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# FLUCTUATIONS AND RELATIONSHIPS OF SELECTED PHYSICOCHEMICAL PARAMETERS IN DARDANELLE RESERVOIR, ARKANSAS, 1975-1982

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## ABSTRACT

Annual and seasonal fluctuations and relationships are described for discharge, turbidity, chloride, total hardness, conductivity and suspended solids over an eight-year period in Dardanelle Reservoir. The parameters fluctuated rather widely primarily in response to seasonal patterns of rainfall. Chloride and conductivity were related and generally fluctuated together as did turbidity and suspended solids. Hardness appeared to vary independently of the others prior to 1979 then varied more closely with chloride after March 1979. Inherent differences between the Illinois Bayou arm and the main Arkansas River sections complicated the precise identification of any overall impact of power plant operation. No significant long term changes were seen, but chloride declined gradually whereas hardness and conductivity increased slightly. Suspended solids exhibited a significant rise in 1982.

## INTRODUCTION

Dardanelle Reservoir is located in west-central Arkansas on the main stem of the Arkansas River near the city of Russellville. The reservoir was constructed approximately 20 years ago by the U.S. Army Corps of Engineers as a part of the Kerr-McClellan Arkansas River Navigation System. The lake has a surface area of approximately 13,720 ha, a shoreline of 510 km, a volume of 656 million m<sup>3</sup> and a mean depth of 4.3 m (range to 16.5 m). The normal pool level stands at 103.3 m (339 ft) above MSL, and the rate of fall is approximately 0.2 m/km. The mean long term river discharge (Q) at this point is 1103 cubic meters/sec (cms) making the average residence time 6.9 days. However, during this study period the average Q was 773.4 and 770.4 cms if calculated from monthly means and sample day means, respectively (USGS 1975-1982). The watershed of the reservoir proper comprises approximately 40,000 ha and contains a variety of natural and man-made environments including areas of mature hardwood, coniferous and mixed forest, row cropping, cattle farming, orchards, timber removal, light industry and limited urban development.

In the late 1960's Arkansas Power and Light Company began construction on a two-unit nuclear generating facility. In conjunction an environmental monitoring program was begun in 1969. Unit I, which began commercial operation in December 1974, utilizes an 875 megawatt dynamo which uses once-through circulation of lake water for condenser cooling at a rate exceeding 48 cms. The primary goal of this project was to identify and quantify any physicochemical or biological changes, especially those caused or accelerated by the operation of Unit I. Other than USGS Water Data (1975-1982), few literature sources are available that report general survey characteristics. Chittenden (1979, 1980) and Chittenden and McFadden (1978) reported on radionuclides, total dissolved solids and selected cations in Dardanelle Reservoir.

## METHODS

Although there have been minor changes in procedures over the years, the general protocol of this project involved monthly sampling at stations 1 (discharge), 5 (mouth of discharge bay into the main part of the lake), 16 (intake) and 21 (upstream control) (Figure 1). The average depths at these stations were 3 m, 3 m, 3.5 m and 12 m, respectively. The water level fluctuated 0.3 m up or down in response to runoff and channel dredging. Water samples from 0.6 m and near the bottom at each station were tested. Turbidity was measured on site, whereas the others were measured in the laboratory. The samples were transported

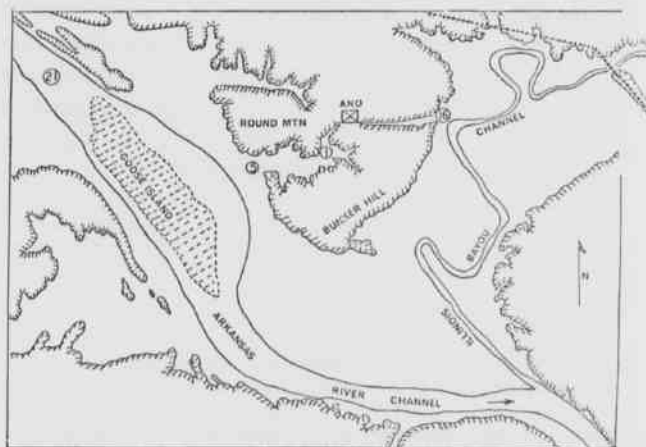


Figure 1. Outline map of Dardanelle Reservoir with key sampling stations, 1975-1982.

on ice and refrigerated continuously until analyzed within three days after collection. All chemical tests were performed according to methods recommended by Standard Methods (1975) as adapted by Hach Chemical Company.

## RESULTS AND DISCUSSION

The individual data collected during this project were too numerous to list in this report. After monthly means and ranges were determined for the six parameters, the months were ranked from highest to lowest by station and test, assigned a rank value from 1 to 12, and the rank values were summed (Tables 1-3). Our data compare favorably with periodic but incomplete readings of conductivity, turbidity and suspended solids reported at the USGS gauging station immediately below the Dardanelle Dam.

Discharge readings (Q) on sampling dates from USGS (1975-1982) data were averaged by month (Table 1). The years 1977 and 1981 experienced dry springs and wet autumns, whereas the other years followed the more expected trend of wet springs and dry autumns. Perhaps the most astonishing fluctuation occurred in 1975 between June and

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Table 1. Monthly Means of Physicochemical Data, Dardanelle Reservoir, Arkansas, 1975-1982. Q is given in cubic meters/sec; conductivity in micromhos; others in mg/l.

| Station          | Q    | Turb | Sus Sol | Chloride | Hard  | Cond  |
|------------------|------|------|---------|----------|-------|-------|
| <b>JANUARY</b>   |      |      |         |          |       |       |
| 1                | 461  | 21.8 | 11.4    | 93.6     | 74.4  | 467.1 |
| 5                |      | 21.3 | 13.8    | 83.5     | 85.3  | 522.7 |
| 16               |      | 20.2 | 14      | 84.3     | 81    | 492.3 |
| 21               |      | 18.9 | 16      | 139.5    | 105.2 | 670.5 |
| <b>FEBRUARY</b>  |      |      |         |          |       |       |
| 1                | 688  | 37.1 | 25.4    | 77       | 71    | 384.9 |
| 5                |      | 27   | 17.2    | 110.1    | 95.2  | 517.9 |
| 16               |      | 26   | 22.7    | 81.9     | 71.3  | 475.1 |
| 21               |      | 23.7 | 33.4    | 136.6    | 94.6  | 597.1 |
| <b>MARCH</b>     |      |      |         |          |       |       |
| 1                | 1540 | 40.6 | 25.2    | 79.8     | 70.2  | 352.3 |
| 5                |      | 46.6 | 31      | 106.3    | 82.2  | 494   |
| 16               |      | 37.5 | 39.4    | 55.6     | 61.1  | 380.1 |
| 21               |      | 39.3 | 32.3    | 124.2    | 116.6 | 647.7 |
| <b>APRIL</b>     |      |      |         |          |       |       |
| 1                | 918  | 31.5 | 15.6    | 81.2     | 56.7  | 362.3 |
| 5                |      | 47.6 | 30.6    | 110.7    | 75.5  | 429.2 |
| 16               |      | 29.8 | 22.9    | 88.1     | 54.9  | 413.2 |
| 21               |      | 50.7 | 32.9    | 178.8    | 92.2  | 545.1 |
| <b>MAY</b>       |      |      |         |          |       |       |
| 1                | 1353 | 44.9 | 22      | 73.7     | 84    | 397.6 |
| 5                |      | 61.6 | 39.1    | 83.5     | 104.5 | 469.9 |
| 16               |      | 41.6 | 15.4    | 74.4     | 80.4  | 462.3 |
| 21               |      | 81   | 36.4    | 103.4    | 107.1 | 520.1 |
| <b>JUNE</b>      |      |      |         |          |       |       |
| 1                | 1361 | 32.5 | 16.4    | 172.1    | 93.6  | 669.2 |
| 5                |      | 49.9 | 29.7    | 192.2    | 100.9 | 718.6 |
| 16               |      | 29.6 | 12.4    | 92.2     | 94.1  | 540.4 |
| 21               |      | 49.9 | 30.1    | 226.4    | 116.1 | 843.7 |
| <b>JULY</b>      |      |      |         |          |       |       |
| 1                | 909  | 24.4 | 19.6    | 144.3    | 114.4 | 722.3 |
| 5                |      | 41.1 | 26.6    | 131.9    | 112.6 | 701.1 |
| 16               |      | 18.1 | 12.4    | 168.6    | 116.9 | 725.6 |
| 21               |      | 35.6 | 21.9    | 129.9    | 124.1 | 750.1 |
| <b>AUGUST</b>    |      |      |         |          |       |       |
| 1                | 432  | 20.1 | 13.6    | 148.2    | 127.8 | 681.4 |
| 5                |      | 28.8 | 16.4    | 157.4    | 119.8 | 704.1 |
| 16               |      | 18.4 | 12.7    | 109      | 118.4 | 764.4 |
| 21               |      | 29.9 | 18.8    | 190.7    | 130.5 | 715.4 |
| <b>SEPTEMBER</b> |      |      |         |          |       |       |
| 1                | 244  | 18.6 | 11.3    | 164.5    | 122.5 | 762.2 |
| 5                |      | 29.6 | 21.5    | 163.8    | 128.5 | 744.3 |
| 16               |      | 17.2 | 18.1    | 139.8    | 124.8 | 852.7 |
| 21               |      | 21.4 | 14.4    | 162.6    | 142.6 | 761.8 |
| <b>OCTOBER</b>   |      |      |         |          |       |       |
| 1                | 235  | 29.7 | 25.2    | 144.4    | 119.4 | 739.1 |
| 5                |      | 31.1 | 21      | 147.4    | 118.1 | 723.3 |
| 16               |      | 22.7 | 16.8    | 169.9    | 115.2 | 804.7 |
| 21               |      | 31.9 | 20.2    | 144.8    | 120.8 | 713.6 |
| <b>NOVEMBER</b>  |      |      |         |          |       |       |
| 1                | 404  | 19.6 | 11.5    | 143.3    | 120   | 704.7 |
| 5                |      | 22.1 | 16.4    | 143.9    | 128.7 | 683.1 |
| 16               |      | 19.1 | 11.6    | 180.7    | 123   | 762.2 |
| 21               |      | 23.7 | 15.6    | 138.3    | 122.8 | 687.7 |
| <b>DECEMBER</b>  |      |      |         |          |       |       |
| 1                | 344  | 22.8 | 17.1    | 114.9    | 91.2  | 549.5 |
| 5                |      | 25.1 | 14.3    | 124.6    | 96.9  | 566.8 |
| 16               |      | 22.8 | 12.3    | 123      | 90.2  | 622.7 |
| 21               |      | 26.6 | 14.8    | 121.1    | 108.4 | 609.1 |

Table 2. Monthly Ranges of Physicochemical Data, Dardanelle Reservoir, Arkansas, 1975-1982. Q is given in cubic meters/sec; conductivity in micromhos; others in mg/l.

| Station          | Q        | Turb   | S.S.  | Chloride | Hard   | Cond     |
|------------------|----------|--------|-------|----------|--------|----------|
| <b>JANUARY</b>   |          |        |       |          |        |          |
| 1                | 17-1543  | 8-52   | 2-28  | 37-195   | 25-176 | 268-805  |
| 5                |          | 8-44   | 2-55  | 8.5-148  | 14-170 | 316-1025 |
| 16               |          | 5-38   | 0-35  | 40-138   | 22-169 | 266-800  |
| 21               |          | 5-32   | 4-38  | 52-206   | 28-206 | 428-1198 |
| <b>FEBRUARY</b>  |          |        |       |          |        |          |
| 1                | 15-1594  | 6-140  | 4-93  | 21-126   | 30-150 | 164-705  |
| 5                |          | 4-72   | 5-42  | 56-180   | 51-152 | 359-710  |
| 16               |          | 3-80   | 6-50  | 38-125   | 36-145 | 326-695  |
| 21               |          | 10-44  | 4-40  | 57-300   | 48-142 | 420-832  |
| <b>MARCH</b>     |          |        |       |          |        |          |
| 1                | 148-3075 | 12-96  | 8-52  | 10-174   | 26-117 | 62-656   |
| 5                |          | 19-90  | 9-60  | 42-203   | 40-142 | 251-884  |
| 16               |          | 14-110 | 6-102 | 9-115    | 18-116 | 52-732   |
| 21               |          | 19-97  | 8-82  | 52-182   | 79-166 | 346-1115 |
| <b>APRIL</b>     |          |        |       |          |        |          |
| 1                | 80-2270  | 12-49  | 0-42  | 32-228   | 12-104 | 215-678  |
| 5                |          | 16-72  | 4-52  | 44-300   | 34-136 | 290-760  |
| 16               |          | 16-50  | 5-45  | 38-225   | 10-116 | 265-720  |
| 21               |          | 18-85  | 1-58  | 45-348   | 34-158 | 350-782  |
| <b>MAY</b>       |          |        |       |          |        |          |
| 1                | 84-2733  | 22-78  | 9-38  | 40-130   | 14-230 | 254-638  |
| 5                |          | 42-95  | 18-95 | 47-158   | 30-232 | 310-666  |
| 16               |          | 18-65  | 6-26  | 46-130   | 24-208 | 298-626  |
| 21               |          | 58-109 | 16-68 | 48-252   | 32-275 | 353-762  |
| <b>JUNE</b>      |          |        |       |          |        |          |
| 1                | 201-3401 | 20-70  | 7-30  | 47-450   | 63-150 | 345-1020 |
| 5                |          | 35-82  | 6-64  | 60-500   | 62-146 | 490-1015 |
| 16               |          | 14-50  | 4-22  | 44-180   | 62-131 | 338-852  |
| 21               |          | 35-79  | 14-70 | 68-455   | 62-162 | 605-1055 |
| <b>JULY</b>      |          |        |       |          |        |          |
| 1                | 329-2526 | 0-50   | 2-56  | 76-372   | 58-146 | 484-948  |
| 5                |          | 6-70   | 5-52  | 75-262   | 56-158 | 515-990  |
| 16               |          | 3-29   | 0-21  | 76-448   | 21-164 | 620-920  |
| 21               |          | 5-50   | 4-34  | 70-199   | 50-179 | 585-1174 |
| <b>AUGUST</b>    |          |        |       |          |        |          |
| 1                | 101-818  | 9-30   | 5-25  | 88-331   | 57-179 | 512-990  |
| 5                |          | 20-42  | 4-32  | 97-402   | 56-177 | 505-950  |
| 16               |          | 9-34   | 0-32  | 86-139   | 47-182 | 591-995  |
| 21               |          | 14-48  | 12-38 | 102-580  | 56-176 | 502-948  |
| <b>SEPTEMBER</b> |          |        |       |          |        |          |
| 1                | 3.7-1156 | 9-30   | 0-22  | 98-420   | 42-176 | 560-885  |
| 5                |          | 20-50  | 4-42  | 94-420   | 45-180 | 550-870  |
| 16               |          | 10-22  | 8-40  | 104-188  | 38-174 | 700-958  |
| 21               |          | 13-42  | 5-32  | 98-405   | 76-194 | 590-892  |
| <b>OCTOBER</b>   |          |        |       |          |        |          |
| 1                | 26-643   | 15-75  | 2-56  | 94-318   | 42-176 | 545-806  |
| 5                |          | 23-58  | 2-32  | 92-312   | 42-174 | 540-873  |
| 16               |          | 12-46  | 5-35  | 102-312  | 36-184 | 670-916  |
| 21               |          | 16-60  | 1-45  | 92-300   | 44-171 | 560-938  |
| <b>NOVEMBER</b>  |          |        |       |          |        |          |
| 1                | 2.5-1411 | 8-38   | 0-22  | 103-288  | 36-189 | 355-860  |
| 5                |          | 6-46   | 2-32  | 74-324   | 34-235 | 358-915  |
| 16               |          | 12-35  | 1-32  | 104-278  | 34-192 | 605-930  |
| 21               |          | 4-59   | 0-40  | 94-302   | 35-172 | 368-889  |
| <b>DECEMBER</b>  |          |        |       |          |        |          |
| 1                | 113-649  | 6-60   | 0-60  | 24-180   | 30-174 | 178-862  |
| 5                |          | 10-60  | 0-44  | 30-185   | 30-172 | 264-870  |
| 16               |          | 12-59  | 0-42  | 38-178   | 29-172 | 224-890  |
| 21               |          | 8-56   | 1-44  | 55-180   | 30-180 | 414-902  |

September when Q declined from 3400 to 3.7 cms. Another sharp decline occurred in 1980 between May and November.

Turbidity and Q values were strongly correlated except during 1976, 1977 and 1981 (Table 4). Turbidity varied considerably among the stations, months and years, but May clearly gave the highest readings, whereas September showed the lowest readings by a slight margin under January and November. These fluctuations closely followed periods of abundant and sparse rainfall, respectively. Typically the Illinois Bayou arm contained less turbid water than the Arkansas River section, but rainfall created variations. A general heavy rain elevated the turbidity at all stations, whereas a local storm in the foothills north of Russellville would cause greater turbidity only in the Illinois Bayou arm. Several

times a rainfall in part of the upper Arkansas River basin would strongly elevate turbidity in the main section of the lake. Using turbidity measurements we observed one aspect of mixing accomplished by passage through the plant. Station 5 typically showed a layering effect produced when the warmer, less turbid water from station 16 came from the discharge and flowed out over the top of the Arkansas River water.

## Fluctuations and Relationships of Selected Physicochemical Parameters in Dardanelle Reservoir, Arkansas

Table 3. Cumulative Ranking Values for Months Listed from Highest to Lowest Physicochemical Concentrations, Dardanelle Reservoir, Arkansas, 1975-1982.

| Variables | 1975 |       |       | 1976 |      |       | 1977 |       |       |
|-----------|------|-------|-------|------|------|-------|------|-------|-------|
|           | n    | r     | p     | n    | r    | p     | n    | r     | p     |
| Q vs T    | 12   | .899  | .0001 | 12   | .332 | .1457 | 11   | -.135 | .3467 |
| Q vs SS   | 12   | .581  | .0228 | 12   | .326 | .1505 | 11   | -.179 | .3015 |
| Q vs Cl   | 12   | -.561 | .0278 | 12   | .271 | .2015 | 11   | -.554 | .0374 |
| Q vs H    | 12   | -.049 | .4366 | 12   | .103 | .3735 | 11   | .529  | .0459 |
| Q vs C    | 12   | -.510 | .0439 | 12   | .107 | .3697 | 11   | .494  | .0600 |
| T vs SS   | -    | -     | -     | 36   | .842 | .0001 | 29   | .092  | .3175 |
| T vs Cl   | 37   | -.572 | .0002 | 36   | .459 | .0016 | 32   | -.030 | .4356 |
| T vs H    | 34   | .136  | .2260 | 36   | .077 | .3050 | 32   | .285  | .0305 |
| T vs C    | 36   | -.344 | .0189 | 36   | .254 | .0554 | 28   | -.021 | .4548 |
| SS vs Cl  | -    | -     | -     | 37   | .471 | .0018 | 32   | -.150 | .2190 |
| SS vs H   | -    | -     | -     | 36   | .252 | .0675 | 32   | -.034 | .4268 |
| SS vs C   | -    | -     | -     | 36   | .405 | .0068 | 28   | -.044 | .4056 |
| Cl vs H   | 33   | -.091 | .3096 | 40   | .138 | .2024 | 32   | .616  | .0003 |
| Cl vs C   | 38   | .645  | .0001 | 40   | .727 | .0001 | 28   | -.881 | .0001 |
| H vs C    | 34   | .289  | .0469 | 40   | .431 | .0028 | 28   | .744  | .0001 |

| Variables | 1978 |       |       | 1979 |       |       | 1980 |       |       |
|-----------|------|-------|-------|------|-------|-------|------|-------|-------|
|           | n    | r     | p     | n    | r     | p     | n    | r     | p     |
| Q vs T    | 11   | .680  | .0102 | 12   | .925  | .0001 | 12   | .704  | .0052 |
| Q vs SS   | 11   | .623  | .0196 | 12   | .973  | .0001 | 12   | .759  | .0022 |
| Q vs Cl   | 11   | -.555 | .0374 | 12   | -.802 | .0010 | 12   | .050  | .4358 |
| Q vs H    | 11   | -.475 | .0688 | 12   | -.877 | .0002 | 12   | -.569 | .0257 |
| Q vs C    | 11   | -.658 | .0134 | 11   | -.884 | .0003 | 12   | -.413 | .0901 |
| T vs SS   | 34   | .841  | .0001 | 46   | .890  | .0001 | 48   | .778  | .0001 |
| T vs Cl   | 34   | -.406 | .0081 | 46   | -.690 | .0001 | 48   | .251  | .0408 |
| T vs H    | 43   | .285  | .0305 | 47   | -.727 | .0001 | 48   | -.269 | .0307 |
| T vs C    | 31   | -.366 | .0204 | 42   | -.738 | .0001 | 48   | -.094 | .2651 |
| SS vs Cl  | 34   | -.116 | .2593 | 46   | -.599 | .0001 | 48   | -.113 | .2250 |
| SS vs H   | 34   | .179  | .1554 | 46   | -.646 | .0001 | 48   | -.221 | .0637 |
| SS vs C   | 31   | -.162 | .1974 | 42   | -.673 | .0001 | 48   | -.118 | .2158 |
| Cl vs H   | 34   | .249  | .0759 | 45   | .950  | .0001 | 48   | .406  | .0022 |
| Cl vs C   | 31   | .737  | .0001 | 42   | .964  | .0001 | 48   | .661  | .0001 |
| H vs C    | 31   | .315  | .0404 | 42   | .971  | .0001 | 47   | .759  | .0001 |

| Variables | 1981 |       |       | 1982 |       |       |
|-----------|------|-------|-------|------|-------|-------|
|           | n    | r     | p     | n    | r     | p     |
| Q vs T    | 12   | .413  | .0901 | 12   | .592  | .0205 |
| Q vs SS   | 12   | .519  | .0406 | 12   | .366  | .1202 |
| Q vs Cl   | 12   | .268  | .2047 | 12   | -.394 | .1016 |
| Q vs H    | 12   | .044  | .4432 | 12   | -.398 | .0989 |
| Q vs C    | 12   | .146  | .3265 | 12   | -.339 | .1403 |
| T vs SS   | 48   | .434  | .0012 | 48   | .606  | .0001 |
| T vs Cl   | 48   | -.099 | .2553 | 48   | -.428 | .0014 |
| T vs H    | 48   | -.272 | .0291 | 48   | -.339 | .0088 |
| T vs C    | 48   | -.300 | .0180 | 48   | .051  | .3648 |
| SS vs Cl  | 48   | .179  | .1103 | 48   | -.202 | .0828 |
| SS vs H   | 48   | .272  | .0290 | 48   | -.408 | .0021 |
| SS vs C   | 48   | .073  | .3147 | 48   | -.302 | .0173 |
| Cl vs H   | 48   | .794  | .0001 | 48   | .704  | .0001 |
| Cl vs C   | 48   | .909  | .0001 | 48   | .918  | .0001 |
| H vs C    | 48   | .893  | .0001 | 48   | .789  | .0001 |

The intensity of this layering was regulated by the volume of water pumped through the plant, the direction of wind and the discharge of the river (Rickett and Watson, 1982). Turbidity at station 21 was greater than at station 16 10 of 12 months by a mean of 12.9 FTU's. Turbidity at station 1 was greater than at station 16 all months by a mean of 3.2 FTU's, which was probably not caused by current disturbance of the bottom sediment. Shortly after the plant began commercial operation, we began experiencing great difficulty obtaining a benthos sample at station 1 because the current had scoured the loose silt away leaving hard gray clay.

The greatest average concentration of suspended solids was measured in March with May showing a close second, whereas November had the lowest (Table 1). The late winter and spring months had the highest values, while the late fall and winter months had the lowest. Again station 21 had larger values than station 16 10 of 12 months by a mean

Table 4. Pearson Correlation Tests on Physicochemical Data, Dardanelle Reservoir, Arkansas, 1975-1982. Q = discharge; T = turbidity; SS = suspended solids; Cl = chloride; H = hardness; C = conductivity.

| Q      | Turb     | S.S.     | Chloride | Hard   | Cond   |
|--------|----------|----------|----------|--------|--------|
| Mar 12 | May 48   | Mar 42.5 | Jun 42   | Sep 46 | Sep 47 |
| Jun 11 | Mar 40   | May 40   | Sep 40   | Aug 43 | Oct 41 |
| May 10 | Apr 39   | Feb 38   | Aug 38   | Nov 42 | Jul 36 |
| Apr 9  | Jun 39   | Apr 36   | Oct 37   | Jul 35 | Aug 36 |
| Jul 8  | Oct 27   | Oct 30.5 | Nov 33   | Oct 34 | Jun 35 |
| Feb 7  | Feb 25.5 | Jun 26.5 | Jul 29   | Jun 26 | Nov 32 |
| Jan 6  | Jul 24   | Jul 26.5 | Apr 24   | Dec 22 | Dec 23 |
| Aug 5  | Dec 20   | Sep 18   | Dec 22   | May 20 | Jan 21 |
| Nov 4  | Aug 17   | Aug 17.5 | Jan 17.5 | Jan 15 | Feb 14 |
| Dec 3  | Nov 11.5 | Dec 13   | Feb 14   | Mar 13 | Mar 10 |
| Sep 2  | Jan 11   | Jan 13   | Mar 10   | Feb 12 | May 9  |
| Oct 1  | Sep 10   | Nov 10.5 | May 5.5  | Apr 4  | Apr 8  |

of 7.6 mg/l. There was no significant difference between stations 1 and 16 with respect to suspended solids. Pearson correlation analysis showed a strong positive correlation between turbidity and suspended solids (Table 4).

Chloride concentrations were highest in June and lowest in May, but there was much inconsistent variation month by month. Apparently the spring rainfall diluted the chloride concentration, which quickly recovered during the next month. There was more chloride at station 21 than 16, eight months out of 12 by a mean of 53.6 mg/l. There was no real difference between stations 16 and 1; the concentration was greater at station 1 five months out of 12 by a mean of 13.9 mg/l. Sinclair and Watson (1978) reported a somewhat stronger correlation between Q and chloride than our data, which show a weak positive correlation in 1976 and 1981, a significant positive correlation in 1977 and zero or negative correlations during the other years (Table 4). The location of a storm might help explain this fluctuating correlation. A localized heavy rain in western Arkansas should dilute the river water giving a negative correlation, whereas a rainfall in the major chloride source areas of eastern and northeastern Oklahoma would result in more chloride with the heavier discharge showing a positive correlation. The zero correlations would be observed with a generalized rainfall or a storm located in an intermediate area.

The greatest conductivity readings occurred in September, whereas the lowest values were obtained in April with May and March showing very low values. Conductivity values increased rather steadily between April and August and declined rather steadily between October and March. Station 21 had greater conductivity than 16 only seven months out of 12, but the mean difference was 109.4 micromhos. Station 16 had higher conductivity readings than station 1 during 11 of 12 months and was greater by a mean of 45.7 micromhos. Apparently the passage through the condenser circuit removed some of the ions. Pearson correlation tests showed a rather strong positive correlation between chloride and conductivity (Table 4). Generally minimum conductivity measurements were observed during the periods of greatest Q because of dilution, although the highest conductivity readings did not necessarily coincide with periods of lowest Q but occurred generally within two or three months following a peak Q reading.

Total hardness was also greatest in September and lowest in April, but the months between were arrayed differently than for conductivity. Station 21 showed higher values than station 16 11 of 12 months by a mean of 21.6 mg/l, but there was no significant difference between stations 1 and 16. Pearson correlations showed a moderate positive correlation between hardness and conductivity (Table 4).

Correlation may also be tested non-statistically using a rank matching technique. If two datasets are positively correlated perfectly, the rank-



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Table 5. Ranking Match Correlations (z), Compared with Mean Pearson r values from Table 3. Physicochemical data from Dardanelle Reservoir, Arkansas, 1975-1982.

| Variable                 | z    | 1/z  | Mean r |
|--------------------------|------|------|--------|
| Q vs turbidity           | 2.00 | .500 | .585   |
| Q vs susp. solids        | 2.33 | .429 | .496   |
| Q vs chloride            | 4.83 | .207 | .146   |
| Q vs hardness            | 5.50 | .182 | -.212  |
| Q vs conductivity        | 5.33 | .188 | -.257  |
| turbidity vs sus. solids | 1.33 | .752 | .640   |
| turbidity vs chloride    | 4.67 | .214 | -.182  |
| turbidity vs hardness    | 5.17 | .193 | -.018  |
| turbidity vs cond.       | 5.17 | .183 | -.190  |
| sus. solids vs chloride  | 5.00 | .200 | -.043  |
| sus. solids vs hardness  | 5.17 | .193 | -.087  |
| sus. solids vs cond.     | 5.42 | .184 | -.117  |
| chloride vs hardness     | 2.00 | .500 | .471   |
| chloride vs conductivity | 1.83 | .546 | .805   |
| hardness vs conductivity | 1.33 | .752 | .640   |

ing of items (months, in this case) should match perfectly. If the correlation is less than perfect and the two ranked lists (Table 3) are compared side by side, the number of positions each entry in the second list must be moved to match its counterpart in the first list should be an indication of the lack of correlation. The total number of positions the entries in the second list must be moved divided by the number of entries in the list yields the average number of positions moved per entry. This was done for each of the 15 possible correlation pairs. These values (z) may be inverted and compared with the Pearson correlation r values (Table 5). Inverted z values could range from zero to one, smaller decimals representing less correlation. While the Pearson r values may be negative (inverse correlation), inspection indicates z values less than about 0.2 show a beginning negative correlation. This shows turbidity and suspended solids and hardness and conductivity to be strongly correlated with a value of 0.752 each. Chloride and conductivity were moderately correlated at a value of 0.546, whereas chloride and hardness and Q and turbidity were correlated at a value of 0.500, each, and Q and suspended solids were correlated at 0.429.

Bi-annual means of Q declined from 904 to 660 cms, whereas the bi-annual means for chloride declined from 170 to 101 mg/l. Bi-annual means for hardness and conductivity increased from 94.4 to 133 mg/l and from 520 to 676 micromhos, respectively. Hardness showed one fluctuation, while the others exhibited uniform trends. Turbidity showed no long term tendency to change, and neither did suspended solids, except in 1982, which revealed a sharp rise.

T-tests (Table 6) showed no significant differences between stations 16 (intake) and 1 (discharge), although turbidity had a near-significant value of 0.1771. However there were significant differences between stations 16 and 21. All parameters except conductivity were significant at  $p = 0.05$  or below, and even conductivity had a lower p value than any test between stations 16 and 1.

Table 6. T-test results for Significant Differences Using Monthly Means of Physicochemical Data, Dardanelle Reservoir, Arkansas, 1975-1982.

| Parameter    | Sta 16 vs 21 |       | Sta 16 vs 1 |       |
|--------------|--------------|-------|-------------|-------|
|              | t            | p     | t           | p     |
| turbidity    | 1.940        | .0312 | 0.986       | .1771 |
| sus. solids  | 1.897        | .0340 | 0.108       | .4558 |
| chloride     | 2.282        | .0154 | 0.359       | .3616 |
| hardness     | 2.496        | .0097 | 0.114       | .4529 |
| conductivity | 1.154        | .1301 | 0.621       | .2738 |

Compared with eutrophic Big Bear Lake (California) (Siegfried, et al., 1982) total hardness was lower and conductivity higher in Dardanelle Reservoir. Holland, et al. (1983) determined that suspended solids, total dissolved solids, organic carbon and pH had minor effects on the rotifer community, whereas temperature and dissolved oxygen were more important. Rickett and Watson (1982, 1983) determined these two parameters were normal and that the rotifer community was abundant and diverse in Dardanelle Reservoir. Arruda, et al. (1983) determined that a heavy suspended solids load (up to 100 mg/l) reduced algal carbon filtering and ingestion by *Daphnia* to near a starvation level. At higher concentrations, though, *Daphnia* were apparently starved to filtering sediment particles to which organic particles had adsorbed and therefore survived. We occasionally measured suspended solid concentrations exceeding 100 mg/l, but the mean was much lower.

## CONCLUSIONS

Fears that an operating generating station would ruin the lake environment have been largely unjustified. Minor changes have occurred, but at this time, they are limited to a local warm water dispersal pattern (Rickett and Watson, 1982), a shift in the dominant taxa of rotifers (Rickett and Watson, 1983), a gradual decline of Q and chloride and a slight increase of hardness and conductivity. These fluctuations may include a minor component of plant operation impact, but so far we have been unable to separate or positively identify the components. However, it is important to be watchful for signs of advanced eutrophication and changes in physicochemical characteristics.

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