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Research paper

Spatial analysis of groundwater chloride anomalies, earthquake sand-blows, and surface soils in the Mississippi River Valley alluvium in southeastern Arkansas

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ABSTRACT

Groundwater samples from the Mississippi River Valley Alluvial (alluvial) aquifer in Desha County, Arkansas (AR) have historically yielded elevated chloride concentrations (> 100 mg/L). Overlapping spatial relationships between earthquake liquefaction sand-blows, soils derived from backswamp deposits, and chloride anomalies in the alluvial aquifer suggest the water quality conditions specific to southeast (SE) AR could be related to the tectonic and geomorphic features. Spatial analysis and statistical techniques are used to determine whether the chloride anomalies in the alluvial aquifer are more closely related to the spatial distribution of liquefaction sand-blows or surface soil types in Desha County.

Pattern analysis suggests an underlying process is controlling the distribution of chloride concentrations in the alluvial aquifer. Cluster analyses show the chloride concentrations are more closely related to sand-blow densities than surface soil types, with high chloride concentrations associated with high sand-blow densities and low chloride concentrations associated with low sand-blow densities. Least squares regression analysis does not show a statistically significant spatial relationship between sand-blow densities, surface soil types, and chloride anomalies. However, the statistical relationship between sand-blow densities and chloride anomalies is stronger than surface soil types and chloride anomalies.

The results from the spatial and statistical analyses are robust enough to conclude elevated chloride concentrations in the alluvial aquifer are more closely related to tectonic features than surface soil types in the study area. The chloride anomalies in the alluvial aquifer are interpreted to be from the intrusion of saline fluids from depth along faults during past earthquakes.

1. Introduction

Groundwater resources are used extensively for irrigation of field crops in many parts of the world and are likely to become even more important in the future. Groundwater from shallow unconfined aquifer sources are commonly utilized for irrigation because of their low cost and ease of access. Excessive pumping of shallow groundwater for irrigation is known to result in depletion (e.g., Wada et al., 2010; Scanlon et al., 2012) and loss of water quality (e.g., Kass et al., 2005; Böhlke, 2002). Water quality loss is commonly a result of infiltration of irrigation runoff, salt water intrusion, or other sources of undesirable runoff.

Water pumped from the Mississippi River Valley (MRV) alluvial aquifer is used for irrigation throughout the south-central United States, with pumping of 9 billion gallons per day, on average (Clark et al., 2011). Water quality problems are generally mild, especially in the northern part of the aquifer in Arkansas, Tennessee, and Missouri (Waldron et al., 2011). However, elevated salinity (as indicated by > 100 mg/L chloride) has been observed in MRV alluvial aquifer in southeastern Arkansas since the 1950's (Onellion and Criner, 1955; Bedinger and Reed, 1961; Kresse and Clark, 2008). Sources for the elevated salinity have commonly been attributed to upward flow from underlying formations (Onellion and Criner, 1955; Broom and Reed, 1973; Fitzpatrick, 1985; Kresse and Clark, 2008), interactions with infiltrated river water (Bedinger and Jeffery, 1964; Kresse and Fazio, 2002), and infiltrated soil water that had been evaporatively concentrated (Kresse and Fazio, 2002; Kresse and Clark, 2008). Previous studies have generally taken a qualitative or graphical approach to

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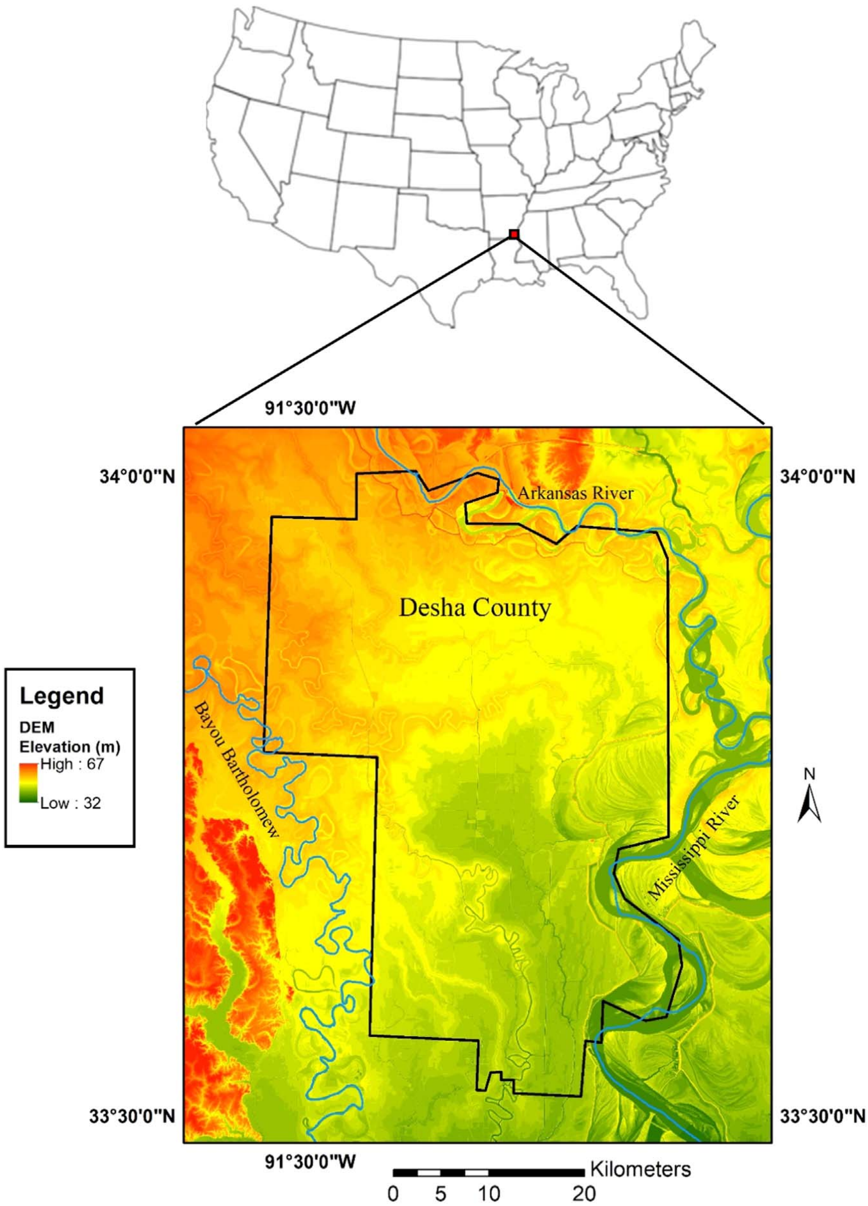

Fig. 1. Digital elevation model (DEM) map of the study area in SE AR. Desha County is outlined and local rivers are labeled.

assessing the contributions of various salinity sources.

In the present study, spatial statistical analysis is used to test the spatial correlation of tectonic and geomorphic features to the distribution of elevated chloride concentrations in groundwater within the MRV alluvial aquifer in Desha County, southeastern Arkansas. Potential avenues of upward flow along faults are evaluated from the distribution of liquefaction sand-blows (Cox et al., 2004, 2007). The distribution of soil types was digitized from Saucier (1994) and chloride data were compiled from Kresse and Clark (2008). Spatial statistical analysis using ESRI ArcGIS 10.2 is used to evaluate the data sets and significant spatial relationships. The results of this study demonstrate the utility of the spatial statistics in evaluating relationships between specific geomorphic features and groundwater quality, as well as provide insight to interaction of tectonic and hydrologic processes in southeastern Arkansas.

1.1. Geologic and hydrologic background of study area

Desha County is in the south-central portion of the Mississippi Embayment (ME) (Fig. 1). The structural basin of the ME contains more than 1.5 km (km) of Mesozoic and Cenozoic sediments overlying metamorphosed sedimentary rocks of the Paleozoic Ouachita fold-thrust belt (Cushing et al., 1964; Cox and Van Arsdale, 2002) (Fig. 2). The lower Mesozoic section unconformably overlies the Paleozoic section and contains upper Triassic through upper Jurassic continental, evaporative, and shallow marine deposits associated with the rifting and development of the Gulf of Mexico (Cushing et al., 1964; Dickinson, 1968; Harry and Londono, 2004). Similarly, the upper Mesozoic and Cenozoic sections unconformably overlie the lower Mesozoic section and contain Cretaceous through Quaternary marine and fluvial deposits (Cushing et al., 1964; Saucier, 1994). The Cretaceous through Quaternary sediments comprise a system of aquifers and aquitards in the ME (Hart et al., 2008).

The MRV alluvial aquifer underlies over 50,000 km^2 in parts of Missouri, Kentucky, Tennessee, Louisiana, Mississippi, and Arkansas, with thicknesses ranging from 15 to 45 m (m). The aquifer materials include Quaternary sand and gravel deposited by the Mississippi River and its tributaries. The alluvial aquifer is capped in most areas by the Mississippi River Valley (MRV) confining unit, which is comprised of 3–15 m of Quaternary clay, silt, and fine grained sand deposited in lower energy facies of the Mississippi River and its tributaries. Areas that are not capped by the MRV confining unit are locally incised and