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A Brief History and Current State of Groundwater Protection in Kentucky

by

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Groundwater is an essential resource that provides water for drinking, industry and agriculture. Although some degradation has occurred, ambient groundwater quality is generally of high quality, and in many areas of the Commonwealth, it is the most inexpensive and readily available source of water.

The importance of this resource was recognized by then Governor Martha Layne Collins who created the Groundwater Advisory Council and a program to address previously neglected groundwater issues as part of the 1984 Kentucky Water Management Plan. The Council was comprised of representatives from various agencies responsible for the protection and management of groundwater, including the Kentucky Division of Water, the Kentucky Geological Survey (KGS) and the United States Geological Survey (USGS).

The Groundwater Advisory Council concluded that most of the problems encountered with protecting the Commonwealth's groundwater were the result of nonexistent or fragmented and uncoordinated programs. The council therefore identified the need for a comprehensive groundwater protection strategy to address present and future needs.

The 1987 Kentucky Groundwater Protection Strategy, developed by the Groundwater Advisory Council, identified Kentucky's Groundwater Protection Goal: to maintain or restore the resource for its highest and best use, and to minimize or prevent waste and degradation. To accomplish this, the council recommended the following:

1. Address groundwater concerns in statewide planning and programming through coordinating the efforts of all state, local and federal agencies, which manage, research, protect or promote groundwater resources.
2. Establish appropriate statutory and regulatory authority to accomplish the groundwater protection management goal.
3. Develop and implement an integrated and comprehensive information system for the collection, management and dissemination of groundwater data.
4. Establish a centralized archival repository for groundwater data.
5. Obtain a comprehensive understanding of Kentucky's groundwater resources, including present and potential threats.
6. Encourage local initiatives to safeguard groundwater resources.

In recognition of the important of this resource, the Groundwater Section was elevated to branch status in the Division of Water in 1985. As its highest priority, the newly formed Groundwater Branch was assigned to implement the above recommendations. In cooperation with other agencies, the Groundwater Branch has played an important role in coordinating groundwater protection efforts throughout the Commonwealth for the last 20 years. Although most, but not all of these goals, have been accomplished, on-going efforts are inherently necessary to maintain those in existence and additional efforts will be required to implement the others. The objectives enumerated above that have been addressed are:

1. The formation in 1998 of the Inter-agency Technical Advisory Committee (ITAC), an advisory group formed to coordinate state groundwater concerns.
2. Statutory and regulatory authority to regulate and protect groundwater was partially implemented through the Water Well Drillers Certification statute (1985) and resultant regulations, and the Groundwater Protection Plan Regulation (1994). The Agriculture Water Quality Act (1994) established the Agricultural Water Quality Authority and required agriculture producers to develop Agricultural Water Quality plans to protect groundwater and surface water. Other regulations have protected groundwater by strengthening the solid waste program (1991) and underground storage tank program (1994), and promoted the remediation of brownfields and other contaminated sites through the Voluntary Environmental Remediation Program (2003).
3. Information management was accomplished through the creation of the Department for Environmental Protection Consolidated Groundwater Database in 1986 and the establishment of KGS Groundwater Data Repository in 1990.
4. Understanding of the state’s groundwater resources was greatly expanded by the creation and implementation of the Ambient Groundwater Monitoring Network in 1995 and increasing other groundwater quality research projects including karst studies, groundwater assessment projects funded through nonpoint source grants, additional groundwater monitoring for pesticides through an MOA with the Division of Pesticides, and expanded sampling in response to complaints and spills.
5. Local initiatives to protect groundwater have been implemented primarily through the Wellhead Protection Program, approved by the USEPA in 1991.

The systematic and comprehensive collection, maintenance and distribution of statewide ambient groundwater quality data over the last ten years, and the detailed analysis of these data, have dramatically expanded our knowledge of the resource. The protection of this resource has been expanded through the creation and administration of appropriate regulations and programs.

Managing and protecting groundwater, educating the public, and providing sound science for policy decisions will remain challenging issues as Kentucky’s population expands and the demand for groundwater resources increases. Most obviously, the advances made over the last two decades need to be maintained, expanded, and certainly improved upon. Among the many emerging issues that should be addressed are the interrelationships, both in quantity and quality, between surface and groundwater systems. Pathogens continue to be an important parameter for which quality data are lacking, and the occurrence, fate, and significance in groundwater of emerging contaminants such as pharmaceutically active compounds, estrogen mimickers, and endocrine interrupters will undoubtedly challenge us as scientists and regulators.

SUMMARY OF GROUNDWATER-QUALITY DATA IN THE JACKSON PURCHASE REGION, KENTUCKY

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Over the past 7 years, Kentucky Geological Survey personnel have sampled 509 domestic water wells throughout the Jackson Purchase Region, Kentucky to assess how land use and well construction influence local groundwater quality. Of the 509 wells sampled, 286 are 4-inch diameter wells (drilled wells) and 223 are 24-inch diameter wells (bored wells). All of the 509 wells have been sampled for nitrate-N, chloride, and field parameters (pH, Temperature, Eh, and Electrical Conductivity). A number of wells were also sampled for herbicides (424 wells), total coliform and *E. coli* (328), caffeine (125), and nitrogen isotopes (96).

The following significant findings have been made with respect to groundwater-quality data and land use, well construction, hydrogeology and human health. Of the 509 wells sampled for nitrate-N, 32 wells (6 percent) contained nitrate-N above the MCL of 10 mg/L. One of these wells is a domestic well in Ballard County located on an abandoned dairy farm operation. The nitrate-N and chloride concentrations are 18.6 mg/L and 129mg/L, respectively. The nitrate-N concentration for this well is two times that of surrounding wells and the chloride concentration is four times that of surrounding wells. The nitrogen isotope ratio is 10.3 per mil, which points to organic waste associated with an animal feeding lot as the source of elevated nitrate-N.

To better determine the role of well construction on local groundwater quality, a bromide trace was performed on 62 (28 drilled and 34 bored) of the 509 wells sampled. Four of the drilled wells and 18 of the bored wells exhibited a breakthrough of bromide, which indicates that surface water moves practically unimpeded into the well. Because surface water or possibly shallow groundwater is able to move unimpeded into the well, these wells are considered to be constructed improperly. Improperly constructed water wells are an important human health concern because bacteria and other contaminates can enter the well by moving directly down the borehole bypassing the natural flow and filtering system.

Total coliform bacteria develop everywhere (soil, water, and in the gut of animals and humans). Generally, these bacteria are harmless, with the exception of a specific group called fecal coliforms. *E. coli* is a fecal coliform that naturally develops only in the gut of animals and humans. If ingested, *E. coli* may cause abdominal cramps, nausea, diarrhea, and bloody diarrhea.

Even though total coliforms are generally harmless, apart from fecal coliforms, their presence is an indication that other harmful organisms and contaminants carried by animals and humans may also be present in drinking water. Therefore, the Environmental Protection Agency has set a drinking water standard of zero for both *E. coli* and total coliforms. Of all the wells sampled (328), 66 percent contained total coliforms and 12 percent contained *E. coli*. Eighty-eight percent and 22 percent of the bored wells contained total coliforms and *E. coli*, respectively. Only 3 of the drilled wells contained *E. coli*, but 40 percent contained total coliforms.

One such case of how improper well construction can adversely affect human health was identified when sampling a bored well in Calloway County for total coliform and *E. coli*. The initial bacteria results showed that total coliform and *E. coli* counts were >200.5 and 3.1, respectively. The home owner was contacted to discuss shock chlorinating the well. It was discovered that the well had not been used for over two years, the present family having recently moved from New Mexico to Kentucky. They were unfamiliar with well maintenance procedures and began using the well without disinfecting with the result that each member of the family was experiencing abdominal cramps and diarrhea. It was recommended that the well water not be used for drinking and that the well be shock chlorinated. Three shock chlorination treatments were required before the bacteria test was negative (no colonies). It was also discovered that within 30 seconds of pouring water around the well head, water entered the well. Additional bacteria samples will be collected to determine how long the shock chlorination treatment lasts.

To better determine the source of elevated nitrate-N in the groundwater, 96 wells were sampled for nitrogen isotopes, and 125 wells were sampled for caffeine. Isotope values for the 96 wells sampled indicate that possible sources of nitrate-N range from chemical fertilizer to animal/septic waste. Caffeine was detected in 19 of the 125 wells sampled for caffeine. Isotope and caffeine results strongly indicate that there are multiple sources of nitrate-N to the shallow groundwater system in the region.

One hundred thirty eight wells were resampled to determine if nitrate-N or herbicide concentrations decrease or increase seasonally. Results show that there is generally very little change between the two sampling events. This indicates that at locations where nitrate-N or herbicides are elevated, the shallow groundwater system is contaminated.

GROUNDWATER-QUALITY ASSESMENT AND SHALLOW AQUIFER MODEL OF CALLOWAY COUNTY, KENTUCKY

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Calloway County is located in the southeastern portion of the Jackson Purchase Region (JPR), just west of Kentucky Lake. The residents of Calloway County rely heavily on the more than 6,000 privately owned water wells for domestic, livestock, and irrigation use (Carey and Stickney, 2005). There are a number of potential factors that can influence groundwater quality, including well depth and construction, proximity to contaminating sources (row crop fields, septic systems, etc), and geology.

Water-quality results of 134 wells sampled from May of 2003 to October of 2005 by the Kentucky Geological Survey in the six eastern-most quadrangles of Calloway County have led to useful conclusions and inferences. Nitrate-N, chloride, total coliform and *E. coli*, and herbicide results were analyzed statistically in relation to well depth, well diameter, and well age. Using data from the 134 wells, we calculated the average nitrate-N concentration in Calloway County to be 3.7 mg/L, and the average chloride concentration to be 21.3 mg/L. These average concentrations are slightly higher than the average nitrate-N and chloride seen throughout the JPR. Six percent of bored wells, as opposed to none of the drilled wells, have nitrate-N concentrations above the MCL of 10 mg/L. Sixteen percent of the bored wells contained *E. coli*, whereas none of the drilled wells contained *E. coli*.

Oil and water well driller logs, groundwater availability maps, geologic quadrangles, and ArcGIS software were used to create an approximate, three dimensional, conceptional hydrostratigraphic model of shallow (<200ft) aquifers in Calloway County. Surface elevation was determined using a georeferenced topographic map, whereas static water level was estimated using measured quantities taken from different locations over a period of several years.

The model presents shallow (<200ft) hydrostratigraphic units that produce enough water for a domestic water supply. The four main shallow producing hydrostratigraphic units in Calloway County are alluvium, continental gravel deposits, the Claiborne Formation (sands/clay), and the McNairy Formation (sand/clay). The model shows that the McNairy Formation is the dominant producing unit in the eastern third of the county. In the middle third of the county, the McNairy is overlain by the Porters Creek Clay aquitard. However, the overlying continental gravels in this area are more continuous than in other areas of the county and are closer to the surface than the McNairy, which makes them the dominant producing units in this portion of the county. The Claiborne Formation is the shallowest hydrostratigraphic unit in the western third of the county and overlies the Porters Creek Clay aquitard.

The proposed goal of this model is to estimate the drilling depth necessary for high-quality domestic water supplies for any geographical location in the county. The current model only presents inferred spatial relationships between hydrostratigraphic units and the wells that penetrate them. Future research can incorporate groundwater-quality data (metals, anions, etc) into the model to make it a hydrogeochemical stratigraphic model, which will allow for a more accurate and useful interpretation of local groundwater-quality trends.

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SUSPENDED SEDIMENT AND PATHOGEN TRANSPORT IN TWO INNER BLUEGRASS KARST GROUND-WATER BASINS

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Almost 40% of Kentucky is underlain by limestone, which is prone to dissolution (karstification). Because karstification results in the development of preferential flow paths through sinkholes and subsurface conduits, karst aquifers are especially vulnerable to nonpoint-source pollution from urban and agricultural runoff. Suspended sediment, which can be carried into the subsurface or remobilized within karst conduits following storms, can adsorb pathogens and other pollutants. However, there have been few studies of the association between pathogens and sediment in karst aquifers in Kentucky, and none in the Inner Bluegrass region.

The objectives of this study were to characterize the relationship between suspended sediment and pathogen indicators at two springs draining karst basins with contrasting land uses (urban and agricultural) in Woodford County, Kentucky. Blue Hole Spring is located in Versailles; spring SP-2 is at the University of Kentucky (UK) Animal Research Center (ARC). At each site, specific conductance (SC), pH, and temperature (T) were manually measured weekly from fall 2002 to spring 2004. Concentrations of fecal coliform bacteria (FC), total coliforms (TC), atypical coliforms (AC), male-specific coliphage (MSP, an indicator of viruses in waste water), and major ions were measured biweekly. Discharge at SP-2, stream stage at Blue Hole (which has been correlated to discharge), SC, pH, T, and turbidity were monitored continuously by sensors linked to digital data loggers. Bed sediments at SP-2 and the sinkhole feeding it were analyzed for mineralogy, petrology, particle size, total organic carbon (TOC), and total inorganic carbon (TIC). During two storms, SC, T, FC, TC, AC, MSP, and total suspended solids (TSS) were measured at both springs, and suspended sediment samples were collected at SP-2 for the same analyses previously performed on bed sediments.

Results of weekly to biweekly measurements indicate relatively consistent differences in several water-quality parameters between the two springs, as well as possible temporal effects. Except for one date, weekly SC values were greater at Blue Hole than at SP-2, and SC ranges were broader at Blue Hole than at SP-2. SC spikes in winter at Blue Hole may reflect road-salt runoff. Ranges of weekly T values for the two springs overlapped, but spring T at Blue Hole was typically higher than at SP-2. Temperatures at both springs tracked air T measured at the ARC, but fluctuated over a narrower range than air T did, as expected for ground water. Weekly pH values at both springs fluctuated around 7.1; near-neutral pH values are characteristic of limestone dissolution. Biweekly FC and TC concentrations tended to be higher at Blue Hole than at SP-2. The fact that FC and TC values tended to be highest from April through October at Blue Hole and from April through November at SP-2 may reflect seasonal variations in T or soil-water content. Biweekly AC/TC ratios were greater at Blue Hole than at SP-2 for 29 of 31 sampling rounds. The range of biweekly AC/TC ratios was much broader at Blue Hole than at SP-2, and the range at SP-2 was similar to values reported for runoff from farm fields in Fayette County. At both sites, average FC and TC concentrations were higher, and average AC/TC ratios were lower, for samples collected during relatively wet periods than for samples collected at other times. Differences in MSP concentrations (detected in 23 of 31 biweekly samples at Blue Hole, but none at SP-2) appear to reflect differences in land use between the two basins.

Monitoring of storm pulses at both springs in September 2003 and March 2004 confirmed previous findings from other sites that storm flow causes temporary increases in suspended sediment and pathogen concentrations. Discharge rose sharply following periods of intense rainfall, then receded. Ranges of discharge were similar for both sites for the September storm, but for the March storm, peak discharge at SP-2 was nearly three times the peak value at Blue Hole. SC, T, and turbidity all responded to changes in discharge at both sites and times. SC and T tended to decrease following peak discharge, which is consistent with movement of cooler, more dilute storm flow through the subsurface. Peak turbidity tended to coincide with peak discharge for both sites and times, but the turbidity response was relatively noisy. TSS values were uniformly lower at Blue Hole than at SP-2 in September, and maximum TSS values were lower at Blue Hole than SP-2 in March. Differences in TSS values may have in part reflected the choice of sampling locations at each site. Maximum FC and TC concentrations for both storms exceeded maximum values for biweekly samples at each site. For storm-flow samples, FC concentrations tended to be higher and TC concentrations tended to be lower at Blue Hole than at SP-2. FC and TC concentrations tended to decrease as the storm pulses receded at Blue Hole, but did not track discharge as closely at SP-2. Ranges of AC/TC ratios for storm flow samples overlapped biweekly-sample ranges at Blue Hole and fell within biweekly-sample ranges at SP-2. Maximum MSP values in both sets of storm-flow samples from Blue Hole exceeded biweekly maximum values. MSP was not detected in storm-flow samples from SP-2.

Sediment mineralogy and grain-size distributions determined for SP-2 and a contributing sinkhole were similar to those previously observed in the Blue Hole basin. Bed sediment from SP-2 and the sinkhole consisted mainly of quartz and calcite, with at least 90% of grains being very fine sand or larger. Suspended sediment sampled at SP-2 during the September 2003 and March 2004 storms was also dominated by quartz and calcite. On average, silt and larger grains at SP-2 comprised 92% of the suspended sediment for the September storm and 99% of the suspended sediment for the March storm. The lack of phyllosilicate minerals and clay-sized particles probably limits the surface area available for sorption of pathogens and other pollutants.

LOCATING AND MAPPING DOMESTIC WATER WELLS IN MARSHALL COUNTY, KENTUCKY

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The Marshall County Board of Health became interested in the water quality of local water wells after Board members attended a seminar where awareness was raised regarding this issue. Upon returning, several Board members began questioning the quality of water the citizens in Marshall County are receiving from domestic water wells. The Health Department had some historical data pertaining to bacterial contamination in residential wells and it was evident that some wells in the county had elevated levels of bacterial contamination.

The Health Department was directed by the Board of Health to conduct a study of the location and bacterial contamination of water wells in the county. The ‘Well Mapping’ project had two primary objectives. The first was to identify, map and sample water supplies for residents without current access to publicly supplied drinking water. The second objective, as requested by the Department for Public Health, was to help establish a method where other local health departments could conduct similar studies. It was determined that field personnel would be trained to visually assess wells for Assembled Kentucky Groundwater database (AKGWA) numbers and KY Division of Water specified characteristics. If no AKGWA number was noted and the well did not appear in an on-line database search, health department personnel would assign a number to that well.

A target area of the county was then defined and informational letters were sent to the affected residences. In this letter, the owner was asked to provide specific information regarding any well on the property that might not be obtainable during field work.

Once field work commenced, Marshall County Health Department personnel traveled to the residences which had responded to the initial informational letter. The well was ‘mapped’ using hand-held Global Positioning Satellite (GPS) devices, pertinent well information was recorded and a water sample was collected from an outside spigot. During field work, residences were visited which did not respond to the initial mailing. If no one was home an informational door hanger was left. The plan is to attempt to reach the non-responsive parties via telephone to ensure all available data is collected.

Collected water samples were analyzed by the Western Kentucky Regional Laboratory for the presence of total coliform and E. coli. Once the sample results were completed, a packet of information regarding well maintenance, groundwater protection and the assigned AKGWA number, if applicable, was sent to the homeowner. If a sample was 'positive' for total coliform and/or E. coli, a sheet outlining disinfection procedures was also included.

As the project continues, the Marshall County Health Department is providing the Department for Public Health GPS coordinates of the located wells and KY Division of Water with well inspection forms and sample results. All involved personnel are hopeful that this will help generate an up-to-date database of the well locations in Marshall County.

The response rate to the initial mailing was approximately 30%. To date, the Health Department has located water wells at over half of the residences, which responded to the mailing. 78% of the sampled wells tested positive for total coliform contamination and approximately 1% tested positive for E. coli. AKGWA numbers were assigned to 81% of the located wells.

Undertaking this project has been very time-consuming and has not progressed as rapidly as hoped, due, in part, to the limited amount of personnel available for field work. It has been determined that this project will be on-going. During the summer months, more personnel may become available, in the form of interns, to assist with the data collection aspect of this project.