Report for 2005AZ89B: Big Chino Basin 3-D Digital Hydrogeologic Framework Model

Publications

- Conference Proceedings:
    - Springer, A.E. and M.C. Fry. 2005. 3-D Visualization of Aquifers of Arizona Using the GeoWall. Annual meeting of the Arizona Hydrological Society, September 22-25, Flagstaff, AZ.
- Unclassified:
    - Springer, A.E. and M.C. Fry. 2005. Using the GeoWall to Visualize Aquifers of Arizona in Three Dimensions. Annual meeting of the Geological Society of America, October 16-19, Salt Lake City, UT.

Report Follows

A. Problem and Research Objectives

Abstract

The Upper Verde River is one the largest remaining free-flowing, perennial rivers in the Southwestern U.S. The headwaters of the Verde River are a series of springs fed by groundwater from a large regional aquifer(s) which are the primary source of water for the first 29 miles of the upper perennial reach of the Verde River. These 29 miles of river support approximately 800 riparian acres with an average discharge of approximately 25 ft^3/sec. Although the location and discharge of the springs which form the Verde Headwaters is known, it has remained uncertain what the source areas of these springs are. The headwaters occur at the intersection of some very complicated geologic terrain at the intersection of Big Chino Basin, Little Chino Basin, Lower Granite Creek area, and bedrock of Big Black Mesa.

The subsurface geology of Big Chino Basin has only recently been defined. A complex combination of interfingering Tertiary sediments, sedimentary rocks, and basalt flows exist, along with faulting of carbonate rocks along the northeastern boundary of the basin. Understanding and quantifying groundwater flow in the Big Chino Basin aquifer first required a complete understanding of the geology of this region.

A Digital Hydrogeologic Framework Model (DHFM) has been constructed using EarthVision, a three-dimensional (3-D) geographic information system (GIS) software. The DHFM will be displayed with a 3-D viewer. Well logs contained in the ADWR well database were interpreted for lithology, and accurately located using GPS or parcel numbers contained within the well logs. These along with contacts digitized from a geologic map (DeWitt, in press) have served as the basis for the DHFM.

Problem

The lack of subsurface geologic knowledge in Big Chino Basin equates to a lack of understanding of the hydrogeologic properties of the region. These factors must be understood for effective use and conservation of groundwater in the region. Preliminary assumptions are that basin-fill sediments, fractured basalt flows, and adjacent/underlying carbonate rocks contain substantial groundwater storage for continued development in the area, but these assumptions largely lacked scientific evidence to support such claims. The primary concern lied in the groundwater contribution of this region to springs that form the Upper Headwaters of the Verde River.

Water managers in this region need to understand the geology and hydrogeology of the area in order to develop their resources effectively, and without causing unnecessary negative environmental impacts. The city of Prescott has pursued the possibility of developing Big Chino Basin as an additional source of water, but has been unable to do so, because the effects of high levels of groundwater pumping in the area have remained unclear. This study has served as one of the first steps in clarifying this issue.

Objectives

The final product is a georeferenced DHFM of the Big Chino Basin aquifer. It will assist local water managers in the region to effectively manage groundwater resources. It will also be used by the USGS Arizona Water Science Center in Tucson to construct a numerical groundwater flow model. The data, model, and study conclusions will be presented in public forums to relevant stakeholders during summer 2006 and will be available on-line.

B. Methodology

Model Area

Selection of the model area boundaries were made with consideration to assumed hydrogeologic boundaries. The northeastern boundary is coincident with the anticlinal axis of Big Black Mesa and approximates a groundwater divide. Northeast of the boundary, stratigraphic units dip to the northeast, and are connected to aquifer(s) on the Colorado Plateau. Southeast of the boundary, beds dip to the southeast, and are connected to the Big Chino Basin aquifer. The northwestern model boundary was selected to incorporate regions of Big Chino Basin critical to understanding the applicable hydrogeologic properties, and at a lineation where all groundwater flow paths within the basin are perpendicular to the model boundary. The southwestern boundary of the model was selected to incorporate all critical areas of the Big Chino Basin. The southwestern model boundary was selected as to overlap a previously existing DHFM compiled by the principal investigators, which models the Lower Granite Creek and the Verde Headwaters bedrock region. The model dimensions are approximately 15 by 30 miles and contain approximately 450 square miles of the Big Chino Basin aquifer.

Lithologic Interpretation

Drillers well logs from over 80 wells contained in the ADWR database have been re-interpreted for lithology by the authors. Interpreted logs were also utilized from a recently published USGS report (Wirt and others, 2004). The tops of respective hydrogeologic units were selected from the interpreted logs and compiled into a database for insertion into EarthVision. Parcel numbers from the well logs and parcel layers obtained from the Yavapai County GIS office were used in ArcGIS v.9 (ESRI, Redlands, CA) to determine accurate locations for the wells.

Selection of Hydrogeologic Units:

Hydrogeologic units were selected based on their respective hydrogeologic properties and the amount of data available to accurately model their extent in the subsurface. The breakdown of hydrogeologic units is as follows:

Quaternary sediment (Qs):

Composed of predominantly alluvium along Big Chino Wash and gravels sourced from the Sullivan Buttes latites and other uplands surrounding the basin. These units are presumed to be of intermediate permeability and allow recharge via precipitation and surface water flow. These units are not considered to be part of the basin fill aquifer.

Tertiary sediments and sedimentary rocks (Ts):

Facies lumped into this category range from high permeability gravels to low permeability playa deposits (Wirt and others, 2004). Because of the limited well data available in all but the southeastern most extent of Big Chino Basin, these facies remain undifferentiated in this model. These facies comprise the majority of the volume of the basin-fill aquifer.

Tertiary volcanics (Tv):

At least three distinct subsurface basalt flows have been identified in Big Chino Basin. The flows have been dated to between 4 to 6 Ma and locally contain interbedded cinders. Geographically, the basalt flows are located in the southeastern reach of the basin, and flowed to the northwest during basin development. Primary porosity of basalt is low, but evidence suggests these units are highly fractured, based on field observations of degassing wells made by the authors. Wirt and others, 2004, suggest water discharging at the Upper Verde River springs may have traveled through significant amounts of basalt, due to elevated silica levels at the springs. The authors suggest the subsurface basalt flows as a potential link between the Big Chino Basin aquifer and the springs of the Upper Verde River.

Paleozoic sedimentary rocks (Ps):

Either the Mississippian Redwall Formation or the Devonian Martin Formation or both, underlie much of Big Chino Basin. Both units are limestones or dolomitic limestones and can have high secondary permeability via dissolution. Regionally, these two units are the predominant aquifer units, and are assumed to be directly linked to and form part of the basin fill aquifer.

Proterozoic basement (Xb):

The Proterozoic crystalline basement is comprised mainly of the Mazatzal Quartzite. Also lumped into this category are the younger Tertiary Latite intrusives of the Sullivan Buttes, and the Cambrian Tapeats sandstone. Primary porosity of the above units is low to very low, but locally fractures may create intermediate permeability (Wirt and others, 2004). These units comprise the lower confining unit for the basin-fill aquifer.

Field Methodology

Conflicting well locations were field checked to insure accuracy of the locations. Also, previously existing geologic map (DeWitt, in press) was field checked where there were uncertainties. Where possible, the surface traces of faults as exist on the geologic map were supplemented via field observations of fault plane dip and fault offset. These exercises served as a measure of QA/QC for data that was input into EarthVision.

Laboratory Methodology

Unit contacts were digitized from a geologic map (DeWitt, in press) in ArcGIS v.9 were compiled into the database created from interpreted well logs, for insertion into EarthVision (Dynamic Graphics, Alameda, CA). A surface was created for the top of each unit in EarthVision, using a minimum tension trend gridding algorithm. Where geologic data was absent or unsubstantial to properly represent strata based on the author's opinions of the subsurface geology, control points were added. A recently published geophysics report by the USGS was used to help the authors determine unit geometry in the subsurface (Langenheim and others, 2005).

C. Principal Findings and Significance

Principal Findings

The extent and geometry of subsurface basalt flows and latite intrusions have been determined in this report. The extent and geometries of these basalt flows have allowed the authors to identify these flows as a potential groundwater link between the Big Chino Basin aquifer and the springs of the Upper Verde River.

Significance

This report has been able to improve on the understanding of the hydrogeologic conditions of the Big Chino Basin aquifer. More importantly, it has produced a georeferenced 3-D DHFM which can be interactively presented to water managers and the general public in order to increase their understanding of the system. Understanding the system is crucial in making water use and policy decisions in the region which have the potential to have significant environmental impacts on the Upper Verde River.

It is the opinion of the authors that continued groundwater pumping of the Big Chino Basin aquifer may impact the discharge of the springs of the Upper Verde River, though the impact is still unable to be quantified at this time. Continued research utilizing the findings of this report, principally the groundwater flow model being constructed by the Water Resources Division of the USGS in Tucson will help to further clarify this issue.

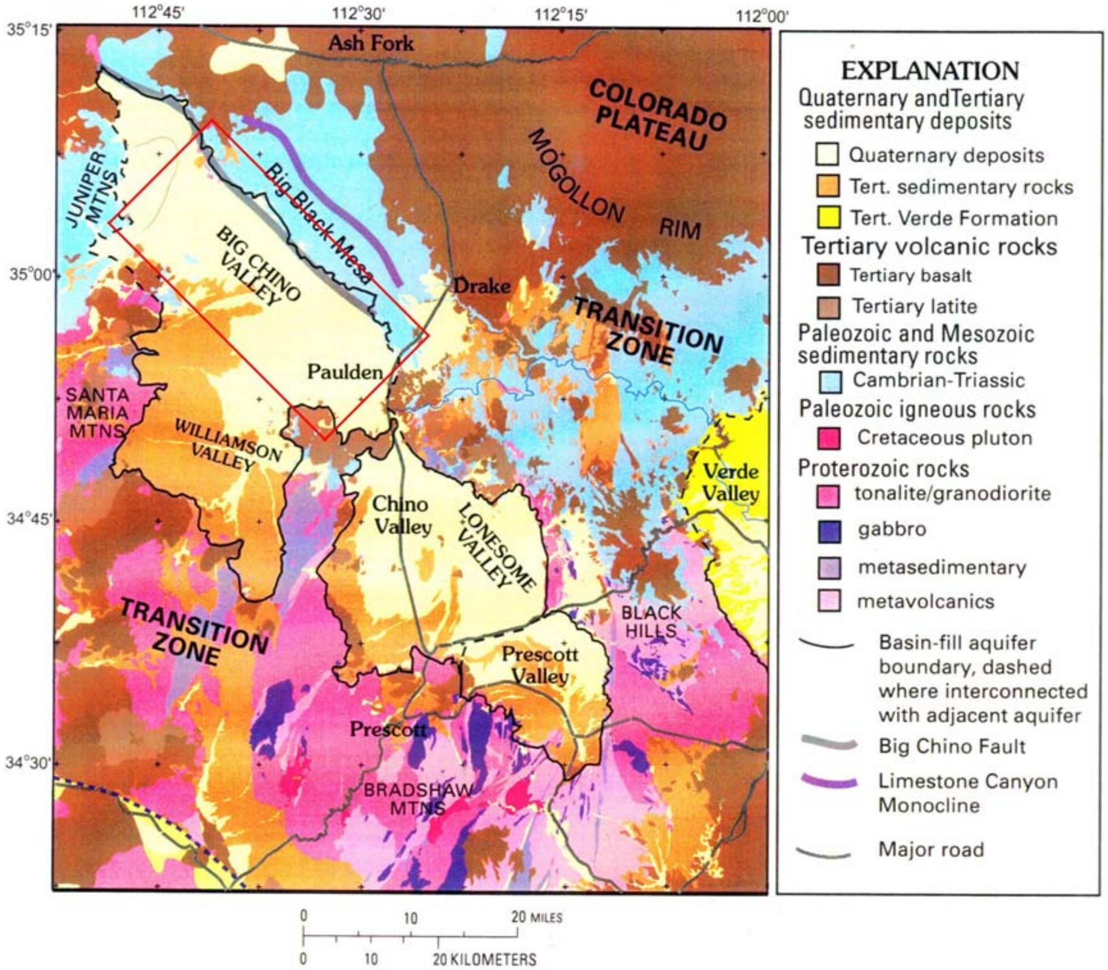

Figure 1: Simplified geologic map of the Verde Headwaters region. Model area shown in red rectangle. Modified from Wirt and others, 2004.

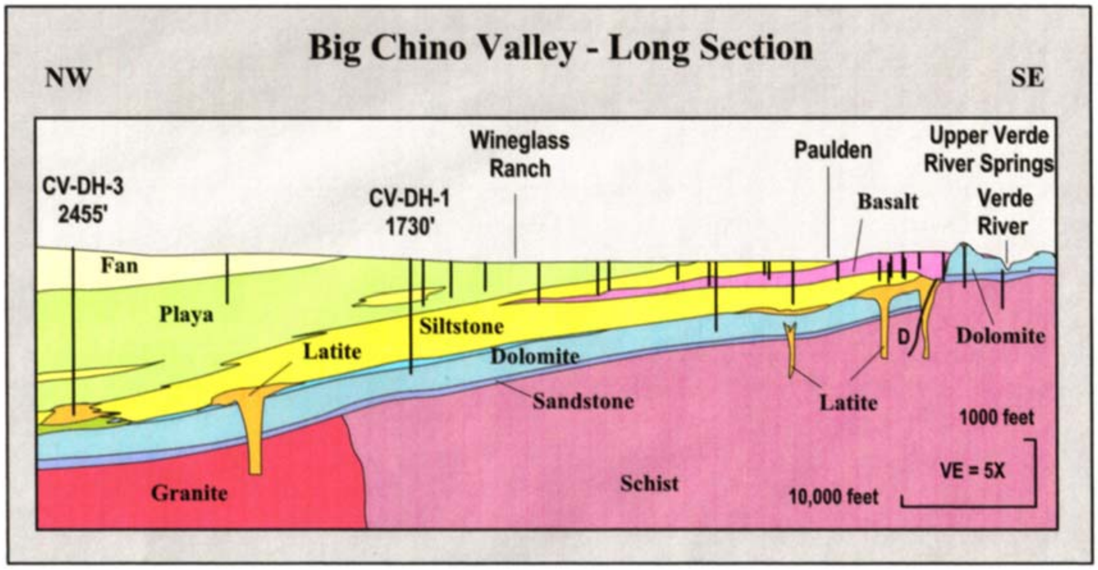

Figure 2: Big Chino Basin long axis cross-section (DeWitt, unpublished).

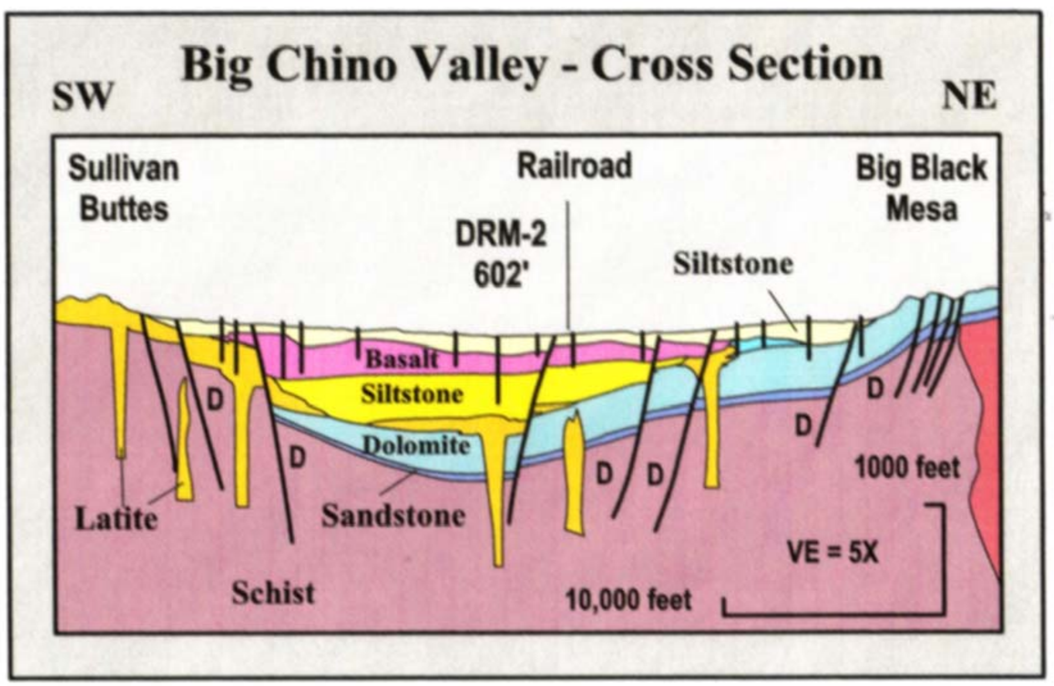

Figure 3: Big Chino Basin short axis cross-section (DeWitt, unpublished).

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