Water Primer for the Town of Clarkdale

Prepared for the Town of Clarkdale by the Water Resources Research Center
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The University of Arizona
College of Agriculture & Life Sciences
WRRC
Water RAPIDS
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Clarkdale Arizona A Historic Town
Sustainable Clarkdale
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EXECUTIVE SUMMARY

Clarkdale is a small town of just over 4,000 people in the Verde Valley. Clarkdale's official municipal boundary encompasses a portion of the Verde River, and although the Town does not hold any surface water rights, protection of the River's flows and resulting health of the adjacent ecosystem is an important part of their considerations in building a water management program.

Municipal water in the town is supplied by two groundwater wells. Within the Town limits, 95% of the water supplied is by the Town, with 5% supplied by small private domestic wells. The dominant water use in the Town is for residential, with 86% of the supply going to homes in Clarkdale or to interconnections with the Town of Cottonwood. Commercial use makes up only 3% of the total water used. Clarkdale's current largest employer is the Phoenix Cement Company plant. Several small business are located in the downtown area, with a notable focus on tourism oriented to cultural heritage, the Verde Valley, and local agriculture. In 2012, total water demand was 224 million gallons (690 acre-feet), while total use was 140 million gallons (429 acre-feet). Industrial pumping occurs at the Phoenix Cement plant northwest of town. The Town produces 43,728,500 gallons of A+ effluent each year, from a new wastewater treatment plant (WWTP). The maximum capacity of the WWTP is 350,000 gallons per day, and average treatment volume is 130,000 gallons per day. Approximately 50% of residents in Clarkdale are on septic systems.

Groundwater modeling for the Town indicates that Haskell Springs Well, Clarkdale's oldest municipal well, has contributed to drawdown of the aquifer of 3.3 feet or more by 2014. Modeling simulations have also shown that prior to 2006, Clarkdale's wells derived most of their water from aquifer storage and had no significant impact on baseflow in the Verde River. However, if pumping is held constant into the future, by 2056 the Town's wells will be capturing Verde River baseflows. By 2076, Clarkdale's simulated pumping is capturing 380 acre-feet per year or roughly 0.5 cubic-feet per second (cfs) of Verde River baseflow and consuming about 330 acre-feet per year in aquifer storage.

The Town of Clarkdale acquired the local water company in 2006 and over the last eight years the Town has utilized a number of water management approaches. The Town is a designated water provider and adopted the adequate water supply requirement for new subdivisions. They have a landscape design ordinance that applies to commercial and multi-family residences and a permaculture demonstration site at Town Hall. Clarkdale has instituted an aggressive block rate pricing as part of the fee structure of the municipally-owned water utility and all municipal connections are metered. The Town has estimated that its infrastructure suffers from a greater than 30% system-wide water loss due to old meters, old piping, and system leaks and evidence suggests that there still remain a few unidentified and potentially unmetered interconnections that were part of the original system when it was purchased by the Town in 2006.

As part of the development of their Water Management Program the Town has identified a series of water resource management issues and questions. These questions and issues include:

1. What would be the best use or uses for the treated effluent in order to support the health of the Verde River and/or supplement the Town's potable water supply?
2. How should the Town manage stormwater to address upland erosion and mitigate damage and maintenance costs associated with complications from runoff?
3. Lost and unaccounted for water is high, between 35% and 37%, despite substantial improvements in the water delivery and management infrastructure. What can the

Town do to decrease the lost and accounted for water, especially considering that some of this water may be due to unknown interconnections to the system?

4. Clarkdale is a small town. What resources exist for a small town to implement progressive water management solutions?
5. What can the Town do to better understand the water use by domestic wells and to encourage conservation by those on private wells?
6. The Verde River continues to decline. What are the management options that the Town can make that will improve the health of the river?
7. Groundwater resources are limited. There are reports from well owners in adjacent parts of the Verde Valley that groundwater supply levels are experiencing locally significant drops and owners of several wells near the mountain front in Clarkdale have stated that their wells have already gone dry. What can the Town do to better understand these declines and keep their municipal wells productive? Is a deeper aquifer an option?

In addition to outlining the water resource management issues the Town has also begun to consider potential solutions. Solutions on the table at this time include:

- Retrofit programs
- Water Wasting Ordinance
- Greywater re-use program
- Rainwater Harvesting
- Education Programs
- Demand-Offset and a Community Water Budget
- Augmentation
- Voluntary septic system conversions
- Aquifer recharge with reclaimed water
- Non-potable reuse
- Potable reuse (direct or indirect)

The full primer that follows provides an introduction to the water resources and community characteristics in the Town of Clarkdale, its current water management practices, challenges for the future, and solutions the Town is currently exploring to meet those challenges. It is our hope that through your expertise and ideas we can create a well-informed and progressive water resource management plan for the Town of Clarkdale that incorporates best practices of other similarly-situated communities across Arizona and the Southwest.

CHAPTER 1: INTRODUCTION

The waters of the Verde Valley have been vital to the long-term presence of humans and all other plant and animal species in the midst of an arid landscape. Maintaining dependable supplies of these water sources into the future will be critical to the continuation of the robust local ecosystems on which the residents of Clarkdale depend for their livelihoods and quality of life. This Primer seeks to review present-day conditions affecting the quality and quantity of water sources in the Clarkdale area with an eye to how these resources may be best managed for meeting the needs of the present while also ensuring future prosperity.

1.1 Community Context

Based on the 2010 US Census, the population in the Town of Clarkdale was 4,097. This included 1,295 individuals aged 20-60, and 1,962 individuals aged 60 and over. There was an average of 2.23 persons per household. A total of 1,836 housing units were located within the town limits, about half of which have been built in the last 20 years. This growth in home construction serves as one measure of Clarkdale's expansion in recent decades. Past growth rates over time observed in Census records, particularly since 1970, reflect periods of varying population increase, depending on local conditions and broader state and national economic trends. Current estimates predict that the population will grow in the near-term at about 2.5% annually.

Based on Census results, 51 housing units are classified as vacant due to seasonal, recreation or occasional use. While typical household water consumption (e.g., due to the use of sinks, dishwashers, showers, toilets) would be expected to decrease for such part-time residents, there is evidence that many have left their outdoor irrigation systems in full operation during the hot summer months.

The residents of Clarkdale have a high level of awareness of water conservation. Public attention has been focused on local water management for several years, as indicated by the community support of the Town's purchase of the private water utility in January, 2006. Per capita water usage has since decreased 46%, demonstrating a widespread ethos of conservation. The continuation of a multi-year drought has only strengthened residents' commitment to wise water use practices.

According to US Census records, the predominant household type in Clarkdale is single family detached homes (73%). Other types include: town homes and duplexes (1.7%), apartments (5.8%), and manufactured homes (19.5%). The predominant landscape type is Xeriscape. Under Town Ordinance 270, commercial and multi-family developments are required to use low-water or drought-tolerant plants from an approved plant list. Single-family homeowners are strongly recommended to consider these landscaping guidelines. The Town does not have firm statistics as to the number of exterior landscapes containing grass or turf, however it is broadly estimated fewer than 30 percent of residences have grass. However, there are also customers who are heavy water users for landscaping other than grass. There are approximately 45 residential pools in the community. There are no public or community pools ("Clarkdale Community Assessment," 2013; US Census Bureau, 2010).

There are large areas of undeveloped land within the town limits, and the time frame for the development of these areas is one to ten years. With the recovery of the overall economy, there are also two previously platted subdivisions coming back on line. The combined total of both neighborhoods includes 646 residential lots to be developed.

In its 2012 General Plan, the Town of Clarkdale affirmed a commitment to sustainable economic development, by which it sought "to convey a goal of creating a local economy serving a variety of needs while creating long-term strength and stability, minimizing adverse impacts, and reflecting the unique environment and character of Clarkdale" ("Clarkdale 2012 General Plan," 2012). In this and other documents created by or in collaboration with Clarkdale in recent years, the ecosystem services and economic development opportunities related to a resilient Verde River have been strongly emphasized ("Clarkdale Community Assessment," 2008; The Nature Conservancy, 2009; US BOR, ADWR, & Yavapai County WAC, 2011; Von Gausig, O'Banion, & Rooney, 2011a). These documents serve as mounting evidence of the integral role the Verde plays in the long-term economic health of a community like Clarkdale.

Several long-standing, existing activities depend on sufficient water flows in the Verde, such as farming and ranching. Activities tied to eco-tourism have also become an ever larger component of the area's economy. The importance of the riparian area as part of an international flyway for migrating birds continues to draw more and more visitors, from small birdwatching groups to large events, such as the Verde Valley Birding and Nature Festival. The river itself, as one of the few rivers with dependable surface flows in a semi-arid region, has garnered increased interest for canoeing and kayaking. Combined tourism events, with ecological, recreational, historical, and/or agricultural elements, are also rising in popularity nationwide and in the Verde Valley in particular. These opportunities have special relevance in a region with multiple state and national parks and forests that showcase remarkable cultural and natural resources. These examples serve as illustrations of how protecting the resources tied to a healthy Verde River directly relate to a healthy local economy (Von Gausig, O'Banion, & Rooney, 2011b).

1.2 Clarkdale and the Verde River

Because of the Verde River, the site of the present-day Town of Clarkdale has been a popular destination for humans for millennia. Today's Clarkdale started as a company town founded in 1913 to support the mining operations of the United Verde Copper Company, which had chosen a nearby site to construct a large smelter in order to take advantage of the river as a water source. Smelting operations ceased in the 1950s, and the Town was officially incorporated in 1957. Clarkdale has continued to grow and develop a more diversified local economy, thanks in large part to its remarkable location by the Verde River.

The waters of the Verde River flow through a semi-arid landscape of varying elevation where scarcity of water controls the abundance and variety of flora and fauna. Shrub oak, prickly pear and crucifixion thorn spread out on the upper slopes along the foothills. Mesquite and cat claw predominate along middle elevation slopes, and a mix of low grasses cover the rocky soils.

Clarkdale's official municipal boundary encompasses a portion of the Verde River and several washes. The perennial flows of the main channel support a major riparian corridor lined with large cottonwoods and several other native tree species. The Verde River flow rate runs from 50-200 cubic feet per second (cfs) in the dry period of the summer to several thousand cfs after the spring runoff. Absent heavy pulses of additional water from monsoon rains or snowmelt, the Verde is typically a slow-flowing stream that attracts a range of wildlife including: blue herons, eagles, hawks, vultures, mountain lion, deer, antelope, javelina, coyote, lizards and snakes ("Clarkdale 2012 General Plan," 2012).

1.3 Regional Geography

The varying soil types and elevation in the Verde Valley, combined with the essential component of water from the river, create a unique landscape that has supported, and continues to support, a broad array of land uses. Large-scale mineral extraction has experienced a marked decline from the early- to mid-twentieth century, but the former rail line that served the mines and smelter has been adaptively re-used as a scenic railroad for residents and tourists alike.

There is a complex, interlocking puzzle of public and private land ownership patterns in the Verde Valley surrounding Clarkdale. Various parcels of private lands in unincorporated Yavapai County are located around the Town. On the northeast border, the National Park Service operates the 42-acre Tuzigoot National Monument, an 800 year old Sinagua pueblo. Marsh borders Tuzigoot National Monument and has been designated as an Important Birding Area by the North American Audubon Society. Arizona State Parks also manages portions of the Verde River Greenway along the Verde River in Clarkdale. The Town is surrounded by lands of the Prescott National Forest to the west and lands of the Coconino National Forest to the east. In addition, trust lands of the Yavapai-Apache Nation are located within the town boundary. The Town of Clarkdale also shares borders to the south and east with the City of Cottonwood. The nearby Town of Jerome lies further to the west (“Clarkdale 2012 General Plan,” 2012, “Clarkdale Community Assessment,” 2013).

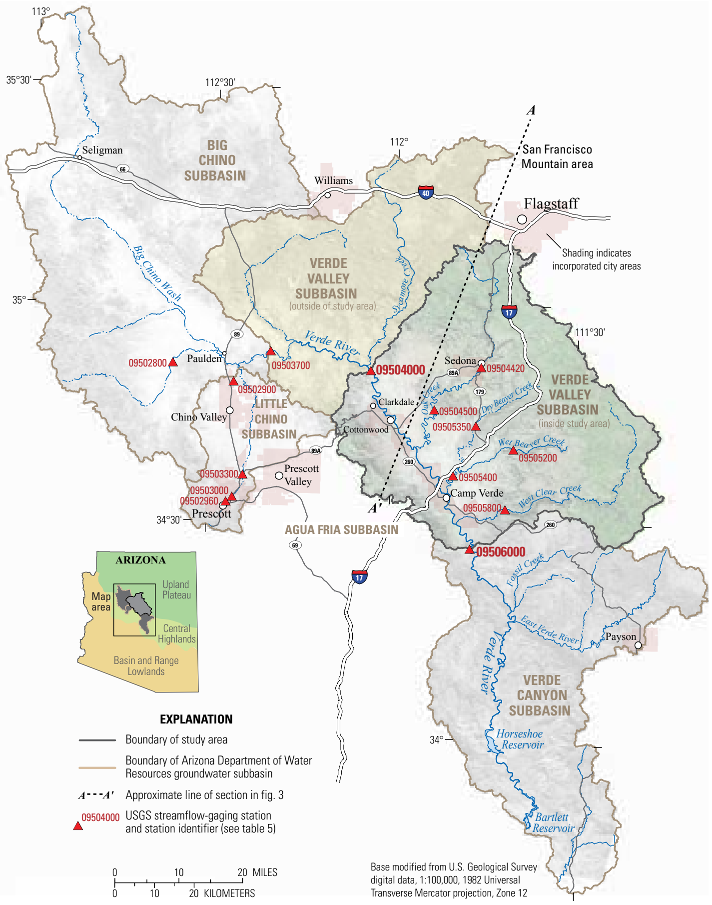

Figure 1. Map showing the location of the Verde River watershed and Verde Valley, central Arizona.

Figure 1 – Map of the Verde Valley
(Source: Garner, Pool, Tillman, & Forbes, 2013)

1.4 Hydrologic Context[1]

The Town of Clarkdale lies on high ground about 200 ft above the Verde River, at an elevation of 3,560 ft (Fig 1, aerial image). Clarkdale is in a semi-desert and receives approximately 12 inches of rain each year (Western Regional Climate Center, 2013). Seventy-five percent of this precipitation occurs during the summer monsoon season. The majority of the remaining precipitation falls during winter season, with fairly extended dry periods between summer and winter. The latitude of the town, combined with a moderate elevation of 3,320 to 4,140 feet above sea level, contribute to winter temperatures that often dip below freezing. Morning temperatures range from the upper 20’s to low 30’s. In typical winters small amounts of snowfall will be observed, with more accumulation at higher elevations and less at the lower elevations of the Verde Valley floor near the river itself (“Clarkdale 2012 General Plan,” 2012, “Clarkdale Community Assessment,” 2013).

The Verde River flows south out of the Verde Canyon, emerging from the narrow canyon just a few miles north of Clarkdale. In general, the river is a gaining stream (fed by groundwater)

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[1] Summarized from “Summary of Hydrologic Conditions at Clarkdale, Arizona” by Laurel Lacher. For more detail on hydrologic conditions see the appendix at the end of the primer.

through most of the middle Verde Valley. A significant diversion created and maintained by Freeport-McMoran, Inc., just upstream from Clarkdale supplies water to Peck's Lake on the east side of the river. Several major diversions downstream of Clarkdale temporarily dry portions of the river at times during peak irrigation periods in the summer, although efforts are underway to automate irrigation headgates and keep more water in the river. See Appendix B for additional maps of the Town of Clarkdale.

Precipitation in the mountains along the valley margins, such as the Black Hills west of Clarkdale, recharges the local groundwater system. Groundwater moves from the hills down into the valley through the Verde Formation aquifer toward the low point in the basin where it is discharged as surface water in the Verde River. Over time, groundwater extraction wells in the valley intercept groundwater that would otherwise discharge as baseflow in the Verde River.

1.4.1 Available Water Resources

The Town uses only groundwater for water supply and owns four public water supply wells, of which two are currently in use. The Mountain Gate well supplies about 40% of Clarkdale's total potable water production, while the Haskell Springs Well supplies the other 60%. The other two wells are not being used at this time because of a structural problem at one and a drill bit stuck at the bottom that may prevent deepening or increasing flow at the other. Within the Town limits, 95% of the water supplied is by the Town, with 5%[2] supplied by private domestic (less than 35 gallons per minute production) wells. At present, there are approximately 398 active domestic private wells in the Town. Industrial pumping occurs at the Phoenix Cement plant northwest of town.

As of 2013, there were 1,867 connections in total to the municipally-owned water utility. All connections are metered, allowing for individualized water billing based on consumption rates. The number of connections, based on type of user, is as follows: 1,498 single-family residential, 297 multi-family residential (8 actual units with 297 users), 35 commercial, 19 other, and 18 government connections. In 2012, total production was 224,961,700 gallons (690 acre-feet/year (af/yr)), or an average daily demand of 616,333 gallons, which is 25% of the 2.4 mgd system capacity. In 2013, total production was 215,220,000 gallons (660 af/yr) and average daily demand dropped to 589,643 gallons. In 2012 total water use was 429 acre-feet (af), indicating significant system water losses of nearly 38%. GPCD (gallons per capita per day) was 67 in 2012, dropping to 57 gpcd in 2013.

Table 1 – Town of Clarkdale Water Use in 2012

Water Use in 2012	**Amount in acre feet (Percent)**
Residential	294.68 (69%)
Water Exports to Town of Cottonwood	74.81 (17%)
Government (Schools, Town Facilities, Parks, etc.)	32.17 (7%)
Other	15.64 4%
Commercial	11.39 (3%)

(Source: Town of Clarkdale, 2013)

Approximately 50% of residents in Clarkdale are on septic systems. There are currently 1,080 sewer connections feeding into the new wastewater treatment plant (WWTP). Notably, a few large subdivisions, like Black Hills and Foothills Terrace, are currently not connected to the municipal sewer system.

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[2] This estimate of 5% of the Town's water being supplied by private domestic wells is derived by dividing the number of residential water connections by the number of residential housing units, which the Town calculated as 95%. Therefore, the Town assumes that the remaining 5% of homes are provided by private wells.

The Town produces 43,728,500 gallons (134 af) of A+ effluent each year, from a new wastewater treatment plant (WWTP) that recently began operations. Currently, the Town disposes of all effluent through land application for the irrigation of off-river riparian habitat. The maximum capacity of the WWTP is 350,000 gallons per day, and average treatment volume is 130,000 gallons per day. The process of wastewater treatment is through activated sludge with nitrification and denitrification and tertiary filtration (“Clarkdale Community Assessment,” 2013).

1.4.2   Current Status and Projections of Groundwater Levels

To understand how water resource conditions are changing in the Verde Valley, local groundwater flow and Verde River baseflow have been modeled with the U.S. Geological Survey’s (USGS) Regional Groundwater Flow Model of Northern Arizona released in 2010 (Pool, Blasch, Callegary, Leake, & Graser, 2011).   See Appendix A for a full Summary of Hydrologic Conditions at Clarkdale, Arizona. Groundwater simulations cover two time periods; the historic period from 1910 to 2006 and into the future from 2006 to 2076. Figure 2 shows simulated 1910 groundwater flow conditions in the Clarkdale area prior to any significant groundwater development. As the arrows in the figure indicate, groundwater generally moved down valley parallel to the Verde River from the surrounding mountain recharge areas. Figure 3 shows simulated groundwater elevations below land surface and flow paths in the same area of the main aquifer near Clarkdale in 2006, which marks the end of the USGS’s groundwater model of northern Arizona. This figure shows a pumping-induced cone of depression with drawdowns exceeding 200 ft in the Clarkdale-Cottonwood area, although the river is still considered a gaining stream in the Verde Valley reach.   Groundwater flow paths are diverted toward the area immediately west of Cottonwood rather than proceeding

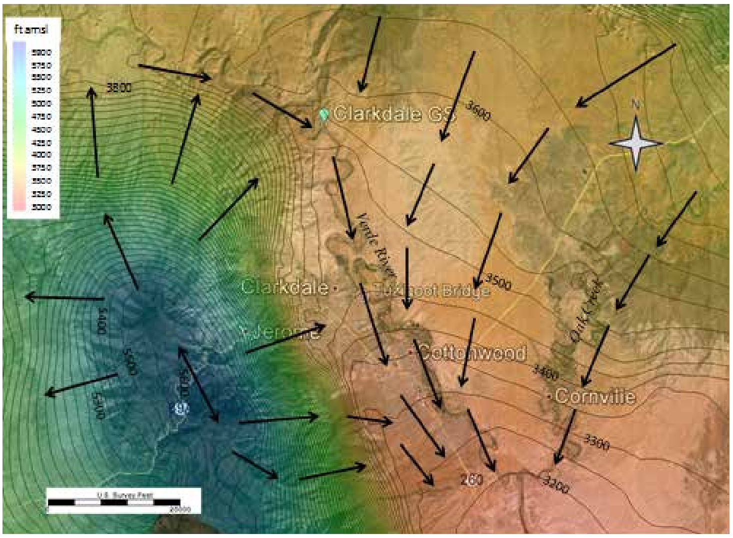

Figure 2 – Simulated predevelopment (1910) groundwater levels and flow paths in the regional aquifer near Clarkdale.

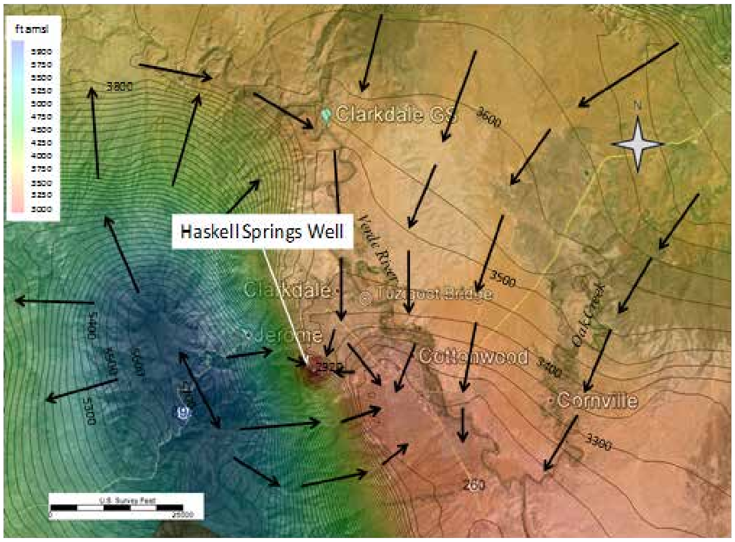

Figure 3 – Simulated groundwater levels and flow paths in the regional aquifer near Clarkdale in 2006.

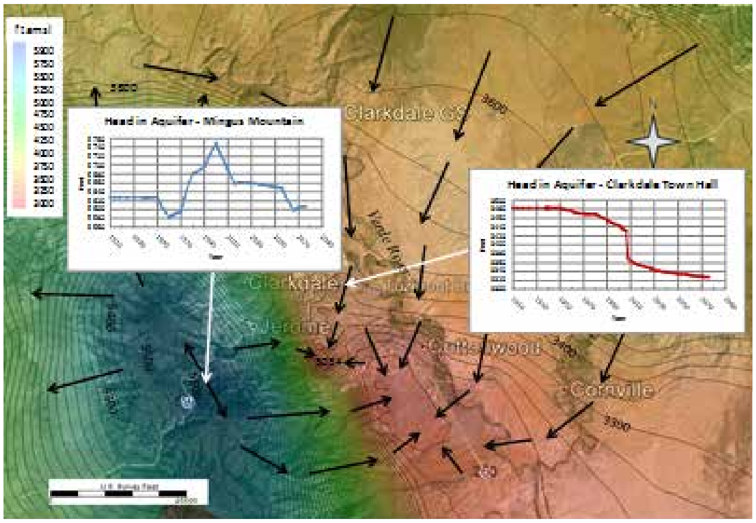

Figure 4 – Simulated groundwater levels and flow paths in the regional aquifer near Clarkdale in 2076.

along their historical down -valley trajectories. By 2076 (Figure 4) simulated heads reflect a deeper (over 300 ft) cone of depression southwest of Cottonwood and southeast of Clarkdale. Groundwater flow paths are more sharply diverted from their historical down-valley trajectories, with the cone of depression capturing groundwater from all directions.

1.4.3 Verde River Baseflow Projections

Figure 5 shows the simulated shift of baseflow change in part of the Verde River and Oak Creek over the period 1910 to 2006. Although the Verde River shows variable levels of baseflow decline, the simulated decline at the “Verde River near Clarkdale” steam-flow gaging station maintained by the USGS was on the order of 8% over the 20th century. By 2076, simulated baseflow declines on the Verde River are more pronounced (Figure 6), with baseflow declining by an estimated 18% at the Clarkdale gaging station from 1910 conditions.

1.4.4 Clarkdale’s Impact on Groundwater and Surface Water Resources

In order to quantify the impacts of Clarkdale’s municipal groundwater extraction and recharge on the underlying aquifer and on baseflow in the Verde River, capture simulations were run using the USGS groundwater flow model of northern Arizona (Pool et al., 2011). To understand Clarkdale’s impact on the region two simulations of this model were run:

- Simulation 1: All historic pumping and recharge in the entire model area (northern Arizona down to the Salt River) through 2006 plus future pumping and recharge to 2076.
- Simulation 2: Same historic and future pumping and recharge as simulation but without the pumping from current and future operations of Clarkdale’s municipal water system.

Subtracting the two simulation results provided the impact that the Town has on groundwater levels, aquifer storage and Verde River baseflow.

Key findings from these simulations are:

<u>Groundwater Levels</u>

- The Haskell Springs Well, Clarkdale’s oldest municipal well, has contributed to drawdown of the aquifer of 3.3 ft or more by 2014 (Figure 5).
- By 2076 the areal extent of the drawdown is larger around the Haskell Springs Well, however, the maximum depth is reduced from 1007 to 640 ft as a result of scaling back pumping at this well and bringing the Mescal Well online (see Figure 6).

<u>Baseflow in the Verde River and Aquifer Storage</u>

- Prior to 2006, Clarkdale’s wells derived most of their water from aquifer storage and had no significant impact on baseflow in the Verde River.
- Simulated increase in pumping between 2006 and 2014 resulted in a 200-af increase in aquifer storage depletion and 100 af of depletion in Verde River baseflow.
- After 2006, simulated pumping begins to capture streamflow rather than just extracting groundwater from aquifer storage.
- By 2056, baseflow capture begins to exceed groundwater storage as a fraction of water pumped by Clarkdale wells.[3] (Figure 7)
- By 2076, Clarkdale’s simulated pumping is capturing of 380 AF/yr (roughly 0.5 cfs) of Verde River baseflow and consuming about 330 af/yr in aquifer storage.
- According to the simulations, Clarkdale’s existing well production will not be limited prior to 2076 (provided Haskell Springs Well pumping is reduced and the Mescal Well is utilized), however, Clarkdale’s impacts to the Verde River have already begun

to manifest. Although the Verde River remains a gaining stream in this section of the Verde Valley, this pattern could eventually reverse if baseflow capture continues.

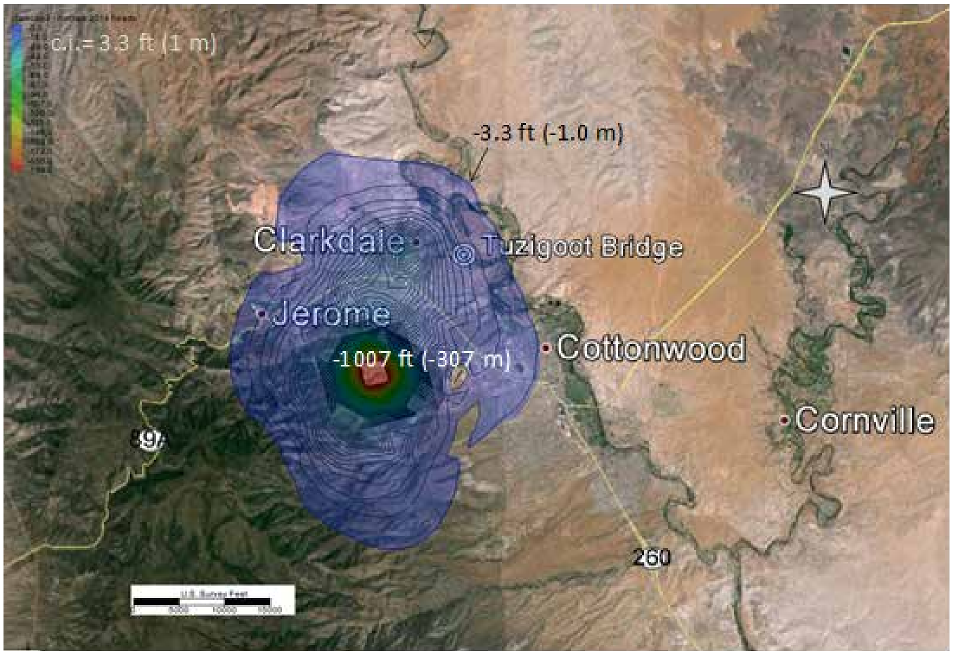

Figure 5 – Simulated drawdown attributable to Clarkdale municipal pumping and recharge for the period 1920-2014.

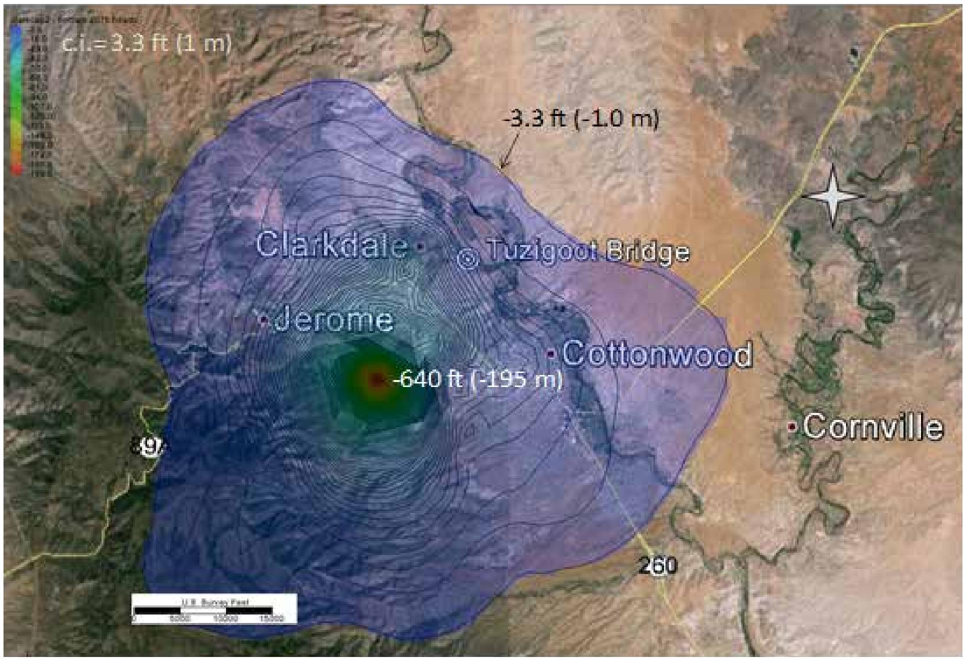

Figure 6 – Simulated drawdown attributable to Clarkdale municipal pumping and recharge for the period 2014-2076.

[3] Note that the combined total of aquifer storage depletion and baseflow capture is about 600 af/yr compared with 700 af/yr produced by the Clarkdale wells. The 100-af difference is made up by recharge of about half of Clarkdale's treated effluent (66 af/yr), and from other sources of capture such as springs and riparian evapotranspiration that are affected by declining water tables because less water is accessible at the land surface.

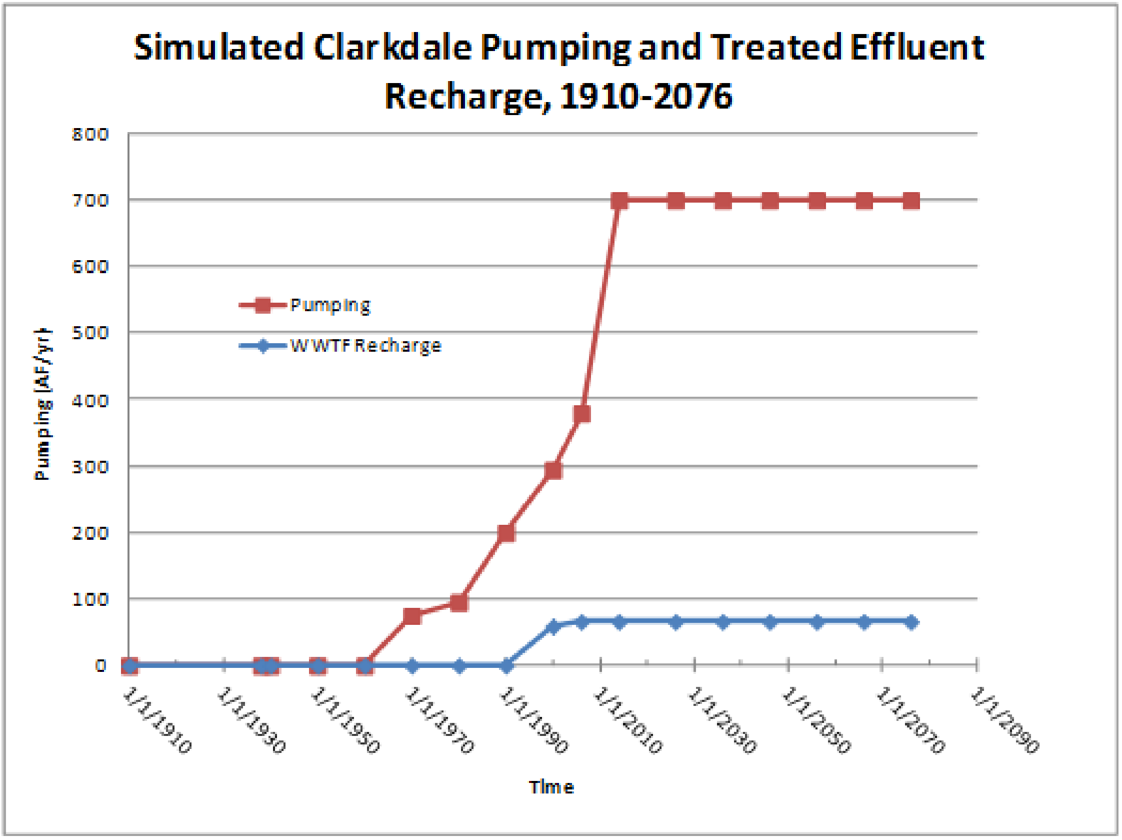

Figure 7 – Simulated Clarkdale pumping and associated aquifer storage depletion and baseflow capture for the period 1910-2076. Beginning in 2056, baseflow capture comprises a greater fraction of Clarkdale's pumping than does aquifer storage depletion.

CHAPTER 2: CURRENT WATER MANAGEMENT AND PROGRAMS

A brief review of the last fourteen years offers both insightful context into the current situation regarding water management in Clarkdale and encouragement regarding the degree to which water conservation and best practices have already been implemented. Table 2 provides an overview of the recent history of Clarkdale's water management.

Table 2: Recent History of Clarkdale's Water Management

YEAR	ACTION
2000	Residents vote for Town water utility in March.
2006	Town acquires local water company in January.
2006	New water service rates billed on an Increasing Block, tiered rate structure.
2007	Drought and Water Shortage Preparedness Plans adopted.
2008	Town adopts SB1525 – Adequate Water Supply Requirements in September.
2012	Town adopts a General Plan, instilling a culture of sustainability in March.
2012	Water Conservation Demonstration Projects – Centennial Plaza.
2012-present	Replacement of aging infrastructure and ongoing funding for water conservation, water resource development and regional organizations.
2013	Complete meter replacement as of September.
2013	Full system leak detection survey identified and fixed 20 leaks.

2.1 Overview of Current Water Management Practices and Context

The Town of Clarkdale is developing a water management program that will provide a mechanism to meet the needs of residents, businesses and its natural environment equitably so the Town can be a robust and resilient community. To build this program it is necessary to understand both the constraints of the local hydrology and those of local, regional, and statewide water policy and law.

Context

1. Clarkdale is not within an Active Management Area
2. Clarkdale does not hold surface water rights to the Verde River
3. 95% of water users are on municipal water, well drilling is not restricted in the Town

Ongoing Water Management Practices

1. Clarkdale submits annual reports for the ADWR Community Water System program

and has a system water plan, conservation plan and drought plan. The Drought Plan has been adopted as an ordinance (Ordinance #296).

2. Clarkdale has a landscape design ordinance (Ordinance #270) that requires the use of low water/drought tolerant plants from an approved plant list for commercial and multi-family developments. This list is optional, but highly recommended, for single-family homes.
3. Clarkdale complies with federal water quality rules and there are no health-based violations listed for the Town in the Safe Drinking Water Information System database.
4. Clarkdale has an Aquifer Protection Permit for Wastewater Treatment Plant and Effluent Disposal Area.
5. Stormwater Management (Clarkdale Zoning Code, Chap. 11, Sec. 13). The Town's Zoning Code prevents stormwater and erosion from having adverse impacts on abutting or downstream properties. This policy helps to ensure that nonpoint source pollution sources will have minimal impact on Verde River water quality.
6. Clarkdale has set out rules in the Town Code generally requiring that when a public sewer becomes available within 300 feet of a property served by a private sewage disposal system, a direct connection shall be made within three years (Clarkdale Town Code, Chap. 11, Section 11-3-5.5). (The Clarkdale zoning code lists several conditions for which sewer connection is required, including septic system fail, but the only condition that is actively enforced is that when a property is sold it is required to connect to the sewer system.)
7. Clarkdale is a Designated Water Provider and passed the requirement for Water Adequacy in 2010. The provision has not been adopted by Yavapai County or adjacent jurisdictions.
8. Clarkdale has instituted an aggressive block rate pricing as part of the fee structure of the municipally-owned water utility. At present, the pricing is set at a base fee of $26.70 for up to 1,000 gallons per billing period, with increasing block rates every 5,000 gallons.
9. All municipal connections are metered and the Town actively works to detect and replace faulty meters.
10. Clarkdale has revised the formatting of its water bills in order to make them more readable and customer-friendly.
11. Clarkdale is developing a voluntary private well metering program for town residents interested in having their water use monitored.
12. The Town has a Clarkdale Kids Conserve water education program that delivers quarterly classroom presentations to all students grades Kindergarten through 8th grade. In addition, 4th graders participate in the Arizona Project WET (Water Education for Teachers) Verde Valley Water Festival.
13. Clarkdale has developed a permaculture demonstration garden at Town Hall in the Centennial Plaza to demonstrate the aesthetic appeal of drought-tolerant plants.
14. The Town has estimated that its infrastructure suffers from a greater than 30% system-wide water loss due to old meters, old piping, and system leaks. To address this problem, water loss detection remains a high priority. (Evidence suggests that there still remain a few unidentified and potentially unmetered interconnections that were part of the original system when it was purchased by the Town in 2006.)
15. A system-wide meter replacement program has also been instituted to upgrade all water meters and the Town has recently replaced the Twin 5 and Lower Clarkdale water mains. In addition, all water usage data is reviewed twice per month to ensure accuracy of billing data sent to customers and to inform customers of possible water leaks.

CHAPTER 3: WATER RESOURCE MANAGEMENT ISSUES IDENTIFIED BY THE TOWN

3.1 Treated Effluent Utilization

With the recent operationalization of the improved wastewater treatment plant, the quality of the effluent produced has been raised from class C (lagoon) rated-effluent to the A+ rating standard. This substantial improvement expands the potential re-use options allowable under state law. In light of the sustainable economic development goals established by the Town of Clarkdale, what would be the best use or uses for the treated effluent in order to support the health of the Verde River and/or supplement the Town's potable water supply? This question becomes even more relevant considering that the Town's lease for land owned by Clarkdale Metals on which effluent is currently sprayed will end on September 24, 2014. While a temporary lease extension may be an option, the time is ripe for a broader consideration of the different options available.

3.2 Stormwater Management

Much of the precipitation received in Clarkdale arrives in the form of brief, yet intense, monsoon storms. In the aftermath of these heavy rains, large amounts of runoff typically drain into the engineered municipal stormwater system or the ephemeral washes in and around the Town. This stormwater often carries a good deal of sediment, creating maintenance problems as well as contributing to increased sediment loads in the Verde River. There is currently a lack of adequate infrastructure to carefully manage runoff for recharge purposes. A re-designed system could offset the depletion effects of groundwater pumping, support the potable water supply, or augment the Verde River's baseflows. Such a system of better stormwater management would also help to address upland erosion in Town, reduce sediment transport to the Verde mainstem, and mitigate damage and maintenance costs associated with complications from runoff.

3.3 Infrastructure

Clarkdale has made substantial improvements in the water delivery and management infrastructure since acquiring the water utility in 2006. Even so, unaccounted-for water remains high, although the level of unaccounted-for water has been decreasing due to investments like system-wide meter replacement and system audits. In 2012, the monthly average unaccounted-for water was 37% of total pumped water, and the monthly average was 35% in 2013.

Possible reasons for this high percentage of unaccounted-for water continue to be studied. A long-standing Municipal Interconnection between Cottonwood, AZ and Clarkdale, AZ, may still be responsible for some unaccounted-for water. In addition to the previous investments in new meters and technology, aging infrastructure in the water delivery system may need replacement.

3.4 Town Size

Clarkdale is considered a small town (with a population of less than 5,000), and no models exist for developing a sustainable water resources management program for a community of this size. Even with the added flexibility provided by a municipally-owned water utility, a small population creates the challenge of limited revenue for investing in strategies to balance supply and demand. Conversely, this also creates an opportunity to engage town residents in meaningful discussions and decisions to create a path toward sustainable water management with active support from the town. Such dynamic engagement and community participation have already been demonstrated through the remarkable water conservation successes since the town's acquisition of the water utility in 2006, as measured by substantial decreases in per capita water consumption.

3.5 Small Domestic Wells (<35 gallons per minute)

As stated in section 2.3, Clarkdale is located outside of a state-designated Active Management Area. Several existing private wells continue to operate within the service area of the Town utility's service area. Private well owners bear the responsibility of monitoring the water quality of their wells. In addition, if their wells begin to deliver insufficient production, the owners must pay the considerable expense of navigating the permit process and drilling a new well.

Under current practices, little actual water consumption information is available regarding domestic wells. At present, only 5% of total water demand is attributed to private wells, although inadequate data collection leaves some uncertainty regarding this estimate. These wells may be metered, but the data generally may not be reported. Without this information, understanding the state of existing water consumption in Clarkdale is challenging. A voluntary metering program for well owners who are willing share this information with the Town is currently under development. Modeling the extent of potential cones of depression in the aquifer is also complicated. These small domestic wells can potentially affect the utility's available water supplies and the private wells of neighbors.

3.6 Decreasing Verde River Flows

The Verde River remains one of the few in Arizona with near-constant surface flows, making it an especially scarce and valuable resource in a semi-arid state. Observations of stream flow in the Verde over time reveal concerning developments, however. USGS modeling shows a baseflow decrease of 8% from 1910 to 2006 at the "Verde River near Clarkdale" stream-flow gaging station.

More recent measurements offer especially troubling news. The reduction of baseflow at this gage has been particularly notable in the last five years. Further, the lowest daily flow on record since measurements began at this gaging station in 1915 occurred in June, 2013. Such historically low water levels underscore the importance of understanding interconnections between the river and the extensive surrounding subsurface water flows that feed into and support the baseflow of the river. Better knowledge of the hydrology may allow for more targeted water conservation efforts, more careful well placement and pumping regimes, and perhaps more strategic use of effluent re-use by the Town of Clarkdale.

3.7 Limited Groundwater Supply

Reports from well owners in adjacent parts of the Verde Valley suggest that groundwater supply levels are experiencing at least locally significant drops. Owners of several wells near the mountain front in Clarkdale have stated that their wells have already gone dry. Individuals living in the vicinity of Tavasci Road, Shiloh Trail, Coyote Hill Road, and Hogan Hill have traditionally relied on well water, but recent developments have made their reliance on private wells especially problematic. A long-time resident on Coyote Hill Road originally drilled a well to a depth of 500 feet, but has now been compelled to drill deeper in the last few years. Residents in and around Shiloh Trail and Coyote Hill will be tying into the water system in the near future. Individuals in the Hogan Hill area will be tying in as well after Shiloh Hill connections are established. Tavasci Road owners have indicated that they are not able to drill new wells, and are reviewing their limited options. Based on reports, while some owners have chosen to attempt to replenish their water supplies by deepening existing wells, no one has drilled a new well.

News regarding such concerns over shifting depths to reliable groundwater supplies has not yet been collected and reviewed for broader analysis. Detailed mapping, with the use of GIS data, would allow a more systematic understanding of where wells have gone dry and how these trends may affect others nearby. There may be particular implications for Clarkdale. The geology of the basin and the location of the Town in proximity to the Verde River may limit the productivity of the municipal utility's pumping wells and the total available aquifer storage capacity.

To the extent that these conditions persist, the Town will need to consider its options in addressing an increasingly uncertain future water supply. Previous discussions have brought up the possibility of seeking relief from deeper aquifers, for instance. These aquifers have not been carefully explored for water quality and productivity. Even if these alternate water sources were available, current understanding regarding their hydrology indicates that their utilization may ultimately still deplete baseflows in the Verde River.

CHAPTER 4: SOLUTIONS ON THE TABLE

As the number of water-conscious communities has continued to grow in recent years, a variety of innovative programs have been developed and improved with practice. These practices have also been reviewed and modified to fit the specific needs of other communities. A similar strategy of study and adaptation may yield dividends for the Town of Clarkdale. Solutions that the Town of Clarkdale is currently considering include:

- Retrofit programs
- Water Wasting Ordinance
- EPA WaterSense codes for new development
- Greywater re-use program
- Rainwater Harvesting
- Reclaimed water
    - Voluntary septic system conversions
    - Aquifer recharge
        - Upland pumping wells
        - Near-stream
- Non-potable reuse
- Potable reuse (indirect or direct)
- Education Programs
- Demand-Offset and a Community Water Budget
- Augmentation

4.1 Retrofit programs

Initiatives aimed at improving water conservation often target changes in the plumbing code in order to create greater efficiency in residential and commercial water use. These kinds of programs have demonstrated a particular level of success by influencing construction projects. Cochise County, for instance, has implemented new regulations for new developments or remodels of greater than 1,000 square feet.

For existing construction, different options have been developed to encourage residents to modify or replace their water-using appliances and devices and benefit from the resulting water savings. These efforts typically aim to lower water usage by promoting low-flow toilets, high efficiency shower heads, faucet aerators, high-efficiency clothes washers and dishwashers, and on-demand hot water heaters. The funding mechanism for these options often are tied to a rebate program, on-bill financing options or for payments structured through a water conservation surcharge. Voluntary in-home water audits offered by water utilities have proven popular in several cities as well, and these are often paired with rebate programs as part of education and outreach initiatives.

For commercial operations, pre-rinse valves and hot water recirculators have been promoted as effective water conservation tools. The cost of these improvements can be covered by development fees. This may prove challenging in Clarkdale, however, since there are currently only a small number of commercial businesses in Town, and Clarkdale is actively engaged in promoting the sustainable growth of its economic base.

4.2 Water “Wasting” policies

Inefficient outdoor watering practices and over watering frequently result in the “wasting” of water. Excess water can run off yards and into the streets. Watering during the hottest part of the day, especially in the heat of an Arizona summer, can lead to high levels of evaporation and low infiltration rates to the root zone of the plants. Over watering can also contribute to suboptimal growth conditions for the plants as root zones become saturated or high moisture levels promote the spread of plant pathogens.

One response to curb these practices has been to pass a water wasting ordinance. The owner of a property where excess water runs into the street can be cited. Water restrictions can be implemented that prohibit outdoor watering during the hottest hours of the day. Restrictions regarding frequency of watering can be established on a day-of-the-week rotation, where certain neighborhoods or even/odd street numbers are designated so that they take care of outdoor watering only on specific days. These regulations can be made temporary or permanent, based on water/drought emergencies or the season of the year. Exemptions can also be included for such activities as water home vegetable gardens or fruit trees.

Enforcement of these ordinances can prove tricky. Many municipalities find it difficult to divert law enforcement personnel from other pressing matters to focus specifically on enforcing water ordinances. Enforcement can become a secondary activity. A self-policing mentality sometimes evolves in certain communities where neighbors will anonymously call in a dedicated hotline to report water ordinance infractions, although this method does not typically help in reinforcing neighborliness and cohesive communities. In Tucson, a resident's first infraction leads to a warning, and subsequent infractions can be addressed with a civil fine. Depending on individual attitudes and income elasticity, the amount or tiering of the fine system can make a difference, as some may choose to continue incurring behaviors.

4.3 Landscape Incentive programs

Even when no overt water wasting occurs, regular outdoor watering of thirsty landscapes in a semi-arid environment requires a tremendous amount of irrigation. This water demand will likely be the largest percentage of a residential water bill during summer months. A mixture of mandatory requirements and behavior-changing incentives have cropped up across the western US. Cities like Las Vegas and Los Angeles have responded with direct payments for the permanent removal of turf from yards. Others have regulations similar to those already enacted in Clarkdale, whereby multi-family and commercial developments must install xeriscaping. Some go further and require it of all new construction, including single-family residential housing. Incentive programs have also been established for existing homeowners to switch to a xeriscape landscape. Voluntary landscape water audits have had popular reception in several communities as well, often paired with incentive programs regarding turf removal, xeriscape plantings, or more efficient irrigation systems.

4.4 Greywater Re-use

Greywater recycling has become an increasingly important component of water-conscious residents, particularly those using biodegradable soaps. Greywater re-use can range from keeping a bucket in the shower to catch water for re-use in flushing the toilet to separate plumbing for channeling used shower/sink/washing machine water to the landscape. Some cities like Tucson have implemented special regulations regarding separate plumbing in new construction in order to facilitate greywater systems and ensure that appropriate safety measure are in place to prevent backflow and related health problems.

Some cities have implemented greywater re-use programs as a way of engaging residents who are interested in reducing the heavy volumes of water channeled into their septic systems as a way of extending functional life expectancies of these private systems. For cities and towns heavily dependent on groundwater for water supplies, this approach has the added benefit of reducing the rate of septic system failures and therefore lowering the likelihood of aquifer contamination.

There are important concerns about water quality that require adequate attention with greywater systems. Improper plumbing can lead to reversed water flow and potential contamination of drinking water. In addition, greywater and blackwater (e.g., from the toilet) should be kept in separate systems to prevent cross-contamination. The use of greywater on landscape plants can be done safely if appropriate precautions are taken regarding surfactants, grease, and other substances in the greywater flows. Effective greywater re-use programs typically involve active community education and outreach programs to ensure careful implementation.

4.5 Rainwater Harvesting

Rainwater harvesting can vary a great deal in its active vs. passive nature and its scale of water collection. Further, concerns regarding legality have been raised in states like Colorado and Utah, where courts have attempted to interpret the “downstream” consequences of rainwater harvesting on surface water rights in light of the prior appropriation doctrine regarding water rights.

Municipal involvement in rainwater harvesting can take several forms. Local codes can be reformed to facilitate projects like curb cuts to allow surface runoff to water trees and other vegetation in medians, which reduces stormwater runoff stresses on municipal infrastructure. Passive rainwater harvesting basins can also collect runoff as well as serve as temporary mini-detention ponds. The runoff can then infiltrate the soil and support shade- and potentially food-producing plants in and around these runoff collection areas. Larger scale rainwater collection sites can be designed into parks and other public spaces such as athletic fields. These areas can serve multiple purposes that supplement their other functions as open space. Ordinances can also encourage or require different types of rainwater harvesting in new developments as well. Tucson requires large new commercial developments within city limits to design landscaping so that about half of water needs will be addressed through rainwater harvesting methods.

Incentives for active/passive residential rainwater harvesting can benefit existing homes as well. In some cases, the local water utility might provide discounts or rebates on rainwater harvesting barrels. Landscape audits might include recommendations regarding rainwater harvesting techniques. Sometimes non-governmental entities will offer in-kind consulting or facilitate a community model of rainwater harvesting, such as that pioneered by Watershed Management Group in Tucson.

Active or passive macro-rainwater harvesting also exist, depending on the square footage available for collection, the topography of the site, and the budgetary flexibility in designing storage spaces. The upfront cost of large-scale water cisterns can be prohibitive for many individuals and small businesses. Incentive programs, financing opportunities, and cost-sharing arrangements can be especially important in promoting such large-volume water collection.

4.6 Reclaimed Water

4.6.1 Incentives for Conversion of Septic Systems to Sewer Connections

Municipal ordinances and the Town’s investment in sewer infrastructure improvements already anticipate expansion of the sewer system. Property owners on septic systems are generally required to make a connection within three years when sewer system growth results in a connection opportunity within 300 feet of the property. Expanded system capacity due to new or improved pumping stations, engineered to accommodate both newly platted subdivisions and new connections from existing properties, allows the Town to handle increased wastewater flows. The design of the newly recommissioned wastewater treatment plant anticipated additional inflows of wastewater, and the high quality Class A+ effluent has a broad array of potential re-use options allowable under state law. Incentives can encourage other property owners on septic systems whose land is beyond the scope of the mandatory connection provisions to make voluntary connections. More connections would result in larger quantities of treated effluent leading to more opportunities for water reuse by the Town.

4.6.2 Aquifer Recharge

Clarkdale's Class A+ treated effluent can be re-used in ways that help to achieve the community's stated goals of protecting groundwater and Verde River flows. Near stream recharge would direct infiltration of the treated water between existing groundwater wells and the riparian area of the river. This plume of recharge water would provide a buffer between current and future cones of depression associated with the groundwater pumping operations and the subsurface flows directly adjacent to the river. Without this buffer, groundwater models suggest that the wells' cones of depression will begin to cause a reversal of subsurface flow with water moving toward the wells and away from the Verde.

Treated effluent could also be recharged in the vicinity of existing wells, although permitting is often confusing and many precautions must be taken include a 100-foot separation rule, monitoring wells and ongoing water quality testing. Recharging effluent, also known as indirect potable recharge, requires careful consideration of the surrounding hydrologeology and an adequate regulatory framework for new projects. The resulting infiltration would counteract the process of groundwater depletion. Depending on the relative volumes of extraction and infiltration, there could be a locally specific net rise in the water table. A blending of recharged water and aquifer water would result. By replenishing the aquifer, Clarkdale can create greater future reliability regarding what is presently its sole source of potable water. Given concerns over the limited groundwater supply and the increasing numbers of dry wells near Clarkdale, as discussed in Section 3.7, protecting the aquifer for future use offers benefits regarding long term sustainability.

Because of the different opportunities for re-using treated effluent through recharge programs, further study will be needed to examine various sites to determine the suitability of each site for the intended recharge method. In addition, given that aquifer recharge is envisioned as a way of storing water for future use, the suitability of sites is not primarily on the soil and substrate conditions for effective infiltration. The sites need to be reviewed as well for optimal recovery of the recharged effluent at some future point when the stored water may need to be tapped for use at that time.

4.6.3 Non-Potable Re-Use

A common sight in many water-stressed cities and towns are purple pipes, along with a sign explaining that the pipes carry reclaimed water for non-potable application. Arizona communities including Tucson, Scottsdale, Chandler and Goodyear, as well as other cities like Clearwater, FL and San Antonio, TX, have all found non-potable re-use to be a highly valued local tool in promoting the recycling of high-quality treated effluent.

Non-potable re-use typically manifests itself through a variety of outdoor applications. Since wastewater treatment plants (WWTPs) are usually operated by a local governmental authority, the treated effluent is commonly applied to other public lands. These can include roadway medians, public parks, athletic fields, outdoor landscaping around public facilities, and school yards. While the effluent has received a high level of treatment to remove biosolids, certain chemicals, and potential pathogens, sites involving the outdoor re-use of effluent generally have signs posted that both explain the benefits of non-potable re-use and discourage any direct consumption of the water from the purple pipes.

Cities and towns with robust non-potable re-use programs may have a sufficient supply of high-quality treated effluent that the WWTPs can contract with private individuals or businesses to provide this water for outdoor landscaping. These agreements are common with golf courses, multi-family housing complexes, or other entities with large outdoor water consumption patterns.

Non-potable re-use has also been explored as a source of irrigation for certain types of local agriculture. This kind of re-use can depend on the specific water quality profile of the treated effluent. High levels of dissolved salts or certain other minerals may serve as a discouragement, as regular application of such water may lead to the build-up of these dissolved solids in the soil and cause declines in fertility or limit crop choices. There is sometimes public concern regarding the application of treated effluent to crops, particularly for fruits or vegetables that are often eaten raw (such as lettuce). Reclaimed water has been successfully used with non-food row crops such as cotton, as well as with drip irrigation for perennial crops such as viticulture. The expansion of vineyards in the Clarkdale area may offer just such an opportunity for re-use.

One drawback to extensive non-potable re-use for outdoor applications is the cost of a second water distribution network. The purple pipes may be installed parallel to existing potable water lines, but there are added expenses in the installation and maintenance of a new set of non-potable water mains. To the extent that private individuals or businesses contract for deliveries of reclaimed water, the pricing structure needs to be set in consideration of the pricing of potable water, as well as with local rules and regulations regarding restrictions on the use of potable water for outdoor uses.

4.6.4 Potable Re-Use

Very high quality treated effluent is being examined much more frequently for potable re-use in several US states. Programs for such re-use are already underway in relatively small communities like Big Spring, TX (2010 population: 27,282), and Cloudcroft, NM (2000 population: 749). Although direct potable re-use is not currently permitted in Arizona, given advances in technology and Arizona's concern about limited water supplies, a taskforce has been established to develop a framework and recommendations for potable reuse in Arizona (C. Rock, personal communication, 02/18/14).

There has sometimes been hesitancy on the part of consumers regarding potable re-use programs. Media descriptions of such programs as "toilet-to-tap" and new stories regarding the persistent presence of very low levels of pharmaceuticals have contributed to this initial reluctance. Despite these reservations, several large-scale wastewater treatment operators, such as Orange County, CA, and the island nation of Singapore, have moved forward with potable re-use programs. These efforts generally involve aggressive public relations initiatives and education programs regarding the high quality of treatment and the safety of the treated effluent.

The cost of achieving high quality effluent for direct potable re-use is substantial. Such systems can involve the use of expensive filtration devices and reverse osmosis technology.

Concentrated byproducts left over from the treatment process must also be disposed of under regulatory guidelines. Public perception may dictate whether a separate system of distribution pipes would be necessary, which could further increase the costs of creating and maintaining direct potable re-use within a community.

4.7 Education

As previous examples have illustrated, public education and outreach are integral elements to successful water conservation and water re-use programs. The establishment of an Office of Water Conservation and Information within a municipal government or directly within the public water utility has proven highly effective for coordinating water conservation and re-use efforts and directing the widespread dissemination of information to the public at large through booklets, the media, public meetings, schools, speaking engagements, the Internet, and other common avenues of communication. Alternatively, a regional approach to sharing resources and developing educational messages could be taken and the institutional support to do this may already exist within the Verde Valley. The Cochise Water Project in Cochise County is an example of how an NGO can fulfill this need for an entire watershed area.

Specific programs tailored to particular ages, interest groups, consumers, or water-related professionals can provide additional value beyond more generalized outreach activities. Arizona Project WET provides age-appropriate information to school children to help them understand the value of local ecosystems and the importance of water conservation. Innovative tools that take advantage of social media networks and interactive online feedback regarding water use measurements also offer some intriguing opportunities (Nakaso, 2014). Training for local landscapers and landscape supply businesses on xeriscaping, passive rainwater harvesting, and efficient irrigation technologies can also deliver large dividends in the form of more widespread water conservation.

These educational programs cost money to design and execute, and communities have tried different methods to raise the necessary funds. Foundations and other grant-making institutions will sometimes support the development of a water conservation curriculum in support of a training or outreach program. Billing surcharges have also been implemented on water bills to spread the costs across the community and lessen the impact on particular individuals or user groups.

4.8 Demand-Offset Program and Community Water Budget

Achieving Clarkdale's community vision of sustainable economic development requires careful planning and a fully committed effort to protecting the vitality of the Verde River and its associated ecosystem services. Sophisticated modeling of underground water flows has demonstrated the integral hydrological relationship between groundwater levels in the Clarkdale area and the surface flows of the river itself. The continuation of present rates of groundwater pumping is projected to lead to additional decreases in the baseflow of the Verde. Increases in groundwater pumping, whether from municipal wells or from additional private wells, will only exacerbate this trend. Population projections for Clarkdale currently estimate an annual growth rate of about 2.5%, which would place further upward pressure on water consumption levels, assuming per capita consumption levels remain steady.

Broad community-supported measures can be implemented in order to address these concerns and allow for growth at levels that can be sustained without endangering the Verde River. Policies can be used that allow a cap to be placed on total demand, while allowing flexibility in managing water consumption patterns so that the Town's economic vigor can remain robust.

Further research is underway regarding the legal issues of such a cap on total demand.

A likely major component of such planning would include the creation of a Community Water Budget. As with any budget, it is first necessary to understand Clarkdale's total water demand and supply metrics, and the individual elements that comprise that consumption portfolio. Projections can be developed regarding future water use patterns, and these goals can be compared against actual measurable results to track progress and allow for adaptive management strategies to take into account new information or changed circumstances.

A Community Water Budget can incorporate a cap to be set on total water demand that is based on a combination of existing/projected water consumption levels and scientifically-informed estimates of safe yields of groundwater pumping. A subsequent step could include the creation of a market-based demand offset trading program for new construction, such as the one implemented by Santa Fe, NM. Under such a system, developers proposing new projects within the Town limits would be required to calculate the water consumption levels in the proposed development and acquire credits for the equivalent amount of water consumption from existing water users in Clarkdale. This trading system has been set up elsewhere to allow the developer to earn these credits by assisting existing water users in the implementation of water conservation measures (such as the installation of new, water-efficient residential appliances such as toilets, shower heads, sink aerators, dishwashers, and washing machines).

Other methods also exist to create demand offsets and sustain economic activity while not exceeding the water demand cap. This can include the development of a system of rebates or other voluntary incentives for existing users and irrigators to decrease water consumption. If overhead costs are not excessive, there is the option of creating a water credit bank that can accumulate and hold credits from successful demand offset activities. The creation of a meaningful water demand cap should make these credits increase in value over time, given estimated population growth rates. The use of rebates and/or other incentive programs could therefore serve as a powerful motivator for existing users and irrigators to implement water conservation methods voluntarily. These credits held by the water credit bank could be made available for new construction or alternately permanently retired.

An operational water demand cap provides several benefits. It serves as an important measuring point to estimate and track adequate safeguards of the Town's water supply and protections for the surface flows of the Verde River. It also establishes an upper limit on a scarce resource. The implementation of a voluntary water consumption credit trading program subsequently creates quantifiable credits that are limited in availability. Increased demand for these credits due to new construction should support a market for the trading of these credits among willing buyers and sellers. Other regulations regarding water conservation help to frame and structure the market. This trading mechanism allows property owners to make their own decisions about the economic benefit to themselves regarding further reductions in their water consumption patterns.

Successful operation of such a Community Water Budget, however, will require regular and accurate measurements regarding total water consumption patterns over time and a meaningful water demand cap. Investments made by the public water utility, including meter replacements and leak monitoring, have improved the accuracy regarding 95% of water consumption supplied through the Town's water distribution network.

Understanding the level of consumption over time from private wells is currently much more problematic. Private wells may have monitoring systems to estimate water pumping rates, and well owners may choose to share this information voluntarily. In fact, Clarkdale is currently developing a voluntary domestic well monitoring program, although town residents are currently under no requirement to provide the data to the water utility or the municipality. There is also the possibility that property owners within the service area who are currently making use of the Town water supply may choose to drill new wells in the future, since Clarkdale is located outside of Arizona's state-designated Active Management Areas. The proliferation of new unmetered wells would only further cloud the measurements regarding over-all water consumption patterns and undermine the Community Water Budget.

An effective Community Water Budget will depend on a meaningful water demand cap. If substantial numbers of residents can bypass the water demand cap by drilling private wells, the market value of the water consumption credits will remain low, creating little incentive to spur additional voluntary water conservation efforts. Further, the new wells will undermine the groundwater protections offered by the water demand cap, which would likely further endanger the surface flows of the Verde.

Further research may reveal other methods to address the conundrum of private well use in a community dealing with sensitive groundwater issues and related challenges regarding impacts on subsurface and surface flows of an adjacent perennial river. Voluntary arrangements, including incentive programs, may have found success in other communities with similar challenges regarding the collective impacts of private well use. Further study of state rules and procedures may reveal other types of well monitoring requirements, health and safety administrative regulations affecting well use, or restrictions regarding permit issuances for well drilling within a public utility's water service area. Adjudication-related determinations or a pre-settlement ruling affecting water rights for near-stream in the Verde Valley could also have similar effects.

4.9 Augmentation

In water management circles, the concept of water augmentation is based on the acquisition of a new source of water supply to augment existing supplies. Elaborate plans for the importation of water from other river basins in others states sometimes garner attention in the media. These proposals would require massive engineering projects, immense amounts of money, byzantine administrative review procedures, complex inter-state negotiations, congressional approval of any compacts, and distant time horizons. The likelihood of such projects given the current legal, political, and federal funding is exceedingly slim, based on the conclusions of the recent Colorado River Seven Basin Demand and Supply Study issued by the US Bureau of Reclamation (U.S. Bureau of Reclamation, 2012).

Any water augmentation strategy will therefore depend on more locally-sourced supplies. Many agricultural users of surface water from the Verde River have senior water rights that offer reliability of water supplies. There is the potential for the leasing of some of these surface water rights, should Clarkdale's water demand outstrip supplies of groundwater. Arrangements have been made in recent years between conservation organizations and local irrigators to permit greater instream flows through mechanisms like conservation easements, fallowing and automated headgates at diversion ditches. Similar agreements might be possible between the Town of Clarkdale and irrigators, although any negotiations will need to be mindful of the opportunity costs and economic tradeoffs that even a temporary transfer might trigger. Because of differences in water quality compared with the existing groundwater supplies, the use of surface water would require investment in additional water treatment capacity in order to provide potable water for residents.

Another possibility discussed previously involves the strategic use of the high quality Class A+ treated effluent from Clarkdale's recently upgraded wastewater treatment plant (WWTP). Whether the reclaimed water is used for non-potable re-use, indirect potable re-use, or potable re-use, such opportunities represent an augmentation of the Town's existing water supplies. Currently about 50% of residents have septic systems for treating their wastewater. Initiatives to increase sewer connections, through some combination of voluntary incentive programs and mandatory hook-up requirements for property owners near sewer lines, would create additional wastewater flows. The improvements at the WWTP were designed in contemplation of such increased capacity, and the ability to produce a greater volume of high quality effluent would expand the augmentation portfolio for the Town.

4.10 Financing

Various financing mechanisms have been mentioned previously in relation to specific water conservation or water-related education programming. Grants or other financing options specifically aimed at small governments or publicly-operated utilities may be available from Arizona's Water Infrastructure Finance Authority (WIFA), the US Bureau of Reclamation's WaterSMART funding program, or other similar sources. Foundations or other non-governmental grant-making entities may also respond favorably to proposals related to projects discussed in this Water Primer. Proposals are often specifically tailored to address a concrete and solvable need or respond to a perceived emerging problem. In the case of Clarkdale, WIFA funding may be needed to do a hydraulic study to understand how to insert the Mescal Well into the Town's water system while providing adequate treatment options for arsenic levels from the well.

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GLOSSARY OF TERMS*

Acre-feet (af): The amount of water it takes to cover one acre of land to the depth of one foot, approximately 325,851 gallons.

Active Management Area (AMA): A geographic area that has been designated pursuant to A.R.S.§ 45-411 as requiring active management of groundwater or, in the case of the Santa Cruz AMA, active management of any water, other than stored water, withdrawn from a well. Subsequent active management areas may be designated through local initiative or by the Director of ADWR.

Advanced primary treatment: The enhanced removal of suspended solids and organic matter in the wastewater treatment process through the use of chemicals and/or filtration.

Agricultural water use: Water applied to two or more acres of land to produce plants or parts of plants for sale for human consumption or for use as feed for livestock, range livestock or poultry.

Aquifer: A geologic formation that contains sufficient saturated materials to be capable of storing water and transmitting water in usable quantities to a well.

Aquifer recharge: Water added to the aquifer through seepage and infiltration.

Aquifer storage: Water stored underground for future use. Also, water stored pursuant to a permit issued under A.R.S. § 45-831.01, the Underground Water Storage, Savings and Replenishment Program.

Artificial recharge: Water recharged to the aquifer through recharge projects, which may be recovered in the future based on accrued recharge credits.

Baseflow: The part of a stream discharge that is not attributable to direct runoff from precipitation or melting snow. It is sustained by groundwater discharge and may be considered as normal day-to-day flow during most of the year.

Calendar year: The 12-month period from January 1 to December 31.

Consumptive use: The part of the water demand that becomes unavailable for future use because it is evaporated or consumed by the use. Consumptive use also refers to diversions from the mainstream of the Colorado River minus the returns.

Continuous flow gage: Mechanical device placed in a stream that measures the volume of water flowing at that specific location over an extended period of time.

Community Water System: A public water system, as defined in A.R.S. § 49-352(B), that serves at least fifteen service connections used by year-round residents of the area served by the system or that regularly serves at least twenty-five year-round residents of the area served by the system. A person is a year-round resident of the area served by a system if the person's primary residence is served water by that system.

Based the glossary from the Arizona Water Atlas, AZ Department of Water Resources, 2010, p. Vol. 1, Executive Summary

Cultural Water Demand: The quantity of water diverted from streams and reservoirs and pumped from wells for municipal, industrial and agricultural purposes. It should not be confused with "consumptive use", which refers to the amount of cultural water demand that is lost from the hydrologic system.

Designation of Assured Water Supply*:* In order to receive such a designation from the Arizona Department of Water Resources, applicants are required to demonstrate an assured water supply that will be physically, legally, and continuously available for the next 100 years before the developer can record plats or sell parcels. This designation applies within Active Management Areas. For an example of a requirement outside of AMAs, refer to the definition of Water Adequacy Program.

Drinking water standards: Criteria developed by the Arizona Department of Environmental Quality and other state and local agencies, the US Public Health Service, and the US Environmental Protection Agency to assure safe water for human consumption.

Drought: A sustained natural reduction in precipitation that results in negative impacts to the environment and human activity.

Effluent: Water that has been collected in a sanitary sewer for subsequent treatment in a facility that is regulated as a sewage system, disposal plant or wastewater treatment facility. Such water remains effluent until it acquires the characteristics of groundwater or surface water.

Effluent dependent water: Surface waters that would generally be ephemeral, except for the discharge of treated effluent.

Ephemeral stream: A stream or part of a stream that flows only in direct response to precipitation; it receives little or no water from springs, melting snow or other sources; its channel is at all times above the water table.

Exempt well: Within an AMA, a well having a pump with a maximum pumping capacity of 35 gallons per minute or less, which is used to withdraw groundwater for non-irrigation purposes. This term is also used to describe any well outside an AMA having a pump with a maximum pumping capacity of 35 gallons per minute or less.

Groundwater: Generally, water below the earth's surface but commonly applied to water in fully saturated soils and geologic formations.

Groundwater flow model: A digital computer model that calculates a hydraulic head field for the modeling domain using numerical methods to arrive at an approximate solution to the differential equation of groundwater flow.

Hydrographs: A graphic representation of the changes in the flow of water or the elevation of water levels over time.

Impaired: A lake or stream that is not meeting one or more surface water quality standards as established in A.R.S. § 49-231

Incidental recharge: The percolation of water to the water table after the water has been used. Components of incidental recharge include recharge that occurs from septic tanks, turf watering and effluent discharge.

Inflow: All water that enters a hydrologic system. Examples include mountain front and stream channel recharge, artificial and incidental recharge and baseflow and underflow into a system.

In-lieu water: Water that is delivered to a groundwater savings facility in an AMA or INA and that is used at the facility by the recipient on a gallon for gallon substitute basis for groundwater that otherwise would have been pumped from within the AMA or INA.

Irrigation non-expansion area (INA): A geographic area that has been designated pursuant to A.R.S. §§ 45-431 or 45-432 as having insufficient groundwater to provide a reasonably safe supply for the irrigation of cultivated lands at the current rate of withdrawal.

Instream flow right: A non-diversionary surface water right for recreation and wildlife purposes, including fish.

Intermittent stream: A stream or part of a stream that flows only at certain times of the year when it receives water from springs, snowmelt, surface run-off or other sources.

Municipal demand: All non-agricultural uses of water supplied by a city, town, private water company, irrigation district, domestic water improvement district, water cooperative or private domestic well.

Non-exempt well: Within an AMA, a well having a pump with a maximum pumping capacity of more than 35 gallons per minute and used for non-irrigation purposes or any well used for irrigation purposes. This term is also frequently used to describe any well outside an AMA having a pump with a maximum pumping capacity greater than 35 gallons per minute.

Outflow: All water that leaves a hydrologic system. Examples include cultural water demand, phreatophyte use and underflow and baseflow out of the system.

Perennial stream: A stream or part of a stream with surface flow throughout the year, drying only during periods of drought.

Phreatophyte: A deep-rooted plant that obtains it water from a permanent groundwater supply.

Primary treatment: The first stage in wastewater treatment where some solids and organic material are removed by screening and sedimentation. It removes about 35% of the biochemical oxygen demand (BOD) and less than half of the metals or toxic organic substances.

Reservoir: An artificially created lake where water is collected and stored for future use.

Return Flow: The amount of water that reaches a groundwater or surface water source after release from the point of use and thus becomes available for further use. In other words, that part of a diverted flow, which is not consumptively used and returns to its original source or another body of water.

Run-off: The portion of precipitation that is not intercepted by vegetation, absorbed by land surfaces or evaporated and that flows overland into a depression, lake, stream or ocean.

Secondary treatment: The second stage in wastewater treatment that involves both chemical and biological processes. The screened wastewater is passed through a series of holding and aeration tanks and ponds further removing organic and inorganic substances. Disinfecting with chlorine may be included.

Secondary treatment with nutrient removal: An additional process in the secondary treatment of wastewater that removes nutrients such as nitrogen and phosphorus.

Spring: A place where water emerges naturally from the earth without artificial assistance onto the land surface or into a body of surface water.

Surface water: An open body of water such as a stream, lake, or reservoir.

Surface water standards: Numeric and narrative criteria developed to ensure surface water quality for 6 designated uses; aquatic and wildlife, body contact, fish consumption, domestic water source, and agricultural use for irrigation or livestock watering.

Tertiary treatment: Wastewater treatment beyond the secondary or biological stage that includes the removal of nitrogen and phosphorus and a high percent of suspended solids through chemical and mechanical means such as additional filtration, carbon adsorption, distillation and reverse osmosis.

Underflow: The downstream flow of water through permeable deposits underlying a stream.

Water Adequacy Program: The program implementing A.R.S. § 45-108, requiring a developer of subdivided land outside an AMA to obtain a determination from the Department regarding the availability of water supplies before the land may be marketed for sale or lease to the public, unless the land will be served by a water provider designated as having an adequate water supply. Under this regulatory program, developers are required to disclose a determination that the water supply is inadequate to potential buyers. The Town of Clarkdale has acted pursuant to SB 1525 to require a demonstration of adequate water supply for new subdivisions.

Well yield: The volume of water discharged from a well in gallons per minute or cubic meters per day.

Summary of Hydrologic Conditions at Clarkdale, Arizona

Laurel J. Lacher, PhD, RG
acher Hydrological Consulting
December 2013

1. Hydrogeologic Setting

The Town of Clarkdale lies on high ground about 200 feet (ft) above the Verde River, at an elevation of 3560 feet above mean sea level (ft amsl) (Figure 1). The town presently utilizes two public water supply wells, one of which (Haskell Spring Well) historically produced artesian flow. The 89A, or Reservoir, Well was discontinued from use in 2009 due to high arsenic concentrations. The Mountain Gate well supplies about 40% of Clarkdale's total potable water production, while the Haskell Springs Well supplies the other 60%. The Mescal Well has been drilled and completed, but is not yet in use. Many exempt (less than 35 gallons per minute production) wells exist within and near the town limits, and industrial pumping occurs at the Phoenix Cement plant northwest of town.

The Verde River flows south out of the Verde Canyon, emerging from the narrow canyon just a few miles north of Clarkdale. In general, the river is a gaining stream (fed by groundwater) through most of the middle Verde Valley. A significant diversion created and maintained by Freeport-McMoran, Inc. just upstream from Clarkdale supplies water to Peck's Lake. Several major diversions downstream of Clarkdale temporarily dry portions of the river at times during peak irrigation periods in the summer.

Precipitation in the mountains along the valley margins, such as the Black Hills west of Clarkdale, recharges the groundwater system (aquifer), and creates a hydraulic gradient that forces groundwater toward the low point in the basin where it is discharged as surface water in the Verde River. Groundwater extraction wells between the recharge areas and the Verde River intercept groundwater that would otherwise discharge as baseflow in the river. After prolonged pumping, extraction wells create a cone of depression – a zone of low pressure or dewatering – in the aquifer surrounding them. Over time, these cones of depression may extend to sources of capture such as streams, riparian ET, or recharge areas. Once a source of capture is intercepted, the modified hydraulic gradients within the cone of depression recruit water from those sources. Eventually, most of the water pumped from the wells will derive from capture rather than aquifer storage.

Clarkdale's wells produce from gravels interbedded with limestone, fine-grained sandstone, and mudstone of the Tertiary Verde (Tv) Formation (SWGC, 2010) between Mingus Mountain to the west and the Verde River to the east. This portion of the basin is structurally down-dropped between the Verde and Bridgeport normal faults relative to adjacent Paleozoic sequences present to the north and west of Clarkdale (Figure 2). No wells have penetrated deep enough to confirm the presence or hydrologic productivity of the Paleozoic sequence of formations believed to underlie the Tv Formation in the Clarkdale area (SWGS, 2010).

2. Current Status and Projections of Groundwater Levels and Baseflow

Figure 3 shows simulated 1910 groundwater flow conditions in the Clarkdale area prior to any significant groundwater development. As the arrows in the figure indicate, groundwater generally moved down valley parallel to the Verde River from the surrounding mountain recharge areas. Figure 4 shows simulated heads and flow paths in the same area of the Tv aquifer near Clarkdale in 2006, which marks the end of the transient calibration period for the US Geological Survey's groundwater model of northern Arizona (Pool, et al, 2010). This figure shows a pumping-induced cone of depression with drawdowns exceeding 200 ft in the Clarkdale-Cottonwood area. Groundwater flow paths are diverted toward the area immediately west of Cottonwood rather than proceeding along their historical down-valley trajectories. By 2076 (Figure 5), simulated heads reflect a deeper (over 300 ft) cone of depression southwest of Cottonwood and southeast of Clarkdale. Groundwater flow paths are more sharply diverted from their historical down-valley trajectories, with the cone of depression capturing groundwater from all directions.

Figure 6 shows the simulated pattern of baseflow change in part of the Verde River and Oak Creek over the period 1910 to 2006. Although the Verde River shows variable levels of baseflow decline, the simulated decline at the "Verde River near Clarkdale" steam-flow gaging station maintained by the U.S. Geological Survey was on the order of 8% over the 20th century. By 2076 (Figure 7), simulated baseflow declines on the Verde River are more pronounced, with baseflow declining by an estimated 18% at the Clarkdale gaging station from 1910 conditions.

3. Clarkdale's Impact on Groundwater and Surface Water Resources

Figure 8 shows Clarkdale's simulated historic pumping and effluent recharge record (estimated and documented) in acre-feet per year (AF/yr) for the period 1910-2013, and pumping and effluent recharge held steady at 2013 levels (700 AF/yr pumping; 66 AF/yr recharge) from 2014-2076. Figure 9 shows how Clarkdale's pumping is partitioned among three municipal wells in the simulation period 1910-2076. In order to quantify the impacts of Clarkdale's municipal groundwater extraction and recharge on the underlying aquifer and on baseflow in the Verde River, capture simulations were run using the USGS groundwater flow model of northern Arizona (Pool, et al, 2010). The first simulation included all historic pumping and recharge in the entire model domain (northern Arizona down to the Salt River) through 2006 plus specified future pumping[1] and recharge to 2076. Figure 10 shows the simulated recharge factor distribution for the period 1910 to 2076. The recharge factor allows scaling of average annual recharge relative to the predevelopment period (pre-1950), where the factor equals 1 (Pool, et al, 2010). The current period (2006-2014) was set equal to the 1950-1960 drought period, and the 2014-2076 period replicates the 1910 to 1970 period. Adding the post-2006 specified recharge rates lowers the average recharge rate for the simulation period 1910-2076 by 9% compared to the 1910-2006 period.

The second capture simulation included all of the same historic and future pumping and recharge *except* that associated with Clarkdale's municipal operations. Subtracting the two simulation results yields the difference in groundwater levels, aquifer storage, baseflow, and other groundwater flow-budget elements attributable solely to the Town of Clarkdale's groundwater use over the period 1910 to 2076.

Figure 11 shows simulated drawdown in early 2014 in the regional aquifer (model layer 3) attributable solely to Clarkdale's groundwater extraction and recharge. The large red center in the colored drawdown contours represents the large change in head (groundwater level) recorded at Haskell Springs Well, Clarkdale's oldest municipal well. The outer edge of the colored contour area represents the area where drawdown equals or exceeds 3.3 ft by 2014. Figure 12 shows simulated Clarkdale-attributable drawdown in 2076. Note that, although the areal extent of the drawdown is larger, the maximum depth is reduced from 1007 to 640 ft as a result of scaling back pumping at the Haskell Springs Well and bringing the Mescal Well online (see Figure 9).

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[1] For this simulation, pumping throughout the Northern Arizona model area was specified as constant from 2006 to 2076, except in Clarkdale, where actual pumping values were used through 2013. Simulated pumping was somewhat less than specified because some model cells went dry, causing wells in those cells to cease pumping.

Figure 13 compares Clarkdale's simulated pumping and resultant aquifer storage depletion and baseflow capture over time. The simulations indicate that prior to 2006, Clarkdale's wells derived most of their water from aquifer storage and had no significant impact on baseflow in the Verde River. The simulated 300 AF of increased pumping between 2006 and 2014 resulted in a 200-AF increase in aquifer storage depletion and 100 AF of depletion in Verde River baseflow. Thus, after 2006, simulated pumping begins to capture streamflow rather than just extracting groundwater from aquifer storage. After 2014, even as simulated pumping remains constant at 700 AF/yr, aquifer storage depletion (consumption) begins to diminish as less water is available in the cone of depression around the wells. Consequently, the fraction of pumped water coming from stream baseflow increases steadily to make up the difference. By 2056 in the simulations, baseflow capture begins to exceed groundwater storage as a fraction of water pumped by Clarkdale wells. Note that the combined total of aquifer storage depletion and baseflow capture is about 600 AF/yr compared with 700 AF/yr produced by the Clarkdale wells. The 100-AF difference is made up by recharge of about half of Clarkdale's treated effluent (66 AF/yr), and from other sources of capture such as springs and riparian evapotranspiration (ET). ET capture occurs as groundwater levels decline in the cone of depression, leaving less water accessible to riparian plants and thereby decreasing groundwater losses to ET. The small increase in storage depletion in the last simulation stress period (2066 – 2076) reflects the fact that a shallow well in the Cottonwood area was deepened in the simulation to prevent a model cell from going dry. The simulated "deepening" of the well provides improved access to aquifer storage for that well in the short term, but the trend of reduced storage depletion and increased baseflow capture is expected to continue until no further aquifer storage is available to these wells. By the end of the simulation period in 2076, Clarkdale's simulated pumping is capturing of 380 AF/yr (roughly 0.5 cubic-feet per second (cfs)) of Verde River baseflow and consuming about 330 AF/yr in aquifer storage.

4. Summary Discussion

Capture of stream baseflow by Clarkdale's municipal wells was quantified by subtracting results from two otherwise identical simulations except that one did not include any of Clarkdale's municipal pumping or recharge. These simulations incorporate several key assumptions:

- Projected natural recharge is distributed in a way that mimics the early part of the 20th century, reflecting a drying trend from 2000 to 2076.
- Clarkdale will operate three existing wells as they are currently configured (without deepening) but at the pumping rates specified in Figure 9.
- Artificial recharge in the entire model domain (primarily treated wastewater) remains constant from 2006 to 2076.
- Except for one well in Cottonwood, no other wells are deepened; because some model cells go dry, without deepening wells in those cells, overall pumping in the model domain (outside of Clarkdale and Cottonwood) decreases by almost 9% from 2006 to 2076.

The capture simulation results indicate that the tipping point at which more of Clarkdale's pumped water will derive from baseflow capture than aquifer storage will occur around 2056. After that point, baseflow capture is expected to continue to increase over aquifer storage as a fraction of the water pumped by Clarkdale's municipal wells. Insufficient drilling information exists to judge whether deepening Clarkdale's wells into some deep, unknown aquifer below the regional aquifer currently being exploited in the Tv Formation is a viable option. However, Clarkdale's position near the toe of the mountains likely means that the regional aquifer is thinner there than at other sites closer to the center of the valley. Even though the simulations described in this study do not indicate that dewatering will limit Clarkdale's existing well production prior to 2076 (provided Haskell Springs Well pumping is reduced and the Mescal Well is utilized), they do suggest that Clarkdale's impacts to the Verde River have already begun to manifest, and will continue to increase over the next half century. Measures to mitigate this impact on the river may include a variety of tactics, including but not limited to: a) reducing consumptive water use through conservation, b) deepening Clarkdale's wells to tap into an unknown aquifer underlying the Tertiary Verde Formation, c) replacing local municipal water supplies with water imported from another region, d) increasing aquifer recharge capture, or e) discharging treated water (most likely effluent) directly to the river. With the exception of water importation, none of these potential tactics will provide a complete and permanent solution to aquifer storage depletion, but they could limit the extent of damage caused by ET and baseflow capture and push the timing of the negative impacts of pumping farther out into the future.

References Cited

Lehner, R.E., 1955, Geology of the Clarkdale Quadrangle, Arizona, Chapter N in CONTRIBUTIONS TO GENERAL GEOLOGY, U.S. Geological Survey Bulletin 1021, pp. 511-592.

Pool, D.R., Blasch, K.W., Callegary, J.B., Leake, S.A., and L.F. Graser, 2010, Regional Groundwater-Flow Model of the Redwall-Muav, Coconino, and Alluvial Basin Aquifer Systems of Northern and Central Arizona, US Geological Survey Scientific Investig. Rpt. 2010-5180, v.1.1, 101 p.

Southwest Groundwater Consultants (SWGC), 2010, Application for a Designation of Water Adequacy – Town of Clarkdale, Yavapai County, Arizona, submitted to AZ Dept. of Water Res. May 31, 18 pp. + fig and app.

Figure 1. Aerial image of Clarkdale showing town center and Verde River elevations in feet above mean sea level (ft amsl).

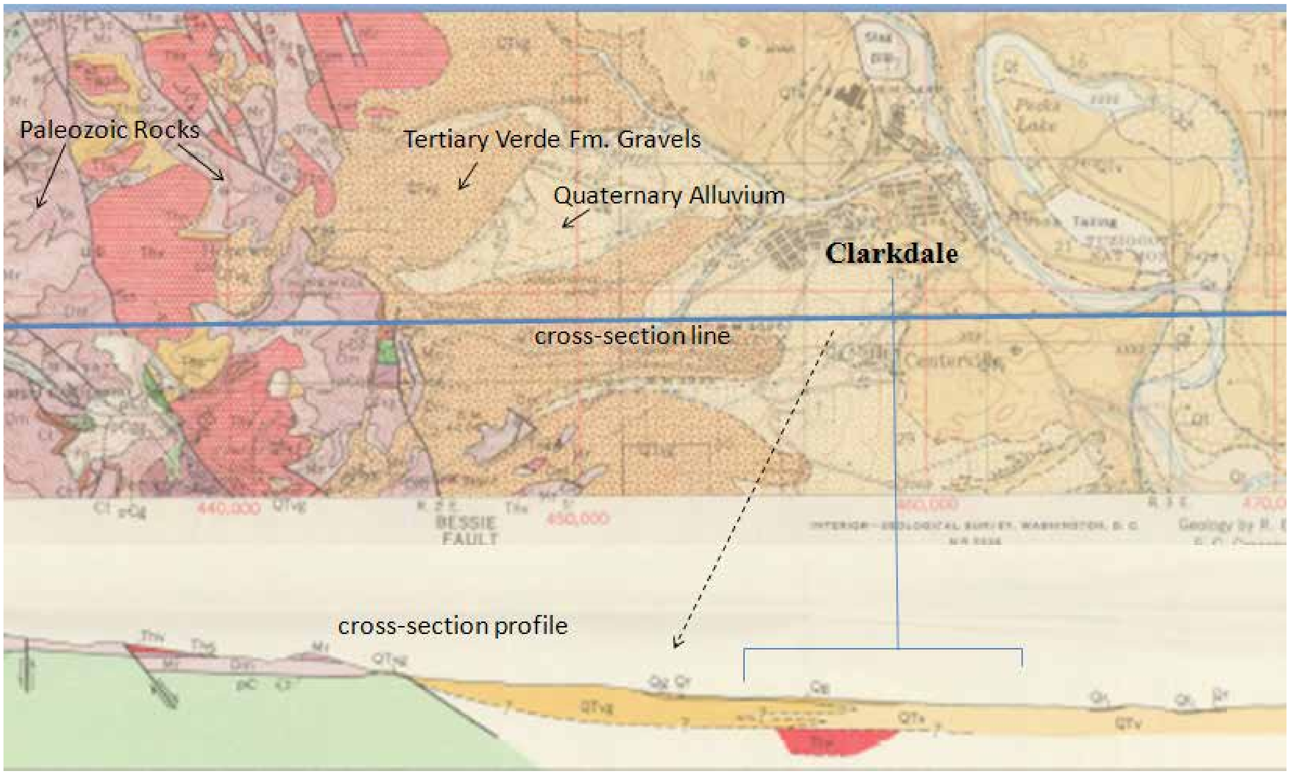
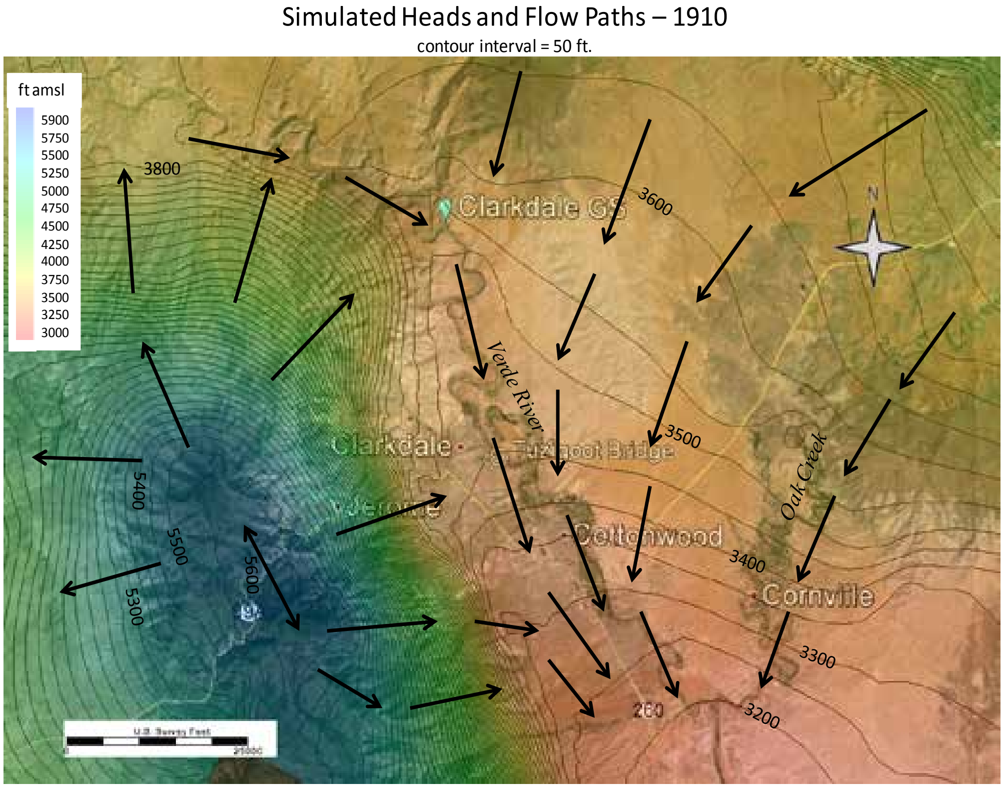
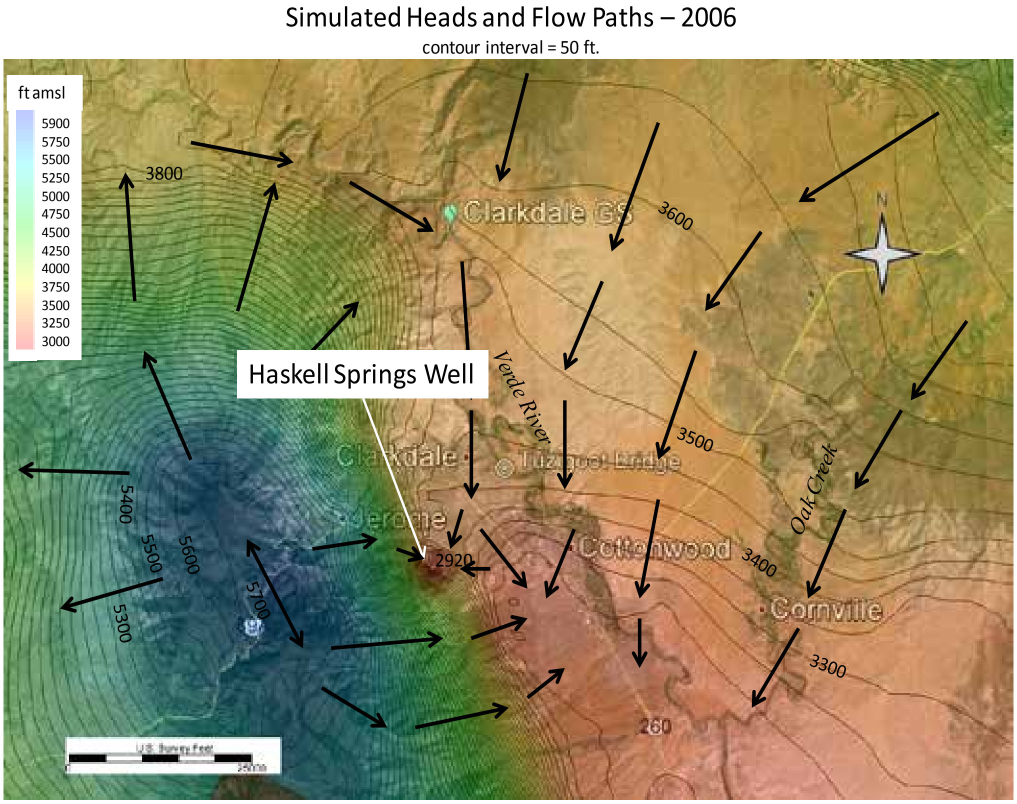


Figure 2. Geologic Map and cross section near Clarkdale showing interbedded Tertiary Verde Formation which comprises the primary aquifer for Clarkdale's wells. (Source: Lehner, 1955)


Simulated Heads and Flow Paths – 1910

contour interval = 50 ft.

Figure 3. Simulated predevelopment groundwater levels and flow paths in the regional aquifer near Clarkdale.


Simulated Heads and Flow Paths – 2006

contour interval = 50 ft.

Figure 4. Simulated 2006 groundwater levels and flow paths in the regional aquifer near Clarkdale.

Simulated Heads and Flow Paths – 2076

contour interval = 50 ft.

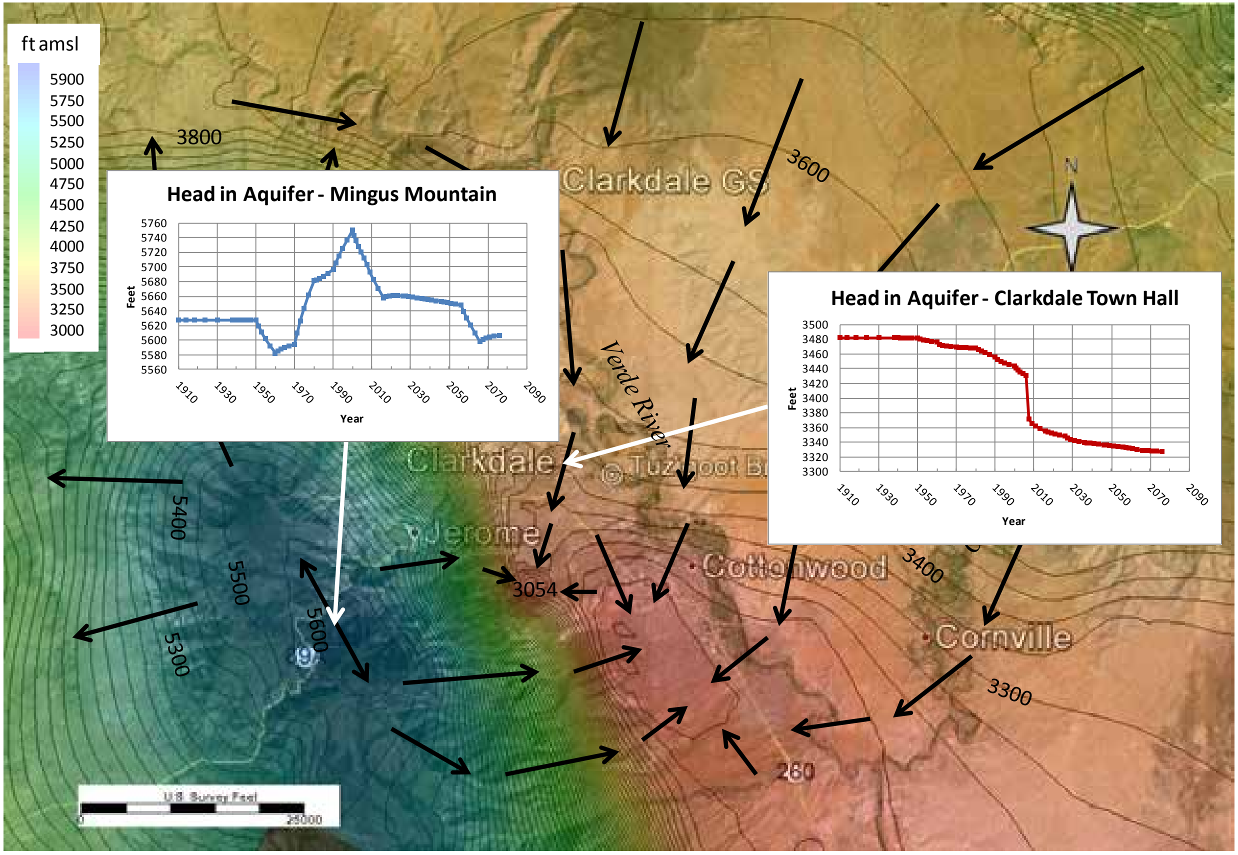


Figure 5. Simulated 2076 groundwater levels and flow paths in the regional aquifer near Clarkdale. Inset graphs show simulated groundwater level hydrographs over time at Mingus Mountain and under Clarkdale from 1910 to 2076.

Simulated Change in Baseflow - 1910 to 2006

contour interval = 1 cubic-foot per second (cfs)

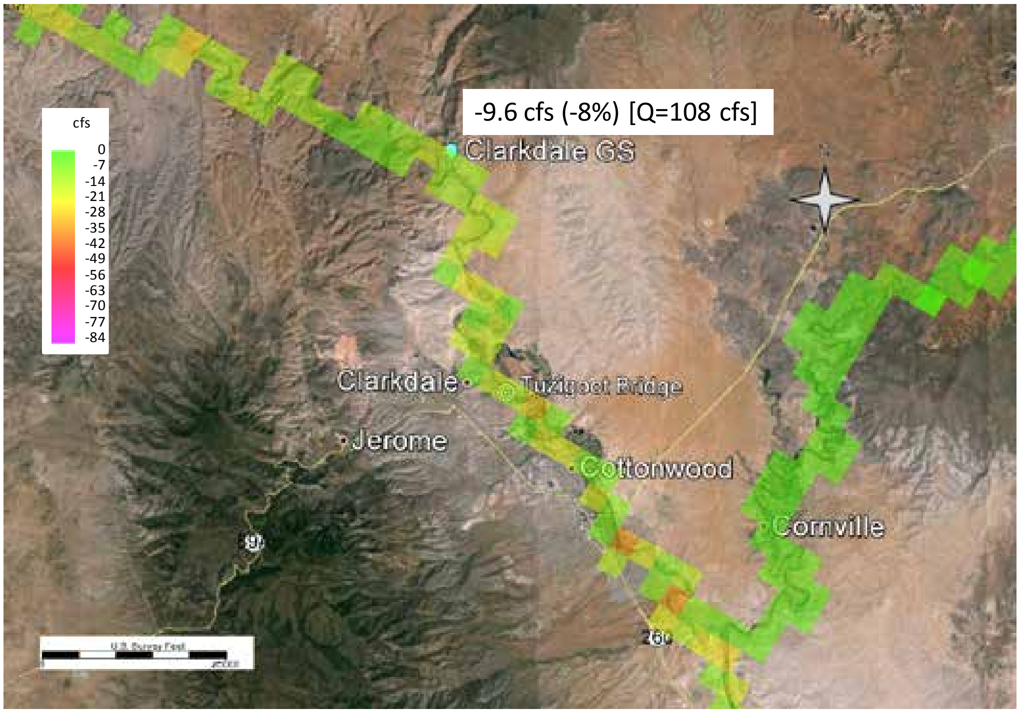


Figure 6. Simulated change in baseflow in the Verde River near Clarkdale and along Oak Creek near Cornville between 1910 and 2006.

Simulated Change in Baseflow - 1910 to 2076

contour interval = 1 cubic-foot per second (cfs)

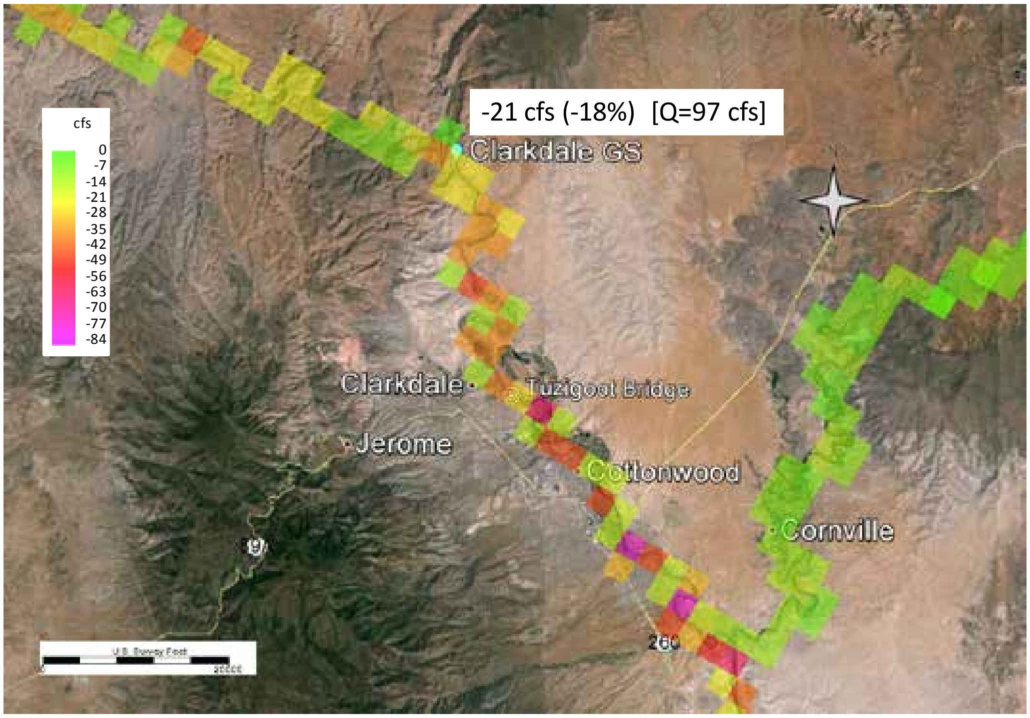


Figure 7. Simulated change in baseflow in the Verde River near Clarkdale and along Oak Creek near Cornville between 1910 and 2076.

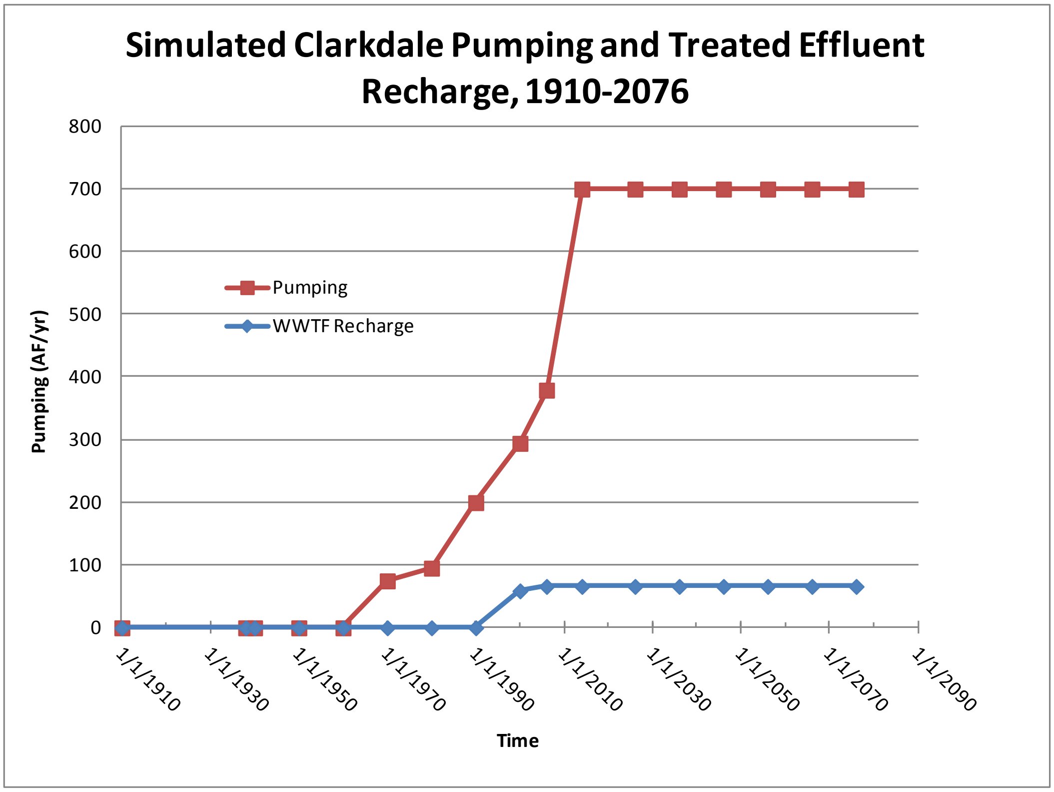


Figure 8. Simulated municipal pumping in Clarkdale and treated effluent recharge at the Clarkdale wastewater treatment facility. Recharge is estimated at 50% of treated effluent volume (Pool et al, 2010).

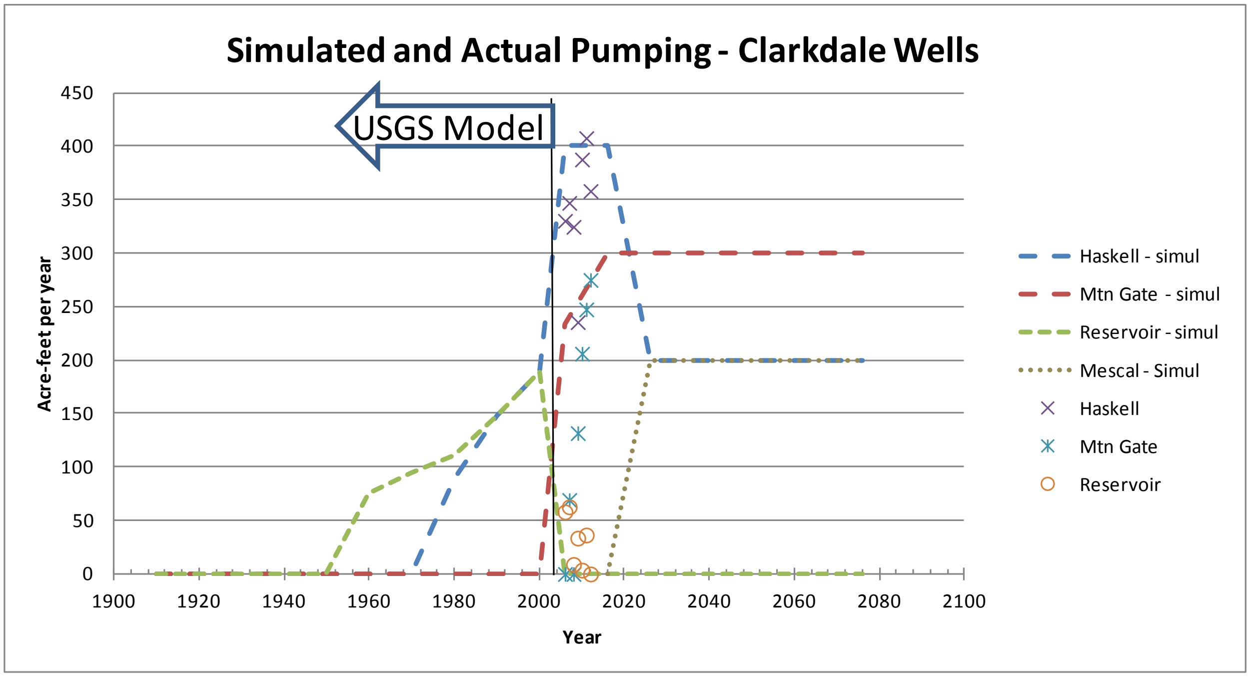


Figure 9. Simulated distribution of Clarkdale pumping among three municipal wells, 1910-2076.

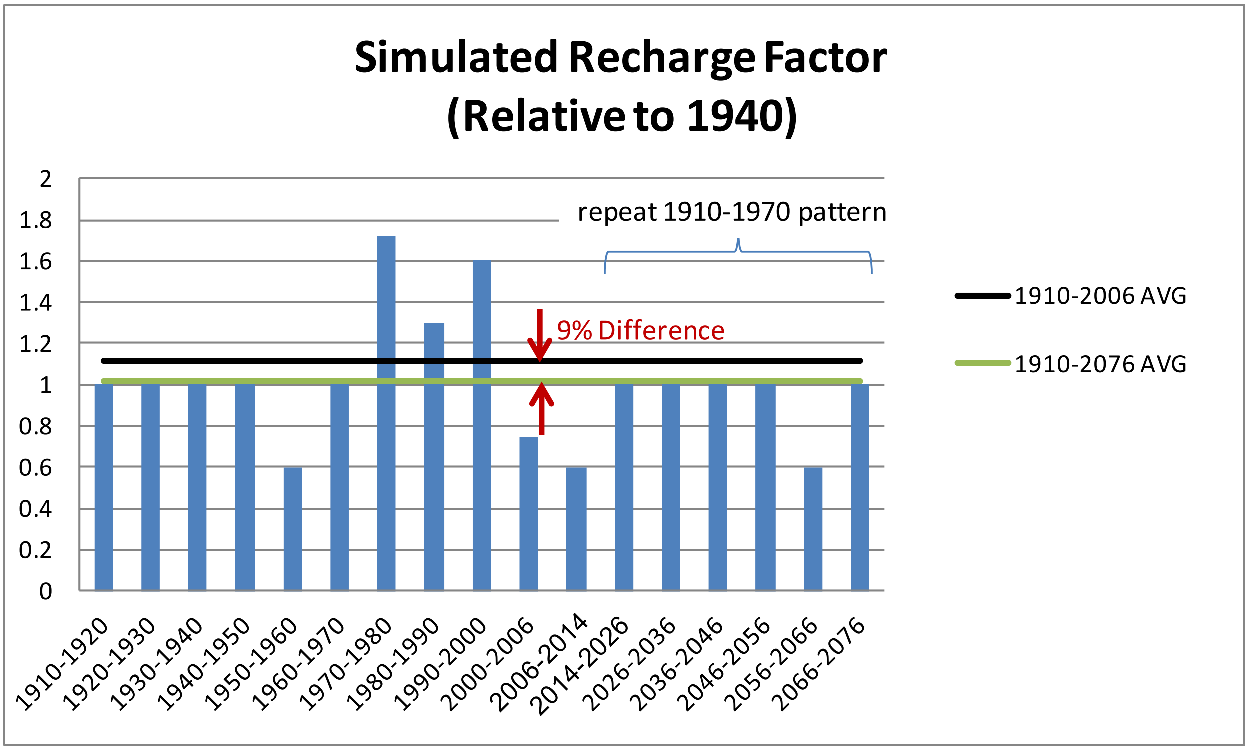


Figure 10. Simulated recharge factor for the period 1910 to 2076. The recharge factor was applied to scale average annual recharge relative to the predevelopment period (pre-1950), where the factor equals 1 (Pool, et al, 2010). The current period (2006-2014) was set equal to the 1950-1950 drought period, and the 2014-2076 period replicates the 1910 to 1970 period. Adding the post-2006 specified recharge rates lowers the average recharge rate by 9% over the simulations period 1910-2076 compared to the 1910-2006 period.

Simulated Drawdown Attributable to Clarkdale - 2014

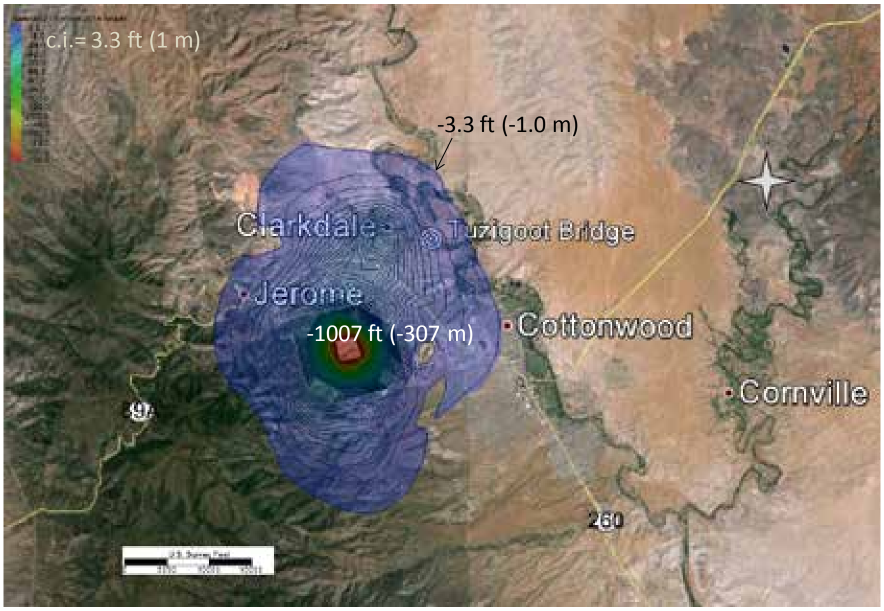


Figure 11. Simulated drawdown attributable to Clarkdale municipal pumping and recharge for the period 1910-2014.

Simulated Drawdown Attributable to Clarkdale - 2076

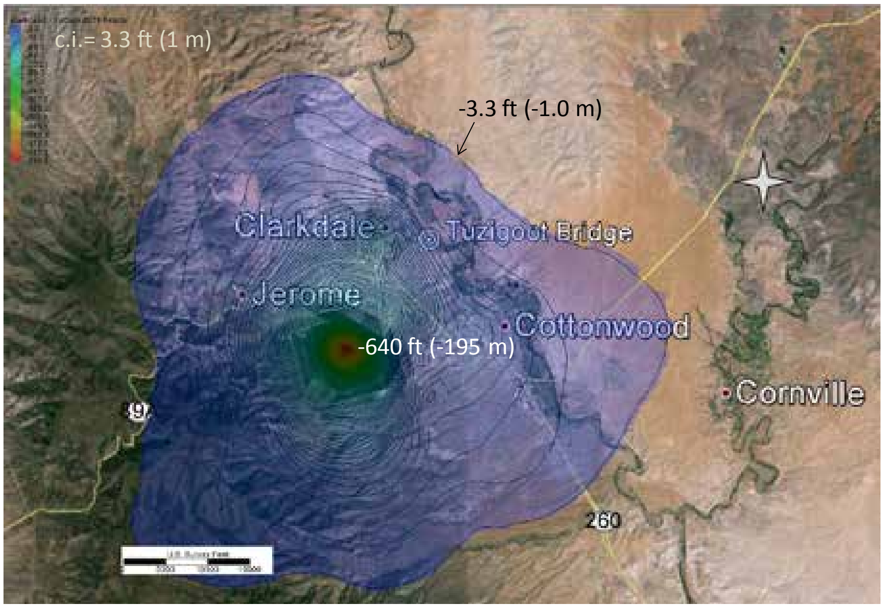


Figure 12. Simulated drawdown attributable to Clarkdale municipal pumping and recharge for the period 1910-2076.

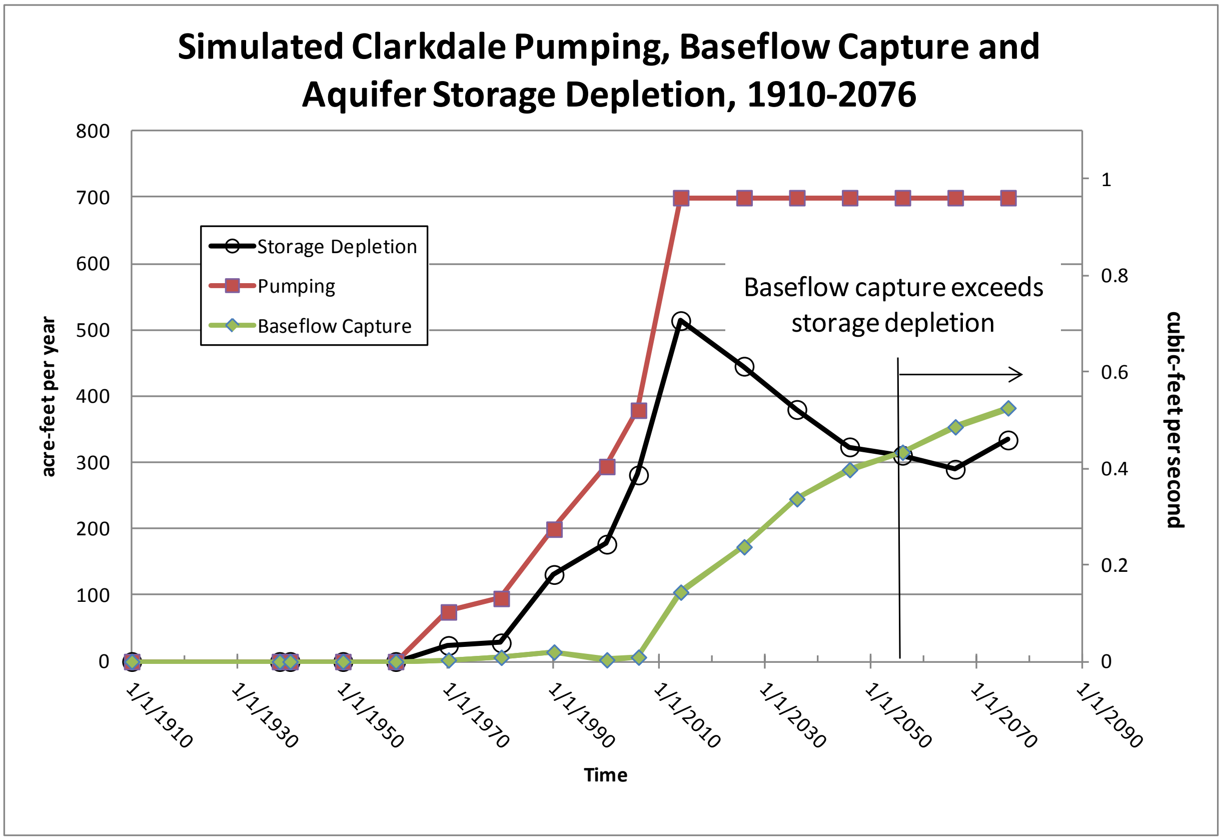
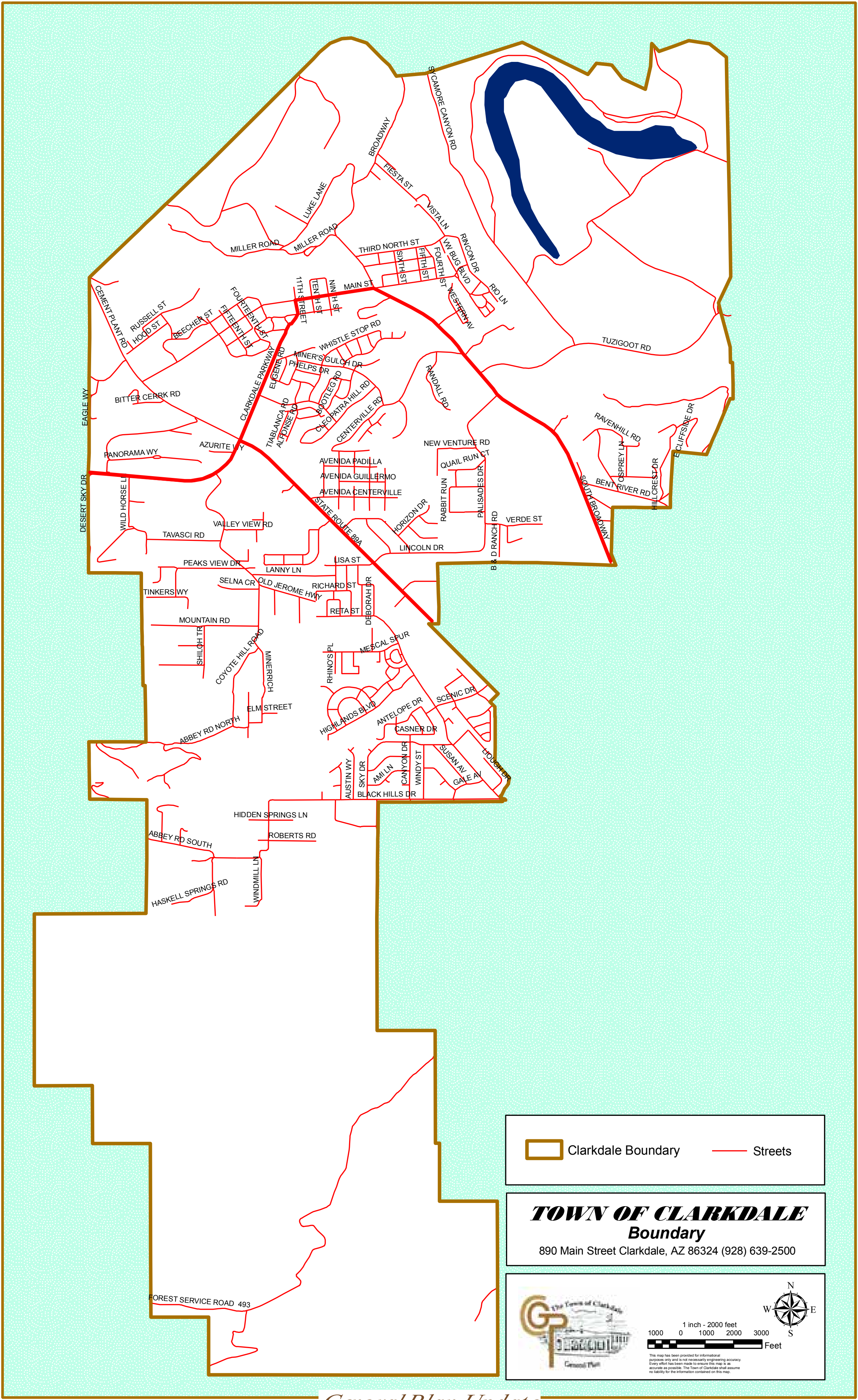


Figure 13. Simulated Clarkdale pumping and associated aquifer storage depletion and baseflow capture for the period 1910-2076. Beginning in 2056, baseflow capture comprises a greater fraction of Clarkdale's pumping than does aquifer storage depletion.

Reference Maps

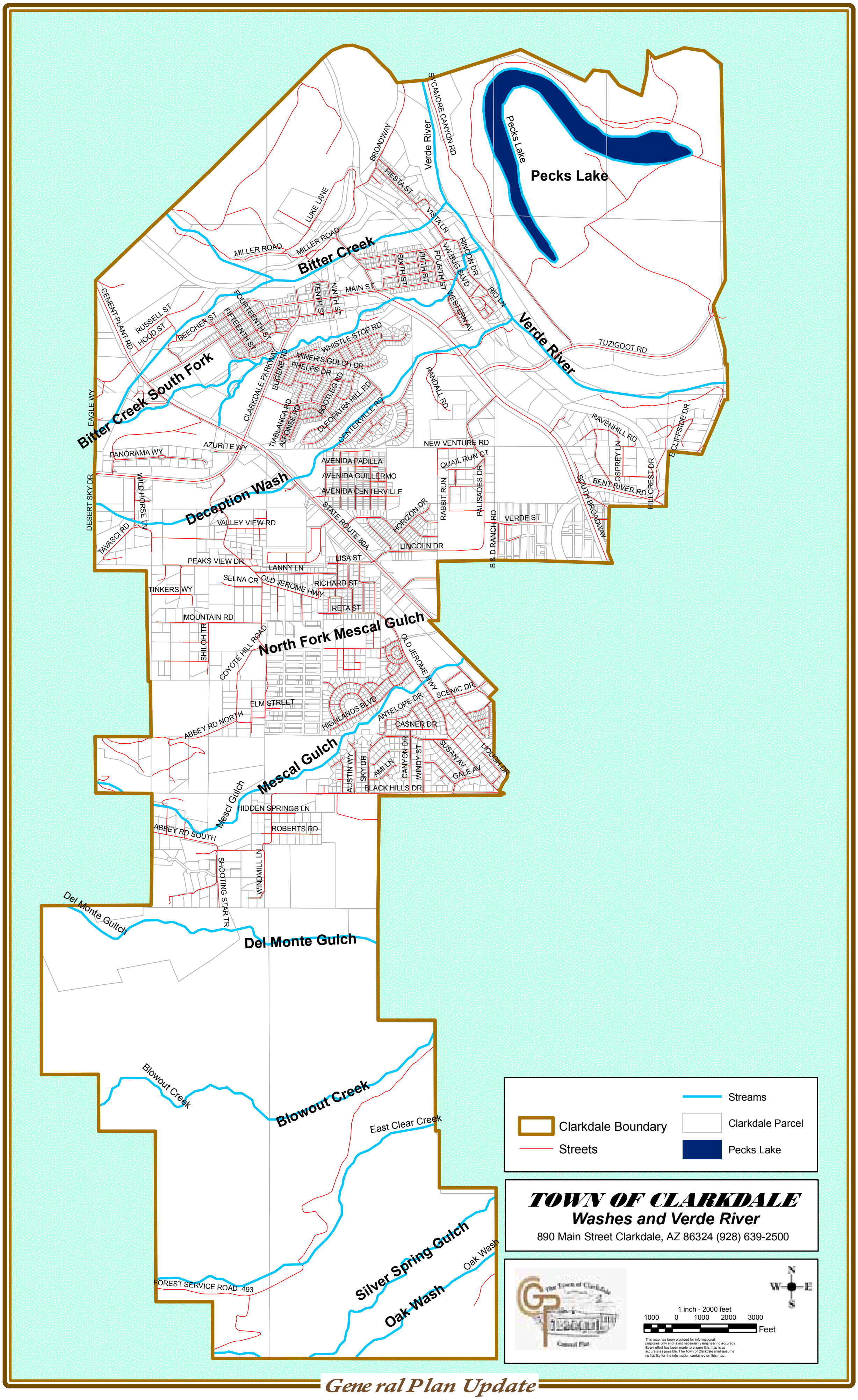


TOWN OF CLARKDALE

Boundary

890 Main Street Clarkdale, AZ 86324 (928) 639-2500

This map has been provided for informational purposes only and is not necessarily engineering accuracy. Every effort has been made to ensure this map is as accurate as possible. The Town of Clarkdale shall assume no liability for the information contained on this map.



TOWN OF CLARKDALE

Washes and Verde River

890 Main Street Clarkdale, AZ 86324 (928) 639-2500

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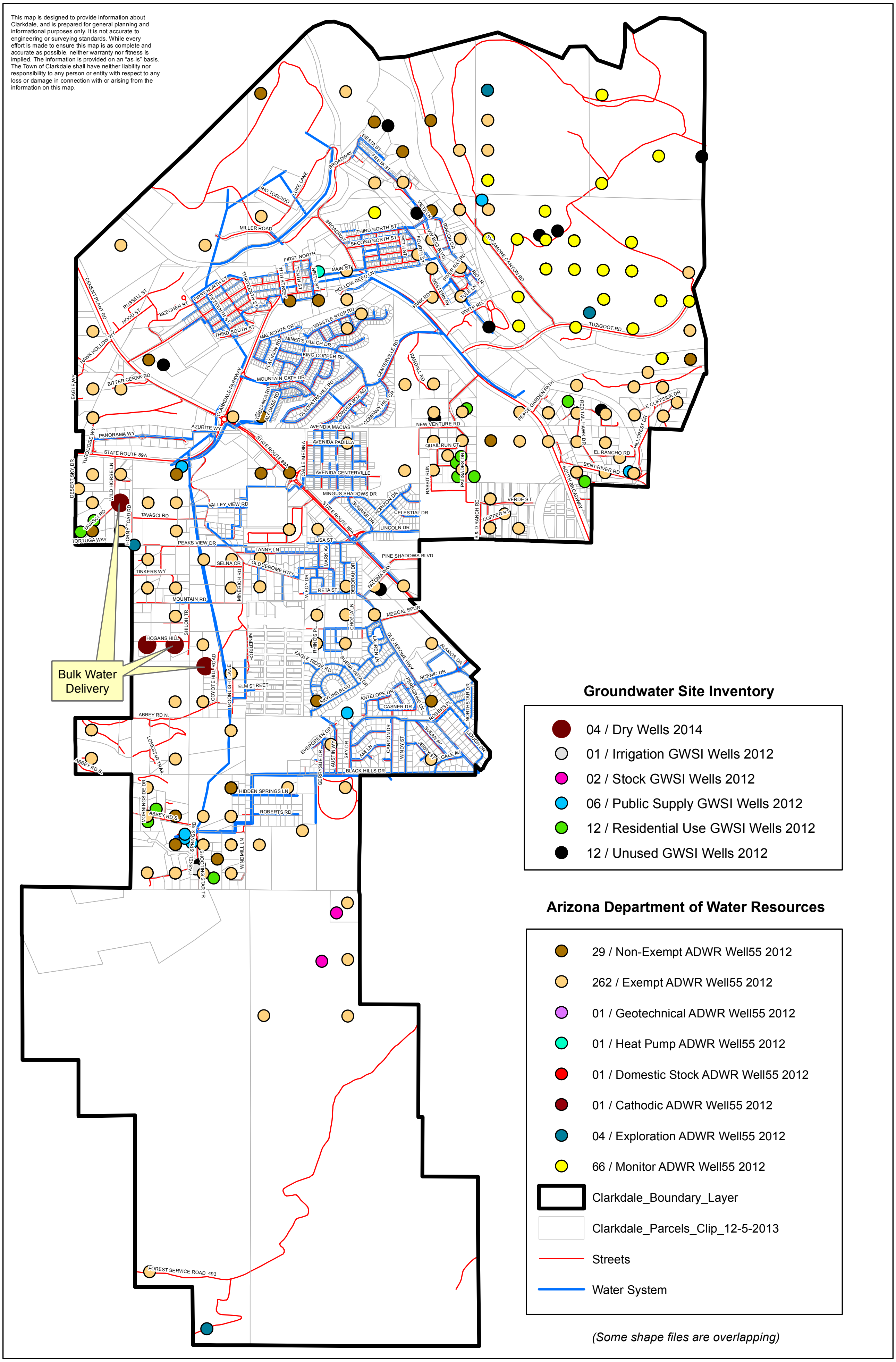

Groundwater Site Inventory

- ● 04 / Dry Wells 2014
- ○ 01 / Irrigation GWSI Wells 2012
- ● 02 / Stock GWSI Wells 2012
- ● 06 / Public Supply GWSI Wells 2012
- ● 12 / Residential Use GWSI Wells 2012
- ● 12 / Unused GWSI Wells 2012

Arizona Department of Water Resources

- ● 29 / Non-Exempt ADWR Well55 2012
- ● 262 / Exempt ADWR Well55 2012
- ● 01 / Geotechnical ADWR Well55 2012
- ● 01 / Heat Pump ADWR Well55 2012
- ● 01 / Domestic Stock ADWR Well55 2012
- ● 01 / Cathodic ADWR Well55 2012
- ● 04 / Exploration ADWR Well55 2012
- ● 66 / Monitor ADWR Well55 2012
- ▢ Clarkdale_Boundary_Layer
- ▢ Clarkdale_Parcels_Clip_12-5-2013
- — Streets
- — Water System

(Some shape files are overlapping)

The Town of Clarkdale
Utilities Department
P.O.Box 308/890 Main Street,
Clarkdale,AZ 86324
(928) 639-2520

Water Service Map with Wells

N

0 950 1,900 3,800 5,700 7,600 Feet

January 23, 2014

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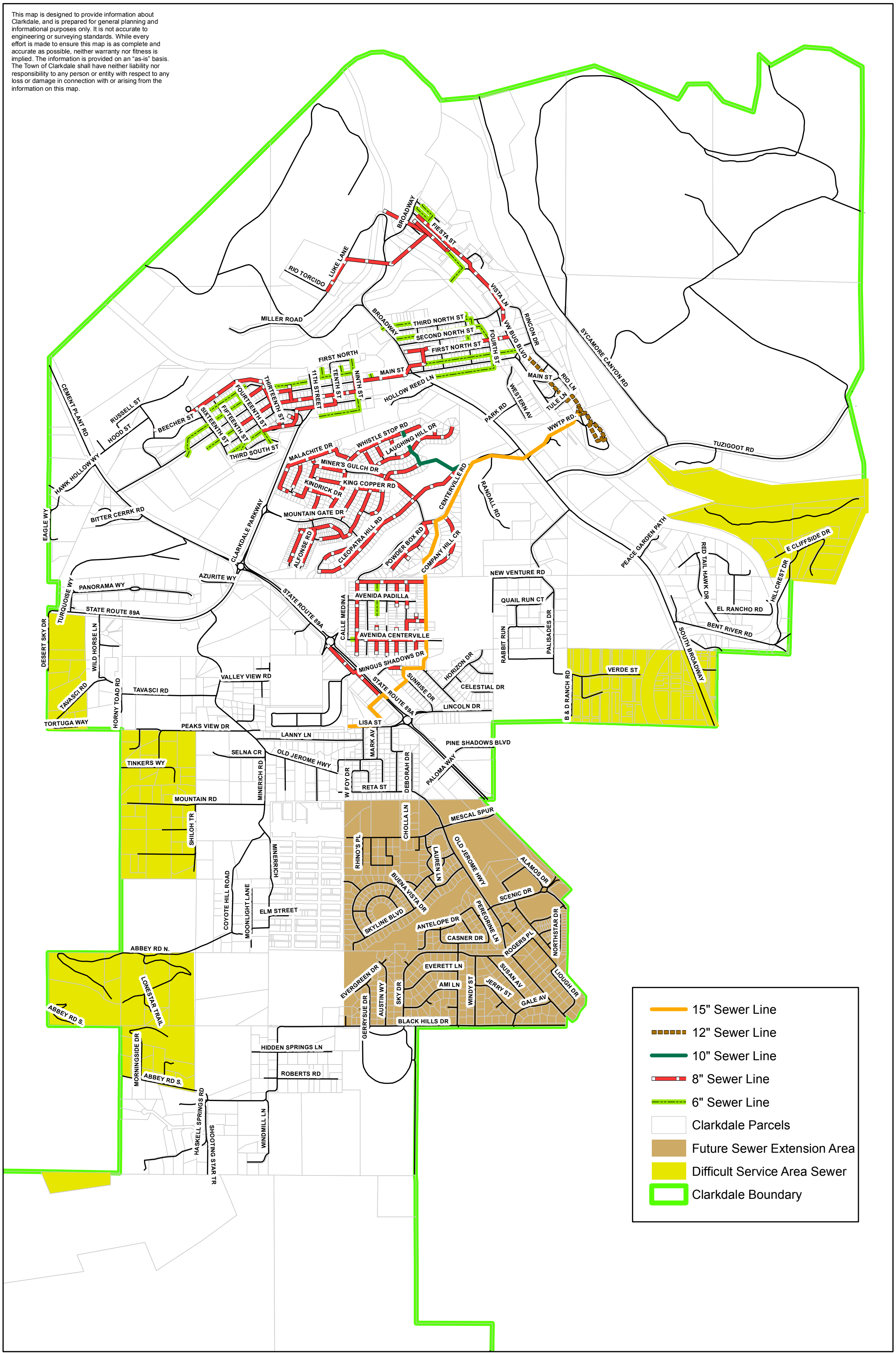


G.E.

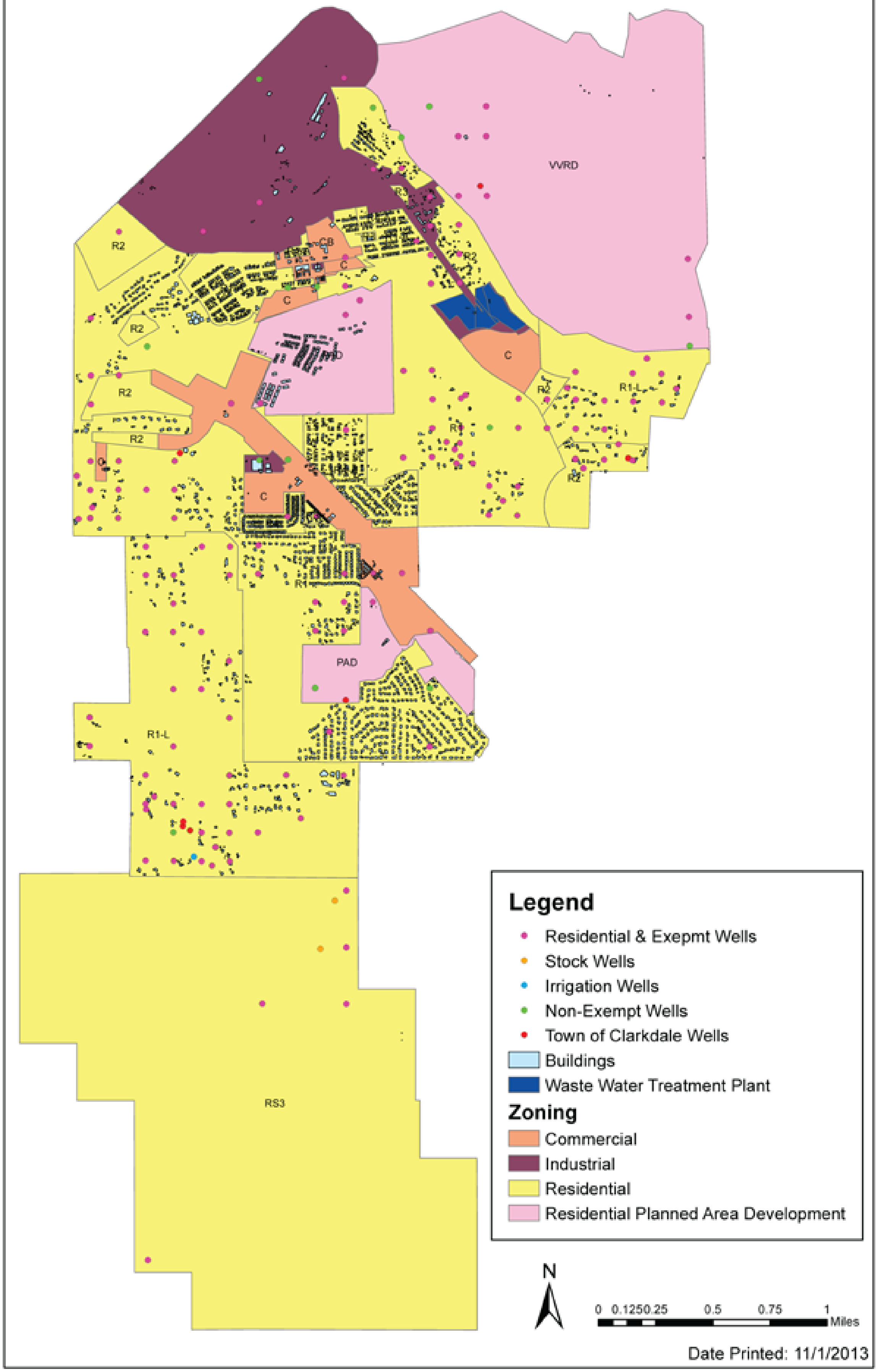
The Town of Clarkdale
Utilities Department
P.O.Box 308/15 N. 9th Street,
Clarkdale,AZ 86324
(928) 639-2520

Sewer Service Map

N
0 0.075 0.15 0.3 0.45 0.6 Miles

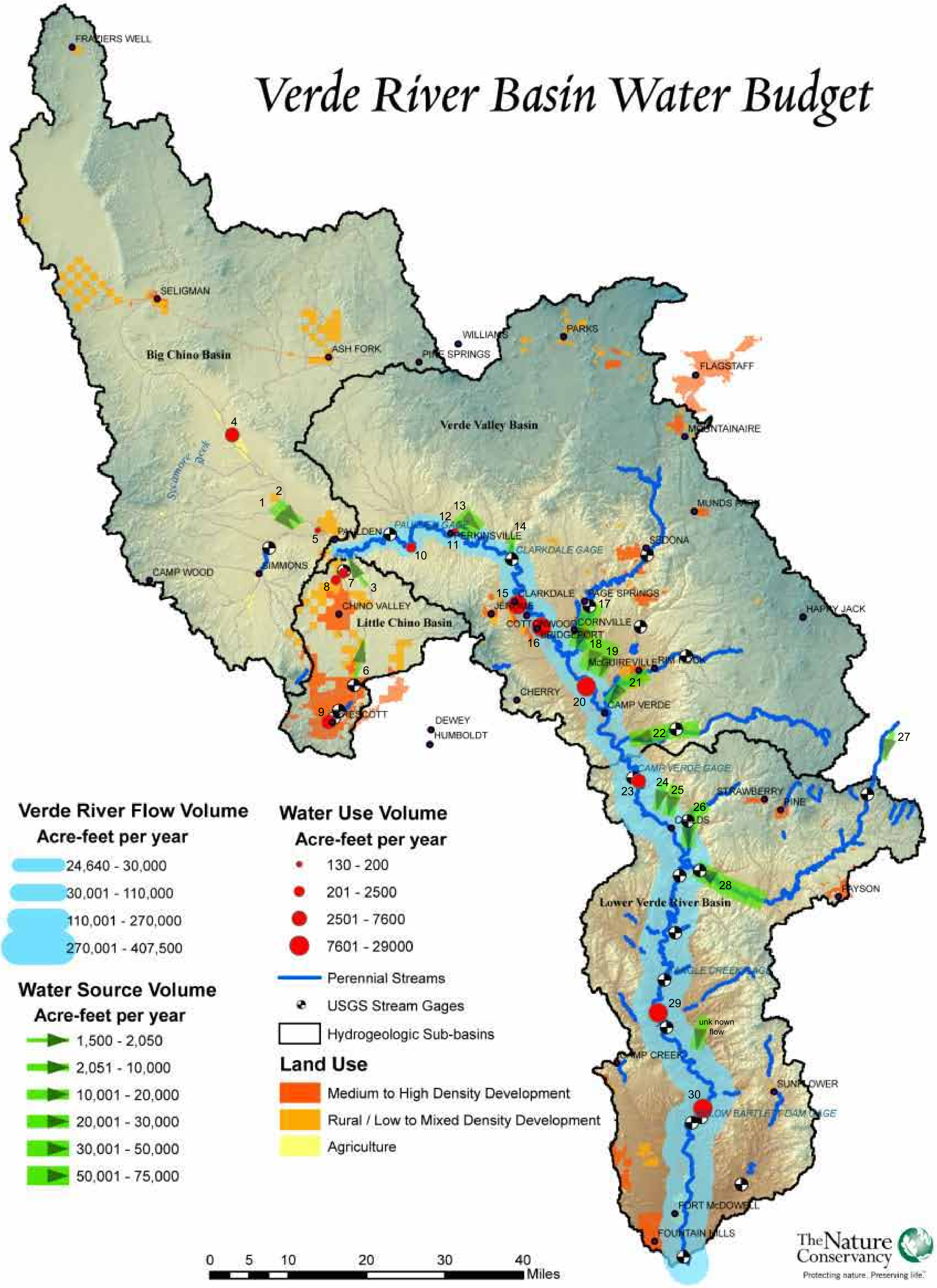
Update on
January 23, 2014

Clarkdale Infrastucture and Wells



Date Printed: 11/1/2013

Verde River Basin Water Budget



The Nature Conservancy
Protecting nature. Preserving life.