

Salt River

Watershed and Inventory Assessment

H. Ross Dames and Brian Todd, Missouri Department of Conservation

For additional information contact Fisheries Regional Supervisor,

Missouri Department of Conservation,

2500 South Halliburton, Kirksville, MO 63501

Table of Contents

Executive Summary	4
Location	5
Physiographic Region/Geology/Soils.....	8
Stream Orders	8
Watershed Area	9
Channel Gradient.....	9
Soil Conservation Projects.....	9
Public Areas.....	9
Corps of Engineers 404 Jurisdiction.....	10
Land Use	26
Historical Land Use	26
Recent Land Use.....	26
Hydrology	30
Precipitation.....	30
USGS Gaging Stations	30
Permanence of Flow and Average Annual Discharge.....	30
Base flow and Low-Flow Frequency Data	30
Flow Duration.....	30
Flood Frequency	30
Dam and Hydropower Influences.....	31
Water Quality and Use.....	36
Beneficial Use Attainment.....	36
Chemical Quality of Stream Flow	36
Fish Contaminant Levels and Health Advisories, Fish Kills.....	37
Water Use	37
Point Source Pollution	38
Concentrated Animal Feeding Operations.....	38
Non-point Pollution	38
Habitat Conditions	43
Channel Alterations and Habitat Problems.....	43
Unique Habitat.....	43
Improvement Projects	43
Biotic Community.....	44
Fish Community	44
Threatened and Endangered Species	45

Fish Stockings.....	45
Aquatic Invertebrates.....	45
Opportunities for Stream Fishery Conservation in the Salt River Watershed	51
Managing MDC Riparian Ownerships	51
Conservation of Aquatic Communities	52
Supporting Other Agencies and Organizations	53
Assisting Citizen-Led Watershed conservation Efforts.....	54
Citizen Primer to Leadership in Watershed Conservation	55
Angler Guide.....	59
Fishing Prospects for Streams in the Salt River Watershed	59
List of Tables	60
Geomorphology	60
Hydrology	60
Water Quality.....	60
List of Figures	61
Location	61
Geomorphology	61
Land Use	61
Literature Cited	62
Glossary	65

Executive Summary

The Salt River basin drains 2,914 square miles of northeastern Missouri and lies in the Dissected Till Plains physiographic region. The North Fork, South Fork, and lower Salt River sub-basins compose 32%, 42%, and 27% of the basin, respectively. Clarence Cannon Dam, located on the Salt River approximately 63 miles upstream from its confluence with the Mississippi River, forms the 18,600 acre Mark Twain Lake. There are 165 third-order and larger streams in the basin. The North Fork Salt River is the longest stream flowing about 119 miles.

In the upper portion of the basin, where local relief is low, glacial till is overlain by loess deposits in most areas. In the valleys of the Middle and South fork sub-basins, streams have eroded to expose limestone bedrock and shales. In the central part of the basin around Mark Twain Lake, relief increases and exposed limestone and shales in the valley walls and streambeds are more prevalent. Till quickly shallows in the lower Salt River sub-basin as valleys become more abrupt with high relief. A relief of 440 feet is attained the lower end of the Salt River basin. Soils throughout most of the basin are typical of the Central Claypan Region, except in the extreme lower portion that is located in the Central Mississippi Valley Wooded Slopes region.

Much of the pre-settlement landscape of the basin was prairie, however western settlers quickly converted most of the land to agriculture. Currently, nearly 70% of the basin is used in some form of agriculture and nearly half of the land is cultivated for crops.

Mineral resources contributed significantly to the economic development of the basin, but agriculture formed and continues to be the economic base of the basin.

The major water quality concern in the basin is severe soil erosion from cultivated lands and the deposition of sediment into stream channels. Excessive turbidity and siltation have both decreased the abundance and diversity of aquatic life and habitat and made boating more difficult due to locally heavy sedimentation. Overall, point source pollution has a minor impact on basin streams relative to non-point sources. Only five municipal waste water treatment facilities in the basin discharge more than 0.5 million gallons per day. Livestock lagoon failures and poor land application practices have caused water quality problems and local fish kills in basin streams and continues to threaten aquatic communities.

A total of 80 fish species have been collected from the Salt River basin. Only 64 species were found in surveys conducted since 1995. Dominant families collected since 1995 were minnows (17 species), perch (10 species), suckers (9 species), sunfishes (9 species), and catfishes (8 species). Bluntnose minnows were the most abundant species collected and were found at 85% of all sample sites. Red Shiners were collected at 70% of all sample sites. Sixteen species were found in the basin prior to 1995, but not collected in recent surveys. Five of these are believed to be extirpated from the basin.

No threatened or endangered species have been collected in recent surveys.

Management Opportunities address the following issues: acquiring new and develop existing stream access areas to increase public use, passively restoring riparian areas on MDC areas, assisting landowners with corridor restoration, long-term aquatic community monitoring, fishery research needs, assisting citizen-led watershed conservation efforts, and educating youth.

Location

The Salt River basin drains 2, 914 square miles of northeastern Missouri covering all or part of twelve counties (Adair, Audrain, Boone, Calloway, Knox, Macon, Monroe, Pike, Ralls, Randolph, Schuyler, and Shelby; Figures ll, ml, ul). The longest stream in the basin is the North Fork Salt River which originates in Schuyler County and flows southeast approximately 119 miles until meeting the South Fork Salt River in Mark Twain Lake. Major streams in the North Fork sub-basin include Bear Creek, Otter Creek, Crooked Creek, Black Creek, Ten Mile Creek, Titus Creek, and Floyd Creek. The South Fork Salt River originates in Audrain County and flows north approximately 68 miles. Middle Fork Salt River, the largest South Fork tributary, begins in Adair County and flows southeast about 116 miles before meeting the South Fork in Mark Twain Lake. Principal streams in the Middle Fork sub-basin include Elk Fork, Bee Creek, Allen Creek, Milligan Creek, Flat Creek, Mud Creek, Hoover Creek, and Narrows Creek. Other major streams in the South Fork sub-basin include Long Branch, Brush Creek, Youngs Creek, Littleby Creek, Skull Lick Creek, Davis Creek, and Beaverdam Creek.

The lower Salt River begins at the confluence of North Fork and South Fork. The first 15 miles are impounded by Clarence Cannon Dam which was completed in 1983 to create Mark Twain Lake. This dam is located about 63 miles upstream from the Salt River's confluence with the Mississippi River at River Mile 284. The Salt River is also regulated for another 9.5 miles downstream of Clarence Cannon Dam by a re-regulation dam. The total length of Salt River from its mouth to the upper forks is 78 miles. Principal streams of the lower Salt River that flow directly into Mark Twain Lake are Lick Creek, Indian Creek, and Little Indian Creek. Major streams in lower Salt River watershed below the re-regulation dam include Spencer Creek, South Spencer Creek, Sugar Creek, and Peno Creek.

The Salt River basin is bounded by the North River and Fabius River basins to the northeast, the Chariton River basin to the west, and by several Missouri River drainages and the Cuivre River basin to the south.

Prior to the construction of Mark Twain Lake by the U.S. Army Corps of Engineers, the Salt River was surveyed in detail by numerous agencies. An environmental assessment was conducted by Missouri Botanical Gardens (Klein and Daley 1974), a final environmental statement (1975) and a pre-impoundment water quality report (1974) were prepared by the St. Louis District of the U.S. Corps of Engineers, and a biological study was conducted by Environmental Science and Engineering, Inc. (Govro 1984). Much of the background and historical information presented in this document were obtained from these references.

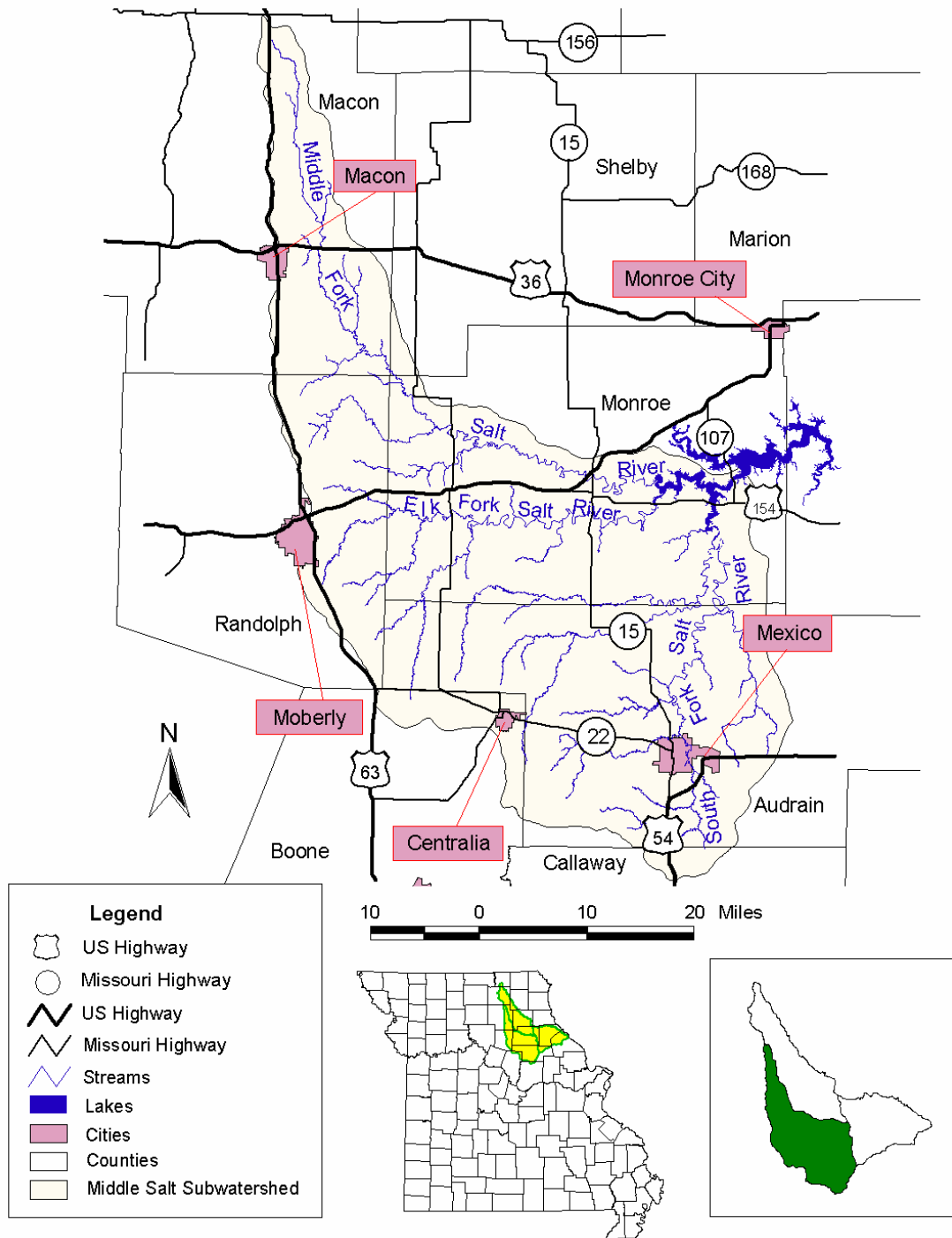


Figure m1. General location of the middle Salt River subwatershed in Missouri.

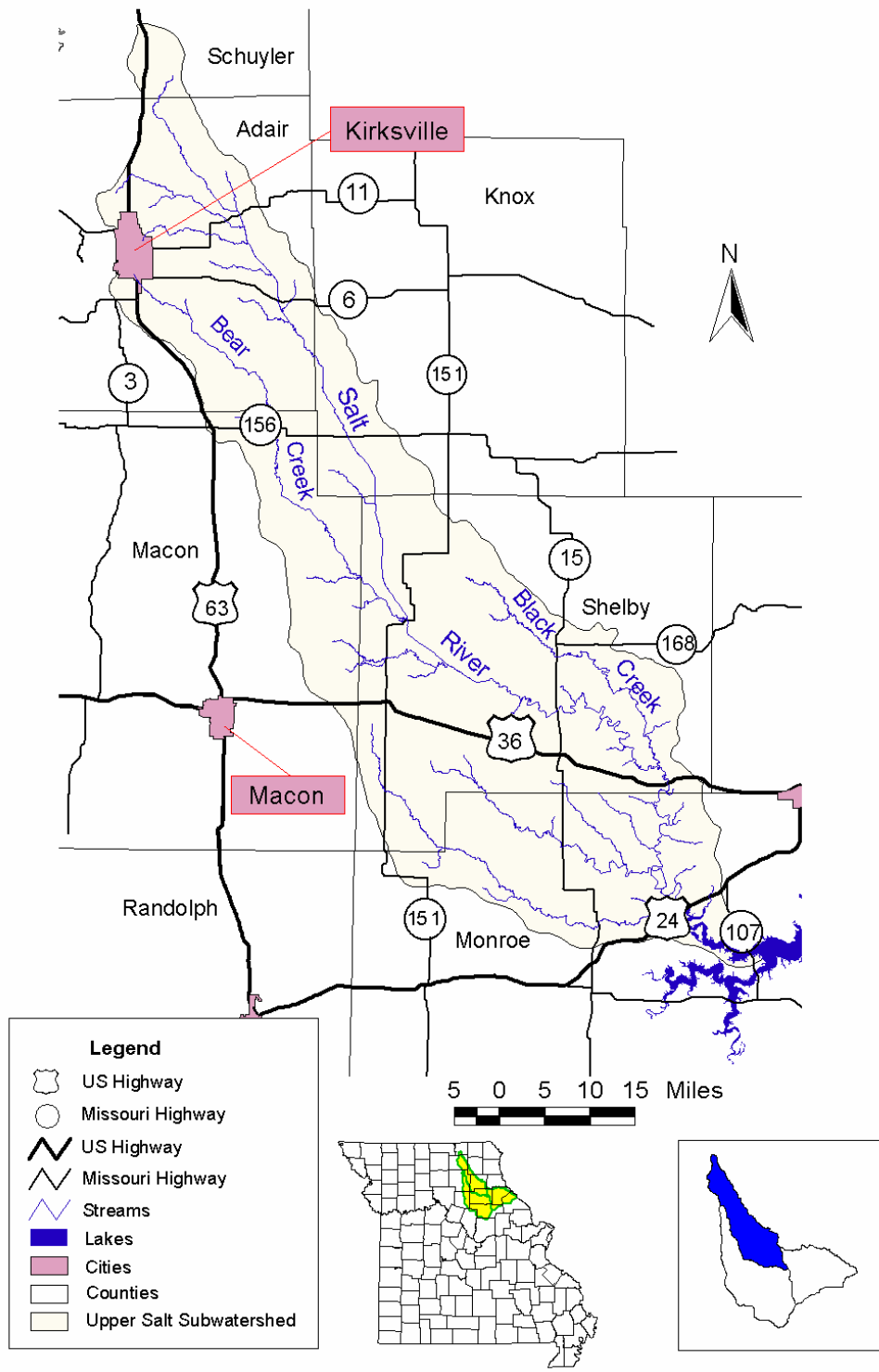


Figure ul. General location of the upper Salt River subwatershed in Missouri.

Geomorphology

Physiographic Region/Geology/Soils

The Salt River basin lies in the eastern section of the Glaciated Plains Division of Missouri (Thom and Wilson 1980), also known as the Dissected Till Plains (Figure nd). The Till Plains were formed by glaciers that deposited drift composed mostly of clay with some rock, gravel, and sand lenses (MDNR unpublished). In the upper portion of the basin, where local relief is generally low (North Fork, Middle Fork, South Fork), the glacial till is overlain by loess deposits, except in a few areas where streams have incised Pennsylvanian or Mississippian aged rock. Although highly variable, till is generally less than 200 feet thick and composed predominantly of clay with some rock fragments and sand lenses. Beneath the till in upland areas may be a thin layer of sand and gravel and then a layer up to 200 feet thick of alternating deposits of Pennsylvanian age sandstone, siltstone, shale, limestone, and coal (Figure ge). An exception is the central portion of the North Fork sub-basin where glacial till is underlain by thickly bedded limestones interbedded with thin Mississippian age shales. In the valleys of the Middle and South Fork sub-basins, streams have eroded the Pennsylvanian rocks to expose limestone bedrock and shales. In the central portion of the basin around Mark Twain Lake, relief increases and glacial till shallows to less than 100 feet thick. Exposed limestone and shales in the valley walls and streambeds are more prevalent. Till quickly shallows in the lower Salt River sub-basin (below the re-regulation dam) to less than 50 feet as valleys become more abrupt with high relief. A relief of 440 feet is attained at the lower end of the basin near Louisiana. Exposed Mississippian and Ordovician age shales and limestone are common in both the valley walls and streambeds. Detailed geological history of the basin can be found in Klein and Daley (1974).

Nearly all of the basin is located in the Central Claypan region (Allgood and Persinger 1980). Central Claypan soils are primarily Putnam-Mexico and Mexico-Leonard-Armstrong-Lindley associations formed in loess or glacial till. Putnam-Mexico soils are generally deep, nearly level to gently sloping soils with a silt loam surface overlying a silty clay subsoil of very low permeability. Mexico-Leonard-Armstrong-Lindley soils are deep, level to steep, well drained to poorly drained, loamy and clayey uplands soils. Mexico and Leonard soils in this association have a silt loam surface overlying a silty clay subsoil while Armstrong and Lindley soils have loam surface overlying a clay loam subsoil. Subsoil permeability is slow.

The extreme lower portion of the basin is located the Central Mississippi Valley Wooded Slopes region. The Menfro-Winfield-Lindley soils in this area are moderately well drained with a loam or silt loam surface overlying silty clay loam subsoil of slow permeability. Poorly drained, loamy soils of the Arbela-Piopolis-Blackoar association are found on the lower floodplains of major streams in the basin. These alluvial soils generally have a silt loam or silty clay loam surface overlying a silt loam subsoil of moderate to slow permeability. As the Salt River enters the Mississippi River floodplain soils turn to loamy, silty, or clayey alluvium of the Westerville-Fatima-Wabash association.

Due to the clay content of the till and underlying shale and limestone, vertical movement of water from the surface to groundwater is limited throughout the basin (MDNR unpublished).

Few significant springs exist in the basin so base flow is not well sustained during dry periods.

Stream Orders

Streams were identified on USGS 7.5 minute topographic maps and ordered according to Strahler (1957). A stream code was assigned to each third-order or higher stream based on the method of Pflieger et al. (1981). There are 165 third-order and larger streams in the basin (Table 1). The mainstem Salt River and the South Fork Salt River are the only seventh-order streams, and North Fork and Middle Fork are the only sixth-order streams. Fifth-order streams include Bear Creek (North Fork sub-basin), Long Branch

(South Fork sub-basin), Elk Fork (Middle Fork sub-basin), and Spencer Creek (lower Salt River sub-basin). All other streams in the basin are fourth-order or smaller.

Watershed Area

The Salt River watershed drains 2,914 square miles (1,867,900 acres) of land. The North Fork, South/Middle Fork, and lower Salt River sub-basins compose 32%, 41%, and 27% of the Salt River basin, respectively (SCS 1992). Drainage area of other fifth-order and larger streams in the basin, estimated by digitizing 1:100,000 topographic maps, are approximately as follows: Bear Creek-124 square miles, Middle Fork-352 square miles (excluding Elk Fork), Elk Fork-292 square miles, Long Branch-188 square miles, and Spencer Creek-215 square miles.

Channel Gradient

Channel gradients for all third-order and higher streams were determined using USGS 7.5 minute topographic maps and digitizing software (Table 1). The average gradient for each stream is based on the change in elevation from the stream's uppermost point to its mouth. Gradients were also calculated separately for each order within an individual stream.

Channel gradients for the major streams in the upper Salt basin are relatively low. Of the fifth-order and larger streams in the basin, Bear Creek (North Fork sub-basin) has the highest gradient (5.4 feet/mile). Although the lower Salt River has an average gradient of only 1.4 feet/mile, many of the smaller streams in its watershed have high gradients due to high local relief. For example, an unnamed third-order stream in Pike County has a gradient of 87 feet/mile. Ten other streams in this sub-basin have gradients exceeding 50 feet/mile.

Soil Conservation Projects

Under the authority of the Watershed Protection and Flood Prevention Act, P.L. 83-566, three soil conservation projects have been proposed for the basin (Table 2). The Middle Fork Salt River application is inactive because a referendum to re-authorize the watershed subdistrict failed. The other two applications are also inactive because they were determined to be economically unfeasible. There are nine SALT projects and one EARTH project in the basin covering 235,688 acres (Table 2).

The North Fork Project, which evolved from the Mark Twain Water Quality Initiative, is an education and outreach program that provides information, training, and networking opportunities on water quality issues, including soil conservation, in the basin. This project is coordinated by the Clarence Cannon Wholesale Water Commission and University of Missouri Outreach and Extension and is partially funded under Section 319 of the Clean Water Act.

Public Areas

There are seventeen conservation and stream access areas totaling 7,648 acres within the Salt River basin (Table 3; Figures 1p, mp, up). Many of the areas provide access to basin streams. Boat ramps are provided at Paris, Santa Fe, Hunnewell, and Indian Camp accesses and at Ted Shanks CA. Several accesses are located within a few miles of each other and provide excellent drop-off and pick-up points for one or two day fishing/float trips (e.g. Pin Oak to Arrow-wood- 10 miles, Arrow-wood to Mound View-12.5 miles, Mound View to Hunnewell-7.3 miles). In addition to Mark Twain Lake, the Missouri Department of Conservation manages the fisheries of eight small impoundments in the basin with a combined total of 566 surface acres.

Other publicly owned areas in the basin includes land managed by the U.S. Army Corps of Engineers surrounding Mark Twain Lake. Much of the 33,845 acres around the lake are available for public use. Mark Twain State Park (Missouri Department of Natural Resources) encompasses another 2,285 acres near the lake.

Corps of Engineers 404 Jurisdiction

The Salt River basin is under the jurisdiction of the St. Louis District of the Army Corps of Engineers. Application for 404 permits should be sent to: 1222 Spruce St. St. Louis, Missouri 63103-2833, (314) 331-8575.

Table 1. Location, mileage, and habitat information for all third-order and larger streams in the Salt River basin. Location=section, township, range at mouth of the stream. nm=not measurable.

Stream Location	S - T - R	Order	Length/ Miles	Gradient (ft/mile) Overall- By order
North Fork Salt River Sub-basin				
North Fork	34 55n 8w	6	119.3	3.6-62.5, 53.3, 46.3, 35.7
Otter Cr.	25 55n 9w	4	50.4	5.0-45.4, 33.3
Little Otter Cr.	36 56n 12w	3	7.3	8.9-35.0
Unnamed	22 55n 10w	3	3.8	22.4-324.2
Buck Cr.	23 55n 9w	3	5.5	30.0-325.7
Crooked Cr.	9 55n 9w	4	36.4	6.0-45.2, 37.4
Unnamed	1 56n 12w	3	3.8	17.6-37.8
Unnamed	8 56n 11w	3	7.3	11.0-36.6
Unnamed	9 56n 11w	3	3.1	19.4-3nm
Little Crooked Cr.	25 56n 11w	3	5.6	15.2-37.8
Clear Cr.	6 55n 9w	3	13.6	11.4-310.7
Brush Cr.	33 56n 9w	3	11.1	14.4-313.4
Horseshoe Br.	27 56n 9w	3	3.8	36.8-3nm
Black Cr.	4 56n 9w	4	50.5	4.5-43.3, 35.4
Perry Br.	32 59n 11w	3	8.2	10.4-310.3
Pallard Br.	14 58n 11w	3	8.4	11.3-37.7
Unnamed	24 58n 11w	3	3.5	20.2-315.4
Unnamed	1 57n 10w	3	3.2	20.5-316.7
Oak Dale Br.	7 57n 9w	3	4.3	23.3-3nm
Baker Br.	29 57n 9w	3	4.3	28.3-317.4
Unnamed	18 57n 10w	3	2.3	47.8-317.4

Stream Location	S - T - R	Order	Length/ Miles	Gradient (ft/mile) Overall- By order
Briggs Br.	12 57n 11w	3	6.1	17.1-310.3
Unnamed	3 57n 11w	3	5.9	18.6-310.3
Cat Br.	36 58n 12w	3	7	16.4-310.0
Unnamed	3 57n 12w	3	2	37.5-310.6
Ten Mile Cr.	31 58n 11w	4	16.4	8.5-43.3, 37.3
Unnamed	31 58n 12w	3	5.8	15.7-36.6
Bear Cr.	15 58n 12w	5	45.6	5.4-53.6, 45.0, 38.3
Unnamed	27 62n 15w	3	3.5	22.9-38.8
Unnamed	6 61n 14w	3	1.8	38.9-321.5
Titus Cr.	1 60n 14w	4	7.2	16.8-412.8, 39.7
Unnamed	12 60n 14w	3	3.6	27.8-313.3
Unnamed	5 59n 13w	3	4.2	22.6-311.9
Unnamed	15 59n 13w	3	4.6	23.9-3nm
Unnamed	15 59n 13w	3	2.5	32.0-3nm
Goodson Br.	31 59n 12w	3	6.6	17.4-310.5
Byar Br.	5 58n 12w	3	7.4	18.2-311.1
Unnamed	31 62n 14w	3	3.5	21.4-318.8
Unnamed	10 58n 12w	3	2.6	36.5-3nm
Saling Br.	5 59n 12w	3	10.6	12.7-38.6
Two Mile Cr.	24 60n 13w	3	4.7	21.3-310.3
Shelton Br.	11 60n	3	4	28.8-316.0

Stream Location	S - T - R	Order	Length/ Miles	Gradient (ft/mile) Overall- By order
	13w			
Surratt Cr.	34 61n 13w	3	8.4	19.0-313.1
Big Deer Br.	15 61n 13w	3	7	15.7-315.6
Unna med	9 61n 13w	3	2.9	41.4-3nm
Brushy Fork	36 62n 14w	3	6.5	20.0-36.1
Timber Br.	32 62n 13w	3	9.9	16.7-310.9
Hog Br.	31 62n 13w	3	6.9	15.9-313.8
Lost Cr.	18 62n 13w	3	8.3	17.5-310.7
Steer Cr.	2 62n 14w	3	13	11.9-38.6
Floyd Cr.	35 63n 14w	4	16.5	9.4-46.9, 37.4
Unnamed	15 63n 15w	3	3.7	21.6-3nm
Bee Br.	27 63n 14w	3	7.7	16.6-313.9
Unnamed	36 64n 15w	3	4	22.5-318.9
Unnamed	23 64n 15w	3	5.3	15.1-313.7
Middle Fork Salt River Sub-basin				
Middle Fork	7 54n 8w	6	116.3	3.5-63.4, 52.3, 44.3, 38.2
Unnamed	2 54n 9w	3	3.8	40.8-327.3
Elk Fork	15 54n 9w	5	53.3	4.9-53.4, 45.3, 34.8
Turkey Cr.	26 54n 10w	3	4.7	30.9-321.9
Bee Cr.	29 54n 10w	4	11.8	13.0-411.8, 38.3

Stream Location	S - T - R	Order	Length/ Miles	Gradient (ft/mile) Overall- By order
Unnamed	7 53n 10w	3	1.9	42.1-3nm
Unnamed	5 53n 10w	3	5	22.0-320.0
Brian Cr.	26 54n 11w	3	5.3	14.2-312.1
Allen Reese Fork Cr.	29 54n 11w	4	24.7	6.3-45.5, 35.1
Saling Cr.	28 53n 12w	3	15.8	5.7-34.5
Milligan Cr.	28 54n 12w	4	18.6	7.2-45.6, 36.0
Unnamed	5 53n 12w	3	5.9	17.8-318.5
Hardin Cr.	18 53n 12w	3	8.8	11.9-39.4
Coon Cr.	19 54n 12w	3	18.2	7.7-34.9
Unnamed	17 54n 13w	3	6	16.7-312.5
Flat Cr.	30 55n 11w	4	19.3	9.3-45.5, 36.9
Bear Br.	36 55n 12w	3	3.5	34.3-321.4
Baker Br.	3 54n 12w	3	3.8	23.7-320.0
Mud Cr.	22 55n 12w	4	21.4	8.4-45.7, 311.1
Unnamed	19 55n 13w	3	4.1	18.3-32.5
Unnamed	20 55n 13w	3	4.9	18.4-3nm
Unnamed	14 55n 13w	3	3	38.3-321.4
Unnamed	17 55n 12w	3	3.4	32.4-316.7
Richland Cr.	6 55n 12w	3	5.9	19.5-313.6
Unnamed	25 56n 13w	3	8	14.4- 310.5

Stream Location	S - T - R	Order	Length/ Miles	Gradient (ft/mile) Overall- By order
Hooven Cr.	27 56n 13w	4	9.5	15.9-47.7, 36.2
Unnamed	32 56n 13w	3	4.4	26.1-317.5
Winn Br.	15 56n 13w	3	12	10.8-38.1
Narrows Cr.	16 56n 13w	4	9.2	15.7-49.4, 310.6
Unnamed	7 56n 13w	3	5.6	18.8-312.5
Unnamed	30 57n 13w	3	3.8	27.6-3nm
Brush Cr.	18 57n 13w	4	6.4	19.5-410.9, 310.3
Sewer Cr.	12 57n 14w	3	4.8	18.8-37.7
Billy's Br.	31 58n 13w	3	11.5	9.1-36.7
Bee Br.	34 59n 14w	3	4.7	19.1-3nm
Unnamed	23 59n 14w	3	4.7	21.9-312.1
Linn Br.	11 59n 14w	3	5.6	17.9-314.0
South Fork Salt River Sub-basin				
South Fork	34 55n 8w	7	68.3	4.3-72.4, 63.5, 53.8, 43.1, 36.4
Brush Cr.	31 54n 8w	4	12.1	16.5-419.5, 319.7
S. Brush Cr.	36 54n 9w	3	6	23.3-322.4
Long Br.	5 53n 8w	5	55.9	5.0-56.8, 45.7, 33.1
Scattering Br.	25 53n 11w	3	7.9	9.5-3nm
Goodwater Cr.	9 52n 10w	3	17	7.1-35.3
Youngs Cr.	30 53n 8w	4	36.6	7.5-47.5, 35.9
Five Mile Cr.	33 53n 9w	3	4.8	24.0-321.2

Stream Location	S - T - R	Order	Length/ Miles	Gradient (ft/mile) Overall- By order
Elm Br.	16 53n 8w	3	6	23.3-323.0
Littelby Cr.	33 53n 8w	4	19.8	9.1-48.2, 37.6
Bean Br.	2 51n 8w	3	12.1	7.9-36.4
Tattys Cr.	6 52n 8w	3	3.5	30.0-327.3
Bean Cr.	19 52n 8w	3	4.7	22.3-314.7
Fish Br.	35 52n 9w	3	10.2	13.7-318.1
Skull Lick Cr.	2 51n 9w	4	20	8.3-45.6, 36.5
Big Br.	12 51n 10w	3	3.1	29.0-316.7
Davis Cr.	24 51n 9w	4	26.4	8.0-44.3, 38.7
Unnamed	25 51n 10w	3	1.8	44.4-3nm
Mayes Cr.	27 51n 10w	3	7	17.6-311.4
Long Br.	31 51n 8w	3	6.8	13.2-310.0
Beaverdam Cr.	30 50n 8w	4	17.4	8.6-44.8, 37.4
Jesse Cr.	35 50n 9w	3	5.5	14.5-38.8
Lower Salt River Sub-basin				
Salt River	12 54n 2w	7	78	1.4-all order 7
Grassy Cr.	2 54n 2w	3	10.7	32.3-325.3
Sugar Cr.	31 55n 2w	4	7.5	28.0-47.1, 324.7
Horn Br.	35 55n 2w	3	3.1	51.6-327.4
Haw Cr.	23 55n 3w	3	5.3	34.2-37.8
Unnamed	9 55n 3w	3	3	86.6-323.8
Peno Cr.	17 55n 3w	4	21	18.3-413.6, 325.5
Little Peno Cr.	11 54n 4w	3	6.3	45.2-321.1
Unnamed	12 54n 4w	3	3.4	79.4-3nm
Unnamed	29 54n 3w	3	3.1	71.0-346.9
Gailey Br.	32 54n 3w	3	3.6	56.9-324.7
Weatherly Br.	5 53n 3w	3	3	55.0-343.8

Stream Location	S - T - R	Order	Length/ Miles	Gradient (ft/mile) Overall- By order
Unnamed	1 55n 4w	3	3	55.0-314.3
Spencer Cr.	10 55n 4w	5	40.5	7.5-54.2, 48.4, 311.8
Plum Cr.	28 55n 4w	3	6.5	31.5-328.4
Crooked Cr.	30 55n 4w	3	6.1	36.9-327.2
Brush Cr.	31 55n 4w	3	8.1	27.2-324.0
S. Spencer Cr.	1 54n 5w	4	17.3	17.1-48.7, 320.1
Clifty Fork	6 53n 4w	3	5.6	39.3-345.8
Coon Cr.	26 54n 5w	3	5.4	37.0-319.2
Hippo Br.	17 54n 5w	3	7.8	23.7-322.4
Hays Cr.	20 54n 5w	3	8.1	24.1-323.8
Straight Br.	34 54n 6w	3	4.3	20.9-329.4
Unnamed	23 53n 6w	3	4.8	10.4-35.0
Unnamed	10 55n 4w	3	5.3	43.4-38.3
Unnamed	3 55n 4w	3	3.6	56.9-313.6
Camp Cr.	32 56n 4w	3	4.8	42.7-317.2
Turkey Cr.	35 56n 5w	3	7.8	30.1-325.4
Unnamed	27 56n 5w	3	4.2	53.6-3nm
Big Cr.	32 56n 5w	3	8.2	28.0-323.6
Sugar Cr.	1 55n 6w	4	5.2	45.0-4nm, 330.3
Owl Cr.	1 55n 6w	3	5.1	42.2-314.7
Cedar Cr.	33 56n 6w	3	8.7	28.2-324.6
Ely Cr.	4 55n 6w	4	11.3	20.9-415.2, 323.3
Nichols Cr.	5 55n 6w	3	7.5	30.7-326.7
Griffin Hollow	16 55n 6w	3	4.6	45.7-333.5
Lick Cr.	26 55n 7w	4	33.5	7.9-48.0, 37.0
Dry Fork	35 55n 7w	3	8.4	19.0-320.9
Burbridge Cr.	21 54n 7w	3	7.8	17.9-318.1
Mace Br.	28 54n 7w	3	3.2	32.8-341.0
Gallaher Cr.	4 53n 7w	3	7.9	13.3-313.7

Stream Location	S - T - R	Order	Length/ Miles	Gradient (ft/mile) Overall- By order
E. Lick Cr.	9 53n 7w	4	13.5	7.8-49.1, 36.9
Middle Lick Cr.	26 53n 7w	3	12.7	6.7-35.4
Unnamed	22 55n 7w	3	2.8	62.5-320.8
Indian Cr.	21 55n 7w	4	17.6	13.1-47.3, 312.6
L. Indian Cr.	20 55n 7w	4	12.4	15.8-415.1, 318.1
Madden Br.	5 55n 7w	3	3.4	42.6-335.7
Ely Br.	32 55n 7w	3	3.3	53.0-340.9
Pigeon Roost Cr.	32 55n 7w	3	7.9	25.9-320.3
Sandy Cr.	31 55n 7w	3	9.8	20.9-316.1
Shell Br.	34 55n 8w	3	7.3	27.4-333.3

Table 2. Soil conservation projects in the Salt River basin.

County	PL-566	SALT	EARTH
Macon, Monroe Randolph, Shelby	Middle Fork Salt* River (225, 730 A)		
Monroe, Shelby	Crooked and Otter creeks* (137, 570 A)		
Pike, Ralls	Pike-Spencer* (239, 746 A)		
Monroe, Shelby			Otter Creek (67,200 A)
Monroe		Matts Branch (6,000 A)	
Pike		Spencer Tributary (3,900 A)	
Ralls		Straight Branch (4,784 A)	
Schuyler		Greentop Lake (2,371 A)	
Macon		Middle Fork Salt (5,300 A)	
Shelby		Clarence Area (4,020 A)	
Adair		Bear Creek (30,323 A)	
Knox		North Fork Salt (44,124 A)	
Shelby		North Fork Salt (67,666 A)	

Table 3. Publicly owned Conservation Areas (CA) and stream accesses (AC) located in the Salt River basin.

Area Name	Miles of Stream Frontage	Stream	Acres	Development ¹
C.L Northcutt Memorial CA	0		80	P, PC, H
Maude Shore Jacks CA	0		23	
Sears Memorial Wildlife Area	0		160	
Redmon CA	0		120	
Cedar Bluff AC	0.25	Elk Fork	40	P, PC, H, F
Paris AC	2.7	Middle Fork	9	P, BRS, R, F
Santa Fe AC	0.1	South Fork	7	P, BRS, F
Robert M. White CA	2.7	Long Br. Youngs Cr.	1,163	P, PC, H, F
Ruby Clark Willingham Memorial Wildlife Area	0		70	P, PC, H
Woodlawn AC	0.5	Middle Fork	65	P, H, F
Ranacker CA	1.4	Peno Cr.	1,598	P, PC, R, H
Ted Shanks CA	10.25	Salt R.	4,026	P, BRL, BRS, R, PC, F, H
Arrow-Wood AC	1	North Fork	153	P, PC, H, F
Hunnewell AC	0.3	North Fork	18	P, BRS, F
Mound View AC	0.3	North Fork	41	H, F
Pin Oak CA	0		65	P, PC, H, F
Indian Camp AC	0.25	Salt River	10	P, PC, BRS, F

¹P=parking lot, BRL=lake boat ramp, BRS=stream boat ramp, R=restroom, PC=primitive camping, F=fishing, H=hunting

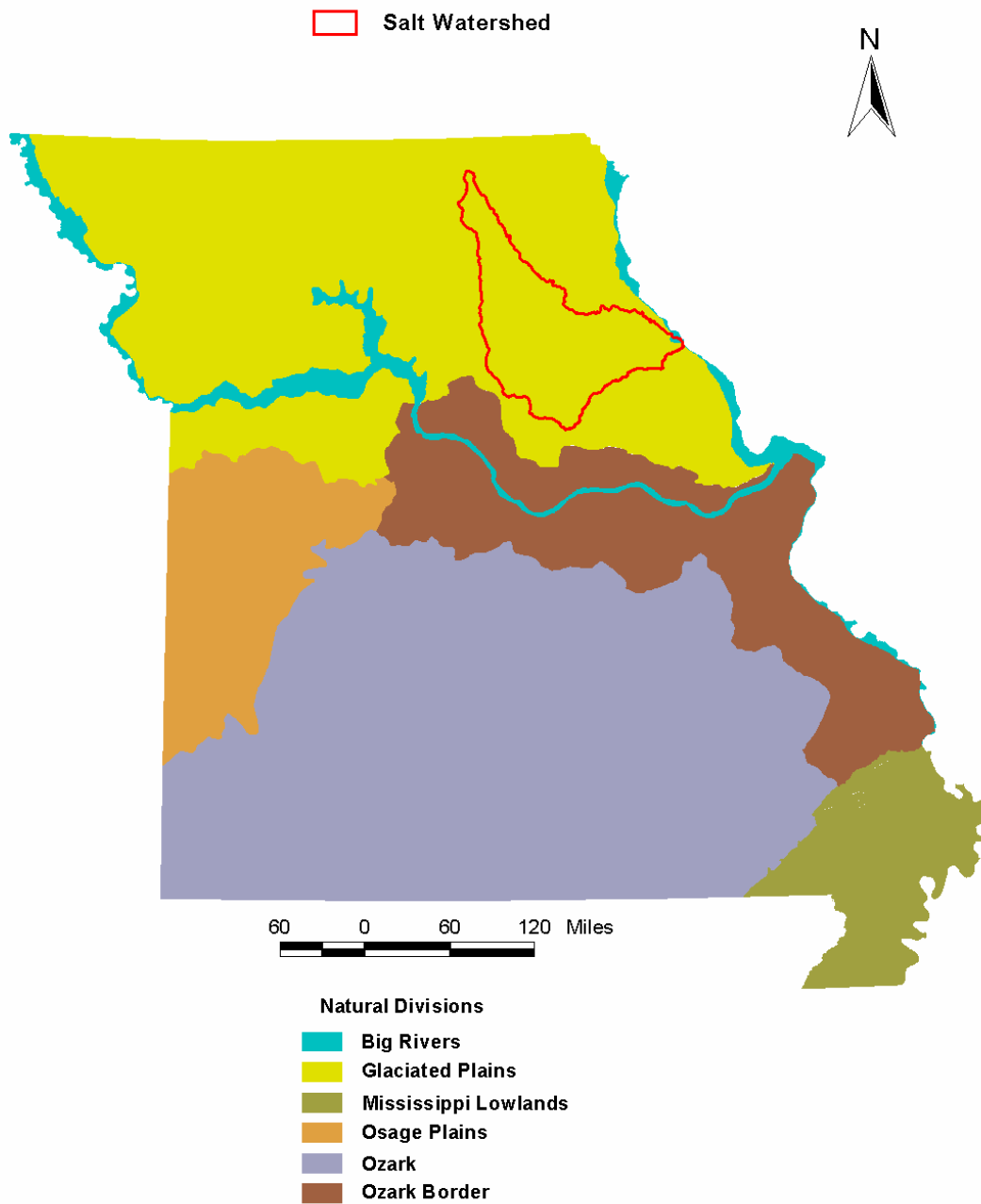


Figure nd. Location of the Salt River Watershed within the natural divisions of Missouri.

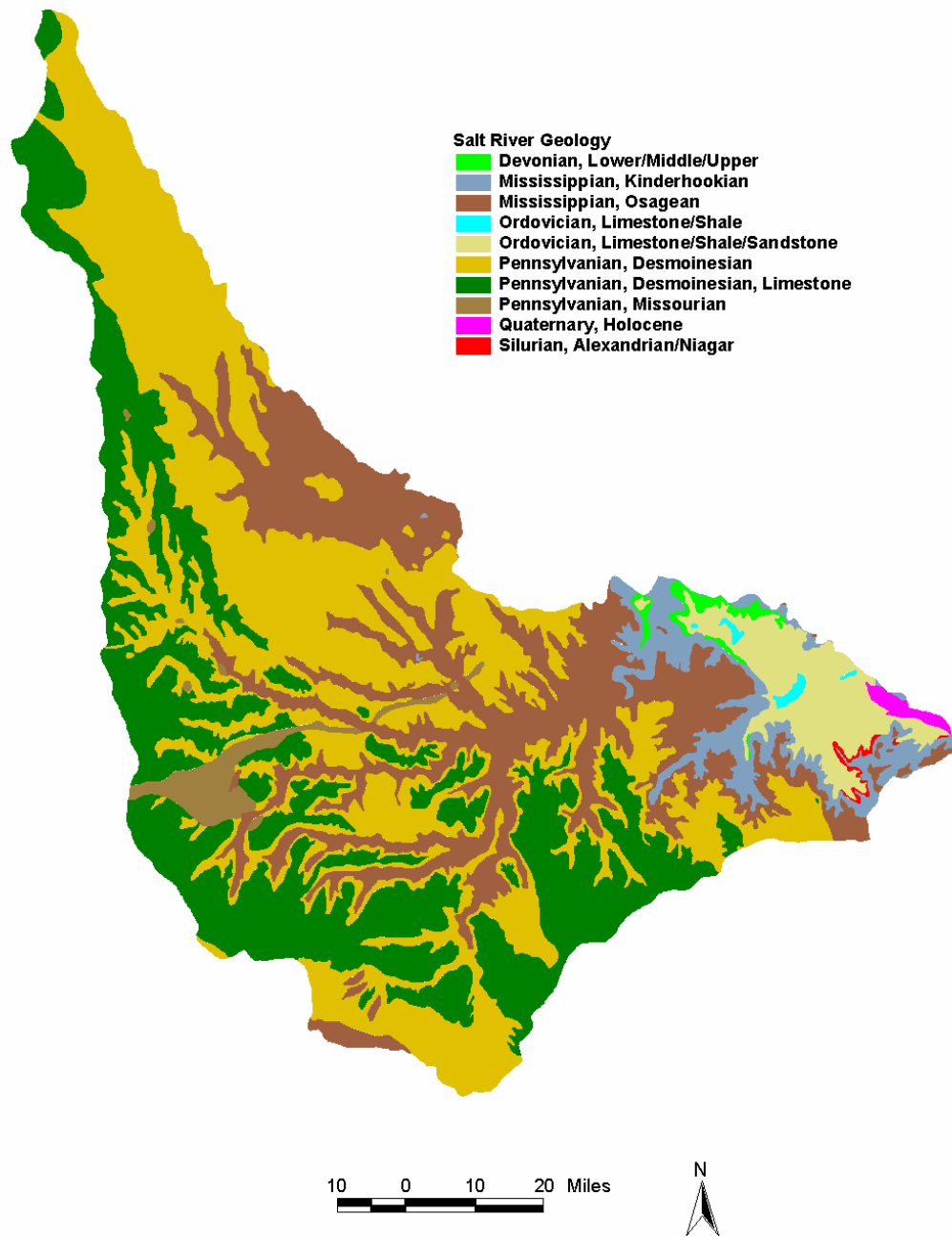


Figure ge. Geological formations in the Salt River Watershed in Missouri.

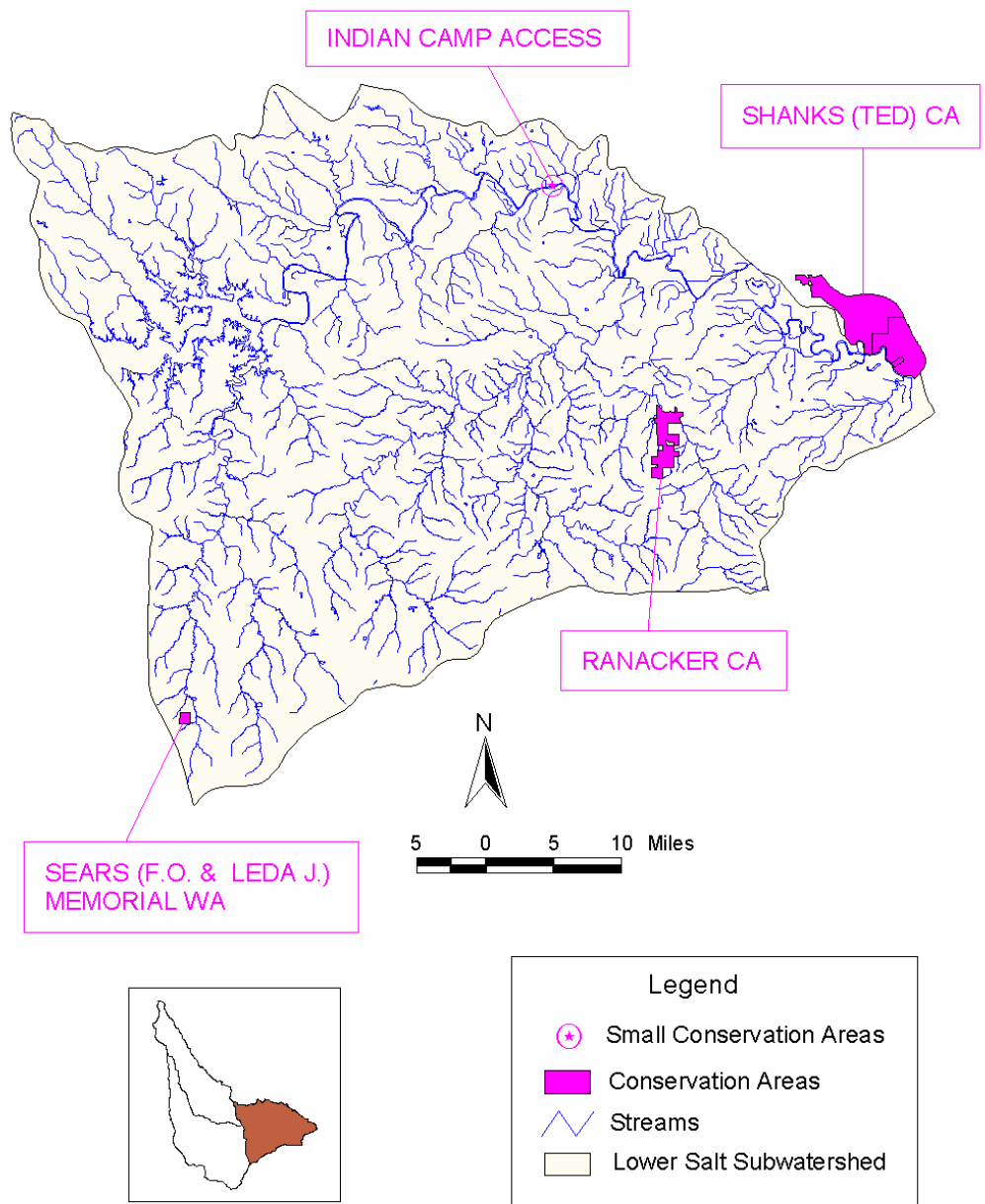


Figure 1p. Public areas in the lower Salt River subwatershed in Missouri. CA = Conservation Area. WA = Wildlife Area.

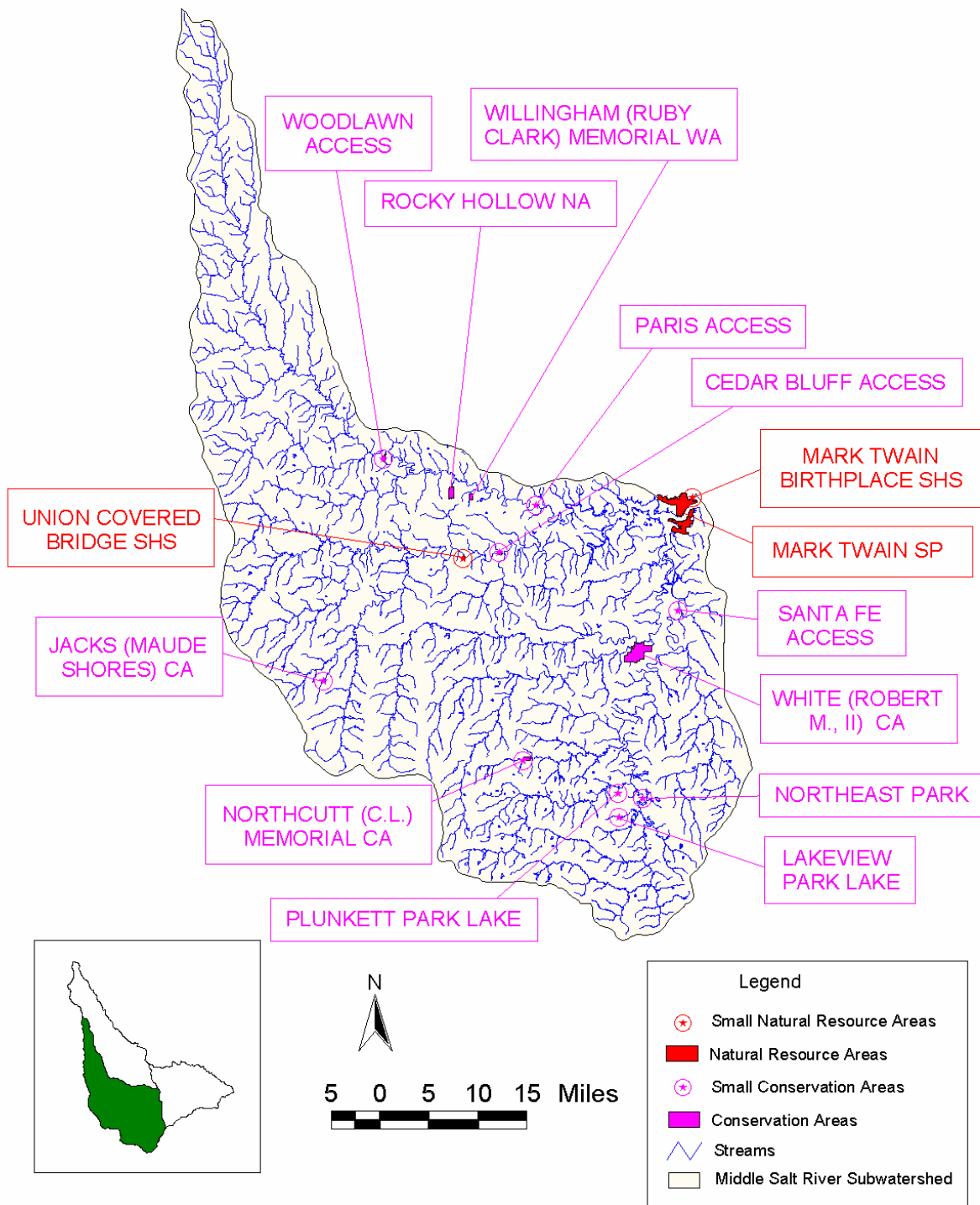


Figure mp. Public areas in the middle Salt River subwatershed in Missouri. CA: Conservation Area, NA: Natural Area, WA: Wildlife Area, SP: State Park, SHS: State Historical Site.

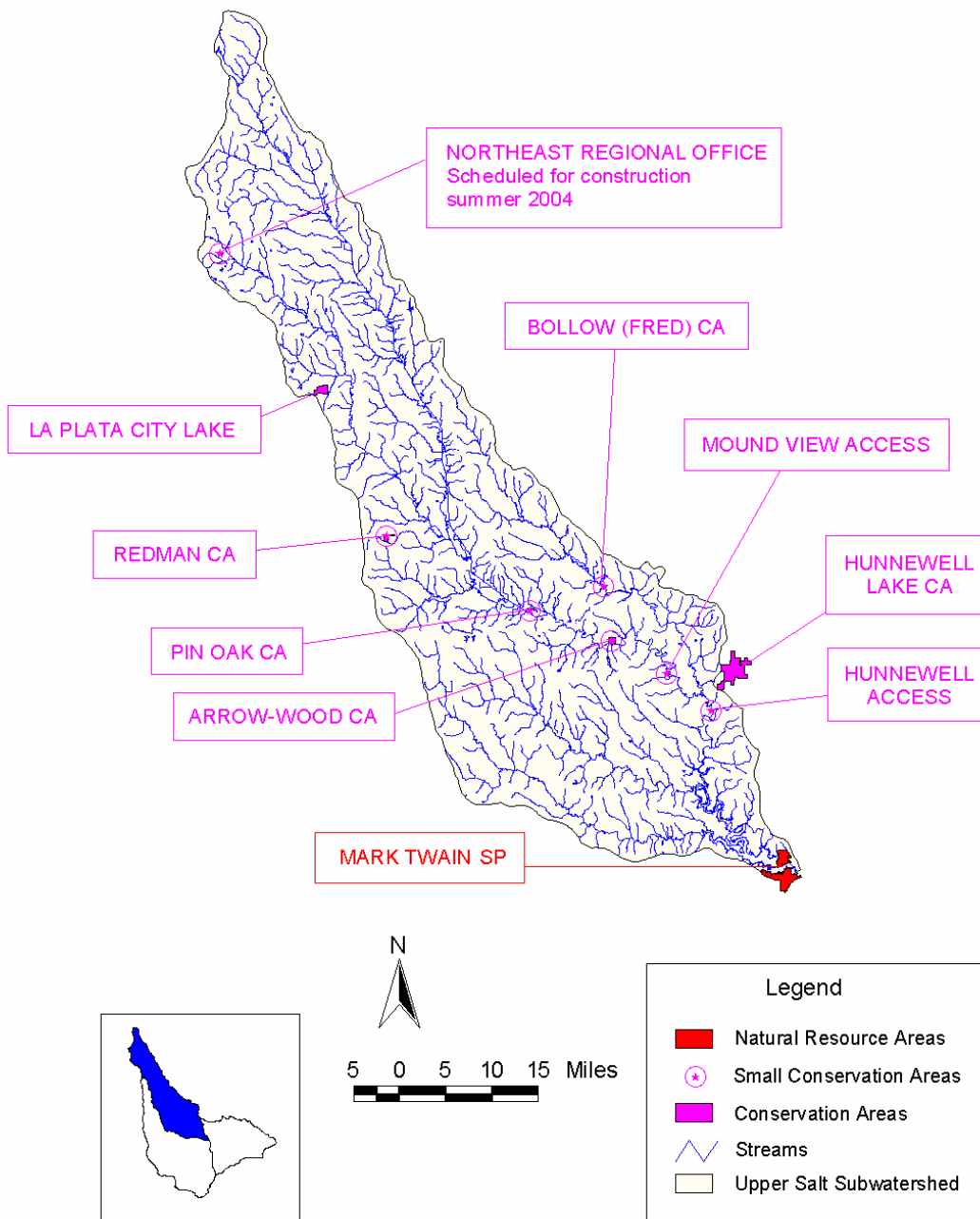


Figure up. Public areas in the upper Salt River subwatershed in Missouri. CA: Conservation Area, SP: State Park.

Land Use

Historical Land Use

Even though the French laid claim to area as early as 1682, Native Americans of the Missouri, Osage, Fox and Sac tribes were in undisputed possession of northern Missouri until the United States took ownership in 1803 as part of the Louisiana Purchase (Klein and Daley 1974, NRCS 1995, NRCS 1997). Beginning in 1804, Native Americans made a series of treaties that eventually relinquished their claims to land in Missouri. Development of the Salt River basin, so named because of its numerous salt springs and licks, proceeded rapidly following the War of 1812. White settlers came mostly from Kentucky and Tennessee, and agriculture quickly became the area's economic base.

Current boundaries for most counties in the basin were established between 1820 and 1836. Human population of the region grew rapidly until about 1920 and then began to decline. For example, the population of Shelby County from 1900 to 1990 fell from 16,167 to 6,942. Most other counties exhibited similar demographic trends.

Much of the presettlement landscape of the basin was prairie (Schroeder 1982). The proportion of prairie land in Macon, Shelby, Monroe, Ralls, and Audrain counties ranged from 38% to 74%. The most notable presettlement prairie in the basin was the Grand Prairie which covered nearly all of Audrain County and portions of Monroe, Ralls, and Pike counties. This prairie, once covered with massive expanses of native blue stem grass and roaming grounds for bison, elk and other wildlife, rapidly diminished with onset of row cropping and livestock grazing in the early 1800's. In 1865, just 10% of the land in Audrain County was cultivated. Currently, nearly 90% of the land is cultivated (NRCS 1995). Narrow, ridge prairies were also found throughout the basin in upland areas between stream valleys, and wet, bottom-land prairies occurred on most floodplains. Wooded areas were usually limited to steeper hills and along streams.

Although agriculture has been the main economic base of the basin, mineral resources also contributed significantly to the economic development of the basin (Klein and Daley 1974). Mining activities have included coal, sand and gravel, limestone, shale, and fire clay. At one time Audrain County was a world leader in the production of refractory brick (NRCS 1995).

Recent Land Use

Estimates of recent land use were determined from the 1992 National Resources Inventory conducted by the Soil Conservation Service (SCS 1992). Similar to other basins in northeast Missouri, 70% of the land in the Salt River basin is used for agricultural purposes (Figures 1l, 1m, and 1n). Half of the land is cultivated for crops. Only about 14% of the land is forested.

Interestingly, cultivated cropland decreased by 102,900 acres and forest land increased by 36,100 acres from 1982 through 1992.

Crop production reports for Adair, Audrain, Monroe, Ralls, and Shelby counties indicate that soybeans are the most important field crop in terms of acres harvested (Missouri Agricultural Statistics Service 1996). Corn and wheat rank second and third. Audrain County is among the state's top producers of soybeans, wheat, and sorghum. Annual livestock production in the above five counties during 1996 ranged from about 18,500 to 39,000 head of cattle and 6,600 to 101,000 hogs. Audrain and Shelby counties are among the state's top swine producers.

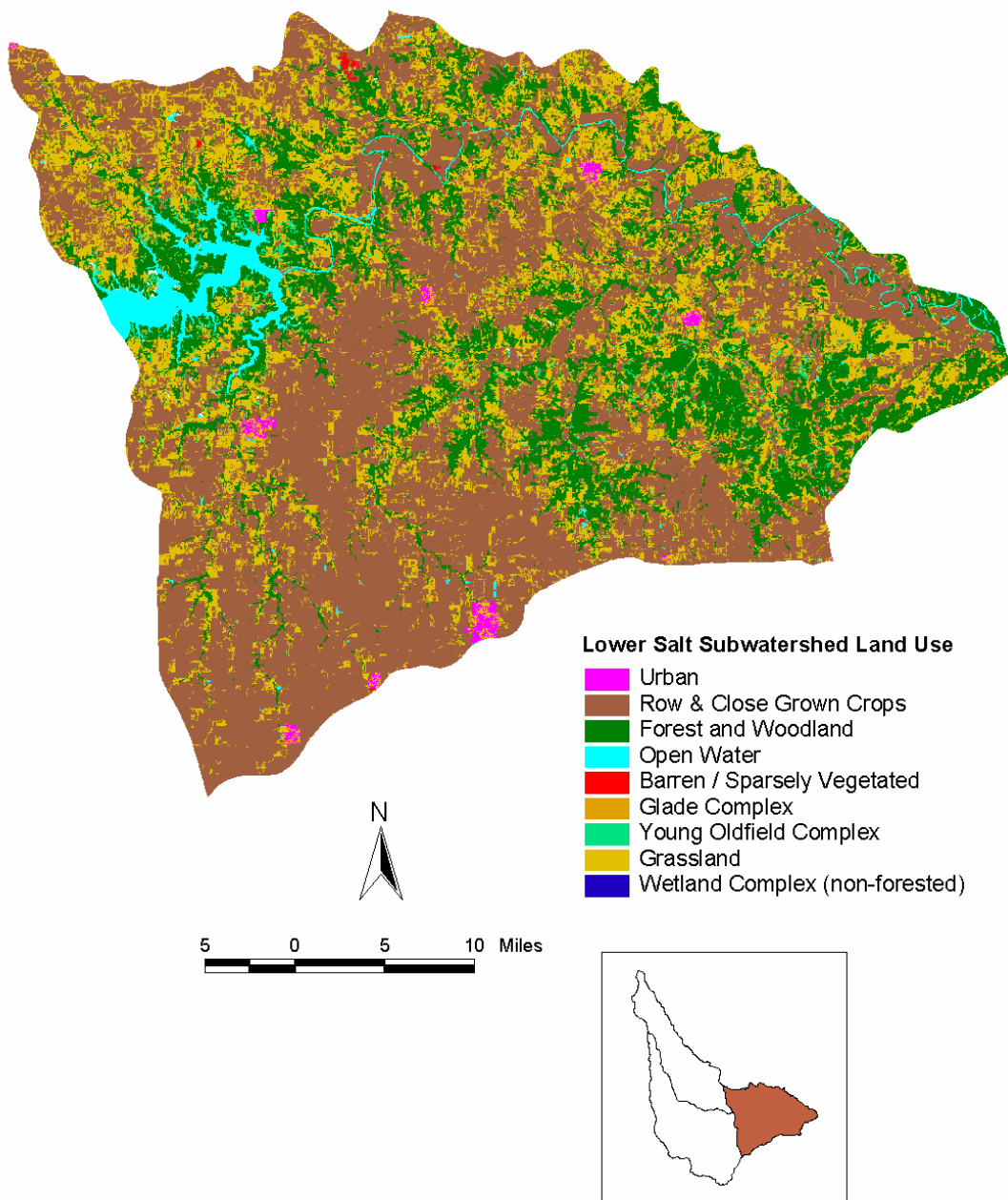


Figure II. Land use in the lower Salt River subwatershed, in Missouri.

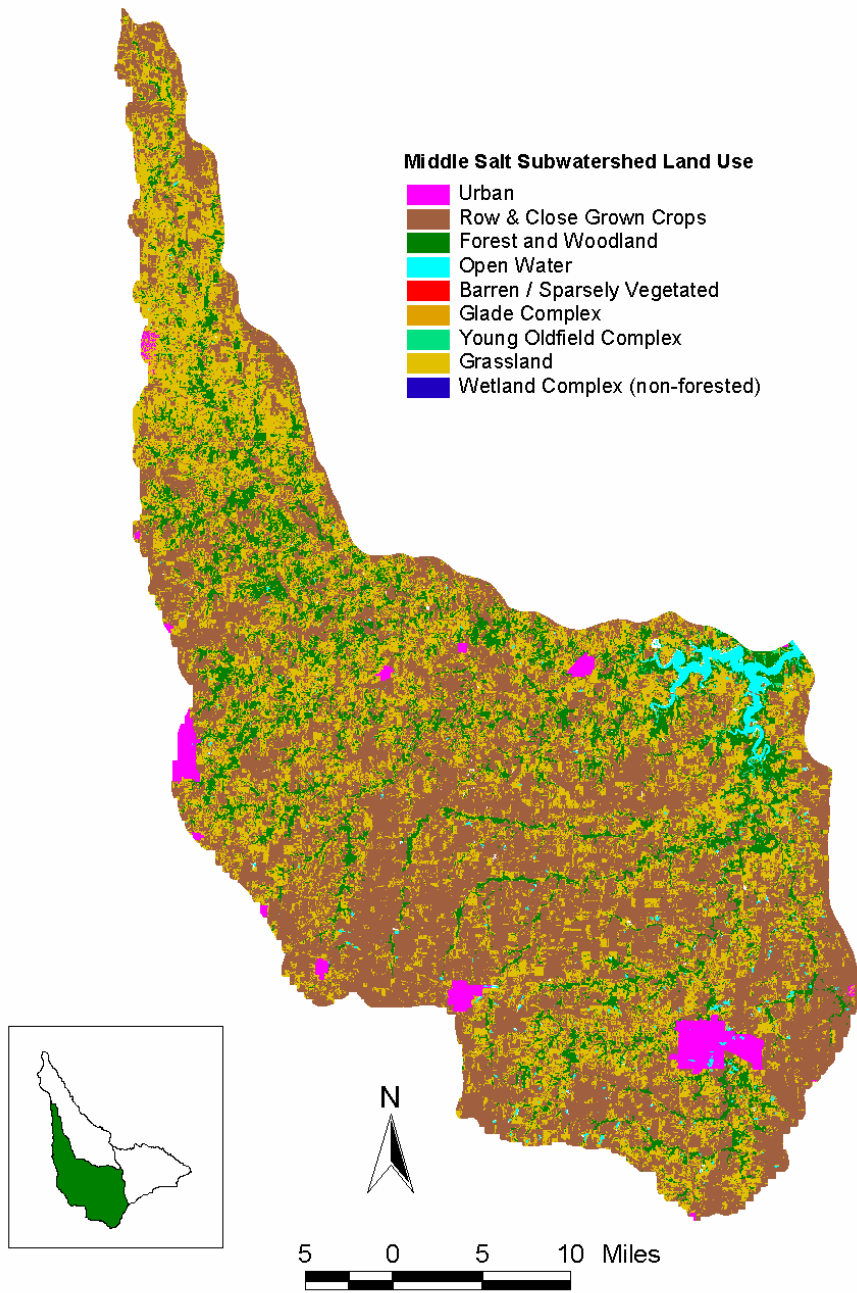


Figure ml. Land use in the middle Salt River subwatershed, in Missouri.

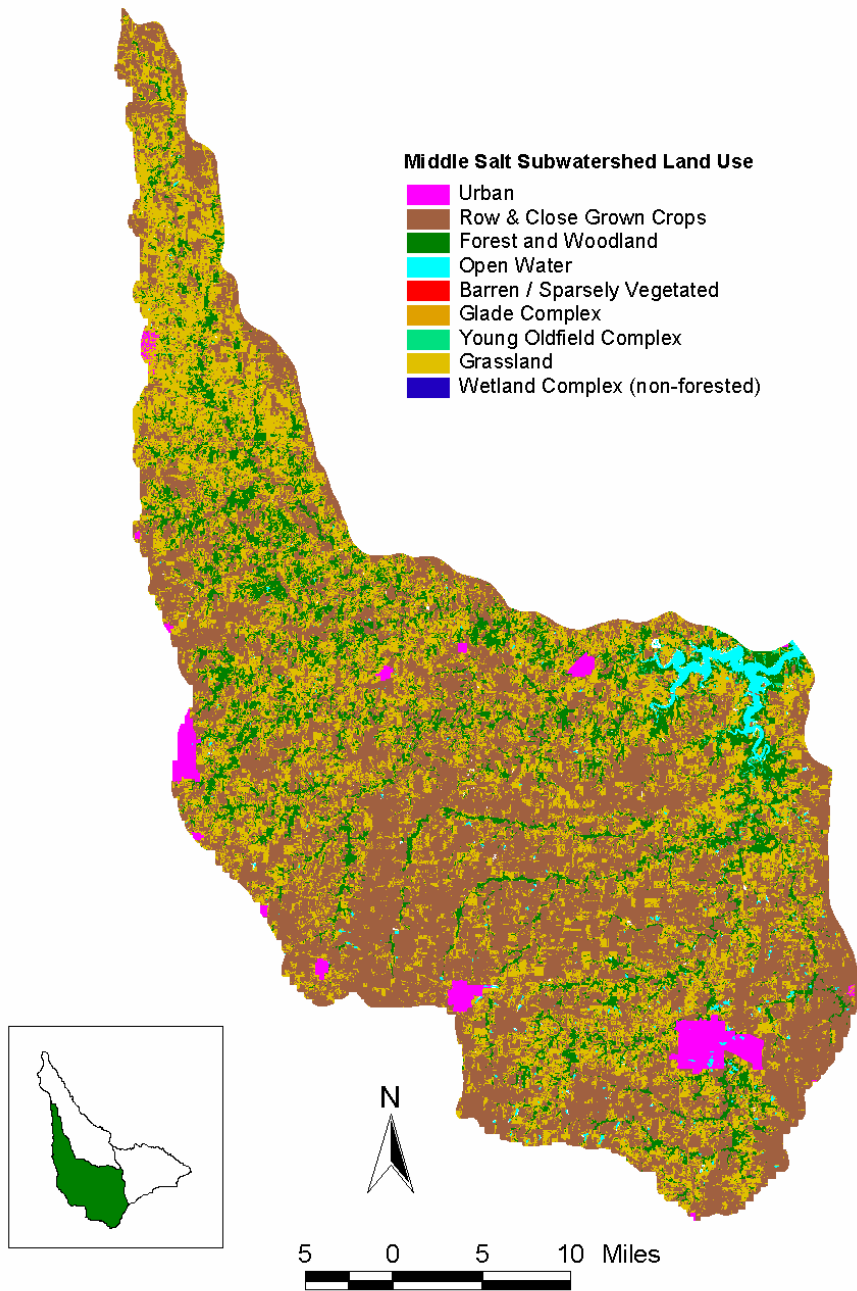


Figure ml. Land use in the middle Salt River subwatershed, in Missouri.

Hydrology

Precipitation

Average annual precipitation ranges between 35 and 37 inches (Klein and Daley 1974, MDNR 1986).

USGS Gaging Stations

There are eleven active gaging stations in streams of the basin (USGS 2001). Water quality was monitored at the Salt River at New London station from 1967 through 1986 and suspended sediment data was collected at the Middle Fork-Paris station from 1980 through 1997. A stage recorder is located in Mark Twain Lake.

Permanence of Flow and Average Annual Discharge

Average annual discharge at the eleven stations ranges between 67 cfs (Crooked Creek) and 2,038 cfs (Salt River). With exception of the lower Salt River, all streams are subject to periods of very low or no discharge. Only the lower Salt River is denoted by a solid blue line along its entire length on USGS maps. Nine other streams are denoted by solid blue lines for over 90% of their length (North Fork, Otter Creek, Bear Creek, Middle Fork, Elk Fork, Flat Creek, Mud Creek, South Fork, and Peno Creek). Many third-order streams are denoted as intermittent along their entire length.

Base flow and Low-Flow Frequency Data

Base flows throughout the basin are not sustained by groundwater inflow during dry weather due to the low conductivity of the underlying clays and rock. Prior to 1976, streams at all gauge sites, except the lower Salt River, were subject to seven day periods of flow less than 0.5 cfs about every five years (Skelton 1976). With the same exception, stream discharge fell below 2.5 cfs for 30 days or longer every five years. Five year recurrence intervals for the lower Salt River indicate that flow can fall to less than 12 cfs for seven days or longer and less than 37 cfs for 30 days or longer. From 1987 through 1996, instantaneous low flows ranged from 20 to 59 cfs.

Flow Duration

Flow duration statistics reflect the stream discharge that is exceeded for a specified proportion of time. Median discharge (flow exceeded 50% of the time) for the lower Salt River exceeds 400 cfs. Median discharge for North Fork, Middle Fork, and South Fork is 31, 31, and 16 cfs, respectively. The ratio of flow that is exceeded 90% of the time to flow exceeded 10% of the time (90:10 ratio) is indicative of the flashiness or variability of stream flow. The 90:10 ratios for gage stations in the Salt River basin range from 1:117 for the Salt River at New London site to 1:4, 400 for Lick Creek at Perry. These ratios indicate that stream flows are highly variable.

Small precipitation event cause rapid increases in stream flow because most water runs off quickly due to the low permeability of the underlying strata.

Flood Frequency

Alexander and Wilson (1995) determined through multiple regression techniques that drainage area and main-channel slope can be used to estimate return period flows for unregulated streams in Missouri. The generalized least squares regression equations are as follows:

$$Q2=69.4A0.703S0.373 \quad Q5=123A0.690S0.383 \quad Q10=170A0.680S0.373 \\ Q25=243A0.668S0.366 \quad Q50=305A0.660S0.356$$

$Q_{100}=376A^{0.652}S^{0.346}$ $Q_{500}=596A^{0.636}S^{0.321}$ where, Q_t =estimated discharge in cubic feet per second (cfs) A =drainage area in square miles S =main channel slope in feet per mile

Discharges in excess of 9,000 cfs occur every five years in the North Fork, Middle Fork, Elk Fork, and South Fork (Table 4). Prior to the construction of Clarence Cannon Dam, discharges in the lower Salt River exceeded 40,000 cfs every two years.

Dam and Hydropower Influences

Actual construction of Mark Twain Lake and Clarence Cannon Dam began in 1970 and was completed in 1983. The dam impounds the upper Salt River about 63 miles upstream from its confluence with the Mississippi River. Approximately 165 miles of the river and its tributaries were inundated. The dam has two hydropower units capable of producing 58,000 kilowatts of electricity. One of the units is designed to become a pump when operated in reverse. It can be used to return water to the lake during extremely low lake level periods to be reused for power generation. A second dam (re-regulation dam) about 9.5 miles downstream of the main dam impounds water for the pump back generation. This pump back feature was tested twice in 1984 and has not been used since. At normal pool of 606 M.S.L., the lake has a surface area of 18,600 acres and storage of 457,000 acre-feet. The top of the tainter gates is 638 M.S.L., at which time the lake would cover 38,400 acres and have 1.43 million acre-feet of storage.

Low dissolved oxygen concentrations in the re-regulation pool caused by hypolimnetic lake water moving through the turbines is a major water quality concern. A temperature control weir was constructed about 400 feet in front of the main dam to act as a skimming weir so the turbines would draw a mixture of epilimnetic and hypolimnetic water during periods of lake stratification. However, when the lake level is high (625 M.S.L.), the metalimnion may stabilize as much as 19 feet above the crest of the weir (580 M.S.L.) allowing poorly oxygenated, hypolimnetic water to pass through the turbines and into the re-regulation pool during generation. During periods of non-generation at this elevation, hypolimnetic water fills the forebay between the weir and main dam. This water leaks through the wicket gates into the tailwater. Upon startup of generation, this poor-quality water is flushed downstream. Current operational procedures during periods when the turbines cannot discharge water with adequate dissolved oxygen concentration calls for opening the tainter gates so that one-third of the discharge is from the tainter gates (surface release from the lake) and two-thirds is through the turbines. Discharge exclusively through the tainter gates will be used when oxygen concentrations in the re-regulation pool remains too low.

Low discharge and poorly oxygenated water moving through the re-regulation dam into the lower Salt River is also a concern. A surface water intake was recently constructed at the re-regulation dam so that oxygenated surface water would pass through the dam instead of bottom water with little dissolved oxygen. A minimum of 50 cfs is released through the dam to maintain downstream flows and adequate water quality. Maximum discharge through the re-regulation dam is 6,000 cfs from April to November (growing season), but during the winter months it may be as much as 12,000 cfs (D. Foss, U.S. Army Corps of Engineers, personal communication).

Discharges are significantly reduced, no more than 2,500 cfs, when the Mississippi River is at flood stage. I used the Indicators of Hydrologic Alteration (IHA) and Range of Variability Approach (RVA) to closely examine how Clarence Cannon Dam has altered streamflows in the lower Salt River (Richter et al. 1996, Richter et al. 1997). This method assumes that natural variation in hydrologic regimes is necessary to sustain native biodiversity and function of aquatic ecosystems. The IHA uses daily discharges to compute measures of central tendency (mean or median) and dispersion (standard deviation or percentiles) for each of 33 hydrologic parameters for each year in a data series, i.e., one set for the pre-dam period and one for the post-dam period (Table 5). The RVA uses the pre-impact values to establish a natural range of variation for each parameter. Post-impact means or medians can then be compared to the RVA target ranges to determine which parameters have been significantly altered (fall outside the natural range of variation). I chose parametric procedures to describe each parameter for the Salt River at New London.

Because construction of Clarence Cannon Dam began in November 1970, the pre- impact period was set as 1923 - 1970. The post- impact period was defined as 1983 - 1996.

RVA target ranges were computed from the pre-dam means + or - one standard deviation unless targets fell outside of the pre-dam data range. When this occurred, the 25th or 75th percentile was used to set the lower or upper limit, whichever fell outside of the data range.

Based on 48 years of pre-dam and 14 years of post-dam data, mean annual flow was higher during the post-dam period (2,077 cfs compared to 1626 cfs), indicating more precipitation and/or run-off during the last 14 years. However, the coefficient of variation was lower from the post-dam period (1.5) than from the pre-dam period (2.6). The means of ten of the 33 flow parameters from the post-dam period were outside the RVA target ranges (Table 5). Post-dam means for 21 of the 33 parameters were outside the RVA target ranges in at least 4 of the post- dam years (>30%), and means of 12 parameters were outside target ranges in at least half of the post-dam years (>50%).

Primarily due to the construction of Mark Twain Lake, Bachant et al. (1982) projected that the recreational value of the Salt River basin would increase from a statewide ranking of 19 to a ranking of 12 (out of 38 basins evaluated).

Table 4. Flood discharges for 5, 25, and 100 year intervals at stream flow gaging stations in the Salt River basin (Alexander and Wilson 1995).

			5	25	100
North Fork Hagers Grove	365	5.2	15,900	25,500	33,300
North Fork Shelbina	481	3.9	10,400	16,800	22,600
Easdale Br. Shelbyville	0.7	59.9	537	842	1,110
Oak Dale Br. Emden	2.6	32.3	1,000	1,620	2,200
Bean Cr. Mexico	3	33.1	1,200	2,410	3,750
South Fork Santa Fe	298	3.6	12,500	19,600	25,800
Youngs Cr. Mexico	67	7.5	4,480	7,480	10,000
Middle Fork Paris	356	2.9	9,320	17,400	26,600
Elk Fork Madison	200	4.1	13,700	26,900	41,600
Salt River Monroe City	2,230	2.8	41,900	67,300	92,300
Lick Cr. Perry	104	6.2	8,560	12,500	15,500
Salt River New London	2,480	2.5	40,200	62,300	83,100
Spencer Cr. Frankford	206	5.6	15,000	19,600	22,800

Table 5. Results of Indicators of Hydrologic Alteration analysis for the Salt River at New London, Missouri. Range of Variability Approach (RVA) targets are based on + or - 1 standard deviation of pre -dam means, except when targets fall outside of pre -dam range limits. When this occurred, the 25th (lower target) or 75th (upper target) percentiles were used. Streamflows in cubic feet per second. * indicate post-dam means falling outside of RVA targets.

Parameter	Pre-Impact Mean	Post-Impact Mean	RVA Targets	Percent of Years Outside of RVA Targets
Monthly Flow				
October	1020	1415	29-2934	14
November	930	1861	42-2377	29
December*	755	2726	49-1828	36
January	1141	1380	65-2495	29
February	1812	1467	177-3447	7
March	2393	2910	439-4348	36
April	2947	2798	680-6035	36
May	2328	2734	382-5135	29
June	2529	2821	546-5214	36
July	1500	2218	189-4055	43
August	895	1333	166-2501	21
September	1053	1220	84-3284	14
Min/Max Flows				
1-day minimum*	17	38	0-34	50
3-day minimum*	18	41	0.5-36	64
7-day minimum*	20	49	0.8-39	64
30-day minimum*	46	139	7-102	43
90-day minimum	165	375	27-381	29
1-day maximum*	28167	11879	14437-41897	71
3-day maximum*	24110	11307	11784-36436	50
7-day maximum	16029	10686	7554-24505	29
30-day maximum	7139	7885	317-24505	
90-day maximum	3918	5043	1819-6017	36
# of zero days	0.5	0	0-3	0

Parameter	Pre-Impact Mean	Post-Impact Mean	RVATargets	Percent of Years Outside of RVA Targets
Base flow	0	0	0-0	43
Day of year minimum flow	263	278	239-287	64
maximum flow*	140	176	109-170	86
Low pulse count	6	8	9-Mar	64
Low pulse duration	11	6	18-May	79
High pulse count	7	6	11-Apr	43
High pulse duration*	3	6	4-Feb	71
low pulse threshold is 65 (25th percentile)				
high pulse threshold is 5878 (+1 sd)				
Rise rate	1352	759	614-2090	21
fall rate	-596	-565	-677	7
# of reversals*	84	155	72-96	93

Water Quality and Use

Beneficial Use Attainment

Thirty-nine miles of the Salt River, 20 miles of Mark Twain Lake, 45 miles of the North Fork, and 49 miles of the Middle Fork are designated for public drinking water supply (MDNR 1986a). Only the lower Salt River from its mouth to Clarence Cannon Dam and Mark Twain Lake are classified for whole-body contact recreation. All streams listed by the Department of Natural Resources are designated for livestock and wildlife watering and protection of aquatic life. The primary deterrents to recreational use in the basin are high turbidity and siltation which are the results of poor soil management and bed scour (MNDR 1986b). Excessive turbidity and siltation have not only decreased the abundance and diversity of aquatic life and habitat (Missouri Department of Conservation 1978), but have also made boating and canoeing more difficult due to locally heavy sedimentation. Fortunately, most streams in the basin have been spared from extensive channelization. Only the North Fork has been significantly channelized (42%).

Channelization also affects recreational use by creating high banks and steep-sided channels making access difficult. The lack of public access in parts of the basin also limits recreational use.

Chemical Quality of Stream Flow

Water quality data was collected from basin streams at 12 sites around Mark Twain Lake prior to impoundment (U.S. Army Corps of Engineers, St. Louis 1974). For the most part, concentrations were within normal ranges during low or moderate stream flows. High measurements of turbidity, fecal coliform, iron, phosphorus, and nitrogen were usually associated with high flows. Although iron concentrations exceeded 20 mg/L at times, most was in the insoluble form which quickly settles out. Pre-impoundment water quality information was also collected throughout the basin during 1969-70 by the Missouri Water Pollution Control Board (1970).

More recent water quality data is scarce. Data was recorded from the lower Salt River at the New London USGS gage station from 1967 to 1986. Selected parameters for the 1986 water year are presented in Table 6. Most measurements were within normal ranges during 1986 except during periods of high flow when fecal coliform and iron concentrations were high. The U.S. Army Corps of Engineers (St. Louis District) periodically collects water quality data at sites within Mark Twain Lake and just below the re-regulation dam on Salt River. The Clarence Cannon Water Treatment Plant monitors several parameters of raw water entering the plant from Mark Twain Lake. Like many reservoirs in agricultural watersheds, Mark Twain Lake has had atrazine levels above the maximum contamination level for drinking water (U.S. Army Corps of Engineers 1996). Rt. J Reservoir, a water supply reservoir owned by the city of Monroe City, has also had elevated atrazine levels. Although water treatment can remove this and other pesticides, the treatment process is expensive. Monroe City, with cooperation and assistance of several state, federal, and local agencies, and landowners, developed a comprehensive watershed management plan. In 1999, the "Route J Watershed Atrazine Abatement and Management Project" was implemented with the goal of reducing atrazine losses in field run-off while maintaining effective weed control.

Other water quality research was conducted in the basin during the 1990's as part of the Agricultural Systems for Environmental Quality Project. This was a joint project of the USDA Agricultural Research Service (ARS), the University of Missouri, University Extension, and the USGS. Information on this project can be obtained by contacting the Cropping Systems and Water Quality Research Unit, USDA ARS, Room 269 Agr. Engineering Building, University of Missouri, Columbia, Missouri 65211. The purpose of the project was to determine the impact of prevailing cropping systems on ground and surface water quality (dissolved herbicides and nutrients). Findings of this work, much of which was conducted in the Salt River basin, can be found in Kitchen et al. (19xx), Donald et al. (1998), Blanchard and Donald

(1997), Blanchard and Lerch (19xx), and Lerch and Blanchard (2003). Among the findings of these researchers was that many stream sites within the Salt River basin had elevated levels of herbicides, and percent losses of herbicides from claypan soil watersheds are high.

Suspended sediment discharge measured at the Middle Fork-Paris gage station during water year 1996 ranged from 0.26 to 26,500 tons/day. At the New London station (partial sediment data site), a suspended sediment discharge of 12,900 tons/day was recorded on May 7, 1996.

Although highly variable from year to year, the average annual suspended sediment load in the Salt River at Monroe City from 1941 to 1965 was 1.215 million tons (Finney 1986).

Concerns listed by the Department of Natural Resources for the lower Salt River include chronic exceedances of secondary drinking water standards for manganese, occasional exceedances of whole fish standards for dieldrin and chlordane (MDNR 1986b). In the re-regulation pool below Mark Twain Lake, low dissolved concentrations caused by low flows of hypolimnetic waters from the lake through the turbines may significantly stress fish in the pool (see Dam and Hydropower Influences). Effluent from sewage treatment facilities or infrastructure in Kirksville, Macon, and Mexico have caused water quality problems in Bear Creek and Steer Creek, Sewer Creek, and South Fork, respectively. Facilities and operations in each of these cities have recently undergone improvements which should lessen impacts on receiving streams. Animal waste in streams can cause low levels of dissolved oxygen, high levels of ammonia, and can lead to nuisance algal blooms (MDNR unpublished). Although surface mining for coal in the Lick Creek and Littleby Creek watersheds has increased sulfate levels in the water, these increases are not of concern and are still below permitted maximums for drinking water supply and protection of aquatic life.

Fish Contaminant Levels and Health Advisories, Fish Kills

All of Missouri, including the Salt River basin, is under a Fish Consumption Advisory posted by the Missouri Department of Health. This advisory advises that women who are pregnant, who may become pregnant, nursing mothers, and children 12 years of age and younger not to eat any largemouth bass over 12 inches in length. This advisory was issued due to concerns about mercury contamination in largemouth bass and because of new risks estimates by the U.S. Environmental Protection Agency. North Missouri was once included in a limited consumption advisory for catfish, carp, drum, suckers, and paddlefish. However, this advisory was removed in 2001 because levels of contaminants, mainly chlordane, have declined.

Low dissolved oxygen concentrations in the re-regulation pool between Clarence Cannon Dam and the re-regulation dam have been a major concern and a persistent problem. However, causes have been identified, water quality is now consistently monitored, and operational procedures at Clarence Cannon Dam are in place that will make oxygen problems in the pool less likely in the future. Other persistent water quality problems and fish kills have occurred in Bear Creek and Steer Creek due to sewage releases and overflows from Kirksville's wastewater treatment plant and infrastructure. Recent improvements at the plant have made future problems less likely.

Water Use

Mark Twain Lake is the largest water supply reservoir in the basin. The Clarence Cannon Wholesale Water Commission (CCWWC) currently distributes about 2.5 million gallons daily (mgd) to a large area around the lake and in some adjoining basins. The lake has the capacity to supply about 16 mgd. The CCWWC supplies water to Perry, Shelbyville, Paris, Madison, New London, Farber, Huntsville, Vandalia, Curryville, Lewistown, LaBelle, Edina, Shelby County PWSD (Public Water Supply District) #1, Knox County PWSD #1, Monroe County PWSD #2, Marion County PWSD #1, and Cannon PWSD #1, Thomas Hill PWSD #1, Pike County PWSD #1, and Lewis County PWSD #1. In addition to Mark Twain Lake, there are about 13 other municipal water supply reservoirs in the basin; however, some of

these are not currently in use (Vandike 1995). The City of Shelbina occasionally pumps water from the North Fork Salt River into their water supply reservoir. Total surface water withdrawals for North Fork, South Fork, and lower Salt River sub-basins are approximately 2.5, 5.5, and 3.0 million gallons per day, respectively. Industrial water withdrawals in the basin are relatively minor, totaling about 1.7 million gallons per day. Seventy-three percent of the 14, 200 acres of irrigated land in the basin occurs in the South Fork sub-basin, mostly in Audrain County.

Point Source Pollution

Overall, point sources have a minor impact on streams in the basin. Waste water treatment facilities are the most common sources of point pollution (Table 7). Most have relatively small daily discharges. Only Shelbina, Macon, Mexico, Moberly, and Kirksville discharge more the 0.5 million gallons daily into receiving streams. The Kirksville waste treatment facility has had problems in the past with the rotating biological contactor resulting in permit exceedances and discoloration and sedimentation of several miles of Bear Creek (MDNR unpublished). Recent improvements should lessen the likelihood of detrimental impacts in the future. Numerous small, privately owned point-source discharges (subdivisions, small businesses, schools etc.) occur in the basin. Stormwater run-off from several sand/gravel quarries, limestone settling ponds, clay pits and storage, and coal mining sites are also potential sources of pollution in the basin, especially in the South Fork sub-basin.

Concentrated Animal Feeding Operations

Audrain and Shelby counties are among Missouri's top swine producing counties. Most swine operations in the Salt River basin are relatively small compared to corporate farms that have recently ventured into the neighboring Chariton River basin. Corporate operations may develop and have significant impacts in the Salt River basin in the future. Currently, the largest hog facility, located in the Spencer Creek watershed, handles about 8, 500 head (Table 8). Another eleven farms retain more than 1, 500 hogs. All of these privately-owned operations use anaerobic lagoons for treatment of excrement.

Non-point Pollution

Sedimentation and turbidity are the basin's most severe water quality problems (MDNR unpublished, Duchrow 1974). Intensive land cultivation has caused severe soil erosion throughout the watershed. Anderson (1980) reported 18 - 24 tons/acre/year of sheet and rill erosion from tilled land in the basin. Erosion from permanent pasture land averaged 2.5 - 5 tons/acre/year. Gully erosion was considered moderate at 100 - 199 tons/square mile annually. As a consequence, the watershed delivered about 2.9 tons/acre of sediment to basin streams annually and was ranked the tenth worst of 45 basins in the state. Streambank erosion contributes about 3% of the annual sediment load to basin streams. Sediment yield to Mark Twain Lake in 1988 was estimated at 1.85 million tons, 58% of which originated from cropland and 17% from floodplain scour (SCS 1988).

Agricultural run-off, which includes fertilizer, pesticides, herbicides, and animal waste, also poses a significant threat to water quality in the basin. During dry periods when stream flows are low, livestock and their waste concentrate around streams. These wastes can promote low levels of dissolved oxygen, high levels of ammonia, and excessive algal growth.

Table 6. Select water quality data for the Salt River near New London, Missouri in 1986 (USGS 1987).

Parameter	State Standards				1986 Water Year
	I	III	VI	VII	
Temperature (F)	90 max				34-80
Specific Conductance (micromhos/cm)					132-270
pH		6.5-9			6.8-8.8
Coliform, fecal (cols/100ml)				200 non-storm runoff	4k-26,000k
Hardness, total (mg/L as CaCO ₃)					59-130
Alkalinity, total (mg/L as CaCO ₃)					44-105
Nitrogen, Ammonia (mg/L as N)	depends on pH and temperature				0.02-0.11
Phosphorus, total (mg/L as P)					0.18-1.1
Manganese, dissolved (microgram/L as Mn)		50		50	29-43
Iron, dissolved (microgram/L as Fe)	1,000	300		300	15-760
Solids, residue susp. (mg/L as 356 degrees)					96-184
Oxygen, dissolved (mg/L)	5				6.4-14.4

I: protection of aquatic life

III: drinking water supply

VI: whole body contact recreation

VII: groundwater

K: non- ideal colony counts

Table 7. Potential point-source pollution sites in the Salt River basin (MDNR unpublished). WWTF = Waste Water Treatment Facility.

Source	County	Receiving Stream	Location
Bowling Green WWTF	Pike	Peno Cr.	27 53n 3w
Center WWTF	Ralls	Sugar Cr.	30 55n 5w
Curryville WWTF	Pike	trib. to Spencer Cr.	21 53n 4w
Frankford WWTF	Pike	trib. to Peno Cr.	35 55n 4w
New London WWTF	Ralls	trib. to Salt R.	6 55n 4w
Greentop WWTF	Schuyler	trib. to North Fork	15 64n 15w
Brashear WWTF	Adair	Hog Br.	29 62n 13w
Clarence WWTF	Shelby	Cat Br./North Fork	9 57n 12w
Kirksville WWTF	Adair	Bear Cr.	22 62n 15w
Queen City WWTF	Schuyler	North Fork	26 65n 15w
Shelbina WWTF	Shelby	trib. to Clear Cr.	29 56n 10w
Shelbyville WWTF	Shelby	trib. to Black Cr.	36 58n 10w
Cairo WWTF	Randolph	trib. to Mud Cr.	36 55n 14w
Jacksonville WWTF	Randolph	Hoover Cr.	3 55n 14w
Clark WWTF	Randolph	Big Cr.	23 52n 13w
Macon WWTF	Macon	Sewer Cr.	14 57n 14w
Madison WWTF	Monroe	trib. to Elk Fork	6 54n 13w
Moberly WWTF	Randolph	trib. to Coon Cr.	6 53n 13w
Paris WWTF	Monroe	Middle Fork	11 54n 10w
Renick WWTF	Randolph	Coon Cr.	30 53n 15w
Sturgeon WWTF	Boone	Saling Cr.	4 51n 12w
Moberly Corrections	Randolph	trib. to Coon Cr.	25 53n 14w
Centralia WWTF	Boone	Goodwater Cr.	9 51n 11w
Laddonia WWTF	Audrain	Youngs Cr.	12 51n 11w
Perry WWTF		Lick Cr.	28 54n 7w
Mexico Works			3 51n 9w
Mexico WWTF	Audrain	South Fork	24 51n 9w
AP Green Indust.	Audrain	South Fork	36 51n 9w

Source	County	Receiving Stream	Location
N. Amer. Refractories	Audrain	E. Lick Cr.	21 52n 6w

Table 8. Concentrated animal feeding operations in the Salt River basin with more than 1,500 units of livestock (source: Missouri Department of Natural Resources 1998).

Type	Location	Units	Receiving Stream
swine finishing	8 52n 10w	1,920	Goodwater Cr.
swine finishing	8 52n 10w	1,920	Goodwater Cr.
swine finishing	13 56n 13w	3,840	trib. Middle Fork
swine finishing	33 55n 11w	5,000	Middle Fork
swine finishing	8 55n 11w	3,840	Little Otter Cr.
swine finishing	28 54n 12w	1,920	Elk Fork
swine finishing	29 54n 12w	1,920	trib. Elk Fork
swine finishing	35 56n 8w	2,880	trib. Indian Cr.
swine finishing	17 54n 10w	2,800	trib. Elk Fork
swine finishing	24 53n 6w	8,520	Spencer Cr.
swine nursery	13 53n 13w	6,400	Galbreath's Cr.
swine finishing	6 56n 11w	2,000	trib. Crooked Cr.

Habitat Conditions

Channel Alterations and Habitat Problems

The only large stream in the basin that has been significantly channelized is the North Fork Salt River. About 42% of its 119 miles have been channelized. The Middle Fork Salt River has about 12 channelized miles. Channelization results in a loss of total stream area and usable habitat, increased streambank erosion, and a homogeneous habitat that supports far less aquatic life. Minor stream alterations, usually associated with bridge construction or replacement, have occurred at numerous locations throughout the basin, especially in the lower Salt River sub-basin. There are many relatively short, channelized reaches scattered throughout the basin; however, these are difficult to detect on topographic maps. Field investigations will be needed before planning any management activity at a particular stream location or stream reach.

The most consistent habitat problem in the basin stems from high erosion rates from tilled land and sediment deposition in basin streams. Sediment not only affects fish reproduction, growth, survival, and food supply, but also fill in pools and reduces the amount of available habitat. Duchrow (1974) attributed low diversity and dominance of silt-tolerant invertebrates in streams of the Salt River basin to heavy siltation.

Unique Habitat

Even though nearly all streams in the basin have been degraded by agricultural encroachment, many still provide excellent aquatic habitat. Most streams in the basin have been spared from extensive channelization. An unchannelized portion of the North Fork Salt River, between Highway 15 and Route T in Shelby County, was named as a Significant Aquatic Area in the Missouri Natural Features Inventory (Anderson 1983). Peno Creek, Pike County, is one of the highest quality streams in northeast Missouri. This fourth-order stream is home to 26 fish species. Nearly half are associated with the Ozark faunal region (e.g. southern redbelly dace, smallmouth bass, rock bass, northern hogsucker) and only seven species are considered wide-ranging.

Natural features inventories for counties in the basin (Bogler and Nigh 1986, Reese 1986, Anderson 1982 and 1983) indicate that the basin provides seasonally important habitat for the state and federally endangered gray bats (*Myotis grisescens*) and Indiana bats (*Myotis sodalis*). Wooded waterways along streams provide preferred foraging habitat and caves in the basin, which are numerous along the lower Salt River, provide shelter and maternity sites. These inventories also list an upland shale glade (ranked significant) and pond marsh (ranked exceptional) in Pike County as notable natural features.

Improvement Projects

No major habitat improvement projects have been undertaken in the basin. The Missouri Department of Conservation recently assisted a landowner install a cedar tree revetment along about 390 feet of eroding bank on Brush Creek, a tributary of Spencer Creek in the lower Salt River watershed. A demonstration project was implemented on a private farm in Monroe County in the Brush Creek watershed. Installed practices include livestock exclusion, alternative watering, and management intensive grazing.

Biotic Community

Fish Community

Fish community data were collected by Missouri Department of Conservation staff from 180 sites throughout the basin during 1995 - 1997 (Table 9). Fish were collected using a seine 15 or 25 feet long with 1/8" mesh. Kick seine methods were used to sample riffles. A boat-mounted electrofishing unit was used where possible to sample deep pools. Large fish were identified on site and returned to the water. Small fish were preserved and later identified in the lab. Data collected prior to 1995 were obtained from the Missouri Department of Conservation fish database.

A total of 80 species from 16 families has been collected in the Salt River basin. Sixty-four species and one *Lepomis* hybrid were found in recent surveys. From a basin wide perspective, the community includes fishes representative of the Prairie, Lowland, Ozark, and Big River faunal regions. Of recently collected species, one-third are wide-ranging, 13% are Big River species, 25% are Prairie species, 31% are Ozark species, and 9% are representative of the Lowlands (Pflieger 1971). Several species are often associated with two faunal regions so the sum of these percentages exceeds 100%. The dominant fish families were the minnows (17 species), perches (10 species), suckers (9 species), sunfishes (9 species) and catfishes (8 species). The most common and abundant species collected in recent surveys were the bluntnose minnow (*Pimehpaless notatus*) and red shiner (*Cyprinella lutrensis*). Bluntnose minnows comprised 13 to 24% of the total fish sample in each of four main sub-basins (lower Salt, North Fork, Middle Fork, South Fork) and occurred at 85% of all sites. Red shiners comprised 14 to 41% of the total sample in each sub-basin and were found at 70% of all sites. Both species are tolerant of high turbidity and siltation that persists throughout much of the basin. Other commonly occurring species (found in at least 60% of all sites) include the following: johnny darter (*Etheostoma nigrum*), creek chub (*Semotilus atromaculatus*), redbfin shiner (*Lythrurus umbratilis*), and green sunfish (*Lepomis cyanellus*).

Sportfish (18 species that provide angling opportunity) comprised 6% of all fish collected in basin streams. These fishes were under-represented numerically because larger adults were not fully vulnerable to our sampling gear. Green sunfish were the most abundant species in this group and were found at 68% of all sites. Channel catfish (*Ictalurus punctatus*), probably the most popular game species outside of Mark Twain Lake, were occurred at 12% of all sites, but accounted for less than 1% of the total fish collected. Largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus*) were collected at 37 and 38% of all sample locations, respectively.

Sixteen species found in the basin prior to 1995 and not found in recent surveys include the following: lake sturgeon (*Acipenser fulvescens*), which were stocked in Mark Twain Lake and last collected in 1986, mooneye (*Hiodon tergisus*) and goldeye (*H. alosoides*) last collected in 1957, threadfin shad (*Dorosoma petenense*), which were stocked in Mark Twain Lake and last collected in 1989, highfin carpsucker (*Carpionodes velifer*) last collected in 1983, spotted sucker (*Minytrema melanops*) last collected in 1986, black redhorse (*Moxostoma duquesnei*) last collected in 1978, goldfish (*Carassius auratus*) last collected in 1957, hornyhead chub (*Nocomis biguttatus*) last collected in 1941, silver chub (*Macrhybopsis storeriana*) last collected in 1983, pallid shiner (*Notropis amnis*) and river shiner (*N. blennioides*) last collected in 1941, spotfin shiner (*Cyprinella spiloptera*) and striped shiner (*Luxilus chrysocephalus*) last collected in 1983, Mississippi silvery minnow (*Hybognathus nuchalis*) last found in 1957, and freckled madtom (*Noturus flavus*) last collected in 1978. Striped shiners, pallid shiners, hornyhead chubs, and Mississippi silvery minnows have likely been extirpated from the basin. Similar declines of these species have occurred in other northeast Missouri streams. Reasons for the declines are not well understood; however, these species prefer clear water and are intolerant of turbidity and siltation (Pflieger 1997). The only species collected in recent surveys that were not found prior to 1995 were paddlefish (*Polyodon spathula*) and walleye (*Stizostedion vitreum*). Although not abundant, both species have been long time inhabitants of the basin due to its connection with the Mississippi River, but apparently avoided sampling

gear during early surveys.

The lower Salt River sub-basin, which had the fewest sample sites, yielded the most species (58), followed by the Middle Fork (48), South Fork (43), and North Fork (41). We also found a higher average number of species per site in the lower Salt sub-basin than in other sub-basins.

Thirty-three species were collected from one site in the lower Salt River just below the re-regulation dam. This sub-basin, in which streams typically have higher gradients and largely gravel substrates, had proportionately more species associated with the Ozark and Big River faunal regions than the other sub-basins. The North Fork, Middle Fork, and South Fork sub-basins were generally dominated by more tolerant, Wide-Ranging species, although Ozarkian species were also common.

Threatened and Endangered Species

Of the species collected in the basin since 1995, two (paddlefish, and ghost shiners, *N. buchanani*) are currently on the state watch list. None are considered state or federal rare or endangered. Although not found in the basin recently, lake sturgeon, which are state endangered, are likely to occur in the periodically in the lower Salt River due to past stockings in Mark Twain Lake and restoration efforts in the Mississippi River.

Fish Stockings

Several fish species have been stocked in basin streams and lakes. Spotted bass (*Micropterus punctulatus*) were stocked in basin streams 1961 in an attempt to provide an additional sportfish (Fajen 1975). Survival of these fish was very low. Other species have been stocked into Mark Twain Lake to improve the lake fishery. Walleye were stocked annually from 1984 to 1996.

Survival of these walleye has been low. Adult walleye currently utilize gravel shoals in streams above Mark Twain Lake each spring for spawning. However, spawning success and survival of the hatch is apparently low. Small and advanced walleye fingerlings were stocked in several basin streams during 1999 and 2002 and the success of these stockings is under evaluation.

Threadfin shad were stocked in Mark Twain Lake during 1986 and 1989 to provide an additional forage species for sportfish in the lake. Survival and reproduction of this species was determined to be insufficient to benefit sportfish survival and growth in the lake so stocking was discontinued. Blue catfish (*Ictalurus furcatus*) were also stocked in Mark Twain Lake, first in 1984 and later in 1992. Lake sturgeon (*Acipenser fulvescens*) were stocked in Mark Twain Lake in 1986 and 2001 as part of Missouri's reintroduction program. Fishes stocked in rearing ponds within the basin of Mark Twain Lake prior to impoundment include largemouth bass (*M. salmoides*), bluegill, channel catfish (*I. punctatus*), black crappie (*Pomoxis nigromaculatus*), orange spotted sunfish (*L. humilis*), gizzard shad (*D. cepedianum*), and fathead minnows (*Pimephales promelas*).

Aquatic Invertebrates

Benthic macroinvertebrate surveys in the basin have been conducted by the Missouri Department of Conservation (Duchrow 1974), Hazelwood (1974-1981), Missouri Botanical Gardens (Klein and Daley 1974), Gass (1979), and Environmental Science and Engineering, Inc. (Govro 1984). The first four studies documented the presence of 298 benthic macroinvertebrate taxa. The most recent survey (Govro 1984) reported 96 taxa. Duchrow (1974) reported that the communities in the Salt River basin were dominated by silt-tolerant forms due to heavy siltation and turbidity from agricultural practices that have degraded the habitat to the point that communities characteristic of undisturbed streams cannot be supported.

Govro (1984) also reported twenty mussel species in the upper Salt basin. The most abundant were three-ridge (*Amblema plicata*) and fat mucket (*Lampsilis radiata luteola*). Only fossil shells of *Quadrula*

pustulosa, *Elliptio dilatata*, *Strophitus undulatus*, *Lampsilis teres*, *Ligumia subrostrata*, and *Obliquaria reflexa* were collected. The Salt River was once one of two Missouri streams where the state endangered Warty-back (*Quadrula nodulata*) occurred.

However, it was likely extirpated from the basin following inundation of Mark Twain Lake. The Missouri of Department of Conservation mussel database list 43 species in streams of the basin (Table 10).

Five crayfish species are known to inhabit basin streams or grasslands (B. DiStifano, Missouri Department of Conservation, personal communication). These species are as follows:

- 1) **Golden Crayfish (*Orconectes luteus*)** - common Missouri crayfish
- 2) **Northern crayfish (*Orconectes virilis*)** - most widely distributed of Missouri crayfish
- 3) **Papershell crayfish (*Orconectes immunis*)** - common to Prairie and Big River faunal regions
- 4) **Devil crayfish (*Cambarus diogenes*)** - burrowing species common in northern Missouri
- 5) **Grassland crayfish (*Procambarus gracilis*)** - burrowing species inhabiting grasslands, often away from water

Table 9. Fish species collected and current status in the Salt River basin.

Common Name	Collected Prior to 1995	Collected 1995-2000	Current Status*
Paddlefish		X	U
Lake sturgeon	X		R
Shortnose gar	X	X	LA
Longnose gar	X	X	LA
Mooneye	X		R
Goldeye	X		U
Gizzard shad	X	X	LA
Threadfin shad	X		E
Bigmouth buffalo	X	X	LA
Black buffalo	X	X	R
Smallmouth buffalo	X	X	LA
Quillback	X	X	C
River carpsucker	X	X	C
Highfin carpsucker	X		R
White sucker	X	X	LA
Northern hogsucker	X	X	U
Spotted sucker	X		R
Black redhorse	X		R
Golden redhorse	X	X	C
Silver redhorse	X	X	R
Shorthead redhorse	X	X	LA
Common carp	X	X	C
Goldfish	X		U
Hornyhead chub	X		E
Silver chub	X		U
Gravel chub	X	X	U
Creek chub	X	X	C
Southern redbelly dace	X	X	LA

Common Name	Collected Prior to 1995	Collected 1995-2000	Current Status*
Bigeye shiner	X	X	LA
Bigmouth shiner	X	X	C
Emerald shiner	X	X	LA
Ghost shiner	X	X	U
Golden shiner	X	X	C
Pallid shiner	X		E
Red shiner	X	X	C
Redfin shiner	X	X	C
River shiner	X		U
Sand shiner	X	X	C
Spotfin shiner	X	X	C
Striped shiner	X		E
Bluntnose minnow	X	X	C
Bullhead minnow	X	X	C
Mississippi silvery minnow	X		E
Fathead minnow	X	X	C
Suckermouth minnow	X	X	LA
Central stoneroller	X	X	C
Channel catfish	X	X	C
Blue catfish	X	X	U
Black bullhead	X	X	LA
Yellow bullhead	X	X	LA
Flathead catfish	X	X	C
Stonecat	X	X	C
Tadpole madtom	X	X	R
Freckled madtom	X		R
Slender madtom	X	X	C
American eel	X	X	U
Blackstripe topminnow	X	X	C

Common Name	Collected Prior to 1995	Collected 1995-2000	Current Status*
Mosquitofish	X	X	U
White bass	X	X	LA
Sauger	X	X	U
Walleye		X	LA
Blackside darter	X	X	LA
Slenderhead darter	X	X	C
Logperch	X	X	LA
Western sand darter	X	X	R
Johnny darter	X	X	C
Bluntnose darter	X	X	R
Orangethroat darter	X	X	C
Fantail darter	X	X	U
Spotted bass	X	X	R
Smallmouth bass	X	X	U
Largemouth bass	X	X	C
Green sunfish	X	X	C
Orangespotted sunfish	X	X	C
Bluegill	X	X	C
Rock bass	X	X	R
Black crappie	X	X	U
White crappie	X	X	LA
Brook silverside	X	X	LA
Freshwater drum	X	X	LA
hybrid sunfish	X	X	R

1-C=common, E=extirpated, LA=locally abundant, R=rare, U=uncommon

Table 10. Mussel species collected from streams in the Salt River basin, 1977-1986 (Missouri Department of Conservation, S. Bruenderman, personal communication).

Species	Species
Paper floater	Flat floater
Giant floater	Cylindrical papershell
Squawfoot	Rock pocketbook
White heelsplitter	Fluted shell
Washboard	Pistolgrip
Mapleleaf	Wartyback
Pimpleback	Rabbit's foot
Monkeyface	Wabash pigtoe
Purple pimpleback	Round pigtoe
Ladyfinger	Pondhorn
Threehorn wartyback	Mucket
Ellipse	Butterfly
Fawnsfoot	Deertoe
Fragile papershell	Pink heelsplitter
Purpleshell	Pink papershell
Liliput shell	Black sandshell
Pondmussel	Yellow sandshell
Pink mucket	Pocketbook
Britt's mussel	Eastern lampmussel

Opportunities for Stream Fishery Conservation in the Salt River Watershed

The following perspectives on problems and opportunities for watershed management will guide MDC management priorities and activities for the foreseeable future. We realize we are only one of many partners whose joint efforts will be needed to protect and restore stream ecosystem integrity in the Salt River watershed.

Managing MDC Riparian Ownerships

Stream Access Acquisition

MDC has purchased small tracts of land along streams in order to provide public access for recreation and to establish an ownership stake that may strengthen our position in resisting system-wide threats to riparian habitat integrity. In the past, statewide planners have assumed that a desirable spacing was approximately ten stream miles between access areas. Experience suggests that it takes much longer to float and/or fish a typical reach of prairie stream than an equivalent length of Ozark stream. Because of slower currents and more frequent channel obstructions in the prairie region, we should seek to shorten the distance between access areas to five to seven miles on floatable, unchannelized prairie streams with high public use potential.

In order to provide a stream access system with optimal one-day trip distances, MDC should acquire at least four additional access sites in the Salt River watershed—one located on the North Fork Salt River between Arrow-Wood and Mound View accesses (T57N R10W S14), one on the Middle Fork Salt River approximately five miles downstream from Woodlawn AC (T55N R11W S29), one on the Elk Fork Salt River near highway 15 (T54N R10W S26), and one on the South Fork Salt River upstream from Santa Fe AC (T53N R8W S28).

Stream Access Development

Because of fiscal restraints, planned developments have not been completed on all existing stream access areas in the Northeast Region. Developments must be completed so citizens can experience the quality recreational opportunities that will build their individual commitment to helping preserve and restore streams in this and other watersheds. As a matter of strategic priority, MDC will complete planned developments on existing areas before acquiring many additional areas.

Development is largely complete at several access areas including: Paris AC, Santa Fe AC, Ted Shanks CA (access to Salt River), Hunnewell AC, and Indian Camp AC. Mound View AC remains undeveloped, but an entrance road, 5-car parking lot, and boat ramp are planned.

Improved parking and a boat ramp are planned for Cedar Bluff AC. Improved boat launching ramps also need to be developed at Woodlawn AC and Arrow-Wood AC.

Site-Specific Stream Restoration

Although stream ecosystem health is almost entirely dependent upon processes occurring upstream and downstream of any given ownership, Department of Conservation riparian areas should serve as model of good stream stewardship. In the Salt River watershed, streambank erosion and forested corridor deficiencies are minor at MDC owned access areas. In areas where the forested corridor is narrow, passive restoration is being used to establish increase corridor width.

Public Use Information

Public use of Salt River watershed streams is low to moderate, partially because most people are unaware of the high-quality fishing/floating opportunities that exist there. People who enjoy Ozark streams may

have stereotyped northern Missouri streams as turbid, unattractive ditches that contain primarily non-game fish. While this may be true of some highly altered channels in the prairie region, several reaches of many streams in the watershed resemble Ozark streams.

Many reaches support diverse aquatic communities that provide good fishing or an even greater variety of sport fish than exist in many Ozark streams.

MDC could increase public use and appreciation of the Salt River watershed streams by developing a brochure describing stream recreational opportunities. Such a brochure would include colored pictures, simple stream maps with mileages, access sites and camping areas clearly marked, descriptions of other local attractions, and fishing opportunities/regulations. Statewide news releases and an article in the Conservationist magazine might also help to inform potential users of the opportunities awaiting them in the Salt River watershed.

Conservation of Aquatic Communities

Statewide, the Department of Conservation has developed a long-term Resource Assessment and Monitoring program (RAM). The objective is to establish standardized sampling methods for several stream ecosystem attributes, especially biotic communities, that will allow scientists to provide an accurate, legally defensible portrayal of conditions and trends. Sampling is occurring at random and fixed sites to allow statewide or individual watershed assessments. Information gathered from this effort may be used to prioritize watersheds for conservation.

Long-Term Fish Community Monitoring

Long-term monitoring to assess stream fish community trends has not been conducted in the Salt River watershed. Although some sites within the basin may be included in the statewide RAM program, extensive sampling within that framework is not likely to occur for several years. In the meantime, in order to monitor trends in fish community composition and population levels, the Department of Conservation should conduct fish community surveys at sites randomly selected from among those surveyed during 1995-97 at least every ten years.

Fishery Management and Research Needs

As in most northeastern Missouri streams, fish communities in the Salt River watershed seem to be imbalanced. Recognizing that our sampling methods may under represent large fishes, surveys in some basin streams still suggests the existence of relatively few fish-eating predators (flathead catfish, black bass or walleye), but large numbers of insect-eating bottom feeders (channel catfish, river carpsuckers, freshwater drum, common carp, and a variety of minnow species). Non-game fishes are represented mostly by species tolerant of the shallow depths and shifting substrates caused by excessive watershed erosion and subsequent stream channel sedimentation. Shifting substrates dramatically reduce biological productivity, so in channelized streams the large populations of insect-eating fish are almost entirely dependent upon terrestrial inputs or whatever invertebrate production occurs on in-channel woody debris. There are not enough predatory fish to control the abundant insect-eating fish. Degraded habitat may be the main factor limiting predator abundance and thereby preventing ecosystem balance.

We know very little about the abundance, migration patterns and minimum habitat requirements of the key-predator—flathead catfish. We need basic research, starting with studies of flathead catfish movement and exploitation rate, to begin developing a broad range of strategies for effectively managing sport fishes in streams (e.g., regulation, stocking, and information/education in addition to habitat protection/restoration).

Walleye represent another major predator in basin streams; however, surveys indicate that natural reproduction and density is low. A stream stocking evaluation was initiated in 1999 with the goal of determining if stream stockings of small or advanced size walleye will result in a quality walleye fishery in Mark Twain Lake and its Salt River tributaries.

Monitoring Contaminants in Fish

Fish contaminant monitoring has been conducted in Mark Twain Lake and some basin streams. The entire basin was included in a limited consumption advisory issued by the Missouri Department of Health for fish species with a high proportion of fat in their edible tissues (catfish, carp, buffalo, drum, suckers). Levels of concern for chlordane were reported in the early 1990s for catfish in this and neighboring watersheds and the Mississippi River. This advisory was lifted in 2001 due to declining chlordane levels. However, another consumption advisory was added in 2001. This new advisory, issued due to mercury contamination, recommends that pregnant or nursing women, women of childbearing age, and children 12 years of age or younger not eat largemouth bass 12 inches long or longer from anywhere in Missouri.

Long-Term Mussel Community Monitoring

Mussels are abundant in some reaches of basin streams. Extensive, basin- wide surveys have not been conducted. The Department of Conservation needs to assess species diversity and abundance by conducting a carefully designed, system- wide survey. Survey sites and sampling periodicities should be consistent with RAM and other fish survey protocols.

Supporting Other Agencies and Organizations

The Missouri Department of Conservation works with many other governmental agencies and private conservation organizations in the process of managing stream resources. The following formal or traditional interactions are among the most significant in frequency and scope, and they should be continued.

Missouri Department of Natural Resources (DNR)

MCD assists DNR by periodically nominating high quality or otherwise valuable stream reaches for “Outstanding State Resource Water” status; recommending water quality standard classifications for stream reaches of special concern; and assisting in water pollution investigations whenever an event results in the loss of aquatic life. In such cases, MDC’s role is to document the number of dead fish and other aquatic organisms and report to DNR the estimated value of animals lost according to formulas established by the American Fisheries Society. MDC should continue its coordination efforts with DNR to ensure efficient use of state government resources in the conservation of streams in the Salt River watershed.

Missouri Department of Health (DOH)

MDC assists DOH by periodically collecting fish from select streams and preparing tissue samples for analysis of pesticide and heavy metal contaminants. We cooperate with DOH in advising anglers about precautions to take in the consumption of fish.

U.S. Army Corps of Engineers (COE)

MDC joins several other agencies in commenting to COE and DNR about activities in streams that require permit and certification under Sections 404 and 401, respectively, of the Federal Clean Water Act. COE requires a Section 404 permit for operators who propose to deposit or stockpile material in stream channels; and DNR requires a Section 401 certification for any activity that could significantly degrade water quality. MDC biologists help to disseminate information about stream- friendly sand and gravel removal practices to county commissions, contractors, and landowners.

MDC personnel are often the first agency representatives contacted by neighbors when individuals or public entities engage in what appears to be unpermitted and destructive practices in and along streams. MDC biologists should remain vigilant advocates for the interests on all riparian residents, upstream and downstream, who may be adversely affected by the activities of those few who knowingly violate Sections 404 or 401 of the Clean Water Act.

MDC recognizes that regulations are necessary to protect streams and their watersheds. Watershed management must be approached in a balanced, market-based manner that falls somewhere in the continuum between regulatory protection and voluntary conservation efforts.

MDC staff also work closely with COE regarding fishery management activities at Mark Twain Lake.

Conservation Federation of Missouri (CFM)

MDC facilitates and promotes Stream Team, a program initiated by CFM that seeks to enlist volunteers in the stream conservation effort. Many Teams have adopted streams in the Salt River watershed; however, most report little to no activity. Far more citizen interest and volunteer effort will be needed for any significant stream improvements to occur within the watershed.

Clarence Cannon Wholesale Water Commission (CCWWC) and University of Missouri Outreach and Extension (MUOE)

The CCWWC and MUOE coordinate the North Fork Project. This watershed project, supported by many governmental agencies, business owners, landowners, and municipal leaders, seeks to provide informational/educational materials and training that leads to better coordinated management activities in the North Fork Salt River watershed. MDC provides technical support to the North Fork Project and assists in major educational efforts.

Assisting Citizen-Led Watershed conservation Efforts

We are convinced that the watershed conservation approach will work only if there is widespread recognition that social, economic, and environmental values associated with streams are compatible. If that can be achieved, success will depend upon local initiatives to form diverse partnerships of committed groups and individuals under the leadership of landowners and other local interests.

Watershed restoration is essential to restoring the primary processes that create and maintain fish habitat in healthy stream ecosystems. The most critical and affordable first step in watershed restoration is passive restoration—the cessation of human activities that are causing degradation or preventing recovery (e.g., channelization, riparian corridor clearing, indiscriminate gravel dredging, and streamside livestock grazing). Active restoration (e.g., tree revetments and riparian corridor plantings) should be considered only if recovery fails to occur over a reasonable period of time while using passive techniques (e.g., livestock exclusion and natural regeneration of woody plants). Because restoring degraded stream ecosystems is more costly and risky than simply protecting fully functional sites, we suggest that protecting and preserving intact riparian ecosystems be the highest priority of watershed-scale restoration efforts.

Protecting Healthy Riparian Corridors –Stream Stewardship

A program aimed at conserving healthy forested stream corridors by placing them into permanent easements using Stream Stewardship Agreements (SSA) was piloted in Marion County between 1992 and 1995. That effort resulted in the permanent conservation of 88 acres of 100- to 200- foot-wide forested corridor on four ownerships along 2.4 miles of the South Fabius River. Although there are no SSA in the Salt River watershed, the infrastructure now exists for MDC to facilitate the permanent conservation of healthy stream corridors, but measurable impact will require funding from a variety of sources.

Enrollment of streamside lands in continuous CRP (Conservation Reserve Program) will not substitute for enrollment in SSA or other permanent easement programs because healthy forested corridors cannot be enrolled in CRP, and land enrolled in CRP buffers may be converted back to crop production at the end of the short-term contract periods (10 to 15 years). However, CRP may provide viable first step for landowners on the long path toward converting eroding floodplain crop fields or pastures into functional riparian corridors. MDC has identified the Elk Fork Salt River as the most likely watershed for SSA and other subsidized stream management practices in the Salt River watershed.

Passively Restoring Mildly Degraded Riparian Corridors—Livestock Exclusion

The activity of livestock can degrade physical aspects of water quality by causing streambank erosion, resulting in turbidity and stream channel sedimentation. Chemical aspects of water quality can be degraded by livestock waste. In some situations, streambank stabilization, corridor reforestation, and improved water quality can be achieved simply by excluding livestock from stream corridors. For fencing to be attractive to landowners, an alternative source of livestock water must be available (e.g., upland ponds, or shallow floodplain wells tapped by nose pumps or solar-powered pumps). Some landowners may have potential alternative water sources on their property, but may not have the money or the technical support to adopt new technology. Cost-share money for fencing and alternative watering may be available through a variety of federal and state programs. Department of Conservation biologists are available to assist landowners in selecting a practical alternative to instream watering of livestock.

Actively Restoring Moderately to Severely Degraded Corridors

A 75% cost-share program for stream restoration practices (e.g., tree revetments and riparian corridor tree plantings) was piloted by MDC in Sullivan County between 1990 and 1993. The program had no participants, despite the fact that 41% of county landowners were aware of monetary incentives. The problems and their solutions were often complex, and MDC assistance had stipulations (ten-year forested corridors 50 to 100 feet wide) which many landowners were unwilling to accept. The lesson learned? These landowners were not prepared to make the personal sacrifices in time, money, and values needed to restore moderately to severely degraded stream habitats on their property. Available funds might be better spent first on protecting healthy riparian corridors and passively restoring those that are only mildly degraded.

Educating Future Watershed Stewards

Educating our youth about the complexities of watershed processes and problems will be critically important in advancing the science and art of watershed conservation. Today's youth are more technologically oriented and therefore likely to embrace complex information systems. And because of changes in classroom teaching strategy, they are likely to work effectively in problem-solving teams once they become adults.

MDC has found that students in and around the 6th grade are particularly receptive to messages about stream conservation because they can understand most concepts and evaluate new ideas with relatively little social or cultural bias. Classroom teachers may find helpful lesson-planning materials in Missouri's Stream Team Curriculum, a watershed-based curriculum developed by teachers, for teachers, that will help students to meet environmental education goals in the Missouri Performance Standards.

Junior high and high school students in vocational agricultural programs may also be prime candidates for watershed conservation education because they are more likely than others to become landowners and other important members of rural communities. Involving these students in hand-on stream conservation activities may contribute to the creation of a new generation of landowners committed to stream ecosystem integrity.

Citizen Primer to Leadership in Watershed Conservation

This section is included as a starting point for citizens who wish to lead or contribute significantly to watershed-based stream conservation efforts. The proliferation of information about watershed planning can be intimidating to individuals or groups who have decided that they have a problem they wish to fix. To facilitate that process, we recommend that potential leaders and contributors to watershed conservation efforts first familiarize themselves with a summary of lessons learned over the past decade about what works and what does not. The list in Table 11 combines the Top 10 Watershed Lessons Learned published by the United States Environmental Protection Agency (1997) with the ten principles for effectively coordinating watershed-based programs listed by Turner (1997). These documents are highly

recommended reading.

Citizens determined to develop and implement watershed conservation plans can also obtain critically important information about organizing and funding such projects by visiting the Internet websites listed in Table 12. These sites contain convenient links to many other sites that, in the aggregate, provide enough information about the watershed conservation process to help any individual or group get started in an informed and effective manner.

Table 11. Ten useful watershed conservation principles.*

- 1) For watershed conservation approach to work, there must be widespread recognition that social, economic, and environmental values are compatible.
- 2) Successful watershed conservation requires the formation and support of diverse partnerships under the authority of landowners and other local interest.
- 3) Leadership is critical in the watershed approach to conservation.
- 4) A good coordinator is key to successful watershed conservation projects.
- 5) The best plans have clear visions, goals, and action items.
- 6) Good tools (planning guides, technical assistance, and funding sources) are available to help watershed groups achieve their goals.
- 7) It is important to start small and demonstrate success before working on larger scales, celebrating even minor success as it occurs.
- 8) Plans are most likely to succeed in implemented on a manageable scale.
- 9) Public awareness, education and involvement are keys to building and maintaining support for watershed conservation efforts.
- 10) Measuring and communicating progress is essential to the success of watershed conservation efforts.

*For EPA Publication 840-F-97-001, call the National Center for Environmental Publications and Information at 1-800-490-9198.

Table 12. Internet websites containing important information for Missouri watershed planners.

- **Conservation Technology Information Center** - www.ctic.purdue.edu CTIC is a non-profit, public-private partnership equipping agriculture with realistic, affordable, and integrated solutions to environmental concerns.
- **EPA Watershed and Wetlands** - www.epa.gov/OWOW This site, created and maintained by the federal Environmental Protection Agency, is a good starting point for information about watersheds and water quality.
- **Funding Sources for Watershed Conservation** - www.epa.gov/OWOW/watersheds/wacademy/fund.html#forward This site contains a comprehensive listing of private and public sources of watershed project funding, with links to many individual sites and references to many useful publications.
- **Know Your Watershed** - www.ctic.purdue.edu.KYW/KYW.html This initiative works to encourage the formation of local, voluntary partnerships among all watershed stakeholders for the purpose of developing and implementing watershed plans based upon shared visions of the future.
- **Missouri Stream Team** - www.rollanet.org/~streams/ This site provides specific information on activities, programs, and funding sources for volunteers who have adopted Missouri streams or otherwise committed themselves to conserving stream resources in Missouri.
- **Missouri Watershed Information Network** - <http://outreach.missouri.edu/mowin/> This site serves as a clearinghouse for information about Missouri watersheds.
- **River Network** - www.rivernetwork.org/wag.htm This organization supports development of local watershed partnerships through its Watershed Assistance Grants Program. They seek to fund projects in diverse geographies that have demonstration value on a national scale.

Angler Guide

Fishing Prospects for Streams in the Salt River Watershed

Although several stream reaches in the watershed have been degraded by localized channelization, gravel mining, and siltation, many areas of high quality fish habitat remain. In addition, streams in the basin provide a wide array of fishing opportunities. Streams in the uppermost portion of the basin are relatively small, but fishable pools are scattered between shallow riffles and sand bars. Public access is limited to county and state road bridge crossings. In these isolated pools, anglers can expect to catch carp, medium-sized channel catfish, sunfish, and small black bass.

All major streams provide good to excellent fishing for several species, often in association with spectacular scenery. Anglers using a variety of methods and focusing on good pools with woody or rocky habitats can expect to encounter channel catfish, flathead catfish, carp, sunfish, crappie, freshwater drum, and small black bass in the North Fork, Middle Fork, South Fork, and Elk Fork rivers. White bass and walleye can also provide seasonally good fishing in these streams, especially during March and April. The Elk Fork Salt River provides one of the best smallmouth bass fishing opportunities in all of northeast Missouri. Many reaches in all of these streams are floatable by small boat or canoe, but during low flow conditions there will be a more frequent need to drag watercraft through gravel riffles or around debris than in popular Ozark float streams. But unlike the Ozarks, anglers will experience isolation, litter-free beauty, and near-wilderness conditions within the forested river corridor, in addition to good fishing for a wide variety of species. Public access is available at several developed access areas (see Table 3).

The lower Salt River downstream of Mark Twain Lake and the reregulation dam also provides diverse fishing opportunities. Water levels along this part of the river can vary greatly, on short notice, due to releases from Mark Twain Lake, so anglers should pay close attention to changing water conditions. This area is floatable by small watercraft and much of it is floatable by larger craft as the stream approaches its confluence with the Mississippi River. Because of its connection to the Mississippi River, anglers can expect to encounter a wide variety of fish species including flathead catfish, channel catfish, carp, crappie, walleye, sauger, freshwater drum, paddlefish, and exotic Asian carp. The area immediately downstream of the regulation dam is one of the most popular fishing spots in the area and is easily fished from land, although a boat ramp is also available. Reaches further downstream also provide good wade fishing for largemouth bass and smallmouth bass. Tributaries of the lower Salt River can provide good fishing as well. Spencer Creek and Penno Creek are excellent wade fishing streams where anglers can catch largemouth bass, smallmouth bass, and sunfishes. Public access along these streams is mostly limited to county road crossings, but a one and a half mile reach of Penno Creek flows through Ranacker CA.

List of Tables

Geomorphology

Table 1. Location, mileage, and habitat information for all third-order and larger streams in the Salt River basin.

Table 2. Soil conservation projects in the Salt River basin.

Table 3. Publicly owned Conservation Areas and stream accesses located in the Salt River basin.

Hydrology

Table 4. Flood discharges for 5, 25, and 100 year intervals at stream flow gaging stations in the Salt River basin.

Table 5. Results of Indicators of Hydrologic Alteration analysis for the Salt River at New London.

Water Quality

Table 6. Select water quality data for the Salt River near New London, Missouri in 1986.

Table 7. Potential point-source pollution sites in the Salt River basin.

Table 8. Concentrated animal feeding operations in the Salt River basin. Biotic

Table 9. Fish species collected and current status in the Salt River basin.

Table 10. Mussel species collected from streams in the Salt River basin. Management Problems and Opportunities

Table 11. Ten useful watershed conservation principles.

Table 12. Internet websites containing important information for Missouri watershed planners.

List of Figures

Location

Figure ll. General location of the Lower Salt River Watershed.

Figure ml. General location of the Middle Salt River Watershed.

Figure ul. General location of the Upper Salt River Watershed. Geomorphology

Geomorphology

Figure nd. Natural divisions of Missouri within the Salt River Watershed.

Figure ge. Geological formations of the Salt River Watershed.

Figure lp. Public areas in the Lower Salt River Watershed.

Figure mp. Public areas in the Middle Salt River Watershed.

Figure up. Public areas in the Upper Salt River Watershed.

Land Use

Figure ll. Land use in the Lower Salt River Watershed.

Figure ml. Land use in the Middle Salt River Watershed.

Figure ul. Land use in the Upper Salt River Watershed.

Literature Cited

- Alexander, T. W., and G. L. Wilson. 1995. *Technique for estimating the 2- to 500-year flood discharges on unregulated streams in rural Missouri*. United States Geological Survey. Water Resources. Investigation Report No. 95-4231. Rolla, Missouri.
- Allgood, F. P. and I. D. Persinger. 1979. *Missouri general soil map and soil association description*. United States Department of Agriculture, Soil conservation Service. Columbia, Missouri.
- Anderson, C. L. 1980. *Best management practices for erosion and sediment control*. University of Missouri-Columbia and the Missouri Department of Conservation. Manual 117.
- Anderson, J. 1982. *Eight-county natural features inventory*. Missouri Department of Conservation. Jefferson City, Missouri.
- Anderson, J. 1983. *Addition to the eight-county natural features inventory*. Missouri Department of Conservation. Jefferson City, Missouri.
- Bachant, J. P., D. J. Witter, and J. D. Martindale. *Ranking the recreational values and associated problems of Missouri's major watersheds*. Missouri Department of Conservation and Missouri Department of Natural Resources. A reference document of the regional Watershed Assessment Plan, Jefferson City, Missouri.
- Blanchard, P. E. and W. W. Donald. 1997. *Herbicide contamination of groundwater beneath claypan soils in north-central Missouri*. Journal of Environmental Quality 26: 1612-1621.
- Blanchard, P. E. and R. N. Lerch. 2000. *Watershed vulnerability to losses of agricultural chemicals: interactions of chemistry, hydrology, and land-use*. Environmental Science and Technology 34: 3315-3322.
- Bogler, D. and T. A. Nigh. 1986. *Missouri natural features inventory: Lincoln Co., Pike Co., St. Charles Co., and Warren Co.* Missouri Department of Conservation. Jefferson City, Missouri.
- Donald, W. W., A. T. Hjelmfelt, and E. E. Alberts. 1998. *Herbicide distribution and variability across Goodwater Creek watershed in north-central Missouri*. Journal of Environmental Quality 27: 999-1009.
- Duchrow, R. M. 1974. *Water quality of the North, Salt, and Cuivre river basins*. Missouri Department of Conservation. Final report, Project F-1-R-22. Jefferson City, Missouri.
- Fagen, O. F. 1975. *The establishment of spotted bass fisheries in some northern Missouri streams*. Proceedings of the 29th Annual Conference of the Southeastern Association of Game and Fish Commissioners 29: 28-35.
- Finney, V. L. 1986. *Seasonal sediment yield to Mark Twain Lake, Missouri*. Bulletin of the Association of Engineering Geologists 23 (3): 333-338.
- Gass, J. F. 1979. *The mayflies (Ephemeroptera) of selected streams in northeastern Missouri, their biology, and relation to water quality*. Master's thesis, Northeast Missouri State University, Kirksville, Missouri. 160pp.
- Govro, K. C. 1984. *Salt River basin biological study*. Annual report. Environmental Science and Engineering, Inc. St. Louis, Missouri. 196pp.
- Hazelwood, D. H. 1974-1981. *Annual reports for biological investigations for the Salt River Basin, Missouri*. Reports prepared for the U.S. Army Corps of Engineers, St. Louis, Missouri.
- Kitchen, N. R., P. E. Blanchard, D. F. Hughes, and R. N. Lerch. 1997. *Impact of historical and current farming systems on groundwater nitrate in northern Missouri*. Journal of Soil and Water Conservation 52: 272-277.
- Klein, W. M. and R. H. Daley. 1974. *Environmental assessment, Clarence Cannon Dam and Reservoir*.

- Missouri Botanical Garden. Final report to U.S. Army Corps of Engineers, St. Louis District. 280pp.
- Lerch, R. N. and P. E. Blanchard. 2003. *Watershed vulnerability to herbicide transport in northern Missouri and southern Iowa streams*. Environmental Science and Technology 37: 5518-5527.
- Missouri Agricultural Statistics Service. 1996. *County agri-facts*. Missouri Agricultural Statistics Service. Columbia, Missouri.
- Missouri Department of Natural Resources. 1986a. *Missouri water atlas*. Missouri Department of Natural Resources. Jefferson City, Missouri.
- Missouri Department of Natural Resources. 1986b. *Missouri water quality report*. Missouri Department of Natural Resources. Jefferson City, Missouri.
- Missouri Department of Natural Resources. *Unpublished. Missouri water quality basin plan: lower Salt River, Mark Twain Lake, North Fork tributaries, Middle Fork and Elk Fork tributaries, and South Fork and Lick Creek tributaries*. Missouri Department of Natural Resources. Jefferson City, Missouri.
- Missouri Water Pollution Board. 1970. *Water quality of Salt, Cuivre, and North river basins*. Missouri Water Pollution Board, Missouri Geological Survey, U.S. Geological Survey. Jefferson City, Missouri.
- Natural Resources Conservation Service. 1995. *Soil survey of Audrain County, Missouri*. United States Department of Agriculture, Columbia, Missouri.
- Natural Resources Conservation Service. 1997. *Soil survey of Pike County, Missouri*. United States Department of Agriculture, Columbia, Missouri.
- Pflieger, W. L., and P. Haverland, and M. Schene. 1981. *Missouri's system for storage and retrieval and analysis of stream resource data*. Pages 284-290 in N. B. Armantrout, editor. Acquisition and utilization of aquatic habitat inventory information symposium. American Fisheries Society. Bethesda, Maryland.
- Reeves, G. A. 1986. *East-central natural features inventory*. Missouri Department of Conservation. Jefferson City, Missouri.
- Richter, B. D., J. V. Baumgartner, J. Powell, and D. P. Braun. 1996. *A method for assessing hydrologic alteration within ecosystems*. Conservation Biology 10(4):1163-1174.
- Richter, B. D., J. V. Baumgartner, and D. P. Braun. 1997. *How much water does a river need?* Freshwater Biology 37: 231-249.
- Schroeder, W. A. 1982. *Pre-settlement prairie of Missouri*. Missouri Department of Conservation, Natural History Series No. 2. Jefferson City, Missouri.
- Skelton, J. 1976. *Missouri stream and spring flow characteristics: low-flow frequency and flow duration*. Missouri Geological Survey, Missouri Department of Natural Resources. Rolla, Missouri.
- Soil Conservation Service. 1988. *Upper Salt River basin erosion and sediment inventory (above Mark Twain Lake, N.E. MO)*. United States Department of Agriculture, Soil Conservation Service, Columbia, Missouri.
- Soil Conservation Service. 1992. *National resources inventory*. United States Department of Agriculture, Soil Conservation Service. Columbia, Missouri.
- Strahler, A. N. 1957. *Quantitative analysis of watershed geomorphology*. Transactions of the American Geophysical Union 38: 913-920.
- Thom, R. H., and J. H. Wilson. 1980. *The natural divisions of Missouri*. Transactions of the Missouri Academy of Science 14: 9-23.

- United States Army Corps of Engineers. 1974. *Pre-impoundment water quality summary report, Salt River, Clarence Cannon Dam and Reservoir*. St. Louis, Missouri.
- United States Army Corps of Engineers. 1975. *Clarence Cannon Dam and Reservoir, Upper Mississippi River basin, Salt River, Missouri*. Final environmental statement. St. Louis, Missouri. 317pp.
- United States Army Corps of Engineers. 1996. *Mark Twain Lake water quality report for 1995 and 1996*. Environmental Quality Section, St. Louis, Missouri.
- United States Geological Survey. 2001. *Water resources data for Missouri, water year 2000*.
- United States Geological Survey water-data report *MO-00-1*.
- United States Geological Survey. 1987. *Water resources data for Missouri, water year 1986*.
- United States Geological Survey water-data report *MO-86-1*.

Glossary

Alluvial soil: Soil deposits resulting directly or indirectly from the sediment transport of streams, deposited in river beds, flood plains, and lakes.

Aquifer: An underground layer of porous, water-bearing rock, gravel, or sand.

Benthic: Bottom-dwelling; describes organisms which reside in or on any substrate.

Benthic macroinvertebrate: Bottom-dwelling (benthic) animals without backbones (invertebrate) that are visible with the naked eye (macro).

Biota: The animal and plant life of a region.

Biocriteria monitoring: The use of organisms to assess or monitor environmental conditions.

Channelization: The mechanical alteration of a stream which includes straightening or dredging of the existing channel, or creating a new channel to which the stream is diverted.

Concentrated animal feeding operation (CAFO): Large livestock (ie. cattle, chickens, turkeys, or hogs) production facilities that are considered a point source pollution, larger operations are regulated by the MDNR. Most CAFOs confine animals in large enclosed buildings, or feedlots and store liquid waste in closed lagoons or pits, or store dry manure in sheds. In many cases manure, both wet and dry, is broadcast overland.

Confining rock layer: A geologic layer through which water cannot easily move.

Chert: Hard sedimentary rock composed of microcrystalline quartz, usually light in color, common in the Springfield Plateau in gravel deposits. Resistance to chemical decay enables it to survive rough treatment from streams and other erosive forces.

Cubic feet per second (cfs): A measure of the amount of water (cubic feet) traveling past a known point for a given amount of time (one second), used to determine discharge.

Discharge: Volume of water flowing in a given stream at a given place and within a given period of time, usually expressed as cubic feet per second.

Disjunct: Separated or disjointed populations of organisms. Populations are said to be disjunct when they are geographically isolated from their main range.

Dissolved oxygen: The concentration of oxygen dissolved in water, expressed in milligrams per liter or as percent.

Dolomite: A magnesium rich, carbonate, sedimentary rock consisting mainly (more than 50% by weight) of the mineral dolomite($\text{CaMg}(\text{CO}_3)_2$).

Endangered: In danger of becoming extinct.

Endemic: Found only in, or limited to, a particular geographic region or locality.

Environmental Protection Agency (EPA): A Federal organization, housed under the Executive branch, charged with protecting human health and safeguarding the natural environment — air, water, and land — upon which life depends.

Epilimnion: The upper layer of water in a lake that is characterized by a temperature gradient of less than 1° Celsius per meter of depth.

Eutrophication: The nutrient (nitrogen and phosphorus) enrichment of an aquatic ecosystem that promotes biological productivity.

Extirpated: Exterminated on a local basis, political or geographic portion of the range.

Faunal: The animals of a specified region or time.

Fecal coliform: A type of bacterium occurring in the guts of mammals. The degree of its presence in a

lake or stream is used as an index of contamination from human or livestock waste.

Flow duration curve: A graphic representation of the number of times given quantities of flow are equaled or exceeded during a certain period of record.

Fragipans: A natural subsurface soil horizon seemingly cemented when dry, but when moist showing moderate to weak brittleness, usually low in organic matter, and very slow to permeate water.

Gage stations: The site on a stream or lake where hydrologic data is collected.

Gradient plots: A graph representing the gradient of a specified reach of stream. Elevation is represented on the Y-axis and length of channel is represented on the X- axis.

Hydropeaking: Rapid and frequent fluctuations in flow resulting from power generation by a hydroelectric dam's need to meet peak electrical demands.

Hydrologic unit (HUC): A subdivision of watersheds, generally 40, 000-50, 000 acres or less, created by the USGS. Hydrologic units do not represent true subwatersheds.

Hypolimnion: The region of a body of water that extends from the thermocline to the bottom and is essentially removed from major surface influences during periods of thermal stratification.

Incised: Deep, well defined channel with narrow width to depth ration, and limited or no lateral movement. Often newly formed, and as a result of rapid down-cutting in the substrate

Intermittent stream: One that has intervals of flow interspersed with intervals of no flow. A stream that ceases to flow for a time.

Karst topography: An area of limestone formations marked by sinkholes, caves, springs, and underground streams.

Loess: Loamy soils deposited by wind, often quite erodible.

Low flow: The lowest discharge recorded over a specified period of time.

Missouri Department of Conservation (MDC): Missouri agency charged with: protecting and managing the fish, forest, and wildlife resources of the state; serving the public and facilitating their participation in resource management activities; and providing opportunity for all citizens to use, enjoy, and learn about fish, forest, and wildlife resources.

Missouri Department of Natural Resources (MDNR): Missouri agency charged with preserving and protecting the state's natural, cultural, and energy resources and inspiring their enjoyment and responsible use for present and future generations.

Mean monthly flow: Arithmetic mean of the individual daily mean discharge of a stream for the given month.

Mean sea level (MSL): A measure of the surface of the Earth, usually represented in feet above mean sea level. MSL for conservation pool at Pomme de Terre Lake is 839 ft. MSL and Truman Lake conservation pool is 706 ft. MSL.

Necktonic: Organisms that live in the open water areas (mid and upper) of waterbodies and streams.

Non-point source: Source of pollution in which wastes are not released at a specific, identifiable point, but from numerous points that are spread out and difficult to identify and control, as compared to point sources.

National Pollution Discharge Elimination System (NPDES): Permits required under The Federal Clean Water Act authorizing point source discharges into waters of the United States in an effort to protect public health and the nation's waters.

Nutrification: Increased inputs, viewed as a pollutant, such as phosphorous or nitrogen, that fuel abnormally high organic growth in aquatic systems.

Optimal flow: Flow regime designed to maximize fishery potential.

Perennial streams: Streams fed continuously by a shallow water table and flowing year-round.

pH: Numeric value that describes the intensity of the acid or basic (alkaline) conditions of a solution. The pH scale is from 0 to 14, with the neutral point at 7.0. Values lower than 7 indicate the presence of acids and greater than 7.0 the presence of alkalis (bases).

Point source: Source of pollution that involves discharge of wastes from an identifiable point, such as a smokestack or sewage treatment plant.

Recurrence interval: The inverse probability that a certain flow will occur. It represents a mean time interval based on the distribution of flows over a period of record. A 2-year recurrence interval means that the flow event is expected, on average, once every two years.

Residuum: Unconsolidated and partially weathered mineral materials accumulated by disintegration of consolidated rock in place.

Riparian: Pertaining to, situated, or dwelling on the margin of a river or other body of water.

Riparian corridor: The parcel of land that includes the channel and an adjoining strip of the floodplain, generally considered to be 100 feet on each side of the channel.

7-day Q^{10} : Lowest 7-day flow that occurs an average of every ten years.

7-day Q^2 : Lowest 7-day flow that occurs an average of every two years.

Solum: The upper and most weathered portion of the soil profile.

Special Area Land Treatment project (SALT): Small, state funded watershed programs overseen by MDNR and administered by local Soil and Water Conservation Districts. Salt projects are implemented in an attempt to slow or stop soil erosion.

Stream Habitat Annotation Device (SHAD): Qualitative method of describing stream corridor and instream habitat using a set of selected parameters and descriptors.

Stream gradient: The change of a stream in vertical elevation per unit of horizontal distance.

Stream order: A hierarchical ordering of streams based on the degree of branching. A first order stream is an unbranched or unforked stream. Two first order streams flow together to make a second order stream; two second order streams combine to make a third order stream. Stream order is often determined from 7.5 minute topographic maps.

Substrate: The mineral and/or organic material forming the bottom of a waterway or waterbody.

Thermocline: The plane or surface of maximum rate of decrease of temperature with respect to depth in a waterbody.

Threatened: A species likely to become endangered within the foreseeable future if certain conditions continue to deteriorate.

United States Army Corps of Engineers (USCOE) and now (USACE): Federal agency under control of the Army, responsible for certain regulation of water courses, some dams, wetlands, and flood control projects.

United States Geological Survey (USGS): Federal agency charged with providing reliable information to: describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect the quality of life.

Watershed: The total land area that water runs over or under when draining to a stream, river, pond, or lake.

Waste water treatment facility (WWTF): Facilities that store and process municipal sewage, before release. These facilities are under the regulation of the Missouri Department of Natural Resources.