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# CHEMICAL CHARACTERISTICS OF SOME MISSOURI RESERVOIRS

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**Introduction.** Studies of regional limnology in various lake districts have established the importance of chemical composition to separate lake types and provide background for interpreting biological differences (Armstrong and Schindler, 1971). In many areas the mineral composition of the lake water is determined by surface geology (Deevey, 1940; Moyle, 1956; Bachmann, 1965), but atmospheric precipitation and the evaporation-crystalization process are also controlling mechanisms (Gibbs, 1970). A regional limnology survey was designed to provide similar information of the surface waters in Missouri. The objectives were (1) to determine the chemical characteristics of waters selected as being geographically representative of Missouri impoundments, and (2) to determine if waters differ in chemical composition among the four physiographic regions of Missouri (Figure 1) (Fenneman, 1938). Major cations and anions were measured during a 6-week period (11 October 1975 to 22 November 1975). By measuring conservative elements during a short sampling period, seasonal fluctuations were considered minimal. Emphasis was placed on waters located in state parks and areas managed by the Missouri Department of Conservation (Figure 1).

**Methods.** Surface water samples were collected in triplicate from several lakes on a single day with chemical analyses completed within the next 2-4 days. Specific conductance was measured with a Radiometer Measuring Instruments type CDM2e conductivity meter corrected for temperature effects and reported as micromhos/cm at 25 C. Total alkalinity was determined by using brom cresol green-methyl red indicator titrated with 0.02N sulfuric acid. Total and calcium hardness concentrations were determined by complexometric titration with 1,2-cyclohexane-diaminetetraacetate-Hexa Ver$^R$ (Hach Chemical Co., Ames, Iowa). Man Ver$^R$ and Cal Ver II$^R$ (Hach Chemical Co.) indicators were used for endpoint determinations. Chloride was determined by titration with mercuric nitrate using diphenol carbazone indicator-buffer power (Hach Chemical Co.). Sulfate was determined turbidimetrically by using Sulfa Ver$^R$ IV (Hach

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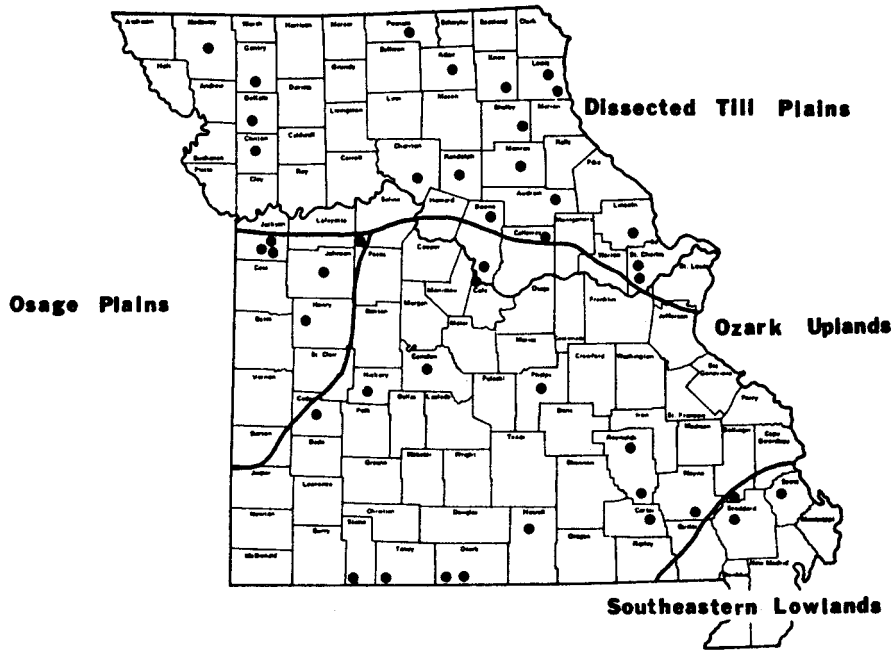


Figure 1. Location of lakes sampled in this study. Lines separate physiographic regions in Missouri.

Chemical Co.). Sodium and potassium concentrations were determined on samples filtered through a type HA 0.45 $\mu g$ Millipore filter by using a Jarrell-Ash 0.5 m spectrophotometer and associated electronics with an air-acetylene flame emission. Values were corrected for the 1.0 ml of 1000 mg La/l added to each sample as $LaCl_3$.

Calcium and magnesium concentrations were calculated using total and calcium hardness values.

**Results—Discussion.** Results of the chemical analyses are summarized in Table 1. Values represent the mean of three samples collected from each lake. In general, ion concentrations ($Ca > Mg > Na > K$ and $HCO_3 > SO_4 > Cl$) of waters in Missouri reservoirs are typical of most natural freshwaters (Rodhe, 1949). Exceptions were found in Montrose and Thomas Hill reservoirs where $SO_4$ is the predominate anion. Coal mining within both watersheds is the likely source of these high $SO_4$ concentrations (Brezina, *et al.*, 1970). Other minor exceptions were noted in proportions of ions in some lakes which could not be explained by watershed characteristics. Agreement between positive and negative ions (as meq/l) in an ion balance of major elements in each lake was within the range found acceptable by Golterman (1969). And there is a good correlation between total concentration of cations or anions (as meq/l) and specific conductance ($r = 0.99$, $P = 0.01$).

Table 1. Chemical analyses of surface waters from 43 Missouri reservoirs located in the Dissected Till Plains (TP), Osage Plains (OP), Ozark Uplands (OU) and Southeastern Lowlands (SL). Collections made between 11 October and 22 November, 1975.[a]

| Location | Specific Conductance Micromhos/cm at 25 C | Alkalinity as mg/l $CaCO_3$ | Total hardness as mg/l $CaCO_3$ | Calcium mg/l | Magnesium mg/l | Sodium mg/l | Potassium mg/l | Sulfate mg/l | Chloride mg/l | Physiographic Region |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Ashland, Boone Co. | 172 | 72 | 78 | 25 | 4 | 2 | 4 | 7 | 3 | OU |
| 2. August A. Bush #34, St. Charles Co. | 295 | 103 | 114 | 29 | 10 | 14 | 3 | 17 | 15 | TP |
| 3. August A. Bush #35, St. Charles Co. | 195 | 58 | 67 | 20 | 4 | 11 | 3 | 14 | 12 | TP |
| 4. Binder, Cole Co. | 272 | 98 | 119 | 24 | 14 | 6 | 4 | 24 | 8 | OU |
| 5. Blind Pony, Saline Co. | 303 | 106 | 130 | 38 | 8 | 8 | 5 | 35 | 6 | OP |
| 6. Bull Shoals, Ozark Co., MO Taney Co., AK | 246 | 116 | 120 | 30 | 11 | 2 | 1 | 5 | 3 | OU |
| 7. Clearfork, Johnson Co. | 256 | 91 | 116 | 36 | 6 | 5 | 2 | 35 | 2 | OP |
| 8. Clearwater, Reynolds Co. | 280 | 130 | 141 | 29 | 17 | 3 | 1 | 10 | 3 | OU |
| 9. Deer Ridge, Lewis Co. | 144 | 56 | 62 | 19 | 4 | 4 | 3 | 9 | 3 | TP |
| 10. Duck Creek, Bollinger Co. | 49 | 19 | 20 | 4 | 2 | 1 | 2 | 2 | 2 | SL |
| 11. Forest, Adair Co. | 316 | 104 | 136 | 44 | 1 | 6 | 3 | 36 | 5 | TP |
| 12. Henry Seaver, Knox Co. | 212 | 74 | 91 | 27 | 6 | 6 | 4 | 21 | 6 | TP |

| | Location | SC | Alk | Total | Ca | Mg | Na | K | $SO_4$ | Cl | Area |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 13. | Hunnewell, Shelby Co. | 152 | 63 | 67 | 21 | 3 | 3 | 4 | 9 | 3 | TP |
| 14. | Jacomo, Jackson Co. | 303 | 109 | 122 | 39 | 6 | 11 | 3 | 20 | 13 | OP |
| 15. | Lake of the Ozarks, Camden and Miller Co. | 275 | 107 | 125 | 34 | 10 | 5 | 3 | 23 | 5 | OU |
| 16. | Limpp, Gentry Co. | 302 | 106 | 119 | 35 | 8 | 13 | 7 | 31 | 10 | TP |
| 17. | Lincoln, Lincoln Co. | 183 | 78 | 87 | 30 | 3 | 3 | 1 | 12 | 2 | TP |
| 18. | Little Dixie, Callaway Co. | 142 | 55 | 58 | 19 | 3 | 4 | 4 | 9 | 4 | TP |
| 19. | Little Prairie, Phelps Co. | 107 | 31 | 42 | 8 | 5 | 3 | 2 | 13 | 3 | OU |
| 20. | Mark Twain, Monroe Co. | 87 | 34 | 35 | 11 | 2 | 2 | 1 | 6 | 1 | TP |
| 21. | Miller, Carter Co. | 23 | 5 | 7 | 2 | 1 | 1 | 1 | 4 | 1 | OU |
| 22. | Montrose, Henry Co. | 842 | 70 | 352 | 87 | 32 | 39 | 10 | 311 | 6 | OP |
| 23. | Nodaway, Nodaway Co. | 236 | 104 | 105 | 29 | 8 | 6 | 4 | 10 | 5 | TP |
| 24. | Norfork, Ozark Co. | 390 | 204 | 206 | 42 | 23 | 4 | 2 | 4 | 3 | OU |
| 25. | Pomme de Terr, Hickory Co. | 260 | 116 | 125 | 27 | 14 | 3 | 2 | 6 | 5 | OU |
| 26. | Pony Express, De Kalb Co. | 206 | 84 | 89 | 27 | 5 | 5 | 4 | 13 | 4 | TP |
| 27. | Prairie Lee, Jackson Co. | 374 | 120 | 140 | 45 | 7 | 19 | 3 | 24 | 22 | OP |
| 28. | Rockhouse, Stoddard Co. | 104 | 38 | 39 | 8 | 5 | 3 | 3 | 3 | 4 | SL |
| 29. | Sims, Howell Co. | 50 | 18 | 19 | 4 | 2 | 1 | 2 | 2 | 2 | OU |
| 30. | Sterling, Chariton Co. | 194 | 76 | 81 | 24 | 5 | 4 | 4 | 7 | 5 | TP |

| | Location | SC | Alk | Total | Ca | Mg | Na | K | $SO_4$ | Cl | Area |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 31. | Stockton, Cedar Co. | 266 | 116 | 125 | 39 | 7 | 2 | 2 | 9 | 5 | OU |
| 32. | Table Rock, Stone Co. | 201 | 89 | 93 | 29 | 5 | 2 | 1 | 5 | 4 | OU |
| 33. | Taneycomo, Taney Co. | 223 | 100 | 105 | 34 | 5 | 2 | 1 | 5 | 4 | OU |
| 34. | Tapawingo, Jackson Co. | 297 | 111 | 121 | 41 | 5 | 11 | 3 | 17 | 13 | OP |
| 35. | Taum Sauk, Reynolds Co. | 148 | 66 | 72 | 14 | 9 | 1 | 1 | 7 | 1 | OU |
| 36. | Thomas Hill, Macon Co. | 373 | 63 | 149 | 43 | 10 | 10 | 3 | 89 | 4 | TP |
| 37. | Thunderhead, Putnam Co. | 245 | 93 | 101 | 30 | 6 | 6 | 5 | 16 | 5 | TP |
| 38. | Tri City, Boone Co. | 103 | 37 | 39 | 12 | 2 | 3 | 2 | 7 | 3 | TP |
| 39. | Trimble, Clay and Clinton Co. | 244 | 102 | 109 | 33 | 6 | 6 | 4 | 15 | 4 | TP |
| 40. | Tywappity, Scott Co. | 78 | 33 | 33 | 8 | 3 | 1 | 3 | 2 | 2 | SL |
| 41. | Vandalia, Audrain Co. | 129 | 55 | 56 | 17 | 3 | 3 | 4 | 5 | 3 | TP |
| 42. | Wakonda, Lewis Co. | 317 | 124 | 140 | 31 | 15 | 8 | 3 | 23 | 11 | TP |
| 43. | Wappapello, Wayne Co. | 239 | 105 | 115 | 23 | 14 | 3 | 2 | 9 | 4 | OU |

[a]mean of three samples rounded to the nearest whole number

The mineral content of water in Missouri reservoirs varies over a wide range (Table 2). For most parameters the mean and median values are similar indicating a near normal distribution. The chemical composition of Nodaway Reservoir,

Table 2. Mean and standard error, median and range of water chemistry parameters measured on 43 Missouri reservoirs in fall 1975.

| Parameter | Mean | Standard Error | Median | Range |
|---|---|---|---|---|
| Specific conductance micromhos/cm at 25 C | 229 | 20.2 | 236 | 23 - 842 |
| Total alkalinity as mg/l $CaCO_3$ | 82 | 5.7 | 89 | 5 - 204 |
| Total hardness as mg/l $CaCO_3$ | 99 | 8.8 | 105 | 7 - 352 |
| Calcium mg/l | 27 | 2.3 | 29 | 1 - 87 |
| Magnesium mg/l | 7 | 0.9 | 6 | 1 - 32 |
| Sodium mg/l | 6 | 1.0 | 4 | 1 - 39 |
| Potassium mg/l | 3 | 0.3 | 3 | 1 - 10 |
| Sulfate mg/l | 22 | 7.2 | 10 | 1 - 311 |
| Chloride mg/l | 5 | 0.6 | 4 | 1 - 22 |

Nodaway Co., is representative of median concentrations in Missouri reservoirs (Table 1). Specific conductance, hardness, Ca, and $SO_4$ concentrations in Nodaway Reservoir are median values for the sampled reservoirs (Table 2) and concentrations of the other parameters are near median. The ionic concentration (in meq/l) of Montrose Reservoir is 50 times higher than Miller Reservoir (Table 1). These water bodies represent the extremes measured within the state. Eighty percent of the reservoirs sampled had alkalinities above 40 mg/1, the concentration used by Moyle (1956) to separate hard and soft water lakes in Minnesota. Values in Missouri are similar to the chemical range found in surface waters of other mid-continent states (Juday and Birge 1933; Lohuis, *et al.*, 1938; Moyle, 1956; Carlander, *et al.*, 1963; Bachmann, 1965).

To analyze for regional differences, data were separated by location into the four physiographic regions of Missouri (Table 1, Figure 1). The four regions are: (1) the Dissected Till Plains, including all of Missouri north of the Missouri River, the maximum limit of glaciation; (2) the Osage Plains, an unglaciated

plain in western Missouri; (3) the Ozark Uplands, elevated country lying in southeastern Missouri; (4) the Southeastern Lowlands, the northern extremity of the Mississippi Embayment, a vast alluvial plain. The physical features of these regions are described by Fenneman (1938) and Pflieger (1971). Mean values by region are given in Table 3. Data from Montrose and Thomas Hill reservoirs were eliminated from the analysis because of sulfuric acid pollution from the strip mines within the watersheds (Brezina, *et al.*, 1970).

Table 3. Mean water chemistry values of reservoir waters within the four physiographic regions of Missouri.[a]

| Parameter | Physiographic Region | | | |
|---|---|---|---|---|
| | Dissected Till Plains (N = 18) | Osage Plains (N = 5) | Ozark Uplands (N = 15) | Southeastern Lowlands (N = 3) |
| Specific conductance micromhos/cm at 25 C | 206 | 307 | 211 | 77 |
| Total alkalinity as mg/l $CaCO_3$ | 78 | 107 | 92 | 30 |
| Total hardness as mg/l $CaCO_3$ | 86 | 126 | 99 | 31 |
| Calcium mg/l | 25 | 40 | 24 | 7 |
| Magnesium mg/l | 6 | 6 | 9 | 3 |
| Sodium mg/l | 6 | 11 | 3 | 2 |
| Potassium mg/l | 3 | 3 | 2 | 2 |
| Sulfate mg/l | 14 | 26 | 9 | 3 |
| Chloride mg/l | 6 | 11 | 4 | 2 |

[a]Data from Montrose and Thomas Hill reservoirs are omitted.

Analysis of variation in sample values among lakes within any region indicated that lakes were a significant source of variation compared to sampling error ($P > 0.025$); the one exception was significant inherent variation for $SO_4$ among lakes in the Southeastern Lowlands. Thus, means were used to represent parameters for any given lake. Further analysis indicated that variation in the value of any parameter among lakes within a region was dominated by significant variation among regions ($P > 0.025$). Independent t-tests were used to further

test differences of mean chemical concentrations among the four physiographic regions (Table 4). The comparisons made were: (1) the Southeastern Lowlands vs the means of the three other regions, (2) the Osage Plains vs the mean of the Dissected Till Plains and Ozark Uplands, and (3) the Dissected Till Plains vs the Ozark Uplands.

Table 4. Results of t-tests of mean water chemistry values measured in reservoirs located on the Dissected Till Plains, the Osage Plains, the Ozark Uplands and the Southeastern Lowlands.[a]

| | Comparisons of: | | |
|---|---|---|---|
| Parameter | Southeastern Lowlands vs Dissected Till Plains, Osage Plains, Ozark Uplands | Osage Plains vs Dissected Till Plains Ozark Uplands | Dissected Till Plains vs Ozark Uplands |
| Specific conductance micromhos/cm at 25 C | X | X | |
| Total alkalinity as mg/l $CaCO_3$ | X | | |
| Total hardness as mg/l $CaCO_3$ | X | | |
| Calcium mg/l | X | X | |
| Magnesium mg/l | | | X |
| Sodium mg/l | X | X | X |
| Potassium mg/l | | | X |
| Sulfate mg/l | X | X | |
| Chloride mg/l | | X | |

[a] X indicates significant difference at P = 0.01.

Collectively, reservoirs in the Southeastern Lowlands have the lowest ion concentrations found within the four physiographic regions. Only Mg, K, and Cl concentrations did not differ significantly from other surface waters measured (Table 3). Mineral content is generally greatest in the Osage Plains region. Specific conductance, Ca, Na, $SO_4$ and Cl values were highest in this region. Reservoirs in the Dissected Till Plains and Ozark Uplands are chemically similar. Waters in the Dissected Till Plains have significantly lower Mg concentrations and significantly higher Na and K concentrations than in the Ozark Uplands.

Similar results were obtained in comparisons of published water chemistry values from rivers within three of the physiographic regions (U.S.G.S., 1974) (Table 5). Water chemistry data was not available from rivers in the Osage Plains to make comparisons. An analysis of variance test indicated that for all parameters difference among rivers within a region was dominated by the significant variation among regions ($P > 0.025$). Independent t-test comparisons among the Southeastern Lowlands, Ozark Uplands and Dissected Till Plains rivers are identical to reservoir comparisons except $SO_4$ and Cl concentrations were significantly greater in the Dissected Till Plains than the Ozark Uplands and Mg concentrations were not significantly different between these regions (Table 6). Rivers tend to have higher ion concentrations than reservoirs within each of the regions.

Differences in mineral content of waters among physiographic regions in Missouri can be related to the water-bearing earth materials in these areas. Because surface streams and ground waters are inter-connected, comparisons of ground water quality within the state are similar to the surface waters (Stout and Hoffman, 1973). The softest waters within the state are associated with the McNairy sands in the Southeast Lowlands. In the Osage Plains, high concentrations of dissolved substances can be ascribed to the low permeability of shales in this region and thus the long residence time of ground water. Similar to the surface waters, ground waters in the Osage Plains contain the highest concentrations of Na, $SO_4$ and Cl within the state. The calcium-magnesium bicarbonate waters of the Dissected Till Plains and, the Ozark Uplands are typical of hard waters associated, respectively, with glacial outwash sediments and carbonate-sandstone bedrock (Stout and Hoffman, 1973).

The biological significance of differences in water chemistry found among the physiographic regions of Missouri is unknown. Pflieger (1971) found the distribution of Missouri fishes can be separated into faunal regions which correspond closely to major physiographic subdivisions. Physical characteristics (such as temperature, flow, turbidity, and bottom type) and competition among species are important factors controlling fish distribution (Pflieger, 1971). The gradients in these environmental factors likely obscure any possible effects of water chemistry. Aquatic production, however, would be expected to differ among Missouri reservoirs based upon morphometric differences and the wide range of total ion concentration and alkalinity (Moyle, 1956: Ryder *et al.*, 1974).

The foregoing relationship between water chemistry and the four physiographic regions within Missouri should be considered a holistic approach to explain the observed differences and similarities in chemical content among surface waters within the physiographic regions. Because of variation in chemical concentrations among lakes within each region this relationship should be used with caution as a basis for comparing the chemical composition of individual water bodies within or between regions.

Table 5. Mean water chemistry of rivers in the Dissected Till Plains, Ozark Uplands and Southeastern Lowlands.[a]

| Location | Specific Conductance micromhos/cm at 25 C | Total Alkalinity as mg/l $CaCO_3$ | Total Hardness as mg/l $CaCO_3$ | Calcium mg/l | Magnesium mg/l | Sodium mg/l | Potassium mg/l | Sulfate mg/l | Chloride mg/l |
|---|---|---|---|---|---|---|---|---|---|
| Dissected Till Plains | | | | | | | | | |
| North River, Marion Co. | 384 | 135 | 194 | 53 | 10 | 9 | 4 | 42 | 8 |
| Salt River, Ralls Co. | 341 | 102 | 136 | 43 | 8 | 12 | 4 | 41 | 12 |
| Cuivre River, Lincoln Co. | 346 | 128 | 153 | 48 | 8 | 7 | 4 | 27 | 8 |
| Nodaway River, Holt Co. | 397 | 158 | 185 | 52 | 13 | 11 | 3 | 36 | 8 |
| Platte River, Platte Co. | 393 | 156 | 177 | 53 | 11 | 12 | 4 | 36 | 9 |
| Thompson River, Livingston Co. | 414 | 170 | 192 | 57 | 12 | 11 | 4 | 38 | 7 |
| Grand River, Charlton Co. | 382 | 155 | 175 | 54 | 10 | 10 | 4 | 34 | 6 |
| Charlton River, Charlton Co. | 300 | 99 | 136 | 40 | 9 | 8 | 4 | 47 | 5 |
| E. Fork Charlton River, Macon Co. | 315 | 100 | 132 | 39 | 9 | 12 | 3 | 48 | 6 |
| Mean | 363 | 134 | 164 | 49 | 10 | 10 | 4 | 39 | 8 |
| Ozark Uplands | | | | | | | | | |
| Meramec River, Franklin Co. | 300 | 147 | 156 | 32 | 18 | 3 | 1 | 9 | 3 |

| | SC | Alk | Hard | Ca | Mg | Na | K | $SO_4$ | Cl |
|---|---|---|---|---|---|---|---|---|---|
| Ozark Uplands | | | | | | | | | |
| Bourbeuse River, Franklin Co. | 242 | 95 | 113 | 23 | 13 | 4 | 2 | 19 | 4 |
| Big River, Jefferson Co. | 400 | 190 | 202 | 43 | 23 | 4 | 1 | 18 | 4 |
| Meramec River, Jefferson Co. | 344 | 146 | 162 | 36 | 17 | 7 | 2 | 19 | 9 |
| James River, Christian Co. near Wilson Creek, MO. | 325 | 144 | 156 | 52 | 6 | 5 | 2 | 9 | 7 |
| James River, Christian Co. near Boaz, MO. | 400 | 160 | 172 | 60 | 5 | 11 | 2 | 13 | 14 |
| Finley Creek, Christian Co. | 306 | 140 | 152 | 50 | 7 | 4 | 2 | 6 | 6 |
| Current River, Ripley Co. | 285 | 148 | 150 | 30 | 18 | 2 | 1 | 4 | 2 |
| Fourche River, Randolph Co. | 401 | 218 | 222 | 45 | 27 | 2 | 1 | 6 | 2 |
| Spring River, Oregon Co. | 435 | 226 | 238 | 50 | 27 | 2 | 1 | 7 | 2 |
| Eleven Point River, Oregon Co. | 328 | 168 | 177 | 37 | 20 | 2 | 1 | 4 | 2 |
| Spring River, Jasper Co. | 262 | 103 | 122 | 44 | 3 | 5 | 2 | 14 | 6 |
| Center Creek, Jasper Co. near Carterville, MO. | 307 | 113 | 133 | 44 | 2 | 5 | 1 | 15 | 7 |
| Center Creek, Jasper Co. near Smithville, MO. | 353 | 107 | 163 | 61 | 3 | 6 | 2 | 44 | 6 |
| Lost Creek, Newton Co. | 229 | 100 | 109 | 41 | 1 | 3 | 1 | 7 | 4 |
| Elk River, McDonald Co. | 258 | 118 | 126 | 46 | 2 | 3 | 1 | 6 | 4 |
| Buffalo Creek, McDonald Co. | 253 | 109 | 117 | 45 | 1 | 4 | 2 | 8 | 5 |
| Current River, Shannon Co. | 251 | 120 | 126 | 27 | 15 | 2 | 1 | 7 | 3 |

| | SC | Alk | Hard | Ca | Mg | Na | K | $SO_4$ | Cl |
|---|---|---|---|---|---|---|---|---|---|
| Jacks Fork River, Shannon Co. | 317 | 161 | 162 | 33 | 20 | 1 | 1 | 4 | 2 |
| Mean | 316 | 143 | 156 | 42 | 12 | 4 | 1 | 11 | 5 |
| Southeastern Lowlands | | | | | | | | | |
| Headwater Diversion, Cape Girardeau Co. | 209 | 94 | 101 | 23 | 11 | 3 | 1 | 8 | 3 |
| St. Francis River, Clay Co. AK | 167 | 71 | 77 | 17 | 8 | 3 | 2 | 11 | 3 |
| Black River, Butler Co. | 197 | 95 | 104 | 22 | 11 | 3 | 1 | 8 | 3 |
| Little Black River, Ripley Co. | 202 | 96 | 102 | 21 | 12 | 2 | 1 | 5 | 2 |
| Mean | 194 | 89 | 96 | 21 | 10 | 3 | 1 | 8 | 3 |

[a] 1974 yearly averages (U.S.G.S., 1974)

Table 6. Results of t-tests of mean water chemistry values measured in rivers within the Dissected Till Plains, the Ozark Uplands, and the Southeastern Lowlands.[a]

| | Comparisons of: | |
|---|---|---|
| Parameter | Southeastern Lowlands vs Dissected Till Plains Ozark Uplands | Dissected Till Plains vs Ozark Uplands |
| Specific conductance micromhos/cm at 25 C | X | |
| Total alkalinity as mg/l $CaCO_3$ | X | |
| Total hardness as mg/l $CaCO_3$ | X | |
| Calcium mg/l | X | |
| Magnesium mg/l | | |
| Sodium mg/l | X | X |
| Potassium mg/l | X | X |
| Sulfate mg/l | X | X |
| Chloride mg/l | | X |

[a] X indicates significant difference at P = 0.01

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