

pH

Introduction

The measurement of pH is one of the most important and frequently used tests in water chemistry. At a given temperature, the intensity of the acidic or basic character of a solution is indicated by the pH or hydrogen ion activity (APHA, 1980). Natural waters have pH values in the range of 4 to 9, and most are slightly basic due to the presence of bicarbonates and carbonates (APHA, 1980). The concept of pH is important in that all living organisms are very sensitive to hydrogen ion concentration, and need to maintain it at a constant level (Mader, 1985).

Baseline

Historic pH trends at BE-0 throughout the months of June through November, remained relatively stable which can be due to the presence of bicarbonates and carbonates, an effective buffering mechanism against large changes in pH. In 1984, pH levels followed historic trends closely in terms of remaining relatively constant throughout the sample period (Figure 43). The pH readings were slightly lower than historic data suggests. The increase at all sites on the 7-23 sampling (not as pronounced at S4) correlates with the closing of the tainter gates and the subsequent filling of the reservoir. The pH in 1984 demonstrated a consistent increase as one moved downstream from S1 to S8. This increase in pH may have been caused by the loss of equilibrium carbon dioxide as you move downstream, which is required to retain calcium bicarbonate (a buffer against changes in pH) in solution (Hynes, 1980). The greater readings during the early sampling period than the late sampling period could be attributed to greater flow during the former.

Readings in 1985 were greater during the late sampling period when flow was greater. Readings were fairly stable throughout the sample period but lower than historic readings at BE-0. Similar to 1984, readings increased as you moved downstream.

The reservoir did not appear to impact downstream pH.

Peaks

The pH at S5 during the 8-9 event, fluctuated between 7.33 to 8.00 which was within the range observed for baseline data during 1984 and 1985 (Figure 44). This fluctuation could be attributed to the particular sediment composition suspended in the water column as it passed through the site. The pH at S3 during the 8-9 event was not available. Site S3 pH during the 8-26 and 8-30 peak-events was much greater than at S5 (8-26) and S5 and S6 (8-30) (Figure 45, 46). An initial increase was seen shortly into both events at S3 followed by a stabilization for the remainder of the sample period. This initial increase may have been due to a concentrating effect as draw-down began at the site. The 8-26 and 8-30 events possessed greater pre-sample readings and peak pH readings at S5 than did the 8-9 event. Higher water levels with greater flow could have been re-suspending calcareous laden sediment, resulting in higher pH readings. Significant changes in pH were not evident during either peak event, however pH did follow the ascending leg, peak plateau, and descending leg with a corresponding increase, leveling off, and decrease respectively at all downstream sites. This study has concluded that pH is not impacted to any significant degree by the peaking operation within the Rapidan Dam's downstream reaches.

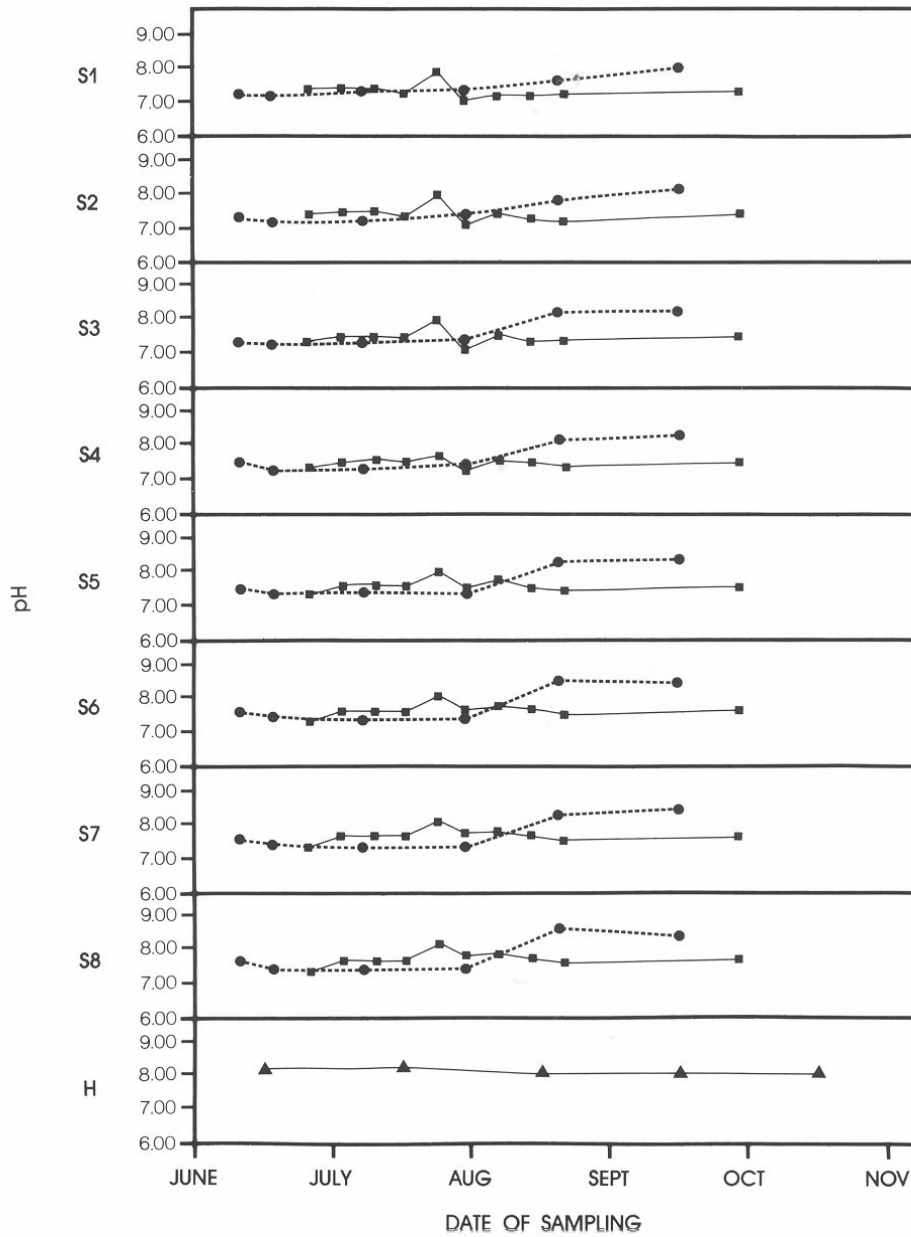


Figure 43. Baseline pH for 1984 (■) and 1985 (●) sampling seasons at Sites S1-S8, and historic record for Blue Earth – 0 (▲)

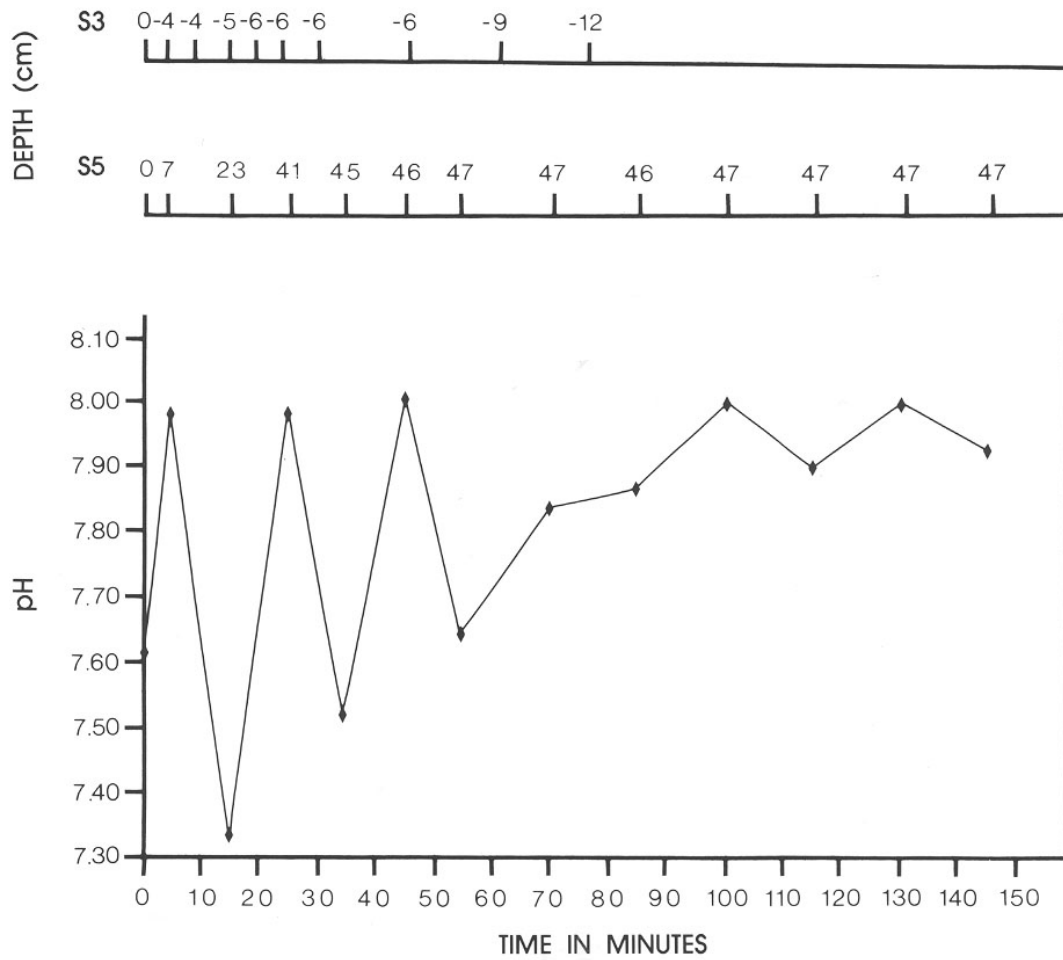


Figure 44. pH for peak event of August 9, 1985 at Site S5 (◆)

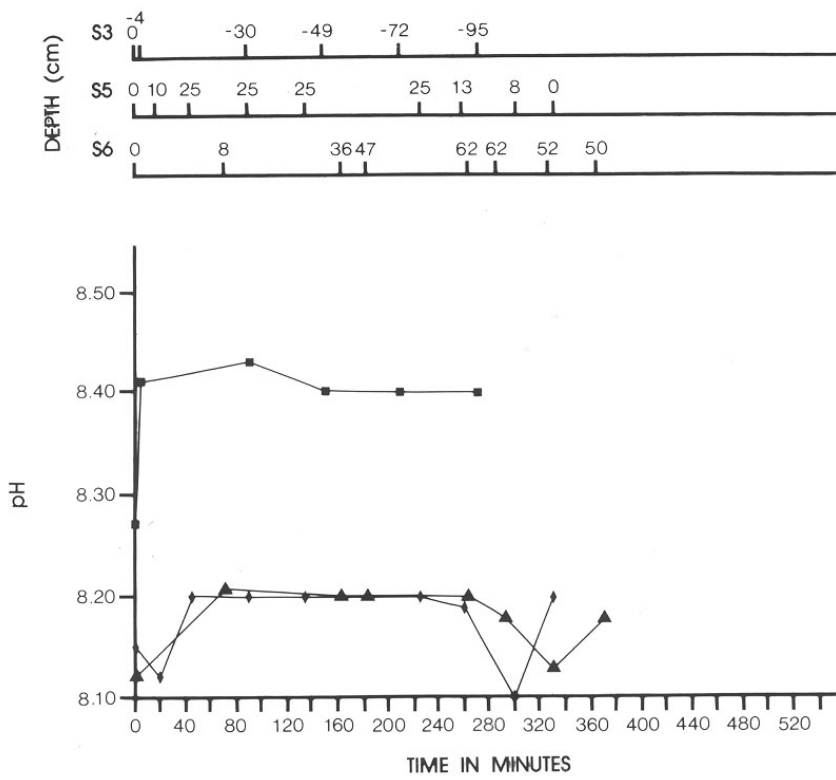


Figure 45. pH for peak event of August 26, 1985 at Sites S3 (■), S5 (◆) and S6 (▲)

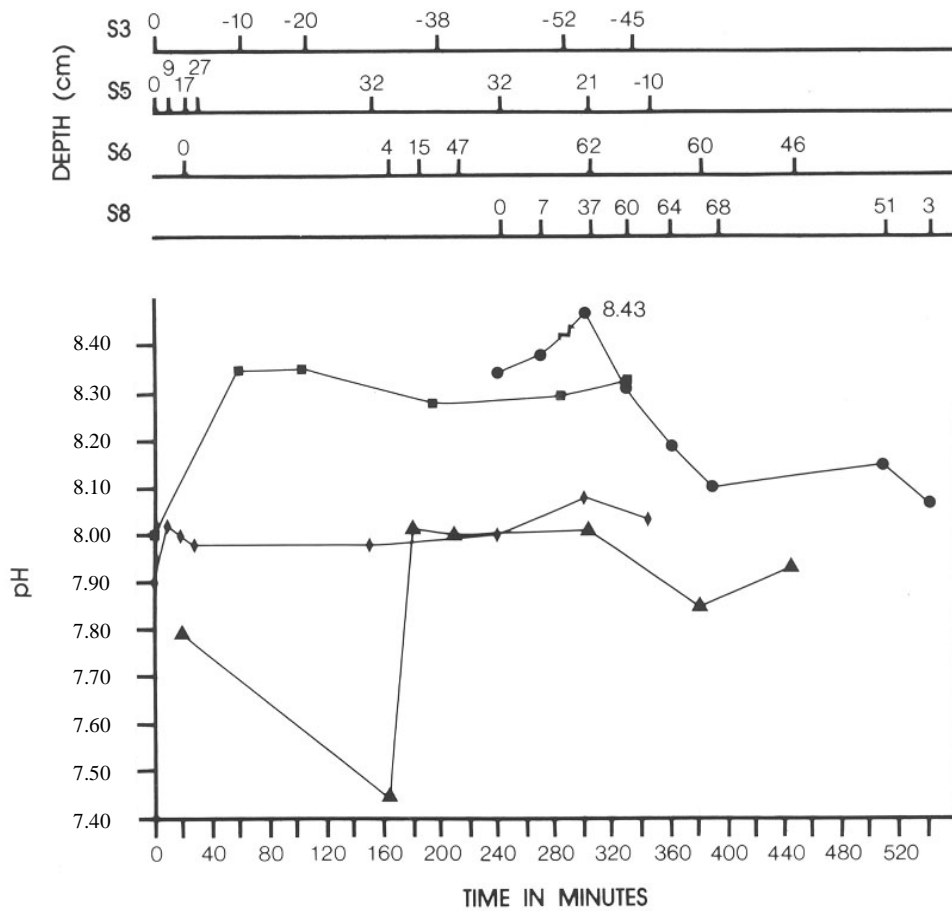


Figure 46. pH for peak event of August 30, 1985 at S3 (■), S5 (◆), S6 (▲) and S8 (●)

Water Temperature

Introduction

The temperature of an aquatic ecosystem has numerous impacts on the biotic and abiotic components of that ecosystem. The water temperature regime will determine the types of aquatic fauna and flora found, and will affect viscosity of the water, the solubility of gases and the suspension of sediments within the water column (Hynes, 1980).

Baseline

Historic data at BE-0 suggests that water temperatures steadily increase throughout the months of June and July, peak in August, and steadily decrease throughout September and October, (Figure 47). In 1984, water temperatures followed historic trends closely, peaking on the 8-6 sampling date along the 51.8 river km stretch of the river within the study area. A river may continue to receive groundwater along its length and its temperature will remain fairly constant for a long distance (Hynes, 1980).

In 1985, as in 1984, fairly stable temperatures between S1 and S8 were evident. Water temperatures peaked one week earlier in 1985 (7-30 sampling) than in 1984 (8-7 sampling). Greater mean water temperatures during the late sampling period of 1985, than the same sampling period of 1984, may be due to the fact that the 1985 sampling period did not extend into October as in 1984. Therefore, the lower temperatures of October were not calculated into the means for the late sampling period of 1985.

The reservoir did not appear to impact downstream water temperature.

Peak

The historic baseline, mean monthly water temperature for August is 23.9°C (75.0°F). The pre-sample temperature at S5 during the 8-9 peak-event was 26.0°C (78.8°F)(Figure 48). The very low flow conditions and high air temperatures preceding this peak-event, may have caused the greater than normal water temperature. The 1.5°C (2.7°F) decreases in water temperature at S5 within the first 25 minutes of the 8-9 event could have been attributed to the inflow of the slightly cooler water from the reservoir into the turbine inlets. The turbine inlets are located at a depth of 7 meters (23 feet) below the surface of the reservoir at normal pool elevation. Whether this drop in water temperature is significant enough to have affected aquatic fauna in the reservoir's tail waters cannot be determined by this study. Water temperature data was not available for S3.

Water temperatures throughout the 8-26 and 8-30 events for all sites except S8 saw near normal water temperatures (Water temperature data was not available at S6 for the 8-30 event) (Figures 49, 50). Site S8, during the 8-30 event, possessed a peak water temperature of 25.0°C (77.0°F) with a pre-sample reading of 23.5°C (74.3°F), compared to pre-sample readings of 21.0°C and 20.5°C at S5 and S3 respectively. Sampling at S8 began much later in the day than at the other sites, and occurred where the river flowed across a large sandbar with a maximum depth of 30 cm (12 in). These two factors could have contributed to considerable warming of the water.

A feature that does stand out in terms of the impacts of the peaking operation on water temperature in the dam's downstream reaches is the increase in water temperature of 1.5°C during the 8-30 event at S8. The increase in conductivity observed during the same time was most likely attributed to this increase in temperature. The initial water surge, as it approached S8, was 1.5°C warmer than the water immediately downstream of it.

Another feature that stands out is the fluctuation of water temperature at S3 during the 8-26 event. An initial increase of 1.5°C, from 21.5°C to 23.0°C, during the first 90 minutes of the event, was followed by a decrease of 2.0°C towards the end of the event. The initial increase may have been due to the draw-down, i.e. less water to distribute solar gain. The decrease of 2.0°C may be related to increased groundwater impact.

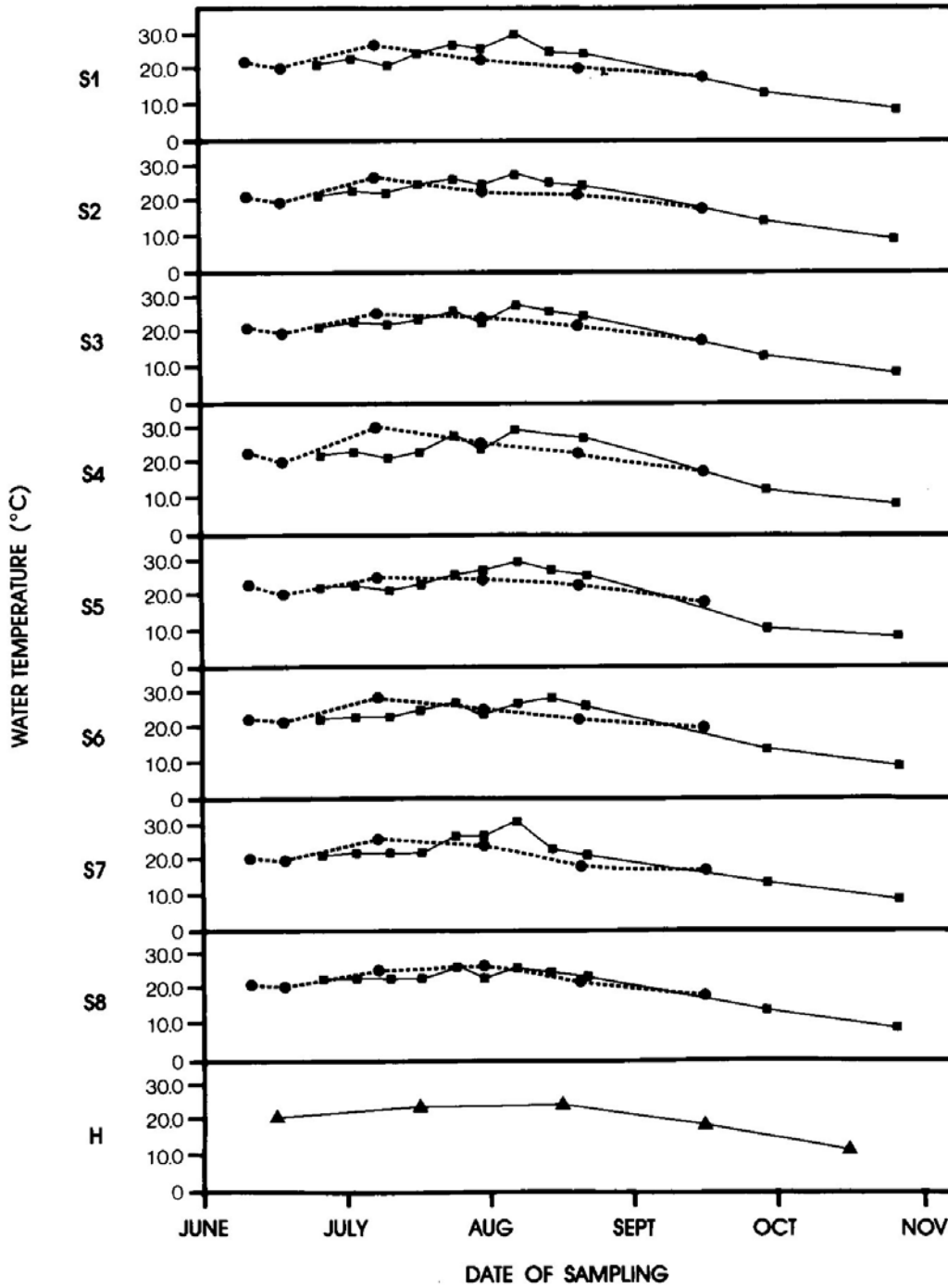


Figure 47. Baseline Water Temperature for 1984 (■) and 1985 (●) sampling seasons at Sites S1-S8, and historic record for Blue Earth - 0 (▲)

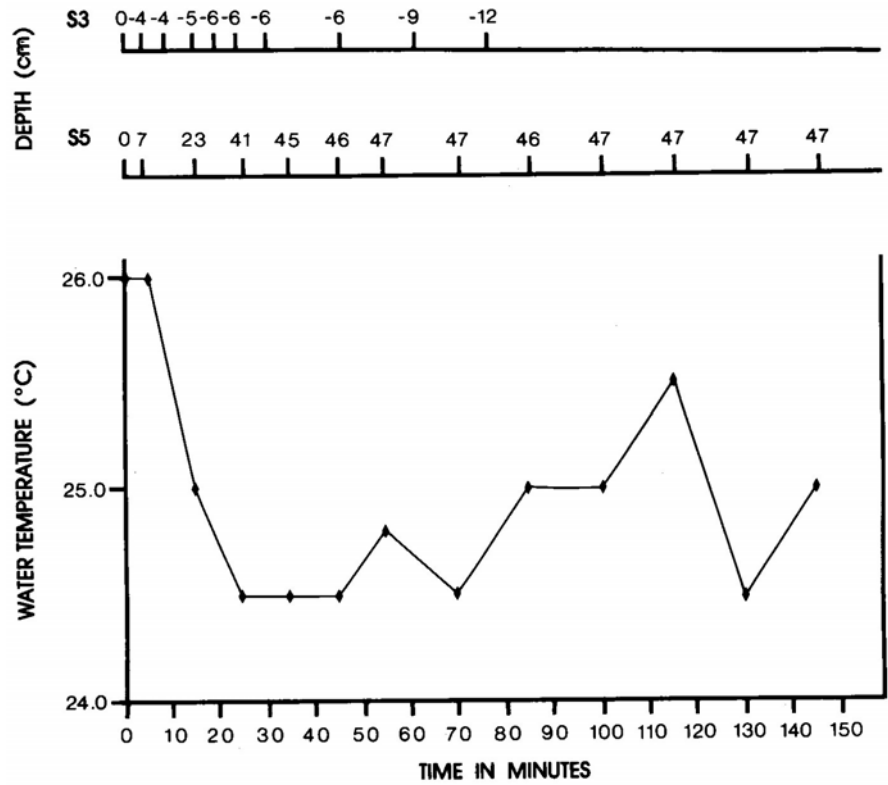


Figure 48. Water Temperature for peak event of August 9, 1985 at Site S5 (◆)

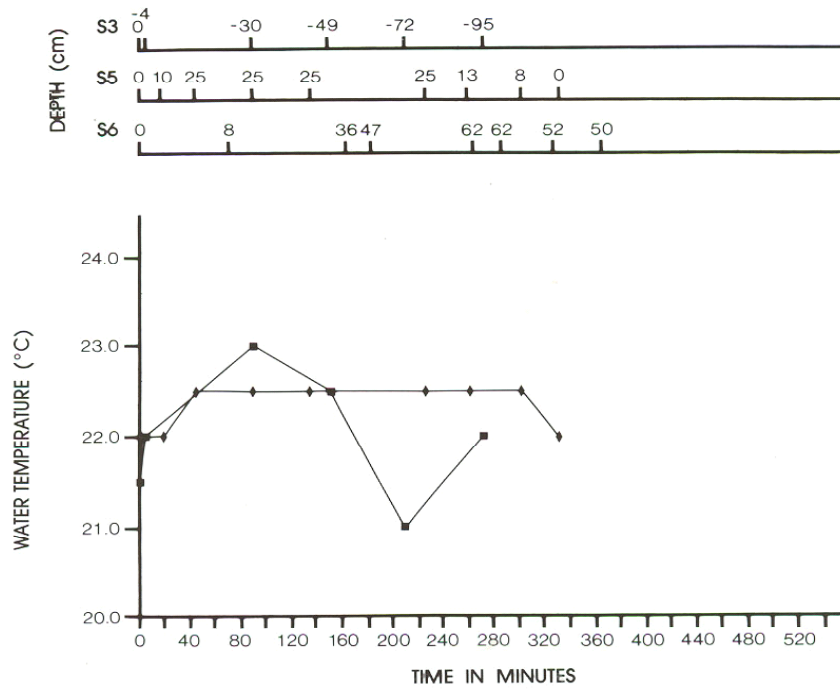


Figure 49. Water Temperature for peak event of August 26, 1985 at Sites S3 (■) and S5 (◆)

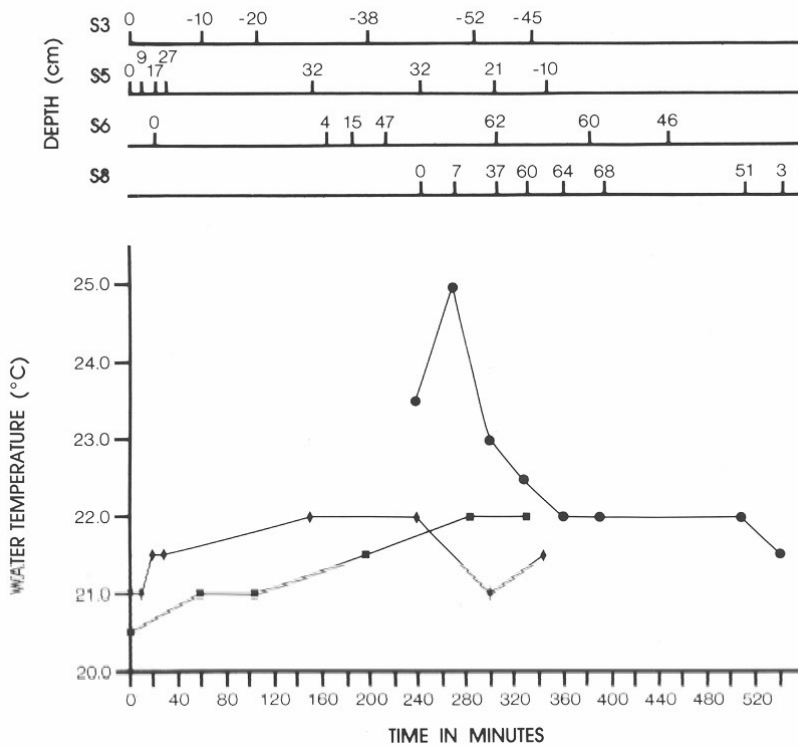


Figure 50. Water Temperature for peak event of August 30, 1985 at Sites S3 (■), S5 (◆) and S8 (●).

Organic Matter

Introduction

Rivers have been called the “gutters down which flow the ruins of continents” (Leopold *et al.*, 1964). Streams transport large quantities of dissolved and particulate material, and in doing so alter the geomorphology of the land. Stream systems, from small headwaters to large rivers, import, produce, process, and store organic material (Vannote *et al.*, 1980). The processing and partial release of organic nutrients from one stream reach to the next has been characterized as processing along a continuum (Vannote *et al.*, 1980). Stream systems also provide habitat to highly specialized biological communities which transform, utilize, and release materials being transported. As a result of their activities, the physical and chemical composition of materials exported at the mouth of a stream, may be quite different from the materials entering the watershed. Streams and rivers are no longer viewed as open export systems for terrestrial products, but rather as sites of production and processing of organic material (Hynes, 1980; Whitton, 1975).

The term “seston” can be defined as all organic and inorganic material suspended in water (Ruttner, 1963). The organic fraction of seston, both living and nonliving, is generally referred to as organic material (OM). A number of studies over the last twenty-five years have demonstrated the importance of OM to the energetics of aquatic ecosystems. The sources of OM can be autochthonous, produced within the stream (live, senescent, on dead algae, microbes, and other organic detritus), or allochthonous, originating from terrestrial sources (non-living detritus such as wood or leaves, etc.) (Liw *et al.*, 1977). The transport of OM within streams is important to the aquatic invertebrates as a food source (Cummins, 1974).

Coarse Particulate Organic matter (CPOM)

Introduction

Coarse particulate organic matter has been defined in this study as OM >1mm in size. CPOM may be allochthonous in origin (leaves, wood, bark, flowers, terrestrial insect grass, etc.) or autochthonous (aquatic macrophytes, filamentous, algae, certain aquatic invertebrates, etc.), (Bird *et al.*, 1981). In a stream the size of the Blue Earth River (sixth order), the importance of allochthonous input of CPOM diminishes as the effects of the riparian vegetation becomes less important (Vannote *et al.*, 1980), and as abiotic-biotic processing is completed (Cummins, 1975).

Baseline

CPOM in 1984, began the sample period in June with lower concentrations than in 1985 (Figure 51). The very high flow occurring during the preceding months of February through May of 1984 may have scoured a majority of the CPOM from the watershed. As flow decreased, the CPOM levels dropped to near 0 mg/l for the remainder of the sample period. It seems reasonable to assume that concentrations did not increase substantially again until the onset of the spring floods of the following year. The greater concentrations in June of 1985 can be due to a more normal flow regime during the months of March through June, resulting in normal scour and suspension of CPOM within the water column. CPOM concentrations began to increase in the latter portion of August and continued into September with increasing flow.

No apparent impacts on mainstem CPOM concentrations due to the reservoir or tributaries were observed.

The percentage of total OM comprised by CPOM remained relatively small but stable during the entire early and late sampling periods of 1984 with 0.5%, 0.6%, and 0.3 respectively (Table X). In 1985, CPOM comprised 1.7%, 2.%, and 1.0% total OM in transport during the entire, early and late periods respectively. The slightly greater percentages can be due to fewer data points than in 1984. The relatively stable percentage of CPOM during both years indicates that although CPOM increased or decreased in concentration in relation to flow, its percentage of total OM remained constant. This was observed with the other three size classifications as well (Table X).

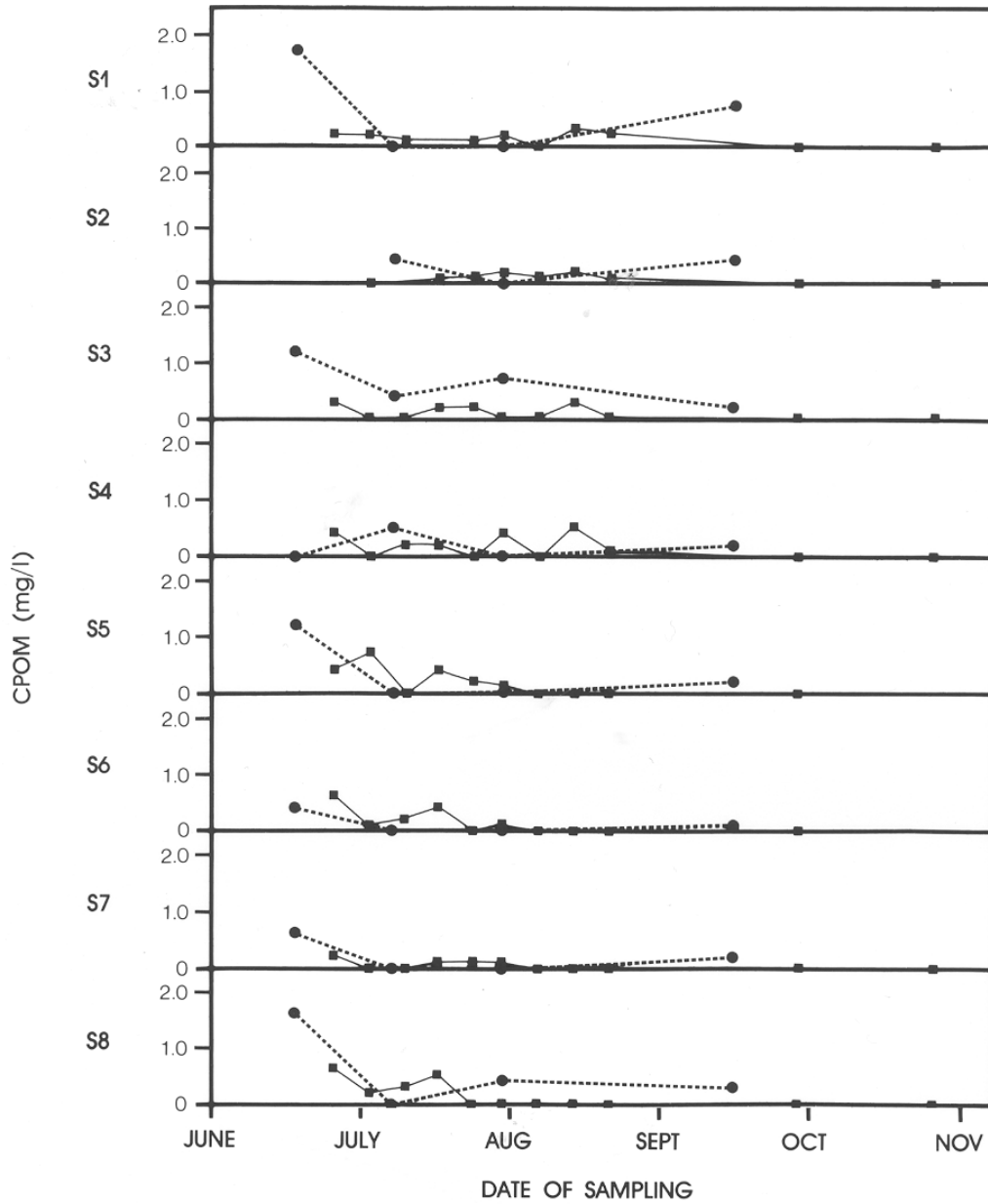


Figure 51. Baseline Coarse Particulate Organic Matter for 1984 (■) and 1985 (●) sampling seasons at Sites S1-S8.

Table X: Percent composition, by grain size, of the total OM in transport during the entire, early and late sampling periods of 1984 and 1985

1984	Entire	Early*	Late**
Coarse Particulate Organic Matter (CPOM) > 1mm	0.5%	0.6%	0.03%
Fine Particulate Organic Matter (FPOM) > 53um to < 1mm	6.2%	5.4%	8.0%
Very Fine Particulate Organic Matter (VPOM) > 0.45um to < 53um	64.7%	67.5%	58.0%
Dissolved Organic Carbon (DOC) < 0.45 um	28.6%	26.5%	33.7%
1985			
Coarse Particulate Organic Matter (CPOM) > 1mm	1.7%	2.1%	1.2%
Fine Particulate Organic Matter (FPOM) > 53um to < 1mm	8.1%	9.6%	6.1%
Very Fine Particulate Organic Matter (VPOM) > 0.45um to < 53um	66.2%	68.4%	63.4%
Dissolved Organic Carbon (DOC) < 0.45 um	23.9%	19.9%	29.3%

* 6/1/84-7/30/84 and 6/24/85 – 7/22/85

** 8/8/84 – 9/28/84 and 8/7/85 – 9/27/85

Peaks

Site S3 and S5 experienced peak CPOM concentrations comparable to early season high water concentrations during the 8-9 peak-event. Site S5 CPOM increased to 0.6 mg/l, while S3 CPOM peaked at 0.5mg/l (Figure 52). The maximum baseline concentrations at S3 for 1984 and 1985 were 0.50 mg/l and 1.20 mg/l respectively. The increase in CPOM at both sites was due to an increase in flow, and the subsequent scour and re-suspension of sediments.

The 8-26 and 8-30 events were similar in that peak concentrations were comparable to June high water concentrations, but the events were different in that the pre-event sample concentrations during the 8-26 event were greater for all upstream and downstream sites than during the 8-30 event (Figure 53, 54). The one exception was site S6, during the 8-30 peak-event, which possessed a very high pre-sample concentration of 0.8 mg/l. This cannot be explained at this time. The greater pre event sample concentrations of the 8-26 event can be attributed to the increasing flow due to abnormally high precipitation levels preceding the event. Prior to the 8-26 event, the NOAA climatological station at Winnegabo, Minnesota recorded 9.63 cm (3.79 in) of precipitation between the dates 8-22 and 8-25 after a prolonged dry period. On 8-29, one day before the 8-30 peak-event sampling, another 6.65 cm (2.62 in) of precipitation occurred. The constant high flow and subsequent scouring of the streambed could have caused the lower pre-sample concentrations during the 8-30 event.

Affects due to the watershed and initial water surge moving downstream were not magnified as with other parameters except at S8 during the 8-30 event. During this event, site S8 possessed the greatest peak concentration of all the sites involved with 1.0 mg/l. Site S3 concentrations increased significantly during the 8-30 event (from 0.3 mg/l to 1.0 mg/l) during the first 40 minutes of the event. This could be attributed to an increase in flow and the possible re-suspension of sediments due to this increase.

The peaking operation of the dam did impact downstream CPOM concentrations by elevating CPOM to concentrations observed during early June high water.

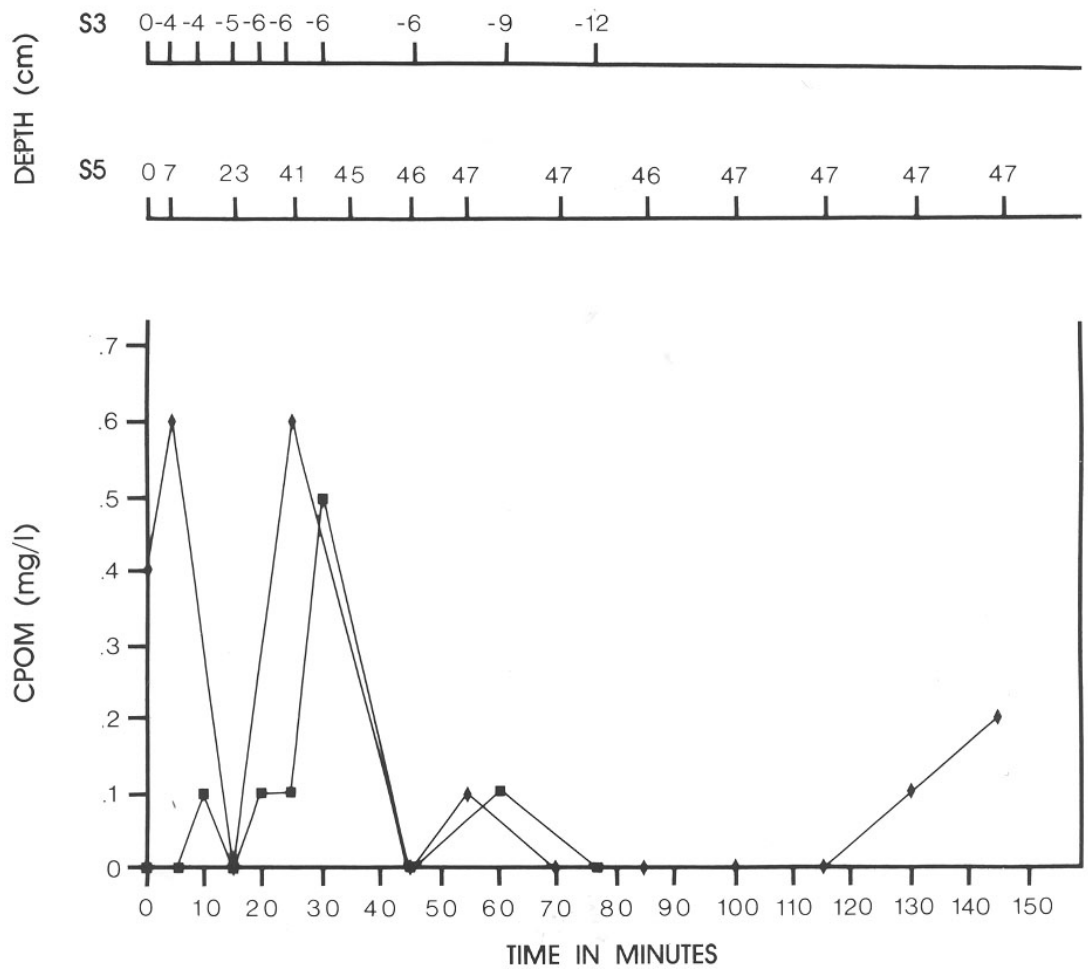


Figure 52. Coarse Particulate Organic Matter for peak event of August 9, 1985 at Sites S3 (■) and S5 (◆)

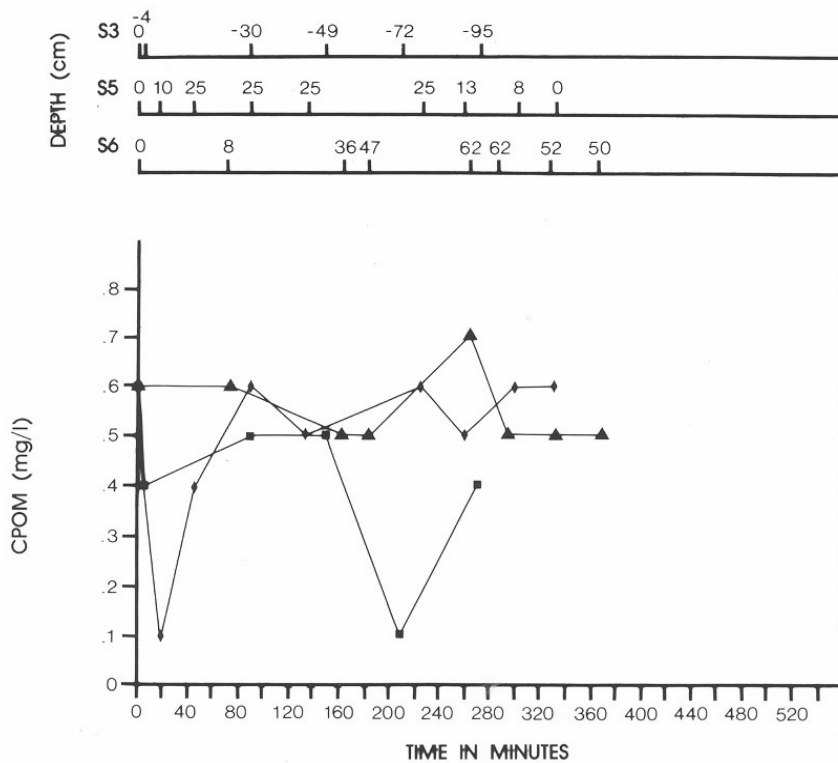


Figure 53. Coarse Particulate Organic Matter for peak event of August 26, 1985 at Sites S3 (■), S5 (◆) and S6 (▲)

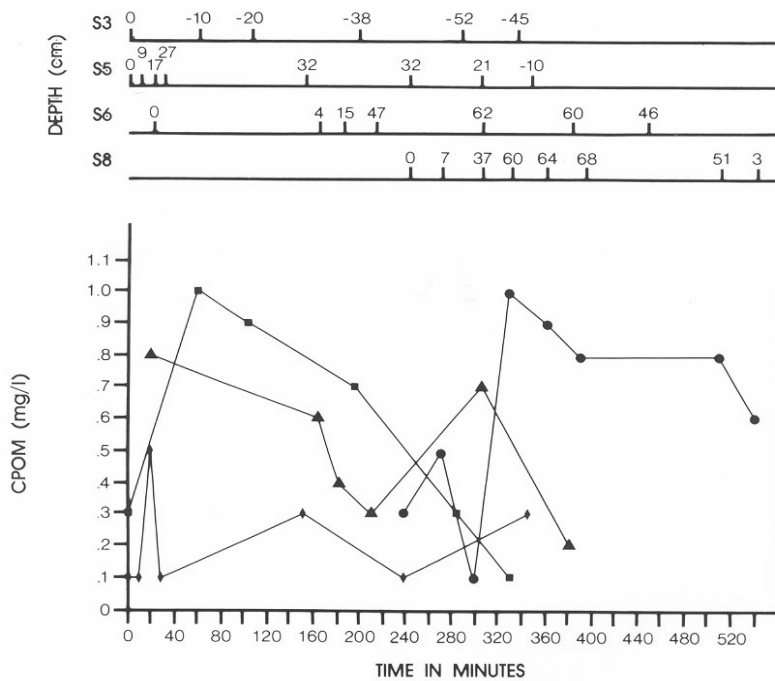


Figure 54. Coarse Particulate Organic Matter for peak event of August 30, 1985 at Sites S3 (■), S5 (◆), S6 (▲) and S8 (●)

Fine Particulate Organic Matter (FPOM)

Introduction

Fine particulate organic matter was defined in this study as OM <1 mm but >53 µm in size. CPOM, both autochthonous and allochthonous, undergoes heterotrophic-mediated biological and mechanical degradation within the stream (Kausnik *et al.*, 1968). Microbes and shredding macroinvertebrates reduce the CPOM to FPOM. FPOM is more easily transported by a stream than CPOM because of its smaller size. Therefore, FPOM will be exported downstream while CPOM may become trapped in organic debris dams (Cummins, 1975). Collecting macroinvertebrates, such as clams and Trichoptera, utilize FPOM for feeding purposes (Cummins, 1979). In a sixth order stream such as the Blue Earth River, FPOM should be relatively low in concentration and contribute a small proportion to the total OM in transport. This hypothesis can be stated because of the low concentrations of CPOM, and the minimal impact of riparian FPOM contributions, both of which are needed for the generation of FPOM.

Baseline

Mean FPOM concentrations were greatest at S1 during 1984 and 1985, and decreased as one moved downstream to S8 (Figure 55). This downstream reduction in concentrations may be due to the further processing of FPOM to smaller size classifications or changes in slope. The reservoir did not demonstrate a consistent pattern of trapping FPOM, however it did reduce downstream concentrations on certain sampling dates.

It was found that FPOM concentration were greater than CPOM (Table X). Vannotes River Continuum Theory predicts CPOM: FPOM will decrease as stream order increases (Vannote *et al.* 1980). In 1984, FPOM comprised 6.2%, 5.4%, and 8.0% of total OM during the entire, early, and late sampling periods. In 1985, it comprised 8.1%, 9.6%, and 6.1% during the same sampling periods. When comparing the early and late sampling periods, FPOM possessed a greater percentage of total OM during the late period of 1984 and the early period of the 1985. Flow was low during these two sampling periods and may indicate that FPOM is greater in percentage of total OM during periods of lower flow.

Peaks

The impacts on FPOM concentrations in the Rapidan Dam's tailwaters was similar to the impacts observed for Total Phosphorus. FPOM concentrations reached or exceeded, by as much as five times, the maximum baseline concentration for the same sites in 1984 and 1985.

The 8-9 event (Figure 56) increased S5 FPOM to a peak concentration of 4.1 mg/l from a pre-sample concentration of 1.4 mg/l (193% increase in 25 minutes). Maximum baseline concentrations at S5 in 1984 and 1985 were 2.60 mg/l and 2.30 mg/l respectively. During the 8-26 and 8-30 peak-events, (Figures 57, 58), concentrations at S5 were 3.7 mg/l (3.7 mg/l pre-sample) and 2.8 mg/l (1.7 mg/l pre-sample), demonstrating the greater impact of the 8-9 event. Concentrations at S3 were very stable during this event, and near the minimum baseline concentration for 1985 (1.10 mg/l).

During the 8-26 and 8-30 events, the water surge magnified the affects of FPOM as it moved farther downstream Site S6 (8-26 event) FPOM peaked at 5.7 mg/l (a 380% increase) and possessed baseline maximum concentrations of 3.0 mg/l and 5.4 mg/l in 1984 and 1985 respectively. Site S8 (8-30 event) FPOM peaked at 10.4 mg/l (increased 329% during the ascending leg) and possessed baseline maximum concentrations of 1.2 mg/l and 2.3 mg/l in 1984 and 1985 respectively. The peak concentration at S6 during the 8-30 event reached 3.1 mg/l. Site S3 concentrations peaked at 3.4 mg/l (8-26 event) which is near the maximum baseline value for 1984 (3.7 mg/l). The 8-30 event saw S3 FPOM remain basically stable and similar to S5 concentrations.

The peaking operation did impact downstream FPOM concentrations by increasing them to early summer high water levels.

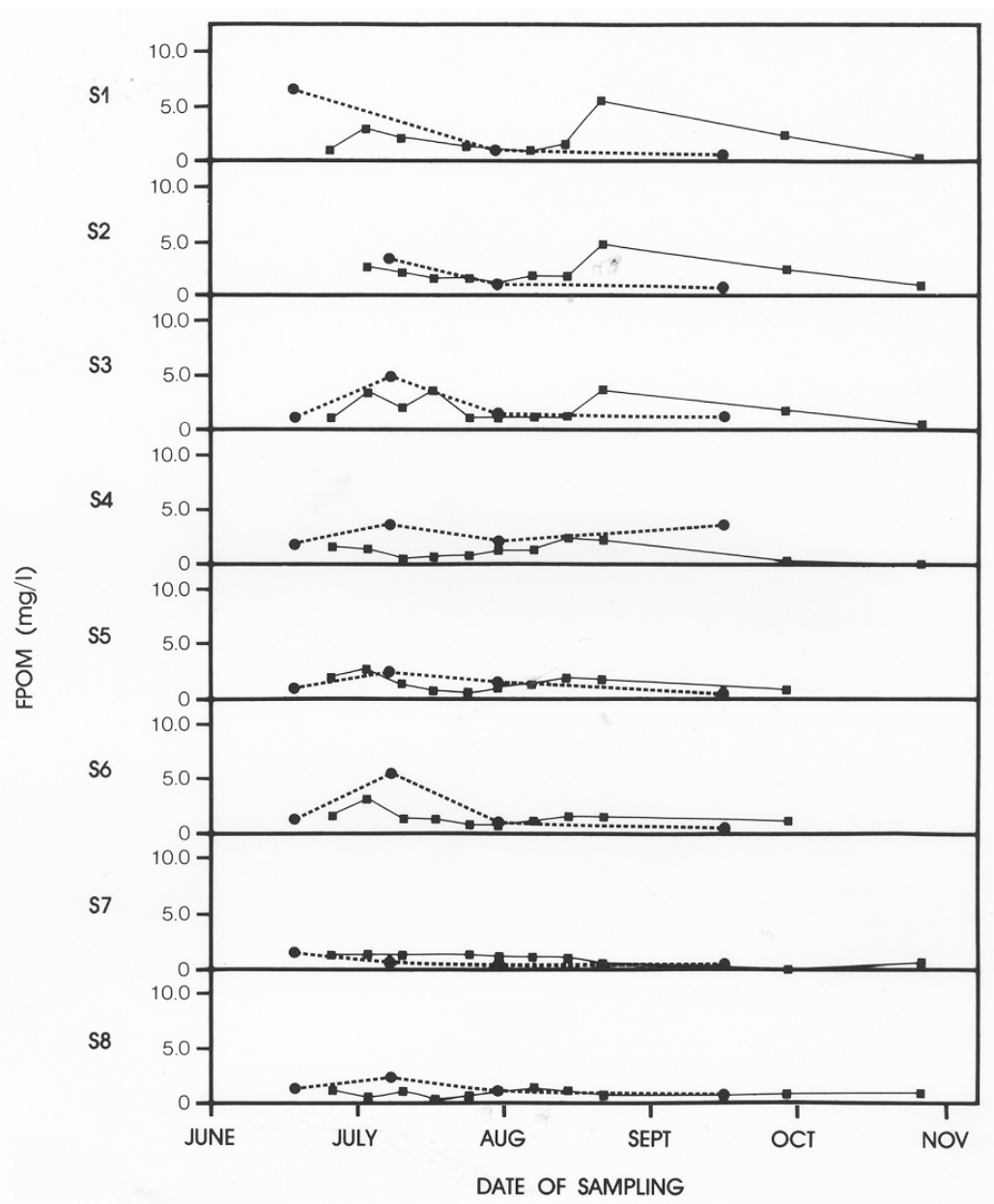


Figure 55. Baseline Fine Particulate Organic Matter for 1984 (■) and 1985 (●) sampling seasons at Sites S1-S8.

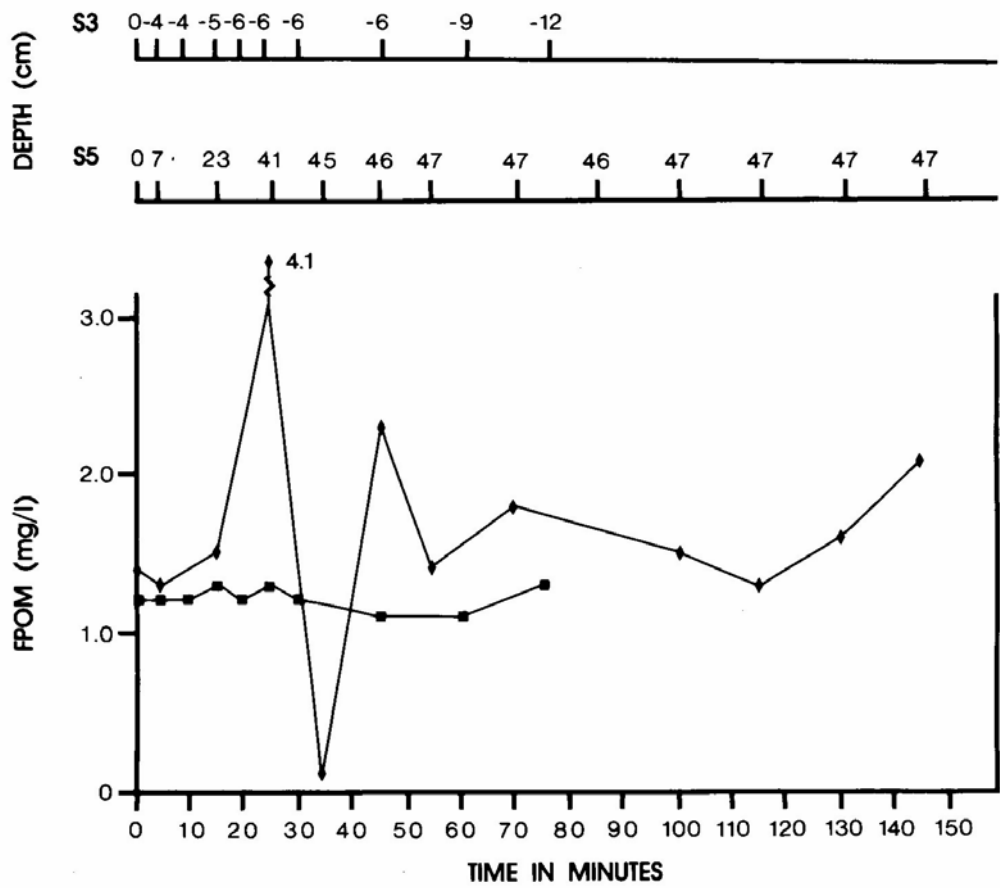


Figure 56. Fine Particulate Organic Matter for peak event of August 9, 1985 at S3 (■) and S5 (◆)

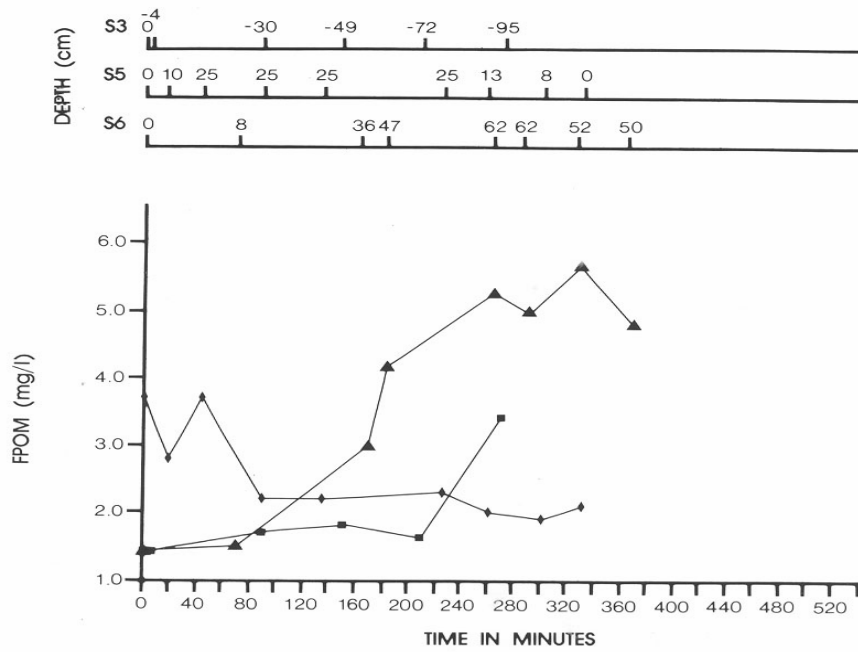


Figure 57. Fine Particulate Organic Matter for peak event of August 26, 1985 at Sites S3 (■), S5 (◆) and S6 (▲)

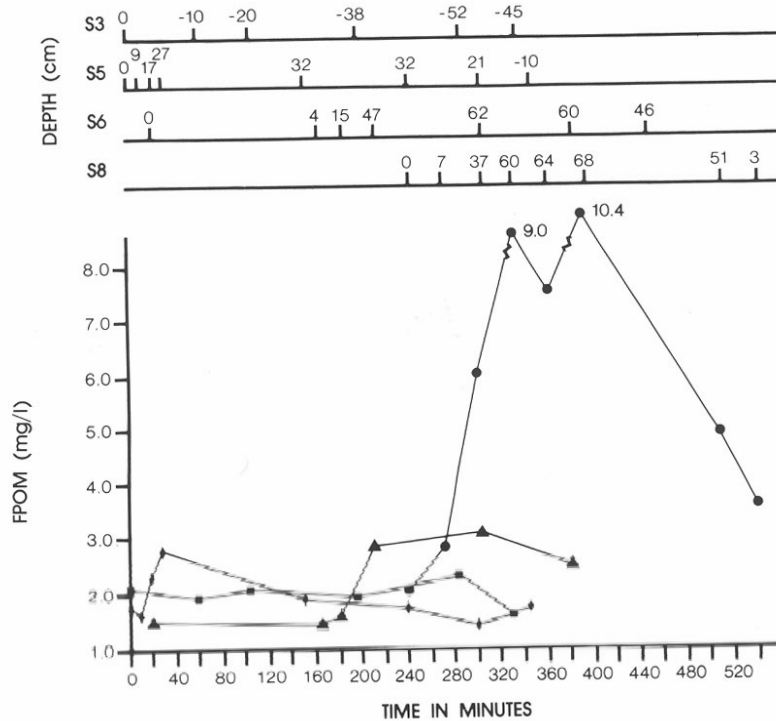


Figure 58. Fine Particulate Organic Matter for peak event of August 30, 1985 at Sites S3 (■), S5 (◆), S6 (▲) and S8 (●)

Very Fine Particulate Organic Matter (VPOM)

Introduction

Very fine particulate organic matter was defined in this study as OM <53 μm but >0.45 μm in size. VPOM in the Blue Earth River contributed the greatest proportion to the total OM in transport. Naimen and Sedell (1979) found that VPOM possessed the greatest proportion of total OM transported by four streams in Oregon ranging in order from first to seventh. They hypothesized that higher order streams transport mostly VPOM because it can be generated very rapidly from CPOM, FPOM and dissolved organic material. Wallace *et al.* (1977), and Maciolek and Tunzi (1968), demonstrated that particle sizes are selectively utilized by the aquatic fauna. Their studies also indicated the importance of VPOM to downstream communities.

Baseline

Although flow patterns were completely opposite in 1984 and 1985, VPOM concentrations followed very similar trends for the two years. The similar patterns, regardless of flow, strengthens the hypothesis that VPOM is generated rapidly and is abundant. The very high concentration of 71.5 mg/l at S3 on the 7-16-84 sampling date, correlates with the closing of the tainter gates of the dam to fill the reservoir (Figure 59).

Similar to FPOM, the reservoir did not demonstrate a trapping affect on VPOM. The small particle size may have allowed VPOM to remain suspended within the water column.

VPOM comprised the greatest percentage of total OM with 64.7%, 67.5%, and 58.0% in 1984, and 66.2%, 68.4%, and 63.4% in 1985, during the entire, early and late sampling periods respectively (Table VII). VPOM did possess a slightly greater percentage of total OM during the early sampling periods of both years. This cannot be attributed to flow since flow was very high during this time in 1984, but lower in 1985.

Throughout the sampling periods, concentrations at each site were initially high, and steadily decreased during the summer and on into fall. A consistent impact by the reservoir or the tributaries on mainstem concentrations is not evident.

Peaks

VPOM concentrations during all three peak-events reached or exceeded maximum baseline concentrations at all tailwater sites. Peak concentrations were again greater as the initial surge moved downstream beyond S5 (Figures 60, 61, 62).

Similar to CPOM and FPOM, VPOM concentrations followed the peak-events ascending leg, peak plateau, and descending leg closely with a respective increase, leveling off, and decrease. Sites S5, S6, and S8 possessed fairly similar pre-sample concentrations, both between sites and between events.

Site S5 experienced its greatest peak concentration during the 8-30 event with 21.0mg/l, as compared to 15.4mg/l, and 15.2 mg/l during the latter two peak-events. The maximum baseline concentrations at S5 for 1984 and 1985 were 20.2 mg/l and 15.4 mg/l respectively. The 8-9 peak-event did not appear to have a greater impact on S5 concentrations than did the 8-26 and 8-30 events.

The peak concentrations at S6 during the 8-26 (a 92% increase) and 8-30 (a 63% increase) events were 22.5 mg/l and 26.2 mg/l respectively. The maximum baseline concentrations at this site were 24.0 mg/l and 18.5 mg/l in 1984 and 1985 respectively.

Site S8 saw a peak concentration of 26.1 mg/l during the 8-30 event, with a baseline maximum of 18.0 mg/l and 13.2 mg/l in 1984 and 1985 respectively.

Site S3 saw VPOM steadily increase to peak at 21.8 mg/l (a 31% increase) from a pre-sample of 16.6 mg/l during the 8-26 event. This peak concentration was well below the maximum baseline concentration in 1984 (71.5 mg/l), but greater than the maximum in 1985 (17.1 mg/l). This increase could have been due to a concentrating effect due to the draw-down occurring at the site.

The peaking operation of the dam had the same impact on downstream VPOM concentrations as early summer floods. The impacts on concentration were magnified as the initial surge moved downstream. The increases in concentration are no doubt due to scour and recruitment from bank storage sources.

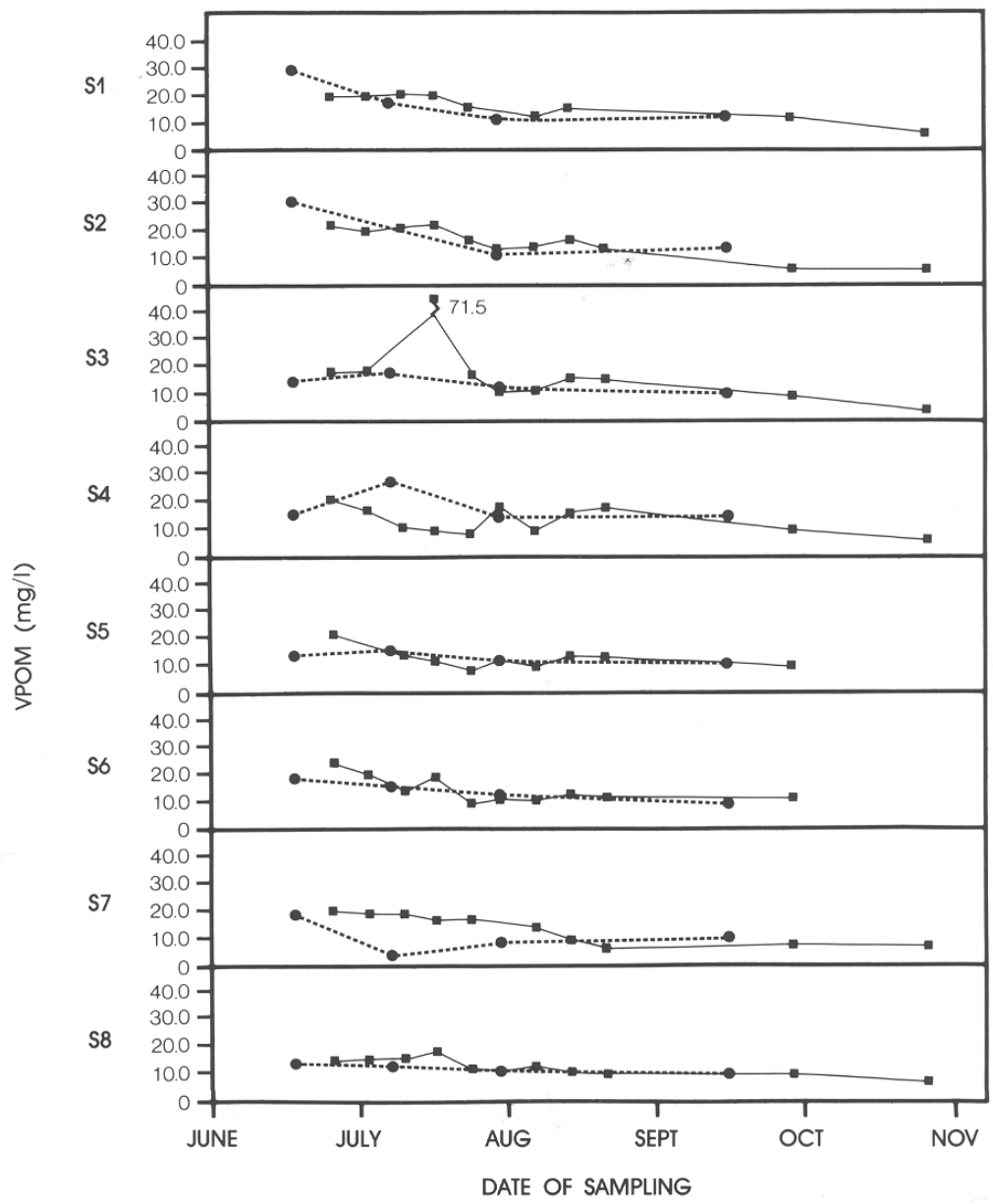


Figure 59. Baseline Very Fine Particulate Organic Matter for 1984 (■) and 1985 (●) sampling seasons at Sites S1-S8.

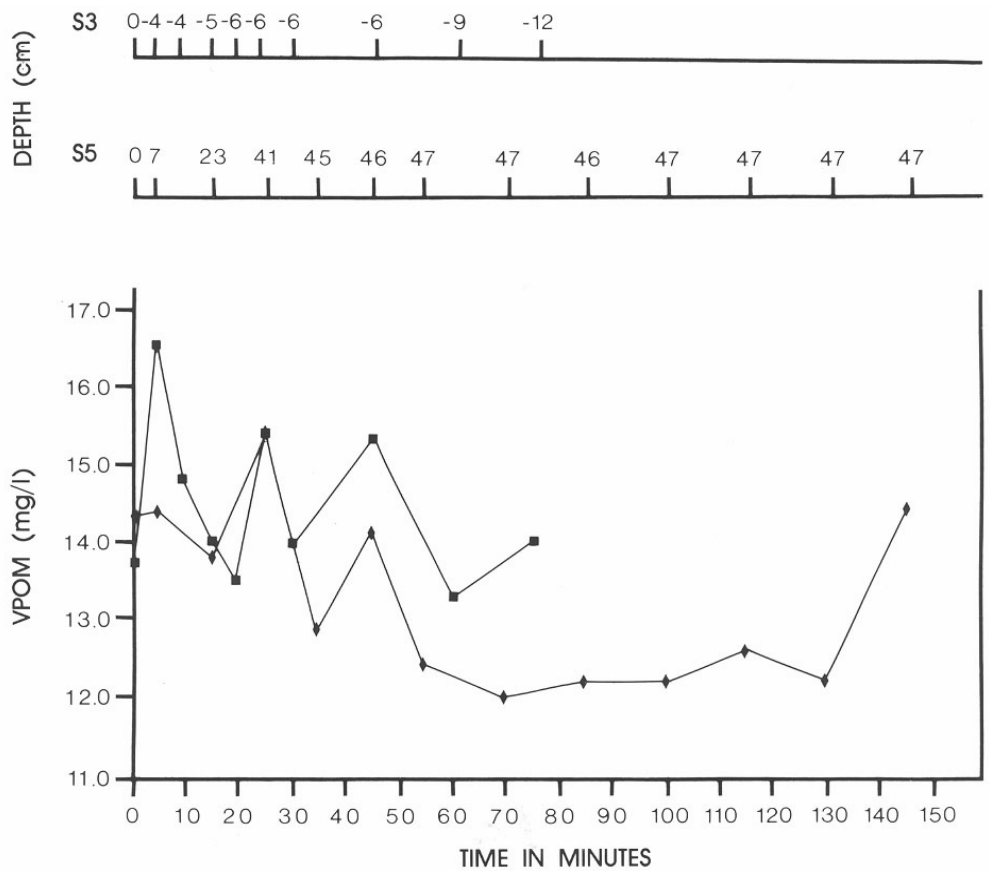


Figure 60. Very Fine Particulate Organic Matter for peak event of August 9, 1985 At Sites S3 (■) and S5 (◆)

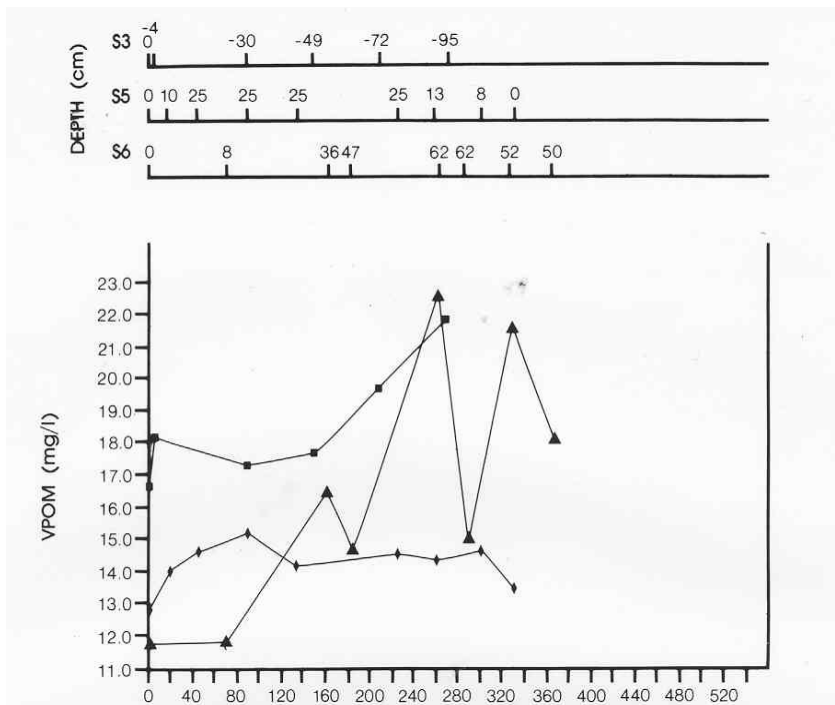


Figure 61. Very Fine Particulate Organic Matter for peak event of August 26, 1985 at Sites S3 (■), S5 (◆) and S6 (▲)

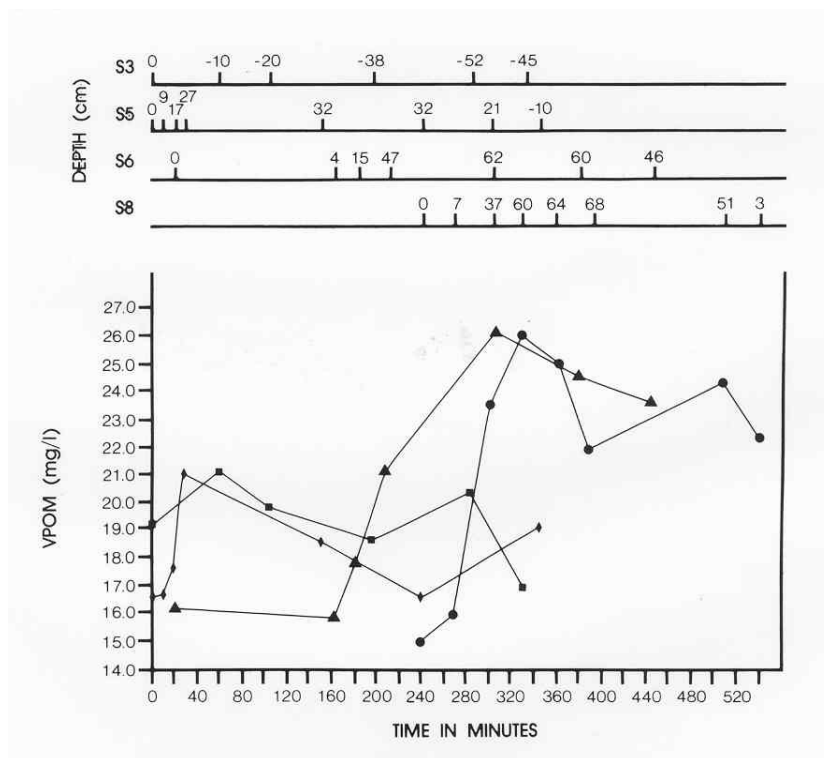


Figure 62. Very Fine Particulate Organic Matter for peak event of August 30, 1985 at Sites S3 (■), S5 (◆), S6 (▲) and S8 (●)