# RESULTS/DISCUSSION

## Hydrology

**Rainfall**

Monthly precipitation for 1984 and 1985, and monthly deviations based on a twenty-nine year average were obtained from state climatological records for the Winnebago sampling station (the closest National Oceanic and Atmospheric Administration (NOAA) station to Mankato at the time) and are summarized in Table III (NOAA, 1984, 1985). During the 1984 sampling period, the combined months of June and July averaged out to a near normal amount of rainfall while August and September were dry. August and September had a combined negative deviation of 5.46 cm (2.15 in). June and July, of the 1985 sampling period, experienced drought conditions for this part of the county with a combined negative deviation of 11.71 cm (4.61 in). August and September of 1985 were abnormally wet with a combined positive deviation of 19.13 cm (7.53 in).

Daily precipitation for the study periods of 1984 and 1985, including baseline and peak event sampling dates are given in Tables IV and V.

**Flow**

Monthly mean, maximum, and minimum flow readings for 1984, 1985 (USGS, 1984 and 1985), and the thirty-five year period of record (USGS, 1986) for the Blue Earth River are given in Table VI. Also included in Table VI are the flow readings for each sampling date of the 1985 and 1985 baseline sampling periods. The 1984 flow data indicates that the 1984 sample period began with well above normal flow readings, which was an extended flush (March: 2.3 times mean average flow for 35 year period, April: 2.2 times mean average flow, May: 2.6 times average flow, June: 3.0 times average flow and July: 1.7 times average flow) and ended with well below normal readings. However, although flow during the sampling period was abnormally higher or lower than historic data, a pattern of greater flow in early summer, followed by decreasing flow as the summer progressed on into October is evident. The latter flow pattern is consistent with historic patterns. The flow pattern during the 1985 sampling period, characterized by well below normal flow in early summer, followed by drought conditions and above normal flow to end the period, was completely opposite the historical and 1984 sampling period patterns. The antecedent precipitation conditions are seen to effect flow with often a month offset (Table VI).

Daily flow data for the 1984 and 1985 study periods including baseline and peaking sampling dates are given in Tables VII and VIII.

**Water Depth per Peak Event**

<u>Peak-Event Sampling of August 9th</u>

Water released between 1215 and 1440 hours during this peak-event increased the river's flow from 2.8 cubic meters per second (cms) or 100 cubic feet per second (cfs) to 17 cms (600 cfs) with one turbine operating. The water level increased 47 cm (19 in) at S5 and decreased 12 cm (5 in) at S3 (Figure 6). The peak plateau at S5 began at 35 minutes following the startup of the turbine. The sample period lasted 145 minutes (2 hours 25 minutes) at S5, and 75 minutes (1hour 15 minutes) at S3.

<u>Peak-Event of August 26th</u>

Water released between 1230 and 1800 hours during the August 26th peak-event increased the river's flow from 17 cms (600 cfs) to 34 cms (1200 cfs) with both turbines operating. Prior to the start of the peak-event, the dam was generating electricity in a run-of-the-river operating mode with one turbine operating, and the minimum flow outlet closed. The peak-event began when the second turbine was placed in operation. The water level increased 25 cm (10 in) at S5, 62 cm (24 in) at S6, and decreased 95 cm (37 in) at S3 (Figure 7).

The peak plateau at S5 began at 48 minutes following the startup of the second turbine and ended with the initiation of the descending leg at 225 minutes (3 hours 45 minutes), lasting for a total of 2 hours 57 minutes. At S6, the plateau began at 262 minutes (4 hours 22 minutes) ending at 292 minutes (4 hours 52 minutes), lasting for 30 minutes.

<u>Peak-Event of August 30th</u>

Water released between 1030 and 1600 hours during the August 30th peak-event increased the river's flow from 17 cms (600 cfs) to 34 cms (1200 cfs) with both turbines operating. Similar to the August 26th peak-event, the dam was generating electricity in a run-of-the-river operating mode with one turbine operating prior to the start of the peak-event. The peak-event began when the second turbine was placed into operation. The water level increased 32 cm (13 in) and decreased 10 cm (4 in) below the original water level after the peak-event ended at S5, increased 62 cm (24 in) at S6, increased 68 cm (27 in) at S8, and decreased 52 cm (20 in) at S3 (Figure 8).

The peak plateau began at 30 minutes after the startup of the second turbine and ended with the beginning of the descending leg at 250 minutes (4 hours), lasting for a total of 3 hours 30 minutes at S5. At S6, the plateau began at 305 minutes (5 hours 5 minutes) after startup of the second turbine and ended at 380 minutes (6 hours 20 minutes), lasting for 1 hour 15 minutes. At S8, the plateau began at 330 minutes (5 hours 30 minutes) and ended at 390 minutes (6 hours 30 minutes), lasting one hour.

In summary, the three 1985 peaking events that were sampled for this study differed as seen in Table IX. The 8/9 event utilized a single turbine, was proceeded by dry conditions and had a short release time, all of which resulted in a minimal 12 cm draw down at Site 3. The 8/26 and 8/30 events both utilized two turbines, started with a background flow of 600 cfs, had similar release time, had precipitation events prior to the events, but differed in their drawdown at Site 3. The reduced drawdown (95 cm during the 8/26 event and 52 cm during the 8/30 event) is hypothesized to be the result of ground saturation and therefore increased runoff by 8/30.

**Table III: Monthly precipitation for 1984 and 1985 with monthly deviations based on a 29 year average as recorded in Winnebago, Minnesota (NOAA, 1984, 1985).**

| Month | Precipitation | | Deviation | |
|---|---|---|---|---|
| 1984 | (cm) | (in) | (cm) | (in) |
| January | 1.88 | 0.74 | -0.38 | -0.15 |
| February | 2.92 | 1.15 | 0.36 | 0.14 |
| March | 4.06 | 1.60 | -0.56 | -0.22 |
| April | 10.19 | 4.01 | 3.91 | 1.54 |
| May | 9.02 | 3.55 | -0.94 | -0.37 |
| June | 17.50 | 6.89 | 4.93 | 1.94 |
| July | 6.32 | 2.49 | -4.42 | -1.74 |
| August | 7.37 | 2.90 | -2.13 | -0.84 |
| September | 4.50 | 1.77 | -3.33 | -1.31 |
| October | 13.28 | 5.23 | 8.43 | 3.32 |
| November | 5.46 | 2.15 | 9.93 | 3.91 |
| December | 3.86 | 1.52 | 1.24 | 0.49 |
| Annual Total | 86.36 | 34.00 | 17.04 | 6.71 |
| | | | | |
| Month | Precipitation | | Deviation | |
| 1985 | (cm) | (in) | (cm) | (in) |
| January | 1.98 | 0.78 | -0.28 | -0.11 |
| February | 2.50 | 1.00 | -2.31 | -0.91 |
| March | 7.47 | 2.94 | 2.84 | 1.12 |
| April | 9.65 | 3.80 | 3.38 | 1.33 |
| May | 7.29 | 2.87 | -2.69 | -1.05 |
| June | 6.15 | 2.42 | -6.48 | -2.53 |
| July | 5.46 | 2.15 | -5.32 | -2.08 |
| August | 23.04 | 9.07 | 13.64 | 5.33 |
| September | 13.41 | 5.28 | 5.63 | 2.20 |
| October | 4.93 | 1.94 | 0.08 | 0.03 |
| November | 4.70 | 1.85 | 1.55 | 0.61 |
| December | 3.81 | 1.50 | 1.19 | 0.47 |
| Annual Total | 88.14 | 34.70 | 11.23 | 4.41 |

**Table IV: Precipitation and sampling dates for the 1984 study period (Winnebago sampling station, NOAA, 1984)**

| | | Precipitation | | | | Precipitation | |
|---|---|---|---|---|---|---|---|
| Date | Sampled | (cm) | (in) | Date | Sampled | (cm) | (in) |
| 6-2 | | 0.23 | 0.09 | 7-20 | | 0.08 | 0.03 |
| 6-4 | | 0.38 | 0.15 | 7-23 | * | | |
| 6-5 | | 3.00 | 1.15 | 7-26 | | 0.30 | 0.12 |
| 6-6 | | 0.20 | 0.08 | 7-28 | | 0.61 | 0.24 |
| 6-8 | | 0.81 | 0.32 | 7-30 | * | | |
| 6-10 | | 0.94 | 0.37 | 8-1 | | 0.10 | 0.04 |
| 6-12 | | 3.02 | 1.20 | 8-2 | | 3.18 | 1.25 |
| 6-15 | | 1.42 | 0.56 | 8-5 | | T | T |
| 6-17 | | 0.76 | 0.30 | 8-6 | * | | |
| 6-18 | | 1.22 | 0.48 | 8-8 | | 2.92 | 1.15 |
| 6-22 | | 4.47 | 1.76 | 8-13 | * | | |
| 6-23 | | 0.91 | 0.36 | 8-16 | | 0.56 | 0.22 |
| 6-25 | * | | | 8-18 | | 0.36 | 0.14 |
| 6-28 | | 0.10 | 0.04 | 8-20 | * | 0.25 | |
| 7-2 | * | | | 8-26 | | 1.07 | 0.10 |
| 7-4 | | 0.58 | 0.23 | 9-4 | | 0.58 | 0.42 |
| 7-8 | | 1.09 | 0.43 | 9-8 | | 0.13 | 0.23 |
| 7-9 | * | | | 9-11 | | 2.03 | 0.05 |
| 7-10 | | 0.38 | 0.15 | 9-12 | | 0.13 | 0.80 |
| 7-11 | | 1.63 | 0.64 | 9-14 | | 0.06 | 0.05 |
| 7-15 | | 0.33 | 0.13 | 9-23 | | 0.13 | 0.02 |
| 7-16 | * | | | 9-24 | | 0.18 | 0.05 |
| 7-17 | | 1.32 | 0.52 | 9-25 | | 0.20 | 0.07 |
| | | | | 9-28 | * | 0.86 | 0.08 |
| | | | | 10-7 | | 0.51 | 0.34 |
| | | | | 10-8 | | 1.09 | 0.20 |
| | | | | 10-9 | | 0.56 | 0.43 |
| | | | | 10-10 | | 3.43 | 0.22 |
| | | | | 10-15 | | 0.43 | 1.35 |
| | | | | 10-16 | | 2.18 | 0.17 |
| | | | | 10-17 | | 1.52 | 0.86 |
| | | | | 10-19 | | | 0.60 |
| | | | | 10-25 | * | 0.41 | |
| | | | | 10-26 | | 2.29 | 0.16 |
| | | | | 10-28 | | | 0.90 |

T= Trace precipitation
* = Baseline Sampling

**Table V: Precipitation and sampling dates for the 1985 study period (Winnebago sampling station, NOAA, 1985)**

| | | Precipitation | | | | Precipitation | |
|---|---|---|---|---|---|---|---|
| Date | Sampled | (cm) | (in) | Date | Sampled | (cm) | (in) |
| 6-2 | | 0.13 | 0.05 | 8-16 | | 0.61 | 0.24 |
| 6-8 | | 0.25 | 0.10 | 8-17 | | 1.80 | 0.71 |
| 6-10 | * | | | 8-19 | * | | |
| 6-11 | | 1.07 | 0.42 | 8-22 | | 5.54 | 2.18 |
| 6-12 | | 2.03 | 0.80 | 8-23 | | 3.71 | 1.46 |
| 6-15 | | 0.69 | 0.27 | 8-25 | | 0.38 | 0.15 |
| | | | | 8-26 | ** | | |
| 6-17 | * | 0.08 | | 8-29 | | 6.65 | 2.62 |
| | | | | 8-30 | ** | | |
| 6-22 | | 1.77 | 0.03 | 9-2 | | 0.18 | 0.07 |
| 6-27 | | 0.05 | 0.70 | 9-3 | | 0.56 | 0.22 |
| 6-28 | | 0.08 | 0.02 | 9-5 | | 3.51 | 1.38 |
| 6-29 | | | 0.03 | 9-6 | | 0.13 | 0.05 |
| 7-7 | * | 0.08 | | 9-9 | | 3.12 | 1.23 |
| 7-12 | | 0.23 | 0.03 | 9-15 | * | | |
| 7-13 | | 0.89 | 0.09 | 9-17 | | 0.38 | 0.15 |
| 7-15 | | 3.43 | 0.35 | 9-18 | | 0.15 | 0.06 |
| 7-25 | | | 1.35 | 9-20 | | 1.02 | 0.40 |
| 7-30 | * | 0.84 | | 9-22 | | 0.89 | 0.35 |
| 7-31 | | 1.07 | 0.33 | 9-23 | | 0.94 | 0.37 |
| 8-9 | ** | 2.39 | 0.42 | 9-24 | | 0.74 | 0.29 |
| 8-10 | | 0.89 | 0.94 | 9-26 | | 0.08 | 0.03 |
| 8-12 | | | 0.35 | 9-27 | | 0.56 | 0.22 |
| 8-13 | | | | 9-30 | | 1.17 | 0.46 |

T= Trace Precipitation
*= Baseline Sampling
**= Peak Sampling

**Table VI: Flow of the Blue Earth River near Rapidan, Minnesota for the 1984 and 1985 calendar years (USGS, 1984, 1985), the historic record (Gunard, 1986) and for each baseline sampling date during the 1984 and 1985 sampling periods (USGS, 1984, 1985). Flow readings are in cfs.**

| Year 1984 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mean | 261 | 1042 | 2857 | 6286 | 4044 | 5184 | 1870 | 313 | 134 | 193 | 357 | 341 |
| max | 280 | 3452 | 8740 | 9100 | 7740 | 9450 | 4310 | 591 | 315 | 501 | 686 | 658 |
| min | 234 | 206 | 1260 | 2970 | 2200 | 2150 | 4761 | 99 | 74 | 61 | 187 | 130 |
| Year 1985 | | | | | | | | | | | | |
| mean | 214 | 149 | 2362 | 2735 | 1634 | 933 | 262 | 159 | 684 | 1884* | - | - |
| max | 465 | 351 | 7940 | 5420 | 3460 | 1550 | 658 | 824 | 1340 | 3000* | - | - |
| min | 91 | 89 | 115 | 1320 | 874 | 551 | 111 | 60 | 163 | 856* | - | - |
| Historic | | | | | | | | | | | | |
| mean | 161 | 214 | 1246 | 2807 | 1532 | 1729 | 1104 | 527 | 449 | 497* | 458 | 270 |
| Standard deviation | 193 | 348 | 1316 | 3136 | 1224 | 1202 | 1041 | 929 | 671 | 905* | 631 | 333 |
| max | 967 (1983) | 1793 (1983) | 6277 (1983) | 13230 (1965) | 4573 (1960) | 5184 (1984) | 3725 (1963) | 5541 (1979) | 8547 (1979) | 5121 (1969) | 2643 (1983) | 1521 (1983) |
| min | 17 (1956) | 14 (1959) | 92 (1968) | 142 (1977) | 144 (1976) | 110 (1976) | 50 (1976) | 38 (1976) | 22 (1976) | 23 (1959) | 30 (1956) | 16 (1956) |
| Year 1984 | | | | | | | | | | | | |
| Flow Deviation Factor | 1.6 | 4.9 | 2.3 | 2.2 | 2.6 | 3.0 | 1.7 | 0.6 | 0.3 | 0.4 | | |
| Precipitation Deviation Factor | 0.8 | 1.2 | 0.9 | 1.6 | 0.9 | 1.4 | 0.6 | 0.8 | 1.5 | 1.5 | | |
| Year 1985 | | | | | | | | | | | | |
| Flow Deviation Factor | 1.3 | 0.7 | 1.9 | 1.0 | 1.1 | 0.5 | 0.2 | 0.3 | 1.5 | 3.8 | | |
| Precipitation Deviation Factor | 0.9 | 0.5 | 1.6 | 1.5 | 0.7 | 0.5 | 0.7 | 2.4 | 1.7 | 1.0 | | |

| 1984 Sample Period | | 1985 Sample Period | |
|---|---|---|---|
| Date | Flow | Date | Flow |
| 6-25 | 9310 | 6-10 | 744 |
| 7-2 | 9800 | 6-17 | 1520 |
| 7-9 | 1990 | 7-7 | 320 |
| 7-16 | 1940 | 7-30 | 132 |
| 7-23 | 1360 | 8-19 | 82 |
| 7-30 | 476 | 9-15 | 401 |
| 8-6 | 484 | | |
| 8-13 | 378 | | |
| 8-20 | 227 | | |
| 9-28 | 74 | | |
| 10-25 | 325 | | |

Key:
Historic = 35 year period of record (1950-1985)

* = provisional data
- = data not available
( ) = year flow occurs

**Table VII: 1984 Daily flow data (discharge) cfs at USGS gauging station near Site 5 (USGS-1984)**

| Day | March | April | May | June | July | August | September |
|---|---|---|---|---|---|---|---|
| 1 | 3580 | 9080 | 4130 | 2620 | 4310 | 591 | 78 |
| 2 | 3460 | 9080 | 4980 | 2420 | *3800 | 340 | 80 |
| 3 | 3130 | 9100 | 5960 | 2240 | 3470 | 547 | 78 |
| 4 | 2860 | 8910 | 6860 | 2150 | 3130 | 459 | 181 |
| 5 | 2460 | 8420 | 7700 | 2330 | 2940 | 425 | 222 |
| 6 | 2200 | 7980 | 7740 | 2650 | 2580 | *484 | 222 |
| 7 | 1900 | 7520 | 7280 | 2770 | 2340 | 427 | 315 |
| 8 | 1690 | 6880 | 6740 | 2660 | 2120 | 410 | 248 |
| 9 | 1680 | 6430 | 6130 | 2530 | *1990 | 484 | 93 |
| 10 | 1670 | 6370 | 5560 | 2980 | 1920 | 447 | 90 |
| 11 | 1630 | 6430 | 5010 | 3400 | 1870 | 388 | 91 |
| 12 | 1580 | 6430 | 4510 | 3330 | 2090 | 379 | 175 |
| 13 | 1480 | 6540 | 4160 | 3480 | 2200 | *378 | 238 |
| 14 | 1420 | 7380 | 3840 | 4240 | 2160 | 362 | 240 |
| 15 | 1430 | 8310 | 6590 | 4800 | 2040 | 221 | 194 |
| 16 | 1370 | 8760 | 3350 | 5410 | *1940 | 159 | 111 |
| 17 | 1320 | 8450 | 3150 | 5820 | 1960 | 425 | 107 |
| 18 | 1290 | 7640 | 2980 | 6420 | 1860 | 303 | 110 |
| 19 | 1260 | 6630 | 2830 | 6870 | 1680 | 240 | 107 |
| 20 | 1290 | 5680 | 2680 | 7330 | 1570 | *227 | 105 |
| 21 | 1290 | 4930 | 2530 | 8120 | 1500 | 242 | 105 |
| 22 | 1310 | 4370 | 2420 | 9220 | 1010 | 149 | 105 |
| 23 | 1320 | 3980 | 2330 | 9450 | *1360 | 99 | 105 |
| 24 | 1570 | 3660 | 2340 | 9390 | 1010 | 132 | 103 |
| 25 | 2480 | 3410 | 2350 | *9310 | 877 | 209 | 101 |
| 26 | 3690 | 3250 | 2270 | 8610 | 826 | 212 | 100 |
| 27 | 6500 | 3100 | 2200 | 7650 | 727 | 227 | 83 |
| 28 | 6890 | 2970 | 2220 | 6680 | 823 | 256 | *74 |
| 29 | 7730 | 3200 | 2290 | 5650 | 784 | 199 | 76 |
| 30 | 8350 | 3690 | 2520 | 5000 | *476 | 164 | 76 |
| 31 | 8740 | --- | 2700 | --- | 610 | 107 | --- |
| Total | 88570 | 188580 | 125350 | 155530 | 57973 | 9692 | 4013 |
| Mean | 2857 | 6286 | 4044 | 5184 | 1870 | 313 | 134 |
| Max | 8740 | 9100 | 7740 | 9450 | 4310 | 591 | 315 |
| Min | 1260 | 2970 | 2200 | 2150 | 476 | 99 | 74 |

*-Baseline Sampling

**Table VIII: 1985 Daily flow data (discharge) cfs at USGS station near Site 5 (USGS-1985)**

| Day | March | April | May | June | July | August | September |
|---|---|---|---|---|---|---|---|
| 1 | 360 | 1520 | 3460 | 1100 | 658 | 111 | 826 |
| 2 | 311 | 1450 | 3100 | 1130 | 617 | 107 | 631 |
| 3 | 279 | 1690 | 2810 | 1150 | 564 | 97 | 532 |
| 4 | 213 | 2280 | 2500 | 1280 | 417 | 97 | 483 |
| 5 | 249 | 3010 | 2220 | 989 | 584 | 94 | 421 |
| 6 | 282 | 3560 | 2040 | 775 | 341 | 91 | 555 |
| 7 | 181 | 3880 | 1920 | 622 | 320 | 91 | 804 |
| 8 | 149 | 3780 | 1760 | 830 | 501 | 81 | 1340 |
| 9 | 115 | 3010 | 1580 | 582 | 389 | **146 | 1240 |
| 10 | 128 | 2370 | 1500 | *744 | 216 | 73 | 1220 |
| 11 | 251 | 2230 | 1410 | 661 | 216 | 74 | 966 |
| 12 | 1970 | 2010 | 1250 | 693 | 216 | 107 | 1010 |
| 13 | 4020 | 1870 | 1240 | 729 | 212 | 141 | 856 |
| 14 | 5460 | 1650 | 1210 | 850 | 199 | 114 | 748 |
| 15 | 7370 | 1680 | 1270 | 1340 | 191 | 127 | *401 |
| 16 | 7940 | 1600 | 1440 | 1340 | 171 | 114 | 745 |
| 17 | 6320 | 1730 | 1630 | *1520 | 315 | 90 | 517 |
| 18 | 4810 | 1380 | 1670 | 1550 | 187 | 91 | 538 |
| 19 | 4280 | 1410 | 1660 | 1350 | 179 | *82 | 552 |
| 20 | 3800 | 1430 | 1650 | 1210 | 155 | 62 | 363 |
| 21 | 3380 | 1320 | 1510 | 1140 | 152 | 60 | 163 |
| 22 | 2980 | 1700 | 1330 | 932 | 131 | 122 | 326 |
| 23 | 2720 | 3080 | 1290 | 836 | 132 | 134 | 415 |
| 24 | 2340 | 4560 | 1240 | 811 | 140 | 167 | 454 |
| 25 | 2200 | 5230 | 1310 | 744 | 140 | 178 | 485 |
| 26 | 1960 | 5420 | 1330 | 651 | 142 | **418 | 661 |
| 27 | 1940 | 5030 | 1250 | 610 | 139 | 187 | 780 |
| 28 | 1870 | 4540 | 1060 | 551 | 136 | 256 | 624 |
| 29 | 1940 | 4080 | 1020 | 638 | 127 | 152 | 723 |
| 30 | 1860 | 3600 | 1130 | 644 | *132 | **450 | 1040 |
| 31 | 1690 | --- | 874 | --- | 111 | 824 | --- |
| Total | 73368 | 82100 | 50664 | 28002 | 8130 | 4938 | 20419 |
| Mean | 2367 | 2737 | 1634 | 933 | 262 | 159 | 681 |
| Max | 7940 | 5420 | 3460 | 1550 | 658 | 824 | 1340 |
| Min | 115 | 1320 | 874 | 551 | 111 | 60 | 163 |

*-Baseline Sampling
** - Peak Sampling

**Table IX: Comparison of hydrologic and water quality characteristics of the three August peaks.**

| 1985 Event Date | # of Turbines | Turbine Flow Increase (cfs) | Turbine Release Time (hrs.) | Precipitation prior to event (inches) | Site 3 drawdown (cm) |
|---|---|---|---|---|---|
| 8/9 | 1 | 100-600 | 2 ½ | Dry | 12 |
| 8/26 | 2 | 600-1200 | 7 ½ | 3.79 (8/22-8/25) | 95 |
| 8/30 | 2 | 600-1200 | 7 ½ | 2.62 (8/29) | 52 |

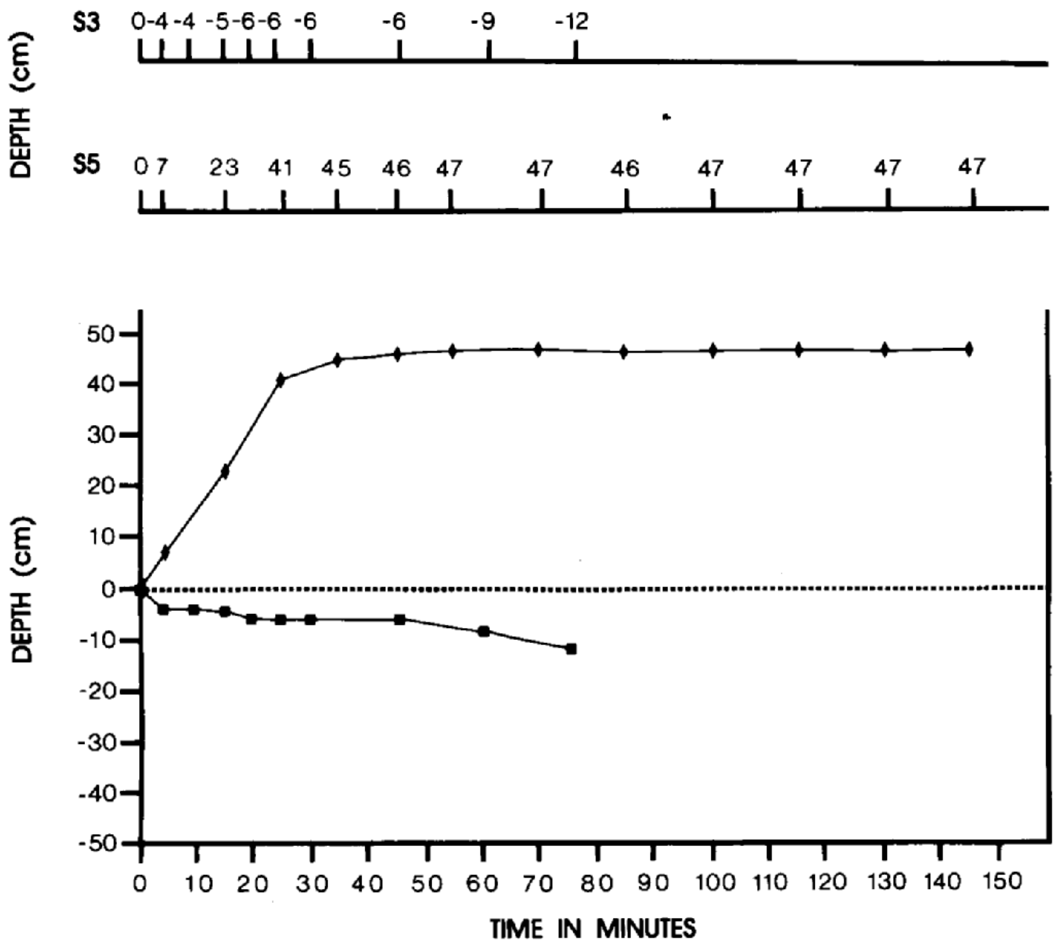


**Figure 6. Water Depth for peak event of August 9, 1985 at Sites S3 ( ■ ) and S5 ( ♦ ).**

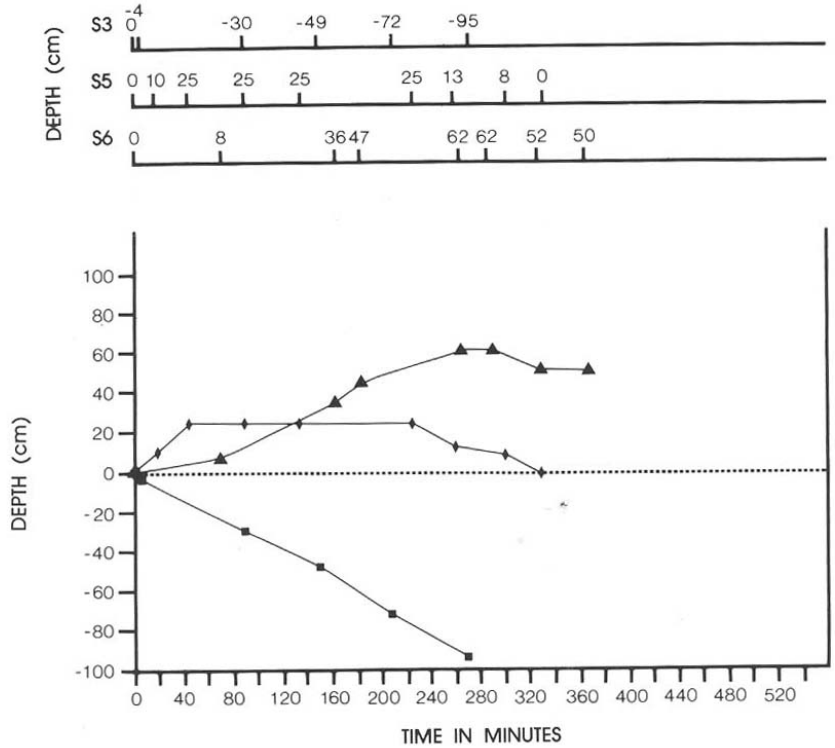


**Figure 7. Water Depth for peak event of August 26, 1985 at Sites S3 ( ■ ), S5 ( ♦) and S6 ( ▲).**

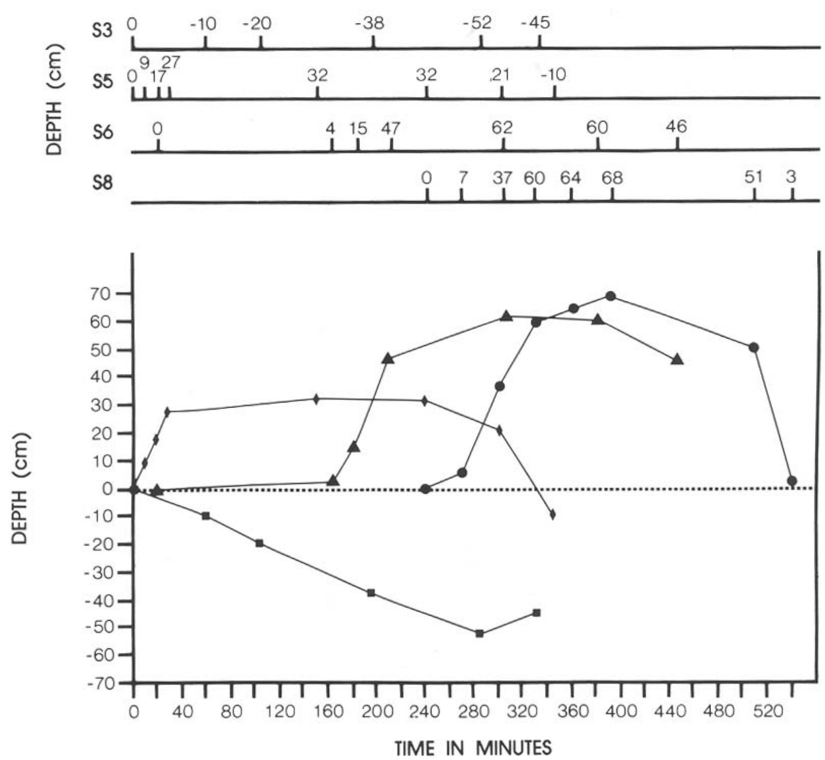


**Figure 8. Water Depth for peak event of August 30, 1985 at Sites S3 ( ■ ), S5 ( ♦ ), S6 ( ▲ ) and S8 ( ● )**

# Water Quality

**Ammonia Nitrogen**

Introduction

Ammonia is generated by heterotrophic bacteria as a primary end product of decomposition of organic matter. Although ammonia is a major excretory product of aquatic animals, this is a minor source in comparison to that generated by bacterial decomposition. Ammonia in water is present primarily as $NH_4^+$ and as un-dissociated $NH_4OH$, the latter being highly toxic to many organisms, especially fish. The proportions of $NH_4^+$ to $HN_4OH$ are governed by pH and temperature with the ratio increasing from 3000:1 at pH 6 to 1:1 at pH 9.5 (Wetzel, 1983).

Baseline

Historic baseline data were not available for 1984 and 1985 sampling periods. The 1984 baseline data which were generated showed that concentrations were generally greater in July, possibly due to higher flow, and reduced in August, followed by an increase in September. The increase in concentration that took place in September could have been attributed to the increase in availability of organic matter and the subsequent increase in organic decomposition during the latter portion of summer. At S5 the baseline data that exists for Ammonia-N shows a minimum concentration of 0.08 mg/l , and a maximum of 0.22 mg/l. The reservoir did not appear to impact downstream Ammonia-N. Because of a lack of data points, a graphics baseline was not produced.

Peak 8/9

Concentrations at S5 followed a pattern for all three peak-events with increasing concentration with the onset of the ascending leg, and decreasing but leveling off during the peak plateau and descending leg. The 8-9 peak-event (one turbine) had minimal impact on S5 Ammonia-N when compared to the latter two peak-events. The peak concentration at S5 during the 8-9 event was 0.18 mg/l, which is near the maximum baseline value (Figure 9). (The greatest peak concentration at S5, for all three events, occurred on the 8-26 peak-event with 0.21 mg/l. This level is just below the maximum baseline level of 0.22 mg/l). Pre-sample concentrations at S5 were very similar between the three events (0.08 mg/l, 0.05 mg/l, and 0.07 mg/l respectively). The increase in flow at S3 during the 8-9 event, because of a 12 cm drawdown, may have caused water lower in Ammonia-N from upstream to dilute concentrations at S3. This diluting may have caused the overall decrease in concentration at S3. A "first flush" phenomenon for Ammonia Nitrogen was observed.

Peak 8/26

Preceding the 8/26 peaking event 3.75 inches of rain fell between August 22nd and August 25th (Table V). The peak concentration of 0.6 mg/l, which occurred at S6 during the 8-26 event (two turbines) was ten times greater than the maximum baseline concentration at that site (0.06 mg/l) (Figure 10). This increase can be attributed to the re-suspension of sediments by scouring and first flush as the water level increased with the downstream movement of the initial water surge. Concentrations at S3 during this event remained very low and quite stable, ranging from 0 mg/l to 0.03 mg/l. The lower concentration at S3, compared to the 8-9 event, may have been due to the greater flow and subsequent dilution which was occurring during the 8-26 event.

Peak 8/30

On August 29th, 2.62 inches of precipitation was recorded (Table V). During the 8-30 event (two turbines) the greatest increase in concentration occurred at S6 again, with a peak concentration of 0.26 mg/l (Figure 11). Site S8 did not show a great increase in Ammonia-N, with the pre-sample concentration (0.07 mg/l) being the greatest concentration. This lack of a significant increase in concentration at S8 may have been due to a diluting affect by the Le Sueur River on S8 concentrations. The ten-fold increase in concentration (0.04 mg/l to 0.41 mg/l) which occurred at S3 during the 8-30 event probably represents a "first flush" and also was following a localized storm event on the upstream Blue Earth River which did not impact the Le Sueur River. This concentration was the greatest concentrations occurring during this peak-event for all sites involved.

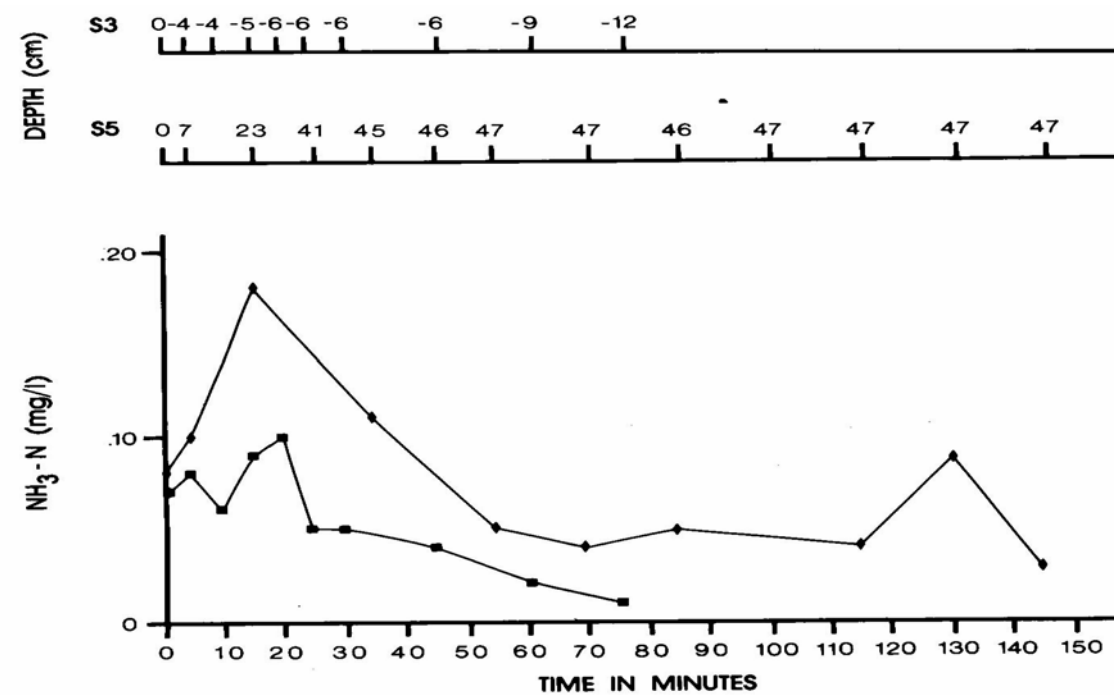


**Figure 9. Ammonia-Nitrogen for peak event of August 9, 1985 at Sites S3 ( ■ ) and S5 ( ♦ ).**

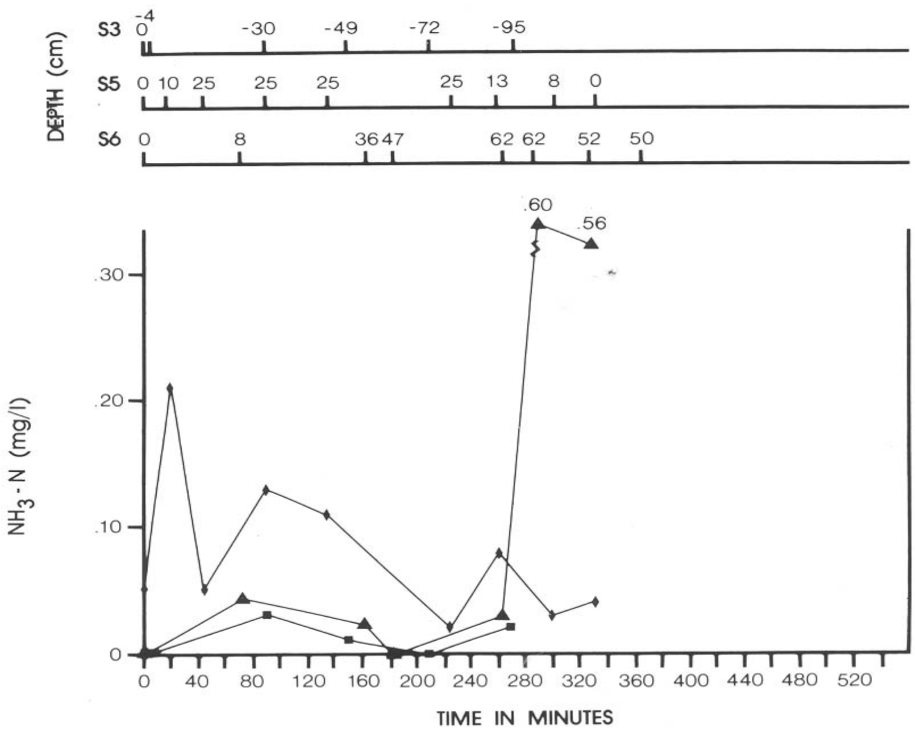


**Figure 10. Ammonia-Nitrogen for peak event of August 26, 1985 at Sites S3 ( ■ ), S5 ( ♦ ) and S6 (▲).**

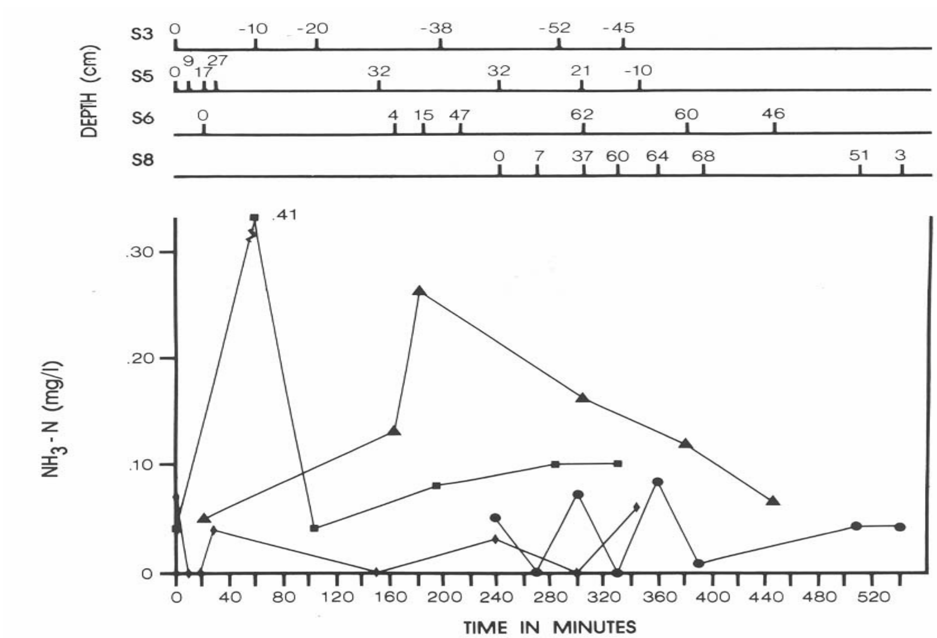


**Figure 11. Ammonia-Nitrogen for peak event of August 30, 1985 at Sites S3 ( ■ ), S5 ( ♦ ), S6 ( ▲ ) and S8 ( ●)**

**Organic Nitrogen**

Introduction

Organic-N is defined as organically bound nitrogen in the tri-negative oxidative state. It does not include all nitrogen compounds such as Ammonia-N, but does include naturally occurring materials such as proteins, peptides, nucleic acids, urea, and numerous synthetic organic materials (APHA, 1980). Dissolved organic nitrogen (DON) often constitutes over 50 percent of the total soluble nitrogen in fresh water and the ratios of DON to particulate organic nitrogen (PON) are usually 5:1 to 10:1 (Wetzel, 1983).

Baseline

Historic Organic-N concentrations at BE-0 were somewhat greater in June, and steadily decreased throughout the summer months on into October (Figure 12). This correlates very well with historic flow patterns (Table VI), where flow is greater in June, and steadily decreases from June to October. The 1984 flow was abnormally higher in June and July, and lower in August through September than historic flow. It was hypothesized that there would be much greater concentrations in June at the mainstem sites due to the abnormally high flow rates, but this did not occur probably because there was abnormally high flow Februarys through May.

In 1985, concentrations were greater than in 1984 at the beginning of the sample period even though flow was much greater in 1984 at that time (5184 cfs in 1984 as compared to 933 cfs in 1985). As the sample period proceeded, concentration patterns resembled the historic data. The 1985 data does differ from the historic data beginning in September when concentrations at all sites began an abrupt increase. This increase can be attributed to abnormally high rainfall occurring at this time and the subsequent increase in flow.

The reservoir does not appear to affect mainstem concentrations

Peaks

Organic-N concentrations at all sites downstream of the dam, during all three peak-events nearly reached or exceeded the maximum baseline concentrations occurring during the entire sampling periods of 1984 and 1985, for their respective sites. However, none of the levels at the downstream sites reached the maximum levels of the historic baseline concentration (2.23 mg/l) for the months of June through October at the Minnesota Pollution Control Agency monitoring station BE-0.

The 8-9 event appeared to have a greater impact on Organic Nitrogen concentrations at S5 than did the 8-26 and 8-30 events (the pre-event concentration to the peak concentration, during the 8-9 event (43% increase) than did the 8-26 event (24%) and the 8-30 event (39%)) (Figures 13, 14, 15). Organic-N at S3 saw an overall decrease during the 8/9 event. The diluting affect from the influx of water from upstream may have caused this decrease, while “first flush” caused the initial peak at S5.

Organic-N concentrations during the 8-26 and 8-30 events did not increase to greater levels at S6 and S8 when compared to S5. Site S3 concentrations during the 8-26 and 8-30 events did not show a consistent decreasing pattern as with the 8-9 event. This may be due to the greater concentrations present, as seen with higher pre-sample readings during the latter two events (1.50 mg/l and 1.46 mg/l), compared to the 8-9 event (1.11 mg/l).

Although peak concentrations at all downstream sites during all three peak events reached or exceeded maximum baseline values, pre-event concentrations for a majority of the sites were already near maximum baseline values. The exception to this was S5 (8-9 event) and S6 (8-26 event), where pre-sample concentrations were within the range of the minimum baseline values for 1984 and 1985. At these two sites, the affects of the peaking operation of the Rapidan Dam on Organic-N resembled early summer high water conditions. The affects on the other downstream sites resembled that of a natural hydrologic event, which could have been produced by approximately one to two inches of rainfall. The increases in concentration at all downstream sites was most likely due to scouring and re-suspension of Organic-N laden detritus and sediment. During the 8-9 event, it is believed that the release of sediment from the reservoir, accumulated during the non-generation days prior to the event in the area of the turbine intakes, was also a contributing source of Organic-N at S5.

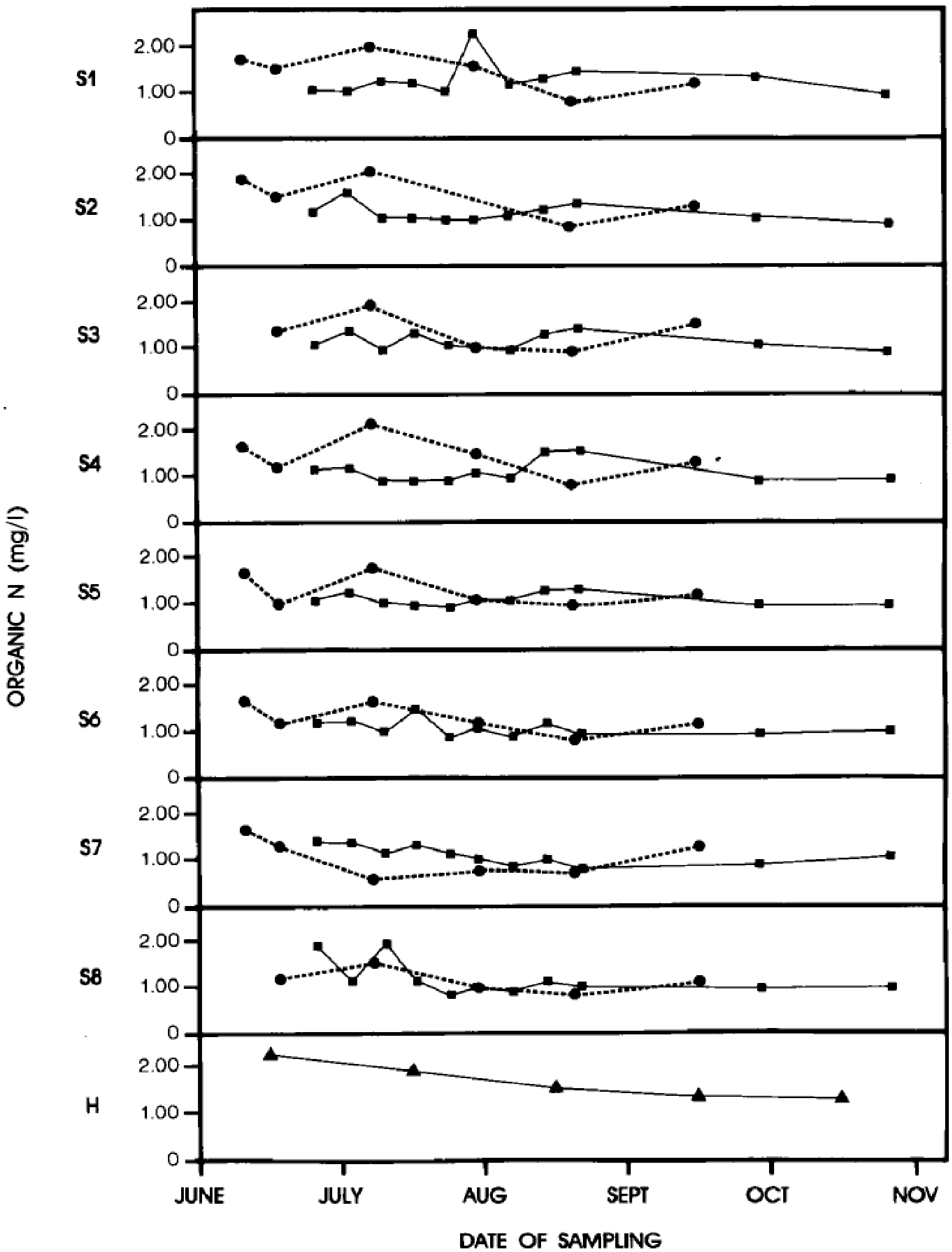


**Figure 12. Baseline Organic-Nitrogen for 1984 ( ■) and 1985 ( ●) sampling seasons at Sites S1-S8, and historic record for Blue Earth- 0 (▲).**

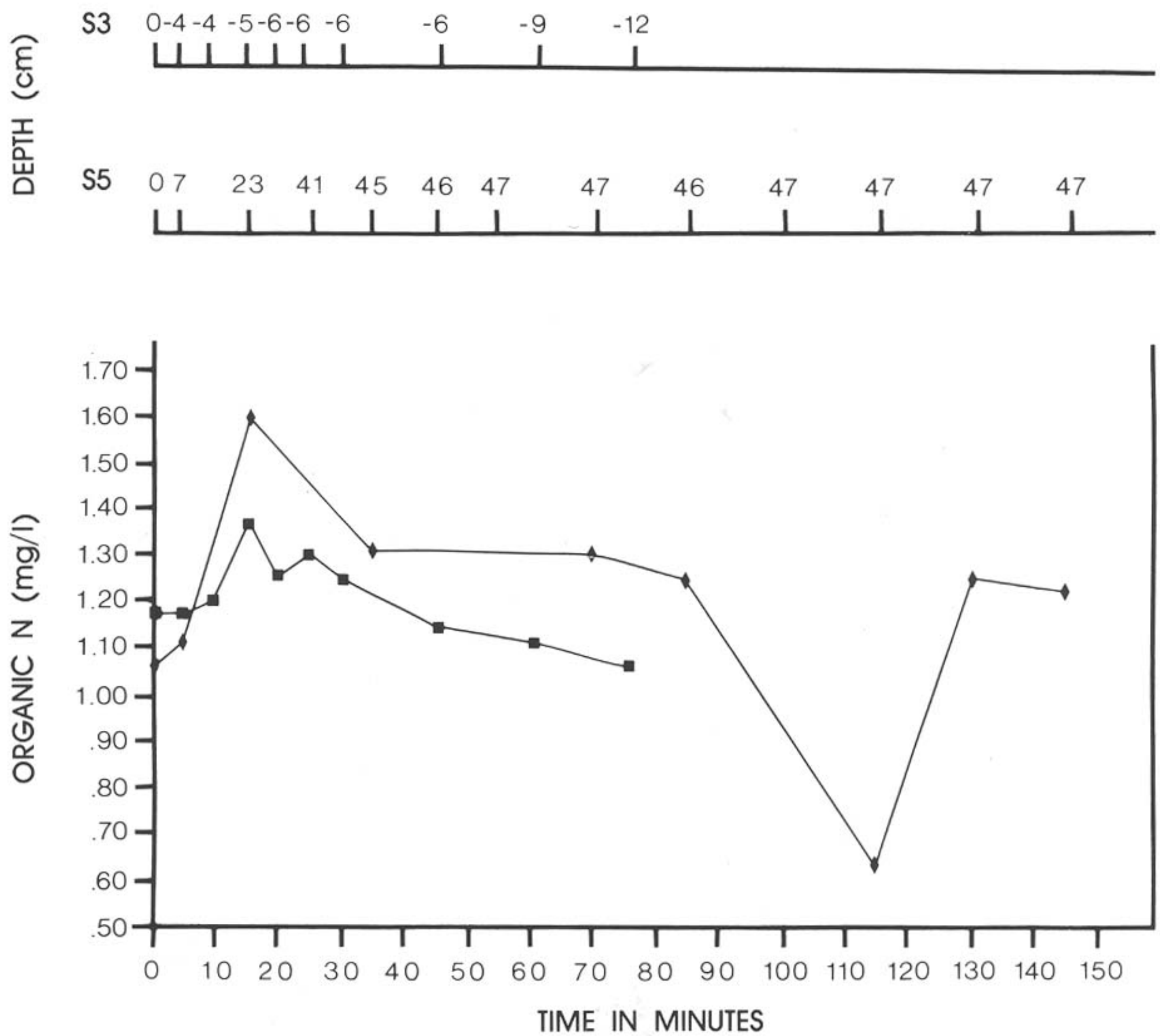


**Figure 13. Organic-Nitrogen for peak event of August 9, 1985 at Sites S3 ( ■ ) and S5 ( ♦ ).**

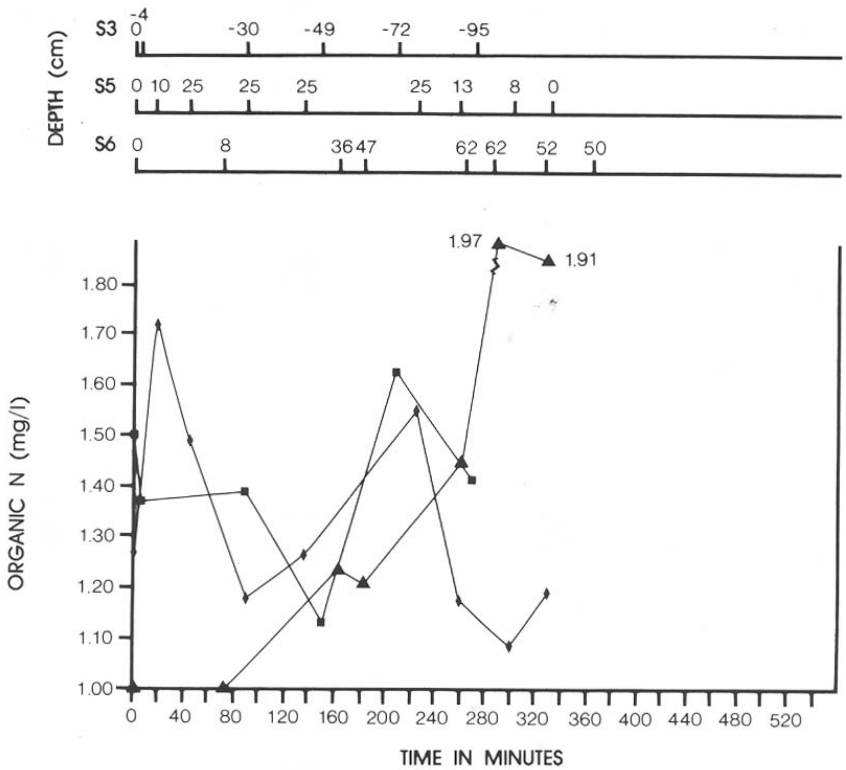


**Figure 14. Organic-Nitrogen for peak event of August 26, 1985 at Sites S3 ( ■ ), S5 ( ♦ ) and S6 ( ▲ ).**

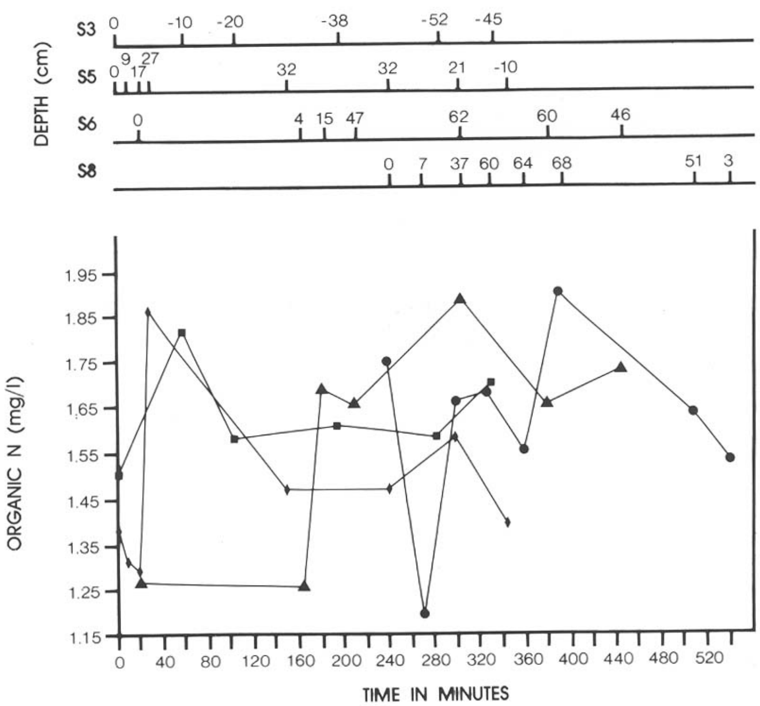


**Figure 15. Organic-Nitrogen for peak event of August 30, 1985 At Sites S3 ( ■ ), S5 ( ♦ ), S6 ( ▲ ) and S8 ( ●) .**