Baton Rouge Geological Society

2nd Annual Louisiana Groundwater Symposium

March 6, 2008

Louisiana Groundwater A Valuable Resource

Energy Coast & Environment Building
Louisiana State University
Baton Rouge, Louisiana

Hosts:

Louisiana Geological Survey

Baton Rouge Geological Society

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Presentation Schedule

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Authors

Theme One: Groundwater Chemistry Throughout Louisiana

March 6, 2007
9:00 am to 11:45 am
Dalton Wood Auditorium

Moderators:

Douglas Carlson
Louisiana Geological Survey

and

Thomas Van Biersel
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Distribution of Chloride concentration in shallow domestic wells screened into the Wilcox Aquifer in the Vicinity of Shreveport, Louisiana

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ABSTRACT

Sampling performed by the Louisiana Geological Survey under a grant from the Louisiana Dept. of Transportation and Development during the fall of 2007 delineated two additional locations in Caddo parish where groundwater concentration of chloride exceed the U.S. Environmental Protection Agency's National Secondary Drinking Water Standard. This data, combined with data from the U.S. Geological Survey identifies at least a dozen locations where the source of the elevated chloride concentration was investigated. The distribution of elevated concentration in the locally shallow Wilcox Aquifer was compared to the distribution of potential surficial and at depth sources. The sources under consideration are the saline Red River, several saline lakes, oil wells/fields, and faulting. The wells sampled were drilled to a depth of 100 to 290 feet below the surface. Locally, the next deeper (~1000 feet) sands are saline and unusable for drinking water purposes, but are separated from the freshwater sands by approximately 600 to 700 feet of clay.

The result of the investigation indicates that most areas where excessive groundwater salinity has been discovered are location at or near surface water bodies which are known to have elevated salinities themselves. Also those locations have little or no surficial clays protecting the aquifer. Furthermore, most locations are located near areas where the piezometric surface is depressed. The elevated saline concentration near Hosston, LA and Black Bayou Lake may be further affected by the presence of faulting.

Chloride Concentrations in Ground Water in East and West Baton Rouge Parishes, Louisiana, 2004-05

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ABSTRACT

Increasing chloride concentrations are a threat to fresh ground-water sources in East Baton Rouge and West Baton Rouge Parishes, Louisiana. Large withdrawals in Baton Rouge have lowered water levels and altered flow patterns in most of the 10 aquifers that underlie the area. Prior to development, freshwater flowed southward to the Baton Rouge fault, an east-west trending growth fault that extends through Baton Rouge and across southeastern Louisiana. Aquifers south of the fault generally contain saltwater. Ground-water withdrawals north of the fault have created gradients favorable for the movement of saltwater from south of the fault into freshwater areas north of the fault.

Water samples were collected from 152 wells during 2004–05 to document chloride concentrations in aquifers underlying East and West Baton Rouge Parishes. The background concentration for chloride in fresh ground water in the Baton Rouge area north of the Baton Rouge fault is generally less than 10 milligrams per liter. Chloride concentrations exceeded 10 milligrams per liter in one or more samples from wells north of the fault screened in the "600-foot," "1,000-foot," "1,200-foot," "1,500-foot," "1,700-foot," "2,000-foot," "2,400-foot," and "2,800-foot" sands. Comparison of the 2004-05 data with historical data indicated that chloride concentrations are increasing at wells in the "600-foot," "1,000-foot," "1,200-foot," "1,500-foot," "2,000-foot," "2,400-foot," and "2,800-foot" sands north of the Baton Rouge fault.

Evidence that filtered samples miss significant contribution of particles for the concentration of various chemical species consumed by well owners

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ABSTRACT

Generally, the filtered water sample collected from wells tapping a sand aquifer yield a representative concentration for various chemical species for the aquifer pore water, but not for the water ingested by the homeowner. In this study, we researched the relationship between the filtered and unfiltered values for a number of elements/ions. From a study of 154 samples collected from 77 wells tapping the Wilcox Aquifer, this is maybe true for only common ions. Samples were collected from a set of domestic and business wells in Caddo Parish. Prior to sample collection the wells were purged on average for 24 minutes yielding a volume removed on average of 150 gallons. This volume is larger than that within pressure tanks, typically 50 gallons, and typically more than the sum of pressure tank and casing volume. After purging, two 45 milliliter samples were collected, one was filtered through a 0.45 micron filter in the field within minutes of collection and the other was unfiltered. Both of these samples were acidified and placed on ice within minutes of collection. Analysis of these samples was completed using the LSU Department of Wetland Biochemistry's Varian Inductively Coupled Plasma-Optical Emission Spectrometer. Concentrations were reported in parts per million (ppm) values. The reduction of concentration was determined due to filtration for between 7 and 77 pairs of samples for 19 chemical species: Al, As, B, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Pb, Rb, Si, Sr, and Zn. Before comparisons of filtered and unfiltered values were completed statistical analysis was performed to removed extreme outliers (observations over 4 standard deviations from the mean) to obtain results based on the vast majority of observations (on average 97 percent of observation pairs) rather than over influence of a few extremely unusual observations.

After completing the statistic analysis, it was determined that filtration removes a significant portion of 13 species with only As, B, Cd, Cr, Ni and Sr as the exceptions. For the other 13 species (Al, Ca, Cu, Fe, K, Mg, Mn, Na, P, Pb, Rb, Si, and Zn), the reduction of species concentration due to filtration is significant with a confidence of that difference over 95%. For nine of the species (Al, Cu, Fe, K, Mg, Mn, Na, P, and Si,), the confidence of difference is over 99.5%. However, the percentage reduction is generally smaller for common ions such as: Ca, K, Mg, Na and Si, which is on average is 2.26% $\pm$ 2.50%. The reduction for minor ions, such as Fe, P, and Sr, is on average is 11.66% $\pm$ 19.46%. For trace ions, such as Al, Cu, Mn and Zn, is on average is 18.61% $\pm$ 39.01%.

As the concentration of species decreases the impact of filtration is an increasing share of a species that is removed, as indicated by the increasing average reduction.

Relations between the composition and mobility of adsorbed cations and the salinity of ground water at a brine-contaminated site in Assumption Parish, Louisiana

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ABSTRACT

Environmental concerns related to crude oil and natural gas exploration and production include: the improper disposal of waters co-produced with hydrocarbons, accidental releases of these fluids, and improperly plugged and abandoned oil and gas wells (Kharaka and Dorsey, 2005; Kharaka and Otten, 2007). The volume of waters co-produced with oil and gas is immense. In the year 2002 alone, 93 x 10^6 bbl (1 bbl = 0.159 m^3) of crude oil and over 1 x 10^9 bbl of co-produced water (Vail et al., 2004) were produced in Louisiana, a volume ratio of water to oil of over 10 to 1. Although most produced waters in Louisiana are disposed of today by underground injection, there are many examples of near surface contamination produced by leaks and by the storage of produced brines in unlined surface pits (Hanor, 1997).

The first ground waters impacted by produced oil-field brines released into near-surface environments in south Louisiana are typically interstitial waters in shallow clay and silt beds (Hanor 1995). Clay minerals within these siliciclastic sediments have the potential for altering the composition of produced water wastes through cation exchange. A large data base of analyses of exchangeable cations in sediments from a near-surface brine-contaminated site in the Napoleonville oil and gas field, Assumption Parish, LA (Fig. 1), provides an unusual opportunity to establish the general relations between the composition and mobility of adsorbed cations and ground water salinity (Hanor, 2007). The divalent cations Ca^{2+} and Mg^{2+} dominate as adsorbed cations at low salinities (TDS <1200 mg/L), but the monovalent cation Na^+ is dominant at moderate to high salinities (TDS =1200 to 53,000 mg/L). The change in the proportions of adsorbed cations is a non-linear function of salinity, and the transition from Ca-dominated adsorption to Na-dominated adsorption occurs over a narrow range of salinities. The shift from preferential adsorption of divalents to monovalents with increasing salinity is controlled by mass-balance and thermodynamic constraints (Appelo and Postma, 2005). Calculated interstitial water compositions, assuming exchange equilibrium between waters and clays, are consistent with the source of contamination being produced waters having Na as the dominant dissolved cation, followed by Ca, rather than some other type of saline waste or a naturally-occurring shallow saline water.

The divalent cations barium, Ba^{2+}, and radium, Ra^{2+}, are elements of both environmental concern and common constituents of produced waters (Zielinski and Budahan, 2007). The calculated partitioning for Ba at the Assumption Parish site

indicates that in low to moderate salinity pore waters, Ba, and by extension Ra, is nearly quantitatively adsorbed on the clays and would thus have low physical mobility in an active ground water flow system. However, at the elevated salinities typical of many produced waters, Ba and Ra would be preferentially partitioned into the aqueous phase and could thus be transported by ground water. However, the presence of dissolved sulfate could cause them to precipitate out instead as radioactive barite, $(Ba,Ra)SO_4$.

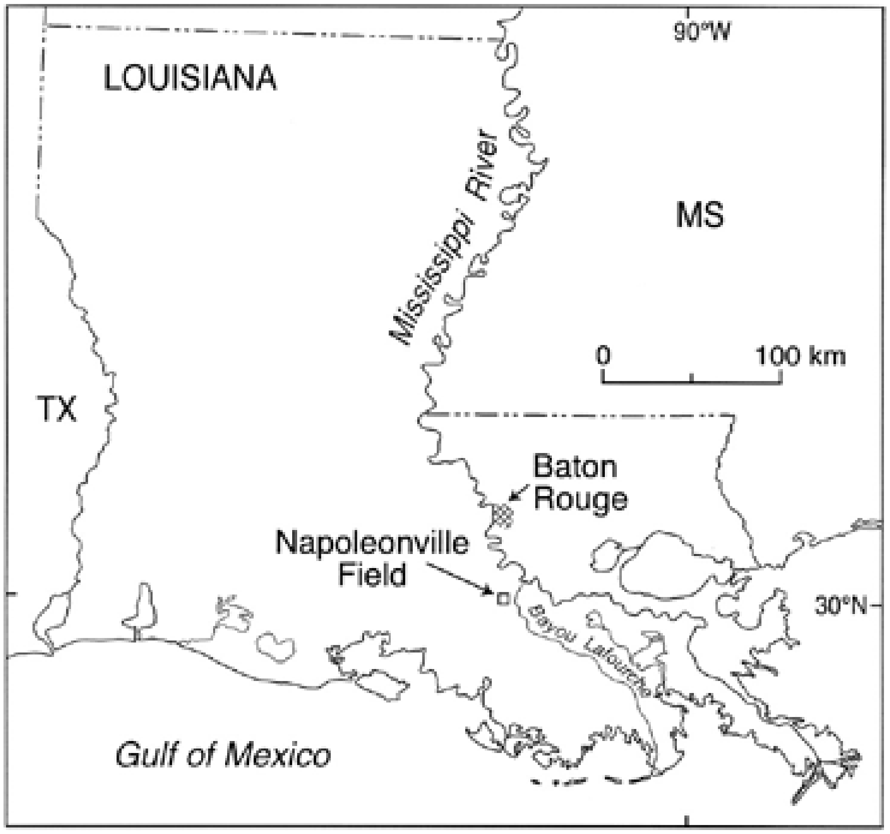

Figure 1. Map of Louisiana showing the location of the Napoleonville oil and gas field.

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Anatomy of Saltwater fronts observed within geophysical logs in East Baton Rouge Parish

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ABSTRACT

For the past fifty years it has been observed that there are fronts of advancing saline water moving northward in Baton Rouge towards a center of water demand under the industrial area north of downtown Baton Rouge. Numerous studies have documented the advance of salt water fronts throughout most of the ten sand aquifers that supply Baton Rouge area with water. A question that has not been considered is what is the water quality across an advancing front? By chance several petroleum wells were drilled and logged across the advancing fronts of saline water. These fronts lie in the "1,200 foot sand ", "1500 foot sand" "2,000 foot sand" and "2800 foot sand".

The total dissolved solids (TDS) profile is determined from analysis of geophysical logs and with an application of Archie's Law. This involves the interpretation of porosity logs to determine porosity within sands of interest. With porosity data and observed resistivity values, Archie's Law is used to determine the water resistivity. This value is converted into specific conductance and then TDS using a standard relationship between specific conductance and TDS for water. Values of TDS are determined every 5 ft (1.67 m) within the profile.

From the analysis of seven profiles, it appears that the decrease in resistivity across profiles is approximately a linear decrease downwards through the advancing front of saltwater. This in turn yields an approximately exponential increase in specific conductance and TDS downwards through the front. This increase range from approximately to 140 to 1590% increase, with an average of 470 %, in TDS from the top to the base within sands.

Theme Two: Groundwater Use, Resources and Value in Louisiana

March 6, 2007
1:15 pm m to 2:45 pm
Dalton Wood Auditorium

Moderators:

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Groundwater a Bargain that Saves Louisiana Citizens Millions of Dollars

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ABSTRACT

It is said that oil wells produce money and water wells cost money. This is true because oil sales for approximately $2.5/gallon, while water sells for approximately $2/1000 gallons. However, the question to consider is: what source of water is more costly for use by consumers, groundwater or surface water? This is where groundwater shows its value by saving millions of dollars.

Studies indicate that a number of factors influence the cost of water charged by public utilities (population served, population density of served area, average demand, type of source, supplier of water). One of the most important factors is the source of water. Of two large utilities in Louisiana; Baton Rouge is the largest utility that is totally supplied by groundwater from sands approximately 800 ft to 2,800 ft below the surface. In comparison, New Orleans is totally supplied by the Mississippi River. The rate for the smallest residential consumer in 2005 is $1.50/1000 gallons for Baton Rouge utility compared to $2.30/1000 gallons for New Orleans. This difference yields approximately 18 million dollar savings for Baton Rouge consumers over the past year. If you consider the whole State of Louisiana, the comparison of groundwater versus surface water utilities yields an average savings is $0.71/1000 gallon for groundwater. This occurs even though the average groundwater supplied utility in this study had a daily pumpage of one million gallons per day (mgd) versus pumpage of 16 mgd for the average surface water supplied utility, thus at a disadvantage due to size alone. Considering groundwater pumpage and average rate savings, the resulting savings in 2000 is estimated to be approximately 100 million dollars. More over the present savings as a result of using groundwater is probably greater due to inflation since 2000. So, although water costs money, groundwater is a source that saves the citizens of Louisiana over a hundred million of dollars every year.

Water Withdrawals and Trends in Ground-Water Levels and Water Use in Louisiana, 1996-2005:

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ABSTRACT

In 2005, approximately 10,299 Mgal/d (million gallons per day) of water was withdrawn from ground-water and surface-water sources in Louisiana; about 15 percent was ground water, and 85 percent was surface water. Total water withdrawals in the State increased about 6 percent from 1995 to 2005. Approximately 92 percent of the ground water withdrawn was from the six aquifers or aquifer systems: the Chicot aquifer system (42 percent), Mississippi River alluvial aquifer (26 percent), Jasper equivalent aquifer system (8 percent), Chicot equivalent aquifer system (7 percent), Evangeline equivalent aquifer system (6 percent), and Sparta aquifer (4 percent). Four of these, the Chicot, Evangeline equivalent, and Jasper equivalent aquifer systems, and the Sparta aquifer, contain areas where declines in ground-water levels were greater than or equal to 1 ft/yr (foot per year) during the approximate period 1996-2005. Approximately 83 percent of ground-water withdrawals in 2005 were for irrigation, public supply, and industry.

Water level trends in selected aquifers and aquifer systems were determined for the approximate period 1996-2005 utilizing water-level data collected from 151 wells. For each well a rate of water-level change, represented by the slope of the trend line, was computed by statistical analysis. Rates of water-level change for 15 wells screened in the Mississippi River alluvial aquifer ranged from -0.4 to +0.2 ft/yr. No regionally extensive areas of decline (less than or equal to -0.5 ft/yr) or rise (greater than or equal to 0.5 ft/yr) were determined. The wells, except well Ib-106 in Iberville Parish, are located in the northern half of Louisiana. Withdrawal rates for the Mississippi River alluvial aquifer have risen since 1995 primarily because of increased irrigation and aquaculture withdrawals.

The water-level surface throughout most of the Chicot aquifer system is greatly influenced by seasonal withdrawals for rice irrigation. In the Lake Charles area, ground-water withdrawals for industry and public supply also affect water levels. Rates of water-level change for 26 wells screened in the Chicot aquifer system indicate water levels generally declined between 0 and 1.1 ft/yr in the rice-growing areas. In Calcasieu Parish, water levels generally rose in response to decreased withdrawal rates in the “500-foot” sand of the Lake Charles area.

Water-level data from 26 wells screened in the Chicot equivalent aquifer system

indicate water-level changes ranged from -0.8 to +2.1 ft/yr. A comparison of water-level changes for the periods 1990-2000 and 1996-2005 indicate water levels in the “400-foot” and “600-foot” sands are declining at lower rates or rising. Since the early 1970’s, water levels have risen in the New Orleans area in response to decreased ground-water withdrawals.

Water-level data from 31 wells screened in the Evangeline equivalent aquifer system indicate water-level changes ranged from -5.5 to +0.5 ft/yr. In the deep aquifers of the system, rates of water-level decline were greatest in East and West Baton Rouge parishes and can be attributed to ground-water withdrawals. A comparison of water-level changes for the approximate periods 1990-2000 and 1996-2005 indicate water levels in the “800-foot” sand generally are declining at a lower rate, while levels in the “1,200-foot” and “1,700-foot”sands generally are declining at a higher rate. Water levels generally declined in the “1,500-foot” sand, lower Ponchatoula, Big Branch, Kentwood, Abita, and Slidell aquifers during the period 1996-2005.

Water-level data from 33 wells screened in the various aquifers of the Jasper equivalent aquifer system indicate water-level changes ranged from -3.9 to -0.3 ft/yr during the period 1996-2005. The rates of greatest water-level decline, over 3 ft/yr, were in East Baton Rouge Parish and can be attributed to ground-water withdrawals. A comparison of water-level changes for the periods 1990-2000 and 1996-2005 indicate inconsistent water-level changes in the “2,000-foot” sand, while water levels in the “2,400-foot” and “2,800-foot” sands generally are declining at lower rates.

Ground-water withdrawals have substantialy lowered water levels in the Sparta aquifer. Water-level data from 20 wells screened in the Sparta aquifer indicate water-level changes ranged from -2.2 to +0.2 ft/yr. Water levels declined throughout most of the Sparta aquifer with the exception of the outcrop and northwestern areas. The highest rate of decline, greater than 2 ft/yr, was in southeastern Winn Parish. Declines generally were less than 1.5 ft/yr in most of the aquifer. A comparison of water-level changes for the periods 1990-2000 and 1996-2005 indicate water levels generally are declining at a lower rate; 9 of 11 wells have improved rates of change. Contributing factors to lower rates of change between 1996 and 2005 include reduced withdrawals in Bienville Parish and Jackson Parish. Conservation efforts in Arkansas have affected water levels in the Sparta aquifer in Louisiana; water levels in northern Claiborne Parish have been rising since about 2000.

GROUND-WATER RESOURCES IN RAPIDES PARISH, LOUISIANA, 2005

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ABSTRACT

In 2000, about 36.6 million gallons per day (Mgal/d) of water was withdrawn from aquifers that underlie Rapides Parish. The most used aquifers in the parish include the Carnahan Bayou (12.6 Mgal/d), upland terrace (10.5 Mgal/d), Williamson Creek (7.1 Mgal/d), and Evangeline (2.8 Mgal/d) aquifers. The cities of Alexandria and Pineville were the largest ground-water users (21.1 and 2.8 Mgal/d in 2000). Water managers and planners are concerned about the capability of aquifers in Rapides Parish to supply sufficient water for future growth.

The Red River alluvial aquifer underlies about 30 percent of Rapides Parish. The Red River alluvial aquifer yields water that is very hard (greater than 180 mg/L, milligrams per liter, as calcium carbonate, $CaCO_3$), and iron and manganese concentrations generally exceed the U.S. Environmental Protection Agency Secondary Drinking Water Regulations (SDWR's). Local areas contain saltwater (chloride concentrations greater than 250 mg/L).

The upland terrace aquifer and Chicot aquifer system combined underlie about 60 percent of the parish. In western Rapides Parish, the aquifer/system yields freshwater that generally is soft (hardness less than 60 mg/L as $CaCO_3$) and does not exceed SDWR's for dissolved solids, chloride, iron, and manganese. About 8.2 Mgal/d was withdrawn from the Kisatchie well field in 2000, and water levels have declined locally 10 to 20 feet since 1968. Throughout most of western Rapides Parish the water table surface is close to predevelopment levels.

The Evangeline and Williamson Creek aquifers underly much of Rapides Parish. The aquifers contain freshwater that is soft and does not exceed SDWR's for dissolved solids, chloride, iron, and manganese. Water levels in the Williamson Creek aquifer generally range from 200 feet above the sea level in the outcrop area to 40 feet below sea level in withdrawal centers.

The Carnahan Bayou aquifer is extensive throughout Rapides Parish; however, large areas contain saltwater or freshwater that is underlain with saltwater. However, in much of the parish, the aquifer can yield water that is soft and does not exceed SDWR's for dissolved solids, chloride, iron, and manganese.

In the Alexandria-Pineville area and the Kisatchie well field area, increased

concentrations of chloride have been detected. Because saltwater is contained in the Carnahan Bayou aquifer nearby the Alexandria-Pineville and the Kisatchie well fields and in sediments underlying the aquifers, movement of saltwater into freshwater areas will likely continue under present pumping conditions.

Theme Three: Analysis of Louisiana Aquifers Involving Groundwater Modeling

March 6, 2007
3:00 pm m to 5:30 pm
Dalton Wood Auditorium

Moderators:

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Potential Contamination of Groundwater in the Kasatchi Forest In Central Rapides Parish, Louisiana

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ABSTRACT

During World War II 30,117 acres of the Kisatchie National Forest in central Rapides Parish was used for troop training and maneuvers. About a half-million men received training in the use of small arms, demolition, and chemical warfare from 1940 to 1945. After the war, Barksdale Air Force Base used part of the site for air-to-ground gunnery practice and bombing missions from 1997 to 1999. The area is now termed "Former Camp Claiborne" and has been "environmentally restored". Restoration consisted of combing the area using Geonics EM61 and G858 instruments for geophysical surface mapping, plus digging 914 excavations. The result was the removal of 114,095 pounds of scrap metal, practice bombs, and projectiles. A total of 26,703 items were found and detonated or scrapped beginning in August, 2000.

The significance of these activities is that part of Former Camp Claiborne overlaps the Kisatchie well field, which is the primary source of drinking water for the City of Alexandria. Remaining unlocated ordinance and residues are potential sources of contamination of groundwater in the surficial Upland Terrace aquifer that blankets the area. A groundwater model contracted by the Louisiana Department of Transportation and Development was completed during 2006 and one of the purposes of the modeling was to determine directions of groundwater movement in the Upland Terrace aquifer, and the catchment areas of the individual wells in the well field (Nyman, 2006). The modeling indicated that groundwater movement is primarily northward, away from the well field, thus moving most of any possible contamination away from the well field. There are currently 19 active wells in the well field, screened in the Upland Terrace aquifer. During 2005 the total demand for the City of Alexandria was about 12.7 Mgal/d, of which the Upland Terrace wells provided an average of 6.1 Mgal/d. Catchment areas are best defined during periods of the highest pumping rates. Stress period 3 of the model reflected the pumping activity in 1980 when the well field was providing an estimated 22.95 Mgal/d to the city. A comprehensive suite of analyses for organic and inorganic chemicals was done during 2004, which included the Upland Terrace wells. No contamination was found, however, defining the catchment areas for each well will help determine the location of contamination, if contamination is found.

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Movement of Saltwater in the "2,000-foot" Sand of the Baton Roug Area, Louisiana

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ABSTRACT

A ground-water modeling study to evaluate saltwater movement towards pumping centers in Baton Rouge, Louisiana is currently underway through the cooperation of the U.S. Geological Survey, the Capital Area Ground Water Conservation Commission, and the Louisiana Department of Transportation and Development. Ground-water withdrawals in Baton Rouge have caused saltwater to encroach into some freshwater-containing sands of the fluvial-deltaic aquifer system beneath Baton Rouge.

Ground-water investigations in the 1960's delineated a freshwater-saltwater interface located at the Baton Rouge fault, across which abrupt changes in water levels also occur. Generally, aquifers south of the fault contain saltwater and aquifers north of the fault contain freshwater, though saltwater encroachment has been detected in six of the ten sand aquifers north of the fault.

Ground-water withdrawals from the "2,000-foot sand" aquifer in East Baton Rouge Parish, which totaled 22.7 Mgal/d in 2002, caused water levels to decline more than 250 feet and induced saltwater movement across the fault within the "2,000-foot sand". This saltwater contamination threatens industrial withdrawals from wells located about 4 miles north of the fault, which account for approximately 70 percent of the withdrawals from the "2,000-ft" sand in East Baton Rouge Parish.

A ground-water model is needed to evaluate strategies for mitigating the northward advance of the saltwater, which include different rates of discharging of saltwater from public-supply well fields located near the saltwater interface between the fault and the industrial district.

Preliminary cross-sectional models of variable-density flow and transport were made to determine appropriate horizontal and vertical discretization for simulating observed concentration breakthrough curves. A regional three-dimensional ground-water flow model of the area is being developed with SEAWAT, which simulates the local saltwater transport within the "2,000-foot sand."

Saltwater intrusion simulation for “1,500-foot’ sand, East Baton Rouge Parish, Louisiana

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ABSTRACT

This research studied the saltwater intrusion problem in East Baton Rouge (EBR) Parish. In EBR, there are fourteen freshwater aquifers. Thirteen of the aquifers were originally named according to their general depth in the Baton Rouge industrial district (Meyer and Turcan, 1955). Most of the aquifers have been reported the saltwater intrusion problem for more than fifty years due to excessive groundwater withdrawal. In this study, we focused on the "1,500-foot" sand, which is one of the major sources of drinking water in EBR. Groundwater withdrawal from the "1,500-foot" sand began in 1927 (Torak and Whiteman, 1982). From 1940 to 2001 water level has declined about 52.8 meters (160 ft) at the observation well EB-168. To better understand the on-going saltwater intrusion problem in the “1,500-foot” sand, this study adopted MODFLOW-2000 (Harbaugh et al. 2000) and MT3DMS (Zheng and Wang, 1999) to develop a saltwater intrusion model.

The study area shown in Figure 1 extended about 300 km^2 and included major part of the Baton Rouge metropolitan area. Northern area of the Baton Rouge Fault was the "1,500-foot" sand and southern area of the fault was the “1,200-foot” sand. Through the USGS National Water Information System website, we collected 706 groundwater head data from 18 observation wells located at the “1,500-foot” sand (see Figure 1A). These head data were recorded between January 1990 and December 2004 and were used to calibrate the groundwater model. The groundwater data at well EB-780A at the “1,200-foot” sand determined the south boundary condition. The Louisiana Capital Area Ground Water Conservation Commission (CAGWCC) provided monthly pumping data of 16 production wells located in the study area (see Figure 1B). The specific storage was 0.0000221 meter^{-1}. We used the groundwater data at EB-917 and EB-780A to estimate hydraulic characteristic (HC) for the Baton Rouge fault. The identified HC value was 0.000155 day^{-1}. USGS Water Resources Division in Louisiana provided electrical resistivity data at 21 E-log sites (see Figure 1A). The resistivity data determined the thickness of the “1,500-foot” sand as well as the average formation resistivity. We used the Archie’s law to interpret the formation factor into porosity and used the Kozeny-Carman equation to estimate hydraulic conductivity.

We adopted the generalized parameterization method (Tsai, 2006) and Bayesian model averaging (BMA) approach (Hoeting et al., 1999) to estimate the hydraulic conductivity distribution. Three GP methods were considered in the BMA including NN-VT (combination of natural neighbor interpolation and Voronoi tessellation methods), ID-VT (combination of inverse distance interpolation and Voronoi tessellation methods), and OK-VT (combination of ordinary kriging and Voronoi tessellation methods).

The groundwater model also incorporated the connector well, EB-1293, which connects the "800-foot" and "1,500-foot" sands. The CAGWCC installed EB-1293 between the municipal supply wells on Government Street and the freshwater-saltwater interface in the "1,500-foot" sand. The connector well started to operate in 1998 as an initial test of a recharge barrier to mitigate saltwater encroachment in the “1,500-foot” sand. The recharge rate from the "800-foot" sand was estimated around 500 gallons per minute (gpm) (CAGWCC Newsletter, January 2002). The groundwater model considered the connector well as a recharge well with a rate of 500 gpm.

After the groundwater flow model was completed, we simulated saltwater intrusion for 90 years based on the 15-year simulated groundwater heads between year 1990 and 2004. This would provide basic information on how saltwater intruded the “1,500-foot” sand. We used MT3DMS (Zheng and Wang, 1999) to simulate the saltwater intrusion. Density effect was not considered in this study. The initial salt concentration at January 1990 was assumed to be clean in the northern area of the fault and 1000 parts per million (ppm) in the southern region of the fault. Figure 2A showed the initial salt concentration distribution. We repeated the 15-year groundwater heads six times to simulate saltwater intrusion over a period of 90 years.

The simulation results in Figures 2B-2G showed the following observations: (1) Saltwater had strong lateral transport along the Baton Rouge Fault once it crossed the fault. The cause of saltwater intrusion is due to the huge cone of depression formed by the production wells at Lula Avenue. The salt dispersion width at the region east of EB-918 was around 850 meters from the fault and was almost unchanged after 30 years simulation. (2) Saltwater accumulated at two spots. One spot was at 600 meters southeast of EB-807A. Higher salt concentrations migrated clockwise across EB-807A toward the Lula Avenue pumping center. The other spot was at 2200 meters southwest of EB-807A. (3) The 100 ppm isochlor (the front line) migrated to the production well adjacent to the observation well, EB-1295A, before year 2035. (4) The 100 ppm isochlor first touched down the observation well, EB-918, and few years later it touched EB-807A. Due to the clockwise movement of saltwater along the fault from the east, the salt concentrations in EB-807A and EB-918 were similar. (5) The 100 ppm isochlor touched EB-917 and EB-792A almost at the same time. The simulation results showed similar salt concentrations in EB-917 and EB-792A due to the clockwise movement of saltwater along the fault. (6) Before year 2080, the 100 ppm isochlor reached the Lula Avenue pumping center. (7)

Saltwater began to move eastward approaching the Government Street pumping center after year 2035. (8) The connector well demonstrated halting the saltwater intrusion northward approaching the Government Street pumping center. (9) Although the saltwater was close to the Government Street pumping center, the simulation results showed that saltwater would reach the Lula Avenue pumping center before it reached the Government Street pumping center.

In inclusion, according to the simulation results major saltwater intrusion would bypass the current network of monitoring wells and reach the Lula Avenue pumping center within 75 years via the west side of EB-807A. An array of additional monitoring wells is suggested at the west of EB-807A to monitor the potential large saltwater intrusion.

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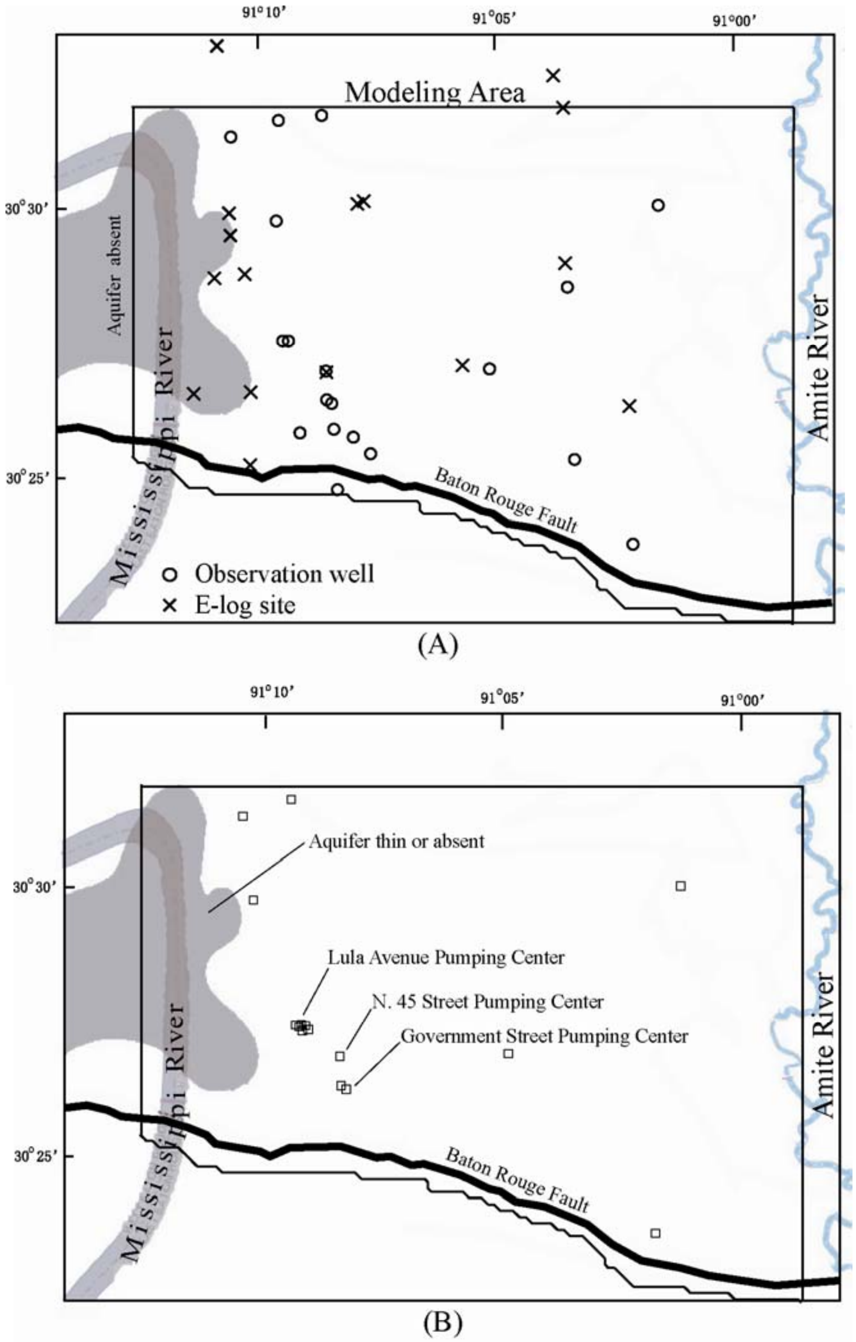

Figure 1. Study area. (A) Location of groundwater head observation wells and E-log wells. (B) Location of production wells. Area in gray is where "1,500-foot" sand is either missing or less than 10 feet thick.

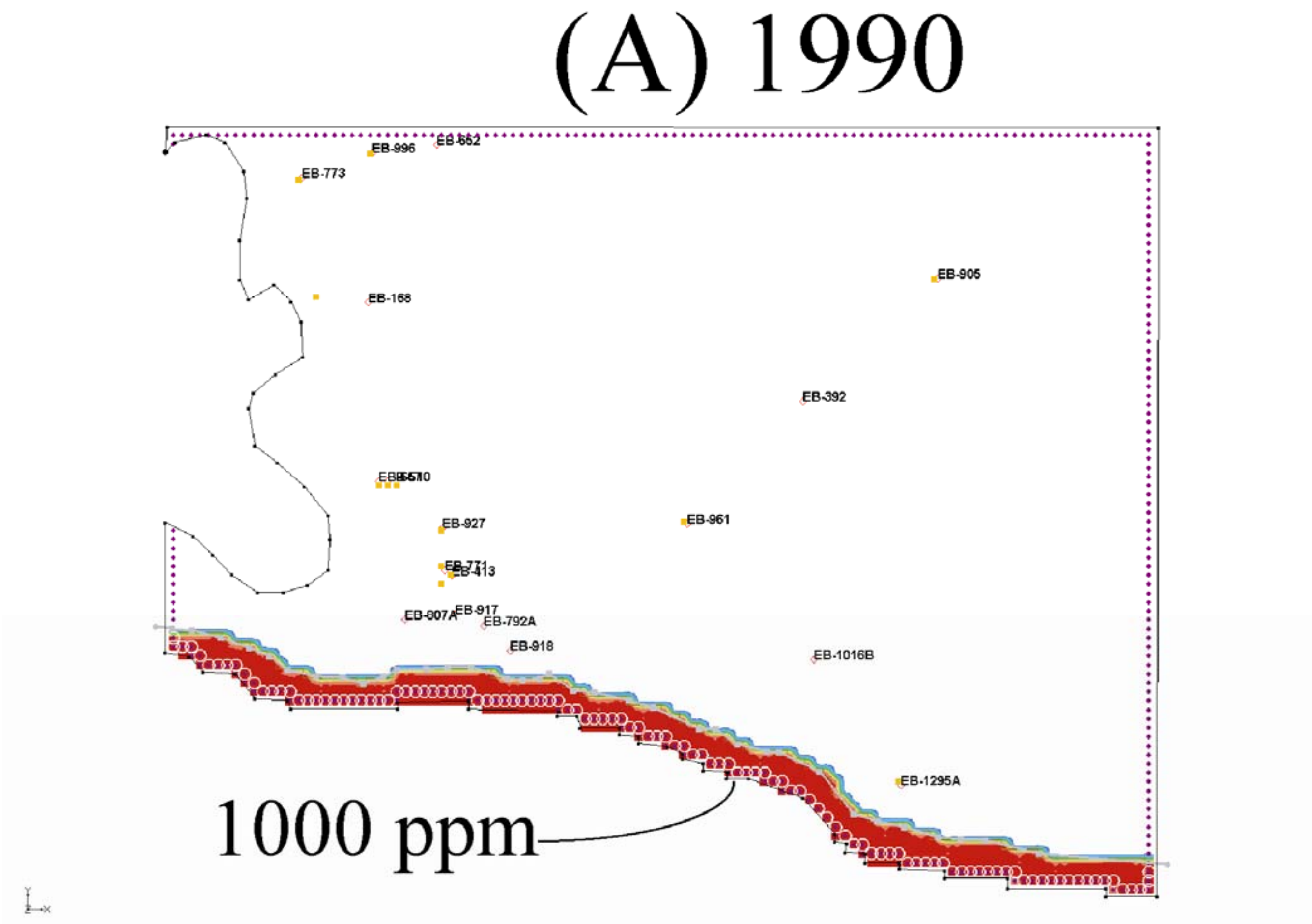

Figure 2. Results of 90-year saltwater intrusion simulation.

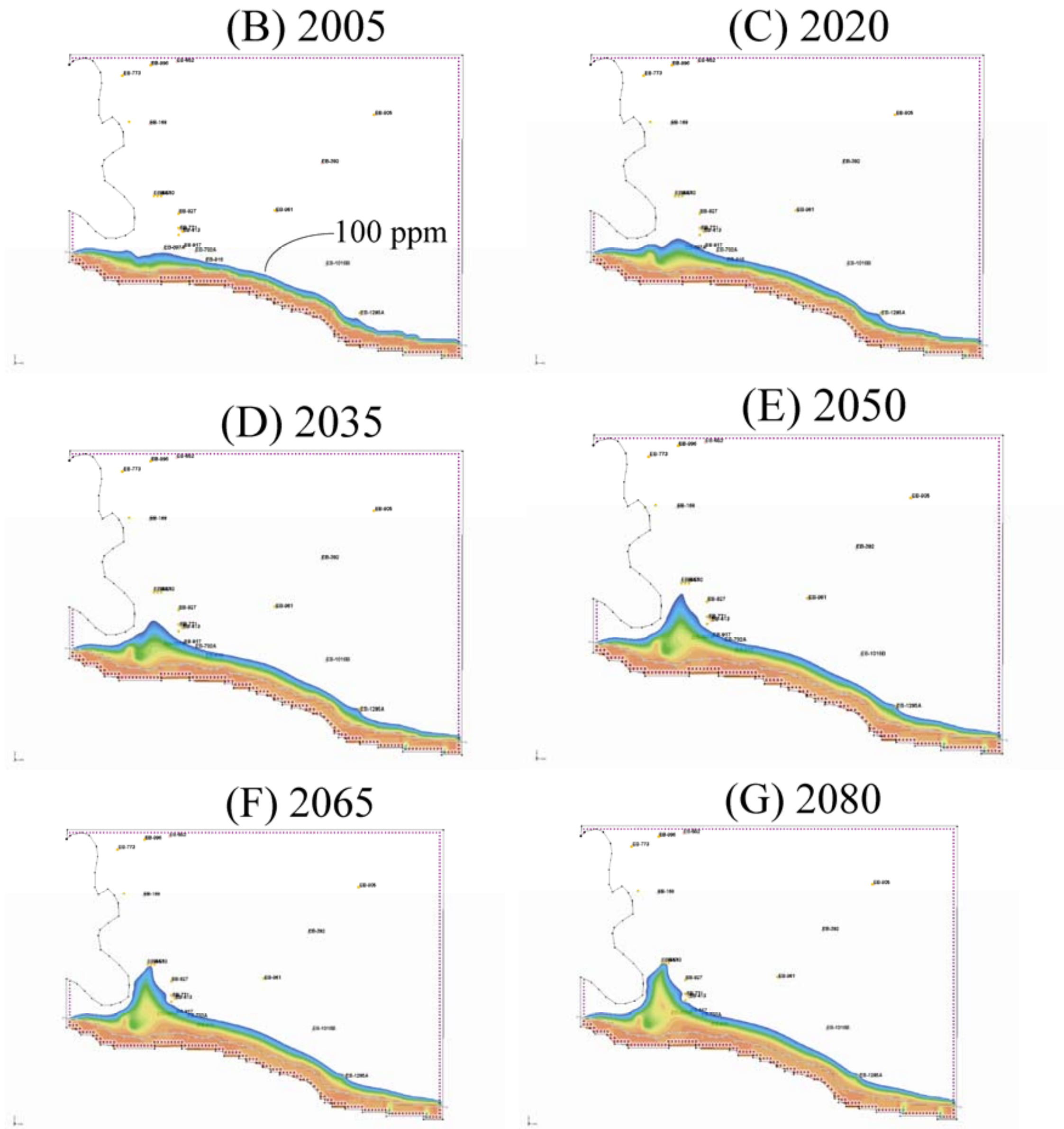

Figure 2. Results of 90-year saltwater intrusion simulation.

Uncertainty propagation using Bayesian multi-model multi-parameterization method

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ABSTRACT

In groundwater modeling, conflict between aquifer complexity and data insufficiency usually results in multiple interpretations of data, which can be represented by multiple conceptual models and multiple parameterization methods for distributed parameters. Relying on only one conceptual model and one parameterization method is prone to biased prediction and tends to underestimate prediction uncertainty. In this study, we present a systematic procedure to predict groundwater heads by Bayesian model averaging (BMA) on multiple conceptual models and multiple parameterization methods. Uncertainty propagation from parameterization uncertainty to prediction uncertainty is also studied. The proposed method is applied to groundwater head predictions on the "1,500-foot" Sand in East Baton Rouge Parish, Louisiana. MODFLOW was used to simulate groundwater flow for 15 years and to solve adjoint equations to obtain the Jacobian matrix. Based on the Baton Rouge Fault structure, we developed three conceptual models: one model with low fault permeability, one model with impermeable fault, and one model without fault. For each model, we applied seven grain size-based methods and Archie law to estimate hydraulic conductivity values at e-log sites and applied seven parameterization schemes using the generalized parameterization method Is there any significant difference among the seven sand results?. The weights of each parameterization method within each model and model weights in BMA were obtained by Bayesian information criterion (BIC) and variance window. The results show that the model with low fault permeability is the best model. The model with impermeable fault shows similar results to the best model, but the no-fault model is literally rejected. This model is reasonable considering past and present observations of a significant head difference across the fault, and there is leakage of saline water across the fault as indicated by increasing salinity for some of the public supply wells north of the fault.

A Synopsis of Two USGS Multi-State Ground-Water Studies

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ABSTRACT

The U.S. Geological Survey (USGS) is conducting two multi-state ground-water studies that includes parts of northern Louisiana. The first study monitors ground-water levels in real-time in southern Arkansas and northern Louisiana. The second study involves constructing a ground-water flow model of the Mississippi Embayment that includes parts of eight states.

The Sparta aquifer supplies the majority of water for industrial, municipal, and agricultural uses in southern Arkansas and northern Louisiana. Withdrawals from the Sparta aquifer in and around Union County, Arkansas have resulted in water-level declines of more than 360 feet in the county. Ground-water flow models developed by the USGS in the late 1990's demonstrated that water levels can be maintained at or above the top of the aquifer by reducing withdrawals from the Sparta aquifer in Union County by 72 percent. In 1999, Union County stakeholders united and legislation was passed to create a water conservation board which began a public education program, initiated ground-water conservation measures, and tapped the Ouachita River as an alternative source for certain industrial uses to reduce pumpage from the Sparta aquifer. In 2002, USGS began a study to provide real-time water-level data on the internet and periodic water-quality sampling from a network of wells to document water changes within the Sparta aquifer. Real-time water-level monitoring is conducted in eight wells. Data are automatically retrieved four-times per day using a telephone modem and displayed on the USGS Arkansas Water Science Center web site. The internet based real-time water-level data allows citizens and officials to quickly assess the changing water levels. During the first few years (October 2004-February 2008) that Ouachita River water (instead of Sparta aquifer water) has been supplied to selected Union County industries, Sparta aquifer water-levels have risen nearly 54 feet in a well near El Dorado, Arkansas. Water levels also have risen in the two northern Louisiana wells that are monitored, one at Junction City (12.8 feet) and one at Spencer (2.9 feet).

A ground-water flow model is being constructed (2006 to 2009) for the Mississippi Embayment Regional Aquifer Study (MERAS) as part of the USGS Ground-Water Resources Program's effort to determine ground-water availability in principle aquifers across the United States. Input data for the MERAS model includes: 2,700 geophysical logs for hydrogeologic framework development; 130 years of ground-water withdrawal information and 130,000 well locations; streamflow information for 39 rivers comprising 6,000 river miles; and precipitation, land use, surficial geology, and aquifer

properties covering 70,000 square miles predominately in Arkansas, Louisiana, Mississippi, and Tennessee. Model calibration data include 40,000 ground-water level observations and streamflows at 21 stream gage locations. The MERAS model is constructed using the modular three-dimensional ground-water flow model code, MODFLOW-2005. The Multi-Node Well package is being used to simulate withdrawals that occur from multiple aquifers. Major streams are simulated using the Stream Flow Routing package which allows simulation of flow through interconnected streams and flow to or from underlying aquifers. The Local Grid Refinement capability of MODFLOW-2005 will allow multiple, local models to be developed within this larger regional model. A digital hydrogeologic surface framework dataset was created for nine hydrogeologic units from the surficial alluvial aquifer down to the Midway confining unit. Available geophysical logs were scanned, the top of the formation was interpreted, and the log image and digital hydrogeologic surface cataloged to be made available on the internet.