Verde River Basin PARTNERSHIP

Informing the community about our water

Verde Watershed Association

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Substantially more water than necessary is diverted from the River during every growing season to support irrigation of farm fields, gardens, and lawns. Increased efficiency of the diversions and the irrigation they support will be essential to keeping more water in the river and protecting the Verde Valley's habitat and lifestyle.

USGS PUBLISHES NEW VERDE VALLEY SEEPAGE-RUNS REPORT

Introduction

Decreased base flow, if not loss of perennial flow, in many of Arizona's once-perennial streams as a consequence of human development of water resources during the 20th century raises concern about possible similar depletion of the Verde River. Thus, the state of base flow and the diversion of surface water are of concern along the river in the Verde Valley, which includes the river-bank municipalities of Camp Verde, Clarkdale, and Cottonwood (fig. 1).

Addressing that concern requires understanding the operation and interactions of the Verde River Basin's surface water and groundwater; such understanding enhances our ability to manage water resources for long-term sustainability. A newly released report by Bradley Garner and Donald Bills of the U.S. Geological Survey (USGS) in cooperation with the Verde River Basin Partnership, Yavapai County, and the Town of Clarkdale represents an important step toward that understanding.

> Garner, B.D., and Bills, D.J., 2012, Spatial and seasonal variability of base flow in the Verde River, Verde Valley, central Arizona, 2007 and 2011: U.S. Geological Survey Scientific Investigations Report 2012-5192.

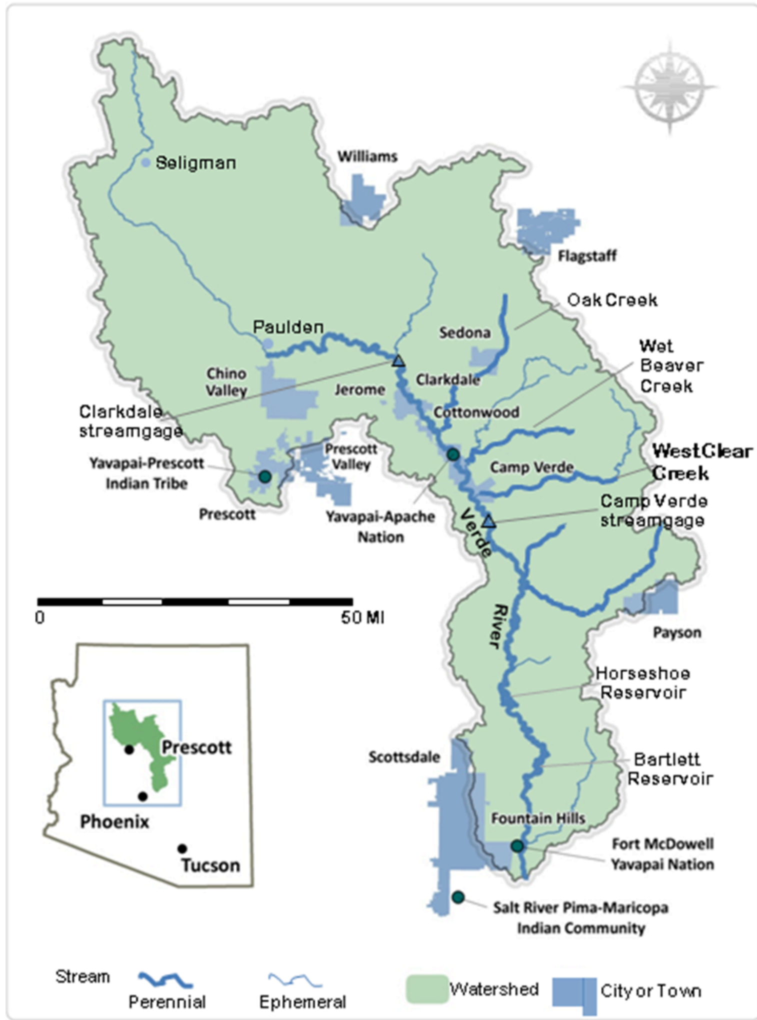

Figure 1. Verde River Basin

Summary of Report

The report presents and analyzes the results of two synoptic base-flow surveys, also called seepage runs. The seepage runs were conducted along the main stem of the Verde River within the Verde Valley—over the stretch of 51 river miles between USGS streamflow-gaging stations 0950400, Verde River near Clarkdale, Arizona (Clarkdale gage) and 0950600, Verde River near Camp Verde (Camp Verde gage).

What was measured?

Measurements of streamflow were made, following well-established USGS protocols, at 53 locations along the Verde River main stem during June 20-21, 2007 and at 36 locations during February 1-3, 2011 (fig. 2).

Measurements of water temperature, specific conductance, dissolved oxygen, and pH were made concurrently with all streamflow measurements. With just a few exceptions, the February 2011 streamflow measurements were co-located with the June 2007 measurement stations. The June 2007 seepage run was conducted by the USGS in cooperation with Yavapai County. The February seepage run was conducted by the USGS in cooperation with the Verde River Basin Partnership and the Town of Clarkdale.

In addition, the June 2007, and February 2011, seepage runs included streamflow measurements in Oak Creek, Beaver Creek, and West Clear Creek as close as possible to their confluences with the Verde River. These tributary measurements were important to evaluate the contributions of these perennial tributaries to Verde River streamflow at the time of each seepage run. Insofar as possible, streamflow entering from the river to the irrigation systems or returning to the river from the irrigation systems was measured or estimated. Additional measurements were made farther upstream on Oak Creek, Beaver Creek, and West Clear Creek on June 26, 2007.

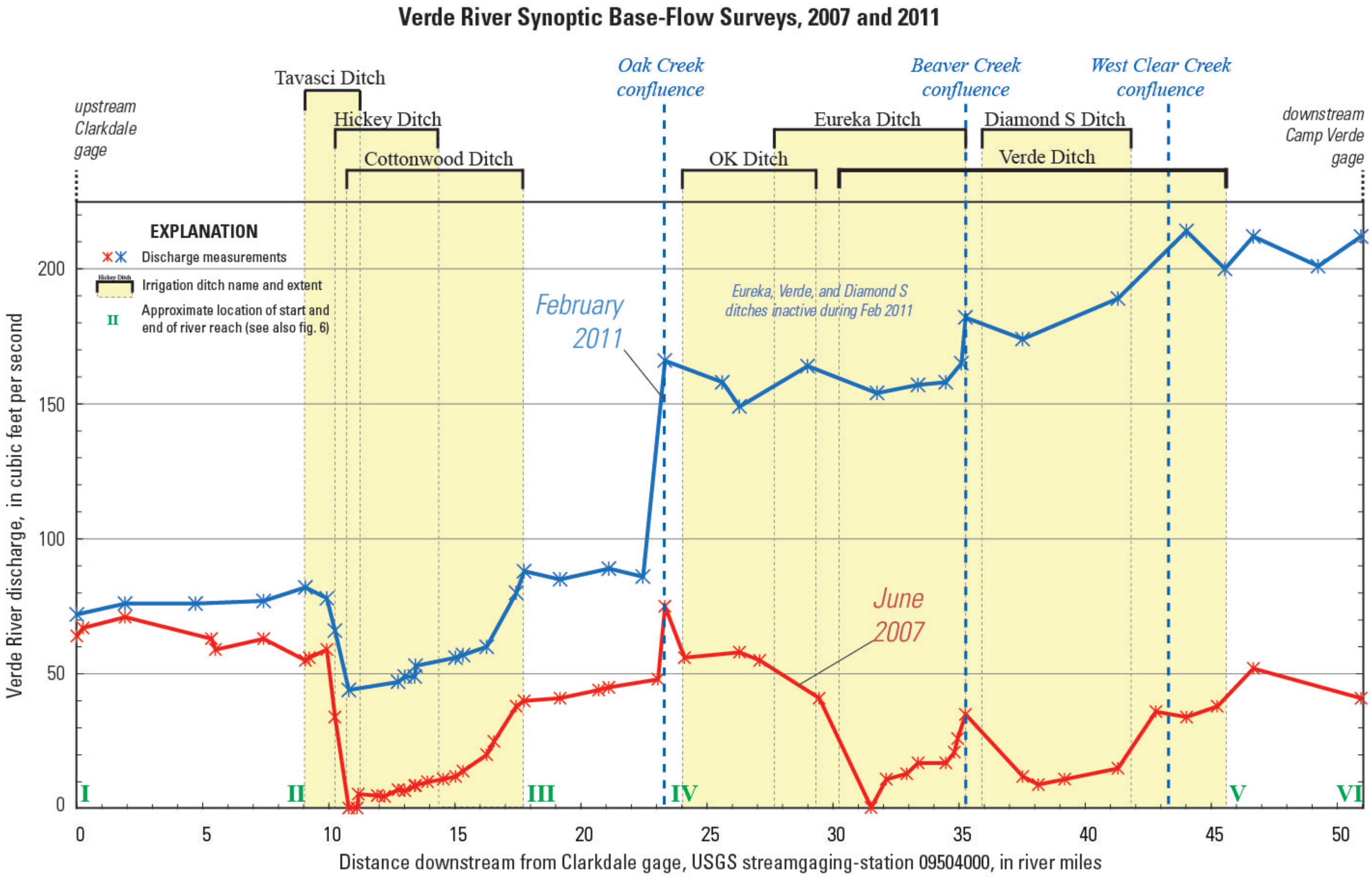

Figure 2. Streamflow measurements on the Verde River, June 20-21, 2007, and February 1-3, 2011. (Garner and Bills, 2012)

The winter and summer streamflow measurements were made essentially under base-flow conditions. That means that the surveys were made at times when there was neither precipitation nor evidence of storm-related runoff or substantial snowmelt-related runoff.

The selection of June and February for the two seepage runs permitted evaluation of streamflow under strongly contrasting seasonal conditions. In June, prior to the onset of summer monsoon rains, both evapotranspiration and diversion of river water for irrigation were in full operation. In February, both evapotranspiration and diversions were minimal.

Diversions, Irrigation, and a Complex Diversion-Supported Groundwater System

In a natural system, in which there has been little or no modification by humans, base flow would be a simple measure of the groundwater component of streamflow. However, the Verde Valley hosts more than 67 surface-water diversions from the Verde River and its perennial tributaries. These currently supply water for irrigation of farm fields, gardens, and lawns. Many date back to the late 19th century. The operation of the diversions, which has occurred for more than a century, represents a major alteration of the predevelopment groundwater/streamflow system in the Verde Valley.

There are seven major diversions and related irrigation systems along the Verde River itself. Streamflow is diverted from temporary dams that partly or completely block the river. It enters human-made ditches that convey water, via gravity, to farms, gardens, and lawns located on low alluvial terraces near the river. Return of surface flow to the river may occur at the downstream ends of the ditches as well as from shallow canals that return excess water from irrigated areas (fig. 3).

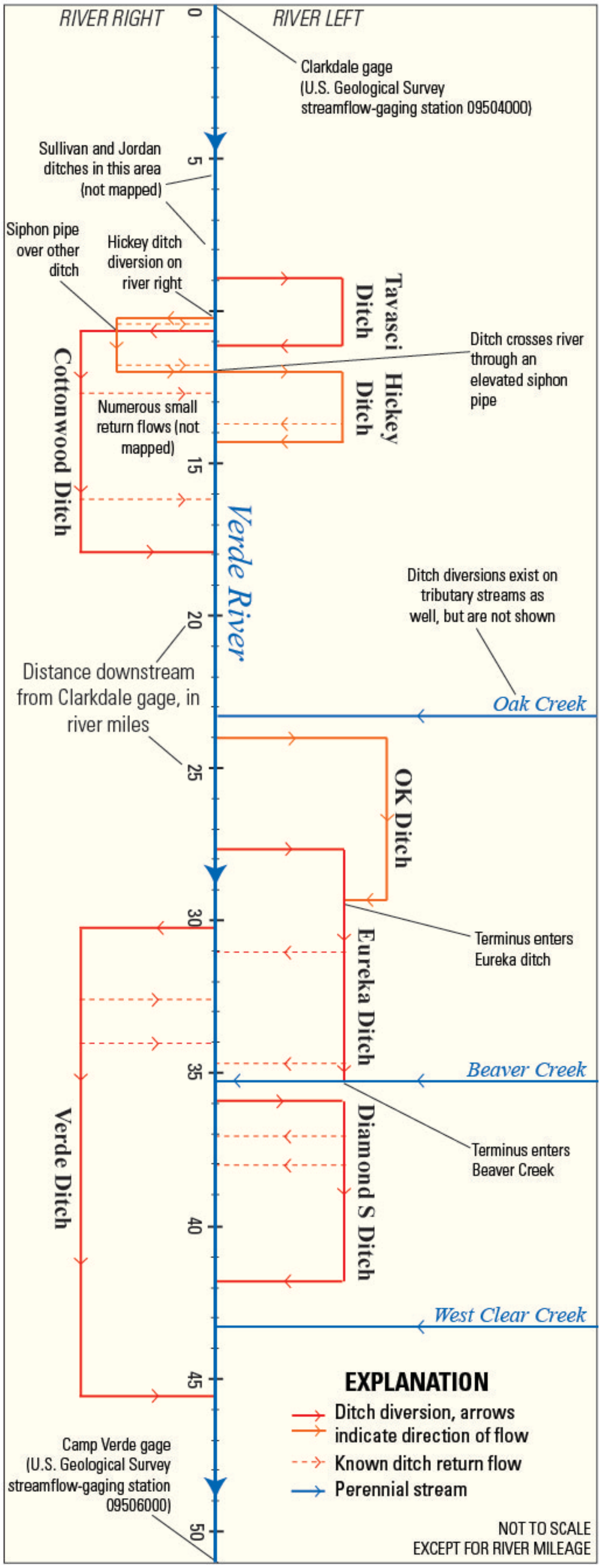

Figure 3. Schematic diagram of major irrigation ditches along the Verde River. Return flows are indicated where known but have not been mapped comprehensively. (Garner and Bills, 2012).

Along the ditches and in the irrigated areas, water is consumed by both evapotranspiration and infiltration. Consumptive use by crops is a form of evapotranspiration, and abundant vegetation supported by the ditches consumes diverted water via evapotranspiration. Water that seeps below the zone of evapotranspiration, either along the ditches or in the irrigated areas, supplies a shallow, diversion-supported groundwater system, from which the infiltrated water eventually returns to the river.

Results

The primary results are: (1) careful measurements that document changes to Verde River streamflow under base-flow conditions (fig. 2) for two brief sample periods—June 20-21, 2007, and February 1-3, 2011; and (2) analysis of the effects of streamflow diversions, surface returns of diverted water to the river, contributions to Verde River streamflow from the river's perennial tributaries in the Verde Valley, and the addition or loss of groundwater as a component of Verde River streamflow.

Winter and Summer Differences at and Between the Clarkdale and Camp Verde Streamgages

As shown in fig. 2, stream flow in the February 2011 survey differed dramatically from streamflow in the June 2007 survey. In February 2011 streamflow increased from 72 cubic feet per second (cfs) at the Clarkdale streamgage to 212 cfs at the Camp Verde streamgage, for a gain of 140 cfs. In June 2007 streamflow decreased from 64 cfs at the Clarkdale streamgage to 41 cfs at the Camp Verde streamgage, for a loss of 23 cfs.

Streamflow at the Clarkdale streamgage in February 2011 was 8 cfs greater than stream flow there in June 2007. The difference is compatible with, although not necessarily fully explained by the seasonal difference in riparian evapotranspiration upstream from the streamgage.

Streamflow at the Camp Verde streamgage in February 2011 was 171 cfs greater than streamflow there in June 2007 (table 1). The difference is explained in part by evapotranspiration throughout the entire watershed above the Camp Verde streamgage and to a substantial degree by the effects of diversions along the Verde River and its perennial tributaries: consumptive use by crops, gardens, and lawns; evapotranspiration along the irrigation ditches; and presumably by delayed return to the river of water that infiltrates from the ditches and the irrigated fields, gardens, and lawns.

Contributions to Verde River Streamflow from the River's Perennial Tributaries

Streamflow entering the Verde River from the perennial tributaries, Oak Creek, Beaver Creek, and West Clear Creek is a major contributor to Verde River base flow. Tributary streamflow during the February 2011 survey was 84-88 cfs (table 2), which represents 60-63 percent of the February 2011 increase in stream flow between the Clarkdale and Camp Verde streamflow gages (table 1).

The greatest part, 72-76 cfs, of this winter tributary streamflow component entered the Verde River at the mouth of Oak Creek. During winter, of course, irrigation and evapotranspiration are lacking or minimal.

During the June 2007 survey, the contribution to Verde River stream flow from the perennial tributaries was far less, 27-30 cfs. The difference, no doubt reflects the effects of summertime riparian evapotranspiration and the diversion, conveyance, and application for irrigation of streamflow diverted from the tributaries.

	Streamflow Clarkdale Streamgage, cfs	Streamflow Camp Verde Streamgage, cfs	Difference between Streamgages, Camp Verde – Clarkdale, cfs
Feb 1-3, 2011	72	212	140
June 20-21, 2007	64	41	−23
Difference at streamgage, winter – summer, cfs	8	171	

Table 1. Streamflow measured at Clarkdale and Camp Verde streamgages, February 1-3, 2011, and June 20-21, 2007.

Groundwater contributions to Verde River base flow near the river's junctions with Beaver and West Clear Creeks were determined as well in both seepage runs (table 2). No groundwater contribution was detected at the confluence of Oak Creek.

Discharge of groundwater to the Verde River at the Beaver Creek confluence was clearly evident from the occurrence of sand boils in the Verde River bed near its confluence with Beaver Creek.

Verde River Inflow Component	Inflow to Verde River, June 2007, cfs	Inflow to Verde River, February 2011, cfs
Confluence of Oak Creek		
Surface-water inflow	27-30	72-76
Groundwater inflow	0	0
TOTAL	**27-30**	**72-76**
Confluence of Beaver Creek		
Surface-water inflow	0	2
Groundwater inflow	18	22
TOTAL	**18**	**24**
Confluence of West Clear Creek		
Surface-water inflow	[a]0-3	10
Groundwater inflow	[a]0-3	0-15
Ditch return flow	[a]16-19	19
TOTAL	**[b]19**	**[b] 25**
[a]Partitioning among flow inflow components in West Clear Creek is uncertain. [b]Total values for in inflows from West Clear Creek are known, as they were calculated directly from flow measurements.		

Table 2. Base-flow contributions to the Verde River main stem from perennial tributaries in the Verde Valley, February 1-3, 2011, and June 20-21, 2007. From table 2 of Garner and Bills (2012).

Rates of Diversion and Observed Return Flows

Only three of the main-stem diversions were in operation during the February 2011 seepage run. They were the Hickey, Cottonwood, and OK diversions. Each was diverting streamflow at a substantially lower rate than their June 2007 diversion rates. The aggregated rate of diversion for the February 2011 seepage run was 45 cfs. Observed return flows, ranging from approximately 1 to 3 cfs, were observed from the Tavasci, Hickey, Cottonwood, and OK ditches, for an aggregated total of 8 cfs.

All seven Verde main-stem diversions were in operation during the June 2007 seepage run. Rates of diversion during the survey ranged from 8 cfs (Tavasci ditch) to 41 cfs (Verde ditch). At the diversions for the Cottonwood and Verde ditches, streamflow declined to less than 1 cfs (fig. 2). The aggregated rate of diversion for the June 2007 seepage run was 162 cfs. Observed return flows, ranged from 0 cfs (OK ditch) to 22 cfs (Verde ditch), and the aggregated total for observed return flows was 57 cfs.

Unaccounted-For Diverted Water

The report identifies the difference between the aggregated rate of diversion and the aggregated rate of observed return flows for each seepage run as unaccounted-for diverted water. Unaccounted-for diverted water for the February 2011 seepage run was 37 cfs.

Unaccounted-for diverted water for the June 2007 seepage run was 105 cfs. These values reflect the effects of evapotranspiration from both the ditch systems and the irrigated fields, gardens, and lawns; infiltration of both ditch and irrigation water; transient groundwater-storage change related to seasonality of infiltration of both ditch and irrigation water; and unmeasured ditch-system return flows to the Verde River.

The relative magnitudes of most of these effects are unmeasured. One important exception is an estimated 10,000 acre-feet per year of evapotranspiration (consumptive use) from irrigated fields for the 2010 growing season in the Verde Valley; it presumably includes consumptive use in fields irrigated by diversions from Oak Creek, Beaver Creek, and West Clear Creek as well. For a 3- to 6-month growing season, this suggests a constant application throughout the Verde Valley of approximately 28 to 55 cfs for the growing season—approximately a quarter to a half of the unaccounted-for diverted water inferred from the June 2007 seepage-run results for the Verde River.

Summary of Streamflow Measurements per River Reach

Table 3 summarizes streamflow measurements with respect to five distinct reaches (fig. 2) that are identified by the presence or absence of diversions and return flows. Reaches I-II, III-IV, and V-VI contain no diversions or return flows. Reaches II-III and IV-V each contain multiple diversions and return flows.

Reach		Verde River Streamflow In, cfs	Verde River Streamflow Out, cfs	Tributary Streamflow In, cfs	Sum of Diversions, cfs	Sum of Measured Return Flows, cfs
[a]I-II	Feb 2011	72	77	0	0	0
	June 2007	64	63	0	0	0
II-III	Feb 2011	77	88	0	37	[b]6
	June 2007	63	40	0	65	14
[a]III-IV	Feb 2011	88	166	74	0	0
	June 2007	40	65	30	0	0
IV-V	Feb 2011	166	200	12	8	[b]3
	June 2007	65	52	0	97	43
[a]V-VI	Feb 2011	200	212	0	0	0
	June 2007	52	41	0	0	0

[a]Reaches with no diversions and no return flows.
[b]Rounded to nearest whole number.

Table 3. Summary of streamflow measurements. From Garner and Bills, (2012, table 3).

Groundwater Flux to the Verde River

Garner and Bills estimated the gain or loss of naturally-occurring groundwater (representing only groundwater exchange between the river and the regional aquifer) in reaches I-II, III-IV, and V-VI, which contain neither diversions nor return flows. The postulated contributions of naturally-occurring groundwater in these reaches for each seepage run represent, for each reach:

Groundwater flux = streamflow rate at the lower end of reach – streamflow rate at the upper end of reach – the rate of surface flow, if any, from tributary streams entering the reach.

A simplifying assumption is that no infiltrated diversion water returns to the river within these three reaches. That assumption is reasonable for the uppermost reach, I-II, because it is located upstream from all of the major diversions. The assumption may not be fully correct for reaches III-IV, and V-VI, which could receive some unknown amount of infiltrated diversion water derived from an adjacent reach.

In any case, the results suggest that each of these three reaches received a small (4 to 12 cfs) contribution of groundwater in February 2011 and lost groundwater (-1 to -11 cfs) via infiltration from the river in June 2007. These seasonal differences in each reach are consistent with greater consumption in summer than in winter of groundwater by riparian evapotranspiration.

It is a more difficult problem to evaluate the gains and losses of groundwater along reaches II-III and IV-V, which are complicated by multiple diversions and return flows. The complexity arises because there are two currently indistinguishable groundwater components: (1) a naturally-occurring groundwater component reflecting discharge to the river from the regional aquifer system and infiltration from the river to the regional aquifer system, and (2) a ditch- and irrigation-related component of infiltrated diverted water that supports, or at least affects, a shallow human-influenced aquifer system. Garner and Bills (2012, table 3) calculated hypothetical upper and lower bounds of natural (regional-aquifer) groundwater discharge to the river and loss from the river. Appropriately, they noted that "the reaches heavily affected by ditch diversions were difficult to interpret because of confounding human factors."

Discussion

Likely future water demands and the likely effects of continuing climate change raise the specter of reduced Verde River streamflow if not the presence of dry reaches, at least during the growing season for both agriculture and riparian vegetation. Reduced streamflow and possible dry reaches would severely degrade the habitat and wildlife now supported by the Verde River as well as the diversion-supported agriculture and the human lifestyle that we enjoy in the Verde Valley.

Substantially more water than necessary is diverted from the River during every growing season to support irrigation of farm fields, gardens, and lawns. Increased efficiency of the diversions and the irrigation they support will be essential to keeping more water in the river and protecting the Verde Valley's habitat and lifestyle.

The USGS report provides an important step in understanding the river as a resource. Additional scientific work designed to more fully evaluate the Valley's hydrologic system with respect to diversions and irrigation—such as year-round monitoring of diverted water, return flows, and river streamflow as it relates to diversion; seasonal changes in groundwater level and in groundwater storage related to diversion, infiltration, and evapotranspiration; and groundwater movement in the system—is essential in guiding steps to increase system efficiency with maximum effectiveness and minimum cost while avoiding unfortunate unintended consequences.

Written by Ed Wolfe

VERDE WATERSHED SUMMER CLIMATE REVIEW; FALL AND WINTER OUTLOOK

There was anticipation for an early, wet start to the 2012 Monsoon following the dry winter. However, hope began to wane, as the much-needed rain was slow to arrive. But by mid-July, showers and thunderstorms appeared with episodes of heavy rain and persistent thunder. Once started, the rains continued well into September making for a productive season with above normal precipitation. The Verde watershed accumulated 7.11 inches during the June 15^{th} through September 30^{th} period, which is 116% of normal. Compared to the previous year, the Monsoon of 2012 bested 2011 by almost 2.25 inches. In addition, peak summer flows on the Verde River actually exceeded the winter peak (Verde River near Camp Verde gauge reported a winter peak of 2,100 cfs, and a summer peak of 2,120 cfs).

What does the upcoming fall and winter have in store for the Verde watershed? The predicted state of the El Niño Southern Oscillation (ENSO) had been the talk of the summer among the weather watchers. At that time, climate models indicated a high likelihood of El Niño setting up for the winter (greater likelihood of wet conditions). However, the momentum in warming sea-surface temperatures over the Equatorial Pacific has slowed, with recent long-range climate forecasts pointing towards neutral to weak El Niño conditions this winter.

While this is not the wet scenario that we would like to hang our hats on, there is still some optimism to be found. That is, wet winters have occurred over the Verde watershed during ENSO neutral events but so have near normal and dry winters. Unfortunately, ENSO neutral conditions do not give much in the way of predictability for winter precipitation. Therefore, the National Weather Services outlook of equal chances of wet, dry, or normal precipitation for the fall, with a slight hint of wet weather for the winter of 2013 seem to be the way to go.

Contributed by the Salt River Project

YAVAPAI COUNTY WATER ADVISORY COMMITTEE (WAC) UPDATE

The Yavapai County Water Advisory Committee (WAC) remains focused on completing the alternative-formulation phase of the Central Yavapai Highlands Water-Resource Management Study (CYHWRMS), with the Arizona Department of Water Resources (ADWR) and U.S. Bureau of Reclamation. Additionally, the WAC will be assessing how to move forward with understanding and appropriately utilizing the Northern Arizona Regional Groundwater Flow Model.

The CYHWRMS Technical Working Group (TWG) has compiled draft information for each alternative identified to meet unmet future water demands in the study area. A draft alternative-analysis report is in preparation. The report and tables describe and summarize the alternative evaluation by the TWG. The report is meant to inform policy makers of potential water-supply alternatives. The evaluation criteria include environmental, economic, legal and institutional analyses as well as Reclamation's four tests-of-viability (completeness, effectiveness, efficiency and acceptability). Upon completion of the alternatives analysis, the WAC and its communities will decide whether to pursue an alternative(s) further through a feasibility analysis. The WAC website has additional information on the study including Phase 3 documentation. The Technical Working Group (TWG) is made up of a broad variety of stakeholders who have contributed significant amounts of in-kind services to help the WAC meet its match requirement with Reclamation. The WAC recognizes the contribution of the organizations and individuals who have given their time and expertise to this process. The TWG typically meets on the first Thursday of each month at 10:30 following the meeting of the Technical Committee of the WAC.

The WAC is assessing the Model Report for the current USGS Northern Arizona Regional Groundwater Flow Model (found here). The Technical Committee (TAC) of the WAC has completed a four-month study with the USGS to investigate the model through a series of short investigations designed to test the model in the Big Chino area and assess some specific aspects. This is part of an ongoing critical review process with the purpose of aiding in understanding appropriate use and confidence in the model. At the October 4th TAC meeting, the TAC will prepare a summary of those investigations and recommendations for the WAC's October 17 meeting. All of the presentations from the previous TAC meetings have been distributed to the email list and are available through the WAC coordinator. The TAC usually meets on the first Thursday of each month at 9:00 AM.

Please contact the WAC Coordinator, John Rasmussen, for more information, meeting dates, or if you would like to be added to the WAC email-recipient list (john.rasmussen@co.yavapai.az.us or 928-442-5199).

Prepared by John Rasmussen, Coordinator, Yavapai County Water Advisory Committee

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The Verde Watershed Currents, formerly the quarterly publication of the Verde Watershed Association, is now the quarterly publication of the combined Verde Watershed Association and Verde River Basin Partnership. Its purpose is to present articles of public interest about the Verde watershed—its science, health, history, and prospects.