CORRELATION BETWEEN TRACE CONTAMINANT MIXTURES IN COMPLEX EFFLUENTS AND STRUCTURE OF BENTHIC MACROINVERTEBRATES

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PREFACE

The primary objective of this study was to determine the levels of trace contaminants which effect the assemblage of benthic macroinvertebrates of Boggy and Skeleton creeks. This study will further elucidate the complex task of protecting our aquatic resources in a fair and equitable manner.

I express appreciation of my major advisor, Dr. S.L."Bud" Burks, for his guidance and assistance throughout this study. Appreciation is also expressed to the other committee members, Drs. Tony Echelle, Rudy Miller, Jan Wagner, and Jerry Wilhm for their invaluable assistance and encouragement during my graduate program.

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CHAPTER I

INTRODUCTION

A national goal of "fishable, swimable" surface waters by 1983 and "zero pollutant discharge" into these aquatic systems by 1985 was mandated by congress in the 1972 amendments to the Federal Water Pollution Control Act. Responsibility for attaining and enforcing this goal on a national level was assigned to the U. S. Environmental Protection Agency (USEPA). Initial monitoring and research concentrated on physicochemical parameters. Numeric water quality criteria, established from acute and chronic laboratory bioassay tests (1976 Redbook), were intended as national guidelines and designed to protect 95% of the species in the aquatic community. Regulatory standards were then established by individual states based on the national water quality criteria as well as local conditions and designated beneficial uses of the particular water body (USEPA 1976).

The applicability of the laboratory derived values to field situations, however, has been questioned repeatedly (Cairns 1977, Lee and Jones 1983, Ruffier and Steven 1984). The national water quality criteria could be underprotective or overprotective of the aquatic life present at a particular site. The sensitivity of the resident species may be different when compared with those used to derive the national criteria. Also, the bioavailability and ultimate toxicity of contaminants could be modified by the local water quality

characteristics relative to laboratory conditions (USEPA 1982).

Early attempts to validate selective water quality criteria used artificial lotic and lentic systems dosed with a toxicant or set of toxicants. A more recent approach involves modifying selected national criteria on a site specific basis (USEPA 1982). Through this process, recalculation, indicator species, resident species, and heavy metal speciation procedures are available to the states for establishing new criterion values at a specific location. Using this new site specific criteria modification process includes the problems of species sensitivity and bioavailability differences between laboratory and field conditions for specific contaminants.

The experimental procedures used, however, remain deficient in reflecting the true nature of the complex natural field environment. Numerous compounds in varying concentrations are introduced into aquatic systems from different sources at any given time. The impact of these potentially deleterious substances on the resident aquatic community would not be assessed adequately by the currently used methods using relatively few contaminants. The USEPA's approach does not allow the following:

1. Determining the Maximum Acceptable Toxicant Concentration (MATC) for all toxic substances.
2. Correlating laboratory derived LC50 and "chronically safe" levels with observed responses in receiving waters.
3. Predicting antagonistic or synergistic interactions of individual toxicants.

4. Predicting effect of the physicochemical environment on the efficacy of toxicants.
5. Correlating "toxic effects" or "safe levels" derived from single species assays to potential responses of biotic communities in receiving waters.

The possibility of present day water quality criteria protecting resident aquatic species remains in question. The ultimate evaluation for the protection of aquatic life, therefore, would include comparing trace contaminant levels concurrently with in situ effects. This approach would give a realistic estimate of what water quality criteria limits are needed for maintaining a healthy aquatic community.

The primary objective of this study was to determine the in-situ levels of trace contaminants which effect the assemblage of the benthic macroinvertebrates of Boggy and Skeleton creeks. The specific objectives are the following:

1. To determine if a correlation exists between concentrations of specific compounds or groups of compounds and changes in structural parameters of the assemblage of benthic macroinvertebrates.
2. To trace the fate of selected trace contaminants.
3. To document physicochemical and biological differences before and after refinery shutdown.

CHAPTER II

REVIEW OF RELATED LITERATURE

Skeleton Creek Research Background

Historically, Skeleton Creek has been used by a number of investigators for a variety of research projects. Wilhm and Dorris (1966) used diversity values calculated from benthic macroinvertebrate populations to assess stream conditions. They found this approach to be more accurate than traditional indicator organisms and physicochemical methods. Phillips (1965) found species diversity of fish increased downstream below the wastewater input. Oxygen balance and water quality was investigated by Baumgardner (1966) by measuring the diurnal rate of change. The highest dissolved oxygen levels occurred in the upper and lower reaches and the lowest concentrations in the middle of the stream. Productivity of periphyton tended to decrease while diversity increased downstream from the point source discharges (Cooper 1972). The concentration of copper, chromium, lead, and zinc in the sediments and chironomid larvae were two to three orders of magnitude greater than levels in the overlying water, with highest concentrations found below point source discharges (Namminga 1975).

The indicator species procedure for criteria modification of chromium and zinc was carried out on Boggy and Skeleton creeks by JRB Associates (1983). This procedure is designed to compensate for changes

in the toxicity of the two metals due to the site specific water quality conditions. No significant difference existed between metal spiked site-water and reconstituted laboratory water bioassay tests under 24 hr static renewal conditions for Cheumatopsyche spp. (caddisflies) and under static daily renewal (recon water) and flow through (Boggy Creek water) conditions for Notropis lutrensis (red shiner) for either chromium or zinc. The Notropis LC50 values determined were similar to values for the fathead minnow (Pimephales promelas) for both metals. Low suspended solids concentrations and/or low turbidity were cited as possible explanations for the inability of Boggy Creek water to alter significantly the toxicity of either chromium or zinc to resident species relative to the laboratory derived national water quality criteria.

Skeleton Creek was also selected by Norberg-King and Mount (1985) as a test site for validity assessment of effluent and ambient toxicity tests for predicting biological impact. The study was one of eight nationwide designed to investigate the use of whole effluent toxicity testing in evaluating adverse water quality impairment caused by the discharge of toxic effluents. Results from chronic toxicity tests measuring the 7 day growth of larval fathead minnows (Pimephales promelas) and reproduction of Ceriodaphnia exposed to effluent and stream water were compared with ecological survey data of plankton, benthic macroinvertebrate, and fish communities. A consistent relationship was found between the toxicity measured and the number of species lost from a particular community at an impacted stream site.

Assessing Receiving Stream Water Quality

Water quality has been used to describe the appearance, chemical nature, and usefulness of aquatic resources. Prior to the twentieth century, water quality was associated with aesthetic value, taste, and odor. Advances in techniques enabled including chemical constituents and concentrations to the concept. Passage of recent environmental legislation emphasized the beneficial use of a particular body of water by man (Lichtenberg 1975, Lee et al. 1982b). As defined by PL 92-500, the desired quality of our nation's waters includes chemical, physical, and biological integrity as well as conditions that provide for protecting and propagating fish, shellfish, and wildlife and provides for recreation in and on the water (fishable, swimable). Integrity has been described as the maintaining aquatic ecosystem structure and function (Hirsch 1980).

Chemical Monitoring

Initial attempts to evaluate the water quality of streams relied solely on the use of standard physicochemical determinations such as temperature, dissolved oxygen, pH, specific conductivity, and suspended solids (Hynes 1974). The 5-day biochemical oxygen demand (BOD_5) analytical test was the first widely applied monitor of gross organic chemical levels. The inherent problems associated with this procedure, however, prompted developing additional gross organic parameters such as chemical oxygen demand, total oxygen demand, and total organic carbon.

The general nature of these analytical tests gave a rough evaluation of the water quality, but not qualitative and quantitative

information about individual constituents in the water. Certain contaminants degrade the water quality and restrict the intended uses. Significant advances were made in determining the chemical makeup of water and wastewater (Lichtenberg 1975). Numerous investigations have been reported that equate physicochemical characteristics of a specific waterbody with inferred water quality.

A single index for assessing surface water quality, based on 13 different physicochemical parameters, was developed by Prati et al. (1971). Mathematical transformations of the data enabled including individual as well as cumulative "polluting capacity" of the different parameters. Although the index included additive and/or synergistic effects that were often overlooked in single parameter comparision of data, toxic substances were not included.

Additional chemical monitoring was mandated by PL 92-500 in which the USEPA established water quality criteria for selected water constitutents (1976 Redbook) that were designed to protect 95% of the species in the aquatic community. Regulatory standards were established by the individual states based on the national water quality criteria as well as reflecting local conditions and designated beneficial uses of the particular waterbody (USEPA 1976). Routine monitoring of these selected chemical parameters provided the information used by the individual states to evaluate the quality of their waters.

The legislated state water quality standards were also incorporated in the National Pollutant Discharge System (NPDES). The NPDES permit issued to a point source discharger for both point-source based effluent limitation and toxic pollutant limitation was based on the water quality standards of the state (Greenwood et al. 1979). As required by law, the

point-source discharger routinely monitored those physicochemical constituents listed on their NPDES permit.

As a result of four lawsuits brought against the agency by environmental groups, the USEPA agreed in 1976 to develop and promulgate effluent guideline limitations for 65 compounds or types of compounds. The resultant "Consent Decree" document of priority pollutants established the legal basis for monitoring the 65 compounds on a routine schedule (Greenwood et al. 1979). The original list was expanded to 129 compounds in 1977 (Mindrup 1978).

The early alliance of chemical monitoring with water quality evaluation was partly due to the availability of well established chemical procedures. Simplistic interpretation of chemical data also contributed to the wide acceptance of the chemical approach. These relatively quick, inexpensive and accurate numbers produced by the different procedures provided spatial and temporal comparisions (Hynes 1974).

Criticism of this methodology surfaced as it became apparent that interpretating chemical data for assessing contamination and its effects on aquatic life was complex and often misleading. Individual toxicity of only a small percentage of potential contaminants had been determined at this time, with investigation of the additive and/or synergistic effects among toxic substances just beginning. The increased time and cost requirements associated with the extensive chemical analysis available today has also generated opposition (Peltier 1978). Additionally, chemical analysis of water provided information for the time sampled (Patrick 1950).

Biological Monitoring

Biological monitoring is using living organisms to assess the strength or toxicity of potentially toxic substances (Cairns *et al.* 1977). In the aquatic environment, a number of biological measures have been developed for assessing water quality. These have ranged from acute to chronic responses at all levels of organization in laboratory and/or field environments as reviewed by Bick (1962), Bartsch and Ingram (1966), and Wilhm (1975). Algae, bacteria, protozoa, zooplankton, macroinvertebrates, and fish are the major groups of organisms used as biological indicators (Wilhm 1975). Hopefully, the information obtained from a biological monitoring approach provides a more realistic evaluation of receiving stream water quality.

The two primary types of biomonitoring used for assessing stream water quality are toxicity tests and ecological surveys (Roop and Hunsaker 1985). The most popular form of toxicity test used today is the bioassay which Sprague (1973) defined as a procedure in which the quantity or strength of a material is determined by the reaction of a living organism to it.

Standardized procedures are available for acute and chronic single-species toxicity tests, with multi-species methods still being developed (Roop and Hunsaker 1985). Acute tests are exposures up to 96 h that generally measure the relative lethality of a potential toxicant. The 24 h laboratory static screening bioassay (Peltier 1978), 48 to 96 h laboratory static renewal bioassay (Committee on Methods for Toxicity Tests with Aquatic Organisms 1975), oxygen consumption evaluation (Darville and Wilhm 1984), on site continuous fish cough response (Cairns *et al.* 1977), and *in situ* fish cage studies

(Hasselrot 1964) are popular examples of acute determinations.

Chronic tests involve studying the lethal and sublethal effects of a toxicant with respect to an organism's life cycle after a continuous long term exposure (Gruber et al. 1979). The effect of different toxicants on reproduction (Westlake et al. 1983a, Nebeker et al. 1984, Mount and Norberg 1984), feeding behavior (Cowles and Remilland 1983, Reish 1974), growth (Conger et al. 1978, Niederlehner et al. 1984, USEPA 1985), chemoreception (Atema et al. 1982), mutagenic activity (Samoiloff et al. 1980, Hinton et al. 1983, Maruoka et al. 1985), locomotor responses (Folmar 1978, Westlake et al. 1983b, Cowles 1983), enzyme activity (Brown 1976, Rutherford et al. 1979),excretion (Reeve et al. 1977), and occurrence of morphological abnormalities (Sheehan 1984) of a variety of aquatic organisms have been investigated.

Ecological surveys for assessing receiving stream water quality date back to the early work on the Illinois River by Forbes and co-workers with the Illinois Natural History Survey. Extensive biological data collected from 1877 to the early 1900's documented the before and after effects of the introduction of the Chicago sewage canal effluent to the Illinois River in 1900 (Forbes 1910). Subsequent biological studies (Forbes and Richardson 1913, 1919) traced the deterioration of the river resulting from the continued sewage contamination.

The development of the "saprobiensystem" by Kolkwitz and Marsson in 1908 was an early attempt to use the association of different taxonomic groups to assess the effects of organic enrichment on a receiving stream. Four stream zones relative to sewage introduction representing decreasing contamination were established based on the presence of

different taxonomic groups. Allanson (1961) and Wilhm (1975) have reviewed the "saprobiensystem" as well as modifications proposed by Liebmann in 1951 and Fjerdingstad in 1963. Hynes (1974) has criticized the rigid structure of the system and concluded that it works best only under limited situations of heavy sewage input into a slow and evenly flowing river. This drawback as well as the greater time and taxonomic knowledge needed for American species has resulted in limited application in North America (Bartsch and Ingram 1966).

Many additional ecological surveys of a variety of organisms and resident communities have been conducted to assess receiving stream water quality. Many studies have used the previously established procedures, while others have designed new conceptual frameworks using indicator organisms, composition of the community, and biotic indices.

The indicator organism concept for assessing receiving stream water quality is based on the presence or absence of specific aquatic organisms. Each organism has a specific tolerance to different environmental contaminants. Goodnight and Whitley (1961) concluded that the optimal features of an indicator organism included abundant year-round presence with low mobility. The mere presence of a tolerant species in moderate numbers, however, is not always indicative of contamination. The presence of intolerant forms could provide valuable information about the condition of the stream (Wurtz 1955).

Forbes (1913) was perhaps the earliest proponent of the indicator organism approach as evidenced by his association of the organic enrichment of the Illinois River with the presence of "sewage fungi" and sludge worms as well as the absence of mayflies, caddisflies, and dragonflies. Additional investigations of sewage contamination have

been carried out with algae (Palmer 1963), protozoa (Cairns 1978), mollusca (Baker 1922), and mayflies (Winona State College 1970). Fish species have also been used, but their high mobility often limits their usefulness.

The presence and/or absence of indicator benthic macroinvertebrate groups have been used to detect environmental stress. Mackenthun (1966) classified sludgeworms, certain midge larvae, leeches, and certain snails as pollutant tolerant organisms, while the immature stages of mayflies, stoneflies, caddisflies, riffle beetles, and hellgrammites were found to be intolerant. Those organisms that were intermediate in tolerance were called facultative and included most snails, sowbugs, scuds, black fly larvae, cranefly larvae, fingernail clams, dragonfly nymphs, and some midge larvae. Additional studies using groups of benthic macroinvertebrates and associated tolerances for water quality assessment have been carried out by Gaufin and Tarzwell (1952), Learner et al. (1971), and Nuttall and Purves (1974) with an extensive review by Thomas et al. (1973).

Using indicator organisms for water quality assessment has been criticized. A few of the organisms typically used have wide tolerance ranges for certain environmental perturbations, and the pollution-tolerant sludge worm is also found in clean streams (Goodnight 1973). Regional differences in species and environmental conditions has also led to the questionable status of many of these organisms (Gaufin 1958). Other investigators have pointed out that the presence or absence of species in a stream is not truly representive of the water quality (Gaufin and Tarzwell 1956)

The composition of the resident stream community has also been used

for assessing receiving stream water quality. Good agreement existed between the degree of enrichment and relative abundance of oligochaetes relative to the total stream benthic macroinvertebrates. A tubificid composition exceeding 80% indicated heavy pollution, 60-80% doubtful stream condition, and less than 60% good conditions. (Goodnight and Whitley 1961). The ratio of aquatic insect weight to tubificid worm weight was suggested by King and Ball (1964) as a simplistic quantitative measure of organic contamination of a stream. Woodward and Riley (1983) found a direct relationship between concentration of dissolved hydrocarbons in oil field discharge water and percentage of dipteran species relative to the total insect population. Van Dyk et al. (1975) concluded that the density of the crustacean and aquatic insect populations of a stream before and after fenthion (organophosphate pesticide) contamination provided an accurate monitoring system that could be used in place of costly chemical analysis.

Analyzing an entire aquatic community provides a more representive and accurate assessment of receiving stream water quality (Goodnight 1973). Early attempts were limited to the cumbersome comparision of species lists which were sometimes difficult to interpret. The previously described "saprobiensystem" simplified matters somewhat by comparing the characteristic association of different taxonomic groups, but the extensive criticisms and disadvantages (Bartsch and Ingram 1966, Goodnight 1973, Hynes 1974) has resulted in limited application in North America. The application in recent years of various graphical and mathematical biotic indices have attempted to fill the need for an

easily comparable community assessment of water quality. In view of the numerous indices listed in the literature, only the more commonly used and popular of those pertinant to assessing receiving stream water quality will be reviewed.

Patrick (1950) used a graphical histogram composed of seven columns, each of which represented a taxonomic group of organisms that had similar responses to ecological conditions to indicate the number of species at a site. Any deviation from the number of species found at typical healthy stations was a measure of stress on the aquatic community. The selection of a healthy site, however, was critical for the validity of the method (Goodnight 1973). The arbitrary classification of organisms into seven groups to evaluate stream conditions has been questioned by Warren (1971). In spite of the criticisms, the novel use of histograms by Patrick was an attempt to provide an overall assessment of stream conditions.

Modifications to Patrick's histogram system were proposed by Wurtz (1955) in which non-planktonic organisms were categorized as burrowing, sessile, foraging, and pelagic in addition to a tolerant or non-tolerant status. If more than 50% of the organisms found at a site were nontolerant species, then the water was considered clean. When the nontolerant species represented less than 50%, then environmental degradation of the stream was evident. The lack of species tolerance information and the wide tolerance ranges of some organisms to different environmental contaminants affects the usefulness of this index.

Additional graphical representations of biological data in the form of log normal curves, circle graphs, bar graphs, and cluster analysis have been used in a number of aquatic communities for evaluating

receiving stream water quality (Wilhm 1975).

Numerical indices have also been used to assess receiving stream water quality. These have included biotic diversity and similarity indices. A biotic index constructed from algal species tolerance to organic contamination was developed by Palmer (1969). The pollution index factor assigned to each species was based on a survey of 269 reports in the literature on pollutant algae, with the 20 most tolerant algal species used to calculate the index value. The pollution index factors of the algae present in a sample at a density greater than 50 individuals/ml are then summed. A score of 20 or more reflects high organic pollution, from 15 -20 suggests that high organic pollution is probable, and less than 15 indicates that organic pollution is not high, that the sample is not representative, or that some substance or factor is interfering with algal persistance.

Beck (1955) attempted to express numerically the proportion of intolerant stream macroinvertebrate species relative to the proportion of species moderately tolerant of organic wastes in the form of an index value. The intolerant group had twice the weight in the index and a computed value of 0 indicated a septic zone, from 1-6 moderate levels of organic wastes, and over 10 of little or no organic waste. Heister (1972) modified Beck's index by assigning all possible macroinvertebrate species into five groups. In spite of the new groupings, Heister only used the two groupings developed by Beck to calculate an index (Washington 1984).

A biotic index based on the feeding habits, contaminant sensitivity, and density of the benthic macroinvertebrate fauna present in a recieving stream was developed by Beck (1965). Index values ranged

from 0 for severely polluted streams to 6 for unpolluted healthy waters. Complete knowledge of the feeding strategies and tolerance characteristics of the organisms collected, however, was required for use of the index.

A number of biotic indices in addition to the saprobiensystem have been used in Europe to evaluate receiving stream water quality. Woodiwiss proposed the Trent Biotic Index in 1960 (Washington 1984) in which the number of benthic macroinvertebrate groups present in the riffles of a stream was related to the key groupings of plecopteran nymphs, ephemeropteran nymphs, trichopteran larvae, Gammarus, Asellus, and tubificid/red chironomid larvae. A ranking relative to the groups present was assigned to each sample, with biotic index values ranging from 0 for polluted water to 10 for clean water. Limited geographic applicability, insensitivity to heavy metal pollution, and deletion of organism density information (Balloch et al. 1976) are the major criticisms expressed.

The Chandler Biotic Score (1970) incorporated the Trent Index as it's basic framework, but has a rearranged order of tolerance to organic contamination and includes an abundance estimate. Improved sensitivity as well as applicability to either riffle or slow moving rivers has prompted some investigators (Balloch et al. 1976, Hellawell 1978) to proclaim this index as the best availabile. Some discrepancy in values obtained for the headwater section of a river relative to pollution status has been noted by Murphy (1978).

Chutter (1972) developed a biotic index for South African streams that measured the effects of readily oxidizable organic matter and its breakdown products on the water quality of receiving waters. Only

benthic macroinvertebrates from "stone in current biotypes" are used in the index. Each organism collected was assigned a literature-derived quality value between 1-10, and then adjusted on a sliding scale relative to the number of baetid Ephemeroptera species present. Clean water species and those species not included in the riffle taxon list were rated at 0 with polluted water species valued at 10. The sum of quality values divided by the number of organisms in the sample generates the index. Limited application to lotic waters possessing riffle areas and contamination due to organic enrichment are major drawbacks to this method. Modifications to Chutter's Index were later proposed by Hilsenhoff (1977) in which a new species list suitable for North American waters was developed with corresponding tolerance values from 0-5 assigned to each species. The sliding scale used by Chutter (1972) was eliminated by limiting the sample to 25 individuals of each taxon that were over 3 mm long.

A number of diversity indices have also been applied to biological data collected from aquatic communities for assessing receiving stream water quality. The theoretical basis of these measures range from arbitrary formulations suited to the needs of the originator (guesses by data fitting) to those derived from information theory (Washington 1984). All include a variable that accounts for the number of species encountered in a sample, but only a few give consideration to the relative abundance of each species. A number of workers (Margalef 1951, Goodman 1975, Pielou 1975) have stated that a diversity index should include species number as well as relative abundance of each species (i.e. evenness).

Gleason (1922) formulated one of the earliest indices in which the

diversity is equated with the total number of species (S) divided by the logarithm of the total number (N) of individuals (D = S/ln N). Index variability with changing sample size was cited by Menhinick (1964) as a major problem with this procedure, and Margalef's (1951) modification of subtracting 1 from the number of species did little to remedy the problem (Washington 1984). Menhinick (1964) used the number of species divided by the square root of the total number of organsims in an attempt to remove the problems associated with the comparision of different sample sizes. Wilhm (1967) concluded that Menhinick's index was in fact more biased than Margalef's with respect to sample size. The obvious absence of an evenness component is an additional drawback of these indices.

A species number approach presented by Kothe in 1962 (Wilhm 1975) quantifies on a percentage basis the difference between the number of species found upstream of a wastewater effluent with those found downstream. This simplistic measure was useful for indicating the effects of a point source discharge (Balloch et al. 1976), but is influenced by seasonal change, requires a control site, ignores a quantitative approach (Washington 1984), and lacks an evenness component. The number of species per thousand individuals was proposed by Odum et al.(1960) as a diversity index. Also easy to understand, the measure has been widely used in spite of its sample size bias (Bechtel and Copeland 1970) and not considering the relative abundance of each species.

The Sequential Comparision Index (SCI) formulated by Cairns et al. 1968) was developed as a rapid method by which a non-biologist could numerically assess the effects of environmental contamination on a

receiving stream. In this method, the random sequential comparision of organisms collected from a particular aquatic community is initiated, with a new run started when different organisms are observed. The number of runs divided by the the number of organisms multiplied by the number of taxa carried out 6-8 times yields a statistically valid SCI. Index values ranged from less than 8 for a polluted stream to greater than 12 for healthy waters. The widespread usefulness and simplicity of this method has merit, but the SCI was never intended as a replacement for the other more accurate and reliable techniques (Cairns et al. 1968). Problems with random distribution of organisms (Chutter 1972) and high index variability among workers due to the boring repetitive nature of the test (Galat 1974) have been noted.

Simpson's diversity index (1949) was perhaps the earliest measure to include both a number of species component and a relative abundance of each species component. His estimation of diversity was:

$$D = \frac{\sum_{i=1}^{s} n_i(n_i-1)}{n\,(n-1)}$$

Where: D = Diversity
s = The number of species in a sample of a population.
n_i = The number of individuals in a species i of a sample from the population.
n = The number of individuals in a sample from a population.

with values ranging from 0 to 1. Krebs (1972) has defined this index as "the probability of picking two organisms at random that are different species. Wilhm (1967) concluded that Simpson's D was primarily related to the abundance of one or more species with a small

positive correlation with the number of individuals. A slight sample size bias and a greater weight assigned to the few species that are abundant with little given to the rarer species has been noted by Williams (1964).

Several diversity indices used today have been derived from information theory of Wiener (1948) and Shannon (1949). The relevency of this approach for assessing biological field data has been challenged by several investigators (Hurlbert 1971, Goodman 1975, Eberhardt 1976) and supported by others (Pielou 1966a, Wilhm 1967, Balloch et al. 1976). The frequent occurrence of these indices in the literature, however, documents the widespread acceptance by the scientific community.

Brillouin's H (1962) and Shannon's H' or H (1949) are two such indices and their relationship has been noted by Patten (1962) with Sterling's approximation used to derive Shannon's equation from Brillouin's formula when N and N_i are reasonably large values. When sample values (n_i/n) are used as an estimate of the population ratio (N_i/N), Shannon's H becomes :

$$\bar{d} = -\sum_{i=1}^{s} (n_i/n) \log_2 (n_i/n)$$

as explained by Wilhm and Dorris (1968).

The earliest use of Shannon's H for assessing biological communities has been credited to Good (1953), followed by Macarthur (1955), and later by the popular work of Margalef (1956) as stated by Washington (1984). Extensive use by Wilhm and Dorris (1966) and Wilhm (1967) contributed to the widespread popularity and use of Shannon's H

as evidenced in the literature. A number of criticisms, however, have been stated against this index. Hurlbert (1971) contends that the diversity value could increase even though the number of species decreased because of an increase in evenness. Chutter (1972) and Goodman (1975) have commented on a slight sample size bias with this index; whereas, Wilhm and Dorris (1968) and Washington (1984) have stated that this index is independent of sample size. Insensitivity of this index to inorganic particulates, pesticides, heavy metals, pH changes, and heat has been charged by Lenat et al. (1980). In spite of these alleged deficiencies, Shannon's index continues to be widely used today.

Two additional indices derived from information theory are redundancy and evenness. Redundancy was defined by Margalef (1958) as a measure of how the individuals of a sample collection are distributed among the species. The redundancy index generally used today was described by Patten (1962) as:

$$R = \frac{H'_{max} - H'}{H'_{max} - H'_{min}}$$

Where: H' = Shannon's diversity

$H'_{max} = \log N! - S \log \frac{N}{S}!$

$H'_{min} = \log N! - \log (n - (S-1))!$

S = the number of species

and indicates the dominance (abundance) expressed by one or more species (Patten et al. 1963). Values range from 0 where many co-dominant species exist (high evenness) to 1 in situations of a few dominant species (low evenness).

The evenness index is similar to redundancy in that it measures the distribution of individuals among species and for the most part has overshadowed redundancy as an index (Washington 1984). The more popular evenness index used today is that of Pielou (1966b),

$$E = \frac{H'}{H'_{max}}$$

Where: H' = Shannon's diversity
H'_{max} = log S
S = the number of species

Equal numbers of organisms in each species is represented by a value of 1 (Pielou 1966).

Similarity indices are an additional tool for assessing receiving stream water quality. Washington (1984) stated that these indices attempt to measure the similarity of structure of two communities. Comparision of sites above and below a point source discharge has been a popular application. The similarity indices that have been frequently used in water pollution studies include the Percent Similarity (PSC) index as discussed by Whittaker (1952) and the Pinkham and Pearson (1976) index. Both consider species number as well as abundance in their formulations, and Brock (1977) found the PSC index to be more sensitive than Pinkham and Pearson's measure to variations in dominant forms and relationships between dominant and semidominant species. The necessity of a healthy control site for comparision has perhaps limited the use of similarity indices.

Considereration for Use of Benthic Macroinvertebrates as Biomonitors

Of the aquatic stream groups available for use as *in situ* biomonitors for environmental contamination, the assemblage of benthic macroinvertebrates appear to offer the greatest predictability as evidenced by numerous reports in the literature. These organisms are ideally suited for *in situ* biomonitors in that they are abundant in most habitats, in several trophic levels, relatively immobile, easily collected and identified, and generally have life cycles of a year or more. These characteristics are necessary for the long term integration of fluctuating water quality conditions. The validity of stream site comparision for assessing environmental perturbation with this assemblage, however, is influenced by the comparative nature of physical features and consistency of sampling methodology (Mackenthun 1966).

Bacterial, algal, protozoan, zooplankton, and fish assemblages have also been used as *in situ* biomonitors, but specific limitations are associated with each group. Bacteria have generally been associated with the measurement of fecal pollution by coliform counts and the presence of "sewage fungi" in areas of high organic input. Additional use of this group to detect contamination has been restricted to the easily identifiable indicator organisms, but a short term fluctuation in water conditions such as a toxic spill could be missed due to their rapid response rate (Bott 1973).

Algal populations, especially diatoms (Patrick 1954), have been used for assessing receiving stream water quality. Identification problems (Goodnight 1973) and their planktonic existance (excluding periphyton) have limited the usefulness of this group. Similar difficulties have also been associated with zooplankton.

Protozoa exhibit sensitivity to different contaminants (Henebry and Cairns 1980). Limited use of this community, however, has stemmed from sampling, preservation, and identification problems (Wilhm 1975).

The extensive information collected on fish populations would make this group an ideal candidate for biomonitoring, but their ability to move away rapidly from stressful conditions is an obvious disadvantage. Reduced numbers relative to other groups and sampling problems in some situations are additional disadvantages.

Biomonitoring and Water Quality Standards

As mandated by PL 92-500, the USEPA (1976) established water quality criteria for selected water constituents in an attempt to maintain the biological integrity of our nations waters. These numeric criteria were mostly based on a variety of acute and chronic laboratory bioassays. These tests consisted of observations from selected organisms exposed to a defined stimulus under identifiable environmental conditions for a specified time period. In some instances, *in situ* data was added to the information base (USEPA 1976). A comprehensive evaluation of the observed responses in the data base along with considerations for complete contaminant availability, bioaccumulation potential, sensitive species, critical life stages, and pertinent application factors were used to calculate a safe concentration for the particular constituent (Lee *et al.* 1982a). The resultant criteria, which were intended as national guidelines, were therefore designed to protect 95% of the species in the aquatic community.

Regulatory standards were established by the individual states based on the national water quality criteria as well as reflecting local conditions and designated beneficial uses of the particular waterbody (USEPA 1976). In some instances, the legal and enforceable state standard for a particular constituent was identical to the 1976 Redbook value (Lee et al. 1982a).

Uncertainties exist with extrapolating laboratory data to field environments. Factors such as the relationship of the test protocol to field situations, the sensitivity of the biological test system used, the physical and chemical conditions of the experimental system, and the toxicant availability must be considered when attempting to establish criteria for protecting aquatic communities.

The biological tests used in developing water quality criteria have ranged from alterating molecular processes to changes in the structure or function of whole communities (USEPA 1976). The more popular of these include the acute and chronic definitive bioassays using fish or invertebrates under static, static renewal, or continuous flow through conditions. The more closely aligned the response is to real world situations, the less uncertainty and more relevent the information obtained from the data (Brungs and Mount 1978). The ability of the test system to measure major, moderate, and subtle changes in the defined stimulus is another important consideration. The observed response selected, as well as the sensitivity of the chosen organism or process to the respective water constituent, influence the final result. When considering field environments, the sensitivity of the resident species may be appreciabily different when compared to those used to derive the

national criteria (USEPA 1976).

The physical and chemical conditions of an experimental system have a major influence on the toxicity of certain constituents. Some well known examples include the relationship of pH to ammonia toxicity (Lloyd 1961), differences between soft and hard water with respect to certain heavy metal effects (Skidmore 1964), and the effects of temperature on bioassay organisms (Warren 1900). The physical and chemical conditions at which the tests are performed must be understood and used when applying laboratory data to field situations.

The bioavailability and ultimate toxicity of specific environmental contaminants could be modified by local water quality characteristics relative to laboratory conditions (USEPA 1982). As emphasized by Lee and Jones (1983), the established criteria reflect safe concentrations of completely available forms of contaminants exposed continuously to the test organism. This could result in excessive spending on waste load reduction with little water quality improvement.

An additional criticism of the established water quality criteria concerns applying single compound laboratory results to the field where complex effluents are routinely released into streams and rivers. Multiple point source discharges in a particular segment of the water body would further complicate the problem. Antagonistic or synergistic (additive and more than additive) effects could exist due to the mixture of chemicals. Chemical mixtures frequently have greater effects on aquatic organisms when compared to similar concentrations of the individual chemicals (Broderius and Kahl 1985). If this is the case, it would suggest that the established criteria could possibly be underprotective of the aquatic community.

In view of the uncertainties associated with the established water quality criteria, a number of investigators (Cairns 1977, Lee and Jones 1983, Ruffier and Steven 1984) have questioned their relevance to protecting aquatic communities. Early attempts to validate selective water quality criteria used artificial lotic and lentic systems dosed with the toxicant or set of toxicants in question. Even natural environments that could be easily monitored were contaminated with specific compounds. A more recent approach currently being investigated involves modifying selected national criteria on a site specific basis (USEPA 1982). Through this process, four procedures (recalculation, indicator species, resident species, and heavy metal speciation) are available to the states for establishing new criteria values at a specific location.

The recalculation, indicator species, and resident species procedures were used to modify the national cadmium criteria for the St. Louis River Basin near Duluth, Minnesota (Spehar and Carlson 1984). The site-specific maximum concentration derived from the recalculation procedure (1.3 ug/l) and resident species (1.9 ug/l) were similar to the national criterion of 2.2 ug/l, but the maximum concentration for the indicator species (7.0 ug/l) was more than three times greater.

Carlson and Roush (1985) investigated the zinc levels in the Straight River, Minnesota below a POTW point source discharge. They concluded that the effluent did not adversely affect the benthic macroinvertebrate taxa composition and abundance 3.2 km downstream of the discharge even though the site-specific criterion average for zinc was three times greater than the national criterion average.

Analytical Procedures for Trace Contaminants

A number of methods for analyzing trace contaminants in water and sediment samples have been reported (Robinson 1975, Barrett and Copeland 1979, Adams et al. 1983, Pellizzari et al. 1985). Little agreement exists among investigators on the best method for each type of analysis. In some cases, the USEPA has approved a procedure or group of procedures for determining a specific environmental contaminant. The procedure selected by the researcher, therefore, is generally determined by the type and concentration of compounds being investigated, amount of sample collected, sensitivity of the instrumentation used, and cost (Rosen 1968, Burks 1969). The necessity of laboratory pure water (Poirier and Sienkiewicz 1980) and ultra-pure reagents (Malaiyandi and Benoit 1981) used in the analysis as well as the inclusion of quality control and blank samples (Kirchmer et al. 1983) has been documented.

Organics in Water

The analysis of organic compounds in water includes collecting a representative sample, extracting the desired analytes into a suitable medium, and identifying and quantifying selected compounds. An accurate determination of the organic substances present in an aquatic environment is initiated with proper sample collection. Water samples should be taken at a depth of 15 cm or greater to avoid the potential hydrophobic surface film (Ludzack et al. 1958, Hardy et al. 1977). Storage in suitably prepared glass, stainless steel, or teflon containers at 4° C is recommended (USEPA 1979) to minimize contamination and alteration of the sample. Analysis should be started as soon as

possible after collection to prevent further alteration.

Extracting organic compounds from aqueous samples has been accomplished by a variety of techniques. The volatility of the target compounds greatly influence which method is chosen, with the decision also influenced by associated advantages and limitations of the available procedures. Volatile organic compounds are routinely determined by the USEPA approved purge and trap technique (Mackay et al. 1982, Otson and Williams 1982, Spingarn et al.). In this method (USEPA 1979), an inert gas is bubbled through an enclosed water sample for a specified time period at room temperature. Any compounds volatilized under these conditions are transported by the gas and subsequently trapped by preconditioned adsorbents (Tenax® and silica gel). The trapped compounds are then desorbed from the adsorbent material with heat and purged into a gas chromatograph equipped with a suitable detector. The relative simplicity, short analysis time, and low cost of this recently introduced method for volatile organics has helped facilitate its rapid acceptance. The volume of water analyzed, however, is limited by the capacity of the purging apparatus. Investigators have substituted Chromasorb 105 (Murray 1977) and activated carbon (Gschwend et al. 1980) as the adsorbent material as well as heated the sample while purging (Gschwend et al. 1980, Murray 1977) in an attempt to improve the sensitivity and applicability of the method.

Additional techniques used for determining volatile organic compounds include freeze concentration (Baker 1965), steam distillation (Peters 1980), and liquid-liquid extraction with n-pentane (Glaze and Lin 1984). These methods are less efficient than a purge and trap apparatus, i.e., generally require more time and effort for analyzing

the limited sample volume.

Semi-volatile organic compounds may be isolated from the water sample by solvent extraction (liquid-liquid) or by adsorption onto a suitable material. Both techniques are efficient methods for extracting semi-volatile substances, but also have certain limitations.

Liquid-liquid extraction offers the versatility of a wide selection of solvents ranging from polar to nonpolar and covering many boiling points. This choice allows for isolating specific groups of closely related compounds. For the complete determination of semi-volatile compounds present in water samples, the USEPA (1979) recommends using methylene chloride as the extracting solvent and pH adjustment (pH > 11) to generate a basic fraction followed by a second pH adjustment (pH < 2) on the same sample to yield an acidic fraction. Emulsion problems encountered with the separatory funnel shake method are alleviated when samples were gently extracted with a continuous reflux technique (Reece 1983). This liquid-liquid extraction procedure is suitable for relatively small water samples (1 -2 L) containing detectable concentrations of the desired analytes, but is inadequate for determining trace quantities of organic compounds. A larger system with increased volumes of water sample and solvent would improve the detection limit, but would also introduce solvent evaporation problems and sample contamination from organic impurities in the solvent (Skrindle and Tomlinson 1963, Burks 1969).

The adsorption of semi-volatile organic compounds from water samples with macroreticular resins and activated carbon achieves lower detection limits due to the larger quantities of water sampled. The retained compounds are subsequently transferred to an appropiate solvent

by column elution or soxhlet extraction of the adsorbent material (Strup et al. 1978).

Some of the more commonly used adsorption resins include Tenax® GC and XAD-2. The choice of one particular resin depends upon the polarity and sorption capacity of the desired analytes, anticipated flow rate, and compatibility of the adsorbent material with eluting solvents. Tenax® is unsuitable due to its incompatibility with most nonhydrocarbon solvents, degradation to diphenyl quinones, and persistent blank contamination problems (Strup et al. 1978). Background contamination problems exist with XAD-2 resin (James et al. 1981), and aromatic hydrocarbon contaminants have been identified in one study (Care et al. 1982).

Activated carbon has been used for adsorbing organic compounds from water since the late 1800's, most noteably those causing taste and odor problems (Zogorski and Faust 1978). In recent years, however, a number of workers have directed their efforts toward accepting this technique as an analytical tool for concentrating trace contaminants from water and wastewater. In 1962, the carbon adsorption method was accepted as a tentative standard for analyzing organics by the American Water Works Association, with later approval and inclusion in subsquent editions of Standard Methods for the Examination of Water and Wastewater (Baker and Malo 1967).

The adsorption of organic compounds on activated carbon occurs when the attractive forces on the carbon surface overcome the kinetic energy of the liquid phase molecules. Adsorption sites are present on the external surface of the carbon as well as the internal pore network. Weak Van der Waal's forces are responsible for the multilayered physical

sorption of organic compounds to the carbon surface, while single-layered chemical sorption occurs when the adsorbate and adsorbent form a chemical compound (Cheremisinoff and Morresi 1978). The adsorption efficiency of activated carbon for organic compounds is affected by the physical and chemical characteristics of the adsorbent, the adsorbate, and the experimental system.

Each type of activated carbon, with its respective origin and activation process, has a characteristic surface to volume ratio and chemical nature (polarity) that influences the adsorption of organic compounds. The large surface to volume ratio typically found (500-1400 m^2/g) is due to the extensive internal pore network formed during the activation process. This interior surface area of the carbon is responsible for the majority of the adsorption that takes place, with only a small amount on the external surface (Weber and Morris 1963). Activated carbon surfaces are for the most part nonpolar, with those of vegetable origin slightly more polar (Cheremisinoff and Morris 1978). This nonpolar characteristic makes them ideally suited for adsorbing hydrophobic (nonpolar) organic compounds such as aliphatic and aromatic hydrocarbons. To a lesser extent, polar organic compounds are hydrogen bonded to the surface oxides (carbonyl groups) on the activated carbon surface (Burks 1980).

The molecular size, polarity, and concentration of the respective adsorbate in solution also affects the carbon adsorption process. The size of the organic compound and its ability to enter the internal pore is the basis of this process. Those organic compounds that fit into the macropores (>1000A) and micropores (10-1000A) of the activated carbon interior are optimally located for adsorption. Larger molecules are

restricted to the external carbon surface and could potentially block micropores (Cheremisinoff and Morresi 1978). A pattern of decreased rate of adsorption with increased molecular size and increased molecular weight of selected organic compounds was observed by Weber and Morris (1963).

Once the organic molecule has reached the potential adsorption site, its polarity and associated water solubility influences the quantity adsorbed. As stated earlier, most types of activated carbon are nonpolar with a high affinity for hydrophobic compounds. The low water solubility of this group of compounds aids the adsorption process. In general, the lower the solubility of the compound in the aqueous phase, the less energy that must be overcome by the attractive forces of the carbon. The nonpolar compounds are adsorbed by Van der Waal attractive forces in the internal pores and by carbon helixes on the carbon surface (Puri 1970). In contrast, polar compounds are highly water soluble with a low affinity for the nonpolar activated carbon. Thus, greater amount of attractive energy must be exerted by the carbon before adsorption will occur. The presence of acidic oxides on the carbon surface impart a polar nature with increased adsorption of polar organic compounds (Cookson 1978).

The adsorbate's concentration and competitive interaction with other organic compounds for activated carbon adsorption sites also affects the degree of adsorption. Rambow (1963) found that low application rates of a single adsorbate to the activated carbon resulted in maximum adsorption efficiency. Excessive quantities of an organic compound, however, overloaded the capacity of the carbon with subsequent breakthrough and reduced adsorption efficiency (Greenberg et al. 1965).

In a solution containing two or more compounds, each adsorbate competes with the other in both the rate and capacity of adsorption (Weber and Morris 1964). In a similar study, Weber (1967) observed that a solute in a mixed solution had a more rapid breakthrough than in solution alone.

The effect of the pH, temperature, and turbidity of the liquid phase as well as the contact time (flow rate) of the experimental system on the adsorption of organics by activated carbon has also been investigated. Maximum adsorption was obtained at acidic and neutral conditions for 3-dodecylbenzenesulfonate (Weber and Morris 1963) and selected phenolic compounds (Zogorski et al. 1976). The interaction of the increasing hydronium ion concentration with the net negative charge of the activated carbon was cited as a possible explanation. The charge exhibited by a compound at a particular pH was also considered important. The same studies showed that an increase in temperature resulted in greater adsorption. Rock et al. (1966) found no difference in the qualitative recovery of organic compounds from natural pH water samples exhibiting a range of turbidity levels. However, the quantitative results were more reproducable after removal of turbidity.

The contact time of the water sample with the activated carbon is directly related to the adsorption efficiency of activated carbon for organic compounds. Rambow (1963) concluded that adsorption efficiency was favored by low flow rates and Booth et al. (1965) recommended a maximum flow rate of 120 ml/min (minimum contact time of 5 min) for optimum adsorption.

The desorption efficiency of those compounds retained by the activated carbon has also been criticized (Baker and Malo 1967).

Phenolic compounds (Hoak 1964) and toxaphene (Nicholson et al. 1964) exhibited a quantitative adsorption pattern, but solvent desorption yielded less than 70% recovery. However, selected chlorinated hydrocarbons showed quantitative recovery (Ettinger 1965). Skrindle and Tomlinson (1963) have suggested incorporating multiple solvents to minimize this problem.

A number of factors, therefore, affect the adsorption efficiency of activated carbon for organic compounds. Such variables as type of activated carbon used, availability of adsorption sites, contact time, pH, turbidity levels, and loading capacity of the activated carbon must be optimized for maximum adsorption. Under these idealized conditions, an adequate number of sites are available for adsorbing most organic molecules from typical water samples. The desorption procedure must also be optimized, with selection of an efficient solvent or group of solvents mandatory. If these criteria are met, the procedure is capable of yielding qualitative and quantitative data that is reproducible and acceptable.

Identifying individual organic compounds isolated from natural water samples is possible only if the complex nature of the sample is simplified. Early attempts involved solubility separations (Cheronis and Entrikin 1963), but were incomplete and time comsuming. Improved separation with reduced time constraints was later obtained with column, paper, and thin layer chromatographic methods. The greatest resolution in the least amount of time, however, has been achieved with gas-liquid chromatography (GLC). Recent advances in capillary or wall coated open tubular (WCOT) columns have further enhanced the resolution capacity of this technique (Webb et al. 1973, Dandeneau et al. 1979).

When using gas-liquid chromatography, the sample is first volatilized in the injection port with the vaporized components transported by means of an inert carrier gas through a heated column. Compounds are separated based on their solubility differences partitioning between the mobile gas phase and the stationary liquid phase. Separations are optimized through modification of column temperature, column materials, and flow rate of the carrier gas (Skrinde and Tomlison 1963).

Additional separation techniques used today include high pressure liquid chromatography (Jolley and Pitt 1978) and high resolution ion exchange chromatography (Katz et al. 1972). These methods have been useful, but are generally limited to analyzing nonvolatile organic compounds.

Identifying organic compounds separated by gas-liquid chromatography has been acomplished with Fourier transformed infrared spectrometry, ^{13}C Fourier transformed nuclear magnetic resonance spectroscopy, and mass spectrometry as well as other analytical techniques. Infrared spectrometry and nuclear magnetic resonance spectroscopy have provided valuable deciphering information, but their inadequate sensitivity and high cost have resulted in limited application to trace organic analysis (Rosen 1976). Increased sensitivity at reduced cost has been obtained with several group specific GC detectors such as electron capture for halogenated compounds, flame ionization for hydrocarbons, and alkali flame ionization for phosphate pesticides (Lovelock and Lipsky 1960). However, positive identification of a detected compound requires retention time comparision with a known standard on two chemically

different columns. If the unknown compound fails to match any of the standards, then identification is not possible (Lindeman and Annis 1960).

Mass spectrometry has become a popular technique for identifying organic compounds separated by gas-liquid chromatography (GC-MS). Increased sensitivity, capillary column compatibility, computerized operation, availability of a large mass spectral reference standard data base, and acceptable cost have all contributed to its rapid widespread acceptance (Updegrove and Haug 1970, Alford 1975).

Each vaporized compound eluted from the GC column is ionized in the mass spectrometer with the subsequent generation of ionic fragments. The summation of all the ions constitutes a fragmentation pattern (mass spectrum) characteristic of each compound. Identifying the detected compound is achieved by either comparing the unknown's spectral pattern with a known reference sample or a computerized search of a mass spectral reference library (Wolf and Walker 1969, Dickson et al. 1980). Adherence to GC-MS analytical quality assurance procedures has been noted as a preresquite for accurate and reproducable compound identification (Eichelberger et al. 1975).

The organic compounds identified in the column elutriate have been quantified by the mass spectrometer based on the chromatographic peak generated by each compound. This method gives approximate concentrations due to the inconsistent quantity of column elutrate that enters the mass spectrometer (Willard et al. 1981). A more precise measurement of a particular compound can be obtained with a group specific detector that analyzes the entire sample. In this procedure, the sample and three bracketing concentrations of the pertinant

reference standard are subjected to analysis under identical operating conditions. The resultant peak areas are compared in a regression equation, with the concentration of the compound in the sample determined.

Organics in Sediment

Analyzing organic compounds in sediment requires similar collection, extraction, and identification protocols as water samples. In an effort to avoid redundancy, only new methods and procedural modifications have been described.

Core and grab devices have been used to obtain a representative sample of lake and stream sediments (Zitko 1980). The top 5-10 cm of the sediment is generally sampled. Wash out of fine material from the sampler upon withdrawal from the streambed or lake bottom has been cited as a major problem with these methods (Feltz 1980). The heterogeneous nature of most bottom material has necessitated wet sieving to remove large extraneous material such as stones, twigs, and benthic organisms (Van Vleet and Quinn 1978, Zitko 1980). Reported loss of organics after wet sieving has been negligible (Boehm and Quinn 1977). Stainken (1979) and Michael et al. (1984) have composited grab samples from a specific location to further reduce some of the heterogeneity. Sample containers and storage requirements are the same as those listed for water samples.

Additional processing of the sediment sample usually includes removal of water by filtration (Lake et al. 1980), lyophilization (Botello et al. 1983), open air drying (Shaw and Wiggs 1980), vacuum oven drying (Overton et al. 1977), or adding anhydrous sodium sulfate

(Ribick et al. 1981). Once dried, the sample is well mixed to ensure homogeniety and ground in a mortar and pestel if clumped or congealed (Stainken 1979).

Extracting organic compounds from sediment has usually been completed with procedures that use a solvent or mixture of solvents in contact with the sample material for a specific time period. These procedures include shaker, tumbler, sonification, blender, column elution, steam distillation, sweep codistillation, and soxhlet extraction techniques for semi-volatile compounds (Zitko 1980, Bellar et al. 1980). Dynamic headspace sampling has been used for volatile organic components May et al. 1975).

Solvent selection is generally dictated by the components of interest and associated polarity required for effective extraction. Polar and nonpolar solvent mixtures are used to include a wide range of compounds. Methylene chloride has been recommended for the general purpose, broad spectrum extraction of organic compounds (Budde and Eichelberger 1979). Contact time between solvent and sample used by the different techniques in a number of studies ranged from 2 to 48 h. Boehm and Quinn (1977) doubled the extraction time from 2 to 4 h with no effect on the extraction efficiency of hydrocarbons. They also re-refluxed a sediment sample for an additional 2 h in fresh solvent with only 1% additional hydrocarbon material recovered. Saponification of the sample has frequently been included when analyzing for hydrocarbons, but organochlorine pesticides may be modified or destroyed in the alkaline medium (Negishi 1978).

The procedure that achieves optimal extraction of organic compounds from sediment samples has been investigated by a number of researchers.

Bellar et al. (1980) found that an acetone/hexane soxhlet extraction yielded higher recoveries of polychlorinated biphenyls (PCB's) and selected chlorinated hydrocarbon pesticides when compared to sonification and steam distillation. These results agreed with an earlier study that compared the extraction of PCB's with soxhlet, shaking, blending, column elution, and high-frequency mechanical dispersion (Bellar and Lichtenberg 1975). The recovery of hydrocarbons from sediments using methanol/benzene soxhlet extraction, methylene chloride reflux, and ball-mill tumbling was studied by Lake et al. (1980). They observed no significant difference between the soxhlet and reflux methods, but significantly lower recoveries were noted for the tumbling procedure.

Once the organic compounds have been extracted from the sediment sample by a suitable solvent, the available identification and quantification procedures are the same as listed for water samples.

Heavy Metals in Water

A number of methods are available for determining heavy metals in water including gravimetric, titrimetric, photometric, electrochemical, atomic fluorescence, flame atomic emission, inductively coupled plasma atomic emission, and atomic absorption spectroscopy. Specific advantages and limitations have been reported for each technique with respect to accuracy, sensitivity, and cost (Lewis 1968, Hansen and Ediger 1980). The USEPA (1979) has recommended nitric acid sample digestion followed by atomic absorption spectroscopy for determining most heavy metals in water. This technique offers good precision and accuracy, low detection limits, and easy operation at a moderate cost

with most interferences corrected to acceptable levels (Robinson 1975). The cold flameless method is used to measure the total mercury in a sample.

The analysis of heavy metals in water by atomic absorption requires proper sample collection. Water samples should be taken from a location and depth that is representative of the water column and stored in acid-rinsed metal-free containers. Heavy metals are enriched in the top 100-150 um of surface water relative to the bulk water 20 cm below the surface (Duce et al. 1972). Polyethylene containers should be used rather than borosilicate glass or soft glass for trace metal sampling (Cheeseman and Wilson 1973). Polyethylene is less susceptable to trace metal contamination, sorption of metals to the walls, and breakage. Storage at 4° C or preservation with 3 ml of concentration nitric acid per 100 ml of sample in the field is acceptable for analyzing total metals. Suspended and dissolved metal determinations require filtration (0.45 um filter paper) and acidification either on site or after refrigerated transport to the laboratory (USEPA 1979).

A nitric acid reflux digestion is used to remove interfering organic matter from either the total, dissolved, or suspended samples. Once digested, the sample is diluted to a specified volume with 0.2N nitric acid prior to atomic absorption analysis (USEPA 1979).

An atomic absorption spectrophotometer (AA) is routinely used for determining most heavy metal concentrations in water samples. The conversion of the sample solution into a cloud of ground state atoms capable of absorbing the analyzing radiation of a specific element is accomplished by atomization. Different methods of atomization include air-acetylene flame, heated graphite furnace, and cold flameless

(Pinta 1971). Ground state atoms are produced by elevated temperatures in the flame and graphite furnace techniques, with the chemical generation at room temperature in the cold flameless method. Absorbing analyzing radiation by these ground state atoms is detected and quantified relative to standards.

Potential interferences encountered with atomic absorption spectroscopy include organic background, matrix, chemical, ionization, and carbide formation. If not corrected when present, erroneous data may result. Organic background interference (non-atomic absorption) is due to absorbing analyzing light by molecular species or light scattering by solid particles in the absorption cell (Sandoz and Murry 1970). A tungsten halide lamp with continuum source emission is used for the simultaneous background correction in the visible range, while a deuterium arc lamp is used for ultraviolet measurements.

Matrix interference occurs when the sample and standards are significantly different with respect to viscosity and surface tension and thus have different nebulization efficiencies. This in turn will affect the number of atoms in the light beam and therefore invalidate the analysis. To correct for this, the method of standard additions is often used where several known quantities of the analyte are added to individual samples. The resultant concentrations are plotted on a graph to yield a corrected concentration. A single standard addition is sometimes used, with the resultant absorbance values entered into an equation (Klien and Hach 1977). Other ways to reduce the effect of the matrix include sample dilution and solvent extraction (Robinson 1975).

Chemical interference occurs when sufficient energy is not available to atomize all the compounds present in the sample which are

composed of the analyte and another constituent. Some of the compounds may dissociate, but other compounds may have sufficient energy in their chemical bond to resist atomization. Higher temperature flames (nitrous oxide-acetylene) are generally used to correct for this. A complexing agent (EDTA) can also be used which has a greater affinity for the metal than the other constituents. Since the metal is now combined with the complexing agent, the bond strengths are all the same (Beaty 1978).

Ionization interference occurs when the thermal energy in the system is sufficient to remove totally the electron from the atom, thus reducing the number of ground state atoms available for light absorption. This interference can be eliminated by adding an excess of an element which is ionized more readily than the analyte (Robinson 1975).

When the graphite furnace is used for atomization, certain elements (e.g. Al, Ni, and Si) will react with the graphite to form refractory carbides which will not absorb light. Recent developments indicate that by using a pyrolytic coating on the graphite substrate, carbide formation is eliminated (Amos 1972).

Heavy Metals in Sediment

A variety of methods are available for determining heavy metals in sediment. The extraction procedure used is generally dictated by the specific aim of the researcher, with several different chemical fractions of the sediment investigated. Modifications have been suggested by other researchers to reduce interferences and optimize extraction efficiencies. The recognition of a well accepted standard method has yet to be established. Collection techniques for sampling

heavy metals in sediments are similar to those listed for organic compounds. Samplers and storage containers must be consistent with those used for heavy metal analysis (Jenne et al. 1980). Considerable disagreement exists as to which extraction procedure should be used for the environmental monitoring of sediment heavy metal levels. The techniques used range from a weak acid leachate to a rigorous concentrated acid digestion. The use of different extractants in sequence that cover the entire spectrum has also been used.

The weak acid extraction procedure analyzes for those heavy metals that are chemically available to the environment under normal geological conditions (Kronfeld and Navrot 1980). The term " biologically available " has also been associated with this fraction. In this method, a weak leachate such as 1 N ammonium acetate at pH 7 or hydroxylamine hydrochloride-acetic acid are used to extract the heavy metals associated with carbonates, sulfides, iron-manganese oxides, and soluble salts.

The total heavy metal concentration of the sediment is determined by a strong digestion with nitric, hydrochloric, perchloric, and hydrofluoric as well as different combinations of each. The surface and structurally bound cations are solubilized by this type of treatment (Rogers 1983).

The sequential extraction scheme developed by Tessler et al. (1979) has been used in a number of studies. This approach determines the heavy metal content of specific chemical fractions that are defined as: 1) exchangeable metals extracted with 1M $MgCl_2$ at pH 7 2) carbonate and surface oxide bound metals leached with 1M NaOAc at pH 5 3) metals bound to iron-manganese oxides extracted with 0.02 M $NH_2OH \cdot HCl$ in 25%

acetic acid 4) organically bound metals leached with 30% H_2O_2 followed by NH_4OAc/HNO_3, and 5) lattice bound residue digested with aqua regia, 30% H_2O_2, HF, and HCl. Once the heavy metals have been extracted from the sediment sample, the resultant extractant is subjected to atomic absorption analysis as reviewed for the water samples.

CHAPTER III

DESCRIPTION OF STUDY AREA

General Description

Skeleton and Boggy creeks are located on the gently rolling prairie of northcentral Oklahoma with their headwaters in the vicinity of Enid, Garfield County (Figure 1). The streams are low gradient, deeply entrenched, have steep sided banks, and exhibit a meandering flow. Riffles, comprising less than 5 % of the creeks, are abundant in upstream sections and pools are more common in lower portions. Low flow occurs throughout most of the year with sporadic flash flooding.

Boggy Creek originates approximately 6 km southwest of Enid and meanders easterly for 16 km to its confluence with Skeleton Creek 8 km southeast of Enid. Stream elevation is 380 m at the headwaters and 347 m at the mouth with an average gradient of 2 m/km. Width ranges from less than a meter at the origin to several meters at the confluence. Depth ranges from several cm in riffles to over 1 m in some pools. The stream bottom is composed of silt, sand, gravel, and small rocks. Flow in Boggy Creek would be intermittent if not for the continuous addition of wastewater from point source dischargers. The creek is classified as a second order stream based on the degree of branching (Horton 1945).

Skeleton Creek originates 13 km northwest of Enid, flows southeasterly for 121 km through Garfield, Kingfisher, and Logan

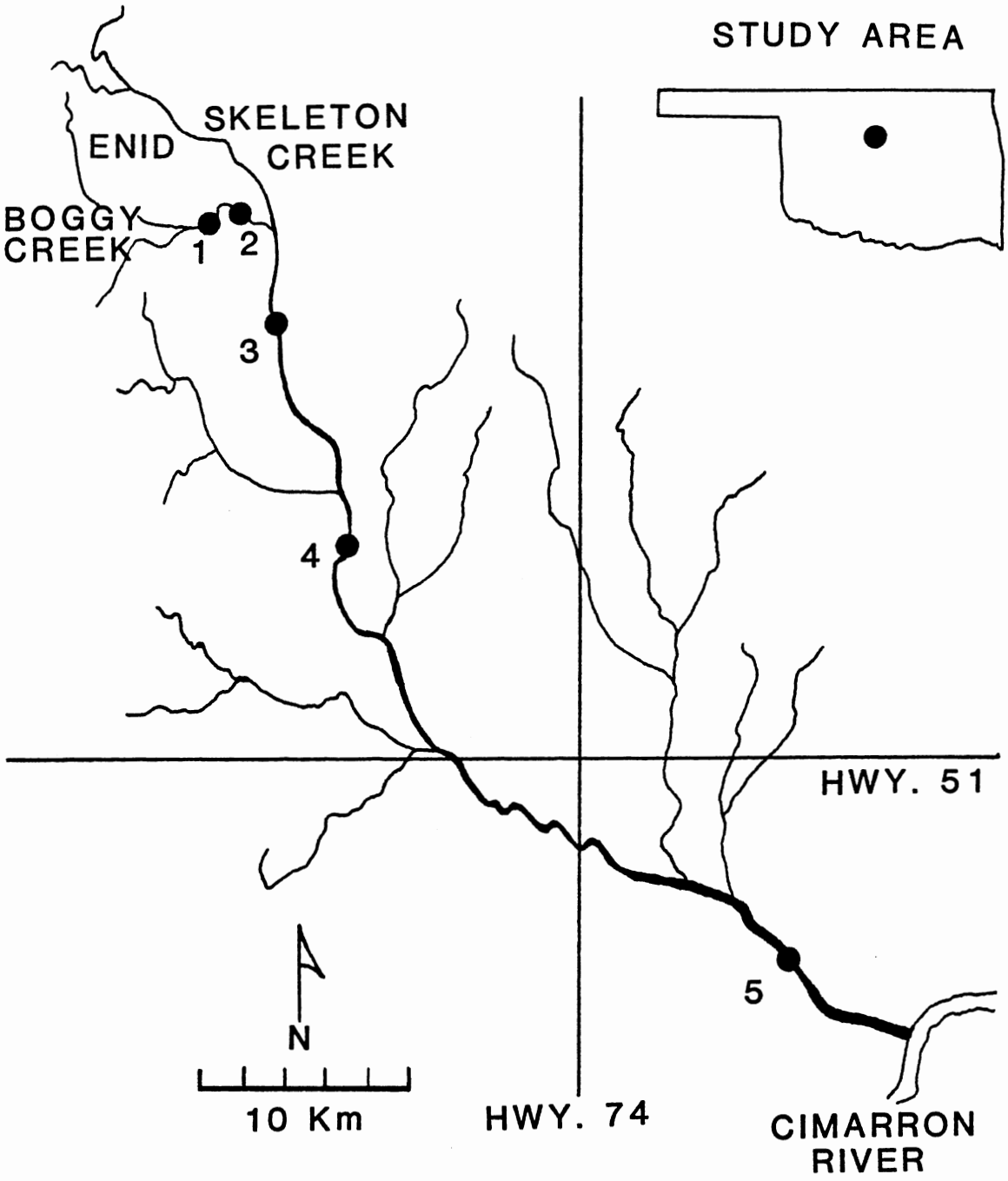

Figure 1. Map of Sampling Stations on Boggy and Skeleton Creeks.

counties to its confluence with the Cimarron River 11 km north of Guthrie, Oklahoma. Stream elevation is 399 m at the headwaters and 285 m at the mouth, with an average gradient of 0.9 m/km. Width ranges from less than a meter at the headwaters to 15 m at the mouth, with depths of 5-15 cm in riffles to over 1.5 m in pools. Silt, sand, gravel, and rocks make up the stream bottom with exposed bedrock in some areas. Skeleton Creek is a permanent stream and ranges from order 1 at the headwaters to order 6 at the mouth (Horton 1945).

The Skeleton Creek drainage basin lies in a mixed-grass prairie association and occupies approximately 162,000 ha with over 80% used for small grain cultivation and livestock grazing. The flood plain area consists of 20,000 ha with 80% under cultivation (Soil Conservation Service 1958).

The principal rocks underlying the watershed are sandstone, shales, and clays belonging to the Enid group of the Permian Red Beds (Galloway 1960). Most soils in the basin belong to the Renfrow-Zaneis-Vernon association of the Reddish Prairie Great Soil Group. They are brown to reddish brown silt loam surface soils with reddish loam to clay subsoils (Gray and Galloway 1959).

The climate of the region is continental with extreme variations in temperature and precipitation. Summers are hot with temperatures sometimes exceeding 40° C. Winters are fairly mild but frequently interrupted by short cold periods. Spring is the wettest season, with the maximum rainfall in May. The summers are dry and droughts often occur. Fall is the second wettest season with rainfall decreasing in January, the driest month (OWRB 1984).

Sources of Contamination

Contamination of Boggy and Skeleton creeks originated from municipal and industrial point source discharges as well as non-point sources. The majority of the wastewater outfalls were located in the vicinity of Enid, with non-point source contamination possible along the entire length of the streams.

Three point sources of wastewater discharged into Boggy Creek. Vance Air Force Base released domestic wastewater into Boggy Creek approximately 16 km above its confluence with Skeleton Creek. The waste treatment system consisted of a primary settling basin, trickling filter, sludge-drying beds, and a final settling basin. The average discharge rate for 1983-84 was approximately 950 m^3/day (OWRB 1986). The Enid Publicly Owned Treatment Works (POTW) discharged municipal wastewater into Boggy Creek approximately 4.2 km upstream from Skeleton Creek. Waste treatment at this facility included preaeration, activated sludge, and sludge drying. Approximately 23,000 m^3 of sewage was treated each day with over 80% of the final effluent pumped to a nearby oil refinery and an ammonia fertilizer manufacturing plant. The remaining wastewater was released into Boggy Creek.

The oil refinery used crude distillation, vacuum distillation, catalytic cracking, polymerization, reforming, coking, and lube oil units to process 52,000 barrels of crude oil per day. Wastewater from these units was sequentially routed through an API separator and a dissolved air flotation unit for removing oil. The water was then pumped to a series of six waste stabilization ponds where it was mixed with boiler blowdown, cooling tower blowdown, and lime slurry. The last stage of treatment was a series of five oxidation ponds. The final

effluent of approximately 3,000 m^3/day traversed a 3 km ditch and emptied into Boggy Creek 300 m above the Enid sewage treatment plant outfall. On December 1, 1983 the refinery initiated permanent shutdown procedures as a result of adverse economic conditions. A continuous treated wastewater discharge reflecting various refinery cleaning procedures was maintained until March 5, 1984. Thereafter, wastewater was discharged for only a few days each month (Personal Communication, Bruce Hodgkin).

The headwaters of Skeleton Creek also received municipal wastewater from several point source discharges. A system of two aeration lagoons in north Enid released approximately 400 m^3/day of domestic waste into Skeleton Creek 10 km above its confluence with Boggy Creek. The Enid State School discharged domestic wastewater into Skeleton Creek 3 km downstream from the outfall of the sewage lagoons. An Imhoff tank, trickling filter and settling basin were the facilities used by the school to treat approximately 3,000 m^3 of sewage daily (OSDH 1985).

An additional intermittent point source discharge from an ammonia fertilizer manufacturer entered Skeleton Creek approximately 0.5 km below the Boggy Creek confluence. Wastewater treatment at this plant included an oil and grease trap, a sulfur dioxide (SO_2) chromate reduction unit, an aeration-digestion basin, two settling ponds, and two final equalization ponds. The daily discharge rate was designed for 5500 m^3 with flow averaging 1900 m^3/day. The plant, however, had the facilities to retain the wastewater up to 48 h for automatic pH adjustment of the final equilization ponds (OWRB 1986).

Non-point source contamination of Skeleton and Boggy creeks was possible along the entire length of the streams. Abundant oilfield

activity and the associated residual oil, soluble hydrocarbons, and brine water could be introduced to the streams via stormwater runoff and groundwater flow. The extensive crop production and livestock grazing in the vicinity of the waterways could contribute nutrients, xenobiotics, and waste organic material. Rainfall also facilitated the transport of contaminants from the adjacent highways, overhanging bridges, and encomposing atmosphere.

Description of Stations

Five sampling stations were established on Boggy and Skeleton creeks to monitor the fate and effect of several wastewater discharges. Site selection was chosen for accessibility and proximity to pertinent discharges. In an attempt to minimize physical differences among stations, each site consisted of a riffle followed by a pool.

Station 1, the control site, was located on Boggy Creek 50 m upstream from the refinery outfall and 4.9 km upstream from the confluence with Skeleton Creek. The impact site, Station 2, was located 50 m downstream from the refinery outfall and 250 m upstream from the Enid municipal wastewater discharge. Station 3, a possible impact-recovery area, was located on Skeleton Creek 8 km downstream from its confluence with Boggy Creek and 7.5 km downstream from the ammonia fertilizer manufacturer discharge. The potential recovery zone, Station 4, was 29.5 km downstream from the confluence of Boggy and Skeleton creeks. Station 5, the recovery zone, was located 97 km downstream from the confluence of the two creeks.

The stream width, depth, and flow gradually increased with increased distance downstream, especially downstream of each point

source discharge. The size of the bottom substrate material of the riffle areas also increased with distance downstream. Steep banks were found at all sites with dense overhanging riparian vegetation present at stations 1 and 2 and less than 50 % of the stream bank covered at stations 3, 4, and 5.

CHAPTER IV

METHODS

Field Methods

Water, sediment, and biological samples were collected concurrently with in situ physicochemical conditions at seasonal intervals from each station. All samples were taken from the transition zone between the downstream portion of a riffle area and the head of a pool.

Physicochemical measurements included dissolved oyxgen, temperature, pH, and specific conductivity. Dissolved oxygen and temperature were determined using a Yellow Springs Model 54 Oxygen-Temperature Meter and probe. The dissolved oxygen meter was air calibrated. An Orion Model 201 field pH meter was calibrated with standard buffers of 7.0 and 10.0. Specific conductivity was determined using a Yellow Springs Model 33 Salinity-Conductivity-Temperature Meter. The conductivity meter was calibrated with a potassium chloride (KCl) standard solution.

Water samples at each site were collected at one half the total water depth in containers recommended for the desired analysis. Water for determining heavy metals, ammonia nitrogen, total organic carbon (TOC), and turbidity was taken in acid-rinsed 1 l polyethylene bottles and immediately stored on ice. Four, 4 l solvent-rinsed amber glass bottles with aluminum foil lined caps were used to collect samples for trace organic analysis. The large size of the containers prevented

icing in the field but were refrigerated upon return to the laboratory.

A 1 l stainless steel beaker was used to obtain sediment samples at each station. Five beaker grabs of the surface sediment equidistant along a transect across the stream were composited and passed through a No. 18 mesh (1.0 mm opening) sieve to obtain uniform size of sediment particles. The sample was placed in solvent-rinsed glass jars for subsequent trace organic analysis and acid-rinsed polyethylene bottles for heavy metal determinations. All samples were placed on ice in the field.

Benthic macroinvertebrates were collected along a transect across the stream with a Surber sampler at each site. The substrate within the 0.0929 m^2 area of the sampler was sifted by hand and any stones gently scrubbed with a toothbrush to release organisms into the current which were retained by the attached trailing net. A composite of six samples at each station was preserved with 10% formalin and transported to the laboratory for further analysis.

Laboratory Methods

Ammonia nitrogen and turbidity were measured in the laboratory within 12 h after collection. Preservation of TOC samples, extraction of organics, and filtration of heavy metals from water samples were started at the same time. Sediment samples were frozen until extraction of organics and analysis of heavy metals could begin. All glassware was cleaned with hot MICRO® solution and sequentially rinsed with tap water, deionized water, and deionized-distilled water to minimize contamination. Reagents were prepared with laboratory pure deionized-distilled water.

Ammonia nitrogen was determined with an Orion Model 407A specific ion meter and accompanying ammonia electrode. Calibration of the log scale of the meter with 0.1, 1.0, and 10.0 mg/l ammonia nitrogen standards was accomplished after adjusting the standard solution to pH 11 with 10 M sodium hydroxide. Ammonia nitrogen concentrations were read directly from the meter for samples treated in the same manner. Turbidity, reported in Nephelometric Turbidity Units (NTU), was measured using a Hach Model 16800 Turbidimeter calibrated with a 40 NTU latex solution. Those samples exceeding the range of the instrument were diluted with deionized-distilled water.

Total organic carbon was determined by the Combustion Infrared Method (APHA 1980) on water samples preserved to a pH of less than 2 with concentrated sulfuric acid. The total carbon and inorganic carbon present in the sample were quantified with a Beckman Model 915 two channel carbon analyzer and accompanying Beckman Model 215B infrared detector. A 20 ul aliquot was injected into the total carbon channel and oxidized at 950° C with subsequent infrared analysis for CO_2. A phosphoric acid column set at 150° C was used to determine the inorganic carbonates present in a 20 ul injected sample. The total organic carbon was calculated from the difference between the total and inorganic carbon.

Analysis of trace organic contaminants in water samples was initiated by concentrating these compounds on XAD-2 resin for the first four sampling dates and on activated carbon for the last four sampling dates. Approximately 12-15 l of each sample plus a deionized-distilled water blank was siphoned through an adsorption column consisting of a

1.5 cm diameter glass tube packed with 4 cm of CELITE® and 3 cm of Amberlite XAD-2 purified resin or 10 cm of Calgon C-400 granular activated carbon. Glass wool was inserted into each end to prevent movement of the column material. A teflon-lined Delrin end cap connected the bottom of the glass column to the BEV-A-LINE® tube inserted into the 4 l amber glass bottle. A No. 5 rubber stopper containing a 5 mm diameter glass tube linked the top of the glass column to the polyethylene tubing attached to the vacuum line. Teflon tape was used to seal all joints and wire to secure all tubing. Water flow was regulated at 1 l/h or less. In addition to the normal cleaning procedures, all labware and adsorption material was rinsed with methylene chloride solvent before use.

The adsorption column contents were then transferred to a glass beaker and dried overnight in an exhaust hood. The material was then placed in a Whatman cellulose extraction thimble and refluxed in a soxhlet extraction apparatus for 4 h, with the trace organics eluted with 200 ml of methylene chloride. The methylene chloride extract was dried over sodium sulfate and concentrated by evaporation in a Kuderna-Danish vessel. A Kontes tube heater and nitrogen gas stream were used to obtain a final concentrate of approximately 200 ul.

The methylene chloride extract was analyzed qualitatively by capillary column gas chromatography-mass spectrometry (GC-MS) in accordance with EPA quality control/quality assurance requirements. Approximately 1 ul of the methylene chloride extract was injected into a Hewlett Packard 5992B GC/MS with a mass spectrum produced for each detected compound eluted off the column. Compound identification was accomplished by comparing the mass spectrum of the unknown compound with

reference spectra contained in the Hewlett Packard and NIH-EPA mass spectral data bases. The level of confidence achieved for the identification of the unknown compounds was: 1) definite identification: based on actual retention and mass spectral pattern of the standard; 2) probable identification: very close match with mass spectrum in reference data base ($r \geq 0.900$), and c) questionable identification: close match with mass spectrum in reference data base ($r \geq 0.800$).

Capillary column gas chromatography coupled with flame ionization detection (GC/FID) was used to quantify those compounds with definite identification. The on-column concentration was determined by comparing the area response of the unknown with different area responses of the respective standard in a regression equation. The remaining compounds with probable and questionable identification were quantified relative to the deuterated anthracene internal standard abundance on GC/MS. The detection limits for all the organic compounds were based partially on their detectibility by GC/MS. Those compounds with a retention time of less than 10 min had a detection limit of 10 ng on column, 10-15 min had 20 ng, 15-20 min had 30 ng, 20-25 min had 40 ng, and greater than 25 min had 50 ng. Once the on-column detection limit was determined, then the microliters of sample injected on column, total microliters of sample in tube, and liters of water extracted were entered into the following equation:

$$\text{Detection Limit(ng/l)} = \left[\frac{\text{ng detected on col.}}{\text{ul injected on col.}}\right]\left[\frac{\text{tube volume in ul}}{\text{liters of water extracted}}\right]$$

Sediment samples were dried on an aluminum foil sheet in a vacuum

oven set at 30° C and 25 cm of vacuum prior to trace organic contaminant analysis. Approximately 50-70 g of dry sediment was soxhlet extracted with methylene chloride for 4 h. The subsequent drying, concentration, and analysis of trace organic compounds in sediment samples was identical to the procedures used for the water samples.

A Perkin-Elmer Model 5000 Atomic Absorption Spectrophotometer (AA) equipped with a tungsten/deuterium continuum background corrector was used to determine the dissolved and suspended concentration of 14 heavy metals in water samples and the total concentration of five elements in sediments. A Perkin-Elmer Model 306 AA was used for total mercury analysis.

Water samples were filtered through a 0.45 um Gelman (Type H-45) membrane filter to separate dissolved and suspended metals. Both the filtrate and suspended material on the filter pad were refluxed with 3 ml of concentrated nitric acid and once digested, diluted to the original 100 ml volume with 0.2 N nitric acid. Sodium, calcium, nickel, magnesium, potassium, iron, copper, manganese, and zinc concentrations were measured with air-acetylene flame atomization, while a heated graphite furnace was used for determining lead, chromium, cadmium, selenium, and arsenic levels.

The cold flameless method was used for analyzing total mercury with the chemical generation of ground state atoms at room temperature. In this method, all forms of mercury in a premeasured water sample were first oxidized by adding concentrated nitric acid, concentrated sulfuric acid, and 5% potassium permangate with subsequent reduction to ground state atoms after adding hydroxyl amine hydrochloride and stannous chloride. Volatile mercury atoms in the solution were air purged into

an enlongated absorption cell aligned in the sample beam of the AA. A plateau shaped absorption signal was recorded as the mercury recirculated through the closed system, with values calibrated against a standard curve and reported in mg/l.

Heavy metals in sediments were determined by procedures outlined by Sinex et al. (1980). Sediment samples were first oven dried at 105° C for 48 h in teflon beakers and then ground in a mortar. A 10 g aliquot was placed in a 500 ml boiling flask and accompanying condenser and refluxed for 4 h with 90 ml of concentrated nitric acid and 10 ml of concentrated hydrochloric acid. Once cooled, the supernatant was filtered through a Whatman No. 1 filter paper and collected in a 250 ml beaker. The remaining sediment was washed twice with deionized distilled water with the resultant supernatant also filtered and collected. The collected extract was concentrated on a hot plate to approximately 20 ml and then diluted to a final volumn of 50 ml with 5% nitric acid. Subsequent analysis of chromium, cadmium, copper, lead, and zinc concentrations with flame atomic absorption was complemented with standards also prepared with 5% nitric acid. Prior to analysis, all labware was rinsed with 12 M sulfuric acid.

Benthic macroinvertebrates were sorted from sediments in the laboratory by washing the contents of the formalin-preserved Surber sample in a No. 30 mesh (0.6 mm opening) sieve. Large stones or twigs were gently scrubbed and rinsed over the retaining screen before discarding. The sample was again preserved with 10% formalin. Organisms were identified to lowest possible taxa and enumerated. The density, total number of taxa, species diversity, and similarity indicies were used to measure the effects of the wastewater discharges.

The readily oxidizable organic carbon content of sediment samples was determined by the Walkley-Black titration method as modified by Gaudette et al. (1974). Each replicate sample was sequentially air dried, ground, and passed through a U.S. No. 10 mesh (2.0 mm opening) sieve to remove gravel. A 0.2 to 0.5 g aliquot ($\pm$ 0.001 g) of each sample and 10 ml of 1.0 N $K_2Cr_2O_7$ solution added by buret were gently swirled in a 500 ml Erlemeyer flask. Exactly 20 ml of concentrated H_2SO_4 was then added by buret to the sample flask and the contents gently swirled for 1 min and then allowed to stand for 30 min. A standardization blank without sediment was run for each new batch of samples.

Once cooled, the solution was diluted to 200 ml volume with distilled water, and 10 ml of 85% H_3PO_4, 0.2 g NaF, and 15 drops of diphenylamine indicator were added to the sample flask. The excess dichromate was back titrated with 0.5 N ferrous ammonium sulfate to a sharp brillent green (1 drop) endpoint. The results of the analysis were calculated by the following equation:

$$\% \text{ Organic Carbon} = 10(1-T/S)\ [1.0\ N(0.003)(100/W)]$$

Where: T = sample titration, ml ferrous solution

S = standardization blank titration, ml ferrous solution

0.003 = 12/4,000 = meq weight of carbon

1.0 N = normality of $K_2Cr_2O_7$

10 = volume of $K_2Cr_2O_7$

W = weight of sediment sample in g

The percent sand, silt, and clay particle size distribution of sediment samples was determined by the sieve-pipet method (Day 1965). Each replicate sample was sequentially air dried, rolled with a pipe to break up clumps, passed through a U.S. No. 10 mesh (2.0 mm opening) sieve to remove gravel, and oven dried at 95° C for 24 h. A 10 g aliquot (± 0.001 g) of each sample was transferred to a 250 ml polypropylene bottle along with 5 ml of distilled water and 5 ml of 30% H_2O_2. Once sample foaming had subsided, the sample bottle was placed in a 75° C water bath with 5 ml increments of 30% H_2O_2 added until foaming of organic matter was insignificant. Each sample bottle was centrifuged at 5000 RPM for 5 min and the clear supernatant discarded. Exactly 10 ml of sodium hexametaphosphate (SHMP) solution (50 mg/l) was added (by buret) to each sample followed by 9-12 h of mixing on an automatic shaker. The dispersed sample was then passed through a U.S. No. 270 mesh (0.053 mm opening) sieve with the sand fraction retained by the sieve and the silt and clay fraction collected in a 1000 ml graduated cylinder. Additional distilled water rinses of the retained material was necessary to faciliate complete transfer of the silt and clay particles to the graduated cylinder.

The sand fraction retained by the sieve was transferred to a preweighed 50 ml beaker, oven dried at 95° C, desiccated, and weighed. The net weight gain represented the amount of sand in the sample.

The graduated cylinder containing the silt and clay fraction was filled to the 1000 ml level, completely mixed with a hand stirer, and left undisturbed. At the appropiate time (temperature and size fraction dependent), 20 ml of the cylinder contents was pipeted from 10 cm below the liquid meniscus and transferred to a preweighed 50 ml beaker, oven

dried at 95° C, desiccated, and weighed. A SHMP cylinder blank (10 ml SHMP) was also run to adjust for the weight gain due to the dispersing agent. The percent fraction was calculated from the following equation:

$$\% \text{ Fraction} = (wV/y - D.A.)\ (100/z)$$

Where: w = weight of pipeted fraction, in g

V = total volume in graduated cylinder, in ml

y = volume pipeted, in ml

D.A. = weight of dispersing agent fraction blank, in g

z = weight of sample, in g

Statistical Methods

The physicochemical and benthic macroinvertebrate data collected during this study was analyzed statistically on an IBM 3081 computer using the Statistical Analysis System (SAS) and the Biomedical Programs (BMDP). Raw data was used for the descriptive statistics, while Pearson's product moment correlation analysis, principal component analysis, and stepwise multiple regressions used log base 10 transformed data.

Descriptive statistics provided means, standard deviations, and ranges of the measured parameters; whereas, Pearson's product moment correlation showed similarities among every pairwise combination of variables on an individual sample basis.

Principal component analysis (PCA) was used to reduce the large data set of potentially correlated variables to a smaller number of uncorrelated hypothetical components (Timm 1975).

A stepwise multiple regression procedure was used to analyze the data on an overall basis, before, and after refinery closure. This program, as outlined by Draper and Smith (1966), determined which combination of parameters would best predict benthic species diversity. The regression equation is as follows:

$$Y = B_o + B_1X_1 + B_2X_2 + \ldots + BpXp + E$$

Where:

Y = the response variable
B_o = the y-intercept
B_i = coefficient of the i^{th} parameter
X_i = the different independent variables
E = random error

and:

$i = 1, 2, \ldots, p$

CHAPTER V

RESULTS AND DISCUSSION

Physicochemical Conditions

Water

Dissolved oxygen, temperature, pH, specific conductivity, ammonia, turbidity, and total organic carbon were measured during daylight at each site seasonally over the 2-year study (Appendix A). Overall mean station values for the physicochemical variables and other parameters were calculated for all eight sampling dates. The first six sampling dates were used to determine station means before the refinery shutdown and the last two dates after closure.

The concentration of dissolved oxygen always exceeded 5.9 mg/l which exceeds the 5.0 mg/l minimum required by the Oklahoma Water Resources Board (OWRB) for protecting non-early life stages in those streams designated as primary warm water fisheries. From 1 April to 15 June, dissolved oxygen levels always exceeded 6.0 mg/l which is the minimum criterion for early life stages (OWRB 1985). The recorded dissolved oxygen levels also exceeded the national warm water 1-day minimum criteria of 5.0 mg/l for early life stages and 3.0 mg/l for other life stages (USEPA 1986). Mean dissolved oxygen concentrations before refinery closure ranged from 9.6 mg/l at Station 2 to 14.1 mg/l at Station 3. After closure mean levels ranged from 7.7 mg/l at Station

5 to 13.6 mg/l at Station 3. These values were taken in daylight and probably do not indicate concentrations at night. Diurnal dissolved oxygen analysis of Skeleton Creek by Baumgardner (1966) showed a rapid decrease in dissolved oxygen at night. Gameson and Griffith (1959) determined that the lowest dissolved oxygen levels occurred at 0600 h in a polluted river.

Water temperature reflected ambient air temperature with a range from 2.2 to 7.0 °C during winter and from 23.8 to 34.0 °C in summer. Point source wastewater discharges did not influence receiving stream water temperature.

Mean pH values before refinery closure ranged from 7.7 at Station 2 to 8.3 at Station 3. After closure mean levels ranged from 7.6 at stations 1, 2, and 5 to 8.1 at Station 3. Wastewater discharges from the Enid POTW and the ammonia fertilizer plant contributed to the consistently higher pH level at Station 3. All values were within the 6.5-9.0 range specified by OWRB (1985) and USEPA (1986) for protection and propagation of aquatic life.

Mean specific conductivity levels before refinery closure ranged from 942 uS/cm at Station 1 to 1980 uS/cm at Station 2. After closure mean values ranged from 823 uS/cm at Station 1 to 2100 uS/cm at Station 4. The elevated levels at Station 2 before refinery closure were due to the refinery wastewater discharge, with similar values found at stations 1 and 2 after closure. The higher levels at Station 4 after closure were possibly due to the May, 1984 heavy rains and associated runoff from surrounding agricultural fields and oilfield operations (Mathis 1965).

Mean total ammonia concentrations before refinery closure ranged from 0.14 mg/l at Station 1 to 2.65 mg/l at Station 3. After closure mean levels ranged from nondetectable at stations 1 and 2 to 4.5 mg/l at Station 3 (Figure 2). These results indicate the relative contributions of ammonia from the wastewaters of the refinery, the POTW, and the ammonia fertilizer plant. A similar trend was evident for levels of unionized ammonia, the toxic form (USEPA 1986). An unionized ammonia limit of 0.02 mg/l has been established as a goal by the state of Oklahoma for protecting and propagating fish and wildlife (OWRB 1985). On 5 October 1983 the unionized ammonia concentration was 0.037 mg/l higher at Station 2 than Station 1 and the species diversity ($\bar{d}$) of benthic macroinvertebrates decreased 1.68 units between these two stations. A decrease in diversity ($\bar{d}$) of benthic macroinvertebrates between sampling locations upstream and downstream (end of mixing zone) from a point source discharge in excess of 1.0 is a violation of the state standards (OWRB 1985). On other occasions the concentration of unionized ammonia exceeded the numerical goal and yet benthic macroinvertebrate diversity exceeded 3.0.

The national unionized ammonia criterion (USEPA 1986) for a stream or lake is determined by the pH and temperature of the water and also by the presence or absence of sensitive coldwater species. For Oklahoma waters where sensitive coldwater species are absent, the 4-day average concentration (Criterion Continuous Concentration) of unionized ammonia (in mg/l NH_3) should not exceed the numerical value given by the following equation more than once every 3 years:

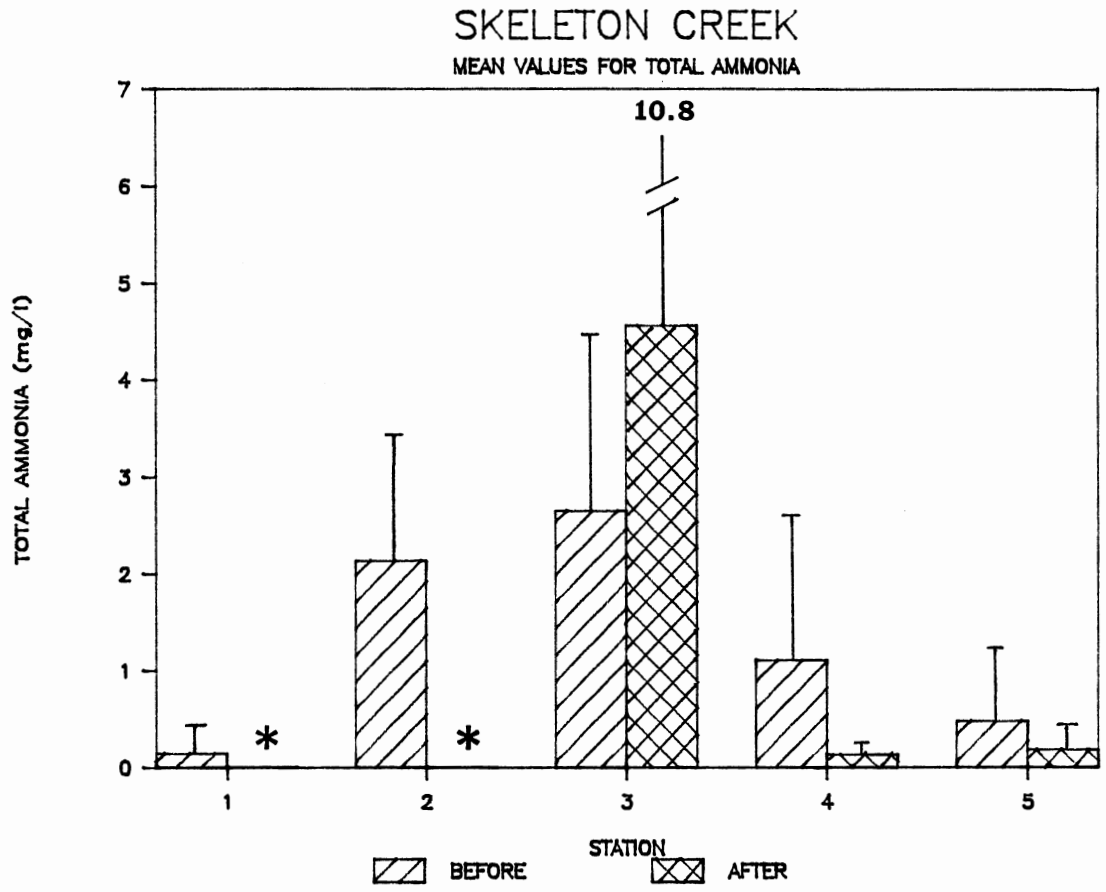

Figure 2. Mean Values of Total Ammonia in Water Samples Collected Before and After Refinery Closure at the Five Collecting Stations. Upper 95% Confidence Limits are Indicated by Vertical Lines and a Nondetectable Level by an Asterisk.

Unionized Ammonia Criterion (mg/l) = 0.80/FT/FPH/RATIO

Where: $FT = 10^{0.03(20-20)}$; if $20^{o}C \leq T \leq 30^{o}C$

$FT = 10^{0.03(20-T)}$; if $0^{o}C \leq T \leq 20^{o}C$

$FPH = 1$; if $7.7 \leq pH \leq 9$

$FPH = (1 + 10^{7.4-pH})/1.25$; if $6.5 \leq pH \leq 7.7$

$RATIO = 16$; if $7.7 \leq pH \leq 9$

$RATIO = 24(10^{7.7-pH}/1+10^{7.4-pH})$; if $6.5 \leq pH \leq 7.7$

Table I lists the 13 samples that exceeded their respective USEPA national criteria for protecting aquatic life.

Mean turbidity levels ranged from 11.6 NTU at Station 3 to 57.8 NTU at Station 5 before refinery closure and from 41.5 NTU at Station 3 to 323.0 NTU at Station 5 after closure. The higher levels at Station 5 could be attributed to erosion of the surrounding agricultural land, inflow from tributaries, and resuspension of stream bed silt (Baumgardner 1966). The higher values after refinery closure are most likely due to heavy rains just prior to May, 1984. The state's maximum turbidity level for warm water streams is set at 50 NTU with higher levels allowed after runoff. The 50 NTU limit was exceeded at stations 1, 2, and 3 on 1 May 84 and several times at stations 4 and 5 with no apparent effect on the diversity of benthic macroinvertebrates.

Mean total organic carbon values before refinery closure ranged fron 8.5 mg/l at Station 1 to 23.0 mg/l at Station 2. After closure mean values ranged from 10.0 mg/l at Station 1 to 16.2 mg/l at Station 5. Similar values existed at stations 1 and 2. Higher concentrations at Station 2 before refinery closure than after reflects organic loading in the creek from the refinery wastewater. The levels at stations 3, 4,

TABLE I

SELECTED UNIONIZED AMMONIA VALUES IN INDIVIDUAL SKELETON CREEK WATER SAMPLES THAT EXCEEDED USEPA (1986) CRITERIA CONTINUOUS CONCENTRATION LIMITS

Date	Station	Unionized Ammonia (mg/1)	Criterion Continuous Concentration (mg/1)
12 Aug 82	2	0.1230	0.0500
	3	0.6248	0.0500
	4	0.0846	0.0500
	5	0.4491	0.0500
7 Dec 82	3	0.0281	0.0190
27 Apr 83	2	0.0717	0.0435
	3	0.1324	0.0483
6 Jul 83	3	0.1310	0.0500
5 Oct 83	2	0.0378	0.0248
	3	0.1342	0.0500
8 Dec 83	3	0.1350	0.0204
	4	0.0540	0.0175
14 Aug 84	3	0.5922	0.0500

and 5 exceed the control site and reflect the dilution of refinery wastewater as well as additional inputs of organic material from the POTW and ammonia fertilizer plant.

Sediment

The percent sand, silt, clay, and organic carbon was determined on sediment samples collected (Appendix E). Sand was the most common size particle of the sediment at all sites followed by silt and clay (Figure 3). Station 3 had the highest percentage of sand, while the lowest occurred at Station 4. The occurrence of silt and clay was greatest at Station 4 and smallest at Station 3.

A similar mean particle size distribution existed before and after refinery shutdown except more silt than sand was at Station 4 prior to closure. The amount of sand increased at each site after shutdown along with a concurrent decrease in silt and clay. This difference was most likely due to the heavy rains before the 1 May 84 sampling followed by scouring, transport, and deposition of sand along the length of the stream. Increased stream discharge was also recorded during this time (Appendix L).

Mean percent organic carbon content of the sediment before refinery closure ranged from 0.08 at Station 5 to 0.41 at Station 4. After closure mean values ranged from 0.04 at Station 1 to 0.17 at Station 4. The higher levels at Station 4 before and after refinery closure were partially due to corresponding higher percentages of silt (Pearson correlation = 0.86) and clay (Pearson correlation = 0.88). Organic carbon levels after shutdown were 50-70% lower at all sites except Station 5. This trend was most likely due to the concurrent increase in sand and decrease in silt and clay at these sites. The lower levels at Station 2 after refinery closure could also be explained by the refinery wastewater discharge termination.

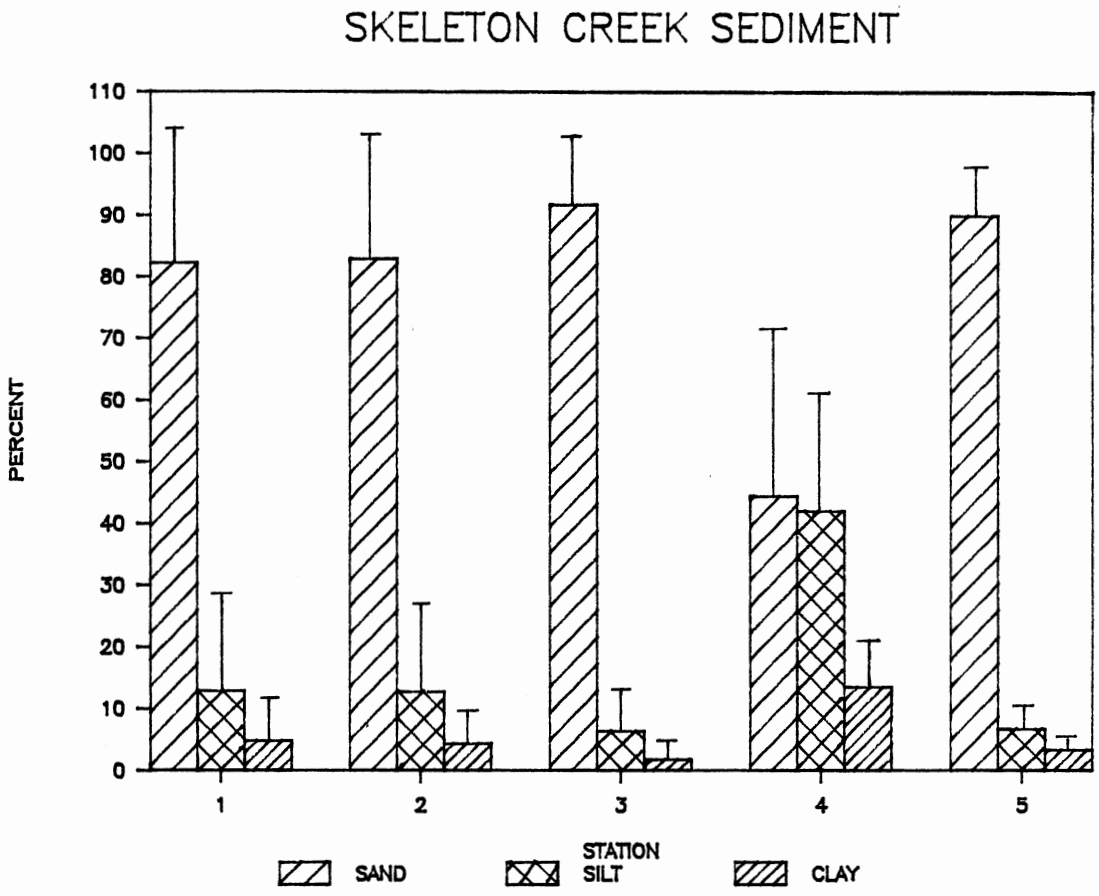

Figure 3. Mean Values for Percent Sand, Silt, and Clay of Sediment Samples Collected at Each Station. Upper 95% Confidence Limits are Indicated by Vertical Lines.

Heavy Metals

Water

Dissolved and suspended concentrations of sodium, calcium, magnesium, potassium, iron, lead, zinc, copper, chromium, nickel, cadmium, manganese, selenium, and arsenic (Appendix B) and total mercury (Appendix C) were determined for water samples. Sodium was predominantly found in the dissolved form with suspended levels consistently less than 2.1 mg/l. Mean dissolved values before refinery closure ranged from 105.0 mg/l at Station 1 to 321.3 mg/l at Station 2. Higher dissolved sodium levels at Station 4 (244.9 mg/l) than at Station 3 (227.5 mg/l) could be due to brine runoff from surrounding oilfield activity (Mathis 1965). Levels at stations 2, 3, 4, and 5 decreased after closure.

Calcium was also primarily found in the dissolved form; suspended concentrations were less than 3.5 mg/l. Dissolved values before refinery closure ranged from 72.7 mg/l at Station 1 to 146.8 mg/l at Station 4. Intermediate levels existed at stations 2, 3, and 5. Mean concentrations after refinery shutdown were lower than before shutdown at all stations.

Dissolved magnesium was the most abundant form of the element in water samples with suspended levels less than 1.8 mg/l. Mean dissolved values before refinery closure ranged from 24.7 mg/l at Station 2 to 35.1 mg/l at Station 5. After closure mean dissolved values were 20-30% lower than before closure levels at stations 1, 2, and 5; whereas, stations 3 and 4 had a 15-25% increase.

Potassium occurred mainly as the dissolved form with suspended

concentrations less than 1.7 mg/1. Mean values before refinery closure ranged from 7.1 mg/1 at Station 1 to 16.4 mg/1 at Station 2. After closure mean levels ranged from 4.8 mg/1 at Station 1 to 20.0 mg/1 at Station 4. Similar values were found at stations 1 and 2.

Iron was predominately associated with suspended material. Mean suspended values before refinery closure ranged from 0.11 mg/1 at Station 3 to 1.15 mg/1 at Station 5. Dissolved iron showed a similar trend except that Station 1 had the lowest mean value (0.008 mg/1). Mean values for suspended iron were greater after refinery shutdown, while dissolved levels were lower. The national total iron criterion has been established at 1.0 mg/1 (USEPA 1986) which was exceeded at a number of stations (Appendix B). The consistent occurrence of iron in the suspended fraction was related to turbidity (Pearson correlation = 0.77) and resuspension of bottom material.

The only detectable quantities of lead were on 14 August 84. The highest dissolved concentration existed at Station 1 (0.21 mg/1) and undetectable levels at Station 3. Suspended lead concentrations were only found at stations 4 and 5. Non-point source runoff from the city of Enid and wastewater effluent from the military base upstream from the control site were probable sources of lead. A 0.12 mg/1 total lead limit has been set by the state which was exceeded at Station 1 with no apparent adverse effects to the benthic diversity ($\overline{d}$ = 4.32). The EPA National Criterion Continuous Concentration (CCC) for lead is water hardness dependent and is determined by the following equation:

$$\text{Lead CCC (ug/1)} = e^{(1.273[\ln(\text{hardness})]-4.705)}$$

Data for Ca and Mg were combined to estimate water hardness for each

sample (APHA 1980). Table II lists the total recoverable lead levels, hardness values, and national lead limits for 14 August 84. All stations except 3 exceeded the national limits.

TABLE II

TOTAL LEAD VALUES AND USEPA NATIONAL CRITERIA CONTINUOUS CONCENTRATIONS FOR SKELETON CREEK SAMPLES COLLECTED ON 14 AUG 1984.

Station	Hardness as $CaCO_3$ (mg/l)	Total Recoverable Lead (mg/l)	EPA National Criterion Continuous Concentration (mg/l)
1	214.3	0.210*	0.008
2	222.2	0.098*	0.009
3	529.5	<0.005	0.027
4	563.5	0.033*	0.028
5	216.4	0.061*	0.009

* National limit for lead was exceeded (USEPA 1986).

Roughly equivalent levels of zinc were found in the suspended and dissolved fractions. Mean suspended zinc concentrations before refinery closure ranged from 0.002 mg/l at Station 1 to 0.040 mg/l at Station 2 (Figure 4). Mean suspended values decreased after refinery shutdown except Station 4 was approximately fifty times higher after the shutdown. This elevated value was due to the 0.28 mg/l recorded for the 1 May 84 sample that was possibly influenced by rainfall and

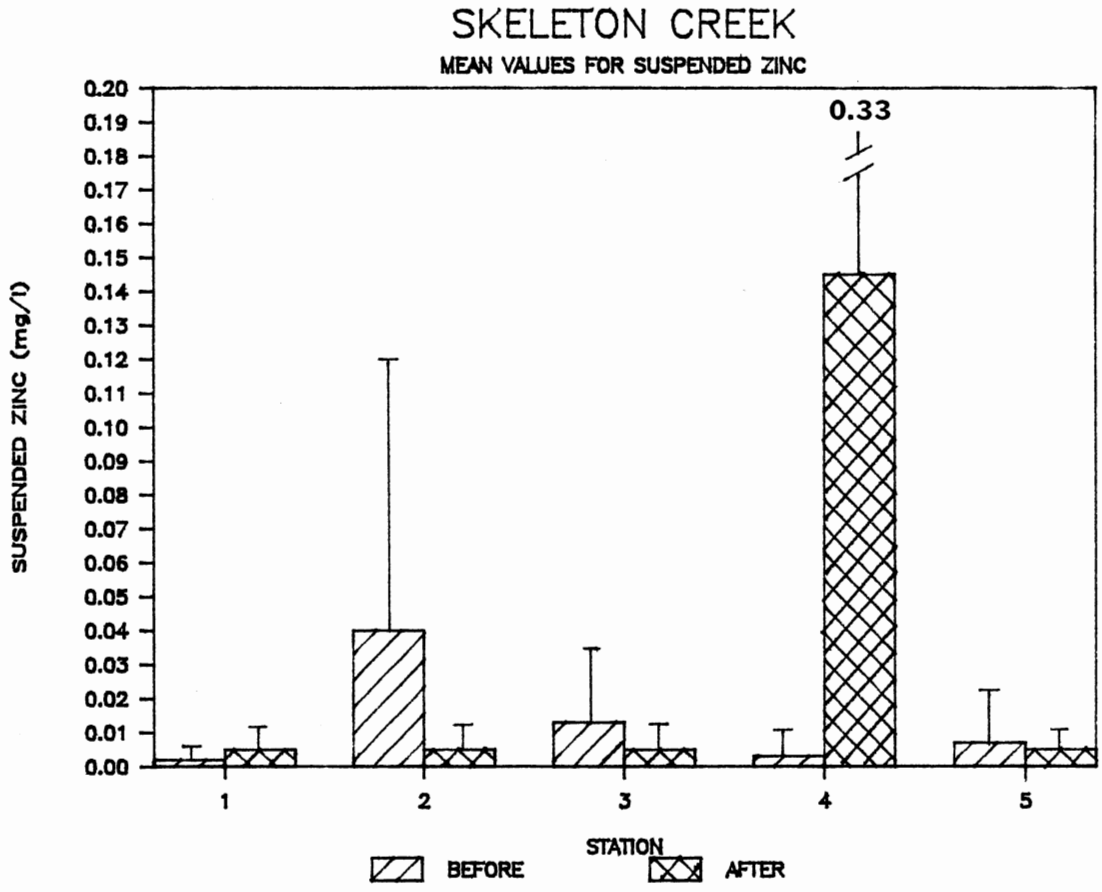

Figure 4. Mean Values of Suspended Zinc in Water Samples Collected Before and After Refinery Closure at the Five Collecting Stations. Upper 95% Confidence Limits are Indicated by Vertical Lines.

resuspension of bottom sediment. Mean dissolved levels before closure ranged from 0.002 mg/l at Station 1 to 0.017 mg/l at Station 3 (Figure 5). Mean dissolved levels increased after closure at all sites. Increased runoff and resuspension of bottom sediments could also explain these elevated levels. All values were below the 0.382 mg/l OWRB (1985) established limit for total zinc. Nine samples (Appendix B) were greater than the 0.047 mg/l 24 hour average national criterion limit (USEPA 1986).

The only detectable level of copper (0.04 mg/l) was found at Station 2 on 14 August 84 in the dissolved fraction. This concentration was in excess of the 0.03 mg/l limit established by the state of Oklahoma for Skeleton Creek (OWRB 1985) and the 0.023 mg/l national CCC (USEPA 1986). The corresponding species diversity value at this site was 3.31.

Chromium was primarily found in the dissolved form and mean values before refinery closure ranged from 0.010 mg/l at Station 1 to 0.143 mg/l at Station 5 (Figure 6). Mean suspended levels before closure ranged from undetectable concentrations at stations 3 and 4 to 0.005 mg/l at Station 2. The only detectable quantities reported after closure were in the suspended fraction at Station 5. Higher suspended chromium values at Station 2 were most likely due to the refinery wastewater in view of the documented use of chromium in the plant. The high dissolved chromium levels at Station 5 could be attributed to resolubilization of the element from bottom sediment and runoff induced turbidity. The statewide total chromium limit of 0.05 mg/l was exceeded at stations 1, 2, 4, and 5 on 27 April 83 with no apparent reduction of the species diversity ($\bar{d}$) of the benthic macroinvertebrates.

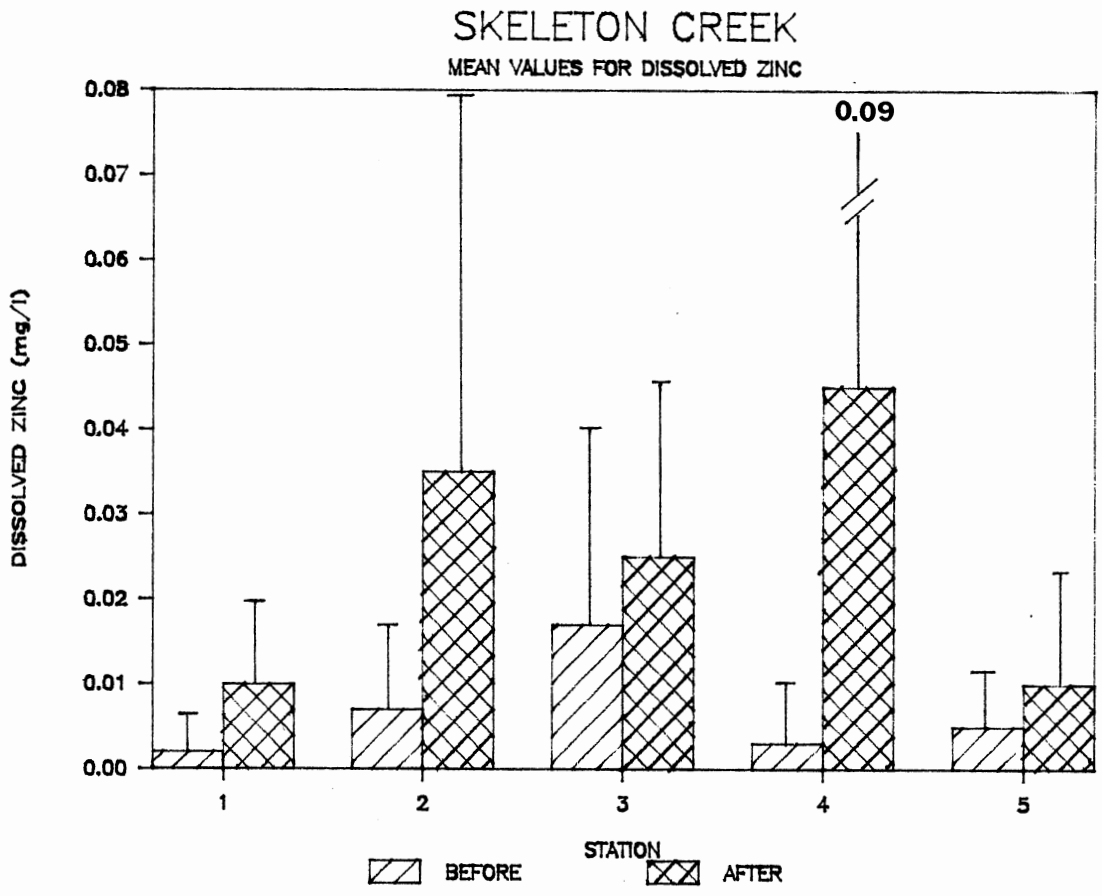

Figure 5. Mean Values of Dissolved Zinc in Water Samples Collected Before and After Refinery Closure at the Five Collecting Stations. Upper 95% Confidence Limits are Indicated by Vertical Lines.

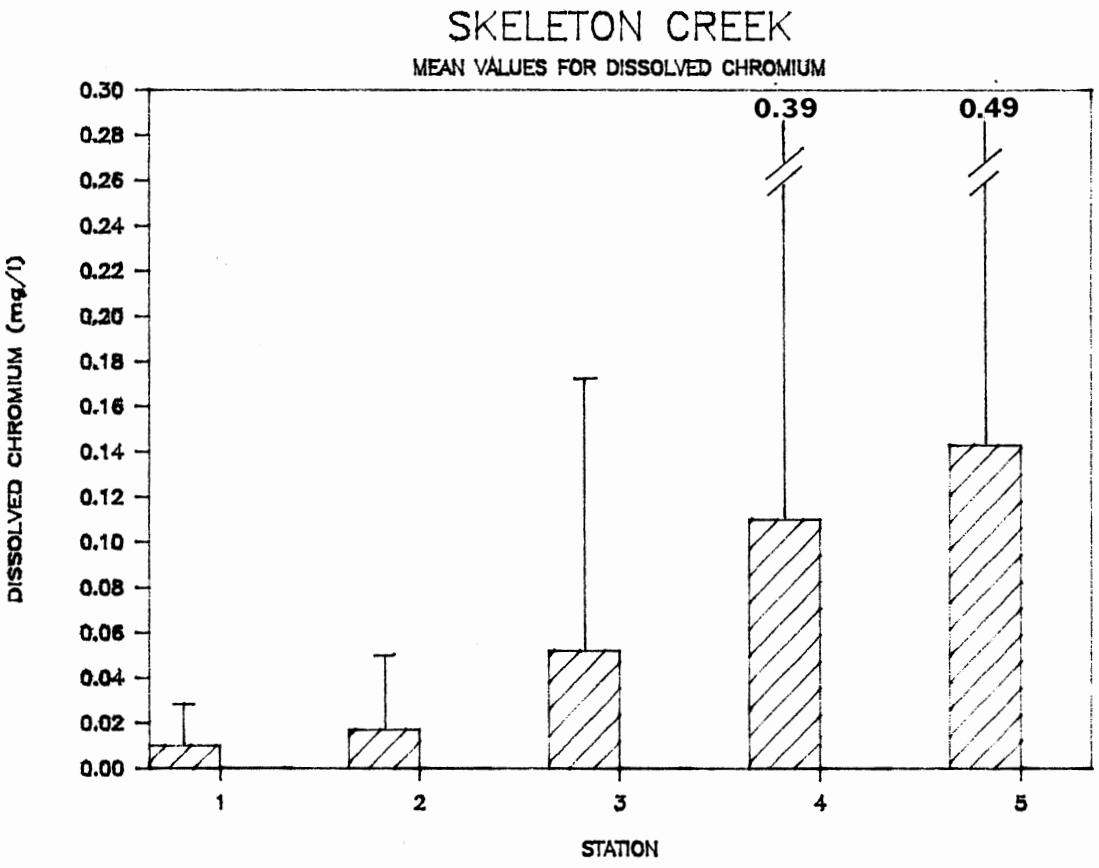

Figure 6. Mean Values of Dissolved Chromium in Water Samples Collected Before Refinery Closure at the Five Collecting Stations. Upper 95% Confidence Limits are Indicated by Vertical Lines. No Chromium was Detected After Closure.

Detected levels of nickel were equally distributed between the suspended and dissolved fractions. Mean suspended values before refinery closure ranged from nondetectable levels at stations 1 and 2 to 0.017 mg/1 at stations 3, 4, and 5. Mean dissolved values ranged from less than detectable levels at Station 1 to 0.033 mg/1 at stations 4 and 5. No detectable quantities were recorded after shutdown. All sample values were below the OWRB (1985) criterion of 0.464 mg/1. The national 24-h average limit (USEPA 1986) is also dependent on the hardness of the water and is determined by the following equation:

$$\text{Nickel 24 h Mean Criterion (ug/1)} = e^{(0.76[\ln(\text{hardness})]+1.06}$$

Table III lists the total recoverable nickel values, hardness levels, and national nickel limits for samples with detectable quantities. Only Station 5 on 27 April 83 exceeded the limit.

Cadmium values for all analyzed samples were below the detection limit of 0.005 mg/1 which is also less than the established state total cadmium limit of 0.012 mg/1. The detection limit of 0.005 mg/1, however, is greater than the national cadmium CCC for all the samples.

Similar levels of manganese were found in the suspended and dissolved fractions. Mean suspended manganese levels before refinery closure ranged from 0.013 mg/1 at Station 3 to 0.119 mg/1 at Station 5. Mean dissolved manganese values before closure ranged from 0.013 mg/1 at Station 5 to 0.070 mg/1 at Station 2. Means were similar before and after shutdown except Station 4 mean dissolved level after closure was four times greater than before. State and national manganese criteria are lacking.

Arsenic and selenium values for all samples collected were

TABLE III

TOTAL RECOVERABLE NICKEL CONCENTRATION, HARDNESS, AND 24 HOUR AVERAGE NICKEL LIMITS FOR SELECTED SKELETON CREEK SAMPLES

Date	Station	Hardness as $CaCO_3$ (mg/l)	Total Recoverable Nickel(mg/l)	National 24 h Average Conc. Criterion (mg/l)
27 Apr 83	2	356.3	0.1	0.251
	3	443.3	0.1	0.296
	4	425.4	0.2	0.287
	5	341.9	0.3*	0.243
6 Jul 83	3	225.5	0.1	0.177
	4	436.1	0.1	0.293

* Limit was exceeded.

consistently less than or equal to the 0.01 mg/l detection limit. This level is also below the state limit of 0.040 mg/l set for arsenic and the 0.035 mg/l criterion for selenium (OWRB 1985, USEPA 1986). The national criterion for arsenic is based on the +3 valence species which was not determined.

Total mercury levels were below the detection limit (0.002 mg/l) for all samples. This value is higher than the 0.001 mg/l state criterion (OWRB 1985) and the 0.00001 mg/l national CCC (USEPA 1986) and thus it cannot be determined if the limit was exceeded.

Sediment

Total concentrations of cadmium, chromium, copper, lead, and zinc were determined on sediment samples (Appendix D). Before refinery closure mean concentrations of cadmium (Figure 7) and lead (Figure 11) decreased from Station 1 to Station 3, increased at Station 4, and decreased at Station 5. Cadmium concentrations ranged from 0.15 ug/g at stations 3 and 5 to 0.33 ug/g at stations 1 and 4. Lead levels ranged from 6.3 ug/g at Station 5 to 21.7 ug/g at Station 1. Considerable fluctuation existed in chromium (Figure 8), copper (Figure 9), and zinc (Figure 10). Values ranged from 6.3 to 23.0 ug/g, 3.8 to 12.0 ug/g, and 20.4 to 80.5 ug/g, respectively. Minima existed at Station 5 for all metals. Heavy metals decreased at all stations after closure. These reductions were approximately 50% for chromium, zinc, and lead; 60% for copper; and 80% for cadmium. The only exception to this was for lead at Station 3, which increased approximately 30%.

The consistent maximum heavy metal levels at Station 4 can be partially explained by the greater percentage of silt and clay at this site. The Pearson correlation value for each element ranged from 0.64 to 0.87 for percent silt and from 0.61 to 0.84 for clay. Thus, greater percentages of silt and clay increased the capacity of the sediment to attract and retain these specific heavy metals. Increased sand and reduced silt and clay percentages recorded after shutdown could help explain the lower heavy metal levels found at all sites.

Numerical goals for selected heavy metals in sediments have been recommended by the state of Oklahoma (OWRB 1985) to protect public health by limiting toxics for human consumption (Table IV). All

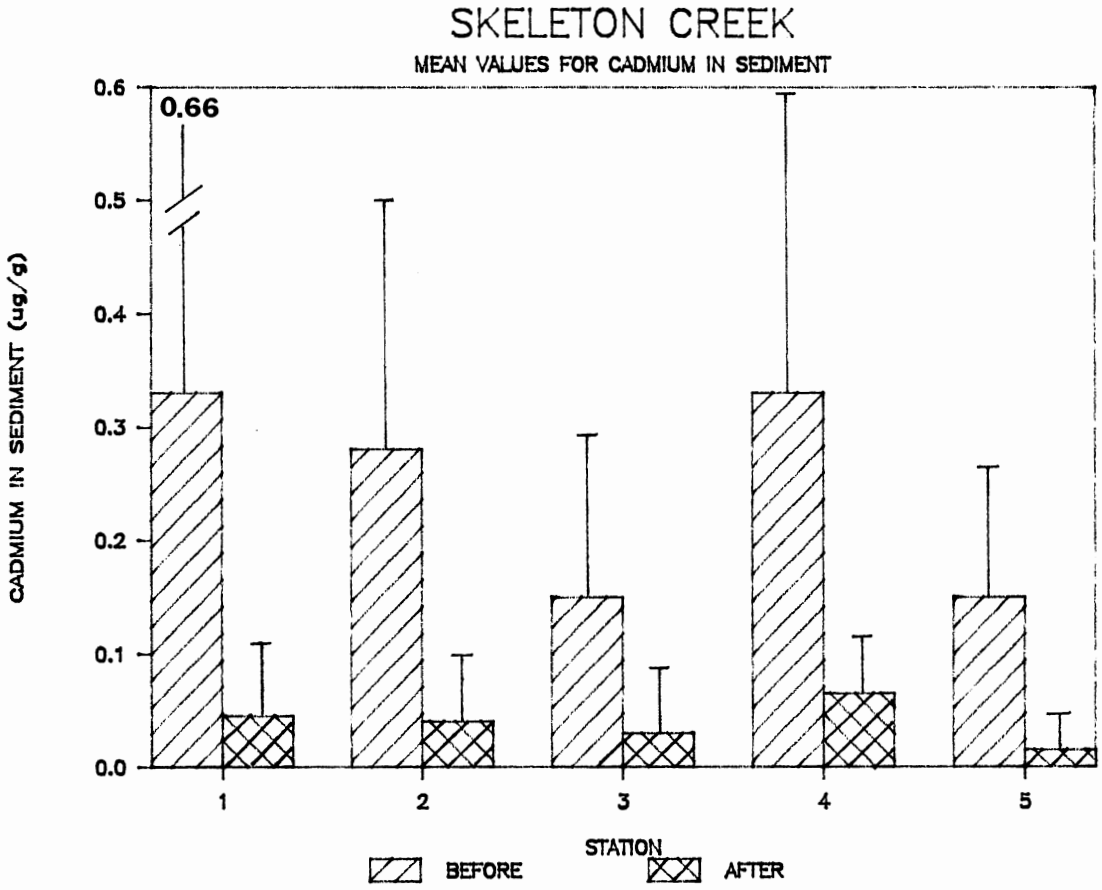

Figure 7. Mean Values of Cadmium in Sediment Samples Collected Before and After Refinery Closure at the Five Collecting Stations. Upper 95% Confidence Limits are Indicated by Vertical Lines.

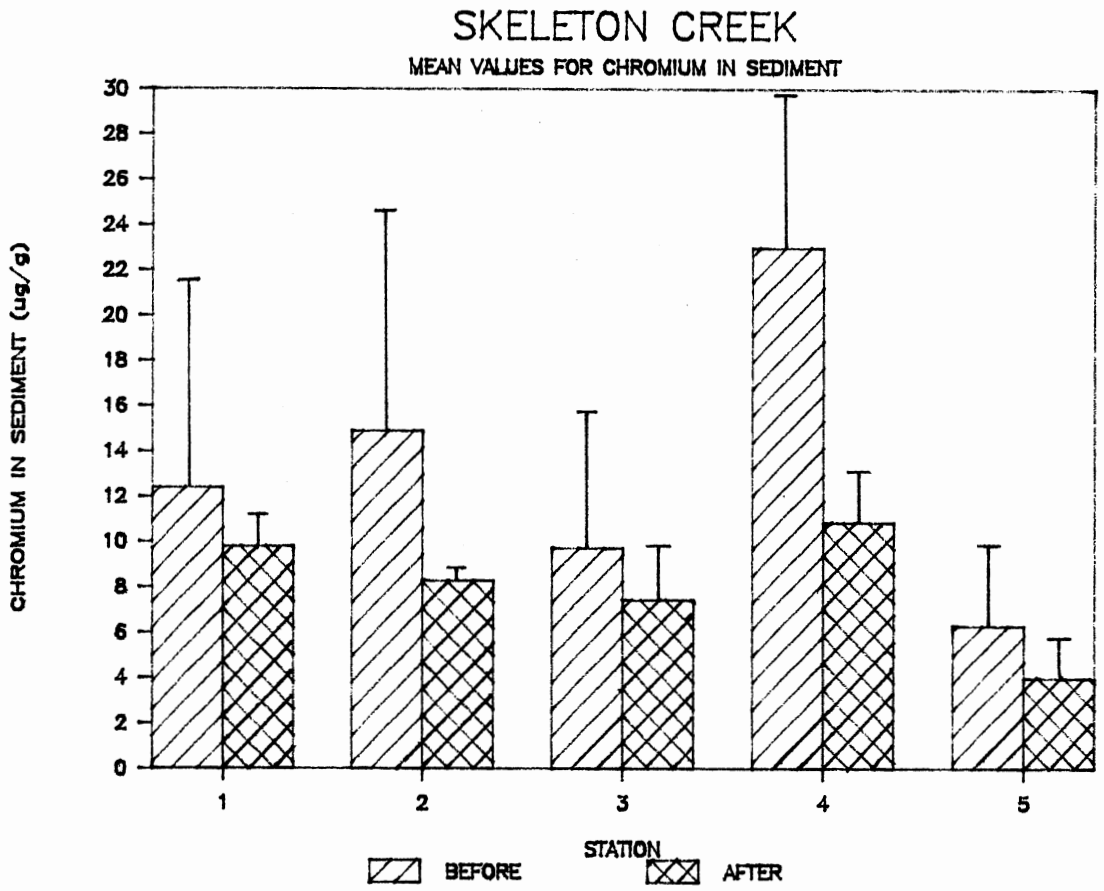

Figure 8. Mean Values of Chromium in Sediment Samples Collected Before and After Refinery Closure at the Five Collecting Stations. Upper 95% Confidence Limits are Indicated by Vertical Lines.

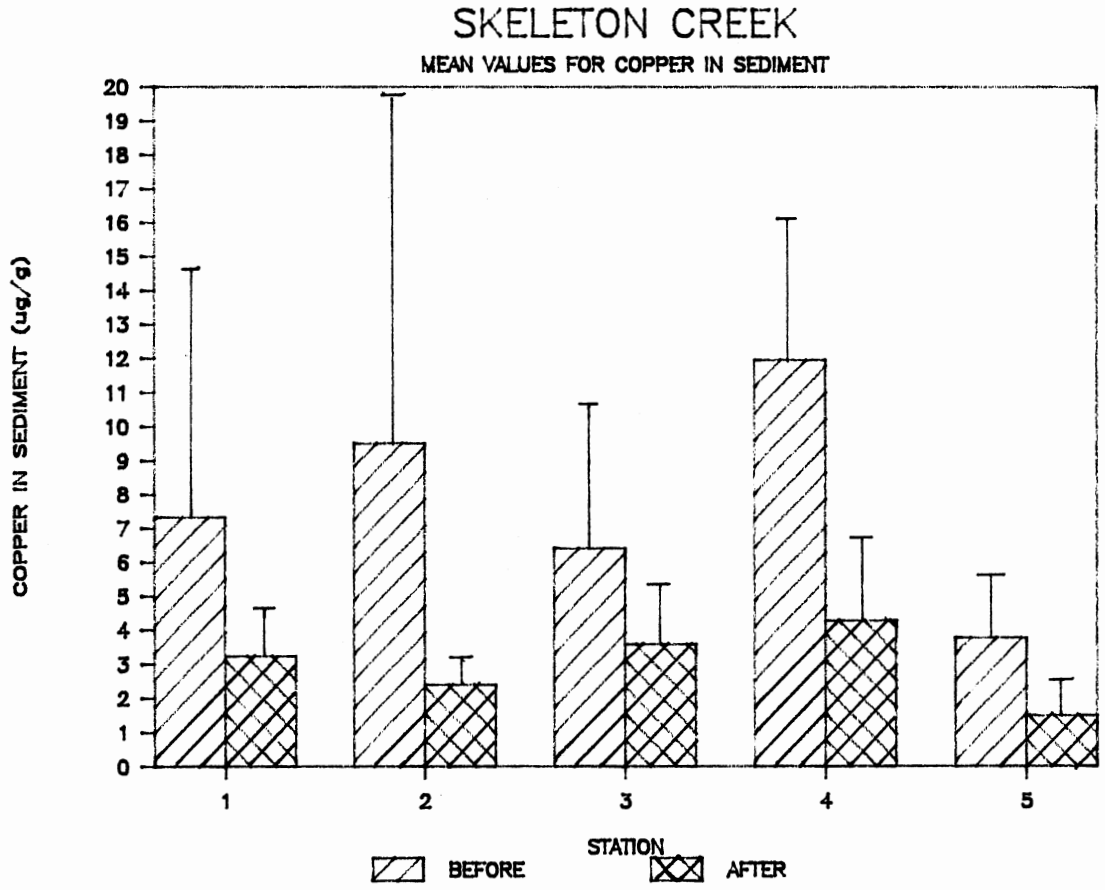

Figure 9. Mean Values of Copper in Sediment Samples Collected Before and After Refinery Closure at the Five Collecting Stations. Upper 95% Confidence Limits are Indicated by Vertical Lines.

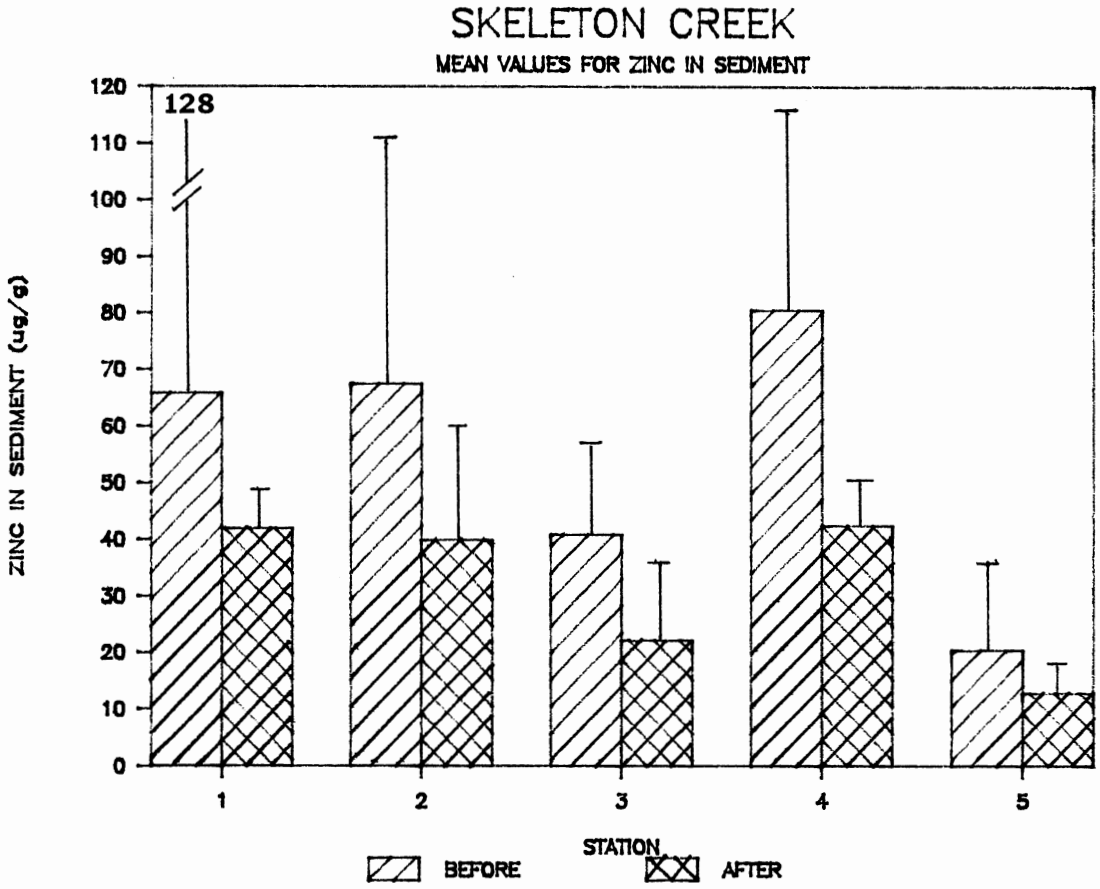

Figure 10. Mean Values of Zinc in Sediment Samples Collected Before and After Refinery Closure at the Five Collecting Stations. Upper 95% Confidence Limits are Indicated by Vertical Lines.

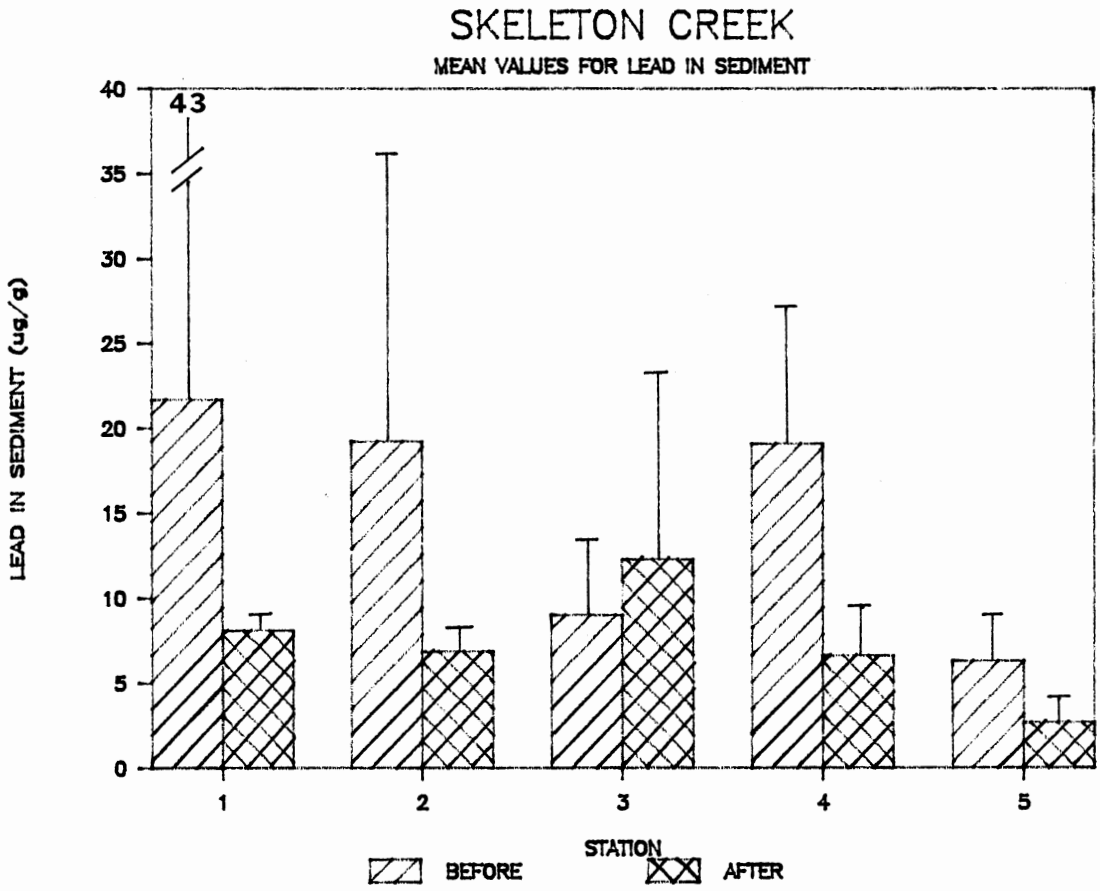

Figure 11. Mean Values of Lead in Sediment Samples Collected Before and After Refinery Closure at the Five Collecting Stations. Upper 95% Confidence Limits are Indicated by Vertical Lines.

TABLE IV

OWRB (1985) NUMERICAL GOALS FOR SELECTED TOXICANTS (ug/g) IN SEDIMENT

Parameter	OWRB (1985) Sediment Limit
Cadmium	2.0
Chromium	100.0
Copper	50.0
Lead	50.0

sediment levels of cadmium, chromium, and copper determined during this study were below recommended limits. The concentration of lead at Station 1 (58.1 ug/g) and Station 2 (50.1 ug/g) on 7 December 82 exceeded the 50 ug/g suggested maximum level. All other sediment lead values were below the limit. A sediment criterion for zinc has not yet been listed. The maximum value was 160.1 ug/g at Station 1 on 7 December 82.

Organics

Water

A total of 56 organic compounds were quantified in extracts of water samples (Appendix F). A total organic concentration was calculated for each sample which represents a summation of the peaks of the methylene chloride extractable base neutral compounds detectable by

gas liquid chromatographic (GLC) analysis (Appendix I).

Mean total organic values before refinery closure ranged from 3.5 ug/l at Station 5 to 78.1 ug/l at Station 3. After closure mean levels were less than 3.0 ug/l at all stations (Figure 12). The maximum level at Station 3 before refinery shutdown reflects contributions from the POTW and ammonia fertilizer plant as well as from the refinery. Subsequent dilution downstream without further point source input resulted in a reduced level (75%) at Station 4.

Numerical goals for selected organic compounds in surface waters have been suggested by the state of Oklahoma (OWRB 1985) and by the USEPA (1986) for the protection and propagation of fish and wildlife. Criteria for those compounds detected in Skeleton Creek water samples are listed in Table V. All concentrations were below the OWRB recommended limits and only the phthalate esters (Table VI) exceeded the national criteria. The large numerical differences between the USEPA and OWRB values in Table V is due to the methodology used by each agency to develop water quality criteria. The freshwater chronic criteria developed by the USEPA represents a 4-day average lowest observed effect level. The OWRB has established grab sample goals reflecting beneficial uses, water chemistry, and physical features of the respective aquatic system. If desired, the OWRB can set lower numerical goals to satisfy these site specific conditions. The dichlorobenzene, naphthalene, and phenol values reflect these differences. The higher ORWB phthalate ester goals relative to USEPA criteria values could be due to the acute grab sample and chronic 4-day average differences. The 1986 USEPA criteria may have used phthalate ester data not available to the OWRB in 1985. Future review of phthalate ester compounds by the OWRB will

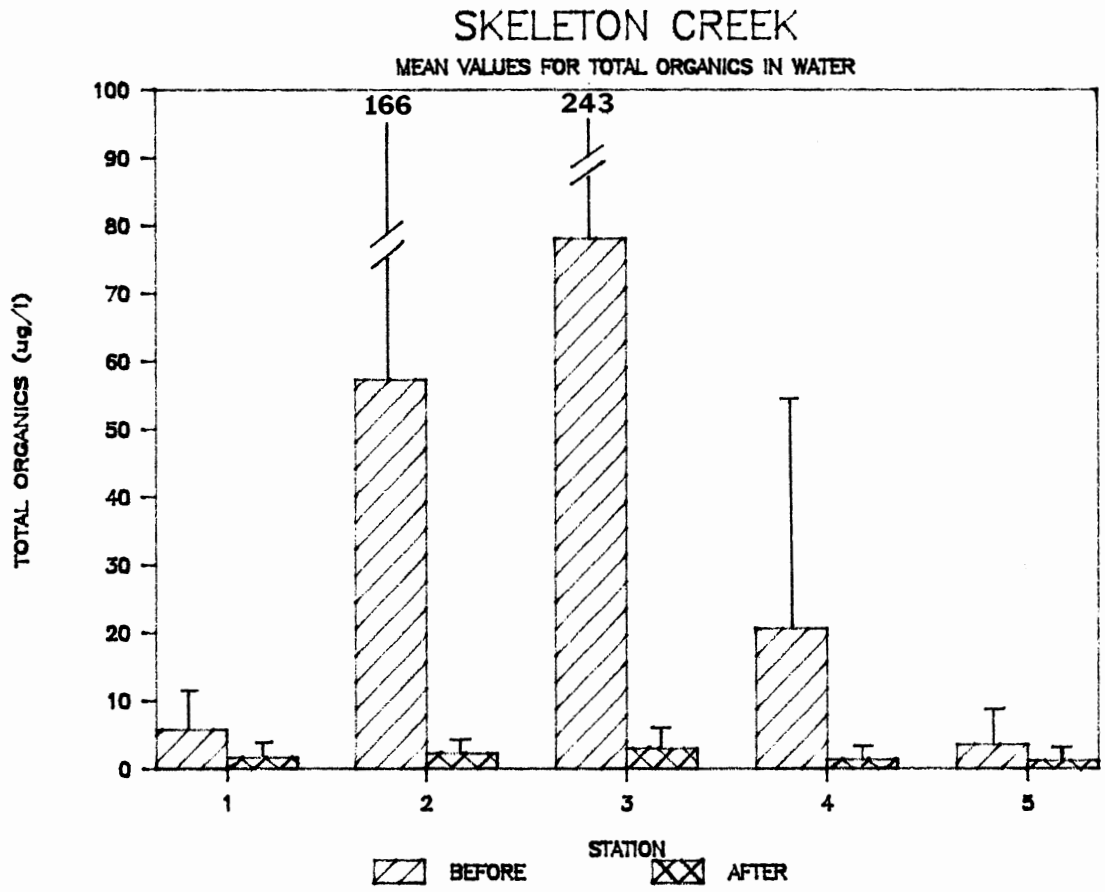

Figure 12. Mean Values of Total Methylene Chroride Extractable Organics in Water Samples Collected Before and After Refinery Closure at the Five Collecting Stations. Upper 95% Confidence Limits are Indicated by Vertical Lines.

hopefully consider the USEPA (1986) criteria.

TABLE V

OWRB (1985) NUMERICAL GOALS AND USEPA (1986) FRESHWATER CHRONIC CRITERIA FOR ORGANIC COMPOUNDS IN SURFACE WATERS

Organic Compound	ORWB Surface Water Limit (ug/1)	USEPA Freshwater Chronic Criteria (ug/1)
Dichlorobenzene	188	763†
Naphthalene	245	620†
Phenol	575	2560†
Dimethyl Phthalate	2475	3†
Diethyl Phthalate	4910	3†
Di-2-ethylhexyl Phthalate	100	3†
Toluene	635	---

† Insufficient data to develop criteria. Value presented is the Lowest Observed Effect Level.

No pattern was observed for samples containing phthalate ester concentrations exceeding the USEPA 3 ug/1 suggested limit. Phthalate esters are ubiquitous in the aquatic environment as a result of their widespread use in plastics. The resin softening phthalate ester plasticizers are leached into water from the numerous plastic products. Thus, the phthalate ester occurrences could be due to numerous non-point sources as well as specific point sources.

TABLE VI

SELECTED PHTHALATE ESTER CONCENTRATIONS IN INDIVIDUAL SKELETON CREEK WATER SAMPLES THAT EXCEEDED THE 3 ug/1 SUGGESTED LIMIT (USEPA 1986)

Date	Station	Phthalate Ester	Concentration (ug/1)
12 Aug 82	2	Di-2-ethylhexyl phthalate	4.14
	4	Di-2-ethylhexyl phthalate	14.17
6 Jul 83	2	Dimethyl phthalate	10.29
	4	Diethyl phthalate	3.01
5 Oct 83	1	Butyl Carbobutoxymethyl phthalate	10.79
	2	Diethyl phthalate	3.38
	5	Butyl Carbobutoxymethyu phthalate	18.69
8 Dec 83	3	Diethyl phthalate	14.42

Sediment

A total of 32 organic compounds were quantified in sediment samples (Appendix G). A total organic concentration was also calculated for each sample which represents a summation of the peaks of the methylene chloride extractable base neutral compounds detectable by GLC analysis (Appendix I).

Mean total organic values before refinery closure ranged from 0.09 ug/g at Station 5 to 1.35 ug/g at Station 2 (Figure 13). The range was similar after closure except the minimum and maximum was recorded at stations 3 and 2, respectively. In contrast to water samples, sediment values before closure reached maximum values at Station 2 and decreased

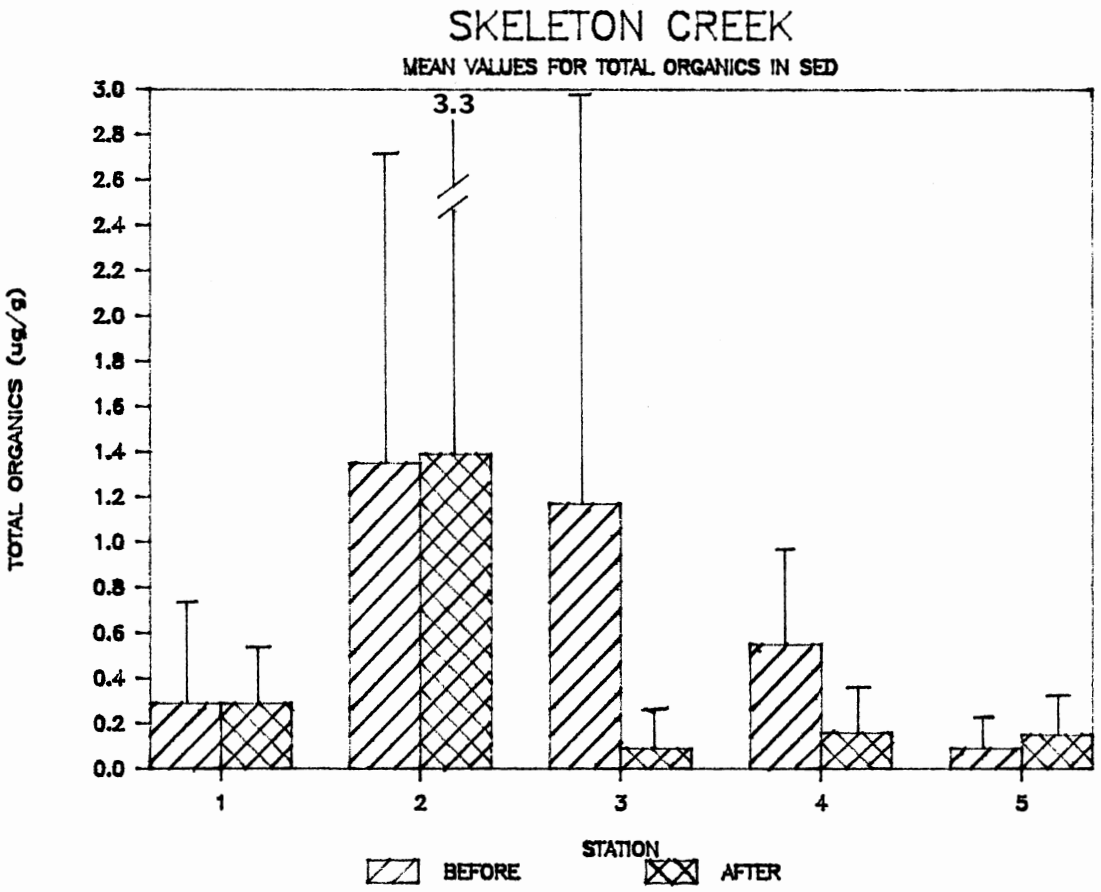

Figure 13. Mean Values of Total Methylene Chroride Extractable Organics in Sediment Samples Collected Before and After Refinery Closure at the Five Collecting Stations. Upper 95% Confidence Limits are Indicated by Vertical Lines.

downstream. After closure, values decreased at stations 3, 4, and 5 and were unchanged at stations 1 and 2. The maximum level before closure at Station 2 reflects the input of organic substances from the refinery wastewater that are sorbed and retained by the bottom sediments. High values at Station 3 may have been due to contributions from the POTW, ammonia fertilizer plant, and refinery wastewaters. Levels at stations 4 and 5 were 50% and 90% less than levels at station 3, respectively. The similarity in mean total organic levels at Station 2 before and after closure suggests that either organic compounds remained after shutdown or upstream originating substances were sorbed and retained by the sediments.

Numerical goals for a limited number of organic compounds in sediments have been established by the Oklahoma Water Resources Board (1985) for public health protection. Limits for organic compounds detected in this study have not yet been listed.

Benthic Macroinvertebrates

A total of 34,803 benthic macroinvertebrates comprising 133 taxa were identified (Appendix J). The species diversity, number of taxa, and number of individuals were determined for each sample (Appendix K).

Mean species diversity values before refinery closure ranged from 2.94 at Station 2 to 3.54 at Station 4. The range increased after closure; from 2.35 at Station 2 to 3.88 at Station 5 (Figure 14). Values at stations 1 and 2 were similar before closure, but considerable differences existed after closure. The diversity value at Station 2 was lower than the control site on all dates except four. Less than 100 organisms were collected on three of these dates which may have biased

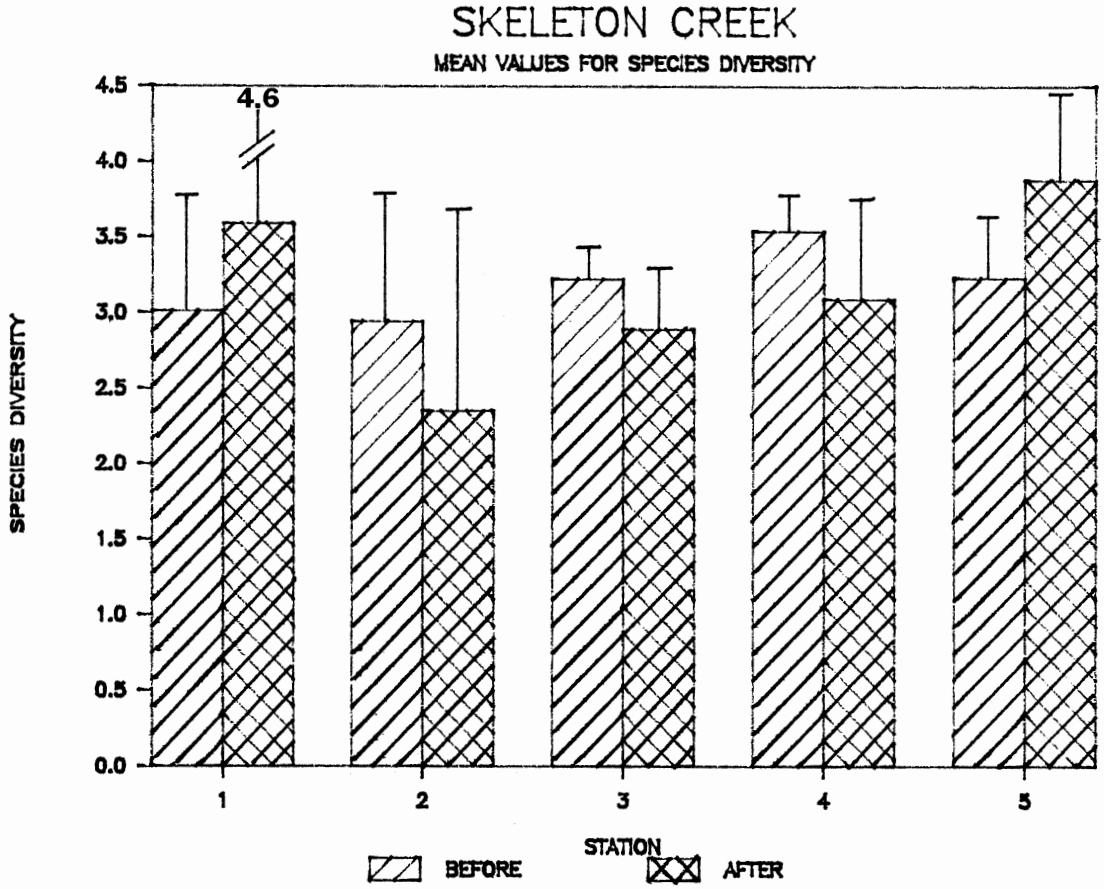

Figure 14. Mean Species Diversity Values of Benthic Macroinvertebrate Organisms for Each Station Before and After Refinery Closure. Upper 95% Confidence Limits are Indicated by Vertical Lines.

results (OWRB 1985). Over 100 organisms were obtained for the other samples at Station 2 suggesting a non-toxic refinery effluent prior to sampling.

Species diversity at stations 1 and 2 decreased after refinery shutdown. The 1.2 mean decrease at Station 2 relative to the control site may reflect operational changes and cleaning procedures involved in closure. Intermittent discharges from this facility before the final sampling date could also be a factor.

The OWRB (1985) has established a limit of one unit species diversity ($\bar{d}$) value decrease between upstream and downstream stations relative to a point source discharge. This criterion was exceeded by the refinery effluent on 5 Oct 83, 1 May 84, and 14 Aug 84.

Similar trends were observed for the number of taxa (Figure 15) and the number of organisms (Figure 16). Values tended to be low at upstream stations and to increase at stations 4 and 5 before and after closure. Before refinery closure, mean number of taxa ranged from 19.7 at Station 2 to 34.5 at Station 4 and mean number of organisms from 370 at Station 2 to 2119 at Station 5. Closure decreased the minimum number of taxa to 14.5 at Station 2, while little change occurred in maximum. The maximum number of individuals collected decreased to 879 at Station 5 after closure. On an individual station basis, a decrease in $\bar{d}$ was generally accompanied by fewer number of taxa (Pearson correlation = 0.65). A low correlation existed (Pearson correlation = 0.36) between diversity and the number of organisms.

A percent similarity index representing pairwise station comparisions of benthic macroinvertebrate species and their respective abundances was computed for each sample date. Before and after refinery

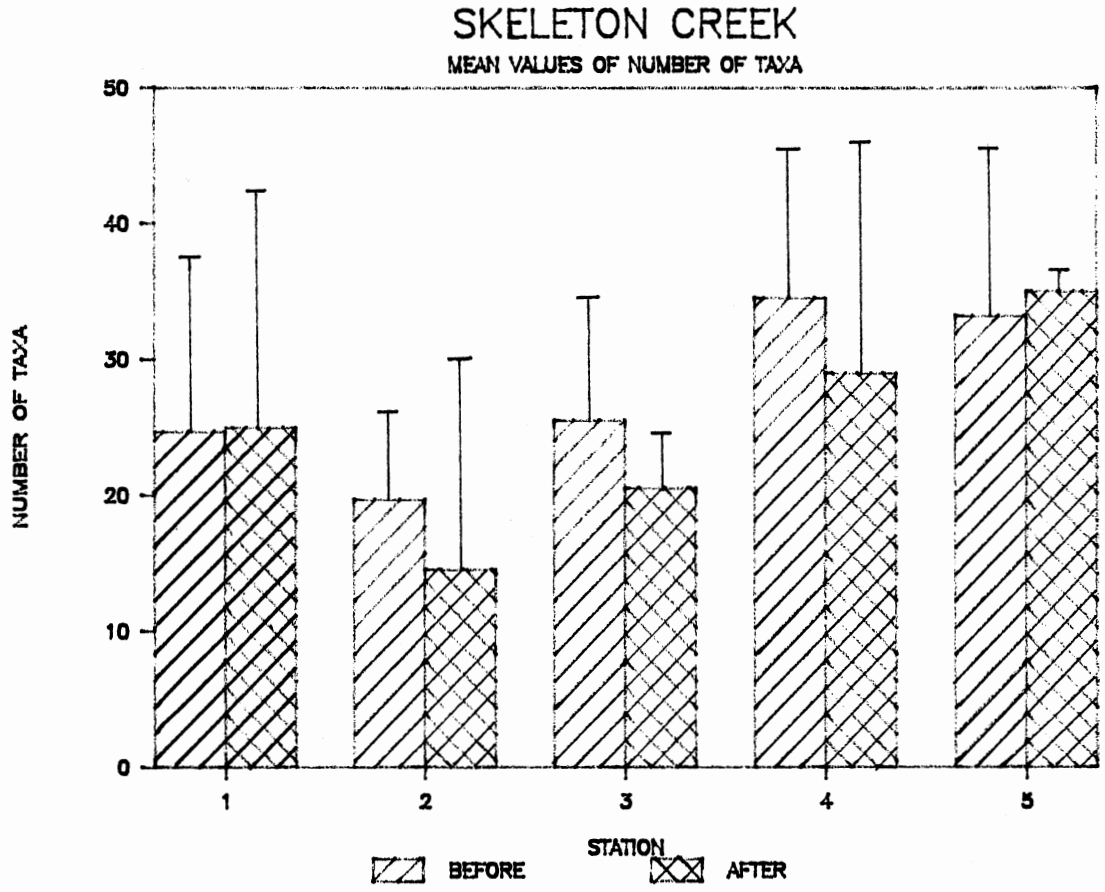

Figure 15. Mean Number of Taxa Values of Benthic Macroinvertebrate Organisms for Each Station Before and After Refinery Closure. Upper 95% Confidence Limits are Indicated by Vertical Lines.

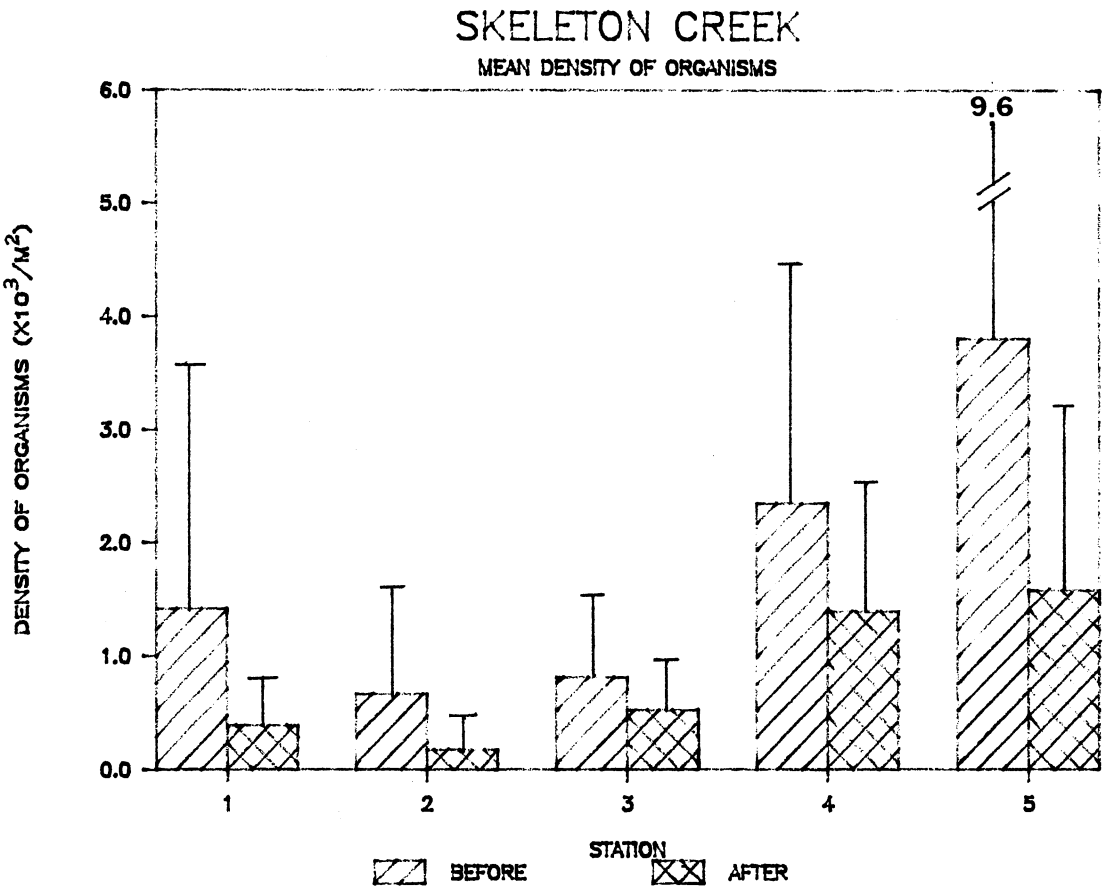

Figure 16. Mean Density of Benthic Macroinvertebrate Organisms for Each Station Before and After Refinery Closure. Upper 95% Confidence Limits are Indicated by Vertical Lines.

shutdown mean values were then compiled (Table VII). Before closure, Station 1 had high mean similarity values with stations 2 and 3. After closure, these similarities decreased abruptly. A relatively high decrease after closure also occurred between stations 3 and 4, from 0.34 to 0.21. The maximum similarity after closure was between stations 4 and 5.

TABLE VII

MEAN SIMILARITY BETWEEN PAIRWISE STATION COMPARISIONS OF BENTHIC MACROINVERTEBRATES BEFORE AND AFTER REFINERY SHUTDOWN

STATION	1	2	3	4	5
		BEFORE REFINERY SHUTDOWN MEANS			
1	-	-	-	-	-
2	0.54	-	-	-	-
3	0.45	0.37	-	-	-
4	0.26	0.26	0.34	-	-
5	0.16	0.13	0.18	0.39	-
		AFTER REFINERY CLOSURE MEANS			
1	-	-	-	-	-
2	0.23	-	-	-	-
3	0.31	0.38	-	-	-
4	0.35	0.16	0.21	-	-
5	0.23	0.09	0.15	0.41	-

The percentage of individuals represented by oligochaetes, chironomids, mayflies, caddisflies, and molluscs was computed for each sample (Appendix L). Chironomids dominated the first three stations (Figure 17), while oligochaetes dominated at Station 4 and caddisflies at Station 5. The largest number of mayflies occurred at Station 1. Caddisflies existed in appreciable numbers only at stations 4 and 5. Molluscs were most abundant at stations 2 and 4. Similar trends were observed before and after refinery closure, except at Station 1 the dominance shifted from oligochaetes to chironomids. This shift might reflect the elevated lead levels measured after refinery closure. At Station 5, chironomids dominated before closure and caddisflies after closure.

Structural changes of the stream benthic macroinvertebrate assemblage in response to wastewater effluents have been reported in other studies. Almost complete elimination of plecopteran and trichopteran groups along with a concurrent increase in dipteran density was observed downstream from an oil field wastewater discharge respective to an upstream control site. The increased petroleum hydrocarbon concentrations in the water and sediment corresponded to the structural changes and decreased species diversity of the benthic organisms (Woodward and Riley 1983). Sewage effluent eliminated mayflies and molluscs, reduced caddisflies, and increased chironomid density below a sewage outfall (Brown et. al. 1983). A direct relationship existed between the percentage of insects represented by chironomids and degree of heavy metal contamination. Chironomids composed over 70% of all insects collected from severely impacted stations and only 10% from clean stations (Winner et. al. 1980).

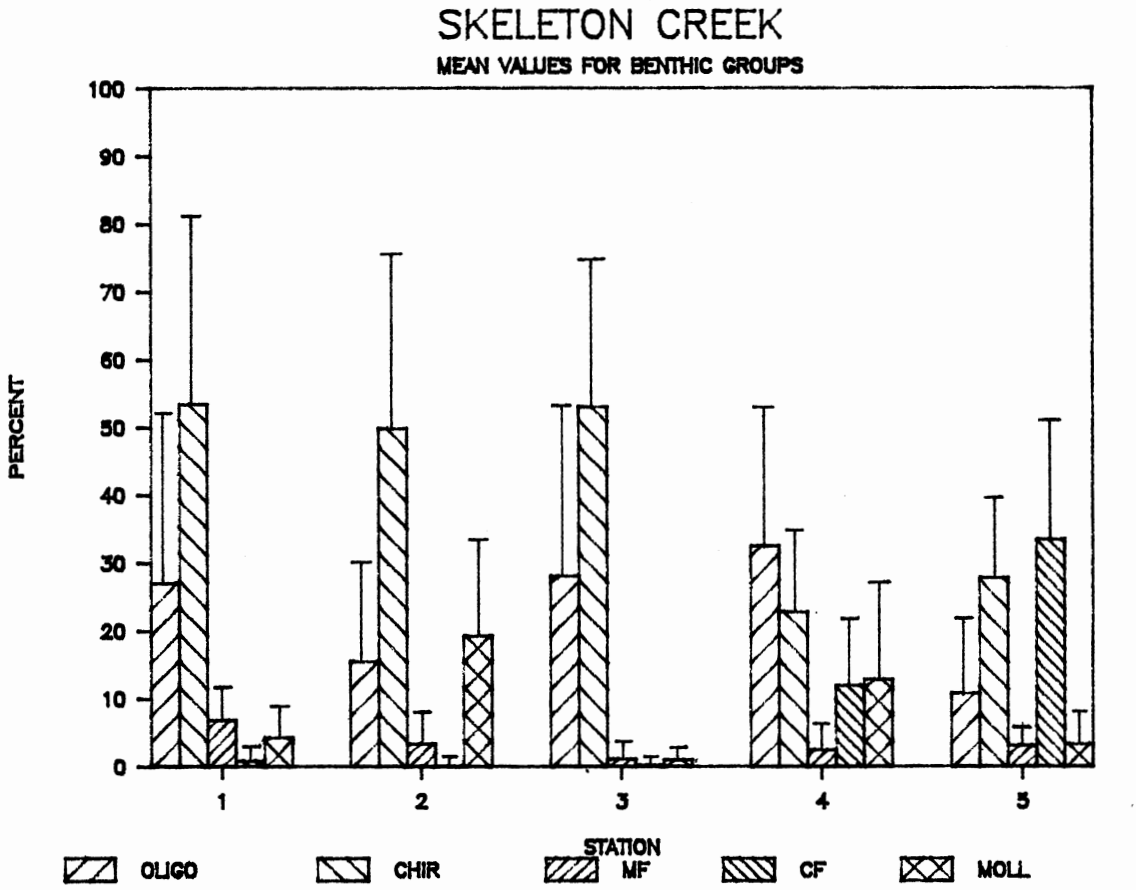

Figure 17. Mean Values for Percent Oligochaetes, Chironomids, Mayflies, Caddisflies, and Mollusca of Benthic Macroinvertebrate Samples Collected at Each Station. Upper 95% Confidence Limits are Indicated by Vertical Lines.

Correlation of Environmental Contaminants with Biological Response

Pearson's product moment correlation, principal component, and stepwise multiple regression analyses were used to determine if a correlation existed between trace environmental contaminant levels and response of benthic macroinvertebrates. Results from Pearson's product moment correlation analysis indicated that 23 parameters had a positive (direct) or negative (inverse) correlation with species diversity ≥ 0.25 (Table VIII). Of these 23 variables, 10 had values ≥ 0.40 and seven were ≥ 0.50. When the number of taxa was the biological response, 27 parameters had correlation values ≥ 0.25, 22 were ≥ 0.40, 11 were ≥ 0.50, and six were ≥ 0.60. Correlation values ≥ 0.32 were significant ($p = 0.05$). In general, the individual toxic heavy metals in water and the organic compounds were inversely correlated with diversity and number of taxa. The correlation analysis also indicated that number of taxa was highly correlated with species diversity (0.65) and number of organisms (0.90).

Principal component analysis of the data generated nine factors that explained 68% of the variation. The sorted rotated factor loadings of the first three factors (Table IX) accounted for 31% of the variation. The individual parameters of each factor can often be examined as a whole to denote a new revelant term respective of the data. Thus, a large data set of potentially correlated variables can be reduced to a smaller number of uncorrelated hypothetical components and still explain the same amount of variance. This procedure is especially useful when no *a priori* pattern of interrelationships is suggested or suspected. Thus, factor 1 could be titled as an organic compounds in sediment variable and factors 2 and 3 as organic compounds in water.

TABLE VIII

PEARSON'S CORRELATION VALUES OF INDIVIDUAL PARAMETERS WITH SPECIES DIVERSITY VALUES AND NUMBER OF TAXA

Parameter	Pearson's Correlation With Species Diversity	Pearson's Correlation With Number of Taxa
Temperature	0.27	< 0.25
Percent Sand	- 0.31	- 0.43
Percent Silt	0.31	0.47
Percent Clay	0.31	0.56
Sed. % Organic Carbon	0.28	0.40
Magnesium-Suspended	< 0.25	0.35
Potassium-Suspended	< 0.25	0.25
Zinc-Suspended	- 0.34	< 0.25
Manganese-Suspended	< 0.25	0.46
Selenium-Dissolved	0.25	< 0.25
Arsenic-Dissolved	- 0.50	< 0.25
Sediment Copper	0.27	0.33
Sediment Chromium	< 0.25	0.27
Acetophenone-Sed.	- 0.50	- 0.60
Benzaldehyde-Sed.	- 0.50	- 0.60
2-Butoxy Ethanol-Sed.	- 0.49	- 0.60
Carbitol-Sed.	- 0.39	- 0.53
2-Ethyl-1-Hexanol-Sed.	- 0.51	- 0.61
o-ethylphenol-Sed.	- 0.41	- 0.48
p-Toluic Acid, methyl ester-Sed.	- 0.50	- 0.60
Tetradecane-Sed.	- 0.35	- 0.45
Toluene-Sed.	- 0.33	- 0.47
Tridecane-Sed.	- 0.59	- 0.69
Carvone-H_2O	- 0.50	< 0.25
Diphenyl Ether-H_2O	- 0.40	- 0.47
Methyl Nervonate-H_2O	- 0.32	< 0.25
Pentadecane-H_2O	- 0.34	- 0.49
Sum of CH_2Cl_2 Ext. Organics-Sed.	< 0.25	- 0.25
Discharge-day of sampling	< 0.25	- 0.52
Discharge-1 week average	< 0.25	- 0.50
Discharge-2 week average	< 0.25	- 0.51
Discharge-30 day average	< 0.25	- 0.49
Discharge-60 day average	< 0.25	- 0.49
Species Diversity	-----	0.65
Number of Organisms	0.36	0.90

TABLE IX

SORTED ROTATED FACTOR LOADINGS (PATTERN) OF INDIVIDUAL PARAMATERS FOR THE FIRST THREE COMPONENTS GENERATED BY PRINCIPAL COMPONENT ANALYSIS OF THE DATA

Parameter	Factor 1	Factor 2	Factor 3
2-Ethyl-1-Hexanol-Sed.	0.952	-----	-----
Acetophenone-Sed.	0.947	-----	-----
Benzaldehyde-Sed.	0.947	-----	-----
p-Toluic Acid,methyl ester-Sed	0.947	-----	-----
2-Butoxyethanol-Sed.	0.934	-----	-----
Carbitol-Sed.	0.907	-----	-----
Tridecane-Sed.	0.882	-----	-----
Toluene-Sed.	0.823	-----	-----
o-ethylphenol-Sed.	0.723	-----	-----
Number of Taxa	- 0.700	-----	-----
Pentadecane-H_2O	0.685	-----	-----
Number of Organisms	- 0.587	-----	-----
Species Diversity	- 0.568	-----	-----
Tetradecane-Sed.	0.529	-----	-----
1-Bromotridecane-Sed.	-----	0.982	-----
Phenyl-N-Methylcarbamate-Sed.	-----	0.982	-----
Methyl-11,14,17-Eicosatrienoate-H_2O	-----	0.982	-----
Methyl Octacosanoate-H_2O	-----	0.982	-----
Methyl Tricosanoate-H_2O	-----	0.982	-----
Thujyl Alcohol Isomer-H_2O	-----	0.982	-----
Methyl-alpha-Ketopalmitate-Sed.	-----	0.899	-----
Oleic Acid-H_2O	-----	0.707	-----
Menthene Isomer-H_2O	-----	0.690	-----
2-Ethyl-2-Methyl-1,3-Dioxolane-Sed.	-----	-----	0.937
Carbromal-H_2O	-----	-----	0.937
Cycrimine-H_2O	-----	-----	0.937
Diphenyl Mercury-H_2O	-----	-----	0.937
Carbitol-H_2O	-----	-----	0.906
Hexadecane-H_2O	-----	-----	0.850
Diethyl Phthalate-H_2O	-----	-----	0.804
Methyl Nervonate-H_2O	-----	-----	0.666
Sum of CH_2Cl_2 Ext. Organics-H_2O	-----	-----	0.654
Sodium-Suspended	-----	-----	0.595
Total Ammonia	-----	-----	0.505
Cumulative Proportion of Total Variance (%)	12.70	22.30	31.00

These new linear functions would suggest that the organic compounds identified in the sediment and water have helped explain a large part of the variation in the data base.

A multiple regression analysis computed from the entire data base indicated that values for tridecane (sediment), carvone (water), percent silt, selenium (dissolved), o-ethylphenol (sediment), diphenyl ether (water), 2-butoxyethanol (water), chromium (sediment), octadecane (sediment), and total ammonia could be used to predict species diversity. Dissolved selenium and sediment tridecane had the largest coefficients of 16.00 and -12.65, respectively. The ten variables had a multiple correlation coefficient of 0.96 and explained 93% of the variation in benthic macroinvertebrate diversity.

If only the data collected before the refinery closure was used, the predictor equation (Table X) was composed of carvone (water), tridecane (sediment), percent sand, dioctyl adipate (sediment), and 2-butoxyethanol (water) and had 91% of the variation explained and a correlation value of 0.95. Sediment tridecane had the largest regression coefficient of -20.85 followed by -0.29 for sediment dioctyl adipate. Several changes existed in the model when only data after closure was considered (Table XI). Four values explained 99% of the variation. Although sediment tridecane had the largest coefficient before closure, dissolved selenium was the largest after closure followed by sediment tridecane. This shift to dissolved selenium could be due the reduced hydrocarbon levels observed after refinery closure.

The results obtained from the regression analyses would also suggest that organic compounds in the sediment and water help explain a

TABLE X

RESULTS OF MULTIPLE REGRESSION ANALYSIS OF BENTHIC MACROINVERTEBRATE SPECIES DIVERSITY AND PHYSICOCHEMICAL PARAMETERS FOR SKELETON CREEK BEFORE REFINERY CLOSURE

$$Y^* = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5$$

$R = 0.95$ $R2 = 0.91$

Parameters	Estimated Regression Coefficient
X_1 = Carvone (Water)	B_1 = - 0.21
X_2 = Tridecane (Sediment)	B_2 = - 20.85
X_3 = Percent Sand	B_3 = - 0.07
X_4 = Dioctyl Adipate (Sediment)	B_4 = - 0.29
X_5 = 2-Butoxyethanol (Water)	B_5 = - 0.19
Y^* = Predicted Benthic Diversity	B_0 = (Intercept) 0.77

large part of the variation and are useful in predicting diversity of the benthic macroinvertebrates. Specifically, the persistent appearance of sediment tridecane in the regression equations would suggest it's potential for predicting benthic macroinvertebrate diversity. Sediment tridecane could also be used as an indicator of past organic contamination of Boggy and Skeleton creeks.

Correlation between contaminant levels and biological response has been reported in other studies. Increased concentrations of saturated aliphatic hydrocarbons in the water and sediment along with increased zinc levels in the sediment corresponded to decreased benthic

TABLE XI

RESULTS OF MULTIPLE REGRESSION ANALYSIS OF BENTHIC MACROINVERTEBRATE SPECIES DIVERSITY AND PHYSICOCHEMICAL PARAMETERS FOR SKELETON CREEK AFTER REFINERY CLOSURE

$$Y^* = B_o + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4$$

R = 0.99 R2 = 0.99

Parameters	Estimated Regression Coefficient
X_1 = Tridecane (Sediment)	B_1 = - 5.76
X_2 = Selenium (Dissolved)	B_2 = 11.60
X_3 = Octadecane (Sediment)	B_3 = 0.75
X_4 = Percent Organic Carbon (Sediment)	B_4 = 0.61
Y^* = Predicted Benthic Diversity	B_0 = (Intercept) 0.61

macroinvertebrate diversity in a stream contaminated with oil field wastewater (Woodward and Riley 1983). Linear regression analysis indicated that specific sediment organic compound levels in Raritan Bay were poorly correlated with benthic macroinvertebrate diversity. Total organic levels in the sediment exceeding 300 mg/l were associated with decreased number of taxa and diversity (Stainken 1984). Multiple regression analysis of water quality data upstream and downstream of a Virginia power plant wastewater discharge indicated that copper concentrations, river flow, and iron levels were the variables that best predicted the percent mayfly variability (Van Hassel and Gaulke 1986).

Future Research

Now that the refinery has been closed since 1984, the Boggy and Skeleton creek study area offers the unique opportunity to invesigate what physicochemical and biological changes have occurred after eliminating refinery wastewater. Performance of the same analyses would enable determining changes in trace contaminants and correlation between biological response and compounds or group of compounds.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

Physicochemical, heavy metal, and organic compounds in water samples measured over a 2-year study were usually highest at stations 2 and 3, reflecting the point source wastewater discharges. Undetectable or low concentrations of these contaminants were routinely found at stations 1 (control), 4 (potentially recovery zone), and 5 (final recovery zone). Most parameters were within limits established by the OWRB (1985) and the USEPA (1986) for protecting aquatic life. Only unionized ammonia, lead, and nickel exceeded limits in selected samples. Sediment heavy metal levels were highest at Station 4, most probably due to the greater percentage of silt and clay also found at this site. The lowest concentrations were found most frequently at Station 5. All sediment levels of cadmium, chromium, and copper were below OWRB (1985) goals. Lead exceeded the recommended limit at stations 1 and 2 on one sample date. Organic compound concentrations in sediment were highest at Station 2 and lowest at Station 5. Physicochemical, heavy metal, and organic compound contaminant levels detected in water and sediment samples decreased after refinery closure.

The highest correlation with species diversity of the benthic population was the methylene chloride extractable organics from sediment and water as shown by principal component, stepwise multiple regression,

and Pearson's product moment correlation analyses. Specifically, acetophenone, benzaldehyde, 2-butoxy ethanol, carbitol, 2-ethyl-1-hexanol, ortho-ethylphenol, p-toluic acid (methyl ester), tetradecane, toluene, and tridecane levels in sediment as well as carvone and diphenyl ether concentrations in water were the statistically significant compounds identified by the analyses. The relative concentration of these compounds could be used as an index to predict the effect on the benthic macroinvertebrate assemblage of Skeleton Creek. Suspended zinc, suspended chromium, and dissolved arsenic levels showed a similar inverse relationship with species diversity. All other parameters had low correlation values.

Conclusions

1. Decreased benthic macroinvertebrate diversity was most strongly correlated with specific water and sediment methylene chloride extractable organic compounds.
2. The effects on benthic macroinvertebrate populations could not be directly correlated with a single specific contaminant. The decrease in diversity appeared to be due to additive effects of a mixture of nonpolar organic chemicals. The concentration of the sum of specific methylene chloride extractable organic chemicals appeared to offer a useful index of the deleterious effect.
3. Sediment criteria are needed for those organic compounds and heavy metals not currently listed by the OWRB (1985) and the USEPA (1986) that pose a potential hazard to aquatic organisms.

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APPENDIX A

THE DISSOLVED OXYGEN, TEMPERATURE, pH, SPECIFIC CONDUCTIVITY, AMMONIA, TURBIDITY, AND TOTAL ORGANIC CARBON LEVELS DETERMINED IN SKELETON CREEK WATER DURING THE STUDY PERIOD

Station	Date	Time	Dissolved Oxygen mg/l	Temp. °C	pH	Specific Conductivity uS/cm	NH_3-N mg/l	Union. NH_3-N mg/l	Turbidity NTU	TOC mg/l
1	8-12-82	1130	7.8	27.0	7.90	650	0.79	0.0393	9.5	5.4
2	8-12-82	1030	6.8	27.0	7.85	2300	2.78	0.1230	20.0	16.0
3	8-12-82	1330	16.4	34.0	8.50	2350	2.50	0.6248	11.0	12.0
4	8-12-82	1530	11.2	30.0	8.10	2150	0.92	0.0846	29.0	10.0
5	8-12-82	1730	15.8	33.0	8.50	2100	1.89	0.4491	36.0	9.6
1	12-7-82	900	10.4	5.0	7.95	800	<0.10	<0.0011	44.0	15.4
2	12-7-82	930	10.7	5.0	7.55	2500	1.40	0.0062	35.0	28.8
3	12-7-82	1040	12.2	6.0	8.15	1650	1.50	0.0281	18.0	26.3
4	12-7-82	1245	11.4	6.0	8.05	1600	0.90	0.0134	15.0	19.3
5	12-7-82	1430	11.4	7.0	8.05	1150	0.20	0.0032	93.0	15.2

Station	Date	Time	Dissolved Oxygen mg/l	Temp. °C	pH	Specific Conductivity uS/cm	NH_3-N mg/l	Union. NH_3-N mg/l	Turbidity NTU	TOC mg/l
1	4-27-83	1000	9.7	18.2	8.05	1300	<0.10	<0.0038	14.0	<2.0
2	4-27-83	1040	9.4	18.0	7.80	2250	3.39	0.0717	21.0	19.9
3	4-27-83	1215	11.7	19.5	7.90	1960	4.49	0.1324	10.5	9.6
4	4-27-83	1300	7.5	19.8	7.65	1950	0.25	0.0043	50.5	3.8
5	4-27-83	1425	10.2	21.0	8.00	1510	<0.10	<0.0041	104.0	0.8
1	7-6-83	1200	11.8	25.0	7.65	1120	<0.10	<0.0025	8.0	6.4
2	7-6-83	1240	11.0	26.5	7.70	1580	<0.10	<0.0031	22.0	12.0
3	7-6-83	1350	16.2	33.0	8.40	1700	0.66	0.1310	10.0	5.3
4	7-6-83	1440	10.5	29.0	8.05	1950	<0.10	<0.0077	31.0	12.8
5	7-6-83	1600	11.1	30.5	8.15	1500	<0.10	<0.0105	38.0	10.4

Station	Date	Time	Dissolved Oxygen mg/l	Temp. °C	pH	Conductivity uS/cm	NH_3-N mg/l	Union. NH_3-N mg/l	Turbidity NTU	TOC mg/l
1	10-5-83	1130	8.7	17.0	7.80	1000	0.06	0.0012	13.0	2.6
2	10-5-83	1110	7.7	17.5	7.55	2200	3.26	0.0378	21.0	22.2
3	10-5-83	1330	15.4	23.0	8.35	1950	1.35	0.1342	8.0	13.5
4	10-5-83	1430	8.2	20.0	7.95	2940	0.58	0.0197	24.0	14.4
5	10-5-83	1545	16.2	23.5	8.50	1900	<0.05	<0.0007	46.0	12.6
1	12-8-83	1050	11.6	3.8	8.15	780	<0.08	<0.0013	15.0	21.3
2	12-8-83	1030	12.0	2.2	7.85	1050	2.00	0.0140	22.0	39.0
3	12-8-83	1300	12.6	7.0	8.25	1450	5.40	0.1350	12.0	28.0
4	12-8-83	1415	12.5	4.8	8.05	1200	4.00	0.0540	20.0	22.1
5	12-8-83	1650	12.8	5.0	8.25	1250	0.78	0.0169	30.0	30.6

Station	Date	Time	Dissolved Oxygen mg/l	Temp. °C	pH	Specific Conductivity uS/cm	NH_3-N mg/l	Union. NH_3-N mg/l	Turbidity NTU	TOC mg/l
1	5-1-84	1100	11.0	14.2	7.55	700	<0.10	<0.0009	162.0	2.2
2	5-1-84	1030	10.8	14.5	7.65	780	<0.10	<0.0012	122.0	5.0
3	5-1-84	1400	12.1	19.5	8.25	1150	0.12	0.0076	68.0	10.0
4	5-1-84	1520	10.8	15.5	8.10	1450	0.11	0.0038	53.0	7.2
5	5-1-84	1645	9.5	18.5	8.15	1400	<0.10	<0.0048	450.0	16.6
1	8-14-84	1115	9.8	24.4	7.60	946	<0.08	<0.0017	19.0	2.2
2	8-14-84	1045	9.0	23.8	7.50	940	<0.08	<0.0013	18.0	5.0
3	8-14-84	1345	15.1	31.4	7.90	2550	9.00	0.5922	15.0	10.0
4	8-14-84	1500	8.2	26.8	7.40	2750	0.15	0.0024	120.0	7.2
5	8-14-84	1630	5.9	29.4	7.00	965	0.35	0.0027	196.0	16.6

APPENDIX B

CONCENTRATION OF DISSOLVED AND SUSPENDED HEAVY METALS (mg/l) IN SKELETON CREEK WATER DETERMINED DURING THE STUDY PERIOD

Sample Identification	Date	Na	Ca	Mg	K	Fe	Pb	Zn
1 - Suspended	8-12-82	<0.5	<0.5	<0.5	<0.5	<0.04	<0.005	<0.01
1 - Dissolved	" "	104.0	78.0	25.7	8.6	<0.04	<0.005	<0.01
2 - S	" "	1.4	0.5	<0.5	<0.5	0.35	<0.005	<0.01
2 - D	" "	438.3	96.7	25.1	16.5	0.08	<0.005	<0.01
3 - S	" "	0.8	2.1	<0.5	<0.5	0.06	<0.005	<0.01
3 - D	" "	278.6	198.4	32.5	13.2	0.18	0.006	<0.01
4 - S	" "	0.9	2.0	0.7	0.6	1.28	<0.005	<0.01
4 - D	" "	247.8	176.4	35.1	13.1	<0.04	<0.005	<0.01
5 - S	" "	0.8	3.5	0.8	0.8	2.03	<0.005	<0.01
5 - D	" "	287.6	138.5	43.9	10.9	<0.04	<0.005	<0.01
Quality Control	EPA	46.6	40.6	1.8	2.1	0.05	0.018	0.20
Analysis	OSU	44.4	40.6	1.5	2.4	0.05	0.020	0.19

Sample Identification	Date	Cu	Cr	Ni	Cd	Mn	Se	As
1 - Suspended	8-12-82	<0.04	<0.01	<0.1	<0.005	0.06	<0.01	<0.01
1 - Dissolved	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
2 - S	" "	<0.04	<0.01	<0.1	<0.005	0.08	<0.01	<0.01
2 - D	" "	<0.04	<0.01	<0.1	<0.005	0.06	<0.01	<0.01
3 - S	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
3 - D	" "	<0.04	0.01	<0.1	<0.005	<0.05	<0.01	<0.01
4 - S	" "	<0.04	<0.01	<0.1	<0.005	0.10	<0.01	<0.01
4 - D	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
5 - S	" "	<0.04	<0.01	<0.1	<0.005	0.27	<0.01	<0.01
5 - D	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
Quality Control	EPA	0.04	0.06	0.25	0.010	0.35	0.04	0.04
Analysis	OSU	0.04	0.06	0.22	0.007	0.34	0.03	0.03

Sample Identification	Date	Na	Ca	Mg	K	Fe	Pb	Zn
1 - Suspended	12-7-82	<0.5	0.5	0.3	0.5	0.83	<0.005	<0.01
1 - Dissolved	" "	54.7	62.5	15.0	5.5	<0.04	<0.005	<0.01
2 - S	" "	1.0	0.4	<0.2	<0.5	0.56	<0.005	<0.01
2 - D	" "	351.7	78.4	15.6	15.2	<0.04	<0.005	0.02
3 - S	" "	0.6	0.6	<0.5	<0.5	0.21	<0.005	<0.01
3 - D	" "	183.3	87.1	24.5	12.3	<0.03	<0.005	0.06
4 - S	" "	<0.5	<0.5	<0.5	<0.5	0.24	<0.005	<0.01
4 - D	" "	172.1	95.9	20.7	11.3	<0.04	<0.005	<0.01
5 - S	" "	<0.5	<0.5	0.5	<0.5	1.34	<0.005	<0.01
5 - D	" "	103.4	69.0	18.8	18.0	<0.04	<0.005	<0.01
Quality Control	EPA	46.6	40.6	1.8	2.1	0.05	0.018	0.20
Analysis	OSU	44.4	40.6	1.5	2.4	0.05	0.020	0.19

Sample Identification	Date	Cu	Cr	Ni	Cd	Mn	Se	As
1 - Suspended	12-7-82	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
1 - Dissolved	" "	<0.04	<0.01	<0.1	<0.005	0.05	<0.01	<0.01
2 - S	" "	<0.04	0.01	<0.1	<0.005	<0.05	<0.01	<0.01
2 - D	" "	<0.04	0.01	<0.1	<0.005	0.08	<0.01	<0.01
3 - S	" "	<0.04	<0.01	<0.1	<0.005	0.08	<0.01	<0.01
3 - D	" "	<0.04	<0.01	<0.1	<0.005	0.07	<0.01	<0.01
4 - S	" "	<0.04	<0.01	<0.1	<0.005	0.08	<0.01	<0.01
4 - D	" "	<0.04	<0.01	<0.1	<0.005	0.08	<0.01	<0.01
5 - S	" "	<0.04	<0.01	<0.1	<0.005	0.14	<0.01	<0.01
5 - D	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
Quality Control	EPA	0.04	0.06	0.25	0.010	0.35	0.04	0.04
Analysis	OSU	0.04	0.06	0.22	0.007	0.34	0.03	0.03

Sample Identification	Date	Na	Ca	Mg	K	Fe	Pb	Zn
1 - Suspended	4-27-83	<0.5	<0.5	<0.5	<0.5	0.21	<0.005	0.01
1 - Dissolved	" "	107.1	83.2	29.4	7.7	0.05	<0.005	0.01
2 - S	" "	0.8	0.6	<0.5	<0.5	0.73	<0.005	0.03
2 - D	" "	289.4	97.9	26.8	18.0	0.39	<0.005	0.02
3 - S	" "	0.5	0.6	<0.5	<0.5	0.08	<0.005	0.06
3 - D	" "	167.5	122.2	33.2	23.6	0.71	<0.005	0.02
4 - S	" "	0.5	0.8	0.7	0.5	1.78	0.005	0.02
4 - D	" "	177.2	106.9	37.3	13.5	0.94	<0.005	0.02
5 - S	" "	<0.5	<0.5	<0.5	<0.5	0.93	<0.005	0.04
5 - D	" "	129.5	75.1	37.5	7.1	1.37	<0.005	0.01
Quality Control	EPA	8.2	40.6	8.4	9.8	0.60	0.018	0.060
Analysis	OSU	7.8	40.6	7.8	10.7	0.55	0.013	0.054

Sample Identification	Date	Cu	Cr	Ni	Cd	Mn	Se	As
1 - Suspended	4-27-83	<0.04	<0.01	<0.1	<0.005	0.05	<0.01	<0.01
1 - Dissolved	" "	<0.04	0.06	<0.1	<0.005	<0.05	<0.01	<0.01
2 - S	" "	<0.04	<0.01	<0.1	<0.005	0.05	<0.01	<0.01
2 - D	" "	<0.04	0.08	0.1	<0.005	0.12	<0.01	<0.01
3 - S	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
3 - D	" "	<0.04	0.03	0.1	<0.005	<0.05	<0.01	<0.01
4 - S	" "	<0.04	<0.01	<0.1	<0.005	0.05	<0.01	<0.01
4 - D	" "	<0.04	0.68	0.2	<0.005	0.07	<0.01	<0.01
5 - S	" "	<0.04	0.01	0.1	<0.005	0.07	<0.01	<0.01
5 - D	" "	<0.04	0.86	0.2	<0.005	<0.05	<0.01	<0.01
Quality Control	EPA	0.040	0.06	0.25	0.010	0.35	0.04	0.04
Analysis	OSU	0.041	0.07	0.22	0.010	0.35	0.04	0.03

Sample Identification	Date	Na	Ca	Mg	K	Fe	Pb	Zn
1 - Suspended	7-6-83	<0.5	0.7	<0.5	<0.5	0.04	<0.005	<0.05
1 - Dissolved	" "	115.8	54.9	28.5	9.2	<0.04	<0.005	<0.05
2 - S	" "	<0.5	0.6	<0.5	<0.5	0.10	<0.005	<0.05
2 - D	" "	186.2	56.8	28.7	12.0	<0.04	<0.005	<0.05
3 - S	" "	<0.5	2.1	<0.5	<0.5	0.07	<0.005	<0.05
3 - D	" "	187.7	83.6	2.8	11.4	<0.04	<0.005	<0.05
4 - S	" "	<0.5	<0.5	<0.5	<0.5	0.54	<0.005	<0.05
4 - D	" "	202.8	120.4	32.9	11.7	<0.04	<0.005	<0.05
5 - S	" "	<0.5	<0.5	<0.5	<0.5	0.8	<0.005	<0.05
5 - D	" "	159.3	71.6	35.4	10.0	<0.04	<0.005	<0.05
Quality Control	EPA	8.2	5.3	1.8	2.1	0.60	0.040	0.060
Analysis	OSU	9.1	5.2	1.4	2.3	0.62	0.037	0.057

Sample Identification	Date	Cu	Cr	Ni	Cd	Mn	Se	As
1 - Suspended	7-6-83	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
1 - Dissolved	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
2 - S	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
2 - D	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
3 - S	" "	<0.04	<0.01	0.1	<0.005	<0.05	<0.01	<0.01
3 - D	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
4 - S	" "	<0.04	<0.01	0.1	<0.005	<0.05	<0.01	<0.01
4 - D	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
5 - S	" "	<0.04	<0.01	<0.1	<0.005	0.10	<0.01	<0.01
5 - D	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
Quality Control	EPA	0.040	0.06	0.25	0.010	0.35	0.020	0.04
Analysis	OSU	0.039	0.05	0.25	0.009	0.34	0.014	0.05

Sample Identification	Date	Na	Ca	Mg	K	Fe	Pb	Zn
1 - Suspended	10-5-83	<0.5	0.5	<0.5	<0.5	0.34	<0.005	<0.01
1 - Dissolved	" "	124.8	62.6	25.6	6.9	<0.04	<0.005	<0.01
2 - S	" "	1.2	1.1	<0.5	<0.5	0.36	<0.005	0.21
2 - D	" "	420.2	83.7	23.2	28.3	<0.04	<0.005	<0.01
3 - S	" "	1.0	3.0	<0.5	<0.5	0.08	<0.005	<0.01
3 - D	" "	269.5	95.0	26.6	17.3	<0.04	<0.005	<0.01
4 - S	" "	0.8	1.6	<0.5	<0.5	0.41	<0.005	<0.01
4 - D	" "	429.5	276.9	49.2	22.9	<0.04	<0.005	<0.01
5 - S	" "	0.5	<0.5	0.5	<0.5	1.48	<0.005	<0.01
5 - D	" "	237.6	109.6	32.1	11.9	<0.04	<0.005	<0.01
Quality Control	EPA	46.5	5.2	8.4	9.8	0.6	0.018	0.06
Analysis	OSU	48.2	5.1	8.4	10.9	0.6	0.011	0.07

Sample Identification	Date	Cu	Cr	Ni	Cd	Mn	Se	As
1 - Suspended	10-5-83	<0.04	0.01	<0.1	<0.005	<0.05	<0.01	<0.01
1 - Dissolved	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
2 - S	" "	<0.04	0.02	<0.1	<0.005	0.05	<0.01	<0.01
2 - D	" "	<0.04	<0.01	<0.1	<0.005	0.06	<0.01	0.01
3 - S	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
3 - D	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
4 - S	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
4 - D	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
5 - S	" "	<0.04	<0.01	<0.1	<0.005	0.14	<0.01	<0.01
5 - D	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
Quality Control	EPA	0.04	0.06	0.25	0.010	0.35	0.040	0.04
Analysis	OSU	0.04	0.06	0.23	0.008	0.35	0.047	0.04

Sample Identification	Date	Na	Ca	Mg	K	Fe	Pb	Zn
1 - Suspended	12-8-83	<0.5	<0.5	<0.5	<0.5	0.28	<0.005	<0.01
1 - Dissolved	" "	123.5	94.9	26.3	4.8	<0.04	<0.005	<0.01
2 - S	" "	2.1	0.9	<0.5	<0.5	0.34	<0.005	<0.01
2 - D	" "	241.8	98.7	28.6	8.5	<0.04	<0.005	<0.01
3 - S	" "	2.0	0.9	<0.5	<0.5	0.16	<0.005	<0.01
3 - D	" "	278.4	110.0	32.7	10.1	<0.04	<0.005	<0.01
4 - S	" "	0.7	0.5	<0.5	<0.5	0.80	<0.005	<0.01
4 - D	" "	240.2	104.4	32.8	9.3	<0.04	<0.005	<0.01
5 - S	" "	<0.5	<0.5	<0.5	<0.5	0.33	<0.005	<0.01
5 - D	" "	234.9	113.5	42.8	6.6	<0.04	<0.005	<0.01
Quality Control	EPA	1.5	5.3	1.8	9.8	0.60	0.022	0.06
Analysis	OSU	1.7	6.0	1.8	9.9	0.57	0.026	0.07

Sample Identification	Date	Cu	Cr	Ni	Cd	Mn	Se	As
1 - Suspended	12-8-83	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
1 - Dissolved	" "	<0.04	<0.01	<0.1	<0.005	0.11	<0.01	<0.01
2 - S	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
2 - D	" "	<0.04	0.01	<0.1	<0.005	0.10	<0.01	<0.01
3 - S	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
3 - D	" "	<0.04	<0.01	<0.1	<0.005	0.12	<0.01	<0.01
4 - S	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
4 - D	" "	<0.04	<0.01	<0.1	<0.005	0.09	<0.01	<0.01
5 - S	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
5 - D	" "	<0.04	<0.01	<0.1	<0.005	0.08	<0.01	<0.01
Quality Control	EPA	0.04	0.060	0.25	0.01	0.35	0.04	0.040
Analysis	OSU	0.04	0.064	0.23	0.01	0.37	0.04	0.043

Sample Identification	Date	Na	Ca	Mg	K	Fe	Pb	Zn
1 - Suspended	5-1-84	<0.5	<0.5	<0.5	<0.5	1.88	<0.005	<0.01
1 - Dissolved	" "	80.8	54.6	18.3	4.7	<0.04	<0.005	<0.01
1 (duplicate) S	" "	<0.5	<0.5	<0.5	<0.5	1.87	<0.005	<0.01
1 (duplicate) D	" "	81.4	56.2	18.4	4.8	<0.04	<0.005	<0.01
2 - S	" "	<0.5	<0.5	<0.5	<0.5	1.73	<0.005	<0.01
2 - D	" "	86.0	55.3	17.9	4.9	0.05	<0.005	<0.01
3 - S	" "	<0.5	<0.5	<0.5	<0.5	0.59	<0.005	<0.01
3 - D	" "	139.9	74.0	23.8	6.5	<0.04	<0.005	0.01
4 - S	" "	0.6	<0.5	<0.5	<0.5	0.42	<0.005	0.28
4 - D	" "	195.2	89.8	37.9	9.3	<0.04	<0.005	0.01
5 - S	" "	<0.5	<0.5	<0.5	<0.5	0.87	<0.005	<0.01
5 - D	" "	163.8	72.6	39.7	5.1	<0.04	<0.005	0.01
Quality Control	EPA	46.5	5.3	1.8	9.8	0.60	0.018	0.08
Analysis	OSU	47.8	5.5	1.8	9.9	0.65	0.018	0.08

Sample Identification	Date	Cu	Cr	Ni	Cd	Mn	Se	As
1 - Suspended	5-1-84	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
1 - Dissolved	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
1 (duplicate) S	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
1 (duplicate) D	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
2 - S	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
2 - D	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
3 - S	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
3 - D	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
4 - S	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
4 - D	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
5 - S	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
5 - D	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
Quality Control	EPA	0.25	0.04	0.25	0.010	0.35	0.044	0.04
Analysis	OSU	0.25	0.03	0.24	0.008	0.37	0.041	0.04

Sample Identification	Date	Na	Ca	Mg	K	Fe	Pb	Zn
1 Suspended	8-14-84	<0.5	<0.5	<0.5	<0.5	0.37	<0.005	0.01
1 Dissolved	" "	101.1	53.2	19.8	4.8	0.28	0.398	0.02
1 S-dup.	" "	<0.5	<0.5	<0.5	<0.5	0.39	<0.005	<0.01
1 D-dup.	" "	103.8	54.0	21.1	5.0	0.04	0.014	0.01
2 S	" "	<0.5	<0.5	<0.5	<0.5	0.34	<0.005	0.01
2 D	" "	103.4	56.0	20.0	5.0	0.11	0.098	0.07
3 S	" "	<0.5	0.6	<0.5	<0.5	0.12	<0.005	0.01
3 D	" "	253.8	152.6	35.7	29.6	<0.04	<0.005	0.04
4 S	" "	<0.5	1.5	1.6	1.4	4.40	0.006	0.01
4 D	" "	265.5	153.3	41.4	30.7	0.06	0.027	0.08
5 S	" "	<0.5	1.4	1.8	1.7	6.59	0.005	0.01
5 D	" "	109.3	58.4	14.5	8.5	0.13	0.056	0.02
Quality control	EPA	1.5	5.3	1.8	9.8	0.90	0.018	0.08
Analysis	OSU	1.3	5.6	1.6	9.4	0.87	0.018	0.08

Sample Identification	Date	Cu	Cr	Ni	Cd	Mn	Se	As
1 Suspended	8-14-84	<0.04	<0.01	<0.1	<0.005	0.10	<0.01	<0.01
1 Dissolved	" "	<0.04	<0.01	<0.1	<0.005	0.05	0.01	<0.01
1 S-dup.	" "	<0.04	<0.01	<0.1	<0.005	0.11	<0.01	<0.01
1 D-dup.	" "	<0.04	<0.01	<0.1	<0.005	0.05	<0.01	<0.01
2 S	" "	<0.04	<0.01	<0.1	<0.005	0.10	<0.01	<0.01
2 D	" "	0.04	<0.01	<0.1	<0.005	0.08	<0.01	<0.01
3 S	" "	<0.04	<0.01	<0.1	<0.005	<0.05	0.01	<0.01
3 D	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
4 S	" "	<0.04	<0.01	<0.1	<0.005	0.12	<0.01	<0.01
4 D	" "	<0.04	<0.01	<0.1	<0.005	0.42	<0.01	<0.01
5 S	" "	<0.04	0.01	<0.1	<0.005	0.24	<0.01	<0.01
5 D	" "	<0.04	<0.01	<0.1	<0.005	<0.05	<0.01	<0.01
Quality Control	EPA	0.25	0.01	0.25	0.013	0.50	0.02	0.040
Analysis	OSU	0.26	0.01	0.22	0.015	0.49	0.02	0.039

APPENDIX C

CONCENTRATION OF MERCURY (mg/l) IN SKELETON CREEK WATER DETERMINED DURING THE STUDY PERIOD

Sample Identification		8-12-82	12-7-82	4-27-83	7-6-83	10-5-83	12-8-83	5-1-84	8-14-84
1		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
2		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
3		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
4		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
5		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Quality Control	OSU	0.009	0.009	0.009	0.003	0.0075	0.0075	0.0075	0.0036
Analysis	EPA	0.008	0.008	0.007	0.0027	0.0065	0.0073	0.0075	0.0035

APPENDIX D

CONCENTRATION OF HEAVY METALS (ug/g) IN SKELETON CREEK SEDIMENT DETERMINED DURING THE STUDY PERIOD

Sample Identification	Date	Pb	Zn	Cu	Cr	Cd
Station 1A	8-12-82	41.8	139.8	19.2	26.8	0.70
Station 1B	" "	35.8	127.6	16.3	21.9	0.70
Station 2A	" "	34.0	108.1	30.1	32.1	0.50
Station 2B	" "	31.9	104.2	27.8	30.6	0.50
Station 3	" "	16.9	67.4	13.6	19.5	0.30
Station 4A	" "	19.4	59.5	11.0	24.4	0.40
Station 4B	" "	19.4	53.2	10.7	23.5	0.40
Station 5	" "	5.0	8.0	3.1	5.8	<0.20
EPAMS	" "	493.0	700.0	1200.0	154.0	17.00
Station 1A	12-7-82	58.1	160.1	16.8	26.8	0.70
Station 1B	" "	56.9	155.0	14.7	23.0	0.80
Station 2A	" "	50.1	137.2	14.1	22.4	0.60
Station 2B	" "	46.3	133.5	13.2	21.4	0.60
Station 3	" "	12.1	41.3	8.3	14.1	0.30
Station 4A	" "	32.7	98.1	18.3	33.2	0.70
Station 4B	" "	34.7	107.8	20.4	37.0	0.70
Station 5	" "	9.1	18.8	5.8	12.5	0.30
EPAMS	" "	544.0	1000.0	1100.0	173.0	19.00
Station 1A	4-27-83	6.2	28.2	2.6	5.8	0.20
Station 1B	" "	6.3	29.4	2.4	5.9	0.20
Station 2A	" "	8.1	60.2	2.4	6.6	0.20
Station 2B	" "	6.3	64.3	2.4	6.3	0.20
Station 3	" "	6.8	48.0	3.6	5.4	<0.20
Station 4A	" "	18.5	107.9	12.8	20.2	0.50
Station 4B	" "	17.7	111.4	12.8	19.2	0.50
Station 5	" "	3.8	9.8	2.9	5.1	0.20
EPAMS	" "	573.0	800.0	1250.0	192.0	19.50
Station 1A	7-6-83	18.5	20.0	3.0	5.5	0.20
Station 1B	" "	12.8	22.1	4.0	5.8	0.20
Station 2A	" "	9.3	20.6	4.5	9.0	0.20
Station 2B	" "	10.5	20.8	4.0	9.3	0.20
Station 3	" "	7.5	27.5	5.8	6.2	0.20
Station 4A	" "	11.2	28.3	7.4	14.2	0.40
Station 4B	" "	11.1	33.8	7.8	13.7	0.30
Station 5	" "	4.7	11.5	6.2	5.2	0.20
EPAMS	" "	506.0	900.0	1250.0	159.5	17.00

Sample Identification	Date	Pb	Zn	Cu	Cr	Cd
Station 1	10-5-83	1.45	5.46	0.47	1.27	0.012
Station 2A	" "	1.80	7.65	0.80	2.07	0.017
Station 2B	" "	1.61	7.70	0.82	2.12	0.012
Station 2C	" "	1.85	7.98	0.84	2.21	0.011
Station 3	" "	0.80	4.61	0.41	1.34	0.011
Station 4	" "	2.52	12.05	1.68	3.74	<0.005
Station 5	" "	1.64	6.40	0.43	1.04	0.020
Station 1	12-8-83	0.88	5.21	0.40	1.40	0.007
Station 2A	" "	1.58	8.03	0.71	1.95	0.032
Station 2B	" "	1.72	8.20	0.72	1.93	0.011
Station 2C	" "	1.61	8.41	0.70	1.91	0.017
Station 3	" "	1.31	7.54	1.01	1.30	0.004
Station 4	" "	3.87	24.50	2.53	5.29	<0.005
Station 5	" "	1.39	8.50	0.49	0.79	0.015
Station 1	5-1-84	1.57	9.38	0.52	1.73	0.017
Station 2A	" "	1.51	11.10	0.44	1.74	0.018
Station 2B	" "	1.13	10.46	0.43	1.65	0.015
Station 2C	" "	1.27	10.67	0.44	1.55	0.013
Station 3	" "	0.83	6.29	0.46	1.79	0.012
Station 4	" "	1.06	7.32	0.50	1.92	0.025
Station 5	" "	0.31	2.08	0.19	0.51	0.006
Station 1	8-14-84	1.65	7.38	0.78	2.17	<0.005
Station 2A	" "	1.36	5.44	0.51	1.78	<0.005
Station 2B	" "	1.67	5.14	0.52	1.72	<0.005
Station 2C	" "	1.30	5.01	0.50	1.47	<0.005
Station 3	" "	4.07	2.53	0.98	1.18	<0.005
Station 4	" "	1.58	9.65	1.22	2.41	<0.005
Station 5	" "	0.73	3.08	0.39	1.08	<0.005
EPA 0.59 gm		5.16	12.60	8.85	1.97	0.0035
EPA 0.29 gm		2.20	4.86	6.00	0.87	0.0014
EPAMS 1.00 gm		10.21	25.40	17.70	3.99	1.785
EPA Ref 1.00 gm		10.18	25.30	17.00	3.98	-0.007
EPA-MS 1.00 gm		9.44	24.70	19.10	3.91	1.395

APPENDIX E

PERCENT SAND, SILT, CLAY, AND ORGANIC CARBON IN SKELETON CREEK SEDIMENT DETERMINED DURING THE STUDY PERIOD

Sample Identification	Date	% SAND	% SILT	% CLAY	% ORGANIC CARBON
Station 1	8-12-82	35.51	48.10	16.39	0.348
Station 2	" "	41.44	42.50	16.06	0.709
Station 3	" "	66.00	27.40	6.60	0.485
Station 4	" "	26.36	50.32	23.32	0.319
Station 5	" "	89.59	7.46	2.95	0.086
Station 1	12-7-82	58.23	28.40	13.37	0.374
Station 2	" "	58.00	32.94	9.06	0.377
Station 3	" "	86.83	9.97	3.20	0.143
Station 4	" "	20.18	55.90	23.92	0.808
Station 5	" "	75.51	18.60	7.89	0.187
Station 1	4-27-83	95.20	3.77	1.03	0.036
Station 2	" "	95.20	3.99	0.81	0.059
Station 3	" "	97.44	2.03	0.53	0.054
Station 4	" "	46.96	39.80	13.24	0.323
Station 5	" "	93.05	5.01	1.94	0.053
Station 1	7-6-83	92.11	6.44	1.45	0.045
Station 2	" "	94.41	4.79	0.80	0.081
Station 3	" "	95.61	4.02	0.37	0.036
Station 4	" "	52.74	39.40	7.86	0.170
Station 5	" "	90.76	6.86	2.38	0.036
Station 1	10-5-83	93.08	4.39	2.53	0.054
Station 2	" "	85.05	10.33	4.62	0.072
Station 3	" "	95.56	1.95	1.49	0.054
Station 4	" "	28.84	57.22	13.94	0.341
Station 5	" "	90.98	5.01	4.01	0.045
Station 1	12-8-83	97.58	1.73	0.69	0.027
Station 2	" "	95.88	2.66	1.46	0.072
Station 3	" "	97.37	1.84	0.79	0.018
Station 4	" "	15.43	66.77	17.80	0.512
Station 5	" "	93.93	3.60	2.47	0.054
Station 1	5-1-84	92.81	5.52	1.67	0.044
Station 2	" "	97.33	2.26	0.41	0.054
Station 3	" "	97.06	2.13	0.81	0.035
Station 4	" "	92.49	5.53	1.98	0.144
Station 5	" "	96.99	2.08	0.93	0.081
Station 1	8-14-84	93.81	4.64	1.55	0.035
Station 2	" "	96.23	2.52	1.25	0.044
Station 3	" "	97.71	1.50	0.79	0.072
Station 4	" "	72.72	21.09	6.91	0.189
Station 5	" "	90.72	5.51	3.77	0.117

APPENDIX F

CONCENTRATION OF ORGANIC COMPOUNDS (ug/1) IDENTIFIED IN SKELETON CREEK WATER SAMPLES COLLECTED DURING THE STUDY PERIOD

Skeleton Creek Water - Date: 12 August 82

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Alpha Phellandrene	<0.27	<0.42	<0.37	<0.40	<0.50
4-Aminobiphenyl	<0.27	<0.42	<0.37	<0.40	<0.50
Benzil	<0.18	<0.28	<0.25	<0.27	<0.33
Bis(2-Ethylhexyl)Phthalate	0.91@	4.14@	<0.62	14.17†	<0.83
Borneol	<0.18	<0.28	<0.25	<0.27	<0.33
2-Butoxyethanol	<0.18	<0.28	<0.25	<0.27	<0.33
Butyl Carbobutoxymethyl Phthalate	<0.44	<0.69	<0.62	<0.67	<0.83
Caproic Acid	<0.09	<0.14	<0.13	<0.13	<0.17
Carbitol	<0.09	3.48*	<0.13	<0.13	<0.17
Carbromal	<0.18	<0.28	<0.25	<0.27	<0.33
Carvone	<0.18	<0.28	<0.25	<0.27	<0.33
2-(2-(2-Chloroethoxy) Ethoxy) Ethanol	<0.35	<0.55	<0.50	<0.54	<0.67
Cymene	<0.35	<0.55	<0.50	<0.54	<0.67
Cycrimine	<0.18	<0.28	<0.25	<0.27	<0.33
Decane	<0.09	<0.14	<0.13	<0.13	<0.17
1,4-Dichlorobenzene	<0.09	<0.14	<0.13	<0.13	<0.17
p,p'-Dichlorobenzophenone	<0.09	1.65†	<0.13	<0.13	3.53†
2,4-Dimethyl Quinoline	<0.27	<0.42	<0.37	<0.40	<0.50
Diethyl Phthalate	<0.35	<0.55	<0.50	<0.54	<0.67
Dimethyl Phthalate	<0.27	<0.42	<0.37	<0.40	<0.50
Dioctyl Adipate	<0.44	<0.69	<0.62	14.70@	<0.83
Diphenyl Ether	<0.44	<0.69	<0.62	<0.67	<0.83
Diphenyl Mercury	<0.35	<0.55	<0.50	<0.54	<0.67
Dodecane	<0.18	<0.28	<0.25	<0.27	<0.33
Ethosuximide-N-Ethyl Der.	0.96@	<0.42	<0.37	<0.40	<0.50
2-Ethyl-1-Hexanol	<0.09	<0.14	<0.13	<0.13	<0.17
Ethylphenylacetate	<0.35	<0.55	<0.50	<0.54	<0.67
Heptadecane	<0.35	<0.55	0.72*	0.63*	<0.67
Hexadecane	<0.35	<0.55	<0.50	<0.54	<0.67
Hydroxycitronellal	<0.09	<0.14	<0.13	<0.13	<0.17
Indomethacin Methyl Ester	<0.44	<0.69	0.55†	<0.67	<0.83
Menthene Isomer	<0.27	0.96@	<0.37	<0.40	<0.50
1-Methyl-1-Methoxy-3(3,4-Dichlorophenyl) Urea	<0.09	<0.14	<0.13	<0.13	<0.17
Methyl Alpha Ketomyristate	<0.35	<0.55	<0.50	<0.54	<0.67
Methyl Alpha Ketostearate	<0.35	<0.55	<0.50	<0.54	2.18@
Methyl Caprate	<0.44	<0.69	<0.62	2.69†	<0.83

* - Compounds identified and confirmed by GC/MS, quantified by GC/FID.

† - Compounds identified by GC/MS ($r \geq 0.900$), quantified by GC/MS.

@ - Compounds identified by GC/MS ($r \geq 0.800$), quantified by GC/MS.

Skeleton Creek Water - Date: 12 August 82 (Continued)

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Methyl Eicosatrienoate	<0.44	1.13†	<0.62	<0.67	<0.83
Methyl Heptadecanoate	<0.44	<0.69	2.21@	<0.67	<0.83
Methyl Isostearate	<0.44	<0.69	<0.62	1.99@	<0.83
Methyl Nervonate	<0.27	<0.42	<0.37	<0.40	<0.50
Methyl Octacosanoate	<0.44	1.26@	<0.62	<0.67	<0.83
Methyl Tricosanoate	<0.35	1.99†	<0.50	<0.54	<0.67
Naphthalene	<0.18	<0.28	<0.25	<0.27	<0.33
Neral	<0.09	<0.14	<0.13	<0.13	<0.17
Oleic Acid	3.03@	3.11@	<0.50	<0.54	<0.67
Pentadecane	<0.27	<0.42	<0.37	<0.40	<0.50
Phenol	<0.09	<0.14	<0.13	<0.13	<0.17
Siduron	<0.35	<0.55	<0.50	<0.54	<0.67
2,6-Di-Tert-Butyl-4-Methyl Phenyl-N-Methylcarbamate	<0.35	<0.55	<0.50	<0.54	<0.67
Terpinene-4-ol	<0.35	<0.55	<0.50	0.56†	0.86@
Tetradecane	<0.27	<0.42	<0.37	<0.40	<0.50
Thujyl Alcohol Isomer	<0.44	14.82†	<0.62	<0.67	<0.83
Toluene	<0.09	<0.14	<0.13	<0.13	<0.17
Tri-2-Butoxymethyl Phosphate	<0.44	<0.69	<0.62	<0.67	<0.83
4-Tri-Butylphenol	<0.27	<0.42	<0.37	<0.40	<0.50
Undecane	<0.09	<0.14	<0.13	<0.13	<0.17

* - Compounds identified and confirmed by GC/MS, quantified by GC/FID.

† - Compounds identified by GC/MS ($r \geq 0.900$), quantified by GC/MS.

@ - Compounds identified by GC/MS ($r \geq 0.800$), quantified by GC/MS.

Skeleton Creek Water - Date: 7 December 82

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Alpha Phellandrene	<0.18	<0.33	<0.33	<0.29	<0.18
4-Aminobiphenyl	<0.18	<0.33	<0.33	<0.29	<0.18
Benzil	0.01†	0.02†	0.04†	<0.20	0.07†
Bis(2-Ethylhexyl)Phthalate	<0.31	<0.55	<0.55	<0.49	<0.29
Borneol	<0.12	<0.22	<0.22	<0.20	<0.12
2-Butoxyethanol	<0.12	<0.22	<0.22	<0.20	1.35@
Butyl Carbobutoxymethyl Phthalate	<0.31	<0.55	<0.55	<0.49	<0.29
Caproic Acid	<0.06	<0.11	<0.11	<0.10	<0.06
Carbitol	<0.06	0.14*	<0.11	<0.10	<0.06
Carbromal	<0.12	<0.22	<0.22	<0.20	<0.12
Carvone	<0.12	<0.22	<0.22	<0.20	<0.12
2-(2-(2-Chloroethoxy) Ethoxy) Ethanol	<0.24	<0.44	<0.44	<0.39	<0.23
Cymene	<0.24	<0.44	<0.44	<0.39	<0.23
Cycrimine	<0.12	<0.22	<0.22	<0.20	<0.12
Decane	<0.06	<0.11	<0.11	<0.10	<0.06
1,4-Dichlorobenzene	<0.06	<0.11	<0.11	<0.10	<0.06
p,p'-Dichlorobenzophenone	<0.06	<0.11	<0.11	<0.10	<0.06
2,4-Dimethyl Quinoline	<0.18	0.43@	<0.33	<0.29	<0.18
Diethyl Phthalate	<0.24	<0.44	<0.44	<0.39	<0.23
Dimethyl Phthalate	<0.18	<0.33	<0.33	<0.29	<0.185
Dioctyl Adipate	<0.31	<0.55	<0.55	<0.49	<0.29
Diphenyl Ether	<0.31	<0.55	<0.55	<0.49	<0.29
Diphenyl Mercury	<0.24	<0.44	<0.44	<0.39	<0.23
Dodecane	<0.12	<0.22	<0.22	<0.20	<0.12
Ethosuximide-N-Ethyl Der.	<0.18	<0.33	<0.33	<0.29	<0.18
2-Ethyl-1-Hexanol	0.78@	<0.11	<0.11	<0.10	1.57@
Ethylphenylacetate	<0.24	<0.44	<0.44	<0.39	<0.23
Heptadecane	<0.24	<0.44	<0.44	<0.39	<0.23
Hexadecane	<0.24	<0.44	<0.44	<0.39	<0.23
Hydroxycitronellal	<0.06	<0.11	<0.11	<0.10	<0.06
Indomethacin Methyl Ester	<0.31	<0.55	<0.55	<0.49	<0.29
Menthene Isomer	0.81@	<0.33	<0.33	<0.29	<0.18
1-Methyl-1-Methoxy-3(3,4-Dichlorophenyl) Urea	<0.06	<0.11	<0.11	<0.10	<0.06
Methyl Alpha Ketomyristate	<0.24	<0.44	<0.44	<0.39	<0.23
Methyl Alpha Ketostearate	<0.24	<0.44	<0.44	<0.39	<0.23
Methyl Caprate	<0.31	<0.55	<0.55	<0.49	<0.29

* - Compounds identified and confirmed by GC/MS, quantified by GC/FID.

† - Compounds identified by GC/MS ($r \geq 0.900$), quantified by GC/MS.

@ - Compounds identified by GC/MS ($r \geq 0.800$), quantified by GC/MS.

Skeleton Creek Water - Date: 7 December 82 (Continued)

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Methyl Eicosatrienoate	<0.31	<0.55	<0.55	<0.49	<0.29
Methyl Heptadecanoate	<0.31	<0.55	<0.55	<0.49	<0.29
Methyl Isostearate	<0.31	<0.55	<0.55	<0.49	<0.29
Methyl Nervonate	<0.18	<0.33	<0.33	<0.29	<0.18
Methyl Octacosanoate	<0.31	<0.55	<0.55	<0.49	<0.29
Methyl Tricosanoate	<0.24	<0.44	<0.44	<0.39	<0.23
Naphthalene	0.02*	<0.22	0.15*	<0.20	0.03*
Neral	<0.06	<0.11	<0.11	<0.10	<0.06
Oleic Acid	<0.24	<0.44	<0.44	<0.39	<0.23
Pentadecane	<0.18	<0.33	<0.33	<0.29	<0.18
Phenol	<0.06	<0.11	<0.11	<0.10	<0.06
Siduron	<0.24	<0.44	<0.44	<0.39	<0.23
2,6-Di-Tert-Butyl-4-Methyl Phenyl-N-Methylcarbamate	<0.24	<0.44	<0.44	<0.39	<0.23
Terpinene-4-ol	<0.24	<0.44	<0.44	<0.39	<0.23
Tetradecane	<0.18	<0.33	<0.33	<0.29	<0.18
Thujyl Alcohol Isomer	<0.31	<0.55	<0.55	<0.49	<0.29
Toluene	<0.06	<0.11	<0.11	<0.10	<0.06
Tri-2-Butoxymethyl Phosphate	1.24†	<0.55	<0.55	<0.49	<0.29
4-Tri-Butylphenol	<0.18	0.19†	<0.33	<0.29	<0.18
Undecane	<0.06	<0.11	<0.11	<0.10	<0.06

* - Compounds identified and confirmed by GC/MS, quantified by GC/FID.

† - Compounds identified by GC/MS ($r \geq 0.900$), quantified by GC/MS.

@ - Compounds identified by GC/MS ($r \geq 0.800$), quantified by GC/MS.

Skeleton Creek Water - Date: 27 April 83

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Alpha Phellandrene	<0.36	<0.26	<0.24	<0.21	<0.17
4-Aminobiphenyl	<0.36	<0.26	<0.24	<0.21	<0.17
Benzil	<0.24	0.01†	0.01†	<0.14	<0.11
Bis(2-Ethylhexyl)Phthalate	2.63†	<0.43	<0.39	<0.35	0.56†
Borneol	<0.24	<0.17	<0.16	<0.14	<0.11
2-Butoxyethanol	<0.24	<0.17	<0.16	<0.14	<0.11
Butyl Carbobutoxymethyl Phthalate	<0.60	<0.43	<0.40	<0.35	<0.28
Caproic Acid	<0.12	<0.09	<0.08	<0.07	<0.06
Carbitol	<0.12	0.40*	<0.08	<0.07	<0.06
Carbromal	<0.24	<0.17	<0.16	<0.14	<0.11
Carvone	<0.24	<0.17	<0.16	<0.14	<0.11
2-(2-(2-Chloroethoxy) Ethoxy) Ethanol	<0.48	<0.34	<0.32	<0.28	<0.23
Cymene	<0.48	<0.34	<0.32	<0.28	<0.23
Cycrimine	<0.24	<0.17	<0.16	<0.14	<0.11
Decane	<0.12	<0.09	<0.08	<0.07	<0.06
1,4-Dichlorobenzene	<0.12	<0.09	<0.08	<0.07	<0.06
p,p'-Dichlorobenzophenone	<0.12	<0.09	<0.08	<0.07	<0.06
2,4-Dimethyl Quinoline	<0.36	<0.26	<0.24	<0.21	<0.17
Diethyl Phthalate	<0.48	<0.34	<0.32	<0.28	<0.23
Dimethyl Phthalate	<0.36	<0.26	<0.24	<0.21	<0.17
Dioctyl Adipate	<0.60	<0.43	<0.40	<0.35	<0.28
Diphenyl Ether	<0.60	<0.43	<0.39	<0.35	<0.28
Diphenyl Mercury	<0.48	<0.34	<0.32	<0.28	<0.23
Dodecane	<0.24	<0.17	<0.16	<0.14	<0.11
Ethosuximide-N-Ethyl Der.	<0.36	<0.26	<0.24	<0.21	<0.17
2-Ethyl-1-Hexanol	<0.12	1.25†	1.05†	<0.07	<0.06
Ethylphenylacetate	<0.48	<0.34	<0.32	<0.28	<0.23
Heptadecane	<0.48	<0.34	<0.32	<0.28	<0.23
Hexadecane	<0.48	<0.34	<0.32	<0.28	<0.23
Hydroxycitronellal	<0.12	<0.09	<0.08	<0.07	<0.06
Indomethacin Methyl Ester	<0.60	<0.43	<0.40	<0.35	<0.28
Menthene Isomer	<0.36	<0.26	<0.24	<0.21	<0.17
1-Methyl-1-Methoxy-3(3,4-Dichlorophenyl) Urea	<0.12	<0.09	<0.08	<0.07	<0.06
Methyl Alpha Ketomyristate	<0.48	<0.34	<0.32	<0.28	<0.23
Methyl Alpha Ketostearate	<0.48	<0.34	<0.32	<0.28	<0.23
Methyl Caprate	<0.60	<0.43	<0.40	<0.35	<0.28

* - Compounds identified and confirmed by GC/MS, quantified by GC/FID.

† - Compounds identified by GC/MS ($r \geq 0.900$), quantified by GC/MS.

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Skeleton Creek Water - Date: 27 April 83 (Continued)

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Methyl Eicosatrienoate	<0.60	<0.43	<0.40	<0.35	<0.28
Methyl Heptadecanoate	<0.60	<0.43	<0.39	<0.35	<0.28
Methyl Isostearate	<0.60	<0.43	<0.39	<0.35	<0.28
Methyl Nervonate	<0.36	<0.26	<0.24	<0.21	<0.17
Methyl Octacosanoate	<0.60	<0.43	<0.39	<0.35	<0.28
Methyl Tricosanoate	<0.48	<0.34	<0.32	<0.28	<0.23
Naphthalene	<0.24	0.13*	0.04*	<0.14	<0.11
Neral	<0.12	<0.09	<0.08	<0.07	<0.06
Oleic Acid	<0.48	<0.34	<0.32	<0.28	<0.23
Pentadecane	<0.36	<0.26	<0.24	<0.21	<0.17
Phenol	<0.12	<0.07	<0.08	<0.07	<0.06
Siduron	<0.48	<0.34	<0.32	<0.28	<0.23
2,6-Di-Tert-Butyl-4-Methyl Phenyl-N-Methylcarbamate	<0.48	<0.34	<0.32	<0.28	<0.23
Terpinene-4-ol	<0.48	<0.34	<0.32	<0.28	<0.23
Tetradecane	<0.36	<0.26	<0.24	<0.21	<0.17
Thujyl Alcohol Isomer	<0.60	<0.43	<0.39	<0.35	<0.28
Toluene	<0.12	<0.09	<0.08	<0.07	<0.06
Tri-2-Butoxymethyl Phosphate	<0.60	<0.43	<0.39	<0.35	<0.28
4-Tri-Butylphenol	<0.36	<0.26	<0.24	<0.21	<0.17
Undecane	<0.12	<0.09	<0.08	<0.07	<0.06

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Skeleton Creek Water - Date: 6 July 83

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Alpha Phellandrene	<0.30	0.42@	<0.38	<0.44	<0.37
4-Aminobiphenyl	<0.30	0.07@	<0.38	<0.44	<0.37
Benzil	<0.20	<0.18	<0.25	<0.29	<0.25
Bis(2-Ethylhexyl)Phthalate	<0.49	<0.44	<0.63	<0.73	<0.61
Borneol	<0.20	<0.18	<0.25	<0.29	<0.25
2-Butoxyethanol	<0.20	<0.18	<0.25	<0.29	0.49@
Butyl Carbobutoxymethyl Phthalate	<0.49	<0.44	<0.63	<0.73	<0.61
Caproic Acid	<0.10	<0.09	<0.13	<0.15	<0.12
Carbitol	<0.10	<0.09	<0.13	<0.15	<0.12
Carbromal	<0.20	<0.18	<0.25	<0.29	<0.25
Carvone	<0.10	<0.09	<0.13	<0.15	<0.12
2-(2-(2-Chloroethoxy) Ethoxy) Ethanol	<0.40	<0.35	<0.50	<0.58	<0.49
Cymene	<0.40	<0.35	0.94*	<0.58	<0.49
Cycrimine	<0.20	<0.18	<0.25	<0.29	<0.25
Decane	<0.10	<0.09	0.04*	<0.15	<0.12
1,4-Dichlorobenzene	<0.10	<0.09	0.25*	<0.15	<0.12
p,p'-Dichlorobenzophenone	<0.10	<0.09	<0.13	<0.15	<0.12
2,4-Dimethyl Quinoline	<0.30	<0.26	<0.38	<0.44	<0.37
Diethyl Phthalate	<0.40	0.86*	<0.50	3.01*	0.36*
Dimethyl Phthalate	<0.30	10.29*	<0.38	<0.44	<0.37
Dioctyl Adipate	<0.49	<0.44	<0.63	<0.73	<0.61
Diphenyl Ether	<0.49	0.86@	<0.63	<0.73	<0.61
Diphenyl Mercury	<0.40	<0.35	<0.50	<0.58	<0.49
Dodecane	<0.20	<0.18	<0.25	<0.29	<0.25
Ethosuximide-N-Ethyl Der.	<0.30	<0.26	<0.38	<0.44	<0.37
2-Ethyl-1-Hexanol	<0.10	<0.09	<0.13	<0.15	<0.12
Ethylphenylacetate	<0.40	<0.35	<0.50	<0.58	<0.49
Heptadecane	<0.40	<0.35	<0.50	<0.58	<0.49
Hexadecane	<0.40	<0.35	2.09*	<0.58	<0.49
Hydroxycitronellal	<0.10	<0.09	<0.13	<0.15	<0.12
Indomethacin Methyl Ester	<0.49	<0.44	<0.63	<0.73	<0.61
Menthene Isomer	<0.30	<0.26	<0.38	<0.44	<0.37
1-Methyl-1-Methoxy-3(3,4-Dichlorophenyl) Urea	<0.10	<0.09	<0.13	<0.15	<0.12
Methyl Alpha Ketomyristate	<0.40	<0.35	0.56†	<0.58	<0.49
Methyl Alpha Ketostearate	<0.40	<0.35	<0.50	<0.58	<0.49
Methyl Caprate	<0.49	<0.44	<0.63	<0.73	<0.61

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Skeleton Creek Water - Date: 6 July 83 (Continued)

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Methyl Eicosatrienoate	<0.49	<0.44	<0.63	<0.73	<0.61
Methyl Heptadecanoate	<0.49	<0.44	<0.63	<0.73	<0.61
Methyl Isostearate	<0.49	<0.44	<0.63	<0.73	<0.61
Methyl Nervonate	<0.30	<0.26	<0.38	<0.44	<0.37
Methyl Octacosanoate	<0.49	<0.44	<0.63	<0.73	<0.61
Methyl Tricosanoate	<0.40	<0.35	<0.50	<0.58	<0.49
Naphthalene	<0.20	<0.18	<0.25	<0.29	<0.25
Neral	1.85@	<0.09	0.11@	0.05@	<0.12
Oleic Acid	<0.40	<0.35	<0.50	<0.58	<0.49
Pentadecane	<0.30	<0.26	<0.38	<0.44	0.06*
Phenol	<0.10	<0.09	<0.13	<0.15	<0.12
Siduron	<0.40	<0.35	<0.50	0.74@	<0.49
2,6-Di-Tert-Butyl-4-Methyl Phenyl-N-Methylcarbamate	<0.40	<0.35	1.72†	1.01†	<0.49
Terpinene-4-ol	<0.40	<0.35	<0.50	<0.58	<0.49
Tetradecane	<0.30	<0.26	<0.38	<0.44	<0.37
Thujyl Alcohol Isomer	<0.49	<0.44	<0.63	<0.73	<0.61
Toluene	0.07*	<0.09	0.12*	0.15*	<0.12
Tri-2-Butoxymethyl Phosphate	<0.49	<0.44	<0.63	<0.73	<0.61
4-Tri-Butylphenol	<0.30	<0.26	<0.38	<0.44	<0.37
Undecane	<0.10	<0.09	0.02*	<0.15	<0.12

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Skeleton Creek Water - Date: 5 October 83

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Alpha Phellandrene	<0.45	<0.49	<0.50	<0.42	<0.48
4-Aminobiphenyl	<0.45	<0.49	<0.50	<0.42	<0.48
Benzil	<0.30	<0.33	<0.33	<0.28	<0.32
Bis(2-Ethylhexyl)Phthalate	<0.75	<0.82	<0.83	<0.70	<0.81
Borneol	<0.30	<0.33	<0.33	<0.28	<0.32
2-Butoxyethanol	<0.30	<0.33	<0.33	<0.28	<0.32
Butyl Carbobutoxymethyl Phthalate	10.79†	2.32†	1.71†	2.87†	18.69†
Caproic Acid	<0.15	<0.16	<0.17	<0.14	<0.16
Carbitol	<0.15	1.50*	0.27*	0.13*	<0.16
Carbromal	<0.30	<0.33	<0.33	<0.28	<0.32
Carvone	<0.30	14.41@	<0.33	<0.28	<0.32
2-(2-(2-Chloroethoxy) Ethoxy) Ethanol	<0.60	<0.66	2.52@	<0.56	<0.65
Cymene	<0.60	<0.66	<0.67	<0.56	<0.65
Cycrimine	<0.30	<0.33	<0.33	<0.28	<0.32
Decane	<0.15	<0.16	<0.17	<0.14	<0.16
1,4-Dichlorobenzene	<0.15	<0.16	<0.17	<0.14	<0.16
p,p'-Dichlorobenzophenone	<0.15	<0.16	<0.17	<0.14	<0.16
2,4-Dimethyl Quinoline	<0.45	<0.49	<0.50	<0.42	<0.48
Diethyl Phthalate	<0.60	3.38*	0.87*	<0.56	<0.65
Dimethyl Phthalate	<0.45	<0.49	<0.50	<0.42	<0.48
Dioctyl Adipate	8.58@	5.26@	5.45@	8.23@	3.27@
Diphenyl Ether	<0.75	0.79@	<0.83	<0.70	<0.81
Diphenyl Mercury	<0.60	<0.66	<0.67	<0.56	<0.65
Dodecane	<0.30	<0.33	<0.33	<0.28	<0.32
Ethosuximide-N-Ethyl Der.	<0.45	<0.49	<0.50	<0.42	<0.49
2-Ethyl-1-Hexanol	<0.15	<0.17	<0.17	1.11@	<0.16
Ethylphenylacetate	<0.60	0.36*	<0.67	1.77*	<0.65
Heptadecane	<0.60	<0.66	<0.67	<0.56	<0.65
Hexadecane	<0.60	<0.66	<0.67	<0.56	<0.65
Hydroxycitronellal	<0.15	<0.16	0.38†	<0.14	<0.16
Indomethacin Methyl Ester	<0.75	<0.82	<0.83	<0.70	<0.81
Menthene Isomer	<0.45	<0.49	<0.50	<0.42	<0.48
1-Methyl-1-Methoxy-3(3,4-Dichlorophenyl) Urea	<0.15	<0.16	<0.17	0.07†	<0.16
Methyl Alpha Ketomyristate	<0.60	<0.66	<0.67	<0.56	<0.65
Methyl Alpha Ketostearate	<0.60	<0.66	<0.67	<0.56	<0.65
Methyl Caprate	<0.75	<0.82	<0.83	<0.70	<0.81

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Skeleton Creek Water - Date: 5 October 83 (Continued)

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Methyl Eicosatrienoate	<0.75	<0.82	<0.83	<0.70	<0.81
Methyl Heptadecanoate	<0.75	<0.82	<0.83	<0.70	<0.81
Methyl Isostearate	<0.75	<0.82	<0.83	<0.70	<0.81
Methyl Nervonate	<0.45	1.22†	<0.50	<0.42	<0.48
Methyl Octacosanoate	<0.75	<0.82	<0.83	<0.70	<0.81
Methyl Tricosanoate	<0.60	<0.66	<0.67	<0.56	<0.65
Naphthalene	<0.30	<0.33	<0.33	<0.28	<0.32
Neral	<0.15	<0.16	<0.17	<0.14	<0.16
Oleic Acid	<0.60	<0.66	<0.67	<0.56	<0.65
Pentadecane	<0.45	<0.49	<0.45	<0.42	<0.48
Phenol	<0.15	<0.16	<0.17	<0.14	<0.16
Siduron	<0.60	<0.66	<0.67	<0.56	<0.65
2,6-Di-Tert-Butyl-4-Methyl Phenyl-N-Methylcarbamate	<0.60	<0.66	<0.67	<0.56	<0.65
Terpinene-4-ol	<0.60	<0.66	<0.67	<0.56	<0.65
Tetradecane	<0.45	<0.49	<0.50	<0.42	<0.48
Thujyl Alcohol Isomer	<0.75	<0.82	<0.83	<0.70	<0.81
Toluene	<0.15	<0.16	<0.17	<0.14	<0.16
Tri-2-Butoxymethyl Phosphate	<0.75	<0.82	<0.83	<0.70	<0.82
4-Tri-Butylphenol	<0.45	<0.49	<0.50	<0.42	<0.48
Undecane	<0.15	<0.16	<0.17	<0.14	<0.16

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Skeleton Creek Water - Date: 8 December 83

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Alpha Phellandrene	<0.50	<0.51	<0.51	<0.48	<0.45
4-Aminobiphenyl	<0.50	<0.51	<0.51	<0.48	<0.45
Benzil	<0.34	<0.34	<0.34	<0.32	<0.30
Bis(2-Ethylhexyl)Phthalate	<0.84	<0.85	<0.85	<0.79	<0.75
Borneol	<0.34	<0.34	<0.34	<0.32	<0.30
2-Butoxyethanol	<0.34	<0.34	<0.34	<0.32	<0.30
Butyl Carbobutoxymethyl Phthalate	<0.84	<0.85	<0.85	<0.79	<0.75
Caproic Acid	<0.17	<0.17	<0.17	<0.16	<0.15
Carbitol	<0.17	<0.17	33.81*	<0.16	<0.15
Carbromal	<0.34	<0.34	1.06@	<0.32	<0.30
Carvone	<0.34	<0.34	<0.34	<0.32	<0.30
2-(2-(2-Chloroethoxy) Ethoxy) Ethanol	<0.67	<0.68	<0.68	<0.64	<0.60
Cymene	<0.67	<0.68	<0.68	<0.64	<0.60
Cycrimine	<0.34	<0.34	1.03@	<0.32	<0.30
Decane	<0.17	<0.17	<0.17	<0.16	<0.15
1,4-Dichlorobenzene	<0.17	<0.17	<0.17	<0.16	<0.15
p,p'-Dichlorobenzophenone	<0.17	<0.17	<0.17	<0.16	<0.15
2,4-Dimethyl Quinoline	<0.50	<0.51	<0.51	<0.48	<0.45
Diethyl Phthalate	<0.67	<0.68	14.42*	<0.64	<0.60
Dimethyl Phthalate	<0.50	<0.51	<0.51	<0.48	<0.45
Dioctyl Adipate	<0.84	<0.85	<0.85	<0.80	<0.75
Diphenyl Ether	<0.84	<0.85	<0.85	<0.80	<0.75
Diphenyl Mercury	<0.67	<0.68	0.89@	<0.64	<0.60
Dodecane	<0.34	<0.34	<0.34	<0.32	<0.30
Ethosuximide-N-Ethyl Der.	<0.50	<0.51	<0.51	<0.48	<0.45
2-Ethyl-1-Hexanol	<0.17	<0.17	<0.17	<0.16	<0.15
Ethylphenylacetate	<0.67	<0.68	<0.68	<0.64	<0.60
Heptadecane	<0.67	<0.68	<0.68	<0.64	<0.60
Hexadecane	<0.67	<0.68	8.14*	<0.64	<0.60
Hydroxycitronellal	<0.17	<0.17	<0.17	<0.16	<0.15
Indomethacin Methyl Ester	<0.84	<0.85	<0.85	<0.79	<0.75
Menthene Isomer	<0.50	<0.51	<0.51	<0.48	<0.45
1-Methyl-1-Methoxy-3(3,4-Dichlorophenyl) Urea	<0.17	<0.17	<0.17	<0.16	<0.15
Methyl Alpha Ketomyristate	<0.67	<0.68	<0.68	<0.64	<0.60
Methyl Alpha Ketostearate	<0.67	<0.68	<0.68	<0.64	<0.60
Methyl Caprate	<0.84	<0.85	<0.85	<0.79	<0.75

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Skeleton Creek Water - Date: 8 December 83 (Continued)

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Methyl Eicosatrienoate	<0.84	<0.85	<0.85	<0.79	<0.75
Methyl Heptadecanoate	<0.84	<0.85	<0.85	<0.79	<0.75
Methyl Isostearate	<0.84	<0.85	<0.85	<0.79	<0.75
Methyl Nervonate	<0.50	3.16@	1.50@	<0.48	<0.45
Methyl Octacosanoate	<0.84	<0.85	<0.85	<0.79	<0.75
Methyl Tricosanoate	<0.67	<0.68	<0.68	<0.64	<0.60
Naphthalene	<0.34	<0.34	<0.34	<0.32	<0.30
Neral	<0.17	<0.17	<0.17	<0.16	<0.15
Oleic Acid	<0.67	<0.68	<0.68	<0.64	<0.60
Pentadecane	<0.50	<0.51	<0.51	<0.48	<0.45
Phenol	<0.17	<0.17	<0.17	<0.16	<0.15
Siduron	<0.67	<0.68	<0.68	<0.64	<0.60
2,6-Di-Tert-Butyl-4-Methyl Phenyl-N-Methylcarbamate	<0.67	<0.68	<0.68	<0.64	<0.60
Terpinene-4-ol	<0.67	<0.68	<0.68	<0.64	<0.60
Tetradecane	<0.50	<0.51	<0.51	<0.48	<0.45
Thujyl Alcohol Isomer	<0.84	<0.85	<0.85	<0.79	<0.75
Toluene	<0.17	<0.17	<0.17	<0.16	<0.15
Tri-2-Butoxymethyl Phosphate	<0.84	<0.85	<0.85	<0.79	<0.75
4-Tri-Butylphenol	<0.50	<0.51	<0.51	<0.48	<0.45
Undecane	<0.17	<0.17	<0.17	<0.16	<0.15

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† - Compounds identified by GC/MS ($r \geq 0.900$), quantified by GC/MS.

@ - Compounds identified by GC/MS ($r \geq 0.800$), quantified by GC/MS.

Skeleton Creek Water - Date: 1 May 84

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Alpha Phellandrene	<0.16	<0.23	<0.26	<0.40	<0.17
4-Aminobiphenyl	<0.16	<0.23	<0.26	<0.40	<0.17
Benzil	<0.11	<0.16	<0.17	<0.26	<0.12
Bis(2-Ethylhexyl)Phthalate	<0.27	<0.39	<0.43	<0.66	<0.29
Borneol	<0.11	<0.16	<0.17	<0.26	<0.12
2-Butoxyethanol	<0.11	<0.16	<0.17	<0.26	<0.12
Butyl Carbobutoxymethyl Phthalate	<0.27	<0.39	<0.43	<0.66	<0.28
Caproic Acid	<0.05	<0.08	<0.09	<0.13	<0.06
Carbitol	<0.05	<0.08	<0.09	<0.13	<0.06
Carbromal	<0.11	<0.16	<0.17	<0.26	<0.12
Carvone	<0.11	<0.16	<0.17	<0.26	<0.12
2-(2-(2-Chloroethoxy) Ethoxy) Ethanol	<0.22	<0.31	<0.34	<0.53	<0.23
Cymene	<0.22	<0.31	<0.34	<0.53	<0.23
Cycrimine	<0.11	<0.08	<0.09	<0.13	<0.06
Decane	<0.05	<0.08	<0.09	<0.13	<0.06
1,4-Dichlorobenzene	<0.05	0.07*	<0.09	<0.13	<0.06
p,p'-Dichlorobenzophenone	<0.05	<0.08	<0.09	<0.13	<0.06
2,4-Dimethyl Quinoline	<0.16	<0.23	<0.26	<0.40	<0.17
Diethyl Phthalate	<0.22	<0.31	<0.34	<0.53	<0.23
Dimethyl Phthalate	<0.16	<0.23	<0.26	<0.40	<0.17
Dioctyl Adipate	<0.27	1.34@	<0.43	<0.66	<0.29
Diphenyl Ether	3.32@	1.34@	2.26@	<0.66	<0.29
Diphenyl Mercury	<0.22	<0.31	<0.34	<0.53	<0.23
Dodecane	<0.11	<0.16	<0.17	<0.26	<0.12
Ethosuximide-N-Ethyl Der.	<0.16	<0.23	<0.26	<0.38	<0.17
2-Ethyl-1-Hexanol	<0.05	<0.08	<0.09	<0.13	<0.06
Ethylphenylacetate	<0.22	<0.31	<0.34	<0.53	<0.23
Heptadecane	<0.22	<0.31	<0.34	<0.53	<0.23
Hexadecane	<0.22	<0.31	<0.34	<0.53	<0.23
Hydroxycitronellal	<0.05	<0.08	<0.09	<0.13	<0.06
Indomethacin Methyl Ester	<0.27	<0.39	<0.43	<0.66	<0.29
Menthene Isomer	0.24@	<0.23	0.12@	<0.40	<0.17
1-Methyl-1-Methoxy-3(3,4-Dichlorophenyl) Urea	<0.05	<0.08	<0.09	<0.13	<0.06
Methyl Alpha Ketomyristate	<0.22	<0.31	<0.34	<0.53	<0.23
Methyl Alpha Ketostearate	<0.22	<0.31	<0.34	<0.53	<0.23
Methyl Caprate	<0.27	<0.39	<0.43	<0.66	<0.29

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Skeleton Creek Water - Date: 1 May 84 82 (Continued)

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Methyl Eicosatrienoate	<0.27	<0.39	<0.43	<0.66	<0.29
Methyl Heptadecanoate	<0.27	<0.39	<0.43	<0.66	<0.28
Methyl Isostearate	<0.27	<0.39	<0.43	<0.66	<0.28
Methyl Nervonate	<0.16	<0.23	<0.26	<0.40	<0.17
Methyl Octacosanoate	<0.27	<0.39	<0.43	<0.66	<0.28
Methyl Tricosanoate	<0.22	<0.31	<0.34	<0.53	<0.23
Naphthalene	<0.11	<0.16	<0.17	<0.26	<0.12
Neral	<0.05	<0.08	<0.09	<0.13	<0.06
Oleic Acid	<0.22	<0.31	<0.34	<0.53	<0.23
Pentadecane	<0.16	0.07*	<0.26	<0.40	0.04*
Phenol	<0.05	<0.08	0.09*	<0.13	<0.06
Siduron	<0.22	<0.31	<0.34	<0.53	<0.23
2,6-Di-Tert-Butyl-4-Methyl Phenyl-N-Methylcarbamate	<0.22	<0.31	<0.34	<0.53	<0.23
Terpinene-4-ol	<0.22	<0.31	<0.34	<0.53	<0.23
Tetradecane	<0.16	<0.23	0.55*	<0.40	<0.17
Thujyl Alcohol Isomer	<0.27	<0.39	<0.43	<0.66	<0.29
Toluene	0.12*	<0.08	<0.09	<0.13	0.04*
Tri-2-Butoxymethyl Phosphate	<0.27	<0.39	<0.43	<0.66	<0.29
4-Tri-Butylphenol	<0.16	<0.23	<0.26	<0.40	<0.17
Undecane	<0.05	<0.08	<0.09	<0.13	<0.06

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Skeleton Creek Water - Date: 14 August 84

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Alpha Phellandrene	<0.27	<0.29	0.16@	<0.22	<0.37
4-Aminobiphenyl	<0.27	<0.29	<0.30	<0.22	<0.37
Benzil	<0.18	<0.19	<0.20	<0.15	<0.25
Bis(2-Ethylhexyl)Phthalate	<0.46	<0.48	<0.50	<0.37	<0.62
Borneol	<0.18	0.02*	<0.20	<0.15	<0.25
2-Butoxyethanol	<0.18	<0.19	<0.20	<0.15	<0.25
Butyl Carbobutoxymethyl Phthalate	<0.46	<0.48	<0.50	<0.37	<0.62
Caproic Acid	<0.09	<0.10	4.87†	<0.07	1.85†
Carbitol	<0.09	<0.10	<0.10	<0.07	<0.12
Carbromal	<0.18	<0.19	<0.20	<0.15	<0.25
Carvone	<0.18	<0.19	<0.20	<0.15	<0.25
2-(2-(2-Chloroethoxy) Ethoxy) Ethanol	<0.36	<0.39	<0.40	<0.30	<0.50
Cymene	<0.36	<0.39	<0.40	<0.30	<0.50
Cycrimine	<0.18	<0.19	<0.20x	<0.15	<0.25
Decane	<0.09	<0.10	<0.10	<0.07	<0.12
1,4-Dichlorobenzene	<0.09	<0.10	<0.10	<0.07	<0.12
p,p'-Dichlorobenzophenone	<0.09	<0.10	<0.10	<0.07	<0.12
2,4-Dimethyl Quinoline	<0.27	<0.29	<0.30	<0.22	<0.37
Diethyl Phthalate	<0.36	<0.39	<0.40	<0.30	<0.49
Dimethyl Phthalate	<0.27	<0.29	<0.30	<0.22	<0.37
Dioctyl Adipate	<0.46	<0.48	<0.50	<0.37	<0.62
Diphenyl Ether	<0.46	0.72@	<0.50	<0.37	<0.62
Diphenyl Mercury	<0.36	<0.39	<0.40	<0.30	<0.49
Dodecane	<0.18	<0.19	<0.20	<0.15	<0.25
Ethosuximide-N-Ethyl Der.	<0.27	<0.29	<0.30	<0.22	<0.37
2-Ethyl-1-Hexanol	<0.09	<0.10	<0.10	<0.07	<0.12
Ethylphenylacetate	<0.36	<0.39	<0.40	<0.22	<0.37
Heptadecane	<0.36	<0.39	<0.40	<0.30	<0.49
Hexadecane	<0.36	<0.39	<0.40	<0.30	<0.49
Hydroxycitronellal	<0.09	<0.10	0.23@	0.67@	<0.12
Indomethacin Methyl Ester	<0.46	<0.48	<0.50	<0.37	<0.62
Menthene Isomer	<0.27	<0.29	<0.30	0.04@	<0.37
1-Methyl-1-Methoxy-3(3,4-Dichlorophenyl) Urea	<0.09	<0.10	<0.10	<0.07	<0.12
Methyl Alpha Ketomyristate	<0.36	<0.39	<0.40	<0.30	<0.49
Methyl Alpha Ketostearate	<0.36	<0.39	<0.40	<0.30	<0.49
Methyl Caprate	<0.46	<0.48	<0.50	<0.37	<0.62

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Skeleton Creek Water - Date: 14 August 84 (Continued)

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Methyl Eicosatrienoate	<0.46	<0.48	<0.50	<0.37	<0.62
Methyl Heptadecanoate	<0.46	<0.48	<0.50	<0.37	<0.62
Methyl Isostearate	<0.46	<0.48	<0.50	<0.37	<0.62
Methyl Nervonate	<0.27	<0.29	0.05@	<0.22	<0.37
Methyl Octacosanoate	<0.46	<0.48	<0.50	<0.37	<0.62
Methyl Tricosanoate	<0.36	<0.39	<0.40	<0.30	<0.49
Naphthalene	<0.18	<0.19	<0.20	0.14*	<0.25
Neral	<0.09	<0.10	<0.10	<0.07	<0.12
Oleic Acid	<0.36	<0.39	<0.40	<0.30	<0.49
Pentadecane	<0.27	<0.29	<0.30	<0.22	<0.37
Phenol	<0.09	<0.10	<0.10	<0.07	<0.12
Siduron	<0.36	<0.39	<0.40	<0.30	<0.49
2,6-Di-Tert-Butyl-4-Methyl Phenyl-N-Methylcarbamate	<0.36	<0.39	<0.40	<0.30	<0.49
Terpinene-4-ol	<0.36	<0.39	<0.40	<0.30	<0.49
Tetradecane	<0.27	<0.29	<0.30	<0.22	<0.37
Thujyl Alcohol Isomer	<0.46	<0.48	<0.50	<0.37	<0.62
Toluene	<0.09	0.04*	<0.10	0.58*	<0.12
Tri-2-Butoxymethyl Phosphate	<0.46	<0.48	<0.50	<0.37	<0.62
4-Tri-Butylphenol	<0.27	<0.29	<0.30	<0.22	<0.37
Undecane	<0.09	<0.10	<0.10	<0.07	<0.12

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APPENDIX G

CONCENTRATION OF ORGANIC COMPOUNDS (ug/g) IDENTIFIED IN SKELETON CREEK SEDIMENT SAMPLES COLLECTED DURING THE STUDY PERIOD

Skeleton Creek Sediment - Date: 12 August 82

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Acetophenone	<0.22	<0.26	<0.14	<0.09	<0.08
Benzaldehyde	<0.22	<0.26	<0.14	<0.09	<0.08
Bis(2-Ethylhexyl)Phthalate	<1.10	<1.30	<0.72	<0.44	<0.40
1-Bromotridecane	<0.88	0.06@	<0.58	<0.35	<0.32
2-Butoxyethanol	<0.44	<0.52	<0.29	<0.17	<0.16
Butyl Carbobutoxymethyl Phthalate	<1.10	<1.30	<0.72	<0.44	<0.40
Carbitol	<0.22	<0.26	<0.14	<0.09	<0.08
Citronellal	<0.44	<0.52	<0.29	<0.17	<0.16
Diethyl Phthalate	<0.88	<1.04	0.56*	<0.35	<0.32
Dioctyl Adipate	<1.10	<1.30	<0.72	<0.44	<0.40
2-Ethyl-1-Hexanol	<0.22	<0.26	<0.14	<0.09	<0.08
2-Ethylhexyl Ester of 2,4,-dichlorophenoxy-Acetic Acid	<1.10	<1.30	<0.72	<0.44	<0.40
2-Ethyl-2-Methyl 1,3-Dioxolane	<0.66	<0.78	<0.43	<0.26	<0.24
Geranial	<1.10	<1.30	<0.72	<0.44	<0.40
Heptadecane	<0.88	<1.04	1.53*	<0.35	<0.32
Hexadecane	<0.88	<1.04	0.23*	<0.35	<0.32
Methyl Alpha Ketomyristate	<0.88	<1.04	<0.58	<0.35	<0.32
Methyl Alpha Ketopalmitate	<0.88	0.18†	<0.58	<0.35	<0.32
Methyl Alpha Ketostearate	<0.88	<1.04	<0.58	<0.35	<0.32
Methyl Nervonate	<0.66	<0.78	0.22@	<0.26	<0.24
Nonadecane	<1.10	<1.30	<0.72	<0.44	<0.40
Octadecane	<1.10	<1.30	<0.72	<0.44	<0.40
Ortho-Ethylphenol	<0.44	<0.52	<0.29	<0.17	<0.16
Pentadecane	<0.66	<0.78	0.29*	<0.26	<0.24
Phenyl N-methylcarbamate	<0.44	0.55@	<0.29	<0.17	<0.16
P-Toluic Acid, Methylester	<1.10	<1.30	<0.72	<0.44	<0.40
Pyrene	<1.10	<1.30	<0.72	<0.44	<0.40
Stearic Acid	<1.10	<1.30	<0.72	<0.44	<0.40
Terpinene-4-ol	<0.88	<1.04	<0.58	<0.35	<0.32
Tetradecane	<0.66	<0.78	0.11*	<0.26	<0.24
Toluene	<0.22	0.06*	<0.14	0.03*	<0.08
Tridecane	<0.44	<0.52	<0.29	<0.17	<0.16

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Skeleton Creek Sediment - Date: 7 December 82

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Acetophenone	<0.22	<0.13	<0.09	<0.26	<0.07
Benzaldehyde	<0.22	<0.13	<0.09	<0.26	<0.07
Bis(2-Ethylhexyl)Phthalate	<1.10	<0.66	<0.47	<1.28	<0.33
1-Bromotridecane	<0.88	<0.53	<0.38	<1.03	<0.27
2-Butoxyethanol	<0.44	<0.27	<0.19	<0.51	<0.13
Butyl Carbobutoxymethyl Phthalate	<1.10	<0.66	<0.47	0.71†	<0.33
Carbitol	<0.22	<0.13	<0.09	<0.26	<0.07
Citronellal	<0.44	<0.27	<0.19	<0.51	<0.13
Diethyl Phthalate	<0.88	<0.53	<0.38	<1.03	<0.27
Dioctyl Adipate	<1.10	<0.66	<0.47	<1.28	<0.33
2-Ethyl-1-Hexanol	<0.22	<0.13	<0.09	<0.26	<0.07
2-Ethylhexyl Ester of 2,4,-dichlorophenoxy-Acetic Acid	<1.10	<0.66	<0.47	<1.28	<0.33
2-Ethyl-2-Methyl 1,3-Dioxolane	<0.66	<0.40	<0.28	<0.77	<0.20
Geranial	<1.10	<0.66	<0.47	<1.28	<0.33
Heptadecane	<0.88	<0.53	<0.38	<1.03	<0.27
Hexadecane	0.07*	<0.53	<0.38	<1.03	<0.27
Methyl Alpha Ketomyristate	<0.88	0.07†	0.13@	<1.03	<0.27
Methyl Alpha Ketopalmitate	<0.88	<0.53	<0.38	<1.03	<0.27
Methyl Alpha Ketostearate	<0.88	0.05†	<0.38	<1.03	<0.27
Methyl Nervonate	<0.66	<0.40	0.07@	<0.77	<0.20
Nonadecane	<1.10	<0.66	<0.47	<1.28	<0.33
Octadecane	<1.10	<0.66	<0.47	<1.28	<0.33
Ortho-Ethylphenol	<0.44	<0.27	<0.19	<0.51	<0.13
Pentadecane	<0.66	<0.40	<0.28	<0.77	<0.20
Phenyl N-methylcarbamate	<0.44	<0.27	<0.19	<0.51	<0.13
P-Toluic Acid, Methylester	<1.10	<0.66	<0.47	<1.28	<0.33
Pyrene	<1.10	<0.66	<0.47	<1.28	<0.33
Stearic Acid	<1.10	<0.66	<0.47	<1.28	<0.33
Terpinene-4-ol	<0.88	<0.53	<0.38	<1.03	<0.27
Tetradecane	<0.66	<0.40	<0.28	<0.77	<0.20
Toluene	<0.22	0.05*	<0.09	0.05†	0.03*
Tridecane	<0.44	<0.27	<0.19	<0.51	<0.13

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Skeleton Creek Sediment - Date: 27 April 83

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Acetophenone	<0.02	<0.01	<0.01	<0.01	<0.01
Benzaldehyde	<0.02	<0.01	<0.01	<0.01	<0.01
Bis(2-Ethylhexyl)Phthalate	<0.07	<0.07	0.03†	0.13†	<0.05
1-Bromotridecane	<0.06	<0.05	<0.05	<0.06	<0.04
2-Butoxyethanol	<0.03	<0.03	<0.02	<0.03	<0.02
Butyl Carbobutoxymethyl Phthalate	<0.07	<0.07	<0.06	0.61†	<0.05
Carbitol	<0.02	<0.01	<0.01	<0.01	<0.01
Citronellal	<0.03	<0.03	<0.02	0.04@	<0.02
Diethyl Phthalate	<0.06	<0.05	<0.05	<0.06	<0.04
Dioctyl Adipate	<0.07	<0.07	<0.06	0.25†	<0.05
2-Ethyl-1-Hexanol	<0.02	<0.01	<0.01	<0.01	<0.01
2-Ethylhexyl Ester of 2,4,-dichlorophenoxy-Acetic Acid	<0.07	<0.07	0.01@	<0.07	<0.05
2-Ethyl-2-Methyl 1,3-Dioxolane	<0.04	<0.04	<0.03	<0.04	<0.03
Geranial	<0.07	<0.07	<0.06	0.04@	<0.05
Heptadecane	<0.06	<0.05	0.05*	0.03*	<0.04
Hexadecane	<0.06	0.01*	0.01†	0.01*	<0.04
Methyl Alpha Ketomyristate	<0.06	<0.05	<0.05	0.04@	<0.04
Methyl Alpha Ketopalmitate	<0.06	0.02†	<0.05	0.03†	<0.04
Methyl Alpha Ketostearate	<0.06	<0.05	<0.05	<0.06	<0.04
Methyl Nervonate	<0.04	<0.04	<0.03	<0.04	<0.03
Nonadecane	<0.07	<0.07	<0.06	0.13*	<0.05
Octadecane	<0.07	0.02*	<0.06	<0.07	<0.05
Ortho-Ethylphenol	<0.03	<0.03	<0.02	<0.03	<0.02
Pentadecane	<0.04	<0.04	<0.03	<0.04	<0.03
Phenyl N-methylcarbamate	<0.03	<0.03	<0.02	<0.03	<0.02
P-Toluic Acid, Methylester	<0.07	<0.07	<0.06	<0.07	<0.05
Pyrene	<0.07	<0.07	<0.06	<0.07	<0.05
Stearic Acid	<0.07	<0.07	<0.06	<0.07	<0.05
Terpinene-4-ol	<0.06	<0.05	0.01@	0.11@	<0.04
Tetradecane	<0.04	<0.04	<0.03	<0.04	<0.03
Toluene	<0.02	<0.01	<0.01	<0.01	<0.01
Tridecane	<0.03	<0.03	<0.02	<0.03	<0.02

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@ - Compounds identified by GC/MS ($r \geq 0.800$), quantified by GC/MS.

Skeleton Creek Sediment - Date: 6 July 83

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Acetophenone	<0.01	<0.02	<0.02	<0.01	<0.01
Benzaldehyde	<0.01	<0.02	<0.02	<0.01	<0.01
Bis(2-Ethylhexyl)Phthalate	0.06†	2.18†	<0.08	<0.07	<0.07
1-Bromotridecane	<0.05	<0.07	<0.06	<0.05	<0.06
2-Butoxyethanol	0.05@	<0.03	<0.03	<0.03	<0.03
Butyl Carbobutoxymethyl Phthalate	<0.06	<0.09	0.06@	<0.07	<0.07
Carbitol	<0.01	<0.02	0.02*	0.06*	<0.01
Citronellal	<0.03	<0.03	<0.03	<0.03	<0.03
Diethyl Phthalate	<0.05	<0.07	0.07†	0.04†	<0.06
Dioctyl Adipate	<0.06	<0.09	<0.08	<0.07	<0.07
2-Ethyl-1-Hexanol	<0.01	<0.02	<0.02	<0.01	<0.01
2-Ethylhexyl Ester of 2,4,-dichlorophenoxy-Acetic Acid	<0.06	<0.09	<0.08	<0.07	<0.07
2-Ethyl-2-Methyl 1,3-Dioxolane	<0.04	<0.05	<0.05	<0.04	<0.04
Geranial	<0.06	<0.09	<0.08	<0.07	<0.07
Heptadecane	0.01*	<0.07	0.03*	0.03*	<0.06
Hexadecane	0.01*	<0.07	<0.06	<0.05	<0.06
Methyl Alpha Ketomyristate	<0.05	<0.07	<0.06	0.03†	<0.06
Methyl Alpha Ketopalmitate	<0.05	<0.07	0.08†	0.03†	<0.06
Methyl Alpha Ketostearate	<0.05	<0.07	<0.06	<0.05	<0.06
Methyl Nervonate	<0.04	<0.05	<0.05	<0.04	<0.04
Nonadecane	0.05*	<0.09	<0.08	<0.07	<0.07
Octadecane	<0.06	<0.09	<0.08	<0.07	<0.07
Ortho-Ethylphenol	<0.03	<0.03	<0.03	<0.03	<0.03
Pentadecane	<0.04	<0.05	<0.05	<0.04	<0.04
Phenyl N-methylcarbamate	<0.03	<0.03	<0.03	<0.03	<0.03
P-Toluic Acid, Methylester	<0.06	<0.09	<0.08	<0.07	<0.07
Pyrene	<0.06	<0.09	<0.08	<0.07	<0.07
Stearic Acid	<0.06	<0.09	<0.08	<0.07	<0.07
Terpinene-4-ol	<0.05	<0.07	<0.06	<0.05	<0.06
Tetradecane	<0.04	<0.05	<0.05	<0.04	<0.04
Toluene	0.07*	<0.02	<0.02	<0.01	<0.01
Tridecane	<0.03	<0.03	<0.03	<0.03	<0.03

* - Compounds identified and confirmed by GC/MS, quantified by GC/FID.

† - Compounds identified by GC/MS ($r \geq 0.900$), quantified by GC/MS.

@ - Compounds identified by GC/MS ($r \geq 0.800$), quantified by GC/MS.

Skeleton Creek Sediment - Date: 5 October 83

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Acetophenone	<0.02	<0.02	<0.01	<0.02	<0.02
Benzaldehyde	<0.02	<0.02	<0.01	<0.02	<0.02
Bis(2-Ethylhexyl)Phthalate	0.16†	<0.09	<0.07	<0.08	<0.08
1-Bromotridecane	<0.08	<0.07	<0.06	<0.07	<0.06
2-Butoxyethanol	<0.04	<0.04	<0.03	<0.03	<0.03
Butyl Carbobutoxymethyl Phthalate	<0.10	<0.09	<0.07	<0.08	<0.08
Carbitol	<0.02	<0.02	<0.01	<0.02	<0.02
Citronellal	<0.04	<0.04	<0.03	<0.03	<0.03
Diethyl Phthalate	<0.08	<0.07	<0.06	<0.07	<0.06
Dioctyl Adipate	<0.10	<0.09	<0.07	<0.08	<0.08
2-Ethyl-1-Hexanol	<0.02	<0.02	<0.01	<0.02	<0.02
2-Ethylhexyl Ester of 2,4,-dichlorophenoxy-Acetic Acid	<0.10	<0.09	<0.07	0.04@	<0.08
2-Ethyl-2-Methyl 1,3-Dioxolane	<0.06	<0.06	<0.04	<0.05	<0.05
Geranial	<0.10	<0.09	<0.07	<0.08	<0.08
Heptadecane	<0.08	0.01*	0.02*	0.04*	0.03*
Hexadecane	0.01*	<0.07	<0.06	0.06†	<0.06
Methyl Alpha Ketomyristate	<0.08	<0.07	<0.06	<0.07	<0.06
Methyl Alpha Ketopalmitate	<0.08	<0.07	<0.06	<0.07	<0.06
Methyl Alpha Ketostearate	<0.08	<0.07	<0.06	0.06†	<0.06
Methyl Nervonate	<0.06	<0.06	<0.04	<0.05	<0.05
Nonadecane	<0.10	<0.09	<0.07	<0.08	<0.08
Octadecane	<0.10	<0.09	<0.07	<0.08	<0.08
Ortho-Ethylphenol	<0.04	<0.04	<0.03	<0.03	<0.03
Pentadecane	<0.06	<0.06	<0.04	0.07†	<0.05
Phenyl N-methylcarbamate	<0.04	<0.04	<0.03	<0.03	<0.03
P-Toluic Acid, Methylester	<0.10	<0.09	<0.07	<0.08	<0.08
Pyrene	<0.10	<0.09	<0.07	0.06@	<0.08
Stearic Acid	<0.10	<0.09	<0.07	0.34†	<0.08
Terpinene-4-ol	<0.08	<0.07	<0.06	<0.07	<0.06
Tetradecane	<0.06	<0.06	<0.04	<0.05	<0.05
Toluene	<0.02	<0.02	<0.01	0.02*	<0.02
Tridecane	<0.04	<0.04	<0.03	<0.03	<0.03

* - Compounds identified and confirmed by GC/MS, quantified by GC/FID.

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@ - Compounds identified by GC/MS ($r \geq 0.800$), quantified by GC/MS.

Skeleton Creek Sediment - Date: 8 December 83

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Acetophenone	<0.01	<0.01	<0.01	<0.01	<0.01
Benzaldehyde	<0.01	<0.01	<0.01	<0.01	<0.01
Bis(2-Ethylhexyl)Phthalate	0.04†	0.09†	0.07†	0.13†	0.07†
1-Bromotridecane	<0.04	<0.05	<0.04	<0.05	<0.05
2-Butoxyethanol	<0.02	<0.02	0.08@	<0.03	<0.03
Butyl Carbobutoxymethyl Phthalate	<0.05	0.20†	0.04†	<0.06	<0.06
Carbitol	<0.01	<0.01	<0.01	<0.01	<0.01
Citronellal	<0.02	<0.02	<0.02	<0.03	<0.03
Diethyl Phthalate	<0.04	<0.05	<0.04	<0.05	<0.05
Dioctyl Adipate	<0.05	1.00†	<0.05	0.09@	<0.06
2-Ethyl-1-Hexanol	<0.01	<0.01	<0.01	<0.01	<0.01
2-Ethylhexyl Ester of 2,4,-dichlorophenoxy-Acetic Acid	<0.05	<0.06	<0.05	<0.06	<0.06
2-Ethyl-2-Methyl 1,3-Dioxolane	<0.03	<0.04	0.56@	<0.04	<0.04
Geranial	<0.05	<0.06	<0.05	<0.06	<0.06
Heptadecane	<0.04	<0.05	<0.04	<0.05	<0.05
Hexadecane	0.01*	0.06†	0.09†	0.09† †	<0.05
Methyl Alpha Ketomyristate	<0.04	<0.05	0.03@	<0.05	<0.05
Methyl Alpha Ketopalmitate	<0.04	<0.05	<0.04	<0.05	<0.05
Methyl Alpha Ketostearate	<0.04	<0.05	<0.04	<0.05	<0.05
Methyl Nervonate	<0.03	<0.04	<0.03	<0.04	<0.04
Nonadecane	0.01†	<0.06	0.03†	<0.06	<0.06
Octadecane	0.01@	<0.06	0.04@	<0.06	<0.06
Ortho-Ethylphenol	<0.02	<0.02	<0.02	<0.03	<0.03
Pentadecane	0.01*	<0.04	<0.03	<0.04	<0.04
Phenyl N-methylcarbamate	<0.02	<0.02	<0.02	<0.03	<0.03
P-Toluic Acid, Methylester	<0.05	<0.06	<0.05	<0.06	<0.06
Pyrene	<0.05	<0.06	<0.05	<0.06	<0.06
Stearic Acid	<0.05	<0.06	<0.05	0.08@	<0.06
Terpinene-4-ol	<0.04	<0.05	0.08@	<0.05	<0.05
Tetradecane	0.02*	0.20*	0.04*	0.01*	<0.04
Toluene	0.01*	0.06*	0.08*	0.10*	<0.03
Tridecane	0.01*	<0.02	<0.02	<0.03	<0.03

* - Compounds identified and confirmed by GC/MS, quantified by GC/FID.

† - Compounds identified by GC/MS ($r \geq 0.900$), quantified by GC/MS.

@ - Compounds identified by GC/MS ($r \geq 0.800$), quantified by GC/MS.

Skeleton Creek Sediment - Date: 1 May 84

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Acetophenone	<0.02	0.06*	<0.03	<0.02	<0.03
Benzaldehyde	<0.02	0.25*	<0.03	<0.02	<0.03
Bis(2-Ethylhexyl)Phthalate	0.00†	<0.23	<0.15	<0.10	<0.14
1-Bromotridecane	<0.06	<0.18	<0.12	<0.08	<0.11
2-Butoxyethanol	<0.03	0.49†	<0.06	<0.04	<0.06
Butyl Carbobutoxymethyl Phthalate	<0.08	<0.23	<0.15	<0.10	<0.14
Carbitol	<0.02	0.63*	<0.03	0.09*	0.24*
Citronellal	<0.03	<0.09	<0.06	<0.04	<0.06
Diethyl Phthalate	<0.06	<0.18	<0.12	<0.08	<0.11
Dioctyl Adipate	<0.08	<0.23	<0.15	<0.10	<0.14
2-Ethyl-1-Hexanol	<0.02	0.54@	<0.03	0.03@	<0.03
2-Ethylhexyl Ester of 2,4,-dichlorophenoxy-Acetic Acid	<0.08	<0.23	<0.15	<0.10	<0.14
2-Ethyl-2-Methyl 1,3-Dioxolane	<0.05	<0.14	<0.09	<0.06	<0.08
Geranial	<0.08	<0.23	<0.15	<0.10	<0.14
Heptadecane	0.08@	0.07*	0.06*	<0.08	0.13†
Hexadecane	0.01*	0.03*	0.02*	0.05*	0.11*
Methyl Alpha Ketomyristate	<0.06	<0.18	<0.12	<0.08	<0.11
Methyl Alpha Ketopalmitate	<0.06	<0.18	<0.12	<0.08	<0.11
Methyl Alpha Ketostearate	<0.06	<0.18	<0.12	<0.08	<0.11
Methyl Nervonate	<0.05	<0.14	<0.09	<0.06	<0.08
Nonadecane	0.09@	<0.23	<0.15	<0.99	<0.14
Octadecane	0.10@	<0.23	<0.15	<0.10	0.09@
Ortho-Ethylphenol	<0.03	0.19*	<0.06	0.23*	0.02*
Pentadecane	0.01*	0.04*	0.02*	<0.06	<0.08
Phenyl N-methylcarbamate	<0.03	<0.09	<0.06	<0.04	<0.06
P-Toluic Acid, Methylester	<0.08	0.13@	<0.15	<0.10	<0.14
Pyrene	<0.08	<0.23	<0.15	<0.10	<0.14
Stearic Acid	0.26@	<0.23	<0.15	<0.10	<0.14
Terpinene-4-ol	<0.06	<0.18	<0.12	<0.08	<0.11
Tetradecane	0.04*	0.13*	0.08*	0.04*	0.03*
Toluene	0.07*	0.27*	<0.03	0.08*	0.12*
Tridecane	0.04*	0.11*	0.03*	0.04*	<0.06

* - Compounds identified and confirmed by GC/MS, quantified by GC/FID.

† - Compounds identified by GC/MS ($r \geq 0.900$), quantified by GC/MS.

@ - Compounds identified by GC/MS ($r \geq 0.800$), quantified by GC/MS.

Skeleton Creek Sediment - Date: 14 August 84

Organic Compound	Site 1	Site 2	Site 3	Site 4	Site 5
Acetophenone	<0.03	<0.03	<0.05	<0.02	<0.02
Benzaldehyde	<0.03	<0.03	<0.05	<0.02	<0.02
Bis(2-Ethylhexyl)Phthalate	<0.17	<0.16	<0.22	<0.08	<0.08
1-Bromotridecane	<0.13	<0.13	<0.18	<0.06	<0.06
2-Butoxyethanol	<0.07	<0.06	<0.09	<0.03	<0.03
Butyl Carbobutoxymethyl Phthalate	<0.17	<0.16	<0.22	<0.08	<0.08
Carbitol	<0.03	<0.03	<0.05	<0.02	<0.02
Citronellal	<0.07	<0.06	<0.09	<0.03	<0.03
Diethyl Phthalate	<0.13	<0.13	<0.18	0.07*	<0.06
Dioctyl Adipate	<0.17	<0.16	<0.22	<0.08	<0.08
2-Ethyl-1-Hexanol	<0.03	<0.03	<0.05	<0.02	<0.02
2-Ethylhexyl Ester of 2,4,-dichlorophenoxy-Acetic Acid	<0.17	<0.16	<0.22	<0.08	<0.08
2-Ethyl-2-Methyl 1,3-Dioxolane	<0.10	<0.09	<0.13	<0.05	<0.05
Geranial	<0.17	<0.16	<0.22	<0.08	<0.08
Heptadecane	<0.13	<0.13	<0.18	<0.06	<0.06
Hexadecane	<0.13	<0.13	<0.18	<0.06	<0.06
Methyl Alpha Ketomyristate	<0.13	<0.13	<0.18	<0.06	<0.06
Methyl Alpha Ketopalmitate	<0.13	<0.13	<0.18	<0.06	<0.06
Methyl Alpha Ketostearate	<0.13	<0.13	<0.18	<0.06	<0.06
Methyl Nervonate	<0.10	<0.09	<0.13	<0.05	<0.05
Nonadecane	<0.17	<0.16	<0.22	<0.08	<0.08
Octadecane	<0.17	<0.16	<0.22	<0.08	<0.08
Ortho-Ethylphenol	<0.07	<0.06	<0.09	<0.03	<0.03
Pentadecane	<0.10	<0.09	<0.13	<0.05	<0.05
Phenyl N-methylcarbamate	<0.07	<0.06	<0.09	<0.03	<0.03
P-Toluic Acid, Methylester	<0.17	<0.16	<0.22	<0.08	<0.08
Pyrene	<0.17	<0.16	<0.22	<0.08	<0.08
Stearic Acid	<0.17	<0.16	<0.22	<0.08	<0.08
Terpinene-4-ol	<0.13	<0.13	<0.18	<0.06	<0.06
Tetradecane	<0.10	<0.09	<0.13	<0.05	<0.05
Toluene	<0.03	<0.03	<0.05	<0.02	<0.02
Tridecane	<0.07	<0.06	<0.09	<0.03	<0.03

* - Compounds identified and confirmed by GC/MS, quantified by GC/FID.

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@ - Compounds identified by GC/MS ($r \geq 0.800$), quantified by GC/MS.

APPENDIX H

CHEMICAL ABSTRACT SERVICE (CAS) REGISTRY NUMBERS FOR ORGANIC COMPOUNDS IDENTIFIED IN SKELETON CREEK WATER AND SEDIMENT SAMPLES COLLECTED DURING THE STUDY PERIOD

Skeleton Creek Water

CAS REGISTRY NUMBER	ORGANIC COMPOUND
99-83-2	Alpha Phellandrene
92-67-1	4-Aminobiphenyl
134-81-6	Benzil
117-81-7	Bis(2-Ethylhexyl)Phthalate
507-70-0	Borneol
111-76-2	2-Butoxyethanol
------	Butyl Carbobutoxymethyl Phthalate
142-62-1	Caproic Acid
111-90-0	Carbitol
77-65-6	Carbromal
99-49-0	Carvone
5197-62-6	2-(2-(2-Chloroethoxy) Ethoxy) Ethanol
99-87-6	Cymene
77-39-4	Cycrimine
124-18-5	Decane
106-46-7	1,4-Dichlorobenzene
5293-97-0	p,p'-Dichlorobenzophenone
1198-37-4	2,4-Dimethyl Quinoline
84-66-2	Diethyl Phthalate
131-11-3	Dimethyl Phthalate
105-23-1	Dioctyl Adipate
101-84-8	Diphenyl Ether
587-85-9	Diphenyl Mercury
112-40-3	Dodecane
------	Ethosuximide-N-Ethyl Derivative
104-76-7	2-Ethyl-1-Hexanol
101-97-3	Ethylphenylacetate
629-78-7	Heptadecane
544-76-3	Hexadecane
107-75-5	Hydroxycitronellal
53-86-1	Indomethacin Methyl Ester
------	Menthene Isomer
------	1-Methyl-1-Methoxy-3(3,4-Dichlorophenyl Urea
------	Methyl Alpha Ketomyristate
------	Methyl Alpha Ketostearate
110-42-9	Methyl Caprate
------	Methyl Eicosatrienoate
1731-92-6	Methyl Heptadecanoate
------	Methyl Isostearate
------	Methyl Nervonate
------	Methyl Octacosanoate
2433-97-8	Methyl Tricosanoate
91-20-3	Naphthalene
5392-40-5	Neral
112-80-1	Oleic Acid
629-62-9	Pentadecane
108-95-2	Phenol
1982-49-6	Siduron
------	2,6-Di-Tert-Butyl-4-Methyl Phenyl-N-Methylcarbamate

Skeleton Creek Water (Continued)

CAS REGISTRY NUMBER	ORGANIC COMPOUND
18479-63-5	Terpinene-4-ol
629-59-4	Tetradecane
------	Thujyl Alcohol Isomer
108-88-3	Toluene
------	Tri-2-Butoxymethyl Phosphate
732-26-3	4-Tri-Butylphenol
1120-21-4	Undecane

Skeleton Creek Sediment

CAS REGISTRY NUMBER	ORGANIC COMPOUND
98-86-2	Acetophenone
100-52-7	Benzaldehyde
117-81-7	Bis(2-Ethylhexyl)Phthalate
765-09-3	1-Bromotridecane
111-76-2	2-Butoxyethanol
------	Butyl Carbobutoxymethyl Phthalate
111-90-0	Carbitol
106-23-0	Citronellal
84-66-2	Diethyl Phthalate
105-23-1	Dioctyl Adipate
104-76-7	2-Ethyl-1-Hexanol
1928-43-4	2-Ethylhexyl Ester of 2,4,-dichlorophenoxy-Acetic Acid
126-39-6	2-Ethyl-2-Methyl 1,3- Dioxolane
5392-40-5	Geranial
629-78-7	Heptadecane
544-76-3	Hexadecane
------	Methyl Alpha Ketomyristate
------	Methyl Alpha Ketopalmitate
------	Methyl Alpha Ketostearate
------	Methyl Nervonate
629-92-5	Nonadecane
593-45-3	Octadecane
90-00-6	Ortho-Ethylphenol
629-62-9	Pentadecane
2603-10-3	Phenyl N-methylcarbamate
99-75-2	P-Toluic Acid, Methylester
129-00-0	Pyrene
57-11-4	Stearic Acid
18479-63-5	Terpinene-4-ol
629-59-4	Tetradecane
108-88-3	Toluene
629-50-5	Tridecane

APPENDIX I

TOTAL CONCENTRATION OF ORGANIC COMPOUNDS IN SKELETON CREEK WATER (ug/l) AND SEDIMENT (ug/g) SAMPLES COLLECTED DURING THE STUDY PERIOD

Sample Identification	Date	Water	Sediment
Station 1	8-12-82	18.48	<0.02
Station 2	" "	27.83	3.51
Station 3	" "	35.25	4.77
Station 4	" "	20.15	0.28
Station 5	" "	6.23	0.12
Station 1	12-7-82	1.07	1.27
Station 2	" "	6.04	1.54
Station 3	" "	0.36	1.01
Station 4	" "	0.08	1.20
Station 5	" "	0.60	0.30
Station 1	4-27-83	1.56	<0.02
Station 2	" "	0.82	0.02
Station 3	" "	0.12	0.07
Station 4	" "	<0.08	0.97
Station 5	" "	0.34	<0.02
Station 1	7-6-83	4.35	0.23
Station 2	" "	3.76	2.18
Station 3	" "	3.59	0.32
Station 4	" "	3.64	0.27
Station 5	" "	0.44	0.03
Station 1	10-5-83	5.15	0.10
Station 2	" "	27.41	0.04
Station 3	" "	15.01	0.05
Station 4	" "	14.67	0.35
Station 5	" "	6.75	0.07
Station 1	12-8-83	3.70	0.14
Station 2	" "	277.86	0.81
Station 3	" "	413.98	0.81
Station 4	" "	85.08	0.25
Station 5	" "	6.83	0.04
Station 1	5-1-84	2.40	0.47
Station 2	" "	3.16	2.76
Station 3	" "	4.49	0.17
Station 4	" "	0.69	0.29
Station 5	" "	0.33	0.30
Station 1	8-14-84	0.84	0.12
Station 2	" "	1.29	0.02
Station 3	" "	1.49	<0.02
Station 4	" "	2.00	0.04
Station 5	" "	2.07	<0.02

APPENDIX J

SPECIES LIST AND NUMBER OF BENTHIC ORGANISMS FOUND AT EACH SKELETON CREEK SAMPLING SITE DURING THE STUDY PERIOD

Skeleton Creek - Date: 12 August 82

	Site 1	Site 2	Site 3	Site 4	Site 5
Insecta					
Ephemeroptera					
Caenidae					
Caenis	84	-	2	6	1
Baetidae					
Baetis	121	-	1	11	3
Tricorythidae					
Tricorythodes	-	-	-	8	76
Heptageniidae					
Stenonema	-	-	-	-	-
Hemiptera					
Gerridae					
Trepobates	-	-	-	-	-
Corixidae					
Trichocorixa	1	-	9	-	-
Trichocorixa verticalis interiores	-	-	-	21	-
Trichocorixa kanza	-	-	-	8	1
Sigara alternata	-	-	2	-	-
Saldidae	-	-	-	2	-
Veliidae					
Rhagovelia	-	-	-	4	-
Mesoveliidae					
Mesovelia mulsanti	-	-	-	-	2
Odonata					
Gomphidae					
Ophiogomphus	-	-	-	1	-
Progomphus	5	2	-	-	-
Erpetogomphus	-	-	-	-	-
Dromogomphus	-	-	-	-	2
Gomphus	-	-	-	-	-
Coenagrionidae					
Argia sp. A	7	-	-	2	2
Argia moesta	-	-	-	12	23
Ischnura	-	-	-	-	-
Enallagma	-	-	-	-	-
Libellulidae					
Perithemis tenera	-	-	-	-	-
Plathemis lydia	-	-	-	-	-
Plathemis subornata	-	-	-	-	-
Megaloptera					
Corydalidae					
Corydalus	-	-	-	-	14

Skeleton Creek - Date: 12 August 82

	Site 1	Site 2	Site 3	Site 4	Site 5
Coleoptera					
Heteroceridae	-	-	-	-	-
Hydrophilidae					
Helophorus	-	-	-	-	-
Ametor	-	-	-	-	-
Berosus	24	2	99	22	-
Enochrus	-	-	-	4	-
Paracymus	-	-	-	3	-
Tropisternus	-	-	2	-	-
Laccobius	-	-	-	-	1
Haliplidae	-	-	-	-	-
Dytiscidae					
Laccophilus	1	29	-	-	-
Gyrinidae					
Dineutus	-	-	9	-	-
Elmidae					
Dubiraphia	-	-	-	-	-
Stenelmis	1	-	-	41	154
Dryopidae					
Helichus	-	-	-	-	1
Lepidoptera	1	-	-	-	-
Trichoptera					
Hydropsychidae					
Cheumatopsyche	12	-	1	271	429
Hydropsyche	-	-	-	26	11
Hydroptilidae					
Hydroptila	20	-	-	118	5
Leptoceridae					
Oecetis	1	-	-	-	3
Polycentropodidae					
Cyrnellus	-	-	-	-	2
Diptera					
Ceratopogonidae					
Forcipomyia	-	-	-	1	-
Palpomyia sp. #1	15	-	2	-	1
Palpomyia sp. #2	2	-	-	-	-
Stratiomyidae					
Caloparyphus	-	-	-	-	-
Simuliidae					
Simulium (larvae only)	-	-	-	1	-
Empididae	-	1	-	17	13
Tipulidae					
Erioptera	-	-	2	-	-
Culicidae					
Culex	-	-	-	-	-

Skeleton Creek - Date: 12 August 82

	Site 1	Site 2	Site 3	Site 4	Site 5
Chironomidae					
Tanypodinae					
Ablabesmyia sp.	184	-	1	-	-
Ablabesmyia mallochi	70	-	-	-	-
Clinotanypus	-	-	-	-	-
Natarsia	-	-	103	11	3
Pentaneura	-	-	-	-	-
Procladius	5	-	-	-	-
Tanypus	5	1	1	-	-
Thienemannimyia gr.	-	45	2	24	11
Zavrelimyia	-	2	-	-	-
Chironominae					
Chironomus	269	16	3	-	5
Cladotanytarsus	133	1	-	-	-
Cryptochironomus	24	3	3	1	1
Dicrotendipes sp.	-	-	-	-	47
Dicrotendipes neomodestus	467	74	191	16	37
Dicrotendipes nervosus(I)	-	-	-	-	-
Glyptotendipes	15	-	9	15	85
Goeldichironomous holopra.	-	1	-	-	-
Harnischia	-	1	-	-	-
Lenziella	-	-	-	2	-
Parachironomus	-	-	-	3	1
Paracladopelma	-	-	-	-	-
Paratanytarsus	3	-	-	-	-
Paratendipes	-	-	-	-	-
Phaenopsectra	-	-	-	-	-
Polypedilum convictum	54	3	123	318	343
Polypedilum illinoense	200	31	25	52	9
Polypedilum scalaenum	659	15	3	3	8
Pseudochironomus	2	-	-	3	11
Rheotanytarsus exiguus gr.	6	-	-	3	2
Tanytarsini sp. #1	83	5	14	2	-
Tanytarsus sp. #1	135	-	-	-	-
Tanytarsus glabrescens gr.	176	-	4	41	6
Tanytarsus guerlus gr.	56	-	-	-	-
Orthocladiinae					
Cricotopus sp.	144	-	143	17	9
Cricotopus sp. A	-	-	-	-	-
Cricotopus sp. B	-	-	-	-	-
Cricotopus sp. C	-	-	-	-	-
Cricotopus sp. D	-	-	-	-	-
Cricotopus bicinctus	134	3	5	3	-
Cricotopus trifascia gr.	-	-	-	-	-
Hydrobaenus	-	-	-	-	-
Nanocladius	1	-	1	-	-
Parametriocnemus	-	-	-	-	-
Rheocricotopus	-	-	-	-	-
Thienemanniella	-	-	-	-	-

Skeleton Creek - Date: 12 August 82

	Site 1	Site 2	Site 3	Site 4	Site 5
Mollusca					
Gastropoda					
Physidae - *Physella*	54	104	1	213	-
Ancylidae - *Ferrissia*	-	-	-	-	1
Pelecypoda					
Pisidiidae - *Musculium*	27	32	-	-	-
Annelida					
Oligochaeta					
Naididae					
Bratislaria unidertata	-	-	-	-	-
Chaetogaster diastrophus	-	-	-	-	-
Dero furcata	31	6	13	-	3
Dero nivea	1	-	-	-	-
Dero obtusa	1	-	-	-	-
Homochaeta naidina	2	3	3	-	-
Nais communis	-	-	-	-	-
Nais elinguis	-	-	-	-	-
Nais paradalis	-	-	-	-	-
Paranais litoralis	-	1	-	-	-
Pristina sp.	3	-	-	2	-
Pristina idrensis	-	-	-	-	-
Pristina longiseta	-	-	-	2	-
Pristina osborni	-	-	-	-	-
Specaria josinae	10	-	-	-	-
Stephensoniana trivand.	-	-	-	-	-
Tubificidae					
Aulodrilus piqueti	-	-	-	-	-
Branchiura sowerbyi	1	-	-	61	12
Limnodrilus cervix	7	-	1	1	1
Limnodrilus hoffmeisteri	3	3	13	1	-
Limnodrilus udekemianus	2	-	39	17	-
Rhyacodrilus coccineus	-	-	-	-	-
Rhyacodrilus montana	-	-	-	-	-
unid w/o capill. chaet.	19	16	35	39	1
unid w/ capill. chaet.	1	-	-	-	-
unid w/ sim. point.chaet.	-	-	-	-	-
Hirudinea					
Hirudinidae					
Haemopis	-	-	-	-	-
Erpobdellidae					
Mooreobdella microstoma	-	1	-	-	-
Glossiphoniidae					
Helobdella triserialis	-	-	-	-	-
Coelenterata (*Hydra*)	-	-	-	-	-
Crustacea					
Amphipoda					
Talitridae					
Hyallela azteca	-	-	-	1	-
Decapoda (crayfish)	-	-	-	-	-

Skeleton Creek - Date: 7 December 82

	Site 1	Site 2	Site 3	Site 4	Site 5
Insecta					
Ephemeroptera					
Caenidae					
Caenis	7	7	-	-	-
Baetidae					
Baetis	2	-	-	-	-
Tricorythidae					
Tricorythodes	-	-	-	-	2
Heptageniidae					
Stenonema	-	-	-	-	-
Hemiptera					
Gerridae					
Trepobates	-	-	-	-	-
Corixidae					
Trichocorixa	-	-	2	-	-
Trichocorixa verticalis interiores	-	-	-	-	-
Trichocorixa kanza	-	-	-	-	-
Sigara alternata	-	-	-	-	-
Saldidae	-	-	-	-	-
Veliidae					
Rhagovelia	-	-	-	-	-
Mesoveliidae					
Mesovelia mulsanti	-	-	-	-	-
Odonata					
Gomphidae					
Ophiogomphus	-	-	-	-	-
Progomphus	-	14	-	2	-
Erpetogomphus	-	1	-	1	-
Dromogomphus	-	-	-	-	-
Gomphus	-	-	-	-	-
Coenagrionidae					
Argia sp. A	-	-	-	1	-
Argia moesta	-	-	1	17	4
Ischnura	-	-	1	-	-
Enallagma	-	-	-	-	-
Libellulidae					
Perithemis tenera	-	-	-	-	-
Plathemis lydia	-	-	-	-	-
Plathemis subornata	-	-	-	-	-
Megaloptera					
Corydalidae					
Corydalus	-	-	-	-	22

Skeleton Creek - Date: 7 December 82

	Site 1	Site 2	Site 3	Site 4	Site 5
Coleoptera					
Heteroceridae	-	-	-	-	-
Hydrophilidae					
Helophorus	-	-	-	-	-
Ametor	-	-	-	-	-
Berosus	8	3	30	41	5
Enochrus	-	-	-	-	-
Paracymus	-	-	-	-	-
Tropisternus	-	-	-	-	-
Laccobius	-	-	-	-	-
Haliplidae	-	-	1	-	-
Dytiscidae					
Laccophilus	-	-	-	-	-
Gyrinidae					
Dineutus	-	-	1	-	-
Elmidae					
Dubiraphia	-	-	-	-	-
Stenelmis	-	-	-	267	475
Dryopidae					
Helichus	-	-	-	3	5
Lepidoptera	-	-	-	-	-
Trichoptera					
Hydropsychidae					
Cheumatopsyche	9	1	1	716	4650
Hydropsyche	-	-	-	63	706
Hydroptilidae					
Hydroptila	3	-	-	49	5
Leptoceridae					
Oecetis	-	-	-	-	-
Polycentropodidae					
Cyrnellus	-	-	-	-	-
Diptera					
Ceratopogonidae					
Forcipomyia	-	-	-	-	-
Palpomyia sp. #1	-	-	-	-	3
Palpomyia sp. #2	-	1	-	1	3
Stratiomyidae					
Caloparyphus	-	-	-	-	-
Simuliidae					
Simulium (larvae only)	5	1	11	187	255
Empididae	-	-	-	-	49
Tipulidae					
Erioptera	20	21	2	-	4
Culicidae					
Culex	-	-	-	-	-

Skeleton Creek - Date: 7 December 82

	Site 1	Site 2	Site 3	Site 4	Site 5
Chironomidae					
Tanypodinae					
Ablabesmyia sp.	-	-	-	-	-
Ablabesmyia mallochi	-	-	-	-	-
Clinotanypus	-	-	-	-	-
Natarsia	-	-	-	2	-
Pentaneura	-	-	1	5	-
Procladius	-	-	-	-	-
Tanypus	-	-	-	-	-
Thienemannimyia gr.	5	4	10	91	88
Zavrelimyia	-	1	1	-	-
Chironominae					
Chironomus	-	1	4	13	7
Cladotanytarsus	-	-	-	-	-
Cryptochironomus	3	3	-	5	1
Dicrotendipes sp.	-	-	-	-	36
Dicrotendipes neomodestus	1	8	1	3	110
Dicrotendipes nervosus(I)	-	-	-	-	3
Glyptotendipes	-	-	-	9	120
Goeldichironomous holopra.	-	-	-	-	-
Harnischia	-	-	-	-	-
Lenziella	-	-	-	-	-
Parachironomus	-	-	-	-	-
Paracladopelma	-	-	-	-	-
Paratanytarsus	-	-	-	1	-
Paratendipes	-	-	-	-	-
Phaenopsectra	-	-	-	-	-
Polypedilum convictum	-	-	-	16	373
Polypedilum illinoense	-	-	-	7	2
Polypedilum scalaenum	-	-	-	6	-
Pseudochironomus	-	-	-	-	15
Rheotanytarsus exiguus gr.	-	-	-	-	2
Tanytarsini sp. #1	-	-	-	-	-
Tanytarsus sp. #1	-	-	-	-	-
Tanytarsus glabrescens gr.	-	-	-	4	1
Tanytarsus guerlus gr.	-	-	-	1	-
Orthocladiinae					
Cricotopus sp.	-	-	-	2	9
Cricotopus sp. A	153	67	46	29	17
Cricotopus sp. B	-	1	2	1	9
Cricotopus sp. C	-	2	3	6	106
Cricotopus sp. D	-	11	2	3	6
Cricotopus bicinctus	1	1	-	1	4
Cricotopus trifascia gr.	-	-	-	-	-
Hydrobaenus	-	-	-	-	-
Nanocladius	-	-	-	-	-
Parametriocnemus	-	-	-	-	1
Rheocricotopus	-	-	-	-	-
Thienemanniella	-	-	-	1	1

Skeleton Creek - Date: 7 December 82

	Site 1	Site 2	Site 3	Site 4	Site 5
Mollusca					
Gastropoda					
Physidae - Physella	23	14	2	911	34
Ancylidae - Ferrissia	-	-	2	5	-
Pelecypoda					
Pisidiidae - Musculium	9	27	-	2	111
Annelida					
Oligochaeta					
Naididae					
Bratislaria unidertata	-	-	-	-	16
Chaetogaster diastrophus	-	4	-	-	4
Dero furcata	-	-	-	-	-
Dero nivea	-	-	-	-	-
Dero obtusa	-	-	-	-	1
Homochaeta naidina	-	-	-	-	-
Nais communis	-	-	-	1	-
Nais elinguis	-	-	-	-	-
Nais paradalis	-	-	-	66	730
Paranais litoralis	-	-	-	-	-
Pristina sp.	-	-	-	-	-
Pristina idrensis	-	-	-	-	54
Pristina longiseta	-	-	-	79	419
Pristina osborni	-	-	-	-	3
Specaria josinae	-	-	-	7	16
Stephensoniana trivand.	-	-	-	-	13
Tubificidae					
Aulodrilus piqueti	-	2	-	37	2
Branchiura sowerbyi	9	-	-	150	25
Limnodrilus cervix	18	4	102	13	5
Limnodrilus hoffmeisteri	20	1	33	110	4
Limnodrilus udekemianus	6	2	16	6	5
Rhyacodrilus coccineus	-	-	-	2	-
Rhyacodrilus montana	-	-	-	-	-
unid w/o capill. chaet.	43	14	84	544	103
unid w/ capill. chaet.	1	-	-	-	-
unid w/ sim. point.chaet.	-	-	-	-	-
Hirudinea					
Hirudinidae					
Haemopis	-	-	-	-	-
Erpobdellidae					
Mooreobdella microstoma	-	1	-	1	-
Glossiphoniidae					
Helobdella triserialis	-	-	-	-	-
Coelenterata (Hydra)	-	-	-	-	-
Crustacea					
Amphipoda					
Talitridae					
Hyallela azteca	-	-	-	-	-
Decapoda (crayfish)	-	-	-	-	-

Skeleton Creek - Date: 27 April 83

	Site 1	Site 2	Site 3	Site 4	Site 5
Insecta					
Ephemeroptera					
Caenidae					
Caenis	37	8	-	-	-
Baetidae					
Baetis	-	-	-	-	-
Tricorythidae					
Tricorythodes	-	-	-	-	-
Heptageniidae					
Stenonema	-	-	-	-	-
Hemiptera					
Gerridae					
Trepobates	-	-	-	-	-
Corixidae					
Trichocorixa	-	1	-	-	-
Trichocorixa verticalis interiores	-	-	-	-	-
Trichocorixa kanza	-	-	-	-	-
Sigara alternata	-	-	-	-	-
Saldidae	-	-	-	-	-
Veliidae					
Rhagovelia	-	-	-	-	-
Mesoveliidae					
Mesovelia mulsanti	-	-	-	-	-
Odonata					
Gomphidae					
Ophiogomphus	-	-	-	-	-
Progomphus	1	1	2	-	-
Erpetogomphus	1	-	-	2	-
Dromogomphus	-	-	-	-	-
Gomphus	-	-	-	-	-
Coenagrionidae					
Argia sp. A	-	-	2	-	-
Argia moesta	-	-	-	2	-
Ischnura	1	-	-	-	-
Enallagma	-	-	-	-	-
Libellulidae					
Perithemis tenera	-	-	-	-	-
Plathemis lydia	-	-	-	-	-
Plathemis subornata	-	-	-	-	-
Megaloptera					
Corydalidae					
Corydalus	-	-	-	-	3

Skeleton Creek - Date: 27 April 83

	Site 1	Site 2	Site 3	Site 4	Site 5
Coleoptera					
Heteroceridae	-	-	-	-	-
Hydrophilidae					
Helophorus	-	-	-	-	-
Ametor	-	-	-	-	-
Berosus	-	-	1	-	4
Enochrus	-	-	-	-	-
Paracymus	-	-	-	-	-
Tropisternus	-	-	-	-	-
Laccobius	-	-	-	-	-
Haliplidae	-	-	-	-	-
Dytiscidae					
Laccophilus	-	-	-	-	-
Gyrinidae					
Dineutus	-	-	-	-	-
Elmidae					
Dubiraphia	-	-	-	-	-
Stenelmis	-	-	-	6	160
Dryopidae					
Helichus	-	-	-	-	-
Lepidoptera	-	-	-	-	-
Trichoptera					
Hydropsychidae					
Cheumatopsyche	-	-	-	1	45
Hydropsyche	-	-	-	-	9
Hydroptilidae					
Hydroptila	-	-	-	-	1
Leptoceridae					
Oecetis	-	-	-	-	-
Polycentropodidae					
Cyrnellus	-	-	-	-	-
Diptera					
Ceratopogonidae					
Forcipomyia	-	-	-	-	-
Palpomyia sp. #1	1	1	-	-	-
Palpomyia sp. #2	-	-	-	-	-
Stratiomyidae					
Caloparyphus	-	-	-	-	-
Simuliidae					
Simulium (larvae only)	-	-	-	-	19
Empididae	-	-	-	-	2
Tipulidae					
Erioptera	5	-	-	-	-
Culicidae					
Culex	-	-	-	-	-

Skeleton Creek - Date: 27 April 83

	Site 1	Site 2	Site 3	Site 4	Site 5
Chironomidae					
Tanypodinae					
Ablabesmyia sp.	-	-	-	-	-
Ablabesmyia mallochi	-	-	-	-	-
Clinotanypus	-	-	-	-	-
Natarsia	-	-	-	-	-
Pentaneura	-	-	-	-	-
Procladius	-	-	-	-	-
Tanypus	-	-	-	-	-
Thienemannimyia gr.	-	1	-	10	1
Zavrelimyia	-	-	-	-	-
Chironominae					
Chironomus	-	-	-	-	-
Cladotanytarsus	-	-	-	-	-
Cryptochironomus	2	-	-	2	-
Dicrotendipes sp.	-	-	-	-	-
Dicrotendipes neomodestus	-	-	7	2	20
Dicrotendipes nervosus(I)	-	-	-	-	-
Glyptotendipes	-	-	-	-	3
Goeldichironomous holopra.	-	-	-	-	-
Harnischia	-	-	-	-	-
Lenziella	-	-	-	-	-
Parachironomus	-	-	-	-	-
Paracladopelma	-	-	-	-	-
Paratanytarsus	-	-	-	-	-
Paratendipes	-	-	-	-	-
Phaenopsectra	-	-	-	-	-
Polypedilum convictum	-	-	-	-	16
Polypedilum illinoense	-	-	-	-	-
Polypedilum scalaenum	-	-	1	2	1
Pseudochironomus	-	-	-	-	3
Rheotanytarsus exiguus gr.	-	-	-	-	-
Tanytarsini sp. #1	-	-	-	-	-
Tanytarsus sp. #1	-	-	-	-	-
Tanytarsus glabrescens gr.	-	-	-	-	1
Tanytarsus guerlus gr.	-	-	-	-	-
Orthocladiinae					
Cricotopus sp.	-	-	-	-	-
Cricotopus sp. A	56	13	16	26	77
Cricotopus sp. B	2	-	-	1	1
Cricotopus sp. C	4	1	-	-	10
Cricotopus sp. D	-	-	-	-	-
Cricotopus bicinctus	-	-	-	-	1
Cricotopus trifascia gr.	-	-	-	-	-
Hydrobaenus	-	-	-	-	-
Nanocladius	-	-	-	-	-
Parametriocnemus	-	-	-	1	-
Rheocricotopus	-	-	-	-	-
Thienemanniella	-	-	-	-	-

Skeleton Creek - Date: 27 April 83

	Site 1	Site 2	Site 3	Site 4	Site 5
Mollusca					
Gastropoda					
Physidae - Physella	8	-	-	13	-
Ancylidae - Ferrissia	-	-	-	-	-
Pelecypoda					
Pisidiidae - Musculium	8	8	-	-	5
Annelida					
Oligochaeta					
Naididae					
Bratislaria unidertata	-	-	-	-	-
Chaetogaster diastrophus	3	-	-	-	-
Dero furcata	-	-	-	-	-
Dero nivea	-	-	-	-	-
Dero obtusa	-	-	1	-	-
Homochaeta naidina	-	-	-	-	-
Nais communis	119	-	-	-	74
Nais elinguis	28	-	3	2	10
Nais paradalis	26	6	2	-	7
Paranais litoralis	-	-	-	-	-
Pristina sp.	-	-	-	-	-
Pristina idrensis	-	-	-	-	-
Pristina longiseta	1	-	-	-	-
Pristina osborni	-	-	-	-	-
Specaria josinae	11	1	9	-	-
Stephensoniana trivand.	-	-	-	-	-
Tubificidae					
Aulodrilus piqueti	-	-	-	3	-
Branchiura sowerbyi	-	-	-	17	7
Limnodrilus cervix	1	5	3	12	1
Limnodrilus hoffmeisteri	12	4	17	28	5
Limnodrilus udekemianus	2	-	9	10	12
Rhyacodrilus coccineus	-	-	-	-	-
Rhyacodrilus montana	-	1	-	-	-
unid w/o capill. chaet.	26	7	10	73	10
unid w/ capill. chaet.	-	-	-	-	-
unid w/ sim. point.chaet.	-	-	-	-	-
Hirudinea					
Hirudinidae					
Haemopis	-	-	-	-	-
Erpobdellidae					
Mooreobdella microstoma	-	1	-	-	-
Glossiphoniidae					
Helobdella triserialis	-	-	-	1	-
Coelenterata (Hydra)	-	-	-	-	-
Crustacea					
Amphipoda					
Talitridae					
Hyallela azteca	-	-	-	-	-
Decapoda (crayfish)	-	-	-	-	-

Skeleton Creek - Date: 6 July 83

	Site 1	Site 2	Site 3	Site 4	Site 5
Insecta					
Ephemeroptera					
Caenidae					
Caenis	11	1	3	-	-
Baetidae					
Baetis	-	-	-	3	1
Tricorythidae					
Tricorythodes	-	-	-	-	-
Heptageniidae					
Stenonema	-	-	-	-	1
Hemiptera					
Gerridae					
Trepobates	1	2	-	5	-
Corixidae					
Trichocorixa	1	3	16	-	-
Trichocorixa verticalis interiores	-	-	-	-	-
Trichocorixa kanza	-	-	-	-	-
Sigara alternata	-	-	-	-	-
Saldidae	-	-	-	-	-
Veliidae					
Rhagovelia	-	-	-	-	-
Mesoveliidae					
Mesovelia mulsanti	-	-	-	-	-
Odonata					
Gomphidae					
Ophiogomphus	-	-	-	-	-
Progomphus	-	1	-	-	-
Erpetogomphus	-	-	-	-	-
Dromogomphus	-	-	-	-	-
Gomphus	-	-	-	-	-
Coenagrionidae					
Argia sp. A	-	-	-	-	-
Argia moesta	-	-	-	-	1
Ischnura	-	-	-	-	-
Enallagma	-	-	-	-	-
Libellulidae					
Perithemis tenera	-	-	-	-	-
Plathemis lydia	-	-	-	-	-
Plathemis subornata	-	-	-	-	-
Megaloptera					
Corydalidae					
Corydalus	-	-	-	-	-

Skeleton Creek - Date: 6 July 83

	Site 1	Site 2	Site 3	Site 4	Site 5
Coleoptera					
Heteroceridae	-	-	-	-	-
Hydrophilidae					
Helophorus	-	-	-	-	-
Ametor	-	-	-	-	-
Berosus	-	-	41	1	-
Enochrus	-	-	-	-	-
Paracymus	-	-	-	-	-
Tropisternus	-	-	-	-	-
Laccobius	-	-	1	-	-
Haliplidae	-	-	-	-	-
Dytiscidae					
Laccophilus	-	-	-	-	-
Gyrinidae					
Dineutus	-	-	-	-	-
Elmidae					
Dubiraphia	-	-	-	-	-
Stenelmis	-	-	-	90	36
Dryopidae					
Helichus	-	-	-	5	13
Lepidoptera	-	-	-	-	-
Trichoptera					
Hydropsychidae					
Cheumatopsyche	-	-	-	15	25
Hydropsyche	-	-	-	25	40
Hydroptilidae					
Hydroptila	-	-	-	3	-
Leptoceridae					
Oecetis	-	-	-	-	-
Polycentropodidae					
Cyrnellus	-	-	-	-	-
Diptera					
Ceratopogonidae					
Forcipomyia	-	-	-	-	-
Palpomyia sp. #1	1	-	-	-	-
Palpomyia sp. #2	-	-	-	-	-
Stratiomyidae					
Caloparyphus	-	-	-	-	-
Simuliidae					
Simulium (larvae only)	-	-	2	3	-
Empididae	-	-	-	2	-
Tipulidae					
Erioptera	-	-	-	-	-
Culicidae					
Culex	-	-	-	-	-

Skeleton Creek - Date: 6 July 83

	Site 1	Site 2	Site 3	Site 4	Site 5
Chironomidae					
Tanypodinae					
Ablabesmyia sp.	-	-	-	-	-
Ablabesmyia mallochi	-	-	-	-	-
Clinotanypus	-	-	-	-	-
Natarsia	-	-	-	-	-
Pentaneura	-	-	-	-	-
Procladius	-	-	-	-	-
Tanypus	-	1	-	-	-
Thienemannimyia gr.	20	12	10	35	1
Zavrelimyia	-	-	-	-	-
Chironominae					
Chironomus	-	1	3	-	-
Cladotanytarsus	-	-	-	-	-
Cryptochironomus	1	-	-	1	-
Dicrotendipes sp.	-	-	-	-	-
Dicrotendipes neomodestus	1	-	3	-	-
Dicrotendipes nervosus(I)	-	-	-	-	-
Glyptotendipes	-	-	-	-	-
Goeldichironomous holopra.	-	-	-	-	-
Harnischia	-	-	-	-	-
Lenziella	-	-	-	-	-
Parachironomus	-	-	-	3	-
Paracladopelma	-	-	-	-	-
Paratanytarsus	-	-	-	-	-
Paratendipes	-	-	-	-	-
Phaenopsectra	-	-	-	-	-
Polypedilum convictum	-	-	15	150	10
Polypedilum illinoense	25	3	90	27	6
Polypedilum scalaenum	1	1	-	-	-
Pseudochironomus	-	-	-	-	-
Rheotanytarsus exiguus gr.	-	-	3	2	2
Tanytarsini sp. #1	-	-	-	-	-
Tanytarsus sp. #1	-	-	-	-	-
Tanytarsus glabrescens gr.	-	-	-	10	4
Tanytarsus guerlus gr.	-	-	1	-	-
Orthocladiinae					
Cricotopus sp.	-	-	-	-	-
Cricotopus sp. A	34	4	77	16	-
Cricotopus sp. B	-	-	-	-	-
Cricotopus sp. C	5	-	15	5	-
Cricotopus sp. D	-	-	-	-	-
Cricotopus bicinctus	-	-	-	1	-
Cricotopus trifascia gr.	-	-	-	-	-
Hydrobaenus	-	-	-	-	-
Nanocladius	-	-	11	2	-
Parametriocnemus	-	-	-	-	-
Rheocricotopus	-	-	-	-	-
Thienemanniella	-	-	-	-	-

Skeleton Creek - Date: 6 July 83

	Site 1	Site 2	Site 3	Site 4	Site 5
Mollusca					
Gastropoda					
Physidae - *Physella*	1	1	-	-	-
Ancylidae - *Ferrissia*	-	-	-	-	-
Pelecypoda					
Pisidiidae - *Musculium*	-	8	-	-	2
Annelida					
Oligochaeta					
Naididae					
Bratislaria unidertata	-	-	-	-	-
Chaetogaster diastrophus	-	-	-	-	-
Dero furcata	-	-	-	-	-
Dero nivea	-	-	-	-	-
Dero obtusa	-	-	-	-	-
Homochaeta naidina	-	-	-	-	-
Nais communis	-	-	2	-	-
Nais elinguis	-	-	-	-	-
Nais paradalis	-	-	-	-	-
Paranais litoralis	-	-	-	-	-
Pristina sp.	-	-	-	-	-
Pristina idrensis	-	-	-	-	-
Pristina longiseta	-	-	-	-	-
Pristina osborni	-	-	-	2	-
Specaria josinae	-	-	-	-	-
Stephensoniana trivand.	-	-	-	-	-
Tubificidae					
Aulodrilus piqueti	-	-	-	-	-
Branchiura sowerbyi	-	-	-	46	2
Limnodrilus cervix	1	-	1	-	-
Limnodrilus hoffmeisteri	8	4	4	8	-
Limnodrilus udekemianus	4	4	8	27	1
Rhyacodrilus coccineus	-	-	-	-	-
Rhyacodrilus montana	-	-	-	-	-
unid w/o capill. chaet.	14	7	17	75	1
unid w/ capill. chaet.	-	-	-	-	-
unid w/ sim. point.chaet.	-	-	-	-	-
Hirudinea					
Hirudinidae					
Haemopis	-	-	-	-	-
Erpobdellidae					
Mooreobdella microstoma	-	-	-	-	-
Glossiphoniidae					
Helobdella triserialis	-	-	1	1	-
Coelenterata (*Hydra*)	-	-	-	-	-
Crustacea					
Amphipoda					
Talitridae					
Hyallela azteca	-	-	-	-	-
Decapoda (crayfish)	-	-	-	-	-

Skeleton Creek - Date: 5 October 83

	Site 1	Site 2	Site 3	Site 4	Site 5
Insecta					
Ephemeroptera					
Caenidae					
Caenis	15	-	1	-	1
Baetidae					
Baetis	16	8	14	69	12
Tricorythidae					
Tricorythodes	-	-	-	43	45
Heptageniidae					
Stenonema	-	-	-	-	-
Hemiptera					
Gerridae					
Trepobates	-	-	-	-	-
Corixidae					
Trichocorixa	-	-	4	-	-
Trichocorixa verticalis interiores	-	-	1	-	-
Trichocorixa kanza	-	-	-	-	-
Sigara alternata	-	-	-	-	-
Saldidae	-	-	-	-	-
Veliidae					
Rhagovelia	-	-	-	20	-
Mesoveliidae					
Mesovelia mulsanti	-	-	-	-	-
Odonata					
Gomphidae					
Ophiogomphus	-	-	-	-	-
Progomphus	2	12	2	-	-
Erpetogomphus	3	-	-	3	-
Dromogomphus	-	-	-	-	-
Gomphus	-	-	-	1	1
Coenagrionidae					
Argia sp. A	-	-	1	-	-
Argia moesta	1	-	-	3	39
Ischnura	-	-	-	-	-
Enallagma	-	-	-	-	-
Libellulidae					
Perithemis tenera	-	-	-	-	-
Plathemis lydia	-	-	-	-	-
Plathemis subornata	-	-	-	-	-
Megaloptera					
Corydalidae					
Corydalus	-	-	-	-	5

Skeleton Creek - Date: 5 October 83

	Site 1	Site 2	Site 3	Site 4	Site 5
Coleoptera					
Heteroceridae	-	-	-	-	-
Hydrophilidae					
Helophorus	-	-	-	-	-
Ametor	-	-	-	-	-
Berosus	4	1	33	2	1
Enochrus	-	-	-	-	-
Paracymus	-	-	-	-	-
Tropisternus	-	-	-	-	-
Laccobius	-	-	-	-	-
Haliplidae	-	-	1	-	-
Dytiscidae					
Laccophilus	-	-	-	-	-
Gyrinidae					
Dineutus	-	-	-	-	-
Elmidae					
Dubiraphia	-	-	-	-	-
Stenelmis	2	3	2	31	255
Dryopidae					
Helichus	-	-	1	1	17
Lepidoptera	-	-	-	-	-
Trichoptera					
Hydropsychidae					
Cheumatopsyche	3	-	-	38	320
Hydropsyche	-	-	-	40	177
Hydroptilidae					
Hydroptila	-	-	-	2	8
Leptoceridae					
Oecetis	-	-	-	-	-
Polycentropodidae					
Cyrnellus	-	-	-	-	1
Diptera					
Ceratopogonidae					
Forcipomyia	-	-	-	-	-
Palpomyia sp. #1	-	-	-	-	-
Palpomyia sp. #2	-	-	-	-	-
Stratiomyidae					
Caloparyphus	-	-	-	-	-
Simuliidae					
Simulium (larvae only)	1	-	129	148	2
Empididae	-	-	-	-	-
Tipulidae					
Erioptera	-	1	1	-	-
Culicidae					
Culex	-	-	-	-	-

Skeleton Creek - Date: 5 October 83

	Site 1	Site 2	Site 3	Site 4	Site 5
Chironomidae					
Tanypodinae					
Ablabesmyia sp.	-	-	-	-	-
Ablabesmyia mallochi	5	2	-	-	2
Clinotanypus	-	-	-	-	-
Natarsia	-	2	37	32	4
Pentaneura	-	-	-	-	-
Procladius	-	-	-	-	-
Tanypus	-	-	-	-	-
Thienemannimyia gr.	1	5	7	-	3
Zavrelimyia	-	-	-	-	-
Chironominae					
Chironomus	225	1159	40	4	-
Cladotanytarsus	1	-	-	-	1
Cryptochironomus	9	2	3	-	-
Dicrotendipes sp.	-	-	-	-	12
Dicrotendipes neomodestus	76	42	231	33	103
Dicrotendipes nervosus(I)	-	-	-	-	-
Glyptotendipes	-	-	-	-	139
Goeldichironomous holopra.	-	20	2	-	1
Harnischia	-	-	-	-	-
Lenziella	-	-	-	-	-
Parachironomus	-	-	-	-	-
Paracladopelma	1	-	-	-	-
Paratanytarsus	-	-	-	-	-
Paratendipes	-	-	-	-	-
Phaenopsectra	-	-	-	-	-
Polypedilum convictum	2	8	11	84	206
Polypedilum illinoense	10	55	26	2	-
Polypedilum scalaenum	9	3	1	-	1
Pseudochironomus	3	-	1	-	23
Rheotanytarsus exiguus gr.	-	-	-	-	9
Tanytarsini sp. #1	2	-	2	-	-
Tanytarsus sp. #1	-	-	1	-	1
Tanytarsus glabrescens gr.	36	2	8	30	26
Tanytarsus guerlus gr.	-	-	-	-	-
Orthocladiinae					
Cricotopus sp.	27	26	296	21	111
Cricotopus sp. A	-	-	-	-	-
Cricotopus sp. B	-	-	-	-	-
Cricotopus sp. C	-	-	-	-	-
Cricotopus sp. D	-	-	-	-	-
Cricotopus bicinctus	-	2	39	-	5
Cricotopus trifascia gr.	-	-	-	-	-
Hydrobaenus	-	-	-	-	-
Nanocladius	-	-	2	-	1
Parametriocnemus	-	-	-	-	-
Rheocricotopus	-	-	-	-	-
Thienemanniella	-	-	-	-	-

Skeleton Creek - Date: 5 October 83

	Site 1	Site 2	Site 3	Site 4	Site 5
Mollusca					
Gastropoda					
Physidae - Physella	-	11	1	35	6
Ancylidae - Ferrissia	-	-	-	-	-
Pelecypoda					
Pisidiidae - Musculium	20	88	-	-	31
Annelida					
Oligochaeta					
Naididae					
Bratislaria unidertata	-	-	-	-	-
Chaetogaster diastrophus	-	-	-	-	-
Dero furcata	1	-	-	-	-
Dero nivea	-	-	-	-	-
Dero obtusa	-	-	-	-	-
Homochaeta naidina	-	-	-	-	-
Nais communis	-	-	-	-	-
Nais elinguis	-	-	-	-	-
Nais paradalis	-	-	-	-	-
Paranais litoralis	-	-	-	6	-
Pristina sp.	-	-	-	-	3
Pristina idrensis	-	-	-	-	-
Pristina longiseta	-	-	-	-	-
Pristina osborni	-	-	-	-	-
Specaria josinae	-	-	-	-	1
Stephensoniana trivand.	-	-	-	-	-
Tubificidae					
Aulodrilus piqueti	-	-	-	-	-
Branchiura sowerbyi	1	-	-	252	39
Limnodrilus cervix	-	-	-	-	-
Limnodrilus hoffmeisteri	7	1	8	10	-
Limnodrilus udekemianus	5	1	-	18	5
Rhyacodrilus coccineus	-	-	-	-	-
Rhyacodrilus montana	-	-	-	-	-
unid w/o capill. chaet.	21	3	6	43	2
unid w/ capill. chaet.	-	-	-	6	-
unid w/ sim. point.chaet.	-	-	-	-	-
Hirudinea					
Hirudinidae					
Haemopis	-	-	1	-	-
Erpobdellidae					
Mooreobdella microstoma	-	-	-	1	-
Glossiphoniidae					
Helobdella triserialis	-	-	-	1	-
Coelenterata (Hydra)	-	-	-	-	-
Crustacea					
Amphipoda					
Talitridae					
Hyallela azteca	-	-	1	-	-
Decapoda (crayfish)	-	-	-	-	-

Skeleton Creek - Date: 8 December 83

	Site 1	Site 2	Site 3	Site 4	Site 5
Insecta					
Ephemeroptera					
Caenidae					
Caenis	4	1	9	1	-
Baetidae					
Baetis	-	-	-	1	4
Tricorythidae					
Tricorythodes	-	-	-	1	-
Heptageniidae					
Stenonema	-	-	-	1	-
Hemiptera					
Gerridae					
Trepobates	-	-	-	-	-
Corixidae					
Trichocorixa	-	-	2	-	-
Trichocorixa verticalis interiores	-	-	-	-	-
Trichocorixa kanza	-	-	-	-	-
Sigara alternata	-	-	-	-	-
Saldidae	-	-	-	-	-
Veliidae					
Rhagovelia	-	-	-	-	-
Mesoveliidae					
Mesovelia mulsanti	-	-	-	-	-
Odonata					
Gomphidae					
Ophiogomphus	-	-	-	-	-
Progomphus	2	2	2	-	-
Erpetogomphus	-	-	-	3	-
Dromogomphus	-	-	-	-	-
Gomphus	-	-	-	-	-
Coenagrionidae					
Argia sp. A	-	-	-	1	-
Argia moesta	-	-	2	1	-
Ischnura	-	-	-	-	-
Enallagma	-	-	-	-	-
Libellulidae					
Perithemis tenera	-	-	-	-	-
Plathemis lydia	-	-	-	-	-
Plathemis subornata	-	-	-	-	-
Megaloptera					
Corydalidae					
Corydalus	-	-	-	-	5

Skeleton Creek - Date: 8 December 83

	Site 1	Site 2	Site 3	Site 4	Site 5
Coleoptera					
Heteroceridae	-	-	-	-	-
Hydrophilidae					
Helophorus	-	-	-	-	-
Ametor	-	-	-	-	-
Berosus	-	-	5	1	-
Enochrus	-	-	-	-	-
Paracymus	-	-	-	-	-
Tropisternus	-	-	-	-	-
Laccobius	-	-	-	-	-
Haliplidae	-	-	-	-	-
Dytiscidae					
Laccophilus	-	-	1	1	-
Gyrinidae					
Dineutus	-	-	-	-	-
Elmidae					
Dubiraphia	-	-	-	2	-
Stenelmis	-	-	1	75	75
Dryopidae					
Helichus	-	-	-	-	-
Lepidoptera	-	-	1	-	-
Trichoptera					
Hydropsychidae					
Cheumatopsyche	-	-	2	82	92
Hydropsyche	-	-	-	25	50
Hydroptilidae					
Hydroptila	-	-	1	5	-
Leptoceridae					
Oecetis	-	-	-	-	-
Polycentropodidae					
Cyrnellus	-	-	-	-	-
Diptera					
Ceratopogonidae					
Forcipomyia	-	-	-	-	-
Palpomyia sp. #1	-	-	-	-	-
Palpomyia sp. #2	-	-	-	-	-
Stratiomyidae					
Caloparyphus	1	-	-	-	-
Simuliidae					
Simulium (larvae only)	8	1	12	65	41
Empididae	-	-	1	-	-
Tipulidae					
Erioptera	-	1	2	-	-
Culicidae					
Culex	-	-	1	-	-

Skeleton Creek - Date: 8 December 83

	Site 1	Site 2	Site 3	Site 4	Site 5
Chironomidae					
Tanypodinae					
Ablabesmyia sp.	-	-	-	-	-
Ablabesmyia mallochi	-	-	-	-	-
Clinotanypus	-	-	-	-	-
Natarsia	-	-	1	34	4
Pentaneura	-	-	-	-	-
Procladius	-	-	-	-	-
Tanypus	-	-	-	-	-
Thienemannimyia gr.	-	-	1	3	4
Zavrelimyia	-	-	-	-	-
Chironominae					
Chironomus	-	-	17	-	-
Cladotanytarsus	-	-	-	-	-
Cryptochironomus	1	1	2	8	1
Dicrotendipes sp.	-	-	-	-	-
Dicrotendipes neomodestus	-	-	3	17	-
Dicrotendipes nervosus(I)	-	-	-	-	-
Glyptotendipes	-	1	-	1	4
Goeldichironomous holopra.	-	-	-	-	-
Harnischia	-	-	-	-	-
Lenziella	-	-	-	-	-
Parachironomus	-	-	-	-	-
Paracladopelma	-	-	-	-	-
Paratanytarsus	-	-	-	-	-
Paratendipes	-	-	-	-	-
Phaenopsectra	-	-	1	-	-
Polypedilum convictum	-	-	-	12	8
Polypedilum illinoense	-	-	1	-	1
Polypedilum scalaenum	-	-	2	2	1
Pseudochironomus	2	-	-	2	4
Rheotanytarsus exiguus gr.	-	-	-	-	-
Tanytarsini sp. #1	-	-	-	-	-
Tanytarsus sp. #1	-	-	-	-	-
Tanytarsus glabrescens gr.	-	-	-	1	3
Tanytarsus guerlus gr.	-	-	-	1	-
Orthocladiinae					
Cricotopus sp.	-	-	-	-	-
Cricotopus sp. A	82	24	76	114	2
Cricotopus sp. B	-	-	-	3	15
Cricotopus sp. C	-	-	-	-	1
Cricotopus sp. D	-	-	-	4	42
Cricotopus bicinctus	-	-	-	5	2
Cricotopus trifascia gr.	-	-	-	-	-
Hydrobaenus	-	-	-	3	1
Nanocladius	-	-	-	-	-
Parametriocnemus	-	-	-	-	-
Rheocricotopus	-	-	-	-	-
Thienemanniella	-	-	-	-	2

Skeleton Creek - Date: 8 December 83

	Site 1	Site 2	Site 3	Site 4	Site 5
Mollusca					
Gastropoda					
Physidae - Physella	2	1	3	114	4
Ancylidae - Ferrissia	-	-	-	-	-
Pelecypoda					
Pisidiidae - Musculium	-	10	-	14	57
Annelida					
Oligochaeta					
Naididae					
Bratislaria unidertata	-	-	-	-	-
Chaetogaster diastrophus	-	-	-	-	-
Dero furcata	-	-	-	-	-
Dero nivea	-	1	-	1	-
Dero obtusa	-	-	-	-	-
Homochaeta naidina	-	-	-	-	-
Nais communis	-	-	-	-	-
Nais elinguis	-	-	-	-	-
Nais paradalis	-	-	-	-	-
Paranais litoralis	-	-	-	-	-
Pristina sp.	-	-	-	2	-
Pristina idrensis	-	-	-	-	-
Pristina longiseta	-	-	-	-	-
Pristina osborni	-	-	-	-	-
Specaria josinae	-	-	-	-	-
Stephensoniana trivand.	-	-	-	-	-
Tubificidae					
Aulodrilus piqueti	-	-	-	-	-
Branchiura sowerbyi	-	-	-	186	11
Limnodrilus cervix	-	-	-	-	-
Limnodrilus hoffmeisteri	2	-	4	5	-
Limnodrilus udekemianus	1	3	12	238	18
Rhyacodrilus coccineus	-	-	-	-	-
Rhyacodrilus montana	-	-	-	-	-
unid w/o capill. chaet.	7	5	19	136	12
unid w/ capill. chaet.	-	-	-	9	-
unid w/ sim. point.chaet.	-	-	-	-	-
Hirudinea					
Hirudinidae					
Haemopis	-	-	-	-	-
Erpobdellidae					
Mooreobdella microstoma	-	-	-	2	-
Glossiphoniidae					
Helobdella triserialis	-	-	-	-	-
Coelenterata (Hydra)	-	-	-	-	-
Crustacea					
Amphipoda					
Talitridae					
Hyallela azteca	-	-	2	-	-
Decapoda (crayfish)	-	-	-	-	-

Skeleton Creek - Date: 1 May 84

	Site 1	Site 2	Site 3	Site 4	Site 5
Insecta					
Ephemeroptera					
Caenidae					
Caenis	2	-	1	-	25
Baetidae					
Baetis	-	-	-	-	-
Tricorythidae					
Tricorythodes	-	-	-	-	-
Heptageniidae					
Stenonema	-	-	-	-	1
Hemiptera					
Gerridae					
Trepobates	-	-	-	-	-
Corixidae					
Trichocorixa	-	-	-	-	-
Trichocorixa verticalis interiores	-	-	-	-	-
Trichocorixa kanza	-	-	-	-	-
Sigara alternata	-	-	-	-	-
Saldidae	-	-	-	-	-
Veliidae					
Rhagovelia	-	-	-	-	-
Mesoveliidae					
Mesovelia mulsanti	-	-	-	-	-
Odonata					
Gomphidae					
Ophiogomphus	-	-	-	-	-
Progomphus	1	1	-	-	-
Erpetogomphus	-	-	-	-	-
Dromogomphus	-	-	-	-	-
Gomphus	-	-	-	-	-
Coenagrionidae					
Argia sp. A	-	-	-	-	-
Argia moesta	-	-	-	-	-
Ischnura	-	-	-	-	-
Enallagma	-	-	-	-	-
Libellulidae					
Perithemis tenera	-	-	-	-	-
Plathemis lydia	-	-	-	-	-
Plathemis subornata	-	-	-	-	-
Megaloptera					
Corydalidae					
Corydalus	-	-	-	-	1

Skeleton Creek - Date: 1 May 84

	Site 1	Site 2	Site 3	Site 4	Site 5
Coleoptera					
Heteroceridae	-	-	-	-	-
Hydrophilidae					
Helophorus	-	-	-	-	-
Ametor	-	-	1	-	-
Berosus	-	-	4	1	-
Enochrus	-	-	-	-	-
Paracymus	-	-	-	-	-
Tropistermus	-	-	-	-	-
Laccobius	-	-	-	-	-
Haliplidae	-	-	1	-	-
Dytiscidae					
Laccophilus	-	-	-	-	-
Gyrinidae					
Dineutus	-	-	-	-	-
Elmidae					
Dubiraphia	-	-	-	-	-
Stenelmis	1	-	1	153	40
Dryopidae					
Helichus	-	-	-	-	2
Lepidoptera	-	-	-	-	-
Trichoptera					
Hydropsychidae					
Cheumatopsyche	-	-	-	-	8
Hydropsyche	-	-	-	-	5
Hydroptilidae					
Hydroptila	-	-	-	-	-
Leptoceridae					
Oecetis	-	-	-	-	2
Polycentropodidae					
Cyrnellus	-	-	-	-	-
Diptera					
Ceratopogonidae					
Forcipomyia	-	-	-	-	-
Palpomyia sp. #1	-	-	-	1	1
Palpomyia sp. #2	-	-	-	-	-
Stratiomyidae					
Caloparyphus	-	-	-	-	-
Simuliidae					
Simulium (larvae only)	1	-	8	3	9
Empididae	-	-	-	-	-
Tipulidae					
Erioptera	7	-	-	2	1
Culicidae					
Culex	-	-	-	-	-

Skeleton Creek - Date: 1 May 84

	Site 1	Site 2	Site 3	Site 4	Site 5
Chironomidae					
Tanypodinae					
Ablabesmyia sp.	-	-	-	-	-
Ablabesmyia mallochi	-	-	-	-	-
Clinotanypus	-	-	-	-	-
Natarsia	-	-	-	-	1
Pentaneura	-	-	-	-	-
Procladius	-	-	-	-	-
Tanypus	-	-	-	-	-
Thienemannimyia gr.	-	-	-	-	3
Zavrelimyia	-	-	-	-	-
Chironominae					
Chironomus	-	-	-	-	-
Cladotanytarsus	-	-	-	-	-
Cryptochironomus	2	-	-	1	-
Dicrotendipes sp.	-	-	-	-	-
Dicrotendipes neomodestus	1	-	-	-	3
Dicrotendipes nervosus(I)	-	-	-	-	-
Glyptotendipes	-	-	-	-	-
Goeldichironomous holopra.	-	-	-	-	-
Harnischia	-	-	-	-	-
Lenziella	-	-	-	-	-
Parachironomus	-	-	-	-	-
Paracladopelma	-	-	-	-	-
Paratanytarsus	-	-	-	-	-
Paratendipes	-	-	-	-	-
Phaenopsectra	-	-	-	-	-
Polypedilum convictum	-	-	-	2	21
Polypedilum illinoense	-	-	-	-	-
Polypedilum scalaenum	-	1	-	-	3
Pseudochironomus	-	-	-	-	7
Rheotanytarsus exiguus gr.	-	-	-	-	-
Tanytarsini sp. #1	-	-	-	-	-
Tanytarsus sp. #1	-	-	-	-	1
Tanytarsus glabrescens gr.	-	-	-	-	3
Tanytarsus guerlus gr.	-	-	-	-	-
Orthocladiinae					
Cricotopus sp.	-	-	-	-	-
Cricotopus sp. A	6	3	87	38	12
Cricotopus sp. B	-	-	1	1	5
Cricotopus sp. C	-	-	-	-	29
Cricotopus sp. D	-	-	7	-	3
Cricotopus bicinctus	-	-	4	-	-
Cricotopus trifascia gr.	-	-	-	-	1
Hydrobaenus	-	-	-	1	2
Nanocladius	-	-	-	-	-
Parametriocnemus	-	-	-	-	-
Rheocricotopus	-	-	-	-	5
Thienemanniella	-	-	-	-	-

Skeleton Creek - Date: 1 May 84

	Site 1	Site 2	Site 3	Site 4	Site 5
Mollusca					
Gastropoda					
Physidae - *Physella*	-	-	-	-	-
Ancylidae - *Ferrissia*	-	-	1	-	-
Pelecypoda					
Pisidiidae - *Musculium*	-	-	2	-	-
Annelida					
Oligochaeta					
Naididae					
Bratislaria unidertata	-	-	-	-	-
Chaetogaster diastrophus	-	-	-	-	-
Dero furcata	-	-	-	-	-
Dero nivea	-	-	-	-	-
Dero obtusa	-	-	-	-	-
Homochaeta naidina	-	-	-	-	-
Nais communis	-	-	3	-	13
Nais elinguis	-	-	3	-	29
Nais paradalis	-	-	-	-	-
Paranais litoralis	-	-	-	-	-
Pristina sp.	-	-	-	-	-
Pristina idrensis	-	-	-	-	-
Pristina longiseta	-	-	-	-	-
Pristina osborni	-	-	-	-	-
Specaria josinae	-	-	13	-	1
Stephensoniana trivand.	-	-	-	-	-
Tubificidae					
Aulodrilus piqueti	-	-	-	-	-
Branchiura sowerbyi	-	-	-	23	1
Limnodrilus cervix	2	-	3	4	-
Limnodrilus hoffmeisteri	18	-	7	15	3
Limnodrilus udekemianus	13	-	4	19	14
Rhyacodrilus coccineus	-	-	-	-	-
Rhyacodrilus montana	-	-	-	-	-
unid w/o capill. chaet.	17	-	3	33	7
unid w/ capill. chaet.	-	-	-	28	-
unid w/ sim. point.chaet.	-	-	-	1	5
Hirudinea					
Hirudinidae					
Haemopis	-	-	-	-	-
Erpobdellidae					
Mooreobdella microstoma	-	-	-	-	-
Glossiphoniidae					
Helobdella triserialis	-	-	-	1	-
Coelenterata (*Hydra*)	-	-	-	-	1
Crustacea					
Amphipoda					
Talitridae					
Hyallela azteca	-	-	-	-	-
Decapoda (crayfish)	-	-	-	-	1

Skeleton Creek - Date: 14 August 84

	Site 1	Site 2	Site 3	Site 4	Site 5
Insecta					
Ephemeroptera					
Caenidae					
Caenis	49	12	3	8	-
Baetidae					
Baetis	1	-	-	-	7
Tricorythidae					
Tricorythodes	1	-	-	64	51
Heptageniidae					
Stenonema	-	-	-	-	-
Hemiptera					
Gerridae					
Trepobates	11	-	-	-	1
Corixidae					
Trichocorixa	7	3	37	8	-
Trichocorixa verticalis interiores	1	3	19	8	4
Trichocorixa kanza	-	-	-	-	-
Sigara alternata	-	-	-	-	-
Saldidae	-	-	-	-	-
Veliidae					
Rhagovelia	-	-	-	2	5
Mesoveliidae					
Mesovelia mulsanti	3	-	-	-	-
Odonata					
Gomphidae					
Ophiogomphus	-	1	-	-	-
Progomphus	7	18	-	-	-
Erpetogomphus	-	-	-	-	-
Dromogomphus	1	-	-	-	-
Gomphus	-	-	-	-	-
Coenagrionidae					
Argia sp. A	-	-	-	1	-
Argia moesta	1	-	-	9	17
Ischnura	3	4	-	-	-
Enallagma	-	-	1	-	-
Libellulidae					
Perithemis tenera	-	1	-	-	-
Plathemis lydia	-	5	-	-	-
Plathemis subornata	-	-	1	-	-
Megaloptera					
Corydalidae					
Corydalus	-	-	-	-	5

Skeleton Creek - Date: 14 August 84

	Site 1	Site 2	Site 3	Site 4	Site 5
Coleoptera					
Heteroceridae	-	-	1	-	-
Hydrophilidae					
Helophorus	1	-	-	-	-
Ametor	-	-	-	-	-
Berosus	12	3	83	29	1
Enochrus	-	-	-	-	-
Paracymus	-	-	-	-	-
Tropisternus	-	-	-	-	-
Laccobius	-	-	-	-	-
Haliplidae	-	-	-	-	-
Dytiscidae					
Laccophilus	-	-	-	-	-
Gyrinidae					
Dineutus	-	-	-	-	-
Elmidae					
Dubiraphia	5	-	-	-	-
Stenelmis	6	1	-	23	75
Dryopidae					
Helichus	1	-	-	16	9
Lepidoptera	-	-	-	-	-
Trichoptera					
Hydropsychidae					
Cheumatopsyche	9	-	-	166	429
Hydropsyche	-	-	-	43	295
Hydroptilidae					
Hydroptila	-	-	-	-	3
Leptoceridae					
Oecetis	-	-	-	-	-
Polycentropodidae					
Cyrnellus	-	-	-	-	8
Diptera					
Ceratopogonidae					
Forcipomyia	-	-	-	-	-
Palpomyia sp. #1	-	-	-	-	-
Palpomyia sp. #2	-	-	-	-	-
Stratiomyidae					
Caloparyphus	-	-	-	-	-
Simuliidae					
Simulium (larvae only)	-	-	-	-	-
Empididae	-	-	-	1	-
Tipulidae					
Erioptera	-	4	-	-	-
Culicidae					
Culex	-	-	-	-	-

Skeleton Creek - Date: 14 August 84

	Site 1	Site 2	Site 3	Site 4	Site 5
Chironomidae					
Tanypodinae					
Ablabesmyia sp.	-	-	-	-	-
Ablabesmyia mallochi	7	1	-	1	-
Clinotanypus	-	-	-	-	-
Natarsia	-	-	11	12	2
Pentaneura	-	-	-	1	-
Procladius	1	-	-	1	-
Tanypus	-	-	1	-	-
Thienemannimyia gr.	51	1	-	32	18
Zavrelimyia	-	-	-	-	-
Chironominae					
Chironomus	-	-	1	-	1
Cladotanytarsus	-	1	-	1	1
Cryptochironomus	4	1	-	-	3
Dicrotendipes sp.	-	-	-	2	35
Dicrotendipes neomodestus	49	2	96	73	81
Dicrotendipes nervosus(I)	-	-	-	-	-
Glyptotendipes	1	-	-	4	130
Goeldichironomous holopra.	-	-	1	3	-
Harnischia	-	-	-	-	-
Lenziella	-	-	-	-	-
Parachironomus	-	-	-	4	11
Paracladopelma	-	4	-	-	-
Paratanytarsus	-	-	-	-	-
Paratendipes	-	1	-	-	-
Phaenopsectra	-	-	-	-	-
Polypedilum convictum	1	-	-	99	101
Polypedilum illinoense	2	1	5	1	1
Polypedilum scalaenum	11	12	-	4	5
Pseudochironomus	6	-	1	6	35
Rheotanytarsus exiguus gr.	-	-	-	1	11
Tanytarsini sp. #1	-	-	-	-	-
Tanytarsus sp. #1	-	-	-	-	-
Tanytarsus glabrescens gr.	10	-	-	36	4
Tanytarsus guerlus gr.	-	-	-	-	-
Orthocladiinae					
Cricotopus sp.	-	-	33	2	8
Cricotopus sp. A	-	-	-	-	-
Cricotopus sp. B	-	-	-	-	-
Cricotopus sp. C	-	-	-	-	-
Cricotopus sp. D	-	-	-	-	-
Cricotopus bicinctus	1	-	2	1	-
Cricotopus trifascia gr.	-	-	-	-	-
Hydrobaenus	-	-	-	-	-
Nanocladius	-	-	-	-	-
Parametriocnemus	-	-	-	-	-
Rheocricotopus	-	-	-	-	-
Thienemanniella	-	-	-	-	-

Skeleton Creek - Date: 14 August 84

	Site 1	Site 2	Site 3	Site 4	Site 5
Mollusca					
Gastropoda					
Physidae - Physella	15	2	13	398	22
Ancylidae - Ferrissia	3	-	-	1	1
Pelecypoda					
Pisidiidae - Musculium	23	78	-	108	87
Annelida					
Oligochaeta					
Naididae					
Bratislaria unidertata	-	-	-	-	-
Chaetogaster diastrophus	-	-	-	-	-
Dero furcata	-	-	1	2	-
Dero nivea	-	-	-	-	-
Dero obtusa	-	-	2	-	-
Homochaeta naidina	-	-	-	-	-
Nais communis	-	-	-	-	-
Nais elinguis	-	-	-	-	-
Nais paradalis	-	-	-	-	-
Paranais litoralis	-	-	-	-	-
Pristina sp.	-	-	-	-	-
Pristina idrensis	-	-	-	-	-
Pristina longiseta	-	-	-	-	-
Pristina osborni	-	-	-	-	-
Specaria josinae	-	-	-	-	-
Stephensoniana trivand.	-	-	-	-	-
Tubificidae					
Aulodrilus piqueti	-	-	-	-	-
Branchiura sowerbyi	15	2	-	25	21
Limnodrilus cervix	-	-	3	-	-
Limnodrilus hoffmeisteri	7	3	42	-	-
Limnodrilus udekemianus	7	2	12	10	1
Rhyacodrilus coccineus	-	-	-	-	-
Rhyacodrilus montana	-	-	-	-	-
unid w/o capill. chaet.	18	13	65	15	-
unid w/ capill. chaet.	-	-	-	1	-
unid w/ sim. point.chaet.	-	-	-	-	-
Hirudinea					
Hirudinidae					
Haemopis	-	-	-	-	-
Erpobdellidae					
Mooreobdella microstoma	5	-	-	3	-
Glossiphoniidae					
Helobdella triserialis	1	8	-	-	-
Coelenterata (Hydra)	-	-	-	-	-
Crustacea					
Amphipoda					
Talitridae					
Hyallela azteca	4	-	-	1	-
Decapoda (crayfish)	-	-	-	-	-

APPENDIX K

SPECIES DIVERSITY ($\bar{d}$), NUMBER OF TAXA, AND NUMBER OF INDIVIDUALS FOR BENTHIC MACROINVERTEBRATE ORGANISMS COLLECTED DURING THE STUDY PERIOD

Sample Identification	Date	$\bar{d}$	# of Taxa	# of Indiv.
Station 1	8-12-82	4.11	50	3282
Station 2	" "	3.41	26	401
Station 3	" "	3.45	33	865
Station 4	" "	3.78	45	1430
Station 5	" "	3.12	39	1340
Station 1	12-7-82	3.02	20	346
Station 2	" "	3.58	27	217
Station 3	" "	3.07	24	359
Station 4	" "	3.40	47	3488
Station 5	" "	2.74	51	8644
Station 1	4-27-83	3.19	22	355
Station 2	" "	3.33	15	59
Station 3	" "	3.26	14	83
Station 4	" "	3.22	20	214
Station 5	" "	3.38	28	508
Station 1	7-6-83	3.05	16	129
Station 2	" "	3.42	15	53
Station 3	" "	3.21	21	324
Station 4	" "	3.48	27	536
Station 5	" "	2.90	16	146
Station 1	10-5-83	3.07	29	509
Station 2	" "	1.39	23	1457
Station 3	" "	3.00	33	914
Station 4	" "	3.74	29	979
Station 5	" "	3.64	38	1619
Station 1	12-8-83	1.62	11	112
Station 2	" "	2.50	12	51
Station 3	" "	3.32	28	186
Station 4	" "	3.64	40	1182
Station 5	" "	3.61	27	464
Station 1	5-1-84	2.86	12	71
Station 2	" "	1.37	3	5
Station 3	" "	2.61	19	154
Station 4	" "	2.63	18	327
Station 5	" "	4.28	36	269
Station 1	8-14-84	4.34	39	361
Station 2	" "	3.34	27	187
Station 3	" "	3.29	23	434
Station 4	" "	3.59	42	1227
Station 5	" "	3.48	35	1489

APPENDIX L

PERCENTAGE OF INDIVIDUALS REPRESENTED BY OLIGOCHAETES, CHIRONOMIDS, MAYFLIES, CADDISFLIES, AND MOLLUSCA FOR EACH SAMPLE COLLECTED DURING THE STUDY PERIOD

Sample	Date	% Oligo-chaetes	% Chir-onomids	% May-flies	% Caddis-flies	% Mol-lusca
Station 1	8-12-82	2.47	86.08	6.26	1.01	2.47
Station 2	" "	7.48	50.12	0.00	0.00	33.90
Station 3	" "	12.02	72.95	0.35	0.12	0.12
Station 4	" "	8.60	35.94	1.75	29.02	14.90
Station 5	" "	1.27	43.13	5.97	33.58	0.07
Station 1	12-7-82	28.03	47.11	2.60	2.60	9.25
Station 2	" "	12.90	45.62	3.22	0.46	18.89
Station 3	" "	65.46	19.50	0.00	0.28	1.11
Station 4	" "	29.13	5.91	0.00	23.74	26.32
Station 5	" "	16.21	10.55	0.02	62.06	1.32
Station 1	4-27-83	64.51	18.03	10.42	0.00	4.51
Station 2	" "	42.37	25.42	13.56	0.00	13.56
Station 3	" "	65.06	28.92	0.00	0.00	0.00
Station 4	" "	68.22	20.56	0.00	0.47	6.07
Station 5	" "	24.80	26.38	0.00	10.83	0.98
Station 1	7-6-83	20.93	67.44	8.53	0.00	0.78
Station 2	" "	28.30	41.51	1.89	0.00	16.98
Station 3	" "	10.91	70.37	0.93	0.00	0.00
Station 4	" "	28.24	44.76	0.53	7.64	0.00
Station 5	" "	2.74	15.75	1.37	44.52	1.37
Station 1	10-5-83	6.88	79.96	6.09	0.59	3.93
Station 2	" "	0.35	92.29	0.56	0.00	6.88
Station 3	" "	1.53	77.44	1.64	0.00	0.11
Station 4	" "	34.42	21.04	11.44	8.17	3.58
Station 5	" "	3.09	40.02	3.58	31.25	2.29
Station 1	12-8-83	8.93	75.89	3.57	0.00	1.79
Station 2	" "	17.65	50.98	1.96	0.00	21.57
Station 3	" "	18.92	56.22	4.86	1.62	1.62
Station 4	" "	48.98	17.77	0.34	9.48	10.83
Station 5	" "	8.84	20.47	0.86	30.60	13.15
Station 1	5-1-84	70.42	12.68	2.82	0.00	0.00
Station 2	" "	0.00	80.00	0.00	0.00	0.00
Station 3	" "	23.38	64.28	0.65	0.00	1.95
Station 4	" "	38.04	13.19	0.00	0.00	0.00
Station 5	" "	27.88	36.80	9.67	5.58	0.00
Station 1	8-14-84	14.68	39.89	14.13	2.49	11.36
Station 2	" "	14.97	12.83	6.42	0.00	42.78
Station 3	" "	28.80	34.79	0.69	0.00	2.99
Station 4	" "	4.57	23.16	5.87	17.05	41.35
Station 5	" "	1.48	30.02	3.89	49.36	7.39

APPENDIX M

RAINFALL DATA (CM) FOR THE SKELETON CREEK AREA DURING THE STUDY PERIOD

Sample Date	Rainfall Day of Sampling	Rainfall Day Before Sampling
12 Aug 82	0.00	0.00
7 Dec 82	0.00	0.18
27 Apr 83	0.00	0.00
6 Jul 83	0.00	0.00
5 Oct 83	0.00	0.00
8 Dec 83	0.00	0.00
1 May 84	0.00	0.00
14 Aug 84	0.00	0.00

APPENDIX N

DISCHARGE DATA (M^3/SEC) FOR SKELETON CREEK NEAR LOVELL, OKLAHOMA DURING THE STUDY PERIOD

Sample Date	Discharge Day of Sampling	Average Discharge One Week Before Samping	Average Discharge Two Weeks Before Sampling	Average Discharge Thirty Days Before Sampling
12 Aug 82	0.37	0.39	0.55	0.92
7 Dec 82	0.19	0.22	0.35	0.45
27 Apr 83	1.25	1.76	1.58	5.47
6 Jul 83	1.25	3.72	11.59	8.28
5 Oct 83	0.04	0.06	0.12	1.56
8 Dec 83	0.34	0.52	0.65	0.50
1 May 84	2.46	3.07	4.99	8.15
14 Aug 84	0.15	0.54	0.33	0.24

VITA

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Candidate for the Degree of

Doctor of Philosophy

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