E. Hydrology

The Verde River originates outside the study area near the downstream end of the Big Chino Valley northwest of Prescott. From its origin, it flows generally south over 160 miles through state, private, and National Forest lands into Horseshoe Reservoir and Bartlett Reservoir, where water is stored by SRP for use by its shareholders, serving millions of citizens in the Phoenix metropolitan area.

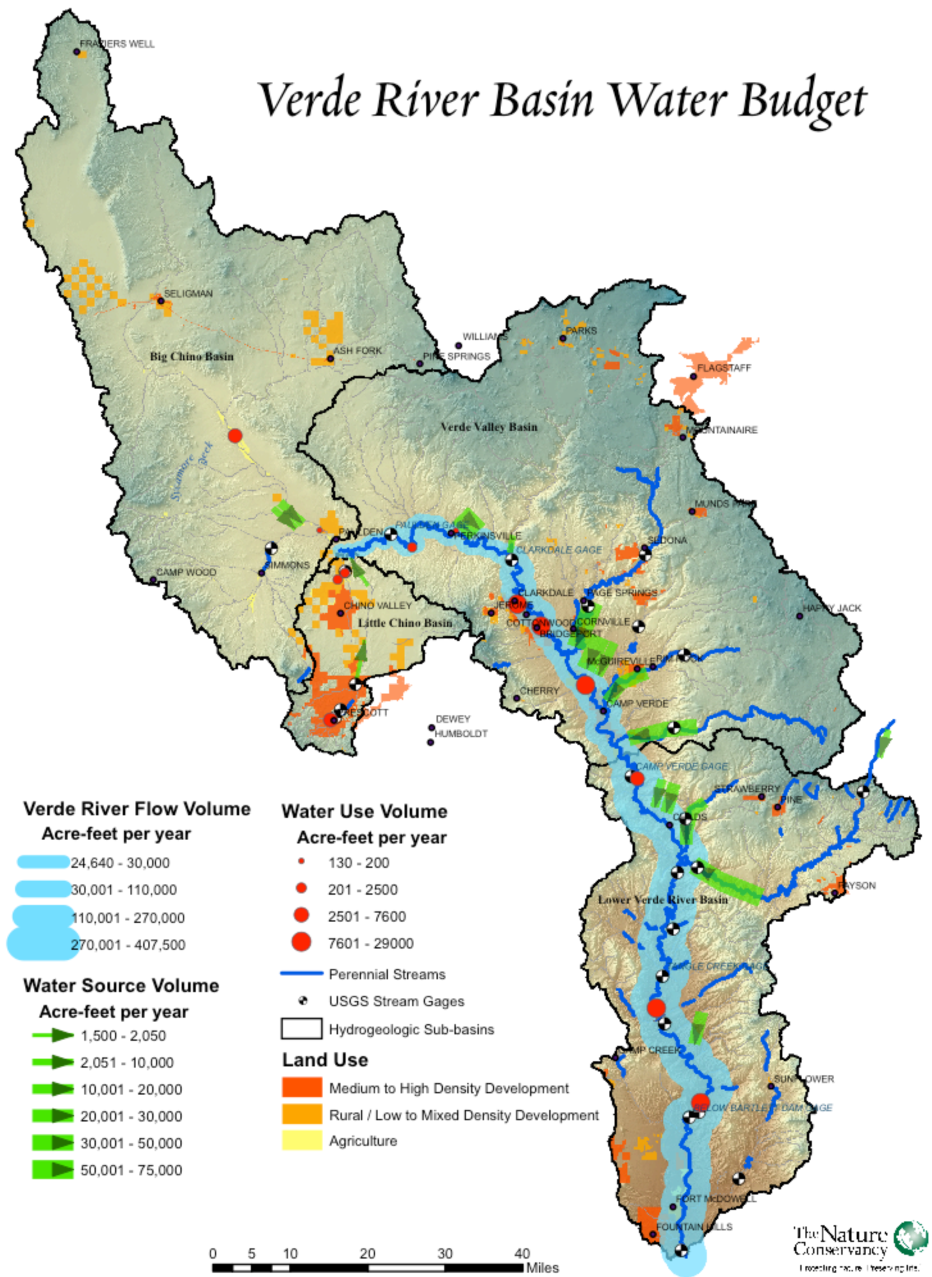

Figure 13. Map M25 – Verde River Basin Water Budget

The base flow of the upper river is from springs and groundwater discharge directly to the river channel; storm driven flood events contribute intermittent strong peak flows (Figure 16 and Photo 69, below). The major tributary in the study area is Sycamore Creek, near the downstream end of the study area.

The upper Verde River flows year-round and is supplied by groundwater discharge via springs and directly to the riverbed (referred to as base flow) and runoff of rain and snowmelt. Total stream flow (Figure 14) is continuously recorded by U.S. Geological Survey stream gages near Paulden (mile 10) and near Clarkdale (mile 39.5); the relative amounts of base flow and runoff are interpreted from the total stream flow data.

	Total Stream flow		**Base flow Component**		**Runoff Component**	
Gaging station	**Acre-feet**	**cfs**	**Acre-feet**	**cfs**	**Acre-feet**	**cfs**
Paulden Jul'63 – Mar'04	30,700	42.4	17,700	24.4	13,000	17.9
Clarkdale Apr'65 – Mar'04	122,100	168.5	57,200	79.0	64,900	89.6

Figure 14. Average annual stream flow in the upper Verde River (Blasch et al, 2006).

Additional water flow measurements have been performed by the Sierra Club Water Sentinels; their data is presented in Appendix A11.1. Additionally, Salt River Project operates a low flow gage (Locator X13, mile 4.1, Map M9) between Verde Springs and the USGS Paulden gage.

Photo 69. Winter storm powers 5000 cfs flood flow overtopping Sullivan Dam, just upstream of the study area boundary.

Figure 15 is a map of the study area showing the locations of USGS water flow measurements within the study area.

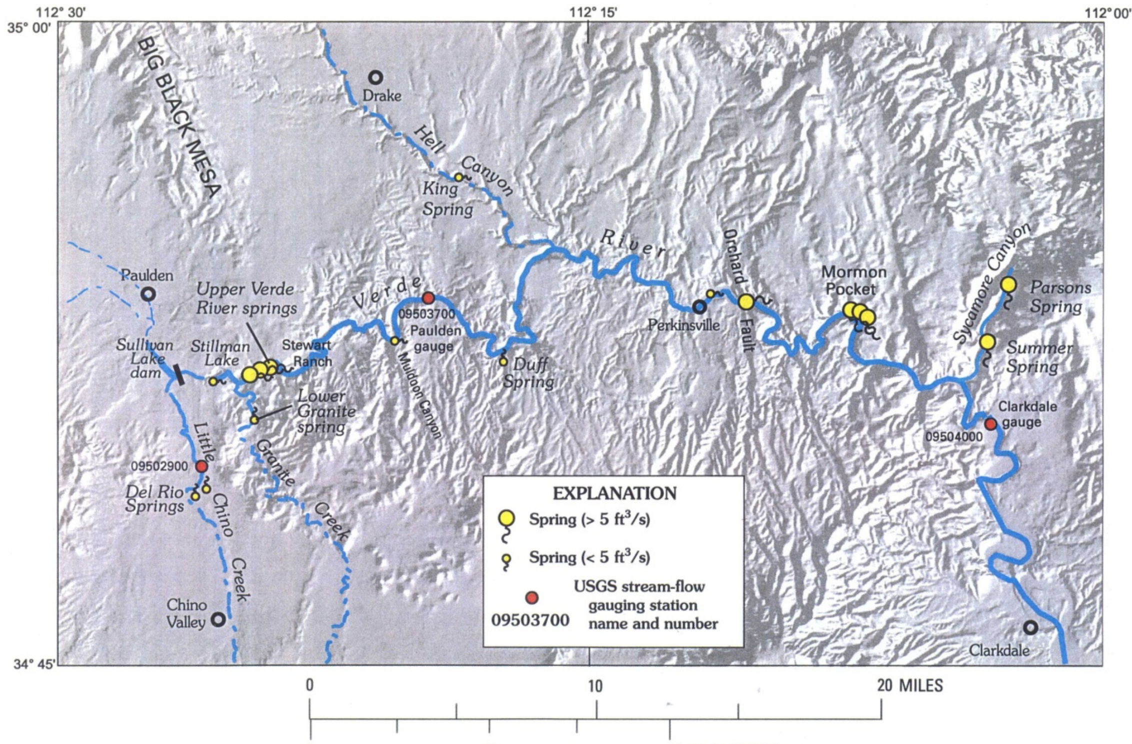

Figure 15. Locations of stream-flow gaging stations and (Wirt and others, 2005).

The Paulden gage record for the year from October 1, 2007 through September 30, 2008 (Figure. 16), representing a typical water-year flow distribution pattern, shows substantial contributions from winter runoff events in late January and early February, and monsoon-related runoff events between mid-July and early September.

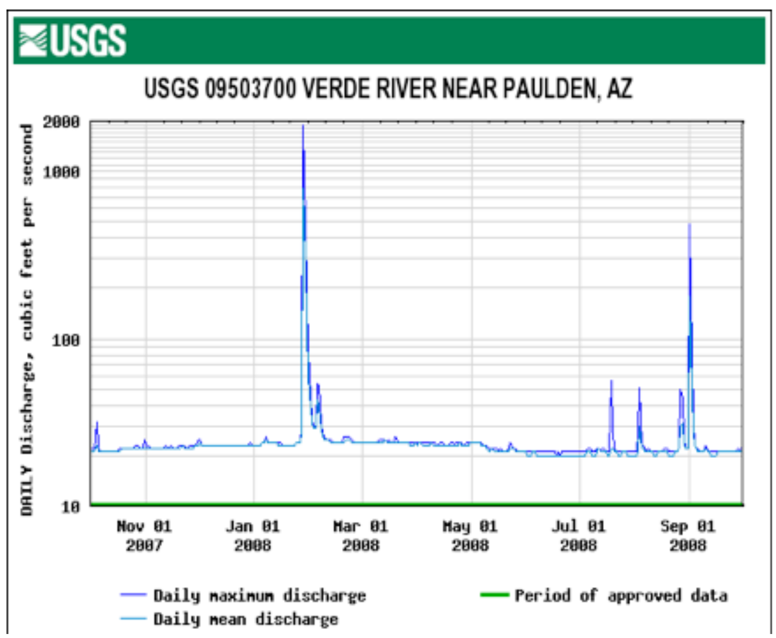

Figure 16. Verde River stream flow, October 1, 2007 through September 30, 2008.

The daily flow data indicate that the summer base flow in 2008 was about 20–21 cfs; winter base flow was about 23 cfs. The difference between winter and summer base flow is interpreted as representing the difference between winter and summer evapotranspiration along the river above the Paulden gage (Appendix A6.3). Perennial year-round flow is dependent on base flow. Without that component, the upper 25 miles of the Verde River upstream of the Orchard Fault would be dry between storms or episodes of snow melt. Seeps in Muldoon Canyon, Duff Spring, Lower Granite Spring, and springs beneath Stillman Lake contribute a very small component of base flow.

Continuous perennial flow of the Verde River begins about 300 feet downstream from the mouth of Granite Creek at the upper end of the upper Verde River springs (Figure 17). In June 2000, Wirt (2005) conducted a careful study of discharge from the upper Verde River Springs. She found that discharge increased in about 2.4 miles from the upstream end of the springs from zero to about 14,130 ac-ft/yr (19.5 cfs). At the time of the study, peak daily flow at the Paulden gage was 15,390 ac-ft/yr (21.2 cfs). Wirt suggested that the difference, about eight percent of the base flow measured at the Paulden stream gage, reflects additional spring discharge within a couple of miles of the gage. She also inferred that this additional spring discharge likely originated from the same sources as the discharge from the upper Verde River springs. Base flow generally decreases slightly – owing to some combination of infiltration and evapotranspiration – downstream from the Paulden gage for the next 14 miles, at which point inflow from springs beginning about two miles below Perkinsville begins increasing the base flow en route to the Verde Valley (Figure 17). Springs downstream from Perkinsville along the upper Verde as well as in Sycamore Canyon add substantial base flow that enters the Verde Valley below the Clarkdale gage.

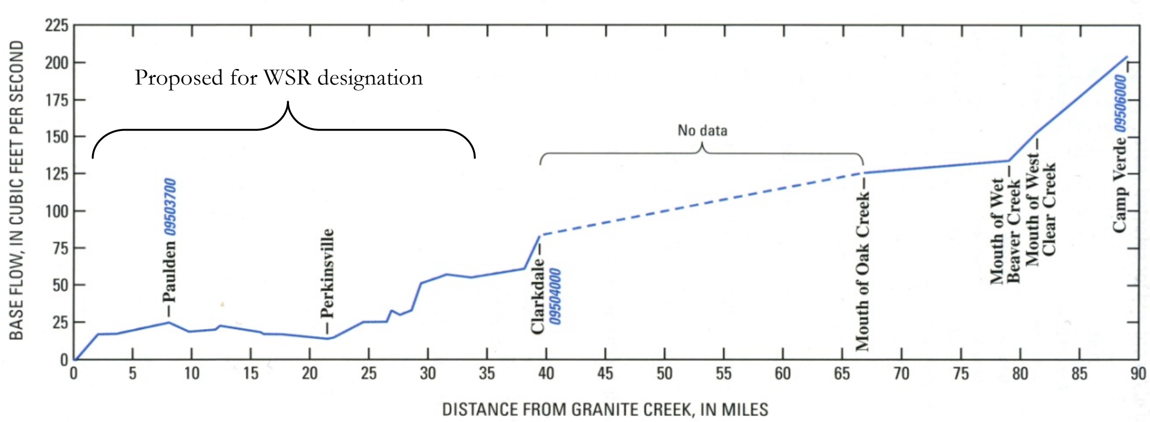

Figure 17. Base flow in the Verde River from the mouth of Granite Creek to the gaging station near Camp Verde (Blasch and others, 2006).

There is broad agreement that the base flow issuing from the upper Verde River springs (Figure 15) is derived primarily from groundwater in the Big and Little Chino Sub-basins (Figure 18). The water table slopes toward the lower ends of these two basins, and the groundwater flows slowly under the force of gravity through their aquifer systems to the upper Verde River springs, which are at the downhill and down-gradient ends of the two sub-basins. Wirt (2005b) concluded that 80 to 86 percent of the groundwater discharge measured at the Paulden gage is derived from the Big Chino Sub-basin; the other 14 percent is from the Little Chino Sub-basin. Blasch and others (2006) showed that most of the discharge from the springs is derived from these two sub-basins. Montgomery and Associates (2007) reported that about 80 percent of the groundwater discharge at the upper Verde River springs originates in the Big Chino Sub-basin.

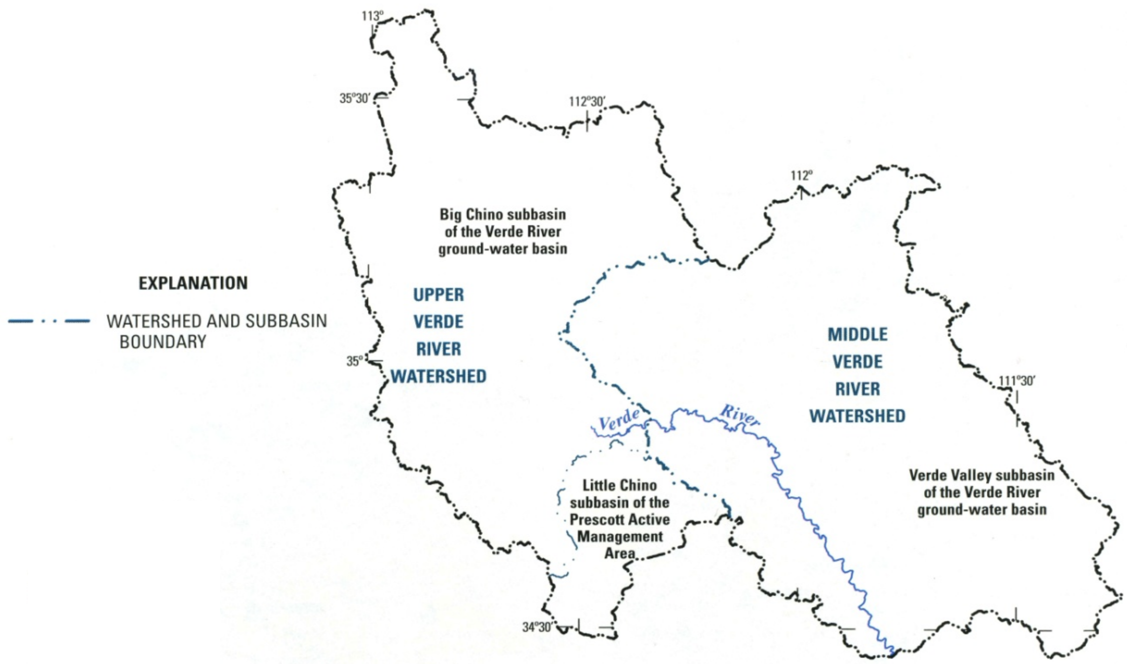

Figure 18. Sub-basins and watersheds of the upper and middle Verde River (Blasch et al, 2006).

In a natural system, in which there has been no development, groundwater leaves the system in two ways: (1) discharge to springs; and (2) discharge to the atmosphere from evaporation where the water table intersects the ground surface and transpiration through plants where the roots are able to reach the water table. Over the long term, such a natural system is in a state of equilibrium in which infiltration (recharge) of water from the ground surface to the aquifer equals the amount of groundwater discharged from the aquifer to springs and by evapotranspiration to the atmosphere. In the Big and Little Chino sub-basins, the volume of water in storage in the aquifer greatly exceeds both the amount of recharge and the amount discharged in any single year to springs and to the atmosphere. An imperfect analog for this natural system might be the water that spills through the overflow drain in a bathtub when the tub is full and water from the tap is left running. There, the discharge from the overflow drain equals the recharge from the tap, and the amount of water in storage in the tub remains constant. If you remove some water from the tub with a bucket, the discharge from the overflow drain ceases until the earlier equilibrium is re-established.

Extraction of water from wells, which is a human-caused form of groundwater discharge, disturbs the natural equilibrium. The extraction lowers the water table, first in the immediate vicinity of the well, but eventually over a broader area. The effect is to dry up wetlands and to reduce the gradients (reflected in the slope of the water table) that enable the groundwater to flow under gravity to the springs. Inevitably, when the extraction by wells exceeds the recharge to the aquifer, the springs eventually go dry. Exactly this kind of capture of discharge to springs by pumping groundwater for irrigation, or for domestic, municipal, and industrial use by the growing population of the Prescott area is clearly demonstrated by steadily decreasing discharge from Del Rio Springs (Figure 15) since the mid-twentieth century (Nelson, 2002). Similarly, likely

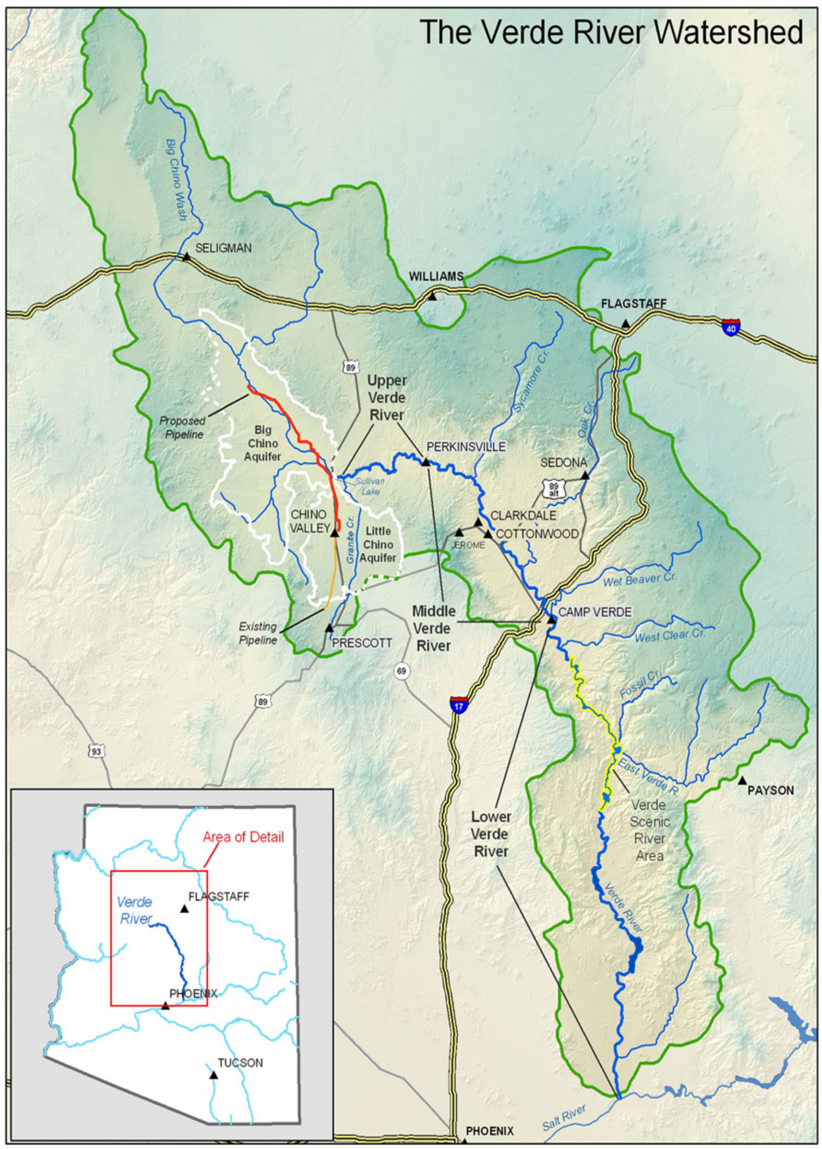

Figure 19. Location of planned groundwater transfer pipeline.

demands for groundwater from the Big Chino Valley — for importation to the Prescott area (Figure 19) and for expected development in the Big Chino Valley itself — are expected to substantially exceed groundwater recharge to the valley and lead to depletion and eventual elimination of groundwater discharge from the upper Verde River Springs. Unless groundwater withdrawals are restricted or mitigated (see *Discussion and Analysis*, page 196), the inevitable consequence is severe depletion of base flow in the upper Verde River with concomitant alteration of its habitat and irreparable damage to the wildlife that depend on it.