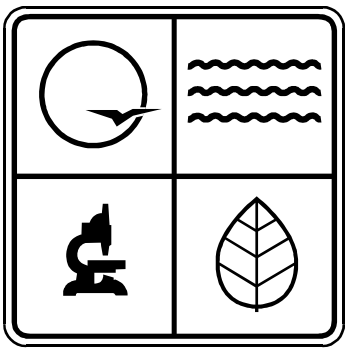
MISSOURI
WATER QUALITY REPORT

2002

MISSOURI DEPARTMENT OF NATURAL RESOURCES



WATER POLLUTION CONTROL PROGRAM

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CHAPTER 1. EXECUTIVE SUMMARY

WATER RESOURCES AND PROBLEMS

Missouri has an area of 69,000 square miles and a population of 5.50 million people. Most of the human population is concentrated on opposite sides of the state in the Kansas City and St. Louis metro areas, leaving most of the state and its waters rural in nature. Surface and ground water in Missouri are quite varied in quantity and quality, corresponding closely with geology and land use.

Northern and Western Missouri

Northern and Western Missouri, originally prairie land, is now used primarily for crop and livestock production and is underlain by bedrock containing several relatively impermeable shale and clay layers. Surface waters are more turbid and are greatly affected by high rates of sediment deposition. These deposits, caused by soil erosion and channelization, result in poor aquatic habitat due to the fine, unstable materials of stream bottoms. About 7,300 miles of classified streams suffer impairment due to these conditions, and, in more than half these miles, streams are further impaired by either periodic water loss or channelization.

Rivers and reservoirs used as drinking water supplies often contain herbicides. Drinking water standards for atrazine or health advisory levels for cyanazine are exceeded in some public water supplies served by reservoirs. Several other herbicides are occasionally found in drinking water reservoirs but at concentrations below health advisory levels.

The quality of ground waters in northern and western Missouri is also influenced by the geology of the area. The public water supply sources include reservoirs and wells. The wells obtain water from glacial drift deposits primarily in portions of north-central and western Missouri. Wells in western Missouri, south of Kansas City, obtain water from limestone aquifers except for the extreme western limits of Missouri near the state border with Kansas. Private water supplies are obtained from glacial drift deposits and from underlying limestone bedrock in portions of northwestern, central, eastern and northeastern Missouri. However, deep bedrock wells in many north-central and northwestern Missouri locations tap water supplies too mineralized for drinking water purposes. About one-third of private wells in this portion of Missouri exceed the drinking water standard for nitrate, and about 2 percent exceed drinking water standards for pesticides. This contamination is often caused by localized surface contamination of the wellhead and does not represent widespread contamination of the underground aquifer. Deeper aquifers are well protected from surface contamination by impermeable strata.

The Ozark Plateau

The Ozark Plateau, including the Springfield Plateau, is predominantly hilly topography. There are some very rugged portions as well as significant areas of gentle to almost flat landscape. The bedrock consisting of limestone, dolomite and sandstone yields ground water of excellent quality and adequate in supply for most urban, industrial and other needs. The soil or overburden has developed by weathering from the bedrock formations and is generally 20 to 80 feet in thickness.

Some areas have extremely thin soils and other locations where weathering has been extensive have a thickness of 100 feet and more. The soil overburden has moderate to high infiltration rates which contribute to the recharge of ground water supplies. Ozark streams are generally clear with baseflows well sustained by many seeps and springs. Some streams and reservoirs in the Ozarks are becoming nutrient and algae enriched due to increasing human and domestic animal production in some watersheds.

Ground water contamination risks are moderate to high due to the permeabilities of the soil and bedrock. Any number of surface activities including agricultural and suburban-urban storm water and waste water disposal, mining, stormwater runoff, lawn care, and improper well and individual waste disposal practices all pose threats

to surface water and ground water quality. However, overall water quality remains good in large part due to the efforts by all parties to protect the aquifers.

Ground water is heavily relied upon for drinking water supply in this part of Missouri. Most municipalities in the southern half of the state rely on ground water for drinking water supply. The number of private drinking water wells statewide is not known but probably is between 100,000 and 250,000 with a greater number of these wells being south of the Missouri River. The major ground water concern is the often rapid and unfiltered transmission of contaminated surface runoff or leachate from some septic tanks, underground storage tanks, landfills, dumps, liquid waste storage ponds, animal production and processing wastes through fractures or sinkholes directly into potable aquifers. Properly cased wells into deep aquifers rarely encounter water quality problems, but shallow or improperly cased wells are at risk.

In the Joplin area, the shallow bedrock aquifer has elevated levels of sulfate and several heavy metals due to mineralization of ground water in flooded mines. Some private wells in this area exceed drinking water standards for lead or cadmium. Localized contamination of shallow private wells due to leaks, spills and improper disposal of industrial or commercial chemicals occur in the larger metro areas of Springfield and Joplin.

The Mississippi Embayment

Missouri's southeastern corner is a large alluvial plain of the Mississippi River. Originally a vast system of wetlands, it has been drained and almost entirely converted to crop production. Almost all surface waters in the area are drainage ditches and are rated as only partially attaining beneficial uses because of degradation of aquatic habitat due to channelization. Channelization creates a homogenous, low quality aquatic habitat. Sloughing of the channel banks, which fill the channel bottoms, burying better habitat and leaving unstable substrate, is a problem.

Ground water is abundant due to high infiltration rates on these flat fields. Public water supplies that tap deeper aquifers provide good quality water, but shallow private wells commonly have nitrates and low levels of pesticides. The frequency of exceedence of drinking water standards for nitrates and pesticides in private wells is similar to northern Missouri, about 30 percent and 2 percent, respectively.

Alluvial Aquifers

The remaining major aquifer is the alluvial aquifer system of the major rivers of the state. In northern Missouri, where surface and deep aquifer supplies are unreliable, many towns depend on the alluvial aquifer of a large nearby stream. Landfills and industrial land use in Kansas City and St. Louis have historically been located on river floodplains and have caused local contamination of the Mississippi, Missouri and Meramec river aquifers in St. Louis and the Missouri River aquifer in Kansas City. Some municipal water supplies have been affected.

WATER POLLUTION CONTROL ACTIVITIES

Authority for enforcement of the Missouri Clean Water Law and for state regulations concerning water pollution resides in the Department of Natural Resources, Water Protection and Soil Conservation Division. Authority for the regulation of pesticides rests with the Missouri Department of Agriculture.

Point Source Controls

The number of miles of classified streams judged to be impaired by point source wastewater discharges has generally held steady since 1984, when statewide data on stream quality first became available. In 1984, 105 miles of classified stream were judged to be impaired by domestic or industrial wastewaters. The lowest estimate of point source impaired stream miles was 42 miles in 1996. Since then estimates were 91 miles in 1998, 93 miles in 2000 and 104 miles in 2002. The increasing number of impaired stream miles since 1996 is probably due primarily to expansion and improvements in the state's water quality monitoring activities that have allowed us to make more accurate estimates of water quality statewide.

The Missouri Clean Water Commission has revised its regulations to bring confined animal feeding operations (CAFOs) into the point source permit program, consistent with federal requirements. Hog and poultry production in CAFOs are now major industries in Missouri. The large amount of animal waste generated at these facilities requires proper management to prevent water pollution.

Concern over eutrophication of large, recreationally reservoirs have led to recent changes in the state regulations for discharges of wastewater. These regulations now impose phosphorus concentration limits on most wastewater discharges in the Table Rock Reservoir and Lake Taneycomo watersheds.

Nonpoint Source Controls

Control of nonpoint water pollution sources such as runoff from farms, cities, mining areas and construction sites is still essentially a voluntary program. Regulations are in place to prevent leakage from underground storage tanks and for the secondary containment of bulk agricultural chemical storage sites. Large sand and gravel mining operations require a general permit for stormwater and smaller operations have been provided with guidelines for best management practices (BMPs), in addition to the 404 permit required of all sand and gravel operations. Stormwater runoff discharge permits are now issued for construction sites and other areas with more than five acres of bared ground. The Water Pollution Control Program plans to reduce the size of bared ground requiring a stormwater permit from five acres to one acre.

Control of many nonpoint sources, such as agricultural erosion from cropland and pasture, runoff of fertilizer, pesticides and animal waste, are addressed by Missouri's nonpoint source management program. This program works with federal, state and local governments, universities, private groups and individual landowners to implement watershed projects that demonstrate nonpoint source control practices and often monitor water quality results.

Programs with dedicated funding sources have worked best. A tax on coal has funded reclamation of abandoned coal mined lands nationwide. Fourteen years of such reclamation in Missouri has reduced the number of stream miles impaired by acid mine drainage from about 100 down to 15. A state sales tax for soil erosion control started providing funds for watershed level soil erosion control programs in 1985. This program, coupled with federal soil conservation programs, is reducing soil erosion in Missouri based on the findings of periodic National Resource Inventories.

STATE CONCERNS

- Channelization has caused aquatic habitat degradation in 17 percent of Missouri's streams. Large channelization projects affecting many miles of streams are no longer occurring but many short projects still occur and continue to reduce the number of miles of natural stream channels statewide. Streams that were channelized many years ago still provide poor aquatic habitat, and these streams still contribute to flooding, high water velocities and streambank erosion.

- Eutrophication of large, recreationally important reservoirs appears to be increasing. Heavy residential development around portions of Lake of the Ozarks and Table Rock Lake threatens water quality in many small coves and shoreline areas. Water clarity in the main portion of Table Rock Lake, which was historically very clear, is apparently declining. The large size of these lakes and rugged local topography make centralized collection and treatment systems for waste water difficult. Nutrient problems from waste water treatment plants and septic tanks are being aggravated by increasing confined animal production in the watersheds of these lakes.

- Mercury levels in fish in Missouri appear to be increasing over time. Re-evaluation of human health risk factors for mercury has led the Missouri Department of Health & Senior Services to issue an advisory against consumption of Largemouth bass greater than 15 inches in length for children 12 years of age and under, pregnant women and women who may become pregnant. The advisory pertains to all waters in Missouri.

- Abandoned lead-zinc mines and their tailings continue to impact waters decades after mining has ceased. Missouri's Superfund program is addressing some of these concerns. But long-term impacts are expected to

remain. Although new mineral extraction operations would be managed under state permits, areas of the state that are very sensitive to disruption are being investigated for mining potential.

- Additional ground water protection measures are needed. Missouri now has in place programs that register and inspect underground storage tanks and oversee the cleanup of leaking underground tank sites, programs for wellhead protection, sealing of abandoned wells and closing of hazardous waste sites. A complete ground water protection program would also include a ground water monitoring network and educational programs for those involved in the application of farm chemicals, transporters of hazardous materials and the general public.

- There are 20 Class I and 380 Class II confined animal feeding operations (CAFOs) located in Missouri. These facilities generate large amounts of animal manure and have the potential to cause serious water pollution problems. We are also concerned by cumulative impacts of numerous small animal production facilities.

- Evidence is accumulating that the fish and invertebrate communities of many streams in Missouri are suffering from the degraded quality of the aquatic habitat. Physical alterations of the channel, alterations in stream flow patterns, degraded conditions in the riparian zone and upland land use changes are all believed to be significant contributors to this problem.

- Continuing suburban development impacts streams by direct loss of stream channels by shortening, culverting, removal of riparian areas and other impacts associated with development and increased storm water flows.

TABLE 1. BENEFICIAL USE SUPPORT STATUS OF MISSOURI CLASSIFIED* WATERS

STATUS	STREAM MILES	%	LAKE ACRES	%
Full Support	10,454.5	47	107,805	37
Full but Threatened	252.8	1	94,863	32
Partial Support	10,657.3	48	43,771	15
Not Supported	626.4	3	46,810	16
Not Assessed	203.2	1	70	0

- Numbers in Table 1 updated December 5, 2001.

Full Support: Water quality meets the needs of all uses that Missouri recognizes for a particular waterbody such as protection of fish and other aquatic life (the water quality does not interfere with the ability of aquatic life to live, feed and reproduce), livestock and wildlife watering (the water will not cause disease or injury to livestock and wildlife using the water for drinking), drinking water supply (the water meets all state and federal standards as a drinking water supply source water), swimming (the water will not cause disease or injury to swimmers or others participating in water-based recreation who may accidentally swallow small amounts of water), irrigation (the water will not cause disease or injury to crops) or industrial water supply (the water will not cause excessive problems with corrosivity or mineral deposits in industrial piping and boilers), fish consumption (fish are safe to eat) and boating and canoeing.

Threatened: Water quality is presently adequate to maintain all recognized uses, but, if harmful trends continue, only partial support may exist in the future.

Partial Support: Water quality has been impaired to the point that at least one of the recognized uses is affected.

Not Supported: Water quality is seriously affected to the point that at least one recognized uses of the waterbody have been lost.

Not Assessed: Streams in some urban and rural watersheds are believed to be significantly different in land use from monitored streams in their region so that their quality cannot be accurately inferred from monitored streams.

NOTE: In this report, "impaired" waters refers to waters rated as partial support or not supported.

* There are 22,194 miles of classified streams (permanently flowing streams or streams which maintain permanent pools during dry weather) and approximately 30,000 miles of unclassified streams (streams which are without water during dry weather). There are 293,319 surface acres of classified lakes. The number of surface acres of small unclassified lakes has not been estimated.

TABLE 1A. INDIVIDUAL USE SUPPORT SUMMARY FOR CLASSIFIED STREAMS

BENEFICIAL USE	SIZE ASSESSED	FULL SUPPORT	PARTIAL SUPPORT	NON-SUPPORT	NOT ASSESSED	USE NOT APPLICABLE
STREAMS (MILES)						
AQUATIC LIFE	21,996.0	11,519.2	10,251.4	225.4	198.2	0
FISH CONSUMPTION	21,878.9	20,771.7	847.2	260	315.3	0
SWIMMING	5,473.3	5,420.3	4.3	48.7	0	16,720.9
DRINKING WATER	3,234.7	3,024.2	0	210.5	0	18,959.5
LAKES (ACRES)						
AQUATIC LIFE	293,249	291,469	50	1730	70	0
FISH CONSUMPTION	293,138	215,388	33,355	44,395	181	0
SWIMMING	261,847	218,565	0	43,282	0	31,472
DRINKING WATER	99,871	87,890	11,478	503	0	193,448

TABLE 2. MAJOR WATER POLLUTION SOURCES IN MISSOURI CLASSIFIED WATERS
(Stream Miles or Lake Acres Impaired)

Source	Stream Miles Impaired	Percent of Total Miles	Lake Acres Impaired	Percent of Total Acres
Agriculture	7,701.9	35	45,138	15
Crop Production/Grazing	7,688.4	35	45,138	15
Confined Animal Feeding Operations	4.0	*		
Hydromodification	3,775.9	17	11,780	4
Channelization	3,711.4	17		
Flow Regulation/Modific.	43.5	*	11,780	4
Streambank Mod./Destab.	21	*		
Mining	172.3	1		
Municipal and other Domestic Point Sources	87.1	*	43110	15

Urban Runoff and Construction	53.5	*	825	*
Industrial Point Sources	11.6	*		
Landfills	0.3	*		
Recreational Activities	7	*		
Atmospheric Deposition	1,114	5	76,805	26
Natural Sources	162.5	1		
Unknown	5	*	182	*

* less than 1 %

TABLE 3. MAJOR CONTAMINANTS IN MISSOURI CLASSIFIED WATERS

Contaminant	Stream Miles Impaired	% of Total Miles	Lake Acres Impaired	% of Total Acres
Sediment	7,741.4	35	--	--
Habitat Degradation	3,734.3	17	--	--
Organic Enrichment /Low D.O.	59.5	*	1780	1
Metals	1,444.0	6	86,805	30
Mercury	1,111.0	5	76,805	26
Bacteria	48.5	*	137	*
Ammonia	18.3	*	--	--
Pesticides	24	*	1,385	*
Suspended Solids	8.8	*	--	--
Nutrients	7.4	*	44,578	15
TDS: Sulfate, Chloride	39	*	--	--
Flow Alterations			50	*
Chlorine	0.4	*		
pH	13.3	*		
Thermal Modification	1.4	*		
Unknown	21.7	*		

* less than 1 %.

NOTE: Many stream miles in Missouri are affected by more than one pollution source or pollutant; therefore, total miles/acres in Tables 2 and 3 can exceed miles/acres in Table 1.

CHAPTER 2. MISSOURI AND ITS WATER RESOURCES

Missouri has an area of 69,000 square miles and a population of 5.50 million people. Most of the population is concentrated along the border areas on opposite sides of the state in the Kansas City and St. Louis metro areas. Population as well as industrial and commercial activity in major urban areas has remained relatively stable for the past few decades. Patterns of rural land use have changed greatly in some areas, particularly residential development around the larger cities, recreational development adjoining Lake Taneycomo and the eastern ends of Lake of the Ozarks and Table Rock Lake and the increasing development of large animal confined feeding operations in north central and southwestern Missouri.

Missouri has an impressive stream network that includes over 22,000 miles of classified streams and over 293,000 surface acres in its 456 classified lakes. Three distinct regions exist within the state's boundaries, and the particular geology and land use of each affect water quality. These areas are a prairie region, which is rolling land predominately used for row crop and pasture; the Ozarks, a hilly area that is mostly pasture and forest; and the Bootheel, a flat alluvial plain adjoining the Mississippi River in southeast Missouri, which is used mainly for row crop production.

Missouri's Water Quality Standards (10 CSR 20-7.031) provide the names and locations of all classified streams and lakes. This state regulation defines over 3,600 individual stream and river segments and 456 lakes, lists which beneficial uses assigned to each of these waters and defines the level of water quality necessary to meet each of these uses.

The remaining waters of the state--such as those in the upper portions of the stream network that do not have permanently flowing or standing water and a number of small lakes--are not listed in the Missouri Water Quality Standards and do not have beneficial uses assigned to them. These unclassified waters are protected by the general criteria in the Water Quality Standards. The general criteria say these waters must be free from such aesthetic problems as demolition debris, trash, tires, odor, discoloration or the presence of objectionable floating or deposited material. The general criteria also say the waters must be free from conditions harmful to livestock or aquatic life.

TABLE 4. MISSOURI'S WATER RESOURCES

Missouri Population (million people)	5.50
Surface Area (square miles)	69,000
Number of Major Basins	8
Classified Stream Miles	22,194
Unclassified Stream Miles (estimated)	30,000
Number of Classified Lakes	456
Total Classified Lake Surface Area (acres)	293,319
Freshwater Wetlands Area (acres)	643,000

CHAPTER 3. SURFACE WATER ASSESSMENT

DESCRIPTION OF MISSOURI'S CURRENT WATER QUALITY MONITORING PROGRAM

Purpose

The major purposes of the water quality monitoring program are (1) to characterize background or reference water quality conditions; (2) to better understand daily, flow event and seasonal water quality variations and their underlying processes; (3) to characterize aquatic biological communities and habitats and to distinguish between the impacts of water chemistry and habitat quality; (4) to assess time trends in water quality; (5) to characterize the impact of local and regional impacts of point and nonpoint source discharges on water quality; (6) to check for compliance with water quality standards or wastewater permit limits, to develop TMDLs to monitor effectiveness of pollution control activities; and (7) to support development of strategies to return impaired waters to compliance with water quality standards. All of these objectives are statewide in scope.

Coordination with Other Monitoring Efforts in Missouri

The department cooperates with other agencies in performing special water quality studies. In 1998, a multi-agency task force including the Missouri Department of Natural Resources, Missouri Department of Conservation, U.S. Environmental Protection Agency, the U.S. Geological Survey, U.S. Forest Service, U.S.D.A. Natural Resources Conservation Service, and University of Missouri convened to develop an outline of a statewide aquatic resources monitoring plan, define partnership roles in this monitoring plan and discuss the kind of research needed to further this new monitoring effort. The first major product of this work group was an agreement to initiate in 2001 a cooperative statewide aquatic invertebrate and fish monitoring program by the Missouri Department of Conservation and the Department of Natural Resources.

To maximize efficiency, the department routinely coordinates its monitoring activities to avoid overlap with other agencies and provide and receive interagency input on monitoring study design. Data from other sources is used for meeting the same objectives as department sponsored monitoring. The agencies most often involved are the U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency (EPA), the Missouri Department of Conservation (MDC), the USDA/Agricultural Research Service (ARS) and the Missouri Department of Health & Senior Services. However, the department also tracks the monitoring efforts of the U.S. Park Service, the U.S. Forest Service, several of the state's larger cities, the states of Arkansas, Kansas, Iowa and Illinois and graduate level research conducted at universities within Missouri. The department also uses monitoring data acquired by wastewater dischargers as a condition of discharge permits issued by the department. The department began using data collected by volunteers that have passed Quality Assurance/Quality Control (QA/QC) tests in 1995.

Networks and Programs

1. Fixed Station Network

   A. Objective: To better characterize background or reference water quality conditions, to better understand daily, flow event and seasonal water quality variations and their underlying processes, to assess time trends and to check for compliance with water quality standards.

   B. Design Methodology: Sites were chosen based on one of the following criteria:
      - site is believed to have water quality representative of many neighboring streams of similar size due to similarity in watershed geology, hydrology and land use, and the absence of any impact from a local point or discrete nonpoint water pollution source.
      - site is downstream of a significant point source or localized nonpoint source area.

C. Number of Sites, Sampling Methods, Sampling Frequency, Parameters:

- USGS/DNR cooperative network: 63 sites statewide, horizontal and vertical integrated grab samples, 6-12 times per year, major ions, nutrient ions, temperature, pH, dissolved oxygen, specific conductance, suspended solids, heavy metals flow 2-4 times annually and pesticides 6 times annually at 6 sites. Crowder College network: 8 sites in southwest Missouri, grab samples 18 times per year for; pH, conductance, temperature, total phosphorus, ammonia nitrogen, nitrate plus nitrite, nitrogen, fecal coliform and fecal strep bacteria. DNR raw water sampling of 32 public drinking water reservoirs: 4 sites, grab samples, 4 times/year, for 8 common agricultural herbicides. UMC/DNR lake monitoring network, circa 100 lakes monitoring during the summer and about 12 monitored spring through fall for nutrients, chlorophyll, turbidity and suspended solids.
- DNR routine monitoring of finished public drinking water supplies for bacteria and trace contaminants.
- Routine bacterial monitoring of swimming beaches at Missouri state parks during the recreational season by the department's Division of State Parks.
- Routine monitoring of sediment quality at 25 fixed sites, on a five-year rotating basis (five sites monitored annually, and 10 discretionary sites annually). All sites are monitored for several heavy metals and organic contaminants. A pore water sample is analyzed for ammonia and a Microtox toxicity test on the pore water is performed.

2. Intensive Surveys

A. Objective: To characterize the water quality impacts from a specific pollutant source area.

B. Design Methodology: Determination of contaminants of concern based on previous water quality studies, effluent sampling and/or NPDES permit applications, use of multiple sampling stations downstream and upstream (if appropriate). If contaminants of concern have significant seasonal or daily variation, season of the year and time of day variation must be accounted for in sampling design. These studies would also require multiple samples per site over a relatively short time frame (e.g., 6-8 visits over a 2-3 day period or 10-15 visits over a 2-3 year period).

C. Number of Sites, Sampling Methods, Sampling Frequency, Parameters:
Missouri Department of Natural Resources conducts or contracts for 10-15 special studies annually. Each study would have multiple sampling sites. Number of sites, sampling frequency and parameters vary greatly depending on the study.

3. Toxics Monitoring Program

Monitoring of toxics is not a separable part of the monitoring program. The fixed station network and many of our intensive studies monitor for toxic chemicals. In addition, major municipal and industrial dischargers must monitor for toxicity in their effluents as a condition of their NPDES permits.

4. Biological Monitoring Program

A. Objective: To develop numeric criteria describing "reference" aquatic macroinvertebrate communities in Missouri's wadeable streams. To implement these criteria within state water quality standards and begin a statewide aquatic invertebrate monitoring program as part of a DNR/MDC cooperative statewide biological monitoring program. This program would sample fish and benthic macroinvertebrates in at least 50 stream locations annually. The network would include long term fixed station sites, sites believed to be impaired by specific point or nonpoint stressors and randomly selected sites.

B. Design Methodology: Development of Biocriteria for Invertebrates involves identification of 45 "reference" streams divided among Missouri's three aquatic ecoregions. Intensive sampling of invertebrate communities to quantify temporal and spatial variation in reference streams within ecoregions and variation between ecoregions. Sampling of chemically and physically impaired streams to test sensitivity of various community metrics to differences in stream quality.

The statewide biological monitoring program will run on a three-year cycle. Each year at least 50 sites will be monitored for fish and aquatic macroinvertebrates. Some water chemistry sampling and a physical habitat assessment will be done at each site. Two-thirds of the work done in a cycle will be monitoring of a combination of fixed stream sites and sites of special interest (those suspected of being impaired by point or nonpoint stressors such as streams on the state 303d list). The remaining third of this sampling effort in each cycle will consist of randomly selected stream sites that should assist in making probability-based statements about biological condition in Missouri streams generally.

C. Number of Sites, Sampling Methods, Sampling Frequency, Parameters:

Biocriteria Development for Aquatic Invertebrates 1991-2000: 45 reference sites, 40 other sites with varying degrees of physical or chemical impairment, modified EPA Rapid Bioassessment Protocol for Invertebrates Sites have been sampled 2-6 times over the last nine years for aquatic invertebrates, temperature, dissolved oxygen, specific conductance and nutrient ions.

Biomonitoring Network: at least 50 sites annually. Fish communities will be sampled once, aquatic invertebrates twice (spring and fall) annually. Aquatic invertebrate monitoring will follow protocols established during the biocriteria development process. The Department of Conservation initiated a pilot fish sampling study in 1999 that will result in codification of fish sampling protocols.

D. Development of Biological Criteria for Large Rivers.

The department contracted with the U.S. Geological Survey in 2001 to conduct a study of aquatic invertebrate communities on the Missouri River. The department sees this work as the first of several steps it will promote in the better understanding of fish and invertebrate communities of large rivers and ultimately the development of biological criteria for the Missouri and Mississippi rivers.

5. Fish Tissue

A. Objective: Measure levels of bioaccumlative toxicants in fish.

B. Design Methodology. Sites were chosen based on one of the following criteria:
- site is believed to have water and sediment quality representative of many neighboring streams of similar size due to similarity in geology, hydrology and land use, and the absence of any known impact from a local point source or discrete nonpoint water pollution source.
- site is downstream of a significant point source or localized nonpoint source area.

C. Number of Sites, Sampling Methods, Sampling Frequency, Parameters:
15 sites, fish taken by electroshocking, ideally a sample is composed of five whole carp *Cyprinis carpio* of equal size (fish of approximately 18" length are preferred). Sites are sampled once every two years and are analyzed for several chlorinated hydrocarbon insecticides, PCBs, lead, cadmium, mercury and fat content.

<u>Laboratory Analytical Support</u>

1. Laboratories Used:
- USGS/DNR Cooperative Fixed Station Network: USGS Lab, Denver, Colorado
- Crowder College Network: Crowder College, Neosho, Missouri
- DNR Public Drinking Water Reservoir Network: Missouri DNR Environmental Lab
- Intensive Surveys: Varies, many are done by Missouri DNR Environmental Lab
- Toxicity Testing of Effluents: many commercial labs
- Biological Criteria for Aquatic Invertebrates: Missouri DNR Environmental Lab and University of Missouri, Columbia
- Fish Tissue: USEPA Region VII Lab, Kansas City, Kansas and Miscellaneous contract labs (Missouri Department of Conservation)
- NPDES self-monitoring: commercial labs

- DNR Public Drinking Water Monitoring: Missouri Department of Natural Resources and commercial labs
- Agricultural Research Service: ARS lab

2. Issues:
   USGS, Denver, Colorado, (1) previously and for several years had used inadequate reagent volumes in Total Phosphorus analysis. The lab has published a paper on the situations where erroneous data was believed to occur. The problem was associated with high levels of phosphorus usually only encountered in certain effluents and should not have caused an error in analysis of phosphorus in Missouri streams. (2) USGS has recommended new "clean procedures" for making accurate measurements of certain heavy metals. Because of the great expense of using these new methods, the USGS/DNR cooperative network continues to use the old methods. The rationale for this decision was that the old method is still reliable enough to discern any exceedences in water quality standards, but may not be of value in correlating heavy metals to water quality or other environmental variables and probably will not allow time trend analysis on most waters of the state.

Quality Assurance/Quality Control Program (QA/QC)

Missouri and Region 7 EPA have completed a Total Quality Management Plan. All environmental data generated directly by the department or through contracts funded by the department or EPA will require a quality assurance project plan (QAPP) following the QAR5 guidance.

Data Storage, Management and Sharing

The department retrieves raw data from the USGS database, WATSTORE and from numerous state, federal and municipal sources that do not store data in WATSTORE. This data is imported into the Missouri state computer system for storage and statistical analysis. The department maintains some water chemistry data in SPFPC files at the state computer center in Jefferson City. Data in these files comes from WATSTORE, STORET and data generated by state agencies and large municipalities and public water supply companies.

The department is now entering this data into ACCESS software, data retrieval and analysis can be done in either ACCESS, EXCEL or SYSTAT software. The department is now working to batch load water quality data from our ACCESS files into the new STORET. Beginning in 1999, the department began linking many separate databases pertaining to water quality, other environmental data and information on regulated facilities via ACCESS software and importing this data into a GIS (ArcView) environment. The majority of the work has been completed.

The Missouri Department of Conservation is in the process of developing statewide databases for both fish and aquatic macroinvertebrates.

Training and Support of Volunteer Monitoring

Two volunteer monitoring programs are now generating water quality data in Missouri. The first is a cooperative program between the Department of Natural Resources, the University of Missouri and volunteers that monitor approximately 16 lakes, including Lake Taneycomo, Table Rock Lake and several lakes in the Kansas City area. Data from this program is used by the University as part of a long-term study on the limnology of Midwestern reservoirs.

The second program monitors water quality of streams throughout Missouri. It is a cooperative project of the Department of Natural Resources, the Department of Conservation and the Conservation Federation of Missouri. By the end of 1997, this program had provided initial training, equipment and supplies to about 971 volunteers, provided secondary training and quality assurance-quality control ratings for 153 members of this group and established a data base for all data reported by the volunteers. In 1998-99 an additional 831 persons had received training. The program now has 321 people who have a Level 2 or higher data quality assurance rating. This rating allows any data they provide to be used in the department's water quality assessment database. During the period 1999 through 2001, level 2 or higher rated volunteers submitted at least three sets of aquatic invertebrate data at 69 stream sites and at least three sets of chemical data on 113 stream sites.

Data Interpretation and Communication

Missouri now uses an ACCESS database for tracking and reporting waterbody use attainment information. An EPA contractor, RTI, completed geo-referencing of Missouri's classified waters in 1998. The stream and lake network of the state, water quality standards information, the locations of permitted wastewater discharges and other potential pollutant sources and information describing them can now all be viewed within a GIS (ArcView) environment.

During 2000 and 2001, the department greatly increased the amount of water quality information available on our web site. This information included: TMDL studies, draft 303(d) lists, water quality information sheets for 303(d) candidate waters and water quality basin plan documents for the White River in southwest Missouri.

Water quality data accessibility is easy. Contact the Water Pollution Control Program for more information.

1. Requests for very general information on water quality. These requests are filled by the 305(b) report, pamphlets or fact sheets. Call 1-800-361-4827. Information on Missouri's 303(d) list and completed Total Maximum Daily Load (TMDL) studies are available on the Internet at:

   http://www.dnr.state.mo.us/wpscd/wpcp/homewpcp.htm

2. Requests for information on a specific waterbody or for more detailed information on a specific topic that might include summaries of major studies or summary of available data. These requests are usually filled by the Missouri Basin Plans, a document that describes Missouri's watersheds and provides information on land use, hydrogeology, stream flow and water quality in each.

3. Requests for published reports or water quality data files. If the report or data was generated by the department, it can be obtained either through the mail (paper copy for small reports and data files or on floppy disk for larger data files) or by visiting the department office at 205 Jefferson Street in Jefferson City and viewing the files directly. If the report or data file did not originate with the department, the request is sent to the organization that published the report/data.

Requests for water quality information or requests to view water quality data files should be sent to:

Missouri Department of Natural Resources
Water Pollution Control Program
ATTN: John Ford
P.O. Box 176
Jefferson City, MO 65102-0176
Phone: (573) 751-7024 Fax: (573) 526-5797
Internet: nrfordj@dnr.state.mo.us

Monitoring Program Evaluation

The water quality monitoring program within the department has traditionally focused on the chemical characterization of water quality in streams both free of and those subject to point source waste water discharges. While the monitoring has been able to keep pace with our more critical point source assessment needs and has done a good job of characterizing regional water quality unimpaired by point source discharges, the size and scope of the department's monitoring has fallen far short of the state's information needs. The advent of large confined animal feeding operations (CAFOs) in Missouri, concern over eutrophication of our large recreational lakes and continuing urban sprawl, among other problems, have spawned questions our present monitoring program was incapable of answering.

Significant steps toward meeting these monitoring needs were made by the department in 1999. These included:

1) Increasing biological monitoring staff from 2.5 FTEs to 6 FTEs in 2000.
2) Increasing other water quality monitoring staff from 2.5 FTEs to 4.5 FTEs in 2000.
3) Increasing water data management staff from 0.5 FTE to 2.5 FTE in 2000.

4) Increases in budget for contracting water quality monitoring by others. This has allowed the addition of 27 stations to the fixed station chemical monitoring network in 1999. The department is now monitoring 63 sites throughout the state.
5) Signing a Memorandum of Understanding with the Department of Conservation to initiate a comprehensive statewide aquatic biological monitoring program.

PLAN FOR ACHIEVING COMPREHENSIVE ASSESSMENTS

Large Rivers

1. Fixed Station Water Quality Monitoring Network. The department's objective is to maintain a minimum of 15 fixed sites dedicated to long term chemical monitoring of large rivers. These sites will be monitored 6-12 times annually for a long list of conventional contaminants, major ions, nutrient ions and heavy metals. Some of the stations will also have pesticide monitoring. These sites will be chosen as those most representative of the physiographic province they are in and ones with the largest existing water quality record. The department, through a cooperative agreement with the U.S. Geological Survey, now monitors 31 such sites.

2. Sediment Monitoring Network. The department's objective is to maintain a minimum of 15 fixed sites where sediments will be monitored at least once every five years. The department's present sediment monitoring program includes a 25 site fixed station network on 17 large rivers with each site being monitored every five years. An additional 10 sites per year are monitored to address known or suspected sediment pollution problems or are sites selected randomly to allow probability based assessment of sediment quality statewide. The program analyzes for bulk sediment chemistry, sediment pore water chemistry and pore water toxicity. These additional sites may or may not be on large rivers.

3. Monitoring Programs for the Mississippi and Missouri Rivers. Very large rivers require special monitoring efforts for several reasons. Among these are 1) the fact that they are unique aquatic ecosystems with specialized habitats and fauna not found in smaller rivers; 2) due to their size, depth and current velocity, they are often difficult to monitor and historically have been studied less effectively than smaller streams; and 3) they tend to attract types of human uses and accompanying environmental stresses (specifically commercial navigation) not found on smaller streams.

   The monitoring concepts embraced by the Long-Term Monitoring Program on the Upper Mississippi River are wide ranging. They involve description of physical, chemical and biological aspects of the river and environs with an eye toward synthesis describing its function as an ecosystem. Missouri supports this approach and supports the development of a similar monitoring project on the Missouri River. In addition to these activities, Missouri has fixed station chemical monitoring at two locations on the Missouri and two on the Mississippi. The department also regularly reviews water quality data on these two rivers from other state, federal and municipal sources. The department contracted with the USGS-BRD in 2001 to conduct an assessment of the aquatic invertebrate communities of the Missouri River. This work will include attempts to document and describe "reference" or "background" aquatic invertebrate communities on the Missouri, a first step in the development of biological criteria for the river.

Discussion: The water and sediment monitoring locations will be chosen so that rivers from all physiographic provinces and predominant land use categories are represented. Thus, most unmonitored larger rivers in the state can be "evaluated" based on monitored representative streams from areas of similar geology, hydrology and land use. As land use patterns change, water quality may become unlike nearby rivers. If this occurs in the watershed of a monitored river, it can no longer be considered representative of other rivers within that physiograhic province. If these changes occur in an unmonitored river, that river would become a high priority monitoring location since other rivers in the province would not be considered adequate indicators of water quality in this stream.

This situation has already occurred in the Elk River basin, where many large poultry operations are now located. Several years ago, the fixed water quality monitoring station on the Elk River at Tiff City was monitored only every

second or third year as a station representative of southwestern Missouri. It is now monitored annually, not as a representative stream for rural southwest Missouri, but as a stream draining a basin with a large amount of poultry production.

Wadeable Streams (Small Rivers and Creeks)

1. Visual/Qualitative Aquatic Invertebrate Rapid Stream Assessment. A protocol for rapid stream assessment was developed and implemented by the department in 1982 and has been practiced unchanged since that time. The goal of the rapid stream assessment program is to make an assessment of the impact of all municipal wastewater discharges, limestone quarries, clay pits and landfills at least once every five years. A second objective is to assess non-municipal wastewater discharges on an as needed basis based on regional office inspection reports, complaints by the public or other agencies or based on volunteer water quality monitoring results.

   Due to the 1999 Department of Natural Resources water quality monitoring expansion, the FTE dedicated to this type of monitoring was increased from 0.15 to 0.6 FTE in 2000. This expansion is expected to allow us to conduct 300 of these surveys annually, an amount that would be approximately 150% of our expected demand for this type of monitoring.

2. Volunteer Water Quality Monitoring. Over 700 volunteers received training during 2000-2001. All reported volunteer data is entered into a volunteer water quality database. In addition, data collected by volunteers who successfully complete a quality assurance workshop is entered into the department's water quality databases and is used by the department in the same way as the visual/qualitative benthic data collected by the department. Some volunteers are doing only chemical monitoring but many are also doing semi-quantitative macroinvertebrate benthic sampling. From 1999 through 2001, volunteers with acceptable quality assurance ratings were monitoring and reporting to the department on 41 stream sites regularly for aquatic invertebrates and 113 stream sites for water chemistry.

3. Aquatic Macroinvertebrate/Fish/Aquatic Habitat Monitoring Program. The department now monitors at least 55 stream sites each year for aquatic invertebrates (spring and fall) and makes a habitat quality assessment at each of these sites. Invertebrate data from study sites are compared to ecoregion "reference" sites to determine if invertebrate communities below point source discharges or localized or dispersed nonpoint sources are impaired. For the past two years and for the next four to six years, the aquatic macroinvertebrate monitoring program will be used mainly to support the 305(b) and 303(d) programs in Missouri.

4. Intensive Surveys. There is a great variety of water quality monitoring efforts generally referred to as "intensive surveys." They have in common only the fact that they are efforts aimed at answering a specific question on a specific waterbody or group of waterbodies. Examples include 1) wasteload allocation studies that result in determining acceptable effluent loads from point source discharges; 2) total maximum daily load (TMDL) studies that determine acceptable contaminant loads from the entire watershed; 3) less intensive studies to generally characterize water quality impacts of specific point or discrete nonpoint source discharges; 4) monitoring in support of Section 319 watershed projects; and 5) a number of other studies relating to effluent quality, surface or ground water quality or hydrology or studies of the aquatic biota.

   To meet our commitment to maintain our TMDL study schedule and other water quality management functions, the department will need to have the capacity to conduct 15-20 such intensive surveys annually. With significant expansion in the department's monitoring activities in 2000 our ability to perform these surveys has increased from about 6 annually in 1999 to about 10-15 annually now. This is only a marginally acceptable figure in terms of our program objectives.

Lakes

1. Lake Monitoring Network. Approximately 60 Missouri lakes are monitored four times during the summer for nutrients, chlorophyll, secchi depth and solids by the University of Missouri under a cooperative program with the department. This project has been ongoing for several years and has provided data on the trophic status of

160 lakes in the state. More importantly, this work has laid the foundation for a basic understanding of the relationship of nutrients, mineral solids and algal productivity in midwestern reservoirs that will improve future efforts to manage water quality in these waters.

2. Lakes of Missouri Volunteer Monitoring Program. This program is administered by the University of Missouri with Clean Water Act funding. During 2001, a total of 55 sites on 22 lakes were monitored by 100 volunteers.

Use of Data Generated by Others

1. DNR has and will continue to actively solicit, import into our databases, analyze and otherwise use any and all water quality data with an acceptable level of quality assurance.

ASSESSMENT METHODOLOGY

This section describes the procedures used by the Missouri Department of Natural Resources to rate the quality of Missouri's waters.

Water quality is judged by its conformance with Missouri's Water Quality Standards. These standards were first implemented for all Missouri streams and a few large lakes in 1970 and are revised every three years. These standards now list over 22,000 miles of classified streams and 456 significant public lakes representing 293,000 surface acres of water, and the uses for which these waters are protected. These standards also list the maximum allowable concentrations of chemicals and bacteria in these waters.

The table below lists the various uses of Missouri's waters and the portions of state waters that are protected for each use.

TABLE 5. MISSOURI WATERS PROTECTED FOR VARIOUS USES

Use	Stream Miles	% of Total	Lake Acres	% of Total
Protection of Aquatic Life and Fish Consumption	22,194.2	100	293,319	100
Subset: Warm-Water Fishery	19,080.2	86	282,575	96
Cool-Water Fishery*	2,756.7	13	0	0
Cold-Water Fishery**	228.5	1	10,730	4
Livestock and Wildlife Watering	22,194.2	100	293,319	100
Whole-Body-Contact Recreation	5,473.3	25	261,847	89
Boating	6,953.7	32	234,990	80
Drinking Water Supply	3,234.7	15	100,283	34
Industrial	1,588.5	7	7,003	2
Non-degradation: Outstanding National	171.2			
State Resource Waters	192.5***			
Irrigation	4,025.5	18	0	0
Total Classified Waters in Missouri	22,194.2		293,319	

* Smallmouth Bass, Rock Bass
** Trout
*** Outstanding State Resource Waters also include 270 acres of marsh in 3 locations.

Classified waters of Missouri are all permanently flowing streams or streams with permanent pools. All classified waters of the state and all significant public lakes are classified for protection of aquatic life, livestock and wildlife watering and fish consumption by humans. The Water Quality Standards for these uses set the maximum allowable concentrations for 110 chemicals in these waters. A subset of these waters classified for drinking water supply have

maximum allowable concentrations for an additional 20 chemicals in the Standards. Waters protected for whole-body-contact recreation such as swimming or water skiing also have a maximum allowable bacteria standard.

Missouri's Water Quality Standards also contain narrative criteria. These standards are not numbers but general statements about the department's expectations for waters of the state. These standards require waters to be free of objectional odors, color, turbidity, trash, floating materials or bottom deposits and to be free of conditions harmful to aquatic life such as high water temperature, low dissolved oxygen or chemical toxicity. Importantly, these standards apply not just to the classified waters, but to all waters of the state including the small intermittent streams that only carry water during and shortly after rainfall or snow melt.

Table 6 below shows how the chemical and bacterial standards and aquatic biological information are used to rate the quality of Missouri's waters.

TABLE 6. METHODS FOR ASSESSING COMPLIANCE WITH WATER QUALITY STANDARDS

BENEFICIAL USES	DATA TYPE	DATA QUALITY CODE*	COMPLIANCE WITH WATER QUALITY STANDARDS
Overall use protection	No data--**evaluated** based on similar land use/ geology as stream with water quality data.		Given same rating as monitored stream with same land use and geology.
	Visual observation of stream and qualitative evaluation of aquatic macoinvertebrates.	1	Full: Stream appearance and aquatic invertebrates typical of reference streams in this region of the state. Partial: Odor, turbidity, objectionable, suspended matter or bottom deposits that would interfere with beneficial uses or reduced diversity of aquatic macroinvertebrates. Non-Attainment: Odor, turbidity, or objectionable suspended matter bottom deposits severe enough to prohibit beneficial use or only pollution tolerant aquatic invertebrates found.
Protection of Aquatic Life	Chemical (toxics)	1-3	Full: No more than 1 exceedence of acute criterion in 3 years; less than 10% of all samples exceed chronic criterion. Partial: More than 1 exceedence of acute criterion in 3 years; less than 10% of all samples exceed chronic criterion. Non-Attainment: More than 10% of all samples exceed chronic criterion.
	Chemical (conventional)	1-3	Full: Less than 10% of all samples exceed criterion. Partial: 10-25% of all samples exceed criterion. Non-Attainment: More than 25% of all samples exceed criterion.
	Biological	1-4	Full: Fauna very similar to regional reference streams. Partial: Diversity or number of intolerant taxa slightly to moderately less than reference streams. Non-Attainment: Diversity or number of intolerant taxa much less than reference stream.

BENEFICIAL USES	DATA TYPE	DATA QUALITY CODE*	COMPLIANCE WITH WATER QUALITY STANDARDS
	Toxicity testing of streams , lakes or sediments	1-4	Full: No statistically significant deviation from controls in chronic test endpoints in at least two representative species. Non-Attainment: Statistically significant mortality in at least one of two representative test species.
Fish Consumption	Chemicals (tissue) Chemicals (tissue + water +sediment)	2 4	Full: Water quality criteria not exceeded as a long-term average; fish consumption advisories allow typical or average fish consumption rates for all commonly eaten species. Partial: Fish consumption advisories allow less than typical or average consumption rate for at least one commonly eaten species. Non-Attainment: Water quality criteria exceeded as long-term average or consumption banned for at least one commonly eaten species.
Drinking Water Supply	Physical, chemical (nutrients)	1-3	Full: Very little loss of lake volume due to sedimentation, low levels of nutrients, no history of taste or odor problems due to algae. Threatened: Rate of sedimentation moderate and no taste and odor problems known but nutrient or algae levels similar to lakes with taste and odor problems. Partial: Water supply may be inadequate in dry years due to loss of volume to sedimentation or supply has infrequent taste and odor problems. Non-Attainment: Water supply has chronic water shortage due to loss of storage volume to sedimentation or frequent taste and odor problems or supply causes infrequent gastrointestinal problems in users.
	Chemical (toxics, raw water)	1-3	Full: Mean values do not exceed criterion or Safe Drinking Water Act (SDWA) maximum contaminant levels (MCLs). Threatened: Chemical use patterns in watershed are similar to watersheds with non-attainment. Non-Attainment: One or more contaminants have mean values in excess of water quality criteria or SDWA MCLs.
	Chemical (Iron, Manganese, Total Dissolved Solids, Raw Water)	1-3	Full: Mean values do not exceed criterion. Threatened: Mean values do not exceed criterion but time trends suggest mean may be exceeded in future. Non-Attainment: Mean values exceed criterion.

BENEFICIAL USES	DATA TYPE	DATA QUALITY CODE*	COMPLIANCE WITH WATER QUALITY STANDARDS
	Chemical (toxics, finished water)	1-3	Full: No MCLs or Water Quality Standards criteria exceeded or significant taste and odor problems using only convention treatment (sedimentation-disinfection). Threatened: Chemical use patterns in watershed are similar to watersheds not in full attainment. Partial: Additional treatment needed to meet MCLs or Water Quality Standards criterion. Non-Attainment: At least one contaminant has annual average exceeding MCL or Water Quality Standards criterion or supply has been closed during the past 2 years due to contamination of raw water entering the plant. NOTE: water quality problems caused by the drinking water treatment process such as the formation of Trihalomethanes (THMs) are not included.
Whole-Body-Contact Recreation	Fecal Coliform count	1-2	Full: Water Quality Standards not exceeded as a geometric mean for samples collected during the recreation season and at times not influenced by storm water flows. Non-Attainment: Geometric mean does exceed Water Quality Standard criterion during recreation season at times not influenced by storm water flows.
Irrigation, Livestock and Wildlife Water	Chemical (boron, cobalt)	1-3	Full: Mean value does not exceed water quality criteria. Non-Attainment: Mean value does exceed water quality criteria.

* Data quality codes have been established by EPA to rate the quality and quantity of data from a specific source. Level one data is the lowest level of useable data and includes infrequent chemical monitoring or qualitative biological monitoring. Level Two data would include intensive water chemistry studies, long-term water chemistry monitoring sites and fish tissue analysis. Levels Three and Four are for detailed biological studies of fish, aquatic invertebrates and toxicity testing of waters.

** LC_{50} The concentration of a contaminant that kills 50% of test organisms.

*** AEC = Acceptable Effluent Concentration. This is the percentage of effluent in a solution of effluent at the effluent design (max.) Flow mixed with 2.5% of the $7Q_{10}$ low flow of the receiving stream. This would simulate the instream toxicity potential of the discharge during dry weather.

WATER QUALITY ASSESSMENT

Table 7. Summary of Fully Supporting, Threatened and Impaired Waters

Degree of Use Support	Evaluated Streams Miles	Monitored Streams Miles	Total Stream Miles Assessed	Evaluated Lake Acres	Monitored Lake Acres	Total Lake Acres Assessed
Fully Supporting All Assessed Uses	**8,799.3**	**1,668.2**	**10,467.5**	**26,467**	**81,338**	**107,805**
Full Supporting All Assessed Uses, But Threatened For at Least One Use	**113.8**	**139.0**	**252.8**	**13,884**	**80,979**	**94,863**
Impaired For One or More Uses	**8,283.8**	**2,986.9**	**11,270.7**	**1,740**	**88,841**	**90,581**
TOTAL ASSESSED	17,196.9	4,794.1	**21,991.0**	42,091	251,158	**293,249**
TOTAL UNASSESSED			**203.2**			**70**

Monitored waters are those where water quality data has been collected in the last five years. Approximately 22% of all classified stream miles and 86% of all classified lake acres were considered to be monitored

Evaluated waters are those which have not been monitored in the last five years but have geology and land use similar to nearby monitored waters and whose water quality assessment is assumed to be the same as those nearby monitored waters. 77% of all classified stream miles and 14% of all classified lake acres were considered to be evaluated.

Unassessed waters are those that are not monitored directly nor do they have nearby monitored waters with similar geology and land use. Thus, these represent the classified waters in the state for which we are unable to make an accurate assessment of their compliance with water quality standards and Clean Water Act goals. 1% of classified stream miles fall into this category. Less than 1% of classified lake acres are considered to be unassessed.

ADDITIONAL INFORMATION ON MISSOURI LAKES

Summary Statistics

Information on beneficial use attainment in significant public lakes is given in Tables 1 and 1A. The acreage of these lakes not fully supporting beneficial uses by major source category are as follows:

Point Sources	43,110 acres
Nonpoint Sources	122,950 acres
Hydromodification	11,780 acres

Background

Missouri's definition of "significant" lakes corresponds to the Department of Natural Resources list of classified lakes and includes any lake that falls into one of the following three categories: (1) small public drinking water reservoirs; (2) large multi-purpose reservoirs; and (3) reservoirs or lakes with important recreational values.

It should be noted that Missouri has only a few naturally occurring lakes, these being primarily depressions or old ox-bows on the Missouri or Mississippi river floodplain. Most significant "lakes" in the state are man-made reservoirs.

Trophic Status

Eutrophication is a natural process that occurs in lakes involving the gradual filling of the lake over time accompanied by increasing aquatic plant growth. This concept also embraces the enrichment of lakes and reservoirs by additions of nitrogen and phosphorus from human activity. This additional nutrient load causes increased aquatic plant growth, predominantly phytoplankton, which causes lake water to become greener and more turbid. Trophic state is an important way to characterize lakes because it relates directly to such factors as lake clarity, better in oligotrophic and mesotrophic lakes, and fish production, better in eutrophic lakes.

The trophic status of lakes typically refers to the amount of nitrogen and phosphorus entering the lake or the amount of algae or other aquatic plants present in the lake. Oligotrophic lakes are clear with few nutrients and very little aquatic plant growth. Mesotrophic, eutrophic and hypereutrophic refer respectively to lakes with increasing levels of nutrients and aquatic plant growth.

Lake studies conducted by the University of Missouri between 1989 and 2000 on trophic status of Missouri lakes follows.

TABLE 8. TROPHIC STATUS OF SELECTED MISSOURI RESERVOIRS

LAKE	COUNTY	LOCATION	SECCHI	TP[1]	Ch1-a[2]	TROPHIC[3] STATE	TN[4]
GLACIAL PLAINS							
*Allaman Lake	Clinton	24, 56N, 30W	1.2	42	16	E	683
Baring C-Club Lake	Knox	26, 63N, 12W	1.3	28	21	E	959
Bean Lake	Platte	12-14,54N,37W	0.1	264	144	HE	1,658
Bethany Lake	Harrison	27, 64N, 28W	1.2	35	11	E	730
Big Lake	Holt	18-19,61N,39W	0.2	328	166	HE	2,508
Bilby Ranch Lake			1.1	54	51	E	936
Bowling Green Lake	Pike	29, 53N, 2W	1.7	27	10	M	542

Brookfield Lake	Linn	33, 58N, 19W	1.1	25	9	M	649
Crystal Lake			0.6	82	34	E	918
D.C. Rogers Lake	Howard	3, 50N, 16W	1.3	31	7	M	533
Daniel Boone Lake	Shelby		0.2	187	38	HE	1424
Dean Lake			0.1	382	5	HE	2,110
Deer Ridge Lake	Lewis	18, 62N, 8W	0.9	49	16	E	781
Edina Reservoir	Knox	12, 62N, 12W	0.7	71	20	E	1,228
Ella Ewing Lake	Lewis	21, 64N 10W	0.6	87	28	E	1,410
Elmwood Lake	Sullivan		0.8	50	19	E	752
Fayette Lake #2	Howard	4, 50N, 16W	0.9	52	24	E	906
Forest Lake	Adair	14, 62N, 16W	1.4	25	5	M	423
Fox Valley Lake			2.6	18	10	M	611
Green City Lake	Sullivan	NE16,63N,18W	0.6	91	36	E	1,107
Hamilton Lake	Caldwell	15, 57N, 28W	0.8	66	14	E	1,002
Harrison County Lake	Harrison		1.0	44	31	E	896
Hazel Creek Lake	Adair	31, 64N, 15W	1.5	29	8	M	630
Henry Sever Lake	Knox	14, 60N, 10W	0.9	51	22	E	1049
Hunnewell Lake	Shelby	25, 57N, 9W	0.9	50	23	E	830
King Lake	Gentry	SW34,61N,32W	0.2	252	12	E	1,690
Kings Lake	Lincoln	25,50N,2E	0.3	278	80	HE	1,573
La Belle #2 Lake	Lewis		0.9	59	29	E	1,235
Lake Contrary	Buchanan	26, 57N, 36W	0.3	365	194	HE	3,060
Lake Mahoney (Unionville)	Putnam	27, 66N, 19W	0.6	105	43	E	1,253
Lake Marie	Mercer	36, 66N, 24W	2.7	15	4	M	445
Lake Paho	Mercer	25, 65N, 25W	0.8	48	14	E	848
Lake Viking	Daviess	9, 59N, 28W	1.3	28	10	M	542
Lancaster New Lake	Schuyler		0.6	77	37	E	876
Little Dixie Lake	Callaway	26, 48N, 11W	0.6	73	17	E	786
Long Branch Lake	Macon	18, 57N, 14W	0.7	52	18	E	863
Macon Lake	Macon	17, 57N, 14W	0.8	55	29	E	902
Marceline Res.	Linn	28, 57N, 18W	0.7	107	45	E	1,092
Mark Twain Res. (Lower)	Ralls	26, 55N, 7W	1.1	73	18	E	1,334
Mark Twain Res. (Upper)	Monroe			101	16	E	1,220
Maysville Lake (NW)	Dekalb	33, 59N, 31W	0.6	202	50	HE	1,322
Memphis #1 Lake	Scotland		0.3	125	108	HE	1,914

LAKE	COUNTY	LOCATION	SECCHI	TP[1]	Ch1-a[2]	TROPHIC[3] STATE	TN[4]
Memphis #2 Lake	Scotland	15, 65N, 12W	0.7	71	47	E	1,221
Memphis #3 Lake	Scotland		0.9	78	39	E	990
Milan Lake (New)	Sullivan	35, 63N, 20W	1.0	43	14	E	689
Monroe City Lake B	Monroe	30, 56N, 7W	0.5	81	30	E	1,109
Mozingo Lake	Nodaway		1.7	26	16	E	777
Nehai Tonkayea Lake	Chariton	11, 55N, 18W	1.6	19	3	M	431
Nodaway Lake			0.9	40	22	E	1,111
Pony Express Lake	Dekalb	33, 58N, 31W	0.8	69	32	E	1,052
Prairie Slough (Oxbow)			0.2	231	72	HE	2,495
Rocky Fork Lake	Boone	31, 50N, 12W	1.9	23	7	M	546
Shelbina Lake	Shelby	20, 57N, 10W	0.6	100	37	E	1,081
Smithville Lake	Clay	13, 53N, 33W	1.1	34	17	E	811
Spring Lake	Adair	SW20,61N,16W	1.2	35	9	M	533
Sterling Price Lake	Chariton	17,53N,17W	0.6	108	83	HE	1,545
Sugar Creek Lake (MOB)	Randolph	16, 54N, 14W	0.8	56	26	E	765
Sugar Lake	Buchanan	27 55N, 37W	0.2	333	173	HE	2,524
Swan Pond			0.3	345	126	HE	1,658
Thomas Hill Res.	Randolph	24, 55N, 16W	0.7	49	16	E	795
Thunderhead Lake	Putnam	15, 66N, 19W	0.8	51	14	E	971
*Tri-City Comm Lake	Boone	24, 51N, 12W	0.7	58	20	E	876
Vandalia Lake	Pike	12, 53N, 5W	1.1	67	35	E	926
Wakonda Lake	Lewis	NE13, 60N, 6W	0.8	95	51	E	1,186
Watkins Mill Lake	Clay	22, 53N, 30W	0.9	42	17	E	614
Waukomis Lake	Platte	17, 51N, 33W	1.7	25	14	E	592
Weatherby Lake			2.0	20	5	M	403
Williams Lake (Rcky Holl)	Clay	33, 53N, 30W	1.4	55	21	E	784
OSAGE PLAINS							
Amarugia Highlands Lake	Cass	10,43N,32W	0.7	64	12	E	731
Atkinson Lake	St. Clair	6, 37N, 28W	0.5	78	36	E	983
Blind Pony Lake	Saline	SE18,49N,22W	0.7	83	48	E	1,260
Blue Springs Lake	Jackson	3, 48N, 31W	1.0	36	16	E	553
Bushwacker Lake	Vernon	27,34N,32W	1.6	28	16	E	605
Cat Claw Lake	Jackson	14,47N,31W	0.2	126	4	E	862
Concordia Lake	Lafayette	20, 48N, 24W	0.6	84	27	E	1,110
Coot Lake	Jackson	22.47N,31W	0.6	50	10	E	856
Cottontail Lake	Jackson	14,47N,31W	0.2	140	15	E	946
Four Rivers CA	Bates	,T38N,R30W	1.0	34	7	M	460
Gopher Lake	Jackson	23,47N,31W	0.4	94	17	E	776
Harmony Mission Lake	Bates	15,38N32W	1.3	50	23	E	844
Harrisonville Lake	Cass	26, 46N, 31W	0.9	50	16	E	946
Hazel Hill Lake			0.8	54	30	E	986
Higginsville Lake	Lafayette	9, 49N, 25W	0.7	101	21	E	1,251
Holden City Lake	Johnson	7,45N,27W	0.7	56	16	E	1,094
H.S. Truman Lake	Benton	7, 40N, 23W	1.1	44	18	E	922
Jackrabbit Lake	Jackson	15,47N,31W	0.2	168	14	E	783
Lake Jacomo	Jackson	11, 48N, 31W	1.3	34	19	E	573
Lake Tapawingo	Jackson	34, 49N, 31W	1.2	34	32	E	842
Lamar Lake	Barton	32, 32N, 30W	0.8	78	42	E	945
Longview Lake	Jackson	20, 47N, 32W	0.8	38	12	E	757

LAKE	COUNTY	LOCATION	SECCHI	TP[1]	Ch1-a[2]	TROPHIC[3] STATE	TN[4]
Lotawana Lake	Jackson	29, 48N, 30W	1.4	31	16	E	672
Maple Leaf Lake	Lafayette	04,48N,26W	1.1	45	24	E	929
Montrose Lake	Henry	33, 41N, 27W	0.2	189	63	HE	1,292
Nell Lake	Jackson	15,47N,31W	0.6	68	12	E	834
North Lake	Cass	28, 45N, 31W	0.7	94	40	E	1,002
Prairie Lee Lake	Jackson	27, 48N, 31W	0.8	55	25	E	915
Raintree Lake	Cass	6, 46N, 31W	0.6	60	17	E	1,008
Spring Fork Lake	Pettis	21, 44N, 21W	0.6	142	43	E	1,118
*Tebo Lake (Westmoreland)	Pettis	12, 44N, 22W	2.8	18	4	M	609
Winnebago Lake	Cass	9, 46N, 31W	0.9	51	18	E	838
OZARK BORDER							
Binder Lake	Cole	36, 45N, 13W	1.1	56	22	E	762
Creve Couer Lake	St Louis	20, 46N, 5E	0.3	154	57	HE	1,053
Glover Spring Lake	Callaway	13, 47N, 9W	1.2	67	22	E	863
Indian Hills Lake	Crawford	23, 39N, w	1.0	36	16	E	626
Kraut Run Lake (Busch WA #33)	St. Charles	23, 46N, 2E	0.5	100	58	HE	1,114
Lake of the Ozarks (Lower)	Miller	19, 40N, 15W	1.8	30	15	E	625
Lake of the Ozarks(Mid)	Camden			44	16	E	618
Lake Northwoods	Gasconade	33, 43N, w	1.0	26	5	M	472
Lake St. Louis	St. Charles	SW26,47N,2E	0.5	86	29	E	1,171
Lake Ste. Louise	St. Charles		1.1	31	6	M	513
Lake Tishomingo	Jefferson	5, 41N, 4E	2.0	22	6	M	495
Lake Wauwanoka	Jefferson	1, 40N, 4E	2.8	14	3	M	613
Lincoln Lake	Lincoln	8, 49N, 1E	2.1	19	6	M	468
Little Prairie Lake	Phelps	21, 38N, 7W	0.9	31	9	M	522
Manito Lake	Moniteau		0.9	59	12	E	936
Pinnacle Lake	Montgomery	24, 47N w	2.6	24	5	M	463
Pleasant Valley	Gasconade	25, 42N, 6W	1.4	38	30	E	868
Pomme de Terre Lake	Hickory	2, 36N, 22W	1.7	30	16	E	581
Stockton Lake	Cedar	15, 34N, 26W	2.8	14	6	M	441
OZARK HIGHLANDS							
Austin Lake	Texas	30, 29N, 11W	1.7	21	7	M	503
*Bella Vista Lake	Cape Girardeau	15, 32N, 13E	1.4	23	12	M	552
Bismarck Lake			1.7	23	9	M	373
*Boutin Lake	Cape Girardeau	15, 32N, 14E	1.5	23	8	M	558
Bull Shoals Lake	Taney	22N, 20W	2.0	19	8	M	355
Clearwater Lake	Reynolds	6, 28N, 3E	1.9	15	5	M	233
Council Bluff Lake	Iron	23, 35N, 1E	3.2	8	2	O	247
Crane Lake	Iron	33,32N,4E	1.1	16	4	M	260
Fellows Lake	Greene	22, 30N, 21W	2.6	15	5	M	378
Fourche Lake	Ripley	22, 23N, 1W	3.5	10	3	O	246
Fredericktown City (Lake)	Madison	6, 33N, 7E	0.7	65	33	E	752
Goose Creek Lake	St. Francois	26, 38N, 6E	2.1	15	5	M	389
*Lake Capri	St. Francois	30, 37N, 4E	4.4	7	2	O	295
*Lake Carmel	St. Francois	18, 37N, 4E	2.8	10	3	O	321

TROPHIC[3]

LAKE	COUNTY	LOCATION	SECCHI	TP[1]	Ch1-a[2]	STATE	TN[4]
Lake Forest,(Lake Ann)	St. Genevieve	36, 38N, 7E	1.3	43	22	E	649
Lake Girardeau	Cape Girardeau	9, 30N, 11E	0.7	73	50	E	1,011
Lake Killarney	Iron	1, 33N, 4E	0.8	68	32	E	655
*Lake Marseilles	St. Francois	29, 37N, 4E	3.7	11	2	O	351
*Lake Pinewoods	Carter	7,26N,3E	1.3	45	26	E	858
Lake Springfield	Greene	20, 61N, 16W	1.0	60	19	E	1,016
Lake Taneycomo	Taney	8, 23N, 20W	3.5	23	3	M	803
Lake Turner (Ziske)	Dent	17, 34N, 07W		20	18	E	
Lake Wapapello	Wayne	3, 26N, 3E	1.0	37	24	E	503
Loggers Lake	Dent	10, 31N, 3W	3.1	10	4	M	237
Lower Taum Sauk	Reynolds	33, 33N, 2E	2.1	13	4	M	201
*Macs Lake	Dent		1.4	25	23	E	622
McDaniel Lake	Greene	26, 30N, 22W	1.4	34	19	E	493
*Miller Lake	Carter	1, 27N, 1E	1.5	19	6	M	469
Monsanto Lake (St. Joe State Park)	St. Francois	20, 36N, 5E	2.3	10	2	O	372
Noblett Lake	Douglas	25, 26N, 11W	2.6	18	5	M	255
Norfork Lake	Ozark	21N, 12W	1.7	23	6	M	631
Perry Co. Lake	Perry	22, 35N, 10E	0.7	71	44	E	1,080
Pomona Lake	Howell	26, 26N, 9W		50	10	E	605
Ripley Co. Lake	Ripley	10, 23N, 1E	1.5	32	26	E	787
Roby Lake	Texas	3, 32N, 11W	2.1	18	5	M	431
*Shane Lake	Dent		2.9	7	1	O	296
*Shawnee Lake	Dent		1.6	30	25	E	610
Sims Valley Lake	Texas	17, 27N, 8W	1.1	27	13	M	504
Sunnen Lake	Washington	4, 37N, 1E	2.6	13	4	M	288
Table Rock Lake	Stone	22, 22N, 22W	3.1	12	6	M	398
Timberline Lake	St. Francois	23, 38N, 04E	4.0	10	2	O	306
Wanda Lee Lake	St. Genevieve	2, 37N, 76	1.3	56	26	E	577
SOUTHEASTERN LOWLANDS							
Tywappity Lake	Scott	8, 29N, 13E	0.8	50	36	E	1,005

[1]Total Phosphorus (UG/L) Secchi depth in meters
[2]Chlorophyll A (MG/Cubic Meter)
[3]Trophic State: O=Oligotrophic, M=Mesotrophic, E=Eutrophic, HE=Hypereutrophic
[4]Total Nitrogen (UG/L)
*Unclassified Lake

Trophic status correlates strongly with physiographic region of the state. In agricultural northern and western Missouri, most lakes of known trophic state are eutrophic, while in the Ozarks and ozark border regions, trophic state is equally divided between eutrophic and either mesotrophic or oligotrophic lakes.

All known hypereutrophic lakes are in glaciated northern Missouri, while all oligotrophic lakes are in unglaciated, highly weathered Ozark terrain.

The method presently used by the state to determine trophic status was derived from the work by Wetzel, R.G., 1975; "Limnology," Table 14-11; and from Vollenweider, R.A. and J.J. Kerekes, 1980. EPA440/5-81-010; "Restoration of Lakes and Inland Waters." The criteria are shown in the table below.

TABLE 9. DEFINITION OF TROPHIC CLASSIFICATION

Trophic Class	Chlorophyll-A (ug/l)	Total phosphorus (ug/l)
Oligotrophic	<3	<10
Mesotrophic	3-10	10-30
Eutrophic	11-56	31-100
Hypereutrophic	>56	>100

STATUS OF WETLANDS

Originally about 4.8 million acres (10.7 percent of the land surface of the state) in Missouri were wetlands. By 1980 this figure had been reduced to about 643,000 acres. Several state and federal programs have recognized the need to preserve and enhance our remaining wetlands.

The Missouri Department of Conservation between 1989 and 1997 purchased 25,000 acres of wetlands and developed new wetland areas on an additional 16,000 acres.

The U.S. Fish and Wildlife Service has begun acquiring land from willing sellers in the Missouri River floodplain for a new national wildlife refuge called Big Muddy. The project authorizes the purchase of up to 16,000 acres in 7 locations. As of September, 1998, the refuge consisted of 6,186 acres of land in 7 units. The Big Muddy Refuge also administers another 992-acre tract of land in the Missouri floodplain, Overton Bottoms, owned by the U.S. Army Corps of Engineers. Almost all of this acreage is in the Missouri River floodplain and lands will be allowed to interact naturally with the river and act as seasonal wetlands.

The Natural Resources Conservation Service Wetlands Reserve Program begun in 1992, purchases easements of wetlands and provides funds for restoration of those wetlands. There are presently 482 easements on 66,012 acres are in place and an addition of 31 easements on 5,400 acres is in progress.

CHAPTER 4. GROUND WATER ASSESSMENT

BACKGROUND

Somewhat less than half of the people in Missouri rely on ground water as the source of their drinking water. Ground water is the major source of drinking water in the Ozarks and the Southeast Lowlands for both public and private supplies. The cities of Independence, Columbia and St. Charles use ground water adjacent to the Missouri River. In the plains region of the state, many small communities are able to obtain adequate water from shallow alluvial wells near rivers or large creeks, and many individual households still rely on the upland shallow aquifer even though it yields only very small amounts of water.

In the Ozarks, ground water yields are usually large and of excellent quality, as witnessed by the fact that unlike cities in other areas of the state, many municipalities pump ground water directly into their water supplies without treatment. However, the geologic character of the Ozarks that supplies it with such an abundance of ground water, namely its ability to funnel large amounts of rainfall and surface runoff to the ground water system, can present problems with ground water quality. This is because much surface water flows directly to ground water through cracks, fractures or solution cavities in the bedrock with little or no filtration. Contaminants in leaking septic tanks, storage tanks and surface waters affected by domestic wastewater, animal feedlots and other pollution sources can move directly into ground water through these cavities in the bedrock.

Like the Ozarks, ground water in the southeast lowlands is abundant and of good quality. Unlike the Ozarks, contaminants are filtered by thick deposits of sand, silt and clay as they move through the ground water system. Thus, while shallow ground water wells are subject to the same problems with elevated levels of nitrate or bacteria as is found locally in the Ozark aquifer and can also have low levels of pesticides, deep wells are generally unaffected by contaminants.

Shallow ground water in the plains of northern and western Missouri tends to be somewhat more mineralized and to have taste and odor problems due to high levels of iron and manganese. Like shallow wells in the southeast lowlands, wells in this part of the state can be affected by nitrates, bacteria or pesticides.

In urban areas, alluvial aquifers of large rivers such as the Missouri and the Meramec that serve water supplies have been locally contaminated by spills or improper disposal of industrial or commercial chemicals.

WELL CONSTRUCTION AND GROUND WATER QUALITY

Well water quality is greatly influenced by well construction. Public drinking water wells and many private wells are deep, properly cased and grouted. These wells rarely have contaminants. However, many private wells are shallow or not properly cased. These wells can be easily contaminated by septic tanks, feedlots or chemical mixing sites near the well. Studies in Missouri have shown that two-thirds of wells contaminated by pesticides are less than 35 feet deep. The three most common problems in private wells are bacteria, nitrate and pesticides. It is estimated that about 30 percent of private wells occasionally exceed drinking water standards for bacteria, 30 percent for nitrate and about five percent for pesticides. State regulations include standards for construction and wellhead protection for all new wells.

MAJOR POTABLE AQUIFERS IN MISSOURI

The location of the major aquifers providing drinkable water in Missouri are shown below. The unconfined aquifers are those under water table conditions (the pressure at the water table is the atmospheric pressure). These unconfined aquifers tend to yield greater amounts of water, but are also more easily contaminated by activities occurring at the land surface. In confined aquifers, the upper level of the saturated zone is restricted so that the pressure level is greater than exists at that level of saturation. Confined aquifers are generally recharged more slowly than unconfined aquifers but are better protected from surface contaminants.

Glacial Till Aquifer

This aquifer covers most of the Missouri north of the Missouri River. Glacial till is an unsorted mixture of clay, sand and gravel with occasional boulders and lenses of sand or gravel. Loess, fine wind-blown silt deposits of four to eight feet in depth, cover the till on the uplands. In places, the till is underlain by sorted deposits of sand or gravel. Although this aquifer is unconfined, surface water infiltrates very slowly, and ground water yields are very small. In scattered areas the till has buried old river channels that remain as large sand or gravel deposits that contain much more ground water than the till.

Some households still rely on this aquifer for drinking water, but it is inadequate as a source for municipal water supply.

Alluvial Aquifer

Alluvial aquifers are the unconfined aquifers on floodplains of rivers and are of Quaternary age. In Missouri, the largest of these aquifers lie along the Missouri and Mississippi rivers, reaching their widest extent in the southeast lowlands where they extend for as much as 50 miles west of the Mississippi River. Many small communities north of the Missouri River use the alluvial aquifers of nearby streams for their drinking water supply, and the Missouri River alluvium supplies the cities of Independence and Columbia and sections of St. Charles County. In the southeast lowlands, most private water supplies and about 45 percent of people served by public water supplies use water from the alluvial aquifer. Agricultural irrigation consumes about five times more water in this area of Missouri than does domestic water use. All agricultural irrigation water is drawn from the alluvial aquifer.

Wilcox-McNairy Aquifer

These two aquifers lie beneath much of the alluvial aquifer of the southeast lowlands. They are in unconsolidated or loosely consolidated deposits of marine sands and clays of Tertiary and Cretaceous age. Except where the McNairy outcrops in the Benton Hills and along Crowley's Ridge, these aquifers are confined. They yield abundant amounts of good quality water, and they provide the water for 55 percent of people served by public supplies. In the southeastern part of this region, the deeper of these aquifers, the McNairy, becomes too mineralized to be used for drinking water supply. These two aquifers appear to be unaffected by contaminants of human origin.

Ozark-St. Francis Aquifer

This aquifer covers most of the southern and central two-thirds of Missouri. It is composed of dolomites and sandstones of Ordovician and Cambrian age. Most of the aquifer is unconfined. This aquifer is used for almost all public and private drinking water supplies in this area of Missouri. Exceptions would include supplies in the St. Francis Mountains, such as Fredericktown and Ironton, where the aquifer has been lost due to geologic uplift and erosion, and in Springfield, where demand is so heavy that ground waters are supplemented with water from two reservoirs and the James River.

Yields and water quality are typically very good, but in many areas, the bedrock is highly weathered, contains many solution cavities and can transmit contaminated surface waters into the ground water rapidly with little or no filtration. Where the confined portion of the aquifer is overlain only by the Mississippian limestones of the Springfield aquifer, the confined Ozark aquifer continues westward for 80 miles or more as a potable water supply, serving the communities of Pittsburg, Kansas and Miami, Oklahoma. However, where it is also overlain by less permeable Pennsylvanian bedrock, the confined Ozark becomes too mineralized for drinking within 20 to 40 miles.

The unconfined Ozark-St. Francis aquifer is susceptible to contamination from surface sources. Increasing urbanization and increasing numbers of livestock are threats to the integrity of portions of this valuable aquifer.

Springfield Aquifer

This aquifer covers a large portion of southwestern Missouri. It is composed of Mississippian limestones that are, particularly in the eastern portion of the aquifer, highly weathered. The aquifer is unconfined and surface water in many areas is readily transmitted to ground water. Urbanization and livestock production affect this aquifer. Elevated nitrates and bacterial contamination are common problems in ground waters of the Springfield aquifer.

GROUNDWATER QUALITY SUMMARY TABLES

Table 10 lists the major sources of ground water contamination in Missouri, major contaminants and reasons why these sources are the most important. Table 11 summarizes ground water quality problems as hazardous waste sites. Tables 12 and 13 provide information on levels of nitrate, pesticides and other toxic organics in public drinking water wells and Table 14 gives the present status of Missouri's ground water protection strategy.

TABLE 10. MAJOR SOURCES OF GROUND WATER CONTAMINATION

Contaminant Source	10 Highest Priority Sources (X) [1]	Factors Considered in Selecting a Contaminant Source [2]	Contaminants [3]
Agricultural Activities			
Agricultural chemical facilities			
Animal feedlots			
Drainage wells			
Fertilizer applications	X	A,C,D,E	E
Irrigation practices			
Pesticide applications	X	A,B,C,D,E	B
Storage and Treatment Activities			
Land application	X	A,D,E	J,K,L,E
Material stockpiles			
Storage tanks (above ground)			
Storage tanks (underground)	X	A,B,C,D,E	D
Surface impoundments			
Waste piles			
Waste tailings			
Disposal Activities			
Deep injection wells			
Landfills			
Septic systems	X	A,D,E	J,K,L,E
Shallow injection wells			

Other			
Hazardous waste generators			
Hazardous waste sites	X	A,B,C,D	B,C,H,I
Industrial facilities	X	A,B,C,E	E,Ammonia, PCP, Dioxin
Material transfer operations			
Mining and mine drainage	X	A,E	H
Pipelines and sewer lines			
Salt storage and road salting			
Salt water intrusion	X	C	G
Spills	X	A,B,C,E	B,C,D,Ammonia
Transportation of materials			
Urban runoff			
Other sources (please specify)			
Other sources (please specify)			

(1) Not in Priority Order

(2) Key: Factors Considered in Selecting Contaminant Source.

A. Human health or environmental toxicity risk
B. Size of population at risk
C. Location of sources relative to drinking water sources
D. Number and/or size of contaminant sources
E. Hydrogeologic sensitivity

(3) Key: Contaminants

A. Inorganic Pesticides
B. Organic Pesticides
C. Halogenated Solvents
D. Petroleum compounds
E. Nitrate
F. Fluoride
G. Salinity/brine
H. Metals
I. Radionuclides
J. Bacteria
K. Protozoa
L. Viruses

TABLE 11. GROUND WATER CONTAMINATION SUMMARY

Hydrogeologic Setting [1] All Aquifers
Spatial Description (optional)[2]
Map Available (optional)[3]
Data Reporting Period[4] Sept.1997- Sept.1999

Source Type[5]	Number of sites[6]	Number of sites that are listed and/or have confirmed releases[6]	Number with confirmed ground water contamination[6]	Contaminants [7]	Number of site investigations (optional)	Number of sites that have been stabilized or have had the source removed (optional)	Number of sites with corrective action plans (optional)	Number of sites with active remediation (optional)	Number of sites with cleanup completed (optional)
NPL	18	18	13	5	23	12	13	9	6
CERCLIS (non-NPL)	51	51	14	7	36	19	32	10	16
DOD/DOE	27	25	11	*6					
LUST	840	840	250	1	141			508	332
RCRA Corrective Action	96	53	43	2	48	29	33	20	6
Underground Injection									
State Sites	33	33	19	3	11	11	8	10	5
Nonpoint Sources[5]									
Other (specify)									

NPL - National Priority List , DOE- Department of Energy ; DOD- Department of Defense; CERCLIS (non-NPL) - Comprehensive Environmental Response, Compensation, and Liability Information System; LUST - Leaking Underground Storage Tanks; RCRA - Resource Conservation and Recovery Act.

* Contaminants

*1 - BTEX, TPH, MTBE, PAH, Metals, SVOA;*2 - Creosote, penta, Organic Solvents, Petroleum, Asbestos, Metals, Chlorinated Solvents
*3 - VOC, PAH, Chlorinated Solvents, Metals;*4 - VOA, PCB, Pesticides, Dioxin, Metals, Radionuclides, SVOCs, etc.
*5 - VOAs, SVOAs, PCBs, Dioxin, PAH, Pesticides, Metals;*6 - Radionuclides, Metals, Semo-volatiles, Volatiles, Pesticides, Explosives

TABLE 12. AQUIFER MONITORING DATA

Hydrogeologic Setting [1] Wilcox and McNairy Aquifers of the Mississippi Embayment in Missouri

Spatial Description (optional)[2] Southeastern Corner of Missouri (Dunklin, Mississippi, New Madrid, Pemiscot, Scott, and Stoddard Counties)

Map Available (optional)[3]

Data Reporting Period[4] April 1996 – April 2001

WILCOX/MCNAIRY AQUIFER SITES	NO_3	SOCs	VOCs	Notes (Contaminant Levels and Detects without MCLs)
Arbyrd	ND	ND	ND	
Benton	**<5 mg/l**	ND	ND	NO3+2N 1.5 mg/l
Bloomfield	ND	ND	ND	BroDichMeth 0.6 ug/l, Bromoform 0.7 ug/l, DiBroChloMeth 1.4 ug/l
Campbell	ND	ND	ND	
Cardwell	ND	ND	ND	
Caruthersville	ND	ND	**<MCL**	CarbTetraCl 0.5 ug/l
Charleston	**<5 mg/l**	ND	ND	NO3+2N 0.22, BroDichMeth 1.3 ug/l, Chloroform 2.5 ug/l
Clarkton	ND	ND	ND	
Dexter	ND	ND	ND	Bromoform 0.9 ug/l, Chloroethane 6.8 ug/l, DiBroChloMeth 0.8 ug/l
Dunklin Co. #1	**<5 mg/l**	ND	ND	NO3+2N 0.07 mg/l
Dunklin Co. #2	ND	ND	ND	
Dunklin Co. #3	ND	ND	ND	
Essex	ND	ND	ND	
Gideon	ND	ND	ND	BroDichMeth 6.4 ug/l, Bromoform 7.3 ug/l, Chloroform 4.5 ug/l, DiBroChloMeth 9.4 ug/l
Holcomb	ND	ND	ND	
Holland	ND	ND	**<MCL**	BroDichMeth 1.1 ug/l, Chloroform 3.3 ug/l, Ethylbenzene 5 ug/l, Tot Xylenes 26.6 ug/l
Hornersville	ND	ND	ND	
Malden	ND	ND	ND	
Matthews	ND	ND	ND	Chloroform 1.1 ug/l
Oran	**<5 mg/l**	ND	**<MCL**	NO3+2N 0.82 mg/l, BroDichMeth 1.4 ug/l, Bromoform 3.2 ug/l, Chloroform 1 ug/l, DiBroChloMeth 2.5 ug/l, MTBE 55.4 ug/l, Tot Xylenes 1.4 ug/l
Parma	ND	ND	ND	Chloroform 3.1 ug/l
Pemiscott Co. #1	**<5 mg/l**	ND	ND	NO3+2N 0.17 mg/l
Risco	**<5 mg/l**	ND	**<MCL**	NO3+2N 1.01 mg/l, Tot Xylenes 1.2 ug/l
Senath	ND	ND	ND	
Sikeston	ND	ND	ND	124 TriMethBenz 0.01, BroDichMeth 4.9 ug/l, Chloroform 4.6 ug/l, DiBroChloMeth 2.7 ug/l
Steele	ND	ND	ND	
Stoddard Co. #1	ND	ND	ND	Bromoform 5.6 ug/l, DiBroChloMeth 2.8 ug/l
Stoddard Co. #3	ND	ND	ND	BroDichMeth 12.5 ug/l, Bromoform 0.5 ug/l, Chloroform 18.5 ug/l, DiBroChloMeth 7 ug/l
Stoddard Co. #5	ND	ND	ND	BroDichMeth 1.4 ug/l, Chloroform 0.7 ug/l, DiBroChloMeth 2 ug/l
Vaughn's Gaslight Village MHP	**<5 mg/l**	ND	ND	NO3+2N 1.79 mg/l
Wardell	ND	ND	**<MCL**	BroDichMeth 1.6 ug/l, Bromoform 1.6 ug/l, DiBroChloMeth 3.2 ug/l, Ethylbenzene 1 ug/l, Methylene Chloride 0.6 ug/l, Toluene 1.3 ug/l, Tot Xylenes 6 ug/l
Wyatt	ND	ND	ND	BroDichMeth 2.4 ug/l, Chloroform 3.9 ug/l, DiBroChloMeth 1.1 ug/l

SOC = synthetic organic compound VOC = volatile organic compound NO_3 = nitrate MCL = maximum contaminant level ND = not detected

TABLE 13. AQUIFER MONITORING DATA

Hydrogeologic Setting Alluvial Aquifer of the Mississippi Embayment in Missouri
Spatial Description (optional) Southeastern Corner of Missouri (Dunklin, Mississippi, New Madrid, Pemiscot, Scott, and Stoddard Counties)
Map Available (optional)
Data Reporting Period July1998 – October 2001

ALLUVIAL AQUIFER SITES	NO_3	SOCs	VOCs	Notes (Contaminant Levels and Detects without MCLs)
360148090023801 (IRRIGATION)	ND	ND	ND	Bentazon 0.08 ug/l, 124TriMethBenz 0.1 ug/l
362858089440901 (AQUACULTURE)	**<5 mg/l**	ND	ND	NO3+2N 0.077 mg/l, Bentazon 0.31 ug/l
363807089485001 (IRRIGATION)	**<5 mg/l**	ND	ND	NO3+2N 0.775 mg/l
Advance	ND	ND	ND	BroDichMeth 3.6 ug/l, Chloroform 10.5 ug/l, DiBroChloMeth 0.6 ug/l
Anniston	ND	ND	ND	BroDichMeth 4.1 ug/l, Chloroform 5.4 ug/l, DiBroChloMeth 1.8 ug/l
Baker Mills MHP	**<5 mg/l**	ND	ND	NO3+2N 0.43 mg/l
Bell City	ND	ND	ND	DiBroChloMeth 0.6ug/l
Bernie	**<5 mg/l**	ND	ND	NO3+2N 0.141 mg/l, BroDichMeth 2.7 ug/l, Chloroform 3.3 ug/l, DiBroChloMeth 1.5 ug/l
Bertrand	ND	ND	ND	BroDichMeth 2 ug/l, Chloroform 3 ug/l, DiBroChloMeth 0.9 ug/l
Big Oak Tree S. P.	ND			
Blodgett	ND	ND	**<MCL**	BroDichMeth 4.6 ug/l, Chloroform 24.2 ug/l, DiBroChloMeth 0.6 ug/l, Ethylbenzene 0.7 ug/l, Tot Xylenes 4.1 ug/l
C. O.'s Market	**<5 mg/l**			NO3+2N 3.01 mg/l, BroDichMeth 3.1 ug/l
Chaffee	**<5 mg/l**	ND	ND	NO3+2N 0.1 mg/l, BroDichMeth 3.1 ug/l, Bromoform 2.1 ug/l, Chloroform 1.1 ug/l, DiBroChloMeth 5.5 ug/l
Dudley	ND	ND	**<MCL**	BroDichMeth 24.9 ug/l, Bromoform 2.1 ug/l, Chloroform 45.1 ug/l, DiBroChloMeth 17.3 ug/l, Toluene 0.7 ug/l, Tot Xylenes 0.5 ug/l
East Prairie	ND	ND	ND	BroDichMeth 2.1 ug/l, Chloroform 2.3 ug/l, DiBroChloMeth 1.5 ug/l
Ferrel's MHP	**<5 mg/l**	ND	ND	NO3+2N 0.83 mg/l
Hayti	ND	ND	ND	BroDichMeth 0.5 ug/l, Chloroform 0.8 ug/l, DiBroChloMeth 0.5 ug/l
Hayti Heights	ND	ND		
Haywood City	ND	ND	ND	
Kennett	**<5 mg/l**	ND	**<MCL**	NO3+2N 0.138 mg/l, BroDichMeth 2.8 ug/l, Bromoform 0.5 ug/l, Chloroform 4.1 ug/l, cis12DiChlEth 0.03 ug/l, DiBroChloMeth 2.1 ug/l, DiChloEthane 0.02 ug/l, DiChloEthylene 0.01 ug/l, DiIsoPropEther 0.6 ug/l, MTBE 0.3 ug/l
Lilbourn	ND	ND	ND	BroDichMeth 2.1 ug/l, Chloroform 4.8 ug/l, DiBroChloMeth 0.6 ug/l
Marston	**<5 mg/l**	ND	ND	NO3+2N 0.05 mg/l
Matthews Trav. Cent.	ND			
Miner	ND	ND	**<MCL**	BroDichMeth 8.7 ug/l, Chloroform 11.8 ug/l, DiBroChloMeth 3.5 ug/l, Tot Xylenes 0.8 ug/l
Morehouse	ND	ND	ND	BroDichMeth 4.5 ug/l, Chloroform 4.8 ug/l, DiBroChloMeth 2.7 ug/l, DiChloEthane 0.04 ug/l
Morley	ND	ND	**<MCL**	BroDichMeth 4.8 ug/l, Chloroform 10.6 ug/l, DiBroChloMeth 1.9 ug/l, Ethylbenzene 0.8 ug/l, Tot Xylenes 5.3 ug/l
New Madrid	ND	ND	ND	BroDichMeth 3.3 ug/l, Chloroform 5.3 ug/l, DiBroChloMeth 1.5 ug/l
New Madrid Co. #2	ND	ND	**<MCL**	Benzene 1.2 ug/l, BroDichMeth 16.8 ug/l, Bromoform 0.5 ug/l, Chloroform 37.6 ug/l, DiBroChloMeth 6.4 ug/l, Methylene Chloride 1.1 ug/l, MTBE 12.8 ug/l
Portageville	ND	ND	**<MCL**	BroDichMeth 7.5 ug/l, Bromoform 1 ug/l, Chloroform 6 ug/l, DiBroChloMeth 6.7 ug/l, Methylene Chloride 1.5 ug/l
Ralston Purina	ND	ND	ND	
Richland R-I High School	ND	ND	ND	BroDichMeth 0.8 ug/l, Chloroform 2.1 ug/l, DiBroChloMeth 0.6 ug/l
Rolling Meadows MHP	ND	ND	ND	
Scott Co. R-V School	ND	ND	**<MCL**	BroDichMeth 1.9 ug/l, Chloroform 2.8 ug/l, DiBroChloMeth 1 ug/l, Ethylbenzene 1 ug/l, Tot Xylenes 4.7 ug/l
Sikeston Health Care	ND	ND	ND	
St. Jude Indust. Pk.	**<5 mg/l**	ND	ND	NO3+2N 0.13 mg/l, BroDichMeth 7.8 ug/l, Bromoform 2.7 ug/l, Chloroform 6.4 ug/l, DiBroChloMeth 8.1 ug/l
Thomas W. Kelly School	ND	ND	ND	
Vanduser	ND	ND	ND	BroDichMeth 2.6 ug/l, Chloroform 3.9 ug/l, DiBroChloMeth 0.6 ug/l

SOC = synthetic organic compound VOC = volatile organic compound NO_3 = nitrate MCL = maximum contaminant level ND = not detected

SUMMARY OF GROUND WATER PROTECTION PROGRAMS

TABLE 14. GROUND WATER PROTECTION STRATEGY

Program or Activities	Check (X)	Implementation Status	Responsible State Agency
Active SARA Title III Program	X		MDPS/SEMA
Ambient ground water monitoring system		NA	
Ground water monitoring at sanitary landfills	X	Fully established	DNR
Aquifer vulnerability assessment	X		DNR
Aquifer mapping		NA	
Aquifer characterization		NA	
Comprehensive data management system		NA	
EPA-endorsed Core Comprehensive State Ground Water Protection Program (CSGWPP)		Under development	DNR
Ground water discharge permits	X	Fully established	DNR
Ground water best management practices (BMPs)	X	Continuing effort	DNR
Ground water legislation	X		DNR
Ground water classification		NA	
Ground water quality standards	X	Fully established	DNR
Interagency coordination for ground water protection initiatives	X	Fully established	DNR*
Nonpoint source controls		Continuing effort	DNR*
Pesticide State Management Plan		Pending	MDA
Pollution Prevention Program		Pending	DNR
Resource Conservation and Recovery Act (RCRA) Primacy	X	Fully established	DNR
State Superfund	X	Fully established	DNR
State RCRA Program incorporating more stringent requirements than RCRA Primacy	X	Fully established	DNR
State septic system regulations	X	Fully established	MDHSS
Underground storage tank installation requirements	X	Fully established	DNR
Underground Storage Tank Remediation Fund	X	Pending	DNR
Underground Storage Tank Permit Program		NA	
Underground Injection Control Program	X	Fully established	DNR
Vulnerability assessment for drinking water/wellhead protection	X	Fully established	DNR
Well abandonment regulations	X	Fully established	DNR
Wellhead Protection Program (EPA-approved)	X	Fully established	DNR
Well installation regulations	X	Fully established	DNR

MDPS/SEMA = Missouri Department of Public Safety, State Emergency Management Agency
MDA = Missouri Department of Agriculture
MDHSS = Missouri Department of Health & Senior Services

Notes:

Active SARA Title III Program: Administered by Department of Public Safety, State Emergency Management Agency.

Ambient ground water monitoring system: There is no system per se. The state has participated in several opportunities to monitor ambient ground water, such as impact analyses following the floods of 1993.

Aquifer vulnerability assessment: These are conducted by the department's Geological Survey & Resource Assessment Division on a county-by-county basis as funding allows.

Aquifer mapping and characterization: No present systematic activity, although these activities may be conducted in concert with hazardous substance release investigations.

Comprehensive data management system: None.

EPA-endorsed Core Comprehensive State Ground Water Protection Program: No formal program established.

Ground water discharge permits: Underground Injection Control permits issued jointly by the department's Geological Survey & Resource Assessment Division and Water Pollution Control Program.

Ground Water Best Management Practices: Some BMPs are established as part of the Nonpoint Source Management Plan.

Ground water legislation: The Cave Resources Act and Clean Water Law deal directly with ground water. Other laws such as the dead animal disposal statute proscribe protections for ground water. There is no comprehensive ground water protection statute per se.

Ground water classification: None, although a utilities group proposed a classification system.

Ground water quality standards: Established as part of state water quality standards.

Interagency coordination for ground water protection initiatives: Opportunities for monthly coordination are provided through the Water Quality Coordinating Committee.

Nonpoint source controls: The nonpoint source management program provides guidance for voluntary controls.

Pesticide State Management Program: A draft generic pesticides and water quality management plan has been prepared by the Department of Agriculture in conjunction with the Department of Natural Resources. The plan will address both ground water and surface water, and has been submitted to EPA for approval.

Pollution Prevention Program: Some activities carried out by one staff member in the department's Technical Assistance Program; budget request for six full time employees proposed for FY97 budget.

Resource Conservation and Recovery Act (RCRA) Primacy: Administered by the department's Hazardous Waste Program.

State Superfund: Administered by the department's Hazardous Waste Program. This provides for a state registry of confirmed abandoned hazardous waste disposal sites.

State RCRA Program: Incorporating more stringent requirements than RCRA Primacy: Administered by the department's Hazardous Waste Program.

State septic system regulations: Administered by the Department of Health & Senior Services under 1994 statute and rules promulgated in 1995.

Underground storage tank installation requirements: Administered by the department's Hazardous Waste Program.

Underground Storage Tank Remediation Fund: The existing insurance fund was converted to a remediation fund by 1995 statute; rules are being prepared.

Underground Storage Tank Permit Program: Tanks are required to be registered but not permitted.

Underground Injection Control Program: Administered by the department's Geological Survey & Resource Assessment Division.

Vulnerability assessment for drinking water/wellhead protection: Administered by the department's Public Drinking Water Program.

Well abandonment regulations: Administered by the department's Geological Survey & Resource Assessment Division.

Wellhead Protection Program (EPA-approved): Administered by the department's Public Drinking Water Program.

Well installation regulations: Administered by the department's Geological Survey & Resource Assessment Division.

The significant additions or changes to the protection of ground water in the past two years are the passage of two statutes, SB 446 in 1994 and HB 251 in 1995. The former revised requirements for onsite sewage systems and the latter established a $100 million remedial fund for underground storage tanks. Each was a revision of an existing statute.

For more information, call the Department of Natural Resources at (573) 751-1300.