ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

An Assessment of Benthic Secondary Production in the Muskeg River of Northeastern Alberta

Project WS 1.3.5

December 1980

Alberta
ENVIRONMENT
15th Floor, Oxbridge Place
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The Hon. J.W. (Jack) Cookson
Minister of the Environment
222 Legislative Building
Edmonton, Alberta

Sir:

Enclosed is the report "An Assessment of Benthic Secondary Production in the Muskeg River of Northeastern Alberta."

This report was prepared for the Alberta Oil Sands Environmental Research Program, through its Water System, under the Canada-Alberta Agreement of February 1975 (amended September 1977).

Respectfully,

W. Solodzuk, P. Eng.
Chairman, Steering Committee, AOSERP
Deputy Minister, Alberta Environment

AN ASSESSMENT OF BENTHIC SECONDARY PRODUCTION IN THE MUSKEG RIVER OF NORTHEASTERN ALBERTA

by

R.A. CROWTHER
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for

ALBERTA OIL SANDS
ENVIRONMENTAL RESEARCH PROGRAM

Project WS 1.3.5

December 1980

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ABSTRACT

This study assessed the level of secondary production in the Muskeg River and tested the validity of hypotheses generated by Crowther and Griffing (1979) regarding the trophic structure and function of the Muskeg River as a "typical" tributary of the Alberta Oil Sands Environmental Research Program study area. A trophic rather than a taxonomic approach to aquatic invertebrate classification was taken and a modification of the Hynes method was used for the calculation of production. The disadvantages and advantages of these methods are discussed.

It was found that secondary production in the Muskeg River was highest upstream by a factor of two times that of a central site and four times that of a downstream site. These production values are compared to benthic production in other researched rivers. The production values are considered assessments of the levels of secondary production instead of true estimates. Reasons for this are discussed and the trophic compartmentalization of production is presented. The data also showed that the trophic economy of upstream sections of the river was based upon detrital and algal feeding and their importance decreased in a downstream direction, whereas the importance of carnivores and omnivores increased in a downstream direction. This was based upon the availability of coarse particulate organic matter (CPOM) at upstream sites, which was degraded to fine particulate (FPOM) and refractory particulate organic matter (RPOM) and exported downstream. These findings are in agreement with the hypotheses generated by Crowther and Griffing (1979). The reasons for the trends in secondary production and the shifts in community structure within each river reach are discussed.

Finally, recommendations are given for further studies in the AOSERP study area, since this area may be impacted in the future by oil sands development.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the assistance of the following people: Nitthila Radhakrishnan and Marcia Wallis, for long hours spent sorting, identifying, and weighing the benthic organisms; Jack Davis, for his help with the many calculations; Maire Luoma for her patience in editing and compiling this report; and Shirley Charlton (Botany Department, University of Alberta), for her constructive comments, criticisms, and advice.

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1. INTRODUCTION

The prime objective of the present study was to assess the approximate magnitude of benthic secondary production in the Muskeg River. The method employed to achieve this estimate was based on hypotheses generated by Crowther and Griffing (1979). Basically a trophic rather than a taxonomic approach to aquatic invertebrate classification was taken and a modification of the Hynes method (Hynes and Coleman 1968; Hamilton 1969) was used for the calculation of production. A brief description of the hypotheses generated during 1979 (Crowther and Griffing 1979) and the Hynes production method follows.

During 1979 a preliminary non-quantitative benthic survey was conducted on five of the major tributaries within the AOSERP study area (Figure 1): Ells, MacKay, Steepbank, Muskeg, and Hangingstone rivers. The invertebrate collections were identified and classified trophically using information gathered either from the literature (Grafius and Anderson 1973; Wiggins 1977) or by utilizing information from feeding studies in various AOSERP reports (Hartland-Rowe et al. 1979; Crowther 1979). All benthic data were then structured into an overall aquatic energy flow hypotheses which utilized information from all facets of aquatic research on the tributaries of the region.

The principal findings of this study were that the headwater sections of each tributary had an economy based on a seemingly symbiotic algal-bacterial-detrital energy linkage which resulted in higher invertebrate species diversity and possibly production than downstream sites. Omnivory and carnivory were more representative of benthic trophic status at downstream sites and invertebrate species diversity and secondary production decreased at these sites. These apparent shifts in the trophic structure of the benthic community from headwater to sites near the mouth were also thought to be a reflection of the decreasing role of coarse particulate organic material (CPOM), offset by increases in fine particulates (FPOM) and refractory particulate organic matter (RPOM)

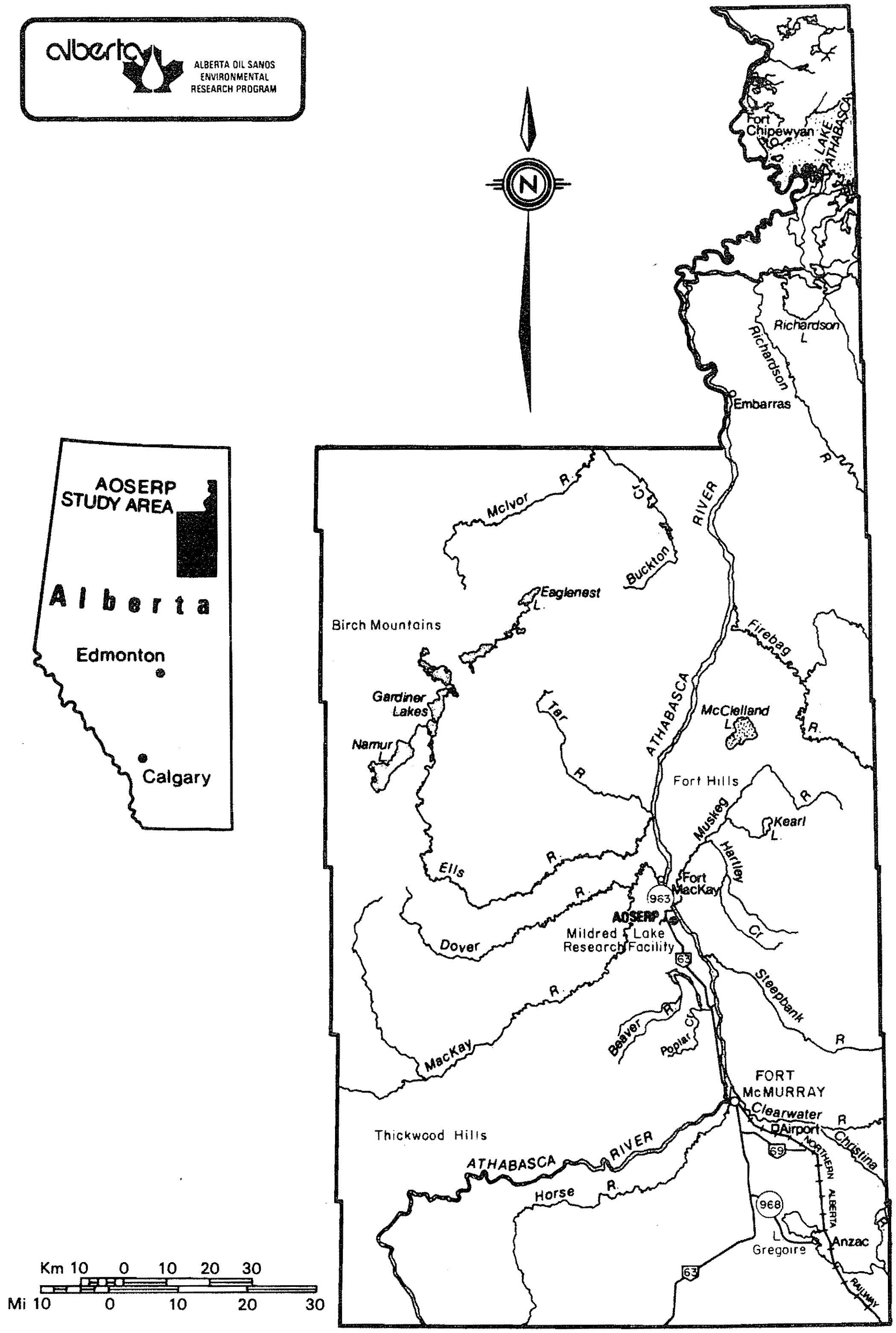

Figure 1. Alberta oil sands study area.

near the mouth of the stream. A further cause for decreasing benthic production and diversity was suspected to be the lowering of substrate complexity and light intensity at downstream as compared to headwater sites.

The purpose of the present study was to confirm or deny the findings of the 1979 study (Crowther and Griffing 1979) in a quantitative manner using the Muskeg River as a "typical" study system. In order to do this, benthic collections were again classified trophically using the Merritt and Cummins (1978) classification system as modified by local knowledge (Barton and Wallace 1980; Hartland-Rowe et al. 1979; Crowther 1979). Benthic production was then calculated for each trophic class using a modification of the Hynes method (Hynes and Coleman 1968; Hamilton 1969).

Basically the Hynes method derives production estimates for the total benthos of the "right order of magnitude" (Hynes and Coleman 1968:573) by summing the losses between successive size groups. The objective is to calculate an approximation of the production rate for a group of species which could be treated in terms of size units, without the necessity of identifying individual cohorts. With the addition of Hamilton's (1969) correction, the basic method is:

1. Sort the benthic invertebrates into selected size groups, usually based on 1 mm groupings;
2. Compute the mean standing crop in numbers over the entire sampling period for each size group;
3. Determine the loss in numbers between successive size groups and multiply by mean weight to obtain the loss in weight;
4. Multiply by a factor equal to the number of size groups; and
5. Sum these productions for an estimate of total production.

Waters (1977) pointed out that it is important that only the sum of the final products be taken as production, rather than considering the productions for individual size groups. Negative values (resulting from an increase in numbers between size groups, probably due to sampling variation or bias) should be included in the sum by adding algebraically.

As Waters (1977) and H.B.N. Hynes (in a conversation with R. Crowther, March 1979) pointed out, to be used effectively it is necessary to initially sort organisms into trophic levels (i.e., at least herbivore, detritivore, predator), and then insure that all organisms have the same life span (i.e., all multi-, uni-, or bivoltine). These factors, however, put severe restrictions on the method since numerous studies (Resh 1975, 1977; Winterbourn 1974; Young and Reynoldson 1966; and others) have shown that many organisms change their trophic status during different life stages. Furthermore, in order to ascertain the voltinism of a species, it must be identifiable and its life history known. For many northern Canadian benthic insects this is unavailable information. However, in the present study problems of voltism were partly overcome by separating known multivoltine species groups such as the Plecoptera and the Chironomidae (Barton and Wallace 1980; Hartland-Rowe et al. 1979) and treating these groups separately. Trichoptera have also been found to be bi- or multivoltine in some tributaries of the AOSERP study area (Crowther 1979) but it was not known if this was the case in the Muskeg River. For this reason Trichoptera were included with other univoltine organisms in the production estimates which may have lead to an underestimate of production.

The Hynes method, with Hamilton's correction, tends to overestimate production. The overestimation is caused by the basic assumptions of the method, namely:

1. That all organisms grow to the same size;
2. That all organisms pass through the same number of size classes;
3. That all organisms grow at the same rate; and
4. That all organisms possess the same voltinism.

These assumptions obviously cannot be met by most benthic organisms. Furthermore, as Fager (1968) pointed out, if the number of samples is much less than the number of size classes, an overestimate is produced. Hamilton (1969), in response to Fager, suggested that the Hynes-Coleman method with his alterations is a useful tool, particularly in situations where cohorts are not discrete entities. Hamilton (1969) realized that their method was only an estimate of production and that, to determine its accuracy, details of the life histories of the species in the community had to be known. In spite of these difficulties, many recent studies have found the Hynes method to compare favourably with the other available methods (Fisher and Likens 1973; Winterbourn 1974; Castro 1975; McClure and Stewart 1976). Moreover, it is the only available method for calculating total benthic production.

2. STUDY AREA

The Muskeg River is a second order tributary of the Athabasca River, located approximately 75 km northeast of Fort McMurray within the AOSERP study area. The stream flows from its source at an altitude of 750 m in the northeast, southwest 35 km to its confluence with the Athabasca River at an elevation of 230 m. The average gradient over its course is 0.04% with the gradient increasing to 0.67% for the last 7 km prior to the Muskeg joining the Athabasca River (Anonymous 1973). The Muskeg River is a brown water, alkaline stream with a yearly mean pH of 8.3 (Charlton in prep.). Total discharge for the Muskeg during 1979 was 138 000 dam^3, with a maximum daily discharge of 28.2 $m^3 \cdot s^{-1}$ and a minimum of 0.440 $m^3 \cdot s^{-1}$, and the mean daily discharge was 4.36 $m^3 \cdot s^{-1}$ (Anonymous 1980).

2.1 STUDY SITES

The locations of the three study sites on the Muskeg River are shown in Figure 2, with site photographs in Appendix 7.1. Site 1 corresponds to Site 6 of the algal survey (Charlton in prep.) located at Latitude $57^o9'$ North, Longitude $111^o30'$ West. Site 1 was a long riffle varying in mean depth from 27 to 37 cm over the course of the survey. Stream profiles constructed from data obtained on each sampling date (Figure 3) show that water levels rose throughout the survey period and that the channel shifted approximately 1 m towards the right bank over the course of the summer.

Substrates at Site 1 were predominantly flat limestone cobble in sizes ranging from 50 to 150 mm underlain with coarse gravels and occassionally granitic boulders greater than 250 mm in maximum dimension.

The surrounding topography of Site 1 was dominated by the nearly vertical limestone valley walls downstream. Upstream banks are lower but still 3 to 4 m above the river. White spruce (Picea glauca), birch (Betula sp.), alder (Alnus sp.), and willow (Salix sp.) grow on or about the river's edge and some sedges occur at its

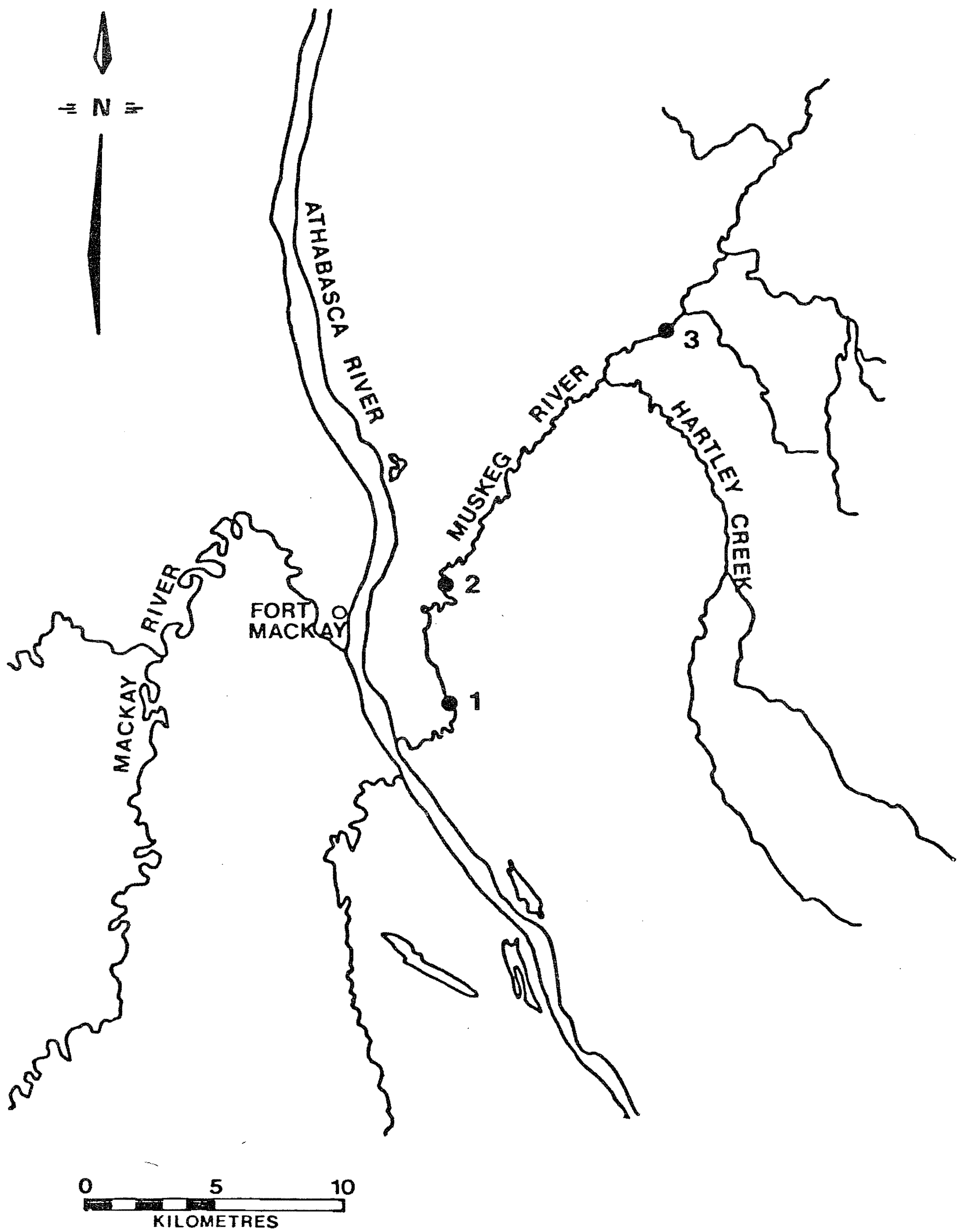

Figure 2. Locations of study sites on the Muskeg River.

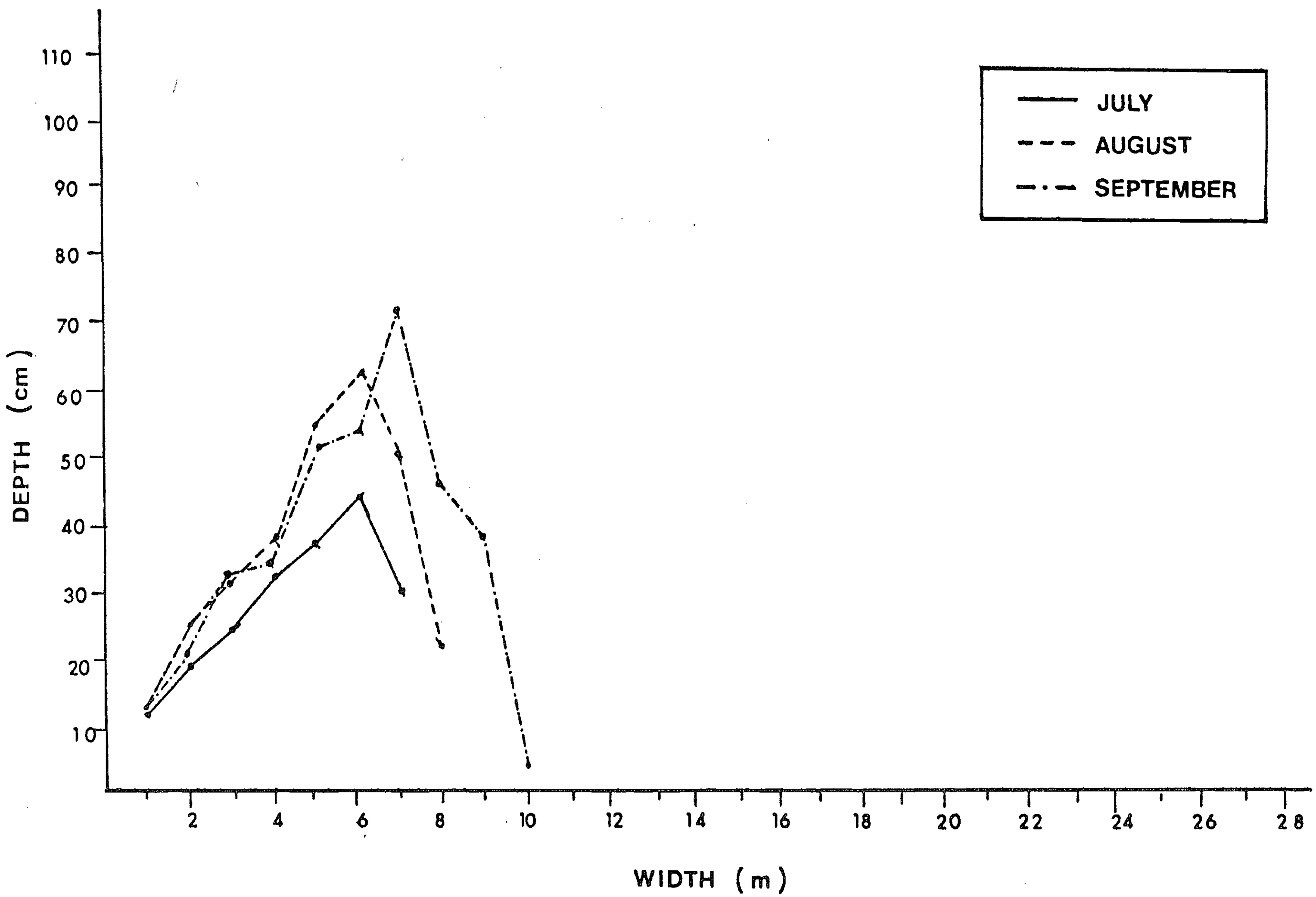

Figure 3. Stream profile for Site 1 at each sample date.

shoreline. Vegetative overhang was negligible at the site but considerable stream shading was provided by the valley wall itself. No emergent or submergent macrophytic vegetation was evident at this site.

Site 2 was located at Latitude 57°15' North, Longitude 111°25' West and corresponds to Site 5 of the algal survey (Charlton in prep.) and Muskeg Site 2 of the 1978 benthic survey (Crowther and Griffing 1979). Site 2 has been studied intensively by numerous researchers involved with the AOSERP program during the period 1979-80:

1. Benthos: Barton and Wallace (1980)
   Crowther and Griffing (1979)
2. Algal studies: Hickman et al. (in prep.)
   Charlton (in prep.)
3. Microbial studies: Lock and Wallace (1979)
4. Water quality and discharge: Anonymous (1980)

Site 2 was the widest and most open of all survey sites and consisted of a 25 to 30 m section of uniform riffle with substrates composed primarily of 10 to 20 mm friable limestone shards underlain by coarse gravels and sands. Figure 4 shows the stream profile at this site and illustrates similar channel movement towards the right bank as noted at Site 1 during September. The mean depth at Site 2 varied between 21 and 34 cm during the course of the survey.

White spruce (Picea glauca), poplar (Populus balsamifera), aspen (Populus tremuloides), and willow (Salix sp.) were the predominant vegetation along the low relief shoreline as well as thick grasses and sedges. In backwater areas and in the upstream pools, occasional areas of Potamogeton richardsonii and Vallisnaria sp. were found.

Site 3 was located approximately 0.5 km above the Shell Canada Experimental Open Pit at 57°16' North Latitude, 111°21' West Longitude and corresponds to algal Site 4 (Charlton in prep.). Figure 5 shows the stream profiles at this site. Mean water depths

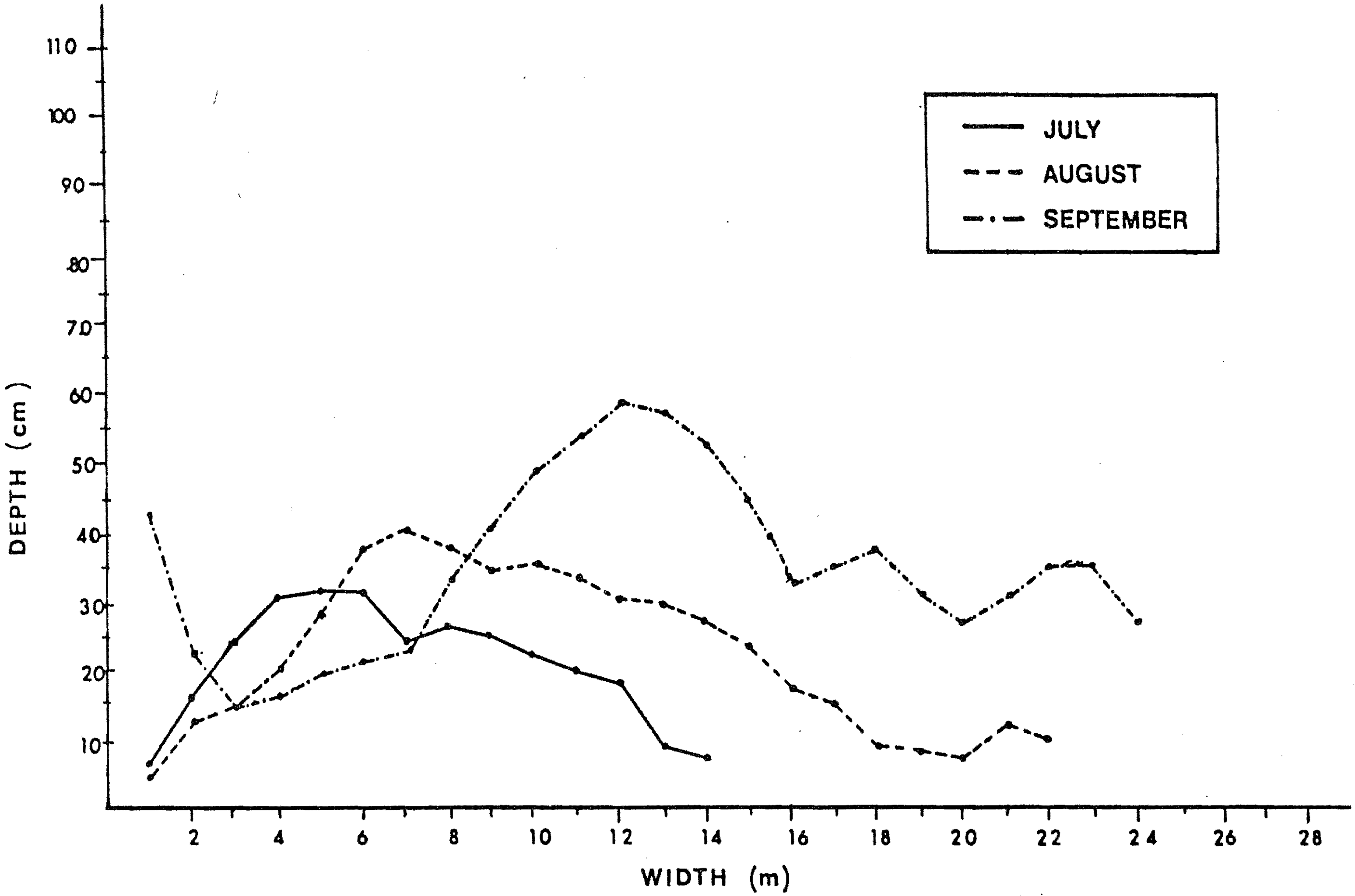

Figure 4. Stream profile for Site 2 at each sample date.

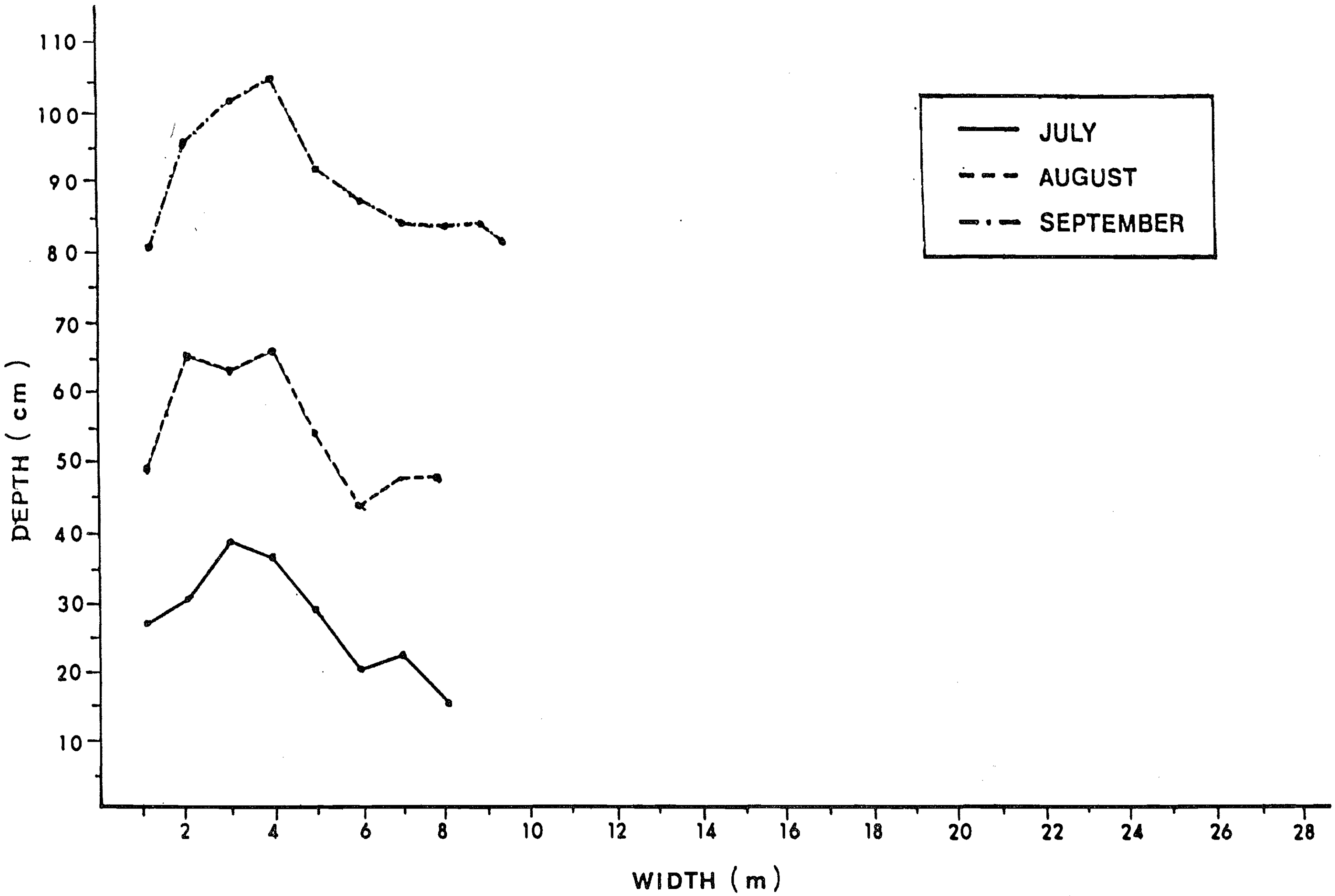

Figure 5. Stream profile for Site 3 at each sample date.

ranged from 26.5 to 88.5 cm over the course of the survey. The extreme water depth and swift flows encountered during September 1979 prevented effective benthic sampling from being carried out at this site as was the case during the 1978 survey.

Site 3 was typical of the upper reaches of the Muskeg River (excluding Muskeg Mountain tributaries) and was typified by a narrow channel with undercut banks and dense overhanging vegetation which provided 10% to 30% solar shading (Charlton in prep.). Riparian vegetation was composed primarily of hazel (<u>Corylus</u> sp.), poplar (<u>Populus</u> <u>balsamifera</u>), and aspen (<u>Populus</u> <u>tremuloides</u>). The substrate at the site was predominantly large cobbles and boulders of limestone and granite ranging in size from 100 to 400 mm in maximum dimension and was underlain by coarse gravels and fine sands. No aquatic macrophytes were present at Site 3.

3. MATERIALS AND METHODS

3.1 FIELD SURVEY

Ten replicate benthic samples were taken at each survey site during July, August, and September 1979 except as noted at Site 3 where high water prevented sampling in September.

Samples were taken using a modified Neill cylinder sampler (Davies et al. 1977) which consisted of a 250 µm Nitex mesh cylinder fastened to a frame 30 cm in diameter and enclosing an area of 0.0707 m^2. The height of the cylinder was adjustable from 30 to 60 cm to accommodate varying water depths. A collection net 60 cm long was attached to the back of the cylinder and organisms dislodged during sampling were retained in this.

During sampling, the Neill cylinder was placed over the substrate and forced into it to a depth of 5 to 10 cm. The large substrates (greater than 16.0 mm in diameter) were removed, placed in a bucket, picked, scrubbed, and washed to remove attached organisms. The loose substrates remaining in the sample area were then agitated to the depth of sampler penetration so that materials and organisms associated with bottom materials became dislodged. The freed organisms were then carried by the stream current and retained in the collection net.

The samples were concentrated using a 180 µm standard sieve, preserved in 10% formalin, labelled, and returned to the laboratory for analysis.

Sampling at each site was conducted in an upstream direction to avoid sampling previously disturbed areas and to limit sampling bias.

3.2 LABORATORY ANALYSIS

Samples were transferred from formalin to 70% ethanol immediately upon returning to the laboratory. Benthic samples were sorted using stereo dissecting microscopes at 30x magnification. Organisms were identified using the keys listed in Table 1.

Table 1. Identification keys used.

TRICHOPTERA LARVAE	Ross 1944; Wiggins 1977; Schuster and Etnier 1978; Hilsenhoff 1970
EPHEMEROPTERA NYMPHS	Burks 1953; Allen and Edmunds 1959, 1961a, 1961b, 1962a, 1962b, 1963a, 1963b, 1965; Hilsenhoff 1970
PLECOPTERA NYMPHS	Gaufin et al. 1972; Hitchcock 1974; Jewett 1959; Hilsenhoff 1970
COLEOPTERA LARVAE AND ADULT	Brown 1972; Usinger 1956
ODONATA NYMPHS	Usinger 1956; Ward and Whipple 1959
DIPTERA LARVAE	Johannsen 1934, 1935, 1937; Usinger 1956
CHIRONOMIDAE LARVAE	Roback 1957
HYDRACARINA	Ward and Whipple 1959
GASTROPODA	Ward and Whipple 1959
AMPHIPODA	Bousfield 1958
OLIGOCHAETA	Ward and Whipple 1959

Following this procedure, all organisms were measured using an ocular micrometer with an accuracy of 0.1 mm and placed into 1 mm size groups (up to size class 10, then 4 mm groupings) according to their trophic class as determined from Meritt and Cummins (1978) and AOSERP literature. All organisms except the Plecoptera and Chironomidae were treated in this manner. Plecoptera, however, were separated to species and each species treated individually and assigned a trophic class. This precaution was necessary since Barton and Wallace (1980) and Hartland-Rowe et al. (1979) have shown that most species of Plecoptera in the AOSERP study area have at least two-year or longer life cycles. Hynes and Coleman (1968) pointed out that the inclusion of such species with univoltine organisms can lead to a gross overestimatation of secondary production. Similarly, Chironomidae were separated into Orthocladiinae, Chironominae and Tanypodinae since most were suspected of being multivoltine. Weights and measurements for each sub-family of chironomid were kept separate.

Seven trophic classes were recognized to reflect changes that occur during the life cycle of most benthic organisms. These classes were as follows: carnivores, omnivores, detritivores, algal/detritivores, algal/carnivores, carnivore/detritivores, and algal. All organisms with the exception of a small percentage at Site 1 (unknown trophic status) were fitted into the classes outlined above.

In order to determine benthic standing crop and subsequently assess secondary production, each trophic class and its attendant size groupings were weighed using a modification of the wet weight technique described by Winberg (1971). Preserved organisms were first filtered onto a #10 Watman Fibre Filter using a Millipore vacuum apparatus, and then rinsed under vacuum with distilled water. The filters were removed, air dried, the organisms taken off with forceps and weighed. A Mettler H 11 electronic balance with an accuracy of 1.0 x 10^4 mg was used for weighing.

A minimum period of one month was allowed for the weight of preserved organisms to stabilize (Winberg 1971) before weighing.

This was done to compensate for fluctuations in weight which are a common problem when determining biomass from preserved benthic materials (Howmiller 1972; Stanford 1973).

Secondary production was then calculated using the modified Hynes method (Hamilton 1969) as outlined in Section 1.

4. RESULTS

4.1 STREAM DISCHARGE

Stream discharge for the Muskeg River near Fort MacKay (Station No. 07DA008) is presented in Figure 6 (Anonymous 1980) which shows a normal hydrograph for the river. The September survey occurred during a rising hydrograph (Figure 6) and, due to the physical properties at Site 3, the rising waters prevented sampling at the site during September 1979.

4.2 BENTHIC SURVEY

Species identifications and trophic classifications with total numbers and standing crop of all benthic organisms for all sample dates and sites are shown in Appendix 7.2.

Figure 7 shows the average monthly benthic density per square metre at all survey sites during 1979. As in 1978, maximum density was obtained at the upper site (Site 3). Benthic density was highest in July at all sites with a sharp drop in August prior to density increasing again in September. This represents a standard pattern in rivers of the AOSERP study area and reflects the loss of larvae during the major flight period (July to August) and subsequent recruitment in August and September.

Figure 8 shows the total benthic biomass for all sites and fauna collected during 1979. Maximum biomass was obtained at Site 2 while Site 3 was intermediate between Sites 2 and 1, at least for the July and August samples. Biomass decreased in August at both Sites 1 and 3, increased above July values in September at Site 1 and increased throughout the study period at Site 2 (Figure 8). A maximum biomass of 4.2 kg was obtained at Site 2 in September and a minimum of 0.8 kg was obtained at Site 1 in August.

Table 2 summarizes the breakdown of benthic biomass by site and date for each trophic class, while Table 3 summarizes only the Chironomidae and Table 4 the Plecoptera biomass (these data were incorporated into the Table 2 summary). Figures 9, 10, and 11

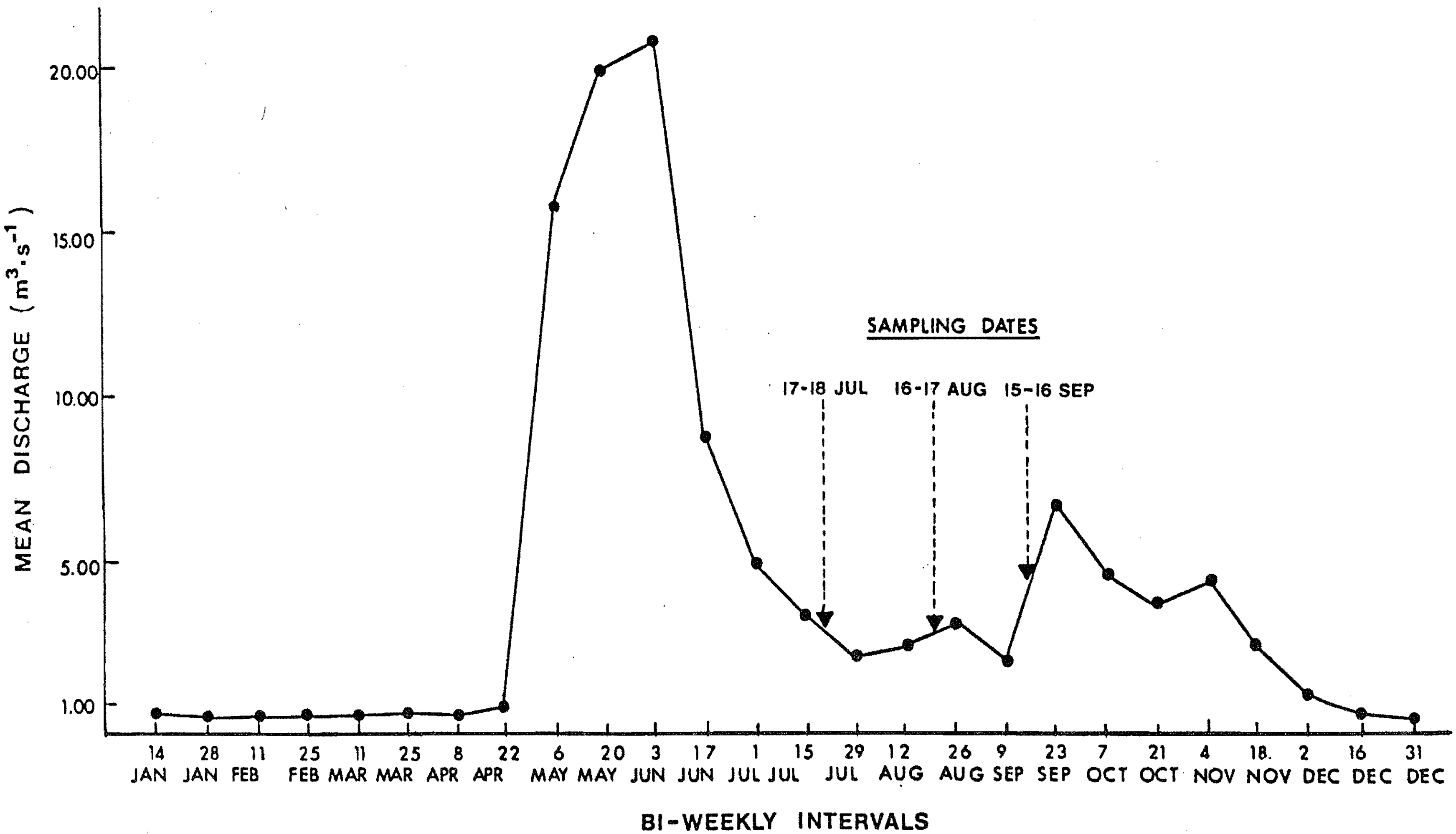

Figure 6. Mean daily discharge for Muskeg River, 1979 (Anonymous 1980).

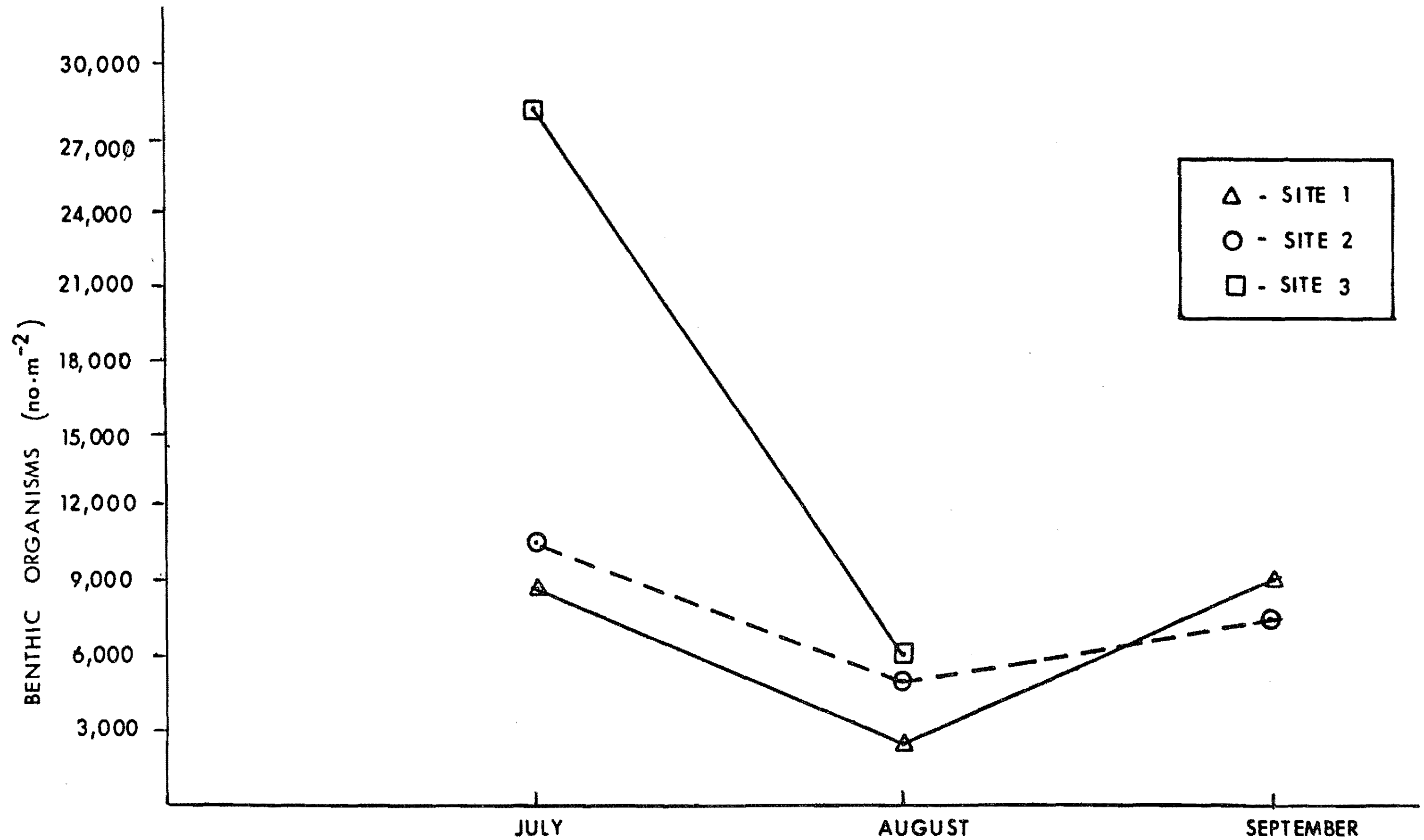

Figure 7. Average benthic organism density per square metre at all sites, from July to September 1979.

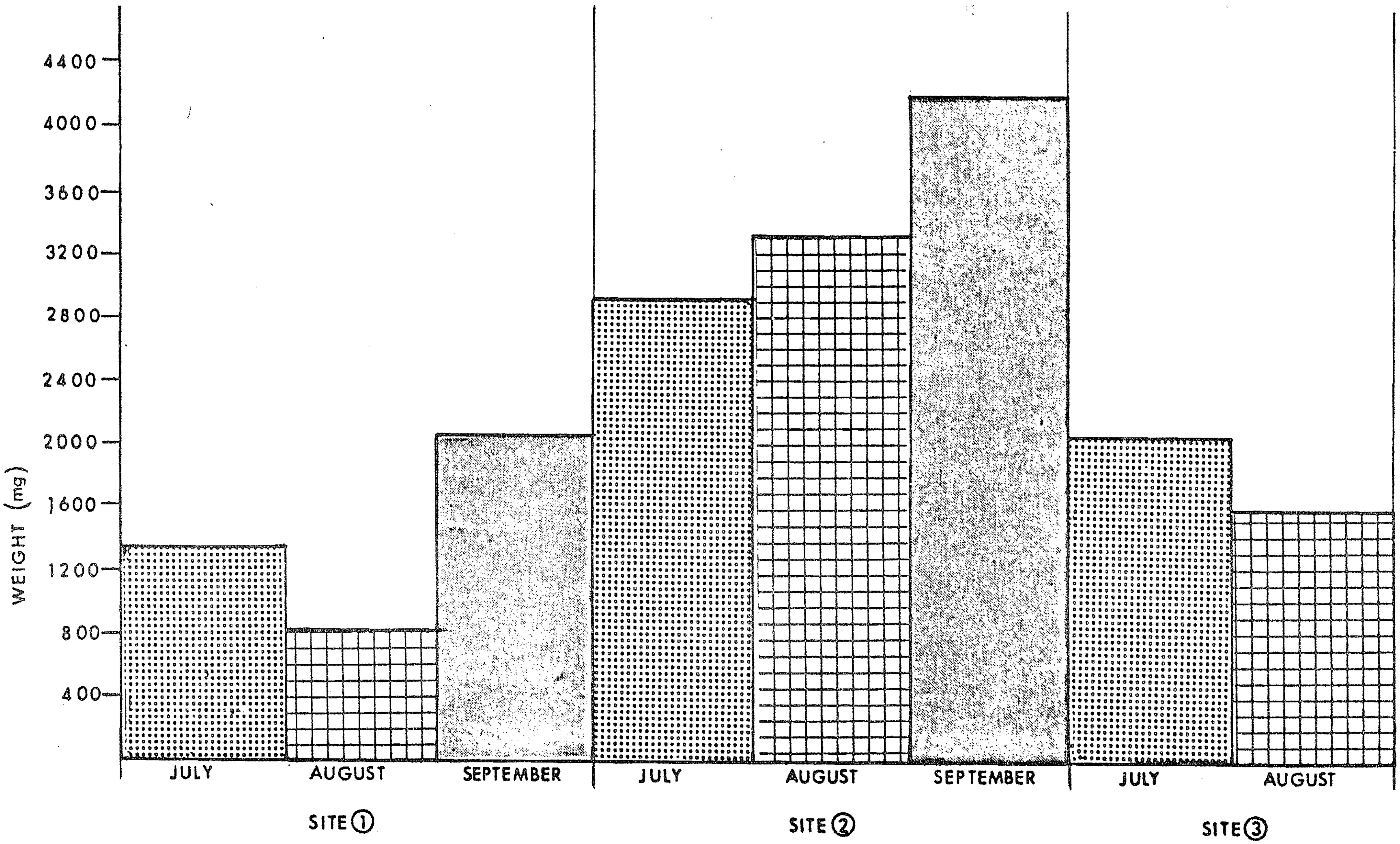

Figure 8. Total benthic biomass at all sites, from July to September 1979.

Table 2. Total weights (mg) of all trophic classes.

Trophic Class	Site 1			Site 2			Site 3	
	July	Aug.	Sept.	July	Aug.	Sept.	July	Aug.
Omnivores	38.22	131.98	845.09	438.54	1245.00	1684.09	3.31	60.53
Algal Feeders	1.64	2.20	-	2.17	8.76	12.47	-	1.00
Algal/Detritivores	358.71	229.75	265.39	359.11	673.56	815.68	151.74	286.95
Carnivores	511.58	186.01	227.10	230.44	249.40	276.65	83.71	40.71
Algal/Carnivores	87.34	119.46	509.84	1082.18	750.04	601.37	-	-
Carnivore/Detritivores	37.98	-	15.49	-	49.96	156.26	5.82	-
Detritivores	330.08	175.89	175.89	993.10	420.68	720.87	1775.42	1201.09
Unknown	2.01	-	-	-	-	-	-	-
Total	1367.56	845.29	2038.80	3105.54	3397.40	4267.39	2020.00	1590.28

Table 3. Total weights (mg) of trophic classes of Chironomidae.

	Site 1			Site 2			Site 3	
Trophic Class	July	Aug.	Sept.	July	Aug.	Sept.	July	Aug.
Carnivore (Tanypodinae)	10.51	13.13	4.65	31.07	9.20	5.28	13.06	5.39
Detritivore (Orthocladiinae)	3.23	11.99	15.73	7.54	19.12	9.94	80.26	13.40
Detritivore (Chironominae)	37.20	46.91	18.58	89.63	17.96	6.66	15.85	9.02

Table 4. Total weights (mg) of trophic classes of Plecoptera.

Trophic Class	Site 1			Site 2			Site 3	
	July	Aug.	Sept.	July	Aug.	Sept.	July	Aug.
Omnivores	1.55	64.87	51.22	14.1	195.88	80.56	-	0.46
Algal Feeders	-	-	-	-	-	-	-	-
Algal/Detritivores	-	-	-	-	-	-	0.43	-
Carnivores	24.07	77.30	59.43	29.72	111.84	177.03	-	-
Algal/Carnivores	87.34	119.46	509.84	1082.18	750.04	601.37	-	-
Carnivore/Detritivores	-	-	-	-	-	-	-	-
Detritivores	-	0.83	2.55	4.32	3.36	14.41	32.34	10.09
Unknown	2.01	-	-	-	-	-	-	-
Total	111.92	262.46	623.04	1130.32	1065.08	873.37	32.77	10.55

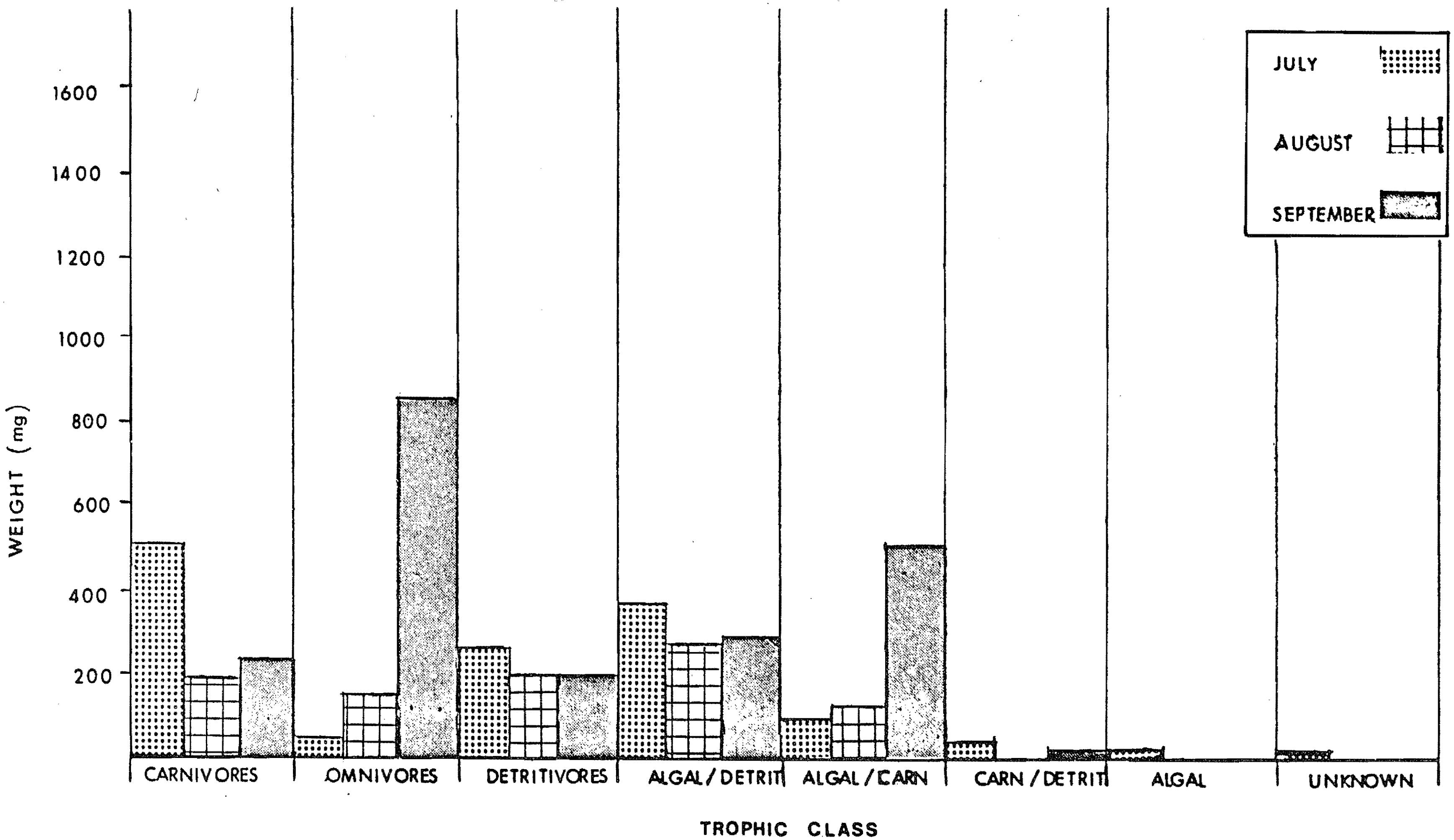

Figure 9. Biomass of trophic classes at Site 1, from July to September 1979.

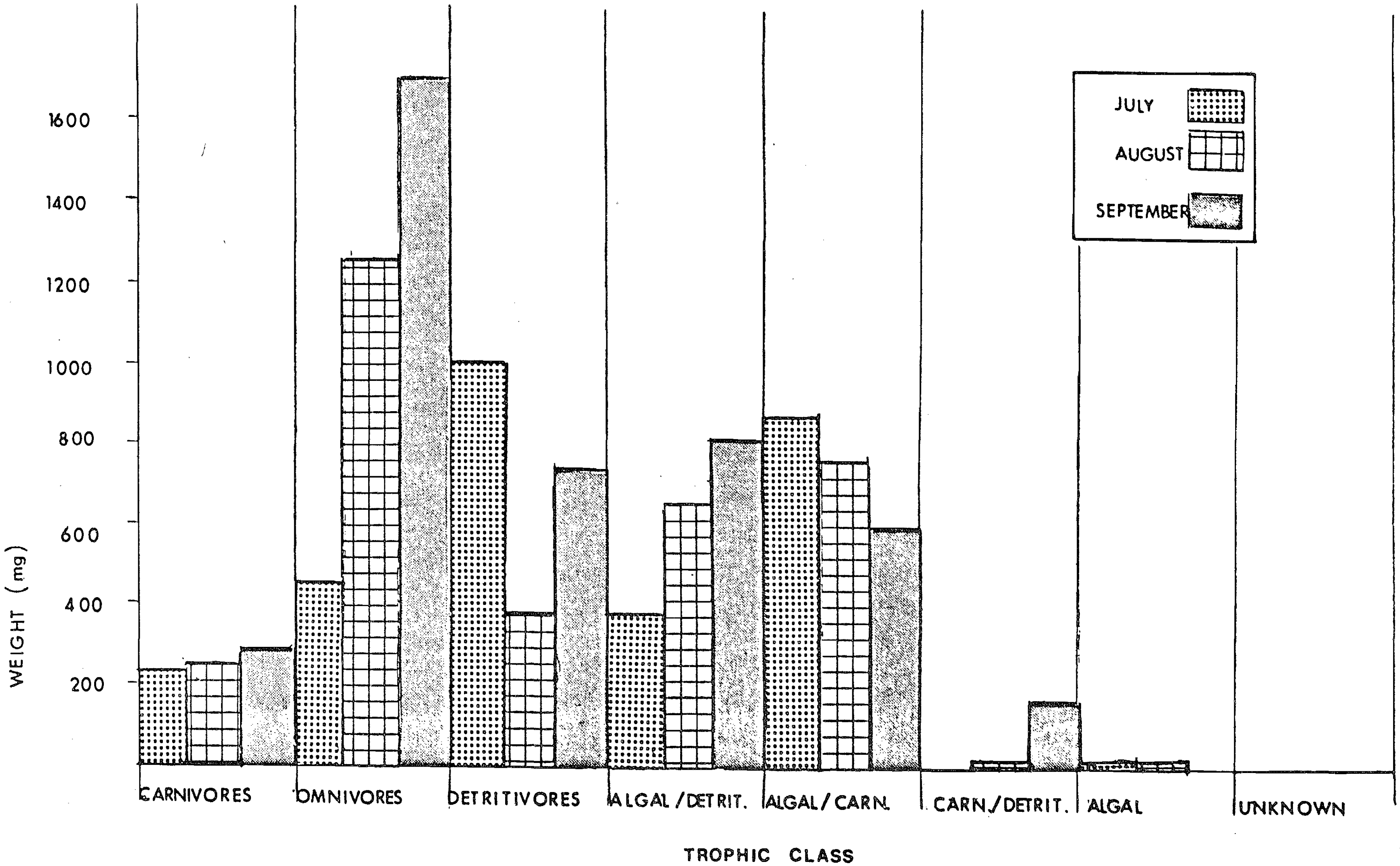

Figure 10. Biomass of trophic classes at Site 2, from July to September 1979.

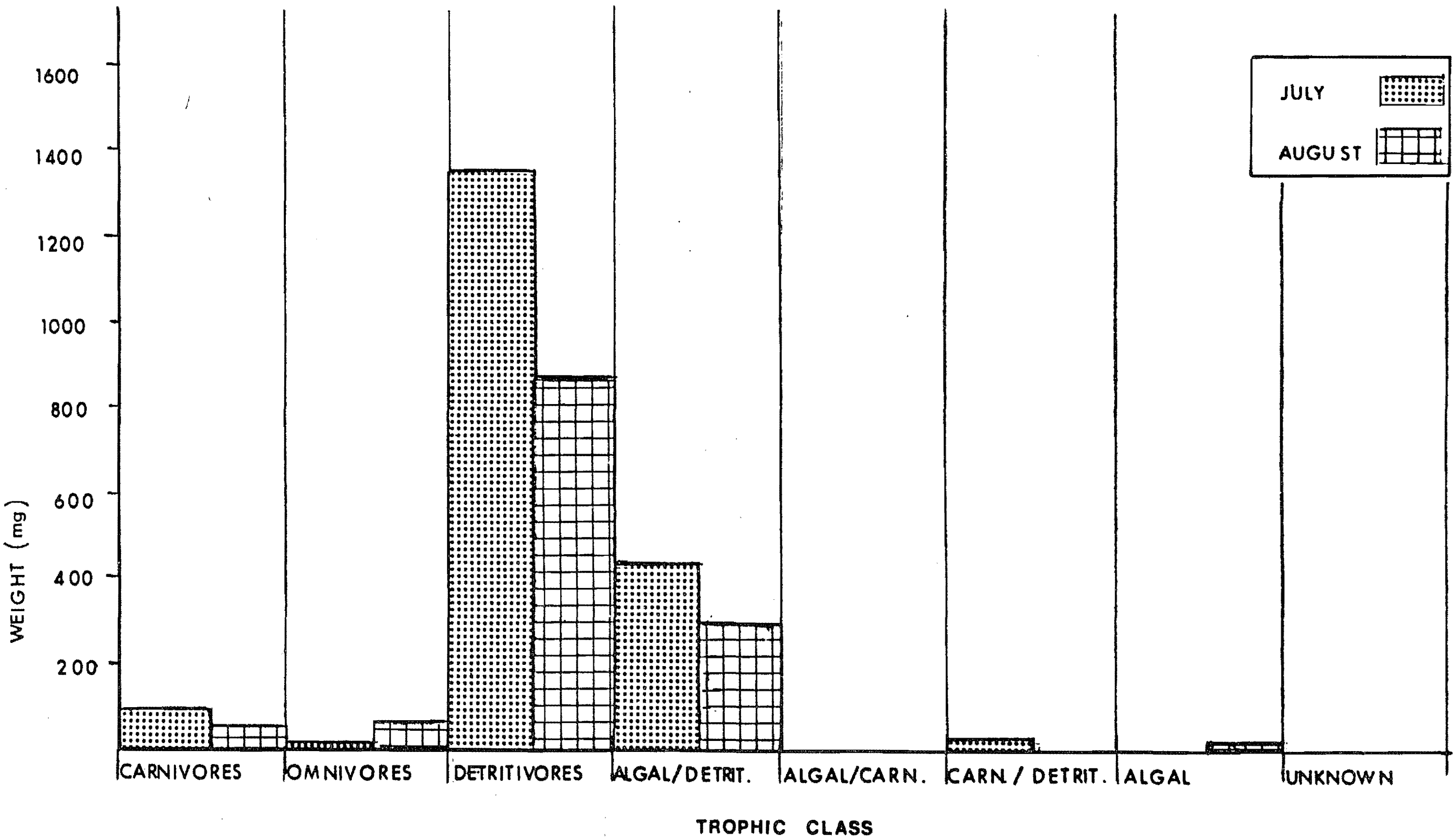

Figure 11. Biomass of trophic classes at Site 3, from July to September 1979.

illustrate the trophic biomass data graphically for each of Sites 1, 2, and 3.

At Site 1 (Figure 9), 45.63% of the total biomass was contained in two trophic classes (i.e., 21.75% carnivores; 23.88% omnivores), while detritivores represent only 16.04% of the total biomass. Biomass contained in the carnivore trophic class decreased from a high in July to a low in August (Figure 9), a reduction of 35.21% of the biomass, before rising again in September by 4.44%. The August reduction in biomass probably reflected the effect of summer emergence while the slight rise in September resulted from recruitment from the new hatch. The low level achieved in August was probably a reflection of the presence of longer lived carnivores, principally Plecoptera. A similar pattern was illustrated by most other trophic classes at Site 1 with the exception of omnivores and algal/carnivores.

At Site 2 (Figure 10), the importance of the carnivore trophic class was reduced to 7.02% of the total biomass while omnivores made up 31.27% of the total benthic biomass. The major concentration of invertebrate biomass at Site 2 was contained in the algal/detritivore and algal/carnivore trophic classes, which in combination represent 39.76% of all invertebrate biomass. There were three apparent trends in biomass accumulation at Site 2. These were as follows: (1) an increased growth was exhibited by the carnivores, omnivores, algal/detritivores, and carnivore/detritivores throughout the study period; (2) an overall reduction in biomass from a high in July to a low in September was exhibited by the algal/carnivores; and (3) a bimodal pattern of biomass was shown by the detritivores. The bimodal biomass displayed by the detritivores probably resulted from a bivoltine life cycle for the majority of these insects.

Site 3 (Figure 11) is the simplest to understand in terms of benthic biomass. The detritivore trophic class accounted for 82.45% of all the biomass while 12.15% was represented by the algal/detritivore trophic class. Therefore, 94.60% of all benthic biomass at Site 3 resulted from detritus related feeding. Both major trophic classes exhibited the same trend in biomass accumulation. Although September data are not available, it is suspected that the bimodality of the detritivore class at Site 2 would also be found at Site 3 since the composition of fauna was similar. Only the omnivore and algal trophic classes exhibited a increasing biomass curve over the study period at Site 3.

4.3 PRODUCTION ASSESSMENT

The production estimates for all sites and trophic classes calculated, using the modified Hynes method (Hamilton 1969), are shown in Table 5. These data incorporate an estimate of production obtained by extrapolation for September at Site 3. These estimates show that secondary production was highest at Site 3 (100.4023 $g{\cdot}m^{-2}$; year estimate, 301.2069 $g{\cdot}m^{-2}$), lower at Site 2 (48.0353 $g{\cdot}m^{-2}$; year estimate, 144.1059 $g{\cdot}m^{-2}$) and lowest at Site 1 (26.2552 $g{\cdot}m^{-2}$; year estimate, 78.7656 $g{\cdot}m^{-2}$). Three major growth periods of April to June, July to September, and October to November contribute substantially to overall benthic standing crop and hence production of a stream within the AOSERP study area (Crowther 1979). Therefore, an estimate of total yearly benthic production was calculated by using a factor of 3.0 to compensate for the growth periods not sampled (April to June and October to November).

Table 6 shows a breakdown of production data for individual trophic classes. In general, the importance of carnivore production decreases while detritivore production increases from Sites 1 to 2 to 3, and algal and omnivore production decreases from Sites 2 to 1 to 3.

Weights for all trophic classes by size class as used for production estimates and an example of production calculation are included in Appendix 7.3.

Table 5. Production ($g \cdot m^{-2}$) assessment of the Muskeg River for July, August, and September 1979.

	July			August			September	
Trophic Class	1	2	3	1	2	3	1	2
Carnivore	4.2875	1.7758	1.0333	-0.0633	1.0259	0.4998	0.4844	-0.2164
Detritivore	3.6774	4.0950	17.2653	0.4876	1.7328	31.1870	-0.1739	2.4848
Algal/Detritivore	3.3238	2.9932	0.8730	1.9217	3.8889	1.7628	1.7316	8.8421
Omnivore	0.1542	0.3258	0.0264	0.6220	5.5030	0.3965	8.2896	8.3520
Algal	-0.0422	0	0	0.0083	0	0.0029	0	0
Carnivore/ Detritivore	0	0	0.0038	0	0	0	0	1.1005
(Plecoptera)								
Algal/Carnivore	0.0307	1.1008	0	0	2.3805	0	0	1.2512
Carnivore	0.0118	0.0585	0	0.0273	0	0	0.3369	0.0485
Detritivore	0	0.0082	0.5727	0.1133	0.0070	0.0213	0.0080	0.0322
Omnivore	0	0.0778	0	0.1221	0.2549	0	0.1486	0.3687
(Chironomidae)								
Carnivore	0.0090	0.0885	0	0.0189	0	0	0.0058	0.0099
Detritivore	0.2379	0.3075	0.5753	0.0329	0.0501	0.0604	0.4603	0.0876
Total	11.6901	10.8311	20.3498	3.2738	14.8431	33.9307	11.2913	22.3611

Production Total For Each Site ($g \cdot m^{-2}$)

1. 25.2552 X 3.0 = 78.7656 ($g \cdot m^{-2} \cdot yr^{-1}$)
2. 48.0353 X 3.0 = 144.1059 ($g \cdot m^{-2} \cdot yr^{-1}$)
3. 54.2805 (100.4023 with Sept. Estimated) X 3.0 = 301.2069 ($g \cdot m^{-2} \cdot yr^{-1}$)

Table 6. Summary of production ($g \cdot m^{-2}$) for the major trophic classes.

Trophic Class	Site	July	August	September	Total
Detritivore	1	3.9153	0.6338	0.2944	4.8435
	2	4.4107	1.7899	2.9733	9.1739
	3	18.4133	31.2687	41.9708[c]	91.6528[d]
Carnivore/[a]	1	4.3083	-0.0171	0.8271	5.1183
	2	1.9228	1.0259	-0.1580	2.7907
	3	1.0371	0.4998	0.0000[c]	1.5369[d]
Omnivore	1	0.1542	0.7441	8.4382	9.3365
	2	0.4036	5.7579	8.7207	14.8822
	3	0.0264	0.3965	0.5000[c]	0.9229[d]
Algal/[b]	1	3.3123	1.9300	1.7316	6.9737
	2	4.0012	6.2694	10.0933	20.3639
	3	0.8730	1.7657	2.4000[c]	5.0387[d]
All Classes	1	11.6901	3.2908	11.2913	26.2722
	2	10.8311	14.8431	22.3611	48.0353
	3	20.3498	33.9307	46.1218[c]	100.4023[d]

[a] Predominately carnivore but second preference another trophic class i.e., detritivore

[b] Predominately algal but second preference another trophic class i.e., detritivore or carnivore

[c] Estimated value obtained by extrapolation

[d] Total incorporates estimate for September

5. DISCUSSION

The purpose of the present study was twofold: (1) to assess the level of secondary production in the Muskeg River; and (2) to test the validity of the hypothesis generated in 1978 (Crowther and Griffing 1979) regarding the trophic structure and functioning of the Muskeg River as a "typical" tributary of the AOSERP study area.

The first objective of this study has been met and an assessment of secondary production for each of the three study sites has been presented. It must be stressed at this point that these values do not represent a true estimate of production, merely an assessment of the levels of secondary production and perhaps more importantly the trophic compartmentalization of production. There are several reasons for this. First, this was not a whole year study and the major growth periods of April to June and October to November were not sampled. As shown by Crowther (1979), these two periods contribute substantially to overall benthic standing crop and hence production of a stream within the AOSERP study area. These growth periods were compensated for by using a factor of 3.0 to arrive at total yearly benthic production which may be an underestimate. This is particularly true in rivers in the AOSERP study area since considerable benthic growth also occurs during the winter months (Crowther 1979). However, this may offset the inherent overestimates of production incorporated by use of the Hynes method of calculation (Hynes and Coleman 1968; Hamilton 1969; Waters and Crawford 1973). Secondly, the placement of organisms into static trophic classes has its own problems since, as Cummins (1972) pointed out, species often change feeding habits and hence trophic status as they mature. Change in trophic status has been partly offset by separating species into trophic classes which take age-related feeding differences into account; i.e., algal/carnivore, which indicates that these organisms predominately consume algae but are also known to be secondarily carnivores. Thirdly, as recent studies in the AOSERP study area have shown, many organisms are bi- or multivoltine (Crowther 1979) while others have multi-year life cycles (Barton and Wallace 1980; Hartland-Rowe et al. 1979). These factors in combination may greatly affect the calculation of total production. The present authors have attempted to decrease this last effect by treating known or suspected non-univoltine life cycle groups separately; i.e., Chironomidae and Plecoptera. Many of the Trichoptera in tributaries of the Muskeg River may also fall into the bi- or trivoltine class (Crowther 1979). These Trichoptera were not separated since not enough was known about their life cycle in the Muskeg River and they have been shown to exhibit life cycle plasticity in response to the availability and quality of food resources (Mackay 1979). The inclusion of such bi- or trivoltine species with univoltine organisms may also have caused an underestimation of benthic production. For the above reasons and for those stated by Hynes and Coleman (1968), this study must remain an assessment which is probably of the right order of magnitude for benthic production in the Muskeg River. The most important function of this study lies in its reproducibility, its definition of trends between different reaches of the river, and the trophic relationships of the benthos within each river section, however crude.

Despite these inherent weaknesses, the results of the study are of great interest. It was found that secondary production was highest upstream at Site 3 (301.2069 $g \cdot m^{-2}$) by a factor of two times that of Site 2 (144.1059 $g \cdot m^{-2}$) and four times that of Site 1 (78.7656 $g \cdot m^{-2}$). These findings are in agreement with the hypotheses generated during 1978 (Crowther and Griffing 1979). By way of comparison, benthic production in the soft water unproductive Afon Hirnant in North Wales was calculated by Hynes and Coleman (1968) to be 4.76 $g \cdot m^{-2}$ in a normal year and 3.81 $g \cdot m^{-2}$ during a flood year. Hamilton (1969), using his modified version of the Hynes method, obtained an increased value of 45.55 $g \cdot m^{-2}$ (3.74 times higher) and, using the same factor, 14.25 $g \cdot m^{-2}$ during the flood year. Since Hynes (in Hamilton 1969) agreed with the corrections to his technique, it must be assumed that his estimate of 620.2 $g \cdot m^{-2}$ for the Speed River in Ontario (Hynes and Coleman 1968) is also low and should be adjusted upward to approximately 1800.0 $g \cdot m^{-2}$. The Speed River is a species-rich hardwater stream in southern Ontario, but in the senior author's opinion, the benthic fauna is neither as diverse nor is turnover as fast as that occurring in the Muskeg River (since most organisms inhabiting the Speed River are univoltine) and therefore this would seem to be a high estimate. Production in the Horokiwi River of New Zealand showed that primary consumers (herbivores and detritivores) represented between 7.6 to 72.1 $g \cdot m^{-2} \cdot y^{-1}$ and secondary consumers (carnivores) 0.8 to 11.9 $g \cdot m^{-2} \cdot y^{-1}$, giving total benthic production estimates of 8.4 to 84.0 $g \cdot m^{-2} \cdot y^{-1}$ (Hopkins 1976). The lowest production estimates for this stream were found in tree-shaded situations, suggesting a more algal than allocthonous energy source than was apparent in the Muskeg River. Given these estimates the benthic production in the Muskeg River appears considerably higher than the Afon Hirnant at all stations, approximately equal to the Horokiwi River at Site 1 but considerably higher at Sites 2 and 3, and lower than the Speed River at all sites. It is unfortunate that other workers have not provided yardsticks with which to correlate the present data to other Canadian rivers, particularly since the method has been available since 1968. If such studies exist, the authors are unaware of them.

Secondly, it was found that the trophic economy of upstream sections of the river was based upon detrital and algal feeding and that the importance of these trophic classes decreased in a downstream direction from Sites 3 to 2 to 1. In addition, the importance of both carnivores and omnivores decreased, in the opposite direction, from Sites 1 to 2 to 3. These findings are in agreement with the 1979 hypotheses.

As stated by Crowther and Griffing (1979), the main reasons for these apparent trends in secondary production were suspected to be: (1) a decrease in substrate heterogeneity between the upper and lower sections of the river; (2) a similar decrease in the availability of CPOM with a corresponding increase in RPOM; and (3) a decrease in the importance of a suspected algal/detrital food chain in a downstream direction.

These factors in combination were thought to explain the observed shifts in community structure within each river reach and the lowering of production since:

1. Decreasing substrate heterogeneity results in a lowering of the number of available niches for benthic invertebrates and consequently species diversity;
2. By increasing the numbers of carnivores and omnivores and decreasing the numbers of detritivores, as CPOM becomes RPOM at downstream sites, the overall turnover rate of benthic organisms and consequently production should decrease;
3. The decrease in an algal/detrital energy compartment at Sites 2 and 1 results from less organic input from riparian vegetation; and
4. The light availability decreases as the valley becomes more incised towards the rivers mouth.

That these hypotheses are upheld is shown by the data and from the physical configuration of the various sites. Site 3 is typical of the Muskeg River above the Shell Canada Experimental pit area but downstream of Muskeg Mountain drainage. At this site, riparian overhang has been calculated to be about 10 to 15% (Charlton in prep.) which would result in a considerable input of allochthonous organic matter, particularly in the fall of the year. In addition, the valley at this point is not very deeply incised and therefore, during the majority of the day the river receives direct sunlight thus enabling it to support a substantial algal flora. The combination of good organic input and sufficient light produces an algal/bacterial/detrital regeneration cycle (Lock and Wallace 1979) which is suspected of being capable of sustaining the high secondary production evident at such sites (Crowther 1979). It was hypothesized during 1979 (Crowther and Griffing 1979) that most of this energy was utilized in situ with FPOM and RPOM being exported downstream. If such is the case, it would suggest that fine filter feeders such as the Hydropsychidae (classified as omnivores) would become more abundant farther downstream and CPOM feeders would decrease in abundance. A subsequent decrease in substrate heterogeneity should then result in fewer taxa and a large proportion of the taxa being omnivores. At Site 2, substrates were uniform and the omnivore trophic class made up 31.27% of the total benthic biomass. However, the two trophic classes, algal/carnivore and algal/detritivore made up an additional 39.76% of the total benthic biomass, which indicates the presence of a substantial algal resource at this site. Site 2 is a very open site with a low shading and overhang factor, which results in a high standing crop of algae. The most abundant algal forms at Site 2 were the blue greens, both colonial and filimentous types, followed by diatoms; however, the highest biomass was represented by the diatoms. Diatoms are utilized primarily by grazing species such as the Trichoptera _Glossosoma_ sp. In addition, substantial suspended algae entered Site 2 from the larger pool area upstream. These suspended algae consisted primarily of Cryptophytes, Crysophytes, and _Clamydomonas_ spp., along with _Spirogyra_, _Cladophora glomerata_, and _Oedogonium_ sp. (Charlton in prep.). As feeding studies have shown (Crowther 1979), these algal groups make up a significant proportion of the gut contents of many omnivorous Trichoptera such as _Arcotpsyche ladogenesis_ and _Brachycentrus americanus_. Therefore, it is not surprising to find that trophic classes represented by omnivores and algal feeding groups predominated at Site 2. In addition, the input of allocthonous materials was lower at Site 2 than at Site 3 due to the general widening of the river valley and less riparian overhang, thus reducing the importance of the detritivore trophic class.

Substrate diversity at Site 2 was significantly lower than that observed at Site 3, but the overall species diversity was slightly higher. This finding does not fit the overall hypothesis generated during the 1978 survey but is explainable in view of the non-taxonomic treatment of groups such as the Chironomidae and Hydracarina. Seventy species of Chironomids were identified from Hartley Creek, a tributary of the Muskeg River (Crowther 1979) and the probability that many more species were present is high. The majority of the species identified were riffle dwelling Orthocladiinae and Tanypodinae. The diversity of these groups was highest at upstream sites with heterogenous substrates and decreased at downstream sites as substrates became less diverse. Similar results were obtained for the Muskeg and Steepbank rivers by Barton and Wallace (1980). The high numbers of species of Chironomids reported for AOSERP rivers are not unusual for brown water streams in Alberta as was shown by Clifford (1978) who reported 109 species of Chironomidae from the Bigoray River. Although lower species diversities due to decreases in substrate complexity were not found by this study, such changes have been quantified in the AOSERP study area. For example, in Hartley Creek, mean yearly values for numbers of species on individual substrate types were: riffle 28, boulder 18, macrophyte 17, cobble 16, and sand 10. Lower substrate complexity and stability have been found to generally reduce invertebrate diversity (Sprules 1947; O'Connell and Campbell 1953; Shadin 1956; Wisely 1962; Sedell et al. 1975). Similarly, invertebrate biomass followed the same trend; i.e., riffle 3575 $mg \cdot m^{-2}$, boulder 3450 $mg \cdot m^{-2}$, cobble 1325 $mg \cdot m^{-2}$, and sand 813 $mg \cdot m^{-2}$ (Crowther 1979). Such lowering of biomass in response to lower diversity could be suspected of also causing lower production. Site 3 substrates corresponded to riffle/boulder sites in Hartley Creek while Site 2 corresponded to cobble. As was shown by the production values for the Muskeg River, the estimates follow the general trend. However, to generalize on this point is tenuous since nothing is known concerning the turnover rates of the fauna in Hartley Creek compared to the Muskeg River, although one would suspect that similar results would be obtained. Therefore, it must be concluded that a major disadvantage of the trophic versus taxonomic classification system is the general lowering of information it furnishes regarding the attributes of the study system. This disadvantage can only be overcome if the system under study is well known in faunistic terms prior to evaluation using trophic classification. Fortunately, the AOSERP study area and particularly the Muskeg River system has this data base (Barton and Wallace 1980; Hartland-Rowe et al. 1979; Lock and Wallace 1979; Hickman et al. in prep.; Charlton in prep.; Bond and Machniak 1977; Crowther 1979; Crowther and Griffing 1979).

At Site 1, the importance of the detritivore and omnivore trophic classes was further reduced, when compared to Sites 2 and 3, while that of the carnivores increased. At Site 1, there is very little direct input of allocthonous organic material due to the steep valley walls and greater width of the river. Therefore, the bulk of organic matter must either be imported from upstream as FPOM or RPOM or manufactured as algae in situ. The deepness of the valley limits the amount of solar radiation which is thought to be responsible for the reduction in the amount of attached algal growth (Charlton in prep.). It has been suggested that in other rivers attached algal forms give way to increased phytoplankton as a stream grades into a river and levels of CPOM decrease as FPOM and RPOM increase (Wetzel 1975). If this was the case in the Muskeg River at Site 1, one would expect a shift in the benthic fauna towards organisms adapted to feeding on fine suspended materials such as net spinning caddisflies (omnivores). That this is not the case can be seen from the data which suggest that phytoplankton is not important and most organic material is in the form of RPOM. Recent algal surveys conducted on the Muskeg River by Charlton (in prep.) confirm that phytoplankton numbers are extremely low in this section of the river. The benthic data do show a rise in September of the omnivore trophic class to a level where this class is dominant at Site 1. This could be due to either a bloom condition of benthic algae, phytoplankton or the influx via catastrophic drift (Waters 1972) of dislodged upstream organisms and detritus caused by flood conditions of the river and the usage in situ of these resources by normally resident or transient species. If algal blooms are occurring and account for the noted benthic biomass increase, such events may occur outside of the current study period and may be similar to the phenomenon known as the Spring Diatom Increase.

Species diversity was slightly lower at Site 1 than that at Site 2, as was substrate complexity. However, in light of the previous discussion, this must be viewed with caution. Production was, however, significantly lower than at Site 2. The lower production estimate can be appreciated if RPOM, which has poor nutritional value for benthic organisms, represents the primary energy resource. The end result of the lack of other sources of organic energy to the benthos would be to cause a trophic shift towards carnivory which appears to be the case. It should also be noted that omnivory infers the capability for the consumption of other organisms. This is certainly the case for some of the Trichoptera in the Muskeg River such as Brachycentrus americanus and the Hydropsychidae, which coincidently made up the greatest proportion of the omnivore trophic class at Site 1.

In summary, it was found that the general hypothesis of a longitudinal ecosystem, functioning in a manner similar to an Eltonian energy pyramid (Elton 1927), derived by Crowther and Griffing (1979) for AOSERP tributaries during a qualitative survey, fit the data from the present quantitative survey of the Muskeg River. The following conclusions can be stated:

1. The assessment of secondary production in the Muskeg River showed that it was highest at the upstream sites and decreased progressively towards the mouth of the river.
2. The trophic economy of upstream sites was based upon the consumption of CPOM, possibly using a suspected algal-bacterial-detritus nutrient recycling pathway. Most of this energy was transformed in situ to FPOM and RPOM and exported as such downstream.

3. Downstream sites showed increasing trophic shifts in their benthic community structure first to omnivory and secondly to carnivory as a response to the decreasing availability of CPOM which was degraded to FPOM and RPOM at upstream locations and exported downstream.
4. The decreasing availability of CPOM was not offset at sites within the gorge by increasing phytoplankton.
5. Substrate heterogeneity decreased in the Muskeg River from high complexity at upstream sites to low complexity at downstream locations. This change in substrate diversity is suspected of causing a lowering of benthic species diversity but this was not substantiated during the present study.
6. Trophic classification appears to be a viable system for determining the functional status of river reaches and allows an investigator to grasp the energy energy relationships in a river more easily. Its major disadvantages lie in the necessity for solid faunistic data prior to its use, the need for familiarity with the system to understand its output, and the need for local information with regard to faunal feeding types.
7. The use of the modified Hynes method of production calculation (Hamilton 1969) is an easy rapid method which, when coupled with the trophic classification system, allows secondary production to be compartmentalized into meaningful segments with which to provide information on the energetic relationships in a stream. As such, it provides a useful tool for watershed management. The main drawbacks of the system are its dependence on life cycle information i.e., voltism and its tendency towards overestimation of production. However, it is usable on the total benthic fauna.

5.1 RECOMMENDATIONS

It is recommended by the authors that a similar assessment of secondary production, using the modified Hynes method coupled with trophic classification, be conducted on each of the major tributaries that may in the future be impacted by oil sands development within the AOSERP study area. Such a study would be a beneficial and simple method of assessing the trophic status of these ecosystems and for determining the subsequent effects of development. These studies would be invaluable to regional watershed management and may be done in a cost effective manner using much of the existing aquatic data base. In order that such studies be comparable to the results from the Muskeg River, the authors suggest that the same sampling techniques be used. Furthermore, it would be advisable to re-use existing sites wherever possible, such as the Algal Helicopter Survey (Hickman et al. in prep.; Charlton in prep.) so that data could be integrated with historical knowledge of the tributaries. Also, the use of geofluvial river reaches (Sekerak and Walder in prep.; Walder et al. 1980) for sample locations would help structure the study.

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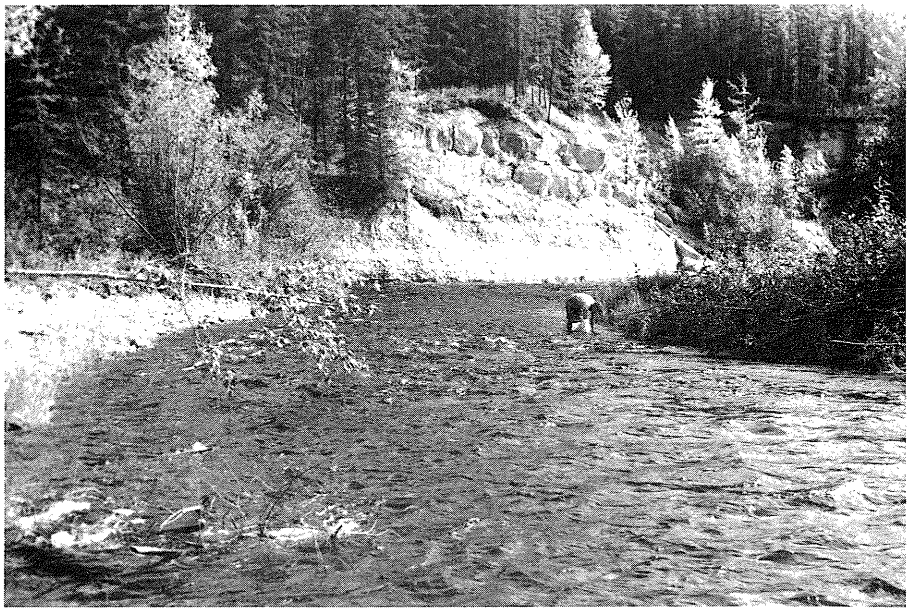
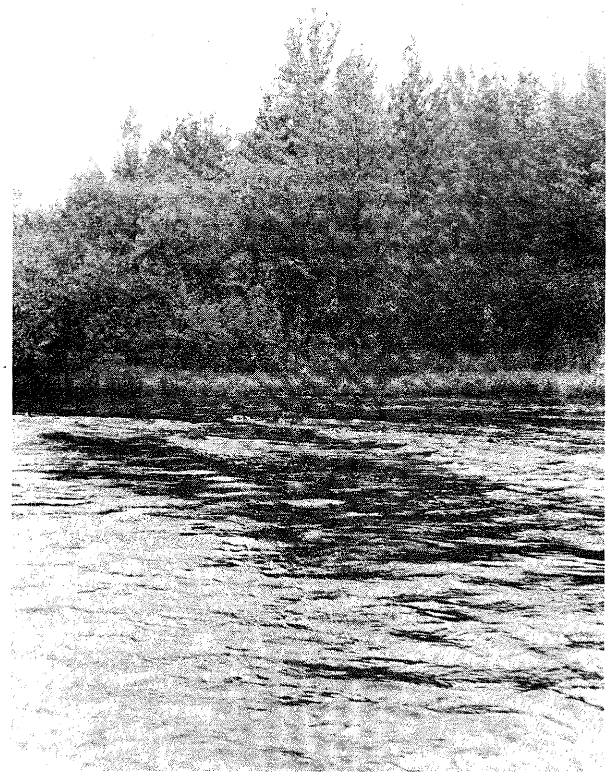
7. APPENDICES

7.1 SITE PHOTOGRAPHS



Site 1. Downstream; 16 September 1979.

Site 1. Upstream; 16 September 1979.



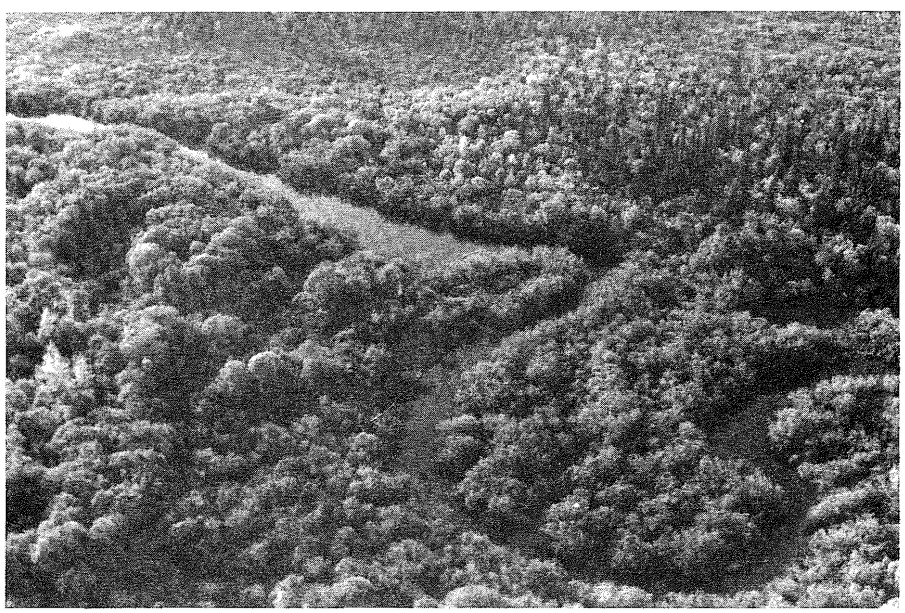
Site 2. Upstream; 16 September 1979.

Site 3. Downstream; 15 September 1979.

Site 3. Upstream; 15 September 1979.

Site 2. Aerial photo; 16 September 1979.

Site 2. Aerial photo; 16 September 1979.



Site 3. Aerial photo; 15 September 1979.

7.2 SPECIES IDENTIFICATIONS AND TROPHIC CLASSIFICATIONS WITH TOTAL NUMBERS AND STANDING CROP FOR SITES 1, 2, AND 3

SITE 1	July		Aug.		Sept.	
	No	$No \cdot m^{-2}$	No	$No \cdot m^{-2}$	No	$No \cdot m^{-2}$
OMNIVORES						
Plecoptera						
Hastaperla sp.	-	-	50	71	150	212
Hastaperla brevis	-	-	-	-	20	28
Isoperla	-	-	81	115	38	54
Trichoptera						
Hydrospsyche betteni	19	27	37	52	84	119
H. slossonae	11	16	13	18	34	48
H. bifida	62	88	114	161	264	373
H. simulans	17	24	26	37	54	76
H. recurvata	-	-	4	6	10	14
Hydropsyche pupae	-	-	-	-	-	-
Brachycentrus	37	52	12	17	26	37
Cheumatopsyche	7	10	158	223	1147	1622
Cheumatopsyche pupae	-	-	-	-	-	-
Oecetis	-	-	-	-	1	-
Ptilostomis semifasciata	-	-	-	-	-	-
Total Omnivores =	153	216	495	700	1828	2585
Total Taxa =	6		9		11	
UNKNOWN STATUS						
Plecoptera						
Paraperla	13	18	-	-	-	-
Total Unknown =	13	18	-	-	-	-
Total Taxa =	1		-		-	

SITE 1	July		Aug.		Sept.	
	No	No·m^{-2}	No	No·m^{-2}	No	No·m^{-2}
ALGAL FEEDERS						
Trichoptera						
Hydroptilidae	9	13	17	24	-	-
Neotrichia	40	57	-	-	-	-
Helicopsyche borealis	-	-	-	-	-	-
Total Algal Feeders =	49	69	17	24	-	-
Total Taxa =	2		1		-	
ALGAL/CARNIVORES						
Plecoptera						
Isogenus	29	41	-	-	-	-
Pteronarcella dorsata	2	3	1	1	5	7
Total Algal/Carnivore =	31	44	1	1	5	7
Total Taxa =	2		1		1	
CARNIVORE/DETRITIVORES						
Trichoptera						
Arctopsyche ladogensis	-	-	-	-	-	-
Polycentropus plexus	-	-	-	-	-	-
Ochrotrichia	-	-	-	-	1	1
Rhyacophila	-	-	-	-	-	-
Total Carn./Detrit. =	3	4	-	-	3	4
Total Taxa =	1		-		2	

SITE 1	July		Aug.		Sept.	
	No	$No \cdot m^{-2}$	No	$No \cdot m^{-2}$	No	$No \cdot m^{-2}$
ALGAL/DETRITIVORES						
Plecoptera						
Taeniopteryx nivalis	-	-	-	-	-	-
Trichoptera						
Glossosoma	13	18	-	-	8	-
Ceraclea	4	6	-	-	11	-
Micrasema	-	-	4	6	3	-
Potamyia flava	-	-	4	6	38	35
Agapetus	-	-	-	-	-	-
Ceraclea pupae	-	-	-	-	-	-
Coleoptera						
Optioservus fastidatus	596	843	234	331	486	687
Ephemeroptera						
Stenonema	226	320	319	451	230	325
Baetis	1742	2464	256	362	190	269
Ephemerella lita	58	82	4	6	20	28
E. grandis ingens	1	1	-	-	-	-
E. spinifera	-	-	1	1	-	-
E. aurivilli	-	-	-	-	-	-
Ephemerella sp.	-	-	-	-	-	-
Leptophlebia	-	-	-	-	-	-
Hexagenia	16	23	35	50	15	21
Caenis sp. 1	22	31	1	1	-	-
Caenis sp. 2	8	11	-	-	-	-
Total Algal/Detrital =	2686	3799	858	1214	1001	1416
Total Taxa =	10		9		9	

SITE 1	July		Aug.		Sept.	
	No	$No \cdot m^{-2}$	No	$No \cdot m^{-2}$	No	$No \cdot m^{-2}$
CARNIVORES						
Plecoptera						
Arcynopteryx	10	14	-	-	-	-
Paragnetina	1	1	4	6	12	17
Claassenia sabulosa	-	-	3	4	2	3
Acroneuria	4	6	-	-	1	1
Hydracarina	465	658	88	124	253	-
Coleoptera						
Gyrinidae	-	-	-	-	-	-
Hirudinea	-	-	-	-	-	-
Diptera						
Ceratopogonidae	2	3	6	8	45	64
Atherix	9	13	9	13	14	20
Limnophila	14	20	6	8	27	38
Tanypodinii	50	71	18	26	15	26
Eriocera	22	31	12	17	1	1
Hemerodromia	1	1	-	-	-	-
Chaoborus	-	-	-	-	-	-
Dicranota	-	-	5	7	2	3
Dicranomyia	-	-	-	-	-	-
Odonata						
Odonata	1	1	8	11	10	14
Aeshna interupta	-	-	11	15	3	4
Gomphus	1	1	-	-	-	-
Total Carnivores =	580	820	170	240	385	545
Total Taxa =	12		10		12	

SITE 1	July		Aug.		Sept.	
	No	$No \cdot m^{-2}$	No	$No \cdot m^{-2}$	No	$No \cdot m^{-2}$
DETRITIVORES						
Trichoptera						
Lepidostoma	-	-	1	1	37	52
Psychomyia flavida	-	-	-	-	13	18
Wormaldia gabriella	5	7	1	1	-	-
W. gabriella pupae	-	-	-	-	-	-
Limniphilidae pupae	-	-	-	-	-	-
Plecoptera						
Nemoura	-	-	4	6	17	24
Diptera						
Orthocladiinae	500	707	97	137	2797	3956
Chironominae	1603	2267	136	192	426	603
Diptera pupae	45	64	41	58	12	17
Simulium	296	419	126	178	8	11
Tipula	-	-	-	-	-	-
Psychoda	-	-	-	-	-	-
Tanytarsus	4	6	-	-	3	4
Dixiniae	-	-	-	-	1	1
Copepoda	8	11	-	-	-	-
Amphipoda	1	1	-	-	-	-
Nematoda	65	92	-	-	2	3
Oligochaeta						
Oligochaeta	14	20	-	-	-	-
Naididae	17	24	17	24	13	18
Lumbricidae	-	-	-	-	-	-
Pelecypoda						
Musculium	50	71	1	1	27	38
Sphaerium	87	123	53	75	56	79

SITE 1	July		Aug.		Sept.	
	No	No·m^{-2}	No	No·m^{-2}	No	No·m^{-2}
Gastropoda						
Ferrissia rivularis	1	1	-	-	-	-
Lymnaea	-	-	-	-	1	1
Helisoma	-	-	-	-	7	10
Corixidae	-	-	-	-	1	1
Lepidoptera						
Nymphula	-	-	2	3	-	-
Collembola	-	-	-	-	-	-
Total Detritivores =	2696	3813	488	690	3421	4839
Total Taxa =	14		11		16	

SITE 2	July		Aug.		Sept.	
	No	No·m^{-2}	No	No·m^{-2}	No	No·m^{-2}
OMNIVORES						
Plecoptera						
Hastaperla brevis	3	4	48	68	279	395
Isoperla	77	109	92	130	103	146
Trichoptera						
Hydrospsyche betteni	291	412	132	187	95	134
H. slossonae	54	76	24	34	18	25
H. bifida	323	457	148	209	106	150
H. simulans	473	669	216	306	156	221
H. recurvata	23	32	12	17	8	11
Hydropsyche pupae	3	4	24	34	-	-
Brachycentrus americanus	-	-	4	6	5	7
Cheumatopsyche annalis	30	42	-	-	390	552
Cheumatopsyche pupae	11	15	8	11	-	-
Oecetis	-	-	-	-	1	1
Ptilostomis semifasciata	-	-	-	-	-	-
Total Omnivores =	1288	1822	708	1001	1161	1642
Total Taxa =	10		10		10	

SITE 2	July		Aug.		Sept.	
	No	No·m^{-2}	No	No·m^{-2}	No	No·m^{-2}
ALGAL FEEDERS						
Trichoptera						
Hydroptilidae	29	41	-	-	-	-
Neotrichia	-	-	-	-	-	-
Helicopsyche borealis	-	-	12	17	17	24
Total Algal Feeders =	29	41	12	17	17	24
Total Taxa =	1		1		1	
ALGAL/CARNIVORES						
Plecoptera						
Isogenus	-	-	-	-	-	-
Pteronarcella dorsata	12	17	8	11	9	13
Total Algal/Carnivore =	12	17	8	11	9	13
Total Taxa =	1		1		1	
CARNIVORE/DETRITIVORES						
Trichoptera						
Arctopsyche ladogensis	-	-	4	6	5	7
Polycentropus plexus	-	-	-	-	-	-
Ochrotrichia	-	-	-	-	-	-
Rhyacophila	-	-	-	-	-	-
Total Carn./Detrit. =	-	-	4	6	5	7
Total Taxa =	-		1		1	

SITE 2	July		Aug.		Sept.	
	No	No·m^{-2}	No	No·m^{-2}	No	No·m^{-2}
ALGAL/DETRITIVORES						
Plecoptera						
Taeniopteryx nivalis	-	-	-	-	-	-
Trichoptera						
Glossosoma	72	102	104	147	101	143
Ceraclea	23	33	20	28	4	6
Micrasema	14	20	192	272	-	-
Potamyia flava	-	-	-	-	8	11
Agapetus	7	10	-	-	-	-
Ceraclea pupae	-	-	-	-	-	-
Coleoptera						
Optioservus fastidatus	898	1270	500	707	857	1212
Ephemeroptera						
Stenonema	220	311	208	294	486	687
Baetis	571	808	280	396	122	173
Ephemerella lita	150	212	40	57	37	52
E. grandis ingens	-	-	-	-	-	-
E. spinifera	-	-	-	-	-	-
E. aurivilli	41	58	16	23	1	1
Ephemerella sp.	11	16	24	34	4	6
Leptophlebia	-	-	-	-	2	3
Hexagenia	175	247	12	17	6	8
Caenis sp.1	1	1	-	-	-	-
Caenis sp.2	-	-	-	-	-	-
Total Algal/Detritvores =	2183	3088	1396	1974	1628	2303
Total Taxa =	12		10		11	

SITE 2	July		Aug.		Sept.	
	No	No·m^{-2}	No	No·m^{-2}	No	No·m^{-2}
CARNIVORES						
Plecoptera						
Arcynopteryx	-	-	-	-	-	-
Paragnetina	-	-	-	-	-	-
Claassenia sabulosa	3	4	4	6	8	11
Acroneuria	-	-	-	-	-	-
Hydracarina	602	852	360	509	903	1277
Coleoptera						
Gyrinidae	-	-	-	-	-	-
Hirudinea	1	1	-	-	1	1
Diptera						
Ceratopogonidae	1	1	4	6	6	8
Atherix	13	18	4	6	22	31
Limnophila	-	-	12	17	44	62
Tanypodinii	101	143	4	6	11	15
Eriocera	2	3	-	-	1	1
Hemerodromia	6	8	-	-	-	-
Chaoborus	-	-	-	-	1	1
Dicranomyia	4	6	8	-	-	-
Dicranota	4	6	-	-	5	7
Odonata						
Odonata	21	30	68	96	17	24
Aeshna interupta	-	-	4	6	-	-
Gomphus	-	-	-	-	-	-
Total Carnivores =	758	1072	468	662	1019	1441
Total Taxa =	11		9		11	

<u>SITE 2</u>	<u>July</u>		<u>Aug.</u>		<u>Sept.</u>	
	No	No·m^{-2}	No	No·m^{-2}	No	No·m^{-2}
<u>DETRITIVORES</u>						
Trichoptera						
<u>Lepidostoma</u>	-	-	8	11	441	624
<u>Psychomyia flavida</u>	-	-	-	-	-	-
<u>Wormaldia gabriella</u>	502	710	4	6	-	-
<u>W. gabriella</u> pupae	17	24	-	-	-	-
Limniphilidae pupae	-	-	-	-	-	-
Plecoptera						
<u>Nemoura</u>	25	35	40	57	64	90
Diptera						
Orthocladiinae	354	501	100	141	196	277
Chironominae	1576	2229	176	249	397	561
Diptera pupae	47	66	80	113	43	61
<u>Simulium</u>	154	217	28	40	-	-
<u>Tipula</u>	-	-	-	-	-	-
<u>Psychoda</u>	1	1	-	-	-	-
<u>Tanytarsus</u>	1	1	-	-	1	1
Dixiniae	-	-	-	-	-	-
Copepoda	-	-	-	-	-	-
Amphipoda	1	1	4	6	1	1
Nematoda	30	42	-	-	17	24
Oligochaeta						
Oligochaeta	-	-	-	-	-	-
Naididae	47	66	20	28	97	137
Lumbricidae	-	-	4	6	-	-
Pelecypoda						
<u>Muscilium</u>	288	407	368	520	234	331
<u>Sphaerium</u>	231	327	2+ 2	413	7	10

SITE 2	July		Aug.		Sept.	
	No	No·m^{-2}	No	No·m^{-2}	No	No·m^{-2}
Gastropoda						
Ferrissia rivularis	-	-	4	6	-	-
Lymnaea	-	-	-	-	3	4
Helisoma	-	-	-	-	7	10
Corixidae	1	1	-	-	-	-
Lepidoptera						
Nymphula	-	-	-	-	-	-
Collembola	-	-	-	-	1	1
Total Detritivores =	3275	4632	1128	1596	1509	2134
Total Taxa =	14		13		14	

SITE 3	July		Aug.	
	No	No·m^{-2}	No	No·m^{-2}
OMNIVORES				
Plecoptera				
Hastaperla brevis	1	1	-	-
Isoperla	1	1	1	1
Trichoptera				
Hydrospsyche betteni	30	42	67	95
H. slossonae	9	13	19	27
H. bifida	1	1	3	4
H. simulans	3	4	4	6
H. recurvata	-	-	-	-
Hydropsyche pupae	-	-	5	7
Brachycentrus americanus	3	4	1	1
Cheumatopsyche annalis	42	59	2	3
Cheumatopsyche pupae	-	-	4	6
Oecetis	-	-	-	-
Ptilostomis semifasciata	-	-	8	11
Total Omnivores =	90	127	114	161
Total Taxa =	8		10	

SITE 3	July		Aug.	
	No	$No \cdot m^{-2}$	No	$No \cdot m^{-2}$
ALGAL FEEDERS				
Trichoptera				
Hydrophilidae	-	-	2	-
Neotrichia	-	-	-	-
Helicopsyche borealis	-	-	-	-
Total Algal Feeders =	-	-	2	3
Total Taxa =	-		1	
ALGAL/CARNIVORES				
Plecoptera				
Isogenus	-	-	-	-
Pteronarcella dorsata	-	-	-	-
Total Algal/Carnivore =	-	-	-	-
Total Taxa =	-		-	
CARNIVORE/DETRITIVORES				
Trichoptera				
Arctopsyche ladogensis	2	3	-	-
Polycentropus plexus	1	1	-	-
Ochrotrichia	81	115	-	-
Rhyacophila	1	1	-	-
Total Carn./Detrit. =	85	120	-	-
Total Taxa =	4		-	

SITE 3	July		Aug.	
	No	No.m^{-2}	No	No.m^{-2}
ALGAL/DETRITIVORES				
Plecoptera				
Taeniopteryx nivalis	4	5	-	-
Trichoptera				
Glossosoma	34	48	36	51
Ceraclea	194	279	387	547
Micrasema	-	-	68	96
Potamyia flava	-	-	-	-
Agapetus	-	-	-	-
Ceraclea pupae	3	4	-	-
Coleoptera				
Optioservus fastidatus	292	413	182	257
Ephemeroptera				
Stenonema	52	73	30	42
Baetis	1203	1702	66	93
Ephemerella lita	35	50	23	32
E. grandis ingens	-	-	-	-
E. spinifera	-	-	-	-
E. aurivilli	2	3	1	1
Ephemerella sp.	7	10	1	1
Leptophlebia	-	-	-	-
Hexagenia	10	14	2	3
Caenis sp.1	1	1	16	23
Caenis sp.2	-	-	-	-
Total Algal/Detrital =	1837	2598	812	1148
Total Taxa =	12		11	

SITE 3	July		Aug.	
	No	No·m^{-2}	No	No·m^{-2}
CARNIVORES				
Plecoptera				
Arcynopteryx	-	-	-	-
Paragnetina	-	-	-	-
Claassenia sabulosa	-	-	-	-
Acroneuria	-	-	-	-
Hydracarina	551	779	224	317
Coleoptera				
Gyrinidae	19	27	-	-
Hirudinea	2	3	9	13
Diptera				
Ceratopogonidae	27	38	6	8
Atherix	3	4	9	13
Limnophila	-	-	-	-
Tanypodinii	258	365	89	126
Eriocera	-	-	-	-
Hemerodromia	-	-	-	-
Chaoborus	-	-	-	-
Dicranota	4	6	5	7
Dicranomyia	-	-	-	-
Odonata				
Odonata	-	-	-	-
Aeshna interupta	-	-	-	-
Gomphus	-	-	-	-
Total Carnivores =	864	1222	342	484
Total Taxa =	6		5	

SITE 3	July		Aug.	
	No	No·m^{-2}	No	No·m^{-2}
DETRITIVORES				
Trichoptera				
Lepidostoma	-	-	2	3
Psychomyia flavida	1	1	-	-
Wormaldia gabriella	57	81	3	4
Wormaldia pupae	-	-	-	-
Limniphilidae pupae	-	-	1	1
Plecoptera				
Nemoura	323	457	28	40
Diptera				
Orthocladiinae	4 589	6 491	349	494
Chironominae	524	741	89	126
Diptera pupae	22	31	12	17
Simulium	8 932	13 559	797	1 127
Tipula	25	35	-	-
Psychoda	2	3	7	10
Tanytarsus	-	-	-	-
Dixiniae	-	-	-	-
Copepoda	-	-	-	-
Amphipoda	1 784	2 523	1 839	2 601
Nematoda	44	62	1	1
Oligochaeta				
Oligochaeta	1	1	-	-
Naididae	65	92	13	18
Lumbricidae	-	-	-	-
Pelecypoda				
Muscilium	21	30	72	102
Sphaerium	1	1	116	164

SITE 3	July		Aug.	
	No	$No \cdot m^{-2}$	No	$No \cdot m^{-2}$
Gastropoda				
Ferrissia rivularis	-	-	-	-
Lymnaea	-	-	1	1
Helisoma	-	-	-	-
Corixidae	-	-	-	-
Lepidoptera				
Nymphula	-	-	-	-
Collembola	-	-	-	-
Total Detritivores =	16 391	24 108	3 330	4 710
Total Taxa =	15		15	

SITE 1 - SUMMARY OF BENTHIC IDENTIFICATION AND CLASSIFICATION

TROPHIC CLASS	July No	July $No \cdot m^{-2}$	Aug. No	Aug. $No \cdot m^{-2}$	Sept. No	Sept. $No \cdot m^{-2}$
Omnivores	153	216	495	700	1828	2586
(Taxa)	(6)		(9)		(11)	
Algal Feeders	49	69	17	24	-	-
(Taxa)	(2)		(1)		-	
Algal/Detritivores	2686	3799	858	1214	966	1366
(Taxa)	(10)		(9)		(6)	
Carnivores	580	820	170	240	388	549
(Taxa)	(12)		(11)		(12)	
Algal/Carnivores	31	44	1	1	5	7
(Taxa)	(2)		(1)		(1)	
Carnivore/Detritivores	3	4	-	-	3	4
(Taxa)	(1)		-		(2)	
Detritivores	2696	3813	488	690	3421	4839
(Taxa)	(14)		(11)		(16)	
Unknown	13	18	-	-	-	-
(Taxa)	(1)		-		-	
Total Benthos	6211	8785	2029	2870	6611	9351
Total Taxa	(48)		(42)		(48)	

SITE 2 - SUMMARY OF BENTHIC IDENTIFICATION AND CLASSIFICATION

TROPHIC CLASS	July No	July $No \cdot m^{-2}$	Aug. No	Aug. $No \cdot m^{-2}$	Sept. No	Sept. $No \cdot m^{-2}$
Omnivores	1 288	1 822	708	1 001	1 161	1 642
(Taxa)	(10)		(10)		(10)	
Algal Feeders	29	41	12	17	17	24
(Taxa)	(1)		(1)		(1)	
Algal/Detritivores	2 183	3 088	1 396	1 974	1 628	2 303
(Taxa)	(12)		(10)		(11)	
Carnivores	758	1 072	468	662	1 019	1 441
(Taxa)	(11)		(8)		(11)	
Algal/Carnivores	12	17	8	11	9	13
(Taxa)	(1)		(1)		(1)	
Carnivore/Detritivores	-	-	4	6	5	7
(Taxa)	-		(1)		(1)	
Detritivores	3 275	4 632	1 128	1 596	1 509	2 134
(Taxa)	(15)		(13)		(14)	
Total Benthos	7 545	10 672	3 724	5 267	5 348	7 564
Total Taxa	(50)		(44)		(49)	

SITE 3 - SUMMARY OF BENTHIC IDENTIFICATION AND CLASSIFICATION

TROPHIC CLASS	July No	July $No \cdot m^{-2}$	Aug. No	Aug. $No \cdot m^{-2}$
Omnivores	90	127	114	161
(Taxa)	(8)		(10)	
Algal Feeders	-	-	2	3
(Taxa)	-		(1)	
Algal/Detritivores	1 837	2 598	812	1 148
(Taxa)	(12)		(11)	
Carnivores	864	1 222	342	484
(Taxa)	(7)		(7)	
Algal/Carnivores	-	-	-	-
(Taxa)	-		-	
Carnivore/Detritivores	85	120	-	-
(Taxa)	(4)		-	
Detritivores	17 045	24 109	3 330	4 710
(Taxa)	(16)		(15)	
Total Benthos	19 921	28 177	4 600	6 506
Total Taxa	(47)		(44)	

7.3 WEIGHTS FOR ALL TROPHIC CLASSES BY SIZE CLASS AND AN EXAMPLE OF PRODUCTION CALCULATION

Values denoted by ( )* were estimated weights (mg) obtained by extrapolation and were used only in calculating production.

OMNIVORES

Size	Site 1 July	Site 1 Aug.	Site 1 Sept	Site 2 July	Site 2 Aug.	Site 2 Sept	Site 3 July	Site 3 Aug.
0-1		0.15	0.49	0.15		1.14		0.20
1-2	2.48	3.76	10.22	2.47	4.88	1.02	0.30	0.31
2-3	4.81	7.46	76.24	11.23	79.56	6.20	0.45	1.15
3-4	6.12	7.19	177.21	24.59	19.68	23.22	0.43	3.30
4-5	9.83	11.01	125.19	19.42	52.20	29.87	1.20	7.56
5-6	5.28	3.06	117.13	55.74	125.64	52.30	0.61	15.67
6-7	8.15	8.01	44.48	86.80	107.92	30.97		(15.89)*
7-8		10.61	44.30	81.45	203.88	77.63	0.32	11.15
8-9		2.04	89.40	90.22	242.96	234.37		7.91
9-10		6.93	97.31	45.18	131.12	885.04		7.00
10-14		6.89	11.90	7.19	81.28	261.77		5.82
14-18								
18-22								
22-26								
26-30								
30-up								
Total	36.67	67.11	793.87	424.44	1049.12	1603.53	3.31	60.07

ALGAL FEEDERS

	Site 1			Site 2			Site 3	
Size	July	Aug.	Sept	July	Aug.	Sept	July	Aug.
0-1	0.68	0.13						0.64
1-2	0.96	0.65		2.17	8.76			
2-3		1.42				12.47		0.36
3-4								
4-5								
5-6								
6-7								
7-8								
8-9								
9-10								
10-14								
14-18								
18-22								
22-26								
26-30								
30-up								
Total	1.64	2.20	-	2.17	8.76	12.47	-	1.00

CARNIVORE/DETRITIVORES

	Site 1			Site 2			Site 3	
Size	July	Aug.	Sept	July	Aug.	Sept	July	Aug.
0-1							0.45	
1-2			0.49				0.46	
2-3							1.33	
3-4							0.62	
4-5							0.29	
5-6							0.45	
6-7								
7-8							0.42	
8-9								
9-10							0.80	
10-14	11.52				49.96		1.00	
14-18			15.00					
18-22	26.46					17.22		
22-26						139.04		
26-30								
30-up								
Total	37.98	-	15.49	-	49.96	156.26	5.82	-

ALGAL/DETRITIVORES

Size	Site 1 July	Site 1 Aug.	Site 1 Sept	Site 2 July	Site 2 Aug.	Site 2 Sept	Site 3 July	Site 3 Aug.
0-1	2.47	2.76	1.09	0.31	0.60	0.40	0.13	1.96
1-2	9.60	12.74	16.64	6.23	17.28	13.90	17.48	17.01
2-3	29.29	51.43	62.48	35.51	44.36	116.35	4.10	16.46
3-4	57.44	67.46	48.52	128.81	174.08	90.01	14.16	40.39
4-5	49.38	70.81	82.91	31.53	228.64	144.62	36.59	56.82
5-6	166.68	18.26	52.75	66.78	185.88	388.57	61.75	103.04
6-7	13.80	6.29	1.00	44.17		52.31	10.87	9.73
7-8	26.76			44.36		8.72	4.41	41.54
8-9	3.29			1.41	22.72			(4.29)*
9-10						0.80	1.82	(10.50)*
10-14								
14-18								
18-22								
22-26								
26-30								
30-up								
Total	358.71	229.75	265.39	359.11	673.56	815.68	151.31	286.95

CARNIVORES

Size	Site 1 July	Site 1 Aug.	Site 1 Sept	Site 2 July	Site 2 Aug.	Site 2 Sept	Site 3 July	Site 3 Aug.
0-1	7.98	11.45	10.55	32.41	32.84	40.65	10.14	6.06
1-2	0.53	3.33	0.54	1.03	3.60	0.82	0.18	(0.25)*
2-3	1.17	0.48	0.51	0.68	2.80	0.05	0.65	0.47
3-4	2.16	2.69	2.03	2.81	9.96	1.24	0.75	3.50
4-5			2.82	0.31	(1.16)*	3.98	0.78	6.22
5-6	0.11	0.69	(5.40)*	1.12	6.76	1.17	0.36	4.94
6-7		4.75	(6.50)*		(3.55)*	1.39	2.17	6.50
7-8				0.14		8.11	1.81	6.69
8-9	21.64		0.39		9.68	4.40	0.80	0.94
9-10						16.14	13.99	
10-14	0.82	53.34	65.46	110.00		16.39	14.10	
14-18	233.35	55.60	79.53	21.15	62.72	(1.15)*	24.92	
18-22	209.24							
22-26								
26-30								
30-up								
Total	477.00	132.33	163.02	169.65	128.36	94.34	70.65	35.32

DETRITIVORES

Size	Site 1			Site 2			Site 3	
	July	Aug.	Sept	July	Aug.	Sept	July	Aug.
0-1	124.59	6.72	5.42	20.79	8.36	5.46	4.19	2.84
1-2	83.84	32.42	43.01	79.15	276.88	52.01	19.45	40.72
2-3	10.80	60.68	76.96	63.76	(79.60)*	321.50	54.44	35.88
3-4	15.72	11.40	9.79	62.14	23.60	(162.44)*	150.57	145.68
4-5	10.45	3.01	1.86	14.59	(7.60)*	51.94	723.46	202.05
5-6	9.98		1.99	72.21	6.24	100.91	226.41	290.56
6-7			(1.46)*	82.23		95.60	28.54	99.36
7-8				86.61			7.73	31.27
8-9				88.65			17.75	12.44
9-10	34.27			162.10			54.77	32.97
10-14	(137.08)*			159.38			170.31	242.79
14-18					56.44		121.97	32.02
18-22							67.38	
22-26								
26-30								
30-up								
Total	289.65	114.23	139.03	891.61	380.24	689.86	1646.97	1168.58

PLECOPTERA: SITE 1-JULY

	1-2	2-3	3-4	4-5	5-6	6-7	7-8	...	18-22	...	30-up
Omnivore											
Isoperla						1.55					
Carnivore											
Arcyopteryx	0.25	1.04	0.53	1.25							
Paragnetina					0.40						
Acroneuria									20.60		
Algal/Carnivore											
Isogenus	0.39	1.48	1.18								
Pteronarcella									84.29		
Unknown											
Paraperla	1.27	0.74									

PLECOPTERA: SITE 1-AUGUST

	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10 ...	18-22 ...	30-up
Omnivore											
Isoperla	0.35	2.14	1.52	4.12	13.06	27.90	11.16		2.43		
Hastaperla	0.87	0.83	0.49								
Carnivore											
Claassenia				1.56						35.19	
Paragnetina			3.80								
Algal/Carnivore											
Pteronarcella											119.46
Detritivore											
Nemoura	0.46	0.37									

PLECOPTERA: SITE 1-SEPTEMBER

	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	14-18	...	26-30	30-up
Omnivore															
Isoperla		0.04	1.10	0.73	0.46		2.53	3.17	3.99	17.22	12.42				
Hastaperla	0.01	1.71	6.53	1.31											
Carnivore															
Claassenia						1.17						45.48			
Paragnetina		0.25	1.84	2.13	2.56										
Acroneuria														6.00	
Algal/Carnivore															
Pteronarcella											16.46				493.38
Detritivore															
Nemoura		0.59	1.54	0.42											

PLECOPTERA: SITE 2-JULY

	0-1	1-2	2-3	3-4	4-5	5-6	6-7	...	10-14	14-18	18-22	22-26	26-30	30-up
Omnivore														
Isoperla		0.05	2.90	4.09	4.03	2.02	0.61							
Hastaperla		0.40												
Carnivore														
Claassenia									8.11	13.66		7.95		
Algal/Carnivore														
Pteronarcella										9.86	11.30	229.80	28.18	803.04
Detritivore														
Nemoura	1.52	1.91	0.56	0.33										

PLECOPTERA: SITE 2-AUGUST

	1-2	2-3	3-4	4-5	5-6	6-7	7-8	...	14-18	18-22	22-26	26-30	30-up
Omnivore													
Isoperla	1.88				14.04	147.08	30.76						
Hastaperla	0.56	1.56											
Carnivore													
Claassenia									111.84				
Algal/Carnivore													
Pteronarcella											745.36	4.68	
Detritivore													
Nemoura	0.48	0.64		0.08		2.16							

PLECOPTERA: SITE 2-SEPTEMBER

	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-14	14-18	18-22	22-26	26-30	30-up
Omnivore															
Isoperla	3.83	4.49	5.13	1.06			9.97	27.98	12.61						
Hastaperla	1.39	12.08	2.02												
Carnivore															
Claassenia					1.56	3.98		6.16			62.88			102.45	
Algal/Carnivore															
Pteronarcella										11.80			37.38		552.19
Detritivore															
Nemoura		4.49	5.58	2.09	2.25										

PLECOPTERA: SITE 3

	1-2	2-3	3-4	4-5	5-6	6-7	...	30-up
JULY								
Detritivore								
Nemoura		0.19	5.05	11.78	12.80	2.52		
Algal/Detritivore								
Taeniopteryx			0.43					
AUGUST								
Detritivore								
Nemoura	1.18	2.08		4.36	2.47			
Omnivore								
Isoperla		0.46						

Example of Hynes' production method. Calculation of production of algal/detritivores for Site 2 in September.

Size Class (mm)	No·m^{-2}	Mean Weight (mg)	Standing Crop (g·m^{-2})	No Loss·m^{-2}	Weight at Loss (mg)	Weight Loss (g·m^{-2})	Production (g·m^{-2})
0 - 1	59	0.0095	0.0006				
1 - 2	693	0.0284	0.0197	-634	0.0190	-0.0120	-0.1201
2 - 3	709	0.2322	0.1647	- 16	0.1303	-0.0021	-0.0208
3 - 4	303	0.4206	0.1274	406	0.3264	0.1325	1.3252
4 - 5	207	0.9905	0.2050	96	0.7056	0.0677	0.6773
5 - 6	376	1.4608	0.5493	-169	1.2257	-0.2071	-2.0713
6 - 7	23	3.2694	0.0752	353	2.3651	0.8349	8.3488
7 - 8	4	2.9067	0.0116	19	3.0881	0.0587	0.5867
8 - 9	0	0.0	0.0	4	2.9067	0.0116	0.1163
9 - 10	1	0.8000	0.0008	- 1	0.8000	-0.0008	-0.0080
10 - 14				1	0.8000	0.0008	0.0080
						Total Production	8.8421

8. LIST OF AOSERP RESEARCH REPORTS

Report	Project	Reference
1	PM	Alberta Oil Sands Environmental Research Program. 1976. First annual report, 1975. Alberta Oil Sands Environmental Research Program. AOSERP Report 1. 58 pp.
2	AF 4.1.1	Kristensen, J., B.S. Ott, and A.D. Sekerak. 1976. Walleye and goldeye fisheries investigations in the Peace-Athabasca Delta--1975. Prep. for the Alberta Oil Sands Environmental Research Program by LGL Ltd., Environmental Research Associates. AOSERP Report 2. 103 pp.
3	HE 1.1.1	McVey, W.W. 1976. Structure of a traditional baseline data system. Prep. for the Alberta Oil Sands Environmental Research Program by the University of Alberta, Population Research Laboratory. AOSERP Report 3. 26 + 266 pp.
4	VE 2.2	Stringer, P.W. 1976. A preliminary vegetation survey of the Alberta Oil Sands Environmental Research Program study area. Prep. for the Alberta Oil Sands Environmental Research Program by Intraverda Plant Systems Ltd. AOSERP Report 4. 108 pp.
5	HY 3.1	Strosher, M.T., and E. Peake. 1976. The evaluation of waste waters from an oil sand extraction plant. Prep. for the Alberta Oil Sands Environmental Research Program by The University of Calgary, Environmental Sciences Centre (Kananaskis). AOSERP Report 5. 103 pp.
6	PM	Patterson, R., and A.M. Lansdown. 1976. Housing for the north--the stackwall system: construction report, Mildred Lake tank and pump house. Prep. for the Alberta Oil Sands Environmental Research Program by the University of Manitoba, Faculty of Engineering, Northern Housing Committee. AOSERP Report 6. 36 pp.
7	AF 3.1.1	Jantzie, T.D. 1977. A synopsis of the physical and biological limnology and fishery programs within the Alberta oil sands area. Prep. for the Alberta Oil Sands Environmental Research Program by Renewable Resources Consulting Services Ltd. AOSERP Report 7. 73 pp.

8 AF 1.2.1 Machniak, K. 1977. The impact of saline waters upon freshwater biota (a literature review and bibliography). Prep. for the Alberta Oil Sands Environmental Research Program by Aquatic Environments Ltd. AOSERP Report 8. 258 pp.

9 ME 3.3 Croft, B.R., A. Lamb, and R.N. Dawson. 1977. Preliminary investigation into the magnitude of fog occurrence and associated problems in the oil sands area. Prep. for the Alberta Oil Sands Environmental Research Program by Stanley Associates Engineering Ltd. AOSERP Report 9. 87 pp.

10 HE 2.1 Millar, J.F.V. 1977. Development of research design related to archaeological studies in the Athabasca Oil Sands area. Prep. for the Alberta Oil Sands Environmental Research Program by the University of Saskatchewan. AOSERP Report 10. 69 pp.

11 AF 2.2.1 Flannagan, J.F. 1977. Life cycles of some common aquatic insects of the Athabasca River, Alberta. Prep. for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Freshwater Institute. AOSERP Report 11. 20 pp.

12 ME 1.7 Mercer, J.M., and R.B. Charlton. 1977. Very high resolution meteorological satellite study of oil sands weather: "a feasibility study". Prep. for the Alberta Oil Sands Environmental Research Program by the University of Alberta, Department of Geography. AOSERP Report 12. 44 pp.

13 ME 2.3.1 Davison, D.S., C.J. Fortems, and K.L. Grandia. 1977. Plume dispersion measurements from an oil sands extraction plant, March 1976. Prep. for the Alberta Oil Sands Environmental Research Program by Intera Environmental Consultants Ltd. AOSERP Report 13. 195 pp.

14 none

15 ME 3.4 Denison, P.J. 1977. A climatology of low-level air trajectories in the Alberta oil sands area. Prep. for the Alberta Oil Sands Environmental Research Program by Acres Consulting Services. AOSERP Report 15. 118 pp.

16	ME 1.6	Barge, B.L., R.G. Humphries, and S.L. Olson. 1977. The feasibility of a weather radar near Fort McMurray, Alberta. Prep. for the Alberta Oil Sands Environmental Research Program by Alberta Research Council. Atmospheric Sciences Division. AOSERP Report 16. 72 pp.
17	AF 2.1.1	Lutz, A., and M. Hendzel. 1977. A survey of baseline levels of contaminants in aquatic biota of the AOSERP study area. Prep. for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Freshwater Institute. AOSERP Report 17. 51 pp.
18	HY 1.1	Loeppky, K.D., and M.O. Spitzer. 1977. Interim compilation of stream gauging data to December 1976 for the Alberta Oil Sands Environmental Research Program. Prep. for the Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Freshwater Institute. AOSERP Report 18. 257 pp.
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