Hydrogeological Characterization and Discharge Variability of Springs in the Middle Verde River Watershed, Central Arizona

by Stephen P. Flora

A Thesis

Submitted in Partial Fulfillment

of the Requirements for the Degree of

Master of Science

in Geology

Northern Arizona University

May, 2004

Approved:

Abraham E. Springer, Ph.D., Chair

Ronald C. Blakey, Ph.D.

Diana E. Anderson, Ph.D.

ABSTRACT

Hydrogeological Characterization and Discharge Variability of Springs
in the Middle Verde River Watershed, Central Arizona

Stephen P. Flora

The demand for water resources is rapidly increasing in the Verde Valley region of Central Arizona, and the understanding of these resources is critical to the their management. The many springs discharging in the 7,000km^2 Middle Verde River Watershed reflect groundwater conditions and surface-water contributions to the watershed. A large number of these springs are uncharacterized or information on the springs is out of date. An inventory of over 160 springs in this region was conducted to better understand the comprehensive physical, chemical, and ecological characteristics of these springs in order to develop a classification for springs in semi-arid landscapes. The spring characteristics including location, discharge, basic water chemistry, geomorphology, vegetation, and geologic unit were used to create an Access Database and GIS map of these springs.

From this inventory, 16 springs located in different geologic formations were selected for a pilot monitoring study to understand seasonal spring discharge fluctuations and their relationship with regional hydrogeology. Out of these springs, 3 springs were located in Precambrian Granitic rocks, 2 in regional Mississippian/Devonian Limestone aquifers, 2 in regional Permian Sandstone aquifers, 2 in a shallow Permian Karst Limestone aquifer, 4 in Tertiary Basalt flows, and 3 in Quaternary deposits and alluvium. The main recharge events for the aquifers in this region are from winter and spring snowmelt. Spring hydrographs show that the springs located in the shallow Permian Karst Limestone aquifer are the most variable. Discharge from one of these springs was

0 gpm in January, before snowmelt occurred, 40 L/s in March during peak snowmelt, and 3 L/s in May after recharge from snowmelt ceased. Of the remaining springs, roughly half have shown small but significant increases in discharge during peak snowmelt or shortly after, while half had little or no change in response to recharge events.

Variability in spring discharge was used to estimate total annual discharge and characterize trends in baseflow. At some springs, discharge measurements were used to study regional hydrogeologic processes, and determine hydraulic properties of aquifers. In addition to monitoring discharge of these springs, stable isotope analyses of ^{18}O and ^{2}H were conducted on samples collected in December 2002, May 2003, and October 2003 for each spring. Stable isotope analyses were used to characterize the hydrogeology of different geologic formations and to determine the source of water from the aquifers influencing spring discharge. The seasonal discharge fluctuations along with stable isotope analyses before and after these recharge events were indicators of the response these aquifers have to recharge and flow through the aquifer. Information from this study will be useful for future management of the water resources in the region.

ACKNOWLEDGEMENTS

I would like to thank Dr. Abe Springer for all of his support and guidance throughout this study and for always going out of his way to help his students succeed. Also, I would like to thank Dr Ron Blakey and Dr. Diana Anderson for reviewing the document and for providing valuable input. In addition, I would like to thank Salt River Project, Water Resources Research Center, and the U.S. Forest Service for providing funding to get this project started; to the Tonto National Forest (Grant Loomis) for providing a GPS unit and access to field sites; Coconino National Forest, Prescott National Forest, and Tonto Bridge State Park for providing assistance and access to field sites; and to the U.S. Geological Survey, especially Laurie Wirt for providing assistance and analyses for this project. Also I would like to thank the Verde Watershed Research and Education Program, Merriam Powell Center for Environmental Research, and the Colorado Plateau Stable Isotopes Lab for providing funding to allow for the completion of this project. In addition, many thanks to the others who assisted me including, Stephanie Brightwell for her enormous help throughout the entire study, to Lanya Ross and Rebecca Lara for their endless days in the field, to Larry Stevens for his assistance with the springs classification, and to Melissa Amentt, Erin Young, Ben Siwiec, Eric North, Patricia Magowan, and others for their assistance in fieldwork.

On a personal note, I would like to thank my parents and the rest of my family for their love and support throughout. I would like to thank the faculty, staff, fellow students, and my friends, both those in Flagstaff (especially Stephanie for all she has done), and those who have given support from afar (Dave, Ben, and others), for the great experience.

TABLE OF CONTENTS

Photographic Library of Springs (Included CD's)

CD #1 – Phase I Spring Photos

Files – Phase I Photos - Geology ID.pdf

Index for Phase I photos

Folders – Phase I Photos - Geology ID

Phase I photographs

CD #2 – Phase II Spring Photos

Files – Phase II Photos - Springs ID.pdf

Index for Phase II photos

Folders – Phase II Photos - Springs ID

Phase II photographs

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

Introduction and Background Geology

Introduction

Springs are the headwaters or sources of water for many watersheds in the Western United States. Even though Arizona has the second highest density of springs of any state west of the Mississippi River, it is estimated that more than half of them are uncharacterized (Springer et al. 2004). The discharge from springs in the Middle Verde River watershed is an essential contribution to the surface-water of the watershed and groundwater conditions in the region that affects the resulting discharge from these springs. The springs reflect groundwater usage as well as affect the resulting surface-water resources of a viable water supply. The importance of springs for providing water to meet the needs for increased usage is becoming more important as the increase of human population puts a higher demand on our water resources. These springs also have a high value for the spring ecosystem services their water provides and management of the resources are important to use for a water supply as well as maintaining these natural systems.

Purposes and Significance of Study

The purposes of this study were to gather new data to characterize the springs in the Verde River watershed, to better understand spring discharge fluctuations, and to monitor the interaction with the hydrogeologic unit in which the spring exists. There are few studies that provide a detailed understanding of the springs in the Middle Verde Valley Region and those that have been done are outdated or only consider discharge measurements at a single time (Owen Joyce and Bell 1983). Monitoring of spring discharge is needed to characterize diurnal, seasonal, and climatic variations in spring discharge for springs in different aquifers or rock types. Low-flow and total discharge information from these springs are critical for effective understanding and management.

The main objective of this study was to describe and where possible quantify changes in spring hydrogeology of the Middle Verde River Area. Specific objectives included:

1) Accumulate all existing information about springs from all available sources,
2) Complete an inventory of over 160 springs throughout the Verde River Watershed (Phase I) by collecting new data to characterize the springs,
3) Create an Access database and GIS map of all of the collected spring data from Phase I and previous existing data. Summarize all existing spring discharge information from all sources to better understand the available resources,
4) Based on Phase I inventory, select 16 springs that corresponded with major stratigraphic units to establish a continuous monthly monitoring program for one year (Phase II) to characterize variability of spring discharge in the region,
5) Describe any significant trends in spring flow during the project using hydrograph analysis. Analyze trends in spring discharge between historic

and current measurements where sufficient data exists. Summarize amounts of discharge per individual geologic units. Use information to describe hydrogeologic properties of individual units, and

6) Use information from Phases I and II to pilot a spring classification system for semi-arid regions to better manage and understand these systems.

Location

The Middle Verde River Watershed is located in Central Arizona between Flagstaff and Phoenix. It is within the Transition Zone of Arizona between the southwestern edge of the Colorado Plateau and the Basin and Range Provinces. The area for this study (Figure 1) is defined as the Verde River watershed from the confluence with Sycamore Creek, downstream to Horseshoe Dam and encompasses a total area of approximately 7,000 km^2.

Elevation of this region ranges from 3,850 meters at Humphreys Peak in the San Francisco Peaks to 610 meters along the Verde River at the Horseshoe Dam. Higher elevations are present along the Coconino Plateau and Mogollon Rim region located to the north and northeast (1,830 – 3,850 meters), Black Hills located to the southwest (1,525 – 2,390 meters) and Mazatzal Mountains to the Southeast (1,525 – 2,410 meters). The Verde River drops in elevation from 1,082 meters at the confluence of Sycamore Creek to 610 meters at Horseshoe Dam over approximately 170 kilometers for an average gradient of 2.8m/km. The upper portion of the Verde River flows through the Verde Valley, a wide flat valley from Clarkdale to Camp Verde (Figure 2). South of Camp Verde the Verde River canyon becomes narrow and steep downstream to Horseshoe Dam (Figure 3). The major perennial tributaries to the Verde River (Figure 1) include

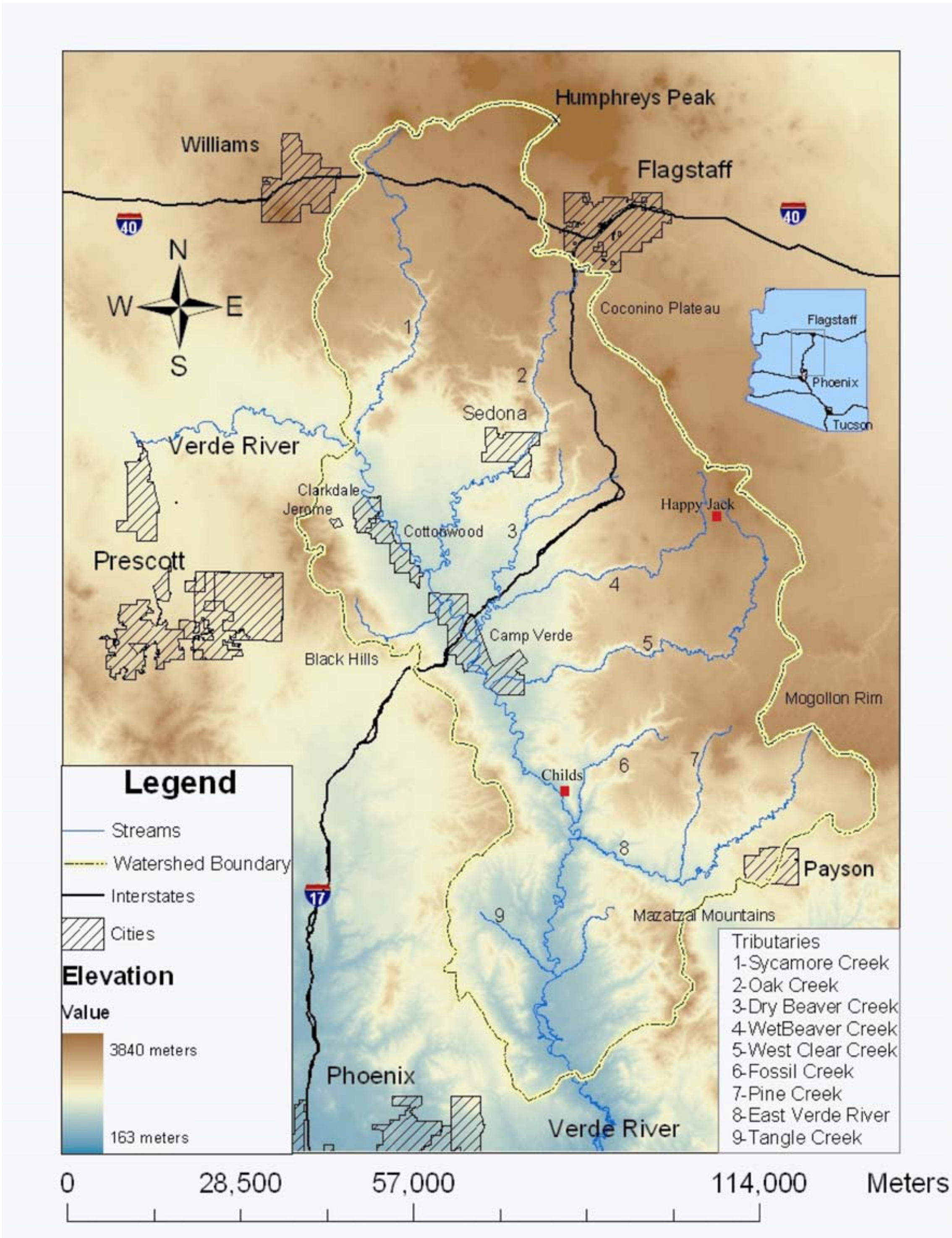

Figure 1 – Map of the Middle Verde River watershed and location of weather stations.

Figure 2 – Photograph of the Verde Valley region between Clarkdale and Camp Verde with the Mogollon Rim pictured in the distance (7/04/02).

Figure 3 – Verde River flow through the southern region of the study area near Tangle Creek at Sheep Bridge (6/15/02).

Sycamore Creek, Oak Creek, Wet Beaver Creek, West Clear Creek, Fossil Creek, East Verde River, and Tangle Creek (intermittent). All of the tributaries excluding Tangle Creek originate on the Coconino Plateau or along the Mogollon Rim to the northeast.

Regional Climate

The Verde River watershed is located in a semi-arid climatic region although temperature, vegetation, and precipitation vary greatly depending on elevation. Average January temperatures range from -9.1ºC to 4.9ºC at Happy Jack (Elevation = 2,279 meters) and -0.2ºC to 15.7ºC at Childs (Elevation = 807 meters). Average July temperatures range from 9.1ºC to 26.2ºC at Happy Jack and 19.8ºC to 38.8ºC at Childs (Table 1, Western Regional Climate Center 2004). Typical terrestrial vegetation throughout the watershed includes ponderosa pine (*Pinus ponderosa*) above 1,830 meters in elevation, pinyon pine (*Pinus edulis*) and juniper (*Juniperus*) between 1,220 and 1,830 meters, and mixed Paloverde (*Cercidium*) and cacti (*Cactaceae*) below 1,220 meters.

Precipitation falls primarily during two seasons. During the winter months (December – April), moisture from the Pacific Ocean produces gentle rainfall in lower elevations and moderate snowfall in higher elevations due to the orographic uplifting of airmasses along edge of the Colorado Plateau accounting for most of the annual recharge. During the summer months (July – September) significant precipitation occurs in intense brief monsoon thunderstorms from moisture derived from the Gulf of Mexico and Sea of Cortez. Figure 4 shows a map of average annual precipitation totals for Arizona and the Verde River watershed. The average annual precipitation ranges from 677 mm at Happy Jack to 457 mm at Childs (U.S. Department of Commerce NOAA 2004). In areas of

Table 1 – Climate Data for (A) Happy Jack, AZ and (B) Childs, AZ weather stations.

A - HAPPY JACK RANGER STN, ARIZONA (023828)
Period of Record : 5/ 1/1969 to 7/31/2003

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max Temp (C*)	4.9	7.4	8.8	12.6	17.8	24.2	26.2	24.7	21.7	15.5	9.3	4.5	14.8
Average Min Temp (C*)	-9.1	-7.1	-6.0	-3.1	0.6	4.8	9.1	8.8	5.2	-0.7	-5.4	-9.3	-1.0
Average Mean Temp (C*)	-1.8	0.3	1.4	5.0	9.1	14.4	17.7	16.8	13.4	7.4	1.9	-9.3	6.9
Average Total Precip (mm)	79.0	73.2	88.6	38.4	21.8	10.2	64.0	75.7	61.0	50.0	51.3	63.5	676.9
Average Total Snowfall (mm)	599.4	502.9	475.0	251.5	15.2	0.0	0.0	0.0	0.0	22.9	215.9	332.7	2413.0
Average Snow Depth (mm)	152.4	152.4	101.6	25.4	0.0	0.0	0.0	0.0	0.0	0.0	25.4	76.2	50.8

B - CHILDS, ARIZONA (021614)
Period of Record : 9/ 1/1915 to 7/31/2003

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max Temp (C*)	15.7	18.4	21.3	26.1	31.4	36.9	38.8	37.2	34.7	29.0	21.5	16.1	27.3
Average Min Temp (C*)	-0.2	1.5	3.4	6.7	10.6	15.1	19.8	18.9	15.3	9.1	3.2	0.3	8.7
Average Mean Temp (C*)	7.7	10.0	12.4	16.4	21.0	26.0	29.3	28.1	25.0	19.1	12.4	8.2	17.9
Average Total Precipitation (mm)	49.0	46.5	45.0	23.9	10.2	8.9	49.8	67.3	43.2	30.5	31.8	51.1	457.2
Average Total Snowfall (mm)	7.6	10.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	2.5	22.9
Average Snow Depth (mm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

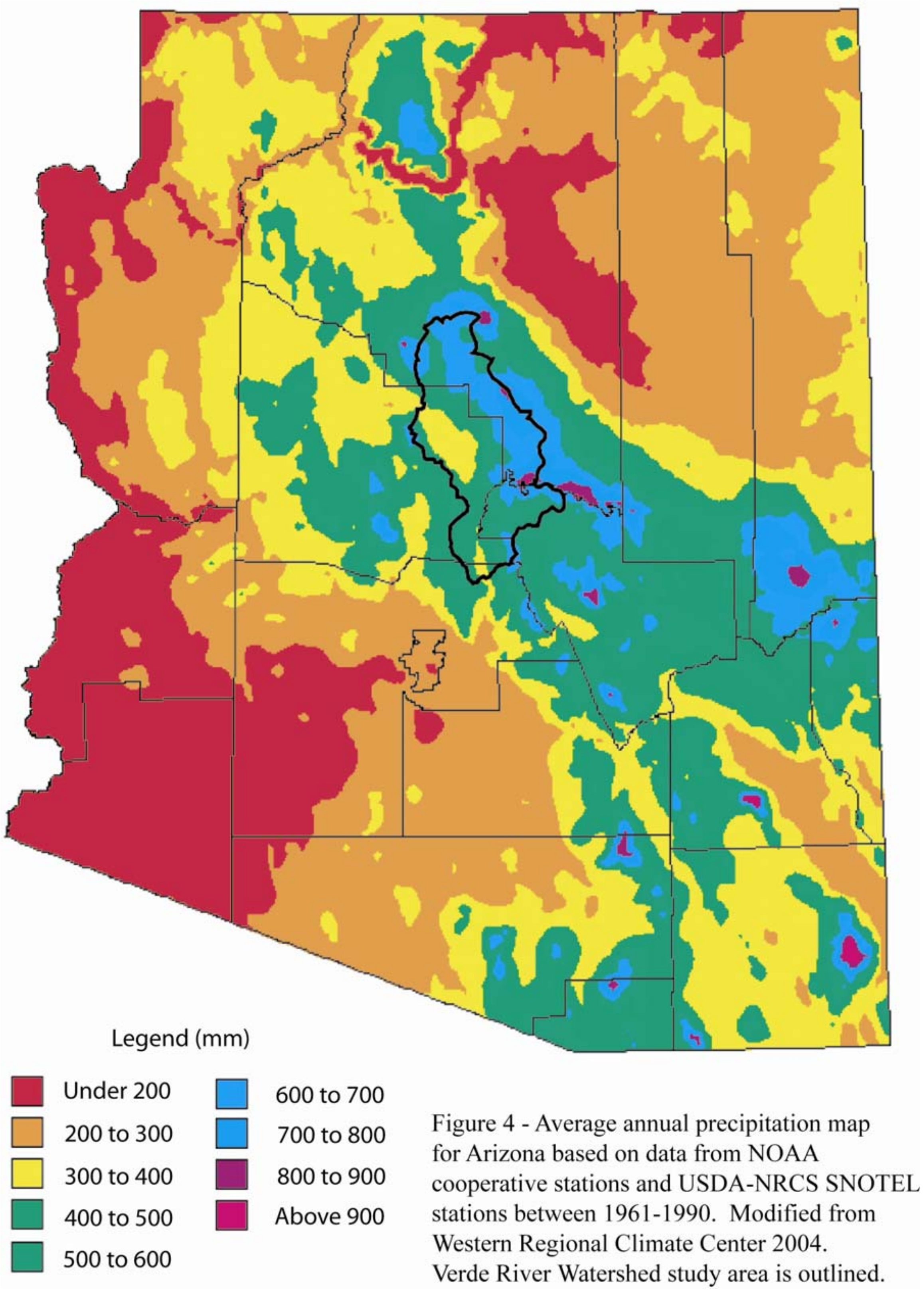

Figure 4 - Average annual precipitation map for Arizona based on data from NOAA cooperative stations and USDA-NRCS SNOTEL stations between 1961-1990. Modified from Western Regional Climate Center 2004. Verde River Watershed study area is outlined.

higher elevation and recharge (Happy Jack), average annual snowfall is 2413 mm. The precipitation for 2001 was similar to an average year based on the period of record (1915-2003) for each location with 604 mm at Happy Jack (Figure 5) and 425 mm at Childs (Figure 6). The precipitation for 2002 was significantly lower than the average annual precipitation with only 435 mm at Happy Jack (Figure 5) and 198 mm at Childs (Figure 6). At Childs the annual precipitation for 2002 was the second lowest amount of annual precipitation from 1930 – 2002 (Figure 7). In 2002, lower amounts of precipitation occurred throughout the watershed resulting in lower than normal amounts of recharge.

Previous Investigations

Twenter and Metzger (1963) made the first comprehensive survey of the hydrogeology of the Verde Valley and listed data for 16 springs in their report. In 1983, Owen-Joyce and Bell published a compilation of water resources data and interpretations for the Upper Verde River Area in Yavapai and Coconino Counties. In this report, they listed 97 selected springs and a few measured parameters from them (Table 2). Owen-Joyce and Bell (1983) reported measurements of spring discharge as acre-feet per year (Table 2). Although these point measurements likely do not represent total annual flow, they are used as such for the annual totals which appear in Owen-Joyce and Bell (1983).

Arizona Department of Water Resources (ADWR 2000) report 335 springs in the Middle Verde region in a summary of the Arizona Land Resources Information Systems (ALRIS). This summary was a compilation of existing data in the United States Geological Survey (USGS) NWIS database, without any new information collected. Most of these measurements were collected prior to the period of study for the Owen-

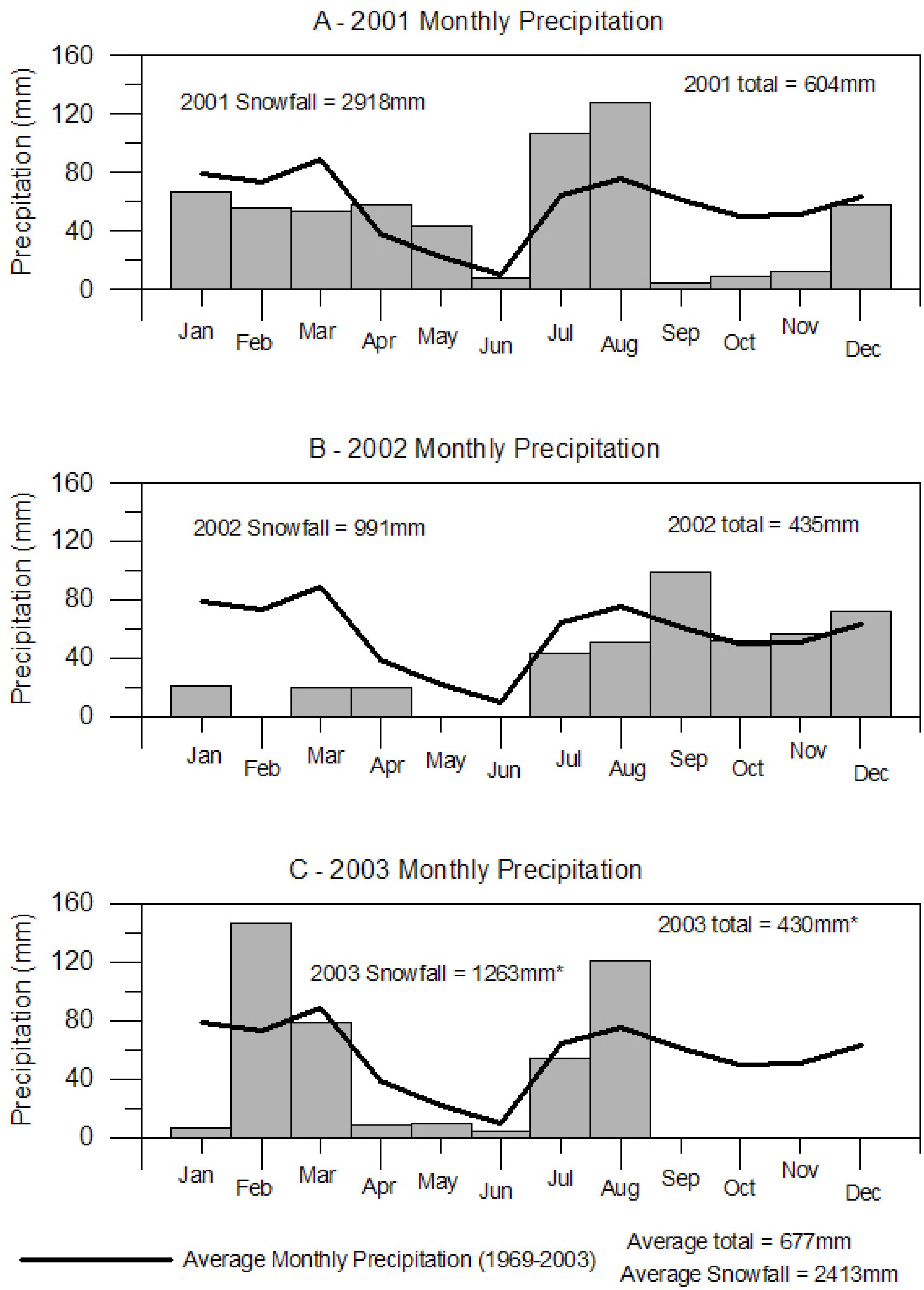

Figure 5 - Monthly precipitation totals measured at Happy Jack Ranger Station, AZ for (A) 2001, (B) 2002, and (C) 2003. Elevation = 2279 meters
*Data for 2003 is only from January 1 to August 31.

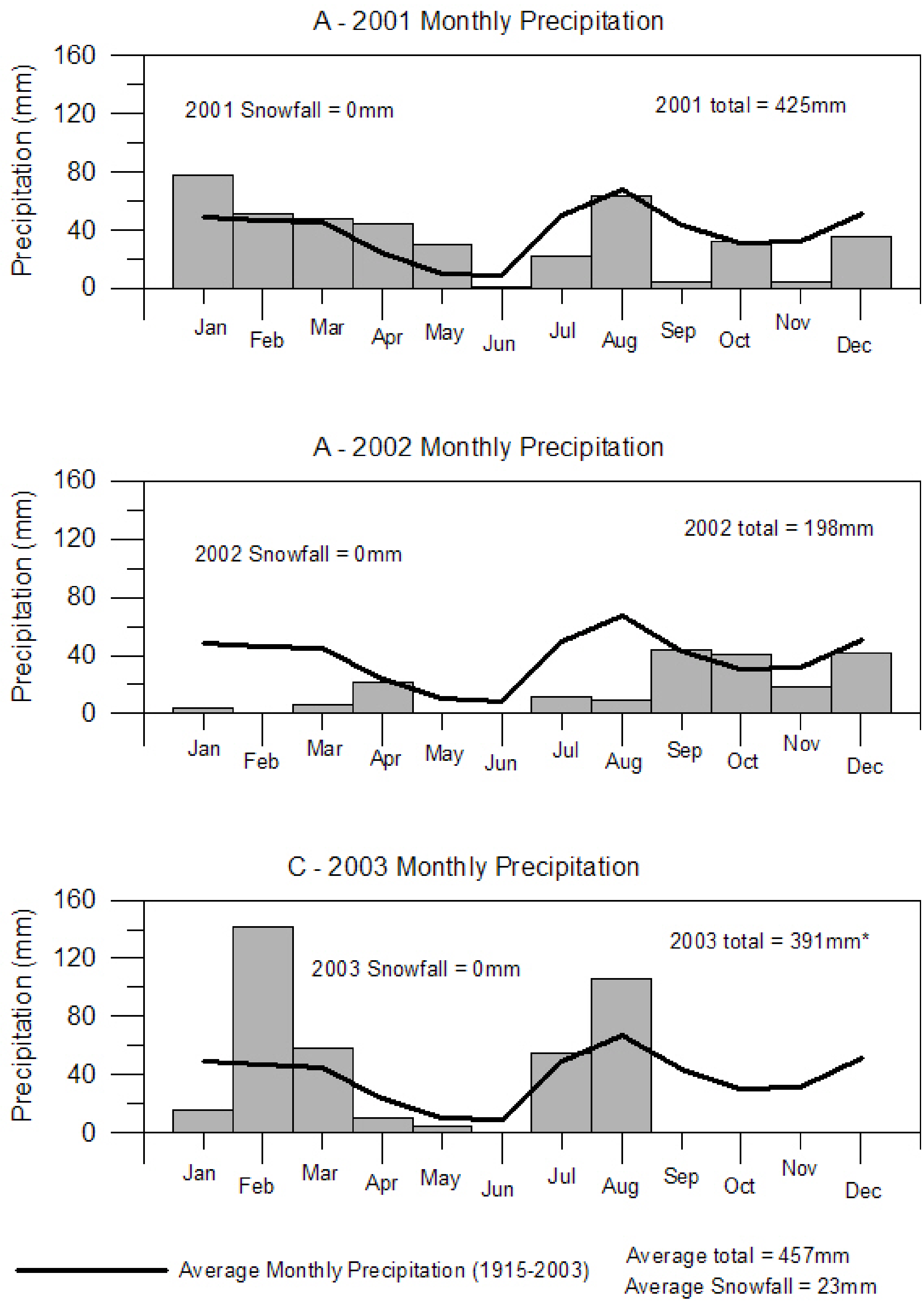

Figure 6 - Monthly Precipitation totals measured at Childs, AZ for (A) 2001, (B) 2002, and (C) 2003. Elevation = 807 meters.
*Data for 2003 is only from January 1 to August 31.

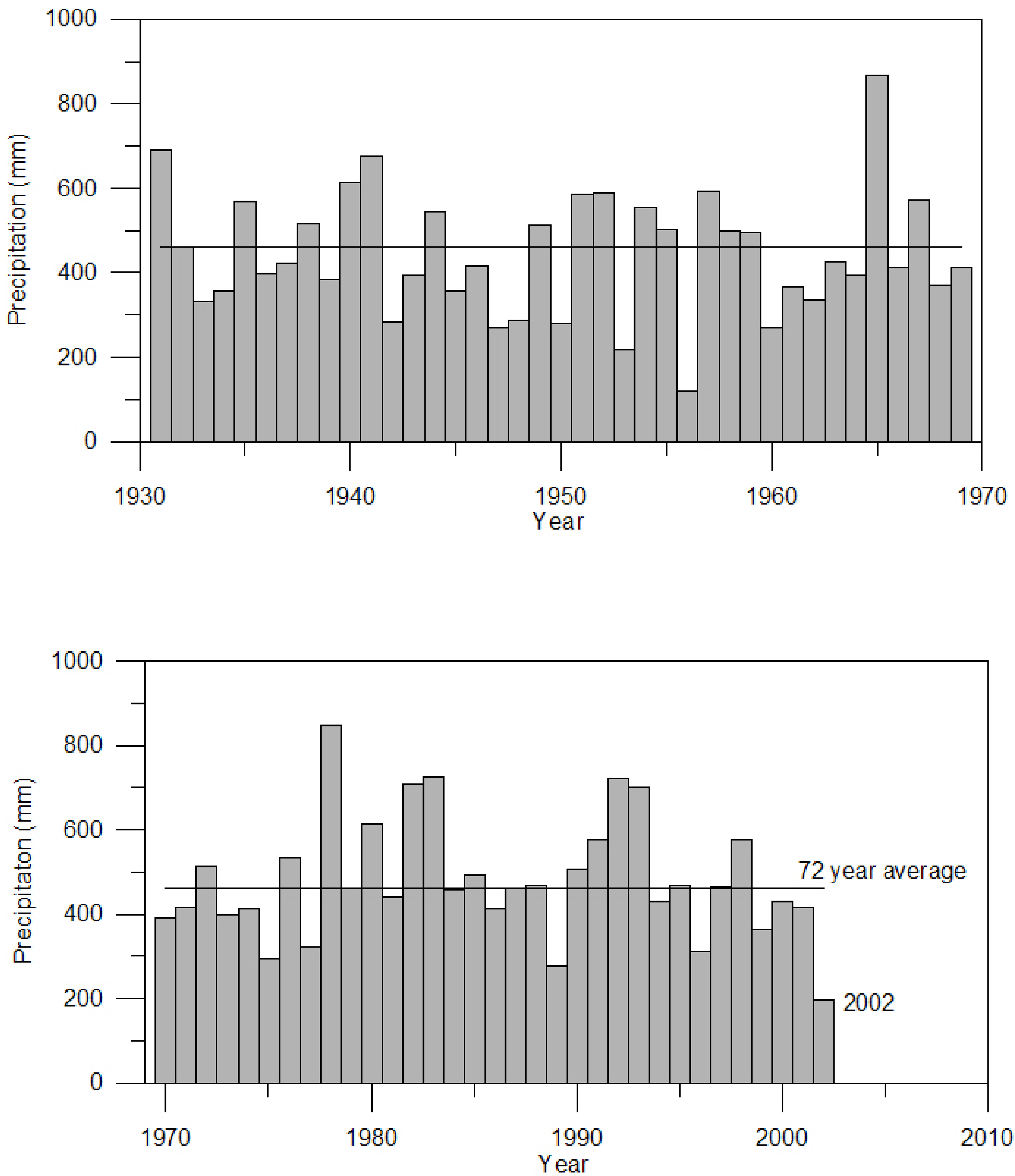

Figure 7 – Annual Precipitation totals measured at Childs from 1931 to 2002. Elevation = 807 meters (U.S. Department of Commerce NOAA 2004).

Table 2 – Summary of springs reported by Owen-Joyce and Bell (1983) in ascending stratigraphic order.

Formation	**Number of springs**	**Total discharge (ac-ft/yr)***	**% of total spring discharge**
Alluvium	2	4.4	0.006
Volcanic Rocks	22	116	0.15
Verde	7	24,300	32
Kaibab	8	60	0.08
Toroweap	1	0.16	0.2
Coconino	7	4,600	6.0
Supai	13	7,000	9.2
Redwall	4	7,000	9.1
Naco	1	30,000	39
Martin	8	168	0.22
Tapeats	2	64	0.08
Granite	4	13	0.02
Unknown	18	3,300	4.2
Total	97	76,500	

***** Note: these were point measurements in time which were assumed to represent average annual flow measurements.

Joyce and Bell (1983) report. Nearly 75 % of these measurements occurred before 1970 or were unknown, 10 % were measured in the 1960s, 25 % were measured in the 1950s, 10 % were measured in the 1940s and the measurement date of the rest were unknown. All water budgets of springs in the Verde Valley calculated since 1980, including the ADWR (2000) report have relied on these reported measurements.

In 2001 the Coconino National Forest of the United States Forest Service (USFS) conducted a survey of springs along the Mogollon Rim region east of the Verde River. The survey included numerous springs with discharge measurements and water chemistry for 8 of the major springs (U.S. Forest Service 2001). The USGS has ongoing studies of the hydrogeology of the Upper and Middle Verde River watershed (Woodhouse et al. 2002) and the Mogollon Highlands (Parker and Flynn 2000). The objectives of these projects include developing a database for all hydrologic data, understanding how the geology influences movement of water, and developing a conceptual model and numerical groundwater flow model for water resources development. In 2003, a more detailed study around Pine, AZ was conducted for the Pine Water District (Kaczmarek 2003). This report provides detailed geology and hydrogeology, but is limited to a small area of the watershed.

Recent unpublished work by Abe Springer of Northern Arizona University (NAU) and his graduate students on springs discharging from volcanic (Camp Navajo, Wilkinson 2000; and Hart Prairie, Gavin 1998), glacial (Higgins 1998), and Kaibab (Clover Spring, Anderson et al. 2004) aquifers indicates that spring discharge can be highly variable. Hence, single-time measurements of spring discharge likely do not accurately reflect average flow conditions.

Geologic Setting

The Middle Verde River Watershed is located along the southwestern edge of the Colorado Plateau and within the transition zone between the Colorado Plateau and Basin and Range provinces. Rocks exposed in this region include Precambrian intrusive igneous and metamorphic rocks, Paleozoic and Triassic sedimentary rocks, and Tertiary and Quaternary extrusive volcanic rocks, sedimentary rocks, and alluvium (Figures 8, 9, and 10). There are only a few places where major folding occurs in the region (Mazatzals), but minor folding in the northeastern edge of the watershed defines the northeast-trending Mormon Mountain anticline. The maximum dip is only four degrees but is regionally significant enough to create a topographic and groundwater divide (Owen-Joyce and Bell 1983). Numerous north-northwest trending normal faults are present in the region contributing to the topography (Figure 8). The most predominate faults are the Verde Fault Zone at the base of the Black Hills that forms a half graben that creates the wide valley for the Verde River between Clarkdale and Camp Verde (Figure 10). Several other smaller north-northwest trending faults are located in the south of the study area near Camp Verde and Payson (Figure 9). These faults expose Precambrian Igneous and Metamorphic rocks in the Black Hills in the west, in the southeast near Payson and the Mazatzal Mountains, and along the Verde River to the south.

The Colorado Plateau is underlain by relatively flat-lying Paleozoic sedimentary rocks that are exposed predominately along the edge of the Mogollon Rim north of Payson, in canyons of major northwest tributaries, in Oak Creek Canyon and the Sedona area, and in the Black Hills to the west (Figure 11). Tertiary Basalts cover areas of the

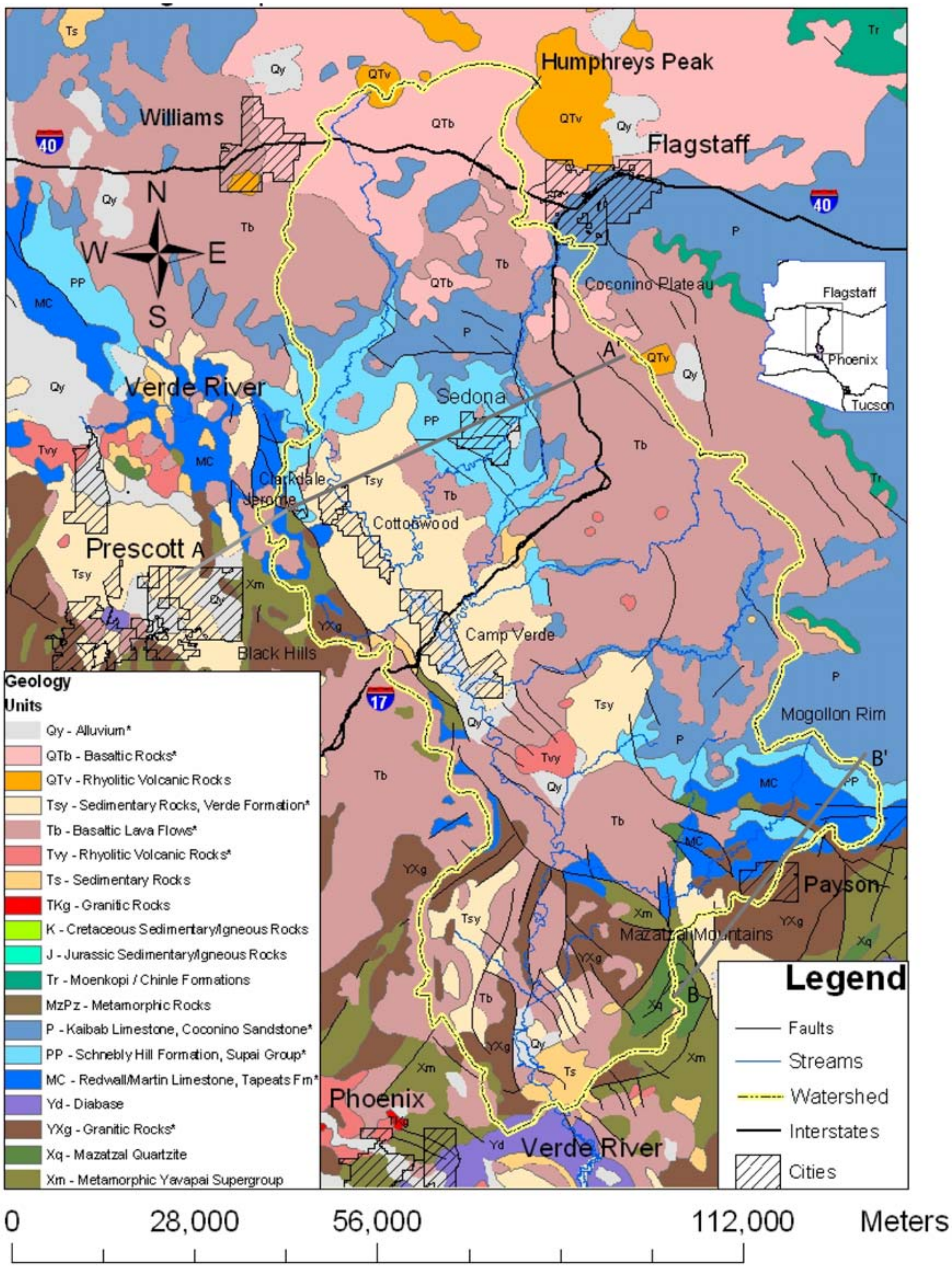

Figure 8 – Generalized Geologic Map of the Middle Verde River watershed. (Modified from Kamilli and Richard 1998). * Indicates geologic units with springs investigated in the Middle Verde Springs study.

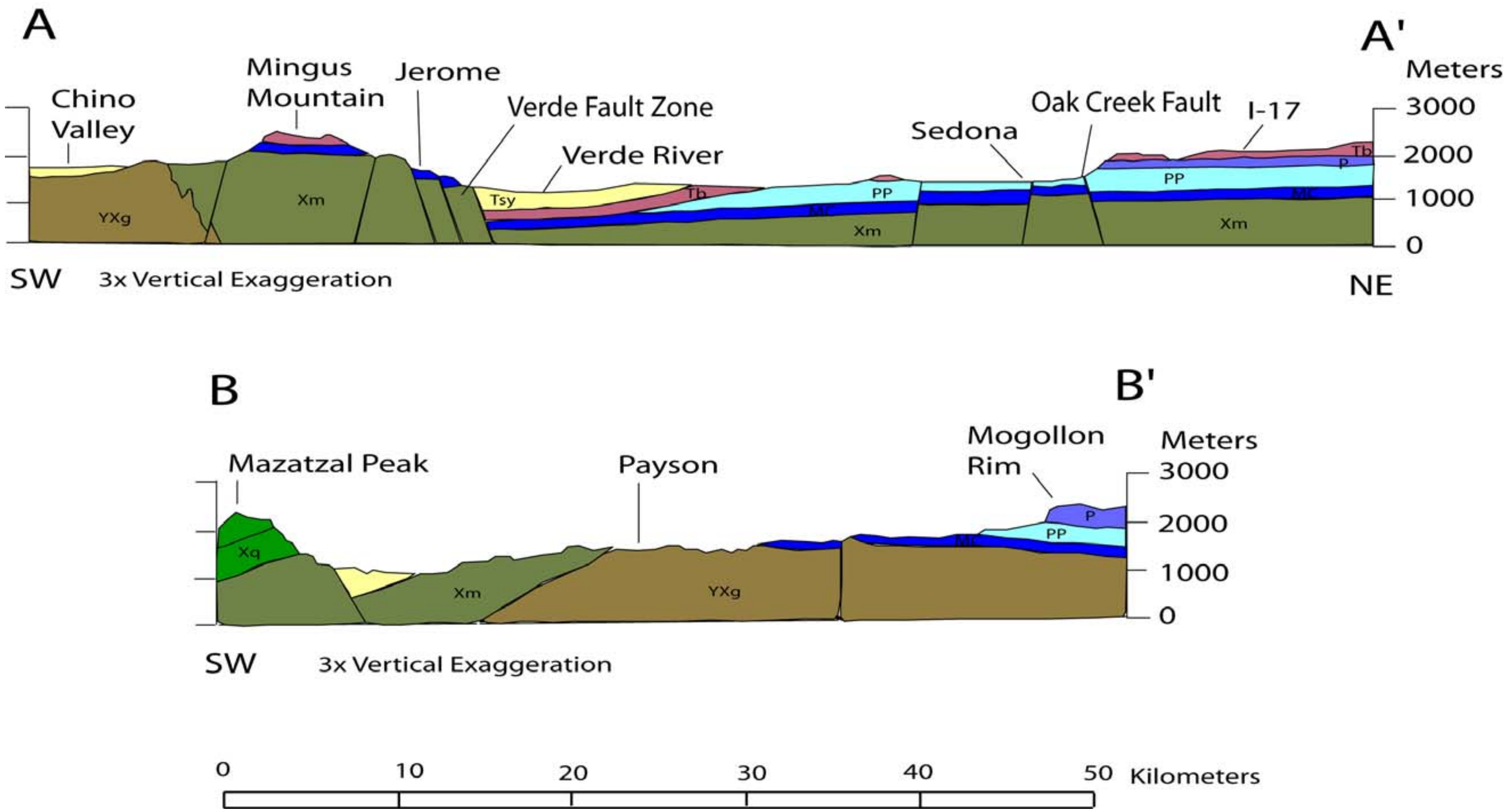

Figure 9 – Generalized geologic cross sections A-A' and B-B' located on Figure 7 in the Middle Verde River watershed. (Modified from Kamilli and Richard 1998).

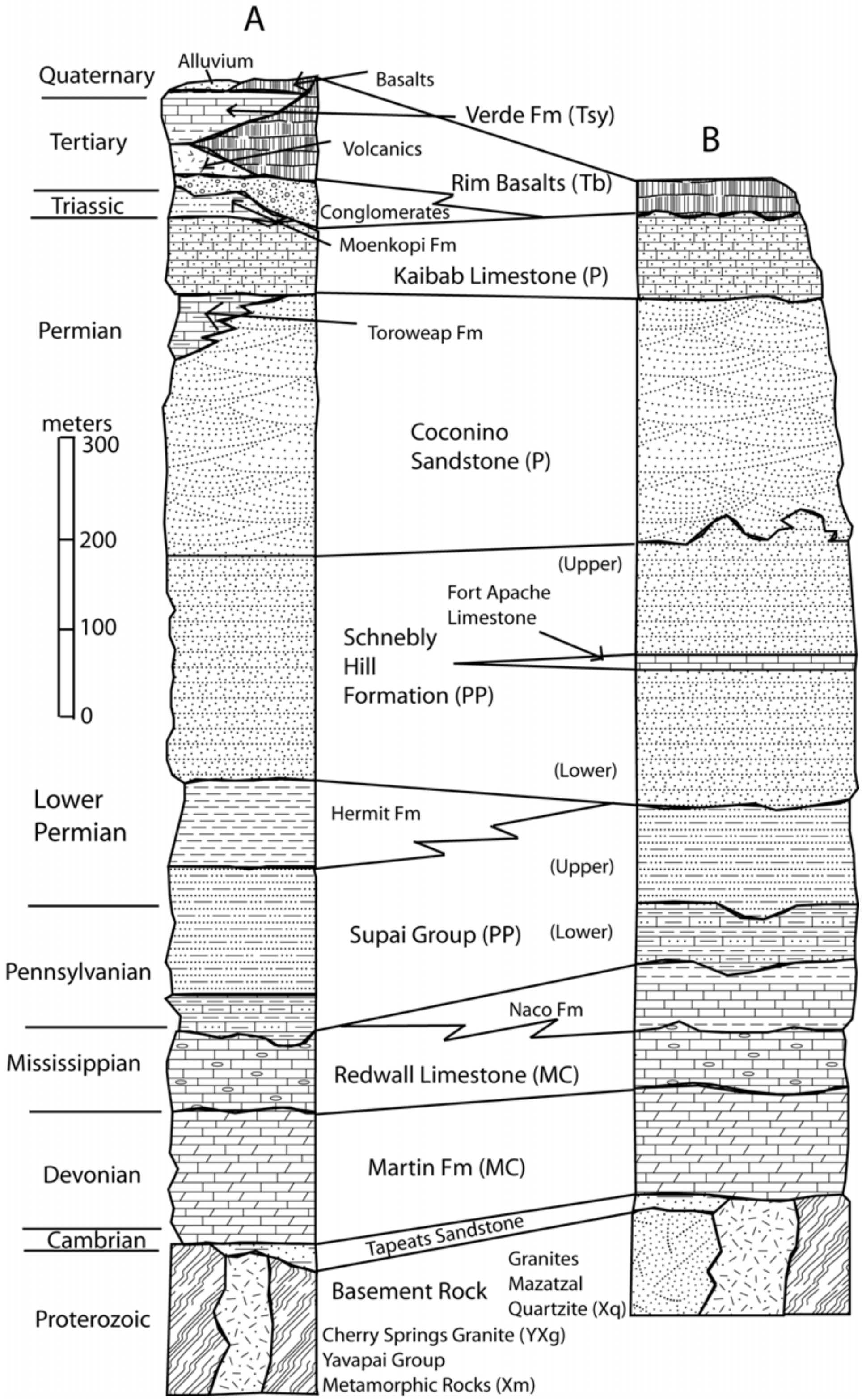

Figure 10 – Generalized stratigraphic sections located (A) along cross section A-A' and (B) along cross section B-B'. (A – modified from Blakey 2002, B – modified from Kaczmarek 2003).

Figure 11 – Geology exposed along the Mogollon Rim north of Payson, AZ (Supai Group, Lower Schnebly Hill Formation, Fort Apache Limestone, Upper Schnebly Hill Formation, and Coconino Sandstone are exposed, 7/29/02.

southern Colorado Plateau region, but late Permian sedimentary rocks also outcrop in several places along the Plateau. The San Francisco Peaks located at the extreme northern edge of the watershed on the Plateau and are composed of Pleistocene and Pliocene andesites and rhyolites. Tertiary felsic volcanic rocks are also present along the Verde River south of Camp Verde. In the Verde Valley the valley floor is mostly alluvium, and sedimentary rocks of Pliocene to mid-Miocene age (dominantly the Verde Formation).

Description of Hydrostratigraphic Units

A hydrostratigraphic unit is defined as a formation, part of a formation, or a group of formations in which there are similar hydrologic characteristics that allow for a grouping into aquifers and associated confining layers (Domenico and Schwartz 1998). An aquifer is a rock unit that is sufficiently permeable so as to supply water to wells (Domenico and Schwartz 1998). Because there are no available categories that can adequately accommodate hydrostratigraphic units (Back et al 1988), the geologic formations in the study area are grouped into general hydrostratigraphic units, which in some cases are identified as local or regional aquifers in the watershed. The geologic units of the hydrostratigraphic units and aquifers of the watershed are briefly described below and more detailed descriptions can be found in the included references.

Precambrian Basement Rocks

Igneous and Metamorphic Precambrian rocks are found in the Black Hills and Payson regions of the watershed where faulting has uplifted and exposed these rocks

(Figures 8, 9). Granitic rocks are found in both of these regions. In the Black Hills near Cherry, the granite is white and typically medium to coarse grained. In the area near Payson, the granite is typically pink and fine to medium-grained. Metamorphic schist and gneiss of the Yavapai Group are present in some areas of the Black Hills near Jerome and brown to maroon Mazatzal Quartzite is present near Payson and in the Mazatzal Mountains (Kaczmarek 2003). These Precambrian rocks have very low permeability expect in areas where the rocks are fractured yielding only small amounts of water to springs and seeps.

Devonian/Mississippian Limestone Units

The Martin Formation (Devonian) is up to 150 meters thick and is exposed in the northern portion of the watershed in lower Sycamore Canyon as well as other areas along the Mogollon Rim near Payson. It consists mainly of gray dolomitic limestone with shaly mudstone and is divided into 3 members (Kaczmarek 2003). The Redwall Limestone (Mississippian) is up to 100 meters thick and is present along parts of the Mogollon Rim and in the Black Hills (Figure 8). It typically consists of reddish-gray crystalline limestone and is fractured and cavernous in certain areas. The Naco Formation is present along the Mogollon Rim east of Fossil Creek and consists mainly of limestone and mudstone. These units are underlain by the Cambrian Tapeats Sandstone, but it is rarely exposed in the study area. These limestones are significant water bearing units in fractured and cavernous regions and are considered the main regional limestone lower aquifer.

Permian Sandstone Units

The Supai Group (Pennsylvanian/Permian) forms a red bed sequence up to 200 meters thick near Sedona and along the Mogollon Rim. It is divided into 4 formations that consists of thick red sandstone, siltstone and gray limestone. The basal Supai Group consists of reworked underlying Redwall Limestone (Blakey 1990) and upper formations consist of red-orange fine-grained sandstone. The Hermit Formation (Permian) is located above the Supai Group and consists of sandy mudstone and siltstones. The Supai Group and Hermit Formation do not yield significant amounts of water.

The Schnebly Hill Formation (Permian) can be up to 600 meters thick in some areas near Sedona and the Mogollon Rim. It is divided into 6 members including the Sycamore Pass, Bell Rock, Rancho Rojo, Big A Butte, Fort Apache, and Corduroy members (Blakey 1990). Most of the members consist of thick, red medium-grained sandstone with minor siltstone and mudstone. The Fort Apache member is exposed along the Mogollon Rim east of Fossil Creek and consists of limestone and dolomite up to 30 meters thick (Figure 11). Much of the Schnebly Hill Formation has moderate porosity and is a moderate water bearing unit.

The Coconino Sandstone (Permian) is approximately 200 meters thick and is present along the Mogollon Rim, near Sedona, and in canyons to the east of the Verde River. It typically consists of a tan to white fine-grained massive cross bedded sandstone. In the Sedona region it is divided into two members (a basal Harding Point Member and upper Cave Spring Member). The Cave Spring Member grades westward into flat-bedded sandstone and near Sycamore Canyon undergoes a lateral change to the Toroweap Formation (Blakey 1990). The Coconino is relatively porous sandstone consisting mostly of wind deposited quartz grains and is one of the principal water bearing units yielding significant amounts of water. The Coconino Sandstone and Schnebly Hill Formation are considered to be the main regional sandstone aquifer.

Upper Permian Limestone

The Kaibab Formation (Permian) is 90 meters thick in regions near Pine (Weisman 1984) and is also present in several places along the Mogollon Rim and southern Colorado Plateau (Figure 8). It typically consists of a gray to tan cherty fractured limestone and is divided into two members (Harrisburg and Fossil Mountain) that consist of fine grained sandstone and sandy limestone or dolomite in some areas. The Kaibab Limestone contains solution cavities allowing for higher areas of permeability where water can move rapidly through the formation (Kaczmarek 2003). Karst regions occur along the Mogollon Rim near upper West Clear Creek and can yield significant amounts of water in a shallow unconfined aquifer.

Tertiary Volcanics and Rim Basalts

Pliocene and Miocene extrusive basaltic lava flows cap much of the Colorado Plateau in the watershed in the higher elevations in the northeast portion of the watershed. The basalts are commonly faulted and jointed and locally contain clay layers and weathered ash (Owen-Joyce and Bell 1983). In these areas the basalts yield water locally from small perched aquifers. Similar Quaternary basalt flows are also present in northwestern portions of the watershed on the Colorado Plateau (Figure 8). Pliocene and

Miocene rhyolite and andesite lava flows are also present along the Verde River between Camp Verde and Fossil Creek.

Verde Formation and Alluvium

The Verde Formation (Fm) is Miocene to Pliocene in age and ranges from 0 to 550 meters in thickness in the Verde Valley (Owen-Joyce and Bell 1983). It consists of fluvial and lacustrine clastic and carbonate sediments. Interbedded freshwater lake limestone and siltstone deposits are typical through the Verde Valley Basin which extends 50km long and 17km wide (Nations et al. 1981). Sandstone, mudstone, evaporate, conglomerate, and interbedded basalt flows also occur in the Verde Fm. The Verde Fm is the main unconfined aquifer for much of the Verde Valley.

Quaternary alluvium up to 30 meters thick is present along the Verde River near Camp Verde (Figure 8). The alluvium consists largely of recent channel and floodplain deposits of gravel, sand, silt, and clay.

General Hydrogeology of Area

Recharge to the aquifer in the watershed mainly occurs in early spring at higher elevations as a result of infiltration of snowmelt through permeable or fractured bedrock (Owen-Joyce and Bell 1983). An estimated 187,699 acre-feet of annual recharge occurs in the Middle Verde watershed from Paulden to Tangle Creek (ADWR 2000). Groundwater flow occurs from the Mormon Mountain anticline and the Mogollon Rim area southwest toward the Verde River as well as from the Black Hills northeast toward the Verde River (Twenter and Metzger 1960). Regional groundwater flow occurs in two main hydrostatigraphic aquifers with deeper groundwater tables and discharge occurring in the major tributaries and springs. The lower Regional Limestone Aquifer consists of the Martin, Redwall, and Naco Formations. The upper predominately regional sandstone aquifer includes the upper Supai Group, Schnebly Hill, and Coconino Formations. Local flow occurs in the perched aquifers in the Tertiary Rim basalts as well fractured or karst regions of the Kaibab Formation where it is unconfined near upper West Clear Creek. The main aquifer in the Verde Valley is the Verde Formation and alluvium in which a shallow groundwater supplies numerous wells to the surrounding communities of Camp Verde and Cottonwood. Ground water is typically used for domestic purposes but surface water in the Verde Valley is mainly used for irrigation.

Perennial flow in the Verde River begins upstream from study area boundary east of Prescott. Perennial flow in the Verde River and its tributaries is maintained by baseflow from groundwater discharge directly to the river and to a large number of springs in the tributaries. Average flow in the Verde River ranges from 5.1 m^3/s at the Clarkdale gaging station to 16.2 m^3/s at the Tangle Creek gaging station. Table 3 shows the average annual, 2001, 2002, and 2003 discharges at gaging stations along the Verde River and major tributaries. Stream discharges for 2001, 2002, and 2003 at all of the gaging stations were below the annual average discharges for the Verde River and the 2002 discharges for most of the gaging stations were approximately half the amount during 2001 and 2003. Figure 12 shows the 2002-2003 daily discharge along the Verde River Watershed. The Verde River increases in discharge through the Verde Valley between Clarkdale and Camp Verde during the winter months and decreases in discharge during the summer months (Figure 12) due to decreased recharge and increased irrigation

Table 3 – Stream discharge at gaging stations in the Verde River Watershed (U.S. Geological Survey 2004).

Location	Gage #	Drainage Area (km^2)	Period of Record	Annual Average (m^3/s)	2001 average (m^3/s)	2002 average (m^3/s)	2003 average (m^3/s)
Verde River near Clarkdale	09504000	9,072	1918-1920, 1966 - 2001	5.1	2.5	2.1	2.7
Verde River near Camp Verde	09506000	12,973	1935-1944, 1989-2001	12.6	6.1	3.9	7.8
Verde River below Tangle Creek and above Horseshoe Dam	09508500	15,172	1946-2001	16.2	9.0	5.1	10.7
Oak Creek near Cornvile	09504500	920	1941-1944, 1949-2001	2.5	1.5	0.8	2.0
Wet Beaver Creek	09505200	368	1962-1981, 1990-2001	0.95	0.5	0.2	0.7
West Clear Creek	09505800	624	1965-2001	1.9	0.95	0.4	1.2
Fossil Creek	09507500	Diversion	1952-2001	1.2	1.2	1.1	1.1
East Verde River	09507980	857	1962-1964, 1968-2001	1.9	0.9	0.06	1.8

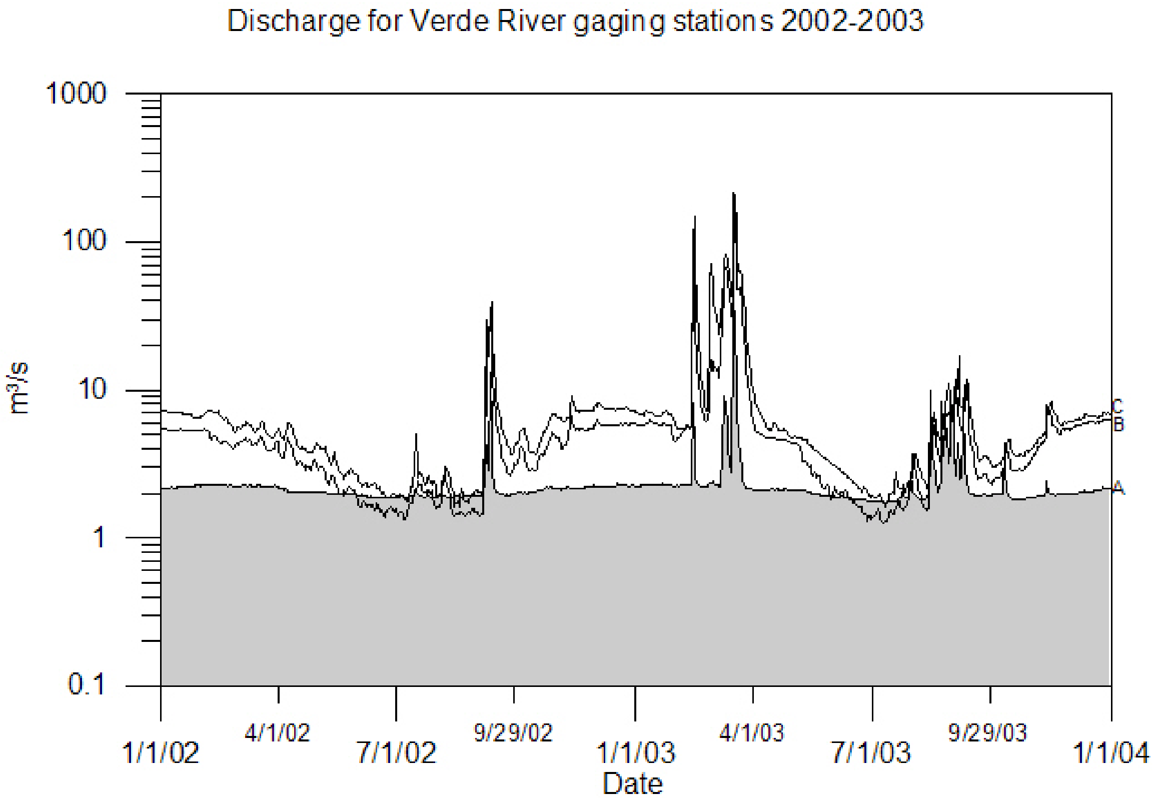

Figure 12 – Stream Discharge for the Verde River at (A) Clarkdale, (B) Camp Verde, and (C) Tangle Creek gaging stations. Average daily discharge from 1/1/02 – 12/31/03.

and water use from the aquifer decreasing the baseflow to the river. The daily stream discharges for the major tributaries are shown in Figure 13. Oak Creek, Wet Beaver Creek, West Clear Creek, and Fossil Creek flow at a certain baseflow with high peaks of flow during snowmelt and smaller peaks during summer monsoon events similar to the Verde River. The East Verde River is highly variable throughout the year with intermittent periods in drier parts of the year. The Verde River and tributaries do not show an increase in stream discharge in early 2002 due to the low amounts winter snowfall and precipitation causing less recharge and resulting in less baseflow to the watershed.

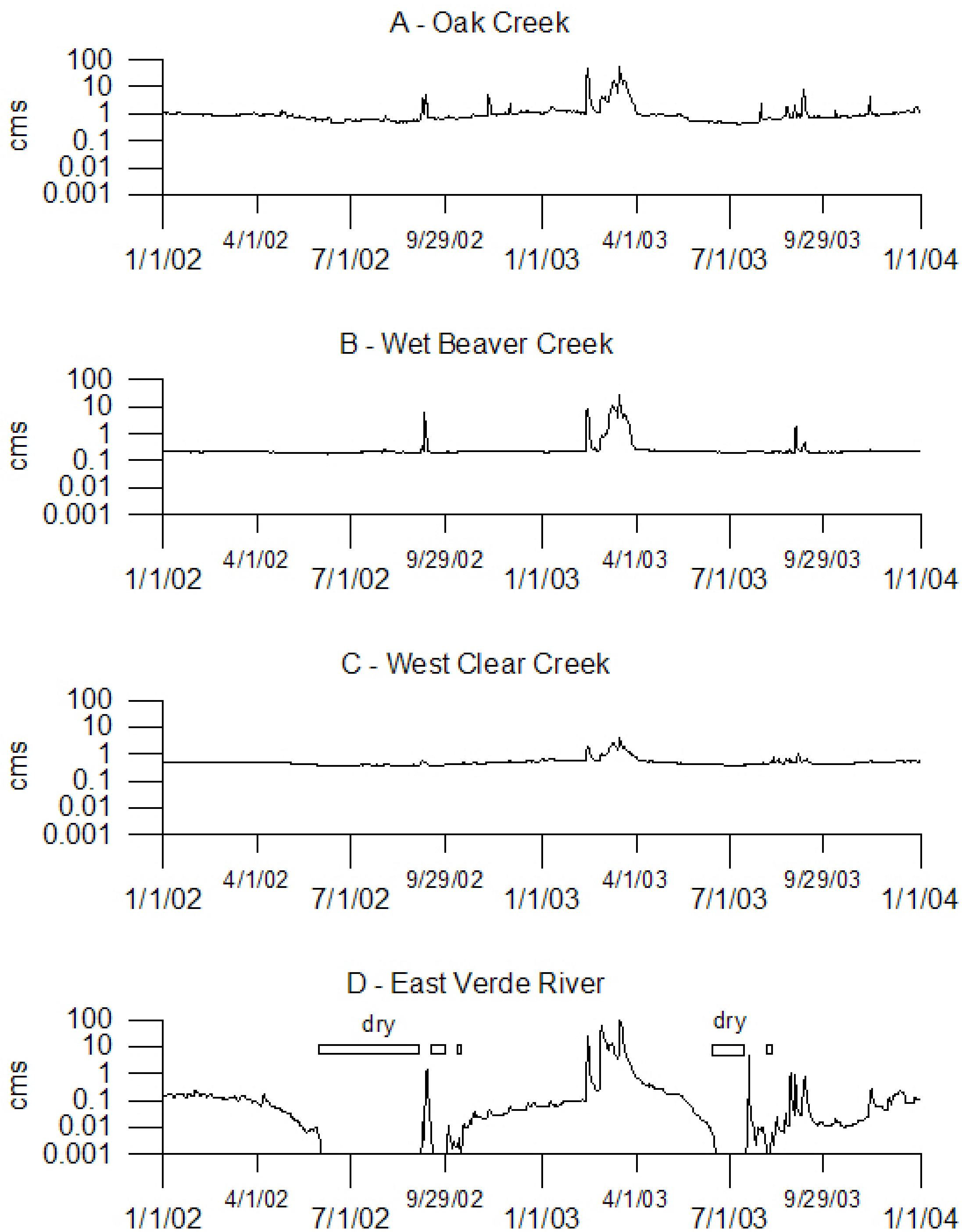

Figure 13 – Stream Discharge for 2002 and 2003 for major tributaries of the Verde River (A) Oak Creek near Cornville, (B) Wet Beaver Creek near Rimrock, (C) West Clear Creek near Camp Verde, and (D) East Verde River near Childs.

CHAPTER 2

Methods and Spring Inventory

Existing Spring Data

Existing information on springs in the Verde River Watershed was collected from the existing USGS database of springs and the USFS database. The USGS database (U.S. Geological Survey 2002) includes information on roughly 300 springs located within the study area with measurements on single or multiple dates. It includes location and discharge measurements that were taken between 1950 and 2000 with most measurements before 1990. The USFS database (U.S. Forest Service 2000) 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 UTM locations, elevation, geologic unit, discharge, USGS quadrangle, date of visit, and comments. Most of the information on these springs were taken from existing information collected from 1950 to1990, but 44 springs included information collected from visits in 1999 and 2000. The data were used to create a database in Microsoft Access of existing spring data to compare historical discharge measurements with recent measurements taken in Phase I of this study.

A study done by HydroGeoChem, Inc. (U.S. Forest Service 2001) for the Coconino National Forest, included information on springs located in the Coconino National Forest. This report is not included in the Phase I inventory and database, but discharge measurements and water chemistry data were used in Phase II of this study.

Phase I - Spring Inventory Methods and Equipment

Phase I of this project occurred in the summer of 2002. Over 160 springs were surveyed and characterized. Field and laboratory methods were used to address the objectives of this study. Field work occurred between May 2002 and October 2002 to best coincide with baseflow and/or low flow conditions of springs. Fieldwork was typically done with a field assistant and consisted of day trips and several camping trips throughout this period 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.

Locating and Documenting Springs

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 while 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.

Table 4 shows the equipment used in locating and documenting each spring. The location of each spring was determined using a survey grade GPS with accuracy of better than 1.0 meter. GPS measurements were taken as close as possible to the main source of each spring when the GPS unit was able to connect with 4 or more satellites. When the survey grade GPS was unavailable or not working, an eTrek hand held GPS was used. When no GPS was available, locations were determined from USGS 7.5’ topographic maps. Springs were photographically documented using a digital camera. Pictures were

Table 4 – Specifications for spring location GPS instruments and digital camera used in the Middle Verde Springs study.

Measurement	Instruments / Manufacturer	Accuracy/specifications
GPS Location UTM NAD 83 UTM NAD 27 Latitude/Longitude Elevation (meters) Elevation (feet)	Starview Survey Grade GPS Trimble Sunnyvale, CA TDS Ranger 133 Data Collector TDS Solo Office Software Tripod Data Systems Corvallis, OR (Provided by Tonto National Forest)	+/-0.1 – 1.0 meter (first choice) used for 90% of springs
	eTrek handheld GPS Garmin International, Inc. Olathe, Kansas	+/-3.0 – 15 meters (second choice) used for 8% of springs
	7.5 minute topographic maps U.S. Geological Survey Denver, CO	+/-3.0 – 30 meters (third choice) used for 2% of springs
Digital Photographs	Kodak DX4900 Zoom Digital Camera Eastman Kodak Company Rochester, New York	4.0 MP, 2448 x 1632 Resolution Optical quality glass lens 6x Zoom (2x Optical, 3x Digital) Focal Length 35 to 70mm EXIF 2.1 (JPEG compression) files

typically taken of the source, channel, flow, vegetation, development, and any other characteristics of the spring.

Field observations at each spring were modified from Sanders (1998). The geologic unit, geomorphology, vegetation/biology, and development of the springs were described at each spring. Identification of geologic units was done using field examination, geologic maps (Kamilli and Richard 1998), existing information (Blakey 1990; Kaczmarek 2003; and Weisman 1984) and personal communication with Ron Blakey when necessary. The description of geomorphology included measuring the length of flow in the channel and total length of channel using a measured pace, describing the bed material and channel by field examination, and classification of the spring source. The sources of the springs were classified based on Hynes (1970) as Rheocrene (flowing spring) (Figure 14), Helocrene (marshy spring) (Figure 15), or Limnocrene (pooling spring) (Figure 16). The terrestrial, riparian, and aquatic vegetation were described using a field guide to the plants of Arizona (Epple 1995). Also, any fauna or evidence of fauna at the spring was noted when appropriate. Any developments or anthropogenic modifications of the spring were described considering pipes/diversions, dams, spring boxes/capture (Figure 17), and certain other modifications.

Discharge Measurements and Water Quality

In the field, discharge measurements for the spring were taken once a month using hand measurements. Equipment used to measure discharge included a flow meter, portable box flume, v-notch weir, and timed flow into a volumetric container (Table 5). The flow meter was used for larger springs generally with discharge greater than 18.9 L/s

Figure 14 – Rheocrene spring using a flow meter to measure discharge in the spring channel (Pieper Hatchery Spring, Abe Springer pictured 12/12/02).

Figure 15 – Helocrene spring using a v-notch weir to measure discharge (Campbell Spring 2/22/03).

Figure 16 – Limnocrene spring flow measured in spring channel using the box flume (LX Spring 6/13/02).

Figure 17 – Spring box in the middle of the spring channel (Barney Spring, Stephen Flora pictured 7/30/02).

Table 5 – Discharge and basic water-quality equipment specifications for Middle Verde Springs study.

Measurement	Instrument	Accuracy
Discharge Gallons per minute (gpm) Cubic feet per second (cfs) Liters per second (L/s)	Collapsible cutthroat flume (portable box flume) (1 inch and 8 inch necks) Baski, Inc. Denver, CO	Variability (75-99% of flow) typically accounts > 95% of flow Discharge Range: 0.16 – 63 L/s Accuracy: +/- 0.016 – 1.6 L/s
	V-notch weir	Variability: > 95% of flow Discharge Range: 0 – 0.63 L/s Accuracy: +/- 0.016 - 0.063 L/s
	Model 1205 Price Type "Mini" Current Meter and CMD 9000 Digimeter Scientific Instruments, Inc. Milwaukee, WI	Variability (75-99% of flow) Flow Velocity Range: 0.075 to 0.914 m/s Discharge Range used: 6.3 – 630 L/s Accuracy: +/- 0.32 – 6.3 L/s
	Volumetric Container	Variable
Basic Water Quality Temperature pH specific conductivity	YSI Model 3500 Water Quality Monitoring System Yellow Springs Instrument Co., Inc. Yellow Springs, OH	**Temperature** Range: -5.0 – 50.0 *C Accuracy: +/- 0.4 *C Resolution: 0.1 *C **pH** Range: 0 – 14.00 pH units Accuracy: subject to calibration Resolution: 0.01 pH **Conductivity** Range: 0.0 to 100.0 ms/cm Accuracy: +/3% to +/-6% Resolution: 0.001 to 0.1 mU/cm

(Figure 14). The width and depth of the channel was measured using a standard tape measure and velocity was measured by the digimeter. A portable cutthroat box flume was used for springs with moderate discharge and a developed channel. The box flume used two adjustable throat sizes. A throat of one-inch was used for springs with discharge ranging from 0.063 L/s to 6.3 L/s, while an eight-inch throat was used for discharge higher than 6.3 L/s. The box flume was placed in the spring channel downstream of the source of the spring in order to take the measurement (Figure 16). The v-notch weir was used for springs with a discharge lower than 0.63 L/s and flow in a soft or loose sediment channel. The weir is pressed into the sediment and flow is funneled through the v-notch and discharge is measured on the scale indicated on the weir (Figure 15). In a few cases, discharge was diverted into a volumetric container of known volume over a measured interval of time. All spring discharge measurements were recorded in gallons per minutes and converted to liters per second. The accuracy of discharge measurements with these instruments is typically greater than 95% for most springs (Table 5). Basic water-quality parameters of water temperature, pH, and specific conductance were taken at each spring using a YSI water quality instrument (Table 5). All data were collected in the field on field sheets like the one in Appendix I.

Results of Spring Inventory

GIS and Access Database

The spring 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 6).

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 data for the first five tables of the database of all 160 springs in the Middle Verde Springs study are included in Appendix II. The database is also available on the NAU Verde Watershed Research and Education Program website (http://www.verde.nau.edu).

Inventory Statistics and Results

Discharge from springs in the Verde River watershed is important to the baseflow of the Verde River and its tributaries. By far, the two highest discharging springs in the watershed are Fossil Springs (~1,260 L/s) and Page Springs (~ 820 L/s). These two springs as well as several other major springs such as Wet Beaver (85 L/s) and Montezuma Well (66 L/s) were not characterized in Phase I of this project since there were current studies on these springs being done. A total of 160 springs were visited during the summer of 2002 and each spring was characterized as described in the methodology section. Figure 18 is a GIS map of all of the springs visited in Phase I of this study and major springs in the study area, but not visited in this study.

The focus of Phase I was on lower discharging springs, typically below 6.3 L/s with the exception of 5 springs (Summer ~160 L/s, Sterling ~20 L/s, Pieper Hatchery ~12 L/s, Spring Creek ~11 L/s, and Tonto Natural Bridge ~7 L/s). The average discharge of

Table 6 – Organization of database for the Middle Verde Springs 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 (L/s), 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

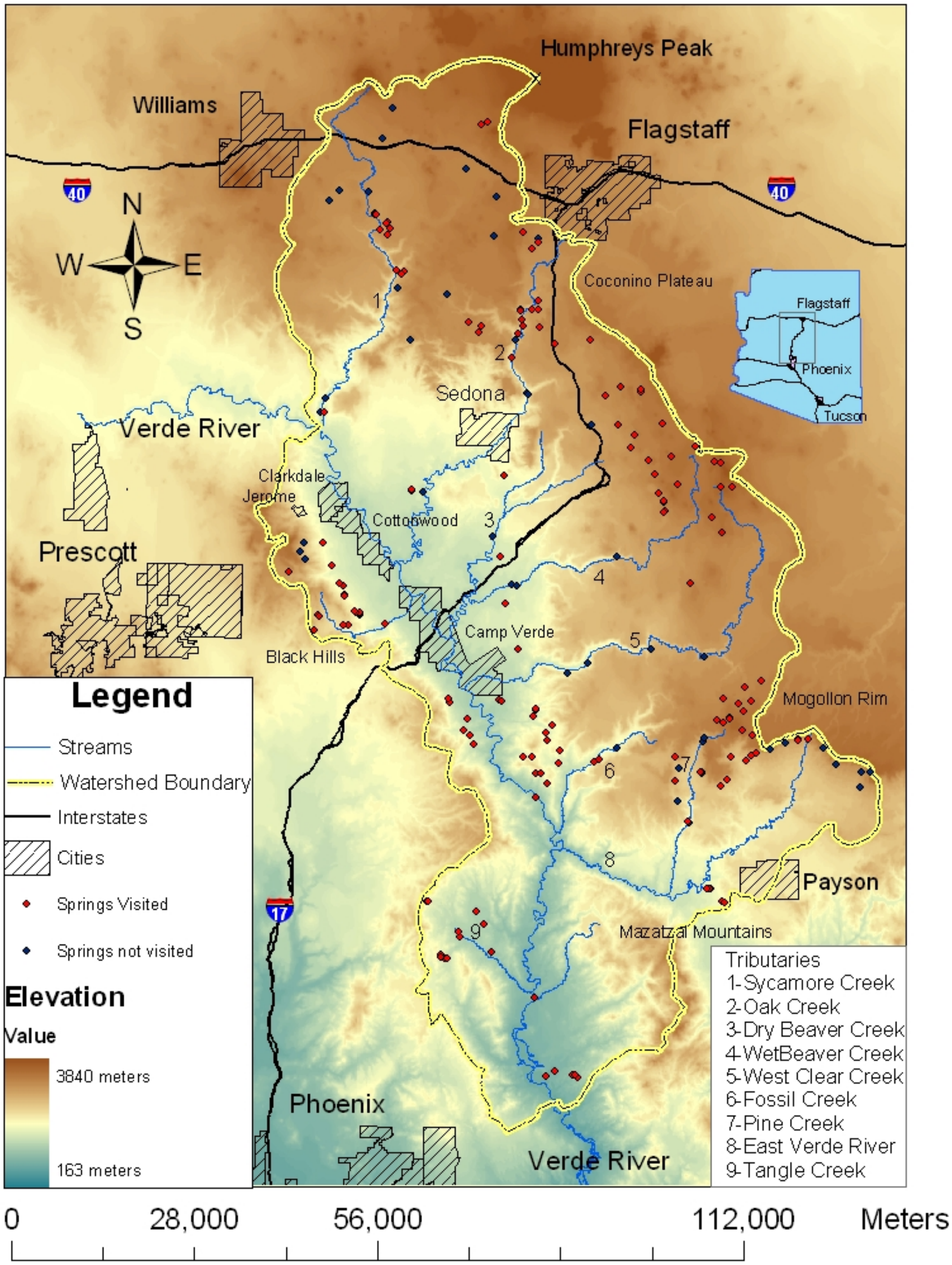

Figure 18 – Map of springs in the Middle Verde River watershed characterized in Phase I of the Middle Verde Springs study.

the springs (excluding Summer Spring) is 0.175 L/s, or 0.364 L/s counting only springs with surface discharge. Figure 19 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 233 L/s. 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.

Thermal classes of springs were determined from mean annual air temperature from annual average temperatures at the closest weather station to each spring. The temperature of water for all the springs averaged 19.2°C and ranged from 7.8°C to 38.2°C. The majority of springs were classified as normal springs. A small number of springs were classified as cold springs and two springs classified as 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) based on source classifications (Hynes 1970). The emergence of each spring was described as bedrock or alluvium, in or on the side of an existing runoff drainage, steep slope or flat grassy area, and other. The channel was described as narrow or wide, deep or shallow, and well defined, moderately defined, or poorly defined. Spring channel material for each spring was identified as bedrock, gravels, sand, silt, clay, organics, and other. The length of flow for the springs ranged from 0 meters to several thousand meters of flow that eventually reached the Verde River

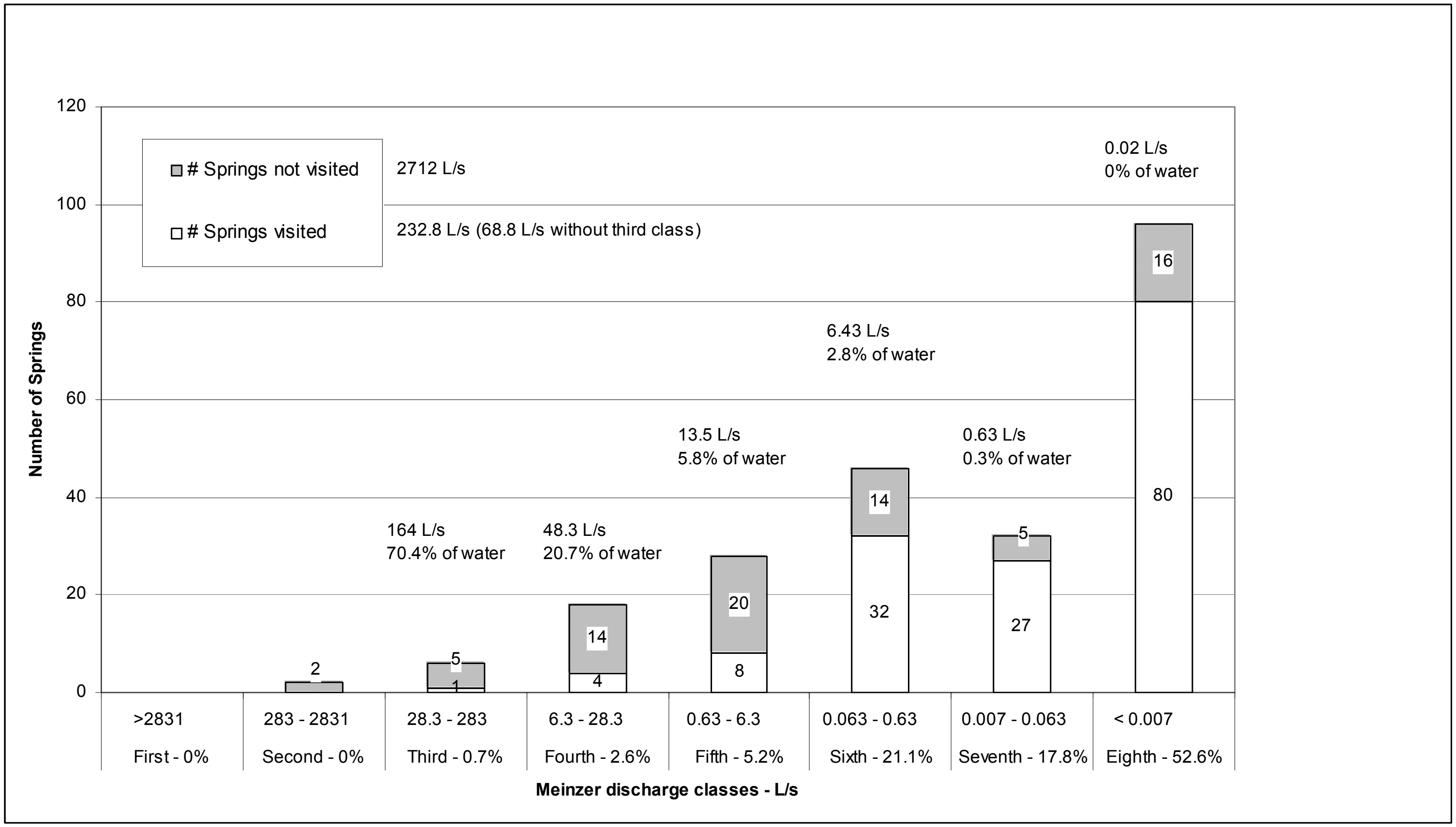

Figure 19 – Distribution of spring discharges measured in Phase I of the Middle Verde River watershed springs study.
Note: Some springs in the original 160 springs were combined to total 152. Meinzer discharge classes based in gallons per minutes were used to classify the springs.

or other major tributary. The average length of flow for the springs with surface discharge was 106.9 meters. Details of spring information are located in Appendix II.

The terrestrial, riparian, and aquatic vegetation were dependent on the elevation (climate) and amount of water at or near the surface. Typical vegetation present at springs at higher elevations (>1,524 m) included pine (*Pinus*) with occasional oak (*Quercus*) and box elder (*Acer negundo*). Sedge is often present in an area around the spring when water is at or near the surface. Typical vegetation at lower elevations (<1,524 m) for springs with water at or near the surface include cottonwood (*Populus fremontti*), sycamore (*Platanus wrightii*), willow (*Salix exigua*), canyon grape (*Vitis arizonica*), and velvet ash (*Fraxinus velutina*). Hackberry (*Celtis*), mesquite (*Prosopis*), acacia (*Acacia greggii*), and manzanita (*Arctostaphylos pungens*), are also present in lower elevations. Sedge and juncus occur at these springs, typically along the channel or at the source. Aquatic vegetation, including cattails, exists for springs with pools or high discharges. Frogs, fish, snails, and other wildlife are often present in or near these springs. Also, roughly half (50%) of the springs characterized in Phase I had some form of anthropogenic modification at the spring. These included cement spring boxes, pipe flow diversions, water storage tanks, stock tanks, cement or earthen dams, and fences. Springs were developed for livestock (Figure 20), wildlife, human use (Figure 21), and recreation. At half of the developed springs (1/4 overall), the spring ecosystem was significantly altered from modification.

Figure 20 – Spring flow diverted to drinkers for livestock (Sheep Spring 6/24/02).

Figure 21 – Dam in spring channel and pipes diverting flow for private use (Washington Spring 8/12/02).

Hydrogeology and Interpretation of Springs

Table 7 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. Most springs were located in the Tertiary rim basalts and volcanic rocks and the Precambrian granite. These springs account for 66.5% of the total number of springs but only account for 5.7% of the total discharge. Because these units are located in shallow perched aquifers with a small amount of storage, there are a large number of springs with only a small amount of discharge due to the short residence times. On the other hand, the regional limestone and regional sandstone aquifers have few springs but high discharge values. These aquifers have greater storage and longer residence times that concentrate flow to specific locations resulting in fewer, but higher discharging springs. The springs in the Redwall, Martin, and Naco Limestone aquifers combine to total only 4.6% of the total number of springs, but account for 73.3% of the total spring discharge. The Coconino, Schnebly Hill, and Supai sandstone aquifers also have a high ratio of discharge to number of springs with 4.6% of the total number of springs and 15.2% of the total spring discharge.

The majority of springs studied have a small discharge (0 to 6.3 L/s) and half of these springs were dry (0 L/s). Because 2002 was a year with very low precipitation (Figures 5 and 6) these measurements likely represent a low flow condition for the springs and can help determine which springs are perennial over periods of drought. There were several springs investigated that were thought to be perennial, but were dry in 2002. One such spring was Clover Spring which was flowing during the summer of 2001, but was completely dry in the summer of 2002. There are a large number of

Table 7 – Summary of number of springs and total spring discharge for each geologic unit from Phase I of Verde springs monitoring study.

<table>
<tr><th>Geologic Unit</th><th>Description</th><th># of springs</th><th>% total springs</th><th>Discharge (L/s)</th><th>% total discharge</th></tr>
<tr><td>Alluvium</td><td>Holocene sand and gravels in channels</td><td>8</td><td>5.3</td><td>0.17</td><td>0.10</td></tr>
<tr><td>Verde Formation</td><td>Lake Sediments, Conglomerates, tan sandstones, gray mudstones limestone</td><td>6</td><td>3.9</td><td>11.4</td><td>4.9</td></tr>
<tr><td>Tertiary Rim Basalts</td><td>Pliocene to Miocene Basaltic lava flows</td><td>45</td><td>29.6</td><td>2.65</td><td>1.2</td></tr>
<tr><td>Tertiary Volcanic Rocks</td><td>Pliocene to Miocene Rhyolitic to Andesitic lava flows</td><td>34</td><td>22.4</td><td>7.75</td><td>3.3</td></tr>
<tr><td>Kaibab Formation</td><td>Gray fractured and cavernous limestone</td><td>11</td><td>7.2</td><td>0.52</td><td>0.20</td></tr>
<tr><td>Coconino Formation</td><td>Permian, fine grained massive sandstone cross bedding</td><td>4</td><td>2.6</td><td>23.4</td><td>10.0</td></tr>
<tr><td>Schnebly Hill Formation</td><td>Red sandstone and shale</td><td>3</td><td>2.0</td><td>12.3</td><td>5.2</td></tr>
<tr><td>Supai Group</td><td>Formations of thick red sandstone, siltstone and limestone</td><td>11</td><td>7.2</td><td>1.35</td><td>0.60</td></tr>
<tr><td>Redwall Formation</td><td>Reddish Gray fractured and cavernous limestone</td><td rowspan="2">7</td><td rowspan="2">4.6</td><td rowspan="2">170.5</td><td rowspan="2">73.3</td></tr>
<tr><td>Martin/Naco Formation</td><td>Gray dolomitic limestone with shaly mudstone</td></tr>
<tr><td>Tapeats Formation</td><td>Medium grained sandstone grading upward to siltstone and limy mudstone</td><td>1</td><td>0.70</td><td>0.00</td><td>0.00</td></tr>
<tr><td>Precambrian Basement Rocks</td><td>Proterozoic granite and metamorphic rocks</td><td>22</td><td>14.5</td><td>2.73</td><td>1.2</td></tr>
<tr><td>Totals</td><td></td><td>152</td><td>100</td><td>232.8</td><td>100</td></tr>
</table>

Note: Some springs in the original 160 springs were combined to total 152.

springs discharging in the Middle Verde River Watershed with only significant information and data on the highest discharging springs. Differing amounts of information and time will be needed for reconnaissance and detailed characterizations of smaller springs in the Middle Verde River Watershed. The higher discharging springs are important as a water resource for humans, but the smaller discharging springs are important for ecosystems and can indicate smaller variations of the water table due to water use (typically groundwater withdrawal) in the region. These smaller springs also show how depletion of water resources in the region can alter spring ecosystems and ultimately affect those that are dependent on these systems.

Phase II – Spring Monitoring Methods and Equipment

Monitoring Monthly Discharge

Spring discharge measurements were collected for 16 springs from November 2002 through October 2003 for Phase II of the study. At each spring, discharge was measured using the methods previously described for Phase I of the study. The spring discharge measurements were used to produce annual spring hydrographs showing the fluctuation of flow over the one-year period of study and for additional results. For a few springs, previous discharge measurements from other studies were included with the year-long measurements in this study to create hydrographs for longer periods. A digital photograph was taken of the spring source and channel during each visit over the year to document any visual changes in the spring morphology or discharge.

Water Chemistry Sample Collection

Water samples from 12 springs in Phase II were collected once in December 2002 and once in May 2003. Only 100ml of water were collected by hand in plastic bottles for each sample taken. Samples were emerged in the flowing water when possible to avoid collecting stagnate water and to prevent air being trapped in the container with the sample. These water samples were analyzed for Oxygen ($\delta^{18}O$) and Hydrogen (δD) stable isotope values in the Colorado Plateau Stable Isotopes Laboratory at Northern Arizona University. Stable isotope results for $\delta^{18}O$ and δD were then plotted on a graph with a meteoric water line generated from $\delta D = 8\delta^{18}O + 10$ (Craig 1961). Stable isotope analyses were used to characterize the chemistry of the water discharging from springs in the Verde Valley. The purpose of using stable isotopes such as $\delta^{18}O$ and δD is to compare the values in the water of the springs to average values for water in this region (Ingraham et al. 1991; Ingraham et al. 2001; and Radenmacher et al. 2002). The type and source of water that recharges the aquifer for the springs are important to understand the hydrogeology of these geologic units in the region and the interaction with the springs

Also, water samples from 11 springs in Phase II were collected in October of 2003 and analyzed by the USGS for the following chemical analysis: Cations, Anions, Uranium Isotopes, Strontium Isotopes, Stable Isotopes (Oxygen and Hydrogen), Alkalinity, tritium, and C-13. USGS procedures for collecting water samples were used to collect these samples. The samples were collected at the point where the spring emerged from the ground at the center of the greatest flow from the spring, when possible. A 2-L plastic jug for tritium and C-13 analysis, a 250ml plastic bottle for Alkalinity analysis, and two 60-ml glass bottles for Oxygen-18 and deuterium stable isotope analysis, were rinsed with copious amounts of sample water and filled with raw water. Four 50ml plastic test tubes were rinsed with filtered water using a syringe-mounted 0.45-µm Gelman Acro-disc. All four test tubes were filled with at least 30ml of filtered water. One was closed and then analyzed for anions. The other three test tubes were also acidified with 1 ampule of HNO_3, closed and then analyzed for U-234, Sr-87, and cations. Gloves and glasses were used when acid was added to the samples and all material was disposed of properly. All analyses of water samples were done by the U.S. Geological Survey in Denver, CO.

Specific conductance, pH and alkalinity were measured by Laurie Wirt (USGS) in Denver, CO. Filtered, acidified water samples were analyzed for dissolved major and trace cations and sulfate by USGS Mineral Resources Program laboratories in Denver, CO. Major elements were determined by inductively coupled plasma-atomic emission spectrometry (ICP-AES; Briggs and Fey 1996) and trace elements and sulfate were measured by inductively coupled plasma-mass spectroscopy (ICP-MS; Lamothe et al. 1999). Concentrations of the anions fluoride, chloride, and nitrate were determined by ion chromatography in filtered, unacidified samples (d'Angelo and Ficklin, 1996). Alkalinity was measured using a HACH titration kit to determine bicarbonate concentration. Analytical detection limits by laboratories used in this study are reported in Lamothe et al. (1999) and d'Angelo and Ficklin, (1996). Stable isotopes and tritium were analyzed at the University of Arizona Laboratory of Isotope Geochemistry in Tucson, AZ. Water chemistry data for the spring samples are in Appendix III.

CHAPTER 3

Spring Monitoring

Spring Monitoring Descriptions

Based on the 160 springs visited during the Spring Inventory (Phase I), 16 springs located in different geologic formations were selected for a pilot monitoring study (Phase II). These springs were monitored once a month for one year to understand seasonal spring discharge fluctuations and their relationship with regional hydrogeology. These 16 springs were located in the following hydrostratigraphic units:

3 springs in Precambrian Granitic rocks,

2 in regional Mississippian/Devonian Limestone aquifers,

2 in regional Permian Sandstone aquifers,

2 in a shallow Permian Karst Limestone aquifer,

4 in Tertiary and Quaternary Basalt flows,

3 in Tertiary Basin fill and Quaternary Alluvium.

The 16 springs selected were distributed throughout the Middle Verde River watershed (Figure 22) and included all regions of the watershed as well as most geologic or hydrostratigraphic units. Table 8 includes the location, specific geologic units, and discharge (L/s) near the beginning of monitoring in December 2002.

The main recharge events for the aquifers in this region are from winter and spring snowmelt. A small amount of recharge may occur for some springs from monsoon storms in late summer. Recharge is greatest in the higher elevations where

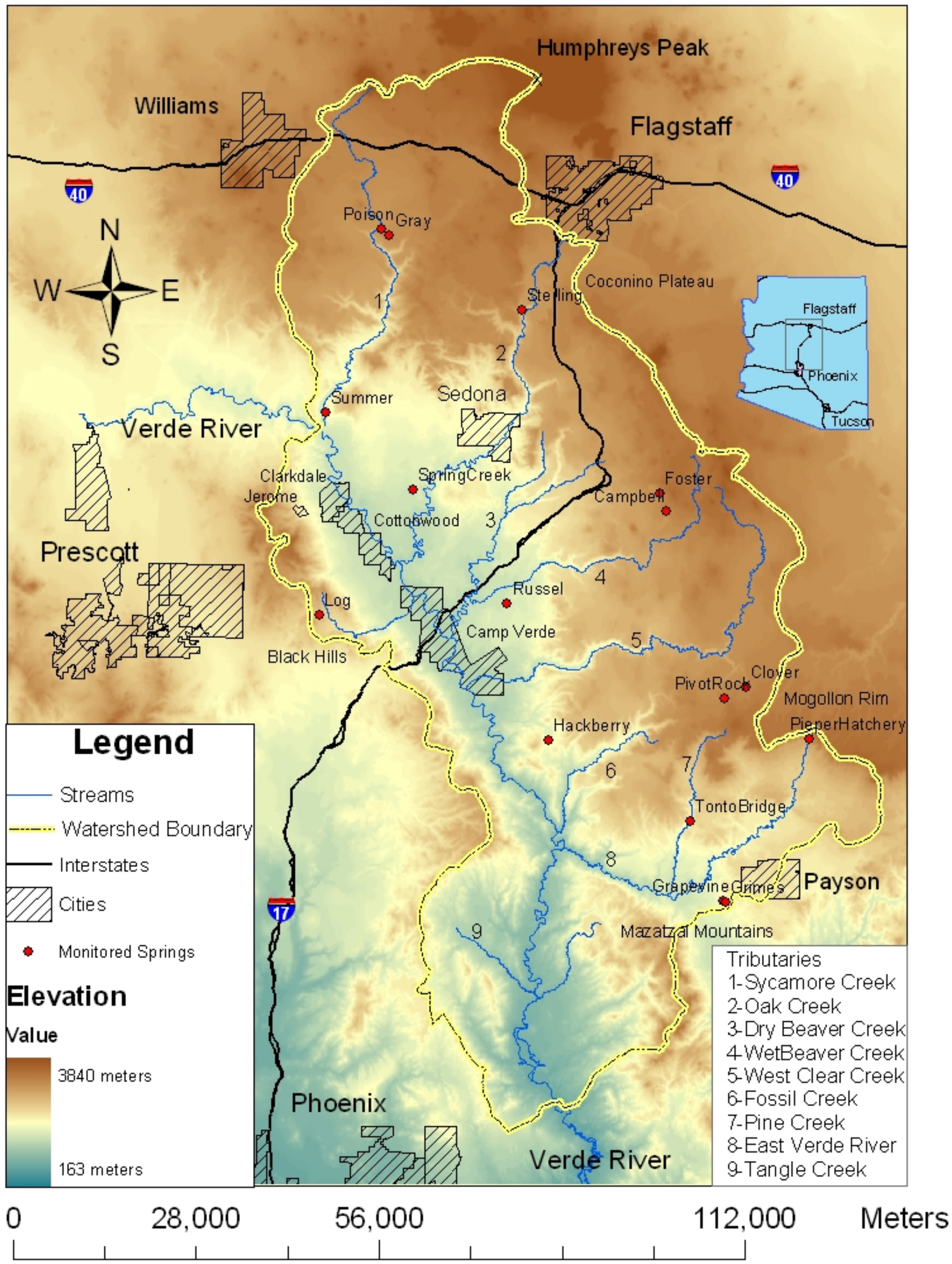

Figure 22 – Locations of springs studied in year-long monitoring for Phase II of the Middle Verde Springs study.

Table 8 – List of springs in Phase II of the Middle Verde springs study by geologic formation.

Name of Springs	Geologic Formation	Location	National Forest	Discharge 12/2002
Foster and Campbell Springs	Tertiary Rim Basalts	Stoneman Lake / Upper Wet Beaver Creek	Coconino	0.03 L/s 0.10 L/s
Poison and Gray Springs	Tertiary Rim Basalts	Upper Sycamore Creek	Coconino	0.70 L/s 0.35 L/s
Clover and Pivot Rock Springs	Kaibab Limestone	Clints Well / Upper West Clear Creek	Coconino	0.00 L/s 0.75 L/s
Sterling Spring	Coconino Sandstone	Upper Oak Creek	Coconino	19.5 L/s
Summer Spring	Redwall / Martin Limestone	Lower Sycamore Creek	Coconino	164 L/s
Spring Creek Spring	Verde Formation / Alluvium	Lower Oak Creek	Coconino	14.5 L/s
Russell Spring	Verde Formation / alluvium	Lower Wet Beaver Creek / Montezuma Well region	Coconino	0.24 L/s
Hackberry Spring	Tertiary Volcanics / Alluvium	Fossil Creek / Hackberry Mtn	Coconino	0.25 L/s
Log Spring	Precambrian Granite	Cherry Creek	Prescott	0.14 L/s
Pieper Hatchery Spring	Schnebly Hill Formation	Upper East Verde River	Tonto	15.3 L/s
Tonto Natural Bridge Spring	Redwall / Naco limestone	South of Pine / Pine Creek	Tonto	6.81 L/s
Grimes and Grapevine Springs	Precambrian Granite	West of Payson / East Verde River	Tonto	0.01 L/s 0.00 L/s

precipitation is higher and fractured rock units of the aquifer are exposed (Bills et al. 2000). Monitoring was designed to describe changes in spring hydrogeology and spring discharge response to recharge throughout the Middle Verde River watershed.

Discharge Variability

Variability in discharge requires multiple measurements. High variability springs can indicate general transport properties of the aquifer and recharge to the system. Spring discharge monitoring data for Phase II (Appendix III) was used to determine spring discharge variability over the period of study for each spring (Table 9). The following two methods were developed for this study where monthly discharges were measured.

Method 1

$$\text{Spring variability} = Q10/Q_{90} \qquad \text{Eq. 1}$$

where:

Q_{10} = monthly discharge which is exceeded 10% of the time.
Q_{90} = monthly discharge which is exceeded 90% of the time.

Variability classes:	1.0 – 2.5	Steady
	2.6 – 5.0	Well Balanced
	5.1 – 7.5	Balanced
	7.6 – 10.0	Unbalanced
	> 10.0	Highly Unsteady
	Infinite	Ephemeral

Method 2

$$\text{Coefficient of Variation} = STD/Mean \qquad \text{Eq. 2}$$

where:

STD = standard deviation of monthly spring discharge
Mean = mean monthly spring discharge.

Variability classes:	0 – 49	Low
	50 – 99	Moderate
	100 – 199	High
	> 200	Very High

Table 9 – Variability of springs in Phase II of the Middle Verde Springs study based on 12 measurements from November 2002 to October 2003.

Spring Name	Q10/Q90 Spring Variability	Q10/Q90 Variability Class	STD/Mean Coefficient of Variation	STD/Mean Variability Class	Geologic Unit
Log	3.7	Well Balanced	35	Low	Granite
Grimes	infinite	Ephemeral	100	High	Granite
Grapevine	infinite	Ephemeral	167	High	Granite
Summer#	1.3	Steady	12	Low	Martin LS
Tonto Bridge	1.6	Steady	17	Low	Naco LS
Pieper Hatchery	5.1	Balanced	72	Moderate	Supai SS
Sterling	1.3	Steady	11	Low	Coconino SS
Clover*	793	Highly Unsteady	226	Very High	Kaibab LS
Pivot Rock	infinite	Ephemeral	243	Very High	Kaibab LS
Foster	12.8	Highly Unsteady	70	Moderate	Basalt
Campbell	14.4	Highly Unsteady	120	High	Basalt
Poison	1.8	Steady	18	Low	Basalt
Gray	1.8	Steady	25	Low	Basalt
Spring Creek	1.3	Steady	13	Low	Verde Fm
Russell	5.6	Balanced	55	Moderate	Verde Fm
Hackberry	6.9	Balanced	77	Moderate	Alluvium

Period of Record from 1999 – 2003, 17 measurements
* Period of Record from 1999 – 2003, 43 measurements
LS = Limestone, SS = Sandstone, Fm = Formation

Hydrograph Variability and Geomorphology of Springs

Precambrian Granites

Log, Grimes, and Grapevine springs are located in Precambrian Granitic rocks. Grimes and Grapevine are small springs located west of Payson. These two springs had only a small increase in discharge during snowmelt in February and March of 2003, but overall had a low variability of flow (Figure 23). These springs support very little riparian dependent vegetation, have no development at the spring and are located in runoff channels. Grimes Spring (Figure 24) seeps into the bottom of a runoff channel creating a small spring channel within the runoff channel. Grapevine Spring (Figure 25) is located in a larger runoff channel and is located at a headcut in the channel. The bottom of the stream bed decreases approximately 3 meters in elevation at the point of spring discharge and flows through a wide sandy channel. Grapevine Spring only had measurable discharges February through April when snowmelt would typically occurs in higher elevations (Figure 23).

Log Spring is located in a runoff channel in the Black Hills region near Cherry. Spring discharge occurred for the entire year of monitoring (Figure 23) and the spring supported a small area of riparian vegetation approximately 250m^2 in area. Also, aquatic fauna were present in ponds at the spring orifice including certain types of snails, fish, and frogs. Discharge emerged from three main sources within the channel at the base of a small granite outcrop. Development at the source consists of a cement spring box at one source with a pipe flowing into a small pond, as well as an old stone spring catchment box 10m downstream from the source which no longer captures any spring flow. The length of flowing stream supported by the spring was approximately 80m

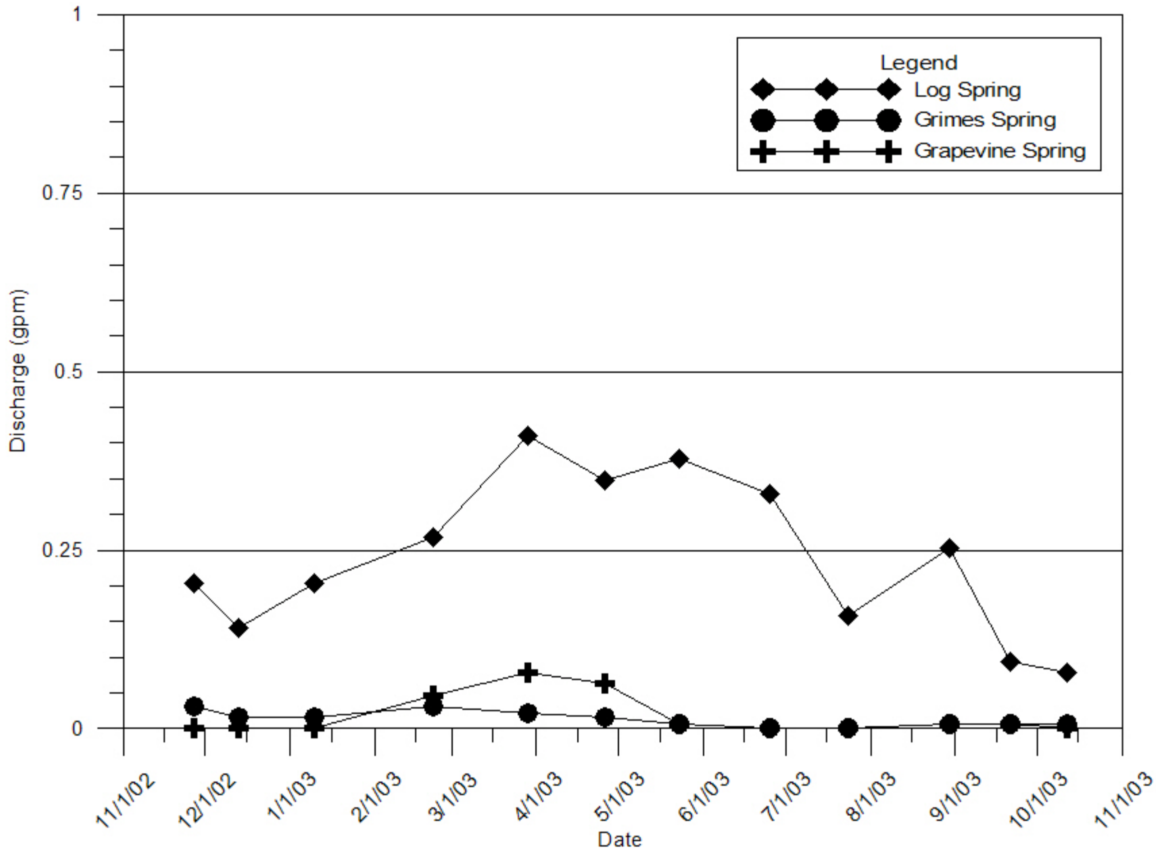

Figure 23 – Hydrograph for Log, Grimes, and Grapevine springs from November 2002 to October 2003 during Phase II of the Middle Verde Springs study. Springs are located in the Precambrian Granite unit.

Figure 24 – Orifice and channel for Grimes Spring on 2/23/03. (Precambrian Granite)

Figure 25 – Orifice and channel for Grapevine Spring on 2/23/03. (Precambrian Granite)

with flow ending at the same point where it infiltrated into the sandy channel each month the spring was visited. A small increase in discharge during peak snowmelt occurred, but was generally a constant perennial discharge with the exception of September and October, 2003 (Figure 23). Between August 31st and September 28th, a large monsoon storm runoff event deposited up to 1 meter of sand at the source of the spring. The orifices of the spring and the supported riparian area were entirely buried with sand. The sand deposited in the channel gradually thinned out downstream from the source and flow reemerged 30m downstream where the sand deposited was only 0.1 meter thick. Discharge measured after the flood (0.06 L/s) was extremely less than discharge before the flood (0.20 – 0.40 L/s, Figure 23). Figure 26 shows the source in January, 2003 (pre-flood) and Figure 27 shows the same view of the source in September 2003 after the source was buried. The Cherry Fire in June of 2003 burned areas in the upper watershed upstream from the spring. The lack of vegetation in these regions upstream created unstable sand at the surface and large amounts of erosion occurred in these regions during high intensity monsoon storms.

Regional Mississippian/Devonian Limestone Aquifer

Summer Spring (Figure 28) and Tonto Natural Bridge Spring (Figure 29) are located in the Martin Formation and Redwall Limestone respectively. Summer Spring had the greatest discharge of all 16 springs monitored. There are several large sources for the spring and spring flow occurs in a spring discharge dominated channel. The spring supports an extensive area of riparian and aquatic vegetation and fauna (0.3 km^2). Spring discharge flows into Sycamore Creek and eventually into the Verde River.

Figure 26 – Source and flow from Log Spring on 1/9/03 (pre-flood)
(Precambrian Granite)

Figure 27 – Source and flow from Log Spring on 9/28/03 (post-flood).
(Precambrian Granite)

Figure 28 – Orifice of Summer Spring on 8/14/2002.
(Regional Limestone Aquifer, Martin Formation)

Figure 29 – Orifice of Tonto Bridge Spring on 10/18/2003.
(Regional Limestone Aquifer, Redwall/Naco Formation)

Discharge from Summer Spring has a low variability and spring discharge measurements taken from 1999 through 2001 (U.S. Forest Service 2001) are similar to measurements taken in 2003 (Figure 30).

Tonto Natural Bridge Spring is located within Tonto Natural Bridge State Park and discharges at the base of a limestone cliff. Flow emerges from two sources, a large developed source where flow is captured and then flows out of the spring box into a developed channel and a small natural source that flows into a developed channel (Figure 31). Spring discharge supports riparian vegetation around the spring channel. Flow variability is extremely low for this spring (Figure 31). Overall the Regional Limestone Aquifer has a low to moderate variability in discharge. Summer and Tonto Bridge Springs appear to have a moderately steady discharge possibly due to longer residence times in the deeper regional aquifer.

Regional Permian Sandstone Aquifer

Pieper Hatchery Spring (Figure 32) and Sterling Spring (Figure 33) discharge from the Schnebly Hill formation and Coconino Sandstone respectively. Pieper Hatchery Spring discharges from two distinct orifices on a steep hillslope. The spring supports a riparian area of 0.2 km^2 and flows approximately 1,000m until merging with the East Verde River. Spring discharge shows a significant increase in discharge during peak snowmelt (March) at 59.7 L/s, which is more than 3 times higher than the mean spring flow of 18.7 L/s (Figure 31). Higher spring discharge variability is due to the location of the spring orifices on a steep hillslope along a contact or fracture within the sandstone and the spring location along the Mogollon Rim, which has high rates of precipitation.

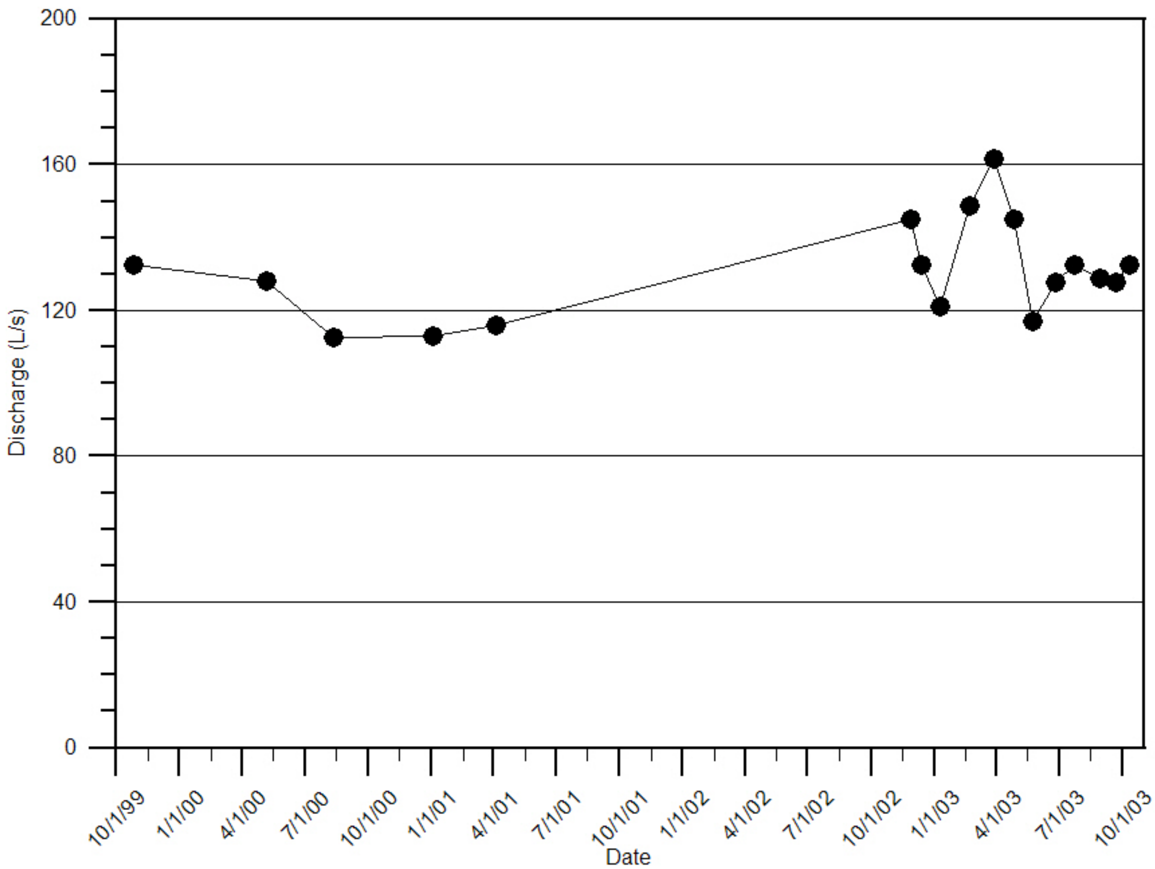

Figure 30 – Hydrograph for Summer Spring from October 1999 to October 2003 during Phase II of the Middle Verde Springs study. Data from 10/1/99 to 10/1/01 taken from U.S. Forest Service (2001). Spring is located in the Regional Limestone Aquifer (Martin Formation).

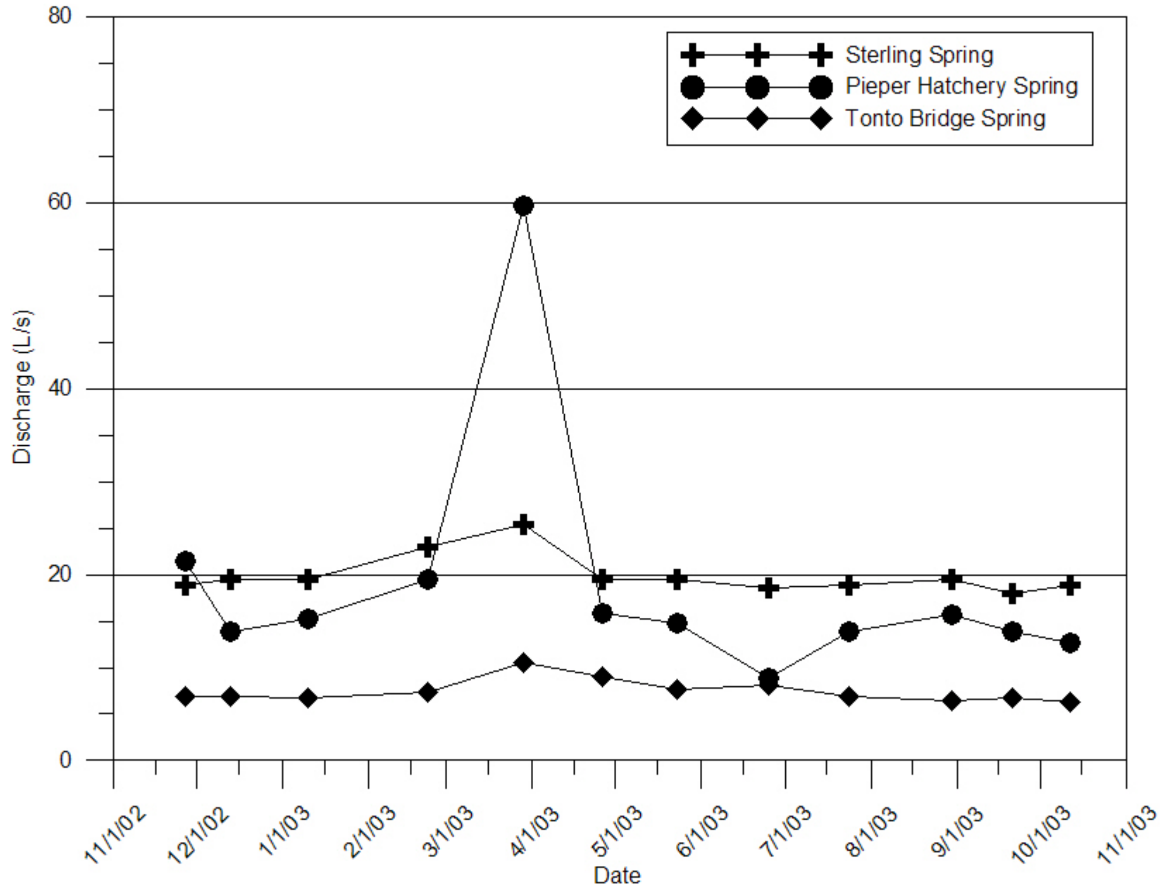

Figure 31 – Hydrographs for Sterling, Pieper Hatchery, and Tonto Bridge Springs from November 2002 to October 2003 during Phase II of the Middle Verde Springs study. Springs are located in the Regional Sandstone Aquifer (Sterling – Coconino Sandstone, Pieper Hatchery – Schnebly Hill Formation) and the Regional Limestone Aquifer (Tonto Bridge – Redwall/Naco Formation).

Figure 32 – Spring flow in channel of Pieper Hatchery Spring on 3/29/03. (Regional Sandstone Aquifer, Schnebly Hill Formation)

Figure 33 – Sterling Spring channel where Sterling fish hatchery discharges spring flow on 3/30/2003. (Regional Sandstone Aquifer, Coconino Sandstone)

Sterling Spring discharges in a tributary to Oak Creek Canyon and is the start of perennial flow for Oak Creek. The spring source has been developed and most of the surface flow is diverted to Sterling fish hatchery located downstream from the source. Spring flow used in the fish hatchery reenters the channel downstream of the source (Figure 33). Sterling Spring only had a slight increase in discharge during peak snowmelt (Figure 31). Overall the Regional Sandstone Aquifer has moderate variability in discharge.

Shallow Permian Limestone Aquifer

Pivot Rock and Clover Springs both discharge from the Kaibab Limestone near Clint's Well in the upper portion of West Clear Creek. Pivot Rock Spring discharges from a karst cave on a limestone cliff along a fracture in the limestone. Discharge for Pivot Rock Spring is highly variable (Figure 34). Figure 35 shows the emergence of Pivot Rock spring in late February with only 1.2 L/s of flow and Figure 36 shows the emergence in late March at peak snowmelt with 71.2 L/s of flow.

Clover Spring discharges into two channels from a developed culvert under Highway 87 from the bedrock orifice. Clover Spring also has a highly variable spring discharge. Figure 37 shows discharge for Clover spring from October 1999 through October 2003 (Anderson, 2004). Discharge dramatically increases during peak snowmelt (March/April) each year with the exception of 2002. The spring was dry the entire year of 2002 due to low amounts of snowfall causing no recharge to the system. Clover Spring is highly dependent on snowmelt for spring discharge throughout the year. Figures 38 and 39 shows Clover Spring in August 2002 (Figure 38) with 0 L/s discharge

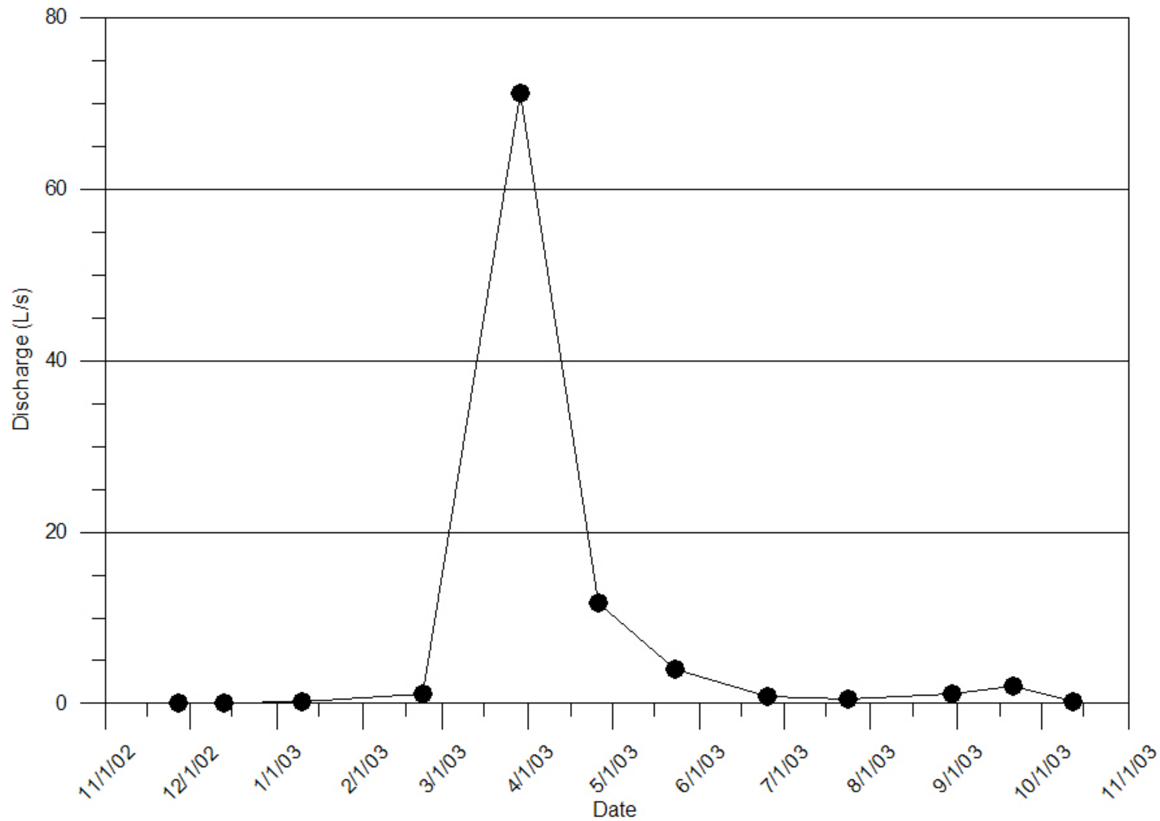

Figure 34 – Hydrograph for Pivot Rock Spring from November 2002 to October 2003 during Phase II of the Middle Verde Springs study. Spring is located in the shallow karst limestone aquifer, Kaibab Formation.

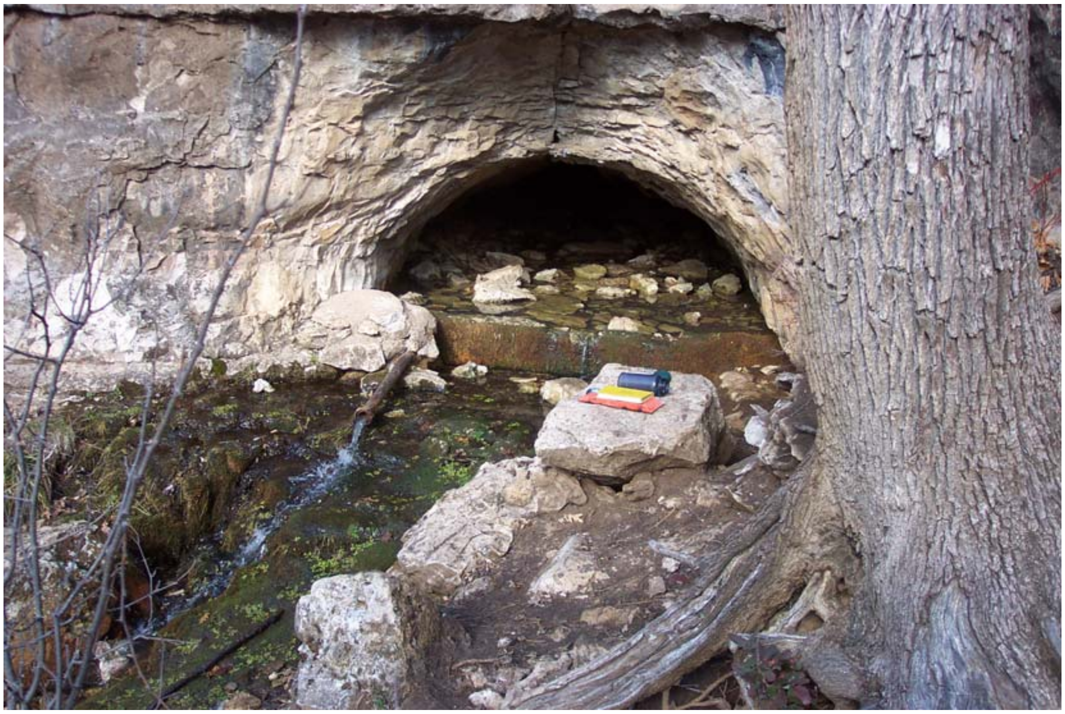

Figure 35 – Orifice and flow from Pivot Rock Spring on 2/23/03 (2 L/s).
(Shallow karst limestone aquifer, Kaibab Formation)

Figure 36 – Orifice and flow from Pivot Rock Spring on 3/29/03 (38 L/s).
(Shallow karst limestone aquifer, Kaibab Formation)

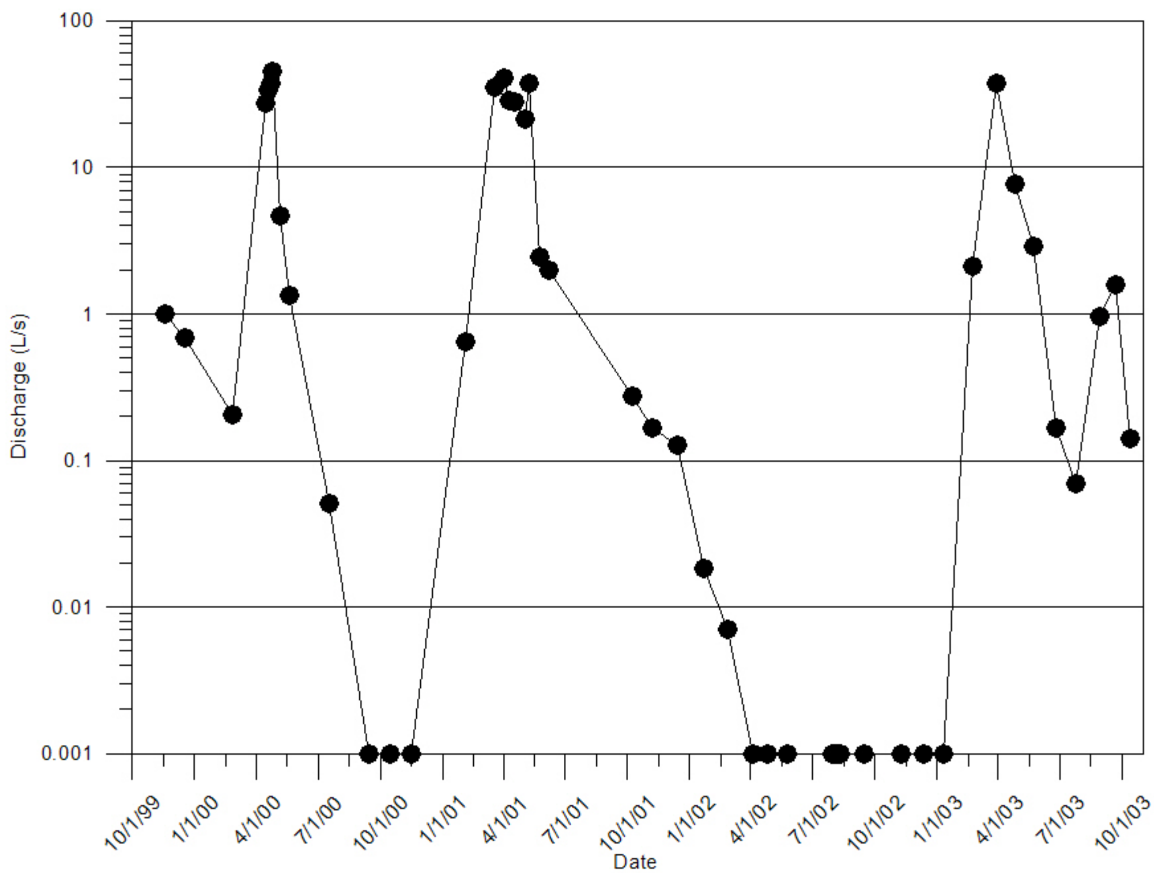

Figure 37 – Semi-log hydrograph for Clover Spring from November 1999 to October 2003 during Phase II of the Middle Verde Springs study (0.001 L/s = No flow/dry). Data from 10/1/99 to 10/1/02 were taken from Anderson et al. (2004). Spring is located in the shallow karst limestone aquifer, Kaibab Formation.

Figure 38 – Orifice and channel of Clover Spring on 8/12/02 (0 L/s).
(Shallow karst limestone aquifer, Kaibab Formation)

Figure 39 – Orifice, channel, and flow from Clover Spring on 8/30/03 (1.2 L/s).
(Shallow karst limestone aquifer, Kaibab Formation)

due to low snowfall earlier in the year and Clover Spring in August of 2003 (Figure 39) with 1.2 L/s due to normal amount of snowfall earlier in the year. Clover Spring also shows a small increase in flow due to late summer monsoon storms (Figure 37).

Flashy immediate response to snowmelt recharge in these karst systems produces dramatic increases in discharge for a short period (Figure 40 and 41) making these springs highly variable. The fractured and karst limestone aquifer creates areas of higher permeability that concentrates flow in conduits to spring discharge locations. High elevation and deep snow pack in winter contribute to higher recharge to the aquifer during peak snowmelt and a small local recharge area for the springs concentrates recharge in one area of discharge.

Tertiary and Quaternary Basalt Flows

Foster (Figure 42) and Campbell Springs (Figure 43) discharge from Tertiary basalt flows near Stoneman Lake. Discharge is moderately to highly variable with a significant increase in discharge during peak snowmelt (Figure 44). These springs discharge on a hillslope (Figure 42) along a fracture in the basalt allowing for the higher flow variability in a perched aquifer. Poison (Figure 45) and Gray (Figure 46) Springs discharge from Quaternary Basalt flows in the upper Sycamore Creek watershed. Discharge from these springs show very little to no change in discharge (Figure 44). These basalt flows do not appear to be fractured and have low variability of spring discharge in the perched aquifer.

Whiting and Moog (2001) reported that hydrographs of spring dominated streams are damped compared to runoff dominated streams that occur in volcanic areas. Peak

Figure 40 – Peak discharge and channel for Clover Spring on 3/29/03.
(Shallow karst limestone aquifer, Kaibab Formation)

Figure 41 – Peak discharge in channel for Pivot Rock Spring on 3/29/03.
(Shallow karst limestone aquifer, Kaibab Formation)

Figure 42 – Orifice and spring flow down hillslope at Foster Spring on 3/28/2003. (Tertiary Basalt flow)

Figure 43 – Orifice and spring box for Campbell Spring on 3/28/2003. (Tertiary Basalt flow)

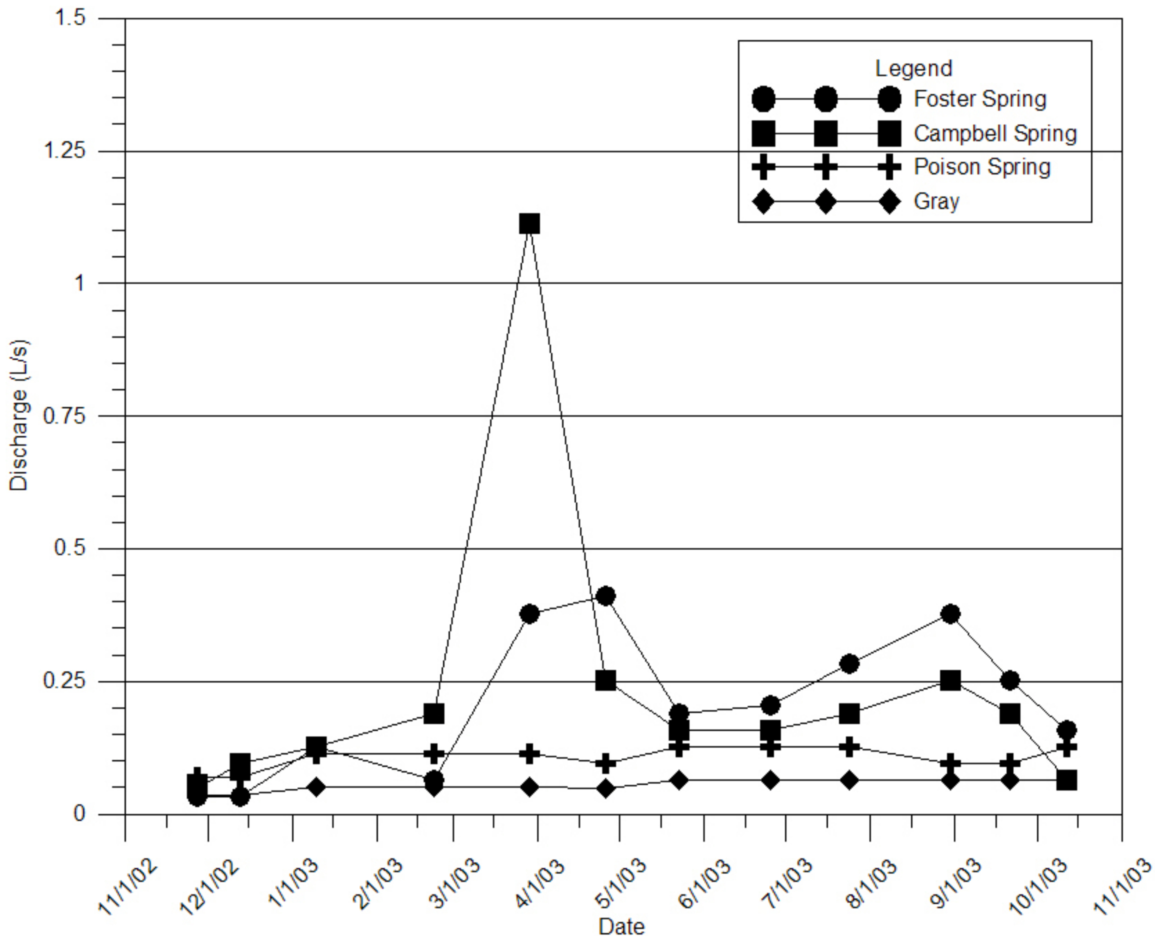

Figure 44 – Hydrographs for Foster, Campbell, Poison, and Gray Springs from November 2002 to October 2003 during Phase II of the Middle Verde Springs study. Springs are located in Tertiary Basalt flows (Foster and Campbell) and Quaternary Basalt flows (Poison and Gray).

Figure 45 – Orifice and flow for Poison Spring on 3/29/2003.
(Quaternary Basalt flow)

Figure 46 – Orifice and spring box for Gray spring on 5/26/2003.
(Quaternary Basalt flow)

flow from the springs and therefore the channels dominated by the spring discharge occur months after precipitation or snowmelt that sources the discharge from the spring. Peak discharge for Foster and Campbell Springs occurs immediately after recharge (snowmelt) indicating the channels are not spring dominated.

Tertiary Verde Formation and Quaternary Alluvium

Spring Creek Spring (Figure 47) discharges from the Verde Formation into Spring Creek. The spring discharges into a spring dominated channel within a runoff drainage. Spring Creek Spring had little to no response to recharge events (Figure 48). Russell (Figure 49) and Hackberry (Figure 50) Springs discharge from the Verde Formation and alluvium overlying Tertiary volcanics respectively. Both springs had a moderate variability in discharge, but had a decreasing trend in discharge during peak recharge events and throughout most of the year (Figure 51).

Hydrogeology of Springs

Total Annual Discharge

Monthly measurements of spring discharge from 11/02 to 10/03 (except for Clover and Summer Springs) were used to estimate total annual discharge in Table 10 using several methods.

Method 1 – Monthly discharge

$$\sum (Q_m) = Q_{jan} + Q_{feb} + \ldots Q_{dec} \qquad \text{Eq. 3}$$

where: Qm = instantaneous monthly discharge for monthly visit is assumed to represent average flow for the entire month.

Figure 47 – Orifice and spring flow for Spring Creek Spring on 1/9/2003. (Tertiary Basin fill and alluvium, Verde Formation)

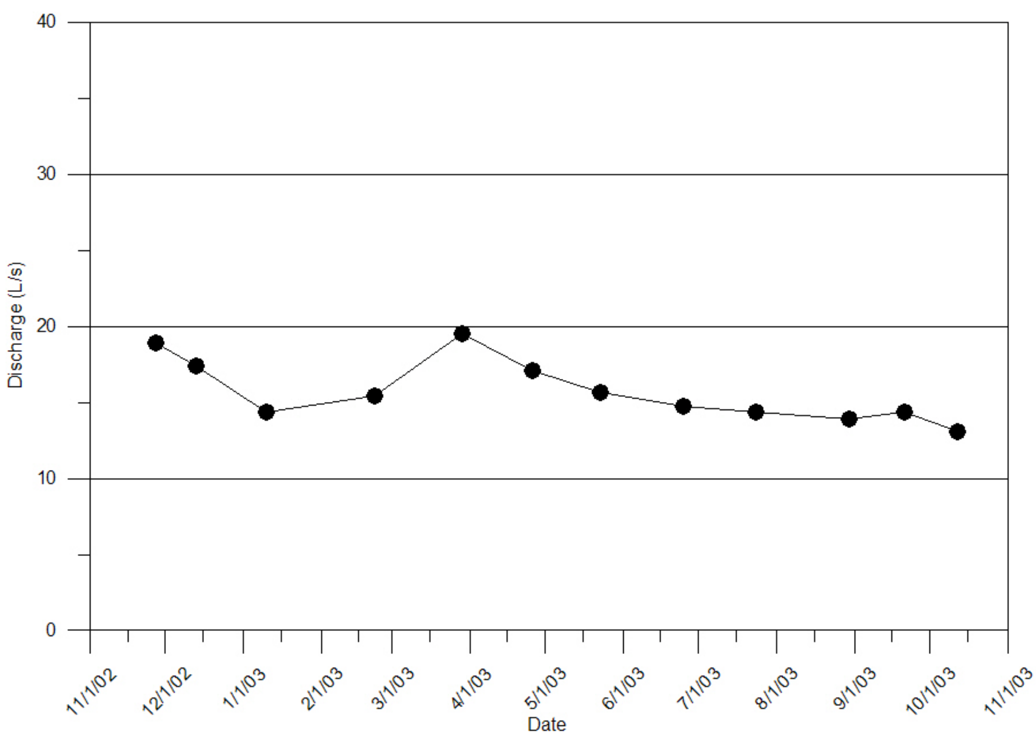

Figure 48 – Hydrograph for Spring Creek Spring from November 2002 to October 2003 during Phase II of the Middle Verde Springs study. (Tertiary Basin fill and alluvium, Verde Formation)

Figure 49 – Orifice and spring flow in channel for Russell Spring on 2/21/03.
(Tertiary Basin fill and alluvium, Verde Formation)

Figure 50 – Orifice and spring flow in channel for Hackberry Spring on 2/21/2003.
(Tertiary Basin fill and alluvium, volcanic alluvium)

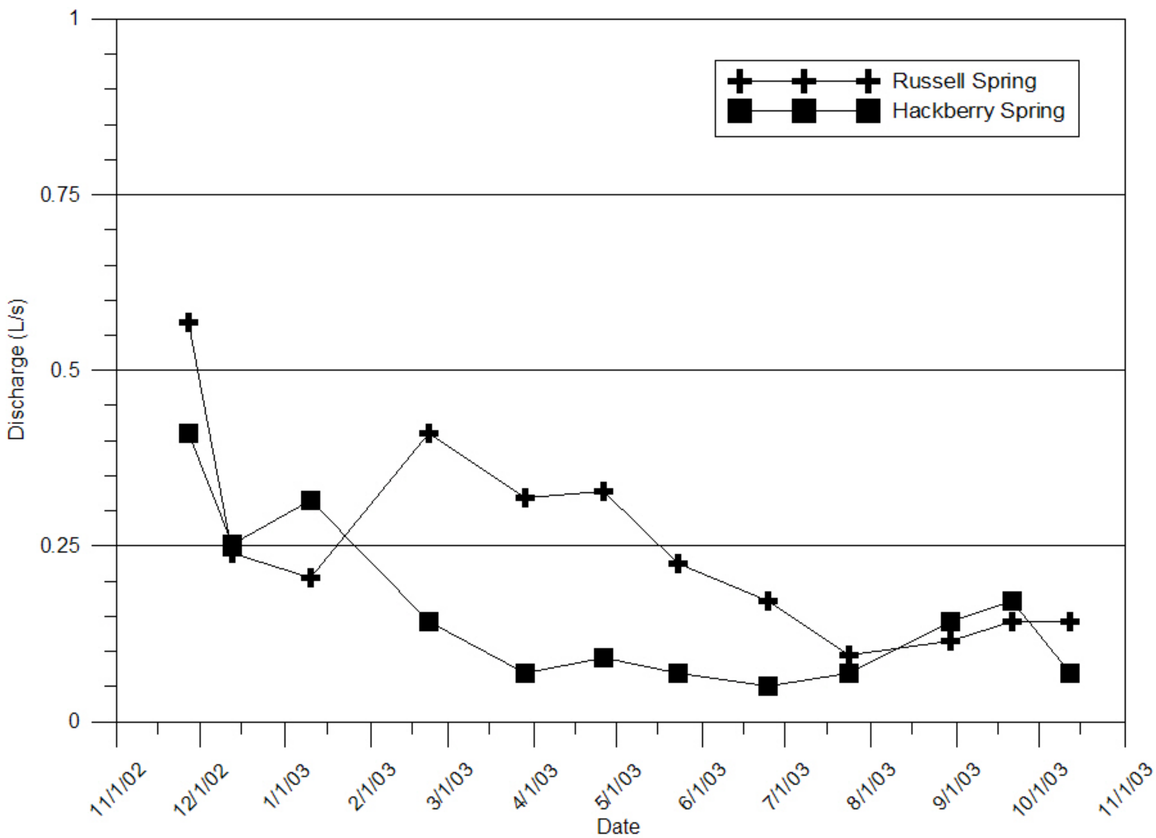

Figure 51 – Hydrographs for Russell and Hackberry Springs from November 2002 to October 2003 during Phase II of the Middle Verde Springs study. Springs are located in the Tertiary basin fill and alluvium (Russell – Verde Formation, Hackberry – volcanic alluvium).

Table 10 – Estimates of total annual discharge for 16 springs in the Middle Verde Springs study.

Spring Name	Method 1 Monthly discharge from Phase II (m^3/year)	Method 2 Monthly average from Phase II (m^3/year)	Method 3 Estimate based on Phase I discharge (m^3/year)	Method 4 Estimate based on Q10 discharge (m^3/year)	Method 5 Average based on Q90 discharge (m^3/year)
Log	7,500	7,500	3,600	12,600	3,470
Grimes	410	410	500	990	0
Grapevine	540	550	0	2,390	0
Summer	4,300,000	4,300,000	5,200,000	4,800,000	3,600,000
Tonto Bridge	240,000	240,000	200,000	320,000	210,000
Pieper Hatchery	590,000	590,000	368,000	1,640,000	315,000
Sterling	630,000	630,000	620,000	790,000	600,000
Clover	140,000	140,000	0	1,200,000	0
Pivot Rock	250,000	250,000	2,400	1,830,000	2,300
Foster	6,600	6,600	560	12,600	990
Campbell	7,500	7,400	1,990	28,000	2,000
Poison	3,300	3,300	2,200	4,000	2,200
Gray	1,700	1,700	2,900	2,000	1,100
Spring Creek	500,000	500,000	340,000	590,000	440,000
Russell	7,700	7,800	7,600	17,000	3,000
Hackberry	4,900	4,900	12,900	12,000	1,800
Total	6,700,000	6,700,000	6,800,000	11,000,000	5,200,000

Method 2 – Monthly average

$$Q_{avg} = (Q_1 + Q_2 + \ldots Q_{12})/12 \qquad \text{Eq. 4}$$

where: Q_{avg} = mean monthly discharge assumed throughout the entire year.

In method 3, the discharge measurements from Phase I for each spring were assumed to represent the spring flow for an entire year and used to estimate total annual discharge based on only a one time measurement of the spring (Table 10).

The first two methods show little to no difference between estimates of total annual discharge because they both use multiple discharge measurements from all 12 months of Phase II monitoring. Since the third method uses only a one time measurement made during low flow for the springs in Phase I of the Middle Verde Springs study, springs with high variability are underestimated for total annual discharge. Clover and Pivot Rock Springs discharging from the karst Kaibab Limestone aquifer and Foster and Campbell Springs discharging from the fractured Basalt perched aquifer are significantly underestimated for total annual discharge using method 3. Using one time measurements, total annual discharge for Pivot Rock Spring was 2,400 m^3/year, but using methods 1 and 2 based on multiple discharge measurements the total annual discharge was more than 100 times higher (250,000 m^3/year). Foster Spring had a total annual discharge more than 10 times higher when using multiple discharge measurements (6,600 m^3/year) versus only a one time measurement (560 m^3/year). Methods 4 and 5 (table 10) use Q_{10} and Q_{90} (Eq. 2) respectively to estimate total annual discharge for each spring to show the difference between estimates taken from measurements at lower spring discharges versus estimates from measurements at higher discharges for highly variable springs. Estimates of total annual discharge for highly variable springs can often be underestimated if using one time measurement during much of the year when spring discharge is lower, but may also be overestimated if one time measurements from peak discharge (during snowmelt) were used to estimate total annual discharge. This indicates that multiple discharge measurements for springs are needed in order to characterize the spring discharge contributing to surface flow in the watershed throughout an entire year.

Aquifer Properties

At certain springs, discharge measurements were used to study regional hydrogeologic processes, and determine hydraulic and transport properties of aquifers. Hydrological timescales characterizing discharge at springs are related to the time of peak discharge at the spring, response of the spring to recharge, and the residence time in the aquifer (Manga 1999). Manga (1999) was able to determine groundwater age for springs discharging from fractured basalts,

$$T_{age} = (\hat{h}\Phi)/\check{N} \qquad \text{Eq. 5}$$

where $\check{N}$ is the mean recharge rate, $\hat{h}$ the mean aquifer thickness, and Φ the effective porosity. Foster and Campbell Springs discharge from fractured basalts and have a high variability of discharge during recharge events (snowmelt). The aquifers are shallow (small $\hat{h}$) and during recharge events these springs would have higher recharge rates in the fractured basalts resulting in a small groundwater age (T_{age}) indicating short residence times for the water.

General properties for Clover and Pivot Rock springs in the Karst Limestone can be estimated from variability. General transmissivity and specific yield values for the unconfined Karst aquifer can be determined using hydrograph recession curves for the springs. Baedke and Krothe (2001) were able to identify distinct portions of the hydrograph recession curve for karst springs from hydrograph recession of spring response to storm events over several days. They identified conduit flow, diffuse matrix flow, and intermediate flow from small fractures between conduit and diffuse flow. Baedke and Krothe (2001) determined ratios of transmissivity and specific yield from the following equation,

$$T/S_y = [\{\log(Q_1/Q_2)\}/(t_2-t_1)] * [L^2/1.071] \qquad \text{Eq. 6}$$

where T is transmissivity, S_y is specific yield, Q_1 and Q_2 are the discharge values at the beginning and end of the recession curve respectively, t_1 and t_2 are the time at the beginning and end of the recession curve respectively, and L is the distance from the discharge point to the drainage divide.

Response of Clover and Pivot Rock Springs to recharge from snowmelt over a several month period was assumed to be similar to response of karst springs to recharge from storm events over a several day period. Equation (6) was used to determine transmissivity and specific yield for Clover spring based on three recessions (2000, 2001, and 2003, Figure 43) and for Pivot Rock Spring based one recession (2003, Figure 39). Only the conduit component of flow was able to be identified for the hydrograph recessions for the springs because monitoring was not continuous and occurred over a longer period of time. Therefore estimates of transmissivity to specific yield ratios were not done for intermediate or diffuse flow. Estimates of transmissivity to specific yield ratios for conduit flow in the unconfined karst aquifer are shown in Table 11. The estimated variable L for both springs ranged from 3000 to 6000 meters creating a range of T/S_y values. Specific yield was assumed to be 1.0 since flow during the conduit

Table 11 – Estimations of transmissivity and specific yield using discharge hydrograph analysis (Baedke and Krothe 2001) for Clover and Pivot Rock Springs from Phase II of the Middle Verde Springs study. *Results form Baedke and Krothe (2001).

Spring	T/S_y (m^2 s^{-1})	S_y	T (m^2 s^{-1})
Clover 2000	10.3 – 23.3	1.0	10.3 – 23.3
Clover 2001	3.9 – 8.8	1.0	3.9 – 8.8
Clover 2003	3.1 – 7.1	1.0	3.1 – 7.1
Pivot Rock 2003	2.1 -11.5	1.0	2.1 -11.5
Spring A*	0.21 -1.1	1.0	0.21 – 1.1
Spring C*	3.8	1.0	3.8

component represents flow moving directly from open conduits to the point of discharge. Estimates for conduit transmissivity in the karst aquifer in this region based on spring hydrograph analyses ranges from 2.1 to 23.3 m^2 s^{-1}. Estimated transmissivity values from Baedke and Krothe (2001) in table 11 are similar to the lower range of transmissivity values estimated in this study.

Spring Chemistry

Major cations and anions are plotted on a Piper Diagram (Fetter 1994) for 11 of 16 springs (Figure 52). Spring waters for all 11 springs were classified for cations as calcium type dominant and for anions as carbonate type dominant. No significant variability was seen in the anions of the spring waters with all 11 springs having greater than 90% HCO_3 + CO_3, but the springs discharging from the Verde formation (Russell and Spring Creek) and alluvium (Hackberry) have slightly higher values of Cl than the other spring waters. Spring waters from springs discharging from the Regional Limestone (Tonto Bridge and Summer), Regional Sandstone (Pieper Hatchery and Sterling), and Upper Kaibab Limestone Aquifer (Clover) are dominated by Ca and Mg

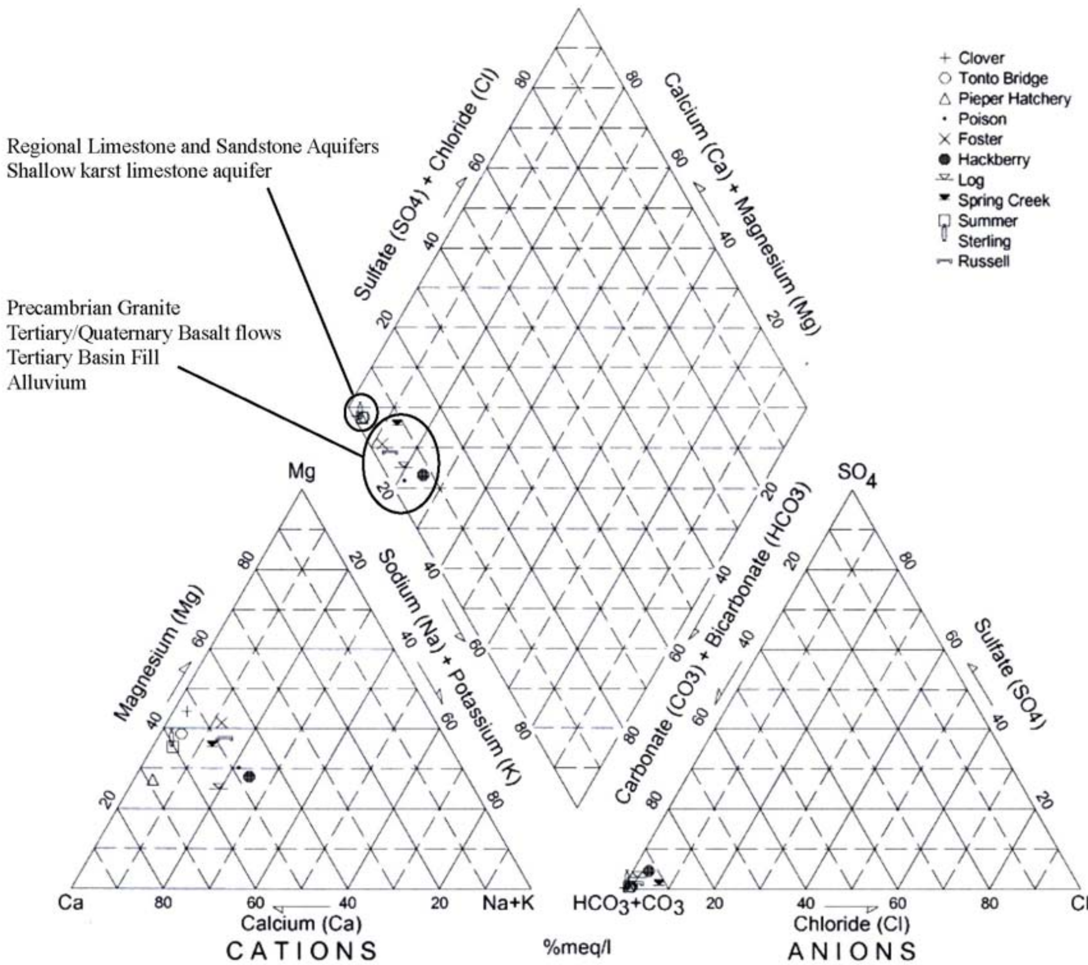

Figure 52 – Piper Diagram from water chemistry data from 11 springs in Phase II of the Middle Verde Springs study.

cations with less than 10% Na + K. The chemical composition of the spring waters for cations shows a shifting toward Na + K for springs discharging from the Verde Formation, alluvium, and basalts (Poison and Foster Springs) with Na + K between 10% and 30%. Hackberry and Log Springs have the highest percent of Na + K and discharge from alluvial channels with felsic volcanic and granite bedrock respectively. Log and Hackberry Springs also are significantly higher in Manganese than the other springs with Log Spring having a concentration of 2,200 μg/L. Complete geochemistry data for waters from these 11 springs are located in Appendix IV.

Stable Isotopes

Stable isotope analyses were used to characterize the chemistry of the water discharging from springs in the Verde River watershed. Stable isotopes can be used to identify original sources of the water and determine groundwater flow characteristics (Ingraham 2001). $\delta^{18}O$ and δD values vary seasonally, being depleted of these isotopes in the winter season and containing higher values in the summer. The stable isotope values indicate whether water that ultimately discharges in these springs is influenced and sourced by monsoon rains or snowmelt recharge to the aquifers.

The $\delta^{18}O$ and δD analyses results for 11 of the 16 springs in Phase II were plotted with a meteoric water line (Figure 53) and compared with water data from the springs. Deviations from the meteoric water line can indicate local meteoric waters, sources of waters, and residence times in the aquifer. Only Hackberry Spring deviates from the meteoric water line (Figure 53) indicating that water discharging from this spring is younger and has a shorter residence time in the alluvial aquifer. Hackberry Spring has a

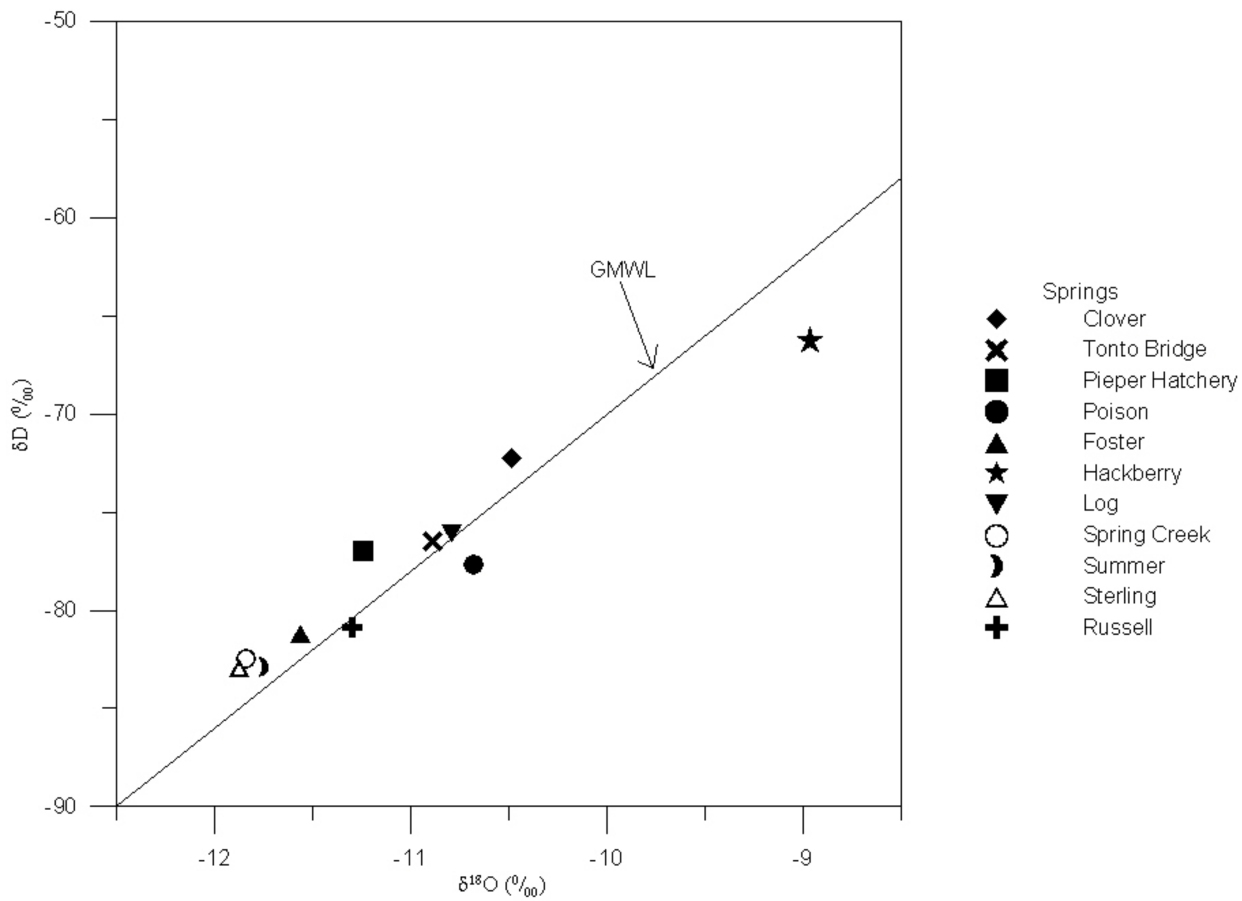

Figure 53 – Relation between δ^{18}O and δD for 11 of the 16 springs in Phase II of the Middle Verde Springs study (October 2003). Global meteoric water line (GMWL; $\delta D = 8\delta^{18}O + 10$, Craig 1961) is shown for reference.

mean $\delta^{18}O$ value of -9.0 ‰ and these heavier $\delta^{18}O$ values may indicate that summer monsoons could influence Hackberry Spring. Sterling and Summer springs discharging from the Regional Aquifers and Spring Creek discharging from the Verde Formation show the lightest $\delta^{18}O$ values of all the springs. This indicates that these springs have longer residence times in the Regional aquifer. Spring discharge into Spring Creek from the Verde Fm. is likely sourced from adjacent regional bedrock aquifer accounting for the longer residence time. Except Hackberry Spring, Clover Spring has the heaviest $\delta^{18}O$ values due to the shorter residence times in the karst aquifer near the area of recharge. The mean values for $\delta^{18}O$ and δD values from December 2002, May 2003, and December 2003 are -11.0 and -78 ‰ respectively. Most of the spring water $\delta^{18}O$ values range from -10.5 to -11.9 ‰ and δD values range from -73 to -83 ‰ except for Hackberry Spring ($\delta^{18}O$ = -9.0 ‰, δD = -66 ‰). The $\delta^{18}O$ and δD values are higher than other values in the Southwestern United States. $\delta^{18}O$ values of spring waters from Grand Canyon National Park range from -11.4 to -13.5 ‰ and δD values range from -86 to -97 ‰ (Ingraham et al. 2001).

Comparing measured $\delta^{18}O$ and δD over time and between different springs can be an indicator of the age, changes in source, and possibly mixing of the waters that are ultimately discharging from the springs in the Verde Valley. Also, Rademacher et. al. (2002) indicated that if relative precipitation is low in winter months then $\delta^{18}O$ values may change to reflect precipitation from summer storms. Precipitation was extremely low in the winter of late 2002 and early 2003. There is no significant difference in $\delta^{18}O$ from December 2002, May of 2003, and October 2003 (Table 12) and therefore does not reflect summer monsoons or indicate different waters recharging the springs.

Table 12 – Stable Isotope results for $\delta^{18}O$ of springs waters for 16 springs in Phase II of the Middle Verde Springs study.

Spring	$\delta^{18}O$ Stable Isotopes			
	December 2002*	May 2003*	October 2003^	Mean
Log	-10.75	-10.83	-10.8	-10.8
Grimes	nd	nd	nd	nd
Grapevine	nd	nd	nd	nd
Summer	-11.70	-11.68	-11.7	-11.7
Tonto Bridge	-10.77	-10.68	-10.9	-10.8
Pieper Hatchery	-11.27	-11.21	-11.2	-11.2
Sterling	-11.73	-11.80	-11.9	-11.8
Clover	nd	-10.99	-10.5	-10.7
Pivot Rock	-11.41	-11.32	nd	-11.4
Foster	nd	-11.54	-11.6	-11.6
Campbell	nd	-10.96	nd	-11.0
Poison	-10.52	-10.55	-10.7	-10.6
Gray	nd	nd	nd	nd
Spring Creek	-11.74	-11.79	-11.8	-11.8
Russell	-10.97	-11.17	-11.3	-11.1
Hackberry	-9.05	-8.87	-9.0	-9.0
Mean Value (All Springs)	10.99	11.03	-11.0	-11.0

nd = no data
*Water samples analyzed by the Colorado Plateau Stable Isotope Lab
^Water samples analyzed by the USGS.

CHAPTER 4

Spring Classification System

Significance of Classifying semi-arid Springs

Springs are places where groundwater flows naturally from bedrock or soil onto the land surface or into a body of surface water (Wilson and Moore 1998). Physical parameters of springs up to their point of discharge have historically been classified (Bryan 1919 and Meinzer 1923), but few studies have classified springs beyond their point of discharge. Meinzer (1923) described 11 physical and chemical classifications for springs (Table 13) and eight classes based on the quantity of discharge for the spring (Table 14). Clarke (1924) considered three criteria to be most important for springs classification: geologic origin, physical properties, and geochemistry. Types of springs have typically been based on the geologic origin by which the groundwater discharges at the surface as shown in Figure 54 (Fetter 1994). Alfaro and Wallace (1994) and Wallace and Alfaro (2001) recently updated many historical classifications for springs, but these and previous classifications of springs describe certain types of springs and do not consider many ecological characteristics of the spring after the point of discharge.

Arizona has the second highest density of springs in the Western U.S. (0.017 springs/km^2), but more than 50% of the springs have not been recognized or mapped (Springer et al. 2004). Many springs in the Verde River watershed in Central Arizona thought to be perennial have been found to be dry based on the 2002 spring inventory

Table 13 – Meinzer (1923) 11 physical and chemical classifications for springs.

#	Classification
1	Character of openings through which the water issues.
2	Rock structure and resulting force that brings the water to the surface.
3	Lithologic character of the aquifer.
4	Geologic horizon of the aquifer.
5	"Sphere" into which the aquifer is discharged.
6	Quantity of water discharged.
7	Uniformity in the rate of discharge.
8	Permanence of the discharge.
9	Quality of the water.
10	Temperature of the water.
11	Features produced by the springs or otherwise related to them.

Table 14 – Eight Meinzer (1923) discharge classes.

Magnitude	**Mean discharge (gpm)**	**Mean discharge**
First	> 44,880	> 10. m^3/s
Second	4,488 – 44,880	1.0 – 10. m^3/s
Third	448.8 – 4,488	0.10 - 1.0 m^3/s
Fourth	100 – 448.8	10. – 100 l/s
Fifth	10 – 100	1.0 – 10. l/s
Sixth	1.0 – 10	0.10 – 1.0 l/s
Seventh	0.12 – 1.0	10. – 100 ml/s
Eighth	< 0.12	< 10. ml/s

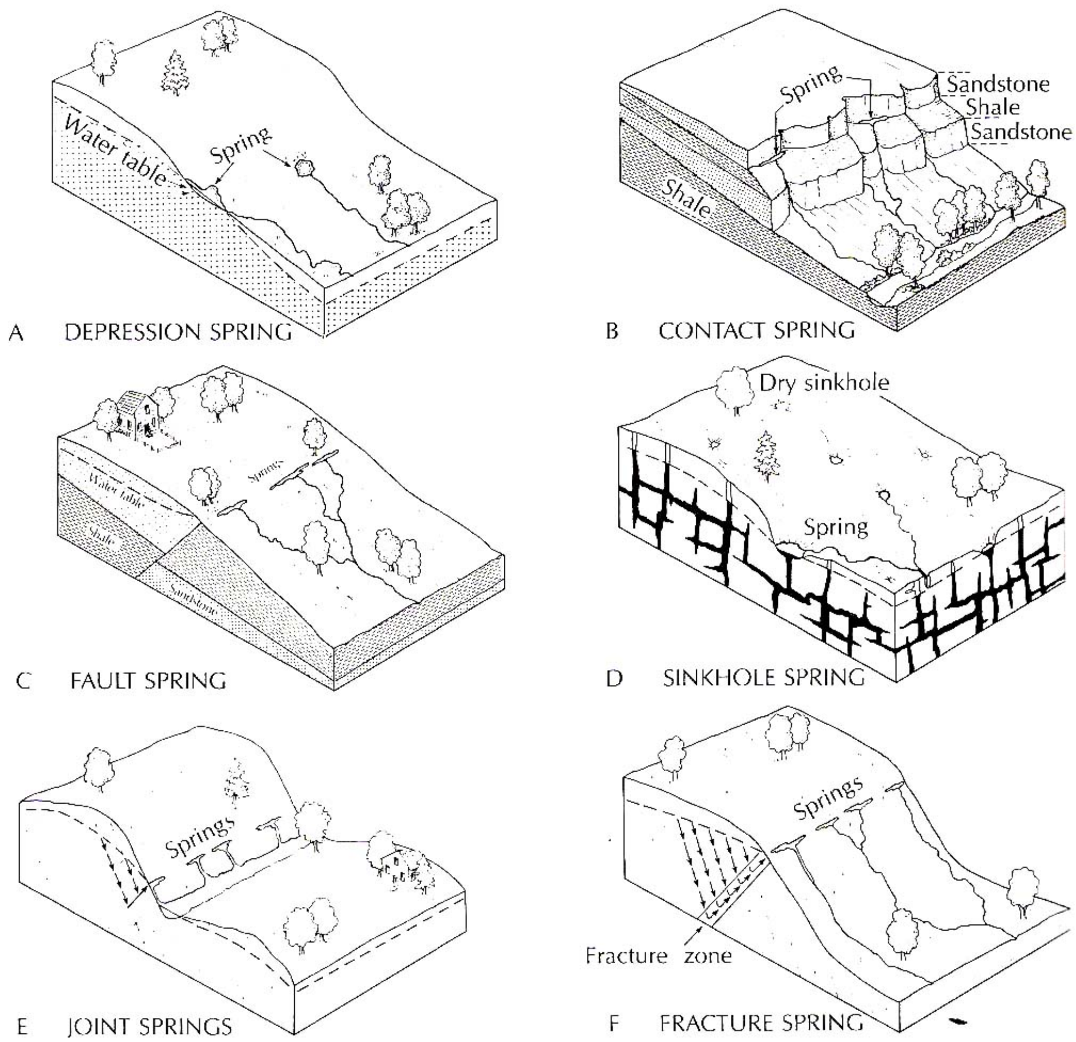

Figure 54 – Types of springs from Fetter (1994).

completed in Phase I of this study. This indicates that certain properties of springs can be variable and require multiple site visits to be classified properly.

Classification for Verde Springs Database

Springer et al. (2004) developed an integrated springs classification system based on previous efforts (Meinzer 1923; Alfaro and Wallace 1994), as well as new ecological and cultural classifications. A modified preliminary version of this classification system (Appendix V) was applied to 160 springs in the Verde watershed based on data collected during the single visit in Phase I of this study and year long monthly monitoring data collected for 16 of these springs during Phase II of this study. Only 21 classes out of a total of 60 classes were able to be classified using the collected data for the 160 springs (Table 15).

Physical and Geomorphic Classifications

The hydrostratigraphic unit of a spring can be classified as Igneous, Sedimentary, Metamorphic, or mixed (Meinzer 1923). Unconsolidated rock units such as alluvium were classified as sedimentary rocks. It is possible that water may travel through multiple rock units before discharging at the surface resulting in a mixed classification. In some cases detailed information on the aquifer would be needed to properly classify the hydrostratigraphic unit. Springs in the Verde watershed were classified based on the geologic unit at the point of discharge. Roughly 2/3 of the springs were classified as Igneous and 1/3 of the springs from Sedimentary rocks (Table 16). Two springs were classified as mixed because they discharge from alluvium above volcanic rocks.

Table 15 – Classes used to classify 160 springs from Phase I of this study in classification system (Springer et. al. 2004). Percentage of springs classified is listed if not 100%.

Category of Classifications	Classes used for Verde Springs Data	Classes unable to be determined from Verde Springs Data
Physical and Geomorphic	Hydrostratigraphic Unit Emergence Environment Aperture Geomorphology Sphere of Discharge Spring Channel Forcing Mechanisms	Persistence
Hydrological	Flow consistency Flow Rate Flow Variability (12%)	
Geochemical	Temperature (54%) TDS (24%) pH (54%) Major Cations (10%) Major Anions (10%)	Minor constituents Pollution Indicators Tracers Alkalinity Nutrient Concentration
Climatological	Elevation Surrounding Ecosystem	Air Temperature Precipitation Seasonality Growing Season
Biological	Biogeographic Isolation Habitat Size	Microhabitat Microhabitat Diversity Plant Species Richness Vegetation Diversity Invertebrate Species Richness Invertebrate Diversity Animal Species Richness Animal Diversity
Cultural	Land Ownership Primary use Microhabitat modification	Legal Authorities Land use history Prehistoric history Secondary uses Other uses Groundwater modification Emergent flow regulation Ecosystem health Data Management Original Data Data quality controls

Table 16 – Summary of the Physical and Geomorphic Classes for springs in the Middle Verde Springs study.

Class (% of springs classified)	**Types**	**# of springs**	**% of springs**
Hydrostratigraphic unit	Igneous	107	67.3
100%	Sedimentary	50	31.4
	Metamorphic	0	0.0
	Mixed	2	1.3
Emergence environment	Cave	6	3.8
100%	Subaerial - Prairie	19	11.9
	Subaerial - Channel	73	45.9
	Subaerial - Canyon Floor	15	9.4
	Subaerial - Canyon Wall	4	2.5
	Subaerial - Mountainside	40	25.2
Aperture geomorphology	Seepage or filtration spring	139	87.4
100%	Fracture spring	4	2.5
	Tubular spring	2	1.3
	Contact spring	14	8.8
Sphere of discharge	Cave	1	0.6
100%	Limnocrene	5	3.1
	Rheocrene	106	66.7
	Helocrene	32	20.1
	Hillslope	9	5.7
	Gushette	1	0.6
	Hanging garden	5	3.1
Spring channel	Spring	69	43.4
100%	Runoff	89	56.0
	Combined	1	0.6
Forcing mechanisms	Gravity Driven	159	100.0
100%			

Emergence environments of springs can vary from in-cave springs, various subaerial springs, subaqueous freshwater springs, and subaqueous marine springs. In the Verde watershed study, there were no springs classified as subaqueous (freshwater or marine). Subaqueous springs may require detailed information of the groundwater and surface-water interaction and typically are more difficult to find and classify. All of the springs for the Verde watershed study were classified as various subaerial environments (Table 16) and cave springs (Figure 35). The largest amount of springs discharge from channel (45%) and mountainside (25%) subaerial environments.

Aperture Geomorphology refers to geologic influence on the emergence of the spring at the surface and occurs in several geomorphic environments (Appendix V). The most common classification for springs in the Verde watershed are seepage or filtration springs (Table 16) where groundwater is exposed or flows from the surface due to filtration through permeable material. Filtration or seepage springs are similar to Depression springs shown in Figure 54A. Most of the springs were classified this way because not enough information about the aquifer and geologic setting of the spring was known and it was assumed to be a seepage or filtration spring. Springs with detailed geologic information or with flow variability indications were classified as fracture, tubular, and contact springs. Many of contact springs occur along the Mogollon Rim in the watershed where there is higher topographic relief similar to that shown as a contact spring in Figure 54B. Two tubular springs occur in the karst environment of the Kaibab Formation and are similar to the sinkhole springs in Figure 54D. Fracture springs include springs similar to those illustrated in fault, joint, and fracture springs in Figure 54C,E,F.

The Sphere of Discharge classifications were based on Meinzer (1923) and Hynes (1970) classifications. Hynes (1970) used three classes. Springs from Phase I were classified using only these three classes for the initial spring inventory in this study. In this classification 7 out of 11 classes were used for springs in the Verde watershed (Table 16). Roughly 2/3 of the springs were classified as rheocrene (Figure 14). Springs without surface flow that appeared to be flowing springs if surface flow was present were classified as rheocrene. Another 20% of the springs were classified as Helocrenes (Figure 15) and 3% as Limnocrenes (Figure 16). Other classes that were present in the Verde watershed include cave (Figure 35), hillslope (Figure 42), gushette (Figure 55), and hanging garden (Figure 56). Some springs that have a highly variable discharge rate can create multiple spheres of discharge over time and need multiple visits to be classified properly. Pivot Rock Spring was classified as a gushette spring based on high flow in winter months observed in Phase II of this study when a high discharge of water gushes out of the cliff.

The channel of the spring can be classified as spring-dominated, runoff-dominated or a combination of the two. If a flowing spring feeds the stream headwaters and there is little to no runoff contributing to the stream flow, the stream is classified as a spring-dominated stream (Whiting and Stamm 1995). A spring with a relatively constant discharge typically has a distinctly defined channel created from spring flow (Figures 14 and 28). If the spring discharges to a channel that has significant components of runoff, it is classified as a runoff-dominated stream (Figure 49 and 50). In a few cases, springs with a relatively constant discharge can flow into a runoff-dominated channel but also have a distinctly defined smaller channel within the larger runoff channel and are

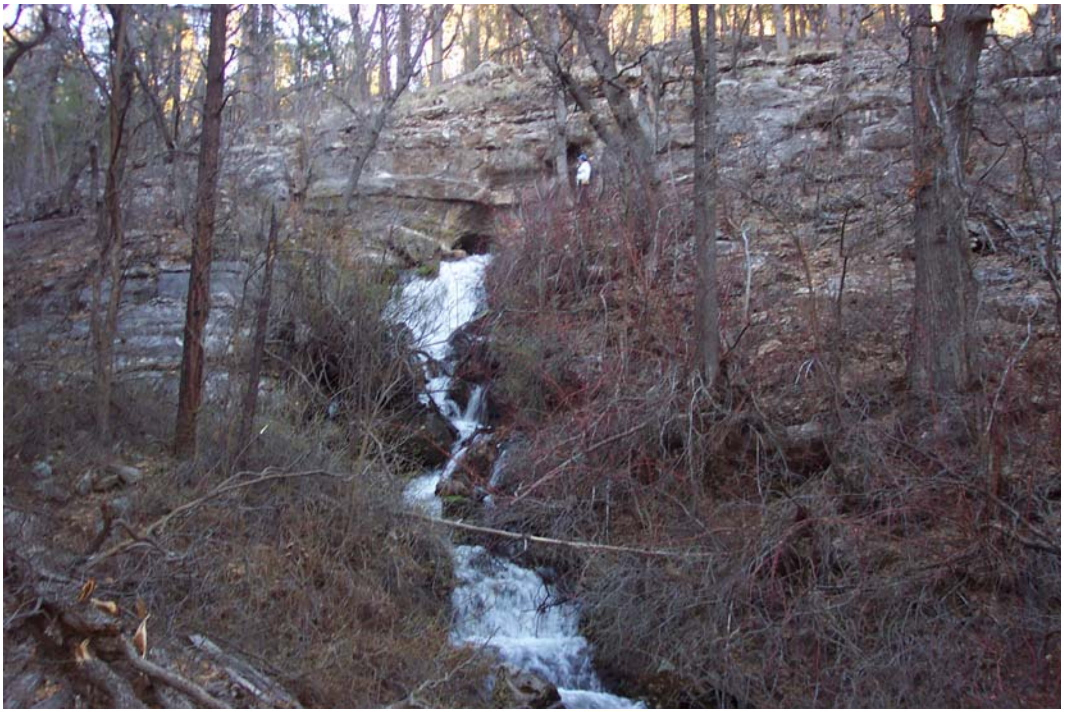

Figure 55 – Gushette Spring (Pivot Rock Spring 3/28/03).

Figure 56 – Hanging Garden Spring (Dripping Spring #1 10/11/02).

classified as a combination spring channel (Figure 24). Roughly half of the springs were classified as spring-dominated channels and half were classified as runoff dominated, with one spring classified as a combined channel (Table 16).

Classification for the flow forcing mechanisms of a spring may be difficult to determine from a site visit to a spring and may require additional information about the subsurface flow of groundwater. All of the springs in the Verde watershed were classified as gravity driven springs where groundwater flow is directed down gradient in the aquifer and discharges at the spring location. No detailed information was gathered on these springs and they were all assumed to be gravity driven springs. Flow persistence was not classified for these springs due to lack of historical data for these springs.

Hydrological and Chemical Classifications

Meinzer (1923) defined two classes of spring perenniality or flow consistency. Springs are considered to be perennial if they discharge continuously, or intermittent if their discharge is naturally interrupted or sporadic. Intermittent springs were broken into three classes including intermittent regular springs (flow and dry on regular basis), intermittent erratic springs (flow and dry on erratic basis), and intermittent dry springs (typically dry). Multiple observations of a spring are required to determine the consistency of discharge. Only 16 springs in the Verde watershed had multiple discharge measurements for flow consistency classification. All of the other 144 springs were classified based on the one time discharge measurements and were classified as perennial if there was spring discharge at the time of visit and intermittent dry if there was no spring discharge at the time of visit. Therefore the majority of springs were classified in these two categories (Table 17). One spring of the 16 springs with multiple measurements was classified as intermittent-regular with seasonal flow and one spring was classified as intermittent erratic with no pattern to flow.

Flow Rate classifications were based on eight discharge classes by the magnitude of discharge from a spring between less than 10 ml/s and greater than 10 m^3/s (Table 14) developed by Meinzer (1923). Springer et al. (2004) reversed the order of this classification and added an unmeasureable class (Appendix V). Because the discharge of many springs varies temporally, the flow rate class will change depending on the time of measurement. For springs in the Verde watershed study roughly half were classified as unmeasureable and the majority of the remaining springs were classified as second (10 - 100 ml/s) and third (0.1 – 1.0 L/s) class discharge rates (Table 17). Three of the 16 springs with multiple discharge measurements had multiple discharge classes. This indicates that many of the springs classified with one time measurements may also have multiple discharge classes.

Meinzer (1923) considered three levels of springs discharge variability: constant, subvariable, and variable. Netopil (1971) and Alfaro and Wallace (1994) used flow duration statistics to calculate a discharge variability ratio (CDR): CDR = $Q_{10\%}/Q_{90\%}$, where $Q_{10\%}$ is the high flow exceeded 10% of the time and $Q_{90\%}$ is the low flow exceeded 90% of the time. Calculation of these flow rates requires monitoring over a certain period of time. Steady discharge results in a CDR of one (extraordinarily balanced), while wildly varying flows may produce CDR >10 (extraordinarily unbalanced, Appendix V). Only 12% of the springs from this study were able to be classified because only 19 springs have multiple discharge measurements from monitoring. Using the CDR,

Table 17 – Summary of the Hydrological Classes for springs in the Middle Verde Springs study.

Class (% of springs classified)	**Types**	**# of springs**	**% of springs**
Flow Consistency	Perennial	81	50.9
100%	Intermittent - regular	1	0.6
	Intermittent - erratic	1	0.6
	Intermittent - dry	76	47.8
Flow Rate	unmeasureable	76	47.8
100%	first	5	3.1
	second	27	17.0
	third	32	20.1
	fourth	11	6.9
	fifth	4	2.5
	sixth	1	0.6
	seventh	0	0.0
	eighth	0	0.0
Flow Variability	Steady	6	3.8
12%	Moderately (well) balanced	1	0.6
	Balanced	6	3.8
	Moderately unbalanced	0	0.0
	Highly Unsteady	4	2.5
	Ephemeral	2	1.3
	unclassified	140	88.1

the springs were spread out in the classification with many springs classified as steady, balanced, and highly unsteady (Table 17). Two springs were classified as ephemeral, but one had a discharge ranging from 0 – 67 L/s while the other ranged from 0 – 0.1 L/s.

Several classifications were developed for the geochemistry of the water discharging from the springs. Temperature classifications were based on a comparison of springs water temperature with the mean annual air temperature (Appendix V). Only 54% of springs in this study were able to be classified. The majority of springs were classified as normal but several springs were classified as cold, warm, and hot (Table 18). Total dissolved solids (TDS) classifications were based on five classifications (Fetter 1994) from specific conductance measurements (Appendix V). Only 25% of springs in this study were able to be classified and the majority of springs were classified as fresh with only a few brackish and hyperfresh springs (Table 18). The pH of water discharging from springs was classified into 5 classes (Appendix V). Only 54% of springs in this study were able to be classified and the majority of springs were classified as neutral with a few moderately basic springs. Temperature, TDS, and pH require field measurements at each spring and indicate the basic water quality at each spring.

Fetter (1994) used a hydrogeochemical classification for major cations and anions based on trilinear and Piper diagrams (Figure 57). Major cations and anions were classified in Springer et al. (2004) from Figure 57 dependent on the dominant cation and anion. Only 10% of the springs in this study had water analyses to determine cation and anion amounts in the spring water. All of these springs were classified as calcium dominated for major cations and carbonate/bicarbonate dominated for major anions. Several geochemical classifications were unable to be determined from the data gathered

Table 18 – Summary of the Geochemical Classes for springs in the Middle Verde Springs study.

Class (% of springs classified)	**Types**	**# of springs**	**% of springs**
Temperature	Cold	5	3.1
54%	Normal	69	43.4
	Warm	10	6.3
	Hot	2	1.3
	unclassified	73	45.9
TDS	Hyperfresh	1	0.6
25%	Fresh	34	21.4
	Brackish	4	2.5
	Saline	0	0.0
	Brine	0	0.0
	unclassified	120	75.5
pH	Strongly Acidic	0	0.0
54%	Acidic	0	0.0
	Neutral	73	45.9
	Moderately Basic	13	8.2
	Strongly Basic	0	0.0
	unclassified	73	45.9
Cations	Ca dominated	15	9.5
10%	Mg dominated	0	0.0
	K+Na dominated	0	0.0
	No dominate cation	0	0.0
	Unclassified	144	90.5
Anions	CO_3 + HCO_3 dominated	15	9.5
10%	SO_4 dominated	0	0.0
	Cl dominated	0	0.0
	No dominate ion	0	0.0
	Unclassified	144	90.5

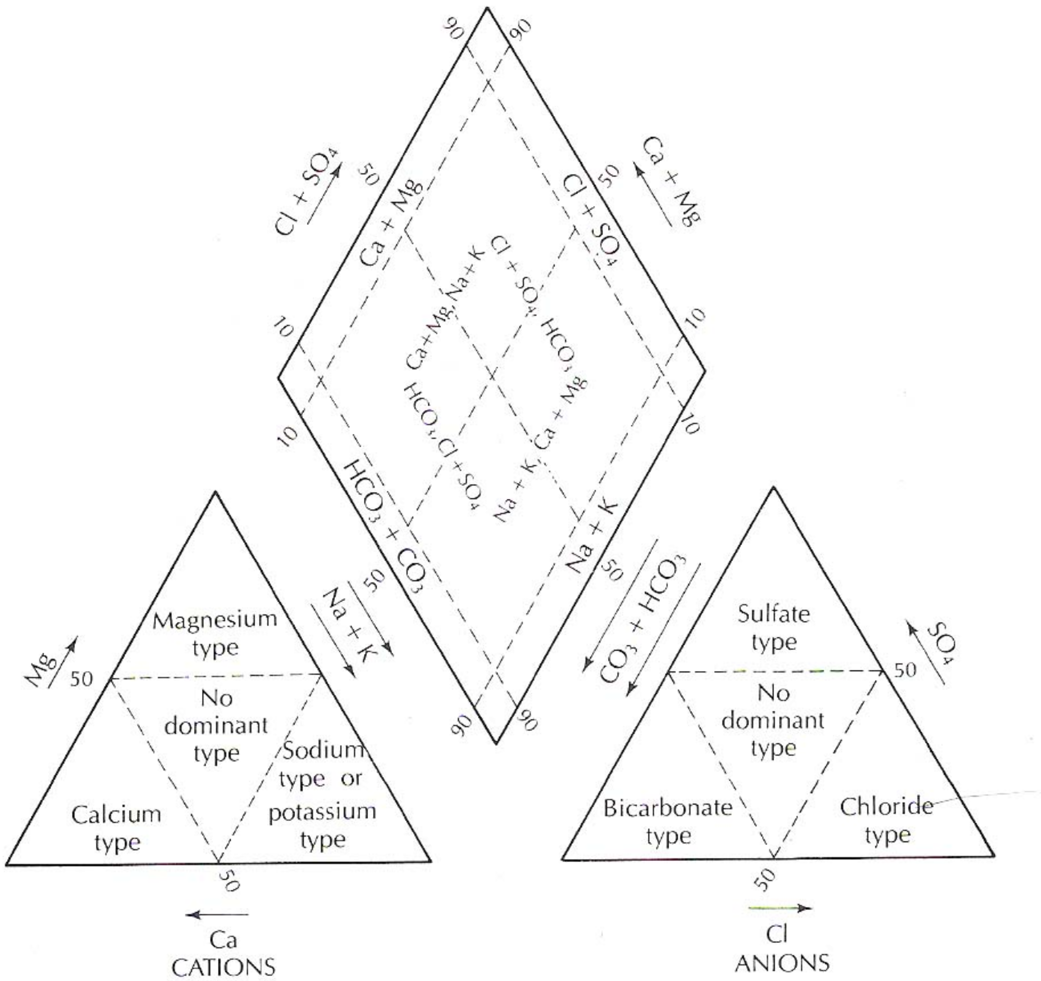

Figure 57 – Piper diagram classification for water chemistry of major cations and anions (Fetter 1994).

for springs in this study. These classes include Minor constituents, Pollution Indicators, Tracers, Alkalinity, and Nutrient Concentration (Appendix V).

Climatological, Biological, and Cultural Classifications

The regional climate of the spring strongly affects the ecosystem of a spring (Springer et al. 2004). Climate classes include elevation, mean air temperature, mean monthly precipitation, precipitation seasonality, growing season length, and surrounding ecosystem (Appendix V). Elevation and surrounding ecosystem were classified for the springs in this study (Table 19). Elevations ranged from low (152 -1,067 m) to high (1,981 – 2,895 m) and elevation has a direct effect on the surrounding ecosystem at the spring. All of the springs in this study were classified as terrestrial with springs in barrenlands, grasslands, shrublands, and woodlands. The majority of these springs were located in shrublands in lower elevations and woodlands in higher elevations. The surrounding ecosystem of springs are likely to influence habitat conditions, colonization, wildlife and human uses, and other springs ecosystem characteristics (Springer et al. 2004).

Several biological classifications were developed for springs (Springer et al., 2004, Appendix V). In this study only biogeographic isolation and habitat size for the springs were classified. Biogeographic isolation classes were nearest spring very near (< 100 m between springs) to highly isolated (> 100km between springs). Most of the 160 springs in this study were classified as moderately isolated or nearest spring nearby (Table 19) with several nearest spring very near and one spring that was isolated. Island biogeographic theory provides a convenient framework for understanding species

Table 19 – Summary of the Climatological, Biological, and Cultural Classes for springs in the Middle Verde Springs study.

Class (% of springs classified)	**Types**	**# of springs**	**% of springs**
Elevation	Very High	0	0.0
100%	High	59	37.1
	Middle	82	51.6
	Low	18	11.3
	Very Low	0	0.0
Surrounding Ecosystem	Terrestrial - Barrenlands	7	4.4
100%	Terrestrial - Grasslands	6	3.8
	Terrestrial - Shrublands	69	43.4
	Terrestrial - Woodlands	77	48.4
Biogeographic Isolation	Nearest spring very near	29	18.2
100%	Nearest spring nearby	60	37.7
	Moderately isolated	69	43.4
	Isolated	1	0.6
	Highly isolated	0	0.0
Habitat Size	Extremely Small	5	3.1
100%	Very Small	3	1.9
	Small	23	14.5
	Medium-small	60	37.7
	Medium-large	42	26.4
	Large	12	7.5
	Very Large	3	1.9
	Extremely Large	0	0.0
Land Ownership	Federal	157	98.7
100%	State	1	0.6
	Local	0	0.0
	Private	1	0.6
Primary use	Culinary	14	8.8
100%	Livestock	8	5.0
	Recreation	9	5.7
	Wildlife	128	80.5
Microhabitat modification	Piping	24	15.1
100%	Fencing	3	1.9
	Tanks	25	15.7
	Spring box/house	36	22.6
	Dams/Ponds	7	4.4
	Other	8	5.0
	None	56	35.2

distribution at springs (MacArthur and Wilson 1963). The area of aquatic, wetland, and riparian spring habitat is important to understanding and classifying springs. Springer et al. (2004) developed eight habitat sizes ranging from extremely small (<2 m^2) to extremely large (>100 ha). Most of the 160 springs in this study were classified in moderate ranges of habit size, but habitat sizes ranged from extremely small to very large (Table 19). Microhabitat, plant, invertebrate, and animal classifications were not possible because the required data were not gathered in Phase I of this study.

Cultural impacts on springs can alter the dependent ecosystem of the spring, such as diversion or capture of spring flow resulting in inadequate support of the spring ecosystem. Land ownership, primary spring use, and microhabitat modification were classified for the 160 springs in this study (Table 19). Almost all of the springs were located on Federal land (National Forest). Most of the springs were primarily used for wildlife, but several springs have been developed primarily for culinary/domestic uses (Figure 21), livestock (Figure 20), and recreation (Figure 58). The microhabitat modification was classified based on the type of modification developed at the spring. Spring boxes, piping, and tanks were the most common type of modification at springs. Only 35 % of the springs in this study were classified with no modification. Springer et al. (2004) also classified modification as undisturbed, partially diverted/disturbed, or fully diverted/disturbed. Figure 59 shows a fully disturbed spring with a spring box, piping, and fencing present at the spring.

Figure 58 – Sheep Bridge Hot Spring modified for recreational use (6/15/02).

Figure 59 – Modification at Seven Anchor Spring (8/7/02).

Conclusions for Spring Classification System

The Spring Classification System developed by Springer et al. (2004), is a comprehensive system that integrates geomorphic, hydrogeochemical, and ecological criteria. It used previous classifications as well as developed new classifications for certain criteria. Of the 160 springs investigated in this study, only 21 of the 60 classes were able to be classified with this system. Most of the geomorphic and hydrogeochemical classifications were conducted for the Verde Springs database, but much of the ecological, biological, and cultural classifications were unable to be conducted due to a lack of appropriate data. Data for most of the 160 springs were collected only during a one time visit in Phase I of this study. Geologic and hydrologic data for the springs were collected and did not include much of the detailed biological/ecological data for the springs. Therefore, a large amount of time, money, and expertise are needed to understand and interpret the many physical, geomorphic, hydrologic, chemical, climatological, ecological, biological, and cultural properties of springs for description and classification.

Also for many classifications, especially hydrological (flow variability, etc.), multiple site visits are needed to properly classify the spring. Because properties of the spring can change daily, monthly, seasonal, annual, or decadal, one time measurements do not necessarily provide the data to get an accurate representation of the spring.

CHAPTER 5

Summary and Conclusions

Summary

The purpose of this study was to gather new data to characterize the springs in the Verde River watershed, to monitor and describe changes in spring discharge and hydrogeology, and to classify the springs in the Middle Verde River watershed. A large number of the springs in the study area were uncharacterized or information on these springs was out of date. An inventory of over 160 springs in this region was conducted in the summer of 2002 to better understand the comprehensive physical, chemical, and ecological characteristics of the springs. The spring characteristics investigated included location, spring discharge, basic water chemistry, geomorphology, vegetation, and geologic unit. All of this data was used to create an Access Database and GIS map of these springs.

From this inventory, 16 springs located in different hydrostratigraphic units throughout the watershed were selected for a pilot monitoring study to understand seasonal spring discharge fluctuations and their relationship with regional hydrogeology. Out of these springs, 3 springs were located in Precambrian Granitic rocks, 2 in regional Mississippian/Devonian Limestone aquifers, 2 in regional Permian Sandstone aquifers, 2 in a shallow Permian Karst Limestone aquifer, 4 in Tertiary and Quaternary Basalt flows, and 3 in Tertiary basin fill and Quaternary alluvium. Spring discharge measurements were taken once a month at each spring from November 2002 until October 2003.

Hydrographs for each spring were analyzed to determine variability in spring discharge and the response of the spring to recharge events from winter snowmelt and summer monsoon storms. Variability in spring discharge was used to estimate total annual discharge and characterize trends in baseflow for each spring. At two springs, discharge measurements were used to estimate hydrogeologic processes, and determine transmissivity of the aquifers using hydrograph analysis.

In addition to monitoring discharge of these springs, stable isotope analyses of $\delta^{18}O$ and δD were conducted on samples collected in December 2002, May 2003, and October 2003 for each spring. Stable isotope analyses were used to characterize the hydrogeology of different geologic formations and to determine the source and age of water from the aquifers influencing spring discharge. Water samples from each spring were also collected in October and analyzed for cations and anions by the USGS. The seasonal discharge fluctuations along with stable isotope analyses at different times throughout the year were indicators of the response these aquifers have to recharge and flow through the aquifer.

All of the spring data gathered during this study was used to classify the 160 springs using a spring classification system developed by Springer et al. (2004). This classification system used 60 classes for physical, hydrological, chemical, biological, ecological, and cultural characteristics of springs.

Conclusions

A total of 160 springs were visited and characterized during the summer of 2002. During the winter in early 2002 very little snowfall occurred resulting in minimal amounts of recharge to the aquifer. Discharge measurements taken in Phase I of this study likely represent low flow conditions for the springs. Over half of the springs visited had no surface discharge (dry, 0 L/s) and several springs that were thought to be perennial dried up due to the extremely low amount of recharge. The majority of springs were smaller discharging springs with an average discharge for all 160 springs of 0.175 L/s, but a total discharge of 233 L/s. A large number of springs were located in Tertiary rim basalt, volcanics, and Precambrian granites because these units are locally fractured, but these units also have a small amount of storage resulting in smaller discharges. The Regional aquifers have fewer springs, but discharges from these springs were much higher because of greater storage and groundwater flow in the aquifers.

The analysis and interpretation of spring hydrographs in the Middle Verde River watershed indicated some general relationships between variability of discharge and regional and local aquifers. Springs located in the Regional Limestone Aquifer, Precambrian Igneous Rocks, and Quaternary (non-fractured) basalts had typically constant discharge (low variability) throughout the year-long study for Phase II. Springs located in the Tertiary basalts and Regional Sandstone aquifers had a significant increase in discharge during recharge events from snowmelt and are moderately variable. These springs (Foster, Campbell, Pieper Hatchery) all discharge from a hillslope and are fractured. The perched aquifers in the basalts responded quickly to snowmelt.

Springs located in the shallow Permian Karst Limestone aquifer were highly variable. These springs had a flashy response to winter recharge, and a slight response to summer monsoon precipitation, because of the karst and fractured limestone and deep snowpack in the small recharge area of spring. Clover Spring discharge increased from 0 L/s in January, before snowmelt occurred, to 40 L/s in March during peak snowmelt, and then decreased to 3 L/s in May after recharge from snowmelt ceased.

Estimates of transmissivity for conduit flow based on Baedke and Krothe (2001) in the karst aquifer for Clover and Pivot Rock ranged from 2.1 to 23.3 $m^2 s^{-1}$. These are general estimates for direct flow in the karst system and continuous monitoring would be needed in order to estimate more accurate values. Using one time discharge measurements to estimate annual discharge can not account for larger amounts of flow at times for highly variable springs and may underestimate a spring's contribution to the watershed and can affect the management of the springs in the watershed.

Stable isotope results for $\delta^{18}O$ and δD for Hackberry Spring were higher than all of the other springs. Hackberry Spring discharges from alluvium and therefore has shorter residence times of flow through the aquifer resulting in the higher values. Log Spring was buried by alluvium during a monsoon storm in late August or early September. The geomorphic and ecological environment was altered dramatically.

Only 21 of the 60 classes in the springs classification system (Springer et al. 2004) were able to be classified. Most of the physical, hydrological, and chemical classifications were done, but many of the biological, ecological, and cultural classifications were unable to be done due to a lack of data. In order to completely classify the springs detailed investigations of the springs are needed with multiple visits.

Recommendations

More detailed monitoring of these springs is needed to fully understand the spring resources and to properly manage them. Instruments for continuous monitoring at a network of springs similar to the 16 springs monitored in this study would increase the understanding of the regional hydrogeology of the aquifers. Springs that appeared to have a constant discharge may have variability on a smaller scale that can not be seen in monthly monitoring. Also, continuous monitoring at the highly variable springs in the Kaibab Limestone in karst regions could be done to find hydrologic properties of the aquifer. There are several studies that have analyzed hydrograph data for springs discharging from karst limestone aquifers (Amit et al. 2002, Baedke and Krothe 2001, Desmarais and Rojstaczer 2002, Eisenlohr et al. 1997, Grasso et al. 2003, and Padilla et al 1994). Also, samples for stable isotope analyses for $\delta^{18}O$ and δD should be taken during snowmelt and summer monsoon storms to determine the difference of $\delta^{18}O$ and δD for snowmelt and monsoon waters recharging the spring. It would also be beneficial to continue monitoring Log Spring or other fire impacted springs to see how the spring ecosystem and source recover from the impacts of forest fire.

The classification of springs in the system developed by Springer et al. (2004) requires a large amount of data for springs with multiple visits. Collaboration between different fields of expertise and large amounts of field work are needed to gather the data for classification. If springs can be classified in this system then managing the resources of these springs and sustaining the hydrological and ecological systems dependent on the spring will be able to be accomplished. This study will hopefully lead to future studies to improve the understanding of the hydrogeology of this region and its water supply.

References

ADWR. 2002. Arizona Department of Water Resources, Verde River Watershed Study.

Alfaro, C. and M. Wallace. 1994. Origin and classification of springs and historical review with current applications, Environmental Geology, v. 24, p. 112-124.

Amit, H., V. Lyakhovsky, A. Katz, A. Starinsky, and A. Burg. 2002. Interpretation of Spring Recession Curves, Groundwater, v. 40, no. 5, p. 543-551.

Anderson, D.E., S. Welch, W. Odem, A. Springer, L. Dewald, J. Kennedy, and D. Fleishman. 2004. Wetland revitalization and channel stabilization at Clover Springs, Mogollon Rim, Arizona, A final report submitted to the Arizona Water Protection Fund for Grant #98-059, Verde River Riparian Restoration Demonstration Project. Arizona Department of Water Resources, p. 61.

Back, W., S.R. Rosenshein, and P.R. Seaber, eds. 1988. Hydrogeology, The Geology of North America, v. 0-2, The Geological Society of America.

Baedke, S.J. and N.C. Krothe. 2001. Derivation of effective hydraulic parameters of a karst aquifer from discharge hydrograph analysis, Water Resources Research, v. 37, no. 1, p. 13-19.

Bills, D.J., M. Truini, M.E. Flynn, H.A. Pierce, R.D. Catchings, and M.J. Rymer. 2000. Hydrogeology of the regional aquifer near Flagstaff, Arizona, 1994-97: U.S. Geological Survey Water-Resources Investigation Report 00-4122.

Blakey, R.C. 1990. Stratigraphy and geologic history of Pennsylvanian and Permian rocks, Mogollon Rim region, central Arizona and vicinity: Geological Society of America Bulletin, v. 102, no. 9, p. 1189-1217.

Blakey, R.C. 2002. Stratigraphic Column, Section in Verde Valley Area. http://jan.ucc.nau.edu/~rcb7/verde.html

Briggs, P.H. and D.L. Fey. 1996. Twenty-four elements in natural and acid mine waters by inductively coupled plasma-atomic emission spectrometry, *in* Arbogast, B.F., ed., Analytical methods manual for the Mineral Resources Surveys Program: U.S. Geological Survey Open-File Report 96-525, p. 95-101.

Bryan, K. 1919. Classification of Springs, Journal of Geology, v. 27, p. 522-561.

Craig, H. 1961. Isotopic variations in isotopic waters, Science, v. 133, p. 1702-1703.

Clarke, F.W. 1924. Mineral wells and springs. Pp. 181-217 *in* U.S. Geological Survey, editor. The data of geochemistry. U.S. Government Printing Office, Washington.

d'Angelo, W.M. and W.H. Ficklin. 1996. Fluoride, chloride, nitrate, and sulfate in aqueous solution by chemically suppressed ion chromatography, *in* Arbogast, B.F., ed., Analytical methods manual for the Mineral Resources Surveys Program: U.S. Geological Survey Open-File Report 96-525, p. 149-153.

Desmarais, K. and S. Rojstaczer. 2002. Inferring source waters from measurements of carbonate spring response to storms, Journal of Hydrology, v. 260, p. 118-134

Domenico, P.A. and F.W. Schwartz. 1998. Physical and Chemical Hydrogeology. John Wiley and Sons, Inc.

Eisenlohr, L., L. Kiraly, M. Bouzelboudjen, and Y. Rossier. 1997. Numerical simulation as a tool for checking the interpretation of karst spring hydrographs, Journal of Hydrology, v. 193, p. 306-315.

Epple, A.O. 1995. Field Guide to the Plants of Arizona, Falcon Publishing, Inc.

Fetter, C.W. 1994. Applied Hydrogeology: Prentice Hall Inc., Englewood Cliffs, N.J.

Gavin, Andrew J. 1998. Hydrogeology and numerical simulation of a spring-dominated, high-elevation riparian community, Hart Prairie, Arizona, unpublished M.S. thesis, Northern Arizona Univ. 177 p.

Grasso, D.A., P. Jeannin, and F. Zwahlen. 2003. A deterministic approach to the coupled analysis of karst springs' hydrographs and chemographs, Journal of Hydrology, v. 271, p. 65-76.

Higgins, Daniel P. 1998. Leakage simulations from a perched mountain aquifer in the Inner Basin, San Francisco Mountain, Arizona, 141 p.

Hynes, H.B.N. 1970. The ecology of running waters, University of Toronto Press, Toronto.

Ingraham, N.L., B.F. Lyles, R.L. Jacobson, and J.W. Hess. 1991. Stable Isotopic Study of Precipitation and Spring Discharge in Southern Nevada, Journal of Hydrology, v. 125, p. 243-258.

Ingraham, N.L., K. Zukosky, and D.K. Kreamer. 2001. Application of Stable Isotopes to Identify Problems in Large-Scale Water Transfer in Grand Canyon National Park, Environmental Science and Technology, v. 35, no. 7, p. 1299-1302.

Kaczmarek, M.C. 2003. Investigation of Groundwater Availability for the Pine/Strawberry Water Improvement District, Morrison Maierle Inc.

Kamilli, R.J. and S.M. Richard, eds. 1998. Geologic Highway Map of Arizona: Tucson Arizona Geological Society and Arizona Geological Survey.

Lamothe, P.J., A.L. Meier, and S.A. Wilson. 1999. The determination of forty four elements in aqueous samples by Inductively Coupled Plasma – Mass Spectrometry: U.S. Geological Survey Open-File Report 99-151, p. 14.

MacArthur, R.H. and E.O. Wilson. 1963. An Equilibrium theory of insular zoogeography, Ecology, v. 17, p.373-387.

Manga, M. 1999. On the timescales characterizing groundwater discharge at springs, Journal of Hydrology, v. 219, p. 56-69.

Meinzer, O. 1923. Outline of Ground-Water Hydrology, USGS Water Supply Paper 494.

Nations, D.J., R.H. Hevly, D.W. Blinn, and J.J. Landye. 1981. Paleontology, Paleoecology, and Depositional History of the Miocene-Pliocene Verde Formation, Yavapai County, Arizona: Arizona Geological Society Digest, v. 13, p. 133-149.

Netopil, R. 1971. The classification of water springs on the basis of the variability of yields. Studia Geographica, v. 22, p. 145-150.

Owen-Joyce, S.J. and C.K. Bell. 1983. Appraisal of water resources in the Upper Verde River Area, Yavapai and Coconino Counties, Arizona, Arizona Department of Water Resources Bulletin 2.

Padilla, A., A. Pudilo-Bosch, and A. Mangin. 1994. Relative Importance of Baseflow and Quickflow from Hydrographs of Karst Spring, Groundwater, v. 32, no. 2, p. 267.

Parker J.T.C. and M.E. Flynn. 2000. Investigation of the Geology and Hydrology of the Mogollon Highlands of Central Arizona: A Project of the Arizona Rural Watershed Initiative: U.S. Geological Survey Fact Sheet 159-00.

Rademacher, L.K., J.F. Clark, and G.B. Hudson. 2002. Temporal changes in stable isotope composition of spring waters: Implications for recent changes in climate and atmospheric circulation, Geological Society of America, Geology, v. 30, no. 2, p. 139-142.

Sanders, L.L. 1998. A Manual of Field Hydrogeology, Prentice-Hall, Inc., Upper Saddle River, New Jersey.

Springer, A.E., L.E. Stevens, D.E. Anderson, R.A. Parnell, D.K. Kreamer, and S.P. Flora. 2004. A Comprehensive Springs Classification System: Integrating Geomorphic, Hydrogoechemical, and Ecological Criteria, In Press

Twenter, F.R., and D.G. Metzger. 1963. Geology and groundwater in Verde Valley – the Mogollon Rim region, Arizona: U.S. Geological Survey Bulletin 1177.

U.S. Department of Commerce – National Oceanic and Atmospheric Administration (NOAA). 2004. National Climate Data Center, Asheville, North Carolina. http://www.ncdc.noaa.gov/oa/ncdc.html.

U.S Forest Service. 2000. Springs database for Sycamore Creek, Oak Creek, Wet Beaver Creek, West Clear Creek, Fossil Creek, and East Verde River watersheds, unpublished data.

U.S. Forest Service. 2001. Spring Sampling and Flow Measurements along the Mogollon Rim between Canyon Creek and Sycamore Creek, Unpublished data, Prepared by Hydro Geo Chem, Inc., Tucson, AZ.

U.S. Geological Survey. 2002. NWISWeb Surface-Water Data for Arizona http://waterdata.usgs.gov/az/nwis/sw

U.S. Geological Survey. 2004. NWISWeb Surface-Water Data for Arizona http://waterdata.usgs.gov/az/nwis/sw

Wallace, M.P. and C. Alfaro. 2001. Geologic/hydrologic setting and classification of springs, in P.E. LaMoreauz and J.T. Tanner eds. Springs and bottled waters of the world: ancient history, source, occurrence, quality and use. Springer, Berlin, Germany.

Weisman, M.C. 1984. Geology of the Pine and Northern Buckhead Mesa Quadrangles, Mogollon Rim Region, Central Arizona: M.S. Thesis, Northern Arizona Univ.

Western Regional Climate Center. 2004. Historical Climate Information http://www.wrcc.dri.edu/CLIMATEDATA.html: Reno, Nevada.

Whiting, P.J. and J. Stamm. 1995. The hydrology and form of spring-dominated channels, Geomorphology, v. 12, p. 233-240.

Whiting, P.J. and D.G. Moog. 2001. The geomorphic, sedimentologic and hydrologic attributes of spring-dominated channels in volcanic areas, Geomorphology, v. 39, p.131-149.

Wilkinson, Randall. 2000. Water resources of Bellemont Park, Coconino County, Arizona, unpublished M.S. thesis, Northern Arizona Univ. p. 262.

Wilson, W.E. and J.E. Moore. eds. 1998. Glossary of Hydrology, American Geological Institute, Alexandria, VA.

Woodhouse, E., M.E. Flynn, J.T.C. Parker, and J.P. Hoffman. 2002. Investigation of Geology and Hydrology of the Upper and Middle Verde River Watershed of Central Arizona: A Project of the Arizona Rural Watershed Initiative: U.S. Geological Survey Fact Sheet 059-02.

Appendix I

Spring Inventory field sheet

Middle Verde River Watershed Springs Inventory and Characterization

Name of Investigators ____

Weather ____ Date ___________

Location ____ Time ___________

Name of spring ____________________ Drainage System____________________

GPS

Unit _____________________________ Lat/Long ___________________

Elevation _________________________ UTM ______________________

Geochemistry

Water temperature _______________ Air temperature _________________

PH of water ____________________ Thermal variability _________________

Specific Conductance ____________________

Discharge

Instrument ___________________ Accuracy________________________

Discharge rate(s) ____

Variability (Ephemeral / Intermittent, Subsurface flow) ________________________

____

Geomorphology

Bed Material ____

Description of emergence and channel _____________________________________

____

Length of flow ____

Length of channel ____

Name of Spring ____

Geology

Hydrostratigraphic unit ____

____

Description of Geologic Setting ____

____

____

Vegetation / Biology (Flora/Fauna)

Amount/Area of riparian vegetation ____

____

Dominate Vegetation ____

Aquatic Vegetation____

Fauna present in spring ____

Evidence of Fauna ____

Additional Comments / Observations / Sketch of site

Appendix II

Phase I Spring Inventory database

Table 20 – Investigators and condition of visit (Background table) for 160 springs in the Middle Verde Springs study database.

Name of Spring	Investigators	National Forest	Date of Visit	Time of Visit	Weather	USGS Quadrangle
101 Spring	SF, LR	Coconino	7-25-2002	1:20pm	80°F, 60% cloud	Kehl Ridge
Babe's Hole Spring	SF, RL	Coconino	8-10-2002	12:50pm	85°F, 10% cloud	Sycamore Point
Baker Spring	SF, RL	Coconino	8-11-2002	9:45am	85°F, 10% cloud	Pine
Banfield Spring	SF, SB	Coconino	10-11-2002	12:00pm	75°F, 90% cloud	Happy Jack
Banjo Bill Spring	SF, SB	Coconino	10-04-2002	12:50pm	70°F, 5% cloud	Wilson Mountain
Barney Spring	SF, LR	Coconino	7-30-2002	12:12pm	87°F, 40% cloud	Wilson Mountain
Basin Spring	SF	Tonto	7-18-2002	12:50pm	95°F, 20% cloud	Horseshoe Dam
Bear Spring (tnf)	SF, LR	Tonto	7-27-2002	12:00pm	90°F, 30% cloud	Kehl Ridge
Bear Spring(pnf)	SF, LR	Prescott	7-01-2002	3:00pm	95°F, 1% cloud	Horner Mountain
Beasley Flat Spring	SF, LR	Prescott	7-01-2002	1:00pm	95°F, 1% cloud	Horner Mountain
Bell Rock Spring	SF, LR	Coconino	6-04-2002	4:00pm	90°F, 50% cloud	Sedona
Big Hutch Spring #1	SF, LR	Tonto	6-12-2002	1:00pm	100°F, 1% cloud	Brooklyn Peak
Big Hutch Spring #2	SF, LR	Tonto	6-12-2002	1:30pm	100°F, 1% cloud	Brooklyn Peak
Bill Back Spring	SF, LR	Coconino	8-06-2002	10:30am	68°F, 100% cloud, rain	Stoneman Lake
Bill Dick Spring	SF, LR	Coconino	8-06-2002	3:05pm	75°F, 75% cloud	Hutch Mountain
Black Canyon Spring	SF, LR	Prescott	7-03-2002	2:15pm	85°F, 60% cloud, rain	Cottonwood
Blue Monster Main Spring	SF, RL	Prescott	7-11-2002	3:20pm	85°F, 30% cloud, windy	Cherry
Blue Monster South Spring	SF, RL	Prescott	7-11-2002	1:53pm	85°F, 30% cloud, windy	Cherry
Bootlegger Spring	SF, AS	Coconino	6-24-2002	2:15pm	87°F, 30% cloud	Mormon Mountain
Bottle Spring	SF, SB	Coconino	10-11-2002	11:00am	75°F, 90% cloud	Happy Jack
Bristow Spring	SF, LR	Coconino	6-27-2002	4:00pm	86°F, 15% cloud	Stoneman Lake
Brushy Wash Spring	SF, RL	Prescott	7-12-2002	2:00pm	90°F, 30% cloud	Cottonwood
Burnt Spring (cnf)	SF, RL	Coconino	6-20-2002	11:00am	95°F, 20% cloud	Hackberry Mountain
Buzzard Spring	SF, LR	Coconino	7-30-2002	2:30pm	87°F, 85% cloud	Wilson Mountain
Campbell Road Spring	SF, LR	Coconino	8-06-2002	1:50pm	75°F, 50% cloud	Happy Jack
Campbell Spring	SF, LR	Coconino	8-06-2002	1:50pm	75°F, 50% cloud	Happy Jack
Cave Spring	SF, SB	Coconino	10-04-2002	12:00pm	70°F, 5% cloud	Munds Park
Cedar Spring	SF, RL	Coconino	6-10-2002	3:10pm	95°F, 20% cloud	Hackberry Mountain
Chalk Spring (cnf)	SF, RL	Coconino	6-20-2002	11:00am	95°F, 20% cloud	Hackberry Mountain

Table 20 – (continued)

Name of Spring	Investigators	National Forest	Date of Visit	Time of Visit	Weather	USGS Quadrangle
Chasm Spring	SF, LR	Prescott	7-01-2002	3:50pm	95°F, 2% cloud	Horner Mountain
Cherry 361a	SF, RL	Prescott	7-11-2002	4:30pm	80°F, 50% cloud, windy	Cherry
Cherry 361b	SF, RL	Prescott	7-11-2002	5:15pm	75°F, 90% cloud, wind, rain	Cherry
Cimarron Spring	SF, RL	Coconino	6-22-2002	1:36pm	95°F, 10% cloud	Hackberry Mountain
Clover Spring	SF, RL	Coconino	8-10-2002	5:23pm	85°F, 10% cloud	Kehl Ridge
Cottonwood Spring (cnf)	SF, RL	Coconino	6-06-2002	1:00pm	100°F, 10% cloud	Horner Mountain
Cottonwood Spring (tnf)	SF, LR	Tonto	7-27-2002	3:45pm	85°F, 30% cloud	Pine
Dow Spring	SF, LR	Kaibab	7-24-2002	1:10pm	83°F, 50% clouds	Garland Prairie
Dripping Spring #1	SF, SB	Tonto	10-11-2002	4:00pm	75°F, 90% cloud	Pine
Dripping Spring #2	SF, SB	Tonto	10-11-2002	4:00pm	75°F, 90% cloud	Pine
Dripping Spring #3	SF, SF	Tonto	10-11-2002	4:00pm	75°F, 90% cloud	Pine
Dripping Spring #4	SF, SB	Tonto	10-11-2002	4:00pm	75°F, 90% cloud	Pine
Fain Spring	SF, LR	Coconino	6-27-2002	1:30pm	86°F, 20% cloud	Stoneman Lake
Fortyfour Spring	SF, RL	Coconino	8-10-2002	4:45pm	85°F, 10% cloud	Kehl Ridge
Foster Spring	SF, LR	Coconino	8-06-2002	11:10am	72°F, 100% cloud	Stoneman Lake
Frog Spring	SF, LR	Tonto	6-13-2002	11:00am	100°F, 1% cloud	Bloody Basin
Fuller Spring	SF, LR	Tonto	7-27-2002	4:30pm	85°F, 30% cloud	Pine
Garden Spring	SF, LR	Coconino	8-07-2002	11:45pm	78°F, 20% cloud	Flagstaff West
Geronimo Spring (1)	SF, RL	Coconino	8-10-2002	2:15pm	85°F, 10% cloud	Sycamore Point
Geronimo Spring (tnf)	SF, LR	Tonto	7-27-2002	10:00am	82°F, 30% cloud	Kehl Ridge
Goat Camp Spring	SF, RL	Prescott	7-12-2002	11:15am	85°F, 10% cloud	Cottonwood
Gooseberry Spring	SF, SB	Coconino	8-14-2002	2:30pm	75°F, 20% cloud	Hutch Mountain
Gould Spring #1	SF, LR	Tonto	7-26-2002	5:30pm	95°F, 5% cloud	North Peak
Gould Spring #2	SF, LR	Tonto	7-26-2002	5:45pm	95°F, 5% cloud	North Peak
Grapevine Spring	SF, LR	Tonto	7-26-2002	1:50pm	96°F, 15% cloud	North Peak
Grassy Meadow Spring	SF, SB	Coconino	10-04-2002	11:52am	70°F, 5% cloud	Mountainaire
Gray Springs	SF, LR	Coconino	7-24-2002	11:35am	76°F, 99% cloud	Garland Prairie
Griffith Spring	SF, LR	Coconino	7-23-2002	3:05pm	75°F, 95% cloud, rain	Mountainaire
Grimes Spring	SF, LR	Tonto	7-26-2002	2:05pm	95°F, 10% cloud	North Peak

Table 20 (continued)

Name of Spring	Investigators	National Forest	Date of Visit	Time of Visit	Weather	USGS Quadrangle
Hackberry Spring #1	SF, LR	Coconino	5-31-2002	12:45pm	90°F, 1% cloud, light wind	Hackberry Mountain
Hackberry Spring #2	SF, LR	Coconino	5-31-2002	1:10pm	90°F, 1% cloud light wind	Hackberry Mountain
Hance Spring	SF, LR	Coconino	5-31-2002	10:15am	80°F, 2% cloud	Walker Mountain
Horseshoe Spring	SF, SB	Coconino	8-14-2002	4:38pm	80°F, 20% cloud	Hutch Mountain
Howard Spring	SF, AS	Coconino	6-24-2002	11:00am	85°F, 30% cloud	Mormon Mountain
Huffer Spring	SF, RL	Coconino	8-11-2002	9:00am	85°F, 10% cloud	Pine
Hull Spring	SF, RL	Prescott	6-29-2002	10:40am	90°F, hazy, 10% cloud	Middle Verde
Irving High Spring	SF, SB	Tonto	10-12-2002	5:00pm	80°F, 90% cloud	Strawberry
Irving Low Spring	SF, SB	Tonto	10-12-2002	4:30pm	80°F, 90% cloud	Strawberry
JM Spring	SF	Tonto	7-18-2002	2:30pm	95°F, 20% cloud	Horseshoe Dam
Jones Spring #1	SF, LR	Coconino	8-06-2002	12:00pm	75°F, 100% cloud	Hutch Mountain
Jones Spring #2a	SF, LR	Coconino	8-06-2002	12:15pm	75°F, 100% cloud	Hutch Mountain
Jones Spring #2b	SF, LR	Coconino	8-06-2002	12:15pm	75°F, 100% cloud	Hutch Mountain
Kelsey Spring	SF, RL	Coconino	8-10-2002	11:30am	86°F, 10% cloud	Sycamore Point
Larson Spring	SF, LR	Tonto	7-26-2002	3:30pm	95°F, 5% cloud	North Peak
Lee Johnson Spring	SF, LR	Coconino	7-25-2002	6:10pm	80°F, 80% cloud	Kehl Ridge
Lee Spring	SF, LR	Coconino	6-27-2002	2:50pm	87°F, 15% cloud	Stoneman Lake
Lindburg Spring	SF, LR	Coconino	8-07-2002	10:30pm	75°F, 20% cloud	Mountainaire
Little Hutch Spring #1	SF, LR	Tonto	6-12-2002	11:20am	95°F, 1% cloud, light wind	Brooklyn Peak
Little Hutch Spring #2	SF, LR	Tonto	6-12-2002	11:40am	95°F, 1% cloud	Brooklyn Peak
LO Spring	SF, LR	Kaibab	7-24-2002	1:35pm	83°F, 50% cloud	Garland Prairie
Log Spring	SF, RL	Prescott	6-29-2002	4:00pm	95°F, 10% cloud	Cherry
Long Valley Spring	SF, LR	Coconino	7-25-2002	11:30am	78°F, 5% cloud	Long Valley
Lower Gould Spring	SF, LR	Tonto	7-26-2002	4:00pm	95°F, 5% cloud	North Peak
Lower Hull Spring	SF, LR	Coconino	7-24-2002	9:40am	70°F, 99% cloud	Garland Prairie
LX Spring	SF, LR	Tonto	6-13-2002	2:50pm	100°F, 1% cloud	Bloody Basin
Maple Spring	SF, LR	Coconino	7-30-2002	1:00pm	85°F, 90% cloud	Wilson Mountain
Maxwell Spring	SF, LR	Coconino	8-07-02	1:25pm	82°F, 15% cloud	Wing Mountain
Mesquite Spring	SF, RL	Coconino	6-06-2002	1:30pm	100°F, 10% cloud	Horner Mountain

Table 20 (continued)

Name of Spring	Investigators	National Forest	Date of Visit	Time of Visit	Weather	USGS Quadrangle
Mine Spring	SF, LR	Prescott	7-01-2002	10:45am	90°F, 1% cloud, light wind	Horner Mountain
Morgan Spring	SF, RL	Prescott	7-12-2002	2:30pm	90°F, 30% cloud	Cottonwood
Mortgage Spring	SF, LR	Coconino	7-23-2002	2:00pm	80°F, 60% cloud, light rain	Mountainaire
Mund Spring	SF, AS	Coconino	6-24-2002	12:30pm	85°F, 30% cloud	Mormon Mountain
North Mine Spring	SF, LR	Prescott	7-01-2002	12:00pm	90°F, 2% cloud	Horner Mountain
North Pass Spring	SF, LR	Tonto	6-14-2002	10:45am	100°F, 1%cloud	Rover Peak
North Pasture Canyon Spring	SF, LR	Tonto	6-14-2002	8:40am	90°F, 1% cloud	Rover Peak
North Pasture Spring	SF, LR	Tonto	6-14-2002	9:30am	95°F, 1% cloud	Rover Peak
Oxbow Spring	SF, LR	Prescott	7-17-2002	1:15pm	80°F, 90% cloud	Cottonwood
Patton Spring	SF, LR	Coconino	7-25-2002	5:45pm	80°F, 80% cloud	Kehl Ridge
Pearson Spring	SF, LR	Coconino	8-07-02	1:50pm	82°F, 15% cloud	Wing Mountain
Pfau Spring	SF, RL	Prescott	7-11-2002	4:00pm	85°F, 40% cloud, windy	Cherry
Phroney Spring	SF, RL	Coconino	6-10-2002	5:20pm	95°F, 40% cloud	Hackberry Mountain
Picnic Spring	SF, LR	Tonto	6-13-2002	2:00pm	100°F, 1% cloud, light wind	Bloody Basin
Pieper Hatchery Spring #1	SF, RL	Tonto	8-12-2002	12:00pm	90°F, 10% cloud	Kehl Ridge
Pieper Hatchery Spring #2	SF, RL	Tonto	8-12-2002	12:00pm	90°F, 10% cloud	Kehl Ridge
Pine Flat Spring	SF, SB	Coconino	10-04-2002	1:20pm	70°F, 5% cloud	Mountainaire
Pine Spring	SF, RL	Tonto	8-11-2002	6:45pm	80°F, 10% cloud	Kehl Ridge
Pivot Rock Spring	SF, LR	Coconino	7-25-2002	3:30pm	85°F, 40% cloud	Pine
Poison Sping (tnf)	SF, LR	Tonto	7-27-2002	1:00pm	90°F, 40% cloud	Kehl Ridge
Poison Spring (1)	SF, LR	Coconino	7-24-2002	10:25am	72°F, 99% cloud	Garland Prairie
Powell Spring	SF, SB	Prescott	8-16-2002	8:15am	80°F, 10% cloud	Cherry
Quail Spring #1	SF, LR	Prescott	7-17-2002	11:00am	80°F, 95% cloud	Cottonwood
Quail Spring #2	SF, LR	Prescott	7-17-2002	11:15am	80°F, 95% cloud	Cottonwood
Quail Spring #3	SF, LR	Prescott	7-17-2002	11:50am	80°F, 90% cloud	Cottonwood
Quail Spring (cnf)	SF, RL	Coconino	6-20-2002	10:00am	95°F, 20% cloud	Verde Hot Spring
Railroad Spring	SF, LR	Coconino	7-24-2002	10:00am	70°F, 99% cloud	Garland Prairie
Red Horse Spring	SF, RL	Prescott	6-29-2002	11:45am	90°F, hazy, 10% cloud	Cherry
Red Rock Spring	SF, RL	Tonto	8-11-2002	6:00pm	90°F, 10% cloud	Kehl Ridge

Table 20 (continued)

Name of Spring	Investigators	National Forest	Date of Visit	Time of Visit	Weather	USGS Quadrangle
Ritter Spring	SF, LR	Coconino	7-23-2002	12:15pm	80°F, 40% cloud	Mountainaire
Rock Top Spring	SF, LR	Coconino	6-27-2002	3:15pm	86°F, 15% cloud	Stoneman Lake
Round Up Park Spring	SF, LR	Coconino	6-27-2002	12:30pm	86°F, 10% cloud	Hutch Mountain
Russel Spring #1	SF, LR	Coconino	6-04-2002	12:30pm	90°F, 40% cloud	Camp Verde
Russel Spring #2	SF, LR	Coconino	6-04-2002	12:30pm	90°F, 40% cloud	Camp Verde
Sally May Spring	SF, RL	Coconino	6-22-2002	12:10pm	95°F, 10% cloud	Hackberry Mountain
Schells Spring	SF, SB	Coconino	8-14-2002	3:30pm	75°F, 20% cloud	Hutch Mountain
Scott Spring	SF, LR	Coconino	7-23-2002	12:55pm	85°F, 60% cloud	Mountainaire
Seven Anchor Spring #1	SF, LR	Coconino	8-06-2002	3:30pm	75°F, 75% cloud	Hutch Mountain
Seven Anchor Spring #2	SF, LR	Coconino	8-06-2002	3:30pm	75°F, 75% cloud	Hutch Mountain
Sheep Bridge Hot Springs	SF, LR	Tonto	6-13-2002	8:30am	90°F, 1% cloud, light breeze	Chalk Mountain
Sheep Spring	SF, AS	Coconino	6-24-2002	3:20pm	87°F, 50% cloud	Mormon Mountain
Spring Creek	SF, SB	Coconino	10-04-2002	3:00pm	75°F, 5% clouds	Page Springs
Sterling Spring 1	SF, SB	Coconino	10-04-2002	10:40am	70°F, 5% cloud	Mountainaire
Sterling Spring 2	SF, SB	Coconino	10-04-2002	10:40am	70°F, 5% cloud	Mountainaire
Stone Camp Spring	SF, RL	Tonto	7-06-2002	11:30am	100°F, 1% cloud	Rover Peak
Summer Spring	SF, SB	Coconino	8-13-2002	1:55pm	95°F, 10% cloud	Sycamore Basin
Sycamore Spring #1a	SF, RL	Coconino	6-07-2002	5:00pm	95°F, 10% cloud	Hackberry Mountain
Sycamore Spring #1b	SF, RL	Coconino	6-07-2002	4:40pm	95°F, 10% cloud	Hackberry Mountain
Sycamore Spring #2	SF, RL	Coconino	6-07-2002	3:00pm	95°F, 10% cloud	Hackberry Mountain
Table Mountain Spring	SF, LR	Prescott	7-01-2002	2:00pm	95°F, 2% cloud, light breeze	Horner Mountain
Thicket Spring	SF, RL	Tonto	7-06-2002	4:04pm	95°F, 1% cloud	Bloody Basin
Tonto Bridge	SF, SB	Tonto	10-11-2002	1:30pm	75°F, 85% clouds	Buckhead Mesa
Towel Spring	SF, RL	Coconino	6-21-2002	12:30pm	90°F, 20% cloud	Hackberry Mountain
Trail Junction Spring	SF	Tonto	7-18-2002	10:30pm	90°F, 70% cloud	Horseshoe Dam
Trail Spring	SF	Tonto	7-18-2002	1:15pm	95°F, 20% cloud	Horseshoe Dam
Tree Spring	SF, LR	Coconino	6-27-2002	2:15pm	86°F, 25% cloud	Hutch Mountain
T-six Spring	SF, LR	Coconino	6-27-2002	5:30pm	83°F, windy, 20% cloud	Mormon Mountain
Tunnel Spring	SF, RL	Prescott	6-29-2002	1:30pm	90°F, hazy, 10% cloud	Cherry

Table 20 (continued)

Name of Spring	Investigators	National Forest	Date of Visit	Time of Visit	Weather	USGS Quadrangle
Turkey Spring	SF, LR	Tonto	7-27-2002	3:00pm	88°F, 60% cloud	Pine
Upper Hull Spring	SF, LR	Coconino	7-24-2002	9:05am	65°F, 99% cloud	Garland Prairie
Van Deren Spring	SF, AS	Coconino	6-24-2002	4:40pm	85°F, 50% cloud	Hutch Mountain
Verde Hot Spring	SF, RL	Tonto	6-20-2002	4:30pm	95°F, 30% cloud	Verde Hot Springs
Washington Spring	SF, RL	Tonto	8-12-2002	10:00am	85°F, 10% cloud	Kehl Ridge
Wet Prong Spring	SF, RL	Coconino	6-21-2002	2:30pm	95°F, 20% cloud	Hackberry Mountain
Wildcat Spring	SF, RL	Coconino	8-11-2002	10:30am	85°F, 10% cloud	Pine
Willard Spring	SF, LR	Coconino	7-23-2002	11:15am	76°F, 50% cloud	Munds Park
Wilson Seep	SF, LR	Coconino	7-23-2002	1:20pm	85°F, 50% cloud	Mountainaire
Windfall Spring	SF, LR	Coconino	7-25-2002	2:10pm	80°F, 60% cloud	Kehl Ridge
Winter Cabin Spring	SF, LR	Coconino	6-04-2002	2:30pm	90°F, 60% cloud	Lake Montezuma
Wire Corral Spring	SF	Tonto	7-18-2002	12:00pm	95°F, 30% cloud	Horseshoe Dam
Yellow Jacket Spring	SF, SB	Coconino	8-14-2002	5:36pm	80°F, 20% cloud	Happy Jack
Zig Zag Spring #1 main	SF, LR	Tonto	6-13-2002	6:00pm	100°F, 1%cloud	Bloody Basin
Zig Zag Spring #2	SF, LR	Tonto	6-13-2002	6:00pm	100°F, 1% cloud	Bloody Basin

Investigators - SF=Stephen Flora, LR=Lanya Ross, RL=Rebecca Lara, SB=Stephanie Brightwell, AS=Sbe Springer

Table 21 – Location and drainages (Background table) for 160 springs in for Middle Verde Springs study database

Name of Spring	Location	Main Drainage	Minor Drainage System
101 Spring	FR 613, in ravine half way up	West Clear Creek	Dirtyneck Canyon-Clover Creek
Babe's Hole Spring	sycamore canyon	Sycamore Creek	Little Lo Spring Canyon
Baker Spring	off SR 87, 1 mile S of FR 613	West Clear Creek	Pivot Rock Canyon
Banfield Spring	FR 9365G	Wet Beaver Creek	Brady Canyon
Banjo Bill Spring	Banjo Bill Campground, SR 89A	Oak Creek	
Barney Spring	off FR 231 and 778, in drainage	Oak Creek	West Fork Oak Creek
Basin Spring	FR 477 on trail	Verde River	
Bear Spring (tnf)	below trail 31 (highline trail)	East Verde River	Webber Creek
Bear Spring(pnf)	off jeep trail FR504A, off FR 574	Verde River	Gap Creek
Beasley Flat Spring	off FR 574, in drainage below road to Beasley Flat	Verde River	
Bell Rock Spring	in drainage south of Bell Rock, east of 89A	Wet Beaver Creek	Bell Canyon-Jacks Canyon-Dry Beaver
Big Hutch Spring #1	end of switchbacks along FR 269 west of drinkers	Tangle Creek	Hutch Gulch
Big Hutch Spring #2	end of switchbacks on FR 269, west of drinkers	Tangle Creek	Hutch Gulch
Bill Back Spring	FR 9244E and 665, next to tank	Wet Beaver Creek	Rattlesnake Canyon-Dry Beaver Creek
Bill Dick Spring	FR 230E on slope near road in meadow	Wet Beaver Creek	Jacks Canyon
Black Canyon Spring	off FR 413	Verde River	Black Canyon
Blue Monster Main Spring	FR 361	Verde River	Hayfield Draw
Blue Monster South Spring	FR 361	Verde River	Hayfield Draw
Bootlegger Spring	FR 91B, on side of road	Oak Creek	Munds Canyon
Bottle Spring	FR 692	Wet Beaver Creek	Brady Canyon
Bristow Spring	FR 9470G off of FR 226	Wet Beaver Creek	Woods Canyon-Dry Beaver Creek
Brushy Wash Spring	jeep trail off of FR 360	Verde River	Black Canyon
Burnt Spring (cnf)	1.5 mile north of FR 502	Verde River	
Buzzard Spring	off FR 792 and 9014H, in drainage	Oak Creek	West Fork Oak Creek
Campbell Road Spring	FR 229F along abandoned road	Wet Beaver Creek	Rocky Gulch
Campbell Spring	FR 229F at end of abandoned road	Wet Beaver Creek	Rocky Gulch
Cave Spring	SR 89A at Cave Spring campground	Oak Creek	
Cedar Spring	off FR 708, east 1 mile	Verde River	Hackberry Canyon-Sycamore Canyon
Chalk Spring (cnf)	1.5 mile north of FR 502	Verde River	

Table 21 (continued)

Name of Spring	Location	Main Drainage	Minor Drainage System
Chasm Spring	off FR 574, up chasm trail in drainage	Verde River	Chasm Creek
Cherry 361a	off FR 361	Verde River	Hayfield Draw
Cherry 361b	off FR 361	Verde River	Hayfield Draw
Cimarron Spring	drainage west of FR 708 after Cimarron Saddle	Fossil Creek	Cimarron Creek
Clover Spring	on SR 87, half mile N of FR 616	West Clear Creek	Clover Canyon-Clover Creek
Cottonwood Spring (cnf)	500m W of FR 500, near of Camp Verde	Verde River	
Cottonwood Spring (tnf)	Trail #16, off FR 428, west of Pine	East Verde River	Pine Creek
Dow Spring	FR 141, Canyon wall near Rim Trail	Sycamore Creek	
Dripping Spring #1	Trail # 26 from 1.5 miles from Pine trailhead	East Verde River	Pine Creek
Dripping Spring #2	Trail # 26 from 1.5 miles from Pine trailhead	East Verde River	Pine Creek
Dripping Spring #3	Trail # 26 from 1.5 miles from Pine trailhead	East Verde River	Pine Creek
Dripping Spring #4	Trail # 26 from 1.5 miles from Pine trailhead	East Verde River	Pine Creek
Fain Spring	FR 127A, next to road	Wet Beaver Creek	Woods Canyon-Dry Beaver Creek
Fortyfour Spring	half mile back jeep trail 2mi S FR 616 on SR 87	West Clear Creek	Forty-four Canyon-Clover Creek
Foster Spring	FR 229E, south of Stoneman Lake	Wet Beaver Creek	Foster Canyon-Rarick Canyon
Frog Spring	1/4 mile on FR 18 off of FR 269 to left	Tangle Creek	
Fuller Spring	in drainage upstream from tank off SR 87near Pine	Fossil Creek	Strawberry Creek-Hardscrabble Creek
Garden Spring	FR 75 and 533 in drainage at pipe	Oak Creek	Pumphouse Wash
Geronimo Spring (1)	end of trail 6 in Sycamore Canyon, end of FR 538G	Sycamore Creek	Little Lo Spring Canyon
Geronimo Spring (tnf)	on trail 31(Highline trail)	East Verde River	Webber Creek
Goat Camp Spring	end of FR 360	Verde River	Wilbur Canyon
Gooseberry Spring	FR 92 in park	Wet Beaver Creek	Jacks Canyon
Gould Spring #1	off FR 502 up drainage left at split	East Verde River	
Gould Spring #2	off FR 502 up drainage right of split	East Verde River	
Grapevine Spring	next to road on west, FR 414-193	East Verde River	Flume Hollow Canyon
Grassy Meadow Spring	SR 89A north of Cave Spring campground	Oak Creek	
Gray Springs	FR 527, next to Road (sign)	Sycamore Creek	
Griffith Spring	SR 89A, on Griffith Spring trail	Oak Creek	Pumphouse Wash
Grimes Spring	off FR 406 at end of jeep trail (fence)	East Verde River	Flume Hollow Canyon

Table 21 (continued)

Name of Spring	Location	Main Drainage	Minor Drainage System
Hackberry Spring #1	FR 708, S of needle rock	Verde River	Hackberry Canyon-Sycamore Canyon
Hackberry Spring #2	FR 708, S of needle rock	Verde River	Hackberry Canyon-Sycamore Canyon
Hance Spring	0.1 mi west of FR 618, 1 mi S of FR 214	West Clear Creek	
Horseshoe Spring	on FR 6058, at the base of Mahan Mountain	Wet Beaver Creek	Jacks Canyon
Howard Spring	FR 700 northeast	Oak Creek	Munds Canyon
Huffer Spring	off SR 87, half mile S of FR 613	West Clear Creek	Pivot Rock Canyon
Hull Spring	off FR 75, 3 miles west of SR 260	Verde River	Cherry Creek
Irving High Spring	FR 708, side of road	Fossil Creek	
Irving Low Spring	FR 708, side of road	Fossil Creek	
JM Spring	FR 477, 1/4 mile after split from FR 479	Verde River	Davenport Wash
Jones Spring #1	FR 9356Y at end of road up drainage	Wet Beaver Creek	Foster Canyon-Rarick Canyon
Jones Spring #2a	FR 9356Y at upper drainage	Wet Beaver Creek	Foster Canyon-Rarick Canyon
Jones Spring #2b	FR 9356Y at upper drainage	Wet Beaver Creek	Foster Canyon-Rarick Canyon
Kelsey Spring	on trail 6, 0.3 miles down from end of FR 538G	Sycamore Creek	Little Lo Spring Canyon
Larson Spring	50 meters before bend in drainage, off FR 502	East Verde River	
Lee Johnson Spring	FR 300 and 6107	East Verde River	Webber Creek
Lee Spring	FR 127 and 226, on side of road	Wet Beaver Creek	Woods Canyon-Dry Beaver Creek
Lindburg Spring	SR89A, side of road in road grade	Oak Creek	Pumphouse Wash
Little Hutch Spring #1	along switchbacks on FR 269 at top of divide	Tangle Creek	Hutch Gulch
Little Hutch Spring #2	along switchvbacks on FR 269 after divide	Tangle Creek	Hutch Gulch
LO Spring	FR 141, in channel downstream of Dow spring	Sycamore Creek	
Log Spring	off FR 132	Verde River	Cherry Creek
Long Valley Spring	FR 147A, in ravine on east side of road	West Clear Creek	Long Valley-Willow Draw
Lower Gould Spring	off FR 502 up drainage	East Verde River	
Lower Hull Spring	FR 527, next to road and homes	Sycamore Creek	
LX Spring	up wash to left at FR 552 and FR 269	Tangle Creek	Hutch Gulch
Maple Spring	off FR 231 and 778, in ravine	Oak Creek	West Fork Oak Creek
Maxwell Spring	FR 222 and 222A, west of wing mtn, top of tank	Oak Creek	Volunteer Wash
Mesquite Spring	500m west of FR 500, near Camp Verde	Verde River	

Table 21 (continued)

Name of Spring	Location	Main Drainage	Minor Drainage System
Mine Spring	next to road FR 138	Verde River	
Morgan Spring	on jeep trail at end of FR 360	Verde River	Black Canyon
Mortgage Spring	FR 253D, end of road next to old buildings	Oak Creek	Pumphouse Wash
Mund Spring	FR 240, in casner park	Oak Creek	Munds Canyon
North Mine Spring	in cave on left side of road, FR 138	Verde River	
North Pass Spring	west of FR 24	Tangle Creek	Roundtree Canyon
North Pasture Canyon Spring	1/4 mile up ravine west of FR 24	Tangle Creek	Roundtree Canyon
North Pasture Spring	west of FR 24	Tangle Creek	Roundtree Canyon
Oxbow Spring	jeep trail off FR 493, follow pipe up road	Verde River	Silver Spring Gulch
Patton Spring	FR 218A, half mile N	East Verde River	Patton Spring Canyon-Webber Creek
Pearson Spring	FR 222A, west of wing mtn at spring box	Oak Creek	Volunteer Wash
Pfau Spring	under FR 361	Verde River	Hayfield Draw
Phroney Spring	west off FR 708 N of Needle Rock	Verde River	Hackberry Canyon-Sycamore Canyon
Picnic Spring	at FR 552 and FR 269 junction	Tangle Creek	
Pieper Hatchery Spring #1	end of FR 296, along trail 290	East Verde River	
Pieper Hatchery Spring #2	end of FR 296, along trail 290	East Verde River	
Pine Flat Spring	Pine Flat campground alongside SR 89A	Oak Creek	
Pine Spring	1 mile east of trail 31 and 194 junction on tr 31	East Verde River	Shannon Gulch-Webber Creek
Pivot Rock Spring	FR 616, along trail	West Clear Creek	Pivot Rock Canyon-Toms Creek-Clover Creek
Poison Sping (tnf)	trail off of trail 31	East Verde River	Webber Creek
Poison Spring (1)	road off FR 527, SW corner of private property	Sycamore Creek	
Powell Spring	in drainage, 200m up from campground	Verde River	Cherry Creek
Quail Spring #1	on trail from trailhead at end of FR 359	Verde River	Black Canyon
Quail Spring #2	end of FR 359, 60m upstream of Quail Spring #1	Verde River	Black Canyon
Quail Spring #3	end of FR 359, upstream of Quail Spring #2	Verde River	Black Canyon
Quail Spring (cnf)	1 mile north of FR 502	Verde River	
Railroad Spring	FR 527, sign on side of road	Sycamore Creek	
Red Horse Spring	off FR 75, jeep trail(wash) 1st right in Cherry	Verde River	Cherry Creek
Red Rock Spring	50 meters west of trail 194 along trail 31	East Verde River	Shannon Gulch-Webber Creek

Table 21 (continued)

Name of Spring	Location	Main Drainage	Minor Drainage System
Ritter Spring	FR 253A, next to road south of Ritter Mtn	Oak Creek	
Rock Top Spring	end of FR 9467L off FR 226	Wet Beaver Creek	Woods Canyon-Dry Beaver Creek
Round Up Park Spring	FR 765, in ravine at district fence line	Wet Beaver Creek	Woods Canyon-Dry Beaver Creek
Russel Spring #1	off Jeep trail outside of Lake Montezuma housing	Wet Beaver Creek	Russel Wash
Russel Spring #2	off Jeep trail outside of Lake Montezuma housing	Wet Beaver Creek	Russel Wash
Sally May Spring	Jeep trail off FR 708	Fossil Creek	Sally May Wash
Schells Spring	FR 135, outside Mahan Ranch	Wet Beaver Creek	Jacks Canyon
Scott Spring	FR 253E, end of road east of Pumphouse wash	Oak Creek	Pumphouse Wash
Seven Anchor Spring #1	FR 92 and 92A, 1.5 miles east of FH3	Wet Beaver Creek	Jacks Canyon
Seven Anchor Spring #2	FR 92 and 92A, 1.5 miles east of FH3	Wet Beaver Creek	Jacks Canyon
Sheep Bridge Hot Springs	end of FR 269, west side river at sheep bridge	Verde River	
Sheep Spring	FR 91 and 91B, sign on side of road	Oak Creek	Munds Canyon
Spring Creek	in Spring Creek near private land off of 89A	Oak Creek	Spring Creek
Sterling Spring 1	SR89A at base of switchbacks	Oak Creek	
Sterling Spring 2	SR89A at Sterling Fish Hatchery	Oak Creek	
Stone Camp Spring	in drainage east of FR 24	Tangle Creek	Roundtree Canyon
Summer Spring	1 mile upsteam on Parsons Trail	Sycamore Creek	
Sycamore Spring #1a	off FR 708 up Sycamore Canyon	Verde River	Sycamore Canyon
Sycamore Spring #1b	off FR 708 on Sycamore Canyon	Verde River	Sycamore Canyon
Sycamore Spring #2	off FR 708 in Sycamore canyon	Verde River	Sycamore Canyon
Table Mountain Spring	off FR 574 up drainage at Table Mountain	Verde River	Chasm Creek
Thicket Spring	FR 39 and FR 1993	Verde River	Red Creek
Tonto Bridge	Tonto Natural Bridge State Park off route 87	East Verde River	Pine Creek
Towel Spring	2 mi off FR 708 along Towel Creek pack trail	Verde River	Towel Creek
Trail Junction Spring	FR 477 off FR 479 east of Horseshoe Dam	Verde River	
Trail Spring	FR 477 on trail	Verde River	
Tree Spring	FR 863, in park next to wash	Wet Beaver Creek	Bar M Canyon-Woods Canyon-Dry Beaver Creek
T-six Spring	FR 226, upper slope at edge of park	Wet Beaver Creek	T-six Canyon-Woods Canyon-Dry Beaver Creek
Tunnel Spring	off FR 75, jeep trail, 2nd right in Cherry	Verde River	Cherry Creek-Verde River

Table 21 (continued)

Name of Spring	Location	Main Drainage	Minor Drainage System
Turkey Spring	along trail 217 near Camp Geronimo	East Verde River	W. Webber Creek-Webber Creek
Upper Hull Spring	FR 527, next to tank in valley (sign)	Sycamore Creek	Sycamore Creek
Van Deren Spring	FR 91, half mile west of FH 3	Wet Beaver Creek	Bar M Canyon-Woods Canyon-Dry Beaver Creek
Verde Hot Spring	1 mile north of Childs Power Plant on Verde River	Verde River	
Washington Spring	end of FR 32	East Verde River	Mail Creek
Wet Prong Spring	2.5 mi off FR 708 along Towel Creek pack trail	Verde River	Towel Creek
Wildcat Spring	off SR 87, half mile S of FR 300	West Clear Creek	Pivot Rock Canyon
Willard Spring	FR 253, fenced in area at end of willard spg rd	Oak Creek	Munds Canyon
Wilson Seep	FR 253, side of road in drainage	Oak Creek	Pumphouse Wash
Windfall Spring	FR 613	West Clear Creek	Dirtyneck Canyon-Clover Creek
Winter Cabin Spring	2nd FR off SR 179, 1 mile west of I-17	Wet Beaver Creek	Hog Canyon-Dry Beaver Creek
Wire Corral Spring	FR 477 on trail	Verde River	
Yellow Jacket Spring	FR 305, 1 mile west of FH 3	Wet Beaver Creek	Brady Canyon
Zig Zag Spring #1 main	in drainage near Red Creek Ranch off FR 16	Verde River	Red Creek
Zig Zag Spring #2	in drainage near Red Creek Ranch of FR 16	Verde River	Red Creek

Location - FR=Forest Road, SR=State Route, FH=Forest Highway

Table 22 –Locations (GPS location table) for 160 springs in the Middle Verde Springs study database.

Name of Spring	Latitude	Longitude	NAD 83 - North	NAD 83 - East	NAD 27 - North	NAD 27- East
101 Spring	34°29'14.28"	111°21'04.40"	3,816,244.84	467,751.64	3,816,045.64	467,814.66
Babe's Hole Spring	35°04'20.67"	111°56'22.64"	3,881,476.57	414,332.29	3,881,276.58	414,395.70
Baker Spring	34°27'29.88"	111°23'49.01"	3,813,044,70	463,540.64	3,812,845.49	463,603.67
Banfield Spring			3834300.00	458400.00		
Banjo Bill Spring			3868761.00	431298.00		
Barney Spring	34°59'38.02"	111°48'33.29"	3,872,664.99	426,148.57	3,872,465.25	426,212.19
Basin Spring	33°58'04.57"	111°38'10.13"	3,758,783.18	441,230.63	3,758,584.08	441,293.68
Bear Spring (tnf)	34°24'46.68"	111°20'58.75"	3,808,001.96	467,867.36	3,807,802.74	467,930.37
Bear Spring(pnf)	34°25'35.85"	111°48'42.40"	3,809,759.68	425,410.12	3,809,560.29	425,473.14
Beasley Flat Spring	34°27'41.18"	111°49'25.38"	3,813,629.03	424,344.50	3,813,429.60	424,407.49
Bell Rock Spring			3850687.00	430069.00		
Big Hutch Spring #1	34°12'31.97"	111°53'11.33"	3,785,671.73	418,335.11	3,785,472.48	418,398.35
Big Hutch Spring #2	34°12'30.87"	111°53'11.15"	3,785,638.05	418,339.47	3,785,438.80	418,402.72
Bill Back Spring	34°47'57.30"	111°30'43.97"	3,850,900.40	453,145.53	3,850,700.78	453,208.96
Bill Dick Spring	34°47'05.27"	111°28'31.00"	3,849,281.16	456,516.75	3,849,081.61	456,580.17
Black Canyon Spring			3836104.29	397128.83		
Blue Monster Main Spring	34°36'13.78"	112°00'14.18"	3,829,568.58	407,947.77	3,829,368.90	408,010.86
Blue Monster South Spring	34°36'06.39"	112°00'12.10"	3,829,340.27	407,998.53	3,829,140.59	408,061.62
Bootlegger Spring	34°54'42.72"	111°32'17.02"	3,863,401.42	450,848.16	3,863,201.47	450,911.62
Bottle Spring			3842000.00	463300.00		
Bristow Spring			3858365.00	447470.00		
Brushy Wash Spring	34°38'44.14"	112°02'16.90"	3,834,231.87	404,869.83	3,834,032.14	404,932.95
Burnt Spring (cnf)			3805257.66	434969.32		
Buzzard Spring	35°00'23.02"	111°49'36.56"	3,874,064.43	424,555.95	3,873,864.66	424,619.55
Campbell Road Spring	34°44'50.98"	111°29'49.25"	3,845,154.13	454,507.49	3,844,954.68	454,570.92
Campbell Spring	34°44'53.50"	111°29'46.71"	3,845,231.60	454,572.54	3,845,032.15	454,635.97
Cave Spring			3872390.00	432137.00		
Cedar Spring			3812375.00	437187.50		
Chalk Spring (cnf)			3805319.01	435607.36		

Table 22 (continued)

Name of Spring	Latitude	Longitude	NAD 83 - North	NAD 83 - East	NAD 27 - North	NAD 27- East
Chasm Spring	34°26'43.11"	111°49'41.77"	3,811,843.66	423,911.50	3,811,644.24	423,974.51
Cherry 361a	34°36'24.76"	112°00'38.42"	3,829,912.82	407,333.92	3,829,713.13	407,397.02
Cherry 361b	34°36'28.63"	112°00'45.67"	3,830,033.94	407,150.48	3,829,834.25	407,213.59
Cimarron Spring	34°25'06.84"	111°40'05.79"	3,808,769.75	438,590.11	3,808,570.44	438,653.13
Clover Spring	34°30'21.32"	111°21'45.32"	3,818,313.75	466,715.48	3,818,114.55	466,778.51
Cottonwood Spring (cnf)			3816503.06	429325.15		
Cottonwood Spring (tnf)			3804167.00	456228.00		
Dow Spring	35°09'17.90"	111°59'08.50"	3,890,673.92	410,222.26	3,890,473.78	410,285.56
Dripping Spring #1			3805167.00	460319.00		
Dripping Spring #2			3805382.00	460089.00		
Dripping Spring #3			3805412.00	460319.00		
Dripping Spring #4			3805413.00	460089.00		
Fain Spring	34°49'07.73"	111°31'25.12"	3,853,075.53	452,111.14	3,852,875.86	452,174.57
Fortyfour Spring	34°29'03.54"	111°22'17.18"	3,815,920.84	465,894.25	3,815,721.65	465,957.27
Foster Spring	34°46'26.17"	111°30'22.98"	3,848,090.57	453,664.74	3,847,891.04	453,728.17
Frog Spring			3777906.25	428046.87		
Fuller Spring	34°24'36.72"	111°28'35.26"	3,807,742.44	456,212.25	3,807,543.22	456,275.31
Garden Spring	35°07'51.19"	111°44'12.48"	3,887,806.22	432,872.32	3,887,606.47	432,936.15
Geronimo Spring (1)	35°04'39.62"	111°56'50.21"	3,882,067.10	413,639.53	3,881,867.10	413,702.93
Geronimo Spring (tnf)	34°24'18.93"	111°21'36.08"	3,807,150.42	466,911.42	3,806,951.19	466,974.43
Goat Camp Spring			3,832,423.90	405,619.28		
Gooseberry Spring	34°48'57.57"	111°24'07.51"	3,852,711.03	463,227.03	3,852,511.67	463,290.42
Gould Spring #1	34°13'44.35"	111°25'02.35"	3,787,624.72	461,565.01	3,787,425.48	461,628.02
Gould Spring #2	34°13'42.83"	111°25'05.76"	3,787,578.11	461,477.52	3,787,378.86	461,540.52
Grapevine Spring	34°12'40.68"	111°23'56.99"	3,785,656.86	463,229.44	3,785,457.61	463,292.43
Grassy Meadow Spring			3873523.00	433032.00		
Gray Springs	35°07'35.68"	111°57'44.91"	3,887,504.00	412,306.73	3,887,303.93	412,370.09
Griffith Spring	35°07'02.76"	111°42'33.72"	3,886,296.41	435,361.18	3,886,096.61	435,424.99
Grimes Spring	34°12'37.96"	111°23'38.69"	3,785,571.34	463,697.54	3,785,372.10	463,760.53

Table 22 (continued)

Name of Spring	Latitude	Longitude	NAD 83 - North	NAD 83 - East	NAD 27 - North	NAD 27- East
Hackberry Spring #1	34°26'02.90"	111°41'16.70"	3,810,510.00	436,791.00	3,810,310.00	436,836.00
Hackberry Spring #2			3810367.00	436586.00		
Hance Spring	34°33'34.80"	111°44'22.10"	3,824,462.00	432,161.00	3,824,262.00	432,206.00
Horseshoe Spring	34°46'56.50"	111°24'08.39"	3,848,981.91	463,189.59	3,848,782.43	463,252.98
Howard Spring	34°59'03.76"	111°37'22.26"	3,871,487.93	443,152.69	3,871,287.96	443,216.25
Huffer Spring	34°27'54.78"	111°23'15.77"	3,813,808.28	464,391.65	3,813,609.07	464,454.67
Hull Spring	34°35'27.93"	111°57'43.16"	3,828,118.64	411,780.87	3,827,919.01	411,843.95
Irving High Spring			3807279.00	444575.00		
Irving Low Spring			3807006.00	443833.00		
JM Spring	33°58'10.47"	111°41'13.90"	3,758,995.20	436,515.98	3,758,796.09	436,579.10
Jones Spring #1	34°45'38.47"	111°29'50.32"	3,846,617.16	454,487.63	3,846,417.68	454,551.06
Jones Spring #2a	34°45'47.17"	111°29'51.41"	3,846,885.31	454,461.33	3,846,685.82	454,524.76
Jones Spring #2b	34°45'47.34"	111°29'54.98"	3,846,891.15	454,370.50	3,846,691.65	454,433.94
Kelsey Spring	35°04'31.16"	111°56'06.70"	3,881,795.90	414,739.01	3,881,595.92	414,802.43
Larson Spring			3787437.50	461062.50		
Lee Johnson Spring	34°26'28.62"	111°20'55.42"	3,811,141.57	467,963.28	3,810,942.36	468,026.28
Lee Spring	34°50'08.48"	111°33'15.09"	3,854,961.94	449,327.87	3,854,762.23	449,391.29
Lindburg Spring	35°06'32.08"	111°43'14.81"	3,885,358.51	434,314.30	3,885,158.74	434,378.10
Little Hutch Spring #1	34°12'32.09"	111°53'15.84"	3,785,676.59	418,219.69	3,785,477.34	418,282.94
Little Hutch Spring #2	34°12'31.56"	111°53'17.16"	3,785,660.58	418,185.79	3,785,461.33	418,249.04
LO Spring	35°09'13.17"	111°58'57.11"	3,890,525.14	410,508.86	3,890,325.01	410,572.16
Log Spring	34°36'05.90"	112°04'20.40"	3,829,390.00	401,673.00	3,829,191.00	401,718.00
Long Valley Spring	34°30'56.95"	111°20'00.30"	3,819,402.01	469,397.02	3,819,202.82	469,460.05
Lower Gould Spring	34°13'42.68"	111°25'12.44"	3,787,574.47	461,306.60	3,787,375.23	461,369.60
Lower Hull Spring	35°08'32.75"	111°57'52.30"	3,889,263.92	412,136.64	3,889,063.83	412,199.99
LX Spring	34°10'04.79"	111°50'05.45"	3,781,098.13	423,054.66	3,780,898.90	423,117.91
Maple Spring	35°00'08.21"	111°48'14.70"	3,873,591.22	426,627.23	3,873,391.47	426,690.87
Maxwell Spring	35°16'59.00"	111°47'47.40"	3,904,724.41	427,568.49	3,904,524.49	427,632.20
Mesquite Spring			3816245.39	429564.41		

Table 22 (continued)

Name of Spring	Latitude	Longitude	NAD 83 - North	NAD 83 - East	NAD 27 - North	NAD 27- East
Mine Spring	34°29'02.66"	111°51'09.03"	3,816,160.77	421,721.08	3,815,961.30	421,784.07
Morgan Spring			3833797.54	405417.17		
Mortgage Spring	35°02'13.38"	111°42'34.23"	3,877,381.86	435,284.84	3,877,182.08	435,348.55
Mund Spring			3864245.39	447852.76		
North Mine Spring	34°29'16.30"	111°51'16.93"	3,816,582.70	421,523.05	3,816,383.23	421,586.04
North Pass Spring			3777656.44	420375.00		
North Pasture Canyon Spring			3776969.32	420871.16		
North Pasture Spring			3777159.50	420435.58		
Oxbow Spring	34°42'08.00"	112°03'55.76"	3,840,538.17	402,419.56	3,840,338.37	402,482.69
Patton Spring	34°26'48.37"	111°21'55.45"	3,811,755.17	466,433.46	3,811,555.96	466,496.47
Pearson Spring	35°16'45.58"	111°48'25.63"	3,904,318.65	426,599.33	3,904,118.72	426,663.02
Pfau Spring	34°36'21.92"	112°00'14.87"	3,829,819.58	407,932.80	3,829,619.90	407,995.90
Phroney Spring	34°26'30.83"	111°41'34.58"	3,811,372.26	436,341.35	3,811,172.94	436,404.34
Picnic Spring	34°09'41.26"	111°49'57.53"	3,780,372.01	423,251.50	3,780,172.78	423,314.75
Pieper Hatchery Spring #1	34°26'06.54"	111°15'21.45"	3,810,436.10	476,483.92	3,810,236.89	476,546.89
Pieper Hatchery Spring #2	34°26'09.06"	111°15'18.55"	3,810,513.28	476,558.18	3,810,314.07	476,621.15
Pine Flat Spring			3874521.47	432736.19		
Pine Spring	34°22'42.96"	111°23'23.18"	3,804,204.61	464,165.72	3,804,005.38	464,228.74
Pivot Rock Spring	34°29'25.84"	111°23'53.97"	3,816,617.18	463,428.26	3,816,417.98	463,491.30
Poison Sping (tnf)	34°24'58.99"	111°20'35.47"	3,808,378.99	468,462.97	3,808,179.77	468,525.97
Poison Spring (1)	35°08'02.34"	111°58'31.13"	3,888,336.58	411,144.83	3,888,136.48	411,208.15
Powell Spring			3827079.75	401061.34		
Quail Spring #1	34°40'15.19"	112°03'01.78"	3,837,048.58	403,756.40	3,836,848.82	403,819.52
Quail Spring #2	34°40'15.63"	112°02'59.62"	3,837,061.58	403,811.57	3,836,861.82	403,874.69
Quail Spring #3	34°40'13.67"	112°02'59.77"	3,837,001.09	403,807.13	3,836,801.33	403,870.25
Quail Spring (cnf)			3803625.00	436562.50		
Railroad Spring	35°08'07.11"	111°57'35.37"	3,888,469.98	412,557.36	3,888,269.90	412,620.72
Red Horse Spring	34°35'16.77"	112°01'19.87"	3,827,829.23	406,256.80	3,827,629.55	406,319.91
Red Rock Spring	34°22'14.96"	111°24'04.43"	3,803,346.17	463,108.96	3,803,146.94	463,171.99

Table 22 (continued)

Name of Spring	Latitude	Longitude	NAD 83 - North	NAD 83 - East	NAD 27 - North	NAD 27- East
Ritter Spring	35°00'05.74"	111°42'23.44"	3,873,447.95	435,530.47	3,873,248.17	435,594.14
Rock Top Spring	34°51'08.82"	111°32'52.69"	3,856,817.29	449,907.14	3,856,617.54	449,970.58
Round Up Park Spring	34°49'25.78"	111°29'07.37"	3,853,613.74	455,613.27	3,853,414.05	455,676.70
Russel Spring #1	34°37'09.24"	111°45'36.60"	3,831,081.57	430,313.11	3,830,882.14	430,376.15
Russel Spring #2	34°37'09.36"	111°45'36.43"	3,831,085.07	430,317.39	3,830,885.64	430,380.48
Sally May Spring	34°24'02.81"	111°40'10.36"	3,806,798.25	438,460.37	3,806,598.95	438,523.40
Schells Spring	34°46'58.57"	111°23'04.63"	3,849,039.22	464,810.42	3,848,839.76	464,873.80
Scott Spring	35°01'32.91"	111°43'16.11"	3,876,142.62	434,214.79	3,875,942.86	434,278.51
Seven Anchor Spring #1	34°49'03.47"	111°24'49.46"	3,852,897.17	462,161.88	3,852,697.59	462,225.28
Seven Anchor Spring #2	34°49'02.14"	111°24'48.17"	3,852,856.22	462,194.63	3,852,656.65	462,258.03
Sheep Bridge Hot Springs			3770937.50	434687.50		
Sheep Spring	34°54'58.48"	111°32'14.22"	3,863,886.56	450,921.96	3,863,686.60	450,985.41
Spring Creek	34°46'33.70"	111°55'11.00"	3,848,591.00	415,844.00	3,848,391.00	415,889.00
Sterling Spring 1	35°01'30.10"	111°44'28.40	3,876,069.00	432,383.00	3,875,869.00	432,427.00
Sterling Spring 2	35°01'29.60"	111°44'21.10"	3,876,054.00	432,567.00	3,875,854.00	432,612.00
Stone Camp Spring	34°07'50.28"	111°51'13.01"	3,776,969.39	421,290.49	3,776,770.19	421,353.75
Summer Spring	34°52'50.30"	112°03'58.47"	3,860,325.00	402,560.75	3,860,125.02	402,623.99
Sycamore Spring #1a	34°28'29.30"	111°42'29.71"	3,815,031.02	434,959.96	3,814,831.68	435,022.90
Sycamore Spring #1b	34°28'25.42"	111°42'32.42"	3,814,912.14	434,889.94	3,814,712.80	434,952.88
Sycamore Spring #2	34°27'53.54"	111°42'48.54"	3,813,932.87	434,471.93	3,813,733.53	434,534.88
Table Mountain	34°26'15.96"	111°49'03.72"	3,810,999.45	424,875.77	3,810,800.05	424,938.78
Thicket Spring	34°11'46.59"	111°48'22.57"	3,784,212.57	425,713.42	3,784,013.32	425,776.66
Tonto Bridge	34°19'18.40"	111°27'16.00"	3,797,928.00	458,192.00	3,797,728.00	458,237.00
Towel Spring	34°24'30.81"	111°42'56.13"	3,807,689.65	434,234.12	3,807,490.33	434,297.13
Trail Junction Spring	33°58'38.20"	111°40'21.66"	3,759,840.57	437,862.09	3,759,641.45	437,925.19
Trail Spring	33°58'19.54"	111°38'23.57"	3,759,246.18	440,888.60	3,759,047.07	440,951.66
Tree Spring	34°52'10.22"	111°30'01.99"	3,858,686.10	454,251.21	3,858,486.23	454,314.65
T-six Spring			3864750.00	445562.50		
Tunnel Spring	34°35'16.71"	112°01'49.03"	3,827,834.97	405,514.13	3,827,635.28	405,577.25

Table 22 – (continued)

Name of Spring	Latitude	Longitude	NAD 83 - North	NAD 83 - East	NAD 27 - North	NAD 27- East
Turkey Spring	34°24'35.74"	111°23'06.92"	3,807,676.70	464,594.08	3,807,477.47	464,657.10
Upper Hull Spring	35°08'39.67"	111°57'51.94"	3,889,476.92	412,147.67	3,889,276.83	412,211.02
Van Deren Spring	34°50'15.67"	111°26'45.83"	3,855,134.12	459,215.66	3,854,934.45	459,279.07
Verde Hot Spring			3801562.50	434812.50		
Washington Spring	34°26'04.40"	111°16'21.99"	3,810,374.17	474,938.81	3,810,174.96	475,001.78
Wet Prong Spring	34°24'30.76"	111°43'49.88"	3,807,697.99	432,861.78	3,807,498.67	432,924.79
Wildcat Spring	34°27'38.00"	111°24'24.39"	3,813,298.33	462,639.12	3,813,099.12	462,702.15
Willard Spring	34°58'39.23"	111°40'53.18"	3,870,767.16	437,800.04	3,870,567.35	437,863.65
Wilson Seep	35°01'27.80"	111°42'37.08"	3,875,978.11	435,202.70	3,875,778.34	435,266.35
Windfall Spring	34°28'24.32"	111°21'52.08"	3,814,710.43	466,530.04	3,814,511.20	466,593.06
Winter Cabin Spring	34°41'04.63"	111°46'09.82"	3,838,338.81	429,522.44	3,838,139.34	429,585.56
Wire Corral Spring	33°58'15.65"	111°38'35.91"	3,759,128.64	440,571.20	3,758,929.53	440,634.26
Yellow Jacket Spring	34°44'23.00"	111°25'02.08"	3,844,259.14	461,805.44	3,844,059.73	461,860.81
Zig Zag Spring #1 main	34°10'40.15"	111°47'34.03"	3,782,156.60	426,939.94	3,781,957.36	427,003.18
Zig Zag Spring #2	34°10'40.83"	111°47'32.99"	3,782,177.11	426,966.75	3,781,977.87	427,029.99

Table 23 – Elevation and GPS method (GPS location table) for 160 springs in the Middle Verde Springs study.

Name of Spring	Elevation (m)	Elevation (ft)	Source/Deviation
101 Spring	2,172.19	7,126.58	Survey GPS (<1m)
Babe's Hole Spring	1,812.01	5,944.92	Survey GPS (<1m)
Baker Spring	2,237.21	7,339.91	Survey GPS (<1m)
Banfield Spring	2066.54	6780.00	USFS Data
Banjo Bill Spring	1536.20	5040.00	USFS Data
Barney Spring	2,069.91	6,791.03	Survey GPS (<1m)
Basin Spring	782.70	2,567.92	Survey GPS (<1m)
Bear Spring (tnf)	1,827.53	5,995.81	Survey GPS (<1m)
Bear Spring(pnf)	1,078.22	3,537.45	Survey GPS (<1m)
Beasley Flat Spring	1,009.78	3,312.93	Survey GPS (<1m)
Bell Rock Spring	1301.50	4270.00	USFS Data
Big Hutch Spring #1	1,375.82	4,513.84	Survey GPS (<1m)
Big Hutch Spring #2	1,363.56	4,473.60	Survey GPS (<1m)
Bill Back Spring	2,180.09	7,152.52	Survey GPS (<1m)
Bill Dick Spring	2,285.26	7,497.56	Survey GPS (<1m)
Black Canyon Spring	1985.47	6514.00	Topo Map
Blue Monster Main Spring	1,252.78	4,110.16	Survey GPS (<1m)
Blue Monster South Spring	1,256.90	4,123.68	Survey GPS (<1m)
Bootlegger Spring	2,228.73	7,312.08	Survey GPS (<1m)
Bottle Spring	2289.05	7510.00	USFS Data
Bristow Spring	2045.20	6710.00	USFS Data
Brushy Wash Spring	1,263.52	4,145.39	Survey GPS (<1m)
Burnt Spring (cnf)	1337.16	4387.00	Topo Map
Buzzard Spring	2,068.94	6,787.83	Survey GPS (<1m)
Campbell Road Spring	2,093.82	6,869.48	Survey GPS (<1m)
Campbell Spring	2,099.48	6,888.04	Survey GPS (<1m)
Cave Spring	1670.30	5480.00	USFS Data
Cedar Spring	1269.50	4165.00	Topo Map
Chalk Spring (cnf)	1362.15	4469.00	Topo Map

Table 23 (continued)

Name of Spring	Elevation (m)	Elevation (ft)	Source/Deviation
Chasm Spring	1,058.88	3,474.02	Survey GPS (<1m)
Cherry 361a	1,305.81	4,284.14	Survey GPS (<1m)
Cherry 361b	1,353.40	4,440.28	Survey GPS (<1m)
Cimarron Spring	1,284.86	4,215.40	Survey GPS (<1m)
Clover Spring	2,085.56	6,842.37	Survey GPS (<1m)
Cottonwood Spring (cnf)	947.93	3110.00	Topo Map
Cottonwood Spring (tnf)	1755.65	5760.00	USFS Data
Dow Spring	2,044.67	6,708.22	Survey GPS (<1m)
Dripping Spring #1	1889.76	6200.00	USFS Data
Dripping Spring #2	1816.60	5960.00	USFS Data
Dripping Spring #3	1889.76	6200.00	USFS Data
Dripping Spring #4	1804.42	5920.00	USFS Data
Fain Spring	2,162.42	7,094.54	Survey GPS (<1m)
Fortyfour Spring	2,151.63	7,059.14	Survey GPS (<1m)
Foster Spring	2,127.91	6,981.31	Survey GPS (<1m)
Frog Spring	848.25	2783.00	Topo Map
Fuller Spring	1,875.78	6,154.11	Survey GPS (<1m)
Garden Spring	2,207.08	7,241.05	Survey GPS (<1m)
Geronimo Spring (1)	1,576.75	5,173.07	Survey GPS (<1m)
Geronimo Spring (tnf)	1,726.49	5,664.32	Survey GPS (<1m)
Goat Camp Spring	1,363.04	4471.91	Topo Map
Gooseberry Spring	2,407.86	7,899.78	Survey GPS (<1m)
Gould Spring #1	1,231.19	4,039.34	Survey GPS (<1m)
Gould Spring #2	1,229.23	4,032.91	Survey GPS (<1m)
Grapevine Spring	1,302.09	4,271.95	Survey GPS (<1m)
Grassy Meadow Spring	1665.73	5465.00	USFS Data
Gray Springs	2,040.48	6,694.48	Survey GPS (<1m)
Griffith Spring	2,091.13	6,860.64	Survey GPS (<1m)
Grimes Spring	1,361.45	4,466.68	Survey GPS (<1m)

Table 23 (continued)

Name of Spring	Elevation (m)	Elevation (ft)	Source/Deviation
Hackberry Spring #1	1,246.00	4,086.00	Handheld GPS (<10m)
Hackberry Spring #2	1247.55	4093.00	USFS Data
Hance Spring	1,129.00	3,705.00	Handheld GPS (<10m)
Horseshoe Spring	2,395.72	7,859.97	Survey GPS (<1m)
Howard Spring	2,132.83	6,997.46	Survey GPS (<1m)
Huffer Spring	2,265.43	7,432.49	Survey GPS (<1m)
Hull Spring	1,108.63	3,637.24	Survey GPS (<1m)
Irving High Spring	1258.82	4130.00	USFS Data
Irving Low Spring	1188.72	3900.00	USFS Data
JM Spring	587.45	1,927.34	Survey GPS (<1m)
Jones Spring #1	2,156.10	7,073.81	Survey GPS (<1m)
Jones Spring #2a	2,154.75	7,069.38	Survey GPS (<1m)
Jones Spring #2b	2,157.39	7,078.05	Survey GPS (<1m)
Kelsey Spring	1,948.87	6,393.92	Survey GPS (<1m)
Larson Spring	1199.39	3935.00	Topo Map
Lee Johnson Spring	2,250.59	7,383.80	Survey GPS (<1m)
Lee Spring	2,067.69	6,783.75	Survey GPS (<1m)
Lindburg Spring	2,109.49	6,920.88	Survey GPS (<1m)
Little Hutch Spring #1	1,401.80	4,599.06	Survey GPS (<1m)
Little Hutch Spring #2	1,396.67	4,582.23	Survey GPS (<1m)
LO Spring	2,043.46	6,704.24	Survey GPS (<1m)
Log Spring	1,664.00	5,460.00	Handheld GPS (<10m)
Long Valley Spring	2,146.76	7,043.17	Survey GPS (<1m)
Lower Gould Spring	1,216.50	3,991.12	Survey GPS (<1m)
Lower Hull Spring	2,050.70	6,728.02	Survey GPS (<1m)
LX Spring	913.71	2,997.74	Survey GPS (<1m)
Maple Spring	2,036.49	6,681.38	Survey GPS (<1m)
Maxwell Spring	2,305.30	7,563.31	Survey GPS (<1m)
Mesquite Spring	951.58	3122.00	Topo Map

Table 23 (continued)

Name of Spring	Elevation (m)	Elevation (ft)	Source/Deviation
Mine Spring	1,123.50	3,686.01	Survey GPS (<1m)
Morgan Spring	1255.75	4120.00	Topo Map
Mortgage Spring	1,970.71	6,465.56	Survey GPS (<1m)
Mund Spring	2108.60	6918.00	Topo Map
North Mine Spring	1,125.18	3,691.51	Survey GPS (<1m)
North Pass Spring	1204.57	3952.00	Topo Map
North Pasture Canyon Spring	1108.86	3638.00	Topo Map
North Pasture Spring	1185.98	3891.00	Topo Map
Oxbow Spring	1,313.84	4,310.49	Survey GPS (<1m)
Patton Spring	2,282.01	7,486.89	Survey GPS (<1m)
Pearson Spring	2,300.21	7,546.61	Survey GPS (<1m)
Pfau Spring	1,250.15	4,101.53	Survey GPS (<1m)
Phroney Spring	1,233.05	4,045.43	Survey GPS (<1m)
Picnic Spring	923.04	3,028.35	Survey GPS (<1m)
Pieper Hatchery Spring #1	1,908.82	6,262.52	Survey GPS (<1m)
Pieper Hatchery Spring #2	1,940.91	6,367.80	Survey GPS (<1m)
Pine Flat Spring	1694.69	5560.00	Topo Map
Pine Spring	1,847.09	6,060.00	Survey GPS (<1m)
Pivot Rock Spring	2,131.13	6,991.88	Survey GPS (<1m)
Poison Sping (tnf)	1,919.52	6,297.62	Survey GPS (<1m)
Poison Spring (1)	2,034.21	6,673.91	Survey GPS (<1m)
Powell Spring	1667.25	5470.00	Topo Map
Quail Spring #1	1,264.93	4,150.03	Survey GPS (<1m)
Quail Spring #2	1,255.17	4,118.02	Survey GPS (<1m)
Quail Spring #3	1,257.23	4,124.75	Survey GPS (<1m)
Quail Spring (cnf)	1189.33	3902.00	Topo Map
Railroad Spring	2,044.80	6,708.65	Survey GPS (<1m)
Red Horse Spring	1,508.57	4,949.37	Survey GPS (<1m)
Red Rock Spring	1,836.30	6,024.59	Survey GPS (<1m)

Table 23 (continued)

Name of Spring	Elevation (m)	Elevation (ft)	Source/Deviation
Ritter Spring	2,070.32	6,792.37	Survey GPS (<1m)
Rock Top Spring	2,128.10	6,981.94	Survey GPS (<1m)
Round Up Park Spring	2,265.06	7,431.27	Survey GPS (<1m)
Russel Spring #1	1,092.68	3,584.92	Survey GPS (<1m)
Russel Spring #2	1,089.35	3,573.99	Survey GPS (<1m)
Sally May Spring	1,130.41	3,708.67	Survey GPS (<1m)
Schells Spring	2,391.73	7,846.88	Survey GPS (<1m)
Scott Spring	2,012.99	6,604.30	Survey GPS (<1m)
Seven Anchor Spring #1	2,363.90	7,755.56	Survey GPS (<1m)
Seven Anchor Spring #2	2,372.07	7,782.36	Survey GPS (<1m)
Sheep Bridge Hot Springs	624.84	2050.00	Topo Map
Sheep Spring	2,192.38	7,192.84	Survey GPS (<1m)
Spring Creek	1,088.00	3,568.00	Handheld GPS (<10m)
Sterling Spring 1	1,745.00	5,726.00	Handheld GPS (<10m)
Sterling Spring 2	1,706.00	5,598.00	Handheld GPS (<10m)
Stone Camp Spring	1,026.72	3,368.48	Survey GPS (<1m)
Summer Spring	1,102.47	3,617.00	Survey GPS (<1m)
Sycamore Spring #1a	1,173.64	3,850.52	Survey GPS (<1m)
Sycamore Spring #1b	1,169.36	3,836.48	Survey GPS (<1m)
Sycamore Spring #2	1,137.81	3,732.96	Survey GPS (<1m)
Table Mountain	1,088.12	3,569.94	Survey GPS (<1m)
Thicket Spring	899.87	2,952.33	Survey GPS (<1m)
Tonto Bridge	1,390.00	4,561.00	Handheld GPS (<1m)
Towel Spring	1,315.65	4,316.41	Survey GPS (<1m)
Trail Junction Spring	606.31	1,989.19	Survey GPS (<1m)
Trail Spring	751.91	2,466.90	Survey GPS (<1m)
Tree Spring	2,212.13	7,257.64	Survey GPS (<1m)
T-six Spring	2063.50	6770.00	Topo Map
Tunnel Spring	1,508.21	4,948.19	Survey GPS (<1m)

Table 23 (continued)

Name of Spring	Elevation (m)	Elevation (ft)	Source/Deviation
Turkey Spring	1,764.62	5,789.42	Survey GPS (<1m)
Upper Hull Spring	2,049.80	6,725.06	Survey GPS (<1m)
Van Deren Spring	2,281.25	7,484.41	Survey GPS (<1m)
Verde Hot Spring	802.38	2632.50	Topo Map
Washington Spring	2,015.67	6,613.08	Survey GPS (<1m)
Wet Prong Spring	1,205.88	3,956.28	Survey GPS (<1m)
Wildcat Spring	2,192.61	7,193.60	Survey GPS (<1m)
Willard Spring	2,060.78	6,761.06	Survey GPS (<1m)
Wilson Seep	2,023.70	6,639.41	Survey GPS (<1m)
Windfall Spring	2,191.70	7,190.60	Survey GPS (<1m)
Winter Cabin Spring	1,099.09	3,605.94	Survey GPS (<1m)
Wire Corral Spring	731.96	2,401.44	Survey GPS (<1m)
Yellow Jacket Spring	2,275.57	7,465.77	Survey GPS (<1m)
Zig Zag Spring #1 main	873.92	2,867.19	Survey GPS (<1m)
Zig Zag Spring #2	874.29	2,868.41	Survey GPS (<1m)

Table 24 – Discharge data (Water quality and discharge data table) for 160 springs for the Middle Verde Springs study.

Name of Spring	Discharge instrument	Q (gpm)	accuracy (+/-)	Q (l/s)	Discharge Description	Discharge variability
101 Spring	Volumetric Container	0.8	0.2	0.050		Perennial
Babe's Hole Spring	Box Flume	8.0	2.0	0.505		Perennial
Baker Spring	none	0.0	0.0	0.000	may be Ephemeral	Intermittent
Banfield Spring	none	0.0	0.0	0.000		Intermittent
Banjo Bill Spring	Volumetric Container	8.0	1.0	0.505		Perennial
Barney Spring	none	0.0	0.0	0.000	may be intermittent	Ephemeral
Basin Spring	V-notch weir	0.25	0.1	0.016		Intermittent
Bear Spring (tnf)	Volumetric Container	0.313	0.05	0.020	may be intermittent	Perennial
Bear Spring(pnf)	none	0.0	0.0	0.000	moist seep, may be perrenial	Intermittent
Beasley Flat Spring	none	0.0	0.0	0.000		Ephemeral
Bell Rock Spring	none	0.0	0.0	0.000		Ephemeral
Big Hutch Spring #1	Estimation	20.0	5.0	1.262	several sources	Perennial
Big Hutch Spring #2	Estimation	20.0	5.0	1.262	several sources	Perennial
Bill Back Spring	none	0.0	0.0	0.000	may be intermittent	Ephemeral
Bill Dick Spring	none	0.0	0.0	0.000		Intermittent
Black Canyon Spring	none	0.0	0.0	0.000		Ephemeral
Blue Monster Main Spring	none	0.0	0.0	0.000	may be intermittent	Ephemeral
Blue Monster South Spring	none	0.0	0.0	0.000	seep pool	Intermittent
Bootlegger Spring	V-notch weir	0.15	0.1	0.009	may be intermittent	Perennial
Bottle Spring	none	0.0	0.0	0.000		Ephemeral
Bristow Spring	none	0.0	0.0	0.000		Intermittent
Brushy Wash Spring	none	0.0	0.0	0.000		Ephemeral
Burnt Spring (cnf)	none	0.0	0.0	0.000		Ephemeral
Buzzard Spring	none	0.0	0.0	0.000		Ephemeral
Campbell Road Spring	V-notch weir	0.5	0.1	0.032	may be intermittent	Perennial
Campbell Spring	V-notch weir	1.0	0.2	0.063		Perennial
Cave Spring	none	0.0	0.0	0.000		Intermittent
Cedar Spring	none	0.0	0.0	0.000	seep pool	Intermittent
Chalk Spring (cnf)	none	0.0	0.0	0.000		Ephemeral

Table 24 (continued)

Name of Spring	Discharge instrument	Q (gpm)	accuracy (+/-)	Q (l/s)	Discharge Description	Discharge variability
Chasm Spring	V-notch weir	1.0	0.5	0.063	may be intermittent	Perennial
Cherry 361a	none	0.0	0.0	0.000	may be intermittent	Ephemeral
Cherry 361b	Box Flume	1.5	0.5	0.095		Perennial
Cimarron Spring	none	0.0	0.0	0.000		Ephemeral
Clover Spring	none	0.0	0.0	0.000		Intermittent
Cottonwood Spring (cnf)	none	0.0	0.0	0.000		Ephemeral
Cottonwood Spring (tnf)	none	0.0	0.0	0.000		Ephemeral
Dow Spring	Volumetric Container	0.06	0.01	0.004		Perennial
Dripping Spring #1	V-notch weir	1.0	0.5	0.063		Perennial
Dripping Spring #2	V-notch weir	0.25	0.1	0.016		Perennial
Dripping Spring #3	V-notch weir	0.25	0.1	0.016		Perennial
Dripping Spring #4	none	0.0	0.0	0.000		Ephermeral
Fain Spring	V-notch weir	0.50	0.1	0.032	may be intermittent	Perennial
Fortyfour Spring	Box Flume	0.563	0.1	0.036		Perennial
Foster Spring	Volumetric Container	0.3	0.1	0.019	some sources intermittent	Perennial
Frog Spring	none	0.0	0.0	0.000	seep pool	Intermittent
Fuller Spring	Estimation	0.1	0.05	0.006		Intermittent
Garden Spring	none	0.0	0.0	0.000		Ephemeral
Geronimo Spring (1)	Box Flume	5.0	2.0	0.315		Perennial
Geronimo Spring (tnf)	V-notch weir	0.15	0.05	0.009		Perennial
Goat Camp Spring	none	0.0	0.0	0.000		Ephemeral
Gooseberry Spring	Volumetric Container	0.20	0.05	0.013	intermittent surface flow	Perennial
Gould Spring #1	none	0.0	0.0	0.000		Ephemeral
Gould Spring #2	none	0.0	0.0	0.000		Ephemeral
Grapevine Spring	none	0.0	0.0	0.000		Ephemeral
Grassy Meadow Spring	Box Flume	0.364	0.1	0.023		Perennial
Gray Springs	Box Flume	1.44	0.2	0.091		Perennial
Griffith Spring	none	0.0	0.0	0.000	may be intermittent	Ephemeral
Grimes Spring	V-notch weir	0.25	0.1	0.016	may be perrenial	Intermittent

Table 24 (continued)

Name of Spring	Discharge instrument	Q (gpm)	accuracy (+/-)	Q (l/s)	Discharge Description	Discharge variability
Hackberry Spring #1	Box Flume	6.50	0.5	0.410		Perennial
Hackberry Spring #2	Volumetric Container	5.0	0.5	0.315		Perennial
Hance Spring	none	0.0	0.0	0.000	pool	Intermittent
Horseshoe Spring	Volumetric Container	0.5	0.1	0.032	may be perrenial	Intermittent
Howard Spring	none	0.0	0.0	0.000	may be intermittent	Ephemeral
Huffer Spring	none	0.0	0.0	0.000		Ephemeral
Hull Spring	none	0.0	0.0	0.000		Ephemeral
Irving High Spring	Box Flume	0.810	0.2	0.051		Perennial
Irving Low Spring	Box Flume	0.360	0.1	0.023		Perennial
JM Spring	none	0.0	0.0	0.000		Intermittent
Jones Spring #1	none	0.0	0.0	0.000		Intermittent
Jones Spring #2a	none	0.0	0.0	0.000		Intermittent
Jones Spring #2b	none	0.0	0.0	0.000		Intermittent
Kelsey Spring	Volumetric Container	1.07	0.1	0.067		Perennial
Larson Spring	none	0.0	0.0	0.000		Ephemeral
Lee Johnson Spring	none	0.0	0.0	0.000		Intermittent
Lee Spring	none	0.0	0.0	0.000	may be ephemeral	Intermittent
Lindburg Spring	V-notch weir	0.25	0.05	0.016	may be intermittent	Perennial
Little Hutch Spring #1	V-notch weir	2.0	0.2	0.126		Perennial
Little Hutch Spring #2	V-notch weir	2.0	0.2	0.126		Perennial
LO Spring	Box Flume / Estimation	24.0	5.0	1.514		Perennial
Log Spring	Box Flume	1.82	0.1	0.115		Perennial
Long Valley Spring	none	0.0	0.0	0.000	may be ephemeral	Intermittent
Lower Gould Spring	Box Flume	0.1	0.02	0.006		Intermittent
Lower Hull Spring	none	0.0	0.0	0.000		Intermittent
LX Spring	Box Flume	20.3	2.0	1.281		Perennial
Maple Spring	none	0.0	0.0	0.000		Ephemeral
Maxwell Spring	none	0.0	0.0	0.000		Ephemeral
Mesquite Spring	none	0.0	0.0	0.000		Ephemeral

Table 24 (continued)

Name of Spring	Discharge instrument	Q (gpm)	accuracy (+/-)	Q (l/s)	Discharge Description	Discharge variability
Mine Spring	Box Flume	0.563	0.1	0.036	some flow diverted to pipe	Perennial
Morgan Spring	none	0.0	0.0	0.000		Ephemeral
Mortgage Spring	none	0.0	0.0	0.000	pool	Ephemeral
Mund Spring	none	0.0	0.0	0.000		Ephemeral
North Mine Spring	none	0.0	0.0	0.000	pool in cave	Intermittent
North Pass Spring	V-notch weir	0.35	0.1	0.022		Intermittent
North Pasture Canyon Spring	Box Flume	3.24	0.5	0.204	may be intermittent	Perennial
North Pasture Spring	V-notch weir	0.25	0.1	0.016		Intermittent
Oxbow Spring	V-notch weir	0.5	0.1	0.032	may be intermittent	Perennial
Patton Spring	none	0.0	0.0	0.000		Ephemeral
Pearson Spring	none	0.0	0.0	0.000		Ephemeral
Pfau Spring	Box Flume	1.10	0.3	0.069		Perennial
Phroney Spring	Box Flume	2.25	0.2	0.142		Perennial
Picnic Spring	Box Flume	3.80	0.5	0.240		Perennial
Pieper Hatchery Spring #1	Box Flume	85	5.0	5.362		Perennial
Pieper Hatchery Spring #2	Box Flume	100	10	6.308		Perennial
Pine Flat Spring	Volumetric Container	50.0	5.0	3.154		Perennial
Pine Spring	V-notch weir	1.20	0.1	0.076		Perennial
Pivot Rock Spring	Volumetric Container	1.20	0.3	0.076		Perennial
Poison Sping (tnf)	Volumetric Container	7.50	1.0	0.473	large amount of flow piped	Perennial
Poison Spring (1)	Box Flume	1.10	0.3	0.069		Perennial
Powell Spring	none	0.0	0.0	0.000	seep pool	Intermittent
Quail Spring #1	none	0.0	0.0	0.000	moist ground	Intermittent
Quail Spring #2	Box Flume	2.25	0.5	0.142		Perennial
Quail Spring #3	none	0.0	0.0	0.000		Intermittent
Quail Spring (cnf)	none	0.0	0.0	0.000		Ephemeral
Railroad Spring	none	0.0	0.0	0.000	moist seep	Intermittent
Red Horse Spring	Estimation	0.25	0.05	0.016	pool in tunnel	Intermittent
Red Rock Spring	none	0.0	0.0	0.000		Ephemeral

Table 24 (continued)

Name of Spring	Discharge instrument	Q (gpm)	accuracy (+/-)	Q (l/s)	Discharge Description	Discharge variability
Ritter Spring	none	0.0	0.0	0.000		Ephemeral
Rock Top Spring	V-notch weir	1.0	0.2	0.063		Perennial
Round Up Park Spring	none	0.0	0.0	0.000		Intermittent
Russel Spring #1	Box Flume	3.80	0.2	0.240		Perennial
Russel Spring #2	Box Flume	0.563	0.1	0.036		Perennial
Sally May Spring	none	0.0	0.0	0.000		Intermittent
Schells Spring	none	0.0	0.0	0.000		Ephemeral
Scott Spring	none	0.0	0.0	0.000		Ephemeral
Seven Anchor Spring #1	V-notch weir	0.75	0.25	0.047		Perennial
Seven Anchor Spring #2	none	0.0	0.0	0.000		Intermittent
Sheep Bridge Hot Springs	Volumetric Container	25.67	2.0	1.619		Perennial
Sheep Spring	Volumetric Container	2.0	0.2	0.126		Perennial
Spring Creek	Box Flume	171	10	10.787		Perennial
Sterling Spring 1	Box Flume	9.31	0.5	0.587		Perennial
Sterling Spring 2	Box Flume	310	20	19.556		Perennial
Stone Camp Spring	Box Flume	20.3	2.0	1.281		Perennial
Summer Spring	Flow Meter / Estimation	2600	100	164.017		Perennial
Sycamore Spring #1a	Box Flume	2.25	0.2	0.142		Intermittent
Sycamore Spring #1b	Box Flume	2.72	0.2	0.172		Intermittent
Sycamore Spring #2	Box Flume	2.25	0.2	0.142		Intermittent
Table Mountain	none	0.0	0.0	0.000	seep pool	Intermittent
Thicket Spring	none	0.0	0.0	0.000		Ephemeral
Tonto Bridge	Box Flume	100	10	6.308		Perennial
Towel Spring	none	0.0	0.0	0.000		Intermittent
Trail Junction Spring	Box Flume	1.10	0.1	0.069		Perennial
Trail Spring	none	0.0	0.0	0.000		Ephemeral
Tree Spring	none	0.0	0.0	0.000		Ephemeral
T-six Spring	none	0.0	0.0	0.000		Ephemeral
Tunnel Spring	Volumetric Container	0.1	0.05	0.006	flow from pipe	Intermittent

Table 24 (continued)

Name of Spring	Discharge instrument	Q (gpm)	accuracy (+/-)	Q (l/s)	Discharge Description	Discharge variability
Turkey Spring	Volumetric Container	3.75	0.2	0.237		Perennial
Upper Hull Spring	none	0.0	0.0	0.000		Intermittent
Van Deren Spring	none	0.0	0.0	0.000	water in tank	Intermittent
Verde Hot Spring	Volumetric Container	12.0	2.0	0.757		Perennial
Washington Spring	Volumetric Container	8.0	1.0	0.505	large amount of flow piped	Perennial
Wet Prong Spring	Box Flume	5.06	0.5	0.319		Perennial
Wildcat Spring	none	0.0	0.0	0.000		Ephemeral
Willard Spring	none	0.0	0.0	0.000		Intermittent
Wilson Seep	none	0.0	0.0	0.000		Ephemeral
Windfall Spring	none	0.0	0.0	0.000		Ephemeral
Winter Cabin Spring	none	0.0	0.0	0.000		Ephemeral
Wire Corral Spring	none	0.0	0.0	0.000	seep pool, may be intermittent	Ephemeral
Yellow Jacket Spring	none	0.0	0.0	0.000		Ephemeral
Zig Zag Spring #1 main	Box Flume	20.3	3.0	1.281		Perennial
Zig Zag Spring #2	Box Flume	2.25	0.3	0.142		Perennial

Notes: Q = Discharge

Table 25 – Water quality data (Water quality and discharge data table) for 160 springs for the Middle Verde Springs study

Name of Spring	Air Temp (°C)	Water Temp (°C)	pH	Specific Conductance (µS/cm)
101 Spring	26.0	7.8	7.91	0
Babe's Hole Spring	29.5	9.7	6.99	0
Baker Spring	0	0	0	0
Banfield Spring	0	0	0	0
Banjo Bill Spring	16.0	13.0	7.50	0
Barney Spring	0	0	0	0
Basin Spring	32.9	26.0	7.86	0.507
Bear Spring (tnf)	31.2	14.6	7.71	0
Bear Spring(pnf)	0	0	0	0
Beasley Flat Spring	0	0	0	0
Bell Rock Spring	0	0	0	0
Big Hutch Spring #1	34.0	21.5	8.17	0.480
Big Hutch Spring #2	34.0	21.5	8.17	0.480
Bill Back Spring	0	0	0	0
Bill Dick Spring	0	0	0	0
Black Canyon Spring	0	0	0	0
Blue Monster Main Spring	0	0	0	0
Blue Monster South Spring	33.0	27.8	7.85	0.752
Bootlegger Spring	28.0	21.7	7.94	0.194
Bottle Spring	0	0	0	0
Bristow Spring	0	0	0	0
Brushy Wash Spring	0	0	0	0
Burnt Spring (cnf)	0	0	0	0
Buzzard Spring	0	0	0	0
Campbell Road Spring	24.2	15.9	6.76	0
Campbell Spring	24.2	16.0	7.36	0
Cave Spring	0	0	0	0
Cedar Spring	35.0	18.2	8.60	0.672
Chalk Spring (cnf)	0	0	0	0

Table 25 (continued)

Name of Spring	Air Temp (°C)	Water Temp (°C)	pH	Specific Conductance (μS/cm)
Chasm Spring	32.1	20.7	7.78	0.638
Cherry 361a	0	0	0	0
Cherry 361b	33.0	28.0	7.37	0.346
Cimarron Spring	0	0	0	0
Clover Spring	0	0	0	0
Cottonwood Spring (cnf)	0	0	0	0
Cottonwood Spring (tnf)	0	0	0	0
Dow Spring	27.3	20.0	9.16	0.324
Dripping Spring #1	21.6	14.0	8.01	0
Dripping Spring #2	21.6	13.5	7.72	0
Dripping Spring #3	21.6	15.0	7.35	0
Dripping Spring #4	0	0	0	0
Fain Spring	28.0	14.6	7.04	0.618
Fortyfour Spring	28.5	12.1	7.30	0
Foster Spring	22.0	16.3	8.20	0
Frog Spring	35.0	23.5	7.74	0.567
Fuller Spring	29.0	18.8	7.14	0
Garden Spring	0	0	0	0
Geronimo Spring (1)	29.4	14.6	8.28	0
Geronimo Spring (tnf)	31.2	18.2	7.58	0
Goat Camp Spring	0	0	0	0
Gooseberry Spring	26.7	19.3	7.80	0
Gould Spring #1	0	0	0	0
Gould Spring #2	0	0	0	0
Grapevine Spring	0	0	0	0
Grassy Meadow Spring	15.0	8.8	7.37	0
Gray Springs	27.5	12.8	8.66	0
Griffith Spring	0	0	0	0
Grimes Spring	32.2	24.0	6.99	0

Table 25 (continued)

Name of Spring	Air Temp (°C)	Water Temp (°C)	pH	Specific Conductance (μS/cm)
Hackberry Spring #1	36.5	19.6	6.74	0.459
Hackberry Spring #2	36.3	17.2	6.83	0.454
Hance Spring	33.2	18.9	6.79	0.765
Horseshoe Spring	26	11.5	8.05	0
Howard Spring	0	0	0	0
Huffer Spring	0	0	0	0
Hull Spring	0	0	0	0
Irving High Spring	22.2	15.8	7.52	0
Irving Low Spring	24.0	20.0	7.28	0
JM Spring	0	0	0	0
Jones Spring #1	0	0	0	0
Jones Spring #2a	0	0	0	0
Jones Spring #2b	0	0	0	0
Kelsey Spring	30.7	12.5	6.77	0
Larson Spring	0	0	0	0
Lee Johnson Spring	0	0	0	0
Lee Spring	0	0	0	0
Lindburg Spring	27.0	13.1	7.07	0
Little Hutch Spring #1	35.0	18.4	6.92	0.405
Little Hutch Spring #2	35.0	18.4	6.92	0.405
LO Spring	31.5	19.9	7.62	0
Log Spring	31.3	17.3	6.63	0.435
Long Valley Spring	0	0	0	0
Lower Gould Spring	33.3	27.4	8.02	0
Lower Hull Spring	0	0	0	0
LX Spring	37.0	20.8	7.36	0.618
Maple Spring	0	0	0	0
Maxwell Spring	0	0	0	0
Mesquite Spring	0	0	0	0

Table 25 (continued)

Name of Spring	Air Temp (°C)	Water Temp (°C)	pH	Specific Conductance (μS/cm)
Mine Spring	32.5	21.2	7.10	0.050
Morgan Spring	0	0	0	0
Mortgage Spring	25.6	20.4	9.18	0
Mund Spring	0	0	0	0
North Mine Spring	32.0	16.2	7.65	1.230
North Pass Spring	33.2	30.0	7.67	0.667
North Pasture Canyon Spring	28.0	20.9	7.37	0.575
North Pasture Spring	33.7	22.8	7.33	0.706
Oxbow Spring	30.0	19.5	7.42	0
Patton Spring	0	0	0	0
Pearson Spring	0	0	0	0
Pfau Spring	38.7	22.4	7.51	0.705
Phroney Spring	31.2	19.7	6.84	0.272
Picnic Spring	34.6	21.0	7.38	0.531
Pieper Hatchery Spring #1	27.1	11.3	7.25	0
Pieper Hatchery Spring #2	27.1	11.3	7.25	0
Pine Flat Spring	15.0	11.5	7.60	0
Pine Spring	25.3	17.6	7.94	0
Pivot Rock Spring	29.0	9.4	7.60	0
Poison Sping (tnf)	31.2	12.3	7.57	0
Poison Spring (1)	23.7	12.7	8.28	0
Powell Spring	21.6	16.7	7.31	0
Quail Spring #1	0	0	0	0
Quail Spring #2	30.0	23.1	7.78	0
Quail Spring #3	0	0	0	0
Quail Spring (cnf)	0	0	0	0
Railroad Spring	0	0	0	0
Red Horse Spring	30.0	22.2	7.44	0
Red Rock Spring	0	0	0	0

Table 25 (continued)

Name of Spring	Air Temp (°C)	Water Temp (°C)	pH	Specific Conductance (µS/cm)
Ritter Spring	0	0	0	0
Rock Top Spring	29.0	19.1	7.80	0.243
Round Up Park Spring	0	0	0	0
Russel Spring #1	28.0	18.6	17.4	0.992
Russel Spring #2	28.0	17.4	6.87	1.035
Sally May Spring	0	0	0	0
Schells Spring	0	0	0	0
Scott Spring	0	0	0	0
Seven Anchor Spring #1	24.0	15.3	6.81	0
Seven Anchor Spring #2	0	0	0	0
Sheep Bridge Hot Springs	22.0	36.3	7.40	1.784
Sheep Spring	28.9	14.3	7.50	0.244
Spring Creek	14	10.6	7.27	0
Sterling Spring 1	13.0	8.7	7.15	0
Sterling Spring 2	13	8.7	7.15	0
Stone Camp Spring	24.8	20.8	7.0	0.575
Summer Spring	32.7	19.5	7.05	0
Sycamore Spring #1a	35.0	18.8	7.06	0.552
Sycamore Spring #1b	35.0	18.9	7.42	0.528
Sycamore Spring #2	35.0	19.5	7.14	0.706
Table Mountain	0	0	0	0
Thicket Spring	0	0	0	0
Tonto Bridge	23.5	19.5	7.24	0
Towel Spring	0	0	0	0
Trail Junction Spring	31.1	25.6	7.48	0
Trail Spring	0	0	0	0
Tree Spring	0	0	0	0
T-six Spring	0	0	0	0
Tunnel Spring	0	0	0	0

Table 25 (continued)

Name of Spring	Air Temp (°C)	Water Temp (°C)	pH	Specific Conductance (µS/cm)
Turkey Spring	30.3	18.4	8.25	0
Upper Hull Spring	0	0	0	0
Van Deren Spring	0	0	0	0
Verde Hot Spring	29.9	38.2	6.30	5.630
Washington Spring	18.0	10.9	7.28	0
Wet Prong Spring	31.8	25.3	6.62	0.250
Wildcat Spring	0	0	0	0
Willard Spring	0	0	0	0
Wilson Seep	0	0	0	0
Windfall Spring	0	0	0	0
Winter Cabin Spring	0	0	0	0
Wire Corral Spring	32.6	30.7	7.80	0
Yellow Jacket Spring	0	0	0	0
Zig Zag Spring #1 main	28.5	22.3	7.64	0.451
Zig Zag Spring #2	28.5	22.3	7.64	0.451

Table 26 – Geologic data (Physical Properties table) for 160 springs in the Middle Verde Springs study.

Name of Spring	Geologic unit	Geologic description	Bed Material
101 Spring	Kaibab	Kaibab Limestone (Toroweap?), above siltstone	limestone bedrock, boulders, organics, ferns
Babe's Hole Spring	Basalt	Basalt	basalt gravel, clay alluvium, pine needles
Baker Spring	Basalt	Basalt	clay alluvium
Banfield Spring	Basalt	Basalt	basalt boulders
Banjo Bill Spring	Supai	Supai	sand and cobble
Barney Spring	Kaibab	Kaibab Limestone	limestone bedrock and boulders
Basin Spring	Volcanics	Tertiary volcanics - Basalt	bedrock with some alluvium
Bear Spring (tnf)	Supai	Supai	mud, organics, boulders
Bear Spring(pnf)	Volcanics	Tertiary volcanics	bedrock
Beasley Flat Spring	Alluvium	alluvium	sand, gravel, cobbles
Bell Rock Spring	Schnebly Hill	Schnebly Hill	bedrock, sand
Big Hutch Spring #1	Volcanics	Tertiary Basalt - Volcanic Conglomerate	organic soil, marshy region
Big Hutch Spring #2	Volcanics	Tertiary Basalt - Volcanic Conglomerate	organic soil, marshy region
Bill Back Spring	Basalt	Basalt	basalt boulders, gravel
Bill Dick Spring	Basalt	Basalt	basalt boulders, grasses
Black Canyon Spring	Redwall	Redwall Limestone (base, at contact with sandstone)	bedrock (limestone, sandstone)
Blue Monster Main Spring	PC Granite	Granite	sand, cobbles, bedrock
Blue Monster South Spring	PC Granite	Granite/Diorite	sand, boulders, bedrock
Bootlegger Spring	Basalt	Basalt-volcanic cinders, located on side of cinder mountain	roadfill volcanic cinders, basalt cobbles
Bottle Spring	Basalt	Basalt	basalt boulders, alluvium
Bristow Spring	Basalt		
Brushy Wash Spring	PC Granite	Granite	sandy alluvium, cobbles
Burnt Spring (cnf)	Volcanics	Tertiary volcanics	none
Buzzard Spring	Kaibab	Kaibab Limestone-fractures	Limestone bedrock and boulders
Campbell Road Spring	Basalt	Basalt (at Kaibab limestone contact)	basalt and limestone cobbles
Campbell Spring	Basalt	Basalt (at Kaibab limestone contact)	limestone and basalt boulders, loamy soil
Cave Spring	Supai	Supai Group	grassy alluvium, bedrock
Cedar Spring	Verde	pinkish tan sandstone/Verde Fm	sandstone
Chalk Spring (cnf)	Volcanics	Tertairy volcanics	none

Table 26 (continued)

Name of Spring	Geologic unit	Geologic description	Bed Material
Chasm Spring	Volcanics	Tertiary basalt	boulders, gravel
Cherry 361a	PC Granite	Granodiorite	sandy alluvium, cobbles, bedrock
Cherry 361b	PC Granite	Granodiorite	gravel, mud, bedrock
Cimarron Spring	Volcanics	Tertiary volcanics (basalt/rhyolite)	weathered volcanic rock
Clover Spring	Kaibab	Kaibab Limestone	limestone bedrock and boulders, grassy alluvium
Cottonwood Spring (cnf)	Volcanics	Tertiary volcanics/alluvium	none
Cottonwood Spring (tnf)	Volcanics		
Dow Spring	Basalt	Basalt	basalt bedrock
Dripping Spring #1	Naco	Naco Limestone	bedrock, alluvium
Dripping Spring #2	Naco	Naco Limestone	bedrock, alluvium
Dripping Spring #3	Naco	Naco Limestone	bedrock, alluvium
Dripping Spring #4	Naco	Naco Limestone	bedrock, alluvium
Fain Spring	Basalt	Basalt-alluvium	loamy clay soil, alluvium
Fortyfour Spring	Kaibab	Kaibab Limestone	clay mud, limestone cobbles
Foster Spring	Basalt	Basalt	basalt boulders, colluvium, loamy soil
Frog Spring	Volcanics	Tertiary Volcanic Conglomerate	silty clay
Fuller Spring	Supai	Supai	boulders, organics
Garden Spring	Basalt	Basalt	basalt bedrock, boulders, organics
Geronimo Spring (1)	Kaibab	Kaibab Limestone - contact with Basalt	basalt and limestone boulders, cobbles, sand
Geronimo Spring (tnf)	Supai	Supai	red mud, silty sand, cobbles
Goat Camp Spring	PC Granite	Granite	soil, bedrock, cobbles
Gooseberry Spring	Basalt	Basalt	basalt boulders and volcanic alluvium
Gould Spring #1	PC Ign/Meta	Precambrian Metamorphic/Igneous Rocks	bedrock, gravel
Gould Spring #2	PC Ign/Meta	Precambrian Metamorphic/Igneous Rocks	
Grapevine Spring	PC Ign/Meta	Precambrian Metamorphic/Igneous Rocks	sand, gravel, boulders
Grassy Meadow Spring	Supai	Supai Group	grassy mud and cobbles
Gray Springs	Basalt	Basalt	mud, gravel, alluvium
Griffith Spring	Basalt	Basalt	basalt boulders, silt, organics
Grimes Spring	PC Ign/Meta	Precambrian Metamorphic/Igneous Rocks	bedrock, organic alluvium

Table 26 (continued)

Name of Spring	Geologic unit	Geologic description	Bed Material
Hackberry Spring #1	Volcanics	Tertiary volcanics / alluvium	silty sand alluvium, basalt cobbles
Hackberry Spring #2	Volcanics	Tertiary volcanic / alluvium	silty sand alluvium
Hance Spring	Verde	contact of basalt and Verde Fm/alluvium	silty sand with basalt boulders
Horseshoe Spring	Basalt	Basalt	basalt cobbles and alluvium
Howard Spring	Basalt	Basalt-fractures	weathered basalt, residual soil
Huffer Spring	Basalt	Basalt	clay and cobbles
Hull Spring	Volcanics	basalt and other volcanics	colluvium, bedrock
Irving High Spring	Volcanics	Tertiary volcanics	silty clay, gravel
Irving Low Spring	Volcanics	Tertiary volcanics	gravel, alluvium
JM Spring	Volcanics	Tertiary Volcanics	bedrock, alluvium
Jones Spring #1	Basalt	Basalt (at Kaibab Limestone contact)	alluvium-basalt dominated
Jones Spring #2a	Basalt	Basalt (just above Kaibab limestone contact)	basalt boulders, loamy soil
Jones Spring #2b	Basalt	Basalt (just above Kaibab limestone contact)	basalt boulders, loamy soil, pine needles
Kelsey Spring	Basalt	Basalt	silty soil, bedrock, pine needles
Larson Spring	PC Ign/Meta	Precambrian Metamorphic/Igneous Rocks	bedrock
Lee Johnson Spring	Coconino	Coconino Sandstone	bedrock and boulders
Lee Spring	Basalt	Basalt	alluvium, basalt boulders
Lindburg Spring	Basalt	Basalt	gravel and cobbles (basalt and road grade)
Little Hutch Spring #1	Volcanics	Tertiary Basalt - Volcanic Conglomerate	boulders, mud
Little Hutch Spring #2	Volcanics	Tertiary Basalt - Volcanic Conglomerate	boulders, mud
LO Spring	Basalt	Basalt	basalt boulders, silt, clay mud
Log Spring	PC Granite	Granite	bedrock, sandy alluvium
Long Valley Spring	Kaibab	Kaibab Limestone (Toroweap?)	limestone bedrock and cobbles
Lower Gould Spring	PC Ign/Meta	Precambrian Metamorphic/Igneous Rocks	bedrock
Lower Hull Spring	Basalt	Basalt	basalt colluvium
LX Spring	Volcanics	Tertiary Volcanic Conglomerate	coarse sandy material
Maple Spring	Kaibab	Kaibab Limestone	Limestone boulders, organic material
Maxwell Spring	Basalt	Basalt - colluvium	colluvium and basalt boulders
Mesquite Spring	Volcanics	Tertiary volcanics/alluvium	none

Table 26 (continued)

Name of Spring	Geologic unit	Geologic description	Bed Material
Mine Spring	PC Granite	Granite	sand, gravel
Morgan Spring	PC Granite	granite	none
Mortgage Spring	Basalt	Basalt	basalt boulders
Mund Spring	Alluvium	Basalt-alluvium	alluvium, soil
North Mine Spring	PC granite	Granite	sand, gravel
North Pass Spring	Volcanics	Tertiary Volcanic Conglomerate	alluvium, silty soil
North Pasture Canyon Spring	Volcanics	Tertiary Volcanic Conglomerate	bedrock
North Pasture Spring	Volcanics	Tertiary Volcanic Conglomerate	colluvium, silty soil
Oxbow Spring	Alluvium	alluvium (basalt boulders)	silty alluvium, poorly sorted boulders
Patton Spring	Basalt	Basalt	alluvium, silty soil, basalt cobbles
Pearson Spring	Basalt	Basalt	basalt colluvium
Pfau Spring	PC Granite	Granodiorite	bedrock, muddy gravel bed
Phroney Spring	Volcanics	Tertiary volcanics/conglomerate	volcanic alluvium
Picnic Spring	Volcanics	Tertiary Volcanic Conglomerate	basalt boulders, silty alluvium
Pieper Hatchery Spring #1	Supai	Supai	sandy alluvium, bedrock and boulders
Pieper Hatchery Spring #2	Supai	Supai	sandy alluvium, bedrock and boulders
Pine Flat Spring	Coconino	Coconino Sandstone	silty alluvium
Pine Spring	Supai	Supai	clay and alluvium
Pivot Rock Spring	Kaibab	Kaibab Limestone, fracture	limestone bedrock and cobbles
Poison Sping (tnf)	Supai	Supai	fine sand, silt, organics
Poison Spring (1)	Basalt	Basalt	mud, basalt boulders
Powell Spring	PC Granite	Granite	granite cobbles and sandy alluvium
Quail Spring #1	Alluvium	alluvium	sand, silt, boulders
Quail Spring #2	Alluvium	alluvium	poorly sorted boulders, ravel, silt
Quail Spring #3	Alluvium	alluvium / weathered metamorphic rocks	poorly sorted colluvium
Quail Spring (cnf)	Volcanics	Tertiary volcanics	none
Railroad Spring	Basalt	Basalt	mud, silt, basalt gravel
Red Horse Spring	PC Granite	Granodiorite	bedrock, muddy alluvium
Red Rock Spring	Supai	Supai	clay, alluvium, gravel

Table 26 (continued)

Name of Spring	Geologic unit	Geologic description	Bed Material
Ritter Spring	Basalt	Basalt	basalt boullders, gravel, and silt
Rock Top Spring	Basalt	Basalt (vesicular)	loamy soil, basalt colluvium
Round Up Park Spring	Basalt	Basalt	basalt boulders, organic debris
Russel Spring #1	Verde	Verde Fm - base of gray limestone and top of red silty sandstone	red silty organics
Russel Spring #2	Verde	Verde Fm - base of gray limestone and top of red silty sandstone	gravel in stream channel
Sally May Spring	Volcanics	Tertiary volcanics (Rhyolite, dacite)	dry cracked mud on bedrock
Schells Spring	Basalt	Basalt	basalt cobbles and alluvium
Scott Spring	Basalt	Basalt	basalt boulders, silt
Seven Anchor Spring #1	Kaibab	Kaibab Limestone (just below contact with basalt, fault?)	limestone boulders, silty mud
Seven Anchor Spring #2	Basalt	Basalt (just above contact with Kaibab limestone, fault?)	basalt cobbles, silty soil
Sheep Bridge Hot Springs	PC Ign/Meta	Red Granite (near contact with basalt)	organic muds
Sheep Spring	Basalt	Basalt	volcanics
Spring Creek	Verde	Verde Formation	alluvium
Sterling Spring 1	Coconino	Coconino Sandstone	sand and sandstone pebbles
Sterling Spring 2	Coconino	Coconino Sandstone	sand and sandstone pebbles
Stone Camp Spring	Volcanics	Basalt	cobbles, sandy alluvium
Summer Spring	Martin	Reddish grey limestone (Redwall or Martin Formations)	cobbles mixed with sand and clay
Sycamore Spring #1a	Volcanics	Tertiary volcanics	silt and sand alluvium
Sycamore Spring #1b	Volcanics	Tertiary volcanics	silt and sand alluvium
Sycamore Spring #2	Volcanics	Tertiary volcanics (Basalt, Andesite)	silt and sand alluvium
Table Mountain	Volcanics	Rhyolite and volcanics	bedrock, sand and gravel
Thicket Spring	Volcanics	Basalt	muddy alluvium
Tonto Bridge	Redwall	Limestone (Redwall/Naco)	sand and alluvium
Towel Spring	Volcanics	Tertiary volcanics	volcanics and silty alluvium
Trail Junction Spring	Volcanics	Limestone	alluvium, sand, gravel
Trail Spring	Volcanics	Tertiary Volcanics	alluvium
Tree Spring	Alluvium	Alluvium-basalt	alluvium, silty soil, cinders
T-six Spring	Alluvium	Alluvium-basalt	alluvium, loamy soil
Tunnel Spring	PC Granite	Granodiorite	bedrock, sandy alluvium

Table 26 (continued)

Name of Spring	Geologic unit	Geologic description	Bed Material
Turkey Spring	Supai	Supai	boulders, silt
Upper Hull Spring	Basalt	Basalt	basalt colluvium
Van Deren Spring	Basalt	Basalt	mud, alluvium, basallt cobbles
Verde Hot Spring	PC Ign/Meta	Precambrian Volcanics	bedrock
Washington Spring	Supai	Supai	bedrock, boulders, sand
Wet Prong Spring	Volcanics	Tertiary volcanics	muddy alluvium with volcanic boulders
Wildcat Spring	Kaibab	Kaibab Limestone	cobbles and bedrock, some alluvium
Willard Spring	Basalt	Basalt	colluvium, basalt boulders, silt and sand
Wilson Seep	Basalt	Basalt	organics, pine needles, basalt boulders, silt
Windfall Spring	Basalt	Basalt	basalt boulders, organic matter
Winter Cabin Spring	Verde	contact of Verde Fm and Basalt	bedrock, conglomerate
Wire Corral Spring	Volcanics	Tertiary Volcanics	bedrock, alluvium
Yellow Jacket Spring	Basalt	Basalt	basalt cobbles, alluvium, loamy soil
Zig Zag Spring #1 main	Volcanics	Volcanic Conglomerate	sand and cobbles
Zig Zag Spring #2	Volcanics	Volcanic Conglomerate	bedrock, sand and cobbles

Table 27 – Spring source and development data (Physical Properties table) for 160 springs in the Middle Verde Springs study.

Name of Spring	Source Class	Emergence	Human Development
101 Spring	Rheocrene	emerges from bedrock on cliff wall along drainage	none
Babe's Hole Spring	Rheocrene	emerges from bedrock	small spring box and pipe, sign
Baker Spring	Helocrene	emerges in grassy drainage	none
Banfield Spring	Rheocrene	emerges in drainage	none
Banjo Bill Spring	Rheocrene	slope off of Oak Creek	Spring Box well developed with pipes at base of road.
Barney Spring	Rheocrene	emerges in spring box in channel	small cement spring box in channel (pipes in box)
Basin Spring	Rheocrene	in drainage	none
Bear Spring (tnf)	Rheocrene	emerges in side of drainage along hillslope	metal tank and pipe, metal lid over pit
Bear Spring(pnf)	Rheocrene	in channel from bedrock	none
Beasley Flat Spring	Rheocrene	emerges in wash	spring box, cement dam and pipe
Bell Rock Spring	Rheocrene		
Big Hutch Spring #1	Helocrene	emerges on hillslope with multiple sources	stock tanks below flow
Big Hutch Spring #2	Helocrene	emerges on hillslope with multiple sources	stock tanks below flow
Bill Back Spring	Helocrene	emerges in grassy swale on hillslope	tank
Bill Dick Spring	Helocrene	emerges on slope at the edge of an open grassy park	fence around source, pipe to old cement tanks (20m)
Black Canyon Spring	Rheocrene	emerges in channel out of bedrock bank	none
Blue Monster Main Spring	Rheocrene	emerges from bank of wash	2 metal pipe to source
Blue Monster South Spring	Rheocrene	emerges in bedrock of channel	two large tanks with pipes from source
Bootlegger Spring	Rheocrene	seeps out of hill on side of road	along side of road
Bottle Spring	Helocrene	side of hillslope	none
Bristow Spring	Rheocrene		
Brushy Wash Spring	Rheocrene	emerges from wash	cement spring box
Burnt Spring (cnf)	none	none	none
Buzzard Spring	Rheocrene	emerges at headcut of channel	none
Campbell Road Spring	Rheocrene	emerges on side of old dirt road from underground	road, could be pipe undergound
Campbell Spring	Helocrene	emerges on slope above drainage	spring box at source, metal tank 20m from source
Cave Spring	Rheocrene	emerges out of cave in bedrock cliff	fence and structures at source, developed grassy area
Cedar Spring	Rheocrene	emerges in wash out of bedrock	none
Chalk Spring (cnf)	none	none	none

Table 27 (continued)

Name of Spring	Source Class	Emergence	Human Development
Chasm Spring	Rheocrene	emerges in channel	none
Cherry 361a	Rheocrene	emerges in channel from bedrock cliff 5m high	none
Cherry 361b	Limnocrene	emerges from hillslope out of bedrock	pipes and tank
Cimarron Spring	Helocrene	side of drainage 10m above channel	old 3mx2m cement trough, rusted pipes
Clover Spring	Rheocrene	emerges from large pipe under limestone bedrock	2m diameter metal pipe under road, fences in drainage
Cottonwood Spring (cnf)	none	none	none
Cottonwood Spring (tnf)	none		
Dow Spring	Rheocrene	emerges from pipe out of basalt canyon wall	metal pipe coming out of bedrock source diverting flow
Dripping Spring #1	Rheocrene	emerges out of bedrock cliff	small spring box
Dripping Spring #2	Rheocrene	emerges out of bedrock on hillslope	none
Dripping Spring #3	Rheocrene	emerges out of bedrock on hillslope	pipes
Dripping Spring #4	Rheocrene	emerges out of bedrock in wash	none
Fain Spring	Helocrene	seeps out of valley floor in wide marshy area	small cement dam at end of marshy region
Fortyfour Spring	Rheocrene	emerges on bank of narrow grassy drainage	cement spring box at source, well, storage tank
Foster Spring	Helocrene	emrges out of slope with multiple seeps	2 rusty barrel drinkers and metal tank at end of flow
Frog Spring	Rheocrene	emerges in depression along side of drainage	none
Fuller Spring	Rheocrene	emerges in steep drainage	tank
Garden Spring	Rheocrene	emerges in runoff drainage	pipe in channel
Geronimo Spring (1)	Rheocrene	emerges from bedrock on steep slope of canyon	Plastic pipe flows down slope to small wooden tank
Geronimo Spring (tnf)	Rheocrene	emerges on slope of drainage	spring box at source, pipes
Goat Camp Spring	Rheocrene	natural emergence from bank in channel	cement wall at source and pipes
Gooseberry Spring	Helocrene	emerges in two locations on edge of grassy park	cement spring box and pipes at source, cement drinker
Gould Spring #1	Rheocrene	emerges in channel	none
Gould Spring #2	Rheocrene	emerges in channel	none
Grapevine Spring	Rehocrene	emerges in channel	none
Grassy Meadow Spring	Rheocrene	emerges in grassy meadow on flood plain of Oak Creek	none, at base of road
Gray Springs	Rheocrene	source in grassy park capped by cement tank	2 spring boxes at source, channelized flow, earthen tank
Griffith Spring	Rheocrene	emerges on hillslope at edge of park	none
Grimes Spring	Rheocrene	emerges in drainage at headcut	old weathered cement tank

Table 27 (continued)

Name of Spring	Source Class	Emergence	Human Development
Hackberry Spring #1	Rheocrene	emerges in runoff channel	none
Hackberry Spring #2	Rheocrene	emerges in runoff channel	bridge over channel and pond below bridge
Hance Spring	Rheocrene	emerges in wash in stream bed	none
Horseshoe Spring	Rheocrene	emerges from hillslope 100m up from main drainage	cement spring box at source, pipe from source to tank
Howard Spring	Helocrene	emerges on slope out of fractured bedrock	3 catchments and storage tank at source, drinkers (20m)
Huffer Spring	Helocrene	emerges along banks of grassy drainage	none
Hull Spring	Rheocrene	emerges on side of hill above large wash	pipes and earthen tank
Irving High Spring	Rheocrene	emerges out of bedrock cliff on hillslope	none
Irving Low Spring	Rheocrene	emerges out of bedrock cliff on hillslope	spring box at source, large metal tnak and pipes
JM Spring	Rheocrene	emerges out of bedrock on hillslope	cement spring box on side of road
Jones Spring #1	Helocrene	emerges at upper end of drainage in channel	pipe in channel underground, source fenced in with sign
Jones Spring #2a	Helocrene	emerges along grassy slope in multiple places	Elk fence around sources, spring box, pipe, well/tank
Jones Spring #2b	Rheocrene	emerges on slope	pipe, well/tank
Kelsey Spring	Rheocrene	emerges from cobbles and bedrock	pipes, small metal tank near source, sign
Larson Spring	Rheocrene	emerges in side of drainage with steep slopes	none
Lee Johnson Spring	Helocrene	emerges at beginning of drainage at grassy region	cement dam/spring box at source with pipes
Lee Spring	Helocrene	emerges in grassy opening near base of hill	cement dam creates dry pool, pipes to cement drinkers
Lindburg Spring	Rheocrene	emerges from base of road grade	road at source of spring, earthen tank
Little Hutch Spring #1	Rheocrene	emerges along hillslope	stock tanks below flow
Little Hutch Spring #2	Rheocrene	emerges along hillslope	stock tanks below flow
LO Spring	Limnocrene	emerges in and on edges of channel	none
Log Spring	Rheocrene	multiple points of emergence out of bedrock and alluvium	pipe at one source, small cement tank
Long Valley Spring	Rheocrene	emerges out of hillslope of limestone bedrock	cement spring box, pipe in channel, earthen tank
Lower Gould Spring	Rheocrene	emerges in channel	tanks and pipes below flow
Lower Hull Spring	Helocrene	emerges in cement box in park	cement spring box (2mx1m)
LX Spring	Limnocene	emerges in large pond in wash at a cement dam	cement dam at sources, pipes divert discharge to ranch
Maple Spring	Rheocrene	emerges out of bedrock on side of drainage	none
Maxwell Spring	Helocrene	emerges in dug pit	hand dug well or pit, earthen tank
Mesquite Spring	none	none	none

Table 27 (continued)

Name of Spring	Source Class	Emergence	Human Development
Mine Spring	Limnocrene	emerges in pools out of bedrock on slope	earthen tank
Morgan Spring	none	none	none
Mortgage Spring	Rheocrene	emerges in runoff drainage	none
Mund Spring	Helocrene	emerges in the middle of an open grassy park	none
North Mine Spring	Rheocrene	emerges from cave in bedrock	pipe and tank
North Pass Spring	Helocrene	emerges in marshy hillslope above drainage	small dry spring box
North Pasture Canyon Spring	Rheocrene	emerges in steep narrow drainage	none
North Pasture Spring	Helocrene	emerges on hillslope of drainage	fence, spring box, and tank
Oxbow Spring	Rheocrene	emerges in channel	pipe from spring to ranch
Patton Spring	Helocrene	emerges in shallow grassy drainage	none
Pearson Spring	Rheocrene	emerges on hillslope	pipe and spring box at source, earthen tank
Pfau Spring	Rheocrene	emerges from bedrock out of tunnel under forest road	pipes and small tanks
Phroney Spring	Rheocrene	emerges in wash	cement box, spring box, pipes
Picnic Spring	Rheocrene	emerges at headcu tin wash	none
Pieper Hatchery Spring #1	Rheocrene	emerges on large steep hillslope above East Verde River	cement dam downstream at abse of hillslope
Pieper Hatchery Spring #2	Rheocrene	emerges on large steep hillslope above East Verde River	cement dam downstream at abse of hillslope
Pine Flat Spring	Rheocrene	pipe out of ground on side of Oak Creek	Cement spring box over spring with pipe, high pressure
Pine Spring	Helocrene	emerges from grassy slope of drainage	wooden tank, cement well at source
Pivot Rock Spring	Rheocrene	emerges from constructed cave in limestone cliff	constucted cave at fracture, cement at cave, pipes
Poison Sping (tnf)	Rheocrene	emerges at base of bedrock cliff	spring box at source, large pipes divert spring discharge
Poison Spring (1)	Rheocrene	emerges out of basalt slope	none
Powell Spring	Rheocrene	emerges in drainage	none
Quail Spring #1	Rheocrene	emerges in wash at nickpoint	pipe from source to tank 10m away
Quail Spring #2	Rheocrene	emerges in channel along bank	tank
Quail Spring #3	Rheocrene	emerges in channel	none
Quail Spring (cnf)	none	none	none
Railroad Spring	Limnocrene	emerges in 30m x 20m pool	earthen tank, fences
Red Horse Spring	Rheocrene	emerges out of bedrock tunnel	pipe from source to tank at the end of the channel
Red Rock Spring	Rheocrene	emerges from side of rocky slope	spring box and metal pipes

Table 27 (continued)

Name of Spring	Source Class	Emergence	Human Development
Ritter Spring	Helocrene	emerges from side of hillslope	cement spring box, cement drinker, earth tank, fence
Rock Top Spring	Helocrene	emerges out of hillslope	earthen dam, cement tank after dam
Round Up Park Spring	Rheocrene	emerges in runoff drainage	fence
Russel Spring #1	Rheocrene	emerges in main runoff channel	none
Russel Spring #2	Rheocrene	emerges in main stream channel	none
Sally May Spring	Rheocrene	emerges in wash at headcut out of bedrock in a pool	none
Schells Spring	Helocrene	emerges at the edge of a wide grassy drainage	pipe from source to metal tank
Scott Spring	Helocrene	emerges on top of hill at end of basalt flow in a tank	Earthen tank at source, tile tank
Seven Anchor Spring #1	Rheocrene	emerges from 2 sources in limestone boulders on slope	1 source excavated, elk fence at end of channel
Seven Anchor Spring #2	Rheocrene	emerges in runoff drainage	elk fence at source, cement spring box with pipes
Sheep Bridge Hot Springs	Rheocrene	emerges out of granite bedrock along edge of Verde River	pipes divert flow from source to cement pool
Sheep Spring	Helocrene	emerges in underground tank	metal underground tank, water diverted to drinkers
Spring Creek	Rheocrene	emerges out multiple sources out of side of Spring Creek	spring box and structures at source
Sterling Spring 1	Rheocrene	emerges in stream channel	cement boxes at source, pipes diverting water
Sterling Spring 2	Rheocrene	emerges in stream channel	cement boxes at source, pipes diverting water
Stone Camp Spring	Rheocrene	emerges in large wash	none
Summer Spring	Rheocrene	3 main points of emergence from base of canyon walls	trail built above source of spring
Sycamore Spring #1a	Rheocrene	emerges in main stream channel	none
Sycamore Spring #1b	Rheocrene	emerges in main stream channel	none
Sycamore Spring #2	Rheocrene	emerges in main stream channel	none
Table Mountain	Rheocrene	emerges out of bedrock in channel	pipe to tank
Thicket Spring	Helocrene	emerges on side of channel	earthen tank at source
Tonto Bridge	Rheocrene	emerges in grassy field at base of limestone cliff	developed spring house at source to capture water
Towel Spring	Rheocrene	emerges in headcut of wash	pipe runs from source 70m to metal trough (dry)
Trail Junction Spring	Limnocrene	emerges in pool on side of main wash	none
Trail Spring	Rheocrene	in wash	none
Tree Spring	Helocrene	emerges near wash in small open grassy park	broken down cement tank (2mx3mx1m)
T-six Spring	Helocrene	emerges on hillslope at upper end of grassy park	cement tank, pipe near source, Elk fence
Tunnel Spring	Rheocrene	emerges from small wash out of bedrock	pipe from source to tank (40m)

Table 27 (continued)

Name of Spring	Source Class	Emergence	Human Development
Turkey Spring	Rheocrene	emerges along hillslope of drainage	tank on source and pipes
Upper Hull Spring	Rheocrene	emerges at edge of park, source excavated	
Van Deren Spring	Helocrene	emerges in earthen tank	earthen tank built on source, disturbed heavily
Verde Hot Spring	Rheocrene	emerges out of bedrock on slopes along the Verde River	flow diverted into cement pools for recreation
Washington Spring	Rheocrene	emerges in channel	cement dam and pipes divert flow to ranch
Wet Prong Spring	Rheocrene	emerges at headcut in wash	none
Wildcat Spring	Helocrene	emerge from bedrock on side of main drainage	cement tank/spring box at source with pipes
Willard Spring	Helocrene	emerges at top of channel on hillslope from cement tank	cement spring box, fenced in riparian region, sign
Wilson Seep	Rheocrene	emerges in runoff drainage	none
Windfall Spring	Helocrene	emerges in drainage channel	cement spring box at source, elk fence
Winter Cabin Spring	Rheocrene	emerges in side drainage of main wash	pipe from source to main wash and cement tanks
Wire Corral Spring	Rheocrene	emerges in wash at headcut	none
Yellow Jacket Spring	Helocrene	emerges in depression off of a small slope	earthen tanks at end of channel
Zig Zag Spring #1 main	Rheocrene	emerges in wash	cement dam at end of flow
Zig Zag Spring #2	Rheocrene	emerges in wash at cement dam	cement dam at source

Table 28 – Channel and spring flow data (Physical Properties table) for 160 springs in the Middle Verde Springs study.

Name of Spring	Channel description	Channel	flow (m)	flow description	length of channel
101 Spring	shallow rocky ravine down side of drainage	spring	100	flows to main drainage	100m to main drainage
Babe's Hole Spring	100m flat 1m wide channel, 100m of steep channel	spring	200		200m
Baker Spring	30m shallow channel, poorly defined	runoff	0		200m +
Banfield Spring	none	runoff	0		0
Banjo Bill Spring	30 defined channel	spring	30	flows to Oak Creek	30m
Barney Spring	no spring related channel (main runoff drainage)	runoff	0		not determined
Basin Spring	narrow channel	runoff	30		100m
Bear Spring (tnf)	small .5m channel in broad shallow wider channel	runoff	30		50m
Bear Spring(pnf)	no defined channel	runoff	1		5m
Beasley Flat Spring	small channel in runoff channel	runoff	0		35m in runoff channel
Bell Rock Spring		runoff	0		
Big Hutch Spring #1	wet marshy wide meadow on hillslope	spring	100		1000m
Big Hutch Spring #2	wet marshy wide meadow on hillslope	spring	200		1000m
Bill Back Spring	no developed channel	runoff	0		2m poorly defined
Bill Dick Spring	poorly defined rocky channel, then grassy region	spring	0		70m
Black Canyon Spring	2m wide bedrock shallow channel	runoff	0		100m
Blue Monster Main Spring	1m wide channel	runoff	0		40m
Blue Monster South Spring	semi-steep narrow channel	runoff	0		55m
Bootlegger Spring	narrow channel (0.5m wide), flows along ditch	spring	110		110m
Bottle Spring	no defined channel	spring	0		0m
Bristow Spring		runoff		possible Helocrene	
Brushy Wash Spring	2m wide sandy channel	runoff	0		100m
Burnt Spring (cnf)	none	none	0		none
Buzzard Spring	deep wide boulder filled channel	spring	0		200m
Campbell Road Spring	small pools at source, flow in channel along road	spring	80		80m
Campbell Spring	poorly defined shallow marshy channel	spring	145	possible Rheocrene	210m to main runoff drainage
Cave Spring	no defined channel, grassy area	spring	0		100m to Oak Creek
Cedar Spring	boulders and alluvium in 3m wide channel	runoff	1	seep	85m
Chalk Spring (cnf)	none	none	0		none

Table 28 (continued)

Name of Spring	Channel description	Channel	flow (m)	flow description	length of channel
Chasm Spring	narrow channel	runoff	30		105m
Cherry 361a	10m wide channel and then narrows	runoff	0		100m to road
Cherry 361b	pool for first 25m then narrow steep channel	spring	35	Rheocrene flows from pool?	100m
Cimarron Spring	non spring developed channel	runoff	0	Rheocrene?	10m
Clover Spring	splits at emergence into 2 narrow rocky channels	spring	0		5m, two 30m channels
Cottonwood Spring (cnf)	none	none	0		none
Cottonwood Spring (tnf)		none			
Dow Spring	flows over basalt, no well defined channel	runoff	30		250
Dripping Spring #1	marshy flow	spring	50	partial Helocrene	50m+
Dripping Spring #2	marshy flow	spring	10	partial Helocrene	10m
Dripping Spring #3	1m wide steep channel	spring	40	partial Helocrene	40m
Dripping Spring #4	main wash	spring	0	dry Helocrene	0m
Fain Spring	wide marshy region (30m), narrow channel (100m)	spring	15	flow in two marshy channels	130m marshy
Fortyfour Spring	narrow well defined channel in small grassy drainage	runoff	60		100m
Foster Spring	irregular, poorly defined marshy wide (5m) channel	spring	40	one source Rheocrene	40m poorly defined
Frog Spring	no defined channel	runoff	0	possible Helocrene	25m
Fuller Spring	steep narrow rocky channel	runoff	0		150m
Garden Spring	no spring dominated channel	runoff	0		undetermined
Geronimo Spring (1)	steep wide channel (65m), narrow flat (65m)	spring	130	dries up in main drainage	130m ends at main canyon
Geronimo Spring (tnf)	wide marshy channel	spring	25	possible Helocrene	40
Goat Camp Spring	steep gradient narrow channel	runoff	0		100m+
Gooseberry Spring	narrow moderaly defined channel	spring	0	possible Rheocrene	40m to drinker
Gould Spring #1	bedrock channel 1m wide	runoff	0		180m
Gould Spring #2	bedrock channel 1m wide	runoff	0		160m
Grapevine Spring	runoff drainage 1m wide channel	runoff	0		20m+
Grassy Meadow Spring	0.5m wide grassy channel with cobbles	spring	20		100m+
Gray Springs	narrow deep straight altered channel to tank	spring	35	flows from spring box to pond	35m (from spring box to tank)
Griffith Spring	poorly defined narrow drainage	spring	0		50m to wet meadow
Grimes Spring	narrow 0.5m channel in 2m wide runoff drainage	runoff	5		250m

Table 28 (continued)

Name of Spring	Channel description	Channel	flow (m)	flow description	length of channel
Hackberry Spring #1	small 1m wide spring channel in 3m wide	runoff	100		100m+ runoff channel
Hackberry Spring #2	small 1m wide channel in runoff channel	runoff	80	pools at end	150m+ runoff channel
Hance Spring	wide and shallow runoff channel	runoff	3		100m+
Horseshoe Spring	moderately defined rocky channel	spring	0	100m from leak in pipe	300m
Howard Spring	no defined channel	spring	0	possible Rheocrene	15m to pool, overflow 50m
Huffer Spring	well defined shallow (1m wide) channel	runoff	0		200m
Hull Spring	poorly defined steep slope to main wash	runoff	0		20m
Irving High Spring	2m wide steep channel on hillslope	spring	100		170m+
Irving Low Spring	0.5 wide narrow flow	spring	110		100m+ to fossil Creek
JM Spring	1m wide poorly defined channel	spring	1		10m
Jones Spring #1	poorly defined narrow channel in drainage	spring	0	possible RheoLimnocrene	240m
Jones Spring #2a	narrow shallow boulder filled channel	spring	0	possible Rheocrene	250m
Jones Spring #2b	poorly defined shallow channel	spring	0		100m
Kelsey Spring	wide grassy channel, flow in narrow channel	spring	300	Shallow Limnocrene	~300m
Larson Spring	narrow channel with steep sides	runoff	0		100m
Lee Johnson Spring	shallow grassy area turns to bedrocks channel	spring	0		500m +
Lee Spring	moderately defined, shallow in grassy park	spring	0		30m
Lindburg Spring	grassy channel with flow ending in a pool	spring	57		95m (source to earthen tank)
Little Hutch Spring #1	narrow shallow steep channel	spring	30		100m
Little Hutch Spring #2	narrow shallow steep channel	spring	100		500m
LO Spring	large pools and several meter channels	runoff	500		1000+
Log Spring	narrow (1m) grassy meandering channel	spring	65	runoff channel also	340m
Long Valley Spring	steep narrow channel flows into earthen tank	runoff	0		65m
Lower Gould Spring	bedrock channel 1m wide	runoff	35		190m
Lower Hull Spring	non defined channel	spring	0		0
LX Spring	1m wide flow in sandy channel that is 5m wide	runoff	200		500m
Maple Spring	no spring related channel (main runoff drainage	runoff	0		not determined
Maxwell Spring	none	spring	0		1.0m to tank
Mesquite Spring	none	none	0		none

Table 28 (continued)

Name of Spring	Channel description	Channel	flow (m)	flow description	length of channel
Mine Spring	narrow 1m channel than widens at 55m	spring	15		55m to earthen tank
Morgan Spring	none	none	0		none
Mortgage Spring	no spring channel	spring	2	pool	2m (no spring channel)
Mund Spring	no defined channel	runoff	0		undetermined
North Mine Spring	no developed channel	spring	0		2m at cave opening
North Pass Spring	marshy channel	spring	10		10m
North Pasture Canyon Spring	1m wide steep rocky drainage	runoff	80		150m
North Pasture Spring	0.2m wide small narrow channel	runoff	8		8m
Oxbow Spring	steep 1m wide narrow channel	runoff	150		300m
Patton Spring	1m wide poorly defined grassy alluvium channel	runoff	0		500m
Pearson Spring	shallow straight channel	spring	0		60m
Pfau Spring	1m wide narrow grassy channel	spring	55		100m+
Phroney Spring	15m wide wash flow in 2m channel	runoff	15		45m+
Picnic Spring	narrow channel 35m to main wash	spring	55		55m (35m to main wash)
Pieper Hatchery Spring #1	well defined 0.5m wide, deep channels	spring	1000	flows to East Verde River	1000m+ to East Verde River
Pieper Hatchery Spring #2	well defined 0.5m wide, deep channels	spring	1000	flows to East Verde River	1000m+ to East Verde River
Pine Flat Spring	1m shallow channel in pine needles	spring	55	flows to Oak Creek	55m to Oak Creek
Pine Spring	marshy channel	spring	80	30m on slope, 50 in drainage	80m
Pivot Rock Spring	shallow ravine, rocky channel	spring	90	90m to main drainage	90m to main drainage
Poison Sping (tnf)	straight narrow 1m wide channel	spring	110		215m
Poison Spring (1)	narrow (2m) shallow rocky channel	spring	700	flows to Sycamore canyon	700m to Sycamore canyon
Powell Spring	narrow 1m wide channel	runoff	5		40m
Quail Spring #1	2m wide chanel	runoff	2		20m
Quail Spring #2	2m wide channel	runoff	70		260m
Quail Spring #3	2m wide channel	runoff	0		220m
Quail Spring (cnf)	none	none	0		none
Railroad Spring	narrow (1m) straight channel from pool to tank	spring	0	seeping in pool-30m x 20m	315m (from pool to tank)
Red Horse Spring	narrow channel	runoff	10	10m water in tunnel	100m
Red Rock Spring	narrow steep poorly defined channel	spring	0		20m

Table 28 (continued)

Name of Spring	Channel description	Channel	flow (m)	flow description	length of channel
Ritter Spring	moderately defined marshy channel 1-2m wide	spring	0	possible Rheocrene	60m from source to tank
Rock Top Spring	3m wide marshy region	spring	15	some Rheocrene	15m (ends at earthen dam)
Round Up Park Spring	no spring dominated channel or poorly defined	runoff	0		200m poorly derfined
Russel Spring #1	wide sandy channel	runoff	180		300m
Russel Spring #2	wide sandy channel	runoff	180		300m
Sally May Spring	wide 10m wash with 1m flow channel	runoff	0	may emerge from pool	50m evidence of flow
Schells Spring	poorly defined broad shallow channel	runoff	0		150m
Scott Spring	poorly defined	spring	0		25m (overflow channel)
Seven Anchor Spring #1	1m wide slightly marshy channel moderately defined	spring	40	small pool (Limnocrene?)	200m
Seven Anchor Spring #2	poorly defined spring channel in main runoff drainage	spring	0		220m
Sheep Bridge Hot Springs	flows in 1m wide channel into Verde River	spring	10	10m into Verde River	10m into Verde River
Sheep Spring	no defined channel	spring	0	no surface flow	undetermined - 200m
Spring Creek	deep meandering well defined spring channel	spring	100	100m to Spring Creek	100m to Spring Creek
Sterling Spring 1	sandy channel with cobbles in channel	spring	1000	flows into Oak Creek 1000m+	flows into Oak Creek 1000m+
Sterling Spring 2	sandy channel with cobbles in channel	spring	1000	flows into Oak Creek 1000m+	flows into Oak Creek 1000m+
Stone Camp Spring	bedrock and sandy channel	runoff	1000		3000m - main wash
Summer Spring	2 channels, converge to one channel 2m wide	spring	300	300m to Sycamore Creek	300m to Sycamore Creek
Sycamore Spring #1a	3m wide channel with boulders	runoff	150		150m+
Sycamore Spring #1b	3m wide channel	runoff	200		200m+
Sycamore Spring #2	3m wide channel with large boulders	runoff	175		175m+
Table Mountain	no defined channel	runoff	1		10m
Thicket Spring	large marshy area	runoff	0		30m
Tonto Bridge	well defined 1m wide 0.5m deep channel	spring	1000		1000m+
Towel Spring	bedrock and boulders 3m wide wash	spring	0		80m
Trail Junction Spring	1m wide deep channel after pool	spring	45		50m
Trail Spring	main wash	runoff	0		0m
Tree Spring	no spring dominated channel	runoff	0		undetermined
T-six Spring	moderately defined 1m wide channel	runoff	0	may be Rheocrene	50m (35m from source to tank)
Tunnel Spring	2m wide sandy channel	runoff	0		40m

Table 28 (continued)

Name of Spring	Channel description	Channel	flow (m)	flow description	length of channel
Turkey Spring	steep slope	spring	85	down hillslope to drainage	85m
Upper Hull Spring	piped from source to tank	spring	0	may be Helocrene	20
Van Deren Spring	no defined spring channel	runoff	15	water in tank, Limnocrene?	muddy region-50mx20m
Verde Hot Spring	developed narrow channel in bedrock	spring	30	30m to Verde River	30m to Verde River
Washington Spring	2m wide rocky channel	spring	50	some runoff channel	50m
Wet Prong Spring	3m wide rocky channel in wider wash	spring	12		50m
Wildcat Spring	poorly defined rocky channel, steep gradient	runoff	0		10m from source
Willard Spring	defined narrow channel	spring	0	may be Rheocrene	250m
Wilson Seep	no spring channel, narrow drainage	runoff	0		no spring channel
Windfall Spring	narrow, shallow, rocky, grassy channel	runoff	0		350m
Winter Cabin Spring	narrow rocky gravel channel	spring	0		120m to main wash
Wire Corral Spring	wide grassy 20m wide channel	runoff	10	may be Helocrene	100m
Yellow Jacket Spring	moderately defined channel from depression	runoff	0	Limnocrene	250m
Zig Zag Spring #1 main	small 0.5m wide flow in 5m wide wash	spring	32	runoff also	32m
Zig Zag Spring #2	1m wide flow in 5m wide wash	spring	142	142m to private land	142m to private land

Table 29 – Vegetation type data (Vegetation/Biology table) for 160 springs in the Middle Verde Springs study.

Name of Spring	Terrestrial Vegetation	Riparian Vegetation	Aquatic Vegetation
101 Spring	Ponderosa Pine, Oak, Aspen, ferns	moss, maple, grasses, brown-eyed susane	none
Babe's Hole Spring	Ponderosa Pine, Black Walnut, Box Elder	grasses, Box Elder	watercress, cattail
Baker Spring	Ponderosa Pine, Maple, Douglas Fir	grasses, locust	none
Banfield Spring	Ponderosa Pine	grasses	none
Banjo Bill Spring	Sycamore, Oak, Box Elder	blackberry, grasses, thorns	watercress
Barney Spring	Ponderosa Pine	grasses, moss	none
Basin Spring	Mesquite, Hackberry	cottonwood, willow	none
Bear Spring (tnf)	Ponderosa Pine, fern	grasses, canyon grape	algae, moss
Bear Spring(pnf)	mesquite	cottonwood, grasses	moss
Beasley Flat Spring	mesquite	cottonwood, grasses	none
Bell Rock Spring			
Big Hutch Spring #1	acacia, oak, juniper	willow, canyon grape, grasses	algae
Big Hutch Spring #2	acacia, oak, juniper	willow, canyon grape, grasses	algae
Bill Back Spring	Ponderosa Pine, fern	grasses, sedge	none
Bill Dick Spring	Ponderosa Pine	grasses, oak	none
Black Canyon Spring	Ponderosa Pine, gamble oak	grasses	moss
Blue Monster Main Spring	Manzanita, Juniper, sugar sumac	Cottonwood	moss
Blue Monster South Spring	Manzanita, Juniper, rosewood, Arizona Walnut	Cottonwood, canyon grape, grasses	watercress
Bootlegger Spring	Ponderosa Pine, Aspen, fern	grasses, sedge	none
Bottle Spring	Ponderosa Pine	grasses	none
Bristow Spring			
Brushy Wash Spring	scrub oak, manzanita, pinyon, buckthorn	cottonwood, canyon grape	none
Burnt Spring (cnf)	none	none	none
Buzzard Spring	Ponderosa, few Oak, ferns	grasses	none
Campbell Road Spring	Ponderosa Pine	none	algae
Campbell Spring	Ponderosa Pine, juniper, oak	grasses, willow	algae
Cave Spring	Oak, Cottonwood, Pine	grasses	none
Cedar Spring	Mesquite, Sycamore, manzanita	willow, cottonwood, canyon grape	none
Chalk Spring (cnf)	none	none	none

Table 29 (continued)

Name of Spring	Terrestrial Vegetation	Riparian Vegetation	Aquatic Vegetation
Chasm Spring	Sycamore, mesquite	cottonwood, willow, ash, canyon grape, grasses	moss, algae
Cherry 361a	Arizona Walnut, manzanita, scrub oak	canyon grape, grasses	moss
Cherry 361b	Manzanita, scrub oak	cottonwood, canyon grape, willow, grasses	moss, algae, watercress
Cimarron Spring	Manzanita, Mesquite	Cottonwoods, sedge, grasses	moss
Clover Spring	Ponderosa Pine	grasses, sedge	none
Cottonwood Spring (cnf)	none	none	none
Cottonwood Spring (tnf)			
Dow Spring	Ponderosa Pine	Canyon Grape, grass, sedge	none
Dripping Spring #1	Pinyon Pine, Oak	willow, canyon grape, grasses	none
Dripping Spring #2	Pinyon Pine, Oak	willow, canyon grape, grasses	none
Dripping Spring #3	Pinyon Pine, Oak, Mesquite	sycamore, willow, canyon grape, grasses	none
Dripping Spring #4	Pinyon Pine, Oak, Mesquite	grasses	none
Fain Spring	Ponderosa Pine, Oak	grasses, moss	none
Fortyfour Spring	Ponderosa Pine, Aspen, Oak, fern	grasses, locust, dandilion	none
Foster Spring	Ponderosa Pine, Oak	willow, grasses, sedge	none
Frog Spring	Acacia	cottonwood, canyon grape, grasses	algae
Fuller Spring	Fir, Oak, Pine, Sycamore	grasses, fern	moss algae
Garden Spring	Ponderosa Pine, Oak	grasses	none
Geronimo Spring (1)	Ponderosa Pine, Juniper	grasses, moss, goseberry	cattails
Geronimo Spring (tnf)	Ponderosa, Sycamore	grasses	algae
Goat Camp Spring	Manzanita, sumac	cottonwood	none
Gooseberry Spring	Ponderosa Pine, Oak	grasses	none
Gould Spring #1	Mesquite	willow, canyon grape, grasses	moss
Gould Spring #2	Mesquite	ash, grasses	moss
Grapevine Spring	Mesquite	Cottonwood, willow, canyon grape, grasses	none
Grassy Meadow Spring	Oak, Pine	Cottonwood, willow, grasses	watercress
Gray Springs	Ponderosa Pine	grasses	watercress, cattails, monkey flower
Griffith Spring	Ponderosa Pine	grasses	none
Grimes Spring	Mesquite	Cottonwood, canyon grape, willow, grasses	algae

Table 29 (continued)

Name of Spring	**Terrestrial Vegetation**	**Riparian Vegetation**	**Aquatic Vegetation**
Hackberry Spring #1	Hackberry, Box elder, mesquite	grass	algae
Hackberry Spring #2	Hackberry, box elder, mesquite	grasses, sedge	cattails
Hance Spring	Mesquite	willow, cottonwood, grasses	none
Horseshoe Spring	Ponderosa Pine, Oak, Mesquite	wax currant, grasses	none
Howard Spring	Ponderosa Pine, Oak, Juniper	sedge, grasses	none
Huffer Spring	Ponderosa Pine, oak, fern	grasses, locust, thistle, geranium	watercress
Hull Spring	catclaw acacia, juniper	none	none
Irving High Spring	Mesquite, sycamore	cottonwood, willow, canyon grape, grasses	cattails
Irving Low Spring	Mesquite, sycamore	canyon grape, sumac, willow	none
JM Spring	Mesquite, hackberry	willow, grasses	none
Jones Spring #1	Ponderosa Pine, Oak	grasses	none
Jones Spring #2a	Ponderosa Pine, Juniperm Oak	grasses, sedge, moss	none
Jones Spring #2b	Ponderosa Pine, Oak	grasses	none
Kelsey Spring	Ponderosa Pine, Pinyon Juniper, gamble Oak	canyon grape, watercress, monkey flower, moss	none
Larson Spring	Mesquite, scrub oak	canyon grape, grasses	none
Lee Johnson Spring	Ponderosa Pine, Oak	thick grasses	none
Lee Spring	Ponderosa Pine, Oak	grasses	none
Lindburg Spring	Ponderosa Pine	grasses	duckweed, cattails
Little Hutch Spring #1	Juniper, acacia	grasses	none
Little Hutch Spring #2	Juniper, acacia	grasses	none
LO Spring	Ponderosa Pine	grass, sedge	cattails, watercrest, lily
Log Spring	Ponderosa Pine, Walnut, manzanita	canyon grape, grasses, monkey flower	moss, algae, watercress
Long Valley Spring	Ponderosa Pine, Oak	grasses, moss	none
Lower Gould Spring	Mesquite	Cottonwood, willow, grasses	algae
Lower Hull Spring	Ponderosa Pine	grasses, few cottonwood/willow	none
LX Spring	Acacia	Canyon grape, willow, cottonwood, grasses	moss
Maple Spring	Ponderosa Pine, Box Elder	grasses, moss, Box Elder	none
Maxwell Spring	Ponderosa Pine	grasses	none
Mesquite Spring	none	none	none

Table 29 (continued)

Name of Spring	**Terrestrial Vegetation**	**Riparian Vegetation**	**Aquatic Vegetation**
Mine Spring	Mesquite	cottonwood, willow, grasses	cattails, algae
Morgan Spring	none	none	none
Mortgage Spring	Ponderosa Pine, Oak	grasses, moss	algae
Mund Spring	Ponderosa Pine	grasses	none
North Mine Spring	mesquite	cottonwood	none
North Pass Spring	Acacia	cottonwood, grasses	cattails
North Pasture Canyon Spring	Acacia	willow, canyon grape	none
North Pasture Spring	Acacia	Sycamore, willow, canyon grape	moss, algae
Oxbow Spring	Mesquite	cottonwood, willow	moss
Patton Spring	Ponderosa Pine, Oak, fern	grasses, locust	none
Pearson Spring	Ponderosa Pine	grasses	none
Pfau Spring	Pinyon, Juniper, Manzanita	willow, grasses	moss, algae
Phroney Spring	Honey Mesquite, ash, Sycamore, Catclaw Acacia	Cottonwood, Canyon grape	none
Picnic Spring	Acacia	canyon grape, velvet ash, cottonwood	moss
Pieper Hatchery Spring #1	Ponderosa Pine, rose, fir, oak	walnut, sycamore, canyon grape	watercress, moss
Pieper Hatchery Spring #2	Ponderosa Pine, rose, fir, oak	walnut, sycamore, canyon grape	watercress, moss
Pine Flat Spring	Ponderosa Pine, Box Elder	grasses	watercress
Pine Spring	Ponderosa Pine, Sycamore, juniper	grasses, sedge	cattails
Pivot Rock Spring	Ponderosa Pine, Oak	willow, moss, monkey flower, currant	algae, watercress
Poison Sping (tnf)	Ponderosa Pine, Oak, fern	grasses	algae
Poison Spring (1)	Ponderosa Pine	grasses, sedge	watercress, monkey flower
Powell Spring	Manzanita	willow, cottonwood, grass, canyon grape	none
Quail Spring #1	Mesquite	grasses, velvet ash	moss
Quail Spring #2	Mesquite	canyon grape, grasses, cottonwood, willow	moss
Quail Spring #3	Mesquite	cottonwood, willow, grasses	moss
Quail Spring (cnf)	none	none	none
Railroad Spring	Ponderosa Pine	grasses, ferns	few cattails, algae
Red Horse Spring	Buckthorn, Mesquite, manzanita	willow, cottonwood, grasses	moss
Red Rock Spring	Juniper, manzanita	none	none

Table 29 (continued)

Name of Spring	Terrestrial Vegetation	Riparian Vegetation	Aquatic Vegetation
Ritter Spring	Ponderosa Pine, Spruce, gambel oak	grasses	none
Rock Top Spring	Ponderosa Pine, Oak	grasses, buckthorn	none
Round Up Park Spring	Ponderosa Pine, Oak	grasses	none
Russel Spring #1	Cottonwood, Mesquite	willow, grasses	moss
Russel Spring #2	Cottonwood, Mesquite	willow, grasses	moss
Sally May Spring	Mesquite	grasses, Cottonwood, Sycamores	pumpkin moss, lichen
Schells Spring	Ponderosa Pine, Aspen	wax currant, grasses	none
Scott Spring	Ponderosa Pine, Juniper	grasses	none
Seven Anchor Spring #1	Ponderosa Pine	grasses	none
Seven Anchor Spring #2	Ponderosa Pine	grasses	none
Sheep Bridge Hot Springs	Mesquite	grasses, willows	grasses, cattails
Sheep Spring	Ponderosa Pine, Oaks	grasses, sedge	none
Spring Creek	Mesquite	Cottonwood, Sycamore, willow, grasses	moss
Sterling Spring 1	Ponderosa Pine, Oak, Box Elder	Cottonwood	grasses
Sterling Spring 2	Ponderosa Pine, Oak, Box Elder	Cottonwood	grasses
Stone Camp Spring	Sycamore	willow, canyon grape, grasses, monkey flower	watercress
Summer Spring	Sycamore, Mesquite, Box Elder	Willow, Canyon Grape, Grasses	watercress
Sycamore Spring #1a	Sycamore, Honey Mesquite	Canyon Grape, Willow	moss, grasses
Sycamore Spring #1b	Sycamore	Willow, grasses	moss, grasses
Sycamore Spring #2	Sycamore, Honey Mesquite	Canyon Grape, Willow	moss, grasses
Table Mountain	mesquite	cottonwood, willow, grasses	moss
Thicket Spring	Acacia, Mesquite	willow, grasses	none
Tonto Bridge	juniper, pinyon, mesquite	cottonwoods, grasses, willow	none
Towel Spring	White Oak, Sycamore	grasses	none
Trail Junction Spring	Mesquite, Hackberry	gooding willow, velvet ash, barnyard grass	cattail, watercress
Trail Spring	Mesquite, Hackberry	grasses, willow	none
Tree Spring	Ponderosa Pine	grasses	none
T-six Spring	Ponderosa Pine, gambel oak	grasses	none
Tunnel Spring	Mesquite, manzanita, scrub oak	canyon grape, willow	none

Table 29 (continued)

Name of Spring	Terrestrial Vegetation	Riparian Vegetation	Aquatic Vegetation
Turkey Spring	Ponderosa Pine, fir, oak	grasses	algae
Upper Hull Spring	Ponderosa Pine	grasses	none
Van Deren Spring	Ponderosa Pine	grasses, sedge	none
Verde Hot Spring	Mesquite	grasses	pumpkin moss
Washington Spring	Ponderosa Pine, fir, maple, sycamore, box elder	grasses, mulberry, geranium, gooseberry	moss, watercress
Wet Prong Spring	White Oak, Sycamore, Mesquite	willow, canyon grape, grasses	algae, moss
Wildcat Spring	Ponderosa Pine, Oak, maple	grasses, locust	none
Willard Spring	Ponderosa Pine, Scrub Oak	grasses	none
Wilson Seep	Ponderosa Pine, gambel Oak	grasses	none
Windfall Spring	Ponderosa Pine, Oak	grasses, geranium, roses	none
Winter Cabin Spring	Cottonwood, mesquite	willow	moss
Wire Corral Spring	Mesquite	willow, cottonwood, deer grass, monkey flower	cattail
Yellow Jacket Spring	Ponderosa Pine, Oak	grasses	none
Zig Zag Spring #1 main	Acacia	willow, cottonwood, canyon grape, grasses	moss
Zig Zag Spring #2	Acacia	willow, cottonwood, canyon grape, grasses	moss

Table 30 – Vegetation area and fauna (Vegetation/Biology table) at 160 springs in the Middle Verde Springs study.

Name of Spring	Vegetation Area	Fauna Present	Evidence of Fauna
101 Spring	20mx100m	none	deer, elk
Babe's Hole Spring	3mx100m	insects, spiders, toads	none
Baker Spring	30mx200m	insects	deer, elk
Banfield Spring	1mx1m	none	deer
Banjo Bill Spring	30mx80m	none	none
Barney Spring	3mx3m	none	none
Basin Spring	20mx100m	none	cows
Bear Spring (tnf)	30mx3m	none	deer
Bear Spring(pnf)	1mx5m	none	none
Beasley Flat Spring	35mx2m	none	none
Bell Rock Spring			
Big Hutch Spring #1	100mx1000m	cows	cows
Big Hutch Spring #2	100mx1000m	cows	cows
Bill Back Spring	100mx50m	none	deer, elk
Bill Dick Spring	30mx100m	none	none
Black Canyon Spring	10mx100m	none	none
Blue Monster Main Spring	40mx2m	none	none
Blue Monster South Spring	55mx3m	lizards	coyotes
Bootlegger Spring	10mx100m	none	none
Bottle Spring	1mx1m	none	deer
Bristow Spring			
Brushy Wash Spring	10mx3m	none	none
Burnt Spring (cnf)	none	none	none
Buzzard Spring	2mx200m	none	none
Campbell Road Spring	1mx80m	none	none
Campbell Spring	10mx200m	insects	elk, deer
Cave Spring	100mx30m	none	none
Cedar Spring	5mx85m	none	none
Chalk Spring (cnf)	none	none	none

Table 30 (continued)

Name of Spring	Vegetation Area	Fauna Present	Evidence of Fauna
Chasm Spring	10mx110m	insects, birds	cows
Cherry 361a	100mx5m	none	cows
Cherry 361b	100mx10m	cows	cows
Cimarron Spring	10mx5m	spiders, insects	none
Clover Spring	20mx200m	none	elk, deer
Cottonwood Spring (cnf)	none	none	none
Cottonwood Spring (tnf)			
Dow Spring	30mx50m	insects	none
Dripping Spring #1	80mx40m	none	deer
Dripping Spring #2	10mx30m	none	deer
Dripping Spring #3	40mx10m	none	deer
Dripping Spring #4	10mx5m	none	deer
Fain Spring	20mx30m	none	cows, deer
Fortyfour Spring	5mx60m	insects	elk, deer
Foster Spring	100mx50m	insects, birds, deer	elk, deer
Frog Spring	50mx10m	insects	cows
Fuller Spring	5mx50m	insects	deer
Garden Spring	20mx5m	none	none
Geronimo Spring (1)	5mx130m	insects, toads	spiders, small mammals
Geronimo Spring (tnf)	5mx15m	insects	deer, horses
Goat Camp Spring	10mx50m	none	cows, coyote, spiders
Gooseberry Spring	10mx10m	cows	none
Gould Spring #1	3mx50m	none	cows
Gould Spring #2	5mx15m	none	cows
Grapevine Spring	10mx115m	insects	deer
Grassy Meadow Spring	50mx100m	none	none
Gray Springs	50mx70m	none	deer
Griffith Spring	50mx10m	none	deer
Grimes Spring	10mx250	insects	deer

Table 30 (continued)

Name of Spring	Vegetation Area	Fauna Present	Evidence of Fauna
Hackberry Spring #1	10mx100m	insects, frog	cow, horse
Hackberry Spring #2	10mx100m	insects, frogs	cow, horse
Hance Spring	100mx10m	insects	cow
Horseshoe Spring	10mx100m	none	deer
Howard Spring	100mx50m	none	Elk, deer
Huffer Spring	10mx200m	insects	deer, elk
Hull Spring	20mx5m	none	none
Irving High Spring	50mx250m	insects	none
Irving Low Spring	50mx150m	none	none
JM Spring	10mx20m	none	cows
Jones Spring #1	15mx10m	none	none
Jones Spring #2a	50mx100m	none	elk, deer, cows
Jones Spring #2b	10mx5m	none	none
Kelsey Spring	10mx230m	insects	spiders, deer
Larson Spring	20mx5m	none	none
Lee Johnson Spring	20mx100m	none	deer, elk
Lee Spring	20mx30m	none	cow
Lindburg Spring	10mx95m	insects	deer
Little Hutch Spring #1	10mx40m	none	cows
Little Hutch Spring #2	10mx40m	none	cows
LO Spring	30mx1000m	blue heron, ducks, fish, frogs, birds	deer, elk
Log Spring	25mx10m	insects	deer, bear, mountain lion
Long Valley Spring	65mx5m	insects	deer
Lower Gould Spring	10mx50m	insects	none
Lower Hull Spring	5mx5m	none	cows, deer
LX Spring	200mx30m	frogs, fish, insects	cows
Maple Spring	5mx20m	insects	deer
Maxwell Spring	5mx5m	cows	cows, deer
Mesquite Spring	none	none	none

Table 30 (continued)

Name of Spring	Vegetation Area	Fauna Present	Evidence of Fauna
Mine Spring	5mx55m	insects, birds	cows
Morgan Spring	none	none	none
Mortgage Spring	50mx20m	insects	deer
Mund Spring	1mx1m	none	cows, deer
North Mine Spring	2mx2m	rattlesnake	rattlesnake, cows
North Pass Spring	10mx20m	insects	cows
North Pasture Canyon Spring	10mx150m	insects, frogs	cows
North Pasture Spring	20mx20m	insects, frogs	cows
Oxbow Spring	5mx150m	insects, cows	cows
Patton Spring	20mx500m	none	elk, deer, cow
Pearson Spring	10mx2m	none	cows, deer
Pfau Spring	35mx5m	insects	cows
Phroney Spring	10mx45m	insects	cows
Picnic Spring	55mx30m	insects	none
Pieper Hatchery Spring #1	1000mx200m	insects, fish	deer
Pieper Hatchery Spring #2	1000mx200m	insects, fish	deer
Pine Flat Spring	50mx30m	none	none
Pine Spring	30mx10m	insects	deer
Pivot Rock Spring	10mx100m	insects	deer
Poison Sping (tnf)	30mx60m	insects	deer
Poison Spring (1)	10mx700m	water bugs	deer, elk
Powell Spring	10mx50m	none	none
Quail Spring #1	10mx2m	insects	cows
Quail Spring #2	70mx5m	rattlesnake, insects	cows
Quail Spring #3	220mx5m	insects	cows
Quail Spring (cnf)	none	none	none
Railroad Spring	30mx20m	insects, deer, birds	cows, deer
Red Horse Spring	3mx100m	spiders	none
Red Rock Spring	2mx20m	none	cows

Table 30 (continued)

Name of Spring	Vegetation Area	Fauna Present	Evidence of Fauna
Ritter Spring	50mx50m	none	deer, cows
Rock Top Spring	30mx80m	none	cow, deer
Round Up Park Spring	10mx200m	none	none
Russel Spring #1	1000mx10m	insects	cow, elk, deer
Russel Spring #2	1000mx10m	insects	cow, elk, deer
Sally May Spring	1mx1m	none	none
Schells Spring	100mx300m	cows	cows, deer
Scott Spring	20mx10m	none	cows, elk, deer
Seven Anchor Spring #1	10mx40m	algae	deer, elk, cow
Seven Anchor Spring #2	20mx20m	none	deer, elk, cow
Sheep Bridge Hot Springs	30mx40m	none	none
Sheep Spring	1000mx1000m	none	cows, deer, elk
Spring Creek	1000x50m	none	deer
Sterling Spring 1	10mx1000m	none	none
Sterling Spring 2	10mx1000m	none	none
Stone Camp Spring	10mx100m	insects	coyote
Summer Spring	1000mx300m	none	none
Sycamore Spring #1a	150mx10m	insects	none
Sycamore Spring #1b	200mx10m	insects	none
Sycamore Spring #2	175m.10m	insects	none
Table Mountain	1mx10m	none	cows
Thicket Spring	200mx100m	none	cows
Tonto Bridge	1000mx200m	javelina	javelina
Towel Spring	5mx80m	none	cows
Trail Junction Spring	50mx20m	fish, tadpoles, frogs	cows
Trail Spring	10mx5m	none	cows
Tree Spring	1mx1m	none	none
T-six Spring	50mx10m	none	none
Tunnel Spring	2mx40m	none	cows

Table 30 (continued)

Name of Spring	Vegetation Area	Fauna Present	Evidence of Fauna
Turkey Spring	10mx25m	insects	none
Upper Hull Spring	10mx20m	none	cows, deer
Van Deren Spring	50mx20m	insects	cows, deer, elk
Verde Hot Spring	30mx20m	none	none
Washington Spring	50mx20m	insects	deer
Wet Prong Spring	5mx50m	spiders, frogs	mountain lion
Wildcat Spring	10mx20m	insects	deer, elk
Willard Spring	100mx100m	deer	deer, elk
Wilson Seep	1mx10m	none	deer
Windfall Spring	20mx30m	none	none
Winter Cabin Spring	100mx10m	insect	none
Wire Corral Spring	30mx20m	none	cows
Yellow Jacket Spring	15mx10m	none	none
Zig Zag Spring #1 main	20mx150m	fish	none
Zig Zag Spring #2	20mx150m	fish	none

Appendix III

Phase II spring monitoring discharge data

Table 31 – Phase II monthly discharge measurements for springs monitoring in gallons per minute (gpm).

	Springs								
	Foster	Campbell	Poison	Gray	Clover	Pivot Rock	Pieper Hatchery	Sterling	Upper Sterling
11/27/2002	0.5	0.75	1.1	0.563	0.0	1.2	340	300	9.31
12/13/2002	0.5	1.5	1.1	0.563	0.0	1.15	220	310	12.2
1/10/2003	2.0	2.0	1.82	0.81	0.0	2.5	242	310	6.84
2/22/2003	1.0	3.0	1.82	0.81	33.5	19	309	365	23
3/29/2003	6.0	17.65	1.82	0.81	598	1128	946.5	402	32.1
4/26/2003	6.5	4.0	1.5	0.75	121.7	187	250	310	21
5/23/2003	3.0	2.5	2.0	1.0	46	62.4	235	310	24.4
6/25/2003	3.25	2.5	2.0	1.0	2.63	14	140	295.2	9.31
7/24/2003	4.5	3.0	2.0	1.0	1.1	9.5	220	300	9.31
8/30/2003	6.0	4.0	1.5	1.0	15.2	19	248	310	15.4
9/21/2003	4.0	3.0	1.5	1.0	25	32.3	220	286	1.5
10/12/2003	2.5	1.0	2.0	1.0	2.25	3	200	300	5.0
Mean	3.3	3.7	1.7	0.9	70.5	123	298	317	14

Table 31 (continued)

	Springs							
	Summer	Spring Creek	Russell	Hackberry	Log	Tonto Bridge	Grimes	Grapevine
11/27/2002	2600	300	9.0	6.5	3.24	110	0.5	0.0
12/13/2002	2100	276	3.8	4.0	2.25	110	0.25	0.0
1/10/2003	1921	228	3.24	5.0	3.24	108	0.25	0.0
2/22/2003	2358	244	6.5	2.25	4.25	117	0.5	0.75
3/29/2003	2565	310	5.06	1.1	6.5	168	0.35	1.25
4/26/2003	2300	270.6	5.2	1.44	5.5	142	0.25	1.0
5/23/2003	1855	248.4	3.56	1.1	6.0	121	0.1	0.1
6/25/2003	2026	234	2.72	0.81	5.2	128	0.0	0.0
7/24/2003	2100	228	1.5	1.1	2.5	110	0.0	0.0
8/30/2003	2044	220	1.82	2.25	4.0	102	0.1	0.1
9/21/2003	2026	228	2.25	2.72	1.5	108	0.1	0.1
10/12/2003	2100	207	2.25	1.1	1.25	100	0.1	0.0
Mean	2170	250	3.9	2.4	3.8	120	0.2	0.3

Table 32 – Phase II monthly discharge measurements for springs monitoring in liters per second (L/s).

	Springs								
	Foster	Campbell	Poison	Gray	Clover	Pivot Rock	Pieper Hatchery	Sterling	Upper Sterling
11/27/2002	0.032	0.047	0.069	0.036	0.000	0.076	21.448	18.925	0.587
12/13/2002	0.032	0.095	0.069	0.036	0.000	0.073	13.878	19.556	0.770
1/10/2003	0.126	0.126	0.115	0.051	0.000	0.158	15.266	19.556	0.431
2/22/2003	0.063	0.189	0.115	0.051	2.113	1.199	19.493	23.025	1.451
3/29/2003	0.379	1.113	0.115	0.051	37.724	71.158	59.708	25.360	2.025
4/26/2003	0.410	0.252	0.095	0.047	7.677	11.797	15.771	19.556	1.325
5/23/2003	0.189	0.158	0.126	0.063	2.902	3.936	14.825	19.556	1.539
6/25/2003	0.205	0.158	0.126	0.063	0.166	0.883	8.832	18.622	0.587
7/24/2003	0.284	0.189	0.126	0.063	0.069	0.599	13.878	18.925	0.587
8/30/2003	0.379	0.252	0.095	0.063	0.959	1.199	15.645	19.556	0.971
9/21/2003	0.252	0.189	0.095	0.063	1.577	2.038	13.878	18.042	0.095
10/12/2003	0.158	0.063	0.126	0.063	0.142	0.189	12.617	18.925	0.315
Mean	0.21	0.23	0.11	0.05	4.44	7.78	18.8	20	0.89

Table 32 (continued)

	Springs							
	Summer	Spring Creek	Russell	Hackberry	Log	Tonto Bridge	Grimes	Grapevine
11/27/2002	164.017	18.925	0.568	0.410	0.204	6.939	0.032	0.000
12/13/2002	132.475	17.411	0.240	0.252	0.142	6.939	0.016	0.000
1/10/2003	121.183	14.383	0.204	0.315	0.204	6.813	0.016	0.000
2/22/2003	148.751	15.392	0.410	0.142	0.268	7.381	0.032	0.047
3/29/2003	161.809	19.556	0.319	0.069	0.410	10.598	0.022	0.079
4/26/2003	145.092	17.070	0.328	0.091	0.347	8.958	0.016	0.063
5/23/2003	117.020	15.670	0.225	0.069	0.379	7.633	0.006	0.006
6/25/2003	127.807	14.762	0.172	0.051	0.328	8.075	0.000	0.000
7/24/2003	132.475	14.383	0.095	0.069	0.158	6.939	0.000	0.000
8/30/2003	128.942	13.878	0.115	0.142	0.252	6.435	0.006	0.006
9/21/2003	127.807	14.383	0.142	0.172	0.095	6.813	0.006	0.006
10/12/2003	132.475	13.058	0.142	0.069	0.079	6.308	0.006	0.000
Mean	137	15.8	0.25	0.15	0.24	7.50	0.01	0.02

Appendix IV

Spring monitoring water chemistry data

Table 33 – Field water quality data for water collected in October 2003 from 11 springs in Phase II of the Middle Verde Springs study.

Spring Name	Latitude	Longitude	Date	Time	Spec. Cond	pH	Temp (°C)	Alk as $CaCO_3$	HCO_3	Q (gpm)	Q (cfs)	Q (l/s)
Clover^	34.50592	-111.36259	10/18/2003	1300	399	6.78	14.7	200.17	244.07	2.25	0.005	0.14
Tonto Bridge	34.32178	-111.45444	10/18/2003	1530	615	7.11	19.5	232.2	283.12	100	0.223	6.31
Pieper Hatchery	34.43515	-111.25596	10/18/2003	1645	226	7.39	10.7	100.08	122.03	200	0.446	12.62
Poison	34.13398	-111.97531	10/19/2003	1600	382	7.29	9.8	179.56	218.93	2	0.004	0.13
Foster	34.77394	-111.50638	10/21/2003	845	182	7.36	5.1	74.06	90.3	2.5	0.006	0.16
Hackberry	34.43414	-111.68797	10/21/2003	1300	443	7.33	8.2	184.16	224.54	1.1	0.002	0.07
Log	34.60164	-112.07233	10/21/2003	1500	516	7.48	11	233.21	284.34	1.25	0.003	0.08
Spring Creek	34.77603	-111.91972	10/21/2003	1650	532	7.43	12	188.56	229.91	207	0.461	13.06
Summer	34.88064	-112.06624	10/23/2003	900	518	7.46	13.1	273.24	333.15	2100	4.679	132.47
Sterling	34.02503	-111.74122	10/23/2003	1100	369	7.27	9.8	182.16	222.1	300	0.668	18.92
Russell	34.61923	-111.76017	10/23/2003	0	879	7.13	15.5	430.38	524.75	2.25	0.005	0.14

Notes:
GPS locations were taken in the Summer 2002
Q - Discharge from October 2003 when water samples were collected at end of monitoring
Temperature and pH are from November 2002 at the beginning of monitoring
^Temperature and pH listed for Clover were taken from Pivot Rock discharging from the Kaibab limestone within a few miles from Clover spring.
Alkalinity as $CaCO_3$ and HCO_3 were analyzed by the USGS

Table 34 – Results for cation analyses using ICP-MS for water collected in October 2003 from 11 springs in Phase II of the Middle Verde Springs study.

Spring Name	**ICPMS_H2O Ag** ug/L	**ICPMS_H2O Al** ug/L	**ICPMS_H2O As** ug/L	**ICPMS_H2O Ba** ug/L	**ICPMS_H2O Be** ug/L	**ICPMS_H2O Bi** ug/L	**ICPMS_H2O Ca** mg/L	**ICPMS_H2O Cd** ug/L
Clover	<3	30.3	<1	28.1	<0.05	< 0.2	35.9	0.07
Tonto Bridge	<3	27.4	2	140	<0.05	< 0.2	66.4	<0.02
Pieper Hatchery	<3	30	<1	130	<0.05	< 0.2	26.6	<0.02
Poison	<3	31	<1	38.9	<0.05	< 0.2	33.2	<0.02
Foster	<3	29.9	<1	11.7	<0.05	< 0.2	14.8	<0.02
Hackberry	<3	70.2	29.8	188	<0.05	< 0.2	36.7	0.09
Log	<3	32.1	4.8	134	<0.05	< 0.2	53.4	<0.02
Spring Creek	<3	30.1	6.2	203	<0.05	< 0.2	52.5	<0.02
Summer	<3	59.1	10.5	199	<0.05	< 0.2	60.3	<0.02
Sterling	<3	31.3	1	90.7	<0.05	< 0.2	41.8	<0.02
Russell	<3	23.3	3	151	<0.05	< 0.2	103	<0.02

Table 34 (continued)

Spring Name	**ICPMS_H2O Ce** ug/L	**ICPMS_H2O Co** ug/L	**ICPMS_H2O Cr** ug/L	**ICPMS_H2O Cs** ug/L	**ICPMS_H2O Cu** ug/L	**ICPMS_H2O Dy** ug/L	**ICPMS_H2O Er** ug/L	**ICPMS_H2O Eu** ug/L
Clover	< 0.01	0.02	2.1	< 0.02	0.69	0.005	< 0.005	< 0.005
Tonto Bridge	< 0.01	<0.02	1.7	0.14	0.5	< 0.005	< 0.005	0.02
Pieper Hatchery	< 0.01	<0.02	1.5	0.15	<0.5	< 0.005	< 0.005	0.02
Poison	< 0.01	<0.02	2.2	< 0.02	<0.5	< 0.005	< 0.005	< 0.005
Foster	0.02	0.05	1.5	< 0.02	0.64	< 0.005	< 0.005	< 0.005
Hackberry	0.14	0.48	1.3	0.46	0.71	0.007	< 0.005	0.03
Log	0.1	2.2	1.3	< 0.02	0.72	0.009	< 0.005	0.02
Spring Creek	0.01	<0.02	2.4	0.52	0.5	< 0.005	< 0.005	0.03
Summer	0.06	0.02	2.3	0.49	0.55	0.005	0.005	0.03
Sterling	0.01	0.03	1.3	0.03	0.69	< 0.005	< 0.005	0.01
Russell	< 0.01	<0.02	1	0.07	0.5	< 0.005	< 0.005	0.03

Table 34 (continued)

Spring Name	ICPMS_H2O Fe ug/L	ICPMS_H2O Ga ug/L	ICPMS_H2O Gd ug/L	ICPMS_H2O Ge ug/L	ICPMS_H2O Ho ug/L	ICPMS_H2O K mg/L	ICPMS_H2O La ug/L	ICPMS_H2O Li ug/L
Clover	<50	< 0.05	< 0.005	< 0.05	< 0.005	0.3	0.01	0.2
Tonto Bridge	<50	< 0.05	< 0.005	< 0.05	< 0.005	0.75	< 0.01	3.2
Pieper Hatchery	<50	< 0.05	< 0.005	< 0.05	< 0.005	0.87	< 0.01	0.8
Poison	<50	< 0.05	< 0.005	< 0.05	< 0.005	1.38	< 0.01	0.6
Foster	<50	< 0.05	< 0.005	< 0.05	< 0.005	0.49	0.01	< 0.1
Hackberry	128	< 0.05	0.01	0.08	< 0.005	3.2	0.08	8.7
Log	334	0.06	< 0.005	< 0.05	< 0.005	1.75	0.03	0.8
Spring Creek	<50	< 0.05	< 0.005	< 0.05	< 0.005	0.92	< 0.01	7.1
Summer	55	< 0.05	0.005	< 0.05	< 0.005	0.98	0.03	12.5
Sterling	<50	< 0.05	< 0.005	< 0.05	< 0.005	0.52	0.01	< 0.1
Russell	<50	< 0.05	< 0.005	0.09	< 0.005	4	0.02	71.9

Table 34 (continued)

Spring Name	ICPMS_H2O Lu ug/L	ICPMS_H2O Mg mg/L	ICPMS_H2O Mn ug/L	ICPMS_H2O Mo ug/L	ICPMS_H2O Na mg/L	ICPMS_H2O Nb ug/L	ICPMS_H2O Nd ug/L	ICPMS_H2O Ni ug/L
Clover	< 0.1	20	0.6	< 2	2.17	< 0.2	0.01	1
Tonto Bridge	< 0.1	27.1	0.5	< 2	5.27	< 0.2	< 0.01	0.8
Pieper Hatchery	< 0.1	6.84	0.2	< 2	1.37	< 0.2	0.01	0.6
Poison	< 0.1	12.8	<0.2	< 2	15.6	< 0.2	< 0.01	0.5
Foster	< 0.1	8.75	4	< 2	4.25	< 0.2	0.01	0.6
Hackberry	< 0.1	13.8	151	2.2	20.7	< 0.2	0.06	1.7
Log	< 0.1	14.7	2040	< 2	20	< 0.2	0.03	2
Spring Creek	< 0.1	20.8	1	< 2	13.3	< 0.2	< 0.01	0.8
Summer	< 0.1	20.2	1.5	< 2	4.11	< 0.2	0.04	0.8
Sterling	< 0.1	14.3	1.7	< 2	2.69	< 0.2	< 0.01	0.5
Russell	< 0.1	41	63.5	2.4	27.4	< 0.2	< 0.01	1.7

Table 34 (continued)

Spring Name	ICPMS_H2O P mg/L	ICPMS_H2O Pb ug/L	ICPMS_H2O Pr ug/L	ICPMS_H2O Rb ug/L	ICPMS_H2O Sb ug/L	ICPMS_H2O Sc ug/L	ICPMS_H2O Se ug/L	ICPMS_H2O Si mg/L
Clover	0.07	0.06	< 0.01	0.32	<0.3	2.4	< 1	6
Tonto Bridge	0.06	0.05	< 0.01	1.28	<0.3	2.6	< 1	6.6
Pieper Hatchery	0.08	<0.05	< 0.01	1.86	<0.3	1.1	< 1	3.2
Poison	0.07	0.05	< 0.01	2.44	<0.3	2.5	< 1	7.1
Foster	0.06	0.06	< 0.01	0.77	<0.3	2.7	< 1	8.8
Hackberry	0.1	0.09	0.02	6.2	<0.3	9.2	1	28.6
Log	0.4	0.07	< 0.01	0.37	<0.3	4.2	< 1	12.4
Spring Creek	0.04	0.05	< 0.01	2.18	<0.3	1.9	< 1	4.6
Summer	0.06	0.06	< 0.01	2.25	<0.3	2	< 1	5
Sterling	0.04	0.06	< 0.01	0.7	<0.3	1.9	< 1	5.2
Russell	0.02	<0.05	< 0.01	5.4	<0.3	3.4	< 1	8.7

Table 34 (continued)

Spring Name	ICPMS_H2O Sm ug/L	ICPMS_H2O SO4 mg/L	ICPMS_H2O Sr ug/L	ICPMS_H2O Ta ug/L	ICPMS_H2O Tb ug/L	ICPMS_H2O Th ug/L	ICPMS_H2O Ti ug/L	ICPMS_H2O Tl ug/L
Clover	< 0.01	3	73.5	< 0.02	< 0.005	< 0.2	1	<0.1
Tonto Bridge	< 0.01	5	138	< 0.02	< 0.005	< 0.2	< 0.5	<0.1
Pieper Hatchery	< 0.01	3	32	< 0.02	< 0.005	< 0.2	< 0.5	<0.1
Poison	< 0.01	5	393	< 0.02	< 0.005	< 0.2	< 0.5	<0.1
Foster	< 0.01	4	172	< 0.02	< 0.005	< 0.2	< 0.5	<0.1
Hackberry	0.01	20	416	< 0.02	< 0.005	< 0.2	1.5	<0.1
Log	< 0.01	17	542	< 0.02	< 0.005	< 0.2	0.9	<0.1
Spring Creek	< 0.01	6	222	< 0.02	< 0.005	< 0.2	< 0.5	<0.1
Summer	< 0.01	7	114	< 0.02	< 0.005	< 0.2	0.8	<0.1
Sterling	< 0.01	4	80.6	< 0.02	< 0.005	< 0.2	< 0.5	<0.1
Russell	< 0.01	17	375	< 0.02	< 0.005	< 0.2	< 0.5	<0.1

Table 34 (continued)

Spring Name	ICPMS_H2O Tm ug/L	ICPMS_H2O U ug/L	ICPMS_H2O V ug/L	ICPMS_H2O W ug/L	ICPMS_H2O Y ug/L	ICPMS_H2O Yb ug/L	ICPMS_H2O Zn ug/L	ICPMS_H2O Zr ug/L
Clover	< 0.005	0.4	1.3	< 0.5	0.03	< 0.005	2.7	< 0.2
Tonto Bridge	< 0.005	0.48	4.3	< 0.5	0.03	< 0.005	1.2	< 0.2
Pieper Hatchery	< 0.005	0.12	0.7	< 0.5	0.02	< 0.005	0.5	< 0.2
Poison	< 0.005	0.63	8.3	< 0.5	0.06	< 0.005	1.8	< 0.2
Foster	< 0.005	0.15	4.5	< 0.5	0.01	< 0.005	8	< 0.2
Hackberry	< 0.005	0.42	4.3	< 0.5	0.1	< 0.005	2.6	< 0.2
Log	< 0.005	0.23	0.8	< 0.5	0.1	0.005	2.5	< 0.2
Spring Creek	< 0.005	0.47	4.9	< 0.5	0.02	< 0.005	3.1	< 0.2
Summer	< 0.005	0.51	5.3	< 0.5	0.07	< 0.005	6.8	< 0.2
Sterling	< 0.005	0.35	1.2	< 0.5	0.01	< 0.005	8.2	< 0.2
Russell	< 0.005	0.79	0.8	< 0.5	0.02	< 0.005	3.3	< 0.2

Table 35 – Results for cation analyses using ICP AES for water collected in October 2003 from 11 springs in Phase II of the Middle Verde Springs study.

Spring Name	**ICP_H2O Ag** ug/L	**ICP_H2O Al** mg/L	**ICP_H2O As** ug/L	**ICP_H2O B** ug/L	**ICP_H2O Ba** ug/L	**ICP_H2O Be** ug/L	**ICP_H2O Ca** mg/L	**ICP_H2O Cd** ug/L	**ICP_H2O Co** ug/L	**ICP_H2O Cr** ug/L	**ICP_H2O Cu** ug/L
Clover	<1	0.035	<100	79	26	<10	46	<5	<10	<10	<10
Tonto Bridge	<1	0.023	<100	86	132	<10	77.2	<5	<10	<10	<10
Pieper Hatchery	<1	0.032	<100	76	125	<10	33	<5	<10	<10	<10
Poison	<1	0.031	<100	76	36	<10	39.1	<5	<10	<10	<10
Foster	<1	0.03	<100	72	11	<10	18.2	<5	<10	<10	<10
Hackberry	<1	0.074	<100	91	172	<10	44	<5	<10	<10	<10
Log	<1	0.033	<100	103	125	<10	63	<5	<10	<10	<10
Spring Creek	<1	0.027	<100	105	195	<10	60.7	<5	<10	<10	<10
Summer	<1	0.058	<100	143	184	<10	67.2	<5	<10	<10	<10
Sterling	<1	0.032	<100	69	86	<10	48.1	<5	<10	<10	<10
Russell	<1	0.014	<100	334	145	<10	105	<5	<10	<10	<10

Table 35 (continued)

Spring Name	ICP_H2O Fe mg/L	ICP_H2O K mg/L	ICP_H2O Li ug/L	ICP_H2O Mg mg/L	ICP_H2O Mn ug/L	ICP_H2O Mo ug/L	ICP_H2O Na mg/L	ICP_H2O Ni ug/L	ICP_H2O P mg/L	ICP_H2O Pb ug/L	ICP_H2O Sb ug/L
Clover	<0.02	0.4	<1	23.3	<10	<20	2.7	<10	<0.1	<50	<50
Tonto Bridge	<0.02	0.97	3.9	31.8	<10	<20	6.6	<10	<0.1	<50	<50
Pieper Hatchery	<0.02	1.1	1.5	7.9	<10	<20	1.6	<10	<0.1	<50	<50
Poison	<0.02	1.7	1.1	14.7	<10	<20	18.6	<10	<0.1	<50	<50
Foster	<0.02	0.57	<1	9.8	<10	<20	5	<10	<0.1	<50	<50
Hackberry	0.094	4	9.1	15.7	160	<20	23.9	<10	<0.1	<50	<50
Log	0.32	2.2	1.3	17.1	2200	<20	24.1	<10	0.39	<50	<50
Spring Creek	<0.02	1.1	8.1	25.2	<10	<20	16.7	<10	<0.1	<50	<50
Summer	<0.02	1.1	15	23.9	<10	<20	5	<10	<0.1	<50	<50
Sterling	<0.02	0.59	<1	17.1	<10	<20	3.3	<10	<0.1	<50	<50
Russell	<0.02	4.3	82	49.6	69	<20	34.4	<10	<0.1	<50	<50

Table 35 (continued)

Spring Name	ICP_H2O Si mg/L	ICP_H2O Sr ug/L	ICP_H2O Ti ug/L	ICP_H2O V ug/L	ICP_H2O Zn ug/L
Clover	8.2	70	<50	<10	<10
Tonto Bridge	8.6	134	<50	<10	<10
Pieper Hatchery	4.2	31	<50	<10	<10
Poison	9.1	376	<50	<10	<10
Foster	11.7	168	<50	<10	<10
Hackberry	40.5	393	<50	<10	<10
Log	17	515	<50	<10	<10
Spring Creek	5.9	217	<50	<10	<10
Summer	6.1	107	<50	<10	<10
Sterling	6.5	80	<50	<10	<10
Russell	10.2	359	<50	<10	<10

Table 36 – Results for anion analyses for water collected in October 2003 from 11 springs in Phase II of the Middle Verde Springs study.

Spring Name	**IC-Aq** **Cl** ppm	**IC-Aq** **F** ppm	**IC-Aq** **NO_3** ppm	**IC-Aq** **SO_4** ppm
Clover	1.5	0.1	<.08	1.7
Tonto Bridge	7.3	0.3	0.7	3.1
Pieper Hatchery	1.9	0.1	<.08	<1.6
Poison	8.7	0.2	3.5	3.6
Foster	2.2	0.1	<.08	2.5
Hackberry	13	0.2	<.08	23
Log	8	0.2	<.08	18
Spring Creek	29	0.1	0.2	4.9
Summer	5.7	0.2	0.5	4.6
Sterling	2.5	0.1	<.08	2
Russell	18	0.4	<.08	15

Table 37 – Results of Stable Isotope analyses for $\delta^{18}O$, δD, and $\delta^{13}C$ from water collected in October 2003 from 11 springs in Phase II of the Middle Verde Springs study.

Spring Name	δ18O ‰	δD ‰	δ13C ‰	DIC Standard	
Clover	-10.5	-72	-9.0	**enr. C**	
Tonto Bridge	-10.9	-76	-6.5	-10.49	
Pieper Hatchery	-11.2	-77	-9.4	-10.43	
Poison	-10.7	-78	-8.7	-10.39	
Foster	-11.6	-81	-8.1		
Hackberry	-9.0	-66	-7.6		
Log	-10.8	-76	-9.2	-10.44	Mean
Spring Creek	-11.8	-82	-3.3	0.05	SD
Summer	-11.7	-83	-3.8	-8.62	Ref. Value
Sterling	-11.9	-83	-8.6	1.82	offset
Russell	-11.3	-81	0.6		
Mean	-11.0	-78	-6.7		
Analytical Precision (1-sigma)	0.08	0.9	0.1		

Appendix V

Spring classifications after Springer et al. 2004

Table 38 – Physical and Geomorphic Classification of Springs after Springer et al. (2004), which was used to classify Middle Verde Springs study database.

Class Variable	Type / Criterion	Value / Descriptor	References
Hydrostratigraphic unit	**Sedimentary**	**(bedrock or Unconsolidated sediments)**	**Meinzer 1923**
	Igneous		**Meinzer 1923**
	Metamorphic		**Meinzer 1923**
	Mixed	**(combination of above)**	**Springer et al., 2004**
Emergence environment	**Cave**	**Special case, not ususally considered as a spring because it may not be directly exposed to the atmosphere**	**Springer et al., 2004**
	Subaerial – floodplain	*Above-ground emergence - Floodplain of primary or secondary drainage*	*Springer et al., 2004*
	Subaerial – prairie	**Above-ground emergence - Relatively flat open region**	**Springer et al., 2004**
	Subaerial – Piedmont	*Above-ground emergence - note geomorphic setting*	*Springer et al., 2004*
	Subaerial – Channel	**Above-ground emergence - Channel of secondary drainage, dry wash, no steep walls**	**Springer et al., 2004**
	Subaerial – Canyon Floor	**Above-ground emergence - Channel of steep walled canyon or primary drainage**	**Springer et al., 2004**
	Subaerial – Canyon Wall	**Above-ground emergence - Emerges from steeply sloping canyon walls**	**Springer et al., 2004**
	Subaerial – Mountainside	**Above-ground emergence - Moderately sloping hillside**	**Springer et al., 2004**
	Subglacial	*Above-ground emergence beneath a glacier*	*Springer et al., 2004*
	Subaqueous-lentic freshwater	*Aquatic emergence into pond or lake*	*Springer et al., 2004*
	Subaqueous-lotic freshwater	*Aquatic emergence into a stream or river*	*Springer et al., 2004*
	Subaqueous-estuarine	*Aquatic emergence in an estuary*	*Springer et al., 2004*
	Subaqueous-marine	*Aquatic emergence in a marine setting*	*Springer et al., 2004*

Table 38 (continued)

Class Variable	Type / Criterion	Value / Descriptor	References
Aperture geomorphology	**Seepage or filtration spring**	**Groundwater exposed or discharged from numerous small openings in permeable material**	**Meinzer 1923**
	Fracture spring	**Groundwater exposed or discharged from joints or fractures**	**Meinzer 1923**
	Tubular spring	**Groundwater discharged from, or exposed in openings of channels, such as solution passages or tunnels**	**Meinzer 1923**
	Contact spring	**Flow discharged along a stratigraphic contact (e.g., a hanging garden)**	**Springer et al., 2004**
Sphere of discharge	**Cave**	**Emergence in a cave**	**Springer et al., 2004**
	Limnocrene - emerges from lentic pool(s)	**Emergence in pool(s)**	**Modified from Meinzer 1923, Hynes 1970**
	Rheocrene - lotic channel floor	**Flowing spring, emerges into one or more stream channels**	**Modified from Meinzer 1923, Hynes 1970**
	(Carbonate) Mound-form	*Emerges from a mineralized mound*	*Springer et al., 2004*
	Helocrene (marsh) or cienega (wet meadow)	**Emerges from low gradient wetlands; often indistinct or multiple sources**	**Modified from Meinzer 1923, Hynes 1970, Springer et al., 2004**
	Hillslope spring	**Emerges from a hillslope (30-60^{o} slope); often indistinct or multiple sources**	**Springer et al., 2004**
	Gushette	**Discrete source flow gushes from a wall**	**Springer et al., 2004**
	Hanging garden	**Dripping flow emerges usually horizontally along a geologic contact**	**Springer et al., 2004**
	Geyser	*Explosive flow*	*Springer et al., 2004*
	Fountain	*Artesian fountain form*	*Springer et al., 2004*
	Hypocrene	*A buried spring where flow does not reach the surface*	*Springer et al., 2004*

Table 38 (continued)

Class Variable	Type / Criterion	Value / Descriptor	References
Spring channel	**Spring-dominated stream**	**Little external flow impact**	**Whiting and Stamm 1995**
	Runoff-dominated stream	**Dominated by external flow impacts**	**Whiting and Stamm 1995**
	Combined stream	**Definite spring impact channel within runoff dominated channel**	**Springer et al., 2004**
Forcing mechanisms	**Gravity driven springs**	**Depression, contact, fracture, or tubular springs**	**Meinzer 1923**
	Increased pressure due to gravity-driven head pressure differential	*Artesian springs*	*Meinzer 1923*
	Geothermal springs	*Springs associated with volcanism*	*Meinzer 1923*
	Springs due to pressure produced by other forces	*Springs associated with deep seated fractures*	*Meinzer 1923*
	Springs due to pressure produced by anthropogenic forces	*Anthropogenic artesian or geyser systems (e.g., hot springs associated with Hoover Dam, Arizona-Nevada)*	*Springer et al., 2004*
Persistence	*Neorefugium*	*Holocene (<12,000 yr old)*	*Nekola 1999*
	Paleorefugium	*Pleistocene or older (≥12,000 yr old)*	*Nekola 1999*
	Paleospring	*Pleistocene but not apparent recent flow*	*Springer et al., 2004*

Table 39 – Hydrological Classification of Springs after Springer et al. (2004), which was used to classify Middle Verde Springs study database.

Class Variable	Type / Criterion	Value / Descriptor	References
Flow consistency	**Perennial**	**Continuous flow**	**Meinzer 1923**
	Intermittent-regular	**Regular - flow occurs regularly on hourly or daily, seasonally, annually, or interannually**	**Meinzer 1923; Springer et al., 2004**
	Intermittent-erratic	**Flow occurs only on an erratic basis**	**Springer et al., 2004**
	Intermittent-dry	**No flow at all times of measurement for data used in classification**	**Springer et al., 2004**
Flow rate	**Unmeasureable**	**No discernable flow to measure**	**Springer et al., 2004**
	First	**<0.12 gpm (<10 ml/s)**	**Meinzer 1923**
	Second	**0.12 - 1.0 gpm (10 - 100 ml/s)**	**Meinzer 1923**
	Third	**1.0 – 10 gpm (0.10 - 1.0 L/s)**	**Meinzer 1923**
	Fourth	**10 – 100 gpm (1.0 - 10 L/s)**	**Meinzer 1923**
	Fifth	**100 - 448.8 gpm (10. - 100 L/s)**	**Meinzer 1923**
	Sixth	**448.8 - 4,488 gpm (0.10 - 1.0 m^3/s)**	**Meinzer 1923**
	Seventh	**4,488 - 44,880 gpm (1.0 - 10. m^3/s)**	**Meinzer 1923**
	Eighth	**>44,880 gpm (>10 m^3/s)**	**Meinzer 1923**
Flow variability (CVR = Q10%/Q90%)	**Steady (extraordinarily balanced)**	**1.0 - 2.5**	**Meinzer 1923, Netopil 1971, Alvaro and Wallace 1994**
	Moderately (well) balanced	**2.6 - 5.0**	**Meinzer 1923, Netopil 1971, Alvaro and Wallace 1994**
	Balanced	**5.1 - 7.5**	**Meinzer 1923, Netopil 1971, Alvaro and Wallace 1994**
	Moderately unbalanced	**7.6 - 10.0**	**Meinzer 1923, Netopil 1971, Alvaro and Wallace 1994**
	Highly unsteady (extraordinarily unbalanced)	**> 10.0**	Meinzer 1923, Netopil 1971, Alvaro and Wallace 1994
	Ephemeral	**Infinite**	**Springer et al., 2004**

Table 40 – Geochemical Classification of Springs after Springer et al. (2004), which was used to classify Middle Verde Springs study database.

Class Variable	Type / Criterion	Value / Descriptor	References
Temperature	**Cold**	**Below mean annual ambient temperature**	**Alfaro and Wallace, 1994**
	Normal	**Within 12.2°C of the mean ambient temperature**	**Alfaro and Wallace, 1994**
	Geothermal - warm	**>12.2oC warmer than mean annual ambient temperature but <37.8°C**	**Alfaro and Wallace, 1994**
	Hot	**Significantly warmer than mean annual ambient temperature 37.8° C-100°C**	**Alfaro and Wallace, 1994**
	Superheated (usually pressurized)	*>100°C*	*Springer et al, 2004.*
	Ambient temperature	*Taken at time of spring water temperature measurment*	*Springer et al., 2004*
Dominant cation type	Magnesium type	Magnesium (Mg) is the dominant	Back 1966
	Calcium type	Calcium (Ca) is the dominant cation	Back 1966
	Sodium type	Sodium and Potassium (Na +K) are the dominant cations	Back 1966
	No dominant type	*No dominant cations*	*Back 1966*
Dominant anion type	**Sulfate type**	**Sulfate (SO_4) is the dominant anion**	**Back 1966**
	Bicarbonate type	**Carbonate and Bicarbonate (HCO_3 + CO_3) are the dominant anions**	**Back 1966**
	Chloride type	**Chloride (Cl) is the dominant anion**	**Back 1966**
	No dominant type	*No dominant anions*	*Back 1966*
Minor constituents		*For example, borate, iron*	*Meinzer 1923, Clarke 1924*

Table 40 (continued)

Class Variable	Type / Criterion	Value / Descriptor	References
Pollution indicators	*Polluted – mineral*	*Selenium, Arsenic*	*Springer et al., 2004*
	Polluted – biological	*Fecal, coliform*	*Springer et al., 2004*
	Polluted - human	*Trash, development pollution*	*Springer et al., 2004*
	Polluted – multiple	*Combination of three above*	*Springer et al., 2004*
	No Pollution	*No pollution at spring*	*Springer et al., 2004*
Tracers		*Stable isotopes, radioactive isotopes, rare-earth elements*	*Kreamer and others 1996*
Alkalinity		*Alkalinity*	*Clarke 1924, Furtak and Langguty 1986*
TDS or specific conductance	**Hyperfresh**	**0 – 100 mg/L**	**Springer et al., 2004**
	Fresh	**100 – 1000 mg/L**	**Fetter 1994**
	Brackish	**1000 – 10,000 mg/L**	**Fetter 1994**
	Saline	**10,000 – 100,000 mg/L**	**Fetter 1994**
	Brine	*> 100,000 mg/L*	*Fetter 1994*
pH	*Strongly Acidic*	*pH range: < 4.0*	*Springer et al., 2004*
	Acidic	**pH range: 4.0 - <6.0**	**Springer et al., 2004**
	Neutral	**pH range: 6.0 – 8.0**	**Springer et al., 2004**
	Moderately Basic	**pH range: >8.0 - 10.0**	**Springer et al., 2004**
	Strongly Basic	**pH range: >10.0**	**Springer et al., 2004**
Nutrient concentration	*High N-P*	*N and P concentration high*	*Springer et al., 2004*
	High N Low P	*Nitrogen concentration high*	*Springer et al., 2004*
	High P Low N	*Phosphorus concentration high*	*Springer et al., 2004*
	Low N-P	*N and P concentration low*	*Springer et al., 2004*

Table 41 – Climatological Classification of Springs after Springer et al. (2004), which was used to classify Middle Verde Springs study database.

Class Variable	Type / Criterion	Value / Descriptor	References
Elevation	*Very High*	*>9500 ft*	*Springer et al., 2004*
	High	**6500 – 9500 ft**	**Springer et al., 2004**
	Middle	**3500 – 6500 ft**	**Springer et al., 2004**
	Low	**500 – 3500 ft**	**Springer et al., 2004**
	Very Low	*<500 ft*	*Springer et al., 2004*
Mean air temperature	*Warm*		*Springer et al., 2004*
	Moderate		*Springer et al., 2004*
	Cold		*Springer et al., 2004*
Mean monthly precipitation	*Arid*		*Springer et al., 2004*
	Semi-arid		*Springer et al., 2004*
	Semi-humid		*Springer et al., 2004*
	Humid		*Springer et al., 2004*
Precipitation seasonality			*Springer et al., 2004*
Growing season length			*Springer et al., 2004*
Surrounding ecosystem(s)	**Terrestrial - Barrenlands**		**Springer et al., 2004**
	Terrestrial - Grasslands		**Springer et al., 2004**
	Terrestrial - Herblands		*Springer et al., 2004*
	Terrestrial - Shrublands		**Springer et al., 2004**
	Terrestrial - Woodlands		**Springer et al., 2004**
	Terrestrial - Forest		*Springer et al., 2004*
	Freshwater - Lentic		*Springer et al., 2004*
	Freshwater - Lotic		*Springer et al., 2004*
	Marine - Euphotic	*shallow - note substrata (e.g., silt, sand, coral)*	*Springer et al., 2004*
	Marine - Aphotic	*deep*	*Springer et al., 2004*

Table 42 – Biological Classification of Springs after Springer et al. (2004), which was used to classify Middle Verde Springs study database.

Class Variable	Type / Criterion	Value / Descriptor	References
Biogeographic isolation	**Nearest spring very near**	**<1-100 m between springs**	**Springer et al., 2004**
	Nearest spring nearby	**100 m -1 km between springs**	**Springer et al., 2004**
	Moderately isolated	**1-10 km between springs**	**Springer et al., 2004**
	Isolated	**10-100 km between springs**	**Springer et al., 2004**
	Highly isolated	*>100 km between springs*	*Springer et al., 2004*
Habitat size	**Extremely small**	**<2 m^2**	**Springer et al., 2004**
	Very small	**2-10 m^2**	**Springer et al., 2004**
	Small	**10-100 m^2**	**Springer et al., 2004**
	Medium-small	**100-1,000 m^2**	**Springer et al., 2004**
	Medium-large	**0.1-1.0 ha**	**Springer et al., 2004**
	Large	**1-10 ha**	**Springer et al., 2004**
	Very large	**10-100 ha**	**Springer et al., 2004**
	Extremely large	*>100 ha*	*Springer et al., 2004*
Microhabitat	*Cave*	*Permanently dark zone*	*Springer et al., 2004*
		Twilight zone	*Springer et al., 2004*
		Entrance	*Springer et al., 2004*
	Wet wall	*Wet , seeping, or dry wall(s)*	*Springer et al., 2004*
	Madicolous	*Falling or fast flowing stream water*	*Springer et al., 2004*
	Hyporheic	*Habitat beneath the floor of the stream*	*Springer et al., 2004*
	Open-water pool(s)	*Mud, ooze, sand, gravel, boulder, or bedrock-floored pond*	*Springer et al., 2004*
	Spring stream(s)	*Fine-grained (sand or silt) floor*	*Springer et al., 2004*
		Gravel floor (note embeddedness of gravels)	*Springer et al., 2004*
		Cobble-boulder floor	*Springer et al., 2004*
		Bedrock floor	*Springer et al., 2004*

Table 42 (continued)

Class Variable	Type / Criterion	Value / Descriptor	References
Microhabitat (continued)	*Wet meadow*	*Cienega - low slope wetlands*	*Springer et al., 2004*
		High slope wetlands	*Springer et al., 2004*
	Riparian	*Note area by vegetation cover type*	*Springer et al., 2004*
	Spray zone	*Areas watered by spray from waterfalls*	*Gressleson et al. 1987, Springer et al., 2004*
	Barren rock	*Cliffs, slopes, or relatively flat*	*Springer et al., 2004*
Microhabitat diversity: $H' = -\Sigma (p_i * logp_i)$	*Microhabitat diversity*	*Shannon diversity index calculated using proportion of each microhabitat area*	*Shannon 1948*
Plant species richness	*Species observed with percent cover of each species in each major vegetation patch by stratum - ground, shrub, mid-canopy=woodland, and tall canopy*		*Springer et al., 2004*
Vegetation diversity $H' = -\Sigma (p_i * logp_i)$	*Shannon diversity index, using percent cover for each stratum in each patch*		*Shannon 1948*
Invertebrate species richness	*Number and species observed*		*Springer et al., 2004*
Invertebrate diversity $H' = -\Sigma (p_i * logp_i)$	*Shannon diversity index, using quantitative measures of diversity for aquatic and terrestrial taxa separately*		*Shannon 1948*
Animal species richness	*Number and species observed*		*Springer et al., 2004*
Animal diversity $H' = -\Sigma (p_i * logp_i)$	*Shannon diversity index, using quantitative measures of diversity for aquatic and terrestrial taxa separately*		*Shannon 1948*

Table 43 – Cultural Classification of Springs after Springer et al. (2004), which was used to classify Middle Verde Springs study database.

Class Variable	Type / Criterion	Value / Descriptor	References
Land ownership	Federal		**Springer et al., 2004**
	State		**Springer et al., 2004**
	Local		**Springer et al., 2004**
	Private		**Springer et al., 2004**
Legal authorities	*Applicable laws, including water rights and environmental protection laws*		*Springer et al., 2004*
Land use history	*Land use history should be referenced or compiled*		*White 1979*
Prehistoric/early historic Use/modification	*Document any use of spring by prehistoric or early historic cultures*		*Springer et al., 2004*
Primary use	**Culinary, livestock watering, recreation,** *religious*, **wildlife,** *conservation, research*, **other**		**Springer et al., 2004**
Secondary use	**Culinary, livestock watering, recreation,** *religious*, **wildlife,** *conservation, research*, **other**		**Springer et al., 2004**
Other uses	*Culinary, livestock watering, recreation, religious, wildlife, conservation, research, other*		*Springer et al., 2004*
Groundwater modification	*Extraction, augmentation, pollution*		*Springer et al., 2004*
Emergent flow regulation	*Dewatering, abstraction, diversion, pollution*		*Springer et al., 2004*

Table 43 (continued)

Class Variable	Type / Criterion	Value / Descriptor	References
Microhabitat modification	**Piping**		**Springer et al., 2004**
	Fencing		**Springer et al., 2004**
	Tanks		**Springer et al., 2004**
	Spring box/house		**Springer et al., 2004**
	Dams/Ponds		**Springer et al., 2004**
Surrounding ecosystem health	*Condition of surrounding ecosystem*		*Springer et al., 2004*
Data management criteria and authorities	*Federal*		*Springer et al., 2004*
	State		*Springer et al., 2004*
	Local		*Springer et al., 2004*
	Private		*Springer et al., 2004*
Location and forms of original data			*Springer et al., 2004*
Data quality control protocols			*Springer et al., 2004*

Notes for Tables 39 – 44:
Classes and Types in Bold were used in the classification for the Middle Verde Springs data.
Classes and Types in Italics and Gray were not classified for the Middle Verde Springs data.

Appendix VI

Verde springs data classification results

Table 44 – Physical and Geomorphic Springs Classification for the Middle Verde Springs study based on Springer et al. (2004).

Name of Spring	Hydrostratigraphic unit	Emergence environment	Aperture geomorphology	Sphere of Discharge	Spring Channel	Flow forcing mechanisms
101 Spring	Sed - Kaibab Limestone	Subaerial - Canyon Wall	Contact	Hanging Garden	Spring	Gravity Driven
Babe's Hole Spring	Ign - Basalt	Subaerial - Mountainside	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Baker Spring	Ign - Basalt	Subaerial	Seepage or filtration	Helocrene	Runoff	Gravity Driven
Banfield Spring	Ign - Basalt	Subaerial	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Banjo Bill Spring	Sed - Supai Group (sandstone)	Subaerial - Canyon Floor	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Barney Spring	Sed - Kaibab Limestone	Subaerial	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Basin Spring	Ign - Volcanics	Subaerial	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Bear Spring (tnf)	Sed - Supai Group (sandstone)	Subaerial - Mountainside	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Bear Spring(pnf)	Ign - Volcanics	Subaerial	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Beasley Flat Spring	Sed - Alluvium	Subaerial	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Bell Rock Spring	Sed - Schnebly Hill (sandstone)	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Big Hutch Spring #1	Ign - Volcanics	Subaerial - Mountainside	Seepage or filtration	Hillslope	Spring	Gravity Driven
Big Hutch Spring #2	Ign - Volcanics	Subaerial - Mountainside	Seepage or filtration	Hillslope	Spring	Gravity Driven
Bill Back Spring	Ign - Basalt	Subaerial	Seepage or filtration	Helocrene	Runoff	Gravity Driven
Bill Dick Spring	Ign - Basalt	Subaerial	Seepage or filtration	Helocrene	Spring	Gravity Driven
Black Canyon Spring	Sed - Redwall Limestone	Subaerial - Channel	Contact	Rheocrene	Runoff	Gravity Driven
Blue Monster Main Spring	Ign - Granite	Subaerial - Mountainside	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Blue Monster South Spring	Ign - Granite	Subaerial - Mountainside	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Bootlegger Spring	Ign - Basalt	Subaerial - Mountainside	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Bottle Spring	Ign - Basalt	Subaerial - Mountainside	Seepage or filtration	Helocrene	Spring	Gravity Driven
Bristow Spring	Ign - Basalt	Subaerial	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Brushy Wash Spring	Ign - Granite	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Burnt Spring (cnf)	Ign - Volcanics	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Buzzard Spring	Sed - Kaibab Limestone	Subaerial - Channel	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Campbell Road Spring	Ign - Basalt	Subaerial - Mountainside	Seepage or filtration	Hillslope	Spring	Gravity Driven
Campbell Spring	Ign - Basalt	Subaerial - Mountainside	Fracture	Hillslope	Spring	Gravity Driven
Cave Spring	Sed - Supai Group (sandstone)	Cave	Seepage or filtration	cave	Spring	Gravity Driven
Cedar Spring	Sed - Verde Fm (Limestone)	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven

Table 44 – continued

Name of Spring	Hydrostratigraphic unit	Emergence environment	Aperture geomorphology	Sphere of Discharge	Spring Channel	Flow forcing mechanisms
Chalk Spring (cnf)	Ign - Volcanics	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Chasm Spring	Ign – Volcanics	Subaerial – Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Cherry 361a	Ign – Granite	Subaerial – Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Cherry 361b	Ign – Granite	Subaerial – Mountainside	Seepage or filtration	Limnocrene	Spring	Gravity Driven
Cimarron Spring	Ign – Volcanics	Subaerial – Canyon Wall	Seepage or filtration	Helocrene	Runoff	Gravity Driven
Clover Spring	Sed – Kaibab Limestone	Cave	Tubular	Rheocrene	Runoff	Gravity Driven
Cottonwood Spring (cnf)	Ign – Volcanics	Subaerial – Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Cottonwood Spring (tnf)	Ign – Volcanics	Subaerial	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Dow Spring	Ign – Basalt	Subaerial – Canyon Floor	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Dripping Spring #1	Sed – Naco/Redwall Limestone	Subaerial – Mountainside	Contact	Hanging Garden	Spring	Gravity Driven
Dripping Spring #2	Sed – Naco/Redwall Limestone	Subaerial – Mountainside	Contact	Hanging Garden	Spring	Gravity Driven
Dripping Spring #3	Sed – Naco/Redwall Limestone	Subaerial – Mountainside	Contact	Hanging Garden	Spring	Gravity Driven
Dripping Spring #4	Sed – Naco/Redwall Limestone	Subaerial – Mountainside	Contact	Hanging Garden	Runoff	Gravity Driven
Fain Spring	Ign – Basalt	Subaerial – Prairie	Seepage or filtration	Helocrene	Spring	Gravity Driven
Fortyfour Spring	Sed – Kaibab Limestone	Subaerial – Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Foster Spring	Ign – Basalt	Subaerial – Mountainside	Fracture	Hillslope	Spring	Gravity Driven
Frog Spring	Ign – Volcanics	Subaerial – Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Fuller Spring	Sed – Supai Group (sandstone)	Subaerial – Canyon Floor	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Garden Spring	Ign – Basalt	Subaerial – Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Geronimo Spring (1)	Sed – Kaibab Limestone	Subaerial – Canyon Wall	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Geronimo Spring (tnf)	Sed – Supai Group (sandstone)	Subaerial – Mountainside	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Goat Camp Spring	Ign – Granite	Subaerial – Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Gooseberry Spring	Ign – Basalt	Subaerial – Prairie	Seepage or filtration	Helocrene	Spring	Gravity Driven
Gould Spring #1	Ign – Granite	Subaerial – Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Gould Spring #2	Ign – Granite	Subaerial – Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Grapevine Spring	Ign – Granite	Subaerial – Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Grassy Meadow Spring	Sed – Supai Group (sandstone)	Subaerial – Canyon Floor	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Gray Springs	Ign – Basalt	Subaerial – Prairie	Seepage or filtration	Rheocrene	Spring	Gravity Driven

Table 44 – continued

Name of Spring	Hydrostratigraphic unit	Emergence environment	Aperture geomorphology	Sphere of Discharge	Spring Channel	Flow forcing mechanisms
Griffith Spring	Ign – Basalt	Subaerial – Prairie	Seepage or filtration	Helocrene	Spring	Gravity Driven
Grimes Spring	Ign – Granite	Subaerial – Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Hackberry Spring #1	Mixed - Alluvium/Volcanics	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Hackberry Spring #2	Mixed - Alluvium/Volcanics	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Hance Spring	Sed - Verde Fm (Limestone)	Subaerial - Channel	Contact	Rheocrene	Runoff	Gravity Driven
Horseshoe Spring	Ign - Basalt	Subaerial - Mountainside	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Howard Spring	Ign - Basalt	Subaerial - Prairie	Seepage or filtration	Helocrene	Spring	Gravity Driven
Huffer Spring	Ign - Basalt	Subaerial - Channel	Seepage or filtration	Helocrene	Runoff	Gravity Driven
Hull Spring	Ign - Volcanics	Subaerial - Canyon Wall	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Irving High Spring	Ign - Volcanics	Subaerial - Mountainside	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Irving Low Spring	Ign - Volcanics	Subaerial - Mountainside	Seepage or filtration	Rheocrene	Spring	Gravity Driven
JM Spring	Ign - Volcanics	Subaerial - Mountainside	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Jones Spring #1	Ign - Basalt	Subaerial - Channel	Contact	Helocrene	Spring	Gravity Driven
Jones Spring #2a	Ign - Basalt	Subaerial - Mountainside	Contact	Helocrene	Spring	Gravity Driven
Jones Spring #2b	Ign - Basalt	Subaerial - Mountainside	Contact	Rheocrene	Spring	Gravity Driven
Kelsey Spring	Ign - Basalt	Subaerial - Mountainside	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Larson Spring	Ign - Granite	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Lee Johnson Spring	Sed - Coconino Sandstone	Subaerial - Channel	Seepage or filtration	Helocrene	Spring	Gravity Driven
Lee Spring	Ign - Basalt	Subaerial - Prairie	Seepage or filtration	Helocrene	Spring	Gravity Driven
Lindburg Spring	Ign - Basalt	Subaerial - Prairie	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Little Hutch Spring #1	Ign - Volcanics	Subaerial - Mountainside	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Little Hutch Spring #2	Ign - Volcanics	Subaerial - Mountainside	Seepage or filtration	Rheocrene	Spring	Gravity Driven
LO Spring	Ign - Basalt	Subaerial - Canyon Floor	Seepage or filtration	Limnocrene	Runoff	Gravity Driven
Log Spring	Ign - Granite	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Long Valley Spring	Sed - Kaibab Limestone	Subaerial - Mountainside	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Lower Gould Spring	Ign - Granite	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Lower Hull Spring	Ign - Basalt	Subaerial - Prairie	Seepage or filtration	Helocrene	Spring	Gravity Driven
LX Spring	Ign - Volcanics	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven

Table 44 – continued

Name of Spring	Hydrostratigraphic unit	Emergence environment	Aperture geomorphology	Sphere of Discharge	Spring Channel	Flow forcing mechanisms
Maple Spring	Sed - Kaibab Limestone	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Maxwell Spring	Ign - Basalt	Subaerial - Prairie	Seepage or filtration	Helocrene	Spring	Gravity Driven
Mesquite Spring	Ign - Volcanics	Subaerial	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Mine Spring	Ign - Granite	Subaerial - Mountainside	Seepage or filtration	Limnocrene	Spring	Gravity Driven
Morgan Spring	Ign - Granite	Subaerial	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Mortgage Spring	Ign - Basalt	Subaerial - Channel	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Mund Spring	Sed - Alluvium	Subaerial - Prairie	Seepage or filtration	Helocrene	Runoff	Gravity Driven
North Mine Spring	Ign - Granite	Cave	Seepage or filtration	Rheocrene	Spring	Gravity Driven
North Pass Spring	Ign - Volcanics	Subaerial - Mountainside	Seepage or filtration	Hillslope	Spring	Gravity Driven
North Pasture Canyon Spring	Ign - Volcanics	Subaerial - Canyon Floor	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
North Pasture Spring	Ign - Volcanics	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Oxbow Spring	Sed - Alluvium	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Patton Spring	Ign - Basalt	Subaerial - Channel	Seepage or filtration	Helocrene	Runoff	Gravity Driven
Pearson Spring	Ign - Basalt	Subaerial - Prairie	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Pfau Spring	Ign - Granite	Cave	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Phroney Spring	Ign - Volcanics	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Picnic Spring	Ign - Volcanics	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Pieper Hatchery Spring #1	Sed - Supai Group (sandstone)	Subaerial - Mountainside	Fracture	Hillslope	Spring	Gravity Driven
Pieper Hatchery Spring #2	Sed - Supai Group (sandstone)	Subaerial - Mountainside	Fracture	Hillslope	Spring	Gravity Driven
Pine Flat Spring	Sed - Coconino Sandstone	Subaerial - Canyon Floor	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Pine Spring	Sed - Supai Group (sandstone)	Subaerial - Mountainside	Seepage or filtration	Helocrene	Spring	Gravity Driven
Pivot Rock Spring	Sed - Kaibab Limestone	Cave	Tubular	Gushette	Runoff	Gravity Driven
Poison Sping (tnf)	Sed - Supai Group (sandstone)	Subeaerial - Mountainside	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Poison Spring (1)	Ign - Basalt	Subaerial - Channel	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Powell Spring	Ign - Granite	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Quail Spring #1	Sed - Alluvium	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Quail Spring #2	Sed - Alluvium	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Quail Spring #3	Sed - Alluvium	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven

Table 44 – continued

Name of Spring	Hydrostratigraphic unit	Emergence environment	Aperture geomorphology	Sphere of Discharge	Spring Channel	Flow forcing mechanisms
Quail Spring (cnf)	Ign - Volcanics	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Railroad Spring	Ign - Basalt	Subaerial - Prairie	Seepage or filtration	Limnocrene	Spring	Gravity Driven
Red Horse Spring	Ign - Granite	Cave	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Red Rock Spring	Sed - Supai Group (sandstone)	Subaerial - Mountainside	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Ritter Spring	Ign - Basalt	Subaerial - Mountainside	Seepage or filtration	Helocrene	Spring	Gravity Driven
Rock Top Spring	Ign - Basalt	Subaerial - Mountainside	Seepage or filtration	Helocrene	Spring	Gravity Driven
Round Up Park Spring	Ign - Basalt	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Russel Spring #1	Sed - Verde Fm (Limestone)	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Russel Spring #2	Sed - Verde Fm (Limestone)	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Sally May Spring	Ign - Volcanics	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Schells Spring	Ign - Basalt	Subaerial - Channel	Seepage or filtration	Helocrene	Runoff	Gravity Driven
Scott Spring	Ign - Basalt	Subaerial - Mountainside	Seepage or filtration	Helocrene	Spring	Gravity Driven
Seven Anchor Spring #1	Sed - Kaibab Limestone	Subaerial - Channel	Contact	Rheocrene	Spring	Gravity Driven
Seven Anchor Spring #2	Ign - Basalt	Subaerial - Channel	Contact	Rheocrene	Spring	Gravity Driven
Sheep Bridge Hot Springs	Ign - Granite	Subaerial - Canyon Floor	Contact	Rheocrene	Spring	Gravity Driven
Sheep Spring	Ign - Basalt	Subaerial - Prairie	Seepage or filtration	Helocrene	Spring	Gravity Driven
Spring Creek	Sed - Verde Fm (Limestone)	Subaerial - Channel	Seepage or filtration	Rheocrene	Combined	Gravity Driven
Sterling Spring 1	Sed - Coconino Sandstone	Subaerial - Canyon Floor	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Sterling Spring 2	Sed - Coconino Sandstone	Subaerial - Canyon Floor	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Stone Camp Spring	Ign - Volcanics	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Summer Spring	Sed - Martin Limestone	Subaerial - Canyon Floor	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Sycamore Spring #1a	Ign - Volcanics	Subaerial - Canyon Floor	Seepage or filtration	Rheocrene	runoff	Gravity Driven
Sycamore Spring #1b	Ign - Volcanics	Subaerial - Canyon Floor	Seepage or filtration	Rheocrene	runoff	Gravity Driven
Sycamore Spring #2	Ign - Volcanics	Subaerial - Canyon Floor	Seepage or filtration	Rheocrene	runoff	Gravity Driven
Thicket Spring	Ign - Volcanics	Subaerial - Channel	Seepage or filtration	Helocrene	runoff	Gravity Driven
Tonto Bridge	Sed - Naco/Redwall Limestone	Suberial - Canyon Floor	Seepage or filtration	Rheocrene	spring	Gravity Driven
Towel Spring	Ign - Volcanics	Subaerial - Channel	Seepage or filtration	Rheocrene	runoff	Gravity Driven
Trail Junction Spring	Ign - Volcanics	Subaerial - Channel	Seepage or filtration	Limnocrene	spring	Gravity Driven

Table 44 – continued

Name of Spring	Hydrostratigraphic unit	Emergence environment	Aperture geomorphology	Sphere of Discharge	Spring Channel	Flow forcing mechanisms
Trail Spring	Ign - Volcanics	Subaerial - Channel	Seepage or filtration	Rheocrene	runoff	Gravity Driven
Tree Spring	Sed - Alluvium	Subaerial - Prairie	Seepage or filtration	Helocrene	runoff	Gravity Driven
T-six Spring	Sed - Alluvium	Subaerial - Mountainside	Seepage or filtration	Helocrene	runoff	Gravity Driven
Tunnel Spring	Ign - Granite	Subaerial - Channel	Seepage or filtration	Rheocrene	runoff	Gravity Driven
Turkey Spring	Sed - Supai Group (sandstone)	Subaerial - Mountainside	Seepage or filtration	Hillslope	Spring	Gravity Driven
Upper Hull Spring	Ign - Basalt	Subaerial - Prairie	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Van Deren Spring	Ign - Basalt	Subaerial - Mountainside	Seepage or filtration	Helocrene	Spring	Gravity Driven
Verde Hot Spring	Ign - Granite	Subaerial - Canyon Floor	Seepage or filtration	Rheocrene	Spring	Gravity Driven
Washington Spring	Sed - Supai Group (sandstone)	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Wet Prong Spring	Ign - Volcanics	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Wildcat Spring	Sed - Kaibab Limestone	Subaerial - Channel	Seepage or filtration	Helocrene	Runoff	Gravity Driven
Willard Spring	Ign - Basalt	Subaerial - Prairie	Seepage or filtration	Helocrene	Spring	Gravity Driven
Wilson Seep	Ign - Basalt	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Windfall Spring	Ign - Basalt	Subaerial - Channel	Seepage or filtration	Helocrene	Runoff	Gravity Driven
Winter Cabin Spring	Sed - Verde Fm (Limestone)	Subaerial - Channel	Contact	Rheocrene	Runoff	Gravity Driven
Wire Corral Spring	Ign - Volcanics	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Yellow Jacket Spring	Ign - Basalt	Subaerial - Mountainside	Seepage or filtration	Helocrene	Runoff	Gravity Driven
Zig Zag Spring #1 main	Ign - Volcanics	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
Zig Zag Spring #2	Ign - Volcanics	Subaerial - Channel	Seepage or filtration	Rheocrene	Runoff	Gravity Driven
% springs classified	100%	100%	100%	100%	97%	100%

Classes notes

Hydrostratigraphic unit determined from data in database

Emergence Environment determined from data in database and pictures

Aperature geomorphology determined from data in database(seepage or filtration used if unknown)

Sphere of discharge determined from data in database and pictures

Spring channel determined from data in database

Flow forcing mechanism determined from data in database(Gravity driven assumed if no data)

Table 45 – Hydrological and Geochemical Classification for the Middle Verde Springs study based on Springer et al. (2004).

Name of Spring	Flow consistency	flow rate	flow variability	Temperature	TDS	pH	Dominant Cation	Dominant Anion
101 Spring	Perennial	second		cold		neutral - 7.91		
Babe's Hole Spring	Perennial	third		normal		neutral - 6.99		
Baker Spring	Intermittent - dry	unmeasureable		none		none		
Banfield Spring	Intermittent - dry	unmeasureable		none		none		
Banjo Bill Spring	Perennial	third		normal		neutral - 7.50		
Barney Spring	Intermittent - dry	unmeasureable		none		none		
Basin Spring	Perennial	second		normal	fresh	neutral - 7.86		
Bear Spring (tnf)	Perennial	second		normal		neutral - 7.71		
Bear Spring(pnf)	Intermittent - dry	unmeasureable		none		none		
Beasley Flat Spring	Intermittent - dry	unmeasureable		none		none		
Bell Rock Spring	Intermittent - dry	unmeasureable		none		none		
Big Hutch Spring #1	Perennial	fourth		normal	fresh	Moderately Basic 8.17		
Big Hutch Spring #2	Perennial	fourth		normal	fresh	Moderately Basic 8.17		
Bill Back Spring	Intermittent - dry	unmeasureable		none		none		
Bill Dick Spring	Intermittent - dry	unmeasureable		none		none		
Black Canyon Spring	Intermittent - dry	unmeasureable		none		none		
Blue Monster Main Spring	Intermittent - dry	unmeasureable		none		none		
Blue Monster South Spring	Intermittent - dry	first		warm	fresh	neutral - 7.85		
Bootlegger Spring	Perennial	second		normal	fresh	neutral - 7.94		
Bottle Spring	Intermittent - dry	unmeasureable		none		none		
Bristow Spring	Intermittent - dry	unmeasureable		none		none		
Brushy Wash Spring	Intermittent - dry	unmeasureable		none		none		
Burnt Spring (cnf)	Intermittent - dry	unmeasureable		none		none		
Buzzard Spring	Intermittent - dry	unmeasureable		none		none		
Campbell Road Spring	Perennial	second		normal		neutral - 6.76		
Campbell Spring	Perennial	third	Highly Unsteady	normal		neutral - 7.36		
Cave Spring	Intermittent - dry	unmeasureable		none		none		

Table 45 – continued

Name of Spring	Flow consistency	flow rate	flow variability	Temperature	TDS	pH	Dominant Cation	Dominant Anion
Cedar Spring	Intermittent - dry	unmeasureable		normal	fresh	Moderately Basic 8.60		
Chalk Spring (cnf)	Intermittent - dry	unmeasureable		none		none		
Chasm Spring	Perennial	second		normal	fresh	Neutral - 7.78		
Cherry 361a	Intermittent - dry	unmeasureable		none		none		
Cherry 361b	Perennial	third		warm	fresh	Neutral - 7.37		
Cimarron Spring	Intermittent - dry	unmeasureable		none		none		
Clover Spring	Intermittent-regular	unmeasureable - fourth	Ephemeral	none		none	Ca	$CO_3 + HCO_3$
Cottonwood Spring (cnf)	Intermittent - dry	unmeasureable		none		none		
Cottonwood Spring (tnf)	Intermittent - dry	unmeasureable		none		none		
Dow Spring	Perennial	second		normal	fresh	Moderately Basic - 9.16		
Dripping Spring #1	Perennial	second		normal		Moderately Basic - 8.01		
Dripping Spring #2	Perennial	second		normal		Neutral - 7.72		
Dripping Spring #3	Perennial	second		normal		Neutral - 7.35		
Dripping Spring #4	Intermittent - dry	unmeasureable		none		none		
Fain Spring	Perennial	second		normal	fresh	Neutral - 7.04		
Fortyfour Spring	Perennial	second		normal		Neutral - 7.30		
Foster Spring	Perennial	third	Highly Unsteady	normal		Moderately Basic - 8.20	Ca	$CO_3 + HCO_3$
Frog Spring	Intermittent - dry	unmeasureable		warm	fresh	Neutral - 7.74		
Fuller Spring	Perennial	first		normal		Neutral - 7.14		
Garden Spring	Intermittent - dry	unmeasureable		none		none		
Geronimo Spring (1)	Perennial	third		normal		Moderately Basic - 8.28		
Geronimo Spring (tnf)	Perennial	second		normal		Neutral - 7.58		
Goat Camp Spring	Intermittent - dry	unmeasureable		none		none		
Gooseberry Spring	Perennial	second		normal		Neutral - 7.80		
Gould Spring #1	Intermittent - dry	unmeasureable		none		none		
Gould Spring #2	Intermittent - dry	unmeasureable		none		none		

Table 45 – continued

Name of Spring	Flow consistency	flow rate	flow variability	Temperature	TDS	pH	Dominant Cation	Dominant Anion
Grapevine Spring	Intermittent-erratic	unmeasureable - sixth	Ephemeral	none		none		
Grassy Meadow Spring	Perennial	second		cold		Neutral - 7.37		
Gray Springs	Perennial	third	Steady	normal		Moderately Basic - 8.66		
Griffith Spring	Intermittent - dry	unmeasureable		none		none		
Grimes Spring	Perennial	second	Ephermal	warm		Neutral - 6.99		
Hackberry Spring #1	Perennial	third	Balanced	normal	fresh	Neutral - 6.74	Ca	$CO_3 + HCO_3$
Hackberry Spring #2	Perennial	third	Balanced	normal	fresh	Neutral - 6.83	Ca	$CO_3 + HCO_3$
Hance Spring	Intermittent - dry	first		normal	fresh	Neutral - 6.79		
Horseshoe Spring	Perennial	second		normal		Moderately Basic - 8.05		
Howard Spring	Intermittent - dry	unmeasureable		none		none		
Huffer Spring	Intermittent - dry	unmeasureable		none		none		
Hull Spring	Intermittent - dry	unmeasureable		none		none		
Irving High Spring	Perennial	second		normal		Neutral - 7.52		
Irving Low Spring	Perennial	second		normal		Neutral - 7.28		
JM Spring	Intermittent - dry	unmeasureable		none		none		
Jones Spring #1	Intermittent - dry	unmeasureable		none		none		
Jones Spring #2a	Intermittent - dry	unmeasureable		none		none		
Jones Spring #2b	Intermittent - dry	unmeasureable		none		none		
Kelsey Spring	Perennial	third		normal		Neutral - 6.77		
Larson Spring	Intermittent - dry	unmeasureable		none		none		
Lee Johnson Spring	Intermittent - dry	unmeasureable		none		none		
Lee Spring	Intermittent - dry	unmeasureable		none		none		
Lindburg Spring	Perennial	second		normal		Neutral - 7.07		
Little Hutch Spring #1	Perennial	third		normal	fresh	Neutral - 6.92		
Little Hutch Spring #2	Perennial	third		normal	fresh	Neutral - 6.92		
LO Spring	Perennial	fourth		normal		Neutral - 7.62		
Log Spring	Perennial	third	Moderately (well) balanced	normal	fresh	Neutral - 6.63	Ca	$CO_3 + HCO_3$

Table 45 – continued

Name of Spring	Flow consistency	flow rate	flow variability	Temperature	TDS	pH	Dominant Cation	Dominant Anion
Long Valley Spring	Intermittent - dry	unmeasureable		none		none		
Lower Gould Spring	Perennial	first		warm		Moderately Basic - 8.02		
Lower Hull Spring	Intermittent - dry	unmeasureable		none		none		
LX Spring	Perennial	fourth		normal	fresh	Neutral - 7.36		
Maple Spring	Intermittent - dry	unmeasureable		none		none		
Maxwell Spring	Intermittent - dry	unmeasureable		none		none		
Mesquite Spring	Intermittent - dry	unmeasureable		none		none		
Mine Spring	Perennial	second		normal	hyperfresh	Neutral - 7.10		
Morgan Spring	Intermittent - dry	unmeasureable		none		none		
Mortgage Spring	Intermittent - dry	unmeasureable		normal		Moderately Basic - 9.18		
Mund Spring	Intermittent - dry	unmeasureable		none		none		
North Mine Spring	Intermittent - dry	unmeasureable		normal	brackish	Neutral - 7.65		
North Pass Spring	Perennial	second		warm	fresh	Neutral - 7.67		
North Pasture Canyon Spring	Perennial	third		normal	fresh	Neutral - 7.37		
North Pasture Spring	Perennial	second		normal	fresh	Neutral - 7.33		
Oxbow Spring	Perennial	second		normal		Neutral - 7.42		
Patton Spring	Intermittent - dry	unmeasureable		none		none		
Pearson Spring	Intermittent - dry	unmeasureable		none		none		
Pfau Spring	Perennial	third		normal	fresh	Neutral - 7.51		
Phroney Spring	Perennial	third		normal	fresh	Neutral - 6.84		
Picnic Spring	Perennial	third		normal	fresh	Neutral - 7.38		
Pieper Hatchery Spring #1	Perennial	fourth	Balanced	normal		Neutral - 7.25	Ca	$CO_3 + HCO_3$
Pieper Hatchery Spring #2	Perennial	fifth	Balanced	normal		Neutral - 7.25	Ca	$CO_3 + HCO_3$
Pine Flat Spring	Perennial	fourth		normal		Neutral - 7.60		
Pine Spring	Perennial	third		normal		Neutral - 7.94		
Pivot Rock Spring	Perennial	third - sixth	Highly Unsteady	cold		Neutral - 7.60		
Poison Sping (tnf)	Perennial	third		normal		Neutral - 7.57		

Table 45 – continued

Name of Spring	Flow consistency	flow rate	flow variability	Temperature	TDS	pH	Dominant Cation	Dominant Anion
Poison Spring (1)	Perennial	third	Steady	normal		Moderately Basic - 8.28	Ca	CO_3 + HCO_3
Powell Spring	Perennial	unmeasureable		normal		Neutral - 7.31		
Quail Spring #1	Intermittent - dry	unmeasureable		none		none		
Quail Spring #2	Perennial	third		warm		Neutral - 7.78		
Quail Spring #3	Intermittent - dry	unmeasureable		none		none		
Quail Spring (cnf)	Intermittent - dry	unmeasureable		none		none		
Railroad Spring	Intermittent - dry	unmeasureable		none		none		
Red Horse Spring	Perennial	second		normal		Neutral - 7.44		
Red Rock Spring	Intermittent - dry	unmeasureable		none		none		
Ritter Spring	Intermittent - dry	unmeasureable		none		none		
Rock Top Spring	Perennial	third		normal	fresh	Neutral - 7.80		
Round Up Park Spring	Intermittent - dry	unmeasureable		none		none		
Russel Spring #1	Perennial	third	Balanced	normal	fresh	Neutral - 7.40	Ca	CO_3 + HCO_3
Russel Spring #2	Perennial	second	Balanced	normal	brackish	Neutral - 6.87	Ca	CO_3 + HCO_3
Sally May Spring	Intermittent - dry	unmeasureable		none		none		
Schells Spring	Intermittent - dry	unmeasureable		none		none		
Scott Spring	Intermittent - dry	unmeasureable		none		none		
Seven Anchor Spring #1	Perennial	second		normal		Neutral - 6.81		
Seven Anchor Spring #2	Intermittent - dry	unmeasureable		none		none		
Sheep Bridge Hot Springs	Perennial	fourth		hot	brackish	Neutral - 7.40		
Sheep Spring	Perennial	third		normal	fresh	Neutral - 7.50		
Spring Creek	Perennial	fifth	Steady	normal		Neutral - 7.27	Ca	CO_3 + HCO_3
Sterling Spring 1	Perennial	fourth	Steady	cold		Neutral - 7.15	Ca	CO_3 + HCO_3
Sterling Spring 2	Perennial	fifth	Highly Unsteady	cold		Neutral - 7.15	Ca	CO_3 + HCO_3
Stone Camp Spring	Perennial	fourth		normal	fresh	Neutral - 7.00		
Summer Spring	Perennial	sixth	Steady	normal		Neutral - 7.05	Ca	CO_3 + HCO_3
Sycamore Spring #1a	Perennial	third		normal	fresh	Neutral - 7.06		
Sycamore Spring #1b	Perennial	third		normal	fresh	Neutral - 7.42		

Table 45 – continued

Name of Spring	Flow consistency	flow rate	flow variability	Temperature	TDS	pH	Dominant Cation	Dominant Anion
Sycamore Spring #2	Perennial	third		normal	fresh	Neutral - 7.14		
Thicket Spring	Intermittent - dry	unmeasureable		none		none		
Tonto Bridge	Perennial	fifth	Steady	normal		Neutral - 7.24		
Towel Spring	Intermittent - dry	unmeasureable		none		none		
Trail Junction Spring	Perennial	third		warm		Neutral - 7.48		
Trail Spring	Intermittent - dry	unmeasureable		none		none		
Tree Spring	Intermittent - dry	unmeasureable		none		none		
T-six Spring	Intermittent - dry	unmeasureable		none		none		
Tunnel Spring	Perennial	first		none		none		
Turkey Spring	Perennial	third		normal		Moderately Basic - 8.25		
Upper Hull Spring	Intermittent - dry	unmeasureable		none		none		
Van Deren Spring	Perennial	unmeasureable		none		none		
Verde Hot Spring	Perennial	fourth		hot	brackish	Neutral - 6.30		
Washington Spring	Perennial	third		normal		Neutral - 7.28		
Wet Prong Spring	Perennial	third		warm	fresh	Neutral - 6.62		
Wildcat Spring	Intermittent - dry	unmeasureable		none		none		
Willard Spring	Intermittent - dry	unmeasureable		none		none		
Wilson Seep	Intermittent - dry	unmeasureable		none		none		
Windfall Spring	Intermittent - dry	unmeasureable		none		none		
Winter Cabin Spring	Intermittent - dry	unmeasureable		none		none		
Wire Corral Spring	Intermittent - dry	unmeasureable		warm		Neutral - 7.80		
Yellow Jacket Spring	Intermittent - dry	unmeasureable		none		none		
Zig Zag Spring #1 main	Perennial	fourth		normal	fresh	Neutral - 7.64		
Zig Zag Spring #2	Perennial	third		normal	fresh	Neutral - 7.64		
% springs classified	100%	100%	12%	54%	24.375	54%		

Classes Notes

Flow consistency, Flow rate, and Flow variability determined from Phase II discharge measurements

Temperateure, TDS, and pH determined from Phase I data

Table 46 – Climatological, Biological, and Cultural classification for the Middle Verde Springs study based on Springer et al. (2004).

Name of Spring	Elevation	Surrounding ecosystems	Biogeographic isolation	Habitat Size	Land Ownership	Primary use	Microhabitat Modification
101 Spring	High	woodlands	Moderately Isolated	Medium-large	Federal	wildlife	
Babe's Hole Spring	Middle	woodlands	Nearest Spring near by	Medium-small	Federal	wildlife	springbox
Baker Spring	High	woodlands	Nearest Spring near by	Medium-large	Federal	wildlife	
Banfield Spring	High	woodlands	Moderately Isolated	Extremely small	Federal	wildlife	
Banjo Bill Spring	Middle	woodlands	Moderately Isolated	Medium-large	Federal	recreation	springbox
Barney Spring	High	woodlands	Moderately Isolated	Very small	Federal	wildlife	springbox
Basin Spring	Low	barrenland	Nearest Spring near by	Medium-large	Federal	wildlife	
Bear Spring (tnf)	Middle	woodlands	Nearest Spring near by	Small	Federal	wildlife	tank
Bear Spring(pnf)	Middle	shrubland	Moderately Isolated	Very Small	Federal	wildlife	
Beasley Flat Spring	Low	shrubland	Moderately Isolated	Small	Federal	wildlife	springbox
Bell Rock Spring	Middle	shrubland	Moderately Isolated		Federal	wildlife	
Big Hutch Spring #1	Middle	shrubland	Nearest Spring very near	Large	Federal	stock	tank
Big Hutch Spring #2	Middle	shrubland	Nearest Spring very near	Large	Federal	stock	tank
Bill Back Spring	High	woodlands	Moderately Isolated	Medium-large	Federal	wildlife	tank
Bill Dick Spring	High	woodlands	Moderately Isolated	Medium-large	Federal	wildlife	pipe
Black Canyon Spring	High	woodlands	Moderately Isolated	Medium-small	Federal	wildlife	
Blue Monster Main Spring	Middle	shrubland	Nearest Spring near by	Small	Federal	wildlife	pipe
Blue Monster South Spring	Middle	shrubland	Nearest Spring near by	Medium-small	Federal	wildlife	tank
Bootlegger Spring	High	woodlands	Nearest Spring near by	Medium-small	Federal	wildlife	other
Bottle Spring	High	woodlands	Moderately Isolated	Extremely small	Federal	wildlife	
Bristow Spring	High	woodlands	Moderately Isolated		Federal	wildlife	
Brushy Wash Spring	Middle	shrubland	Moderately Isolated	Small	Federal	wildlife	springbox
Burnt Spring (cnf)	Middle	shrubland	Moderately Isolated		Federal	wildlife	
Buzzard Spring	High	woodlands	Moderately Isolated	Medium-small	Federal	wildlife	
Campbell Road Spring	High	woodlands	Nearest Spring very near	Small	Federal	wildlife	other
Campbell Spring	High	woodlands	Nearest Spring very near	Medium-large	Federal	wildlife	springbox
Cave Spring	Middle	woodlands	Nearest Spring near by	Medium-large	Federal	culinary	springbox
Cedar Spring	Middle	shrubland	Moderately Isolated	Medium-small	Federal	wildlife	

Table 46 – continued

Name of Spring	Elevation	Surrounding ecosystems	Biogeographic isolation	Habitat Size	Land Ownership	Primary use	Microhabitat Modification
Chalk Spring (cnf)	Middle	shrubland	Moderately Isolated		Federal	wildlife	
Chasm Spring	Low	shrubland	Moderately Isolated	Medium-small	Federal	wildlife	
Cherry 361a	Middle	shrubland	Nearest Spring near by	Medium-small	Federal	wildlife	
Cherry 361b	Middle	shrubland	Nearest Spring near by	Medium-small	Federal	stock	tank
Cimarron Spring	Middle	shrubland	Moderately Isolated	Small	Federal	wildlife	pipe
Clover Spring	High	woodlands	Moderately Isolated	Medium-large	Federal	wildlife	fence
Cottonwood Spring (cnf)	Low	shrubland	Moderately Isolated		Federal	wildlife	
Cottonwood Spring (tnf)	Middle	shrubland	Moderately Isolated		Federal	wildlife	
Dow Spring	High	woodlands	Nearest Spring near by	Medium-large	Federal	wildlife	pipe
Dripping Spring #1	Middle	woodlands	Nearest Spring very near	Medium-large	Federal	wildlife	springbox
Dripping Spring #2	Middle	woodlands	Nearest Spring very near	Medium-small	Federal	wildlife	
Dripping Spring #3	Middle	woodlands	Nearest Spring very near	Medium-small	Federal	wildlife	pipe
Dripping Spring #4	Middle	woodlands	Nearest Spring very near	Small	Federal	wildlife	
Fain Spring	High	woodlands	Moderately Isolated	Medium-small	Federal	wildlife	dams/ponds
Fortyfour Spring	High	woodlands	Nearest Spring near by	Medium-small	Federal	culinary	springbox
Foster Spring	High	woodlands	Nearest Spring near by	Large	Federal	wildlife	pipe
Frog Spring	Low	shrubland	Moderately Isolated	Medium-small	Federal	wildlife	
Fuller Spring	Middle	woodlands	Moderately Isolated	Medium-small	Federal	wildlife	tank
Garden Spring	High	woodlands	Moderately Isolated	Small	Federal	wildlife	pipe
Geronimo Spring (1)	Middle	woodlands	Nearest Spring near by	Medium-small	Federal	wildlife	pipe
Geronimo Spring (tnf)	Middle	woodlands	Nearest Spring near by	Small	Federal	culinary	springbox
Goat Camp Spring	Middle	shrubland	Moderately Isolated	Medium-small	Federal	wildlife	pipe
Gooseberry Spring	High	grassland	Nearest Spring near by	Small	Federal	wildlife	springbox
Gould Spring #1	Middle	shrubland	Nearest Spring very near	Small	Federal	wildlife	
Gould Spring #2	Middle	shrubland	Nearest Spring very near	Small	Federal	wildlife	
Grapevine Spring	Middle	shrubland	Nearest Spring near by	Medium-small	Federal	wildlife	
Grassy Meadow Spring	Middle	woodlands	Nearest Spring near by	Medium-large	Federal	recreation	other
Gray Springs	High	grassland	Nearest Spring near by	Medium-large	Federal	wildlife	springbox

Table 46 – continued

Name of Spring	Elevation	Surrounding ecosystems	Biogeographic isolation	Habitat Size	Land Ownership	Primary use	Microhabitat Modification
Griffith Spring	High	woodlands	Moderately Isolated	Medium-small	Federal	recreation	
Grimes Spring	Middle	shrubland	Nearest Spring near by	Medium-large	Federal	wildlife	tank
Hackberry Spring #1	Middle	shrubland	Nearest Spring very near	Medium-large	Federal	wildlife	
Hackberry Spring #2	Middle	shrubland	Nearest Spring very near	Medium-large	Federal	wildlife	other
Hance Spring	Middle	shrubland	Moderately Isolated	Medium-small	Federal	wildlife	
Horseshoe Spring	High	woodlands	Nearest Spring near by	Medium-small	Federal	wildlife	springbox
Howard Spring	High	woodlands	Moderately Isolated	Medium-large	Federal	wildlife	tank
Huffer Spring	High	woodlands	Nearest Spring near by	Medium-large	Federal	wildlife	
Hull Spring	Middle	shrubland	Moderately Isolated	Small	Federal	wildlife	pipe
Irving High Spring	Middle	shrubland	Nearest Spring near by	Large	Federal	wildlife	
Irving Low Spring	Middle	shrubland	Nearest Spring near by	Medium-large	Federal	culinary	springbox
JM Spring	Low	barrenland	Moderately Isolated	Medium-small	Federal	wildlife	springbox
Jones Spring #1	High	woodlands	Nearest Spring very near	Medium-small	Federal	wildlife	springbox
Jones Spring #2a	High	woodlands	Nearest Spring very near	Medium-large	Federal	wildlife	springbox
Jones Spring #2b	High	woodlands	Nearest Spring very near	Small	Federal	wildlife	pipe
Kelsey Spring	Middle	woodlands	Nearest Spring near by	Medium-large	Federal	wildlife	tank
Larson Spring	Middle	shrubland	Nearest Spring near by	Small	Federal	wildlife	
Lee Johnson Spring	High	woodlands	Nearest Spring near by	Medium-large	Federal	wildlife	springbox
Lee Spring	High	woodlands	Moderately Isolated	Medium-small	Federal	wildlife	dams/ponds
Lindburg Spring	High	woodlands	Moderately Isolated	Medium-small	Federal	wildlife	other
Little Hutch Spring #1	Middle	shrubland	Nearest Spring very near	Medium-small	Federal	stock	tank
Little Hutch Spring #2	Middle	shrubland	Nearest Spring very near	Medium-small	Federal	stock	tank
LO Spring	High	woodlands	Nearest Spring near by	Large	Federal	wildlife	
Log Spring	Middle	woodlands	Moderately Isolated	Medium-small	Federal	wildlife	springbox
Long Valley Spring	High	woodlands	Moderately Isolated	Medium-small	Federal	wildlife	springbox
Lower Gould Spring	Middle	shrubland	Nearest Spring near by	Medium-small	Federal	wildlife	pipe
Lower Hull Spring	High	woodlands	Nearest Spring near by	Small	Federal	wildlife	springbox
LX Spring	Low	shrubland	Nearest Spring near by	Medium-large	Federal	culinary	dams/pond

Table 46 – continued

Name of Spring	Elevation	Surrounding ecosystems	Biogeographic isolation	Habitat Size	Land Ownership	Primary use	Microhabitat Modification
Maple Spring	High	woodlands	Moderately Isolated	Medium-small	Federal	wildlife	
Maxwell Spring	High	grassland	Moderately Isolated	Small	Federal	wildlife	tank
Mesquite Spring	Low	shrubland	Moderately Isolated		Federal	wildlife	
Mine Spring	Middle	shrubland	Nearest Spring near by	Medium-small	Federal	wildlife	tank
Morgan Spring	Middle	shrubland	Moderately Isolated		Federal	wildlife	
Mortgage Spring	Middle	woodlands	Moderately Isolated	Medium-small	Federal	wildlife	
Mund Spring	High	grassland	Moderately Isolated	Extremely Small	Federal	wildlife	
North Mine Spring	Middle	shrubland	Nearest Spring near by	Small	Federal	wildlife	pipe
North Pass Spring	Middle	shrubland	Nearest Spring near by	Medium-small	Federal	wildlife	springbox
North Pasture Canyon Spring	Middle	shrubland	Nearest Spring near by	Medium-small	Federal	wildlife	
North Pasture Spring	Middle	shrubland	Nearest Spring near by	Medium-small	Federal	wildlife	springbox
Oxbow Spring	Middle	shrubland	Moderately Isolated	Medium-small	Federal	culinary	pipe
Patton Spring	High	woodlands	Nearest Spring near by	Medium-large	Federal	wildlife	
Pearson Spring	High	grassland	Moderately Isolated	Small	Federal	wildlife	springbox
Pfau Spring	Middle	shrubland	Moderately Isolated	Medium-small	Federal	wildlife	pipe
Phroney Spring	Middle	shrubland	Nearest Spring near by	Medium-small	Federal	wildlife	springbox
Picnic Spring	Low	shrubland	Nearest Spring near by	Medium-large	Federal	wildlife	
Pieper Hatchery Spring #1	Middle	woodlands	Moderately Isolated	Very Large	Federal	wildlife	dams/ponds
Pieper Hatchery Spring #2	Middle	woodlands	Nearest Spring very near	Very Large	Federal	wildlife	dams/ponds
Pine Flat Spring	Middle	woodlands	Nearest Spring near by	Medium-large	Federal	recreation	other
Pine Spring	Middle	shrubland	Moderately Isolated	Medium-small	Federal	wildlife	tank
Pivot Rock Spring	High	woodlands	Moderately Isolated	Medium-large	Federal	culinary	other
Poison Sping (tnf)	Middle	woodlands	Nearest Spring near by	Medium-large	Federal	culinary	springbox
Poison Spring (1)	Middle	woodlands	Nearest Spring near by	Medium-large	Federal	wildlife	
Powell Spring	Middle	woodlands	Moderately Isolated	Medium-small	Federal	recreation	
Quail Spring #1	Middle	shrubland	Nearest Spring very near	Small	Federal	wildlife	pipe
Quail Spring #2	Middle	shrubland	Nearest Spring very near	Medium-small	Federal	wildlife	tank
Quail Spring #3	Middle	shrubland	Nearest Spring very near	Medium-small	Federal	wildlife	

Table 46 – continued

Name of Spring	Elevation	Surrounding ecosystems	Biogeographic isolation	Habitat Size	Land Ownership	Primary use	Microhabitat Modification
Quail Spring (cnf)	Middle	shrubland	Moderately Isolated		Federal	wildlife	
Railroad Spring	High	grassland	Nearest Spring near by	Medium-small	Federal	wildlife	tank
Red Horse Spring	Middle	shrubland	Moderately Isolated	Medium-small	Federal	wildlife	pipe
Red Rock Spring	Middle	shrubland	Moderately Isolated	Small	Federal	wildlife	pipe
Ritter Spring	High	woodlands	Moderately Isolated	Medium-small	Federal	wildlife	springbox
Rock Top Spring	High	woodlands	Moderately Isolated	Medium-large	Federal	wildlife	dams/ponds
Round Up Park Spring	High	woodlands	Moderately Isolated	Medium-large	Federal	wildlife	fence
Russel Spring #1	Middle	shrubland	Nearest Spring very near	Medium-large	Federal	wildlife	
Russel Spring #2	Middle	shrubland	Nearest Spring very near	Medium-large	Federal	wildlife	
Sally May Spring	Middle	shrubland	Moderately Isolated	Extremely small	Federal	wildlife	
Schells Spring	High	woodlands	Nearest Spring near by	Large	Federal	wildlife	pipe
Scott Spring	High	woodlands	Moderately Isolated	Medium-small	Federal	wildlife	tank
Seven Anchor Spring #1	High	woodlands	Nearest Spring very near	Medium-small	Federal	wildlife	fence
Seven Anchor Spring #2	High	woodlands	Nearest Spring very near	Medium-small	Federal	wildlife	springbox
Sheep Bridge Hot Springs	Low	barrenland	Isolated	Medium-large	Federal	recreation	pipe
Sheep Spring	High	woodlands	Nearest Spring near by	Large	Federal	stock	tank
Spring Creek	Middle	shrubland	Nearest Spring near by	Large	Private	culinary	springbox
Sterling Spring 1	Middle	woodlands	Nearest Spring very near	Large	Federal	culinary	springbox
Sterling Spring 2	Middle	woodlands	Nearest Spring very near	Large	Federal	culinary	springbox
Stone Camp Spring	Low	shrubland	Nearest Spring near by	Medium-large	Federal	wildlife	
Summer Spring	Middle	shrubland	Moderately Isolated	Very Large	Federal	recreation	other
Sycamore Spring #1a	Middle	shrubland	Nearest Spring near by	Medium-large	Federal	wildlife	
Sycamore Spring #1b	Middle	shrubland	Nearest Spring near by	Medium-large	Federal	wildlife	
Sycamore Spring #2	Middle	shrubland	Nearest Spring near by	Medium-large	Federal	wildlife	
Thicket Spring	Low	barrenland	Moderately Isolated	Medium-large	Federal	stock	tank
Tonto Bridge	Middle	shrubland	Moderately Isolated	Large	State	recreation	springbox
Towel Spring	Middle	shrubland	Nearest Spring near by	Medium-small	Federal	wildlife	pipe
Trail Junction Spring	Low	barrenland	Nearest Spring near by	Medium-small	Federal	wildlife	

Table 46 – continued

Name of Spring	Elevation	Surrounding ecosystems	Biogeographic isolation	Habitat Size	Land Ownership	Primary use	Microhabitat Modification
Trail Spring	Low	barrenland	Nearest Spring near by	Small	Federal	wildlife	
Tree Spring	High	woodlands	Moderately Isolated	Extremely small	Federal	wildlife	tank
T-six Spring	High	woodlands	Moderately Isolated	Medium-small	Federal	wildlife	tank
Tunnel Spring	Middle	shrubland	Moderately Isolated	Small	Federal	wildlife	pipe
Turkey Spring	Middle	woodlands	Moderately Isolated	Medium-small	Federal	wildlife	tank
Upper Hull Spring	High	woodlands	Nearest Spring near by	Medium-small	Federal	wildlife	
Van Deren Spring	High	woodlands	Moderately Isolated	Medium-small	Federal	wildlife	tank
Verde Hot Spring	Low	shrubland	Moderately Isolated	Medium-small	Federal	recreation	springbox
Washington Spring	High	woodlands	Nearest Spring near by	Medium-large	Federal	culinary	pipe
Wet Prong Spring	Middle	shrubland	Nearest Spring near by	Meidum-small	Federal	wildlife	
Wildcat Spring	High	woodlands	Nearest Spring near by	Medium-small	Federal	wildlife	springbox
Willard Spring	High	woodlands	Moderately Isolated	Large	Federal	wildlife	springbox
Wilson Seep	High	woodlands	Nearest Spring near by	Very small	Federal	wildlife	
Windfall Spring	High	woodlands	Nearest Spring near by	Medium-small	Federal	wildlife	springbox
Winter Cabin Spring	Middle	shrubland	Moderately Isolated	Meidum-small	Federal	stock	pipe
Wire Corral Spring	Low	barrenland	Nearest Spring near by	Medium-small	Federal	wildlife	
Yellow Jacket Spring	High	woodlands	Moderately Isolated	Medium-small	Federal	wildlife	tank
Zig Zag Spring #1 main	Low	shrubland	Nearest Spring very near	Medium-large	Federal	culinary	dams/ponds
Zig Zag Spring #2	Low	shrubland	Nearest Spring very near	Medium-large	Federal	culinary	dams/ponds
% springs classified	100%	100%	100%	100%	100%	100%	65

Classes notes

All classes were classified from data in Phase I database