HYDROLOGY

Precipitation

Precipitation for the basin averages 40 inches per year. The months with the highest precipitation are March-May, with an average of 13 inches for this three-month period. Evaporation averages about 54 inches per year for the basin. Runoff averages about 10 inches per year (MDNR 1986). The highest average runoff occurs in April-May and the lowest in December-January, coinciding with seasonal rainfall patterns.

USGS Gauging Stations

The USGS lists 13 discontinued and 3 active gauging stations operated to monitor stream flows and water quality in streams and rivers of the basin (Table 10). Seven of these gauges were located upstream of Bagnell Dam in HUC 10290109, within Benton, Laclede, and Morgan counties. Six of the gauging stations were located downstream of Bagnell Dam in HUC 10290111, within Cole, Maries, Miller, and Osage counties. Descriptions of the three active gauges are given below.

Gauging station number **06922450** is located on the Osage River 2,000 feet downstream of Truman Dam near Warsaw, Missouri. This gauge was installed after the construction of Harry S Truman Reservoir and measures flow from an area of 11,500 $mi.^2$. The available period of record is from 1981 to 2000, excluding October 1989 through September 1990. This station is important because it measures the majority (82% on average) of all water flowing into Lake of the Ozarks. Real-time river stage data for the Osage River below Harry S Truman Dam at Warsaw, MO are provided by the USGS.

Gauging station number **06926000** is located on the Osage River at the State Route 54 bridge, near Bagnell, Missouri. The station is 1.3 miles downstream of Bagnell Dam, which is located at Osage RM 81.7 and impounds Lake of the Ozarks. This gauge, which is jointly operated by USGS and AmerenUE, records flows from an area of 14,000 $mi.^2$. Mean monthly flow data are available for 1880-1925. Mean daily flow data are available from 1925 to 2000. This station is important because it provides information on the flow regime prior to impoundment of Lake of the Ozarks. It also continuously measures the discharge from Bagnell Dam, which controls most of the water flowing into the lower 82 miles of the Osage River. Real-time river stage and discharge data for the Osage River near Bagnell, MO are provided by the USGS.

Gauging station number **06926510** is located on the Osage River below St. Thomas, Missouri at Osage RM 34.5, about 47 miles downstream of Bagnell Dam. This station was installed in 1996 and replaced gauging station number 06926500, which was about 9 miles upstream. Station 06926510 below St. Thomas records flows from an area of 14,500 $mi.^2$. The available period of record is from 1931 to 2000. This station provides information on the combined discharge from Bagnell Dam and inflowing tributaries between Bagnell Dam and the station. Real-time river stage and discharge data for the Osage River below St. Thomas, MO are provided by the USGS.

Stream Order

Stream orders were assigned using 7.5 minute USGS topographic maps and methodology originally proposed by Horton (1932) and detailed by Gordon et al (1992). There are 59 streams 4th order and larger, totaling 855 stream miles, in the basin. Fourth order and larger streams and their mileages are outlined in Table 11.

Losing Streams

There are 22 identified losing streams within the basin (Table 12). These are primarily located in the center of the basin and the southward extending leg of the basin, with a few located in the eastern part of the basin (Figure 16). The longest losing stream is Dry Auglaize Creek which extends for 34 miles of the Dry Auglaize Creek Subbasin. Other subbasins with identified losing streams are the Wet Glaize Creek Subbasin, Lower Lake of the Ozarks River Hills Subbasin, Miller County River Hills Subbasin, and the Lower Maries River Subbasin.

Springs

One hundred and six (106) springs have been recorded throughout the basin (Table 13, Figure 17). Spring location information was gathered from USGS 7.5 minute topographic maps. The majority (87) of the springs are found in six of the basin's fourteen subbasins: Osage River Hills Subbasin (28 springs), Upper Lake of the Ozarks Hills Subbasin (28 springs), Tavern Creek Subbasin (12 springs), Deer Creek Subbasin (7 springs), Lower Lake of the Ozarks Hills Subbasin (6 springs), and Wet Glaize Creek Subbasin (6 springs).

The basin's 4 largest springs have average flows greater than 1 cubic foot per second (cfs). Three of the 4 largest springs are located in the center of the Wet Glaize Creek Subbasin. The largest is Armstrong East Spring with an average flow of 11.6 cfs. Blue Hole Spring is the second largest with an average flow of 7.16 cfs. Armstrong Spring is the fourth largest with an average flow of 1.18 cfs. Gravois Mills Spring in the Gravois Arm Subbasin is the third largest spring with an average flow of 1.36 cfs.

Dam and Hydropower Influences

Bagnell Dam and Harry S Truman Dam are located on the mainstem of the Osage River. Bagnell Dam impounds Lake of the Ozarks and was completed in 1931. Lake of the Ozarks is operated primarily for hydroelectric generation and recreation. Truman Dam is immediately upstream of Lake of the Ozarks, was completed in 1979, and is primarily operated for flood control and hydroelectric generation. Positive impacts of the dams and the reservoirs they create are ample water supply, electricity production, flood control, lake fishing and other recreation, and tourism.

Construction and operation of Bagnell Dam and Truman Dam have adversely affected 175 miles of river habitat in and along the Osage River within the basin. Lake of the Ozarks inundates a total of 93 miles of the Osage River. In addition, seventy years of Bagnell Dam operation have significantly changed the flow regime and habitats of the lower 82 miles of the Osage River, negatively affecting the river and its tributaries. Operation of Truman Dam also has affected hydrology and habitats of the lower Osage River by influencing water level and water quality in Lake of the Ozarks. Some of the known and suspected negative effects of construction and operation of Bagnell and Truman dams include rapid flow fluctuations, extended bankfull flows, frequent and unnaturally low flows, erosion and siltation in the Osage River and its tributaries, loss of riparian corridor, loss of wetlands, barriers to fish migration, limited spawning habitat for fish, lowered water temperatures, low dissolved oxygen, reduction of mussel populations, and fish kills due to low dissolved oxygen levels, impingement of fish on turbine intakes, and entrainment of fish through the turbines. Some problems have been addressed, but additional information is needed to implement strategies that improve habitat and water quality, prevent fish kills, and mitigate for the losses of fish and wildlife habitats.

Stream Flow

Flooding

Historically, major Osage River floods were caused by long periods of rainfall over large areas. Major floods most frequently occurred during April-June, but were not restricted to the spring season. Lake of the Ozarks has water storage of 1,927,000 acre-feet and only limited flood control capability. After construction of Bagnell Dam, floodwater from the Osage River still contributed to flooding along the lower Missouri River and portions of the Mississippi River. The highest flood stage at the gauging station at St. Thomas was recorded on May 20, 1943. The peak discharge at St. Thomas on that date was 216,000 cfs. To reduce flooding, the USACE constructed Harry S Truman Reservoir in the East Osage River Basin and 5 reservoirs upstream in the West Osage River Basin between 1961 and 1979 (Dent et al. 1997). Before Truman Dam was completed in 1979, there was still considerable flooding along Lake of the Ozarks and the lower Osage River. Since construction of Truman Dam and Reservoir, which has flood control storage of 5,209,000 acre-feet, destructive out-of-channel flooding along the lower Osage River downstream of Bagnell Dam is of much less concern. Flood control and hydropower generation reduce the peak flood flows downstream of Bagnell Dam but extend bankfull flow duration. Most floods since completion of Truman Dam have considerably lower peak flows but are weeks to even months longer in duration than floods that occurred in the years immediately prior to completion of Bagnell Dam.

Below Truman Dam

Other than flood control, the stream flow effects of Truman Dam are not as significant as those of Bagnell Dam because Truman Dam discharges directly into the impounded water of Lake of the Ozarks. However, a three-week long release of 4,000 cfs in the spring is needed to create adequate conditions for spawning of walleye and white bass downstream of Truman Dam. Although water discharged from Truman Dam spreads out as it travels 93 miles through Lake of the Ozarks, operation of Truman Dam does affect the water levels and water quality in Lake of the Ozarks and the Osage River downstream of Bagnell Dam.

Below Bagnell Dam

Impoundment of the Osage River by Bagnell and Truman dams has dramatically affected the hydrology of the lower Osage River. The timing, frequency, magnitude, duration, and fluctuation of flows have all been affected. Such changes can increase channel instability, decrease habitat availability, and limit diversity and abundance of aquatic and riparian biota.

Hydropower operations at Bagnell Dam have increased the frequency of both moderately high flows and very low flows. Hydropower operations at Bagnell Dam frequently produce bankfull flows when pulses of water are released through the generation turbines to meet peak demand for electricity. Between pulses, drought-like minimum flows (385-450 cfs) are released. Daily flow fluctuations are dramatic, with flows often varying between the minimum releases and hydropower releases of 30,000 cfs and higher.

Increased frequency of high flows can cause channel instability by increasing sediment transport and channel erosion, and can affect the amount and distribution of aquatic, riparian, and terrestrial habitats. Annual flow duration curves show that hydropower discharges cause mean daily flows between about 5,000-30,000 cfs to occur more frequently today than before Bagnell Dam. For example, a mean daily flow of 20,000 cfs was equaled or exceeded only 20% of the time before Bagnell Dam, but has occurred 26% of the time since 1980.

Frequent and persistent low flows can limit diversity and abundance of aquatic and riparian biota

by reducing habitat availability and affecting water quality. Due to the minimum releases between hydropower discharges, extremely low downstream flows occur more often now then before construction of Bagnell Dam. For example, a mean daily flow of 1,000 cfs flow in the Osage River near Bagnell, Missouri was equaled or exceeded about 90% of the time before Bagnell Dam, but only 75% of the time since 1980. In other words, flows less than 1,000 cfs now occur about 25% of the time compared to only 10% of the time before Bagnell Dam.

Low flows can have different harmful effects throughout the year. Low flows in the winter can reduce water temperatures. Springtime low flows can limit spawning of fish. Mussel spawning and fish nursery areas can be limited by low flows in the summer and fall. Although mean annual flows and average monthly flows in the Osage River since 1980 are comparable to flows before construction of Bagnell Dam, changes in low flow frequency due to operation of Bagnell Dam have occurred for most months. For October-June, the 75% and 95% monthly exceedance flows since 1980 are lower than those for water years 1926-1930 (October 1925 to September 1930), indicating that low mean daily flows now occur more often during the fall, winter, and spring. In particular, the unnatural minimum releases from Bagnell Dam during October-June cause mean daily flows less than 500 cfs to occur more often today than before the dam controlled flow. For example, 95% exceedance values for May show that flows less than 2,000 cfs occurred on about 5% of the days during May before Bagnell Dam. Since 1980, however, May daily flows less than 500 cfs occur 5% of the time. Table 16 shows monthly flow statistics for the entire pre-Bagnell Dam record of daily flows (June 1925-December 1931).

Hydropower operation of Bagnell Dam has caused mean daily and hourly flows to be much more variable today than before Bagnell Dam was built. Rapid increases in flow can disrupt feeding and spawning by fishes, displace aquatic insects, and initiate excessive transport of sediment. Rapid decreases in flow can result in bank erosion and stranding of fish, mussels, and aquatic insects. Frequent and rapid flow fluctuations can increase stream channel instability, change habitat availability, reduce ecological integrity, and interfere with recreational use of the lower Osage River.

Although mean daily flows show considerable flow fluctuations, hourly flow data reveal the true variability and extremes of flows and river levels (stage) due to hydropower peaking operation of Bagnell Dam. Mean daily flows do not show the rapid within- and between-day flow fluctuations that occurred during late summer and early fall of 2001. Flows often fluctuated from low flows to nearly 30,000 cfs over just a few hours, producing rapid changes of up to 12 feet in river stage. Stage fluctuations of 12 feet in stage on August 5-6, 2001 are shown as minimal changes by mean daily stage. Fluctuations in stage near Bagnell Dam were considerably higher than those for the nearby, unregulated Gasconade River near Rich Fountain, MO during fall 2001. Although the Gasconade River is smaller than the Osage River near Bagnell, standardized hourly flow data show the unnatural characteristics of flow fluctuations created by hydropower operation of Bagnell Dam. Standardized hourly flow data also indicate how unnaturally low the minimum flow releases from Bagnell Dam were during the fall of 2001.

Flow fluctuations at Bagnell Dam affect flows and water levels for many miles downstream. Although the magnitudes of flow and stage changes lessen as hydropower releases travel downstream, hourly and daily variability are still considerable. Standardized hourly stage data show releases from Bagnell Dam create substantial changes in river levels 42 miles downstream at St. Thomas, MO (Figure 45). A daily stage change of 13 feet at Bagnell Dam can equate to a daily change of 7 feet or more at St. Thomas. Hydropower releases from Bagnell Dam are still evident in the Missouri River at Hermann, Missouri, 114 miles downstream of Bagnell Dam, (Figures 46 & 47), and may affect water temperature, water quality, and availability of terrestrial habitats in and along the Missouri River when its flow is low.

Small Impoundments

According to the National Wetlands Inventory, there are an estimated 13,978 small water impoundments totaling 8,633 acres within the basin. These include small public and private lakes, ponds, and restored wetlands. Concern exists over the effects that these impoundments have on low-flow conditions of streams as they intercept runoff and allow little or no adjustment for maintenance of stream flows.

WATER USE AND QUALITY

Surface water and groundwater quality in the basin are generally good (Vandike 1995). The area covered by the basin is part of the Salem Plateau groundwater province, otherwise known as the Ozark aquifer. Streams draining from the Salem Plateau generally contain water that is calcium-magnesium-bicarbonate type with low sulfate and chloride levels (Vandike 1995). Sink holes and losing stream segments of the Ozark aquifer provide a direct conduit for surface water to enter groundwater. This allows for relatively quick groundwater recharge, and also provides a direct link for surface contamination to enter groundwater. This relatively quick recharge time is also responsible for great variations in the water quality of springs in the basin.

Water Use

There are over 85,000 people served in the basin by either public supplied surface water (9%), public supplied groundwater (39%), or private wells (52%) (Table 14). A greater proportion of people from the Lower Osage River HUC 10290111 below Bagnell Dam are served by public supplied surface water (19%) than are served by public supplied surface water in Lake of the Ozarks HUC 10290109 above Bagnell Dam (only 4%). A greater proportion of people (45%) above the dam are served by public supplied groundwater, whereas below the dam only 25% of the people are served by public supplied groundwater.

Throughout the basin, total water withdrawals equaled 11.32 million gallons per day (mgd). The majority of these withdrawals are from the HUC below Bagnell Dam (54% or 6.09 mgd). Above Bagnell Dam (HUC 10290109) has only 5.23 mgd or 46% of the total water withdrawals from the basin.

Total withdrawals from groundwater in the basin equaled 8.01 mgd whereas total withdrawals from surface water were only 7.61 mgd. There are more withdrawals from groundwater in the HUC above Lake of the Ozarks (56%) than below Bagnell Dam (45%). However there are more withdrawals from surface water (2.48 mgd) below the dam than in the HUC above Bagnell Dam (0.83 mgd). There are 10 public water supply districts in the basin (MDNR 1986).

Beneficial Use Attainment

The MDNR maintains a list of beneficial uses for classified waters of the basin. All classified waters have been assigned the beneficial uses of aquatic life protection, livestock and wildlife watering, and fish consumption by humans. In addition there are 298.5 miles of streams in the basin classified as supporting whole body contact. These streams are the Osage River (82 miles), Lake of the Ozarks (121 miles), Maries River (41.5 miles), Tavern Creek (37 miles), Grand Auglaize Creek (7 miles), and Wet Glaize Creek (10 miles)(MDNR 1986). Sections 303(d) and 305(b) of the Clean Water Act are a means for determining if beneficial uses are being attained.

Chemical Water Quality

Water quality of the basin is generally good. Ambient water quality data is monitored by the USGS at their gauging station on the Osage River near St. Thomas. For a detailed look at quarterly water quality constituents for the Osage River, see Table 15 for years 1984 and 1995. During those years, temperature ranged from 1.5 C to 27.5 C, pH ranged from 7.2-8, DO ranged from 3.9 to 12.8, fecal coliform ranged from <4 colonies/100ml in the spring of 1984 to 1,100 colonies/100ml in the spring of 1995, total nitrogen ranged from 0.12 mg/l to 0.8 mg/l (see Table 19 or Missouri Water Quality Assessment Report 47, Volume III, 1997).

Water quality problems associated with increased urban and commercial development are an ongoing concern in the area surrounding Lake of the Ozarks. Increases in population density and recreational use are the primary reason for elevated nitrification and algal growth in Lake of the Ozarks.

The MDNR noted several water quality concerns for the basin (MDNR 1994). The first concern dealt with the continued commercial and residential development along the shoreline of Lake of the Ozarks. This development has increased the amount of treated sewage discharged to the lake. Many coves have excess algal growth from nutrients discharged into the lake by sewage. A second concern is groundwater contamination by improperly functioning septic tanks, leaking storage tanks and agricultural runoff or wastewater discharges to losing streams. Poorly constructed wells also greatly increase the chance for groundwater contamination. The problem is especially severe where the human population center sits atop geologic strata, such as the Lebanon area, which allow high rates of infiltration of surface water to groundwater. A third concern is the increasing number of CAFOs which have the potential, if not properly managed, to discharge harmful amounts of animal waste into spring branches and streams thereby degrading the water quality of those water bodies.

Pesticides have been detected in wells and springs throughout the Ozark aquifer, including the basin. Recent studies have detected a higher level of pesticide occurrences in springs than in wells. Most occurrences of pesticides in this groundwater province are probably directly related to the land use of the area surrounding the spring or well sampled.

Nitrates were found in only about 5% of the wells tested in the Salem Plateau groundwater province. Land use practices such as the application of fertilizer and human and animal waste can contribute high levels of nitrates to groundwater. Data collected between 1972 and 1990 found that less than 15% of samples from this groundwater province contained phosphorus at concentrations above detection levels. Springs and shallow wells were found to have higher phosphorus levels on average than deeper wells.

Sections 305(b) and 303(d) of the Clean Water Act

The MDNR reports on the status of water quality in surface waters according to section 305(b) of the Clean Water Act. MDNR summarizes the quality of Missouri waters every two years in these reports. Significant improvements in water quality have been made over the past quarter century in controlling pollution from municipal sanitary wastes, but major problems still exist from non-point source pollution.

Section 303(d) of the Clean Water Act requires states to list waters not expected to meet established state water quality standards even after application of conventional technology-based controls for which total maximum daily load (TMDL) studies have not yet been completed. The impaired waters list is produced every four years by the MDNR and includes waters for which existing required pollution controls are not stringent enough to maintain state water quality standards.

There are approximately 1.9 miles of 303(d) listed impaired streams and 50 acres of impaired reservoir found within the basin. Sources of biological impairment include damming, riparian degradation, channel alteration, urbanization, flow alteration, sedimentation, point source pollution, and non-point source pollution.

Fifty acres of the upper section of Lake of the Ozarks, downstream from Truman Dam, is included in the 303(d) list due to periodic gas supersaturation, occasional low DO levels and fish kills due to physical trauma (MDNR 1996, MDNR 2000). Truman Dam is listed as the source of the problem. The priority for development of TMDL is medium priority for this section of Lake of the Ozarks.

For the Lower Osage River, two separate 0.2 mile sections of river are listed due to loss of aquatic habitat resulting from sand and gravel dredging operations (MDNR 1996, MDNR 2000). TMDL development for this section of the river is listed as high priority.

Dry Auglaize Creek near Lebanon, Missouri is also listed as an impaired stream on the 303(d) list. A 1.5 mile section of this stream downstream from the Lebanon Waste Water Treatment Plant has been repeatedly polluted by sewage. Major concerns listed in this reach of stream include biological oxygen demand (BOD) and non-filterable residue (NFR). TMDL development for this section of Dry Auglaize Creek has not been completed.

For more information, contact MDNR's Water Pollution Control Program at 1-800-361-4827 or (573) 751-1300.

Point Source Pollution

Several waste water treatment facilities of the basin have historically violated their discharge permits. As human population increases, these problems are likely to increase. Water quality concerns associated with point sources are listed in the Missouri Water Quality Basin Plan (MDNR 1996). The problems associated with point source discharges at this time include an increase in continued commercial and residential development at Lake of the Ozarks, which increases untreated sewage discharged to the lake. Many coves have excessive algal growth due to the nutrients in sewage.

The Clean Water Act requires wastewater dischargers to have a permit establishing pollution limits, and specifying monitoring and reporting requirements. The National Pollutant Discharge Elimination System (NPDES) regulates household and industrial wastes that are collected in sewers and treated at municipal wastewater treatment plants. These permits also regulate municipal and industrial point sources that discharge into other wastewater collection systems or that discharge directly into receiving water.

The EPA also issues permits and maintains lists of toxic release, regulated hazardous waste, and permitted compliance system water dischargers into the basin. Current lists of permitees and supplemental information can be accessed at EPA's Surf Your Watershed website (EPA 2001).

Non-Point Source Pollution

Significant forms of non-point source pollution which enter streams of the basin include untreated sewage, fertilizer, animal manure, and atmospheric deposition.

While much of the highly developed areas along Highway 54 have been sewered and their waste waters treated and discharged to the Osage River downstream of LOZ, sewage from thousands of lakeside homes is discharged to LOZ. The effects of this has been studied and to date this discharge source has not been recognized as a significant source of pollution. Although coves with high numbers of households do often have increased algae blooms associated with increased nutrients, there has not been sufficient documentation to warrant poor water quality conditions as a result of this form of nutrient input on Lake of the Ozarks.

A portion of the fertilizer which is applied to fields and lawns returns to the atmosphere as ammonia gas, and most of the rest is either taken up by plants or converted to nitrate in the soil. Consequently, most of the dissolved nitrogen that enters streams from runoff of fertilizer occurs as nitrate. Nitrate is a very mobile form of nitrogen. It is not readily retained by the soil and is highly soluble in water. Because of this mobility, nitrate is often applied in greater quantities than crops or lawns require. Also, given its high solubility, nitrate may be washed into adjacent streams by rain, or it may leach into the groundwater system (Pucket 1994)

The basin has a sizeable number of livestock operations. If not properly handled and disposed of, the accumulated manure from these operations can add nutrients to streams. Where livestock roam freely, large amounts of nutrients in the form of manure are distributed over the landscape and represent a true non-point source of pollution. However, where animals are confined to feedlots, barns, or sheds, they become more of a point-source pollution problem. In these situations, large quantities of manure commonly are concentrated in one location, and the nutrients that leach to ground and surface waters from storage areas may pose a water-quality problem (Pucket 1994).

When livestock waste enters a stream, nutrient contents of the stream rise and fecal coliform counts increase. Increases in nitrogen can result in dense algal growth which can deplete dissolved oxygen in the stream. Fish become stressed under these conditions, and in some cases fish kills occur. Also, cattle which drink the contaminated water may experience reduced weight gains. Increases in fecal coliform counts also make streams unsafe for human recreation.

Atmospheric deposition of nutrients such as nitrogen originates primarily from the combustion of fossil fuels, such as gas, coal, and oil. Atmospheric deposition of these nutrients often occurs with precipitation such as rain, snow, hail, or fog. The largest sources of these pollutants are coal and oil-burning electric facilities and large industries. However, automobiles, trucks, buses, and other forms of transportation can account for more than one-third of these sources. Even though these nutrients often come from point sources such as industrial plants, they still are called non-point source pollutants when they reach water bodies through precipitation. In the past, this type of non-point source pollution was largely ignored because it did not fit the traditional definition of a non-point source. This form of non-point source pollution can be significant. Over half of the nitrogen emitted from fossil-fuel-burning plants, vehicles, and other sources are deposited in watersheds (Pucket 1994).

Sediment input from construction sites which do not use best management practices can have serious negative impacts on streams and impoundments. Sediment input from crop fields is not as much of a concern throughout the basin, but can have localized negative impacts. Land use in the basin is listed as approximately 54.8% forest, 39.7% grassland, 2.5% open water, 1.6% cropland, and 1.6% urban. Sheet and rill erosion in the basin is estimated by the NRCS to be 2.5 tons/acre/year. Gully erosion is considerably less with 0-0.16 tons/acre/year. Since the majority of the land cover in this basin is forest and grassland, streams of the basin generally do not receive large amounts of sediment, and agricultural erosion is not considered to be a basin- wide problem. However, urbanization is continually increasing throughout the basin. With urbanization comes the destruction of vegetative cover and construction parking lots, buildings, shopping centers and residences, all impervious surfaces. With the steep hillsides and tremendous runoff effects of rainfall in the basin, if construction sites do not use best management practices to control erosion during their operations, sediment is transported and deposited in streams and reservoirs of the basin.

Prior to the construction of Truman Dam, the Upper Osage River carried significant amounts of sediment, as well as nitrogen and phosphorus into the basin. With the construction of Truman Dam, however, the sediment and nutrient inputs from the Upper Osage River have decreased.

Water Quality Studies and Concerns

A series of limnological studies have been conducted to monitor the water quality of Lake of the Ozarks.

Initially the studies were designed to evaluate the effect of Truman Dam on Lake of the Ozarks (Jones and Novak 1981, Jones and Kaiser 1988). Sampling was continued to monitor and evaluate any changes in water quality over time (Jones 1993, Kaiser and Jones 1999). Jones and Kaiser (1988) found decreased loading of total phosphorus and suspended solids, and increased levels of chlorophyll, suggesting that Lake of the Ozarks had increased in productivity. Indirect evidence suggested that conditions were more favorable for algal growth after the construction of Truman Dam because of increased water clarity in Lake of the Ozarks. The water which entered Lake of the Ozarks had lower amounts of dissolved solids since these were now settling out in Truman Reservoir.

Water quality concerns associated with increased urban development will need to be addressed in the future for Lake of the Ozarks and streams around Lebanon, Missouri. The lower part of Lake of the Ozarks receives substantial nutrient inputs associated with development. Point source discharges, septic tanks, and lawn maintenance are causing localized, high levels of suspended algae in some coves.

Bacterial contamination in coves of lower Lake of the Ozarks is a continuing concern. However, studies in the past have shown that all coves tested had low levels of fecal coliform bacteria well within state water quality standards for whole body contact recreation (MDNR 1996).

Mitzelfelt (1985) studied Lake of the Ozarks to determine if urbanization and development was affecting water quality. Small but consistent differences in trophic state of near shore waters were found as development of the adjacent shoreline increased. Data based on nutrient levels, chlorophyll a levels, and secchi disk readings categorized the lower Lake of the Ozarks as mesotrophic although chlorophyll a and secchi readings bordered on eutrophic. Fecal coliform data showed large increases with increased development particularly over summer weekends and holidays. Many of the samples exceeded standards for whole body contact recreation. The high levels of fecal coliform bacteria were attributed to inadequate septic systems and occasional pleasure boat discharges of untreated sewage. Mitzelfelt (1985) also suggested it was unlikely that urbanization and development would have a major impact on Lake of the Ozarks water quality because of dilution and flushing effects of the reservoir.

The Missouri Department of Health (MDOH) and MDNR continue to monitor the water quality of Lake of the Ozarks to ensure that adequate wastewater and stormwater management are undertaken. Study results indicate that there is an increase in fecal coliform counts after heavy rainfall, suggesting the waste load is a result of runoff. Acknowledging this fact, state water quality regulations stipulate that the standard for fecal coliform bacteria does not apply during periods of stormwater runoff (10 CSR20-7.031(4)(c)).

Mitzelfelt (1985) also found that Lake of the Ozarks becomes temperature stratified during the summer months. The cold, lower layer of water, termed the hypolimnion, has very little or no dissolved oxygen (DO). Each summer, leakage and release of this hypolimnetic water through the turbines causes many miles of the Osage River downstream from the Bagnell Dam to have unnaturally low DO. Many fish kills have occurred in dam’s tailwater as a result.

AmerenUE and MDC jointly developed and agreed upon operational changes to increase tailwater DO and reduce the likelihood of fish kills due to low DO. To increase DO of hydropower generation releases, AmerenUE allows more air to mix with the water by opening vents on all main turbines when DO is less than 3 mg/l at the turbine intakes. From June 1 to July 14, the DO of minimum releases (455 cfs; 25% gate setting) is improved by operating the house turbines with vents open. From July 15 to September 30, the house turbines are operated at 16% gate setting with vents open, which increases DO but reduces the flow to 385 cfs. In addition, when DO about 2,000 feet downstream near the MDC boat ramp is less than 2.5 mg/l, one main turbine is operated for one hour on and one hour off from 8:00 P.M. to 8:00 A.M. each night. Since implementation of the operating agreement in 1996, no fish kills have been reported due to low DO problems below Bagnell Dam.

Even with the operating agreement, summer DO levels still remain below the MDNR standard of 5 mg/l for many miles downstream of Bagnell Dam. During minimum flow conditions (385-455 cfs), DO can be 1 mg/l in some locations near the dam and can remain below 5 mg/l for up to 10 miles downstream. DO can remain below 5 mg/l for up to 70 miles downstream during peak generation. Although fish kills have been prevented since implementation of the 1996 agreement, DO levels below the 5 mg/l standard can stress fish, mussels, and aquatic insects, likely reducing growth, spawning, distribution, and diversity of aquatic biota.

The effects of gravel mining (the removal of gravel from streambeds) can be disastrous to a stream and the surrounding stream corridor as well as upstream and downstream stream reaches. Water quality problems associated with gravel mining in the basin include: increased turbidity downstream from mining, increase in gradient, increased water temperatures due to a disruption in the stream flow, and increased sedimentation. Little information on the extent of past or present gravel mining is known for the basin.

In recent years, there has been a relaxing of the rules and case laws concerning instream gravel mining operations in the United States. From 1995-1998, the USACE regulated instream removal of gravel from streams in the basin. Currently, there are no permits required for non-commercial gravel mining operations. Permits are required for commercial gravel mining operations. These are handled through the MDNR’s Land Reclamation Division.

In the past, large commercial gravel operations have caused major upstream and downstream erosion within the basin. Linn Creek is one such example. A commercial gravel mining operation adjacent to the town of Linn Creek, Missouri mined considerable quantities of gravel from the adjacent streambed causing a 5-10 foot deep headcut to move upstream (Greg Stoner, MDC, personal communication). The effects of this operation were documented upstream for miles on Linn Creek and into two tributaries. A grade control structure built to protect one bridge later failed due to further incision. Other infrastructure damage along Linn Creek required $20,000 worth of repairs for telephone poles, cables, and phone lines and $19,000 worth of repairs for a sewer line. Up to 100 ft of lateral bank erosion occurring over a nine year period undermined nine residences and two businesses, resulting in an $875,000 buyout of those properties in 1994 by the Federal Emergency Management Agency. Numerous structures are still in jeopardy. It is estimated that the damages caused by this gravel mining operation alone may exceed $1 million dollars before the streambed re-stabilizes. Sellar’s Creek and Tavern Creek are two more examples where gravel removal has severely damaged habitat, water quality, and caused fish kills.

The majority of the gravel removal operations are non-commercial and presently not regulated. These mining operations are typically operated by landowners or local road districts to remove gravel from streams for use on farm roads. Landowners also rearrange gravel bars in an attempt to alleviate stream bank erosion. The cumulative effects of this small-scale but widespread gravel removal and streambed alteration are unknown at this time.

Although the cumulative effects of non-commercial gravel removal have not been well documented, they are considered to be a significant concern and possible source of habitat and water quality degradation.

Between 1993-1998, the USACE regulated all instream gravel mining operations including non-commercial operations. The extent that gravel mining was permitted both commercially and non-commercially in the basin was extensive and is shown in Figure 32. Since the USACE now has limited involvement regulating this activity, the extent that these operations are currently removing gravel in most cases may be going unmonitored and having severe local impacts on streambeds, streambanks, riparian vegetation, and the species that rely on them.

Volunteer Water Quality Monitoring and Stream Clean-up

Volunteer water quality monitoring in the basin is conducted by both the Missouri Stream Teams program and the Lakes of Missouri Volunteer Program. The Missouri Stream Teams program was initiated by MDC, MDNR, and the Conservation Federation of Missouri. The Lakes of Missouri Volunteer Program is coordinated by the University of Missouri-Columbia, School of Natural Resources and funded by the EPA through MDNR.

Missouri Stream Team sampling sites for the basin are depicted in Figure 50. These volunteers participate in various projects such as litter cleanup, macroinvertebrate sampling, tree planting for bank stabilization, stream inventories, and educational exhibits. For a complete listing of the Missouri Stream Teams and to obtain the data that they have collected, please see the official Missouri Stream Team website.

Fish Consumption Advisories

The MDOH issues fish consumption advisories for Missouri. MDC collects fish annually for use in consumption advisories. The most current consumption advisory information is available from the MDOH.

During 2001 the MDOH issued a statewide advisory regarding the consumption of largemouth bass in Missouri. The advisory targets pregnant women, nursing mothers, and children advising that they not consume largemouth bass. It also advises consumption of no more than a specified amount of bass by the remainder of the population. This advisory was issued due to a reduction in EPA's action level for mercury in fish tissue from 1,000 ppb to 200-300 ppb. Missouri's largemouth bass population has for many years had fish with mercury levels in the 200-300 ppb range. In 2001, 100% of the bass collected in Missouri and analyzed for metals contained mercury. Of those samples approximately 32% exceeded 200 ppb. The primary source of mercury to the environment is through air emissions. In Missouri, coal burning boilers account for 90% of mercury emissions.

Fish Kills

MDC maintains a listing of all reported fish kills within the basin and a list of pollution occurrences where no fish kill was reported but may have in fact been detrimental to aquatic populations. The earliest reported fish kill on record was in April of 1960 on a creek near Gravois Mills. Unfortunately, there is no record of the number killed or the cause of that fish kill. The most recent fish kill to date occurred in Lake of the Ozarks in October of 2001. An estimated 70 paddlefish were killed after becoming impinged on turbine intakes on the front of the dam.

The causes of recorded fish kills in the basin have included: low dissolved oxygen, sludge, petroleum, diesel fuel, sewage, gas bubble disease, temperature, parasites, physical injury from turbines, impingement on the face of Bagnell dam, detergent, hog manure, dairy cattle manure, molasses, severe siltation, stream habitat destruction, channelization, and herbicide. The estimated numbers of fish killed per incident range from as few as 3 fish killed in Lake of the Ozarks due to herbicide application to as many as 421,785 in Lake of the Ozarks due to a gas supersaturation in the water resulting from to the operation of Truman Dam.

Figure 16. Losing streams of the East Osage River Basin

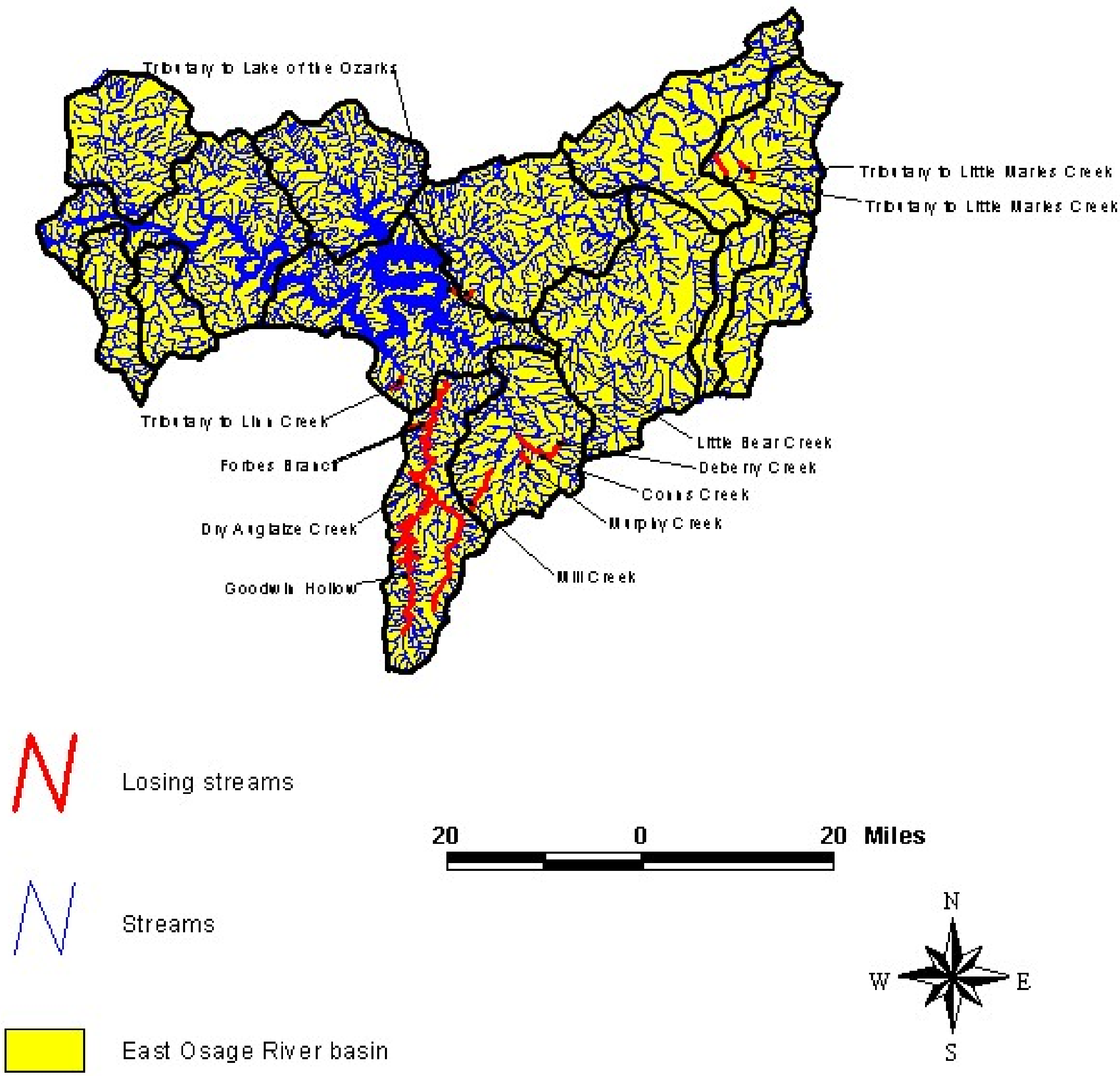

Figure 17. Springs of the East Osage River Basin

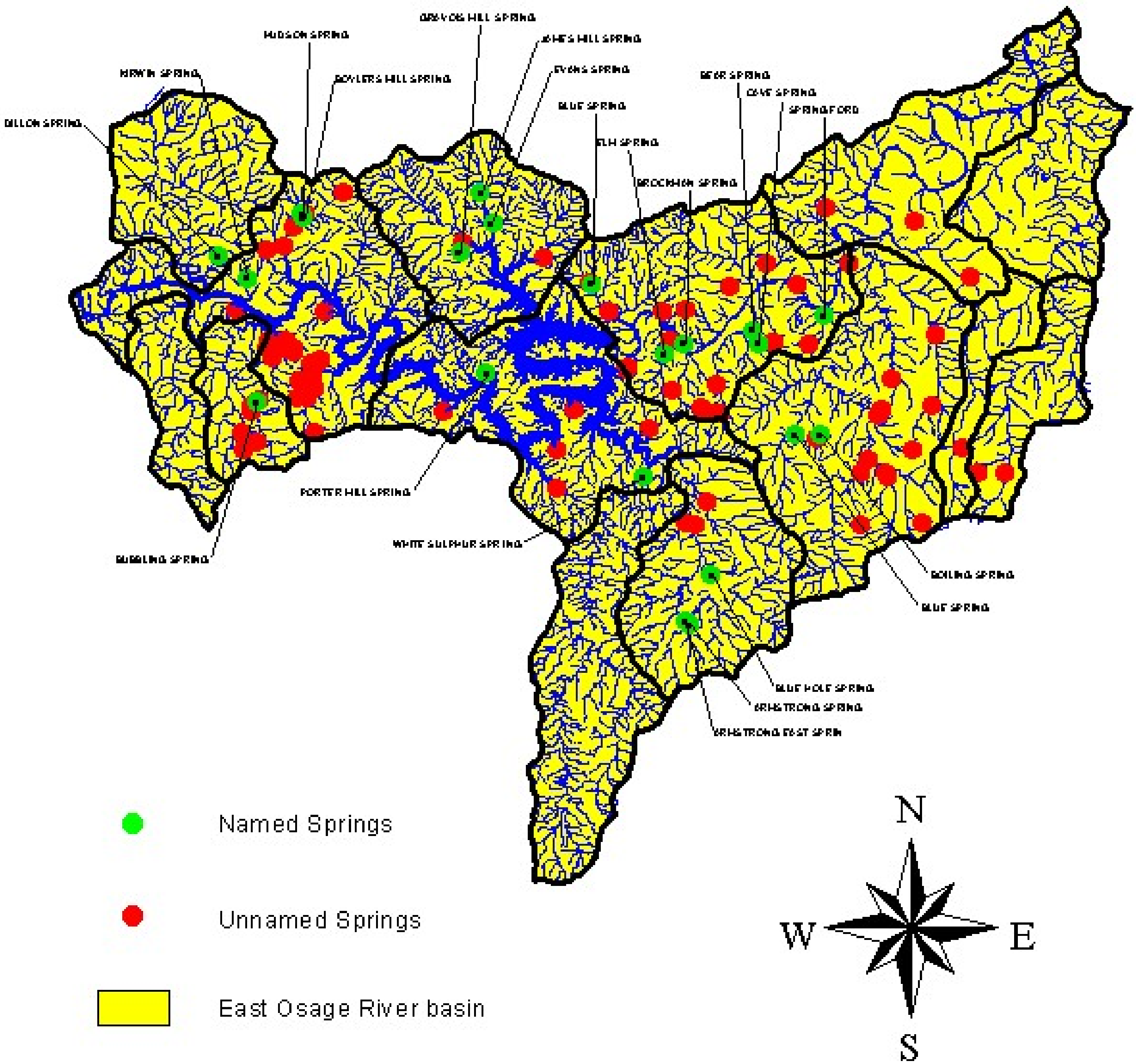

Table 10. Gauging stations operated in the East Osage River Basin (bold indicates active station).

Gauge Number	Station Name	County	Years of Record
06922450	Osage River below Truman Dam at Warsaw, Missouri	Benton	1981-2000 minus Oct. 1989-Sept. 1990
06922500	Osage River at Warsaw, Missouri	Benton	1925-1931
06922600	Little Turkey Creek Tributary near Warsaw, Missouri	Benton	1959-1979
06922700	Chub Creek near Lincoln, Missouri	Benton	1958-1979
06922800	Big Buffalo Creek near Stover, Missouri	Benton	1965-1967 1968-1977
06925270	Dry Auglaize Creek Tributary near Lebanon, Missouri	Laclede	1955-1970
06925300	Prairie Branch near Decaturville, Missouri	Laclede	1955-1979
06925450	Little Gravois Creek near Versailles, Missouri	Morgan	1955-1979
06910430	Dickerson Creek Tributary near Jefferson City, Missouri	Cole	1970-1979
06926150	Jack Buster Creek at Eugene, Missouri	Cole	1961-1979

06926500	Osage River near St. Thomas, Missouri	Cole	1931-1996
06926510	Osage River below St. Thomas, Missouri	Cole	1996-2000
06926000	Osage River near Bagnell, Missouri	Miller	1925-1998
16926200	Van Cleve Branch near Meta, Missouri	Maries	1956-1972
06926800	Long Branch near Vienna, Missouri	Maries	1957-1979
06927000	Maries River at Westphalia, Missouri	Osage	1948-1970

Table 11. Number of streams 4th order and larger and stream mileage by subbasin for the East Osage River Basin.

Subbasin	Number of streams $\geq$ 4th order	Total stream miles
Lower Osage River	3	69.3
Lower Maries River	3	65.4
Upper Maries River	4	42.1
Little Maries River	1	25.5
Tavern Creek	6	109.7
Wet Glaize Creek	7	60.8
Dry Auglaize Creek	2	71.1
Deer Creek	2	24
Turkey Creek	1	24.2
Cole Camp Creek	5	61
Upper Lake of the Ozark Hills	7	88.2
Gravois Arm	4	37.4
Lower Lake of the Ozarks Hills	2	59.9
Miller County Osage River Hills	12	116.7

Table 12. Known losing streams of the East Osage River Basin.

Stream Name	County	Length (miles)	Start T R S	End T R S
Trib. to Linn Creek	Camden	2.4	38N 16W 19	38N 16W 17
Murphy Creek	Camden	1.8	37N 14W 33	37N 14W 29
Conns Creek	Camden	4.3	37N 14W 26	37N 14W 17
Deberry Creek	Camden	3.3	37N 14W 13	37N 14W 22
Mill Creek	Camden	4.5	36N 15W 28	37N 15W 35
Trib. to LOZ	Camden	0.9	39N 15W 06	39N 15W 06
Little Bear Creek	Miller	1.5	39N 15W 05	39N 15W 04
Dry Auglaize Creek	Camden/Laclede	34.4	34N 16W 11	38N 15W 18
Forbes Branch	Camden	3.1	37N 16W 09	37N 16W 11
Trib. to Dry Auglaize Creek	Laclede	0.6	36N 16W 03	36N 16W 03
Trib. to Dry Auglaize Creek	Laclede	1.2	36N 16W 04	36N 16W 03
Goodwin Hollow	Laclede	20.0	34N 16W 20	36N 16W 14

Trib. to Goodwin Hollow	Laclede	0.8	36N 16W 33	36N 16W 33
Trib. to Goodwin Hollow	Laclede	0.6	36N 16W 32	36N 16W 33
Trib. to Goodwin Hollow	Laclede	1.1	36N 16W 32	36N 16W 33
Trib. to Goodwin Hollow	Laclede	2.1	35N 16W 10	35N 16W 04
Trib. to Goodwin Hollow	Laclede	2.2	35N 16W 18	35N 16W 08
Trib. to Goodwin Hollow	Laclede	1.4	35N 16W 22	35N 16W 16
Trib. to Goodwin Hollow	Laclede	1.2	35N 16W 20	35N 16W 21
Trib. to Goodwin Hollow	Laclede	0.6	35N 16W 22	35N 16W 21
Trib. to Little Maries	Osage	3.1	41N 11W 01	42N 11W 26
Trib. to Little Maries	Osage	2.6	41N 10W 05	42N 10W 30

Source: MDNR (1986a).

Table 13. Known springs within the East Osage River Basin.

Spring Name	County	Topographic Map	Twp	Rng	Sec	Average Flow (cfs)
Unnamed	Benton	Edwards	40N	20W	17	--
Unnamed	Benton	Edwards	39N	20W	9	--
Unnamed	Benton	Edwards	38N	20W	17	--
Unnamed	Benton	Edwards	39N	20W	17	--
Unnamed	Benton	Knobby	40N	20W	26	--
Unnamed	Benton	Knobby	40N	20W	36	--
Unnamed	Benton	Knobby	39N	20W	12	--
Unnamed	Benton	Knobby	39N	20W	12	--
Unnamed	Benton	Knobby	39N	20W	1	--
Unnamed	Benton	Knobby	40N	20W	35	--
Unnamed	Benton	Knobby	40N	20W	34	--
Unnamed	Benton	Knobby	40N	20W	35	--
Unnamed	Benton	Knobby	39N	20W	1	--
Unnamed	Benton	Knobby	40N	20W	36	--
Unnamed	Benton	Knobby	40N	20W	36	--
Unnamed	Benton	Knobby	40N	20W	25	--

Unnamed	**Benton**	**Knobby**	**40N**	**20W**	**27**	**--**
Unnamed	**Benton**	**Cross Timbers**	**39N**	**20W**	**30**	**--**
Unnamed	**Benton**	**Cross Timbers**	**39N**	**20W**	**31**	**--**
Unnamed	**Benton**	**Cross Timbers**	**39N**	**20W**	**33**	**--**
Unnamed	**Benton**	**Boylers Mill**	**41N**	**20W**	**22**	**--**
Unnamed	**Benton**	**Boylers Mill**	**41N**	**20W**	**23**	**--**
Unnamed	**Benton**	**Boylers Mill**	**41N**	**20W**	**12**	**--**
Bubbling Spring	**Benton**	**Edwards**	**39N**	**20W**	**8**	**0.08**
Kirwin Spring	**Benton**	**Lakeview Heights**	**41N**	**20W**	**32**	**--**
Dillon Spring	**Benton**	**Lakeview Heights**	**41N**	**20W**	**25**	**0.031**
Unnamed	**Camden**	**Knobby**	**40N**	**19W**	**16**	**--**
Unnamed	**Camden**	**Knobby**	**40N**	**19W**	**16**	**--**
Unnamed	**Camden**	**Knobby**	**40N**	**19W**	**32**	**--**
Unnamed	**Camden**	**Knobby**	**39N**	**19W**	**6**	**--**
Unnamed	**Camden**	**Climax Springs**	**39N**	**19W**	**30**	**--**
Unnamed	**Camden**	**Camdenton**	**39N**	**16W**	**29**	**--**
Unnamed	**Camden**	**Camdenton**	**38N**	**16W**	**8**	**--**
Unnamed	**Camden**	**Conns Creek**	**37N**	**14W**	**21**	**--**

Unnamed	**Camden**	**Knobby**	**30N**	**19W**	**16**	**--**
Unnamed	**Camden**	**Montreal**	**38N**	**15W**	**30**	**--**
Unnamed	**Camden**	**Montreal**	**38N**	**15W**	**30**	**--**
Blue Hole Spring	**Camden**	**Conns Creek**	**37N**	**14W**	**17**	**7.16**
Armstrong East Spring	**Camden**	**Montreal**	**36N**	**14W**	**6**	**11.6**
Armstrong Spring	**Camden**	**Montreal**	**36N**	**15W**	**1**	**1.18**
Unnamed	**Camden**	**Sunrise Beach**	**39N**	**18W**	**14**	**--**
Porter Mill Spring	**Camden**	**Sunrise Beach**	**39N**	**17W**	**5**	**--**
White Sulphur Spring	**Camden**	**Toronto**	**38N**	**15W**	**9**	**--**
Unnamed	**Camden**	**Lake Ozark**	**39N**	**16W**	**9**	**--**
Unnamed	**Cole**	**St. Elizabeth**	**42N**	**13W**	**25**	**--**
Unnamed	**Maries**	**Big Bend**	**38N**	**11W**	**2**	**--**
Unnamed	**Maries**	**Big Bend**	**39N**	**11W**	**27**	**--**
Unnamed	**Maries**	**Argyle**	**41N**	**11W**	**23**	**--**
Unnamed	**Maries**	**Van Cleve**	**39N**	**11W**	**6**	**--**
Unnamed	**Maries**	**Van Cleve**	**40N**	**11W**	**16**	**--**
Unnamed	**Maries**	**Big Bend**	**38N**	**11W**	**6**	**--**

Bear Spring	**Miller**	**Tuscumbia**	**40N**	**14W**	**13**	**--**
Blue Spring	**Miller**	**Iberia**	**39N**	**13W**	**21**	**--**
Boiling Spring	**Miller**	**Iberia**	**39N**	**13W**	**23**	**--**
Cave Spring	**Miller**	**Tuscumbia**	**40N**	**13W**	**19**	**--**
Unnamed	**Miller**	**Lake Ozark**	**40N**	**15W**	**7**	**--**
Unnamed	**Miller**	**Rocky Mount**	**41N**	**16W**	**35**	**--**
Unnamed	**Miller**	**Bagnell**	**40N**	**15W**	**11**	**--**
Unnamed	**Miller**	**Bagnell**	**40N**	**15W**	**11**	**--**
Brockman Spring	**Miller**	**Bagnell**	**40N**	**14W**	**19**	**--**
Unnamed	**Miller**	**Bagnell**	**40N**	**15W**	**24**	**--**
Unnamed	**Miller**	**Bagnell**	**40N**	**14W**	**6**	**--**
Blue Spring	**Miller**	**Rocky Mount**	**41N**	**16W**	**35**	**--**
Unnamed	**Miller**	**Iberia**	**39N**	**13W**	**22**	**--**
Unnamed	**Miller**	**Tuscumbia**	**39N**	**14W**	**7**	**--**
Unnamed	**Miller**	**Tuscumbia**	**39N**	**14W**	**5**	**--**
Unnamed	**Miller**	**Bagnell**	**39N**	**15W**	**2**	**--**
Unnamed	**Miller**	**Bagnell**	**40N**	**15W**	**32**	**--**
Unnamed	**Miller**	**Bagnell**	**40N**	**15W**	**32**	**--**

Elm Spring	**Miller**	**Bagnell**	**40N**	**15W**	**26**	**0.09**
Unnamed	**Miller**	**Tuscumbia**	**40N**	**13W**	**20**	**--**
Spring Ford	**Miller**	**St. Anthony**	**40N**	**13W**	**12**	**--**
Unnamed	**Miller**	**St. Anthony**	**40N**	**13W**	**23**	**--**
Unnamed	**Miller**	**St. Elizabeth**	**41N**	**12W**	**20**	**--**
Unnamed	**Miller**	**St. Elizabeth**	**41N**	**13W**	**28**	**--**
Unnamed	**Miller**	**Eugene**	**41N**	**14W**	**27**	**--**
Unnamed	**Miller**	**Eugene**	**41N**	**13W**	**19**	**--**
Unnamed	**Miller**	**Brays**	**38N**	**12W**	**3**	**--**
Unnamed	**Miller**	**Brays**	**38N**	**12W**	**3**	**--**
Unnamed	**Miller**	**Brays**	**39N**	**12W**	**9**	**--**
Unnamed	**Miller**	**Brays**	**39N**	**12W**	**9**	**--**
Unnamed	**Miller**	**Brays**	**39N**	**12W**	**25**	**--**
Unnamed	**Miller**	**Van Cleve**	**39N**	**12W**	**9**	**--**
Unnamed	**Miller**	**Van Cleve**	**39N**	**12W**	**3**	**--**
Unnamed	**Miller**	**Toronto**	**39N**	**15W**	**21**	**--**
Unnamed	**Miller**	**Brumley**	**38N**	**14W**	**17**	**--**
Unnamed	**Miller**	**Brumley**	**39N**	**14W**	**17**	**--**
Unnamed	**Miller**	**Brumley**	**39N**	**14W**	**9**	**--**

Unnamed	**Miller**	**Brumley**	**39N**	**14W**	**17**	**--**
Unnamed	**Miller**	**Iberia**	**38N**	**12W**	**5**	**--**
Unnamed	**Miller**	**Iberia**	**39N**	**12W**	**32**	**--**
Unnamed	**Miller**	**Tuscumbia**	**40N**	**13W**	**20**	**--**
Unnamed	**Miller**	**Tuscumbia**	**40N**	**13W**	**20**	**--**
Boylers Mill Spring	**Morgan**	**Boylers Mill**	**41N**	**19W**	**6**	**1.36**
Gravois Mill Spring	**Morgan**	**Gravois Mills**	**41N**	**17W**	**19**	**--**
James Mill Spring	**Morgan**	**Versailles**	**42N**	**17W**	**28**	**--**
Unnamed	**Morgan**	**Boylers Mill**	**42N**	**17W**	**6**	**--**
Unnamed	**Morgan**	**Rocky Mount**	**41N**	**16W**	**20**	**--**
Hudson Spring	**Morgan**	**Boylers Mill**	**42N**	**19W**	**6**	**--**
Unnamed	**Morgan**	**Gravois Mills**	**41N**	**17W**	**18**	**--**
Unnamed	**Morgan**	**Crockerville**	**42N**	**19W**	**27**	**--**
Evans Spring	**Morgan**	**Gravois Mills**	**41N**	**17W**	**3**	**--**
Unnamed	**Morgan**	**Rocky Mount**	**41N**	**16W**	**20**	**--**
Unnamed	**Osage**	**Meta**	**42N**	**11W**	**31**	**--**
Unnamed	**Pulaski**	**Hancock**	**38N**	**11W**	**30**	**–**

– = No data recorded

Table 14. Water use in the East Osage River Basin .

Category	10290109 Lake of the Ozarks	10290111 Lower Osage	Total
POPULATION SERVED			
Number of People Served by Public Supplied Surface Water	2,210 (4 %)	5,730 (19 %)	7,940 (9 %)
Number of People Served by Public Supplied Groundwater	25,350 (45%)	7,630 (25%)	32,980 (39%)
Total Number of People Served by Public Water Supply	27,560	13,360	40,920
Total Number of People Served by Private Wells	28,500 (51%)	16,170 (56 %)	44,670 (52 %)
Total Number of People Served in Area	56,060 (65% of total)	29,530 (35 % of total)	85,590 (100 %)
GROUNDWATER WITHDRAWALS (Million Gallon/Day (mgd))			
Groundwater Withdrawals for Commercial Use	0.54	0.18	0.72
Groundwater Withdrawals for Livestock Use	0.28	0.27	0.55
Groundwater Withdrawals for Public Water Supply	1.72	2.04	3.76
Groundwater Withdrawals for Irrigation	0.04	0	0.04
Private Well Withdrawals	1.71	0.96	2.87
SURFACE WATER WITHDRAWALS (mgd)			

Private Surface-water Withdrawals	**0**	**0**	**0**
Surface Water Withdrawals for Public Water Supply	**0.15**	**1.53**	**1.68**
Surface Water Withdrawals for Livestock Use	**0.04**	**0.85**	**0.89**
Surface Water Withdrawals for Commercial Use	**0**	**0**	**0**
Surface Water Withdrawals for Irrigation	**0.07**	**0.05**	**0.12**
TOTAL WITHDRAWALS (mgd)			
Total Groundwater Withdrawals	**4.4**	**3.61**	**8.01**
Total Surface Water Withdrawals	**0.83**	**2.48**	**3.31**
Total Withdrawals for Public Water Supply	**1.87**	**3.57**	**4.44**
Total Withdrawals for Livestock Use	**0.91**	**1.12**	**2.03**
Total Withdrawals	**5.23 (46 % of total)**	**6.09 (54 % of total)**	**11.32 (100%)**

Table 15. Quarterly water quality data from the Osage River near St. Thomas, Missouri, 1984 and 1995. (Data source USGS, 1985, and 1996).

CONSTITUENT	FALL		WINTER		SPRING		SUMMER	
	1984	1995	1984	1995	1984	1995	1984	1995
Instanteneous discharge, (ft3/second)	20,400	12,300	6,730	21,600	35,100	52,700	2,020	31,600
Temperature, (Celcius)	12.0	15.5	1.5	3	16.5	19	25	27.5
Specific Conductance, (Fs/cm)	28	272	251	254	255	281	283	248
pH, whole water, field measurement	8	7.7	7.8	7.2	7.9	7.7	7.6	7.5
Oxygen, dissolved (mg/l)	8.2	9	12.8	12.6	9.2	9.7	6	3.9
Fecal coliform, (colonies/100 ml)	96	1	10	13	<4	1,100	39	5
Fecal streptococci, (colonies/100 ml)	220	475	52	115	80	1,260	22	205
Alkalinity, (mg/l as $CaCO_3$)	106	102	106	83	91	105	123	90
Bicarbonate, dissolved (mg/l)	–	125	–	99	–	126	–	109
Nitrate + Nitrite, total as N (mg/l)	0.33	0.12	0.56	0.47	0.8	0.24	0.45	0.17
Phosphorus, dissolved (mg/l)	0.01	0.03	0.02	0.03	<0.02	0.09	0.02	0.02

Calcium, dissolved (mg/l)	39	0.4	37	33	33	34	40	34
Magnesium, dissolved (mg/l)	11	9.8	11	7.9	7.7	10	8.8	6.9
Sodium, dissolved (mg/l)	5.5	4.3	5.2	5.7	7.9	4.5	5.4	8.2
Potassium, dissolved (mg/l)	2.9	2.8	3.2	3.4	2.4	2.3	2.6	3.2
Sulfate, dissolved (mg/l)	26	18	27	22	29	20	26	17
Chloride, dissolved (mg/l)	5.2	8.9	6.3	8.4	5.1	5.4	4.9	3.7
Flouride, dissolved (mg/l)	0.1	0.1	0.1	0.1	0.1	<0.1	0.2	0.1
Total solids, dissolved (mg/l)	159	155	170	216	159	158	153	142
Aluminum, dissolved (Fg/l)	<10	<10	30	–	20	80	20	–
Iron, dissolved (Fg/l)	14	6	21	13	18	93	9	<3
Manganese, dissolved (Fg/l)	8	6	8	69	6	7	22	6
Nickel, dissolved (Fg/l)	11	<1	4	<1	<1	<1	10	1
Strontium, dissolved (Fg/l)	120	97	110	89	110	83	130	120