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Exh. 2

Project Proposal:

Augmented Hydrologic Assessment of the Arbuckle-Simpson Groundwater Basin

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Proposal Summary

The Arbuckle-Simpson aquifer encompasses parts of Carter, Coal, Garvin, Johnston, Murray, and Pontotoc Counties and is the principal source of drinking water for more than 150,000 residents of Ada, Ardmore, Sulphur, Tishomingo and other cities in south-central Oklahoma. Because of the importance of the aquifer for water supply, the U.S. EPA designated the eastern segment of the Arbuckle-Simpson as a sole source aquifer. The Oklahoma Water Resources Board (OWRB) recently proposed a maximum annual yield (MAY) of 78,404 acre-feet per year for the Arbuckle-Simpson Groundwater Basin (comprised of the western, central, and eastern segments), with the goal of sustaining groundwater storage and instream flows in the region. The proposed MAY was developed in response to SB 288 and followed a 6-year Arbuckle-Simpson Hydrology Study (ASHS) of the eastern segment. An equal proportionate share (EPS) of 0.20 acre-feet per acre per year was also proposed for consumptive use within the Arbuckle-Simpson Groundwater Basin.

Because of the far reaching impacts of SB 288 and subsequent MAY and EPS on the citizens, municipalities, and industry in Oklahoma, it is imperative to base regulation on thorough scientific studies. Although numerous geologic and hydrologic studies have been conducted in the region, hydrogeologic conditions have not been adequately characterized for approximately one-third of the Arbuckle-Simpson Groundwater Basin. The ASHS and associated reports examined only the Hunton anticline (eastern segment), and did not consider the much more complex hydrogeology of the Tishomingo anticline (central segment) or Arbuckle anticline (western segment). In addition, hydrologic conditions in the western and central segments were not monitored or modeled before proposing the MAY or EPS. It is difficult to say that the aquifer storage or recharge rate, estimated from hydrogeologic characteristics of the eastern segment, have hydrologic significance throughout the entire Arbuckle-Simpson Groundwater Basin. Therefore, is it appropriate to apply the proposed MAY or EPS to the entire Arbuckle-Simpson Groundwater Basin? There are also questions regarding effects of cyclic and recent droughts versus human impacts to the hydrologic system. What is the relative impact of climate versus human activity, and how is that accounted for in the MAY, EPS or future pit water management issues accompanying SB 597?

The project proposed here builds upon the OWRB-led ASHS that focused on the eastern segment between August 2003 and September 2009. The Oklahoma Geological Survey (OGS) would be the principal investigating agency, but would seek cooperation from all stakeholders

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and collaboration with other technical groups as necessary. The objectives of the proposed project are threefold (1) extend the geographic and temporal extent of hydrologic monitoring in the Arbuckle-Simpson Groundwater Basin beyond that which was covered by the ASHS, (2) evaluate the relative impacts of climatic variability or consumptive use on hydrologic conditions, and (3) establish baseline conditions upon which water management and regulatory decisions can be formed. Proposed project tasks include compilation of existing hydrologic and climatic data from numerous sources (e.g., OWRB, USGS, NPS, OGS, OCS, Municipal Users, Industrial Users, etc.), evaluation of long-term and short-term trends in the hydrologic system, continued monitoring of established monitoring points, instrumentation of new monitoring points (e.g., wells, springs, streams) particularly in data sparse areas, and dissemination of an Arbuckle-Simpson Groundwater Basin-wide hydrologic assessment.

OGS is chartered in the Oklahoma Constitution and is charged with investigating the state's land, water, mineral, and energy resources and disseminating the results of those investigations to promote the wise use of Oklahoma's natural resources. Because the OGS serves the state of Oklahoma as a research and service agency, while maintaining an academic affiliation, it is well positioned to conduct applied research and cooperate with multiple stakeholders within the Arbuckle-Simpson Groundwater Basin. Upon completion of the proposed project, the OGS would provide an improved scientific understanding upon which the SB 288 related MAY and EPS could be developed for the Arbuckle-Simpson Groundwater Basin. Cooperation from numerous stakeholders would allow OGS to disseminate the results and promote the wise use of one of Oklahoma's natural resources – the Arbuckle-Simpson aquifer.

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1 INTRODUCTION

The Oklahoma Water Resources Board (OWRB) recently published the Oklahoma Comprehensive Water Plan (OCWP) with the objective to "ensure a dependable water supply for all Oklahomans through integrated and coordinated water resources planning by providing the information necessary for water providers, policy-makers, and end users to make informed decisions concerning the use and management of Oklahoma's water resources" (OWRB 2012a). It was recognized in the OCWP that Data is one of the four core factors to the strategic vision for Oklahoma's water future. Without reliable water data the other three core factors: Infrastructure, Management, and Regional Planning cannot be effectively designed or implemented.

The OCWP provides a reasonable framework for statewide planning and well-intended directives for the Regional Planning groups; however, prominent groundwater systems will present unique challenges within this framework. For example, the Arbuckle-Simpson aquifer underlies and crosses the boundaries of two major watersheds (Lower Washita and Blue-Boggy), is designated as a sole source aquifer by the U.S. Environmental Protection Agency (EPA), and is the subject of Senate Bill (SB) 288 and SB 597.

In the spirit of the OCWP, this proposal is written for the Arbuckle-Simpson aquifer to develop "monitoring programs that provide foundational data for critically important water management decisions" (OWRB 2012a). An augmented hydrologic assessment developed and implemented by the Oklahoma Geological Survey (OGS) would provide these data for the Arbuckle-Simpson Groundwater Basin and promote good stewardship of this important natural resource.

1.1 Arbuckle-Simpson Aquifer Overview

The Arbuckle-Simpson aquifer is a highly fractured bedrock aquifer comprised of the Simpson, Arbuckle, and Timbered Hills Groups in south-central Oklahoma. The aquifer is exposed at the surface in three areas sometimes referred to as the western, central, and eastern aquifers (i.e., segments), which correspond geologically to prominent uplifted areas also referred to as the Arbuckle, Tishomingo, and Hunton anticlines, respectively (Osborn 2009). Middle Ordovician age Simpson Group bedrock consists of sandstones, shales, and limestones up to 2,300 ft. thick in the western segment, but generally less than 1,000 ft. thick in the eastern segment. The Arbuckle Group consists of as much as 6,700 ft. of limestone in the western segment, but transitions and thins to approximately 3,000 ft. of dolostone in the eastern segment. The lowermost Timbered Hills Group is comprised of the Honey Creek Limestone and Reagan Sandstone, which is underlain by low-permeability Cambrian igneous and metamorphic rocks (Christenson et al. 2011). Explanations for the Simpson, Arbuckle, and Timbered Hills Groups are provided in Figure 1, and used to illustrate the stratigraphy and structure in Figures 2, 3, and 4.

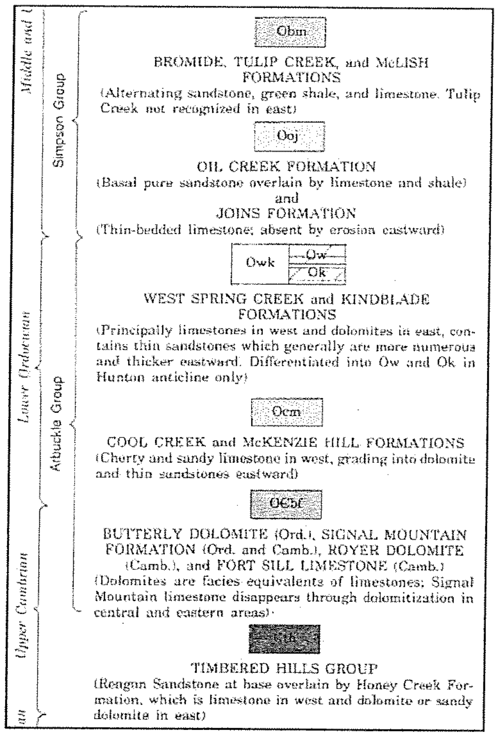

Figure 1: Explanation of geologic units that comprise the Simpson, Arbuckle, and Timbered Hills Groups (from Ham et al., 1990)

Geologic structure within the Arbuckle, Tishomingo, and Hunton anticline areas are drastically different. The extremely complex Arbuckle anticline (western segment) shown in Figures 2 and 3 is comprised of highly folded beds that are generally dipping steeply toward the south/southwest (Ham et al. 1990). Many formations within the Simpson Group, for example, are exposed in multiple places across the western segment due to recurring limbs of smaller folds and faults. The Tishomingo anticline (central segment) is bounded on the south by the Washita Valley fault and on the north by the Reagan fault (Figure 3). Geologic units comprising the

Arbuckle-Simpson aquifer in the central segment are gently dipping to the west and appear to have a lower fault and fracture density than the western segment (Ham et al. 1990). The geologic structures in the Hunton anticline (eastern segment) are the least complex and form a gently dipping dome with the Kinblade Formation of the Arbuckle Group exposed at the center of the dome (Ham et al. 1990). Fault and fracture density in the eastern segment appears to be much lower than the western or central segments, except close to the Reagan fault zone that divides the central segment and eastern segment. By overlaying results of a groundwater modeling study (Christenson et al. 2011) and geologic mapping (Ham et al. 1990), it is clear that the recharge area of the eastern segment is located where the Kinblade Formation is exposed at the surface.

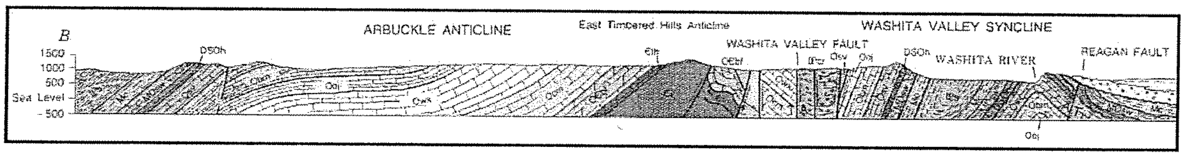

Figure 2: Geologic units and structure within the Arbuckle anticline, western segment of the Arbuckle-Simpson aquifer (from Cross-Section B-B' in Ham et al., 1990)

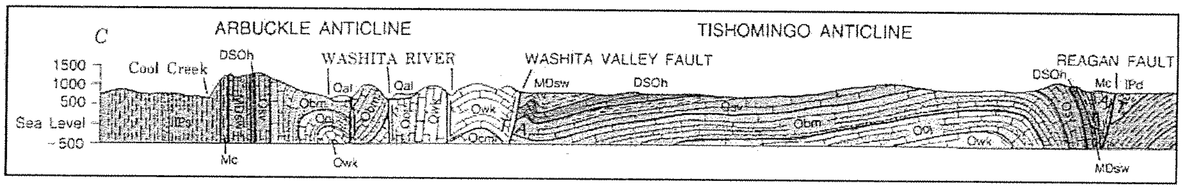

Figure 3: Geologic units and structure within the Tishomingo anticline, central segment of the Arbuckle-Simpson aquifer (from Cross-Section C-C' in Ham et al., 1990)

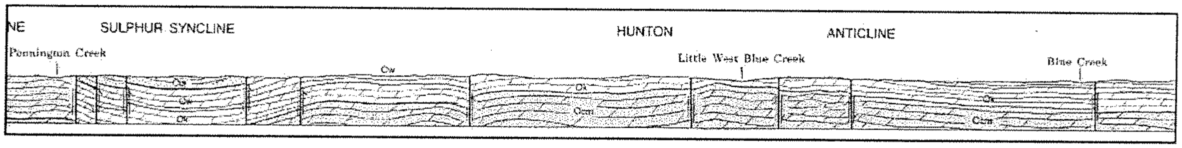

Figure 4: Geologic units and structure within the Hunton anticline, eastern segment of the Arbuckle-Simpson aquifer (from Cross-Section D-D' in Ham et al., 1990)

The aquifer is under artesian conditions in the northern part of the eastern segment (i.e., Eastern Confined Aquifer), where it is confined by younger, and lower permeability sedimentary units. Therefore, the Arbuckle-Simpson aquifer can be geospatially delineated as four segments: Western Aquifer (WA), Central Aquifer (CA), Eastern Confined Aquifer (ECA), and Eastern Unconfined Aquifer (EUA) shown in map-view in Figure 5.

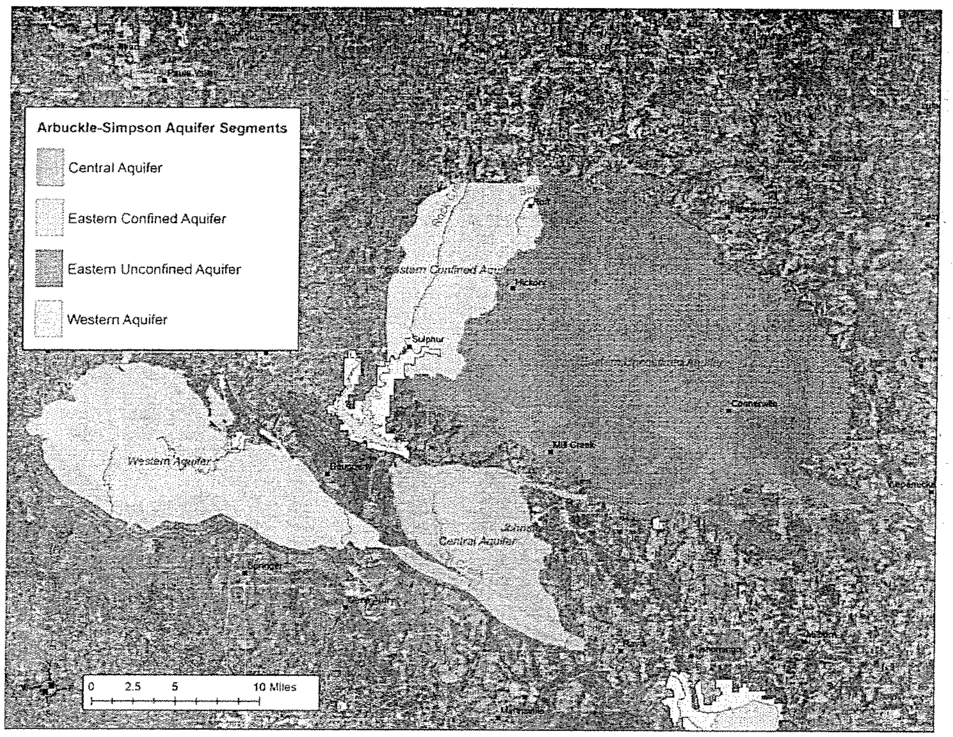

Figure 5: Boundaries of Arbuckle-Simpson Groundwater Basin aquifer segments

Groundwater wells completed in the Simpson Group yield 100 to 200 gallons per minute (gpm), while those completed in the Arbuckle Group yield 200 to 500 gpm (Fairchild et al. 1990). The Vendome Well is a well-known artesian well that epitomizes the confined conditions of the ECA within the Chickasaw National Recreation Area (CNRA), where approximately 20 artesian wells are still flowing (Osborn 2009). Most groundwater withdrawals are from the ECA or EUA along with the greatest stream and spring discharge (Christenson et al. 2011). Groundwater discharge from seeps and springs occur where the geologic formations of the Arbuckle-Simpson are exposed at the land surface and groundwater levels are higher than the point of contact. The WA, CA, ECA, and EUA have 26, 19, 12, and 67 mapped springs, respectively. Byrds Mill Spring, emanating from the EUA, is an important source for municipal supply to the City of Ada. Recorded discharge from Byrds Mill Spring ranged from <0.1 to 30.7 cubic feet per second (cfs) between May 1959 and Feb 2012 with a median recorded discharge of 8.7 cfs (USGS-NWIS 2012). Discharge from Antelope Spring, emanating from the ECA, was recorded intermittently by the National Park Service (NPS) and the USGS between May 1957 and Feb 2012. Recorded discharge from Antelope Spring ranged from <0.1 to 7.5 cfs with a median recorded discharge of 2.9 cfs. When the discharge of these two springs are plotted versus annual precipitation (Figure 2) at the Sulphur precipitation gage there is an apparent increase in Byrds Mill Spring discharge and an apparent decline in Antelope Spring discharge.

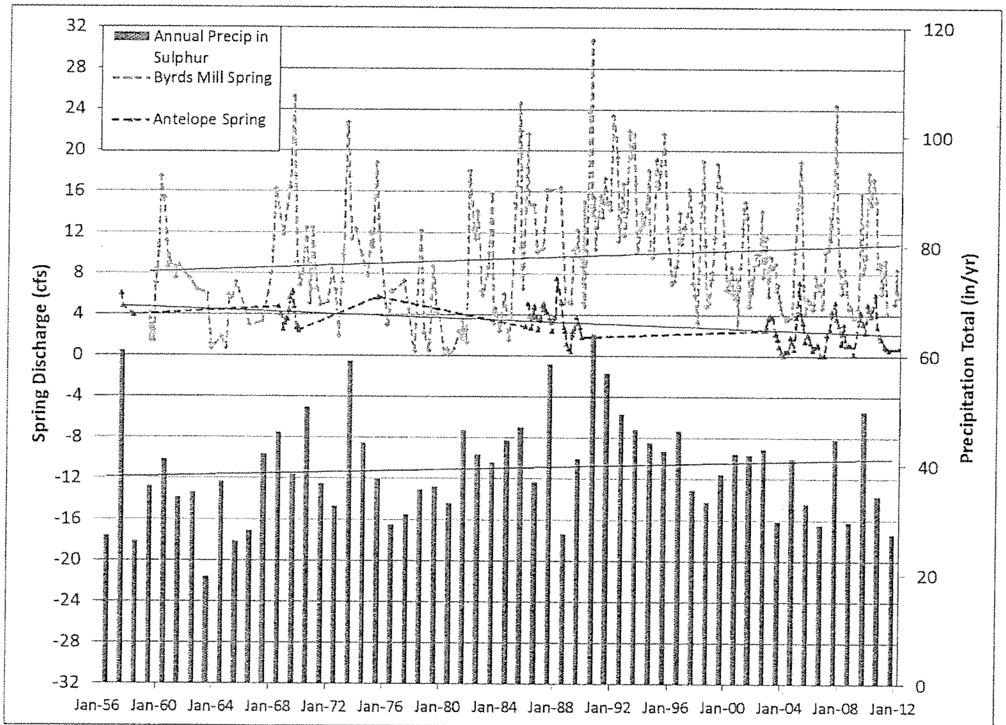

Figure 6: Historic record of spring discharge and precipitation with superimposed linear trend lines

Recharge to the aquifer was estimated to be 5.58 in/yr or approximately 14.4% of the average annual precipitation (38.8 in/yr) during the 2004 to 2008 water years (Christenson et al. 2011). The area overlying the Arbuckle-Simpson aquifer is approximately 612.5 square miles (392,019 acres); therefore, recharge volume was estimated to be 182,288 acre-feet of water per year for the entire Arbuckle-Simpson aquifer (Christenson et al. 2011). Recharge rate was estimated using hydrogeologic characteristics and modeling within the eastern segment; however, this estimated rate may be conservative since the degree of faulting/fracturing in the eastern segment is lower than in the western and central segments. The amount of groundwater in storage in the Arbuckle-Simpson aquifer was estimated as 9,408,461 acre-feet, calculated by using the storage coefficient of 0.009 and an average thickness of 3,000 feet (Christenson et al. 2011). Groundwater storage volumes were based on hydrogeologic characteristics and modeling in the eastern segment; however, this may also be conservative because the thickness is greater for Arbuckle-Simpson geologic units in the western and central segments.

1.2 Regulatory Measures and Planning

In 1989, the regional administrator of the U.S. EPA determined pursuant to Section 1424(e) of the Safe Drinking Water Act (SDWA) that a portion (eastern segment) of the Arbuckle-Simpson aquifer is the sole or principal source of drinking water for an area comprising portions of Johnston, Murray and Pontotoc counties in south-central Oklahoma. The Arbuckle-Simpson is the principal source of drinking water for more than 150,000 residents of the region, providing more than 50% of the water used by the cities of Ada, Ardmore, Sulphur, Tishomingo and others.

Contrary to prior geologic and hydrogeologic studies, all segments (i.e., WA, CA, ECA, and EUA) were considered hydrologically contiguous and would be collectively managed by OWRB as the "Arbuckle-Simpson Groundwater Basin." Due to the sole source designation there is a moratorium on the issuance of permits that allow for municipal use of Arbuckle-Simpson groundwater in counties that do not overly the Arbuckle-Simpson aquifer. However, it is unclear whether this moratorium should apply to only the eastern segment of the Arbuckle-Simpsonaquiferorthe"Arbuckle -Simpson Groundwater Basin,"whichincludesallsegments.

SB 288 was passed by the Oklahoma legislature in 2003 and led to a 6-year Arbuckle-Simpson Hydrology Study (ASHS) of the eastern segments (i.e., ECA and EUA) of the Arbuckle-Simpson aquifer. After completion of the ASHS, a maximum annual yield (MAY) of 78,404 acre-feet per year and an equal proportionate share (EPS) of 0.20 acre-feet per acre per year for consumptive use were proposed (OWRB 2012b). Although the ecological services of streams (recreational use and habitat for aquatic life) emanating from the aquifer were not identified in SB 288, their value is being considered in the development of a water management plan for the Arbuckle-Simpson aquifer (Seilheimer and Fisher 2008). The phrase "will not reducenaturalflow"inSB288impliesthatwaterflowconstitutesanessentialcomponentofthe natural habitat of area streams. Permitted groundwater use must not interfere with streams and springs emanating from the aquifer.

1.3 Project Need

Because the Arbuckle-Simpson is important for drinking water supply it is necessary to manage the aquifer as a sustainable resource. Although numerous geologic and hydrologic studies have been conducted in the Arbuckle-Simpson aquifer region, hydrologic relationships have not been fully characterized at the basin-wide or site-specific scale. For example, hydrologic conditions in the western and central segments were not monitored or modeled prior to proposing the MAY or EPS. So, do the MAY or EPS have hydrologic significance throughout the entire groundwater basin? Allocation of water from the Arbuckle-Simpson aquifer, as evidenced by the proposed MAY, is an issue that will only increase in importance. The ability to effectively manage or regulate the Arbuckle-Simpson aquifer will depend on the foundation of data that support these management decisions.

In addition, effects of cyclic and recent droughts on hydrologic conditions have not been carefully examined. What is the relative impact of climate versus human activity, and how is that accounted for in the MAY, EPS or future pit water management issues accompanying SB 597? After evaluating basin-wide conditions and drought related impacts would a different MAY or EPS be more appropriate? Because of the far reaching impacts of the proposed and developing regulation on the citizens, municipalities, and industry in Oklahoma, it is imperative to extend the ASHS and fill existing gaps in our understanding of the Arbuckle-Simpson Groundwater Basin prior to establishing regulatory mandates.

It has also been shown that the springs and spring-fed streams of the Arbuckle-Simpson aquifer form unique groundwater dependent spring habitats or ecosystems. Spring habitats differ from other lotic (i.e., flowing water) systems because they maintain nearly constant discharge and temperature, and exist as small and isolated habitats that are an important refuge for aquatic life. Seasonal trends in spring discharge must be maintained (higher in winter and lower in late summer) for spring habitats to sustain spring-dependent aquatic life (Seilheimer and Fisher 2008). Groundwater levels in the nearby aquifer largely control the spring discharge; therefore, monitoring of these expressions of the Arbuckle-Simpson aquifer is essential to establishing baseline relationships between climate, water management practices and aquifer conditions. Selheimer and Fisher (2008) suggest that monitoring spring flows in the Arbuckle-Simpson is an important step in establishing the relationship between groundwater and surface water flows. In addition to the physical role that springs play in the Arbuckle-Simpson aquifer, it may also be important to ask: What is the ecological and cultural significance of springs emanating from the Arbuckle-Simpson aquifer?

Unfortunately, the questions that will develop after the proposed MAY will only become more complex and difficult to address. For example, how is conjunctive use handled? Conjunctive use of surface and groundwater consists of harmoniously combining the use of both sources of water to minimize the undesirable physical, environmental and economic effects of each solution and to optimize the water demand/supply balance. Usually conjunctive use of surface and groundwater is considered within a river basin management program (i.e., both the river and the aquifer belong to the same basin). With the advent of an augmented hydrologic assessment of the entire Arbuckle-Simpson Groundwater Basin, the questions posed above and many others could be categorically investigated.

2 PROJECT OBJECTIVES

The objectives of the proposed project are threefold (1) extend the geographic and temporal extent of hydrologic monitoring in the Arbuckle-Simpson Groundwater Basin beyond the ASHS, (2) evaluate the relative impacts of climatic variability or consumptive use on hydrologic conditions, and (3) establish baseline conditions upon which water management and regulatory decisions can be formed.

3 PROPOSED TASKS

The tasks proposed here build upon the Arbuckle-Simpson Hydrology Study (ASHS) led by the OWRB between August 2003 and September 2009. The objective of the ASHS was to "obtaininformationnecessarytodeterminehowmuchwatercanbewithdrawnfromtheaquifer whileprotectingspringsandstreams"and as an "assessmentofwaterresourcesfortheallocation of water rights" (Osborn 2009). The ASHS focused on the ECA and EUA, whereas the tasks proposed here would expand the geographic extent to include the WA and CA.

Proposed project tasks include compilation of existing hydrologic and climatic data from numerous sources (e.g., OWRB, USGS, NPS, OGS, OCS, Municipal Users, Industrial Users, etc.), evaluation of long-term and short-term trends in the hydrologic system, continued monitoring of established monitoring points, instrumentation of new monitoring points (e.g., wells, springs, streams) particularly in data sparse areas, and dissemination of an Arbuckle-Simpson Groundwater Basin-wide hydrologic assessment.

3.1 Compile Existing Hydrologic and Climatic Data

This task would involve compiling existing hydrologic and climatic data from reports, on-line data repositories, and unpublished digital or hard-copy records. OGS key personnel would request these data from numerous agencies and stakeholders (e.g., USGS, OWRB, OGS, OCS, etc.). After obtaining the data, it would be compiled into an Arbuckle-Simpson hydrologic geodatabase that is based on the ArcGIS ArcHydro groundwater data model (Strassberg et al. 2007). This geodatabase format would allow for data to be efficiently appended or updated when additional monitoring points or measurements are available.

OGS key personnel would expand the existing database to include all sources of geographically-referenced and temporal data. Temporal data will be stored in a TimeSeries table and linked to feature class data for monitoring locations. Preliminary data referred to in the text and presented as figures in this proposal represent the beginning of the geodatabase.

3.1.1 Groundwater Well Data

OWRB completed synoptic water level events on a quarterly basis between 2005 and 2007 using a network of 101 wells. In addition, 16 wells were equipped with pressure transducers by OWRB so that water levels could be recorded continuously during the study period. Among the 117 wells monitored by OWRB during the ASHS, 5 wells were located in the ECA while 112 were located in the EUA. Access to each of the wells in the monitoring network was granted by private landowners, and coordinated by the OWRB. It is believed that several of the wells are still instrumented and the OWRB is periodically downloading the data (Osborn, 2012 personal communication). Because a field technician must visit OWRB well sites to retrieve the data from a data logger and publish the data, these data may not be publicly available for a month or several years. In preparation of this proposal, water level measurements from 101 quarterly synoptic ASHS wells and 16 continuous ASHS wells were obtained from OWRB staff.

Undoubtedly, there are additional groundwater well locations and historic water level measurements from other locations within the Arbuckle-Simpson Groundwater Basin. There are approximately 30 more well locations from the OWRB website (http://www.owrb.ok.gov/maps/data/owrbdata_Arbuckle.php) and up to 203 well locations from the USGS NWIS website (http://waterdata.usgs.gov/nwis). Water level measurements from 6 long-term USGS monitoring locations were downloaded and compiled during preparation of this proposal.

3.1.2 Spring and Stream Data

Antelope Spring near the City of Sulphur and Byrds Mill Spring near the City of Fittstown are the only springs currently instrumented by the USGS for long-term monitoring. Both of these springs are part of the eastern aquifer and had reported flows of < 1 cfs and ~6 cfs, respectively in February 2012.

Active stream monitoring sites exist along Wildhorse Creek - upstream from the WA boundary, Washita River - downstream from the WA near Dickson, Honey Creek at Turner Falls – downstream from the WA boundary, Rock Creek - within the ECA and upstream from Arbuckle Lake, Mill Creek – downstream from the EUA and upstream from the CA near Mill Creek, Pennington Creek – within the EUA and east of Mill Creek, Pennington Creek - downstream from the EUA, Blue River downstream from the EUA near Connerville, and the U.S. Army Corps of Engineers (USACE) Arbuckle Lake gaging station that is upstream from the CA. Historic/discontinued sites existed at Rock Creek – downstream from Arbuckle Lake and upstream from the WA near Dougherty (discontinued), and outflow from Vendome Well – near Sulphur (discontinued).

3.1.3 Precipitation Data

Precipitation data from 1956 to present are available for a gaging station located in Sulphur, and represent the longest, nearly continuous precipitation record in the Arbuckle-Simpson Groundwater Basin. Average annual precipitation for the Sulphur location was estimated to be 38.2 in/yr for the 1956 to 2011 time period by compiling data from a variety of sources (DAYMET 2012, Hanson and Cates 1994, OCS-Mesonet 2012a). Beginning in 1994, Mesonet climatic stations were instrumented by the Oklahoma Climatological Survey (OCS) in the Arbuckle-Simpson Groundwater Basin or in nearby cities. At present there are 8 operating Mesonet stations in the counties that encompass the Arbuckle-Simpson Groundwater Basin (see Table 1). Estimated average annual precipitation for the area based on the Mesonet period of record was 35.8 in/yr versus a 30yr average annual precipitation estimate of 40.3 in/yr (OCS-Mesonet 2012b). Data from these Mesonet stations and other precipitation gages in the area would be added to the project geodatabase, and used to map precipitation patterns in the Arbuckle-Simpson Groundwater Basin for various time periods.

Table 1: Average annual precipitation values for Mesonet locations

Station	County	Mesonet Avg (in/yr)	30yr Normal (in/yr)
Ardmore	Carter	33.1	38.4
Newport	Carter	32.6	38.1
Pauls Valley	Garvin	35.8	38.6
Tishomingo	Johnston	37.3	43.0
Sulphur	Murray	36.6	40.7
Ada	Pontotoc	37.9	41.1
Fittstown	Pontotoc	36.8	41.7
Vanoss	Pontotoc	36.2	41.0
	Average	**35.8**	**40.3**

3.2 Evaluate Trends in Hydrologic System

Hanson and Cates (1994) stated in their study of the hydrogeology of the CNRA that, "The influence on the hydrologic system of local municipal and industrial pumping from the Arbuckle-Simpson is difficult to discern because the system is more sensitive to precipitation than to pumpage." Some of the relationships can be seen in the coarsest resolution data, such as Byrds Mill Spring discharge versus average annual precipitation in Figure 6. In addition, Figure 7 shows an apparent increasing trend in the groundwater level of GWWatch501 (USGS ID 343457096404501), which represents the longest known "continuous" record (Dec 1958 to present) of water levels in the Arbuckle-Simpson Groundwater Basin. Another well shown in Figure 7 (85152), was recently monitored by OWRB as part of the ASHS and has an apparent increasing trend in water level between March 2004 and March 2011. GWWatch501 and OWRB 85152 are both located in the EUA. Trends of two wells (USGS ID 343017096561501 and OWRB 89388) located in the ECA show a general decline in water levels (shown in Figure 8), possibly due to local municipal pumping or unrestricted flow from artesian wells.

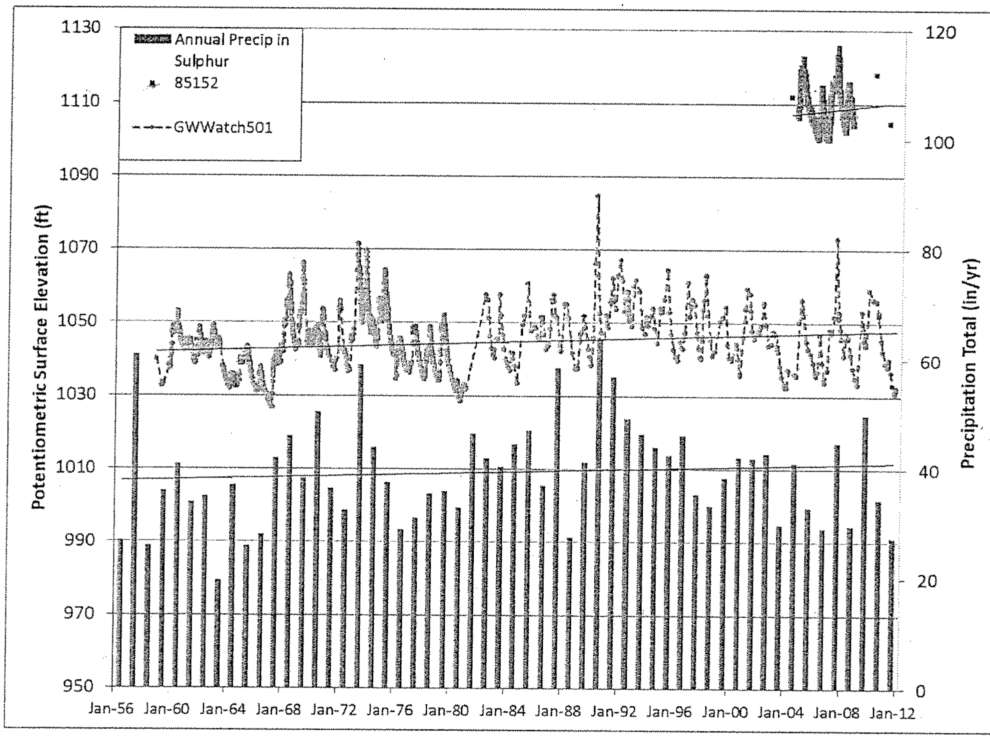

Figure 7: Groundwater levels in EUA wells and precipitation with superimposed linear trend lines

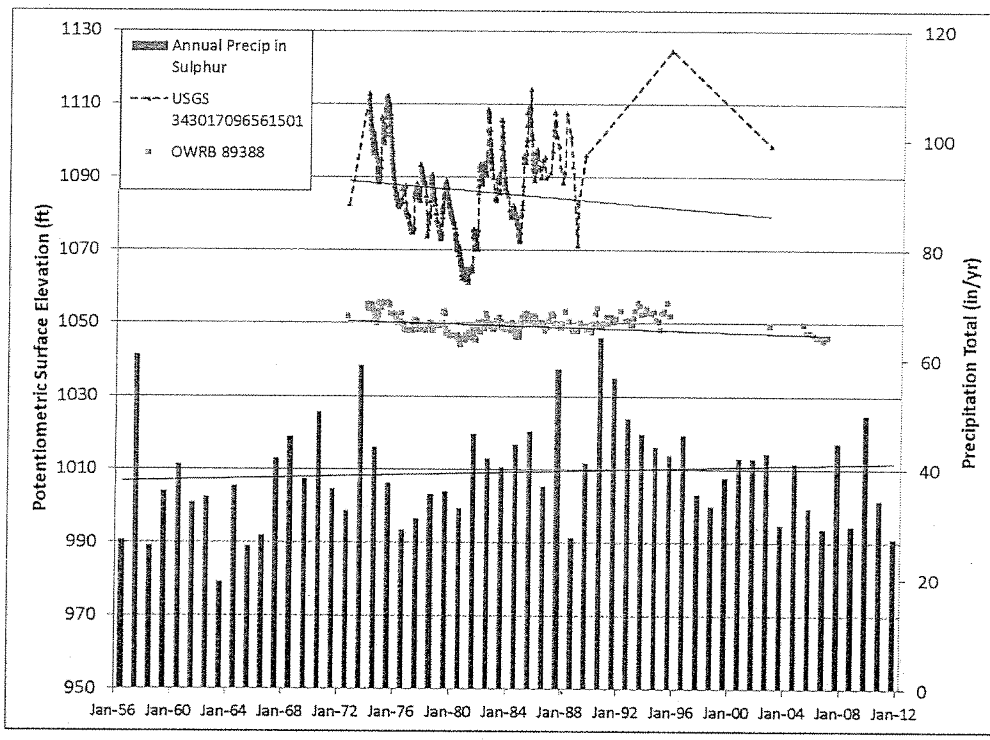

Figure 8: Groundwater levels in ECA wells and precipitation with superimposed linear trend lines

These comparisons of annual-scale precipitation data to groundwater levels confirm the statement by Hanson and Cates (1994) and suggest that shorter-term (e.g., monthly, weekly, or daily time-scale) comparisons of climatic variability and consumptive use to hydrologic fluctuations are warranted. It is imperative to carefully define these relationships before implementing regulatory controls on municipal or industrial consumptive use.

3.3 Continue Monitoring of Established Monitoring Points

OGS proposes to continue monitoring that was previously carried out by the OWRB in the ECA and EUA, including quarterly monitoring in synoptic events and continuous water levels in wells that were instrumented with pressure transducers. OGS also proposes to be the steward of continued spring and stream discharge monitoring at existing points. These activities would be coordinated with OWRB and USGS to ensure that there is no duplication of effort.

3.4 Monitor or Instrument New Monitoring Points

The goal of this task would be to identify a broad network of monitoring points (e.g., wells, springs or streams) in the western and central segments that could be monitored on a quarterly basis throughout the project period. OGS would request access to potential monitoring points and ensure a cooperative arrangement with the property owner for the duration of the project. Coordinates (longitude and latitude) and measuring point elevation would be confirmed and basic infrastructure assessed (e.g., well diameter or well depth) so that field records could be matched against any existing records for the potential monitoring point. Necessary site modifications (i.e., channelization of spring discharge) would be considered and implemented when possible. Quarterly synoptic monitoring would occur throughout the project period. During the second year of the proposed project, after selecting a reasonable set of monitoring points, approximately 8 wells and 2 springs or streams in the WA and CA would be instrumented with pressure transducers (e.g., Solinst LeveLogger Model 3001) for continuous (i.e., 15-minute interval measurement) monitoring. Water level and discharge data would be downloaded on a quarterly basis and incorporated into the project geodatabase.

3.5 Disseminate Basin-Wide Hydrologic Data and Assessment

Hydrologic data and hydrogeologic characteristics will be reported on an annual basis to the sponsoring agency, and published in an OGS open-file report. The PI of the proposed project and key personnel will present the results and findings at annual scientific meetings or at public forums designated by the sponsoring agency. Data, reports, and presentations will be posted to an OGS/OU maintained web-site dedicated to the project.

4 EXPECTED PRODUCTS AND OUTCOMES

4.1 Products

An annual report describing progress on the Augmented Hydrologic Assessment of the Arbuckle-Simpson Groundwater Basin would be submitted to the primary funding agency, and published as an OGS Open-File Report. Data compiled and collected during the proposed project would be maintained in a format (e.g., ArcGIS geodatabase using the ArcHydro data model) that could be easily updated and served via the internet to stakeholders in the Arbuckle-Simpson Groundwater Basin. The geodatabase developed during the proposed project would be delivered electronically to the primary funding agency at the end of the project performance period. Extensions of this proposed project may include automatic telemetry of groundwater well, spring and streamflow, or climatic data to a publicly accessible Arbuckle-Simpson data repository.

4.2 Outcomes

Anticipated outcomes of the proposed project are: (1) a quantitative understanding of the western and central segments including: temporal and spatial variability of hydrologic conditions, groundwater flow patterns, hydraulic properties of aquifer material, role of faults and fractures in recharge and groundwater flow; and (2) a public awareness of Arbuckle-Simpson Groundwater Basin-wide conditions because of OGS cooperation with all stakeholders and information dissemination via reporting and public presentation.

5 PROJECT MANAGEMENT

The project presented in this proposal is expected to require cooperation and coordination between numerous stakeholders in the state of Oklahoma. OGS would build the cooperative relationships required for a successful project and welcome contributions from all stakeholders. A short description of the primary institution and lead principal investigator are provided;

however, OGS is willing to assemble a multi-institutional project team to complete the proposed project.

5.1 Primary Institution

The OGS in the Mewbourne College of Earth and Energy at The University of Oklahoma (OU) is the lead agency presenting the proposed project. The OGS is chartered in the Oklahoma Constitution and is charged with investigating the state's land, water, mineral, and energy resources and disseminating the results of those investigations to promote the wise use of Oklahoma's natural resources. Because the OGS serves the state of Oklahoma as a research and service agency, while maintaining an academic affiliation it is well positioned to provide the proper combination of scientific knowhow, resource base, and public coordination.

5.2 Personnel

Dr. Kyle E. Murray, Hydrogeologist for the OGS, is the lead principal investigator for the proposed project. Between 2004 and 2011 Dr. Murray lived in San Antonio, TX and conducted research in south Texas and the Edwards Aquifer region as a faculty member with the Center for Water Research at the University of Texas at San Antonio (UTSA). His projects in the Edwards Aquifer region included assessing the relationship between groundwater flow direction and geologic structure in the recharge area of the Edwards aquifer using optical brighteners as incidental tracers, developing guidelines for best management of natural waterways, treating biofouling of groundwater wells, and conducting a system-wide water audit for the San Antonio Water System. His breadth of experience in the Edwards Aquifer Region and many other hydrogeologic settings would be of great value to this type of project that involves scientific investigation, geospatial and temporal data integration, public coordination, and regulatory awareness. Dr.Murray'sCV and most relevant project experience is included as an appendix to this proposal.

A staff scientist and graduate student would work under the supervision of Dr. Murray to complete the proposed project tasks. Skills and experience of the technical staff would include geologic and hydrogeologic sampling, electronic instrumentation, database management, web-page publication, and GIS.

6 FACILITIES AND EQUIPMENT

6.1 Laboratory Space and Equipment

Dr. Murray's Hydrogeology Lab was established in January 2012 for the purpose of developing hydrogeologic research projects that are most critical to water issues in the state of Oklahoma. The 440 square-foot facility in Sarkeys Energy Center at OU will serve as a staging and testing area for field hydrology equipment, bench-top experiments, computer-based data processing, GIS integration, and modeling. The Hydrogeology Lab is located adjacent to the OGS Seismic Network facility, which may allow for shared computing resources in the event that automated telemetry is desired in the long-term maintenance and operation of an Arbuckle-Simpson monitoring network.

6.2 Field Vehicles and Equipment

The OGS and OU fleet services maintain several 2-wheel and 4-wheel drive vehicles that are available to OGS staff for travel and field research. Hydrogeologic field equipment and instrumentation required for the project will be borrowed from the OGS Hydrogeology Lab for use during the project. Pressure transducers and related instrumentation needed for the proposed continuous monitoring points are included in the requested project budget.

7 PROPOSED BUDGET AND TIMELINE

The proposed project performance period is July 1, 2012 through June 30, 2017 – a 5-year project period coinciding with the OU and OGS fiscal years (2013 through 2017). The proposed budget uses an indirect cost rate of 26%, which was approved by OU's Office of Research Services assuming that the primary funding agency would be another state agency.

7.1 Annual Costs and Timeline

Proposed project costs are shown in Table 2 and a tentative project task timeline is given in Table 3. Many of the project tasks will occur simultaneously and will need to be flexible to allow OGS staff to coordinate with cooperating stakeholders.

Table 2: Proposed project budget using OU budget categories and 26% indirect cost rate

BUDGET CATEGORY	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	ALL YEARS
A. SENIOR PERSONNEL - Salary	$ 24,000	$ 24,720	$ 25,461	$ 26,225	$ 27,012	$ 127,418
B. OTHER PERSONNEL - Salary/Wages	$ 64,000	$ 86,800	$ 89,404	$ 92,086	$ 94,849	$ 427,139
C. FRINGE BENEFITS (5.5% for student, 46.2% for faculty/staff)	$ 39,028	$ 41,347	$ 42,587	$ 43,865	$ 45,181	$ 212,008
D. PERMANENT EQUIPMENT	$ -	$ -	$ -	$ -	$ -	$ -
E. TRAVEL (Domestic or International)	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 50,000
F. PARTICIPANT SUPPORT COSTS	$ -	$ -	$ -	$ -	$ -	$ -
G. OTHER DIRECT COSTS (Supplies, Publication Costs, Tuition)	$ 8,640	$ 32,000	$ 12,120	$ 12,244	$ 12,371	$ 77,375
H. TOTAL DIRECT COSTS (A THROUGH G)	$ 145,668	$ 194,867	$ 179,572	$ 184,420	$ 189,413	$ 893,940
I. INDIRECT COSTS: (26% on all direct costs, except tuition)	$ 37,707	$ 49,625	$ 45,618	$ 46,846	$ 48,111	$ 227,907
J. TOTAL COSTS	$ 183,375	$ 244,492	$ 225,190	$ 231,266	$ 237,524	$ 1,121,847

Table 3: Tentative project task schedule and timeline

Proposed Project Task	YEAR 1				YEAR 2				YEAR 3				YEAR 4				YEAR 5			
	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4	Qtr1	Qtr2	Qtr3	Qtr4
3.1 Compile Existing Hydrologic and Climatic Data	■	■	■	■																
3.2 Evaluate Trends in Hydrologic System			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
3.3 Continue Monitoring of Established Monitoring Points	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
3.4 Monitor or Instrument New Monitoring Points					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
3.5 Disseminate Basin-Wide Hydrologic Data and Assessment		■		■		■		■		■		■		■		■		■		■

7.2 Budget Justification

Brief descriptions of the expected costs in each budget category shown in Table 2 are provided here:

A: Senior Personnel (Dr. Kyle E. Murray) would be dedicated to the proposed project 24% during each fiscal year (FY). As principal investigator (PI), Dr. Murray would be responsible for project management and deliverables.

B: Other Personnel would include a staff level scientist (TBD) at 100% each FY and a graduate student (Mr. Jordan Carrell for part of FY2013-FY2014; TBD for FY2015-FY2017) at 50%. The staff level scientist would coordinate day-to-day project activities with the PI and cooperating stakeholders. Graduate students would work directly with the staff scientist to complete project activities.

C: Fringe Benefits are provided to OU/OGS staff at 46.2% of their salary, and at 5.5% for student salary/stipend.

D: Permanent Equipment is not requested.

E: Travel is expected between Norman, OK and the Arbuckle-Simpson Groundwater Basin or Oklahoma City, OK to complete field activities or project progress meetings at least twice per quarter. Travel expenses associated with this in-state travel may include lodging, fuel, per diem, and incidentals to support OGS vehicles and staff. The PI and staff level scientist would attend a minimum of one public presentation and one scientific meeting per FY to disseminate project findings to the public, academic and professional community.

F: Participant Support Costs are not requested.

G: Other Direct Costs include miscellaneous field, laboratory, computer, or publication costs incurred by OGS during the project period. One-half of graduate student tuition is also budgeted with the other half being an OU cost share.

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9 APPENDIX

KYLE E. MURRAY - CV

EDUCATIONAL BACKGROUND

Doctor of Philosophy, Geological Engineering, Minor: Computer Science *2003*
Colorado School of Mines, Golden, CO

Master of Science, Geological Sciences, Concentration: Hydrogeology *1997*
Wright State University, Dayton, OH

Bachelor of Arts, Geography/Environmental Studies *1995*
Shippensburg University, Shippensburg, PA *CUM LAUDE*

PROFESSIONAL EMPLOYMENT HISTORY

Hydrogeologist *2011 - present*
Oklahoma Geological Survey, The University of Oklahoma, Norman, OK

Assistant Professor *2004 - 2011*
Department of Geological Sciences, The University of Texas at San Antonio, San Antonio, TX

Research Associate *2003 - 2004*
Department of Geology & Geological Engineering, Colorado School of Mines, Golden, CO

Hydrologist/GIS Specialist *1999 - 2003*
Earth Surface Processes Team, Geologic Division, U.S. Geological Survey, Denver, CO

Hydrogeologist *1997 - 2000*
Harding Lawson Associates, Engineering and Environmental Services, Denver, CO

Instructor *1995 - 1997*
Center for Ground Water Management, Wright State University, Dayton, OH

MOST RELEVANT RESEARCH AND SCHOLARLY ACTIVITY

Refereed Journal Articles

Muhlestein, K.N., and Murray, K.E., 2012-*in preparation*, Multi-scale variation and certainty in emissivity and thermal signature patterns for karst limestone features. *For submission to*: Journal of Geophysical Research.

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