Yavapai County Water Advisory Committee (WAC)

Information Series* 2009 #1
Where is the water? (And where isn't the water?)

The question is interpreted by the TAC of the WAC to ask: where is developable groundwater? This is a high priority question for the WAC and much of the work that the WAC has funded has resulted in information relevant to the question.

While there are many sub-questions to the question of "where is the water?" the most simple answer is geographical and is supported by general geology, geophysics, and information obtained from wells. **The most reliable and accessible groundwater resource in Yavapai is the aquifers composed of younger (Cenozoic age) sedimentary and volcanic rocks**, not the older granite and metamorphic "basement" rocks. For instance, in the Verde Basin these younger materials fill the basins beneath the Big Chino, Little Chino and Verde Valleys. The map below shows the thickness of saturated sediments in the Verde River sub basins (modified from Blasch *et al* 2006, p. 55). The water is accessible through wells drilled into the saturated materials (aquifers).

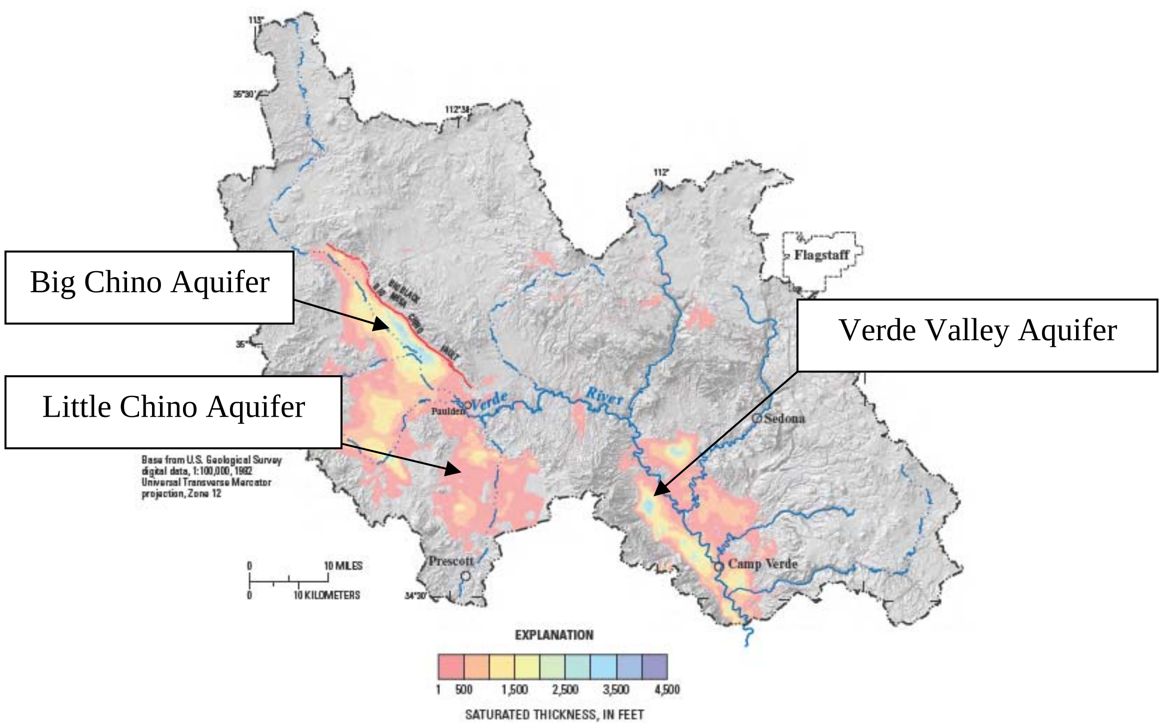

Figure 22. Thickness of saturated Cenozoic sediments and volcanic rocks, upper and middle Verde River watersheds, central Arizona. Thickness data from Langenheim and others, 2005.

The basin-fill sediments, illustrated by thickness (colors) in the figure above, are the major aquifers as determined by interpretation of geophysical information (Langenheim et al 2005; Blasch *et al* 2006 (Figure 22)). The exact boundaries are not discernable at the scale of the map. The saturated areas are the places (aquifers) where water is collected and stored until it is pumped, consumptively used by vegetation, or discharged to an outflow point such as a spring. The areas depicted in the figure are interpreted to be the most reliable source of developable groundwater in the Upper and Middle Verde River Basin. The Blasch *et al* report provides a written description of the regional geology and the aquifer units along with maps and cross sections (e.g. pp 37-58). Where possible, the references section below provides links to electronic versions of the reports.

The primary reference for the Verde Basin is the USGS report by Blasch *et al*, 2006 (SIR 2005-5198) "Hydrogeology of the Upper and Middle Verde River Watersheds, Central Arizona". (This is the conceptual report; the WAC has received presentations and it serves as a basis for the Northern Arizona Regional Groundwater Flow Model in preparation by the USGS). For the Verde and other basins, The Arizona Water Atlas by ADWR is also a good source of information related to this question as are several other reports listed in the references section of this document (along with web links where available).

The Verde Basin and the other watersheds in the County (Agua Fria, Hassayampa, and Bill Williams) are examined in more detail below in the "Discussion" section that follows the references list.

*Informational Series Background: This is intended as an informational item for the Yavapai County Water Advisory Committee (WAC) and the public. This document is prepared by the WAC Coordinator in consultation with the Technical Committee of the WAC.

The Informational Reports Series is a result of the WAC's desire to systematically address questions raised by the WAC member representatives. Questions were solicited from the WAC members during 2007 and 2008.

References:

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DeWitt, Ed, Langenheim, Victoria, Force, Eric, Vance, R.K., Lindberg, P.A., and Driscoll, R.L., 2008, **Geologic map of the Prescott National Forest and the headwaters of the Verde River, Yavapai and Coconino Counties, Arizona**: U.S. Geological Survey Scientific Investigations Map 2996, scale 1:100,000, 100-p. pamphlet. http://pubs.usgs.gov/sim/2996/

VERDE-SPECIFIC REFERENCES:

Arizona Department of Water Resources, April 2000, **Verde River Watershed Study**

Blasch, Kyle W., John P. Hoffmann, Leslie F. Graser, Jeannie R. Bryson, and Alan L. Flint, 2006, **Hydrogeology of the Upper and Middle Verde River Watersheds, Central Arizona (**Version 2, Updated 05/04/2007) U.S. GEOLOGICAL SURVEY Scientific Investigations Report 2005–5198 http://pubs.usgs.gov/sir/2005/5198/

Fry, Matthew C, 2006, **Digital Hydrogeologic Framework Models and Implications for Fault Scaling, Upper Verde River Headwaters, Arizona**, Northern Arizona University, Masters Thesis. http://www4.nau.edu/geology/theses/fry06.pdf

Langenheim, V.E., DeWitt Ed, and Wirt Laurie, 2005, **Geophysical Framework Based on Analysis of Aeromagnetic and Gravity Data, Upper and Middle Verde River Watershed, Yavapai County, Arizona**, U.S. Geologic Survey, Scientific Investigations report 2005-5278 (http://pubs.usgs.gov/sir/2005/5278/)

Owen-Joyce**,** S.J. and C.K. Bell, 1983, **Appraisal of Water Resources in the Upper** Verde **River Area, Yavapai and Coconino Counties, Arizona**, Phoenix: USGS March 1983 (Arizona Dept of Water Resources Bulletin; No 2) http://www.verde.org/usgs/usgsstud.html

Owen –Joyce, Sandra, 1984 **Hydrology of a Stream-Aquifer System in the Camp Verde Area, Yavapai County, Arizona**, ADWR Bulletin 3, Prepared by the U.S. Geological Survey

Wirt, Laurie, Ed DeWitt, and V.E. Langenheim, 2004, **Geologic Framework of Aquifer Units and Ground-Water Flowpaths, Verde River Headwaters, North-Central Arizona** , U.S. Geological Survey, Open-File Report 2004–1411 http://pubs.usgs.gov/of/2004/1411/

AGUA FRIA-SPECIFIC REFERENCES:

Wilson, Richard P, 1988, **Water Resources of the Northern Part of the Agua Fria Area, Yavapai County, Arizona**, Arizona Department of Water Resources, Bulletin 5, Prepared by the U.S. Geological Survey, Dept of Interior, Tucson, Arizona

Barnett, Loyd, O, Hawkins, Richard H., and Guertin D. Phillip, 2002, **Reconnaissance Watershed and Hydrologic Analysis on the Upper Agua Fria Watershed,** School of Renewable Natural Resources, University of Arizona , Tuscon, Arizona http://www.srnr.arizona.edu/nemo/characterizations/UpperAguaFria/UppAguFriWatRep.pdf

Leon, Elizabeth and Ferre, Ty, 2003, Thesis, **A Conceptual Model of Groundwater Flow in the Upper Agua Fria**, University of Arizona, Hydrology and Water resources, Tucson, Arizona.
http://www.srnr.arizona.edu/nemo/characterizations/UpperAguaFria/AFconceptmodel.pdf

HASSAYAMPA REFERENCES:

ADWR Water Atlas Volume 5:
http://www.azwater.gov/dwr/Content/Find_by_Program/Rural_Programs/content/water_atlas/v5/Vol_5_UHA.pdf

ADWR Rural Water Program Documents:
http://www.azwater.gov/dwr/Content/Find_by_Program/Rural_Programs/OutsideAMAs_PDFs_for_web/CentralHighlands/hssayampa_river_watershed.pdf

http://www.azwater.gov/dwr/Content/Find_by_Program/Rural_Programs/OutsideAMAs_PDFs_for_web/CentralHighlands/upper_hassayampa.pdf

http://www.azwater.gov/dwr/Content/Find_by_Program/Rural_Programs/OutsideAMAs_PDFs_for_web/CentralHighlands/references.pdf

BILL WILLIAMS REFERENCES:

ADWR Water Atlas Volume 4:
http://www.azwater.gov/dwr/Content/Find_by_Program/Rural_Programs/content/water_atlas/v4/Bill_Williams_draft.pdf

ADWR Rural Water Program Documents:
http://www.azwater.gov/dwr/Content/Find_by_Program/Rural_Programs/OutsideAMAs_PDFs_for_web/Upper_Colorado_River_Planning_Area/Bill_Williams_Basin.pdf

http://www.azwater.gov/dwr/Content/Find_by_Program/Rural_Programs/OutsideAMAs_PDFs_for_web/Upper_Colorado_River_Planning_Area/References.pdf

Discussion:

General:
The water is located both above ground and below ground. The above-ground, or surface water, flows in defined stream channels. In some locations the water flows continuously and some places surface water only flows intermittently during storms or other run off events. Surface water flow is monitored by stream gages. Data for the stream gages can be obtained from USGS website (http://az.water.usgs.gov/portals/realtime-portal.html)

Groundwater flows through, and is stored in pore spaces and cracks in the subsurface. The geologic units that have underground water in sufficient quantities for wells are known as aquifers.

Subsurface conditions are known by observing data from wells, geologic mapping of rock types, and geophysical techniques such as gravity and electromagnetism.

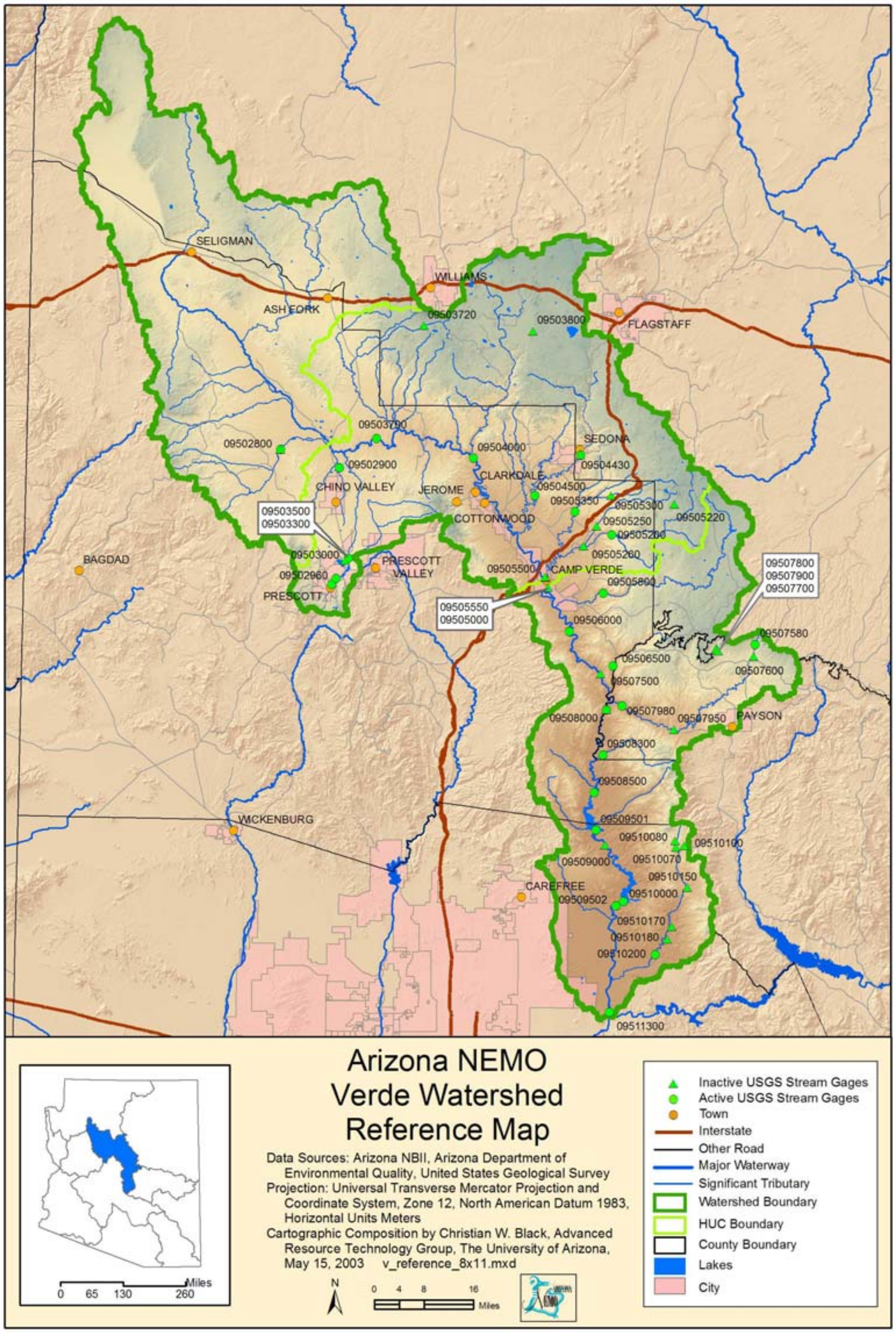
In many areas the surface water and groundwater interact through flow into and out of streams.

There are many references to basic terminology and basic theory about water and geology. This document is not intended as a detailed review of basic principles. The WAC coordinator is available to WAC members to provide appropriate reference material.

Verde River Basin:

Surface Water - The Verde River and several tributaries have perennial flow. Most channels and washes have seasonal or event based flow. During precipitation events, above-ground water also flows off roof tops, pavement and other impervious surfaces.

Data from stream gages allow us to monitor surface water volumes and timing. The gage network is shown as green dots or triangles in the figure below. Dots represent active gages and triangles represent inactive gages. The eight digit identification number for the gage station is adjacent to the dot in the figure.



NEMO: http://www.srnr.arizona.edu/nemo/index.php

Groundwater - The water below ground suitable for significant pumping to wells is located in aquifers. Typically, the most accessible groundwater is found in younger, Cenozoic, sediments that fill depressions in the underlying older "hard rock". Blasch et al, 2005 (Blasch Report) is a good reference for background and current estimates in the Verde River basin. The Hydrogeology section of the Blasch Report is a good summary current state of knowledge. For instance, the rock units are described and illustrated from page 37-43 in the Blasch Report. The geologic structure and aquifer characteristics are given on pages 43-47. Generalized geologic cross sections are shown in Figures 18, 19, and 20 (reproduced below). Hydrologic properties of the water bearing units are explained on pages 48-52 and groundwater levels are explained (http://pubs.usgs.gov/sir/2005/5198/).

The figure on page 1 of this document is Figure 22 from the Blasch Report (page 55); it shows estimated thickness and extent of saturated Cenozoic materials (sediments and volcanic rocks). Table 13 on page 46 of the Blasch Report shows the estimated volume of saturated sediments in the Big Chino sub basin, the Little Chino sub basin, and the Verde Valley sub basin. The following figures, from the Blasch Report show the general geology and cross sections showing representative underground conditions of the major sub basins.

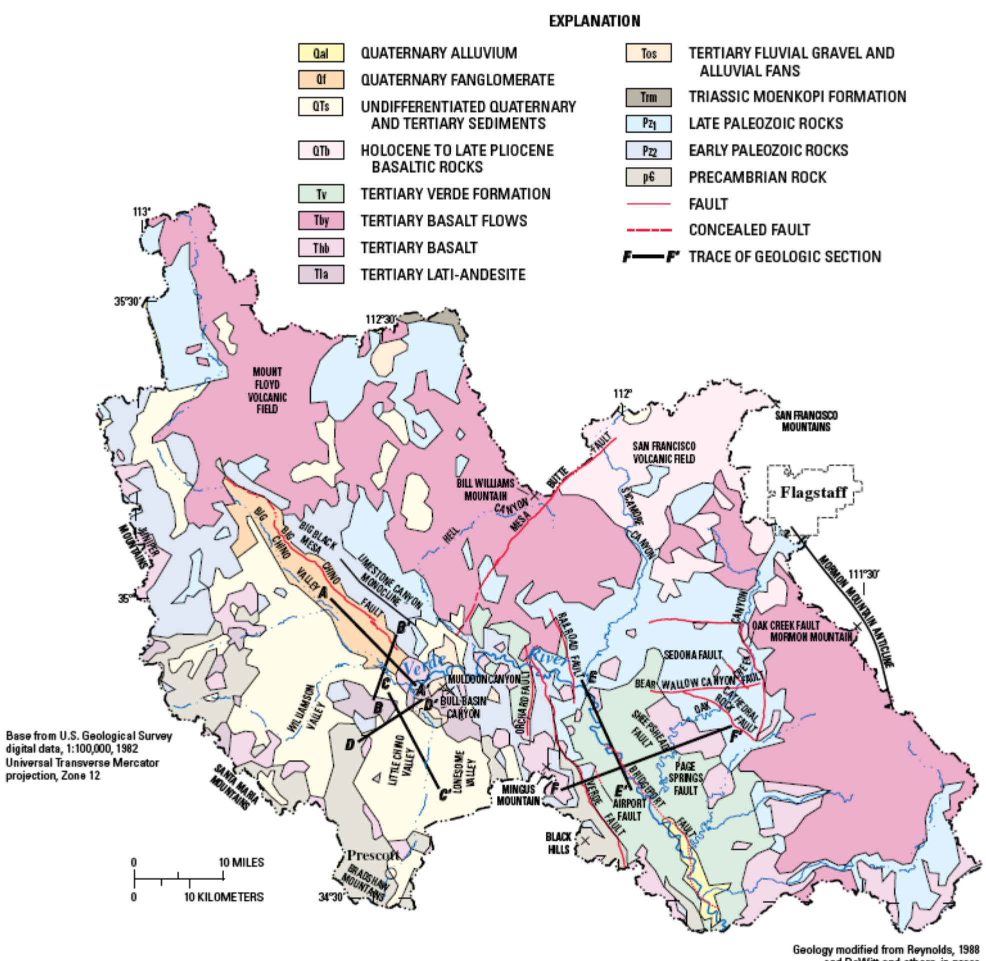


Figure 2. Generalized geology, geologic structures, and location of geologic sections, upper and middle Verde River watersheds, central Arizona.

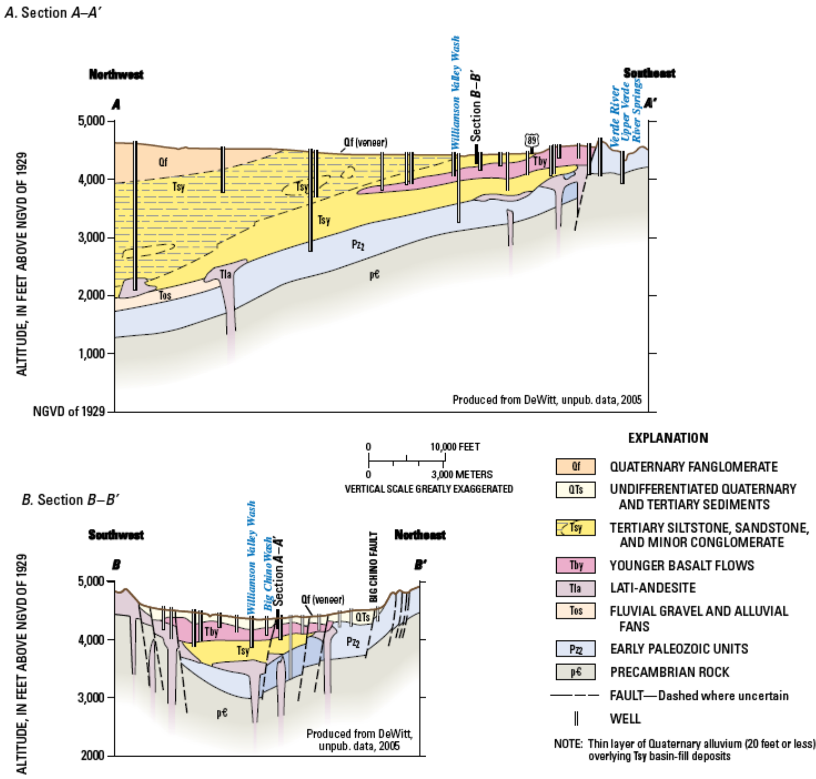


Figure 18. Generalized geologic sections of Big Chino Valley. *A*, Along the axis of the valley (A–A′); *B*, Across the axis of the valley (B–B′). See figure 2 for traces of sections.

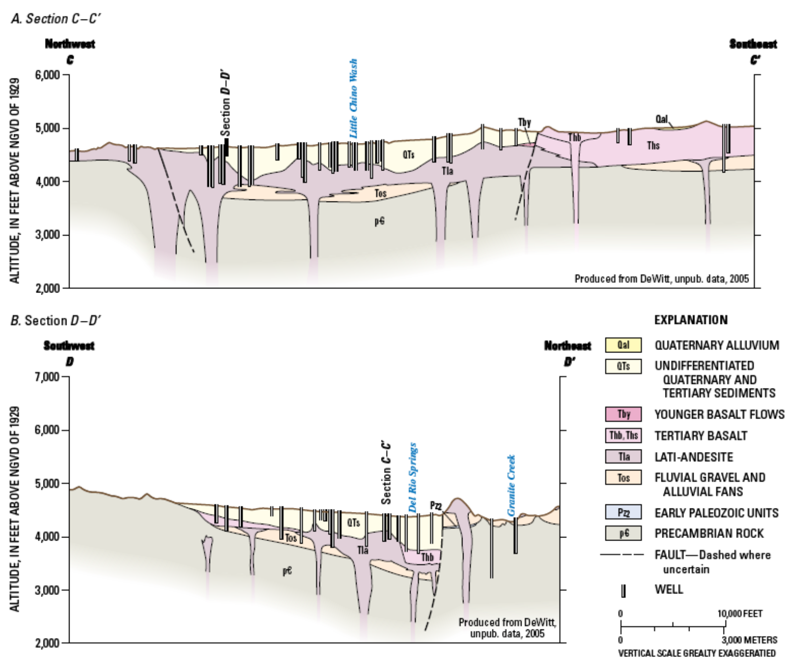


Figure 19. Generalized geologic sections of Little Chino Valley. *A*, Along the axis of the valley (C–C′); *B*, Across the axis of the Valley (D–D′). See figure 2 for traces of sections.

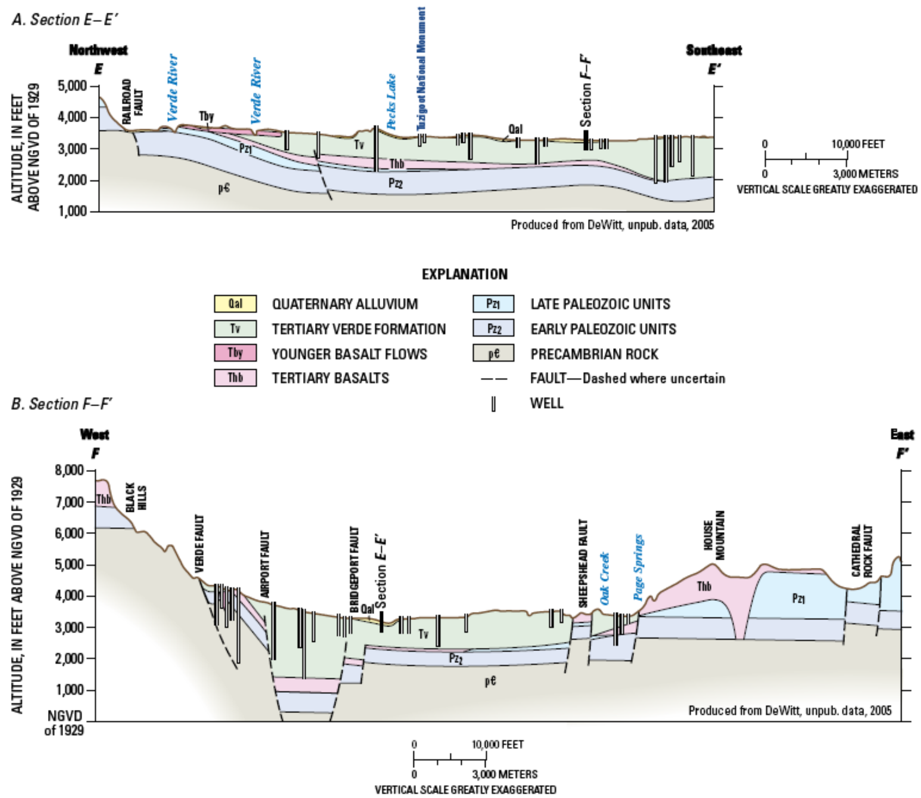
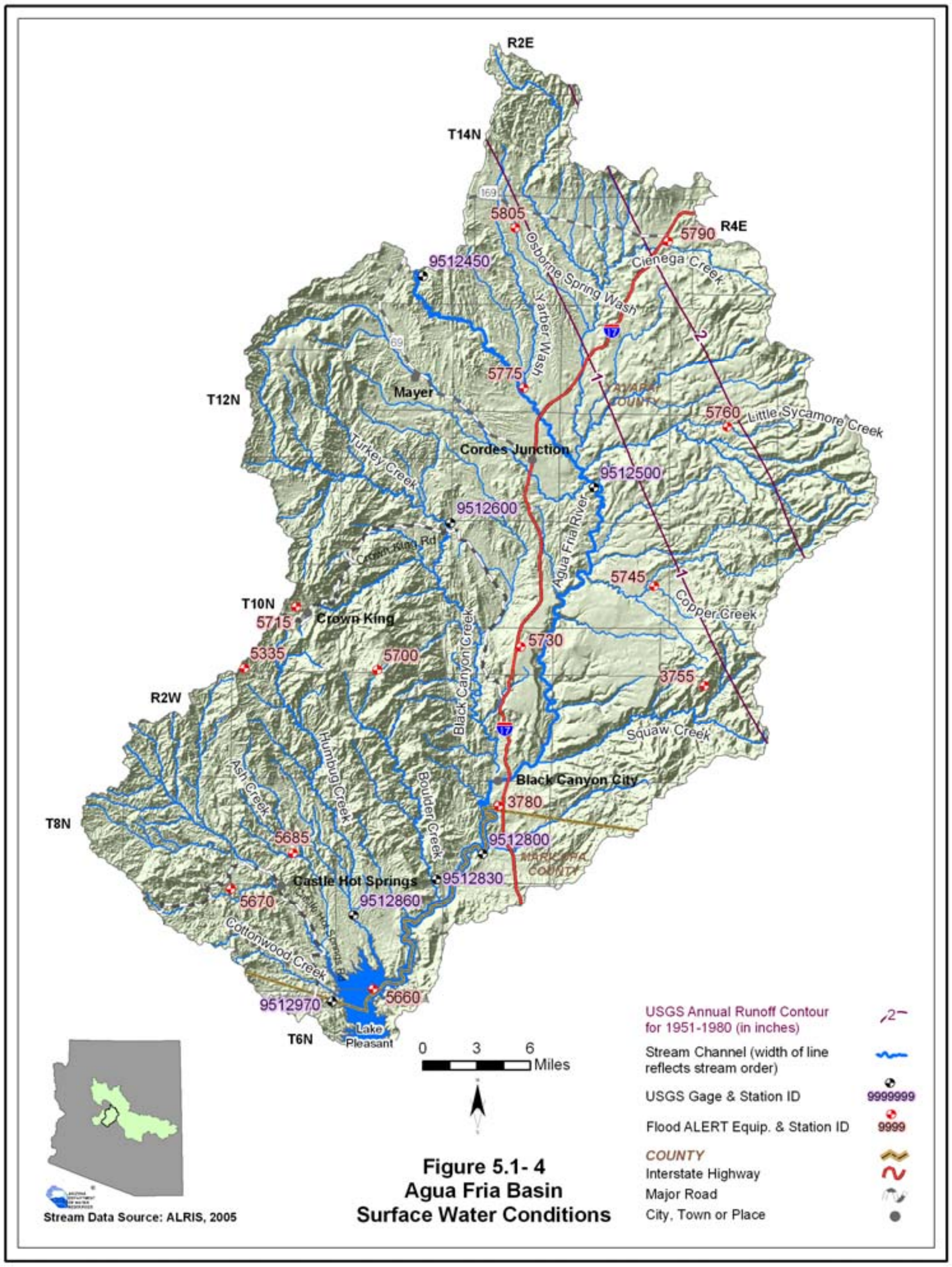


Figure 20. Generalized geologic sections of the Verde Valley. *A*, Along the axis of the valley (E–E′); *B*, Across the axis of the valley (F–F′). See figure 2 for traces of sections.

<u>*Agua Fria Sub Basin:*</u>

Surface water – The basin's main drainage is the Agua Fria River, which flows north to south through the basin and empties into Lake Pleasant. Major tributaries to the Agua Fria are Big Bug, Silver, Sycamore, and Yellow Jacket Creeks. The Agua Fria and its tributaries are generally intermittent streams except for some perennial stretches where impermeable bedrock forces groundwater into the streambed.



ADWR Water Atlas – Surface Water gages in Upper Agua Fria (note: does not include Prescott AMA portion of basin.

Groundwater - Primary descriptions of the geologic units and discussion of their significance to groundwater hydrology can be found in Wilson, 1988 (e.g. page 6-9). Barnett et al, 2002, summarizes the geology of Wilson (pages 13-16 including Figure 8, reproduced below). Wilson describes the rock units, in order of oldest to youngest, “basement, marine, sedimentary, volcanic and basin fill”. The Arizona Water Atlas, Section 5.1.6, provides data and references for the major aquifers in the Upper Agua Fria Basin (“basin fill” and “sedimentary rock”).

The sedimentary unit is noted to be the major aquifer in the study area and contains large volumes of groundwater (generally north of Cordes Junction and west of I-17) (Wilson, 1988). This unit is shown as “sedimentary” in Figure 8 from the Barnett et al report, reproduced below. The older crystalline “basement” rocks are generally not productive as aquifers.

ADWR provides a concise description of groundwater conditions in the basin, reproduced in the excerpt below. The figure that follows is from Barnett, et al 2002.

> “The main water-bearing units are the basin-fill sands and the conglomerates. The volcanics and crystalline rocks yield only small amounts of water.
>
> The basin-fill consists of sands and gravels and readily transmits recharge into the underlying conglomerate (Wilson, 1988). Because the basin-fill unit is thin it does not contain large quantities of groundwater in storage.
>
> The volcanic rocks provide small amounts of water to low-yield stock wells in the northeastern sections of the basin. Well yields are best from cinder beds and fractured sections of the volcanics. A number of seasonal springs flow from the volcanics in response to precipitation or snowmelt (Littin, 1981).
>
> Conglomerates occur widely throughout the basin and contain the largest volume of groundwater. Faulting formed the present-day drainage basins and separated the unit into several smaller, discrete groundwater basins that are separated by impermeable crystalline rocks. As a result, there is little direct subsurface hydrologic connection between the, sedimentary units in the smaller groundwater basins (Wilson, 1988).
>
> The water-bearing ability of the igneous and metamorphic rocks depends on their degree of fracturing. Most wells have low yields, however, near Black Canyon City wells drilled into the Precambrian schist can produce up to 20 gallons per minute (Littin, 1981). A number of perennial springs flow from the crystalline rocks. Normal discharges are 1 to 5 gallons per minute. Castle Hot Springs, located in the southwest part of the basin, discharges 200 gallons per minute from the Precambrian rocks (Littin, 1981).”
>
> Source of ADWR text:
> http://www.adwr.state.az.us/dwr/Content/Find_by_Program/Rural_Programs/content/map/UppAguFri.htm

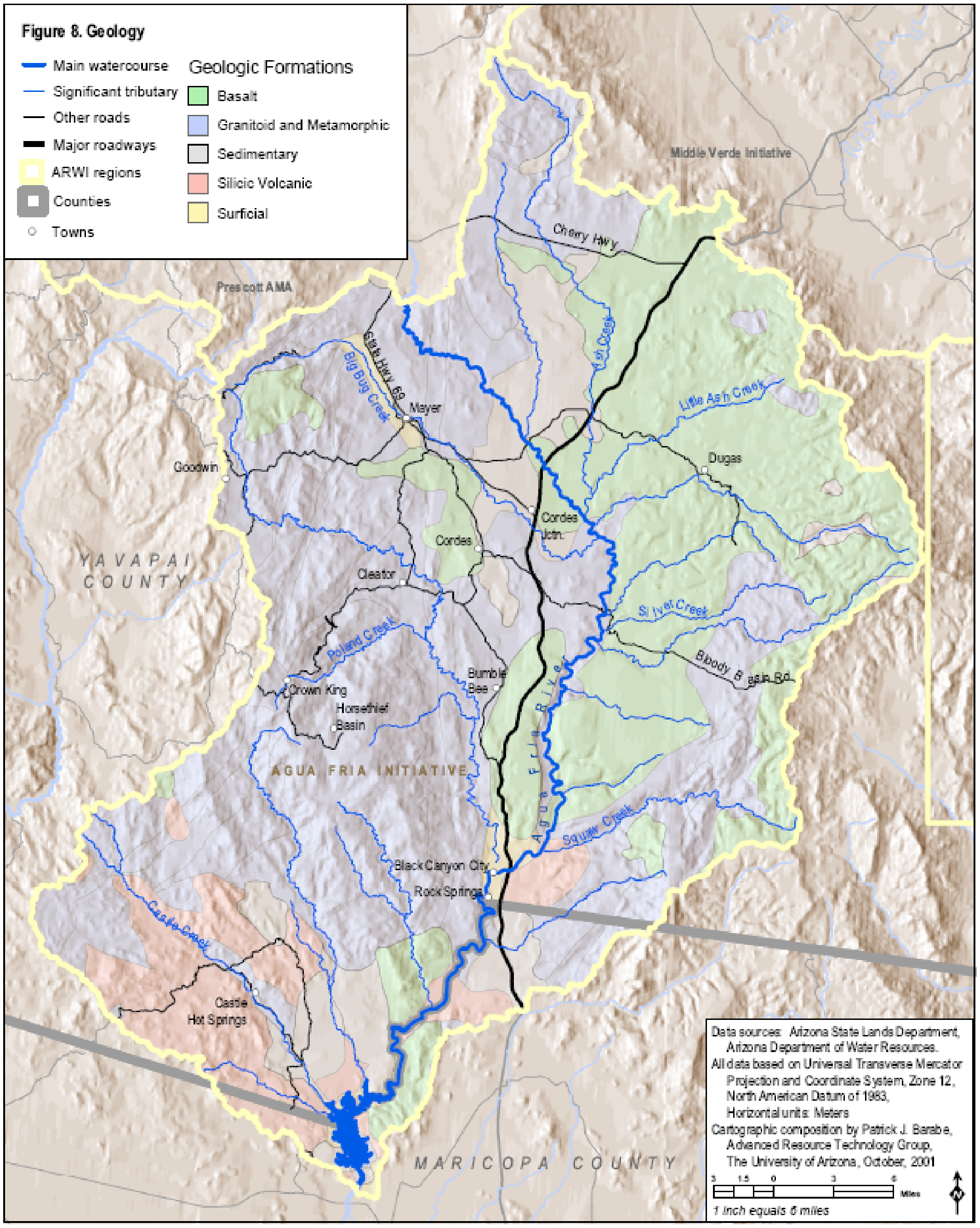


Figure: Figure 8 from the Barnett et al, 2002 report. Note: does not include Prescott AMA portion of the Upper Agua Fria basin.

<u>*Hassayampa Sub Basin:*</u>

For the other basins in Yavapai County, ADWR is a good source of information. Such as the water atlas and Rural water program descriptions. Excerpt from ADWR regarding Hassayampa Basin (references below):

Surface Water - Perennial flow occurs at only a few locations within the Hassayampa River watershed (Hassayampa River (3 reaches) 14 miles; Minnehaha Creek -1 mile) (Source: Brown and others, 1981).

There is a substantial network of smaller tributary washes that drain the basin. These washes are ephemeral and flow mainly in response to summer rainstorms. Most of the runoff in these washes infiltrates into the ground before reaching the Hassayampa River (Halpenny and Halpenny, 1988).

There have been several stream gages on the Hassayampa River at various locations since 1910. The U.S. Geological Survey has established and abandoned at least eight gages upstream from the Hassayampa Plain. Currently, the U.S. Geological Survey maintains two gages: 09516500 is near Morristown, seven miles south of Wickenburg, and 09517000 is near Arlington, 1.8 miles upstream from the Gila River. Both gages record only flood runoff events and do not record flows that average less than 500 cubic feet per second in 24 hours (Halpenny and Halpenny, 1988). Water Atlas Map:

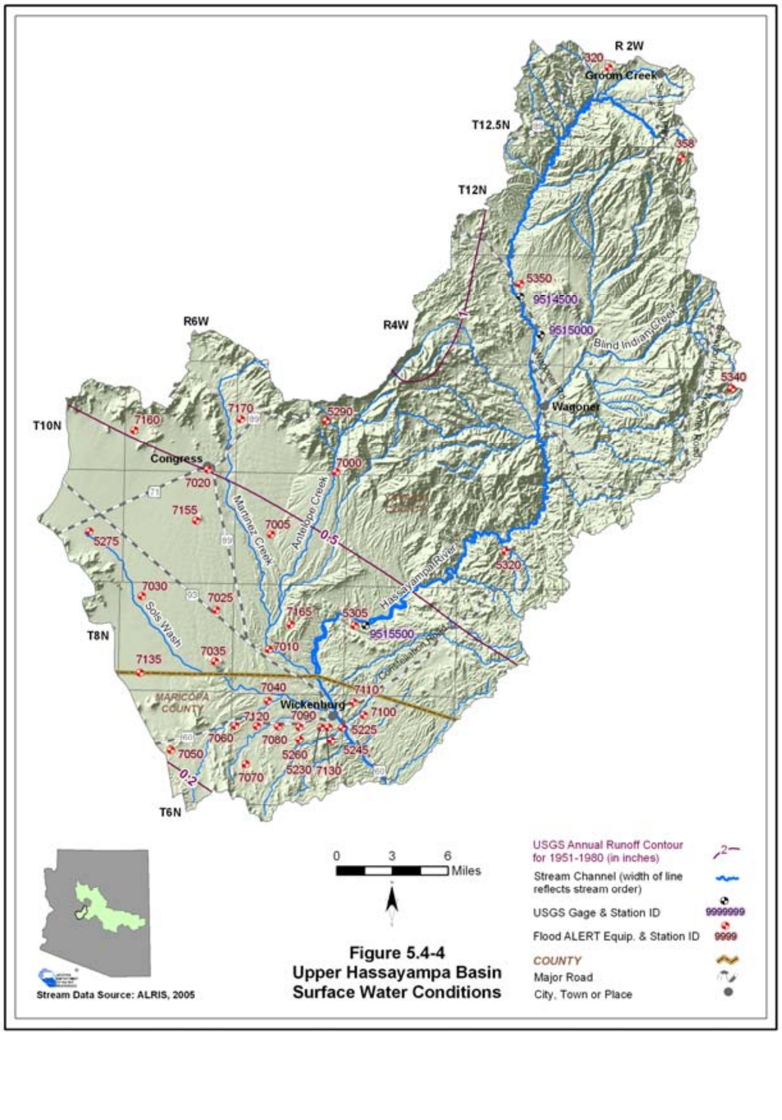


Figure 5.4-4
Upper Hassayampa Basin
Surface Water Conditions

Groundwater - The Upper Hassayampa basin includes about 740 square miles of the Central highlands physiographic province of central Arizona (Figure 3) and contains relatively small basins filled with alluvial deposits. The basin is bounded on the north by the Weaver Mountains, on the northwest by the Date Creek Mountains, on the south by the Vulture Mountains, and on the east by the Bradshaw Mountains. The mountains are composed of crystalline and sedimentary rocks. Elevations in the area range from 2,000 feet to over 7,000 feet above mean sea level.

The main water-bearing unit is the basin-fill deposits which are found in the valleys between the mountains. These deposits consist of gravel, sand, silt, and clay and may yield several hundred gallons per minute to wells. Where fractured, the crystalline and consolidated sedimentary rocks which make up the mountains may yield less than 10 gallons per minute (Sanger and Appel, 1980). In the alluvial basin north of the Vulture Mountains, the main water-bearing unit ranges from a few tens of feet thick near the margins to over 1,000 feet thick toward the middle (Sanger and Appel, 1980). In a few areas along the Hassayampa River, the crystalline rock is overlain only by a thin cover of stream deposits. Near Wagner, these deposits are up to 135 feet thick (Sanger and Appel, 1980). Figure below is from the ADWR Water Atlas Section 5.4 (fig 5.4-6).

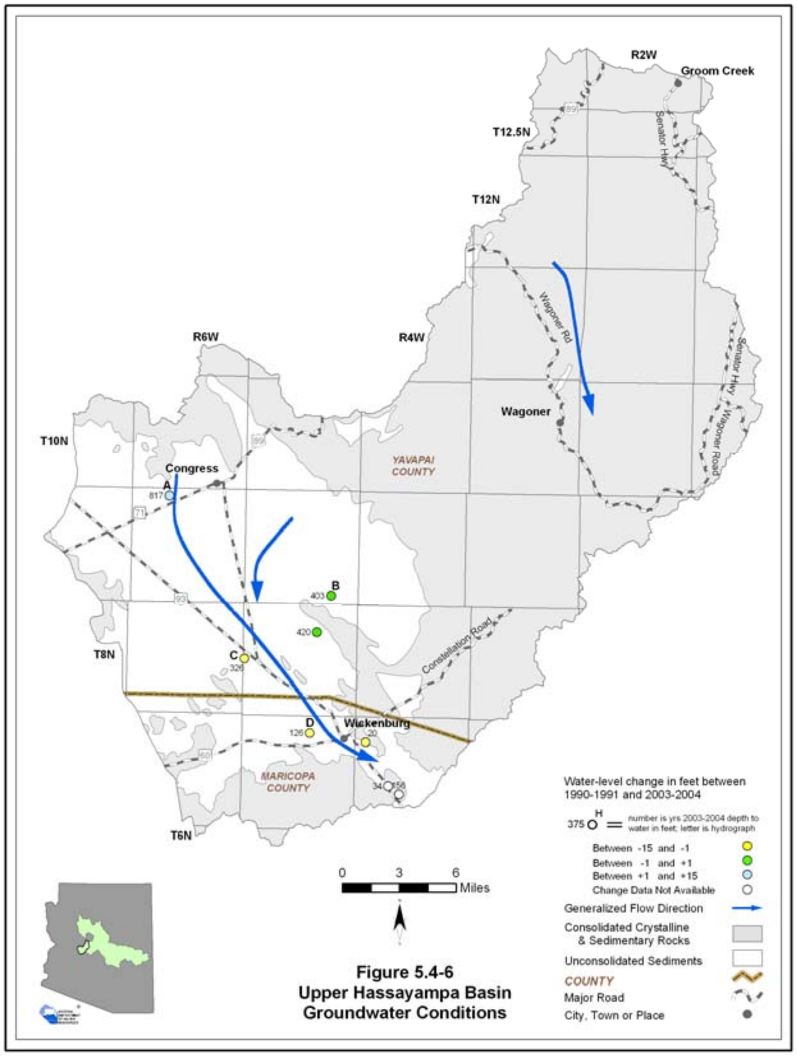


Figure 5.4-6
Upper Hassayampa Basin Groundwater Conditions

Bill Williams Basin:

Excerpt from ADWR regarding Bill Williams Basin (Also see ADWR Water Atlas):
The Bill Williams basin consists of approximately 3,200 square miles (Figure 13). The west portion of the basin is in the Basin and Range province and the east portion is in the Central Highlands province. The basin is bounded by the Hualapai Mountains on the north, the Mohave Mountains on the east, and the Harcuvar and Buckskin Mountains to the south. Land surface elevations in this area range from approximately 6,000 feet above mean sea level in the north near Bear Mountain to less than 1,000 feet above mean sea level in Mohave Wash to the east.

Groundwater in the Bill Williams basin occurs in younger alluvial deposits, in basin-fill, and in fractured and porous volcanic rocks. The water-bearing ability of these units vary within the basin. The younger alluvium consists of gravel, sand, and silt and is present in places along the Bill Williams River and its major tributaries. These deposits are also the main water-bearing unit in Peeples Valley, which is located in the southwest corner of the Bill Williams basin. Except for the Peeples Valley area, these deposits are of small areal extent. However, where present, the alluvial deposits have high water-yielding potential. Wells tapping this unit along the Bill Williams River and its major tributaries, are used primarily for irrigation and domestic supplies. Yields from large-capacity irrigation wells are reported at 100 to 4,000 gallons per minute. Wells in the Peeples Valley are used mainly for domestic and livestock supplies and just a few wells are used for irrigation. Well yields in the Peeples Valley area range from 20 to 2,000 gallons per minute and water levels have fluctuated in the past 33 years (Sanger and Littin, 1981).

The main water-bearing unit is the basin-fill. These deposits are recharged from streamflow infiltration and precipitation along the mountain fronts. Groundwater movement in this area generally is in the same direction as streamflow. Thickness of basin-fill deposits, which has been estimated from test-hole data, range from 200 feet to more than 1,000 feet in Copper Basin in the Central Highlands province and may be more than 5,000 feet in the Bullard Wash - Date Creek area in the Basin and Range province. Large-capacity wells which tap the basin-fill are reported to yield 50 to 1,200 gallons per minute.

An important water-bearing unit in the Copper Basin area is a 1,000-foot thick sequence of volcanic rocks. The volcanic sequence is separated from the overlying basin-fill deposits by a 35-foot thick confining bed of well-cemented sand and clay. The upper 350 to 400 feet of these volcanics may produce more than 2,000 gallons per minute (Sanger and Littin, 1981). In addition to the water-bearing formations discussed above, schist, gneiss, and granite, where sufficiently fractured or decomposed, may contain enough water for domestic and livestock supplies. In the Bagdad area, there are zones in the granite that have been crushed by faults. Wells that tap these areas yield more than 100 gallons per minute. Groundwater in faults and fractures is sensitive to recharge and may not constitute a dependable supply.

http://www.azwater.gov/dwr/Content/Find_by_Program/Rural_Programs/OutsideAMAs_PDFs_for_web/Upper_Colorado_River_Planning_Area/Bill_Williams_Basin.pdf

http://www.azwater.gov/dwr/Content/Find_by_Program/Rural_Programs/OutsideAMAs_PDFs_for_web/Upper_Colorado_River_Planning_Area/References.pdf