WATER QUALITY SNAPSHOT SURVEY IN THE JAMES RIVER WATERSHED, MISSOURI

A Masters Thesis
Presented to
The Graduate College of
Missouri State University

In Partial Fulfillment
Of the Requirements for the Degree
Master of Natural and Applied Science

By
Loring Bullard
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WATER QUALITY SNAPSHOT SURVEY IN THE JAMES RIVER WATERSHED, MISSOURI

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Loring Louis Bullard

ABSTRACT

Population growth and land-uses have created water quality impairment in the James River watershed of southwest Missouri. Many studies have been completed in the watershed, but these have focused primarily on specific problem areas or used data from a few fixed sites. This thesis describes the use of a relatively new method, called the snapshot survey, to examine spatial patterns in water quality across the entire James River watershed within a very short time frame. Seventy sites on streams and springs in the watershed were sampled by volunteers in a three hour period on July 13, 3013. Measured variables included temperature, pH, conductivity, chlorides, total nitrogen, total phosphorus and *E. coli*. Spatial patterns indicate that Wilsons Creek elevates total nitrogen and total phosphorus levels in the James River above the Total Maximum Daily Load target levels. Pearson Creek was found to have high *E coli* levels, from unknown sources. Sites on the upper James and upper Finley Rivers were elevated with respect to nutrients and *E. coli,* which may be non-point source related. Snapshot survey data compared well with that collected in previous studies, indicating that the volunteer-collected data is of good quality. Snapshot sampling appears to be a viable method for discerning broad spatial patterns related to both point and non-point sources of pollution. The application of this method in the James River basin can be used as a template for future snapshot events in the James River or other watersheds.

KEYWORDS: water quality sampling, snapshot sampling, land use, James River watershed, Missouri

This abstract is approved as to form and content

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CHAPTER 1: INTRODUCTION

The Ozark region of southern Missouri and northern Arkansas has an abundance of high quality water resources. These waters include a dense network of streams, numerous large reservoirs, thousands of springs and plentiful groundwater. Natural waters in the Ozarks are primarily of the calcium bicarbonate type, reflecting the predominance of carbonate rocks underlying the Ozark plateaus. Rivers are generally low in dissolved solids, in the range of 100-300 mg/l (Petersen et al., 1995). Springs are very numerous in the extensive areas of karst terrain in the Ozarks, and sustain the flows of most Ozark waterways (Brookshire, 1997). Because of their open flow networks, springs are vulnerable to contamination. Their relatively constant flows and temperatures provide important ecological benefits to Ozark rivers.

The water resources of the Ozark region, especially the large reservoirs in the Branson-Springfield area of Missouri, contribute significantly to the state’s economy (Brookings Institute, 2002). Table Rock Lake, a large Corps of Engineers reservoir in southwest Missouri, brought in over $114 million in visitor spending in 2012 (Kasul et al., 2010). Diversified local economies and relatively low costs of living have resulted in population booms in certain parts of the Ozarks (Brookings Institute, 2002). The city of Springfield, for example, grew much faster through the decade of the 1990s than the state as a whole (Brookings Institute, 2002). A consequence of population growth is continuing land development and the proliferation of potential sources of pollution, which have placed increasing pressure on the quality of the region’s water resources (Brookshire, 1997).

Many studies have been conducted in the region in an attempt to link land-use types with water quality degradation and to quantify the effects of land-uses. However, most studies have focused on specific problem areas or used existing data sources. Additional water quality monitoring and evaluation of trends is needed to better understand the sources of pollution and the distribution of water quality threats in Ozark streams. The use of short-term, high density water quality monitoring across an entire watershed is one way to gather spatial information that can be linked to various land-use types and pollutant source areas in the watershed.

The James River Watershed

The James River drains a portion of the Ozark Plateaus Physiographic Province (hereinafter called "the Ozarks") in southwestern Missouri. The Ozarks is an elevated area of land in the central United States covering about 125,000 km^2 (48,000 mi^2), mostly in southern Missouri and northwestern Arkansas but also including portions of southeastern Kansas and northeastern Oklahoma (Peterson, 1995).

The James River and its receiving waterbody, Table Rock Lake, are very important to the tourism and recreation industries of southwest Missouri. Population growth and widespread land development have affected the quality of these water resources (Brookshire, 1997). The James River has been classified by the Missouri Department of Natural Resources (MDNR) as impaired due to nutrient enrichment and nuisance algae conditions (Missouri Department of Natural Resources, 2001). Eutrophication in the James River arm of Table Rock Lake and the potential detriment to tourism were driving factors for the establishment of a nutrient TMDL in the James River in 2001 (Missouri Department of Natural Resources, 2001). Two urbanizing tributaries of the James River, Wilsons Creek and Pearson Creek, have also been listed as impaired, in these cases due to unknown sources of toxicity (Brookshire, 1997).

Water quality concerns in the James River have a fairly long history. In the 1960s and 1970s, studies of the James River and Wilsons Creek, its most urbanized tributary, drew attention to poor water quality conditions resulting from urban runoff and poorly treated wastewater from the city of Springfield (U.S. Dept.of the Interior, 1969; Harvey and Skelton, 1968; Berkas, 1980). In the 1990s, the James River was studied by the United States Geological Survey (USGS) as part of the Ozark Plateaus Study Unit during the National Water Quality Assessment (NAWQA) program. NAWQA data showed that nutrient levels in the James River were elevated above most other Ozark streams (Bell et al., 1996; Bell, 1995). More recent studies have focused on water quality in the James River and its tributaries, largely as a result of concerns over excessive nutrients, toxic constituents and other pollutants generated in areas of high population growth. These studies have resulted in multiple datasets and a large mass of accumulated water quality data, providing answers to at least some of the questions regarding how and where water quality has been negatively affected by land-uses.

In spite of this abundance of data, a data gap analysis on the James River watershed completed in 2007 noted that more data is needed to firmly link land-uses to their water quality effects (MEC Water Resources Inc. and OEWRI, 2007). Much of the monitoring in the past has been focused on known problem areas, leaving large parts of the basin uncharacterized, particularly above urban influences. Much of the monitoring in the past was also focused near fixed monitoring sites such as at USGS flow gaging stations, where long-term discharge and water quality data were available. The gap analysis called for a permanent and denser monitoring network and the establishment of a formal group to review, synthesize and report water quality data (MEC Water Resources Inc. and OEWRI, 2007).

Missouri has experienced an increase in volunteer monitoring since the 1990s. Fore et al. (2001), using a statistical index, found that the ability to detect significant differences between monitoring sites improved by only 13% for assessments by professionals rather than volunteers. However, some volunteer tasks, such as classifying macroinvertebrates or performing chemical analyses with test kits, have lower reproducibility rates than with professional (Nerbonne et al., 2003; Nicholson et al., 2002). Volunteer-generated data has increasingly used as background information in examining general water quality trends and in preliminary assessments of the effects of point and non-point sources of water pollution. Thirty-nine sites in the upper White River Basin, including several in the James River Watershed, have now been sampled by trained water quality monitors for four or more years, a sufficient length of time for generally classifying water quality into categories from excellent to poor (Missouri Department of Conservation et al., 2013). The Missouri Department of Conservation and the Missouri Department of Natural Resources both support citizen volunteer monitoring efforts in Missouri. The use of volunteers in the snapshot survey of the James River watershed was thus in line with trends in monitoring supported by state water quality agencies.

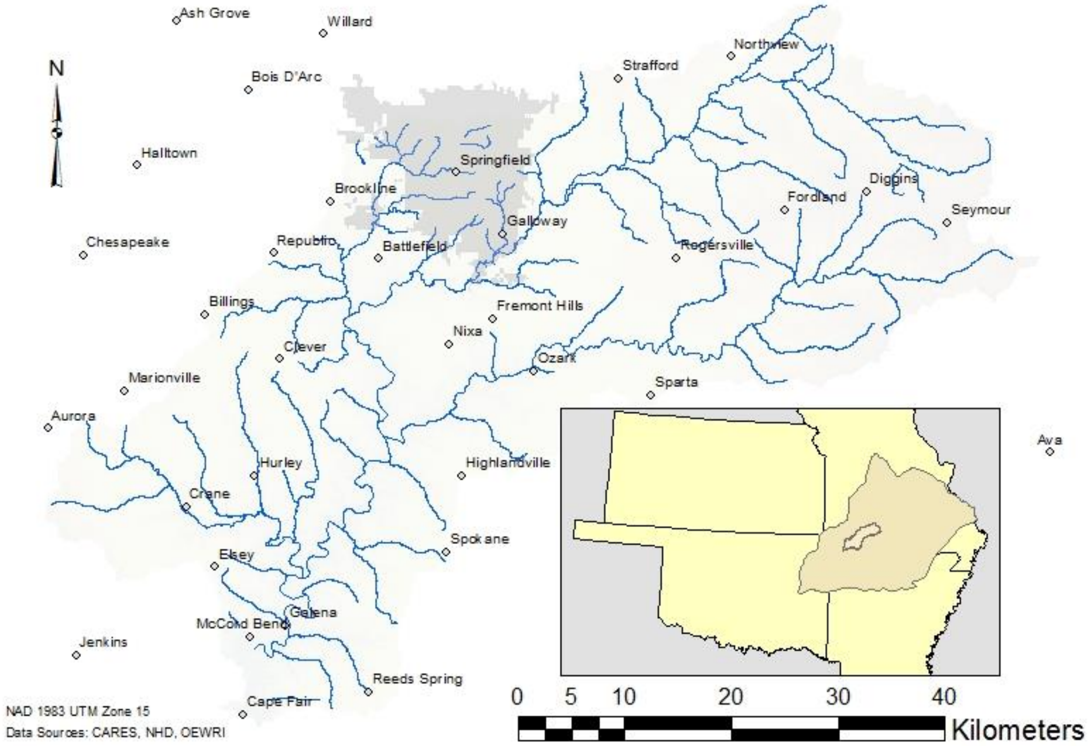
Study Purpose and Objectives

This paper describes a relatively new method for obtaining water quality data at the watershed level—the “snapshot” survey. With snapshot sampling, a large number of sites are sampled simultaneously, or within a very short time period, usually across an entire watershed (Grayson et al., 1997). The three primary objectives for organizing and implementing a snapshot sampling survey in the James River watershed were: 1) to field test the suitability and applicability of the snapshot methodology as a means to quickly gather useful and meaningful water quality information; 2) to compare data from the snapshot survey with data from previous water quality monitoring programs; and 3) to use the data obtained during a snapshot survey to examine spatial patters of water quality variability to generally evaluate the effects of point and non-point source pollution in the James River watershed.

Snapshot monitoring addresses two important problems brought out in the Data Gap Analysis of the James River completed in 2007: 1) In the current study, the snapshot monitoring was implemented at relatively equal intervals over the courses of all of the major streams in the study area, rather than focused solely on specific water quality problem areas or near existing fixed monitoring sites or gaging stations, and 2) the method has the capacity to determine source areas for both non-point and point sources of pollution over the entire watershed. It at least fills spatial gaps in information to help identify source inputs and problem locations.

The greatly compressed time scale of snapshot sampling dramatically reduces the effects of temporal variability. The spatial variability among pollution source types or areas is thus emphasized. The James River snapshot survey was performed under low flow conditions. Typically, water quality varies greatly with discharge fluctuations (Jordan et al., 1997), and most water quality standards are based on stable, low flow conditions. By sampling at low flows, the effects of point versus non-point sources of pollution could be more clearly discerned.

The James River snapshot survey took place in the James River upstream of Table Rock Lake (Figure 1). The survey included volunteer sampling in conjunction with professional project oversight and laboratory expertise. The recruitment and training of volunteers, selection of the water quality variables to be sampled and analyzed, and methods for planning, organizing and carrying out the event are discussed in detail in the Methods section of this thesis. The results of the water quality analyses and discussion of the results, as well as comparisons of results with those of previous studies, are described in the Results and Discussion section. In the Conclusions and Recommendations section, spatial patterns are evaluated for potential land-use effects and recommendations are made for future work.



NAD 1983 UTM Zone 15
Data Sources: CARES, NHD, OEWRI

Figure 1: Location map for the study area. Inset map shows Ozarks Physiographic Province with location of Snapshot Survey Study Area.

CHAPTER 2: BACKGROUND

Water quality monitoring in the James River watershed is an important part of environmental assessment and management of pollution sources. Many types of monitoring programs are used for the collection of water quality data, and all have certain advantages and drawbacks. Increasingly, volunteer monitoring programs are being supported by state water quality agencies because many more data points can be assessed. The James River snapshot method is a relatively new type of monitoring approach that uses short-term, high density sampling across an entire watershed to ascertain spatial patterns in water quality data. This is the first time this monitoring method has been used in the James River watershed, and only the second time it has been used in Missouri.

Monitoring programs are necessary for gaging the effects of land-use on water quality and discerning trends. All water quality monitoring programs should have certain elements in common, including clear objectives, representative sampling locations, suitable sampling frequencies and attention to budgets and logistical constraints (Strobl and Robillard, 2008). The objectives of the monitoring program must be carefully considered in designing the program in order to collect the amount and type of data that are needed. Most water quality monitoring programs seek to: 1) discern trends over time; 2) quantify the impacts of an activity or land-use; or 3) detect and measure fluxes, or the quantity of change per unit of time (Biswas, 1996).

The Clean Water Act in 1972 set aside huge amounts of federal money to reduce pollutant loads to U.S. waterways. A large network of water quality monitoring sites was established, mainly after 1970, to measure the success of this effort and to identify areas where problems remain (Hirsch et al., 1982). Fixed-site sampling has been the mainstay for collection of data on water flows and pollutants over the last four decades, resulting in the creation of long-term datasets at thousands of station points in the U.S. Much effort has gone into examining this dataset for trends in pollutant concentrations and to calculate loading rates. Trend analyses on such large amounts of data are often difficult, however, because of seasonal and flow variations, missing values and non-normal data distributions (Hirsch et al., 1991).

Monitoring programs can vary widely in scope and duration. Monthly sampling on a river is a vastly different undertaking than attempting to characterize the chemical signature of storm flows, which exhibit rapid changes in pollutant concentrations over short time periods (Deletic, 1998). Slow acting groundwater influences may produce long lag times between changing land-uses and the quality of surface waters, so historical land-use patterns and the residence time of pollutants in groundwater must be taken into consideration in terms of legacy effects on water quality (Wayland et al., 2003).

Volunteer Monitoring Programs

There has been a dramatic increase in volunteer-generated water data since the 1990s. Many states now have robust volunteer water quality monitoring programs. Missouri began its Stream Team program in 1989 and now has over 80,000 volunteers, many of whom are water quality monitors. Over 5,700 water quality monitoring volunteers have been trained in the state since 1993, collecting data at 2,154 stream sites in the state (Missouri Department of Conservation et al., 2013).

With proper training, volunteers can collect data comparing favorably in quality with that collected by professionals (Fore et al., 2001). The degree of variability in results depends on the type of monitoring done by volunteers, however, with chemical and biologic field evaluations (e.g. macroinvertebrate surveys) producing more variability than tests done by professionals or in laboratories (Nicholson et al., 2002; Nerbonne et al., 2003). Volunteers often use simple field methods such as inexpensive test kits (e.g., nitrates, dissolved oxygen, pH). For more complex analyses or more accurate results, grab samples may be taken for later analyses by professionals in laboratories. For many water quality constituents, the degree of accuracy in results is increased when samples are analyzed in laboratories by trained professionals (Fore et al., 2001). The result of many widespread volunteer monitoring efforts is a greatly expanding body of data, which is increasingly being used by resource professionals (Nicholson et al., 2002).

Sampling Considerations

The frequency of sampling is an important consideration in a water quality monitoring program. Monitoring strategies that employ infrequent sampling usually have distinct disadvantages. Weekly sampling on a stream misses almost all storm events, for example, and even daily measurements may not detect the finer fluctuations in water quality behavior. In spite of its high costs, continuous monitoring has proven valuable in understanding high frequency variations in water quality. But because conventional laboratory analyses involving large numbers of samples are laborious and time consuming, high frequency sampling has typically been limited to studies of individual storm events (Kirchner et al., 2004).

The timing of sample collection with respect to flow is also important. Concentrations of many water quality variables are flow dependent, and may either rise or fall with increasing flows. For example, total phosphorus may rise with increasing flows, while specific conductance may drop. Pollutant levels can vary by several orders of magnitude between base flows and storm flows. Point-source pollutants are least diluted at low flows, so concentrations are often highest at those times (Bartram and Ballance, 1996). For this reason, violations of wastewater discharge regulations are more likely to occur and easier to detect during periods of low flow.

Sampling frequency should be keyed to length of the intended monitoring period and the rate of expected change in the waterbody. If daily variations in water quality are of interest, or peak concentrations of pollutants, then it may be necessary to sample as often as once every two or three hours (Bartram and Ballance, 1996). Even at base flow, there may be significant variability over time that is difficult to relate to upstream land-uses (Wayland et al., 2003).

The form, solubility and transport mechanisms of pollutants all need to be considered in monitoring programs. For example, because phosphorus binds readily to sediments, TP concentrations can decrease with initial increases in storm flow until sediment is mobilized, after which TP will rapidly increase (Davis and Bell, 1998). Sampling at springs produces other complexities. Because phreatic karst conduits contain stored water, rapid inflows from storms will initially propagate head changes and higher flows at the spring outlet, with the first pulse of outflow reflecting primarily the quality of stored water. There can be a significant delay between the initial increase in discharge and the arrival of runoff, as evidenced by eventual increases in specific conductance and bacteria (Ryan and Meiman, 1996).

The exact point in a waterbody at which samples are collected can significantly affect pollutant concentrations. Proximity to a source of pollution is an obvious factor. But considerable variation can also occur in the absence of proximate sources of pollution. In a well-mixed river, sampling at mid-stream or in mid channel will typically provide a sample that can adequately represent all of the water in the river at that location (Bartram and Ballance, 1996). However, sampling in a pool, eddy or near the shore can produce samples that vary greatly in pollutant concentrations from the main mass of the water body.

Temperature changes occurring daily or seasonally can affect water quality variable concentrations and distributions. For example, higher temperatures can limit dissolved oxygen, which can affect biota and the rate of oxidation reactions. Generally, water temperatures increase downstream as streams grow larger and wider and therefore less of the water surface is shaded (Allen and Castillo, 2007). Higher temperatures can also be found in impoundments on streams, as surface layers warm in quiescent water. Temperature can vary in rivers with inputs of colder groundwater in summer. Depending on the time of year, springs, which have fairly constant year-round temperatures, can lower or raise the temperature of the stream they enter. Because urban surfaces retain heat in summer, urban runoff can be much warmer than receiving streams, so input points of urban runoff into a receiving stream or lake must be taken into consideration (Paul and Meyer, 2001).

Sampling Methods

The United Nations “Environmental Monitoring Program Guide to Surface Water Sampling” describes a range of methods and their capital costs, field costs and reliability (Chapman, 1996). Six basic strategies are described: 1) hand-sampling only, 2) hand-sampling with a simultaneous discharge measurement, 3) hand-sampling with discharge recording, 4) discharge-weighted automatic sampling, 5) time-weighted automatic sampling, and 6) continuous concentration and discharge recording. Costs generally escalate upward through the six strategies. Costs for all methods vary greatly depending on the number of sample sites and the time workers are in the field. Because of its low cost and simplicity, hand or grab sampling is still extensively used, especially in volunteer-based water quality monitoring programs.

Snapshot sampling involves the collection of many samples over a large area within a short period of time. The watershed is the geographic scale of effort typically employed. A primary advantage of snapshot sampling is that temporal variability is greatly reduced, thereby emphasizing spatial variability in results. In a snapshot survey, all of the sites should be subject to similar flow conditions, weather patterns, air temperature and seasonal influences.

Snapshot sampling programs are usually undertaken during low flow periods, often in summer (Iowa Department of Natural Resources, 2005). As a practical matter, sampling at low flows is safer for field personnel. Sampling at base flow also provides a means to better delineate the locations and relative magnitudes of point sources of pollution. Snapshot sampling can provide new insights into the spatial distribution of water quality conditions, including quantification of unknown point sources and identification of non-point source “hot spots” in discrete portions of the watershed (Grayson et al., 1997).

During base flow, groundwater provides the primary component of stream flow, so groundwater quality and its effect on the stream are indirectly measured when samples are collected at that time (Loper and Davis, 1998). From the ecological standpoint, stream organisms are exposed for much longer periods of time to low flows, so base flow water quality is critical to aquatic ecosystem health (Grayson et al., 1997). For this reason, water quality sampling during base flow periods can help to understand factors related to some aquatic ecosystem stressors.

Snapshot water sampling events have been gaining in popularity over recent years, partly because they provide good ways to involve local citizens in large-scale monitoring efforts. The Iowa Department of Natural Resources has been implementing volunteer-based snapshot events for the last two decades, and sponsored over fifty events between 2000 and 2005 (Iowa DNR, 2005). From the standpoint of resources that are required, the scale of the effort undertaken in a snapshot survey is an important consideration. For a snapshot event in Pennsylvania using volunteers, a small watershed was chosen in order to make it simpler to involve local citizens in the training and outreach efforts (Loper and Davis, 1998).

Snapshot sampling does have significant drawbacks. An individual sampling event is unlikely to adequately characterize the complexities of the processes controlling interactions between land-uses and water quality (Wayland, 2003). The temporal coverage of snapshot sampling is by design very limited, so it must be assumed that conditions measured are representative of the flow regime being monitored (e.g., base flow) (Grayson et al., 1997). During low flow periods, some scheduled sampling sites may have no flow. And depending on the type of personnel involved and scale of the effort, the cost of resources can be high and major logistical difficulties may be encountered.

Land Use/Water Quality Relationships

Despite ever increasing volumes of long-term water data, providing empirical evidence of the associations between land-uses and their specific water quality effects has proven challenging (Allen, 2004). Providing this linkage has been difficult due to natural and human-influenced gradients across watersheds, multiple scale-dependent mechanisms and problems in distinguishing between historical and modern day influences (Allen, 2004). Typically, many land-use changes occur simultaneously across a watershed. The effects on water resources are often gradual and may go unnoticed until major hydrologic and/or water quality changes occur. At this point, it is often difficult to evaluate the importance of different causal factors (Baker et al., 2004).

Water quality monitoring programs coupled with remote sensing, refined modelling and Geographic Information System applications have strengthened the associative capacity and predictability of studies quantifying relationships between land-uses and water quality. Using a Better Assessment Science Integrating Point and Non-Point Source (BASINS) model, Tong and Chen (2002) showed significant relationships between intensive land-uses and poor water quality. Modelling was used successfully to predict base-flow nitrate concentration based on the percentages of major land-use categories in Pennsylvania watersheds (Gburek and Folmar, 1999).

Pollutant Sources

Municipal Wastewater.

Direct discharges to surface waters from industries and sewage treatment facilities, referred to as point sources of pollution, were among the first areas to receive attention in water quality standards and state and federal water pollution laws (Melosi, 2008). By the time the United States Public Health Service established the first bacterial standards for water supplies in 1914, pervasive sewage pollution of the nation’s waterways was already a major concern (Melosi, 2008). At that time, very little sewage received treatment of any kind; so many receiving streams were grossly polluted with oxygen-demanding organic wastes and bacteria.

In 1971, the newly created United States Environmental Protection Agency (USEPA) was given responsibility for protecting the quality of the nation’s waters. The agency’s powers were broadened in 1972 with the passage of the Federal Water Pollution Control Act, now known as the Clean Water Act (CWA), which among other things mandated secondary treatment by 1988 for all municipal sewage treatment plants, or publicly-owned treatment works (POTWs) (Melosi, 2008). Only when these point sources of pollution were better controlled did non-point source pollution, now recognized as the leading cause of water quality impairment in the U.S., become readily apparent (Bhaduri et al., 2000).

Microbes, such as typhoid organisms, have long been known to create hazards from sewage contamination. Concern about microbes and waterborne disease led to the practice of disinfection of drinking water on a large scale beginning in 1908 in New Jersey (Baker and Taras, 1949). Wastewater was not routinely disinfected until much later (Melosi, 2008). Today, most wastewater treatment facilities that discharge into streams where human contact is likely are required to disinfect, at least during recreational seasons.

Even after secondary treatment, wastewater can be a major source of nutrients to receiving waters. These nutrients can cause eutrophication and deteriorated water quality (Nichols, 1983). The primary aquatic plant nutrients of concern are usually nitrogen and phosphorus. Many states have adopted standards limiting the discharge of nutrients in treated wastewater, especially in situations where discharges have access to nutrient-sensitive water bodies such as high quality recreational rivers and lakes (Mueller and Helsel, 1996). In spite of these efforts, nutrient standards are not in place in many areas and levels of nutrients above background or reference conditions can still be found downstream of many POTWs. For example, In the Ozark Plateaus portion of NAWQA, the highest total phosphorus (TP) found was in the Kings River ten miles downstream of the Berryville, Arkansas POTW (Davis and Bell, 1998).

Urban Runoff. Runoff from urban zones contribute significant levels of pollution to streams and lakes, and has caused declines in water quality expressed by declining richness of invertebrate and fish communities (Paul and Meyer, 2001). Water quality degradation can result from discharges of sediment, nutrients, bacteria, metals and other chemicals in urban runoff (Lee et al., 2000). Drastic changes to aquatic ecosystems have been linked to urbanization and these problems have proven very difficult to correct (Booth and Jackson, 1997).

In the 1977 amendments to the Clean Water Act, Congress included funding for a Nationwide Urban Runoff Program (NURP). The NURP study used ten standard water pollutants to characterize urban runoff at 81 urban sites in 28 large cities across the United States (Smullen et al., 1999). Revisions to the Clean Water Act in 1987 for the first time placed federal requirements on the management of urban stormwater runoff. After 1992, large urban areas were required to obtain National Pollutant Discharge Elimination System (NPDES) permits for stormwater discharges, in effect bringing the outlets of urban sub-watersheds into the permitting process as point sources (Dodson 1999). Since that time, large cities and counties with expanding urbanization (such as Christian County in the James River watershed) have been required to develop plans to monitor stormwater quality and implement measures to protect receiving waters from the harmful effects of runoff.

<u>Nutrients in Runoff</u>: Urban runoff can contribute significant nutrient loads from leaves, grass, pet wastes and other organic materials, as well as increased biological demand in waters. Fertilizer and atmospheric deposition are also sources of nitrogen and phosphorus to urban stormwater. Nitrogen is typically found in urban runoff at levels of about 0.6 mg/l to 1.4 mg/l total nitrogen (Hsieh et al., 2007a). Phosphorus arrives in stormwater from lawn fertilizers, detergents, soil erosion and animal wastes (Hsieh et al., 2007b). Generally, phosphorus levels in runoff are lower than those of nitrogen, but values up to 0.4 mg/l TP have been recorded (Cowen and Lee, 1976).

<u>Microbes</u>: Pet wastes and leaking or surcharging sewers (wastewater overflowing sewer systems because of increased infiltration of runoff into sewer pipes and manholes) can contribute high bacterial loads to urban runoff. Survival and persistence of these

organisms in stormwater could create health hazards. Marino and Gannon (1991) found that fecal coliform organisms could survive in storm drain sediment for up to nine days.

Heat: Because of the prevalence of heat absorbent surfaces, urban runoff can be very warm compared to the temperature of receiving waters. In one study in New York State, the temperature of urban streams after a summer thunderstorm was 10-15^0 C warmer than nearby streams draining forested watersheds (Paul and Meyer, 2001). This presents the possibility of heat shock to temperature-sensitive aquatic organisms. Temperature typically changes much more slowly in larger streams, so the volume of urban runoff compared to the size of the receiving stream is an important mitigating factor.

Combined Effects. In many urban areas, urban runoff and wastewater discharges are co-mingled in receiving streams. Generally, point sources such as wastewater treatment plant discharges are diluted by stormwater runoff, while non-point source pollution is increased by stormwater runoff. The relative effects of the two types of flow on receiving waters are very site specific. Taebi and Droste (2004) showed that in urbanized areas with very low precipitation and therefore low total volumes of runoff, annual pollution loads contributed by stormwater were much lower than loads derived from wastewater. In more humid areas, the opposite can be true. In a study of the Little Sac River in southwestern Missouri, which receives both stormwater runoff and wastewater effluent from the city of Springfield, Baffaut (2006) estimated that only 3% of the annual bacterial loading of the stream came from the single large POTW in the watershed.

Onsite wastewater systems. Onsite wastewater systems, usually referred to as "septic tanks," release hundreds of billions of gallons of partially treated wastewater to the subsurface each year in the United States and constitute the most frequently reported cause of groundwater contamination (Yates, 1985). Onsite wastewater systems can also contaminate surface waters. Using antibiotic resistance pattern source tracking, Carroll et al. (2005) found that the percentage of human bacterial isolates increased significantly in streams draining areas where onsite wastewater systems were used. Onsite systems can also pollute water with chemicals such as pharmaceuticals and personal care products. Hinkle et al. (2005) found that onsite systems had contaminated a shallow, unconfined aquifer in Oregon not only with coliform bacteria but also with 45 of the 63 organic wastewater compounds measured. Nutrient levels in surface waters can also be affected by onsite wastewater systems. Heisig (2004) measured high concentrations of nitrate and orthophosphate in base flow stream samples collected downstream of villages on septic tanks.

Agriculture. Agriculture is a predominant land use over large portions of the United States, with about 26% of the land base in grassland and range, and 20% in crops (Lubowski et al., 2006). Forty-two percent of wadeable streams in the U.S. are in poor or degraded condition, with excess nutrients and sediment major factors (USGS, 2013). Agriculture is a major source of nutrients and sediment to aquatic ecosystems and a significant contributor to environmental stress in these systems (Cooper, 1993).

<u>Nutrients</u>. Nutrients in agricultural runoff can cause algae blooms, depletion of dissolved oxygen, fish kills and loss of biological diversity in receiving waters. Simultaneous nitrogen and phosphorus enrichment creates strong additive effects leading

to heightened eutrophication (Elser et al., 2007). In a poultry-raising area in Arkansas, nutrients in runoff were 3 to 10 times higher than in runoff from streams draining undeveloped watersheds (Haggard et al., 2003). Soil erosion enhances the transport of phosphorus, which is mostly found bound to particulate matter (Jordan et al., 1997). Impaired aquatic ecosystems can recover over time if nutrient inputs are reduced (Cooper, 1993). Recovery rates of different water bodies are highly variable (Carpenter et al., 1998).

Grazing. Nutrient levels in runoff from grazing lands have been directly related to animal stocking densities (Trimble and Mendel, 1995). Excess manure from livestock creates reservoirs of highly mobile nitrogen in soils (Carpenter et al., 1998). Cows tend to concentrate and linger in riparian zones, placing manure and waste-derived nutrients close to streams and increasing the compaction and erosion of near-stream soils. The time that cattle spend grazing in riparian areas can be five to 30 times higher than in upland areas (Trimble and Mendel, 1995). Grazing can also exert significant effects on the bacteriological quality of water. Runoff from grazed areas in a Nebraska watershed contained five to ten times more fecal coliform than fenced, ungrazed areas (Doran and Linn, 1979).

Agricultural effects on groundwater. Groundwater can become contaminated with excess nutrients and bacteria of agricultural origin, particularly in karst regions (White, 1988). Since springs provide much of the base flow to surface streams in karst areas, the bacteriological and chemical quality of springs is important in maintaining stream water quality (Baffaut, 2006). In four karst watersheds in the Appalachians, Boyer and Pasquarell (1995) found a strong linear relationship between nitrate concentrations and the percent of agricultural land. In another study in the same region, Boyer and Pasquarell (1999) found fecal bacterial densities of 4,000 cfu/100 ml in dairy-influenced karst aquifers and 10 cfu/100 ml in pasture-affected aquifers.

Other sources. Land-uses such as forestry and mining can contribute a variety of pollutants to waterways. However, these land-uses are not prevalent in the James River watershed, the area of interest for this project. Recreation, on the other hand, is a common use on the clear, swiftly flowing streams of southern Missouri, such as the James River. One study on an Ozark stream illustrated how pollutants created by one type of recreation can affect other recreational uses. A five mile segment of the Jacks Fork River within the Ozark National Scenic Riverways was listed by the state of Missouri as impaired due to fecal coliform bacteria. During sampling in 2003, two sites exceeded the whole-body-contact recreation standard (WBC) of 200 fecal coliform colonies per 100 ml (Davis and Barr, 2006). Each of these exceedences occurred just downstream of and shortly after horseback trail riding events.

CHAPTER 3: LAND-USE AND WATER QUALITY IN THE JAMES RIVER WATERSHED

The James River and other Ozark streams have been significantly affected by land-use practices since times of European settlement, if not before. Some pre-European practices, such as forest burning for game propagation, may have had water quality effects (Jacobson and Primm, 1994). Since settlement, Ozark streams have been directly affected by logging and agricultural practices. More recently, urban and suburban development have become areas of water quality concern, especially with the high population growth that has occurred in some sections of the Ozarks (Figure 2).

Agriculture

Agricultural practices, along with mining, probably have the longest history of water quality impairment of any land-use types in the Ozarks. Jacobson and Primm (1994) suggested that the peak of Ozark stream channel destabilization occurred in the period after 1920, with the most destructive practice being open range livestock grazing. Clearing trees for pasture followed by continuous grazing in riparian areas destroyed much of the vegetation in channels and on banks. Owen et al. (2011) concluded that about one-half to one meter of overbank sedimentation occurred on the James River floodplain since settlement, with the largest rate of deposition corresponding to the peak of corn production in the late 1800s to early 1900s. Upland erosion, stream gravel movement, downstream sedimentation and channel instability all resulted from intensive or poor agricultural land-use practices (Jacobson and Primm, 1994).

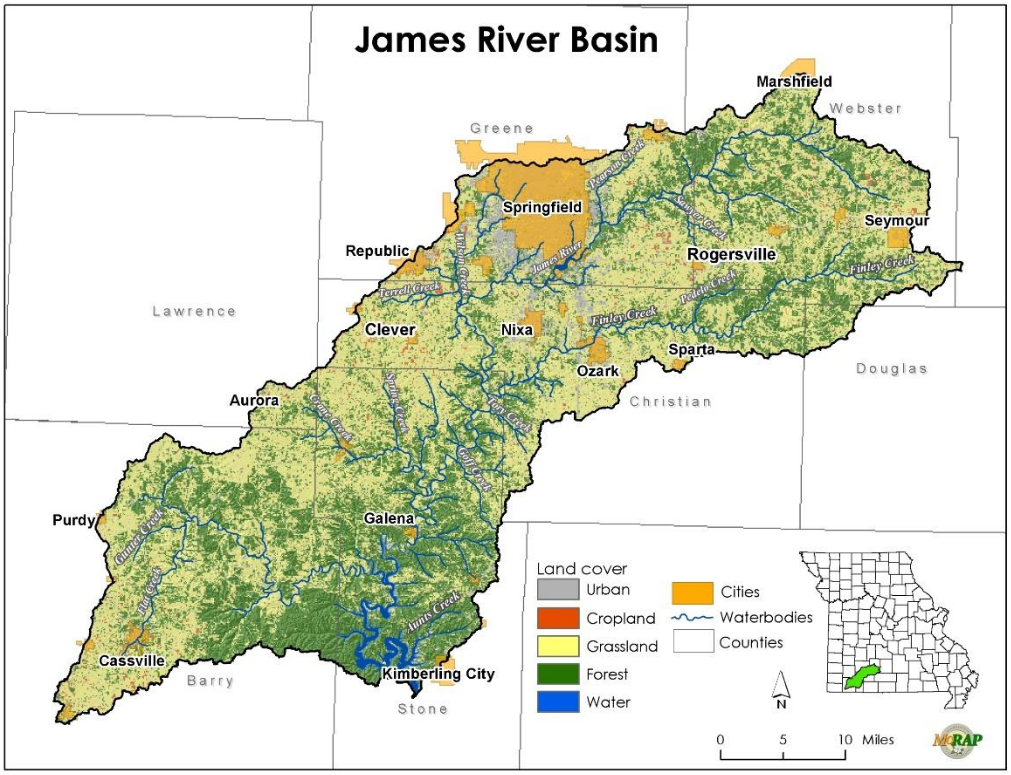


Figure 2: Land cover/land-use in the James River Watershed

The peak time of agricultural land development in southwest Missouri, including the James River watershed, was in the period 1890 to 1900 (Rafferty and Holmes, 1982). Greene County was the second highest corn producing county in the Ozarks by 1909, with over 2,000,000 bushels produced (Sauer, 1920). An agricultural shift in the James River watershed that occurred after this period was the transition from row crop agriculture to pasturing. As mechanized agriculture advanced statewide, Ozark counties, with their relatively poor soils, lower crop yields, smaller areas of contiguous cultivable land and poorly developed transportation networks, could not compete successfully with more fertile regions elsewhere (Sauer, 1920). The largest proportion of agricultural production in the Ozarks today is beef or dairy cattle on pastures.

Elevated levels of bacteria in Ozark streams have been linked to agriculture. In the early 1980s, water quality in Sayers Creek (formerly Sawyer Creek) was surveyed by the Springfield-Greene County Health Department. High levels of fecal coliform, above the standard for whole-body contact (200 colony forming units-CFU/100ml), were found in stream and spring sites in this agricultural watershed (Watershed Committee of the Ozarks, 1997). In the NAWQA study of watersheds on the Springfield Plateau, fecal coliform densities had a strong positive correlation with the percent of agricultural land in the watershed (Davis and Bell, 1998).

Wastewater

Springfield was the first city in the James River watershed to have sewers and the first to be heavily industrialized. As early as the 1870s, city leaders received water quality-related complaints from citizens concerned that woolen mill, tannery and gasworks wastes were polluting Jordan Creek, a tributary of the James River in the center of Springfield (Watershed Committee of the Ozarks, 2008). Springfield began installing sewers along Jordan Creek in the early 1890s to replace outhouses and cesspools. The city of Springfield constructed its first sewage treatment plant in 1912 (Watershed Committee of the Ozark, 2008).

With the advent of regulations on wastewater discharges, Wilsons Creek was designated by the state as the receiving stream for the city of Springfield’s sewage, meaning it was intended to dilute the city's treated wastewater. Protection of water quality in the James River downstream of Wilsons Creek was the primary consideration (Harvey and Skelton, 1968).

Springfield upgraded and expanded its wastewater treatment facilities several times over the years, but overloaded treatment facilities, inadequate funding for timely expansions and stormwater by-passes were continuing problems (Harvey and Skelton, 1968). Major fish kills in Wilsons Creek and the James River were reported in 1954, 1960 and 1966, all at times of low flows (<25 ft^3/sec) in the James River. In October 1977, a larger and more advanced treatment plant was placed into operation at the city's southwest location. Dissolved oxygen levels in the James River downstream of its confluence with Wilsons Creek increased, but so did levels of total nitrogen and phosphorus (Berkas, 1982).

More recently, nutrient levels in wastewater discharges have been of concern. Missouri's Water Quality Standards after 2000 required that all wastewater discharges into the Table Rock Lake watershed, including facilities in the James River watershed, achieve a discharge limit of less than 0.5 mg/l of phosphorus (Missouri Department of Natural Resources, 2001). Nixa and Springfield, both discharging on average over 1 MGD, had to comply by November 2003, while smaller facilities in the watershed had until November 2007.

Most of the small communities in the James River watershed were originally served by onsite wastewater systems, or septic tanks, and did not construct secondary sewage treatment plants until the 1980s (Perkins, 2013). Recently, there were 14 permitted POTWs in the James River watershed. Table 1 shows the permitted POTWs in the snapshot survey area and their design flows (Missouri Department of Natural Resources, 2013). None of the wastewater plants in the James River watershed discharge directly into the James River. Springfield, as mentioned above, discharges into Wilsons Creek. Rogersville, Fremont Hills, Galena and Reeds Spring discharge into tributaries of the James River. Clever, Hurley and Crane discharge into Crane Creek or its tributaries. Five municipal wastewater plants discharge into the Finley River, the largest tributary of the James River in the study area. Nixa and Ozark discharge directly into the Finley River, while Seymour, Fordland, and Sparta discharge into Finley River tributaries.

All of these plants now have phosphorus removal capabilities, most often using chemical treatment and precipitation (Perkins, 2013). Almost all of them also utilize tertiary filtration and ultraviolet light (UV) for disinfection. The exceptions are Fordland, Reeds Spring and Hurley, which do not have tertiary filtration; Springfield, which disinfects with ozone; and Fordland and Seymour, which disinfect with chlorine. Sparta, Clever, Fordland, Fremont Hills and Rogersville all discharge to losing streams. Several of the facilities have had various kinds of operating problems in the past (MDNR records). However, in July 2013, during the James River snapshot sampling event, all of the plants were believed to have been operating satisfactorily (Perkins, 2013).

Table 1: James River snapshot area publicly-owned treatment works (POTW) and design flows

POTW Facility Name (in Snapshot Survey Area)	Design or Actual Flow Million Gallons/Day
Clever	0.2
Crane	0.3
Diggins	0.045
Fordland	0.1
Fremont Hills	0.09
Hurley	0.052
Nixa	1.7
Ozark-Finley	1.0
Ozark-Elk Valley	2.1
Reeds Spring	0.27
Rogersville	0.22
Seymour	0.37
Sparta	0.2
Springfield	33.4

Stormwater Runoff

In the 1970s, when effluent from Springfield's poorly performing Southwest POTW polluted Wilsons Creek, urban runoff was noted as a significant factor (Berkas, 1982). Runoff was observed to lower dissolved oxygen levels in Wilsons Creek and the James River, but unlike that of the wastewater treatment facility, this effect was of relatively short duration (Berkas, 1980). In 1991, using *Ceriodaphnia*, Pulley et al.

(1998) detected toxicity in Wilsons Creek downstream of Springfield's Southwest POTW. Wilsons Creek was listed on the 1998 Missouri 303(d) impaired waters lists for toxicity due to unknown sources. Similarly, Pearson Creek, a James River tributary draining the Springfield's southeast urban area, was placed on the 1998, 2002 and 2006 Missouri 303(d) lists for toxicity due to unknown sources (MEC Water Resources Inc. and OEWRI, 2007).

Karst Related Problems

Water quality problems in the James River watershed have often been related to the area's development on karst topography. Shepard (1883) linked cases of typhoid fever to a cemetery located in an area of intense sinkhole development. By the latter half of the 20th century, onsite wastewater systems (septic systems) had become so numerous in the James River watershed that effects on the shallow groundwater became very noticeable. For example, the village of Galloway, just southeast of Springfield, was formerly served by septic tanks and was located on a karst plain above Sequiota Spring. Formerly the site of a state fish hatchery, Sequiota Spring became so grossly polluted with sewage that the hatchery was moved to another location (Bullard et al., 2001). Strong sewage odors emanated from the cave opening, discouraging visitation to the city park. In 1973, dye was injected into a septic tank (via a urinal) serving Sequiota School and the dye was recovered at Sequiota Spring, about 0.8 km. away (Aley, 1974).

In 1983, 75 springs in Greene County were sampled for the presence of optical brighteners, color-enhancing fabric dyes used in laundry detergents. Since laundry waste in rural areas is usually discharged into septic tanks, the presence of optical brighteners in springs indicates potential groundwater contamination by onsite systems. Forty-eight (64%) of these 75 springs were moderately positive for optical brighteners and 18 (24%) were strongly positive (Aley and Thomson, 1984). The authors concluded that 60% of the septic systems in Greene County added detectable levels of contamination to groundwater.

Nutrients

One of the first major studies focusing on nutrient levels in Ozark streams was performed as part of the National Water Quality Assessment, using water quality data collected from 1970 to 1990. The two sites on the James River had over 600 sample results recorded between 1964 and 1987, and both sites showed upward trends in both nitrogen and phosphorus over the 20-year period (Bell, 1995). At a site on the James River above Wilsons Creek and the outfall of the Springfield POTW, the maximum total phosphorus (TP) value recorded was 0.83 mg/l, while at a site on the river below Wilsons Creek the maximum TP value was 4.4 mg/l (Bell, 1995).

Other studies since 2000 have focused on nutrient levels in the James River watershed. Borchelt (2007) examined nutrient concentrations at base flow in the upper White River Basin, including the James River, finding a strong positive correlation between nutrient concentrations and wastewater discharges. In a baseline study of the Finley River, OEWRI (2007) found the highest levels of TN in the city of Ozark (3.84 mg/l), while all other sites were below 1.5 mg/l.

In the summer of 1999, a major algae bloom in the James River arm of Table Rock Lake brought immediate attention to the problems of nutrient enrichment and eutrophication. In the absence of numeric water quality standards for nutrients, heavy growths of benthic algae in the James River and James River arm of Table Rock Lake prompted the Missouri Department of Natural Resources (MDNR) to issue violations of the state’s narrative standards (Missouri Department of Natural Resources, 2001). Nutrient impairment was identified in three segments of the James River totaling 58 miles in Stone, Christian, Greene and Webster counties (Missouri Department of Natural Resources, 2001).

The James River nutrient Total Maximum Daily Load (TMDL) was approved by the Missouri Clean Water Commission in May 2001. The stated goal of the TMDL was to reduce benthic algae blooms in the river and lake to less than 100 mg. of algal mass per square meter of substrate (Missouri Department of Natural Resources, 2001). James River in-stream target limits for total nitrogen (TN) and total phosphorus (TP) were set at 1.5 mg/l and 0.075 mg/l, respectively, to be determined during base flow conditions. The new targets were intended to reduce the phosphorus loading in the James River at Galena from an estimated 850,000 pounds per year in 2001 to 155,600 pounds, and nitrogen from 5.4 million pounds per year in 2001 to 3.1 million pounds per year (Missouri Department of Natural Resources, 2001).

The Springfield Southwest POTW went on line with full phosphorus removal capabilities in February 2001. Springfield and Nixa had to be in compliance with this limit by November 2003, while the other wastewater treatment facilities in the watershed had until November 2007. Nixa began biological phosphorus removal in 2003 but because of technical problems soon switched over to chemical removal. In 2004, MDNR reported that monitoring in the James River and Table Rock Lake had documented "dramatic decreases" in phosphorus levels (Missouri Department of Natural Resources, 2004). A data gap analysis completed in 2007 showed that geometric means of TP at a site on the James River downstream of Springfield had trended downward from a high of over 1.4 mg/l TP in 1969 to less than 0.1 mg/l TP in 2004 (OEWRI and MEC Inc., 2007).

Summary

Land-uses in the James River, especially the wastewater generated by an ever increasing urban population, have had significant effects on water quality in the James River watershed. Through optical brightener analyses and *E.* coli sampling, many springs have been shown to be contaminated from onsite wastewater systems or other organic wastes. Wastewater treatment plants have contributed large loads of nutrients to the James River, especially the largest POTW in the region at Springfield. Studies have already documented these problems and steps have been taken to reduce pollutant loadings, for example by adding phosphorus-reducing equipment at wastewater plants and requiring better design and installations of onsite wastewater systems.

In spite of our better understanding of water quality problems in the James River watershed, there are still questions about the best means of attaining water quality goals. Better monitoring programs can help to understand where more work is needed, and what portions of the watershed are still experiencing water quality degradation. But monitoring programs in the past have been too restricted in geographic scope to evaluate relative inputs of pollutant from different parts of the watershed. Only larger scale programs that examine the entire watershed can discern overall spatial variability in water quality that can highlight the remaining problem areas, or delineate areas of the watershed that may need applications of better land management practices. Snapshot monitoring offers one type of strategy that can provide general guidance toward these goals.

CHAPTER 4: STUDY AREA

The James River was described by explorer Henry Rowe Schoolcraft in 1819 as a “large, clear and beautiful stream” (Schoolcraft, 1821). The river drains a portion of the Springfield Plateau, a 26,800 km^2 (10,300 mi^2) southwestern subarea of the Ozark Physiographic Province. The headwaters of the James River originate at just over 1740 feet above mean sea level (msl) in Webster County, Missouri. The river flows generally southwesterly through Greene, Christian and Stone counties to its outlet in Table Rock Lake at an elevation of about 960 msl. Major tributaries of the James River include Wilsons Creek, Finley River and Flat Creek. Smaller tributaries include Panther Creek, Pearson Creek and Crane Creek. Flat Creek, which empties into the James River arm of Table Rock Lake, was not included in the study area for this project.

The James River watershed and the Springfield Plateau are characterized by rolling hills and relatively low relief, with local elevation differences rarely exceeding 300 feet. The watershed of the James River is about 3,800 km^2 (1,450 mi^2) to its confluence with the White River in Table Rock Lake. However, the study area for this project includes only that portion of the watershed above the USGS gage at Galena, about four miles above the normal pool elevation of Table Rock Lake, comprising a watershed of 2,556 km^2 (987 mi^2) (figure 3).

Table Rock Lake, a 17,200 hectare (43,000 acre) reservoir formed by an impoundment on the White River, was completed in 1958 (Kasul, 2010). There are four other significant impoundments in the James River watershed, the largest being Lake

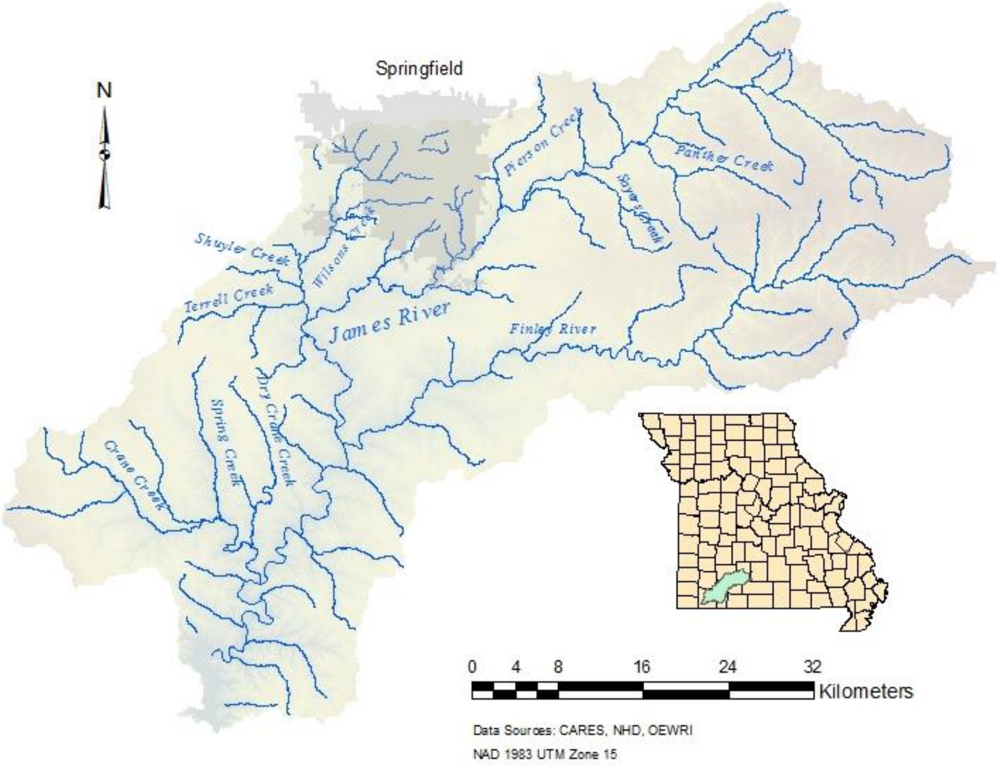


Figure 3. James River Snapshot Survey Area

Springfield, a 360-acre "run of river" reservoir serving as a source of cooling water for the city of Springfield's James River Power Plant. Three smaller reservoirs were formed by small overflow dams on the Finley River at Linden, Ozark and Riverdale, Missouri.

Geology

Bedrock in the James River watershed is mostly Mississippian age limestone that has weathered into a landscape of rolling hills (Thomson, 1894). The Burlington-Keokuk limestone is at or near the surface over much of the basin. At its upper and lower ends, the James River has incised into Ordovician rocks, primarily dolomite but also sandstone and shale. The predominance of limestone causes the streams and groundwater in the watershed to primarily be of the calcium bicarbonate type (Brookshire, 1997).

Carbonate rocks of the James River watershed are fractured and subterranean openings have been enlarged through solution by downwardly percolating rainwater. The resulting karst terrain is indicated by hundreds of springs, caves, sinkholes and losing streams (Berkshire, 1997). Sinkhole formation is greatest on the relatively flat inter-basin divides in the Springfield-Nixa-Ozark urban area (Waite and Thomson, 1993).

Solutional weathering of the carbonate rocks leaves behind previously imbedded chert fragments, which form the bulk of the bed load of Ozark streams (Jacobson and Primm, 1994). Most of the stream bed of the James River is composed of chert cobbles and gravel. Many streams in the James River watershed traverse fractured limestone and are classified as “losing,” meaning that water seeps from the channel into subsurface karst networks (Missouri Department of Natural Resources, 2014).

Soils

Upland soils in the James River watershed are largely alfisols and ultisols, which formed under deciduous forests, mostly from residuum of local limestone (Petersen et al., 1995). These soils are moderately to strongly weathered and tend to have abundant residual clays such as kaolinite and illite, as well as iron and aluminum oxides. They are also largely depleted in organic matter (Petersen et al., 1995). Most soil units in the James River watershed have a high potential for nutrients and other dissolved constituents to be leached into groundwater.

Common soil associations in the James River watershed include the following: the Pembroke-Keeno-Eldon-Creldon series, which are deep, well drained soils found primarily on uplands; the Wilderness-Tonti series, which are deep, moderately well drained soils, often with fragipans; the Viraton-Ocie-Mano series, which are deep, moderately drained soils with fragipans found on ridges and terraces; and the Reuter-Moko-Clarksville series, which are shallow to deep well drained soils found on steep slopes as well as on dissected uplands. All of these soils are classified as Ozark border soils. Sheet, rill and hill slope erosion are common forms of soil loss in the watershed. In some areas, deep fragipans have formed, particularly in the Wilderness, Keeno and Creldon soil types (MEC Water Resources and OEWRI, 2007).

Climate

The climate in southwest Missouri is temperate, with an average annual temperature of 15 degrees C (59 degrees F). Average daily temperatures in Springfield range from -1.1 degrees C (30 degrees F) in January to 26.6 degrees C (80 degrees F) in July. Precipitation is about 104 cm/yr. (41 in/yr.) (NOAA, 2014). The greatest amount of precipitation falls as rain in the spring and fall. The lowest precipitation months are typically January and February and the highest are June and September. The lowest average monthly precipitation in Springfield is in January, with 5.36 cm. (2.11 in.), and the highest is in June, with 12.75 cm. (5.02 in.). The average monthly temperature in July during the time of this snapshot survey is 25 degrees C (77 degrees F). (NOAA, 2014)

Hydrology

The mean annual discharge of the James River is 981 cubic feet per second (ft^3/sec) at the Galena, Missouri gage, the lowermost gaging site on the river before it empties into Table Rock Lake. The record high flow at Galena was 85,100 ft^3/sec on March 19, 2008, and the record low of 10 ft^3/sec was recorded on September 20, 1954 (USGS, 2014). Base flow, representing the time that most of the stream flow is contributed by groundwater, varies seasonally from about 100 ft^3/sec to 300 ft^3/sec at Galena.

Land-Use

Land uses in the James River watershed change significantly from the upper, easternmost end to the lower, southwestern end (Figure 2). Agricultural uses, primarily cattle on pastures interspersed with small patches of timber, predominate in the upper basin. In the middle section of the watershed near the cities of Springfield, Ozark and Nixa, urban and suburban uses dominate. About ten miles south of Nixa agricultural uses predominate again and continue southward. Near Table Rock Lake, forests on steep slopes and low density residential uses prevail, along with isolated areas of high density residential development near the reservoir (MEC Water Resources Inc. and OEWRI, 2007).

Agriculture. Over 50% of the land in the James River watershed is in agricultural uses, with cattle raising the most prevalent use (Kiner and Vitello, 1997). Greene and Webster counties, in the upper part of the watershed, are top ten beef cattle producing counties in the state. Although the most common agricultural use is cattle grazing, the watershed contains significant numbers of horses and other livestock, with some dairy farms interspersed.

Forests and Mining. About 30% of the land in the James River basin is forested (Kiner and Vitello, 1997). The most heavily forested sections are found in the steeper, more rugged lower sections of the watershed near Table Rock Lake and along rivers and small drainages in the upper end of the watershed. Some timber harvesting has been done in the past, particularly in the lower sections of the watershed, and limited harvesting of timber still occurs throughout the watershed. However, timber harvesting is not a major commercial activity in the watershed. Mining is also very limited, except quarrying for limestone. Some areas near Springfield were mined for lead and zinc in the late 1800s and early 1900s (Thomson, 1986), but none of this type of mining occurs in the James River watershed today.

Urban and Suburban Development. About 7% of the land area in the James River watershed is in medium and high density urban development (Kiner and Vitello, 1997). The watershed contains the largest urban center in the Ozarks, the city of Springfield. It and the surrounding communities form the Greater Springfield Metropolitan Area, containing over 300,000 people. The region has seen steep increases in population since the 1960s. Counties containing the James River watershed are among the fastest growing in the state. Projections of growth of these counties from 2000 to 2030 range from 37.2% in Greene County to 40.8% in Stone County, 71.6% in Webster County and 141.4% in Christian County (Missouri Office of Administration, 2013). Greene County grew by 15.6% in the 1990s, adding over 32,000 people. Springfield is the state’s third largest metropolitan area, but over the last few decades has grown much faster than Kansas City or St. Louis, the state's two largest urban centers. Springfield, along with the adjacent Branson area, was termed the state's leading "growth hotspot" in 2002 (Brookings Institute, 2002).

Webster and Christian counties adjacent to Springfield grew even more rapidly than Greene County. The population of Christian County, containing the middle section of the James River watershed, increased 90% between 1970 and 1990 (Brookings Institute, 2002). In the 1990s, the county grew at 66.3%, far faster than any other county in the state. Much of the growth in the James River watershed has been in unincorporated areas. In fact, this growth has been even faster than in the cities. Over 200,000 people now live in open-country areas of the Springfield-Branson region, a large portion of them in the James River watershed (Brookings Institute, 2002).

CHAPTER 5: METHODS

A water quality snapshot survey was conducted in the James River watershed in July 2013. The event was organized as a thesis project, but the sampling was done almost entirely by trained volunteers. The successful completion of the project depended on several months of prior planning; the assistance of professional water quality managers in the planning and implementation phases; the selection of volunteers who for the most part had prior field experience; and the expertise and support of the Ozarks Environmental and Water Resources Institute (OEWRI) and its staff. Fortunately, the date chosen for the event worked out well. Base flow conditions prevailed on that day. Weather conditions were favorable and all volunteers completed their sampling rounds as planned. The following sections describe details of the planning of the event, the selection of water quality variables that were monitored, the field and laboratory methods that were used and the recruitment and training of volunteers.

Event Planning

Planning of the snapshot survey began in January 2013. A planning committee assembled by the project organizer included a Project Manager from a local watershed organization and a hydrologist formerly employed by the USGS. Two meetings were held with these professionals in February and March 2013 to discuss in detail the logistics of the survey, including potential sampling sites to be used; the physical, chemical and biological tests to be conducted; and the field and laboratory resources that would be needed to carry out the project. Further discussion centered on the timing of the survey; how and where laboratory analyses would be performed; methods of recruiting and training volunteers; and the field and chain-of-custody forms that would be required. By the end of March a formal work plan had been formulated.

Sampling Event Timing

July 2013 was selected as the sampling month, as base flow conditions were anticipated at that time. Base flow conditions were desired for three primary reasons: 1) water quality is normally relatively stable during base flow conditions; 2) the influence of point sources on water quality is most noticeable during base flow periods when input loading rates are relatively high in comparison to river discharges, stormwater runoff and non-point source loads; and 3) base flow conditions present the safest time for volunteers to collect samples.

Saturday, July 13 was chosen as the target date for sampling, with subsequent Saturdays placed on the calendar as back-up dates. A summer weekend was chosen since this was felt to be the best time to obtain volunteer assistance. The trigger for deciding whether sampling would occur on the target date was as follows: if significant rain (enough to increase flow by >10% of base flow) occurred within two days of the intended sampling period and the hydrograph was still rising on the sampling day, sampling would be postponed until the next back-up date. On July 13, trigger conditions were met and the sampling event proceeded.

Site Selection

In consultation with OWERI personnel, the project organizer determined that a maximum of 100 sampling points would be selected. This would help to ensure that enough volunteers could be found to sample all sites and that no volunteer or team would have to sample more than four sites. OEWRI laboratory personnel determined that this number of samples would be within the capacity of the laboratory for analytical work. The cost of laboratory and field materials was also a consideration, as OEWRI would bear these costs.

Sample sites were tentatively selected using the following criteria:

1) The largest number of sites would be on the James River itself above Galena. The length of the river from first flow during base flow conditions to the mouth was measured on maps at about 160 km. At least 20 sites in this distance would be selected on the main stem of the James River.

2) The furthest downstream site selected on the James River would be where Table Rock Lake backed water into the river. This site might or might not be used in the subsequent data analyses. If flow was present at the time of sampling, data from this site would be used.

3) The James River and its major tributaries would be sampled from the point of first significant base flow to their mouths. The point of first flow was predetermined in March by field surveys during a low flow period.

4) The three largest tributaries of the James River (Finley River, Wilsons Creek, Crane Creek) would each have multiple sites. The length of these streams and the location and number of potential point and non-point sources of pollution in their watersheds led to the decision to include multiple sites on them.

5) Smaller tributaries with significant base flow would be sampled at one point as close to the mouth as practicable. During the assessment phase, eight small tributary streams were found to have significant flow at their mouths during base flow conditions (water was flowing in the streams and deep enough for sample bottles to be submerged). These tributaries were located in areas of differing land uses and potential sources of pollution in their watersheds, so it was desirable to include them in the monitoring event.

6) Flat Creek, a 4th order tributary entering Table Rock Lake downstream of the point where the James River entered the lake, would be excluded from the survey due to

its large size and distance from the OEWRI laboratory. Numerous sites would have been necessary to adequately characterize water quality in this large watershed, and adding that many more volunteers and sample sites to the program would have presented major logistical and financial challenges.

7) Where practicable, sampling sites on the James River and its major tributaries would be located upstream and downstream of significant tributaries. In this way, the effect of the small tributaries on the James River or on a larger tributary could potentially be determined.

8) Sampling sites on the James River and major tributaries would be no more than 10 km apart. This distance was somewhat arbitrary, but was based on the length of river miles to be sampled and the objective of having no more than 100 samples collected in the entire watershed.

9) Large springs with over 1 million gallons per day (MGD) average flows as reported in *Springs of Missouri* (Vineyard and Feder, 1974), would be sampled. Large springs in both urban and rural areas contribute a significant portion of base flow to the James River and its tributaries.

10) Sample sites would be easily accessible to volunteers. This may have been the most important criteria of all, since an attempt would be made to sample the sites very quickly in order to get the samples back to the laboratory within maximum allowable holding times.

11) Sites that had been sampled in previous studies would be given preference for the James River snapshot survey. This would be useful for comparing the snapshot data with previously collected data and for examining water quality trends over time with multiple datasets.

With these criteria in mind, maps and aerial photographs were consulted to locate potential sampling sites. On the James River and its major tributaries, most of the criteria were met rather easily due to a fairly dense network of state and county roads and numerous bridge crossing and public access points. Bridges or low water crossings were also found on most of the minor tributaries near their confluence with the larger rivers. However, due to the distance between suitable access points, three reaches on the James River exceeded the distance criterion (max. 12.1 km), and one reach of the Finley River exceeded the criterion (11.2 km). Exceptions to the criterion were made in these locations since there were no easily accessible intermediate access points.

Map reviews and exploratory field work resulted in the selection of 75 sites for further investigation. Each of these potential sampling sites was visited in the early spring of 2013 to verify flow conditions (flows were relatively low in March) and determine accessibility. Potential sites were also evaluated for degree of public use (e.g., fishing, swimming), ease of access from parking areas to the water (e.g., fences, high bridges, steep slopes) and volunteer safety (e.g., dangerous shoulder parking). In several stream reaches, there were several access points in succession that were less than 10 km apart, so the one with the best access and spatial considerations (e.g., about halfway between two set sampling points) was chosen. Several of the bridge sites identified on maps were rejected from further consideration because access was poor and/or suitable parking was not available. At springs, attempts were made to contact landowners, often by leaving notes on doors, but few contacts were made in this manner. Some spring landowners were reached after obtaining contact information from previous researchers who had sampled these springs. Flow conditions were visually assessed over the next few months at sites on smaller streams to determine if base flows were likely to be available for sampling in July. Because of this preparatory field work, only one of the sites visited on July 13 had insufficient flow for sampling.

Seventy-one sites were eventually selected for snapshot sampling. Figure 4 is a map of the study area showing all of the selected sampling locations. Appendix A is a list of these sites, their general locations and notes about some sites. The coordinates of each of the sampling sites is given in Appendix B. Figure 5 shows the distribution of sites by

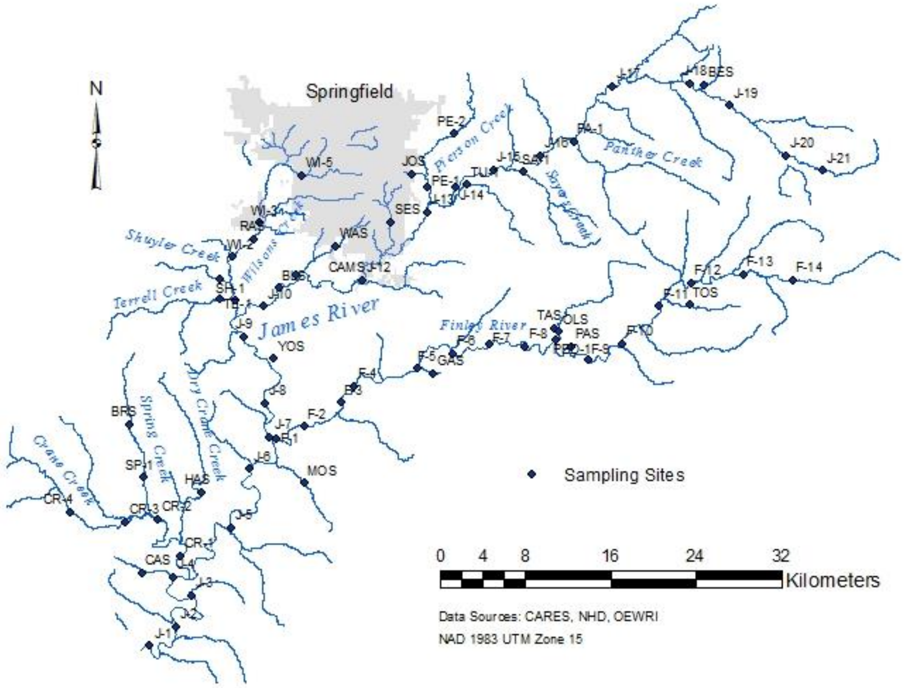


Figure 4: Sampling sites used in the James River Snapshot Study Area

waterbody type. Twenty-one sites were located on the main stem of the James River, 14 on the Finley River, 5 on Wilsons Creek, 4 on Crane Creek, 2 on Pearson Creek, 7 on smaller tributaries and 17 at springs.

These sites were plotted into a GIS watershed base map using Arc-Map and aerial photography to identify to the extent possible the precise location of the sampling point. After the snapshot survey, water quality results were entered into an Excel spreadsheet for water quality data assessments and GIS manipulations.

After the sites for the James River snapshot survey were selected, site selection methods from other snapshot surveys were reviewed for consistency with plans for the

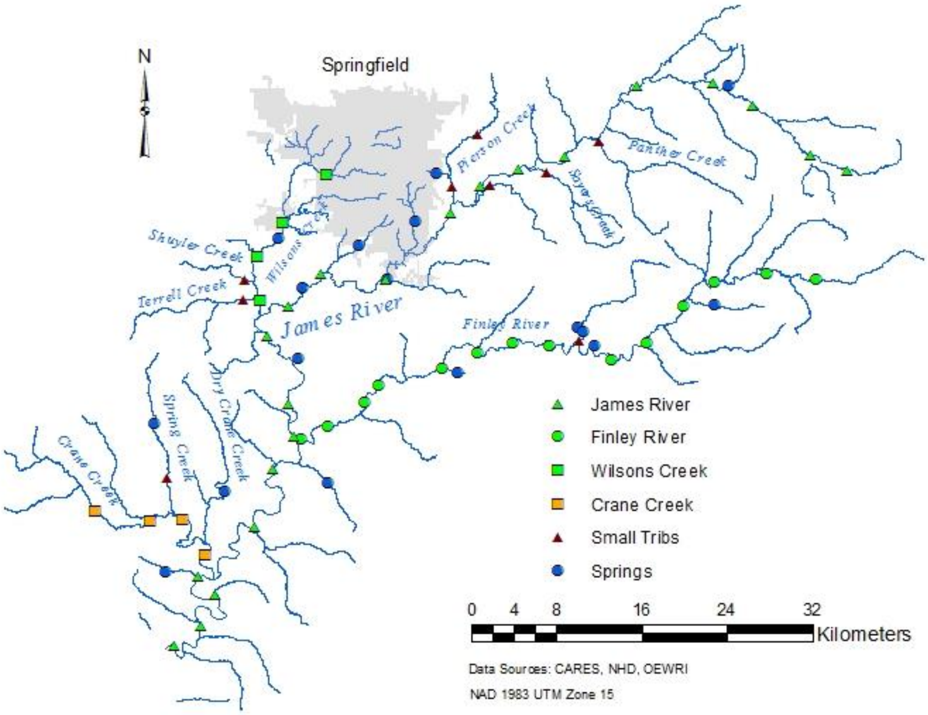


Figure 5: James River snapshot survey sites by waterbody type

James River event. In a USGS sponsored base flow snapshot sampling event in Pennsylvania, 15 sites were sampled across a 170 km^2 watershed, representing a sampling density of 11.4 km^2 per site (Loper and Davis, 1998). In an Australian base flow snapshot event, 64 sites across a 5,000 km^2 watershed were sampled, a density of 78 km^2 per site (Grayson et al., 1997). A 2011 snapshot event on the Niangua River in Missouri used 85 sites across a 2,690 km^2 watershed, a density of 31.6 km^2 per site (Thorpe, 2013). The James River watershed area to be sampled in this study was about 2,560 km.^{2} Seventy-one sampling sites in this watershed represented a density of about 36.5 km^2 per site. Thus, the James River effort generally fit within the range of values for site density computed from previous snapshot studies. After consulting with OEWRI staff, it was determined that this sampling density should fairly represent the water quality conditions found across the entire James River watershed.

Water Quality Variable Selection

For a water quality variable to be the chosen for the James River snapshot survey, the following conditions had to be met: 1) the field sampling method used by volunteers had to be quick, simple and reliable, 2) satisfactory laboratory results had to be obtainable through the collection of grab samples, 3) test to be run had to be within the capability of the OEWRI laboratory to perform and levels had to be detectable by OEWRI laboratory methods at concentrations that would typically be found at base flow, 4) to the extent possible, water quality variables should be the same as those used in previous studies, and 5) the variables should relate to known water quality concerns (e.g., TN and TP were subjects of TMDLs in the James River) With these criteria in mind, the following variables were chosen for the James River snapshot study:

Temperature. Water temperature can be taken easily, quickly and reliably by volunteers using inexpensive thermometers. The main determinants of stream temperature are solar radiation, air temperature, stream morphology, riparian zone condition and the influence of groundwater inputs (Poole and Berman, 2001). Sampling in July at base flow was expected to maximize the detection of temperature differences between spring outlets and surface streams.

Temperature can be an indicator of potential pollution sources such as wastewater discharges or power plant cooling water. Temperature is regulated as a potential “pollutant” by the Missouri Clean Water Commission. According to the state water quality standards, the highest allowable temperature in cool water fisheries, such as the James River, is 30 degrees Celsius (86 degrees F) (Missouri Department of Natural Resources, 1996).

pH. In natural waters, pH is a measure of the concentrations of hydrogen ions arising from dissociation of carbonic acid and hydroxyl ions from the hydrolysis of bicarbonate (Allen and Castillo, 2007). Rain is normally slightly acidic because of its carbon dioxide content, but water becomes more basic as dissolved acids are neutralized in soils. Very acid or alkaline water in streams or lakes is harmful to aquatic life. Because of the buffering capacity of Ozark streams in limestone or dolomite terrain, pH levels are normally on the basic side, in the 7-8 range. The Missouri Department of Natural Resources (MDNR) has established pH standards for Missouri streams of 6 to 9.

Specific Conductance. Conductivity arises from the concentration of charged ions in solution, and to a lesser extent from the composition of ionic species and temperature (Allen and Castillo, 2007). Values of specific conductance are normally reported as microSiemens per centimeter (uS/cm) by USGS water quality monitoring programs. Rock weathering and anthropogenic surface sources account for the majority of dissolved ions in river waters, but atmospheric deposition can be locally important (Allen and Castillo, 2007). Specific conductance varies a great deal spatially depending on the solubility of the local bedrock, the time that water has been underground in contact with bedrock, whether the source is dominated by inputs of groundwater or rainwater, the presence of pollution sources (such as road salt), and whether the stream is located in arid or humid climates. Conductivity varies greatly with flow rates. Base flows typically contain a relatively high but fairly consistent level of dissolved ions, largely reflecting the degree of groundwater influence.

Chlorides. Chlorides in water can derive from atmospheric deposition and the weathering of rocks. In agricultural areas, chlorides often are released to water from the application of potassium fertilizer in the form of potassium chloride (KCl). In many areas, especially in northern climates, the largest source of chlorides is the deicing of roads and bridges (Gardner and Royer, 2010). Chloride can be acutely toxic to aquatic life at high concentrations (> 900 mg/l) and chronically toxic over long time periods at much lower levels (about 250 mg/l) (USEPA, 2013).

Chloride can also be an indicator of pollution sources such as septic tanks or municipal sewage. Since chloride is biologically unreactive, it tends to pass through wastewater treatment processes unchanged. For this reason, it is also a useful tracer in nutrient release experiments and wastewater plume tracking (Vandenberg, 2005). It can be used to locate leaking sewer lines or broken infrastructure where wastewater is accessing ground or surface waters. Chloride in undisturbed Ozark streams is typically in the range of 5-10 mg/l (Brookshire, 1997).

Total nitrogen (TN). Nitrogen is a major nutrient influencing primary productivity and the activity levels of heterotrophic microbes in fresh water. Benthic and suspended algae can be limited by nitrogen or phosphorus or co-limited by both (Allen and Castillo, 2007). Due to uptake by vegetation, nitrogen levels in streams tend to be lower during the growing season. Principal sources of nitrogen in streams include fertilizers, human and animal waste, nitrogen-fixing crops such as alfalfa, and atmospheric deposition. Atmospheric deposition of nitrogen has increased greatly in recent decades due primarily to the burning of fossil fuels. In the James River TMDL, total nitrogen (TN) was established a maximum in-stream value of 1.5 mg/l (Missouri Department of Natural Resources, 2001). For this reason, the TN test was used in James River snapshot sample analyses.

Total phosphorus (TP). Phosphorus is an essential plant nutrient and enters complex biological processes in many forms. Phosphorus often occurs in streams as the soluble orthophosphate ion (PO_4), which is readily bioavailable to plants. It may also be found in aquatic environments attached to organic molecules in suspension, in dissolved organic molecules, or in particulate organic forms, primarily in bacteria and detritus (Allen and Castillo, 2007). Sources include municipal wastewater, fertilizers, manure and eroded soil particles. Most phosphorus found in wastewater is in the dissolved form, which is highly bioavailable. Non-point source derived phosphorus is usually in the particulate form, especially where erosion rates are high. Total phosphorus (TP) is considered a good measure of the overall availability of phosphorus for aquatic organisms. A TMDL has been established on the James River for TP at 0.075 mg/l in-stream concentration. This value was based on a determination of the eutrophic threshold, below which algae growth was not expected to be excessive (Missouri Department of Natural Resources, 2001). For this reason, the TP test was selected for the snapshot survey.

Escherichia coli. *E. coli* bacteria are found in the intestinal tracts of warm blooded animals. Inexpensive and reliable methods are now available for the detection of *E. coli*. Their presence in water could indicate pollution from human sewage or animal waste. The EPA has established a health level for human whole-body contact (WBC) waters at 126 *E. coli* per 100 ml. Because of its simplicity and reliability, the Colilert test method (IDEXX Company) was used for bacteriological analysis in the James River snapshot survey. Although this test also provides enumeration of total coliform bacteria as well as *E. coli*, only *E. coli* results were used in the survey since without dilution almost all samples collected were too numerous to count with total coliform.

Volunteers

With 71 sites selected for sampling, it was determined that at least 20 volunteers or volunteer teams would be needed in order to assign four or less sites to each person or team. This maximum number of sites per team was desirable from the standpoint of reducing sample collection and travel times. Volunteers were recruited through meetings with the Ozark Mountain Paddlers and through contacts with representatives of the Missouri Stream Team Program and Missouri State University. Several local watershed groups, including the Watershed Committee of the Ozarks, Table Rock Lake Water Quality Inc., James River Basin Partnership and Ozarks Water Watch also contributed volunteers.

Volunteers with previous water sampling experiences or with some knowledge of water quality monitoring were sought, and most of the volunteers selected met this description. Some volunteers were asked to help because of their laboratory backgrounds or other technical skills. The OEWRI lab manager volunteered to supervise the incoming sample station on snapshot survey day. Thirty-eight volunteers were eventually signed up for the snapshot event (see Appendix C for list of volunteers). From this pool, 25 teams or site groups were assembled, consisting of one to three individuals per team.

Site Assignments. Volunteers were assigned from one to four sampling sites each. Most teams had two or three sites. One volunteer was assigned to one remote site, and two volunteers had four sites each. An attempt was made to assign sites to volunteers that were close to their homes in order to reduce travel times and fuel costs (no one was paid mileage). However, several volunteers indicated no preference on the locations of sites for which they would be responsible. Site layout and volunteer match-ups were designed to make collection routes as short and expeditious as possible.

Training. Each volunteer who signed up for the snapshot survey received a written project overview explaining the purpose of the event and the expectations of volunteers (Appendix D). Once volunteers were firmly committed, they received an overview of sampling procedures to be used during the survey (Appendix E).

All volunteers also received training in the field on proper sampling procedures. Training sessions were mostly held in areas close to where volunteers lived or worked. No attempt was made to conduct a single training session at a central location, as was originally proposed, because getting all of the volunteers to attend such an event would most likely have proven difficult. One training session was held in the southern part of the watershed in Crane, Missouri, with volunteers who lived nearby. Training with several members of the Ozark Mountain Paddlers took place on the James River at Crighton Access in southeast Springfield. A third training session was held at Buseik State Park, about 15 miles south of Springfield. About 20 volunteers were trained during these sessions. Several volunteers were individually trained at the stream sites of their choosing, often at the sites they would later be sampling.

Each training session with volunteers lasted about an hour and consisted of the following procedural steps:

1) <u>Data Sheets</u>. Volunteers reviewed the field data sheets and the trainer explained how the sheets were to be filled out on the day of sampling (see Appendix F for sample field sheet). Each site had one corresponding field sheet. On the sheet, the volunteers recorded their names along with site conditions, water temperature and information from the pre-labelled sample containers for that site. Thus, the volunteer simply had to make sure that the correct sample containers were matched to the site.

2) <u>Grab Samples</u>. Trainers demonstrated for the volunteers the correct method of grab sampling, including pre-rinsing of the bottle and sampling in the stream facing upstream. Volunteers were instructed to collect the sample from the thalweg, if possible, or at a suitable point of turbulent flow in shallow water (in the middle of a glide or riffle) where mixing of water would be maximized.

3) <u>Bacteriologic Sampling</u>. Trainers demonstrated how to properly collect a bacteriological sample in a whirl-pak bag without contaminating the sample. This was the most difficult task for volunteers, as sometimes the bags were difficult to fill or to seal properly. Extra whirl-pak bags were taken to the training sessions to allow volunteers to practice their sampling techniques.

4) <u>Temperature Measurement</u>. Trainers demonstrated how and where to take a temperature reading. The temperatures were to be taken in the thalweg where the samples were collected and where water mixing was maximized. Thermometers had to be left immersed in the water until the temperature stabilized, and then the temperature recorded on the field data sheet.

5) <u>Sampling Location</u>. Trainers discussed with volunteers exactly where at their sites would be the best location to take samples to avoid potential contamination on the day of sampling (e.g., upstream of large groups of swimmers or cattle in the stream), especially with respect to bacteriological sampling. Since the sampling would be done in summertime, there was a good chance that swimmers might be in “swimming holes” at access points.

6) Timing of Sample Collection. Trainers discussed with each volunteer the timing of sample collection on the day of the event. This was the most difficult logistical detail in the overall sampling plan. The objective was to collect all samples within a three hour period and then perform all of the bacteriological analyses within four hours of sample collection. In order to accomplish this objective, volunteers were asked to back-calculate the overall time of their sampling run in order to determine when they should be able to deliver their samples to a runner, or in a few cases, directly to the lab. Volunteers were asked to conduct a practice run before the actual sampling day in order to determine exact travel and sampling times and then compute the earliest and latest times at which they could obtain samples and deliver them to the appointed location at the correct time. In other words, they needed to construct their own sampling window in order to minimize holding times of samples.

On sampling day, volunteers demonstrated that they were capable of working within these parameters as in almost all cases samples were collected in the planned locations and delivered within a few minutes of the appointed time. No samples were collected too early, or too late, to be used in the laboratory analyses.

Sample kits for volunteers were made up in advance and placed into sturdy cloth bags. These contained field sheets, the required number of pre-labelled bottles, whirl-pak bags, thermometers and instruction sheets for each site. Each bag was labelled with the team name and site numbers. The kits of four teams contained bottles of deionized water and extra sample bottles for use as field blanks and field duplicates. Sample kits were assembled and left for volunteer pick-up at the Watershed Committee office in downtown Springfield. Kits were made available two weeks prior to the sampling date. In some cases, volunteers had trouble getting to Springfield so kits were delivered to them at their homes, places of work or individual sampling sites.

Another group of volunteers served as “runners.” On sampling day, these people were stationed in vehicles at three sites in the watershed remote from Springfield (and the OEWRI lab). One site was about thirty miles upstream (east) of Springfield, the other two about thirty miles downstream (southwest and due south of Springfield). The runners accepted incoming samples packed in coolers from one or more teams working close by. Times were pre-arranged so that runners could pick up coolers from different teams at successive places and times along the route toward Springfield. Time was a critical factor, so runners were given the cell phone numbers of their assigned volunteers, and vice versa, in the event of problems. Runners did not remove samples from coolers but took the closed coolers directly to the OEWRI lab to be handed off along with chain-of-custody forms. Volunteers were asked to put their names on coolers so they could be returned after the sampling event.

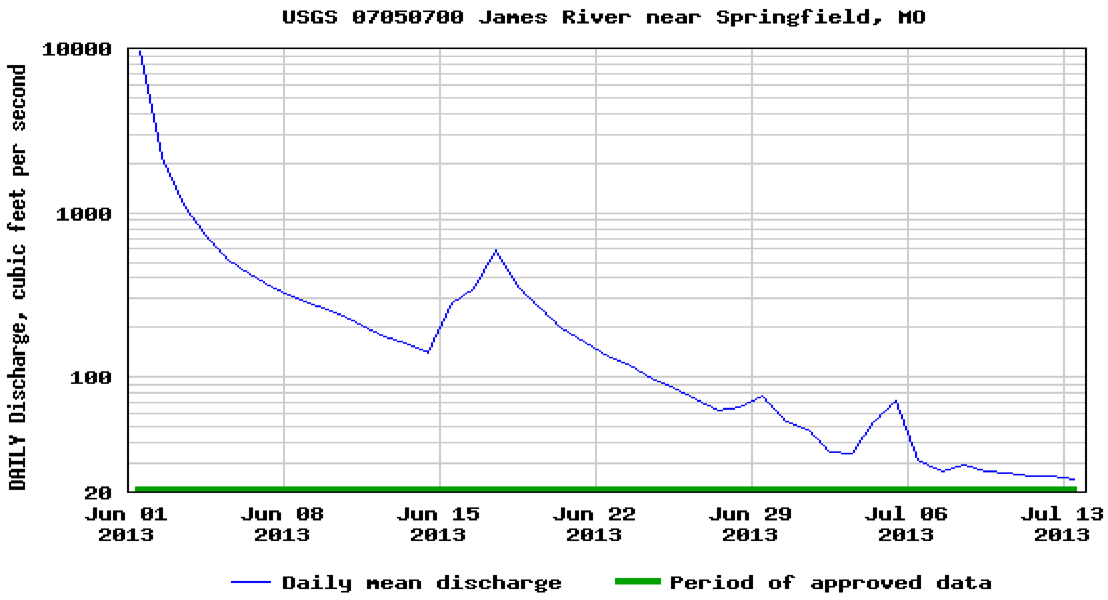
In the few days leading up to the planned July 13 snapshot survey, volunteers were kept notified by e-mail or phone of the likelihood of suitable sampling conditions. A few volunteers developed conflicts prior to sampling day and replacements had to be obtained. Fortunately, a small pool of back-up volunteers had already been recruited and trained. Runners were in close contact with the project organizer in the few days preceding the event in case of vehicle problems or if any of the planned pick-up sites had to be changed due to road construction or other factors. Some of the rural routes were scouted for possible road work, bridge closings, etc. Field checks by the planning team in the days preceding the event at sites on the uppermost sections of the James River and its major tributaries indicated there would be enough flow to sample on July 13.

Event Day Logistics

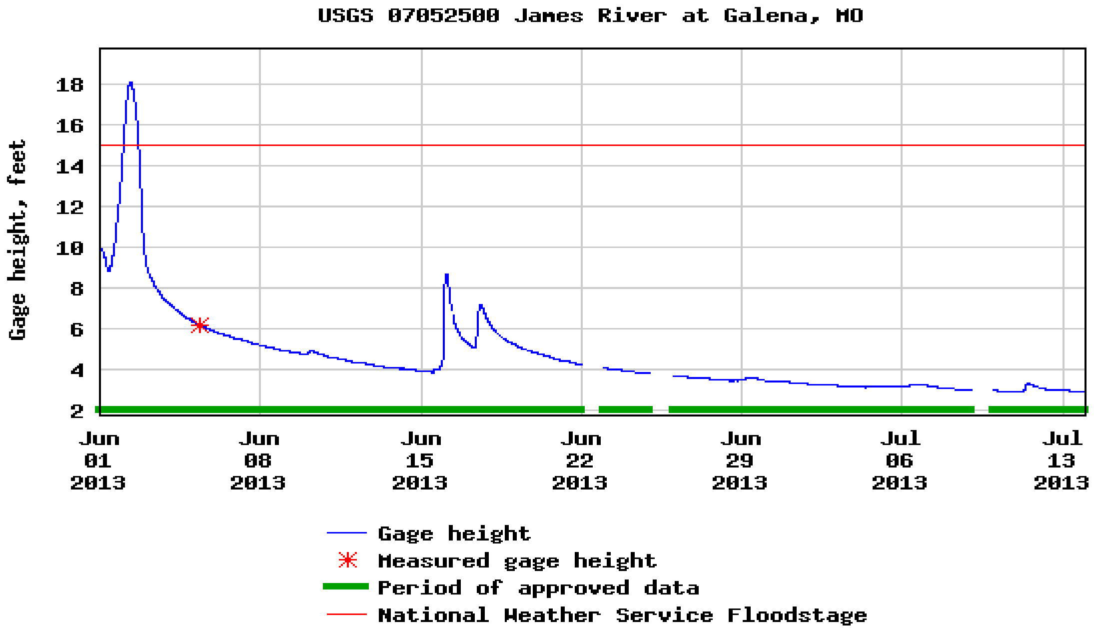
Antecedent Conditions. In the week before the survey day, volunteers were notified that conditions appeared favorable for collection. The last rain event occurred two days prior to the event, with only a small and quickly subsiding hydrographic peak. In Springfield, only 5.7 cm (2.26 in) of rain had been recorded in the month of June (average 12.3 cm), with over 2.5 cm (1.0 in) of this amount falling June 15-17. The previous greater than flood stage event had occurred on June 2-3, when the river reached a gage height of 18 feet at Galena, corresponding to about 24,000 ft^3/sec. A smaller peak in the hydrograph of about 7,000 ft^3/sec occurred after the June 15-17 rainfall event. In July, it rained on two days preceding the July 13 sampling event: 1.1 cm (0.45 in) on July 3 and 1.9 cm (0.73) inches on July 10. After the July 10 event, the river rose slightly at Galena from 220 ft^3/sec to 400 ft^3/sec, but quickly fell back to less than 300 ft^3/sec and was still declining on July 13. Near Springfield, the James River hydrograph was also declining, with a discharge on sampling day of about 25 ft^3/sec. No rain had fallen in the two days preceding the snapshot sampling event (see Figure 6, James River hydrograph for June 1 through June 13, 2013 at the Galena USGS gaging station).

On July 13, the low air temperature recorded at the Springfield Airport was 17.6^0 C, 1.6^0 below average. Maximum air temperatures in the preceding five days had ranged from 31^0 C to 35^0 C. July 13 was warm and dry, but not excessively hot at 20^0 C

Sample Collection. All sample sites were visited by volunteers within the required time frames. Volunteers recorded data on their field sheets along with any observations about the site surroundings. Because of the time of day when sampling



6a.



6b.

Figure 6: James River hydrographs at USGS gaging station sites at Springfield (6a) and stage height at Galena (6b) for the week preceding the July 13, 2013 snapshot survey.

occurred (around noon) and the relative coolness of the weather, there were few swimmers at or near most of the sampling sites. No major problems were reported with site access or sampling procedures. All samples were returned to runners within the allotted time frames and all runners delivered coolers to the OEWRI laboratory within the allotted time frames. Seventy sites in the James River watershed were sampled. One of the planned sites on Wilsons Creek, WI-4, was not sampled on July 13 due to no flow (this is in a prominent losing section of the stream).

Laboratory. Six volunteers were assigned to the incoming sample station and laboratory at Missouri State University. One volunteer collected coolers from runners who pulled up in their vehicles at the west door of Temple Hall (where the OEWRI laboratory is located) so they would not have to take time to find places to park. This volunteer then took the coolers to a receiving station set up in the hallway of Temple Hall near the laboratory. At this station, the OEWRI lab manager, volunteering for the day, logged in samples and signed chain-of-custody forms. He marked samples off the master list as they were received. He also checked the time of sample collection on the field sheets and made sure that the earliest collected samples were sent to the laboratory first. The volunteer at the receiving station placed logged-in sample containers into boxes along with data sheets and transported them into the laboratory.

For the purpose of the snapshot sample analyses, the OEWRI laboratory had previously been functionally divided into four stations, with one volunteer in charge at each station. Samples arriving in the laboratory were organized at the first station, a large table near the door. A volunteer at this station poured about one half of each one-liter sample container into a 500-ml sample container. At a second station, under an exhaust hood, another volunteer (a trained lab analyst) acidified the 500-ml bottles for later nutrient analyses and placed these bottles into the refrigerator. The remainders of the samples in one-liter bottles were also capped and placed in the refrigerator.

At a third station, a trained OEWRI volunteer received and prepared the bacteriological samples in whirl-pak bags by adding Colilert reagent to each bag. The bags were then placed in a rack and delivered to the next volunteer at the tray filling and incubation station.

At this fourth station, an OEWRI trained volunteer labelled Quanti-trays, placed samples into them, sealed the trays and placed them into the pre-heated incubator. Twenty-four hours later, the trays were pulled from the incubator and the results read by OEWRI personnel. On that day, pH and conductivity tests were also run by OEWRI personnel on all samples in the one-liter containers pulled from the refrigerator. Within the next two weeks, OEWRI personnel ran chlorides, total nitrogen and total phosphorus on the samples in 500-ml containers pulled from the refrigerator.

Field and Laboratory Methods

The following sections describe the field and laboratory methods used for each of the seven water quality variables in the snapshot survey. The results of all the analyses can be found in Appendix G.

Temperature was measured in the field at each site by trained volunteers using thermometers supplied by the Missouri Stream Teams Program. A water temperature reading in degrees Celsius was recorded on each field sheet along with the time and volunteer's name and site observations. Thermometers were obtained from the Missouri Stream Team Program and are accurate to about ± 0.5 degree C.

pH determinations were made on refrigerated samples in the OEWRI laboratory within twenty-four hours of sample collection using an Oakton hand-held pH meter. The precision of this instrument is ± .01 pH unit. The instrument was calibrated using pH buffer calibration standards of 7.00 pH and 4.00 pH. The pH probe tip was rinsed with deionized water between each measurement. Both field and laboratory bench sheets were used and all results were recorded on laboratory data sheets.

Conductivity was measured on refrigerated samples in the OWERI laboratory within 30 hours of collection using a Hach Model 44600 Meter. The practical detection limit for this meter is 2 uS/cm. Temperature compensation on this meter is automatic. The conductivity probe was rinsed with deionized water between each reading. Both field and laboratory blanks were used and all results were recorded on laboratory data sheets.

Chlorides were measured in the OEWRI laboratory on refrigerated samples within two weeks of collection (maximum holding time 28 days) using an Accumet Excel XL25 Dual Channel pH/Ion Meter for chloride concentration determination. The practical detection limit for this instrument is 0.1 mg/l. The accuracy of the instrument is ± 10% Relative Percent Difference (RPD) and the precision is ± 10% RPD. Both field and laboratory blanks were used and all results were recorded on laboratory data sheets. The Standard Operating Procedure for the OEWRI laboratory chloride determination can be found at <http://oewri.missouristate.edu/assets/OEWRI/chloride/R02.doc>

Total nitrogen (TN) was measured in the OEWRI laboratory on refrigerated samples within two weeks of collection using a spectrophotometer. Samples were combined with an alkaline persulfate oxidizing solution and heated to approximately 120 degrees C, thus converting nitrogen compounds to nitrates. Digested samples were acidified with HCl and then absorbance was measured at three wavelengths (230 nm, 225nm, and 220 nm). Absorbance data were used to compute the second derivative at 225 nm. Comparison of the second derivative with that of similarly treated standards allowed an estimation of TN. The detection limit for this method is ≤ 0.1 mg/l TN. The upper range is 5 mg/l TN, the precision is ± 20% RPD, and the accuracy is ± 20% RPD. Both field and laboratory blanks were used and all results were recorded on laboratory data sheets. The Standard Operating Procedure for the OEWRI laboratory Total Nitrogen determination can be found at http://oewri.missouristate.edu/assets/OEWRI/Total_N_Genesys10SUV-VIS

Total phosphorus (TP) was measured in the OEWRI laboratory on refrigerated samples within two weeks of collection using a spectrophotometer (EPA method 365.2). All forms of phosphorus were converted to orthophosphate using an acid-persulfate digestion. Ten milliliter volumes of sample were combined with sulfuric acid and potassium persulfate and heated to approximately 120 degrees C, thus converting phosphorus compounds to orthophosphate. The digested samples were then analyzed for orthophosphate based on reactions with a combined reagent containing ammonium molybdate, antimony potassium tartrate, and ascorbic acid to form intensely colored molybdenum blue. The detection limit for this method is 0.005 mg/l TP, the precision is ± 20% RPD, and the accuracy ± 20% RPD. Both field and laboratory blanks were used and all results were recorded on laboratory data sheets. The Standard Operating Procedure for the OEWRI laboratory Total Phosphorus determination can be found at http://oewri.missouristate.edu/assets/OEWRI/Total_P_AbsorbanceGenesysR01.doc

E. coli determinations were made in the OEWRI laboratory immediately upon receipt of the samples using the IDEXX Quanti-Tray 2000 System. All samples were run within four hours of collection time. The detection limit for this method is 1 most probable number (MPN) per 100 ml. Samples were collected in EPA-approved Whirl-Pak Coli-Test Bags. Colilert reagent was added to undiluted samples either directly in the Coli-Test bag or in sterilized glass beakers. The Colilert reagent was mixed in the samples to dissolve. Samples were transferred to IDEXX Quanti-Trays and sealed using the Quanti-Tray sealer and then incubated at 35.0 degrees C (± 0.5 degrees C) for 24 hours. Quanti-Tray cells with color change were counted, with a yellow color indicating total coliform and fluorescence under a U.V. “black light” indicating *E. coli*. Colored cells were counted in both cases and a chart used to determine MPN. Field blanks and sample results were recorded on laboratory data sheets. The Standard Operating Procedure for the OEWRI laboratory *E. coli* determination can be found at http://oewri.missouristate.edu/assets/OEWRI/4010R03_EcoliIDEXX.doc

Data Management and Quality Assurance

All SOPs for laboratory methods were strictly followed. Data was entered into the OEWRI laboratory database in Excel spreadsheets from results recorded on the bench sheets. Graphs were made and rank correlations were run with SPSS (version 19). For each water quality variable, analysis of variance (MiniTab, version 16) was used to test for differences in means among waterbody types. When the null hypothesis was rejected, a Tukey Test was used to determine which groups were different from each other. Assumptions of homogeneous variance and normality were checked and, if not met, data were transformed or a nonparametric Kurskal-Wallis test was employed.

Due to the large number of *E. coli* samples that needed to be run on snapshot sampling day and an attempt to stay within a tight deadline for getting the samples prepared for incubation, an "assembly line" process was utilized in the laboratory where several (up to 12) whirl-pak bags were opened at the same time and reagents poured into each bag. Each bag was then closed and the reagent mixed by shaking. But since some bags were not mixed for several seconds after reagent addition, and possibly because the water in the bags was cold, the reagent may not have become completely mixed. This could explain why there was no color change in some or all of the cells in several IDEXX trays after incubation. There is also a possibility that because so many trays were stacked in the incubator, incubation temperatures were not distributed evenly among the trays.

For quality assurance purposes, only cells in trays that exhibited strong color change were counted. Sites whose trays showed no color in cells, or very light or erratic color changes (e.g., all or most vertical cells on one side of the tray colored, the other side clear) were selected for resampling. Samples from nineteen sites met these criteria. These sites were re-sampled by the project organizer with 72 hours of the July 13 event. The discrepancies in sampling times are noted in the results, found in the Appendix G. However, since there had been no rain in that 72 hour period since July 13 and all sites remained at base flow, these later samples were included in the overall bacteriological results.

Problems were encountered with snapshot sites SH-1 and WI-2, located on Shuyler Creek and Wilsons Creeks. Upon examination of the results from the two sites, and after discussions with the volunteer responsible for collecting the samples from both sites, it was determined that samples from the two sites had inadvertently been placed in the wrong pre-labeled containers. The data from the two sites were subsequently switched in the water quality results database.

CHAPTER 6: RESULTS AND DISCUSSION

The following sections report and discuss the analytical results and spatial distributions of each of the seven water quality variables used in the snapshot survey: 1) temperature; 2) pH; 3) specific conductance; 4) chloride; 5) total nitrogen (TN); 6) total phosphorus (TP); and 7) *E. coli* bacteria. The results are examined by individual waterbody type, beginning with the James River followed by tributaries and then springs. For each indicator, the results are compared with those of recent studies on that individual waterbody or waterbody type, especially where sampling sites in those studies matched up precisely with locations used during the snapshot survey. The results of the James River snapshot survey were also compared with those from a similar snapshot event held in the Niangua River watershed in May 2011. The Niangua watershed is adjacent to the James River Watershed to the northeast. That study included a similar number of sites and waterbody types.

Temperature

The high air temperature recorded on July 13, 2013 was 30^0 C at the airport in Springfield. The previous three days had near normal temperatures for summer, with daily high temperatures between 30^0 C and 32.5^0 C. Water temperatures at all sample sites were below the air temperature on July 13, ranging from a low of 13^0 C at Patterson Spring on the Finley River to 27^0 C at two sites on the upper James River (Figure 7). Springs had the lowest median temperatures of 15^0 C, while James River sites had the

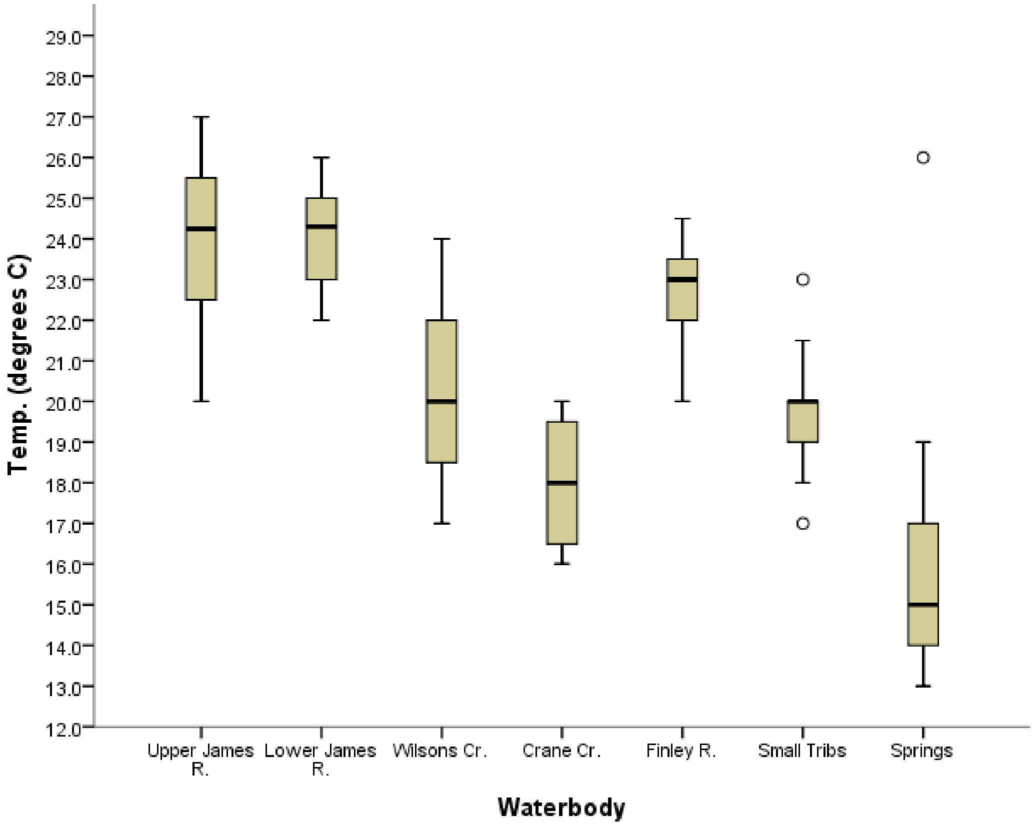


Figure 7: Temperatures of snapshot sites by waterbody type. Note: All boxplots show minimum, first quartile, third quartile and maximum, with a line representing medium values. o = outliers, cases with values between 1.5 and 3 box lengths from upper and lower edges. * = extremes, cases with values > 3 times the box length. For this and all succeeding boxplots, n = 12 for upper James River, n = 9 for lower James River, n = 4 for Wilsons Creek, n = 4 for Crane Creek, n = 7 for tributaries and n = 17 for springs. For temperatures, variance among waterbody types was significant (F = 29.02, P < 0.001).

highest median temperature of 24^0 C. Differences in mean temperature among waterbody types was statistically significant (ANOVA, F = 29.02, P < 0.001). Tukey Test results indicated that springs were significantly cooler than all other waterbody types except Crane Creek, and the James River and Finley River were significantly warmer than all other waterbody types except Wilsons Creek.

James River. Temperatures at sites on the James River ranged between 20^0 and 27^0 C. However, the general pattern of temperature change in the James River did not follow the “normal” pattern of large streams, where temperatures typically increase rather uniformly downstream as streams grow larger and wider (Allan and Castillo, 2007). Normally, this is particularly true in summer, as wider streams have less overhanging riparian cover and more surface area is exposed to sunlight. In contrast, the highest temperatures in the James River were found in the upper reaches (Figure 8).

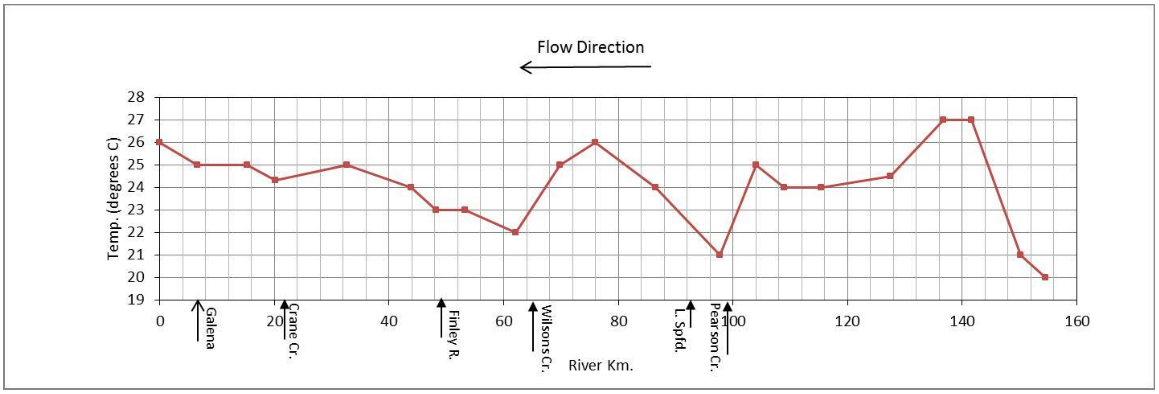


Figure 8: Snapshot site temperatures on the James River by kilometers upstream of Table Rock Lake

The temperature gradient in the James River may show the effects of groundwater influences during base flow conditions. The lowest temperature recorded in the river (20^0 C) was at the uppermost site, just below the point where first flow arises from a series of springs in the riverbed. The water warms rapidly, however, reaching its maximum temperature of 27^0 C only about 13 km downstream. Temperatures then decrease below this point as spring-fed tributaries such as Panther Creek enter, but especially near Springfield where Pearson Creek, a largely spring-fed stream (containing the major flow of Jones Spring) and Galloway Creek (containing the flow of the even larger Sequiota Spring) enter the river.

The river warms significantly again in Lake Springfield, as would be expected in open, quiescent water in summer. Warmed cooling water from the James River Power Plant also enters Lake Springfield just upstream of the dam. The temperature of the river drops again after passing Camp Cora Spring and the confluence with Wilsons Creek (range of three sites 20^0 C to 24^0 C). Below this point, temperatures in the James River increased slowly downstream from about 23.5^0 C at the confluence with the Finley River to 26^0 C at Blunks Access (site J-1), 48.2 km downstream.

Tributaries. Spring-influenced tributaries generally had lower median temperatures (19.5^0 C) than the James River (24.3^0 C). Crane Creek had an even lower median temperature (18^0 C) than tributaries in general, which may be explained by the large springs in its headwater regions that provide permanent flow. This relatively constant low temperature has allowed Crane Creek to become important trout habitat and provides a unique fishing resource, one of only two creeks in Missouri where self-sustaining populations of trout are found (Kiner and Vitello, 1997).

Springs. Springs ranged in temperature from a low of 13.5^0 C at Ollie Lasley Spring in Webster County to a high of 26^0 C at Bell Spring, also in Webster County. Bell Spring rises in an extended area of about 100 yards along a tributary stream, and there is some mixing with surface stream water above the sampling point. However, this temperature reading may have been in error. All of the other springs in the snapshot survey were within the range of 14^0 C to 17^0 C.

Summary. To a great extent, the temperature of surface streams in the study area reflects the influence of groundwater, particularly the inputs of springs to smaller streams. Larger streams, such as the James River and Finley River, tend to have temperatures elevated above those of smaller tributary streams. Tributary streams such as Crane Creek that largely emanate from springs and that have fairly dense riparian cover tend to maintain lower temperatures throughout their lengths. Stream sites immediately downstream of Lake Springfield tend to have somewhat elevated temperatures due to the surface warming effects of the reservoir and the rebounding of temperatures below the confluence of spring-fed Pearson Creek.

Springs tend to have the lowest temperatures of all the waterbody types, since this groundwater reflects the average annual air temperature and therefore the temperature of the host bedrock (which tends to remain at a constant temperature). Most bedrock springs in the Ozarks remain near the average annual air temperature of about 15 degrees C (Vineyard and Feder, 1974). Variations of temperature among springs in the snapshot survey are difficult to explain. Some of the differences may be due to sampling errors. But the differences could also reflect urban influences such as stormwater runoff (e.g., Sequiota Spring) or treated wastewater accessing subsurface conduits during low flows in Wilsons Creek (e.g., Rader Spring).

pH

The pH values at all snapshot survey sites were between 7.0 and 8.1, as would be expected of springs and streams draining well-buffered limestone terrain (Figure 9, 10) (Allen and Castillo, 2007). Nineteen sites in the study had a pH greater than 8. For evaluating differences among waterbody types, ANOVA assumptions failed, and so the null hypothesis was evaluated using a Kruskel-Wallis Test. Test results indicated a significant difference between springs and other waterbody types (H = 19.71, 5 d.f., P = 0.001).

James River. The highest pH reading in the survey (8.16) was recorded in the James River at Jamesville, just above its confluence with Finley River. Generally, pH increased from the upper to the lower James River, from 7.85 pH at the uppermost site to 8.07 pH at Galena. However, the lowest pH reading was found at Camp Cora on the middle section of the river south of Springfield, just above the confluence with Camp Cora Spring (7.62).

Tributaries. pH values at sites on the Finley River generally increased downstream, from 7.73 at site F-14 on the upper river to 8.13 at site F-1, near the mouth. Crane Creek pH values also increased downstream, from 7.33 at the uppermost site (CR-4) to 8.11 at site CR-1 near the mouth. Wilsons Creek had the lowest median pH values of the tributary streams, at 7.74. All Wilson Creek sites had pH values between 7.35 and 7.94. The pH values of the seven smaller tributaries ranged from 7.28 pH (Pedelo Creek) to 8.02 pH (Spring Creek).

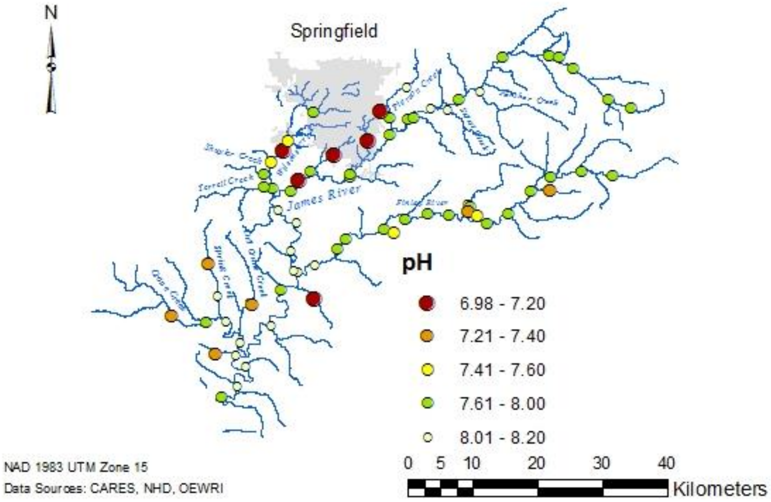


Figure 9: Snapshot survey site pH values.

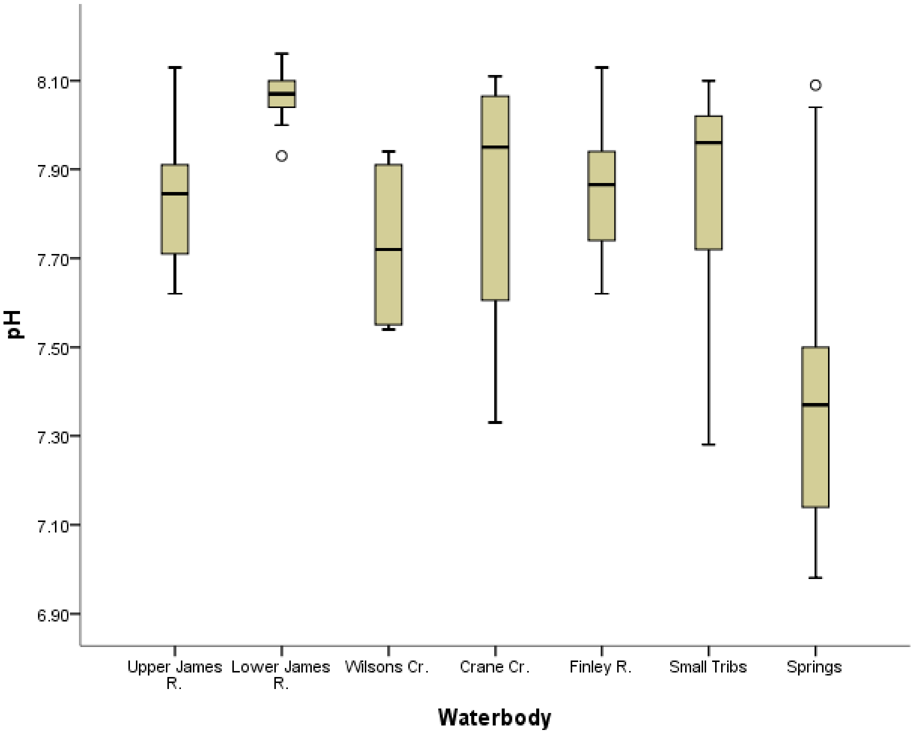


Figure 10: Snapshot Survey pH values by waterbody type (H = 19.71, P = 0.001)

Springs. The lowest pH recorded in the snapshot survey, 6.98, was at Jones Spring. The lowest median value of all waterbody types was also in springs, at 7.36, although Young Spring and Tallman Spring, both in rural areas, were outliers with pH values above 8.00. Generally, springs have lower pH values than surface streams because of the absorption of CO_2 and resulting acidification of downwardly percolating water (White, 1988). When spring waters emerge and are aerated, pH values tend to rise.

The pH readings of Ozark streams and springs have rather consistently fallen between 7 and 8.1 in all of the datasets examined (e.g., OEWRI, 2007; Borchelt, 2007; MEC Water Resources Inc., 2007). To a large extent, this reflects the bicarbonate buffering system of groundwater and streams in carbonate terrain, which tends to keep the pH fairly stable and slightly above neutral pH (Allan and Castillo, 2007).

As in other studies, springs in the study area tended to have lower pH values than surface streams. Most of the surface stream sites had median pH values between 7.85 pH and 7.95 pH. Wilsons Creek was the exception, with a median pH value near 7.75 pH, which may reflect the influence of treated municipal wastewater. Treatment processes at the Springfield POTW may tend to alter the pH of the effluent, or the lower pH value in Wilsons Creek might reflect the fact that the treated wastewater is primarily drinking water that has been “softened” in the lime-softening process at the drinking water treatment plant.

Specific Conductance

Specific conductance values in the survey ranged from a high of 1106 uS/cm in Wilsons Creek just downstream of the Springfield Southwest POTW to a low of 314 uS/cm in Pedelo Creek, a spring-fed tributary of the Finley River flowing through a heavily wooded and fairly remote portion of the watershed (Figures 11, 12). Specific conductance median values were highest in Wilsons Creek downward through springs, tributaries, James River, Crane Creek and Finley River. For differences among waterbody types, ANOVA assumptions failed, and so the null hypothesis was evaluated using a Kruskel-Wallis Test. Results indicated a significant difference among groups (H = 19.71, P = 0.001). Wilsons Creek had significantly higher conductivity than the other waterbody groups.

James River. Specific conductance levels in the James River reach a high in the upper river of 456 uS/cm at site J-19 (Highway A), then recede downstream to about 350 uS/cm at Crighton Access, at the southeastern edge of Springfield above Lake Springfield. Levels remain in the 400+ uS/cm range from Crighton Access to the confluence of Wilsons Creek. Below the confluence of Wilsons Creek, levels rise again to above 500 uS/cm, and remain above 500 uS/cm at the next two sites downstream. Levels gradually decrease again downstream. However, at Galena, the conductance level (449 uS/cm) is still above the level at Crighton Access (416 uS/cm).

Tributaries. The highest tributary conductance value in the snapshot study was on Wilsons Creek at site WI-3 (1106 uS/cm), just below the outfall of the Springfield Southwest POTW. The levels declined downstream to 736 uS/cm at the lowermost site

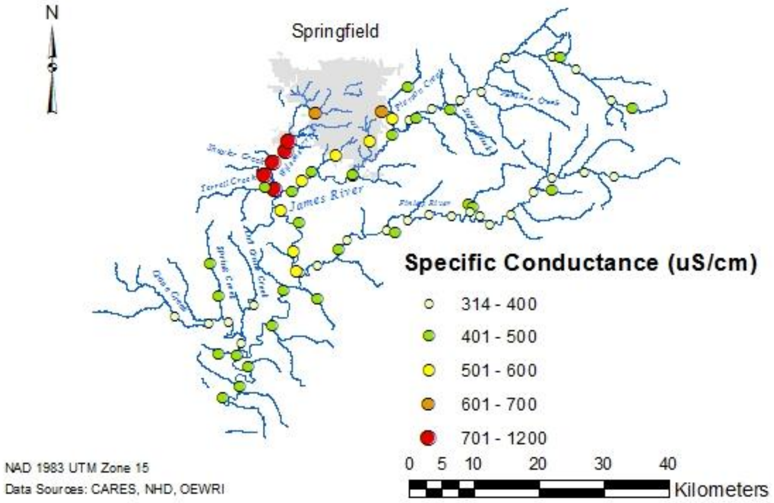


Figure 11: Snapshot survey site conductance values

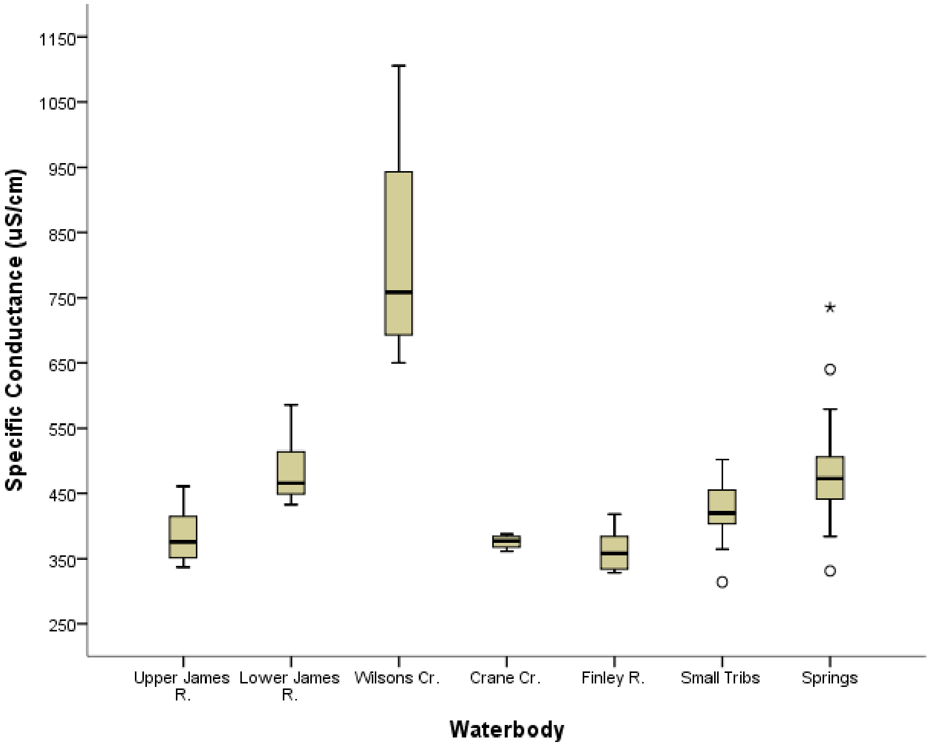


Figure 12: Snapshot survey site conductance by waterbody type (H = 31.94, P < 0.001)

on Wilsons Creek, WI-1. The uppermost site on Wilsons Creek (WI-5, Scenic Ave.), above the POTW outfall, also had a relatively high reading (650 uS/cm). The median specific conductance value in Wilson Creek (700 uS/cm) was the highest of waterbody types, and the median value in the in Finley River (360 uS/cm), was the lowest of the waterbody types. Values increased slightly at the four sites on the Finley River below the Ozark/Nixa POTW influence (383 uS/cm to 413 uS/cm). Crane Creek had the second lowest median value (370 uS/cm) of the tributaries, with all four sites tightly clustered. Small tributaries ranged between 314 uS/cm at Pedelo Creek to 455 uS/cm at Turners Creek.

Springs. After Wilsons Creek, springs had the second highest median conductivity value of waterbody types (470 uS/cm). The four highest spring conductivities were found in urban springs, with Rader Spring the highest (735uS/cm), followed by Jones Spring (640 uS/cm), Ward Spring (579 uS/cm) and Sequiota Spring (575 uS/cm). Most springs in rural areas had lower levels, from the mid-400s down to the lowest value, 331 uS/cm, at the remote and undeveloped site of Patterson Spring. These spring conductance results match up rather well with the spring chloride results, in that four of the five highest chloride readings were also at urban springs: Rader (85.68 mg/l), Ward (58.47 mg/l), Jones (44.05 mg/l), and Sequiota (43.75 mg/l). The third highest spring chloride reading, however, was at Ollie Lasley Spring, which had a chloride level of 52.09 mg/l but a specific conductivity of only 409 uS/cm. This spring is in a remote and undeveloped, heavily forested area.

Previous Studies. Borchelt (2007), in the Upper White River Basin Study (WRBS) collected conductivity results at 7 of the same sites that were utilized in the

James River snapshot survey. Table 2 shows the comparisons of the values between the two studies, with the single snapshot value and the minimum, maximum, mean and median values of the WRBS samples. For all sample sites in the snapshot survey except WI-3, specific conductance values were between the minimum and mean values in the WRBS. At site WI-3 on Wilsons Creek just below the outfall of the Springfield Southwest POTW, the snapshot value (1100 uS/cm) was slightly higher than the mean value from the WRBS. Generally, these results show no significant changes in conductance values at these sites between 2007 and 2013.

Summary. Conductivity values were by far the highest in Wilsons Creek, largely reflecting the influence of the outfall of the Springfield Southwest POTW (USEPA, 2014). However, the uppermost site on Wilsons Creek, above the outfall of the Southwest POTW, was also elevated above most of the other surface sites in the snapshot survey. The elevated conductivity at this site could indicate an influence from the surrounding urbanized zone. Springs generally had higher conductivity values than the James River and tributaries, reflecting the effects of the dissolution of limestone on groundwater chemistry.

Chlorides

James River chloride values were generally higher than its tributaries, except for Wilsons Creek. Of the tributaries, Wilsons Creek had the highest chloride values and Crane Creek the lowest, with the Finley River the second lowest. However, tributaries and springs exhibited a relatively wide range of chloride values (Figures 13, 14). For

Table 2: Specific conductance: snapshot survey results compared with the Upper White River Basin Study (WRBS) results

Site	Upper White River Basin Study Conductivity (uS/cm)				Snapshot Cond. uS/cm
	Min.	Max.	Mean	Median	
WI-5	310	1000	730	740	650
WI-3	560	1520	1050	1040	1100
J-8	110	850	500	450	520
J-13	400	670	530	550	420
J-2	330	970	620	590	450
PE-1	420	770	580	580	500
F-3	380	690	510	490	420

differences among the waterbody types, ANOVA assumptions failed, and so the null hypothesis was evaluated using a Kruskel-Wallis Test. Results indicated a significant difference between Wilsons Creek and the other waterbody types ($H = 28.70$, $p < 0.001$), and on the James River above and below the confluence with Wilsons Creek.

James River. James River sites had the second highest median chloride value of all waterbody types at 25 mg/l. Relatively high chloride values were found at the uppermost sites on the James River, tending downward as the river approached the Springfield urban zone (Fig. 15). Levels remained generally elevated (58.2 mg/l to 32.11 mg/l) at all sites in the James River downstream of its confluence with Wilsons Creek. This is not surprising, as chloride is a conservative anion which does not enter readily

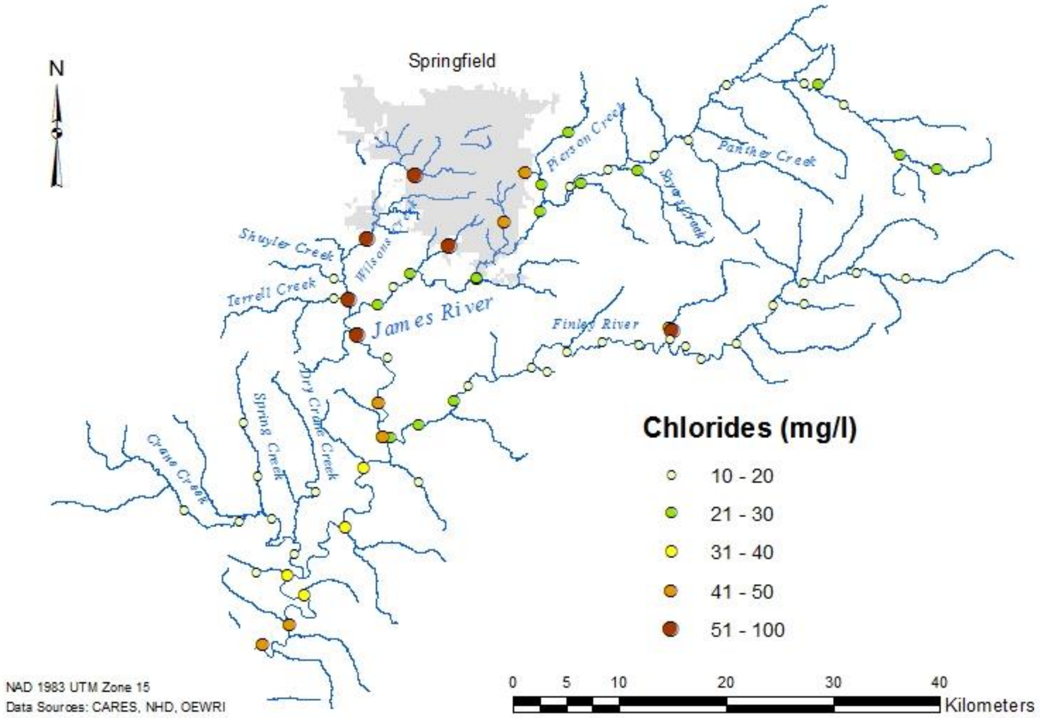


Figure 13: Snapshot survey sites and chlorides

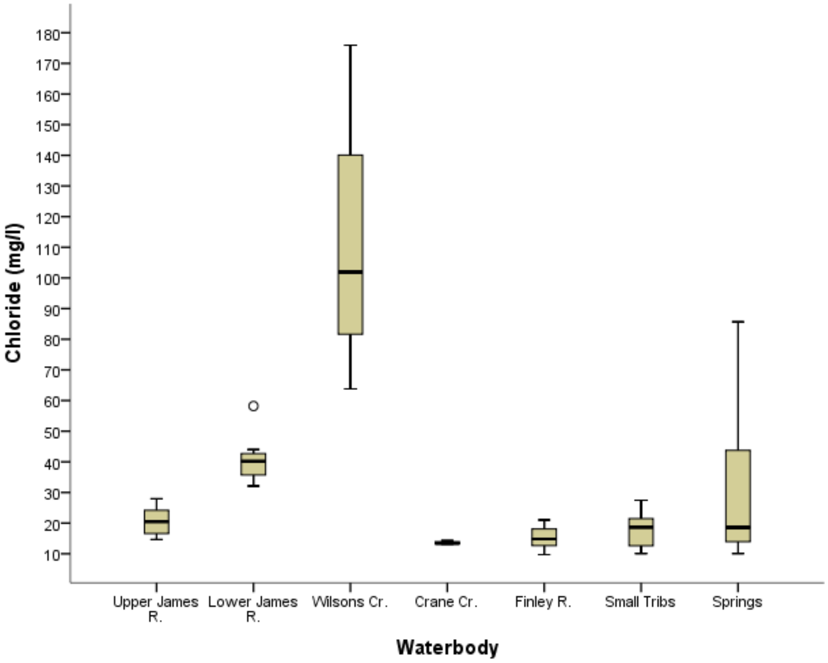


Figure 14: Snapshot survey chloride values by waterbody type (H = 28.70, P < 0.001)

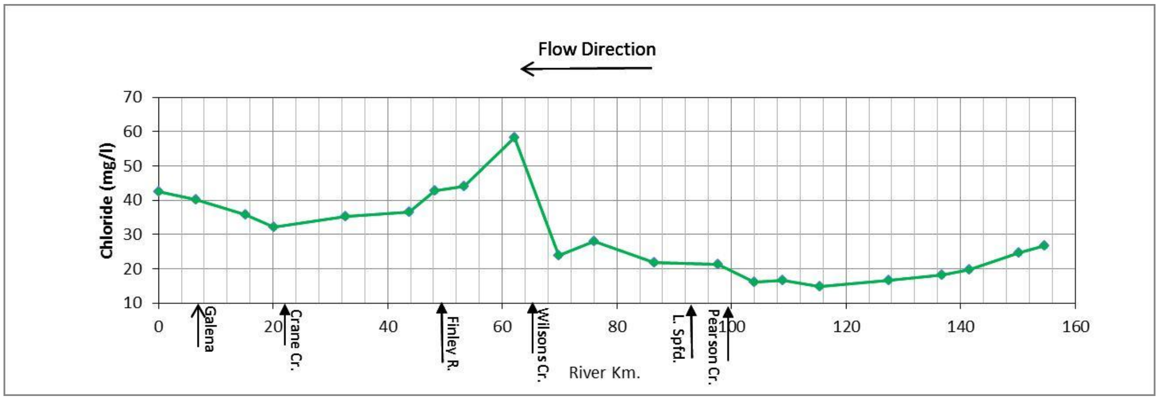


Figure 15: Snapshot site chloride values in the James River by kilometers upstream of Table Rock Lake

into biological reactions (Allan and Castillo, 2007).Chloride levels trend upward in the lowermost three sites, which cannot be as easily explained. Crane Creek, for example, had the lowest chloride levels of any tributary, but levels in the James River increased below its confluence with Crane Creek.

Tributaries. The highest chloride reading in the snapshot study was at Wilsons Creek site WI-3 (175.9 mg/l), just below the outfall of the Springfield Southwest POTW. Levels then fell to 104.3 mg/l at the next site downstream (WI-2) and then to 99.53 mg/l at Manley Ford (WI-1), the lowermost site on the creek. Wilsons Creek had the highest median value of tributaries at 80 mg/l, and Crane Creek had the lowest at 13 mg/l. All sites on the Finley River were relatively low (< 16.1 mg/l) until below the Ozark and Nixa POTW outfalls, where levels rose slightly (18.1 mg/l to 21.01 mg/l). Of the seven smaller tributaries, Sayers Creek and Turners Creek had the highest chloride concentrations (21.48 mg/l and 20.86 mg/l, respectively), while Terrell Creek and Spring Creek had the lowest (10.06 mg/l and 10.65 mg/l, respectively).

Springs. Most springs in rural areas had between 10 mg/l and 30 mg/l of chloride. The urban springs tended to have much higher values. The highest was Rader Spring (85.68 mg/l), probably influenced by effluent from the Springfield Southwest POTW, followed by Ward Spring (58.47 mg/l), Jones Spring (44.05 mg/l) and Sequiota Spring (43.75 mg/l). Surprisingly, Ollie Lasley Spring, which had an *E. coli* count of <1 MPN/100ml, had a relatively high chloride level of 52.09 mg/l.

Previous Studies. On May 7, 2011 volunteers sampled sites in the Niangua Watershed during a snapshot survey event, including both stream and spring sites (Thorpe, 2013). This was not a base flow sampling event, as the discharge of the Niangua River was well above base flow at the time of the survey. At Windyville on the middle Niangua River, the discharge on the survey day was between 400 and 550 cfs (the hydrograph was rising the entire day), and the base flow during that time would normally be less than 100 cfs. The Niangua Watershed sampled is about 1,650 km^2 (1,028 mi^2), roughly the same size as the James River snapshot watershed. A comparable number of sampling sites were used in both surveys. The Niangua Snapshot survey included 72 sites on rivers, streams, tributaries and springs, compared to 71 in the James River snapshot survey.

Chloride levels at all of the Niangua River sites were clustered near 5 mg/l, while all of the sites in the James River exceeded 15 mg/l and ranged upward to almost 60 mg/l. Chloride comparisons between the James River snapshot sites and Niangua survey sites are shown in Fig. 16. While all of the Niangua survey springs contained less than 3 mg/l chloride, all of the James River watershed springs contained over 5 mg/l chloride, with levels up to 86 mg/l chloride.

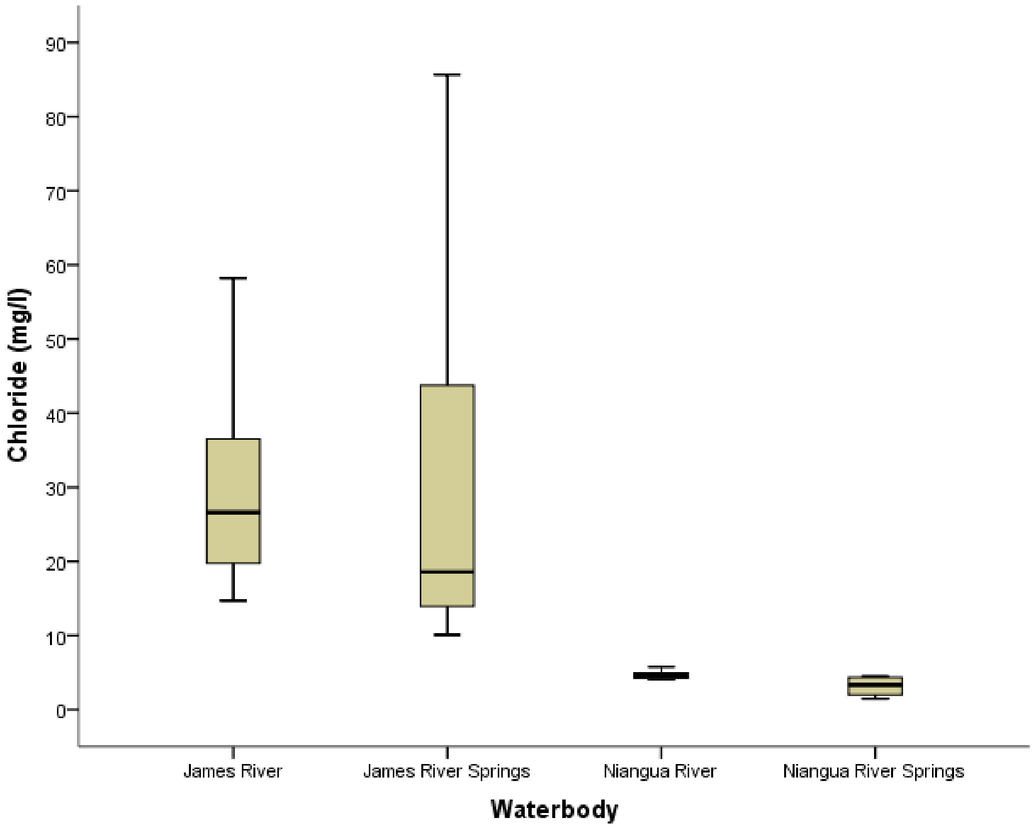


Figure 16: Chlorides in James River snapshot sites and Niangua River snapshot sites.

Summary. Wilsons Creek had the highest chloride levels of any waterbody in the James River snapshot survey, most likely reflecting the dominating influence of the Springfield POTW. Chloride tends to remain in wastewater after treatment. All three sites below the outfall had chloride readings of 100 mg/l or higher. However, the uppermost site on Wilsons Creek, WI-5 at Scenic, also had an elevated chloride reading (63.78 mg/l), which could indicate influences from urban runoff or other pollution sources.

Chloride levels in Wilsons Creek had a significant effect on the James River. Chloride levels increased from 23.82 mg/l above to 58.20 mg/l below the confluence. Thus, Wilsons Creek may have more than doubled the chloride level in the James River.

Variations in chloride levels among tributaries are more difficult to explain. Some tributaries, such as Sayers Creek, may be influenced by upstream POTWs. The discharge from the Rogersville POTW is relatively large in comparison to the flow in Sayers Creek when compared to some of the other POTWs in the basin, which have very small discharges (e.g., Fordland, Seymour). However Turners Creek, which does not have a POTW in its watershed, had an only slightly lower chloride reading than Sayers Creek (20.86 mg/l versus 21.48 mg/l).

High chloride levels in urban springs (44 mg/l to 86 mg/l) could indicate urban influences such as stormwater runoff or onsite wastewater system effluent seeping into the shallow groundwater system. Ollie Lasley Spring, in a remote and mostly undeveloped area, had surprisingly high chloride levels, which could indicate proximate pollution sources such as onsite wastewater systems or animal waste (it is in a primarily agricultural area). The much higher chloride concentrations in James River watershed springs compared to Niangua River watershed springs could result from more numerous sources of pollution in the more developed James River watershed, but could also be due to the different flow conditions between the two surveys. The higher flows of the Niangua River during the snapshot survey there could indicate an increased proportion of surface water recharge to springs at the time, leading to dilution of groundwater.

Total Nitrogen (TN)

The target level for total nitrogen (TN) in the James River has been established by the James River TMDL at an in-stream concentration of 1.5 mg/l (Missouri Department of Natural Resources, 2001). Many sites in the watershed sampled during the survey exceeded the target level (Figure 17). Wilsons Creek had the highest median value for TN (3.5 mg/l), followed by Crane Creek (2.5 mg/l), springs (2.4 mg/l), James River (2.0 mg/l), smaller tributaries (1.85 mg/l), and Finley River (0.3 mg/l) (Figure 18). For differences among the waterbody types, ANOVA assumptions failed, so the null hypothesis was evaluated using a Kruskel-Wallis Test. Results indicated a significant difference between Wilsons Creek and the other waterbody types ($H = 28.48$, $p < 0.001$), and on the James River above and below the confluence with Wilsons Creek.

James River. The two uppermost sites on the James River exceeded the target level (1.96 mg/l and 2.35 mg/l), and all sites on the James River below the confluence with Wilsons Creek exceeded the target level (2.21 mg/l to 4.98 mg/l) (Figure 19). TN levels generally fall below the uppermost two sites, then rise slightly in the vicinity of Springfield, then increase markedly below the confluence with Wilsons Creek. Levels then fall consistently below this point, but still remain above the target level.

Tributaries. All four sites on Wilsons Creek exceeded the target level for TN, from 1.71 mg/l at the uppermost site (WI-5 at Scenic) to 20.33 mg/l at site WI-3, immediately downstream of the outfall of the Springfield Southwest POTW. This site had the highest TN level in the entire snapshot survey. The lowermost site on Wilsons Creek (WI-1, Manley Ford) had a TN level of 7.28, almost five times the target level. All four

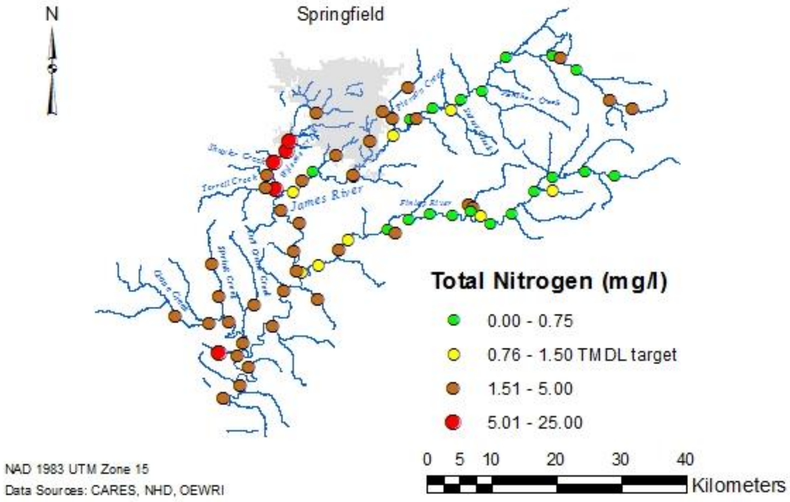


Figure 17: Snapshot survey sites and total nitrogen (TN).

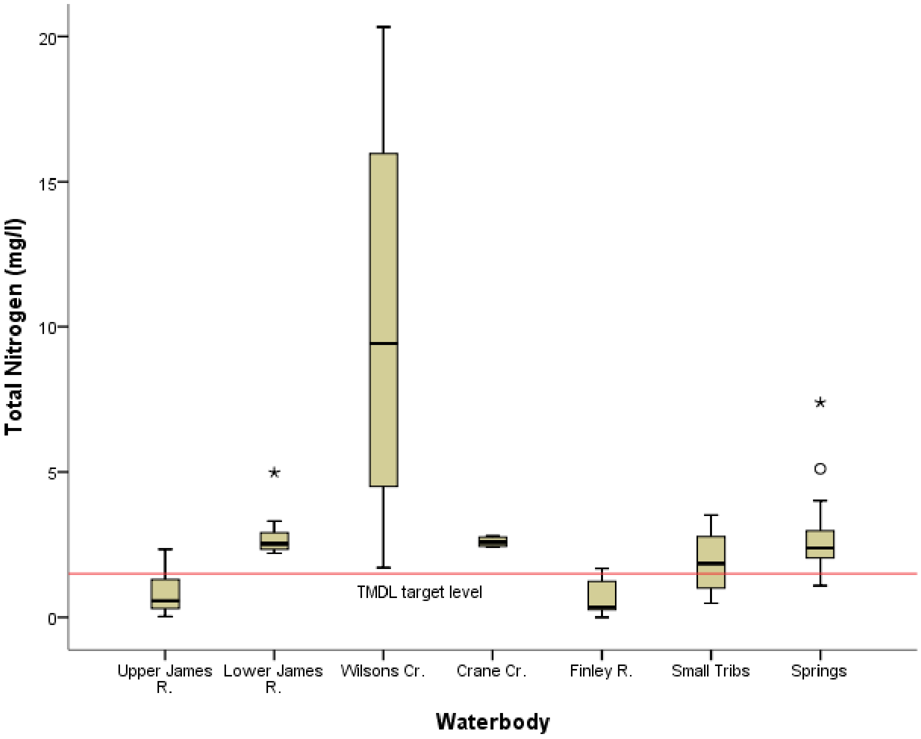


Figure 18: Snapshot survey TN values by waterbody type. (H = 28.48, P < 0.001).

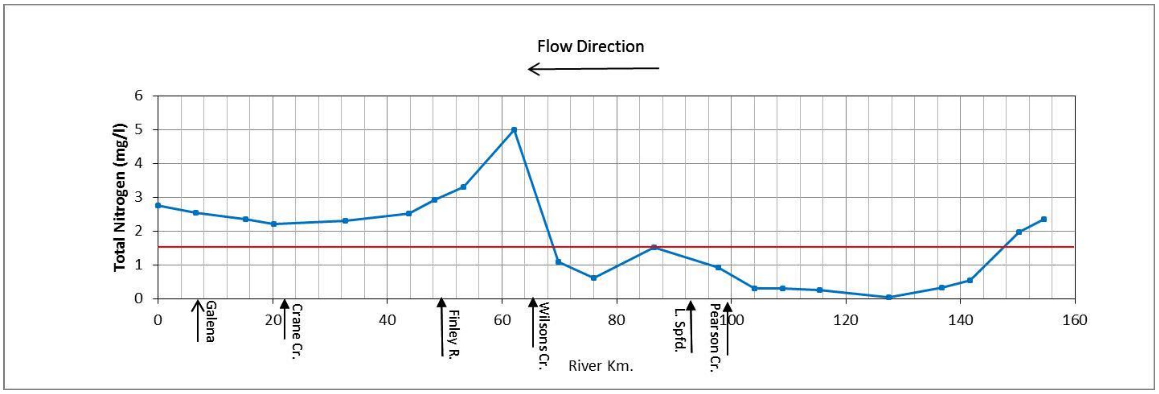


Figure 19: Snapshot site total nitrogen on the James River by kilometers upstream of Table Rock Lake (red line indicates TMDL target value for TN).

sites on Crane Creek exceeded the target level for TN (2.43 mg/l to 2.80 mg/l), as did both sites on Pearson Creek (1.68 mg/l and 1.85 mg/l). All sites on the Finley River above Ozark were well below the target level (0.14 mg/l to 0.62 mg/l), while all sites below Ozark were just below to slightly above the target level, ranging from 1.23 mg/l to 1.68 mg/l TN. The latter site, F-3, was located downstream of the Ozark and Nixa POTW outfalls. Levels decreased from this point to the mouth of the Finley River (1.23 mg/l at F-1). For the seven smaller tributaries, three were below the target level for TN (Panther Creek, Pedelo Creek and Sayers Creek), while four were above (Spring Creek, Terrell Creek, Shuyler Creek and Turners Creek). The small tributary with the highest TN value was Spring Creek at 3.52 mg/l, twice the target level.

Springs. Only 3 of the 17 springs sampled were below the target level for TN (Camp Cora Spring, Patterson Spring and Todd Spring) (Fig. 20). The lowest value (1.08 mg/l) was recorded at Patterson Spring, the highest at Rader Spring (7.40 mg/l), followed

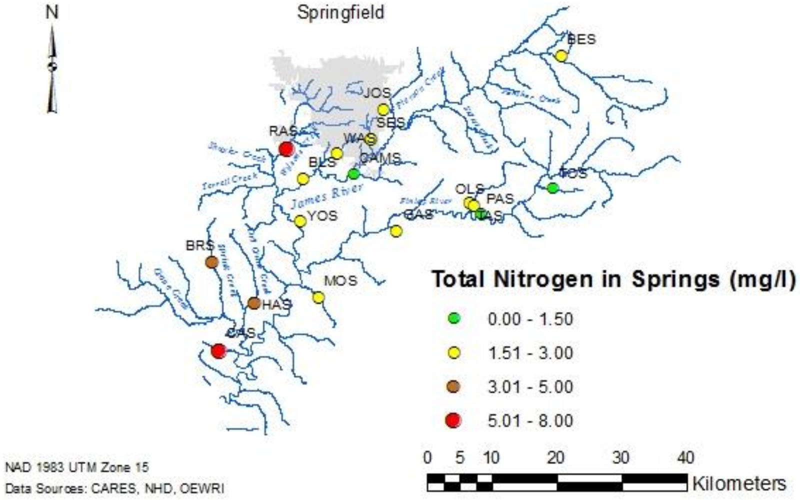


Figure 20: Snapshot survey springs and total nitrogen.

by Cave Spring (5.11 mg/l) and Hayes Spring (3.18 mg/l). Thus, 82% of the surveyed springs exceeded the TMDL target level for this watershed.

Previous Studies. The most complete summary of water quality data in the James River was accomplished as part of the data gap analysis (DGA) performed by MEC Water Resources Inc. and the Ozarks Environmental and Water Resources Institute (OEWRI) in 2007. Many of the same sites were used in both studies. However, the DGA analysis includes sample results from a range of flow conditions, not just base flow. Table 3 provides a comparison of TN results between the DGA and those recorded during the snapshot survey at the same sites. At 10 of the 12 sites, the snapshot values were between the minimum and mean values in the DGA. These results indicate relatively stable water quality at most of the sites with respect to TN between 2007 and 2013.

In a study of nutrient concentrations during base flow conditions in the Upper White River Basin, Borchelt (2007) included 7 of the same sites that were used in the James River snapshot survey. This White River Basin Study (WRBS) was also conducted during base flow conditions, with samples taken monthly over the course of a year. Table 3 shows the sites in the WRBS study, the corresponding sites in the snapshot survey (or the closest sites), and the values for TN at each of the sites. For 5 of the 7 sites, the snapshot value is between the minimum and maximum values from the WRBS. For site F-3 (Finley River at Riverdale), the snapshot value was two times the maximum recorded in the WRBS. At site WI-3, just below the outfall of the Springfield Southwest POTW, the snapshot value was significantly higher than the maximum recorded in the WRBS.

In 2007, OEWRI completed a Finely River Baseline Study (FRBS) (OEWRI, 2007). 18 sites were used, five of which corresponded to sites used in the snapshot survey. Those five sites and the corresponding TN values are also shown in Table 3. With respect to TN, results for snapshot sites F-2 and F-3 on the lower Finley River are significantly higher than the maximums recorded in the FRBS. Site F-7 (Lindenlure) on the upper river is slightly above the maximum of the FRBS and the snapshot value for site F-8, upstream, is near the mean of the FRBS.

In comparing results from the Niangua snapshot against the James River snapshot, the James River had higher TN values in general and a much greater range of values than the Niangua River (Fig. 21). James River watershed springs were much higher in nitrogen than Niangua River springs. However, the results can be misleading because the James River snapshot was performed during base flow, while the Niangua snapshot was not.

Table 3: Total Nitrogen: James River Data Gap Analysis; Upper White River Basin Study; Finley River Baseline Study and James River Snapshot Survey

Site	DATA GAP ANALYSIS TN mg/l					WHITE RIVER BASIN STUDY TN mg/l					FINELY RIVER BASELINE STUDY TN mg/l					SNAPSHOT SURVEY TN mg/l
	min	max	mean	med	N	min	max	mean	med	N	min	max	mean	med	N	
J-2	0.67	27.10	2.89	2.31	184	1.1	6.6	2.8	2.2	12						2.53
J-6	0.81	30.26	4.43	2.93	64											2.51
J-8	2.10	22.43	4.75	3.93	41	1.6	14.6	6.3	5.2	12						3.31
J-13	0.50	23.12	2.06	11.72	37	0.5	1.1	0.9	1.0	12						0.93
F-1	0.74	30.80	3.39	1.64	56											1.23
F-2											0.26	0.67	0.44	0.39	5	1.23
F-3						0.6	1.5	1.1	1.1	12	0.46	0.82	0.63	0.60	5	1.68
F-6	0.74	30.80	3.39	1.64	56						0.02	0.21	0.14	0.15	5	0.27
F-7											0.04	0.21	0.14	0.15	5	0.27
F-8											0.09	1.14	0.36	0.19	5	0.40
PE-1	1.45	20.24	2.97	2/59	89	1.7	2.8	2.2	2.1	12						1.85
WI-3						2.5	17.7	11.7	12.4	12						20.33
WI-5						0.8	2.5	1.4	1.2	12						1.71
PA-1	0.19	20.28	2.02	0.63	28											0.49
SH-1	1.55	17.18	3.37	3.15	46											2.91
TE-1	1.32	35.01	4.95	3.15	46											2.77
CR-1	1.55	19.45	3.03	2.30	36											2.43

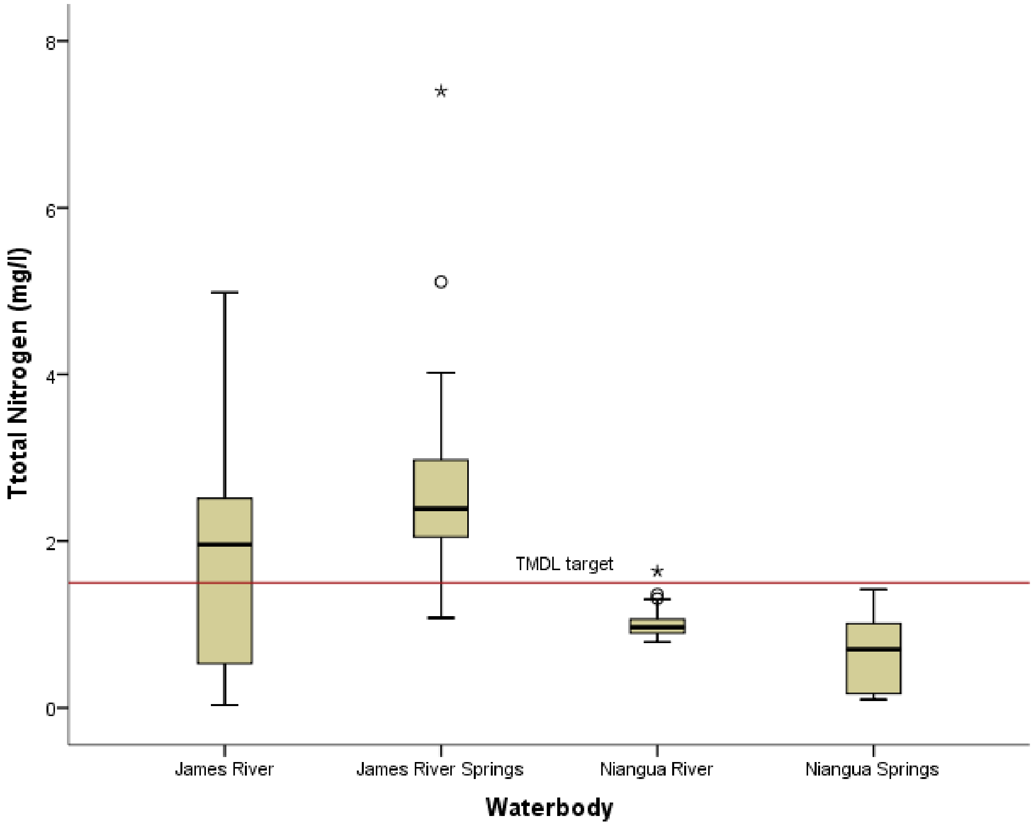


Figure 21: TN in James River snapshot sites and Niangua River snapshot sites

Summary. The effect of Springfield’s Southwest POTW on Wilsons Creek with respect to nutrients is not surprising, since nitrogen and phosphorus are found at fairly high levels in wastewater effluent (even though phosphorus has been reduced). The magnitude of the effect of Wilsons Creek on the James River can be seen by comparing the sites upstream of the confluence (J-10) with the site downstream (J-9). TN increases from 1.08 mg/l above the confluence to 4.98 mg/l below, a nearly five-fold increase.

Levels of TN in the lower James River may be attenuated by TN values in the Finley River (1.23 mg/l at the lowermost site), which could be lowering the values downstream of Shelvin Rock (3.31 mg/l) above the Finley River confluence. The value of TN at Crane Creek (2.43 mg/l near the mouth) is only slightly higher than the value at J-5, the site on the James River above its confluence (2.31 mg/l), and J-4, the site below its confluence (2.21 mg/l). Values in the river increase slightly at the next site downstream, J-3 (2.35 mg/l) to Galena, J-2 (2.53 mg/l). This trend is difficult to explain, but the input of Wheeler Branch above site J-4 includes the flow from Cave Spring, which had a rather high TN value of 5.11 mg/l.

TN concentrations in the James River were plotted with temperature (Figure 22). The effects in the upper river may be related to the influence of groundwater and springs on both temperature and TN values. In the uppermost reaches of the James River, TN values are generally high (1.96 mg/l and 2.35 mg/l), corresponding with the lowest temperature values and a high volume of groundwater inputs. TN levels generally drop downstream of this point, accompanied by an increase in water temperature. TN levels rise at the confluence of spring-fed Pearson Creek and Jones Spring, but drop again below Lake Springfield. Below the confluence of Wilsons Creek, TN levels rise to their highest levels in the snapshot study and generally remain elevated to the lowermost site. Inputs of high TN water from Rader Spring, Browns Spring, Spring Creek, Hayes Spring, Cave Spring and Crane Creek probably tend to keep TN values in the James River elevated below its confluence with Wilsons Creek.

In general, urban springs other than Rader did not have significantly higher TN values than springs in rural or more remote or forested areas. For example, Hayes Spring

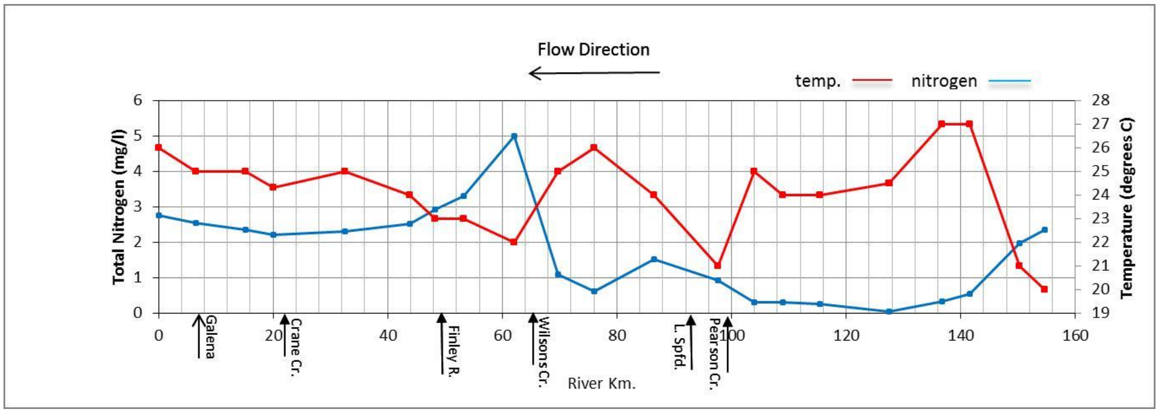


Figure 22: TN and temperature at James River sites by kilometers downstream of Table Rock Lake.

(HAS), which discharges from a cave in a relatively undeveloped part of the watershed (in a Missouri Department of Conservation Area), had a TN value of 3.18 mg/l, twice the TMDL target level, while Jones Spring (JOS), which has a primarily urban recharge area, had a TN value of 2.87 mg/l. The relatively high TN values seen in Hayes Spring and Cave Spring in the lower basin could be attributable to local pollution sources such as onsite wastewater systems, or could result from the wastes of bat populations living in these caves.

TN values for sites on the James River and in James River watershed springs obtained during the snapshot were much higher than those on the Niangua River and in Niangua River springs collected during the snapshot there. Median values for TN were above the target level for James River waterbodies and below the target level for Niangua River waterbodies. To some extent, this could indicate the effects of increased development and a larger number of pollution sources in the James River watershed relative to the Niangua watershed. But the results are not directly comparable because the Niangua snapshot was not performed during base flow conditions.

Total Phosphorus (TP)

Historically, phosphorus has been the primary nutrient of concern because of its link to eutrophication in the James River and Table Rock Lake (Missouri Department of Natural Resources, 2001). During the TMDL process, the target level for TP was established as 0.075 mg/l TP in-stream value, to be measured at base flow (Missouri Department of Natural Resources, 2001). In the snapshot survey, Wilsons Creek had the highest median value at 0.093 mg/l TP, above the target level (Figs. 23, 24). The next highest was the James River, with a median value of 0.039 mg/l TP, below the target level. The lowest median value was in the Finley River, at 0.015 mg/l TP. In fact, the lowest TP value of any surface stream in the watershed was found at F-9 in the upper Finley River, with a value of 0.003 mg/l TP. For differences among waterbody types, ANOVA assumptions failed, so the null hypothesis was evaluated using a Kruskel-Wallis Test. Results indicated a significant difference between Wilsons Creek and the other waterbody types ($H = 24.30$, $P < 0.001$).

James River. All sites on the upper James River were below the target level for TP, although one site on the uppermost James (J-20) had a slightly elevated TP value of 0.039 mg/l. Three sites on the James River below its confluence with Wilsons Creek were slightly over the target level (0.092 mg/l to 0.125 mg/l TP), but below these points on the lower river all sites were below the target level (0.039 to 0.066 mg/l TP).

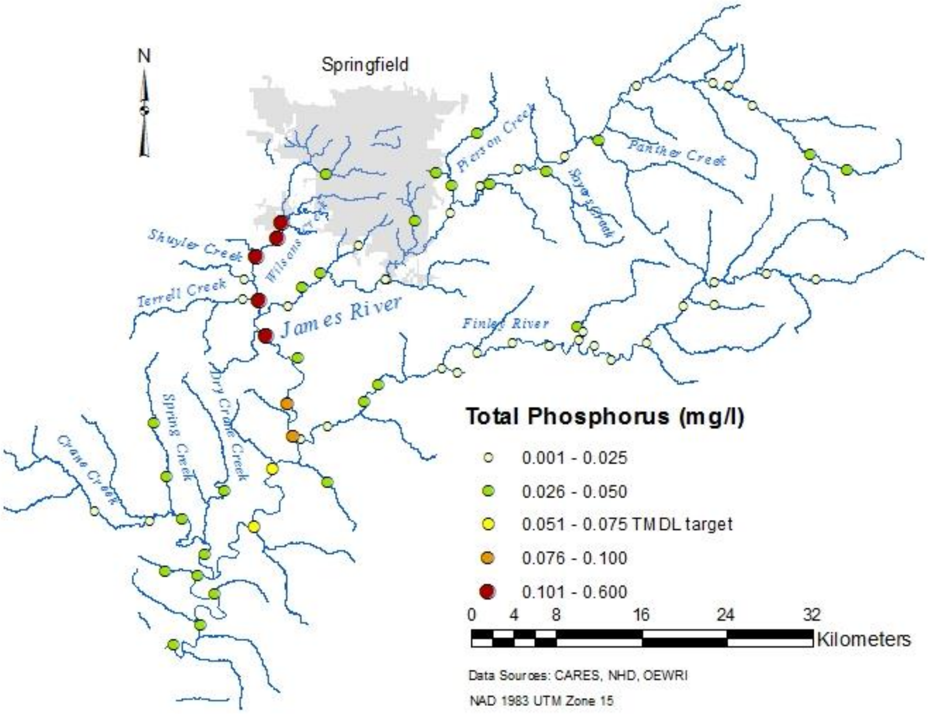


Figure 23: Total phosphorus (TP) values at snapshot sites

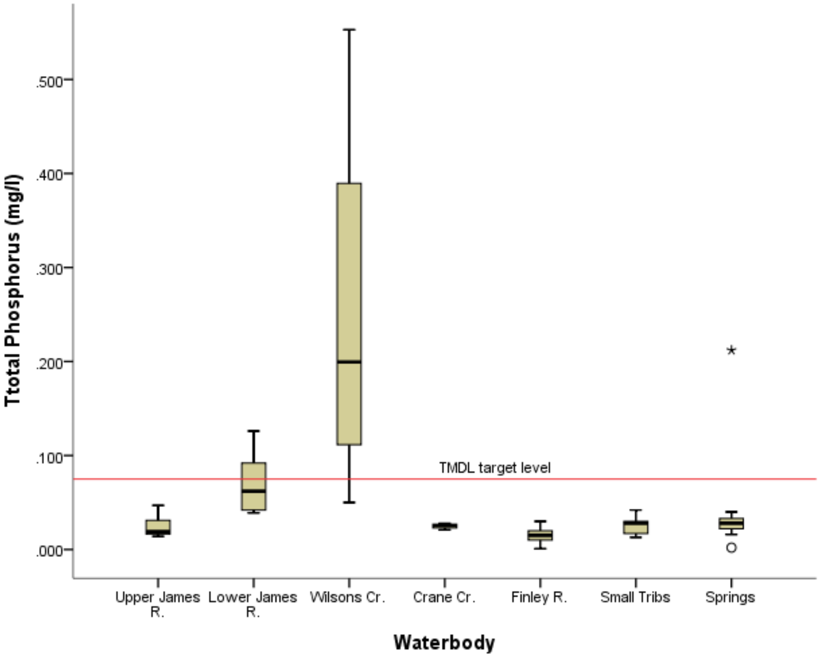


Figure 24: TP at snapshot sites by waterbody type (H = 24.33, P < 0.001)

Tributaries: The highest TP value recorded in the study was in Wilsons Creek (0.553 mg/l). Of the four sites sampled in Wilsons Creek, three exceeded the target level (0.173 mg/l, 0.226 mg/l and 0.553 mg/l). The highest value was found at WI-3, the site immediately downstream of the outfall of the Southwest POTW. This is perhaps not surprising, given that the treatment facility has a phosphorus discharge limit of 0.5 mg/l. Even the lowest TP value in Wilsons Creek (0.050 mg/l), found at the uppermost site (WI-5 at Scenic St.), was higher than most of the other stream TP values in the snapshot survey. At the lowermost site on Wilsons Creek (W-1), levels had decreased to 0.173 mg/l, still well above the target level.

The seven small tributary sites were well below the target level for TP, but had a fairly wide range of values, from a low on Pedelo Creek (0.013 mg/l) to a high on Turners Creek (0.042 mg/l). The highest TP found in the Finley River was at site F-4, below the discharge of the Nixa and Ozark-Elk Valley POTWs (and a few km. below the discharge of the Ozark-Finley POTW), at 0.029 mg/l TP. Panther, Sayers and Spring Creek were tightly grouped with TP values near 0.03 mg/l TP. Crane Creek had a median TP value of 0.026 mg/l, less than half the target level, with all four sites on Crane Creek tightly grouped (0.021 to 0.028 mg/l TP).

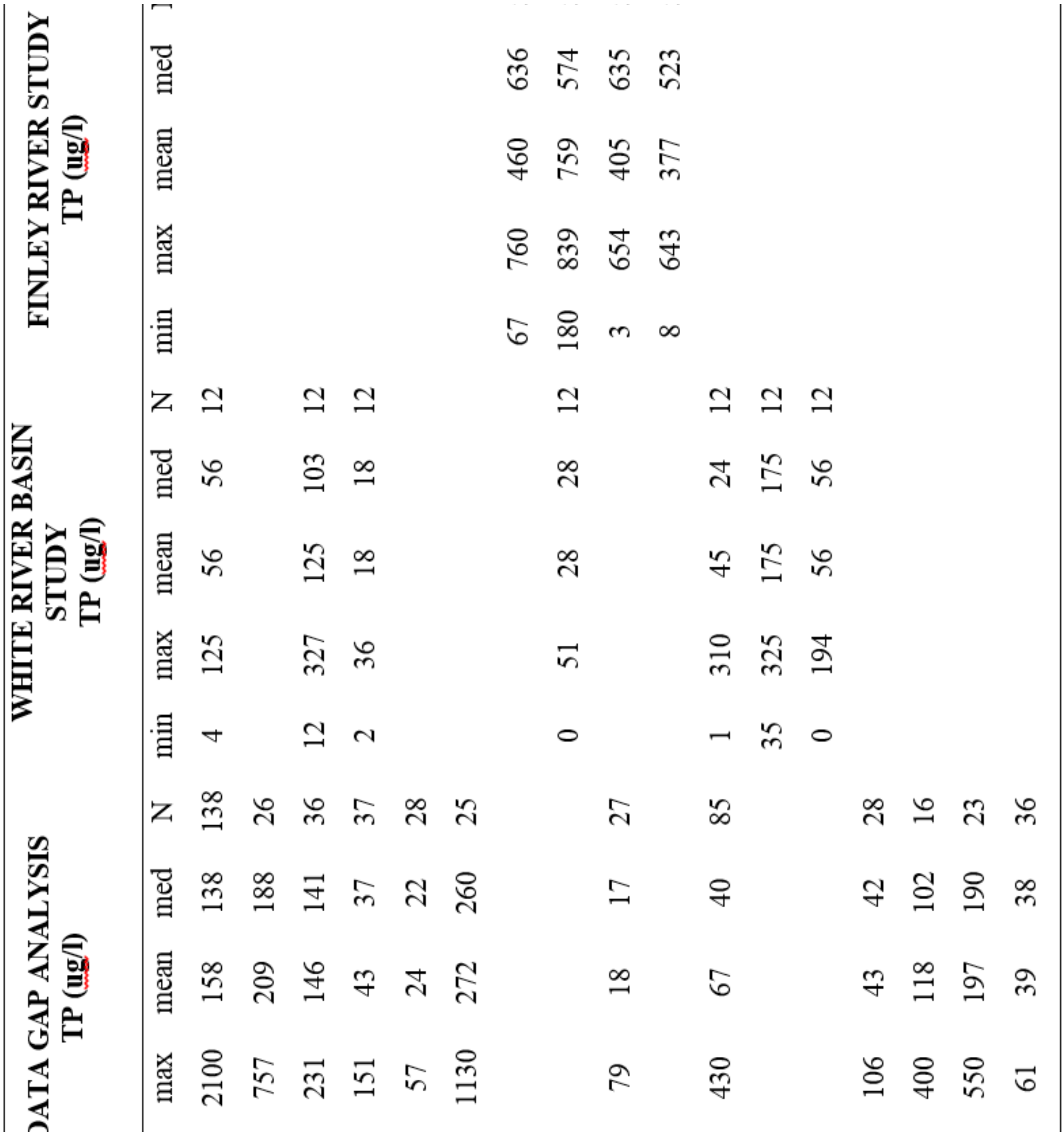
Springs. Springs had a fairly wide range of TP values, from 0.002 mg/l TP at Camp Cora Spring (CAMS) to 0.212 mg/l TP at Rader Spring (RAS). Springs generally had very low TP values, however, with only Rader Spring exceeding the TMDL target level. With the exception of Rader Spring, which is influenced by effluent from the Springfield Southwest POTW at low flow levels in Wilsons Creek, few springs in the study exceeded half the target level.

Previous Studies. Much of the data collected for preparation of the Data Gap Analysis extended back to the early 1990s or earlier, before the Springfield Southwest POTW and other POTWs had added phosphorus removal equipment. The Springfield POTW added phosphorus removal capabilities in 1993 and 2001. Therefore, TP results from the DGA and those collected during the snapshot survey are not directly comparably unless sites above the influence of the Springfield Southwest POTW and Wilsons Creek are used, or tributaries other than Wilsons Creek are considered. For example, geometric means of TP at the Boaz USGS gaging station on the James River downstream of Wilsons Creek went from a high of 1.4 mg/l TP in 1969 to 0.05 mg/l in 2004. TP geometric means dropped from about 0.5 mg/l in 2000 to 0.1 mg/l in 2001, after the final upgrade to the Springfield Southwest POTW.

James River snapshot values for TP agree fairly well with the James River values collected during the WRBS of 2007, falling between the minimum and the mean or very near the mean (Table 4). However, the James River snapshot value for site WI-3 on Wilsons Creek, below the Springfield Southwest POTW outfall, is much higher than the mean value obtained in the WRBS (0.553 mg/l vs. 0.175 mg/l) and even higher than the maximum (0.325 mg/l).

James River TP values are much lower than the minimum values on the lower Finley River (F-2 and F-3) recorded in the FRBS, and lower than the mean values for sites F-6 and F-8 on the upper river. However, the Finley River study was conducted during a time of very low flows, which may have had pronounced influences on phosphorus levels.

Table 4: Total phosphorus: James River Data Gap Analysis (DGA); Upper White River Basin Study (WRBS); Finley River Baseline Study (FRBS) and James River snapshot survey



ATA GAP ANALYSIS TP (ug/l)				WHITE RIVER BASIN STUDY TP (ug/l)					FINLEY RIVER STUDY TP (ug/l)			
max	mean	med	N	min	max	mean	med	N	min	max	mean	med
2100	158	138	138	4	125	56	56	12				
757	209	188	26									
231	146	141	36	12	327	125	103	12				
151	43	37	37	2	36	18	18	12				
57	24	22	28									
1130	272	260	25									
									67	760	460	636
				0	51	28	28	12	180	839	759	574
79	18	17	27						3	654	405	635
									8	643	377	523
430	67	40	85	1	310	45	24	12				
				35	325	175	175	12				
				0	194	56	56	12				
106	43	42	28									
400	118	102	16									
550	197	190	23									
61	39	38	36									

With respect to the DGA, snapshot TP values are between the minimum and mean values for all sites on the James River. The DGA included data from these sites from 2000 to 2005, so some sampling periods may have preceded the installation of major phosphorus removal equipment at the Springfield Southwest POTW. For the lowermost site on the Finley River (F-1), the snapshot value is below the minimum from the DGA. Snapshot values are also slightly below the DGA minimums for Shuyler Creek (SH-1) and Terrell Creek (TE-1) and between the minimum and means for Pearson Creek (PE-1), Panther Creek (PA-1), and Crane Creek (CR-1).

Table 5 shows the results of TP sampling at sites on the James River and Wilsons Creek between 1992 and 1999 in preparation for the TMDL. The snapshot results were near the median values for sites on the lower river (Hootentown and Galena), slightly below the median value at Delaware Town (below the confluence with Wilsons Creek), below the median value at Nelson Bridge (above the confluence with Wilsons Creek), and somewhat above the median value at Wilsons Creek site WI-2, below the outfall of the Springfield Southwest POTW.

TP readings were taken during the May 2011 Niangua River snapshot survey. Figure 25 shows the TP values of the James River collected during the James River survey versus those of the Niangua River, and James River watershed springs versus Niangua River watershed springs. Phosphorus values were greater in the Niangua River than the James River, but the values in the two sets of springs were similar. The NS survey was not conducted at base flow, but during higher flow conditions.

Table 5: Total phosphorus: Snapshot and James River TMDL data

Site	**TMDL Results (1992-1999) TP (mg/l)**			**Snapshot Results TP (mg/l)**
	min	max	med	
J-2 (James River at Galena)	0.015	2.5	0.05	0.042

J-6 (James River at Hootentown)	0.015	1.7	0.06	0.066
J-9 (James River Delaware Town)	0.02	3.5	0.18	0.126
J-10 (James River Nelson Bridge)	0.01	2.5	0.03	0.020
WI-2 (Wilsons Creek at Park)	0.02	5.6	1.8	0.226

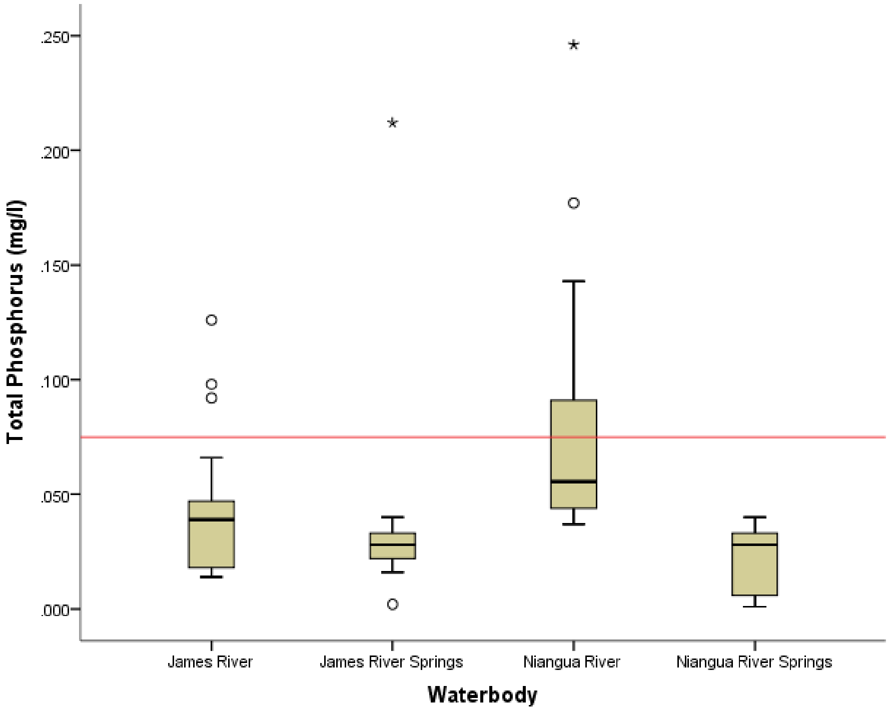


Figure 25: TP in James River snapshot sites and Niangua River snapshot sites.

Summary. The effect of Wilsons Creek on TP levels in the James River is rather dramatic. The TP value in the James River above the confluence with Wilsons Creek is 0.020 mg/l, while below the confluence the value rises to 0.126 mg/l, a six-fold increase. TP values tend to decrease steadily in the James River downstream of its conflence with Wilsons Creek. This probably reflects a dampening out of effects below the confluence as less nutrient-enriched tributaries enter and possibly biological update of nutrients by plants and microbes occurs. TP values in the James River are somewhat lower below the mouth of the Finley River (0.020 mg/l at the furthest downstream site on the Finley River) and below the mouth of Crane Creek (0.026 mg/l at the furthest downstream site on Crane Creek), both of which add significant flow to the James River and may dilute TP levels in the larger stream to some extent. The levels of TN and TP in the James River tend to track each other rather closely (Figure 26). The primary departure from the trend is in the vicinity of Springfield, below Lake Springfield. The different nutrient cycling mechanisms between streams and lakes may account for some of these differences. Excess phosphorus may be exported from the reservoir in the form of algae, which may be consumed by river fish downstream of the dam.

TP values obtained for tributaries during the snapshot survey fall between the minimum and mean values from the other studies, for the most part. Snapshot results indicate that the quality of the Finley River near its mouth may have improved slightly with respect to TP. The James River snapshot value at this site of 0.020 mg/l is less than the DGA minimum (0.025 mg/l) and much less than the DGA geometric mean (0.190 mg/l). Terrell Creek may have also improved somewhat, with a James River snapshot value of 0.017 mg/l, much less than the DGA geometric mean of 0.156 mg/l and slightly lower than the DGA minimum of 0.020 mg/l. These results could suggest fairly stable or even slightly improving water quality conditions at these sites with respect to TP between 2007 and 2013.

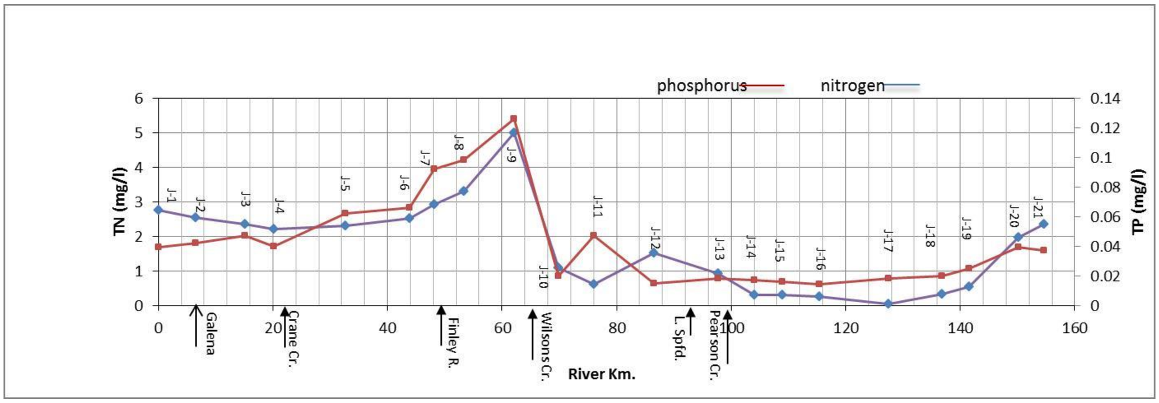


Figure 26: TN and TP in the James River by kilometer upstream of Table Rock Lake.

Escherichia coli

The USEPA has established an *E. coli* limit of 126 *E* coli/100 ml. for whole body contact (WBC) recreation waters. The James River and Finley River are included in this designation. The vast majority of sites in the James River snapshot study were below the WBC standard for *E. coli* (Fig. 27, 28). The data are rather tightly grouped, with median values between 10 and 75 *E. coli* per 100 ml. The median values for all sites were below the WBC limit of 126 *E coli* per 100 ml. The Finley River had the lowest median value at 10 MPN/100 ml, with Wilsons Creek and Crane Creek sharing the second highest medians at about 70-90 MPN/100 ml. Springs showed a range of values from 0 MPN/100

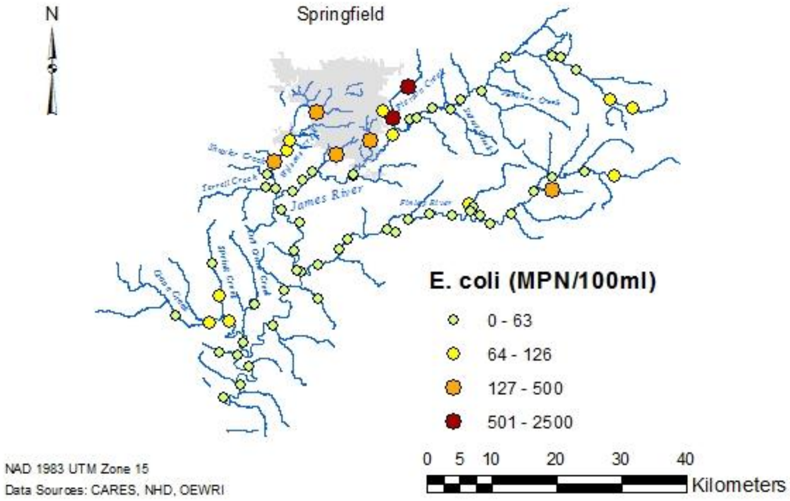


Figure 27: *E. coli* values at James River snapshot sites.

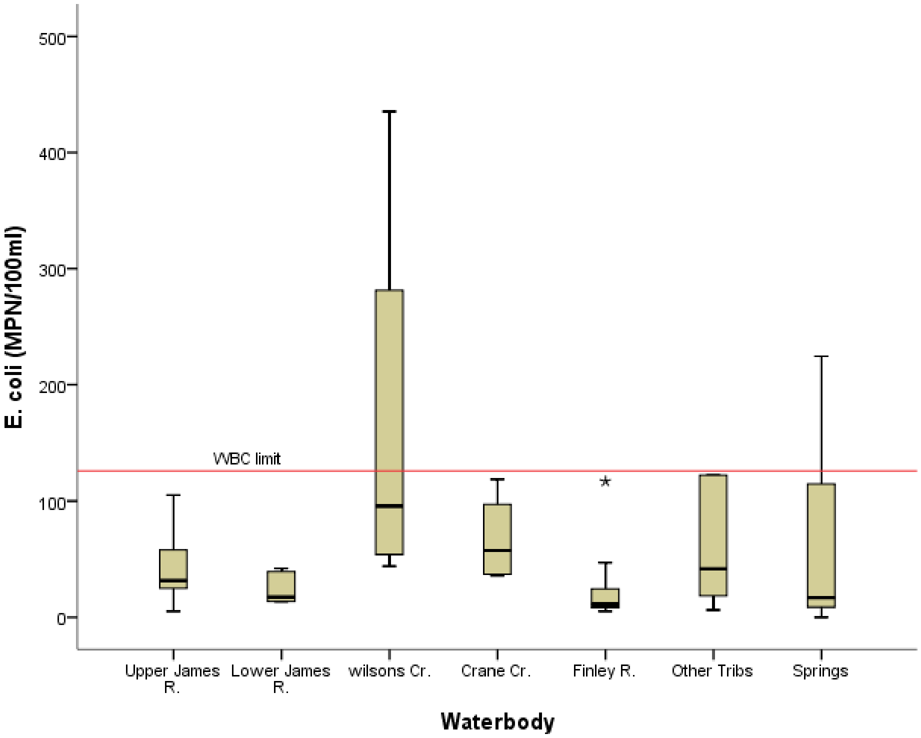


Figure 28: Snapshot *E. coli* values by waterbody type (H = 13.11, P = 0.022)

ml to 224.7 MPN/100 ml. Tributaries had the largest overall range, but the Pearson Creek sites at >2419 MPN/100ml each were statistical outliers. For differences among waterbody types, ANOVA assumptions failed, so the null hypothesis was evaluated using a Kruskel-Wallis Test. Results indicated a significant difference between Wilsons Creek and the other waterbody types (H = 13.10, P = 0.022).

James River. Most of the sites on the James River were well below the WBC level, with few sites exceeding even half this level. The two uppermost sites on the James River had the highest *E. coli* levels of 79.8 and 105 MPN/100 ml.

Tributaries. Only two sites on the Finley River exceeded half the WBC limit. The highest value on the Finley River was 116.9 MPN/100ml, at the uppermost site on the river. The uppermost site on Wilsons Creek (WI-5) far exceeded the WBC limit for *E.coli* at 435.2 MPN/100ml. Another site on Wilsons Creek (WI-2), below the Springfield Southwest POTW, barely exceeded the WBC limit at 128.1 MPN/100 ml. The other sites on Wilsons Creek exceeded half the WBC limit. Two of the four sites on Crane Creek and the single site on Spring Creek also exceeded half the WBC limit. Somewhat surprisingly, the highest *E. coli* values obtained in the entire snapshot survey were in Pearson Creek, just east of Springfield, with both sites too numerous to count (TNTC) with *E. coli.* With the IDEXX method, the highest number that can be obtained without dilution is >2419 MPN per 100 ml, so the data points were recorded as 2419 to enable them to be used in computations. The third highest *E. coli* reading in the snapshot survey (after the two sites on Pearson Creek) was the uppermost site on Wilsons Creek (WI-5, Scenic Avenue), with 435.2 MPN/100ml, over three times the WBC standard.

Springs. Relatively high numbers of *E. coli* were found at springs compared to most surface sites, with the highest being Todd Spring (TOS) at 224.7 MPN/100ml, followed by Ward Spring (WAS) at 193.5 and Sequiota Spring (SES) at 145.5, all above the WBC standard (Fig. 29). There was no clear distinction between urban and rural springs. Ward Spring and Sequiota Spring are urban springs, but Todd Spring discharges in a relatively remote section of the upper Finley watershed. Rader Spring (RAS), which also had relatively high TN and TP values, was the fourth highest spring (119.8 MPN/100ml), followed by another urban spring, Jones Spring (JOS), with111.2 MPN/100ml. Most other springs had low *E. coli* readings, several even below those of most river sites. Ollie Lasley Spring (OLS), discharging in a mostly forested section of the Pedelo Creek watershed (Pedelo Creek is a Finley River tributary), had an *E. coli* level of <1 MPN/100ml, the only site in the study area with no *E coli* found. Blue Spring (BLS), Camp Cora Spring (CAMS), Garrison Spring (GAS), Hayes Spring (HAS) and Patterson Spring (PAS) all had < 10 MPN/100ml *E. coli*.

Previous Studies. Table 6 compares James River snapshot *E. coli* data with the same sites used in the Data Gap Analysis (DGA) and Finley River Baseline Study (FRBS). Only minimum and mean values from the DGA are used, since this summary involved samples collected from a range of flows. The FRBS was conducted as a base flow study. In the James River snapshot survey, both Wilsons Creek below the Springfield Southwest POTW (Site WI-3) and Rader Spring (RAS) had snapshot *E. coli* values below the minimum values recorded in the DGA. For most of the other sites, the snapshot values were near the mean values from the DGA. For two sites on the upper Finley River (F-6 and F-8), the snapshot values were lower than the minimums from the

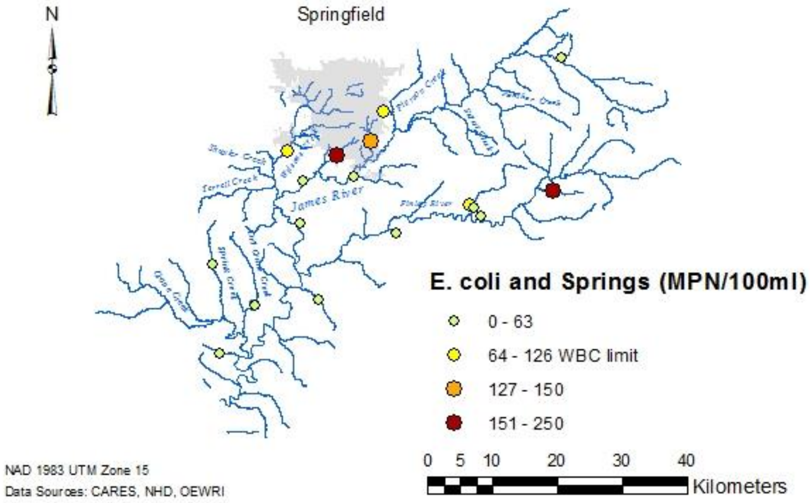


Figure 29: *E. coli* values and snapshot springs.

FRBS. At site F-3 on the lower Finley River, the snapshot value was higher than the mean value from the FRBS.

Pearson Creek clearly stands out in the James River snapshot survey, with *E coli* values (at both sites) far exceeding the DGA (at least 8 times). Pearson Creek had by far the highest *E. coli* levels of any site in the James River snapshot event. Furthermore, Pearson Creek sites have a history of elevated *E.coli* levels. In an OEWRI study of Pearson Creek, the mean levels of *E. coli* at sites PE-1 and PE-2 (the same sites as used in the James River snapshot survey) were elevated above the WBC standard, with the lowermost site (PE-1) having a mean *E. coli* value of 668 MPN/100ml, 5 times the WBC limit.

Table 6: *E. coli* snapshot values and results from the Data Gap Analysis (DGA) and Finley River Baseline Study (FRBS)

Site	**DGA** *E.coli* **(MPN/100ml)**		**FRBS** *E. coli* **(MPN/100ml)**					**Snapshot** *E. coli* **(MPN/100 ml)**
	min	mean	min	max	mean	med	N	
J-2	<1	8						13.5
J-3	1	14						13.2
J-6	<1	26						13.4
J-8	2	35						41
F-1	2	21						9.6
F-2			1.0	41.4	14.5	8.6	5	8.4
F-3	2	50	4.1	84.2	29.0	19.9	5	46.5
F-5	1	14						17.3
F-6			18.1	57.8	37.1	37.9	5	11
F-7			1.0	15.8	8.3	7.5	5	5.4
F-8			19.9	88.4	46.1	37.3	5	6.3
PE-1	1	290						2419.6
WI-3	122	460						63.7
RAS	172	413						119.8

Summary. Pearson Creek and Wilsons Creek both have sites with high levels of *E. coli.* The uppermost site on Wilsons Creek, with an *E. coli* value of 435.2 MPN/100ml, was also elevated in nutrients and chloride. This may reflect the fact that upper Wilsons Creek drains a very urbanized watershed, with possible influences from leaking sewers, pet wastes and other urban pollutants. The high *E. coli* values in Rader, Ward, Sequiota and Jones Spring may similarly indicate urban and suburban influences, particularly onsite wastewater systems and urban runoff. Tallman Spring, in the Pedelo Creek portion of the Finley River Watershed, at 114.5 MPN/100ml was below the WBC limit for *E. coli*, but was still generally elevated above most rural springs. Water quality in this spring could be influenced by numerous onsite wastewater systems in the area. Todd Spring, in the very upper part of the Finley River watershed, is in a remote and mostly forested part of the watershed, but may be influenced by animal waste from agriculture or onsite wastewater systems.

Results Overview

Several potential “hot spots” were indicated by the results of the James River snapshot survey. The most significant is Wilsons Creek. The relatively high levels of TN, TP, chloride, conductivity and *E. coli* found at sites in the Wilsons Creek watershed need further investigation. A more thorough study could better define the relative roles of urban runoff, leaking sewers and septic tanks, the Springfield Southwest POTW and Rader Spring in affecting water quality in Wilsons Creek. A more rigorous study based on a longer time period and varying flow conditions would probably be instructive.

In any event, Wilsons Creek is exerting a tremendous effect on the James River downstream of the Springfield urban area. Differences in chloride, total nitrogen and total phosphorus values between the upper and lower James River were significant. Nitrogen values, in particular, (and to a lesser extent, phosphorus) are above the TMDL target in Wilsons Creek and these effects extend far downstream into the James River, where the TMDL for nutrients applies. Upper Wilsons Creek at Scenic Street, above the outfall of the Springfield Southwest POTW, also should be further investigated to determine, if possible, the sources of elevated nutrient and *E. coli* levels at this site. The combined effects of Wilsons Creek on the James River constitute the single most evident trend highlighted during the James River snapshot survey.

Another area in need of further investigation is Pearson Creek, which had the highest *E. coli* levels of any waterbody in the survey. In comparison, almost all other stream and river sites had very low *E coli* counts. The bacterial loading in Pearson Creek could also be affecting the James River at Crighton Access (78 MPN/100 ml), although this access point was below the WBC standard during the snapshot survey. Crighton Access hosts heavy public use including fishing, swimming, wading and boating. Pearson Creek also discharges into the James River a short distance above the city of Springfield's drinking water intake. High *E coli* levels could signal a greater potential for waterborne pathogens to be present. Therefore, the sources and pathways of *E. coli* in the Pearson Creek watershed need further investigation.

A third potential hotspot is the uppermost portions of the James and Finley rivers, although the negative water quality effects here are not severe. The uppermost sites on both rivers were somewhat elevated with *E. coli* in comparison to most sites downstream.

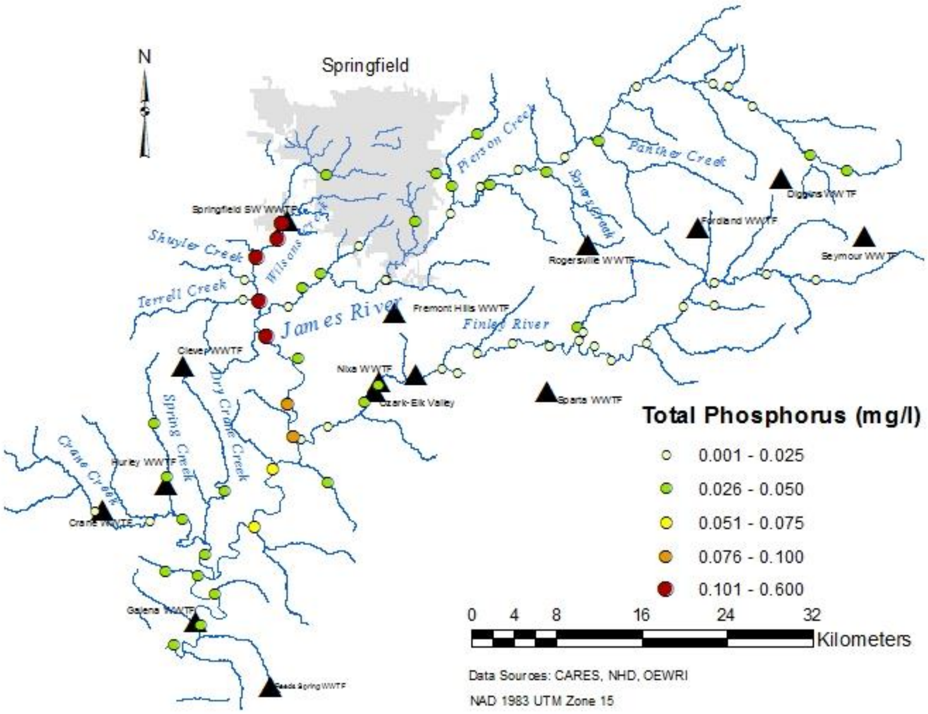
Sites on the upper James were also elevated with respect to TN, TP and chloride in comparison to sites further downstream. There are no point sources in the upper James Watershed, and only one in the upper Finley River watershed, the city of Seymour POTW, which discharges into a tributary of the Finley River above the highest point sampled on the river (F-14). The negative water quality effects in the upper James River are most likely non-point source related.

The upper portions of both the James River and Finley River watersheds are primarily in agricultural uses. During the preparatory work for the snapshot survey, several areas of overgrazing, concentrations of livestock in spring-fed drainages and areas of concentrated animal wastes were noted. Many small spring branches augment flow in the upper parts of these rivers. Animal wastes deposited in these perennially wet areas may have greater access to the river than wastes deposited in upland or drier areas. These perennially wet, hydrologically sensitive zones tend to accumulate nutrients and bacteria and quickly mobilize them to flow into rivers with the first pulse of runoff (Walter et al., 2000). In both the Finley and James River watershed, agricultural uses diminish in extent and becomes less intense downstream of headwater areas.

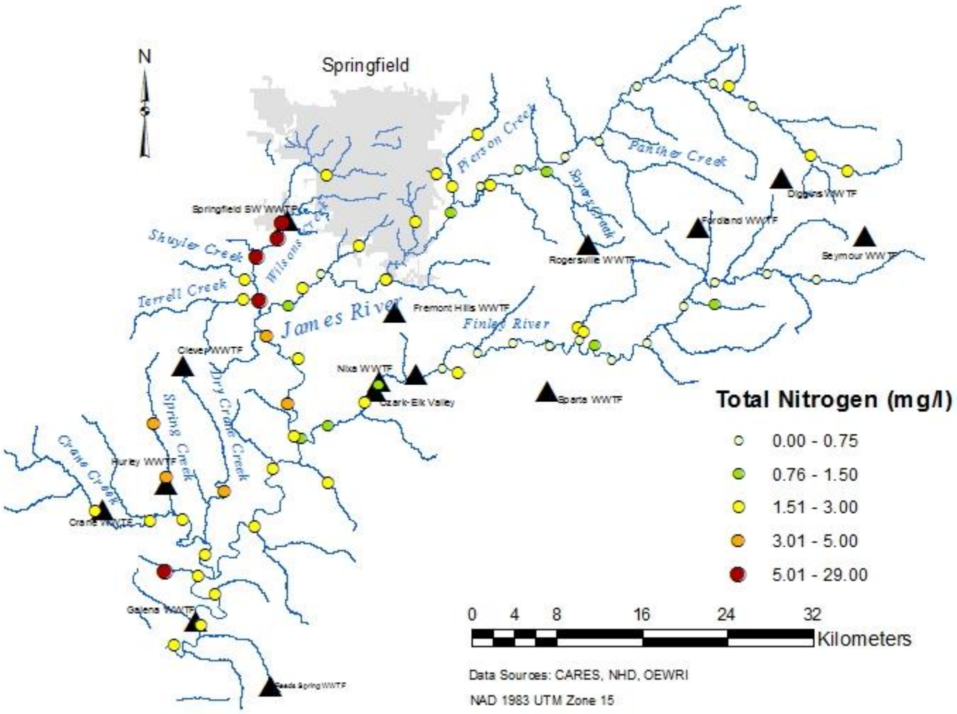
Another trend seen during the snapshot survey was the generally high *E. coli* levels in many springs, particularly those in the Springfield urban area. Ward Spring (193.5 MPN/100 ml) and Sequiota Spring (145.5) were above WBC standards and Rader and Jones Springs were close to the standard (119.8 and 111.2). In comparison, very few surface sites other than those in Wilsons Creek had *E. coli* levels above about half of the WBC standard. One spring in a remote area, however, Todd Spring, had the highest *E coli* reading of any spring in the snapshot survey (224.7). This seems unusual, although just north of this spring is the high intensity agricultural area in the upper Finley River watershed described above. Bacterial source tracking or optical brightener sampling in suspect springs could help to determine the likely sources of *E. coli* in springs, whether human or animal in origin.

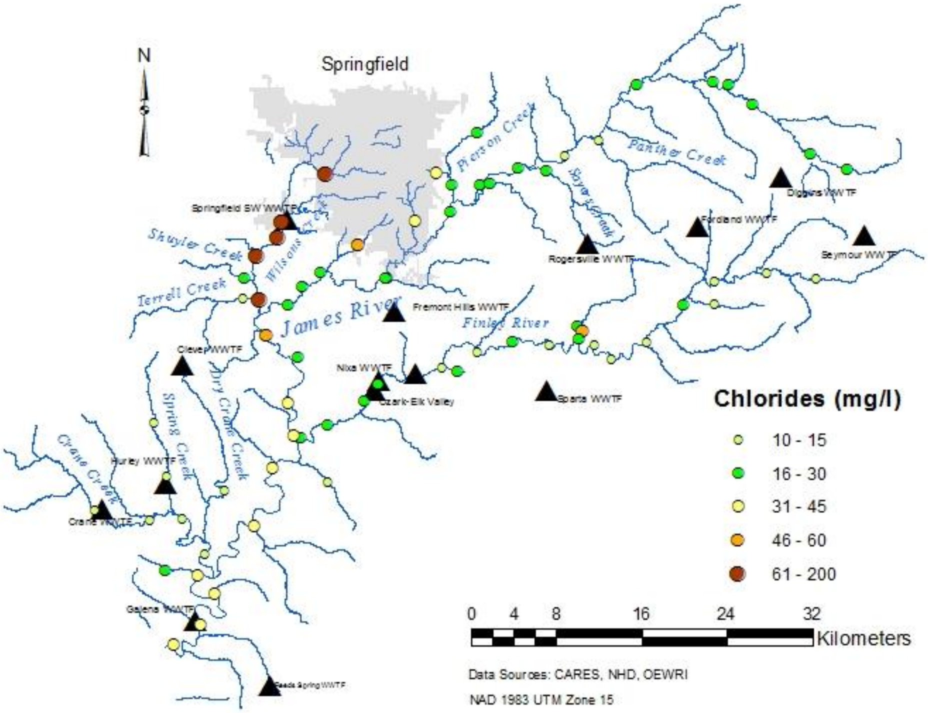
A fifth potential hot spot identified in the snapshot survey is Crane Creek. Crane Creek and its major tributary Spring Creek had elevated conductivities when compared to sites on the upper Finley and James Rivers. Crane Creek sites also had elevated TN when compared to most sites on the upper James River and Finley River, and somewhat elevated *E. coli* when compared to all river sites. These factors could at least partly be explained by the heavy influence of spring flow in both Crane Creek and Spring Creek. Nearby Cave Spring, south of the Crane Creek watershed, had a TN value of 5.11 mg/l, the second highest spring TN value in the snapshot survey after Rader Spring (7.4 mg/l). The high TN at Cave Spring might be explained by the presence of bats or the spring could be subject to contamination by septic tanks or other pollution sources, although the spring was relatively low in *E. coli* (13.6/100ml). The springs feeding Crane Creek and Spring Creek and were not sampled during the snapshot survey, but may have levels of TN comparable to those found in Cave Spring. Crane Creek is a high quality resource and the base of a unique fishery in Missouri, so water quality there should be of interest to state agencies and resource managers.

With respect to wastewater-related point source problems, three potential areas of concern were found in the James River snapshot survey (Figs. 30, 31, 32). The first is Wilsons Creek, which is subject to the effects of discharges from the Springfield Southwest POTW and possibly urban runoff, as described above. The second is the



Figures 30, 31: Snapshot TP and TN values in relation to POTWs in study area.





Data Sources: CARES, NHD, OEWRI
NAD 1983 UTM Zone 15

Figure 32: Snapshot chloride values in relation to POTWs in the study area.

combined effects on the Finley River from the POTWs for the cities of Ozark and Nixa, although these effects seem to be slight and diminish rather rapidly. TN, conductivity and chloride levels in the Finley River rose slightly below the Ozark and Nixa POTW discharges, but returned to their upstream levels within a relatively short distance downstream. In general, water quality in the Finley River at its mouth probably improves water quality in its receiving stream, the James River. The third potential POTW-related hot spot is Sayers Creek, where chloride and total nitrogen levels increased somewhat below the outfall of the Rogersville POTW. However, this effect does not seem to contribute to a significant rise in chloride or TN in the James River below its confluence with Sayers Creek.

For all of the other POTWs in the James River watershed, no upstream to downstream effects were discernible based on this snapshot survey. Most of these discharges are very small and several are located on tributary streams or drainages several kilometers above a snapshot survey sampling point on a larger stream. However, several of the POTWs discharge into losing streams, so could be affecting shallow groundwater quality more than surface water quality.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

The snapshot survey in the James River watershed accomplished all of its major objectives. The planning and implementation of the event went smoothly, providing a "blueprint" for future snapshot surveys in this or other watersheds. All of the designated sampling sites except one (where there was no flow) were successfully sampled within a three-hour time period on July 13, 2013. The sheer scale of the effort helped to ensure public interest in the project and in water quality issues in general. Meaningful monitoring results were obtained that will be of assistance in tracking progress toward addressing point and non-point source pollution problems and for assessing future water quality trends. Moreover, the James River Basin Partnership, a local watershed group, has expressed an interest in continuing snapshots in the James River watershed.

Thirty-eight volunteers were involved in planning, field sampling and laboratory analyses for the snapshot survey. These volunteers were very interested and enthusiastic about their participation in the snapshot survey. The use of volunteers for the field sampling portion of the survey greatly reduced costs in that volunteer time and fuel costs were donated to the project. OEWRI covered the costs of the analytical work and OEWRI personnel assisted in the laboratory work. This expertise ensured that laboratory results were of high quality.

The use of volunteers for a snapshot survey does present technical difficulties. The organization of such a large work force to sample 70 sites across a large watershed almost simultaneously presents a major logistical challenge. Training for such a large group, originally intended to be held at a one-day event at a central location in the watershed, instead had to be dispersed through multiple sessions and sites in the watershed. Problems were also encountered when two samples were placed in the wrong containers by one site group. A detailed map with sample sites numbered for volunteers to take with them in the field in their sample kits might have avoided that problem. Instead, volunteers received a sample location sheet with written directions to the sites far in advance of the event, and many or most of them may not have carried this information with them on the sampling run.

This snapshot survey provided a quick way to obtain a good overall picture of water quality conditions across the James River watershed. Because many parameters, such as pesticides and organic chemicals, are difficult to sample for, identify or quantify, these are not typically used in volunteer-based monitoring efforts and were not included here. Therefore, it cannot be claimed that all or even the most serious sources of water pollution in the watershed have been identified. However, James River snapshot results did match up rather well with those obtained previously in other professionally implemented water quality studies. For the most part, snapshot results were comparable to values for most of the water quality variables recorded in these studies. The general agreement between datasets indicates that the volunteer-based snapshot survey methodology used in the James River watershed provided data that is useful, meaningful and can be used with confidence.

As expressed by Wayland et al. (2003), an individual sampling event cannot be expected to adequately characterize complex land-use/water quality interactions. One sample at a site cannot be used to draw sweeping conclusions. However, a large number of samples gathered nearly simultaneously over a wide area can illuminate broad spatial patterns in water quality. Conducting a snapshot during base flow conditions can help to discern point versus non-point effects, and can be useful in developing a picture of pollutant “hot spots.” The James River watershed snapshot survey seems to have accomplished that objective. These findings, which were explained in detail in the Results and Discussion chapter, led to the following recommendations for possible further work:

1) The James River snapshot survey presented here provides a good means of addressing some monitoring deficiencies noted in the James River Data Gap Analysis: it was widespread rather than narrowly or problem focused and covered parts of the watershed not normally monitored. The snapshot survey works best in conjunction with other datasets and when used over time. Additional base flow snapshots in the James River watershed would help to better discern trends and delineate point versus non-point source water quality effects.

2) The snapshot approach was used in 2011 in the Niangua watershed, but not at base flow. While results from the two surveys can be compared, they may primarily indicate variable differences due to different flow conditions. The much higher chloride and nitrogen levels in James River watershed sites compared to Niangua sites could indicate the presence of pollution sources. It would be best to use base flow conditions in most or all surveys so that watershed water quality differences could be more easily highlighted. James River snapshot surveys should be compared with those in other watersheds, as they occur, with an emphasis on discerning land-use effects on Ozark streams.

3) In spite of efforts to reduce nutrient loadings and improve stormwater quality, Wilsons Creek continues to exert a tremendous effect on the James River. In the future, total nitrogen limits may be imposed. In order to understand how to best reduce the loading of nutrients and other pollutions, a more rigorous and long-term study would need to be conducted in the Wilsons Creeks watershed. This might help to better understand the fluxes of nutrients and their sources and effects, especially related to high levels of TN. It would be difficult to address some potential problems such as high nitrogen inputs from springs.

4) The levels of *E. coli* in Pearson Creek, and to a lesser extent in many springs and stream sites, are of concern from a public health standpoint. Additional bacteriological sampling, optical brightener analyses, or bacteriological source

tracking on springs and streams with high bacterial loadings might help to differentiate human and non-human sources. This is especially important in Pearson Creek, a component of the city of Springfield’s drinking water supply.

5) Some of the sites on the upper James River, and to a lesser extent the upper Finley River, were elevated in nutrients and *E. coli* above most of the other sites on those streams above urban influences. This could indicate non-point source pollution. The water quality conditions in the upper James River and Finley River should be examined more closely to assess the effects of land-use, groundwater influences and hydrologically sensitive areas. Although the negative water quality effects in these river sections are not yet severe, changes in land-use practices or other measures might help to prevent further water quality degradation.

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APPENDICES

Appendix A: List and Locations of Snapshot Survey Sites

Site ID	Waterbody Type	Waterbody Name	Location	Notes
J-1	James River	James River	Blunks Access; km. 0	Riffle at boat ramp
J-2	James River	James River	Cox Access; km. 6.5	Y-Bridge at Galena
J-3	James River	James River	Kerr Access; km. 15.2	
J-4	James River	James River	Wheeler Branch; km. 20.1	Just above confluence
J-5	James River	James River	V Pullout; km. 32.6	End of V Highway
J-6	James River	James River	Hootentown Access; km. 43.8	
J-7	James River	James River	Jamesville; km. 48.2	Under bridge above Finley confl.
J-8	James River	James River	Shelvin Rock Access; km. 53.3	
J-9	James River	James River	Delaware Town Access; km. 62.1	
J-10	James River	James River	Nelson Bridge; km. 69.8	Under bridge
J-11	James River	James River	Rivercut Golf C. km. 76.0	In front of Club H.
J-12	James River	James River	Camp Cora; km. 86.5	Just above spring
J-13	James River	James River	Crighton Access; km. 97.7	
J-14	James River	James River	Old Sunshine; 104.0	Riffle above bridge
J-15	James River	James River	Highway 125; km. 109.0	Glide under bridge
J-16	James River	James River	Division St.; km. 115.0	Glide under bridge
J-17	James River	James River	Highway B; km. 127.5	Glide under bridge
J-18	James River	James River	Bell Spring Rd.; km. 136.8	Riffle under bridge
J-19	James River	James River	Highway A; km. 141.6	Glide under bridge
J-20	James River	James River	Gentry Rd.; km. 150.2	Upstream of box

J-21	James River	James River	Skyline Rd.; km. 154.6	Upstream of box
F-1	Tributary	Finley River	Two Rivers Rd; 0.5 km. above James River	
F-2	Tributary	Finley River	Seneca Rd.; 5.2 km. above James	
F-3	Tributary	Finley River	Riverdale; 10.5 km. above James	Below dam
F-4	Tributary	Finley River	Elk Valley POTW; 13.0 km. above James	Just above outfall of POTW
F-5	Tributary	Finley River	Finley River Park; 17.7 km. above James	Ozark at highway 14 bridge
F-6	Tributary	Finley River	Green Bridge; 23.5 km. above James	Smyrna Road
F-7	Tributary	Finley River	Lindenlure; 28.0 km. above James	Riffle under bridge
F-8	Tributary	Finley River	Reeds Bridge; 33.0 km. above James	
F-9	Tributary	Finley River	Johns Ford; 44.2 km. above James	
F-10	Tributary	Finley River	LaRose Rd.; 49.9 km. above James	Just off N. Marshfield Rd.
F-11	Tributary	Finley River	Arapaho Rd.; 56.2 km. above James	Pool under bridge
F-12	Tributary	Finley River	Highway Z; 61.9 km. above James	Under bridge
F-13	Tributary	Finley River	Cardwell Rd; 68.5 km. above James	Near Dillon Rd. Riffle at bridge
F-14	Tributary	Finley River	Highway B; 74.3 km. above James	Beginning of flow during base flow
WI-1	Tributary	Wilsons Creek	Manley Ford; 1.3 km. above James	
WI-2	Tributary	Wilsons Creek	Farm Rd. 182; 6.7 km. above James	North edge of Wilsons Creek Park
WI-3	Tributary	Wilsons Creek	Farm Rd. 168; 11.7 km. above James	Just downstream of Spfd. POTW
WI-4	Tributary	Wilsons Creek	Farm Rd. 156; 15.0 km. above James	USGS gage. Not sampled on July 13
WI-5	Tributary	Wilsons Creek	Scenic St.; 20.6 km. above James	USGS gage
CR-1	Tributary	Crane Creek	Otto Rd; 3.6 km. above James	Rd. AA-50 bridge
CR-2	Tributary	Crane Creek	Swinging Br. Rd.; 10.2 km. above James	

CR-3	Tributary	Crane Creek	Quail Spur Rd.; 14.5 km. above James	
CR-4	Tributary	Crane Creek	Crane City Park; 21.2 km. above James	Just above footbridge
PE-1	Tributary	Pearson Creek	Farm Rd. 148; 1.7 km. above James	Old Sunshine Bridge
PE-2	Tributary	Pearson Creek	YY Bridge; 9.1 km. above James	Division Street Bridge
SP-1	Tributary	Spring Creek	Hurley above bridge	Enters Crane Cr. 0.7 km above site C-2
PED-1	Tributary	Pedelo Creek	Jude Ranch	0.5 km. above conf. w Finely River
PA-1	Tributary	Panther Creek	Highway B low water bridge	Enters James R. 3.6 km. above site J-16
SA-1	Tributary	Sayers Creek	Farm Rd. 241	Enters James R. 1.5 km. above site J-15
SH-1	Tributary	Shuyler Creek	Highway ZZ bridge	Enters Wilsons Cr. 2.2 km above WI-1
TE-1	Tributary	Terrell Creek	Highway ZZ bridge	Enters Wilsons Cr. 0.4 km. above site WI-1
TU-1	Tributary	Turners Creek	Behind Turners Store	Enters James River 4.4 km. above site J-13.
CAS	Spring	Camp Cora Spring	At mouth	Issues from cave
BRS	Spring	Brown Spring	Downstream of Highway M	Spring enters riverbed
HAS	Spring	Hayes Spring	At mouth	Spring on MDC property
MOS	Spring	Montague Spring	At road crossing below spring	Private trout ranch
GAS	Spring	Garrison Spring	E. Jackson St., Ozark	Spring issues from low bluff
TAS	Spring	Tallman Spring	On Jude Ranch	Near guest house
OLS	Spring	Ollie Lasley Spring	On Jude Ranch	South of Tallman Spring
PAS	Spring	Patterson Spring	Off Spring Hill Rd.	Discharges into Finley River
TOS	Spring	Todd Spring	Martins Branch Rd.	Small cave just south of road
BES	Spring	Bell Spring	Bell Ford Road	

JOS	Spring	Jones Spring	Jones Spring Lane off E. Catalpa	Issues from small cave into Jones Br.
SES	Spring	Sequiota Spring	At Sequiota Park	Large cave
CAS	Spring	Cave Spring	Cave Springs Rd. off Wheeler Branch Rd.	Issue from cave; former fish hatchery
RAS	Spring	Rader Spring	Off Farm Rd. 174 south of Republic Road	Largest spring in Greene County (?) not on topo map
BLS	Spring	Blue Spring	Farm Rd. 194 s. of Battlefield	Discharges into James River just above bridge
YOS	Spring	Young Spring	Inman Rd. off of Nicholas Rd. west of Nixa	
WAS	Spring	Ward Spring	Just east of Highway 160 s. of Springfield	Small cave under Waffle House

Appendix B: Sample Site Locations

Site	POINT_X	POINT_Y
BES	-92.9056	37.26342
BLS	-93.3553	37.09204
BRS	-93.5119	36.97647
CAMS	-93.267	37.09878
CAS	-93.4981	36.85098
CR-1	-93.4572	36.86573
CR-2	-93.4816	36.89611
CR-3	-93.5158	36.89379
CR-4	-93.5738	36.90222
F-1	-93.3566	36.9642
F-10	-92.9923	37.04511
F-11	-92.9537	37.07703
F-12	-92.9206	37.09672
F-13	-92.8654	37.10405
F-14	-92.8132	37.09916
F-2	-93.328	36.97483
F-3	-93.2896	36.9952
F-4	-93.2754	37.0093
F-5	-93.2081	37.02424
F-6	-93.171	37.03707
F-7	-93.1336	37.04554
F-8	-93.0952	37.04309
F-9	-93.0292	37.03168
GAS	-93.1918	37.02031
HAS	-93.4363	36.9193
J-1	-93.4895	36.78937
J-10	-93.3712	37.07625
J-11	-93.3367	37.1031
J-12	-93.2672	37.09908
J-13	-93.1992	37.15583
J-14	-93.1686	37.17745
J-15	-93.1284	37.19216
J-16	-93.0794	37.20364
J-17	-93.003	37.26283
J-18	-92.9213	37.26488
J-19	-92.8795	37.2464
J-2	-93.4617	36.806
J-20	-92.8192	37.20403
J-21	-92.7807	37.19148
J-3	-93.4464	36.83193
J-4	-93.4649	36.84771
J-5	-93.4046	36.88928

J-6	-93.3858	36.93909
J-7	-93.3641	36.9661
J-8	-93.3694	36.99432
J-9	-93.392	37.05092
JOS	-93.215	37.1887
MOS	-93.3276	36.9272
OLS	-93.0594	37.05558
PA-1	-93.0435	37.21625
PAS	-93.0466	37.04283
PE-1	-93.1985	37.1779
PE-2	-93.1709	37.22235
PED-1	-93.0629	37.04842
RAS	-93.3817	37.13293
SA-1	-93.0977	37.19009
SES	-93.2369	37.1477
SH-1	-93.417	37.09908
SP-1	-93.4972	36.93136
TAS	-93.0647	37.05832
TE-1	-93.4174	37.08221
TOS	-92.921	37.07788
TU-1	-93.1572	37.17946
WAS	-93.2957	37.1271
WI-1	-93.401	37.08086
WI-2	-93.4041	37.11784
WI-3	-93.3763	37.1466
WI-4	-93.3704	37.16852
WI-5	-93.3314	37.18678
YOS	-93.3601	37.03218

Appendix C: July 13, 2013 James River Snapshot Sampling Event Volunteer List

Tim Davis
Dave Sturdevant
Gary Dierking
Jud Whitlinger
Susan Bolyard
Jessica Luraas
Bob Korpella
Gopala Borchelt
Linda Coroleuski
Bob Ranney
Allan Keller
Dick Stiefvater
Bob Kipfer
Chris Dunnaway
Carrie Lamb
Felix Corrodi
Michael Baird
Rachel Posey
Tom Howell
Phil Maez
Ray Jones
Ronna Haxby
Rob Hunt
Dave Casaletto
Joe Pitts
Danny Tavares
Kevin Barnes
Stacey Armstrong
J. D. Slaughter
Jason Frantz
Mike Martin
Mona Menezes
Tim Smith
Bruce Martin
Mike Howell
Samantha Bley

Appendix D: Snapshot Sampling Event Project Overview (Given to Volunteers)

July 13, 2013 James River Snapshot Sampling Event

PROJECT OVERVIEW

Idea: Sample about 75 sites in the James River watershed at the same time (about) on the same day, in order to assess spatial trends in water quality across the basin. Sites include streams and springs, and almost all are at bridges or public accesses.

Three kinds of samples will be taken: 1) in the field, stream water temperatures will be recorded. 2) grab samples will be collected for nutrient analyses in the lab (total phosphorus and total nitrogen). 3) grab samples will be collected for bacteriological analyses in the laboratory (E coli.).

Samples will be collected by volunteers. Analyses will be run by laboratory personnel at the OWERI (Ozarks Environmental and Water Resources Institute) lab at MSU.

Expectations of volunteers:

1) Volunteers will agree to collect samples, take water temperatures and fill out data sheets at three to five pre-determined sites on July 13. Samples will be collected within a pre-determined time frame (tentatively, between 11 AM and 2 PM).
2) Volunteers will be assigned sample sites in June 2013, if not before.
3) If there are high flows on July 13, the event may be postponed for two weeks until July 27. Back-up for that date is August 10, and then two more weeks, etc.
4) Volunteers will let Loring Bullard know ASAP if they will not be able to perform the sample run on the target date(s).
5) Volunteers will be trained in June on how to collect the samples and fill out the data sheets. This training may either be individual or in small groups.
6) Volunteers will perform a “dry run” on their sample sites before the actual sampling event to determine travel times and how long it will take to get samples to a “runner.”
7) Runners will be stationed at several places in the watershed (e.g., Fordland, Highlandville) to receive samples from volunteers and take samples to the OEWRI lab.
8) Volunteers will receive no monetary compensation (pay, mileage, etc.—sorry), but will get a warm, heartfelt thank you—oh yes, and we’ll have a post-sampling party/education event, with free food and beverages for volunteers.
9) Volunteers must be covered by their own insurance—no coverage is extended.
10) If you are interested in being a volunteer, contact Loring Bullard
11) Volunteers who participate will be widely recognized as being cool.

Appendix E: Sampling Procedures for the Snapshot Survey Event (Given to Volunteers)

Sampling Procedures for the July 13, 2013 James River Snapshot Event

Preparation:

1. Read the instructions fully and try to follow procedures as closely as you can so data will be usable and reliable
2. Receive training on how to collect the samples, if you haven't already. Stacey Armstrong or Carrie Lame will provide training while I'm gone in June. It's best if they can do this for you in Springfield, on a creek there.
3. Visit all of your sampling sites before the event, before the end of June if possible. We may be able to make you a good map if you need one. You can also make yourself a pretty good map using google maps and can mark your sampling route on this map. At each site, check to see where you are going to park and any access issues you might have. Figure out your best route of travel so you can collect samples at all sites as quickly and efficiently as possible (but don't speed). For the day of the event, we'll have you either bring samples directly to the lab at MSU (if you're near Springfield) or drop them off with a "runner" stationed near your sites (outlying areas). I will contact each sampler to let them know where the samples will be delivered. When you are figuring your travel times, please determine how long it will take to get the samples collected and get them to the lab or rendezvous point. When I have this information from you, I can let you know when to have the samples delivered. From this, you can back calculate when you need to leave home (or wherever you are) to get the samples at the rendezvous point at the appointed time. **It is important that you don't start sampling too early.** The holding times on the bacterial samples are critical, so please start sampling as close as possible to your pre-determined time. If you are a few minutes late to the rendezvous point, it's no big deal. That's better than collecting your samples an hour early.
4. Sample kits will be available after July 1. I will keep them at the Watershed Committee office, 320 N. Main in Springfield (about two blocks northwest of the Square). Stacey Armstrong will be managing the sampling kits. If you happen to be in Springfield in the first two weeks of July, please stop by the Watershed office to get your kit (they will be closed July 4). Call first (XXX-XXXX) to make sure someone is there. I will make sure everyone gets their kits before July 13, as I'll be around the second week of July and can deliver them to you, if necessary. Make sure you get the right kit, and that it contains all the pre-labeled bottles and bags for your particular sites. The kit should also contain field sheets for each site. There should be one bottle for collecting nutrients (hard plastic) and 2-3 "whirl-paks" for bacterial analyses for each site. The extra whirl-paks are in case you goof up. There will also be a thermometer in each kit (if you already have one, or extra ones, please let me know ASAP). We will also be running field

duplicates on some of the sites, to check our lab accuracy. Not all samplers will have to collect field duplicates. If you do, the container (or bag) will be marked with the site name and also “f.d.” These will be collected at the same time and in the same way as the others on July 13.

Day of the Event:

1. You will be performing four actions at each site (2-5).
2. Fill out the field (data) sheets provided with the sample kits—one sheet per site. Most of the information will already be filled in. Just put your initials by your name on the sheet. Record the time the samples are collected in the blanks on the sheet, along with the water temperature. Also note anything about the site that you think could possibly affect the results (people swimming, cows in the creek, etc.). If there are a lot of people swimming at your sampling site, it is best to try to sample upstream of this. However, due to time constraints you may not be able to reach a better sampling location quickly. In that case, take the sample where you originally intended and just note the swimmers (number estimate) on the field sheet.
3. Fill the hard plastic bottle as instructed. Wade into shallow water (at a riffle or glide) to the center of the thalweg (the place where most of the flow is going). Facing upstream, open the bottle and submerge it upstream of you with the opening held downward. Turn the bottle upstream to fill and when filled pull it up with a sweeping motion and quickly cap. Rinse the bottle out and pour it behind you. Then collect the sample in the same manner. Sample at about elbow depth or at half the water depth.
4. Fill the whirl-pak as instructed. Tear off the perforated top. Grab the two white loops to open the pack. Be careful not to contaminate the bag with your hands during sampling. To do this, keep your hands to the sides of the bag in the current. Fill it in the same way as the plastic bottle. You may have to get some of the trapped air out with your hand by squeezing the bottom of the bag while it’s under water. Get it filled completely underwater before bringing it up. Twirl the bag two or three times using the twist-tie handles and then twist the ends of the handles together to seal. This bag should be stacked upright in the cooler in case there is some leakage from the twist-tie top.
5. If you have field samples and field duplicates, they are collected in this manner. Fill the field duplicate bottle (or whirl-pak bag) the same way as the primary sample. For the field blank, pour the deionized water into the sample container marked “field blank” and cap, including it with the other samples along with the empty deionized water bottle.
6. Take a water temperature using the thermometer. Allow a minute or so for the reading to stabilize. Record the temperature on the data sheet (in degrees Celsius).

7. Place the sample bottles and bags in a cooler. Bring a small cooler just large enough to hold all your samples from all sites, with ice or ice-packs in it. Put your name on your cooler. You will deliver the cooler to the lab, or to a runner. The runner (or a lab person) will sign off on your field sheets that they've received the samples (chain-of-custody requirement for QA/QC). If you deliver to the lab, we can give your cooler back then. If you send it with a runner, we'll get it back to you later.
8. In the event of high water (this is designed to be a base flow sampling event) we'll postpone the event for two weeks until July 27, then do it exactly the same way. If we cancel for July 13, please let me know ASAP if July 27 will work for you.

Appendix F: Snapshot Sampling Event Field Sheet (Given to Volunteers)

July 13 Snapshot Event
FIELD SHEET
(one sheet per site)

Site Number:___________________________ Location (stream or spring)_______________________
Date: _______________ _________________ Time of Sampling_______________________________
Sampler Name(s): ___________________________________
Sample Numbers:
1.
2.
3.
4.

Site Observations:

Appendix G. Site Results Data Table

Site	Temp (C)	pH	Cond. (uS/cm)	E coli (MPN/100 ml)	TN (mg/l)	TP (mg/l)	Cl (mg/l)
BES	26	7.94	485	20.1	1.82	0.020	22.75
BLS	16	7.00	506	8.6	2.61	0.029	17.66
BRS	15	7.30	471	30.5	4.02	0.033	10.33
CAMS	18	7.47	460	8.6	1.38	0.002	22.70
CAS	14.8	7.37	494	13.4	5.11	0.038	15.41
CR-1	20	8.11	374	35.5	2.43	0.026	13.14
CR-2	19	8.02	388	118.7	2.80	0.028	13.52
CR-3	17	7.88	380	75.9	2.70	0.025	13.27
CR-4	16	7.33	361	38.4	2.47	0.021	14.35
F-1	23	8.13	389	9.6	1.23	0.020	21.01
F-10	21	7.74	344	24.3	<0.01	0.008	13.57
F-11	21.5	7.62	364	5.2	0.21	0.010	16.02
F-12	23.5	7.76	362	10.9	0.30	0.015	9.75
F-13	22	7.89	354	n.v.	0.40	0.014	10.44
F-14	20	7.73	384	116.9	0.62	0.017	14.86
F-2	23	8.13	396	8.4	1.23	0.022	20.85
F-3	23.5	7.85	418	46.5	1.68	0.030	20.82
F-4	23.5	7.89	383	47.1	1.45	0.029	18.10
F-5	24.5	7.64	332	17.3	0.29	0.015	14.48
F-6	23	7.94	334	11.0	0.27	0.017	12.69
F-7	24	7.97	332	5.2	0.27	0.001	16.07
F-8	22	7.85	328	6.3	0.40	0.014	11.83
F-9	24	7.88	343	13.4	0.15	0.003	14.83
GAS	14	7.50	500	4.1	2.39	0.022	16.51
HAS	14	7.37	384	6.3	3.18	0.028	10.68
J-1	26	7.93	466	20.3	2.75	0.039	42.57
J-2	25	8.07	449	13.5	2.53	0.042	40.19
J-3	25	8.08	433	13.2	2.35	0.047	35.72
J-4	24.3	8.14	435	17.1	2.21	0.040	32.11
J-5	25	8.10	460	13.4	2.31	0.062	35.26
J-6	24	8.00	472	13.4	2.51	0.066	36.51
J-7	23	8.16	514	39.3	2.91	0.092	42.69
J-8	23	8.04	520	41.0	3.31	0.098	44.00
J-9	22	8.06	586	42.0	4.98	0.126	58.20

Site	**Temp**	**pH**	**Cond.**	**E. coli**	**TN**	**TP**	**Cl**
J-10	25	7.69	424	28.1	1.08	0.020	23.82
J-11	26	7.75	410	34.5	0.62	0.047	27.97
J-12	24	7.62	461	25.6	1.51	0.015	21.69
J-13	21	7.92	416	78.0	0.93	0.018	21.16
J-14	25	7.90	358	37.4	0.30	0.017	16.12
J-15	24	8.13	354	24.1	0.31	0.016	16.48
J-16	24	7.73	349	28.5	0.25	0.014	14.68
J-17	24.5	7.67	337	36.8	0.03	0.018	16.69
J-18	27	7.90	347	11.0	0.32	0.020	18.12
J-19	27	7.94	356	5.2	0.53	0.025	19.75
J-20	21	7.84	393	105.0	1.96	0.039	24.59
J-21	20	7.85	413	79.8	2.35	0.037	26.61
JOS	15	6.98	640	111.2	2.87	0.028	44.05
MOS	17	7.14	441	16.6	2.27	0.032	13.94
OLS	13.5	7.77	409	<1.0	2.15	0.022	52.09
PA-1	23	8.01	364	15.5	0.49	0.030	12.62
PAS	13	7.41	331	7.5	1.08	0.024	10.08
PE-1	19.5	7.86	502	2419.6	1.85	0.027	27.45
PE-2	18	8.10	446	2419.6	1.65	0.030	24.12
PED-1	21.5	7.28	314	6.3	0.54	0.013	18.63
RAS	18	7.14	735	119.8	7.40	0.212	85.68
SA-1	20	8.09	403	18.3	1.00	0.032	21.48
SES	19	7.05	575	145.5	2.05	0.040	43.75
SH-1	20	7.35	500	47.3	2.91	0.017	15.16
SP-1	17	8.02	420	122.2	3.52	0.028	10.65
TAS	14	8.09	452	114.5	2.55	0.035	27.28
TE-1	19	7.72	455	28.8	2.77	0.017	10.06
TOS	14	7.21	429	224.7	1.21	0.019	13.42
TU-1	20	7.96	412	41.7	2.53	0.042	20.86
WAS	17	7.03	579	193.5	2.27	0.016	58.47
WI-1	20	7.88	736	44.1	7.28	0.173	99.53
WI-2	17	7.54	780	128.1	11.59	0.226	104.3
WI-3	24	7.56	1106	63.7	20.33	0.553	175.9
WI-5	n.d.	7.94	650	435.2	1.71	0.050	63.78
YOS	16	8.04	473	14.6	2.97	0.028	18.57