly cropped in May 2013 imagery and were assumed 75% active.

i Includes grass adjacent to homes and horse properties plus mixed grass and orchards, including an area larger than two acres in size. Also includes about 29 acres in Camp Verde not previously identified by USGS that Plateau assumed were flood irrigated turf.

j Does **not** include smaller (typically less than 0.3-acre) lawns. Plateau observed around 100 homes in the May 2013 Camp Verde imagery and USGS identifed about 20 homes in other areas. For purposes of this study, these lawns are considered incidental exterior uses already accounted for in the residential use rates. Also does not include about ten acres of fields irrigated by Camp Verde School District which provided Plateau with their metered well use, or playing fields at Oak Creek Elementary School that are included in "Commercial/Non-residential" category.

Table A-7 Agricultural Well Use, 2013 [a,b]

Category	Irrigation Method	Number of Areas Mapped	Total Irrigated Area (acres)	Watering Requirement (ft/yr)[c]	Irrigation Efficiency[c]	Water Demand (ft/yr)[d]	CROP CONSUMPTIVE USE (AFY)[e]	IRRIGATION LOSSES (AFY)[f]	TOTAL WATER DEMAND (AFY)[g]
	TYPE OF USE			USE COEFFICIENTS					
CAMP VERDE									
Alfalfa	Flood	5	59.7	3.5	50%	7.2	215	215	430
Pasture	Flood	1	2.0	3.1	50%	6.2	6	6	12
	Subtotals	**6**	**61.7**				**221**	**221**	**442**
CAMP VERDE SOUTH (90-100%)									
Corn	Flood	1	7.7	1.9	50%	3.8	15	15	30
Horticulture	Drip	1	9.0	3.6	90%	4.0	32	4	35
Pasture	Flood	1	2.2	3.1	50%	3.9	7	7	14
	Subtotals	**3**	**18.9**				**54**	**26**	**79**
CLARKDALE/COTTONWOOD (70-80%)									
Grapes	Drip	1	3.1	2.3	90%	2.6	7	1	8
Pasture	Sprinkler	1	9.5	3.1	80%	3.7	29	7	35
	Subtotals	**2**	**12.6**				**37**	**8**	**43**
CORNVILLE/OAK CREEK (80-90%)									
Grapes	Drip	1	3.1	2.3	90%	2.6	7	1	8
Pasture	Flood	1	3.1	3.1	50%	3.9	10	10	20
	Subtotals	**3**	**6.2**				**17**	**11**	**28**
	TOTALS	**14**	**99.4**				**328.3**	**265.1**	**592.0**

Notes:

ft/yr = feet per year, AFY = acre-feet per year.

a USGS initially identified acreages using 2010 aerial photography and verified through 2010 and 2013 summer field visits. Plateau further verified Camp Verde irrigation by aerial photography flown on May 28, 2013. Does not include previously irrigated areas that appeared to Plateau as discontinued in the 2013 imagery.

b Includes irrigated areas that each cover at least 2.0 acres and appear to be used for commercial purposes. Some areas less than 2.0 acres are included here if likely part of the same farming operation.

c Average watering requirements from (USDA 2013) and (ADWR 2000); (USGS 2013) provided typical irrigation efficiencies.

d Caluclated by dividing the watering requirment by the irrigation efficiency.

e Calculated by multiplying the total irrigated area by its watering requirement.

f Based on the total irrigated area, watering requirement and irrigation efficiency; can include evaporation, irrigation return flows and percolation.

g Calculated by adding crop consumptive use and irrigation losses.

Commercial/Non-residential Water Demand

Some wells in the study area have commercial or other types of non-residential uses, including public use. In total, 131 non-residential users were identified, with an estimated annual demand of 221.2 acre-feet, as shown in Table A-8. Of this, about 145 acre-feet are used within the Camp Verde incorporated limits and 41 acre-feet are used in the Cornville/Oak Creek subarea, with most in the 70% to 80% SIA. The type and volume of use varies widely, from recreation areas to auto sales, churches, offices, retail, schools, and storage warehouses.

There are relatively limited numbers of these wells compared to residential wells; however, the water use of some individual non-residential users can be large. For example, the WRA Camp Verde study identified 98 acre-feet of well use by 3 large water users that provided their water use data. This included Camp Verde School District (74 acre-feet), Out of Africa Wildlife Park (13 acre-feet), and Cemex Sand and Gravel (11 acre-feet).

The current investigation identified additional large water users, although the demand was estimated — not reported by the user — based on a number of sources and methods described in Table A-8. These include Oak Creek Elementary School (20 acre-feet) and Verde Valley RV and Camping Resort (8 acre-feet) in Cornville/Oak Creek; Dead Horse Ranch State Park (11 acre-feet) in Clarkdale/Cottonwood; and Montezuma Castle National Monument (9 acre-feet) in Beaver Creek.

Table A-8 Non-residential Well Use in Stream Impact Areas[a] *

TYPE OF USE[b]		USE METRIC			UNIT TOTAL [d,e]	ESTIMATED QUANTITY OF USE (AFY)
Category	Number in Study Area	Value	Units	Source[c]		
			BEAVER CREEK 90			
Recreation Area	1	5.00	gal/visitor/day	II	574,000 visitors	8.8
			BEAVER CREEK 80			
Boarding School [f]	1	60.00/20.00	gal/person/day	IV	74 students/24 staff	5.5
			BEAVER CREEK 70			
Convenience Store	1	7.92	gal/ft²/mo	I	2,122 heated square ft	0.6
Restaurant	1	25.52	gal/ft²/mo	I	4,237 heated square ft	3.8
Retail	1	0.11	gal/ft²/mo	III	3,509 square ft	0.4
Service Garage	1	12.47	gal/ft²/mo	I	1,365 heated square ft	0.6
					Beaver Creek Subtotal	**19.8**
			CAMP VERDE			
Auto Sales	1	3.84	gal/ft²/mo	I	56,208 heated square ft	7.9
Church	7	1.26	gal/ft²/mo	I	44,927 heated square ft	2.1
Clubhouse	4	5.16	gal/ft²/mo	I	7,981 heated square ft	1.5
Convenience Store	1	7.92	gal/ft²/mo	I	785 heated square ft	0.2
Heavy Manufacturing	1	1.20	gal/ft²/mo	I	5,771 heated square ft	0.3
Light Manufacturing	6	0.87	gal/ft²/mo	I	28,303 heated square ft	0.9
Medical	4	3.98	gal/ft²/mo	I	1,058 heated square ft	0.2
Municipal	1	15.19	gal/ft²/mo	I	7,110 heated square ft	4.0
Office Building	9	5.39	gal/ft²/mo	I	8,214 heated square ft	1.6
Restaurant	1	25.52	gal/ft²/mo	I	2,300 heated square ft	2.2
Retail	8	0.11	gal/ft²/day	III	13,502 square ft	1.7
RV Park	3	30	gal/vehicle/day	II	130 vehicles	4.4
Service Shop	13	12.47	gal/ft²/mo	I	36,738 heated square ft	16.9
School (private)	1	4.57	gal/ft²/mo	I	1,693 heated square ft	0.3
Storage Warehouse	27	0.76	gal/ft²/mo	I	108,058 heated square ft	3.0
					Small Subtotal	**47.1**
Camp Verde School District	1				Reported data	74.0
Cemex Sand and Gravel	1				Reported data	11.0
Out of Africa	1				Reported data	13.0
					Large Subtotal	**98.0**
					Camp Verde Subtotal	**145.1**
			CAMP VERDE SOUTH 90			
Light Manufacturing	1	0.87	gal/ft²/mo	I	1,469 heated square ft	0.05
					Camp Verde South Subtotal	**0.05**
			CLARKDALE/COTTONWOOD 90			
Office	1	5.39	gal/ft²/mo	I	1,500 square ft	0.3
Recreation Area[g]	2	5.00	gal/visitor/day	II	146,556 visitors	2.2
Recreation Area Camping	1	25.00	gal/visitor/day	II	103,016 visitors	7.9
Restaurant	1	25.52	gal/ft²/mo	I	5,048 heated square ft	4.7
Retail	1	0.11	gal/ft²/day	III	4,100 square ft	0.2
Service Shop	1	12.47	gal/ft²/mo	I	2,500 square ft	1.1
					Clarkdale/Cottonwood Subtotal	**15.1**
			CORNVILLE/OAK CREEK 90			
Camp	1	55.00	gal/visitor/day	IV	3,200 visitor days	0.5
Event Center	1	5.00	gal/visitor/day	II	1,500 visitors	0.02
Office	2	5.39	gal/ft²/mo	I	2,426 heated square ft	0.5
Restaurant	1	25.52	gal/ft²/mo	I	1,849 heated square ft	1.7
Retail	3	0.11	gal/ft²/day	III	4,100 square ft	0.7
School (private)	1	4.57	gal/ft²/mo	I	1,129 square ft	0.2
			CORNVILLE/OAK CREEK 80			
Light Manufacturing	1	0.87	gal/ft²/mo	I	1,195 heated square ft	0.04
Office	1	5.39	gal/ft²/mo	I	3,870 heated square ft	0.8
Retail	1	0.11	gal/ft²/day	III	5,000 square ft	0.6
Storage Warehouse	2	0.76	gal/ft²/mo	I	20,971 heated square ft	0.6
Treatment Center[h]	1	100.00/35.00	gal/visitor/day	IV	2,000 visitor days	1.0
			CORNVILLE/OAK CREEK 70			
Clubhouse	1	5.16	gal/ft²/mo	I	4,542 heated square ft	0.9
Convenience Store	1	7.92	gal/ft²/mo	I	1,645 heated square ft	0.5
Fire Station (staffed)	1	0.5	acre-feet/facility/yr	V	1 facility	0.5
Office	1	5.39	gal/ft²/mo	I	3,982 heated square ft	0.8
Restaurant	2	25.52	gal/ft²/mo	I	4,025 heated square ft	3.8
Retail	2	0.11	gal/ft²/day	III	5,709 square ft	0.7
RV Park[i]	2	30.00	gal/vehicle/day	II	208 vehicles	8.7
School (public)[j]	1	70.00	gal/student/day	IV	250 students	19.6
Storage Warehouse	1	0.76	gal/ft²/mo	I	1,908 heated square ft	0.1
					Cornville/Oak Creek Subtotal	**41.2**
					TOTAL	**221.3**

* Notes for Table on next page

Notes:

[a] Some estimates, e.g. schools, include adjustments for days of operation.
[b] Identified using county assessor parcel files and ADWR well records; verified using (ADEQ 2013) public water system files, Internet research, and water provider data on which parcels/uses they currently serve. Not listed in table if found to be out of business.
[c] I = (Morales and Heaney 2011); II = (USFS 2007); III = (AWWA 2000); IV = (Washington State 2001); V = (Plateau Resources 2013)
[d] Square footage from county assessor and verified by aerial imagery; average number of vehicles reported by operator and verified with Google images.
[e] Heated square footage calculated by applying an adjustment factor in (Morales and Heaney 2011) to assessor data.
[f] Includes use by residents and day staff.
[g] Known deep well pumps an estimated 1.3 acre-feet/year at Tuzigoot National Monument.
[h] Includes guests, full-time and part-time staff, and garden.
[i] Known deep well pumps an estimated 7.7 acre-feet/year at Verde Valley RV and Camping Resort (Thousand Trails).
[j] Includes students, staff and irrigation of playing fields and landscape.

Water Provider Demand

A number of water provider service area wells are located within the study area. The systems that are defined as Community Water Systems are required to report their annual water withdrawals from each service area well and deliveries to customers. However, smaller systems may lack customer delivery meters or even meters at the well and must estimate their pumpage. Even larger systems may not submit complete reporting data, and there is little enforcement if they do not. Table A-9 shows the 2014 withdrawals from service area wells located within the study area. As shown, there is substantial water provider pumping within the SIAs, including in the highest stream impact area. For example, On the Greens in Clarkdale/Cottonwood includes a nine-hole golf course with a reported use of 92 acre-feet/year. Some wells are pumping below layer 1; however, the aggregate groundwater withdrawals from these wells is substantial, at 289 acre-feet. Other large withdrawals include those by Verde Lakes Water Corporation, White Hills Trailer Park (although this use is estimated), and City of Cottonwood.

Table A-9 Reported Water Provider Well Use in Stream Impact Areas, 2014[a]

Subarea	System	Number in Study Area (Active)	Estimated Use (AFY)
CAMP VERDE 90-100%[b]	Buffalo Run MHP	1	12
	Camp Verde Water System Verde Lake Estates[c]	1	9.0
	Clear Creek MHP	1	4
	Montezuma Hts. Water	2	22.0
	Verde Lakes Water Corp	2	121.0
	White Hills Trailer Park	2	50.3
CAMP VERDE 80-90%	Rainbow Acres Community Water System	1	17.0
		CAMP VERDE Subtotal	**223.2**
CAMP VERDE SOUTH 90-100%	Lake Verde Water Co.	1	**19.3**
CLARKDALE/COTTONWOOD 80-90%	City of Cottonwood	1	35.7
	On the Greens[d]	2	102.0
CLARKDALE/COTTONWOOD 70-80%	City of Cottonwood[d]	1	93.1
		CLARKDALE/COTTONWOOD Subtotal	**230.7**
CORNVILLE/OAK CREEK 90-100%	Oak Creek Public Service[d]	1	55.4
CORNVILLE/OAK CREEK 70-80%	Oak Creek Valley Home Owners Assoc.[d]	2	38.8
		CORNVILLE/OAK CREEK Subtotal	**94.2**
TOTAL			**567.4**

Notes:

a Well pumping data from Community Water System Annual Reports submitted to the Arizona Department of Water Resources. The Yavapai Apache Nation may pump from wells in the study area but their location is not known.
b Camp Verde water provider well locations were able to be assigned to individual SIAs.
c Camp Verde Water System Mongini System wells are located outside the study area.
d Wells drilled below Layer 1.
MHP = mobile home park
AFY = Acre-feet/year

End Notes

[1] An acre-foot is 325,851 gallons – enough water to fill an acre of land to a depth of one foot. In the Verde Valley, this amount of water can serve about 4 households or 10 people for 1 year.

[2] Community Water Systems are public water systems that regularly serve at least 15 service connections or at least 25 year-round residents of the area served by the system.

[3] See Table A-1, in Appendix A, for the results of the Camp Verde telephone survey.

[4] The location of residential parcels with age data, non-residential parcels, and parcels without age data are shown in Appendix A, Figures A-2 through A-6.

[5] Estimates from City of Sierra Vista (Plateau Resources 2012) and (San Antonio Water System Conservation Program 2012)

[6] (Arizona Municipal Water Users Association n.d.)

[7] See website page at http://cals.arizona.edu/cochise/waterwise/events.html

[8] See website page at https://www.tucsonaz.gov/files/water/docs/Rainwater_Harvesting_MRI_0.pdf

[9] See website page at http://www.thecochisewaterproject.com/page26/

[10] Personal communication with Kimberly Schonek at The Nature Conservancy, January 2016.

[11] See website page at http://www.awwa.org/home/awwa-news-details/articleid/2641/awwa-free-water-audit-software-version-5-0-now-available.aspx

[12] See website page at http://www.allianceforwaterefficiency.org/Commercial_Institutional_and_Industrial_Library_Content_Listing.aspx

[13] See website page at http://www.azwater.gov/AzDWR/StatewidePlanning/Conservation2/Documents/documents/WaterUseCheckListFacilityMaintenanceStaff.pdf

[14] (Arizona Municipal Water Users Association. n.d.)

[15] See website page at http://www3.epa.gov/watersense/pubs/fixleak.html

[16] (City of Tucson, Arizona 2008)

[17] (City of Tucson, Arizona 2013)

[18] See website page at http://oakcreekwatershed.org/projects/settlers-rest-stormwater-project?limit=4

[19] Community Water Systems are public water systems that regularly serve at least 15 service connections or at least 25 year-round residents of the area served by the system.

[20] The use of 1997 to distinguish homes with higher and lower water-use fixtures reflects passage of the U.S. Energy Policy Act in 1992, which mandated that only water-efficient plumbing fixtures could be manufactured from January 1994 onward. Accounting for the use of existing plumbing stocks, it was probably not until 1995 or 1996 that only lower water-use fixtures were being installed in new homes and older fixtures in existing homes began to be replaced with more efficient models. In the 1999 AWWA study, data on indoor water use was collected between May 1996 and March 1998 from 1,200 existing homes in fourteen towns and cities.

[21] Demand from wells located within water provider service areas that are pumping below layer 1 were removed. Identification of individual parcels outside service areas with a deep well is not possible but the number of these wells in each subarea (with the exception of Camp Verde) is known. Water demand adjustments for these wells are shown in Table A-4 notes.

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