In the matter of

State of Oklahoma, ex rel., A. Drew Edmondson in his capacity as Attorney General of the State of Oklahoma, and Oklahoma Secretary of the Environment, C. MILES TOLBERT, in his capacity as the Trustee for Natural Resources for the State of Oklahoma, Plaintiffs
v.

Tyson Foods, Tyson Poultry, Tyson Chicken, Inc., Cobb-Vantress, Inc., Aviagen, Inc., Cal-Maine Foods, Cal-Mane Farms, Inc. Cargill, Inc., Cargill Turkey Products, LLC, George's, Inc., George's Farms, Inc., Peterson Farms, Inc., Simmons Foods, Inc. and Willowbrook Foods, Inc., Defendants.

CASE NO. 05-CV-329- GFK-SAJ

in the United States District Court
for the Northern District of Oklahoma

Expert Report

of

J. Berton Fisher, Ph.D., CPG, RPG (TX #0201; MS#0301)
Lithochimeia, Inc.
110 West 7th Street, Suite 105
Tulsa, Oklahoma 74119
May 15, 2008

Introduction

Summary of Qualifications

I am a geochemist and geologist with expertise in the transport and fate of materials in the environment. I hold a Ph.D. and M.S. in Earth Sciences from Case Western Reserve University and a B.S. in Geology and Geophysics from Yale University. I am a Certified Professional Geologist, a Registered Professional Geoscientist in the State of Texas and a Registered Professional Geologist in the State of Mississippi. I have published scientific papers regarding technical environmental matters in peer-reviewed publications, and I have given numerous technical presentations regarding environmental matters at scientific meetings. I have worked on the engineering and scientific aspects of numerous environmental litigation, regulatory and transaction matters, including, specifically, environmental matters related to the land disposal of poultry wastes. I have worked professionally as a geochemist and geologist since 1973 and have worked on matters related to agricultural, industrial, petroleum and mining environmental contamination for nearly twenty-five years. My work experience includes consulting, industrial and academic positions. My experience in technical environmental matters includes site investigations, review of site investigation data, analysis of the chemical and physical characteristics of environmental samples, historic research on industrial and agricultural activities and processes, petroleum exploration and production, mining, the environmental chemistry of organic and inorganic contaminants and studies of the fate and transport of organic and inorganic contaminants in soils, sediments and water, including the collection of undisturbed cores of unconsolidated lake sediment and the geochronological analysis of undisturbed cores of unconsolidated lake sediments using natural and anthropogenic radioactive nuclides and paleontological markers.

Since 1997 I have worked on matters related to the environmental contamination by poultry wastes including the chemistry, generation and land disposal of poultry wastes, the identification of poultry waste constituents in the environment, their fate and transport in the environment, the effects of poultry waste contaminants on water quality, and the management of poultry waste land disposal in eastern Oklahoma and western Arkansas. I have served as a consultant to the Tulsa Metropolitan Utility Authority and the City of Tulsa with respect to poultry waste issues from 1997 to the present.

Retention and Purpose Thereof

I was retained by the Oklahoma Attorney General, beginning in 2004, to evaluate, provide analysis regarding and to advise on matters pertaining to poultry waste generation, poultry waste disposal practices and the fate and transport of land applied poultry waste.

Summary of Opinions

1. Defendants' actions and practices have polluted surface water, ground water, soil and sediment within the Illinois River Watershed.

2. Defendants have a long and substantial history of poultry production within the Illinois River Watershed.

3. The contaminants of concern within the Illinois River Watershed are phosphorous and bacteria.

4. Poultry are the primary contributors to the phosphorus pollution of soils, surface waters, ground waters, and sediments within the Illinois River Watershed.

5. Poultry are highly significant contributors to bacterial pollution of surface and ground water within the Illinois River Watershed.

6. The population of poultry within the Illinois River Watershed has shown an overall increase since at least 1950.

7. The amount of waste generated by poultry with in the Illinois River Watershed has increased since at least 1950.

8. A substantial mass of poultry waste is produced within the Illinois River Watershed.

9. Poultry waste is disposed by land application without incorporation (simple broadcast spreading).

10. Waste generated by poultry within the Illinois River Watershed has been applied near to where it is generated.

11. Poultry waste has been widely disposed on pasture and grasslands within the Illinois River Watershed.

12. Poultry waste generated by poultry within the Illinois River Watershed is disposed year-round, but is dominantly disposed from late winter through spring.

13. All Defendants have disposed of poultry waste within the Illinois River Watershed.

14. The mass of poultry waste generated within the Illinois River Watershed but disposed of outside the watershed is a minority of the waste generated within the Illinois River Watershed.

15. Defendants' feed formulas show that Defendants add chemical compounds, including compounds containing phosphorous, and metals (sodium, potassium, calcium, copper, zinc, arsenic and selenium).

16. Because of the addition of compounds containing phosphorous and metals (including sodium, potassium, calcium, copper, zinc and arsenic), poultry waste contains high levels of nutrients, including phosphorous, and metals (including sodium, potassium, calcium, copper, zinc and arsenic).

17. The chemistry of cattle diets differs from that of poultry diets.

18. The chemical composition of poultry waste is distinctly different from the chemical composition of cattle waste and waste water treatment plant effluent.

19. The geology of the Illinois River Watershed produces a circumstance in which both the surface and ground water within the Illinois River Watershed are highly susceptible to pollution from the constituents of land applied poultry waste.

20. Shallow ground water within the Illinois River Watershed is highly susceptible to contamination from surface-applied pollutants.

21. Constituents of land disposed poultry waste run off fields and surface water and infiltrate through geologic media and contaminate ground

water and are poorly attenuated.

22. Soils to which poultry waste has been applied within the Illinois River Watershed are contaminated by poultry waste constituents.

23. Runoff water captured in edge of field (EOF) samples within the Illinois River Watershed is contaminated by poultry waste.

24. Ground water within the Illinois River Watershed is contaminated by poultry waste.

25. Stream Sediments within the Illinois River Watershed are contaminated by poultry waste

26. Reservoir sediments are important archives of environmental and geomorphic processes occurring within their drainage basins.

27. Sediment has accumulated in Lake Tenkiller since dam closure.

28. Poultry waste constituents have accumulated and are accumulating within the sediments of Lake Tenkiller, and sediment concentrations of phosphorous and other poultry waste constituents within Lake Tenkiller sediments have increased over time.

29. The change in sediment concentrations of and other poultry waste constituents within Lake Tenkiller sediments are directly related to changes in poultry production within the Illinois River Watershed.

Opinions and Basis

1. Defendants' actions and practices have polluted surface water, ground water, soil and sediment within the Illinois River Watershed. Defendants' actions have produced a circumstance in which a large population of poultry is sustained and regenerated within the confines of the Illinois River Watershed. Based on review of governmental agency data and authoritative texts, this poultry population has shown a pattern of overall growth from at least 1950 to the present.[1] Based on review of feed formulations, Defendants design and

1 U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1950 – Arkansas; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1954 – Arkansas; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1959 – Arkansas; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1964 – Arkansas; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1969 – Arkansas; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1974 – Arkansas; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1978 – Arkansas; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1982 – Arkansas; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1987 – Arkansas; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1992 – Arkansas; U.S. Department of Agriculture, National Agricultural Statistics Service, United States Census of Agriculture – 1997– Arkansas; U.S. Department of Agriculture, National Agricultural Statistics Service, United States Census of Agriculture – 2002 – Arkansas; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1950 – Oklahoma; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1954 – Oklahoma; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1959 – Oklahoma; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1964 – Oklahoma; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1969 – Oklahoma; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1974 – Oklahoma; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1978 – Oklahoma; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1982 – Oklahoma; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1987 – Oklahoma; U. S. Department of Commerce, Bureau of the Census, United States Census of Agriculture – 1992 – Oklahoma; U.S. Department of Agriculture, National Agricultural Statistics Service, United States Census of Agriculture – 1997– Oklahoma; U.S. Department of Agriculture, National Agricultural Statistics Service, United States Census of Agriculture – 2002 – Oklahoma; Data from the 2002 Census of Agriculture can be downloaded as from http://www.nass.usda.gov/index.asp; Data for 1992, 1997 and 2002 Census of Agriculture, and agricultural census data for 1840 through 1950, on a decennial basis, can be viewed or downloaded as Adobe. pdf files from: http://www.agcensus.usda.gov/Publications/Historical Publications/index.asp; Strausberg, S. F. 1995. From Hills and Hollers: Rise of the Poultry Industry in Arkansas. Fayetteville: Arkansas Agricultural Experiment Station; Crisp, H. 1989. Lloyd Peterson and Peterson Industries, An American Story. August House, Little Rock; (Cal-Maine Exhibits 46 47.pdf; Cargill Inc 2nd supp answer.pdf; Cargill Turkey 2nd supp answer.pdf; CARTP177361.pdf; CART177359.pdf; cover.pdf; DOC20080107140732.pdf; DOC20080107140753.pdf;

control the composition of feeds provided to their poultry.[2] These feeds contain high levels of phosphorous and metals. Historically, wastes produced by poultry owned by the Defendants have been land disposed by simple broadcast spreading near where such wastes are generated.[3] At present, nearly all of poultry waste is land disposed near where the waste is generated.[4] Once applied to the land, constituents of these wastes interact

---

DOC20080107140816.pdf; DOC20080107140838.pdf; Georges.mdb; IRW Breeders -- Created by Court Order-Not Kept in Ordinary Course of Business.xls; IRW Broilers -- Created by Court Order - Not Kept in Ordinary Course of Business.xls; Peterson 2nd Supp Response to First Interr and RFP.pdf; SIMAG32198- number Birds and feed.pdf; Total Bird Counts.xls).

2 CM003472 - CM003581; CARTP007982 - CARTP010833; GE 34777 – GE 35008; GE 35127 – GE 35138; GE 36091 – GE 36458; PFIRWP-063697 - PFIRWP-064049; SIM AG 31786- SIM AG 32150; TSN0001NCFF – TSN0570NCFF; TSN0001SCFF – TSN0535SCFF.

3 Tyson Environmental Poultry Farm Management TSN0060CORP-TSN0118CORP; Deposition of Tommy Daniel, Ph. D. November 26, 2007, Page 26 line 23-25; Page 27 line 1-23; Page 50 line 17-25; Page 51 line 1-16; of Michael Langley, November 7, 2007, page 24 lines 6-19; page 26 lines 2-19; Deposition of Bart Snyder, November 8, 2007, page 19 line 1-11; page 19 line 17-line 25; page 20 line 1; Bell, D. D. and W. D. Weaver. 2002. Chicken, Meat and Egg Production, 5th Edition. Kluwer Academic Publishers, Norwell, Massachusetts, PI-Fisher00005909-PI-Fisher00007209); Wilson, W. O. 1974. Housing. Pp 218-247, in: Hanke, O. A.,, J. L. Siknner and J. H. Florea (eds.), American Poultry History 1823-1973. American Printing and Publishing, Madison, Wisconsin (PI-Fisher00008114 - PI-Fisher00008505).

4 PI-Fisher00027498-PI-Fisher00031831; Deposition of Tommy Daniel, Ph. D. November 26, 2007, Page 26 line 23-25; Page 27 line 1-23; Page 50 line 17-25; Page 51 line 1-16; Deposition of Michael Langley, November 7, 2007, page 24 lines 6-19; page 26 lines 2-19; Deposition of Bart Snyder, November 8, 2007, page 19 line 1-11; page 19 line 17-line 25; page 20 line 1.; TSN19381SOK-TSN19435SOK; TSN20629SOK-TSN20640SOK; TSN20598SOK-TSN20628SOK; TSN20569SOK-TSN20595SOK; TSN20561S0K-TSN20568S0K; TSN20538S0K- TSN20556S0K; TSN19835S0K-TSN19846S0K; TSN19241S0K-TSN19257S0K; TSN18746S0K-TSN18757S0K; TSN20517S0K-TSN20529S0K; TSN20504S0K-TSN20516S0K; TSN20470S0K-TSN20503S0K; TSN20480S0K-TSN20503S0K; TSN20455S0K-TSN20469S0K; TSN19685S0K-TSN19708S0K; TSN20417S0K-TSN20425S0K; TSN19098S0K-TSN19127S0K; TSN20403S0K-TSN20416S0K; TSN19847S0K-TSN19874S0K; TSN19875S0K-TSN19885S0K; TSN19278S0K-TSN19293S0K; TSN20381S0K-TSN20402S0K; TSN20372S0K-TSN20380S0K; TSN19294S0K-TSN19308S0K; TSN19294S0K-TSN19294S0K; TSN20300S0K-TSN20335S0K; TSN20426S0K-TSN20454S0K; TSN20431S0K-TSN20454S0K; TSN19804S0K-TSN19817S0K; TSN20171S0K-TSN20264S0K; TSN20252S0K-TSN20264S0K; TSN20118S0K-TSN20170S0K; TSN20088S0K-TSN20117S0K; TSN20051S0K-TSN20087S0K; TSN19993S0K-TSN20050S0K; TSN19900S0K-TSN19908S0K; TSN19197S0K-TSN19222S0K; TSN20186S0K-TSN20216S0K; TSN19886S0K-TSN19895S0K; TSN20336S0K-TSN20346S0K; TSN18819S0K-TSN18835S0K; TSN18836S0K-TSN18903S0K; TSN19672S0K-TSN19682S0K; TSN18929S0K-TSN18918S0K; TSN18930S0K-TSN18943S0K; TSN18791S0K-TSN18801S0K; TSN07386S0K-TSN07401S0K; TSN19128S0K-TSN19151S0K; TSN19709S0K-TSN19776S0K; TSN19726S0K-TSN19776S0K; TSN18716S0K-TSN18735S0K; TSN19777S0K-TSN19783S0K; TSN19152S0K-TSN19189S0K; TSN18687S0K-TSN18715S0K; TSN18554S0K-TSN18589S0K; TSN18944S0K-TSN18956S0K; TSN18661S0K-TSN18686S0K; TSN18667SOK-TSN18686SOK; TSN18977S0K-TSN19005S0K; TSN19479S0K-TSN19495S0K; TSN19591S0K-TSN19623S0K; TSN59962SOK-TSN59985SOK; TSN61804SOK-TSN61822SOK; TSN60176SOK-TSN60192SOK; TSN62084SOK-TSN62090SOK; TSN60502SOK-0TSN61603SOK; TSN60679SOK-TSN60711SOK;

with environmental media (soils, surface water, ground water, stream and lake sediments). As a consequence, these constituents are found as contaminants in soils, edge of field run off, surface waters in streams and in Lake Tenkiller, ground water, stream sediments and lake sediments.[5] Since these constituents would not be present as contaminants in soils, edge of field run off, surface waters in streams and in Lake Tenkiller, ground water, stream sediments and lake sediments except for the actions and practices of Defendants, the Defendants' actions and practices have resulted in the pollution of surface water, ground water, soil and sediment within the Illinois River Watershed.

2. Defendants have a long and substantial history of poultry production within the Illinois River Watershed. Northwest Arkansas, particularly Washington and Benton counties, presently produces and has historically produced the majority of poultry in Arkansas.[6] Poultry production in this region was known as early as around the turn of the century, but transitioned from a supplemental income business to a highly organized industry beginning in the 1920s.[7] In 1927, a severe drought devastated northwest

---

TSN115069SOK-TSN115091SOK; TSN115092SOK-TSN115112SOK; TSN115113SOK-TSN1151132OK; TSN61878SOK-TSN61899SOK; TSN61528SOK-TSN61537SOK; TSN60756SOK-TSN60770SOK; TSN47940SOK-TSN47956SOK; TSN60030SOK-TSN60046SOK; TSN59901SOK-TSN59916SOK; TSN60503SOK-TSN60507SOK; TSN72021SOK-TSN72032SOK; PFIRWP-01058-PFIRWP-01097; PFIRWP-000185-PFIRWP-000195; PFIRWP-000703-PFIRWP-001427; PFIRWP-000317-PFIRWP-000330; PFIRWP-000383-PFIRWP-000383; PFIRWP-000333-PFIRWP-000346; PFIRWP-060344-PFIRWP-060377; PFIRWP-000690-PFIRWP-000702; PFIRWP-000459-PFIRWP-000461; PFIRWP-000489-PFIRWP-000515; PFIRWP-000565-PFIRWP-000589; PFIRWP-000108-PFIRWP-000113; PFIRWP-024980-PFIRWP-024983; GE4030-GE4046; GE7055-GE7076; GE34065-GE34081; GE34209-GE34245; GE2357-GE2351; GE34003-GE34013; GE34147-GE34163; Cal-Maine East Farm; Cal-Maine West-East appl Sites; Cal-Maine West-East Farms IRW; Dick Latta SunBest Farm; Dick Latta SunBest Farm appl sites 2; CM-000003160-CM-000003204; CM-000002945-CM000003132.

5 Expert Report of Roger L. Olsen, 2008; Expert Report of Bernie Engle, 2008; Expert Report of Gordon V. Johnson, 2008; Expert Report of G. Dennis Cooke and Eugene Welch, 2008; Expert Report of Valerie Harwood; Expert Report of Jan Stevenson.

6 Poultry in the Arkansas Encyclopedia of History and Culture, http://encyclopediaofarkansas.net/encyclopedia/entry-detail.aspx?entryID=2102; Strausberg, S. F. 1995. From Hills and Hollers: Rise of the Poultry Industry in Arkansas. Fayetteville: Arkansas Agricultural Experiment Station.

7 Poultry in the Arkansas Encyclopedia of History and Culture, http://encyclopediaofarkansas.net/encyclopedia/entry-detail.aspx?entryID=2102; Strausberg, S. F. 1995. From Hills and Hollers: Rise of the Poultry Industry in Arkansas. Fayetteville: Arkansas Agricultural Experiment Station.

Arkansas' fruit industry and many farmers in the area began raising chickens.[8] From 1935 to 1940, Arkansas witnessed a 500 percent increase in the number of chicken producers. The industry received a boost during World War II, as poultry escaped government rationing. [9]

The Defendants have a long history of poultry production within the Illinois River Watershed. Significant investment in an industrialized poultry infrastructure was initiated in the mid 1940s and accelerated through the 1950s. In 1943, Tyson initiated vertical integration of his company by raising his own chicks and feed, and during the late 1940s, major food producers such as Armour, Swift, and Campbell's Soup began locating poultry processing plants in northwest Arkansas. By 1950, nineteen poultry-related plants were located in Springdale alone. Chickens were raised and slaughtered locally, packed in ice, and then shipped to markets.[10]

Tyson: In about 1936, Springdale-based trucker John Tyson hauled broilers to Kansas City and Chicago, and soon was raising and shipping his own broilers, and Tyson emerged as a leader in Arkansas' rapidly growing poultry industry. [11] In 1950, Tyson's company was processing about 96,000 broilers a week. [12] Tyson built its first processing plant in 1958, and by the early 1960s was fully integrated (i.e. it controlled every aspect of

8 Poultry in the Arkansas Encyclopedia of History and Culture, http://encyclopediaofarkansas.net/encyclopedia/entry-detail.aspx?entryID=2102; Strausberg, S. F. 1995. From Hills and Hollers: Rise of the Poultry Industry in Arkansas. Fayetteville: Arkansas Agricultural Experiment Station.

9 Poultry in the Arkansas Encyclopedia of History and Culture, http://encyclopediaofarkansas.net/encyclopedia/entry-detail.aspx?entryID=2102; Strausberg, S. F. 1995. From Hills and Hollers: Rise of the Poultry Industry in Arkansas. Fayetteville: Arkansas Agricultural Experiment Station.

10 Poultry in the Arkansas Encyclopedia of History and Culture, http://encyclopediaofarkansas.net/encyclopedia/entry-detail.aspx?entryID=2102; Strausberg, S. F. 1995. From Hills and Hollers: Rise of the Poultry Industry in Arkansas. Fayetteville: Arkansas Agricultural Experiment Station.

11 Poultry in the Arkansas Encyclopedia of History and Culture, http://encyclopediaofarkansas.net/encyclopedia/entry-detail.aspx?entryID=2102; Strausberg, S. F. 1995. From Hills and Hollers: Rise of the Poultry Industry in Arkansas. Fayetteville: Arkansas Agricultural Experiment Station.

production, from hatchery to the retail sales of broilers).[13]

Willow Brook Foods: Willow Brook Foods came into being in 1998 as the consequence of a merger between Hudson Foods and Tyson Foods, and the desire of Tyson to focus on its chicken business. Willow Brook's turkey operation, which began in 1920, had been sold to Hudson Foods in 1979.[14] In early 2008, Willow Brook Foods employed more than 1,000 people in southwest Missouri and northern Arkansas. These operations included a feed mill, a turkey harvesting facility and a processing facility for turkey, pork, beef and chicken. In late March 2008, a unit of Cargill, Cargill Value Added Meats, announced that it had acquired certain assets of Willow Brook Foods including Willow Brook's operations in Springfield, Missouri where the original poultry plant was built in 1927.[15] Willow Brook's agricultural operations, including the contract turkey production continue to operate.[16]

Cargill: Cargill and/or its affiliated companies began operating in Arkansas in the early 1960s. A Cargill document listing barn area by the year the barns were built (dated October 11, 2004) shows that at least one barn still used in the turkey growing operation was built in 1960, and that 23.25% of Cargill's listed turkey barn capacity at that time was built 25 or more years previously (before 1980).[17] In 2007, Cargill and/or its affiliates employed approximately 2,000 people in Arkansas. Cargill and/or its affiliates have operations located in the Arkansas Communities of Booneville, Glenwood, Gentry, London,

---

12 http://www.tyson.com/Corporate/AboutTyson/History/1950s.aspx

13 Poultry in the Arkansas Encyclopedia of History and Culture, http://encyclopediaofarkansas.net/encyclopedia/entry-detail.aspx?entryID=2102; Strausberg, S. F. 1995. From Hills and Hollers: Rise of the Poultry Industry in Arkansas. Fayetteville: Arkansas Agricultural Experiment Station.

14 Springfield News Leader, April 1, 2008. Willow Brook Foods sold; 780 local jobs to be lost available at http://www.news-leader.com/apps/pbcs.dll/article?AID=/20080401/NEWS01/804010374; http://www.willowbrookfoods.com/corporate/corp.htm.

15 O'Keefe, T., April 24, 2007. Willow Brook Foods Precision Slicing Underground available at http://www.wattpoultry.com/PrintPage.aspx?id=12032.

16 Press Release March 31, 2008: "Cargill acquires Willow Brook Foods"; available at http://www.cargillmeatsolutions.com/press_releases/2008/tk_cms_pr_willbrook.htm#TopOfPage.

17 CARTP158579.

Ozark, Russellville and Springdale.[18] Cargill entered the turkey business in 1967, and the headquarters of Cargill Turkey Products business unit are located in Springdale, Arkansas.[19] Between 1974 and 1975, Cargill purchased the turkey operations of Ralston Purina located in Springdale, Arkansas, and California, Missouri.[20] The "Springdale Complex" comprises Cargill Turkey Products operations in Springdale, Gentry and Ozark, Arkansas, employs approximately 1,000 people and was established in 1964.[21] Cargill sold Sunny Fresh Foods with operations within the Illinois River Watershed to Cal-Maine between about 1989 and 1990.[22]

The operations at Springdale and Gentry, Arkansas formerly operated by Cargill and now operated by Cargill Turkey Products are located within the Illinois River Watershed.[23] The Springdale, Arkansas operations include a feed mill, and the Gentry, Arkansas operations include a hatchery. Cargill turkey operations within the Illinois River Watershed include six company-owned breeder farms, pre-production farms and production farms.[24]

---

18 Affidavit of Steven Willardsen in support of the Cargill Defendants' response to Plaintiffs' motion to compel, Document 1136, Case 4:05-cv-00329-GKF-SAJ, Filed in USDC ND/OK on 04/26/2007.

19 Affidavit of Steven Willardsen in support of the Cargill Defendants' response to Plaintiffs' motion to compel, Document 1136, Case 4:05-cv-00329-GKF-SAJ, Filed in USDC ND/OK on 04/26/2007.

20 http://www.cargill.com/about/history/history_1950.htm; CARTP114667.

21 Affidavit of Steven Willardsen in support of the Cargill Defendants' response to Plaintiffs' motion to compel, Document 1136, Case 4:05-cv-00329-GKF-SAJ, Filed in USDC ND/OK on 04/26/2007.

22 Videotaped 30(B)(6) Deposition of Cal-Maine Foods (Steve Storm), October 8, 2007, page 36 line 19-25; page 37 line 1-3; Videotaped 30(B)(6) Deposition of Cal-Maine Foods (Steve Storm), October 9, 2007, page 233 line 2-21.

23 Affidavit of Steven Willardsen in support of the Cargill Defendants' response to Plaintiffs' motion to compel, Document 1136, Case 4:05-cv-00329-GKF-SAJ, Filed in USDC ND/OK on 04/26/2007.

24 CARTP158224-158226; ACA0007, BCA000149, BCA000150, BCA000152, BCA000153, BCA000154, BCA00082, CARTP000003, CARTP000004, CARTP000773, CARTP000836, CARTP000915, CARTP000977, CARTP000989, CARTP000997, CARTP001062, CARTP001070, CARTP001118, CARTP001218, CARTP001275, CARTP001377, CARTP001383, CARTP001484, CARTP001542, CARTP001610, CARTP001655, CARTP001723, CARTP001784, CARTP001879, CARTP001953, CARTP001993, CARTP002065, CARTP002085, CARTP002177, CARTP002262, CARTP002304, CARTP002312, CARTP002366, CARTP002431, CARTP002508, CARTP002676, CARTP002785, CARTP002835, CARTP002838, CARTP002881, CARTP002886, CARTP002962, CARTP003043, CARTP003060, CARTP003228, CARTP003365, CARTP003532, CARTP003561, CARTP003578, CARTP003762, CARTP003907, CARTP004091, CARTP004242, CARTP004386, CARTP004403, CARTP004529, CARTP004692, CARTP004854, CARTP005036, CARTP005239, CARTP005402, CARTP005537, CARTP005729, CARTP005857, CARTP006005, CARTP006008, CARTP006061, CARTP006208, CARTP006210, CARTP006456, CARTP006486, CARTP006521, CARTP006684, CARTP006858, CARTP007038, CARTP007212, CARTP007331, CARTP007447, CARTP007457, CARTP007568, CARTP007576, CARTP007721, CARTP007724, CARTP007887, CARTP011058,

Cobb-Vantress: In 1961, Cobb-Vantress opened a hatchery in Siloam Springs, Arkansas, which became Cobb's international headquarters in the late 1980s. In 1994, Tyson Foods, Inc. acquired 100% of Cobb's stock from the Upjohn Company.[25]

Peterson Farms: In 1939, Lloyd Peterson began the Peterson Produce and Hatchery Company. In 1947, the company changed its name to Peterson Industries. By 1952, the company had an incubator capacity of 356,000 and was hatching 75,000 chicks each week. Additionally, the company had a breeding farm with a capacity of 44,000 birds and an experimental farm with a capacity of 25,000 birds. The company's feed mill could produce 80 tons/8-hour shift. Peterson Farms began broiler processing in 1963. In 1966 Peterson Industries formed Decatur Foods, a processing and marketing company that at that time processed 250,000 birds per week. [26]

Simmons: Simmons' history in the Illinois River Watershed area begins in 1949 when M. H. "Bill" Simmons and a partner, Frank Pluss, purchased a converted motel to form Pluss

---

CARTP082823, CARTP082849, CARTP082863, CARTP082877, CARTP082904, CARTP082917, CARTP082930, CARTP082947, CARTP082964, CARTP082981, CARTP082998, CARTP083015, CARTP083032, CARTP083049, CARTP083066, CARTP083083, CARTP083100, CARTP083117, CARTP083134, CARTP083151, CARTP088204, CARTP088271, CARTP088319, CARTP088449, CARTP088507, CARTP091380, CARTP091489 , CARTP091591, CARTP091654, CARTP091737, CARTP091828, CARTP091855, CARTP091942, CARTP092020, CARTP092111, CARTP092173, CARTP092253, CARTP092382, CARTP092528, CARTP092602, CARTP092703, CARTP092788, CARTP092980, CARTP093059, CARTP093150, CARTP093199, CARTP093289 , CARTP093428, CARTP093516, CARTP093603, CCA00016, CCA00017, CM000000354, CM000000427, CM000000430, CM000000444, CM000000699, CM000000703, CM000000848, CM000001044, CM000001058, CM000001294, CM000001372, CM000001378, DCA00026, OKDA01107, OKDA02994, OKDA06302, OKDA10055, OKDA1124, OKDA15917, OKDA16237, OKDA17587, (note OKDA prefix records are also within PI-Fisher00027498-00031831)OK-PL-0000004, OK-PL-0000251, OK-PL-0000632, OK-PL-0001109, OK-PL-0001506, OK-PL-0001875 thru OK-PL-0001924, OK-PL-0002541 thru OK-PL-0002591, OK-PL-0002592 thru OK-PL-0002642, OK-PL-0002696 thru OK-PL-0002747, OK-PL-0002850 thru OK-PL-0002900, OK-PL-0002870, OK-PL-0002952 thru OK-PL-0003003, OK-PL-0003004 thru OK-PL-0003054, OK-PL-0003055 thru OK-PL-0003105, OK-PL-0003712, OK-PL-0003823, OK-PL-0003835, OK-PL-0003854, OK-PL-0003862, PFIRWP-000186, WCA000192, WCA000193, WCA000195, WCA000196, WCA000198, WCA000199, ODAFF Database ID 1032, ID 260, ID 294, ID 432, ID 532, ID 727, ID 732, ID 789.

25 http://www.cobb-vantress.com/AboutUs/CobbHistory.aspx.

26 This discussion is drawn from Crisp, H. 1989. Lloyd Peterson and Peterson Industries, An American Story. August House, Little Rock; http://www.petersonfarms.com.

Poultry in Decatur, Arkansas. In 1952 the company built a new processing plant in Siloam Springs with a capacity of 10,000 birds per day, the largest and most modern in the world at the time.[27] In 1954, Simmons bought out Frank Pluss and changed the name of the company to Plus Poultry. In the early 1970s the name of the company was changed to Simmons Industries.[28]

George's, Inc.: C. L. George's & Sons, a poultry and egg producer had headquarters in Springdale, Arkansas in the 1950s[29], but had operated growout barns within the Illinois River Watershed in the 1940s.[30] The original poultry processing plant in Springdale was purchased by George's in the 1960s.[31] In 2007 Cal-Maine acquired a 90% ownership interest in Benton County Foods, LLC which has production in the Arkansas portion of the Illinois River Watershed.[32] Benton County Foods, LLC was formerly George's Commercial Egg Division (a producer of commercial table eggs).[33] This acquisition included production facilities (i.e. houses with hens in them that produced the eggs) and an egg packing plant where the eggs were processed and packed as well as miscellaneous equipment.[34]

Cal-Maine: Cal-Maine Foods, Inc. is the largest fresh egg producer in the United States, and had operations in the Illinois River Watershed between 1990 and 2005.[35] Cal-Maine became involved in operations located within the Illinois River Watershed between about 1989 and 1990 when it acquired Sunny Fresh Foods, a division of Cargill, and other assets

27 http://www.simmonsprotein.com/plant.htm.

28 Strausberg, S. F., 1995. From Hills and Hollers: Rise of the Poultry Industry in Arkansas. Fayetteville: Arkansas Agricultural Experiment Station.

29 Strausberg, S. F., 1995. From Hills and Hollers: Rise of the Poultry Industry in Arkansas. Fayetteville: Arkansas Agricultural Experiment Station.

30 30(B)(6) Deposition of Bennie McClure, August 15, 2007; page 27 line 4-7.

31 30(B)(6) Deposition of Bennie McClure, August 15, 2007; page 27 line 7-10.

32 Cal-Maine Foods 10-Q SEC Quarterly Filing, April 1, 2008 http://sec.edgar-online.com/2008/04/01/0001144204-08-019825/Section12.asp.

33 30(B)(6) Deposition of Bennie McClure, August 15, 2007; page 20 line 7-11; page 21 line 7–25, page 22 line 1-18; page 95 line 4-25.

34 30(B)(6) Deposition of Bennie McClure, August 15, 2007; page 21 line 7–25, page 22 line 1-18.

35 http://www.answers.com/topic/cal-maine-foods-inc?cat=biz-fin; Videotaped 30(B)(6) Deposition of Cal-Maine Foods (Steve Storm), October 8, 2007, page 20 line 18-25.

within the Illinois River Watershed.[36] In 2007 Cal-Main acquired a 90% ownership interest in Benton County Foods, LLC that has production in the Arkansas portion of the Illinois River Watershed.[37] Benton County Foods, LLC was formerly George's Commercial Egg Division (a producer of commercial table eggs).[38] This acquisition included production facilities (i.e. houses with hens in them that produced the eggs), an egg packing plant where the eggs were processed and packed and well as miscellaneous equipment.[39]

3. The contaminants of concern within the Illinois River Watershed are phosphorous and bacteria. Many streams within the Illinois River Watershed show excessive algal growth, proliferation of non-desirable algal species and adversely altered fish communities as a consequence of high phosphorous levels.[40] In addition, many streams within the Illinois River Watershed, including the Illinois River, show high levels of fecal bacterial contamination during periods of high flow.[41] Similarly, Lake Tenkiller, due to increases in phosphorous load, experiences decreased water clarity due to excessive algal growth, changes in the composition of algal species to less desirable species that dominate under high nutrient conditions and adversely altered fish communities. [42]

4. Poultry are the primary contributors to the phosphorus pollution of soils, surface waters, ground waters, and sediments within the Illinois River Watershed. Dr. Bernie Engle reviewed numerous studies regarding phosphorus loads to streams and rivers within the Illinois River Watershed and found that observed data and modeling evaluations presented in these studies indicate that the non-point phosphorous sources are the major

---

36 Videotaped 30(B)(6) Deposition of Cal-Maine Foods (Steve Storm), October 8, 2007, page 36 line 19-25; page 37 line 1-3; Videotaped 30(B)(6) Deposition of Cal-Maine Foods (Steve Storm), October 9, 2007, page 233 line 2-21.

37 Cal-Main Foods 10-Q SEC Quarterly Filing, April 1, 2008 http://sec.edgar-online.com/2008/04/01/0001144204-08-019825/Section12.asp.

38 30(B)(6) Deposition of Bennie McClure, August 15, 2007; page 20 line 7-11; page 21 line 7–25, page 22 line 1-18; page 95 line 4-25.

39 30(B)(6) Deposition of Bennie McClure, August 15, 2007; page 21 line 7–25, page 22 line 1-18.

40 Expert Report of G. Dennis Cooke and Eugene Welch, 2008.

41 Expert Report of Christopher Teaf;, 2008; Expert Report of Valerie Harwood, 2008; Expert Report of Roger Olsen, 2008.

42 Expert Report of Jan Stevenson, 2008.

contributor to phosphorus within the streams and rivers of the Illinois River Watershed and to Lake Tenkiller.[43] A report concerning phosphorous mass balance within the Illinois River Watershed[44] found that poultry production is currently responsible for 76% of the annual phosphorous additions to the Illinois River Watershed. The phosphorous mass balance report also reports an allocation of phosphorous to sources other than poultry as: (1) commercial fertilizers (7.5%), (2) dairy cattle (5.2%), (3) humans (3.2%), (4) swine (2.9%), industrial sources – mostly poultry processing facilities (2.7%) and (5) beef cattle (1.7%). The remaining sources of phosphorus evaluated by Engle in his 2008 Expert Report (urban runoff, golf courses, wholesale nurseries, and recreational users) were negligible (< 1%). This report also found that historical data indicated that poultry production has been the major contributor of phosphorus to the watershed since 1964. The report also stated that from 1949 to 2002, there has been a net addition of more than 219,600 tons of phosphorus in the Illinois River Watershed with 68% of it, or more than 148,000 tons, attributable to poultry production.

The phosphorous mass balance report concludes that most of the phosphorus entering the Illinois River Watershed is retained upstream from the dam pooling Lake Tenkiller. Of the three phosphorus exports from the watershed (harvested crops, harvested deer, and water leaving Lake Tenkiller through the spillway) outflow of phosphorus through the spillway at the south end of Lake Tenkiller was the largest. According to current data, the flow of water through the spillway removes just over 1% of the annual phosphorus additions to the watershed. The remaining two phosphorus exports combined remove less than 0.5% of current annual phosphorus additions to the watershed.

The phosphorous mass balance report presented by Engle is also concordant with prior independent work that identified between 50 and 83% of the phosphorous mass balance in

43 Expert Report of Bernie Engle, 2008.
44 Expert Report of Bernie Engle, 2008.

the Illinois River Watershed as attributable to livestock.[45] Indeed, work done in 1997 showed that livestock were responsible for 78.63% of phosphorus inputs to the Illinois River Watershed River while fertilizer represented 7.21% of inputs and point sources represented 4.5% of inputs.[46] Work published by Slaton, et al.[47] that studied nutrient mass balance in Arkansas, found that the area with the greatest excess phosphorus was northwest Arkansas which includes Benton and Washington counties, and that the source of this excess phosphorus was animal manure, specifically poultry waste. In this study, nutrients contained in beef cattle manure were ignored because, "a large proportion of these nutrients are obtained from forage and deposited directly (i.e., recycled) to pastures during grazing rather than collected in lagoons or stockpiled from confined animal production facilities." Finally, the Slaton, et al. publication states that the accumulation of excess P in soils is problematic, since soil P levels are correlated to the amount of P in runoff, and concludes that current nutrient application strategies in western Arkansas are not sustainable without the danger of creating and/or exacerbating water quality issues from excessive nutrients. Dr. Roger Olsen, using a pathway sampling approach has shown that phosphorous and other constituents from poultry waste are transported from poultry waste disposal sites to surface water, ground water and stream and lake sediments within the Illinois River Watershed.[48]

5. Poultry are highly significant contributors to bacterial pollution of surface and ground water within the Illinois River Watershed. Dr. Valerie Harwood has shown that bacterial DNA unique to poultry is found in poultry waste, soils that have received poultry

45 Smith, R. and R. Alexander, 2000. Sources of Nutrients in the Nation's Watersheds Managing Nutrients and Pathogens from Animal Agriculture. Proceedings from the Natural Resource, Agriculture, and Engineering Service Conference for Nutrient Management Consultants, Extension Educators, and Producer Advisors, March 28-30, 2000. Camp Hill, Pennsylvania; Smith, R. A., G. E. Schwartz and R. B. Alexander, 1997. Regional interpretation of water-quality monitoring data. Water Resources Research, 33: 2781-2798.

46 Smith, R. A., G. E. Schwartz and R. B. Alexander, 1997. Regional interpretation of water-quality monitoring data. Water Resources Research, 33: 2781-2798.

47 Slaton, N. A. Brye, K. R., Daniels, M. B., Daniel, T. C., Norman, R. J. and Miller, D. M. 2004. Nutrient Input and Removal Trends for Agricultural Soils in Nine Geographic Regions in Arkansas. J. Environ. Qual. 33:1606–1615 (PI-Fisher00005182 - PI-Fisher00005191).

48 Expert Report of Roger Olsen, 2008.

waste, edge of field runoff from fields upon which poultry waste has been disposed, surface waters and some ground water samples within the Illinois River Watershed.[49] Dr. Roger Olsen, using a pathway sampling approach combine with a principal component analysis (PCA), has shown that fecal bacteria from poultry waste are transported from poultry waste disposal sites to waterways and ground water within the Illinois River Watershed. [50] Dr. Christopher Teaf has evaluated the amount of fecal bacteria contributed to the Illinois River Watershed. He has determined that 41.1 % is contributed from poultry waste, 44.4% percent is contributed by cattle, 13% is contributed by swine, 0.9% is contributed by failing septic tanks and 0.01% is contributed by WWTP effluents. [51]

6. The population of poultry within the Illinois River Watershed has shown an overall increase since at least 1950. Based on Defendants documents[52], a total of at least 1.1 billion birds of all types[53] have been produced by Defendants within the Illinois River Watershed during the period 2000 through 2007. The total number of birds produced within the Illinois River Watershed by Defendants is shown in Table 1 below.

49 Expert Report of Bernie Engle, 2008.
50 Expert Report of Roger Olsen, 2008.
51 Expert Report of Christopher Teaf, 2008.
52 Defendants' information concerning recent poultry production within the Illinois River Watershed (Cal-Maine Exhibits 46 47.pdf; Cargill Inc 2nd supp answer.pdf; Cargill Turkey 2nd supp answer.pdf; CARTP177361.pdf; CART177359.pdf; cover.pdf; DOC20080107140732.pdf; DOC20080107140753.pdf; DOC20080107140816.pdf; DOC20080107140838.pdf; Georges.mdb; IRW Breeders -- Created by Court Order-Not Kept in Ordinary Course of Business.xls; IRW Broilers -- Created by Court Order - Not Kept in Ordinary Course of Business.xls; Peterson 2nd Supp Response to First Interr and RFP.pdf; SIMAG32198- number Birds and feed.pdf; Total Bird Counts.xls).
53 The total is 1,130,938,719 birds of all types.

Table 1. Illinois River Watershed Bird Production (2000-2007) as Reported by Defendants by Year	
Year	**Birds Produced**
2000	117,119,742
2001	138,044,793
2002	137,595,261
2003	140,688,827
2004	160,147,813
2005	157,851,957
2006	150,087,828
2007	129,402,498
TOTAL	**1,130,938,719**
Notes: 2000 is a partial year for George's and Peterson; 2005 is a partial year for Cal-Maine; 2007 is a partial (½) year for all Defendants	

The average annual bird production between 2000 and 2007 was 141,367,340 birds/year. The fewest birds (117,119,742) were produced in 2000 and the most birds (160,147,813) were produced in 2004. Bird production totals reported by each Defendant are tabulated for the period 2000 through 2007 in Table 2.

Table 2. Aggregate Illinois River Watershed Bird Production (2000-2007) as Reported by Defendants by Defendants, all years		
Defendant	**Total Birds 2000-2007**	**Percent (%) of Total Birds 2000-2007**
Cal-Maine	4,813,119	0.43%
Cargill	23,102,585	2.04%
Cob-Vantress	10,018,183	0.89%
Georges	105,791,524	9.35%
Peterson	121,736,097	10.76%
Simmons	162,400,000	14.36%
Tyson	703,077,211	62.17%

An estimate of poultry production within the Illinois River Watershed based land use and land cover data and agricultural census data[54] for the period (1949/1950 - 2002) is provided in Table 3 and shown graphically in Fig 1. Inspection of Table 1 and Table 3 shows that the estimate of poultry production obtained from a consideration of the poultry census data and land use and land cover data for 2002 compares favorably with the poultry production information provided by the Defendants (151,781,155 versus 137,595,261; a difference of approximately 10.3%).

Table 3.
Estimated Poultry Production Within the Illinois River Watershed
Based on USDA Agricultural Census Data and Land Use and Land Cover Data

Year	Broilers (Sold)	Layers (Inventory + Sold)	Pullets (Inventory + Sold)	Turkeys (Inventory + Sold)	Total Poultry
1949/50	11,924,434	No data	No data	38,497	11,962,932
1954	18,617,043	No data	No data	302,795	18,919,838
1959	35,685,225	No data	No data	489,136	36,174,360
1964	60,681,482	1,759,742	No data	No data	62,441,223
1969	75,718,474	6,687,861	No data	No data	82,406,334
1974	80,779,485	3,881,138	No data	No data	84,660,623
1978	87,085,705	6,358,778	4,041,266	2,274,966	99,760,715
1982	91,645,666	7,730,130	3,951,899	2,899,320	106,227,014
1987	100,090,686	9,386,334	4,354,641	5,443,358	119,275,019
1992	124,834,505	7,550,895	4,476,492	4,013,895	140,875,787
1997	126,788,271	5,895,940	3,503,572	4,780,619	140,968,402
2002	139,700,237	4,870,617	3,186,207	4,024,094	151,781,155

7. The amount of waste generated by poultry within the Illinois River Watershed has increased since at least 1950. The amount of waste generated by poultry is a function of bird type, bird size (weight) and bird life span; for a given type of bird, the greater the total weight of birds grown, the greater the amount of waste produced by the birds.[55] Consequently, the increase in the poultry population within the Illinois River Watershed since about 1950 through the present, combined with the increase in the weight of marketed birds from 1950 through the present,[56] leads to the inescapable conclusion that

54 Expert Report of Bernie Engle, 2008.
55 Expert Report of Bernie Engle, 2008.
56 Expert Report of Bernie Engle, 2008.

the amount of waste generated by poultry within the Illinois River Watershed has increased from 1950 through the present.

8. A substantial mass of poultry waste is produced within the Illinois River Watershed. A 0.7-meter resolution orthorectified air photo was obtained for both the Oklahoma and Arkansas portions of the Illinois River Watershed in the spring of 2005.[57] All imaged structures were reviewed and structures with characteristics of poultry houses (long, relatively narrow buildings often with feed silos, incinerators and other features potentially characteristic of poultry houses) were identified. In addition, the length and width of all potential poultry houses was measured using ArcView spatial analysis tools. This preliminary air photo interpretation was ground-truthed by investigator teams. These teams recorded relevant characteristics of each structure (including any signage) that could be seen from a public right-of-way.[58] In addition, Oklahoma Department of Agriculture Food and Forestry (ODAFF) records[59] and county tax assessor records (which recorded location, bird type and bird inventory data for poultry farms by school district) were reviewed and compared to the air photo and investigator information.[60] Lastly, as Defendant's discovery documents[61] became available, information from these documents concerning the location

57 STOK 20439-20440.
58 OK-PL 0001 - OK-PL 3946.
59 PI-Fisher00027498-00031831.
60 PI-Fisher00032084-PI-Fisher00032818.
61 SIM AG 32151-SIM AG 32197; SIM AG 31736-SIM AG 31785; SIM AG 31653-SIM AG 31735; SIM AG 30399-SIM AG 31652; PFIRWC-000001-PFIRWC-006983; PFIRWE0000661-PFIRWE0002161; PFIRWE0002162-PFIRWE0003520; PFIRWE0004642-PFIRWE0005180; PFIRWP-000001-PFIRWP-024309; PFIRWP-024310-PFIRWP-046185; PFIRWP-064359-PFIRWC-007186; TSN00001-TSN06780SOK; TSN00002-TSN19196SOK; TSN0023CORP-TSN0309CORP; TSN06781-TSN15670SOK; TSN107974SOK-TSN111185SOK; TSN111186SOK-TSN111806SOK; TSN111807SOK-TSN111898SOK; TSN15674-TSN31529SOK; TSN19197-TSN35683SOK; TSN31530-TSN51256SOK; TSN35686-TSN54038SOK; TSN47108-TSN47113SOK; TSN51257-TSN86676SOK; TSN54039-TSN69119SOK; TSN69120-TSN84710SOK; TSN84711-TSN86919SOK; TSN86920SOK-TSN87982SOK; TSN87985-TSN107973SOK; GE0720700001-GE0720700589; GE 10968-GE 12958; GE 13017-GE 17615; GE 17739-GE 18531; GE 18532-GE 19319; GE 19320-GE 34028; GE 1-GE 10951; GE 34029-GE 37800; GE 37801-GE 48211; GE08240700001-GE08240700555; GE10941-GE27129; GE27130-GE42353; GE28231A-GE28490A; CARTP000005-CARTP015015; CARTP015018-CARTP015020; CARTP015022-CARTP016842; CARTP016844-CARTP042986; CARTP043590-CARTP082822; CARTP082823-CARTP088174; CARTP088175-CARTP095208; CM000000001-CM000001436; CM000001437-CM000001868; CM000002656-CM000002799; CM000002800-CM000002923; CM000002924-CM000003157; CM000003158-

and number and size of poultry houses and type(s) of poultry grown were integrated with the existing spatial database. The product of this analysis was a spatial database containing the location of each structure abstracted from the air photo, the length and width of each structure, the Defendant responsible for the structure, the farm name, the grower's name, the type of bird grown, and bird capacity of each house.

As shown in Table 4, at the time the air photo was taken (Spring 2005) there were a total of 3,226 active, inactive, abandoned or removed (foundations still visible) poultry houses within the Illinois River Watershed. In addition there were 294 houses whose status could not be determined (no visibility from a public right-of-way and/or no relevant documents).

Table 4.
Poultry Houses and Probable Poultry Houses
in the Illinois River Watershed
by Status (c. 2005-2006)

Status	Active	Inactive	Abandoned	Removed	Unknown (probably poultry)	**TOTAL Active, Inactive, Abandoned and Removed**
Houses	1,917	838	361	110	294	**3,226**

These data are in good agreement with information produced by the Defendants after this assessment had been made. For example, Simmons reported an average of 346 total houses (276 active + 76 inactive) for the period 2003-2007.[62] The air photo, ground truth and document work done prior to receiving Simmons' information produced an estimate of 354 total houses (307 active + 47 inactive); within 2.3% of the total house count and within 11.2% of the active house count. Likewise, George's provided documents that described 286 active houses within the Illinois River Watershed in December 2004. The air photo, ground truth and document work done prior to receiving Georges' information produced an estimate of 353 total houses (311 active + 42 inactive). Shown in Fig 2 is a map of active

CM000003284; CM000003285-CM000003471; CM001333-CM001371.
62 SIMAG32198.

poultry house locations with identified integrators within the Illinois River Watershed.

The amount of waste generated by active poultry houses was calculated based on a consideration of the amount of waste produced per unit area of house by bird type. The amount of waste produced per unit area of house by bird type was calculated from data presented in animal waste management plans prepared under the supervision of the U. S District Court (N.D. Okl.) by the Eucha/Spavinaw Watershed Management Team.[63] Each of these waste management plans provided the lengths and widths of each poultry house as well as an assessment of the amount of waste produced by each poultry operation. Because these plans were prepared under Court supervision and were prepared by a small number of professionals working within a single administrative unit, the data in these plans was considered to be reliable and consistent. Moreover, the Eucha/Spavinaw Watershed is contiguous with the Illinois River Watershed and has similar poultry operations.[64] The waste yield per unit area data obtained from the analysis of the Eucha/Spavinaw animal waste management plans is provided in Table 5.

Table 5.
Annual Unit Area Waste Yield by Poultry Type.

Bird Type	Waste Yield ($lbs/ft^2/yr$)
Broiler	24.164
Breeder/hen	17.317
Turkey	15.111
Cornish	12.082
Pullet	10.267

Based on this approach, the total amount of waste generated within the Illinois River Watershed was calculated as 354,000 tons.

63 PI-Fisher00015544 through PI-Fisher00025356 (also as ESWM 000001 through ESWM 009815).

64 Operations of all defendants except Cal-Maine and Willowbrook Farms, are present within the Eucha/Spavinaw Watershed. As in the Illinois River Watershed, poultry operations in the Eucha/Spavinaw Watershed are dominated by broiler production with, on average, 5.5 flocks/year; are largely supplied by the same feed mills as supply operations in the Illinois River Watershed and deliver their birds to the same processing plants as poultry operations located in the Illinois River Watershed.

To be included in this computation, it was required that a poultry house be classed as "active" (or recently so, in the case of Willowbrook Farms) and that its responsible integrator (Defendant) was known. Inactive houses and houses for which an integrator (Defendant) had not been determined were not included in this computation. The results of this computation are given in Table 6. This estimate is conservative, other poultry waste production estimation approaches discussed in Dr. Engle's report, yield estimates that exceed 500,000 tons of annual poultry waste production within the Illinois River Watershed.[65] Thus currently, and for an appreciable time previously, the Defendants have produced substantial amounts of waste within the Illinois River Watershed.

Table 6.
Poultry Waste Production Within the Illinois River Watershed Estimated from a Consideration of the Total Area of Active Poultry Houses Operated by a Known Defendant

Defendant	Broiler	Breeder	Turkey	Pullet	Cornish	Hen	TOTAL	%
Cal-Maine		358		112		2,280	2,750	0.78%
Cargill		2,860	15,108				17,968	5.08%
Georges	49,813	5,911		2,489		1,888	60,101	16.98%
Peterson	35,063	491		277		1,311	37,143	10.49%
Simmons	58,724	5,757		1,818			66,299	18.73%
Tyson	129,421	18,593		7,735	9,874	1,521	167,144	47.22%
Willowbrook			2,597				2,597	0.73%
TOTAL	273,022	33,970	17,704	12,430	9,874	6,999	**354,000**	100%
%	77.12%	9.60%	5.00%	3.51%	2.79%	1.98%	100%	

9. Poultry waste is disposed by land application without incorporation (simple broadcast spreading). Based on my personal observations, the observations of investigators[66], deposition testimony[67], and technical publications[68], poultry waste is

65 Expert Report of Bernie Engle, 2008.
66 OK-PL-0004334 – 00058963; PI-Fisher 00025471 – 00025547; PI-Fisher00027362-PI-Fisher00027368.
67 Deposition of Tommy Daniel, Ph. D. November 26, 2007, Page 26 line 23-25; Page 27 line 1-23; Page 50 line 17-25; Page 51 line 1-16; Deposition of Michael Langley, November 7, 2007, page 24 lines 6-19; page 26 lines 2-19; Deposition of Bart Snyder, November 8, 2007, page 19 line 1-11; page 19 line 17-line 25; page 20 line 1.
68 Tyson Environmental Poultry Farm Management TSN0060CORP-TSN0118CORP Bell, D. D. and W. D.

broadcast spread on pastures and hay land within the Illinois River Watershed, and is not incorporated into the soil surface by tilling. A photograph illustrating the typical waste disposal practice within the Illinois River Watershed is provided in Fig 3. This method of disposal creates a circumstance in which the poultry waste is susceptible to being carried by runoff from the fields in which it has been disposed to waterways within the Illinois River Watershed.

10. Waste generated by poultry within the Illinois River Watershed has been applied near to where it is generated. Information regarding land disposal of poultry waste in Oklahoma and the location of poultry operations in Oklahoma maintained by the Oklahoma Department of Agriculture, Food and Forestry (ODAFF) was reviewed for the purpose of determining the relationship between the locations of poultry waste sources (poultry houses) and locations of poultry waste land disposal. Data for this purpose was abstracted directly from primary records.[69] Records were independently entered in duplicate and conflicts between records were resolved by reference to the primary documents. The relational database structure developed by ODAFF for data pertaining to land disposal of poultry waste, and the registration of poultry operations was used as the backbone for the analysis. The data analyzed comprised both records related to the disposal of poultry waste by poultry waste applicators (waste applicator records) and records related to the disposal of poultry waste by individual growers (grower application records). The records maintained by ODAFF do not, of course, record any instances of poultry waste disposal that were not reported to ODAFF[70], and do not reflect any waste disposed in Arkansas.

All records considered in the analysis had the following attributes: (1) a legal description (Section – Township – Range) of the waste source location was available, (2) a legal

---

Weaver. 2002. Chicken, Meat and Egg Production, 5th Edition. Kluwer Academic Publishers, Norwell, Massachusetts, PI-Fisher00005909-PI-Fisher00007209); Wilson, W. O. 1974. Housing. Pp 218-247, in: Hanke, O. A.,, J. L. Siknner and J. H. Florea (eds.), American Poultry History 1823-1973. American Printing and Publishing, Madison, Wisconsin (PI-Fisher00008114 - PI-Fisher00008505).

69 PI-Fisher00027498-00031831.

70 Although some waste application records from as early as 1998 are present in the ODAFF database, filing of waste application reports was not mandatory until 2001.

description (Section – Township – Range) of the waste disposal location was available, (3) a date of application was available, and; (4) the amount of waste applied was available and given in units of tons.[71] Prior to the application of the foregoing selection criteria there were a total of 1,280 grower application records, and 3,484 waste applicator records. Application of the selection criteria reduced the number of records considered to 910 grower application records and 2,297 waste applicator records (a total of 3,207 records). The selected records were from the time period 1998-2006, with the bulk (~85%) of the records from the period 2001-2004. The distances between waste sources and the waste disposal sites were estimated by calculating the distances between the centroids (as calculated by ArcView and expressed in UTM coordinates) of the legal descriptions for paired source and disposal locations. This analysis does not include any instances of poultry waste disposal that were not reported to ODAFF and is limited to those waste disposal reports that fulfilled the selection criteria for this analysis.

The overwhelming majority of poultry waste was disposed near where it was generated. For the data set as a whole, approximately 30% of the waste generated was land disposed in the same square mile within which it was generated, approximately 60% of the waste was land disposed within two miles and 80% was land disposed within 5 miles (see Fig. 4) of where it was generated. Likewise, considering only wastes generated within the Illinois River Watershed[72], the overwhelming majority of waste was disposed near where it was generated. For the Illinois River Watershed, however, there exists a greater localization of waste disposal. Approximately 30% of the waste generated was land disposed within the same square mile within which it was generated, approximately 67.5% of the waste was land disposed within two miles of where it was generated and approximately 80% was land

---

71 A limited number of records were excluded because the amount of waste disposed was reported in units that, given the information available, could not be reliably converted to tons (e.g. gallons, truck loads, etc).

72 For the purpose of this discussion, the Illinois River Watershed is considered to be all Public Land Survey sections (i.e. all Section – Township – Range legal descriptions) that are either completely within the watershed boundary of the Illinois River Watershed (inside) and all sections intercepted by the

disposed within 3.6 miles (see Fig. 5).

Review of nutrient management plans produced by Defendants[73] demonstrated that the spatial pattern of waste disposal in the Arkansas portion of the Illinois River Watershed was similar to that described above for the Oklahoma portion of the Illinois River Watershed. Defendants' nutrient management plans all contemplated disposal of poultry waste within two miles or less from its point of generation.[74] Review of investigator records which tracked waste disposal trucks from farms where poultry waste had been generated to

---

watershed boundary and all sections immediately contiguous to sections intercepted by the watershed boundary or completely within the watershed boundary.

73 TSN19381SOK-TSN19435SOK; TSN20629SOK-TSN20640SOK; TSN20598SOK-TSN20628SOK; TSN20569SOK-TSN20595SOK; TSN20561S0K-TSN20568S0K; TSN20538S0K- TSN20556S0K; TSN19835S0K-TSN19846S0K; TSN19241S0K-TSN19257S0K; TSN18746S0K-TSN18757S0K; TSN20517S0K-TSN20529S0K; TSN20504S0K-TSN20516S0K; TSN20470S0K-TSN20503S0K; TSN20480S0K-TSN20503S0K; TSN20455S0K-TSN20469S0K; TSN19685S0K-TSN19708S0K; TSN20417S0K-TSN20425S0K; TSN19098S0K-TSN19127S0K; TSN20403S0K-TSN20416S0K; TSN19847S0K-TSN19874S0K; TSN19875S0K-TSN19885S0K; TSN19278S0K-TSN19293S0K; TSN20381S0K-TSN20402S0K; TSN20372S0K-TSN20380S0K; TSN19294S0K-TSN19308S0K; TSN19294S0K-TSN19294S0K; TSN20300S0K-TSN20335S0K; TSN20426S0K-TSN20454S0K; TSN20431S0K-TSN20454S0K; TSN19804S0K-TSN19817S0K; TSN20171S0K-TSN20264S0K; TSN20252S0K-TSN20264S0K; TSN20118S0K-TSN20170S0K; TSN20088S0K-TSN20117S0K; TSN20051S0K-TSN20087S0K; TSN19993S0K-TSN20050S0K; TSN19900S0K-TSN19908S0K; TSN19197S0K-TSN19222S0K; TSN20186S0K-TSN20216S0K; TSN19886S0K-TSN19895S0K; TSN20336S0K-TSN20346S0K; TSN18819S0K-TSN18835S0K; TSN18836S0K-TSN18903S0K; TSN19672S0K-TSN19682S0K; TSN18929S0K-TSN18918S0K; TSN18930S0K-TSN18943S0K; TSN18791S0K-TSN18801S0K; TSN07386S0K-TSN07401S0K; TSN19128S0K-TSN19151S0K; TSN19709S0K-TSN19776S0K; TSN19726S0K-TSN19776S0K; TSN18716S0K-TSN18735S0K; TSN19777S0K-TSN19783S0K; TSN19152S0K-TSN19189S0K; TSN18687S0K-TSN18715S0K; TSN18554S0K-TSN18589S0K; TSN18944S0K-TSN18956S0K; TSN18661S0K-TSN18686S0K; TSN18667SOK-TSN18686SOK; TSN18977S0K-TSN19005S0K; TSN19479S0K-TSN19495S0K; TSN19591S0K-TSN19623S0K; TSN59962SOK-TSN59985SOK; TSN61804SOK-TSN61822SOK; TSN60176SOK-TSN60192SOK; TSN62084SOK-TSN62090SOK; TSN60502SOK-0TSN61603SOK; TSN60679SOK-TSN60711SOK; TSN115069SOK-TSN115091SOK; TSN115092SOK-TSN115112SOK; TSN115113SOK-TSN1151132OK; TSN61878SOK-TSN61899SOK; TSN61528SOK-TSN61537SOK; TSN60756SOK-TSN60770SOK; TSN47940SOK-TSN47956SOK; TSN60030SOK-TSN60046SOK; TSN59901SOK-TSN59916SOK; TSN60503SOK-TSN60507SOK; TSN72021SOK-TSN72032SOK; PFIRWP-01058-PFIRWP-01097; PFIRWP-000185-PFIRWP-000195; PFIRWP-000703-PFIRWP-001427; PFIRWP-000317-PFIRWP-000330; PFIRWP-000383-PFIRWP-000383; PFIRWP-000333-PFIRWP-000346; PFIRWP-060344-PFIRWP-060377; PFIRWP-000690-PFIRWP-000702; PFIRWP-000459-PFIRWP-000461; PFIRWP-000489-PFIRWP-000515; PFIRWP-000565-PFIRWP-000589; PFIRWP-000108-PFIRWP-000113; PFIRWP-024980-PFIRWP-024983; GE4030-GE4046; GE7055-GE7076; GE34065-GE34081; GE34209-GE34245; GE2357-GE2351; GE34003-GE34013; GE34147-GE34163; Cal-Maine East Farm; Cal-Maine West-East appl Sites; Cal-Maine West-East Farms IRW; Dick Latta SunBest Farm; Dick Latta SunBest Farm appl sites 2; CM-000003160-CM-000003204; CM-000002945-CM000003132.

poultry waste disposal sites showed that in 80% of the operations observed in Arkansas and Oklahoma, poultry waste was hauled no more than 3 miles, and was never hauled more than 15 miles from its source.[75]

There are no official records regarding poultry waste disposal for Arkansas that are equivalent to those available for Oklahoma, and those official Arkansas records that do exist lack the geographic specificity and temporal scope to replicate the Oklahoma waste disposal contiguity calculation. Nonetheless, all of the information that pertains to industry practices in general, and specifically to practices within the Arkansas portion of the Illinois River Watershed demonstrates that disposal practices in the Arkansas portion of the watershed are (and would be expected to be) similar to those practiced in the Oklahoma portion of the Illinois River Watershed. As a general premise it is commonly known that, "in many areas, manure is rarely transported more than 10 miles from where it is produced. As a result manure is often applied to soils that already have sufficient nutrients to support crop growth."[76] Deposition testimony[77] and academic research[78] indicates that there is no structural or technical reason that waste disposal practices in the Arkansas portion of the Illinois River Watershed should materially differ from those practiced in the Oklahoma portion of the Illinois River Watershed (i.e. poultry waste will be disposed close to where it is generated). With respect to the Illinois River Watershed in particular, BMPs, Inc in their final report to EPA in 2007[79] indicated that poultry waste within the IRW has been land

---

74 Ibid.

75 OK-PL-0004334 – 00058963; PI-Fisher 00025471 – 00025547; PI-Fisher00027362-PI-Fisher00027368

76 Sharpley, A.N., S. Herron, and T. Daniel. 2007. Overcoming the challenges of phosphorus-based management in poultry farming. Journal of Soil and Water Conservation 62(6):375-389.

77 Deposition of Michael Langley, November 7, 2007, page 24 lines 6-19; page 26 lines 2-19; Deposition of Bart Snyder, November 8, 2007, page 19 line 1-11; page 19 line 17-line 25; page 20 line 1.;

78 Rutherford, A. L. 1993. A descriptive analysis of the poultry litter industry in Washington County, Arkansas. M.S. Thesis, University of Arkansas. (PI-Fisher00007926- PI-Fisher00008046); Buchberger, E. 1991. An Economic and Environmental Analysis of Land Application of Poultry Litter in Northwest Arkansas. M. S. Thesis, University of Arkansas (PI-Fisher00007263 - PI-Fisher00007370); Moore, P.A. Jr., T.C. Daniel, A.N. Sharpley, and C.W. Wood. 1998. Poultry Manure Management,(Chapter 3) in: Robert J. Wright, W.D. Kemper, P.D. Millner, J.F. Power, and R.F. Korcak, eds. Agricultural Uses of Municipal, Animal, and Industrial Byproducts. U.S. Department of Agriculture, Agricultural Research Service, Conservation Research Report 44, pp 60-77 (PI-Fisher00004534-PI-Fisher00004551).

79 BMPs Inc. 2007. Final Report. Poultry Litter Transport from Nutrient Limited Watersheds in Northwest

applied in large quantities leading to potential to impact water quality. The BMPs Inc. proposal for transport of a small portion of the poultry waste out of the Illinois River Watershed was built on this premise. The USDA published that a significant part of the water quality problems in the Illinois River Watershed were the result of the large amount of poultry waste generated and disposed within the watershed.[80] Non-point source modeling work conducted in the Illinois River Watershed found that a maximum poultry waste transport distance of 8000m (approximately five (5) miles) from poultry houses in the Illinois River Watershed provided the best observed fit between estimated soil test phosphorus and observed soil test phosphorus.[81] Data obtained from the Arkansas Soil and Water Conservation Commission show that substantial amounts of poultry waste were applied in the Illinois River Watershed during the period 2004-2007 (see Table 7). [82] Lastly, the Defendant's own experts assumed all poultry waste produced in the Illinois River Watershed was land applied within the Illinois River Watershed.[83]

Table 7.
Arkansas Soil and Water Conservation Commission Estimate of Poultry Waste Land Applied in the Illinois River Watershed
(all data in tons)

	Year			
County	2004	2005	2006	2007
Benton	11,440	7,925	5,935.75	36,180
Washington	24,457	19,269	20,009	30,010

<u>11. Poultry waste has been widely disposed on pasture and grasslands within the</u>

Arkansas.

80 USDA SCS and FS. 1992. Illinois River Cooperative River Basin Resource Base Report.

81 Storm, D.E., G.J. Sabbagh, M.S. Gregory, M.D. Smolen, D. Toetz, D.R. Gade, C.T. Haan, T. Kornecki. 1996. Basin-Wide Pollution Inventory for the Illinois River Comprehensive Basin Management Program. Oklahoma State University. Submitted to the Oklahoma Conservation Commission for the US EPA , Final Report.

82 Arkansas Soil and Water Conservation Commission District Reports for Washington and Benton County, Arkansas 2004-2007.

83 Rausser, G. And M. Dicks. 2008. Declaration of Dr. Gordon Rausser and Dr. Michael Dicks in Opposition to Plaintiff's Motion for Preliminary Injunction.

<u>Illinois River Watershed.</u> ODAFF records[84], nutrient management plans in Defendants' discovery documents[85] , and investigator notes[86] demonstrate that poultry waste has been applied on pasture and grasslands throughout both the Oklahoma and Arkansas portions of the Illinois River Watershed. Shown in Fig. 6 are Public Land Survey sections in which poultry waste is known to have been disposed within the Illinois River Watershed based on ODAFF records, investigator reports and discovery documents. This map demonstrates that poultry waste disposal is widespread throughout grassland and pasture areas within the Illinois River Watershed.

---

84 PI-Fisher00027498-00031831.

85 TSN19381SOK-TSN19435SOK; TSN20629SOK-TSN20640SOK; TSN20598SOK-TSN20628SOK; TSN20569SOK-TSN20595SOK; TSN20561S0K-TSN20568S0K; TSN20538S0K- TSN20556S0K; TSN19835S0K-TSN19846S0K; TSN19241S0K-TSN19257S0K; TSN18746S0K-TSN18757S0K; TSN20517S0K-TSN20529S0K; TSN20504S0K-TSN20516S0K; TSN20470S0K-TSN20503S0K; TSN20480S0K-TSN20503S0K; TSN20455S0K-TSN20469S0K; TSN19685S0K-TSN19708S0K; TSN20417S0K-TSN20425S0K; TSN19098S0K-TSN19127S0K; TSN20403S0K-TSN20416S0K; TSN19847S0K-TSN19874S0K; TSN19875S0K-TSN19885S0K; TSN19278S0K-TSN19293S0K; TSN20381S0K-TSN20402S0K; TSN20372S0K-TSN20380S0K; TSN19294S0K-TSN19308S0K; TSN19294S0K-TSN19294S0K; TSN20300S0K-TSN20335S0K; TSN20426S0K-TSN20454S0K; TSN20431S0K-TSN20454S0K; TSN19804S0K-TSN19817S0K; TSN20171S0K-TSN20264S0K; TSN20252S0K-TSN20264S0K; TSN20118S0K-TSN20170S0K; TSN20088S0K-TSN20117S0K; TSN20051S0K-TSN20087S0K; TSN19993S0K-TSN20050S0K; TSN19900S0K-TSN19908S0K; TSN19197S0K-TSN19222S0K; TSN20186S0K-TSN20216S0K; TSN19886S0K-TSN19895S0K; TSN20336S0K-TSN20346S0K; TSN18819S0K-TSN18835S0K; TSN18836S0K-TSN18903S0K; TSN19672S0K-TSN19682S0K; TSN18929S0K-TSN18918S0K; TSN18930S0K-TSN18943S0K; TSN18791S0K-TSN18801S0K; TSN07386S0K-TSN07401S0K; TSN19128S0K-TSN19151S0K; TSN19709S0K-TSN19776S0K; TSN19726S0K-TSN19776S0K; TSN18716S0K-TSN18735S0K; TSN19777S0K-TSN19783S0K; TSN19152S0K-TSN19189S0K; TSN18687S0K-TSN18715S0K; TSN18554S0K-TSN18589S0K; TSN18944S0K-TSN18956S0K; TSN18661S0K-TSN18686S0K; TSN18667SOK-TSN18686SOK; TSN18977S0K-TSN19005S0K; TSN19479S0K-TSN19495S0K; TSN19591S0K-TSN19623S0K; TSN59962SOK-TSN59985SOK; TSN61804SOK-TSN61822SOK; TSN60176SOK-TSN60192SOK; TSN62084SOK-TSN62090SOK; TSN60502SOK-0TSN61603SOK; TSN60679SOK-TSN60711SOK; TSN115069SOK-TSN115091SOK; TSN115092SOK-TSN115112SOK; TSN115113SOK-TSN1151132OK; TSN61878SOK-TSN61899SOK; TSN61528SOK-TSN61537SOK; TSN60756SOK-TSN60770SOK; TSN47940SOK-TSN47956SOK; TSN60030SOK-TSN60046SOK; TSN59901SOK-TSN59916SOK; TSN60503SOK-TSN60507SOK; TSN72021SOK-TSN72032SOK; PFIRWP-01058-PFIRWP-01097; PFIRWP-000185-PFIRWP-000195; PFIRWP-000703-PFIRWP-001427; PFIRWP-000317-PFIRWP-000330; PFIRWP-000383-PFIRWP-000383; PFIRWP-000333-PFIRWP-000346; PFIRWP-060344-PFIRWP-060377; PFIRWP-000690-PFIRWP-000702; PFIRWP-000459-PFIRWP-000461; PFIRWP-000489-PFIRWP-000515; PFIRWP-000565-PFIRWP-000589; PFIRWP-000108-PFIRWP-000113; PFIRWP-024980-PFIRWP-024983; GE4030-GE4046; GE7055-GE7076; GE34065-GE34081; GE34209-GE34245; GE2357-GE2351; GE34003-GE34013; GE34147-GE34163; Cal-Maine East Farm; Cal-Maine West-East appl Sites; Cal-Maine West-East Farms IRW; Dick Latta SunBest Farm; Dick Latta SunBest Farm appl sites 2; CM-000003160-CM-000003204; CM-000002945-CM000003132.

12. Poultry waste generated by poultry within the Illinois River Watershed is disposed year-round, but is dominantly disposed from late winter through spring. The same data used for computation of the distance between points of waste generation and points of waste disposal was used to determine the timing of waste disposal within the Illinois River Watershed. Analysis of these data demonstrated that the principal period during which poultry waste is land disposed within the Illinois River Watershed extends over five months from February through June. Based on disposal records from 1999 through 2004, approximately 63.4% of the poultry waste land disposed within the Illinois River Watershed is disposed during this period (see Fig. 7). This period of intensive poultry waste disposal coincides with the period during which most rain falls and most runoff events occur within the Illinois River Watershed. As a consequence, this practice of poultry waste disposal produces a circumstance in which disposed poultry waste is more likely to runoff fields shortly after it is disposed, and before it has an opportunity to become incorporated in surface soil.

13. All Defendants have disposed of poultry waste within the Illinois River Watershed. ODAFF records showed that all Defendants have disposed of poultry waste within the Illinois River Watershed. A summary of this analysis is presented in Table 8. In this analysis, the locations of origin and disposal of waste are categorized as being outside the Illinois River Watershed, inside the Illinois River Watershed, on the Illinois River Watershed boundary, and not given. These data demonstrate that each of the Defendants have disposed of waste within the watershed boundary of the Illinois River Watershed. Some of the defendants (Cobb-Vantress [Tyson], George's, Petersons and Tyson) have actually imported waste to the Illinois River Watershed, that is waste generated outside of the Illinois River Watershed boundary has been disposed within the Illinois River Watershed.

---

86 OK-PL-0004334 – 00058963; PI-Fisher00025471 – 00025547.

The Oklahoma portion of the Illinois River Watershed, according to the ODAFF records, experienced a net importation of poultry wastes. As summarized below, the ODAFF records show that a total of 98,054 tons of poultry waste originated completely within the Oklahoma portion of the Illinois River Watershed, but a total of 30,953 tons of poultry waste that originated outside of the Oklahoma portion of the Illinois River Watershed were disposed within the Oklahoma portion of the Illinois River Watershed, while 12,606 tons that originated entirely within the Oklahoma portion of the Illinois River Watershed were disposed outside the Oklahoma portion of the Illinois River Watershed. As consequence, a total of 116,401 tons were disposed entirely within the Oklahoma portion of the Illinois River Watershed, or about 18.7% more poultry waste was disposed entirely within the Oklahoma portion of the Illinois River Watershed that was generated entirely within the Oklahoma portion of the Illinois River Watershed. Again, the ODAFF data analyzed are only those records that fulfilled the selection criteria (see above). The records maintained by ODAFF do not, of course, record any instances of poultry waste disposal that were not reported to ODAFF, and do not reflect any waste disposed in Arkansas.

Table 8. Location of Waste Generation and Location of Waste Disposal by Defendants

Defendant	Location of Waste Generation	Location of Waste Disposal: Not Given (tons)	Border ILLINOIS RIVER WATERSHED (tons)	Inside ILLINOIS RIVER WATERSHED (tons)	Outside ILLINOIS RIVER WATERSHED (tons)	Total (tons)
Aviagen	Not Given	0	0	0	146	146
	Inside ILLINOIS RIVER WATERSHED	360	0	110	0	470
	Border ILLINOIS RIVER WATERSHED	0	0	0	0	0
	Outside ILLINOIS RIVER WATERSHED	0	0	0	2559	2559
Cal-Maine Foods	Not Given	0	0	0	0	0
	Inside ILLINOIS RIVER WATERSHED	69	0	3327	792	4188
	Border ILLINOIS RIVER WATERSHED	0	0	0	0	0
	Outside ILLINOIS RIVER WATERSHED	0	0	0	0	0
Cargill	Not Given	583	0	1472	0	2055
	Inside ILLINOIS RIVER WATERSHED	0	0	3066	30	3096
	Border ILLINOIS RIVER WATERSHED	0	5777	0	714	6491
	Outside ILLINOIS RIVER WATERSHED	0	2784	0	616	3400
Cobb-Vantress (Tyson)	Not Given	7032	752	10792	43191	61768
	Inside ILLINOIS RIVER WATERSHED	364	478	31737	555	33134
	Border ILLINOIS RIVER WATERSHED	0	3740	1721	1627	7088
	Outside ILLINOIS RIVER WATERSHED	1862	3336	2740	62078	70016
George's Inc	Not Given	415	0	0	0	415
	Inside ILLINOIS RIVER WATERSHED	0	0	3165	0	3165
	Border ILLINOIS RIVER WATERSHED	0	1096	45	108	1249
	Outside ILLINOIS RIVER WATERSHED	0		270	114	384
Peterson Farms	Not Given	2778	90	240	1056	4164
	Inside ILLINOIS RIVER WATERSHED	0	1281	2959	633	4873
	Border ILLINOIS RIVER WATERSHED	0	5110	0	1679	6789
	Outside ILLINOIS RIVER WATERSHED	301	1043	180	10277	11801
Simmons Foods	Not Given	945	405	4544	2988	8882
	Inside ILLINOIS RIVER WATERSHED	184	2733	16103	1512	20532
	Border ILLINOIS RIVER WATERSHED	219	4891	636	984	6730
	Outside ILLINOIS RIVER WATERSHED	579	748	3589	29444	34360
Tyson Foods	Not Given	717	232	2305	2570	5823
	Inside ILLINOIS RIVER WATERSHED	117	2404	23678	420	26619
	Border ILLINOIS RIVER WATERSHED	300	4486	0	2327	7113
	Outside ILLINOIS RIVER WATERSHED	66	1258	515	17920	19759
Willow Brook Foods	Not Given	0	24	345	0	369
	Inside ILLINOIS RIVER WATERSHED	0	648	0	1120	1768
	Border ILLINOIS RIVER WATERSHED	0	1194	997	2400	4591
	Outside ILLINOIS RIVER WATERSHED	0	0	0	0	0

14. The mass of poultry waste generated within the Illinois River Watershed but disposed of outside the watershed is a minority of the waste generated within the Illinois River Watershed. A conservative estimate of the amount of poultry waste generated within the Illinois River Watershed is 354,000 tons/year (see above). In the recent past, a non-profit entity, BMPs, Inc., established as a result of the settlement agreement in *Tulsa v Tyson et al.*[87], has been engaged in hauling poultry waste from points within the Illinois River Watershed to locations outside the Illinois River Watershed. BMPs, Inc's documents show that BMPs, Inc. began hauling poultry waste from the Illinois River Watershed in 2004. In 2006, BMPs, Inc. reports hauling just less than 60,000 tons of poultry waste from the Illinois River Watershed. Georges' records indicate the first year in which they hauled poultry waste out of the Illinois River Watershed was 2003, and the peak hauling year for George's was 2005 in which they hauled a total of 11,406.30 tons of poultry waste form the Illinois River Watershed.[88] The amount of poultry waste hauled by BMPs, Inc. and George's from the Illinois River Watershed during the period 2003-2006 is given in Table 9. Given the conservative estimate of poultry waste produced within the Illinois River Watershed of about 354,000 tons/year, in the peak year of 2006, no more than 19.5% of the total amount of poultry waste generated was hauled from the Illinois River Watershed. For the period of record (2003-2006) no more than about 8.8% of the total waste generated was hauled from the Illinois River Watershed.

---

87 Order Approving Settlement Agreement, Vacating Order of March 14, 2003, and Administratively Closing Case. City of Tulsa and Tulsa Metropolitan Utility Authority v Tyson Foods, Inc. et al., Case No. 01 CV 0900EA(C) in the United States District Court for the Northern District of Oklahoma, July 16, 2003.

88 GE[07/2/07]00263, GE[07/2/07]00265, GE[07/2/07]00267, GE[07/2/07]00269, GE[07/2/07]00339.

Table 9.
Tons of Poultry Waste Hauled from the Illinois River Watershed to Locations Outside the Illinois River Watershed by BMPs, Inc. and George's (2003-2006)

Year	2003	2004	2005	2006	TOTAL
BMPs, Inc. Tons	0.00	905.88	14,783.57	59,736.56	**75,426.01**
George's Tons	8,877.60	11,406.30	19,651.13	9,282.45	**49,217.48**
TOTAL Tons	**8,877.60**	**12,312.18**	**34,434.7**	**69,019.01**	***1,246,43.50***
% of Poultry Waste Produced that was Hauled	**2.51%**	**3.48%**	**9.73%**	**19.50%**	***8.80%***

15. Defendants' feed formulas show that Defendants add chemical compounds, including compounds containing phosphorous, and metals (sodium, potassium, calcium, copper, zinc, arsenic and selenium). Poultry diets contain numerous chemical elements, including phosphorous, copper and zinc and arsenic.[89] Moreover, standard reference diets for chicks are specifically formulated using chemical compounds containing phosphorous, copper and zinc.[90]

The feed formulations[91] used by Tyson, Simmons, Peterson, Cargill, George's and Cal-Maine demonstrate that the Defendant's design and control the composition of feed provided to their poultry. In general, the feed formulations specified by the Defendants are dominantly comprised of corn and soybean meal, but frequently contain appreciable quantities of other grains and/or grain processing wastes as well as poultry by-product meal,[92] feather meal, meat and bone meal, animal fat (including poultry fat), and various organic nutrients, including vitamins and amino acids. In nearly all cases, Defendants' feed formulations specify the addition of numerous chemicals (other than the materials specified in the foregoing list). The chemical compounds added to feeds by Tyson, Simmons,

89 See Chapters 1, 2 and 3, National Research Council. 1994. Nutrient Requirements of Poultry 9th Revised Edition, National Academy Press, 155 pp.

90 See Chapter 10, Standard Reference Diets for Chicks, National Research Council. 1994. Nutrient Requirements of Poultry 9th Revised Edition, National Academy Press, 155 pp.

91 CM003472 - CM003581; CARTP007982 - CARTP010833; GE 34777 – GE 35008; GE 35127 – GE 35138; GE 36091 – GE 36458; PFIRWP-063697 - PFIRWP-064049; SIM AG 31786- SIM AG 32150; TSN0001NCFF – TSN0570NCFF; TSN0001SCFF – TSN0535SCFF.

92 Poultry byproduct meal is made by grinding the rendered parts of poultry carcasses (see http://en.wikipedia.org/wiki/Chicken_by-product_meal).

Peterson, Cargill, George's and Cal-Maine include: calcium phosphates, calcium carbonate, calcium iodate, sodium chloride, manganese oxide, iron sulfate, potassium sulfate, zinc oxide, zinc propionate, copper chloride, copper sulfate, arsenic in the form of 3-nitro-4-hydroxyphenylarsonic acid (a/k/a Roxarsone)[93], selenium, molybdenum, trace minerals, vitamins and numerous antibiotic compounds.[94]

16. Because of the addition of compounds containing phosphorous and metals (including sodium, potassium, calcium, copper, zinc and arsenic), poultry waste contains high levels of nutrients, including phosphorous, and metals (including sodium, potassium, calcium, copper, zinc and arsenic). Analytical data for the twenty-five (25) samples of poultry waste obtained by CDM are presented in Table 10. As would be expected from the composition of poultry feed, these wastes display a high level of calcium (average = 27,869.40 mg/Kg) due to the addition of crushed limestone and other calcium compounds to poultry feed mixtures, a high level of potassium (average = 22,741.76 mg/Kg) consistent with the addition of potassium salts to poultry feed, a high level of total phosphorous (average = 15,183.44 mg/Kg) consistent with addition of calcium phosphate salts, bone and blood meal and poultry byproduct meal to poultry feed, a high level of sodium (average = 5,971.42 mg/Kg) consistent with the addition of salt (NaCl) to poultry feed, and high levels of copper (average= 323.89 mg/Kg) and zinc (average= 379.04 mg/Kg), both consistent with the addition of copper sulfate and/or copper chloride and zinc propionate and, possibly other zinc salts in the form of compositionally unspecified "trace minerals", to poultry feeds. In addition, a high level of arsenic was present (average = 16.14 mg/Kg) consistent with the addition of 3-nitro-4-hydroxyphenylarsonic acid (a/k/a Roxarsone) to poultry feeds.

---

93 PFIRWP-064360-PFIRWP-064363.

94 CM003472 - CM003581; CARTP007982 - CARTP010833; GE 34777 – GE 35008; GE 35127 – GE 35138; GE 36091 – GE 36458; PFIRWP-063697 - PFIRWP-064049; SIM AG 31786- SIM AG 32150; TSN0001NCFF – TSN0570NCFF; TSN0001SCFF – TSN0535SCFF; 30(B)(6) Deposition of Chester Wiernusz, August 20, 2007; page 17, line 6-8; page 18, lines 14-23; page 27 line 8-10.

Poultry have low body retention of trace elements. For example, poultry retain only about 6% of the Cu and Zn that they are fed. This low body retention is mainly ascribed to the relatively high dietary intakes of trace elements because poultry diets contain trace elements far in excess of dietary requirements.[95] It is not surprising, therefore, that the

Table 10.

Summary Statistics for the Composition of 25 Samples of Poultry Waste Collected by CDM[96]

Parameter	Units	Obs.	ND	Max	Q3	Median	Average	Std. Dev.	Q1	Min
Moisture	%	25	0	70.60	23.30	18.80	20.73	14.143	13.70	5.28
Organic Matter	%	25	0	97.90	77.00	74.50	72.44	13.311	65.00	40.60
Total Calcium	mg/Kg	25	0	69,800.00	31,100.00	28,900.00	27,869.40	12,099.758	18,700.00	8,030.00
Nitrogen Total (Inorganic + Organic)	mg/Kg	25	0	39,800.00	35,900.00	33,200.00	25,021.60	13,249.729	12,600.00	2,350.00
Total Potassium	mg/Kg	25	0	37,600.00	27,700.00	23,000.00	22,741.76	8,174.667	20,300.00	1,474.00
Total P (6020)	mg/Kg	25	0	23,700.00	19,800.00	16,800.00	15,183.44	5,654.101	10,500.00	4,466.00
Phosphorus (Mehlich 3)	mg/Kg	25	0	13,120.00	5,490.00	3,760.00	4,447.28	2,911.890	2,347.00	362.00
Phosphorus (Water Soluble)	mg/Kg	25	0	4,880.00	1,348.00	695.00	1,173.12	1,094.836	500.00	76.00
Total Sodium	mg/Kg	25	0	11,200.00	6,940.00	5,910.00	5,971.42	2501.238	4,950.00	75.60
Total Magnesium	mg/Kg	25	0	6,840.00	6,030.00	5,270.00	5,009.28	1,368.394	4,150.00	2,130.00
Sulfate (Water Soluble)	mg/Kg	25	1	7,090.00	4,050.00	3,090.00	3,009.72	1,872.857	1,520.00	10.00
Chloride (Water Soluble)	mg/Kg	25	1	5,870.00	3,720.00	2,780.00	2,799.24	1,500.267	1,680.00	50.00
Total Aluminum	mg/Kg	25	2	9,140.00	1,780.00	955.00	1,690.36	2,054.09	500.00	150.00
Ammonium (Water Soluble)	mg/Kg	25	1	6,280.00	2,360.00	1,130.00	1,582.64	1,644.135	441.00	5.00
Total Iron	mg/Kg	25	0	6,180.00	1,210.00	676.00	1,140.64	1,253.863	490.00	272.00
Total Manganese	mg/Kg	25	0	951.00	623.00	591.00	558.16	197.284	424.00	222.00
Total Zinc	mg/Kg	25	0	582.00	478.00	385.00	379.04	135.278	287.00	96.10
Total Copper	mg/Kg	25	0	448.00	411.00	355.00	323.89	117.718	287.00	20.20
Total Barium	mg/Kg	25	0	164.00	51.30	32.80	41.54	28.991	27.70	12.20
Total Arsenic	mg/Kg	25	4	38.30	29.50	17.40	16.14	13.643	2.45	0.50
Total Vanadium	mg/Kg	25	6	125.00	9.67	5.00	14.73	26.270	4.69	2.51
Total Nickel	mg/Kg	25	0	15.20	12.50	10.30	10.25	3.163	8.11	3.14

levels of trace elements such as Zn, Cu, and Mn in poultry waste are far in excess of crop

95 Van der Klis, J. D. and P. A. Kemme. 2002. An appraisal of trace elements: Inorganic and organic (Chapter 6) in: McNab, J. M. and K. N. Boorman, eds.. Poultry Feedstuffs, Supply, Composition and Nutritive Value. Poultry Science Symposium Series, Vol. 26., CABI Publishing, New York.

96 Sample IDs: Litter 3, Litter 4, Litter 2, Litter 5, FAC 01A (020206-Normal 1), FAC 01B (020206-Normal 2), FAC-06, FAC-04, FAC-05, FAC1, FAC2, FAC-07, FAC-03, FAC-08, FAC09, FAC-10, LAL1-A-Compost, FAC 1-C (020206-Cake), FAC-11, FAC-12-113007, FAC-12-112907, FAC-14, FAC-15, FAC-16, FAC-17.

requirements, and disposal of these wastes on soils results in a build up of these trace elements in the soil. [97]

The chemical data obtained by CDM for poultry waste within the Illinois River Watershed is comparable to, and statistically not differentiable from, analytical data for moisture, calcium, total nitrogen, total potassium, total phosphorus and total water soluble phosphorus for poultry waste samples obtained in support of nutrient management plans prepared by the Eucha/Spavinaw Watershed Management team (see Table 11).[98] These data are also similar to published values for total elemental compositions of poultry waste.[99]

Table 11.

Summary Statistics for the Composition of 369 Samples of Poultry Waste from Animal Waste Analyses Presented in Nutrient Management Plans Prepared by the Eucha/Spavianw Watershed Management Team (2005)

Parameter	Units	Obs.	Max	Q3	Median	Average	Std. Dev.	Q1	Min
Moisture	%	369	72.04	37.40	27.70	31.64	12.35	23.54	10.20
Total Carbon	%	309	78.71	38.15	36.58	35.59	5.64	33.69	3.74
Total Calcium	mg/Kg	323	174,774.77	47,598.42	35,111.11	49,786.01	33,948.30	30,027.50	11,270.98
Total Nitrogen	mg/Kg	366	107,743.00	47,021.21	41,933.97	40,793.71	9,987.00	34,489.40	2,402.40
Total Potassium	mg/Kg	365	276,859.50	36,963.19	33,558.86	34,159.01	14,437.07	29,499.32	12,322.86
Total Phosphorus	mg/Kg	365	51,654.98	24,571.43	21,067.82	21,896.07	5,628.95	18,958.61	8,215.24
Phosphorus (Water Soluble)	mg/Kg	361	14,485.88	1,700.97	1,325.49	1,488.26	981.52	1,051.95	365.30

17. The chemistry of cattle diets differs from that of poultry diets. Cattle diets differ from poultry diets. As a consequence, fecal wastes generated by cattle would be expected to differ chemically from fecal wastes generated by poultry. For example, the concentration of copper in beef cattle diets is 10 mg Cu/kg diet, while zinc in beef cattle

97 Van der Klis, J. D. and P. A. Kemme. 2002. An appraisal of trace elements: Inorganic and organic (Chapter 6) in: McNab, J. M. and K. N. Boorman, eds.. Poultry Feedstuffs, Supply, Composition and Nutritive Value. Poultry Science Symposium Series, Vol. 26., CABI Publishing, New York.
98 PI-Fisher00015544 through PI-Fisher00025356 (also as ESWM 000001 through ESWM 009815).
99 Jackson, B. P., P. M. Bertsch, M. L. Cabrera, J. J. Camberato, J. C. Seaman and C. W. Wood. 2003. Trace element speciation of poultry litter,. J. Environ. Qual. 32: 535-540. (PI-Fisher00003652- PI-Fisher00003657).

diets is 30 mg Zn/kg.[100] The consequent Zn:Cu ratio in a beef cattle diet is 3:1. The ratio of Zn to Cu in cattle waste samples collected in the Illinois River Watershed by CDM ranged from 4.237:1 to 8.901:1 with an average value of 6.102:1. In contrast, the analysis of poultry feed obtained by CDM[101] had a measured zinc concentration of 128 mg/kg and a measured copper concentration of 119 mg/kg or a Zn:Cu ratio of 1.076:1, a value very different from those in beef cattle diets or in cattle waste, but quite similar to the Zn:Cu ratio of 1.317:1 for the average values of Zn and Cu measured by CDM in poultry wastes.

18. The chemical composition of poultry waste is distinctly different from the chemical composition of cattle waste and waste water treatment plant effluent. Crossplots of Total P, Total Zn, Total Cu and Total As that compare poultry waste, cattle waste and wastewater treatment plant effluent are provided in Fig 8.[102] Cattle waste is chemically distinguishable from poultry waste. Cattle waste contained substantially less (~ 10 times less) Total P per unit mass than poultry waste, and contained no detectable Total As. Further, cattle waste contains much less Total Zn and Total Cu than poultry waste and the ratio of Total Cu to Total Zn in cattle waste is smaller than the ratio of Total Cu to Total Zn found for poultry waste. Wastewater treatment plant effluent is also chemically distinguishable from poultry waste. Compared to poultry waste, wastewater treatment plant effluent is depleted in Zn, Cu and As with respect to P, and is depleted in Cu with respect to Zn compared to poultry waste.

Data concerning the ratios Total Zn/Total P, Total Cu/Total P, Total As/Total P and Total Zn/Total Cu in poultry waste, cattle waste and wastewater treatment plant effluent are

---

100 See Chapter 5, National Research Council , 2000. Nutrient Requirements of Beef Cattle: Seventh Revised Edition: Update 2000, National Academy Press, 232 pp.

101 Sample ID FAC 01-FEED.

102 Sample IDs: Litter 3, Litter 4, Litter 2, Litter 5, FAC 01A (020206-Normal 1), FAC 01B (020206-Normal 2), FAC-06, FAC-04, FAC-05, FAC1, FAC2, FAC-07, FAC-03, FAC-08, FAC09, FAC-10, LAL1-A-Compost, FAC 1-C (020206-Cake), FAC-11, FAC-12-113007, FAC-12-112907, FAC-14, FAC-15, FAC-16, FAC-17; MAN-BC-20D; MAN-BC-20F; MAN-BC-21D; MAN-BC-21F; MAN-BC-22D; MAN-BC-22F; MAN-BC-23D; MAN-BC-23F; MAN-BC-24D; MAN-BC-24F; MAN-BG-20F; Lincoln WWTP-01 Non-filtered; Rogers WWTP Non-filtered; Silom Springs WWTP Non-filtered; Springdale WWTP Non-filtered , Lincoln WWTP-01.

given in Table 12. The ratio of Zn to P (Zn/P) in poultry waste ranged between 0.022:1 and 0.130:1 with an average value of 0.085:1. In comparison, the ratio of Zn to P in cattle waste ranged from 0.002:1 to 0.007:1 with an average value of 0.004:1 while in wastewater treatment plant effluent (unfiltered) the ratio of Zn to P ranged from 0.000001:1 to 0.000007:1 with an average value of 0.000004:1. With respect to P then, on average, Zn is approximately 22 times more abundant in poultry waste than in cattle waste and more than 19,000 times more abundant in poultry waste than in wastewater treatment plant effluent.

The ratio of Cu to P (Cu/P) in poultry waste ranged between 0.210:1 and 4.622:1 with an average value of 3.370:1. In comparison, the ratio of Cu to P in cattle waste ranged from 0.022:1 to 0.039:1 with an average value of 0.029:1 while in wastewater treatment plant effluent (unfiltered) the ratio of Cu to P ranged from 0.000011:1 to 0.000045:1 with an average value of 0.000022. With respect to P then, on average, Cu is approximately 115 times more abundant in poultry waste than in cattle waste and more than 151,000 times more abundant in poultry waste than in wastewater treatment plant effluent.

The ratio of As to P (As/P) in poultry waste ranged between 0.025:1 and 1.896:1 and had an average value of 1.317:1. In comparison, no arsenic was detected in cattle waste; while in wastewater treatment plant effluent (unfiltered) the ratio of As to P ranged from 0.000054:1 to 0.000063:1 with an average value of 0.000060:1. With respect to P then, As is approximately 13,400 times more abundant in poultry waste than in wastewater treatment plant effluent.

The ratio of Zn to Cu (Zn/Cu) in poultry waste ranged between 0.893:1 and 4.757:1with an average value of 1.317:1. In comparison, the ratio of Zn to Cu in cattle waste ranged from 4.237:1 to 8.901:1 with an average value of 6.102:1 while in wastewater treatment plant effluent (unfiltered) the ratio of Zn to Cu ranged from 5.731:1 to 14.190:1 with an average value of 9.762:1. With respect to Cu then, on average, Zn is approximately 4.6 times more abundant in poultry waste than in cattle waste and 7.4 times more abundant in poultry waste than in wastewater treatment plant effluent.

Given these differences in chemical ratios, these wastes are distinctly different from one another, and these differences can be used to identify the presence of these wastes in environmental samples.

Table 12.
Ratios of Total Zn/Total P, Total Cu/Total P, Total As/Total P and Total Zn/Total Cu for Poultry Waste, Cattle Waste and Wastewater Treatment Plant Effluent (unfiltered)

		Total Zn / Total P	Total Cu/'Total P	Total As/Total P	Total Zn/Total Cu
Poultry Waste	Maximum	0.130	4.662	1.896	4.757
	Q3	0.107	4.277	1.460	1.367
	Mean	0.085	3.370	0.799	1.317
	Median	0.086	3.694	0.861	1.115
	Q1	0.064	2.986	0.121	1.034
	Minimum	0.022	0.210	0.025	0.893
Cattle Waste	Maximum	0.007	0.039	As not detected	8.901
	Q3	0.004	0.034	As not detected	6.852
	Mean	0.004	0.029	As not detected	6.102
	Median	0.004	0.028	As not detected	5.955
	Q1	0.003	0.024	As not detected	5.431
	Minimum	0.002	0.022	As not detected	4.237
Wastewater Treatment Plant Effluent	Maximum	0.000007	0.000045	0.000063	14.190
	Q3	0.000006	0.000028	0.000062	12.427
	Mean	0.000004	0.000022	0.000060	9.762
	Median	0.000004	0.000017	0.000060	9.563
	Q1	0.000003	0.000011	0.000058	6.897
	Minimum	0.000001	0.000011	0.000054	5.731

<u>19. The geology of the Illinois River Watershed produces a circumstance in which both the surface and ground water within the Illinois River Watershed are highly susceptible to pollution from the constituents of land applied poultry waste.</u> The Illinois River Watershed contains approximately 1,672 mi^2 (1,069,530 acres), and lies within the southwestern portion (Springfield Plateau) of the Ozark Uplift physiographic province within portions of Washington and Benton Counties in Arkansas and Delaware, Adair, Cherokee and Sequoyah Counties in Oklahoma. Approximately 53% of the Illinois River Watershed is in Oklahoma and the remaining 47% is in Arkansas.[103] The Springfield plateau is generally deeply dissected with rolling upland areas separated by V-shaped stream valleys that range from 20 to 30 feet in depth.

As shown in Fig 9, the Illinois River arises in the Boston Mountains of northwestern Arkansas in Washington County. From its headwaters, it flows in a northerly and westerly direction to its crossing of the Oklahoma/Arkansas border south of Siloam Springs in Benton Country, Arkansas. From there, the Illinois continues westerly to its confluence with Flint Creek in Delaware County, Oklahoma where it changes course to a southerly direction. The Illinois is impounded by Tenkiller dam just north of its confluence with the Arkansas River at Gore, Oklahoma. From its headwaters to its confluence with the Arkansas, the Illinois flows approximately 162 miles.

Two of the primary tributaries to the Illinois River also arise in the Ozark region of Arkansas. Flint Creek originates in Benton Country and flows generally westerly toward its confluence with the Illinois just south of Kansas, Oklahoma. Baron Fork Creek arises in Washington County, Arkansas and flows southwesterly to its confluence with the Illinois south of Tahlequah, Oklahoma. The third major tributary to the Illinois River, Caney Creek, originates at Stillwell, OK and flows generally southwesterly to its confluence with the Illinois in the northern portion of Lake Tenkiller.

Surface water movement within the Illinois River Watershed is controlled by its underlying geology. The major streams in the Illinois River Watershed (Illinois River, Flint Creek, Baron Fork and Caney Creek) have developed within geological faults and fractures.[104] As shown

---

103 Lyhane. T. E., 1987. Hydrologic Investigation of the Illinois River. Technical Report 87-3. Oklahoma Water Resources Board, Stream Water Division.

104 Adamski, J. C., J. C. Peterson, D. A. Freiwald and J. V. Davis. 1994. Environmental and hydrologic setting of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri, and Oklahoma, USGS WRI 94-4022 ((PI-Fisher00002644 - PI-Fisher00002719) ; Salisbury, D. O. and Davis, R. K. 1997. A hydrogeological and hydrochemical connection between the Decatur City Spring and Crystal Lake,

in the digital elevation map given in Fig 10, these streams flow westerly and southwesterly, and become, in general, progressively more deeply incised as they pass from the Arkansas portion of the Illinois River Watershed to the Oklahoma portion of the Illinois River Watershed. As shown on the land use/land cover map in Fig 11, the Arkansas portion of Illinois River Watershed is dominated by broad open grassed areas of low topographic relief that are dissected by numerous tributary drainages. In contrast, in the Oklahoma portion of the Illinois River Watershed, topographic relief is greater, and the major streams there form broader more steeply-sided forested valleys that separate more isolated grassed areas. Urban areas within the Illinois River Watershed are located largely along the watershed's boundary, dominantly along the far northeastern boundary of the watershed, and adjacent to the primary east-west transportation corridor. Simply stated, the Arkansas portion of the Illinois River Watershed is more open, contains a greater proportion of pasture land and those pasturelands are more contiguous in Arkansas than in Oklahoma. This condition facilitates the disposal of poultry wastes through land application. In contrast, the Oklahoma portion of the Illinois River Watershed is generally hillier, going westward and southwestward, and thus becomes less topographically suitable for the disposal of poultry wastes through land application traveling from east to west.

Structural features found in the region suggest episodes of uplift and extensional stress. Compressional forces are attributed to the Ouachita orogeny, a plate collision that climaxed in the Mississippian.[105] Extensional forces are represented by large-scale normal faults, dipping to the south that commonly extend to basement[106], and smaller scale faulting on

Benton County, Arkansas. J. Arkansas Academy of Science, 51: 159 – 168 (PI-Fisher00000092- PI-Fisher00000101); Bedrock Geologic Map of Arkansas, Northwest Quadrant, 1800x1600, available at http://geology.about.com/library/bl/maps/n_statemap_ARnw.htm; also see PI-FISHER00026686.

105 Flawn, P.T., Goldstein, A. Jr, King, P.D., and Weaver, C.E., 1961, The Ouachita System, The University of Texas, Austin, TX.

106 Orndorff, R.C., Weary, D.J., Sebela, S., 2001, Geologic Framework of the Ozarks of South-Central Missouri- Contributions to a Conceptual Model of Karst, In Eve L. Kuniansky, editor, 2001, U.S. Geological Survey Karst Interest Group Proceedings, Water-Resources Investigations Report 01-4011, p. 18-24.

the order of 30 m displacements.[107] Joints are common and appear to be controlled by uplift that resulted in extensional fractures. The faults and fractures that control drainage within the Illinois River Watershed are primarily associated with the Ozark uplift. The Ozark uplift postdates the deposition of the youngest bedrock (Mississippian) within the Illinois River Watershed.[108] As a result, this uplift disturbed all strata within the Illinois River Watershed. Consequently, significant fracturing and faulting observed at the surface within the Illinois River Watershed penetrates deeply into all of the geologic formations within the Illinois River Watershed. This deep fracturing is significant, because its presence means that the constituents from land application of poultry waste can not only easily move into shallow aquifers along dissolution-expanded (karsted) infiltration routes, it can also penetrate to greater depths along the deep seated fractures and faults, and thus threaten deeper aquifers. A map showing major faults fractures and significant linemaments is given in Fig 12.

The terrain of the bulk of the Illinois River Watershed is mantled karst.[109] In mantled karst terrains the dissolution of carbonate units beneath a covering of soil and regolith creates expanded infiltration pathways including, sinkholes, solution expanded fractures, faults and caves. The fracturing and faulting within the Illinois River Watershed, combined with karstification (which enlarges subsurface faults and fractures) produces areas of high

---

107 Stanton, G.P., and Brahana, J.V., 1996, Structural control on hydrogeology of a mantled karst aquifer in northwestern Arkansas: Geological Society of America Abstracts with Programs, v. 28, no. 7, p. 334.

108 Hudson, M. R. 2000. Coordinated strike-slip and normal faulting in the southern Ozark dome of northern Arkansas: Deformation in a late Paleozoic foreland. Geology, 28:511-514 (PI-Fisher00001752- PI-Fisher00001755); Imes, J. L. and L. F. Emmett. 1994. Geohydrology of the Ozark Plateaus Aquifer System in Parts of Missiouri, Arkansas, Oklahoma and Kansas. USGS Professional Paper 1414-D (PI-Fisher00002912. - PI-Fisher00003051).

109 Stanton, G.P., and Brahana, J.V., 1996, Structural control on hydrogeology of a mantled karst aquifer in northwestern Arkansas: Geological Society of America Abstracts with Programs, v. 28, no. 7, p. 334; Adamski, J. C., J. C. Peterson, D. A. Freiwald and J. V. Davis. 1994. Environmental and hydrologic setting of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri, and Oklahoma, USGS WRI 94-4022 ((PI-Fisher00002644 - PI-Fisher00002719) ; Salisbury, D. O. and Davis, R. K. 1997. A hydrogeological and hydrochemical connection between the Decatur City Spring and Crystal Lake, Benton County, Arkansas. J. Arkansas Academy of Science, 51: 159 – 168 (PI-Fisher00000092- PI-Fisher00000101).

permeability, and results in a circumstance in which shallow ground water aquifers are particularly susceptible to impact by surface contamination, including contamination by bacteria, that can readily travel from the soil surface to surface water and ground water during rainfall events. A diagram illustrating the relationship between fractures and solution activity in carbonate rocks is provided in Fig 13. Within such a karst terrain, there is little attenuation (reduction) of contaminants as they move from the land surface into and through the karst aquifer. Thus, land application of poultry waste to the karst terrain of the Illinois River Watershed means that constituents of this waste (including bacteria) travel readily through the soils and underlying geologic media to discharge at and into ground water springs and surface streams throughout the Illinois River Watershed. Further, because of the ready flow of water through a karst terrain of the type present in the Illinois River Watershed, there is strong interaction between surface water flow and ground water flow so that surface waters readily become ground water and ground water readily becomes surface water. The phenomenon is readily shown by the numerous springs and gaining and losing streams found within the Illinois River Watershed.

Soils within the Illinois River Watershed are formed mostly from the weathering of carbonate rocks, and are of low natural fertility.[110] The soils are typically loams and are often rocky due to the presence of chert fragments. Loam soils are mixtures of sand, silt, clay and organic matter. Depending on the relative proportion of sand, silt and clay, these

---

110 Osborn, N. L. 2001. Minor Basin Hydrogeologic Investigation Report of the Boone Groundwater Basin, Northeastern Oklahoma. Oklahoma Water Resources Board Technical Report GW2001-2. (PI-Fisher00003605 - PI-Fisher00003630); United States Department of Agriculture Soil Conservation Service and Forest Service In cooperation with Arkansas Agricultural Experiment Station. 1977. Soil Survey of Benton County, Arkansas; United States Department of Agriculture Soil Conservation Service and Forest Service In cooperation with Arkansas Agricultural Experiment Station. 1969. Soil Survey of Washington County, Arkansas; U.S. Dept. of Agriculture, Soil Conservation Service. 1965. Soil survey, Adair County, Oklahoma; U.S. Dept. of Agriculture, Soil Conservation Service. 1970. Soil survey, Cherokee and Delaware Counties, Oklahoma; United States Department of Agriculture, Natural Resources Conservation Service, in cooperation with the Oklahoma Agricultural Experiment Station and the Oklahoma Conservation Commission. Supplement to the Soil Survey of Adair County, Oklahoma; United States Department of Agriculture, Natural Resources Conservation Service, in cooperation with the Oklahoma Agricultural Experiment Station and the Oklahoma Conservation Commission. Supplement to the Soil Survey of Delaware County, Oklahoma.

soils will be susceptible to infiltration or surface runoff.[111] As shown in Fig 14, soils more susceptible to run off dominate in the eastern and western portions of the Illinois River Watershed, while soils that are more susceptible to infiltration dominate in the central portion of the Illinois River Watershed.[112] Thus, contaminants deposited on the surface within the Illinois River Watershed are prone to runoff from soils in about half of the watershed and are prone to infiltration through soils in the remaining half of the watershed.

The features discussed above are schematically shown in Fig 15 which provides a site conceptual model for the Illinois River Watershed. The fractured and karsted bedrock is shown in brown in the cross section.

20. Shallow ground water within the Illinois River Watershed is highly susceptible to contamination from surface-applied pollutants. The shallow bedrock aquifer within the

---

111 Al-Qinna, M. I. 2003. Measuring and modeling soil water and solute transport with emphasis on physical mechanisms in karst topography. M.S. Thesis, University of Arkansas. . (PI-Fisher00003977- PI-Fisher00004270); Davis, R. K., J. V. Brahana, J. S. Johnson. 2000. Ground water in northwest Arkansas: Minimizing nutrient contamination from non-point sources in karst terrane. Arkansas Soil and Water Conservation Commission, Publication No. MSC-288 (PI-Fisher00003116 - PI-Fisher00003288); United States Department of Agriculture Soil Conservation Service and Forest Service In cooperation with Arkansas Agricultural Experiment Station. 1977. Soil Survey of Benton County, Arkansas; United States Department of Agriculture Soil Conservation Service and Forest Service In cooperation with Arkansas Agricultural Experiment Station. 1969. Soil Survey of Washington County, Arkansas; U.S. Dept. of Agriculture, Soil Conservation Service. 1965. Soil survey, Adair County, Oklahoma; U.S. Dept. of Agriculture, Soil Conservation Service. 1970. Soil survey, Cherokee and Delaware Counties, Oklahoma; United States Department of Agriculture, Natural Resources Conservation Service, in cooperation with the Oklahoma Agricultural Experiment Station and the Oklahoma Conservation Commission. Supplement to the Soil Survey of Adair County, Oklahoma; United States Department of Agriculture, Natural Resources Conservation Service, in cooperation with the Oklahoma Agricultural Experiment Station and the Oklahoma Conservation Commission. Supplement to the Soil Survey of Delaware County, Oklahoma.

112 The eastern portion of the Illinois River Watershed comprises upland soils belonging to hydrologic class "C", and to a lesser areal extent, soils within valley alluvium belonging to hydrologic class "B". The central portion of the Illinois River Watershed is dominated by soils belonging to hydrologic class "B", while the western portion of the Illinois River Watershed comprises soils belonging to hydrologic class "D". The least transmissive layer of soils belonging to hydrologic class "B" have a saturated hydraulic conductivity of between 1.42 – 5.67 in/hour (10-40 mm/s), and thus have much a greater infiltration potential (and, consequently, a much lower runoff potential) than soils in hydrologic class "C" in which the least transmissive layer has a saturated hydraulic conductivity of between 0.14 - 1.42 in/hour (1-10 mm/s) or soils in hydrologic class "D in which the least transmissive layer has a saturated hydraulic conductivity of < 0.14 in/hour (< 1 mm/s). See USDA NRCS 2007. National Engineering Handbook,

Springfield Plateau of the Ozark Uplift is the Boone. The Boone aquifer consists of the Mississippian Keokuk and Reeds Spring formations and the St. Joe Group, commonly called the Boone Chert or Boone Formation. The Boone Formation consists of dense, fine-grained limestone and massive gray chert. Where the chert is fractured, the formations are permeable[113]. The Boone aquifer is absent because of erosion in a few areas in Delaware, Cherokee, and Adair counties, Oklahoma. In these areas the Chattanooga Shale of Devonian age and the Burgen Sandstone, Sylvan Shale, and Cotter Dolomite of Ordovician age are exposed at the surface. The Burgen Sandstone and Cotter Dolomite are part of the underlying Roubidoux aquifer. [114]

The vulnerability of the Boone aquifer within the area of the Illinois River Watershed to pollution from surface-applied contaminants has been addressed in both Oklahoma[115] and Arkansas[116]. The aquifer vulnerability analysis conducted in Oklahoma and in Arkansas considered the same factors: (1) depth to water, (2) net recharge, (3) soil media, (4) topography, (5) vadose zone media; and (6) aquifer hydraulic conductivity.

The depth to water is the distance, in feet, from the ground surface to the water table. It determines the depth of material through which a contaminant must travel before reaching the aquifer. The shallower the water depth, the more vulnerable the aquifer is to pollution.

The primary source of recharge is precipitation, which infiltrates through the ground surface and percolates to the water table. Net recharge is the total quantity of water per unit area,

---

Part 630 Hydrology, Chapter 7. Hydrologic Soil Groups.

113 Imes, J.L., and Emmett, L.F., 1994, Geohydrology of the Ozark Plateaus Aquifer System in Parts of Missouri, Arkansas, Oklahoma, and Kansas: U.S. Geological Survey Professional Paper 1414-D, 127 p.; Marcher, M.V., and Bingham, R.H., 1971, Reconnaissance of the Water Resources of the Tulsa Quadrangle, Northeastern Oklahoma: Oklahoma Geological Survey Hydrologic Atlas 2, 4 sheets, scale 1:250,000.

114 Osborn, N. I. and Hardy, R. H. 1999. Statewide Ground water Vulnerability Map of Oklahoma. Oklahoma Water Resources Board Technical Report 99-1.

115 Osborn, N. I. and Hardy, R. H. 1999. Statewide Ground water Vulnerability Map of Oklahoma. Oklahoma Water Resources Board Technical Report 99-1.

in inches per year, which reaches the water table. Recharge is the principal vehicle for leaching and transporting contaminants to the water table. As recharge rate increases, opportunity for contaminants to reach the water table increases.

Soil media is the upper weathered zone of the earth, which averages a depth of six feet or less from the ground surface. Soil has a significant impact on the amount of recharge that can infiltrate into the ground. In general, the less the clay shrinks and swells and the smaller the grain size of the soil, the less likely contaminants will reach the water table.

Topography refers to the slope of the land surface. Topography helps control the likelihood that a pollutant will run off or remain long enough to infiltrate through the ground surface. Where slopes are low, runoff is small, and the potential for pollution via infiltration is greater. Conversely, where slopes are steep, runoff capacity is high and the potential for pollution to reach ground water via infiltration is lower.

The vadose zone is the unsaturated zone above the water table. The texture of the vadose zone determines the time of travel of the contaminant through it. Coarse textured materials allow, in general, more rapid transport than finely textured materials.

Hydraulic conductivity refers to the rate at which water flows horizontally through an aquifer. Aquifer vulnerability increases with increasing hydraulic conductivity.

In Oklahoma, the Boone was among the four bedrock aquifers considered highly vulnerable to surface contamination because it contains karst features such as caves, sinkholes, and disappearing streams, which provide direct conduits for precipitation and runoff to transport contaminants to the water table.

---

116 The Nature Conservancy, 2007. Karst Area Sensitivity Map for Northwest Arkansas: Benton County. The Nature Conservancy, 2007. Karst Area Sensitivity Map for Northwest Arkansas: Washington County.

Recharge to the Boone hydrogeologic basin is almost entirely from direct infiltration of precipitation. The factors that make the outcrop of the Boone Formation favorable to ground water recharge also make it vulnerable to contamination. Because soil and subsoil in the Ozarks is thin, near-surface faults and fracture systems are common, and dissolution of the carbonate rocks is widespread, precipitation can quickly infiltrate the unsaturated zone.

Based on a review of Oklahoma Water Resources Board and Arkansas Geological Survey well records[117] there are 3,563 ground water wells in the Illinois River Watershed including 1,717 wells in the Oklahoma portion of the Illinois River Watershed. The vast majority of the wells in the Oklahoma portion of the Illinois River Watershed (1,679 of 1,717 wells, or 98%) are registered for "Domestic" use (for drinking and other household purposes), and about 50% of the wells in Oklahoma are shallow (i.e. less than 200' total depth). Based on my experience and observations these domestic wells do not typically employ treatment systems that would eliminate any bacterial hazard. Given the above analysis of the geology and terrain of the Illinois River Watershed, surface water contaminated with land applied poultry waste will readily travel to shallow, and often deep, ground water aquifers.

The analysis conducted for the Arkansas portion of the Illinois River Watershed[118] is more detailed spatially, and predicts that the highest areas of aquifer vulnerability are within fractures, stream courses and on slopes.

Considering the numerous factors in play that permit surface-applied contaminants to enter groundwater, the karst of northwestern Arkansas and northeastern Oklahoma is vulnerable to ground-water contamination because of the unique geology of the region in combination with the large volume of poultry waste spread on pasture land as fertilizer. The waste produced by more than I billion chickens and other poultry, and livestock operations

---

117 Groundwater well completion records for Oklahoma can be downloaded from www.owrb.ok.gov; Arkansas Reports on Water Well Construction (AWC-0001 - AWC-3852).

118 The Nature Conservancy, 2007. Karst Area Sensitivity Map for Northwest Arkansas: Benton County. The Nature Conservancy, 2007. Karst Area Sensitivity Map for Northwest Arkansas: Washington County.

constitutes a threat to ground-water quality because of rapid recharge of ground water through karst features and associated conduit flow of ground water through the bedrock.[119]

21. Constituents of land disposed poultry waste run off fields and surface water and infiltrate through geologic media and contaminate ground water and are poorly attenuated. Poultry waste is disposed on fields within the Illinois River Watershed by simple broadcast spreading. The poultry waste is not mechanically incorporated into soils. As a consequence, both soluble and particulate fractions of this material are readily available for transportation through the agency of rainfall. When rain interacts with poultry waste, some of the material goes into solution. This dissolved material can then travel with the water as it moves downward through the soil and vadose zone to pollute the ground water. Additionally, if sufficient rainfall occurs in a short enough period of time, runoff is produced (i.e. not all of the water can be taken up by the soil and it runs off the field). The dissolved material derived from the poultry waste will also move with the runoff and pollute surface water. Further, this runoff water can also carry particles of poultry waste that will pollute surface water, stream sediments and lake sediments. Because pores can be large in karst, particles can also be transported through the ground water in karst aquifers. Both runoff and ground water eventually end up in surface streams that flow to Lake Tenkiller. Thus pollution of the surface of the ground by the disposal of poultry waste as practiced within the Illinois River Watershed results in the pollution of surface water, ground water, stream sediments and lake sediments.

---

119 Davis, R. K., J. V. Brahana, J. S. Johnson. 2000. Ground water in northwest Arkansas: Minimizing nutrient contamination from non-point sources in karst terrane. Arkansas Soil and Water Conservation Commission, Publication No. MSC-288 (PI-Fisher00003116 - PI-Fisher00003288); Osborn, N. I. and Hardy, R. H. 1999. Statewide Ground water Vulnerability Map of Oklahoma. Oklahoma Water Resources Board Technical Report 99-1; Osborn, N. L. 2001. Minor Basin Hydrogeologic Investigation Report of the Boone Groundwater Basin, Northeastern Oklahoma. Oklahoma Water Resources Board Technical Report GW2001-2. (PI-Fisher00003605 - PI-Fisher00003630).

22. Soils to which poultry waste has been applied within the Illinois River Watershed are contaminated by poultry waste constituents. Composite samples of soils to which poultry waste had been applied were collected at seventy-three (73) locations. Data for all collection depths (0-2", 2-4" and 4-6") for Total P, Total Zn, Total Cu and Total As are shown in Fig 16 Total Zn, Total Cu and Total As all trend upward with increasing Total P, and Total Zn and Total Cu appear well correlated with Total P. The relationships between the concentrations of Total P and Total Zn, Total P and Total Cu, Total P and Total As and Total Cu and Total Zn found in the 0-2" soil samples, and poultry wastes collected from the Illinois River Watershed are shown in Fig 17. The 0-2" interval of soil is the sampled soil depth interval most impacted by broadcast spreading of poultry waste and represents the portion of the soil column most susceptible to erosion. In each of the crossplots, projection of the regression line calculated from the 0-2" soil samples intersects the poultry waste data. This shows that the excess concentrations of P, Zn, Cu and As found in the 0-2" soil samples are from land disposed poultry waste.

23. Runoff water captured in edge of field (EOF) samples within the Illinois River Watershed is contaminated by poultry waste. Shown in Fig 18 are locations where samples of runoff water (edge of field samples) were collected adjacent to sites shortly after poultry waste had been disposed at that site. Examination of the analytical data from these samples shows a high degree of correlation between Total P, Total Zn, Total Cu and Total As (see Fig 19) The relationships between the concentrations of Total P and Total Zn, Total P and Total Cu, Total P and Total As and Total Cu and Total Zn found in edge of field runoff samples (EOF) and poultry wastes collected from the Illinois River Watershed are shown in Fig 20. In each of the crossplots, projection of the regression line calculated from the EOF samples intersects the poultry waste data. This shows that the concentrations of Total P, Total Zn, Total Cu and Total As found in the EOF samples are from land disposed poultry waste.

24. Ground water within the Illinois River Watershed is contaminated by poultry waste. Shown in Fig 21 are ground water collection locations within the Illinois River Watershed. Shown in Fig 22 are the relationships between the concentrations of dissolved phosphorus, dissolved copper, dissolved zinc and dissolved arsenic found in ground water samples and the concentrations of dissolved phosphorus, dissolved copper, dissolved zinc and dissolved arsenic found in edge of field runoff samples (EOF). Dissolved constitutents were used in this analysis because materials in solution rather than materials in suspension are more likely to infiltrate soils and enter ground water.[120] The crossplots of dissolved phosphorous and dissolved zinc dissolved phosphorous and dissolved copper and dissolved zinc and dissolved copper all show that the concentration relationships found for the edge of field samples blend seamlessly with those found in the ground water samples. This is especially pronounced in the crossplot of dissolved copper and dissolved zinc. The crossplot of dissolved phosphorus and dissolved arsenic shows that the concentration of dissolved arsenic is very low in the ground water samples collected, and that the concentration of arsenic in the edge of field runoff samples rapidly decreases with decreasing dissolved phosphorus concentration.

25. Stream Sediments within the Illinois River Watershed are contaminated by poultry waste. Shown in Fig 23 are stream sediment collection locations within the Illinois River Watershed. Shown in Fig 24 are the relationships between the concentrations of total phosphorus, total copper, total zinc and total arsenic found in stream sediment samples and the concentrations of concentrations of total phosphorus, total copper, total zinc and total arsenic found in poultry waste and in the 0-2" interval samples of soil that was uncontaminated by poultry waste. The crossplot of total phosphorus and total zinc shows that, with respect to total phosphorus, total zinc in stream sediments is somewhat enriched compared to poultry waste, but is generally on a mixing trend between uncontaminated soil and poultry waste. The crossplot of total phosphorus and total copper shows that, with

120 Particulate matter can also enter ground water, but is more susceptible to filtering or other types of loss during its passage from the surface to ground water than dissolved materials.

respect to total phosphorus, total copper in stream sediments is somewhat depleted compared to poultry waste, but is generally on a mixing trend between uncontaminated soil and poultry waste. The crossplot of total copper and total zinc shows that, as would be expected from the crossplots of these parameters against total phosphorus, that there is an enrichment in zinc with respect to copper from the e mixing of poultry waste with uncontaminated soil. These trends for total zinc and total copper are reasonable given the greater water solubility of copper compared to that of zinc. The crossplot of total phosphorus and total arsenic shows that, with respect to total phosphorus, total arsenic in stream sediments is substantially enriched compared to poultry waste. This may reflect enhanced transport of arsenic from fields in which poultry waste has been disposed. The overall conclusion that can be drawn from these data is that stream sediments within the Illinois River Watershed are contaminated by poultry waste.

26. Reservoir sediments are important archives of environmental and geomorphic processes occurring within their drainage basins. Reservoirs, such as Lake Tenkiller, are effective traps for incoming sediment.[121] Once materials entering or produced in a reservoir settle to the bottom, energy levels and hydrodynamics are usually insufficient to transport these materials from the reservoir. Because of their sediment trapping ability, reservoirs have the unique capacity for recording variations in sediment loadings and sediment-associated water quality parameters within the drainage basin. Reservoir sediments are derived from both allochthonous (external) and autochthonous (internal) sources. Allochthonous materials are transported by water movements from the reservoir's drainage basin (e.g. eroded soil, particulate pollutants) or fall from the air as particulates (e.g. leaves, dust, etc.). Autochthonous materials are produced within the reservoir and settle from the water column (dead organic matter, chemical precipitates, etc.).[122] Consequently, reservoir sediments record changes in watershed land use, sediment and water quality, pollutant and nutrient loadings, and ecological response in the reservoir's

121 Poff, N. L. and D. D. Hart. 2002. How dams vary and why it matters for the emerging science of dam removal.. Bioscience 52: 659 – 738; McHenry, J.R. 1974. Reservoir sedimentation. Water Resour. Bull. 10:329–337.

water column. [123] Because sediments are important archives of environmental and geomorphic processes occurring within their drainage basins, numerous studies have used dated sediment cores to reconstruct pollution histories reservoirs, as well as lakes, marine coastal embayments and other coastal zones.[124] Poultry waste leaving land disposal sites within the Illinois River Watershed will be transported to and deposited within Lake Tenkiller.

<u>27. Sediment has accumulated in Lake Tenkiller since dam closure.</u> During the period July 13-18, 2005, Global Remote Sensing conducted a shallow sub-bottom acoustic survey of Lake Tenkiller. The purpose of this survey was to determine the distribution of post dam-closure muds (recent fine grained sediments) within the lake. Acoustic data was acquired using an Edgetech Model Xstar system was with a model SB216 towfish (operating frequencies 2 to 16 kHz). The system was controlled using Edgetech's Discover acquisition and control software. Navigation data were acquired with a CSI Wireless Vector Differential Global Positioning System. Navigation and acoustic data were real-time integrated using the Hypack Survey System. The towfish was towed on the port side of the vessel. The data were clean with high signal to noise ratio and had excellent vertical resolution and sufficient sediment penetration. The full extent of the Tenkiller lakebed was

---

122 Wetzel, R. G. 2001. Limnology, 3rd Edition. Academic Press, 1006 p.

123 Foster, I.D.L., and J.A. Lees. 1999. Changes in the physical and geochemical properties of suspended sediment delivered to the headwaters of LOIS river basins over the last 100 years: A preliminary analysis of lake and reservoir bottom sediments. Hydrol. Processes 13:1067–1086; Menounou, N., and B.J. Presley. 2003. Mercury and other trace elements in sediment cores from Central Texas Lakes. Arch. Environ. Contam. Toxicol. 45:11–29; Hambright, K.D., W. Eckert, P.R. Leavitt, and C.L. Schelske. 2004. Effects of historical lake level and land use on sediment and phosphorus accumulation rates in Lake Kinneret. Environ. Sci. Technol. 38:6460–6467; Van Metre, P.C., and B.J. Mahler. 2004. Contaminant trends in reservoir sediment cores as records of influent stream quality. Environ. Sci. Technol. 38:2978–2986; Van Metre, P.C., and B.J. Mahler. 2005. Trends in hydrophobic organic contaminants in urban and reference lake sediments across the United States, 1970–2001. Environ. Sci. Technol. 39:5567–5574; Shotbolt, L.A., A.D. Thomas, and S.M. Hutchinson. 2005. The use of reservoir sediments as environmental archives of catchment inputs and atmospheric pollution. Prog. Phys. Geogr. 29:337–361.

124 Valette-Silver, N. J., 1993. The Use of Sediment Cores to Reconstruct Historical Trends in Contamination of Estuarine and Coastal Sediments. Estuaries Vol. 16, No. 3B, p. 577-588; Van Metre, P.C., Wilson, J.T., Fuller, C.C., Callender, Edward, and Mahler, B.J., 2004, Collection, analysis, and agedating of

mapped. The sonar mapping track lines are shown in Fig 25. The result of Global Remote Sensing's interpretation of the sub-bottom sonar data is presented in Fig 26 as an isopach map of recent fine grained sediment thickness. Fine grain recent sediments (post dam closure muds) vary in thickness within the lake, but tend to be thickest and most continuous within the lacustrine and transition zones of the lake (see Fig 27 where the thickest sediments are typically about 0.5 m (~ 1.6 ft.) thick. The primary purpose of this sediment thickness mapping was to select locations for the collection of sediment cores for chemical and geochronological analysis.

28. Poultry waste constituents have accumulated and are accumulating within the sediments of Lake Tenkiller, and sediment concentrations of phosphorous and other poultry waste constituents within Lake Tenkiller sediments have increased over time. In August 2005, sediment cores were hand-collected using SCUBA from six locations within Lake Tenkiller.[125] The locations for core collection were chosen taking into consideration anticipated sediment thickness based on review of individual data lines from the sub-bottom sonar survey, pre-existing and consistently sampled limnological stations and the limnological zonation of the reservoir.[126] Ultimately a full chemical and geochronological analysis was performed for sediments recovered from four locations (LK-SED01, LKSED02, LK-SED03 and LKSED-04; see Figs 26 and 27). The cores were sectioned into 2-cm intervals and analyzed for numerous chemical parameters.[127] In addition, the sediment sections were analyzed for their content of two radionuclides, lead-210 (^{210}Pb) and cesium-137 (^{137}Cs). The isotope ^{210}Pb is a naturally occurring radionuclide

---

sediment cores from 56 U.S. lakes and reservoirs sampled by the U.S. Geological Survey, 1992–2001: U.S. Geological Survey Scientific Investigations Report 2004–5184, 180 p.

125 Although six locations were cored, only material form four locations was fully analyzed. There was insufficient sediment recovered from one location near the dam (N35.60895 W95.04792) to have adequate temporal resolution. This material was not analyzed. At the riverine location (N35.73920 W94.94655), the pre-reservoir surface could not be reached by the diver, and the recovered sediments appeared to be homogenized; segments of this core were analyzed chemically, but not age dated.

126 Expert Report of G. Dennis Cooke and Eugene Welch, 2008.

127 Sample IDs: LKSED-1-01-01 through LKSED-1-19-01; LKSED-2-01-01 through LKSED-2-01-22; LKSED-3-01-01 through LKSED-3-17-01; LKSED-4-01-01 through LKSED-4-23-01; PI-Fisher00001760

with a half-life of 22.26 years that is produced from the radioactive decay of radium-226 which itself is produced during the radioactive decay of uranium-238 (^{238}U). The source of ^{137}Cs in sediments is atmospheric testing of nuclear weapons and, more recently, from atmospheric releases form the nuclear accident at Chernobyl.

The time at which the sediments within the 2-cm intervals were deposited was determined based on the ^{210}Pb content of the sediment. The ^{210}Pb method of sediment dating is based the amount of "unsupported" ^{210}Pb found in the sediments. Radium-226 (^{226}Ra) in soils decays to radon-222 (^{222}Rn), a gas. Some of the ^{222}Rn gas escapes to the atmosphere where it decays to ^{210}Pb. This ^{210}Pb falls on surfaces within the watershed, is carried to the lake by runoff and eventually becomes incorporated in sediments. This ^{210}Pb is termed "unsupported" ^{210}Pb because it was produced from ^{226}Ra located outside the sediments. Dating by ^{210}Pb relies upon the difference in total ^{210}Pb activity in the sediment and the"supported" ^{210}Pb activity[128] that is produced by ^{226}Ra present within the sediments. The difference between the activity of total ^{210}Pb and the activity of supported ^{210}Pb is the activity of "unsupported" ^{210}Pb that resulted from atmospheric deposition. Both "supported" and "unsupported" ^{210}Pb undergo radioactive decay within the sediments, but the "unsupported" ^{210}Pb is not replenished by ongoing decay of ^{226}Ra, the activity of "unsupported" ^{210}Pb decreases with depth. Provided the input of ^{210}Pb to the reservoir is relatively constant, the residence time of ^{210}Pb is relatively constant, and there is no significant migration within sediments, the age of the sediment at any particular depth can be calculated from the depth distribution of the activity of "unsupported" ^{210}Pb. The short half-life of ^{210}Pb (22.26 years) provides the ability to resolve sediment age precisely.

^{137}Cs can also be used to date sediments, but this radionuclide, in contrast to ^{210}Pb, was

through PI-Fisher00002336; PI-Fisher00001605 through PI-Fisher00001613; also produced as STOK 28872-29424.

128 The activity of a given amount of radioactive material is calculated as the decay constant λ multiplied by the number of radioactive nuclei. The activity, R, of one kilogram of a pure radioactive isotope with the decay constant λ is given by: $R= \lambda$ (N/A), where $N = 6.023x10^{26}$ /kmol is the Avogadro number and A [kg/kmol] is the mass number.

put into the atmosphere in pulses (atmospheric nuclear testing, nuclear reactor accidents). This leads to two limitations. First, using ^{137}Cs permits only average sedimentation rates to be calculated based upon, at best, three dates: (1) the date of first appearance of ^{137}Cs (~ 1953), (2) the date of the ^{137}Cs maximum (~1962), and; (3) the present sediment surface. Second, because it has a pulsed input, interaction between ^{137}Cs and geological, botanical or other features of the watershed leads to a delay in the appearance of ^{137}Cs within reservoir sediments. This is in contrast to ^{210}Pb which has a steady-state rather than a pulsed input to a watershed. As a consequence, any chemical or biological interactions between ^{210}Pb and watershed components will not alter the input of ^{210}Pb to watershed sediments. This contrast between the input signal for ^{210}Pb to sediments and the input signal of ^{137}Cs to sediments results in a circumstance in which concordant ages cannot be obtained for ^{210}Pb and ^{137}Cs methods.

Results of ^{210}Pb and ^{137}Cs analysis are given in Fig 28. These diagrams show that sediments in the recovered cores were undisturbed; the ^{210}Pb data show the anticipated exponential decline from the shallow depths to deeper depths in the cores, and do not show evidence of mixing or loss. Second, as would be anticipated from the consideration of their differing input functions (discussed above), the ^{137}Cs maximum in each core (nominally a 1962 date) is displaced forward in time when compared to the ^{210}Pb dates. Average sedimentation rates obtained for the cores are provided in Table 13 below, and varied between 1.8 cm/yr to 2.69 cm/yr with, as would be expected, a higher sedimentation rate in the transition zone than in the lacustrine zone.

Table 13. Average Sedimentation Rate for Tenkiller Core Sediments	
Core Location	Average Sedimentation Rate (cm/yr)
LKSED-01 @ N35.61875 W95.04932	1.80
LKSED-02 @ N35.66052 W94.99742	2.10
LKSED-03 @ N35.69297 W94.96512	1.90
LKSED-04 @ N35.71482 W94.94637	2.69

Data for the concentrations of total phosphorous (Total P), total copper (Total Cu), total zinc (Total Zn) and total arsenic (Total As) in Tenkiller sediments, are plotted against time of deposition in Fig 29 for all four core locations. Also plotted are the concentrations of phosphorous (Total P), total copper (Total Cu), total zinc (Total Zn) and total arsenic (Total As) in uncontaminated control surface soils.[129] The concentrations of Total P, Total Cu, total Zn and Total As all trend upward over time, and the oldest sediments in the cores trend toward the observed mean values for Total P, Total Cu, total Zn and Total As in the uncontaminated control surface soils. This pattern of temporal concentration increase for Total P, Total Cu, total Zn and Total As observed in the Tenkiller sediments is consistent with the chemistry of poultry feeds and poultry wastes. This association of chemicals shows the influence of poultry waste on Lake Tenkiller sediments from land disposed poultry wastes, and is consistent with the conceptual fate and transport model for poultry wastes. Compounds containing large amounts of Total P, Total Cu, total Zn and Total As compared to surface control soils are added to poultry feed by the Defendants, and Total P, Total Cu, total Zn and Total As are all present in poultry wastes at concentrations far in excess of the Total P, Total Cu, total Zn and Total As concentrations found surface control soils.

129 0-2 " samples from Station IDs: CL-1A, CL-1B, CL-2A, CL-2B, CL-3B, CP-1-A, CP-1-B, CP-2-A.

Data for the concentration of total lead (Total Pb) are plotted against time of deposition in Fig 30. Also shown in Fig 20 are the concentration ranges for Total Pb in surface control soils and in Defendants' contract growers' poultry wastes. Lead is not intentionally added to poultry feed by the Defendants, and in analyses of the Defendants' contract growers waste, when detected, ranged in concentration from 0.61 – 8.49 mg/kg, much lower than the lead concentration found in Tenkiller sediments or in control soils which showed a concentration range for Total Pb of between 9.38 and 17.5 mg/kg. As can be seen in Fig 20, the concentration of Total Pb in Tenkiller sediments increased to a maximum in the early 1980s, then subsequently decreased in concentration. This temporal pattern of Total Pb concentration in Tenkiller sediments is consistent with the history of lead addition to motor gasoline. Under regulations issued by the U. S. Environmental Protection Agency (USEPA), the amount of lead in gasoline was reduced beginning in 1975, and between 1975 and 1982 USEPA calculated a decrease in ambient lead levels of about 64%.[130] This observed temporal concentration pattern for lead in Tenkiller sediments is consistent with a known and well documented trend for anthropogenic input of lead to the environment and provides an additional line of evidence supporting the validity of the core dating.

The basal sediment recovered at LKSED-01 is pre-impoundment Illinois River floodplain sediment. It represents the chemistry of the sediments derived from the erosion of soils within the Illinois River Watershed and transported by the Illinois River in about 1954 and prior to widespread and intensive poultry production within the Illinois River Watershed. Consequently, the chemistry of sediments within Tenkiller, in the absence of intensive poultry production, should be similar to the chemistry of the basal sediment in LKSED-01. As shown in Table 14, when chemistries of soils that have not been impacted by poultry waste application are examined, their chemistry is similar to the chemistry of the basal sediment in LKSED-01. Therefore, poultry waste contaminates Lake Tenkiller sediments.

---

130 Lerwis, J. 1985. Lead Poisoning: A Historical Perspective. EPA Journal (May, 1985), available at http://www.epa.gov/history/topics/perspect/lead.htm.

Table 14
Comparison of Average Total P, Total Cu and Total Zn Concentrations Observed in Control Soil Surface Samples to Average Total P, Total Cu and Total Zn Concentrations Observed in Pre-Dam Closure Illinois River Floodplain Sediment (c. 1954) recovered in the (38-42 cm sample) from Tenkiller Core LAKESED-01.

Material	Total P (mg/kg)	Total Cu (mg/kg)	Total Zn (mg/kg)	Total As (mg/kg)	Total Pb (mg/kg)
Control Soils (0-2 " samples) Control field-Nickel Preserve	391.6	6.25	26.54	2.44	13.79
Pre-Dam Closure Illinois River Floodplain Sediment c. 1954 (38-42 cm sample) LAKESED-01	313.3	3.5	23.5	1.94	9.61

As discussed earlier, compounds containing substantial amounts of phosphorus, copper, zinc and arsenic are added to poultry feed and are present in poultry wastes at levels well in excess of those found in soils.

It should be noted, that an increasing trend in phosphorus content was also shown in the core collected and analyzed by the Oklahoma Water Resources Board Clean Lakes Study, and the levels of total phosphorous found in these 2005 Tenkiller cores are similar to those found in sediments of the same age in the core collected and analyzed by the Oklahoma Water Resources Board Clean Lakes Study.[131] This further validates the sediment analysis in this study.

As shown in Fig 31, the concentrations of Total P, Total Cu, Total Zn and Total As found in Tenkiller sediments are highly correlated with one another. As Total P increases in Tenkiller sediments, Total Cu, Total Zn and Total As also increase. This is consistent with these materials having the same concentrated source (i.e. poultry waste). The relationship among the concentrations of Total P, Total Cu, Total Zn and Total As in

131 Oklahoma Water Resources Board, 1995. Diagnostic and feasibility study on Tenkiller Lake, Oklahoma, Phase 1, Oklahoma Water Resources Board, Oklahoma City, OK.

Tenkiller sediments, the concentrations of these parameters in poultry wastes and the concentrations of these parameters in uncontaminated surface soils is further explored in Fig 32. On this plot, the concentrations of Total P, Total Cu, Total Zn and Total As observed in Tenkiller sediments appear to represent a mixture between sediments derived from uncontaminated surface soils and poultry wastes. Total Zn and Total P appear to behave conservatively relative to a mixture of uncontaminated soils and poultry waste. Total Cu appears to become somewhat depleted in sediments relative to Total P in relative to a mixture of uncontaminated soils and poultry waste. This may reflect the somewhat greater environmental mobility of Cu as compared to Zn.[132] Total As appears to become somewhat enriched in Tenkiller sediments with respect to a mixture of uncontaminated soils and poultry waste.

29. The change in sediment concentrations of and other poultry waste constituents within Lake Tenkiller sediments are directly related to changes in poultry production within the Illinois River Watershed. Concentrations of Total P in Tenkiller sediments from all cores are plotted against year of deposition in Fig 33 as are the populations of total poultry, beef cattle, dairy cattle, swine and humans within the Illinois River Watershed from the data presented in the phosphorus mass balance study.[133] The animal and human population data are given in units of biomass (animal units).[134] The use of animal units places all of the animal populations on a common scale relevant to phosphorus excretion. The concentration of total phosphorus in the dated sediments increases from 313 mg/kg in pre-impoundment sediment to 1,495 mg/kg in the youngest sediment recovered by LKSED-01 (a factor of 4.8). The overall functional form and slope of the sediment total phosphorus concentration is more concordant with the overall functional form and slope of the total poultry population than it is to the overall form and slope of the populations of beef cattle, dairy cattle, swine or humans. Secondly, combining the curves for beef cattle, dairy cattle, swine or humans would not change the functional form or slope of the graph of non-

132 Kabala, C. and Singh, B. R. 2001. Fractionation and Mobility of Copper, Lead, and Zinc in Soil Profiles in the Vicinity of a Copper Smelter. J. Environ. Qual. 30:485–492.
133 Expert Report of Bernie Engle, 2008.

poultry animal population from that of beef cattle. Between 1954 and 2002 the number of animal units attributable to poultry increases from 59,587 to 850,201, a factor of 14.27 whereas beef cattle increase form 19,108 animal units to 97,616 animal units, a factor of 5.44; diary cattle show an overall decrease of nearly threefold from 41,081 animal units to 14,135 animal units, and swine show an increase from 5,934 animal units to 32,278 animal units, a factor of 5.11. The pattern and scale of the poultry population increase within the Illinois River Watershed provides a better explanation of the increase in sediment Total P in Lake Tenkiller than humans, beef cattle, dairy cattle, swine, or any combination of humans and non-poultry animals. Moreover, beef cattle have only a minor role in phosphorous mass balance, and were, in fact, not considered in a recent extensive study of nutrient mass balance in agricultural soils in Arkansas because,

> "Nutrients contained in beef cattle manure were ignored in nutrient source estimates since a large proportion of these nutrients are obtained from the forage average and deposited directly (i.e., recycled) to pastures during grazing rather than collected in lagoons or stockpiled from confined animal production facilities."[135]

134 An animal unit, or AU, is 1000 pounds of live animal weight.

135 Slaton, N. A. Brye, K. R., Daniels, M. B., Daniel, T. C., Norman, R. J. and Miller, D. M. 2004. Nutrient Input and Removal Trends for Agricultural Soils in Nine Geographic Regions in Arkansas. J. Environ. Qual. 33:1606–1615.

Billing Rate

My billing rate for work in this matter is $220/hr.

Signature

I reserve the right to supplement, modify and amend this opinion based on discovery of any new facts or data, reinterpretation of any existing or new facts or data, or to rebut opinions or evidence provided by other experts in this matter.

J. Berton Fisher, Ph.D.

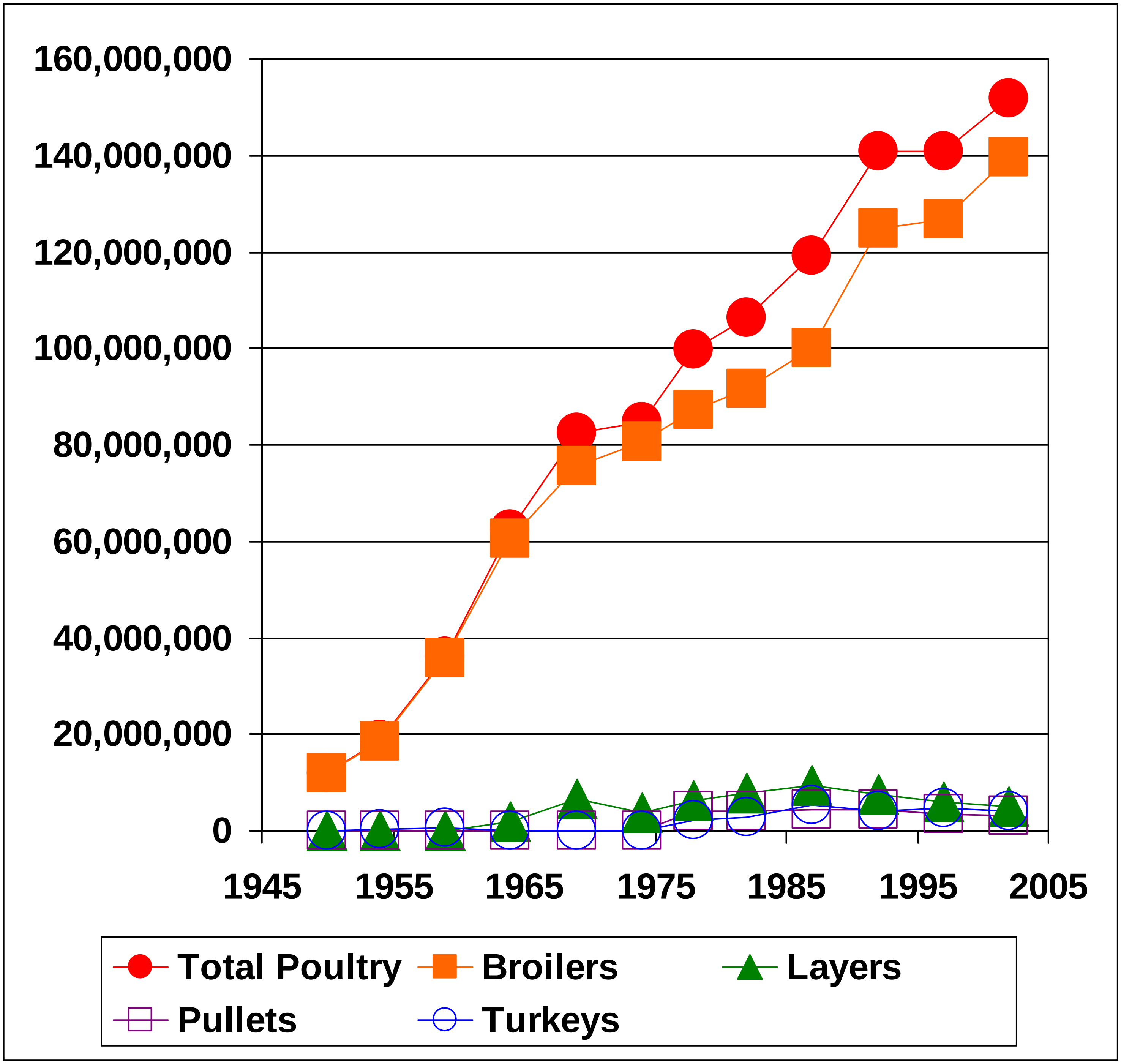


Figure 1. Poultry production within the Illinois River Watershed 1949/1950 – 2002 determined from USDA agricultural census data and land use/land cover data.

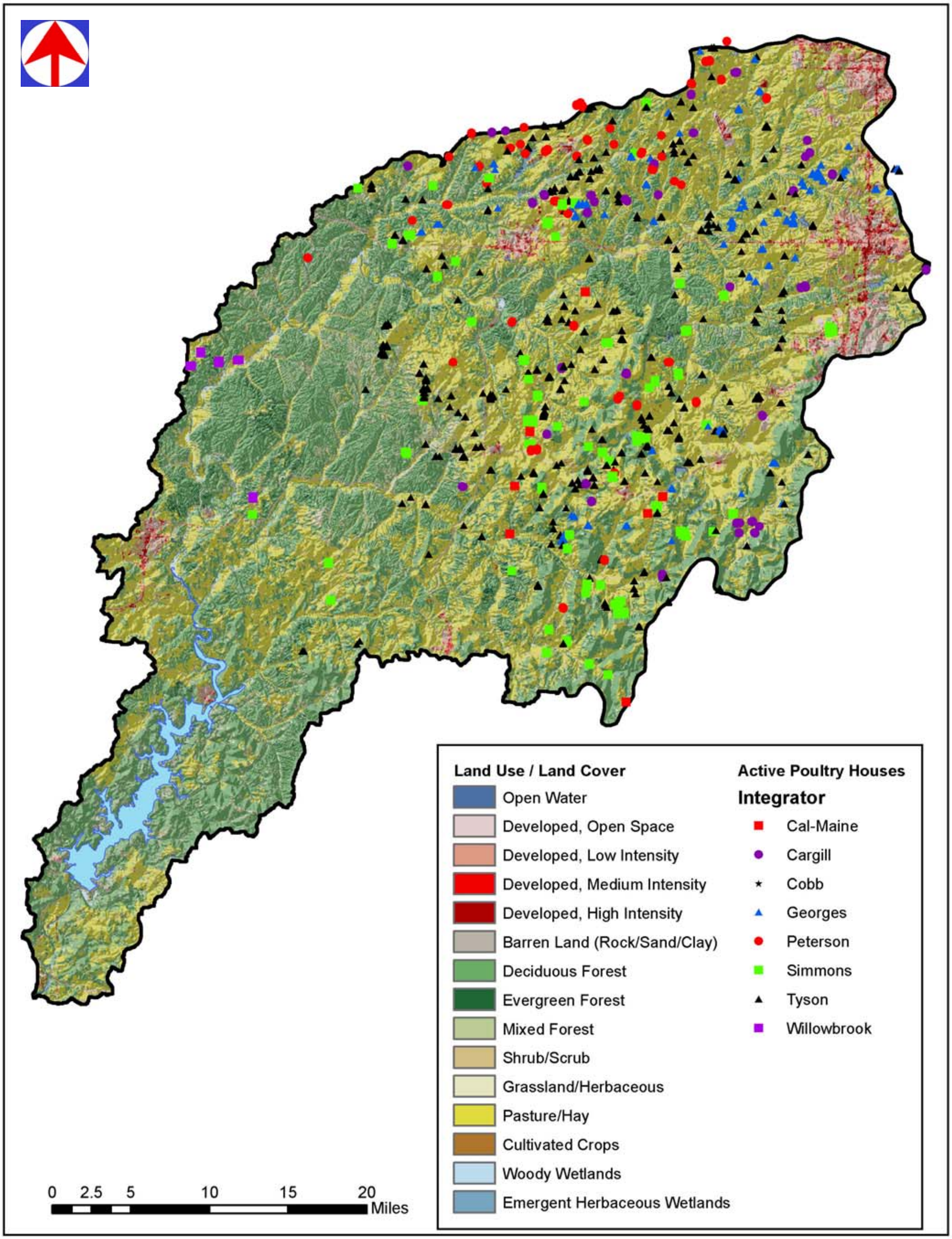
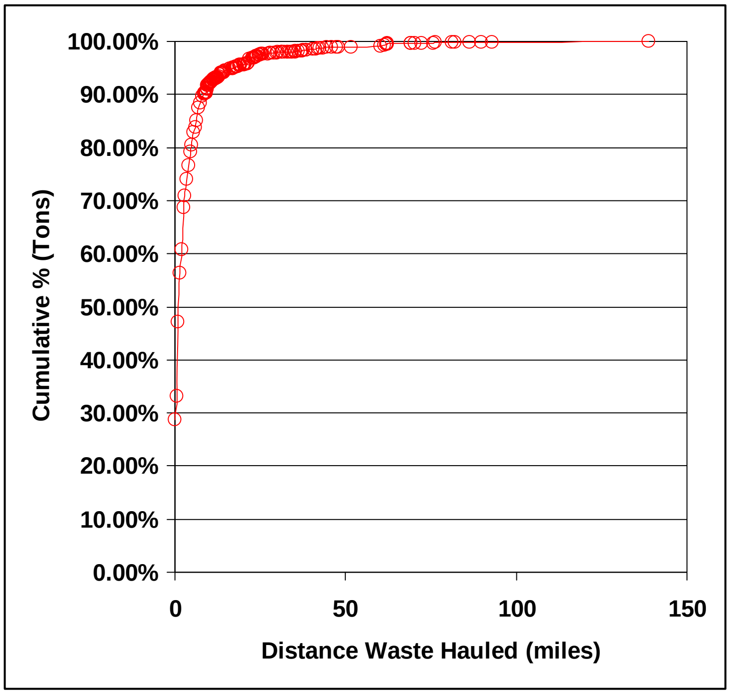


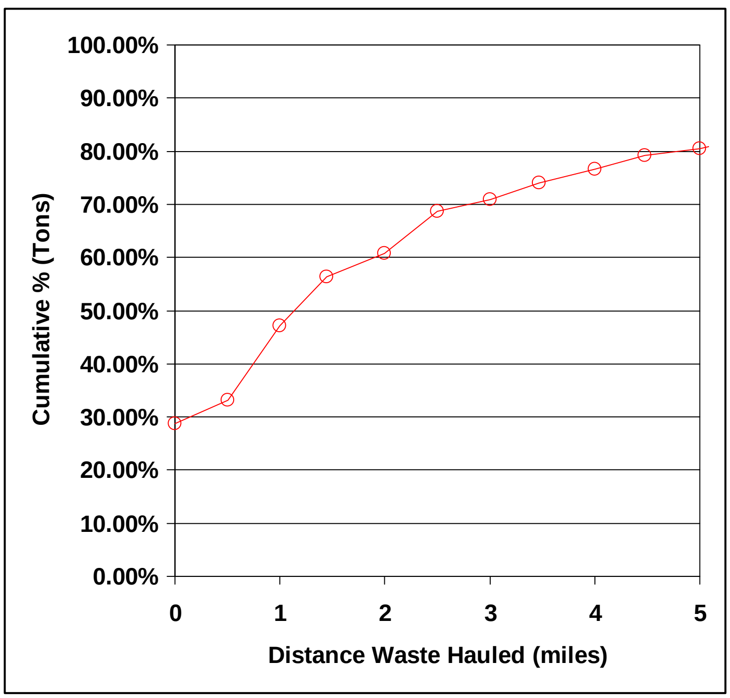
Figure 2. Locations of active poultry houses with identified integrators in the Illinois River Watershed.

OK-PL-0008526

Figure 3. Disposal of poultry waste from Peterson Circle Farms by land application taken from N36.25636 W94.51073 on May 5, 2005
(Investigator Notebook OK-PL-0004948)

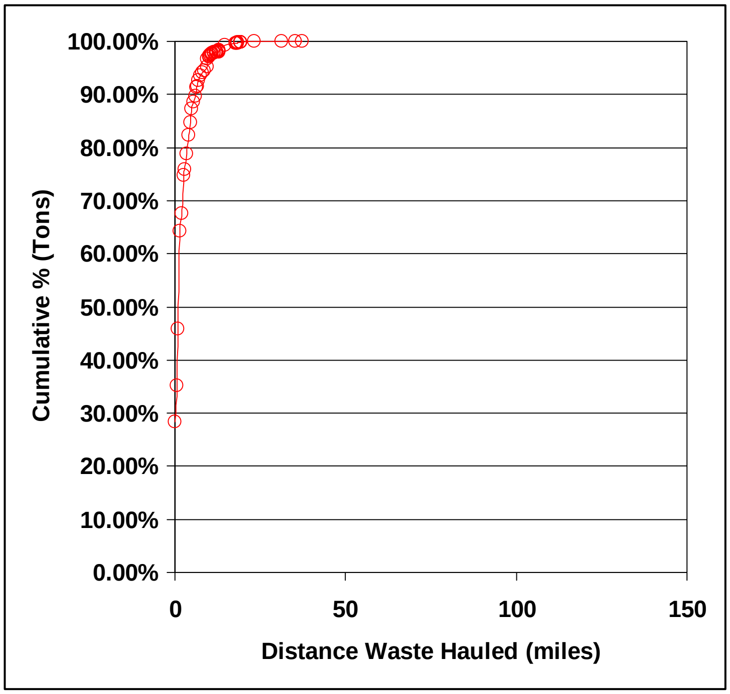


All Data for Land Disposal Of Poultry Waste In Oklahoma

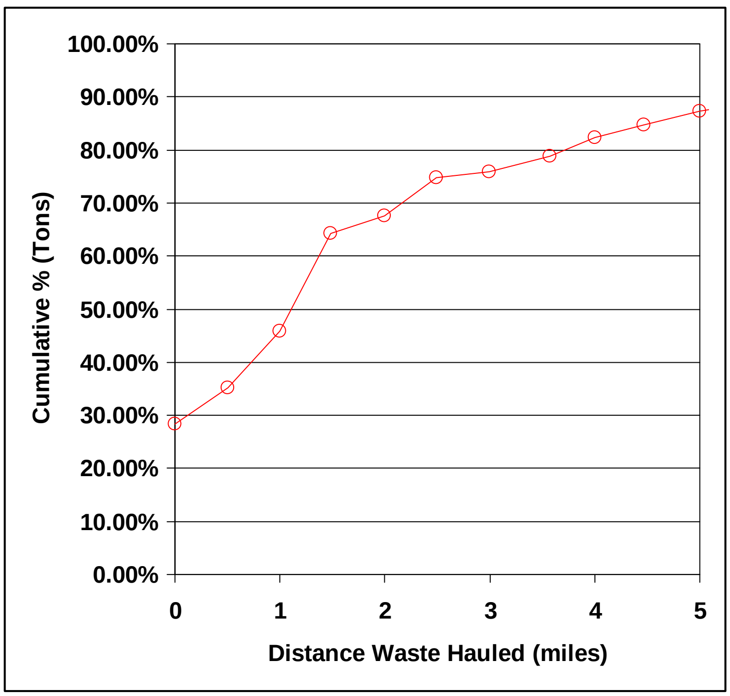


80% of waste disposed within < 5 miles

Figure 4. Cumulative frequency plot of the distances between the location of poultry waste production and the location of poultry waste disposal in Oklahoma based on records maintained by the Oklahoma Department of Agriculture Food and Forestry



Data for Land Disposal Of Poultry Waste Originating Entirely Within the Oklahoma Portion of the Illinois River Watershed



80% of waste disposed within < 4 miles

Figure 5. Cumulative frequency plot of the distances between the location of poultry waste production and the location of poultry waste disposal for wastes originating within the Illinois River Watershed in Oklahoma based on records maintained by the Oklahoma Department of Agriculture Food and Forestry

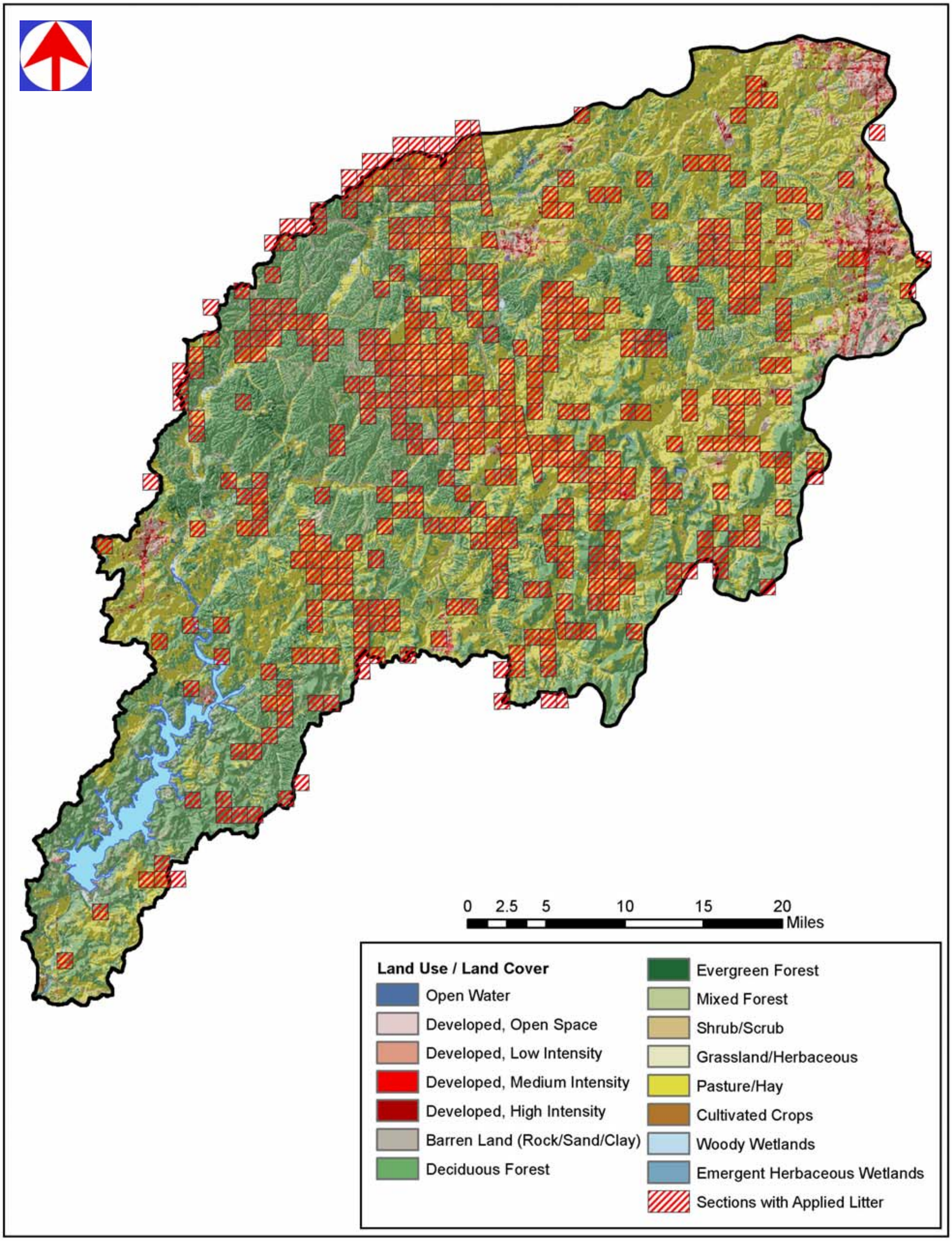


Figure 6. Public land survey sections in which poultry waste has been disposed within the Illinois River Watershed based on records maintained by the Oklahoma Department of Agriculture, Food and Forestry, investigator reports and Defendants' documents.

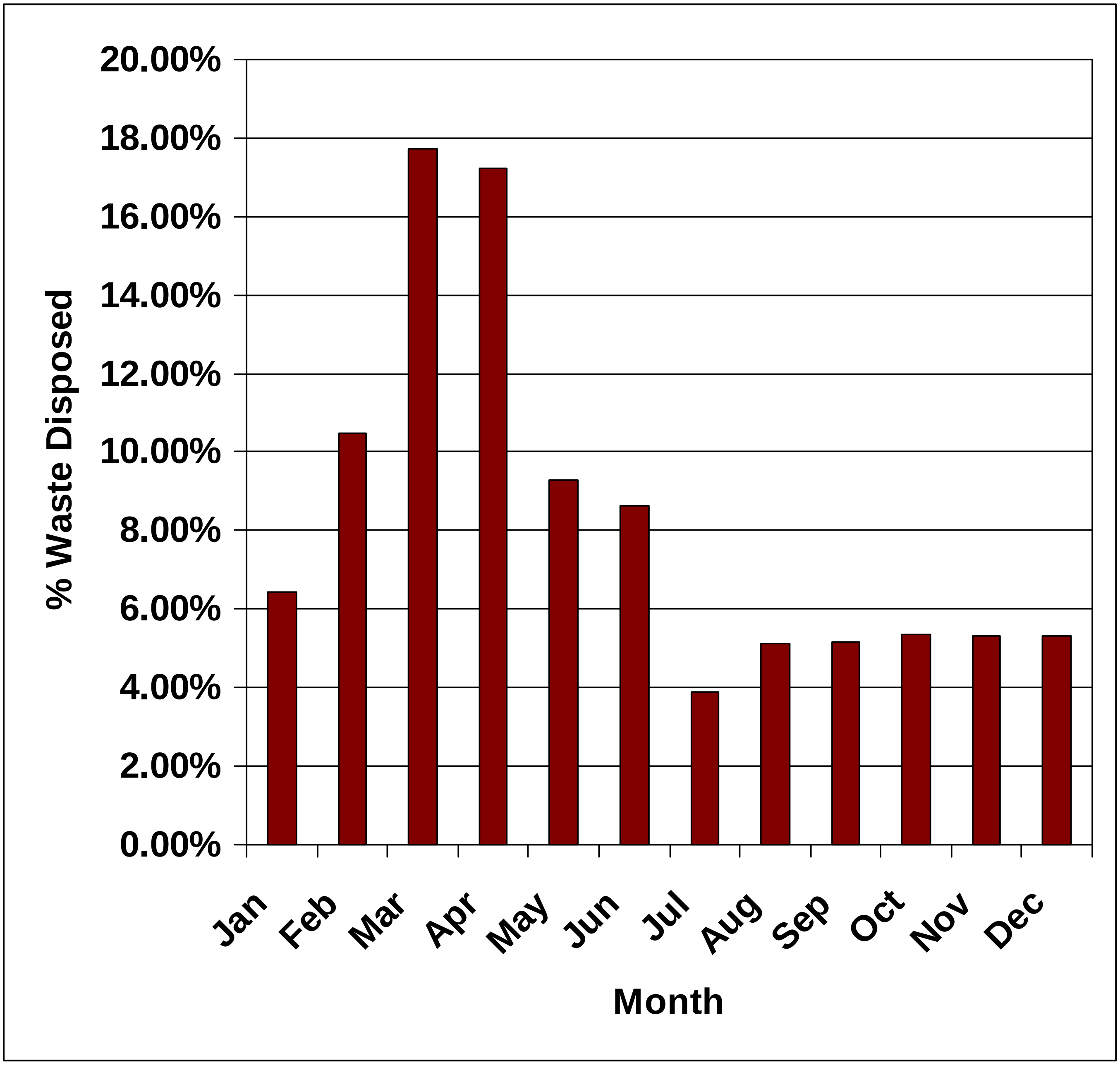


Figure 7. Timing of poultry waste disposal within the Oklahoma portion of the Illinois River Watershed determined from records maintained by the Oklahoma Department of Agriculture Food and Forestry (1999-2004 data).

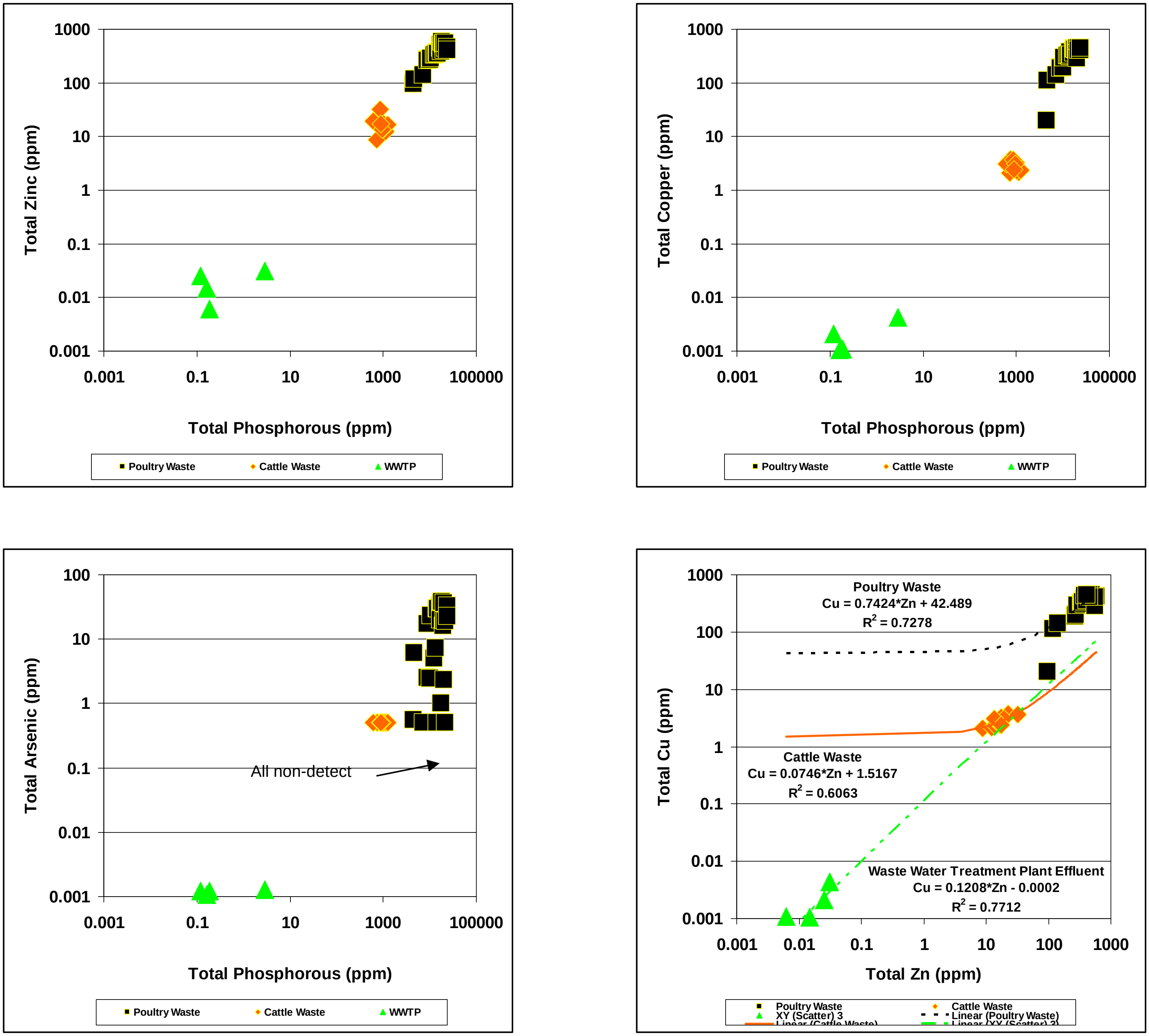


Figure 8. Relationship between the concentrations of total phosphorus, total copper, total zinc and total arsenic found in poultry waste, cattle waste and unfiltered wastewater treatment plant effluent.

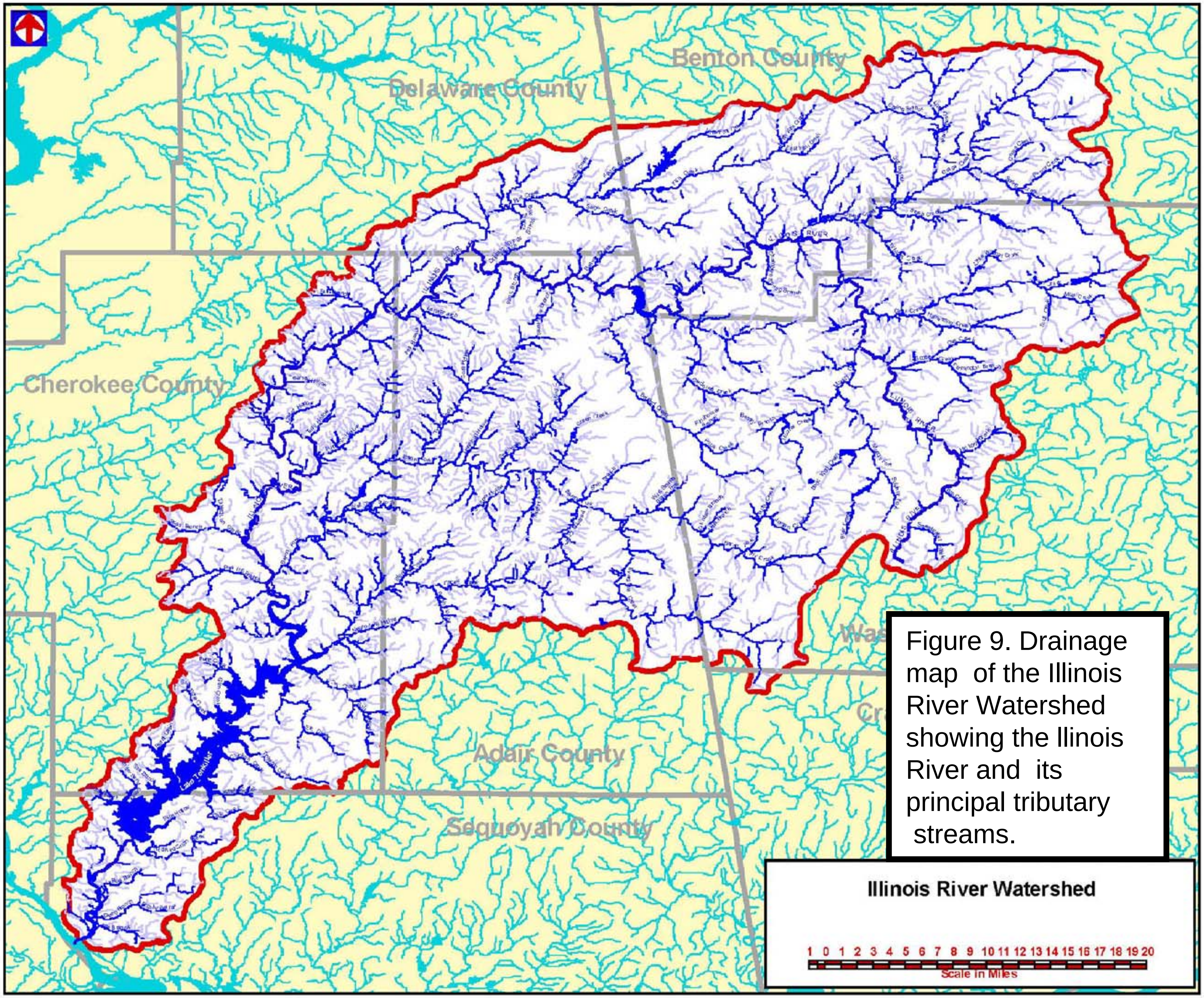


Figure 9. Drainage map of the Illinois River Watershed showing the llinois River and its principal tributary streams.

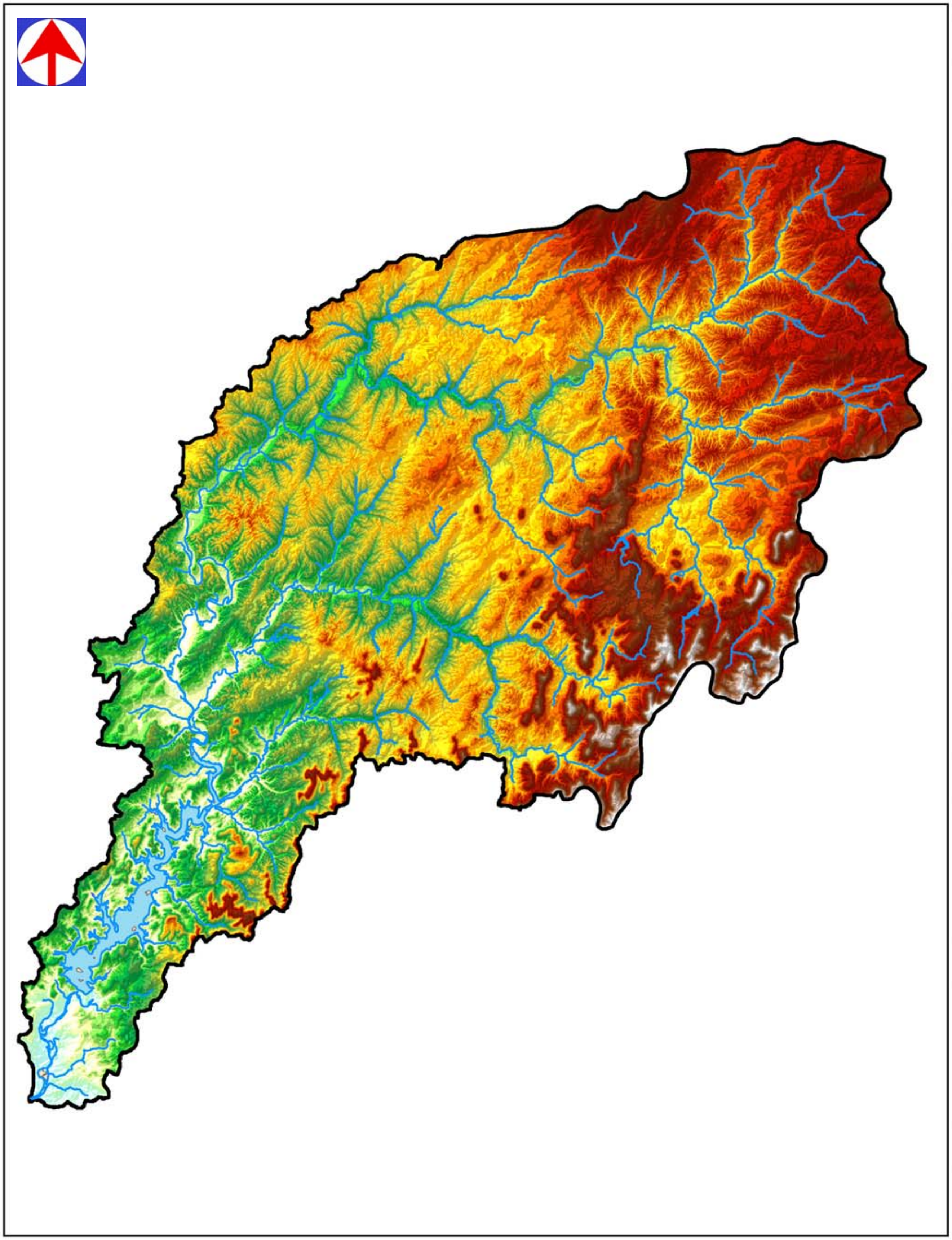


Figure 10. Digital elevation map of the Illinois River Watershed.

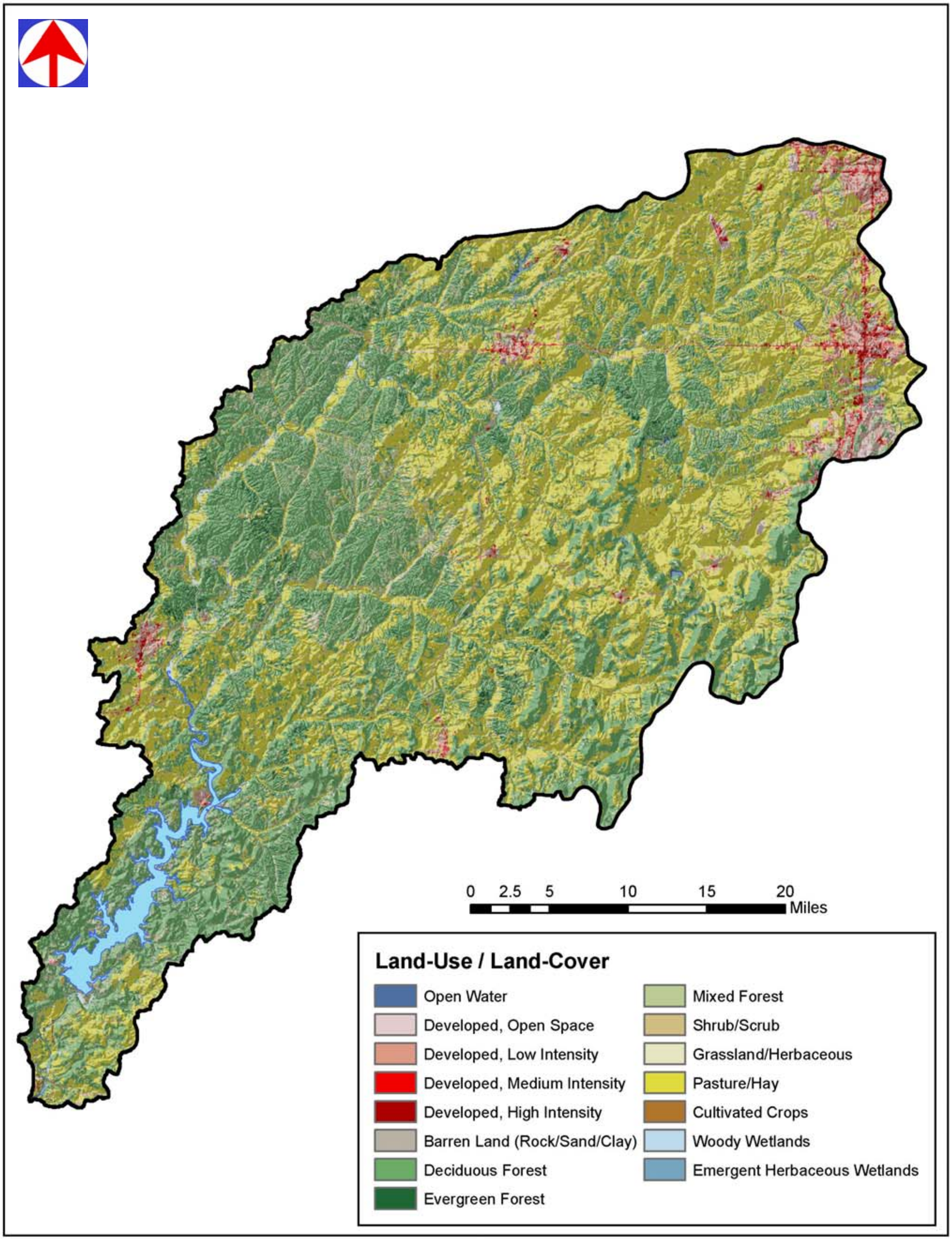


Figure 11. Land Use / Land Cover in the Illinois River Watershed

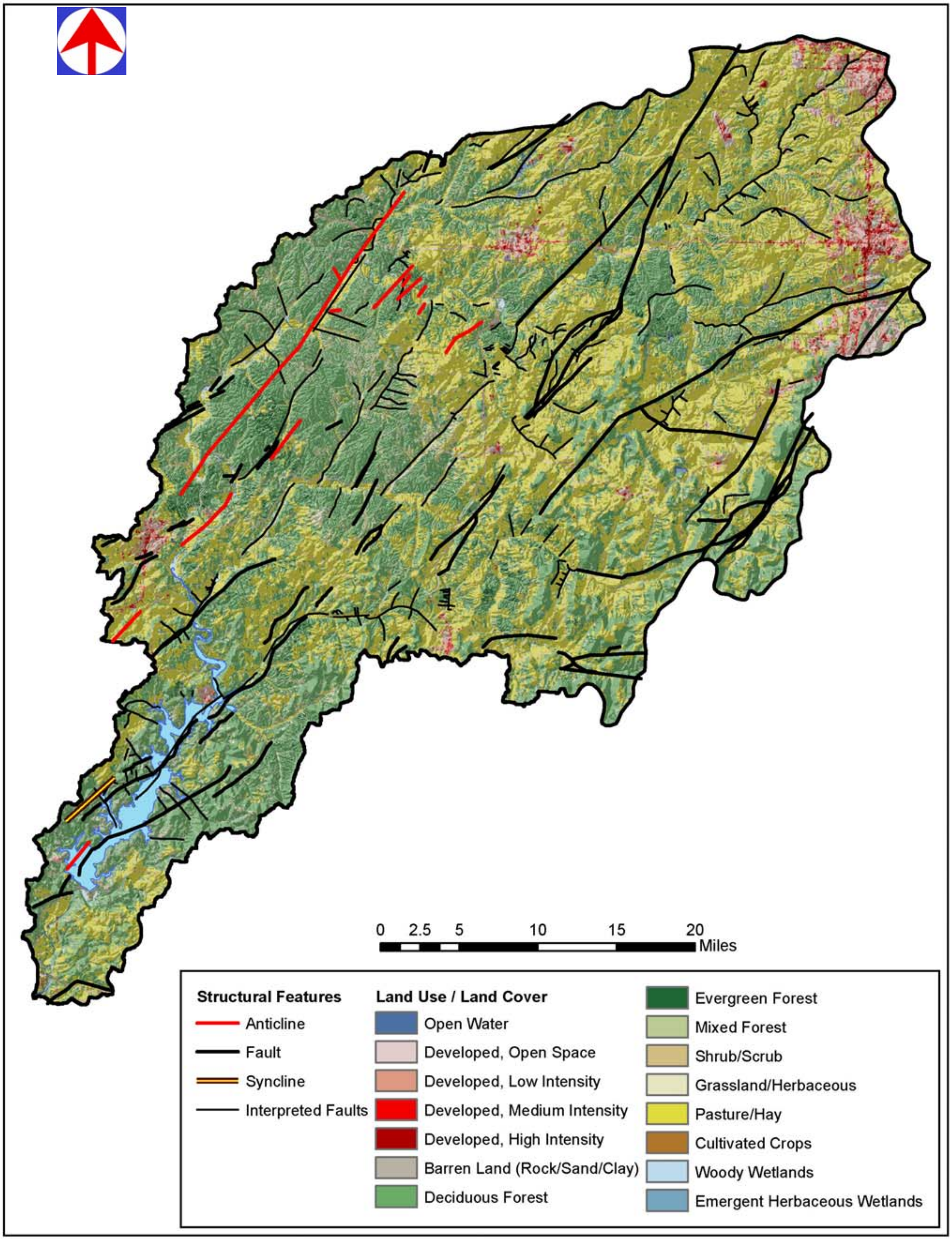


Figure 12. Major faults and structural features in the Illinois River Watershed

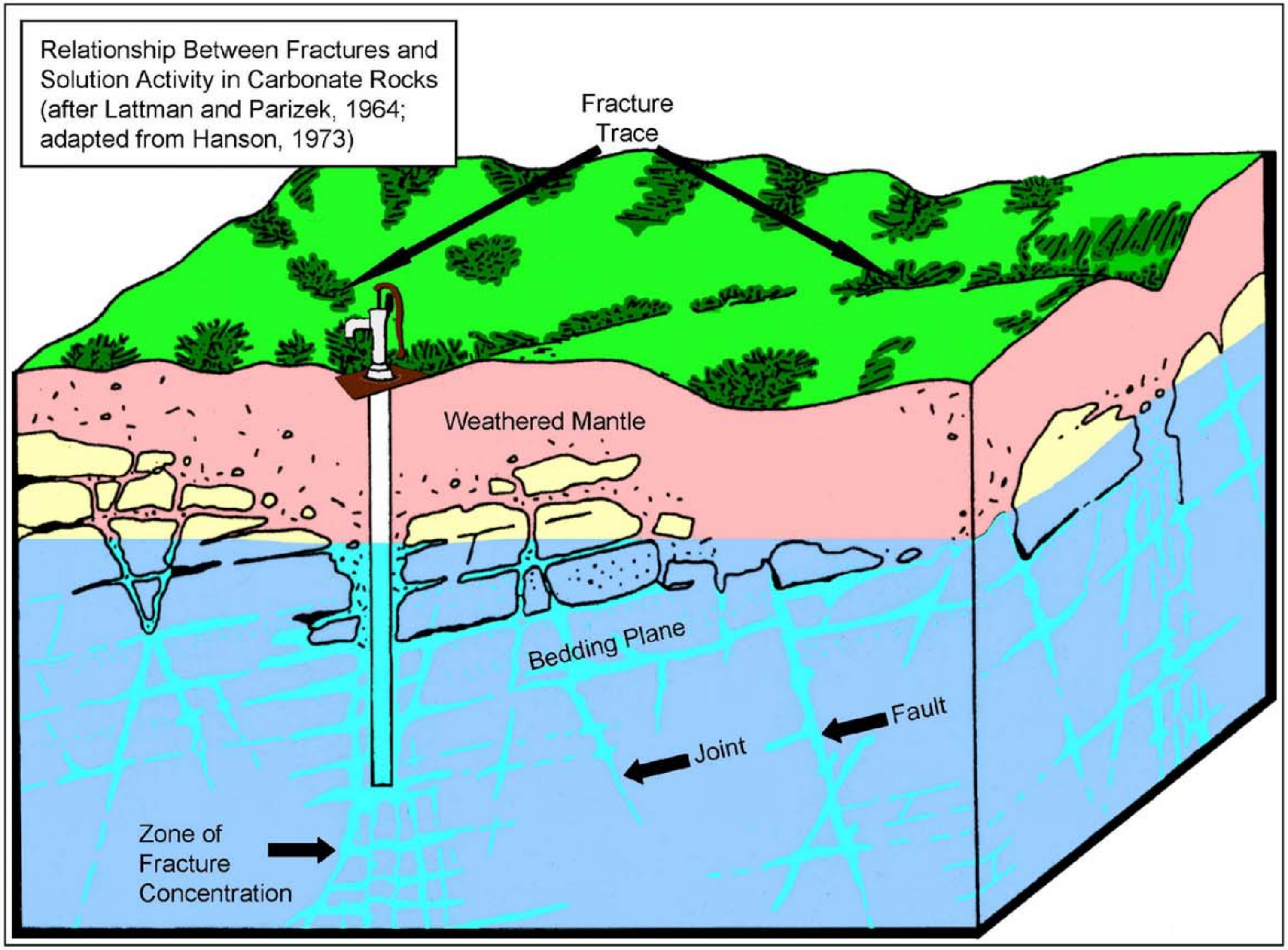


Figure 13. Relationship between fractures and solution activity in carbonate rocks.

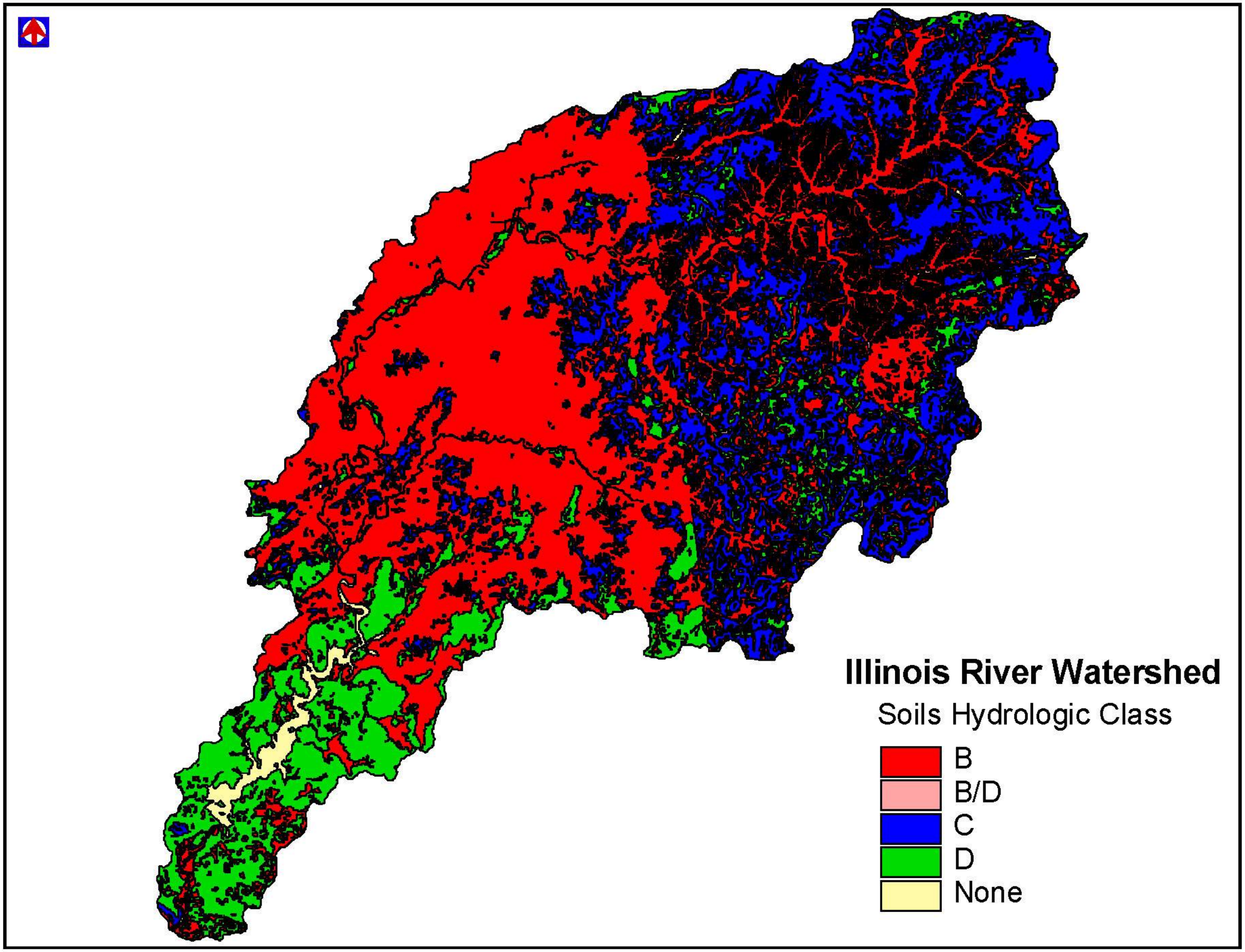


Figure 14. Hydraulic properties of soils within the Illinois River Watershed

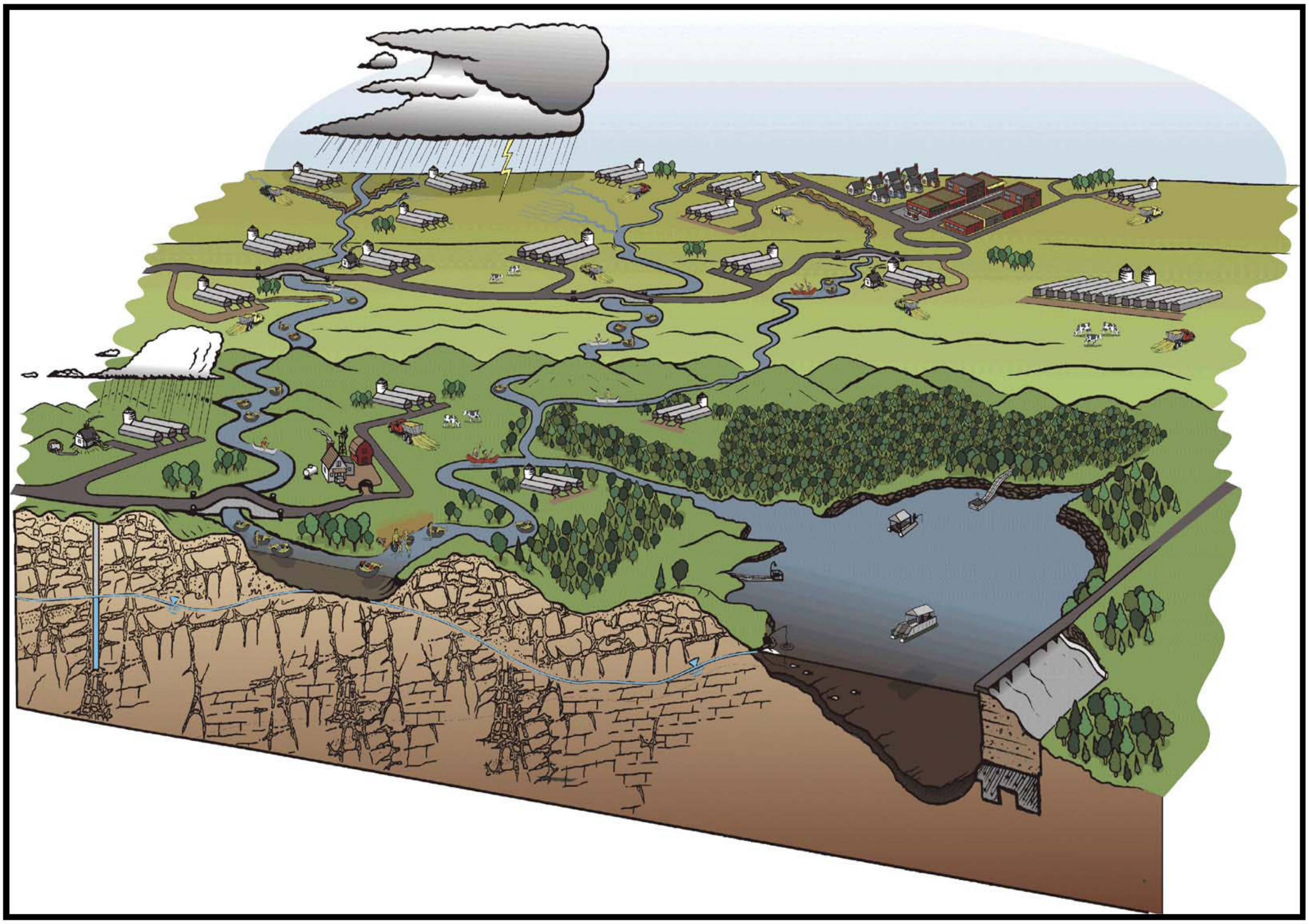


Figure 15. Site Conceptual Model for the Illinois River Watershed

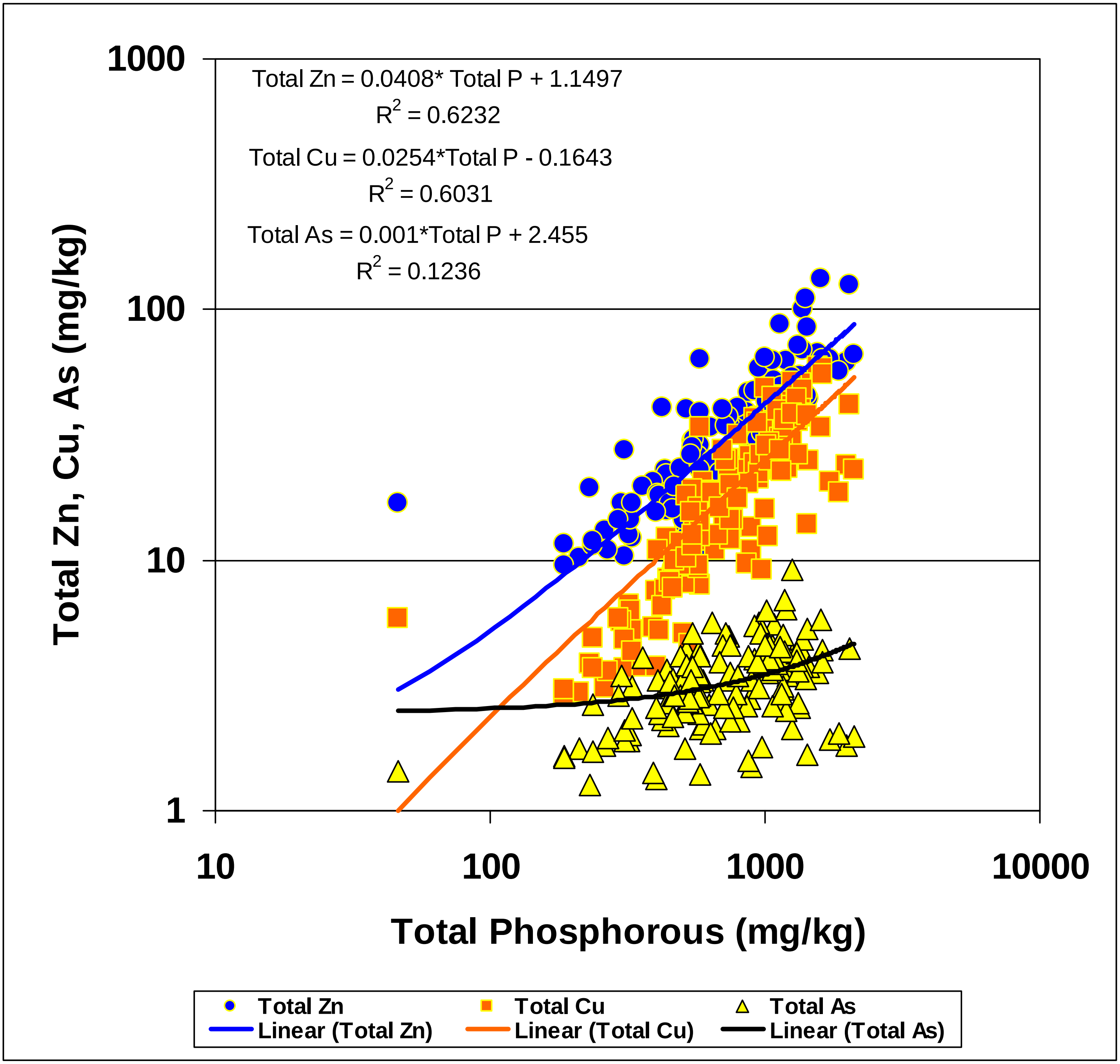
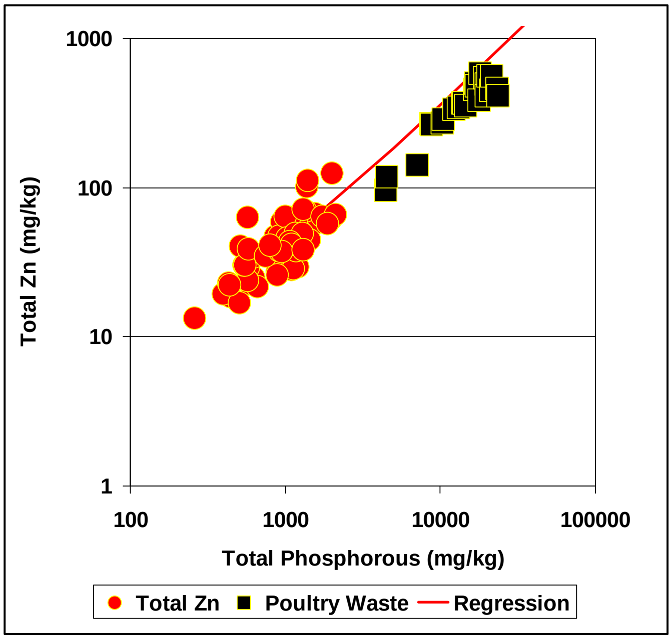
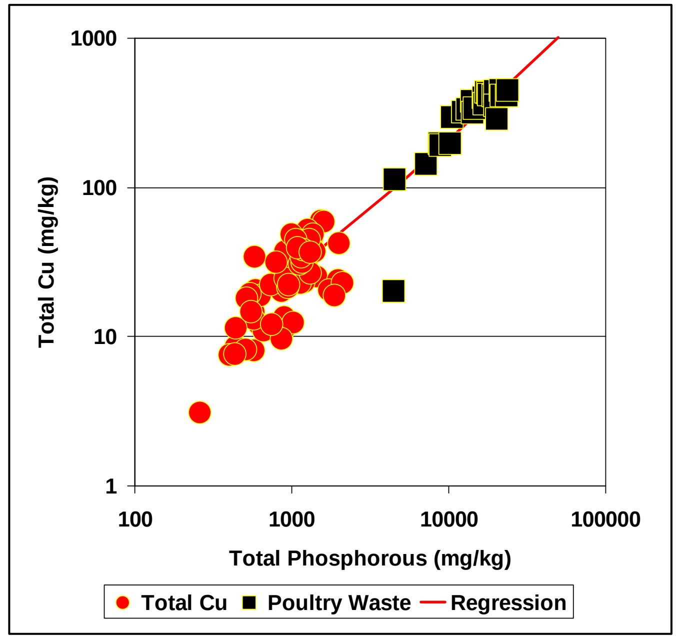


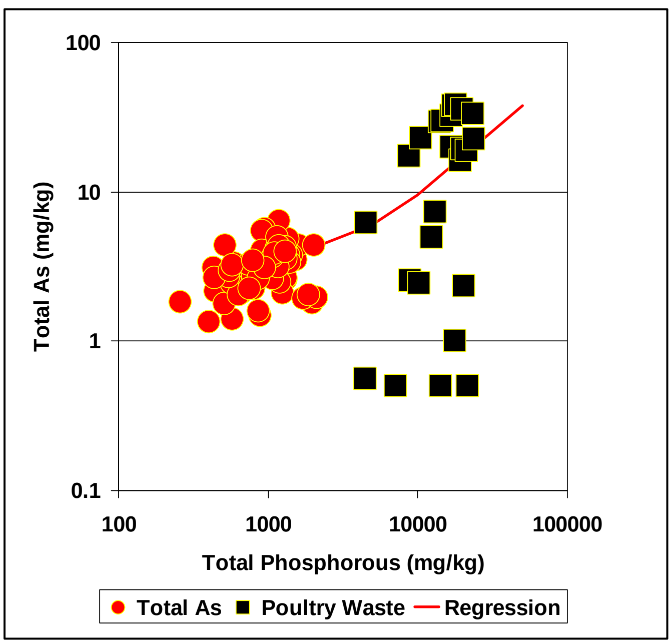
Figure 16. Total Zn, Total Cu and Total As in composited soil samples from litter application location (LAL) soils plotted against Total P (All collection depths: 0-2"; 2-4"; 4-6").



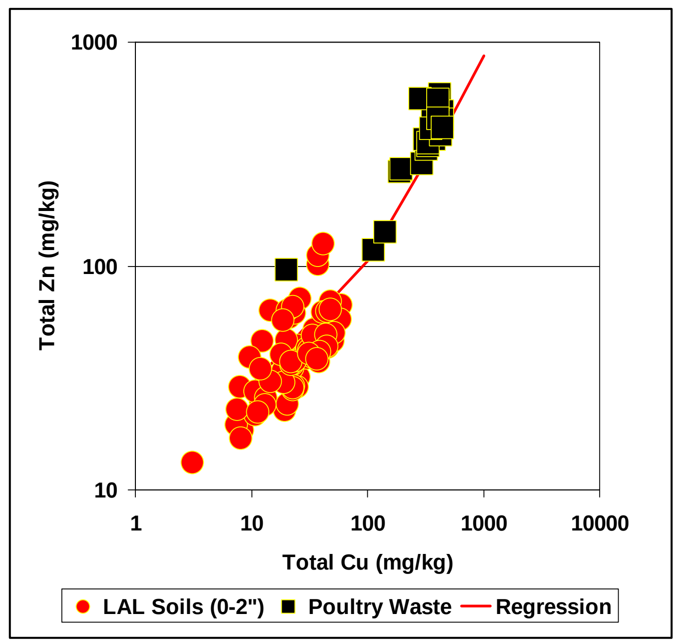
Regression: Total Zn = 0.0351*Total P + 8.030



Regression: Total Cu = 0.0202*Total P + 6.728



Regression: Total As = 0.0007*Total P + 2.523



Regression: Total Zn = 0.846*Total Cu + 20.994

Figure 17. Relationship between the concentrations of total phosphorus, total copper, total zinc and total arsenic found in litter application location (LAL) soil samples (0-2" collection depth) and poultry waste.

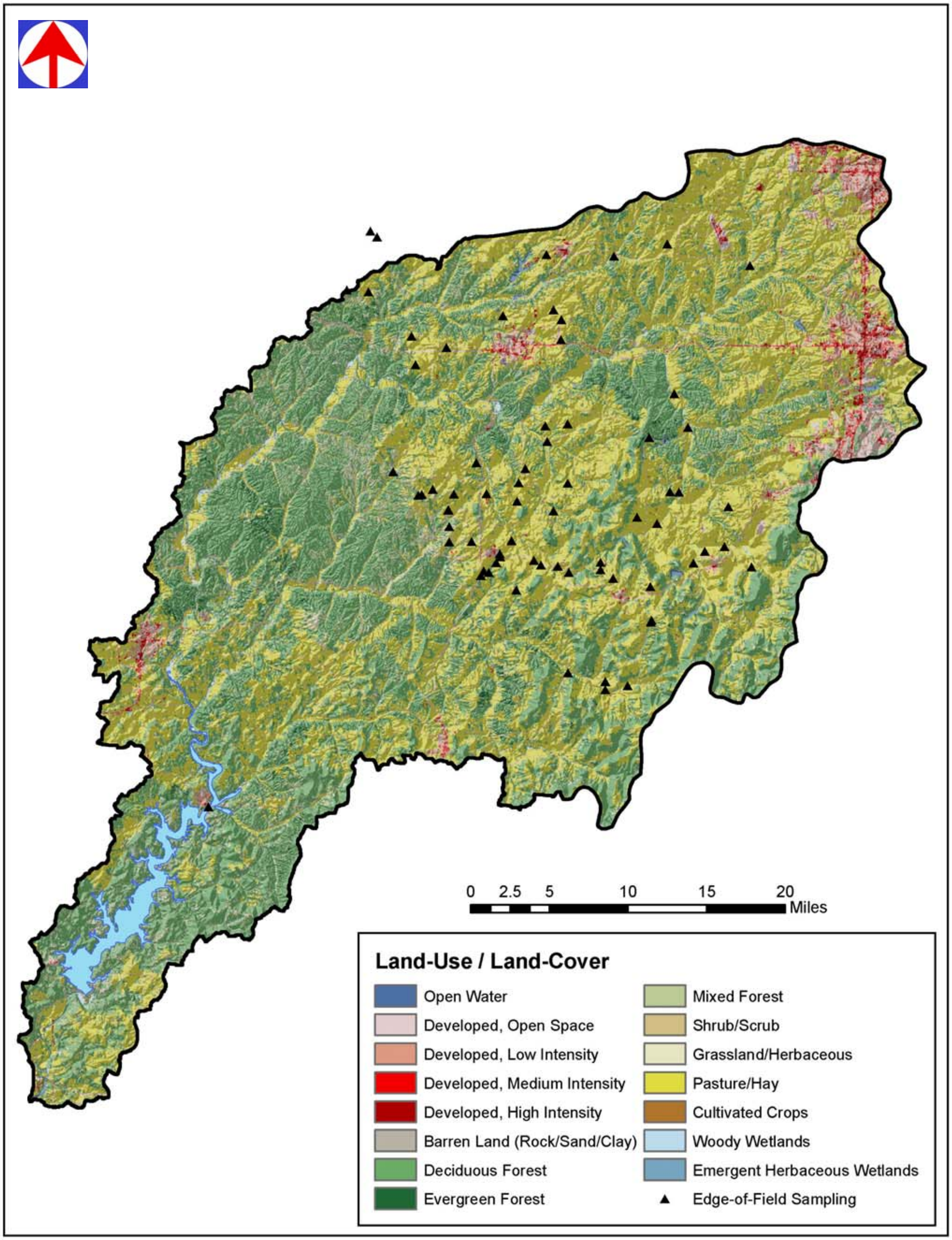


Figure 18. Locations where runoff water (edge of field samples) was collected adjacent to poultry waste disposal sites within the Illinois River Watershed.

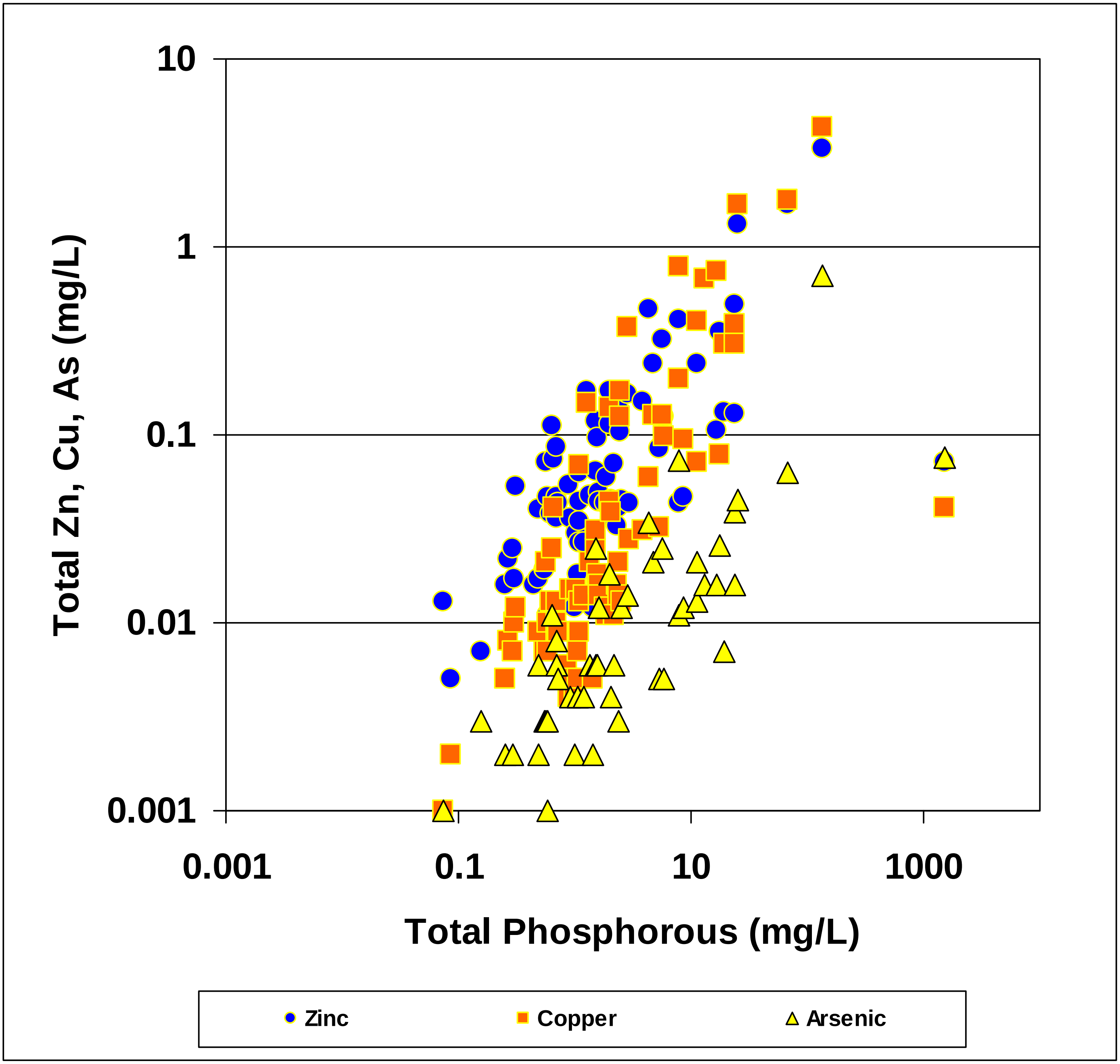
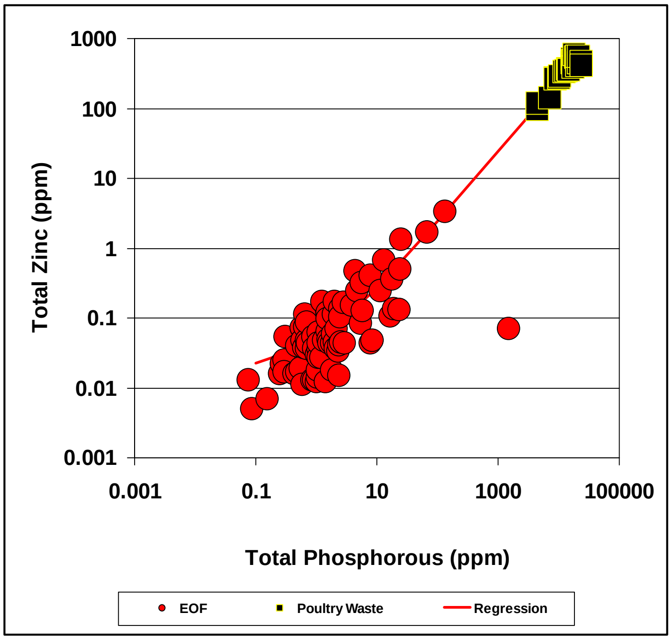
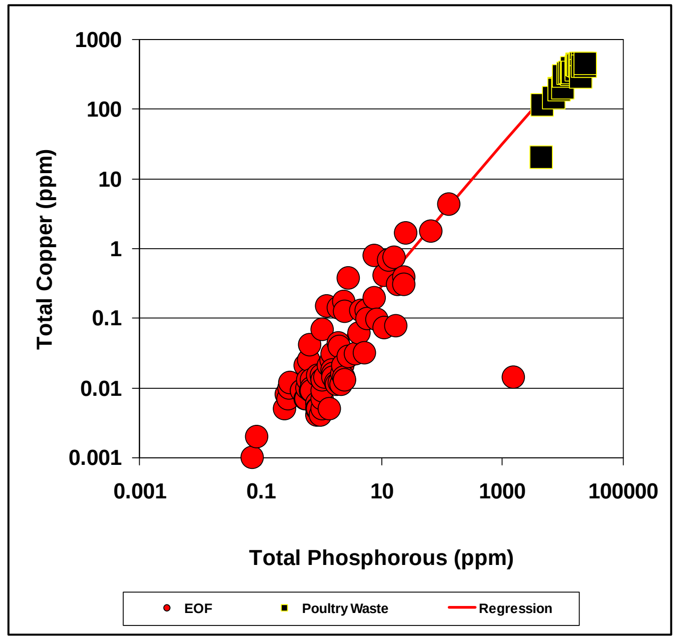


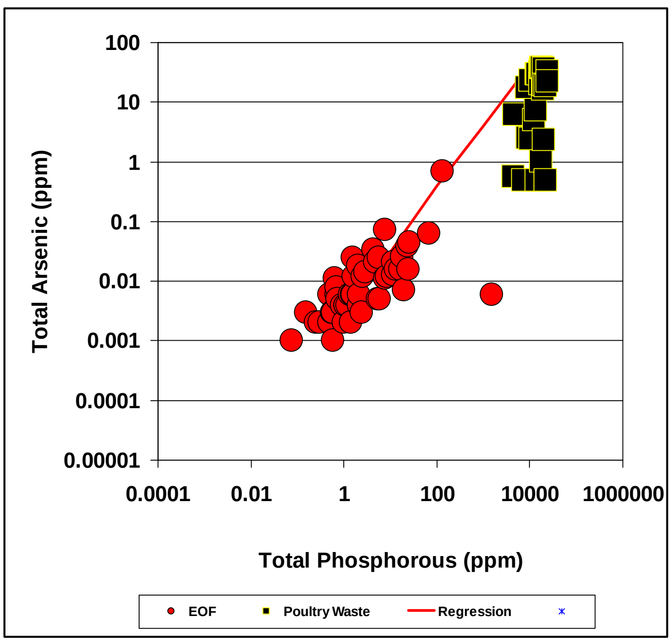
Figure 19. Total Zn, Total Cu and Total As in edge of field runoff samples plotted against phosphorous concentration.



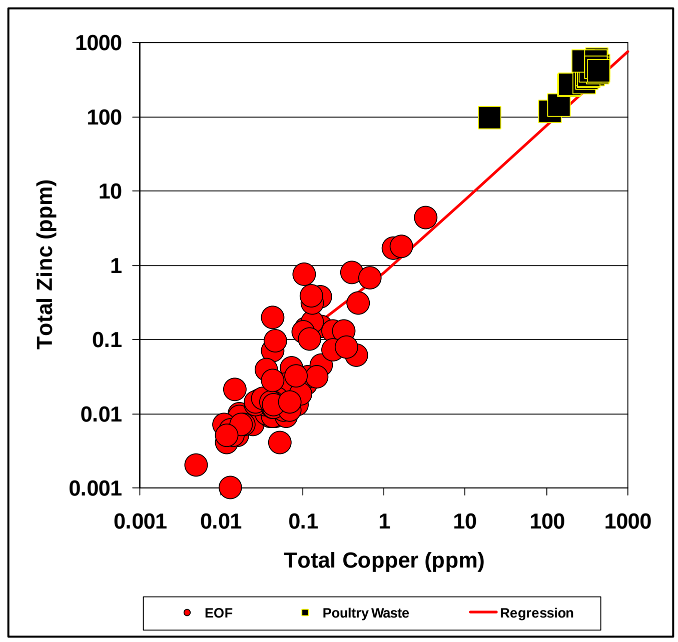
Regression: Total Zn = 0.0246*Total P + 0.0204



Regression: Total Cu = 0.0313*Total P - 0.0156



Regression: Total As = 0.0041*Total P + 0.0104



Regression: Total Zn = 0.759*Total Cu + 0.0387

Figure 20. Relationship between the concentrations of total phosphorus, total copper, total zinc and total arsenic found in edge of field runoff samples (EOF) and poultry waste.

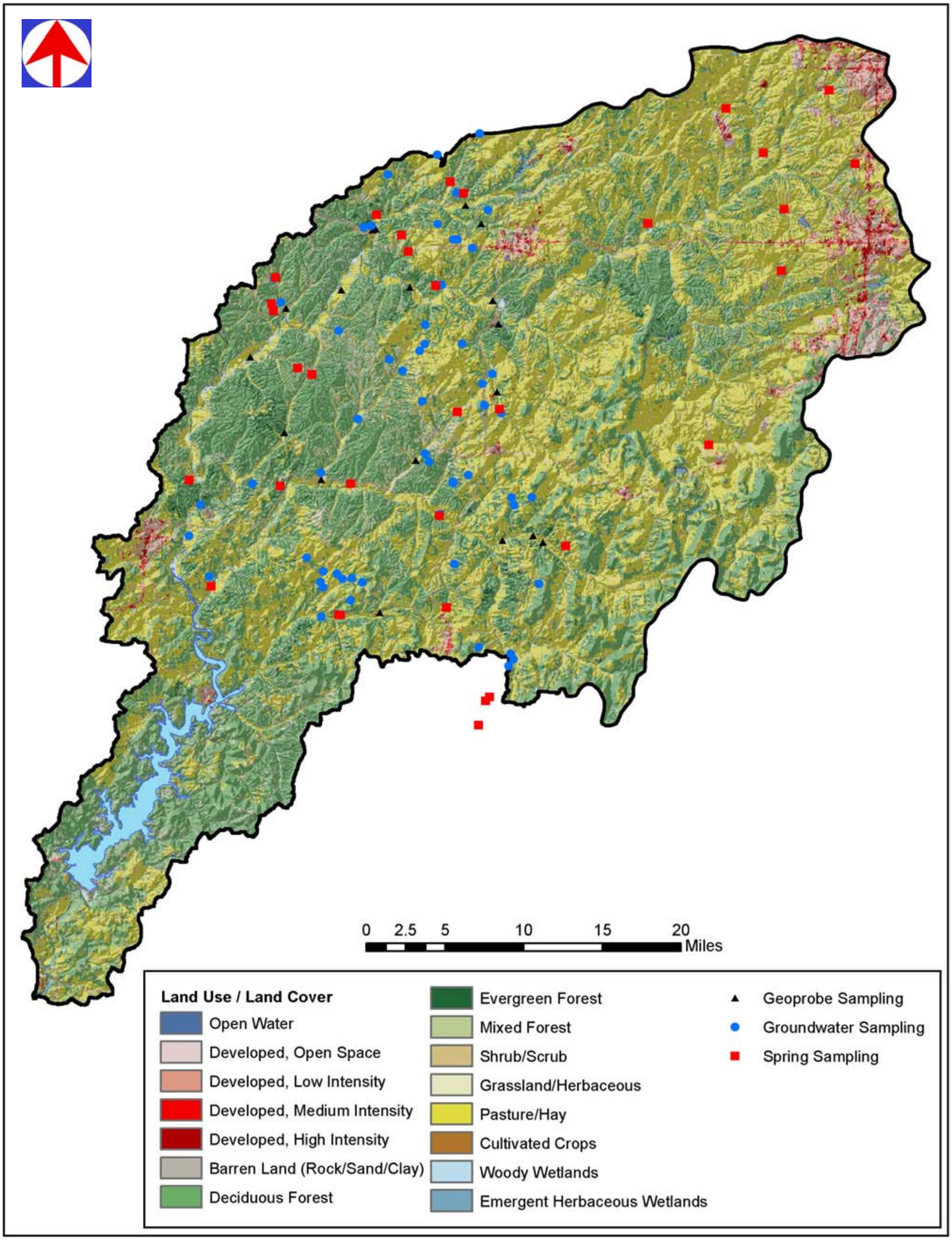


Figure 21. Groundwater collection locations within the Illinois River Watershed showing type of groundwater collection.

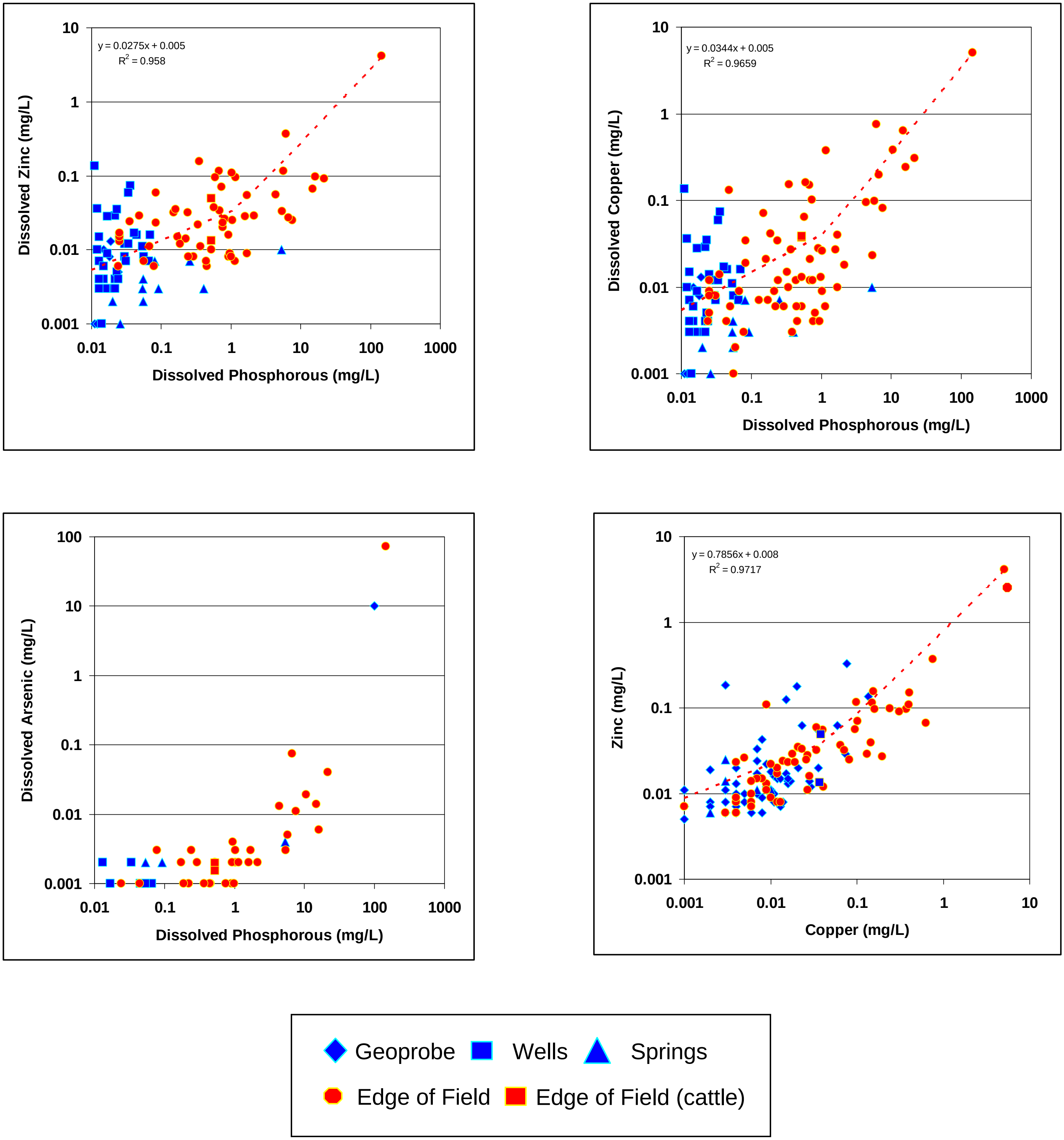


Figure 22. Relationship between the concentrations of dissolved phosphorus, dissolved copper, dissolved zinc and dissolved arsenic found in groundwater samples and dissolved phosphorus, dissolved copper, dissolved zinc and dissolved arsenic found in edge of field runoff samples (EOF).

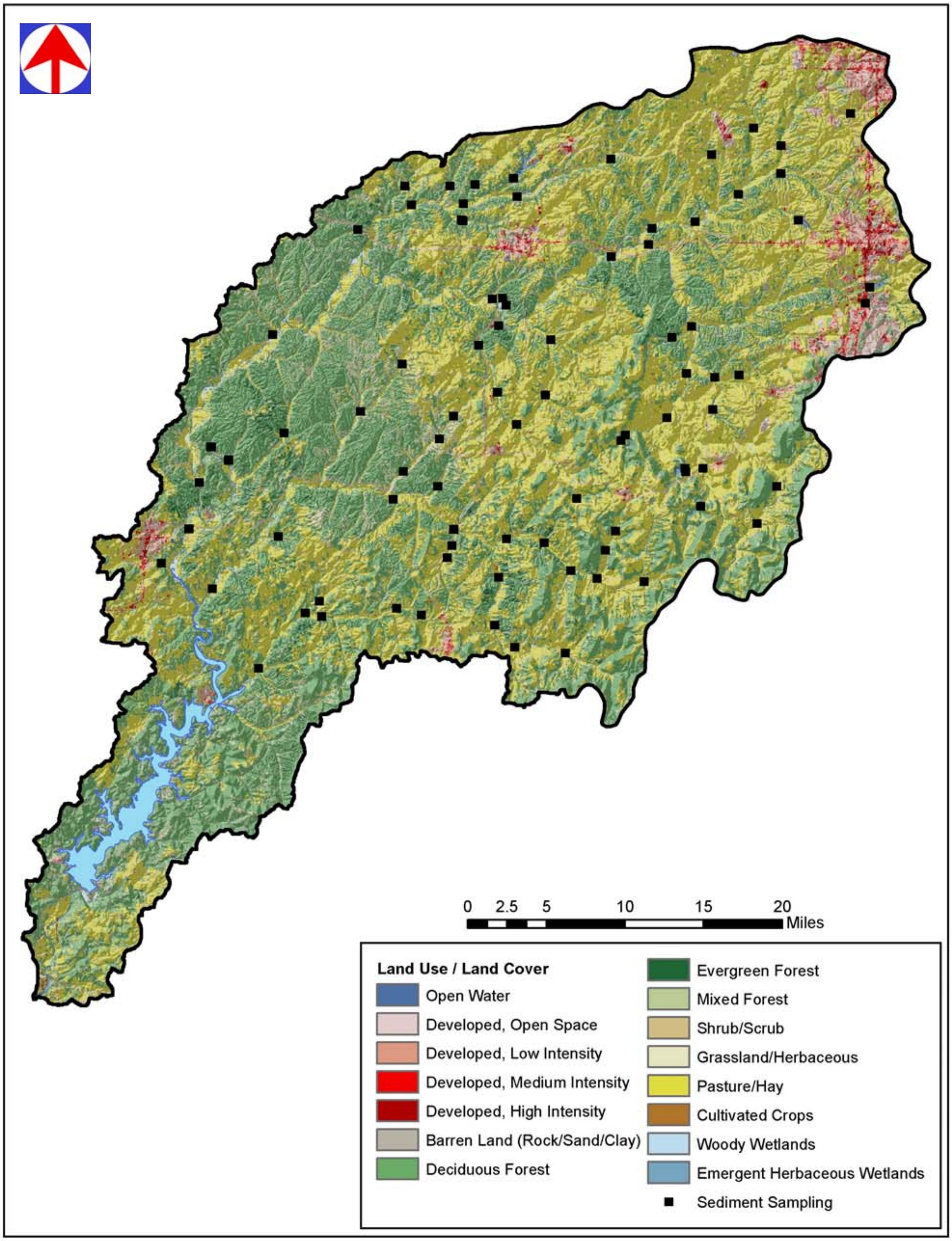


Figure 23. Stream sediment collection locations within the Illinois River Watershed.

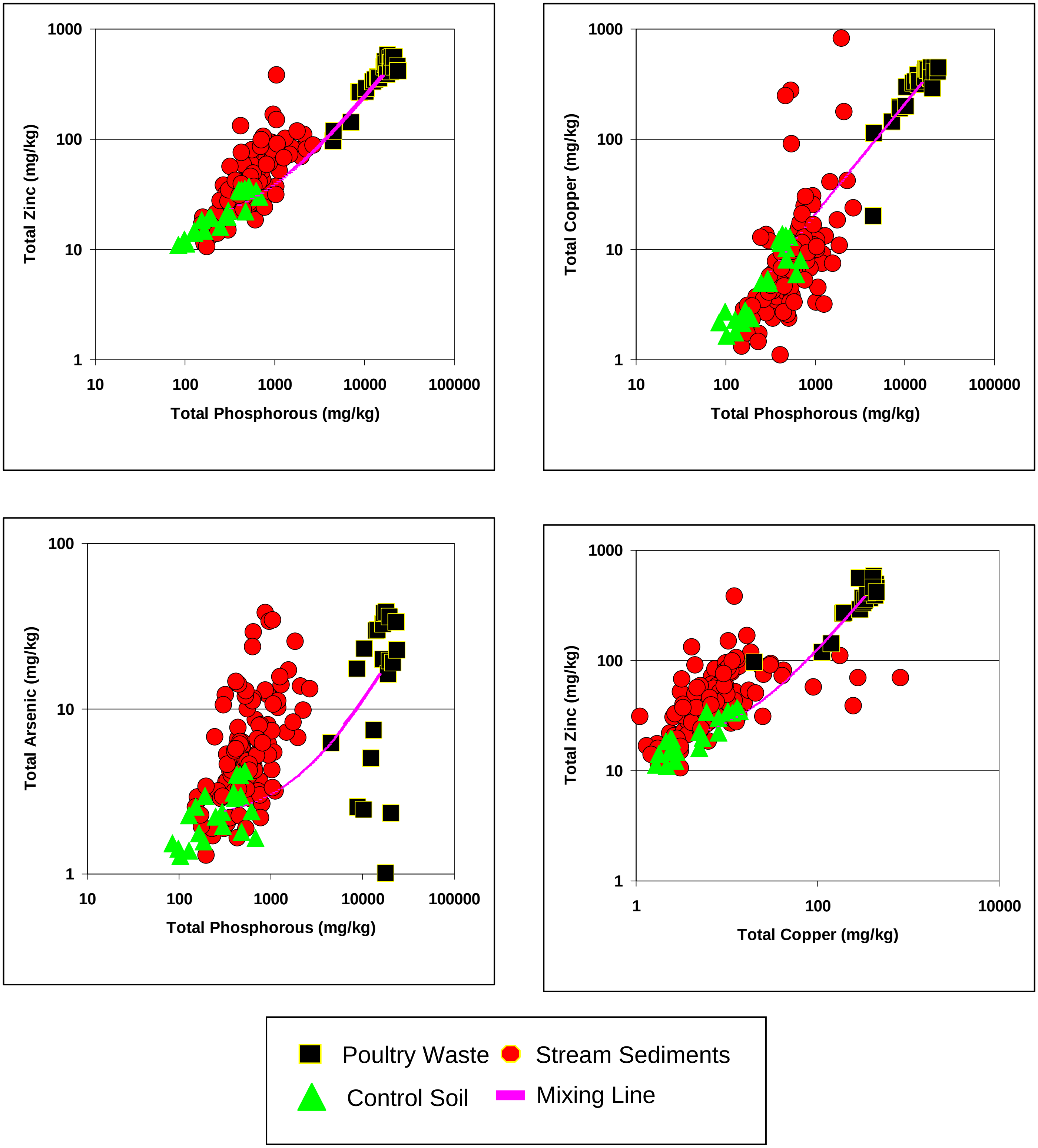


Figure 24. Relationship between the concentrations of total phosphorus, total copper, total zinc and total arsenic in sediments collected form Illinois River Watershed streams, control soils and in poultry waste.

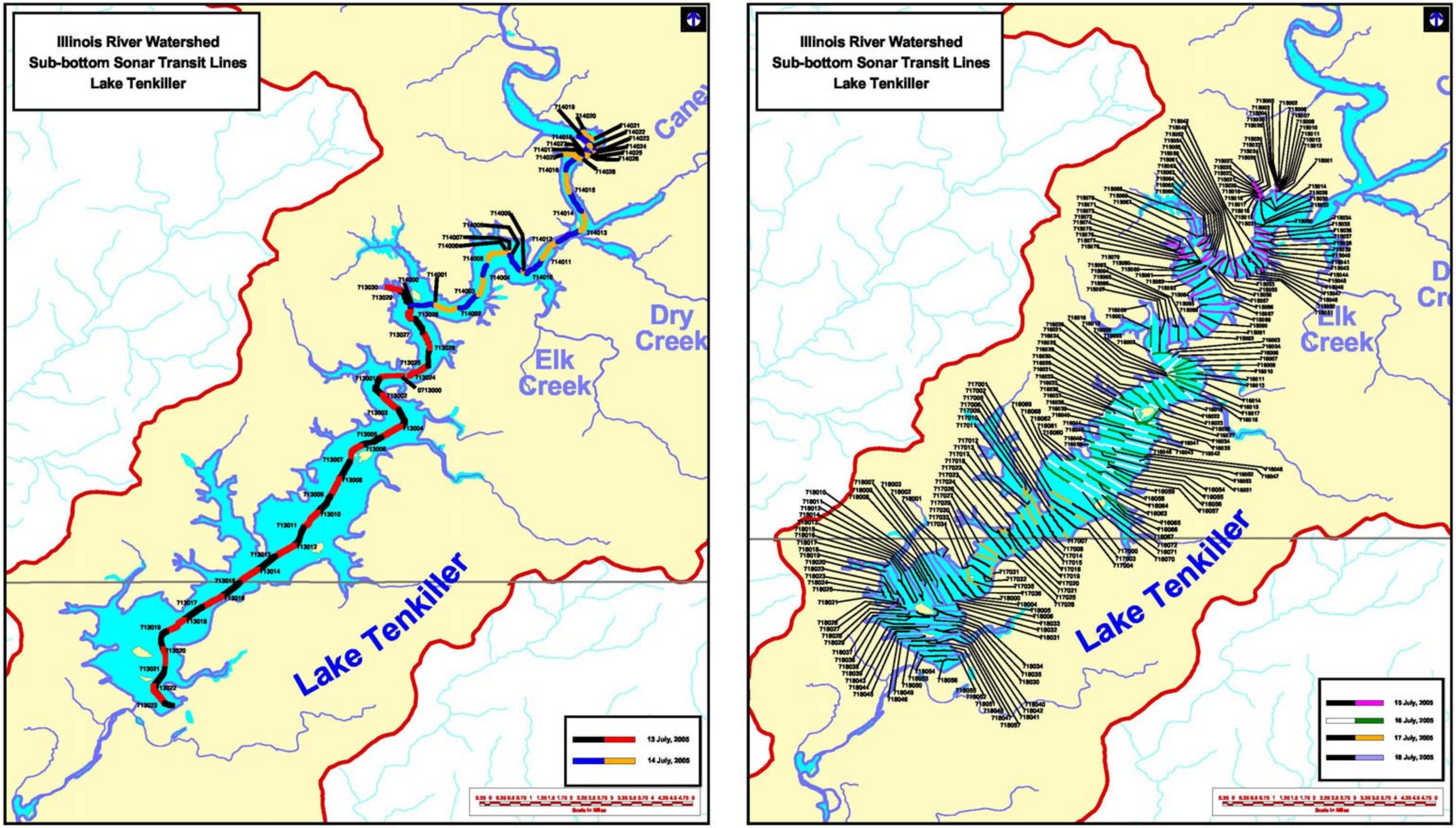


Figure 25. Lake Tenkiller showing the locations of sub-bottom acoustic survey data collection transects.

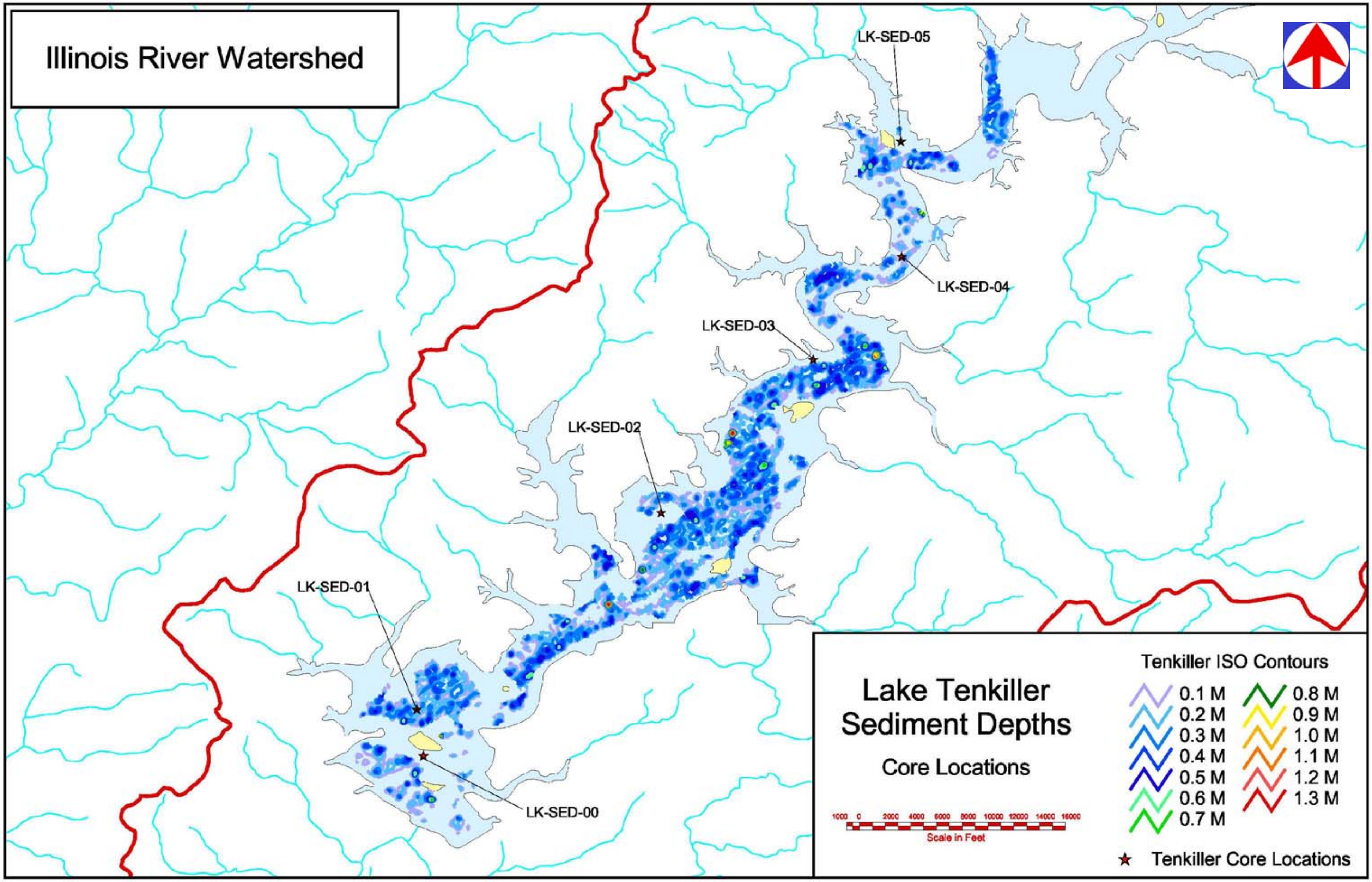


Figure 26. Isopach map of post impoundment sediments in Lake Tenkiller and locations of sediment cores.

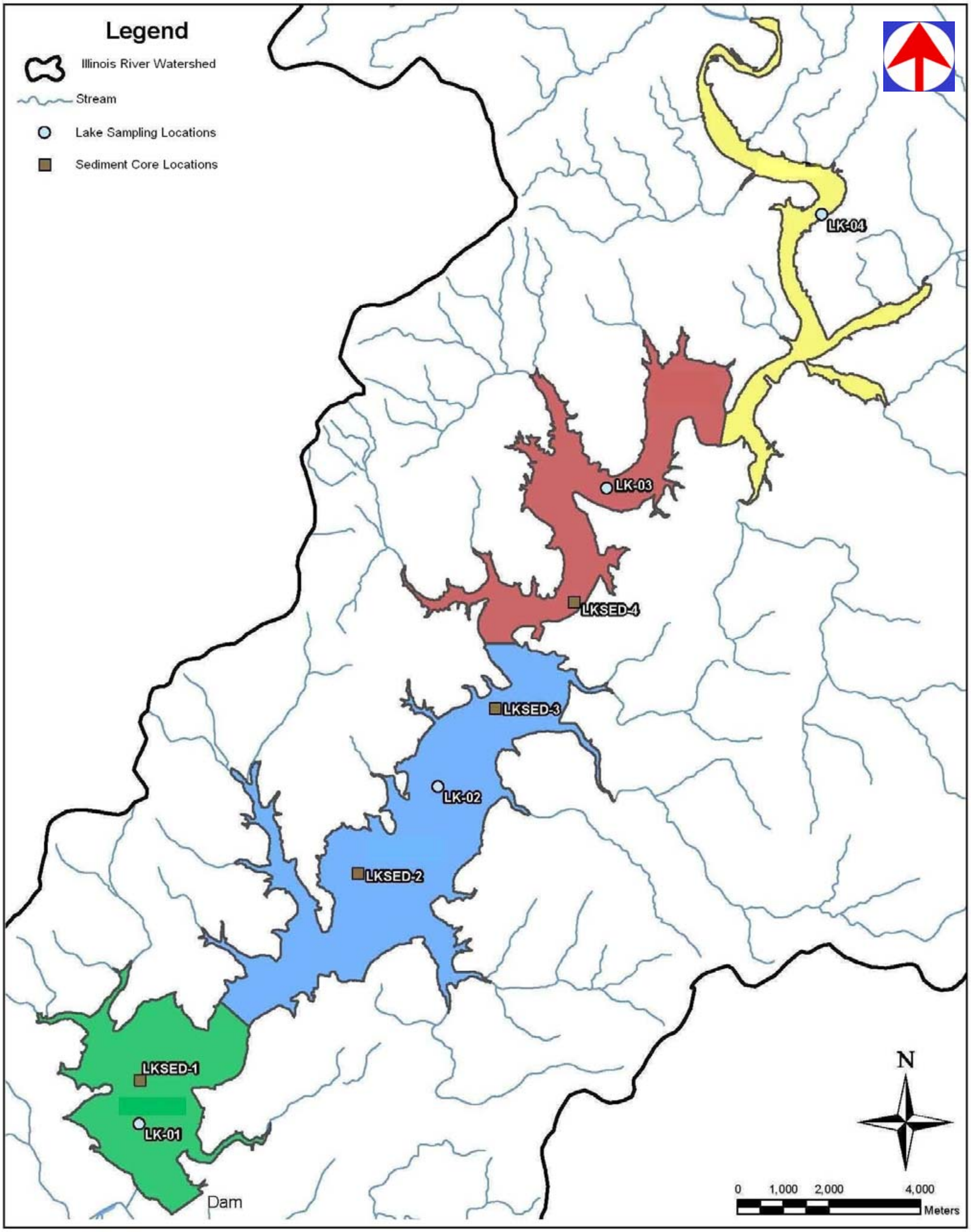


Figure 27. Tenkiller showing water and core sampling locations and approximate reservoir zones: Riverine – yellow, Transition – red and Lacustrine – blue and green

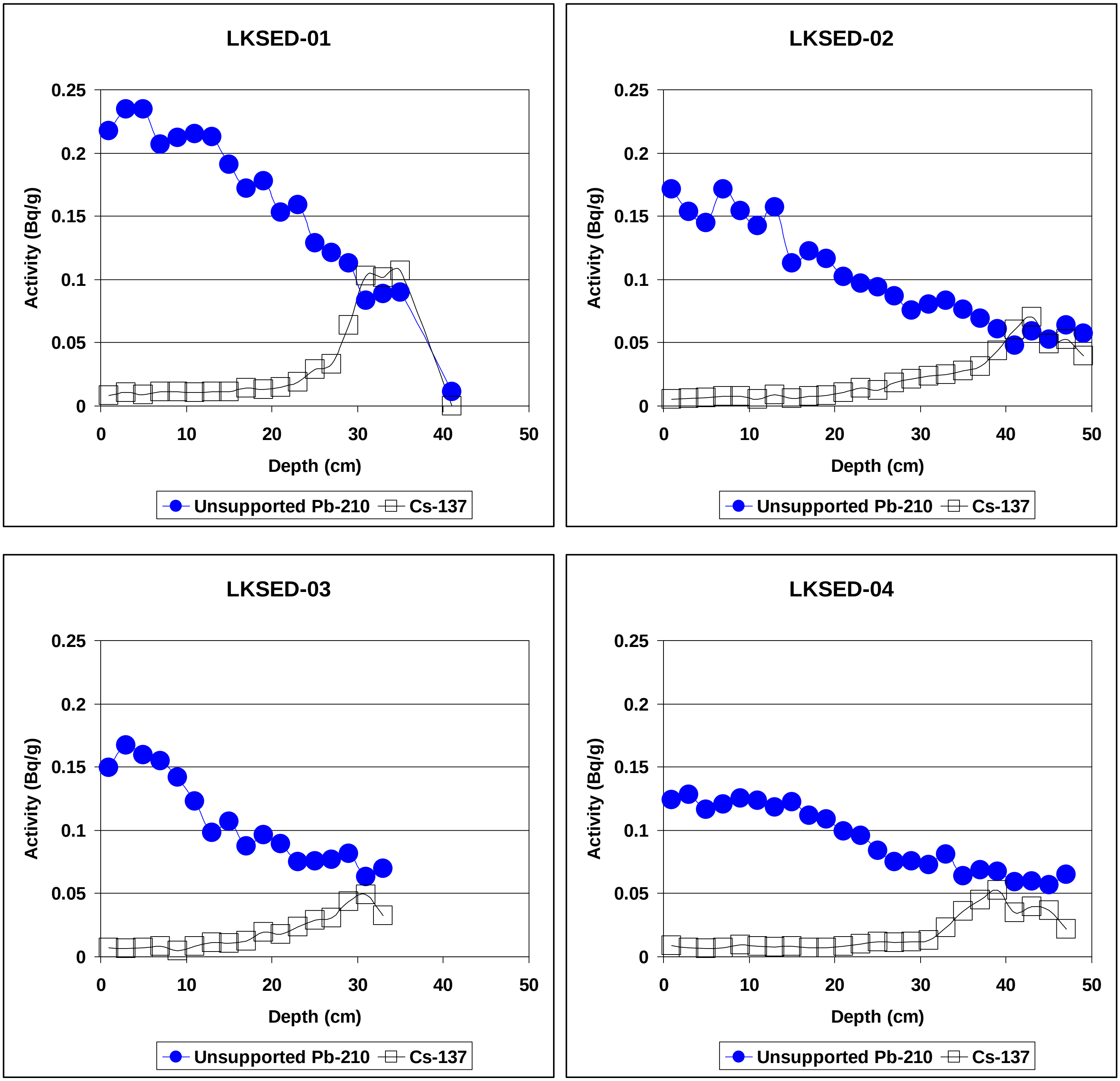


Figure 28. Measured activity of Pb-210 and Cs-137 in sediment cores collected from Lake Tenkiller.

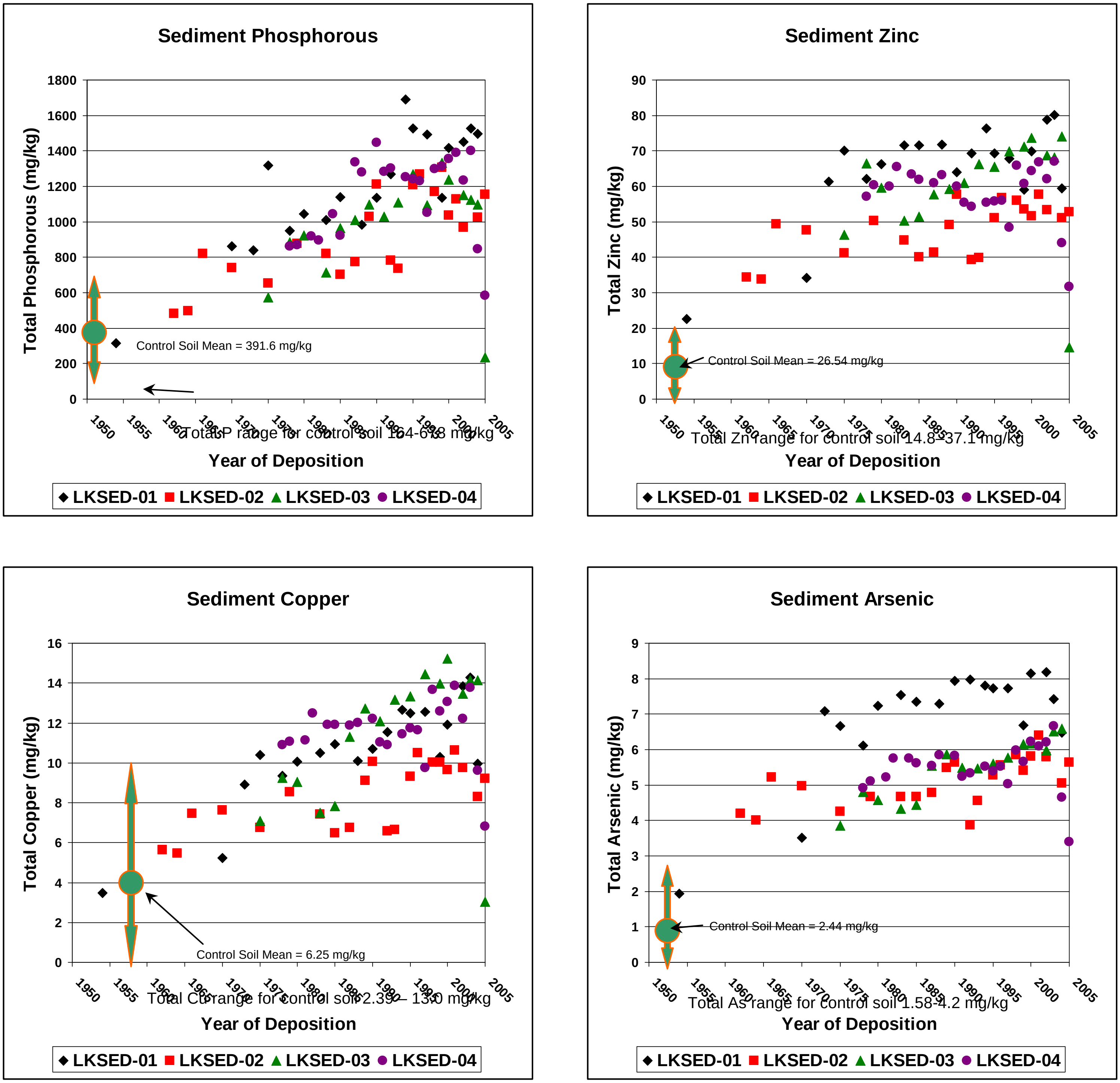


Figure 29. Concentrations of total phosphorus, total zinc, total copper and total arsenic found in sediment cores collected from Lake Tenkiller plotted against age of deposition with comparison to values for total phosphorus, total zinc, total copper and total arsenic obtained from control soils.

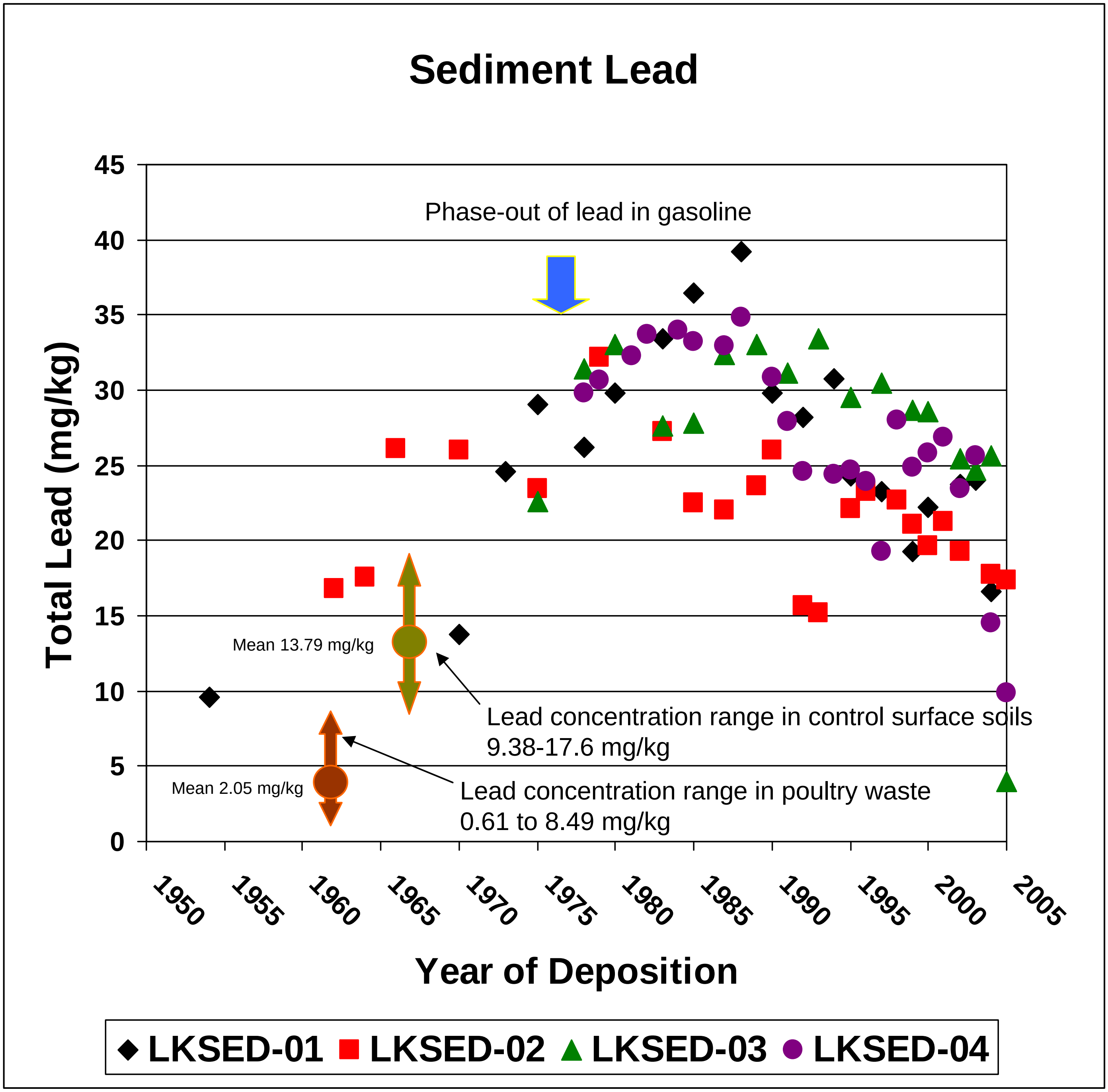


Figure 30. Concentrations of total lead found in Lake Tenkiller sediment cores plotted against age of deposition with comparison to values obtained for poultry waste and for control soils.

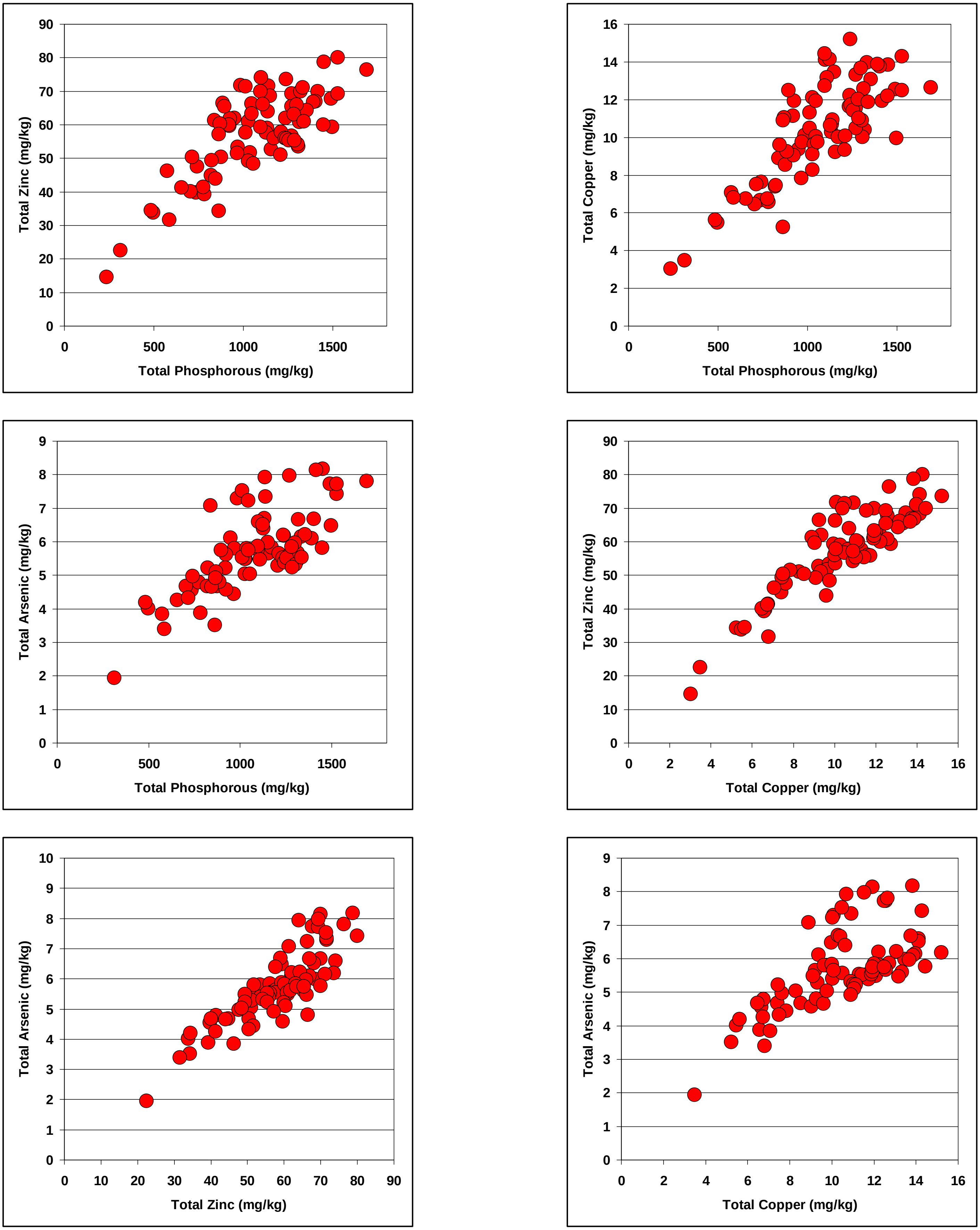


Figure 31. Relationship between the concentrations of total phosphorus, total copper, total zinc and total arsenic found in sediments collected in Lake Tenkiller sediment cores.

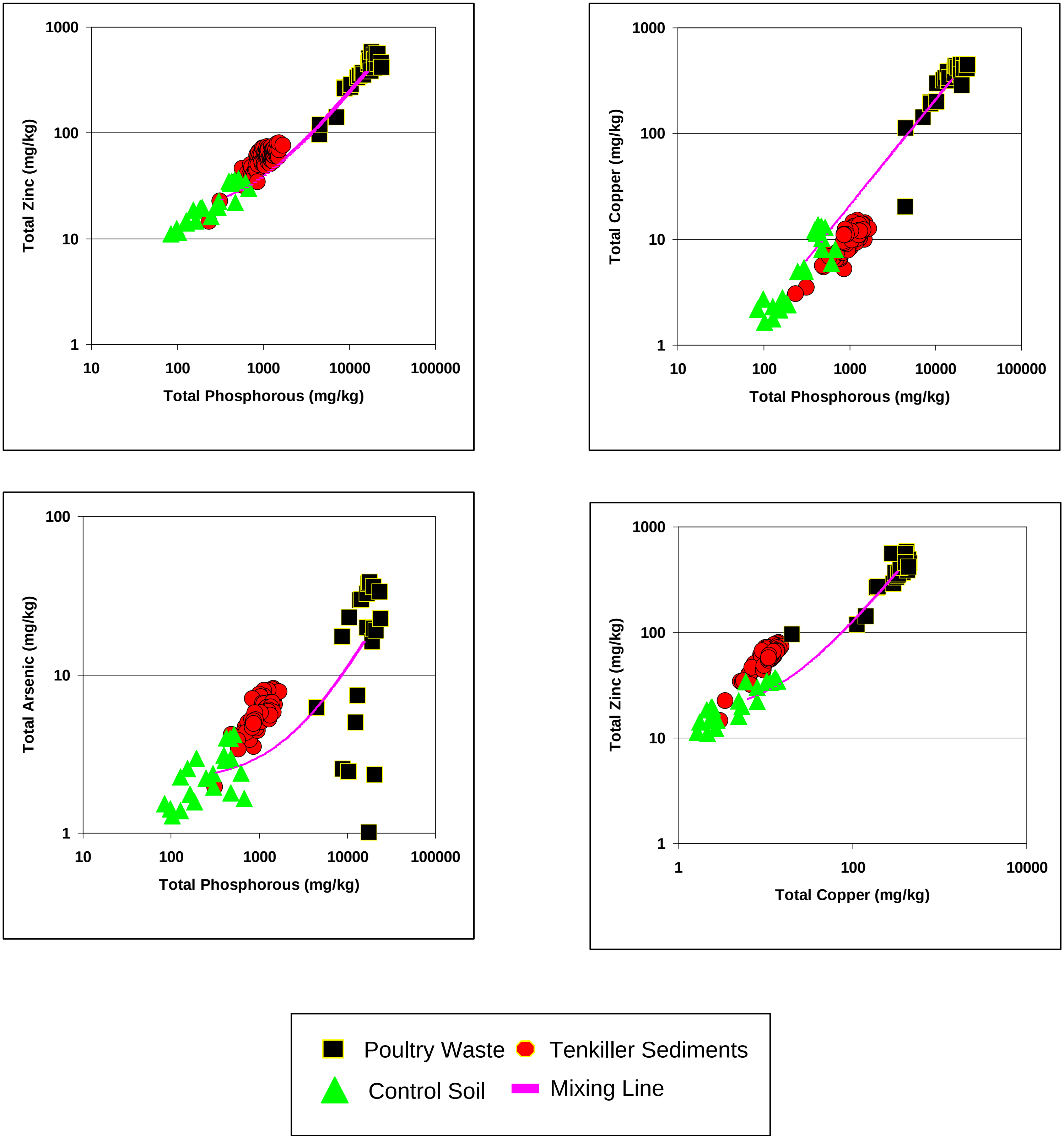


Figure32. Relationship between the concentrations of total phosphorus, total copper, total zinc and total arsenic found in sediments collected in Lake Tenkiller sediment cores, uncontaminated soils and in poultry waste.

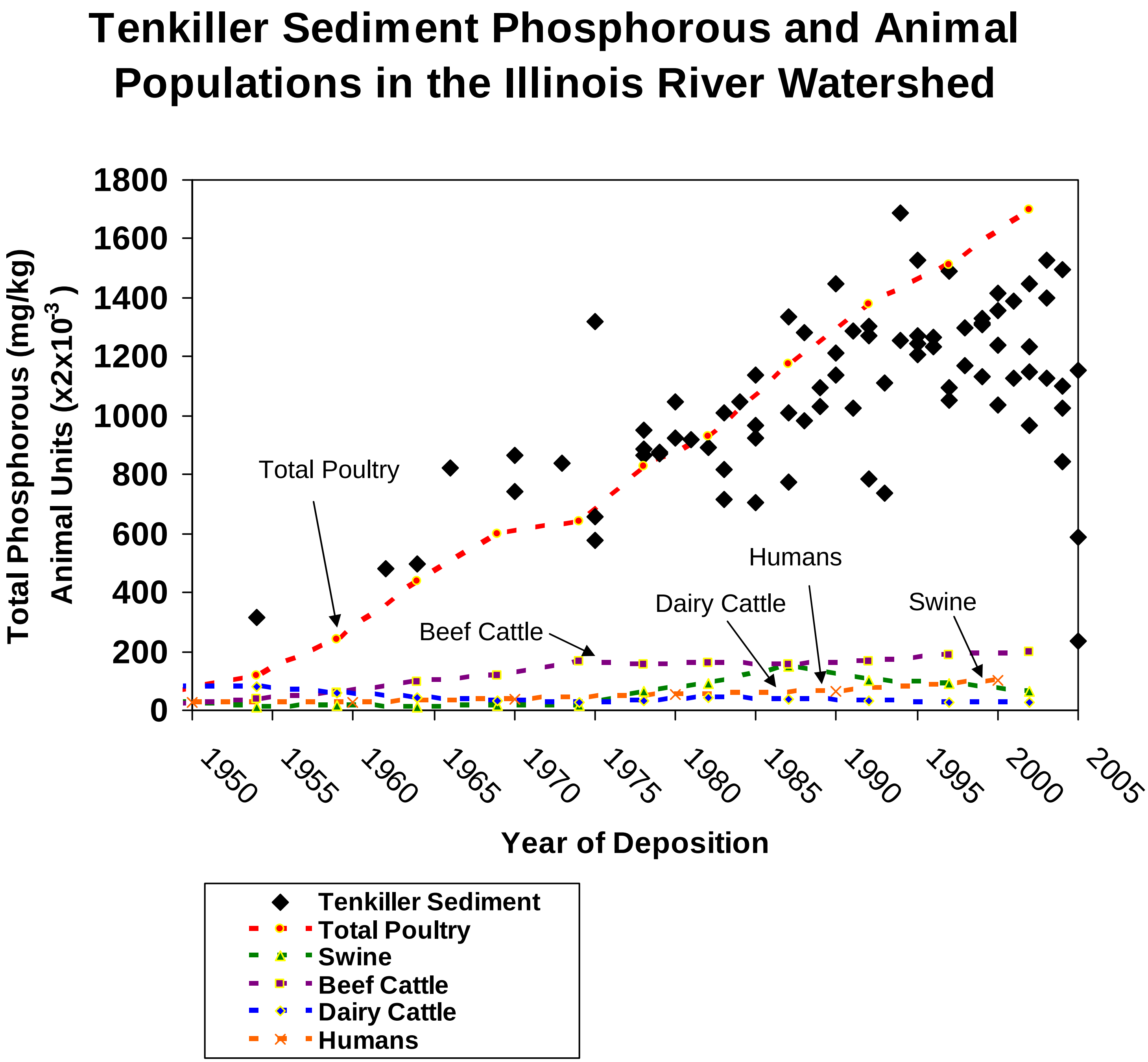


Figure 33. Total phosphorous concentrations in Lake Tenkiller sediment cores as a function of age of sediment deposition and populations of total poultry, beef cattle, dairy cattle, swine and humans in the Illinois River Watershed in animal units (AUs).