Report for 2002AZ5B: Regional Aquifers Characterization Through Spring Discharge Analysis

- Book Chapters:
  - Springer, A.E., L.E. Stevens, D.E. Anderson, S.P. Flora, D.K. Kreamer, in press, Springs Classification, Hydrology, Geomorphology, Geochemistry, and Distribution, in Spring Ecosystems of the North American Deserts: Ecology, Hydrology, and Conservation, U. Arizona Press, Tucson, AZ.
- Conference Proceedings:
  - Flora, Stephen P. and Springer A.E. 2002. Hydrogeological Characterization of Springs in the Verde River Watershed, Central Arizona: Geological Society of America Abstracts with Programs, vol. 34, no. 6, p. 25.
  - Flora, S. and A. Springer, 2002. Hydrogeological characterization of springs in the Verde River Watershed, 15th Annual Symposium of the Arizona Hydrological Society, September 18-21, 2002, Flagstaff, AZ.
  - Springer, A.E., L.E. Stevens, D.E. Anderson, R.A. Parnell, D.K. Kreamer, and S.P. Flora, 2002. Springs classification, hydrology, geomorphology, geochemistry, and distribution. Joint annual meetings of the Ecological Society of America and Society for Ecological Restoration, August 4-9, Tucson, AZ. p. 49.

Report Follows:

A. Problem and Research Objectives

The Problem

The problem we addressed is the lack of understanding of spring discharge fluctuations and the relationship between the hydrogeologic unit in which the spring discharges to determine the unit characteristics. There are not many studies that provide a detailed understanding of the springs in the Lower and Middle Verde Valley Region and those that have been done are outdated or only consider discharge measurements at a single time. Water planning for the future will be highly inaccurate based on these out-of-date, historical measurements of these dynamic springs.

Objectives

The purpose of the proposed project is to describe and where possible quantify changes in spring hydrogeology of the Middle Verde River Area. The study area is defined as the Verde River watershed from Horseshoe Dam at the Yavapai/Maricopa County Line, upstream to the confluence with Sycamore Creek above Clarkdale.

Specific objectives of this study included

1. Developing routine monitoring program for springs characteristic of each hydrogeologic unit,

2. Comparing recent monitoring to any available historic monitoring and characterize any change, and

3. Determining aquifer properties from spring discharge monitoring.

B. Methodology

Background Database

Existing information on springs in the Verde River Watershed was collected from the existing USGS database of springs and USFS database. The USGS database includes information on roughly 300 springs located within the study area with single or various measurements. It includes location and discharge measurements (gpm) that were taken between 1950 and 2000 with most measurements before 1990. The USFS database includes information on roughly 160 springs located in the eastern portion of the Verde River watershed from Sycamore Creek to the East Verde River. This database includes information on UTM locations, elevation, geologic unit, discharge (gpm), USGS quadrangle, date of visit, and comments. Most of these springs are taken from existing information collected from 1950 –1990, but 44 springs include information from visits in 1999 and 2000. The information from these two databases was combined with the information from springs visited in Phase I of this project in an Access database to compared historical discharge measurements with recent measurements taken in the summer of 2002.

Phase I

Phase I of this project was done throughout the summer of 2002 and over 150 springs were visited and characterized to build an inventory of springs in the watershed. Springs were located by using USGS topographic maps, USFS maps, and from information in existing USGS and USFS databases. There were a small number of springs (5 to 10) that were not present on the topographic maps or in existing databases that were located in searching for other springs. There were also a small number of springs (5 to 10) that were present on topographic maps, but were not found because they were dry and there was no evidence of the spring. Fieldwork was conducted with the help of NAU student field assistants Lanya Ross and Rebecca Lara and consisted of day trips and several camping trips throughout the summer and early fall to visit as many springs in the watershed as possible. The accessibility of springs varied from parking at or near the spring to 1 to 5 mile hikes to get to the springs.

At each spring several measurements and descriptions were taken to characterize and inventory each spring (Table 3). For Phase I, each spring was characterized, photographed, and located with an accurate survey grade GPS unit (Table 1). Spring Discharge and water chemistry were measured at each spring using the instruments described in Table 1. At each spring descriptions of the geomorphology, vegetation/biology, and development of the springs were described. Also the geologic unit from which the spring discharges was identified. The description of geomorphology includes measuring the length of flow in the channel using a measured pace, describing the bed material, channel, and source of the spring. The sources of the springs were classified as Rheocrene (flowing spring), Helocrene (marshy spring), or Limnocrene (pooling spring). The vegetation was described using a field guide to the plants of Arizona. The terrestrial, riparian, and aquatic vegetation was dependent on the elevation (climate) and amount of water at or near the surface. Also any fauna or evidence of fauna at the spring was described as well as any development of the spring. Summarize amounts of discharge per individual geologic units.

Table 1. Summary of instruments used to take measurements at springs during Phase I of Verde springs monitoring study.

Measurement	Instruments	Accuracy/measurement
GPS Location UTM NAD 83 UTM NAD 27 Lat/Long Elevation (meters) Elevation (feet)	Survey Grade GPS (TDS Ranger Solo) from Tonto National Forest (first choice) 90% of springs	0.1 – 1.0 meter
	Handheld GPS (second choice) 8% of springs	10 – 40 feet
	Topographic map (third choice) 2% of springs	10 – 100 feet
Discharge Gallons per minute	Baski portable Box Flume (1 inch and 8 inch necks) 0 – 1000 gpm	Variable (75-99% of flow) typically accounts for greater than 95% of flow
	V-notch weir (0 –10 gpm)	> 95% of flow +/- 0.25 gpm
	Flow meter (100 – 10000 gpm)	Variable (75-99% of flow) +/- 5.0 - 100 gpm
Basic Water Quality	YSI water quality instrument	temperature, pH, and specific conductance

Phase II

Phase II involved monthly monitoring of discharge at a select number of springs in different geologic units throughout the Verde River watershed based on the reconnaissance of Phase I. Phase II began mid-way through this project and will continue for 6 months past the end of this funded 104b project. Discharge was measured at each spring monthly by regular site visits with hand measurements of discharge using the instruments described in Table 1. Stable isotopes analysis samples have been collected once in December and will be collected again in May (pending availability of funding). Also changes in basic water chemistry, geomorphology, and vegetation at the spring were noted if there were significant changes. Sites corresponded with each major stratigraphic unit (alluvium, volcanic rocks, Verde Formation, Kaibab Formation,, Coconino Sandstone, Supai Formation, Naco Formation, Redwall Limestone, Martin Formation, Basement rocks). The monitoring was designed to use appropriate techniques to characterize appropriate diurnal, seasonal, and climatic variations in spring discharge. Monitoring was designed to characterize variability in flow which would affect estimates of total annual discharge or characterize trends in baseflow. Information was used to describe hydrogeologic properties of individual units.

C. Principal Findings and Significance

We were able to complete Phase I of the study in 2002 largely with funds from sources other than the 104b funds reported here. This phase included the synoptic survey of as many springs as we could visit and completion of a database and GIS map of the springs. We did not receive any continuing funds to finish Phase II of the study. We have begun Phase II by using some unexpended resources saved from Phase I and the USGS Section 104b funds, which expired February 28, 2003.

Database

The spring database has been built. The database includes detailed information on springs visited in Phase I of this project and limited information on springs located in existing USGS and USFS databases. The database was built in Microsoft Access and consists of five tables that include information on springs visited and one table on existing information on springs. The six tables are separated into background information, GPS location, water quality and discharge data, physical properties, vegetation information, and existing information and data on springs (Table 2).

Table 2: Organization of database for Verde Springs monitoring study.

Table	**Fields**
Background information	Name of spring, investigators, national forest, date and time of visit, weather, location, drainage system, and USGS quadrangle
GPS location data	Name of Spring, Latitude, Longitude, NAD83 UTM north, NAD83 UTM east, NAD27 UTM north, NAD27 UTM east, Elevation (meters), Elevation (feet), Accuracy
Water Quality and Discharge data	Name of Spring, discharge instrument used, discharge (gpm), Discharge accuracy, discharge variability, air temperature (°C), water temperature (°C), pH, specific conductance
Physical Properties	Name of Spring, geologic unit, bed material, source classification, emergence description, channel description, length of flow (meters), length of channel (meters), human development
Vegetation/Biology	Name of Spring, area of spring related vegetation, terrestrial vegetation, riparian vegetation, aquatic vegetation, fauna present, evidence of fauna
Existing information	Name of Spring, source of data, UTM north, UTM east, elevation, discharge (gpm), geologic unit, USGS quadrangle, dates visited, and other comments

All of the six tables were related by the name of the spring. The database is searchable by several fields and displayed in Reports. The database is available as a searchable database on the NAU Verde Watershed Research and Education Program website at http://verde.nau.edu.

Phase I

Discharge from springs in the Verde River watershed is important to the baseflow of the Verde River. By far, the two highest discharging springs in the watershed are Fossil Springs (~20,000 gpm) and Page Springs (~13,000 gpm). These two springs as well as several other major springs were not characterized in Phase I of this project since there are recent studies on these springs. A total of 160 springs were visited during the summer of 2002 and each spring was characterized as described in the methodology section. Figure 1 is a GIS map of all of the springs visited in Phase I of this project and major springs not visited.

The focus of phase I was on lower discharging springs, typically below 100 gpm with the exception of 5 springs (Summer ~3,600 gpm, Sterling ~310 gpm, Pieper Hatchery ~185 gpm, Spring Creek ~171 gpm, and Tonto Natural Bridge ~108 gpm). The average discharge of the springs below 100 gpm is 2.77 gpm or 5.77 gpm, counting only springs with surface discharge. Figure 2 shows the distribution of springs based on their discharge using the Meinzer (1923) discharge classes. The total amount of discharge for the springs visited and characterized in Phase I was 4691.36 gpm. The 5 highest discharging springs in the third and fourth classes account for only 3.3% of the springs characterized but account for 93.0% of the total discharge for all of the springs. Table 3 shows the number of springs characterized in Phase I that discharge from the different geologic units in the watershed. The total discharge for each geologic unit is also shown in this table.

Temperature, pH, and specific conductance of the water discharging from each spring were also measured during Phase I. The temperature of water for all the springs averaged 19.2°C and ranged from 7.8°C to 38.2°C and included two hot springs. The pH ranged from 6.30 to 9.18 and was an average of 7.48. The specific conductance ranged from 0.05 to 5.63ms/cm, but the average value was only 0.700ms/cm. As for geomorphology classifications for the springs, roughly 62% of the springs were classified as Rheocrenes (flowing springs), 28% Helocrenes (marshy springs), and 10% Limnocrenes (pooling springs). The length of flow for the springs ranged from 0 meters to several thousand meters of flow that eventually reached the Verde River or other major tributary. The average length of flow for the springs with surface discharge was 106.9 meters. Also roughly half (50%) of the springs characterized in Phase I had some form of anthropogenic modification at the spring. These include cement spring boxes, pipes diverting flow, water storage tanks, stock tanks, cement or earthen dams, and fences.

Figure 1 – GIS Map of springs from Phase I of Middle Verde River Watershed springs monitoring study.

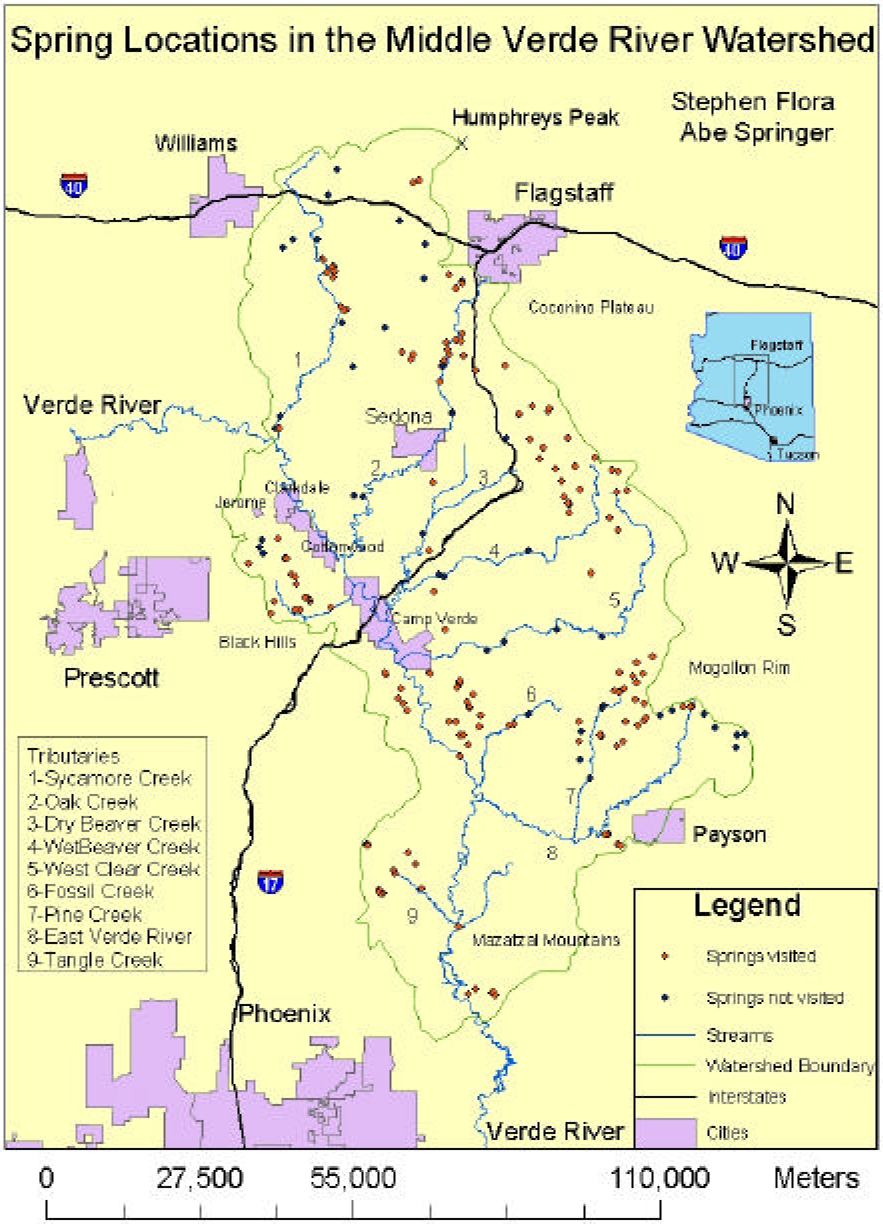

Figure 2 – Distribution of spring discharges measured in Phase I of the Verde Springs monitoring study.

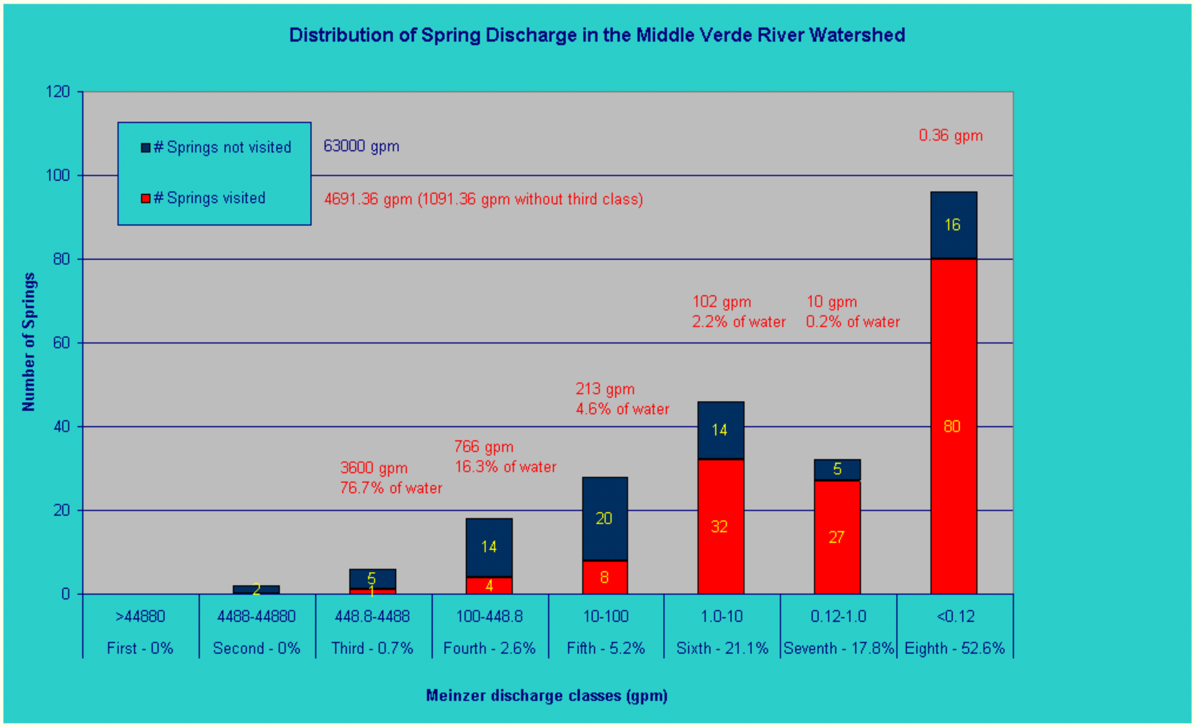

Table 4. Summary of number of springs and total spring discharge for each geologic unit from Phase I of Verde springs monitoring study.

Geologic Unit	Description	# of Springs	% springs	Total Discharge (gpm)	% Discharge
Alluvium	Holocene sand and gravels in channels	8	5.3	2.75	0.06
Verde Formation / Quaternary deposits	Lake Sediments, Conglomerates, tan sandstones, gray mudstones limestone	6	3.9	180.46	3.85
Tertiary Rim Basalts	Pliocene to Miocene Basaltic lava flows	45	29.6	42.07	0.9
Tertiary Volcanic Rocks	Pliocene to Miocene Rhyolitic to Andesitic lava flows	34	22.4	122.94	2.62
Kaibab Formation	Gray fractured and cavernous limestone	11	7.2	8.31	0.18
Coconino Formation	Permian, fine grained massive sandstone cross bedding	4	2.6	369.31	7.88
Schnebly Hill Formation	Red sandstone and shale	1	0.7	0.00	0.00
Supai Group	Formations of thick red sandstone, siltstone and limestone	13	8.5	214.38	4.58
Redwall Formation	Reddish Gray fractured and cavernous limestone	7	4.6	3701.50	79.01
Martin/Naco Formation	Gray dolomitic limestone with shaly mudstone				
Tapeats Formation	Medium grained sandstone grading upward to siltstone and limy mudstone	1	0.7	0.00	0.00
Precambrian Basement Rocks	Proterozoic granite and metamorphic rocks	22	14.5	43.10	0.92
Totals		152	100	4684.82	100

Phase II

In fall of 2002, we developed a list of potential springs to visit in Phase II of the study. We circulated this list to all stakeholders involved in the project. We incorporated their comments into our final list of sites to use for Phase II. We will only report on the partial results of Phase II (in progress) here, but following (Table 4) is a list of springs being visited monthly from November 2002 to October 2003 (pending availability of funding) and a GIS map (Figure 3) of these springs in the watershed. Discharge is measured at each spring monthly. So far results have shown no significant change in spring discharge from November 2002 through February 2003. Significant fluctuations in spring discharge are not expected until after March when snowmelt occurs and recharges the aquifers that provide water for these springs. Stable isotopes analysis samples have been collected once in December and will be collected again in May (pending availability of funding). Results from the Stable Isotope analysis in December have not yet been completed. Table 4 also includes the geologic unit, location, national forest, and December 2002 measured discharge for the springs for Phase II.

Table 4. List of springs in Phase II of the Verde springs monitoring study by geologic formation.

Name of Springs	**Geologic Formation**	**Location**	**National Forest**	**Discharge 12/2002**
Foster and Campbell Springs	Basalt	Stoneman Lake Upper Wet Beaver Creek	Coconino	0.5 gpm / 1.5 gpm
Poison and Gray Springs	Basalt	Upper Sycamore Creek	Coconino	1.10 gpm / 0.563 gpm
Clover and Pivot Rock Springs	Kaibab Limestone	Clints Well / Upper West Clear Creek	Coconino	0 gpm / 1.2 gpm
Sterling Spring	Coconino Sandstone	Upper Oak Creek	Coconino	310 gpm
Summer Spring	Redwall/Martin Limestone	Lower Sycamore Creek	Coconino	3600 gpm
Spring Creek Spring	Verde Formation	Lower Oak Creek	Coconino	228 gpm
Russell Spring	Verde Formation / alluvium	Lower Wet Beaver Creek / Montezuma Well region	Coconino	3.80 gpm
Hackberry Spring	Tertiary Volcanics / Alluvium	Fossil Creek, Hackberry Mtn	Coconino	4.0 gpm
Log Spring	Precambrian Granite	Cherry Creek	Prescott	2.25 gpm
Pieper Hatchery Spring	Supai Group	Upper East Verde River	Tonto	242 gpm
Tonto Natural Bridge Spring	Redwall / Naco limestone	South of Pine Pine Creek	Tonto	108 gpm
Grimes Spring	Precambrian Metamorphic / Igneous Rocks	West of Payson East Verde River	Tonto	0.25 gpm

Figure 3 – Map showing locations of springs (in Phase II) of Verde springs monitoring study.