Kentucky River Watershed Watch:

A Summary of Volunteer Water Quality Sampling Efforts in the Kentucky River Basin from 1999 to 2009

U.K. Kentucky Water Resources Research Institute

Malissa McAlister
Madhu Akasapu
Ben Albritton
Lindell Ormsbee
Dan Carey, Kentucky Geological Survey

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Kentucky River Watershed Watch: A 10-Year Summary (1998 – 2008)

History of Kentucky River Watershed Watch Organization

In 1997, the Sierra Club, Kentucky Waterways Alliance, the Kentucky Division of Water's Water Watch Program, and the Kentucky Water Resources Research Institute collaborated to form the Kentucky River Watershed Watch (KRWW). The purpose of this new organization was to support a citizen monitoring effort and improve and protect water quality by raising community awareness and supporting implementation of the goals of the Clean Water Act and other water quality initiatives.

KRWW has grown to include approximately 250 volunteers living throughout the Kentucky River Basin. The Kentucky River Basin extends over much of the central and eastern portions of the state and is home to approximately 710,000 Kentuckians. The watershed includes all or parts of 42 counties and drains over 7,000 square miles, with a tributary network of more than 15,000 miles. (See Figure 1.) The KRWW organization is also affiliated with a larger organization, the Watershed Watch in Kentucky (WWK), which includes similar organizations from eight different watershed basins in the state, as shown in Figure 2.

Since its inception in 1997, the KRWW has trained approximately 900 citizens on the proper techniques for collecting water samples, assessing aquatic habitat and macroinvertebrate presence, and identifying potential causes and sources of water pollution. Volunteers across the Kentucky River Basin have decided to apply their sampling results toward the development of Citizen Action Plans, which interpret localized water quality findings and make subsequent recommendations for improving and/or protecting water quality.

The functioning of the KRWW is overseen by a 12-member Board of Directors, a Scientific Advisor, and a representative to the Watershed Watch in Kentucky Board of Directors, who discuss statewide issues from the eight Watershed Watch organizations in Kentucky. The Scientific Advisor also represents KRWW at meetings of the statewide Scientific Advisory Committee. This scientific committee developed, and continues to update, a plan which describes water quality monitoring objectives, methods, parameters, quality assurance, and data management.

Annual sampling results are compiled and distributed to volunteers, as well as posted on an online database. (See Appendix A for instructions on using the database). A year-end Data Report summarizes water quality findings and provides some overall analysis, including a listing of the sites of greatest water quality concern. The online database is regularly updated by the Kentucky Geological Survey and is linked to the KRWW website (www.krww.org). The KRWW website, which is maintained by the University of Kentucky's Water Resources Research Institute, also provides volunteers and other interested parties with relevant event postings, watershed project summaries, and other information.

An annual KRWW Conference is held in January each year and provides volunteers with the opportunity to hear first-hand presentations on their sampling results, informational presentations on current water quality issues in the Kentucky River Basin, and to participate in open discussion with other samplers and the KRWW officers. A report summarizing the results of the water quality sampling and analysis is also distributed at the annual conference.

Major funders that have supported KRWW through the years are the Kentucky River Authority (which has essentially provided continuous funding since KRWW's inception), Eastern Kentucky PRIDE, Bluegrass PRIDE, Sierra Club, Kentucky Waterways Alliance, Toyota Manufacturing Company, Brown-Forman Corporation, Lexington-Fayette Urban County Government, Kentucky American Water, and the Virginia Environmental Endowment. KRWW is now also accepting membership contributions to assist with the sustainability of the organization. In 2004, the Kentucky River Authority (KRA) began providing small grants in support of various watershed management projects, many of which were extensions of previous sampling efforts. The KRA also provided funding for the publication of this report.

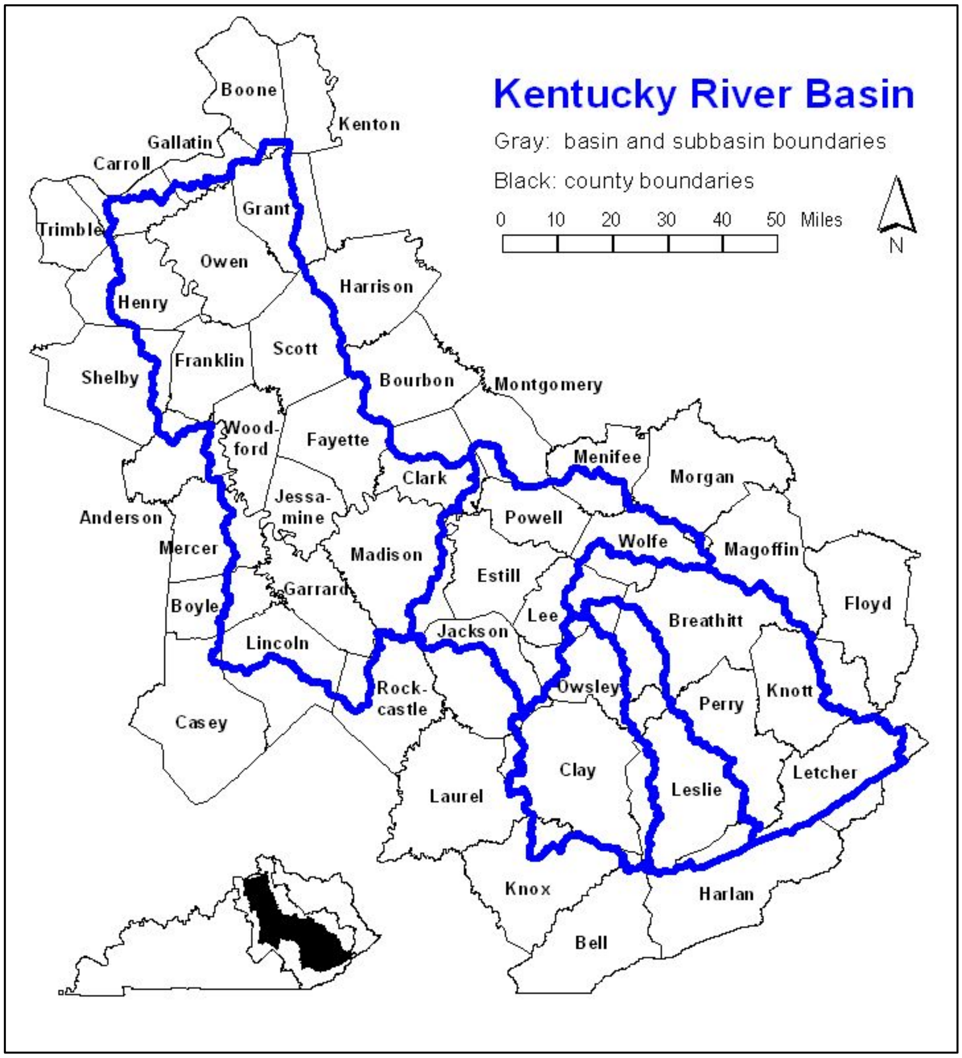

Figure 1: Map of the Kentucky River Basin (i.e., domain of Kentucky River Watershed Watch)

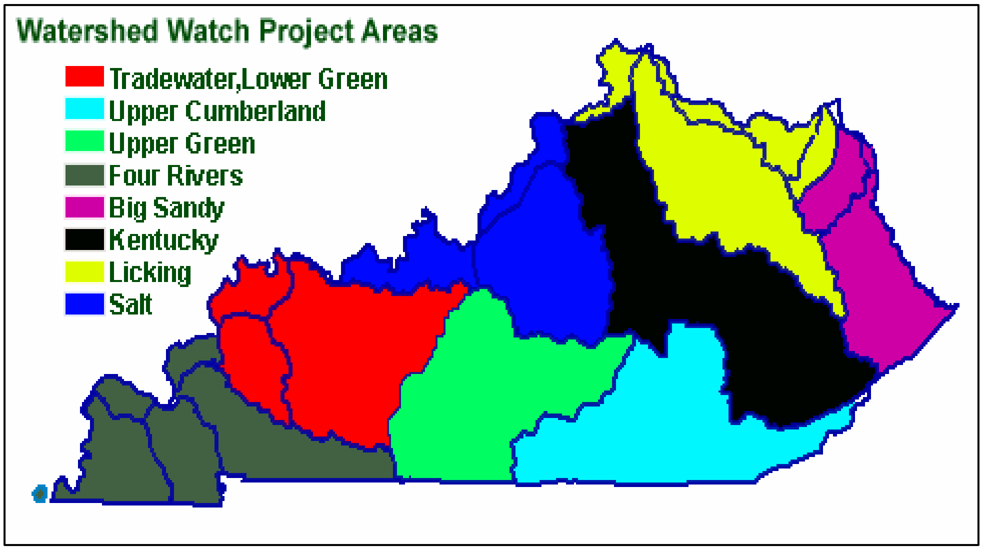

Figure 2: Map of the project areas of the *Watershed Watch in Kentucky* Organizations

Overview of Sampling Efforts

In 1999, Kentucky River Watershed Watch volunteers sampled at 87 sites throughout the basin. The number of sampling sites tested each year grew until 2003, when there was a decline. After reaching an overall high of 248 sites in 2006, the number of sites again decreased to 176 sites in 2009.

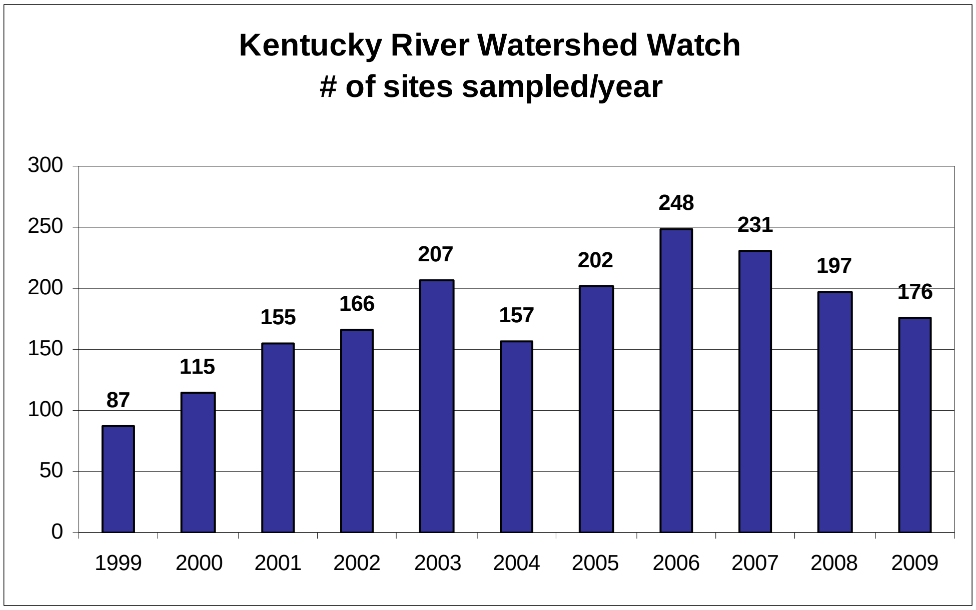

Figure 3: Total Number of KRWW Sampling Sites from 1999 to 2009

Sampling has become increasingly more concentrated in the central region of the Kentucky River Basin, which includes the more densely populated, urbanized areas. Thus, there are more KRWW data results for this central region than for the upper basin areas in southeastern Kentucky or the lower basin in northern Kentucky. The map comparison below illustrates the changes in sampling site distribution from 1999 to 2009. As of 2009, there were fewer sites located in the South and Middle Forks of the Kentucky River, as well as in the northern portion of the Kentucky River Basin.

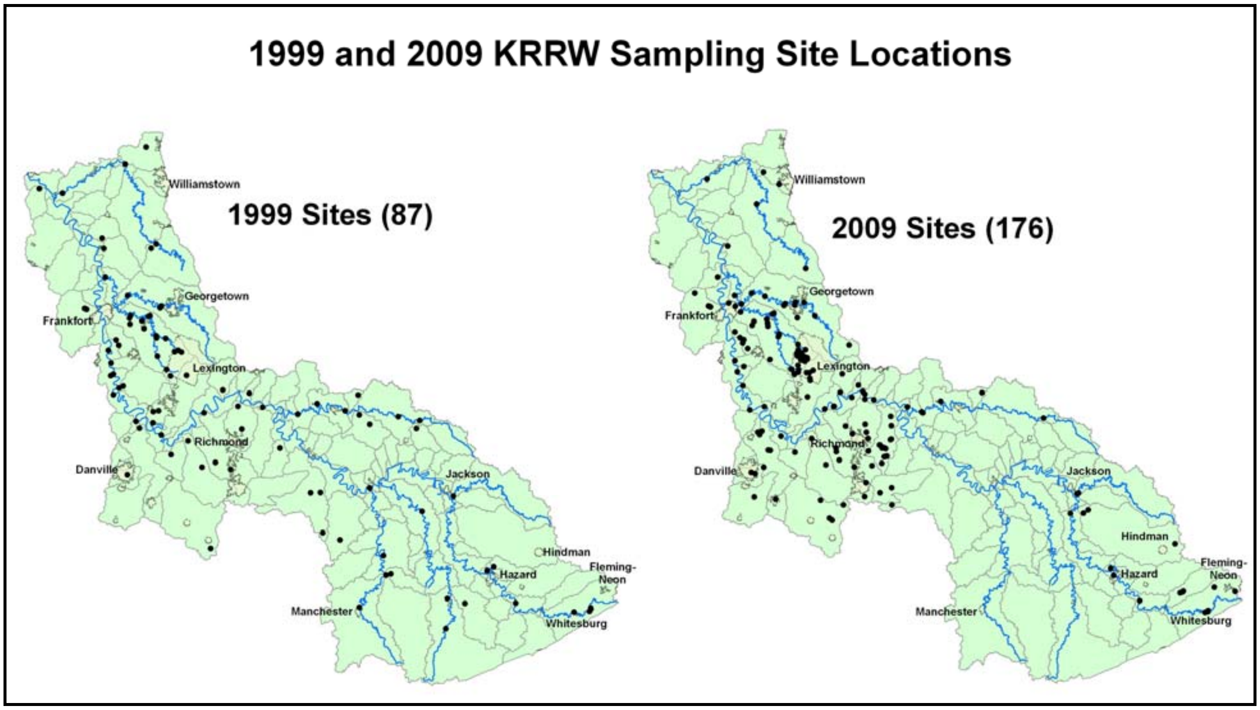

Figure 4: 1999 vs. 2009 KRWW Sampling Site Locations

KRWW volunteers typically sampled the water quality at their chosen sites three to four times each year. The sampling events included those for herbicides and insecticides (spring), synoptic and follow-up pathogens (twice in summer), and metals, chemistry, and nutrients (fall, usually with lower instream flows). Herbicides and insecticides were analyzed during the spring sampling event due to the increased likelihood of recent crop applications. Pathogens were assessed during the summer months, when people are more likely to be coming in direct contact with waterways through various recreational activities. The nutrient, chemical and metal parameters were analyzed during the fall water sampling event because of the typically lower flows observed during this time of year and, thus, potential for increased concentration of these pollutants.

Samplers analyzed dissolved oxygen, pH, temperature, conductivity, and habitat condition in the field. Flow rate estimates were also included on the sample recording forms, along with estimates of recent precipitation amounts and stream turbidity.

Figure 5 illustrates the number of samples collected during each major sampling event from 1999 through 2009. Sample numbers for herbicide and insecticide assessment are lower, because they are generally only collected for newly sampled sites. Follow-up pathogen sites are those where pathogen concentrations exceeded the safe swimming standard during the initial, synoptic sampling event. Finally, the number of sites sampled for metals are also less, because metals were also only assessed for new sites or sites where high concentrations of specific metals had been detected in the past. In 2009, no metals were collected due to a problem with the distribution of the acidic preservative.

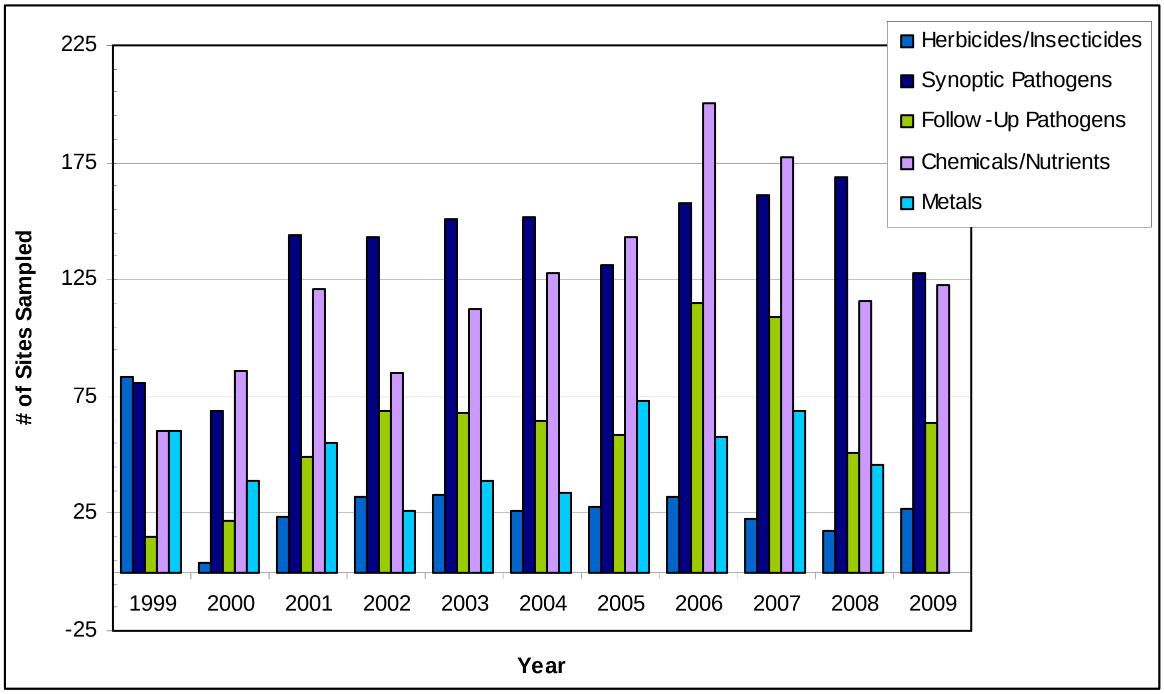

Figure 5: Number of Sites Sampled During Regular Sampling Events (1999-2009)
**NOTE: Because of a miscommunication with regard to sample preservatives, no metals were assessed during the 2009 sampling year.*

Table 1 lists the annual sampling dates, along with the number of samples collected during each sampling event from 1999 through 2009. In addition, the table provides a descriptive ranking of representative flow conditions within the Kentucky River Watershed during each of the sampling windows. Flow conditions concurrent with water quality data often provide additional information about the stream environment. For instance, high pathogen concentrations during high flows are typically indicative of nonpoint sources or illicit wet weather discharges (e.g. sanitary sewer overflows), while high pathogen concentrations during low flows generally indicate point sources. The flow conditions within the Kentucky River Watershed are represented by the flow of the Kentucky River itself at three evenly spaced locations where USGS historical flow data is available (see Figure 6). The average flow of the Kentucky River during a sample window at a location is ranked relative to all historical four day average flows at that location. Figure 7 shows the flow rank categories and the flow duration curve for the Kentucky River at Lock and Dam #7. Similar curves were also developed for USGS gaging stations at Lock and Dam 2 and 14, as well. All of the curves were then used in the construction of Table 1, which provides the range of flows during a particular sampling event. For more detailed flow descriptions, one can refer to the actual KRWW Chain of Custody forms associated with a particular sample or refer to the USGS website for Kentucky at: ky.water.usgs.gov

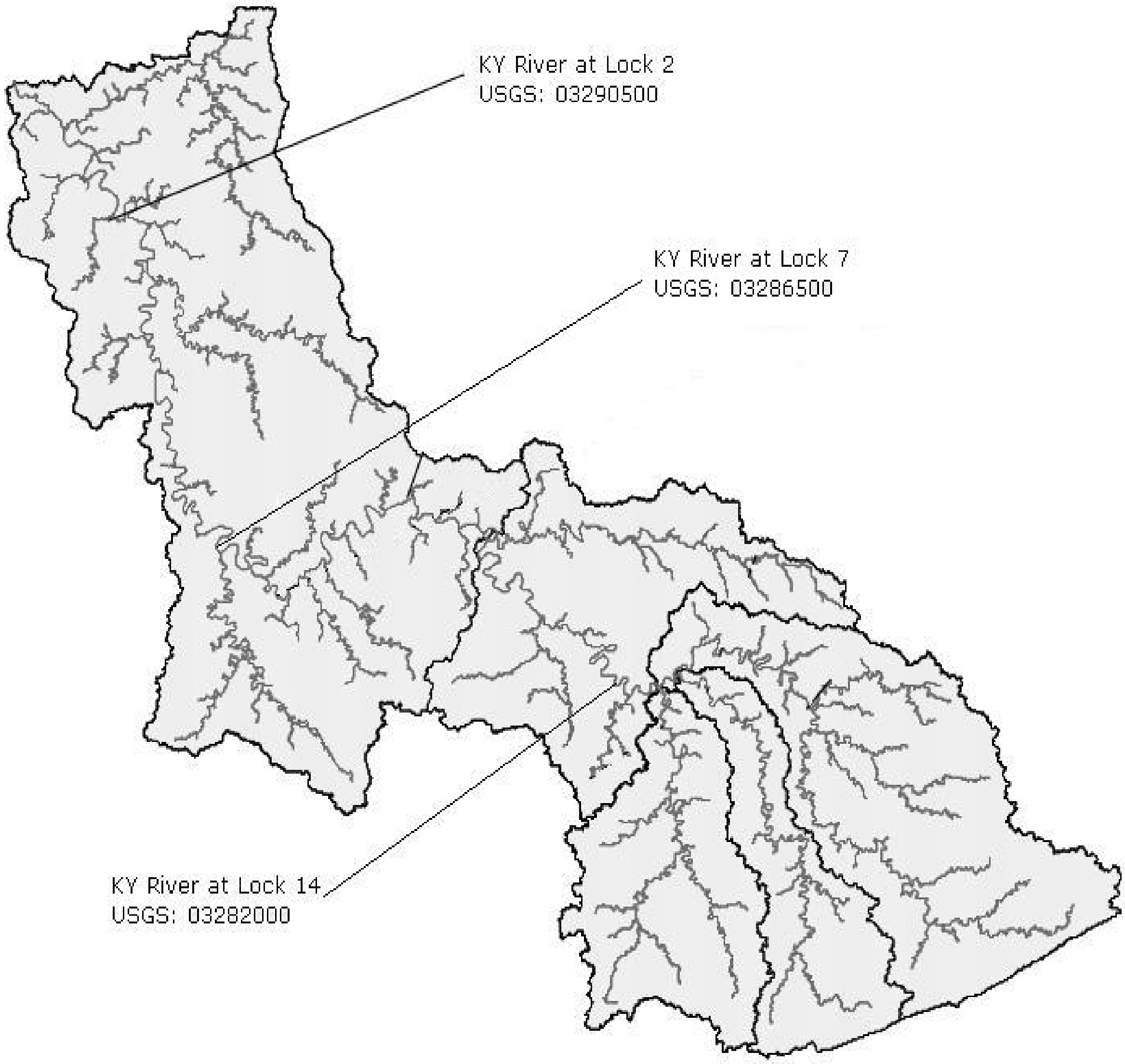

Figure 6: Map of USGS Flow Gaging Stations at Kentucky River Lock & Dams 2, 7 and 14

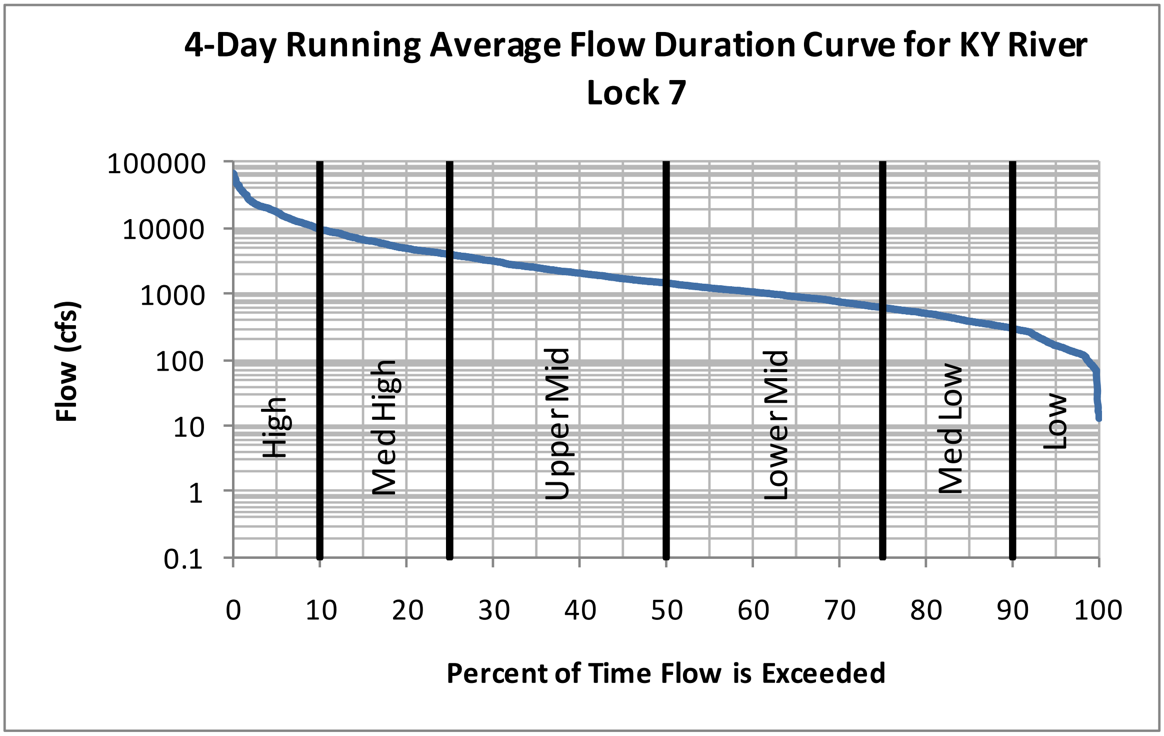

Figure 7: Flow Duration Curve for Running Four-Day Average Flows, May through September, 1993 to 2009, at the Kentucky River Lock #7 USGS Gaging Station

Table 1: KRWW Sampling Efforts by Year (1999 - 2009)

1999			**Flow Conditions**		
Sampling Event	**Sampling Dates**	**# Samples Collected**	**KY River Dam #2**	**KY River Dam #7**	**KY River Dam #14**
Herbicide/Insecticide	5/7 - 5/10/99	83	Med High	Med High	Med High
Synoptic Pathogens	7/16 - 7/19/99	81	Med Low	Low	Low
Follow-Up Pathogens	8/13 - 8/18/99	15	Low	Low	Low
Chemicals/Nutrients	9/18 - 9/20/99	60	Low	Low	Low
Metals	9/18 - 9/20/99	60	Low	Low	Low
2000			**Flow Conditions**		
Sampling Event	**Sampling Dates**	**# Samples Collected**	**KY River Dam #2**	**KY River Dam #7**	**KY River Dam #14**
Herbicide/Insecticide	6/25 - 6/28/00	4	Upper Mid	Upper Mid	Upper Mid
Synoptic Pathogens	7/7 - 7/10/00	69	Med High	Med High	Med High
Follow-Up Pathogens	7/29 - 7/31/00	22	Lower Mid	Lower Mid	Lower Mid
Chemicals/Nutrients	9/8 - 9/10/00	86	Lower Mid	Lower Mid	Lower Mid
Metals	9/8 - 9/10/00	39	Lower Mid	Lower Mid	Lower Mid
2001			**Flow Conditions**		
Sampling Event	**Sampling Dates**	**# Samples Collected**	**KY River Dam #2**	**KY River Dam #7**	**KY River Dam #14**
Herbicide/Insecticide	5/26 - 5/28/01	24	Upper Mid	Med High	Med High
Synoptic Pathogens	7/13 - 7/17/01	144	Upper Mid	Upper Mid	Upper Mid
Follow-Up Pathogens	7/27 - 7/31/01	49	High	High	Med High
Chemicals/Nutrients	9/21 - 9/23/01	121	Med Low	Low	Med Low
Metals	9/21 - 9/23/01	55	Med Low	Low	Med Low
2002			**Flow Conditions**		
Sampling Event	**Sampling Dates**	**# Samples Collected**	**KY River Dam #2**	**KY River Dam #7**	**KY River Dam #14**
Herbicide/Insecticide	5/17 - 5/20/02	32	High	High	High
Synoptic Pathogens	7/12 - 7/16/02	143	Upper Mid	Upper Mid	Lower Mid
Follow-Up Pathogens	7/27- 8/2/02	69	Lower Mid	Lower Mid	Lower Mid
Chemicals/Nutrients	9/14 - 9/16/02	85	Low	Low	Low
Metals	9/14 - 9/16/02	26	Low	Low	Low
2003			**Flow Conditions**		
Sampling Event	**Sampling Dates**	**# Samples Collected**	**KY River Dam #2**	**KY River Dam #7**	**KY River Dam #14**
Herbicide/Insecticide	5/16 - 5/22/03	33	High	High	High
Synoptic Pathogens	7/11 - 7/14/03	151	Med High	Med High	Med High
Follow-Up Pathogens	8/1 - 8/4/03	68	Med High	Upper Mid	Upper Mid
Chemicals/Nutrients	9/12 - 9/15/03	112	Upper Mid	Upper Mid	Upper Mid
Metals	9/12 - 9/15/03	39	Upper Mid	Upper Mid	Upper Mid
2004			**Flow Conditions**		
Sampling Event	**Sampling Dates**	**# Samples Collected**	**KY River Dam #2**	**KY River Dam #7**	**KY River Dam #14**
Herbicide/Insecticide	5/21 - 5/24/04	26	Upper Mid	Upper Mid	Upper Mid
Synoptic Pathogens	7/9 - 7/12/04	152	Med High	Upper Mid	Upper Mid
Follow-Up Pathogens	7/30 - 8/1/04	65	Med High	Med High	Med High
Chemicals/Nutrients	9/10 - 9/12/04	128	High	High	High
Metals	9/10 - 9/12/04	34	High	High	High

Table 1 (continued)

2005			**Flow Conditions**		
Sampling Event	**Sampling Dates**	**# Samples Collected**	**KY River Dam #2**	**KY River Dam #7**	**KY River Dam #14**
Herbicide/Insecticide	5/19 - 5/23/05	28	Med High	Upper Mid	Med High
Synoptic Pathogens	7/8 - 7/12/05	131	Upper Mid	Lower Mid	Lower Mid
Follow-Up Pathogens	7/30 - 8/2/05	59	Lower Mid	Med Low	Med Low
Chemicals/Nutrients	9/16 - 9/20/05	143	Low	Low	Low
Metals	9/16 - 9/20/05	73	Low	Low	Low
2006			**Flow Conditions**		
Sampling Event	**Sampling Dates**	**# Samples Collected**	**KY River Dam #2**	**KY River Dam #7**	**KY River Dam #14**
Herbicide/Insecticide	5/17 - 5/21/06	32	Upper Mid	Upper Mid	Upper Mid
Synoptic Pathogens	7/6 - 7/10/06	158	Med High	Upper Mid	Upper Mid
Follow-Up Pathogens	7/27 - 7/29/06	115	Med Low	Med Low	Lower Mid
Chemicals/Nutrients	9/14 - 9/18/06	200	Lower Mid	Lower Mid	Lower Mid
Metals	9/14 - 9/18/06	58	Lower Mid	Lower Mid	Upper Mid
2007			**Flow Conditions**		
Sampling Event	**Sampling Dates**	**# Samples Collected**	**KY River Dam #2**	**KY River Dam #7**	**KY River Dam #14**
Herbicide/Insecticide	5/18 - 5/23/07	23	Upper Mid	Upper Mid	Upper Mid
Synoptic Pathogens	6/29 - 6/30/07	161	Med Low	Med Low	Low
Follow-Up Pathogens	7/27 - 7/30/07	109	Upper Mid	Lower Mid	Lower Mid
Chemicals/Nutrients	9/13 - 9/17/07	177	Low	Low	Low
Metals	9/13 - 9/17/07	69	Low	Low	Low
2008			**Flow Conditions**		
Sampling Event	**Sampling Dates**	**# Samples Collected**	**KY River Dam #2**	**KY River Dam #7**	**KY River Dam #14**
Herbicide/Insecticide	5/16 - 5/19/08	18	Med High	Med High	Med High
Synoptic Pathogens	7/11 - 7/12/08	169	Lower Mid	Lower Mid	Med Low
Follow-Up Pathogens	7/27 - 7/30/08	51	Med Low	Med Low	Med Low
Chemicals/Nutrients	9/10 - 9/15/08	116	Low	Low	Low
Metals	9/12 - 9/15/08	46	Low	Low	Low
2009			**Flow Conditions**		
Sampling Event	**Sampling Dates**	**# Samples Collected**	**KY River Dam #2**	**KY River Dam #7**	**KY River Dam #14**
Herbicide/Insecticide	5/14 - 5/18/09	27	High	High	High
Synoptic Pathogens	7/10 - 7/12/09	128	Lower Mid	Lower Mid	Lower Mid
Follow-Up Pathogens	7/31 - 8/3/09	64	Med High	Med High	Med High
Chemicals/Nutrients	9/10 - 9/14/09	123	Upper Mid	Lower Mid	Lower Mid
Metals	N/A	N/A	N/A	N/A	N/A

NOTE: Flow conditions are based on the relative ranking of the sampling period's average flow to running four-day average flows of USGS historical data on May through September flows for years 1993 through 2009. High = High flows are exceeded no more than 10% of the time. Med High = Medium high flows are exceeded no more than 25% of the time. Upper Mid = Upper middle flows are exceeded no more than 50% of the time. Lower Mid = Lower middle flows are exceeded at least 50% of the time. Med Low = Medium low flows are exceeded at least 75% of the time. Low = Low flows are exceeded at least 90% of the time.

Spring Sampling Event: Herbicides and Insecticide Sampling

Each year, Kentucky River Watershed Watch volunteers collect water samples at new sites for analysis of herbicide and/or insecticide concentrations. The pesticides that have been assessed include Alachlor, Metolachlor, Triazine, Chlorpyrifos and 2,4-D. Very few sites have been sampled for herbicides or insecticides in multiple years, mainly because significant detections were so rare. For example, Alachlor was never detected at any of the sites, Chlorpyrifos was only detected at three sites, and 2,4-D was only detected once. Thus, trend analyses are not possible for these parameters. Instead, background information is provided for each of the chemical substances, and any sites with notable findings are noted below.

Water Quality Parameter:
Metolachlor

Metolachlor is usually applied to crops before plants emerge from the soil and is used to control certain broadleaf and annual grassy weeds in field corn, soybeans, peanuts, grain sorghum, potatoes, cotton, safflower, stone fruits, nut trees, highway right-of-ways and woody ornamentals. Currently, there are no water quality standards for Metolachlor. *(See Appendix B for additional information.)*

Metolachlor was analyzed for KRWW samples in 2000 through 2007, and was detected in samples collected during six of the eight years it was assessed. In 2004, 35% of the 26 water samples resulted in a Metolachlor detection. The greatest Metolachlor concentration detected was 3.38 μg/L in 2006 at Eagle Creek in Owen County (K501).

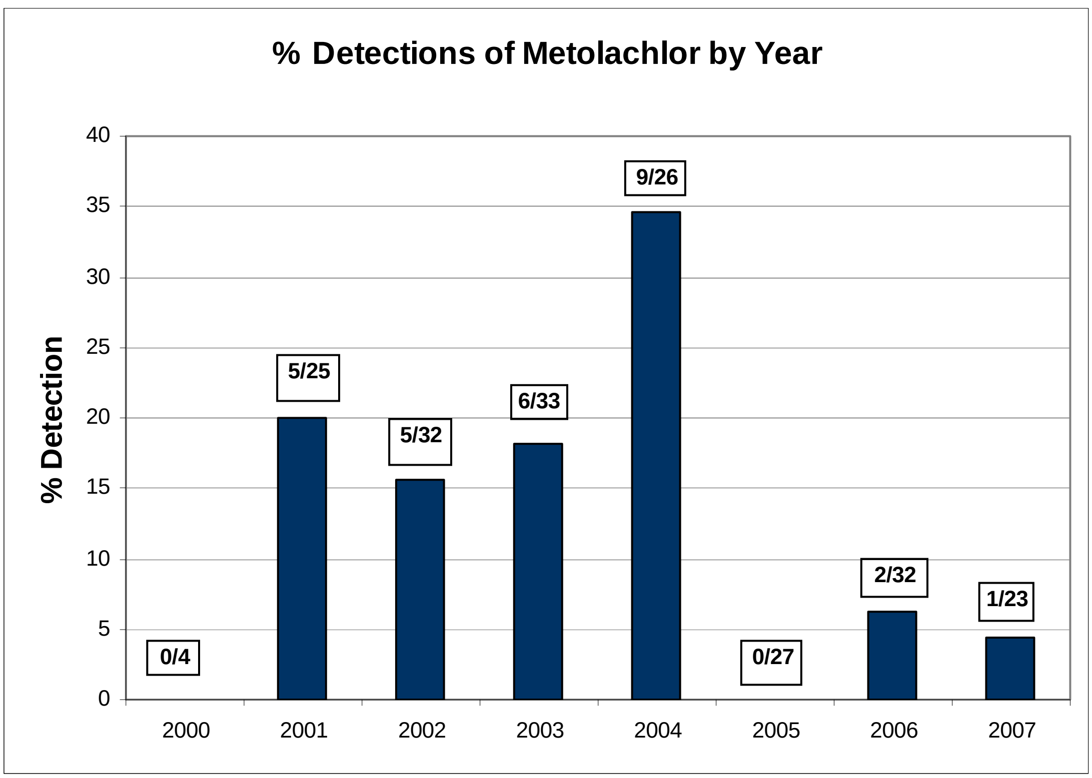

Figure 8: Percent of Metolachlor Detections by Sampling Year
 # sites w/detections over total # samples

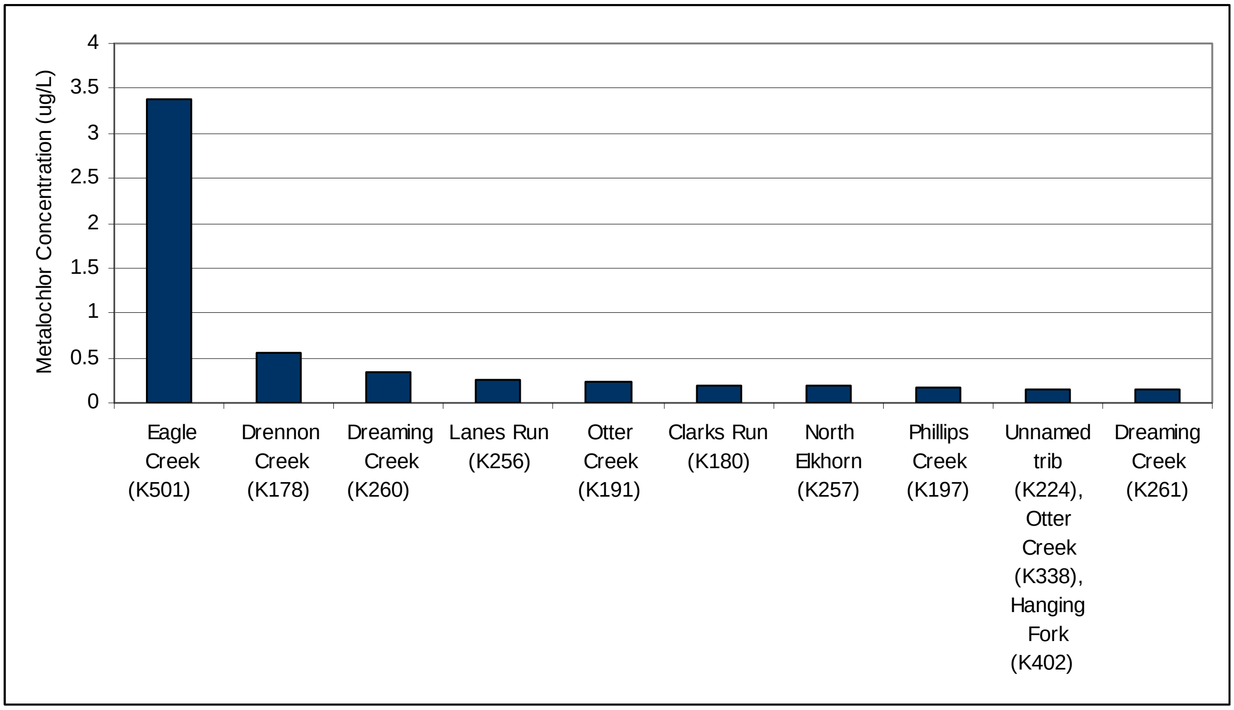

Figure 9: Ten Greatest Observed Metolachlor Concentrations at KRWW Sites (1999-2007)

Water Quality Parameter:
<u>Triazine/Atrazine Herbicide</u>

Triazine (or Atrazine) is a selective herbicide used to control broadleaf and grassy weeds in corn and other crops, and in conifer reforestation plantings. It is also used as a nonselective herbicide on non-cropped industrial lands and on fallow lands. *(See Appendix B for additional information.)*

The EPA's maximum contaminant level for Atrazine in drinking water is 3 μg/L (http://www.epa.gov/safewater/mcl.html). The EPA's Office of Water has published a draft ambient water quality criteria document for atrazine containing acute and chronic criteria recommendations for the protection of aquatic life in both freshwater and saltwater. The procedures described in the "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses" indicate that, except possibly where a locally important species is very sensitive, freshwater aquatic life and their uses should not be negatively affected if the one-hour average concentration does not exceed 350 μg/L more than once every three years on the average (acute criterion) or if the four-day average concentration of atrazine does not exceed 12 μg/L more than once every three years on the average (chronic criterion).

Atrazine (or Triazines) was analyzed for KRWW samples every year between 1999 through 2009. It was detected in at least one sample each year except in 2008. In 1999, atrazine was detected in 65%, or 54 of the 83, samples assessed. The greatest atrazine concentration of 8.6 μg/L was detected in 2006 at Eagle Creek in Owen County (K501), the same site and location of the greatest Metolachlor concentration. This basin-wide high concentration did not exceed the EPA's recommended chronic criterion. It is also notable that five of ten sites with the greatest atrazine concentrations are also among the ten sites with the greatest Metolachlor concentrations (K178, K224, K256, K402 and K501), suggesting that these sites may be considered for additional herbicide testing in the future.

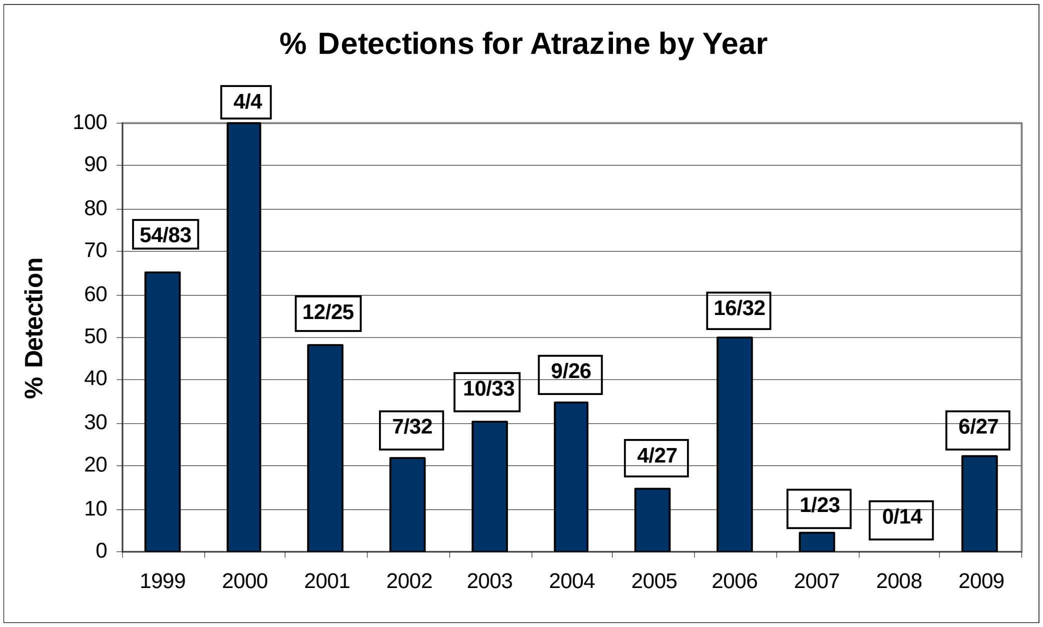

Figure 10: Percent of Atrazine Detections by Sampling Year
 # sites w/detections over total # samples

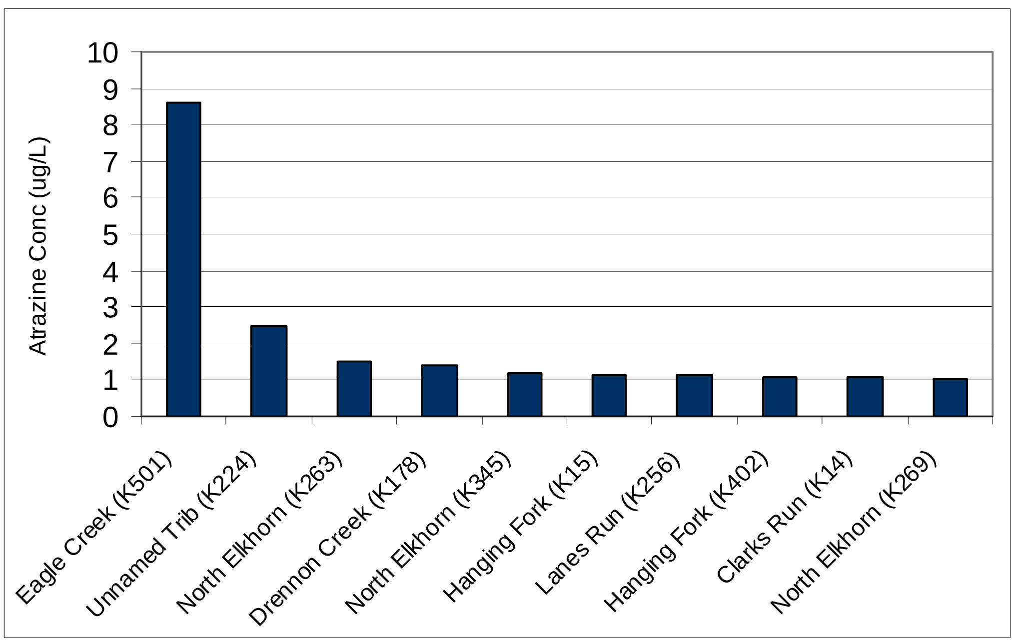

Figure 11: Ten Greatest Observed Atrazine Concentrations at KRWW Sites (1999-2009)

Water Quality Parameter:
Chlorpyrifos

Chlorpyrifos is a broad-spectrum organophosphate insecticide. While originally used primarily to kill mosquitoes, it is no longer registered for this use. Chlorpyrifos is effective in controlling cutworms, corn rootworms, cockroaches, grubs, flea beets, flies, termites, fire ants and lice and is used as an insecticide on various crops, as well as on lawns and ornamental plants. It is also registered for use on sheep, turkeys, for horse site treatment, dog kennels, domestic dwellings, farm buildings, storage bins and commercial establishments. *(See Appendix B for additional information.)*

Chlorpyrifos was sampled at KRWW sites between 1999 and 2001. It was only detected in the initial collection year of 1999 at three sites, as described below. The Kentucky Division of Water has established warm water aquatic habitat criteria for Chlorpyrifos as being 0.083 μg/L for acute conditions and 0.041 μg/L for chronic conditions. These three detections exceed both the acute and chronic water quality standards.

Table 2: KRWW Chlorpyrifos Detections, Detection Year, and Locations

KRWW ID#	Year	Stream Name (County)	Chlorpyrifos (μg/L)
K005	1999	Cane Run (Scott Co.)	0.15
K025	1999	South Elkhorn Creek (Fayette Co.)	0.15
K033	1999	UT of South Elkhorn Creek (Scott Co.)	0.14

Water Quality Parameter:
2,4-D

2,4-Dichlorophenoxyacetic acid (2,4-D) is a common systemic herbicide used in the control of broadleaf weeds. It is the most widely used herbicide in the world, and the third most commonly used in North America. According to the US EPA's website, the short-term health effects of exposure to high levels of 2,4-D in drinking water can include nervous system damage. Long-term exposure to 2,4-D can potentially cause damage to the nervous system, kidney and liver. The US EPA has set a maximum contaminant level of 70 ppb in drinking water.

When 2,4-D was analyzed in KRWW samples between 1999 and 2001, it was only detected once (0.9 μg/L) at Cane Run in Scott County (K005) in 1999.

Overall Pesticide Summary

The following table summarizes the most notable pesticide findings at KRWW sites between 1999 and 2009. The concentrations in bold exceeded at least one of the associated water quality standards. Based on these findings, KRWW volunteers have not detected a problematic level of herbicides or insecticides in Kentucky River Basin waterways.

Table 3: KRWW Sites with Maximum Pesticide Concentrations between 1998 and 2009

Site ID / Sample Year	Parameter	Maximum concentration, µg/L	Water Quality Standard*
K005 (1999)	2, 4-D	0.9	70 µg/L for Drinking Water MCL (USEPA)
K005 (1999)	Chlorpyrifos	**0.15**	0.083 µg/L for Acute WWAH 0.041 µg/L for Chronic WWAH
K025 (1999)		**0.15**	
K033 (1999)		**0.14**	
K261 (2003)	Metolachlor	0.15	N/A
K224 (2002)		0.16	
K197 (2002)		0.17	
K257 (2003)		0.19	
K180 (2001)		0.2	
K191 (2001)		0.24	
K256 (2003)		0.25	
K260 (2003)		0.35	
K178 (2001)		0.55	
K501 (2006)		3.38	
K269 (2003)	Triazine	1.01	3.0 µg/L for DWS 350 µg/L for Acute WWAH 12 µg/L for Chronic WWAH
K014 (1999)		1.05	
K402 (2005)		1.07	
K256 (2003)		1.11	
K015 (1999)		1.15	
K345 (2005)		1.2	
K178 (2001)		1.42	
K263 (2003)		1.49	
K224 (2002)		2.48	
K501 (2006)		**8.6**	

* Water Quality Standards:
MCL= Maximum Contaminant Level
WWAH=Warm Water Aquatic Habitat
DWS=Drinking Water Supply

Summer Sampling Events: Synoptic and Follow-Up Pathogens

A number of pathogenic (disease causing) viruses, bacteria, and protozoans can enter a water body via exposure to fecal contamination. Human illness can result from drinking water or swimming in water that contains pathogens. Eating shellfish harvested from such waters may also result in human illness.

Unfortunately, direct testing for pathogens is impractical. Pathogens are rarely present in large numbers, and many are difficult to cultivate in the lab. Instead, microbiologists look for "indicator" species – so called because their presence indicates that fecal contamination may have occurred. The indicators most commonly used today include the following bacteria: total coliforms, fecal coliforms, Escherichia coli, fecal streptococci, and enterococci. Each of these bacteria are normally prevalent in the intestines and feces of warm-blooded animals, including humans. The indicator bacteria themselves are not usually pathogenic. All but Escherichia (E. coli) are composed of a number of species of bacteria that share common characteristics such as shape, habitat, or behavior. E. coli is a single species in the fecal coliform group, which will normally not make you ill. However, there is one special strain of E. coli (e.g. 0157:h7) that can make you ill and is the strain associated with E. coli "outbreaks." Thus, when a water sample contains E. coli, it does not mean that this dangerous strain is present and, in fact, it probably is not. However, it does indicate that fecal contamination is present, which could indicate the possible presence of pathogens

KRWW utilized a variety of parameters between 1998 and 2009 to assess pathogen levels in the basin's waterways, including fecal coliform, fecal streptococci, total coliforms, atypical coliforms, and E. coli. Beginning in 2008, all pathogen analysis was conducted using E coli, since the Kentucky Division of Water began basing its recreational primary contact standards on this indicator organism. Recent research at the University of Kentucky has resulted in a mathematical relationship between fecal coliforms (FC) and E. Coli (EC) of the following form: $EC = 1.44*FC^{0.8093}$ with an $R^2 = 0.76$ (Akasapu et. al. , 2010). The relationship was developed using data from the Kentucky River Basin and should only be considered applicable for samples taken from this basin.

Water Quality Parameters:
<u>Fecal coliform</u>

Fecal coliforms, a subset of total coliform bacteria, are more fecal-specific in origin than total coliform. For recreational waters, this group was the primary bacteria indicator until relatively recently, when the USEPA began recommending E. coli and enterococci as better indicators of health risk from water contact. However, fecal coliforms are still being used in some cases as the indicator bacteria and were used in KRWW analysis from 1999 until 2008.

The state criteria previously used for fecal coliform are based on the designated use of the particular stream and are summarized below.

Primary Contact Recreation (swimming from May 1 thru October 31): fecal coliform shall not exceed 200 colonies per 100 ml as a monthly geometric mean, based on not less than 5 samples per month; nor exceed 400 colonies per 100 ml in 20 percent or more of all samples taken during the month. (NOTE: As a result of the sampling frequency requirement with the first criteria, the state of Kentucky used the 400 colonies/100 ml criteria for its regular 305b Water Quality Report. KRWW also used this standard in its analysis.)

Secondary Contact Recreation (fishing and boating): fecal coliform shall not exceed 1,000 colonies per 100 ml as a monthly geometric mean, based on not less than 5 samples per month; nor exceed 2,000 colonies per 100 ml in 20 percent or more of all samples taken during the month.

Domestic Water Supply: fecal coliform shall not exceed 2,000 colonies per 100 ml as a monthly geometric mean, based on not less than 5 samples per month.

Escherichia coli (E. coli)

The bacteria, **E. coli**, is commonly found in intestines of healthy humans and animals and produces the K and B– complex vitamins that are then absorbed for nutritional benefit. The presence of E. coli in water indicates fecal contamination and the potential for waterborne disease. EPA recommends E. coli as the best indicator of health risk from water contact in recreational waters. Kentucky has transitioned from a fecal coliform standard to an E. coli standard. The state criteria for E. coli are based on the designated use of the particular stream and may be summarized as follows:

Primary Contact Recreation (swimming from May 1 thru Oct 31): E. coli shall not exceed 130 colonies per 100 ml as a monthly geometric mean based on not less than 5 samples per month; nor exceed 240 colonies per 100 ml in 20 percent or more of all samples taken during the month. [Note: As a result of the sampling frequency requirement with the first criterion, the state of Kentucky uses the 240 colonies per 100-ml criteria for classifying streams in the 305(b) report. KRWW used this standard for E coli analysis.]

Bacteriological Sampling Results

Each year, KRWW pathogen sampling is conducted twice during the summer. The first round of sampling, or the synoptic event, is available for all samplers at all sampling sites. The second round, or follow-up event, is only available at those sites that produced pathogen results greater than the recreational water quality standard during the synoptic sampling event. Intensive pathogen sampling has also been conducted in specific streams, based on previous results of concern and volunteer interest. These "focus studies" produce pathogen sampling results that can be incorporated in Citizen Action Plans and may serve as the basis for targeted water quality improvement recommendations.

A graph of the percent of pathogen values exceeding the primary contact recreational (swimming) criteria shows that percentages have fluctuated from a low of 19% during the synoptic event in 1999 (which corresponded to a 25 year drought year) to a high of 68% during the synoptic event in 2003. The percentages for follow-up events are normally higher, since these sites were already detected as having water quality standard exceedances during that year's prior, synoptic event.

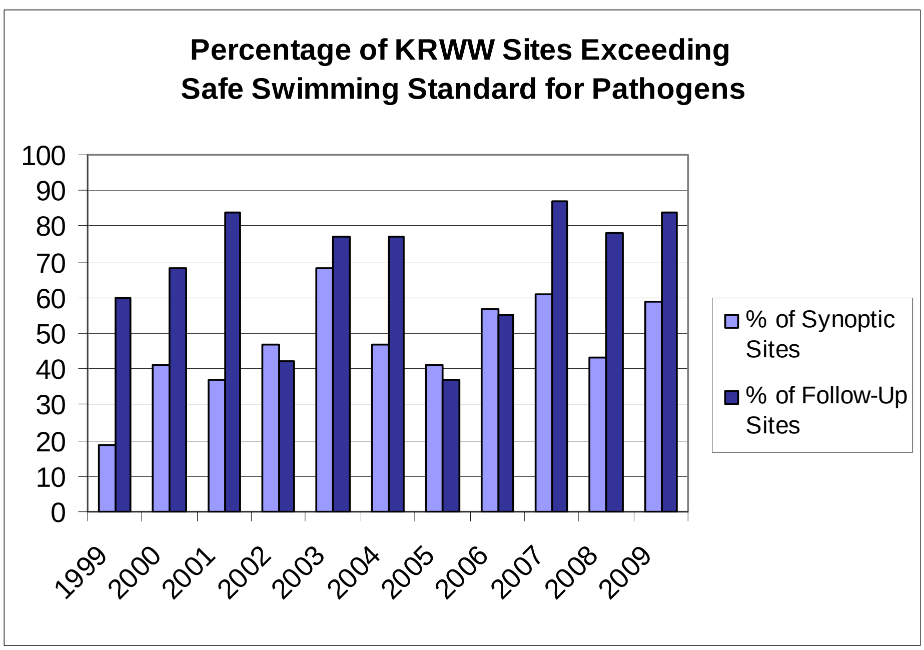

Figure 12: Percent of KRWW Sampling Sites with Pathogen Concentrations Greater than Kentucky Safe Swimming Standard <u>by Event</u> by Year

In order to standardize and compare the fecal coliform and E coli concentrations recorded during the analysis period of 1999-2009, a statistical analysis was conducted to determine a relationship between the two pathogen indicators (Akasapu et. Al, 2010). Once this relationship was established, a statistical comparison was used (i.e., a t-test) to determine if there was an improvement, decline or no change in the pathogen levels between the 1999-2003 five-year time period and the 2004-2009 six-year time period. Unfortunately, there are many sites in the KRWW database with insufficient data to carry out the comparative analysis. However, a few sites exhibited very significant signs of improvement -- K174, K198 and K303. Sites with very significant declines in pathogen status are K085 and K096. Other sites showing signs of improvement are K054, K105, K156, K157, K199, K213, K245, K249 and K301, and sites showing signs of worsening are K005, K055, K057 and K247. All other sites either fail to show statistically significant changes or lack adequate data to perform the statistical comparison.

Table 4: KRWW Pathogen Trends from 1998-2003 and 2004-2009

KRWW Site ID#	Condition	Stream Name	Sampling Site Location	County
K002	Worsening	Lee's Branch	150 yds. downstream of Stephens St	Woodford
K005	Much worse	Cane Run Creek	0.2 mi upstream of Hwy 460 bridge	Scott
K016	Worsening	North Elkhorn Creek	At Great Crossings	Scott
K055	Worsening	Town Branch	Jimmy Campbell Lane Bridge	Fayette
K057	Worsening	Spring Stn	At spring, Beals Run	Woodford
K085	Much worse	Glenn's Creek	At Glenn's Creek Baptist Church	Woodford
K096	Much worse	Graddy Spring	Spring on Greenwood Farm, Steele Road	Woodford
K215	Worsening	Lost Creek	Below Lost Creek Post Office	Breathitt
K247	Worsening	Viney Creek	Bluegrass Army Depot - Rt 10 E area	Madison
K054	Improving	McConnell Springs	Off Leestown Road	Fayette
K105	Improving	Blair Branch	At mouth of Blair Br	Letcher
K156	Improving	Four Mile Creek	At mouth of creek	Clark
K157	Improving	Kentucky River	Boonesboro Beach	Clark
K174	Much better	South Fork Elkhorn	Hwy 421 to Forks	Woodford
K198	Much better	Ky River	Pool 6 main stem	Woodford
K199	Improving	Ky River	Pool 6	Mercer
K245	Improving	Muddy Creek	Bluegrass Army Depot	Madison
K249	Improving	Muddy Creek	Dreyfus Rd, @ culvert where creek exits Central Ky WMA	Madison
K301	Improving	Hickman Creek	At Mackey Rd bridge, directly upstream of convergence of W.Hickman Cr	Jessamine
K303	Much better	Hickman Creek	At KY1980 Bridge	Jessamine

Fall Sampling Event: Nutrient and Metals

Nutrient Sampling

Each year, KRWW water quality samples have been assessed for nutrient concentrations, specifically those of nitrogen, phosphorus and sulfates. Nitrogen and phosphorus are important water quality parameters due to their influence on aquatic plant and algae growth. When these two nutrients are in abundance, they stimulate algal growth and can cause eutrophication of a water body. Eutrophication refers to the process during which a water body’s ability to support aquatic life declines, mainly due to low dissolved oxygen levels (see Figure 13).

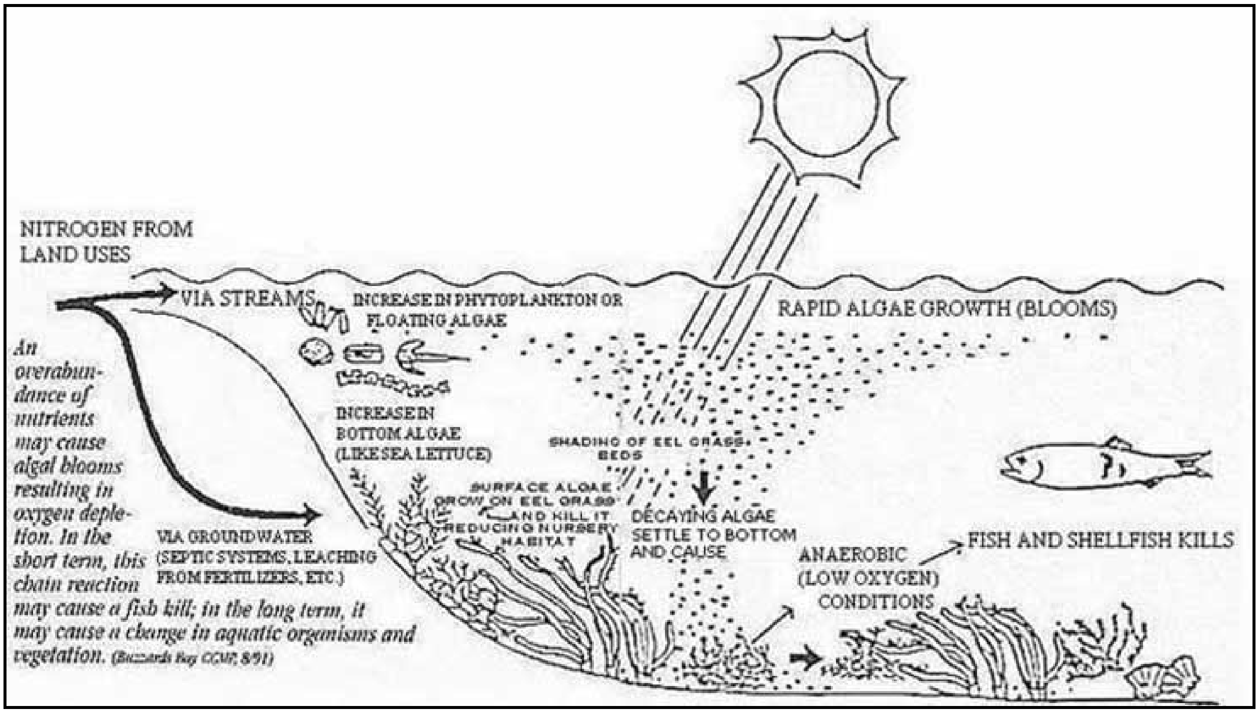

Figure 13: The Eutrophication Process (*graphic depiction from Nantucket Land Council, Inc.*)
Nutrient runoff to waterbody ⇨ Stimulate algae blooms/aquatic plant growth ⇨ Plants die and decompose ⇨ Bacteria consume dead plant material through respiration, consuming oxygen ⇨ Oxygen levels, especially in lower strata of waterbody decrease ⇨ Aquatic organisms die off or leave

The eutrophication process occurs naturally in freshwater, saltwater and estuarine waterbodies, but can happen more rapidly when human activities increase nutrient runoff, such as through lawn and crop fertilization, sewage and livestock manure runoff, and riparian vegetation removal. Referred to as "cultural eutrophication," this process is believed to be the cause for a growing "Dead Zone" in the Gulf of Mexico where no shelfish or marine life can exist due to low or absent oxygen levels. The USEPA and others are working toward the development of water quality criteria and regulations to address and reduce the size of this anoxic zone in the Gulf. Similarly, the Kentucky Division of Water is working to develop aquatic life standards for nitrogen and phosphorus levels in state waterbodies. Currently, the KDOW has only established criteria for the nutrient parameters of nitrates and sulfates in waters used for a drinking water supply, issued at 10 milligrams/liter for nitrate-nitrogen (NO_3-N) and 250 milligrams/liter for sulfate (SO_4). It is anticipated that numerical criteria will eventually be established for both total phosphorus and total nitrogen, but it is expected that these criteria will likely be spatially dependent on eco-regions. For example, the Kentucky River Basin is split between eco-region 9 (Southeastern temperate plains and hills in the lower basin) and eco-region 11 (the Central and Eastland Forested Uplands in the upper basin). The Kentucky Division of Water is currently considering the establishment of tentative nutrient standards for the central Bluegrass Region to be 0.3 mg/L for total phosphorus and 10.0 mg/L for total nitrogen.

Water Quality Parameter:
Total Phosphorus

Phosphorus is a key element required for plant and animal growth. Orthophosphates are naturally produced and are found in sewage. Polyphosphates are found in detergents and convert to orthophosphate in water. Organic phosphates are also found in pesticides and may wash from soils into nearby waterways. Phosphates will stimulate the growth of plankton and aquatic plants, which provide food for fish. However, excessive phosphates in waterbodies can cause the overfertilization of receiving waters. Phophsates are not directly toxic to people or animals unless they are present in very high levels, at which point they may cause digestive problems.

KRWW samples have traditionally been assessed for phosphorus content through analysis of "total phosphorus." Total phosphorus measurements capture all forms of phosphorus in the water, dissolved or particulate. In Kentucky, particularly in regions of the state with limestone bedrock, ambient phosphorus levels are naturally higher than those found in other areas of the country. Background levels may be as high as 0.25 mg/L and provide an ample supply of this nutrient for aquatic plant growth. Although formal, quantitative nutrient criteria for water quality protection are still under development by the state of Kentucky, the Kentucky Division of Water has tentatively recommended a total phosphorus limit of 0.30 mg/L for aquatic life protection for streams in the central Bluegrass region of Kentucky. The following graph shows the annual number of sampling sites with total phosphorus readings greater than 0.30 mg/L.

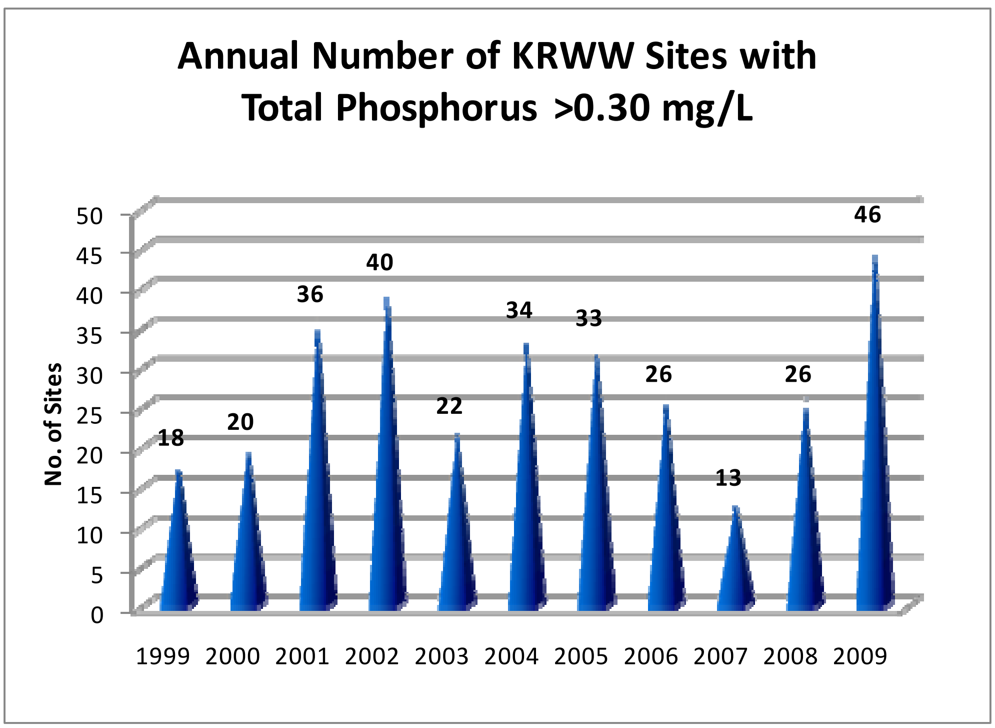

Figure 14: Annual Number of KRWW Sampling Sites with Total Phosphorus > 0.30 mg/L

For sampling sites with at least three years of total phosphorus results, averages were calculated. The graph and associated table, shown below, displays those sites with the ten greatest average total phosphorus concentrations over the analysis period of 1999-2009.

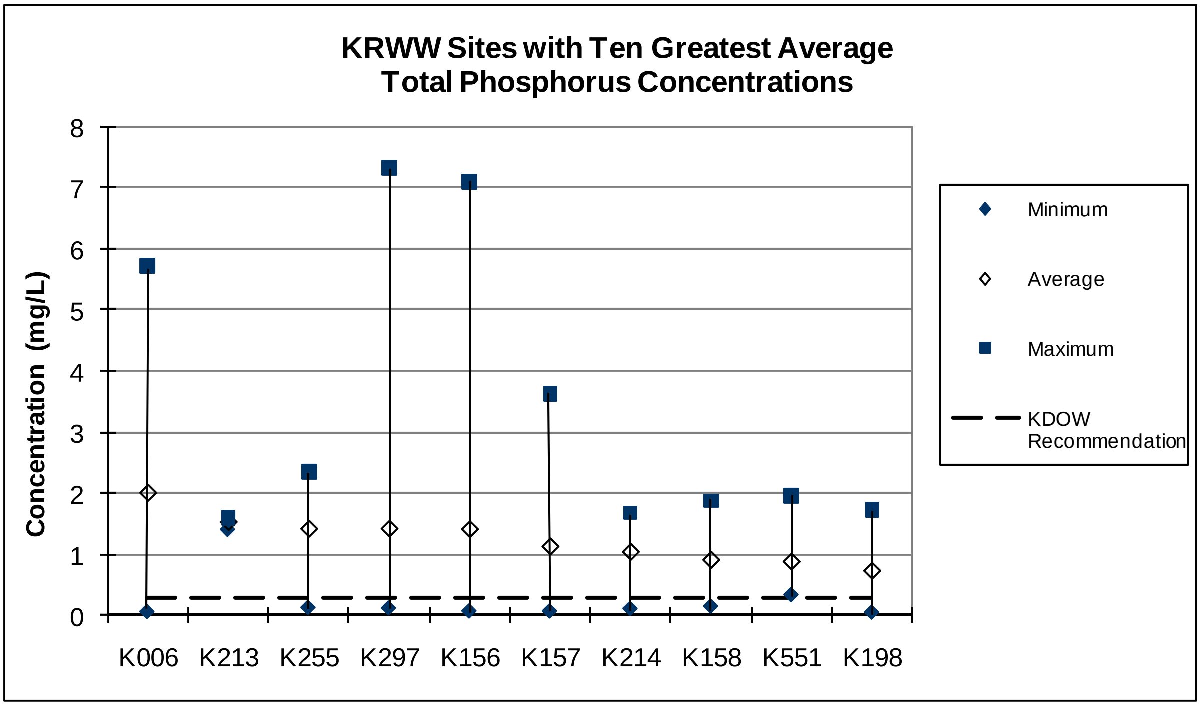

Figure 15: KRWW Sites with Ten Greatest Average Total Phosphorus Concentrations (1999-2009)

Table 5: KRWW Sites with Greatest Average Total Phosphorus Concentrations

KRWW Site ID#	Stream Name	County	Average Total Phosphorus Concentration (mg/L)
K006	Upper Red River	Wolfe	2.02
K213	Quicksand Creek	Breathitt	1.54
K255	Dry Run	Scott	1.43
K297	Penitentiary Branch	Franklin	1.43
K156	Four Mile Creek	Clark	1.42
K157	Kentucky River	Clark	1.14
K214	South Fork Quicksand Creek	Breathitt	1.05
K158	Howards Creek	Clark	0.92
K551	UT to South Elkhorn Creek	Fayette	0.89
K198	Kentucky River	Woodford	0.74

The following map shows the location of these ten sites within the Kentucky River Basin.

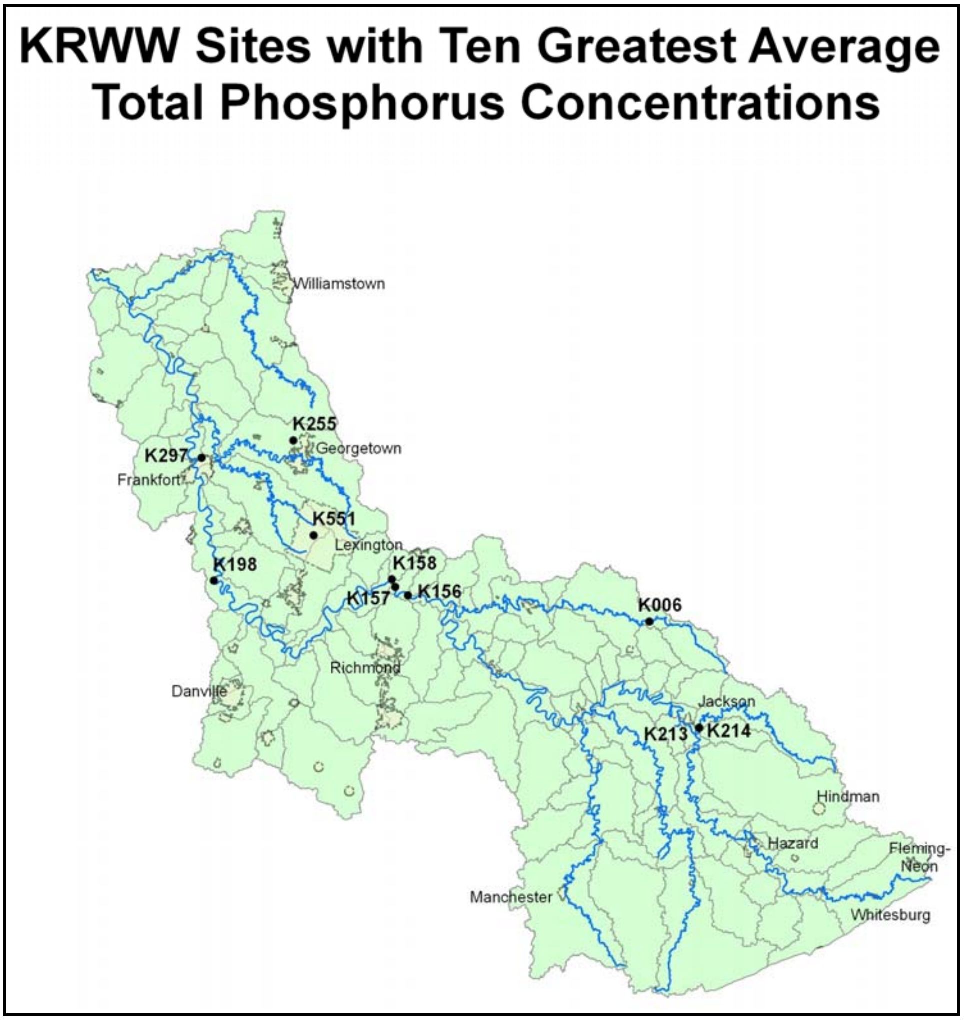

Figure 16: KRWW Sites with Ten Greatest Total Phosphorus Concentrations

Water Quality Parameter:
<u>Nitrogen</u>

Nitrogen is one of the most abundant elements on earth and comprises about 80% of the air that we breathe. It is found in the cells of all living things and is a major component of proteins. Inorganic nitrogen may exist in the free state as a gas (N_2), or as a nitrate (NO_3), nitrite (NO_2) or ammonia (NH_3). Nitrogen-containing compounds act as nutrients in streams, rivers and reservoirs. The major sources of nitrogen within a watershed are municipal and industrial wastewater, septic tanks, livestock feedlot discharges, animal wastes (including birds and fish), runoff from fertilized agricultural fields and lawns, and car exhaust.

Excessive nitrites in waterbodies can cause a disease in fish called "brown blood disease". Nitrites can also react with hemoglobin in the blood of humans and other warm-blooded animals to produce methemoglobin, which destroys the ability of red blood cells to carry oxygen. This condition, know as methemoglobinemia or "blue baby disease" can be especially dangerous for babies younger than three months old. Water with nitrate levels above 1 mg/L should not be used for feeding babies. High nitrate levels in drinking water can also cause digestive disturbances for humans.

KRWW samples were tested for various forms of nitrogen during the 1999-2009 assessment period, including ammonia (NH_3 and NH_3-N), nitrate (NO_3 and NO3-N), and total nitrogen. The Kentucky Division of Water's water quality standards include a drinking water supply standard for nitrate-nitrogen (NO_3-N) of 10 mg/L and an aquatic life standard for ammonia-nitrogen which depends on the water pH and water temperature. The standard is 6.4 mg/L based on a pH of 7.0 and a temperature of 27°C. Although formal quantitative nutrient water quality criteria are still under development by the state of Kentucky, the Kentucky Division of Water has tentatively recommended a total nitrogen limit of 10.0 mg/L for aquatic life protection for streams in the central Bluegrass Region of Kentucky.

Water Quality Parameter:
Ammonia
For sites with at least three years of ammonia-nitrogen (NH_3-N) data, only one resulted in an average ammonia-nitrogen concentration greater than the 6.4 mg/L Kentucky aquatic life standard at a pH of 7.0 and a temperature of 27°C. KRWW site K001 at Lee's Branch in Woodford County had an average ammonia concentration of 6.55 mg/L.

Water Quality Parameter:
Nitrate
Due to the high background presence of phosphorus in soils of the Kentucky River Basin, nitrate is frequently the "limiting nutrient" for algal and aquatic plant growth. Thus, an influx of nitrate can stimulate problematic algal blooms.

Kentucky's existing water quality standard for nitrate applies to drinking water supply sources, and does not relate to the conditions favorable for plant growth. This standard of 10 mg/L (measured as nitrate-nitrogen) addresses the toxicity of high nitrate levels in drinking water, a condition commonly known as "blue baby syndrome." Nitrates can react with hemoglobin in the blood of humans and other warm-blooded animals to produce methemoglobin, which destroys the ability of red blood cells to transport oxygen, a condition that is especially serious in babies under three months old.

The following graph shows the number of sampling sites that exceeded the drinking water supply standard of 10 mg/L for nitrate-nitrogen during each of the sampling years between 1999 and 2009.

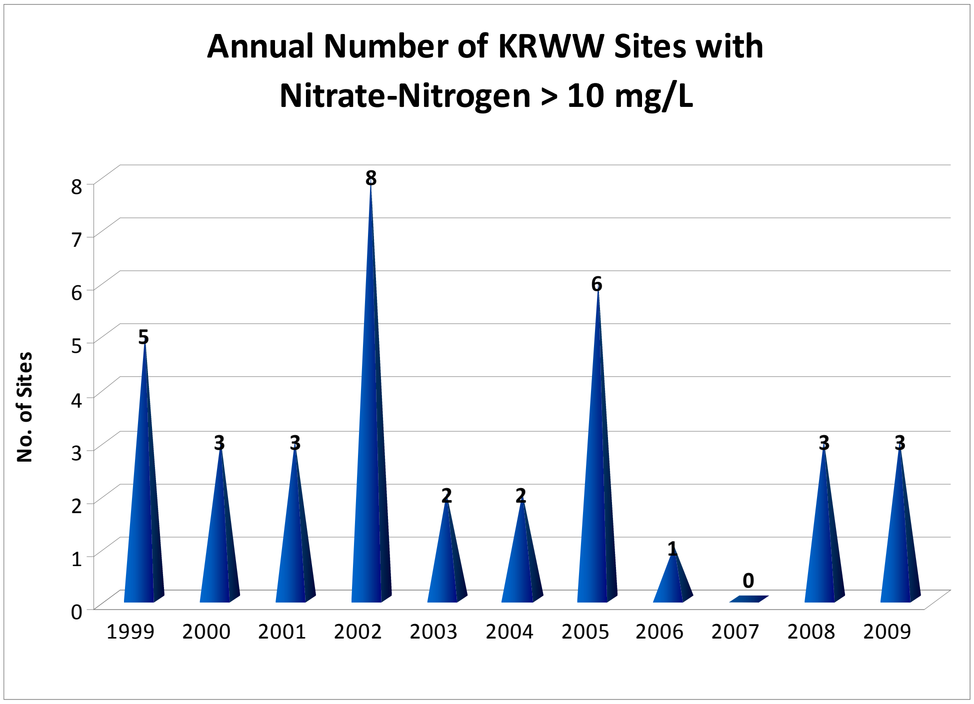

Figure 17: Number of KRWW Sampling Sites with Nitrate-Nitrogen Concentrations > 10 mg/L between 1999 and 2009

For sites with nitrate-nitrogen data from at least three sampling years, the ten greatest average concentrations were observed at the following sites. Three KRWW sites produced average nitrate-nitrogen concentrations (with at least three years of sampling data) greater than the drinking water supply standard of 10 mg/L. These sites were K014 (Clark's Run, Boyle County), K075 (Town Branch, Fayette County) and K260 (Dreaming Creek, Madison County). Both Clark's Run and Town Branch are also formally listed by the Kentucky Division of Water as being impaired due to high nutrient levels, as well as other pollutants.

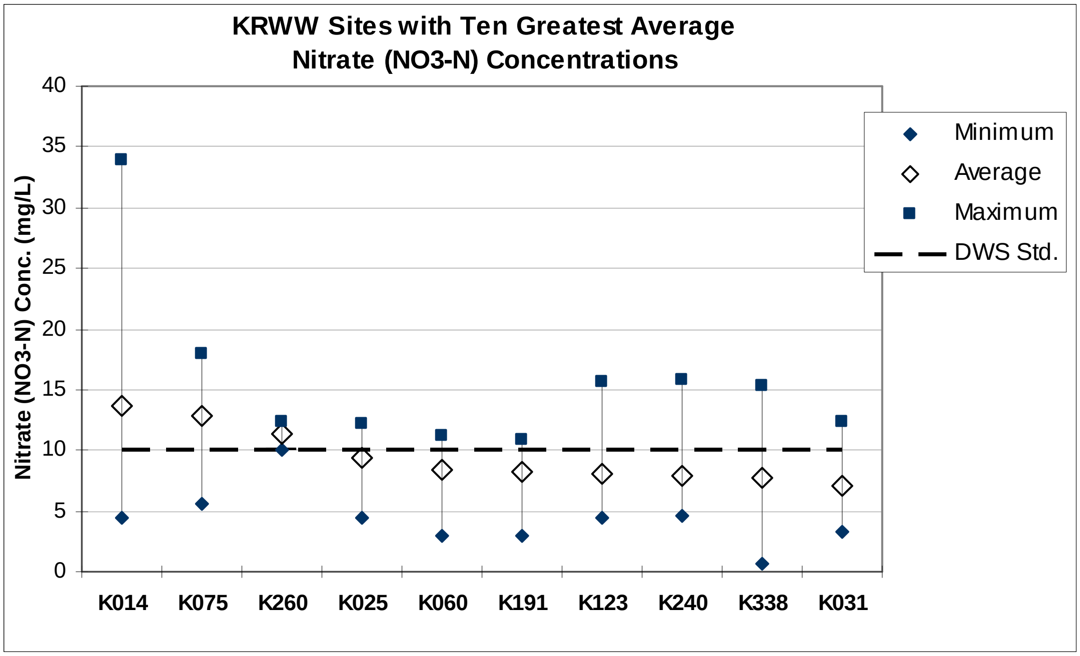

Figure 18: KRWW Sites with Ten Greatest Average Nitrate-Nitrogen Concentrations (1999-2009)

Table 6: KRWW Sites with Greatest Average Nitrate-Nitrogen Concentrations

KRWW Site ID#	Stream Name	County	Average Nitrate-Nitrogen Concentration (mg/L)
K014	Clark's Run	Boyle	13.6
K075	Town Branch	Fayette	12.8
K260	Dreaming Creek	Madison	11.4
K025	South Elkhorn Creek	Fayette	9.4
K060	Dreaming Creek	Madison	8.4
K191	Otter Creek	Madison	8.3
K123	South Elkhorn Creek	Woodford	8.1
K240	Clark's Run	Boyle	7.9
K338	Otter Creek	Madison	7.7
K031	South Elkhorn Creek	Woodford	7.0

These ten sites that produced the highest average nitrate-nitrogen concentrations are labeled on the following map.

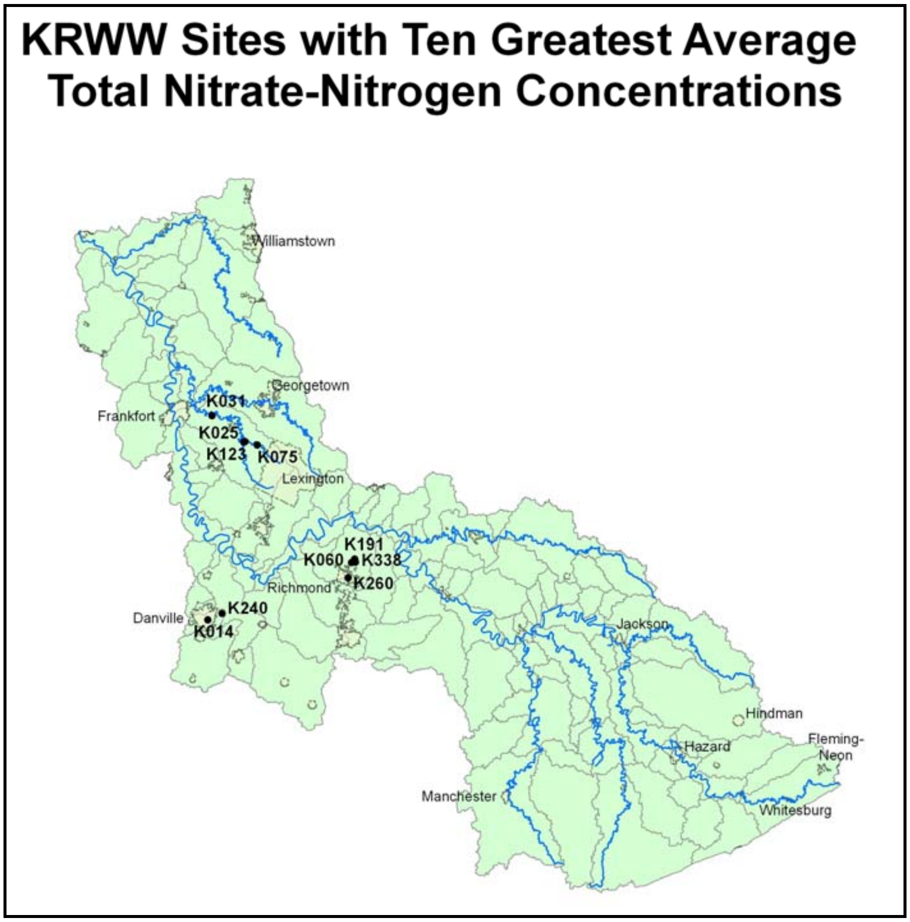

Figure 19: KRWW Sites with Ten Greatest Average Nitrate-Nitrogen Concentrations

Water Quality Parameter:
<u>Sulfate</u>

Sulfates in Kentucky River Basin waterways are usually related to coal mining activities in the area, when high sulfur coal is removed from the bedrock. Thus, high sulfate levels will often correspond to recent mining activity.

> **Sulfur**, like nitrogen and phosphorus, is an essential plant nutrient and can affect algal growth in waterbodies. The most common form of sulfur in well-oxygenated waters is sulfate (SO_4). **Sulfate** is the second most abundant anion in hard waters and can be naturally occurring or the result of municipal or industrial discharges. When naturally occurring, sulfates are often formed from the breakdown of leaves that fall into the waterbody, of water flowing through rock or soil containing gypsum and other common minerals, or from atmospheric deposition. Human-caused point sources can include sewage treatment plants and industrial discharges, such as those from tanneries, pulp mills and textile mills. Runoff from fertilized lands can also contribute sulfates to waterbodies.
>
> When sulfate levels are below 0.5 mg/L, algal growth will not occur. However, excessive sulfate levels can also act as waterbody pollutants. Problems caused by sulfate most often result from their ability to form strong acids, which affect pH levels. The presence of sulfate ions can also affect the solubility of metals and other substances, which can be a critical factor for industrial water uses.

Each fall between 1999 and 2009, KRWW samples were assessed for sulfate levels. The Kentucky Division of Water has established a drinking water supply standard for sulfate of 250 mg/L, but it does not have a standard for the protection of aquatic life. The following graph shows the number of sampling sites with sulfate concentrations greater than 250 mg/L. The large increase in high sulfate sites in 2005 is largely due to the addition of several sampling sites in the North Fork of the Kentucky River watershed.

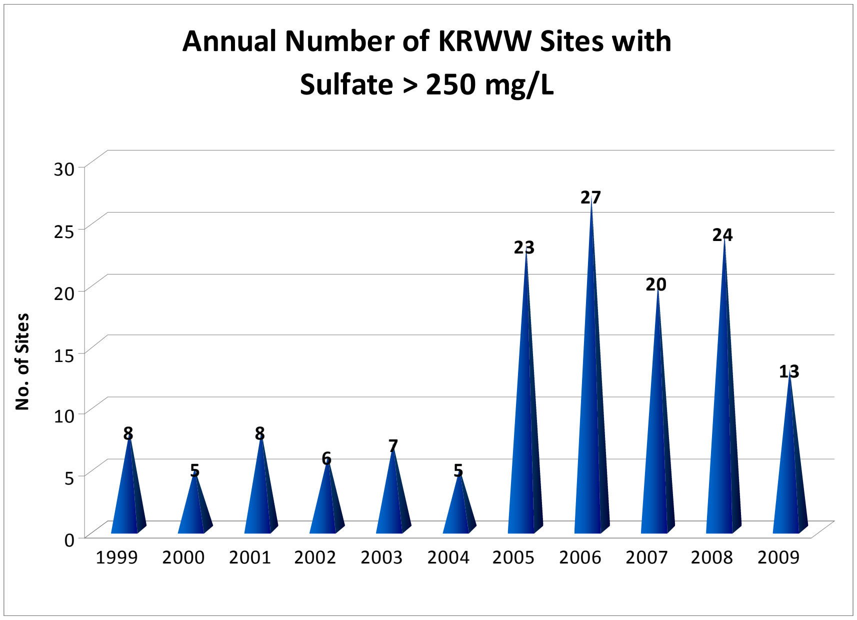

Figure 20: Number of KRWW Sampling Sites with Sulfate Concentrations > 250 mg/L between 1999 and 2009

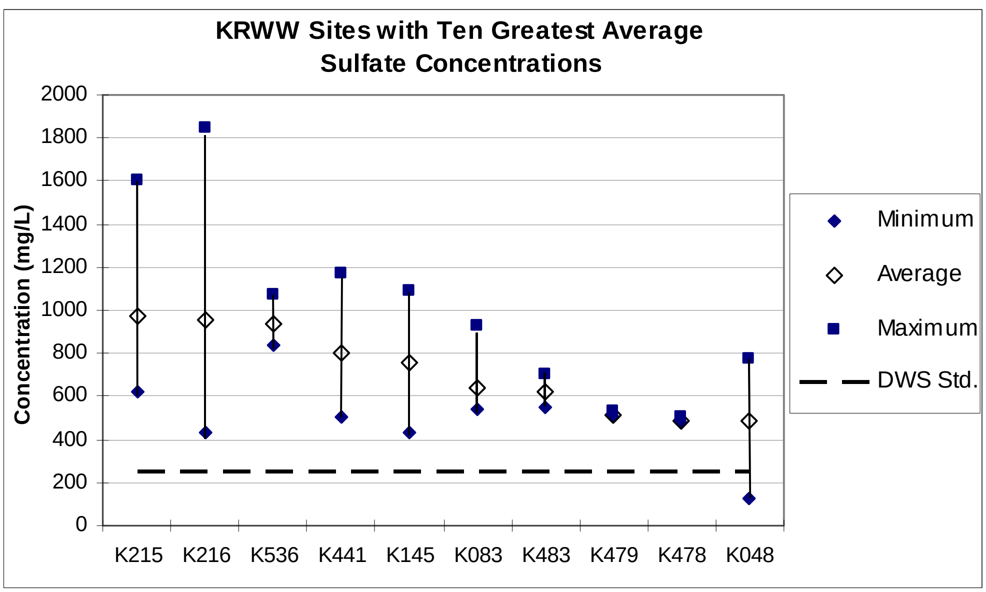

Figure 21: KRWW Sites with Ten Greatest Average Sulfate Concentrations (1999-2009)

Table 7: KRWW Sites with Greatest Average Sulfate Concentrations

KRWW Site ID#	Stream Name	County	Average Sulfate Concentration (mg/L)
K215	Lost Creek	Breathitt	970
K216	Troublesome Creek	Breathitt	951
K536	Long Branch	Letcher	937
K441	Scuddy Branch	Perry	802
K145	Troublesome Creek	Breathitt	753
K083	Lotts Creek	Perry	637
K483	Henry Ison Hollow	Letcher	624
K479	Rockhouse Creek	Letcher	517
K478	Millstone Creek	Letcher	489
K048	North Fork Kentucky River	Breathitt	485

The locations of these ten sites are shown in the following map of the Kentucky River Basin.

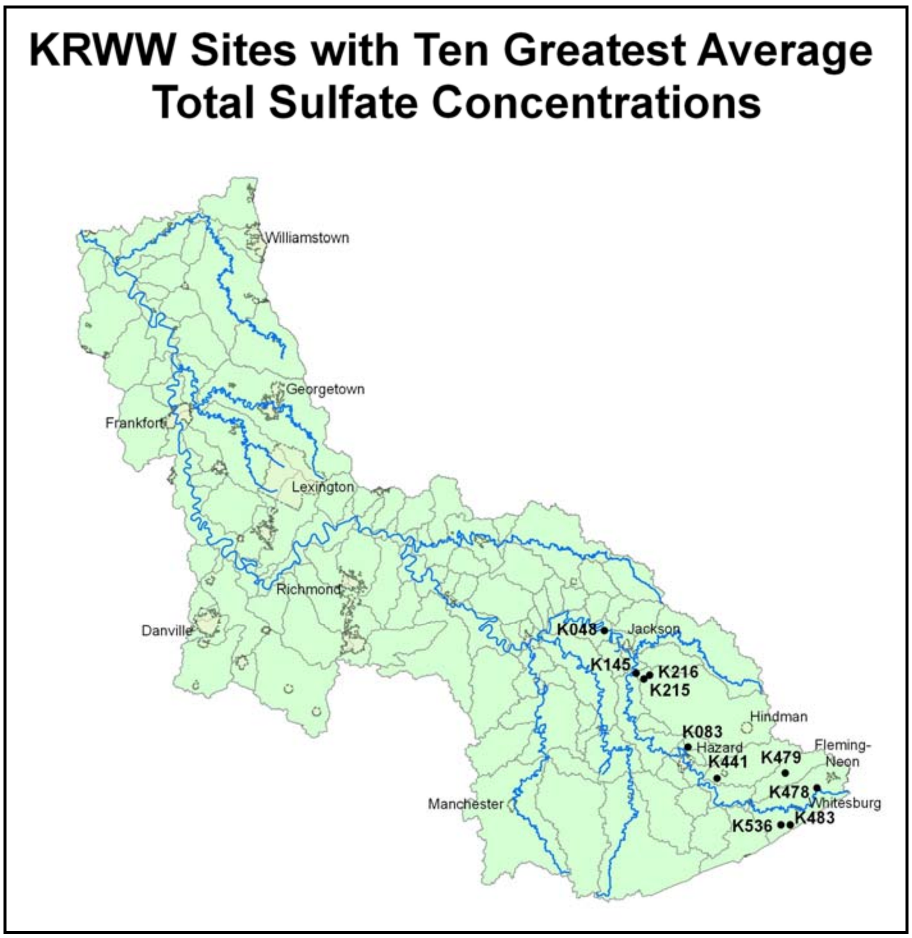

Figure 22: KRWW Sites with Ten Greatest Average Sulfate Concentrations

Metal Sampling

Metal concentrations in KRWW water samples have been assessed annually due to the potential for high concentrations of many metals to create conditions toxic for aquatic life. Metals in drinking water can also be toxic to humans. Thus, the state of Kentucky and the USEPA have established metal standards for instream water quality as it pertains to both aquatic and human health. Of the 30 metals analyzed for KRWW samples each year, standards are available for fourteen. Drinking water supply standards are available for twelve metals: antimony, arsenic, barium, beryllium, cadmium, copper, iron, lead, nickel, selenium, thallium and zinc. Warm water aquatic life standards are available for ten metals: arsenic, cadmium, chromium, copper, iron, lead, nickel, selenium, silver and zinc. Additionally, the USEPA has established maximum contaminant levels for finished (or treated) drinking water for antimony, barium, beryllium, chromium, selenium and thallium. This analysis will focus on the aquatic life and drinking water supply standards for these metals, detailed descriptions of which can be found in Appendix B.

Metals and Drinking Water Supply Criteria

The following standards have been established by the state of Kentucky for waterbodies serving as human drinking water supplies. (See Appendix B for descriptions of these metal parameters.)

Table 8: Drinking Water Supply Standards Associated with Sampled Metals

Metals	Drinking Water Supply Standards
Antimony	5.6 micrograms/liter
Arsenic	10 micrograms/liter
Barium	1,000 micrograms/liter
Beryllium	4 micrograms/liter
Cadmium	5 micrograms/liter
Copper	1,300 micrograms/liter
Iron	300 micrograms/liter
Lead	15 micrograms/liter
Nickel	610 micrograms/liter
Selenium	170 micrograms/liter
Thallium	0.24 micrograms/liter
Zinc	7,400 microgram/liter

Taken from 401 KAR 10:031. Surface water standards (http://www.lrc.ky.gov/kar/401/010/031.htm)

A comparison of KRWW historical results to these standards is made difficult by the lack of sites with ample data to draw conclusions. For sites with at least three years of metals data, very few produced average concentrations that exceeded the respective drinking water supply criteria. Seven sites had antimony concentrations greater than the water supply standard of 5.6 micrograms/liter. Fifteen sites had average iron concentrations greater than the water supply standard of 300 micrograms/l. And, four sites produced an average thallium concentration greater then the water supply standard of 0.24 micrograms/liter. Average concentrations for the other nine metals at assessable sites did not exceed the associated drinking water supply standards.

Table 9: KRWW Sites with Average Metal Concentrations in Exceedance of Kentucky's Drinking Water Supply Standards

Site ID#	Stream Name, County	Metals for which Drinking Water Supply Standards were Exceeded *(data avg of at least 3 sampling yrs.)*
K003	East Fork Eagle Creek, Scott Co.	Iron
K021	Town Branch, Jessamine Co.	Antimony, Iron, Thallium
K028	Clear Creek, Woodford Co.	Antimony, Lead
K050	Benson Creek, Franklin Co.	Iron, Thallium
K081	Kentucky River, Perry Co.	Antimony, Iron
K082	Kentucky River, Perry Co.	Antimony, Iron, Thallium
K083	Lotts Creek, Perry Co.	Antimony, Thallium
K114	Colley Creek, Letcher Co.	Iron
K125	Clarks Run, Boyle Co.	Iron
K145	Troublesome Creek, Breathitt Co.	Antimony, Iron
K189	Muddy Creek, Madison Co.	Iron
K192	Kentucky River, Woodford Co.	Iron

K200	Kentucky River, Mercer Co.	Iron
K215	Lost Creek, Breathitt Co.	Antimony, Iron
K245	Muddy Creek, Madison Co.	Iron
K288	Troublesome Creek, Knott Co.	Iron
K448	Cowan Creek, Letcher Co.	Iron

Metals and Aquatic Life Support Criteria

In order for waterbodies to support aquatic life, the state of Kentucky has set the following standards for various metals concentrations, with acute standards for short-term exposure and chronic standards for long-term exposure. The pH of a water sample can actually affect the amount of metal that will precipitate out. Thus, many of the water quality standards are expressed in terms of the hardness of the water, which is usually expressed in terms of the concentration of calcium carbonate ($CaCO_3$).

Table 10: Kentucky's Aquatic Life Standards for Metals[1]

Metal	Acute[2] Aquatic Life Standard (µg/L)	Chronic[3] Aquatic Life Standard (µg/L)	Acute Standard (µg/L) Based on a Hardness of 100 mg/L	Chronic Standard (µg/L) Based on a Hardness of 100 mg/L
Arsenic	340	150	n/a	n/a
Cadmium	$0.01976(Hard^*)^{1.0166}$	$0.008924(Hard)^{0.7409}$	2.13	0.27
Chromium III	$41.4961(Hard)^{0.8190}$	$1.9834(Hard)^{0.8190}$	1803	86
Copper	$0.1827(Hard)^{0.9422}$	$0.1823(Hard)^{0.8545}$	14.00	9.33
Iron	4000	1000	n/a	n/a
Lead	$0.2322(Hard)^{1.2730}$	$0.0091(Hard)^{1.2730}$	82	3.18
Nickel	$9.5353(Hard)^{0.8460}$	$1.0601(Hard)^{0.8460}$	469	52
Selenium	20	5	n/a	n/a
Silver	$0.00137(Hard)^{1.7200}$	0.12 **	3.78	n/a
Zinc	$2.4206(Hard)^{0.8473}$	$2.4206(Hard)^{0.8473}$	120	120

Taken from 401 KAR 10:031 Surface water standards. Formulas shown in table are equivalent to those found on http://www.lrc.ky.gov/kar/401/010/031.htm.

1 Kentucky standards are for metal concentrations in terms of total recoverable metal in an unfiltered sample. Other governing agencies may publish standards in terms of dissolved metals which are numerically lower.
2 Acute criteria = protective of aquatic life based on one hour of exposure that does not exceed the criterion for a given pollutant.
3 Chronic criteria = protective of aquatic life based on ninety-six hour exposure that does not exceed the criterion of a given pollutant more than once every three years on the average.
* Hard = Water hardness in mg/L of CaCO3. Note: the formula result is in ug/L.
**Former USEPA Criteria. At the time of the writing of this report EPA does not have a chronic criterion for silver.

A comparison of KRWW historical results to these standards is again made difficult by the lack of sites with ample data to draw conclusions. For sites with at least three years of metals data, very few produced average concentrations that exceeded the respective aquatic life criteria.

Two sites had average copper concentrations greater than the aquatic life standard. Nine sites exceeded either or both the acute or chronic criteria for iron. One site produced an average lead concentration greater than the chronic standard for aquatic life support. One site had an average nickel concentration greater than the chronic standard. Four sites exceeded the chronic aquatic life criteria for selenium. And, finally, one site exceeded the acute and chronic critera for zinc. Average concentrations for the other four metals (arsenic, cadmium, chromium III, and silver) did not exceed the associated aquatic life standards.

Table 11: KRWW Sites with Average Metal Concentrations in Exceedance of Kentucky's Aquatic Life Standards

Site ID#	Stream Name, County	Metals for which Aquatic Life Standards were Exceeded *(data avg of at least 3 sampling yrs.)*
K003	East Fork Eagle Creek, Scott Co.	Iron, Selenium (chronic only)
K021	Town Branch, Jessamine Co.	Copper (chronic), Nickel (chronic), Selenium (chronic)
K028	Clear Creek, Woodford Co.	Lead (chronic)
K050	Benson Creek, Franklin Co.	Iron, Selenium (chronic)
K081	Kentucky River, Perry Co.	Iron (chronic), Selenium (chronic)
K082	Kentucky River, Perry Co.	Iron (chronic)
K125	Clarks Run, Boyle Co.	Copper, Iron (chronic)
K189	Muddy Creek, Madison Co.	Iron (chronic)
K192	Black Spring, Woodford Co.	Iron (chronic)
K200	Kentucky River, Mercer Co.	Iron
K260	Dreaming Creek, Madison Co.	Zinc
K261	Dreaming Creek, Madison Co.	Zinc (acute)
K288	Troublesome Creek, Knott Co.	Iron (chronic)

Field Chemistry (pH, dissolved oxygen, temperature)

During each sampling event, KRWW volunteers are asked to record specific field data to assist with water quality analysis. Dissolved oxygen, pH and water temperature are very helpful in basic water quality interpretation. Volunteers also record subjective observations of instream flow, stream turbidity, recent precipitation and general condition of the stream site and surrounding area.

Dissolved Oxygen

Dissolved oxygen is one of the most critical parameters in aquatic ecosystems, as it is a requirement for the survival of aerobic organisms and influences a variety of inorganic chemical reactions. Thus, a knowledge of oxygen solubility is essential to understanding the status of biological and chemical processes occurring in a waterbody.

Oxygen gets into water through diffusion from the surrounding air, by aeration (rapid movement) of the water, or as a waste product of plant photosynthesis. The level of dissolved oxygen is highly dependent on temperature. Its presence is inversely proportional to temperature—with higher levels observed at lower temperatures, and lower dissolved oxygen concentrations at higher temperatures. Atmospheric pressure also influences the concentration of dissolved oxygen.

Kentucky's water quality criteria for protection of aquatic life specify that 24-hour average dissolved oxygen concentrations remain above 5 milligrams/liter, and that the instantaneous minimum not fall below 4 mg/L. Between 1998 and 2009, dissolved oxygen concentrations observed by KRWW samplers were typically between 5 and 8 mg/L. Far fewer observations fell within the poor range below 5 mg/L. The pie graph below shows a breakdown of the number of dissolved oxygen readings in each of two regulatory categories, as well as readings above 5 mg/L, as recorded between 1998 and 2009.

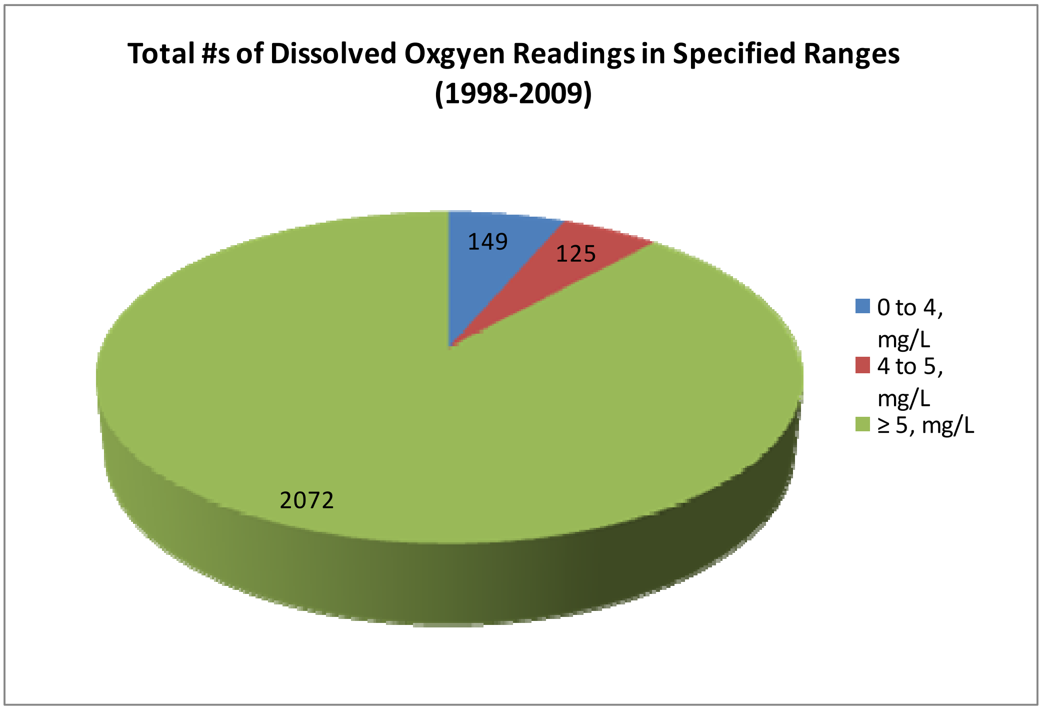

Figure 23: Ranges of Observed Oxygen Values in Kentucky River Basin Streams (1998-2009)

Of the total dissolved oxygen readings taken each year, a relatively small number were below the 5 mg/L threshold. The following graph portrays this relationship. The years of 2002, 2005 and 2008 are notable as having a larger proportional number of samples that had dissolved oxygen levels in the range at which aquatic life struggle.

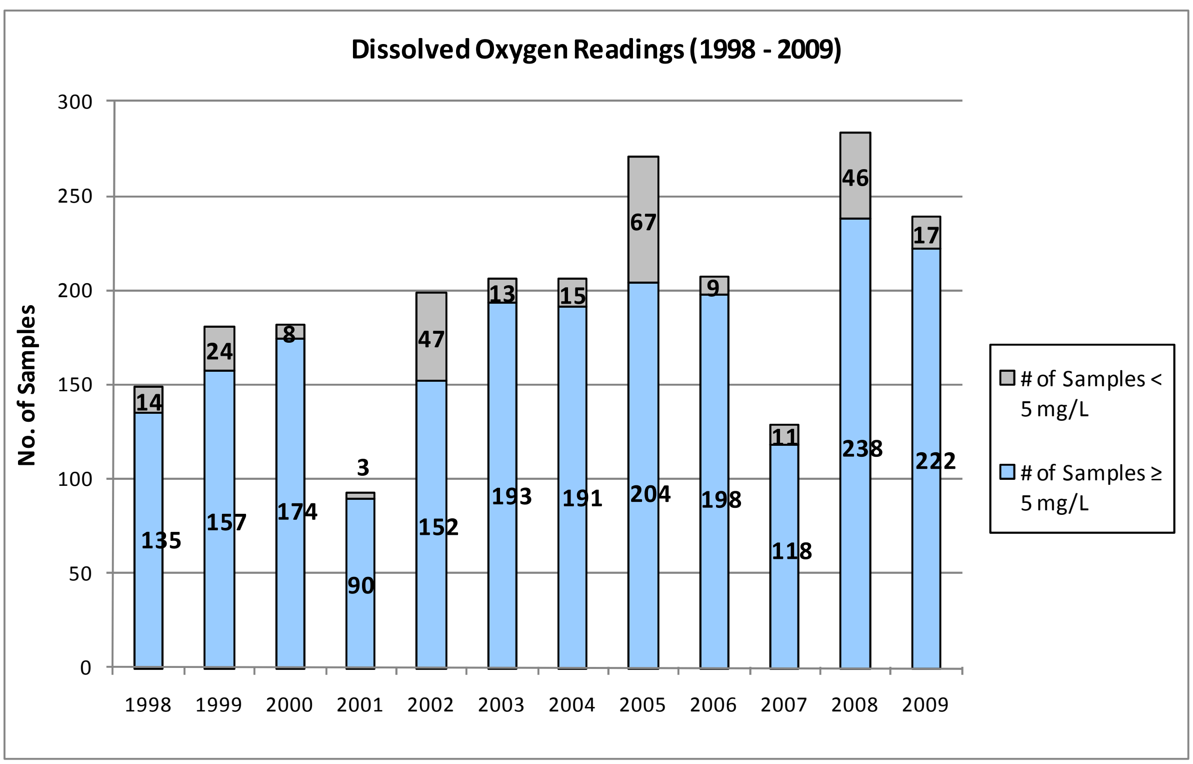

Figure 24: Annual Proportion of KRWW Sites with Dissolved Oxygen Values < or ≥ 5 mg/L

Only five KRWW sites produced average dissolved oxygen levels below the aquatic life threshold value, as illustrated below.

Table 12: KRWW Sites with Average Dissolved Oxygen Concentrations < 5 mg/L

Site ID#	Stream	County	Average D.O. Concentration (mg/L)
K243	Vega Creek	Madison	2.9
K640	Clark's Run	Boyle	3.2
K054	McConnell Springs	Fayette	3.5
K314	Mallard Point Lake	Scott	4.3
K189	Muddy Creek	Madison	4.9

pH

The **pH** level in a waterbody refers to the water's acidity, as expressed by the concentration of hydrogen ions (H^+) in solution. A pH of 7 is neutral. pH levels less than 7 are increasingly acidic, and pH levels greater than 7 are increasingly basic. Each change in pH unit represents a tenfold change in hydrogen ion activity.

When pH levels in a waterbody are less than 6, conditions are more favorable for toxic metals to dissolve and be more available for uptake by aquatic organisms. At pH levels greater than 9, toxic ammonia concentrations increase.

In Kentucky, low pH levels are frequently associated with nearby coal mining activities. The runoff from mining areas can contribute sulfate to nearby waterbodies, which combines with hydrogen ions to form sulfuric acid. The sulfuric acid, in turn, lowers the stream pH and may create toxic conditions for aquatic life. It is rare to observe pH levels greater than nine in the Kentucky River basin, thus it is not a significant water quality concern.

The following graph shows the number of water quality samples that produced pH readings under a value of 6 each sampling year. This graph suggests that acidic waters were not significantly present among the sites sampled by KRWW during the analysis period.

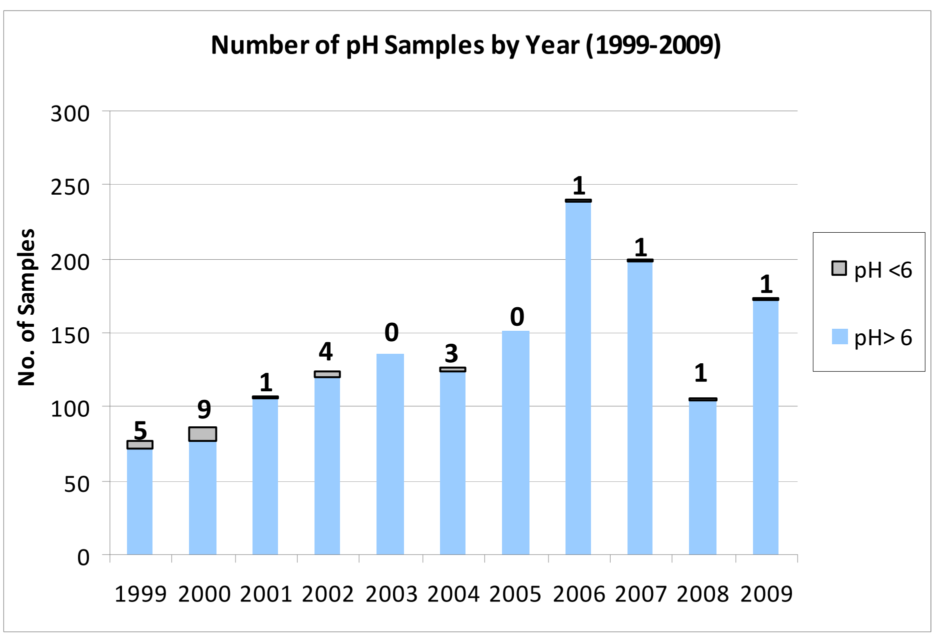

Figure 25: Frequency of High pH Readings Among KRWW Samples (1999-2009)

In general, the coal fields in Eastern Kentucky contain a less acidic form of coal those in Western Kentucky. Thus, while low values of pH can still be observed in mining impacted watersheds in the Kentucky River Basin headwaters, the pH values will normally be observed to significantly increase within a mile or so downstream of the source. This observation is primarily due to the higher buffering characteristics of the natural soils and geology. As a result, higher values of concentrations of specific conductivity and/or sulfates may be more useful in identifying the presence and potential impacts of upstream mining in downstream watersheds.

Temperature

Water **temperature** can have its own toxic effect on aquatic life, as well as influence the solubility of other substances that can become toxic. Generally, the solubility of solids increases with increasing temperature, while gases tend to be more soluble in colder water. Natural heat loadings to waterbodies include direct sunlight (especially where water is not adequately shaded by surrounding vegetation) and warmer water that flows in from shallow ponds or reservoirs. Human-caused temperature increases can come from industrial wastewater or water used for cooling machinery, as well as runoff from sun-heated roads, parking lots, and roofs.

Ideally, humans should not influence water temperatures beyond natural, seasonal fluctuations. Appropriate temperatures are dependent on the type of stream being monitored. Lowland streams, known as "warmwater" streams, are different from mountain or spring-fed streams that are normally cooler.

Kentucky's warmwater aquatic life temperature standards state that water temperatures should never exceed 31.7°Celsius, or 89°Fahrenheit. Streams designated as "cold water" should never exceed 20°C, or 68°F. Often summer heat can result in fish kills in ponds, as higher temperatures reduce the available oxygen in the water. Due to seasonal temperature fluctuations, an additional standard applies for temperature readings in the latter half of October, at which time the average temperature should not exceed 22.2°C, or 72°F.

A few sites produced temperature readings above 31.7° C during a single sampling season. However, no sites produced an average temperature above this reading over the 1999-2009 analysis period. The sites with the highest average temperatures were K156 (Fourmile Creek, Clark County) with an average temperature of 26.8° C (80.2° F) and K157 (Kentucky River at Boonesboro Beach, Clark County) with an average temperature of 26.5° C (79.7° F).

Sites and Watersheds of Concern

Each year, a list of sampling sites of concern is included in the annual Data Summary Report, developed by the Kentucky Water Resources Research Institute. KRWW volunteers can refer to these annual lists for opportunities to address water quality problems identified through their sampling efforts. Frequently, KRWW data can be supplemented by water quality data from other sources, such as the Kentucky Division of Water (KDOW), individual municipalities, Kentucky Fish & Wildlife, Kentucky Division of Forestry, the U.S. Geological Survey, private consultants, or others. The U.S. Environmental Protection Agency also maintains a national database of water quality data, called STORET, which can be accessed online for review or for subsequent downloading and analysis. All of these data sources may be useful in the event that a sampler would like to further investigate the causes or sources of the water quality observed their particular station of interest.

Hydrologic Unit Code (HUC): Hydrologic unit codes are a way of identifying all of the drainage basins in the United States in a nested arrangement from the largest (Regions – specified with a 2 digit code) to the smallest (watersheds – specified with a 11 digit code). Hydrologic unit codes were initiated by the U.S. Geological Survey's Office of Water Data in the fall of 1972 in cooperation with the U.S. Water Resources Council and supported by the U.S. Geological Survey's Resources and Land Information program.

A review of the KRWW sites of concern between 1999 and 2009 suggests that sixteen watersheds (associated with 11-digit Hydrologic Unit Codes) are of greatest concern among those that have been sampled consistently during this 10-year period. The following table and map provide the locations of these watersheds, along with KRWW sampling site ID #s and the water quality parameters of concern. Citizen Action Plans have been developed and approved for two of these watersheds of concern (Clark’s Run and West Hickman Creek) and Total Maximum Daily Load (TMDL) studies are being conducted in several others. In addition, there are a variety of watershed initiatives underway in several of the other watersheds that would lend support to the development of associated CAPs. Some of these initiatives are being supported by the Kentucky River Authority watershed grant program. For more information on how you can translate your sampling results into action, visit the KRWW website at www.krww.org.

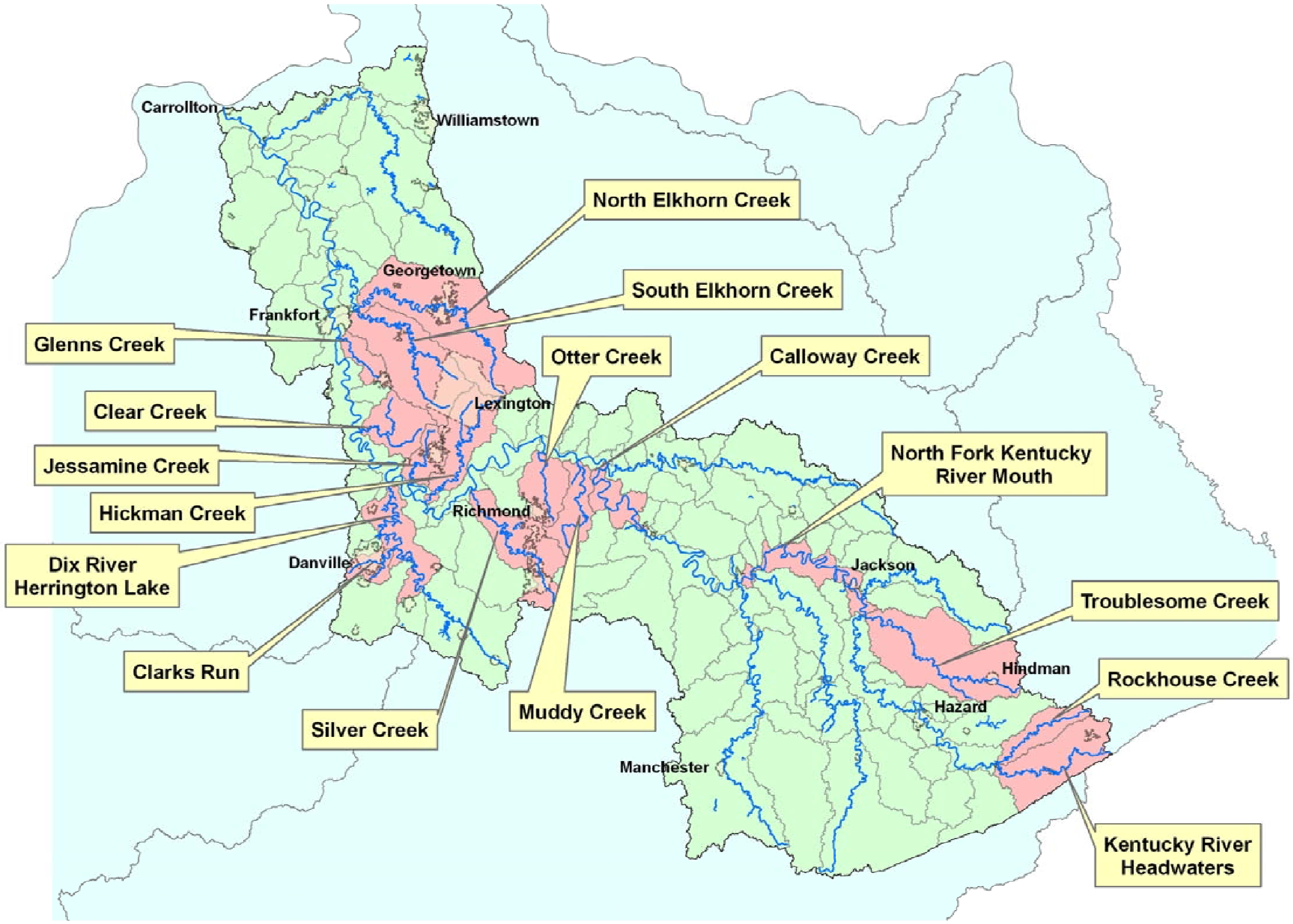

Figure 26: KRWW Watersheds of Concern (1999-2009)

Table 13: Kentucky River Basin Watersheds of Concern (identified by HUC 11 code)

HUC-11 #	Year	Site IDs	County	Parameters of Concern
5100201010 - Kentucky River Headwaters	1999, 2005, 2006, 2009	K062, K063, K098, K445, K447, K481, K542, K536	Letcher	conductivity, metals, pathogens, sulfate
5100201020 - Rockhouse Creek	2006, 2008, 2009	K105, K110, K111, K479, K585, K586	Letcher	conductivity, pathogens, sulfate
5100201120 - Troublesome Creek	2001, 2003 thru 2006, 2008	K145, K215, K216, K286, K488	Breathitt, Knott, Perry	metals, pathogens, sulfate
5100201150 - North Fork Kentucky River Mouth	1999, 2001, 2003, 2008	K048, K081, K082, K205	Breathitt, Perry	metals, pathogens
5100204080 - Calloway Creek	2003 thru 2005, 2009	K195, K428, K508	Estill, Madison	conductivity, pathogens, sulfate
5100205020 - Muddy Creek	2001, 2002, 2004, 2005	K187, K188, K189, K244, K247, K264, K294, K334	Madison	metals, pathogens
5100205040 - Otter Creek	2000 thru 2009	K060, K191, K260, K261, K264, K338, K339	Madison	conductivity, metals, nitrogen, pathogens, phosphorus
5100205090 - Silver Creek	2002, 2004, 2009	K039, K161, K627	Madison	pathogens
5100205120 - Hickman Creek	1999 thru 2005, 2007 thru 2009	K020, K021, K053, K131, K132, K133, K267, K299, K300, K303, K311, K418	Fayette	pathogens, phosphorus
5100205130 - Jessamine Creek	1999 thru 2001	K022, K023	Jessamine	metals, pathogens, phosphorus
5100205170 - Dix River/ Herrington Lake	2003 thru 2006	K282, K283	Mercer	nitrogen, pathogens
5100205190 - Clark's Run	2000, 2002 thru 2005, 2007	K014, K125, K180, K240	Boyle	nitrogen, pathogens
5100205220 - Clear Creek	1999 thru 2001, 2005	K028, K029, K192, K329, K342	Woodford	pathogens
5100205240 - Glenn's Creek	1999 thru 2002, 2005 thru 2007, 2009	K085, K126, K531	Woodford	nitrogen, pathogens, phosphorus
5100205270 - South Elkhorn Creek	1999 thru 2009	K001, K025, K026, K032, K033, K034, K054, K055, K071, K072, K075, K084, K120, K121, K122, K123, K174, K183, K184, K206, K323, K364, K307, K365, K462, K463, K466, K468, K499, K517	Fayette, Scott, Woodford	nitrogen, pathogens, phosphorus
5100205280 - North Elkhorn Creek	1999, 2000, 2003 thru 2005, 2009	K005, K257, K316, K348	Fayette/ Scott	pathogens, phosphorus

Regional differences in Water Quality throughout Kentucky River Basin

As previously indicated, the Kentucky River Basin cuts across two different eco-regions. The geology and soils of the basin also vary significantly from the upper headwaters to the confluence with the Ohio River near Carrollton, Kentucky. As a result, there tend to be some significant differences between water quality parameters depending on which region one is sampling in. For example, high sulfate and low pH values are normally more associated with the headwaters, while nutrient values (and in particular total phosphorus) tend to be higher in the central bluegrass region of the basin. Unfortunately, higher pathogen values (as measured by indicator organisms such as fecal coliforms or E. coli) tend to be consistent across the basin. While one might tend to associate higher values with the headwaters or rural areas of the basin (e.g. due to straight pipes or failing septic systems), urban areas like Lexington, are not devoid of such problems. In fact, in many cases, some of the highest levels of fecal coliforms or E. coli have been observed in the urban streams of Lexington – most likely due to the presence of failing pump stations or overflowing manholes that tend to occur when the existing sanitary sewer system cannot accommodate the volume of infiltrating stormwater or otherwise has inadequate capacity – both of which recently led EPA to issue a consent decree against the city of Lexington. Unfortunately, such problems are not limited to Lexington.

Ways that KRWW Volunteers Can Apply their Data

KRWW volunteers have many options for addressing the problems associated with identified water quality issues. Volunteers may adapt a template for Citizen Action Plans (CAPs) that assess needs of the watershed and identify actions that they will take to address those needs. Currently, KRWW has approved four CAPs and four others are pending completion and approval.

In addition to developing Citizen Action Plans, volunteers can pursue other watershed improvement paths outside of the KRWW domain. These include the development of formalized Watershed Based-Plans with guidance from the Kentucky Division of Water. These plans can be partially funded by KDOW's Nonpoint Source (319h) grant program. Once a watershed plan is approved, local partners can also apply for Nonpoint Source grant funding to conduct implementation of the plan's recommendations.

KRWW participants can also partner with communities on stormwater management compliance measures, including many low-impact development practices that protect and improve water quality from nonpoint source runoff. Protective measures may include stormwater retention areas, grass swales, wetland and riparian zone enhancement, rain gardens, green roofs and rain barrel programs.

Additional funding opportunities exist through the KRA watershed grant program (with grants typically up to $3000) or potentially through various non governmental organizations such as Eastern Kentucky PRIDE or Bluegrass PRIDE.

Status of the KRWW Organization

In June of 2009, Kentucky River Watershed Watch held a planning retreat to clarify the organization's mission, goals and activities. All KRWW volunteers were invited to participate in the retreat in person and/or by responding to a volunteer survey. Based on this feedback, and with assistance from the River Network organization, the KRWW Steering Committee developed an Annual Work Plan to guide the organization into the future.

The 2009 Volunteer Survey produced the following findings on the importance and status of KRWW's general functions.

Table 14: KRWW Volunteer Survey Results, June 2009

Survey Items by Function	Important or Very Important	Running Great or Fairly Smoothly	KRWW has Frequent Glitches	KRWW's Doing this Poorly
	% of Replies	**% of Replies**	**% of Replies**	**% of Replies**
General Coordination				
Volunteer Input to Goals & Objectives	96.1	37.5	16.7	45.8
Monitoring				
Volunteer Recruitment	100	43.4	34.8	21.7
Regular, Basin-Wide Sampling	96	83.3	8.3	8.3
Data Analysis	100	91.6	0	8.3
Communicating Results to Volunteers	100	54.1	33.3	12.5
Training				
Training of Volunteers	100	92	4	4
Volunteer Events				
Annual Conference	69.5	95.5	0	4.5
Celebration	29.7	70	10	20
Subwatershed Projects: CAPS & Focused Sampling				
Action Planning	96	48	20	32
Focused Sampling Projects	96	63.7	22.7	13.6
Advocacy				
Regulatory Advocacy	75	55	25	20

According to the survey results, volunteers feel that their input, training, regular and focused sampling, and action planning are all very important. Advocacy, the annual conference and celebrations are less important. The responses also indicate that the organization is succeeding in training, sampling, data analysis and organizing the annual conference. However, KRWW could make improvements to volunteer recruitment, inclusion of volunteer input, action planning and focused sampling projects. There was some uncertainty among volunteers about the importance or appropriateness of regulatory advocacy, causing the retreat facilitators to suggest a reexamination of KRWW's overall mission statement.

The KRWW Work Plan (see http://kywater.org/watch/2000/plan_of_work.htm) details the organization's overall mission, goals and activities. The Plan includes goals and activities for six main organizational functions: 1) volunteer training and communications; 2) sampling; 3) data management; 4) translating water quality findings to action; 5) fundraising and financial management, and 6) overall organizational management. Along with each of the activities is a responsible party and a timeline for completion. This Work Plan is critical, as KRWW is currently transitioning from paid administrative support to reliance on Board members and volunteers for its day-to-day functioning. This plan details specific organizational activities that can be completed by volunteers and their area coordinators, in order to assist the KRWW board members and officers.

Conclusions

This eleven-year analysis of KRWW sampling data from 1999 through 2009 provides evidence of various water quality concerns throughout the Kentucky River Basin. In the future, this type of analysis could be strengthened by the availability of more continuous data for the individual sampling sites. By sampling regularly year-to-year, volunteers will be more likely to gain valuable insights to the status and changes of water quality at their chosen sites.

For many of the sampling parameters, water quality issues were most evident in the central region of the Kentucky River Basin. Although these findings are instructive, it should also be noted that a disproportionate share of the KRWW sampling sites are located in this region of the basin. Since more sampling results are available for this area, water quality issues may appear to be skewed toward this area.

This analysis of KRWW water quality results is intended to provide KRWW volunteers and organizers with information to guide continued sampling, focused sampling, and water quality improvement efforts. Additional sampling data from future sampling years will build on this analysis and strengthen its conclusions.

APPENDIX A – How to use the Watershed Watch Online Database

In 2006, the Kentucky Geological Survey created an online, interactive database to provide easy access to KRWW water quality sampling results. This online database has been expanded to provide historical water quality sampling results from all eight of the Watershed Watch programs in the state of Kentucky and will continue to be updated as new data become available. The Watershed Watch volunteers and organizers greatly appreciate the assistance provided by Kentucky Geological Survey (KGS) staff in creating and updating this online database tool. This service is invaluable as a way of providing easy, direct access to Watershed Watch sampling data. Users can access the database directly at http://kgs.uky.edu/kgsmap/krww/viewer.asp or through the KRWW website at www.krww.org.

The online database provides a variety of search options for locating specific data needs. Viewers can search by volunteer name, organization, Watershed Watch project area, or site ID. A table will be displayed, with the identifying data for each site returned, a link to view the sampling data for each site, and a link to zoom to each site on the map. A button is also displayed, which enables the user to download all the analyses results for the returned sites as a text file.

Viewers can also use map tools to zoom to a specific map location (i.e., county, place names, road names, state parks, streams, lakes, 8-digit and 14-digit HUC watersheds, etc.). Viewers can also see aerial images of the sampling sites by reducing the map scale ratio to 1:12,000.

You can also use the map tools (below the map) to zoom to an area of interest. There are 3 options for zooming: use the "zoom in" tool, use the "Zoom to a Location" tool to find and zoom to a specific geographic area (such as a watershed or stream name), or simply choose a scale. Once zoomed into any scale, the KRWW monitoring points will be turned on and are symbolized by the red pushpin markers. Then, by using the id point  tool or the id area  tool, you can access location information about a single sample site or group of sampling sites and the site-specific data.

Other map functions enable the user to measure the distance between two points on the map ("measure" tool) and to identify the latitudinal and longitudinal coordinates ("id cords").

APPENDIX B – Selected Water Quality Parameter Descriptions

Antimony is a USEPA priority pollutant that can be toxic to plants and animals. In addition to the natural occurrence of antimony in bedrock and streambed sediments in the Knobs Region of the Kentucky River Basin, antimony salts are used in the fireworks, rubber, textile, ceramic, glass, and paint industries.
The proposed maximum contaminant level (MCL) in finished drinking water for antimony ranges from 5 to 10 micrograms per liter.

Arsenic occurs naturally in rocks and soil, water, air and plants and animals. It can be further released into the environment through natural activities, such as volcanic action, erosion of rocks, and forest fires, or through human actions. Approximately 90 percent of industrial arsenic in the U.S. is currently used as a wood preservative, but arsenic is also used in paints, dyes, metals, drugs, soaps and semi-conductors. High arsenic levels can also come from certain fertilizers and animal feeding operations. Industry practices, such as copper smelting, mining and coal burning also contribute to arsenic in our environment. Arsenic levels tend to be higher in ground water than in surface water (lakes and rivers). Levels also tend to be higher in the western United States.

Atrazine is moderately soluble in water. The main route of breakdown is chemical hydrolysis, followed by biodegradation. Atrazine is highly persistent in soil. Chemical hydrolysis followed by microbial breakdown accounts for most of its degradation in soil. Although hydrolysis is rapid in acidic or basic soil environments, it is slower at neutral pHs.

Barium is a yellowish-white alkaline earth metal. It combines with water to produce barium hydroxide and is found in nature as barites ($BaSO4$), witherite ($BaCO3$), and other ores. Barium and its salts are often used in metallurgical industries for special alloys, in paints, and concrete. Because of the insolubility of most of its compounds, it is not considered to be an ecological threat.

Beryllium is an uncommon alkaline-earth element that is recognized as a USEPA priority pollutant and potential carcinogen. The USEPA has proposed a MCL of 1.0 micrograms per liter for beryllium, and Kentucky has adopted the USEPA lowest-observed effect levels (LOEL) for protection of aquatic life, which are 130 micrograms/liter (1.3 mg/L) and 5.3 micrograms/liter (0.053 mg/L) for acute and chronic toxicity, respectively. In addition, Kentucky water-quality criteria establish a beryllium criterion of 0.117 micrograms per liter for the protection of human health from the consumption of fish tissue. The criterion is based upon an acceptable risk level of no more than one additional cancer case in a population of 1 million people.

Cadmium s a non-essential element and it diminishes plant growth. It is considered a potential carcinogen. It also has been shown to cause toxic effects to the kidneys, bone defects, high blood pressure, and reproductive effects. Cadmium is widely distributed in the environment at low concentrations. It can be found in fairly high concentrations in sewage sludge. Primary industrial uses for cadmium are plating, battery manufacture, pigments, and plastics.

Chlorpyrifos acts on pests mainly as a contact poison, but may also act as a stomach poison. Its trade names include Brodan, Detmol UA, Dowco 179, Dursban, Empire, Eradex, Lorsban, Paqeant, Piridane, Scout and Stipend. Chlorpyrifos has been found to be moderately to very highly toxic to birds, and is very highly toxic to freshwater fish, aquatic invertebrates and estuarine and marine organisms. Its use may also pose a serious hazard to wildlife and honeybees. It is moderately persistent in soils, and its half-life in soil is usually between 60 to 120 days, but can vary depending on soil, climate, and other conditions.

Chromium is ubiquitous in the environment, occurring naturally in the air, water, rocks and soil. It is used in stainless steel, electroplating of chrome, dyes, leather tanning and wood preservatives. It occurs in several forms, or oxidation states. The two most common are chromium VI and chromium III. The form depends on pH. Natural sources of water contain very low concentrations of chromium. It is a micronutrient (or essential trace element). High doses of chromium VI have been associated with birth defects and cancer; however, chromium III is not associated with these effects. Plants and animals do not bioaccumulate chromium; therefore, the potential impact of high chromium levels in the environment is acute toxicity to plants and animals. In animals and humans this toxicity may be expressed as skin lesions or rashes and kidney and liver damage.

Copper is a USEPA priority pollutant that is a micronutrient for the growth of plants and animals, but even small concentrations of copper in surface water can be toxic to aquatic life. Copper sulfate is frequently used to control nuisance growths of algae in water supply reservoirs. The toxicity of copper is a function of the total hardness of the water, because copper ions are complexed by anions that contribute to water hardness. Although detectable concentrations of copper in water are not known to have an adverse effect on humans, the MCL for copper has been established at 1,000 micrograms/liter, which corresponds with the taste threshold concentration for this element (National Academy of Sciences National Academy of Engineering, 1972). [USGS]

Iron is the fourth most abundant element, by weight, in the earth's crust. Natural waters contain variable amounts of iron depending on the geological area and other chemical components of the waterway. Iron in groundwater is normally present in the ferrous or bivalent form ($Fe2+$), which is soluble. It is easily oxidized to ferric iron ($Fe3+$) or insoluble iron upon exposure to air. This precipitate is orange-colored and often turns streams orange. Iron is a trace element required by both plants and animals. It is a vital part of the oxygen transport mechanism in the blood (hemoglobin) of all vertebrate and some invertebrate animals. Ferrous $Fe2+$ and ferric $Fe3+$ irons are the primary forms of concern in the aquatic environment. Other forms may be in either organic or inorganic wastewater streams. The ferrous form can persist in water void of dissolved oxygen and usually originates from groundwater or mines that are pumped or drained. Iron in domestic water supply systems stains laundry and porcelain. It appears to be more of a nuisance than a potential health hazard. Taste thresholds of iron in water are 0.1 mg/L for ferrous iron and 0.2 mg/L for ferric iron, giving a bitter taste or an astringent taste. Water to be used in industrial processes should contain less than 0.2 mg/L iron. Black or brown swamp waters may contain iron concentrations of several mg/L in the presence or absence of dissolved oxygen, but this iron form has little effect on aquatic life.

Lead is primarily found in nature as the mineral galena (lead sulfide). It also occurs as carbonate, as sulfate and in several other forms. The solubility of these minerals and also of lead oxides and other inorganic salts is low. Major modern day uses of lead are for batteries, pigments, and other metal products. In the past, lead was used as an additive in gasoline and became dispersed throughout the environment in the air, soils, and waters as a result of automobile exhaust emissions. For years, this was the primary source of lead in the environment. However, since the replacement of leaded gasoline with unleaded gasoline in the mid-1980's, lead from that source has virtually disappeared. Mining, smelting, and other industrial emissions and combustion sources and solid waste incinerators are now the primary sources of lead. Another source of lead is paint chips and dust from buildings built before 1978 and from bridges and other metal structures.

Metolachlor is highly persistent in water over a wide range of acidity. At 20° Celsius, its half-life is greater than 200 days in highly acidic water and is 97 days in highly basic water. Metolachlor is moderately persistent in the soil environment, with observed half-lives of 15 to 70 days. Breakdown rates are mainly dependent on microbial activity, and are therefore temperature-dependent. Metolachlor is currently unregulated by the U.S. Environmental Protection Agency, and therefore is not assigned a maximum contaminant level.

Nickel is a USEPA priority pollutant that can adversely affect humans and aquatic organisms. Nickel is an important industrial metal that is used extensively in stainless steel. Substantial amounts of nickel can be contributed to the environment by waste disposal (Hem, 1989) and atmospheric emissions. Nickel ions are toxic, particularly to plant life, and can exhibit synergism when present with other metallic ions (National Academy of Sciences National Academy of Engineering, 1972). [USGS]

Selenium is a nonmetallic trace element that is listed as a primary pollutant by the USEPA. Selenium is an essential micronutrient for plants and animals, but can be toxic in excessive amounts. Selenium is a relatively rare element, and concentrations of selenium in natural waters seldom exceed 1.0 microgram/liter (Hem, 1989). Sources of selenium in the Kentucky River Basin include sedimentary rocks and fly ash from coal-fired power plants that operate in Kentucky.

Silver is a USEPA priority pollutant that is extensively used for photography and various industrial and commercial purposes. Although average concentrations of silver in natural waters are small (0.3 micrograms/liter), elevated silver concentrations can be acutely or chronically toxic to aquatic organisms, and sublethal amounts can bioaccumulate in fish and invertebrate organisms (Hem, 1989). [USGS]

Thallium is a USEPA priority pollutant that can be toxic to humans and aquatic life. Thallium salts are used as poison for rats and other rodents, as well as in dyes, pigments in fireworks, and optical glass (National Academy of Sciences National Academy of Engineering, 1972).

Zinc is found naturally in many rock-forming minerals. Because of its use in the vulcanization of rubber, it is generally found at higher levels near highways. It also may be present in industrial discharges. It is used to galvanize steel, and is found in batteries, plastics, wood preservatives, antiseptics, and in rat and mouse poison (zinc phosphide). Zinc is an essential element in the diet. It is not considered very toxic to humans or other organisms.
