Mar 22nd, 9:00 AM

Session 1A

Kentucky Water Resources Research Institute, University of Kentucky

Kentucky Water Resources Research Institute, University of Kentucky, "Session 1A" (2010). *Kentucky Water Resources Annual Symposium*. 3.
https://uknowledge.uky.edu/kwrri_proceedings/2010/session/3

THE WESTERN DEEPS—3D GRAPHIC MODELS OF DEEP AQUIFERS IN THE WESTERN COAL FIELD

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Existing mapping by several researchers has provided structure and isopach maps for deep aquifers in the western coal field region of Kentucky. McFarlan (1943) provided a general description of the coal field, while Kosanke, et al. (1960) discussed the classification of the Pennsylvanian strata within which the aquifers occur. Shawe and Guildersleeve (1969) described the unconformity at the base of the Pennsylvanian as the lower limit of fresh water within the western coal field. Davis, Plebuch, and Whitman (1974) completed extensive mapping and interpretation of certain deep aquifers in the western part of the field.

In this research, mapping by Davis, Plebuch, and Whitman (1974) was digitized for use in three dimensional (3D) modeling. Two questions were posed: (1) What routines and workflows expedite hard-copy-to-digital conversion? (2) What graphic techniques provide flexible and realistic 3D aquifer models?

To address the first question, maps of the pre-Pennsylvanian surface and the 600 foot (Vienna datum) aquifer were digitized using a CalComp digitizing table and Didger 3 software (Golden Software, 2001). Separate layers were created for faults, structural contours, isopachs, drillholes, and areas to be blanked. Digital data then were exported to Surfer (Golden Software, 2002) and gridded using the minimum curvature algorithm. Faulting was accommodated during gridding to ensure that contours did not cross fault locations, and data-free areas were blanked. To monitor data quality, a structural contour or isopach map (as appropriate) generated from gridded data was prepared and overlain on the source map. Where the two contour sets did not match, the grid was manually edited.

To address the second question, structure and isopachs of the 600 foot aquifer and isopachs of the pre-Pennsylvanian surface were modeled using (a) a contour (or isopach) map, (b) a wireframe model, and (c) a contour-draped surface model. Traditional *contour and isopach maps* prepared digitally retained a customary presentation method while enabling the drafter to edit map content and control information overload. *Wireframe* aquifer models employed a multi-chromatic color scheme on a black background. This provided a high-impact presentation tool, but the multi-chromatic color scheme did not correctly represent subsurface conditions. The contour draped *surface model* was effective with both aquifer isopach and structure models. Various rotations and tilts were employed, illumination was varied in both azimuth and altitude, and both orthometric and perspective projections were employed. Natural colors were used to provide realistic aquifer models that would support interpretation.

In conclusion, digital modeling provides a means of viewing and manipulating subsurface data digitally. This extends the usefulness of the significant data analysis and interpretative effort in the original aquifer mapping effort. When defined workflows are used, data quality can be assured. Various graphic presentation techniques can be employed for presentation or interpretation, and the triaxial coordinate data developed for each aquifer are potentially useful in hydrologic modeling of aquifer flow, recharge, and storage, and volume determination.

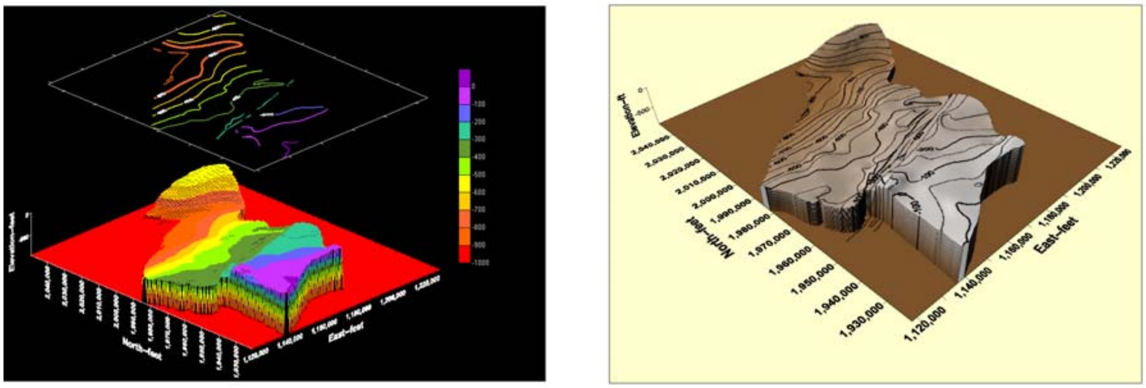

Figure 1. Wireframe (left) and structural model (right) of 600 foot aquifer from mapping by Davis, Plebuch, and Whitman (1974).

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LOCATING KARST CONDUITS IN CANE RUN WATERSHED OF CENTRAL KENTUCKY USING ELECTRICAL RESISTIVITY METHODS

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The Cane Run watershed and underlying karst aquifer in central Kentucky is the recharge area of Royal Spring, the primary source of drinking-water for the city of Georgetown, Kentucky. This watershed, including the associated karst aquifer, is degraded by pathogens, nutrients, siltation, and organic enrichment and is listed by the Kentucky Division of Water as one of four focus watersheds for clean-up under the State's nonpoint-source pollution program. The pollution sources include both municipal point sources and agricultural and nonagricultural nonpoint sources. The relative contribution of different parts of the watershed to the pollution is not well understood. The geology of Cane Run watershed consists of Ordovician thin-bedded limestone with sparse interbeds of shale. The landscape is dominated by karst features such as sinkholes and springs. Cane Run only flows on the surface during times of significant rainfall, usually in the spring of the year. The remainder of the year, most water is recharged to a karst conduit system that leads from Lexington to Royal Spring.

To help locate the actual source of contamination and to track progress of remediation efforts, it is important to monitor contaminants before they reach the point of groundwater use. Kentucky Geological Survey (KGS) is attempting to drill into the conduit to establish a water quantity (discharge) and quality (temperature, pH, conductivity, dissolved oxygen, turbidity, and sampling capability) monitoring station, just a few hundred meters up gradient from where the conduit diverges from the Can Run surface watershed. However, there is no known entrance into the Royal Spring Conduit. This study is using geophysics to assist in locating the karst conduit. We have applied electrical resistivity (ER) in four scenarios: (1) 2D surveys, (2) quasi 3D surveys, (3) synthetic time-lapse simulation, and (4) time-lapse survey with calcium chloride injection. A 2D survey conducted in 2008 showed some low resistivity anomalies and subsequent field drilling and tracer tests indicated these anomalies are mud-filled voids that are not located in the main conduit system. A quasi 3D survey consisting of twelve parallel survey lines was conducted to further investigate a prominent low resistivity anomaly identified by a 2D survey conducted in summer 2009. The quasi 3D survey shows the anomaly disappears approximately 40 meters northwest from the first parallel line Figure 1). The synthetic time-lapse simulation showed that, given our hypothesis of conduit depth and size, a time-lapse survey can potentially pick up the signal disturbed by calcium chloride injection. The field time-lapse survey conducted in October 2009 showed noticeable resistivity change for a low resistivity anomaly in the southwest portion of an ER line. This anomaly will be further studied through additional time-lapse surveys and microgravity measurements. This work is being carried out in cooperation with the University of Kentucky's College of Agriculture and Department of Earth and Environmental Sciences.

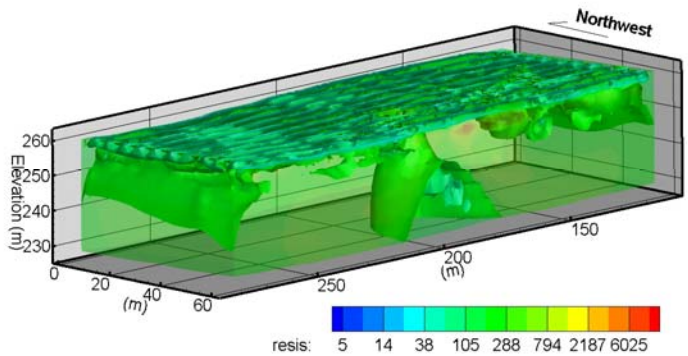

Fig 1. Inverted Electrical Resistivity for a Quasi 3D Survey

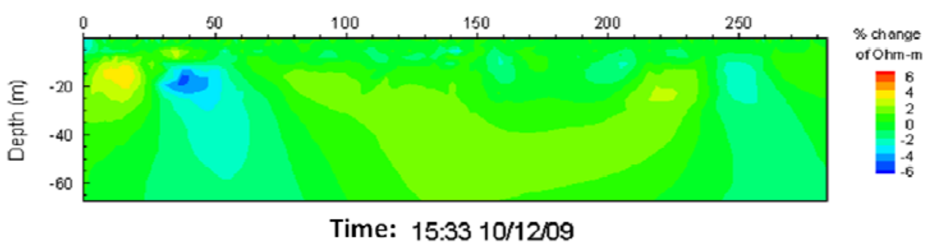

Fig.2 Resistivity Change During a Time-Lapse Survey

Reference:

R. Paylor and J. C. Currens, Royal Spring karst groundwater travel time investigation, prepared for Georgetown Municipal Water and Sewer Service, Kentucky Geological Survey, University of Kentucky, June 2004.

NEW GROUNDWATER RESOURCES MAP FOR KENTUCKY

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The USGS Hydrologic Atlas maps for Kentucky have been used extensively over the years to facilitate the search for groundwater. Each atlas included an "Availability of Groundwater" map, which indicated the most likely areas to obtain groundwater, as well as possible flow rates and general water-quality information. These maps were completed in the 1950's and early 1960's using extremely limited water-well and geologic mapping data, however.

KGS personnel recently used GIS techniques to overlay current digital geology and water-well data onto the groundwater availability maps. This process revealed that the older maps are occasionally inaccurate in locating groundwater resources. The availability of digital geology and up-to-date water-well information has made possible a new detailed groundwater resource map for Kentucky. The new map(s) will be created in three formats: statewide, physiographic region, and by county. An interactive Web site will also be created to allow users to view these maps. The maps will help users determine the likelihood of obtaining groundwater from any point in the State, and provide basic information on the probable quantity and quality of water available. This presentation will summarize the compilation process for the statewide groundwater resource map, and review possible end-products that could result from this project.

Figure 1 illustrates a section of the USGS Hydrologic Atlas 25 "Availability of groundwater" map showing actual water well locations in the eastern part of Bourbon County that are outside the primary producing zones (dark-colored areas).

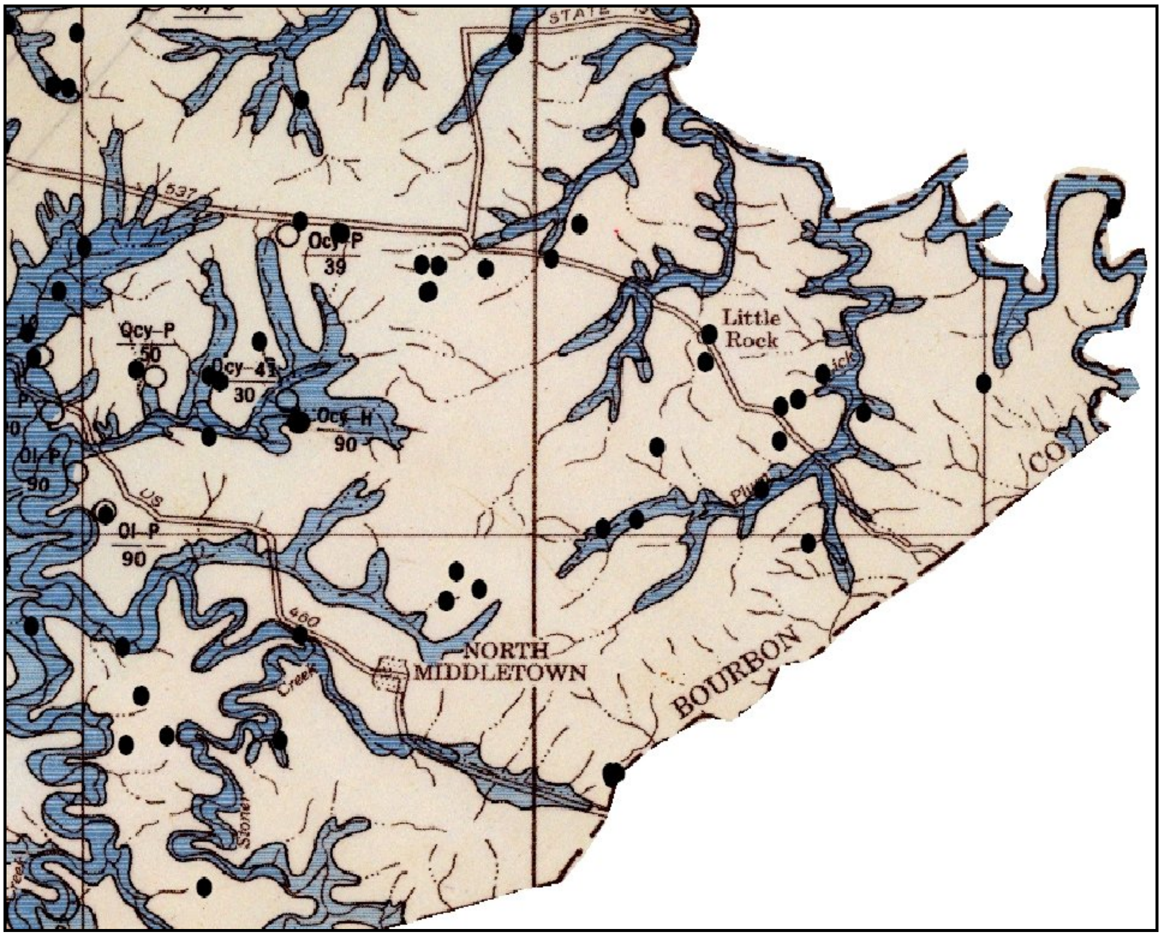

Figure 1. Section of USGS Hydrologic Atlas 25 “Availability of groundwater” map showing water well locations in the eastern part of Bourbon County that are outside the primary producing zones (dark-colored areas).

IMPACT OF RAINFALL AMOUNT, INTENSITY AND TIME LAG
ON LEACHING BEHAVIOUR OF A SURFACE-APPLIED BROMIDE TRACER

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Introduction

Amount and intensity of rainfall are known as important characteristics that affect the leaching of surface-applied agri-chemicals. Besides these, the effect of the time interval between a fertilizer or tracer application and subsequent rainfall on solute leaching is not well understood. Moreover, little is known about the spatial representativity of the solute concentration based on a relatively small soil sample in field-scale transport studies.

The objectives of this study were to identify the impact of rainfall intensity and amount as well as the application time delay on solute transport in a well-drained Maury silt loam soil. Moreover, an experimental design and protocol had to be developed that exhibited spatial variability structure and representativity of bromide concentration. The spatial association between treatments imposed and pattern of solute leaching depth should be quantified using spatial statistics and frequency-domain techniques, such as spectral and cospectral analysis.

Materials and Methods

The study was conducted in a Maury silt loam soil at the University of Kentucky, College of Agriculture Experimental Farm Spindletop. Along a 64-m transect, 32 plots each 2-m long and 4-m wide were established. Two different rainfall amounts at four different rates were applied in a non-random cyclically repeating pattern (Figure 1). Application time

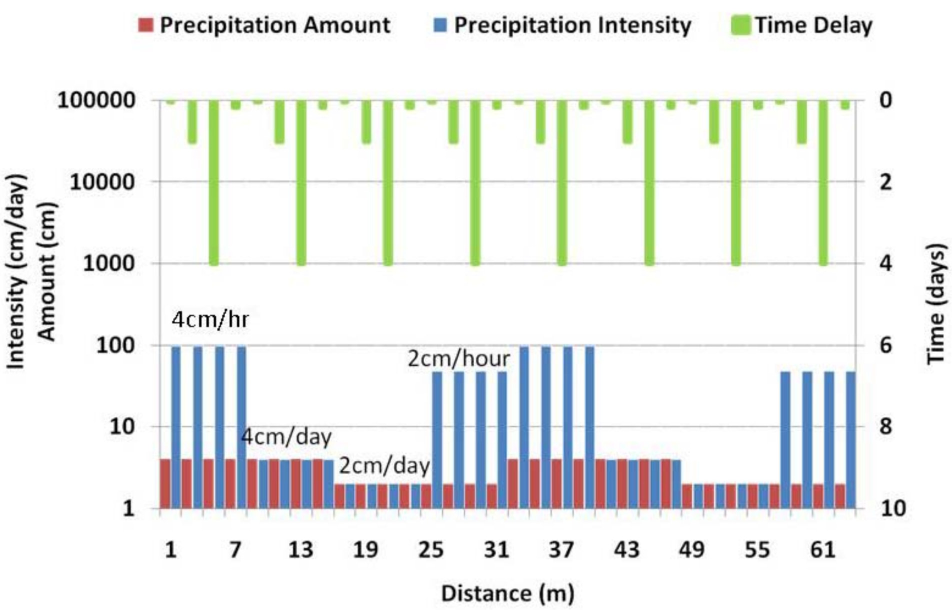

Figure 1. Upper boundary condition and its spatial distribution along the experimental field.

was also spatially arranged in a sinusoidal pattern. This design allows to base the statistical analysis on special frequency domain-based methods. Bromide leaching under different treatments was quantified with the spatial distribution of the center of mass.

Results and Discussion

Rainfall amount showed the largest effect on Bromide leaching. The effect of rainfall intensity of leaching became only obvious for the highest and lowest intensity. With increasing time delay between tracer application and subsequent rainfall, the shallower the leaching depth. Application of agri-chemicals should be delayed if there is a moderate or high chance of a rainfall event. Long and low-intensity rainfall events may cause deeper leaching than short and high-intensity rainfall events. The experimental design was efficient to study impact of transport-relevant rainfall characteristics of solute leaching.

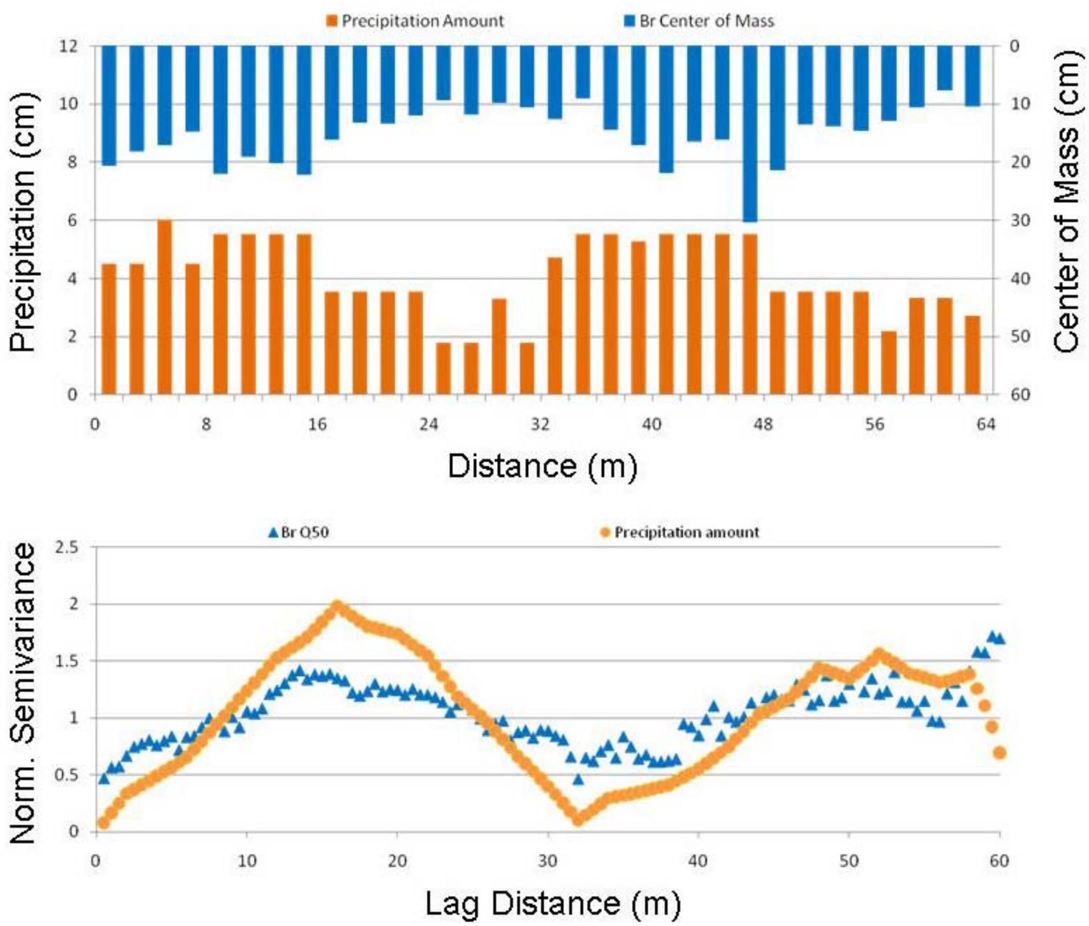

Figure 2. Spatial distribution of precipitation amount and center of mass of Bromide along the 64-m-transect (top) and normalized semivariograms for both variables (bottom).

Acknowledgement:

This work was funded by the SB-271 program.